Appendix 1

Ballycar Wind Farm Aviation Technical Assessment

Ballycar Wind Farm Aviation Technical Assessment

Greensource Limited

05 November 2021

CL-5715-RPT-002 V1.0

www.cyrrus.co.uk

info@cyrrus.co.uk

Executive Summary

Cyrrus Limited has been engaged by Malachy Walsh and Partners to undertake an Aviation Study for the proposed Ballycar Wind Farm development in County Clare in the West of Ireland. The proposal comprises 12 wind turbines with a maximum tip height of up to 156.5m Above Ground Level.

An assessment of the Building Restricted Areas associated with the Instrument Landing Systems and Distance Measuring Equipment installed at Shannon Airport shows that the proposed turbines will have no impact on these navigation facilities.

Detailed radar modelling of the indicative layout against the combined Primary Surveillance Radar/Monopulse Secondary Surveillance Radar (PSR/MSSR) facility at Shannon Airport shows the following:

- Radar Line of Sight (RLoS) exists between Shannon PSR and 11 of the 12 proposed turbines;
- There is a high probability that Shannon PSR will detect turbines T1 to T9 and turbines T11 and T12, leading to turbine-induced clutter and false targets, and track seduction of aircraft targets;
- It is unlikely that Shannon PSR will detect turbine T10;
- Mitigation for Shannon PSR may be required;
- The proposed turbine sites are outside the Eurocontrol recommended 16km turbine assessment zone for Shannon MSSR, therefore an impact assessment for the facility was not required;
- No mitigation measures are necessary for Shannon MSSR.

Detailed radar modelling of the indicative layout against the MSSR at Woodcock Hill shows the following:

- RLoS exists between Woodcock Hill MSSR and all 12 proposed turbine towers;
- Aircraft between 5,250m and 10,536m from the proposed turbines may respond to bistatic reflections from these turbine towers, resulting in false targets on the bearings of the turbines;
- Provided the MSSR reflector file is updated with the turbine positions, the MSSR should be able to process out false targets caused by reflections from the turbine towers;
- The maximum heights of shadow regions from the turbines will be below published Air Traffic Control surveillance minimum altitudes and should therefore be operationally tolerable.

It is recommended that mitigation options are discussed with the Irish Aviation Authority (IAA), specifically Air Traffic Services. It is the surveillance network and operational use that will largely influence a suitable mitigation.

Possible mitigation solutions for Shannon PSR include blanking of PSR transmissions over the wind farm. This can be combined with the application of a Transponder Mandatory Zone in the affected airspace, or with in-fill data from a remote radar source.

Existing remote PSR data can be used as in-fill provided it has suitable airspace coverage and does not have visibility of the turbines. This relies on suitable terrain screening and can be problematic in terms of synchronisation and slant range errors.

In-fill mitigation can be provided using a dedicated 2D radar from a company such as Terma. The mitigation radar must be located in close proximity to the airport PSR and be synchronised with it. Terma radars filter out turbines while continuing to track aircraft.

The Aveillant Holographic Radar™ offers a 3D radar mitigation solution that can discriminate turbines from aircraft without the need for masking. It does not require locating close to the airport PSR and its target output can be coordinate transformed to the PSR origin without slant range errors.

Abbreviations

AGL	Above Ground Level
AMSL	Above Mean Sea Level
ATC	Air Traffic Control
ATCO	Air Traffic Control Officer
BRA	Building Restricted Area
CFAR	Constant False Alarm Rate
DME	Distance Measuring Equipment
DOC	Designated Operational Coverage
DTM	Digital Terrain Model
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
MSSR	Monopulse Secondary Surveillance Radar
MWP	Malachy Walsh and Partners
NM	Nautical Miles
PD	Probability of Detection
PSR	Primary Surveillance Radar
RCS	Radar Cross Section
RLoS	Radar Line of Sight
RPM	Revolutions Per Minute
TMZ	Transponder Mandatory Zone
VPD	Vertical Polar Diagram

Contents

List of figures

List of tables

1. Introduction

1.1. Overview

1.1.1. A new wind farm development, Ballycar Wind Farm, is being proposed in County Clare in the West of Ireland. The proposed development is planned to comprise 12 wind turbines with a maximum tip height of up to 156.5m Above Ground Level (AGL).

1.2. Aviation Study

1.2.1. Cyrrus Limited has been engaged by Malachy Walsh and Partners (MWP), on behalf of Greensource Limited, to undertake an Aviation Study for the development.

1.2.2. This report is concerned with the possible impacts the turbines may have on aviation navigation and surveillance facilities and includes an assessment of the Instrument Landing System (ILS) and combined Primary Surveillance Radar/Monopulse Secondary Surveillance Radar (PSR/MSSR) installations at Shannon Airport, and the MSSR at Woodcock Hill.

1.2.3. A review of the Building Restricted Areas (BRAs) that safeguard the ILS Localiser, Glidepath and Distance Measuring Equipment (DME) facilities at Shannon Airport will be used to determine the likelihood of any impact from the turbines.

1.2.4. Radar Line of Sight (RLoS) assessments will determine the degree of visibility of the proposed turbines to each of the radars and detailed Probability of Detection (PD) calculations will assess the likelihood of an impact on radar caused by signal reflections from the turbine blades and towers.

2. Evaluation Tools Used

2.1. Software

- ATDI HTZ communications v23.4.2 x64;
- Global Mapper v21.1;
- ZWCAD+ 2015 SP1 Pro v2014.11.27(26199).

2.2. Terrain Data

- ATDI 20m Digital Terrain Model (DTM), 2020, Irish Grid projection.

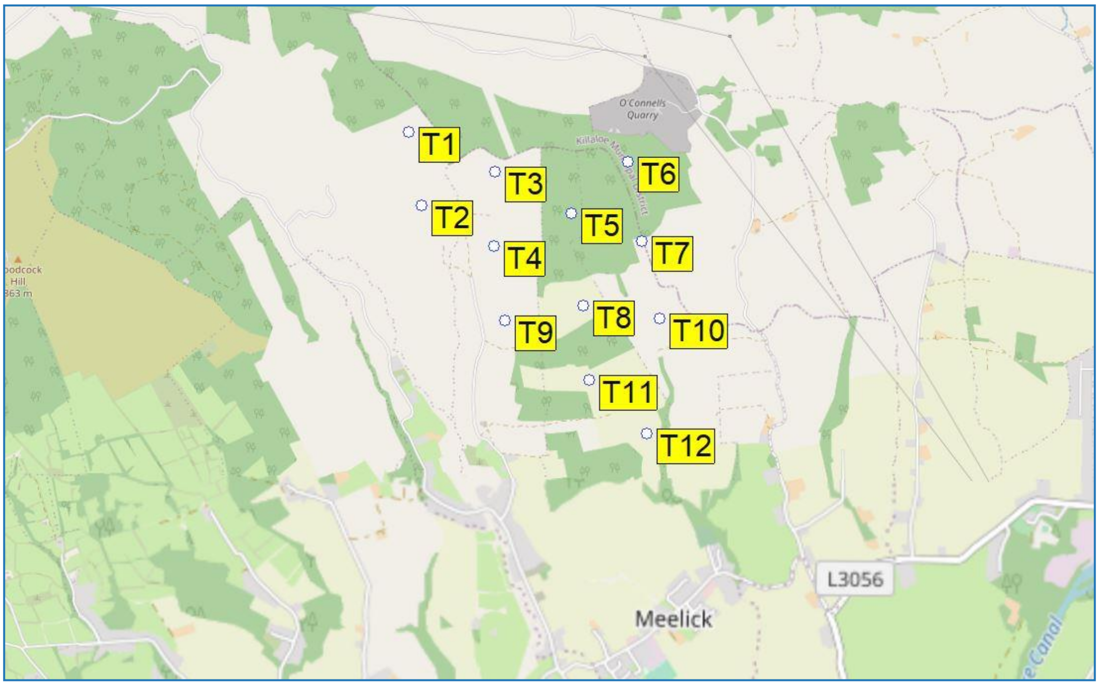
2.3. Data Provided by the Client

- 22156-MWP-00-00-SK-C-0003-P01 Site Location.pdf;
- Turbine Layout 2021-09-29.xls.

3. Development

3.1. Location

3.1.1. The indicative 12 turbine layout used for the modelling is shown in Figure 1.



© OpenStreetMap contributors

Figure 1: Indicative turbine layout

3.2. Turbine Data

3.2.1. Turbine T10 has a planned hub height of 83m AGL and blade length of 66.5m, to give a tip height of 149.5m AGL.

3.2.2. The other turbines have a planned hub height of 90m AGL and blade length of 66.5m, to give a tip height of 156.5m AGL.

3.2.3. Location data for the 12 proposed turbines has been supplied by MWP. The Irish Transverse Mercator grid coordinates for each turbine are presented in Table 1, together with each site elevation Above Mean Sea Level (AMSL).

Turbine ID	Easting (m)	Northing (m)	Site Elevation AMSL (m)
T01	554531.3	664275.1	234
T02	554604.7	663847.3	207
T03	555029.9	664043.7	238
T04	555027.2	663611.2	198

Turbine ID	Easting (m)	Northing (m)	Site Elevation AMSL (m)
T05	555475.6	663803.6	243
T06	555804.8	664103.9	254
T07	555885.7	663643.1	198
T08	555546.9	663267.0	160
T09	555090.4	663180.2	166
T10	555989.9	663191.0	124
T11	555582.0	662836.6	113
T12	555912.5	662520.8	77

Table 1: Turbine location data

4. ILS Assessment

4.1. Locations of Turbines and Shannon Airport

4.1.1. The closest turbine within the proposed development lies approximately 17.3km east of the centre of the main runway at Shannon Airport, as shown in Figure 2.

© OpenStreetMap contributors

Figure 2: Locations of turbines and Shannon Airport

4.2. Building Restricted Areas

4.2.1. The navigation facilities under consideration at Shannon Airport are the ILS Localisers, Glidepaths and DMEs that provide guidance for aircraft landing on runways 06 and 24. The minimum safeguarded areas for these facilities are defined by the International Civil Aviation Organisation (ICAO) in the document ICAO EUR DOC 015[1].

[1] ICAO EUR DOC 015 European Guidance Material on Managing Building Restricted Areas, Third Edition 2015

4.2.2. Figure 3 shows an example of the BRA shape for directional facilities such as ILS Localisers, Glidepaths and DMEs, as depicted in ICAO EUR DOC 015 Figures 3.1, 3.2, 3.3 and 3.4.

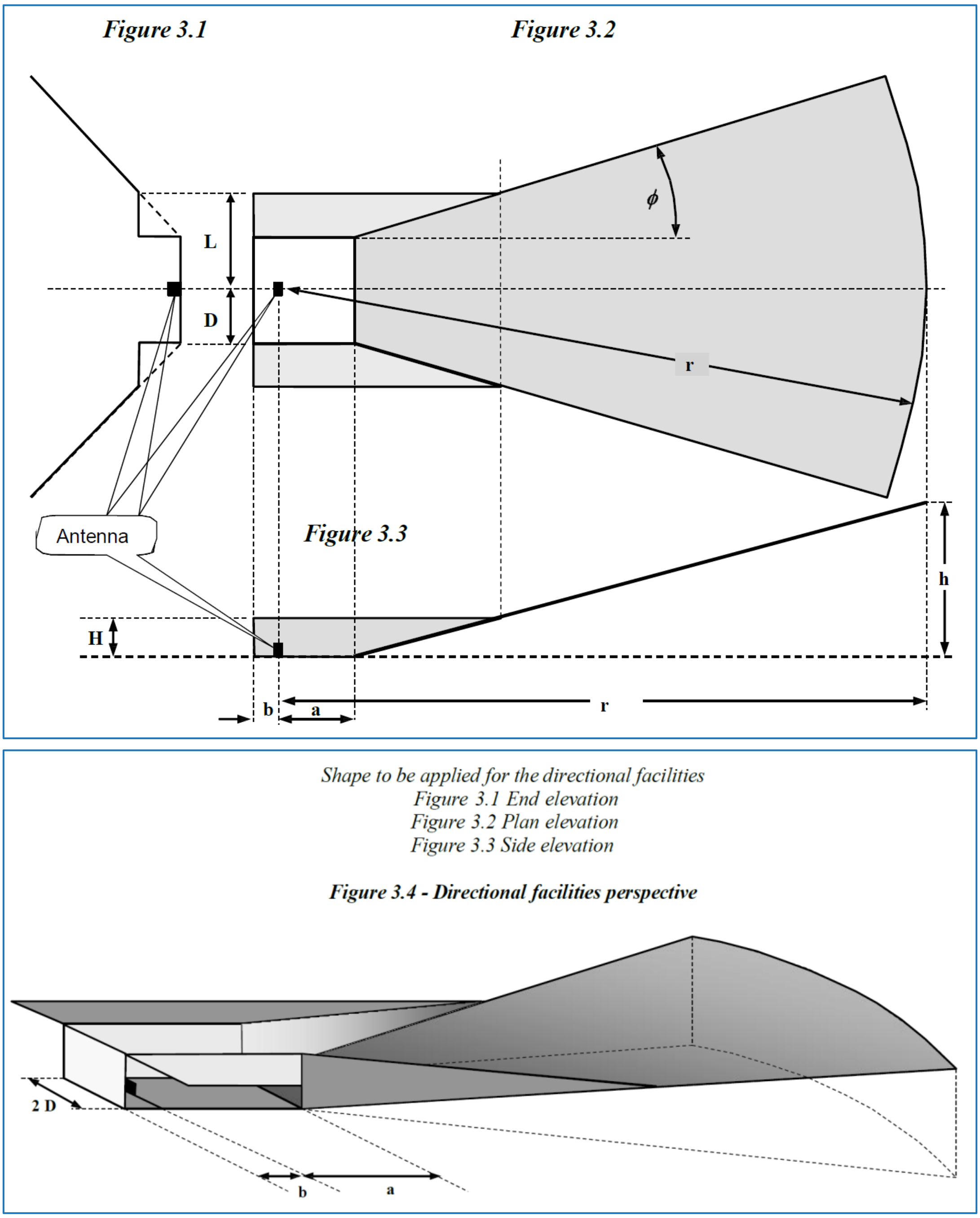


Figure 3: ICAO EUR DOC 015 Figures 3.1-3.4 – BRA shape for directional facilities

4.2.3. Applicable dimensions to be applied for the various directional navigation facilities are reproduced in Figure 4.

*Type of **navigation** facilities*	***A*** *(m)*	***b*** *(m)*	***h****(m)*	***r*** *(m)*	***D*** *(m)*	***H*** *(m)*	***L*** *(m)*	ϕ (°)
ILS LLZ (medium aperture single frequency)	Distance to threshold	500	70	a+6000	500	10	2300	30
ILS LLZ (medium aperture dual frequency)	Distance to threshold	500	70	a+6000	500	20	1500	20
ILS GP M–Type (dual frequency)	800	50	70	6000	250	5	325	10
MLS AZ	Distance to threshold	20	70	a+6000	600	20	1500	40
MLS EL	300	20	70	6000	200	20	1500	40
DME (directional antennas)	Distance to threshold	20	70	a+6000	600	20	1500	40

Figure 4: ICAO EUR DOC 015 Table 2 – Harmonised guidance figures for directional navigation facilities

4.2.4. The purpose of the safeguarded areas is to identify developments with the potential for causing unacceptable interference to navigation facilities. Developments that infringe a safeguarded area must undergo technical assessments to determine the degree of interference, if any, and whether the interference will be acceptable to the Airport operator.

4.2.5. The ILS Localiser, Glidepath and DME safeguarded areas for runways 06 and 24 are shown in Figure 5 and Table 2.

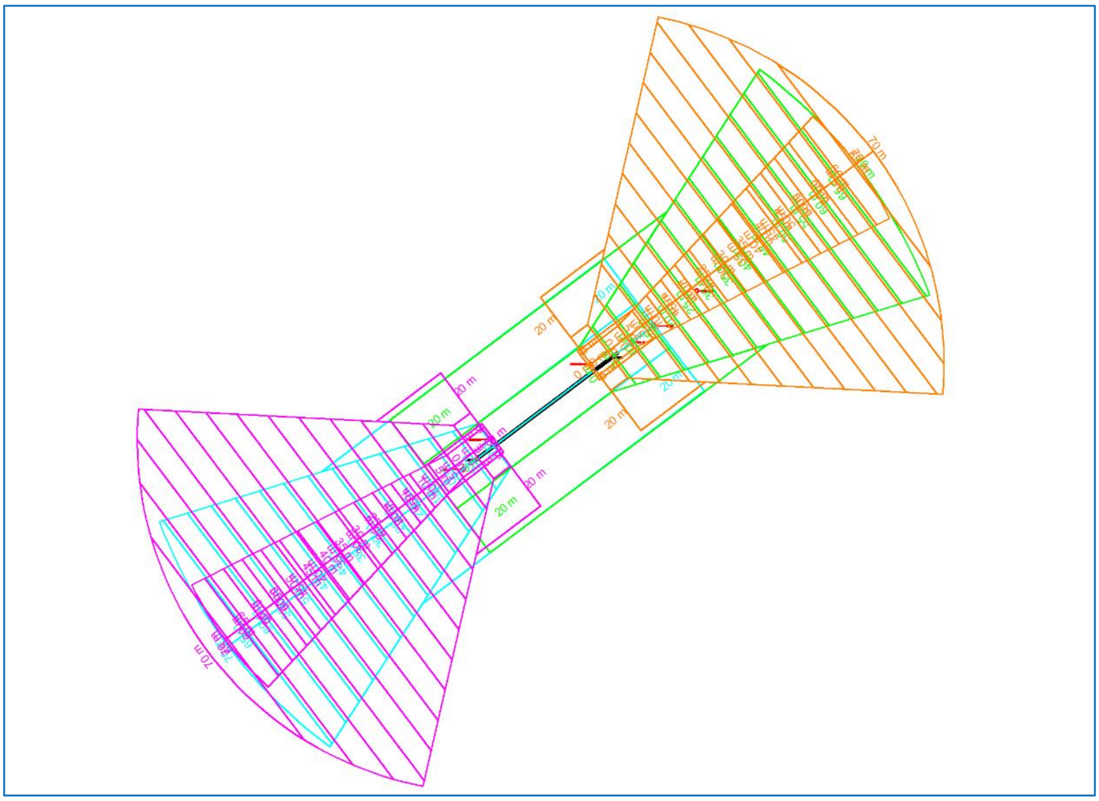


Figure 5: ILS safeguarded areas at Shannon Airport

Area Colour	Description
Magenta	Glidepath/DME 06
Orange	Glidepath/DME 24
Cyan	Localiser 06
Green	Localiser 24

Table 2 - Safeguarded areas colour reference

4.2.6. The same safeguarded areas are shown in Figure 6 relative to the proposed turbines.

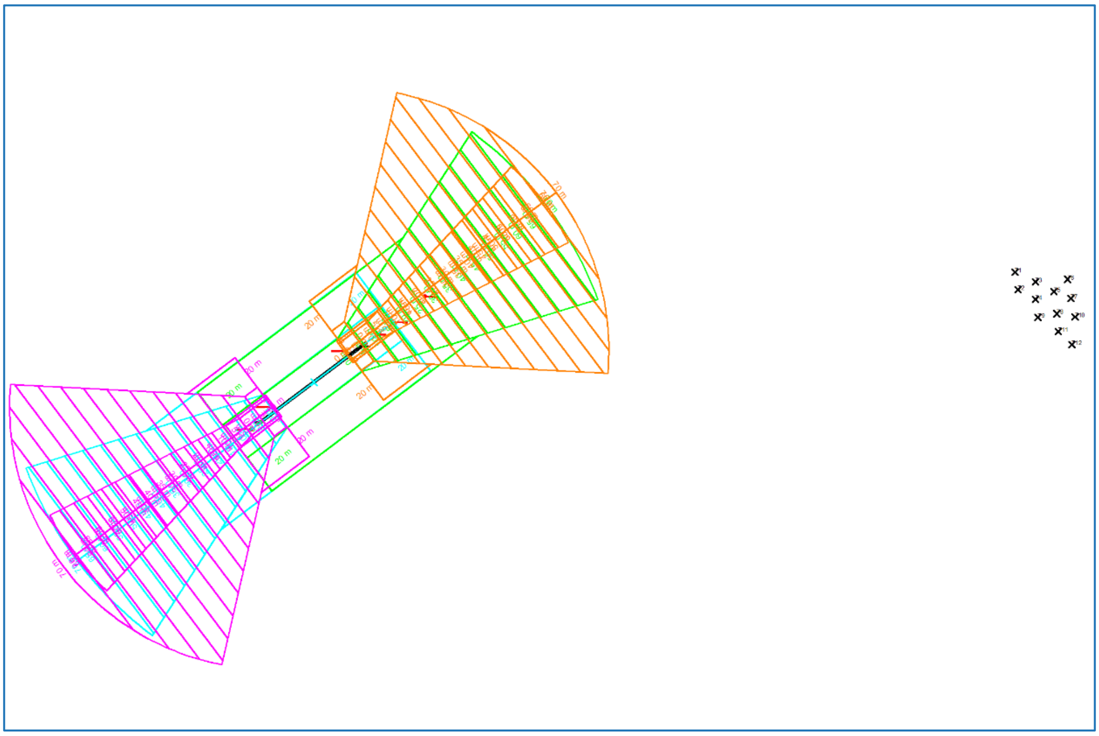


Figure 6: ILS safeguarded areas relative to proposed turbines

4.2.7. The proposed turbines lie outside the ILS safeguarded areas and will have no impact on ILS signals. No further technical assessment for the ILS facilities at Shannon Airport is required.

5. Radar Assessment

5.1. Potential Impact of Wind Turbines on PSR

5.1.1. A PSR transmits pulses of energy that are reflected back to the radar's receiver by objects that are within RLoS. Wind turbines can act as reflectors presenting a static target to the radar system. This phenomenon is no different to any other reflection received from ground obstacles (buildings, electricity pylons etc) except that each turbine structure reflects an amount of energy several orders of magnitude larger than that caused by an aircraft. This has the potential effect of causing a shadow behind the obstacle rendering the receiver blind to wanted targets in the immediate area beyond the turbine. It is thus not possible to reduce the gain of the radar in this range cell and still see the wanted targets.

5.1.2. PSRs will 'see' any reflecting object that the radar energy illuminates. To discriminate wanted targets (aircraft) from the unwanted clutter, the radar ignores static objects and only displays moving targets. The rotating blades of a wind turbine impart a Doppler frequency shift to the reflected radar pulse, which the radar receiver 'sees' as a moving target; these targets are then presented on the Air Traffic Control Officers (ATCOs) radar display as primary radar returns, indistinguishable from those returns originating from aircraft. This is not a steady effect but has dependency on the axis of rotation of the turbine in relation to the radar. Such unwanted radar returns are known as 'clutter'.

5.1.3. PSRs are usually designed to manage the amount of clutter within defined cells using Constant False Alarm Rate (CFAR) algorithms. In areas of high clutter returns, as experienced from wind turbines, the CFAR action is to reduce the sensitivity of the receiver. Whilst this has the positive benefit of keeping the displayed data usable by the ATCOs rather than being totally swamped with clutter returns, it does have the adverse effect of reducing the PD of aircraft within the affected cells.

5.1.4. A consequence of these effects is that the tracking mechanism in the radar processing is no longer able to reliably report the aircraft's passage in the vicinity of the turbines. The aircraft's track is liable to either be lost or 'seduced' by the turbine returns to create an erratic course.

5.1.5. If the radar cannot distinguish a wanted target (aircraft) amongst the returns originated by the turbines it can result in an undecipherable data display to the ATCO. In the worst case, the presence of a real aircraft, possibly in confliction with another aircraft under control, may be hidden by turbine-induced clutter or a desensitized receiver thereby increasing the risk of collision. Furthermore, false targets when presented on the ATCO's radar screen may appear as conflicting traffic to other real aircraft, resulting in the issuance of unnecessary avoiding action. In addition, the establishment by the ATCO of aircraft identity may be delayed or subsequently lost altogether in the vicinity of a wind farm.

5.2. Potential Impact of Wind Turbines on MSSR

5.2.1. Unlike PSR, MSSR is an 'active' system. It operates by the radar transmitting a coded pulse sequence which is received and decoded by suitably equipped aircraft. The aircraft responds with a coded pulse sequence on a different frequency which is received by the MSSR. Range and azimuth information is derived in the same way as PSR, but additional information in the coded reply allows the identification of a particular aircraft and its height. Other data may also be made available dependant on the mode of operation.

5.2.2. MSSR is immune to direct reflections (monostatic back scatter) from large objects such as wind turbines because the transmitted and received frequencies differ and the message structure is different for transmit and receive paths.

5.2.3. Bistatic reflection is where the signal transmitted by the radar is 'forward' reflected to an aircraft, and the aircraft reply is also reflected back to the radar. The effect of this is best understood by considering the following diagrams.

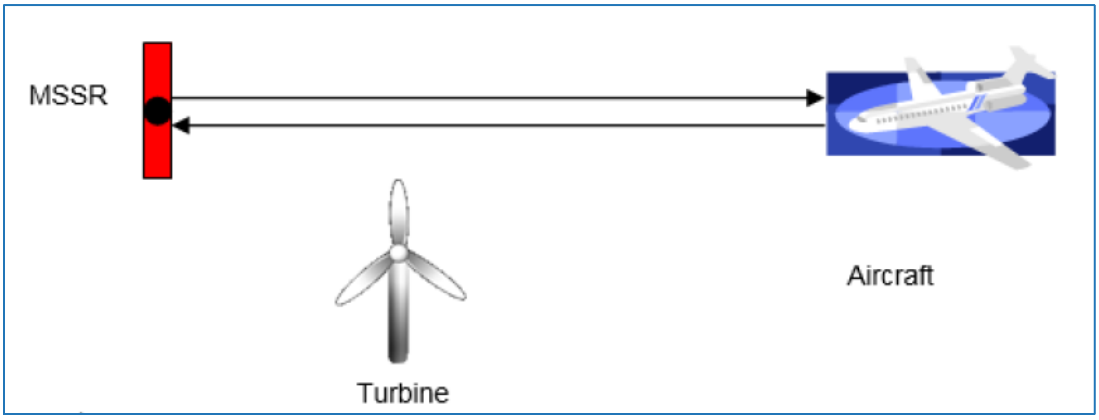


Figure 7: Direct interrogation and reply pulses

5.2.4. In Figure 7, the MSSR transmits an interrogation pulse sequence and the aircraft, on receiving the interrogation sequence, replies with a coded pulse sequence. The time delay between interrogation and receipt of reply is proportional to the distance of the aircraft from the radar. The bearing of the aircraft is the physical bearing of the radar antenna.

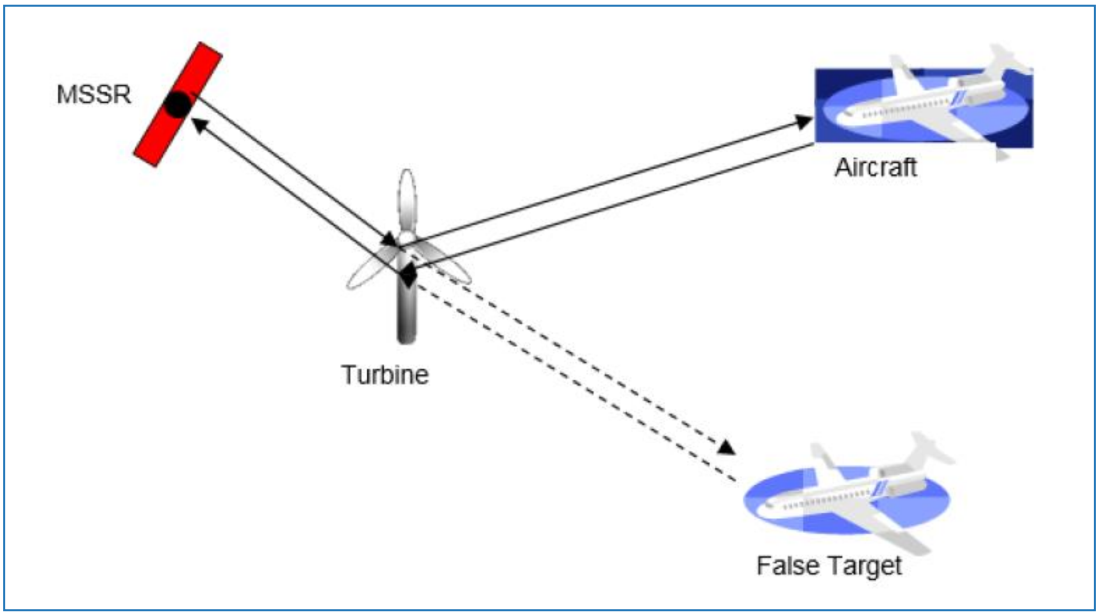


Figure 8: Reflected interrogation and reply pulse

5.2.5. In Figure 8, the MSSR beam illuminates a wind turbine which reflects the interrogation to an aircraft on a different bearing. The aircraft transponder replies, and this is received by the radar via the turbine. The radar processes this as a false target on the bearing of the wind turbine and at a distance proportional to the path length, which is slightly longer than the direct path length.

5.2.6. Objects can produce a radar shadow in the airspace behind the object. As a wind turbine is narrow compared to the radar beam width, assuming the turbine is >2km from the radar, the shadow will be relatively small, and will reduce with increasing distance behind the turbine. Shadowing effects are likely to be insignificant but, due to diffraction of the beam around the turbine tower, small azimuth angular errors may be introduced. Aircraft targets in this area can potentially be subject to track jitter causing the returns to meander from side to side. This can only occur where the turbine is in the direct RLoS between the radar and the aircraft target.

5.3. Shannon Airport Radar

5.3.1. The radar at Shannon Airport is a combined head with co-mounted PSR and MSSR antennas.

5.3.2. The PSR model is a Thales Star 2000, operating in the S-Band frequency, turning at 15 Revolutions Per Minute (RPM) and with an instrumented range of 60 Nautical Miles (NM). As with all PSRs of this type, it is vulnerable to the adverse effects of wind turbines, however, Thales claim to have newer processing capabilities which are more turbine tolerant.

5.3.3. The MSSR model is a Thales RSM 970 S. It meets the current standard of MSSR capability to the European Mode S Functional Specification[2] and has an instrumented range of 256NM.

Image © 2021 Google © 2021 Europa Technologies
Figure 9: Shannon PSR/MSSR

5.3.4. The WGS84 coordinates for the radar are: 52° 42' 05.03'' N, 08° 56' 11.74'' W

5.3.5. The PSR antenna height is 16m AGL, the MSSR antenna height is 18m AGL.

[2] EUROCONTROL European Mode S Station Functional Specification v3.11, May 2005

5.3.6. The location of Shannon PSR/MSSR is shown in Figure 10.

© OpenStreetMap contributors

Figure 10: Location of Shannon PSR/MSSR

5.4. Woodcock Hill Radar

5.4.1. The radar at Woodcock Hill is a Thales RSM 970 S MSSR and is housed in a polycarbonate radome.

Image © 2021 Google

Figure 11: Woodcock Hill MSSR

5.4.2. The WGS84 coordinates for the radar are: 52° 43' 15.77'' N, 08° 42' 26.78'' W

5.4.3. The MSSR antenna height is 10m AGL.

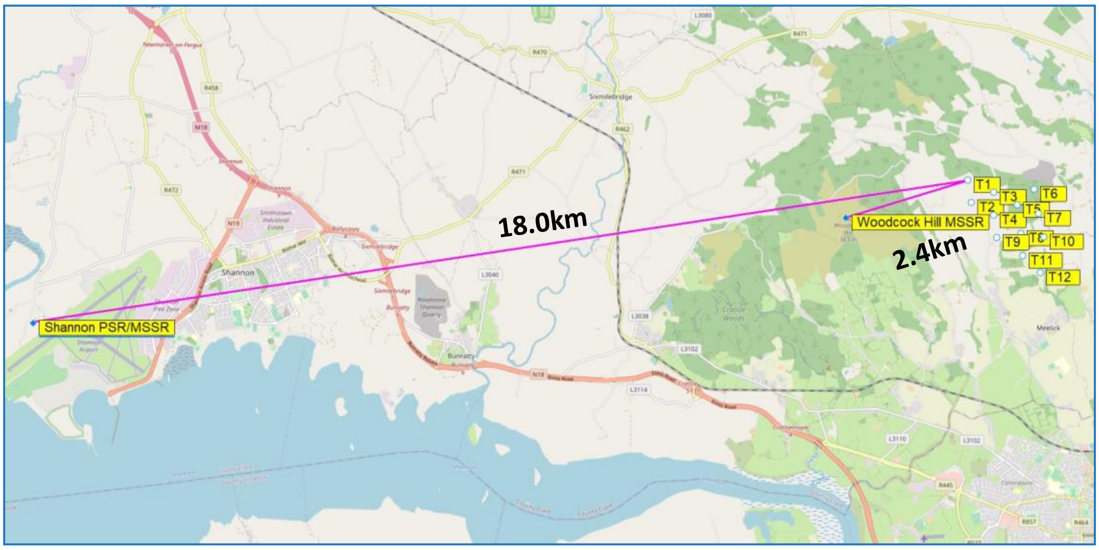
5.4.4. The location of Woodcock Hill MSSR is shown in Figure 12.

© OpenStreetMap contributors

Figure 12: Location of Woodcock Hill MSSR

5.5. Locations of Turbines and Radars

5.5.1. The relative locations of the proposed turbines and the radars at Shannon Airport and Woodcock Hill are shown in Figure 13.



© OpenStreetMap contributors

Figure 13: Locations of radars and proposed turbines

5.5.2. The closest proposed turbine within Ballycar Wind Farm (T1) is 18.0km from the Shannon PSR/MSSR, and 2.4km from Woodcock Hill MSSR.

5.5.3. In accordance with Eurocontrol Guidelines[3], the wind turbine assessment zone for MSSR facilities extends to 16km. Beyond this range the impact of a wind turbine is considered to be tolerable. Therefore, an assessment of the impact on the Shannon MSSR is not required.

5.6. Radar Line of Sight Modelling

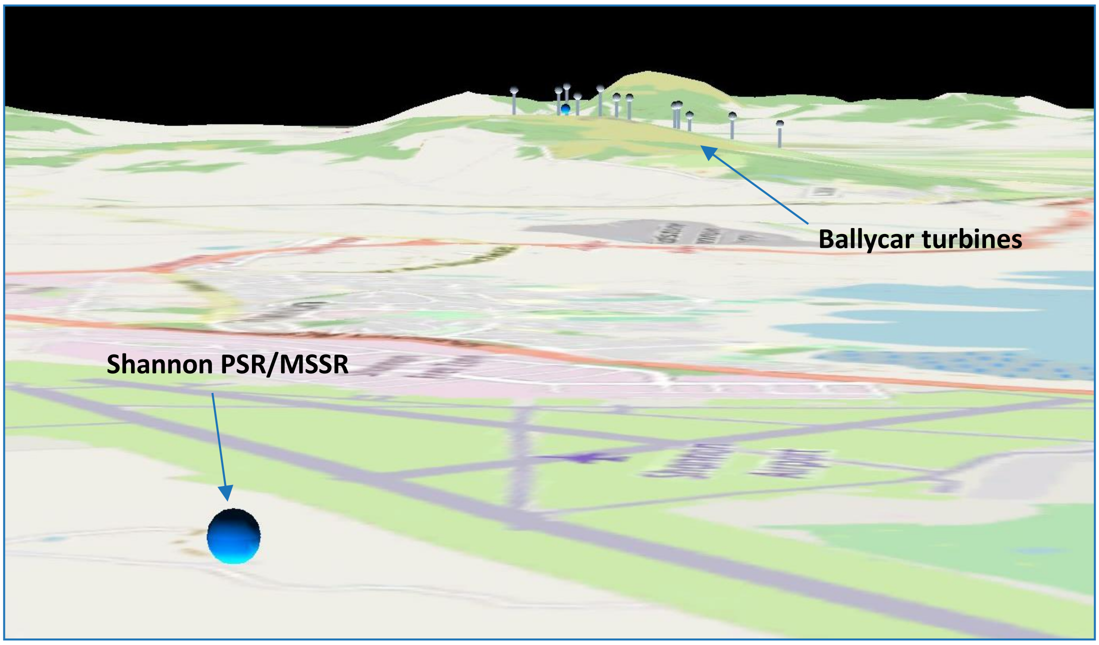
5.6.1. RLoS is determined from a radar propagation model (ATDI HTZ communications) using 3D DTM data with a 20m horizontal resolution. Radar data is entered into the model and RLoS to the turbines from the radars is calculated.

5.6.2. Note that by using DTM no account is taken of possible further shielding of the turbines due to the presence of structures or vegetation that may lie between the radars and the turbines. Thus, the RLoS assessments are worst-case results.

5.6.3. For PSR, the principal sources of adverse wind farm effects are the turbine blades, so for Shannon PSR RLoS is calculated for the maximum tip height of the turbines, i.e. 156.5m AGL.

5.6.4. In the case of MSSR, adverse effects are generated by the turbine towers, so for Woodcock Hill MSSR RLoS is calculated for the maximum hub height of the turbines, i.e. 90m AGL.

5.6.5. A 3D view of the turbines and the terrain model, as viewed from Shannon PSR/MSSR, is shown in Figure 14.

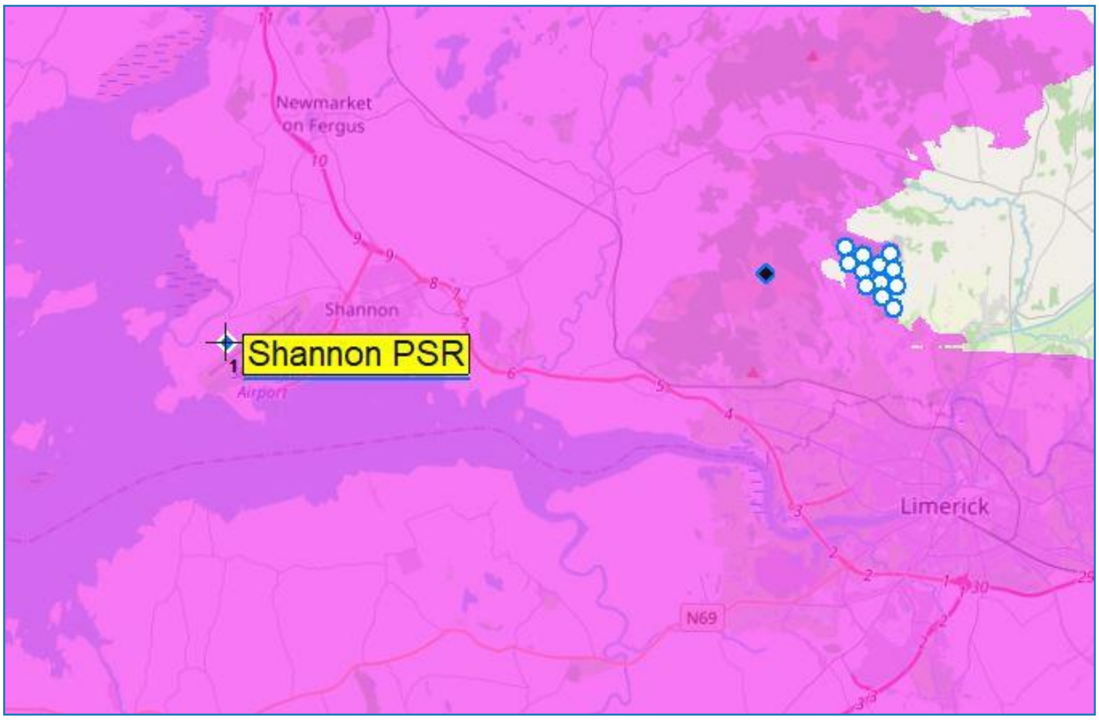


© OpenStreetMap contributors

Figure 14: 3D view from Shannon PSR/MSSR towards turbines

[3] EUROCONTROL Guidelines for Assessing the Potential Impact of Wind Turbines on Surveillance Sensors, EUROCONTROL-GUID-0130 Edition Number 1.2, September 2014

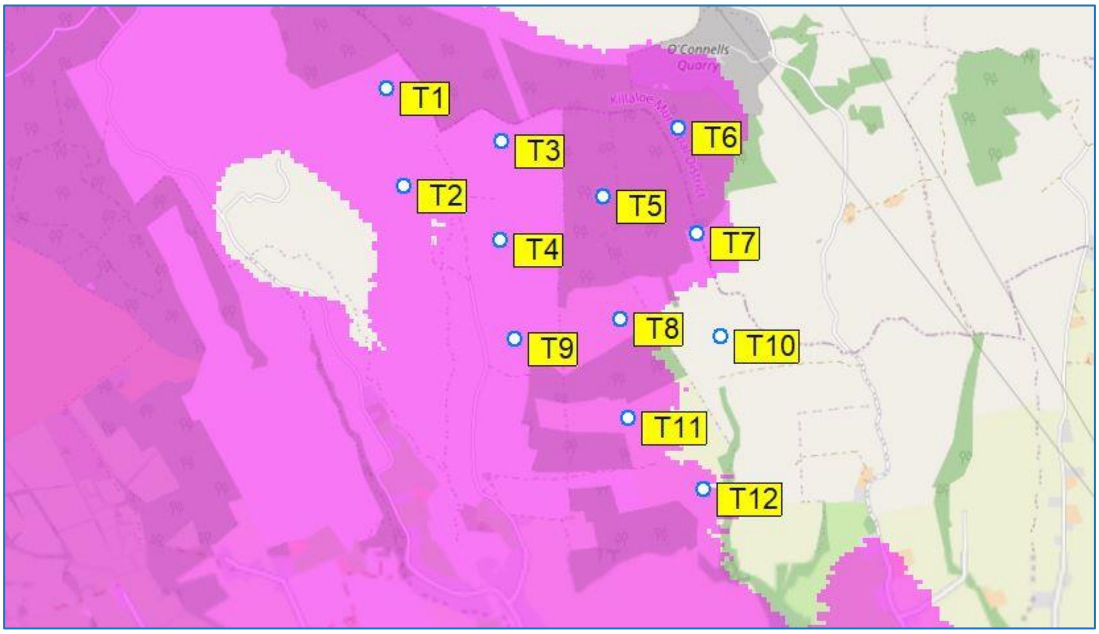
5.6.6. The magenta shading in Figure 15 illustrates the RLoS coverage from Shannon PSR to turbines with a blade tip height of 156.5m AGL.



© OpenStreetMap contributors

Figure 15: Shannon PSR RLoS to 156.5m AGL

5.6.7. A zoomed view of the RLoS coverage in the vicinity of the proposed turbines is shown in Figure 16.



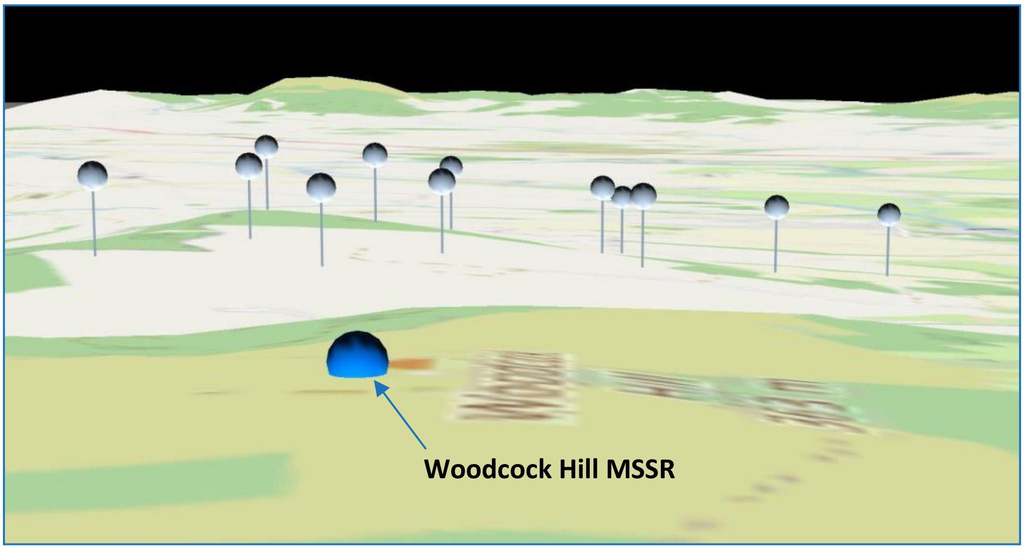
© OpenStreetMap contributors

Figure 16: Shannon PSR RLoS to 156.5m AGL – zoomed

5.6.8. The magenta shading indicates that RLoS exists between Shannon PSR and all the turbines except turbine T10 in the indicative layout. The planned turbine T10 tip height is 149.5m AGL. RLoS will not exist between Shannon PSR and turbine T10 at the lower tip height.

5.6.9. Where RLoS exists it can be assumed that the PSR will detect the turbines, and where there is no RLoS it can generally be assumed that the turbine will not be detected. However, this can only be confirmed by analysing the path profiles between the PSR and each turbine and calculating the PD using known PSR parameters. This is undertaken in Section 5.7.

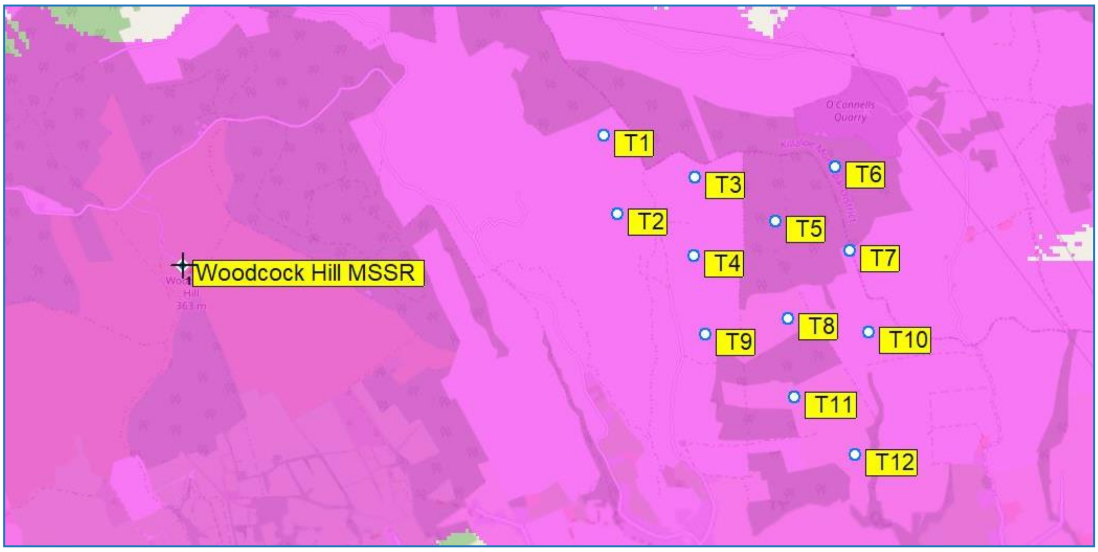
5.6.10. A 3D view of the turbines and the terrain model, as viewed from Woodcock Hill MSSR, is shown in Figure 17.



© OpenStreetMap contributors

Figure 17: 3D view from Woodcock Hill MSSR towards turbines

5.6.11. The magenta shading in Figure 18 illustrates the RLoS coverage from Woodcock Hill MSSR to turbines with a tower hub height of 90m AGL.

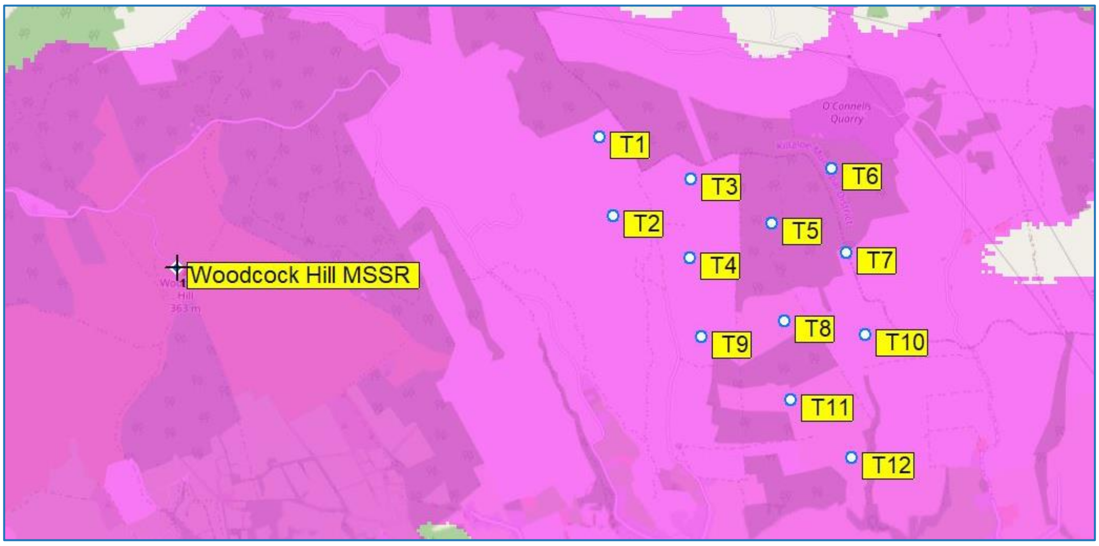


© OpenStreetMap contributors

Figure 18: Woodcock Hill MSSR RLoS to 90m AGL

5.6.12. RLoS at 90m AGL exists between Woodcock Hill MSSR and all the turbines in the indicative layout.

5.6.13. To account for the reduced T10 hub height, RLoS coverage at 83m AGL is shown in Figure 19.



© OpenStreetMap contributors

Figure 19: Woodcock Hill MSSR RLoS to 83m AGL

5.6.14. RLoS between Woodcock Hill MSSR and turbine T10 still exists at the reduced hub height of 83m AGL.

5.7. Shannon PSR Path Loss and Probability of Detection

5.7.1. Using the radar propagation model the actual path loss between Shannon PSR and various parts of each turbine can be determined.

5.7.2. An illustration of the path loss profile between Shannon PSR and the tip of turbine T1 is shown in Figure 20. Shannon PSR has uninterrupted RLoS to the turbine tip.

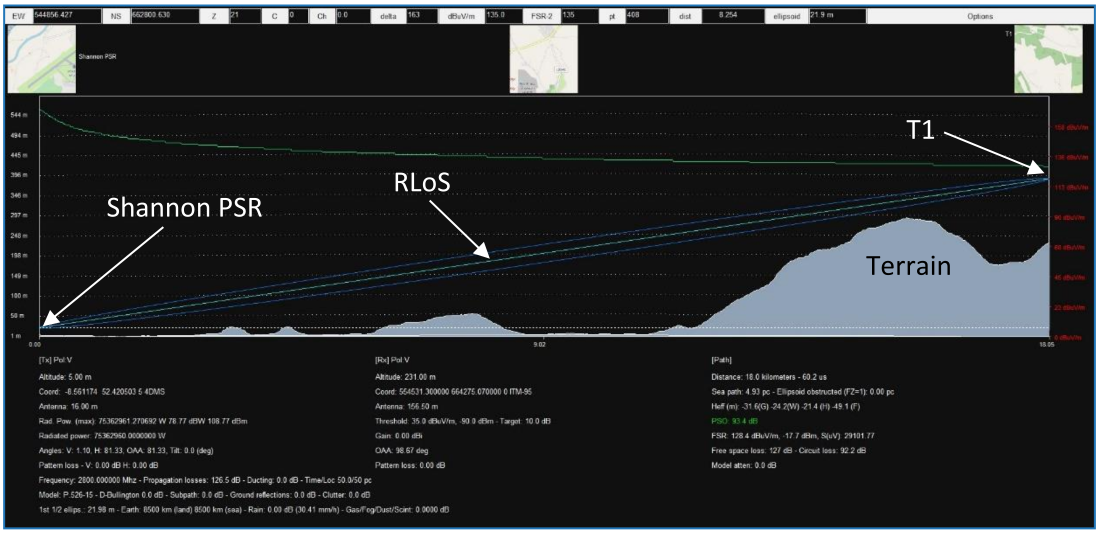


Figure 20: Path loss profile between Shannon PSR and tip of turbine T1

5.7.3. The path loss profile between Shannon PSR and the tip of turbine T10 is shown in Figure 21. In this case there is intervening terrain which blocks RLoS.

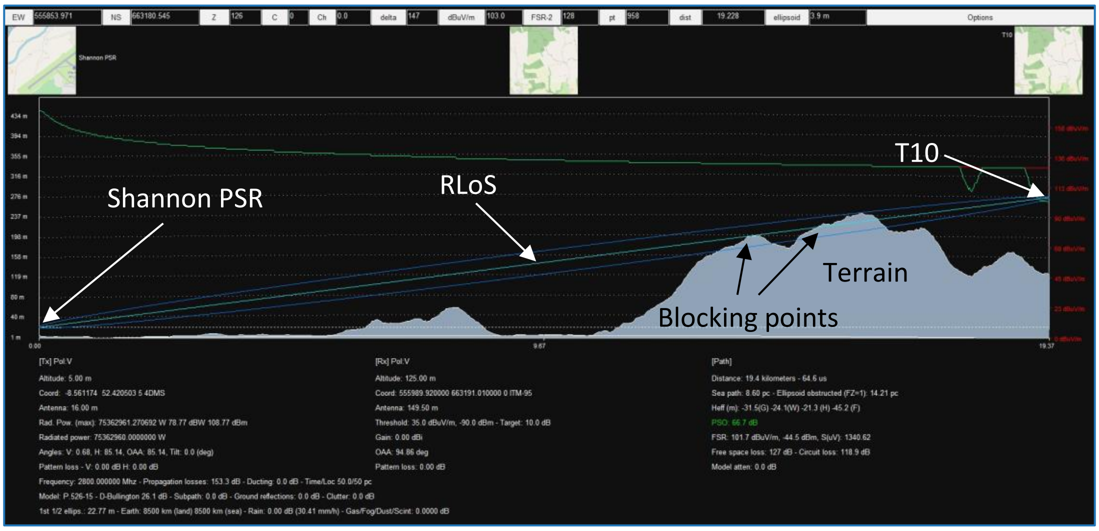


Figure 21: Path loss profile between Shannon PSR and tip of turbine T10

5.7.4. All the path profiles between Shannon PSR and the 12 Ballycar turbines are shown in Annex A of this report.

5.7.5. Even with no intervening terrain between the PSR and the turbines, the probability that a turbine will be detected by the radar is still dependant on several factors including the radar's power, the angle of antenna tilt and distance to the turbine.

5.7.6. The radar propagation model can determine the actual path loss between the PSR and various parts of the turbine. By knowing the PSR transmitter power, antenna gain, 2-way path loss, receiver sensitivity and the turbine Radar Cross Section (RCS) gain, the probability of the radar detecting the target (PD) can be calculated.

5.7.7. The static parts of the turbine (tower structure) are ignored in the calculation as these will be rejected by the radar Moving Target filter. In this refined model, 3 parts of the turbine blade are considered: the hub, the blade tip, and a point midway along the turbine blade. Each part of the turbine blade is assigned an RCS of $50m^2$ based on a blade length of 66.5m. Path loss calculations are made to all turbines. The received signal at the radar from each component part of the turbine is then summed to determine the total signal level.

5.7.8. The path loss calculation carried out for each turbine component is as follows:

	Tx Power	dBm
+	Antenna Gain	dB
-	Path Loss	dB
+	RCS Gain	dB ($60m^2$ ~ +47dB)
-	Path Loss	dB
+	Antenna Gain	dB
=	Received Signal	dBm

5.7.9. The received signal is then compared with the radar receiver Minimum Detectable Signal level.

5.7.10. An example of the calculation from Shannon PSR to turbine T1 is shown in Figure 22.

Radar 2-Way Path Loss Calculator

Data		
Tx Frequency	2800	MHz
Tx Power	28000	Watts
Antenna Gain	34	dBi
Rx Sensitivity	-125	dBm
Target		
RCS	50	m^2
Path Loss (1-way)	126.5	dB
Calculations		
Tx Wavelength	0.11	m
Tx power	74.47158	dBm
EIRP	108.4716	dBm
Power at Target	-18.02842	dBm
RCS Gain	47.39	dB
Power at Rx	-63.14	dBm
dB over Rx Threshold	61.86	dB

Figure 22: Example path loss calculation

5.7.11. The two-way path losses from the turbine components are tabulated and combined to give total radar received signals from each turbine. The results are colour-coded to indicate the likelihood of detection. Radar returns >3dB above the detection threshold are coloured green as these values show a high probability of detection. Those between +3dB and -3dB are coloured yellow and indicate a possibility of detection. Between -3dB and -6dB, results are coloured orange to show only a small possibility of detection. Signals >6dB below the threshold of detection are shaded red as these values show that detection is unlikely.

5.7.12. Using this representation provides a ready visual comparison of different scenarios. The result is shown in the final column (TOTAL) of each colour-coded chart.

5.7.13. The results of the Shannon PSR PD calculations for each turbine are shown in Table 3.

Initial data from '2-Way'				KEY:	
A	126.5	Path Loss			Unlikely to be detected
B	61.86	dB over Rx Thr			Small possibility of detection
C	50.00	RCS (m^2)			Possibility of detection
					High probability of detection

Turbine	Turbine Nacelle Path Loss dB	Blade mid-point Path Loss dB	Blade Tip Path Loss dB	TOTAL dB over RX threshold
1	152.2	126.5	126.5	64.87
2	161.4	151.1	126.5	61.86
3	155.1	130.2	126.7	62.25
4	160.1	148.3	126.7	61.46
5	154.5	130.0	126.9	62.00
6	152.6	127.1	127.1	63.67
7	160.6	152.0	127.1	60.66
8	160.5	150.6	126.9	61.06
9	158.0	139.9	126.7	61.47
10	165.5	161.3	153.3	8.39
11	161.6	152.7	126.9	61.06
12	162.5	155.5	137.0	40.86

Table 3: Shannon PSR PD results

5.7.14. From Table 3 it appears that there is a high probability that Shannon PSR will detect all the Ballycar turbines.

5.7.15. The above calculations are based on the optimum performance of the radar, however the gain of a radar antenna in the vertical axis is not uniform with elevation angle. The beam is a complex shape to minimise ground returns by having low gain at elevations close to the horizontal but having high gain at elevations just a few degrees above the horizon.

5.7.16. The Star 2000 PSR has a dual beam antenna. At short ranges the radar uses a high beam to reduce the effects of close-in ground clutter. Beyond these ranges a low beam is used. It is likely that the proposed wind farm lies in Shannon PSR's high beam area.

5.7.17. The maximum high beam gain for a Star 2000 antenna usually occurs at an elevation angle of 6.5° above the horizontal and the maximum low beam gain at about 3°. If the mechanical tilt of the antenna is altered, then the angles of maximum gain will change by a corresponding amount. The mechanical tilt of the antenna is set at the commissioning of the radar to achieve the best compromise between suppressing ground returns and detecting low altitude aircraft targets. Gain falls off rapidly at lower elevation angles as a function of the antenna Vertical Polar Diagram (VPD). Radar VPD data can be plotted as a smoothed line of elevation versus gain to enable intermediate values of antenna gain to be determined.

5.7.18. The Star 2000 VPD data gives the graph shown in Figure 23.

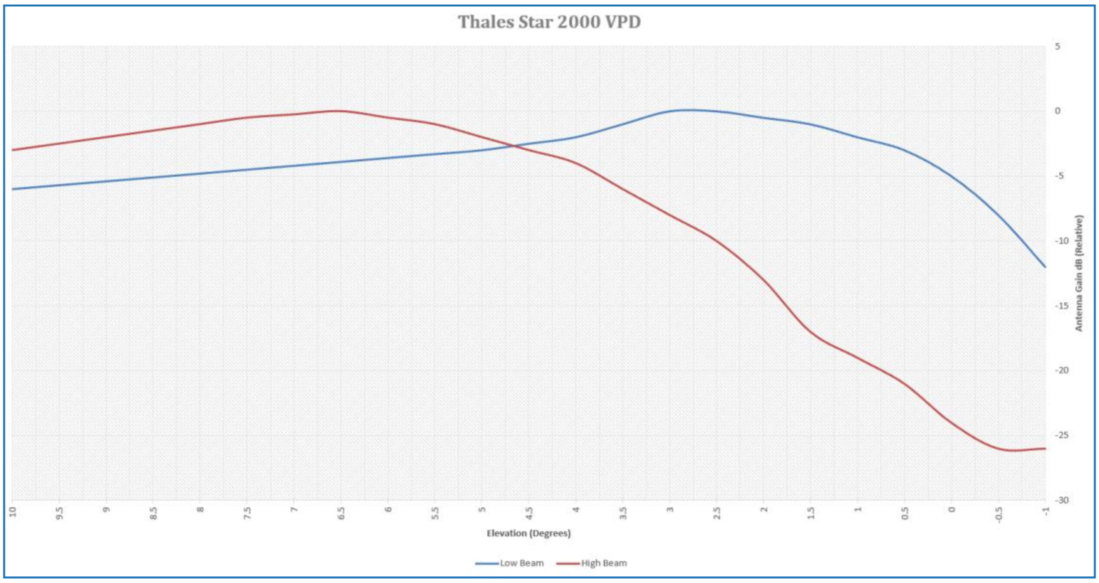


Figure 23: Thales Star 2000 VPD

5.7.19. The vertical angle from Shannon PSR to the tips of the turbines varies between 0.57° (turbine T12) and 1.10° (turbine T1). If a 0° mechanical antenna tilt is assumed, this means a high beam gain reduction of approximately -20dB and a low beam gain reduction of approximately -3dB at these elevations. Table 4 shows the results of the PD calculations incorporating the reduction in antenna gain.

Initial data from '2-Way'				KEY: Unlikely to be detected
A	126.5	Path Loss		Small possibility of detection
B	38.86	dB over Rx Thr		Possibility of detection
C	50.00	RCS (m^2)		High probability of detection
	Turbine Nacelle	Blade mid-point	Blade Tip	TOTAL
Turbine	Path Loss dB	Path Loss dB	Path Loss dB	dB over RX threshold
1	152.2	126.5	126.5	41.87
2	161.4	151.1	126.5	38.86
3	155.1	130.2	126.7	39.25
4	160.1	148.3	126.7	38.46
5	154.5	130.0	126.9	39.00
6	152.6	127.1	127.1	40.67
7	160.6	152.0	127.1	37.66
8	160.5	150.6	126.9	38.06
9	158.0	139.9	126.7	38.47
10	165.5	161.3	153.3	-14.61
11	161.6	152.7	126.9	38.06
12	162.5	155.5	137.0	17.86

Table 4: Shannon PSR PD results – corrected for VPD

5.7.20. With the gain reduction, it is unlikely that Shannon PSR will detect turbine T10. However, there is still a high probability that Shannon PSR will detect the rest of the Ballycar turbines.

5.8. Woodcock Hill MSSR Path Loss

5.8.1. Using the radar propagation model the actual path loss between Woodcock Hill MSSR and the tops of the Ballycar turbine towers can be determined.

5.8.2. An illustration of the path loss profile between Woodcock Hill MSSR and turbine T1 is shown in Figure 24. As with all the other Ballycar turbines, Woodcock Hill MSSR has uninterrupted RLoS to the top of the turbine tower.

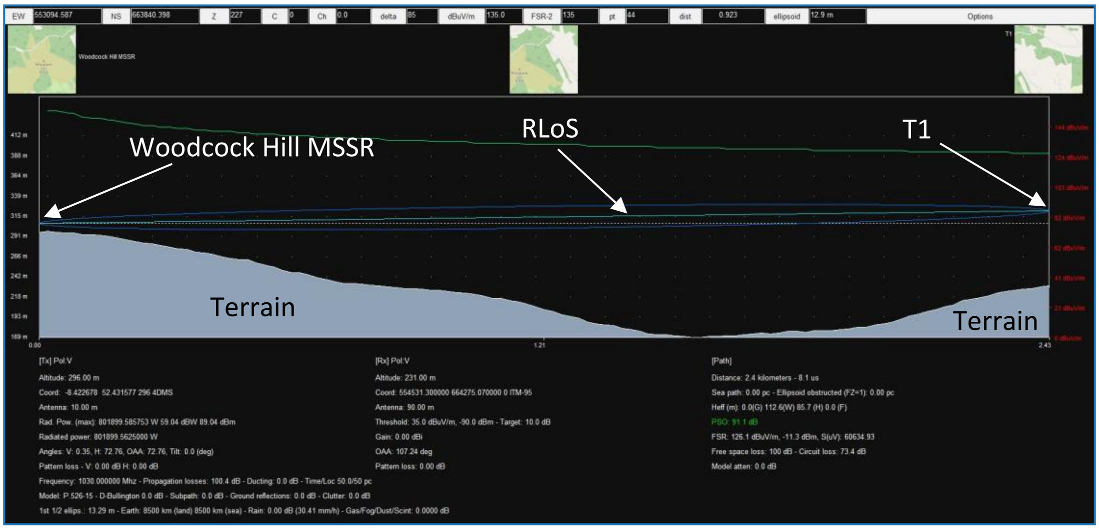


Figure 24: Path loss profile between Woodcock Hill MSSR and top of turbine tower T1

5.8.3. All the path profiles between Woodcock Hill MSSR and the 12 Ballycar turbines are shown in Annex B of this report.

5.8.4. As explained in Section 5.2, multipath, or bistatic, reflections from turbine towers can potentially cause 'ghost' targets on MSSR. This occurs when an aircraft replies through a signal reflected from an obstruction; the radar attributes the response to the original signal and outputs a false target in the direction of the obstruction, which can lead to ATCOs deconflicting real traffic from targets that do not physically exist.

5.8.5. The likelihood of bistatic reflections can be determined by knowing the MSSR transmitter power, antenna gain, path loss to the turbine tower, RCS gain and aircraft receiver sensitivity.

5.8.6. The amount of signal reflected by a turbine tower is a function of the tower's RCS. A typical RCS value for a 100m steel tower of 8m diameter is 3,000,000m^2. However, a 0.5° taper of the tower can reduce this figure from millions to hundreds of square metres.

5.8.7. EUROCONTROL Guidelines[4] recommend an RCS value of $10^{3.5}m^2$ or $35dBm^2$ for a turbine tower which equates to an RCS gain of 57dB at the MSSR uplink frequency of 1030MHz.

[4] EUROCONTROL Guidelines for Assessing the Potential Impact of Wind Turbines on Surveillance Sensors, EUROCONTROL-GUID-0130 Edition Number 1.2, September 2014

5.8.8. The following calculation can be used to determine the power of a radar signal reflected by a wind turbine tower:

	Tx Power	dBm
+	Antenna Gain	dB
-	Path Loss	dB
+	RCS Gain	dB (35dBm^2 ~ +57dB)
=	Reflected Power	dBm

5.8.9. Free Space Path Loss can be used to calculate the maximum distance from the reflecting obstacle an aircraft can be in order for the reflected signal to trigger a response from the aircraft transponder.

5.8.10. The maximum range at which a reflection can trigger a response is proportional to the reflected power of the signal. From the above calculation, reflected power is greatest when the path loss between the MSSR and a turbine is the least.

5.8.11. Using the radar propagation model the actual path loss between Woodcock Hill MSSR and the tops of the Ballycar turbine towers can be determined.

5.8.12. The path loss results between Woodcock Hill MSSR and the tops of the 12 Ballycar turbine towers are shown in Table 5.

Turbine	Path Loss (dB)
T1	100.4
T2	100.4
T3	101.8
T4	101.7
T5	103.0
T6	103.9
T7	104.0
T8	103.2
T9	102.0
T10	104.3
T11	103.4
T12	104.4

Table 5: Woodcock Hill MSSR path loss results

5.8.13. From Table 5 the worst-case or smallest path loss is 100.4dB to turbines T1 and T2.

5.8.14. The Tx Power for a Thales RSM 970 S MSSR is 60.35dBm at the antenna input. As with the PSR, MSSR antenna gain varies with elevation angle, with peak gain of 27dB at an elevation of between 8° and 9° above the horizontal, as shown in Figure 25.

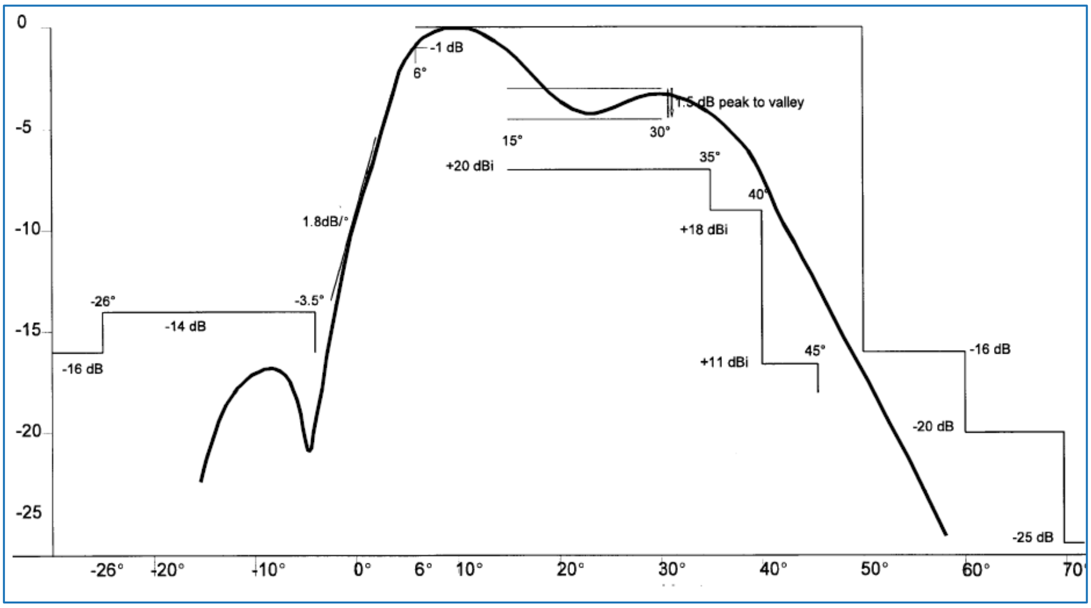


Figure 25: Thales RSM 970 S VPD

5.8.15. The vertical angle from Woodcock Hill MSSR to the hub of turbine T1 is 0.35° and to the hub of turbine T2 is -0.27°. If a mechanical tilt of 0° is assumed this means a reduction in gain of -7.5dB for T1 and -8.5dB for T2 at these elevations.

5.8.16. The T1 reduction in gain will be worst-case, and results in a reflected power of 36.2dBm from turbine T1.

5.8.17. If an aircraft receiver sensitivity of -77dBm is assumed, the reflected signal will not trigger a response if the Free Space Path Loss from the turbine to the aircraft is more than 77+36.2=113.2dB.

5.8.18. The Free Space Path Length for an MSSR frequency of 1030MHz and path loss of 113.2dB is 10,536m. This means that aircraft beyond this distance from the turbine will not detect a reflected signal. Reflected signals from other Ballycar turbines will only be detected at ranges less than 10,536m.

5.8.19. Annex D of the EUROCONTROL Guidelines states that an airborne transponder will be insensitive for 35µs following reception of a radar interrogation through radar sidelobes. Thus, an aircraft closer than 5,250m (half of the distance corresponding to 35µs) to the source of a reflected interrogation will not reply to reflected interrogations because the path length between the direct and reflected signals will always be smaller than 35µs.

5.8.20. Aircraft between 5,250m and 10,536m from the proposed turbines may respond to reflected Woodcock Hill MSSR interrogations, potentially resulting in MSSR 'ghost' targets.

5.8.21. The calculations can be repeated to determine the maximum reflection ranges for all the Ballycar turbines, as shown in Table 6.

Turbine	Maximum Reflection Range (m)
T1	10,536
T2	9,390
T3	8,967
T4	8,085
T5	7,810
T6	7,041
T7	6,204
T8	5,724
T9	6,571
T10	4,243
T11	4,443
T12	3,738

Table 6: Woodcock Hill MSSR maximum reflection ranges

5.8.22. Table 6 shows that for turbines T1 to T9 the maximum reflection range is more than 5,250m. Reflections from these turbines may result in MSSR 'ghost' targets.

5.8.23. The maximum reflection ranges for turbines T10 to T12 are less than 5,250m. An aircraft will not respond to reflected Woodcock Hill MSSR interrogations from these turbines as they will only be detected when the aircraft is within 5,250m of the turbines.

5.8.24. An array of turbines can create a radar shadow in the space beyond it from the radar. The EUROCONTROL Guidelines provides a means of calculating the dimensions of this shadow region.

$$Dwr = Dtw/[\lambda.\frac{Dtw}{S^2}\left(1-\sqrt{PL}\right)^2 - 1]$$

- *Dwr* = depth of the shadow region.
- *Dtw* = distance of turbines
- λ = wavelength (0.29m)
- S = diameter of support structures (6m)
- PL = acceptable power loss (0.5/3dB as per guidelines)

5.8.25. The EUROCONTROL Guidelines also provide equations for calculating the width and height of the shadow regions.

5.8.26. The volumes of the Woodcock Hill MSSR shadow regions created by each of the Ballycar turbines are shown in Table 7.

Turbine	Depth of shadow region (km)	Width of shadow region (m)	Height of shadow region AMSL (m)
T1	3.6	65	352
T2	3.6	65	285
T3	2.9	58	351
T4	3.0	59	270
T5	2.6	55	355
T6	2.4	53	370
T7	2.3	52	277
T8	2.5	54	210
T9	2.9	58	208
T10	2.3	52	147
T11	2.5	54	128
T12	2.3	52	83

Table 7: Woodcock Hill MSSR shadow regions

5.8.27. The depth of the shadow regions beyond the Ballycar turbines will vary between 2.3km and 3.6km for Woodcock Hill MSSR, with widths of up to 65m and with a maximum height of 352m or 1,155 feet AMSL.

5.8.28. Figure 26 shows an extract of Shannon Airport's ATC Surveillance Minimum Altitude Chart, as published by the Irish Aviation Authority in the current Integrated Aeronautical Information Publication[5]. The Ballycar turbine locations are overlaid on the chart, which shows that turbines T1 to T10 are within Sector 1 where the minimum altitude is 2,300 feet AMSL. Turbines T11 and T12 are in Sector 2 where the minimum altitude is 3,000 feet AMSL. Aircraft at these minimum altitudes will not be low enough for the shadow regions to have any impact, and therefore the shadow regions that may be generated beyond the proposed turbines should be operationally tolerable.

[5] ATC SURVEILLANCE MINIMUM ALTITUDE CHART – ICAO, EINN AD 2.24-16.1, 17 JUN 2021

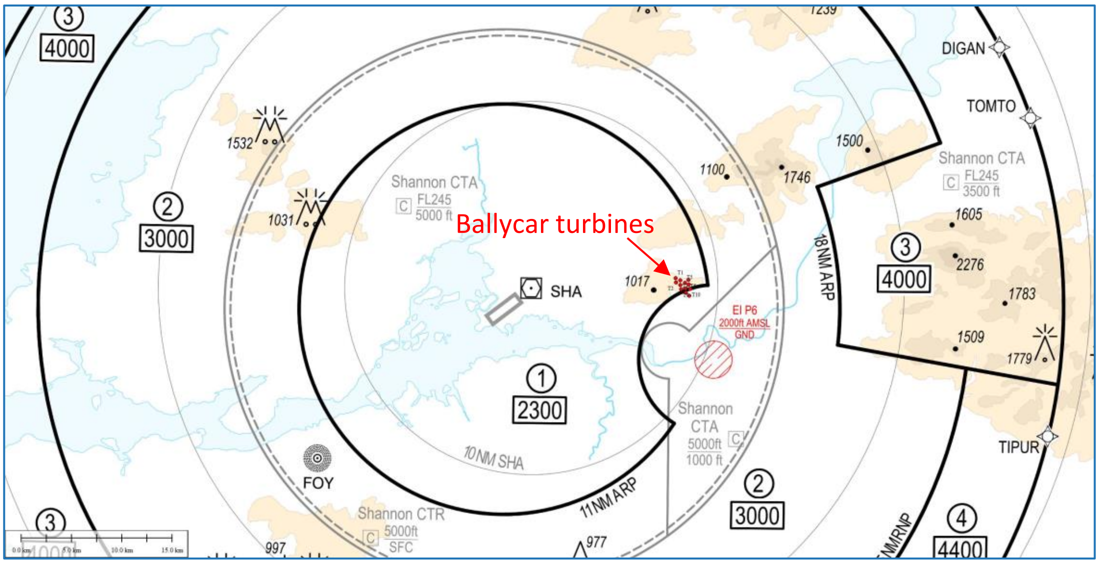


Figure 26: Shannon Airport ATC Surveillance Minimum Altitude Chart

5.9. Conclusions

5.9.1. All the proposed Ballycar turbines except turbine T10 are likely to be detected by Shannon PSR. This can result in turbine-induced clutter and false targets. In such areas of high clutter, the radar receiver sensitivity is reduced which can lead to track seduction of genuine aircraft targets in the vicinity of the turbines. A form of mitigation for Shannon PSR over the proposed Ballycar development may be required and this is discussed in Section 6.

5.9.2. All the proposed sites for the Ballycar turbines are outside the Eurocontrol recommended 16km turbine assessment zone for Shannon MSSR, therefore an impact assessment on this facility was not required. No mitigation measures are therefore necessary for Shannon MSSR.

5.9.3. Calculations have shown that false targets due to bistatic reflections from the turbine towers may occur for Woodcock Hill MSSR. Aircraft between 5,250m and 10,536m from the proposed turbines may respond to reflected Woodcock Hill MSSR interrogations, potentially resulting in MSSR 'ghost' targets appearing on the bearings of the turbines.

5.9.4. The Woodcock Hill MSSR has a reflection processing capability which enables the positions of permanent reflecting objects, such as the turbine towers, to be stored in a 'reflector file'. Once the reflector file is updated it should eliminate any false targets caused by reflections from the turbine towers.

5.9.5. The maximum heights of shadow regions from the turbines will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable.

6. Shannon PSR Mitigation

6.1. Mitigation Strategy

6.1.1. It is generally not tolerable for an airport to have to cope with a variety of mitigation solutions, each tailored for individual wind farm developments. Ideally, an airport is best served by a single coherent strategy which will cope with the turbine developments foreseen within its designated operational coverage (DOC). New development applications can then be assessed on whether they will be covered by that strategy. Terms of inclusion within the strategy can then be negotiated with the developer as part of the planning approval process. This approach keeps the airport in control of its destiny and able to work positively with the renewables industry, rather than reacting against each application on the grounds that it will cause interference.

6.1.2. It is recommended that mitigation options are discussed with the Irish Aviation Authority (IAA), specifically Air Traffic Services. It is the surveillance network and operational use that will largely influence a suitable mitigation.

6.2. Mitigation Solutions

6.2.1. Physical PSR mitigation options include blanking of PSR transmissions in the azimuth sector over the proposed wind farm, or suppressing radar returns in the wind farm range azimuth sector. Both of these options may need to be combined with in-fill of the blanked sector from another source of radar information.

6.2.2. An operational PSR mitigation solution could involve the application of a Transponder Mandatory Zone (TMZ) in the airspace over the PSR blanked area. A TMZ means detecting aircraft using MSSR facilities only and requires aircraft within the TMZ to be equipped with a functioning transponder.

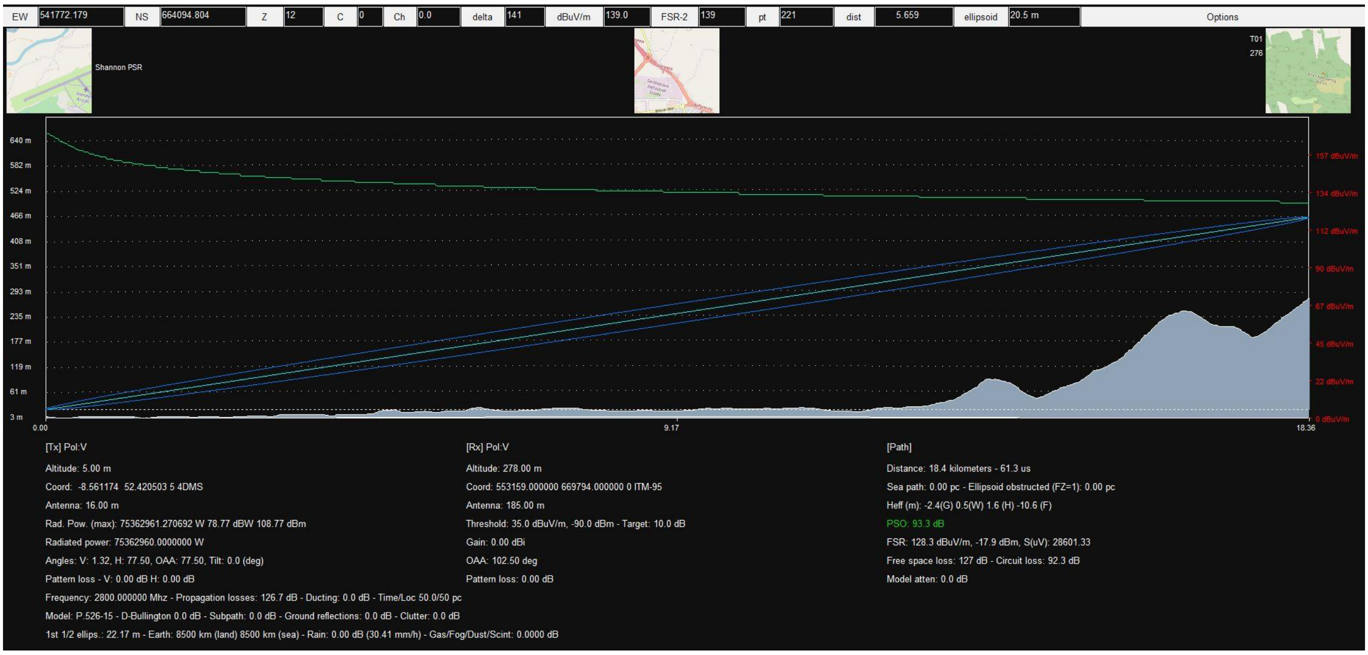
6.2.3. In-fill solutions using existing remote PSR data rely on the remote radar having suitable airspace coverage in the blanked area without having visibility of the turbines and depends on suitable terrain screening. A remote in-fill radar may also introduce problems of synchronisation with Shannon PSR and slant range errors.

6.2.4. Companies such as Terma offer dedicated 2D in-fill radar solutions for wind turbines. The in-fill radar must be located in close proximity to the airport PSR and be synchronised to it, enabling the mitigation radar to be used instead of the Airport PSR in the wind farm area. Terma radars have a narrow beamwidth that enables them to filter out turbines while continuing to track aircraft and can provide mitigation to a range of up to approximately 40NM.

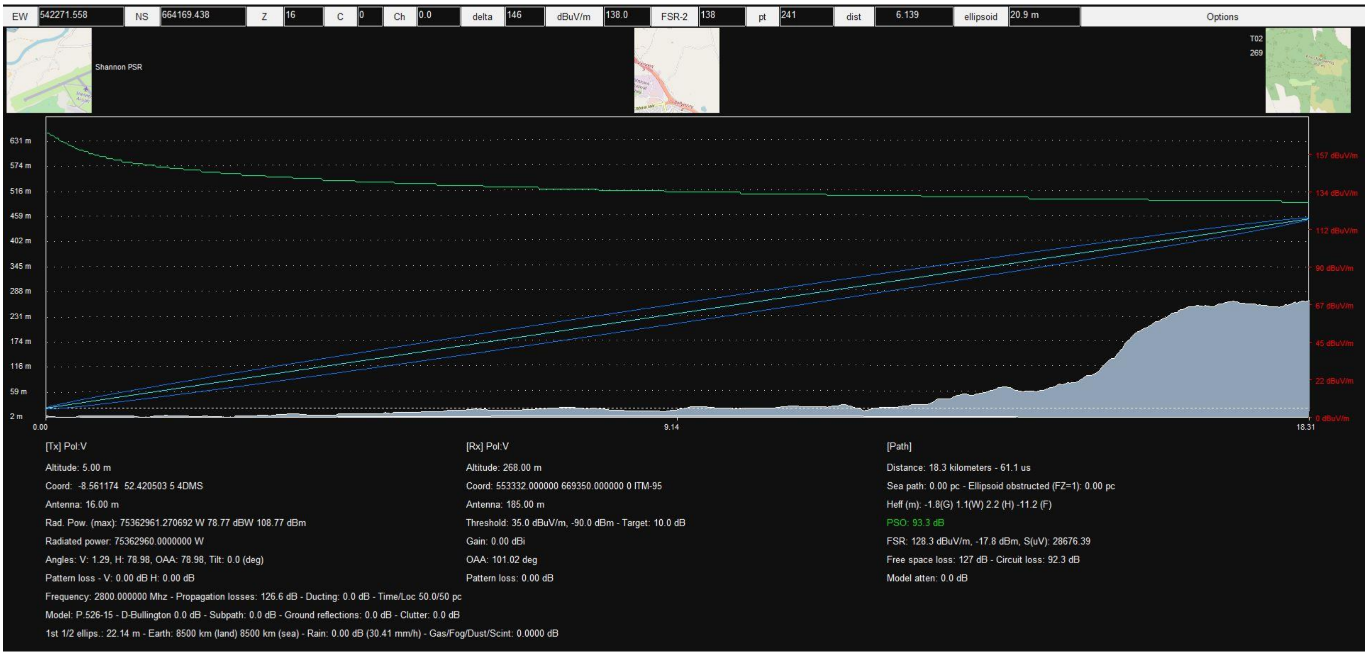
6.2.5. Aveillant offer a 3D radar mitigation solution with their Holographic Radar™. It is quite different to 2D mitigation radars as it has no rotating antenna and has continuous surveillance throughout its coverage volume. It can discriminate the distinct Doppler signatures of turbines from aircraft and as a result does not need to mask turbine returns to eliminate their false reports. The 3D output of this mitigation radar means that it does not need to be located in close proximity to the airport PSR and its target output can be coordinate transformed to the PSR origin without introducing slant range errors.

A. Annex A – Shannon PSR Path Profiles

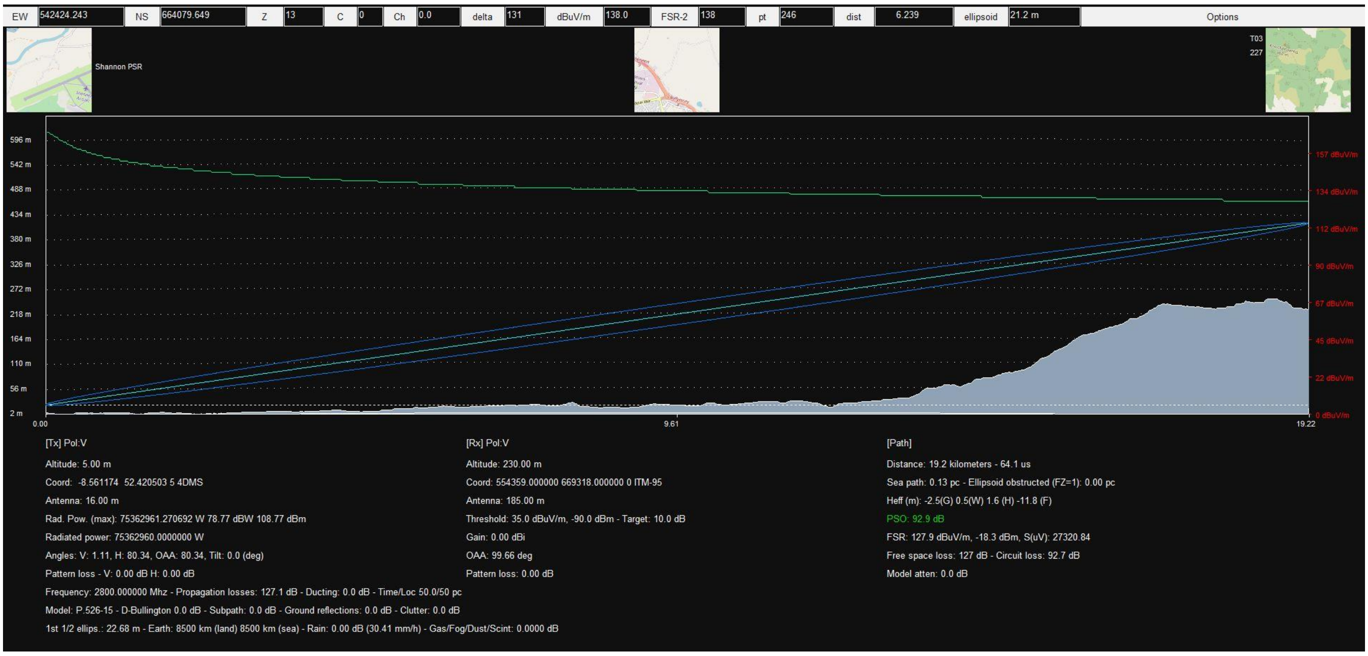
A.1. Turbine T1



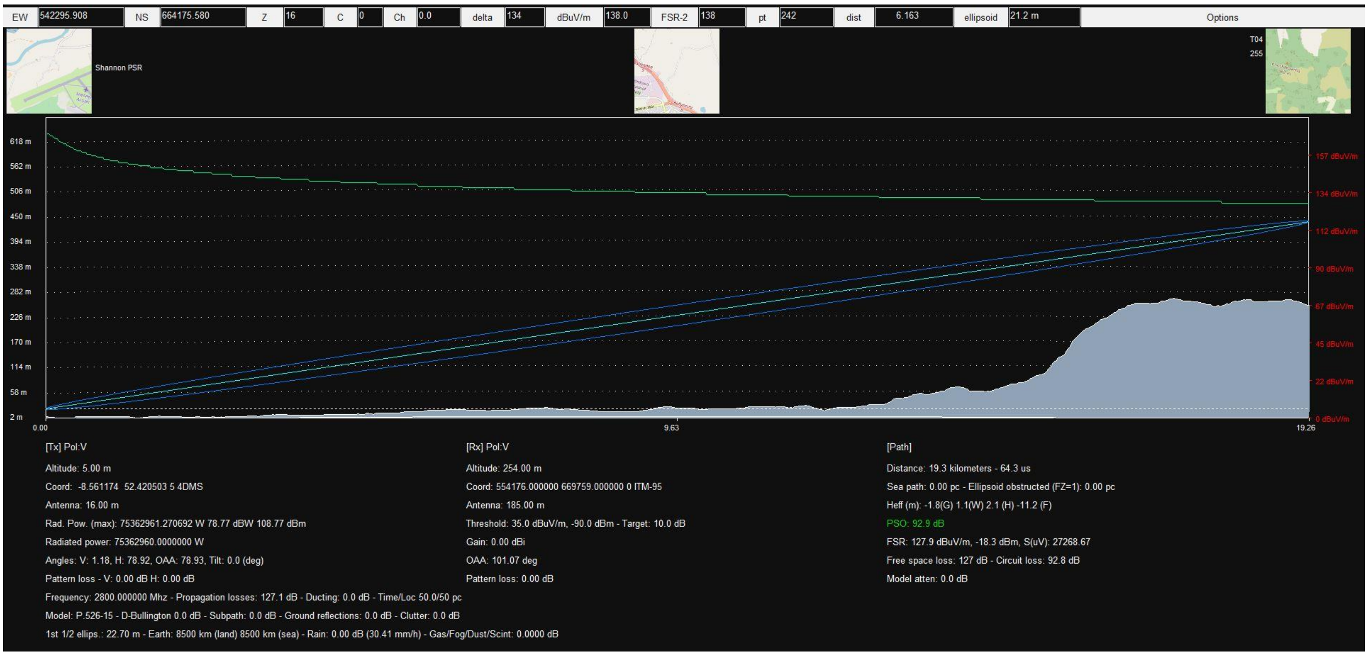
A.2. Turbine T2



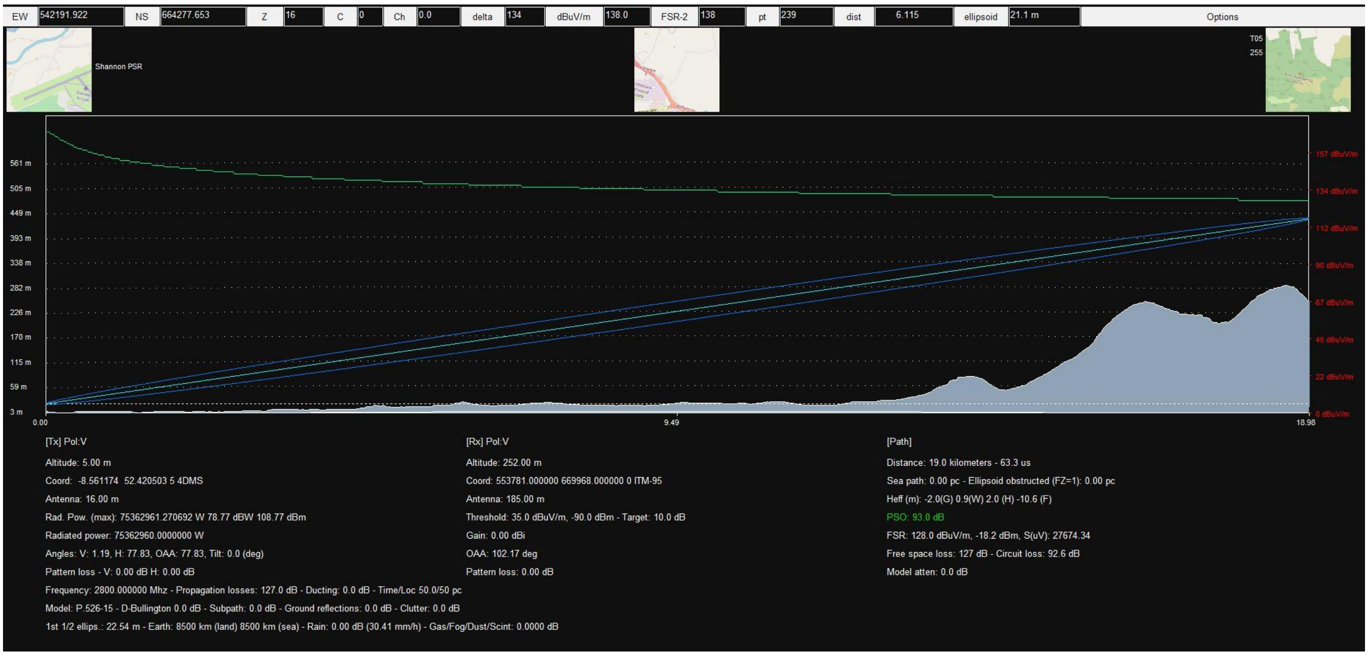
A.3. Turbine T3



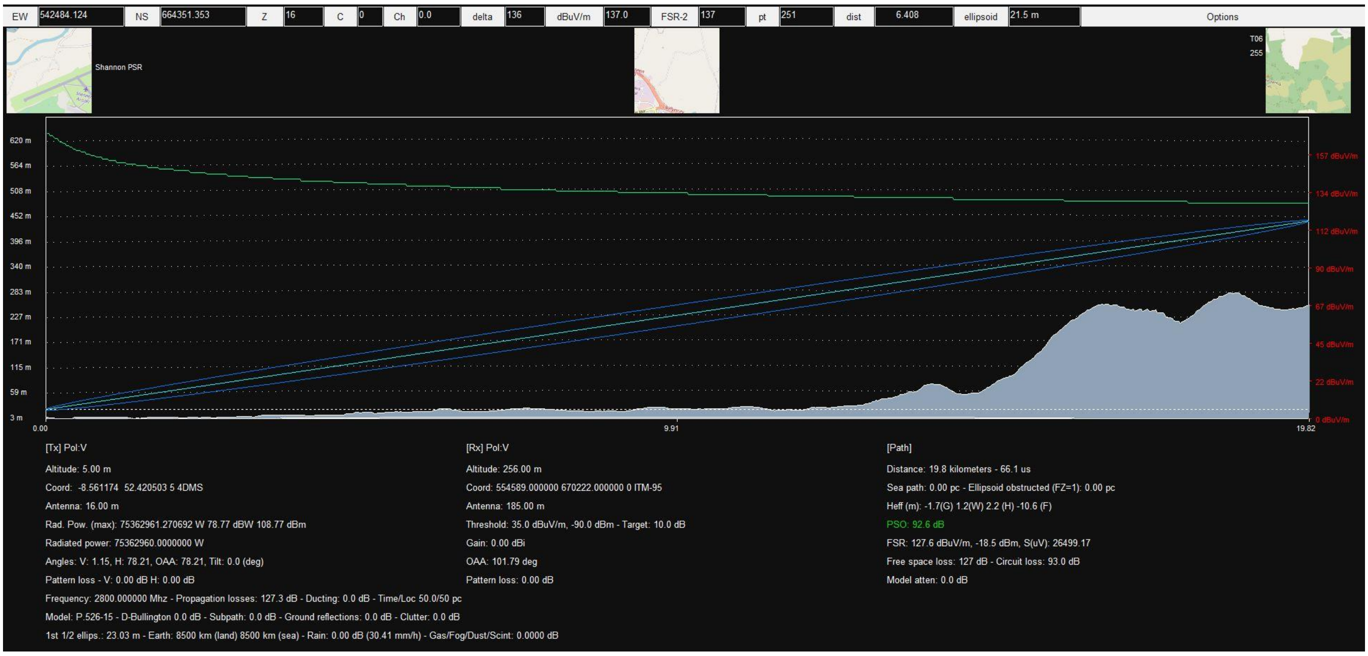
A.4. Turbine T4



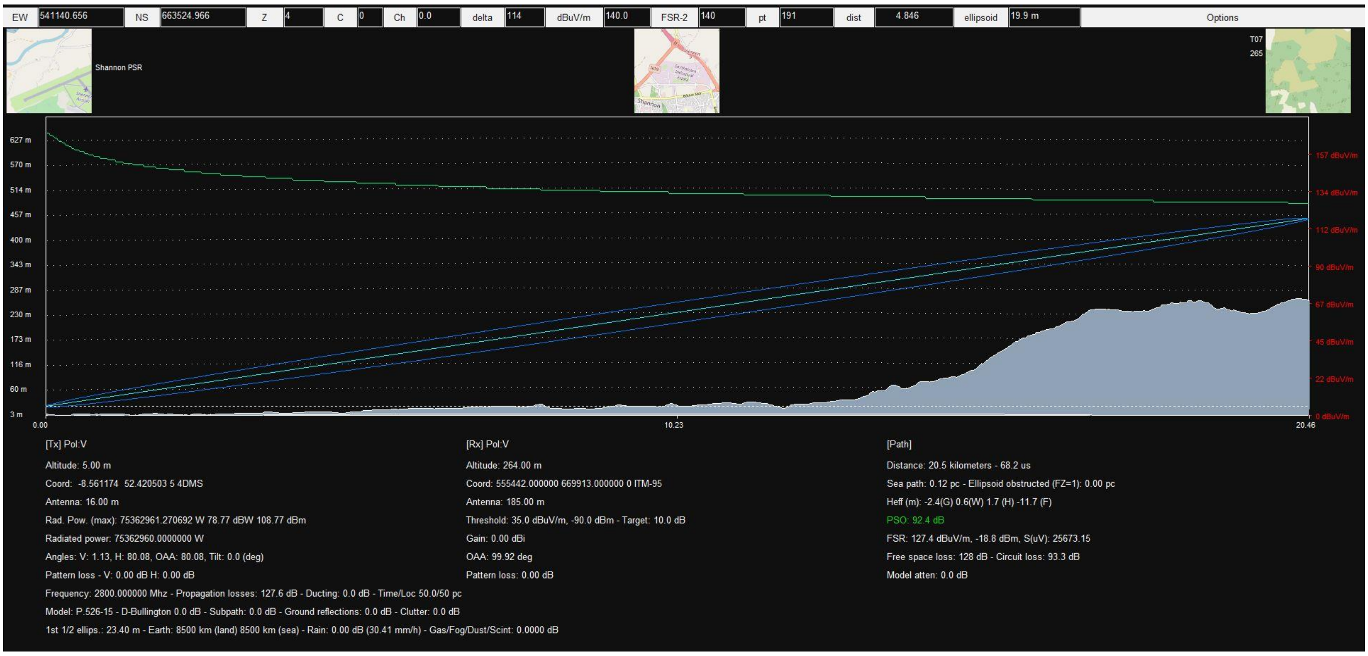
A.5. Turbine T5



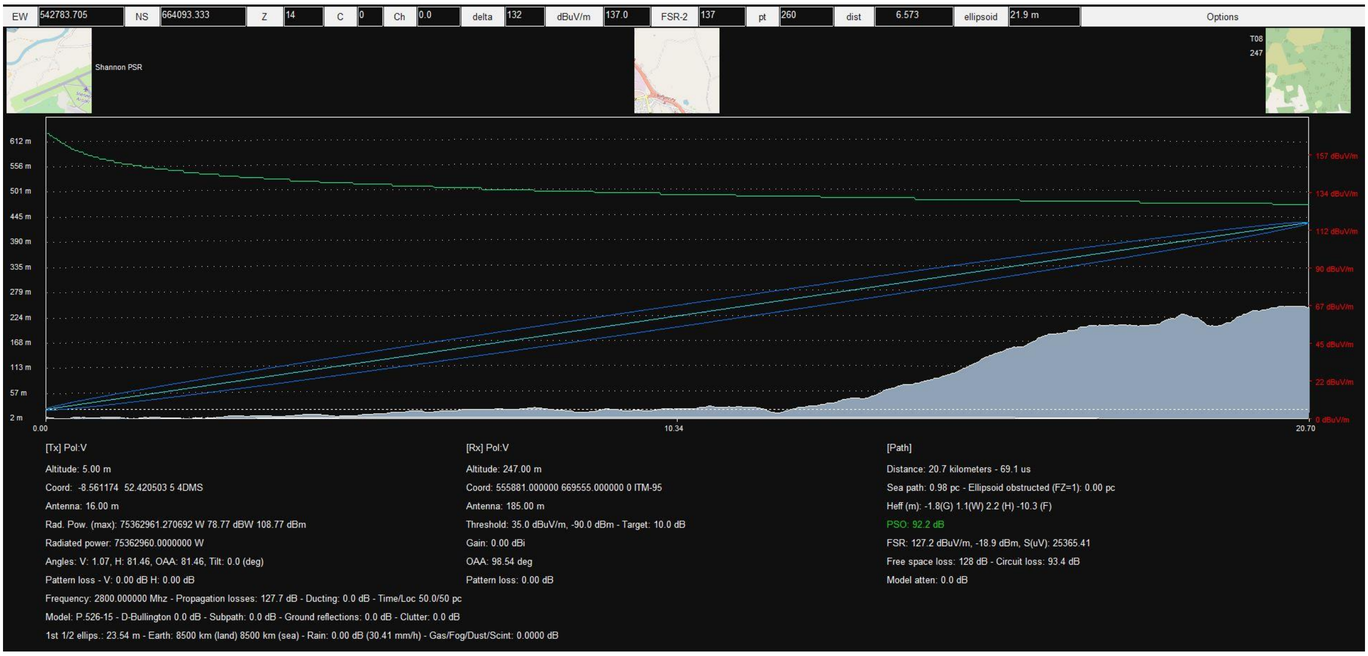
A.6. Turbine T6



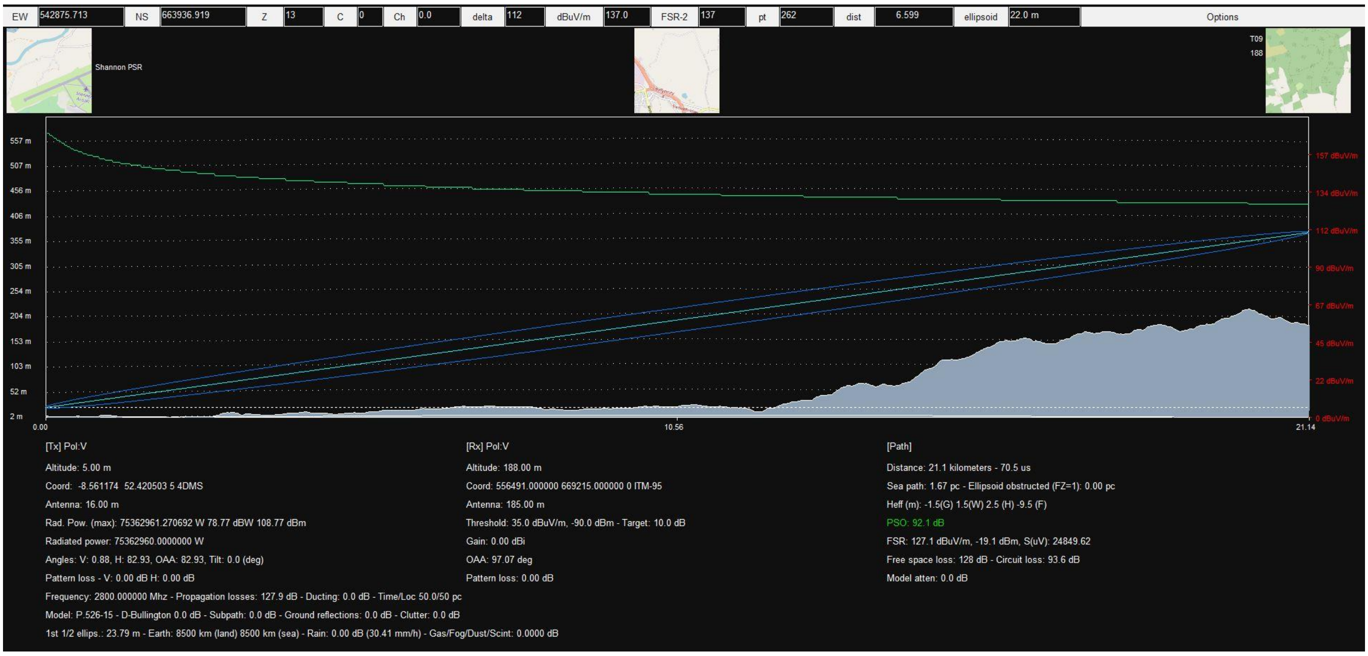
A.7. Turbine T7



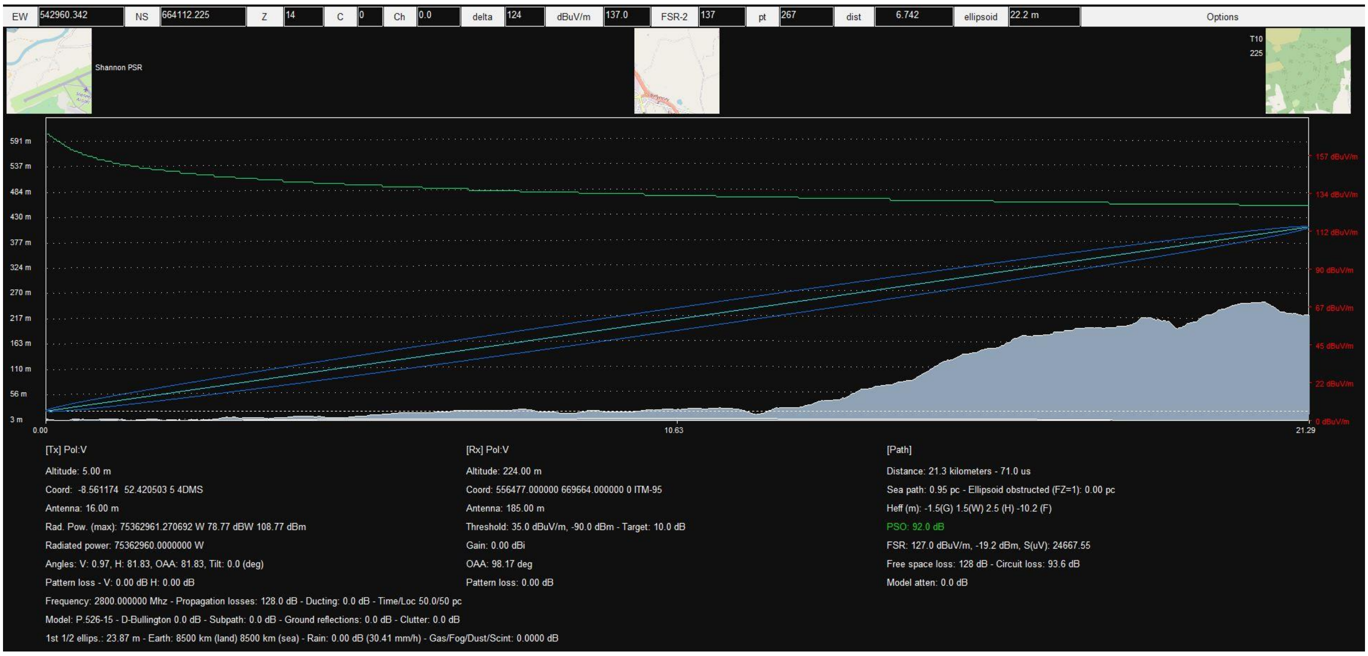
A.8. Turbine T8



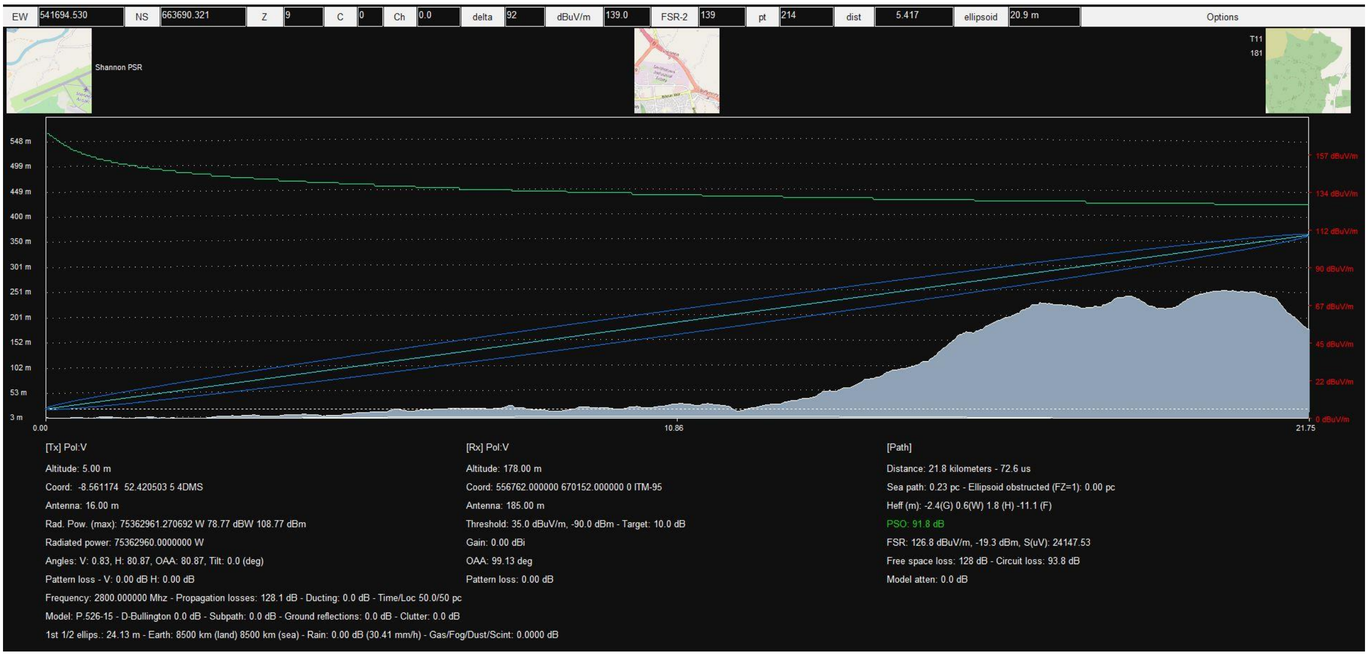
A.9. Turbine T9



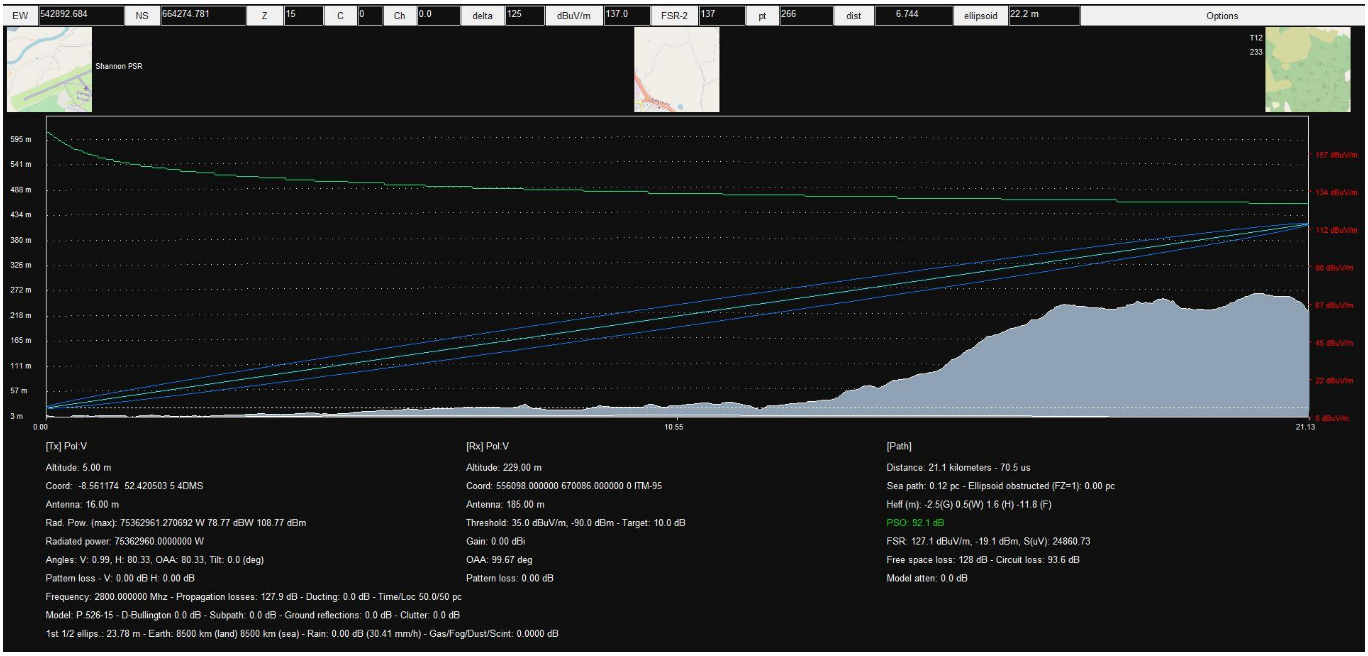
A.10. Turbine T10



A.11. Turbine T11

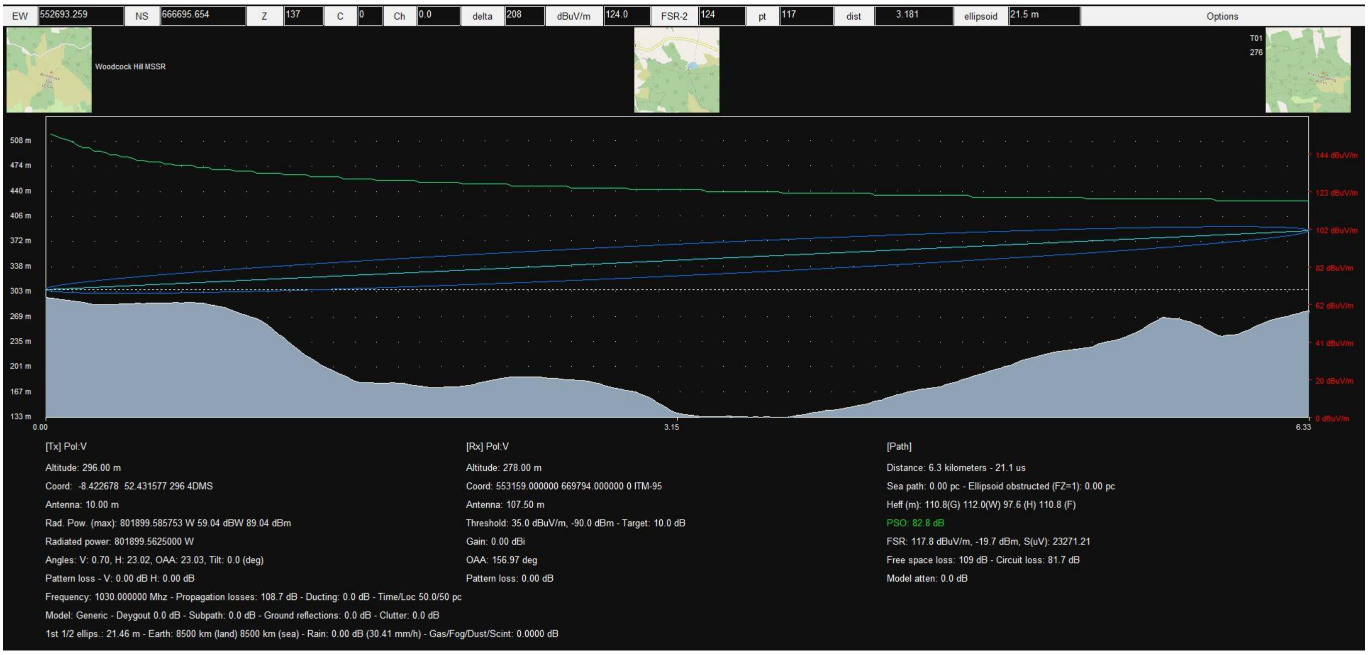


A.12. Turbine T12



B. Annex B – Woodcock Hill MSSR Path Profiles

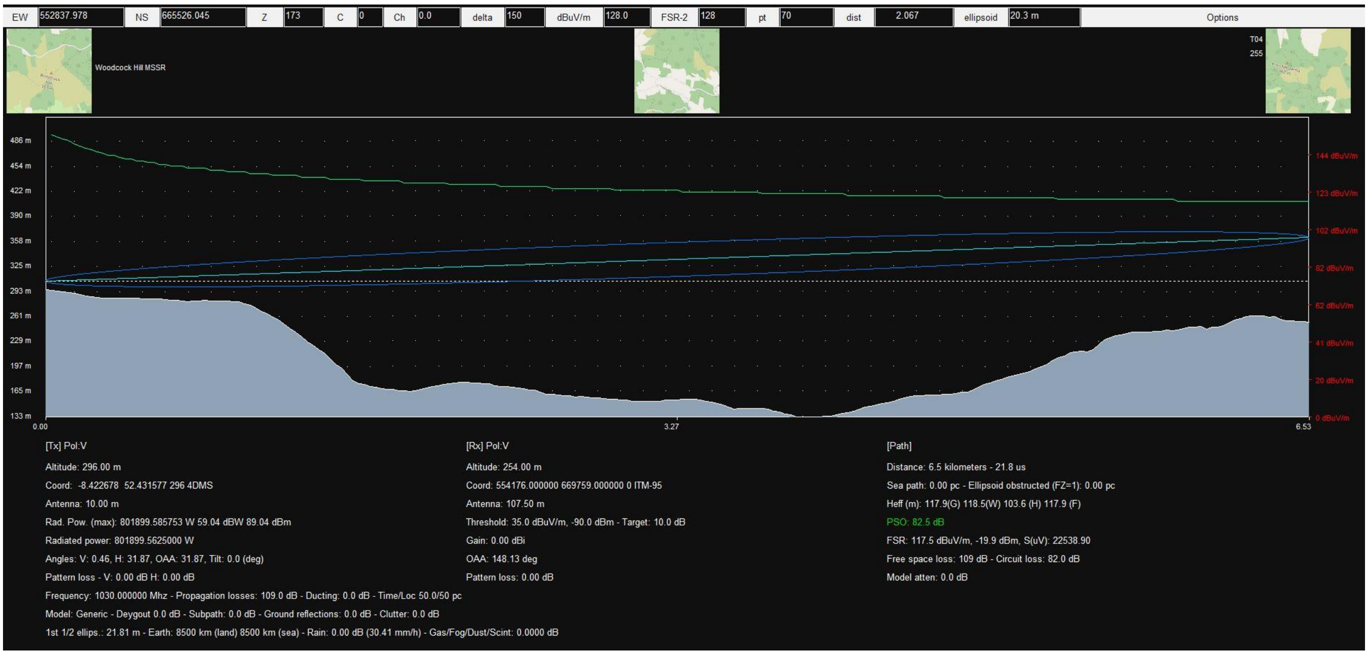
B.1. Turbine T1



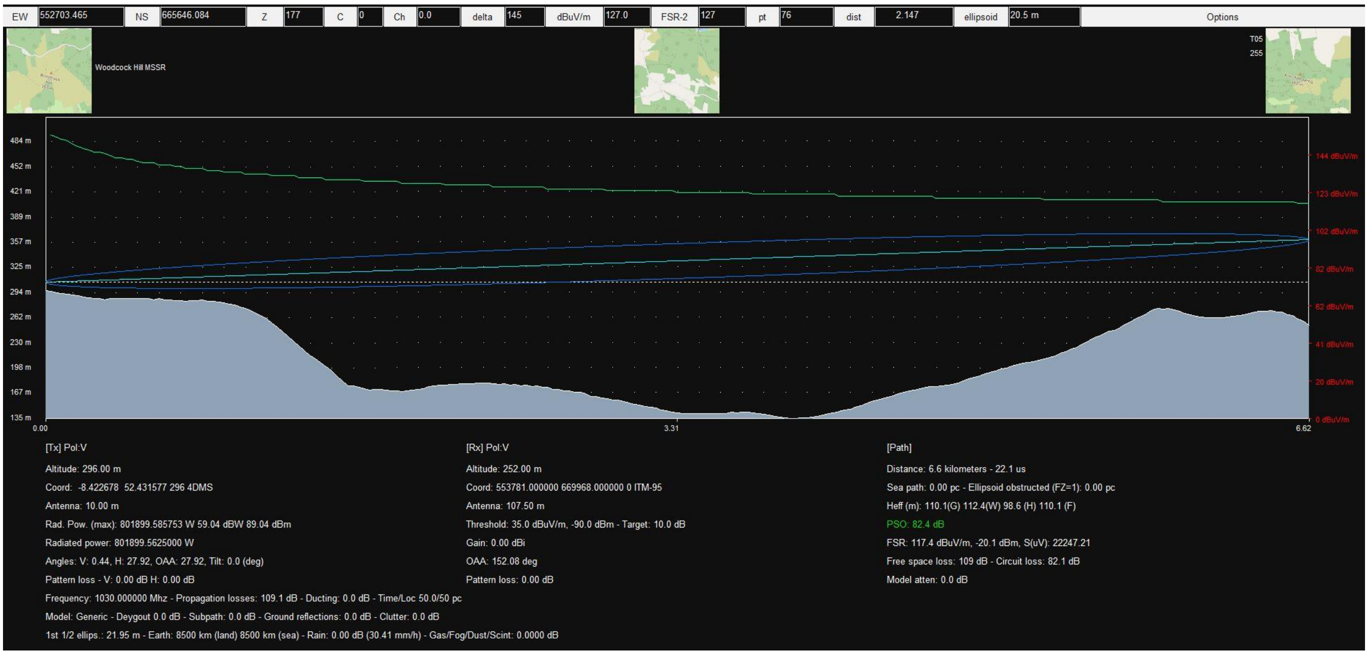
B.2. Turbine T2

B.3. Turbine T3

B.4. Turbine T4

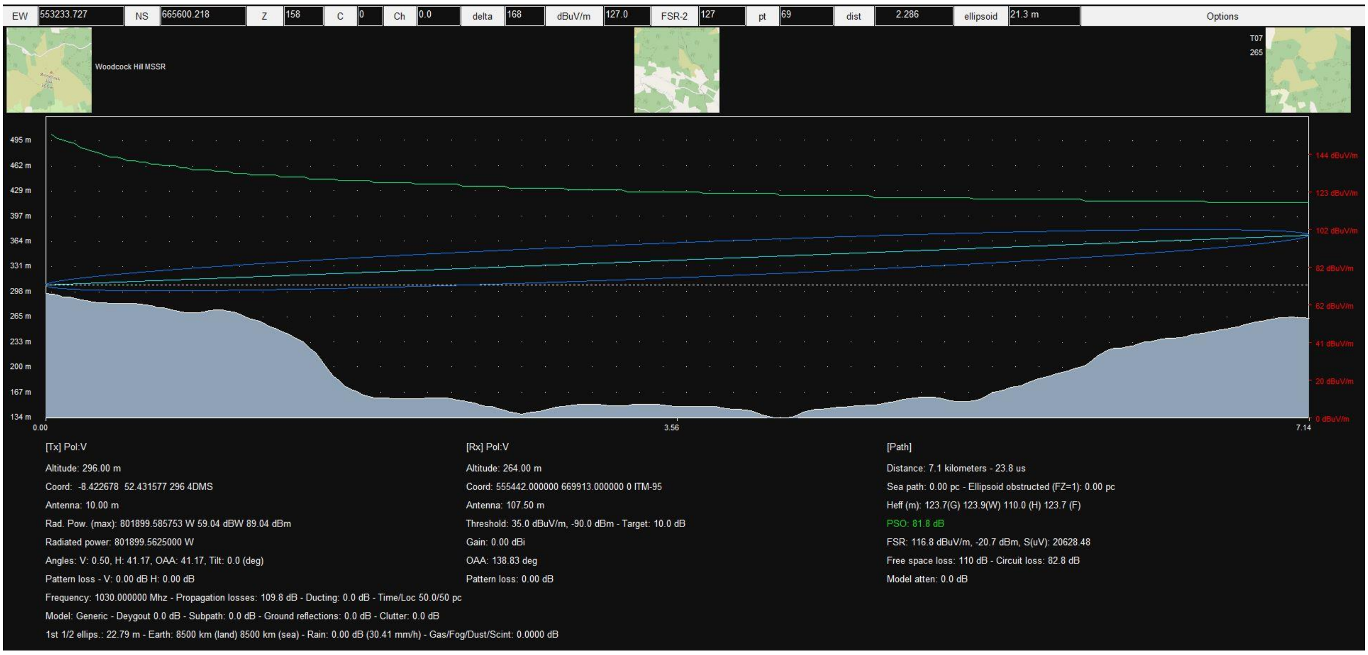


B.5. Turbine T5

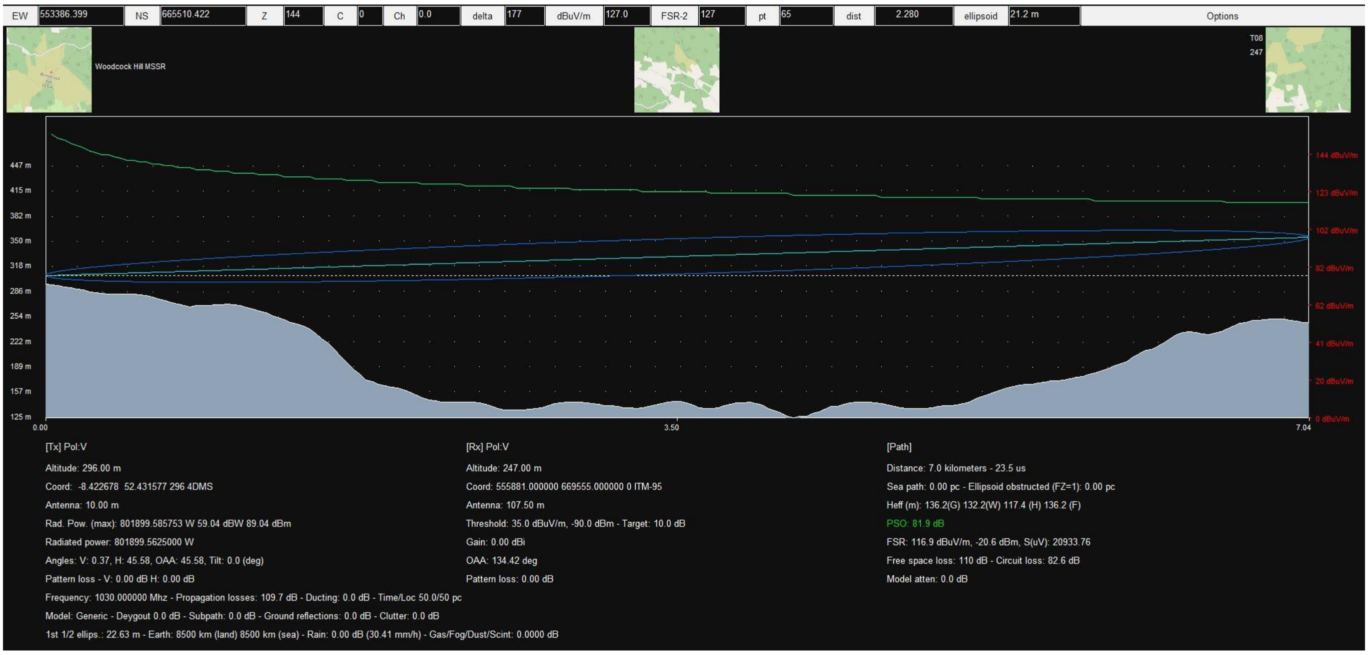


B.6. Turbine T6

B.7. Turbine T7

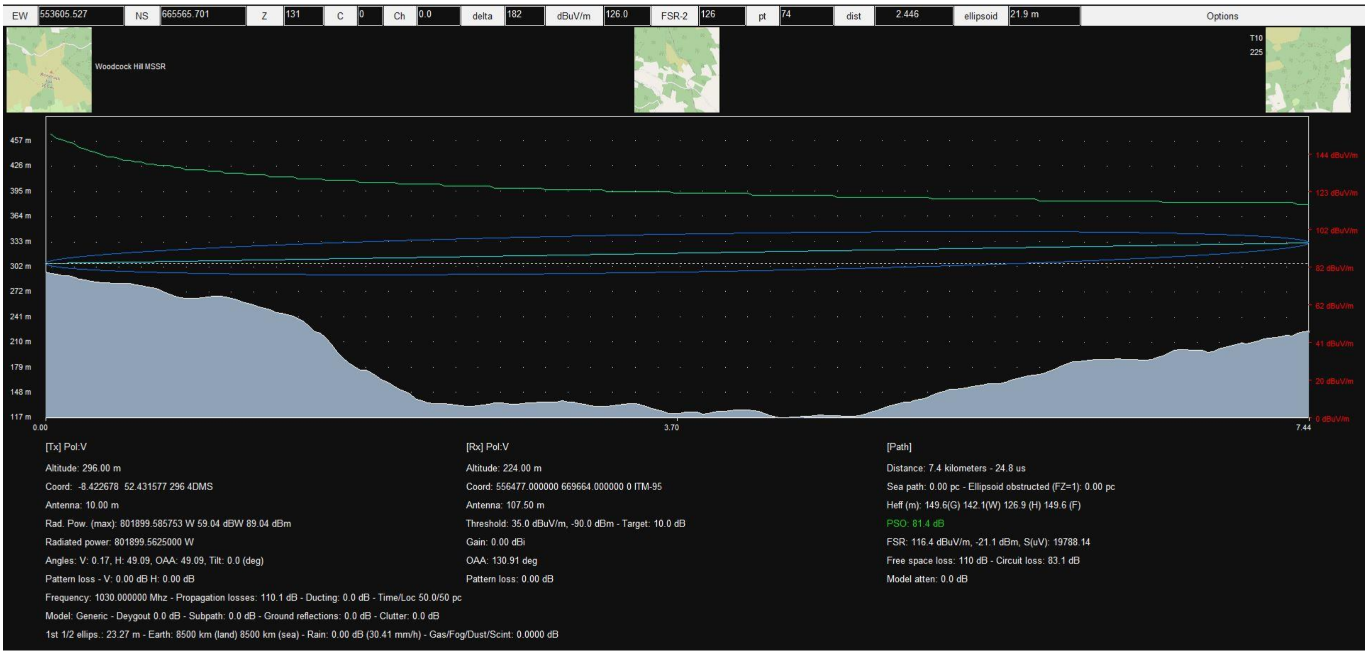


B.8. Turbine T8



B.9. Turbine T9

B.10. Turbine T10



B.11. Turbine T11

B.12. Turbine T12

This Page Is Intentionally Blank

Appendix 2

Ballycar Wind Farm IFP Opinion

CYRRUS

IFP Opinion

Ballycar Wind Farm

Shannon Airport

05 November 2021

CL-5715-RPT-002 V1.0

www.cyrrus.co.uk

info@cyrrus.co.uk

ISO 9001 QUALITY MANAGEMENT

ISO 14001 ENVIRONMENTAL MANAGEMENT

Executive Summary

MWP (hereafter referred to as the Client) has requested an Instrument Flight Procedure (IFP) review in respect of a proposed windfarm development (Ballycar) near Shannon Airport.

The process of providing an ‘opinion’ still requires a review of the applicable IFP lateral and horizontal surfaces. This process only determines whether there is a ‘surface penetration’ and not whether the obstacle impacts the IFP. If there is a penetration a full IFP assessment will be noted.

The proposed development is approximately 10NM north-east of Shannon Airport, as shown in Figure 1.

The windfarm does impact to the current published IFPs for Shannon Airport but is only limited to the ATC Surveillance Minimum Altitude Chart. Although a full IFP assessment is normally required for any identified impact, it is recommended to submit this report to the IAA for consideration whether a full assessment is required.

Figure 1: Wind Farm Position from Threshold 24

IFP's Assessed

The following IFPs, as published in the IAA Aeronautical Information Publication (AIP) were assessed.

- RNAV STANDARD INSTRUMENT DEPARTURES RWY06
- RNAV STANDARD INSTRUMENT DEPARTURE RWY24
- RNAV STANDARD ARRIVALS RWY06
- RNAV STANDARD ARRIVALS RWY24
- INSTRUMENT APPROACH ILS OR LOC RWY06
- INSTRUMENT APPROACH VOR RWY06
- INSTRUMENT APPROACH ILS CAT I & II OR LOC RWY24
- INSTRUMENT APPROACH VOR RWY24
- ATC SURVEILLANCE MINIMUM ALTITUDE

Data

The assessment undertaken by Cyrrus has been based upon the latest promulgated aeronautical information for Shannon contained in the Ireland AIP, reference EINN AD Section 2.

The following data was used for the assessment:

- Irish AIP – AIRAC 10/2021 effective 26 August 2021
- Email titled "RE_CYB1329 –Ballycar Wind Farm Aviation Studied.msg"

Table 1 below provides the base co-ordinates of the Turbines, the co-ordinates were provided in Irish Transverse Mercator (ITM) and converted to World Geodetic System 84 (WGS84) using the ordinates survey's GridInQuestII conversion tool.

Turbine No	Easting (ITM)	Northing (ITM)	Lat (UTM29N)	Long (UTM29N)
1	554531	664275	522072.59	5842025.21
2	554605	663847	522152.51	5841598.38
3	555030	664044	522574.63	5841801.22
4	555027	663611	522577.64	5841368.32
5	555476	663804	523023.81	5841567.49
6	555805	664104	523348.54	5841871.96
7	555886	663643	523435.91	5841412.23
8	555547	663267	523102.25	5841031.65
9	555090	663180	522646.61	5840938.34
10	555990	663191	523546.15	5840961.83
11	555582	662837	523143.2	5840602.28
12	555912	662521	523477.48	5840290.97

Table 1: Positional Data

Turbine dimensions as indicated in Table 2 were used.

In the absence of surveyed ground elevations, a vertical tolerance of 10 m was added.

Turbine No	Hub Height (m)	Rotor (m)	Ground Elevation (m)	Vertical Tolerance (m)	Max Tip Height
1	90	66.5	234	10	400.5
2	90	66.5	207	10	373.5
3	90	66.5	238	10	404.5
4	90	66.5	198	10	364.5
5	90	66.5	243	10	409.5
6	90	66.5	254	10	420.5
7	90	66.5	198	10	364.5
8	90	66.5	160	10	326.5
9	90	66.5	166	10	332.5
10	83	66.5	124	10	283.5
11	90	66.5	113	10	279.5
12	90	66.5	77	10	243.5

Table 2: Data used for the Assessment

Conclusion

The proposed wind farm does impact the current published procedures at Shannon airport. This is however limited to the ATC Surveillance Minimum Altitude Chart.

Although a full IFP assessment is normally required for any identified impact, it is recommended to submit this report to the IAA for consideration whether a full assessment is required.

Page Intentionally Left Blank

Appendix 3

Ballycar Wind Farm Impact on ILS Inspection Report

FLIGHT CALIBRATION SERVICES LTD

BALLYCAR WIND FARM

IMPACT ON ILS FLIGHT INSPECTION

Prepared For:	Malachy Walsh & Co Ltd
Author:	John Wilson
Reviewed by:	David Bartlett
Reference:	FCSL 0140
Issue:	1
Date:	14 May 2022

BALLYCAR WIND FARM

Impact on ILS Flight Inspection

TABLE OF CONTENTS

ABBREVIATIONS

AIP	Aeronautical Information Publication
AMSL	Above Mean Sea Level
ARP	Aerodrome Reference Point
DME	Distance Measuring Equipment
FCSL	Flight Calibration Services Ltd
FIP	Flight Inspection Procedure
GP	Glide Path
GPS	Global Positioning System
ha	hectare
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
ITM	Irish Transverse Mercator
LOC	Localiser
NM	Nautical Mile
RF	Radio Frequency
VMC	Visual Meteorological Conditions
WGS	World Geodetic System

1 INTRODUCTION

Ballycar Wind Farm is a proposed renewable energy project in County Clare located approximately 16 km (8.6 NM) east of Shannon Airport.

The wind farm developer has requested that an assessment be performed to establish any adverse effect the proposed wind farm may have on flight inspection procedures and profiles associated with the Shannon Airport Runway 24 Instrument Landing System (ILS).

This report provides an assessment of the impact of terrain and obstacles on ILS flight inspection procedures. It does not provide an assessment of any impact the proposed wind farm may have on the integrity of the Runway 24 ILS guidance signals.

2 DETAILS OF PROPOSED WIND FARM

The proposed Ballycar Wind Farm comprises 12 wind turbines and associated infrastructure including turbine foundations, access tracks, an electricity substation and underground cabling located in an area of approximately 140 ha as shown in Figure 2.1 below. Figure 2.2 below shows the location of the wind farm in relation to Shannon Airport.

The proposed wind turbine coordinates are shown in Table 2.1 below.

The maximum height of the proposed wind turbines (to blade tip) is 158 m (518 ft) above ground level. Ground height at the highest turbine (T6) is 253 m (830 ft) AMSL.

The height of the highest turbine (to blade tip) is therefore 411 m (1,348 ft) AMSL.

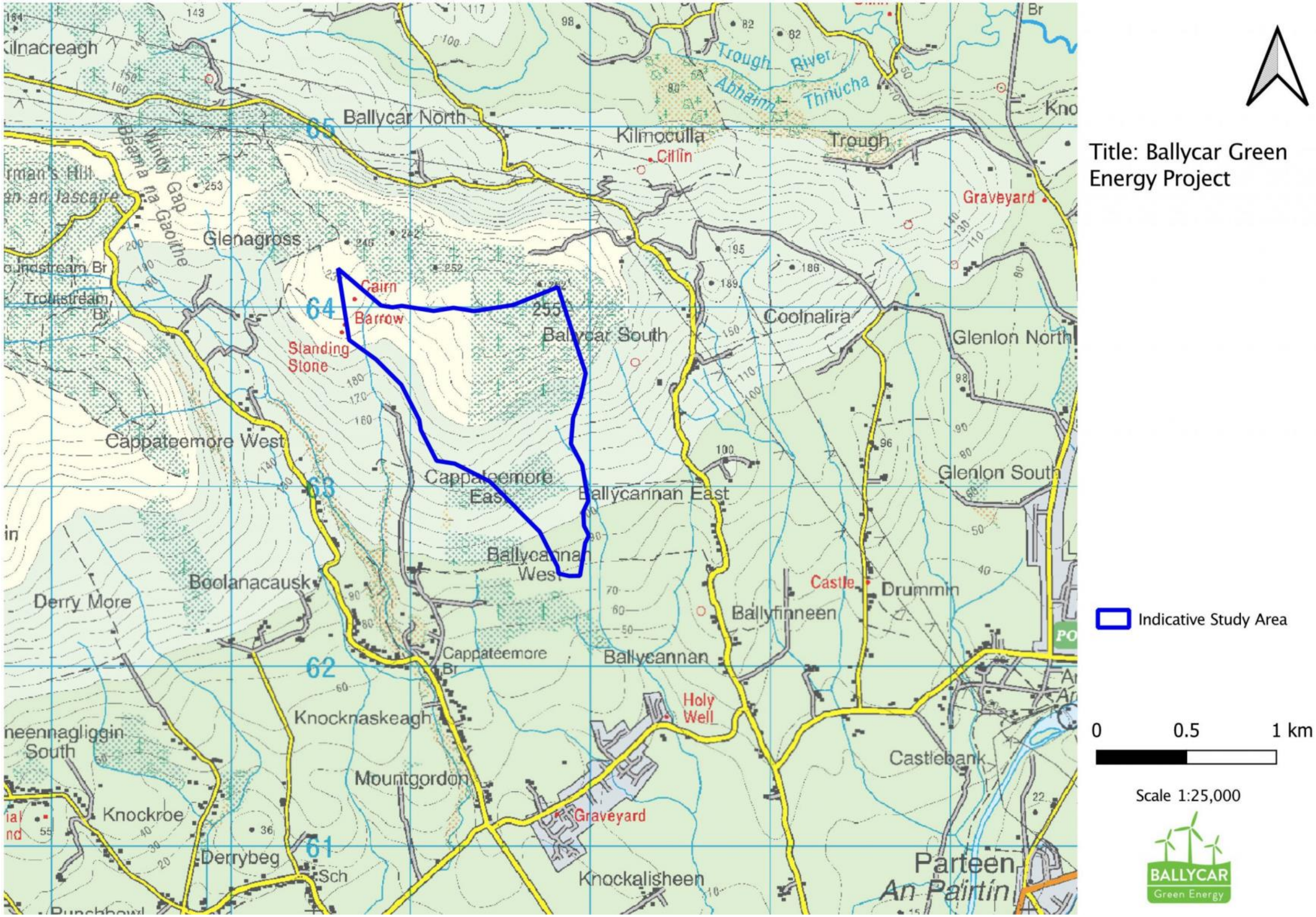


Figure 2.1 - Proposed Ballycar Wind Farm Site

Figure 2.2 – Location of Proposed Ballycar Wind Farm and Shannon Airport

Turbine	ITM Coordinates		WGS-84 Coordinates		Ground Level AMSL (m)
	X	Y	Latitude	Longitude	
T1	554589	664237	52.727317	-8.672287	234
T2	554609	663823	52.723595	-8.671932	205
T3	554964	664122	52.726317	-8.666729	232
T4	554981	663600	52.721624	-8.666394	193
T5	555405	663769	52.723181	-8.660152	241
T6	555821	664101	52.726198	-8.654033	253
T7	555913	663616	52.721845	-8.652613	192
T8	555503	663247	52.718497	-8.658624	160
T9	555084	663192	52.717965	-8.664818	166
T10	556023	663087	52.717097	-8.650911	115
T11	555645	662822	52.714689	-8.656465	107
T12	555899	662525	52.712041	-8.652666	236

Table 2.1 - Proposed Turbine Coordinates

3 ILS INFORMATION

3.1 ILS Site Information

The Runway 24 ILS provides radio navigation information to aircraft in the initial and final approach phases of flight towards Runway 24 within 25 NM of Shannon Airport. The ILS ground installation comprises:

- Localiser equipment (providing lateral guidance to the runway centreline) located on the extended runway centreline approximately 300 m from the stop end of Runway 24.
- Glide Path equipment (providing vertical guidance to a 3.0° glide path) located approximately 130 m offset from runway centreline and backset 360 m from Runway 24 threshold.
- Distance Measuring Equipment (DME) transponder (providing distance to runway threshold information). The DME antenna is mounted on the Glide Path mast.

ILS Localiser, Glide Path and DME antenna coordinates are shown in the extract from AIP Ireland shown in Figure 3.1 below.

3.2 ILS Coverage Information

International Standards and Recommended Practices (SARPS) for ILS are published by the International Civil Aviation Organization (ICAO). ICAO Annex 10 Chapter 3.1 defines ILS Localiser and Glide Path lateral coverage sectors as described below.

3.2.1 Localiser Coverage

The Localiser coverage sector shall extend from the centre of the localiser antenna system to distances of:

- 46.3 km (25 NM) within plus or minus 10 degrees from the front course line;
- 31.5 km (17 NM) between 10 degrees and 35 degrees from the front course line;
- 18.5 km (10 NM) outside of plus or minus 35 degrees from the front course line if coverage is provided.

Figure 3.2 below shows ILS Localiser lateral coverage sector as defined in ICAO Annex 10.

Figure 3.3 below shows the Runway 24 ILS Localiser lateral coverage sector in relation to the proposed Ballycar Wind Farm.

3.2.2 Glide Path Coverage

The Glide Path equipment shall provide signals sufficient to allow satisfactory operation of a typical aircraft installation in sectors of 8 degrees in azimuth on each side of the centre line of the ILS glide path, to a distance of at least 18.5 km (10 NM).

ICAO Annex 10 Volume I states that ILS Glide Path coverage shall extend to a range of 10 NM, up to 1.75θ and down to 0.45θ above the horizontal, or to a lower angle, down to 0.3θ as required to safeguard the promulgated Glide Path intercept procedure (where θ is the nominal Glide Path angle).

Figure 3.4 below shows ILS Glide Path coverage as defined in ICAO Annex 10.

Figure 3.5 below shows the Runway 24 ILS Glide Path lateral coverage sector in relation to the proposed Ballycar Wind Farm.

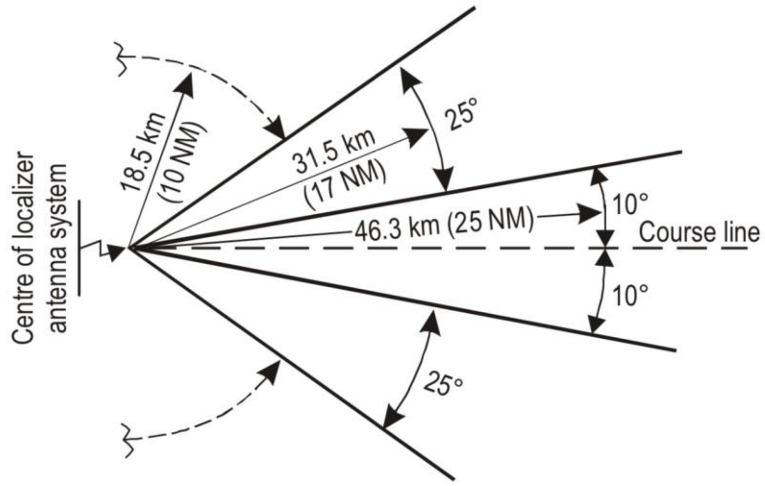
3.2.3 DME Coverage

The DME equipment shall provide aircraft with distance to threshold information throughout the Localiser coverage sector as defined in 3.2.1 above.

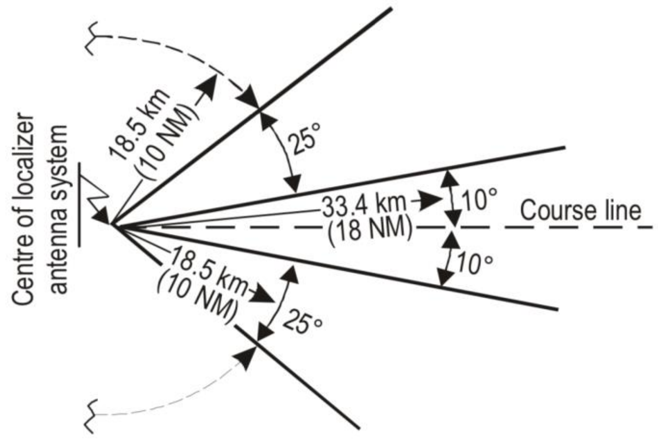
EINN AD 2.19 RADIO NAVIGATION AND LANDING AIDS

Type of aid, MAG VAR, Type of supported OP (for VOR/ILS/ MLS/GNSS/ SBAS and GBAS, give declination)	ID	Frequency	Hours of operation	Position of transmitting antenna coordinates	Elevation of DME transmitting antenna or SBAS: ellipsoid height of LTP/FTP	Service Volume Radius from the GBAS Reference Point	Remarks
1	2	3	4	5	6	7	8
DVOR/DME 4º W 2017	SHA	113.300 MHz	H24	524315.6N 0085306.8W	200ft		Designated Operational Coverage 300 NM/70,000ft 180ºTrue BRG to 360º True BRG. Designated Operational Coverage 100 NM/50,000ft.
NDB	FOY	395 kHz	H24	523358.5N 0091143.5W			Designated Operational Coverage 50 NM
ILS LOC RWY 06 CAT 1 4º W 2017	ISE	109.5 MHz	H24	524245.3N 0085408.2W			Coverage restricted to 35º either side of course line. Signals received outside coverage sector, (including back beam radiation), should be ignored.
ILS GP RWY 06		332.6MHz	H24	524147.2N 0085623.1W			GP Angle 3º RDH 55ft Full scale fly down indication may not be maintained when above GP sector. Full scale fly up indication may not be maintained when left of LOC sector and below GP.
ILS DME RWY 06	ISE	CH32X (109.5 MHz)	H24	524147.2N 0085623.1W	100ft		DME Zero ranged to THR 06. DME zero range is displaced from DME antenna by 445M.
ILS LOC RWY 24 CAT II 4º W 2017	ISW	110.95MHz	H24	524129.4N 0085649.6W *			Coverage restricted to 35° either side of the course line. Signals received outside coverage sector, (including back beam radiation), should be ignored. No LOC coverage below 3000ft MSL AT 25 NM EINN *Data whose accuracy has not been quality assured.
ILS GP RWY 24		330.65MHz	H24	524232.1N 0085447.7W			GP Angle 3° RDH 59ft
LO RWY 24	OL	339 kHz	H24	524456.4N 0084926.0W			Designated Operational Coverage 15NM
OM RWY 24	2 Dashes per sec	75 MHz	H24	524455.5N 0084927.0W			
MM RWY 24	Dots and Dashes	75 MHz	H24	524254.8N 0085347.9W			
ILS DME RWY 24	ISW	CH46Y (110.95 MHz)	H24	524232.1N 0085447.7W	100ft		DME Zero ranged to THR 24. DME zero range is displaced from DME antenna by 391M.

Figure 3.1 - AIP Ireland



When topographical features dictate or operational requirements and alternative navigation facilities permit, the following coverage may be provided:



Note.— If coverage as prescribed in Chapter 3, 3.1.3.3.1 is required outside the plus or minus 35-degree sector, this is provided to 18.5 km (10 NM), as indicated by the broken arc above.

Figure 3.2 - ILS Localiser Lateral Coverage Sector

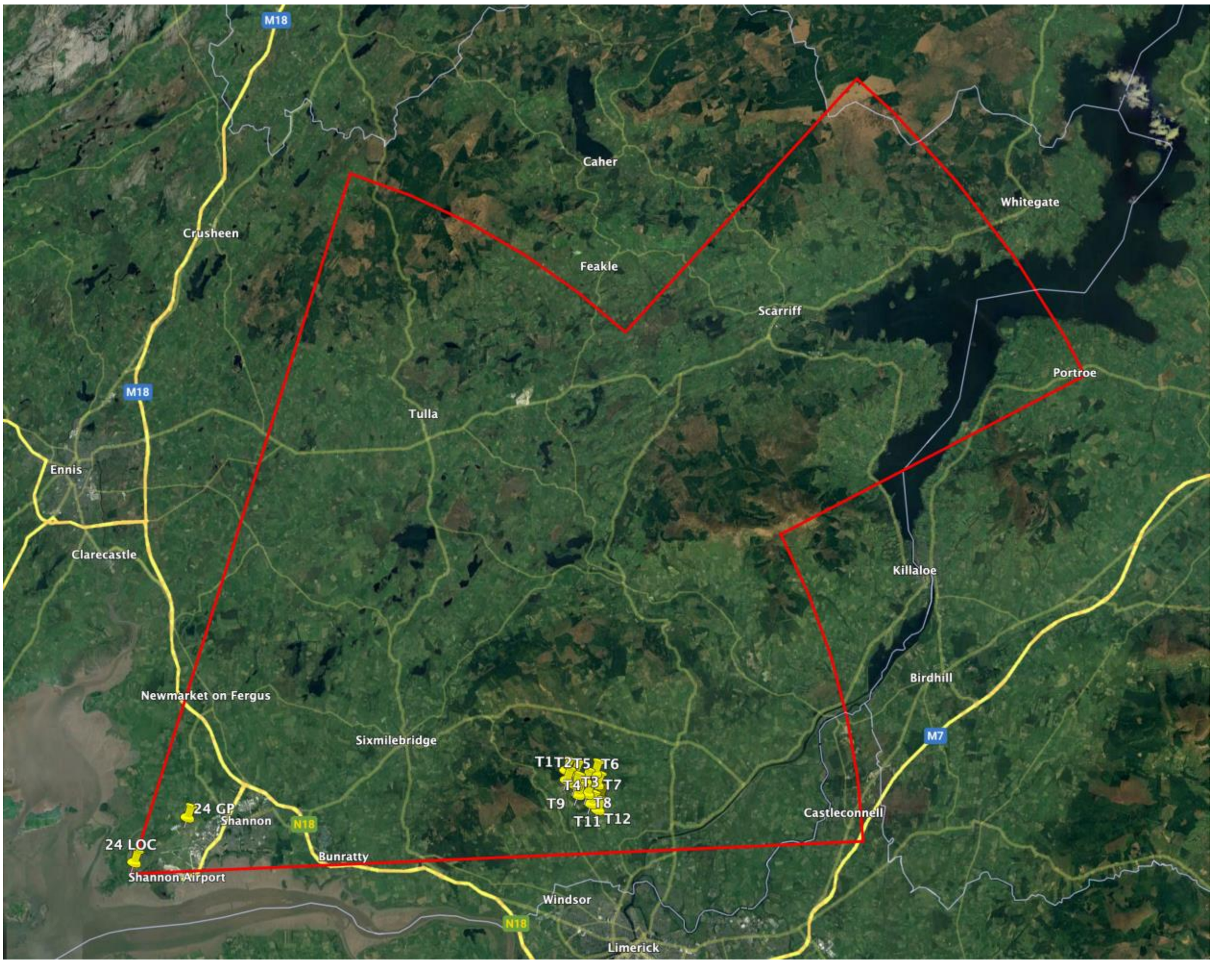


Figure 3.3 - Runway 24 ILS Localiser Lateral Coverage Sector

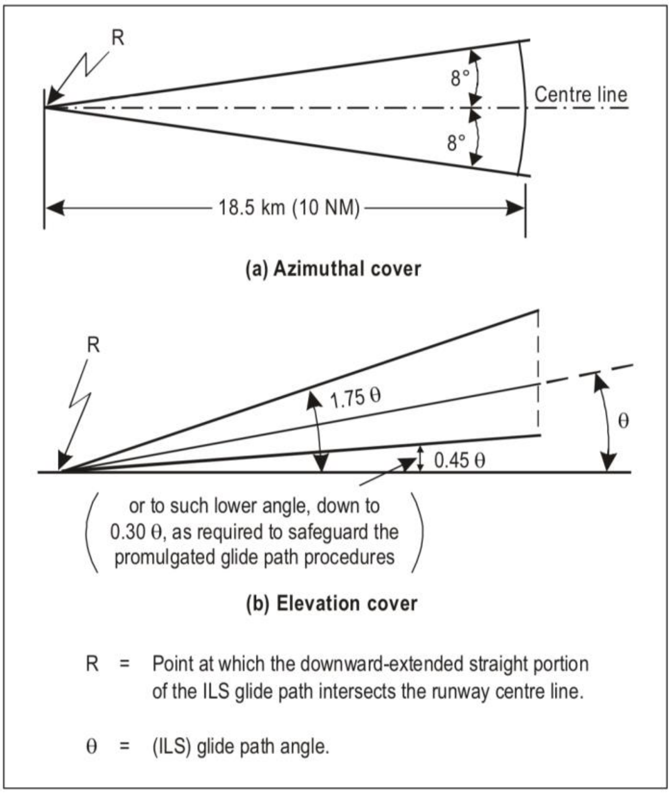


Figure 3.4 - ILS Glide Path Coverage

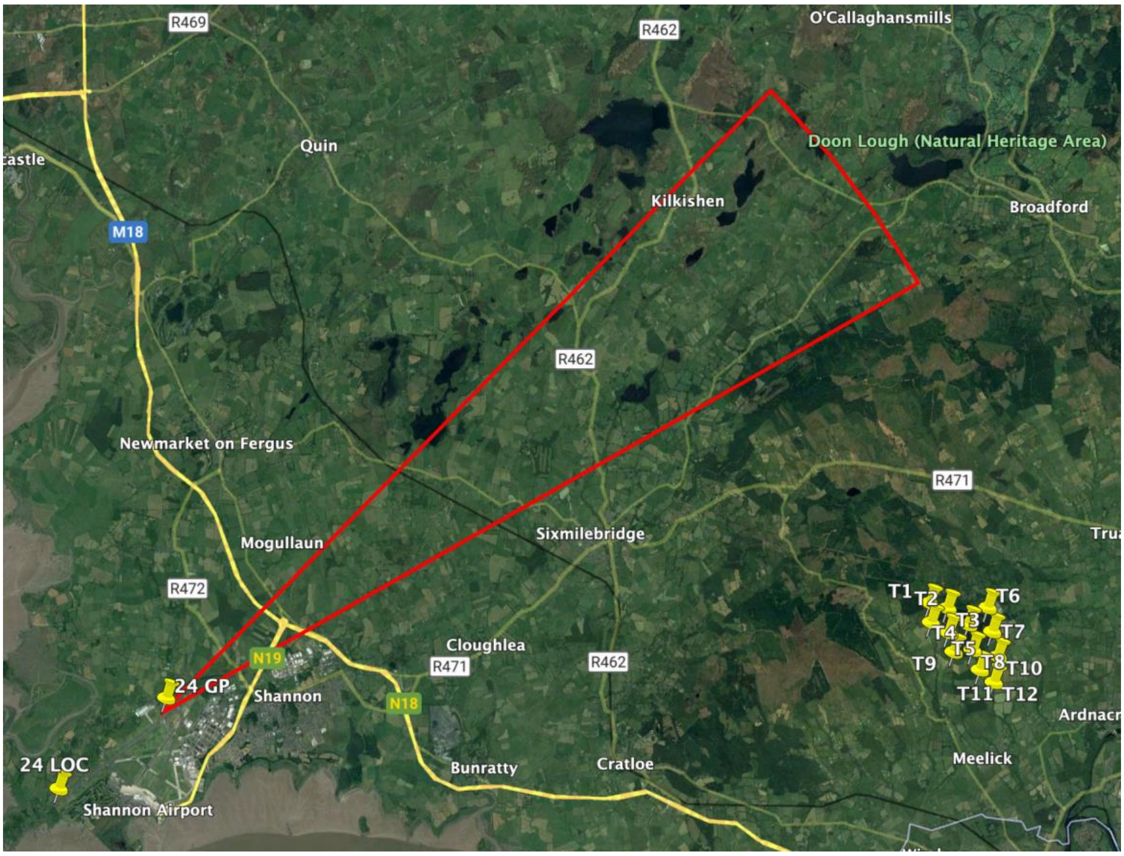


Figure 3.5 - Runway 24 ILS Glide Path Lateral Coverage Sector

4 ICAO ILS FLIGHT INSPECTION RECOMMENDATIONS

International Standards and Recommended Practices (SARPS) for ILS are published by the International Civil Aviation Organization (ICAO). Guidance material on factory, ground and flight testing of ILS installations is published in ICAO Doc 8071 Volume I. The purpose of ICAO Doc 8071 Volume I is to provide general guidance on the extent of testing and inspection normally carried out to ensure that radio navigation systems meet the SARPS published by ICAO.

To verify guidance signal accuracy within the ILS coverage volume, ICAO Doc 8071 recommends that a normal centreline approach should be flown, using the glide path, where available. For a Category II and III Localisers, the aircraft should cross the threshold at approximately the normal design height of the glide path and continue downward to normal touchdown point.

To verify that the ILS Localiser and Glide Path guidance signals provide the correct information to the user throughout the area of operational use, coverage checks should be performed. At periodic inspections, it is necessary to check coverage only at 31.5 km (17 NM) and 35 degrees either side of the course, unless use is made of the localiser outside of this area. Arc (part orbit) profiles may be flown at distances closer than this, provided an arc profile is flown at the same distance and altitude during the commissioning inspection to establish reference values.

To verify Glide Path displacement sensitivity, ICAO Doc 8071 recommends that approaches be made on centreline, 0.12θ below and 0.12θ above the nominal glide path angle (θ), where aircraft should receive 50% full-scale fly up (below path) and 50% full-scale fly down (above path) guidance indications.

The clearance of the Glide Path sector is verified by flying towards the facility on centreline at a constant height (level run) starting at a distance corresponding to an angle of 0.3θ (where θ is the nominal glide path angle) continuing to a point where twice the glide path angle (2θ) has been passed. Glide Path RF signal level is also measured during the level run to ensure the received signal level meets ICAO minimum requirements at the limits of coverage.

5 FCSL FLIGHT INSPECTION PROCEDURES

FCSL have developed company procedures for commissioning and routine flight inspection of ILS Localiser and Glide Path facilities. Customer flight inspection requirements are initially captured on a Client Facility Data Sheet (Form 101). Form 101 records the technical details of the navigation aid to be flight checked and the specified interval between flight checks. For the Runway 24 ILS, the interval between flight checks is 180 days.

In the case of the Runway 24 ILS, the ILS is flight checked in accordance with FCSL Flight Inspection Procedure (FIP) FIP 23 (ILS Flight Inspections GPS Southern Ireland).

FIP 23 specifies that the following flight profiles are flown as defined in FCSL Form 102 (Flight Profile Chart):

Profile No	Profile Description	See Figure
01	Centreline Approach	5.1
04	Part Orbit	5.2
12	Top Edge	5.3
13	Bottom Edge	5.4
14	Slice (Level run)	5.5
15	Left Slice 8° (Level run)	5.6
16	Right Slice 8° (Level run)	5.7

Figures 5.1 to 5.7 below show the flight profiles to be flown during ILS flight inspection.

The start points, heights and distances for each flight profile are decided by the FCSL Flight Inspector in conjunction with the pilots to ensure correct and sufficient data is recorded while taking into account local terrain and obstacle clearance requirements.

FCSL FIP 23 states that flight inspection pilots will not fly within 1,000 ft of the ground in IMC (unless on centreline and edge approaches) and commissioning flights should be carried out in sight of the surface at all times. FIP 23 also states that Inspection Pilots will not fly within 1,000 ft of the highest obstacle within 5 NM either side of track in IMC.

Glide Path flight inspection procedures include checks below the Glide Path sector to assure a safe flight path area between the bottom edge of the Glide Path sector and any obstacles on the approach path. The Glide Path slice and left slice 8° (level runs) flight profiles must therefore ensure that the flight inspection aircraft clears obstacles by at least 500 ft in VMC and by at least 1,000 ft in IMC.

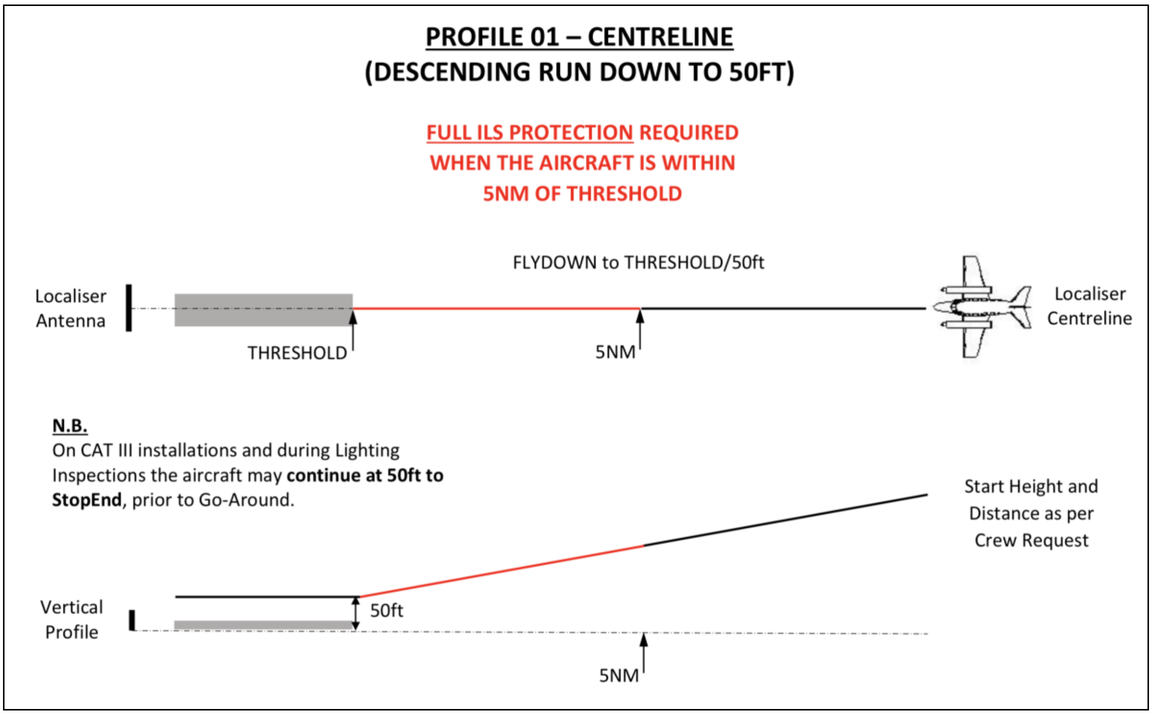


Figure 5.1 - Centreline Approach Flight Profile

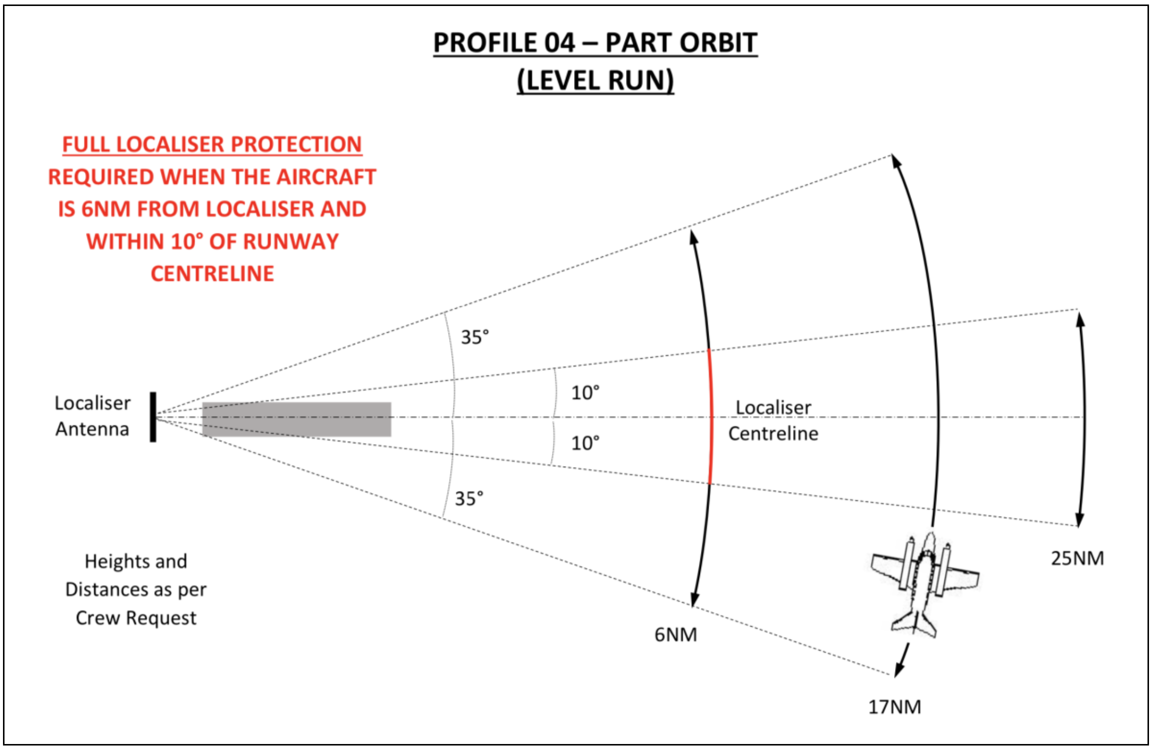


Figure 5.2 – Part Orbit Flight Profile

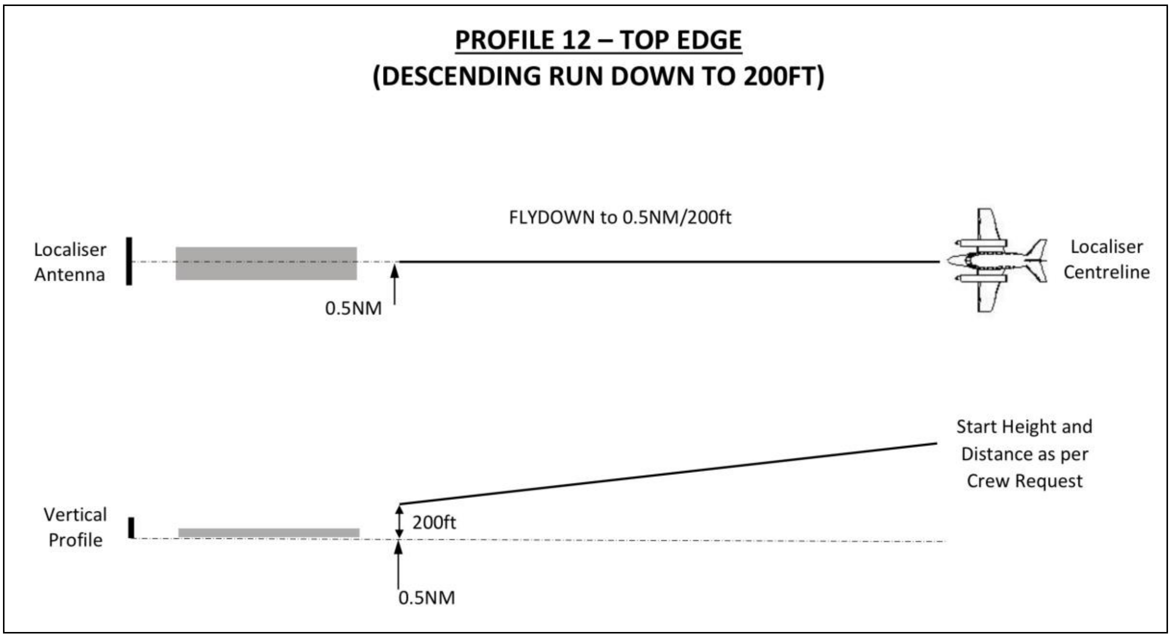


Figure 5.3 – Top Edge Flight Profile

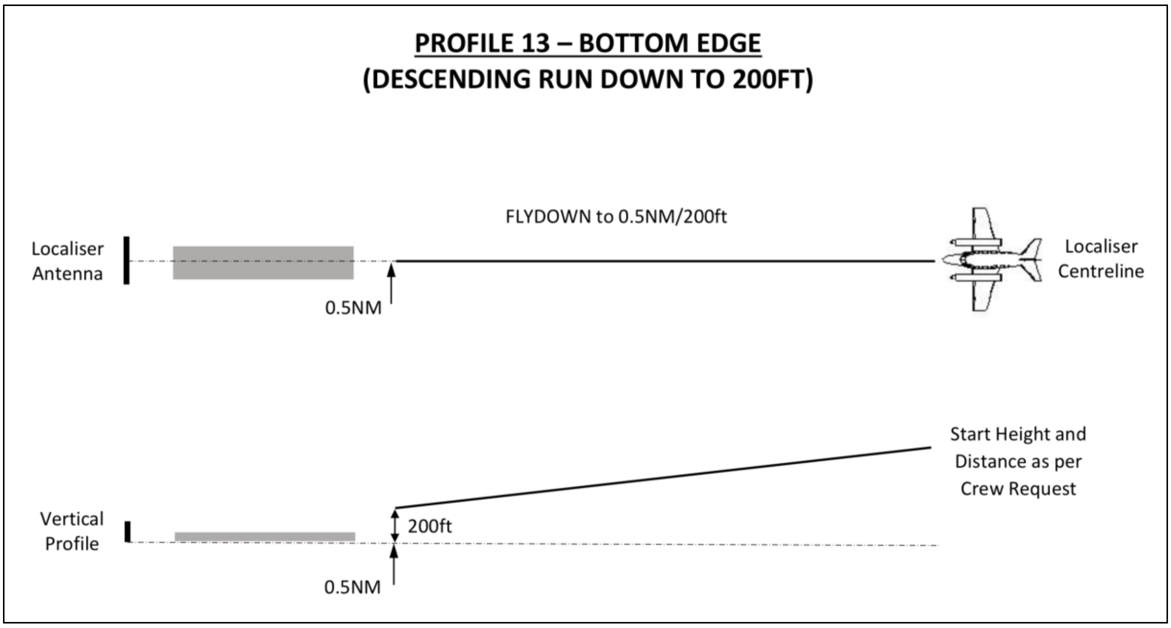


Figure 5.4 – Bottom Edge Flight Profile

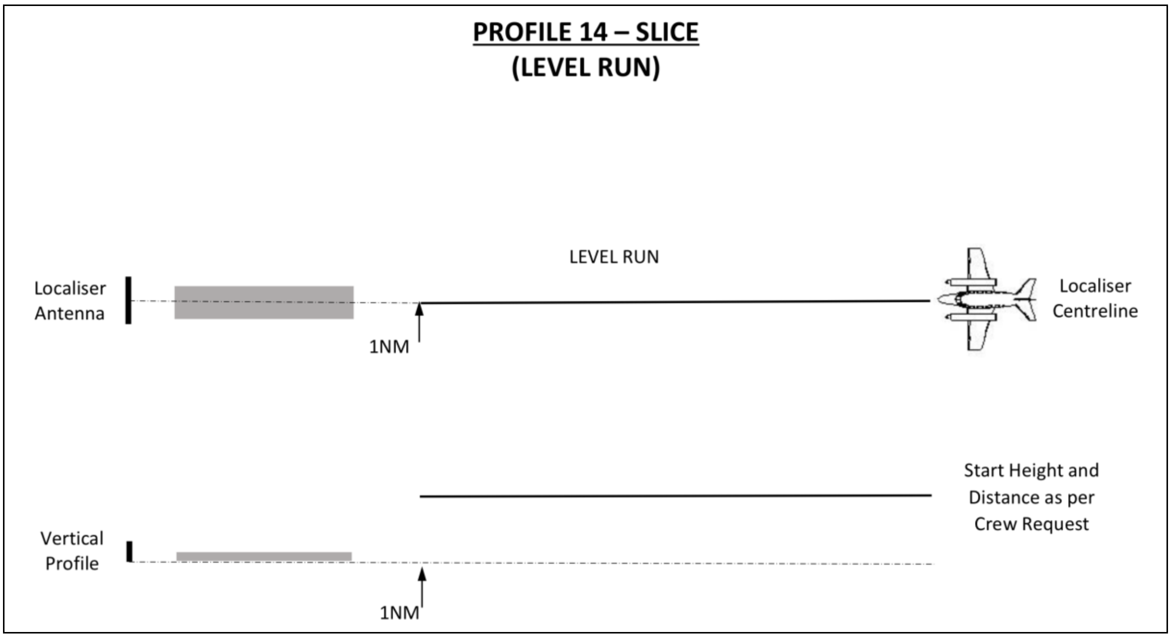


Figure 5.5 – Slice Flight Profile

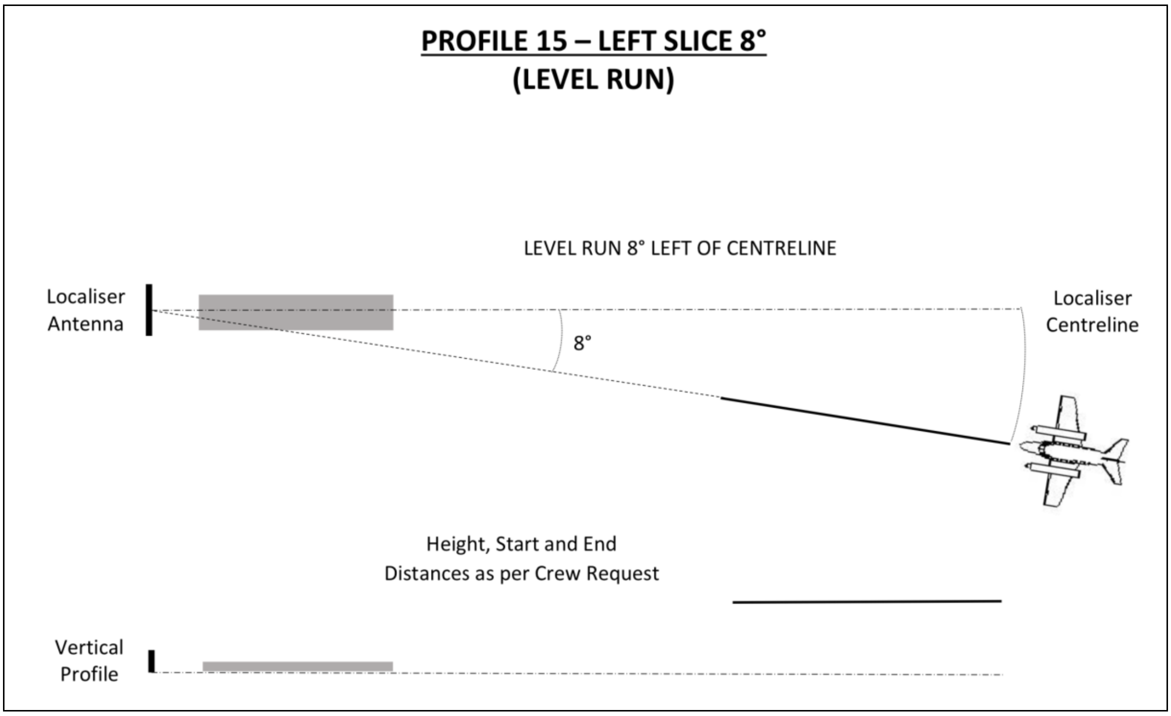


Figure 5.6 – Left Slice 8° Flight Profile

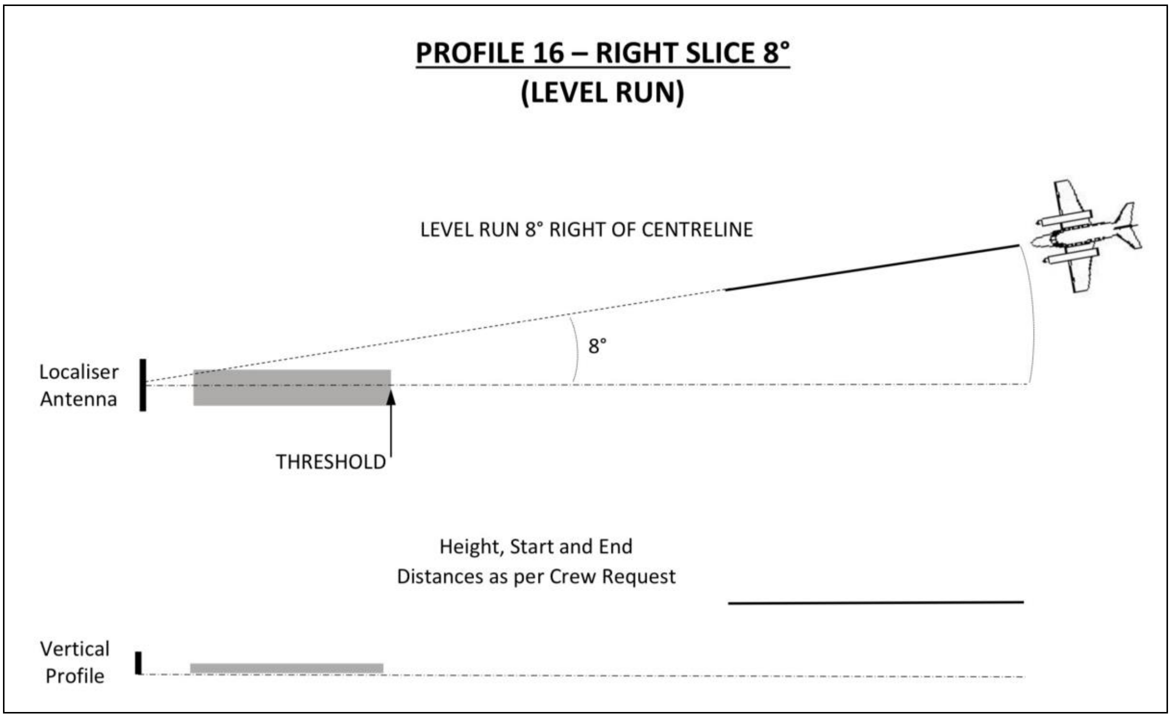


Figure 5.7 – Right Slice 8° Flight Profile

6 IMPACT ASSESSMENT

6.1 ILS Centreline Approach Flight Profile

For ILS centreline approach flight profiles, heights and distances are decided by the FCSL Flight Inspector in conjunction with the pilots to ensure correct and sufficient data is recorded while taking into account local terrain and obstacle clearance requirements.

For the most recent routine Runway 24 ILS flight inspections conducted by FCSL, centreline approaches were flown from a range of 25 NM.

6.1.1 Horizontal Obstacle Clearances

For a centreline approach profile, the flight inspection aircraft will be approximately 4.4 NM laterally from the nearest wind turbine (T1) at a point on the extended runway centreline closest to the wind farm. This distance is less than the minimum clearance required from any object in IMC, as defined in FIP 23.

6.1.2 Vertical Obstacle Clearances

For a centreline approach on a 3.0° glide path, the flight inspection aircraft will pass above, but 4.4 NM laterally distant from, the proposed Ballycar Wind Farm site. The flight inspection aircraft vertical clearance above the highest turbine (T6) can be estimated as follows (see Figure 6.1):

Horizontal distance from 24 Glide Path antenna (on boresight) to Turbine T6

= 15,208 m

Assume ground height at 24 Glide Path Antenna = ARP height = 46 ft = 14 m

Clearance (h) above highest turbine (T6)

$= (15{,}208\ m \times \tan 3.0°) - (253\ m - 14\ m) - 158\ m = 400\ m = 1{,}312\ ft$

This height exceeds the minimum clearance required above terrain and obstacles in IMC and VMC.

6.2 ILS Part Orbit Flight Profile

For ILS part orbit flight profiles, heights and distances are decided by the FCSL Flight Inspector in conjunction with the pilots to ensure correct and sufficient data is recorded while taking into account local terrain and obstacle clearance requirements.

For the six most recent routine Runway 24 ILS flight inspections conducted by FCSL, part orbits were flown at a range of 6 NM from the Localiser antenna and a height of 1,500 ft AMSL.

The tracks of the 6 NM and 17 NM part orbit profiles are shown in Figure 6.2 below. Figure 6.3 below shows the terrain elevation profile for the 17 NM part orbit.

6.2.1 Horizontal Obstacle Clearances

For a 6 NM part orbit flight profile, the flight inspection aircraft will be at least 4.2 NM from the nearest wind turbine (T2) at a point on the part orbit track closest to the wind farm site. This distance is less than the minimum clearance required from any object in IMC, as defined in FIP 23.

For a 17 NM part orbit flight profile, the flight inspection aircraft will be at least 6.1 NM from the nearest wind turbines (T6, T7 and T10) at a point on the part orbit track closest to the wind farm site. This distance is greater than the minimum clearance required from any object in IMC and VMC, as defined in FIP 23.

6.2.2 Vertical Obstacle Clearances

In accordance with FCSL FIP 23, pilots must not fly within 1,000 ft of the ground in IMC. The 17 NM part orbit flight must therefore be flown at a height of at least 1,000 ft above the highest obstacle to be encountered.

Figure 6.3 below shows that a flight inspection aircraft flying a 17 NM part orbit will pass overhead and close to the summit of Moylussa mountain (1,745 ft). The 17 NM part orbit must therefore be flown at a height of at least 2,745 ft AMSL to remain at least 1,000 ft clear of the summit of Moylussa mountain.

The maximum height of the highest wind turbine (T6) can be estimated as:

Ground height + maximum turbine height = 253 m + 158 m = 411 m (1,348 ft).

For an orbit height of 2,745 ft AMSL, a flight inspection aircraft will therefore have a clearance of 1,397 ft above the highest wind turbine. This height exceeds the minimum clearance required above terrain and obstacles in IMC and VMC.

6.3 ILS Bottom Edge Flight Profile

6.3.1 Horizontal Obstacle Clearances

For the bottom edge flight profile (flown on centreline), the flight inspection aircraft will be approximately 4.4 NM laterally from the nearest wind turbine (T1) at a point on the extended runway centreline closest to the wind farm. This distance is less than the minimum clearance required from any object in IMC, as defined in FIP 23.

6.3.2 Vertical Obstacle Clearances

For the bottom edge flight profile (flown on centreline), the flight inspection aircraft is flown at a glide path angle 0.12θ below the nominal glide path angle (θ).

Bottom edge glide path angle = $\theta - 0.12\theta = 3° - 0.36° = 2.64°$.

The flight inspection aircraft will pass above, but 4.4 NM laterally distant from, the proposed Ballycar Wind Farm site. The flight inspection aircraft vertical clearance above the highest turbine (T6) can be estimated as follows:

Horizontal distance from 24 Glide Path antenna (on boresight) to Turbine T6

= 15,208 m

Assume ground height at 24 Glide Path Antenna = ARP height = 46 ft = 14 m

Clearance (h) above highest turbine (T1)

= (15,208 m × tan 2.64°) − (253 m − 14 m) − 158 m = 304 m = 997 ft

This height exceeds the minimum clearance required above terrain and obstacles in VMC, but is less than the minimum clearance required in IMC.

6.4 ILS Slice Flight Profile

6.4.1 Horizontal Obstacle Clearances

For the slice flight profile (flown on centreline), the flight inspection aircraft will be approximately 4.4 NM laterally from the nearest wind turbine (T1) at a point on the extended runway centreline closest to the wind farm. This distance is less than the minimum clearance required from any object in IMC, as defined in FIP 23.

6.4.2 Vertical Obstacle Clearances

Figure 6.4 below shows the track of the ILS slice flight profile. The slice profile is normally flown at a height of 1,000 ft AMSL.

Figure 6.5 below shows the terrain elevation profile for the slice flight profile. The highest terrain on the slice profile from a range of 11 NM (12.7 miles) is approximately 150 ft AMSL. The 1,000 ft slice flight profile must therefore be flown within sight of the surface and not flown in IMC.

Figure 6.5 below shows that for a Runway 24 ILS Glide Path flight inspection slice profile (level run) at an altitude of 1,000 ft, clearance above the highest terrain will be adequate at approximately 850 ft. However, in IMC, Glide Path level runs will need to be flown at an altitude of at least 2,348 ft to remain 1,000 ft above the highest wind turbine. The altitude will be rounded up to the nearest 100 ft, so the ILS Glide Path slice profile will therefore have to be flown at 2,400 ft in IMC.

6.5 ILS Left Slice 8° Flight Profile

6.5.1 Horizontal Obstacle Clearances

For the left slice 8° flight profile (flown at an angle of 8° left of centreline with respect to the Localiser antenna), the flight inspection aircraft will be approximately 3.1 NM laterally from the nearest wind turbine (T1) at a point on the extended runway centreline closest to the wind farm. This distance is less than the minimum clearance required from any object in IMC, as defined in FIP 23.

6.5.2 Vertical Obstacle Clearances

Figure 6.4 below shows the track of the ILS left slice 8° flight profile. The slice profile is normally flown at a height of 1,000 ft AMSL.

Figure 6.6 below shows the terrain elevation profile for the left slice 8° flight profile.

The highest terrain on the left slice 8° profile from a range of 11 NM (12.7 miles) is approximately 900 ft AMSL. The 1,000 ft left slice 8° flight profile must therefore be flown within sight of the surface and not flown in IMC.

Figure 6.6 below shows that for a Runway 24 ILS Glide Path flight inspection level run (left slice 8°) at an altitude of 1,000 ft, clearance above the highest wind turbine will not be adequate. However, in IMC, Glide Path level runs will need to be flown at an altitude of at least 2,348 ft to remain 1,000 ft above the highest wind turbine. The altitude will be rounded up to the nearest 100 ft, so the ILS Glide Path left slice 8° (level run) will therefore have to be flown at 2,400 ft in IMC.

6.6 Analysis

If Glide Path flight inspection level runs (slice profiles) are to be flown at higher altitudes to provide sufficient clearance above obstacles, the length and duration of the runs, and distance from the runway will increase correspondingly. This could result in some increased flight inspection costs.

In addition, at increased ranges, there may not be sufficient Glide Path RF signal to ensure correct ILS receiver operation.

6.7 Runway 24 Glide Path Special Flight Inspection

As part of an impact assessment for another proposed wind farm, to be located approximately 9 NM north east of Shannon Airport, FCSL recently performed additional Runway 24 Glide Path level runs at an altitude of 2,600 ft AMSL. These additional level runs were flown on 20 April 2022, to verify that adequate RF signal level is achieved (to ensure correct ILS receiver operation) and to ensure that adequate fly-up guidance is obtained below the Glide Path sector.

The results of the additional Glide Path level runs are shown in Figures 6.7 and 6.8 below.

6.7.1 Slice 2,600 ft

Figure 6.7 below shows that for Glide Path left slice level run flown at an altitude of 2,600 ft AMSL, the minimum signal level of -95 dBW/m^2 is achieved at a range of approximately 20 NM from runway threshold. Figure 6.7 also shows that adequate fly-up guidance exists from this range.

6.7.2 Left Slice 2,600 ft

Figure 6.8 below shows that for Glide Path left slice level run flown at an altitude of 2,600 ft AMSL, the minimum signal level of -95 dBW/m^2 is achieved at a range of approximately 18.4 NM from runway threshold. Figure 6.8 also shows that adequate fly-up guidance exists from this range.

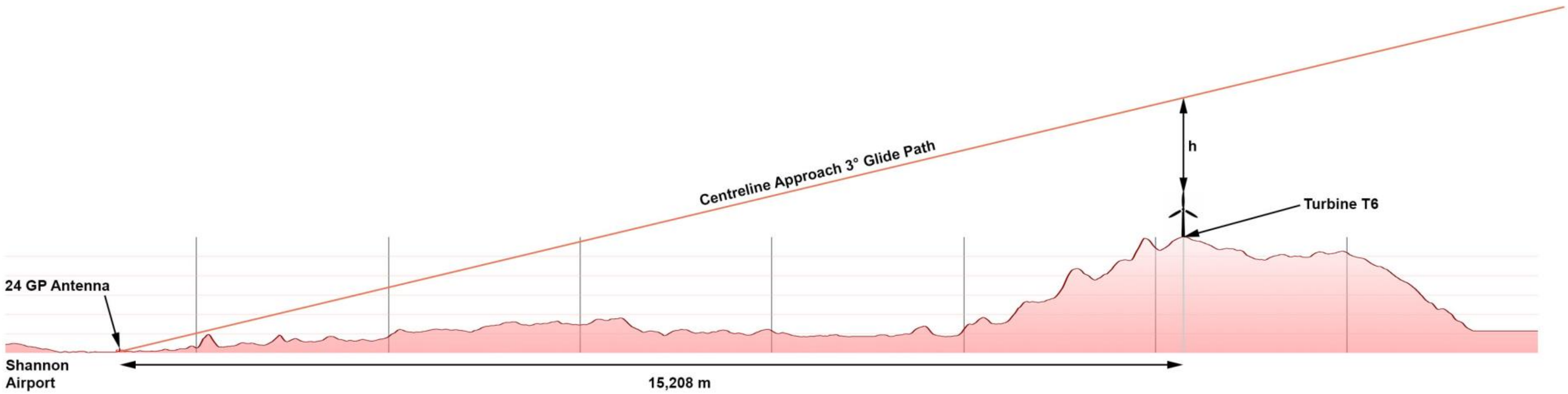


Figure 6.1 – ILS Centreline Approach Profile

(Not to scale)

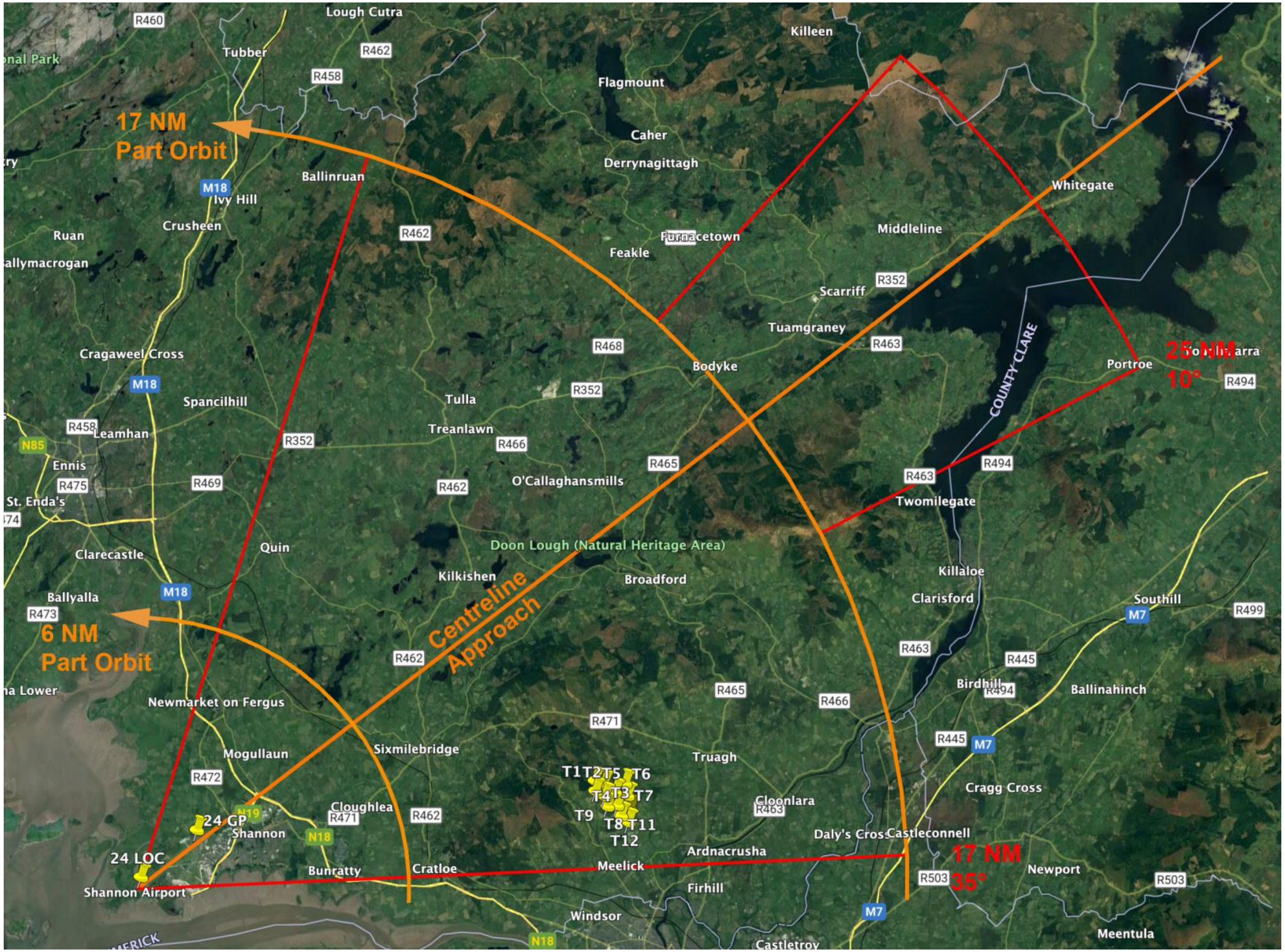


Figure 6.2 – ILS Centreline Approach and Part Orbit Tracks

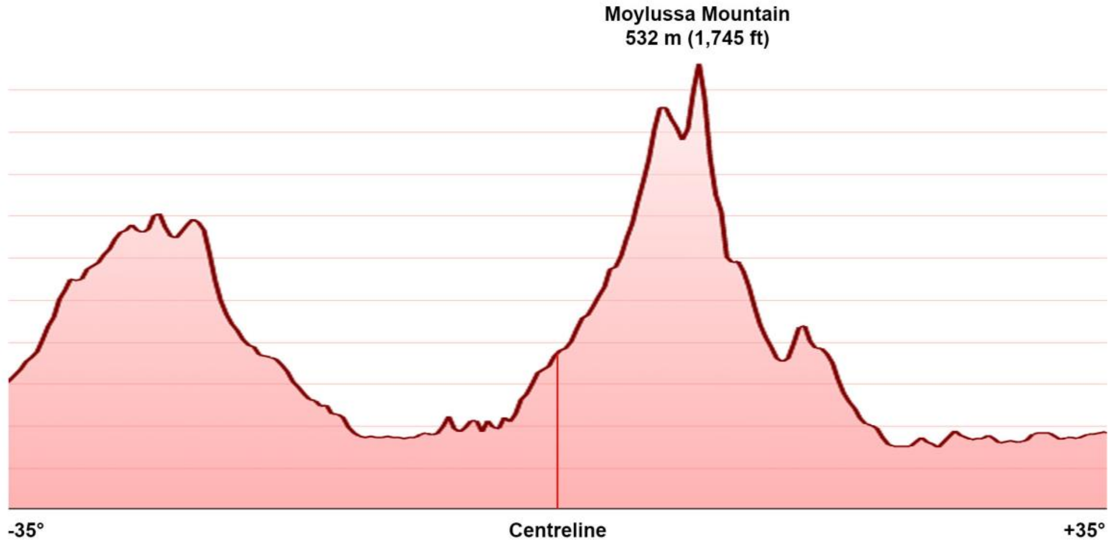


Figure 6.3 – 17 NM Part Orbit Terrain Elevation Profile

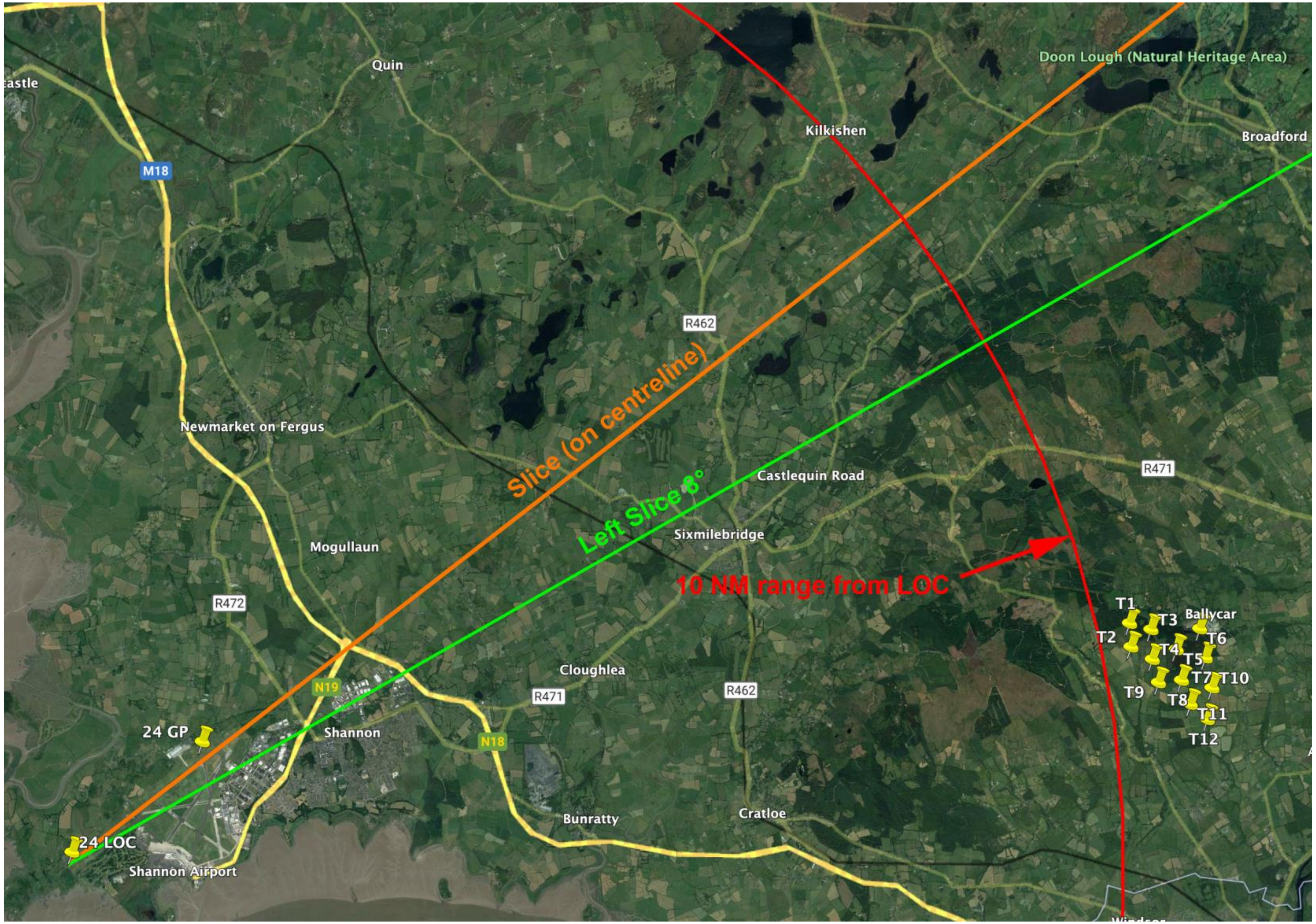


Figure 6.4 – Slice and Left Slice 8° Tracks

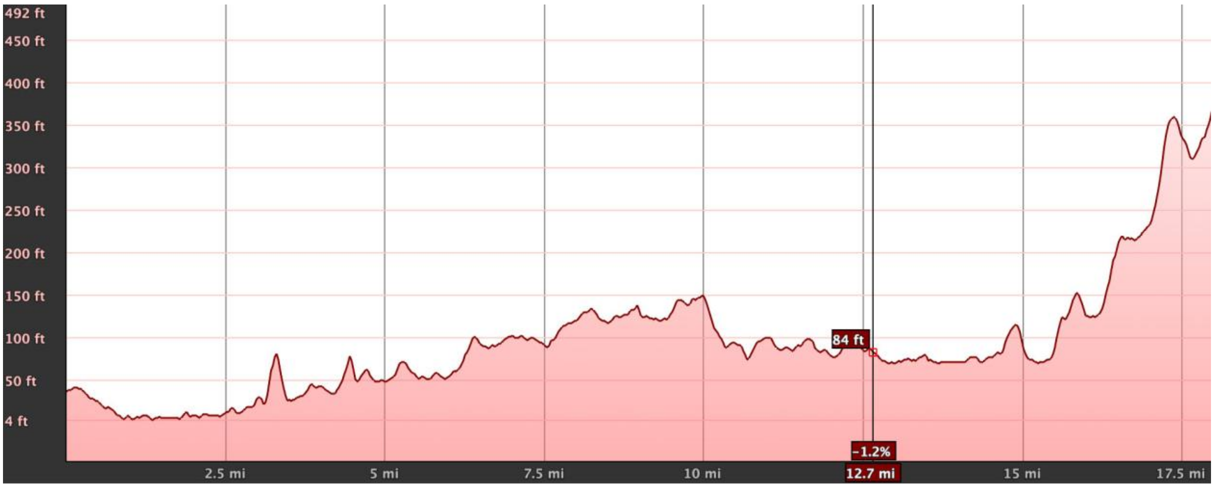


Figure 6.5 – Slice Terrain Elevation Profile

Figure 6.6 – Left Slice 8° Terrain Elevation Profile

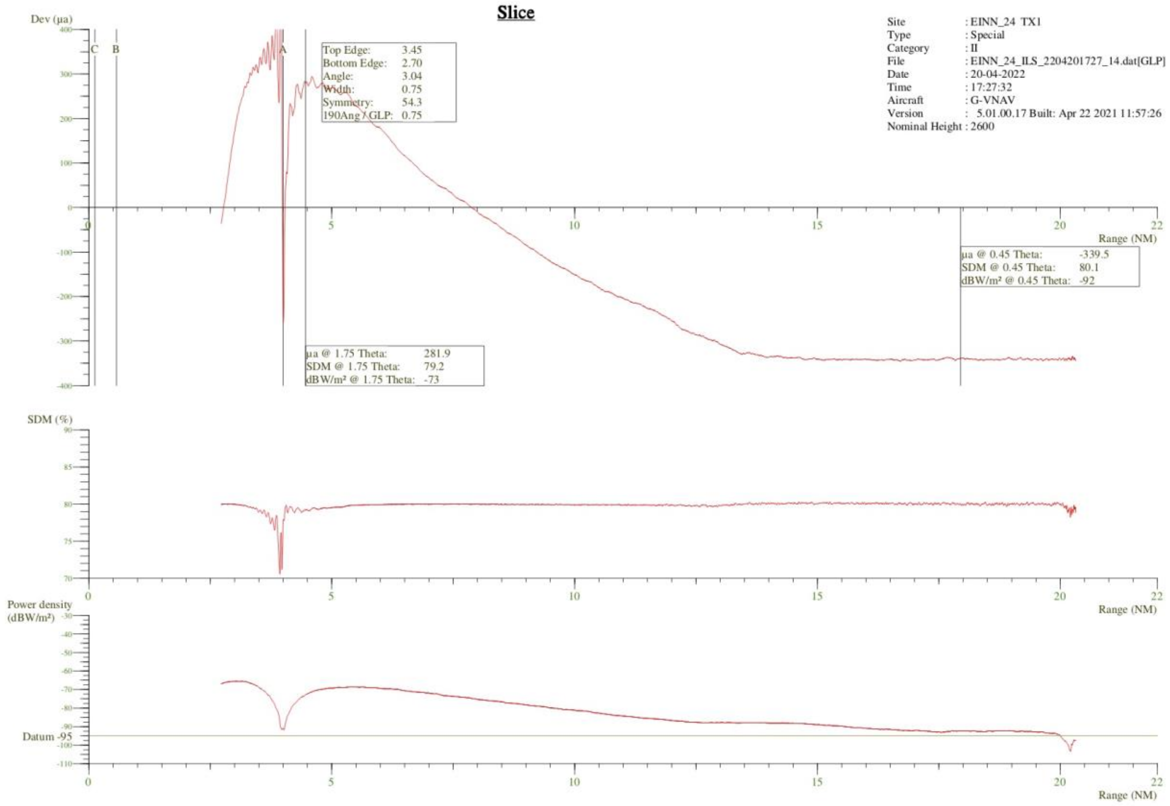


Figure 6.7 - Slice 2,600 ft

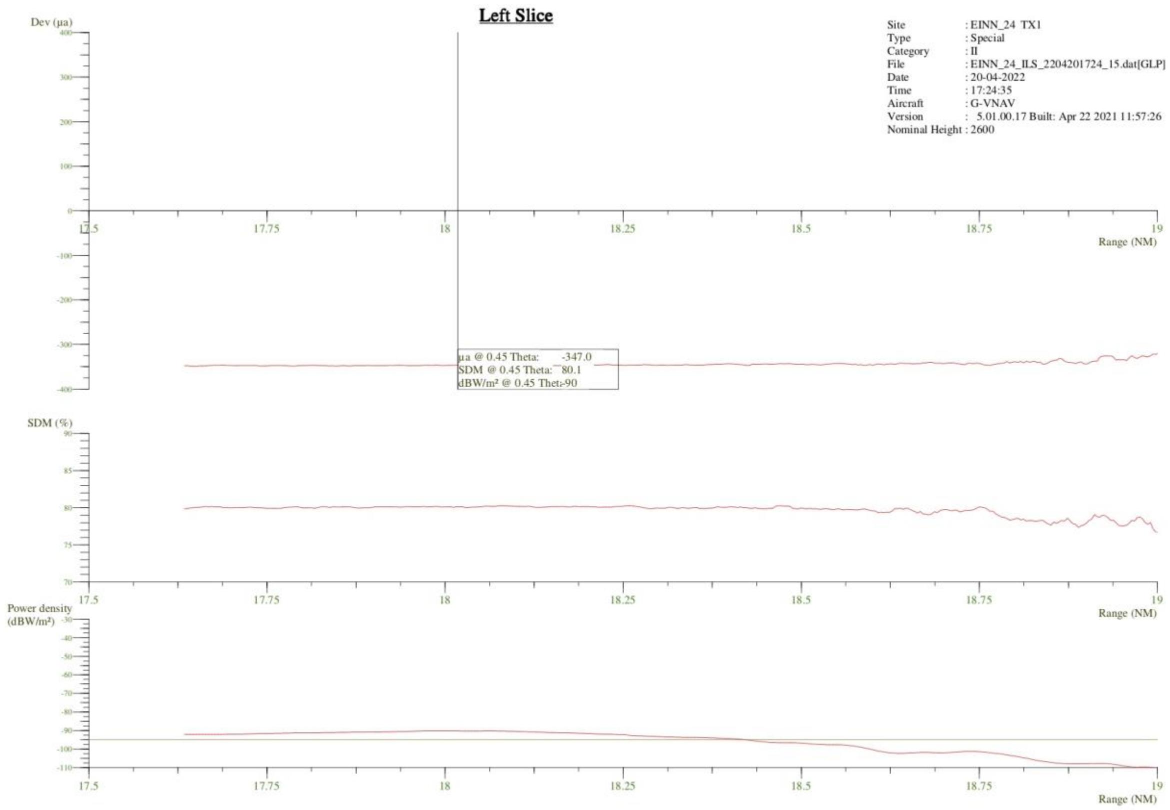


Figure 6.8 - Left Slice 2,600 ft

7 CONCLUSIONS

The assessment presented in Section 6 above has shown that a flight inspection aircraft flying centreline, part orbit and bottom edge flight profiles associated with the Shannon Airport Runway 24 ILS will remain sufficiently clear of the proposed Ballycar Wind Farm site.

However, for the slice and left slice 8° profiles, the proposed wind farm will require that these profiles are flown at higher altitudes to provide sufficient clearance above the proposed wind turbines. The flight inspection Glide Path slice and left slice 8° profiles (level runs) will have to be raised to an altitude of 2,400ft in IMC to provide the flight inspection aircraft adequate coverage over the proposed wind turbines.

Section 6.7 above shows that for level runs flown at an altitude of 2,600 ft, Glide Path RF signal levels exceed minimum level of -95 dBW/m^2 and sufficient fly-up guidance is achieved below the Glide Path sector.

The proposed Ballycar wind farm will therefore not have any adverse effect on Runway 24 ILS flight inspection procedures and flight profiles.

This report provides an assessment of the impact of terrain and obstacles on ILS flight inspection procedures. It does not provide an assessment of any impact the proposed wind farm may have on the integrity of the ILS guidance signals.

Appendix 4

Ballycar Wind Farm Aviation Impact Assessment & Mitigation Report

Report

Ballycar Wind Farm
Aviation Impact Assessment
& Mitigation Report

Document Number:	001/VH202104			
Author:	PT\DMG\KH			
Approved for Release:	Rev 3.0	KH	**Date:**	11/08/23
Document Filename:	*Ballycar Wind Farm – Aviation Impact Assessment & Mitigation Report*			

Executive Summary

Ai Bridges Ltd was commissioned by the Environmental Planning Consultants, Malachy Walsh and Partners (hereafter referred to as MWP) to review a consultation response from the Irish Aviation Authority (hereafter referred to as IAA) received in November 2022 in relation to the possible interference impacts of the proposed Ballycar wind farm on the Surveillance Radar equipment at Shannon Airport and Woodcock Hill.

In their response the IAA noted that there was:

> *"… no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections, reflections and shadowing from the proposed turbines…"*

The IAA also noted that:

> *"… the proposed development would introduce false primary targets or clutter on the Shannon Primary radar. Mitigation for the primary clutter would degrade the performance of the Shannon primary radar…"*

Ai Bridges subsequently conducted a full review of all correspondence between MWP and the IAA and recommended a further detailed technical assessment to be carried out by a third party IAA Approved Procedure Designer, Cyrrus Limited, to investigate all possible Mitigation Measure options to remediate the impacts on surveillance radar systems. It was also recommended to engage with the manufacturers of the Surveillance Radar equipment being used by the IAA to confirm if said equipment supported wind farm mitigation features.

The findings from the Mitigation Options Study included the following recommendation that states that the radar technical documentation provides assurance that mitigation for proposed the Ballycar Wind Farm is possible subject to an on-site condition survey to ascertain if updates or upgrades would be required :

> *" … The technical documentation provided by the manufacturer (Thales) of the two systems provides assurance that mitigation for the Ballycar Windfarm is possible. Cyrrus would recommend that an onsite condition survey is carried out by Thales on both the Shannon Airport and Woodcock Hill systems to confirm their current operational state and ascertain whether updates or upgrades would be required …"*

IAA Consultations

1. In January 2022, MWP engaged and submitted a scoping report to the IAA with a request for comments in relation to a proposed wind farm on lands at and near Ballycar, Co. Clare.

2. There were further rounds of consultations in January 2022 with the Airspace and Navigation Team at the IAA where it was highlighted that there are a number of

aviation surfaces under the responsibility of the IAA Air Navigation Service Provider (ANSP) regarding safeguarding around Shannon Airport. These were referred internally within the IAA and the Shannon Airport Operator for further response on potential impacts to the following:

- Navigational Aids
- Surveillance Radar
- Instrument Flight Procedures (IFPs)

The MWP consultation engagements with the IAA from January 2022 to May 2022 served to:

i) Identify the main concerns of the IAA in relation to the potential impacts on aviation surfaces.

ii) Present the findings of the detailed Aviation Technical Assessments to the IAA in relation to Instrument Flight Procedures, showing a ***"No Impact"*** condition.

iii) Present the findings of the detailed Aviation Technical Assessments to the IAA in relation to Navigational/Flight Calibration Impact Assessments , demonstrating a **"No Impact"** condition.

iv) Present the findings of the detailed Aviation Technical Assessments to the IAA in relation to Radar Surveillance including the Primary Surveillance Radar (PSR) at Shannon Airport and the Monopulse Secondary Radar (MSR) at Woodcock Hill, showing a **"Potential Impact"** condition which can be appropriately mitigated.

IAA Consultation Reponses

The IAA has welcomed and accepted the findings presented within the detailed Aviation Technical Assessments and in a consultation response to MWP on February 28th 2022 responded as follows:

1. *In relation to the IFP Opinion (Attachment 1) I'm happy to accept that the proposed turbines will not affect the Shannon Airport Instrument Flight Procedures and nothing further is required from this perspective.*

   Note: If planning is granted and the construction goes ahead, these turbines will need to be notified to the IAA Aviation Safety Regulator, each being higher than 100m elevation.
2. *Technical Assessment Report:*
   - *Building Restricted Areas: SAA's Paul Hennessy copied for information.*
   - *NAVAIDs: The report conforms no issues for Airport NAVAIDs: Fergal Doyle copied to confirm this.*
   - *Surveillance: The report notes that mitigations are required for the Shannon PSR and the Woodcock Hill MSSR most particularly not prevent false targets and ghost signals respectively. While the report outlines how these mitigations could be applied, this must be assessed by our surveillance team*

On November 29th 2022 there was a response from the IAA Surveillance M&E Division following their review of the detailed Technical Assessment Report by Cyrrus. The response stated as follows:

> *"… The IAA Surveillance Domain conclusion is that this proposed Ballycar Wind Farm development, would degrade the performance of the Woodcock Hill Radar. As a consequence the IAA would object to a Ballycar Wind Farm development planning application …"*

Wind Farm Mitigation Measures

It was identified through the consultation process with the IAA that there were no impacts on Instrument Flight Procedures, Navigational Aids or Flight Inspection Procedures and that no mitigation measures were required.

In their detailed technical aviation assessment report Cyrrus, did identify potential surveillance radar impacts stating that:

> " a form of mitigation for Shannon PSR over the proposed Ballycar development may be required … "
>
> " .. It is recommended that mitigation options are discussed with the Irish Aviation Authority (IAA), specifically Air Traffic Services. It is the surveillance network and operational use that will largely influence a suitable mitigation.."

Ai Bridges commissioned Cyrrus to review the possible Mitigation Measures and undertake a Mitigation Options Study Report that would address the ten concerns identified by the IAA in their final consultation response on November 28th 2022. Cyrrus were requested to engage with the manufacturer of the radar equipment in use at Shannon Airport and Woodcock Hill to provide supporting evidence of "wind farm mitigation" features including upgrade availability.

Cyrrus produced a "Mitigations Options Study" report following research conducted over a three-month period with references to other wind farm mitigation projects as well as reliance on data provided by the radar equipment manufacturer. The report addressed all of the IAA concerns on radar performance degradation and provides viable mitigation measures. The report has been provided with supporting evidence of workable mitigation measures with references to third-party Wind Farm Mitigation Projects.

Summary

Following the investigation of the mitigation options along with discussions with the manufacturer of the radar equipment, it has been shown that there are viable options available for the mitigation / remediation of the ten concerns raised by the IAA . The Mitigation Options Study report concludes that:

- The development of the Windfarm at Ballycar would require minimal optimization of the Woodcock Hill and Shannon Airport radars.
- The systems in place have the capacity to provide a service even if a large number of turbines were developed in the coverage area.
- The manufacturer can also provide upgrades and enhancements to both systems should they be required in future.

Sections

Appendices

1. Introduction

Malachy Walsh and Partners (MWP) commissioned an independent aviation assessment in reponse to concerns raised by the IAA in relation to a Scoping Report consultation request in January 2022 concerning the proposed Ballycar Wind Farm development. The IAA raised concerns in relation to:

- Instrument Flight Procedures (IFP) surfaces
- Navigational Aids\ ISL Flight Inspection surfaces
- Surveillance Systems

MWP commenced the consultation process with the IAA in January 2022 with the final response from the IAA being received in November 2022. The consultations and communications are detailed in Appendix A of this report.

A series of technical aviation assessment reports were submitted by MWP to the IAA Air Navigation Service Provider which satisfied the concerns raised in relation to Instrument Flight Procedures detailing that there is no impact to the IFP surfaces. This report, prepared by Cyrrus, is included in Appendix B (Ballycar Wind Farm IFP Opinion). MWP also commissioned FCSL Ltd., a certified flight inspection company retained by the IAA for bi-annual flight inspection services, to prepare a study to assess the impacts on ILS Inspection flights. The study findings reported that there were no impacts to ILS flight inspections. The full details of the report are included in Appendix D (Ballycar Wind Farm Impact on ILS Inspection Report).

MWP commissioned Cyrrus to undertake a further Technical Aviation Assessment Study to assess the impacts of the proposed wind farm development on surveillance radar systems. The study reported that there would be an impact on the surveillance radar and outlined some mitigation options. The IAA Airspace Navigation Team referred the report to their Surveillance M&E Systems Team. A response from the IAA in November in 2022 to MWP noted that the proposed Ballycar Wind Farm development would degrade the performance of the radar at Woodcock Hill and also introduce false targets or clutter on the Shannon Airport primary surveillance radar.

Ai Bridges conducted a full review of all the consultations and the aviation assessment reports and then engaged with Cyrrus to undertake a review of the IAA consultation response and undertake further research into the concerns raised by the IAA. Ai Bridges also requested Cyrrus to engage with the manufacturer to further investigate the capabilities of the radar equipment at Woodcock Hill and Shannon Airport for possible service upgrades and/or feature upgrades to mitigate the impacts. Cyrrus produced a Mitigations Options Study, shown in Appendix E, that addressed each of the concerns raised by the IAA and provided mitigation measure proposals that would allow the development of the Ballycar Wind Farm, without any residual impact on the radar systems.

Sections 1.1 to 1.3 below provides a more detailed description of the concerns raised by the IAA Air Navigation Service Provider in relation to IFP, Navigational Aid surfaces and Surveillance Radar systems.

1.1 Instrument Flight Procedures (IFP)

The Ballycar Wind Farm IFP Opinion Report, in Appendix B, identifies that the proposed wind farm does impact the current published procedures at Shannon airport. This is however limited to the ATC Surveillance Minimum Altitude Chart (ATC SMAC). Although a full IFP assessment is normally required to identify an impact, it is normally recommended to submit the opinion report to the IAA Air Service Navigation Provider for consideration as to whether a full assessment is required. Following a review of the IFP Opinion, the IAA deemed that a full IFP Assessment is not required and that there would be a No Impact condition on IFP surfaces and that no mitigation is required.

Aviation Impact Assessment	Mitigation Measure Action	Residual Impact
Instrument Flight Procedures surfaces	No action	None

1.2 Flight Inspection Procedures

The Ballycar Wind Farm Impact on ILS Inspection Report, in Appendix D shows that there is no impact on the Airport Navigational Aids at Shannon Airport. The IAA requested that an assessment be performed to establish any adverse effect the proposed wind farm may have on flight inspection procedures and profiles associated with the Shannon Airport Runway 24 Instrument Landing System (ILS). This report provides an assessment of the impact of terrain and obstacles on ILS flight inspection procedures. The assessment presented within the report outlines that the flight inspection aircraft flying centreline, part orbit and bottom edge flight profiles associated with the Shannon Airport Runway 24 ILS will remain sufficiently clear of the proposed Ballycar Wind Farm site and therefore there would be no impacts.

Aviation Impact Assessment	Mitigation Measure Action	Residual Impact
Runway 24 ILS Flight Inspection Procedures	No action	None

1.3 Surveillance Radar Systems

The Aviation Technical Assessment, in Appendix C conducted by Cyrrus identified that there would be wind farm impact degradation on the PSR at Shannon Airport which would require some form of mitigation.

Ai Bridges then engaged with Cyrrus, to undertake a Mitigations Options Study, included in Appendix E, that would investigate and address all of the concerns of the IAA in radar performance degradation, false targets and clutter raised by the IAA Surveillance M&E Systems Division.This Mitigations Options Study by Cyrrus provides a constructive technical view on how both the Woodcock Hill **Thales RSM970** Monopulse Secondary Surveillance Radar (MSSR), and the Shannon Airport **Thales STAR 2000** Primary Surveillance Radar (PSR) with co-mounted MSSR can operate without disruption to the controlled airspace and allow the development of Ballycar Windfarm. Below is an extract from this Mitigation Options Study:

> *"..Cyrrus have engaged with the manufacturer of both radar systems to confirm their capability to operate in the presence of Wind Turbines with minimal intervention. The RSM970 MSSR at Woodcock Hill and STAR 2000 PSR with co-mounted MSSR at Shannon Airport have been developed to allow this capability. The STAR 2000 PSR was designed to work in areas with wind turbines, a continual development cycle has been carried out by Thales to ensure the systems performance is not impacted by Wind Turbines. If required upgrades and enhancements for the STAR 2000 are available. Thales have provided evidence that they are confident that with minor optimisation the proposed wind turbines at Ballycar should have minimal effect on the coverage provided by the radars. This evidence is provided as commercial in confidence. Cyrrus have permission from Thales to reference relevant parts but not provide the Thales documents in full.."*

> *"..Table 1 below highlights the IAAs concerns, and the expected impacts should the windfarm be permitted to be developed. Thales have provided evidence that each of their systems has the capability of handling multiple windfarms within the coverage area. Examples include the Star 2000 sited at Schiphol Airport and the STAR 2000 based at Newcastle. The Aeronautical Information Service (AIS) for Newcastle Airport, Reference [9], has been provided for reference. The UK MoD has contracted NATS / AQUILA under project Marshall to provide a large number of these systems due to their inbuilt capability. Reference [10] gives some detail of project Marshall. Thales have also provided a structured list of upgrades, Reference [6] within the Mitigations Options Study, available to ensure the systems can continue to provide this service into the future.."*

1.3.1 IAA Concerns in relation to Surveillance Radar Systems

The IAA have raised ten concerns in relation to impacts on the Surveillance Radar Systems. Each of these concerns is individually addressed below by referencing the evidence-based material identified in the Mitigation Options Study.

1.3.1.1 IAA Concern #1 :

This concern relates to the false returns from deflected targets which are known as FRUIT (False Returns Un-correlated in Time). The Thales Monopulse Secondary Surveillance Radar (MSSR) operated at Woodcock Hill can use one of its own specific inbuilt processing techniques within its Surveillance Data Processor (SDP) to remove these false targets. This technique is used within most MSSR radars and is called a DE-FRUITER.

The Mitigation Measure solution to eliminate the radar beam deflections is highlighted within the radar manufacturer's documentation under section 3.1.3.1.1 of Reference [3] in the Mitigation Options Study and is shown in Figure 1 below.

3.1.3.1.1 MSSR/Mode S beam management

The MRP_SBM function manages all activities that must be performed within the main beam of the antenna and regulates the use of the RF channel. Its main functions are the followings:

- it prepares all information necessary to process All-Call and Roll-Call periods,
- it processes all SSR and Mode S replies received during All-Call periods,
- it manages the real-time scheduling of Mode S surveillance and data link transactions within the Roll-Call periods.

The MRP_SBM function is composed of the following sub-functions:

- Mode S Modulator and eXtractor Control (SBM_MMXC), which manages the interface between MRP CSCI and MMXC,
- Roll Call Period Processing (SBM_RCPP), which manages activities within the Roll Call periods,
- Mode S All Call Period Processing (SBM_MACPP), which manages Mode S activities within the All Call periods,
- SSR All Call Period Processing (SBM_SACPP), which manages SSR activities within the All Call periods. It includes the defruitor function.

Figure 1: Evidence of the Mitigation Measure Solution for Radar beam deflections

Additional supporting evidence within the radar manufacturer's documentation in relation to the concern of false returns is highlighted in Figure 2 below from the radar manufacturer's documentation in section 1.3.1 of Reference [3] in the Mitigation Options Study :

1.3.1 General

The RSM 970S Mode S ensures a high quality and reliable coverage to contribute to radar operational separation of 3 NM, 5 NM and 10 NM according to EUROCONTROL standard.

The radar is capable of determining range, azimuth and height positional data, along with the identity, on each target detected, during each revolution of the antenna.

Since the MSSR systems are used in an environment which often includes multiple SSR coverage, the system has been designed in order to cope with a high fruit density (MSSR and/or Mode S fruit). Therefore, the performance will be optimised such that the output of the false data is minimised, while meeting the guaranteed parameters.

The MSSR RSM 970 S Mode S is designed to meet all the guaranteed performance in the presence of a fruit rate of 11,000 replies per second.

The performance of the RSM 970 S MODE S equipment have been confirmed through the various fields and validated by Eurocontrol and French DSNA in the frame of the POEMS pre-operational European Mode S programme. Significant breakthroughs have been achieved in the fields of:

- Discrimination,
- Phantom processing,
- Reflection processing.

Typical performance characteristics are summarised below :

GENERAL	
Modes	1; 2; 3/A; C; S
Output transmitter peak power	2570 W
Transmitter frequency	1030 ± 0.01 MHz
Range	Up to 256 NM
Scan rate	Up to 15 rpm
Antenna:	
- Azimuth beamwidth	2.4°
- Maximum gain	27 dBi
Fruit density	11,000 fruit/sec in the main lobe

Figure 2: Evidence of the Mitigation Measure Solution for Radar beam deflections

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below. Based on the inbuilt DE-FRUITER capability of the MSSR, no residual impact is envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
1	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. **Reference 3 –3.1.3.1.1**Thales description of how the system automatically deals with deflections (FRUIT).	None

1.3.1.2 IAA Concern #2 :

This concern relates to the reflections that will caused by the proposed turbines. The Surveillance Data Processor (SDP) in Thales RSM970 Monopulse Secondary Surveillance Radar (MSSR) can use a two-stage reflection removal process to eliminate this problem of reflections.

The Mitigation Measure solution to eliminate the radar beam deflections is highlighted within the radar manufacturer's documentation under section 1.2.2.3 of Reference [3] in the Mitigation Options Study and is shown in Figure 3 below.

1.2.2.3 Signal and Data Processor

The signal and data processing chain performs:

1. MSSR/Mode S Processor (MMXC)
   - MSSR/Mode S scheduling,
   - MSSR/Mode S signal processing,
2. Data Processor Computer (DPC)
   - MSSR/Mode S extractor and
   - PSR/MSSR/Mode S plot combination and tracking.

The MMXC and DPC cope with garbling situations in dense surveillance areas. The Off Boresight Angle measure on each code pulse is associated to the reply message with specific flags and is routed to the monopulse post-processing. The monopulse post-processing performs plot extraction and solves conflict conditions such as garbling, phantoms, saturated presences and specifically processes emergency and distress codes.

Reflections which are common phenomena in SSR systems, are detected and processed using the monopulse information. This reflection may be found either at track level or at plot level. At track level, this function is based on an auto-adaptive process : the reflections are identified as permanent or temporary. This Thales unique feature provides automatic site environment adaptation. At plot level (prior to scan-to-scan correlation), the site environment is taken into account by windows programming.

Figure 3: Evidence of the Mitigation Measure Solution for reflections

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below highlighting the Concern versus Residual Impact condition. Based on the inbuilt two stage reflection processing capability to eliminate reflections, no residual impact is envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
2	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar reflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. **Reference 3 – 1.2.2.3**	None

1.3.1.3 IAA Concern #3 :

This concern relates to the volumes of the Woodcock Hill MSSR shadow regions that may be created by the proposed turbines. The concern relating to shadowing has been addressed within the Aviation Technical Assessment Report prepared by Cyrrus which concluded that the effects of shadowing would be minimal and should be operational tolerable.

As shadowing from the proposed wind farm development at Ballycar will be below the Air Traffic Control (ATC) surveillance minimum altitudes and should be operationally tolerable then no Mitigation Measure solutions are required. This is addressed under section 5.9.5 of Reference [1], the CL-5715-RPT-002 V1.0 Ballycar Wind Farm Aviation Technical Assessment, and is shown in Figure 4 below

5.9.5. The maximum heights of shadow regions from the turbines will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable.

Figure 4: Evidence showing Shadowing is operationally tolerable

Further evidence from Reference [1], sections 5.8.24 – 5.8.28 as shown below in Figure 5, provides the technical calculation of the shadow regions based on the EUROCONTROL Guidelines. The volumes of the shadow regions created by each of the turbines have been calculated and tabulated. In the Aviation Technical Assessment, the proposed turbines have been overlaid on the Air Traffic Control Surveillance Minimum Altitude Chart (ATC SMAC) with a maximum height of 352m or 1,155 feet AMSL for turbine T1 which is located within Sector 1 where the minimum altitude is 2,300 feet AMSL . Also, turbines T11 and T12 are in Sector 2 where the minimum altitude is 3,000 feet AMSL . Any aircraft flying at these minimum altitudes will not be flying low enough to be impacted by the shadow regions of the turbines and therefore the shadow regions should be operationally tolerable

5.8.24. An array of turbines can create a radar shadow in the space beyond it from the radar. The EUROCONTROL Guidelines provides a means of calculating the dimensions of this shadow region.

$$Dwr = Dtw/[\lambda.\frac{Dtw}{S^2}\left(1-\sqrt{PL}\right)^2 - 1]$$

- Dwr = depth of the shadow region.
- Dtw = distance of turbines
- λ = wavelength (0.29m)
- S = diameter of support structures (6m)
- PL = acceptable power loss (0.5/3dB as per guidelines)

5.8.25. The EUROCONTROL Guidelines also provide equations for calculating the width and height of the shadow regions.

5.8.26. The volumes of the Woodcock Hill MSSR shadow regions created by each of the Ballycar turbines are shown in Table 7.

5.8.27. The depth of the shadow regions beyond the Ballycar turbines will vary between 2.3km and 3.6km for Woodcock Hill MSSR, with widths of up to 65m and with a maximum height of 352m or 1,155 feet AMSL.

5.8.28. Figure 26 shows an extract of Shannon Airport's ATC Surveillance Minimum Altitude Chart, as published by the Irish Aviation Authority in the current Integrated Aeronautical Information Publication[5]. The Ballycar turbine locations are overlaid on the chart, which shows that turbines T1 to T10 are within Sector 1 where the minimum altitude is 2,300 feet AMSL. Turbines T11 and T12 are in Sector 2 where the minimum altitude is 3,000 feet AMSL. Aircraft at these minimum altitudes will not be low enough for the shadow regions to have any impact, and therefore the shadow regions that may be generated beyond the proposed turbines should be operationally tolerable.

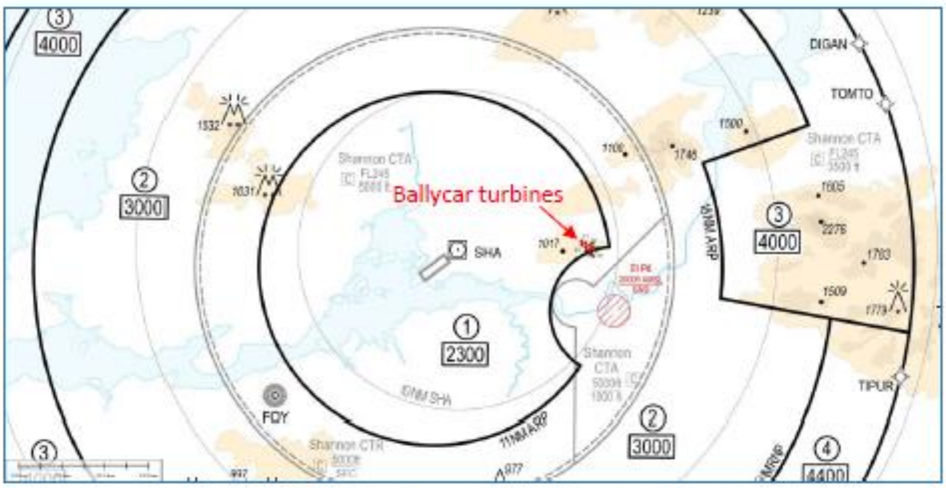


Figure 26: Shannon Airport ATC Surveillance Minimum Altitude Chart

Figure 5: Calculation of the shadow regions

The Concern versus Residual Impact condition has been extracted from Table 1 of the Mitigation Options Study showing no Mitigation Measure Solution is required as the shadowing from the proposed Ballycar windfarm will be below the published ATC SMAC altitudes and should therefore be operationally tolerable. The effect of shadowing will be minimal and of no consequence to Air Traffic Control, therefore there is no residual impact.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
3	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar shadowing from the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. **Reference 1 – 5.9.5**	None

1.3.1.4 IAA Concern #4 :

This concern relates to the false primary targets or clutter on the Primary Radar (Thales STAR 2000) at Shannon Airport. To address the concern relating to clutter, the Mitigation Options Study by Cyrrus concluded that the effects of shadowing would be minimal and should be operational tolerable. The STAR 2000 radar is quite advanced with a number of existing in-built capabilities for mitigating the effects of wind turbines. The STAR 2000 is an S-band solid-state approach radar. The current data sheet, Reference [2] of the Mitigation Options Study, for the STAR 2000 radar addresses wind farm mitigation:

> *"Windfarms: dedicated impact studies and implementation of optimal mitigation, among a large panel of solutions"*

Thales, as stated on its website, offers upgrades for its radars including a feature enabling a proper windfarm mitigation. The Windfarm Filter is a dedicated algorithm that uses a specific adaptive Constant False Alarm Rate (CFAR) mechanism designed to minimize track loss and reduce false alarms above and around windfarms. It can be integrated to address both civil and military needs and, as a software capability, can also be activated into other Thales ATC radars already in service. Based on the fact that the Thales STAR 2000 uses an advanced SDP to prevent wind turbines causing clutter to be displayed on the controllers display and the availability of the Windfarm Filter upgrade , no residual impact is envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
4	*Ballycar Wind Farm development would introduce false primary targets or clutter on the Shannon Primary radar*	Thales STAR 2000 uses an advanced SDP to prevent wind turbines causing clutter to be displayed on the controllers display. Windfarms : dedicated impact studies and implementation of optimal mitigation, among a large panel of solutions **Reference 2**	None

1.3.1.5 IAA Concern #5 :

This concern relates to the possible performance degradation of the PSR radar at Shannon Airport that may occur if mitigation measures for the impact of primary radar clutter were to be implemented.

The Thales STAR 2000 was designed to work in areas of wind farms without degradation of coverage . The Thales STAR 2000 would be able to process out the clutter by the processing capability of the Surveillance Data Processor (SDP). In the Mitigation Option Study prepared by Cyrrus, Reference [6], they highlight that Thales can provide upgrade options. The STAR 2000 has the processing capabilities to deal with wind turbines to ensure that the radar system performance is not impacted.

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below highlighting that the Surveillance Data Processor (SDP) within the existing Shannon Airport Primary radar together with minimal optimisation will result in minimal impact, and therefore no significant residual impact is envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
5	*Mitigation for the primary clutter would degrade the performance of the Shannon primary radar*	Thales STAR 2000 was designed to work in areas with wind turbines without degradation of coverage. If required upgrade options are available from Thales. A list of upgrade options has been provided. **Reference 6**	None

1.3.1.6 IAA Concern #6 :

This concern states that a non-mitigation approach relating to clutter would be operationally un-acceptable for Air Traffic Control.

The STAR 2000 would be able to process out the clutter by the Surveillance Data Processor. In the Mitigation Option Study prepared by Cyrrus, Reference [6], they highlight that Thales can provide upgrade options. The STAR 2000 has the processing capabilities to deal with wind turbines to ensure that the radar system performance is not impacted.

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below highlighting that the clutter would be processed out by the Surveillance Data Processor (SDP) in the STAR 2000 radar and upgrade options are available if required to mitigate out clutter impacts and therefore no significant residual impact is envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
6	*Not mitigating for the clutter would be operationally unacceptable and unsafe for Air traffic control*	Clutter would be processed out by the Thales STAR 2000 SDP. If required upgrade options are available from Thales. A list of upgrade options has been provided. **Reference 6**	None

1.3.1.7 IAA Concern #7 :

This concern relates to a maintenance service outage that may be required to mitigate reflections. A significant outage period would not be acceptable to the IAA and would compromise the safety of Air Traffic in Irish airspace.

The Thales RSM970 MMSR radar at Woodcock Hill has inbuilt two-stage processing to eliminate reflections and the radar would not have to be taken out of service for any significant period if optimisation was carried out. Only minor optimization would be required and Thales have completed successful upgrades based on a proven upgrade plan which would not require any operational downtime of the radar. In the Mitigation Option Study prepared by Cyrrus they conclude in Figure 6 below that :

The development of the Windfarm at Ballycar would require minimal optimisation of the Woodcock Hill and Shannon Airport radars. The systems in place have the capacity to provide a service even if a large number of turbines were developed in the coverage area. Thales can also provide upgrades and enhancements to both systems should they be required in future.

Figure 6: Minimal Optimization Requirement

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below highlighting that the existing Woodcock Hill RSM970 MSSR radar will use its inbuilt two stage reflection processing to eliminate against reflections. Therefore, the radar would not be taken out of service for a significant period. The radar in question has a modular architecture and in the event that upgrades are required any downtime would be minimal. As Thales have completed may prjects involving similar upgrades thay have upgrade implementation plans to allow that radars to remain operational throughout. Based on the inbuilt capabilities and potentially minor optimisation, a residual impact is not envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
7	*Taking the Woodcock Hill radar out of service for the many months required to mitigate reflections is not acceptable to IAA operations and would compromise the safety of Air Traffic in Irish airspace.*	The Woodcock Hill radar would not require to be taken out of service for any significant periods. Only minor optimisation should be required. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. **Reference 3 – 1.2.2.3**	None

1.3.1.7 IAA Concern #8 :

This concern relates to the potential that radar reflection mitigations may be bypassed when the radar detects aircraft squawking Emergency, Hijack or Comms failure codes.

The Thales RSM970 MMSR radar at Woodcock Hill has inbuilt two-stage processing to eliminate reflections.

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below highlighting that the Surveillance Data Processor (SDP) within the existing radars will mitigate against reflections. Based on the inbuilt capabilities, a residual impact is not envisaged.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
8	*Radar reflection mitigations are bypassed when the radar detects aircraft squawking Emergency, Hijack or Comms failure codes.*	This is not correct. The radars SDP will still mitigate against reflections. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. **Reference 3 – 1.2.2.3**	None

1.3.1.7 IAA Concern #9 :

This concern relates to the possible reduction of radar coverage and the scale of the non-initialisation area that would be required to mitigate deflections generated by the proposed wind turbines, with a reduction in radar performance below mandated requirements.

In the Mitigation Options Study, Cyrrus investigated the processing used to prevent deflected targets being displayed. The false returns from deflected targets are known as False Returns Uncorrelated in Time (FRUIT). The Surveillance Data Processor (SDP) within the Woodcock Hill MSSR will use a DE-FRUITER to remove these false targets. This technique is used in most MSSR systems.

Any deflections generated by the proposed wind turbines will be eliminated by the DE-FRUITER and a non-initialisation area should not be required. The Thales RSM970 MSSR radar at Woodcock Hill has an inbuilt DE-FRUITER to eliminate deflected targets. The Mitigation Options Study highlights, in Reference [3], the manufacturer's description of how the Woodcock Hill radar surveillance system automatically deals with deflections (FRUIT) as part of the MSSR/Mode S beam management of the Radar Processing hardware function (shown below in Figure 7).

3.1.3.1.1 MSSR/Mode S beam management

The MRP_SBM function manages all activities that must be performed within the main beam of the antenna and regulates the use of the RF channel. Its main functions are the followings:

- it prepares all information necessary to process All-Call and Roll-Call periods,
- it processes all SSR and Mode S replies received during All-Call periods,
- it manages the real-time scheduling of Mode S surveillance and data link transactions within the Roll-Call periods.

The MRP_SBM function is composed of the following sub-functions:

- Mode S Modulator and eXtractor Control (SBM_MMXC), which manages the interface between MRP CSCI and MMXC,
- Roll Call Period Processing (SBM_RCPP), which manages activities within the Roll Call periods,
- Mode S All Call Period Processing (SBM_MACPP), which manages Mode S activities within the All Call periods,
- SSR All Call Period Processing (SBM_SACPP), which manages SSR activities within the All Call periods. It includes the defruitor function.

Figure 7: MSSR/Mode S beam management DE-FRUITER function.

The Mitigation Measure Solution in relation to this IAA concern has been extracted from Table 1 of the Mitigation Options Study and is shown below highlighting that the Surveillance Data Processor (SDP) within the existing Woodcock Hill MSSR radar will use a DE-FRUITER to mitigate deflected targets. Based on this inbuilt capability, no residual impact in envisaged in relation to a reduction in radar coverage and performance below mandated requirements.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
9	*Due to the proximity of the proposed Ballycar wind turbine development to Woodcock hill, the scale of the non-initialisation area required to mitigate for the Ballycar generated deflections would in effect remove almost 30-degrees of the radars 360-degree coverage, reducing its performance below mandated requirements*	This is not correct, any deflections generated by the Ballycar wind turbines will be eliminated by the DE-FRUITER. A non-initialisation area should not be required. Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. **Reference 3 – 3.1.3.1.1**, Thales description of how the system automatically deals with deflections (FRUIT).	None

1.3.1.7 IAA Concern #10 :

This concern relates to the volumes of the Woodcock Hill MSSR shadow regions that may be created by the proposed turbines. The concern relating to shadowing has been addressed within the Aviation Technical Assessment Report prepared by Cyrrus which concluded that the effects of shadowing would be minimal and should be operational tolerable.

As shadowing from the proposed wind farm development at Ballycar will be below the Air Traffic Control (ATC) surveillance minimum altitudes and should be operationally tolerable then no Mitigation Measure solutions are required. This is addressed under section 5.9.5 of Reference [1], the CL-5715-RPT-002 V1.0 Ballycar Wind Farm Aviation Technical Assessment, and is shown in Figure 8 below.

5.9.5. The maximum heights of shadow regions from the turbines will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable.

Figure 8: Evidence showing Shadowing is operationally tolerable

Further evidence from Reference [1], sections 5.8.24 – 5.8.28 as shown below, provides the technical calculation of the shadow regions based on the EUROCONTROL Guidelines. The volumes of the shadow regions created by the proposed turbines have been calculated and tabulated. In the Aviation Technical Assessment, the proposed turbines have been overlaid on the Air Traffic Control Surveillance Minimum Altitude Chart (ATC SMAC) with a maximum height of 352m or 1,155 feet AMSL for turbine T1 which is located within Sector 1 where the minimum altitude of 2,300 feet. Also, turbines T11 and T12 are in Sector 2 where the minimum altitude is 3,000 feet for this sector . These minimum altitudes for each of these sectors can be seen below in the ATC Surveillance Minimum Altitude Chart excerpt in Figure 9 below. Any aircraft flying at these minimum altitudes within these sectors will not be flying low enough to be impacted by the shadow regions of the turbines and therefore the shadow regions should be operationally tolerable. The calculation methods are shown below in Figure 9 below.

5.8.24. An array of turbines can create a radar shadow in the space beyond it from the radar. The EUROCONTROL Guidelines provides a means of calculating the dimensions of this shadow region.

$$Dwr = Dtw/[\lambda.\frac{Dtw}{S^2}(1-\sqrt{PL})^2 - 1]$$

- *Dwr* = depth of the shadow region.
- *Dtw* = distance of turbines
- λ = wavelength (0.29m)
- S = diameter of support structures (6m)
- PL = acceptable power loss (0.5/3dB as per guidelines)

5.8.25. The EUROCONTROL Guidelines also provide equations for calculating the width and height of the shadow regions.

5.8.26. The volumes of the Woodcock Hill MSSR shadow regions created by each of the Ballycar turbines are shown in Table 7.

5.8.27. The depth of the shadow regions beyond the Ballycar turbines will vary between 2.3km and 3.6km for Woodcock Hill MSSR, with widths of up to 65m and with a maximum height of 352m or 1,155 feet AMSL.

5.8.28. Figure 26 shows an extract of Shannon Airport's ATC Surveillance Minimum Altitude Chart, as published by the Irish Aviation Authority in the current Integrated Aeronautical Information Publication[5]. The Ballycar turbine locations are overlaid on the chart, which shows that turbines T1 to T10 are within Sector 1 where the minimum altitude is 2,300 feet AMSL. Turbines T11 and T12 are in Sector 2 where the minimum altitude is 3,000 feet AMSL. Aircraft at these minimum altitudes will not be low enough for the shadow regions to have any impact, and therefore the shadow regions that may be generated beyond the proposed turbines should be operationally tolerable.

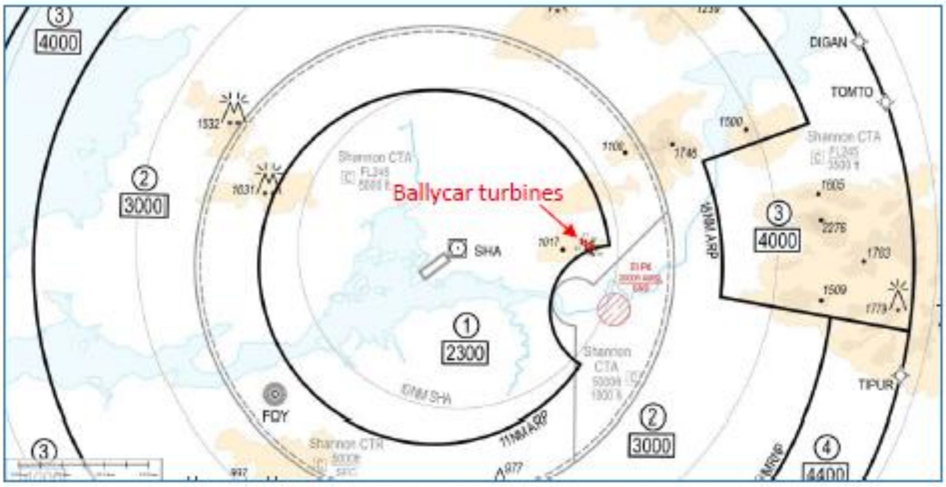


Figure 26: Shannon Airport ATC Surveillance Minimum Altitude Chart

Figure 9: Calculation of the Shadow Regions

The Concern versus Residual Impact condition has been extracted from Table 1 of the Mitigation Options Study showing no Mitigation Measure Solution is required as the shadowing from the proposed Ballycar windfarm will be below the published ATC SMAC altitudes and should therefore be operationally tolerable. The effect of shadowing will be minimal and of no consequence to Air Traffic Control and therefore, there is no residual impact.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
10	*Shadowing from the turbines results in a degradation of the probability of detection of aircraft flying behind the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. **Reference 1 – 5.9.5**	None

2. Summary

Table 1 (taken from the Mitigation Options Study) shows the concerns raised by the IAA and the likely impact on the Woodcock Hill and Shannon Airport systems. Based on the below it is apparent that the proposed Ballycar wind farm will not result in any residual impact on the systems due to the inbuilt systems capabilities and minor optimisation opportunities.

No	Description of Concern	Mitigation Measure Solution	Residual Impact
1	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. **Reference 3 – 3.1.3.1.1,** Thales description of how the system automatically deals with deflections (FRUIT).	None
2	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar reflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. **Reference 3 – 1.2.2.3**	None
3	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar shadowing from the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. **Reference 1 – 5.9.5**	None
4	*Ballycar Wind Farm development would introduce false primary targets or clutter on the Shannon Primary radar*	Thales STAR 2000 uses an advanced SDP to prevent wind turbines causing clutter to be displayed on the controllers display. Windfarms: dedicated impact studies and implementation of optimal mitigation, among a large panel of solutions **Reference 2**	None
5	*Mitigation for the primary clutter would degrade the performance of the Shannon primary radar*	Thales STAR 2000 was designed to work in areas with wind turbines without degradation of coverage. If required upgrade options are available from Thales. A list of upgrade options has been provided. **Reference 6**	None
6	*Not mitigating for the clutter would be operationally unacceptable and unsafe for Air traffic control*	Clutter would be processed out by the Thales STAR 2000 SDP. If required upgrade options are available from Thales. A list of upgrade options has been provided. **Reference 6**	None
7	*Taking the Woodcock Hill radar out of service for the many months required to mitigate reflections is not acceptable to IAA operations and would compromise the safety of Air Traffic in Irish airspace.*	The Woodcock Hill radar would not require to be taken out of service for any significant periods. Only minor optimisation should be required. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. **Reference 3 – 1.2.2.3**	None
8	*Radar reflection mitigations are bypassed when the radar detects aircraft squawking Emergency, Hijack or Comms failure codes.*	This is not correct. The radars SDP will still mitigate against reflections. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. **Reference 3 – 1.2.2.3**	None
9	*Due to the proximity of the proposed Ballycar wind turbine development to Woodcock hill, the scale of the non-initialisation area required to mitigate for the Ballycar generated deflections would in effect remove almost 30-degrees of the radars 360-degree coverage, reducing its performance below mandated requirements*	This is not correct, any deflections generated by the Ballycar wind turbines will be eliminated by the DE-FRUITER. A non-initialisation area should not be required. Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. **Reference 3 – 3.1.3.1.1**, Thales description of how the system automatically deals with deflections (FRUIT).	None
10	*Shadowing from the turbines results in a degradation of the probability of detection of aircraft flying behind the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. **Reference 1 – 5.9.5**	None

Table 1: IAA Concerns v Residual Impact

3. Recommendations

From the findings of the Mitigations Options Study Report prepared by Cyrrus the following recommendations have been made to remediate the concerns raised by the IAA ANSP in relation to surveillance radar impacts on the Woodcock Hill MSSR and the Shannon Airport PSR. Below is an extract from this Mitigation Options Study:

i) The technical documentation provided by the manufacturer (Thales) of the two systems provides assurance that mitigation for the Ballycar Windfarm is possible. Cyrrus would recommend that an onsite condition survey is carried out by Thales on both the Shannon Airport and Woodcock Hill systems to confirm their current operational state and ascertain whether updates or upgrades would be required.

ii) A limited operational flight trial may also be prudent at this stage to provide a baseline of the current systems coverage over the area of the proposed Windfarm.

iii) Once the windfarm is built, the systems may require minor optimisation by Thales. Once completed, a further Flight Check would be recommended to confirm the systems performance was acceptable over the Windfarm area

Appendix A – IAA Consultations

APPENDIX A - IAA Consultations

The consultations between Malachy Walsh & Partners (MWP) and the Irish Aviation Authority (IAA) in relation to Ballycar wind farm are presented below.

IAA Email to MWP - 05 January 2022

From: *O'LEARY Geraldine <Geraldine.O'LEARY@IAA.ie>*
Sent: *Wednesday 5 January 2022 14:04*
Subject: *Proposed Ballycar Wind Farm [Filed 07 Jan 2022 11:03]*

Dear Mr. Barry,

Thank you for your letter and scoping report and request for comments in relation to a proposed wind farm on lands at and near Ballycar, Co. Clare.

As the blade tip height proposed is not included, nor specific turbine positions and the ground elevation of each site is not provided, Safety Regulation Division - Aerodromes cannot make any specific comments at this time.

The development appears to be approximately 16km East of Shannon Airport, as such, the applicant should engage with Shannon Airport Authority and the IAA's Air Navigation Service Provider (ANSP) as a matter of urgency to undertake a preliminary screening assessment to confirm that the proposed wind farm and the associated cranes that would be utilised during its construction would have no impact on instrument flight procedures, communication and navigation aids or flight checking at Shannon Airport. Contact details are as below:

Aerodrome Operator – Shannon Airport:	IAA-ANSP:	Shannon Tower Business Unit
Mr. Paul Hennessy Safety Compliance and Environment Manager Shannon Airport Authority DAC t: +353-61-712471 m: +87-2382453 e: paul.hennessy@shannonairport.ie	Mr. Cathal Mac Criostail Airspace & Navigation Manager Údarás Eitlíochta na hÉireann / Irish Aviation Authority The Times Building, 11-12 D'Olier Street, Dublin 2, D02 T449, Ireland cathal.maccriostail@iaa.ie +353 (0)1 6031173 +353 (0)86 0527130	Mr. Jonathan Byrne Operations Manager STBU/CTBU Air Traffic Control Irish Aviation Authority jonathan.byrne@iaa.ie +353 61 703704 +353 87 9375486

Subject to any study noting a potential impact on the safety of operations at Shannon Airport, during the formal planning process, the Safety Regulation Division – Aerodromes would likely make the following general observation:

In the event of planning consent being granted, the applicant should be conditioned to contact the Irish Aviation Authority to: (1) agree an aeronautical obstacle warning light scheme for the wind farm development, (2) provide as-constructed coordinates in WGS84 format together with ground and tip height elevations at each wind turbine location and (3) notify the Authority of intention to commence crane operations with at least 30 days prior notification of their erection.

Yours sincerely

Deirdre Forrest
Corporate Affairs

MWP Email to IAA - 13 January 2022

From: *Peter Barry <Peter.Barry@mwp.ie>*
Sent: *Thursday 13 January 2022 10:35*
Subject: *RE: Proposed Ballycar Wind Farm*

Hi Geraldine,

Please find attached the turbine coordinates, hub height, rotor diameter and ground elevation as requested (email thread below).

If you need any more information, please let me know.
I would appreciate if you would acknowledge receipt of this email.

Peter Barry
BSc MSc CEnv
Principal Environmental Scientist

IAA Email to MWP - 13 January 2022

From: *MACCRIOSTAIL Cathal <Cathal.MacCriostail@IAA.ie>*
Sent: *Thursday 13 January 2022 13:41*
Subject: *220112 Proposed Ballycar Wind Farm*
Importance: *High*

Dear Peter,

Happy New Year and many thanks for the data supplied in the attached file.

There are a number of surfaces that the IAA Air Navigation Service Provider (ANSP) are responsible for safeguarding around Shannon Airport, including Navigation Aids, Surveillance Radar and Instrument Flight Procedures (IFPs).

In regard to the IFP surfaces, I am responsible for safeguarding here and we have a safeguarding grid to guide as to whether there is a potential impact on the IFP surfaces, generated by new obstacles, such as the proposed (12) wind turbines.

Below is a depiction of this safeguarding grid with a pin at Ballycar:

The values each grid cell represent an Above Mean Sea Level (AMSL: Site elevation + Height of obstacle) elevation value, above which, an IFP impact assessment will be required. In the case of the Ballycar area and taking the highest turbine height supplied, 254m added to an approximate site elevation of 240m, gives an AMSL elevation of in excess of 400m, which is above the safeguarding values in this area.

Separately, the heights proposed will likely impact the Surveillance Radar at Woodcock Hill and navigation aids for approaches to Shannon Airport. I've copied colleagues from the ANSP in these areas, for information.

This is not the only wind turbine proposal for this area and to be completely upfront, nearly all are creating issues for the surfaces referenced.

If you could supply confirmation of the AMSL elevations of the turbines and give co-ordinates in WGS 84 format (Latitude and Longitude), this would be appreciated and will allow me to give greater clarity on requirements for the ANSP and indeed SAA. If I have picked up on information incorrectly, please do correct me.

Kind regards,

Cathal
Cathal Mac Criostail
Údarás Eitlíochta na hÉireann / Irish Aviation Authority

MWP Email to IAA - 13 January 2022

From: *Peter Barry <Peter.Barry@mwp.ie>*
Sent: *Thursday 13 January 2022 15:16*
Subject: *RE: 220112 Proposed Ballycar Wind Farm*

Hi Cathal,

Attached table with Lat/ Long coordinates included. Also, to clarify the column rotor diameter was labelled wrong in the earlier table I emailed, it should have been labelled blade length, rotor diameter is then double. Corrected table attached with AMSL as requested.

We are happy to discuss findings once you have had a chance to carry out your internal studies. We are still in the design and assessment stage. Let me know if I can do anything else.

Peter

IAA Email to MWP - 14 January 2022

From: *MACCRIOSTAIL Cathal <Cathal.MacCriostail@IAA.ie>*
Sent: *Monday 14 February 2022 17:44*
Subject: *220214 Proposed Ballycar Wind Farm ANSP Update*
Importance: *High*

Dear Peter,

Many thanks for the email and the attached detailed outline of the proposed Turbine co-ordinates and AMSL elevations. Thanks also for the phone-call by way of reminder on this.

As I outlined there are three areas of concern for us the IAA Air Navigation Service Provider:

1. ***Instrument Flight Procedures (IFPs) surfaces:*** *Below is a Google Earth outline of the turbines with our IFP safeguarding girds overlayed:*

As you can see the guide (IFP) elevation which does not affect the IFPs, is exceeded for many of the proposed turbines. This does not mean that this is not acceptable. It does however require an IF assessment to be carried out by a certified IFP designer to assess possible impacts. When you're ready to engage on this I can advise on which companies are certified for this work. The result should confirm no impact, or recommend mitigations, e.g. lowering of some turbines elevations possibly

2. ***Navigation Aids:*** *The nearest turbine proposed is c. 16.5 km from Shannon Airport and as such should be outside area of concern for our ground-based navigation aids. This may need to be confirmed by the company who carry out flight checking if these systems. Fergal Arthurs and Fergal Doyle, Could you review and provide an opinion please?*

3. ***Surveillance:*** *The turbines as proposed are close to our surveillance systems at Woodcock Hill and will need to be considered for an effect on these systems. Attached is some guidance material and I'll refer this element to my colleague Charlie O'Loughlin for a view on this.*

If you are proceeding to planning application, could you advise all copied please and we can assess where we are at that point?

I hope this all makes sense.

Kind regards,
Cathal

Cathal Mac Criostail
Údarás Eitlíochta na hÉireann / Irish Aviation Authority

MWP Email to IAA – 25 February 2022

From: *Peter Barry <Peter.Barry@mwp.ie>*
Sent: *Friday 25 February 2022 14:47*
Subject: *RE: 220214 Proposed Ballycar Wind Farm ANSP Update*

Hi Cathal,

Thank you for below. We are proceeding with the application.

I attached a couple of reports which we commissioned by Cyrrus. You might review and we could discuss the findings and recommended mitigation. There have been a couple of iterations of the layout since, but the mitigation measures should be the same.

Do we need to have a meeting to discuss the attached?

IAA Email to MWP - 28 February 2022

From: *MACCRIOSTAIL Cathal <Cathal.MacCriostail@IAA.ie>*
Sent: *Monday 28 February 2022 12:50*
Subject: *220228 Proposed Ballycar Wind Farm ANSP Update (2)*
Importance: *High*

Dear Peter,

Many thanks for the attached reports.

1. *In relation to the IFP Opinion (Attachment 1) I'm happy to accept that the proposed turbines will not affect the Shannon Airport Instrument Flight Procedures and nothing further is required from this perspective.*

   Note: If planning is granted and the construction goes ahead, these turbines will need to be notified to the IAA Aviation Safety Regulator, each being higher than 100m elevation

2. *Technical Assessment Report:*

   - *Building Restricted Areas: SAA's Paul Hennessy copied for information*
   - *NAVAIDs: The report conforms no issues for Airport NAVAIDs: Fergal Doyle copied to confirm this*
   - ***Surveillance:*** *The report notes that mitigations are required for the Shannon PSR and the Woodcock Hill MSSR most particularly not prevent false targets and ghost signals respectively. While the report outlines how these mitigations could be applied, this must be assessed by our surveillance team (Charlie O'Loughlin and his team copied).*

This last item will be the main issue for then IAA ANSP in my experience. This proposed development is one of multiple application in the same general area which is all cases is leading to an assessment of Surveillance impacts. While in isolation "filtering" of PSR and /or updates to the reflector file for Woodcock Hill MSSR may seem straightforward, it may be of significant cost to the ANSP and if required for multiple developments, lead to a realistically unusable radar system for aircraft targets between 3500 and 10000 feet, which would be the altitude band serving Shannon Airport. Added to this, such system upgrades have not been planned for in the Surveillance work programme.

I suggest that Charlie and his team will need to assess and revert with their position. Please follow up with me in a week's time and I'll in turn check with Surveillance.

Best regards,
Cathal

Cathal Mac Criostail
Údarás Eitlíochta na hÉireann / Irish Aviation Authority

MWP Email to IAA – 09 March 2022

From: *Peter Barry <Peter.Barry@mwp.ie>*
Sent: *Wednesday 9 March 2022 09:46*
Subject: *RE: 220228 Proposed Ballycar Wind Farm ANSP Update (2)*

Hi Cathal,

Just following up on below, as you advised.

FYI, I have emailed FCSL and am waiting to hear back.

IAA Email to MWP - 09 March 2022

From: *MACCRIOSTAIL Cathal <Cathal.MacCriostail@IAA.ie>*
Sent: *09 March 2022 10:28*
Subject: *RE: 220228 Proposed Ballycar Wind Farm ANSP Update (2)*

Many thanks for all this Peter.

I appreciate your proactive engagement on this.

Kind regards,

Cathal

Cathal Mac Criostail
Údarás Eitlíochta na hÉireann / Irish Aviation Authority

IAA Email to MWP - 29 November 2022

From: *OLOUGHLIN Charlie <Charlie.OLOUGHLIN@IAA.ie>*
Sent: *Tuesday 29 November 2022 13:47*
Subject: *[Pending]RE: 220516 Proposed Ballycar Wind Farm ANSP Update-Surveillance Request*

Hi Peter,

My apologies for not replying to you sooner with a response from the IAA's Surveillance Domain in relation to the proposed Ballycar Wind Farm and our review of the Cyrrus Technical Assessment Report.
We assessed the Cyrrus report back in the summer but neglected to close the circle by replying with our comments and conclusions.

Our assessment is that the proposed Ballycar Wind Farm development would introduce Woodcock hill radar reflections, deflections and shadowing.

The IAA Surveillance Domain conclusion is that this proposed Ballycar Wind Farm development, would degrade the performance of the Woodcock Hill Radar.

As a consequence the IAA would object to a Ballycar Wind Farm development planning application.

I have outlined below a brief summary of Woodcock Hill radar impact concern. Reflections and shadowing are also identified in the CYRRUS report but the deflection issue is not.

IAA Radars must now meet EU mandated (EU 1207/2011) performance criteria in order to support 5 nautical Mile separation of aircraft in IAA airspace. Radar performance is assessed on an ongoing periodic basis as well as prior to implementation of any Radar configuration change. From our assessment Woodcock hill radar, without mitigation would not meet the mandated surveillance performance required relating to False Target reports and positional accuracy. The implementation of mitigations for the false target reports will compromise the radars probability of detection requirements and the testing of the mitigations will compromise our availability requirements. We believe there are no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections, reflections and shadowing from the proposed turbines.
We also note the proposed Ballycar Wind Farm development would introduce false primary targets or clutter on the Shannon Primary radar. Mitigation for the primary clutter would degrade the performance of the Shannon primary radar. Not mitigating for the clutter would be operationally unacceptable and unsafe for Air traffic control.

> *Reflections generate dual aircraft tracks which set off IAA automation system (COOPANS) safety-net alarms such as Short-Term Conflict Alert (STCA) and Duplicate (DUPE) alerts. These alerts distract Air Traffic controllers who may attempt to deconflicting real Air traffic tracks from tracks that do not physically exist.*
> *Each Safety Net Alarm initiates a safety occurrence report.*
> *Reflections occur when an aircraft replies to both a radar interrogation directly and to an interrogation reflected by the Turbine tower or rotor blade; the radar generates both a real aircraft track and a false reflected track in the direction of the turbine.*
> *It is possible to reduce the probability of reflections through mitigation. This is normally done at the commissioning phase, where reflection mitigations for existing structures are implemented and tested prior to the operational use of the radar. Mitigating for multiple changing reflections during the construction and operation of wind Turbines within 4km of the woodcock radar, may require the radar to be taken out of service for the duration of the construction phase to implement and test the reflection mitigations. Taking the Woodcock Hill radar out of service for the many months required to mitigate reflections is not acceptable to IAA operations and would compromise the safety of Air Traffic in Irish airspace.*
> *Radar reflection mitigations are bypassed when the radar detects aircraft squawking Emergency, Hijack or Comms failure codes.*
>
> *Deflections also generate dual aircraft tracks which set off COOPANS safety-net alarms such as Short-Term Conflict Alert (STCA) and Duplicate (DUPE) alerts. These alerts distract Air Traffic controllers who may attempt to deconflicting real Air traffic tracks from tracks that do not physically exist.*
> *Each Safety Net Alarm initiates a safety occurrence report.*
> *Deflections occur when a Radar interrogation signal is deflected by the Wind Turbine introducing an error in the measured bearing of the Aircraft. This bearing error increases with range of the aircraft from the radar, becoming significant at ranges beyond 100Nautical miles. The radar bearing errors become an issue when the deflected Radar tracks are fused with the track data from other radars which calculate a different position for the aircraft track, and the deflected track is not associated with the true track position and a new Duplicate track is generated.*
> *We have mitigated for deflections from individual masts by implementing non-initialisation-areas in our Tracking systems (ARTAS). However, this non-initialisation-area mitigation must be kept to a minimum to avoid introducing holes in radar coverage. Due to the proximity of the proposed Ballycar wind turbine development to Woodcock hill, the scale of the non-initialisation area required to mitigate for the Ballycar generated deflections would in effect remove almost 30-degrees of the radars 360-degree coverage, reducing its performance below mandated requirements.*

Shadowing from the turbines results in a degradation of the probability of detection of aircraft flying behind the proposed turbines. This may result in the Woodcock hill radar not meeting its mandated Surveillance performance requirements.

Regards,
Charlie O'Loughlin.
Manager Surveillance M&E Systems,
Irish Aviation Authority,
Shannon Area Control Centre,
Ballycasey Cross, Shannon, Co. Clare, Ireland.

Appendix 5

Mitigation Options Study Ballycar Windfarm

Mitigation Options Study

Ballycar Windfarm

AI Bridges Ltd

16 May 2023

CL-5912-RPT-002 v1.0

www.cyrrus.co.uk

info@cyrrus.co.uk

ISO 9001 QUALITY MANAGEMENT

ISO 14001 ENVIRONMENTAL MANAGEMENT

Document Information	
Document title	Mitigation Options Study
Author	Kevin Sissons
Reviewed by	Project Manager Name
Produced by	Cyrrus Limited Cyrrus House Concept Business Court Allendale Road Thirsk North Yorkshire YO7 3NY T: +44 (0) 1845 522 585 F: +44 (0) 8707 622 325 E: info@cyrrus.co.uk W: www.cyrrus.co.uk
Document reference and Version	CL-5912-RPT-002 v1.0
Date of release	16 May 2023

Change History Record

Issue	Change Reference	Date	Details
1.0	Initial Issue	16 May 2023	Initial Issue

Executive Summary

Cyrrus have been requested by AI Bridges to provide a response to the Irish Aviation Authority email [6] which states *"**We believe there are no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections, reflections and shadowing from the proposed turbines.**"*

This report provides a constructive technical view on how both the Woodcock Hill **Thales RSM970** Monopulse Secondary Surveillance Radar (MSSR), and the Shannon Airport **Thales STAR 2000** Primary Surveillance Radar (PSR) with co-mounted MSSR can operate without disruption to the controlled airspace and allow the development of Ballycar Windfarm.

Cyrrus have engaged with the manufacturer of both radar systems to confirm their capability to operate in the presence of Wind Turbines with minimal intervention. The RSM970 MSSR at Woodcock Hill and STAR 2000 PSR with co-mounted MSSR at Shannon Airport have been developed to allow this capability. The STAR 2000 PSR was designed to work in areas with wind turbines, a continual development cycle has been carried out by Thales to ensure the systems performance is not impacted by Wind Turbines. If required upgrades and enhancements for the STAR 2000 are available. Thales have provided evidence that they are confident that with minor optimisation the proposed wind turbines at Ballycar should have minimal effect on the coverage provided by the radars. This evidence is provided as commercial in confidence. Cyrrus have permission from Thales to reference relevant parts but not provide the Thales documents in full.

Table 1 below highlights the IAAs concerns, and the expected impacts should the windfarm be permitted to be developed. Thales have provided evidence that each of their systems has the capability of handling multiple windfarms within the coverage area. Examples include the Star 2000 sited at Schiphol Airport and the STAR 2000 based at Newcastle. The Aeronautical Information Service (AIS) for Newcastle Airport[9] has been provided for reference. The UK MoD has contracted NATS / AQUILA under project Marshall to provide a large number of these systems due to their inbuilt capability. Reference [10] gives some detail of project Marshall. Thales have also provided a structured list of upgrades [6] available to ensure the systems can continue to provide this service into the future.

Table 1 shows the concerns raised by the IAA and the likely impact on the Woodcock Hill and Shannon Airport systems.

	Description of Concern	Mitigation Measure Solution	Residual Impact
1	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. Reference 3 – 3.1.3.1.1, Thales description of how the system automatically deals with deflections (FRUIT).	None

2	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar reflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. Reference 3 – 1.2.2.3	None
3	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar shadowing from the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. Reference 1 – 5.9.5	None
4	*Ballycar Wind Farm development would introduce false primary targets or clutter on the Shannon Primary radar*	Thales STAR 2000 uses an advanced SDP to prevent wind turbines causing clutter to be displayed on the controllers display. Windfarms: dedicated impact studies and implementation of optimal mitigation, among a large panel of solutions Reference 2	None
5	*Mitigation for the primary clutter would degrade the performance of the Shannon primary radar*	Thales STAR 2000 was designed to work in areas with wind turbines without degradation of coverage. If required upgrade options are available from Thales. A list of upgrade options has been provided. Reference 6	None
6	*Not mitigating for the clutter would be operationally unacceptable and unsafe for Air traffic control*	Clutter would be processed out by the Thales STAR 2000 SDP. If required upgrade options are available from Thales. A list of upgrade options has been provided. Reference 6	None
7	*Taking the Woodcock Hill radar out of service for the many months required to mitigate reflections is not acceptable to IAA operations and would compromise the safety of Air Traffic in Irish airspace.*	The Woodcock Hill radar would not require to be taken out of service for any significant periods. Only minor optimisation should be required. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. Reference 3 – 1.2.2.3	None

8	*Radar reflection mitigations are bypassed when the radar detects aircraft squawking Emergency, Hijack or Comms failure codes.*	This is not correct. The radars SDP will still mitigate against reflections. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. Reference 3 – 1.2.2.3	None
9	*Due to the proximity of the proposed Ballycar wind turbine development to Woodcock hill, the scale of the non-initialisation area required to mitigate for the Ballycar generated deflections would in effect remove almost 30-degrees of the radars 360-degree coverage, reducing its performance below mandated requirements*	This is not correct, any deflections generated by the Ballycar wind turbines will be eliminated by the DE-FRUITER. A non-initialisation area should not be required. Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. Reference 3 – 3.1.3.1.1, Thales description of how the system automatically deals with deflections (FRUIT).	None
10	*Shadowing from the turbines results in a degradation of the probability of detection of aircraft flying behind the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. Reference 1 – 5.9.5	None

Table 1: IAA Concerns v Impact

Conclusion

The development of the Windfarm at Ballycar would require minimal optimisation of the Woodcock Hill and Shannon Airport radars. The systems in place have the capacity to provide a service even if a large number of turbines were developed in the coverage area. Thales can also provide upgrades and enhancements to both systems should they be required in future.

Abbreviations

AIS	Aeronautical Information Service
AIP	Aeronautical Information Publication
IAA	Irish Aviation Authority
MSSR	Monopulse Secondary Surveillance Radar
PSR	Primary Surveillance Radar
SDP	Surveillance Data Processor

References

[1] CL-5715-RPT-002 V1.0 Ballycar Wind Farm Aviation Technical Assessment

[2] Thales Star 2000 Datasheet

[3] Thales RSM970 Technical Description

[4] Thales Windfarm Mitigation Presentation

[5] IAA email detailing their concerns

[6] Thales structured list of upgrades

[7] Eurocontrol Mode S station Functional Specification (EMS 3.1.1)

[8] ICAO annex 10 vol IV

[9] AIS AIP Newcastle Airport

[10] An in-depth look at Project Marshall | Thales Group

Contents

List of figures

List of tables

1. Introduction

1.1. Overview

1.1.1. Cyrrus have been requested by AI Bridges to provide Aviation support for the Ballycar Windfarm proposal. Previously Cyrrus issued a report [1] which provided the technical evidence demonstrating that both the Shannon Airport and Woodcock Hill radars would have Radar Line of Sight with the Windfarm.

1.2. Aim

1.2.1. This report provides evidence that current systems at Woodcock Hill and Shannon Airport can mitigate the proposed Ballycar Windfarm with minimal intervention.

1.2.2. The following sections address the concerns raised by the IAA in email [5].

1.3. Woodcock Hill Radar

1.3.1. The Woodcock Hill RSM 970 Radar is a tried and tested system used throughout the UK and Europe. The Thales datasheet detailing the systems technical characteristics and ability to meet the Eurocontrol Mode S station Functional Specification (EMS 3.11)[7] and ICAO annex 10 vol IV latest edition standards[8] which have been included for reference.

1.3.2. The IAA have raised concerns that reflections, deflections, and shadowing will cause unacceptable issues. Evidence is provided to constructively address each of these concerns, including confirmation from Thales of the System's ability to address these issues with minimal intervention.

1.3.3. To address the issue of reflections, the Thales RSM970 technical submission details how the system can automatically process sporadic reflections, also known as dynamic reflections, to prevent degradation of the radar picture. The system utilises a second stage of reflection processing which is used to address repeated reflections from one area, these are placed in the static reflector file and automatically processed out by the system. A full explanation of how the radar does this is provided in the Thales RSM970 technical description [3].

1.3.4. The IAA's 2nd concern was that Beam deflection can take place on the Woodcock Hill MSSR. Cyrrus investigated the processing used to prevent deflected targets being displayed. The false returns from deflected targets are known as False Returns Uncorrelated in Time (FRUIT). The Surveillance Data Processor (SDP) within the Woodcock Hill MSSR will use a De-FRUITER to remove these false targets. This technique is used in most MSSR systems. A detailed explanation of how this is done is provided in reference [3].

1.3.5. The IAA's 3rd concern, that shadowing would degrade the area behind the windfarm. Cyrrus and Thales are confident that any effect would be minimal and have no impact on aeronautical operations.

1.4. Shannon Airport STAR 2000 Radar

1.4.1. The Shannon Airport radar is a Thales Star 2000 PSR with co-mounted MSSR.

1.4.2. Rotating wind turbine blades will be processed as moving targets by the PSR and will be displayed as clutter. Modern SDP systems can use advanced techniques prevent this clutter from the Wind turbines from being displayed.

1.4.3. The Thales datasheet [2], confirms the STAR 2000 was designed to operate in areas with wind turbines. Thales have confirmed that the STAR 2000 systems at both Schiphol Airport in the Netherlands and Newcastle Airport in the UK, both operate successfully with multiple windfarms within close proximity of the radars. The Aeronautical Information Service (AIS) for Newcastle Airport [9] has been provided for reference.

1.4.4. The UK MoD have under project Marshall contracted for the supply of a large number of these systems due to their inbuilt capability to operate alongside windfarms.

1.4.5. Thales have undertaken extensive trials documented in their Windfarm Mitigation presentation [4] which concludes the issue of false plots and desensitisation from wind turbines has been solved.

2. IAA Issue Summary

2.1. Table of Results

2.1.1. Table 2 contains a summary of the IAA concerns and if they can be addressed. A traffic Light system has been used to highlight the fact that currently there are no impacts with either the Woodcock Hill or Shannon Airport Radars which cannot be addressed.

	Description of Concern	Mitigation Measure Solution	Residual Impact
1	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar beam deflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. Reference 3 – 3.1.3.1.1, Thales description of how the system automatically deals with deflections (FRUIT).	None
2	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar reflections from the proposed turbines*	Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. Reference 3 – 1.2.2.3	None
3	*no credible and implementable mitigations on the Woodcock hill radar itself to eliminate the Radar shadowing from the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. Reference 1 – 5.9.5	None
4	*Ballycar Wind Farm development would introduce false primary targets or clutter on the Shannon Primary radar*	Thales STAR 2000 uses an advanced SDP to prevent wind turbines causing clutter to be displayed on the controllers display. Windfarms: dedicated impact studies and implementation of optimal mitigation, among a large panel of solutions. Reference 2	None
5	*Mitigation for the primary clutter would degrade the performance of the Shannon primary radar*	Thales STAR 2000 was designed to work in areas with wind turbines without degradation of coverage. If required upgrade options are available from Thales. A list of upgrade	None

		options has been provided. Reference 6	
6	*Not mitigating for the clutter would be operationally unacceptable and unsafe for Air traffic control*	Clutter would be processed out by the Thales STAR 2000 SDP. If required upgrade options are available from Thales. A list of upgrade options has been provided. Reference 6	None
7	*Taking the Woodcock Hill radar out of service for the many months required to mitigate reflections is not acceptable to IAA operations and would compromise the safety of Air Traffic in Irish airspace.*	The Woodcock Hill radar would not require to be taken out of service for any significant periods. Only minor optimisation should be required. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. Reference 3 – 1.2.2.3	None
8	*Radar reflection mitigations are bypassed when the radar detects aircraft squawking Emergency, Hijack or Comms failure codes.*	This is not correct. The radars SDP will still mitigate against reflections. Thales RSM970 MSSR has inbuilt two stage reflection processing to eliminate reflections. Reference 3 – 1.2.2.3	None
9	*Due to the proximity of the proposed Ballycar wind turbine development to Woodcock hill, the scale of the non-initialisation area required to mitigate for the Ballycar generated deflections would in effect remove almost 30-degrees of the radars 360-degree coverage, reducing its performance below mandated requirements*	This is not correct, any deflections generated by the Ballycar wind turbines will be eliminated by the DE-FRUITER. A non-initialisation area should not be required. Thales RSM970 MSSR has inbuilt DE-FRUITER to eliminate deflected targets. Reference 3 – 3.1.3.1.1, Thales description of how the system automatically deals with deflections (FRUIT).	None
10	*Shadowing from the turbines results in a degradation of the probability of detection of aircraft flying behind the proposed turbines*	Shadowing from Ballycar Windfarm will be below the published ATC surveillance minimum altitudes and should therefore be operationally tolerable. Reference 1 – 5.9.5	None

Table 2: IAA Concerns v Impact

2.2. Recommendations

2.2.1. The technical documentation provided by the manufacturer (Thales) of the two systems provides assurance that mitigation for the Ballycar Windfarm is possible. Cyrrus would recommend that an onsite condition survey is carried out by Thales on both the Shannon Airport and Woodcock Hill systems to confirm their current operational state and ascertain whether updates or upgrades would be required. A limited operational flight trial may also be prudent at this stage to provide a baseline of the current systems coverage over the area of the proposed Windfarm.

2.2.2. Once the windfarm is built, the systems may require minor optimisation by Thales. Once completed, a further Flight Check would be recommended to confirm the systems performance was acceptable over the Windfarm area.

This Page Is Intentionally Blank

Appendix 6

AIRNAV Response Statement Ballycar Wind Farm

Response AIRNAV Ireland

Ballycar Windfarm

Al Bridges

[Date] 25 April 2024

CL-6056-DOC-002 DA

www.cyrrus.co.uk

info@cyrrus.co.uk

Document Information	
Document title	Response AIRNAV Ireland
Author	Kevin Sissons
Reviewed by	Simon McPherson
Produced by	Choose an item. Cyrrus House Concept Business Court Allendale Road Thirsk North Yorkshire YO7 3NY T: +44 (0) 1845 522 585 F: +44 (0) 8707 622 325 E: info@cyrrus.co.uk W: www.cyrrus.co.uk
Document reference and Version	CL-6056-DOC-002 DA
Date of release	25 April 2024

Change History Record

Issue	Change Reference	Date	Details
1.0	Initial Issue	25 April 2024	Initial Issue

Response Statement

This statement has been prepared in response to the concerns raised by AIRNAV Ireland in the letter received Friday 8th March 2024.

The main concerns raised are that the Windfarm could introduce Reflections, Deflections and Shadowing which would compromise the Woodcock Hill radars ability to support 5NM Separation in Enroute Airspace and 3NM Separation in Dublin Airspace.

Previously evidence has been provided that the Thales Monopulse Secondary Surveillance Radar sited at Woodcock Hill can operate safely in area's with high numbers of reflections and deflections as these common issues will be processed out.

Some minor shadowing in the area directly behind the windfarm may occur. Previous secondary radar studies have found the affected area is usually only a few hundred metres and of minimal operational consequence.

A further concern was also raised that a 30-degree sector extending over the Irish sea in which AIRNAV Ireland have responsibilities for Enroute traffic would suffer from degraded performance.

This concern was demonstrated by drawing two straight lines from the radar over the most northern and southern turbines as seen in Figure 1.

Figure 1: AIRNAV Ireland Affected Area

Extensive trials have been done with radars operating in area's with windfarms which show Figure 1 is not indicative of how the radar will perform. The CAA state the following:

"***Shadowing behind the Turbines caused by Physical Obstruction*** *SUR13A.68 Trials have indicated that wind turbines also create a shadow beyond the wind farm so that low flying aircraft flying within this shadow go undetected. The magnified shadows of the turbine blades and the moving rotors are visible on the radar screens of weather and ATC radars [Reference 3]. However recent trial measurements have indicated that the shadow region behind the wind turbines would last only a few hundred meters and would hide only very small objects."*

"Low Level Coverage

SUR13A.85 Existence of a shadow region means the radar's ability to detect targets directly behind the wind turbines can be affected. Since a shadow region is thought to exist only a few kilometres behind a wind farm and the size is believed to be defined by a straightforward geometric relationship between the radar and the wind turbine farm, only the low level coverage is affected."

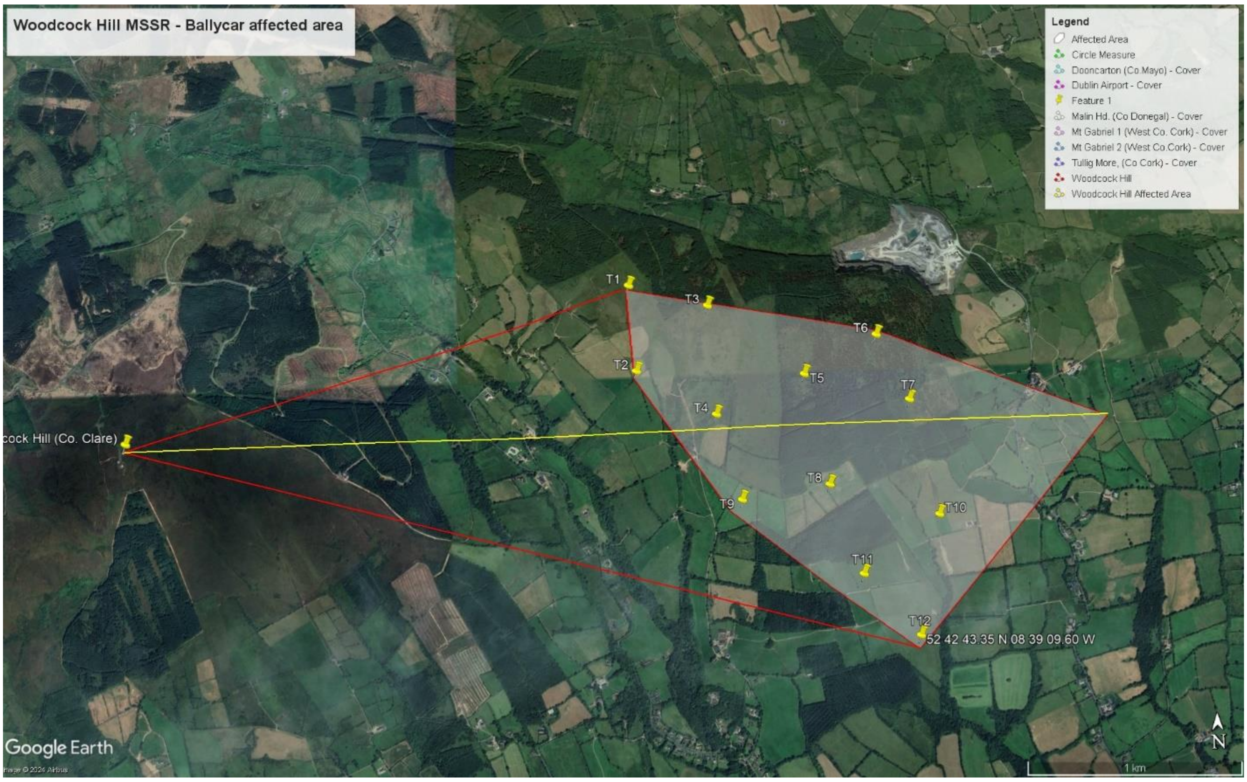


Figure 2: Woodcock Hill - Ballycar Affected Area

Figure 2 shows an indication of the area around the proposed Ballycar windfarm which may be affected.

Enroute traffic is generally expected to be between FL100 and FL400, as only the low-level coverage is likely to be affected there will be no degradation in the radar performance for enroute traffic.

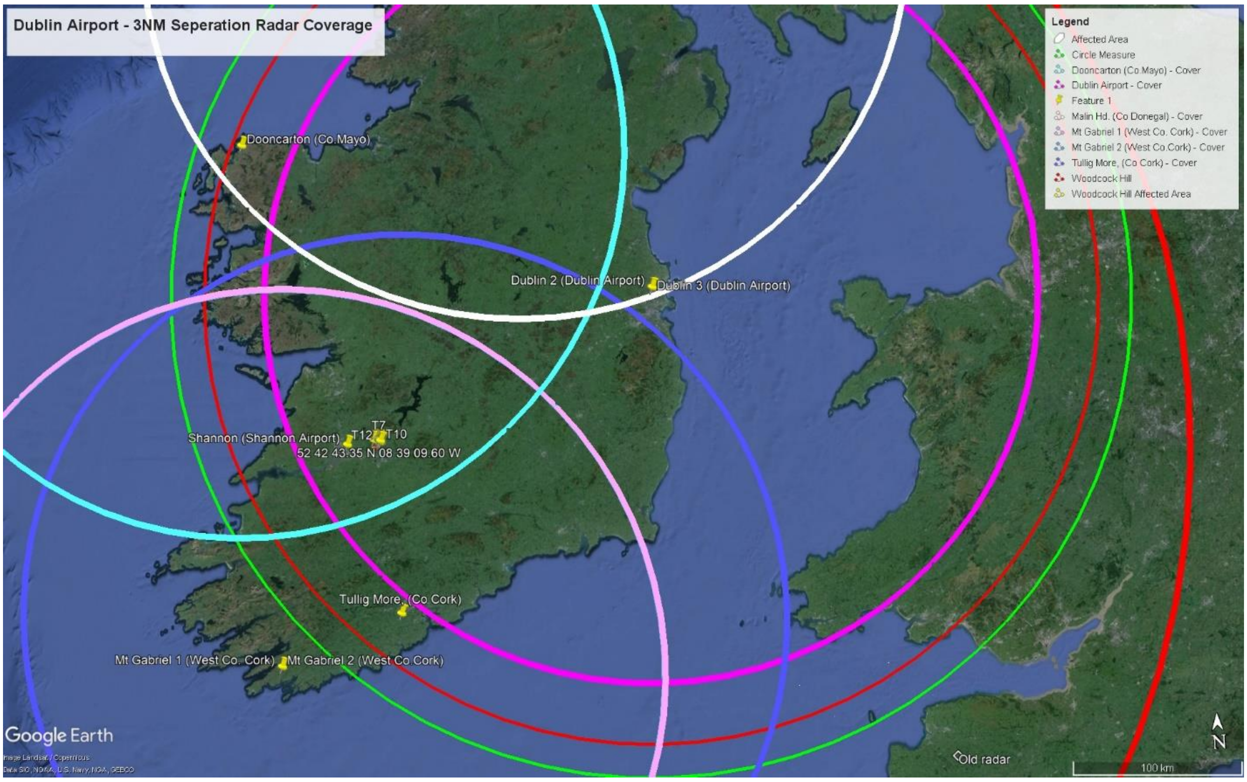


Figure 3: Dublin Terminal Area 3NM Coverage

To further address the concern that the 3NM Separation in Dublin Airspace may be degraded, The coverage from the Airport and Enroute Sensors are shown in Figure 3. As can be seen, the Airspace has overlapping radar coverage from at least 3 Systems closer to the Airport than Woodcock Hill. The AIRNAV Ireland website states: ***"The ARTAS systems merge the radar data and distribute the appropriate air situation picture to our controllers in Shannon, Dublin and Cork."***.

It is unlikely that the Woodcock Hill radar which is > 90NM from the Dublin Airport wood be used for maintaining the 3NM Separation when A minimum of four other systems provide closer cover in this area.

Appendix 7

Aviation Assessment Methodology

7.0 Aviation Assessment Methodology

There are four stages in preparing and compiling an aviation review of the study area which are shown below:

- Consultation with relevant aviation authorities and aviation stakeholders.
- Undertaking field survey and desktop screening of the receiving aviation & aeronautical environment.
- Undertake desktop network modelling and software screening analysis of all aviation & aeronautical surfaces with reference to all legislation and ICAO and EASA EUROCONTROL Guidelines.
- Aviation Impact Assessment Report.

7.1 Aviation Consultations

Consultations are commenced with relevant statutory consultees, aviation and aerodrome operators, Air Navigation Service Providers (ANSP), Aviation Authority Safety Regulation Divisions as well as Air Corp and Emergency Service Response Units who are requested to raise any concerns they have regarding the impact of the proposed wind farm development on critical surfaces (Aeronautical Surfaces, Instrument Flight Procedures, Navigational Aids, Communications and Radar Surveillance networks).

7.2 Aviation Surveys

Desktop surveys of the critical aeronautical infrastructure and aerodromes sites are undertaken to assess aviation communications, navigation and surveillance infrastructure. This is to ensure that all aeronautical activities in the controlled Class C and uncontrolled Class G (including private air strips) airspace have been identified for review at the desktop network analysis and modelling stage. The survey process is used to assist in identifying aeronautical infrastructure that could be impacted by the proposed wind farm development to ensure aviation safeguarding (e.g. identification of Primary and Secondary radar surveillance for low coverage and en-route navigation, Navigational & Communication Aids including ILS landing system).

7.3 Aviation Desktop Network Analysis & Modelling

Desktop network analysis & modelling are carried out against relevant aviation and aeronautical infrastructure identified during the desktop survey process. Software based communications and radio planning tools are used to construct a 3D model of the wind farm morphology that can be layered on a topography layer and shown relative to the proposed development layout. The radio planning tool uses GIS and terrain mapping databases to enable accurate 3D modelling, and the aviation and aeronautical surfaces can then be layered on the proposed wind farm topology. An assessment is carried out to determine if there will be any impacts on aviation and aeronautical safeguarding surfaces including Navigational Aids, Instrument Flight Procedures communication of critical networks due to the proposed development. The impacts are screened as per the matrix shown in Table 1. This matrix is completed in the Aviation Review Statement

All assessment work at this stage would assist in establishing a baseline environment. Any cumulative effects of the proposed wind farm development is then considered and included for analysis at this stage.

Aeronautical Aid \ System	Residual Impact	Impact Summary	Mitigation Measure
Annex 14 - Obstacle Limitation Surfaces (OLS)	Take-off :		
	Approach		
Annex 15 - Aerodrome Surfaces			
Minimum Sector Altitudes (MSA)			
Instrument Flight Procedures: Departures, Approaches and ATCSMAC charts			
Communication and Navigation Systems			
Radar Surveillance Systems Safeguarding			
Enroute Radar Surveillance			
Flight Inspection and Calibration			
Aeronautical Obstacle Warning Light Scheme			
Irish Air Corps Policy on Wind Farms			
Garda Air Support Unit			

Table 1: Screening Matrix

7.4 Aviation Impact Assessment Report

Following the network analysis & modelling screening assessment the findings and outcomes are documented in a screening matrix showing all aeronautical surfaces and aids \ infrastructure with reference to residual impacts with high level Mitigation Measure Strategies. The report would also include detailed recommendations and considerations, where required, for further consultation with the Aviation Authorities appointed approved Designer & Vendors. A detailed scope for further technical assessment by approved design and vendor specialists would be included and managed to provide implementable mitigation measure strategies to bring to the wind farm planning application stage.

Appendix 8

Thales RSM970 Technical Description

THALES AIR SYSTEMS

Technical Description of the products

Secondary Surveillance Radar

RSM 970S

Thales Air Systems S.A.S 3, avenue Charles Lindbergh BP20351 – 94628 Rungis Cedex (FRANCE)	Tel.: +33(0) 1 79 61 40 00 Fax: +33(0) 1 79 61 11 78

PAGE LEFT INTENTIONALLY BLANK

CONTENTS

LIST OF FIGURES

1. GENERAL PRESENTATION

1.1. OVERVIEW OF RSM 970 S

1.1.1 General

The RSM 970 S, the latest generation Monopulse SSR designed by Thales, for Approach and En-route surveillance.

Including major improvements:

- Mode S Transmitter
- SSR/Mode S Interrogator and reply processor,
- EMC compatibility,
- Full Mode S capability,
- Mode S / SCF* capability.

Benefiting from the experience gained throughout an impressive number of contracts implemented all over the world (more than 300 RSM 970 S / RSM 970 I / RSM 970 / RSM 870 systems sold), the RSM 970 S fully meets the standards and recommendations of ICAO Annex 10, and its electronics is fully duplicated.

The technical concepts incorporated in the equipment, such as monopulse techniques and Mode S, have been validated through field trials initially carried out as a joint programme with the French Civil Aviation Authorities, and full Mode S operation has been validated by Eurocontrol during the development of the Pre-Operational Mode S station (POEMS), which features the Mode S standard for Europe.

When fitted with the appropriate options (time stamping, dual channel site monitor), the RSM970S fully complies with the Eurocontrol Mode S Specification (EMS).

Thales is the only manufacturer which can propose the full range of SSR/Mode S applications (conventional MSSR, Mode S elementary surveillance, Mode S enhanced surveillance and Full Mode S datalink) with a single product. This feature allows the user to secure his purchase against future requirements.

The RSM 970 S may be operated in a full stand-alone configuration or in conjunction (co-mounted) with a primary radar. It can be interfaced with control centres through a wide range of formats and protocols.

The equipment is designed to be remotely controlled and monitored for all its main functions from a central point (Remote Control and Monitoring System (RCMS)).

* SCF: Surveillance Coordination Function

1.1.2 Global Functionalities of a Mode S Radar Station

1.1.2.1 General

The Mode S is an evolution of the traditional Secondary Surveillance Radar (SSR), which is based upon Mode A/C interrogation/reply scheme. In the Mode S system, this scheme has been enhanced, by uniquely identifying each aircraft using a worldwide unique 24 bit aircraft address, and by allowing the transmission of interrogations selectively addressed to a unique aircraft, instead of being broadcast over the whole antenna beam.

A Mode S radar is able to perform surveillance, i.e. to output the aircraft position, the standard SSR modes (Mode 3/A, Mode C) and the aircraft unique Modes address. It also has data-link capabilities, i.e. the ability to send or extract frames containing binary data. The data-link can operate only on aircraft being tracked by the surveillance processing. From an operational point of view, priority is always given to the surveillance processing (the detection of a target and the transmission of the corresponding information shall never be degraded for any data-link reasons).

In order to provide standard services, ICAO has standardised the Mode S subnetwork, which is the air-ground subnetwork, ATN[*] compatible, making use of the Mode S interrogators data-link features. Such a subnetwork is also able to provide non ATN services, known as Mode S Specific Services.

1.1.2.2 Mode of Operation

For a radar, the surveillance processing is responsible for determining the aircraft position for all aircraft flying in the radar coverage. It is also responsible for transmitting this position information to the users requiring it (usually Air Traffic Control Centres).

The principle of a classical SSR (Secondary Surveillance Radar) is as follows:

- The radar sends an interrogation, asking for aircraft identity (Mode A interrogation) or aircraft altitude (Mode C interrogation).
- This interrogation is detected by all aircraft located in the main antenna lobe.
- These aircraft then reply to the radar with the requested information.

The onboard equipment responsible for the interrogation detection and reply transmission is known as Transponder. A Mode S radar can perform surveillance on both SSR and Mode S transponders. Mode S transponders also behave as SSR transponders when interrogated with a standard SSR interrogation. The Mode S is fully compatible with classical SSR system. In Mode S, the interrogation-reply scheme has been enhanced, as each aircraft can be selectively interrogated, and much more information transferred in both interrogations and replies. Each aircraft is identified with a world-wide unique 24 bit address.

To achieve this selective interrogation scheme, the time has been divided into two short periods respectively called All-Call (AC) and Roll-Call (RC), which are continuously interleaved.

[*] ATN: Aeronautical Telecommunications Network

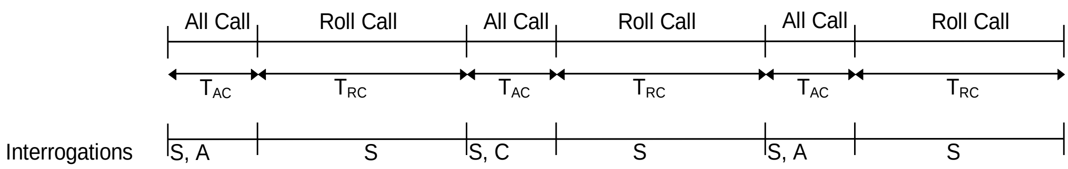
- During the Roll-Call Period, the radar will perform the selectively addressed interrogations, and listen for the associated replies, optimising the Roll-Call time by properly scheduling the interrogations and replies for the aircraft being reachable in the antenna beam at that time. But in order to selectively address an aircraft, the radar needs to know the aircraft address, as well as the approximate aircraft position. Note that the radar will not send a selective interrogation for a given aircraft during the whole scan, because this would highly generate noise in the RF link. Instead the radar will send such interrogations in the direction where the aircraft is expected to fly in.

- During the All-Call period, the radar will ask new aircraft to identify themselves, by returning their Mode S address. Once these address are acquired (i.e. known), the radar will start to perform selective interrogations on the corresponding aircraft, asking these aircraft in Roll-Call interrogations to no longer reply to All-Call interrogations (this is known as lock-out). In order to allow multiple radars to acquire the same aircraft, each radar will be given an II Code (Interrogator Identifier Code). This II Code is put into the All-Call interrogations, and the radar locks out an aircraft only with its own II Code. Note that only 15 II Codes are available. Please refer for details hereafter to the chapter related to the SI codes and II/SI code operation.

- During the All-Call period, in addition to new Mode S aircraft addresses acquisition, the radar also performs surveillance with the standard SSR transponders.

- The IRF (Interrogation Repetition Frequency) is the number of All-Call periods divided by the total All-Call/Roll-Call pattern duration. It is always adjusted, depending on the system configuration (rotation speed, instrumented range, scheduling, etc.) to the lowest practicable value for the specified performance.

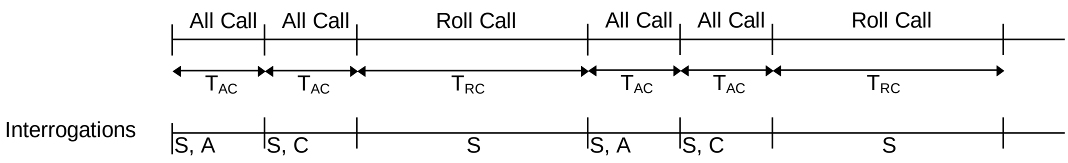
- Two examples of All Call / Roll Call scheduling patterns are shown on following figures:



Type « A » All Call / Roll Call Scheduling

In type A, one All Call occurs for the duration of one All Call and one Roll Call, so:

$$IRF = \frac{1}{T_{AC} + T_{RC}}$$



Type « B » All Call / Roll Call Scheduling

In type B, two All Call occur for the duration of two All Call and one Roll Call, so:

$$IRF=\frac{2}{2T_{AC}+T_{RC}}$$

A/C SSR interrogations are alternated from one All Call to the next.

For an imposed IRF, the Roll Call duration is directly related to the choice of the pattern type. The choice of the most appropriate scheduling is guided by comparison of the Roll Call duration imposed by the IRF, with the minimum RC duration imposed by the operational parameters like range.

1.1.2.3 Elementary Surveillance

The elementary surveillance (ELS) consists in extracting for each aircraft the following information:

- Unique 24-bit aircraft address
- Mode A code
- Aircraft identification (i.e. call-sign): BDS 20

  This feature allows a better flight plan correlation for Mode S capable ATC Centre.

- Flight level in 25 ft increments (depending on aircraft equipment)

  This feature allows a better altitude tracking at ATC level.

- Flight Status (airborne or ground)
- Transponder Capability Report: BDS 10
- Common Usage GICB Capability Report: BDS 17
- ACAS Resolution Advisory: BDS 30

1.1.2.4 Enhanced surveillance

The Mode S transponder contains 256 registers, called BDS (Comm B Data Selector). Note that the first register (register 0) is used for AICB (Airborne Initiated Comm B). Each of these registers is 56 bits long, and can be read at any time by the interrogators. These registers will be filled with aircraft derived information, like aircraft speed, waypoints, meteorological information, call sign, ACAS (Airborne Collision Avoidance System) information, etc. Some of these BDS are useful only when used together with the aircraft position at the time of extraction (like speed, meteorological report, etc.), whereas others (like waypoints, aircraft capability, call sign, etc.) are useful irrespective of the aircraft position.

It is interesting to enhance the usual target report, produced as part of the surveillance processing, with the contents of some of these BDS. This use of BDS is called “Enhanced Surveillance” (EHS).

Today’s defined Downlink Aircraft Parameters (DAP) are:

- BDS 40: Aircraft Intention (Selected Altitude),

- BDS 50: Track and Turn Report (Roll Angle, Track Angle Rate, True Airspeed, True Track Angle, Ground Speed),

- BDS 60: Heading and Speed Report (Magnetic Heading, Indicated Airspeed, Mach Number, Vertical rate).

The extraction of these BDS may be decided by the interrogator, on a simple periodic basis, or based on more sophisticated criteria such as track initiation, turn detection, etc. (routine enhanced surveillance). In a further step, the user may decide additional extraction on its own criteria, and request them to one interrogator (directed enhanced surveillance).

For safety reasons, each radar will extract the BDS involved in routine enhanced surveillance for all targets.

This enhanced surveillance can be considered as a data-link application making use of the GICB (Ground Initiated Comm B) specific service.

For RSM-970S/Mode S, GICB automatic extraction is used to improve track information sent to ATCC.

1.1.2.5 SI codes and II/SI code operation

For a correct operation, all radars interrogating and locking out aircraft in a given geographical area must use a different II code. It means the II code and associated lockout map allocation to radar must be coordinated to avoid multiple coverage using the same II code.

In Europe the II code allocation is performed by Eurocontrol upon ICAO delegation. Today, in the high radar density of the European Core area, shortage of II code is experienced.

An initial solution to II code allocation was to allocate a single code to several radar in the same area, either with a reduction of radar coverage volume, or in conjunction with the implementation of the Surveillance Coordination Network (i.e. Mode S Cluster). The radar coverage volume reduction does not allow to offer a service similar to those of previous SSR systems. The SCN implementation as a strong impact on radar operation and requires a data networking between all radars.

The new graceful solution, which is advised by Thales, is to operate using SI (Surveillance Identifier) code.

SI codes

The SI codes have been defined in the ICAO standard, in order to provide more codes than the 16 II codes. A total of 63 SI codes are available. Radar operation in SI code is similar than in II, and SI is selected using radar parameter in the same way than II code.

Because SI codes were not defined in the first versions of ICAO Annex 10 for Mode S, few aircraft are not yet SI capable. Today in Europe almost all aircraft are SI equipped: in May 2008, 98.36% of Mode S flights were SI capable.

SI and II codes being exclusive, an aircraft not capable of SI code (i.e. II only) would not be detected by a radar using SI code. In order to be able to operationally use SI codes before 100% of aircraft are equipped, a special mode has been defined by Eurocontrol: the “II/SI code operation”.

II/SI code operation

This radar special mode of operation is based on the characteristics of aircraft transponders capable of II codes only. These transponders reply to SI code Mode S All Call interrogation using the "matching" II code (i.e. the II code corresponding to the radical field of the SI code). Thus it can be detected using the appropriate decoding.

This mode allows to process a specific decoding of the All Call replies using this "matching" II code, then to selectively interrogate these aircraft with the II code. All other aircraft replying using SI code are processed using the SI code. It is a solution to correctly detect all aircraft, SI capable and II only capable. To maintain the interoperability between radars using different SI codes, but the same "matching" II code, the non-SI aircraft are not locked-out (in order to enable the acquisition by other radars).

This special mode is specified in the Eurocontrol EMS specification Ed3.11, as an optional requirement in §13.16.1. The SI code operation and the special mode named "II/SI code operation" have been already selected by some ANSPs (e.g. French DSNA). Eurocontrol has started the allocation of SI code, instead of II code.

European Implementing Rule for Mode S interrogator codes

Eurocontrol has prepared an Implementing Rule (IR) in response to a European Commission's mandate, laying down requirements for the coordinated allocation and use of Mode S interrogator codes for the Single European Sky. These specifications aim to cope with the interrogator code allocation issue concerning the interrogator identifier (II), limited to 16 codes. The increasing number of Mode S interrogators leads to a shortage of available II codes, in the high radar density of European Core area. The allocation of Surveillance Identifier (SI) codes by Eurocontrol allows overcoming this issue without the need to settle a SCN cluster solution.

The related European Commission regulation (EC) No 262/2009 of 30 March 2009 is already entered into force for application from 1st January 2011.

Mode S operators will have to ensure that their Mode S interrogators:

- supports the use of SI codes, in accordance with ICAO Annex 10,
- supports the use of the special "II/SI code operation" mode, in accordance with EMS Ed3.11 requirements of §13.16.1.

The regulation defines Contingency Requirements for Mode S operators, to detect potential interrogator codes conflicts.

At radar level, a measure to prevent code conflicts is to have means to detect any use of a wrong, non-allocated interrogator code.

The RSM970S Thales radar is fully compliant with this EC 262/2009 European Commission regulation.

It already includes the SI code and II/SI code operation features and complies with the Eurocontrol EMS Ed3.11 requirements §13.16.1. It also provides means to detect any use of a wrong interrogator code. The interrogator code (II or SI) is permanently checked at RCMS level by comparison of the expected code value with the one effectively used by radar processing. In case of difference a failure is reported a RCMS operator. The RSM970S SI code and II/SI code operation functions have been fully validated by the French DSNA.

The French civil aviation authority DSNA has validated and operates the Marseille Mode S radar (RSM970S delivered by Thales within the frame of AROMES Mode S programme) in SI code and II/SI mode.

1.1.2.6 Surveillance Co-ordination Network (SCN)

Usually, a radar has an overlapping area with other radars. In such a case, the Mode S system allows the radars to be co-ordinated in these overlapping areas, via the surveillance co-ordination network.

For safety reasons, all radars shall provide track information to ATCC users for all targets flying in their entire coverage, including the overlapping areas.

This surveillance co-ordination network allows radars to exchange track information to allow an aircraft acquisition directly in Roll-Call, in case where radars use the same II code (the group of radars having overlapping coverage and using the same II code is called a “cluster”) or to overcome a potential track miss.

This surveillance co-ordination network may use either a centralised approach (i.e. involving a central controller, which is responsible for maintaining the overall coherence) or a distributed approach (i.e. the interrogators are able to co-ordinate themselves). In both cases, due to failures or other events, a radar may reconfigure its coverage and its II code, to continue fulfilling its surveillance mission, in accordance with the surveillance network policy.

1.1.2.7 Data-Link

The Data link capabilities can be provided by the secondary radar, using its rotating antenna.

The Mode S data-link is defined at two levels.

The first level concerns the dialogue between one interrogator and one transponder, and provides a service comparable to the data-link layer in the ISO scheme, by allowing the exchange of frames of up to 1280 bits. In addition, three additional services are available:

- The uplink broadcast service, which allows an interrogator to send a 84 bit long message to all aircraft in the beam,
- The downlink broadcast service, which allows an aircraft to send a 56 bit long message to all interrogators in view,
- The GICB service, which allows an interrogator to extract one of the BDS registers.

Above this first level, a second level has been defined by ICAO in order to offer a more complete and more inter-operable service. The second level :

- Offers an ISO 8208 service, compliant with the ATN specifications, (called Switched Virtual Circuit (SVC) services)
- Offers Mode S specific services (i.e. data transfer specific to Mode S, making optimal use of Mode S features).
- Allows to manage several interrogators transparently for the user (a flying time in a single interrogator coverage could be very short).

1.2. SYSTEM DESCRIPTION

1.2.1 Radar Design

The RSM 970 S MODE S mainly consists of:

- a Large Vertical Aperture (LVA) AS 909 antenna,
- two electronics cabinets including transmitter, receiver, signal and data processor units.

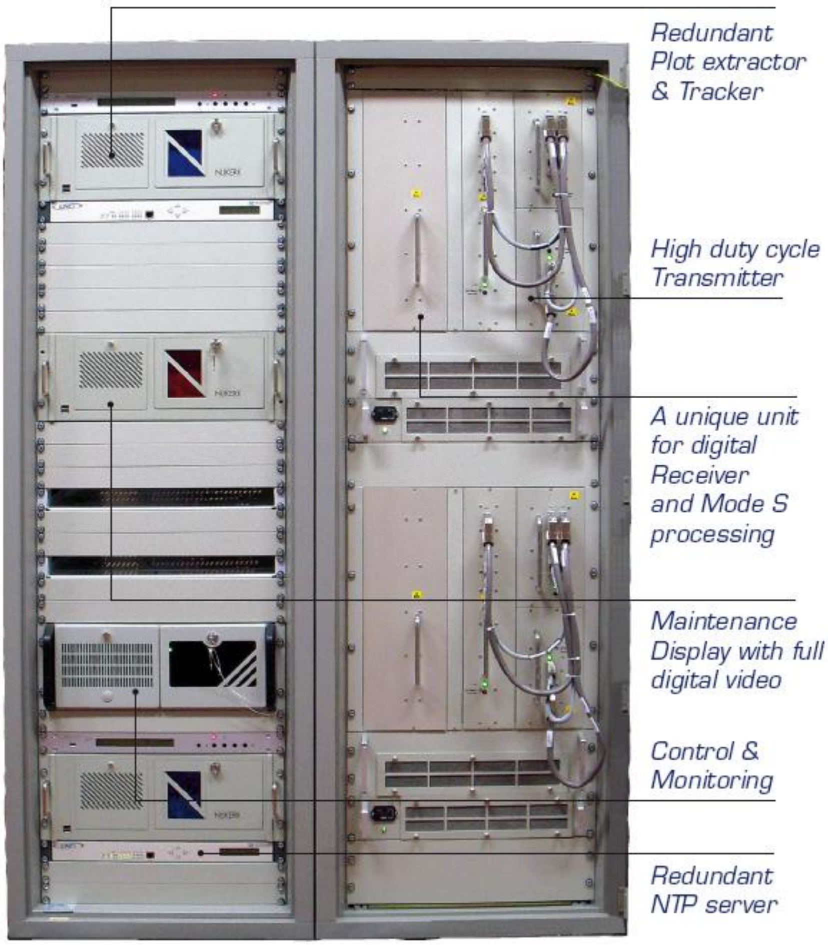


Figure 1 - RSM 970 S electronics cabinets

This equipment can provide full Mode S operation and conforms to or exceeds in every aspect the requirements and recommendations set out in the appropriate subsections of:

- ICAO Annex 10 (up to and including latest amendment),
- EUROCONTROL Standards Radar Surveillance Standards in En-Route Airspace and Major Terminal Areas (March 1997).

The AS 909 antenna provides the Control, Difference and Sum patterns required for the monopulse measurement techniques. The antenna Large Vertical Aperture (LVA) characteristics feature a sharp pattern cut-off at low and negative elevation angles which counteracts ground reflections that affect the pattern of classical antennas.

The Electronic Cabinets, one per channel, are the POEMS designed I/R Mode S cabinets. They are Mode S wired and they house a fully solid state equipment including:

- One high duty cycle Mode S transmitter STX2000 which results from works initiated with the French Civil Aviation Authorities (DSNA/DTI),
- One digital receiver MDR of the latest generation,
- One MSSR / Mode S processor (MMXC),
- One Data Processor (DPC),

All these equipments are qualified within the POEMS programme.

All electronics equipments are duplicated. One channel is connected to the antenna while the other one is connected to a dummy load.

The equipment incorporates the necessary fault detection circuitry and the switching systems to ensure the correct changeover from the main (operational) equipment to the standby equipment.

For co-mounted operation, the DPC can perform PSR/MSSR/Mode S plot combination.

The Data Processor performs adaptative reflection suppression to prevent MSSR unwanted reflection, and tracks PSR/MSSR plots to provide formatted plots or track messages to the Control Centre.

ISLS is always activated. IISLS is provided as a basic feature and may be activated if required.
The RSM 970 S mode S complies with the EEC regulation relative to EMC.

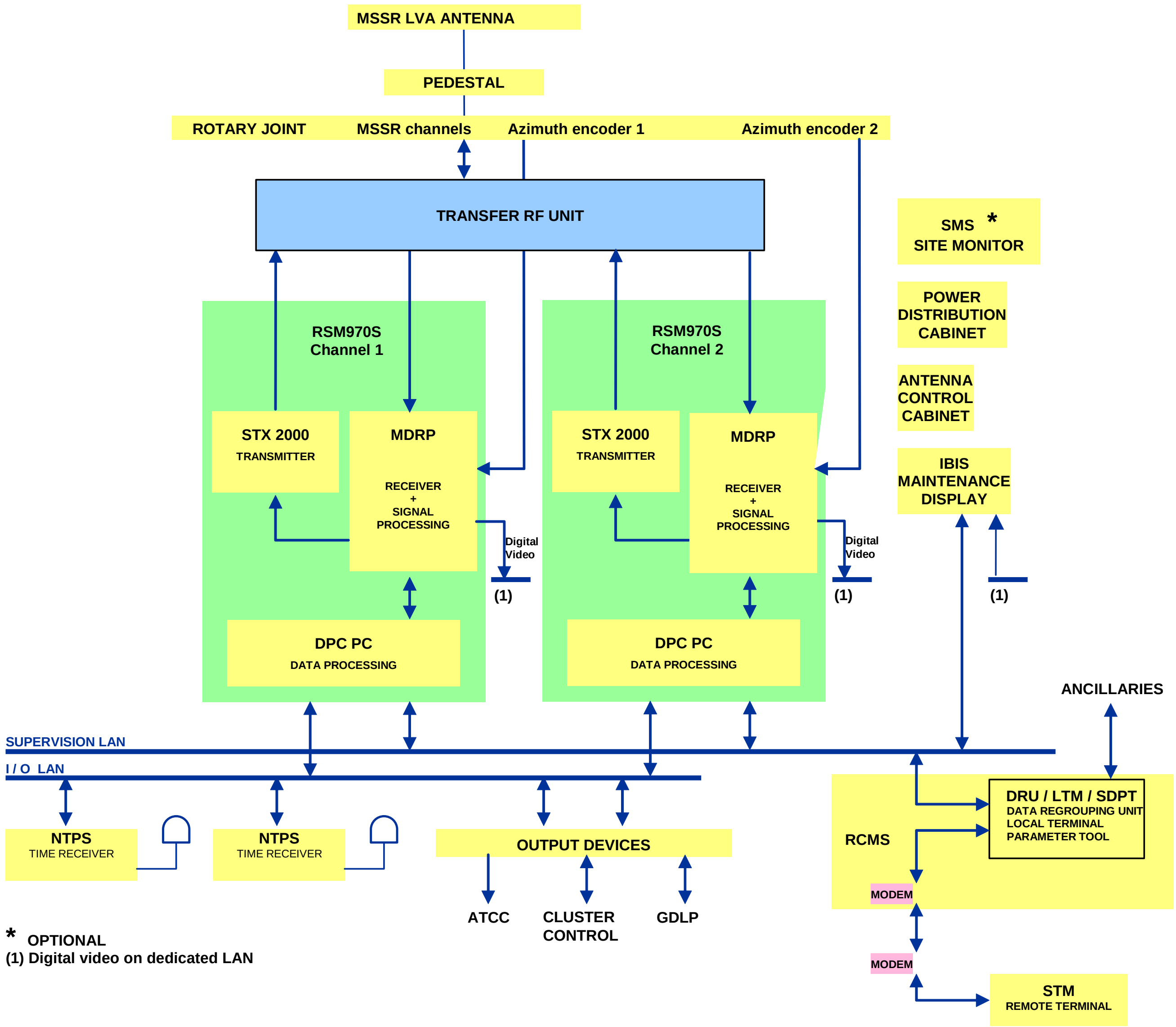


Figure 2 - Stand-alone RSM 970 S – General Configuration

1.2.2 Functional Characteristics

1.2.2.1 Antenna

The open array antenna AS 909 provides a directional sum pattern (Σ), a monopulse difference pattern (Δ) and an omnidirectional pattern (Ω). The gain exceeds 27 dB and the underside cut-off slope is better than 1.8 dB/degree.

Integrated with the rotary joint and mounted directly on the main shaft are the dual optical encoders giving a 14-bit accuracy (or 0.022°) for the azimuth rotation information. The antenna azimuth position is transmitted to both Mode S processing channels.

1.2.2.2 Interrogator and receiver

The RSM 970 S Mode S is capable of MSSR and full Mode S operation (elementary surveillance, enhanced surveillance, data link).

The RSM-970 S fully solid state transmitter is composed of three modules:

- Interface driver module
- Control HPA module
- SUM HPA module

As two separate modules are used for the SUM and Control amplifiers, the transmitter includes the Improved Interrogator Side Lobes Suppression (IISLS) feature.

The fully solid state transmitter has been designed to work with a duty cycle (peak) of 63.7% over 2.4 ms length of time, consistent with the ICAO Annex 10 requirement of transmission of 48 Mode S roll-call Interrogations within 2.4 ms (equivalent to 3 sets of Uplink Extended Length Messages (UELMs) each composed of 16 long messages (112 bits) spaced every 50µs. This requirement can be repeated every 24 ms.

The Interrogator / Receiver has a wide adjustment capability to match any site situation: sectorized output power setting, sectorized ISLS/IISLS operation, selectable RSLS control and attenuation.

The system is able to interrogate in the modes 1, 2, 3/A, C and S and is designed to have a flexible (single, double, triple interlacing) interrogator pattern and mode interlacing capability.

It is possible to change the mode interlacing on a scan by scan basis and on a sector by sector basis.

The system is able to operate in Mixed Mode, in which Mode A/C SSR interrogations are used in All Call periods to trigger Mode A/C SSR replies from SSR and Mode S transponders. This allows detecting faulty Mode S transponders that do not reply to Mode S only All Call interrogations.

The MDR receiver is based on a new digital technology providing a better azimuth accuracy and improved reliability.

1.2.2.3 Signal and Data Processor

The signal and data processing chain performs:

1. MSSR/Mode S Processor (MMXC)
   - MSSR/Mode S scheduling,
   - MSSR/Mode S signal processing,
2. Data Processor Computer (DPC)
   - MSSR/Mode S extractor and
   - PSR/MSSR/Mode S plot combination and tracking.

The MMXC and DPC cope with garbling situations in dense surveillance areas. The Off Boresight Angle measure on each code pulse is associated to the reply message with specific flags and is routed to the monopulse post-processing. The monopulse post-processing performs plot extraction and solves conflict conditions such as garbling, phantoms, saturated presences and specifically processes emergency and distress codes.

Reflections which are common phenomena in SSR systems, are detected and processed using the monopulse information. This reflection may be found either at track level or at plot level. At track level, this function is based on an auto-adaptive process : the reflections are identified as permanent or temporary. This Thales unique feature provides automatic site environment adaptation. At plot level (prior to scan-to-scan correlation), the site environment is taken into account by windows programming.

1.2.2.4 Remote Control and Monitoring

In normal operation the RSM 970 S Mode S is unattended. A Remote Control and Monitoring System is provided so that the major equipment of the RSM 970 S Mode S are monitored and controlled from a remote point. In a co-mounted configuration, the RCMS controls both the RSM 970 S Mode S and the Primary Surveillance Radar (PSR).

1.2.3 Fail Safe Capabilities

Whatever the configuration, the RSM 970 S Mode S consists of a single Antenna/duplicated electronics with automatic changeover of I/R channel should the unit in service fail. Internal fault detection facilities are incorporated into the RSM 970 S Mode S and automatic reconfiguration takes place in case of failure without use of the remote control and monitoring system.

1.2.3.1 Antenna System

The MSSR antenna can be mounted on a stand-alone turntable or at the top of the primary antenna. The antenna system, the drive mechanism and the rotary joint have very high inherent reliabilities and require low preventive maintenance actions.

The azimuth pointing position data is generated by a dual optical encoder, mounted as an integral part of the rotating joint, fixed to the shaft of the turning gear. Thus, there is no back-lash or mechanical play, an essential feature where an angular measurement having an accuracy of 14 bits (0.022°) is required. Each optical encoder, using LED devices, generates a serial message transmitted to the MMXC, using a call/reply protocol for noise and spurious signal rejection.

1.2.3.2 Electronic Equipment

Under normal conditions, one of the two I/R channels (designated as « to Antenna » channel) provides control and interrogation for the MSSR antenna while the other (designated as « To Load » channel) is in a "hot" condition, i.e. ready for immediate transmission.

In the event of the failure of the I/R channel in service, this condition is detected by internal monitoring circuits, and changeover is initiated by the channel Bite function to the « To Load » I/R channel.

1.2.4 Stand-Alone Configuration

The equipment supply as shown in Figure 2 includes:

- An LVA antenna AS 909 comprising 36 radiating elements,
- A pedestal assembly with dual motorization,
- One (3 channels) rotary joint with dual optical encoders,
- One antenna control cabinet,
- One I/R cabinet (TRC) including :
  - Two Mode S transmitters (STX 2000)
  - Two Mode S digital receivers (MDR)
  - Two MSSR/Mode S Processors (MMXC)
- One Processing cabinet (TOM) including :
  - Two Data Processor Computers (DPC)
  - Two Serial lines devices (LINES)
  - Two GPS time stamping
- A Remote Control and Monitoring System RCMS, equipped with:
  - Two computers (Local position (LTM) and Remote position (STM)),
  - Two associated printers (optional),
  - One Data Regrouping Unit/Function DRU in charge of discrete I/O interfaces.
- A radar maintenance monitor display IBIS,

- A Site Dependent Parameter Tool (SDPT) software, allowing operational parameter setting, integrated in the RCMS local position (LTM).
- A Mains Power supply cabinet,
- A dual channel Mode S level 2 Site Monitor SMS may be optionally provided.

1.2.5 PSR Co-Mounted Configuration

When the RSM 970 S Mode S is co-mounted with a Primary Surveillance Radar, some items of the stand-alone configuration are redefined (Figure 3).

The equipment involved are:

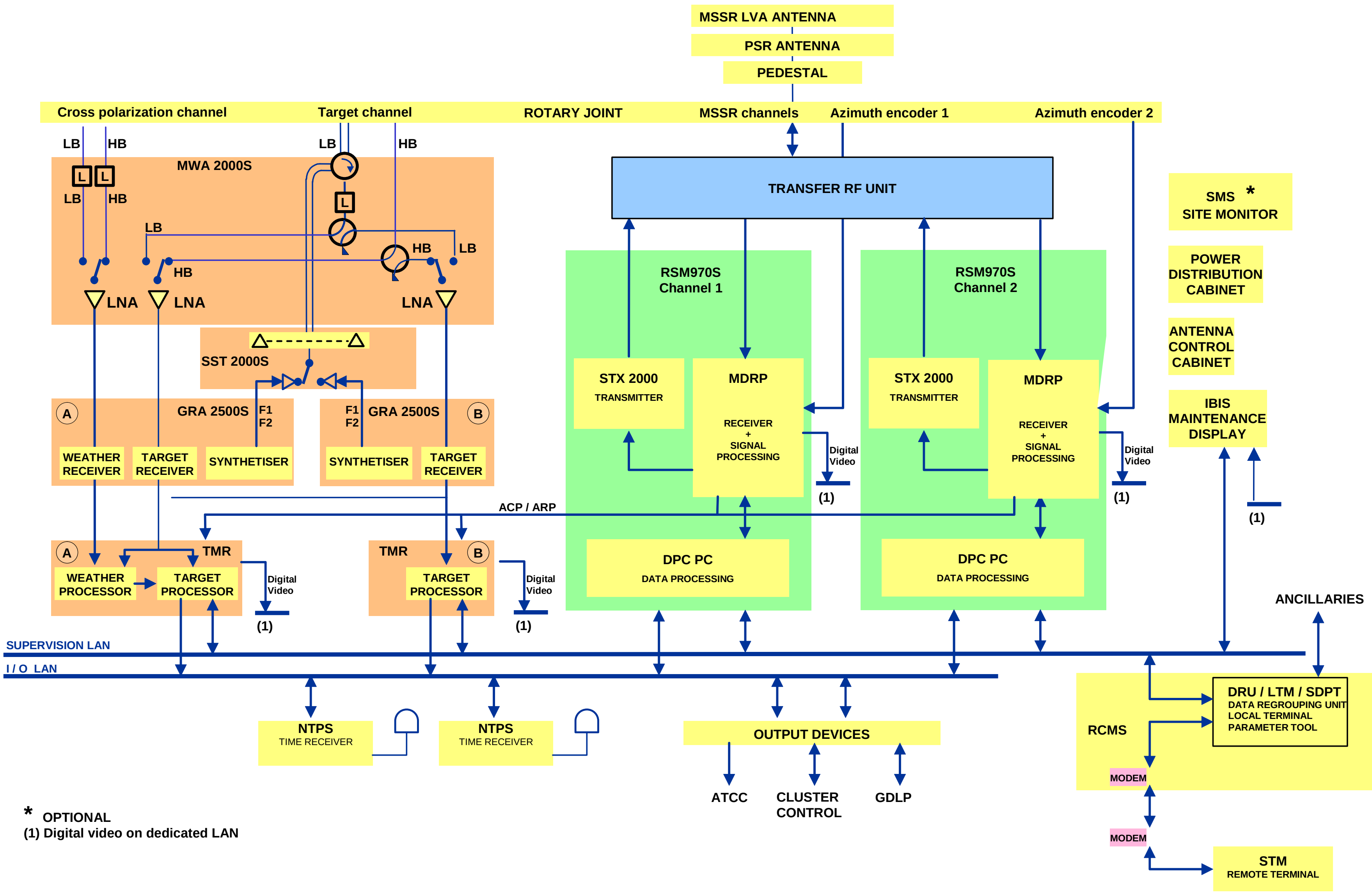
- Pedestal assembly: the PSR antenna is used to support the AS 909 LVA antenna.
- Antenna control unit: The antenna control unit version depends on the Primary radar antenna selected.
- Rotary joint: the rotary joint is designed to duct PSR + MSSR RF links. A 5 or 7-path rotary joint composed of two or four (with weather channel) PSR and three MSSR RF channels is usually selected.

Other parts as:

- Remote Control and Monitoring System (RCMS),
- Radar maintenance monitor display (IBIS),
- Main Power Supply cabinet,

become common equipment to both MSSR and PSR system.

The PSR + MSSR/Mode S plot merging is performed in the DPC when co-mounted with a STAR2000 PSR.



* OPTIONAL
(1) Digital video on dedicated LAN

Figure 3 - Co-Mounted Configuration (Example of STAR 2000)

1.3. PERFORMANCE

1.3.1 General

The RSM 970S Mode S ensures a high quality and reliable coverage to contribute to radar operational separation of 3 NM, 5 NM and 10 NM according to EUROCONTROL standard.

The radar is capable of determining range, azimuth and height positional data, along with the identity, on each target detected, during each revolution of the antenna.

Since the MSSR systems are used in an environment which often includes multiple SSR coverage, the system has been designed in order to cope with a high fruit density (MSSR and/or Mode S fruit). Therefore, the performance will be optimised such that the output of the false data is minimised, while meeting the guaranteed parameters.

The MSSR RSM 970 S Mode S is designed to meet all the guaranteed performance in the presence of a fruit rate of 11,000 replies per second.

The performance of the RSM 970 S MODE S equipment have been confirmed through the various fields and validated by Eurocontrol and French DSNA in the frame of the POEMS pre-operational European Mode S programme. Significant breakthroughs have been achieved in the fields of:

- Discrimination,
- Phantom processing,
- Reflection processing.

Typical performance characteristics are summarised below :

GENERAL	
Modes	1; 2; 3/A; C; S
Output transmitter peak power	2570 W
Transmitter frequency	1030 ± 0.01 MHz
Range	Up to 256 NM
Scan rate	Up to 15 rpm
Antenna:	
- Azimuth beamwidth	2.4°
- Maximum gain	27 dBi
Fruit density	11,000 fruit/sec in the main lobe

DETECTION PERFORMANCE (See Paragraph 1.3.3 for details)	
Target Position Detection	
- Mode A/Mode C Probability of detection	> 99 %
- Mode S Probability of detection	> 99 %
False Target Reports	
- Overall False target report ratio	< 0.1 %
- Overall multiple target report rate over 1 hour	< 1 per scan
Code Detection and Validation	
- Mode A probability of code detection	> 99 %
- Mode C probability of code detection	> 99 %

QUALITY PERFORMANCE (See Paragraph 1.3.4 for details)	
Positional Accuracy	
Systematic errors:	
- Slant range bias	< 14 m
- Azimuth bias (degree)	
- for elevation angles between 0° and +6°	< 0.022°
- for elevation angles between +6° and +10°	< 0.033°
- Slant range gain error	< 1 m/NM
- Time stamp error when not synchronised on external signal	< 20 ms per month
Random errors (standard deviation values) :	
- Azimuth (degree)	< 0.068°
- Slant range	< 30 m (SSR)
	< 15 m (Mode S)
Position Jumps:	
- Overall ratio of jumps	< 0.05 %
False Code Information	
- Overall false codes ratio	< 0.2 %
- Validated false Mode A codes	< 0.1 %
- Validated false Mode C codes	< 0.1 %

RESOLUTION PERFORMANCE in double Mode Interlacing A, C		
Area 1*	Pd Pvcc	98 % 98 %
Area 2*	Pd Pvcc	98 % 90 %
Area 3*	Pd Pvcc	60 % 30 %

* The areas are defined in paragraph 1.3.4.3

CAPACITY for 256 NM instrumented range	
System capacity at 15 RPM	1000
Peak load per 45° wedge	222
Peak load per 3.5° wedge	54

RELIABILITY, AVAILABILITY, MAINTAINABILITY	
Stand-Alone Configuration (including mechanical part):	
• MTBF	>2700h
• MTBCF	>54000h
• MTTR	0.41 h
• Inherent Availability Ai = MTBCF/(MTBCF + MTTR)	0.99999
• Operational Availability Ao = MTBCF/ (MTBCF + MTTR + MLDT) including an assumed Mean Logistic Down Time (MLDT) of 3 hours	0.9999
• BITE Coverage	90 %
Preventive Maintenance:	
• Preventive maintenance and inspection periodicity	90 days
• Antenna oil change periodicity	365 days

ENVIRONMENTAL AND POWER CONDITIONS	
– **Climatic:**	
• Storage indoor:	
- Temperature	-10°C to +60°C
- Relative humidity	93 % at +40°C
- Altitude	0 to 10 000 m
• Operating indoor:	
- Temperature	+10°C to +40°C
- Relative humidity	5 % to 80 % at 40°C
- Altitude	0 to 3 000 m
• Operating outdoor	-40°C to +70°C (including solar radiation)
• Storage outdoor	-40°C to +70°C (including solar radiation)
– **Wind** (including AS 909 antenna):	
• Rotation	160 km/h - 130 km/h (with ice)
• Survival	220 km/h - 180 km/h (with ice)
– **Mains** (3-phase) 230 V/400 V 50/60 Hz	Voltage ± 10 % - Frequency ± 5 %
• Power dissipation	3.6 kW (equipment room) 3.5 kW (drive mechanism)
• Consumption (including the antenna in rotation)	12 kVA (without wind nor ice) 20 kVA (with extreme wind/ice)

1.3.2 Link Power Budget Calculations

The power budget calculation depends on several parameters:

- Antenna speed
- Instrumented range
- Type of scheduling (SSR vs. Mode S)
- Mode S functionality (Elementary vs. Enhanced surveillance, Datalink)
- Tower height
- Presence of a radome
- Etc.

The most usual configurations (instrumented range vs. antenna speed and scheduling) are listed in the following table:

	10 rpm	12 rpm	15 rpm
Conventional SSR, 2-Mode interlace	256 NM	256 NM	256 NM
Mode S, elementary surveillance	256 NM	250 NM	230 NM
Mode S, enhanced surveillance (2 GICB per aircraft)	256 NM	250 NM	200 NM
Mode S, full EMS functionality, including Datalink	256 NM	200 NM	170 NM

Depending on user's needs, other configurations may be proposed.

The typical RSM 970 S configuration is considered in the following calculations:

- 10 rpm antenna speed
- 256 NM instrumented range
- Mode S scheduling
- Full EMS performance
- 25 m RF cables
- Radome

POWER BUDGET CALCULATION WITH BEAM MODULATION

RSM 970 S
Product
Mode S 10 rpm

			Instrumented range	256	NM
Standalone SSR			Antenna speed :	10	rpm
With radome			IRF :	150	Hz
Cable length :	25	m	Tx attenuation:	0	dB
Antenna tilt :	-1,5	deg.	Scheduling type :		Mode S
			Scheduling pattern :		A C S

Up-Link Budget.

Operationnal Range = 256 NM Target elevation = 0,5 °

1	Transmitted power at cabinet output (dBm)	62,80
2	Losses between cabinet output and antenna input (dB)	-2,45
3	Antenna gain (dBi)	27,00
4	Gain decrease at specified elevation angle and tilt (dB)	-5,00
5	Free Space Attenuation (dB)	-146,22
6	Atmospheric and radome (if any) attenuation (dB)	-1,95
7	Transponder antenna gain (dB)	0,00
8	Interrogation beam modulation losses (dB)	-3,00
9	**Total budget at transponder input (dBm)**	**-68,81**
10	Minimum triggering level for 90 % of reply (at transponder antenna end)	-69,00
11	**Power budget uplink margin (9 - 10)**	**0,19**

Down-Link Budget.

Operationnal Range = 256 NM Target elevation = 0,5 °

1	Transponder output power (dBm)	51,00
2	Transponder antenna gain (dB)	0,00
3	Free Space Attenuation (dB)	-146,71
4	Atmospheric and radome (if any) attenuation (dB)	-1,95
5	Antenna Gain (dB)	27,00
6	Gain decrease at specified elevation angle and tilt (dB)	-5,00
7	Losses between antenna and cabinet input	-2,45
8	Reception beam modulation losses (dB)	-3,41
9	**Total budget at receiver input (dBm)**	**-81,52**
10	Minimum processing threshold at cabinet input (dBm)	-82,70
11	**Power budget downlink margin (9 - 10)**	**1,18**

1.3.3 Detection Performance

The RSM 970 S Mode S meets the following requirements for target returns consisting of replies with the specified round reliability from a transponder with capabilities in Mode 3/A, C or Mode S.

A mode interlace pattern of the two modes 3/A and C or the three modes 3/A, C, S is assumed for the performance assessment.

1.3.3.1 Target Position Detection

The probability of detection is measured for traffic of opportunity in the measurement volume (excluding terrain masks and lobbing effects).

It is determined as the ratio of the number of target reports used to calculate target position to the number of total expected reports. Those are the reports contained between the first and the last report from the same aircraft before it leaves the measurement volume.

Mode A / Mode C

The probability of detection of a non Mode S target in the measurement volume, separated from another target in range by more than 2 NM, and in azimuth by more than $2\Theta_{3dB}$ (4.8°), is at least 99 %.

Mode S

The probability of detection of a Mode S target in the measurement volume, is at least 99% when using selective surveillance interrogations

1.3.3.2 False Target Report

The overall false target report rate is the number of false target reports (due to asynchronous or synchronous fruits, and second time around echoes) in relation to the number of detected target reports.

The overall false target report rate is less than 0.1 %.

1.3.3.3 Multiple Target Reports

Multiple target reports are due to:

- Reflections
- Ring around
- In-line multipath
- Splits
- Answers on sidelobes.

The overall multiple Mode S / SSR target reports ratio is less than one target per scan on average.

Discrete Mode 3/A codes are considered for the above figure.

1.3.3.4 Code Detection and Validation

These performances are achieved at Data Processor output (track level).

Mode A / Mode C

The probability of Mode A/Mode C detection is determined by the ratio of the number of target reports with validated correct Mode A/Mode C code data to the number of target reports used to calculate the target position detection.

The Mode 3/A probability of correct and valid code detection for the RSM 970 S equipment is better than 99 % for large samples of opportunity traffic when the aircraft replies are not overlapping (see paragraph 1.3.3.1).

The Mode C probability of correct and valid code detection for the RSM 970 S equipment is better than 99% for large samples of opportunity traffic when the aircraft replies are not overlapping (see paragraph 1.3.3.1).

The above performances are from commonly agreed Eurocontrol requirements.

Mode S

The overall ratio of the number of times a target is detected and output with all reply data correct compared to the number of times a target is detected and output, within the whole radar coverage area, is at least 99% for target replying in Mode S.

1.3.4 Quality

The quality of the data provided is expressed by the following characteristics :

- Positional accuracy,
- False code information,
- Resolution.

1.3.4.1 Positional Accuracy

Azimuth Accuracy

The guaranteed figures for a target located within the coverage volume are:

- Azimuth bias

  - for elevation angles between 0° and +6° : < 0.022°
  - for elevation angles between +6° and +10°: < 0.033°

- Standard deviation ≤ 0.068°
- Azimuth precision 0.0219° (14 bits encoder)

Range Accuracy

The range accuracy is a function of various parameters, some of them independent of the radar system, for example the airborne transponder reply time is specified by ICAO to be accurate to within + 0.5 µs i.e. + 75 m. Fortunately this figure is much smaller on modern equipment.

The MSSR system range accuracy is only limited by the quantization step (50 ns), the (ρ, θ) to (x,y) coordinates conversion and the clock stability.

The guaranteed figures are:

▪ Slant range bias	< 14 m
▪ Slant range gain error	< 1 m/NM
▪ Slant range standard deviation	• Modes A/C ≤ 30 m • Mode S ≤ 15 m

1.3.4.2 False Code Information

Code Information is considered as false, if in a target report, code information is provided which has been wrongly accepted as correct by the radar (validated data).

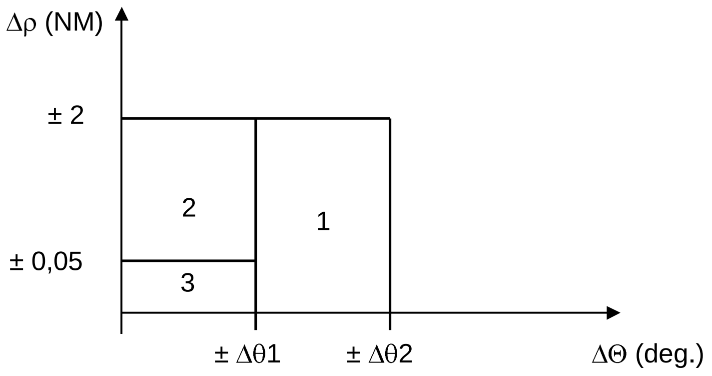
The false code information ratio is the number of target reports with false codes in relation to the number of detected target reports with code information.

Performance of the MSSR are given as :

▪ Validated false Mode A codes	< 0.1 %
▪ Validated false Mode C codes	< 0.1 %.

1.3.4.3 Resolution

The Eurocontrol standards use areas as defined below:



Δρ and ΔΘ are the differences of the two aircraft positions respectively in slant range and azimuth.

ΔΘ1 = 0.6°

ΔΘ2 = 4.8° (i.e. 2 x 3 dB beamwidth).

In the RMS 970 S configurations described in paragraph 1.3.2, the guaranteed detection performances averaged on each specified area are:

Area	1	2	3
Probability of detection	> 98 %	> 98 %	> 60 %
Probability of correct valid Mode A code	> 98 %	> 90 %	> 30 %
Probability of correct valid Mode C code	> 98 %	> 90 %	> 30 %

Assuming the following parameters:

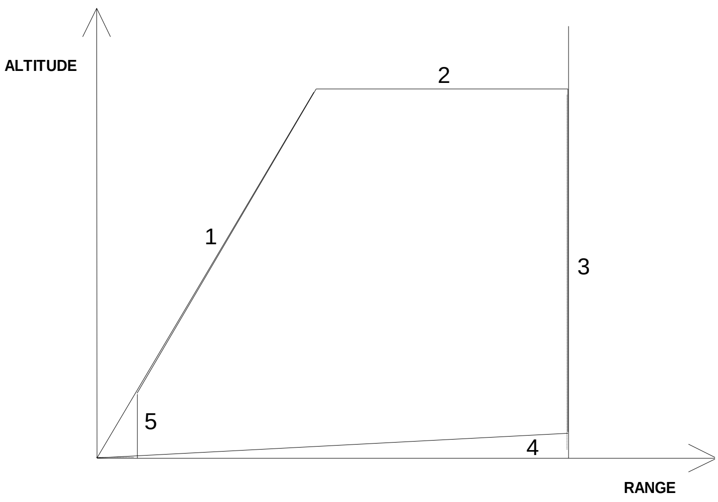
- Round reliability of transponder = 100 % in Mode A and Mode C,
- No FRUIT.

1.3.5 Data Processing Delay

For an antenna rotation rate of 15 RPM, the output delay is better than 1.2 s.

1.3.6 Coverage Area

The volume of coverage is defined by the following figure. It assumes free space detection volume for aircraft carrying ICAO compliant SSR transponders and Mode S transponders.



COVERAGE DIAGRAM

(1) Max. elevation angle : 45 °

(2) Maximum altitude : 66 000 ft

(3) Range	:	256 NM
(4) Min. elevation angle	:	0.5 °
(5) Minimum range	:	0.5 NM

1.3.7 Tracking Performance

1.3.7.1 References

- The tracker implemented in the DPC is the MUST tracker field tested and evaluated by EUROCONTROL in mono and multiradar configurations (RFS) and by French Civil Aviation within the DACOTA programme.

  It has been demonstrated by the French Civil Aviation that the tracker performance level makes possible the application of the following separation between aircraft:

  - 3 NM below 40 NM from the centre of the terminal approach,
  - 5 NM beyond 40 NM.

- The performance of the tracker has been checked on simulated data representing all aircraft trajectories of interest as defined in the Eurocontrol « Standard Document for En-Route Radar Surveillance and Major Terminal Areas » :

  - Uniform motion (radial or transversal position),
  - Uniform speed change up to 1.2 g,
  - Standard turn (2 up to 8 m/s2),
  - Landing and take-off with a combination of uniform speed change, standard turn and climb/descent.

  Mono-radar situation (primary and secondary) as well as for a multi-radar situation (one primary and one secondary) have been taken into account.

- The performance of the tracker has been operationally checked and the results of this evaluation are presented in a report (reference CENA/NT/96 712 June, 1996).

  The operational configuration used for the evaluation has been the approach of Toulouse-Blagnac Airport, with rather stringent conditions:

  - Only two radar sensors are integrated : a primary radar used for approach (100 NM range maximum) and a monopulse secondary radar (256 NM range maximum).

  The distance between radar sensors is small (less than 15 NM) adding difficulties especially for radar observability and radar biases assessment function.

  - Various traffic such as VFR, IFR, low speed, high speed, manoeuvres for approach or not, approach and en-route traffic, military traffic and aircraft testing (for AIRBUS Industries).

The correctness of the Mode C tracking logic has been demonstrated (accuracy, response time, stabilisation time of the tracked Mode C).

1.3.7.2 Typical Features

Track initiation and track continuity performances are supposed to be evaluated using opportunity flights and taking into account all detected plots within the MSSR coverage: PSR only plots, MSSR only plots and combined PSR/MSSR plots.

Track initiation performance, defined in terms of the following time parameters :

- Track initiation delay mean (TIDmn) in seconds or scans,
- Track initiation delay standard deviation (TIDsd) in seconds or scans,
- False track probability (Ftprob) in number of tracks initiated/false target report,

are better than or equal to the values given below :

Track Initiation Requirements

Parameter	Value	Unit
TIDmn	PSR/MSSR => 12.5 (2.5)	seconds (scans)
TIDsd	PSR/MSSR => 2.5 (0.5)	seconds (scans)
Ftprob	PSR/MSSR => 0.001	track/false report

Track continuity, expressed by the following time parameters:

- Track drop rate (Tdr),
- Track swap rate (Tsr),

will be equal or better of the figures presented below:

Track Continuity Requirements

Value for Tracks in MOF (Mode of Flights)			
Parameter	**Uniform Motion**	**Standard Turn & Unit Speed Change**	**Unit**
Tdr	0.01	0.1	/track hours
Tsr	0.01	NA	/swap opportunities

2. INTERROGATOR/RECEIVER

2.1. RF UNIT

2.1.1 Introduction

The RF Unit (RFU) main functions are :

- to perform RF switching between channels 1 and 2,
- to perform, inside each channel, RF decoupling between transmitter and receiver,
- to provide RF DIFFERENCE channel phase adjustment capability.

The elements constituting the RFU are located inside the I/R cabinet. They are accessible through the rear door of the cabinet.

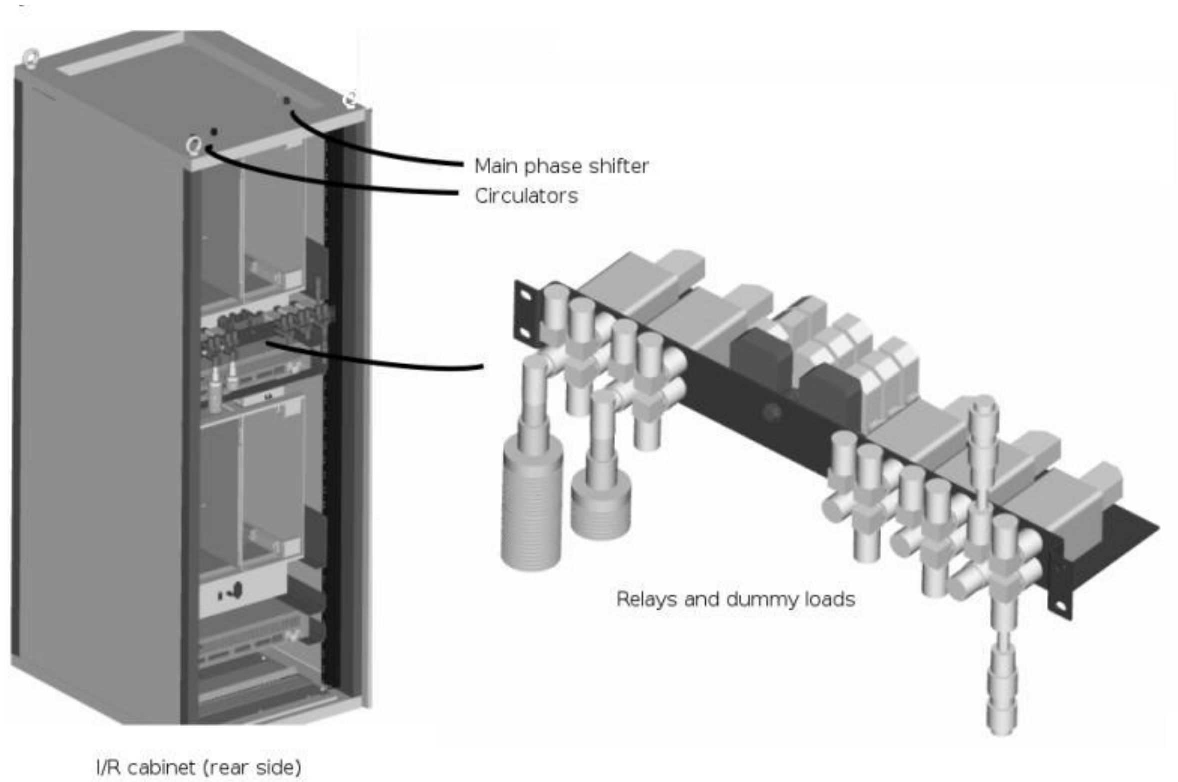


Figure 4 - RF unit view

2.1.2 Interfaces

The RFU is interfaced with the following equipment:

- feeders (FD) which enable RF signals exchange with the aerial,
- transmitter (TX) which transmits RF signals,
- receiver (RX) which receives RF signals,
- MSSR Modulator and Extractor (MMXC) which controls and monitors the RF switches.

2.1.3 Description

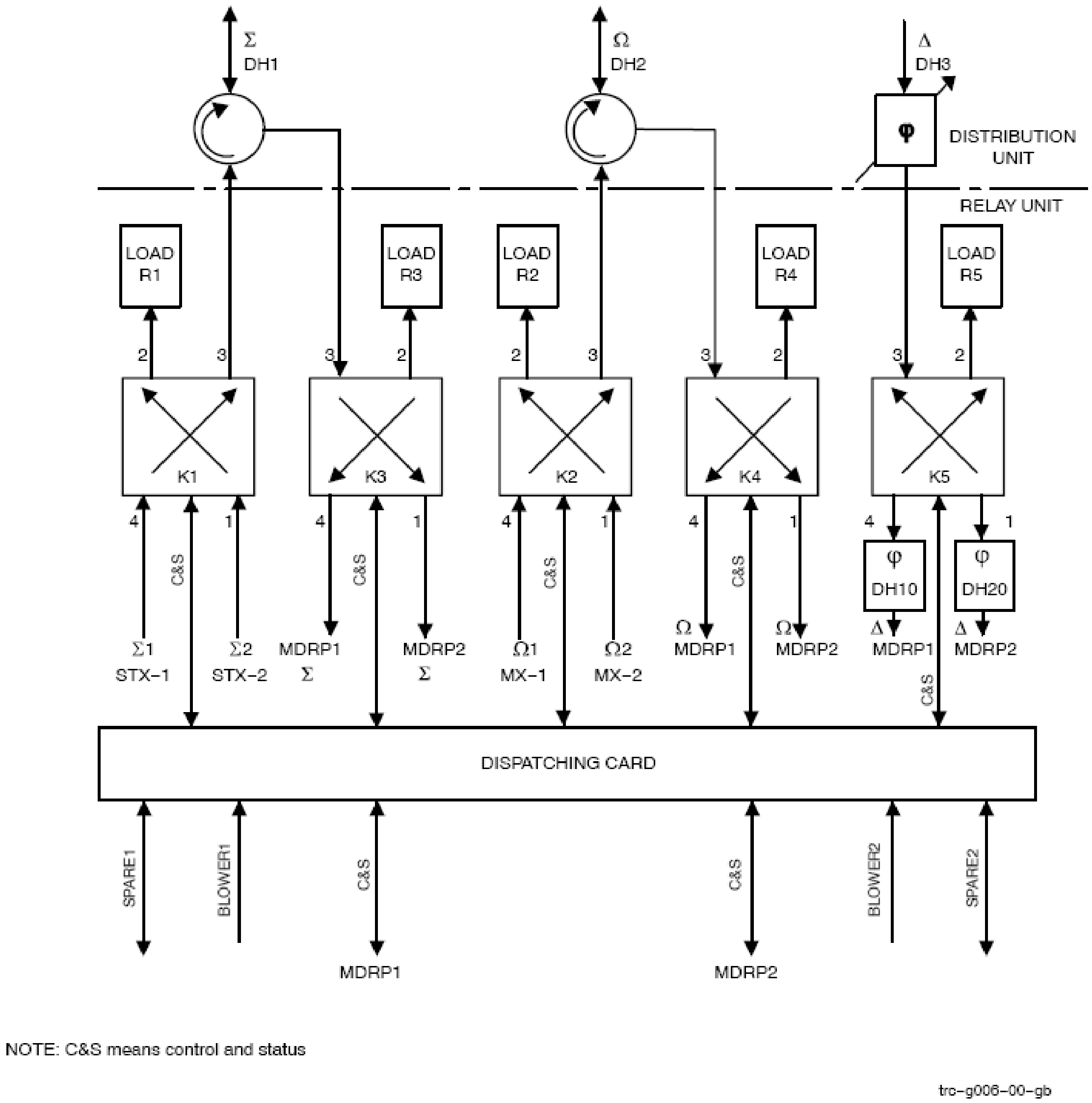
Σ and Ω RF signals coming from the transmitter are driven respectively to the Σ and Ω Tx switches. These switches allow the connection between the antenna and the outputs of the active transmitter. The outputs of the standby transmitter are connected to dummy loads.

Σ, Ω and Δ RF signals coming from the antenna are driven respectively to the Σ, Ω and Δ Rx switches. These switches allow the connection between the antenna and the inputs of the active receiver. The inputs of the standby receiver are connected to dummy loads.

The Σ and Ω duplexers (circulators) perform the separation between transmitting and receiving paths, preventing the transmitted power to be forwarded to the receivers.

The differential phase of the RF path (from antenna to the I/R cabinet) is compensated thanks to a phase shifter (φ1) located at the Δ input of the cabinet. This setting is performed during the on-site installation of the radar.

Two other phase shifters (φ2 and φ3) allow the balancing of RF paths of both radar channels. This setting is performed once for all in factory.



2.1.4 Key Features

- RF path peak power handling on SUM and CONTROL channels:
  - 66 dBm
- RF path mean power handling long term :
  - 53 dBm on SUM channel.
  - 38.5 dBm on CONTROL channel.
- Uplink losses between transmitter output and I/R cabinet output < 1.3 dB.

- Downlink losses between I/R cabinet input and receiver input:

SUM and CONTROL channel:	< ± 1.3 dB.
DIFFERENCE channel:	≤ 2 dB.

- Difference between channel 1 and channel 2 downlink differential gain SUM/DIFFERENCE, from the RFU input to the receiver input: < ± 0.1 dB.

- Downlink cross channel phase variation between SUM and DIFFERENCE channels from RFU input to the receiver input: < 5 degrees peak to peak.

- Difference between channel 1 and channel 2 downlink differential phase SUM/ DIFFERENCE, from the RFU input to the receiver input: < 5 degrees peak to peak.

- Switching time: < 35 ms

- Isolation between the two channels: > 70 dB at used RF frequencies

- Isolation between any 2 of the 3 RF ports: > 70 dB at used RF frequencies.

- RF signal VSWR on SUM, CONTROL and DIFFERENCE: < 1.3 upstream
  < 1.5 downstream

- Manual phase shift capability for 1090 ± 3 MHz: 270°.

2.2. INTERROGATOR STX 2000

2.2.1 Introduction

The transmitter STX 2000 is designed to be used in RSM-970-S air-traffic control radar stations.

It ensures the modulation and amplification of SSR and Mode S interrogation signals delivered to the "SUM" and "CONTROL" channels of the antenna.

It is mounted in an "Interrogator/Receiver cabinet".

It is made of three modules:

- Interface Driver module (item 1),
- Control HPA module (item 2),
- Sum HPA module (item 3).

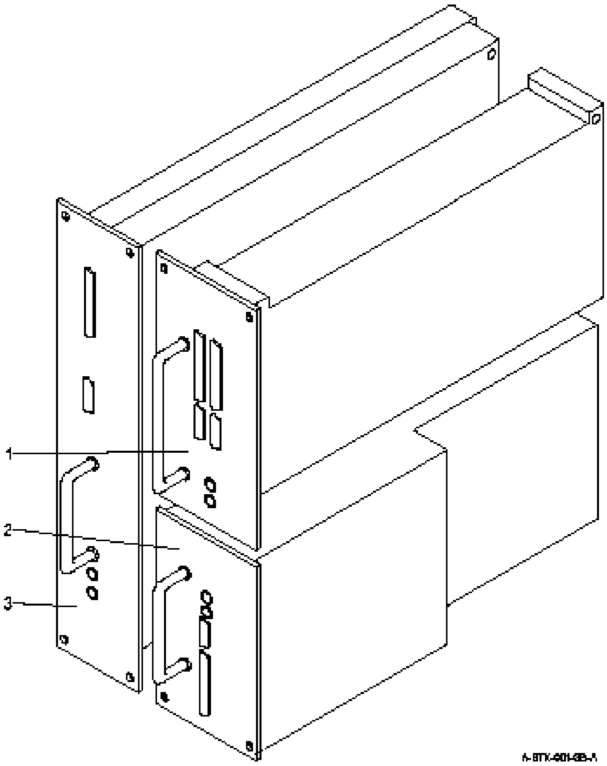


Figure 5 - Transmitter STX 2000 Presentation

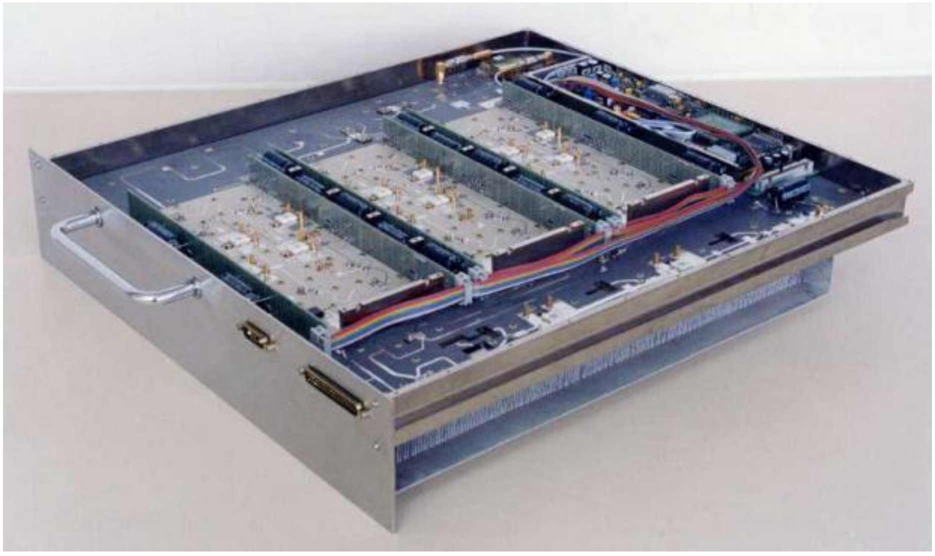


Figure 6 - STX 2000 SUM HPA Module

2.2.2 Interfaces

The STX 2000 is interfaced with:

- The receiver:
  Local Oscillator 1030 MHz CW signal which is generated by the RX, is received by the STX 2000,

- The MSSR Modulator/Extractor (MMXC):
  The function of this interface is to transmit the interrogation modulation commands and the BITE synchronisation commands from MMXC to STX 2000. The BITE reports are sent from STX 2000 to the MMXC.

- The I/R cabinet:

  - Mechanical interface:

    The transmitter is housed by the I/R cabinet.

  - Power supply interface:

    The function of this interface is to provide DC supply (5V, ± 15V, 28V, 50/55V) to the STX 2000.

  - Air flow interface:

    The STX 2000 is cooled by the TX/RX fan unit of the I/R cabinet.

- The RF Unit:
  The function of this interface is to transmit the SUM and CONTROL RF signals to the antenna via the duplexers.

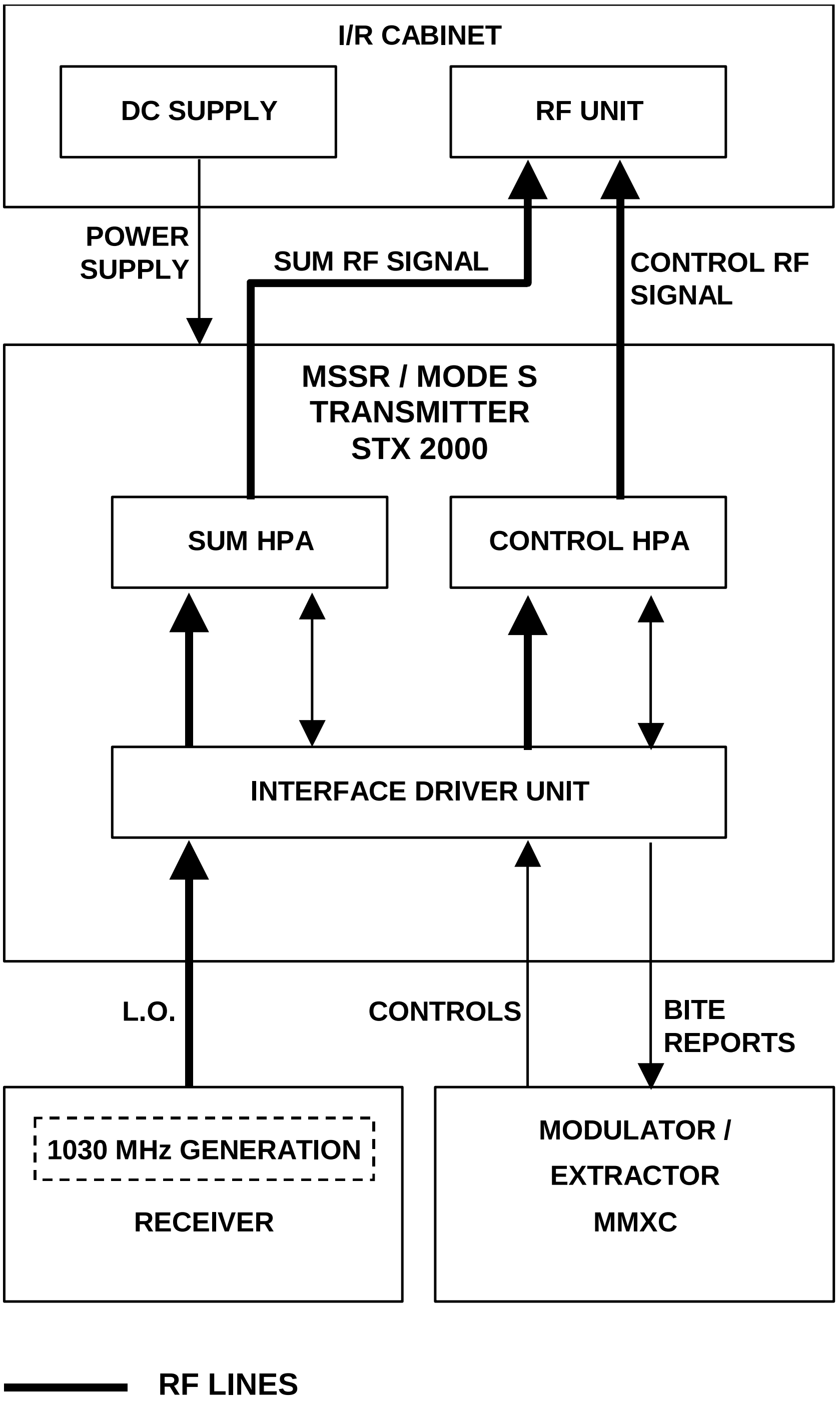


Figure 7 - STX 2000 Transmitter Associated Equipment

2.2.3 Description

The STX 2000 is able to transmit SSR interrogations signals (P1, P2, P3) and also Mode S interrogations signals (P1, P2, P4, P5, long and short P6 with DPSK).

The transmitter is configured such that the P1 pulse can be transmitted on the Control Ω channel so as to implement improved INTERROGATOR Side Lobe Suppression (IISLS).

It is divided into three modules: Sum HPA, Control HPA and Interface Driver.

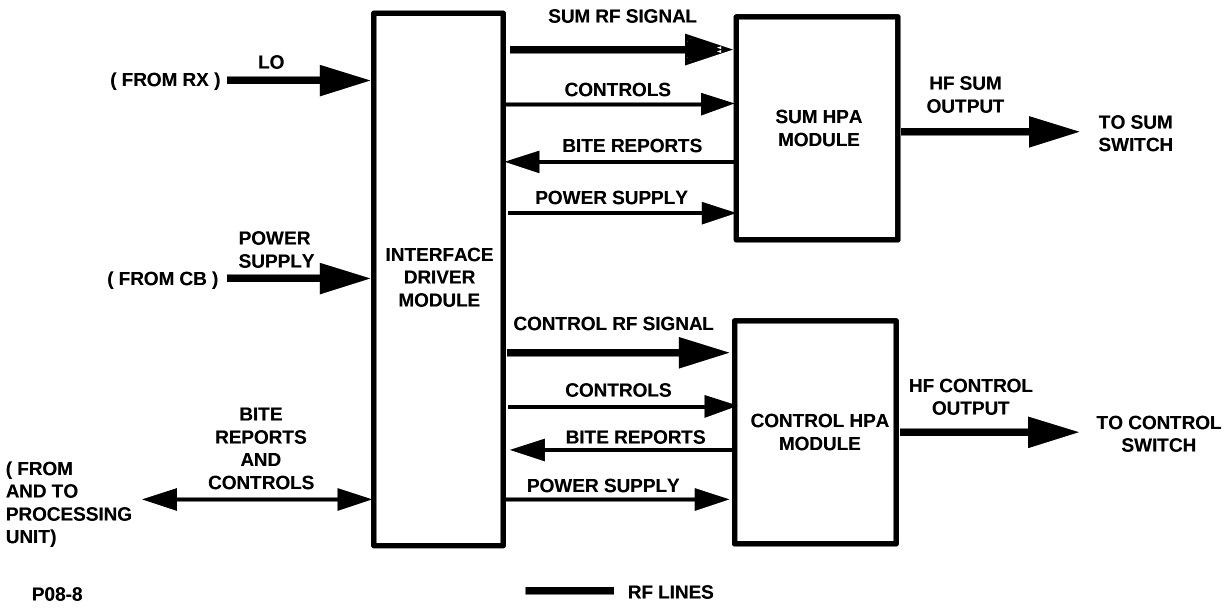


Figure 8 - Main Function of STX 2000

2.2.3.1 Interface Driver Module Functions

The main functions of the Interface Driver module are:

- Interface processing with Processing Unit related to RF modulations, attenuation commands and Built-In Test reports; controls dispatching to HPA modules,
- Storage of all failure reports stemming from BITE functions of HPA modules,
- Power supply dispatching to HPA modules,
- Perform the following RF modulation functions:
  - Differential Phase Shift Keying (DPSK) for the sum channel for Mode S interrogations,
  - Local Oscillator preamplification in order to drive HPA modules,
- Internal interface driver Bite functions.

2.2.3.1.1 RF Modulation Function

The RF signal stemming from the Receiver (LO) is first divided by a 2-way splitter. One output is used to allow a signal detection and a verification of the RF input signal presence. The other drives an amplifier. The LO presence is monitored by an RF detector connected to a coupler located at the interface driver LO input.

The output signal is then divided into a Sum channel and a Control channel.

The Sum channel is composed of amplifiers that ensure an amplification gain and the Local Oscillator shaping according to the interface card control.

In order to realise the DPSK function, a DPSK Modulator shifter is inserted in the Sum channel amplification chain introducing or not a 0/180° phase-shift in pulse P6. The phase modulation control is received from the Processor Unit and transmitted to the DPSK modulator shifter via the interface card.

An output circulator allows to protect the output transistor against reflected power with the help of a dummy load.

The output power is detected via a coupler and an RF detector. The measurement is used by the BITE functions.

The Control channel is identical to the Sum channel but without DPSK system. In this case, the amplifiers are powered according to the Control amplitude modulation stemming from the Processing Unit, via the interface card.

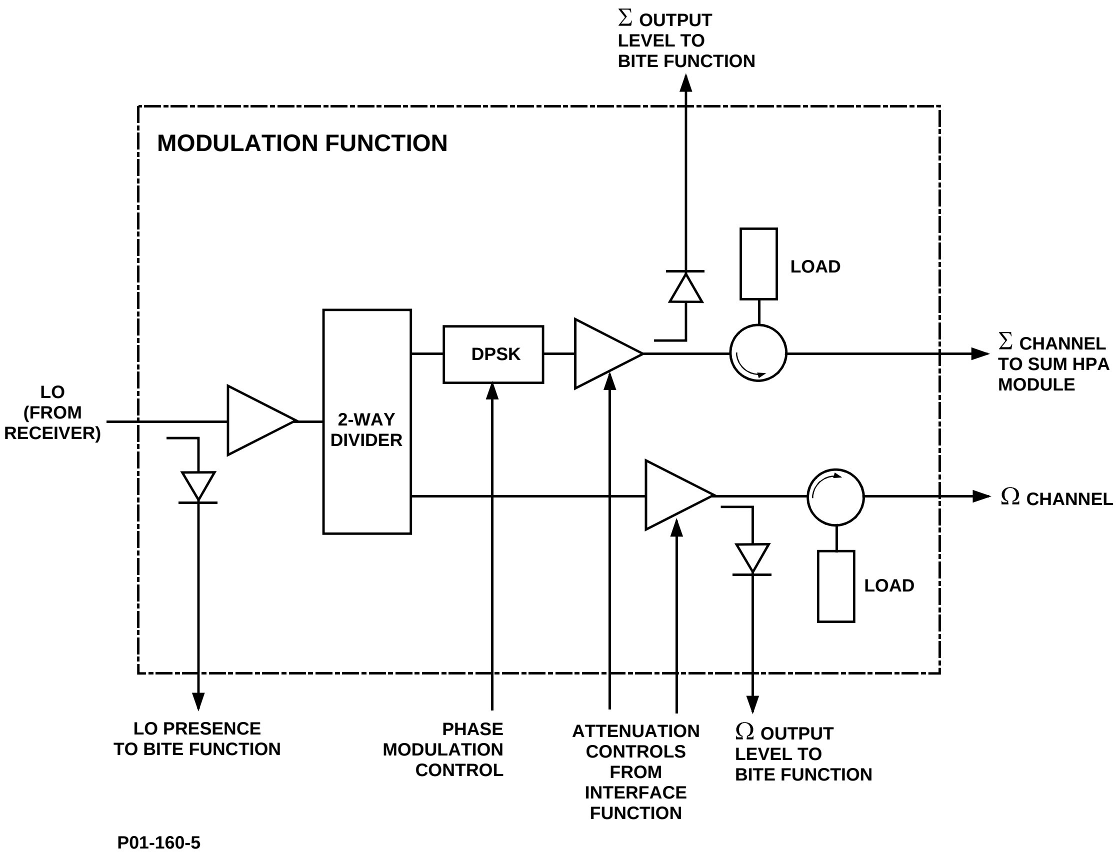


Figure 9 - Interface Driver Module Functions

2.2.3.1.2 Interface Function

The interface function enables to:

- Process the amplitude and phase modulations in order to:
  - ensure consistency of the Processing Unit commands by analysis of SUM and CONT pulse widths, and modulation presence,
  - inhibit modulations in case of alarms detected in HPA module:
    - power reflection at the SUM RF output,
    - power reflection at the CONT. RF output,
    - SUM RF modulation overload detected by junction temperature alarm,
    - ambient over-temperature.

- Transmit controls to the modulation function for the LO shaping and DPSK realise the Management of a command bus which allows to interface with Processing unit for the BITE reports and the attenuation commands.

  The command bus operates with:

  - a selection signal which requires or signals the availability of addresses and data,
  - a bi-directional address bus (4 bits + parity),
  - a data bus (8 bits + parity).

- Interfaces with the HPA modules in order to:

  - transmit the attenuation values to SUM and CONT HPA modules and for the IISLS mode from the data bus,
  - transmit the validation order to authorise the corresponding HPA modules to take into account individually the attenuation values (SUM, CONT, IISLS),
  - receive and memorise the BITE results from the SUM and CONT HPA modules,
  - distribute DC power supply to HPA modules (+ 5V, ± 15V, + 28V, + 50/55V).

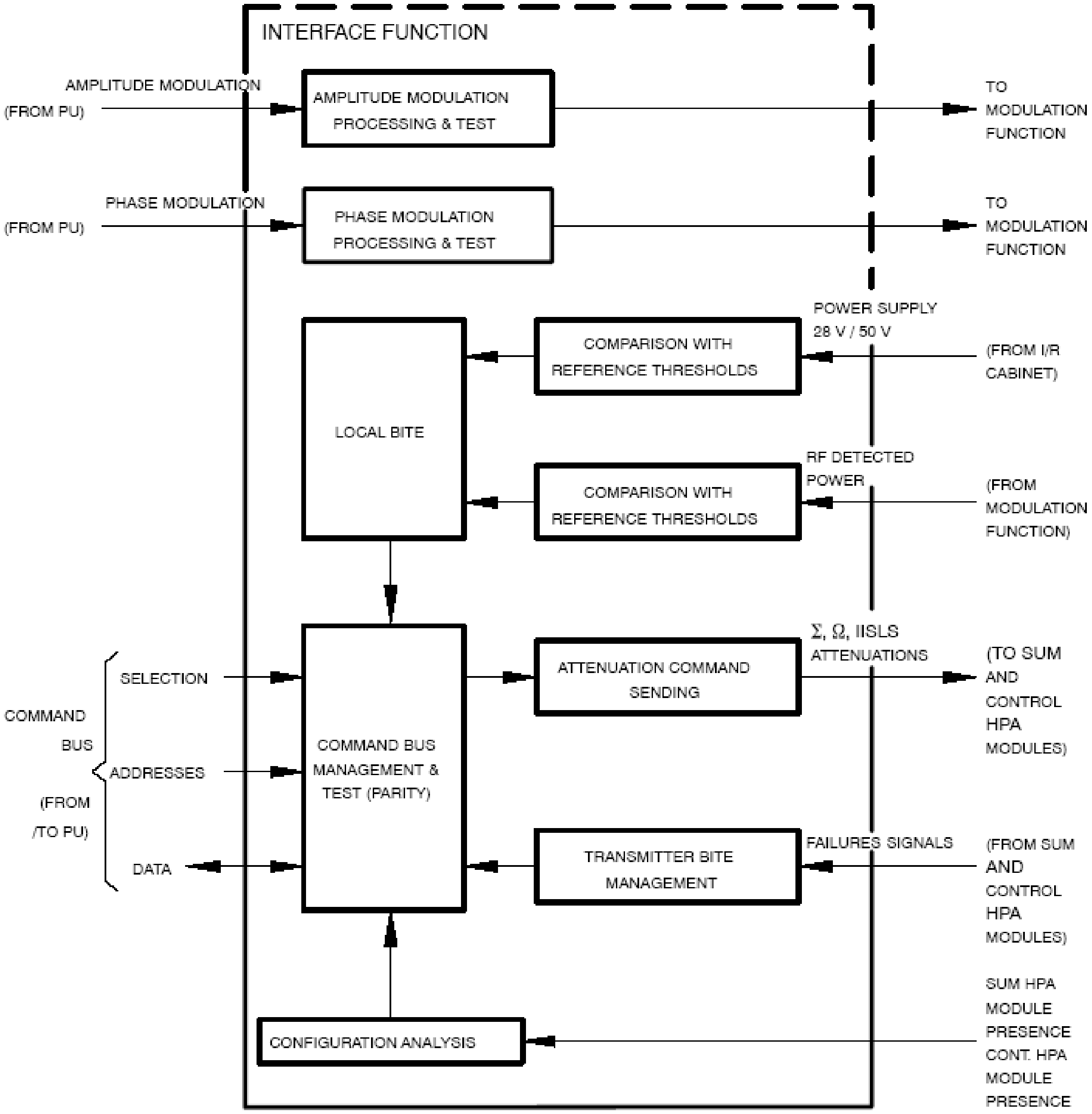


Figure 10 - Interface Function

2.2.3.1.3 Built-In Test Function

Some internal tests are made in the module and for each failure detection, a failure message is prepared to be sent to a Processing Unit (PU) on the bus and a LED on the front panel indicates the failure presence.

These failure signals are related to:

- Ambient temperature,
- Local Oscillator presence,
- Output power,
- Power supply,
- HPA modules presence,
- Time-out on pulse widths,
- Modulation presence.

The LEDs on the front panel give the state of the module:

- The green one is lighting, when the module receives the 5V power supply, otherwise it doesn't light,
- The red one is lighting (with a 1s delay) when an internal failure is detected, otherwise it doesn't light.

Ambient Temperature Measurement

A temperature sensor measures the ambient temperature in the module to detect if the temperature exceeds 70°C (estimated maximum operating temperature). In this case, a failure report is taken into account in the BITE function.

Input Local Oscillator Presence

The Local Oscillator signal is detected by a diode. The detected signal is sent to the Interface card which makes a comparison to a minimum level. Below this level, the Local Oscillator is considered to be off and the failure detection is generated and written into the BITE report.

Output RF Signals

A coupler and a detector at the output of the Sum and Control channels allow to measure the output levels, which are compared to a threshold. Under this threshold, the output is considered as being lost and a failure detection is generated and written into the BITE report.

Power Supply

The presence of the 28V and 55V input voltages is tested and in case of failure, a failure detection is generated and is written into the BITE report.

Time-Out on Pulse Widths

When a Sum or Control amplitude modulation is received from PU, a time counter is started. If the time counter exceeds 2 µs in case of a Control modulation or 40 µs in case of a Sum modulation, the corresponding pulse command is immediately stopped for a pre-determined time. A failure detection is generated and written into the BITE report. Stopping the modulation on the Control channel allows to limit the duty cycle.

Modulation Presence

When the Sum amplitude modulation is not received within 40 µs after a Sum attenuation command, a failure detection is generated and is written into the BITE report.

When the Sum phase modulation is not received within 40 µs after a Sum attenuation command, a failure detection is generated and is written into the BITE report.

When the Control amplitude modulation is not received within 40 µs after a Control attenuation command, a failure detection is generated and is written into the BITE report.

2.2.3.2 Sum HPA Module Functions

The Sum HPA module enables:

- High power amplification to the Sum channel from the RF signal stemming from Interface Drive module,
- Output power attenuation from 0 dB up to 12 dB according to a command received from Interface Driver module,
- BITE functions.

The Sum amplification is performed by a HPA module identical to the Control HPA in the MSSR version, or by a high duty cycle Sum HPA module in the Mode S version.

The description hereafter applies to the Mode S version high duty cycle Sum HPA.

The Sum HPA module function is divided into five sub-functions:

- driving-dividing,
- amplification,
- combination,
- attenuation,
- Built-In Test.

2.2.3.2.1 Driving-Dividing

The Sum driver-divider allows the pre-amplification and the pulse shaping of the RF input signal.

A circulator is inserted after the preamplifier in order to protect it from the power reflected by the 3-way divider. The reflected power is sent to a load.

The RF signals is divided (12-ways) The 12-ways drive their RF signals to the SUM amplification function.

2.2.3.2.2 Amplification

The Sum amplification function is performed by 12 transistors fed from 12-ways of the SUM driving-dividing function. This function enables attenuation controlled by the SUM attenuation function.

The first driver stage is controlled by a pulse shaping system in order to get RF pulses compliant with the requirements for spectral purity and fall time.

The Sum amplification function enables temperature measurement system which is used by the BITE function in order to detect RF modulation overload.

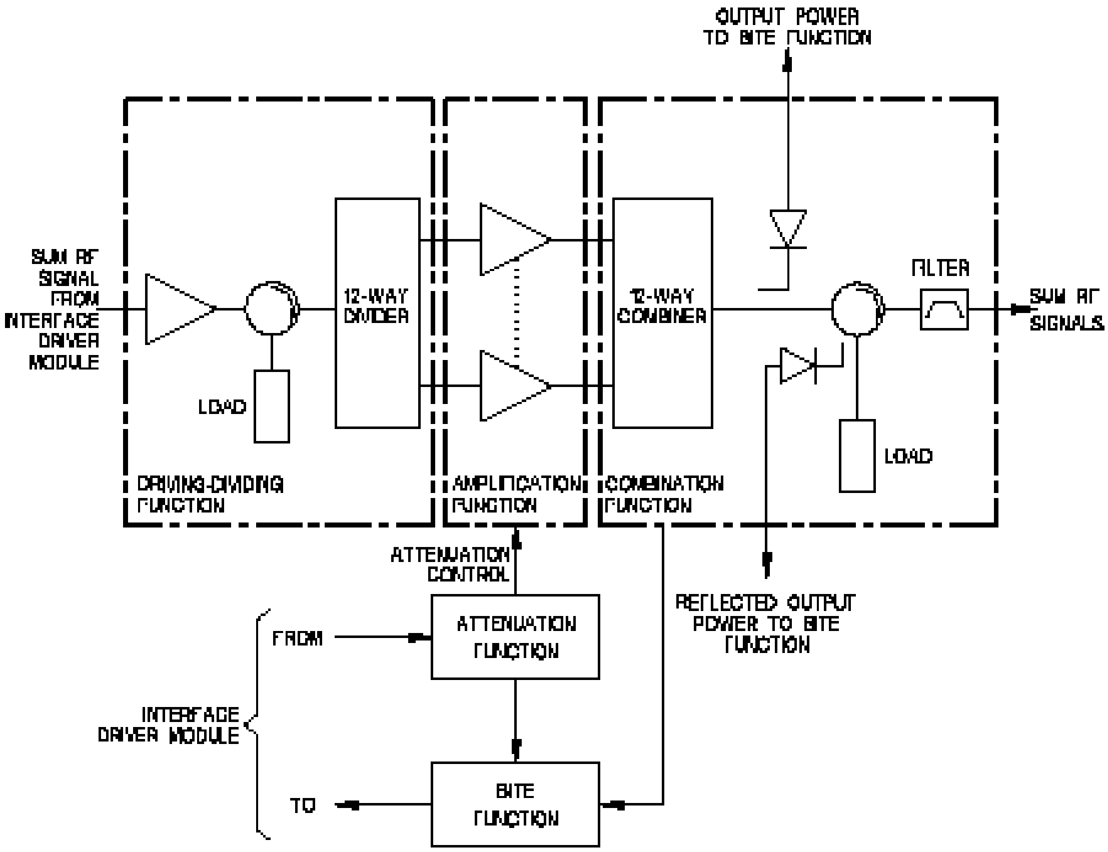
2.2.3.2.3 Combination

The Sum combiner allows to combine the power stemming from the 12 transistors.

An output circulator protects the module against reflected power and infinite VSWR. The reflected power is also detected. The measurement is processed in the BITE function.

A part of the transmit power is measured by a detector. The measurement is processed by the BITE function in order to check if the output power is greater than a minimal value.

A low pass filter reduces the harmonic and spurious level and a band pass filter allows to respect the ICAO standard close to the carrier frequency (± 60 MHz).



P01-160-13.PPT

Figure 11 - High Duty Cycle Sum HPA Module Function

2.2.3.2.4 Attenuation

The Sum attenuation function enables to:

- Process the attenuation code received from the Interface Driver module and generates the control transmitted to the attenuation function,
- Adjust the RF Level for testing of the module.

2.2.3.2.5 Built-In Test

Some internal tests are done in the module and for any failure detection, a failure signal is sent to Interface Driver module and a LED indicates the failure presence. These failure signals are related to:

- Ambient temperature,
- RF modulation overload,

- Reflected output power,
- Output power,
- Power supply,
- Module presence.
- A red LED on the front panel gives the state of the module: it is lighting (with 1 sec. delay) when an internal failure is detected, otherwise it doesn't light.
- Ambient Temperature
- A temperature sensor measures the ambient temperature in the module to detect if the temperature exceeds 70°C (estimated maximum ambient temperature in the module). In this case, a failure report is sent to Interface Driver module and written into the BITE report.
- RF Modulation Overload
- In order to protect the RF a device is used to detect Modulation overload.
- Warning and alarm signals are generated towards Interface Driver module and are written into the BITE report.
- In order to protect RF transistors against Modulation overload, when an alarm signal is generated, the Interface Driver module stops the RF Modulation for a fixed time.
- Reflected Output Power
- The output circulator on the Sum combiner card allows to measure the reflected power with a detector. If the detected power exceeds a fixed value, an error signal is generated to module interface Driver and a failure report is written in the BITE report. In order to protect the RF transistors, the Interface Driver module stops the RF modulation for a fixed time.
- Output Power
- The output power is measured by a detector on the Sum combiner card. The resulting level is compared to reference levels according to the attenuation command and the nominal power P0 (for 0 dB attenuation).
- When for a given attenuation, the output power is outside the reference range, an error signal is generated towards Interface Driver module and is taken into account by the BITE.
- Power Supply
- The presence of the + 28V and + 50/55V input voltages is tested and in case of failure, an error signal is sent towards Interface Driver module and a failure report is written in the BITE report.

Module Presence

The power supply 5V is returned to Interface Driver module.

2.2.3.3 Control HPA Module Functions

The Control HPA module enables:

- High power amplification to the Control channel from the RF signal stemming from Interface Driver module (the same module is also used for the Sum channel in the MSSR version),
- Output power attenuation from 0 dB up to 12 dB according to a command from Interface Driver module,
- IISLS attenuation from 0 dB up to 6 dB,
- BITE functions.

The Control HPA module function is divided into five sub-functions:

- Driving,
- Dividing,
- Control amplification,
- Control combination/attenuation,
- Control Built-In Test.

2.2.3.3.1 Driving

This function enables the pre-amplification and the pulse shaping of the RF input signal.

2.2.3.3.2 Dividing

Preamplified RF signals are divided by a 4-way divider.

2.2.3.3.3 Amplification

The Control amplification function is performed by RF transistors, fed from the 4-ways of the Control dividing function.

2.2.3.3.4 Combination

The Control combination function enables the combination of the power stemming from the 4 RF transistors.

The output circulator protects the module against a too high VSWR.

The output power is measured via a detector. The measurement is used in the BITE function in order to check if the output power is greater than a minimal value.

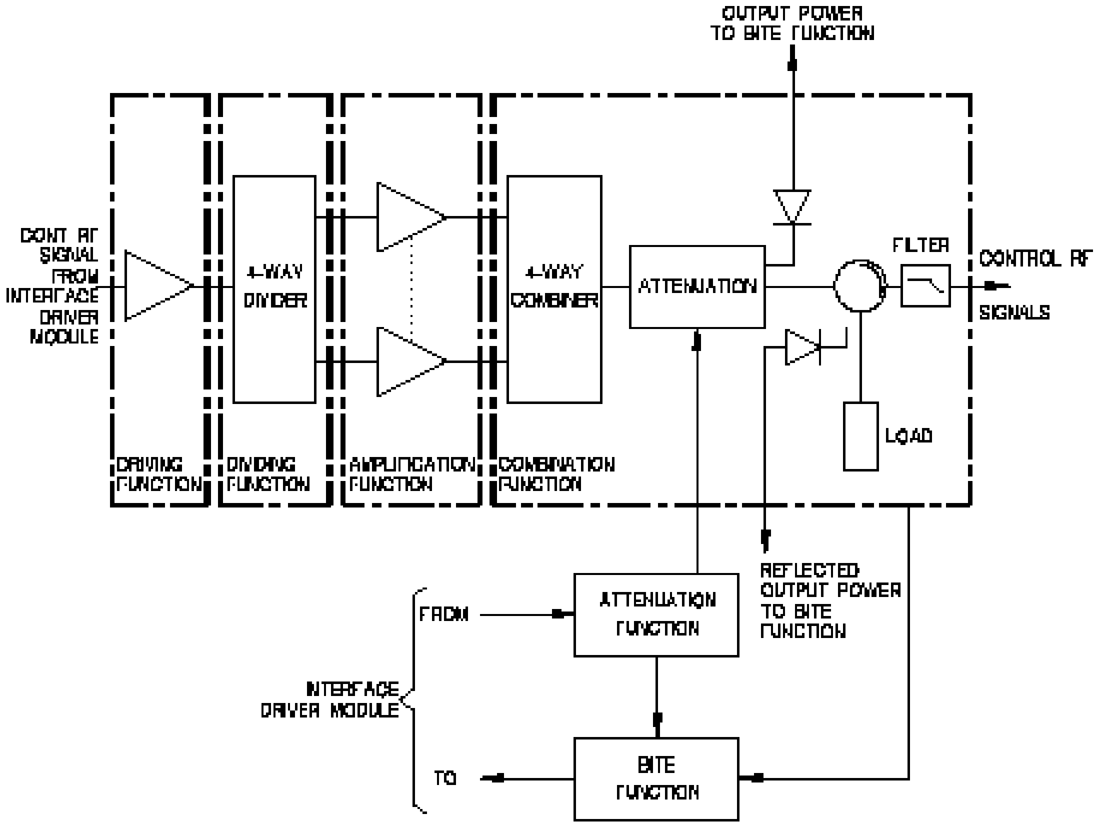
The reflected power is also detected and the measurement is sent to the BITE function.

A low pass filter reduces the harmonic and spurious levels.

2.2.3.3.5 Control Attenuation Function

The Control attenuation function enables to:

- Process the attenuation codes (Cont. and IISLS) received from Interface Driver module and generates the control to the combination function.



P01-160-14.PPT

Figure 12 - Control HPA Module Function

2.2.3.3.6 Built-In Test

Some internal tests are done in the module and for any failure detection, a failure signal is sent to Interface Driver module and a LED indicates the failure presence. These failure signals are related to:

- Ambient temperature,
- Reflected output power,
- Output power,
- Power supply,
- Module presence.
- A red LED on the front panel gives the state of the module: it is lighting (with a 1 s delay) when an internal failure is detected, otherwise it doesn't light.

Ambient Temperature

A temperature sensor measures the ambient temperature in the module to detect if the temperature exceeds 70°C (estimated maximum value). In this case, a failure report is sent to Interface Driver module and is written into the BITE report.

Reflected Output Power

The output circulator on the Control combiner card allows to measure the reflected power with a detector. If the detected power exceeds a fixed value, the signal is generated to Interface Driver module and a failure report is written in the BITE report.

Output Power

The output power is measured by a detector on the Control combiner. The result is compared to reference levels according to the attenuation command and the nominal power P0 (for 0 dB attenuation).

When for a given attenuation, the output power is outside the reference range, the error signal is generated towards Interface Driver module and is taken into account by the BITE.

Power Supply

The presence of the + 28V and + 50/55V input voltages is tested and in case of failure, an error signal is sent towards Interface Driver module and a failure report is written in the BITE report.

Module Presence

The power supply 5V is returned to the Interface Driver module.

2.2.4 Key Features

The following values are typical:

- Operational frequency: 1030 ± 0.01 MHz,
- Output power: 64.1 dBm on Sum and Control channels,
- Mode S version peak duty cycle 63.7% during 2.4 ms on Sum channel. The STX 2000 Mode S duty is compatible with full Data link operation, as defined for the EUROCONTROL POEMS programme,
- Mode S version mean duty cycle: 5% long term. The STX 2000 Mode S duty cycle is compatible with full Data link operation, as defined for the EUROCONTROL POEMS programme,
- RF pulses compliant with ICAO standard,
- IISLS operation on Control channel,
- Output power attenuation from 0 dB up to 12 dB by step of 2 dB (independently on Sum & Cont.).

2.3. MONOPULSE DIGITAL RECEIVER (MDR)

2.3.1 Introduction

The receiver of the RSM 970S radar system performs the digital processing of the signals received from the antenna over the Σ (sum), Δ (difference) and Ω (control) channels in order to deliver the following data needed for the operation of the extractor (part which processes the video data):

- QRSLS: Quantized video generated from the log Σ, log Ω and log Δ videos.
- OBA f(Δ/Σ): Off-Boresight Angle used in Monopulse operation. It defines the angular position of a target detected in the main Sum channel beam.
- Video Log: Log Σ and Log Δ.

The receiver sends the master oscillator frequency signal (1030 MHz) to the transmitter. The master frequency generator is also permanently tested. It is checked using a comparison with the master oscillator frequency generated by the adjacent channel. In the event the frequency of any radar channel exceeds ICAO limits (1030 MHz ± 0.01), a warning is reported at RCMS.

The receiver also contains test circuitry. Internal stimuli are generated from an oscillator at the same frequency as the signals received from the antenna (1090 MHz), via couplers located at the Σ, Δ and Ω RF inputs, these stimuli simulate the various functions of the receiver and detection circuits on the video outputs of the receiver.

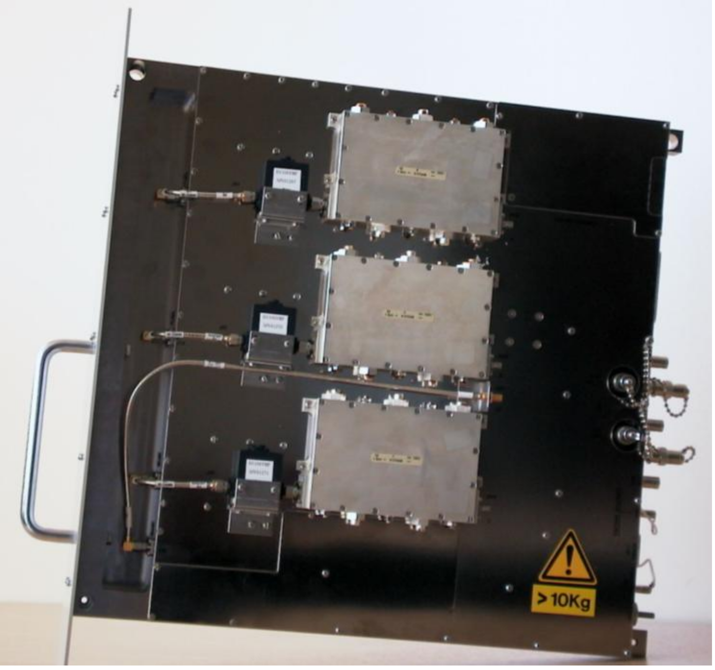


Figure 13 - View of MDR Digital Receiver

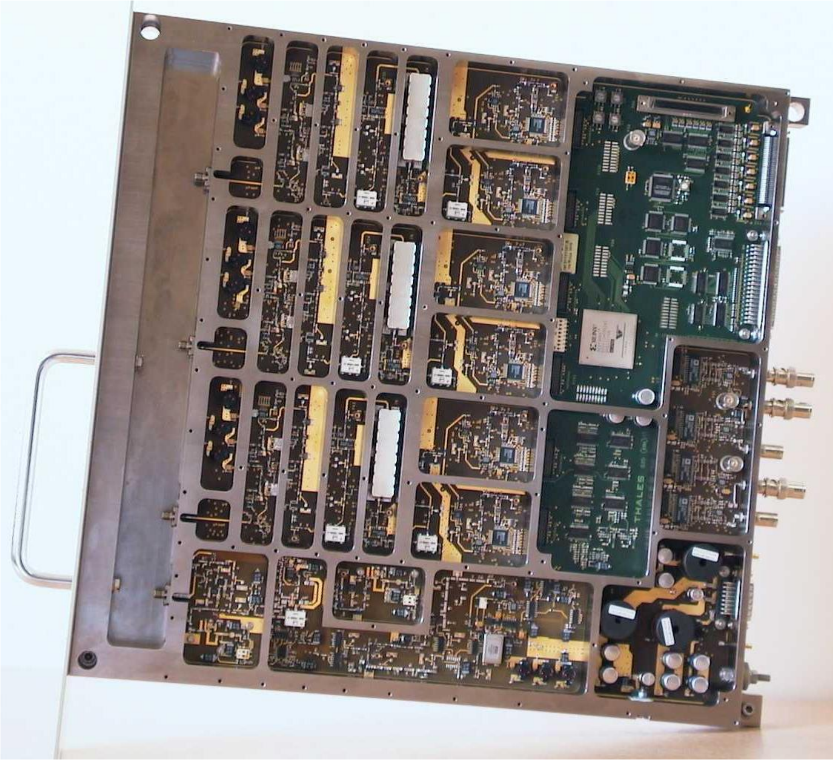


Figure 14 - View of MDR Open Case

2.3.2 Interfaces

The receiver (channel 1 or 2) interfaces with:

- The Interrogator/Receiver cabinet from which it receives DC power supplies and RF signals (Σ, Δ, Ω),
- The transmitter which receives the Local Oscillator from the receiver,
- The processor/control unit :
  - which receives the digital videos and the BITE results from the receiver,
  - which sends operating controls to the receiver,
- The IBIS radar maintenance display in order to display digital videos from either receiver (1 or 2).

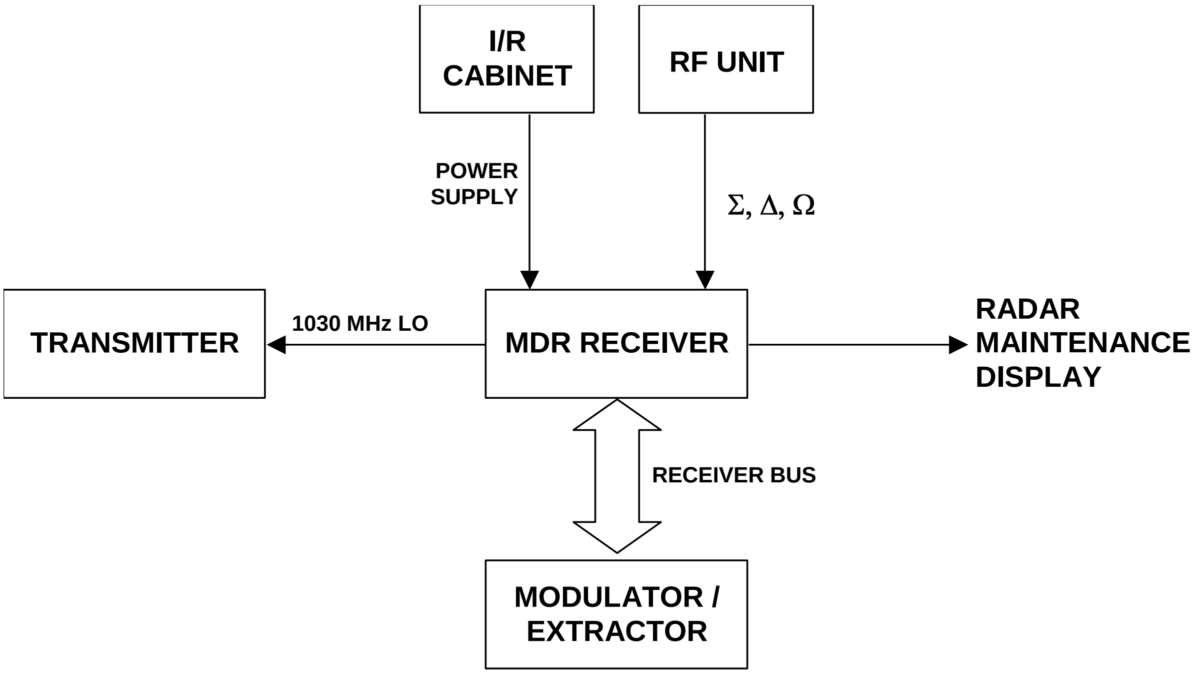


Figure 15 - Associated Equipment

2.3.3 Description

2.3.3.1 General

Signals generated by the receiver are the following:

- the log Σ and log Δ signals are obtained from digital processing.
- the signal QRSLS is determined by digitally comparing the logarithmic video signals:
  - log Σ and log Ω,
  - log Σ and log Δ.

The Σ - Ω comparison allows to suppress signals received within secondary lobes.

The Σ - Δ comparison allows to narrow the received lobe;

- the angle error signal f(Δ/Σ) represents the function $\tan^{-1}\left(\frac{\vec{\Sigma}.\vec{\Delta}}{\Sigma^2}\right)$.

A reduced noise factor is obtained on the three channels by low-noise pre-amplification at the reception frequency.

Filtering is performed upon reception at the RF frequency (1090 MHz) and also at the intermediate frequency (110 MHz) and in digital Amplitude Phase Detection (APD) unit .

The RF signal at 1090 MHz is translated to 110 MHz by mixing with the 1200 MHz Local Oscillator (LO). The LO signal at 1200 MHz is generated by a VCO driven at a crystal oscillator frequency. The signal for the transmitter 1030 MHz is also generated by a VCO.

A bus controls exchanges between the processor unit and the receiver:

- to trigger the receiver BITE tests and to collect BITE reports,
- to set the RSLS thresholds applied in the receiver,
- to set the RSLS validation states in the receiver.

2.3.3.2 Functional description

The receiver can be divided into three sub-functions:

- Analog to digital stages which converts the RF signals coming from transponders after analog amplification, filtering and demodulation into digital signals,
- Local frequency generation which generates the frequency used for down conversion and sent to the transmitter,
- Signal processing which generates the signals intended for the associated equipment and manages the BITE.

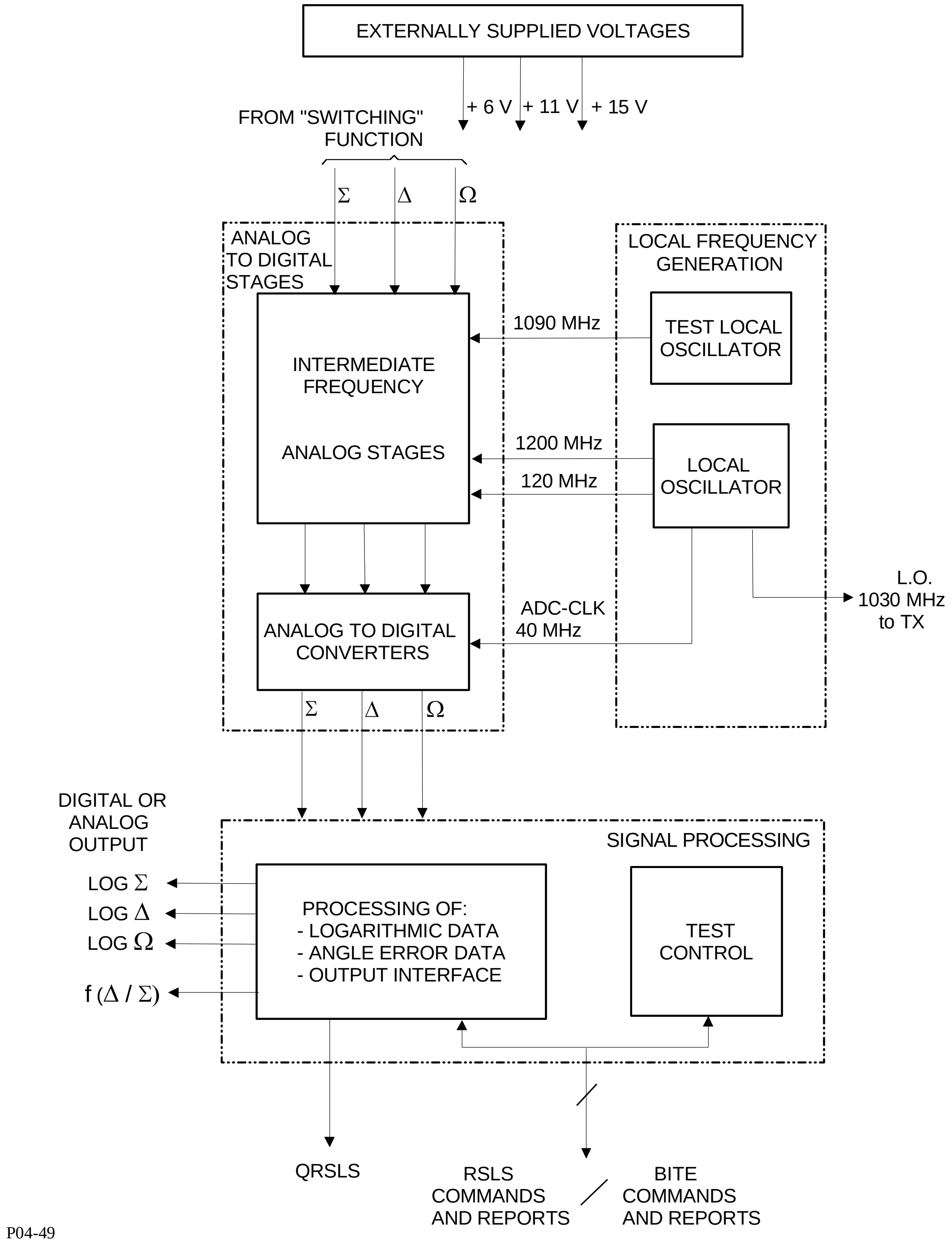


Figure 16 - Reception Function

2.3.3.2.1 Analog to Digital Stages

Analog to digital stages consist of 3 identical linear channels of reception Σ, Δ and Ω. Each one is encoded by two Analog to Digital Converters respectively called MSB chain and LSB chain.

The analog stages function consists of:

- Filtering the 1090 MHz received signal by RF filters.

These filters are fitted on the side panel of the receiver on the Σ, Δ and Ω channels, at the beginning of the demodulation chain. They enable the receiving frequency to be selected at 1090 MHz and they reject the transmitting frequency at 1030 MHz.

The 1090 MHz RF signals from the antenna pass directly to the filters in the Σ, Δ and Ω channels.

- Signals test input:
  - The first signal of test at -20 dBm (generated by Local Frequency Generation) is injected by the first switch, just after the 1090 MHz RF filter, enables the receiver to be tested. The signal of test undergoes all the high dynamic analog chain called MSB (except RF filter);
  - The second signal of test at -53 dBm (also generated by Local Frequency Generation) is injected every second through the switch after the LNA and is going to test all the low dynamic analog chain called LSB (except RF filter and 1st ampli LNA);
  - These signals of test validate also the local frequency generation;
- Preamplifier-mixers and IF filters.

The first stage preamplifier-mixer receives the LO signal (1200 MHz) from the Local Frequency Generation, divided so as to give identical levels on the Σ, Δ and Ω channels. The second stage preamplifier-mixer receives the LO signal (120 MHz) from the Local Frequency Generation. The function of the Preamplifier-Mixer is to perform low-noise amplification, to convert the received signal into 10 MHz IF signals, and to filter them before they are processed in the Angle Error Measurement - Log Amplifier function by the signal processing function.

- Analog to Digital Conversion.

In each reception channel Σ, Δ and Ω, two 14 bits Analog Digital Converters interface the analog chain to the digital chain.

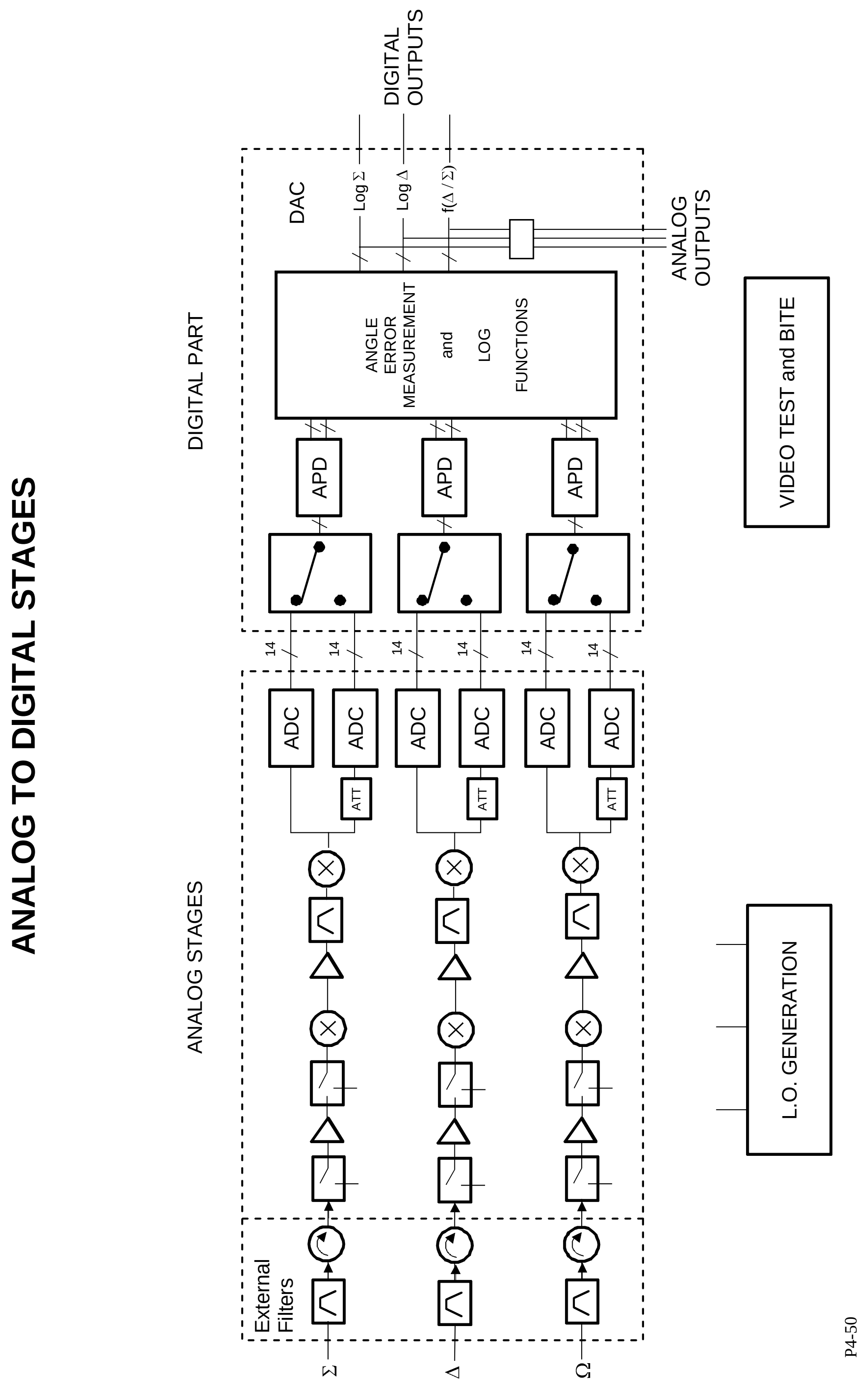


Figure 17 - Analog to Digital Stages

2.3.3.2.2 Local Frequency Generation

The Local Frequency Generation ensures several functions:

- it delivers the LO signal (local oscillator at 1030 MHz) to transmitter,
- it generates the ADC_CLK 40 MHz signal clock for the Analog to Digital Converters,
- it delivers two LO signals (LO 1200 MHz and LO 120 MHz) which when mixed successively with the signal received from the antenna (1090 MHz) and then with the first IF (110 MHz) gives the second IF signal (10 MHz),
- it enables the receiver to be tested by delivering a 1090 MHz signal to the input switches.

The LO 1030 MHz signal is generated by a Voltage Control Oscillator (VCO1) controlled on the 40 MHz source by a phase locked loop PLL1.

The source 40 MHz (TCXO) is a quartz oscillator, compensated in temperature, which delivered also the clock signal ADC_CLK for the Analog to Digital Converter.

The LO 1200 MHz signal is generated by a Voltage Control Oscillator (VCO2) controlled on the 40 MHz source by a phase locked loop PLL2.

The LO 120 MHz signal is generated by multiplying the signal of the TCXO by 3.

LO 1090 MHz signal for test is generated by mixing LO 1030 MHz signal with the LO 120 MHz divided by 2.

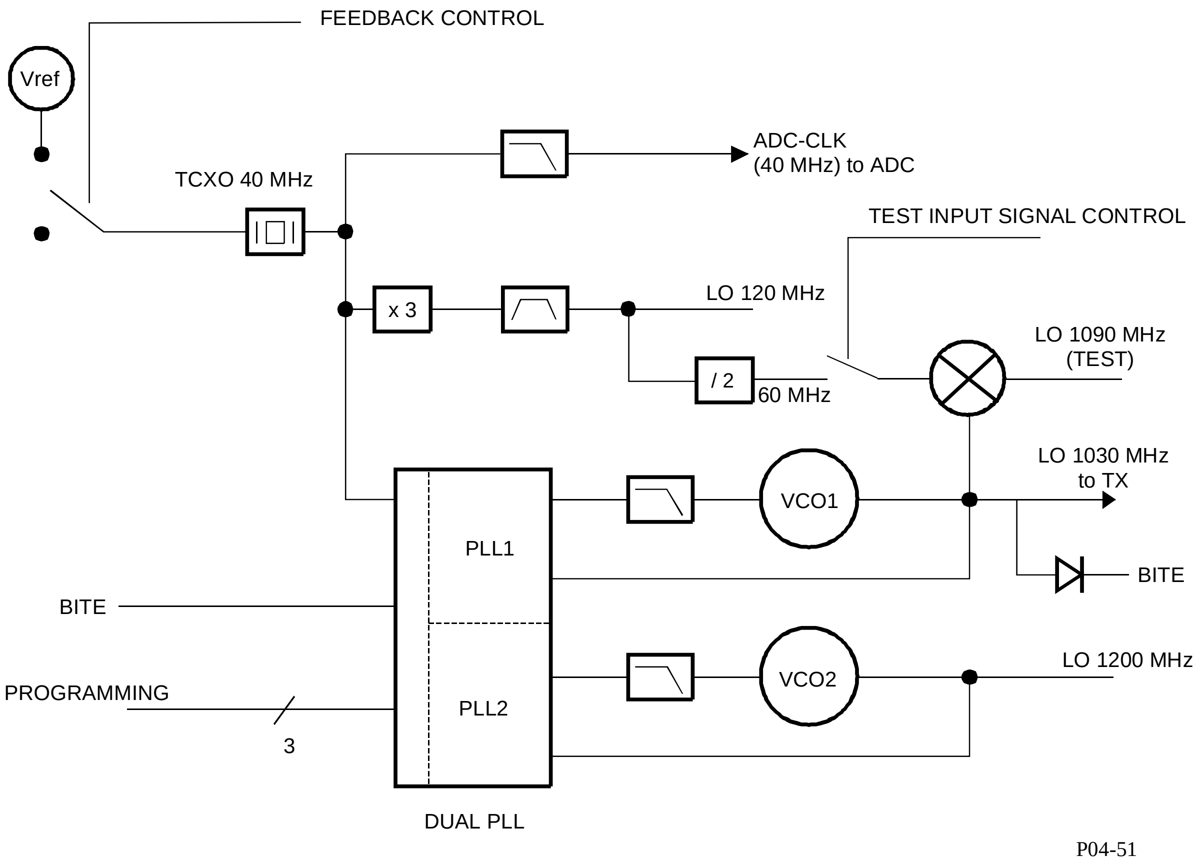


Figure 18 - Local Frequency Generation

2.3.3.2.3 Signal Processing

The purpose of this function is to deliver to the processor unit:

- video QRSLS output. These signals indicate whether the video has been detected on the main lobe of the antenna,
- Log Σ and Log Δ videos,
- Angle error measurement f(Δ/Σ).

It also manages the BITE of the receiver unit.

The processor unit (master) controls all information exchanged between the processor unit and the receiver via a bus. The receiver (slave) executes operations according to processor unit request.

The main functions of the digital chain are:

- Switching between ADC (MSB) and ADC (LSB),

- Amplitude Phase Detection,
- Video signals generation,
- Angle error measurement,
- LOG Conversion,
- Calibrations during operation,
- BITE,
- Digital to Analog Conversion (for maintenance).

Except Digital to Analog Conversions, the other major functions are built in a FPGA circuit.

VIDEO SIGNALS GENERATION

The signal log Ω is assigned a coefficient K1, adjustable between 0 to +10 dB, by step of 1 dB.

The signal log Δ is assigned a coefficient K2, adjustable between -10 dB to +10 dB, by step of 1 dB.

K1 and K2 received on the receiver interface bus is converted in analog signals before assignation to log Ω and log Δ.

The result of comparing log Σ and log Ω + K1 indicates reception on the main (or secondary) lobe. The result of comparing log Σ and log Δ + K2 refines the reception on the main lobe.

Combining these two results gives the video signal QRSLS (Σ).

This system eliminates noise and spurious pulses coming in particular from the area near the secondary radar.

The QRSLS, Log ∑, Log Δ and f(Δ/∑). videos are sent to the radar processing unit (for decoding of replies) in digital form (LVDS type).

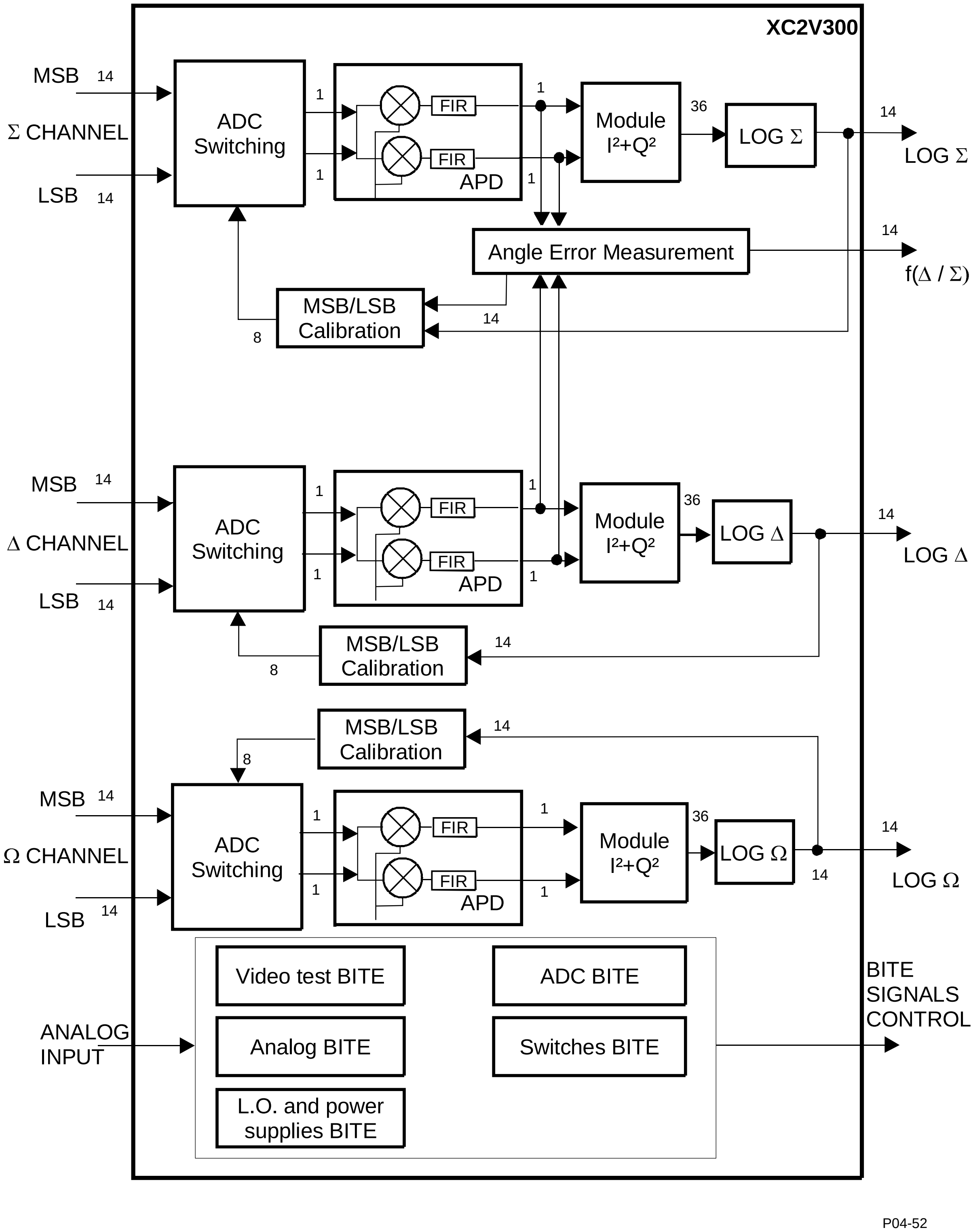


Figure 19 - Signal Processing Function

2.3.3.3 BITE (Built-In Test Equipment)

General

The BITE allows to test the correct operation of the MDR.

A set of tests is made, some of them are performed continuously others upon periodic signals injection.

The main functions BITE are:

- Video test signals,
- Outputs analog and digital LVDS,
- Analog Digital Converters,
- Switches (calibration, injection),
- Local oscillator signals,
- Power supplies.

The BITE report is sent to the processor control/unit via the receiver bus QRSLS/BITE interface. The Processor/Control unit sends the overall BITE report to the Remote and Control Monitoring System.

Angle Error Measurement

The f(Δ/Σ) video is compared to thresholds for 3 Δ/Σ values (-1, 0, +1). The test result is formatted to be sent to the processing unit on the receiver interface bus.

Noise Sensitivity

Each of the signals log Σ, log Δ and log Ω is compared to thresholds so as to check a noise test, a test in the middle of the dynamic range and a test in the high of the dynamic range. The test result is formatted to be sent to the processing unit on the receiver interface bus.

Reception Test Controls

The Controls and Tests function transmits an end-of-range sync signal. From this signal, the Signal Processing function generates the test oscillator control signal and the various attenuation and phase-shift control signals needed by the Σ, Δ and Ω test signals. The test result is formatted to be sent to the processing unit on the receiver interface bus.

2.3.4 Key Features

The following values are typical:

- Received signal frequency: 1090 MHz ± 3 MHz
- Intermediate frequency: 10 and 110 MHz
- Efficient dynamic range: From -20 dBm to -85 dBm
- Pass band at -3 dB: ≥ 8 MHz
- Input impedance on all 3 channels: 50 Ω
- Local oscillator frequency: 1030 MHz ± 10 kHz
- Sensitivity: ≤ -88 dBm

2.4. MONOPULSE MODULATOR AND EXTRACTOR (MMXC)

2.4.1 Introduction

In an RSM 970 S radar channel, the MMXC performs SSR and Mode S radar processing in conjunction with the MSSR Radar Processor (MRP).

The MMXC performs real time processing. Its operational purpose is, according to controls sent by the MRP, to schedule aircraft interrogations and associated listening windows in a succession of all-call periods (for the acquisition of Mode S aircraft and surveillance of aircraft equipped with SSR-only transponders) and roll-call periods (for the surveillance and enhanced surveillance of Mode S aircraft, including data link exchanges in the ATN), in order to:

- generate SSR and Mode S interrogation modulation controls as well as attenuation controls to the transmitter,
- generate RSLS controls to the receiver,
- compute SSR and Mode S replies from the digital videos provided by the receiver, and send the detected replies to the MRP for further processing.

In the dual I/R channel architecture of the Mode S radar, the MMXC of the "to antenna" (i.e.”ON-LINE”) channel processes operational radar data, the MMXC of the "to load" (i.e. “standby”) channel processes test data.

The MMXC controls the switches of the RFU, once it has received an I/R channel switchover control from its associated DPC (MRP part).

For maintenance purpose, the MMXC manages the real time processing of the BITE information gathered from itself and other radar equipment.

The MMXC is housed in a case which is attached to the Monopulse Digital Receiver. The grouping of the MDR and the MMXC is called MDRP (Monopulse Digital Receiver and Processor) and constitutes a single LRU.

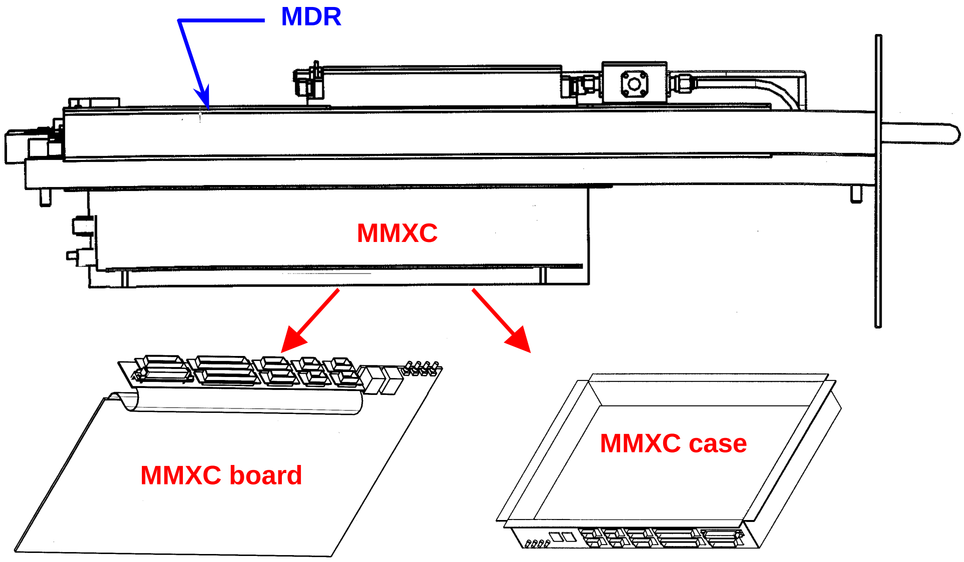


Figure 20 - MDRP configuration

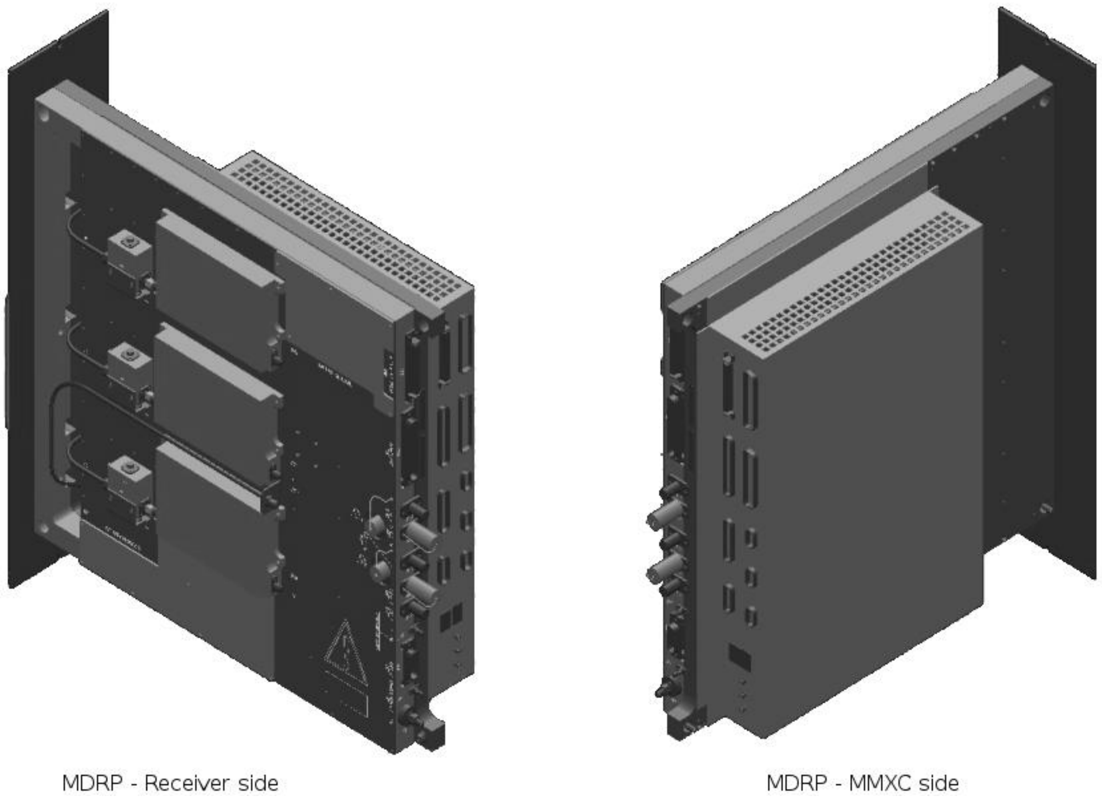


Figure 21 - MDRP view

2.4.2 Interfaces

The MMXC manages the following interfaces:

- Transmit data:
  - to the RFU: RF switch controls,
  - to the transmitter: attenuation and modulation controls,
  - to the receiver: RSLS controls and receiver test synchronization control,
  - to the IBIS radar maintenance display: synchronization pulse, pulse presence signals and reply presence signals, digital videos,
  - to the antenna control cabinet: transmission inhibition report
- Receive data:
  - from the RFU: RF switch statuses,
  - from the transmitter: BITE reports,
  - from the receiver: digital videos, QRSLS signal and BITE reports,
  - from the I/R cabinet ancillaries: DC supply, DCS BITE report, fan BITE reports, thermal sensor BITE reports,
  - from the optical encoder: antenna azimuth,
  - from the antenna control cabinet: transmission inhibition control

2.4.3 Description

2.4.3.1 Architecture

The MMXC performs 6 functions distributed on 2 functional blocks :

- Front End Processing (one FPGA + one DSP)
  - MMXC - Cabinet Interface
  - Space Time Management (STM)
  - Video Pulse Processing
  - SSR Reply Processing
  - Mode S Reply Processing
- Ethernet Interface Processing (one FPGA)
  - MMXC - MRP Interface

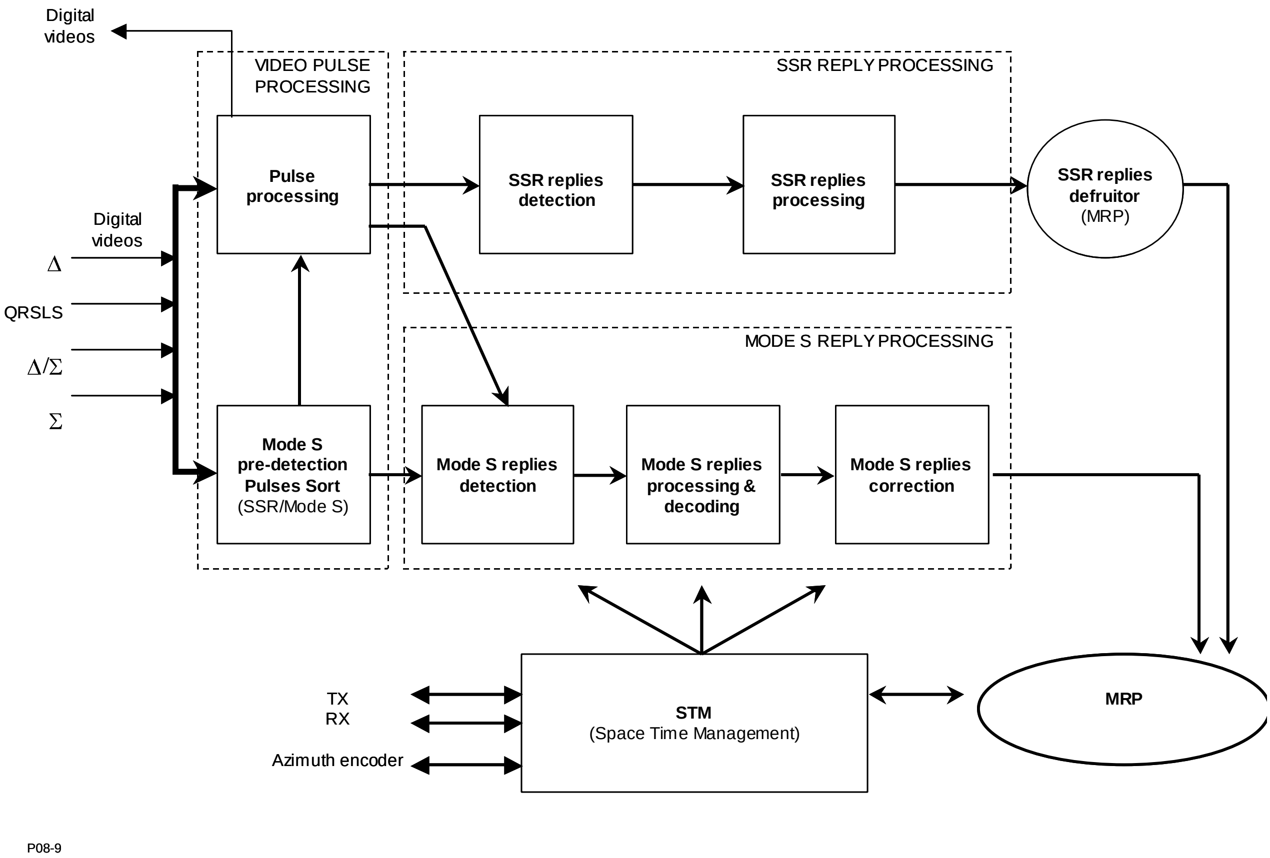


Figure 22 - MMXC functional architecture

2.4.3.2 Front-End functions

2.4.3.2.1 Cabinet interface

The purpose of this function is to convert all the external signals (LVDS digital video, dry contact, ...) into standard digital data.

2.4.3.2.2 Space and time management

This function performs:

- the real time management of the All-Call/Roll-Call pattern,
- the processing of the antenna azimuth and Azimuth Distribution,
- the generation of SSR and mode S interrogation to the transmitter,
- the control and monitoring of the transmitter and the receiver.
- the management of the RF Unit
- the management of the Video and Reply Processing functions.
- the monitoring of the cabinet ancillaries (power supplies, cooling fans…)
- the monitoring of the MMXC Thermal Sensor

2.4.3.2.3 Video pulse processing

This function:

- analyses the shape of video signals sent by RX to detect secondary pulses (SSR or mode S),
- generates TVBC values function of range according to current TVBC law number
- validates pulses according to TVBC values,
- eliminates pulses belonging to Mode S message for SSR Reply Processing,
- computes the characteristics of each detected pulse,
- generates, during test period, test target digital videos.

2.4.3.2.4 SSR reply processing

This function:

- detects SSR replies,
- computes the characteristics of the replies,
- generates an SSR reply message for each validated reply,
- generates an SSR interrogation acknowledgement message for each All-Call SSR interrogation,
- reports the results of the analysis performed during the test period (to the “Space and Time Management” function).

2.4.3.2.5 Mode S reply processing

This function:

- detects Mode S replies:
  - in the range coverage during All-Call period,
  - in each listening window during Roll-Call period

- computes the characteristics of each validated reply,
- detects and corrects, when possible, errors in the data field of the Mode S message,
- generates a Mode S reply message for each listening window,
- generates a Mode S interrogation acknowledgement message for each All-Call or Roll-Call Mode S interrogation
- reports the results of the analysis performed during the test period (to the “Space and Time Management” function).

2.4.3.3 Ethernet interface

This function:

- manages the physical link between MRP and MMXC (Gigabit Ethernet),
- routes the messages between MMXC functions and MRP.

3. DATA PROCESSOR

3.1. DATA PROCESSING COMPUTER (DPC)

3.1.1 Introduction

The Data Processor (DPC) is composed of a Personal Computer (PC) installed in the radar cabinets (one Data Processor per MSSR/Mode S channel).

The online DPC transmits controls to the associated MMXC, in order to schedule SSR, Mode S All-Call and Mode S Roll-Call interrogations. In return, it receives MSSR and Mode S replies elaborated by the MMXC.

In a PSR + MSSR/Mode S configuration, the online DPC also receives PSR plots and weather maps from both PSR radar processors. According to the status of the PSR processors, it selects one of them for processing.

The DPC performs the PSR/MSSR/Mode S plot combination and scan-to-scan correlation (i.e. tracking). Tracks or filtered plots are then transmitted to the ATC Centre via two LINES devices. Eight ATC Center data flows are available with ASTERIX or AIRCAT (Tracks only) formats.

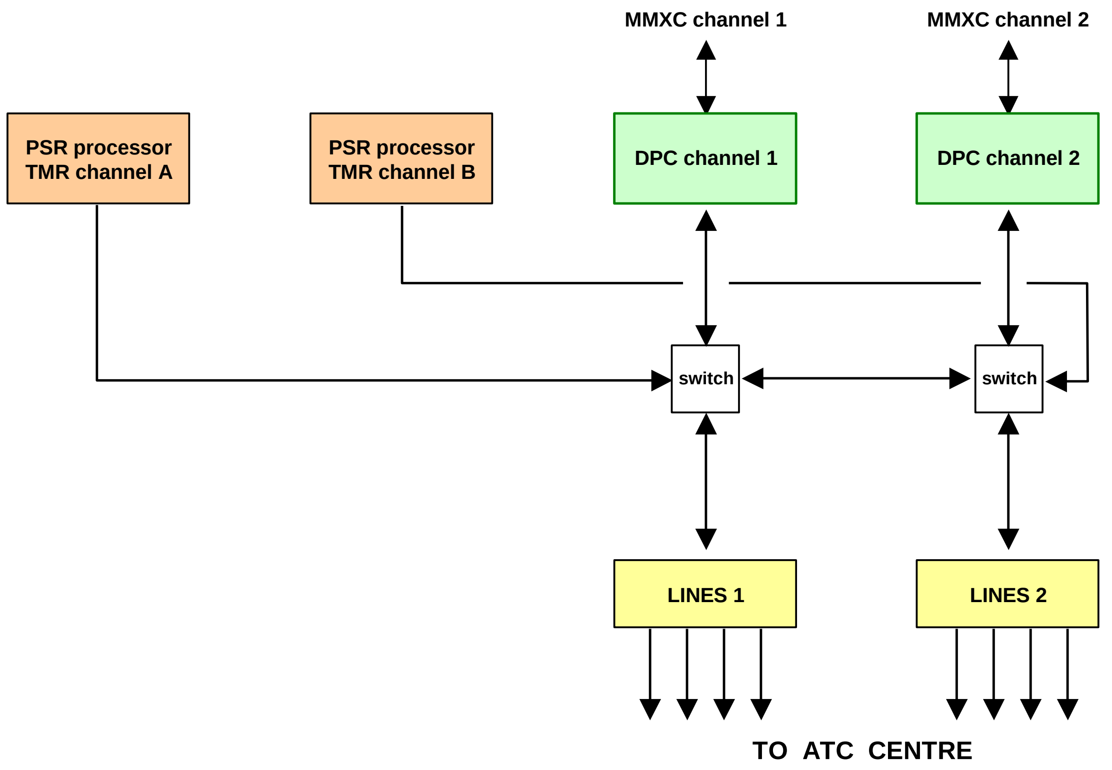


Figure 23 - DPC Environment

3.1.2 Hardware

The Data Processor is composed of a PC (Personal Computer) supporting the GNU/Linux operating system. It is composed of a basic frame and several options, which allow to achieve main requirements.

The chassis is installed horizontally in a standard 19” cabinet, and has a height of 4U (4x44.4 mm).

It is equipped with two front handles in order to be easily extracted from the cabinet.

It is equipped with:

- One 3,5" SATA hard disk drive, with a minimum capacity of 160 GB,
- One IDE DVD drive,
- One 3,5" Floppy disk drive,
- Two Network Interface boards
- One PCIe graphic board ,
- One watchdog PCI board.

3.1.3 Description

The DPC hardware supports two CSCIs:

- MSSR/Mode S Radar Processing (MRP)
- MSSR/Mode S Radar Communications (MRC)

3.1.3.1 MSSR/Mode S Radar Processing (MRP)

The MRP CSCI consists of the following functions:

- Mode S Beam Management (MRP_SBM): this function programs All Call and Roll Call periods, schedules Roll Call interrogations and listening windows for Mode S aircraft within the current beam, processes Roll Call replies and extracts SSR and All Call Mode S plots.
- Scheduling Management (MRP_SM): this function prepares for each 1/64th scan, the list of Mode S and SSR aircraft to be processed by the MRP_SBM function. For each Mode S aircraft, it selects the data link request(s) to be performed. It receives once per sector the aircraft information processed by MRP_SBM and dispatches the detection information to tracking (MRP_TRM) and the data link related information to the data link management function (MRP_DLM). This function also transmits detection information to other MRP channel.

- Tracks Management (MRP_TRM): this function manages aircraft tracking, and transmits appropriate tracks and plots to the MRC CSCI, and to Local Display.
- Datalink Management (MRP_DLM): this function manages the data link requests and results. It prepares data link activity to be performed for each aircraft according to the requests received from internal clients and external clients of MRC CSCI. It transmits appropriate reports and responses to these clients. It transmits data link information to Local Display.
- Channel Bite Management (MRP_CBM): this function manages Built In Tests, Modes, States, Status and Parameters, and monitors the DPC behaviour with RCMS and CBP.

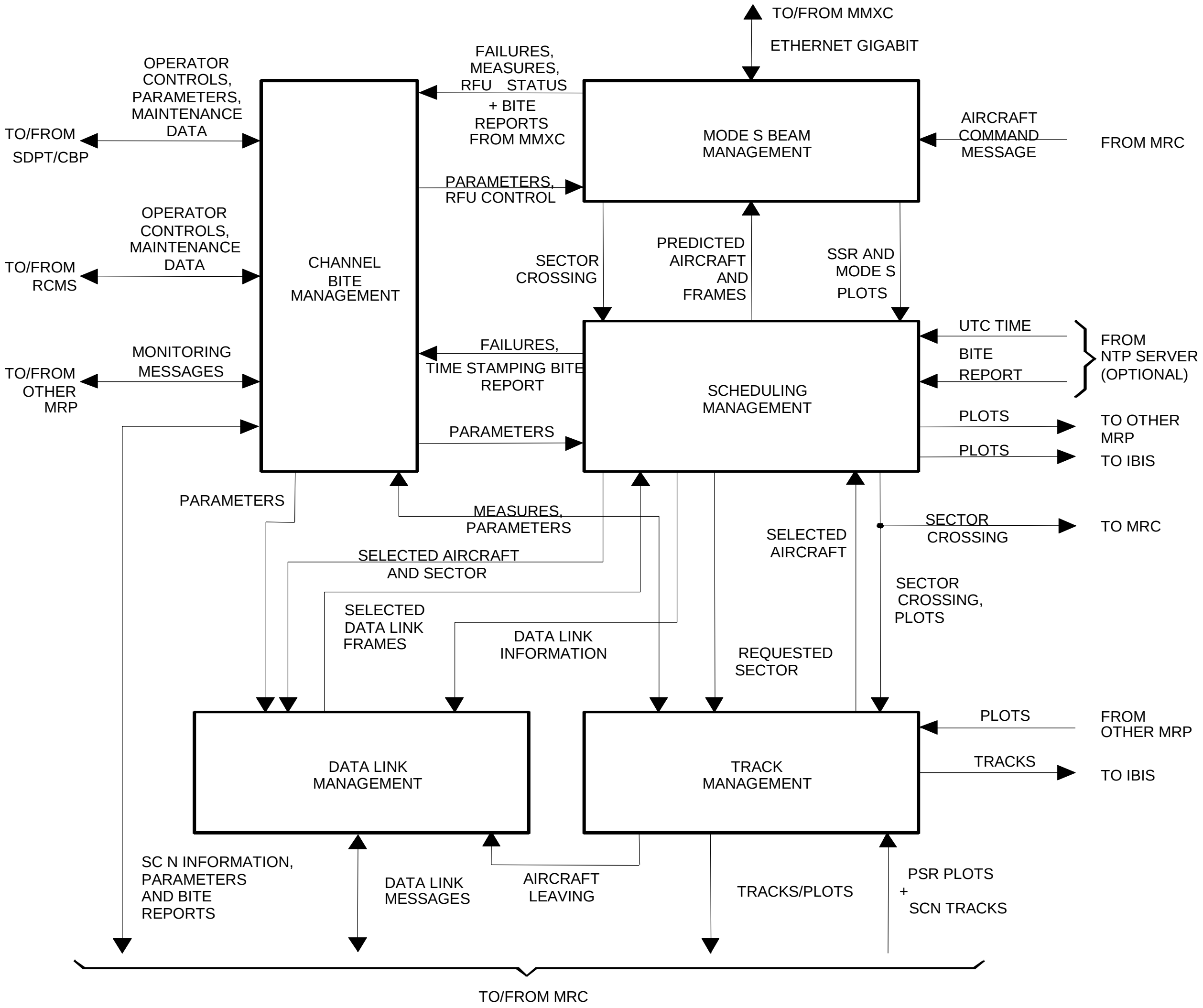


Figure 24 - MRP functions

3.1.3.1.1 MSSR/Mode S beam management

The MRP_SBM function manages all activities that must be performed within the main beam of the antenna and regulates the use of the RF channel. Its main functions are the followings:

- it prepares all information necessary to process All-Call and Roll-Call periods,
- it processes all SSR and Mode S replies received during All-Call periods,
- it manages the real-time scheduling of Mode S surveillance and data link transactions within the Roll-Call periods.

The MRP_SBM function is composed of the following sub-functions:

- Mode S Modulator and eXtractor Control (SBM_MMXC), which manages the interface between MRP CSCI and MMXC,
- Roll Call Period Processing (SBM_RCPP), which manages activities within the Roll Call periods,
- Mode S All Call Period Processing (SBM_MACPP), which manages Mode S activities within the All Call periods,
- SSR All Call Period Processing (SBM_SACPP), which manages SSR activities within the All Call periods. It includes the defruitor function.

3.1.3.1.2 Scheduling management

The MRP_SM function manages the synchronisation of the CSCI.

The MRP_SM function prepares the information to be processed by the MRP_SBM function. For each 1/64th sector, it selects all the Mode S and SSR aircraft of the sector and the data link associated to the Mode S tracks and sends the information to MRP_SBM.

At the end of each 1/64th sector the MRP_SBM sends to MRP_SM the Roll-Call and All-Call information which were processed during the sector. On reception of these released data, MRP_SM dispatches the received information to the concerned users:

- the plot report to the MRP_TRM function, and to the other MRP.
- the data link report to the data link servers (MRP_DLM function),
- the reply report to LD.

The MRP_SM function is composed of the following sub-functions:

- Waiting Aircraft Selection (SM_WAS), which requests aircraft, their surveillance and data link from MRP_TRM and MRP_DLM functions, memorizes them, and places them at MRP_SBM function disposal,
- Aircraft Release Management (SM_ARM), which dispatches the data released by MRP_SBM to MRP_TRM, MRP_DLM, the other MRP and LD.

3.1.3.1.3 Tracks management

The MRP_TRM function is broken down into 5 sub-functions:

- Plot Input (TRM_PIP),
- Tracking (TRM_TRK),
- Data Output (TRM_DOP).
- Reflector Identification (TRM_RFI)
- External Track Correlation (TRM_ETC)

The Plot Input sub-function manages the acquisition of primary and secondary information and associates the primary plots with the secondary plots (SSR + Mode S).

The Tracking sub-function establish the aerial situation. It initialises and maintains tracks. It also computes track windows for Mode S interrogations and SSR detection enhancement.

The Data Output sub-function adds information to the track, sends the tracks to MRC CSCI, sends the tracks and the plots to the Local display.

The Reflector Identification sub-function identifies the dynamic reflectors and sends the static and dynamic reflectors to the Tracking sub-function.

The External Track Correlation sub-function correlates external tracks received from the MRC CSCI with tracks maintained by the radar. According to the result of this correlation, it sends to the Tracking sub-function, commands to create new tracks or to update existing tracks.

3.1.3.1.4 Datalink management

The Datalink Management function manages all data link activities. This function is a server achieving the data link service and will be referred to as the data link server. It can also be seen as a group of servers, each one dedicated to a specific type of Mode S data: broadcast server, GICB server, packet server.

The data link server works for clients which have subscribed to the data link service. Each client declares itself to the data link server. Once known by the data link server, a client can send uplink data link and GICB extraction request to the server. During the subscription, the client indicates to the data link server which downlink data it is interested in: downlink broadcast, downlink packet. The downlink data are only sent to the clients which have requested their transmission.

The data link server collects data link requests from its clients. These request are stored in the DATALINK_DB database. On request from the MRP_SM function, it decides which requests imply a data link exchange with aircraft and sends them to MRP_SM.

Upon reception of data link reports from MRP_SM, uplink data link transmission reports and extracted GICB are sent to the clients which requested it, downlink broadcast and downlink packet are sent to the clients which subscribed to this type of information. The DATALINK_DB is updated according to the data link reports.

This function is composed of the following sub-functions:

- Broadcast Server (DLM_BCSTS),
- GICB Server (DLM_GICBS),
- Packet Server (DLM_PKTS).

3.1.3.1.5 Channel BITE management

The purpose of the Channel Bite Management is to evaluate the ability of the radar channel to perform its mission. The specific functions are:

- to co-ordinate the start-up and initialisation of the DPC,
- to manage the on-line and off-line Built In Tests of the radar channel equipment and establish the operability of component for RCMS Operator,
- to synthesize the states of the radar channel, and decide the switching between To Antenna and To Load channel,
- to co-ordinate the parameters updating, dialoguing with SDPT terminal (CBP CSCI).

On-line BITE testing is defined as BITE tests performed while the radar channel is in the OPERATIONAL or MAINTENANCE operating mode. Such tests are conducted with normal operating signals or internally injected stimuli that do not interfere with normal operation.

Off-line BITE tests are tests conducted while the system is in the maintenance mode using internal test checks and routines. The Off-line tests managed by the CSCI concern the Data Processing Computer. They are performed by rebooting the Computer.

This function is composed of the following sub-functions:

- Data Processing Monitoring (CBM_DPM),
- Built In Test (CBM_BIT),
- States and Modes Management (CBM_SMM),
- Control Management (CBM_CM),
- Monitoring Interface (CBM_MI).

3.1.3.2 MSSR/Mode S Radar Communications (MRC)

The MRC CSCI consists of the following functions:

- Site Monitor Management (SMM): this function tests the system using site monitors.
- Enhanced Surveillance Management local application (ESM): this function programs the automatic extractions of GICBs in order to enhance the data transmitted to the ATCC.
- Air Traffic Control Centre Interface (ATCC_INT): this function relays MRP tracks and tracked plots to the ATCC. It manages up to eight independent logical links to the ATCC.
- Primary Surveillance Radar Interface (PSR_INT): this function relays PSR data to the MRP CSCI. It manages two independent logical links.
- Ground Data Link Processor and Local User Interface (GDLP_LU_INT): this function manages the communications between the MRC CSCI, the GDLP and the Local User. It manages two independent logical links for GDLP and one for LU.
- Surveillance Coordination Network Interface function (SCN_INT): this function manages two independent physical lines and up to five independent logical links on the same physical line.

3.1.3.2.1 Site Monitor Management

The purposes of this function are:

- to carry out on-line tests using site monitors located in the vicinity of the Mode S station,
- to compute and report to the MRP CSCI the corresponding BITE information

These tests may be performed simultaneously on two site monitors, as follows:

<u>First site monitor : Dual channel SMS</u>

The SMS is the Mode S (level 2) site monitor which may be delivered in option with the RSM970S.

The SMS has a dual channel architecture which allows the test of the Mode S station through the following main tests: checks of the SMS position, codes, etc. on each SMS track received.

The BITE status of each SMS channel is gathered by the radar through:

- the extraction of a dedicated BDS E1 register, in Mode S scheduling, or
- the 4 LSBs of the Mode C replies, in SSR (A,C) scheduling.

In Mode S scheduling, additional tests (called “long loop tests”) can be performed. These tests are periodically triggered by the transmission of specific short form MSP packets from the RSM970S to the SMS.

The following table shows type of each test and the associated action performed by the SMS:

Test name	Action of the SMS
II/SI codes delivery	Report the II codes being set.
Alert bit	Temporarily change its Mode A code from standard to test value, which triggers the alert bit.
Downlink capability report	Temporarily change its BDS 10 from standard to test value, which triggers downlink broadcast.
Flight identity change	Temporarily change its BDS 20 from standard to test value, which triggers downlink broadcast.
Unlocking	This test does not correspond to any specific action from the SMS, but to a track unlocking performed by the MRP CSCI.

Second site monitor : Generic SSR / Generic Mode S

The following types of legacy site monitors are supported by the RSM970S:

- SME974: SSR (A, C) dual channel, with BITE status reporting,
- Generic SSR (A, C), single or dual channel,
- Generic Mode S (level 1 or above), single or dual channel.

3.1.3.2.2 Enhanced Surveillance Management

The purpose of this function is to extract GICB registers for all tracks, in order to enhance the information transmitted to the ATCC.

Whenever the MRP CSCI signals a track entry, the functions capability sends back GICB requests for the extraction of the registers:

- which are necessary for Mode S elementary surveillance: Aircraft capabilities and Call-Sign (BDS 10, 17 and 20),
- which are defined by the user (through an operational parameter) for Mode S enhanced surveillance (up to five additional registers may be extracted this way).

3.1.3.2.3 Air Traffic Control Centre Interface

The purposes of this function are:

- to format tracks in the Asterix or Aircat-500 format and to output them to the ATCC logical links
- to detect output overloads on any of the ATCC logical links
- to suppress some data on the overloaded ATCC logical links

3.1.3.2.4 Primary Surveillance Radar Interface

The purpose of this function is to relay primary radar detection data received from a Primary Surveillance Radar (PSR) to the MRP CSCI.

The Weather data received from PSR are directly provided to the ATCC interface function.

The PSR information may be received through a serial line, or from the TMR processor connected on the radar communication LAN.

The function manages an active and a standby logical link. While the messages received on the active link are relayed to the MRP CSCI, the messages received on the standby link are discarded.

3.1.3.2.5 Ground Data Link Processor and Local User Interface

The purposes of this function are the following:

- to establish, maintain and monitor connections with the GDLP,
- to establish, maintain and monitor connections with the LU,
- to relay the GDLP and LU messages to the MRP CSCI
- to relay the MRP CSCI messages to the GDLP and LU

3.1.3.2.6 Surveillance Coordination Network Interface

The purpose of this function is to enable the mode S station to be coordinated with up to six other mode S stations with which it is connected into a cluster. This coordination is used in order to reduce FRUIT and cater for the limited number of II codes available within mode S, since it enables all mode S stations from a given cluster to share the same II code.

The function is in charge of three protocols: NMP, TASP and NNCOP.

- NMP is the Network Monitoring Protocol, it enables the mode S station to determine the network topology, i.e. the list of mode S stations from the cluster which operate network-aided, and the cluster mode (distributed mode or central mode, depending on the presence of a cluster controller within the network topology).

- TASP is the Track Acquisition and Support Protocol, it enables the mode S station to acquire tracks locked by other mode S stations from the cluster and located in the station surveillance coverage. It also enables the mode S station to request track support from the cluster mode S stations in case of miss. TASP is only active when the cluster operates in distributed mode.

- NNCOP is the New Node and Change-Over Protocol, it enables a mode S station to prevent useless exchanges of messages by TASP by sending to the other mode S stations in the cluster the list of unique mode S addresses it knows. This is done either when entering a cluster or when executing a channel switch-over. NNCOP is only active when the cluster operates in distributed mode.

3.2. INTERFACE MANAGEMENT (LINES)

3.2.1 Introduction

The RSM970S is equipped with two external devices (“LINES”) in charge of external interfaces (ATC centres, Mode S Datalink, Mode S Surveillance Coordination…)

According to user’s needs, two additional LINES devices may be delivered in option.

At a given time, each LINES device performs data routing between the active radar channel and the output lines. All lines carry the same data (i.e. target reports processed by the active channel).

Switch-over between radar channels (i.e. Interrogator and reply processors) is transparent for the ATC centres, i.e. the physical and logical (at protocol level) connections are maintained. This event may influence track numbering.

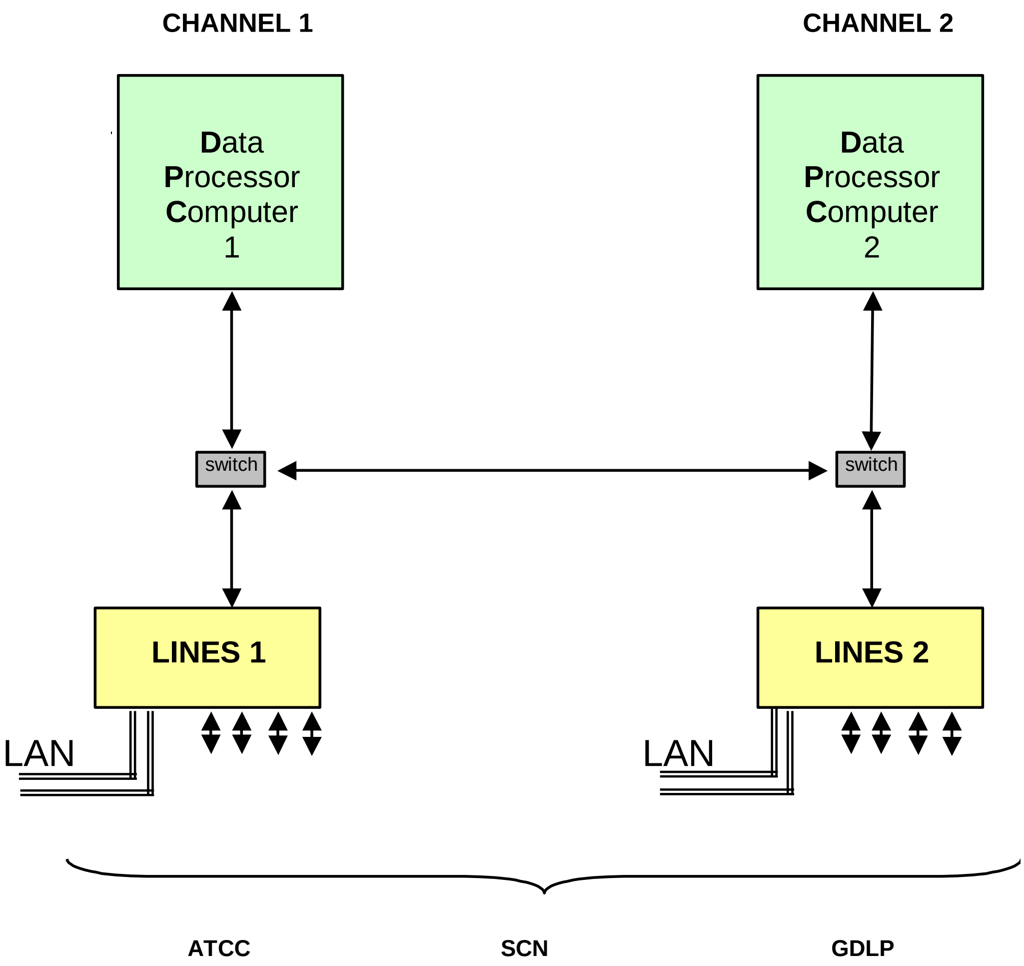


Figure 25 - Interface Architecture

3.2.2 Hardware

The pLINES-E4 box is equipped with:

- 3 Ethernet ports (one for internal use)
  - 10/100bT Ethernet interfaces
  - Auto-negotiation, auto-sensing, half or full duplex mode
- 4 Serial ports
  - DTE multiprotocol (Async/Sync)
  - RS232/422/485/EIA530A/X21 ports, speed up to 250 kbps,
- Processor
  - MPC8250 master CPU & communication processor at 200 MHz (280 MIPS)
- Memory
  - 32 Mbytes of DRAM
  - 8 Mbytes of FLASH EEPROM
  - 128 Kbytes SRAM
- Backlight screen and keyboard

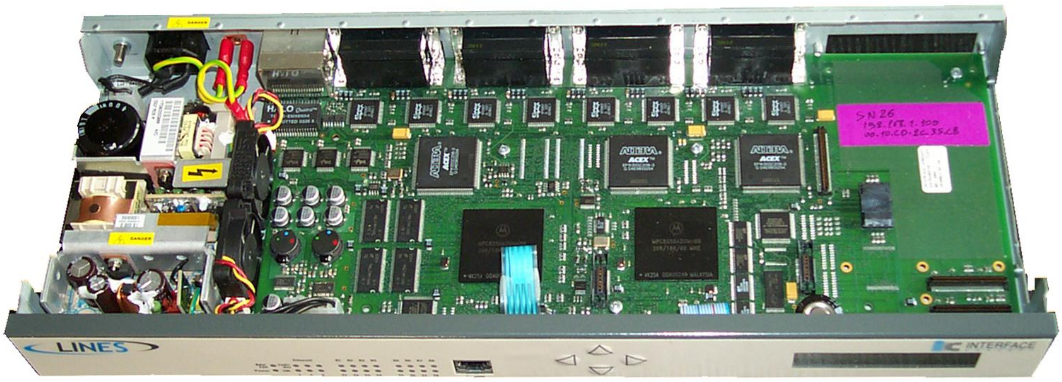


Figure 26 - pLINES-E Internal View

3.2.3 Description

In addition to the delivery of operational data (target reports) to the ATC centres, the external interfaces of a Mode S station may include Datalink (from/to a GDLP – ground Data Link Processor – and/or a local user) and Surveillance Coordination (from/to a Cluster Controller or neighbouring Mode S stations).

Each possible logical link can be mapped onto a physical link, according to the following table:

External Interface	Role	Number of logical links	Protocol	Format
ATCC	Target reports Weather maps	8 (simultaneously)	HDLC-UI HDLC LAP-B X25.3-88 Aircat-500 TCP/IP(**) UDP/IP (***)	Asterix CAT 1, 2, 8 Asterix CAT 48, 34, 8 Aircat-500 tracks
PSR (*)	PSR plots	2 (one active, one stand-by)	HDLC-UI HDLC LAP-B	Asterix CAT 1, 2, 8 Asterix CAT 48, 34, 8
SCN	Surveillance coordination	up to 6	X25.3-88	Asterix CAT 17
GDLP	Mode S Datalink	2 (one active, one stand-by)	HDLC LAP-B X25.3-88	Asterix CAT 18
LU	Mode S Datalink	2 (one active, one stand-by)	HDLC LAP-B X25.3-88	Asterix CAT 18

(*) These interfaces are used for interfacing legacy PSRs only. THALES radars with TMR processors (e.g. STAR2000) use a LAN for exchanging data with the DPCs, without routing through the LINES.

(**) Client or Server; Complies with IP V4 and IP V6.

(***) Unicast or multicast; Complies with IP V4 and IP V6.

3.3. TIME STAMPING

The time stamping is constituted by two NTP servers.

Each server includes:

- one GPS receiver providing an accurate UTC time source,
- one internal clock,
- one Ethernet interface for exchanging time information with external equipment.

Each server is connected to the I/O LAN of the radar (also used for exchanges between the DPC and the LINES and for PSR plots acquisition).

The protocol used is NTP (Network Time Protocol) which allows the automatic synchronization of the DPC, thanks to the built-in service of the GNU/Linux operating system.

In case of a missing GPS signal (e.g. due to too few visible satellites), the internal clock of the NTP server maintains the time information until the recovery of GPS signal. The maximum drift of the NTP internal clock is 20 ms per month.

Additionally to the time messages, the DPC gathers the status of the NTP server in order to compute the availability of the Time stamping function.

Furthermore, the DPCs exchange their time information in order to make a consistency check between both NTP servers.

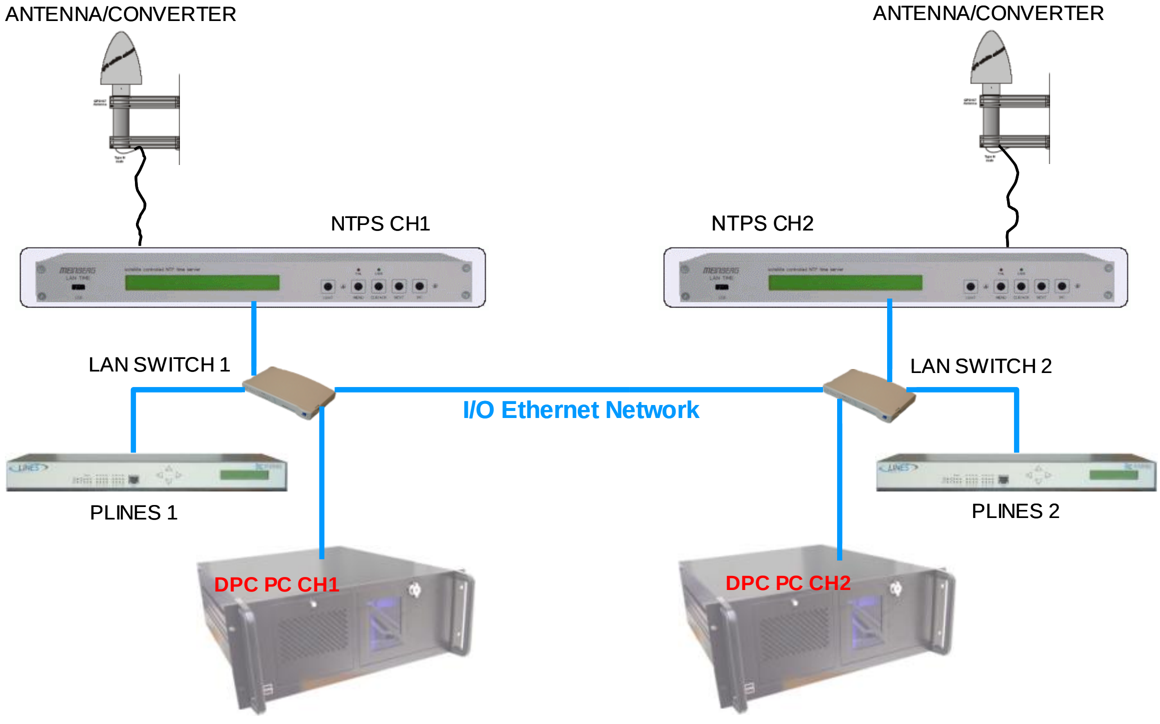


Figure 27 - Time stamping block diagram

4. MAINTENANCE EQUIPMENT

4.1. SITE DEPENDENT PARAMETERS TOOL

4.1.1 General

The Site Dependent Parameter Tool (SDPT) software (called **CBP** for Cabinet Parameters tool) enables the operator to display and change all the operational parameters of each radar channel (setting up purpose) when it is in local control. The operational parameters are all parameters of the radar channel which are software adjustable for installation, operation and maintenance of the system.

The CSCI CBP runs either on the RCMS local terminal (as a separate application) or on an optional dedicated PC.

The purpose of this CSCI is to:

- set up or display operational parameters of the radar channel,
- display measurements and other variables (states, failure codes) within the radar channel,
- send local operator commands.

The programming from SDPT requires the equipment to be switched to the local mode (called "SDPT control"), inhibiting the RCMS orders.

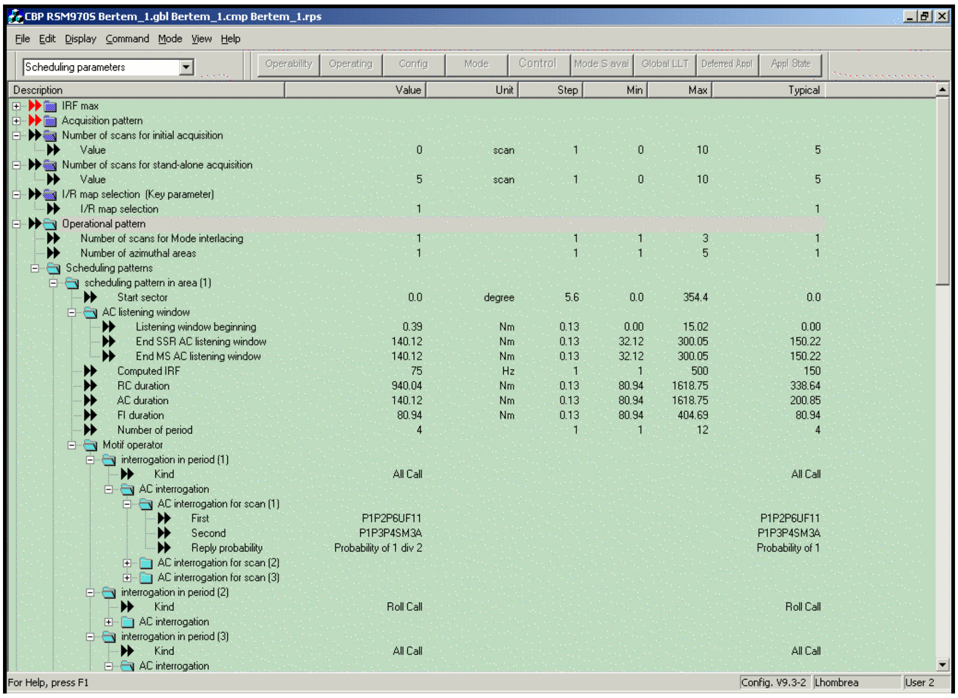


Figure 28 - Example of CBP Display

4.1.2 CBP functions

The CBP CSCI performs the following functions:

- management of the CBP mode of operation,
- edition of MSSR/Mode S parameter sets in SDPT (creation, display, modification, copy of parameter set content),
- generation of coverage map files in MRP (local cartesian cells) format, conversion of coverage map files from Eurocontrol format to MRP format,
- creation and sending of commands to one MSSR/Mode S channel (operator command, direct parameter read/write command),
- management of the parameter set transfer from/to one I/R cabinet channel (parameter set sending to one MSSR/Mode S channel, parameter set reading from one I/R cabinet channel),
- real-time display of monitoring data from one MSSR/Mode S channel (measurements, states and failure codes),
- comparison of parameter sets stored on SDPT disk,
- transmission of coverage map files to the IBIS maintenance display.

4.1.3 Controls

The following controls are available for each radar channel, from the SDPT:

- Failure code reset
- Off line test activation
- SDPT control release/request
- Operational operating state
- Maintenance operating state
- Stand alone / Network aided mode (SCF)
- I/R channel switchover
- Transmission on/off
- I/R map selection, allowing to select the map 1 or map 2 for TVBC law divided into sectors, ISLS / IISLS, transmitted power attenuation
- PSR channel selection (if present).
- Site monitor presence.

These controls are also available from the RCMS, when the equipment is switched to the remote mode (called “RCMS control”).

4.1.4 Parameters

The SDPT allows the setting of the following operational parameters:

- Antenna scan duration
- RSLS control and attenuation values
- I/R map 1 and map 2 definition
- Defruiter correlation choice
- Extraction criteria
- TVBC laws (up to 8 user programmable laws)
- Operational interrogation mode pattern
- Staggering
- Off Boresight Angle (OBA) table
- PSR/SSR bias adjustment
- Anti reflection parameters
- Optional Mode S Site Monitor parameters.

4.2. IBIS MAINTENANCE DISPLAY

4.2.1 Introduction

The proposed Indicator of Radar Information System (IBIS) is a display equipment, featuring radar picture, used for the maintenance operation.

The maintenance display is used for display of plots on tracks and of geographical maps. It also provides windowing of the radar video.

Plots/tracks are superimposed on the radar video, with a geographical maps background. IBIS also enables the display of radar adjustment patterns (OBA).

IBIS can display up to-1000 tracks and 1000 plots simultaneously.

4.2.2 Radar Interfacing

The purpose of the IBIS display is to provide engineers with the means to assess the operational performance and serviceability of the radar system.

The following different types of data can be displayed (if present):

- Digital PSR Video (aircraft and maintenance video), for co-mounted radars
- Digital Log SUM secondary Video.
- Digital Log DELTA secondary Video.
- Digital f(DELTA/SUM) secondary Video
- Digital SSR and Mode S pulse presence video
- Digital SSR and Mode S reply presence video
- PSR / MSSR / Combined plots and tracks (ASTERIX Category 1, 48).
- System status (ASTERIX Category 2, 34).
- Weather data, for co-mounted radars with weather channel (ASTERIX Category 8)
- Specific processing areas (ASTERIX category 245)
- Mode A/C and Mode S Reply-report Data (ASTERIX category 242)
- Datalink information (ASTERIX category 243)
- Surveillance Co-ordination Network data (ASTERIX category 244 if present)
- Coverage maps
- List of Mode S aircraft currently surveyed
- Anomalous data (plots flagged as anomalies)
- Geographical map
- User-defined graphical items
- Range and Bearing lines

The tracks and plots are available on an ETHERNET LAN, the “SUPERVISION" LAN. The video is distributed on a dedicated ETHERNET LAN, the “VIDEO" LAN. The operator has selection devices on IBIS screen to choose the displayed data and the sensor data channel. The status of the selected lines is displayed using a colour code.

The IBIS is designed such that the various categories of data are presented in a manner which allows the data to be viewed simultaneously. For example, the analogue video signals are presented as a backdrop to the target symbols which in turn have labels attached to them containing further track data. This data is refreshed every radar scan.

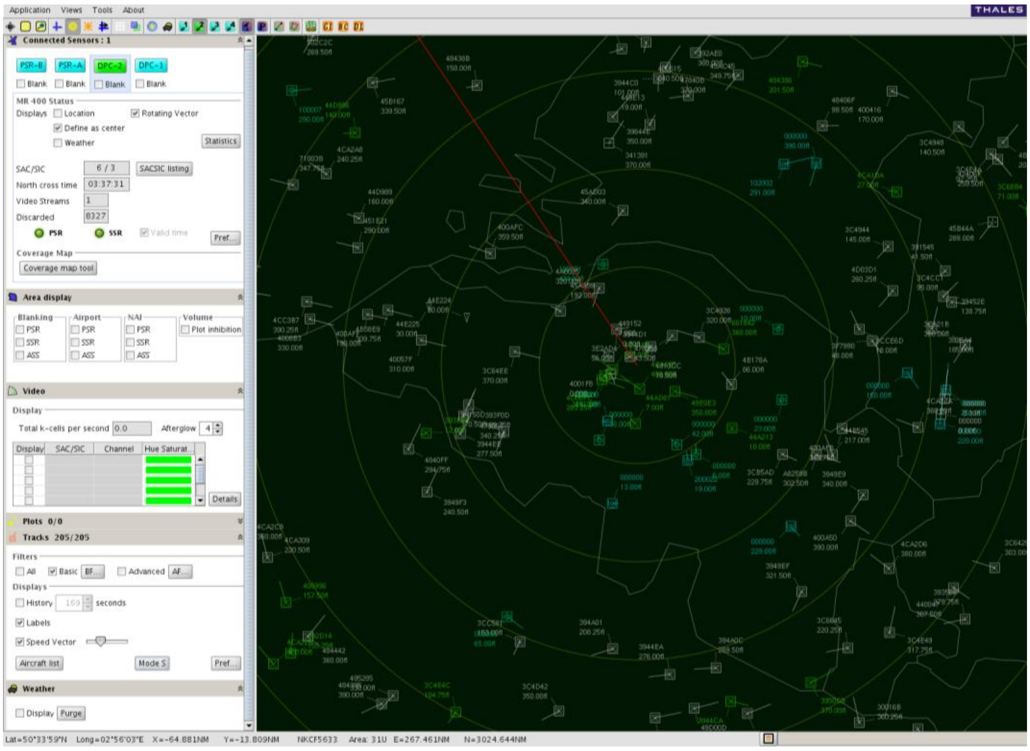


Figure 29 - Example of IBIS Display

4.2.3 Recording and replay

The IBIS features a function to record the received radar data and to replay them afterwards.

The replay can be performed on the same IBIS display or on another IBIS (option). The replay function allows to select a timeframe within the recording and the speed of playback.

All real-time presentation preferences and filtering are also available during play back.

4.3. REMOTE CONTROL AND MONITORING SYSTEM (RCMS)

4.3.1 Basic Principles

The Remote Control and Monitoring System (RCMS) enables the operator, through graphical synoptics and text pages to assess the status of the equipment and identify faults quickly. It also enables the monitoring or the control of a restricted set of operational parameters (supervision and maintenance purpose).

The RCMS is monitoring all the functions of the radar system and provides means for controlling major system elements (on/off, rotation, etc...)

Whereas, the following functions are performed at the level of the BITE of each equipment:

- Acquisition of digital and analogue status,

- Processing of this information to verify the correct operation or, in the event of failure, the determination of the faulty unit,
- Management of front panel indicators,
- Continuous monitoring of the configuration status,
- Management of controls from/to remote control function,

Equipment test and control information is transmitted to/from the Data Regrouping Unit function (DRU) of RCMS via a Local Area Network (LAN) carrying the following information:

- Correct operation codes,
- In case of a failure, code corresponding to the faulty function,
- Command and acknowledgement of remote control orders,
- Any equipment status or parameter requested through the local or remote monitoring position.

The DRU function interfaces ancillary units such as mains and antenna control cabinets and possibly, air cooling system, UPS and other safety devices using opto-couplers and relays.

The RCMS uses basically two consoles, one local, the other remote.

Either console can be declared master or slave. The same information is displayable on both the local and the remote station consoles.

The system hard disk is used for log files storage. The files are in standard text format and list all the monitoring and control action previously done. The files download can be done either on the local position or on the remote position.

Note:

The availability of radar surveillance data is monitored through the monitoring of the data distribution function of the radar data processors. Due to the fact that the RCMS data link is separated from the radar data link(s), in case of failure of radar data links, the monitoring of the radar system, and of the radar data distribution, is still possible.

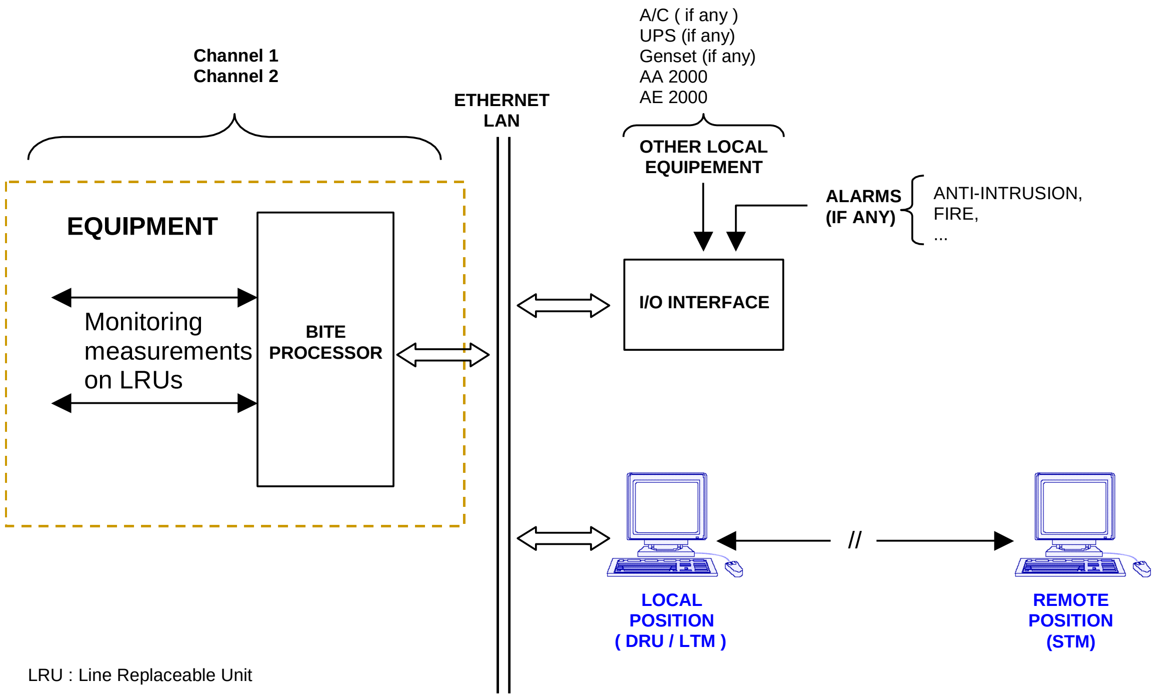


Figure 30 - RCMS Architecture

Figure 31 - Example of RCMS Display for a co-mounted version

4.3.2 RCMS Operation

RCMS provides its functions:

- at station level during system optimisation and preventive / corrective maintenance;
- at Remote Maintenance Room level for the remote system control and monitoring.

The corresponding control and monitoring consoles are provided with a multi-function keyboard and a mouse.

4.3.2.1 Monitoring

A synopsis of the station status is presented, in the form of a block diagram. The selection of any system element is possible from the block diagram using pull out menus for presentation of more detailed status monitoring.

The console provides:

- a graphic coloured indication of the status of a designated equipment element, particularly faults, unavailability,
- pull out menus showing functions and parameters monitored, where appropriate indicating the actual value,
- the indication of a system status as mentioned above.

4.3.2.2 Control

The operator position has the possibility, by selection of a special operating mode, of controlling all major system elements. This is done by means of keyboard and mouse.

This remote control facility will only be operational if the equipment in question, for control, is set to the "remote control" mode of operation. Selection of "local control" on the equipment will inhibit all remote control actions from all remote control consoles. It will not inhibit the feasibility to monitor system status. All control actions are recorded.

4.3.2.3 Description of the RCMS windows

Configuration and remote control windows

The configuration signals are binary data that refer to the operational state of a system or equipment (for example: operational/maintenance, on-line/stand-by, equipment ON/OFF, etc.). The state of the configuration signals generally results from an automatic action of the system or equipment or from a locally or remotely controlled action.

There is one window of text for each equipment or system comprising a title (name of equipment or system). Each configuration is defined with a name and a text corresponding to a binary value (such as true/false). Controls will be issued from this window through direct selection on the screen.

Parameter and Remote Control Window

This window contains discrete or numerical values which may define:

- Nominal settings (frequency of operation),
- Threshold limits (warning, alarms limits),
- Operation modes (channel in use for a receiver).

The parameters may be locally or remotely controlled. Each parameter is identified by a name and its value.

Parameter entry may be selected. A new value may then be entered using the entry window that is presented. This entry window contains a list of valid selections or the limits and a default value for the parameter.

Status and measures windows

These windows can be selected for the display of data that cannot be classified as configuration or parameter data but is relevant to operational or maintenance use.

The status information displayed indicates the current state of equipment and cannot be remotely controlled (e.g. breaker ON/OFF, equipment FAULT/OK, etc.).

The measurements are numerical information generally used for the system's maintenance.

Each window contains a title and the list of status or measures. Each status item is defined with a name and an indication such as "yes" or "no". Each measure is provided with a title, its value, and its unit of measure.

Special control window

Unlike configuration and parameter, which are modifiable data, this window allows the operator to execute other controls.

Alert Window

This window displays information regarding currently active alerts, i.e. those not discarded by the operator.

Failure window

This window groups all the current failures of a given equipment item, and identifies when possible the faulty unit and the failure identification in the functional unit.

Help window

Help indications are displayed at the level of each useful window, and provide the user with information on the use of the RCMS functions.

4.3.2.4 Screen and Peripheral Management Commands

The following commands are available to an operator:

- Designation capability by means of the keyboard or the mouse,
- Block diagram call,
- Upstream - downstream window,
- Return to the highest level window of the group,
- Window management: Scrolling, Sizing, Windowing,
- Enable/Disable printer (if any),
- Audible alarm ON/OFF,
- Pop-up display ON/OFF.

4.3.2.5 Alert Logging and Display

When an alert condition is detected on a supervised equipment, the DRU or its equivalent sends, if relevant, the corresponding information to the operator position(s) that supervise this equipment. Depending on the alarm and the operator position off-line configuration, the alarm may be:

- stored in the daily log file,
- stored in the alert window,
- stored in the failure window,
- displayed in a pop-up window (if enabled),
- printed (if the printer is enabled).

An audible signal on the operator position is activated (if enabled).

4.4. SITE MONITOR – FIELD TEST TRANSPONDER

A single or dual channel MSSR/Mode S site monitor (SMS) can be proposed in option.

In Mode S scheduling, the “long loop test” functionality described in para. 3.1.3.2.1 requires that one Dual channel SMS is dedicated to the radar station.

The SMS-2 site monitor is a solid-state dual channel test beacon. The two channels are operating simultaneously, each channel being fitted with one directional antenna. The two SMS antennas are the Log-periodic antenna ref 2155.

Transmitted power and reply delay are adjustable independently on each channel in order to simulate range.

The SMS-2 operates like an ICAO Mode S aircraft transponder, with additional capabilities, such as programmable attenuation and range. It operates on Modes 3/A, C and S. It complies with the latest Amendment of ICAO Annex 10, concerning pulse and reply characteristics, and Mode S protocols. It acts as a Mode S level 2 transponder.

Figure 32 - View of SMS Dual Channel Equipment

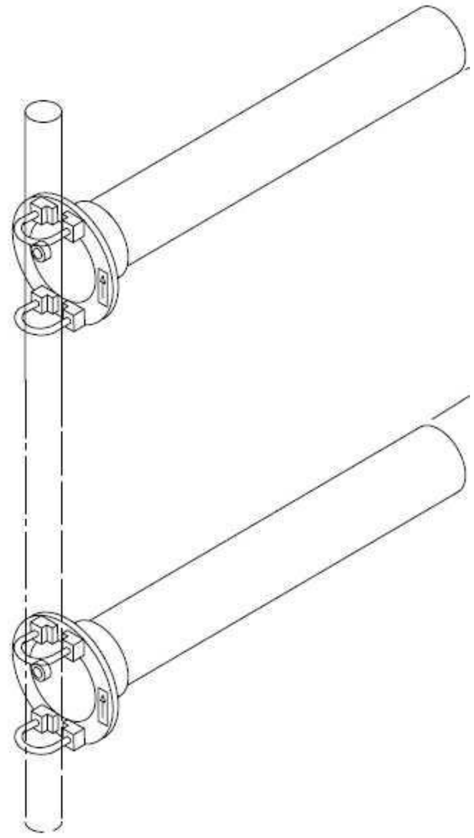


Figure 33 – SMS Directional Antennas

5. ANCILLARIES

5.1. ANTENNA CONTROL UNIT

The Antenna Control Unit is housed in a cabinet installed in the equipment room.

It is used to switch on or off the antenna rotation by controlling the power supply of the motor.

At start-up, the motors are supplied through a 'star' connection and after a delay the connection is automatically switched to a 'delta' connection.

The Antenna Control Unit also generates the DC power supply used for the security checking circuitry.

The security circuits stop the antenna in case of problem detection on the pedestal (temperature, oil level, etc.) It also ensures rotation stops when an emergency push button is activated, when the access door to the antenna platform is opened, or when the motor brake is on.

5.2. POWER DISTRIBUTION UNIT

The functions of the Main Power Cabinet are:

- to ensure mains power distribution to the radar parts of equipment,
- to protect the parts of equipment,
- to ensure human safety.

The power distribution cabinet is equipped with:

- Central breaker,
- Phase order detector,
- Earth leakage protection device,
- Thermomagnetic breaker for each equipment.

6. INSTALLATION

6.1. PHYSICAL CHARACTERISTICS

The RSM 970 S Mode S radar comprises mainly two radar electronic cabinets. EMC cabinets are used where necessary (RF elements).

These cabinets are standard 19" wide and can be installed separately in the radar room or factory mounted on a skid (**1**) thus reducing time and the installation works.

The following figures show the standard layout of the Mode S cabinets and radar room :

- One cabinet housing the duplicated interrogator/receiver and signal processor (**5**);
- One cabinet housing the duplicated data processor, the RCMS and IBIS computers (**4**);
- One power supply cabinet and one antenna control cabinet (installed back-to-back) (**2**), for a standalone MSSR/Mode S configuration.

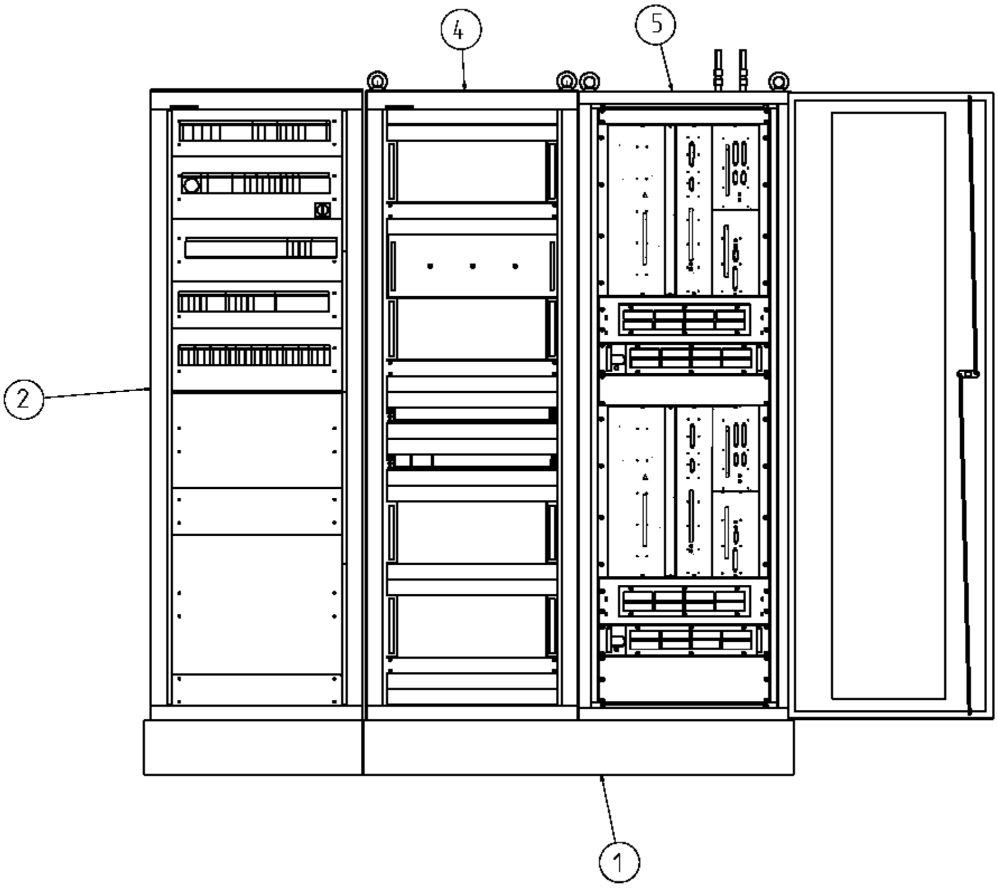


Figure 34 - RSM970S Cabinet Layout (standalone configuration)

The Cabinets skid for a standalone configuration has the following dimensions:

	Cabinets skid
Length	1.80m
Width	1.20m
Height	1,94m
Weight	1.03 t

The RCMS and IBIS displays (including LCD screen, keyboard and mouse) are installed on a separate table (not part of the delivery).

The following figures show an example of installation layout:

Figure 35 - RSM 970 S – Front View

Figure 36 - RSM 970 S – Rear View

6.2. ELECTRICAL CHARACTERISTICS

OVERALL RADAR POWER CONSUMPTION AND DISSIPATION

The following figures are given for a standalone configuration, with a pedestal equipped with 2 motors:

Unit	Power Consumption (kVA)	Power Dissipation (kW)	Power Supply
Aerial system (steady/extreme)*	8/16	3.5	400V 3-phase
RSM 970 S radar cabinets	4	3.6	230V
Total RSM 970 S	12/20		

* Note: steady: without environmental effects or under the protection of a radome (if any).

extreme: 15 rpm, extreme environmental conditions as defined in paragraph 1.3.

Start-up: The peak current at motor start-up is limited to 60 A per phase.

The Main Power Cabinet must be fed by a three phases four wire mains supply:

- 230V/400V ± 10% 50Hz or 60Hz ± 5%

Mechanical and electrical grounds

Cabinet ground and signal ground are separated in most units. The mechanical and electrical grounds of each equipment are grouped together at the outside of the equipment.

Strips are used insofar as possible because they present less impedance at high frequencies than circular section cables. Otherwise 10 square mm yellow/green cable is used. The links are the shortest possible. Each cabinet is equipped with a single vertical copper ground bar. The ground of each equipment of this cabinet is connected to this single bar.

The vertical bar of each cabinet is connected to the horizontal copper ground bar of the skid. The horizontal bar of the skid is linked to the external ground network of the technical building.

6.3. RADAR EQUIPMENT INSTALLATION

Radar equipment installation consists in:

- Aerial system installation,
- Technical room equipment,
- Cable laying and interconnection.

Once the antenna and cabinets have been installed, cables from the antenna to the cabinets are installed and fixed. Mains input is then checked and connected to the mains distribution cabinet. Ground link is connected to the skid assembly. Output data lines are connected to the data transmission devices.

Location and fixing

The skid which supports the equipment cabinet and inter-cabinet cabling is fixed to the floor.

The outside cabling is laid either in false floor or in cable trays trunks.

Interconnection of the equipment

Thales standards for cables identification and marking enables cabling to be separated in groups and functions.

Power supply and signal cables are separately routed in the skid cable duct.

All cables are equipped with plugs and connectors with suitable locking devices.

Air-cooling

The equipment are equipped with their own fans for air-cooling and dust filtering (when applicable) is done at the air inlet.

Electrical

An emergency cut-off device is provided near the entrances of the radar room. It must cut-off the distribution of electric power immediately. Other emergency breakers are usually located in the radar room and at the antenna tower access door for safety reasons.

UPS equipped with an automatic by-pass (changeover) may be optionally connected to the power distribution cabinet. This COTS equipment may be supplied by Thales or by the Customer.

6.4. ENVIRONMENT AND SAFETY

The RSM 970 S Mode S is designed for round the clock operation. The redundant configuration allows for maintenance operation on the stand-by channel without affecting on-line operational data.

Redundant parts can be put off-line at the same time as normal operation is going on.

6.4.1 Environment Requirements

Operational Conditions

- Ambient temperature:
  - Indoor: + 10°C to 40°C
  - Outdoor: -40°C to + 70°C (including solar radiation)
- Change of outdoor temperature: ≤ 10°C / hour
- Relative indoor humidity: ≤ 80 %
- Change in ambient humidity: 20 % / hour

Storage (indoor equipment)

- Temperature: --40°C to 70°C *(in dry atmosphere and under cover)*
- Humidity: ≤ 93 %

6.4.2 Electromagnetic Compatibility

Compliance with European Directive R&TTE 1999/5/CE and with following standards.

ETSI EN 301 489-1 V1.2.1	Electromagnetic and Radio spectrum Matters (ERM) Electromagnetic Compatibility (EMC) standard for radio equipment and services Part 1: Common technical requirements
CEPT/ERC/74-01	SPURIOUS EMISSIONS “unwanted emissions in the spurious domain”
Rec ITU-R SM.329-10	Rayonnement non désirés dans le domaine des rayonnements non essentiels *Union Internationale des Telecommunications
ICAO Annex 10 volume 4	Para 3.1.2.1 and 3.1.2.11

6.4.3 Safety

6.4.3.1 Development Safety

A hazard identification, analysis and risk assessment has been carried out for the RSM970S. The objective of this analysis is to expose any hazards that will require additional design work to incorporate mitigating features. The analysis has not only considered reasonable use, but also reasonably identifiable misuse, manufacture, testing, installation, commissioning, operational failure and fallback modes and maintenance.

6.4.3.2 Product Safety

Compliance with 73/23/CEE Low Voltage Equipment Directive and with following standards:

- EN60950
- Directive 2004/40/CE
- Recommandation 1999/519/CE

Compliance with 98/37/EC Machinery Directive annex 1 and with following standards:

- EN60204-1
- EN292-1
- EN292-2
- EN294
- EN349
- EN418
- EN457

6.4.3.3 Site Installation Safety Considerations:

The Air Navigation Service Provider as owner, has charge of civilian radar sites, as a consequence, he is legally responsible for any harm towards all the people which are physically present, with an authorised access, on these sites. This includes all the workers present on provisional work installation site.

On the other hand, Thales has the responsibility to check that exposure of his workers to risk is compliant with French law.

7. ACRONYMS

AC	All-Call
ACAS	Airborne Collision Avoidance System
AICB	Airborne Initiated Comm B
ADC	Analog to Digital Converter
ANSP	Air Navigation Service Provider
ASTERIX	All Purpose Structured Eurocontrol Radar Information Exchange
ATCC	Air Traffic Control Centre
ATN	Aeronautical Telecom Network
BDS	Comm B Data Selector
BITE	Built In Test Equipment
CBP	Cabinet Parameters
COTS	Commercial Off The Shelf
CSCI	Computer Software Configuration Item
DAP	Downlink Aircraft Parameters
DPC	Data Processor Computer
DCS	Data Communication System
DPSK	Differential Phase Shift Keying
DRU	Data Regrouping Unit
DSNA	French Civil Aviation Authorities
DTE	Data Terminal Equipment
EEC	European Economic Community
EHS	Enhanced Surveillance
ELS	Elementary Surveillance
EMC	Electro Magnetic Compatibility
EMS	Eurocontrol Mode S Specification
FPGA	Field Programmable Gate Array
GDLP	Ground Data Link Processor
GICB	Ground Initiated Comm B
GPS	Global Positioning System
HDLC	High level Data Link Control
HPA	High Power Amplifier
IBIS	Radar maintenance monitor display
ICAO	International Civil Aviation Organisation
I/R	Interrogator / Receiver
IRF	Interrogation Repetition Frequency
ISLS	Interrogator Side Lobe Suppression
II/SI	Interrogator Identifier/Surveillance Identifier
IISLS	Improved Interrogator Side Lobes Suppression
I/O	Input / Output
LAN	Local Area Network
LD	Local Display
LO	Local Oscillator
LNA	Low Noise Amplifier
LRU	Line Replaceable Unit
LSB	Less Significant Bit
LTM	Local Terminal Monitor
LU	Local User
LVA	Large Vertical Aperture
LVDS	Low Voltage Differential Signaling
MDR	Monopulse Digital Receiver
MDRP	Monopulse Digital Receiver and Processor

MLDT	Mean Logistic Down Time
MMXC	Monopulse Modulator and Extractor
MRC	Mode S Radar Communication
MRP	MSSR Radar Processor
MSB	Most Significant Bit
MSSR	Monopulse Secondary Surveillance Radar
MTBF	Mean Time Between Failure
MTBCF	Mean Time Between Critical Failure
MTTR	Mean Time To Repair
NTP	Network Time Protocol
OBA	Off Bore-sight Angle
PSR	Primary Surveillance Radar
PU	Processing Unit
POEMS	Pre-Operational European Mode S station
QRSLS	Quantized Received Side Lobe Suppression
RFU	RF Unit
RCMS	Remote Control and Monitoring System
RC	Roll-Call
RPM	Rotation Per Minute
RSLS	Received Side Lobe Suppression
SCN/SCF	Surveillance Co-ordination Network / Surveillance Co-ordination Function
SDPT	Site Dependent Parameter Tool
SSR	Secondary Surveillance Radar
STM	Space Time Management
SVC	Switched Virtual Circuit
TOM	Tracking-Output-Miscellaneous
TRC	Transmitter Receiver Cabinet
TCXO	Temperature Compensated Crystal Oscillator
TVBC	Time Variation Base Clipping
UELM	Uplink Extended Length Message
UTC	Coordinated Universal Time
VCO	Voltage Control Oscillator
VSWR	Voltage Standing Wave Ratio

PAGE LEFT INTENTIONALLY BLANK

Appendix 9

Thales Windfarm Mitigation Presentation

WINDFARM MITIGATION

Maintain air surveillance around windfarms

Enabling the wind of change safely

The wind is changing in the energy industry, and is doing so fast. Nations across the world are taking important steps to transition into renewable energies, seeking to cut emissions and, over the long term, curb global warming. In this context, the implementation of windfarms – whether offshore or onshore – has emerged, over the past decade, as one of the key elements to facilitate this transition.

Yet what may constitute a solution to one problem may in fact, become a problem in a different context: the development of windfarms across the world interferes with radars' detection capabilities, making the mission of air surveillance more complex. Working closely with diverse partners across a global industry, Thales offers solutions and services that can mitigate windfarms' impact on radars – whether civil or military – saving time and cost while safeguarding required safety levels.

Thales offers a dedicated field-proven innovative windfarm mitigation solution, providing improved safety as well as facilitating windfarm developments.

Thales Windfarm Mitigation – Video Presentation :

https://youtu.be/G0rSns9ILns

Thales offers a dedicated field-proven innovative wind farm mitigation solution, providing improved safety as well as facilitating wind farm developments.

Disruptive winds

The development of windfarms – groups of wind turbines – around the world to address the need for renewable energy sources has to be done in cooperation with civil aviation authorities when required. Wind turbine blades' radar reflections can either appear as false aircraft detections on radar displays or mask the real aircraft tracks, increasing the probability of real targets being lost. The slightest uncertainty regarding an aircraft position in the sky, even for just a few seconds, can have significant consequences on air traffic safety and security in countries with a growing wind industry can be significant.

Addressing this issue, however, is a challenge in itself. It requires careful adjustments to the radar's signal processing capabilities so that sensitivity is not too high – creating too many false alerts – or too low – decreasing false alerts to the detriment of real targets.

Windfarm mitigation in civil air surveillance

Leveraging years of experience in the development of radars for various threats, missions and purposes – whether civil or military – Thales offers the STAR NG (S-band up to 100nm) and the TRAC NG (L-band up to 250nm) radars, both including a feature enabling a proper a windfarm mitigation.
The Windfarm Filter is a dedicated algorithm that uses a specific adaptive Constant False Alarm Rate (CFAR) mechanism designed to minimize track loss and reduce false alarms above and around windfarms. It can be integrated to address both civil and military needs and, as a software capability, can also be activated into other Thales ATC radars already in service.

Finding the most appropriate solution, and the most accurate balance for the algorithm, is specific to every client's needs. What works for one radar, operating around one windfarm characterised by a certain type of wind turbines, may not work for another radar in a different context. Evaluating the impact of each windfarm on potential radars is therefore crucial to de-risking investments.

To this end, Thales has developed a unique simulation tool, WINRAD, for evaluating the impact of proposed windfarms on its radars. Combining environment characteristics – terrain and windfarm visibility, windfarm boundary and layout, wind turbines – with radar behaviour, WINRAD can confirm the windfarm's impact on radar performances. On this basis, it can then predict achievable performance criteria over and around the windfarm area, supporting the identification of the most appropriate radar solution to maintain required detection performance while reducing the false alarm rate.

Windfarm mitigation in military air surveillance

Thales' military air surveillance are all 3D radars using AESA technologies and sophisticated doppler analysis. This enables the radars to separate the target signal from wind turbine signal and discriminate between wind turbines and targets. As a result no plots and tracks are reported on wind turbines and at the same time minimize performance effects on real targets.

Working closely with all stakeholders

Thales works closely with all the stakeholders in the aviation sector, ministries of defence and the wind energy industry to provide an end-to-end service to identify and deliver the optimum solution for each circumstance. Through our windfarm tolerant radars, our radars not only continue to ensure sky safety; they also contributes to unlocking the development of windfarm, increasing their contribution towards a greener future.

Did you know?

- The Thales Wind Farm Filter is field proven, with several dedicated flight trials performed in difficult circumstances, such as low Radar Cross Section (RCS) targets, ground and sea clutter, and low altitudes.
- The Wind Farm Filter is already operational in Europe and Africa

Reference : https://www.thalesgroup.com/en/windfarm-mitigation

Appendix 10

Thales structured list of upgrades

THALES
Building a future we can all trust

NATS

Air Traffic Management for Air Surveillance & Airports

RADAR upgrade presentation to NATS

22 November 2022

Agenda

1. **Introduction to Surveillance Radar Portfolio**
2. **STAR NG – Key benefits**
    1. The new STAR 2000
    2. Performances improvements & new features
    3. Upgrade benefits
3. **RSM NG – Key benefits**
    1. The latest RSM 970S Tech Refresh
    2. Performances improvements & new features
    3. Upgrade benefits
4. **STAR NG/RSM NG – Upgrade proposal**
    1. Electronics modification
    2. Cybersecurity Virtual Machine
    3. Upgrade benefits

THALES
Building a future we can all trust

1. Introduction
Surveillance Radar Portfolio

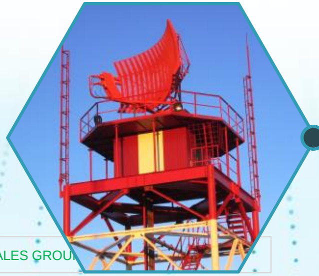
ATM & Surveillance Radar Portfolio

ATC RADAR Portfolio

RSM NG
Approach &
En-Route Mode S

- **Full range of products for Approach and En-Route**
  - Air Traffic Management (Civil & Military)
  - Air Surveillance of Illegal Traffic
- **Largest surveillance installed base**
- **Portfolio recently renewed with lot of commonalities**
  - ***STAR NG*** June 2015 (≥ **60** radars already sold)
  - ***TRAC NG*** June 2017 (≥ **26** radars already sold)
  - ***RSM NG*** March 2021 (≥ **20** radars already sold)
- **Development focused on**
  - Performances improvement
  - Extended & New Features
  - Life Cycle Cost reduction & maintenance easiness

TRAC NG
En-Route PSR



STAR NG
Approach PSR

Thales radar – Worldwide References

50 years experience in Air Traffic Management
1000+ radars awarded

THALES
Building a future we can all trust

Track records – Recent installation examples

THALES

Building a future we can all trust

2. STAR NG – Key Benefits

Non-Cooperative Approach Primary Surveillance Radar

THALES
Building a future we can all trust

2.1 Star NG – The new STAR 2000

STAR NG – The improved STAR 2000

Aerial system

- Antenna, pedestal, motors, rotary joint, encoders…
  - *Unchanged*

SST Cabinets — reduction of one cabinet

- Power Amplifiers and Pre-Amplifiers Modules
  - ***Unchanged***
- Divide by 2 number of TX modules
- TCC integrated into new GR rack

AA/AE & MWA — reduction of one cabinet

- Antenna Control (AA) & Power Distribution (AE) cabinets merged into single cabinet.
  - ***Unchanged*** (same configuration than stand alone RSM 970S)
- MicroWave Assembly (MWA) repackaged to reduce size
  - ***Reuse*** of existing RF Line equipment (duplexer, coupler, guide limiter…)
  - ***Reuse*** of existing PRFU equipment (A/B switch, coaxial limiter…)
- RF822 (LNA & STC) integrated in new GR rack (new QuadRF board)

STAR NG – The improved STAR 2000

PRP Cabinet — reduction of one cabinet

- New Generator/Receiver including
  - TCC, TMR Unit, PSU, GRU & RF822
  - New boards developed: CIRA, S-CONV & S-QuadRF
- Technology partially coming from other radars
  - ***Limited technical risks***
- Radar Processing
  - ***Minor evolutions*** due to improved characteristics

TOM Cabinet — Unchanged

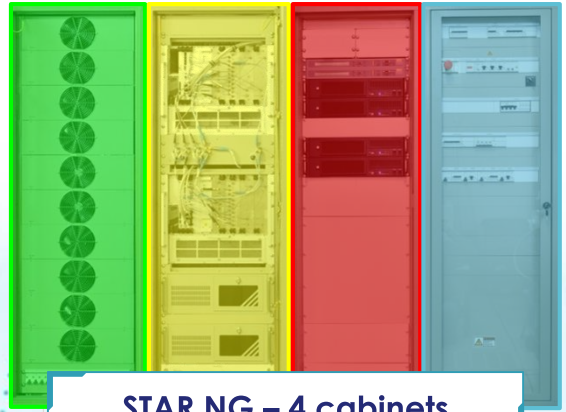
- RCMS & IBIS SW
  - ***Unchanged***
- Time Stamping & P-Lines
  - ***Unchanged***
- Data Processing (plots & tracks, combination)
  - ***Unchanged***

Maintenance strategy and optimization tools

- ***Unchanged***

STAR NG – The improved STAR 2000

STAR 2000 – 7 cabinets



STAR NG – 4 cabinets

- SST Cabinets
- AA/AE & MWA
- PRP Cabinet
- TOM Cabinet

THALES
Building a future we can all trust

2.2 Star NG
Performance improvements & new features

STAR NG – Overview

S-Band Primary Surveillance Radar for Civilian Airports & Military Air Bases

Scalable configuration for Approach Surveillance

- ***Adapted rotation speed***
  - 15 RPM ⇔ 60 NM
  - 12 RPM ⇔ 80 NM
  - 10 RPM ⇔ 100 NM
- ***Optimized peak power***
  - 4 Tx Modules ⇔ 8 kW
  - 8 Tx Modules ⇔ 15 kW
  - 16 Tx Modules ⇔ 28 kW
- ***High detection capability*** to achieve target separation within Major Terminal Maneuvering Areas

High detection performance even in harsh environment

- Under adverse conditions: 4G/5G telecommunication stations, WindFarms, electromagnetic interferences…
- Innovative dynamic clutter suppression: ground, sea & atmospheric clutters
- ***High Resolution/Accuracy***

High reliability 24/7 radar

- ***Redundant design*** with automatic switchover
- ***High level of Reliability, Availability & Maintainability***

Provide Approach radar data to ATCC and/or Military Operation centers

THALES
Building a future we can all trust

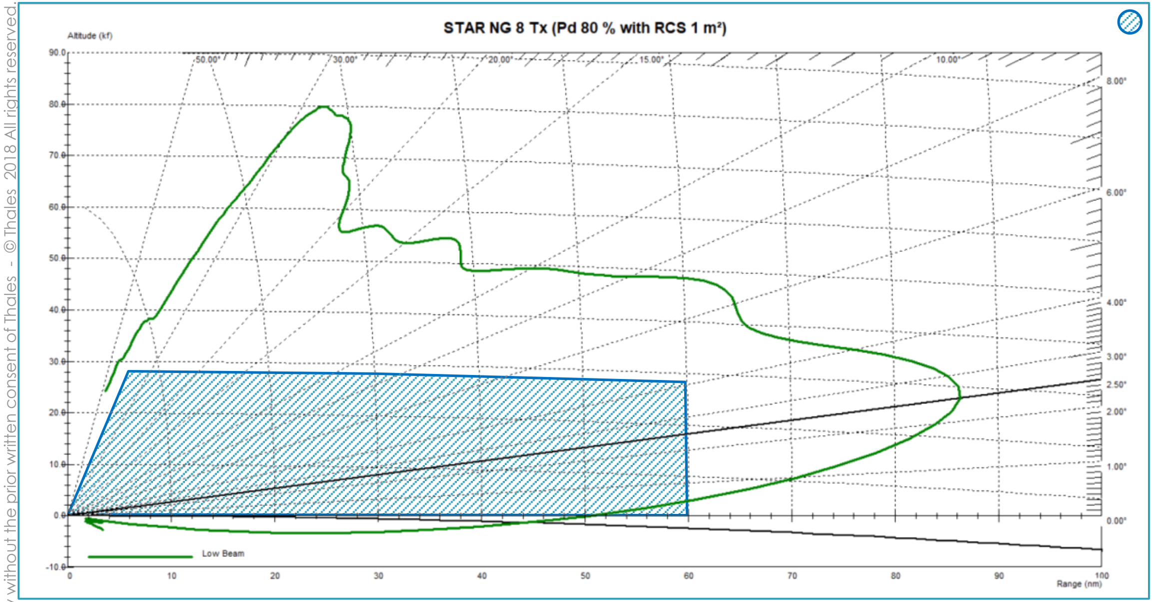
STAR NG – The improved STAR 2000

Characteristics	STAR NG	STAR 2000
Faulty Tx Modules	• N-1 without stopping radar operation • Graceful degradation design	• 1 without stopping radar operation • Graceful degradation design
Range Cell	• 30 m	• 115 m
Instantaneous Bandwidth	• 4 MHz	• 1.5 MHz
Accuracy	• 50 m • 0.15°	• 60 m • 0.15°
Discrimination (@ 80 %)	• 90 m • 2.6°	• 230 m • 2.8°
Analog to Digital Converter	• 16 bits	• 12 bits
Cybersecurity	• By design	• antivirus

(*) Dual Use classification

STAR NG – Improved Coverage Performances

15 RPM / 60 NM



Required Coverage

- Altitude 28 kft
- Coverage 60 NM
- Pd 80 %
- RCS 1 m²
- P_{fa} 10^{-6}

STAR NG configuration

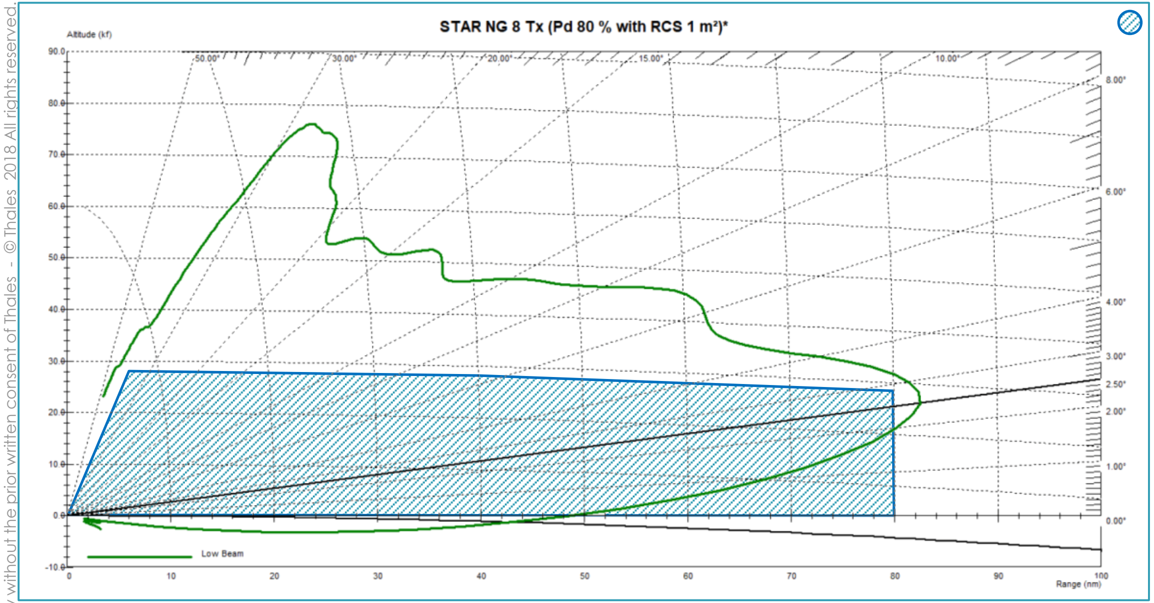
- Rotation speed 15 RPM
- Instrumented Range 60 NM
- Maximum Coverage **86 NM**
- **8 Tx** Modules **15 kW**

STAR NG$_8$ ⇔ 15 RPM / 60 NM (80 % & 1 m²)

THALES
Building a future we can all trust

STAR NG – Extended Coverage Performances

15 RPM / 80 NM



Required Coverage

- Altitude 28 kft
- Coverage 60 NM

- Pd 80 %
- RCS 1 m²
- P_{fa} 10^{-6}

STAR NG configuration

- Rotation speed 15 RPM
- Instrumented Range *80 NM*

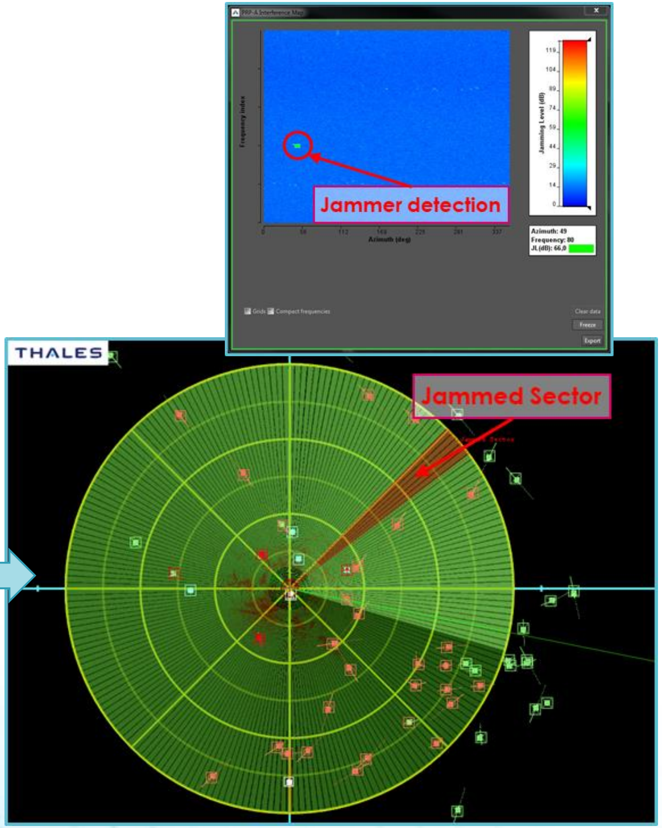
- Maximum Coverage **83 NM**
- **8 Tx** Modules **15 kW**

STAR NG$_8$ ⇔ 15 RPM / 80 NM (80 % & 1 m²)

THALES
Building a future we can all trust

STAR NG – Main Performances

Characteristics	STAR NG
System Stability	• ≥ 65 dB
Minimum Detectable Signal (for Long Pulse)	• - 127 dBm
Dynamic range	• 163 dB
Doppler Filters Banks	• Automatic selection via adaptive map • 8 Filter Banks
Included features	• 4 reception channels processing • Vertical & circular polarization • Redundant weather channel with automatic polarization switch • Interference Map on the local & Interference Report via ASTERIX



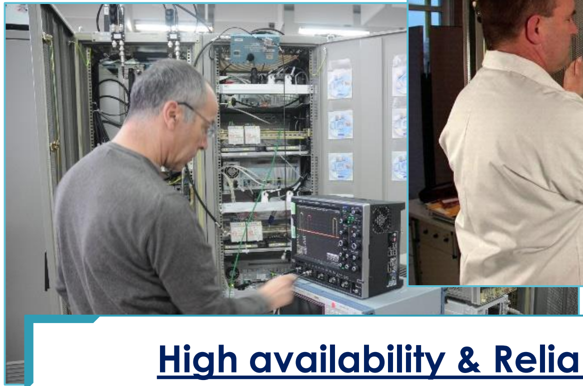
(*) Dual Use classification

STAR NG – New Features and options

Function / Characteristics	Description
4G/5G Filter	• 1 x Waveguide (Rx/Tx) • 3 x Coaxial (Rx)
Improved WindFarm Filter (*)	***Dedicated radar processing*** • Reduce false alarms from wind turbines • Optimize detection of aircraft flying above wind farms

(*) Dual Use classification

STAR NG – Life Cycle Cost improvement



High availability & Reliability

- MTBCF	58 000 h to 66 000 h	(vs 40 000 h)
- MTBF	1 800 h to 2 200 h	(vs 1 000 h)
- Reliability	99.99 %	

Reduced constraints on infrastructure

- Footprint	-40 % of volume
- Weight	-15 % of the electronics
- Consumption	-20 % of power consumption

The lowest Life Cycle Cost of the market

THALES
Building a future we can all trust

Carbon footprint reduction

Main actions

- *The improvements already made on NG versions*
  - *STAR NG scalability 8 kW,15 kW or 28 kW*
  - *Only 8 Tx Modules are sufficient for most cases*

Example

- *Hypothesis*
  - *Using a 8 modules instead a 16 modules : 5kW saved*
  - *Cost of energy in coming years: 1kWh = 1,6€ (was 0.16€ in 2020)*
  - *If electricity is produced with coal: 1KWh eq. 1k*
  - *Life cycle of 10 years = 87 600h*
- *Conclusion*
  - **Saving**= 700k€ + 428 tons eq. CO_2

Carbon footprint reduced by 40% compared to previous generation

THALES
Building a future we can all trust

STAR NG at a glance

New *Approach* Control Primary Radar for Medium-Range *Air Surveillance*

Increased detection & tracking performances

- High range resolution
- Dynamic clutter suppression
- Wind Farm mitigation

Dual-Use Primary Radar for Civil & Military Cooperation (as option)

- 3D Function
- Fighter & helicopter detection
- Frequency Agility & ECCM

Cybersecured by design

- Based on NIST framework
- Cybersecurity Virtual Machine

Optimized Maintenance

- High Reliability & Availability
- Limited cost of ownership

ICAO & **EUROCONTROL** compliant

Solid State & **Digital** technology

S-Band	2 700 MHz – 2 900 MHz	
Scalable	8 kW, 15 kW or 28 kW	
Range	110 – 185 km	(60 to 100 NM)
Update rate	4 – 6 s	(10 to 15 RPM)
MTBCF	66 000 h	

185 STAR in operation (24/7) since 2000
60 countries worldwide

THALES
Building a future we can all trust

2.3 Star NG – Upgrade benefits

Upgrade benefits

Characteristics	STAR NG	STAR 2000
Faulty Tx Modules	• N-1 without stopping radar operation • Graceful degradation design	• 1 without stopping radar operation • Graceful degradation design
Instantaneous Bandwidth	• 4 MHz	• 1.5 MHz
Accuracy	• 50 m • 0.15°	• 60 m • 0.15°
Discrimination (@ 80 %)	• 90 m • 2.6°	• 230 m • 2.8°
Range Cell	• 30 m	• 115 m
Analog to Digital Converter	• 16 bits	• 12 bits
Increased availability	• MTBCF 58 000 h to 66 000 h • MTBF 1 800 h to 2 200 h	• MTBCF 40 000 h • MTBF 1 000 h
Reduced footprint	• Footprint -40 % • Weight -15 % • Consumption -20 % • Carbon footprint -40%	
Cybersecurity	Cybersecured by design	
Increased Lifetime	**Product end of life ~ 2040 (+16 years)**	**Product end of life in 2034**

(*) Dual Use classification

THALES
Building a future we can all trust

3. RSM NG upgrade

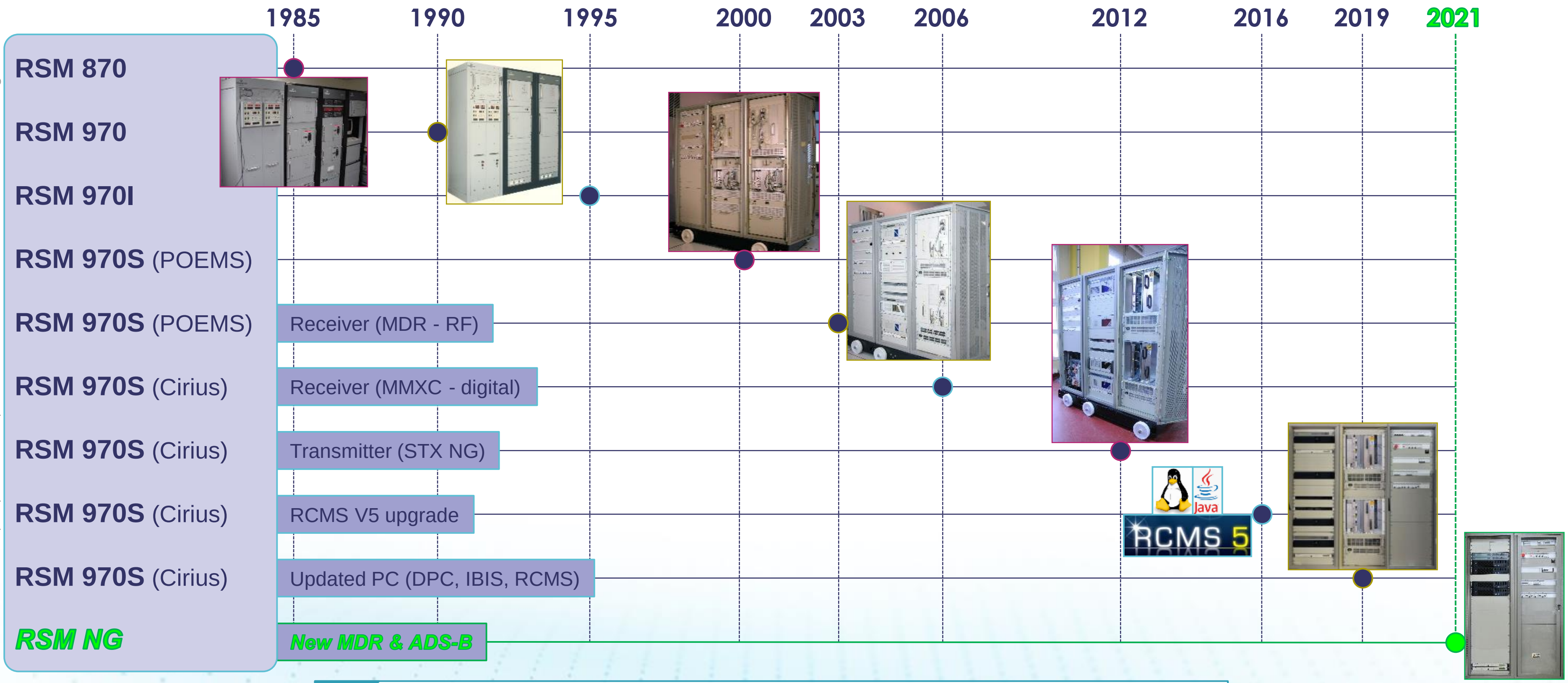
Cooperative Approach & En-Route Mode S Radar

THALES
Building a future we can all trust

3.1 RSM NG
The latest RSM 970S Tech Refresh

The latest RSM 970S Tech Refresh

RSM main evolutions



Software releases following evolutions & new functionalities from ICAO & EUROCONTROL

THALES
Building a future we can all trust

RSM NG – Latest RSM 970S Tech Refresh

New TOM-M Cabinet

- Reuse of STX NG, NTP Servers & P-Lines
- MDRP replaced by a new MDR-M and Front-End in PC
- New PSU & FAN units
- Data processing with new powerful PC
- RCMS & IBIS Merge in single PC (redundant in option)
- Cybersecurity Virtual Machine included

Reuse of AA & AE

Compact design

- 2 cabinets instead of 3
- 30% reduction in weight & volume

RSM NG – Latest RSM 970S Tech Refresh

RSM NG – Latest RSM 970S Tech Refresh

Characteristics	RSM NG	RSM 970S
Instrumented Range @ 15 RPM • SSR – 2 interlaced modes • Mode S – ELS • Mode S – EHS • Full EMS with Datalink	• 256 NM • 256 NM • 256 NM • 170 NM	• 256 NM • 230 NM • 200 NM • 170 NM
Mode of interrogation	• Mode 1, 2, 3 • Mode 5 predisposed • Mode A/C • Mode S • ADS-B Extended Squitter reception	• Mode 1, 2, 3 • - • Mode A/C • Mode S -
External interface	• 64 logical links simultaneously • Full IP links using routers • Serial link optional with pLines	• 8 logical links simultaneously • 4 IP links • 8 serial links

(*) Dual Use classification

THALES

Building a future we can all trust

3.2 RSM NG
Performance improvements & new features

RSM NG – Overview

- **L-Band Secondary Surveillance Radar for Civilian Airports & Air Bases**
- **Digital Meta Sensor**
  - Mode 1, 2, 3, A/C
  - ***Mode S*** Elementary (ELS) & ***Enhanced (EHS)*** including datalink
  - ***ADS-B*** Extended Squitter detection over 360°
  - Compatible with distributed and centralized ***Cluster Mode*** (SCN)
- **Enhanced Performances for Approach & En-Route Surveillance**
  - Rotation speed 5 to 15 RPM
  - Instrumented Range up to 256 NM (even @ 15 RPM)
  - Stand-alone or co-mounted with PSR
- **High reliability 24/7 radar**
  - ***Redundant design*** with automatic switchover
  - ***High level of Reliability, Availability & Maintainability***

Full Mode S functionalities validated by EUROCONTROL since early 2000's

THALES
Building a future we can all trust

Digital Meta Sensor

Transmitted Peak Power

- 3 000 W

Probability of Detection

- > 99 % (international regulation)
- > 99.5 % (typical)

Accuracy (1 σ)

- In SSR Mode
  - Range 30 m
  - Azimuth 0.068° (0.040° typical)
- In Mode S
  - Range 15 m
  - Azimuth 0.068° (0.040° typical)

Up to 2 000 tracks per scan

Compliant with latest version of EUROCONTROL Mode S Station

THALES
Building a future we can all trust

Digital Meta Sensor

RSM NG is able to receive the 1090 Extended Squitter

- Via the three channels Σ, Δ, Ω of the LVA antenna
- 360° detection without additional hardware

ADS-B reception & processing

- Integrated ADS-B receiver without additional hardware
- Same degarbling algorithm as the one for Mode S All-Call
- Digital receiver filters adapted for ADS-B functionality

ADS-B reports allow

- Faster track initialization (direct Roll-Call without All-Call)
- To maintain Mode S and combined Mode S tracks
- Reduction of Cone of Silence
- Reduce RF pollution by removing useless All-Call phases

Reports

- ADS-B reports in ASTERIX Cat 021 using specific data stream
- Service data in ASTERIX Cat 025

RSM NG ADS-B is compliant with the non-physical requirements of ED-129B

Ready for tomorrow

Detection of II/SI Code conflict due to proximity of other radars

- Error in the radar station code
- Error in the coverage map setting
- Presence of a mobile radar

Interference & Jamming analysis

- Strobe detection in case of sectorized Signal Processing overload
- Automatically alert on the presence of jammer

Interference map

- Real time monitoring of FRUITS in each azimuth
- Display FRUITS counting on IBIS

Robustness to jammer

- Adaptation of processing sensitivity to the level of RF pollution
- Maintain the best detection in presence of CW jammer

Local pollution is monitored to optimize radar processing

RSM NG

Approach & En-Route Control radar for Mode S Secondary Surveillance

New digital metasensor

- Military Modes 1, 2 & 3
  Mode 5 predisposition
- Civil Modes A/C
- Mode S Elementary (ELS)
  Enhanced (EHS)
- Integrated 360° ADS-B detection

Cybersecured by design

- Based on NIST framework
- Cybersecurity Virtual Machine

Optimized Maintenance

- Improved Reliability & Availability
- Limited number of spares required
- Reduced cost of ownership

ICAO & **EUROCONTROL** compliant

Digital technology

L-Band	1 030 MHz & 1 090 MHz	
Peak Power	3 000 W	
Range	460 km	(256 NM)
Update rate	4 – 12 s	(5 to 15 RPM)
MTBCF	81 000 h	

400 RSM in operation (24/7) since 2000
70 countries worldwide

THALES
Building a future we can all trust

Building a future we can all trust

3.3 RSM NG – Upgrade benefits

RSM NG – Upgrade benefits

Characteristics	RSM NG	RSM 970S
***Instrumented Range* @ 15 RPM** • SSR – 2 interlaced modes • Mode S – ELS • Mode S – EHS • Full EMS with Datalink	 • 256 NM • 256 NM • 256 NM • 170	 • 256 NM • 230 NM • 200 NM • 170 NM
Mode of interrogation	• Mode 1, 2, 3 • Mode 5 predisposed • Mode A/C • Mode S	• Mode 1, 2, 3 • - • Mode A/C • Mode S
External interface	• 64 logical links simultaneously • Full IP links using routers • Serial link optional with pLines	• 8 logical links simultaneously • 4 IP links • 8 serial links
ADS-B integration	• ADS-B data output (ASTERIX Cat 021) • Radar performances improvement	
Increased availability	• MTBCF 81 000 h • MTBF 3 100 h	• MTBCF 54 000 h • MTBF 2 700 h
Reduced footprint	• 2 cabinets instead of 3 • 30 % reduction in weight & volume	
Cybersecurity	Cybersecured by design	
Increased Lifetime	**Product end of life ~ 2047 (+7 years)**	**Product end of life in 2040**

(*) Dual Use classification

THALES
Building a future we can all trust

4. STAR NG/RSM NG

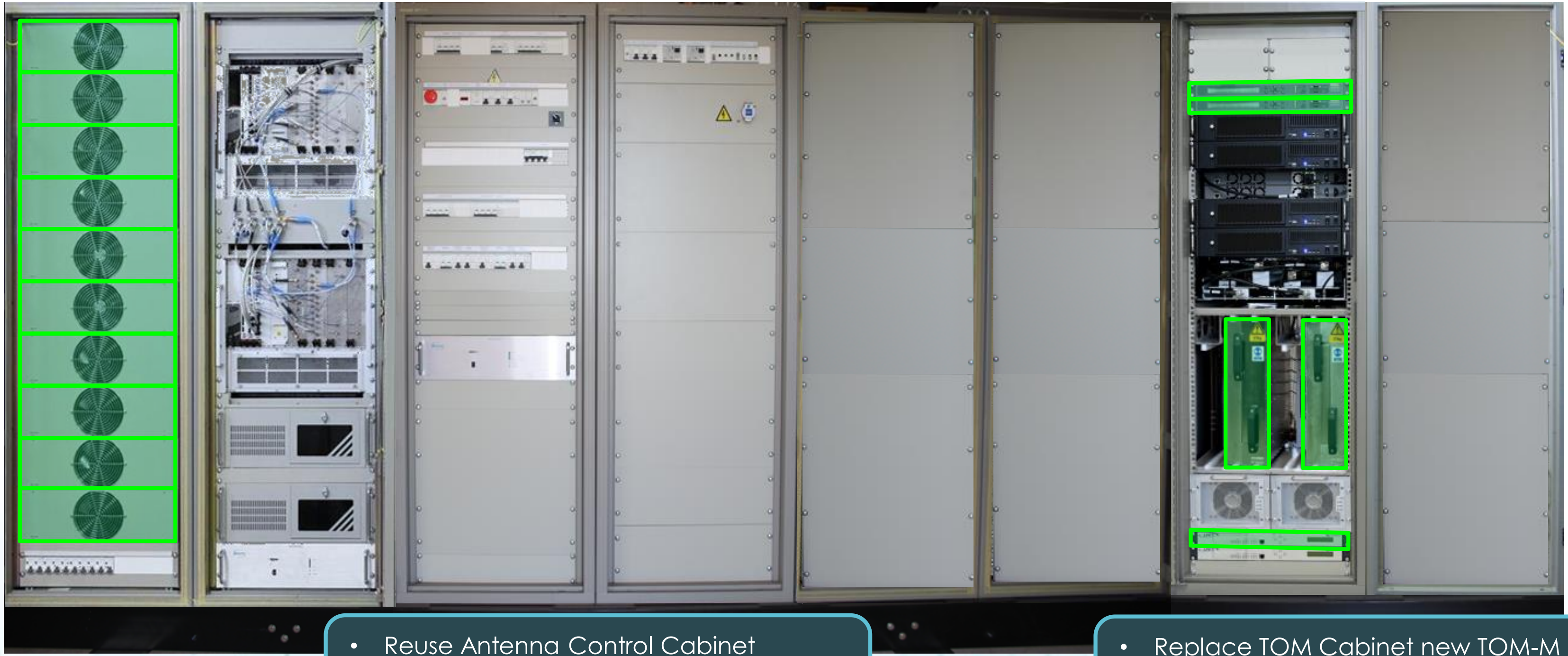
Perfect solution for Approach Surveillance

STAR NG/RSM NG – Upgrade proposal N°1

Up-to-date solution

- Remove the SST Cabinets
- Replace with new SST & PRP Cabinets
- Reuse MES 1400 & MES 110 after refresh

- Remove the LRU from PRP Cabinets
- New GR & Signal Processing in new PRP
- Cover the empty slots



- Reuse Antenna Control Cabinet
- Reuse Power Distribution Cabinet
- Modify MicroWave Assembly

- Replace TOM Cabinet new TOM-M
- Reuse STX NG, NTP & pLines
- Remove the LRU from TRC Cabinets

STAR NG/RSM NG – Upgrade proposal N°3

After the upgrade

Maintenance Console

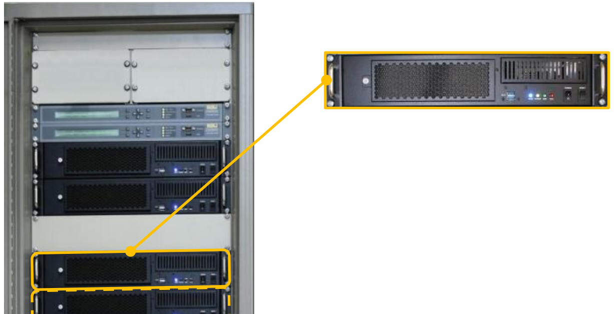
Integrated in the TOM-M cabinet and equipped with

- 2 wide LCD screens of 24" (1920x1200 resolution)
- 3-buttons mouse & QWERTY keyboard
- 19'' rackable workstation
  - Powerful processor & 3D graphic board
  - 4 GB SDRAM
  - 1 TB Hard Disk
  - 4 Gigabit Ethernet

It includes the following functions

1. Control & Monitoring System (LTM Local position)
2. Radar Display (IBIS)
3. Parameter Tool (CBP)
4. Cybersecurity Virtual Machine (CVM)

Redundant design proposed as an option



Maintenance Console

Cybersecured by design

- Cybersecurity based on NIST framework
  - ***Protect*** the radar against modification of reference configuration
  - ***Verify*** periodically the system integrity
  - ***Enforce the access right*** policy
  - ***Prevent*** intrusion in the radar cabinets
  - ***Protect*** the physical access even when off-line

Cybersecurity strategy

- System OS hardening
  - Secured BIOS
  - Updated OS with limited packages & services
  - Antivirus & Firewalls
  - Access control with passwords & security logs
  - Encrypted Hard Drive Disks
- Internal network hardening
  - Only required ports, protocols and services activated
  - Switch hardening

Maintenance Console

- **Single interface to control the cybersecurity functions**
  - Manage users Login & Password via LDAP directory server
  - Prevent from installing unauthorized software
  - Allow to perform Cybersecurity checks on the channel under maintenance
  - Only USB port of entry to collect data or deploy software upgrades
- **Maintain cybersecurity without disturbing radar operational behavior**
- **Radar operational availability & operational safety are not impacted**

2021 Thales Data Threat Report
https://cpl.thalesgroup.com/data-threat-report

Thank you for your attention

Antoine Chapelon

THALES
Building a future we can all trust

Appendix 11

Eurocontrol Mode S station Functional Specification (EMS 3.11)

EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

European Mode S Station Functional Specification

SUR/MODES/EMS/SPE-01
(form. SUR.ET2.ST03.3114-SPC-01-00)

Edition	:	3.11
Edition Date	:	9 May 2005
Status	:	Released Issue
Class	:	General Public

EUROPEAN AIR TRAFFIC MANAGEMENT PROGRAMME

DOCUMENT IDENTIFICATION SHEET

DOCUMENT DESCRIPTION

Document Title

European Mode S Station Functional Specification

EATMP INFOCENTRE REFERENCE: 05/05/29-03

PROGRAMME REFERENCE INDEX:	**EDITION:**	3.11
SUR/MODES/EMS/SPE-01 (form. SUR.ET2.ST03.3114-SPC-01-00)	**EDITION DATE:**	9 May 2005

Abstract

Keywords

Mode S	SSR	Monopulse	Radar
Surveillance	Datalink	Station	PILOT
Cluster	ATN	GDLP	SCN

CONTACT PERSON:	Nicolas EERTMANS	**TEL:** 3363	**UNIT:**	DIS/SUR

DOCUMENT STATUS AND TYPE

STATUS		**CATEGORY**		**CLASSIFICATION**	
Working Draft	☐	Executive Task	☐	General Public	☑
Draft	☐	Specialist Task	☑	EATMP	☐
Proposed Issue	☐	Lower Layer Task	☐	Restricted	☐
Released Issue	☑				

ELECTRONIC BACKUP

INTERNAL REFERENCE NAME:

HOST SYSTEM	**MEDIA**	**SOFTWARE**
Microsoft Windows NT4	Type:	Microsoft Word 97
	Media Identification:	

DOCUMENT APPROVAL

This version (3.11) of the Mode S Ground Station specification represents the best-available state of requirements at the time of issue and it may be used for the purposes of procurement at the risk of the procuring agency only. In the event of changes to this specification, every effort will be taken to ensure that such changes are brought to the attention of those who have formally been issued with a copy.

The following table identifies all management authorities who have successively approved the present issue of this document.

AUTHORITY	NAME AND SIGNATURE	DATE
Author	Nicolas EERTMANS	9/05/05
Mode S System TF Chairman	Eric POTIER	18/05/05
Mode S Programme Manager	John LAW	10/08/05

DOCUMENT CHANGE RECORD

The following table records the complete history of the successive editions of the present document.

EDITION	DATE	REASON FOR CHANGE	SECTIONS PAGES AFFECTED
2.00	13 Dec 1996	POEMS Functional Specification, baseline version for POEMS contract (was SUR.ET2.ST03.3110-SPC-01-00).	
2.01-2.19	12/96-10/99	POEMS TSC internal working drafts of European Mode S Station Functional Specification.	All
2.99	21 Oct 1999	Proposed Issue of European Mode S Station Functional Specification.	All (mostly editorial)
3.00	25 Oct 1999	Inclusion of comments from DFS, NATS and STNA.	
3.01	13 Dec 1999	Released Issue	
3.02	24 Jul. 2000	Technical additions from POEMS TSC	All
3.03	27 Sep 2000	Review of 3.02 and additional modifications during TSC13.	4,7,8,9
3.04	22 Nov 2000	Additional modifications resulting from TSC13	All
3.05	29 Nov 2000	Additional modifications resulting from TSC14	All
3.06	29 Jan 2001	Additional modifications resulting from TSC15	All
3.07	6 Mar 2001	Inclusion of comments from STNA.	All
3.08	19 April 2001	Released issue. References updated.	
3.09	30 March 2005	Correction of typos. Addition of optional SPI, position reports processing & Internet Protocols.	4.2.4.2.3, 4.9.2.1, 4.9.4.2, 7.2.1, 7.3.2.8, 13.2.2.5, Annex B new sections 13.18 and 13.19.

3.10	27 April 2005	Proposed issue following review by MSTF#22. SPI processing becomes advisory. GICB extraction limited to datalink map removed.	7.2.1 changed and 13.19 removed.
3.11	9 May 2005	Released Issue.	-

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The present document describes the functional specification for the European Mode S Ground Station.

European Administrations who wish to take part in the initial implementation programme may use this document as a kernel for their procurement specification.

CHAPTER 1

INTRODUCTION

1.1 Overview

1.1.1 This chapter provides an overview to the implementation of an European Mode S ground station.

1.1.2 Europe currently operates Secondary Surveillance Radar (SSR) stations for the surveillance function. These stations act autonomously, each providing a radar service to the Air Traffic Control Centre (ATCC). The radar systems are required to operate unattended and must therefore rely on control and monitoring information via a Control And Monitoring (CAM).

1.1.3 The Mode S ground station detailed in this document is described as a ‘PILOT’ system. ‘PILOT’ systems may be procured by Administrations in the core area who wish to take part in the initial implementation programme. The term ‘PILOT’ is used to describe a production standard equipment offered for operational implementation. This implementation will introduce Enhanced Surveillance Services to ATC through use of data link services known as the Mode S Specific Services.

The necessary functionality to support the Mode S Specific Services shall be resident in the ground station. These shall be capable of automatically extracting aircraft derived data which may be selected by programmable criteria (e.g. periodic, on initiation of track, within an azimuth window etc.). Extracted aircraft data shall be transmitted to the requesting application and could be included in Mode S extended report messages. Examples of such data are aircraft address, capability, altitude, aircraft identity, ACAS resolution data and aircraft intention data.

The Airborne Data Link Processor (ADLP) will link various aircraft systems to the Mode S transponder and will provide a means for avionics data to be transmitted to the ground via 'Mode S Specific Services'. The ADLP also provides the necessary functionality to support the full Mode S sub network.

1.1.4 A further stage of development in Mode S implementation is expected to be the addition of the Ground Data Link Processor (GDLP) to provide the full functionality of the Mode S Subnetwork.

The Mode S subnetwork provides a reliable point-to-point Switched Virtual Circuit (SVC) communication service across the Mode S air-ground link. It is fully compatible with the Aeronautical Telecommunication Network which provides complete inter-operability between alternative air-ground data-links. The SVC service of the Mode S Subnetwork may also be used by stand-alone applications outside or alongside the ATN environment (see Figure 1).

The Mode S interrogator includes the necessary functionality to interface to the GDLP (including the frame processing function of the Subnetwork).

1.1.5 The Mode S station can operate in a co-operative way with other Mode S stations (see Figure 2).

This makes it possible:

(a) To reduce the Mode S FRUIT rate, by allocating the same II code to all the stations of a cluster; in this case, the aircraft acquisition can be performed, via the ground network;

(b) To compensate for a possible detection miss, by getting additional Mode S data originating from neighbouring stations.

This mode requires an interconnection between the involved stations.

In the event of a radar failure, the adjacent stations can re-configure their coverage area, according to a pre-programmed scheme, so as to limit the uncovered areas.

1.2 Specification Status

1.2.1 Compliance with the specification is required unless departure from the specification requirements can be demonstrated during the call for Tenders to provide advantages technically or to provide advantages in cost terms without any degradation of performances.

1.2.2 The response to the specification is required to be comprehensive with a completed Compliance Summary as set out below.

The identification or referencing of each paragraph or set of paragraphs is standardised to enable a concise compliance status summary to be provided in the proposals. Each paragraph or set of paragraphs has a suffix in square brackets which is one of:

(a) [An] indicating that the immediately preceding paragraphs contain information for the Contractor and is therefore ADVISORY;

(b) [En] indicating that the requirements of the immediately preceding paragraphs are considered ESSENTIAL;

(c) [On] indicating that the requirements of the immediately preceding paragraphs are considered OPTIONAL;

(d) [In] indicating that the immediately preceding paragraphs are requesting essential INFORMATION.

1.2.3 The compliance summary provided shall be completed and returned with the proposal. This compliance summary is in the form of a table, constructed from the following column headings:

Chapter:	Paragraph:	Item:	Compliance:	Proposal Ref:

Each row of the table uniquely identifies each paragraph requiring response in this specification by the Chapter, Paragraph (and sub paragraph) and Item references in the consecutive order in which they appear in this specification, where the Item reference is in the specification paragraph suffix in square brackets referred to above.

The Tenderer compliance status shall be indicated against each paragraph and Item of this specification in the 'Compliance' column with a C for Compliance or an N for Not Compliant. No other response will be recognised during the evaluation and absence of C or N will be counted as Non-Compliant, as will statements such as 'Read and Understood'. This includes Item references [An], [En], [On] and [In] where:

(a) For [An] 'C' indicates that the paragraph has been read, understood, agreed and accepted;

(b) For [En] 'C' indicates that the requirement is fully met in all respects, exactly as stated in this specification;

(c) For [On] 'C' indicates that the option is offered, it will meet the requirements in all respects, exactly as stated in the specification, and is itemised and priced separately in the commercial response and

(d) For [In] 'C' indicates that the information is supplied complete as requested in the specification and the information shall become contractual after the signature of the contract.

Each response to any of [An], [En], [On] or [In] requires a readily identifiable full qualification in the proposal, otherwise it will be counted as unconditionally Non-Compliant.

If an option [On] is offered as a standard without additional cost, and is fully compliant with the requirement as specified, then this must be clearly stated by 'C STANDARD' in the compliance summary, and itemised as a zero cost option in the commercial response.

All reference to cost implications and specific cost details shall be confined to the Commercial response and shall not appear in the technical response. **[E1]**

The information or the data provided in the proposal descriptions and specifications pertinent to each of the paragraphs of this specification shall be cross referenced via the Proposal Ref column in the Compliance summary. **[E2]**

It should be noted that compliance information not included, or included but in error, in the compliance status summary will be counted as a Non-Compliant statement. **[A1]**

1.2.4 The operational and technical facilities defined by this Specification shall be regarded as essential. Within the defined limits of the specification the Contractor has the freedom of design on the condition that the Eurocontrol Agency and the participating States agree that the system meets the requirements. **[E1]**

1.2.5 In the event of conflict between any of the requirements expressed for the Mode S ground station in any reference documents, the requirements expressed in ICAO Annex 10 ([Ref.1.]), and STANAG 4193 ([Ref.2.]) and the Mode S subnetwork SARPS ([Ref.3.]) shall take priority, followed by the requirement in this Specification. **[E1]**

Where conflict occurs between this specification and any other specification or document, the Agency shall be notified. **[E2]**

1.3 Specification Language

1.3.1 Throughout this document, the word 'shall' denotes a mandatory requirement, 'may' a preferred requirement and 'will' a statement of intent. **[A1]**

'The Tenderer' means the company submitting the Tender and 'the Contractor' means the successful Tenderer to whom the contract arising from the Tender has been awarded. **[A2]**

1.3.2 The Contractor shall be wholly responsible for the consistency and correct working of all interfaces between equipment and subsystems within the complete radar systems, including all the interfaces between and within SSR, Mode S and remote control subsystems as specified within this document. **[E1]**

Therefore, as part of the Tender response, the Tenderer shall advise the Agency of any amendments to any of the interface specification material included in this document which is either considered desirable or necessary. **[E2]**

1.3.3 In the absence of any agreed amendments or relaxations, the specification and associated attachments and other documents or specifications referred to, herein shall be the definitive document(s) for all equipment supplied. **[E1]**

1.3.4 Note that throughout this document the term ‘Agency’ is used to mean EUROCONTROL or the National Administration responsible for procurement. **[A3]**

CHAPTER 2

SCOPE

2.1 General

2.1.1 The Contractor shall develop, supply, install and commission a working system that is complete in every respect, provides specified outputs and meets the performance requirements to the full specification detailed in this document and referenced documents. **[E1]**

Acceptance of the ground station equipment will comprise the full system up to and including all the interfaces described in this specification. **[A1]**

For guidance the following issues are anticipated to be confirmed during the 12 month Interoperability Validation exercise:

(a) Interoperability with an ATCC for Enhanced Surveillance services (data requests and delivery) **[A2]**

(b) Interoperability with an ATCC during Network-Aided cluster operation (surveillance integrity) **[A3]**

(c) Interoperability with an adjacent station during cluster co-ordination (failure modes and effects) **[A4]**

2.1.2 The station shall be functionally modular and include facilities to evaluate the performance of individual processes (as described in [Ref.12.]) for the specified operating conditions of Annex G. **[E1]**

2.1.3 Tenderer shall provide a proposal and separate quotation for all options specified in this document. **[E1]**

2.1.4 The Tenderer shall provide all proposal material on a CD-ROM and in a hard copy form. **[E1]**

2.2 Equipment to be Supplied

2.2.1 The Mode S system will be installed on a site to be decided. **[A1]**

2.2.2 The following items shall be supplied with the Mode S system:

(a) Antenna and turning gear system (optional) **[O5]**

(b) 20m tower (optional) **[O1]**

(c) Shelter (optional) **[O2]**

(d) Interrogator **[E2]**

(e) Processing (SMF, DLF, SCF) **[E3]**

(f) Local display **[E4]**

(g) Local playback and recording (optional) **[O3]**

(h) Control and Monitoring **[E5]**

(i) Far field site monitor **[E6]**

(j) Cluster Controller (optional) **[O4]**

(k) Dual GPS Receiver (optional) **[O7]**

(l) All Dedicated Terminals required for parameter configuration **[E8]**

2.2.3 The system shall be provided with dual channel functionality for items (d),(e) and (i) above. **[E1]**

The Tenderer shall advise where an alternative approach to dual functionality may be more appropriate. **[E2]**

2.2.4 The system shall be designed to be located in a building which has been constructed for the purpose of containing the Mode S system. **[E1]**

2.2.5 The Tenderer shall provide the necessary interface functionality to support the Mode S system to be collocated with a primary surveillance radar. **[E1]**

"Collocated" includes both co-mounted and off-mounted configurations. **[A1]**

2.2.6 The Tenderer shall provide in the proposal details of the ground station's modularity. This shall include the design philosophy regarding technological updates and functional upgrade of the hardware and software. **[I1]**

The Tenderer may refer to Ref 13 regarding modular design. **[A1]**

In particular the Tenderer shall indicate how their design approach can accommodate subsequent updates to [Ref.5.] and [Ref.6.]. **[I2]**

CHAPTER 3

SYSTEM DESCRIPTION

3.1 General

3.1.1 As expressed in 1.2.5, the Mode S ground station shall primarily meet all the requirements of [Ref.1.] and those described in the Mode S Subnetwork SARPS followed by the requirements as detailed in this document. **[E1]**

The Mode S ground station shall meet the requirements of Military SPI, Military Emergency train and Mode 3 as defined in STANAG 4193 [Ref.2.]. **[E2]**

The Tenderer shall provide equipment as described in [Ref.2.] which includes Mode 1 and 2. **[E3]**

There is no requirement to include Mode 4. **[A1]**

3.1.2 Each ground station shall support the following functions:

(a) interrogation, detection and acquisition of Mode S, 3/A and C to comply with [Ref.1.]:

- (i) Mode 3/A,C,S All-Call interrogation;
- (ii) Mode A/C only All-Call;
- (iii) Mode S only All-Call. **[E1]**

(b) addressed surveillance and standard length communication transactions as described in [Ref.1.] which include:

- (i) Surveillance, altitude request;
- (ii) Comm A altitude request;
- (iii) Surveillance identity request;
- (iv) Comm A identity request;
- (v) Surveillance altitude reply;
- (vi) Comm B altitude reply;
- (vii) Surveillance identity reply;
- (viii) Comm B identity reply;
- (ix) Lockout protocols;
- (x) Basic data protocols including:
  - Flight status;
  - Capability reporting.
- (xi) Standard length communication protocols:

- Comm A
- Comm A broadcast
- Ground initiated Comm B
- Air initiated Comm B
- Comm B broadcast
- Enhanced Comm-B protocol for Level 5 transponders **[E2]**

(c) Extended length communication transactions as defined in [Ref.1.], including:

(i) Comm C

(ii) Comm D

(iii) Multisite uplink ELM protocol

(iv) Non selective uplink ELM

(v) Multisite downlink ELM protocol

(vi) Non selective downlink ELM

(vii) Enhanced ELM protocol for Level 5 transponders **[E3]**

(d) Aircraft Identification Protocol including:

(i) Aircraft identification reporting

(ii) Aircraft capability reporting

(iii) Change of aircraft identification **[E4]**

(e) Data link function including:

(i) Frame processing;

(ii) Mode S specific services processing. **[E5]**

3.1.3 The station shall manage the following:

(a) Mode S specific services to minimise the use of the RF channel e.g. combining identical requests; **[E1]**

(b) The Mode S packets (e.g. prioritise packets, delay the frame processing in order to achieve maximum benefit from multiplexing); **[E2]**

(c) Uplink and downlink broadcasts. **[E3]**

3.1.4 The grouping of functional elements as described in chapters 6 through 9 does not impose any physical implementation. **[A1]**

3.2 Cluster Operation

3.2.1 The number of interrogator identity (II) codes available is limited and therefore unique codes cannot be allocated to each Mode S ground station. A Surveillance Co-ordination Network (SCN) will allow a common II code structure to be implemented for clusters of ground stations. **[A1]**

The Surveillance Identifier (SI) codes described in [Ref.1.] provide additional codes that can be allocated to interrogators which only perform a surveillance function. **[A2]**

The capability to interrogate and set lockout for an SI code and decode and process replies from an SI capable transponder shall be provided in the ground station. **[E1]**

3.2.2 The objective of Surveillance Co-ordination is to allow any Mode S ground station to operate effectively within any radar siting plan while keeping the levels of RF pollution as low as possible. This means preventing interference between stations by the correct use of II/SI codes, Mode S protocols, transponder all-call lockout, coverage map configuration and target handover. **[A1]**

3.2.3 A Surveillance Co-ordination Function (SCF) shall be incorporated into each ground station, as described in chapter 8, and shall provide:

(a) Network control and management including failure detection and resolution; **[E1]**

(b) Co-ordination procedures, as defined in [Ref.1.], between coverage areas of networked ground stations to allow targets to be acquired without need for All-Call; **[E2]**

(c) Track data to adjacent stations upon request. **[E3]**

3.2.4 When operating as part of a cluster the stations operation is termed ‘network-aided’. This operation shall support the following modes which are described more precisely in subsequent chapters:

(a) Central mode where the coverage map and II/SI code are determined by a cluster controller (CC) as described in Appendix A of [Ref.1.]; **[E1]**

(b) Distributed mode where the Ground station SCFs co-ordinate to ensure correct cluster operation, as defined in [Ref.1.]. **[E2]**

In addition to ‘network-aided’ operation the SCF shall also support ‘stand-alone’ operation where each station shall operate independently from cluster. **[E3]**

3.2.5 The data format to be used over the Surveillance Co-ordination Network shall be as described in [Ref.6.]. **[E1]**

3.2.6 The Mode S ground station shall be capable of forming a cluster with any Mode S ground station whose network interface comply with [Ref.1.]. **[E1]**

The Surveillance Ground Network will provide the infrastructure to support communications between the Mode S ground stations and the Cluster Controller. **[A1]**

CHAPTER 4

GENERAL EQUIPMENT AND PERFORMANCE REQUIREMENTS

4.1 Scope

4.1.1 This chapter details the equipment functional and performance requirements which shall be met to satisfy the requirements for the provision of the Mode S system. **[A1]**

4.1.2 Where performance parameters are specified as a standard deviation, this shall always refer to the standard deviation of a Normal Distribution, unless it is specifically stated otherwise. Also the terminology root mean square shall be taken as synonymous with standard deviation (σ1), unless it is specifically stated otherwise. **[A1]**

4.2 Performance Requirements

4.2.1 General

The following paragraphs specify the coverage requirements and specify the system performance parameters. **[A1]**

The performance requirements specified in the following paragraphs are the minimum operational performance requirements. They shall be met with all site dependant operational parameters set following commissioning including antenna tilt, gain time control and any other variable thresholds. **[E1]**

To ensure that the performance requirements are met the system will be subjected to Factory Acceptance Tests (FAT), Site Acceptance Tests (SAT) along with system performance evaluations, flight trials and live traffic performance evaluations to cover Mode 3/A,C operation and Mode S operation prior to acceptance. In addition to coverage confirmation, targets of opportunity will be used to establish accuracy performance. **[A2]**

Tools approved by the Agency shall be used to check compliance to the required performances. In particular, the Contractor shall obtain and use, where appropriate, the PTE tools for acceptance testing. Characteristics of this equipment are included in Annex I, and a fuller description is available from the Agency. **[E2]**

Supplementary or alternative tools may be proposed to satisfy the compliance and safety requirements of the individual member states, the use of which shall be agreed by the Agency. **[E3]**

The contractor shall fund all costs associated with the provision and use of whichever test tool is selected. **[E7]**

Full coverage and performance details compliant with this specification shall be supplied with the proposal. **[I2]**

It is assumed that SSR Mode 3/A, C and S transponders conform to all the requirements of [Ref.1.]. **[A3]**

The Mode S sensor shall process transponders compliant with ICAO Annex 10 Amendment 69, 71 and 73. **[E4]**

The Tenderer shall clearly describe how he intends to fulfil the previous requirement, and more specifically the determination of transponder's communication capability. **[I3]**

The Tenderer shall in particular indicate the effects on the acquisition processing, internal application list, DLF,GDLP/LU, the use of the continuation subfield/flag, on RAs, and on Asterix reporting. **[I4]**

The Mode S sensor shall solicit and detect replies from Mode 3/A,C only and Mode S transponders within the specified coverage subject to the system performance requirement detailed in this Chapter. **[E5]**

For aircraft tracked with selective Mode S interrogations the Mode S ground station shall extract Mode C information from those Mode S transponder equipped aircraft on every scan, in addition to any Mode 3/A code update subject to the system performance requirement detailed in this Chapter. **[E6]**

In addition to the general operating model of Annex G, the performance requirements shall be met for the operational configurations (IRF vs. range/turning rate) of the sites to be commissioned. **[E8]**

The Tenderer shall define how many re-interrogations, in function of range, are assumed to achieve the Mode S performance requirements for all configurations given in Annex G, and target velocity limits specified in 4.6.10. This shall be supported by field data. **[I5]**

It is a goal for the system to minimise the re-interrogation rate while meeting all required performances. **[A4]**

The Tenderer shall describe in detail how non-discrete Mode A codes are handled by the station. **[I6]**

4.2.2 Radar Coverage

4.2.2.1 The Mode S Radar shall provide continuous, gap-free cover through 360° of azimuth and over a range of 0.5 NM to at least 256 NM. **[E1]**

The upper limit of cover shall be at least 66,000 ft. **[E2]**

It is expected that, due to site conditions and earth curvature the lower limit of coverage shall not be horizontal all the way to 256 NM. **[A1]**

The Tenderer shall state the lower limit of coverage in elevation and under what conditions this lower limit shall be achieved. **[I1]**

The zenithal gap, shall not extend below an elevation angle of 45° above the horizontal. **[E3]**

4.2.2.2 The Tenderer shall provide horizontal and vertical polar diagrams for the ICAO defined transponder frequency bands to achieve the accuracy and detection performance of 4.2.3 and 4.2.6 throughout cover. **[I1]**

The vertical polar diagrams shall include the following conditions:

(a) Free space; **[E1]**

(b) Antenna height 20m, medium dry ground with a Relative Permittivity of 15 and Conductivity of 0.04 Siemens per metre; **[E2]**

(c) Antenna height 20m, sea water with a Relative Permittivity of 70 and Conductivity of 5 Siemens per metre. **[E3]**

For the purposes of calculation the reflection surfaces of (b) and (c) may be assumed to be spherical and optically smooth and conform to the WGS 84 Earth Model. **[A1]**

The Mode S equipment provided by the Contractor shall meet the requirements detailed in the polar diagrams as agreed by the Contractor and the Agency prior to the award of the Contract. **[E4]**

The Tenderer shall state in their proposals any non compliance with the performance requirements of 4.2.3 and 4.2.7 within the first null above the horizontal. **[I2]**

4.2.2.3 The Tenderer shall also clearly explain the technique used and the effects on the performance of sensitivity time control (STC) and any other thresholding in the system (e.g. short pulse elimination and received signal strength), specifically stating the STC levels assumed. **[I1]**

The antennas performance shall be such that with a receiver STC of 42dB at 0.25 NM, the zenithal gap shall not extend below an elevation angle of 45°. **[E1]**

4.2.2.4 During the commissioning phase, the Contractor shall analyse the radar sensor performance in order to define the Commissioning Volume where the radar sensor can provide radar services according to local environmental and operational constraints. This Commissioning Volume shall be agreed between the Contractor and the Agency. **[E1]**

The Measurement Volume is defined as the area below the flight level 500, above the flight level 100 until 100 NM, above the flight level 200 between 100 NM and 135 NM, above the flight level 300 between 135 NM and 170 NM. **[A1]**

The Measurement Volume is defined for a normal site, however in certain cases (e.g. area of mountains) this volume should be adapted by using the Eurocontrol RASCAL tool in order to define the volume which is not subject to terrain screening. **[A2]**

Annex G provides the volumes (Commissioning or Measurement Volume) against which the site performances requirements shall be tested. **[E2]**

All theoretical or required site performances can be verified in factory with simulated targets and without any volume restriction. **[A3]**

4.2.3 Position Detection Performance

4.2.3.1 General

The Probability of Detection (Pd) shall be determined by the ratio of the number of target reports with measured position to the number of total expected reports. **[A1]**

The expected reports are the reports contained between the first and the last report from the same aircraft before it leaves the volume to be analysed. The method of chaining will be that which is defined in PTE tool. **[A2]**

The Tenderer should anticipate that the verification of probability of detection will be undertaken using the PTE tool set for a monoradar analysis. **[A3]**

The European Surveillance Standard recommends that the SSR probability of detection for surveillance should be greater than 97% and code validations of 98% and 96% for Modes 3/A and C respectively. **[A4]**

The above figures shall be met by the Mode S equipment for the overall coverage area. **[E1]**

‘Overall’ means that the measurement method shall be applied without further geographical restrictions to the whole sample of the recorded data obtained from opportunity traffic within the Commissioning Volume. **[A5]**

The performance characteristics for existing operational Monopulse sites shall be the benchmarks against which the detection and code validation of Mode S operational stations will be validated. **[A6]**

The Tenderer shall state, for each performance justification, the values for All Call and Roll Call period durations, Mode 3/A,C and Mode S All Call IRF using the values for antenna rotation speed given in the Annex G. **[I1]**

The Tenderer shall provide, as part of the Tender response, evidence that his proposed system can fully meet the performance requirements, and stating under what conditions (e.g. site, garbling, FRUIT rate). **[I2]**

The Tenderer shall detail in the proposal the effect of an increase of FRUIT rate to 20 000 FRUIT/s in the 3dB beamwidth on the Probability of Detection **[I3]**

In order to provide an adequate sample size for performance verification, the data collected for peak traffic hours will include at least 50000 reports. **[A7]**

The Tenderer shall state and justify the round trip reliability for all surveillance Mode S transactions. **[I5]**

The Tenderer shall state all assumptions made in response to paragraphs 4.2.3.1 to 4.2.3.3, and shall also indicate any circumstances where the values given will be modified. **[I6]**

4.2.3.2 SSR Detection without synchronous garbling

4.2.3.2.1 SSR Theoretical Detection

The Tenderer is advised that in addition to transponders which operate with 21dBW, SSR transponders having power outputs of 18.5 dBW are permitted for aircraft not flying above 15000 ft. **[A1]**

The Tenderer shall provide a downlink power budget for transponders having a power output of 18.5 dBW, stating the maximum detectable range at 15000 ft. **[I1]**

The Tenderer shall state any deviation from the accuracy and detection performance of 4.2.3 and 4.2.6 for transponders having power outputs of 18.5 dBW. **[I2]**

The Tenderer shall provide detection analysis, including uplink and downlink budgets for 256 NM range; 150 Hz IRF, vertical polar diagrams for the conditions of Annex G and for each of the following transponder reply frequencies:

(a) 1090 MHz

(b) 1087 MHz

(c) 1093 MHz **[I3]**

The Tenderer shall state, for each detection analysis, the All Call and Roll Call period durations, Mode 3/A,C and Mode S All Call IRF. **[I4]**

The Tenderer shall state the achievable plot detection and correct code validation figures for each transmitted mode (3/A, C) for the conditions stated in **[I3]**, assuming that the transponder code responses conform to [Ref.1.] and [Ref.2.]. **[I5]**

The Tenderer shall also include in the proposal details of the minimum number of replies required at the receivers' inputs to detect a target and output a report with an agreed accuracy and level of confidence when interrogating on the following:

(a) Mode 3/A only; **[I6]**

(b) Mode C only; **[I7]**

(c) 3/A, C mode interlace. **[I8]**

For the above, assume that the detected target is subjected to the full target processing in the system, and that it shall be output as a confirmed report. **[A2]**

The Tenderer shall provide in the proposal an analysis of how the system will achieve a theoretical SSR probability of detection better than 99%, for aircraft which are not close (slant range > 2 NM, azimuth > 2 * nominal 3dB interrogation beamwidth), with the following hypotheses:

- 4 interrogations in the 3 dB beam (2 mode A and 2 mode C);
- a transponder probability of reply equal to 90%;
- a target and FRUIT rate as defined in Annex G;
- Mode A/C transponder. **[I9]**

The Tenderer shall detail in the proposal how this probability of detection will be tested in FAT. **[I10]**

4.2.3.2.2 SSR Site Performance

On a site, with the parameters used for the commissioning of the radar, the SSR probability of detection shall be at least 99% for the set of aircraft:

(a) Which are in the Measurement Volume;

(b) Which are not in the zenithal gap (elevation angle below 40);

(c) Which are not in close proximity (slant range > 2 NM, azimuth > 2 * nominal 3dB interrogation beamwidth). **[E2]**

The definition of the above filter is made in order to avoid taking into account problems due to the site or due to the distribution of the traffic between this clear area and the remainder of the radar coverage. **[A1]**

The probability of detection shall be verified at FAT & SAT as defined in section 14.15 **[E4]**

4.2.3.3 Mode S Detection in Selective mode

4.2.3.3.1 Mode S Theoretical Detection

The Tenderer shall provide detection analysis, including uplink and downlink budgets for 80, 150, 200 and 256 NM ranges, vertical polar diagrams for the conditions of Annex G and for each of the following transponder reply frequencies:

(a) 1090 MHz

(b) 1087 MHz

(c) 1093 MHz **[I1]**

The Tenderer shall state, for each detection analysis, the values for antenna rotation speed, range, All Call and Roll Call period durations, Mode 3/A,C and Mode S All Call IRF. **[E1]**

The Tenderer shall state the achievable plot detection and correct Mode S address validation figures for each transmitted Mode S surveillance/SLM replies (Downlink Formats 4, 5, 20 and 21). **[I2]**

The Tenderer shall provide in the proposal an analysis of how the system will achieve a theoretical Mode S probability of detection better than 99%, with the following hypotheses:

- A transponder probability of reply equal to 90%,
- A target and FRUIT rate as defined in Annex G,
- Mode S transponder. **[E2]**

The Tenderer shall explain how, during handover, the probability of detection will be maintained in a cluster whereby each station will share the same II/SI code. **[I4]**

The Tenderer shall detail in the proposal how the probability of detection and the number of re-interrogations will be tested in FAT. **[I5]**

The Tenderer shall detail in the proposal how the probability of detection, during handover, will be tested in the case of operation as part of a cluster whereby each station will share the same II/SI code. **[I6]**

4.2.3.3.2 Mode S Site Performance

For Mode S targets, track reports using external data coming from an adjacent sensor will be considered as extrapolated data and shall not be taken into account as a target report with measured position. **[E1]**

On site, the probability of detection shall be measured when the station does not operate network aided. **[E2]**

On a site, with the parameters used for the commissioning of the radar, the Mode S probability of detection shall be at least 99% for the set of aircraft:

- Which are in the Measurement Volume;
- Which are not in the zenithal gap (elevation angle below 40);
- Which are not in close proximity to each other (slant range > 5.3 NM, azimuth > 2 * nominal 3dB interrogation beamwidth). **[E4]**

The definition of the above filter is made in order to avoid taking into account problems due to the site or due to the distribution of the air traffic between this clear area and the remainder of the radar coverage. **[A1]**

The 99% of probability of detection (defined in **[E4]**) shall be achieved in roll call with, on average, 2 GICB requests per aircraft. **[E6]**

With the probability of detection measured in the volume described above, the Contractor shall provide the average number of interrogations per aircraft. **[I1]**

The probability of detection shall be verified at FAT & SAT as defined in section 14.15. **[E7]**

The Tenderer should anticipate that the verification of probability of detection as defined above will be undertaken for each site using a long duration recording (more than 50,000 reports) and the PTE tool set. **[A3]**

4.2.4 Code Detection without Synchronous Garbling

4.2.4.1 Code Detection and Validation for SSR

4.2.4.1.1 The Mode S system shall detect all Mode 3/A, C, as defined in [Ref.1.] and shall perform a credibility check to remove the possibility of delivering erroneous data to the surveillance users. **[E1]**

4.2.4.1.2 All of the height codes defined in Appendix 1 of [Ref.1.] shall be translated from the corresponding mode C responses and any codes outside the range of values in Appendix 1 shall not be translated from any mode C responses. **[E1]**

4.2.4.1.3 The special civil codes 7500, 7600 and 7700 shall be detected and recognised, as defined in [Ref.1.]. **[E1]**

The special Military Emergency reply train, as defined in [Ref.2.], shall be detected, recognised and the appropriate fields set in the target report. **[E2]**

The special Military Identity reply train, as defined in [Ref.2.], shall be detected, recognised and the appropriate fields set in the target report. **[E3]**

The above codes shall be output immediately upon detection, and not subject to any delay. **[E4]**

The appropriate identifier bits as specified in Ref 5a shall be set in the output message. **[E5]**

4.2.4.1.4 The probability of code detection is defined as, at each scan, for a given target, a radar target report with correct and validated code data, corresponding to the interrogation modes, is produced. **[A1]**

The probability of Mode A/Mode C code detection is determined by the ratio of the number of target reports with correct Mode A/Mode C code data to the number of target reports used to calculate the target position detection. **[A2]**

As a minimum, the overall Mode 3/A probability of correct and valid code detection shall be better than 98% for large samples, without any geographical restrictions, of opportunity traffic. **[E1]**

As a minimum, the overall Mode C probability of correct and valid code detection shall be better than 96% for large samples, without any geographical restrictions, of opportunity traffic. **[E2]**

4.2.4.1.5 It is expected that achieved performance figures will be higher than in 4.2.4.1.4 above. The Tenderer shall provide in the proposal details of the performance figures which the equipment shall be able to meet and state under what conditions. **[I1]**

4.2.4.1.6 The Tenderer should anticipate that the verification of code detection and validation as defined above will be undertaken for each site using large live traffic samples and the PTE tool set. **[A1]**

4.2.4.1.7 As a maximum the percentage of incorrect but validated Mode A codes shall be lower than 0.1%. **[E1]**

4.2.4.1.8 As a maximum, the percentage of incorrect but validated Mode C codes shall be lower than 0.1%. **[E1]**

4.2.4.2 Code Detection and Validation for Mode S

4.2.4.2.1 As a minimum, the ratio of the number of times a target is detected and output with all reply data correct compared to the number of times a target is detected and output shall be at least 99% for all targets replying in Mode S. **[E1]**

4.2.4.2.2 The Tenderer shall provide in the proposal details of the performance figures which the equipment shall be able to meet and state under what conditions. **[I1]**

The Tenderer should anticipate that the verification of code detection and validation as defined above will be undertaken for each site using large live traffic samples and the PTE tool set. **[A1]**

4.2.4.2.3 No more than one message segment containing false data of a Comm-B or Comm-D reply shall be delivered from the Mode S system in 10^7 messages. **[E1]**

4.2.4.2.4 The special civil codes 7500, 7600 and 7700 shall be detected and recognised, as defined in [Ref.1.]. **[E1]**

The above codes shall be output immediately upon detection, and not subject to any delay. **[E2]**

The appropriate identifier bits as specified in Ref 5a shall be set in the output message. **[E3]**

4.2.5 False and Multiple Target Processing (Mode 3/A,C,S)

4.2.5.1 False Target Processing

SSR Target reports generated by one or more of the following shall be classified as false target reports:

(a) FRUIT;

(b) Second time around echoes. **[E1]**

The false target report ratio is the number of false target reports in relation to the number of detected target reports. **[A1]**

The overall false target report ratio shall be less than 0.1%. **[E2]**

The Tenderer shall provide full analysis of the false target processing subject to the FRUIT rates and distribution of Annex G and state the maximum False Target Rate likely to be incurred under the operating conditions described in Annex G paragraphs G.2 and G.4. **[I1]**

The Tenderer shall anticipate that the verification of the false target rate as defined above will be undertaken for each site using the PTE tools set. **[A2]**

4.2.5.2 Multiple Target Processing

Multiple Mode S/SSR target reports shall include all those target reports generated by:

(a) Replies from an aircraft interrogated by the radar via an indirect path (reflection);

(b) Replies from an aircraft interrogated through a sidelobe of the directional antenna pattern and which are not inhibited by the sidelobe suppression antenna pattern (sidelobes);

(c) Target split in several sequences either in azimuth or in distance (splits). **[E1]**

The overall Multiple Mode S/SSR Target Rate, measured over one hour, shall be less than one target per scan on average. **[E2]**

The multiple target processing shall discriminate between false and real, non-unique addressed Mode S targets. The latter shall be flagged in the ASTERIX data item I048/030 Warning Error/Conditions bit 16 "Duplicated or Illegal Mode S Aircraft Address”. **[E3]**

The Tenderer shall provide details in the proposal of candidate methods to achieve such discrimination when targets are detected in the same beam-dwell. **[I1]**

The Tenderer shall provide full analysis of the multiple target processing subject to the FRUIT rates and distribution of Annex G and state the maximum

Multiple Target Rate likely to be incurred under the operating conditions of Annex G. **[I2]**

The Tenderer shall anticipate that the verification of the Multiple Target Rate as defined above will be undertaken for each site using the PTE tools set. **[A1]**

4.2.6 Surveillance Position Accuracy

4.2.6.1 General

The range and azimuth accuracy requirements specified herein shall be the minimum requirements. The Tenderer shall provide as part of the technical proposal:

(a) Detailed accuracy performance characteristics of the proposed equipment; **[E1]**

(b) Any conditions which impact the proposed performance characteristic; **[E2]**

(c) Detailed system level accuracy error budget analysis as described in Annex H. **[E3]**

Existing monopulse SSR system performance characteristics will be used as a benchmark for evaluating the Tenderers proposal. **[A1]**

The conditions, under which the random errors (azimuth and slant range error standard deviation) and systematic errors (azimuth and slant range bias) will be measured, shall be: **[E4]**

(a) Plot position data measured at the output interface to the Surveillance users;

(b) Non garbled pulse reply conditions;

(c) Aircraft within the Commissioning Volume;

(d) Interrogation conditions, received power and frequency levels as stated in Annex G;

(e) Separate measurements for:

  (i) Mode 3/A, C reports;

  (ii) Mode S all call reports;

  (iii) Mode S roll call reports.

(f) Long term effects (i.e., stability with time);

(g) Any combination of units/subsystems which are configured to meet redundancy requirements;

(h) Measurements using the conditions for accuracy test requirements stated elsewhere in this document and as stated by the Tenderer in his proposal.

The Tenderer should anticipate that the verification of accuracy as defined above will be undertaken for each site using some combination of live traffic, the fixed far field monitor, a Target/FRUIT generator and the PTE tool set. **[A2]**

4.2.6.2 Range Accuracy

The Mode S sensor slant range errors, for any modes (3/A, C or S), shall be within the following limits:

(a) Systematic Errors

(i) The slant range bias shall be < +1/128 NM (+14 metres). **[E1]**

(b) Random Errors

(i) All SSR Random errors shall be less than 30 m RMS (1 sigma) **[E2]**

(ii) All Mode S Random errors shall be less than 15 m RMS (1 sigma) **[E3]**

The speed of light value shall be a Site Dependant Parameter programmable, providing 2 values:

(a) The vacuum value (the only internationally recognised one): c = 299,792,458 $m.s^{-1}$;

(b) Another value (to be specified by the Agency) **[E4]**

The programming of this site-dependant parameter shall be possible at the CAM or at the Dedicated Terminal to be delivered. **[E5]**

The Tenderer shall clearly describe the effects of this SDP on the systematic and random range errors. **[I1]**

4.2.6.3 Azimuth accuracy

All detected targets within the stated coverage volume for any modes (3/A, C or S), measured using live traffic or controlled test transponders shall be within the following limits:

(a) Systematic Errors

(i) The azimuth bias for elevation angles between 0 and +6° shall be less than 1 AU (0.022°) where 1 AU represents 360/16384°). **[E1]**

(ii) The azimuth bias for elevation angle values between 6 and +10° shall be lower than 0.033° (excluding ice and wind effects on the antenna). **[E2]**

(b) Random Errors

(i) All azimuth random errors shall be less than 0.068° (one sigma) **[E3]**

The azimuth bias shall not increase at elevation angles more than 10° by an amount attributable to the antenna (e.g. beam widening effects -normally the inverse cosine of the elevation angle). **[E4]**

The system azimuth bias elevation changes attributable to the antenna beam widening at large elevation angles shall be stated by the Tenderer in his proposal. **[I1]**

This value shall be verified by tests of the antenna as part of the overall system test. **[E5]**

4.2.6.4 Bias Adjustment and Stability

The bias null adjustment in range and azimuth shall be applied by site dependent adaptation values. **[E1]**

The bias adjustments for the redundant channels shall be capable of being applied separately and independently such that the system bias requirements are met irrespective of the channel in use. (e.g., the data from either channel must meet the system requirement.). **[E2]**

Operationally compatible calibration procedures, employing these capabilities, shall be developed and used as part of accuracy tests. **[E3]**

Once the system bias values are nulled, the long term measured bias value (bias drift) shall remain within the specified limits, irrespective of the channel in use. **[E4]**

The angular offset shall be adjusted in order to calibrate the angular measurement of the Mode S system to within 1AU (i.e. AU = 0.022°) **[E5]**

4.2.6.5 Range and Azimuth precision

Target range shall be reported to a precision of at least 1/128 NM at all ranges. **[E1]**

Target azimuth shall be reported to a precision of at least 360/16384 (0.022)° at all ranges and azimuths. **[E2]**

The Tenderer should anticipate that the verification of range and azimuth precision as defined above will be undertaken for each site using a Target/FRUIT generator and the PTE tool set. **[A1]**

4.2.6.6 Jumps

Jumps are defined in [Ref.11.] as being reports with positional error higher than 1° in azimuth or 700 m in range. **[A1]**

The overall jump rate, defined in [Ref.11.] as being the number of jumps divided by the number of detected reports, shall be less than 0.05%. **[E1]**

4.2.7 Target Processing

4.2.7.1 Performance with Garbling Targets

4.2.7.1.1 General

4.2.7.1.1.1 It is expected that the achieved performance figures will be higher than the following minimum requirements of 4.2.7.1.2 to 4.2.7.1.5. **[A1]**

It is anticipated that the figures below are achieved for all operational ranges and associated turning rates and IRF specified in Annex G. **[A2]**

The Tenderer shall provide in the proposal details of the performance figures which the equipment shall be able to meet and state under what conditions. **[I1]**

4.2.7.1.1.2 The Tenderer shall include in the proposal a detailed analysis of the resolution and garble performance of their system (including Mode 3/A, C codes and Mode S addresses), stating any conditions for which the requirements of 4.2.7.1 will not be achieved including the limits of relative amplitudes and relative off boresight angles of interfering replies. **[I1]**

4.2.7.1.1.3 The Tenderer shall detail in the proposal how the azimuth's accuracy of the reply is determined. **[I1]**

4.2.7.1.1.4 The system shall be capable of processing up to four discrete, mutually overlapping replies simultaneously rejecting all possible phantoms produced by them, including C2/SPI phantoms. **[E1]**

Genuine targets, including relative targets with C2/SPI spacing, shall not be rejected as phantoms. **[E2]**

The Tenderer shall provide details in the response on his proposed method of handling phantom replies. **[I1]**

4.2.7.1.1.5 The Tenderer shall include in the Power Up Checks a test with simulated targets generated by the TTG function (Test Target Generator). This function shall generate artificial plots within a complete scan to test the basic functionalities of the Link Control (LC). This test process will not result in a plot delivered off the site. **[E1]**

The Tenderer shall provide details in the response of the proposed method of TTG. **[I1]**

4.2.7.1.2 SSR Positional Detection with Garbling Target

4.2.7.1.2.1 Within a separation window area of 0 NM to less than 0.05 NM in range and 0 to 0.6° in azimuth, the overall probability of detecting two SSR targets shall be at least 60%. **[E1]**

4.2.7.1.2.2 Within a separation window area of greater than 0.05 NM to less than 2 NM in range and by less than 0.6° in azimuth, the overall probability of detecting two SSR targets shall be at least 98%. **[E1]**

4.2.7.1.2.3 Within a separation window area less than 2 NM in range and by more than 0.6° and by less than 4.8° in azimuth, the overall probability of detecting two SSR targets shall be at least 98%. **[E1]**

4.2.7.1.2.4 Outside the separation window areas as defined in 4.2.7.1.2.1 to 4.2.7.1.2.3, the probability of detection shall be the same as described in paragraph 4.2.3.1. **[E1]**

The Tenderer should employ a Target/FRUIT Generator and the PTE tool set to verify the average Pd of two SSR Mode 3/A,C targets as defined above. **[A1]**

The Tenderer shall provide guaranteed values for the probability of detecting an SSR target for each of the above defined areas. **[I1]**

4.2.7.1.3 Mode S Detection with Garbling Reply

4.2.7.1.3.1 Whatever the relative position of both targets, the radar shall maintain the Probability of detection specified in 4.2.3 when using selective surveillance interrogations. **[E1]**

The Tenderer shall state in the proposal the expected acquisition performance for both targets when using stochastic acquisition. **[I1]**

4.2.7.1.3.2 If two replies were to be received simultaneously by the radar, The Tenderer shall provide in the proposal details of the probability of detection for a Mode S short and long reply garbled over an overlapping time ‘ t’ as listed below with an SSR or Mode S reply.

(a) t =< 20 microseconds **[I1]**

(b) 20 < t =< 32 microseconds **[I2]**

(c) 32 < t < 64 microseconds **[I3]**

(d) t => 64 microseconds **[I4]**

The Tenderer should anticipate that the verification of Mode S detection with a garbling target as defined above will be undertaken for each site using a Target/FRUIT generator and the PTE tool set. **[A1]**

4.2.7.1.4 SSR Correct Code Detection with Garbling Targets

4.2.7.1.4.1 Within a separation window area of 0 NM to less than 0.05 NM in range and 0 to 0.6° in azimuth, the overall probability of detecting two SSR targets with correct and valid Mode 3/A, Mode C codes shall be at least 30%. **[E1]**

4.2.7.1.4.2 Within a separation window area of greater than 0.05 NM to less than 2 NM in range and by less than 0.6° in azimuth, the overall probability of detecting two SSR targets with correct and valid Mode 3/A, Mode C codes shall be at least 90%. **[E1]**

4.2.7.1.4.3 Within a separation window area less than 2 NM in range and by more than 0.6° and by less than 4.8° in azimuth, the overall probability of detecting two SSR targets with correct and valid Mode 3/A, Mode C codes shall be at least 98%. **[E1]**

The Tenderer should anticipate that the verification of SSR code validation with a garbling target as defined above will be undertaken for each site using a Target/FRUIT generator and the PTE tool set. **[A1]**

4.2.7.1.5 Mode S Decoding Performance with Garbling Replies

4.2.7.1.5.1 Whatever the relative position of both targets, the radar shall maintain the decoding probability and reply integrity specified in 4.2.4.2 for all Mode S selective interrogations. **[E1]**

4.2.7.1.5.2 If two replies were to be received simultaneously by the radar, The Tenderer shall provide in the proposal details of the decoding probability for a Mode S short and long reply garbled over an overlapping time ‘t’ as listed below with an SSR or Mode S reply.

(a) t =< 20 microseconds **[I1]**

(b) 20 < t =< 32 microseconds **[I2]**

(c) 32 < t < 64 microseconds **[I3]**

(d) t => 64 microseconds **[I4]**

The Tenderer should anticipate that the verification of Mode S code validation with a garbling target as defined above will be undertaken for each site using a Target/FRUIT generator and the PTE tool set. **[A1]**

4.2.7.2 Target Loads

4.2.7.2.1 The number of targets to be processed will depend on the operational range of the radar and the range distribution of the targets. For modelling and test purposes the target load shall be assumed to vary with range as shown in G.4. **[A1]**

4.2.7.2.2 The radar systems offered shall be capable of processing at least the following number and distribution of targets from 0.5 NM to 256 NM instrumented range with a rotating antenna turning rate of at least 10 rpm:

(a) A steady state maximum of 900 transponder equipped aircraft in cover; **[E1]**

(b) A large sector peak of 45° containing 25% of the total number of aircraft. Only one large sector peak shall be present in each 90° quadrant; **[E2]**

(c) A small sector peak of 3.5° containing 6% of the total number of aircraft. Two small sector peaks, centrally located within each of two large sector peaks separated by 180° shall be the maximum number of small peaks occurring. **[E3]**

The numbers of targets specified above are considered to be numbers of real targets and do not include false target replies. **[A1]**

The distribution of sectors, described above, is illustrated in Figure 16. **[A2]**

The Tenderer shall state in the proposal details of the minimum processing capabilities for the sectors defined above for each of the scenarios of the following:

(a) All transponders shall be Mode S. **[I1]**

(b) 50% of transponders shall be Mode 3/A,C and 50% shall be Mode S. **[I2]**

(c) 25% of transponders shall be Mode 3/A,C and 75% shall be Mode S. **[I3]**

4.2.7.2.3 The Interrogator-Receiver and System Management Function shall EACH be demonstratively capable of processing without data loss or corruption or overload, and within the maximum system delay (refer to 4.2.7.3.2), the target and FRUIT loads defined by the models in paragraph 4.2.7.2.2 and Annex G with the following additional condition:

(a) The system shall be able to maintain the tracks of up to 12 targets simultaneously through the "Cone of Silence" using historical data, so as to facilitate target to track correlation following the targets exit from the Cone of Silence; **[E1]**

The Tenderer shall provide in the proposal an outline test specification and procedure as part of the Test Strategy, including a description of load models to demonstrate the load capability, taking account of both main beam and sidelobe received replies. **[I1]**

Equipment acceptance testing will be required to demonstrate load processing capability based on the models of this section. **[A1]**

4.2.7.2.4 The Mode S station shall be designed to optimise the number of transactions (i.e. minimising the number of interrogations/replies required for the particular protocol whilst also making most efficient use of the available channel time) by using techniques such as interleaving, azimuth offset and interrogation combination. **[E1]**

The Tenderer shall provide in the proposal details of the methods used in the scheduler to optimise the number of transactions. **[I1]**

If the aircraft indicates in a surveillance reply that data (including Mode A code and Flight ID) is waiting to be extracted from the transponder, the ground station shall be able to extract the data during the same beam dwell, unless the surveillance reply is received in the last roll-call period of the beam dwell. **[E2]**

In the case of absence of a reply to a Comm-A interrogation also used for surveillance purpose, the system shall re-interrogate the aircraft with separated surveillance (UF4, 5) and Comm-A interrogations (UF20, 21), and shall attempt to schedule these new interrogations in the same scan. **[E3]**

The Tenderer shall describe how the above function will be implemented. **[I6]**

For Mode S targets, the system shall extract the Mode A code and BDS 2,0 on acquisition and on change. **[E4]**

Mode A code and BDS 2,0 shall automatically be extracted by the station when the last measured position of the track is older than 18 seconds. **[E5]**

The Tenderer shall include in his proposal details of the Mode S radar's processing capabilities for the uplink and downlink transfer of SLM and ELM, including details of how messages are prioritised. **[I4]**

For the purposes of modelling it shall be assumed that:

(a) The target load distribution conforms with that described in G.4

(b) The interrogation limits for Mode S interrogators are at the maximum as defined in [Ref.1.].

(c) The performance level of Mode S transponders is as defined in [Ref.1.]. **[A2]**

The Tenderer shall clearly state any assumptions made in the response. **[I5]**

4.2.7.3 Processing Delays and Overload Conditions

4.2.7.3.1 The Mode S system shall combine PSR, SSR and Mode S target reports for all instrumented ranges up to 256 NM. **[E1]**

The Input Angle is defined as the angle at which the antenna is pointing when a plot is received by the PAF. **[A1]**

The Output Angle is defined as the angle at which the antenna is pointing when a plot is queued for output to the data transmission system. **[A2]**

The Overload Angle is defined as the maximum angular delay between the input and output angle that can be tolerated. Plots still queued for output to line after the overload angle are subject to data rate control. **[A3]**

The Tenderer shall provide all necessary information about the combination processing:

(a) Criteria used (proximity, quality,.....)

(b) Correlation window (size,....)

(c) Measured position definition for combined plots (weighting,.....)

(d) Processing time **[I1]**

The Tenderer shall state how many SSR/Mode S targets and PSR targets can be combined per second. **[I2]**

The Tenderer shall state how the following cases are processed:

(a) There are multiple PSR targets candidates for combination with one SSR/Mode S target;

(b) There is only one PSR target candidate for combination with several SSR/Mode S targets;

(c) There is one SSR target report candidate for combination with one Mode S target. **[I3]**

4.2.7.3.2 The target delays from the time of illumination by the antenna boresight to the input of the target report to the PAF under full load conditions shall be, for normal continuous scanning, in azimuth order within the equivalent of 45° scanning time. **[E1]**

The total system delay from illumination of the target by the antenna boresight to transmission of the target report from the PAF under full load conditions shall not exceed a time equivalent to 120° of an LVA antenna rotation and shall not exceed more than 2 seconds independent of the turning rate as defined in [Ref.11.]. **[E2]**

The overall Mode S system delay for a co-located system, defined as the overload angle shall be programmable between 0°-120°, but it shall not exceed more than 2 seconds independent of the turning rate. **[E3]**

This will enable the waiting time to be programmed. A larger value will increase the probability of combination. **[A1]**

The Tenderer shall state in the proposal the maximum target and system delays accounting for plot processing delays and full loads, but not accounting for data delays due to output clock rates. **[I1]**

4.2.7.3.3 The Tenderer shall provide in the proposal a budget of the delays incurred by each part of the processing for the load conditions of paragraph 4.2.7.2, Annex G. **[I1]**

4.2.7.3.4 The system shall be able to 'manage' overload or potential target processing delays in excess of the target and reply rates specified in paragraph 4.2.7.2, and Annex G, in particular minimising loss and preventing corruption of target data at the output. **[E1]**

4.2.7.3.4.1 Plot Output Overload

A priority scheme has been defined, from the highest priority information (a) to the lowest (e):

(a) Any Real Time Quality Control* messages, Status, Sector messages, Military and SSR emergencies (7500, 7600, 7700), Mode S alert flags, Military Identity;

(b) Mode S/SSR plots (combined plots if the primary option has been chosen) in the area of interest;

(c) Mode S/SSR plots (combined plots if the primary option has been chosen) not in an area of interest;

(d) Primary only data (if the primary option has been chosen);

(e) Enhanced Surveillance transactions only (inclusive ACAS broadcast). **[A1]**

* Real Time Quality Control messages are delivered each scan to report the system status and health to the Air Traffic Control Centre.

When these Real Time Quality Control messages (test targets) are output to the ATCC users, the corresponding Asterix Category 48 target reports shall be labelled accordingly with the bit "TST" set within the field I048/020" Target Report Descriptor ". **[E1]**

A site-dependant parameter shall enable:

(a) Either to output the RTQC (test targets) to the ATCC users;

(b) Or not to output these RTQC (test targets). **[E2]**

The programming of this site-dependant parameter shall be possible either at the CAM locally or remotely **[E3]**

If processing delays or overloads occur due to limitations at the plot output (eg data transmission link) then reduction shall use the above priority scheme. **[E4]**

The above priority scheme shall reference to an area of interest which shall be defined in data rate control maps. **[E5]**

'Areas of Prime Interest' (a maximum of 1 per sector) are defined in the system in which plots are raised to a higher priority level than those plots not in the 'Area of prime Interest'. The plots which attain the highest priority will be selected for transmission first. **[A2]**

The Tenderer shall describe in the proposal operationally acceptable methods of overload management employed and detail the effects of overload, in particular on the performance of the system, and state the conditions under which data may be lost. **[I1]**

4.2.7.3.4.2 Internal Overloads

Each part of the system processing shall be monitored for overload conditions which shall be reported locally and remotely. **[E1]**

On completion of overload conditions the event shall be reported locally and remotely. **[E2]**

When conditions are such that an overload of the system occurs, the subsequent removal of the overload shall allow the system to recover and to function normally without the need for any manual intervention. **[E3]**

The system shall be able to cope with, and to recover from, any overload caused by an out of specification input loading of PSR plots. **[E4]**

The Tenderer shall describe in the proposal any form of dynamic thresholding or limiting employed to manage overloads by reducing the detection and output of pulses, replies or target reports including:

(a) The point of application of the threshold ie receiver output, reply output. **[I1]**

(b) The conditions under which the threshold is activated. **[I2]**

(c) The effect of the threshold on target detection. **[I3]**

(d) The indications that are provided to show that the threshold is in operation. **[I4]**

(e) The effect on the Surveillance Co-ordination Function **[I5]**

4.2.7.4 Datalink Scenarios

4.2.7.4.1 General

The radar system offered shall be capable of processing the two following data link models. **[E1]**

The Tenderer shall include in the response details of the proposed methods to test the models outlined below, detailing all the assumptions and calculations. **[I1]**

4.2.7.4.2 Datalink Model ‘A’

The aim of this model is to prove the capabilities of the Interrogator Transmitter. **[A1]**

12 aircraft are to be serviced by 5 Mode S scheduling periods in a 40 ms beamwidth. Each schedule is allocated a 5 ms period. The data link transactions which occur are as follows:

(a) Schedule 1: 12 short interrogations (i.e. an UELM reservation is transmitted to each aircraft and assume that the reply from each aircraft includes the DELM announcement);

(b) Schedule 2: 48 Comm Cs are transmitted (i.e. 4 Comm-Cs to each aircraft);

(c) Schedule 3: 12 short interrogations (i.e. a combined DELM reservation and surveillance to each aircraft);

(d) Schedule 4: 12 Comm C (i.e. Extract a single DELM from each aircraft);

(e) Schedule 5: 12 short interrogations are transmitted (i.e. an interrogation combining Comm C and Comm D closeout functions for each aircraft). **[A2]**

The Contractor shall test the above scenario for a defined number of random runs (minimum 250) each using a different time distribution. **[E1]**

The minimum probability of success for each scenario shall be 90%. **[E2]**

Between each of the above Roll-Call schedules, there shall be an All-Call period with a UF11 and a Mode A or C interrogation. **[A3]**

4.2.7.4.3 Datalink model 'B'

The aim of this model is to prove the ability of the RTCC to optimise the scheduling sequence for interrogations and replies subject to constraints of [Ref.1.] on Mode S transponders and Mode S interrogators. **[A1]**

In order to reflect the current strategy for Mode S, to perform Enhanced Surveillance in the early years, the scenarios assume a background rate for GICB on each aircraft. **[A2]**

For each scenario the traffic shall be considered as equally distributed in azimuth, and distributed in range as follows:

(a) Scenario 1

Range NM	5-10	10-20	20-40	40-60	60-80	80-90	90-130	130-150
Distribution	1	3	12	7	7	2	6	10

(b) Scenario 2,3,4

Range NM	5-10	10-20	20-40	40-60	60-80	80-90	90-130	130-150
Distribution	1	1	6	4	3	1	3	5

(c) Scenario 5

Range NM	5-10	10-20	20-40	40-60	60-80	80-90	90-130	130-150
Distribution	0	1	3	2	2	1	1	2

Note: The above definition shall be applicable for a random distribution in each range band. **[A3]**

The site parameters are assumed to be:

(a) Min range: 5 NM

(b) Max range:150 NM

(c) Scan rate: 4 seconds **[A4]**

The normal (background) traffic density is 6 aircraft distributed in all 3.5° sectors, except in two adjacent peak sectors, for scenario 2-5 and a single peak sector for scenario 1. The density of these peak sectors is defined in each scenario. The peak sectors are met only once per scan. The background load can be considered as 1 aircraft every 0.6° **[A5]**

The aircraft involved in the datalink transactions shall always be those aircraft encountered in the first peak sector. **[A6]**

The station operates in multisite mode and each datalink transaction includes all consequent protocol (reservation, closeout etc.). **[A7]**

All requested BDS registers end in ‘0’, and all interrogations elicit a decodable reply. **[A8]**

(a) Scenario 1

(i) Traffic density: 48 aircraft in 3.5° sector;

(ii) GICB rate: 1 GICB per aircraft;

(iii) Datalink transactions: 4 Comm-C and 4 Comm-D on three of them.

(b) Scenario 2

(i) Traffic density: 24 aircraft in 3.5° sector;

(ii) GICB rate: 3 GICBs per aircraft.

(c) Scenario 3

(i) Traffic density: 24 aircraft in 3.5° sector;

(ii) GICB rate: 2 GICBs per aircraft;

(iii) Datalink transactions: 16 Comm-C on only two aircraft.

(d) Scenario 4

(i) Traffic density: 24 aircraft in 3.5° sector;

(ii) GICB rate: 2 GICBs per aircraft;

(iii) Datalink transactions: 16 Comm-D on one of them.

(e) Scenario 5

(i) Traffic density: 12 aircraft in 3.5° sector;

(ii) GICB rate: 3 GICBs per aircraft;

(iii) Datalink transactions: 16 Comm-C on three aircraft and 16 Comm-D on three other aircraft.

The Contractor shall test each scenario for a defined number of test runs (minimum 250) with a different range distribution for each test run. **[E1]**

These tests will provide an overall probability of success for the scenario. **[A9]**

A test run will be considered as successful if all the transactions are achieved in one scan. **[A10]**

The minimum probability of success to complete transactions in one scan for each scenario shall be 90%. **[E2]**

4.2.8 Data Link Delays

4.2.8.1 All SVC/MSP packets delivered by an aircraft shall not be delayed more than 2/16th of a scan period (i.e. 44°) from the time of receipt i.e. the reception of the last segment of a frame at the receiver input until the contents of the frame is ready to be transmitted through the GDLP/Local User interface. **[E1]**

The Tenderer shall include in the proposal details of the calculations of what delays would be incurred for the transmission of downlink messages. **[I1]**

All SVC/MSP packets arriving at the GDLP/Local User interface, and not subject to any congestion due to priority management, shall not be delayed for more than 2/16 of a scan period (i.e. 44°) from receiving the last bit in the message from the GDLP/Local User interface, until they are available in the transmitter for transmission to the aircraft. **[E2]**

The Tenderer shall include in the proposal details of the calculations of what delays could be incurred for the transmission of uplink data messages, i.e. from the time of receipt from the GDLP/Local User interface until they are available for transmission to the aircraft. **[I2]**

4.2.8.2 The Mode S station shall be capable of performing the extraction of the ACAS broadcast, not later than one antenna revolution after its announcement subject to the probability of detection described in 4.2.3.1. **[E1]**

4.2.8.3 The Mode S station shall be capable of retrieving the new Mode A code not later than one antenna revolution after detecting the alert flag subject to the probability of detection described in 4.2.3.1. **[E1]**

4.3 SSR Monopulse upgrade

4.3.1 Some states might choose to go to Mode S by upgrading their existing monopulse ground stations. **[A1]**

The Tenderer shall provide details in the proposal of their development plans to upgrade their monopulse systems to Mode S. **[I1]**

The Mode S system shall be designed in such a modular way that by using part of the Mode S system it will be possible to upgrade an SSR monopulse sensor. **[E1]**

4.4 Spare

4.5 Provision for E-SCAN communication only antenna collocation

4.5.1 It is anticipated that E-SCAN will not be used for the first step of the Mode S implementation. **[A1]**

4.6 General Requirements

4.6.1 Equipment Qualification

4.6.1.1 The Mode S Interrogator Receiver, Antenna, System Management Function, Surveillance Co-ordination Function, Data Link Function, Control Monitoring and Local Display System shall be supplied as a fully integrated system. **[E1]**

4.6.1.2 Information shall be included in the proposal on current operational identical equipments and/or field trials previously carried out on the same type and functionally identical equipments to those offered. **[I1]**

4.6.1.3 The statement of compliance and the proposal shall indicate the development stage of the relevant item against the Specified paragraph number. **[E1]**

The Tender Response shall include a complete description of the equipment design along with a development plan for completion of the equipment design. **[E2]**

The Tenderer shall identify in the Tender Response the main elements of the proposed system and whether they are readily available. **[I1]**

The subsystems and equipment which are to be developed shall be identified in the Tender Response and the proportion of development, hardware and software, shall be indicated with timescales in the development plan. **[I2]**

The appointed Contractor shall be required to prove the equipment by factory and site acceptance testing (times and frequency to be decided). **[E3]**

4.6.1.4 The Tenderer shall provide full information on:

(a) The stability of the proposed system, particularly with regard to amplitude and phase variations. **[I1]**

(b) The maintenance requirements of the proposed system **[I2]**

4.6.1.4.1 The Tenderer shall describe in the proposal the setting up and calibration procedures to obtain range and azimuth registration (i.e. north alignment and range zero relative to P3 or P6 synch phase reversal) and quote the accuracy obtainable. **[I1]**

4.6.2 Configuration

4.6.2.1 The system to be supplied shall be dual channel, complete with changeover capability, controlled both locally and remotely by the CAM. **[E1]**

4.6.2.2 Each channel of the dual channel Mode S station shall operate in any of the three operating modes as follows:

(a) Active: the equipment is used for the operation of the station **[E1]**

(b) Stand-by: the equipment is switched on and normally available for operation, i.e. a reconfiguration, automatic or controlled, can take place. **[E2]**

(c) Only the redundant equipment can be in the stand-by mode. **[A1]**

(d) Maintenance: the equipment is under maintenance and is not available for operation. **[E3]**

For dual channel configurations any fault state shall be reported to CAM. **[E4]**

4.6.2.3 In a dual channel system there is only one channel which shall be Active. **[E1]**

Switching from a Stand-by mode to an Active mode is performed according to a 'cold switch-over' procedure by an operator command or by a 'hot switchover ' when the Active equipment fails. **[E2]**

Switching from Active to Stand-by mode is performed by a 'cold switch-over' procedure, by an operator command. **[E3]**

The normal procedure for switching to Maintenance mode is performed from the Stand-by mode, by an operator command. When exiting the Maintenance mode, switching is always performed to Stand-by. **[E4]**

Exiting the Maintenance Mode shall be possible by two mutually exclusive modes: 1) remotely via the CAM; or 2) locally by operator command authorised from the front panel. **[E5]**

4.6.2.4 The 'hot switch-over' procedure shall correspond to a failure of an Active equipment, where an automatic reconfiguration of the processing occurs through switching. **[E1]**

In case of 'hot switch over' the failing channel shall be automatically switched to Maintenance mode. **[E2]**

In the case of failure a 'hot switch-over' shall be inhibited in case of additional failure of the now active channel. **[E3]**

The Tenderer shall include in the proposal details of how the automatic configuration occurs and the effect on the overall system performance. **[I1]**

The switching shall be effective within one antenna revolution after the fault has been detected and comply with the requirements of 6.5.2. **[E4]**

The tenderer shall describe how the failures from the different LRUs and/or functions (Surveillance, SCF, DLF) are managed by the BITE and taken into account for switching decision. **[I2]**

4.6.2.5 The 'cold switch-over' procedure corresponds to the controlled switching of all the processing chains (in local or remote mode). It shall guarantee that no data, essential for surveillance, is lost during the switching. **[E1]**

The 'cold switch-over' shall take one antenna revolution to perform from operator input. **[E2]**

The Tenderer shall provide details in the proposal how the 'cold switch-over' is performed and how it affects the operation of the system. **[I1]**

4.6.3 Equipment Cabinets

4.6.3.1 The Tenderer shall describe in the proposal the means of maintenance and cable access. **[I1]**

Installed cabinets will generally be grouped on a channel basis. **[A1]**

4.6.3.2 The Tenderer shall state in the proposal the height, width, depth and weight of all the major equipment units, including equipment cabinets, identifying their location with respect to each other. **[I1]**

The Tenderer shall state in the proposal the height, width, depth and weight of all additional peripheral devices required to support the system. **[I2]**

The Tenderer shall give power consumption and heat dissipation figures for all the preceding equipment units. **[I3]**

4.6.3.3 The equipment installation shall be such that access to any equipment cabinet, the removal of any sub-unit, PCB, and the use where required of extender cards, external test equipment etc. is not impeded by any adjacent cabinets, units etc. **[E1]**

4.6.3.4 The Tenderer shall state in the proposal where forced air cooling is employed. **[I1]**

4.6.4 Interference

4.6.4.1 The Interrogator Receiver and the System Management Function shall both withstand and recover, with minimum delay, from the effects of cw interference. **[E1]**

At no time shall cw interference saturate or overload any part of the Mode S Ground System. **[E2]**

The receiver shall be capable of operating in the presence of cw (from -95dBm to -20dBm) and pulsed cw interference (illustrated as two overlapping pulse trains (with characteristics of Mode 3/A replies and Mode S preambles, except pulse width from 0.50 to 0.55 us). The first at -40dBm at the RF port, the second at -60dBm and lagging the first with a 0.7 us delay. The quantised output due to the second pulse train must be present); both types of interference may be received over the range 1080 MHz to 1100 MHz. **[E3]**

Following the removal of the detected cw interference replies shall be detected, decoded and processed, 2ms after the end of the interference. **[E4]**

The Tenderer shall provide information on the level and effects of interference that the Mode S ground system can tolerate. **[I1]**

The Tenderer shall state the modes accommodated and specify the level of protection from both ground and airborne IFF/SSR frequency systems that will be achieved. **[I2]**

The Tenderer shall state the reaction and recovery times of the protected system. **[I3]**

4.6.5 Peripheral Devices

4.6.5.1 The number of peripheral equipments required to support the system shall be minimal. **[E1]**

4.6.5.2 The Tenderer shall provide in the proposal a list of the peripheral equipments required to support the system. **[I1]**

All peripheral equipment required to support the operation of the system shall be included in the delivered equipment. **[E1]**

The Tenderer shall provide in the proposal details of all peripheral equipments, including any required for commissioning of the system such as PROM Programmers, special measurement tools, data recording devices etc. **[I2]**

The Specification for any peripheral equipment requirements (e.g. MMI, printer etc) shall be agreed with the Agency. **[E2]**

4.6.5.3 Common and internationally recognised interface standards shall be employed for all peripheral devices. **[E1]**

Wherever possible, the use of common peripheral equipments between different functions is preferred. **[A1]**

4.6.6 Processing Capacity

4.6.6.1 For the maximum loading conditions and for the FRUIT and reflection rates specified in Annex G,

(a) each single processor shall not be utilised for more than 50% of the time when this time stands for a complete antenna revolution. **[E1]**

(b) each single processor shall not be utilised for more than 80% of the time when this time stands for a small sector peak of 3.5°. **[E2]**

The Tenderer shall describe the maximum utilisation of each single processor for a scanning time corresponding to a large sector peak of 45°. **[I1]**

The Tenderer shall state in the proposal the processor utilisation contingencies over and above the maximum loading defined in Annex G **[I2]**

4.6.6.2 The system software shall not take up more than 50% of the available memory allocated for the system software. **[E1]**

The Tenderer shall state in the proposal the available storage contingency for the software for each part of the system. **[I1]**

4.6.6.3 For the maximum loading conditions of Annex G, the amount of Random Access Memory and disc storage in use at any time shall not exceed 50% of that available. **[E1]**

The spare random access memory above shall apply independently to global memory, and all individual processors within the proposed system. **[E2]**

The contingencies above shall be demonstrated and proved to be met during Factory Acceptance Testing of the systems, under maximum load conditions. **[E3]**

The Tenderer shall provide in the proposal an outline of how the achievement of the above contingencies will be demonstrated. **[I1]**

4.6.7 System Response Time

4.6.7.1 The response times of the Mode S system and any associated control and changeover equipment shall be as follows:

(a) For an off-mounted Mode S system, the maximum time between the start-up command of a ground station and the sending of a report on the surveillance line, regardless of the ON/OFF power states of the turning gear and electronics, shall not exceed one minute + two scans period after passing North. **[E1]**

(b) For a off-mounted Mode S system, the maximum time between the start-up command of a ground station and the sending of a report on the surveillance line, with the antenna rotating at its operational rate and with no power applied to the rest of the Mode S system, shall not exceed 21 s + three scans period after passing North. **[E2]**

The Tenderer shall provide in the proposal the maximum system response time for each of the requirements a) to b) above, where "passing North" is assumed to mean "first North crossing after azimuth data is reported as correct by CAM". **[I1]**

4.6.8 System Recovery

4.6.8.1 Upon the restoration of any of the inputs listed below, following a failure of that input, and irrespective of the duration of the failure, the ground station shall be fully restored to the operating conditions that applied before the failure occurred, without the need for any manual intervention:

(a) Azimuth data; **[E1]**

(b) External data clocks; **[E2]**

(c) Mains power supply; **[E3]**

(d) RF and SMF interfaces; **[E4]**

(e) Station CAM. **[E5]**

The Tenderer shall state in the proposal the maximum duration of any interruption of the above external inputs that can occur without affecting or impairing the operational status of the system. **[I1]**

The Tenderer shall state in the proposal for every external input, the effect on the plot assignor function of failure of that input, and the recovery state and recovery time following restoration. **[I2]**

4.6.9 System Expansion

4.6.9.1 It is essential that any proposed system is not only capable of fully meeting the load requirements defined in this Chapter but is also capable of meeting the indicated increases in loading during the life of the equipment. **[A1]**

The Tenderer shall state in his proposal the cost and the possible additional boards that are required to achieve the safety margin described in all the following requirement. **[I1]**

The systems load capacities shall be expandable to accommodate further growth in air traffic movements. **[E1]**

Traffic growth to 120% of the SSR and Mode S target figures specified in the model for target processing capacity shall be attainable without extension of the system delays of 4.2.7.3 and 4.2.8. **[E2]**

The design architecture shall be capable of supporting the above expansion requirements. **[E3]**

The Tenderer shall advise how the above expansion can be achieved. **[I2]**

This increase in capacity shall be attainable for a conventional rotating antenna scan rate of up to 15rpm or background surveillance update rate of 4 secs. **[E4]**

The Tenderer shall state in the proposal the maximum Mode S target, secondary target, and combined target capacities of the proposed system for delays not exceeding those above. **[I3]**

It is assumed that primary echo returns, secondary transponder replies, FRUIT and false target rates should increase in the same proportion as the traffic expansion. **[A2]**

4.6.10 Target Velocity Limits

4.6.10.1 The aircraft population to be controlled includes rotary winged and high performance fixed wing aircraft. Therefore the Mode S radar shall be capable of detecting and processing aircraft operating to the following performance parameters, in any combination. **[E1]**

(a) A steady state speed from 0 kn to 2000 kn; **[E2]**

(b) Spare;

(c) A vertical rate of climb or descent, as reported by the received Mode C data from 0 ft/min to 25000 ft/min; **[E4]**

(d) A vertical rate of climb as in (c) above with no horizontal displacement; **[E5]**

(e) A straight line acceleration/deceleration from any initial velocity in the range 0-2000 kn, from 0.01g to 5g, to achieve a steady state speed of between 0-2000 kn e.g. from 300 kn steady state, accelerating at 2g to 2000 kn. **[E6]**

The Tenderer shall advise what impact a combination of these parameters will have on the Mode S surveillance and datalink performance, particularly for aircraft at less than 25 NM range. **[I1]**

Provision shall be made for the values of the above parameters to be set to any value within the ranges specified. **[E7]**

Civil traffic is defined with the vertical rates and maximum speed defined above and accelerations (transversal and/or longitudinal) up to 2g. **[A1]**

Military traffic is defined with the vertical rates and maximum speed defined above and accelerations (transversal and/or longitudinal) up to 5g. **[A2]**

By default, all performance verifications shall be performed with a station configured to track at least civil traffic **[E8]**

The Contractor shall demonstrate, when configured for military traffic, that the system is capable of meeting the Probability of detection and the accuracy requirements for trajectories covering the military traffic velocity limits. **[E9]**

The Tenderer shall describe in the proposal how this range of aircraft performance will be accommodated and how the values of the above parameters are preset. **[I2]**

4.6.11 Power Up Checks

4.6.11.1 The following requirements will ensure that the radar system is not knowingly returned to service without the correct software/hardware build state or site default parameter settings. **[A1]**

(a) The Mode S system shall confirm the serviceability of RAM on power-up **[E1]**

(b) Each sub-system shall verify that the software issue of each board and prom on power up or reset is current. **[E2]**

(c) The Tenderer shall advise how each sub-system can verify that the hardware issue of each board on power up or reset is current. **[I1]**

(d) The Tenderer shall advise how each sub-system can verify that the site dependent default parameters on power up or reset is current. **[I2]**

In each of the requirements above an error message shall be produced if the test fails, but not cause a reset or shutdown. **[E3]**

The Tenderer shall include in the proposal details of the power up and reset checks. **[I3]**

4.6.12 Site Dependent Parameters

4.6.12.1 Site Dependent Parameters (SDPs) shall, wherever practical, be set by link settings, switches or stored in a suitable non-volatile medium (eg PROM). **[E1]**

SDPs shall not be hard-coded within any software of the system. **[E2]**

The adjustment of any SDPs shall not require any alteration or recompilation of the software. **[E3]**

SDPs contained in a PROM or other suitable medium shall be easily adjustable, for example via a connected terminal, or the local display facility. **[E4]**

It shall be possible to display all operational and 'key' site dependent parameters. **[E5]**

The CAM facility shall be employed to re-configure Agency designated operational parameters at the ground station. **[E6]**

Parameters that may be altered via a connected terminal, such as described in 4.6.5, require protection as follows:

(a) It shall only be possible to change parameters with the relevant system in 'local mode'; **[E7]**

(b) It shall not be possible to configure to 'remote' mode with temporary changes present, except by special action which shall ensure that the ATCC is advised of this special status via the CAM for as long as the condition exists; **[E8]**

(c) Unauthorised or inadvertent alterations shall be prevented, e.g. by password entry; **[E9]**

Details of the protection method shall be supplied in the Tender response. **[I1]**

The design approach shall be capable of ensuring that SDPs will not change in the event of a 'switch-over' of the active channel. **[E10]**

4.7 Environmental Conditions

4.7.1 Internal Conditions

4.7.1.1 Any equipment housed within the radar station equipment room(s) shall operate and maintain its full operational performance under the following conditions:

(a) Temperature: 0°C to +40°C **[E1]**

(b) Relative Humidity: 90% (non-condensing at +25°C) **[E2]**

Where it is agreed that COTS equipment may be employed in the radar station equipment room, the following condition is considered acceptable for that equipment:

(a) Humidity 80% (non-condensing at +25°C);

(b) Temperature +10 to +40°C. **[A1]**

4.7.2 External Conditions

4.7.2.1 Any equipment not housed within the radar station equipment room(s) or remote equipment shelter including Far Field Monitor, LVA antenna, turning gear together with any pedestal mounted electronics shall operate and maintain its full operational performance under the following conditions:

(a) Ambient Air Temperature: -40°C to +50°C; **[E1]**

(b) Relative Humidity: Up to 100% (Lower than 90% at 40°C); **[E2]**

(c) Driving Rain: Up to 60 mm/h; **[E3]**

(d) Snow load: Up to 200 kg/m^2 (in or out of operations and in transport); **[E4]**

(e) Solar radiation: 1135 W/m^{2}h during 4 hours; **[E7]**

(f) Hail: Up to 10 mm at 18 m/s; **[E5]**

(g) Wind resistance:

(i) In operation, bursts up to 160 km/h without frost or ice, up to 130 km/h with 12 mm frost or ice;

(ii) In survival, bursts up to 220km/h, without frost or ice, up to 180 km/h with 12 mm ice or frost. **[E6]**

4.7.2.2 All external equipment antennas and turning gear shall be resilient to salt atmospheres. **[E1]**

DEF-STAN 07-55 Test C6 provides guidance to the salt resilience to be attained. **[A1]**

4.7.2.3 The Tenderer shall provide in the proposal information on the effects on the detection and accuracy performance of 4.2.3 and 4.2.6 for a Mode S radar subject to severe fresh and salt water rime ice formation on the antenna. **[I1]**

The Tenderer shall provide in the proposal information on the effects listed above on the array gain and beam patterns. **[I2]**

The Tenderer shall provide in the proposal information on prevention of rime ice formation and/or recommendations to reduce the effects of these climatic conditions. **[I3]**

4.7.2.4 Full, individual environmental specifications for all external equipment shall be provided in the proposal. **[I1]**

4.7.3 Storage Conditions

4.7.3.1 All types of equipment, including spares, shall be capable of being stored under cover for a period of up to two (2) years at varying temperatures from -40°C to +60°C with an ambient relative humidity ranging from 40% to 90%, damp heat lower than 93% at 40°C without affecting either their operation and performance to specification, or their normal expected operational life. **[E1]**

Where it is agreed that COTS equipment may be employed, the following condition is considered acceptable for that equipment: Humidity 80% (non-condensing at +25°C); Temperature -10 to +60°C. **[A1]**

4.7.3.2 Any equipment with components whose operational life could include time in storage, for example memory devices dependent upon batteries, shall be identified and the appropriate precautions to be taken shall be described in the proposal, together with the maximum storage life. **[I1]**

The equipment items shall be capable of undergoing, in their package, the constraints related to the transport by air, sea or land. **[E1]**

4.8 Radar System Overview

4.8.1 System Interconnections

4.8.1.1 The Tenderer shall provide in the proposal system diagrams for the Mode S system showing the offered system configurations, equipment types and interconnections. **[I1]**

4.8.1.2 Where appropriate, specific details shall be given for signals, data formats etc., particularly where an interface is required between the Mode S system being provided against this specification, and another system outside the scope of this specification. **[I1]**

In other areas, where interface details have yet to be decided, general information shall be given by the Tenderer. The specific details of these interfaces will be defined and agreed with the Agency after contract award. **[I2]**

4.8.1.3 For the rotating antenna the Tenderer shall provide, in the proposal, detailed specifications of the rotating joints, with drawings, to meet the Mode S performance and interface requirements. **[I1]**

4.8.2 System Interfaces

4.8.2.1 The Mode S system shall provide interfaces for:

(a) Surveillance users; **[E1]**

(b) Networked Mode S stations; **[E2]**

(c) Datalink users; **[E3]**

(d) The Control and Monitoring System remote terminal; **[E4]**

(e) Primary Surveillance Radar; **[E5]**

(f) A playback and recording facility; **[E6]**

(g) An RF analysis facility. **[E7]**

4.8.2.2 In accordance with the above the Mode S system shall conform to the requirements of:

(a) [Ref.5.] **[E1]**

(b) [Ref.6.] **[E2]**

(c) [Ref.9.] **[E3]**

(d) [Ref.1.] **[E4]**

(e) [Ref.17.] **[E8]**

The ASTERIX formats described in [Ref.5.] and [Ref.6.] are likely to evolve; the current agreed version shall be used. **[E5]**

Design precautions shall be taken to minimise the impact of, and the effort necessary, to accommodate the introduction of ASTERIX format modifications; in particular to avoid any re-compilation when upgrading these formats. **[E6]**

The contents of the PSR-related data received in Asterix Category 1 and Category 2 shall be translated into the corresponding fields of the data to be delivered to ATCC users (Asterix Category 48 and Category 34) **[E7]**

4.9 Data Transmission

4.9.1 Time Function

4.9.1.1 The equipment shall include a Time Function to provide time to the system (including CAM) for the purpose of synchronisation and time-stamping. **[E1]**

The Time Function shall time-stamp the information using the information provided either by an external source or by an internal clock. **[E2]**

The system shall be capable to be interfaced with two external time sources. **[E3]**

In the event that the external source fails to deliver a time reference, the Time Function shall revert to the internal clock. This condition shall be reflected in the Time Source Status as part of the Station Configuration Status item of the ASTERIX Category 34 messages. **[E4]**

The maximum drift of the internal clock shall be less than 20ms per month. **[E5]**

The Tenderer shall state in the proposal the accuracy, resolution and drift of the internal and external time sources which are used for time-stamping. **[I1]**

The time-stamping process accuracy shall be such that measured position accuracy requirements defined in 4.2.6 are met for all aircraft speeds specified in 4.6.10 (i.e. position errors include those due to time-stamping inaccuracies). **[E6]**

The Tenderer shall state in the proposal at which level and how the time stamping information is effectively derived and output in the following target reports:

(a) For Mode S solo targets;

(b) For SSR solo targets;

(c) For PSR solo targets;

(d) For combined targets. **[I2]**

The Tenderer shall explain clearly in the proposal how the TSV bit of the data item I034/050 will be set, in particular for the following cases:

(a) At start-up;

(b) When the external time signal (e.g. GPS satellites signal) fails;

(c) When the time receivers (e.g. GPS receivers) fail;

(d) When the internal clock fails or drifts out of specification. **[I3]**

The Tenderer shall also state the consequences on the system behaviour (switch-over, data output...). **[I4]**

The Tenderer shall provide detailed information on the protocol and data format used between the external time sources and the Interrogator. **[I5]**

4.9.2 Transmission Network

4.9.2.1 The ground station shall be capable of processing continuously:

(a) Output of ASTERIX Cat 34 and Cat. 48 messages on up to three simultaneous, independently configurable, channels at an average rate of 250 messages/second each; **[E1]**

(b) Time stamping and merging of 32 Sector Messages per 360° rotation; **[E2]**

(c) Conversion of all equipment status messages into the Station Configuration Status message; **[E3]**

(d) Exchange of ASTERIX Cat. 17 messages to/from Surveillance Co-ordination Network at an average rate of 150 messages/second; **[E4]**

(e) Exchange of ASTERIX Cat. 18 messages to/from each of the GDLP/Local User interfaces at an average rate of 150 messages/second. **[E5]**

The Tenderer shall state in the proposal the maximum number of combined plot messages per second that can be processed and output, and under what conditions. All assumptions shall be stated. **[I1]**

Each channel shall be configurable independently in terms of data rate (9.6 to at least 128 Kbps for WAN interfaces and at least 100 MB for LAN interfaces), protocol (X.25 or HDLC Lap-B for WAN and TCP/IP, UDP/IP, IP v4 and v6 for LAN) and physical interface (RS-232/V.24 and a standard supporting RS-422/V.11 balanced circuits for WAN and IEEE 802.3 100BASE-T for LAN). **[E6]**

The type of standard supporting RS-422/V.11 balanced circuits shall be agreed with Agency prior to contract let (e.g. X.21, RS-449, RS-530...). **[E15]**

Channel throughput and protocol requirements differ from application to application (ATCC output, SCN or datalink connection) and are detailed in paragraphs 7.3.2.8, 8.3.1 and 9.2.1. **[A1]**

The HDLC Lap-B data link layer protocol and X.25 packet layer protocol implementations shall comply with the ITU-T/CCITT Recommendation X.25 1988. **[E8]**

The IPv4, IPv6, TCP, and UDP protocols shall comply respectively with the IETF RFC 791, 2460, 793 and 768. **[E16]**

The following restrictions shall be applied to X.25 connections used for the PILOT station:

(a) For SCN connections, only SVCs shall be allowed; **[E9]**

(b) The system shall support SVCs for all other connections; **[E10]**

(c) The address shall conform to the ITU-T X.121 Recommendation (non-TOA/NPI format); **[E12]**

(d) No optional X.25 user facility shall be used unless otherwise agreed with the Agency. **[E13]**

The Tenderer shall provide a completed ISO/IEC PICS Proforma to the Agency for the X.25 (ISO/IEC 8208) and the HDLC Lap-B (ISO/IEC 7776) implementations as part of their proposal, according to [Ref.15.] and [Ref.16.]. **[I3]**

The Tenderer shall provide information on the adaptation of channels to other communication protocols (such as TCP/IP), and other Wide Area Networks (such as frame relay, ATM...). **[I4]**

The Contractor shall provide external conformance certificate of the X.25 and HDLC Lap-B interfaces, by an independent 3rd party, to confirm compliance to the ISO/CCITT/ITU-T standards. **[E14]**

The size of the X25 packets should preferably be up to 512 bytes. **[A2]**

4.9.3 Cross Site Data Transmission

4.9.3.1 Digital and video signals transmitted within the confines of the off-mounted collocated site shall utilise high integrity data transmission methods. **[E1]**

4.9.3.2 The immunity to lightning strike shall be specified and detailed information on the protection methods employed shall be provided in the proposal. **[I1]**

4.9.4 Output Link Management (OLM)

4.9.4.1 The Contractor shall provide each Mode S ground station with a facility to manage the following services: communication to ATCC, SCN, PSR, Local User and GDLP. **[E1]**

A number of physical interfaces, to be defined by the Agency, shall be available to the communication services. **[E2]**

The Agency may choose, for some site configurations, not to have a physical PSR interface. **[A1]**

4.9.4.2 The OLM functionality shall:

(a) Ensure that no single failure condition has a critical consequence on communication services; **[E1]**

(b) Allow physical interface switchover without any resulting radar channel switchover; **[E2]**

(c) Allow radar channel switchover without any resulting physical interface switchover; **[E3]**

(d) Be monitored and controlled by the CAM; **[E4]**

(e) Be monitored by both radar channels; **[E5]**

(f) Allow to assign any communication service to any physical interface; **[E6]**

(g) Allow to assign several communication services to the same physical interface; **[E7]**

(h) Allow to assign several physical interfaces to the same communication service:

(i) To allow diverse routing of the same ATCC data through different physical interfaces;

(ii) To offer to use either two X.25 connections or two TCP/IP connections to access to the SCN;

(iii) To allow each radar channel to be connected to both PSR channels. **[E8]**

The provisions of (g) and (h) are intended to reduce the total number of physical connections, whilst still supporting diverse routing of the ATC outputs and meeting throughput requirements. **[A1]**

When several communication services are assigned to the same physical interface (i.e. multiple SVCs on a DTE-DCE link), the routing of each communication data flow to the right application should be done according to one of the following criteria:

(a) Distant DTE address;

(b) Content of the USER DATA field in Call Requests and Incoming Calls;

(c) Content of the X.121 sub-address. **[A2]**

The Contractor shall perform the above routing according to the criteria to be chosen by the Agency. **[E9]**

The provisions of (h) would still facilitate pre-configurable mapping of DTE or IP addresses to particular services (e.g. SCN). **[A3]**

An example configuration could be:

(a) 2 ATC services (all active);

(b) 1 GDLP service (only one active communication port);

(c) 1 Local User service (only one active communication port);

(d) 1 SCN service for each other node of the cluster (only one active communication port); and

(e) 2 PSR services. **[A5]**

4.10 Test Equipment

4.10.1 The Tenderer shall provide details of all equipment considered necessary to provide analysis of the ground station functionality and interfaces that cannot be achieved using PTE or an equivalent tool. This shall identify which items are available at no cost, and those requiring development. Where development is anticipated an associated plan, describing the proposed timescales, qualification and cost (quoted separately in the Commercial Response) shall be presented in the Tender Response. **[I1]**

4.11 Power

4.11.1 The equipment items shall be connected to a power distribution network supplying a nominal line voltage of 3 phase 400V -6%, +10% of frequency 50Hz +/-2%. **[E1]**

CHAPTER 5

ANTENNA SYSTEM

5.1 LVA Requirements

5.1.1 The requirements for the LVA antenna are specified in Chapter 13. **[A1]**

CHAPTER 6

INTERROGATOR SYSTEM

6.1 General

6.1.1 Introduction

6.1.1.1 The interrogator (Figure 5) shall consist of:

(a) A transmitter, providing sum and control channel output **[E1]**

(b) A monopulse receiver, accepting sum, difference and control channel input. **[E2]**

(c) A video signal process that provides processed Sum, RSLS and OBI signals **[E3]**

(d) An RF changeover unit to allow the standby channel to become the active channel. **[E4]**

The transmitter shall issue Mode S, Mode 3/A,C and Mode 1/2 interrogations and the receiver shall accept the Mode S, Mode 3/A,C and Mode 1/2 replies. **[E5]**

6.1.2 Functions

6.1.2.1 The interrogator shall have the following capabilities:

(a) Interrogation and reception on Modes 3/A, C, S and Modes 1/2; **[E1]**

(b) Mode S only all-call preceding either a Mode 3/A or Mode C interrogation by between 45 microseconds and 128 microseconds timed from the sync phase reversal to the leading edge of the P3, Mode 3/A,C. **[E2]**

(c) Operation on 3 mode interlace programmes, including stochastic All-Call and lockout override as shown in Figure 12; **[E3]**

(d) Operation in azimuth selectable improved interrogator sidelobe suppression (IISLS) for Mode 3/A,C or intermode; **[E4]**

(e) Operation of receiver sidelobe suppression (RSLS); **[E5]**

(f) Output of data suitable for plot processing; **[E6]**

(g) Control of all main functions of the interrogator shall be provided locally and remotely via the CAM interface; **[E7]**

(h) To receive interrogation modulation commands from the RTCC or external test equipment. **[E8]**

6.2 Transmitter

6.2.1 The transmitter shall provide:

(a) One sum channel (Pulse P1, P2, P3, P4 and P6 (with DPSK modulation) transmissions); **[E1]**

(b) One control channel (pulse P2, and P5 transmissions). **[E2]**

The P5 shall be transmitted on the control channel, in the case of Mode S All-Call or selective interrogations. **[E3]**

A detailed description of the interrogator transmitter with block diagram and specification shall be provided in the proposal. **[I1]**

6.2.2 The transmitter shall not require any adjustment or setting up following replacement of any unit. **[E1]**

6.2.3 The transmitter shall not require any regular or preventative maintenance of any unit. **[E1]**

6.2.4 As a minimum, the transmitter shall be capable of operating at a peak duty cycle of 63.7% over 2.4ms length of time. **[E1]**

It is expected that the above requirement can be repeated every 24ms. **[A1]**

The transmitter shall be capable of operating at a duty cycle of at least 5% over a whole scan. **[E2]**

The Tenderer shall include in the proposal information on the Mode S duty cycle capability, including Mode S modes of operation, intermode interlace, power and range performance and transmitter modularity. **[I1]**

6.2.5 The SSR/All-Call period shall be used for the surveillance of Mode A/C transponder equipped aircraft and the acquisition of Mode S transponder equipped aircraft. **[E1]**

The Selective Interrogation period shall be used for the Mode S Roll-Call surveillance and data link transactions. **[E2]**

The internal IRF for the SSR/All call period shall be adjustable from 50Hz to 250Hz with increments no greater than 1Hz. **[E3]**

The SSR/All Call period shall be constant or staggered. The stagger may be a fixed sequence, random or pseudo random (eg 64 stagger periods which are selectable and a deviation of 0% up to +10% in 1/2% steps from the mean IRF). **[E4]**

The Tenderer shall describe the method of stagger generation. **[I1]**

A Mode S only All-Call interrogation shall occur once every 'm' SSR/All-Call periods, where 'm' shall be a site configurable parameter between 1 to 9 in steps of 1. **[E5]**

6.2.6 Stochastic lockout over-ride shall be selectable to acquire aircraft (see Figure 12 for examples). **[E1]**

The Tenderer shall provide details on how stochastic lockout override shall be implemented in their proposal. **[I1]**

6.2.7 A number of mode programmes shall be selectable on an antenna scan basis. It shall be possible to set-up at least the following mode programmes:

(a) Single SSR Mode; **[E1]**

(b) Dual SSR Mode Interlace; **[E2]**

(c) Triple SSR Mode Interlace (eg A,A,C); **[E3]**

Antenna scan interlace, whereby different triple mode interlaces may be transmitted, each on up to three alternate antenna revolutions shall be available. **[E4]**

Change in interlace shall be applied on the North crossing. **[E5]**

The Tenderer shall state in the proposal the modes and interlace programmes available as standard and as options, including Mode S. **[I1]**

The Tenderer shall describe in the proposal how Mode S interrogations may be selected, interlaced and transmitted. **[I2]**

The triple mode interlace shall include Mode 1 and Mode 2. **[E6]**

6.2.8 A number of programmes shall be selectable on a per sector basis (each sector representing 1/32 antenna revolution). The illumination period for an aircraft by the beam shall be divided into a defined number of intervals. Each interval shall represent one All Call or one Roll Call period. The minimum number and the content of All Call periods shall be defined according to the previous selected antenna scan mode programme, i.e. for two hits per SSR mode:

(a) Single mode: two All Call periods,

(b) Dual mode: four All Call periods

(c) Triple mode interlace: six All Call periods

The interlace of the modes is defined in 6.2.7, and the minimum duration of each All Call period shall be adjustable to the operational range in the particular sector. The total number of intervals shall not exceed 12; and the duration and type of each interval shall be defined separately, but consistently. All parameters associated to the sector scan programme shall be considered as Site Dependent Parameters. **[E1]**

6.2.9 The peak transmitter power output on both the sum and control channels shall be determined from the max. range requirement described in 4.2.2.1. **[E1]**

The Tenderer shall submit uplink and downlink power budget calculations to support the above requirement. **[I1]**

The Tenderer shall state in the proposal the peak output power available. **[I2]**

It shall be possible to vary the output power of the interrogator and control pulses. **[E2]**

Variation of the interrogate and control output powers shall allow a power variation at least over the range from maximum power to 12dB below maximum power. **[E3]**

Output power variation for both interrogate and control outputs shall be in increments no greater than 2.0dB and to an accuracy of at least +1.0dB. **[E4]**

The Tenderer shall state in the proposal the minimum independent power variation between the interrogator and the control pulses, the incremental steps and the accuracy of the incremental steps. **[I3]**

The Tenderer shall provide details in the proposal of the method to vary power depending upon the range of the Mode S transponder equipped aircraft. **[I4]**

6.2.10 It shall be possible to vary the interrogate and control output power, on each selective interrogation, according to the range of the target. **[E1]**

It shall be possible to programme as a function of azimuth over a number of unequal sectors, not less than 32, over 360°, the interrogate and control powers pertinent to both Mode S All Call and SSR operation. **[E2]**

The Tenderer shall describe the method of achieving power variation with azimuth and range. **[I1]**

6.2.11 A system limiting the number of interrogations shall protect the transmitter against overloads and shall guarantee that the requirements as specified in [Ref.1.] para 3.1.2.11.1.2 are not exceeded. **[E1]**

If the limits are exceeded then the surveillance interrogations shall have priority. **[E2]**

The Tenderer shall provide in the proposal details of the protection of the transmitter. **[I1]**

6.2.12 IISLS shall be available for interrogations by transmitting both pulses P1 and P2 on the control channel. **[E1]**

When IISLS is enabled it shall be possible to manually adjust the power of pulse P1,in steps of 1.4° for the azimuth and in steps of 2dB for the power till the decrease does not exceed the level of 6dB below the power of pulse P2. **[E2]**

The Tenderer shall provide in the proposal information on IISLS to clearly show its method of implementation and performance, including the radar range over which it is available, effects on transmitted powers, detection and false targets, particularly in a congested Mode S/SSR environment. **[I1]**

6.3 Receiver

6.3.1 Configuration

6.3.1.1 The receiver shall provide:

(a) Sum, difference and control channels; **[E1]**

(b) Outputs to the receiver video process utilising data from the sum, difference and control channels. **[E2]**

The Tenderer shall provide a detailed description of the receivers with block diagrams and specification in the proposal. **[I1]**

6.3.2 Functions

6.3.2.1 The receiver shall perform the following functions:

(a) RF filtering **[E1]**

(b) RF amplification if necessary **[E2]**

(c) IF conversion, IF filtering and logarithmic IF amplification. **[E3]**

6.4 Receiver Video Processing

6.4.1 Functions

6.4.1.1 The azimuth data, received from the azimuth data generator, shall be decoded and used to determine boresight. **[E1]**

Processed Sum Video, RSLS and Off Boresight Indication signals shall be provided to the RTCC. **[E2]**

SSR and Mode S All Call Processed Sum video, together with OBI, shall be provided for local monitoring. **[E3]**

6.4.1.2 The detected pulse output, following pulse detection and quantisation, shall accurately reflect the received pulse. **[E1]**

The Tenderer is referred to the definition for quantised video for monopulse systems in [Ref.12.]. **[A1]**

6.4.1.3 STC, or an equivalent thresholding method, shall be provided and it shall be possible to select either a linear or programmable action. **[E1]**

6.4.1.4 The off-boresight angle (OBA) look up table shall be site dependent. **[E1]**

The off-boresight angle precision shall be within 0.022°. **[E2]**

6.4.1.5 Monopulse data from received pulses shall be accumulated and checked for long term consistency against the conversion facility, so as to detect any change or drift in the system monopulse azimuth accuracy. **[E1]**

The Tenderers proposal shall include details of any on-line monitoring of monopulse accuracy. **[I1]**

6.4.1.6 The Tenderer shall provide in the proposals details on the receiver channel amplitude and phase response matching requirements of the system offered stating the required tolerances to be maintained in the matching of the channels. **[I1]**

Systems that automatically compensate for any mismatch of channels are preferred. **[A1]**

6.4.1.7 The system maintenance shall not require any adjustment or setting up following the replacement of a unit. **[E1]**

6.5 RF Change-over Unit

6.5.1 The RF Changeover Unit shall enable the in service interrogator to be connected to the antenna and the standby interrogator to be connected to the dummy load. **[E1]**

6.5.2 During changeover the system shall provide uninterrupted service without any corruption to the output surveillance data. **[E1]**

An example of how this could be achieved is to enable the receive signal to be fed to both channels of the dual system. i.e. The standby receiver and processor sub-systems are fed with the same receive signals as the main in service receiver. **[A1]**

For the purpose of this paragraph, “uninterrupted service” is assumed to neglect the finite switching time (<100ms). **[A2]**

6.5.3 The RF Changeover Unit shall only be powered by low voltage d.c. supplies, derived from both channels of the system. **[E1]**

6.5.4 A remote indication of the RF Changeover selection shall be available. **[E1]**

This will enable verification that the channel selected for output is that actually connected to the antenna. **[A1]**

6.5.5 The interruption of transmissions to the antenna when changing over interrogation channels shall meet the requirements of 4.6.2. **[E1]**

6.5.6 The RF Changeover Unit shall retain its selected state in the absence of control signals and power supplies. **[E1]**

An indication to determine which is the Active channel shall be provided. **[E2]**

This will ensure that in the event the equipment is switched off, and there is no further controlling or switching action, the same channels will be connected to the antenna or dummy load when power is returned. **[A1]**

6.5.7 The equipment shall be of passive design and require no routine maintenance. **[E1]**

6.5.8 The design shall include a 20dB bi-directional high power precision coupler in each of the SUM / Difference and control channels to facilitate RF injection and measurement of downlink polar diagrams on Sum, Difference and Control channels. **[E1]**

6.5.9 The Tenderer shall state the Insertion Loss for Transmit and Receive frequencies **[I1]**

6.5.10 The Tenderer shall state the VSWR and Phase shift between Sum and Difference channels **[I1]**

6.5.11 The isolation between ports and channels shall be:

(a) >40dB between channel 1 and channel 2 ports; **[E1]**

(b) >70dB between ports of the same channel (i.e. with the receiver disconnected). **[E2]**

Isolation shall be measured at the RF Changeover Unit with the receiver disconnected, i.e. the test will be performed with sigma, delta and omega disconnected. **[A1]**

CHAPTER 7

SYSTEM MANAGEMENT FUNCTION

7.1 General

7.1.1 Configuration

7.1.1.1 The System Management Function (SMF, Figure 6) controls all the activity on the RF channels. **[A1]**

The SMF shall be considered as containing the following sub-functions:

(a) Real Time Channel Controller (RTCC) containing:

- (i) a Mode A/C reply processor
- (ii) a Mode S reply processor
- (iii) an interrogation scheduler

(b) Link Controller (LC) containing:

- (i) Plot Assignor Function (PAF)
- (ii) Station Roll-Call lists
- (iii) Mode S Link Management Processor (LMP)
- (iv) Communications Management Processor (CMP) **[E1]**

The Tenderer shall include in the proposal a block diagram showing the functionality and input/output ports of the SMF and detail any differences and the reason for the different approach. **[I1]**

7.1.2 General Requirements

7.1.2.1 The SMF shall be able to receive and process reply data from the interrogator when it is receiving replies consistent with the requirements of G.4. **[E1]**

It shall form plots for all aircraft and output them to ATC and to the monitor display. **[E2]**

The SMF shall be able to take in uplink data link transactions from the DLF, process and output them to the interrogator, at a rate which equals the maximum interrogation rates specified in [Ref.1.] when combined with the surveillance update interrogations. **[E3]**

The surveillance update interrogations shall have had priority over the data link interrogations should the interrogation rates exceed the defined limits. **[E4]**

It shall also be able to process downlink data link transactions generated both by requests from the ground system and by transactions initiated by the airborne system. **[E5]**

The Tenderer shall include in the proposal details of the SMF. **[I1]**

7.1.3 Interfaces

7.1.3.1 The SMF will have interfaces to:

(a) The antenna system, to receive information on the azimuth of the boresight of the beam when replies are received; **[E1]**

(b) The interrogator:

(i) To send interrogation modulation commands (including power level, probability of reply and Lockout flags) and data content; **[E2]**

(ii) To obtain processed video and Off Boresight Information (OBI) for all reply pulses. **[E3]**

(c) ATCC, to provide ASTERIX. Cat 34, Cat 48 data (each interface being dual channel); **[E4]**

(d) The DLF to obtain data link transactions for sending to the aircraft, and to send received downlink data link transactions to the DLF; **[E5]**

(e) The SCF to obtain information on aircraft acquired through SCN, and details of aircraft for which the ground station is responsible for surveillance and data link; **[E6]**

(f) Control and Monitoring to enable the control and monitoring functions to be performed; **[E7]**

(g) External time source to serve as a time reference and permit time stamping of plots etc... **[E8]**

The Tenderer shall include in the proposals details of any changes/additions/deletions etc... to the interfaces outlined above, stating the reasons for the different approach. **[I1]**

7.2 Real Time Channel Controller (RTCC)

7.2.1 The RTCC (Figure 7), by using interrogation algorithms, employing interleaving and azimuth off-set techniques (where message delivery azimuth is optimised with respect to interrogation type and priority) combined with the data-link and Mode S specific services interrogation requests from the LC, shall schedule the interrogations to be sent to the transmitter. **[E1]**

The resulting replies received from the video processor function are processed by the Mode A/C reply processor and the Mode S processor to create a report for each reply before it is sent to the LC. **[E2]**

A Mode S Reply Report is defined as a Mode S summary report with, as a minimum, Address, associated position, message data and status (eg reservation) for all successful transactions to a given target in the beam-dwell. **[A1]**

An SSR Reply Report is defined as an SSR report with, as a minimum, positional information correlated from all the decoded replies associated with the target received during the beam-dwell. **[A2]**

The tenderer shall provide information on how the system will proceed if a valid Mode 'S' reply is not decoded in the expected listening period. **[I3]**

The RTCC shall also perform automatic extraction for Air Initiated Comm B (AICB). **[E4]**

The overall rate of (re-)interrogation required to obtain a valid selective reply shall be used as a performance monitoring indicator. This indicator shall be obtained by dividing the number of roll-call interrogations actually performed by the number of expected roll-call interrogations. **[E5]**

As an example, there will be 1 expected interrogation if 0 or 1 GICB extraction per scan is programmed and 2 expected interrogations if 2 GICBs are required per scan. **[A3]**

The Tenderer shall provide detailed information on how this performance monitoring indicator will be computed and reported. **[I3]**

As a minimum, the Mode S Reply Processing shall perform preamble detection and error detection and correction **[E6]**

The Tenderer shall include in the proposal details of the operation of the RTCC, including details of the Mode A/C Reply Process, Mode S reply process, scheduler and performance monitoring indicator.. **[I1]**

As part of the acquisition process, the system shall extract:

(a) BDS 1,0; and

(b) if bit 33 of BDS 1,0 is set then extract BDS 2,0; and

(c) if bit 25 of BDS1,0 is set then extract BDS 1,7 and BDS 1,D **[E7]**

The Tenderer shall provide detailed information on the Acquisition Processing of Mode S targets (in particular the delay in completing the acquisition process; algorithms used in the form of pseudo-code, extraction of CA field, BDS 1,0, BDS 2,0, BDS 1,7, BDS 1,D, and impact on the Asterix output data.....) **[I2]**

The Tenderer is advised that the following modification has been proposed, in combination with a procedure where the ATCO would request the pilot to transmit an SPI, to mitigate for the potential lack of detection of alert conditions when targets are missed for more than 18s: Upon reception of a

Mode S reply with a FS field equal to 4 or 5 (i.e.,SPI), the system shall for the corresponding target:

(a) restart the acquisition process as defined in 7.2.1 [E7] in order to re-acquire airborne information only acquired at track initialisation or on change (aircraft capabilities, Mode A code, Aircraft Identification), and

(b) optionally re-establish the data-flash contracts previously established if still supported. **[A4]**

The SPI announcement will last for 18 +/- 1s and the acquisition process may last for several scans. It is therefore recommended to complete an acquisition process before starting a new one. **[A5]**

When the SPI remains set for a long period of time the system should foresee to re-acquire data at a given configurable time interval in order to avoid to stay in a continuous acquisition process. **[A6]**

7.2.2 The interrogation scheduler shall:

(a) Control the rate and content of the Mode S only All Call interrogations; **[E1]**

(b) Control variable all call interrogation scheduling (which allows for the concatenation of Roll Call periods for extended datalink activities); **[E7]**

(c) Control the rate of output of intermode A/C/S All Call interrogations; **[E2]**

(d) Control the rate of output if intermode A/C only all Call interrogations; **[E3]**

(e) Control the rate and output of Mode 3/A and C interrogations; **[E4]**

(f) Control the timing of the Mode S selective interrogations; **[E5]**

(g) Provide an interface to record the Mode A/C and Mode S reports. **[E6]**

7.3 Link Controller (LC)

7.3.1 General

7.3.1.1 The LC (Figure 8) shall pass data-link and Mode S specific services requested interrogations to the RTCC for action. **[E1]**

The Mode A/C and the Mode S replies received from the RTCC are sent to the Plot Assignor Function (PAF) in order to track targets. **[E2]**

Correlation with the corresponding PSR shall be performed by the PAF. **[E3]**

Data link information shall be sent to the appropriate interfaces, except some GICB replies which can be passed also directly to plot formatting for delivery as Enhanced Surveillance data [Ref.5.]. **[E4]**

The Tenderer shall provide information on how he will achieve the enhancement of plot data in ASTERIX format. **[I1]**

7.3.1.2 When a reply is not required from the aircraft, the RTCC shall inform the LC whether an interrogation has been sent. **[E1]**

7.3.2 Plot Assignor Function (PAF)

7.3.2.1 The PAF shall include at least the following sub-functions:

(a) False target processing that can discriminate against reflected replies, FRUIT replies, split targets, ring around targets and distinguish between multiple occurrence of targets in the same beam dwell, with the same non-unique address; **[E1]**

(b) Track initialisation, maintenance and prediction; **[E2]**

(c) Track association and combination of primary and secondary radar data; **[E3]**

(d) ASTERIX plot formatting which delivers Cat 48 and Cat 34 data, and for Mode S targets appends plot messages for delivery of Enhanced Surveillance data to the ATC. **[E4]**

7.3.2.2 A track shall be initialised and maintained, both upon detection (SSR and Mode S aircraft) or upon receiving supplementary data (Mode S aircraft only). **[E1]**

The PAF shall track all the aircraft, including aircraft with duplicated addresses and shall maintain the Roll Call list. **[E2]**

Aircraft information shall be sent to the ATCC and a track initiated for a Mode A/C transponder equipped aircraft that has been confirmed to be in the surveillance responsibility area. **[E9]**

The Tenderer shall describe how a report is localised in the coverage map when the report lacks credible altitude information (PSR or Mode S/SSR target without credible altitude code). **[I6]**

Aircraft information shall be sent to the ATCC and a track initiated for a Mode S transponder equipped aircraft that has been confirmed to be in the surveillance responsibility area, and:

(a) At least one All Call reply has been detected and confirmed by a selective surveillance reply or **[E3]**

(b) A selective surveillance reply has been received from a selective interrogation which was initiated by supplementary data from the SCF. **[E4]**

At track initiation, the first roll call reply will normally provide altitude information. As this is the first reply received, then it will not be possible to perform the credibility check. However, it can be assumed that in the majority of cases the altitude information will be valid. For this reason, the altitude information can be used to determine the surveillance responsibility. **[A1]**

When a Mode S aircraft is detected in the lockout map, the station shall apply as soon as possible the all call lockout protocol defined in that map. **[E11]**

The Mode C shall be updated on the track for each antenna revolution. **[E5]**

Aircraft surveillance data and measured position information shall be sent for every antenna revolution until the track is cancelled. **[E6]**

The position information shall originate, by decreasing priority, from a detection (All- Call or a selective surveillance reply), or from an extrapolation (miss). **[E7]**

An operational parameter, when enabled, shall force the output of extrapolated target reports to Local Display and/or ATCC in case of miss. **[E14]**

Position information originating from extrapolation, if sent, shall be flagged accordingly. **[E8]**

An operational parameter, when enabled, shall force the output of target reports to ATCC, containing at least position (range, azimuth and altitude) and identification (Mode A and, if applicable, Aircraft ID), after a user selectable number of scans following first detection (minimum 1, i.e. on the second scan), provided the corresponding target has been confirmed to be in the surveillance responsibility area. **[E12]**

An operational parameter, when enabled, shall force the output of target reports to ATCC (irrespective of the detection type, e.g. 3/A, C, Roll Call and All Call), after a user selectable number of scans following first detection (minimum 0, i.e. on the first scan). **[E10]**

Such forced target output may be preferable for approach radar in order to track as soon as possible taking-off targets. **[A2]**

This mode of operation shall be limited to user defined geographical areas, and the resulting “early reports” reserved to selected ATCC outputs. **[E13]**

The rules stated in [E3] and [E9] may not always be met in the mode described in [E10]. **[A3]**

The Tenderer shall provide detailed information (in particular, algorithms used in the form of pseudo-code, impact on the ASTERIX output data…) on the processing required to initiate a track and deliver an SSR report to the ATCC. This information, supported by field data analysis results, should take the form of a probability of initialising and delivering a SSR report to the ATCC output in function of time. **[I1]**

The Tenderer shall provide detailed information (in particular, algorithms used in the form of pseudo-code, impact on the ASTERIX output data…) on the processing required to initiate a track and deliver a Mode S report to the ATCC. This information, supported by field data analysis results, should take the form of a probability of initialising and delivering a Mode S report to the ATCC output in function of time. **[I2]**

The Tenderer shall provide detailed information (in particular algorithms used in form of pseudo-code, impact on the Asterix output data.....) on the track processing in particular concerning the following points:

(a) Type of filter e.g., Alpha/Beta-filter, Kalman Filter;

(b) Algorithms used;

(c) Slant range correction;

(d) Tracking in rho/Theta or X,Y;

(e) Method of projection used. **[I3]**

The Tenderer shall provide detailed information (in particular algorithms used in form of pseudo-code, impact on the Asterix output data.....) on the following points related to the delivery of a SSR report to the ATCC:

(a) Resolution of multiple assignment;

(b) Combining of Split Plots;

(c) Code Swapping;

(d) Code Validation;

(e) Code Change;

(f) Mode C Credibility Checking. **[I4]**

The Tenderer shall provide detailed information (in particular algorithms used in form of pseudo-code, impact on the Asterix output data.....) on the following point related to the delivery of a Mode S report to the ATCC: Mode C Code Validation and Credibility Checking. **[I5]**

7.3.2.3 A track shall be cancelled when:

(a) An aircraft traverses from a cell with Surveillance Responsibility to one without (there is no need to coast), or **[E1]**

(b) the track is not in the cone of silence and has not been updated within three antenna revolutions and no additional information has been received during that time period from neighbouring stations. **[E2]**

7.3.2.4 Reflection Suppression

Target reports identified as reflections shall not be output as genuine targets but all the tracks including those consisting of false targets shall be initiated and maintained. **[E1]**

7.3.2.5 False targets due to any of the causes listed below shall be identified (marked) as false in the category indicated and shall be rejected (ie not output as genuine targets):

(a) False targets due to multipath; **[E1]**

(b) False targets at similar range to, but at different azimuths from, an originating genuine target at short range shall be identified as ‘ringaround’; **[E2]**

(c) False targets at similar azimuths to, but at increasingly longer ranges from an originating genuine target shall be identified as ‘in-line multipath’; **[E3]**

(d) False targets split from an originating genuine target due to antenna beam distortion or splitting as a result of multipath or local obstruction diffraction shall be identified as ‘splits’; **[E4]**

(e) False targets with angular separations from an originating target due to reflection of the interrogations and/or transponder responses by reflecting surfaces in the signal paths shall be identified as ‘reflections’. **[E5]**

7.3.2.6 Mode A/C Reflection Processing

The processing shall continuously and automatically locate and identify the orientation and position of the reflecting objects within range of the radar by analysis of the geometry of reflection data from targets with unique codes. **[E1]**

The reflector data shall be used to maintain dynamic reflector surface data. **[E2]**

It shall be possible to program into the PAF reflector surface position and orientation data for permanent reflectors, such as hangars. **[E3]**

The processing shall employ the reflector data stored in the dynamic and permanent reflector surfaces to identify reflections by analysing the geometry of the real target, the reflections and the stored reflector data. **[E4]**

The Tenderer shall provide detailed information on the methods proposed to eliminate both permanent and dynamic reflection surfaces. **[I1]**

The Tenderer shall state in the proposal the reflector storage capacities and the method of handling both the permanent and dynamic reflecting surfaces. **[I2]**

7.3.2.7 Mode S Reflection Processing

The Tenderer shall include in the proposal details of the Mode S reflection processing. **[I1]**

7.3.2.8 Surveillance Data Output

The network protocol for transmitting the surveillance data to ATCC shall be X.25 or HDLC Lap-B, up to a 128 Kbps maximum output rate for WAN protocols or UDP/IP (unicast or multicast over IPv4 or IPv6), TCP/IP(client or server over IPv4 or IPv6) for LAN protocols. **[E1]**

The type of the protocol used shall be a site dependent parameter. **[E2]**

7.3.3 Station Roll-Call List

7.3.3.1 The Station Roll-Call List shall contain at least identification and positional information on targets that the station is tracking. **[E1]**

7.3.3.2 The PAF will maintain the station Roll Call list and the SCF will update it. The CMP and the SCF will use the station Roll Call list to ensure that requesting applications will be able to send interrogations to the required aircraft via the ground station. **[E1]**

7.3.4 Communication Management Processor (CMP)

7.3.4.1 The CMP processes all requests for data link transactions which are input to it from the DLF. It is responsible for co-ordination of interrogation instructions. **[E1]**

The data packets are passed to the scheduler for transmission and the Mode S downlink information is received from the PAF via the LMP to pass onto the DLF. **[E2]**

An aircraft shall be reported to the GDLP in accordance with [Ref.9.]. **[E3]**

An aircraft shall be reported to the GDLP as leaving when the aircraft is leaving the datalink coverage map or if no reply to a selective interrogation reply has been received for more than three antenna revolutions. **[E4]**

The CMP shall operate flow control procedures when it is unable to process the incoming requests received from the GDLP / Local User Interface. **[E5]**

The operation of flow control shall be reported in the appropriate fields in the ASTERIX Cat. 18 messages of [Ref.6.]b. **[E6]**

7.3.5 Mode S Link Management Process (LMP)

7.3.5.1 The LMP shall control all the Mode S link activities except Mode S All -Call interrogations which are controlled directly by the RTCC. **[E1]**

The LMP shall schedule the interrogations which result in the acquisition of Mode S aircraft from the replies being formed into plots and tracked in the PAF which in turn ensures that they are presented to the Roll Call List. **[E2]**

For each target on the Station Roll Call List that the ground station is responsible for, and for new targets input from the SCF, the LMP shall assemble and send interrogation instructions to the RTCC. **[E3]**

The LMP shall take the Mode S frames from the queues in the CMP, highest priority queue first, and form them into interrogation instructions to send to the RTCC. **[E4]**

They shall be delivered in azimuth order and with control information to ensure that a sequence of interrogations to a particular aircraft (e.g. Linked Comm A or UELM with its reservation and close out) can be maintained. **[E5]**

The LMP shall take Mode S reply status information (e.g. successful or failed delivery) to enable it to perform frame repair by making new attempts at succeeding polling intervals and report the final result to the CMP. **[E6]**

The Tenderer shall include details in the proposal of the functions of the LMP. **[I1]**

7.3.5.2 A transaction shall be considered as a failure if it is not completed within the time delays given below, from the moment when the first interrogation concerning it is transmitted. **[E1]**

Transaction Type	Typical values (in antenna revolutions)
Comm A (1 to 4 segments)	3
Comm B (1 to 4 segments)	3
Comm C (2 to 16 segments)	4
Comm D (1 to 16 segments)	5

These values shall be adjusted separately for each type of transaction between 1 and 20 antenna revolutions. **[E2]**

The Tenderer shall include in the proposal details of how the above is to be managed and implemented. **[I1]**

CHAPTER 8

SURVEILLANCE CO-ORDINATION FUNCTION

8.1 Overall Objective

The overall objective of Surveillance Co-ordination is to allow any Mode S ground station to operate effectively within any radar siting plan, while keeping the levels of RF pollution as low as possible. This means preventing interference between stations by the correct use of II/SI codes, Mode S protocols, transponder All-Call lockout, coverage map configuration and target handover. **[A1]**

The SCF function achieves this by ensuring co-operation between stations operating as part of a networked cluster. **[A2]**

The cluster modes of operation and the interfaces are defined in more detail in the SCN ICD [Ref.1.]. **[A3]**

8.2 Overview

8.2.1 Global Operation

The ground station shall be capable of operating as part of a networked cluster of ground stations as outlined in section 3.2, whereby each station in the cluster will share the same code. **[E1]**

The National Authorities will provide the main communications structure required for the operational Surveillance Co-ordination Network. II/SI code allocation schemes will ensure that Mode S will operate without interference in Europe. These schemes will provide the II/SI code and cluster configurations required to meet operational requirements and siting plans. **[A1]**

When operating as part of a cluster, each station shall advise other cluster stations of the arrival of aircraft in their respective coverage as defined in the ICD for Intersite Co-ordination [Ref.1.]. **[E2]**

The station shall acquire the aircraft by placing it on the Roll-Call List and sending it a surveillance interrogation. (This aircraft is already locked out on the same II/SI code, therefore it does not respond to an All-Call). **[E3]**

The SCF shall provide track data to adjacent stations within a cluster upon request. **[E4]**

The SCF shall be designed to minimise the amount or extent of II/SI code reconfiguration. **[E5]**

The SCF shall be designed to interface with up to 5 other Mode S stations, as well as a Cluster Controller, if present, via the Surveillance Co-ordination Network (SCN). **[E6]**

8.2.2 Description of Cluster Operation and modes

When operating as part of a cluster (i.e. the stations are connected to the SCN) the station's operation is termed 'Network Aided'. This operation will include two 'modes', which are central and distributed. **[A1]**

In central mode, the station shall operate with the coverage map and II/SI code determined by the Cluster Controller (CC). **[E1]**

In distributed mode, the coverage map and II/SI code shall be selected by the algorithm as defined in [Ref.1.] operating at the radar node. **[E2]**

In addition to network aided operation within a cluster, the SCF shall also support 'Standalone' operation, when ground stations are not connected to the Surveillance Co-ordination Network (SCN). **[E3]**

8.2.3 Operation and Mode Transitions

When performed manually by operational staff, the connection or disconnection of the station to the SCN shall be possible either locally or through the CAM. **[E2]**

Transitions shall proceed according to the rules detailed in [Ref.1.]. **[E5]**

The addition of a station to the cluster shall be achieved without disruption to the operational service. **[E6]**

The Tenderer shall describe, in the Tender Response, a method to achieve the above. **[I1]**

8.2.4 Failure recovery

The handling and recovery of failures shall proceed according to the rules detailed in [Ref.1.]. **[E1]**

For node failure, the Tenderer is referred to the method used to set the NOGO bit in ASTERIX item I034/050 ([Ref.5.]). **[A1]**

If the node is NOGO then it shall not be part of the cluster. **[E4]**

The node shall be removed from the cluster by disabling the SCN connection. **[E5]**

When a node's NOGO bit is subsequently cleared, its SCN connection shall be re-enabled. **[E6]**

The NOGO bit shall be changed by the node's internal test logic 'BITE'. The NOGO bit in Cat 34/050 is automatically set to 0 whenever the system is active and therefore released for operational use. **[E8]**

All network and nodal failures shall be reported to the CAM. **[E9]**

8.3 Functionality

8.3.1 The SCF shall include the following:

(a) Coverage maps indicating the surveillance, lockout and datalink coverage to be maintained, as defined in [Ref.13.]; **[E1]**

The extent of each cell shall be as defined in [Ref.13.] and the radar coverage limit shall be adapted to the border of the cell; **[E2]**

(b) A means to add or delete targets to the station Roll-Call list in accordance with the SCF state; **[E3]**

(c) A network system status list containing information on the latest SCF state; **[E4]**

(d) A network control and failure control process which contains the processing and protocols required to maintain the station within the cluster; **[E5]**

(e) A communication interface to the SCN. The interface shall support the exchange of ASTERIX messages for surveillance co-ordination as defined in [Ref.1.]; **[E6]**

(f) A track acquisition and support protocol to ensure that any interrogator is aware of any new track entering its coverage, and used by a radar to request track information from a neighbouring node when a track miss has occurred, as detailed in [Ref.1.]. **[E7]**

8.3.2 Provision for intermittent lock-out shall be made in a selected area which shall be detailed in the lock-out responsibility coverage map. In these areas the station shall send lockout instructions for an aircraft on one scan only. The station shall continue to perform surveillance on the aircraft without sending any more lockout instructions until the aircraft responds to an All-Call. Following reception of an All-Call reply, the station shall wait for a given period and then repeat the above procedure. **[E1]**

The above timer value shall be a site dependent parameter (from 0 to 30s, with a step of 1s). **[E2]**

8.3.3 Provision for Lockout over-ride shall be made in selected sectors, determined from the lock-out override coverage map, within which the station shall interrogate the Mode S aircraft during the All Call period by using a value of PR as indicated in the example of Figure 12. **[E1]**

8.3.4 Spare.

8.3.5 The Contractor shall provide a facility to allow the loading of coverage maps compliant with [Ref.13.] into the radar system software. **[E1]**

The coverage maps will be provided, in the format defined in [Ref.13.], by the Agency. **[A1]**

8.3.6 The Tenderer shall provide details in the response of how the following processes operate:

(a) Station Roll Call list; **[I1]**

(b) Periodic Monitoring Process; **[I2]**

(c) Network and Failure Management Process; **[I3]**

(d) Coverage Map; **[I4]**

(e) Network System Status List; **[I5]**

(f) Network Link. **[I6]**

8.3.7 It shall be possible to load another solution list for the ground station without affecting its current operation. **[E1]**

It shall be possible to set the date and time at which the update of a solution list becomes effective. **[E2]**

When this new solution list becomes effective, the radar shall first operate standalone. **[E3]**

8.3.8 The Surveillance Co-ordination Function shall provide a Co-ordinate Transformation as defined in [Ref.6.]a, Annex A, to the local co-ordinate set for the track data received from the connected stations. **[E1]**

The Surveillance Co-ordination Function shall provide a Co-ordinate Transformation as defined in [Ref.6.]a, Annex A, from the local co-ordinate set for track data sent to connected stations. **[E2]**

CHAPTER 9

DATA LINK FUNCTION

9.1 General

9.1.1 The Data Link Function (DLF) provides the functionality to support the air/ground data link and is illustrated in Figure 13. **[A1]**

9.1.2 The DLF shall include the functionality of the Specific Service Entity, as defined by section 5.2.7 of Mode S Subnetwork SARPs [Ref.3.]. It shall support all the Mode S Specific Services, namely Ground Initiated Comm Bs (GICBs), Broadcast Comm Bs, Broadcast Comm As and the Mode S Specific Protocol (MSP). **[E1]**

9.1.3 The DLF shall also include the Frame Processing function as defined by section 5.2.2 of Mode S Subnetwork SARPs [Ref.3.] to support Switched Virtual Circuit communication over the Mode S Subnetwork via the Ground Data Link Processor. **[E1]**

9.2 DLF Functionality

9.2.1 The DLF shall have two interfaces, one to receive/send data to the GDLP and the other an interface to a Local User. **[E1]**

The data formats that shall be used are defined in [Ref.6.](b). **[E2]**

The DLF shall be able to support simultaneous operation with both a GDLP and Local User. **[E3]**

The DLF shall enable the connection to the GDLP and the Local User via X.25 and/or through HDLC Lap-B. The minimum throughput shall be 19.2 Kbps, and shall be configurable up to 128 Kbps. **[E4]**

The type of the protocol used shall be a site dependent parameter. **[E5]**

9.2.2 The DLF shall contain the following:

(a) The DLF-GDLP packet level interface that sends and receives data (i.e. SVC requests and Mode S Specific Services) from the GDLP to the DLF as defined in [Ref.9.]; **[E1]**

(b) The DLF-Local User packet level interface that sends and receives Mode S Specific Service requests from the Local User interface to the DLF as defined in [Ref.9.]; **[E2]**

(c) The Internal Applications that allow pre-configured GICB extractions and Dataflash contracts. These Internal Applications can be accessed locally/remotely via the CAM or a dedicated terminal; **[E3]**

(d) The Broadcast Manager shall process the broadcast requests from the DLF-GDLP interface, the DLF Local User Interface. **[E4]**
The Broadcast Manager shall send all downlink broadcasts to the GDLP, Local User and Internal Applications. **[E5]**

(e) The GICB Manager shall combine duplicated GICB requests onto a single data flow. The GICB Manager shall send the responses to the requesting applications. **[E6]**

(f) The SVC/MSP Manager shall manage the uplink and downlink SVC/MSP data flows, perform the frame processing and multiplexing functions and shall not perform L, M and S bit processing as defined in [Ref.3.]. **[E7]**

GICB and downlink broadcasts shall be extracted from all aircraft in the surveillance responsibility of the ground station. **[E8]**

The Tenderer shall provide details in the proposal of the above functionality and details of how they will be implemented. **[I1]**

9.2.3 The internal applications contain the following pre-configured contracts:

9.2.3.1 Internal GICB Application

The System shall be capable to extract automatically via programmed GICB requests at least 4 BDS registers for all aircraft in surveillance responsibility. **[E1]**

The System shall enable the programmed extraction of any kind of BDS register through these GICB requests. **[E2]**

These GICB requests shall be programmed on a periodic basis. **[E3]**

A priority shall be assigned to each of these GICB requests by the IAL, in consistence with the GICB priority field specified in data item I018/030 (see [Ref.9.]). **[E4]**

The BDS registers to be extracted, the periodicity of extraction of each BDS and their priority shall be site-dependant parameters programmed either at the CAM or at a dedicated terminal. **[E5]**

No GICB extraction programmed internally shall be attempted by the system if the programmed BDS register is not supported by the aircraft installation. **[E6]**

A BDS register shall be detected as supported by the aircraft installation when bit 25 of the BDS register 1,0 is set to 1 as well as the associated bit of register 1,7. **[E7]**

If a BDS register is not listed in BDS 1,7, it is assumed to be available and shall be extracted if requested. **[E8]**

No GICB extraction request received from the GDLP/LU should be accepted by the system if the programmed BDS register is not supported by the aircraft installation. **[A1]**

The Tenderer shall state whether the BDS register extracted as a consequence of an internal GICB request is used to update asynchronous GICB requests received from GDLP/LU. **[I1]**

9.2.3.2 Internal Dataflash Application

Dataflash is a protocol that enables event driven transmission of aircraft information (indicated air speed, selected heading, waypoints...). It is an efficient way for a ground application to receive data that do not change very often and in an unpredictable manner. The Dataflash protocol allows a ground application to retrieve the contents of aircraft registers (BDS). BDS transmission upon register changes is performed as a result of a request from the station. **[A1]**

Dataflash uses MSP packets (Mode S Specific Protocol). The MSP protocol provides a datagram service within the Mode S Sub-Network. The MSP service provides 63 uplink channels and 63 downlink channels. Specific channels have been allocated to the Dataflash application. Ground initiated requests use uplink channel 6 (“ground to air service request”). Aircraft Dataflash information are downlinked on channel 3 (“Dataflash”). **[A2]**

The System shall be capable to manage at least 4 Dataflash contracts for each aircraft in datalink coverage, supporting the Dataflash application. **[E1]**

No Dataflash contract shall be initiated with an aircraft if the related BDS register is not supported by the aircraft installation (see 9.2.3.1 **[E7]**). **[E2]**

The Internal Dataflash application shall determine through bit 6 and bit 31 of BDS 1,D whether the aircraft does support the Dataflash protocol. **[E3]**

When all the above conditions are met for an aircraft entering the datalink coverage, the programmed Dataflash contracts shall be initiated for this aircraft. **[E4]**

The internal Dataflash application shall be able to perform the following functions:

(a) Extract BDS embedded in any MSP Dataflash packets transmitted by aircraft; **[E5]**

(b) Transmit these BDS along with track data of the same scan to the ATCC (using the MB data item of Cat. 48 or specific items for particular BDS); **[E6]**

(c) For each Dataflash packet, transmit a GICB response to the GDLP/LU interfaces for users which requested an asynchronous update of this particular BDS (i.e. either the GDLP or the LU had used the AU flag in a GICB request for this BDS); **[E7]**

The conditions of the contract (BDS register to be monitored, contract number, event, change or time criteria which will trigger the AICB) shall be site-dependant parameters programmed either at the CAM or at a dedicated terminal. **[E9]**

The station shall not attempt to terminate any established Dataflash contract. **[E10]**

The implementation of the Dataflash application shall be compliant with [Ref.3.]. **[E11]**

9.2.4 It is recommended to stop downlink extraction and output queued ASTERIX Cat 18 messages from the DLF before making a cold switch-over. **[A1]**

9.2.5 Spare.

9.2.6 The DLF shall indicate to the SMF whether any BDS data acquired should be appended to the report data to provide Enhanced Surveillance Data to ATCC. **[E1]**

All BDS data requested through category 18 for transmission in category 48, or requested via the IAL (through GICB requests or Dataflash contracts), shall be delivered to ATC (Surveillance Users) using the MB data item of category 48 except were a dedicated data item exists (48/240 & 48/260) and also be provided to the MMI. **[E2]**

9.2.7 The DLF shall be monitored via the control and monitoring system. **[E1]**

The Tenderer shall provide in the proposal details of what is available to the control and monitoring system. **[I1]**

9.3 Data link storage

The DLF shall be able to have a data link storage capacity equivalent to a two scans time period in both uplink and downlink direction in order to avoid immediate application of flow control in case of slight overload. **[E1]**

The Tenderer shall provide details of the data load capacity and the data link storage capability. **[I1]**

CHAPTER 10

CONTROL AND MONITORING (CAM)

10.1 General

10.1.1 The overall objective of the control and monitoring is to ensure that an unattended Mode S ground station shall provide continuous surveillance throughout its required coverage. **[E1]**

The Tenderer shall state in the proposal how the control and monitoring of the following is performed:

(a) Radar sensor, including antenna, turning gear, RF change-over and azimuth data; **[E2]**

(b) Interrogator; **[E3]**

(c) System Management Function (SMF); **[E4]**

(d) Surveillance Co-ordination Function (SCF); **[E5]**

(e) Data Link Function (DLF); **[E6]**

(f) Data transmission facilities (modem, multiplexer and network terminating units); **[E7]**

(g) Far Field site monitor; **[E8]**

(h) General site utilities (fire and intruder alarm, air conditioning equipment); [E9

10.2 Control and Monitoring Interfaces

10.2.1 Provision for interfaces to enable local and remote control and monitoring shall be provided using industry standard interface and protocol. **[E1]**

The Tenderer shall provide a detailed description of the interfaces, protocols and message formats used for the above function. **[I1]**

The Tenderer shall indicate whether the following statistical information (on a Scan or timely basis) are provided by the CAM interfaces (locally or remotely):

(a) Information about the data supplied to the ATCC users:

(i) Number of solo Mode S reports;

(ii) Number of solo SSR reports;

(iii) Number of solo PSR reports;

(iv) Number of combined SSR/PSR reports;

(v) Number of combined Mode S /PSR reports;

(vi) Number of Splits plots;

(vii) Number of code swaps;

(viii) Number of reports with duplicated Mode S address;

(ix) Number of test transponders;

(x) Number of test targets.

(b) Information about the data transferred through the SCN:

(i) Number of Track Initiations sent out;

(ii) Number of Track Initiations received;

(iii) Number of Track Data messages sent out;

(iv) Number of Track Data messages received;

(v) Number of Track Data Requests sent out;

(vi) Number of Track Data Requests received;

(vii) Number of Tracks for which SCN Track Support is being given;

(viii) Number of Tracks for which SCN Track Support is being received.

(c) Information (including the rationale) about the data exchanged with the GDLP;

(d) CPU loading on the different processing boards;

(e) measured data rate on each link (surveillance, SCN and DLF). **[I3]**

Control of every facility and function of the system shall be provided via these interfaces. **[E2]**

A disconnection of the CAM link shall not create an interruption to the operational service. **[E3]**

Under CAM link failure full control shall automatically be provided locally, either through the local CAM interface or through another terminal. **[E4]**

When under control of the remote terminal, all local control of the system shall be inhibited except for the request for local control. Transfer to local control is executed only after permission by the remote terminal. **[E5]**

When under local control at the equipment itself all control via the remote terminal shall be inhibited, however monitoring and recording of all functions shall continue. **[E6]**

The Tenderer shall provide details in the proposal of the list of parameters subject to remote control and monitoring in their proposed system. **[I4]**

10.2.2 The CAM interface shall enable the connection or disconnection of the ground station from the Surveillance Co-ordination Network (SCN). **[E1]**

10.2.3 The Contractor shall supply, at a date to be agreed with the Agency, interface control documents defining the interfaces, protocols and message formats used for the CAM function. **[E1]**

10.3 Built in Test Equipment (BITE)

10.3.1 Comprehensive on-line and off-line BITE shall be provided in the Mode S system. **[E1]**

On-line BITE testing is defined as BITE tests performed while the system is in the operating mode or in the standby mode; such tests would normally be conducted with normal operating signals or internally injected stimuli that did not interfere with normal operation. Off line BITE tests are those conducted while the system is in the maintenance mode using internal test checks and routines. **[A1]**

Off line BITE shall be capable of being initiated locally and remotely. **[E2]**

BITE shall be provided for both on-line and off-line testing of the Mode S systems and shall be able to detect any fault affecting the performance of the system. **[E3]**

The BITE coverage rate (part of the system [including all units, boards and components] monitored by BITE) shall be at least 90%. **[E4]**

The BITE fault finding rate shall be at least 95%. That is, at least 95% of all failures shall be detected and isolated by test to within a three LRU group (In most instances a PCB is defined as a single LRU). The BITE fault-finding rate is algebraically equal to the product of the fault detection rate and the fault isolation rate. **[E5]**

It is anticipated that the above requirement be met by on-line BITE. **[A2]**

The Tenderer shall state in the response the on-line and off-line fault finding rate that shall be achieved. **[I1]**

It is expected that achieved performance figures will be higher. The Tenderer shall provide in the proposal details of the performance figures which the equipment shall be able to meet and state under what conditions. **[I2]**

10.3.2 The on-line and off-line testing of the system shall work without the need for any additional external test equipment. **[E1]**

The on-line fault reporting time shall be less than 2 seconds after detecting the fault. **[E2]**

The on-line and off-line BITE shall register the faulty equipment (LRU) and report the information through the CAM interfaces. **[E3]**

The Tenderer shall provide details in the proposal of the BITE facilities available and what on-line tests the system will be able to perform. **[I1]**

10.3.3 On-line testing shall provide radar performance data through the CAM interfaces, in particular performance degradation providing advance warning of a developing fault condition or the need for maintenance. **[E1]**

In the proposal, The Tenderer shall state the performance parameters and describe the method of reporting the performance data both locally and remotely for the Mode S ground station. **[E2]**

CHAPTER 11

LOCAL DISPLAY

11.1 Local Display

11.1.1 An autonomous, readily moveable and transportable raster scan radar display shall be provided with interfaces as described in Figure 14. **[E1]**

11.1.2 By using the display, maintenance and commissioning engineers shall be able to fully assess the operational performance and serviceability of the Mode S system. **[E1]**

11.1.3 The display hardware shall make use of an industry standard graphics (minimum 1000 line) work station with an industry standard operating system. **[E1]**

Where specialised external processing hardware is proposed, it shall be interfaced to the same operating system as the display. **[E2]**

The display shall be capable of handling the target loads as specified in Annex G. **[E3]**

The Tenderer shall provide details of the hardware which will be supplied. **[I1]**

11.1.4 The display system shall accept and display signals or data from the Mode S radar system (live) or from the optional data recording and playback facility, if any, consisting of at least:

(a) Turning and trigger information (for SSR Mode A/C and Mode S All Call); **[E1]**

(b) SSR/Mode S video signals; **[E2]**

(c) PSR video signals; **[E3]**

(d) Quantised Processed Sum Video (Analogue video converted to digital words synchronised to the monopulse plot extractor master clock timing) Signals (SSR and Mode S All Call); **[E4]**

(e) Reply Report Data (messages output from the Mode A/C and Mode S reply processor); **[E5]**

(f) Plot Assignor data (ASTERIX Cat. 1, 48); **[E6]**

(g) Mode S enhanced surveillance information (ASTERIX Cat. 48); **[E7]**

(h) Status information (ASTERIX Cat. 2, 34); **[E8]**

(i) Track data exchanged on the Surveillance Co-ordination Network (content of ASTERIX Cat. 17 messages); **[E9]**

(j) Presentation of the currently operational local Surveillance Coverage maps, for a user-defined altitude; **[E10]**

(k) Data flagged as Anomalies and false plots in the PAF and NOT sent to ATCC; **[E11]**

(l) A list of the Mode S aircraft under surveillance (Mode S address, height & position); **[E12]**

(m) The data link capability of each aircraft; **[E13]**

(n) The last received message decoded per aircraft; **[E14]**

(o) The Broadcast Comm Bs received; **[E15]**

(p) The GICB's received; **[E16]**

(q) MSPs (for Dataflash); **[E17]**

(r) TCAS resolution advisories. **[E18]**

Data (b), (c), (d), (f), (g), (i), (j) and (k) shall be displayed in a geographical representation. **[E19]**

The Tenderer shall provide information on the subset of these signals that can be displayed simultaneously. **[I1]**

The Tenderer shall provide detailed information about the editing and display of border and coastline maps. **[I2]**

The Tenderer shall provide detailed information about the editing and display of other geographical maps (other radar positions, airways, runways…). **[I3]**

The Tenderer shall provide detailed information about the display of the coverage maps (surveillance, lockout and datalink). **[I4]**

The Tenderer shall provide detailed information about the display of Asterix Cat 17 data. **[I5]**

The system shall provide the operator with the ability to select any combination from the above list for display. **[E20]**

The Tenderer shall provide detailed information on how the above data is selected and retrieved from the station (software or hardware selection…). **[I6]**

11.1.5 The system shall be able to display the content of the ASTERIX data sent on the ATCC output specified in 4.9.2.1. **[E1]**

11.1.6 The display system shall recognise, process and interpret all message types in ASTERIX and display the data from these messages [Ref.5.]b,c and [Ref.6.]a. **[E1]**

11.1.7 The Contractor shall supply any peripherals and/or ancillary equipment that are necessary for the operation of the display **[E1]**

11.1.8 The symbology (and/or colour) shall be such as to distinguish between different plot types. **[E1]**

A background map facility shall be provided for up to 300 NM radius of the origin. **[E2]**

It shall be possible to import the map parameter co-ordinate set. **[E3]**

11.1.9 The Tenderer shall include in the response details of how all the information for selected plots could be displayed (including additional data such as GICB reply data, status information). **[I1]**

11.1.10 There shall be a facility to record the data defined in 11.1.4, (l) to (r), and to display this stored information. **[E1]**

The Tenderer shall provide details in their proposal of the method used to store the above data. **[I1]**

CHAPTER 12

FAR FIELD MONITOR

12.1 General

12.1.1 The far field site monitor shall be a self contained unit acting as a Mode S level 3 transponder (as defined in [Ref.1.] 2.1.5.1.3) located externally to the ground station site. **[E1]**

12.1.2 It shall be a dual channel system with redundant capacity in the event of a single channel failure. **[E1]**

The radar processing shall enable the definition of multiple far field monitors and provide the capability to suppress their reports from delivery to ATC. **[E2]**

12.1.3 The Mode S site monitor shall include the following features:

(a) Operation on Modes 3/A,C, intermode and Mode S (II and SI codes); **[E1]**

(b) Simulated range and flight level reporting; **[E2]**

(c) Robustness to common-mode failure (i.e. one channel shall transmit in the event of failure in the other channel); **[E3]**

(d) Comprehensive BITE facilities to enable fault diagnosis to module level; **[E4]**

(e) Modular construction with plug/socket connections on all modules; **[E5]**

(f) Fully solid state; **[E6]**

(g) BITE status and configuration status shall be reported to CAM; **[E7]**

(h) Configuration shall be controlled by CAM; **[E8]**

(i) User definable data as described in 12.2.1. **[E9]**

The far field monitor shall comply with all the requirements of [Ref.1.]. **[E10]**

The Tenderer shall advise what additional features could enhance the capability of the far field monitor (e.g. external frequency selection, battery back-up, power attenuation adjustment) **[I1]**

The Tenderer shall include in the proposal details of the Mode S site monitor configuration and how the changeover action is reported to the CAM. **[I2]**

12.2 Reply Processing

12.2.1 User definable data shall include:

(a) The Mode S technical address for each channel shall be selectable as a 6 character Hexadecimal address. **[E1]**

(b) Separate altitude and identity information for each channel shall be selectable (in terms of octal Mode A code and FL respectively). **[E2]**
Each code shall remain configured during periods of power interruption. **[E3]**

(c) Separate Flight Identity (or call-sign) information for each channel shall be selectable. During switch-over (due to equipment failure) the change of Flight ID shall be announced by the use of the standard Mode S broadcast protocol. Such a facility will provide the ground station with an indication of site monitor failure. **[E4]**

(d) Separate range offset parameters for each channel shall be selectable.

(e) It is anticipated that the data defined in a, b, c and d are all selectable via portable test equipment (e.g. lap top computer). **[A1]**

(f) The portable test equipment shall be provided with each site monitor equipment **[E5]**

12.2.2 In addition the following test functions shall be provided:

(a) Delivery of "active" II/SI code; **[E1]**

(b) Remote Setting Failure. That is the ground station shall be able to set remotely (or "trigger"):

(i) The Alert bit; **[E2]**

(ii) The Downlink Capability Report announcement; **[E3]**

(iii) Change of Flight Identity; **[E4]**

(iv) Test RA broadcast. **[E5]**

The use of MSP uplink channel 6 (ground to air service request) allows the ground station to be able to set remotely (or " trigger") such features. **[A1]**

The Tenderer shall provide in the proposal implementation details of the test functions which have been listed above. **[I1]**

12.2.3 The equipment shall function on a power supply consistent with the requirements of 4.11. **[E1]**

12.2.4 The Tenderer shall provide power budget calculations to support a ‘typical’ far field monitor installation. **[I1]**

The equipment supplied shall include all ancillary equipment including antenna, cabling power supplies and any necessary mounting hardware. **[E1]**

CHAPTER 13

OPTIONAL REQUIREMENTS

13.1 General

This chapter contains a number of optional requirements that, if exercised by the customer, will be identified as deliverable items in the List of Price & Deliverables (under 'Optional Deliverables') that accompanies any call for tender. **[A1]**

13.2 Cluster Controller

13.2.1 Surveillance Co-ordination Network

The objective of surveillance co-ordination is to allow any Mode S ground station to operate effectively within any radar siting plan as was stated in Chapter 8. **[A1]**

Figure 11 shows the overall layout of a typical Surveillance Co-ordination Network Cluster. It consists of a number of nodes which are all using the same limited set of II codes. A Cluster Controller (CC) is connected via a network to a number of ground station SCFs in order to provide centrally controlled mode of operation. The ground station SCFs are also connected via the network so as to provide a distributed mode in the event of the CC not being available. **[A2]**

The central controlled mode has been designed to take advantage of the central and therefore global view of the cluster. This view can be established in one of two ways:

(a) by passing track information from the connected cluster radars to the CC using track data messages in ASTERIX Category 17. This information is then processed by the CC to construct a CC global roll-call.

(b) by using system track data already available and processed in Radar Data Processing (RDP) systems. This option allows the CC and RDP systems flexibility in configuring the cluster to optimise the overall surveillance performance. The CC can take advantage of this pre-processing if a suitable interface is provided between the CC and the RDP system. **[A3]**

13.2.2 Functionality

The Cluster Controller is an optional item and as such the act of exercising this option shall not require a modification to the basic functionality of the ground station equipment. **[E1]**

The functions of the CC SCF are designed to optimise the Surveillance Co-ordination Network. They are illustrated in Figure 10, referred to in [Ref.1.] and described below. **[A1]**

13.2.2.1 Global Roll-Call

The CC SCF's function is to maintain the global roll-call by using knowledge of all the solution lists for each connected ground station. Three types of target lists shall exist:

(a) The Global Tracked Target list which contains information on every aircraft currently tracked by the connected ground stations. **[E1]**

(b) For each connected station, a Station Tracked Target List containing only those targets that are fully tracked (ie successfully added to the roll call list) by the station. **[E2]**

(c) For each connected station, a Station Potential Track List containing targets that the station is capable of tracking. **[E3]**

13.2.2.2 Track Data and Surveillance Processing.

Track information to maintain the Global Roll-Call lists can be received from:

(a) The SCF via the SCN, or **[E1]**

(b) The Radar Data Processing system (in the future). **[E2]**

The surveillance processing function maintains the Global Tracked Target List. Track data received from connected stations shall also be inserted into the respective Station Tracked List to which they are associated. **[E3]**

The Surveillance Processing Function shall be responsible for the deletion of Roll-call entries when no further track data is received. **[E4]**

The Surveillance Processing Function shall provide a Co-ordinate Transformation to the local co-ordinate set for the track data received from the connected stations. **[E5]**

The particular algorithms required for the Co-ordinate Transformation will be provided to the Contractor by the Agency. **[A1]**

13.2.2.3 CC Surveillance Co-ordination function.

13.2.2.3.1 The CC SCF shall contain the following functions:

(a) A pre-defined cluster coverage map indicating all ground station responsibilities for providing lockout and handover on targets located in different regions of the cluster. The map structure shall be defined as in [Ref.1.] and shall be at least capable of mapping a cluster covering an area of 600 NM by 600 NM; **[E1]**

(b) A network system status list containing the cluster topology determined by the Network Monitoring Protocol (NMP) running in the `Network Failure and Control' function of the CC. It shall consist of a table containing the status of all connections between the network nodes; **[E2]**

(c) A periodic monitoring process shall be responsible for the routine monitoring of the global roll-call, the coverage map and the network system status list. The process shall ensure that status changes result in the appropriate cluster handover activity; **[E3]**

(d) A network and failure control process which runs the protocols required to maintain the central mode of operation within the cluster. The acquisition and lockout responsibilities shall also be noted in the Station Potential Track list for subsequent processing and monitoring of cluster, station and target status. **[E4]**

13.2.2.3.2 The Periodic Monitoring Process (PMP) shall:

(a) Monitor the network system status list; **[E1]**

(b) Monitor the CC global roll-call; **[E2]**

(c) Based on the cluster topology, select the coverage map and maintain the global roll-call based on that map. **[E3]**

When the PMP detects a change of target status in global roll-call, or of cluster topology in the network system status list, it shall update the global roll-call target lists and ensure that the Network and Failure control process is made aware of the targets to which this change applies. **[E4]**

The PMP shall check the consistency between the Station Potential and Station Tracked target lists and ensure that inconsistencies which could indicate a cluster fault (e.g. Targets which should be being tracked but which are not and which are not subject to a lost track request) are resolved consistent with the cluster system configuration. **[E5]**

The Tenderer shall provide information in the Tender Response on the inconsistencies that shall be checked. **[I1]**

The simplest solution to be adopted in these cases is for a CC failure to be declared and actioned as in 13.2.2.3.3 below. **[A1]**

The PMP shall handle at least the following changes of status:

(a) Newly acquired targets - those targets which have flown into the cover of the CC cluster coverage area; **[E6]**

(b) Targets flying into the surveillance coverage of cluster radars; **[E7]**

(c) The network system status list indicates a change of cluster topology. In this case the PMP shall select the appropriate coverage map and amend target details on the global roll-call to reflect the new target status. **[E8]**

The Tenderer shall propose in the Tender Response a method used to select the appropriate coverage map. **[I2]**

The method to be used shall be agreed between the Contractor and the Agency. **[E9]**

13.2.2.3.3 The Network and Failure Controller shall perform: **[E1]**

(a) Handover management - which shall include running the following protocols defined in [Ref 10]:

(i) Track acquisition protocol to ensure that any interrogator is aware of any new track entering its coverage; **[E2]**

(ii) Track support protocol used when a radar requests track information from the CC on targets where a track miss has occurred. **[E3]**

(b) Cluster topology and state determination: **[E4]**

(i) This shall be achieved using the network monitoring protocol (NMP). **[E5]**

(ii) The NMP derived cluster topology shall then be communicated to the cluster stations as defined in [Ref 10]; **[E6]**

(c) Failure management, where: **[E7]**

(i) The SCF shall be able to safely reconfigure the cluster in the event of failures. **[E8]**

(ii) The reconfiguration shall ensure the fault is isolated and that the remaining cluster can continue to provide for correct Mode S operation. **[E9]**

(iii) The SCF shall reconfigure the cluster in the case of CC failure and network failures as described in [Ref 10]. **[E10]**

The Network and Failure Control process shall determine the cluster response to the changes in target status. **[E11]**

The Tenderer shall provide in the proposal details of all the functions defined below:

(a) The coverage map, and adaptations of it **[I1]**

(b) The network system status list. **[I2]**

(c) The periodic monitoring process. **[I3]**

(d) The network and failure controller. **[I4]**

13.2.2.4 Cluster Size

The cluster is normally considered to consist of up to six ground stations. **[A1]**

The Cluster Controller shall be able to handle at least 4000 targets. **[E1]**

The Tenderer shall provide information on the upgradeability of the CC functionality to support a larger cluster size. **[I1]**

13.2.2.5 Network Link

The link shall be able to provide a communication interface with the SCN and the CAM and optionally a local RDP system. **[E1]**

The SCN interface shall support X.25 at a minimum data rate of 19.2 Kbps for out going and incoming data. **[E2]**

The SCN interface shall support TCP/IP connections (client and server over IPv4 or IPv6). **[E3]**

The interface shall support the ASTERIX formats for surveillance co-ordination data defined in [Ref.6.]a. **[E4]**

Note that if an optional RDP connection is not provided additional bandwidth will be required. **[A1]**

The Tenderer shall propose information on the data rate to be used, and how it has been calculated. **[I1]**

13.2.2.6 Control and Monitoring (CAM)

The Cluster Controller shall be provide with local and remote control and monitoring. **[E1]**

The Tenderer shall provide details of the CAM capabilities provided with the CC. **[I1]**

13.3 LVA Antenna Requirements

13.3.1 The Tenderer shall propose a Large Vertical Aperture (LVA) antenna, providing monopulse sum and difference channels with an additional omnidirectional control channel, suitable for SSR and Mode S, that enables the requirements of this specification (Chapters 4 and 6) to be met in all respects. **[E1]**

13.3.2 The Tenderer shall detail in their proposal where they consider their antenna will not enable the requirements of this specification (Chapters 4 and 6) to be met in all respects. **[I1]**

13.3.3 The Tenderer shall provide details in their response of the antenna characteristics, with guaranteed parameter limits, and supported with measured antenna polar diagram. **[I1]**

13.3.4 As a minimum the following information shall be supplied by the Tenderer in their response:

(a) Vertical sum polar diagrams (field strengths, -3dB beamwidth, sidelobes, underside rolloff rate, etc.); **[I1]**

(b) Sum horizontal polar diagrams (peak forward gain, beamwidth at -3dB, -10dB, -20dB, symmetry/alignment of sum peak and beamwidths over elevation, sidelobes, etc.); **[I2]**

(c) Control pattern (coverage of sum sidelobes, crossover points, notch/minimum, symmetry/alignment over elevation, etc.); **[I3]**

(d) Difference pattern (crossover points, peak gain, difference null, symmetry/alignment over elevation, etc.); **[I4]**

(e) Fully dimensioned drawings; **[I5]**

(f) Safety (maintenance personnel, lightning strike protection); **[I6]**

(g) Mechanical requirements (dismantling/reassembly of columns, transportation, lifting); **[I7]**

(h) Environmental protection; **[I8]**

(i) Maximum operational wind speeds and ice depth such that the antenna can function within the conditions of 4.2; **[I9]**

(j) Maintenance requirements and lifetime of the array. **[I10]**

13.3.5 Prior to acceptance and delivery of each antenna the Contractor shall provide measured azimuth and elevation patterns for the antenna supplied, according to an agreed test procedure. **[E1]**

13.4 The LVA Turning Gear Requirements

13.4.1 The Tenderer shall propose in their response turning gear and azimuth take off equipment for the ground station that enables the requirements of this specification to be met in all respects. **[E1]**

The radar gear and associated components, i.e. rotating joint, slip ring assemblies, etc. shall be based on proven equipment of established mechanical accuracy and reliability. **[E2]**

The turning gear shall have dual azimuth take off to a resolution of 360/16384°. **[E3]**

The Tenderer shall provide in the tender response information on the format of the azimuth data. **[I1]**

The Tenderer shall provide detailed information on the turning gear and the associated pedestal mounted electronics on the following configurations:

(a) 1 Motor Drive **[I2]**

(b) 2 Motor Drives **[I3]**

The Tenderer shall describe in detail the behaviour of the system when the turning gear speed fluctuates too much due to excessive loading (due to the wind for example). In particular the Tenderer shall indicate the consequences of such conditions on the output of the data to the ATCC users. **[I4]**

The Tenderer shall detail in their response where their proposed turning gear will not enable the requirements of this specification to be met in all respects. **[I5]**

13.4.2 As a minimum the following information shall be supplied by the Tenderer in their response:

(a) LVA weight and details of the on mounting interfaces **[I1]**

(b) Details of the tilt and horizontal mechanisms **[I2]**

(c) Rotation speeds and speed variations under the worst conditions of 4.7.2 (include effects on system performance, tracking, etc.) **[I3]**

(d) Details of braking and locking the antenna **[I4]**

(e) Details of safety interlocks to immobilise the antenna during maintenance **[I5]**

(f) Horizontal stability of the antenna/tower interface and the main antenna drive Dearing over the full turning rate and tilt range of the antenna **[I6]**

(g) Details of the azimuth take off systems **[I7]**

(h) Details of alignment and maintenance of the azimuth data and north marker **[I8]**

(i) Details of how the turning information is to be validated **[I9]**

(j) Details of the rotating joint including power handling capabilities **[I10]**

(k) Details of the drive assembly and couplings **[I11]**

(l) Details of the lifting points for each major component **[I12]**

(m) Details of the turning gear lubricating system **[I13]**

(n) Details of the maintenance of the turning gear system **[I14]**

(o) Detailed list of the tools being delivered in order to perform the preventive and corrective maintenance operations for the LVA and the turning gear (including lifting devices) **[I15]**

13.5 Shelter

13.5.1 This section details the requirements which a shelter holding the Mode S ground station shall meet if this option is accepted. **[A1]**

13.5.2 The structure of the shelter shall be of metal construction designed in accordance with the accepted practices. The structure shall meet the building codes and other relevant regulations of the country in which it is situated. **[E1]**

The Tenderer shall state any specific exceptions. **[E2]**

The Tenderer shall provide in the proposal details of the shelter's structure. **[I1]**

The shelter shall have a design life of 25 years with a time to first maintenance of 10 years **[E3]**

The shelter shall have two access doors, separated for fire safety purposes. One of the doors shall be of sufficient size to permit all equipment to be loaded or removed from the shelter. **[E4]**

It is anticipated that the main personnel door has a lobby area (foyer) and internal door. **[A1]**

The shelter shall be provided with suitable fixings at each corner to allow the shelter to be secured to the concrete foundations so as to prevent movement (or structural damage)in wind speeds up to the specified wind load environment. **[E5]**

13.5.3 The shelter, building services and equipment shall be designed to meet all current planning requirements and provide an environment that enables staff to carry out their work in a manner that it acceptable to the Agency and permits the delivered equipment to be installed and operated without modification to the shelter or equipment. **[E1]**

The shelter shall be capable of housing all technical equipment required for the system and the following items of furniture, desk, chair, filing cabinet (4 drawer) and stationery cupboard. **[E2]**

The Tenderer shall provide in the proposal details of the layout of the shelter. **[I1]**

13.5.4 The shelter shall be approved by the Agency for fire protection and security. **[E1]**

13.5.5 The shelter shall have suitable lifting points at each corner to allow for cranage on and off a lorry and be capable of transportation in the EC area without police escort. **[E1]**

The shelter shall be capable of being transported with the full technical load installed. **[E2]**

The above is not a requirement for the equipment to be ruggedised for transportation; delicate equipment may be removed for subsequent transportation. **[A1]**

The shelter roof shall be capable of supporting the necessary snow and maintenance loads **[E3]**

13.5.6 The 3 phase 400V 50Hz distribution system shall comprise of at least the following:

(a) Main incoming fuse switch for isolation and protecting the full installation; **[E1]**

(b) Domestic distribution board with circuit breaker protection for:

- (i) Lighting;
- (ii) Domestic ring main;
- (iii) Heating/cooling plant;
- (iv) Obstruction light and tower power;
- (v) Fire alarm system;
- (vi) Intruder alarm system; **[E2]**

(c) Technical distribution board with circuit breaker protection for the technical equipment; **[E3]**

(d) Connection for mobile 3 phase 400V 50Hz generator, with change-over switch for selection between mains and generator for supplying the full load requirements of (b) and (c) above. **[E4]**

The Tenderer shall provide details in the proposal of the electrical components of the shelter. **[I1]**

13.5.7 The shelter should be considered in two modes of operation occupied and unoccupied. **[A1]**

In either mode the shelter shall be maintained at a temperature of 21° +/- 5° of the selected temperature for the period at the limit of the hot (with sun loading) and cold soak specified extremes. **[E1]**

A spare (redundant) heating and cooling system shall be provided. **[E2]**

The Tenderer shall detail in the proposal how the air temperature shall be maintained within the shelter. **[I1]**

13.6 Tower

13.6.1 This section details the tower requirements which shall be met if this option is accepted. **[A1]**

The tower is not considered as a mobile facility. **[A2]**

13.6.2 The aerial support shall be designed to meet the operational needs of the system proposed including structural requirements at the environmental extremes and access for maintenance of all antenna elements. The tower shall be capable of providing a mount for the standalone designated LVA antenna type (i.e. no co-located primary antenna) **[E1]**

The torsional deflection shall not exceed 1.5 minutes of Arc. **[E2]**

Deflection in the vertical plane shall not exceed 2.0 minutes of Arc. **[E3]**

Both of these are measured with the antenna installed and at the aerial/tower interface level over the specified operational wind speeds. **[A1]**

The required tolerance of horizontal level shall not to exceed +/-2 minutes of Arc through the azimuth of 360°. **[E4]**

The design of the structure shall be such that this tolerance shall not be subject to deterioration with age. Alternatively the design shall allow for easy adjustment of the level. **[E5]**

13.6.3 The steelwork of the tower shall be to BS4360 (or equivalent). **[E1]**

All steelwork of the tower shall be galvanised in accordance with BS 729 (or equivalent) after fabrication. **[E2]**

The tower shall comply with the requirements of BS CP3 Chap V:Part 2: 1972 including amendments AMD 4952, 5152, 5343(or equivalent). **[E3]**

13.6.4 The tower shall have a design life of 25 years, allowing for preventative visits every year, and a time to first maintenance of 10 years. **[E1]**

13.6.5 The tower shall have staircase access to the top inspection/working platform. **[E1]**

The staircase shall have suitable lighting. **[E2]**

The top inspection/working platform shall have all necessary handrails and toeboards. **[E3]**

The top platform shall have an access hatch with lifting beam over capable of lowering the elements of the array necessary for maintenance to the ground. **[E4]**

The top of the staircase on to the platform shall have a lockable door to prevent unauthorised access to the top platform. **[E5]**

The tower shall be fitted with obstruction lights of 2000 candela (steady red light) in such a way that they are visible for 360° of the azimuth. **[E6]**

The Tenderer shall include in the proposal details of the design of the tower. **[I1]**

13.6.6 The Contractor shall design, supply and install a lightning protection system to cover the tower and antenna system in accordance with BS6651(or equivalent). **[E1]**

13.7 Data Recording and Playback

13.7.1 The Tenderer shall provide in the proposal details of the record/replay facilities which shall be used to evaluate radar data and details of how these facilities shall be connected with the Mode S ground system, as indicated in [Ref.12.]. **[I1]**

13.7.2 The system shall be capable of selective and full data recording and replaying of the following time-stamped data:

(a) Plot Assignor Data (inc. SSR/PSR/combined RDIF/ASTERIX Cat. 001, 2, 34, 48 data); **[E1]**

(b) Mode S enhanced surveillance information (ASTERIX Cat. 48 data); **[E2]**

(c) Status information (time, date, scan no.); **[E3]**

(d) Data flagged as Anomalies and false in the PAF and NOT sent to ATC; **[E4]**

(e) Interrogation instructions; **[E5]**

(f) Mode A/C and Mode S reply report data; **[E6]**

(g) Data from the Surveillance Co-ordination Network. **[E7]**

The bulk data recording capability shall be capable of recording up to four of the above simultaneously. **[E8]**

In addition it shall be capable for up to four of the above to be selectively recorded with time-stamp for up to eight hours without interrogation instructions (2 hours with interrogation instructions) with all radar systems operating at full capacity. **[E9]**

The selection of inputs shall be independent of the data being displayed. **[E10]**

The Tenderer shall provide in the response the proposed method for data recording and playback, stating the expected duration for the above signals. **[I1]**

13.7.3 It shall be capable to record full data of a given type and selectively record in order to replay, the following information together with azimuth information where appropriate:

(a) SSR quantised processed sum video signals; **[O1]**

(b) Mode S All-Call quantised processed sum video signals. **[O2]**

The Tenderer shall provide information in the response of the preferred approach. **[I1]**

13.7.4 Control of full and selective data recording shall be via the operator interface. **[E1]**

13.7.5 The medium to be used for bulk and selective digital recording shall allow recordings to be replayed for analysis on another computer. **[E1]**

13.7.6 Selection of digital recording shall be by any logical and/or combination of the following criteria:

(a) All aircraft within a static volume bounded by any azimuth and altitude interval. **[E1]**

(b) Aircraft with selected Mode 3/A codes (from a definable list of up to 20 Mode 3/A codes) **[E2]**

(c) All aircraft Mode S addresses selected (from a definable list of up to 20 Mode S addresses). **[E3]**

(d) All plot data which falls within a dynamic log box (size defined by the user). The centre of the box to be given by an aircraft defined as in (b) or (c) above. **[E4]**

(e) All data described as ‘anomaly’ or ‘false’. **[E5]**

13.8 RDIF Requirements

13.8.1 As an option, Data Rate Control and Real Time Quality Control shall be implemented in the RDIF format as described in CAA Paper 87002 § 5.1.2 and 5.1.4. **[O1]**

13.8.2 Each input port shall receive filtered primary plot data in RDIF/ASTERIX format, HDLC protocol, synchronous and simplex; at a rate in the range 7.2 to 38.4 Kbps in increments of 2.4 Kbps. **[E2]**

13.8.3 For Surveillance data, there shall be 3 interfaces per SMF and each interface shall be dual channel. Thus, each interface should be software configurable to be either both ASTERIX (or optionally both RDIF) **[A1]**

13.8.4 As an option, output of RDIF messages on three simultaneous, independently configurable, channels at an average rate of 250 messages/second **[O1]**

13.8.5 As an option, the SMF shall have an RDIF interface. **[O1]**

13.8.6 As an option the PAF shall include RDIF plot formatting. **[O1]**

13.8.7 As an option the data shall be provided at the same rate to the local display in RDIF. **[O1]**

13.8.8 As an option, the display system shall recognise, process and interpret all messages types in RDIF including the extensions as defined in (CAA Paper 87002) and display the data from these messages. **[O1]**

13.8.9 The system shall be capable of selective and full data recording and replaying of time-stamped data Plot Assignor Data (inc. SSR/PSR/combined RDIF/ASTERIX Cat. 001, 2, 34, 48 data) **[E1]**

13.9 FFM Optional Requirements

13.9.1 The Tenderer shall provide a detailed proposal for the following FFM optional items:

(a) Power Attenuator **[O1]**

(b) Battery back-up **[O2]**

(c) Outdoor packaging **[O3]**

13.9.2 The test functions described in 12.2.2 [E2] to [E5] shall independently be selectable through dedicated SDPs. **[E1]**

13.10 Test and Development System

A Test and Development System may not be appropriate for this project but the Agency may wish to support a tool for the operational implementation of Mode S. **[A1]**

To ensure that the Agency always has access to hardware to enable testing of new versions of software to be performed, the Tenderer shall provide as an option a proposal for the following: A test system comprising a representative sub-set of all the hardware in the system that can be used to perform system tests of the software. Sufficient hardware shall be provided to ensure that all fall-back, fail-safe and automatic switchover mechanisms can be tested. **[O1]**

The Tenderer shall state in his proposal what constitutes a representative sub-set and give reasons why this is sufficient. **[I1]**

13.11 Software Development System

A Software Development System may not be appropriate for this project but the Agency may wish to support a tool for the operational implementation of Mode S. **[A1]**

This Software Development System shall be separate from the Test and Development system specified above. **[E1]**

The Tenderer shall provide as an option a Software Development system to hold all of the source code under control of CM software, and on which compilation, linking etc. is carried out. **[O1]**

The Tenderer shall state the processing power and disc capacity for this bureau and provide performance figures for the following:

(a) An estimate of the time to complete a single complete rebuild of the system software. (assuming that no other build/compilation processes are running). **[I1]**

(b) Development System Storage capacity. **[I2]**

(c) Storage capacity required for one build. **[I3]**

The Build software shall allow for a minimum of 5 software engineers to generate different versions of a complete set of system software simultaneously. **[O2]**

The first item in an acceptance test of a Software Development System would commence with an 'empty' machine and load all operating systems, applications programs and source code onto it, to arrive at a working system. **[A2]**

13.12 Control and Monitoring Terminals

13.12.1 General

13.12.1.1 The Tenderer shall state how the following data is displayed on the local and remote terminal:

(a) Radar sensor, including antenna, turning gear, RF change-over and azimuth data; **[E1]**

(b) Interrogator; **[E2]**

(c) System Management Function (SMF); **[E3]**

(d) Surveillance Co-ordination Function (SCF); **[E4]**

(e) Data Link Function (DLF); **[E5]**

(f) Data transmission facilities (modem, multiplexer and network terminating units); **[E6]**

(g) Far Field site monitor; **[E7]**

(h) General site utilities (fire and intruder alarm, air conditioning equipment); **[E8]**

The Tenderer shall indicate whether the following statistical information (on a Scan or timely basis) are provided for display at the CAM terminals (locally or remotely):

(a) Information about the data supplied to the ATCC users:

- (i) Number of solo Mode S reports;
- (ii) Number of solo SSR reports;
- (iii) Number of solo PSR reports;
- (iv) Number of combined SSR/PSR reports;
- (v) Number of combined Mode S /PSR reports;
- (vi) Number of Splits plots;
- (vii) Number of code swaps;
- (viii) Number of plots with duplicated Mode S address;
- (ix) Number of test transponders;
- (x) Number of test targets.

(b) Information about the data transferred through the SCN:

- (i) Number of Track Initiations sent out;
- (ii) Number of Track Initiations received;
- (iii) Number of Track Data messages sent out;
- (iv) Number of Track Data messages received;

(v) Number of Track Data Requests sent out;

(vi) Number of Track Data Requests received;

(vii) Number of Tracks for which SCN Track Support is being given;

(viii) Number of Tracks for which SCN Track Support is being received.

(c) Information (including the rationale) about the data exchanged with the GDLP;

(d) CPU loading on the different processing boards;

(e) measured data rate on each link (surveillance, SCN and DLF). **[I1]**

13.12.1.2 The CAM terminals shall enable the connection or disconnection of the ground station from the Surveillance Co-ordination Network (SCN). **[E1]**

13.12.1.3 The Tenderer shall provide detailed information about the BITE of the CAM terminal (local or remote). **[I1]**

Each CAM terminal shall be delivered with a printer capable of printing all controlled and monitored data. **[E1]**

13.12.2 Local Terminal

13.12.2.1 Control and monitoring of the system and all subsystem shall be provided through a local (i.e. local to the equipment) terminal. **[E1]**

The Tenderer shall provide details on the HMI, including screen layout, used in the local terminal. **[I1]**

The Tenderer shall provide details on the platform used in the local terminal. **[I2]**

The Tenderer shall state the number of days over which the local terminal can store the control and monitoring messages received and sent. **[I3]**

13.12.3 Remote Terminal

13.12.3.1 Control and monitoring of the system and all subsystem shall be provided through a remote terminal. **[E1]**

The Tenderer shall provide details on the HMI, including screen layout, used in the remote terminal. **[I1]**

The Tenderer shall provide details on the platform used in the remote terminal. **[I2]**

The Tenderer shall state the number of days over which the remote terminal can store the control and monitoring messages received and sent. **[I3]**

13.13 GPS Receiver

As an option, the system shall be fitted with two GPS receivers acting as the external source. **[E1]**

13.14 Mode S interrogator with primary radar collocation

13.14.1 Some states might choose to collocate primary L-band or S-band radar with Mode S interrogators as defined below. **[A1]**

The Tenderer shall provide interfaces for the L-band 23cm HSA primary radar and co-locating with the L-band SRE-M5 AEG or Alenia/Thomson S-band: **[A2]**

Each channel of the Mode S ground station shall have a configurable primary interface to each primary channel, which may be selectable locally and remotely. **[E1]**

Each input port shall receive filtered primary plot data in RDIF/ASTERIX format, HDLC protocol, synchronous and simplex; at a rate in the range 7.2 to 38.4 Kbps in increments of 2.4 Kbps. **[E2]**

Each input port data rate shall be independently set to any output data rate in the range 7.2 to 38.4 Kbps in increments of 2.4 Kbps. **[E3]**

Each input port shall be able to be independently synchronised with either an external or internal clock, where the internal clock accuracy shall be better than one part in one million. **[E4]**

The clock and data levels shall conform to RS232-C or RS422. **[E5]**

The Mode S ground station shall perform plot combination with the primary radar data that is found to be associated with an SSR/Mode S target. **[E6]**

The Tenderer shall provide all necessary information of how it is intended to solve the problem of mutual interference. **[I1]**

The Mode S system shall be capable of operating asynchronously with the co-located radars. **[E7]**

The Tenderer shall provide details in the response of the proposed PSR interface. **[I2]**

13.15 Additional equipment and performance requirements

The system shall support PVCs for all connections except the SCN ones **[E1]**

In the case of repeated absence of a reply to a UF 4 or UF 5 interrogation containing a RR field higher or equal to 17, the system shall re-interrogate the aircraft with a UF 4 or UF 5 interrogation containing a RR field lower or equal to 16, and shall attempt to schedule this new interrogation in the same scan. **[E2]**

The Tenderer shall provide details on how the above function will be implemented. **[I1]**

13.16 Additional System Management Function requirements

An operational parameter shall be available to override the check of bit 33 of BDS 1,0 for the extraction of BDS 2,0 during the acquisition process. **[E1]**

An operational parameter shall be available to override the check of bit 25 of BDS 1,0 for the extraction of BDS 1,7 and BDS 1,D during the acquisition process. **[E2]**

An operational parameter shall be available to override the check of BDS 1,7 for the extraction of BDS registers. **[E3]**

13.16.1 II/SI code operation

An SI code, defined in [Ref.1.], is composed of the IC field and the CL field. Only transponders complying with Amendment 73 of Annex 10 will decode the CL field in order to determine if the content of the IC field is an II code or an SI code. Transponders which have not been upgraded to handle SI code will, by default, consider the content of the IC field as being an II code value. Therefore, if CL is not equal to zero (meaning that the IC field contains a SI code), the non-upgraded transponders will encode the parity sequence of the reply using the "matching" II code rather than the SI code contained in the interrogation. **[A1]**

The system, when operating with an SI code and if enabled by an operational parameter, shall also acquire targets through all-call replies which are encoded using the "matching" II code. This transponder shall be considered as a non SI equipped transponder. **[E1]**

Even if the content of BDS 1,0 states that the transponder has the SI capability, if this transponder is detected as using the "matching" II code to encode the parity sequence of the replies, it shall be considered as a non SI equipped transponder. **[E2]**

The system, if operating with an SI code and if enabled by an operational parameter, shall interrogate targets equipped with non SI transponders using the Mode S selective protocols foreseen for II code operation. The II code to be used shall be the "matching" II code. **[E3]**

The system, if operating with an SI code and if enabled by an operational parameter, shall be configurable by the user to either:

(a) not lockout non SI transponders on the "matching" II code ; **[E4]**

(b) use intermittent lockout for this "matching" II code. **[E5]**

The system, if operating with an II code and if enabled by an operational parameter, shall be configurable by the user to either:

(a) not lockout Mode S transponders which do not report the SI capability in BDS 1,0 ; **[E6]**

(b) use intermittent lockout for Mode S transponders which do not report the SI capability in BDS 1,0. **[E7]**

The above requirements are to allow neighbouring stations operating with an SI code and the “matching” II code to acquire the non SI targets. **[A2]**

When this additional system management function is activated, the lockout maps are not taken into account for non SI equipped transponders. **[E8]**

This additional system management function will only be activated when the aircraft population consists of a significant proportion of SI equipped transponders. **[A3]**

13.17 Additional DLF requirements

When the station extracts a downlink Dataflash message following the announcement of the event, the station shall check if the message is associated to a contract that has been set-up by the station's IAL and if so, shall identify the register which is subject to monitoring. **[E1]**

If the Dataflash contract was set-up by the Internal Application List, the station shall program a GICB extraction for the monitored register during the same scan as the reception of the downlink Dataflash message. **[E2]**

This function shall be selectable by an SDP, for each contract independently. **[E3]**

The above option does not modify the normal operation of the station Dataflash application. Consequently, the operator should normally not select this function for a two-segments contract. **[A1]**

13.18 Processing of Position Reports

Mode S ground stations, when not clustered, exclusively rely on All Call interrogations and replies for Mode S targets acquisition. The processing of additional, indepedent target reports could support Mode S targets acquisition, anti-reflection processing as well as identifying Mode S detection failures. Such independent target position reports could come from Extended Squitters decoded on the omni antenna, or from target reports decoded on an external interface (e.g. ADS-B ASTERIX target reports). **[A1]**

The Tenderer shall provide details on the extensibility of their design to accommodate such enhancements, and the expected benefits. **[I1]**

CHAPTER 14

GENERAL EQUIPMENT CONDITIONS

14.1 Logistic Support

14.1.1 General

All parts of the ground station to be provided under this contract shall be designed and constructed in order to withstand possible operations of 24 hours per day, 7 days per week, 52 weeks per year for a minimum 10 year life cycle. **[E1]**

A modular approach, with easy access to each LRU and test point, shall be employed. The approach shall facilitate rapid replacement of faulty units, in order to satisfy the availability and maintainability requirements, whilst minimising impact on personnel and equipment safety. **[E2]**

It is preferred that duplicated items in the antenna turning gear can be replaced without the need to stop the antenna rotating. **[A1]**

The Tenderer shall state in his response the antenna turning gear items that require the antenna to be stopped when replaced. **[I1]**

It is preferred that no rear access is required for maintenance purposes. **[A2]**

It is required that related equipment maintenance actions shall be carried out from the same side of the equipment. **[E3]**

Maintenance philosophy for the ground station shall be consistent with unattended operation and shall be as follows:

(a) Restoration of service by Line Replaceable Unit (LRU) exchange at Organisational level. This may be carried out by appropriately trained Contractor, Agency or National personnel. **[A3]**

(b) Further diagnosis and exchange of Field Replaceable Units (FRU) to be carried out by engineering staff, either Contractor, Agency or National, utilising Intermediate or Depot level facilities. **[A4]**

(c) Defective LRU/FRU shall be returned for appropriate action (e.g. repair, recalibration, replacement) to the Contractor or a designated National Repair Centre. **[A5]**

A Logistic Support Plan shall be provided by the Tenderer with his Proposal regarding cost efficient approaches to Engineering, Logistic Support and Maintenance of the system(s), equipment(s) and software. This shall cover the entire planned life cycle of the system(s). **[I2]**

The Plan shall detail the methods & standards to be employed to achieve the Availability, Reliability and Maintainability objectives (including safety aspects) contained in this Specification. **[E4]**

The Plan shall also provide outline details of types of personnel, training, Support & Test Equipment requirements, Spares availability and Corrective & Preventative maintenance tasks (particularly those expected to exceed 30 minutes in length). **[E5]**

The Tenderer shall indicate in his Tender response the level of support available from their own resources to provide backing for the Agency or the National organisation's support facilities. **[E6]**

The Commercial Response shall include appropriate cost scales for:

(a) Maintenance Support Contract set-up and renewal **[E7]**

(b) Manufacturer's repair of LRUs and FRUs **[E8]**

(c) Post Design Services contract to provide technical information and assistance to component level and to allow any changes or improvements resulting from the test and validation period to be accommodated **[E9]**

Examples of the above, where available, shall be included in the Tender Response. **[E10]**

The Agency, or the National organisations may be required to perform Logistic Support Analysis to MIL STD 1388-1A. **[A6]**

The Tenderer shall indicate in the Tender Response his ability to comply with the objectives of this Standard (or equivalent) by citing previous examples of deliveries using Logistic Support Analysis. **[I3]**

The Tenderer shall guarantee the availability of all items required to support the system(s) supplied for at least 10 years after final acceptance of the last station to be installed. **[E11]**

Advance warning of at least 12 months shall be required for inability to meet this commitment to allow the Agency the option of a Lifetime spares procurement. **[E12]**

All components used in the Mode S system shall be available from more than one source, except with the prior written agreement of the Agency. **[E13]**

The Agency retains the right to purchase items required to support the system(s) supplied directly from the original equipment or component manufacturers. **[A7]**

Software maintenance, including PROM/EPROM programming shall be addressed specifically by the Tenderer who shall include details of his intended software Maintenance Policy in his Tender Response **[E14]**

14.2 Reliability, Availability, and Maintainability (RAM)

14.2.1 General

Availability, Reliability and Maintainability are characteristics of the overall system which shall be specified, designed, implemented, tested, validated and documented. **[E1]**

The methodology, techniques, processes and tools The Tenderer intend to use to achieve the specified RAM objectives shall be described or referenced in specific plans addressing architecture, hardware and software aspects. **[I1]**

The Military Standards Referenced in Annex C provide the preferred methodology. **[A1]**

14.2.2 Availability

For the purposes of this specification, Availability is defined as a ratio of the total time the system is capable of performing it's mission, against the time for which it is required to perform that mission, expressed as a percentage. **[A1]**

The availability calculation excludes all planned downtimes. **[A2]**

The figures for Availability quoted in this Specification are for Operational Availability (Ao) and shall be calculated using the following equation:

$$A(o) = \frac{MTBF}{MTBF + MTTR + MRT}$$

MTBF = Mean Time Between Failures in hours.

MTTR = Mean Time To Repair in hours.

MRT = Mean Response Time in hours (i.e. the average time from notification of failure for a technician to be ready to commence repair action). **[A3]**

14.2.2.1 Failure Definition

The Mode S System is to be considered as failed when coherent and full radar data is no longer provided by that system to Air Traffic Control. **[A1]**

The Mode S System is defined in Chapter 2 of this specification. **[A2]**

14.2.2.2 System Availability

The operational availability of coherent and full radar data from the Mode S ground station site shall be greater than 99.98%. **[E1]**

The Tenderer shall use availability figures for the customer-supplied components in order to predict the overall system availability. **[E6]**

The system reliability requirement for each Mode S ground station as described in Figure 3 (excluding Local Display and Recording/Playback facility) shall be greater than 20,000 hrs MTBF. **[E2]**

MTTR at Organisational Level shall be 30 (thirty) minutes. **[E3]**

The following figures are given for Tender Evaluation purposes:

(a) The MRT shall be 3.5 hours;

(b) The maximum time to repair shall not exceed 8 (eight) hours for 95% of all repairs;

(c) The maximum response time shall not exceed 8 (eight) hours. **[A2]**

When procuring equipment during the operational implementation phase of Mode S the Agency will provide the MRT based on their individual maintenance philosophy. **[A3]**

If the option is taken, the operational availability of the cluster controller shall be greater than 99.99% using the MTTR and MRT above. **[O1]**

The operational availability of the site monitor shall be greater than 99.995% using the MTTR and MRT above. **[E5]**

14.2.3 Reliability

Reliability is the probability that an item will perform it's intended function without error, under stated conditions, for a specified period of time. **[A1]**

14.2.3.1 Reliability Model

The Tenderer shall substantiate his ability to meet the specified RAM by providing in his response a reliability model consisting of reliability block diagrams covering all functions of the system. **[E1]**

The MTBF and MTTR in hours and the Availability shall be clearly shown in either the block diagram or in a list showing the equipment breakdown to functional unit level, with identification of specific common failure mode (e.g. switch over equipment). **[E2]**

14.2.3.2 Reliability Goals

Where appropriate hardware and software shall be separately identified and included in the Reliability predictions. **[E1]**

The Tenderer shall state the individual MTBF's of the equipment listed below and identify which items are duplicated to achieve the required availabilities of 14.2.2.2:

(a) SSR Antenna and cabling; **[I1]**

(b) Main bearing and drive ring; **[I2]**

(c) Rotary Joint and slip rings; **[I3]**

(d) Drive Motors and clutch; **[I4]**

(e) Antenna controllers; **[I5]**

(f) Azimuth Encoders; **[I6]**

(g) Control and Monitoring (Single Channel); **[I7]**

(h) Mode S Electronics (Single Channel); **[I8]**

(i) Monitor Display; **[I9]**

(j) Site Monitor; **[I10]**

(k) Cluster Controller. **[I11]**

The above info is required only if the corresponding equipments are being procured. **[A2]**

The Tenderer shall ensure the design minimises system outage due to preventative maintenance. **[E2]**

The Tenderer shall state in the Tender Response all expected outages. **[I12]**

14.2.3.3 Reliability Prediction

The Tenderer shall provide in his Response reliability predictions and analysis for each site as per MIL-HDBK-217 using exclusively a generic parts count method. **[I1]**

A Ground Fixed environment shall be used for all calculations. **[E1]**

Predictions for single channel MTBF and System MTBF shall be provided for the following:

(a) Line replaceable units; **[I2]**

(b) Each major equipment group; **[I3]**

(c) Each single channel of the system. **[I4]**

Where existing equipments are being offered to fulfil the contractual requirements then field failure rates and MTBF data shall be provided to substantiate the predicted data. **[E2]**

The Tenderer shall indicate the condemnation rate for the following:

(a) Line replaceable unit; **[I5]**

(b) Each major equipment group; **[I6]**

(c) Each single channel of the system. **[I7]**

14.2.3.4 Reliability Predictions Update

Reliability Predictions shall be provided within ninety (90) days of contract award and at agreed intervals thereafter for approval by the Agency. **[E1]**

14.2.3.5 Reliability Demonstration

The Contractor shall conduct a Reliability Demonstration. **[E1]**

The preferred methodology is described in MIL STD 785. **[A1]**

The Tenderer may propose an alternative methodology, to be described in the SAT Test Strategy, subject to Agency approval. **[I1]**

14.2.4 Maintainability

Maintainability is the measure of the ability of an item to be retained in or restored to a specified condition when maintenance is performed by personnel having specified skill levels, using prescribed procedures and resources, at each prescribed level of maintenance and repair.. **[A1]**

MTTR is the sum of corrective maintenance times at any specified level of repair, divided by the total number of failures within an item repaired at that level, during a particular interval under stated conditions. **[A2]**

14.2.4.1 Maintainability Goals

The Contractor shall meet or improve on the MTTR targets for the following functional areas:

(a) Mode S Antenna - 4 hrs; **[E1]**

(b) Main Bearing - 8 hrs; **[E2]**

(c) Motors & Encoders - 4 hrs; **[E3]**

(d) Mode S Electronics - 0.5 hrs; **[E4]**

(e) CAM - 0.5 hrs; **[E5]**

(f) Monitor Display - 1 hr; **[E6]**

(g) Site Monitor - 0.5 hrs; **[E7]**

(h) Cluster Controller - 0.5 hrs. **[E8]**

The above info is required only if the corresponding equipments are being procured. **[A1]**

The Tenderer shall provide in Tender response the MTTR estimates for each of the following:

(a) Line Replacement Unit; **[I1]**

(b) Each major equipment group; **[I2]**

(c) Each single channel of the system; **[I3]**

14.2.4.2 Maintainability Predictions

The Tenderer shall provide in the Tender response Maintainability Predictions for the following equipments:

(a) Line Replaceable Unit; **[I1]**

(b) Each major equipment group; **[I2]**

(c) Each single channel of the system. **[I3]**

MTTR predictions shall be in accordance with MIL HDBK 472. **[E1]**

The Tenderer shall conduct a Maintenance Task Analysis in accordance with MIL STD 470. **[E2]**

14.2.4.3 Maintainability Prediction Updates

Maintainability Predictions shall be provided within ninety (90) days of contract award and at agreed intervals thereafter for approval by the Agency. **[E1]**

14.2.4.4 Maintainability Costs

The Tenderer shall provide in the Tender response the average material cost of repair, the average cost per repair and the depot response time for the following:

(a) Line Replaceable Unit; **[I1]**

(b) Each major equipment group; **[I2]**

(c) Each single channel. **[I3]**

14.2.4.5 Maintainability Demonstration

The Contractor shall conduct a Maintainability demonstration in accordance with MIL STD 471. **[E1]**

14.3 Life Cycle Aspects

The ground station equipment shall be designed to have an in-service life of at least 10 years and shall be designed in such a manner that it may be progressively upgraded in functionality and performance. **[E1]**

The Tenderer shall indicate in the Tender Response the expansion capability of his proposed equipment (processor power, memory capacity, etc.). **[I1]**

The Tenderer shall be prepared to provide data for life cycle costing (Refer to Annex F for Data Requirements List). **[A1]**

To enable the Agency to fully calculate Life Cycle Cost implications, the Tenderer shall include as part of his proposal a provisional Build List of all repairable items. **[I2]**

The following information shall be provided for each item listed:

(a) Mean Time Between Failure, **[E2]**

(b) Mean Time To Repair, **[E3]**

(c) Original Manufacturer (Name, Address & Telephone Number) (include Alternative Manufacturer if available) **[E4]**

(d) Manufacturer's Part Number and Designation, **[E5]**

(e) Supply Price (including volume discount if any) and initial escalation rate. **[E6]**

The sources for all data shall be quoted. **[E7]**

Where any item of data is not supplied, the reason for non inclusion is to be stated. **[E8]**

All data shall be supplied by the Contractor within 12 months of Contract Let. **[E9]**

The Tenderer shall provide as part of the Commercial Response a Life Cycle Cost analysis. **[E10]**

14.4 Documentation

14.4.1 General Requirements

The Tenderer shall provide a detailed list of technical documents to be delivered, which include, but is not limited to, the following documents:

(a) System Overview; **[E1]**

(b) List of Deliverable Items; **[E2]**

(c) Statement of Compliance; **[E3]**

(d) Project Management Documentation:

- (i) Project Management Plan (PMP); **[E4]**
- (ii) Configuration Management Plan (CMP); **[E5]**
- (iii) Quality Plan (QP); **[E6]**
- (iv) Software Development Plan (SDP); **[E7]**
- (v) Verification and Validation Plan (VVP); **[E8]**

(vi) Installation and Commissioning Plan. **[E9]**

(e) Reliability, Maintainability and Availability Predictions (RMA). **[E10]**

(f) Lifecycle Documentation:

(i) System Requirement Specification (SRS or DOD-2167 SSS). **[E11]**

(ii) System Architecture Design Document (SAD or DOD-2167 SSDD). **[E12]**

(iii) Software Requirement Documents (SRD or DOD-2167 SRS), for each CSCI. **[E13]**

(iv) Software Architectural Design Documents (ADD or DOD-2167 SDD), for each CSCI. **[E14]**

(v) Interface Control Documents (ICD) for internal and external interfaces. **[E15]**

(vi) Hardware Development Specifications, for each HWCI. **[E16]**

(vii) Hardware Architectural Design Documents, for each HWCI. **[E17]**

(viii) COTS customisation documents. **[E18]**

(ix) Operator Handbooks. **[E20]**

(x) Verification and Validation Documents (for the system, the hardware and software components). **[E21]**

(g) COTS standard documentation. **[E22]**

(h) Training and Maintenance documentation. **[E23]**

(i) System Documentation **[E24]**

The Tenderer shall state when these documents will be delivered. **[I1]**

The exact delivery schedule shall be subject to agreement with the Agency. **[E25]**

The Tenderer shall deliver preliminary versions of the documents listed in (a), (b), (c), (d) and (e). **[E32]**

The Contractor shall deliver the documents identified in the Tenderer’s list. **[E26]**

All deliverable documentation shall be written in English, using standardised presentation and notation. **[E27]**

All deliverable documentation shall be provided as paper and computer readable in a format to be agreed with the Agency prior to contract let. **[E28]**

The Contractor shall ensure that the Agency has the right to a free licence to copy the deliverable documentation called for under the contract, and to circulate or use the copies within the establishments of the Agency. The Agency will not disclose such documents outside its establishments without the prior written consent of the Contractor which shall not be unreasonably withheld. **[E29]**

The Tenderer shall identify in their Tender Response any deliverable documentation which will not be subject to the licence above. **[I2]**

Delivered documentation shall always be identified on the cover page with the assigned code referred to in the List of Deliverables. **[E30]**

In addition to the requirements above; flow charts, block diagrams and preventative/ corrective procedures (including diagnostics) shall be required. **[E31]**

These may be provided as a separate document or included in the main document. **[A1]**

14.4.2 Requirements Traceability

Traceability through cross references of the functional requirements shall exist throughout all levels of the documentation produced, including maintenance phases documentation. **[E1]**

14.4.3 Operator Handbooks and Maintenance Documents

The purpose of the Operator Handbooks and Maintenance Documents is to enable operation, maintenance, fault diagnosis and repair of the equipment by trained personnel in the Agency . **[A1]**

Although service restoration will be effected by replacing faulty LRUs with serviceable items, all the data needed to enable staff to locate faults to LRU level is required. **[A2]**

14.4.4 Cable Schedules

The System Cabling Schedule shall form part of the System Documentation. **[E1]**

The system cabling comprises all the cables used to interconnect the complete system. **[A1]**

14.4.5 Lifecycle Documentation

Either a component needs to be newly developed, or it exists already as a product or as part of a product. Those existing products are Off The Shelf products. They can be classified into Commercial Off the Shelf products (COTS) and Non Commercial Off The Shelf products (OTS). **[A1]**

A component shall only be categorised as COTS if it satisfies the following conditions:

(a) It has been developed ready for sale (in stock) by a third party, prior to receiving the contract (e.g. standard PC…);

(b) It is available to the market;

(c) It has an established history of use by different customers;

(d) It is a product of a reputable, well-established company;

(e) It is maintained by the vendor;

(f) The vendor possesses the source (in case of a software component);

(g) It is not modified for the contract (customisation in the form of setting/tuning parameters is not considered a modification). **[E1]**

A component shall only be categorised as OTS reused component if it satisfies the following conditions:

(a) It has been developed by the Tenderer and used outside the current contract;

(b) The product is developed according to an acceptable QA system, the complete lifecycle documents belonging to the product are available;

(c) It needs minor modifications (no more then 30 % of the original source code is to be modified/extended for the contract, in case of software) **[E2]**

Full lifecycle documentation shall be produced and delivered for newly developed components. **[E3]**

The existing lifecycle documents belonging to the OTS products shall be provided, updated if they were modified to fit in the procured system. **[E4]**

The COTS standard documentation (User Manual, Reference Manual…) shall be provided, together with documents describing how they were customised to fit in the procured system. **[E5]**

The Tenderer shall state, for each Configuration Item, whether it classifies as COTS, OTS or needs to be developed. **[E6]**

In addition to the above requirements, all source code listings of new and OTS reused software modules shall be provided in hardcopy and an appropriate computer readable format and provide the full definition and identification of the software development environment used (compilers, testing tools, simulator). **[E7]**

14.4.6 Amendments

The Tenderer shall advise the Agency in the Tender response on the exact procedures that will be employed to amend the documentation to include subsequent updates. **[I1]**

Specific Procedures shall be defined to control the various status of documentation, its approval and to ensure that the pertinent issues of appropriate documents are available at the appropriate locations, particularly when computerised documentation is used distributed and archived. **[E1]**

14.5 Training

Training for the delivered equipment shall be sufficient to enable Agency engineers to efficiently undertake the necessary trials to evaluate the ground station. **[E1]**

The following 'minimum training requirements' are identified for the ground station system:

(a) System description, including data flows;

(b) Interpreting system status;

(c) Initiate changes to system configuration;

(d) Reinstating equipment after failure/maintenance;

(e) Routine maintenance;

(f) Fault location;

(g) Restoration of service by module changing;

(h) Running and interpreting diagnostic software. **[A1]**

The Tenderer shall provide in the Tender responses a Training Plan for the ground station equipment as part of the Tender response. **[I1]**

The Training Plan shall describe the objectives, pre-requisites, duration and approach for training personnel involved with the delivered equipment (both hardware and software). **[E2]**

The Tenderer shall provide as part of the Commercial Response a separately cost proposal for the training of staff, stating how they intend to comply with the Training Plan objectives. **[I2]**

It is anticipated that all Training Courses shall be held at the Contractors premises. **[A3]**

The Contractor's training personnel shall utilise a complete and fully functioning system for all practical training. **[E3]**

To ensure a good standard of training, the Contractor shall employ Instructors who are fully trained in Instructional Techniques. **[E4]**

14.6 Safety Requirements for Personnel and Environment

14.6.1 Safety Regulations and Standards

The Contractor shall meet all International, European and National Health and Safety standards, rules and practices and the legislation that has relevance to the equipment being supplied. **[E1]**

'National' Health and Safety standards, rules and practices in this context is considered to be the standards of the country in which the equipment is to be installed, as specified in the local language. **[A1]**

The Tenderer shall state the National Health and Safety at Work requirements which will be adhered to. **[I1]**

The Tenderer shall state the standards relevant to the equipment being supplied. **[I2]**

The Contractor shall at all times observe the local rules regarding health and safety at work, relative to the personnel in his service The expenses which arise from this obligation (including any necessary translation of documentation) shall be borne by the Contractor. **[E2]**

The Tenderer shall show his understanding of the rules in force for the sites selected for the implementation of the Mode S ground system. **[E3]**

The Tenderer shall provide in Tender response details of their management system for Health and Safety and demonstrate the processes used to ensure compliance. **[I3]**

The Tenderer shall provide in Tender response details of the acoustic noise level of the proposed equipment. **[I4]**

14.6.1.1 Pre-Contract Audit

The Agency shall have the right to carry out a Pre-Contract Audit to confirm that the standards and the management system detailed by the Tenderer fully meet the Agency's requirements. **[E1]**

The audit will confirm that the Tenderer is operating to the standards defined in the Tender Response. **[A1]**

14.6.1.2 Climbing Devices

All ladders that may be required to gain access to areas that are out of reach from ground level in areas where particular hazard may exist shall be fitted with "Railok" to prevent personnel falling. **[E1]**

All installations shall require the approval of the Agency’s delegated Safety Officer. **[E2]**

14.7 Air Traffic Service Safety

14.7.1 Introduction

14.7.1.1 The Agency's safety policy is to secure high standards of safety within the air traffic services and systems it plans, provides and operates by minimising those risks which contribute to aircraft accidents as far as reasonably practicable. Safety is afforded the highest priority and it is an integral part of the Management function. **[A1]**

14.7.1.2 The Contractor shall demonstrate his understanding of the safety requirements and that their design and implementation plans will meet all of the safety criteria. The necessary demonstrations shall be through analysis of the design, components and maintenance procedures. **[E1]**

14.7.1.3 The safety activities and analysis present the evidence, arguments and assumptions, at significant points in the system life cycle, to provide assurance that:

(a) The Safety Requirements of the system are either met or that any shortcomings, limitations or unresolved hazards are understood and accepted. **[A1]**

(b) When introduced into operational service the new system does not, of itself, exhibit any hazards due to installation, commissioning and integration activities. **[A2]**

(c) The introduction of the new system does not adversely affect the safety of the existing ATS. **[A3]**

14.7.1.4 The safety assurance activities provide the necessary confidence that the following objectives have been met:

(a) The Safety Requirements of the system have been correctly identified. **[A1]**

(b) The procedures and standards used to design, develop and analyse the system are adequate and have been implemented correctly. **[A2]**

(c) There is sufficient evidence available to show compliance with the Safety Requirements, and to allow the system to proceed to the next life cycle phase or continue in operation, as appropriate. **[A3]**

14.7.2 Safety Plan

14.7.2.1 The Safety Plan shall define the safety management, safety analysis and assurance activities to be performed by the Contractor. **[E1]**

14.7.2.2 The Tenderer shall provide a preliminary Safety Plan. **[E1]**

The Tenderer's Safety Plan shall, as a minimum, address the items detailed at Annex D and shall confirm that they are commensurate with ensuring the Safety Plan deliverables are met. **[E2]**

14.7.2.3 The Contractor shall provide a Safety Plan. **[E1]**

14.7.3 Safety Plan Deliverables

14.7.3.1 The Contractor shall deliver the following documented deliverables resulting from the activities defined in their Safety Plan:

(a) Design Process and Assurance Deliverable; **[E1]**

(b) Installation, Commissioning, Integration and Test and Evaluation Deliverable. **[E2]**

14.7.3.2 The Design Process and Assurance deliverable shall:

(a) Provide a summary description of the Mode S functions, supported with diagrams, showing their physical location(s) and role. The boundaries of the Mode S System and its interface with other systems or facilities should be clearly identified. **[E1]**

(b) Identify or reference the Safety Requirements of the Mode S System. **[E2]**

(c) Describe the physical configuration of Mode S, including permitted variations of the configuration during operation. **[E3]**

(d) Identify the documentation and its status, which records the system build state for Mode S. **[E4]**

(e) Provide a description of the design process used for the development of the hardware and software aspects of Mode S. **[E5]**

(i) This description shall show the design, coding, verification and validation methods to be employed that will allow the software to meet the Safety Requirements. **[E6]**

(ii) This description shall provide evidence, arguments and assumptions for claiming that the hardware design has been implemented to a level consistent with the Safety Requirements. **[E7]**

(f) Identify any dependencies on other systems or facilities that affect the ability of Mode S to meet its Safety Requirements. **[E8]**

(g) Address each Safety Requirement: **[E9]**

(i) Providing arguments to support the claim that the Mode S design will meet the Safety Requirement; **[E10]**

(ii) Summarising, and referencing, any evidence available that supports the arguments that the design will meet the Safety Requirement; **[E11]**

(iii) Identifying the current compliant status of the Safety Requirement (met, not met, not proven); **[E12]**

(iv) Identifying any further verification and subsequent validation that is to be performed during the Installation, Commissioning and Integration activities; **[E13]**

(v) Identifying any features in the design that specifically address the Safety Requirement. **[E14]**

(h) State any limitations on the use, or maintenance, of Mode S or other shortcomings identified in the design. **[E15]**

(i) Specify any aspects of the Mode S performance that should be monitored in service to provide assurance that the Safety Requirements continue to be met in operation. **[E16]**

(j) Detail the confidence that has been gained that the Installation, Commissioning and Integration activities will not have an adverse effect on the safety of the existing ATS. **[E17]**

14.7.3.3 The Installation, Commissioning, Integration and Test and Evaluation Deliverable shall:

(a) Describe the installation, commissioning, integration and test and evaluation process and provide evidence, arguments and assumptions for claiming that this process was effective in maintaining the safety of Mode S and the existing ATS. **[E1]**

(b) Identify any dependencies on other systems or facilities that affect the ability of the Mode S System to meet the Safety Requirements. **[E2]**

(c) State any limitations on the use, or maintenance, of Mode S or other shortcomings identified in the design. **[E3]**

(d) Address each Safety Requirement: **[E4]**

(i) Identifying the compliant status of the Safety Requirement. **[E5]**

(ii) Identifying and reference the results of any other evidence that confirms or otherwise that the Safety Requirement will be met, and revise the status of the Safety Requirement accordingly. **[E6]**

(iii) Where it has not been concluded that a Safety Requirement will be met provide information about the possible impact to ATS. **[E7]**

(e) Declare and identify any other deficiencies in Mode S that may affect the safety of the ATS. **[E8]**

(f) Identify any aspects of the Mode S performance that should be monitored in service to provide assurance that the Safety Requirement continue to be met in operation. **[E9]**

(g) Identify any Mode S operation and maintenance requirements necessary to preserve the safety, including the identification and provision of relevant training. **[E10]**

(h) Detail the confidence that has been gained that the transition to operational use will not have an adverse effect on the safety of the existing ATS. **[E11]**

(i) Identify the documentation and its status, which records the Mode S build state. **[E12]**

(j) Identify or reference the process and responsibilities for initiating, performing and approving changes to Mode S. **[E13]**

14.7.4 Mode S Safety Requirements

14.7.4.1 A provisional analysis has been undertaken for the Mode S Safety Requirements and was derived by consideration of the failure modes on Air Traffic Operations. Annex E provides the target figures for the Mode S system in the operational phase, for a limited list of failure modes. The contribution of Radar Data Processing Systems, communication links and ATC workstations to the Mode S system are not included in Annex E. **[A1]**

The list of failure modes for the ground station shall be developed and refined by the Contractor, in consultation with the Agency. **[E1]**

Note that the strategy for the initial implementation of Mode S across the core area of Europe is defined as dual coverage (derived from two independent sources working simultaneously), wherever possible. **[A2]**

The Contractor shall demonstrate that ground stations based on their design can meet the refined Mode S System Safety Requirements. **[E2]**

Loss of radar data is defined as radar information that is not available from the ground station. **[A3]**

The loss of radar data for less than 10 seconds is considered to have no safety effect. **[A4]**

Corruption is defined as radar information that is available from the ground station(s) that is incorrect. **[A5]**

Detected corruption is defined as corrupt radar information available from the ground station(s) that has been identified as corrupt. **[A6]**

Undetected corruption is defined as corrupt radar information available from the ground station(s) that has not been identified as corrupt. **[A7]**

The corruption of any sequence of reports from the same aircraft for less than 10 seconds is considered to have no safety effect. **[A8]**

Height and Identity data is used to define the surveillance information of both Modes A/C and S. **[A9]**

14.7.5 Mode S Safety Analysis

14.7.5.1 General

In support of the Safety Plan deliverables the following specific safety activities shall be conducted by the Contractor. The product of these analyses, where appropriate, are deliverables to the Agency. **[E1]**

14.7.5.2 Standards

Relevant standards for the conduct of Mode S safety activities are indicated at Annex C. **[A1]**

The Tenderer shall state in his response the standards they will be using for each safety activity. **[I1]**

14.7.5.3 Hazard Log

14.7.5.3.1 The Contractor shall:

(a) Produce and maintain a Hazard Log; **[E1]**

(b) Ensure that all changes initiate a review of existing and new hazards that may arise as a result of such changes; **[E2]**

(c) Use a common tool (Word, Excel etc.) to maintain the Hazard Log (Refer to Section 14.13.3). **[E3]**

14.7.5.3.2 The Contractor's Hazard Log shall be provided as soon as it is updated throughout the life cycle of the product, including updates resulting from third contracts. **[E1]**

14.7.5.4 Hazard Identification and Analyses

14.7.5.4.1 The Contractor shall conduct a programme of Hazard Identification and Analyses, building on that of Annex E, and stating any assumptions about other systems; to ensure that the identification of hazards within Mode S are both refined and extended. **[E1]**

14.7.5.4.2 The ground station Safety Requirements shall form the initial assessment of the safety criticality of Mode S. The Contractor shall use this assessment as the basis for the subsequent hazard analysis as the design progresses. **[E1]**

14.7.5.4.3 The Contractor shall incorporate the results of the Hazard Identification and Analyses into the Hazard Log. **[E1]**

14.7.5.4.4 The Hazard Identification and Analyses shall include, but not be limited to:

(a) A system FMECA (Failure Modes Effect and Criticality Analysis) for Mode S hardware and software updating it regularly during system development. In the case of hardware, the FMECA shall decompose Mode S to Line Replacement Unit level. Where the FMECA has identified a safety significant failure, the Contractor shall take steps to eliminate, mitigate, circumvent, or otherwise reduce the safety significance of the failure. **[E1]**

(b) A Fault Tree Analysis (FTA) to complement the FMECA and to derive quantitative probabilities of occurrences of all hazards and to demonstrate that the Safety Requirements have been met. The FTA shall explicitly state the source and justification of all failure probabilities used in the derivation of quantitative probabilities for each hazard. **[E2]**

The Tenderer shall provide in the Tender Response his approach to the above with respect to software. **[I1]**

14.7.5.5 Spare.

14.7.5.6 Independent Safety Assessment

14.7.5.6.1 The Contractor shall carry out an Independent Verification and Validation (IV&V) of the implementation of the Contractor Safety Plan and its products. Suitably qualified personnel independent of the development team shall be used. **[E1]**

14.7.5.7 Safety Assurance Traceability

14.7.5.7.1 The Contractor shall document, implement and maintain traceability procedures to allow for full forward and backward traceability of all documents, components, materials, designs, reviews, records pertaining to the safety assurance activities. **[E1]**

14.8 Hardware Requirements

14.8.1 General Hardware Requirements

The construction of the system and all its components shall be in accordance with the best current practices and standards in force at the International and European levels. **[E1]**

As part of the Tender Review Process the Agency will carry out an on-site audit of the Tenderers Hardware Design and Management processes. **[A1]**

The audit will involve an assessment of the controls used in the hardware design and management process and an evaluation of their effectiveness. **[A2]**

14.8.2 Hardware Standards and Codes of Practice

The Tenderer shall state in the Tender Response the Hardware Standards and Codes of Practice which will be applied to the system. **[I1]**

Copies of these standards and codes of practice shall be made available on request. **[E1]**

The Tenderer shall identify where each of the following hardware aspects are defined in the standards quoted:

(a) Component Selection, including, but not limited to, semiconductor devices, fuses, fans etc; **[I2]**

(b) Circuit Design; **[I3]**

(c) Electrical Wiring; **[I4]**

(d) Connections; **[I5]**

(e) Printed Circuits and Wiring; **[I6]**

(f) Circuit and Equipment Layout; **[I7]**

(g) Circuit and Equipment Assembly; **[I8]**

(h) Protective Devices; **[I9]**

(i) Interchangeability of equipments, sub-assemblies and components; **[I10]**

(j) Full accessibility of components for maintenance, with easily accessible connection, testing and fixing points; **[I11]**

(k) Replaceable parts located and secured so as to permit inspection, servicing and replacement without damage to, or interference with adjacent part of wiring; **[I12]**

(l) Fail safe characteristics for each component, circuit and equipment; **[I13]**

(m) Use of autotest and automatic detection and indication of failed components; **[I14]**

(n) Protection of cables, wiring, and board against damage from liquids, heat, shock and vibration; **[I15]**

(o) Marking and labelling of the various components, boards, equipment, cables and wiring; **[I16]**

(p) Use of warning and instruction labels for any risk of danger. **[I17]**

14.8.3 Spares Availability

The Tenderer shall undertake to ensure that spares will be available for at least 10 years after acceptance of the equipment. **[E1]**

14.8.4 Modification After Delivery

Modification to the type of equipment supplied under the Contract made by the Contractor subsequent to delivery shall be notified to the Agency in order that consideration may be given to the embodiment of such modifications in ancillary equipments. **[E1]**

Post Contract Support shall be available for a minimum of five years after acceptance of the equipment. **[E2]**

14.8.5 Handling Requirements

Panels, units and chassis which require removal for maintenance should not normally exceed 10 kg in weight (including the weight of the transit case). **[E1]**

Units exceeding 10 kg in weight shall be provided with suitable lifting facilities. **[E2]**

Such equipment shall be clearly labelled as being heavier than 10 kg with a warning label. **[E3]**

The Tenderer shall identify in the proposal any special handling requirements. **[I1]**

The design of panels, units, chassis etc. shall be such that they can be safely set down without damage. **[E4]**

Fragile components shall not be positioned in exposed places, but should be protected in the best way possible (e.g. guard rails). **[E5]**

The Contractor shall bring to the Agency's notice components or devices supplied under the Contract that could be in any way affected by electrostatic discharge and which might as a consequence be damaged by incorrect handling or storage. **[E6]**

14.8.6 Air Conditioning

Air Conditioning shall be provided as required by National Administration regulations. **[E1]**

14.9 Software Requirements

14.9.1 General

For the purpose of this specification, firmware is defined as software burned in hardware devices. **[A1]**

The following software requirements shall apply for firmware and software. **[E1]**

The software shall be designed to preclude abnormal behaviour and to limit the consequences of system failure conditions through appropriate fault avoidance techniques, fault tolerant design architecture, verification and validation methodologies. **[E2]**

Software design, development, verification, validation and maintenance shall be carried out according to methodical and rigorous procedures to ensure that the system fully complies with the specification, and to ensure that performance, safety and quality objectives allocated to the software are met. **[E3]**

The Tenderer shall list the software deliverables in a preliminary Configuration Management Plan, to be provided as part of the Tender Response. **[I1]**

As part of the Tender Review Process the Agency will carry out an on-site audit of the Tenderers Software Development and Management processes. **[A2]**

This audit will involve an assessment of the controls used in the software development and management process and an evaluation of their effectiveness. **[A3]**

14.9.2 Software Standards

The software deliverables shall be produced in accordance with the best current practices and standards in force at the International and European levels. **[E1]**

High order languages conforming to a recognised ISO or ANSI standard shall be used. **[E2]**

The Tenderer shall state in his response the software language to be used. **[I1]**

The Tenderer shall identify in the Tender Response the Software Standards and Codes of Practice which will be applied to the Project. **[I2]**

The Contractor shall review with the Agency the appropriate software standards for this Project. **[E3]**

14.9.3 Design Methods

An important factor in an orderly software development program is an early establishment of a design discipline which makes the software traceable, testable, maintainable and understandable to persons other than the developers. **[A1]**

An industry standard method of software design shall be employed. **[E1]**

If new software developments are needed, the Tenderer shall state in a preliminary Software Development Plan the software development environment in terms of hardware and software including as a minimum:

(a) Software development objectives (criticalities of the software functions, quality, safety, etc.); **[E2]**

(b) Team organisation; **[E3]**

(c) Interfaces; **[E4]**

(d) Design methodology and all tools which will be employed; **[E5]**

(e) Standards and activities with regards the software life cycle; **[E6]**

(f) Technical milestones; **[E7]**

(g) Support environment to be used or implemented (tools, simulator, etc.); **[E8]**

(h) Hardware platform(s) for the tools to be used. **[E9]**

The standard for airborne software embedded system RTCA DO 178B/EUROCAE 12B may be used as guidelines for coping with the software requirements and tailoring the effort of development, verification and validation versus the criticality of the software functions. **[A3]**

14.9.4 Software Safety

The required Safety Requirements are defined in 14.7. In order to meet these requirements it is essential that the software processes shall be examined as part of the FMECA. The criticality of each software module/process shall be identified according to the role carried out by the process within the system. **[E1]**

The Tenderer shall identify in the Software Development Plan the various criticalities of the tasks carried out by the software functions and the measures (in terms of developments, verification, validation and assurance activities and techniques) to ensure that the characteristics of the software, in particular its failure modes, do not impact on the overall system safety level as defined in 14.7. **[E2]**

The Tenderer shall state the levels according to which they have developed, or intend to develop the software components in terms of the Mode S ground station (see RTCA DO 178). **[I1]**

14.9.5 Operating System Standards

The Tenderer shall provide in the Tender response details of the Operating System to be used. **[I1]**

The Contractor shall ensure that the Operating System design shall allow for future hardware, software and communication enhancements. **[E1]**

The Tenderer shall state the level to which the Operating System can analyse the type and cause of detected system errors. The level of ability to record data concerning the error and its cause for error notification and subsequent investigation from a maintenance position shall be stated. **[I2]**

Where an Operating System has been written by, or is owned by the Tenderer, the source code for the operating system shall be defined as a deliverable item in the Contract. **[E2]**

The Tenderer shall state the system reload time. **[I3]**

14.9.6 System Compatibility

Where any form of distributed processing architecture is used, the Contractor shall provide details of procedures and specific techniques to ensure that the software that runs in each processor is compatible with the software running in all the other processors that make up one channel of the overall system. **[E1]**

Suitable recovery mechanisms shall be coded for the case where incompatible versions are found to be running in different processors. **[E2]**

14.9.7 Upgrades and Reversion

Unless a version of software for a processor is to be kept on removable media, where changing the version of software that is running is performed by changing the media and reloading the system, the storage medium built into the system is to be capable of holding two versions of the system software. **[E1]**

The time taken to switch between software versions shall be no more than 3 minutes plus the system reload time as given in 14.9.5. **[E2]**

14.9.8 Adaptation

For flexibility of operation and ease of maintenance it is essential that all variables within the software that control site configurable parameters can be modified without the need for software recompilation/rebuild. **[E1]**

All such operational parameters shall be referred to as adaptation parameters, which are a software adjustable, agreed subset of the SDPs. **[A1]**

All adaptation parameters within the system shall be stored in a manner that allows for any parameter to be easily changed without any impact on the operational software and system safety. **[E2]**

A method shall be provided for changing the content of adaptation file(s). The method provided shall be capable of range checking the variable(s) to be changed and of providing a plain language description of each parameter that can be changed. This method shall be separate from any commands used to change the values of these parameters while the system is running. **[E3]**

The site configuration parameters shall be defined in a logical manner in units which relate to the parameter concerned. (e.g. Range in NM; azimuth in degrees or Azimuth units etc.). **[E4]**

All parameters shall be accessible and/or modified through the CAM interfaces or a dedicated terminal. **[E5]**

In case a dedicated terminal is necessary to fulfil these requirements the Tenderer shall include this terminal within the bid. **[E7]**

The Tenderer shall provide detailed information on this dedicated terminal **[I1]**

The Contractor shall deliver a special document:

(a) Listing all the software parameters that could be accessed and/or modified via the CAM or any dedicated terminal;

(b) Indicating for each parameter the default value, increment, minimum & maximum values, units, etc;

(c) Listing all the hardware parameters (switches, jumpers, DIP,......) that are accessible and/or configurable;

(d) Indicating for each hardware parameter the default configuration, the possible ones and the physical location on concerned PCB by means of a lay-out diagram;

(e) Describing for each parameter the impact of a change at the component, LRU, sub-system and system levels, especially from the point of view of the functionality being modified, and the effects on the output and input data. **[E8]**

14.9.9 Verification

The Contractor shall define in a Verification and Validation Plan the verification process being used to ensure that the results of a particular phase/activity in the software development has met the requirements of the previous phase. **[E1]**

Verification shall be carried out according to methodical and rigorous procedures to ensure that performance, safety and quality objectives allocated to the software are met. **[E2]**

14.9.10 Validation

The Contractor shall define in the Verification and Validation Plan the validation process being used to ensure that the results of the software development has met the requirements of the project. **[E1]**

Validation shall be carried out according to methodical and rigorous procedures to ensure that performance, safety and quality requirements are met. **[E2]**

There the Contractor identifies the use of simulation as appropriate to the validation process the level of simulation shall be identified. **[E3]**

Any testbeds etc. used for module/sub-system testing shall be retained under configuration control for the duration of the Contract (including maintenance period). All such software and associated test specifications shall be maintained so that any test performed at any time during system development may be re-performed on the versions of software modules that form the final delivery of software. **[E4]**

The Contractor shall state what special arrangements will be undertaken to test and validate critical software. **[E6]**

The above information is essential from the safety aspect. **[A1]**

The Test Specification shall detail and identify the test harnesses used. **[E7]**

The Contractor shall identify in the Software Development Plan the verification and validation processes used to integrate the operating system and software with the hardware. **[E8]**

Results of all tests shall be recorded for subsequent audit. **[E9]**

14.9.11 Software Development Environment

The Software Development and Verification Environment is a significant factor in the production of high quality software. **[A1]**

Qualified or intensively validated tools shall be used to achieve the necessary level of confidence for minimising potential environment related errors. **[E1]**

The development and verification environment shall be subject to Configuration Management. **[E2]**

If the Software Development and Verification environment is changed during the software life cycle, the validity of previous tests and coverage analyses shall be reconsidered by the Agency. **[A2]**

The Agency reserves the right to request the re-verification of modules in the event of changes to the Software Development and Verification Environment. **[E3]**

14.10 Design

14.10.1 General

Fault tolerant design shall be applied wherever the potential for critical consequences results from the design or operation of the Mode S ground station and associated equipment. **[E1]**

The following deterministic safety design principles shall be implemented as a minimum:

(a) No single failure condition shall have a critical consequence for ATC Services; **[E2]**

(b) No single operator error shall have a critical consequence for ATC services and the operator; [E3;

(c) Hardware or software failures shall not cause additional failures with hazardous effects; **[E4]**

(d) Safety-critical functional paths (both hardware and software) shall be isolated or partitioned from non safety-critical functions, in order to prevent propagation of errors and failures; **[E5]**

(e) Alternate or redundant safety critical functional paths shall be separated or protected in such a way that any event that causes the loss of one functional path will not result in the loss of alternate back-up, or redundant paths; **[E6]**

(f) Parametric operating ranges and performance limits for safe operation shall be established for the design and shall be specified by the Contractor; **[E7]**

(g) The design shall provide protection to avoid the erroneous acceptance of commands that may affect personnel safety or cause hardware or software damage. **[E8]**

Multiple failures that result from common cause or common mode failure mechanisms shall be considered as single failures for the purpose of determining and designing the fault tolerant system. **[E9]**

Failures modes shall be considered to originate from:

(a) Hardware; **[E10]**

(b) Software; **[E11]**

(c) Firmware; **[E12]**

(d) Procedures as the result of design error; **[E13]**

(e) Random failure due to environmental effects. **[E14]**

The Design shall allow expansion to accommodate future growth (in functional and performance requirements to achieve full Mode S) through scalable, modular design, built on structured techniques that ensure traceability and consistency between the functional requirements and the ultimate design specifications. **[E15]**

The Tenderer shall define the methodology, techniques and tools employed to achieve the system design objectives. **[I1]**

The Tenderer shall demonstrate that they are compliant with the requirements in chapters 14.2, 14.4, 14.6 and 14.7 of this specification, by delivery of sample design specification documentation described in MIL-STD-1521. **[I2]**

Traceability, consistency and completeness shall be ensured between design specification and the system requirements. **[E16]**

The system design shall take into account the necessary features for verification and validation testing, and for maintenance. **[E17]**

The Agency believes that it will be in the Projects' best interest for there to be a continuous free exchange of technical information between the Contractor and the Agency's' technical staff, especially in the early stages of the project. **[A1]**

The Tenderer shall state how such relationships will be fostered. **[I5]**

14.10.2 Ongoing technical dialogue

The Agency considers it essential that there is an ongoing dialogue with the Contractor on all technical issues. **[A1]**

If necessary the Agency shall convene additional meetings at short notice to discuss specific problems or technical issues. **[E1]**

14.11 Delivery

The Contractor shall deliver the items as described in the 'List of Deliverables' at the dates agreed and to the locations specified by the Agency. **[E1]**

The Contractor shall deliver the Mode S ground station to site for Site Acceptance Testing as specified in this document, following successful completion of all Formal Acceptance Tests on his factory test bench, in addition to any internal verification and validation testing normally described in the project quality assurance and development plans. **[E2]**

The Contractor shall provide for software, the description and the identification of each delivered version, and the associated source and executable code, the identification of the development and testing tools, the updated corresponding documentation (specifications, design, test plan, test results, listing). Compatibility with the various hardware version shall be indicated. **[E3]**

14.12 Installation and Commissioning

The Contractor shall prepare, deliver and apply an Installation and Commissioning Plan, describing the objectives, the strategy, the milestones, the installation and site testing procedures, acceptance criteria, the respective responsibilities between the Agency, the user and the Contractor. **[E1]**

This shall be subject to a specific planned review, not later than 120 working days before delivery of the Mode S ground station. **[E2]**

The Agency and the user will provide, according to an agreed plan, details of the sites where the Contractor shall install the Mode S ground station. **[A1]**

The Contractor shall provide all necessary studies and equipment to complete installation at the chosen user site, and shall provide all welfare and temporary services in support of their installation team **[E3]**

The installation and commissioning Plan shall be approved by the Agency and shall include, but not be limited to, the following aspects:

(a) Physical dimensions and weight of all equipment; **[E4]**

(b) Power consumption of all equipment; **[E5]**

(c) Heat dissipation of all equipment; **[E6]**

(d) Full wiring schedules, interconnection diagram and routing for power, signal, earthing cables; **[E7]**

(e) Full details of waveguide and RF co-ax connections and fixing including full dimensions and routing; **[E8]**

(f) All details for lifting, assembling and fixing the Antennas; **[E9]**

(g) Alignment Procedures for the PSR and SSR Antennas; **[E10]**

(h) Details of site accommodation requirements; **[E11]**

(i) Details of site plant requirements. **[E12]**

The documentation shall be updated periodically in order to reflect accurately the complete installation. **[E13]**

In order to provide a consistent response for the cost of Installation the following site facilities will be provided by states:

(a) Tower foundation (Contractor shall state size and bearing load);

(b) Equipment cabin foundation (Contractor shall state size and bearing load);

(c) Electricity supply (Contractor shall state requirements);

(d) Data lines and telephone lines (Contractor shall state requirements);

(e) Access to site;

(f) Hardstanding for 2 Agency vehicles. **[A2]**

The Tenderer shall state in the proposal the aspects of the installation to be included in the documentation concerning:

(a) Cabling Arrangements, routing, identification; **[I3]**

(b) Interference, susceptibility to radio frequency; **[I4]**

(c) Earthing arrangements; **[I5]**

(d) Equipment mounting, cooling. **[I6]**

Compliance with the EMC recommendations contained within EEC Directive (89/336/EC) on Suppression of Interference shall be required. **[E14]**

The Contractor will be required to demonstrate that the delivered system conforms to the EMC recommendations. The cost of this demonstration shall be borne by the Contractor. **[E15]**

The Contractor shall be responsible for all transportation and delivery of equipment to the sites where installation shall take place. **[E16]**

Commissioning will be granted after successful on site testing with a specified operational environment and acceptance of the associated deliverables specified in the plans. **[A3]**

14.13 Project Management

14.13.1 Project Management Plan (PMP)

The Tenderer shall provide in their Tender Response a PMP that clearly describes all stages of the project including flight trial, SAT, FAT etc. **[I1]**

The PMP shall include the following list as a minimum:

(a) Project Plan with milestones and timescales. **[E1]**

(b) Resource Schedule, showing the contribution from team members. **[E2]**

(c) A Work Breakdown Structure, showing the work packages, responsibilities, and expected duration. Each work package shall be described with the input needed and expected deliverables. **[E3]**

(d) Delivery Schedule, showing dates and deliverables. **[E4]**

(e) A description of the Tenderer's proposed project team including Curriculum Vitae for the key project team members. **[E5]**

(f) Organisation / Roles and Responsibilities:

The role and the responsibilities of each key member for the various project phases and steps shall be described. **[E6]**

(g) Interfaces with SubContractors and Suppliers:

Any Subcontract and/or Consortium arrangements shall be described, covering the respective involvement and responsibility. **[E7]**

(h) Key risks and jeopardise to satisfactory project progress and how these will be managed. **[E8]**

(i) Methods to manage and control the work performed under the project. **[E9]**

(j) Method used to monitor internal communication and reporting. **[E10]**

(k) Methods and procedures to manage Quality Assurance. **[E11]**

This plan shall be updated throughout the life of the Contract to continually reflect the project team organisation and the work breakdown structure. **[E12]**

Any change in the responsibilities during the project shall be formally reported to the Agency. **[E13]**

The Tenderer shall state in the Tender Response his requirements in terms of resources required from the Agency at all phases of the Project. All Agency resources required shall be scheduled into the plan. **[I2]**

If different development sites are planned, co-ordination links and procedures shall be provided. **[E14]**

14.13.2 Spare.

14.13.3 Project Support Tools

The Contractor shall ensure that it uses PC tools which are compatible with the Agency standards. **[E1]**

The Tenderer shall state any conversion methods that may be necessary for documents produced automatically by CASE tools. **[I1]**

The Agency currently uses the following support tools:

(a) Microsoft Word 97; **[A1]**

(b) Microsoft Excel 97; **[A2]**

(c) Microsoft Project 98; **[A3]**

(d) Windows NT4; **[A4]**

(e) Microsoft Access 97; **[A5]**

(f) Adobe Acrobat Reader 4.0. **[A6]**

In order to reduce the size of electronic documents sent to the Agency, and to avoid the spreading of macro-viruses, the Tenderer is advised to use a lean and safer format such as Rich Text Format (RTF) or Portable Document Format (PDF). **[A7]**

14.13.4 Control and Reporting

The Control and Reporting mechanisms are defined by the Agency responsible for the procurement. **[E1]**

14.13.5 Spare.

14.13.6 Spare.

14.13.7 Spare.

14.13.8 Configuration Management

14.13.8.1 General

Configuration Management (CM) is an essential discipline applying to all deliverable items including documentation, hardware, spares and software (Application software, system software, compilers & testing facilities). **[A1]**

CM identifies the function and physical configuration of an item. **[A2]**

CM controls changes to the item and records and reports those changes as well as implementing the changes into all identical items. **[A3]**

14.13.8.2 Preliminary Configuration Management Plan

The Tenderer as part of their Tender Response shall provide details of the hardware and software CM plans they would implement following contract award. **[I1]**

The Preliminary CM Plan shall include as a minimum:

(a) List of internal and external items of the project established as Configuration Items. **[E1]**

(b) Responsibilities and relevant procedures to be used; **[E2]**

(c) Configuration Management tools and techniques; **[E3]**

(d) Configuration Identification and modification policy; **[E4]**

(e) Configuration Status Accounting; **[E5]**

(f) Configuration Auditing; **[E6]**

(g) Software/Hardware Interface Management; **[E7]**

(h) Configuration Control for spares ranging and maintenance; **[E8]**

Change procedures shall be consistent with the configuration approach. **[E9]**

14.13.8.3 Hardware Configuration Management Plan

The Contractor shall provide a detailed hardware CM Plan for Agency approval. **[E1]**

The CM Plan shall include details of how the configuration of subcontracted hardware is dealt with. **[E2]**

The plan shall describe the Contractor's CM programme that will be used to ensure adequate control of the status of all "configured items", documentation and spares. **[E3]**

The hardware CM plan shall also identify proposals for the Agency to assume the CM responsibility post technical completion from the Contractor. **[E4]**

14.13.8.4 Software Configuration Management Plan

The Contractor shall provide a detailed software CM plan for Agency approval. **[E1]**

The plan shall describe the Contractor's software CM programme that will be used to ensure adequate control of the System software including documentation and deliverable software. **[E2]**

The software CM plan shall identify the participation of the Contractor SQA department in software CM activities. **[E3]**

Key personnel shall be identified using organisation charts. **[E4]**

The software CM plan shall also identify proposals for the Agency to assume software CM authority post technical completion from the Contractor. **[E5]**

14.13.8.5 Audit

A specific Configuration audit can be decided by the Agency e.g. if significant discrepancies are detected. This audit would be carried out by the representatives of the Agency, and/or its partners in the project, and/or a third party. **[A1]**

The Contractor shall then allow access to the necessary information, in conformity with the agreed audit objectives and process. **[E1]**

14.13.8.6 Change Control

Design records shall be maintained by the Contractor as part of his CM programme. **[E1]**

Any changes, which may alter the agreed Contract production baseline shall be referred to the Agency for their approval. **[E2]**

The Tenderer shall propose specific procedures to monitor the project and control change. **[E3]**

Shortcomings and subsequent corrective actions and/or proposed evolutions shall be described in a "Technical Issue Form" and submitted to the Agency. If the proposed amendment is accepted, a "Change Request" shall be raised using an appropriate agreed procedure. **[E4]**

Before a change is made official, its validity shall be confirmed and the effects on other items shall be identified and thoroughly examined. Methods to show the traceability and compatibility between changes and modified parts of system/software shall be provided. **[E5]**

Any change having a contractual impact shall be the subject of a formal Contract amendment. **[E6]**

Where necessary the Agency's representative will attend change control meetings at the Contractor's premises. **[A1]**

The CM Plan shall state the Configuration Management procedures to be used on the project. **[E7]**

The system for identifying the configuration shall be defined and how the identification is allocated should be documented. The Contractor shall maintain a system to ensure that the configuration of each configured item within a system may be identified. **[E8]**

The Configuration Management system should be subject to audits by the Contractor to demonstrate that it is suitable and effective. The audits shall verify the accuracy of the configuration information. **[E9]**

The results of these audits shall be made available to the Agency on request. **[E10]**

Configuration control shall also be applied to spares in the maintenance process if applicable. **[E11]**

The CM Plan shall state how this is achieved. **[E12]**

The Tenderer shall document his controls over software/hardware interfaces **[E13]**

14.13.8.7 Software Configuration Management / Configuration Control

The Contractor shall use configuration management software to ensure that only authorised changes are made to source code modules. **[E1]**

All Modules/files that make up the system and/or the development environment (compilers / linkers etc.) shall be under the control of the CM software at all times. This includes the output files from the compile/link process in addition to the input source files. **[E2]**

Compatibility between various versions of hardware and software of the Mode S ground station shall be permanently addressed in the CM Plan. **[E3]**

14.13.8.8 Operating System Configuration Management / Configuration Control

Where a 3rd party operating system is used, changes to the code shall only be allowed through formal Configuration Control procedures. **[E1]**

All such changes shall allow future operating system upgrades to be provided by the original vendor. **[E2]**

All configuration details for the operating system employed shall be supplied to the Agency. **[E3]**

For an in-house operating system, formal Configuration Control procedures shall be fully applied. **[E4]**

14.13.8.9 Documentation Configuration Management

Shortcomings and subsequent corrective actions and/or proposed evolutions to all documents shall be described in a "Technical Issue Form" and submitted to the Agency. If the proposed amendment is accepted, a "Change Request" shall be raised using an appropriate agreed procedure. **[E1]**

14.13.9 Project Risk

The Tenderer shall provide in their Tender Response a Risk Management Plan (RMP) detailing how they will manage risks associated with this project. **[I1]**

The areas to be covered in the RMP shall be, as a minimum, financial, technical (hardware and software), quality, programme, etc. **[E1]**

The Contractor shall maintain a Risk Register (RR) which shows, as a minimum:

(a) What activities may be affected by each risk; **[E2]**

(b) The probability of risk; **[E3]**

(c) The areas of impact; **[E4]**

(d) Suggested risk reduction measures; **[E5]**

(e) Ownership of the risk. **[E6]**

The Contractor shall report all risk areas, using the agreed reporting procedures. **[E7]**

14.14 Quality Assurance

14.14.1 General

Quality Assurance (QA) is a planned, controlled and systematic programme to ensure the deliverable equipment or service meets specified requirements. **[A1]**

Quality Assurance shall be applied to all activities necessary for the achievement of the Mode S ground station project. **[E1]**

Quality Assurance shall ensure the quality targets, requirements and specifications are correctly and completely fulfilled and ensure traceability and visibility throughout the project. **[E2]**

14.14.2 Quality Standards

The Tenderer shall be approved to BS EN ISO 9001/9002 or to an equivalent standard. **[E1]**

For the software elements of the Contract, approval to ISO 9000-3 or equivalent is preferred. **[A1]**

These approved Quality procedures shall apply to both hardware and software aspects of the Contract. **[E2]**

The terms of the applicable standard shall apply throughout the period of the Contract. **[E3]**

The scope of registration shall also cover the scope of the activities relating to the Contract. **[E4]**

The Tenderer not certified to these standards shall demonstrate that he is working towards such a standard and can be audited against it. **[E5]**

14.14.3 Quality Assurance Authority

The Agency shall nominate one of its representatives as the Quality Assurance Authority for the purpose of the contract. The Agency Quality Assurance Authority shall have unrestricted access during normal working hours to verify at source that the activities, processes and techniques employed in the design and manufacture of the hardware, software and associated documentation conforms to the requirements of the contract, Quality Plan and associated documents. **[A1]**

14.14.4 Quality Plans

14.14.4.1 Preliminary Quality Plan

The Tenderer and his proposed major SubContractors shall submit, as part of their technical proposal, a Preliminary Quality Plan (QP) based on the requirements of this specification and which details the QA programme which would be implemented in the event of a Contract being awarded. **[I1]**

The Preliminary QP shall list all QA related and supporting documents. **[E1]**

A copy of QA manuals and other related documents shall be supplied to the quality authority upon request. **[E2]**

14.14.4.2 Quality Plan

A Quality Plan, in accordance with BS EN ISO 9001/9002, shall be submitted by the successful Tenderer and their major SubContractors, detailing how QA will be applied to the Contract. **[E1]**

This plan shall be submitted for approval by the Agency. The QP shall be implemented immediately. **[E2]**

The QP shall identify the product specified by the Contract and shall state the procedures of the Contractor's Quality Manual that apply to the Contract. **[E3]**

The QP shall identify additional procedures and amplifications to existing procedures that are required to meet the Contract conditions. **[E4]**

The QP shall highlight the critical control and review stages for the whole Quality task from Contract inception to final acceptance of the product by the Agency. **[E5]**

The QP shall identify the entry criteria for these milestones and define how satisfactory completion is recorded. **[E6]**

The QP shall include Quality organisation charts for the Contractor, and all major SubContractors, showing reporting and responsibility lines within the Companies. **[E7]**

Names and designations shall be provided for all staff with responsibilities for the Contract. **[E8]**

All defining documents shall be subject to document control procedures. **[E9]**

The QP shall require Agency approval at all issues. **[E10]**

The QP shall list those documents that will be submitted to the Agency for approval prior to issue. **[E11]**

The Contractor shall pass down to his SubContractors all aspects of his QP necessary to ensure the quality of the product and/or service. **[E12]**

The Contractor shall remain totally responsible for his SubContractors and shall describe how SubContractors have been selected. **[E13]**

The QP shall state which SubContractors have produced their own QP. **[E14]**

14.14.4.3 Software Quality Plan

A Software Quality Plan (SQP), in accordance with ISO 9000-3, shall be submitted by the Tenderer and their major SubContractors detailing how QA will be applied to the Contract. **[E1]**

The SQP shall describe the quality objectives, the methodologies, the quality verification and assurance activities to be implemented and the software and associated documentation to be supplied under the contract. It shall state the general procedures of the Contractor's Quality Manual that apply to the Contract. **[E3]**

The SQP shall identify additional procedures and amplification to existing procedures that are required to meet the Contract conditions. **[E4]**

The SQP shall include, but not be limited to, the following:

(a) Description of software quality objectives; **[E5]**

(b) Definition of software life cycle model to be used; **[E6]**

(c) Software staff and SQA organisation and their relationship to the project team; **[E7]**

(d) Definition of deliverable items and deliverable media; **[E8]**

(e) Verification and Quality Assurance activities throughout the life cycle; **[E9]**

(f) What techniques, notations, languages, methods, standards (internal and national), conventions and tools are to be used during the project and to which activity and deliverable each applies; **[E10]**

(g) How the quality of deliverables is assessed; **[E11]**

(h) Configuration Management and Change Control procedures; **[E12]**

(i) Documentation to be provided and to what standards; **[E13]**

(j) Procedures for subcontracting of software; **[E14]**

(k) Defect and Non Compliance reporting; **[E15]**

14.14.5 Quality Assurance Audits

The Agency reserves the right to audit the Contractor's and all major SubContractor's QA organisations against procedures agreed with the Agency at any time during the Contract. **[A1]**

The Agency will nominate a Quality Assurance Representative (QAR) for the project. **[A2]**

Reasonable access and accommodation at the Contractor's premises shall be provided to the QAR, or his representative, in order to perform assessment activity including:

(a) A Quality assessment of the Contractor's Quality Management System to the relevant standard and to the Quality Plans prior to the start of the Contract work; **[E1]**

(b) Selective Quality surveillance audits against the relevant standard and Quality Plans during the term of the Contract; **[E2]**

(c) Similar access as described above to the premises of the major SubContractors; **[E3]**

(d) Quality Progress statements, required monthly, to be provided as part of the regular project reporting procedures. **[E4]**

14.14.6 Communication and Interfaces

The Tenderer shall state what information is to be recorded to monitor the control of the manufacture and test process. **[I1]**

The Tenderer shall state how the information is to be recorded and how it will be shared with the Agency. **[I2]**

The Tenderer shall state how problems are escalated internally and how these are to be discussed with the Agency, where required, to ensure an agreed solution is reached. **[I3]**

The Tenderer shall state what quality initiatives are in place to ensure that all staff are involved in the quality process. **[I4]**

The Tenderer shall state what Quality Training their staff receive. **[I5]**

14.15 Testing and Acceptance

14.15.1 General

It is particularly important that all Test Specifications used for proving that the system fulfils the requirement shall be generated directly from the overall system requirement specification. Cross references shall be placed in the Test Specification so that any test can be traced back to the requirement that it is proving. **[E1]**

In addition, module and sub-system Test Specifications shall be generated directly from the relevant design document. Cross references shall be placed in these test specifications so that any test can be traced back to the relevant area of the design. **[E2]**

A Verification Cross Reference Index (VCRI) shall be produced to trace continuity from the Specification through the Design Document to the FAT and SAT Acceptance Test Specifications. **[E3]**

It would be acceptable for all such cross references to be placed in a separate document. **[A1]**

In this case the cross reference document shall be updated and re-issued whenever any other document changes. In addition, the cross reference document shall be updated, and distributed with the first draft issue of any other document. **[E4]**

Should a deliverable be non-conformant, the Contractor shall correct it at his own expense, and after rectification, shall resubmit it for acceptance, within a time schedule agreed by the Agency. **[E5]**

The purpose of the testing is to prove the Mode S ground equipment fulfils the performance requirements of this specification. **[A2]**

This Chapter identifies the minimum tests to be performed across all the equipment at sub-system, system, site and network level up to and including Provisional Acceptance of the equipment. **[A3]**

The Contractor shall formulate, arrange and conduct tests to satisfactorily demonstrate, to the Agency, compliance of the deliverable equipment with all the performance requirements of this specification. **[E6]**

The Tenderer shall include in the proposal a preliminary Verification and Validation Plan, as detailed in section 14.15.4, which outlines their test programme. **[I1]**

The Contractor shall develop an overall Verification and Validation Plan, as detailed in section 14.15.4, which will detail how the performance requirements of this specification will be verified, recorded and accepted. **[E7]**

It shall be the responsibility of the Contractor to arrange and perform the acceptance testing. **[E8]**

These tests shall be witnessed by Agency personnel in accordance with an agreed plan. **[E9]**

14.15.2 Test Equipment

The Contractor shall bear the cost of all resources required for testing (including personnel, and premises) to complete SAT as defined in 14.15.12.4. **[E1]**

Where possible, the equipment will be identical to that recommended for field maintenance. **[A1]**

The Contractor shall provide details in the Verification and Validation Plan to show that all resources (test equipment, procedures, personnel and premises etc.) are adequate and available to perform the testing. **[E2]**

Ideally the Contractor shall utilise live data for testing. **[A2]**

If live data is not available at the Contractor's premises the Contractor may use recorded or simulated traffic data. **[A3]**

The Tenderer shall state the methods they intend to use to perform high load testing of the system. **[I1]**

The Performance demonstration may be deferred until live data is available as part of the site acceptance testing. **[A4]**

The Contractor shall provide details in the Verification and Validation Plan of all tests that cannot be performed at the Contractors or SubContractors premises, including the reasons. **[E3]**

Agreement shall be required with the Agency of any tests that are to be deferred. **[E4]**

14.15.3 Accuracy of Testing

The Contractor shall satisfactorily prove to the Agency that the methods of testing provide confirmation that the equipment actually meets the performance requirements of this specification, and that the test procedures provide the required precision and accuracy. **[E1]**

Such proof shall be submitted with the proposed Verification and Validation Plan. **[E2]**

14.15.4 Test Methodology

14.15.4.1 Preliminary Verification and Validation Plan

The Tenderer shall include in the Tender Response a preliminary Verification and Validation Plan for the project. **[I1]**

This plan shall include at least the following:

(a) A list of the systems and sub-systems to be tested; **[E1]**

(b) A list of the types of test to be employed (e.g. QT, FAT, SAT, System) and the tools required at each stage; **[E2]**

(c) A verification matrix that will show for each paragraph of this specification which of the types of tests in (b) applies; **[E3]**

(d) The names, positions, authority, role and interrelationships of the personnel to be involved in the tests stated in (b). **[E4]**

14.15.4.2 Verification and Validation Plan

The Contractor shall develop and supply a comprehensive Verification and Validation Plan which shall include at least all of the following:

(a) List of the systems and sub-systems to be tested with identification of the hardware and software versions for the equipment under test, and for the development and testing support tools; **[E1]**

(b) Identification of all the parameters which will be tested; **[E2]**

(c) A Test Specification for FAT and SAT detailing the methods and procedures that will show compliance with the performance requirements of this specification; **[E3]**

(d) A verification matrix that relates each and every performance requirement of this specification to the specific test(s) that will be performed to demonstrate compliance with that requirement; **[E4]**

(e) A verification matrix that relates each and every requirement of this specification to the specific test(s) that will be performed to demonstrate compliance with that requirement; **[E5]**

(f) The names, positions, authority, role and interrelationships of the personnel to be involved in the tests stated in (c). **[E6]**

Each test specification shall be a standalone document specifically tailored to this Contract and shall not refer to test specifications that the Contractor has used previously for other contracts or development work. **[E7]**

The above requirement does not preclude the Contractor copying relevant test paragraphs from other test specifications into that required by the Agency. **[A1]**

The agreed procedures and test data sheets shall form the basis for the testing of the deliverable items. **[E9]**

14.15.5 Start of Testing

Testing, as identified in 14.15.12, shall not begin until the test specifications have been agreed between the Agency and the Contractor. **[E1]**

After agreement has been reached the Contractor shall provide 10 working days notice of the commencement of scheduled testing. **[E2]**

This will allow the Agency to make the necessary arrangements for witnessing the test. **[A1]**

14.15.6 Preliminary Testing

Test notification shall not be given until the Contractor has carried out preliminary tests to ensure the equipment is fully compliant with the test procedures. **[E1]**

A QA certified copy of the preliminary test results shall be provided 10 working days prior to the commencement of official testing. **[E2]**

14.15.7 Certification of Test Results

Two copies of all test results, certified by an authorised representative of the Contractor's QA organisation, shall be provided to the Agency. **[E1]**

One copy shall be sent to site with the tested equipment, the second copy shall be forwarded to the Agency's designated Project Manager. **[E2]**

The test result sheets shall clearly identify the equipment name, type, serial number, test specification number and the test date. **[E3]**

Each individual test result shall be clearly identified and the test result sheet shall be signed by the Contractor's QA representative and countersigned by the Agency witness. **[E4]**

14.15.8 Test Failures

Any failed units shall be repaired and the cause of failure shall be determined and if necessary processes and/or materials or components changed so that all requirements of the specification are met. **[E1]**

Repaired units, and all other units that may have been affected by the failed unit, shall be re-tested to demonstrate final compliance with the test specification. **[E2]**

All software shall be rectified and the cause of the error determined. All software modules that may have been affected by the failed module should be re-tested. **[E3]**

All test failures shall be logged as Problem Reports by the Contractor's QA Representative and shall be subject to closure, following explanation which shall be agreed by the Agency, or the raising of an approved engineering change order. **[E4]**

All test failures shall be categorised and agreed with the Agency. **[E5]**

14.15.9 Location of Testing

Unless otherwise agreed by the Agency, all factory testing shall occur at the Contractor's or major SubContractor's premises. **[E1]**

To confirm the performance parameters not tested at the factory the Contractor shall make provision for demonstrations of the systems functionality prior to delivering the equipment for SAT. This test site shall be nominated by the Contractor. **[E2]**

14.15.10 Damage to Equipment

Any equipment damage caused as a result of any testing shall be corrected and the equipment refurbished at the Contractor's expense prior to Agency acceptance. **[E1]**

14.15.11 Electromagnetic Compatibility

EMC requirements shall conform to EEC Directive (89/336/EEC with amendments 92/31/EEC and 93/68/EEC). **[E1]**

Each subsystem shall function to specification both in its own environment and in the full system environment. **[E2]**

This requirement shall apply for all combinations of operational and maintenance configurations, and shall include mutual interference between systems and within systems. **[E3]**

14.15.12 Stages of Testing

This section outlines the minimum testing that shall be performed **[E1]**

14.15.12.1 Spare

14.15.12.2 Factory Acceptance Tests (FAT)

Complete and thorough testing shall be conducted to demonstrate compliance with the equipment design criteria. **[E1]**

FAT testing shall be carried out using the deliverable hardware and software. **[E2]**

The FAT shall prove conclusively that the equipment meets all applicable specifications and will meet the operational and performance requirements of this specification. **[E3]**

A representative(s) of the Agency will attend the FAT. **[A2]**

Subject to agreement with the Agency FAT testing may be deferred to testing on site to demonstrate design features that cannot be performed at the Contractor's premises. **[A3]**

The Factory Acceptance Test shall include the following software/operating system aspects:

(a) Configuration Identification of every file/module under test. No file or module used in this process shall be in a development state as reported by the CM software. All files shall be registered/authenticated before the process starts. **[E4]**

(b) Recompilation of every source file to be built into the system software followed by rebuilding the executable software loads. **[E5]**

If a Software Development Facility is one of the deliverables, every file used in the above process, at the version used in this process, shall be delivered to the Agency under the control of CM software. **[E6]**

(c) Recreation of the operating system from either:

(i) The delivery kit and configuration details if a third-party operating system is used. **[E7]**

(ii) The source code and configuration details if an in-house operating system is used. **[E8]**

(d) Validation of operating system performance. **[E9]**

(e) Confirmation that each adaptation parameter can be changed, and that the changes have the required impact on the operation of the overall system. **[E10]**

14.15.12.3 Site Acceptance Tests (SAT)

The following shall be provided to the Agency 10 working days prior to the commencement of SAT testing:

(a) Evidence of closure of all previously raised observations, or agreement of action with respect to outstanding observations. **[E1]**

(b) Records of changes made since the FAT. **[E2]**

(c) The hardware and software build states. **[E3]**

(d) All test documentation to be available and agreed. **[E4]**

(e) Justification and explanation in writing of the choice of site parameters. **[E5]**

The SAT testing shall demonstrate the accuracy, stability, electromagnetic compatibility, availability, reliability and maintainability of the deliverable hardware and software over all parameters to meet all the operational and performance requirements of this specification **[E6]**

The SAT shall utilise all the deliverable hardware and software of all sub-systems, both individually and as a complete system, and will be performed using test equipment and live target data as appropriate. **[E7]**

The SAT specification may be a sub-set of the FAT specification as agreed between the Contractor and the Agency. **[A1]**

A representative(s) of the Agency will attend the SAT. **[A2]**

14.15.12.3.1 SAT Composition

Site Acceptance testing shall comprise the following discrete elements:

(a) Software Generation; **[E1]**

(b) Deferred FAT Tests; **[E2]**

(c) System; **[E3]**

(d) Reliability Demonstration; **[E4]**

(e) Maintainability Demonstration; **[E5]**

(f) Environmental Tests. **[E6]**

In respect of PILOT and production systems to be supplied, provided any changes to the Build Standard of the equipment have been properly taken into account, and that traceability can be assured, then Site Acceptance testing may comprise only elements (b) and (c) above. **[A1]**

14.15.12.3.2 Software Generation

The deliverable Operational, run-time, software (or PROM based firmware) shall be officially generated from the deliverable source code using Agency approved generation procedures. **[E1]**

The generation shall be witnessed by the Contractor's QAR and may be witnessed by the Agency. **[E2]**

It is this build of Operational software that shall be used in all subsequent Site Acceptance Tests. **[E3]**

14.15.12.3.3 Deferred FAT Tests

The Contractor shall conclude the Factory Acceptance Testing by performing all tests deferred to site due to lack of live data or associated facilities **[E1]**

14.15.12.3.4 System

The Contractor shall perform complete and thorough testing of all units, modules and subsystems interconnected to form the whole deliverable System to demonstrate the System's compliance with all the operational and performance requirements of this specification. **[E1]**

The System tests shall include network or site to site interfaces and functional tests as necessary to prove compliance with the requirements of this specification. **[E2]**

14.15.12.3.5 Reliability Demonstration

The Reliability demonstration shall be performed in accordance with 14.2.3.5. **[E1]**

14.15.12.3.6 Maintainability Demonstration

The Maintainability demonstration shall be performed in accordance with 14.2.4.5. **[E1]**

14.15.12.3.7 Environmental Testing

The Contractor shall provide a QA-approved report which ensures that the System continues to operate and meet all the operational and performance requirements of this specification whilst operating in a steady, ambient environment of +40°C with ambient humidity. **[E1]**

14.15.12.4 Acceptance

Following satisfactory completion of all Site Acceptance Tests the Contractor shall offer the System for formal acceptance by the Agency. **[E1]**

A formal Technical Completion (TC) meeting shall be held to consider the Provisional Acceptance of the system. **[E2]**

The TC meeting will examine the following areas to establish their completion or identify outstanding observations that have to be cleared within prescribed timescales:

(a) Equipment - A complete build state will be provided for all deliverable hardware and software. Special to type test equipment and support/test software shall be included as part of the build state. A complete list of all major concessions and production permits shall be provided with their relevant build states. **[E3]**

(b) Training - All training shall be complete to ensure that adequately trained engineers are available to undertake equipment maintenance. **[E4]**

(c) Spares - A build state of all deliverable spares shall be provided. All spares shall have been tested and delivered prior to TC. The build state of spares shall be identical to that of the main equipment. **[E5]**

(d) Documentation- All deliverable documentation shall have been provided. **[E6]**

(e) Test Equipment- All deliverable test equipment including software and hardware support facilities (if applicable) shall have been provided. **[E7]**

All Problem Reports and observations shall be closed or action assigned and agreed. **[E8]**

Completion of the SAT shall be recorded on the SAT Completion Certificate. **[E9]**

Certificate of Conformance documentation shall be provided for all deliverable items (including software). **[E10]**

Technical Completion may occur on a subsystem basis, if this option is chosen then a System Technical Completion meeting shall be held to ensure all System aspects have been completed. **[E11]**

ANNEX A

GLOSSARY

°C	Degree Celsius
ACAS	Airborne Collision Avoidance System
ACP	Azimuth Count Pulses
ADLP	Airborne Data Link Processor
AICB	Air Initiated Comm B
ASTERIX	All Purpose Structured Eurocontrol Radar Information Exchange
ATC	Air Traffic Control
ATCC	Air Traffic Control Centre
ATN	Aeronautical Telecommunication Network
AU	Azimuth Unit
BDS	Comm B Data Selector
BITE	Built In Test Equipment
CC	Cluster Controller
CMP	Communication Management Process
DCE	Data Circuit-terminating Equipment
DELM	Downlink Extended Length Message
DLF	Data Link Function
DRC	Data Rate Control
DUP	Duplicated address
EASIE	Enhanced Air Traffic Management and Mode S Implementation in Europe
EATCHIP	European ATC Harmonisation and Integration Programme
ELM	Extended Length Message
E-SCAN	Electronically Scanned
FAT	Factory Acceptance Tests
FL	Flight Level (1FL = 100 ft)
FRUIT	False Replies Unsynchronised In Time
GDLP	Ground Link Data Processor
GICB	Ground Initiated Comm B
GPS	Global Positioning System
HDLC	High level Data Link Control
ICAO	International Civil Aviation Organisation
ICD	Interface Control Document
IFF	Identification Friend or Foe
II	Interrogator Identifier
IISLS	Improved Interrogator SideLobe Suppression
IRF	Interrogation Repetition Frequency
Kbps	Kilo bit per second
kn	Knot ($NM.h^{-1}$, 1 kn = 0.514444 $m.s^{-1}$)
LC	Link Control
LMP	Link Management Process
LRU	Lowest Replaceable Unit
LVA	Large Vertical Aperture (rotating antenna)

MSP	Mode S Specific Protocol
MSSR	Monopulse Secondary Surveillance Radar
MTBF	Mean Time Between Failures
MTL	Minimum Triggering Level
MTTR	Mean Time To Repair
NM	Nautical Mile (1 NM = 1852 m)
OBI	Off Boresight Indication
PAF	Plot Assignor Function
PCB	Printed Circuit Board
PMB	Project Management Board
PMC	Project Management Cell
PMPP	Project Management Programme Plan
POEMS	Pre Operational European Mode S Station
PRF	Pulse Repetition Frequency
PSR	Primary Surveillance Radar
PTE	POEMS Test Equipment
RA	Resolution Advisory
RASCAL	Radar Sharing Calculation software
RASS	Radar Analysis Support System
RDIF	Radar Data Interchange Format
RDP	Radar Data Processing
RF	Radio Frequency
RMS	Root Mean Square
RSLS	Receiver SideLobe Suppression
RTCC	Real Time Channel Control
RTQC	Real Time Quality Control
SARPs	Standards And Recommended Practices
SAT	Site Acceptance Tests
sd	Standard Deviation
SCF	Surveillance Co-ordination Function
SCN	Surveillance Co-ordination Network
SICASP	SSR Improvements and Collision Avoidance Systems Panel
SLM	Standard Length Message
SMA	System Management Application
SMF	Systems Management Function
SPI	Special Position Identification pulse
SSE	Mode S Specific Service Entity
SSR	Secondary Surveillance Radar
STC	Sensitivity Time Control
SVC	Switched Virtual Circuit
TCAS	Traffic Alert and Collision Avoidance System
UELM	Uplink Extended Length Message

ANNEX B

REFERENCE DOCUMENTS

[Ref.1.] ICAO Annex 10, third edition of Volume IV (incorporating Amendments 70-77 to second edition).

[Ref.2.] STANAG 4193 NATO Technical characteristics of IFF MK XA and MKXII Interrogators and Transponder.

[Ref.3.] Mode S Subnetwork SARPs described as Volume III, Part 1, Chapter 5 to Amendment 77 of ICAO Annex 10, including appendices, November 2002

[Ref.4.] Manual of SSR Systems, third edition (2004): ICAO Doc.9684.

[Ref.5.] Standard STFRDE ASTERIX documents:

(a) EUROCONTROL Standard Document for Radar Data Exchange Part 1 ASTERIX, SUR.ET1.ST05.2000-STD-01-01, Edition: 1.26, November 2000

(b) EUROCONTROL Standard Document for Surveillance Data Exchange Part 2b Transmission of Monoradar Service Messages, SUR.ET1.ST05.2000-STD-02b-01, Edition: 1.26, November 2000

(c) EUROCONTROL Standard Document for Surveillance Data Exchange Part 4 Transmission of Monoradar Target Reports, SUR.ET1.ST05.2000-STD-04-01, Edition: 1.14, November 2000

[Ref.6.] European Mode S ASTERIX Documents:

(a) EUROCONTROL Standard Document For Surveillance Data Exchange Part 5 Category 017 Mode S Surveillance Coordination Function Messages, SUR.ET2.ST03.3111-SPC-02-00, Edition: 1.0, October 2004 + Annex A: Co-ordinate transformation algorithms for the hand-over of targets between POEMS interrogators

(b) EUROCONTROL Standard Document For Surveillance Data Exchange Part 6 Category 018 Mode S Datalink Function Messages, SUR.ET2.ST03.3112-SPC-01-0, Edition: 1.5, March 1999

[Ref.7.] RDIF 'Radar Data Interchange Format' CAA Paper 87002, November 1991.

[Ref.8.] Regional Supplementary Procedures (SUPPs) – ICAO. Doc.7030/4, EUR, Part 1 (Carriage and Operation of SSR Mode S airborne equipment)

[Ref.9.] EATCHIP GDLP/Local User ICD for POEMS, SUR.ET2.ST03.3112-SPC-02-00, Edition: 1.7, Edition Date, 17 March 1999, Status: Working Draft.

[Ref.10.] European Mode S Station Intersite Surveillance Co-ordination Interface Control Document, SUR/MODES/EMS/ICD-01 (form. SUR.ET2.ST03.3110-SPC-02-00), 2.06, 9 May 2005.

[Ref.11.] EUROCONTROL Standard Document for Radar Surveillance in En-Route Airspace and Major Terminal Areas, Edition 1.0, March 1997 RELEASED issue.

[Ref.12.] ICAO "Manual on Testing of Radio Navigation Aids: Volume III (Testing of Surveillance Radar Systems): ICAO Doc.8071

[Ref.13.] European Mode S Station Coverage Map Interface Control Document, SUR/MODES/EMS/ICD-03 (form. SUR.ET2.ST03.3113-SPC-01-00)), 1.16, 9 May 2005.

[Ref.14.] ICAO AIR NAVIGATION PLAN - EUROPEAN REGION DOC 7754/24 Corrigendum 17/2/99

[Ref.15.] International Standard ISO/IEC 8208: 1995 (E): Information Technology-Data communications-X25 Packet Layer Protocol for Data Terminal Equipment.

[Ref.16.] International Standard ISO/IEC 7776: 1995 (E): Information Technology-Telecommunications and information exchanges between systems-High level data link control procedures-Description of the X.25 Lap-B compatible data link procedures.

[Ref.17.] European Mode S Station Surveillance Output Interface Control Document, SUR/MODES/EMS/ICD-04, 1.02, 19 April 2001.

ANNEX C

LIST OF RELATED DOCUMENTATION & STANDARDS

The Contractor will be required to undertake a "Standards Tailoring" exercise with a working group chaired by the Agency. The purpose of this working Group will be to state for each standard whether it is accepted in full; whether they wish to tailor it; or wish to use an alternative. **[A1]**

Agency personnel shall approve the agreed standards to be applied. **[E1]**

The Tenderer shall advise in the Tender Proposal on suitable related or alternative standards. **[I1]**

The Tenderer shall include the issue number and amended state of each document to be applied. **[I2]**

ISO 9001 (1994)	Model for Quality Assurance in design, development, manufacturing, installation and servicing
ISO 9000 3 (1991)	Quality management and quality assurance standards - part 3: Guidelines for the application of ISO 9001 to development, supply and maintenance of software.
ISO/CD 12207	Software engineering organisation.
ISO 10011	Audit of quality assurance
IEEE/EIA 12207.0	Industry Implementation of International Standard ISO/IEC 12207 1995 - (ISO/IEC 12207) Standard for Information Technology - Software Life Cycle Processes
IEEE/EIA 12207.1	Guide for Information Technology - Software Life Cycle Processes, Life Cycle Data
IEEE/EIA 12207.2	Guide for Information Technology - Software Life Cycle Processes, Implementations Considerations
MIL STD 973	Configuration Management.
RTCA DO 178 B(1992)	Software considerations in airborne systems and equipment certification.
IEEE STD 730	Software quality assurance plans
IEEE STD 829,1008 & 1012	Software specification, development, testing and validation
MIL STD 470	Maintainability Program
MIL STD 471A	Maintainability Verification/Demonstration
MIL STD 721C	Definition of Terms for Reliability and Maintainability

MIL STD 785	Reliability Program
MIL STD 1388-1A	Logistic Support Analysis
MIL STD 1388-2B	Logistic Support Analysis Record
MIL STD 1629	Failure Modes, Effects and Criticality Analysis
MIL STD 2165A	Testability Program
MIL HDBK 217F	Reliability Prediction
MIL HDBK 338	Reliability Design
MIL HDBK 472	Maintainability Prediction
MIL STD 454	Standard General Requirements for Electronic Equipment
MIL STD 498	Military Standard for Software Development and Documentation
MIL STD 882B	System Safety Program Requirements
IEC 812/BS 5760 (all parts)	Reliability of systems, equipment and components
IEC 812/BS 5760 Part 5	Guide to failure modes, effects and criticality analysis (FMEA and FMECA)
IEC 812/BS 5760 Part 7	Guide to fault tree analysis
IEC 812/BS 5760 Part 8	Guide to the assessment of reliability of systems containing software
ARP 926A	Fault/Failure Analysis Procedure

ANNEX D

OUTLINE SAFETY PLAN

The following outline shall be used as a basis for the Safety Plan for the Mode S Ground Station Tender response and to form the basis of the subsequent contractual requirements. **[E1]**

D.1 Purpose

The purpose of the safety plan is to ensure the Mode S Ground Station safety activities are clearly defined and co-ordinated with other project activities. Furthermore, the plan shall ensure that key safety related activities, procedures and responsibilities are clearly defined and understood.

D.2 Scope

The scope of the safety plan is the total scope of supply of Mode S by the Contractor.

D.3 Definitions

Contractor to provide appropriate definitions consistent with the Safety Plan terminology.

D.4 Safety Management

Contractor's approach to Safety Management including sub-Contractor's Safety Management. Include organigram, responsibilities, accountabilities, reporting structure and interfaces with the Agency.

D.5 Mode S Safety Requirements

Contractor's approach to performing a PHA and deriving the Mode S Failure Modes as detailed in 14.7.5.4.

D.6 Hazard Log

Contractor's approach to the development and maintenance of a system hazard log as detailed in 14.7.5.3.

D.7 Hazard Identification and Analysis

Contractor's approach to System and Software Hazard Analyses as detailed in 14.7.5.4.

D.8 Progress Monitoring and Reporting

Contractor's approach to progress monitoring and reporting as detailed in 14.13.4.

D.9 Independent Safety Assessment

Contractor's approach to Independent Safety Assessment as detailed in 14.7.5.6.

D.10 Safety Assurance Traceability

Contractor's approach to Safety Assurance Traceability as detailed in 14.7.5.7.

D.11 Deliverables

Deliverables are detailed in paragraphs 14.7.3, 14.7.4 and 14.7.5 and include, but are not limited to:

(a) Design Process and Assurance, paragraph 14.7.3.2

(b) Installation, Commissioning, Integration, Test and Evaluation, paragraph 14.7.3.3

(c) PHA and Failure Mode Derivation, paragraph 14.7.5.4.

(d) Hazard Log, paragraph 14.7.5.3.

(e) Hazard Identification and Analyses:

   (i) FMECA, paragraph 14.7.5.4.4 (a).

   (ii) FTA, paragraph 14.7.5.4.4 (b).

(f) Progress Monitoring and Reporting, paragraph 14.13.4.

(g) Safety Reviews.

(h) Independent Safety Assessment, paragraph 14.7.5.6.

(i) Safety Assurance Traceability, paragraph 14.7.5.7.

D.12 Standards

Standards (e.g. IEC; Mil Std etc.) pertinent to the Safety Plan, their scope and applicability.

ANNEX E

MODE S SAFETY REQUIREMENTS

Failure Modes (<10 seconds)	Probability
Loss of all surveillance information	No Effect
Delay of all surveillance information	No Effect
Any corruption of surveillance information	No Effect
Failure Modes (>10 seconds)	**Probability**
Loss of all surveillance information	$<10^{-7}$
Detected Loss of all Height data Detected Loss of all Identity data Detected Loss of all target range Detected Loss of all target azimuth Detected Loss of all target time Detected Corrupted all Height data Detected Corrupted all Identity data Detected Corrupted all target range Detected Corrupted all target azimuth Detected Corrupted all target time	$<10^{-5}$ $<10^{-7}$ $<10^{-7}$ $<10^{-7}$ $<10^{-7}$ $<10^{-5}$ $<10^{-7}$ $<10^{-7}$ $<10^{-7}$ $<10^{-7}$
Undetected Corrupted Height data(for individual target reports) Undetected Corrupted Identity data(for individual target reports) Undetected Corrupted target range(for individual target reports) Undetected Corrupted target azimuth(for individual target reports) Undetected Corrupted target time(for individual target reports)	$<10^{-7}$ $<10^{-7}$ $<10^{-7}$ $<10^{-7}$ $<10^{-7}$
Undetected delay of all surveillance information	$<10^{-7}$
Failure to acquire Mode S equipped aircraft	$<10^{-7}$
Failure to release Mode S equipped aircraft	$<10^{-5}$
Undetected spurious plots	$<10^{-5}$
Undetected missing plots	$<10^{-7}$

ANNEX F

LIFE CYCLE COSTING: INPUT DATA REQUIREMENTS

F.1 SYSTEM DATA

PRODUCTION SYSTEM UNIT COST	
PREDICTED MTBF	Comes from historical data, testing, predictions or the product specification
MEAN TIME TO REPAIR	Comes from the product specification.
O LEVEL	Predicted or actual MTTR for O level.
I LEVEL	Predicted or actual MTTR for I level.
D LEVEL	Predicted or actual MTTR for D level.
% BIT/BITE FAULT DETECTION	The percent of failures that BIT/BITE is capable of detecting
% MANUAL FAULT DETECTION	The percent of failures that must be detected using manual procedures or assistance of support equipment
% BIT/BITE FAULT ISOLATION	The percent of failures that BIT/BITE can isolate to a single repairable or replaceable item
% MANUAL FAULT ISOLATION	The percent of failures that must be isolated using manual procedures

F.2 INVESTMENT DATA

INVESTMENT SPARES/REPAIR PARTS	Provisioned Spares

F.3 SUPPORT EQUIPMENT DATA

O LEVEL SE UNIT COST (CM)	Actual or estimated cost for one location
O LEVEL SE UNIT COST (PM)	Actual or estimated cost for one location
I LEVEL SE UNIT COST (CM)	Actual or estimated cost for one location
I LEVEL SE UNIT COST (PM)	Actual or estimated cost for one location
D LEVEL SE UNIT COST (CM)	Actual or estimated cost for one location
D LEVEL SE UNIT COST (PM)	Actual or estimated cost for one location
OPERATIONAL SE COST	Actual or estimated cost for one set
OPERATIONAL SE RATIO TO END ITEMS	The number of end items that one set of operational support equipment will support.
SE MAINTENANCE	Percentage of SE acquisition costs required for yearly maintenance

F.4 SPARES AND CONSUMABLES DATA

REPLENISHMENT SPARES - O LEVEL (CM)	Cost of spares for a maintenance action expressed in actual/average cost
REPLENISHMENT SPARES - I LEVEL (CM)	Cost of spares for a maintenance action expressed in actual/average cost
REPLENISHMENT SPARES - D LEVEL (CM)	Cost of spares for a maintenance action expressed in actual/average cost
CONSUMABLES PER HOUR OF OPERATION	Cost of fuels, lubricants, etc. required to operate one system for one hour.
COST OF CONTRACTOR REPAIR (PER REPAIR)	Average cost of a single repair performed by Contractor or non-standard repair facility

F.5 PERSONNEL DATA

NUMBER OF SYSTEM OPERATORS	Number of persons necessary to operate one system
NUMBER OF MAINTENANCE PERSONNEL	
O LEVEL	Number of persons assigned to a single O level maintenance unit
I LEVEL	Number of persons assigned to a single I level maintenance unit
D LEVEL	Number of persons assigned to a single D level depot

F.6 TRAINING DATA

TRAINING TIME PER OPERATOR	Duration of Operator training course
TRAINING TIME PER MAINT TECH	Duration of maintenance training course
TRAINING SUPPORT COST	Incremental cost per student for training
INITIAL TRAINING PROGRAM COST	Cost of developing training program
COST OF TRAINING EQUIPMENT	
NUMBER OF TRAINING EQUIPMENT SETS	

F.7 MAINTENANCE DATA

% FAILURES R/R AT 1 LEVEL	Percent of failures that will be fixed by removal and replacement of defective items at organisational level
% FAILURES DISCARD AT 1 LEVEL	Percent of failures resulting in discard of the failed item
% FAILURES REPAIR AT 2 LEVEL	Percent of failed items that will be repaired at 2 Level
% FAILURES DISCARD AT 2 LEVEL	Percent of failed items repaired by removal and discard of a lower level assembly
% FAILURES REPAIR AT 3 LEVEL	Percent of failed items that will be repaired at Depot 3 level
% FAILURES REPAIR AT CONTRACTOR	Percent of failed items repaired by Contract
3 LEVEL/CONTRACTOR REPAIR CONDEMNATION RATE	Percent of items that will not be repaired

F.8 PREVENTIVE MAINTENANCE DATA

NUMBER OF DAILY PM TASKS	TASKS
AVG DAILY PM TASK TIME	HOURS
COST OF RESOURCES CONSUMED	
NUMBER OF WEEKLY PM TASKS	TASKS
AVG WEEKLY PM TASK TIME	HOURS
COST OF RESOURCES CONSUMED	
NUMBER OF MONTHLY PM TASKS	TASKS
AVG MONTHLY PM TASK TIME	HOURS
COST OF RESOURCES CONSUMED	
NUMBER OF SEMI-ANNUAL PM TASKS	TASKS
AVG SEMI-ANNUAL PM TASK TIME	HOURS
COST OF RESOURCES CONSUMED	
NUMBER OF ANNUAL PM TASKS	TASKS
AVG ANNUAL PM TASK TIME	HOURS
COST OF RESOURCES CONSUMED	
NUMBER OF PM TASKS PERFORMED AT 2 LEVEL	TASKS
AVERAGE 2 LEVEL PM TASK TIME	HOURS
TIMES 2 LEVEL PM PERFORMED IN 5 YEARS	TIMES
COST OF RESOURCES CONSUMED	
NUMBER OF PM/OVHL TASKS PERFORMED AT 3 LEVEL	TASKS
AVG 3 LEVEL PM/OVHL TASK TIME	HOURS
TIMES 3 LEVEL PM/OVHL PERFORMED IN 5 YEARS	TIMES
COST OF RESOURCES CONSUMED	

F.9 PHS&T DATA

INITIAL SPARES TRANSPORTATION COST	% OF SPARES COST
PACKAGING COST PER REPAIR	K PER ONE-WAY SHIPMENT
TRANSPORTATION COST PER REPAIR	K PER ONE-WAY SHIPMENT

F.10 SOFTWARE MAINTENANCE DATA

NUMBER OF SW LINES/MODULES	LINES/MODULES
ESTIMATED ANNUAL GROWTH	% PER YEAR
COST OF MAINTENANCE PER LINE/MODULE	
COST OF SW MAINTENANCE FACILITY PER YEAR	
COST OF SW MAINTENANCE EQUIPMENT	
SW MAINTENANCE EQUIPMENT MAINTENANCE PER YEAR	% OF COST

COST OF DOCUMENTATION PER MAINT ACTION	

F.11 INFLATION / ESCALATION DATA

ANNUAL ESCALATION RATE	% PER YEAR

ANNEX G

GENERAL OPERATING MODEL FOR MODE S GROUND STATION

G.1 System Parameters

G.1.1 Zenithal gap

Not below 45° above horizontal upper limit of cover >40 000ft

G.1.2 Vertical coverage

66,000 ft

G.1.3 Azimuth coverage

360°

G.1.4 Gap Free Cover

0.5 NM to 256 NM

G.1.5 Maximum Operating Range

256 NM at 4.5,7.5 and 10 rpm

150 NM, 80 NM at 15 rpm

G.1.6 Rotating Antenna Turning Rates

4.5,7.5, 10 and 15 rpm

G.1.7 IRF

2 Mode Interlace 3/A,C, nominal IRF is 150 Hz

Mode S Only All Call interrogations, nominal IRF is 50 Hz

G.1.8 IRF vs Range/Turning Rate

256 NM; 4.5 rpm; 70Hz

256 NM; 7.5 rpm; 115Hz

256 NM; 10 rpm; 150 Hz

150 NM and 80 NM; 15 rpm; 150 Hz

G.1.9 Transmitted modes

2 Mode Interlace 3/A,C

Intermode (P4 - long and short)

Mode S Only All-Call Mode S Selective

Interrogations Uplink Format 4, 5, 20, 21 and 24

G.1.10 Transponder Sensitivity

-69dBm for SSR Mode 3/A,C transponders

-71dBm for SSR Mode S transponders

G.1.11 Transponder Output Power

21dBW

18.5 dBW (for aircraft < 15,000')

G.1.12 Round Trip Reliability[1]

0.9 SSR Modes 3/A,C

G.2 Environmental Parameters

G.2.1 Mean FRUIT rate[2]

11000 FRUIT /second in the 3dB beamwidth (each of which exceeds a power level of -79 dBm referred to the sum channel RF port).

G.2.2 Number of SSR code pulses

At least 7 per FRUIT reply.

G.2.3 Target load

As in section G.4, equally distributed in azimuth and randomly distributed in range.

G.2.4 45° sectors

[1] Defined in [Ref.13] as "the probability of receiving a correct reply from an SSR interrogation".
[2] Note that it is anticipated that the level of Mode 3/A,C FRUIT is significantly higher than the level of Mode S FRUIT. The Tenderer may assume a figure of 1000 Mode S FRUIT (of which half are short and half are long replies), and assume 11,000 per second FRUIT rate is equivalent to 1/3 total; remaining 2/3 distributed over the backlobe and sidelobes.

4 off, 1 per 90°

G.2.5 3.5° sectors[3]

4 off, each centred in a diametrically opposite 45° sector.

G.2.6 Reflection False Targets

The greater of 40 targets/scan or 12% of target load.

G.3 Airborne Equipment Models

G.3.1 Model one, 100% Mode S Aircraft

(a) Mode Responses

(i)	S	100% of all aircraft

(b) Mode S Responses

(i)	Aircraft with a 24 bit aircraft address identical to that of another aircraft:	1% of all aircraft
(ii)	Aircraft with ACAS broadcast:	5% of all aircraft
(iii)	Aircraft with special flight status:	2% of all aircraft

Note: For the Mode S aircraft it can be assumed they reply initially to All-Call interrogations and are then locked out to All-Calls and reply only to selective interrogations.

G.3.2 Model Two, 50% Mode A/C and 50% Mode S Aircraft

(a) Mode Responses

(i)	3/A and C	40% of all aircraft
(ii)	3/A or C (exclusive)	10% of all aircraft
(iii)	S	50% of all aircraft

(b) Mode A/C Responses

(i)	Non-unique identity	25% of all aircraft
(ii)	Same identity	5% of all aircraft
(iii)	Same identity, no mode C	2.5% of all aircraft
(iv)	Mil Emergency	1% of all aircraft
(v)	Codes 7500, 7600, 7700	1% of all aircraft
(vi)	SPI (3/A)	4% of all aircraft
(vii)	Number of code pulses	at least 5 per reply

[3] Four 3.5° sectors total, two separated by at least 20°,
within each of two large sector peaks, diagrammatically opposite in 360° (see figure 16).

(c) Mode S Responses

(i) Aircraft with a 24 bit aircraft address identical to that of another aircraft 1% of Mode S aircraft

(ii) Aircraft with ACAS broadcast 5% of Mode S aircraft

(iii) Aircraft with special flight status 2% of Mode S aircraft

Note: For the Mode S aircraft it can be assumed they reply initially to All-Call interrogations and are then locked out to All-Calls and reply only to selective interrogations.

G.3.3 Model Three, 25% Mode A/C and 75% Mode S Aircraft

(a) Mode Responses

(i) 3/A and C 22.5% of all aircraft

(ii) 3/A or C (exclusive) 2.5% of all aircraft

(iii) S 75% of all aircraft

(b) Mode S Responses

(i) Aircraft with a 24 bit aircraft address identical to that of another aircraft 1% of Mode S aircraft

(ii) Aircraft with ACAS broadcast 5% of Mode S aircraft

(iii) Aircraft with special flight status 1% of Mode S aircraft

Note: For the Mode S aircraft it can be assumed they reply initially to All-Call interrogations and are then locked out to All-Calls and reply only to selective interrogations.

G.4 Target Load Model

Range (NM)	**5**	**10**	**20**	**40**	**60**	**80**	**90**	**130**	**150**	**200**	**256**
Aircraft Capacity	45	105	180	270	382	495	540	638	800	850	900
Large Sector Peak (45°)	12	26	45	68	96	124	135	160	200	211	222
Small Sector Peak (3.5°)	3	6	11	16	23	30	32	38	48	51	54

G.5 Volumes to be used for site performances requirements

In the table below, C means the Commissioning Volume and M the Measurement Volume.

Volume	Measurement	Requirement summary	Requirement
C	False Targets Distribution	False plots ratio < 0.1 % Multiple plot rate < 1/scan	4.2.5.1 E2 4.2.5.2 E2
C	Mode S Pd on duplicated addresses.	>=97%	7.3.2.2 E2 & 4.2.3.1 E1

Volume	Measurement	Requirement summary	Requirement
C	Range Error Distribution	Bias < 14 m	4.2.6.2 E1
C	Azimuth Error Distribution	Bias < 0.022 deg	4.2.6.3 E1
C	Overall SSR Pd	>=97%	4.2.3.1 E1
C	Overall SSR Pv&cA	>=98%	4.2.3.1 E1
C	Overall SSR Pv&cC	>=96%	4.2.3.1 E1
C	SSR Pd with Garbling	>=60% >=98% >=98%	4.2.7.1.2.1 E1 4.2.7.1.2.2 E1 4.2.7.1.2.3 E1
C	SSR Pv&cA with Garbling	>=30% >=90% >=98%	4.2.7.1.4.1 E1 4.2.7.1.4.2 E1 4.2.7.1.4.3 E1
C	SSR Pv&cC with Garbling	>=30% >=90% >=98%	4.2.7.1.4.1 E1 4.2.7.1.4.2 E1 4.2.7.1.4.3 E1
C	SSR Pv&cA for not close aircraft	>=98%	4.2.4.1.4 E1
C	SSR Pv&iA for not close aircraft	<0.1%	4.2.4.1.7 E1
C	SSR Pv&cC for not close aircraft	>=96%	4.2.4.1.4 E2
C	SSR Pv&iC for not close aircraft	<0.1%	4.2.4.1.8 E1
C	Overall Mode S Pd	97%	4.2.3.1 E1
C	Overall Mode S PcS	>=99%	4.2.4.2.1 E1
C	Overall Mode S Pv&cA	>=99%	4.2.4.2.1 E1
C	Overall Mode S Pv&cC	>=99%	4.2.4.2.1 E1
C	Jumps rate	<0.05%	4.2.6.6 E1
M	SSR Pd for not close aircraft	>=99%	4.2.3.2.2 E2
M	SSR Range Error RMS for not close aircraft	<30m	4.2.6.2 E2
M	SSR Azimuth Error RMS for not close aircraft	<0.068deg	4.2.6.3 E3
M	SSR Azimuth Bias for not close aircraft (elevation < 6°)	<0.022deg	4.2.6.3 E1
M	SSR Azimuth Bias for not close aircraft (elevation 6-10°)	<0.033deg	4.2.6.3 E2
M	Mode S Pd	>=99%	4.2.3.3.2 E4
M	Mode S Range Error RMS	<15m	4.2.6.2 E3
M	Mode S Azimuth Error RMS	<0.068deg	4.2.6.3 E3
M	Mode S Azimuth Bias (elevation < 6°)	<0.022deg	4.2.6.3 E1
M	Mode S Azimuth Bias (elevation 6-10°)	<0.033deg	4.2.6.3 E2

ANNEX H

SYSTEM ERROR ANALYSIS

H.1 General

As required in Chapter 4, Sections 4.2.6.1 the Tenderer shall include in the proposal a fully detailed error analysis with calculations and quoting assumptions. **[I1]**

This shall take into account the appropriate contributory effect of at least all of the sources of error detailed below on the overall system range, azimuth and position error for the Mode S sensors with:

(a) No radome; **[E1]**

(b) Above with rain falling at a rate of 25mm/hr and 60mm/hr. **[E2]**

The mean and standard deviation for each individual item, for range and azimuth as appropriate, shall be stated over the full range of operating and environmental conditions defined within this specification. **[E3]**

The cumulative range and azimuth error, with both mean and standard deviation values for each, shall be stated. **[E4]**

From the values for range and azimuth errors the system positional error shall be stated as a function of target range. Mean and standard deviation values shall be stated. **[E5]**

H.2 Error sources

As a minimum, the following sources of error for the radar sensor shall be stated and included in the system error analyses:

H.2.1 Antennas

(a) Wind deflection where appropriate **[E1]**

(b) Beam skewing **[E2]**

(c) Mechanical alignment **[E3]**

(d) Turning moment **[E4]**

(e) Target elevation angle **[E5]**

(f) Beam defocusing **[E6]**

H.2.2 Antenna Turning Gear

(a) Tower deflection/twist **[E1]**

(b) Drive gear backlash **[E2]**

(c) Drive shaft twist **[E3]**

(d) Azimuth encoding **[E4]**

H.2.3 Rotating Joint

(a) Insertion loss variation per channel and cross channel mis-match. **[E1]**

(b) Phase variation per channel and cross channel mis-match. **[E2]**

H.2.4 Mode S Cabling - Antenna to Tx/Rx

(a) Cable delays. **[E1]**

(b) Insertion loss per channel and cross channel mis-match. **[E2]**

(c) Phase variations per channel and cross channel mis-match. **[E3]**

(d) Insertion loss/phase variation with age. **[E4]**

(e) Insertion loss/phase variation with temperature. **[E5]**

H.2.5 Mode Transmitter-Receiver/PAF

(a) Interrogator mode to mode jitter. **[E1]**

(b) Receiver signal/noise ratio. **[E2]**

(c) Receiver gain, frequency and phase drift. **[E3]**

(d) Cross channel receiver gain, frequency and phase mis-match. **[E4]**

(e) Local oscillator drift. **[E5]**

(f) Quantisation clock drift. **[E6]**

(g) Target input signal strength. **[E7]**

(h) Target input frequency. **[E8]**

(i) Pulse sampling error. **[E9]**

(j) Analogue to digital conversion error. **[E10]**

(k) Off boresight angle table calibration error. **[E11]**

(l) Pulse quantisation error. (Mode A/C) or synch phase reversal (Mode S) **[E12]**

(m) P3 (mode A/C) or synch phase reversal (Mode S) start range error. **[E13]**

(n) Range clock accuracy. **[E14]**

(o) Pulse to reply OBA averaging error. **[E15]**

(p) Reply to plot azimuth calculation error. **[E16]**

(q) Transponder delay variation. **[E17]**

It should be noted that trials have shown some Mode S transponder replies to SSR Mode 3/A,C interrogations with a transponder delay of between 3.1 and 3.5 μs. **[A1]**

H.3 Applicability

The Tenderer shall state whether the values provided in responses to the preceding paragraphs apply to both stationary and moving targets. If they do not, two sets of values shall be provided, one set for stationary targets and one set for moving targets. **[I1]**

H.4 Verification

Verification of the overall system errors will be carried out for each of the sites on target data obtained from each system, which will be evaluated using independent software analysis tools (e.g. PTE) together with measurements made on a stationary target (e.g. Mode S Monitor). **[A1]**

Separate calculations for the on-mounted PSR/Mode and free-standing Mode S systems shall be provided in the proposal. **[I1]**

In the case of the on-mounted systems (or where the supplier is interfacing with an existing LVA/Turning Gear/Rotating Joint/cabling), where error details are required for system elements not being proposed by the Tenderer, the Tenderer shall state and clearly indicate the error limits required for their proposed system to meet the requirements of this specification. **[I2]**

ANNEX I

DESCRIPTION OF THE POEMS TEST ENVIRONMENT (PTE)

I.1 Introduction to PTE tools

The Figure 17 illustrates the different radar processing levels accessed by the PTE tools

I.2 PTE P1-P2B

I.2.1 General

The PTE-P1 and P2B tools will be built around an enhancement of the existing RASS-S system, as developed by Intersoft Electronics. As such it will comprehensively test the radars functioning by simulating radar returns, recording data present at various processing stages within the radar, verifying interfaces and conducting limited data analysis. This test tool will permit the evaluation of Mode S stations as part of FAT. Through the nature of its design it is possible for the operator to ‘follow’ a target reply through the various processing stages that the PTE P1-P2B system monitors - this capability is defined as multi-level analysis.

The verification of the Asterix syntax of the messages generated by the Mode S station will be performed by RAPS II. RAPS II is a COTS product developed by Comsoft and which has been qualified by Eurocontrol. A specific configuration of the RAPS II tool has been defined to be able to record and analyse all the Asterix messages produced by the Mode S stations. This configuration is called RAPS-PTE.

I.2.2 PTE-P1

The main enhancements of PTE-P1 regarding RASS-S are relating to the specific capabilities of a Mode S ground station compared to a classical SSR. They are listed below:

(a) Data link functionality;

(b) Enhanced RF accuracy;

(c) Specific Mode S protocol;

(d) FRUIT environment simulation using the RFT (RF Test set) as a BSG (Basic Scenario Generator);

(e) FRUIT environment simulation using one RES (Radar Environment Simulator) channel;

(f) Number of targets (1080) and maximum number of overlapping targets (4);

(g) Exporting of recorded data to PTE-P4;

(h) Figure of merit calculation (Mode S probability of detection and accuracy);

(i) Serial communication protocol viewer (separate investigation tool).

Consequently the main functions of RASS-S (scenario generation, environment simulation and data analysis) have been upgraded within PTE-P1 to allow Mode S station testing.

PTE-P1 recording capabilities:

(a) ACP (Azimuth Change Pulse) / ARP (Antenna Reference Pulse);

(b) Interrogations;

(c) Simulated scenario;

(d) Video;

(e) Primary Radar inputs;

(f) Asterix Cat 48 (Target report message) and 34 (Sector message);

(g) Asterix Cat 17 (Surveillance Co-ordination Function message);

(h) Asterix Cat 18 (Data Link Function message).

PTE-P1 generation capabilities :

(a) Target replies (according to the simulated target scenario (trajectories + datalink) and to the interrogations performed by the Mode S station);

(b) FRUIT environment (according to the FRUIT environment defined in the scenario) either using a RFT/BSG or using one RES channel;

(c) Simulated ACP/ARP;

(d) Cat 18 (according to the simulated data link scenario);

(e) Exporting of data to PTE-P4.

PTE-P1 figure of merit calculation capabilities:

(a) Mode S probability of detection;

(b) Mode S positional accuracy.

PTE-P1 Protocol viewer display capabilities:

(a) OSI layer 1 messages;

(b) LAPB (OSI layer 2) messages;

(c) X.25 (OSI layer 3) messages;

(d) Asterix (application layer) messages (Mode S categories 017, 018, 034 & 048 are supported).

PTE-P1 Protocol viewer will appear as an independent tool in the PTE top level menu.

I.2.3 PTE-P2B

The PTE-P2 (Phase B) additional capabilities are the following:

(a) PSR scenario preparation to define the characteristics of the PSR information that will be provided through the real time PSR data bsimulation;

(b) Additional scenario preparation capabilities (including simulation of either Amendment 69 or 71 transponders as specified in ICAO Annex 10 Volume III Part 1);

(c) Real time PSR data simulation;

(d) Importing of data from various sources;

(e) Merging, filtering and managing the imported data;

(f) Various data analysis computation (data link performance, sector message delay, etc...);

(g) Display and output of analysis results.

PTE-P2B generation capabilities:

(a) Primary Radar inputs (from a simulated primary radar and according to the simulated scenario).

I.3 RAPS-PTE

This tool is a standard RAPS II platform including specific Mode S and PTE Asterix categories detailed below.

The RAPS-PTE recording capabilities are the following :

(a) Asterix Cat 48 (Target report message) and 34 (Sector message)

(b) Asterix Cat 17 (Surveillance Co-ordination Function message)

(c) Asterix Cat 18 (Data Link Function message)

The RAPS-PTE will then perform Asterix verification of the recorded data.

The RAPS-PTE will also be able to check the Asterix format of PTE-P1/P4 interface file (Category 48/34, Reference scenario, Reference DGPS, Reference video extractor).

I.4 PTE-P2A - TRANSMITTER TEST TOOL

I.4.1 General

PTE-P2A is a specific transmitter test tool that can generate a range of scenarios to test the interrogation load as specified in Datalink Model A (4.2.7.4.2). It records and analyses the outputs of the transmitter of the Mode S station either when inputs are provided by the Mode S station or when inputs are provided by the transmitter test tool. The context of PTE-P2A is briefly summarised in Figure 18.

I.4.2 Functions

PTE-P2A recording capabilities:

(a) Interrogations either in passive (interrogations requested by the Mode S interrogation scheduler) or active (interrogations requested by PTE-P2A scenario replay) context. The recording is performed in compressed mode (user defined samples of each interrogation) and/or in detailed mode (recording at 16 MHz rate of interrogations during user defined period of times);

(b) Scenario of interrogation requests.

PTE-P2A generation capabilities:

(a) Interrogation requests (according to the simulated scenario of interrogation requests).

PTE-P2A analysis capabilities:

(a) In case of scenario replay, the tool will check whether the requested interrogations have been actually correctly performed by the transmitter (based on ICAO and PILOT requirements) and will calculate a global rate of success for the whole scenario.

PTE-P2A will appear as an independent tool in the PTE top level menu.

I.5 PTE-P3 - CLUSTER SIMULATION AND TESTING

I.5.1 Introduction

The role of PTE-P3 is to test (including FAT) the compliance of the SCF (Surveillance Co-ordination Function) of a Mode S station against its requirements. It will be performed through the real time simulation of adjacent Mode S stations with which the tested station form a cluster. A functional schematic of the system PTE-P3 and its interfaces is given in Figure 19.

The role of the SCF is to support surveillance co-ordination between the local Mode S station and the other Mode S stations forming a cluster and connected to a WAN (SCN, Surveillance Co-ordination Network).

This co-ordination is based on a series of protocols to be established between the different Mode S stations forming a cluster, which are :

(a) The X25 Connection Management protocol which is at the network layer;

(b) The Network Monitoring Protocol (NMP) which is at the transport/session layer;

(c) The Central Mode System Control Protocol which is at the application layer;

(d) The Track Acquisition and Support Protocol (TASP) which is at the application layer;

(e) The New Node Change Over Protocol (NNCOP) which is also at the application layer.

So, the role of PTE-P3 is to simulate the establishment of those protocols between a Mode S station under test and adjacent stations forming a cluster.

In order to provide a representative behaviour of the two application layer protocols (TASP and NNCOP) PTE-P3 will only work in conjunction with PTE P1 which simulates targets detection at the RF level of the Mode S station, in order to provide surveillance co-ordination data consistent with what the Mode S station is detecting.

An on-line assessment will be undertaken during simulation and statistics will be provided at the end of simulation run.

In parallel, the system will record, time stamp and mark all the messages exchanged between PTE-P3 and the Mode S station under test.

By processing the above information the operator will be able to quantify various performance levels for the Mode S station under test.

I.5.2 The Scenario Preparation Task

This scenario preparation encompasses the definition of the following elements:

(a) Characteristics of the simulated stations (scan rate, radar name, etc.);

(b) Characteristics of the Mode S station under test (radar name, etc.);

(c) Mode S surveillance coverage map of the simulation domain;

(d) Scenarios coming from PTE-P1;

(e) Events scenario for the simulated stations (e.g. connection, disconnection, failure, tracking request, etc.).

I.5.3 The Simulation Processing Task

The first step includes the simulation of the low level X25.3 Connection Management protocol which establishes the logical links between stations, the second step include the simulation of the NMP protocol by which a station under test joins the simulated running cluster and the third step includes the TASP and NNCOP protocols (distributed mode) or the Central Mode System Control protocol and the track acquisition and support process (central mode) which correspond to the exchanges between running applications on different stations in a cluster.

PTE-P3 recording capabilities:

(a) Asterix Cat 17;

(b) Asterix Cat 48.

PTE-P3 generation capabilities:

(a) Asterix Cat 17 (from simulated adjacent sensors and according to the simulated scenario).

The PTE-P3 tool kit consists of one SUN Workstation including standard devices and specific interface cards.

I.6 PTE-P4

I.6.1 Introduction

The function of this site analysis tool (PTE-P4) is to provide additional mono-radar analysis capabilities to those available in the PTE-P1/P2B phase for site analysis.

This analysis will be run off-line and will derive it's information from a number of sources, namely:

(a) Measured target reports recorded by the PTE-P1 system, which means that at least the PTE P1 EDR (Extended Data Recorder), including an Apple PowerMac is required.

(b) Data from an external source:

(i) DGPS positions declared by the aircraft (if available)

(ii) The reference trajectory derived by the Video Reference Extractor from the radar video (if available)

(iii) The PTE-P1 scenario generator output

(iv) Map Data

(v) RASCAL Maps providing terrain information.

(vi) Mode S Maps to support the analysis, detailing particular Mode S constraints applied to the radar (power levels, lockout etc.).

By processing the above information the operator will be able to quantify various performance levels for the radar under test. Of particular interest to this phase of the development will be the accuracy of the radar and the Probability of Detection it achieves.

The PTE-P4 system is designed to allow the user to analyse and validate conventional PSR and SSR radar data as well as Mode S radar data in a flexible and efficient manner. (Please note that interfaces to PSR and conventional monopulse SSR have not been developed). To do this, the system is broken down into a number of separate functional components. The relationships and high level data flows between these components are shown in the figure below. The user is able to control the system by carrying out the available functional operations in any appropriate order. The user will be prevented, however, from attempting to carry out functional operations in an inappropriate order (e.g. attempting internal reference generation prior to object correlation).

The outline of the individual functions in the PTE-P4 system (see figure below) are shown joined by solid lines to indicate data flow and dashed lines to indicate control flow.

I.6.2 Functional Architecture

The PTE-P4 functional architecture is as in Figure 20.

I.6.3 PTE-P4 functions

These PTE-P4 functions may be broadly grouped:

(a) Data acquisition (DA) - is the process that allows the user to import data, including target reports, radar service messages and external references (DGPS, reference extractor output, scenario generator data) from the PTE-P1 system via file transfer. The imported data is checked and added to the database as part of the current data set. Chained and tagged target report data may also be re-exported to the PTE-P1 tool for further analysis.

(b) Display filter (DF) - allows the user to select a subset of the current data for display on the screen. The filtering of the data is carried out by specifying one or more filters (e.g. time window, Mode S address range, SALADT screening angle volume) when the data matching the current filtering criteria are selected.

(c) Analysis filter (AF) - performs a similar role to the display filter, but is used for selecting data for input to the analysis functions.

(d) Graphical user interface (GUI) - allows the user to control the operation of the tool and displays the various results of the analyses.

(e) Object correlator (OC) - forms a key element in the PTE-P4 tool as it links target reports into target report chains, which are believed to be associated with a single aircraft, and associates them with the external reference data.

(f) Analysis reference generator (ARG) - calculates the bias model parameters (e.g. range gain) between data sets originating from different sources (e.g. target reports and DGPS data). The bias model parameters may then be used to effect target report position corrections. ARG also has the task of “completing” those external references requiring addition of velocity/acceleration data.

(g) Internal reference generator (IRG) - calculates a smoothed internal reference trajectory with full state vector information from the chained target report data.

(h) Plot accuracy analysis (PAA) - calculates statistics for the residual positional errors between the target reports and the reference trajectories, resolved onto the radar’s frame of reference.

(i) Plot resolution analysis (PRA) - identifies and calculates statistics on target reports from portions of trajectories which are within the resolution of the Mode S ground station (i.e. likely to give rise to co-channel interference within the radar’s plot extractor processing).

(j) Plot detection analysis (PDA) - calculates detection probabilities for target reports and the probabilities of successfully extracting the correct SSR codes and/or Mode S address information when applicable.

(k) False plot analysis (FPA) - calculates statistics for false plots, i.e. target reports arising from radio frequency (RF) propagation pathways other then direct path main lobe to transponder to main lobe.

(l) Airborne parameter analysis (APA) - calculates the frequency of extraction of MB fields reported by the radar and the frequency of interrogations required for extraction.

(m) Load measurement analysis (LMA) - calculates statistics to measure the work load of the radar in terms of the numbers of targets as functions of azimuth and range.

I.7 Physical Configuration

I.7.1 PTE-P1

The PTE-P1 tool kit consists of the following hardware items:

(a) 3 Apple PowerMac Laptops;

(b) 1 Apple PowerMac Desktops;

(c) 1 RVR (Radar Video Recorder) steel box, including an RVI (Radar Video Interface);

(d) 1 EDR SGR (Extended Data Recorder Scenario Generation Recorder) steel box;

(e) 1 RES (Radar Environment Simulator) consisting of:

(i) an ESG (Extended Scenario Generator) steel box;

(ii) a RIU (Radar Interface and Upconvertor) steel box.

(f) 1 RIU (Radar Interface Unit) steel box;

(g) 1 RFA (Radar Field Analyser) steel box;

(h) 1 RFT (RF Test set) steel box;

(i) 1 ACC (ACCessories) steel box, including a Gyroscope, a GPS unit and an AFU (Acp/arp Fanout Unit).

I.7.2 PTE-P2A

The PTE-P2A tool kit consists of the following hardware items :

(a) 1 RTI (Radar Transmitter Interface);

(b) 2 PDMs (Power Detector Module).

Those items will be included in a single steel box.

In order to operate the PTE-P2A tool the following PTE-P1 items are also needed:

(a) 1 RVR equipment and 1 RVI (Radar Video Interface) equipment, included in the RVR steel box;

(b) 1 Apple PowerMac (Desktop or Laptop).

I.7.3 RAPS-PTE

The RAPS-PTE platform consists of the following hardware items :

(a) 1 RAPS II standard platform (Portable x86 PC running under SCO Unix);

(b) 1 serial line extension;

(c) 1 Ethernet extension.

I.7.4 PTE-P2B

PTE-P2B will be implemented purely as a software solution, running partly on the PTE-P1 platform (PSR simulation) and partly on a platform yet to be chosen, but constrained to be identical to one of the existing ones (PowerMac as for P1, SUN as for P3 or x86/NT4 as for P4).

I.7.5 PTE-P3

The PTE-P3 tool kit consists of one SUN Workstation including standard devices and specific serial interface cards.

I.7.6 PTE-P4

The PTE-P4 tool kit consists of one x86 PC running under Microsoft Windows NT4, with standard devices.

ANNEX J

FIGURES

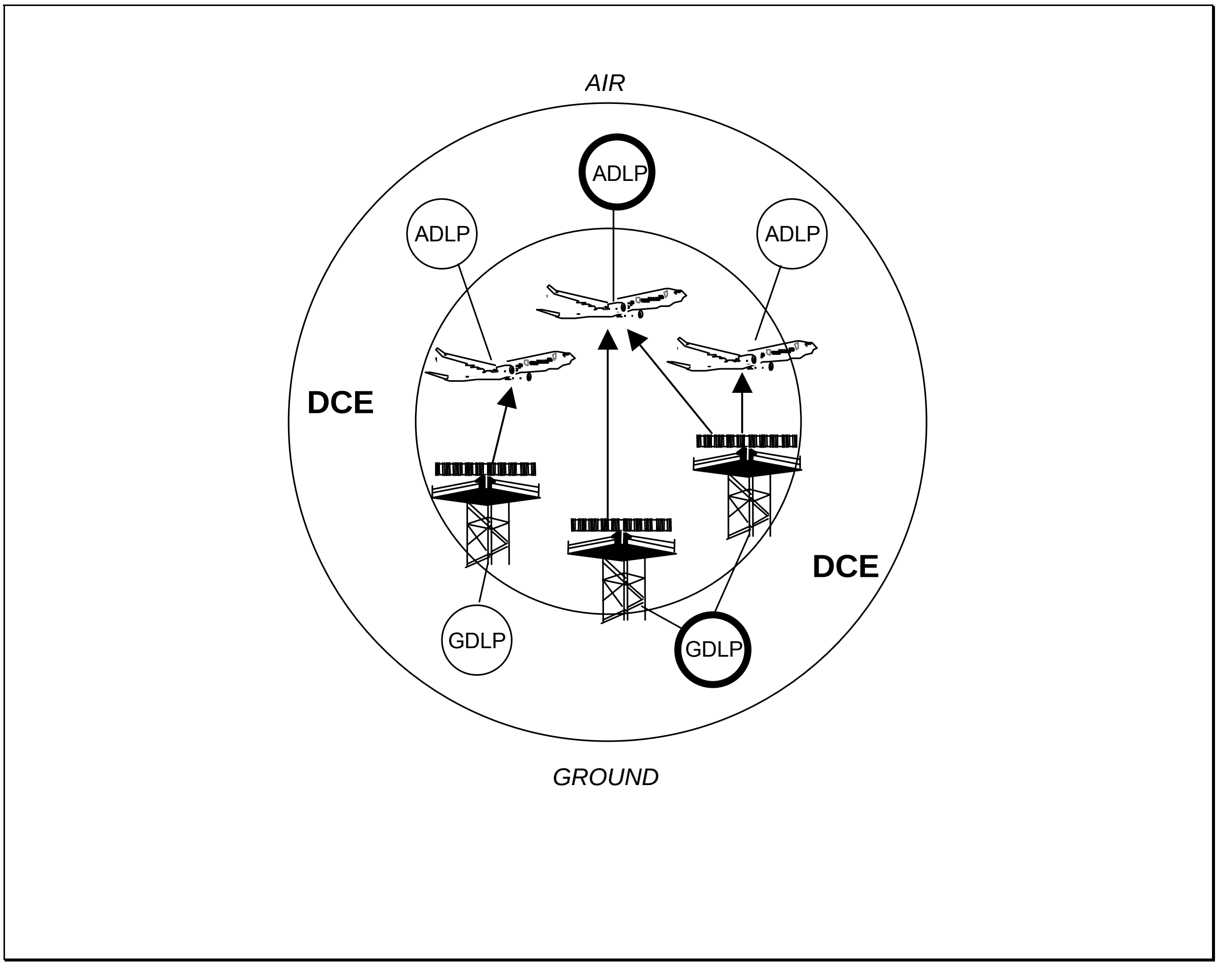


Figure 1 Mode S Subnetwork Environment

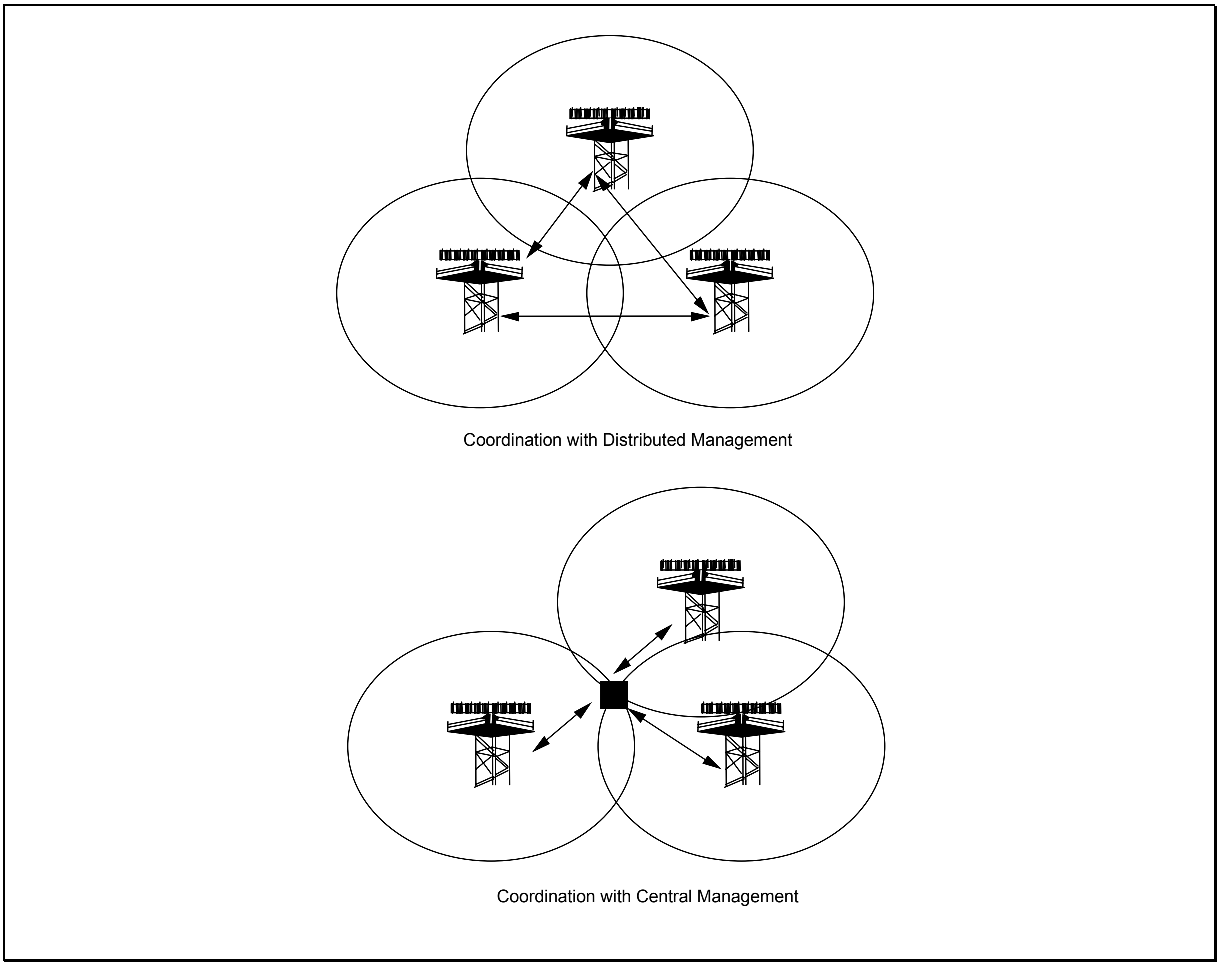


Figure 2 Cluster Co-ordination Options

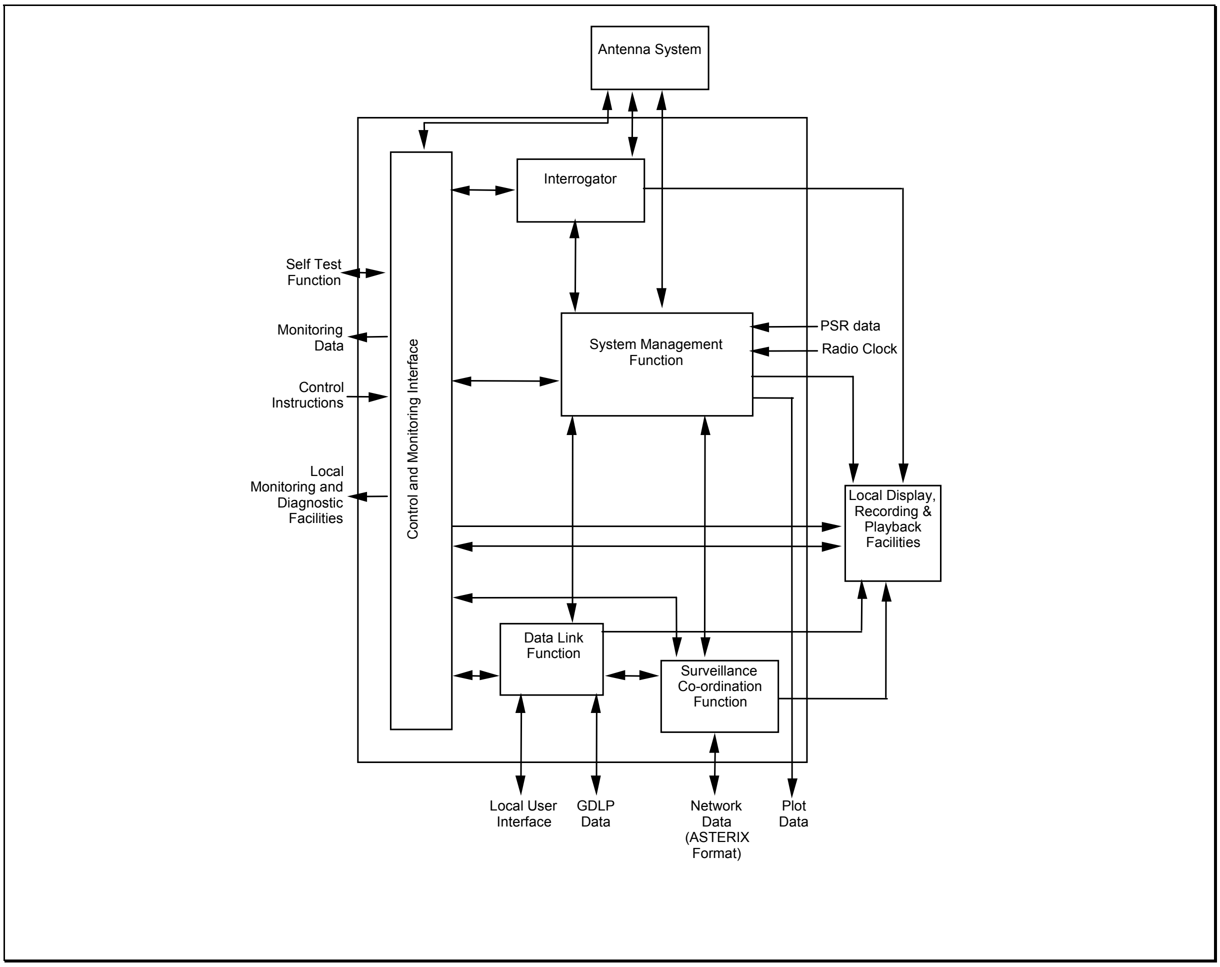


Figure 3 Mode S Ground Station Functional Overview

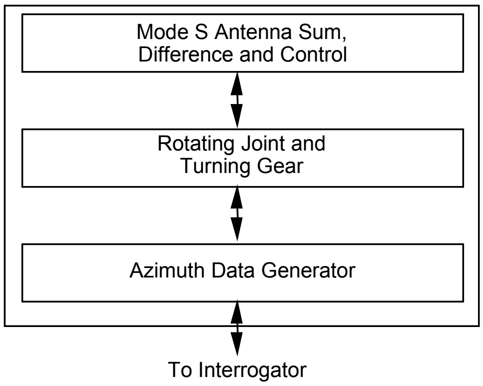


Figure 4 Antenna Functional Overview

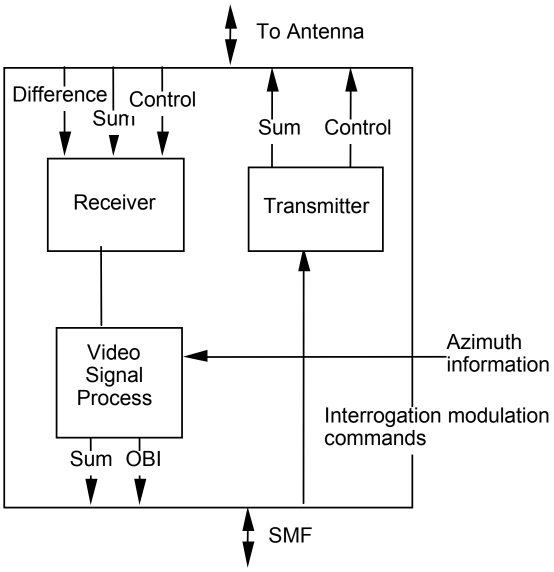


Figure 5 Interrogator Functional Overview

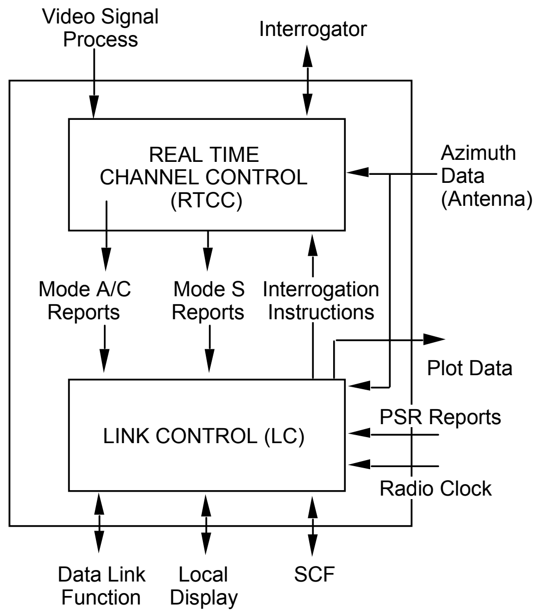


Figure 6 System Management Function (SMF) Overview

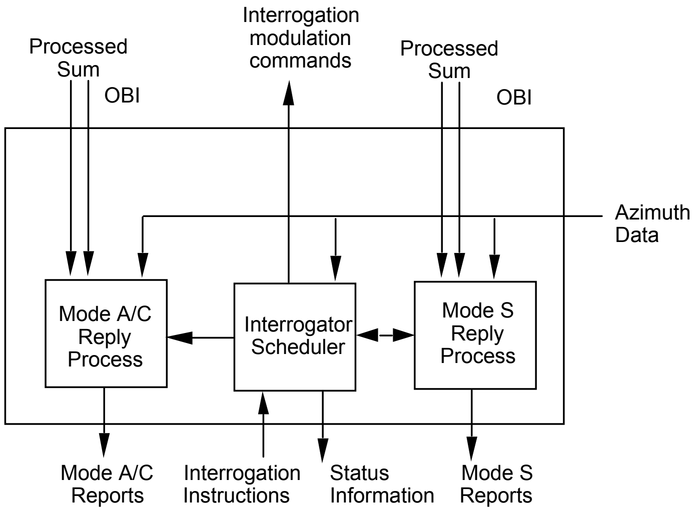


Figure 7 Real Time Channel Controller (RTCC) Functional Overview

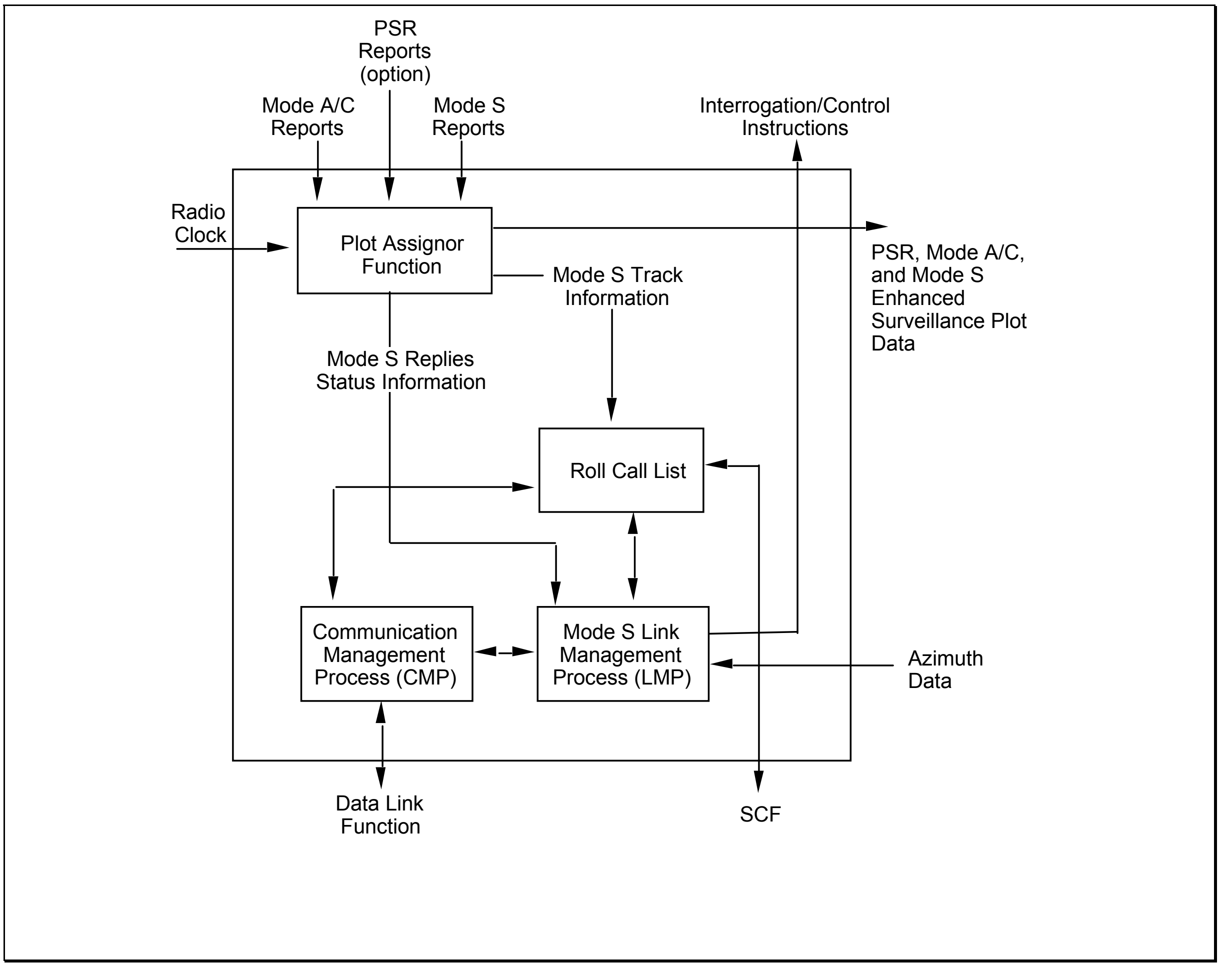


Figure 8 Link Control Functional Overview

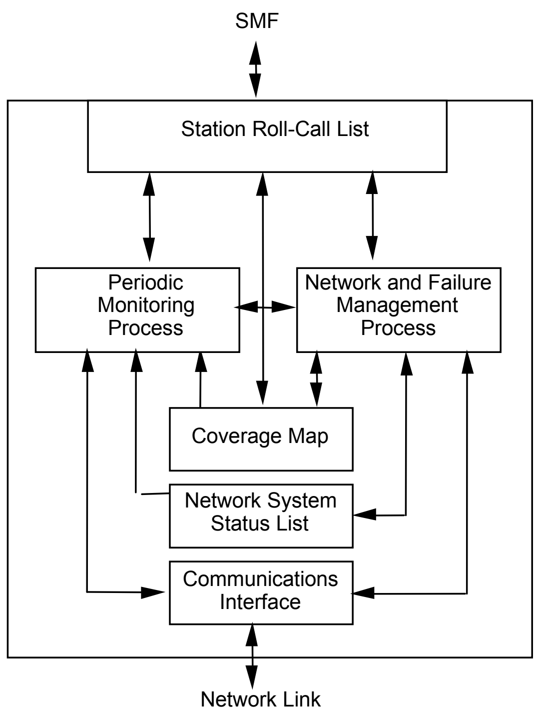


Figure 9 Surveillance Co-ordination Function (SCF) Overview

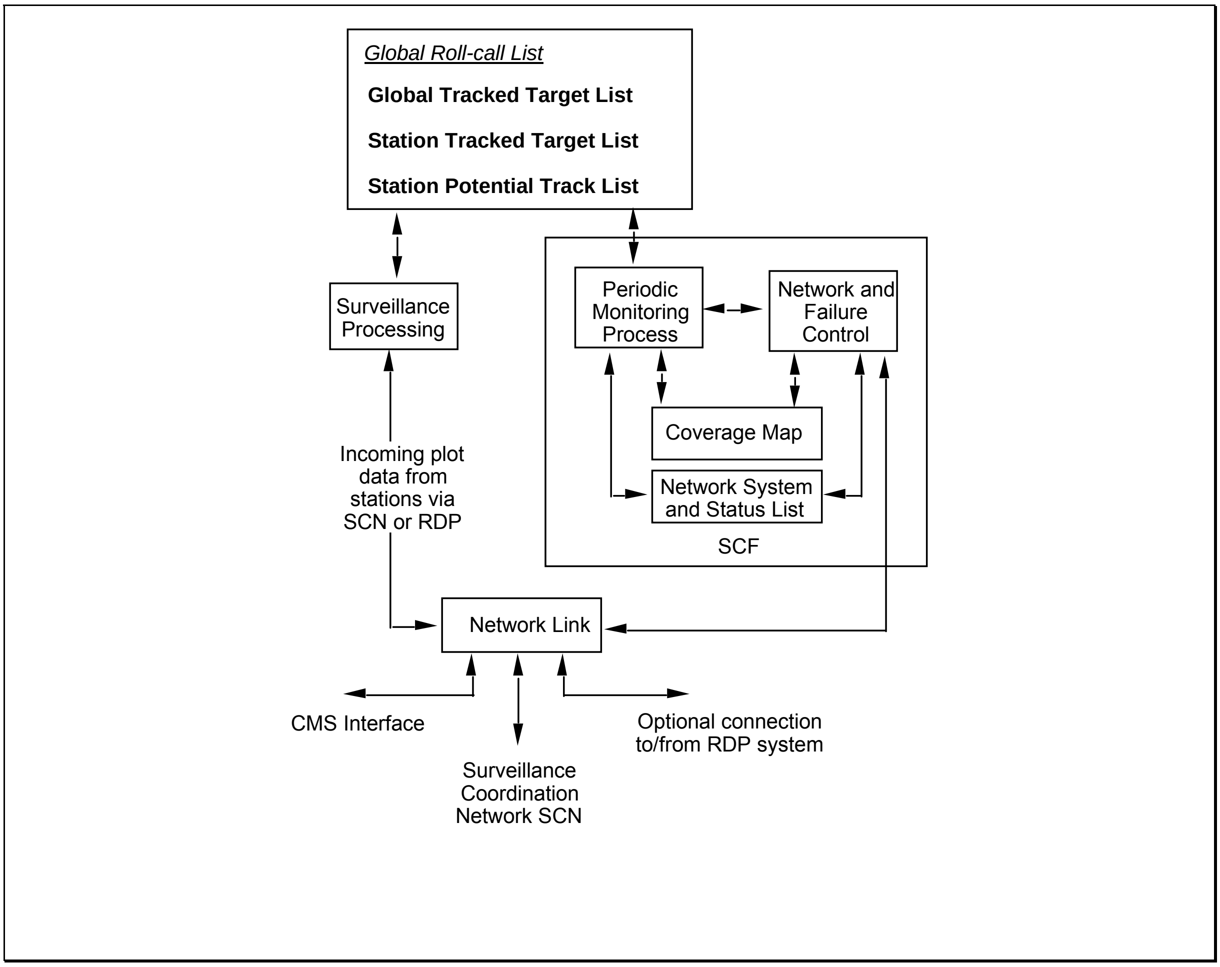


Figure 10 Cluster Controller (CC) Functional Overview

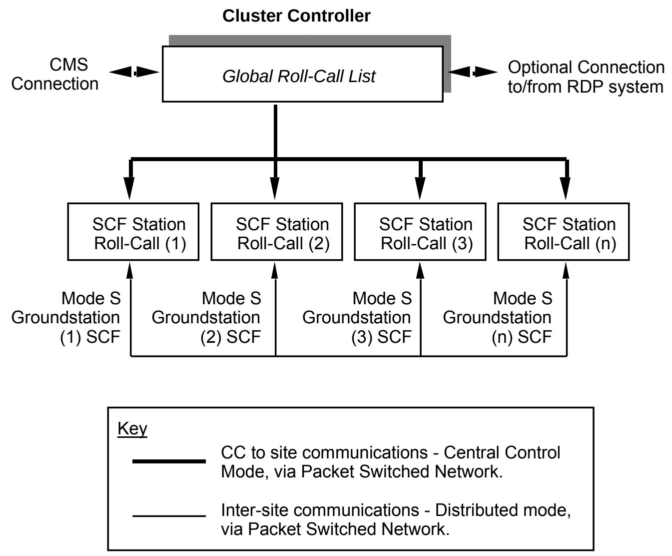
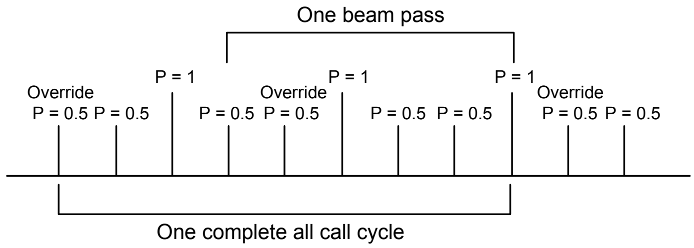
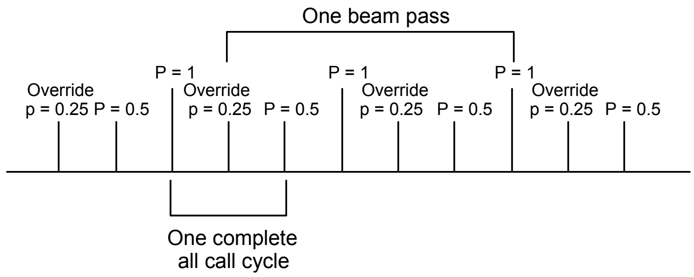


Figure 11 Surveillance Co-ordination Network (SCN)



Pattern A to achieve 90% probability in two aerial revolutions



Pattern B to achieve 90% probability in three aerial revolutions

Note:

Pattern A always gives four interrogations with a probability of 0.5 but every fourth pattern has two override interrogations instead of one. Pattern B always gives two interrogations with a probability of 0.5 and two override interrogations with a probability of 0.25

Figure 12 Stochastic All Call Example

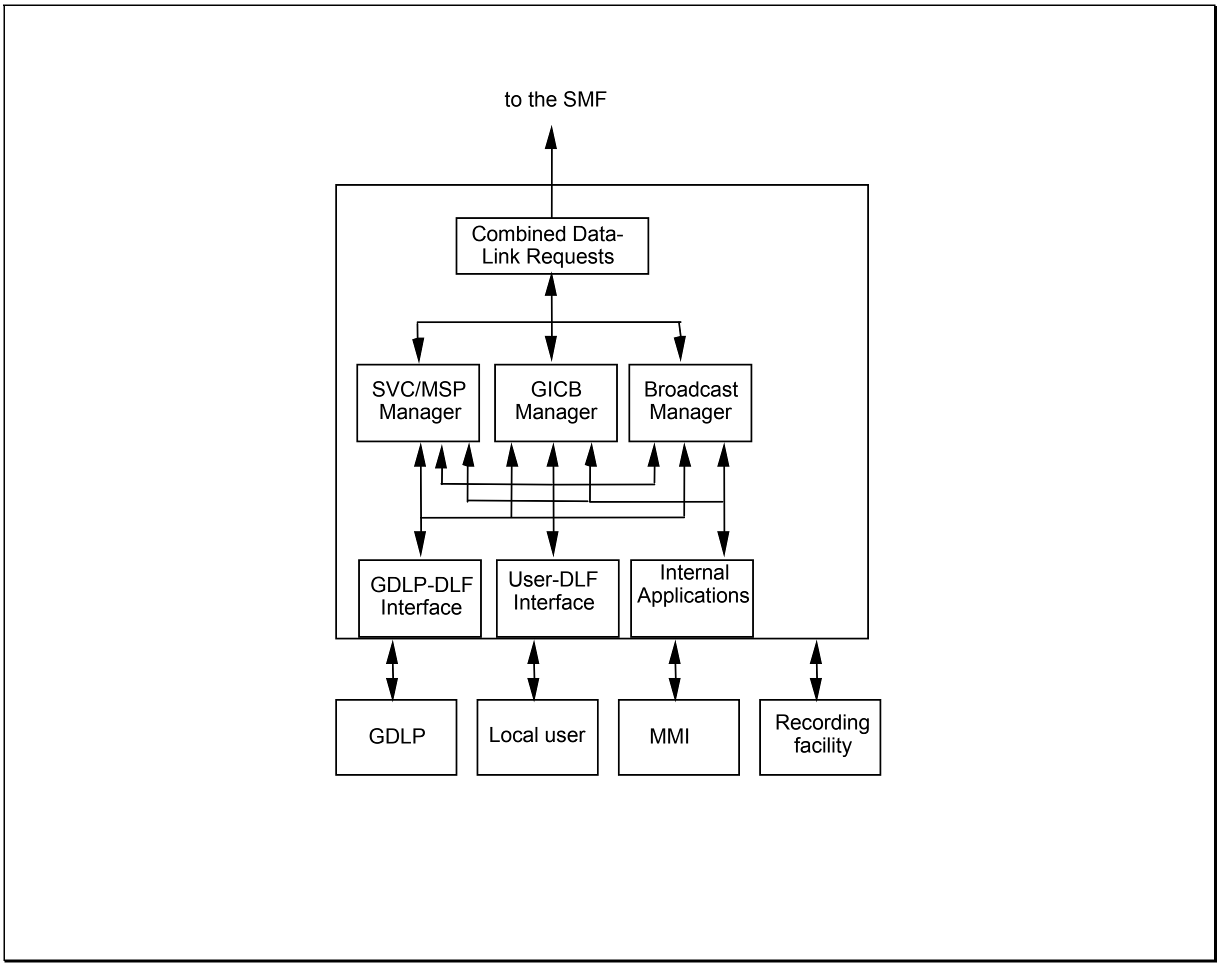


Figure 13 Datalink Function (DLF) Overview

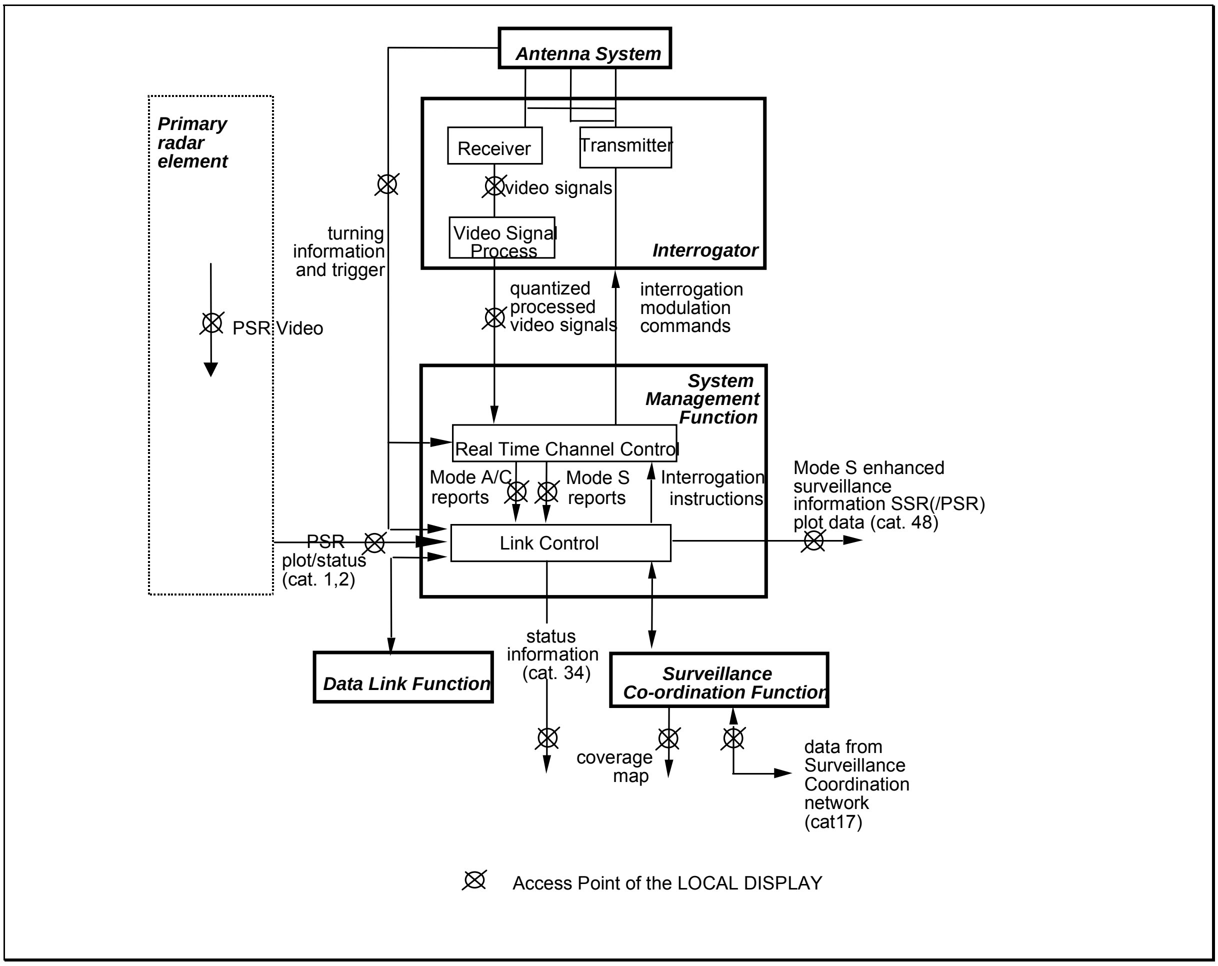


Figure 14 Local Display (LD) Acces Points

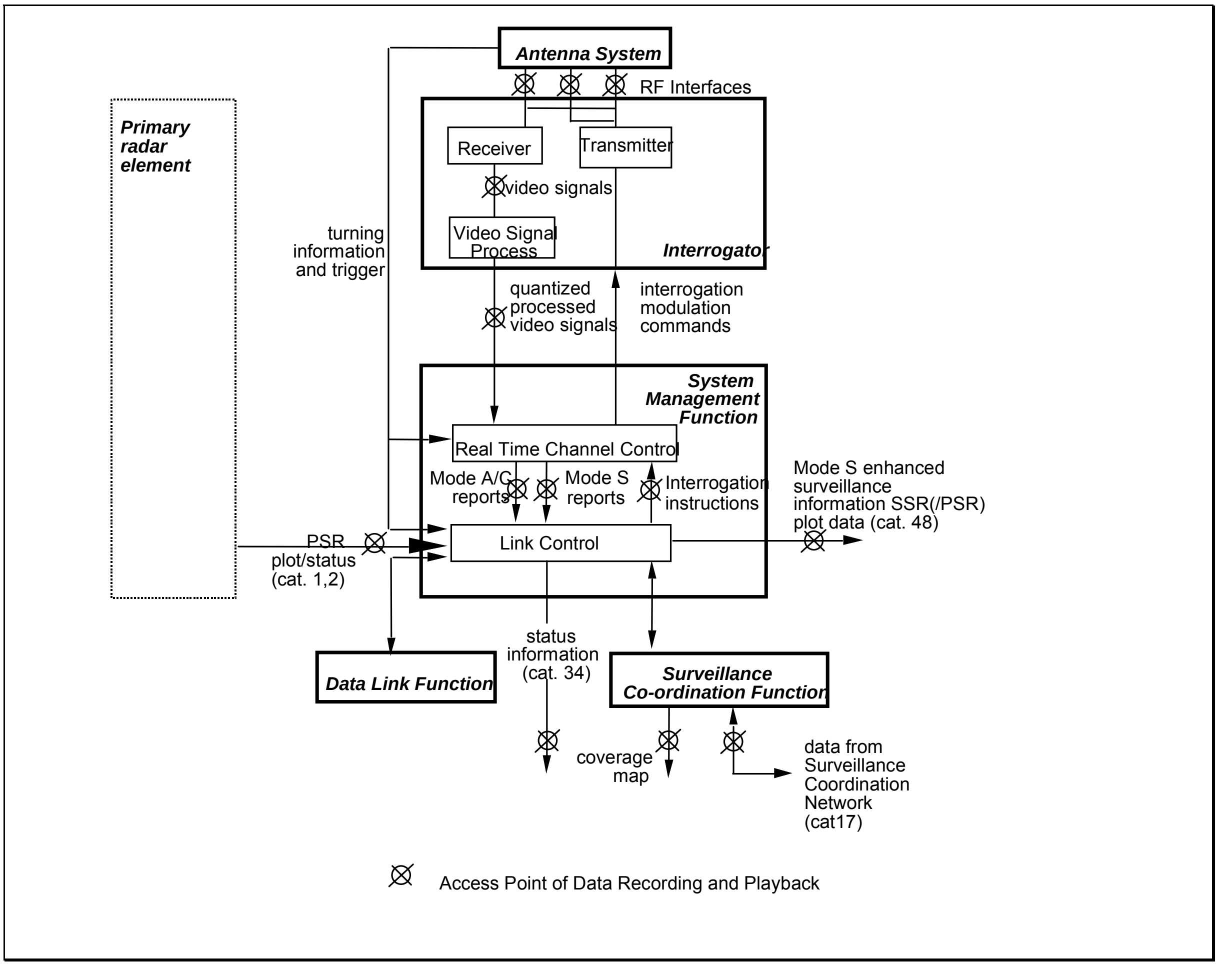


Figure 15 Data Recording and Playback Access Points

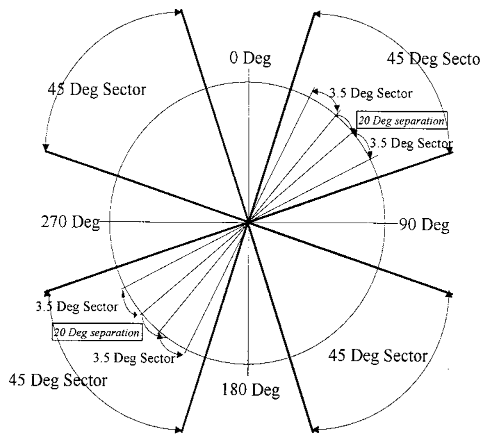


Figure 16 Illustration of Sector Distribution

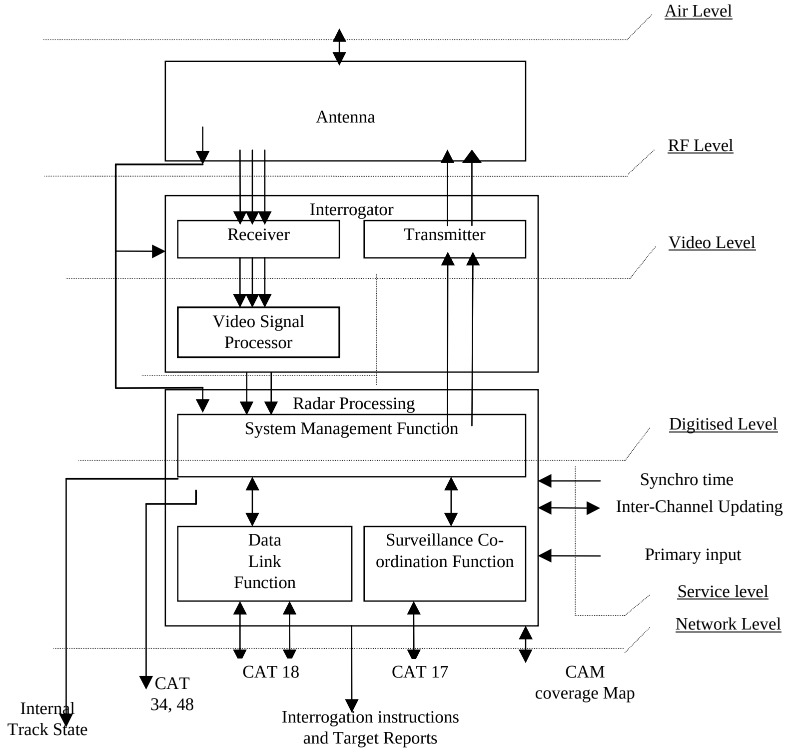


Figure 17 PTE Access Level Overview

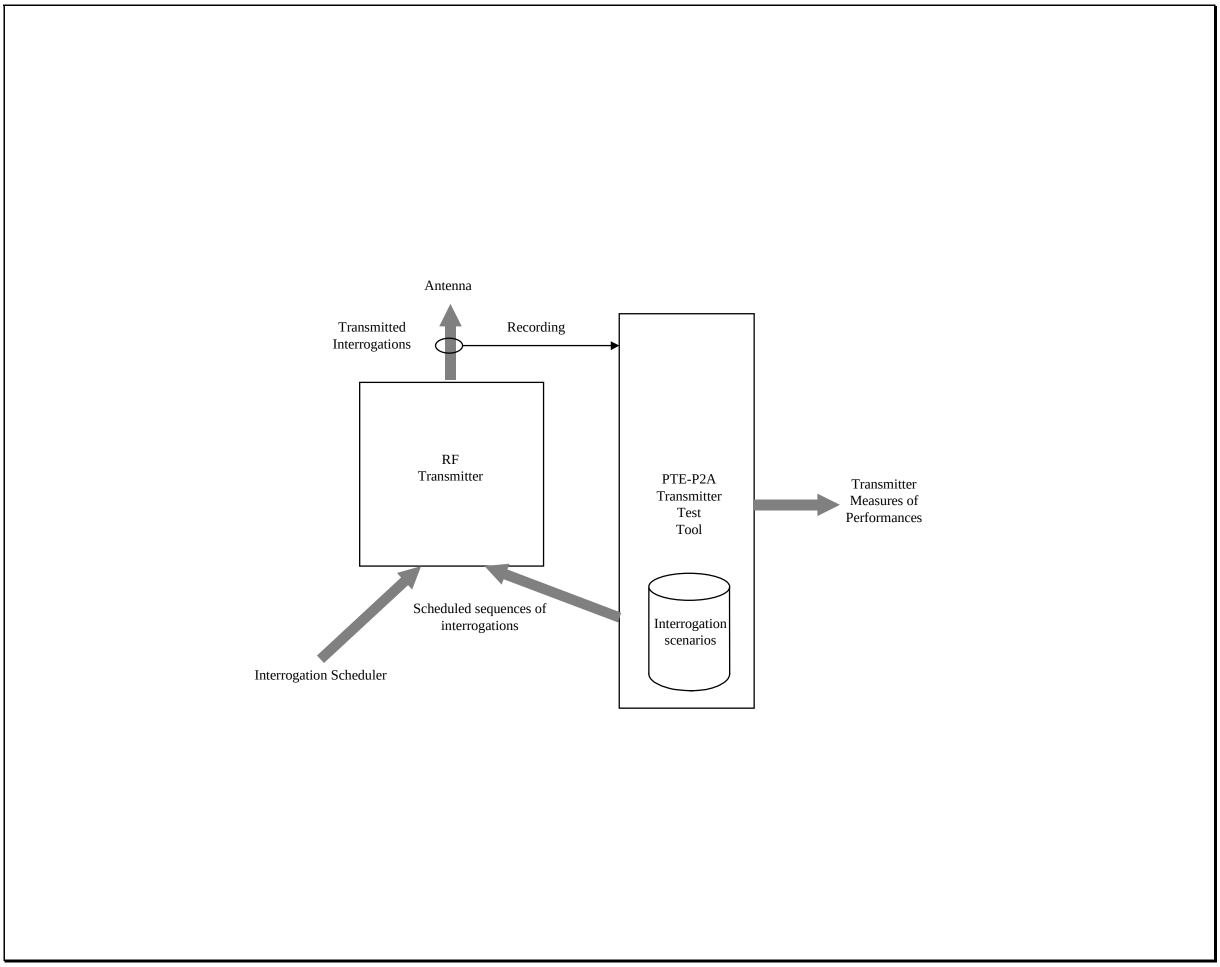


Figure 18 PTE-P2A Context

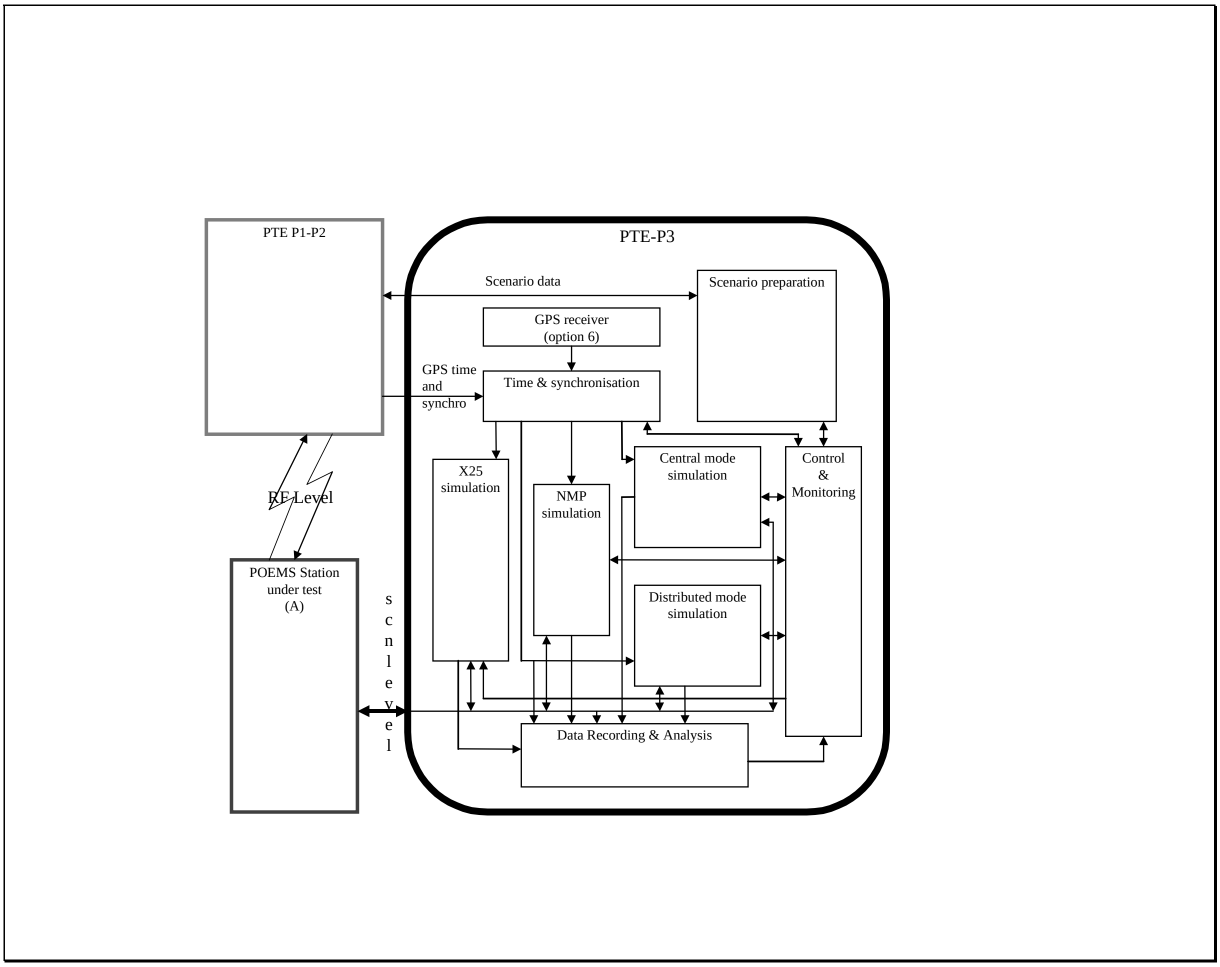


Figure 19 PTE-P3 Functional Overview

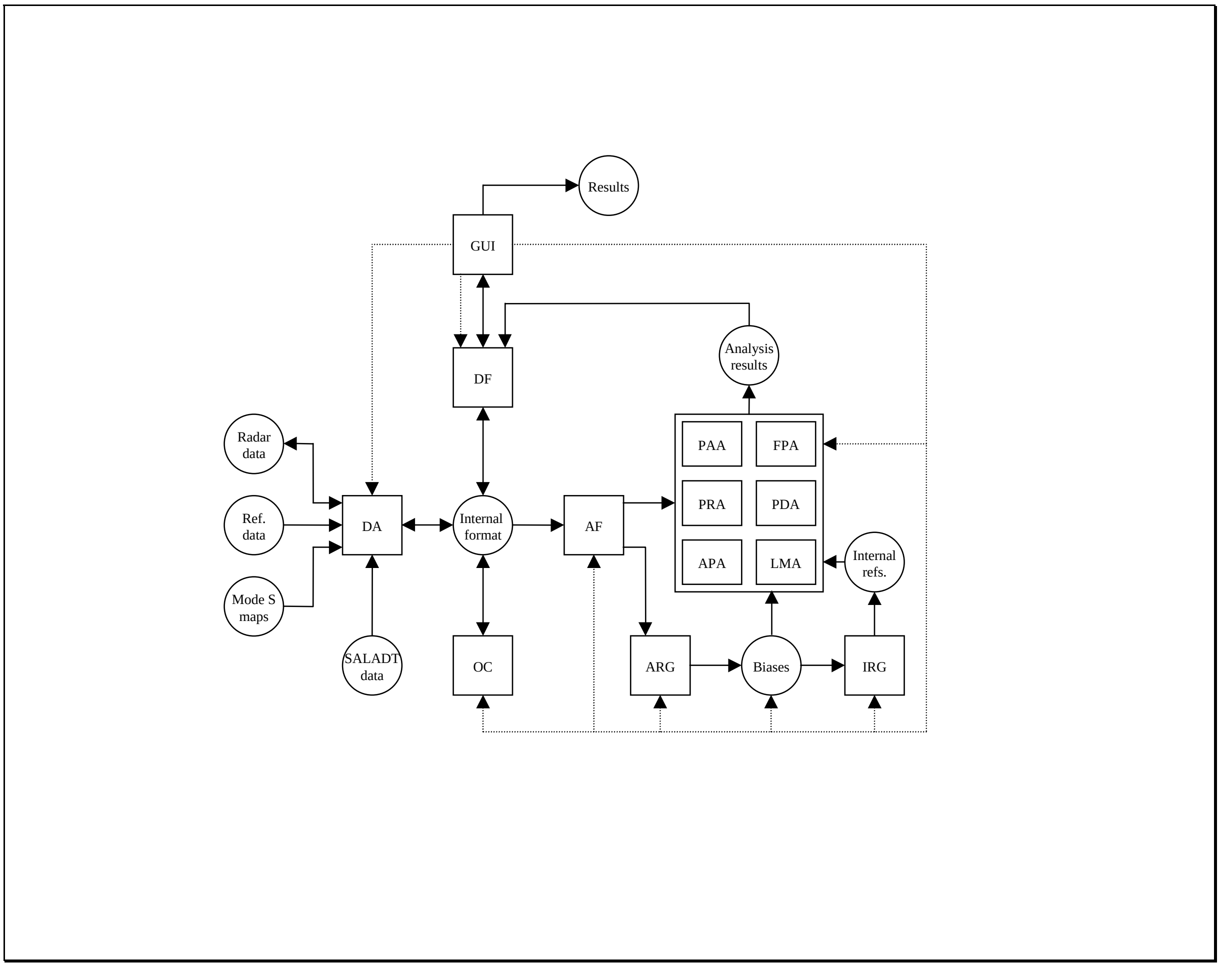


Figure 20 PTE-P4 Functional Architecture

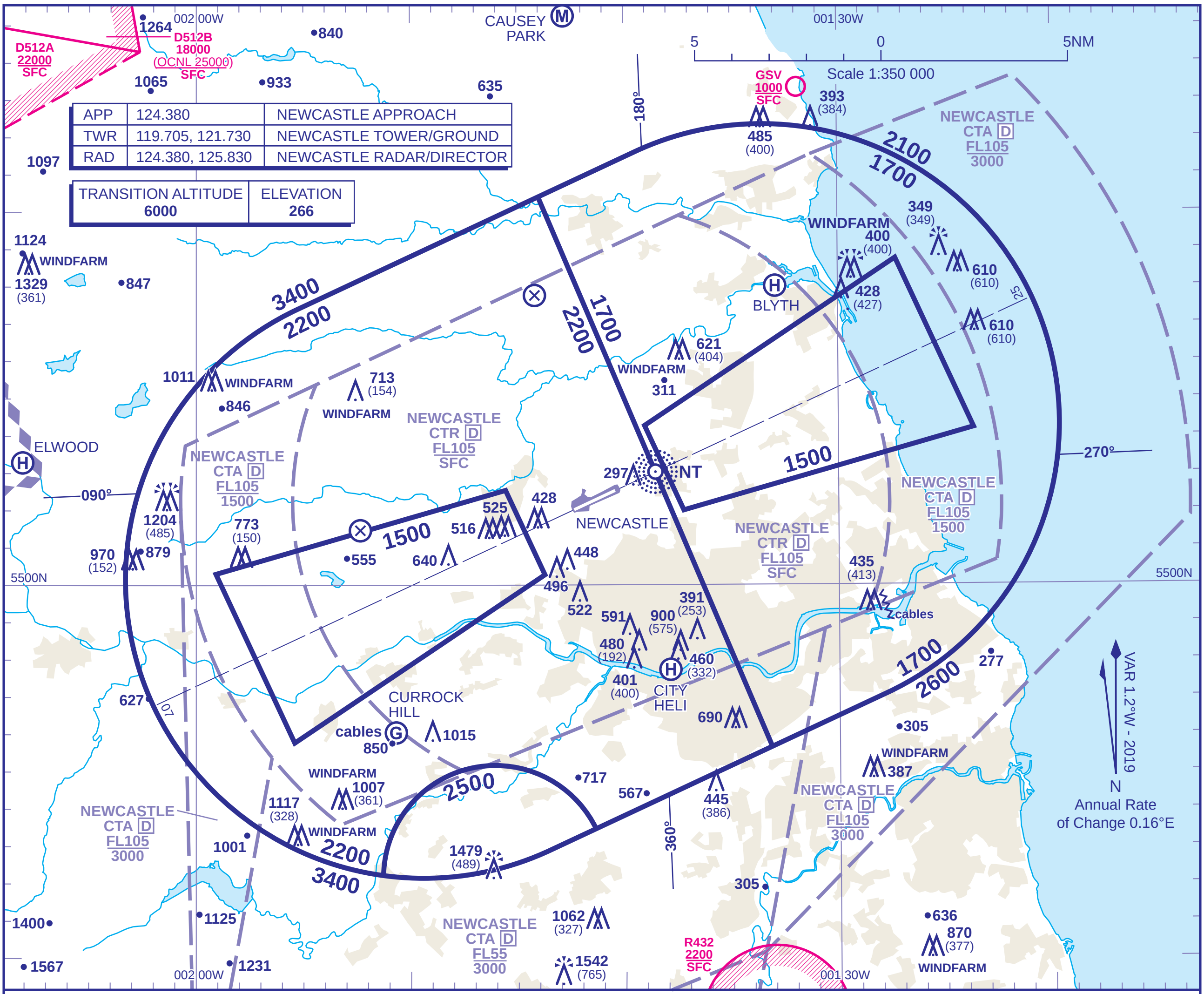
Appendix 12

AIS AIP Newcastle Airport

ATC SURVEILLANCE MINIMUM ALTITUDE CHART - ICAO

BEARINGS, TRACKS AND RADIALS ARE MAGNETIC
ELEVATIONS IN FEET AMSL 1542
HEIGHTS IN FEET AGL (765)

NEWCASTLE



MINIMUM INITIAL ALTITUDE

Within the ATC Surveillance Minimum Altitude area the minimum initial altitude to be allocated by the approach surveillance controller is:

a) **1700** in the sector defined by the lateral limits; 551023N 0014359W - 551137N 0013926W thence clockwise by an arc of a circle radius 8NM centred on 550420N 0013337W to 545705N 0012748W - 545539N 0013310W - 551023N 0014359W.

b) **2200** in the sector defined by the lateral limits; 550724N 0015517W - 551023N 0014359W - 545539N 0013310W - 545329N 0014123W thence anti-clockwise by an arc of a circle radius 3NM centred on 545210N 0014605W to 545214N 0015117W thence clockwise by an arc of a circle radius 8NM centred on 550009N 0014923W to 550724N 0015517W.

For right hand circuits to RWY 07 further descent to **2200** may be given on base leg when north of CTA boundary.

c) **2500** in the sector defined by the lateral limits; 545214N 0015117W thence clockwise by an arc of a circle radius 3NM centred on 545210N 0014605W to 545329N 0014123W - 545254N 0014331W thence clockwise by an arc of a circle radius 8NM centred on 550009N 0014923W to 545214N 0015117W.

OUTSIDE THE DESIGNATED ATC SURVEILLANCE MINIMUM ALTITUDE AREA

The minimum altitude to be allocated by the approach surveillance controller will be either the Minimum Sector Altitude, or **1000** above any fixed obstacles:

a) within 5NM of the aircraft*, and

b) within the sector 15NM ahead of and within 20° either side of the aircraft's track*.

*When the aircraft is within 15NM of the radar antennae, the 5NM in a) and the 15NM in b) may be reduced to 3NM and 10NM respectively.

LOSS OF COMMUNICATION PROCEDURES

Initial Approach

Continue visually or by means of an appropriate approved final approach aid. If not possible proceed at **2500**, or last assigned level if higher to **NDB(L) NT**†.

Intermediate and Final Approach

Continue visually or by means of an appropriate final approach aid. If not possible follow the Missed Approach Procedure to **NDB(L) NT**†.

† In all cases where the aircraft returns to the holding facility the procedure to be adopted is the Radio Failure Procedure detailed at ENR 1.1.3.

GENERAL INFORMATION

1. Levels shown are based on QNH.
2. Only significant obstacles and dominant spot heights area shown.
3. The minimum levels shown within the ATC Surveillance Minimum Altitude Area are in conformance with the Standard European Rules of the Air - SERA.5015.
4. Minimum Sector Altitudes are based on obstacles and spot heights within 25NM of NDB(L) NT.
5. Controlled airspace with a base in excess of **5000** or FL55, as appropriate, is not shown.
6. **This chart may only be used for cross-checking of altitudes assigned when in receipt of an ATC Surveillance service.**
7. **When vectoring an aircraft within the Final Approach Vectoring Area descent clearance below the SMAA to the FAVA altitude may only be issued if the aircraft is either established on the final approach track or on an intercept of 40° or less, and in the case of instrument approaches other than SRA is cleared to intercept the final approach track.**

CHANGE (5/19): D512B NAMING. OBSTACLES.

Appendix 13

Project Marshall ATC Radar Upgrade

Appendix 13

Project Marshall ATC Radar Upgrade

Project Marshall - Installation of new and upgraded radars at MOD sites

Site	Planned start date for transition work (correct at June 2019 but subject to change in accordance with the Marshall contract)	Planned date of commission or to complete the upgrade and/or replacement. (correct at June 2019 but subject to change in accordance with the Marshall contract).	Type & Model of Radar
RAF Akrotiri	Quarter (Q) 2 2020	Quarter (0)1 2022	Co-mounted Thales Star NG PSR, SSR (Thales RSM970S)
RAF Aberporth	Q1 2020	042020	Co-mounted Thales Star NG PSR, SSR (Thales RSM970S)
RAF Benson	Q1 2020	Q1 2021	Thales Star NG PSR
RAF Brize Norton	01 2020	Q1 2021	Thales Star NG PSR
RAF Coningsby	Q4 2019	Q4 2020	Thales Star NG PSR
RAF Cranwell	Q2 2019	02 2020	Thales Star NG PSR
RNAS Culdrose	Q3 2019	Q3 2020	SSR (Thales RSM970S)
	042020	Q3 2021	BAE Watchman PSR
Gibraltar	042020	Q4 2021	Co-mounted Thales Star NG PSR, SSR (Thales RSM970S)
RAF Leuchars	Under review	Under review	Under review
RAF Linton-on-Ouse	Q1 2021	Q1 2022	Thales Star NG PSR
RAF Lossiemouth	Q4 2019	Q3 2021	Thales Star NG PSR
RAF Marham	Q1 2019	02 2020	Thales Star NG PSR
RAF Odiham	Q1 2020	Q1 2021	Ihales Star NG PSR
RAF Mount Pleasant	Q1 2021	04 2021	Thales Star NG PSR
RNAS Portland	Q3 2020	Q2 2021	.SSR (Thales RSM970S),
	Q1 2021	Q4 2021	BAE Watchman PSR .
Porton Down	Under review	Under review	Thales Star NG PSR
RAF Shawbury	01 2019	Q4 2019	Thales Star NG PSR

Site	**Planned start date for transition work** (correct at June 2019 but subject to change in accordance with the Marshall contract)	**Planned date of commission or to complete the upgrade and/or replacement.** (correct at June 2019 but subject to change in accordance with the Marshall contract).	**Type & Model of Radar**
RAF Spadeadam (Dead Water Fell)	02 2019	Q4 2021	Upgrade existing radar to Thales STAR NG PSR
RAF Spadeadam (Berry Hill)	03 2019	01 2021	Co-mounted Thales Star NG PSR, SSR (Thales RSM970S)
RAF St !<ilda	02 2020	Q1 2021	Co-mounted Thales Star NG PSR, SSR (Thales RSM970S)
RAF Valley	03 2019	032020	Thales Star NG PSR
RAF Wattisham	02 2019	02 2020	Thales Star NG PSR
RAFWembury	03 2019	032020	SSR (Thales RSM970S),
	04 2020	03 2021	BAE Watchman PSR
RAF West Freugh	03 2020	02 2021	Thales Star NG PSR
RAF Wittering	Under review	Under review	Under review