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A12.2

Trinity College Dublin Direct Current and Near Direct Current Electromagnetic Radiation Survey Report

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LIST OF ACRYNOMS

EM	Electromagnetic
EMF	Electromagnetic fields
EMR	Electromagnetic Radiation
EMI	Electromagnetic Interference
DC	Direct Current
AC	Alternating current
RF	Radiofrequency

1.0 Introduction

As part of stakeholder consultations, and with the intention of informing the EIAR for MetroLink, CEI liaised with the University Departments and groups from within Trinity College who had outlined concerns in relation to potential EMI with their equipment from the proposed MetroLink development.

An equipment list was obtained from Trinity College in which buildings and equipment potentially sensitive to EMI were outlined. Further equipment information was obtained in follow up visits to the Trinity campus in February and March 2019. Below is a non-exhaustive list which omits non-sensitive equipment such as PCs, TVs and other laboratory equipment identified by Trinity as being sensitive to vibrations as opposed to EMI. The focus was on specialised machinery and equipment that the stakeholder identified as potentially sensitive to EMI from an electrified rail underground rail system. Table 1 below contains the equipment list.

Table 1: Trinity College Dublin Equipment List with concerns for EMI

Building	Equipment	Comments
Centre for Research on Adaptive Nanostructures and Nanodevices (CRANN)	1. E-Beam lithography	1. When CEI visited the site it was established that this equipment was de-commissioned an no longer in the building
	2. Multiple Scanning Tunnelling Microscopes	2. See section 2.1
Fitzgerald Building	3. Scanning Tunnelling Microscope (room 0.1)	3. See section 2.2
	4. Scanning Tunnelling Microscope (room 0.2)	4. See section 2.2
	5. Alternating Gradient Field magnetometer (room 1.5)	5. See section 2.2
Sami Nasr Institute of Advanced Materials (SNIAM)	6. Single Nanoparticle Spectroscopy – Dark Field Microscope (-room 1.16)	6. Not considered at risk of EMI from the proposed development
	7. Time resolved single film spectroscopy – FLIM (room -1.26)	7. Not considered at risk of EMI from the proposed development
	8. Superconducting Quantum Interference Device (SQUID) (room 0.16)	8. See section 2.3

Chemistry	9. Three Nuclear Magnetic Resonance (NMR) Machines	9. See section 2.4
Lloyd Institute	*Trinity College Institute of Neuroscience* 10. Computer clusters 11. Two Magnetic Resonance Imaging Systems (MRIs) 12. Transcranial Magnetic Stimulation (TMS) machine 13. Electroencephalogram (EEG) machine 14. Confocal Microscope	10. Not considered at risk of EMI from the proposed development 11. See section 2.5 12. Not considered at risk of EMI from the proposed development 13. Not considered at risk of EMI from the proposed development 14. Not considered at risk of EMI from the proposed development
Panoz (EE4) building	*Irish Centre of research in applied Geosciences (iCRAG)* 15. Three Scanning Electron Microscopes (SEMs)	15. See section 2.6

As illustrated from Table 1 certain equipment, despite being listed in the table has been classified as “not considered at risk from EMI from the proposed development”. Due to the operational nature of these machines there is no doubt sensitivities to EMI of a certain type originating from other sources. However, the type of electromagnetic radiation that will be generated by the proposed development would not be of a magnitude in the applicable frequency ranges to cause issues. For example, it was noted that the Single Nanoparticle Spectroscopy – Dark Field Microscope in the SNIAM building was being operated with the lights switched off in the laboratory to limit its exposure to interference from the ceiling lights.

The type of sensitivities that we are focused on are DC, near DC and 50 Hz and harmonics frequencies. The equipment known to have potential sensitivities within these frequency ranges are discussed in the following sections.

It is worth noting that before obtaining equipment lists from Trinity College, CEI had already visited the campus in November 2018 to perform a baseline survey of the electromagnetic spectrum from DC up to 18 GHz. The results of this survey are detailed in report “*19E7901-1 MetroLink EMR Baseline Survey”*. Notably, these were conducted outside the Zoology Department and in the basement corridor of the SNIAM building.

On 25 Feb 2019 CEI visited Trinity College again to view some of the equipment listed in Table 1 and identify their locations more accurately with respect to the proposed development. On this day CEI visited the CRANN, Fitzgerald and SNIAM buildings. Some additional baseline measurements of DC and near DC magnetic fields were also conducted.

Another visit was conducted on 19 Mar 2019 and where the Chemistry, Lloyd and Panoz buildings were toured, equipment identified, and their locations noted. Again, some baseline measurements were conducted.

The main equipment locations relative to the proposed alignment and magnetic field measurement locations are illustrated in Figure 1.

Table 2 provides an index for this figure.

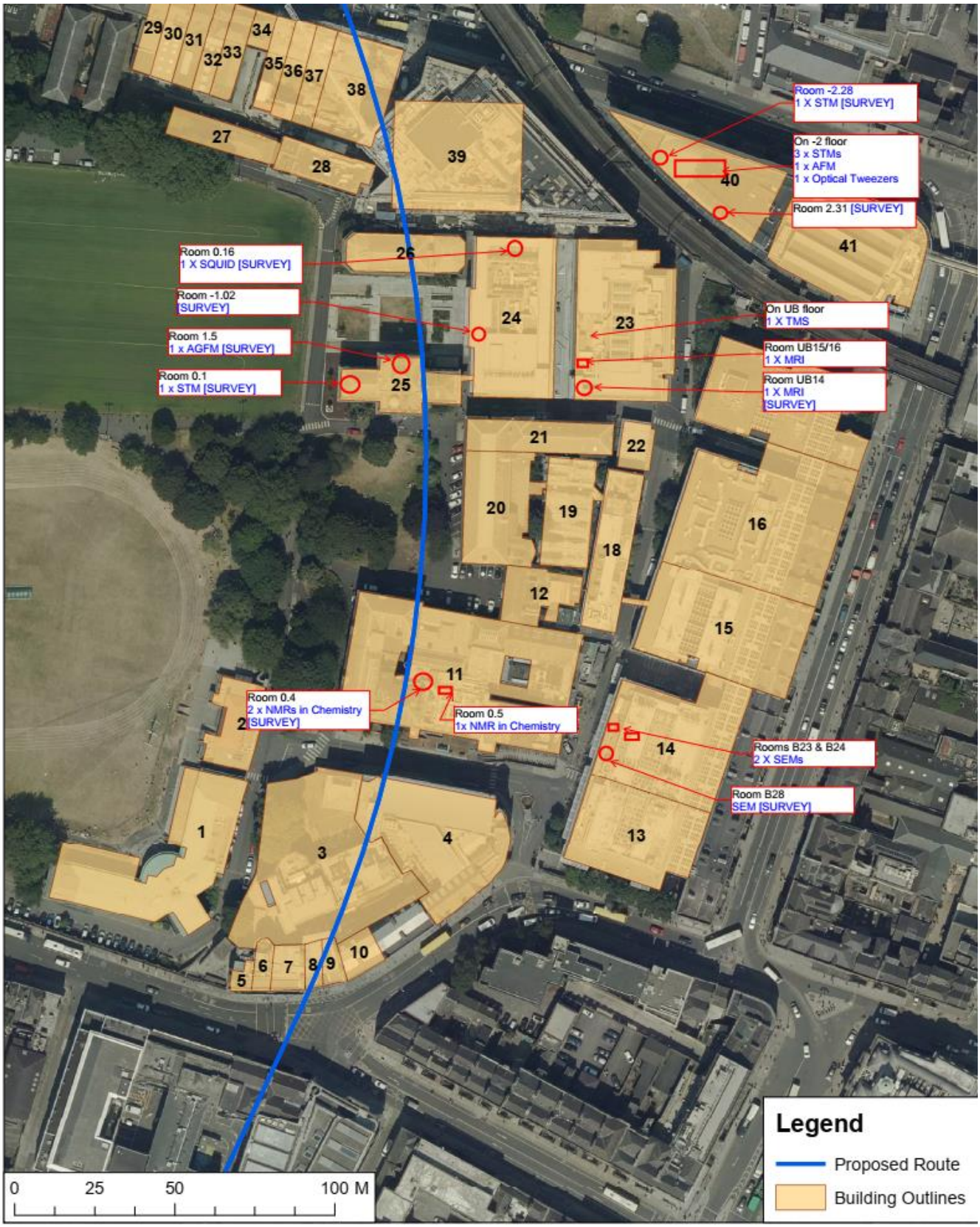

Figure 1: Equipment locations and measurement locations within Trinity College Dublin

Table 2: Trinity College Dublin Building numbers and measurement locations

Index	Building Name	Measurement location
11	Chemistry	• Room 0.4 (middle of room between 600 and 400 NMRs)
14	Panoz (EE4)	• iCRAG Room B28 beside the Tescan S8000
23	Lloyd Institute	• Room UB14 (approx. 8 metres below ground level) in the room adjacent to the 7 Tesla MRI
24	SNIAM	• Room 0.16, beside SQUID machine • Room -1.02
25	Fitzgerald	• Room 0.1, beside an STM • Room 1.5, beside the AGFM
40	CRANN	• Room -2.28 beside an STM • Room 2.31 close to window overlooking the DART. Room contained an XPS machine

Note, the room numbering typically indicated the floor in the first numeral. For example, room -1.02 was 1 floor below ground level while room 0.1 as at ground level.

2.0 Case Studies

2.1 CRANN Building

Equipment listed as a cause for concern were the following within the building:

- Scanning Tunnelling Microscopes
- E-Beam Lithography

CEI visited the following locations within the CRANN building:

- Room -2.28 contained an STM which currently experiences acoustic interference from the nearby DART line
- Room containing an Atomic Force Microscope (AFM)
- Room -2.38 containing an STM
- Room -2.32 containing two STMs
- Room -2.12
- Room 2.31 containing an XPS

Baseline DC and near DC magnetic field measurements were performed in rooms -2.28 and 2.31. These are depicted in the plots below.

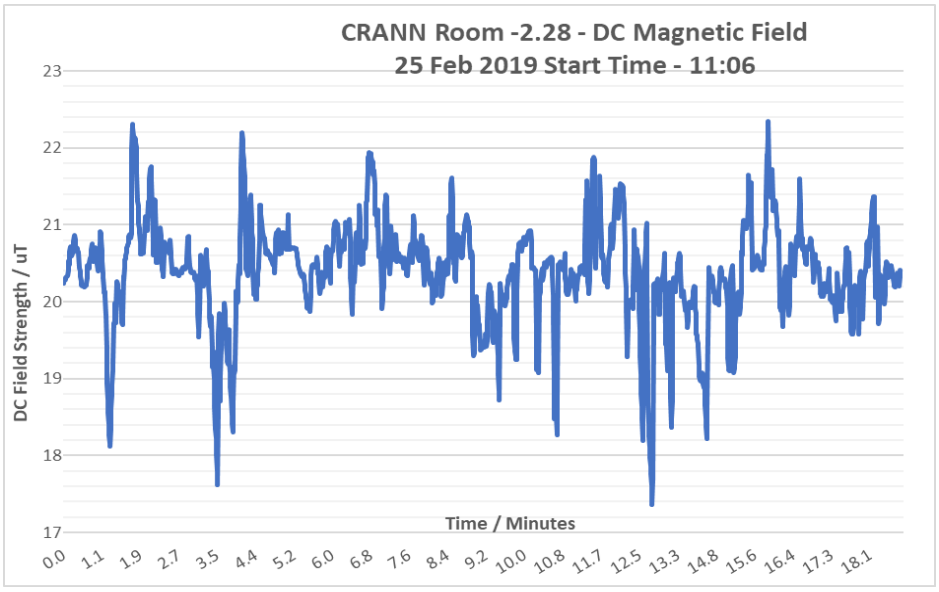

Figure 2: CRANN Room -2.28, DC Magnetic Field

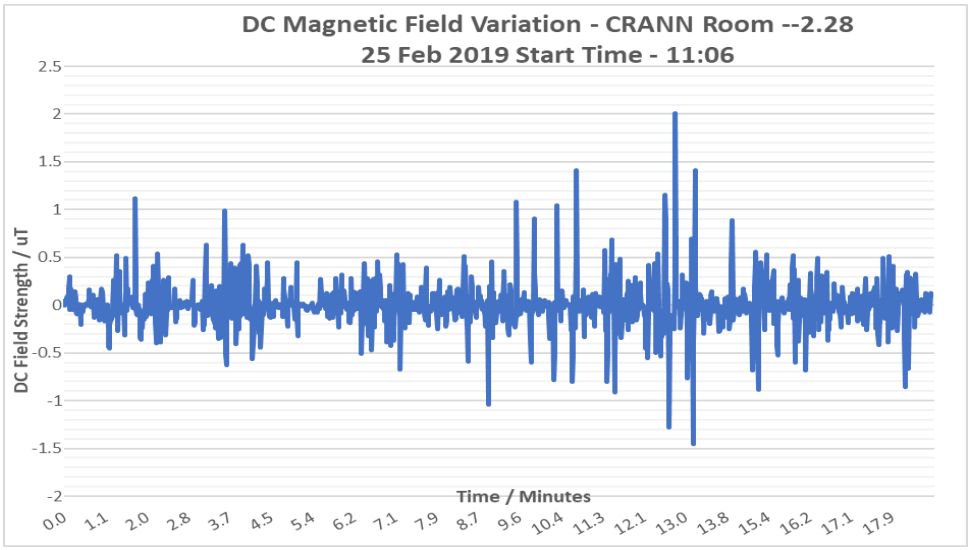

Figure 3: CRANN Room -2.28, DC Magnetic Field variations

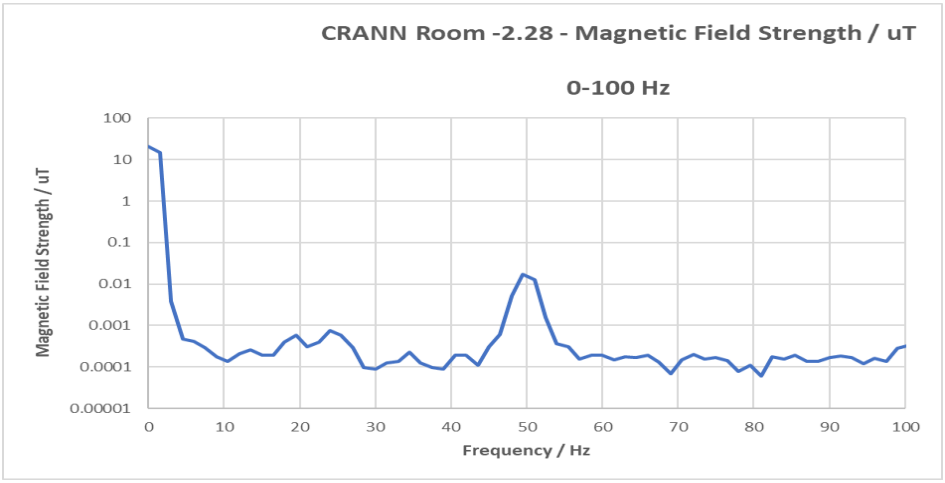

Figure 4: CRANN Room -2.28 A, 0 Hz to 100 Hz (Mag Field)

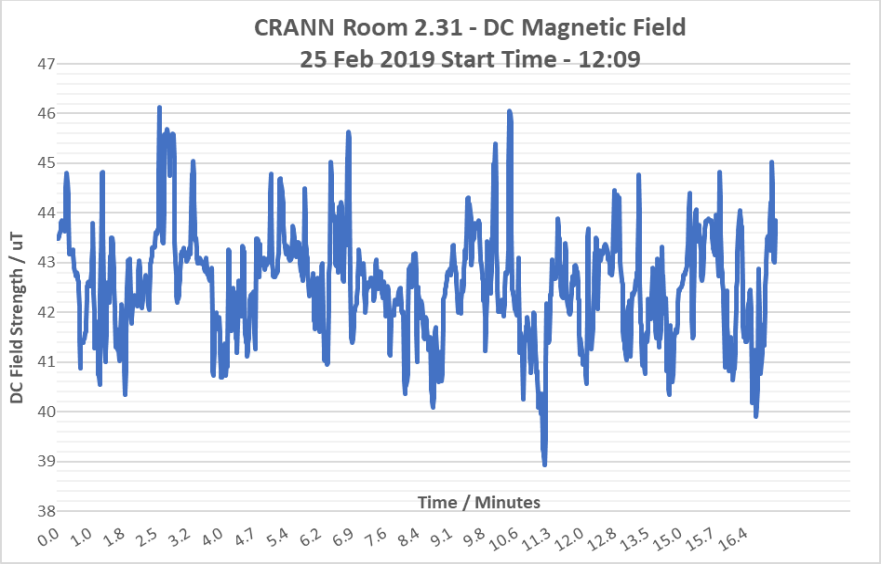

Figure 5: CRANN Room 2.31, DC Magnetic Field

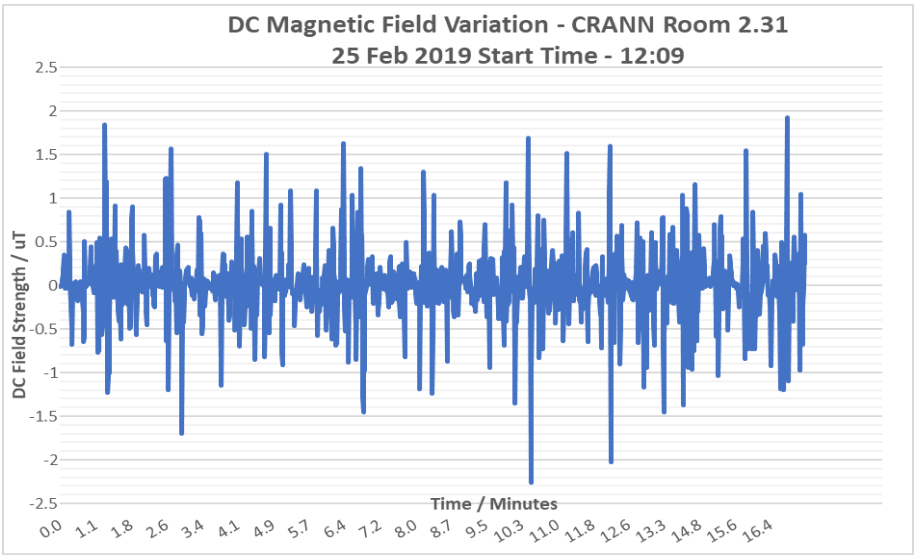

Figure 6: CRANN Room 2.31, DC Magnetic Field variations

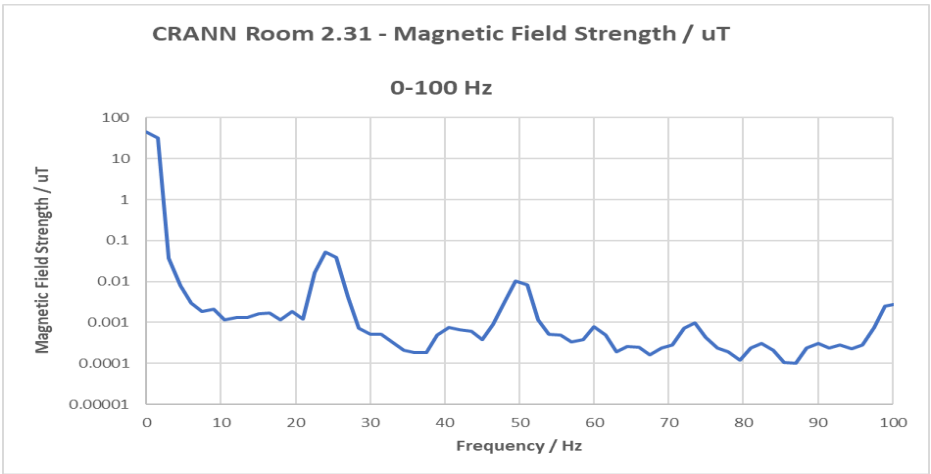

Figure 7: CRANN Room 2.31, 0 Hz to 100 Hz (Mag Field)

In room -2.28 beside the STM an average DC magnetic field of 20.5 uT was noted with a maximum fluctuation of 2 uT occurring during our 20-minute recording interval. The 50 Hz magnetic field 0.017 uT with near DC frequency levels below 0.001

Room 2.31 was on the second floor and a location close to the adjacent DART line was chosen to get an indication of the magnetic field properties of the electrified system. The measurement point was approximately 13 m from the centre line.
An average DC magnetic field of 43 uT was noted with fluctuations approaching 2 uT continually occurring. During our measurement interval 2 trains passed the measurement location indicating that there would have been a current load on the line at the time commensurate with typical operating loads on the lines. The 50 Hz magnetic field was approximately 0.01 uT while an unusual 25 Hz field was noted at a level of 0.05 uT (likely a result of the traction system on the DART). Other near-DC frequency levels were between 0.001 and 0.01 uT.

2.2 Fitzgerald Building

Equipment listed as a cause for concern were the following within the building:

- Scanning Tunnelling Microscope (STM) (room 0.1)
- Scanning Tunnelling Microscope (STM) (room 0.2)
- Alternating Gradient Field magnetometer (AGFM) (room 1.5)

CEI visited the following locations within the CRANN building:

- Room 0.1 containing an STM
- Room 1.5 containing an AGFM

Baseline DC and near DC magnetic field measurements were performed in rooms 0.1 and 1.5. These are depicted in the plots below.

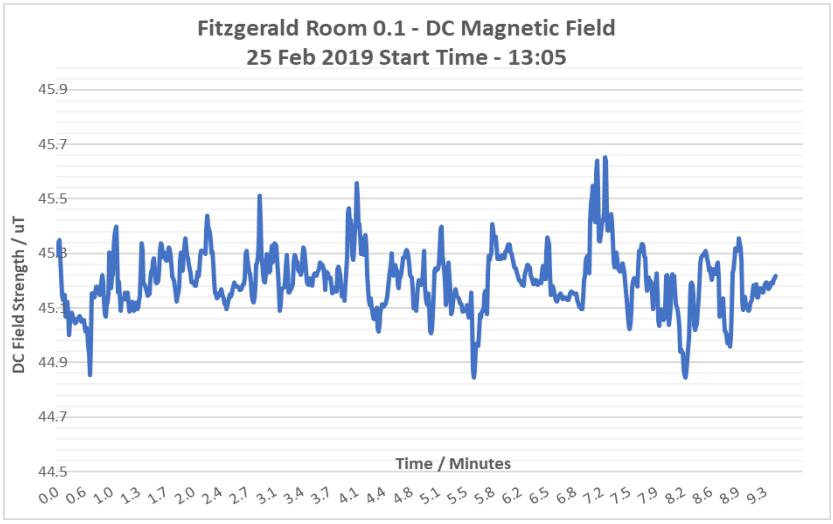

Figure 8: Fitzgerald Room 0.1, DC Magnetic Field

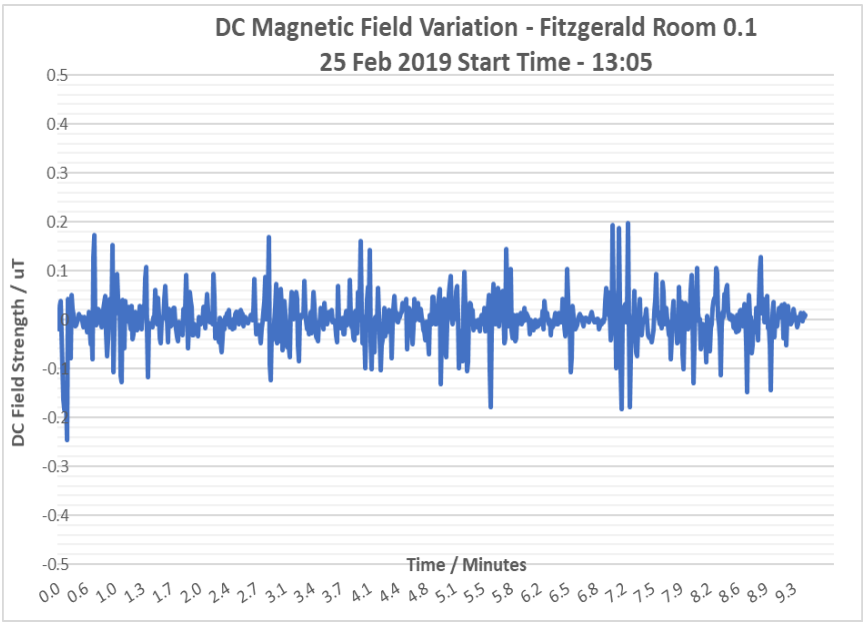

Figure 9: Fitzgerald Room 0.1, DC Magnetic Field variations

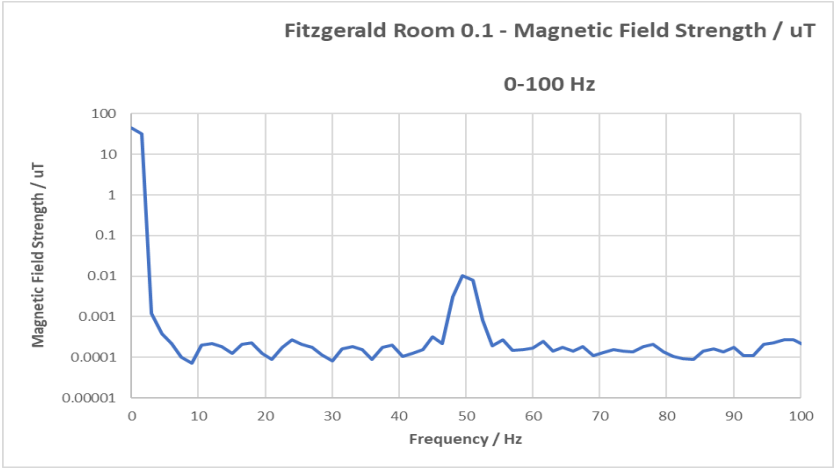

Figure 10: Fitzgerald Room 0.1, 0 Hz to 100 Hz (Mag Field)

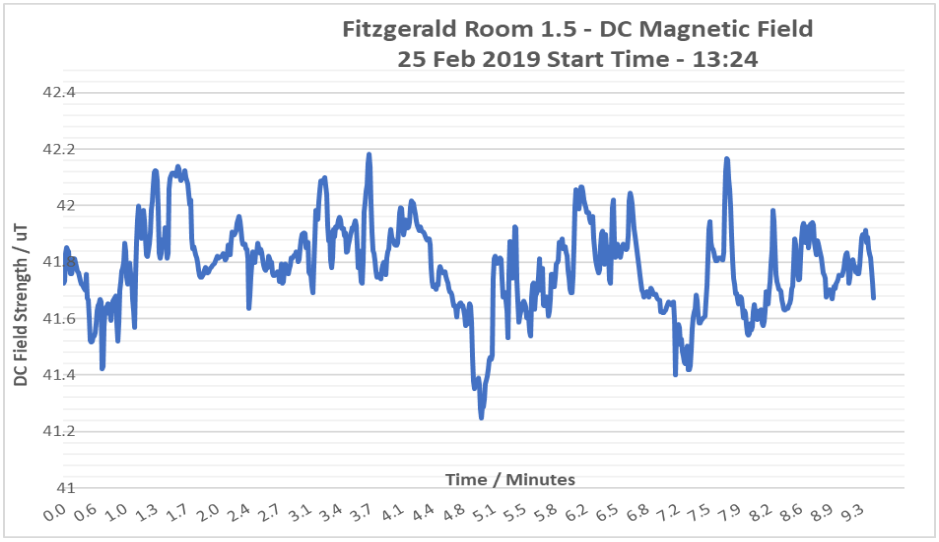

Figure 11: Fitzgerald Room 1.5, DC Magnetic Field

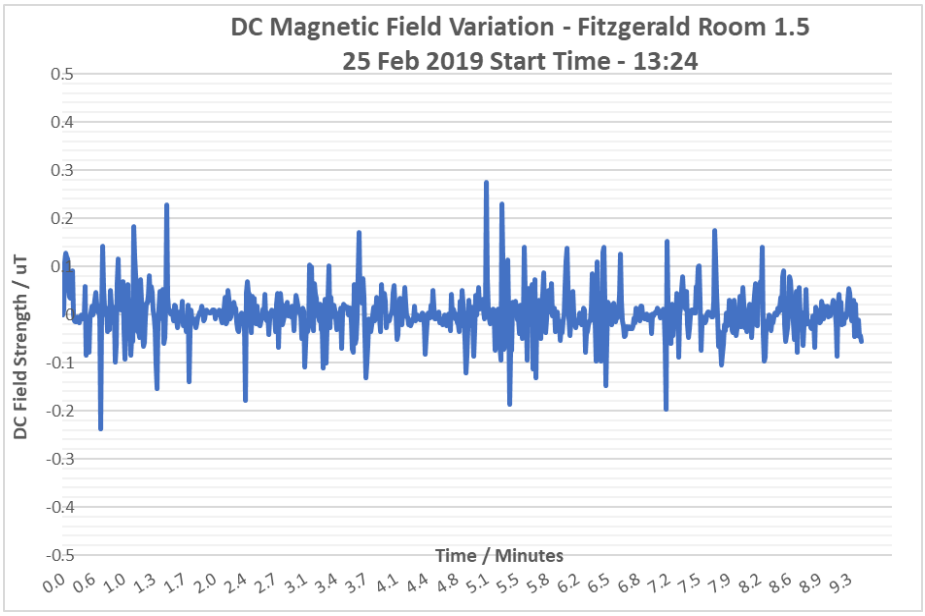

Figure 12: Fitzgerald Room 1.5, DC Magnetic Field variations

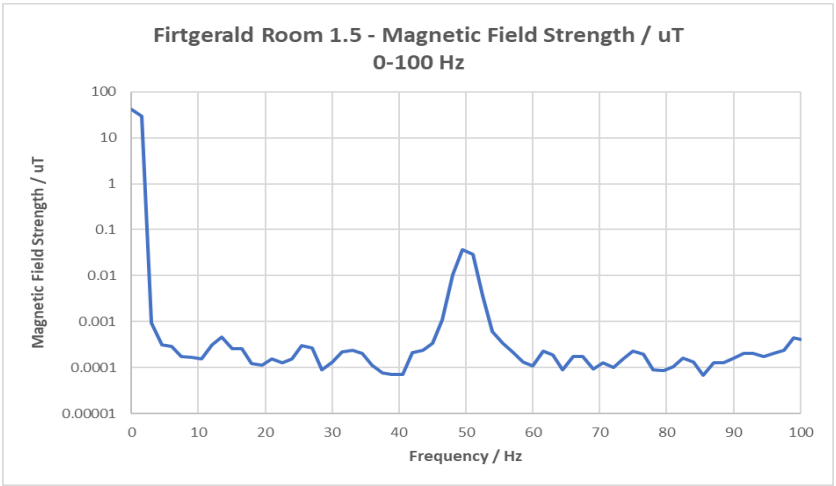

Figure 13: Fitzgerald Room 1.5, 0 Hz to 100 Hz (Mag Field)

In room 0.1 beside the STM an average DC magnetic field of 45.2 uT was noted with maximum fluctuations of only 0.2 uT. he 50 Hz magnetic field 0.01 uT with near DC frequency levels below 0.001. The STMs in this building would not be expected to experience EMI from the proposed development as the nature of the equipment means it is more sensitive to vibration effects.

Room 1.5 was on the first floor with measurements taken beside the AGFM that was installed at this location. Studying the equipment's specification documentation suggests that although it is extremely sensitive to magnetic fields, it would only be Magnetic fields at a certain frequency. It is specifically designed to operate at frequencies not associated with the proposed development i.e. it operates at 83 Hz and should not see an impact from fields and harmonics at DC, 50 Hz, 100 Hz, 150 Hz etc. An average DC magnetic field of approximately 41.8 was measured with typical fluctuations of 0.2 uT – 0.3 uT being experienced. The 50 Hz magnetic field was measured to be 0.017 uT.

2.3 SNIAM Building

Equipment listed as a cause for concern within the building were the following:

- Single Nanoparticle Spectroscopy – Dark Field Microscope (-room 1.16)
- Time resolved single film spectroscopy – FLIM (room -1.26)
- Superconducting Quantum Interference Device (SQUID) (room 0.16)

As discussed in section 1 the Dark Field Microscope and the FLIM were not considered a risk to EMI from the proposed development and did not warrant further investigation.

CEI visited the following locations within the SNIAM building:

- Room -1.02 due to its underground location and being the closest point of the building to the proposed alignment
- Room 0.16 containing the SQUID

Baseline DC and near DC magnetic field measurements were performed in rooms -1.02 and 0.16. These are depicted in the plots below.

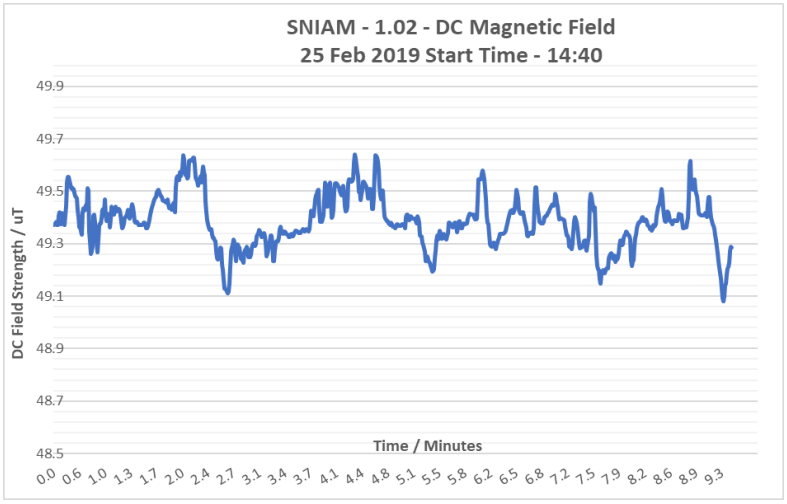

Figure 14: SNIAM Room -1.02, DC Magnetic Field

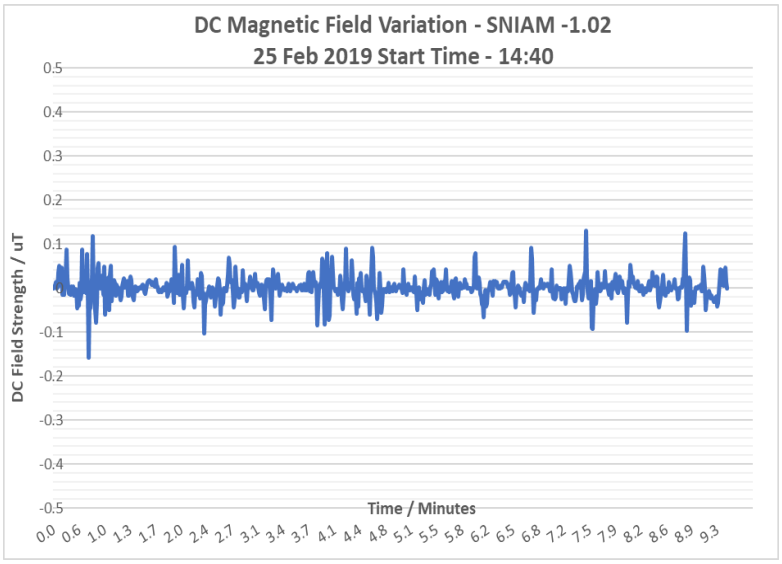

Figure 15: SNIAM Room -1.02, DC Magnetic Field variations

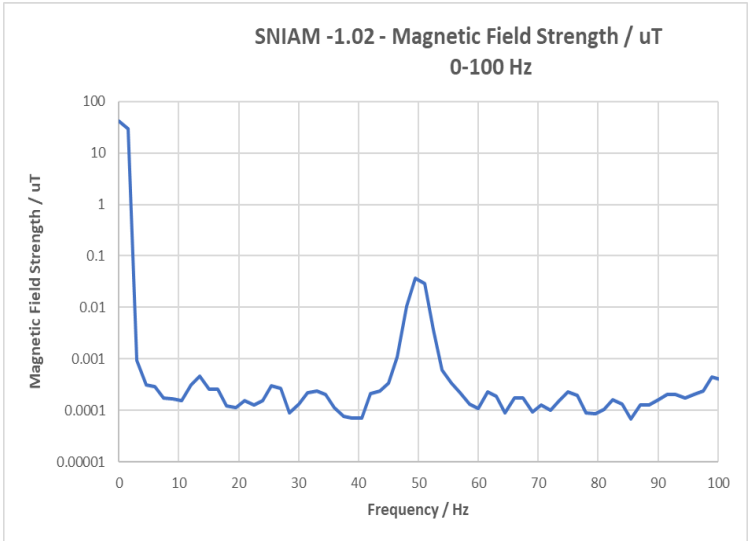

Figure 16: SNIAM Room -1.02, 0 Hz to 100 Hz (Mag Field)

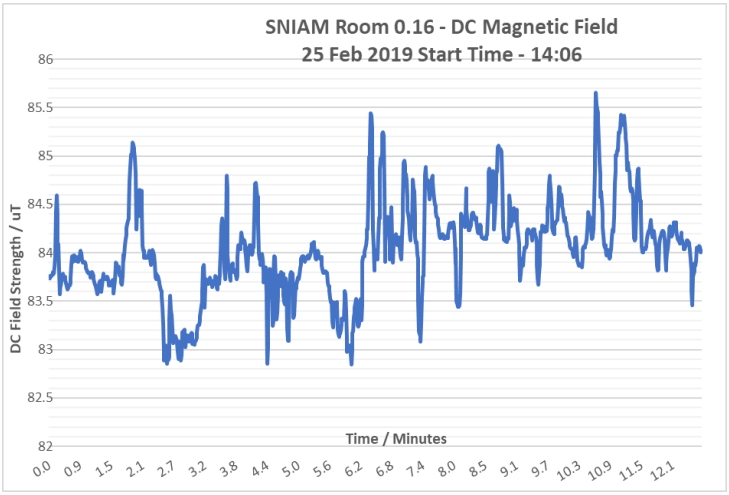

Figure 17: SNIAM Room 0.16, DC Magnetic Field

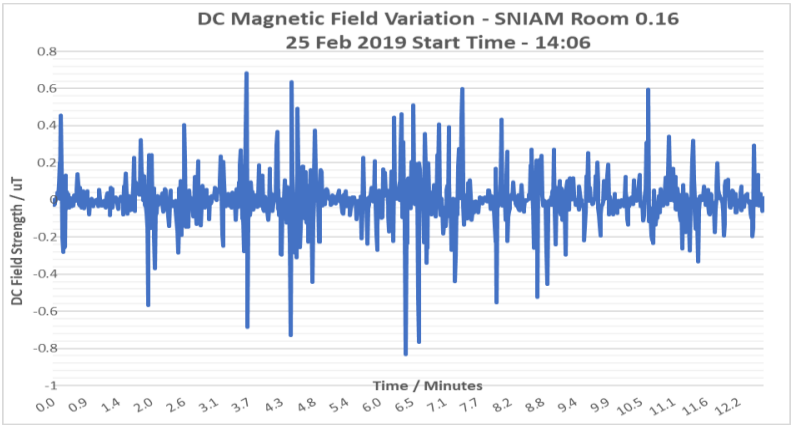

Figure 18: SNIAM Room 0.16, DC Magnetic Field variations

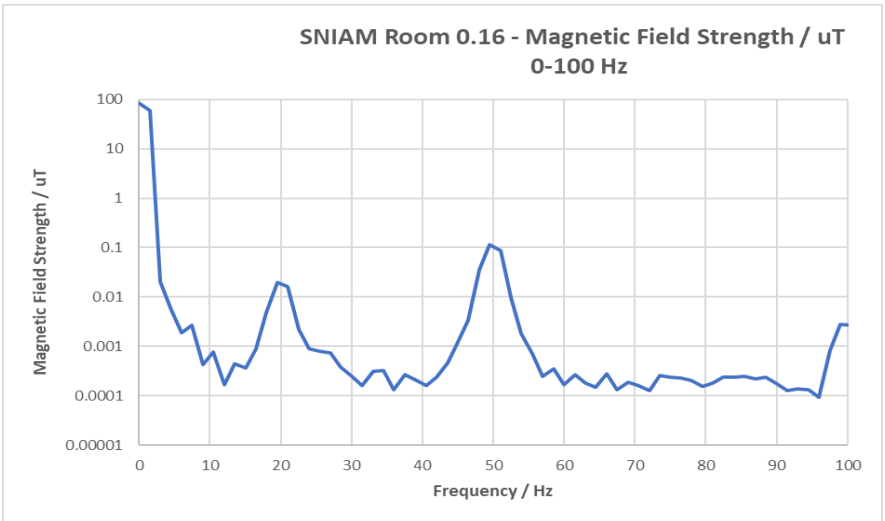

Figure 19: SNIAM Room 0.16, 0 Hz to 100 Hz (Mag Field)

Room -1.02 had a very quiescent DC environment with an average field of 49.4 uT and fluctuations often less than 0.1 uT. The 50 Hz magnetic field was 0.017 uT with near DC fields below 0.001 uT.

In room -0.16 beside the SQUID an average field of 84 uT was observed. This was well in excess of a typical measurement for the earth's magnetic field (approx. 45 uT). The likely cause for the variation was the SQUID itself which contained an electromagnet which although was powered down during our measurements would have contained a residual magnetism. DC Fluctuations of up to 0.7 uT were noted during our measurement interval. The 50 Hz magnetic field was measured at 0.1 uT with a noteworthy peak at 20 Hz also with a magnitude of 0.013 uT the likely source of which was the SQUID.

2.3.1 SNIAM - SQUID and EMI

Reviewing the specifications for the SQUID it was stated to be sensitive to DC magnetic field levels of 10 nT or 0.01 uT. It also had previously experienced interference from the DART which was just under 40 metres away. The interference had subsided however with the construction of the new business school which seemed to have provided sufficient attenuation of the fields emanating from the DART line.

Although the SQUID currently operate in an environment where fluctuations of 0.7 uT were measured, currently modelled levels from the proposed development are estimated to be of a magnitude of 2.75 uT. Therefore, mitigation may need to be employed for this equipment unless it can be proven that DC field fluctuations of this order does not affect the equipment's operation.

2.4 Chemistry Building

Equipment listed as a cause for concern within the building were the following:

- Three Nuclear Magnetic Resonance (NMR) Machines (two in room 0.4 and one in room 0.5)

CEI visited the following location within the Chemistry building:

- Room 0.4 containing two NMRs

Baseline DC and near DC magnetic field measurements were performed in room 0.4 beside two of the NMRs. These are depicted in the plots below.

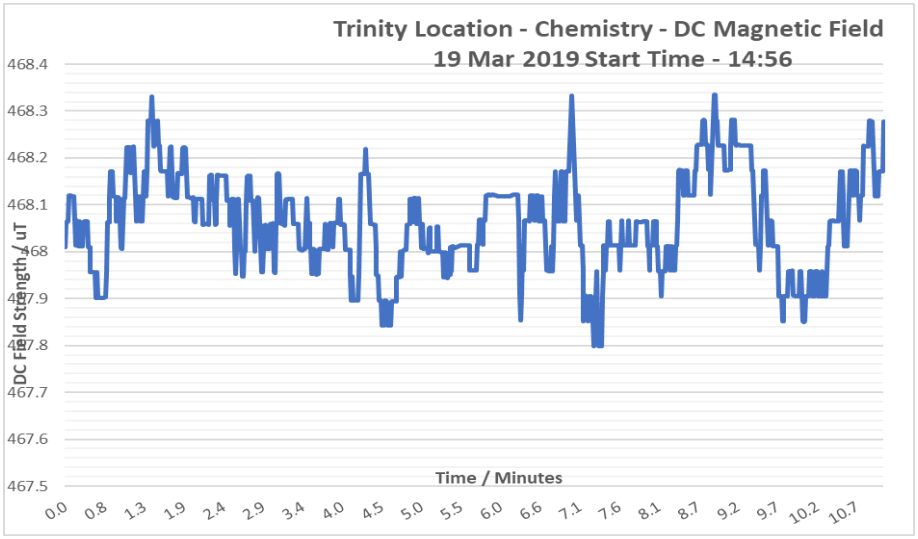

Figure 20: Chemistry Room -0.4, DC Magnetic Field

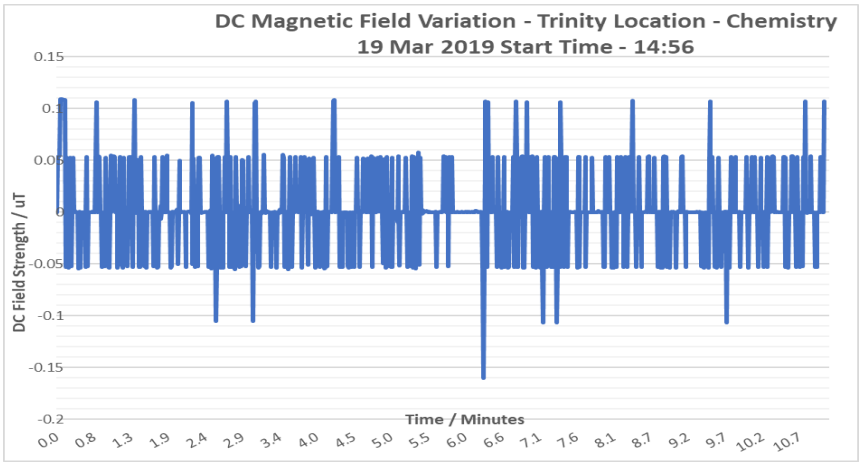

Figure 21: Chemistry Room -0.4, DC Magnetic Field variations

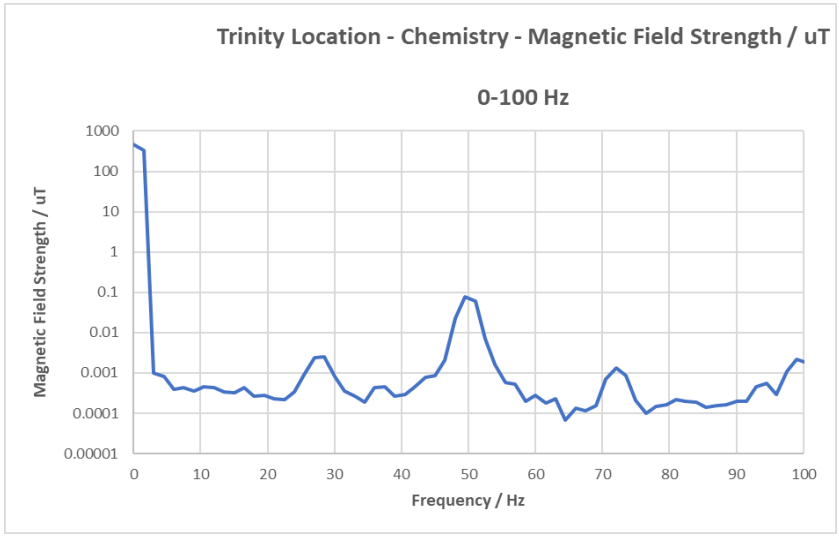

Figure 22: Chemistry Room -0.4, 0 Hz to 100 Hz (Mag Field)

A static DC magnetic field of 468 uT was recorded. This was clearly a result of the electromagnets utilised by both machines. Fluctuations of only 0.1 uT were noted during our

recording interval although the equipment was not in operation at the time. In the frequency domain the 50 Hz magnetic field was measured at 0.1 uT with some atypical peaks at 28 Hz and 72 Hz again likely attributable to the NMRs.

2.4.1 Chemistry - NMRs and EMI

Reviewing the specifications for the NMRs (outlined on the right) it was stated to be sensitive to DC magnetic field levels of 5 mG which equates to 0.5 uT. And, 2 mG (0.2 uT) for AC fields.

The NMRs currently appear to operate in a relatively quiescent DC magnetic field environment with minimal levels of 0.1 uT noted albeit with the equipment not in operation but with their magnetic coils energised. Currently modelled levels from the proposed development are in the range 10 – 14 uT (3 - 9 metres from the proposed alignment). Therefore, mitigation may need to be employed for this equipment unless it can be proven that DC field fluctuations of this order doesn't affect the equipment's operation.

Guidelines: DC Interference ***12.1.3***

When determining the effect of fluctuating magnetic fields, two parameters are important: the size of the fluctuation and the rate of change (gradient).

- **Field changes of between 0-5 mG**, regardless of the gradient, are generally considered harmless for standard NMR work. Likewise with UltraShield magnets (only), field changes up to 10 mG are considered harmless. The effect of such changes would be observable in only the most critical of experiments such as NOE difference experiments.
- For field changes **larger than 5 mG** the lock system will compensate the fluctuation, as long as the gradient is less than 5 mG/sec. (10 mG for UltraShield magnets, 50 mG for UltraShield Plus magnets).
- For field gradients **greater than 5 mG per second** (10 mG for UltraShield magnets, 50 mG for UltraShield Plus magnets), NMR performance may be affected.

Table 12.1. lists the minimum distances between the source of interference and the magnet center.

Table 12.1. Minimum Distances from Electromagnetic Interference Sources.

Source of Interference	Recommended Minimum Distance from UltraShield Magnet	Recommended Minimum Distance from UltraShield PLUS Magnet
DC Trams, subways*	100 m	80 m
Elevators, fork-lifts**	8 m	6 m
Mass spectrometer (slow ramp)	10 m	8 m
Mass spectrometer (sudden fly-back)	30 m	24 m

* **Trams and subways are also a source of vibrational interference** (refer to section ***"Vibrations" on page 61***).
** Depends on the lift geometry and material. These specifications may vary.

2.5 Lloyd Building

Equipment listed as a cause for concern within the building were the following:

- Computer clusters
- 2 Magnetic Resonance Imaging Systems (MRIs)
- Transcranial Magnetic Stimulation (TMS) machine
- Electroencephalogram (EEG) machine
- Confocal Microscope

As discussed in section 1 the computer clusters, TMS, EEG and Confocal microscope were not considered a risk to EMI from the proposed development and did not warrant further investigation.

CEI visited the following location within the Lloyd building:

- Room UB 14/15 adjacent to a 3 Tesla MRI machine

- Room UB 14 adjacent to a 7 Tesla MRI machine
- Rooms containing the TMS and EEG

Baseline DC and near DC magnetic field measurements were performed in room UB 14 which was adjacent to the 7 Tesla MRI machine. These are depicted in the plots below.

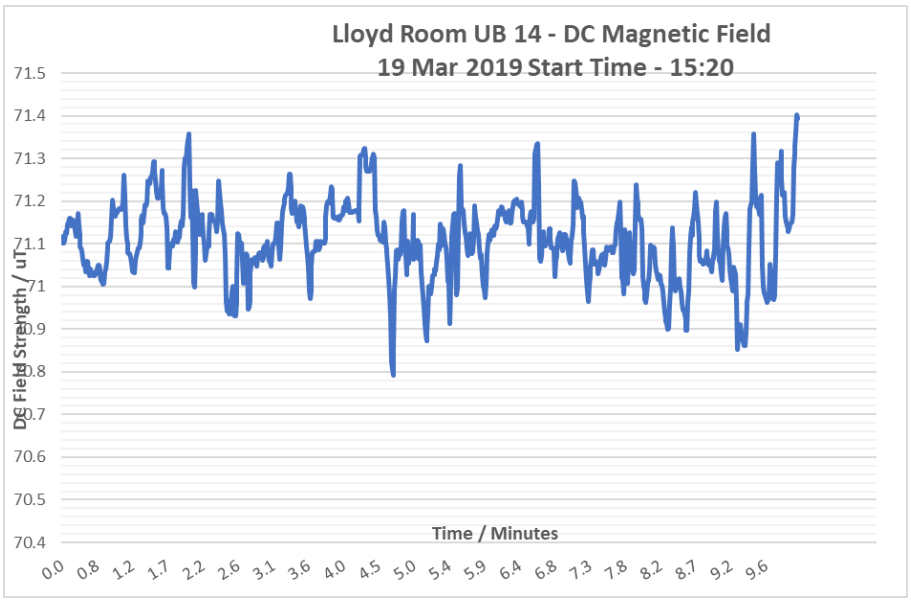

Figure 23: Lloyd Room UB 14, DC Magnetic Field

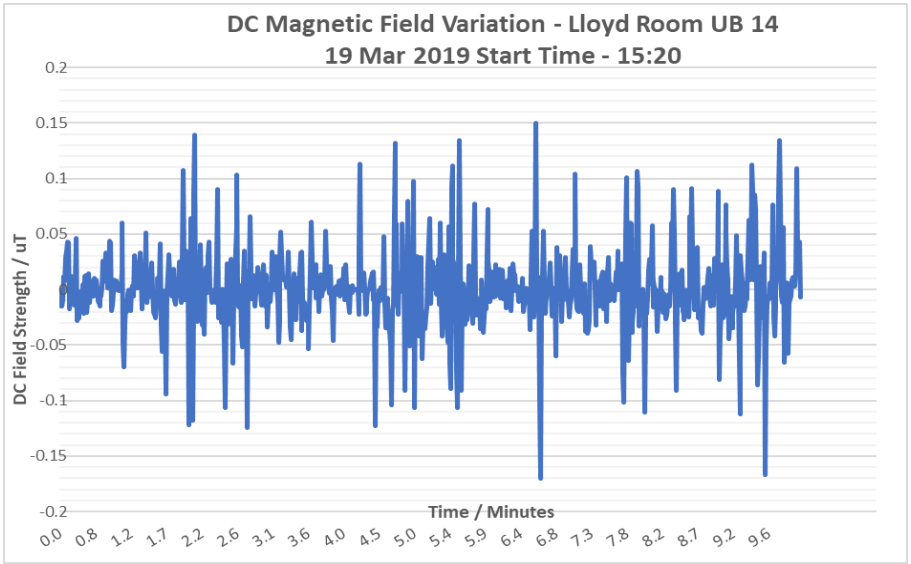

Figure 24: Lloyd Room UB 14, DC Magnetic Field variations

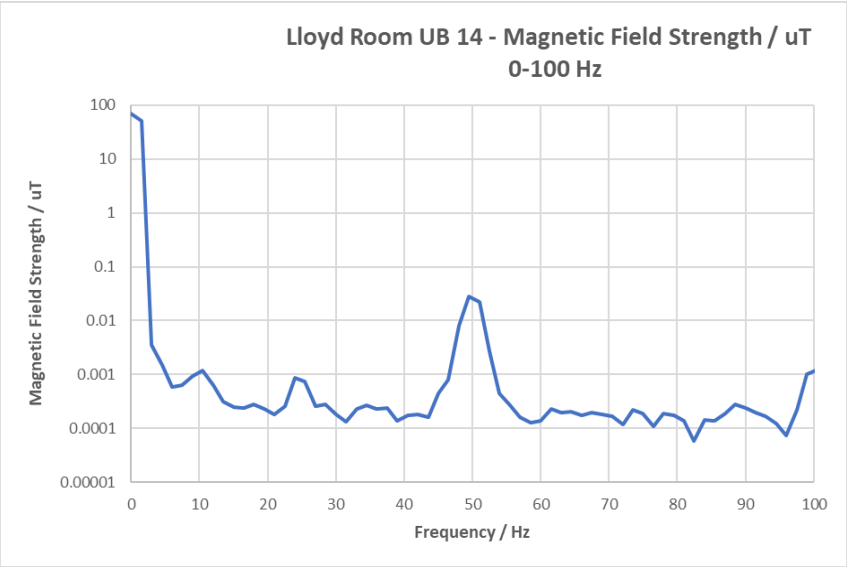

Figure 25: Lloyd Room UB 14, 0 Hz to 100 Hz (Mag Field)

The equipment was not operating during the measurement sequence. A static DC magnetic field of 71.1 uT was recorded with the elevated level likely due to the MRI machine itself. The DC magnetic field environment was relatively quiescent with typical fluctuations of only 0.1 – 0.2 uT. In the frequency domain the 50 Hz magnetic field was measured at 0.015 uT with some peaks noted at 10 Hz and 25 Hz likely attributable to the MRI.

2.5.1 Lloyd - MRIs and EMI

Specifications were not received for the MRI systems however sensitivity to DC magnetic field perturbations of as low as 1 uT can exist for this type of equipment.
The MRIs currently appear to operate in a relatively quiescent DC magnetic field environment with typical levels of 0.1-0.2 uT noted albeit with the equipment not in operation.

Currently modelled levels from the proposed development are in the range 52 m horizontally 9 m vertically due to the floor being at -8 m are approximately 1.3 uT. Therefore, mitigation may need to be employed for this equipment unless it can be proven that DC field fluctuations of this order doesn't affect the equipment's operation.

2.6 Panoz Building

Equipment listed as a cause for concern within the building were the following:

- Three Scanning Electron Microscopes (SEMs)

CEI visited the following location within the Panoz building:

- Room B-23 containing an SEM (model: Zeiss Supra 35VP)
- Room B-24 containing an SEM (model: Tescan Mira3 Tiger
- Room B-28 containing an SEM (model: Tescan S8000)

Baseline DC and near DC magnetic field measurements were performed in room B-28 beside the Tescan S8000 SEM. These are depicted in the plots below.

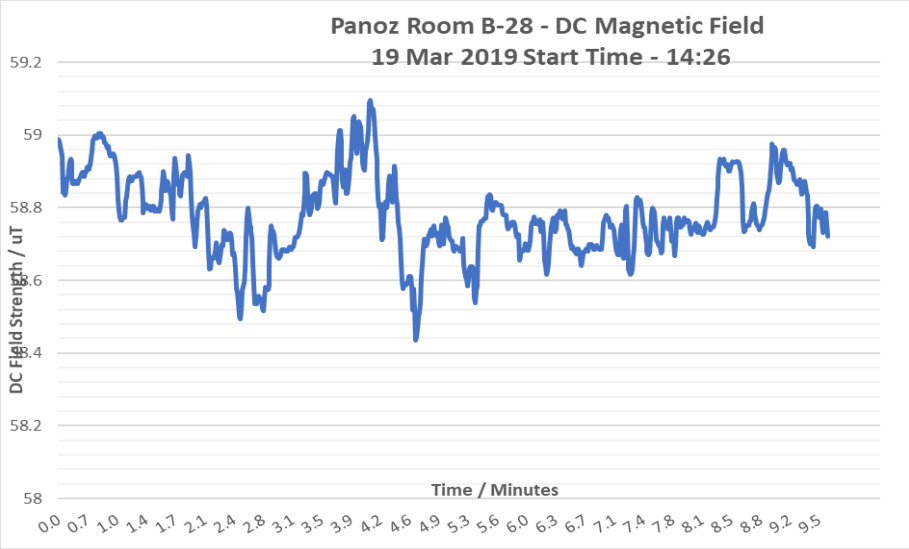

Figure 26: Panoz Room B-28, DC Magnetic Field

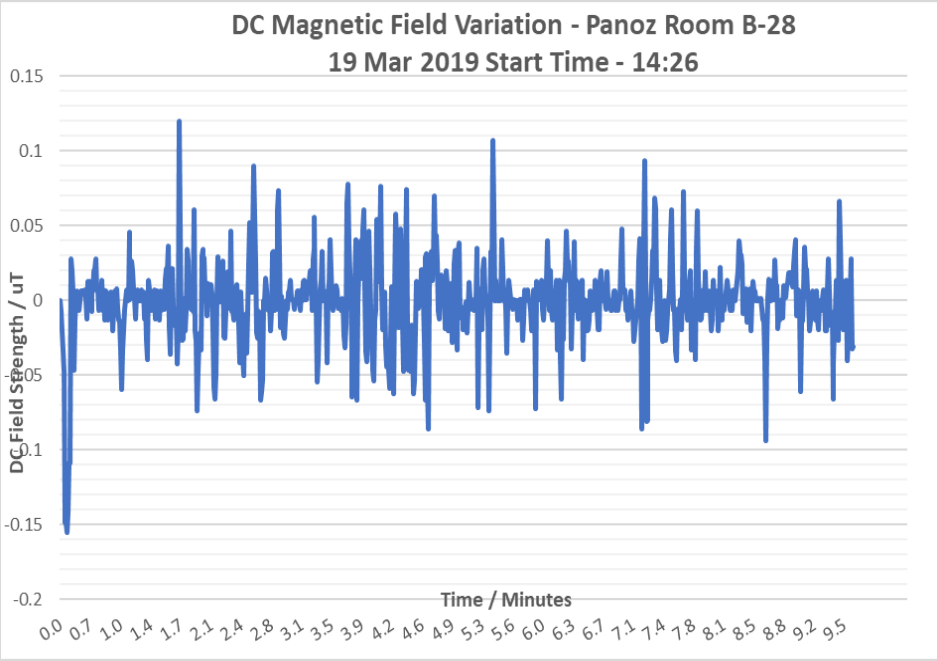

Figure 27: Panoz Room B-28, DC Magnetic Field variations

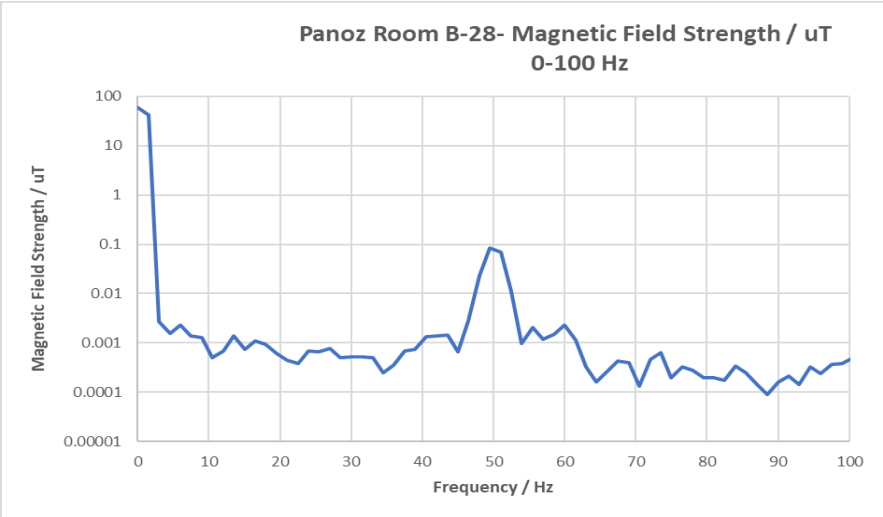

Figure 28: Panoz Room B-28, 0 Hz to 100 Hz (Mag Field)

In room B-28 beside the Tescan S8000 SEM a static DC magnetic field of 58.8 uT was recorded. DC magnetic field fluctuations of only 0.1 to 0.15 uT were seen to occur during the measurement interval indicating that the DC magnetic environment was relatively quiescent. The 50 Hz AC field was noted to be 0.1 uT.

2.6.1 Panoz - SEMs and EMI

The environmental specification for the TESCAN Mira3 SEM which was received from Trinity College stated the following:

> 3) The magnetic field: to obtain the specified microscope performance, the magnetic field in the room must not exceed values below while the microscope is in operation:
> Synchronous magnetic field: $<3 \times 10^{-7}$ T
> Asynchronous magnetic field: $<1 \times 10^{-7}$ T

That equates to a magnetic field susceptibility of 0.1 uT which is on the limit of the current environment within which it is operating. A similar sensitivity would be expected for the other SEMs with the iCRAG department. This does not distinguish between DC and AC fields, so this single limit is applied to both.

Currently modelled levels from the proposed development are in the range 63 m horizontally 12 vertically from the running rails (due to the floor being at -4 m) are approximately 0.8 uT. Therefore, mitigation may need to be employed for this equipment unless it can be proven that DC field fluctuations of this order doesn't affect the equipment's operation.

3.0 Summary

The main equipment of note from section 2.3.1, 2.3.2, 2.3.3 and 2.3.4 were the following.

Table 3: Trinity College Dublin – Equipment sensitive to DC and near DC fields

Building Name	Equipment	Current DC Field fluctuations	Sensitivity	Modelled levels
SNIAM	SQUID machine	± 0.7 uT	0.01 uT	2.75 uT
Chemistry	Three NMRs	± 0.1 uT	0.5 uT (DC) 0.2 uT (AC)	10-14 uT (DC) 0.14-0.2 uT (AC)
Lloyd Institute	Two MRI Systems	± 0.2 uT	1 uT*	1.5 uT
Panoz (EE4)	Three SEMs	± 0.15 uT	0.1 uT	0.8 uT

* Estimated since data has not been received to date

4.0 Conclusions

As can be seen in Table 3 the modelled DC levels for the listed equipment exceeds their stated sensitivities for each.

Modelled AC field levels are at least a factor of 70 lower than the DC field levels and so will not pose a problem for any of the equipment which are already installed and operating in AC magnetic field environments of approximately 0.1 uT currently.

With regards to determining the validity of the stated sensitivity levels for DC magnetic fields for the listed equipment the recommended course of action would be to simulate and apply the modelled levels to each of the machines while they are in use and performing typical scanning functions. If it is determined that the modelled levels will in fact cause an issue, then mitigation measures will need to be employed.