

EMFCOMP-02-C-2023-2

**EMC Pre-Energisation Assessment for:
Secondary Substation, Great Ancoats Street, Manchester**

2 February 2023

Contract Report

EMFcomp Limited
www.emfcomp.com

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Domis Construction
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EMC Pre-Energisation Assessment: Secondary Substation, Great Ancoats Street, Manchester

Executive Summary

EMFcomp Limited was commissioned to carry out an electromagnetic compatibility (EMC)/ interference (EMI) safety assessment of areas within a new development adjacent to Great Ancoats Street in Manchester. The primary objective of this study was to assess potential electromagnetic interference sources to rail infrastructure and equipment from a secondary substation, intended to be installed. A source of low frequency magnetic fields within the proposed development would be produced by on site substations and associated conductors, when operated. There was a concern related to interference from electromagnetic fields (EMFs) produced by the secondary substation to the Transport for Greater Manchester (TFGM) tramline. The equipment is to be installed close to this tram line. To address this concern, an EMI assessment of fields produced by the equipment is carried out. By comparing field levels to UK guidance and standards on EMI including limits presented in EN 55024, EN 61000-6-1, IEC 61000-6-4:2018, EN 50121 and associated standards, a view can be formed on whether these EMF emissions are potentially hazardous. EMFcomp carried out pre-energisation measurements at the development site on 2 February 2023.

EMFcomp Limited has measured the low frequency (5 Hz to 400 kHz) magnetic fields across the site, to determine the current locations of maximum field strengths. We have measured low frequency electric fields on the site. We have also carried out broadband and narrowband high frequency (30 MHz to 10 GHz) measurements to determine the locations of maximum radiofrequency field strengths. The field levels for the pre-existing electromagnetic environment within the development, where the substation was due to be installed, were found to be relatively low. The maximum low frequency field was measured as 0.264 μT , and the maximum measured radiofrequency field was 0.0022 W m^{-2} . Utilising equipment immunity EMC interference standards such as IEC 61000-6-4:2018 and BS EN 50121, both the low frequency and high frequency fields measured were below some of the most conservative limits presented in these. Hence, we can conclude that the pre-existing electromagnetic environment does not present a risk of interference to electrical or electronic equipment - and this situation is unlikely to change significantly post-energisation, so no mitigation measures are necessary. Similarly, the low and high frequency electromagnetic field strengths measured on site were below the Reference Levels in the Council Recommendation 1999/519/EC document. This contains some of the UK's most restrictive human exposure guidance. Therefore, the pre-existing low frequency field environment does not present an interference hazard with electrical equipment or exposure hazard to equipment and people either within the secondary substation installation area or within the adjacent TFGM tramline region.

Calculations have indicated that it is not expected that fields from the secondary substation, once installed and operating, will add to the measured field environment in such a way as to exceed any of the EMC/EMI/ EMF limits (EN 55024, EN 61000-6-1, IEC 61000-6-4:2018, BS EN 50121 and associated standards) discussed outside of the substation enclosure.

A post energisation EMC assessment of the substation equipment surveyed will be carried out, once this equipment has been installed and is operational. If field levels are found to be non-compliant with the electromagnetic field limits and guidance set out in this report, the equipment will be de-energised until mitigation measures have been agreed and installed.

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1 Introduction

1.1 Background

The primary objective of this electromagnetic compatibility (EMC) study was to assess potential electromagnetic interference (EMI) sources to rail infrastructure and equipment from a secondary substation. This equipment is to be installed close to a tram line boundary as part of Domis Construction's Great Ancoats Street development.

There was a concern related to interference from electromagnetic fields (EMFs) produced by the secondary substation to the Transport for Greater Manchester (TFGM)/ Metrolink tramline. The equipment is to be installed relatively close to this tram line. To address this concern, an EMI assessment of fields produced by the equipment is to be carried out. By comparing field levels to UK guidance and standards on EMI, a view can be formed on whether these EMF emissions are potentially hazardous.

There are no unshielded electrical conductors associated with the secondary substation equipment, therefore there are no significant sources of low frequency electric fields or radiofrequency present. Hence, the main focus of this assessment was low frequency magnetic fields produced by power frequency electrical equipment and associated cabling.

1.2 EMC/EMI Guidance and Standards

1.2.1 EMC/EMI and Electrical Equipment

(i) Background to EMC, the EMC Directive & EMC Regulations

Electromagnetic fields can present interference hazards to electrical equipment. Electromagnetic compatibility is the engineering discipline that deals with ensuring that electrical and electronic equipment:

- does not emit such high levels of electromagnetic disturbances that they cause too much electromagnetic interference (EMI) to other equipment.
- functions well enough despite the electromagnetic field disturbances in its environment.

The European Union (EU) has a Directive on EMC, 2014/30/EU, which has been transposed into the legislation in the UK, the EMC Regulations 2016. However, of course the financial and safety risks associated with inadequate EMC can be more important than complying with any Directive. This is true for all EMC issues - the techniques that are required to make them work in real-life are not described in EMC Directive or the UK's associated 2016 EMC Regulations. The documents describe what techniques are required, but they do not describe how to do them. The situation is made more difficult by the fact that many of the practical EMC engineering techniques that are now required, are not yet commonly used in electrical installations, and there tend to be no tradition of EMC engineering amongst some trades.

The EMC Directive 2014/30/EU applies to equipment that is placed on the market or put into service. Apparatus is not within the scope of this project, so its requirements are not described here. Fixed installations are defined as 'apparatus intended for use in a specified fixed installation and not otherwise commercially available to an end user as a single commercial item'. All fixed installations in the must

comply fully with the EMC Directive 2014/30/EU in the European Union and the subsequent UK's EMC Regulations 2016.

There exists equipment ('inherently benign equipment') that is incapable of emitting any significant electromagnetic field disturbances, and incapable of being interfered with by the normal field disturbances in its environment. As such, it is excluded from the scope of the EMC regulations, whether it is an apparatus or a fixed installation.

The EC EMC Guide states what is currently considered to be inherently benign. This includes:

- Cables and cabling, cables accessories, considered separately.
- Equipment containing only resistive loads without any automatic switching device; e.g., simple domestic heaters with no controls, thermostat, or fan.
- Batteries and accumulators (without active electronic circuits).
- Headphones, loudspeakers without amplification.
- Pocket lamps without active electronic circuits.
- Protection equipment which only produces transitory disturbances of short duration during the clearing of a short-circuit fault.
- High voltage types of equipment in which possible sources of disturbances are due only to localised insulation stresses which may be the result of the ageing process and are under the control of other technical measures included in non-EMC product standards, and which do not include active electronic components.
- Capacitors (e.g., power factor correction capacitors).
- Induction motors.
- Quartz watches (without additional functions, e.g., radio receivers).
- Filament lamps (bulbs).
- Home and building switches which do not contain any active electronic components.
- Passive antennas used for TV and radio broadcast reception.
- Plugs, sockets, terminal blocks, etc.

(ii) EMC in Practice

Electromagnetic field disturbances are EMF phenomena that exist to a sufficient level to cause electromagnetic interference. Whether an EMF phenomenon could cause an EMI incident depends on the susceptibility of the equipment concerned for that phenomenon. The problems faced by electrical installations within complex environments such as clinical settings can be outlined by considering the frequencies used and noise emitted by electrical and electronic equipment, shown in Figures 1.1 and 1.2. EMC considerations are required because:

- Modern electronics - especially digital, switch-mode, and wireless - employ a wide band of frequencies from audio up to at least 100 MHz, maybe even up to several GHz (thousands of MHz). For them to operate correctly and to achieve EMC it may be necessary to control some or all their frequency range by using EMC techniques in cabling and assemblies, and in the cabinets that house them.

- Conductors can have significant impedance at frequencies above a few 10s of kHz, caused by skin effect (which increases their resistance) and inductance. The result is that wires cannot be used to provide an effective circuit reference voltage at frequencies above a few hundred kHz (usually much less), and so cannot provide any EMI control at RF.
- Conductors - such as metal work, wires, and cables - can make good 'accidental antennas', and so can leak a proportion of the power and/or signals they carry into their external environment. Cables can be shielded to reduce their antenna efficiency, but it is never 100% effective and if done incorrectly (e.g., cable shield bonded at only one end) it can have no benefits at RF.

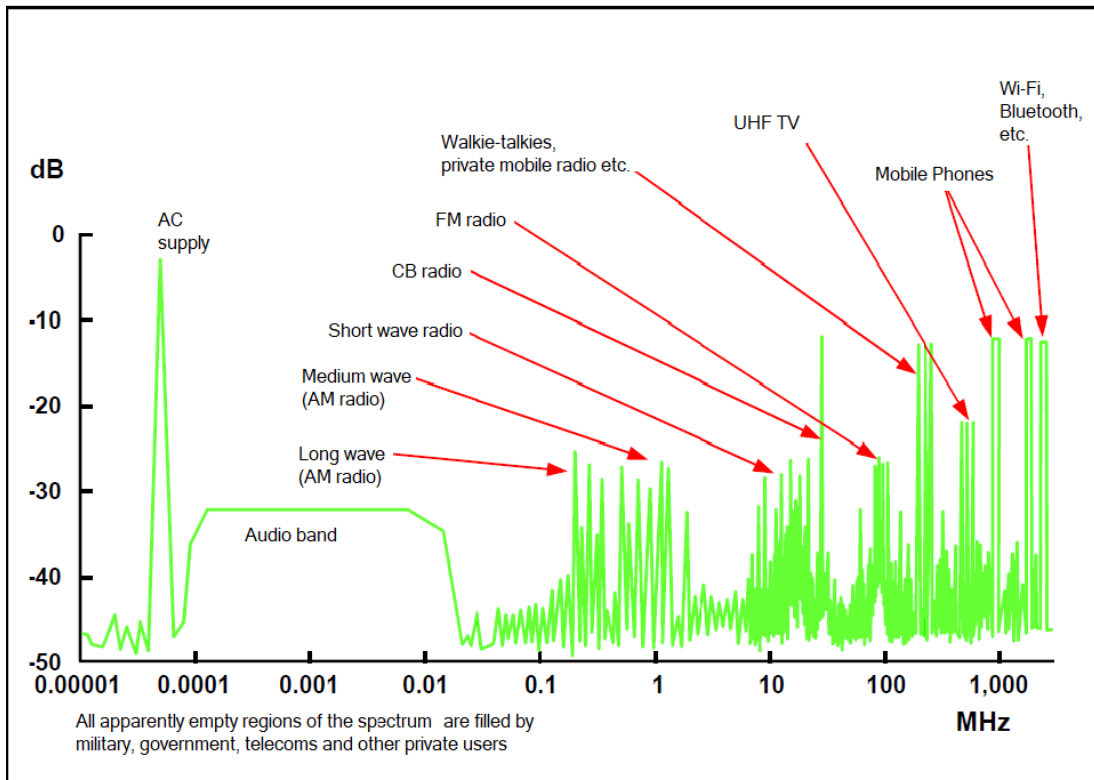


Figure 1.1 The electromagnetic field frequencies we use.

Low frequency magnetic fields from power distribution systems and cabling can interfere with a variety of electrical and electronic devices, equipment, and systems. Therefore, electronic products are generally tested to ensure that they work correctly in their intended operating environment.

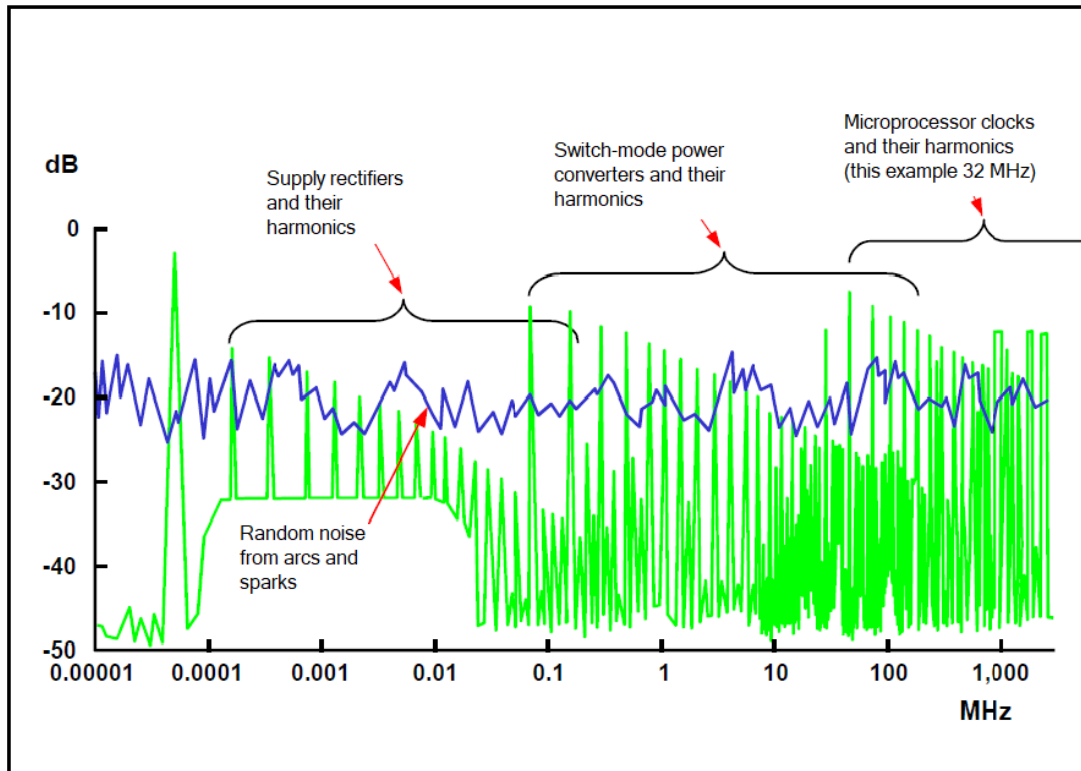


Figure 1.2 The electromagnetic field noise emitted by electrical and electronic devices.

Electronic products in the UK are often assessed against the IEC 61000-4-8 power-frequency magnetic field immunity test method (IEC 2009) for low frequency emissions. This has been adopted as the harmonised European standard EN 61000-4-8, which is called up as a basic test method by immunity standards listed under the Electromagnetic Compatibility (EMC) Directive (EC 2014).

The EMC Directive's generic and product-family immunity standards that call up EN 61000-4-8 apply to a product group that includes magnetically sensitive components, such as cathode-ray tubes (CRTs - large, non-flat screen computer monitors or TVs), electron-multiplier tubes, moving-coil microphones, microphone transformers, hall-effect sensors and so on.

Where problems occur, magnetic field shielding is an option, but using ordinary materials can be impractical. 'Mu-metal' and other exotic/expensive high-permeability metals can be used to achieve better shielding of power-frequency magnetic fields, however due to its high cost it is rarely used in non-specialist shielding applications.

Where magnetic susceptibility may be a problem, products are often tested using EN/IEC 61000-4-8 at a test level of 30 A m^{-1} or $37.6 \text{ } \mu\text{T}$ (microtesla).

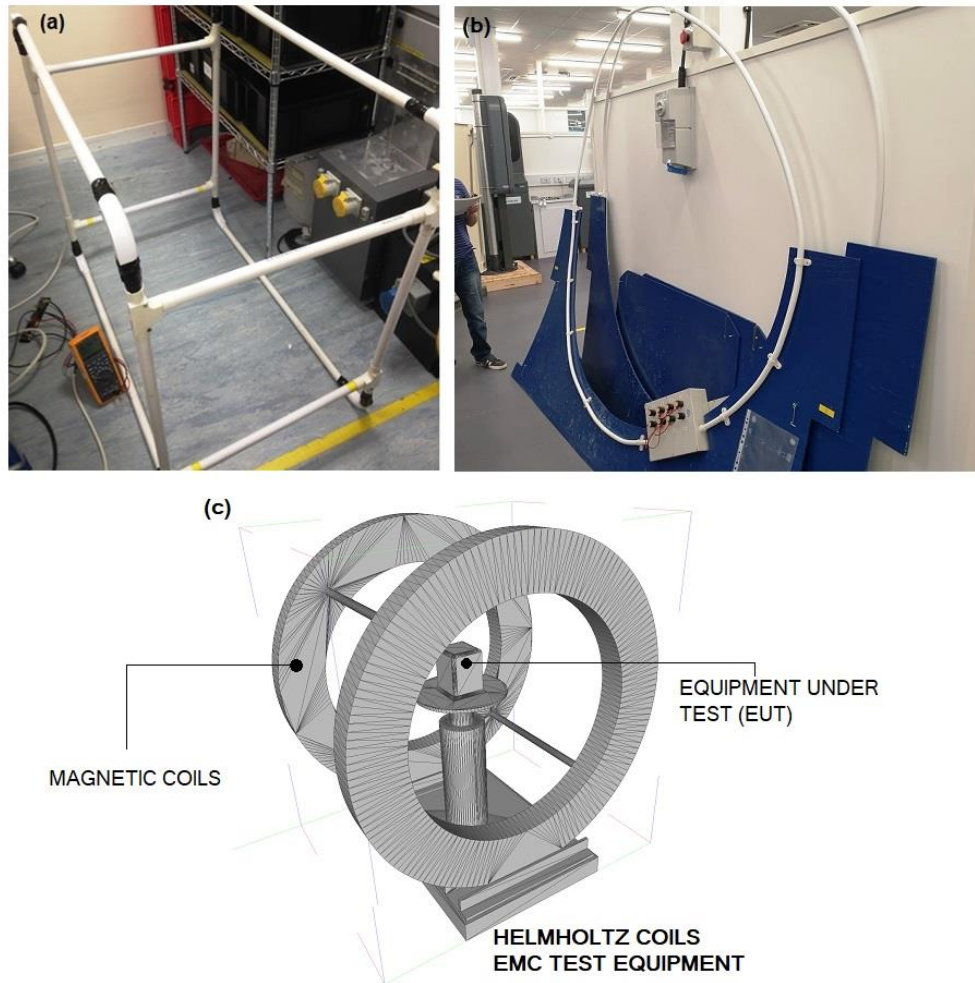


Figure 1.3 (a) An example of a magnetic immunity test rig (b) more substantial coils are required for larger equipment such as trackside cabinets etc. (c) Traditional test setup showing Helmholtz coils and equipment under test (EUT).

The test method immerses the equipment under test (EUT) in a power frequency field created by induction coils. Example test rigs are shown in Figure 1.3. Typically, Helmholtz coils are used, utilising two induction coils spaced apart to create a uniform magnetic field over a volume.

It is recommended in guidance by Members of the IEE's Working Group on EMC and Functional Safety that all products using analogue signals (and maybe some digital products) should be tested using EN/IEC 61000-4-8:2009 in an environment where the magnetic flux density is above $37.6 \mu\text{T}$ (30 A m^{-1}) - as there is a possibility of interference.

Experimental studies have shown that magnetic field levels in excess of approximately $2 \mu\text{T}$ can cause interference with CRT based VDUs. Although rarely used now in professional environments, it is important to consider legacy or other electrical equipment that may still employ these devices.

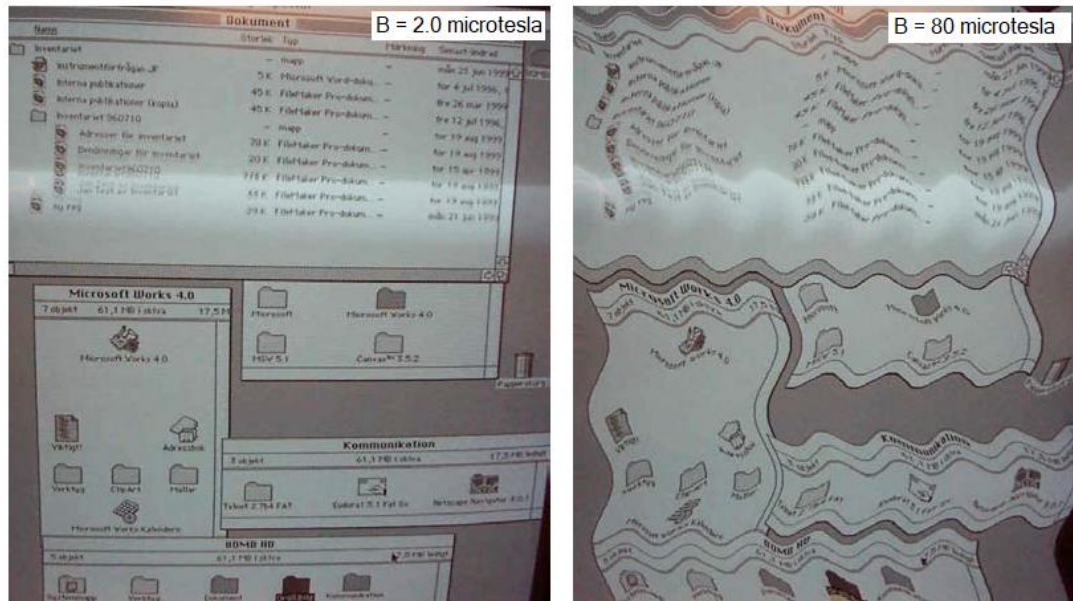


Figure 1.4 Typical distortion of a CRT VDU at magnetic flux densities of (a) 2.0 μT and (b) 80 μT .

The interference manifests itself in the form of a distorted screen (for example, see Figure 1.4). In summary, for the environment for which this report is concerned and addressed by, amongst other guidance, the generic EMC emissions, and immunity test standards in the series IEC/EN 61000-6-1 to 61000-6-4, or similar test standards, most EMC problems can be solved by:

- Taking care to only utilise electrical/electronic equipment that have proven good EMC performance when tested to those standards or tougher ones.
- Obtaining and fully applying their supplier's EMC instructions in design and construction.
- Taking account of the build-up of emissions caused by having multiple units.

It is still advisable to employ good EMC practices wherever suppliers provide EMC instructions, to help resolve conflicts between different units' EMC instructions. However, most normal electromagnetic field environments are worse than the ones described by the generic or similar test standards, because those standards specifically do not cover the situation where portable radio transmitters are used nearby - which is now commonplace in all environments.

The standards also ignore several other EMF environmental situations that can easily occur, such as the proximity of Group 2 ISM equipment, or electrosurgery units. So, in almost all real-life situations, and especially in certain industrial, medical, scientific, or military sites where the EMF environment is more extreme than usual, the use of good EMC engineering practices can be very important for preventing costly problems due to EMI,

1.2.2 EMC/EMI and Workers

Electromagnetic fields can also present health hazards to railway workers. The Control of Electromagnetic Fields at Work (CEMFAW) Regulations were introduced by the HSE in the UK in 2016 to protect workers from EMF exposure. CEMFAW was a result of the transposition of the EMF Directive 2013/35/EU (EU 2013), produced by the European Commission, into UK law. The Treaty of Rome (now the Treaty on the Functioning of the European Union) set an objective to encourage improvements in the working environment regarding the health and safety of workers. To help achieve this objective it allows for the introduction of Directives to set minimum requirements. In 1989 the Framework Directive 89/391/EEC was introduced as an overarching Directive in this area. The Framework Directive sets out general requirements for assessing and reducing risks, emergency preparedness, worker information, participation and training, worker obligations, and health surveillance. It also provides for the introduction of individual Directives, which essentially give additional detail on how to achieve the objectives of the Framework Directive in specific situations. The EMF Directive was the twentieth such individual directive.

The CEMFAW Regulations are intended to help employers achieve compliance with their legal obligations for the specific situation of work that involves exposure to EMFs. The main emphasis of the CEMFAW Regulations is to assess risks arising from electromagnetic fields in the workplace and then, if necessary, put in place measures to reduce them. The Regulations seek to introduce minimum requirements for health and safety in relation to work with equipment that produces EMFs.

Table 1.1 Recognised Adverse Health Effects of Electromagnetic Fields.

Field & Frequency Range	Effects	Examples of Activities
Low Frequency Fields (50-300 Hz)	Health effects: Nerve stimulation, effects on the central & peripheral nervous system of the body. Tingling, muscle contraction, heart arrhythmia.	High voltage power lines; production and distribution of electricity, induction heating, electric welding and melting, industrial electrolysis, industrial magnetisers/demagnetisers, any high sources of current/voltage.
	Sensory effects: Nausea, vertigo, metallic taste in the mouth.	
	Indirect effects: Interference with active or passive implanted or body worn medical devices, electric shocks.	

The first step to creating a safer workplace is to assess the risks that are present. It is important to note that it is not sufficient to simply demonstrate compliance with the limits in the CEMFAW Regulations as this may not be sufficient to adequately protect workers and patients 'at particular risk' or avoid safety risks from indirect effects.

When assessing risks from EMF within a facility, it is necessary to understand the nature of the fields that are present. Hence, the legislation also requires employers to identify and assess EMF in the workplace. However, it allows employers to take account of information provided by others and only requires them to assess fields themselves where it is not possible to demonstrate compliance by any other means.

Where risks have been identified, then appropriate information and training should be provided. However, it is recognised that many workers may be unfamiliar with the nature of the hazards associated with EMF, possible symptoms, or concepts such as EMF limits and so these should be specifically covered in any

training. Employees should also be given information about the results of assessments for their specific workplace. It is important that risks are put in perspective. Workers should be aware that many of the sources of electromagnetic fields in the workplace do not present a risk to their health or safety. Indeed many, such as communication devices, may contribute to their welfare or make their work much easier.

The Council Recommendation 1999/519/EC (EC 1999) is a non-binding document that sets out a system of Basic Restrictions (BRs - conceptually equivalent to the CEMFAW Exposure Limit Values (ELVs)) and Reference Levels (RLs - conceptually equivalent to the CEMFAW Action Levels (ALs)). The recommendation sets out guidance to protect people with implanted medical devices and members of the public from established adverse health effects resulting from exposure to EMFs.

The Council Recommendation BRs and RLs are more restrictive than CEMFAW ELVs and ALs. The Council Recommendation system of protection for EMF exposure has been adopted in the UK as a framework for protection of workers at particular risk and the general public.

The RLs specified in the Council Recommendation are used as a basis for managing exposures in publicly accessible areas. Additionally, the RLs have been used to inform the development of standards for the electromagnetic immunity of active implanted medical devices. These are discussed in the following sections.

The practical EMF guide (EC 2015) and published HSE guidance (HSE 2016b) recommend that the Council Recommendation (EC 1999) Reference Levels, based on the ICNIRP public Reference Levels in their 1998 guidance (ICNIRP 1998), are used for 'workers at particular risk'. Factors categorising a worker at particular risk are shown in Table 1.2 and described in more detail in the following sections.

The Council Recommendation Reference Levels are, amongst other things, intended to prevent electromagnetic interference with a pacemaker, defibrillator or similar, hence avoiding undesired behaviour of the implanted device, such as resetting and pacing inhibition. At 50 Hz, the Council Recommendation Reference Levels are 100 μT and 5 kV m^{-1} for magnetic and electric fields respectively.

Table 1.2 Examples of 'workers at particular risk', also applicable to the public, contractors etc.

Workers at particular risk	Examples
Workers wearing active implanted medical devices (AIMD)	Cardiac pacemakers, cardiac defibrillators, cochlear implants, brainstem implants, inner ear prostheses, neurostimulators, retinal encoders, implanted drug infusion pumps
Workers wearing passive implanted medical devices (PIMDs)	Artificial joints, pins, plates, screws, surgical clips, aneurism clips, stents, heart valve prostheses, annuloplasty rings, metallic contraceptive implants, penile implants
Workers wearing body-worn medical devices	Insulin pumps, hormone infusion pumps, continuous glucose monitoring systems, metallised drug-delivery patches
Pregnant workers	-

(i) Active Implanted Medical Devices (AIMDs)

Active Implanted Medical Devices or AIMDs, such as those detailed in Table 1.2, are considered to be immune to interference at field levels below the general public/Council Recommendation Reference Levels. Manufacturing standards for electronic devices state they should be unaffected at these field levels.

For electromagnetic fields above these levels, it should be assumed that interference is possible - although the susceptibility of particular devices is often significantly higher and can be assessed on a case-by-case basis.

(ii) Passive Implanted Medical Devices (PIMDs)

Passive Implanted Medical Devices (PIMDs), such as those listed in Table 1.2, are considered not to be a risk for LF fields at levels below the general public Reference Levels. They have been identified as potentially presenting problems above Reference Levels, mainly because they can experience heating from exposure to high frequency fields.

However, there are no known biological mechanisms or compelling reports of any health and safety issues arising in practice from passive devices at power frequency fields. Therefore, EMFcomp advise that there is no significant risk to passive devices from power frequency fields and any general control measure would be disproportionate to the risk presented. That said, the option to investigate particular employee specific exposure situations on a case-by-case basis should be retained.

(iii) Expectant Mothers

Workers who inform their employer that they are pregnant should be given the option of complying with the public exposure limits (equivalent to the Council Recommendation Reference Levels) for the duration of their pregnancy. The EMF Directive 2013/35/EU, on which the UK legislation is based, encourages employers to take account of expectant mothers in risk assessments, however it does not give specific requirements.

The 2011 draft of the EMF Directive stated that 'The employer shall enable the worker to avoid having to enter areas where exposures exceeding the exposure limits for the general public given in the Council Recommendation 1999/519/EC, or its subsequent revisions'. However, this was removed from the final 2013 document.

The HSE Guidance to the Regulations (HSE 2016b) states 'As working with certain levels of EMFs could result in a greater risk to an expectant mother, you should encourage your workers to advise you in writing if they become pregnant. An organisation may wish to take a practical approach and limit the exposure to the public exposure limits. These are stated in Council Recommendation 1999/519/EC.'

EMFcomp Limited would recommend that, as a matter of precaution and reassurance, expectant mothers should be allowed to be restricted to the Council Recommendation Reference Levels. However, it is important to note that this is a precautionary measure and there is no clear evidence of any actual risk up

to the standard worker CEMFAW Action Levels. Additionally, note that EMF exposure could occur before the female worker knows that she is pregnant or chooses to notify her employer.

1.2.3 CEMFAW Action Levels and Council Recommendation Reference Levels

As previously described, for workers not at particular risk, the CEMFAW Action Levels apply. For workers at particular risk (workers with active medical devices such as pacemakers, pregnant workers etc.), the more restrictive Council Recommendations 1999/519/EC (EC 1999) Reference Levels (RLs) are applicable instead of CEMFAW Action Levels.

Table 1.3 - CEMFAW Action Levels and EC Reference Levels at 50 Hz for Magnetic Fields.

Body Region	Magnetic Flux Density (microtesla (μT))	
	CEMFAW Occupational Action Levels (ALs)	Council Recommendation Public Reference Levels (RLs)
Low Action Level (Head)	1000	100
High Action Level (Trunk)	6000	100
Limb Action Level (Limbs)	18000	100

The CEMFAW Action Levels and Council Recommendation Reference Levels for measured magnetic fields at 50 Hz (power frequency) are shown in Table 1.3. Action Levels and Reference Levels for electric fields at 50 Hz are shown in Table 1.4. If field values are below these values, known adverse health effects will be avoided. If the field levels are above these values, further work is required to ensure safety.

For magnetic field ALs across the low frequency range, please see Figure 1.5. This demonstrates the difference in levels for the head, trunk, and limbs, as there are different adverse health effects for these body regions. Note that the region of interest for this work, approximately 50 Hz to 300 Hz, is shaded in yellow.

Table 1.4 - CEMFAW Action Levels and EC Reference Levels at 50 Hz for Electric Fields.

	Electric Field (kV m^{-1})	
	CEMFAW Occupational Action Level (AL)	Council Recommendation Public Reference Level (RL)
Low Action Level (Head)	10	5
High Action Level (Rest of body)	20	5

Occasionally in this assessment, measurement values using handheld magnetic field measurement probes from previous EMF surveys are quoted. These measurement probes use a technique to assess the multiple frequency components waveforms commonly produced by power applications known as the 'weighted peak method', as mentioned in the Control of EMF at Work Regulations 2016 and associated documents.

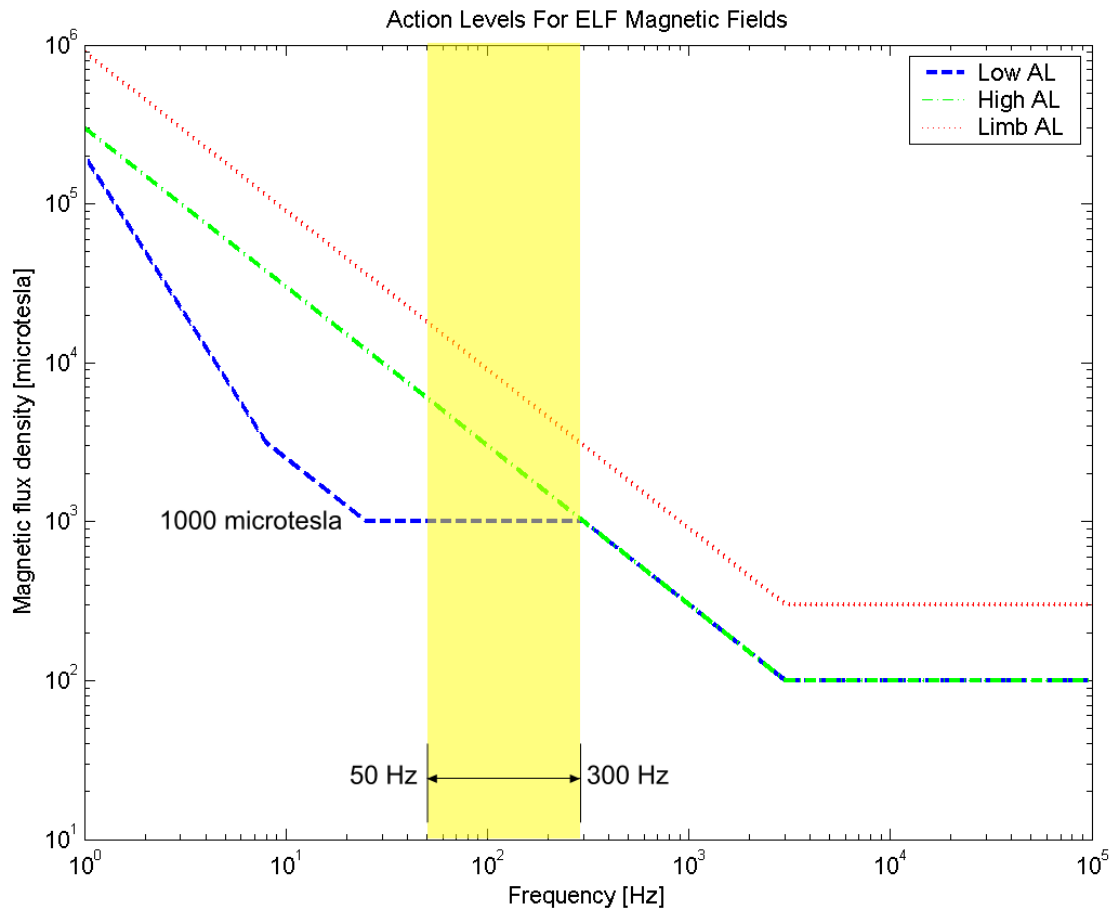


Figure 1.5 The Control of EMF at Work Regulations 2016 Action Levels for low frequency magnetic fields. Highlighted in yellow is the frequency range of interest for the assessments carried out in this assessment. Note that x and y axes are log scales.

The collected magnetic field waveform is processed through a filter that has an instantaneous amplifying response, equivalent to the frequency dependent limits. When a waveform passes through this filter, it is scaled to an output value, corresponding to a percentage of the relevant Action Level (or Reference Level).

Therefore, for some field values given in this report, the values are given as percentages of the Action Levels (or Reference Levels for 'at risk' workers) rather than field values in Tesla. Any value under 100% is in compliance with the Action Level (or Reference Level). Any number above 100% is not in compliance with the Action Level (or Reference Level).

1.2.4 BS EN 50121-4:2016 Railway applications - EMC

The standards related to EMC/EMI in a railway environment have adopted the $37.6 \mu\text{T}$ (30 A m^{-1}) field level for power frequency magnetic field immunity, notably in BS EN 50121-4:2016 Railway applications. Electromagnetic compatibility. Emission and immunity of the signalling and telecommunications apparatus (BS 2016).

The rail sector has also recommended limits on radiofrequency fields, as rail telecommunications and signalling systems can be susceptible to high frequency fields. The radiated immunity limits are 10 V m^{-1} (80-1000 MHz), 20 V m^{-1} (800-1000 MHz), 20 V m^{-1} (1.4 - 2.1 GHz) and 5 V m^{-1} (2.1 - 2.5 GHz).

1.3 Workplan

Measurement of magnetic flux densities (known as B, unit of measure - tesla or microtesla (μT) and commonly called 'magnetic fields'), electric fields and power densities were performed for relevant areas around the intended secondary substation installation site on the Great Ancoats Street development. EMFcomp's Dr Richard Findlay carried out this EMI assessment.

A measurement approach using calibrated measurement probes was used to assess the field region around the installation site. The magnetic flux density, electric field and power density was determined in areas around the intended area for phase conductors and associated equipment.

1.4 Report Structure

The methods for the measurements are outlined in Section 2. The results of the electromagnetic field assessment are described in Section 3. Section 4 presents a discussion of the results obtained. Conclusions are presented in Section 5 and references are listed in Section 6.

2 Methods

The equipment used by EMFcomp for the field measurements presented in this report were:

- Narda NBM-550 (serial no. G-0214, calibrated 11/19). A broadband meter used with relevant probes in order to make measurements of high frequency fields.
- Narda ED-5091 (S/N 01134), calibrated 03/22). An E-field shaped ICNIRP isotropic probe for use with the NBM-550.
- Narda RadMan 2XT (serial no. C-0109, calibrated 03/21). A three-axis high frequency, power density measurement device.
- Narda ELT-400 (serial no. C-0023, calibrated 03/22). A three-axis low frequency magnetic field meter. Used for EC Council Recommendation Reference Level measurements, applicable to 'at risk' workers. For the measurements carried out in this report, the frequency range used was 30 Hz to 400 kHz.
- Narda EHP-50F (serial no. 000WX50939, calibrated 03/22). A three-axis low frequency electric and magnetic field meter. Capable of measuring electric fields up to 100 kV m^{-1} and magnetic fields up to 10 mT.

Selected equipment can be seen in Figure 2.1. As recommended by the measurement device manufacturer, instruments are calibrated regularly. Calibrations are performed in an accredited laboratory using sources traceable to international standards.



Figure 2.1 Electromagnetic field measurement equipment used during the assessment, including the Narda EHP-50F, Narda ELT-400, Narda NBM-500 and Narda ED-5091.

The site was surveyed by Dr Richard Findlay of EMFcomp Limited on the 2nd of February 2023 between 9:00 am and 12:00 pm. The weather conditions were dry and overcast. The surveyor carried out EMF measurements for various positions around the intended secondary substation site, in positions as outlined in future figures.

Incident field values can change over time, hence the maximum value was recorded over a measurement period of about 1 minute in each location for each measurement type, to allow for any changing power of the nearby field sources.

3 Results

The areas within the Great Ancoats Street development, focused on the installation area for the secondary substation, were assessed for significant electromagnetic fields. Low frequency magnetic fields, typically produced by mains electricity supplies and devices powered from these supplies, were considered. Also considered were low frequency electric fields (as there were unshielded overhead transmission lines nearby, due to the tramline) and high frequency fields, produced by antennas or equipment containing antennas such as telecommunications base stations (commonly known as mobile phone masts). All areas were measured for comparison with the Action Levels and Reference Levels and other relevant limits. However, in no area were the CEMFAW Action Levels exceeded, therefore the focus of this section is comparisons with the Council Recommendation Reference Levels and electromagnetic immunity guidance presented in Section 2.

(i) Exposure Situation

The region to be assessed was part of a larger site, the Domis development site next to Great Ancoats Street in Manchester. The corner of the site that the pre-energisation survey was focused on is shown Figure 3.1, with the proposed location of the Schneider 800 kVA secondary substation highlighted in blue. It is estimated that the substation is situated approximately 6 metres from the tram line area on the construction site.

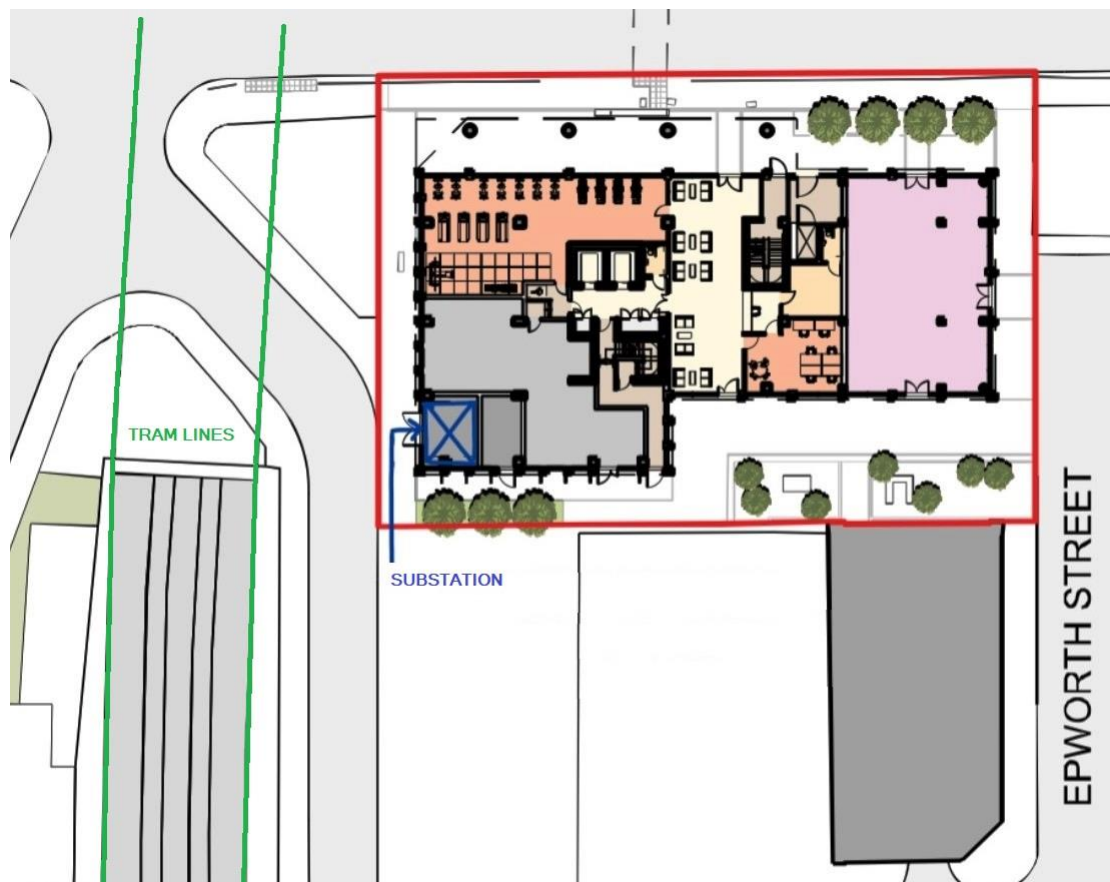


Figure 3.1 Detail of the engineering sketch, showing the tram lines on the left and road, with the bridge tunnel and the location of the secondary substation within the main development highlighted in blue.



Figure 3.2 Images showing (a) the site with the tram line tunnel (in foreground) and the secondary station on the day of the pre-energisation survey with the substation doors highlighted in red (b) a close up of the substation.

Figure 3.2 shows the location of the secondary substation, tunnel and tram lines on the day of the survey - 2 February 2023. To recap, the main purpose of the assessment was to ascertain any existing fields in the area, be these low frequency magnetic fields, low frequency electric fields, or radiofrequency fields, and predict field levels once the substation is installed. No significant magnetic fields were anticipated, as we understood that there were no high-power cables installed. Similarly, we were not expecting any radiofrequency fields as there were no antennas associated with the substation and no nearby base stations, as far as could be observed. There may be some low frequency electric fields, as unshielded electrical conductors produce these, and tram lines had associated overhead electrical lines.

Low frequency magnetic fields, low frequency electric fields, and radiofrequency fields were measured in twelve positions covering the area between where the secondary substation was to be installed and the tram line was, using the Narda ELT-400, Narda EHP-50 and Narda NBM-550 respectively. These measurements positions P1 to P12 are presented in Figure 3.3 (denoted by red squares). Figure 3.4 shows the NBM-550 in use measuring fields at the site.

Additionally, measurements were taken in other areas to identify the highest field values in the nearby area. This was found to be position P10 (shown in the map in Figure 3.3 and the image in Figure 3.5). Field values were measured when the nearby tram line was unoccupied, or when trams passed. The presence (or otherwise) of a tram made no significant difference to the measurement results.

At each point, low frequency and radiofrequency field measurements were taken at a height of approximately 1 metre above ground. The results of these measurements are presented in the following sections.

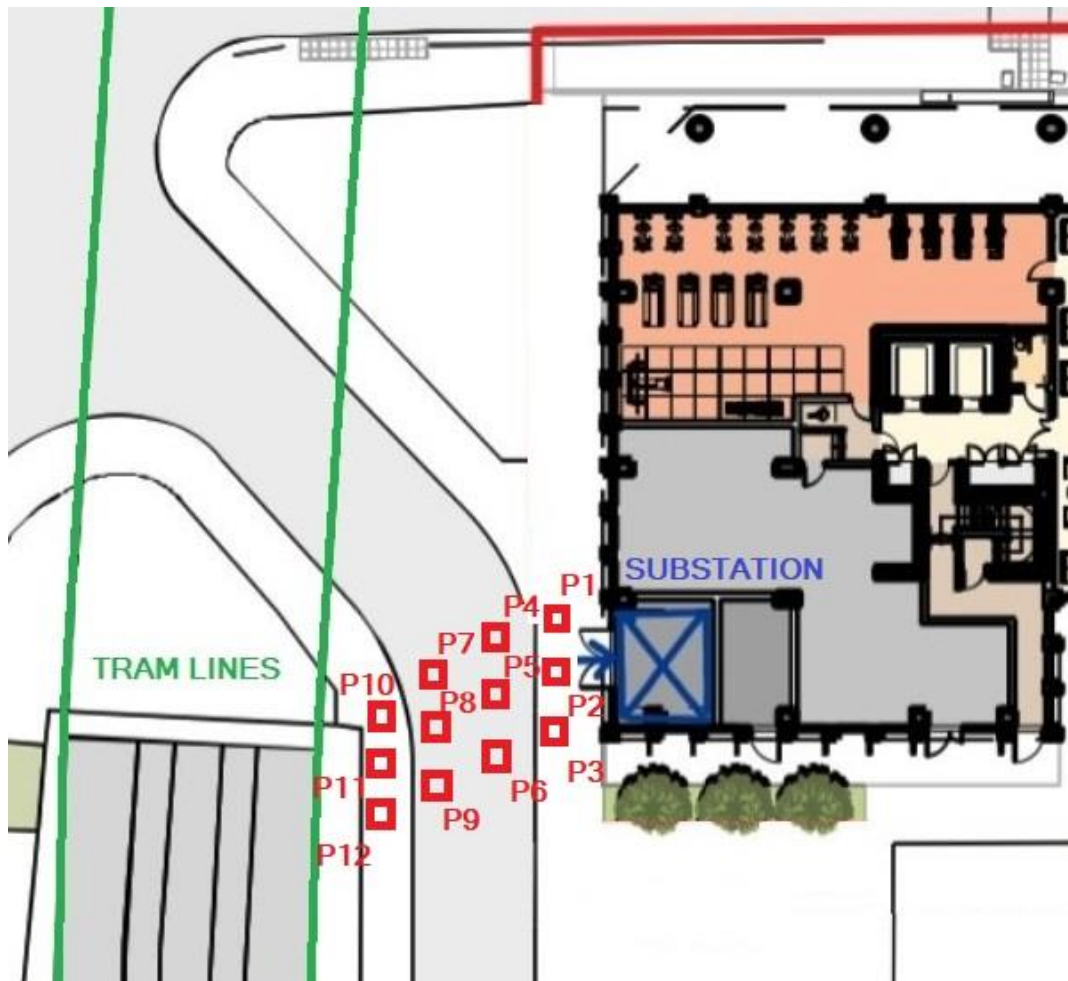


Figure 3.3 Measurement positions P1 to P12 shown on the drawing of the secondary substation location as red squares. Also shown is the perimeter between the construction site and tram lines.

(ii) Measurement Results

Table 3.1 - Low frequency (5 Hz - 400 kHz) magnetic field levels for measurement positions P1 to P12 at the Great Ancoats Street site.

Location	Magnetic Field (μT)	% Of EN/IEC 61000-4-8 Test Level (37.6 μT)	% Of Public Reference Level (100 μT)
P1	0.087	0.23%	0.09%
P2	0.096	0.26%	0.10%
P3	0.150	0.40%	0.15%
P4	0.151	0.40%	0.05%
P5	0.264	0.70%	0.26%
P6	0.236	0.63%	0.24%
P7	0.062	0.17%	0.06%
P8	0.072	0.19%	0.07%
P9	0.251	0.67%	0.25%
P10	0.079	0.21%	0.08%
P11	0.077	0.21%	0.08%
P12	0.207	0.55%	0.21%

The results of the low frequency (5 Hz - 400 kHz) magnetic field measurements for positions P1 to P12 at the Great Ancoats Street site are presented in Table 3.1. Also shown in Table 3.1 are comparisons with the field values presented in EN/IEC 61000-4-8 "Electromagnetic compatibility (EMC) - Part 4-8: Testing and measurement techniques - Power frequency magnetic field immunity test" and the Council Recommendation 1999/519/EC "Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)".

Table 3.2 - Low frequency (5 Hz - 400 kHz) electric field levels for measurement positions P1 to P12 at the Great Ancoats Street site.

Location	Electric Field ($V m^{-1}$)	% Of Public Reference Level ($5 kV m^{-1}$)
P1	0.58	0.012%
P2	0.67	0.013%
P3	0.95	0.019%
P4	1.45	0.029%
P5	0.68	0.014%
P6	1.43	0.029%
P7	1.12	0.022%
P8	1.09	0.022%
P9	0.36	0.007%
P10	0.99	0.019%
P11	1.72	0.034%
P12	1.18	0.024%

Table 3.3 - Radiofrequency (700 MHz - 2.5 GHz) field levels for measurement positions P1 to P12 at the Great Ancoats Street site.

Location	Power Density ($W m^{-2}$)	% Of EN/IEC 61000-6-4 Test Level ($0.066 W m^{-2}$)	% Of Public Reference Level ($3.5 W m^{-2}$)
P1	0.0011	1.60%	0.030%
P2	0.0007	1.09%	0.020%
P3	0.0008	1.26%	0.024%
P4	0.0006	0.96%	0.018%
P5	0.0020	3.04%	0.057%
P6	0.0022	3.33%	0.063%
P7	0.0011	1.65%	0.031%
P8	0.0009	1.35%	0.025%
P9	0.0008	1.22%	0.023%
P10	0.0007	1.09%	0.020%
P11	0.0009	1.40%	0.026%
P12	0.0007	1.09%	0.020%

For potential interference with electrical equipment, the value of 37.6 μT has been chosen as products are often tested at this level where magnetic susceptibility may be a problem, as recommended by the standard EN/IEC 61000-4-8. For potential adverse health effects in people, the value of 100 μT has been chosen as this is the Reference Level (at 50 Hz) for members of the public. If fields are below this value, authoritative bodies such as ICNIRP state that known adverse health effects associated with

electromagnetic field exposure will be avoided. Additionally, interference with a person's active implanted medical device (such as pacemakers and ICDs) should not occur.

As can be seen, the measured magnetic field values were relatively low. They typically varied between 0.08 μT and 0.26 μT . These are almost background levels commonly seen in residential environments, and can be put into context by comparisons with the EN/IEC 61000-4-8 Test Level of 37.6 μT and Council Recommendation public Reference Level of 100 μT . The highest field measured was 0.264 μT at Position 5. This was 0.7% of the 37.6 μT equipment interference limit and less than 0.25% of the public Reference Level, treated as a limit in this study.

Regarding low frequency electric fields and potential interference with electrical equipment, the value of 5 kV m^{-1} has been chosen as this tends to be the lowest low frequency electric field limit for electronic devices. This includes potential adverse health effects in people, the value of 5 kV m^{-1} is the Reference Level (at 50 Hz) for members of the public. If fields are below this value, authoritative bodies such as ICNIRP state that known adverse health effects associated with electromagnetic field exposure will be avoided. Additionally, interference with a person's active implanted medical device (such as pacemakers and ICDs) should not occur. As can be seen, the measured electric field values were relatively low. They typically varied between 0.36 V m^{-1} and 1.72 V m^{-1} . These are low levels commonly - although slightly higher than those seen in residential environments, due to the presence of the overhead lines associated with the nearby tramline. The measurement values can be put into context by comparisons with the Council Recommendation public Reference Level of 5 kV m^{-1} . The highest field measured was 1.72 V m^{-1} at Position P11. This was less than 0.1% of the public Reference Level, treated as a limit in this study.

The results of the high frequency (700 kHz to 50 GHz) RF field measurements for locations P1 to P10 at the development site are presented in Table 3.3. Also shown in Table 3.3 are comparisons with the most restrictive field values presented in standards such as IEC 61000-6-4:2018 Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments, BS EN 50121 - Railway applications. Electromagnetic compatibility and EN/IEC 61000-4-3 "Testing and measurement techniques - Radiated, radiofrequency, electromagnetic field immunity test" along with the Council Recommendation 1999/519/EC "Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz)". For potential interference with electrical equipment from RF fields, EN/IEC 61000-4-3 and its related standards present some of the most restrictive RF limits for particularly sensitive equipment, e.g., telecommunications, IT, and rail infrastructure. The value of 0.066 W m^{-2} (5 V m^{-1}) has been chosen as this is the most conservative electric field limit presented, generally applied between 2.1 and 2.5 GHz (other limits are 10 V m^{-1} (80-1000 MHz), 20 V m^{-1} (800-1000 MHz), 20 V m^{-1} (1.4 - 2.1 GHz)). For potential adverse health effects in people, the value of 3.5 W m^{-2} has been chosen as this is the Reference Level (at 10 MHz to 400 MHz - the most restrictive in the frequency range seen at the site) for members of the public. Again, if fields are below this value for radiofrequency field exposure, authoritative bodies such as ICNIRP state that known adverse health effects will be avoided.

The radiofrequency fields measured were very low. The highest radiofrequency field, measured at position P6 was recorded as 3.3% of EN/IEC 61000-6-4 Level (0.066 W m^{-2}) and 0.06 % of the 3.5 W m^{-2} Reference Level (recall that, below 100% of the RLs, the fields are in compliance with the Council Recommendation Reference Levels, used as limits in this instance for members of the public etc.). To confirm the frequencies of the emissions measured, the Narda EHP-50 was used to measure the magnetic and

electric field spectrums, and the results can be seen in Figures 3.6 to 3.9. The results were as expected, with peaks at 50 Hz and significant harmonics.



Figure 3.4 Measuring radiofrequency fields at the site within the substation enclosure using the Narda NBM-550.



Figure 3.5 Ducts for HV cables into the substation enclosure within the cable trenches under the floor.

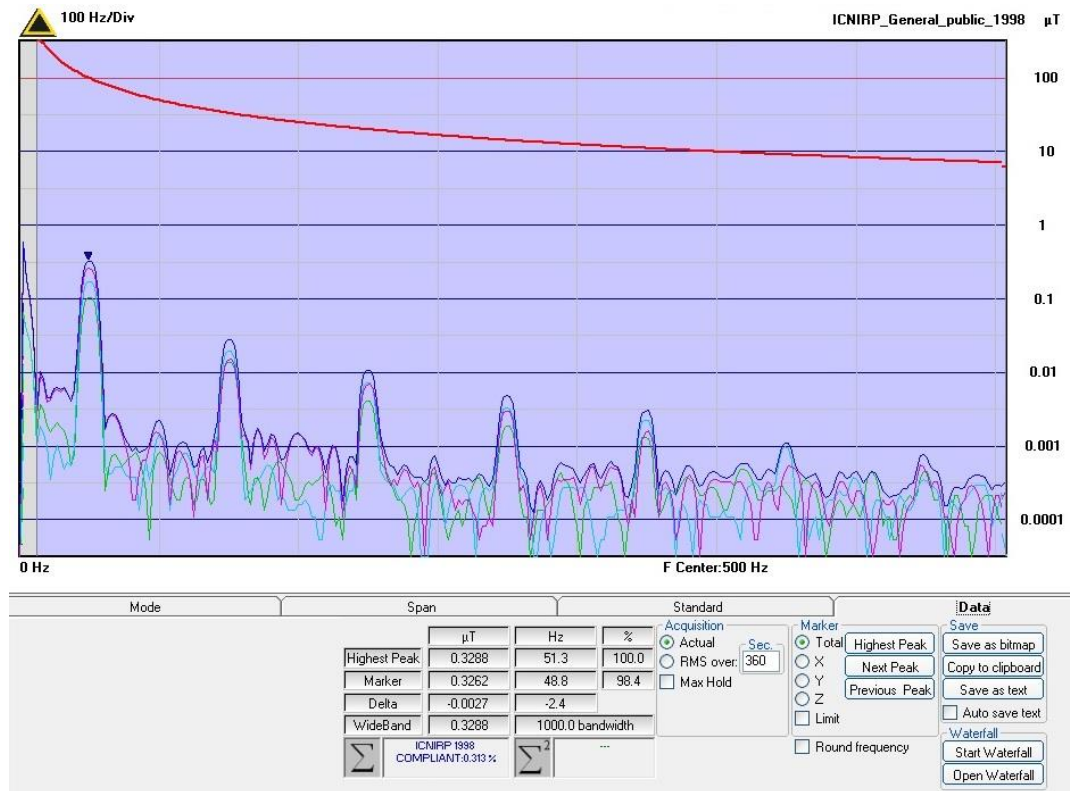


Figure 3.6 Magnetic field spectrum at measurement position 3.

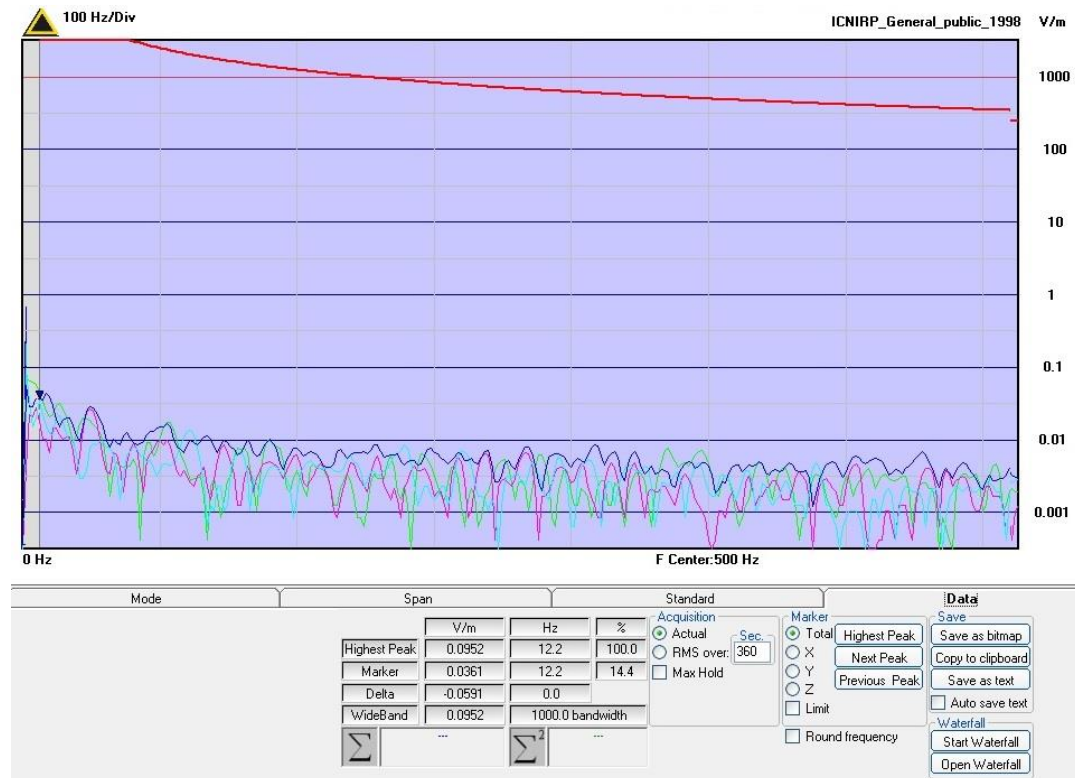


Figure 3.7 Electric field spectrum at measurement position 3.



Figure 3.8 Magnetic field spectrum at the boundary between the development site and the substation.

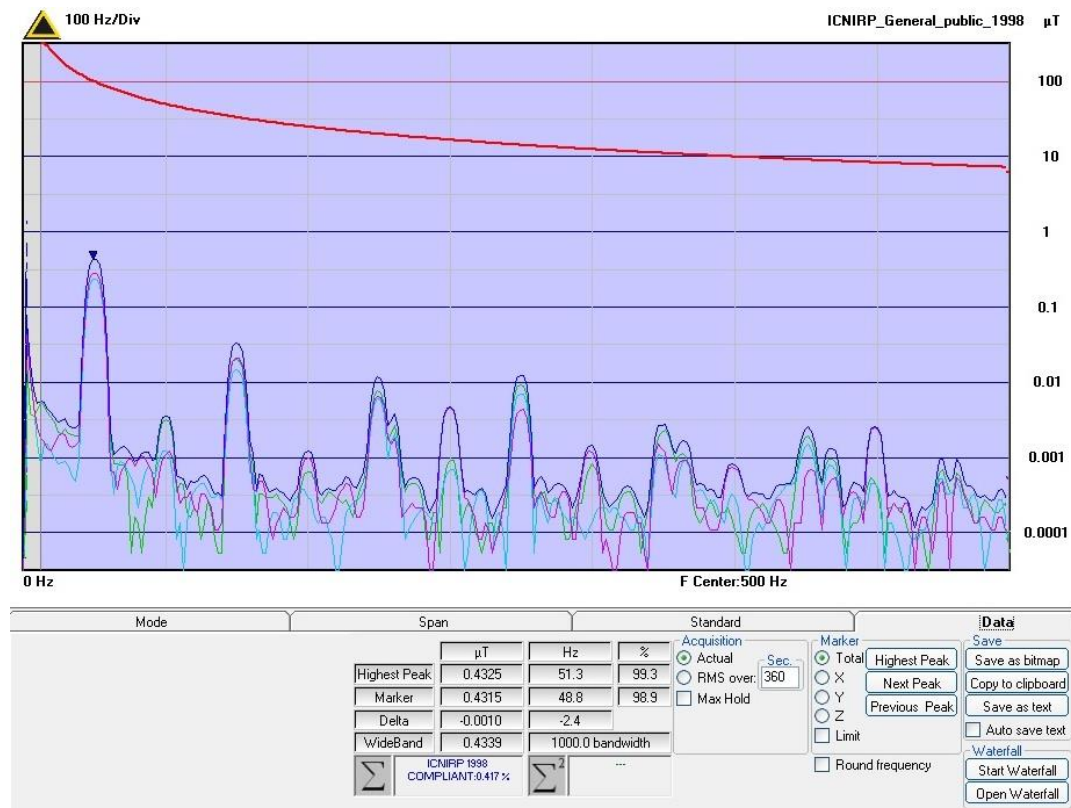


Figure 3.9 Magnetic field spectrum showing the contributions from the various frequencies at the highest point measured for magnetic fields near the secondary substation location.

(ii) Calculation Results

(a) Low Frequency Fields

To clarify, the substation transformer and associated electrical conductors had not been installed at the time of the measurements. Once installed, these will produce additional low frequency fields (but no additional high or radiofrequency fields, as no antennas are associated with the substation). In order to predict low frequency magnetic fields after the substation equipment is operational, field calculations have been performed. The following theory has been used to calculate fields present in this report. The magnetic field, or magnetic flux density, produced by the electrical conductors was modelled as a series of straight current-carrying thin wire segments. The magnetic flux density B_θ produced by these conductors was proportional to the electrical current passing through them. The field at separation distance r from each such conductor carrying a current I is calculated using Ampere's law:

$$B_\theta = \frac{\mu_0 I}{2\pi r} \quad (2.1)$$

B and I are frequency dependent quantities. Equation (1) can be rewritten:

$$B(x, y) = \frac{\mu_0 I}{2\pi \sqrt{(x - x_c)^2 + (y - y_c)^2}} \quad (2.2)$$

where x_c, y_c are the conductor centre point coordinates; and

x, y are the coordinates of the point at which the field is to be calculated.

The 880 kVA transformer to be installed is an oil type transformer with aluminium windings. It is anticipated that, from the maximum electrical currents potentially used, a magnetic field of 37.6 μT (IEC 61000-6-8:2020 and BS EN 50121) is predicted to be produced within a radius of 0.56 m of these cables for the HV conductors. The closest HV conductor is a number of metres away from the tram line. Therefore, these HV cables are predicted to present no EMI hazard from an EMF exposure point of view to rail equipment or infrastructure within the tram line regions.

It is also anticipated that, from the maximum electrical currents potentially used, a magnetic field of 37.6 μT (IEC 61000-6-8:2020 and BS EN 50121) is predicted to be produced within a radius of approximately 0.40 m of these cables for the 400 V (LV) conductors. The closest LV conductor is again due to be installed a number of metres away from the tram line. Therefore, these 400 V LV cables are predicted to present no EMI hazard from an EMF exposure point of view to rail equipment or infrastructure within the tram line regions.

(b) Radiofrequency Fields

There are no antennas associated with the electrical equipment to be installed in the substation on the construction site. Therefore, there will be no radiofrequency fields produced by the installation of substation equipment to add to the existing radiofrequency field environment.

4 Discussion

As previously mentioned, this EMC study was set up to assess potential electromagnetic interference (EMI) sources to rail infrastructure, equipment, and rail employees from the nearby substation equipment. From the point of view of compliance with the CEMFAW Regulations 2016 Action Levels (relevant for occupational exposure), fields were significantly below any limits and so these are not explored in any detail within this work.

Fields from low frequency and high frequency sources (and the potential adverse effects) are very different, hence the requirement in the scope of work to measure these separately. Discussion of these results are presented in the following sections.

4.1 Low Frequency Fields

The low frequency fields measured within the development site region where the secondary substation is due to be installed were typically very low, as can be seen in the results in the previous section when put into context by comparisons with relevant standards and guidance.

The highest magnetic fields were measured in position P10. The fields did not significantly approach the EN/IEC 61000-4-8 Test Level of 37.6 μT or the Council Recommendation 1999/519/EC Public Reference Level of 100 μT , used as limits in this instance. Similarly, the low frequency electric fields measured were very low.

Low frequency magnetic and electric fields decrease very quickly as one moves away from the field source, typically a one-over-distance-squared relationship. Hence, the field level can reduce significantly in a matter of metres.

We now are aware of a baseline of low frequency fields at the position where the substation equipment is due to be installed. Despite the installation location being close to tram lines for the development, calculations have shown it is not expected that fields from the secondary substation will add to the measured field environment in such a way as to exceed the limits previously discussed. Frequency plots indicated that, as expected, the frequency of the field produced was 50 Hz with other harmonics.

In summary, the pre-existing low frequency field environment does not present an interference hazard with electrical equipment or exposure hazard to equipment and people either within the secondary substation installation area or within the adjacent Transport for Greater Manchester (TFGM)/ Metrolink tramline region. It is not expected that fields from the secondary substation, once installed and operating, will not add to the measured field environment in such a way as to exceed the EMC limits discussed.

A post energisation EMC assessment of the substation equipment surveyed will be carried out, once this equipment has been installed and is operational. If field levels are found to be non-compliant with the electromagnetic field limits and guidance set out in this report, the equipment will be de-energised until mitigation measures have been agreed and installed.

4.2 Radiofrequency Fields

Similar to the low frequency fields measured, the high frequency fields measured within the development site region were typically very low, as can be seen in the results in the previous section when put into context by comparisons with relevant standards and guidance. The field measurements demonstrated that the RF emissions were overwhelming being transmitted by base station antenna arrays in the near vicinity. This is to be expected in a highly developed urban environment such as that presented in Manchester city centre. Measurements indicated that the fields were produced primarily by 4G and 5G masts.

Regarding radiofrequency fields, the pre-existing high frequency field environment does not present an interference hazard with electrical equipment, as defined in standards such as IEC 61000-6-4:2018 and BS EN 50121, or exposure hazard to people or equipment in and around the development area, and as secondary substation does not produce radiofrequency fields (e.g., there are no significant antennas associated with the equipment), this is not expected to change once the equipment is installed and operating.

5 Conclusions

An area adjacent to Great Ancoats Street in Manchester is currently undergoing development. There was a requirement to carry out an electromagnetic compatibility (EMC) surveys of the region intended for installation of a secondary substation, to assess the electromagnetic environment and identify the need for interference mitigation measures if required. EMFcomp Limited has measured the low frequency (5 Hz to 400 kHz) magnetic and electric fields across the site, to determine the locations of maximum field strengths. We have also carried out broadband and narrowband high frequency (700 MHz to 2.5 GHz) measurements to determine the locations of maximum radiofrequency field strengths. The field levels for the pre-existing electromagnetic environment within the region were found to be relatively low. The maximum low frequency field was measured as 0.264 μT , and the maximum measured radiofrequency field was 0.0022 W m^{-2} .

To assess the potential hazard associated with such field levels, both to humans and electrical equipment, the levels were compared to relevant UK EMF exposure guidance and limits. For human exposure, these limits were contained in the Control of Electromagnetic Fields at Work Regulations 2016 Action Levels (equivalent to the ICNIRP occupational Reference Levels) and Council Recommendation 1999/519/EC public Reference Levels (equivalent to the ICNIRP public Reference Levels). For equipment immunity EMC interference, these were limits presented in EN 55024, EN 61000-6-1, IEC 61000-6-4:2018, EN 50121 and associated standards.

Utilising equipment immunity EMC interference standards, including IEC 61000-6-4:2018, IEC 61000-6-8:2020 and BS EN 50121, both the low frequency and high frequency fields were below some of the most conservative limits presented in these. Therefore, we can conclude that the pre-existing electromagnetic environment does not present a risk of interference to electrical or electronic equipment. Similarly, the low and high frequency electromagnetic field strengths measured on site were below the Reference Levels in the Council Recommendation 1999/519/EC document. This contains some of the UK's most restrictive human exposure guidance.

Hence, the pre-existing electromagnetic field environment does not present an interference hazard with electrical equipment or exposure hazard to equipment and people either within the secondary substation installation area or within the adjacent Transport for Greater Manchester (TFGM) tramline region. Calculations have indicated that it is not expected that fields from the secondary substation, once installed and operating, will add to the measured field environment in such a way as to exceed any of the EMC/EMI/EMF limits (EN 55024, EN 61000-6-1, IEC 61000-6-4:2018, EN 50121 and associated standards) discussed outside of the substation enclosure.

A post energisation EMC assessment of the substation equipment surveyed will be carried out, once this equipment has been installed and is operational. If field levels are found to be non-compliant with the electromagnetic field limits and guidance set out in this report, the equipment will be de-energised until mitigation measures have been agreed and installed.

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Date Produced: 6 March 2023

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