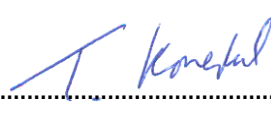


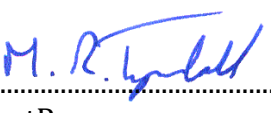
Results of the Electromagnetic Field Site Survey at the Fairfax Buildings (Uncontrolled Electronic Copy)

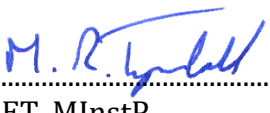
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Issue	Description	Issued by	Date
1	First issue	TK	2 nd July 2025

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CHANGE HISTORY SHEET

Date	Issue	Section	Description
02.07.2025	1	-	First issue

EXECUTIVE SUMMARY

Swept frequency electromagnetic (EM) field emissions measurements were made at the site of the newly built Fairfax buildings in Manchester on Thursday 5th June and Friday 6th June 2025, prior to the energisation of the buildings. The Fairfax buildings are located approximately 20m from the adjacent 750V DC Manchester tram. The measurement results were compared to the requirements for DC tram systems operating at 630V or 750V DC, as specified in UK Designated standard EN 50121-2: 2006 (emissions of the whole railway to the outside world), with the result summarised below.

Standard	Status
EN 50121-2:2006	Compliant*
*See text below	

The measurements are intended to benchmark the existing electromagnetic environment prior energisation of the Fairfax buildings. Although there were some exceedances observed of the limits provided in EN 50121-2: 2006, these could nearly all be ascribed to *bona fide* transmitting radio services. Only one exceedance at the (unlicensed) frequency of 915MHz could not readily be ascribed to a bona fide transmitter, though it is possible that this emission is due to a 4G or 5G mobile phone handset. The maximum overall field level observed was 111dB(µV/m) or 0.355V/m at ~959MHz, which was due either to a 4G or 5G mobile phone base station. Despite the fact that this is 51dB above the EN 50121-2:2006 limit, it is at a licensed frequency and is still 19dB below the level of immunity (3V/m) normally expected from even sensitive radio receiver apparatus. It is therefore unlikely to result in EMC issues.

A second site survey is planned to be carried out at the same test locations after the Fairfax buildings have been energised. The post-energisation results will be compared with the measurement results presented in this report, with the aim of demonstrating that the new Fairfax buildings and tramway are in compliance with the UK EMC Regulations SI 2016 No. 1091.

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LIST OF TERMS AND ABBREVIATIONS

AM	Amplitude Modulation
ARA	Active Receive Antenna
BBC	British Broadcasting Company
CEMFAW	Control of Electromagnetic Fields At Work
DAB	Digital Audio Broadcasting
DC	Direct Current
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMF	Electromagnetic Field
EMI	Electromagnetic Interference
EN	Euronorm
ERP	Effective Radiated Power
ETSI	European Telecommunications Standards Institute
FAT	Frequency Allocation Table
FM	Frequency Modulation
3G, 4G, 5G	Third, fourth, fifth Generation
GSM-R	Global System for Mobile communications - Railway
ICNIRP	International Commission on Non-Ionising Radiation Protection
ISM	Industrial, Scientific and Medical
LEO	Low Earth Orbit
LW	Long Wave (Radio)
MW	Medium Wave (Radio)
OFCOM	Office of Communications
PMR	Private Mobile Radio
PMSE	Programme Making and Special Events
POCSAG	Post Office Code Standardization Advisory Group
RCLI	Residential, Commercial and Light Industrial
RFID	Radio Frequency Identification
SI	Statutory Instrument
SW	Short Wave (Radio)
TETRA	Terrestrial Trunked Radio (emergency services digital telecoms)
TP	Test Position
TV	Television
UK	United Kingdom
UMTS	Universal Mobile Telecommunications System (3G mobile)
WiFi	IEEE 802.11 family of wireless network protocols

1 INTRODUCTION

This report presents the results of radio frequency electromagnetic (EM) measurements that were undertaken on Thursday 5th June and Friday 6th June 2025 at the site of the new Fairfax buildings in Manchester, with address:

The Fairfax,
Portugal St East,
Manchester,
M1 2WL.

Measurements were undertaken at ground level, prior to energisation of the buildings. The measurements are described in detail in an associated Test Plan, Y6009CR1 [1] and Method Statement, Y6010CR1 [2].

The purpose of these measurements is to benchmark the existing electromagnetic environment prior to energisation of the Fairfax buildings and compare it with the limits set out for emissions to the outside world for a 630V or 750V DC tramway, as set out in UK designated standard EN 50121-2:2006 [3]. The measurements are intended to highlight any frequencies where there are unusually high levels of EM fields which might impact on new apparatus installed within the Fairfax buildings, and also to provide assurance (through comparison with a repeat post-energisation site survey) that the new Fairfax buildings have not significantly degraded the EM environment. In particular, the aim is to demonstrate that the final energised buildings and tramway are in compliance with the UK EMC Regulations SI 2016 No. 1091 [4]. In the event that there are complaints of electromagnetic interference (EMI) due to the new Fairfax buildings, it will be possible to compare the post installation site survey measurements with the measurements made in this report. This will enable a judgement to be made as to whether the offending EMI phenomenon was already present before the construction and energisation of the Fairfax buildings or is indeed highly likely to be due to the Fairfax complex itself.

A railway that adheres to the limits on emissions prescribed by UK designated standard EN 50121-2:2006 is endowed with a legal presumption of conformity with the UK EMC Regulations SI 2016 No. 1091 [4]. Although there are no similar designated standards for buildings such as The Fairfax, the limits on emissions set in EN 50121-2:2006 are set with the explicit intention of protecting radio services. It can be argued therefore that where

a building complex such as The Fairfax or other fixed installation is similarly compliant with the limits set out in EN 50121-2:2006 (particularly the most stringent limits that are considered in this report), the EMC risk to third party radio services is acceptably low. This in turn can be considered to demonstrate compliance of the Fairfax buildings (and nearby tramway) with the EMC Regulations.

Section 2 describes the measurement method and measurement locations. Section 3 summarises the results of the measurements. Section 4 presents analysis and conclusions for the project.

2 MEASUREMENT DETAILS

2.1 Test locations

Figure 1 shows the four locations (test positions TP1, TP2, TP3 and TP4) at which measurements were planned to be undertaken in the Test Plan [1]. (Figure 1 pre-dates the construction of the Fairfax complex, but does indicate the position of the tramway).



Figure 1. Site of Fairfax buildings (shown prior to any construction work).

In practice it was not possible to access both TP1 and TP4 exactly as planned. Instead, a single position between TP1 and TP4 (though closer to TP4) was measured, to replace TP1 and TP4. This position is indicated in Figure 2 and is labelled as TP1(4) throughout the remainder of this document. The remaining test positions TP2 and TP3 were measured as planned.

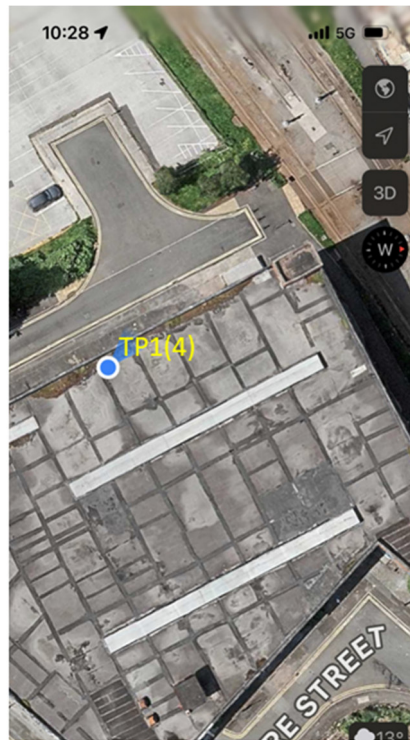


Figure 2. Test position TP1(4), replacing TP1 and TP4.

Test positions TP2 and TP3 were located 10m from the centre line of the nearest tramway, as is generally required by EN 50121-2:2006. Measurements at these two test positions were also conveniently located approximately ~10m from the nearest Fairfax buildings. Measurements at TP1(4) were at 10m from the westernmost Fairfax building, with the exception of measurements above 1GHz where a separation distance of ~7m was achieved (note that measurements above 1GHz do not form a normative part of EN 50121-2:2006). In general, the sites were cluttered and it was not always possible to maintain a large distance from metallic fencing/barriers, which have the potential to distort electric (and magnetic) field measurements. In particular, at TP1(4) the horizontal electric field measurements below 1GHz were made with the ARA antenna axis pointing directly at an otherwise undesirable nearby metallic mesh fence. This was designed to capture maximum emissions, since the metallic fence will tend to distort electric fields in the manner of a partial ground plane, such that the axis of the ARA antenna will align in the (distorted) plane of polarisation. Photographs of the experimental set ups at the three test positions TP1(4), TP2 and TP3 appear in Appendix 3.

2.2 Electromagnetic field measurement method

Measurements were made in line with EN 50121-2:2006, with a test receiver and appropriate magnetic and electric field antennas as specified in UK designated standard EN 50121-3-1:2017 [5]. Data were gathered using repeated swept frequency measurements, each frequency range reading over several (8+) minutes. The actual frequency ranges used during sweeps are indicated by 6 different coloured contiguous frequency bands in Table 1 (the end/start frequencies in the two split cells are 15MHz and 3.6GHz respectively). Given that each band of frequencies contains 500 sweeps over 8min 20s, the sweep times per band, allowing for data writing to memory, are less than $(8 \times 60 + 20)/500 = 1\text{s}$. The actual sweep times achieved per sub range are as indicated in Table 1. These sweep times permit variations in emissions owing to transient events and the passage of rolling stock to be discerned where necessary. However, the default data display for comparison with the EN 50121-2:2006 limits is in terms of a peak hold (maximum) envelope of emissions over the entire set of 500 sweeps. Guidance for the target sweep times of sub-ranges is taken from UK Designated standard EN50121-3-1: 2017 [5] (rolling stock measurements). These are not critical (they will ultimately depend on the characteristics of the receiver used for measurements) providing that transient events such as tram passages can be discerned where necessary. Where the peak hold readings are below the levels permitted by EN 50121-2:2006, there is generally no requirement to investigate whether the measurements are transient in nature or have a more persistent origin.

It is noted that EN 50121-2:2006 sets limits on EM emissions only in the frequency range 9kHz – 1GHz. However, since many modern computing and communication devices also use frequencies above 1GHz, the measurement frequency range has been extended up to a highest frequency of 6GHz, as indicated in Table 1. Note that in the frequency range below 150kHz, the recommended measurement bandwidth of 200Hz in EN 50121-2:2006 has been substituted in practice for the value of 1kHz (see Table 1), in order to complete measurements in a manageable time frame. This is permitted by EN 50121-2, which directs that the readings should then be adjusted at the reporting stage assuming that the noise is impulsive. That is, the *amplitude* of the signal is reduced by a factor of 5 (14dB). (Uncorrelated, random noise would result in a reduction in *power* by a factor of 5 [7dB]. A continuous wave, narrowband signal would appear unchanged by the increase in bandwidth). This adjustment has been made in the figures presented in Section 3.

	Sub-range (Hz)	Measurement Bandwidth (Hz)	Sweep time Target/actual (ms)	Antenna	Measurement Instrument
Requirement of EN 50121-2: 2006	9k – 59k	1k	300/101	EMCO 6511	Agilent MXE N9038A
	50k – 150k	1k	300/203		
	150k – 1.15M	9k	37/24	EMCO 6512	
	1M – 11M	9k	370/244		
	10M – 20M	9k	370/244		
	20M – 30M	9k	370/244		
	30M – 230M	120k	60/23	ARA+	
	200M – 500M	120k	90/34		
	500M – 1G	120k	125/57		
	1G – 2G	1M	NA/13	Horn	
	2G – 6G	1M	NA/27	Horn	
+ The ARA is an active antenna with performance comparable to a BiLog antenna, but which is very much smaller. Saturation does not occur for fields less than 130dB(μV/m).					

Table 1. Sub-ranges measured at each location.

Appendix 1 presents a list of the measurement equipment used, with asset numbers.

2.3 Siting and polarisation of Antennas

The antennas were mounted on a tripod at heights above ground level of:

1. 1.5m to the antenna centre for magnetic antennas.
2. 1.5m to the antenna centre for the Active Receive Antenna (ARA).
3. 1.5m to the antenna centre for the horn antenna.

These heights are broadly in line with the requirements of EN 50121-2: 2006 [3]. (The ARA antenna has been used in place of a normally used BiLog antenna for convenience. The BiLog antenna is normally positioned at a height of 3m, partially on account of its large size. The much smaller size of the ARA antenna enabled a smaller antenna height to be used.) Two polarisations of each antenna were measured for each measurement position. For electric antennas both horizontal and vertical polarisations were measured. For magnetic loop antennas, two orthogonal polarisations (loop ‘parallel’ and ‘perpendicular’ to the rails or building) were used with the loop mounted vertically. Appendix 2 presents the definitions used.

Antennas were sighted on the building at a distance of 10m, and in the case of TP2 and TP3 this happened also to coincide with a distance of approximately 10m from the rails (as required by EN 50121-2:2006). Note that in practice the magnetic antennas and the ARA antenna at TP2 and TP3 will have responded to EM emissions from both the railway

and the Fairfax buildings with equal sensitivity, due to the particular broad directivity patterns of the antennas. This enables a fair general assessment of the EM environment to be made. For TP1(4), the more directional horn antenna was positioned slightly closer to the Fairfax buildings at a distance of ~7m. Although horn antenna measurements above 1GHz do not form a normative part of EN 50121-2:2006, measurements have been adjusted to accord with a 10m measurement distance, in accordance with Clause 5.1.6 of EN 50121-2: 2006 [3]. In this case the factor 'n' used in Clause 5.1.6 of EN 50121-2: 2006 has been extrapolated to a value of unity above 1GHz, from its value (also unity) at 1GHz. This value assumes that we are in the far field at such frequencies, where the field levels will reduce by a factor that is inversely proportional to the distance from the source. At 1GHz and above, the value of $kr = \frac{2\pi r}{\lambda} > 146 \gg 1$ at a distance of 7m so that the far field approximation is a good one.

2.4 Measurement Display

For magnetic fields, measurements made with the loop antenna facing the railway or building ('parallel' orientation as indicated in Appendix 2) are shown in red, with the 'perpendicular' antenna orientation shown in blue. For electric fields, horizontally polarised measurements are shown in red, with vertically polarised measurements shown in blue. Limit lines (from EN 50121-2:2006, see below) are indicated in pale blue.

Limits on emissions from the railway infrastructure to the outside world are set out in EN50121-2:2006, between 9kHz and 1GHz. The limit lines are specified at a measurement distance of 10m. A correction has been made for the permitted higher bandwidth of 1kHz used in the frequency range below 150kHz, according to the procedures outlined in EN 50121-2:2006. The limits lines displayed are for a 750V DC railway; these limit lines are the most stringent limits appearing in EN 50121-2:2006 and are in fact also applicable to non-electrified lines.

2.5 Test positions, Dates, Times and Weather Conditions

Measurements were undertaken on Thursday 5th June and Friday 6th June 2025 at three different test positions near the Fairfax buildings in Manchester (see Figure 1, Figure 2 and Table 2).

TP	Location	Date/Time	Weather	Remarks
1(4)	See position TP1(4) in Figure 2	05/06/2025 10:51-13:27	Cloudy with broken sunshine, ~20°C, dry	Emissions captured from southernmost/westernmost Fairfax building, with less influence from railway.
2	See position TP2 in Figure 1	06/06/2025 09:56-12:10	Cloudy with broken sunshine. Rain in previous 24hr, ~15°C	Emissions captured from both Fairfax buildings and railway.
3	See position TP3 in Figure 1	05/06/2025 15:01-16:55	Cloudy with broken sunshine and sporadic showers, ~15°C	Emissions captured from northernmost/easternmost Fairfax building and railway.

Table 2. Summary of measurement locations.

3 MEASUREMENT RESULTS

3.1 EN50121-2:2006 measurements at test position TP1(4)

The detailed measurement results, which directly compare the measured emissions with the limits provided in EN50121-2:2006 (appropriate for a 750V DC tramway or non-electrified railway line) are shown in Figure 3. The levels of exceedance are also shown explicitly in the final graph of Figure 3, irrespective of polarisation. Note that for frequencies in the range 9kHz –150kHz, the measured data have been corrected for 200Hz bandwidth, as directed by EN50121-2:2006 (see Section 2.2), and that there are in fact no exceedances at all seen below a frequency of 30MHz.

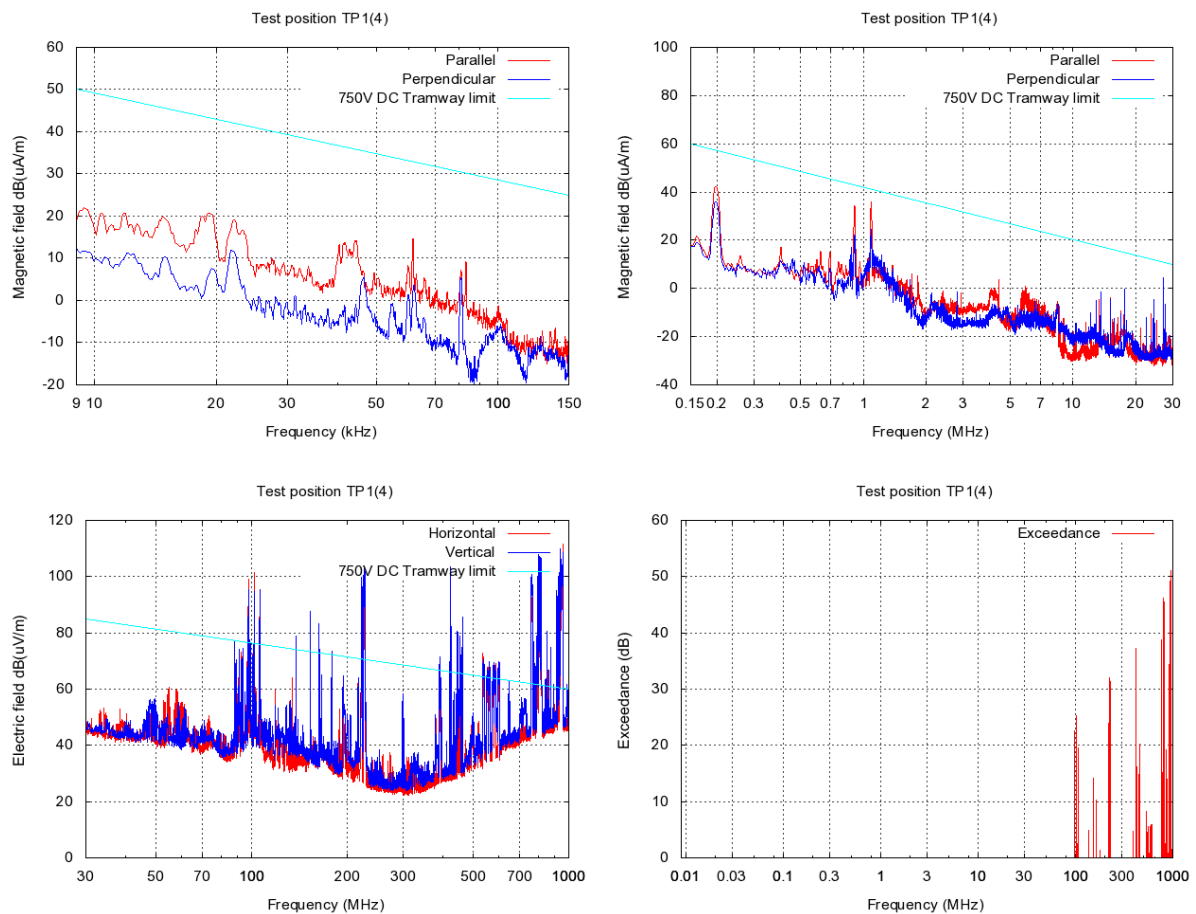


Figure 3. EMC site measurements at test position TP1(4) (see Figure 2) according to EN 50121-2:2006, including permitted limits for 750V DC tramway.

Analysis of these results is provided in Section 4.1.

3.2 EN50121-2:2006 measurements at test position TP2

The detailed measurement results, directly comparing the measured emissions with the limits provided in EN50121-2:2006 (appropriate for a 750V DC tramway or non-electrified railway line) are shown in Figure 4. The levels of exceedance are also shown explicitly in the final graph of Figure 3, irrespective of polarisation. For frequencies in the range 9kHz –150kHz, the measured data have been corrected for 200Hz bandwidth, as directed by EN50121-2:2006 (see Section 2.2). As was the case for TP1(4), there are no exceedances at all seen below a frequency of 30MHz at TP2.

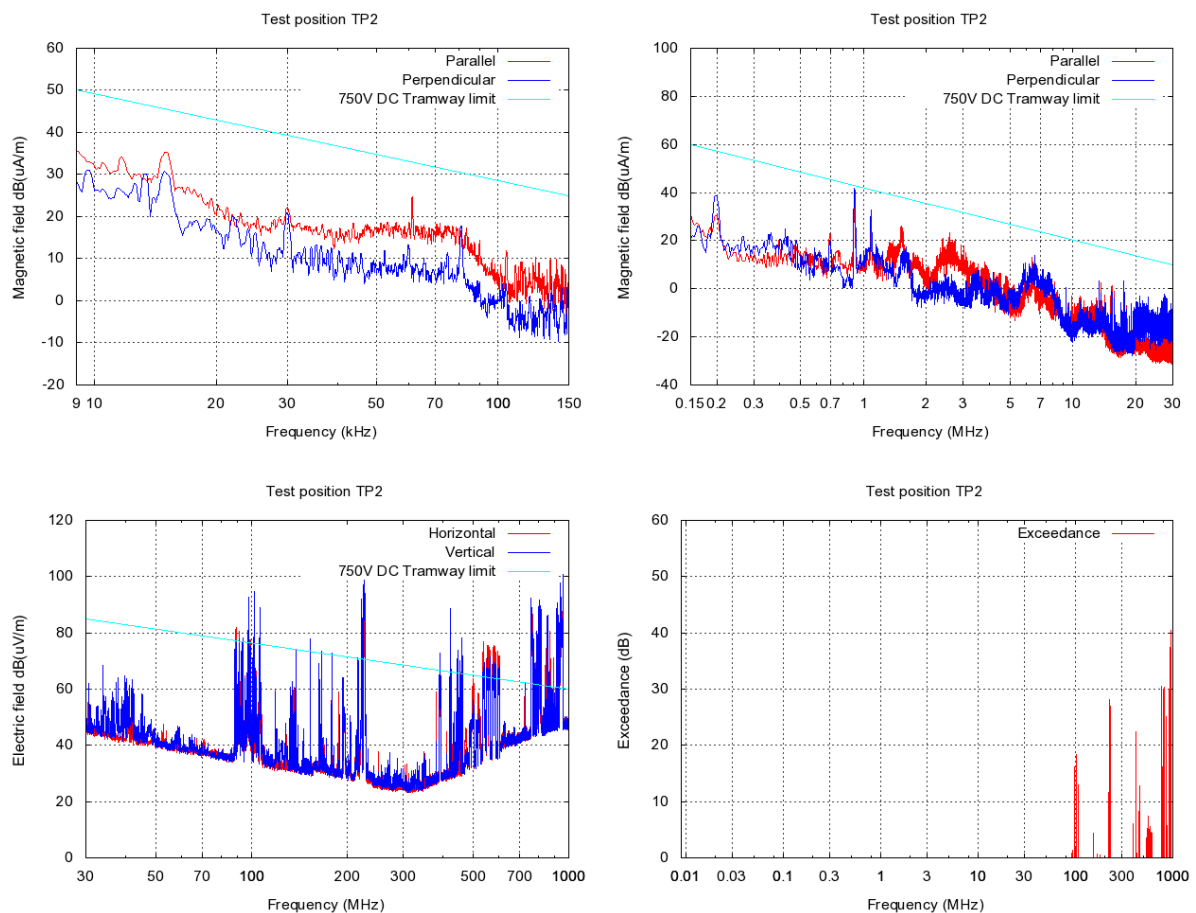


Figure 4. EMC site measurements at test position TP2 (see Figure 1) according to EN 50121-2:2006, including permitted limits for 750V DC tramway.

Analysis of these results is provided in Section 4.2.

3.3 EN50121-2:2006 measurements at test position TP3

The measurement results and limits provided in EN50121-2:2006 for a 750V DC tramway are shown in Figure 5. The levels of exceedance are also shown explicitly in the final graph of Figure 5, irrespective of polarisation. Measurements at frequencies in the range 9kHz – 150kHz have been corrected for 200Hz bandwidth, as directed by EN50121-2:2006 (see Section 2.2).

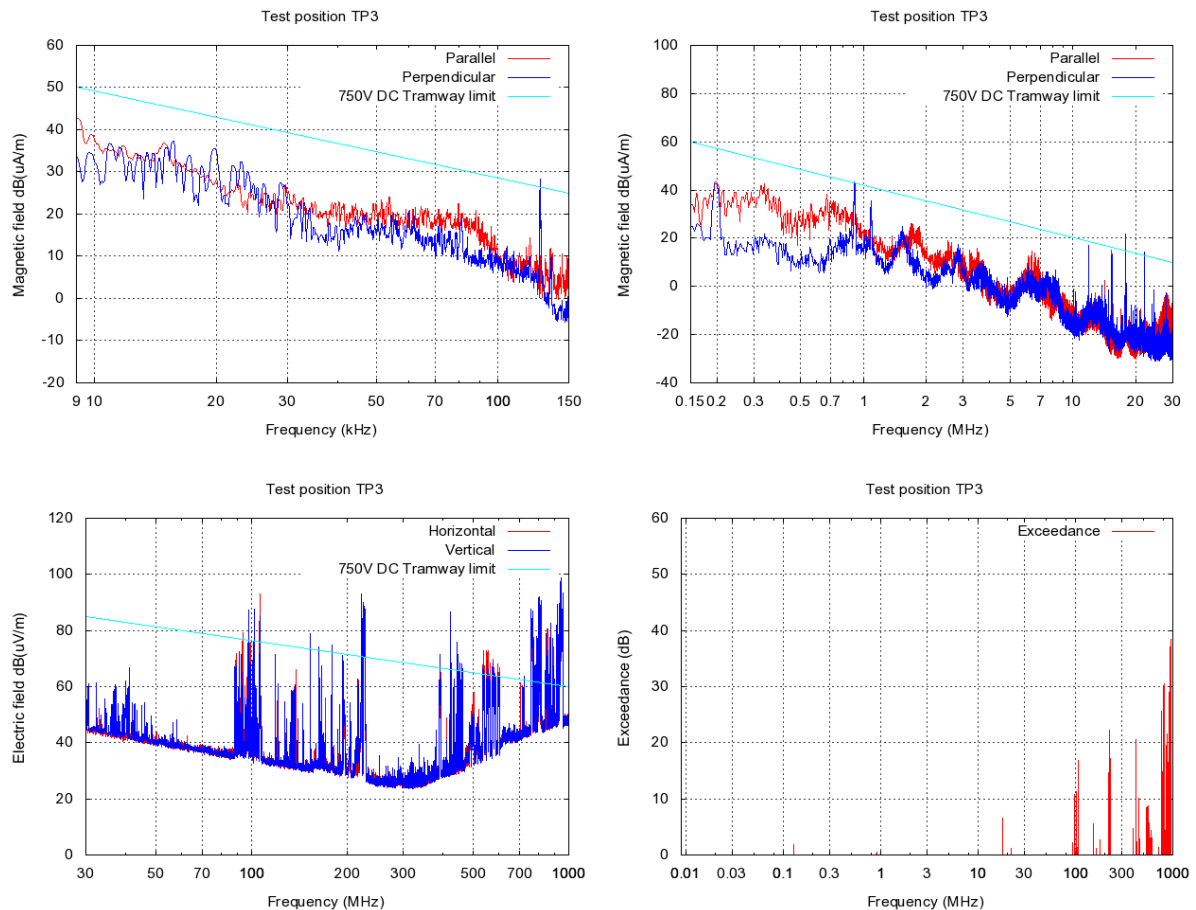


Figure 5. EMC site measurements at test position TP3 (see Figure 1) according to EN 50121-2:2006, including permitted limits for 750V DC tramway.

Analysis of these results is provided in Section 4.3.

3.4 Additional high frequency measurements

Details of the additional measurement results for frequencies higher than 1GHz (which do not form part of the normative requirements of EN 50121-2:2006) are provided in Figure 6.

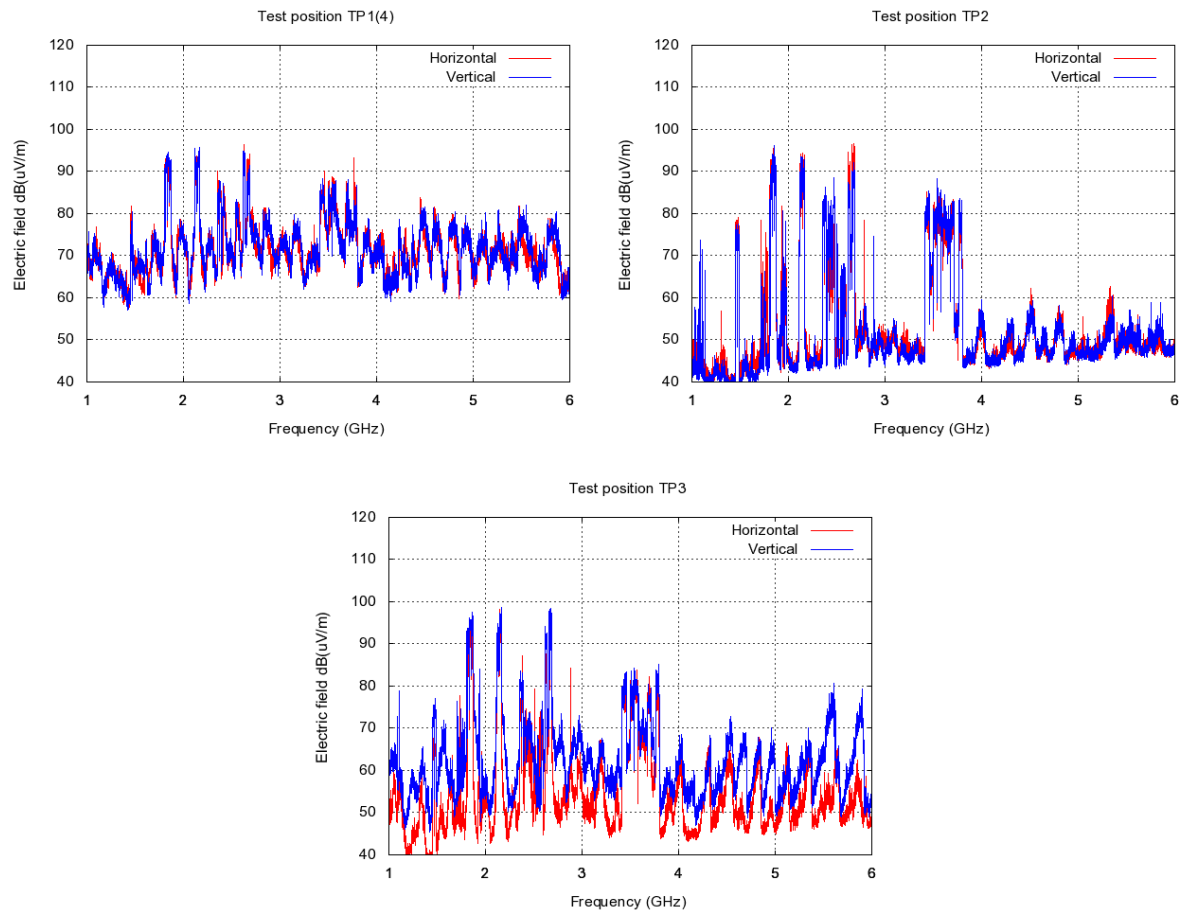


Figure 6. EMC site measurements at frequencies above 1GHz.

Analysis of these results is provided in Section 4.4.

4 ANALYSIS AND CONCLUSIONS

4.1 EN 50121-2:2006 measurements at test position TP1(4)

Detailed graphs providing the measurement results are shown in Section 3.1. The frequencies and magnitudes of the exceedances of the EN 50121-2 limits are summarised and analysed in Table 3.

Frequency Range	Comments		
9kHz to 30MHz	No exceedances due to railway or other assets		
30MHz to 1GHz	Frequency (MHz)	Exceedance (dB)	Comments
	97.7	23	Bona fide FM radio broadcast emissions
	98.9	1	
	102.0	25	
	106.1	19	
	137.95	5	Bona fide Satellite communication (Space to Earth) or Wide Area Paging system (POCSAG 1200) (see text)
	153.35	14	Bona fide Emergency Services emission (POCSAG radio pager)
	163.1	10	Bona fide PMR transmission (Bus inspectors, parking enforcement)
	178.75	1	Bona fide Programme Making and Special Events (PMSE) transmissions
	179.15	1	
	221.2 to 223.0	29	Bona fide DAB radio broadcast emissions
	224.8 to 228.3	32	
	391.0 to 393.6	5	Bona fide Emergency Services (TETRA) emission
	422.45	37	Bona fide Emergency Services, PMSE, Business Radio (PMR) or Defence related emissions
	425.2	16	
	445.7	15	
	453.6 to 462.3	20	Bona fide Emergency Services or PMSE transmissions (9 individual exceedances)
	534.3 to 541.5	8	Bona fide TV broadcast emissions
	550.9 to 565.5	6	
	575.7 to 589.8	6	
	598.3 to 605.8	6	
	758.1 to 767.9	38	Bona fide 4G/5G base station emissions
	768.5 to 777.6	16	
	778.3 to 787.7	7	Bona fide 4G mobile phone emission

Frequency Range	Comments		
30MHz to 1GHz	791.0 to 821.9	46	Bona fide 4G/5G base station emission
	844.5 to 845.2	2	Bona fide 4G/5G mobile phone emission
	853 to 855.9	19	Bona fide 4G base station emissions
	858.6	6	
	865.7 to 868.0	6	Bona fide 4G/5G base station emissions
	878.2	14	Bona Fide GSM-R (Uplink) emission
	895.1	0.8	Bona fide 4G/5G mobile phone emission
	914.8 to 915.2	34	Unidentified emission within an allocated Industrial, Scientific and medical (ISM) frequency band (this emission does not require a licence)
	921.9 to 924.3	32	Bona Fide GSM-R (Railway) base station emission
	925.1 to 960.1	51	Bona fide 4G/5G base station emission
	988.4	1	Bona fide aeronautical mobile or aeronautical radionavigation emission
	No exceedances due to railway assets (excepting bona fide GSM-R base station transmissions). There is a single exceedance of unknown origin within an ISM band at 915MHz (where no licence is required and no particular limits are set by UK Regulations).		

Table 3. Summary of exceedances of EN50121-2:2006 limits, test position TP1(4). Relevant radio services have been compiled from the information provided in [6, 7, 8 and 9].

The vast majority of the emissions or exceedances seen in Section 3.1 are at frequencies that are attributable to bona fide transmissions (e.g. MW broadcasts at ~1MHz, SW broadcast at ~11MHz – 27MHz, FM broadcast at ~100MHz, DAB radio at ~225MHz, Terrestrial TV at ~550MHz, mobile phones and their base stations at ~760MHz – 960MHz, in addition to a number of PMR, Emergency Services TETRA/paging transmissions, the GSM-R [railway related] system and aeronautical related radio services).

The 5dB exceedance seen at 137.95MHz was present in only a single data file out of 500 recorded; all of the other 499 data files showed signals at this frequency that were at least 36dB below the limit line. The transmission was therefore brief in nature and certainly less than 2s in duration. This frequency band has been allocated to space to earth satellite communications by the UK FAT [6], and indeed there are numerous examples of LEO and other satellites that have historically used this frequency on the Internet (many of the satellites are now defunct). However, it would be slightly unusual for a satellite to

broadcast with a level of power that would breach the EN50121-2:2006 limit, albeit at the most stringent limit (for a 750V DC tramway) considered in this document, and with only a 5dB exceedance. Instead, it is noted that the frequency of 137.95MHz is within 25kHz of a frequency (137.975MHz) used by the nationwide Wide Area Paging (POCSAG 1200) system used by the emergency services. Since 25kHz is less than half the 120kHz bandwidth used to carry out the measurements (see Table 1 of Section 2.2), it is most likely that the exceedance is due to a POCSAG paging transmission (a transmission at 137.975MHz will be captured by a receiver operating with 120kHz bandwidth and centred on 137.95MHz).

The only exceedance (by 34dB) of unknown origin is due to an isolated (line) emission at 915MHz. Examination of the relevant data files reveals that this exceedance is not due to an isolated event. The exceedance is persistent over an 8 minute period, with an average value of 22dB (vertical polarisation) and 20dB (horizontal polarisation). Indeed, the horizontal polarisation exceedance was permanent with a minimum value of 2.6dB. Although there are generally no restrictions on the level of emissions that may be produced at ~915MHz (this frequency is within an ISM band for which no licence is required for transmission), there is generally a 4W ERP limit on transmit power imposed by OFCOM for RFID equipment operating in the frequency band 916.1MHz - 918.9MHz [10]. The maximum field level observed at 915MHz was 95.1dB($\mu\text{V}/\text{m}$) or 56mV/m. Given that even sensitive radio receiver apparatus that is compliant with the relevant ETSI standards will possess a minimum level of immunity to (out of reception band) radiated emissions of 3V/m, there will be an immunity safety margin to interference of at least $20 \log_{10}(\frac{3}{0.056}) = 35\text{dB}$. This generally indicates that the exceedance at 915MHz will not be problematic. The highest overall exceedance of the EN 50121-2:2006 limit was a value of 51dB, a field level of 111dB($\mu\text{V}/\text{m}$) or 0.355V/m at 959.4MHz. This emission was due to a *bona fide* 4G or 5G mobile phone base station. Again, it is noted that this field level is 19dB below the threshold immunity level of 3V/m at which radiated emissions might be capable of causing electromagnetic interference (EMI) to even sensitive radio receiver apparatus. This (licensed) exceedance, though large, is therefore unlikely to be problematic.

It is of interest to note that the highest magnetic field recorded (~42dB[$\mu\text{A}/\text{m}$] at ~198kHz, a BBC Radio 4 LW transmission) is approximately 88dB below the minimum

test level used for 50Hz magnetic fields (3A/m or 130 dB[μ A/m]), for RCLI (domestic grade) apparatus. Although the frequencies here are not the same, making the comparison somewhat unfair, there is still a very large gap (four orders of magnitude) between the immunity level and the emissions level. This indicates generally that EMC problems are unlikely.

Similarly, the maximum 42dB(μ A/m) level of emissions at 198kHz is 89dB lower than the maximum level of field (3.68A/m or 131dB[μ A/m]) permitted by the ICNIRP 1998 guidelines [11] and UK CEMFAW Regulations 2016 [12], at 198kHz (note that in this case the levels compared are specified at the *same* frequency). The risks to human health due to exposure to low frequency EMF from the railway/buildings are therefore expected to be low. (Note that a full EMF survey was not undertaken; the procedure involved in assessing the EMF threat is not as simple as the above analysis suggests and involves taking into account further frequencies below 9kHz. Nevertheless, there is a large safety margin for the frequencies that were measured. Similarly, the maximum electric field level of 0.355V/m at 959.4MHz is a large margin [42dB] below the maximum value of exposure permitted [42.6V/m at 959.4MHz] for human beings by the ICNIRP 1998 guidelines and the UK CEMFAW Regulations).

4.2 EN 50121-2:2006 measurements at test position TP2

Detailed graphs providing the measurement results are shown in Section 3.2. The frequencies and magnitudes of the exceedances of the EN 50121-2 limits are summarised and analysed in Table 4.

Frequency Range	Comments		
9kHz to 30MHz	No exceedances due to railway or other assets		
30MHz to 1GHz	Frequency (MHz)	Exceedance (dB)	Comments
	89.25, 91.5, 93.7	5, 4, 1	Bona fide FM radio broadcast emissions
	97.6, 99.0, 101.1	16, 1, 2	
	102.0, 106.1	18, 13	
	152.95 to 153.4	4	Bona fide Emergency Services emission (POCSAG radio pager)
	166.4	1	Possible sonobuoy (Channel 22) or Lancashire ambulance service PMR repeater

Frequency Range	Comments		
30MHz to 1GHz	179.15	1	Bona fide Programme Making and Special Events (PMSE) transmissions
	216.6	0.5	
	221.3 to 222.9	21	Bona fide DAB radio broadcast emissions
	224.8 to 228.3	28	
	392.1 to 393.6	6	Bona fide Emergency Services (TETRA) emission
	422.45	22	Bona fide Emergency Services, PMSE, Business Radio (PMR) or Defence related emissions
	425.2	1	
	446.1	8	Bona fide Defence related emission
	453.3 to 461.5	13	Bona fide Emergency Services or PMSE transmissions (6 individual exceedances)
	534.2 to 541.8	12	Bona fide TV broadcast emissions
	550.2 to 565.8	11	
	574.3 to 589.9	11	
	598.3 to 605.9	10	
	758.2 to 767.9	30	Bona fide 4G/5G base station emissions
	768.5 to 777.6	16	
	778.3 to 787.6	8	Bona fide 4G mobile phone emission
	791.2 to 820.7	30	Bona fide 4G/5G base station emission
	844.6 to 845.7	13	Bona fide 4G/5G mobile phone emission
	847.0 to 848.0	11	
	853.4 to 860.4	25	Bona fide 4G base station emission or 4G/5G mobile phone emission
	867.3	0.5	Bona fide 4G/5G base station emissions
	868.2	5	
	869.6	20	
	878.2	10	Bona Fide GSM-R (Uplink) emission
	893.7	10	Bona fide 4G/5G base station emission or 4G/5G mobile phone emission

Frequency Range	Comments		
30MHz to 1GHz	914.8 to 915.1	28	Unidentified emission within an allocated Industrial, Scientific and medical (ISM) frequency band (this emission does not require a licence)
	921.9 to 924.5	30	Bona Fide GSM-R (Railway) base station emission
	925.4 to 960.0	40	Bona fide 4G/5G base station emission
	No exceedances due to railway assets (excepting bona fide GSM-R base station transmissions). There is a single exceedance of unknown origin within an ISM band at 915MHz (where no licence is required and no particular limits are set by UK Regulations).		

Table 4. Summary of exceedances of EN50121-2:2006 limits, test position TP2. Relevant radio services have been compiled from the information provided in [6, 7, 8 and 9].

As with TP1(4), the vast majority of the emissions or exceedances seen in Section 3.2 are at frequencies that are attributable to bona fide transmissions (e.g. MW broadcasts at ~1MHz, FM broadcast at ~100MHz, DAB radio at ~225MHz, Terrestrial TV at ~550MHz, mobile phones and their base stations at ~760MHz – 960MHz, in addition to a number of PMR, Emergency Services TETRA/paging transmissions and the GSM-R [railway related] system). There is a similar persistent exceedance (by 28dB) of unknown origin at 915MHz. The highest overall exceedance of the EN 50121-2:2006 limit was a value of 40dB, a field level of 100.8dB(μ V/m) or 0.110V/m at 957.2MHz. This emission was due to a *bona fide* 4G or 5G mobile phone base station. It is noted that this field level is 29dB below the threshold immunity level of 3V/m at which radiated emissions might be capable of causing electromagnetic interference (EMI) to even sensitive radio receiver apparatus. This high exceedance is therefore unlikely to be problematic.

4.3 EN 50121-2:2006 measurements at test position TP3

Detailed graphs providing the measurement results are shown in Section 3.3. The frequencies and magnitudes of the exceedances of the EN50121-2 limits are summarised and analysed in Table 5.

Frequency Range	Comments		
9kHz to 30MHz	Frequency (MHz)	Exceedance (dB)	Comments
	0.1274	2	Bona fide pulsed radionavigation emissions. (It is noted that there was only one single exceedance in the 500 data sets. Of the remaining data sets, the next highest signal at this frequency was a large factor of 26 dB lower. Such observations are consistent with a pulsed system.)
	0.909	0.5	Bona fide MW (AM) broadcast. Also present without exceedance at TP1(4) and TP2. Exceedance is marginal.
	17.814	7	Bona fide SW broadcast
	21.957	1	Bona fide Defence related transmission (aeronautical mobile). (It is noted that there was only one single exceedance over the 500 data sets. Of the remaining data sets, only 4 data points were within 15dB of [under] the limit. All other data were a large factor [exceeding 30dB] below the limit. Such observations are consistent with an infrequent transmission.) Exceedance is marginal.
	No exceedances due to railway assets		
30MHz to 1GHz	Frequency (MHz)	Exceedance (dB)	Comments
	93.7	2	Bona fide FM radio broadcast emissions
	97.75	10	
	102.0	11	
	106.1	17	
	153.05	6	Bona fide Emergency Services emissions (POCSAG radio pager)
	153.35	5	
	163.1	1	Bona fide PMR transmission (Bus inspectors, parking enforcement)
	179.15	3	Bona fide Programme Making and Special Events (PMSE) transmission
	221.2 to 222.9	22	Bona fide DAB radio broadcast emissions
	224.8 to 228.2	19	
	391.5 to 393.6	5	Bona fide Emergency Services (TETRA) emission
	422.0 to 422.9	20	Bona fide Emergency Services, PMSE, Business Radio (PMR) or Defence related emissions
	425.1	2	
	445.5	10	

Frequency Range	Comments		
30MHz to 1GHz	454.3, 458.7 and 462.3	3, 2 and 1	Bona fide Emergency Services or PMSE transmissions (3 individual exceedances)
	534.5 to 540.6	8	Bona fide TV broadcast emissions
	550.2 to 564.8	9	
	574.5 to 588.0	6	
	598.5 to 605.8	4	
	721.85	1	Bona fide TV broadcast emission or 4G/5G mobile phone emission
	758.2 to 767.9	26	Bona fide 4G/5G base station emissions
	768.5 to 777.6	15	
	778.3 to 787.7	6	Bona fide 4G mobile phone emission
	791.2 to 820.8	30	Bona fide 4G/5G base station emission
	844.7 to 850.9	17	Bona fide 4G/5G mobile phone emission
	853.8 to 860.2	20	Bona fide 4G base station emissions
	868.0 to 869.7	16	Bona fide 4G/5G base station emissions
	878.3	22	Bona Fide GSM-R (Uplink) emission
	890.8 to 902.2	16 to 2	Bona fide 4G/5G mobile phone emissions (5 individual exceedances)
	914.8 to 915.1	21	Unidentified emission within an allocated Industrial, Scientific and medical (ISM) frequency band (this emission does not require a licence)
	921.9 to 924.5	29	Bona Fide GSM-R (Railway) base station emission
	925.4 to 960.0	38	Bona fide 4G/5G base station emission
	No exceedances due to railway assets (excepting bona fide GSM-R base station transmissions). There is a single exceedance of unknown origin within an ISM band at 915MHz (where no licence is required and no particular limits are set by UK Regulations).		

Table 5. Summary of exceedances of EN50121-2:2006 limits, test position TP3. Relevant radio services have been compiled from the information provided in [6, 7, 8 and 9].

As with TP1(4) and TP2, the vast majority of the emissions or exceedances seen at TP3 are at frequencies that are attributable to bona fide transmissions (e.g. MW, SW, FM, DAB radio, Terrestrial TV broadcasts, mobile phones and their base stations, in addition to a number of PMR, Emergency Services TETRA/paging transmissions and the GSM-R [railway related] system). There is similarly a persistent exceedance (by 21dB) of unknown origin at 915MHz. The highest overall exceedance of the EN 50121-2:2006 limit was a value of 38dB, a field level of 98.7dB(μV/m) or 86.1mV/m at 947.2MHz. This emission was due to a *bona fide* 4G or 5G mobile phone base station. This field level is

31dB below the threshold immunity level of 3V/m at which radiated emissions might be capable of causing electromagnetic interference (EMI) to even sensitive radio receiver apparatus, and is therefore unlikely to be problematic.

4.4 Additional high frequency measurements

Detailed graphs providing the measurement results are shown in Section 3.4. A commentary on the measurement results is provided in Table 6.

Frequency Range	Comments		
1GHz to 2GHz	Frequency (MHz)	Max Level (dB[μV/m]) and TP	Comments
	1018 to 1146	79 (TP3)	Aeronautical radionavigation
	1452 to 1491	82 (TP1[4])	Fixed links, broadcasting satellite services
	1708 to 1782	78 (TP2)	Bona fide 3G/4G/5G mobile phone emissions
	1804 to 1878	97 (TP3)	Bona fide 3G/4G/5G mobile phone base station emissions
	1921 to 1978	84 (TP3)	Bona fide 3G/4G/5G mobile phone emissions
	No limits applicable		
2GHz to 3GHz	2110 to 2170	99 (TP3)	Bona fide 3G/4G/5G mobile phone base station emissions
	2350 to 2389	90 (TP1[4])	Bona fide 4G/5G mobile phone base station and 4G/5G mobile phone emissions
	2400 to 2482	88 (TP2)	Bona fide WiFi emissions
	2620 to 2688	98 (TP3)	Bona fide 4G/5G mobile phone base station and 4G/5G mobile phone emissions
	2780	78 (TP2)	Aeronautical radionavigation and radio location
	2881	84 (TP3)	
	No limits applicable		
3GHz to 6GHz	3410 to 3800	93 (TP1[4])	Bona fide 5G mobile phone base station and 5G mobile phone emissions
	No limits applicable		

Table 6. Commentary on high frequency measurements (1GHz – 6GHz). Relevant radio services have been compiled from the information provided in [6, 7, 8, 9 and 13]

The graphs shown in Section 3.4 indicate considerable activity in the radio spectrum above 1GHz, which is perhaps to be expected given the urban environment. The highest individual spectral emission was at 2168.0MHz, a value of 98.6dB(μV/m) at TP3. That is, the highest recorded electric field level was 85.0mV/m. If the relevant UK designated

generic RCLI and industrial immunity standards EN 61000-6-1:2007 and EN 61000-6-2:2005 are examined, it is found that both standards specify a minimum immunity to radiated emissions at a level of 1V/m in the frequency range 2.0GHz – 2.7GHz. Since this level of immunity is 21dB higher than the highest field level seen over the three test positions, interference to such apparatus is deemed to be unlikely.

4.5 Conclusions

Measurements made at Test location TP1(4) and TP2 showed levels of electromagnetic fields that were compliant with the requirements of UK designated standard EN 50121-2:2006 in the frequency range 9kHz to 30MHz. For TP3, there was a single marginal exceedance of 2dB in this frequency range, at a frequency of 127.4kHz. However, this exceedance was present in only one of 500 data sets encompassing this frequency, captured over a time period exceeding 8 minutes. All other data sets exhibited signals at this frequency that were at least 24dB below the EN 50121-2:2006 limit. Such an observation is consistent with the infrequent pulsed nature of the radionavigation service allotted to this frequency range by the UK FAT [6]. Indeed, the infrequent nature of the observation is also consistent with the fact that this emission was not observed at either TP1(4) or TP2. Similarly, there was a marginal exceedance of the EN 50121-2:2006 limit at TP3 in one single data set out of 500 measured, at a frequency of 21.957MHz. This observation is also consistent with the expected infrequent nature of the defence related (aeronautical mobile) transmissions allotted to this frequency by the UK FAT.

Although there were a number of exceedances of the EN 50121-2:2006 limits in the frequency range 30MHz to 1GHz, these were nearly all attributable to *bona fide* radio services, including the GSM-R system used for railway signalling and telecommunications purposes. The only anomalous exceedance was due to an unknown and persistent source at 915MHz which was present at all three sites, with a maximum field strength of 56mV/m at TP1(4). However, this field level is a large margin of 35dB below the radiated immunity level (3V/m) of even sensitive radio receiver apparatus and is unlikely to cause EMC issues. It is possible that these emissions are due to a 5G mobile phone handset operating on one of the channels n8, n81, n93 or n94, or a 4G handset operating on channel 8. However, the emission is at the very edge of the allocated frequency bands for these channels and there may be some other explanation for the emissions. Assuming

that the 915MHz source is licensed, the site can be considered to be compliant with EN 50121-2:2006.

With regard to electromagnetic emissions above a frequency of 1GHz, a comparatively large number of spectral lines were observed. However, the maximum field level seen (which was at TP3) was not excessive at 85.0mV/m (at ~2.168GHz, either a 3G, 4G or 5G mobile phone base station) and is unlikely to result in EMC issues.

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APPENDIX 1 - LIST OF EQUIPMENT USED

Item	Model	Identifier
Receiver	Keysight/Agilent MXE N9038A	C0339
Loop Antenna	ETS Lindgren 6511	C0227
Loop Antenna	ETS Lindgren 6512	C0226
Active Receive Antenna	York EMC Services ARA01	C0750
Horn Antenna	ETS Lindgren	C0509

APPENDIX 2 - PARALLEL & PERPENDICULAR ORIENTATIONS

Figure 7 presents the antenna orientations referred to as “facing” (“parallel” below) and “perpendicular” in this document.

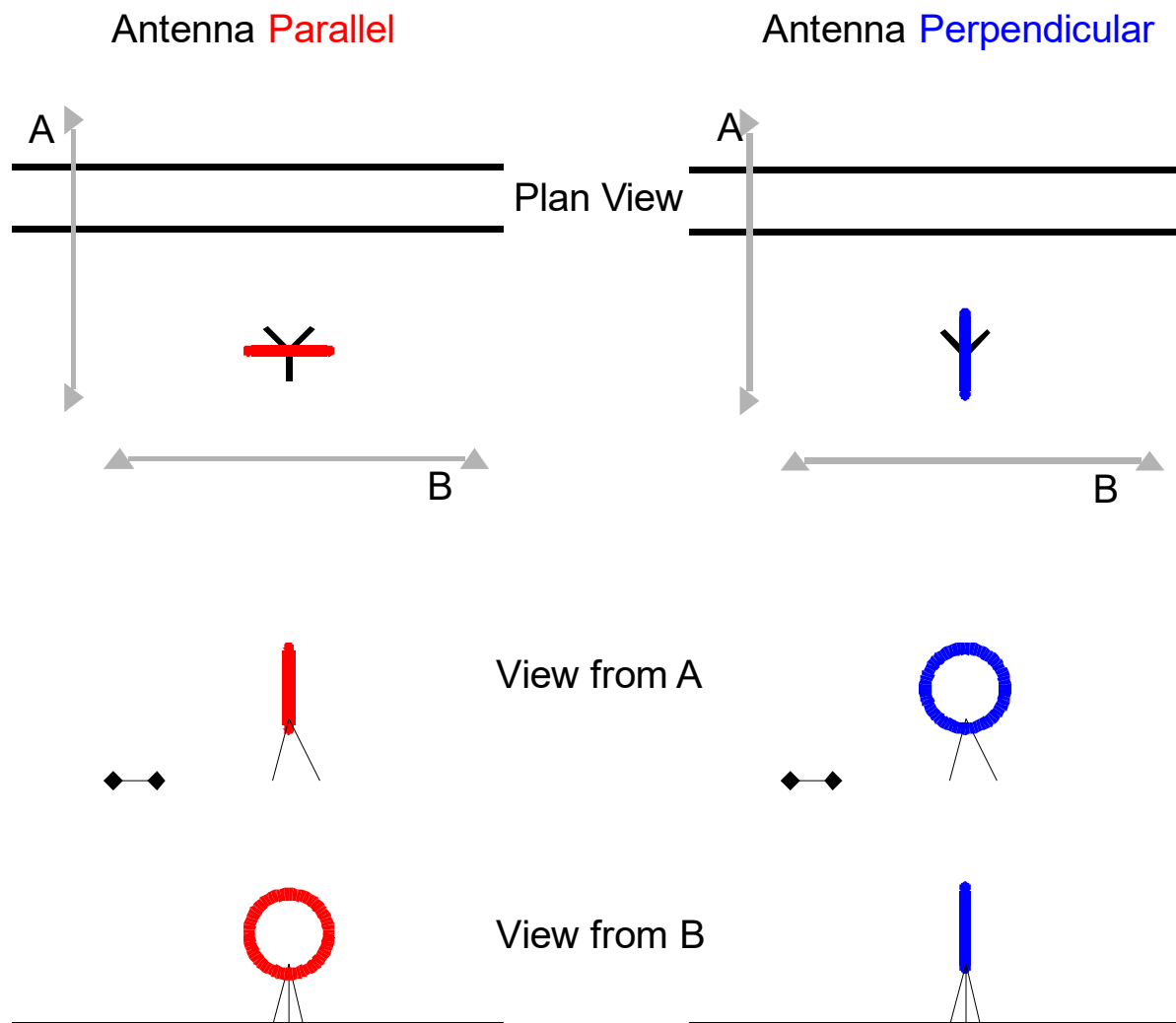


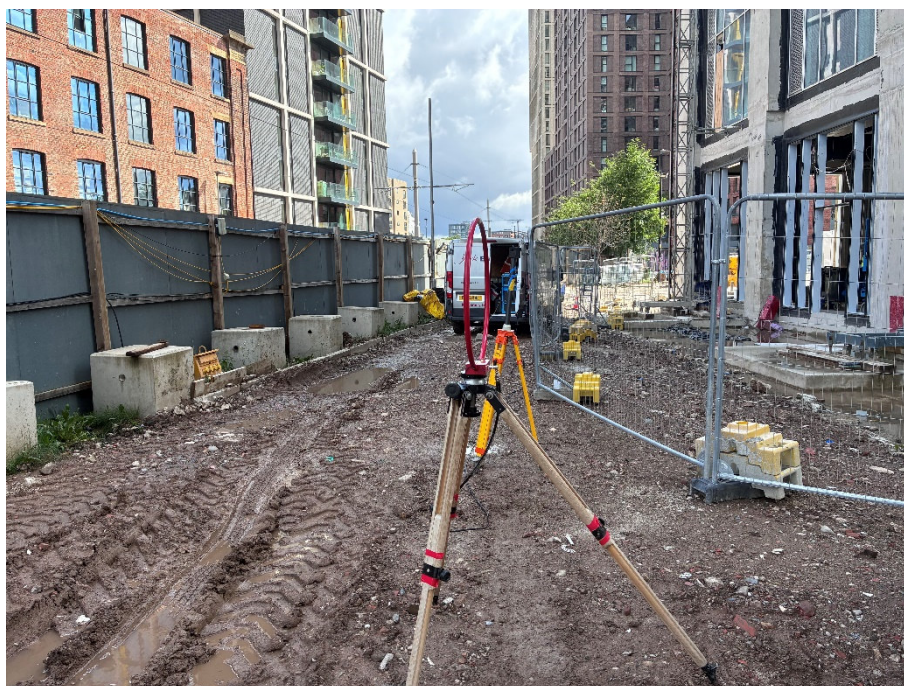
Figure 7. Definitions of facing/parallel and perpendicular antenna facings used in this document.

APPENDIX 3 – MEASUREMENT PHOTOGRAPHS

Test Position TP1(4):



Top: ARA antenna at 10m from building. Bottom: Horn antenna at ~7m from building.

Test Position TP2:

Top: Loop antenna at 10m from railway. Bottom: ARA antenna at 10m from railway.

Test Position TP3:

Top: ARA antenna at 10m from railway. Bottom: Horn antenna at 10m from building.