RPA
Railway Procurement Agency

METRO NORTH
ORAL HEARING

PROOF OF EVIDENCE

John McCauley

Radiation and Stray Current

Thursday 9th April 2009

Metro North Oral Hearing

Proof of Evidence

Electromagnetic Compatibility EMC

John McAuley

1.0 INTRODUCTION

1.1 *Name and Qualifications*

1.1.1 My name is John McAuley.

1.1.2 I am an Electrical and Electronic Engineer and have a Degree in Engineering, a Masters Degree in Electronics and am a Member of the Institute of Engineers in Ireland. I am based at Compliance Engineering Ireland's offices in Ashbourne, Co Meath.

1.1.3 I am Chairman of the Electrotechnical Council of Ireland committees on Electromagnetic Compatibility (EMC) and Electromagnetic Fields (EMF) and Human Health which provide the national position on these subjects. As the Irish lead delegate I attend committees of the European standards agency CENELEC TC210 on EMC and TC106X on EMF.

1.1.4 I am the Managing Director of Compliance Engineering Ireland Ltd (CEI). CEI is currently the only accredited electrical test laboratory in Ireland and carries out electromagnetic testing, electrical safety testing, Machinery Directive assessments and radiation hazards surveys. CEI is a member of the European Community Association of EMC Notified Bodies (ECACB) and the Radio and Telecommunications Terminal Equipment Compliance Association (RTTECA).

1.2 *Experience*

1.2.1 I have specialised in the subjects of EMC and radio frequency engineering. I have been a designer and consultant in these subjects for more than twenty years. I have managed a number of local and international projects modelling the coupling between railway systems, the local environment, trackside signalling and telecommunications, and the consideration of the

effects of railway and other radio communication transmitters on co-located equipment.

1.2.2 I carried out extensive testing of the Luas red line as part of the system qualification and to verify the absence of interference with medical laboratories routed along the route. In addition, I measured the coupling of the rail system and HV power lines into signalling circuits.

1.2.3 I have been the lead assessor of a number of electric and diesel train certification programmes including verification of the EMC with lineside signalling systems. I have carried out a number of EMC investigations on board trains to provide remediation of Electromagnetic Interference issues where internal components were exhibiting poor immunity to electrical noise generated by other on board systems.

1.2.4 I have also supervised the EMC and electrical safety compliance testing of over one thousand electrical and electronic products. I have designed and installed a number of successful radiofrequency and power frequency magnetic field shielding systems.

1.2.5 I provide courses on the subjects of EMC, electromagnetic fields and human health, machinery assessments and electrostatics.

1.3 *Role in Project*

1.3.1 I have peer reviewed the EIS and following the delivery of the railway order applications I have carried out investigations in relevant areas to determine the implications for sensitive receptors at hospitals, health clinics, universities, commercial centres and residential areas. I have undertaken computer simulations of the emissions and compared the results to the immunity levels of receptor equipment determined from mandatory

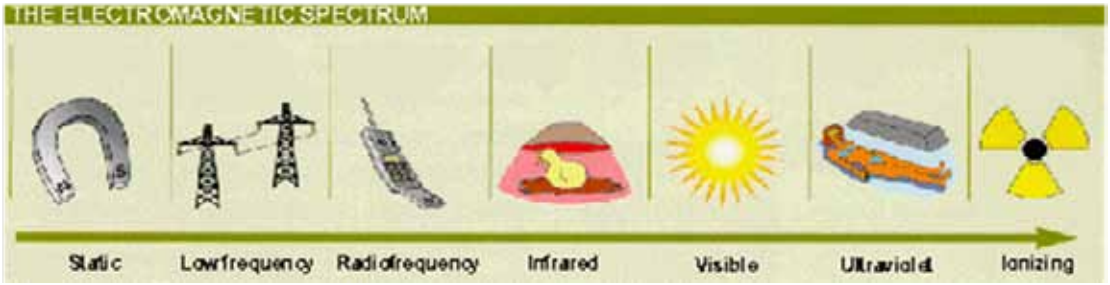
regulations and measurements on similar systems located adjacent to existing rail systems.

1.3.2 The scope of my evidence concerns the impacts of EMC and stray current from the construction and operation of Metro North system.

2.0 ELECTROMAGNETIC COMPATIBILITY

2.1 *General Introduction*

2.1.1 The Electromagnetic Spectrum covers a very wide frequency range and there are many aspects of it with which we are familiar and exposed to on a daily basis. The following figure shows the Electromagnetic Spectrum and the relationship between the different aspects of the proposed system.



2.1.2 The electromagnetic spectrum is so called because it comprises electric and magnetic fields, hence the term “electromagnetic”. At the beginning of the electromagnetic spectrum we have static fields. The most common static field is the earth’s magnetic field in which we are all immersed at all times. As we move up the electromagnetic spectrum we reach the frequency used by electricity (50 Hz) and we are also surrounded by fields of this type as they are caused by our house wiring. At higher frequencies we enter the radiofrequency range. These are so called as they radiate and pass freely through the air. We rely on radiofrequency waves to receive TV and radio. There are also many communications systems using these frequencies for mobile phones, air traffic control, Garda radio etc.

2.1.3 As the electromagnetic spectrum is a scarce resource and is used for safety critical applications it is carefully protected by EU Directives. This means that

all equipment placed on the EU market, including rail systems, must meet strict emissions limits.

2.1.4 The proposed Metro system will generate electric and magnetic fields which can be categorised in three ranges:

· Direct Current (d.c.) fields, generated by the traction system which powers the trams

· Alternating Current (a.c.) fields , generated by the electricity drawn by the system from the ESB and used to power the equipment at all the stops

· Radiofrequency fields, generated by the radio systems used for communications and also as a by-product of every electrical and electronic systems such as the train drive system

2.1.5 I will now discuss each of the three ranges, looking in detail at how they are produced, examining the Metro North route for any receptors which might potentially be vulnerable to interference from them and assessing the overall risk to each receptor.

3.0 DC FIELDS

3.1 *Sources of DC Fields*

3.1.1 The magnitude of d.c. electric fields are dependent on the line voltage, which in the case of Metro North is nominally 750V dc. The magnitude of d.c. magnetic fields depend on the current drawn by the vehicle, which will vary considerably throughout a vehicle's journey.

3.1.2 The electric fields are very small as they only exist between the overhead line and ground. The line voltage associated with the proposed system is relatively low and electric fields are easily attenuated by common materials in walls. Much larger naturally occurring electric fields exist in the environment.

3.1.3 The magnetic field intensity depends upon three factors:

· The traction current drawn by the vehicle. The value of this current is determined by technical performance and operating conditions, such as alignment, gradients, curvature, train acceleration and maximum speed, train headway, train weight and passenger load

· The distance between the source of magnetic fields (for example, the overhead conductor wire) and the potential recipients

· The physical structure of the equipment, including the track, overhead traction equipment and the feeding and return current cables

3.1.4 The magnitude of magnetic fields arising from the traction power supply systems and electricity supply systems decrease at a rate equal to the square of the distance. That means if you are twice as far away from the source, the field strength will have decreased by a factor of four. Therefore,

these fields are likely to have a minimal impact on potential receptors along the route.

3.1.5 It should be noted that the earth's magnetic field is 50 microTesla which is much larger than any fields produced by Metro North. Therefore, even on a worst case basis no receptor will exposed to levels greater than this.

3.2 *DC Field Receptors*

3.2.1 The equipment types that are most susceptible to emissions from electric railways are those that use electron beam technology. The most common example of this is the traditional cathode ray tube type (CRT) display such as TVs and computer monitors. It should be noted that the cathode ray tube type of computer monitor is virtually obsolete having been replaced by flat screen displays. Some special medical and scientific equipment also use electron beam technology. The magnetic field that is emitted by the rail system, if sufficiently strong, can modulate the electron beam and cause distortion. On computer monitors the picture is formed by an electron beam and any movement of the beam means that colour distortion or a movement in the picture can occur. For rail situations the system only emits a magnetic field for a short period of time every few minutes as a train leaves a station. As a result, unless the interference is particularly strong it usually goes unnoticed.

3.2.2 Medical equipment types that are known to be potentially susceptible to magnetic fields are Linear Accelerators, CT Scanners and Scanning Electron Microscopes. To a lesser extent X Ray machines, Nuclear Magnetic Resonance Spectroscopy, and Magnetic Resonance Imaging (MRI) are also susceptible. Again the interference takes the form of beam movement. The

effect is dependent on the application for which the particular equipment is being used. For example, state of the art scanning electron microscopes used for nanotechnology research are more sensitive to interference than those used in hospital laboratories.

3.2.3 The magnetic field emissions will be controlled by standards listed under EU Directives which means that there will be compliance with human health guidelines.

3.3 *Risk to Receptors from DC fields*

3.3.1 The risk to receptors from d.c electric fields is negligible as these fields only exist between the overhead line and the ground.

3.3.2 The risk to receptors from d.c magnetic fields is more complicated. As noted above, the fields die away very quickly with distance, so that for the vast majority of receptors along the route there will be no risk whatsoever.

3.3.3 For the extremely sensitive equipment found near the line at Mater and Rotunda, a more detailed study has been undertaken, which is described shortly. In brief, I am satisfied that the d.c. magnetic fields produced by Metro North will not cause any adverse effects at these sensitive locations.

4.0 DC STRAY CURRENT

4.1 *Sources of Stray Current*

4.1.1 One additional item to be addressed when dealing with electric railways is that some electric current may leave the normal rail return path and enter the ground, coming back to the rails at some further point along the line. Such current is known as stray current. If there happens to be a metal pipe in the ground nearby, the current may enter the pipe and flow through it for some distance before exiting to come back to the rails. The point where the current enters and leaves may become subject to corrosion.

4.2 *Stray Current Receptors*

4.2.1 The primary receptors of stray currents are long underground based conductive systems such as telecommunications lines, high and medium voltage cables, water pipes and gas pipes. Non-conductive systems, for example, plastic pipes, are not affected. The effects are not immediately noticeable and the effect of the stray currents is to cause long term corrosion.

4.3 *Risk to Receptors from Stray Currents*

4.3.1 Stray current is a well known phenomenon and standards have been developed to mitigate the potentially damaging effects that it might otherwise cause. The principle standard is European Standard EN 50122-2, which sets out a number of ways for dealing with the issues:

· Ensure that the track is constructed with a high rail to earth resistance, to prevent stray current from happening in the first place

· Implement a monitoring regime to prove that the rail to earth resistance remains high or that detects any stray current that may be generated. Special attention is to be paid to any areas where vulnerable equipment in the ground is known to be located

4.3.2 Metro North is being designed to a level that imposes even higher quality standards than those demanded by EN 50122-2 and, in particular, imposes rail to earth resistance target levels at least 10 times higher than those in the EN standard. It also requires that the upper layer of reinforcement in the track support structure is bonded together under the running rails as a stray current collection mat and that any stray current generated is channelled to a collector cable to prevent it from reaching any vulnerable equipment.

4.3.3 Furthermore, a Code of Practice has been developed with the relevant utility companies which will be strictly adhered to in the construction and subsequent operation of Metro North. This Code of Practice sets out both the ongoing consultation measures that must be undertaken to identify any potentially vulnerable infrastructure and the measures that must be in place to continually monitor that the traction return system is performing correctly.

4.3.4 The combination of very high construction standards and a rigorous management strategy will ensure that stray current will be controlled to a safe and harmless level.

5.0 POWER FREQUENCY A.C. (50 HZ) FIELDS

5.1 *Sources of Power Frequency Fields*

5.1.1 We will now deal with the next emissions range which is alternating current fields as caused by the electricity circuits. The mains electricity in Ireland operates at 50 Hz, causing electric and magnetic fields at this frequency.

5.1.2 Metro North will take power from the ESB network at 110kV at three locations on the route. It will then utilise a 20 kV ring running alongside the tracks to distribute this power throughout the line.

5.1.3 The 20kV ring calls into a number of substations located at regular intervals throughout the line and is transformed down to 400V or 230V to power the electrical equipment needed to operate the system, such as lifts, escalators, ventilation fans and the like.

5.2 *Power Frequency Field Receptors*

5.2.1 The potential receptors of 50 Hz fields are largely the same as those for d.c. fields listed above.

5.3 *Risk to Receptors from Power Frequency Fields*

5.3.1 The power frequency electric fields are negligible as they are completely contained within the various cables that carry the power. There will therefore be no risk arising from these a.c. electric fields.

5.3.2 The magnetic fields arising from the 110kV connections, the 20 kV ring circuit and the lower voltages will also tend to be negligible. This is because the phase and return currents are all grouped together within a single cable run and therefore the magnetic fields from the phases are effectively cancelled by those from the returns.

5.3.3 In very close proximity, to a substation, within one metre, there may be elevated levels of 50 Hz magnetic fields. From an EMC and safety point of view the location of the sub stations relative to any possible sensitive receptor have been reviewed and I am satisfied that the emissions will not exceed the immunity levels of nearby receptors as defined by standards listed under the EMC Directive 2004/108/EC and the safety limits referenced under the Low Voltage Directive 2006/95/EC.

5.3.4 The exposure scenario for 50 Hz magnetic fields from Metro North are projected to be much lower than those from high voltage overhead power lines. For magnetic fields, the field strength directly below high voltage power lines is in the range of 5 to 50 microTesla (µT) whereas the emissions from the proposed scheme will typically not exceed 1 µT. The 50 Hz exposure levels along the route of the line will be similar or lower than those from common on street power cables.

5.3.5 The power frequency magnetic fields emitted from Metro North will not therefore cause any interference to neighbours alongside the line.

6.0 RADIOFREQUENCY FIELDS

6.1 *Sources of Radiofrequency Fields*

6.1.1 Radiofrequency fields, from 9 kHz to 1 GHz, will be caused by two primary sources on Metro North:

- licensed two way radio used by the system and
- emissions from the vehicles and signalling systems

6.2 *Radiofrequency Field Receptors*

6.2.1 The possible receptors of radiofrequency fields extend to virtually all electronic equipment. Radiofrequency fields, if sufficiently strong, can interfere with the operation of the equipment.

6.3 *Risk to Radiofrequency Field Receptors*

6.3.1 The radiofrequency emissions from the rail system are controlled by the EMC Directive 2004/108/EC which references the EN 50121 series of harmonised standards (parts 1-5). This ensures that radio and TV receptors along the route will not be affected. Mandatory compliance with EU Directives on EMC and Radio and Telecommunications Terminal Equipment (1999/5/EC) also ensures that EMF health limits are met. The EU directives are implemented in Irish legislation.

6.3.2 Prior to the introduction of the EMC Directive, which controls the emissions and the immunity of all products placed on the market, common examples of interference were noise bars on TV screens as caused by devices such as hairdryers and audible noise on a car radio as, for example, a motorcycle passed close to the antenna.

6.3.3 As the EMC directive ensures that all equipment has adequate immunity and as emissions from sources such as railways are controlled to low levels no interference from radiofrequency fields will arise.

7.0 RECEIVING ENVIRONMENT (BASELINE) AND POTENTIAL IMPACTS

7.1 *Introduction*

7.1.1 The following section describes the environment through which Metro North will run and assesses whether any electrical interference associated with the scheme. is likely. Areas which are mostly unlikely to have sensitive equipment are deeming to be of low functional value, while those with sensitive equipment are said to have medium, high or very high functional values, depending on the equipment and its usage.

7.2 *Belinstown to Airside Business Park*

7.2.1 This area is dominated by open greenfield areas where there are no EMC sensitive receptors. Some residential areas of low functional value, a categorisation based on the absence of sensitive receptors, exist between Estuary and Malahide Roundabout. St Finians Community College, located approximately 50m to the west of the alignment to the south of Seatown Roundabout, is of medium value and is adequately segregated to ensure absence from interference. Siemens Plant is also located in this area, close to Seatown stop. The Airside Business Park contains a number of office uses that are classified as being of medium function value and these areas are also adequately distant from the route to be free from interference.

7.3 *Airside Business Park to the northern boundary of Dublin Airport*

7.3.1 This area is dominated by open green spaces of very low functional value used for agriculture and recreation e.g. Forrest Little Golf Course. The Airside Retail Park is also located in this area and is of medium functional value; however it is located sufficiently distant from the proposed route to prevent any impact. To the south of the retail park is the Tara Winthrop

private health clinic which is categorised as of high functional value. The facility comprises a nursing care centre, which will be 70m from the development, does not contain sensitive receptors and will not be impacted. A number of residential areas in the vicinity of Pinnock Hill roundabout are also located in this section and have been classified as of low functional value because of the absence of sensitive receptors.

7.4 *The northern boundary of Dublin Airport to the southern boundary of Dublin Airport*

7.4.1 This area is dominated by open green spaces and airport landuses. Consultation with Dublin Airport has indicated that the airport has sensitive equipment on the premises. The threat to Dublin airport is from radio frequency emissions from the proposed rail system which could interfere with critical safety frequencies and has resulted in a high to medium functional value designation. The radiofrequency emissions from the rail system will be controlled to low levels by compliance with mandatory EU directives and as such the airport can be considered to be adequately protected and no additional mitigation measures are necessary.

7.5 *The southern boundary of Dublin Airport to Northwood*

7.5.1 This area is dominated by areas of low functional value e.g. open green spaces (such as sports grounds of Cumann Parnell and parts of Sillogue Golf Course and Sillogue Park) as well as the National Car Test Centre. There are also some limited areas of residential use. These areas have been designated as of low functional value and they are also adequately distant from the route to be free from interference.

7.6 *Northwood to Albert College Park*

7.6.1 This area is dominated by residential areas that have been classified of low functional value because of the absence of EMC sensitive receptors. A number of schools are also located on either side of Ballymun Road. Schools have been classified as being of medium functional value and in this case these are adequately distant from the route to be free from interference. A medical clinic is also located in the Civic Centre on Ballymun Road to the east of the alignment. The clinic comprises a number of General Practitioner surgeries that do not contain sensitive receptors and will not be impacted. An electricity station is also shown on the utilities drawings for this area. This station is of low functional value. No mitigation measures are necessary.

7.7 *Albert College Park to the Mater Hospital*

7.7.1 This area is dominated by residential areas with adequate segregation to have low functional value. Corpus Christi Girls National School on Home Farm Road, St. Patrick's College and the schools on the grounds of the college are also located in this area. Both of these facilities have good segregation and as the line is underground the electromagnetic interference (EMI) levels will be very low with no impact.

7.7.2 The Mater Public and Private Hospitals are located in this area and use sensitive equipment including Linear Accelerators and CT scanners which are potentially susceptible as they use electron bema technology.

7.8 *Mater Hospital to St. Stephen's Green*

7.8.1 The area to the south of the Mater Hospital is dominated by residential areas of low functional value because of the absence of EMC sensitive receptors. Moving south, the study area changes and commercial landuses of very low functional value become more common. To the south of the Mater Hospital,

two schools and a college are located on opposite sides of the alignment: all are adequately distant from the route to be free from interference. To the south of this is the Rotunda Hospital. At the time of preparing the EIS the details and specifications of the hospital sensitive equipment was not available. The only potentially sensitive equipment identified in the Rotunda Hospital was a scanning electron microscope (SEM).

7.8.2 To the southeast of the Rotunda, DIT is located on Marlborough Street and has been classified as of medium functional value as there may be sensitive receptors. The facilities are sufficiently segregated from the proposed scheme to result in low field strengths that will not impact on equipment located in these buildings. To the south of the Liffey, Trinity College is located to the east of the alignment. Consultation with this college has indicated that sensitive equipment is used on the premises but is sufficiently distant from the line not to be affected. The Royal College of Surgeons is also located to the west of St. Stephen's Green and is also too distant to be affected by magnetic fields. The area between the River Liffey and St. Stephen's Green is otherwise dominated by commercial landuses of low functional value. No mitigation measures are necessary.

8.0 DETAILED EXAMINATION OF SELECTED AREAS

8.1 *Background*

8.1.1 To assess EMI impacts in more detail, four representative typical cross sections were identified and examined in depth. One location is an 'at-grade' section and the other three locations are chosen within the tunnel section and close to sensitive receptors. Specific magnetic filed strengths have been predicted for these sensitive receptors.

8.1.2 The modelling was carried out assuming worst case conditions under normal operation which ensures that the conclusions reached have a good margin of compliance.

8.2 *Seatown Stop*

8.2.1 This location was chosen because the dwellings are close to the alignment.

8.2.2 The receptors show a low sensitivity to EMI, because usual household appliances are not sensitive to EMI as all of the products supplied to consumers are required to be compliant with EU Directives.

8.2.3 The Siemens plant located in this area is adequately distant from the route to be free from interference.

8.3 *Albert College*

8.3.1 The Metro North alignment crosses the Albert College Park area underground, in a tunnel within a depth lower than 10 m.

8.3.2 DCU is located in this area and as a university was classified as medium functional value. The university buildings are well segregated from the line and considering that all installed equipment is required to be compliant with the EMC Directive 2004/108/EC there will be no impact from emissions from the proposed development.

8.4 *Mater Hospital*

8.4.1 Both of the Mater Hospitals (Private and Public) are close to the alignment.

8.4.2 The alignment is in a tunnel section, which is 17 metres below the surface. The Mater Stop of the Metro North scheme is directly situated under the hospital sites within 17 metres.

8.4.3 The Mater Private and Public Hospitals are considered to be highly sensitive to EMI due to the purposed medical equipment (linear accelerators, CT scanners x-ray, gamma cameras).

8.4.4 A study has been completed on the levels of fields emanating from the proposed scheme including modelling of the emissions and measurements carried out on the existing light rail infrastructure in Dublin. In addition, a survey was carried out at another hospital in the US where sensitive items of equipment including a similar Linear Accelerators and CT scanner is exposed to higher levels of magnetic fields. This study has shown that there is an adequate margin between the emissions from the proposed scheme and the immunity thresholds for the sensitive equipment. at the Mater Private Hospital site.

8.5 *Rotunda Hospital*

8.5.1 The Rotunda Hospital equipment is also classified as being highly sensitive to EMI (like the Mater Hospitals).

8.5.2 The alignment is in a tunnel section, which is at least 23 metres below the surface. The Parnell stop is proposed to be located close to the Rotunda HARI unit and includes a scanning electronic microscope (SEM).

8.5.3 A review of the equipment in the HARI unit showed that the equipment was not of a type that was sensitive to d.c. or a.c. magnetic fields.

8.5.4 The SEM at the Rotunda is potentially susceptible to d.c. magnetic fields from the proposed system. Analysis has shown that the predicted levels of electrical interference will be below the levels that could impact the SEM.

8.5.5 An assessment has been carried out on an SEM of a similar make, model and age located close to the Luas Red Line at St James's Hospital in Dublin which is exposed to similar levels of magnetic fields to those predicted at the unit at the Rotunda. The staff at St James's Hospital have declared that no interference has been experienced with the operation of this SEM. Therefore, assurance is yielded that the SEM at the Rotunda will not experience operational problems because of magnetic field emissions from the proposed development. As such, no mitigation measures are necessary.

8.6 *Result of the Examination of Selected Areas*

8.6.1 The additional modelling and examination of the impact carried out subsequent to the publication of the EIS has determined that the impact at all locations will be low.

8.6.2 Further detailed analysis of the known sensitive sites at Mater and Rotunda has shown that the electrical interference levels produced by Metro North will be below that which could cause negative impacts for these sites.

8.6.3 For the specific sensitive equipment located at Mater and Rotunda analysis has shown that operation of even the most sensitive equipment will not be affected by electrical interference from Metro North.

9.0 CONCLUSIONS

9.1 *Summary*

9.1.1 The Environmental Impact Statement reports the findings of the Environmental Impact Assessment which was undertaken for the Metro North scheme.

9.1.2 I have peer reviewed the EIS and carried out additional works in relation to sensitive equipment. I am satisfied that the EIS as prepared is appropriate and complete and identifies and deals with all the likely EMC effects associated with the project.

9.1.3 I have carried out additional works in relation to sensitive equipment which is close to the alignment and have determined that there will be no adverse electrical impacts on these receptors resulting from the construction or operation of Metro North.

9.1.4 In accordance with the Environmental Impact Statement and the additional studies I can conclude that there will be no impact from d.c., a.c. and radiofrequency field emissions and that stray current impacts will be controlled to minimum levels by a combination of very high construction standards and a rigorous management strategy.

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