Investigations into electromagnetic noise coupled from lighting to safety related communications equipment in an operational metro

Leslie McCormack
Principal Engineer
Rail

Abstract

High frequency ballasted lighting presents a well known electromagnetic interference threat. Switching frequencies from these types of lighting control-gear are typically 40kHz - 120kHz producing significant interference up to 10's of MHz. During a large scale modernisation of urban metro rail stations in London, UK, it was necessary to implement an unusual combined lighting and communications cable management system which co-located lighting and safety related communications systems due to heritage planning restrictions at a particular station. There were Electro-Magnetic Compatibility concerns expressed by the railway operator about the proximity of the fluorescent lamps and high frequency ballasts to the communications assets. The station was to remain open throughout the site works and so assurance was required that the proposed design would function satisfactorily once installed, as the cost implications of unsatisfactory functionality and associated delays, were prohibitive. This paper is based on previously published work[1] and details laboratory and site measurements which were performed to investigate the effects of co-locating these systems and demonstrate that they would function satisfactorily.

Introduction

Fluorescent lighting presents a well known electromagnetic interference (EMI) threat to nearby vulnerable equipment. For older lighting equipment this threat was at power frequency harmonics and was generated from the wire wound ballasts that were commonly employed to control the current flowing in the fluorescent tube. More recently however, the lighting industry has developed high frequency ballasted lights which have improved lighting performance and consume less power. Switching frequencies from these types of lighting control gear can be in the region 40kHz – 120kHz. The high frequency ballast behaves essentially like a switched mode power supply and can produce significant interference up to 10's of MHz[2]. High frequency ballasted lighting therefore presents a very different threat than that presented by earlier fluorescent lighting.

During a major modernisation program of urban metro stations in London, UK, heritage and space constraints at a particular location resulted in an unusual combined lighting and communications system Cable Management System (CMS) being proposed by the designer.

The CMS placed high frequency ballasted fluorescent lighting in close proximity to the station safety related communications system, upon which the station relied for operation. The CMS design was extruded aluminium with space for power cables to either side of the light fittings and space for communications cables immediately above the light fittings. Fluorescent lamps with high frequency ballasts were fitted in alternate compartments with Public Address (PA) speakers filling the gaps. The railway is a complex electromagnetic environment and Electro-Magnetic Compatibility (EMC) is a significant area of concern in many railway projects[3]. EMC concerns had been expressed about the proximity of the fluorescent lamps and high frequency ballasts to the communications cables which would be much closer than the 130mm separation required by the designer's own cable separation guidelines, EN 50174-2[4] & industry guidelines[5]. The station was to remain open throughout the site works and so assurance was required that the proposed design would function satisfactorily once installed, as the cost implications of unsatisfactory functionality and associated delays, were prohibitive.

Therefore preliminary laboratory EMC measurements were performed on a specially constructed short 10m representative measurement jig to assess the likelihood of interference to the communications system. The quality of the final installation in controlling the coupled interference was later confirmed through site verification measurements.

Measurements

In order to provide indicative information on the likely coupling of disturbances into the communications system cabling, a measurement jig was constructed from representative CMS and cabling. Measurements were then made of the longitudinal and transverse noise voltages (VL & VT) present on the victim circuit formed from typical shielded twisted pair PA cable. The Root Mean Square (RMS) psophometric noise voltage (VP) was calculated by applying a psophometric filter to the VT data. Following site installation, site validation measurements were performed.

Longitudinal and transverse induced noise voltage

Longitudinal voltage is a term often used in telecommunications engineering and refers to a common-mode voltage which is induced along the length of a transmission circuit. Excessive VL can be an electrocution hazard to maintenance staff and can affect the operability of equipment. The term transverse voltage refers to a differential-mode voltage appearing between the pairs of a transmission circuit. Excessive transverse voltage can lead to reliability problems for affected systems. In addition excessive transverse voltage in the audio band can result in performance degradation for audio circuits. Applying psophometric weighting to the transverse voltage data provides an indication of the level of degradation that the noise voltage may cause to the intended signal, as perceived by a human listener.

The measurements were performed over the frequency range 5Hz – 30MHz and were intentionally similar in nature to those already performed at other stations on the network[6] and in associated laboratory investigations[7]. For the shielded twisted pair (STP) victim cable the shield was left disconnected at both ends as this was thought to represent worst case site installation. For VL measurements the 2 legs of the twisted pair (TP) were connected together and tied to a local earth at the far (field equipment) end. At the near (measurement equipment) end the 2 legs of the TP were connected together and VL was measured between the combined lines and earth. The measurement analyser & transducer were earthed through a strap to the ground plane. For VT measurements, the shield of the STP was again left disconnected at both ends. The 2 legs of the TP were terminated at the far end by a 600Ω resistor. At the near end VT was measured between the 2 legs of the TP. London Underground Manual of EMC Best Practice G-222[8] limits VL to a maximum of 25V at 50Hz and the RMS VP to be 1mV. EN 61000-4-16[9] which is referenced by G-222, gives expected immunity levels of equipment to longitudinal voltages above 50Hz. The measured data was compared against these limits.

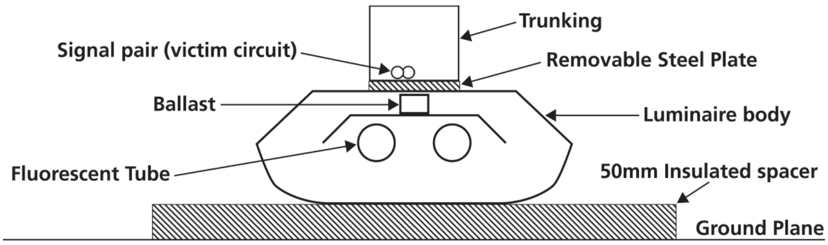

Figure 1 - Section view of CMS measurement jig setup

Laboratory measurement jig

The laboratory measurement jig consisted of a short 10 m section of representative CMS with fluorescent lamps, ballasts and PA speakers installed in adjacent compartments (Figure 1) as follows:

- 4 off 1800mm luminaire sections each containing twin 1500mm fluorescent lamps pre-wired with 3 core 1.5mm^2 flex to the connector of each fitting
- 4 off 800 mm Infill sections which contained 4 off PA rectangular speakers affixed with brackets centrally to the circular aperture of approximately 120mm diameter
- 4 off 2600mm CMS approximately 110mm x 75mm in dimensions
- (DRAHA UK) FIRETUF OHLS BASEC LPCB BS7629 Part 1 BS6387 CAT C, W, Z 300/500V H2 x 1.0mm^2 IEC 332 Part 3G shielded 2 core communications cabling for wiring speakers
- 4 off steel plates of approximately 1800mm x 100mm x 2mm in size.

Power was supplied to the lights from a local 230V supply. The measurement jig was assembled in a manner typical of site installation (Figure 2). During the measurements steel plates were added as a remedial measure to reduce the coupling into the communications cables as the original design had no provision for a solid floor in the communications cable trunking. Measurements were made both with and without the steel plates fitted. The paint finish on the extruded CMS was removed to allow for a good low impedance contact between the CMS and the steel plates.

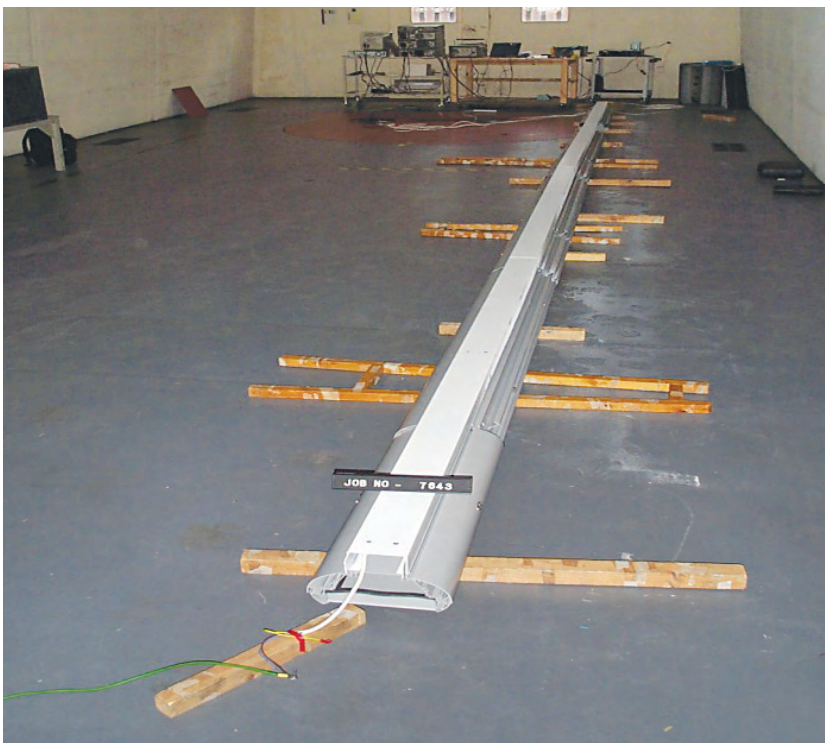

Figure 2 - Photograph of CMS measurement setup

Measurement results

Figure 3 shows an example of the VL measurement ambient in the frequency range 9kHz to 30MHz. Figure 4 shows the effect of energising the CMS luminaires. Emissions due to the luminaires are visible in the region 300kHz to 6 MHz. The limit derived from[9] is 3V (129.54 dBµV) under normal railway operating conditions and the measurement data showed that the coupled VL was below this limit.

Figure 5 shows typical onsite VP data over the frequency range 5Hz to 6kHz. The limit given in[8] was an RMS value of 1mV (60dBµV) over the frequency range 5Hz to 6kHz.

The CMS deployed onsite was expected to extend for approximately 100m and so it was assumed that actual VL & VP at the station would be higher than the laboratory measurement results. This proved to be the case when site measurements were made, however, both VL & VP measured onsite were significantly below the required limits.

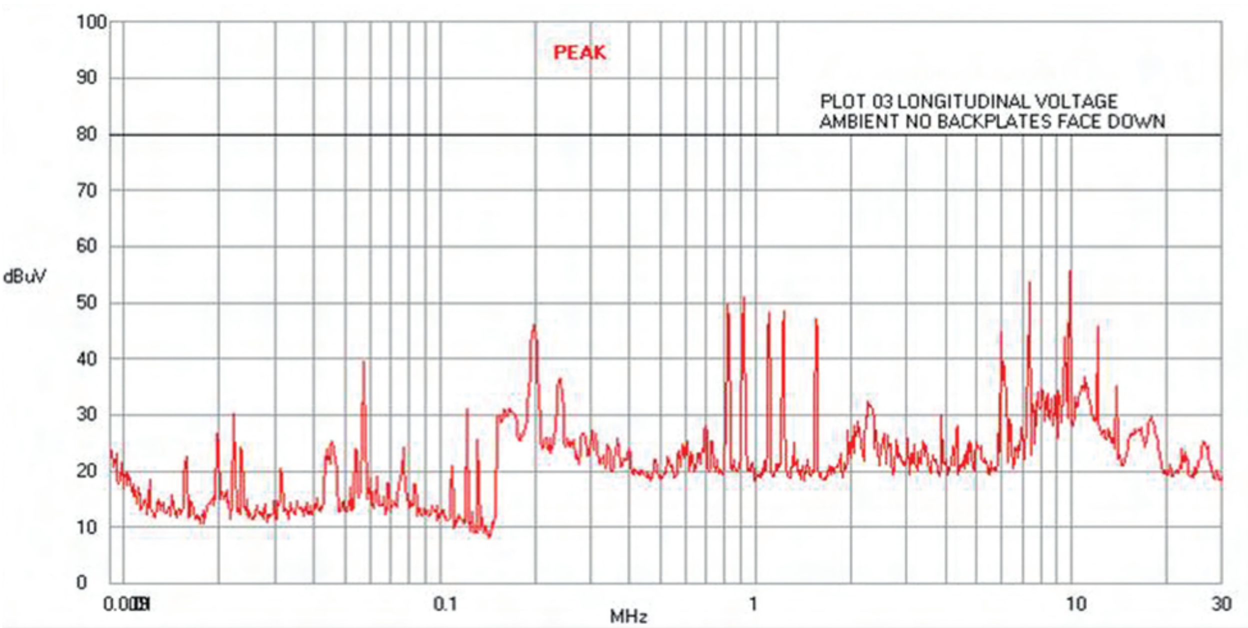

Figure 3 - Longitudinal Voltage 9kHz to 30MHz, Ambient, No Steel Plates

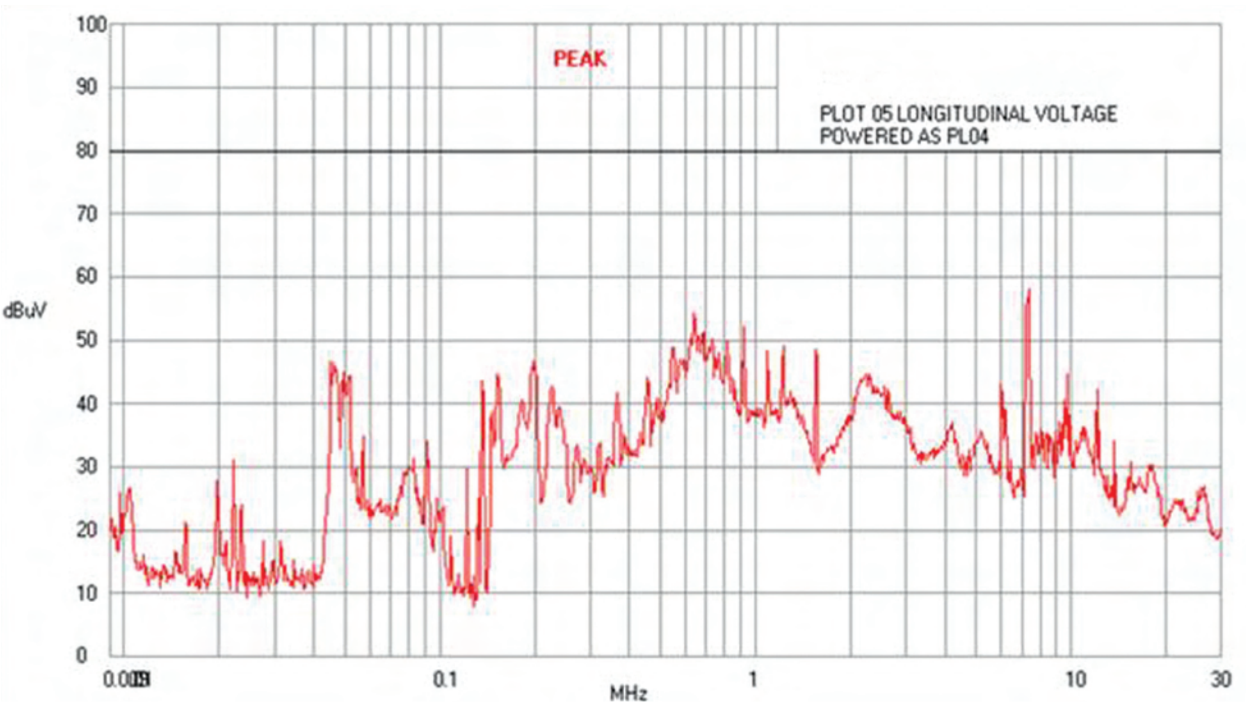

Figure 4 - Laboratory Longitudinal Voltage 9kHz to 30MHz, Lights Energised, (Without Steel Plates)

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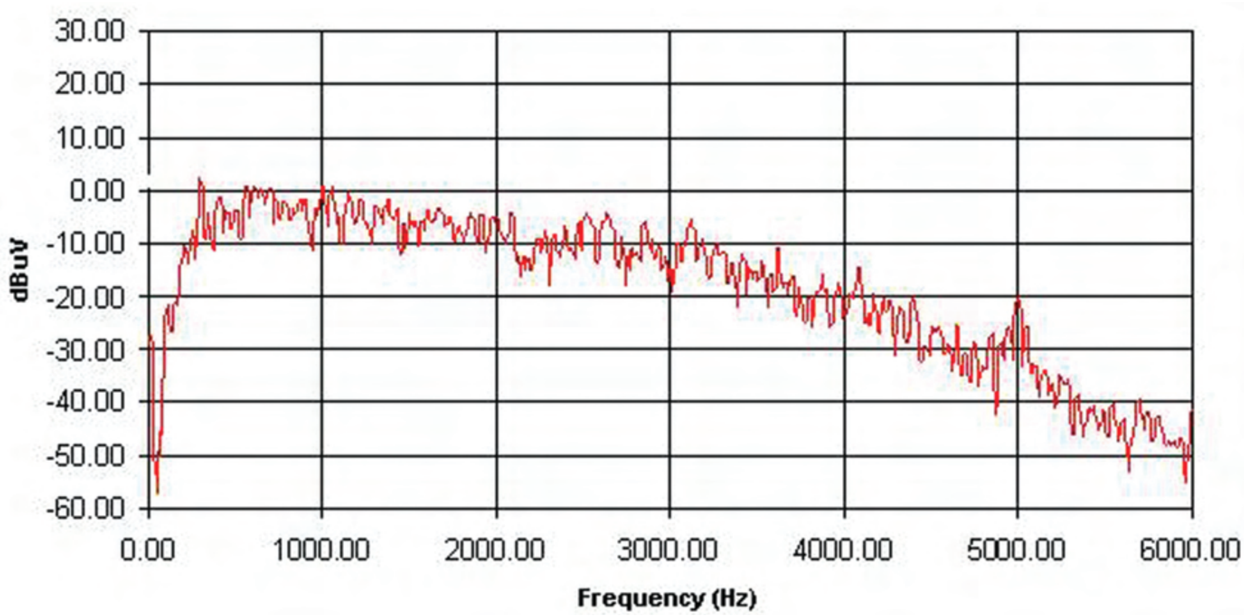

Figure 5 - Onsite VP, 5Hz to 6kHz, Lights Energised

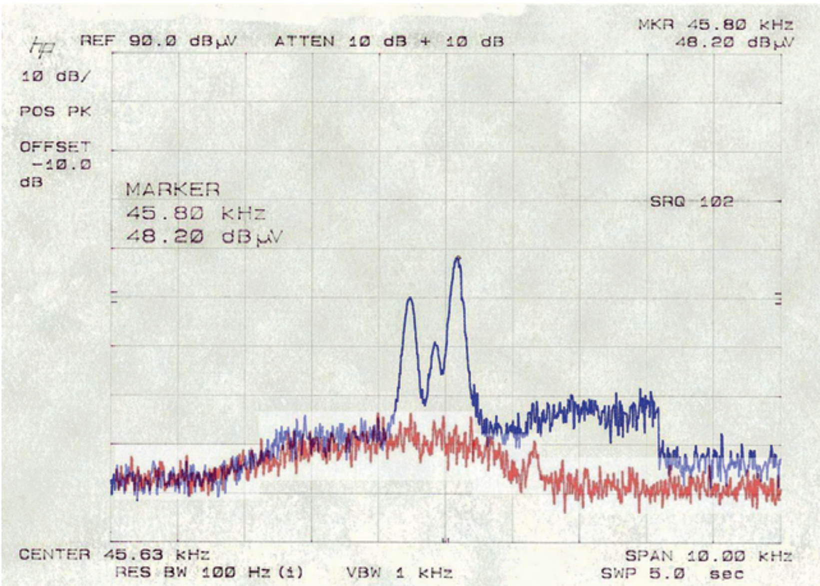

Figure 6 - VL Ballast Emissions in the 45kHz region (blue) & Ambient (red) with Steel Plates

Frequency (kHz)	No Plates	With Plates	Difference
	Level (dBμV)	Level (dBμV)	Level (dB)
1.973	38.2	27.1	10.1
409	32.5	30	2.5
455.5	41.5	36.5	5
500.5	35.7	33.7	2
546	45.9	42	3.9
637.5	48.5	45.9	2.6

Table 1 - Effect of the Steel Plates in the Laboratory VL Measurements

The effect of the steel plates in the laboratory measurements

Figure 6 shows the effect of energising the luminaries in the measurement jig. The emissions profile due to the switching frequency of the Tridonic ECG electronic lighting ballast is clearly visible. Removing the steel plates increased the levels at ~45kHz by 5.3dB.

Table 1 summarises the VL laboratory results with and without steel plates added. It shows that in the 2kHz to 640kHz region the effect of removing the steel plates from the CMS increased coupling by between 2 to 10dB. For VT the effect of removing the steel plates from the CMS increased coupling by up to 10dB. For Psophometric Voltage (VP) removing the plates increased the RMS VP value by 1.57dB.

Other considerations

The originally proposed CMS design did not provide adequate containment for the communications cables. The communications trunking had a steel roof and sides but no solid floor. The laboratory measurements demonstrated that well bonded steel trunking, which surrounded the communications cables, did provide attenuation at the frequencies of interest. Following the laboratory measurements the installer proposed a modification to the design which involved adding a well bonded steel plate between the communications trunking and the luminaires. This was a result of the effect of adding steel plates to the CMS (thus providing shielding to the communications cables above) being examined during the laboratory measurements. At the relatively high ballast frequency the dominant coupling mechanism was radiated coupling, rather than inductive cable related (per unit length) coupling. It was thought that the interference from the fluorescent lights was unlikely to be in phase and so would not significantly sum linearly with the number of luminaires deployed. This was confirmed during site measurements. It was reported that at a particular installation in Finland interference from luminaires became a problem over time as the luminaires aged[10]. However, the railway infrastructure maintainer responsible for the station had a policy to replace all fluorescent lamps on an annual basis, regardless of condition. This maintenance policy should provide protection from similar aging problems occurring at this site in the future.

Conclusions and acknowledgments

The laboratory measurements showed that the likely levels of VL and VP onsite would be below the limits and therefore provided the necessary confidence to progress with the installation & commissioning. The site measurements validated this and functional testing further confirmed the satisfactory performance of the installed communications system.

This paper reflects the views of the author alone. The author would like to thank colleagues within Atkins who have supported this work.

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