Noise Generated By Modern Lamps and the Influence on the Smart-Grid Communication Network

A. Emleh, A.S. de Beer, H.C. Ferreira
Department of Electrical and Electronic Engineering Science
University of Johannesburg, P.O. Box 524,
Auckland Park, 2006, South Africa
{aemleh, asdebeer, hcferreira}@uj.ac.za

A.J. Han Vinck
Institute for Experimental Mathematics
Duisburg-Essen University
Ellernstr. 29, D-45326, Essen, Germany
{han.vinck}@uni-due.de

***Abstract*—The metal halide lamp is a high energy electric lamp that produces visible light by an electric arc tube and it is a type of high-intensity discharge (HID) that contains a fused quartz and mixture of gases. These lamps inject noise into the smart-grid power line communications (PLC) network. This can have a strong and negative effect when using the PLC system to control the automatic switching of lamps in public places. In this paper we investigate the effects when the metal halide lamps with electronic or electromagnetic ballasts are seen as noise sources on the smart-grid power line network. It is shown that in the CENELEC band: (3 kHz – 150 kHz) the interference level from metal halide lamps is significantly below the allowed maximum PLC signal levels. In the band 150 kHz – 30 MHz however, PLC signals compete with Electromagnetic Compatibility (EMC) levels. The operational methods of the electronic and electromagnetic ballasts when connected to the metal halide lamps are explained.**

Keywords*—Metal Halide Lamp; Electronic Ballast; Electromagnetic Ballast; Power Line Communications; PLC; Interference; EN 50065-1; EMC.

I. INTRODUCTION

The metal halide lamp is a high energy light source, typically 150, 250, 400, 575 and 1200 watts, mostly used for outdoor purposes and is a compound of mixture of gases, such as: metal with bromine, argon or iodine which gives an average luminous output of 65-115 Lumens/Watt, but they require a few minutes of a warm-up period in order to reach the full light output status. The lamp is used for industrial, commercial, and public spaces, such as parking lots, factories, security lighting, street lighting, sports arenas and automotive headlamps. Fig. 1 shows the inside components of a metal halide lamp [1].

Metal halide lamps use igniters and electrical ballasts to start and regulate the lamp operating current flowing through the lamp after it has been started, as well as to maintain suitable voltage and current wave shapes. There are two main types of ballasts, electronic and electromagnetic ballasts that can have different names, such as probe-start ballasts, pulse-start ballasts, and solid-state ballasts.

Electrical ballast is a device intended to limit the amount of current in an electric circuit and it uses a half-bridge inverter and a boost dc-dc converter. A familiar and widely used example is the inductive ballast used in fluorescent lamps or metal halide lamps [2], [3].

Ballasts vary in design complexity: they can be as simple as electromagnetic ballasts or as complex as electronic ballasts used with metal halide lamps and high-intensity discharge lamps. The electronic ballasts are considered better than the electromagnetic ballasts since they provide better energy efficiency (Lumen/Watt), cause less interference to the low voltage network, they are smaller and lighter than the electromagnetic counterparts and they prolong the lamp's life [4].

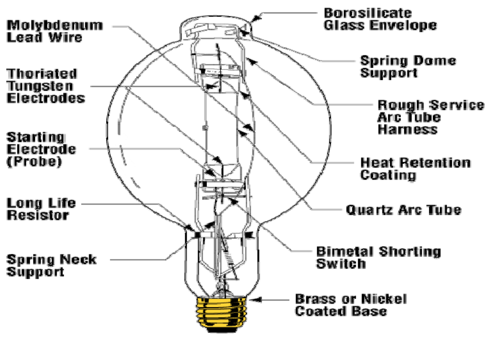

Fig. 1. The inside structure of the metal halide lamp

However, metal halide lamps with electronic/electromagnetic ballasts do inject undesired noise into the power-line communications channel.

It is shown that in the CENELEC band: (3 kHz – 150 kHz) the interference level from the metal halide lamps is significantly below the allowed maximum PLC signal levels and therefore poses no threat to the power-line communications. In the band 150 kHz – 30 MHz however, PLC signals compete with Electromagnetic Compatibility levels.

This paper investigates the effects when metal halide lamps with electronic/electromagnetic ballasts are seen as interference sources on the wiring system of the smart-grid communication network. Two different measurement set-ups (depending on the ballast type) are given.

The procedure of the measurements was made to comply with CENELEC narrowband rules in one case, and to serve the broadband signals in the other case [5]. The power-line regulations were considered when performing related measurements.

II. MEASUREMENT SET-UP

The measurement set-up used is shown in Figs. 2 & 3.

A metal halide lamp is supplied with 220VAC through an isolation transformer and Line Impedance Stabilization Network (LISN). The isolation transformer is used as the LISN causes an earth-leakage current to flow, that trips the supply. Floating the LISN rectifies this fault condition. The LISN as used in this set-up has two functions

Firstly, it filters noise from the AC supply. The measurement side (current probe and metal halide lamp in Figs. 2 & 3) is therefore clean from any noise on the power-line and an accurate assessment of the noise produced by the metal halide lamp can therefore be made. A clean 50Hz 220V AC is supplied to the metal halide lamp.

Secondly, it supplies a standardized noise load to the conducted interference created by metal halide lamp. At higher frequencies (typically > 1MHz) the noise load impedance presented by the LISN (and seen by the metal halide lamp) is 50Ω.

Measurements and conclusions in this paper are made for two regions of the emission spectrum:

- 3 kHz – 150 kHz: This is the frequency range of the so called *CENELEC* bands as defined by EN 50065-1 [6]. Measurements for these bands were made in the frequency domain to obtain harmonics from the resulted spectral density shape. A Rhode & Schwarz Spectrum Analyzer and Tektronix TCP0030 current probe were used. It was assumed that the Common Mode (CM) currents are negligible in this band and that all interference is in Differential Mode (DM) – an assumption also used in EN 50065-1. Results were downloaded to a PC for processing. This is shown in Figs. 3 & 4, depending on the used ballast.

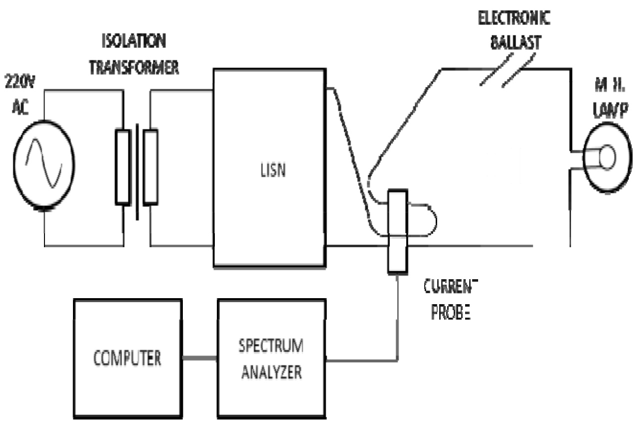

Fig. 2. Set-up for measurements in the 3kHz – 30MHz range (Electronic Ballast).

- 150 kHz – 30 MHz: This is the frequency range for *Broadband* PLC. It spans the range traditionally used to measure conducted emissions as per CISPR-16 [7]. Measurements for this frequency range were also made using a Rhode & Schwarz Spectrum Analyzer and Tektronix TCP0030 current probe as shown in Figs. 2 & 3.

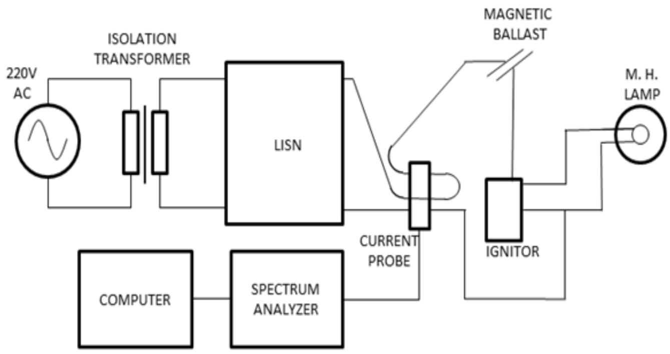

Fig. 3. Set-up for measurements in the 3kHz – 30MHz range (Electromagnetic Ballast).

ELECTRICAL BALLAST DRIVER

There is a common structure of the electrical ballast drivers used with the metal halide lamps, which consists of different amplifiers and electronic components as shown in Fig. 4.

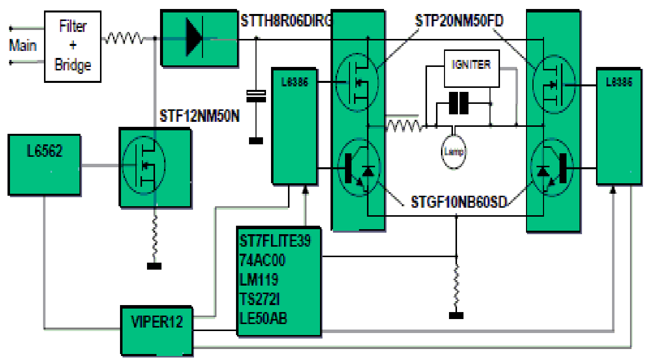

Fig. 4. Electrical ballast driver.

Metal halide lamps require a ballast to start and regulate the starting of the lamps, and stabilize the current through the lamp, as well as to provide an appropriate sustaining supply voltage. Those electrical ballasts employ transistors to change the supply frequency into high-frequency AC while also

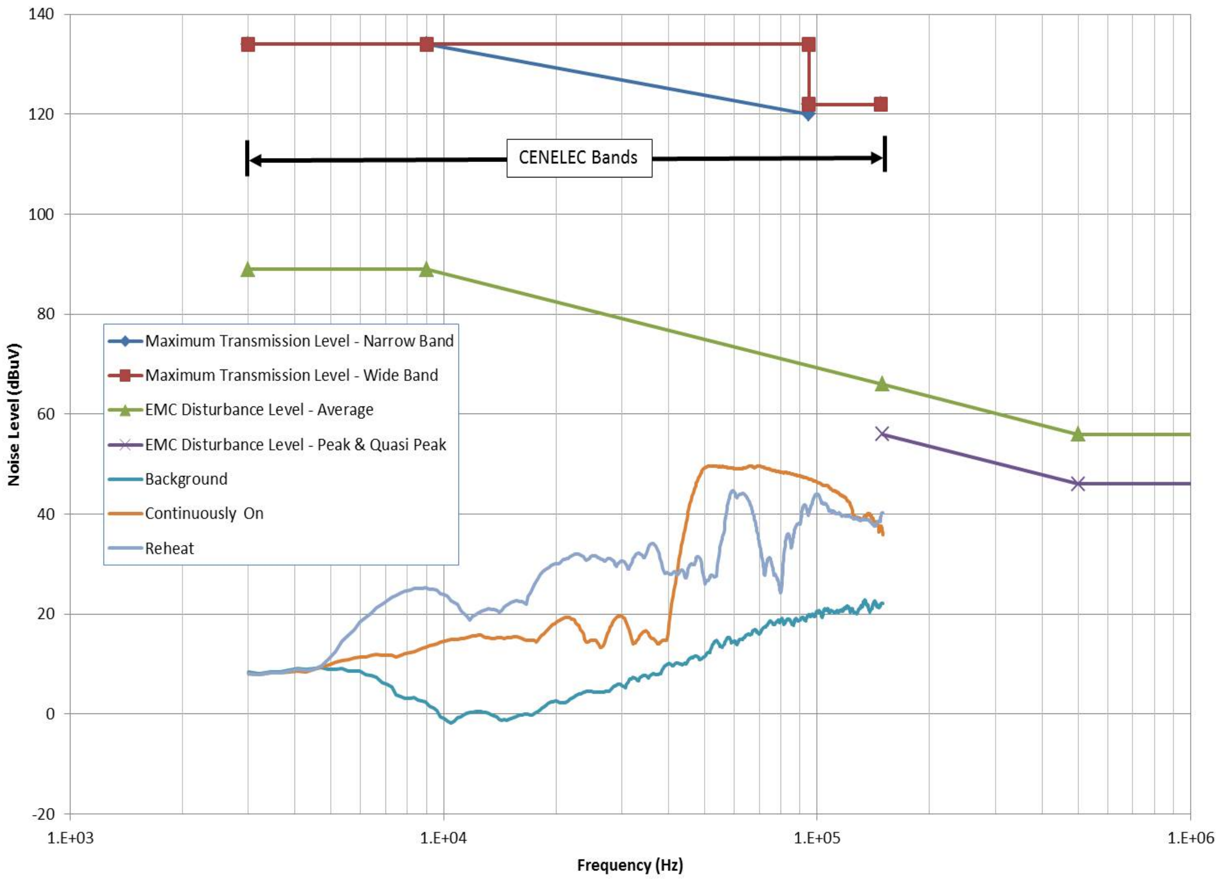

Fig. 5. Frequency domain waveforms and harmonics for 3 kHz – 150 kHz range (Electronic Ballast).

regulating the current flow in the lamp. Electrical ballasts typically work in rapid start or instant start mode, and are commonly supplied with AC power, which is internally converted to DC and then back to a variable frequency AC waveform. However, metal halide lamps require a few minutes to warm-up and reach their full light output.

III. Harmonics - CENELEC Bands

Harmonics are seen as a serious challenge to the power line system. In order to determine what effect the harmonics of a metal halide lamp have on the power-line communications channel, a Tektronix TCP0030 current probe is used in this type of measurements. The obtained current harmonics (magnitude) must be represented in frequency domain waveforms. This is done by performing a Discrete Fourier Transform (DFT) and multiplying the current harmonics with the LISN impedance values that is used for measurements (Figs. 2 & 3) to get the voltage values. The LISN characteristics are specified in EN 50065-1.

Fig. 5 gives the results when the harmonics (in voltage) are plotted against the CENELEC EN 50065-1 standards for maximum power-line communications signal and EMC levels. The frequency domain harmonics (magnitude) for the waveforms in Fig. 5 are performed using electronic ballast when having a steady-state (continuously on) noise measurement. The steady-state means that the 220V AC is on and the harmonics are continuously shown on the screen of the spectrum analyzer. This is the so-called warm-up period, the time that the lamp needs to reach its full output. Another measurement is performed when applying switch-off to the metal halide lamp power button, and having the lamp switched on within a small period of time, typically a few seconds. This status is called the re-power or re-heats period. The obtained signal during this period can be categorized as an affected signal that partially affects the power line communications channel.

Fig. 6 shows the harmonics when using electromagnetic ballast for this type of measurements. Higher interference levels are noticed when performing the repower measurements, as well as when the lamp reheated itself and went on again. By

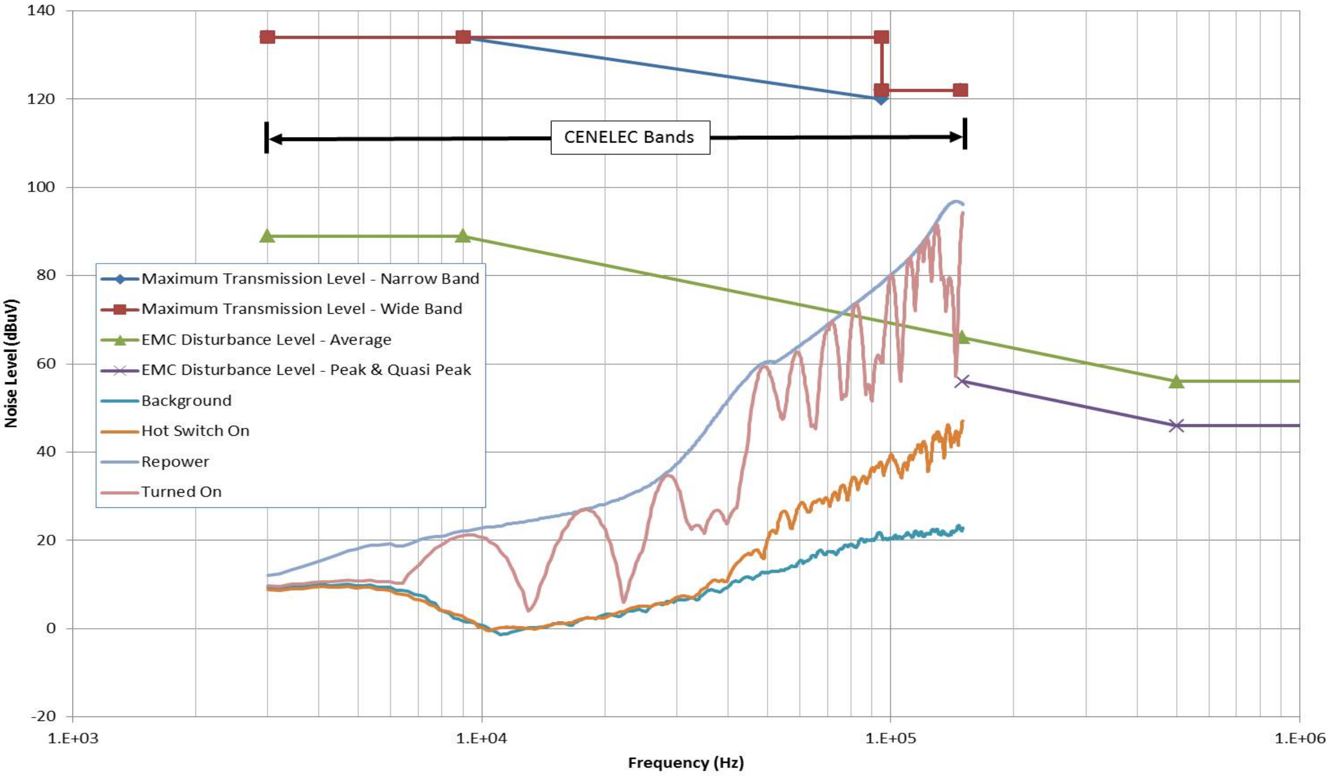

Fig. 6. Frequency domain waveforms and harmonics for 3 kHz – 150 kHz range (Electromagnetic Ballast).

comparing the obtained results from both types of ballasts, one can assume that the PLC channel gets more affected by the harmonics that were obtained from the electromagnetic ballast in this band.

IV. Broadband Spectrum

This section presents the broadband spectrum measurements where a similar procedure of experiments and measurements to those of the CENELEC bands was performed. The metal halide lamps with electronic or electromagnetic ballasts do generate undesired noise in the broadband PLC spectrum (150 kHz – 30 MHz). This is shown in Figs. 7 & 8.

Fig. 7 shows the measurements that were performed using a metal halide lamp with electronic ballast on several stages. The PLC channel gets more infected when the lamp is switched on after it was switched off and a few minutes were allowed before it reheated itself.

A metal halide lamp with electromagnetic ballast was used for the measurements shown in Fig. 8. This is the worst scenario for power line communications, as the obtained frequency domain harmonics in this set of measurements compete with or exceed the Electromagnetic Compatibility levels.

Fig. 7 shows the interference voltage from the metal halide lamp versus the EMC average and peak/quasi-peak disturbance level limits in the band 150 kHz – 30 MHz. In the CENELEC bands from 3 kHz – 150 kHz there are dedicated maximum signal transmission levels. These do not exist in the 150 kHz – 30MHz band and maximum signal transmission is assumed to be at the EMC limit levels. The EMC level is the maximum level at which PLC signals are allowed to be transmitted. For the 150 kHz – 30 MHz band therefore the signal to noise ratio (S/N) is low. This will affect the maximum theoretical PLC transmission capacity as can be seen from the Shannon theorem:

$$C = B\ log_2(1 + \frac{S}{N}) \tag{1}$$

Where: C is the channel capacity in bits per second, B is the bandwidth of the channel in hertz, S is the average received signal power over the bandwidth measured in watts (or volts squared); N is the average noise or interference power over the

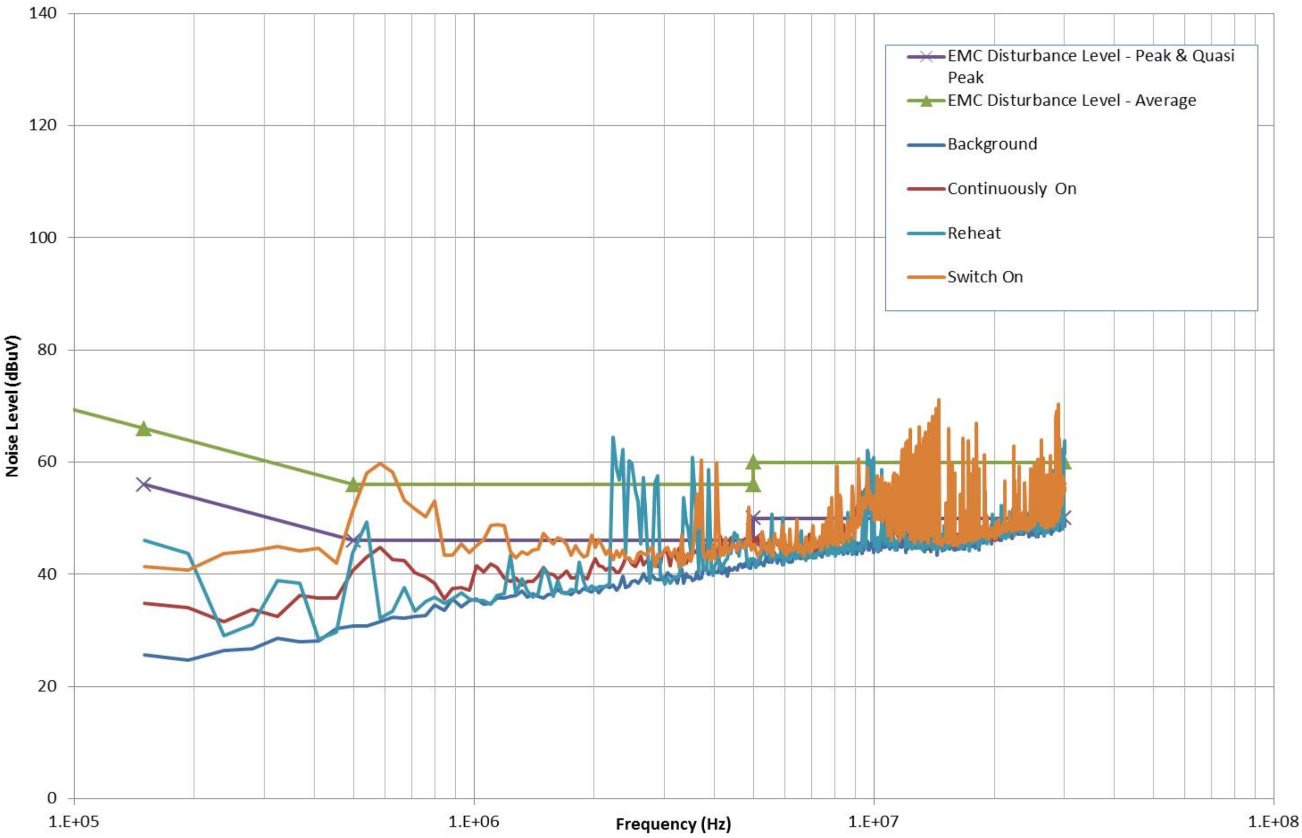

Fig. 7. Frequency domain waveforms and harmonics for 150 kHz – 30 MHz range (Electronic Ballast).

bandwidth, measured in watts (or volts squared); and S/N is the signal-to-noise ratio (SNR) or the carrier-to-noise ratio.

V. Discussion And illustration

From a PLC standpoint, the metal halide lamp with electronic or electromagnetic ballast is preferred as it doesn't cause noise (close to the maximum allowable PLC signal level) in the 3 kHz – 150 kHz band. The metal halide lamps will only become a more favorable lighting solution (in PLC terms) if statuary signal limits are lifted in the 150 kHz – 30 MHz band. However, by comparing the noise measurements in Figs. 5 – 8 to the measured noise floor, we can describe the power line communications channel as an affected channel.

VI. Conclusion

This paper studied the behavior of the electronic and electromagnetic ballasts that are used with metal halide lamps. Several experiments and measurements have been conducted to illustrate the effects of metal halide lamps with electrical ballasts on the power line communications channel.

It has been shown that metal halide lamps produce noise and affect the 3 kHz – 150 kHz CENELEC bands, but this interference level is below the allowable PLC signal level and therefore poses no threat to the PLC channel.

For the broadband spectrum (150 kHz – 30 MHz), metal halide lamps however inject noise into the PLC channel, where the signal level is governed by EMC standards. This interference competes with the EMC levels and can be seen as a serious risk to the power line communications.

Acknowledgment

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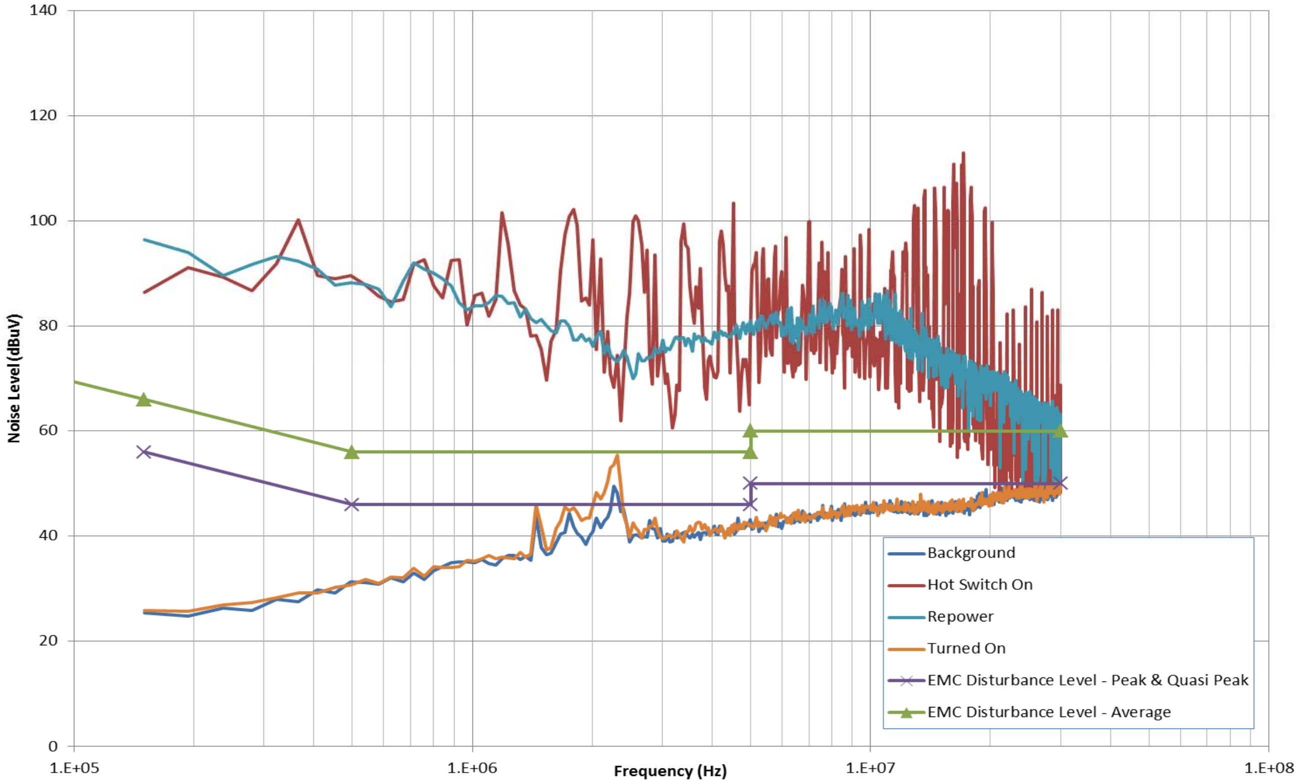

Fig. 8. Frequency domain waveforms and harmonics for 150 kHz – 30 MHz range (Electromagnetic Ballast).

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