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A Study of Conducted-Emission Stable Source Applied to the EMC US and EU Standards

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Abstract

In this paper, a single-phase stable and inexpensive switching power supply (SPS), which gives three values when spectrum analyzer (SA) settings are setting in peak, quasi-peak and average detecting modes, is identified. These three modes are associated with the conducted emission measurement techniques called for in the US [1] and EU [2-4] standards. An uncertainty is another quality to describe the source stability. To address this issue, several measurements at four frequencies have been repeated five times in one-month span. The selected SPS is stable after 20 minutes. In order to have a stable source, the SPS needs more than 20 minutes as a warm up time. As a preliminary result, it is determined that an amplitude variation of ±1.0 dB can be achieved. Furthermore, the inter-laboratory correlation results in about 3 dB variations for the three modes of detection.

Introduction

It is a common knowledge that the electromagnetic waves generated by high-speed digital unit can interfere with sensitive electronic devices if the emission amplitude is high enough. The effected device (victim) may exhibit degradation of performance, which may be depicted in the form of snow (white dots) on TV, slow transmitting data rate, computer hung, etc. In the US, the Federal Communications Commission (FCC) is an authorized branch of government to control such an electromagnetic Interference (EMI) for the public. The rules are published in the Code of Federal Regulations (CFR), Title 47, Part 15, which is the most commonly referred Part when dealing with the EMI issue [1]. For European Union (EU), the International Electrotechnical Commission (IEC) issues standards that have been sanctioned by the international members. Examples of IEC standards that are relevant to EMI are CISPR 11 (EN 55011) [2], CISPR 22 (EN 55022) [3], CISPR 16 [4].

The digital device operating above 9 kHz clock has to comply, at the minimum, with the aforementioned [1] in the conducted and radiated emission sections. The emissions were performed in a well-defined environment as described in ANSI C63.4-2003 [5]. A single phase Line Impedance Stabilization Network (LISN) is a transducer that measures the level of conducted emissions and is used in this study. The LISN output is connected to the spectrum analyzer (SA), such as HP 8566B together with a Quasi-peak adapter and a pre-selector. The radiated emissions are done on either an open field test site or a semi-anechoic chamber, where the site and chamber must satisfy the Normalized Site Attenuation criteria [5]. Similar to the conducted emission measurements, the antenna output is connected to an amplifier (to improve the receiving system sensitivity) and then SA.

The ANSI/ISO/IEC 17015-2005 [6] calls for an inter-laboratory verification as well as periodic self-assessment. Before this issue can be implemented, the characteristics of conducted source will be analyzed, including an uncertainty. This source can also be used in a university undergraduate laboratory having spectrum analyzer (SA). The students will learn and develop a feel and understand the nature of the conducted emissions.

Reference Conducted Source

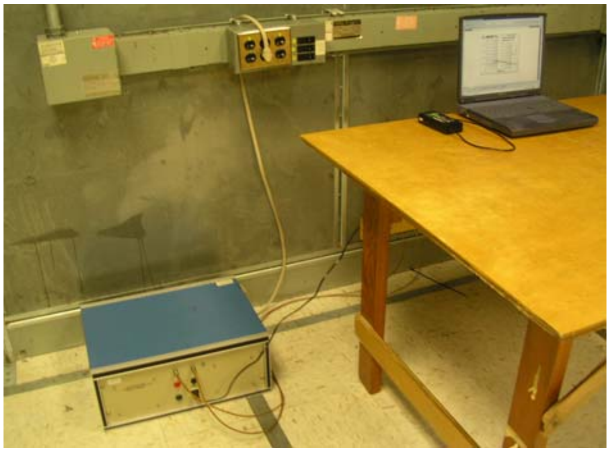
The basic requirements for the source are the stabilities of amplitude and frequency. A source based on an oscillator gives only one value of emission level for three mode of detection. Hence, it deems less useful for EMC application. There are commercial available conducted sources on the market, such as York CNE 2 [7]. Typical values of the uncertainty are ±2 dB for conducted emission and ±4 dB for radiated emission.

Several switching power supplies (SPS) were procured and tested. The objective is to select a stable and less cumbersome device to setup. A laptop computer SPS and cell phone (CP) SPS were evaluated. Depending upon the status of the loads including the condition of an internal battery, the amplitude and frequency of the emissions vary significantly. The load seems to influence more on the amplitude. Also, the orientation and placement of the power utility cord as well as the low voltage cord on the metallic floor affects the emission levels. This was due to mainly the capacitive coupling between the cords and the floor.

To eliminate the variation due to the power cord, a cellular phone (CP) SPS was selected over the laptop SPS, as the CP SPS has no power cord. The unit was plugged directly to the receptacle. To eliminate the CP battery conditions, an 8-Ohm, 20-watt resistor was substituted and was connected near the output of the SPS. The stability of the switching frequency remarkably improved to an acceptable level of less than 5%. However the amplitudes are still varied quite a large amount. It was determined further that not only the cords and load influenced the SPS stability, the temperature is also a factor as well. Like most RF instrument, the device needs warm up time to reach its steady state. Therefore, the time for the SPS stability is investigated.

Conducted Measurements, Setup and Results

The SPS was placed in the shielded conducted emission room and it was plugged into the equipment under test (EUT) receptacle of an EMCO LISN Model 3825/2R. LISN was solidly bond to the metallic ground floor. In a normal configuration to evaluate conducted emission compliance, the EUT was placed on a wooden table 80 cm above a metallic floor and was 40 cm from the vertical metallic wall bonded with the floor. The phase or neutral 50-Ω output port was connected to the spectrum analyzer via a 20' RG142 coaxial cable. A 50-Ω load must be used to terminate the un-used port. Photograph 1 was the set up for a laptop SPS (normal setup). Photograph 2 was the setup for CP SPS where it was plugged directly to the LISN, which is located on the floor. The system resolution bandwidth and limits are computer software (HP 85864B) set based on the CISPR 22, Class B. It should be noted that the purpose of this investigation does not involve product compliance, but only for its electrical stability characteristics. Figure 1 is the plot of laptop SPS and CP SPS conducted emissions, where the laptop SPS emissions are much higher than of CP SPS due to the electrical cords and the laptop computer, which may add the fluctuation to the emissions. Hence, only the CP SPS was selected for further study.



Photograph 1: The Laptop SPS Conducted Measurement Setup

Photograph 2: The CP SPS Conducted Measurement Setup

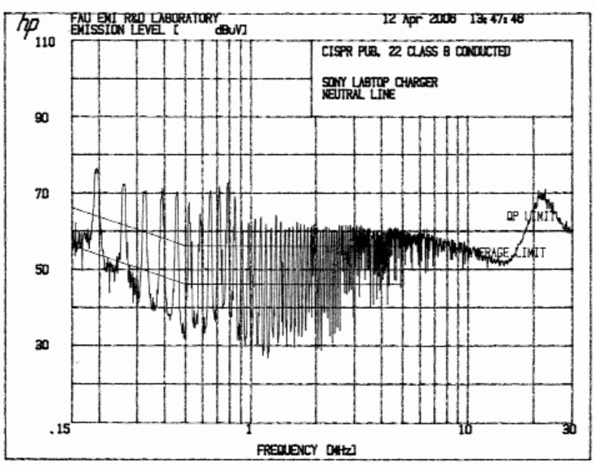


Figure 1: The Laptop SPS Conducted Emissions for Neutral Line

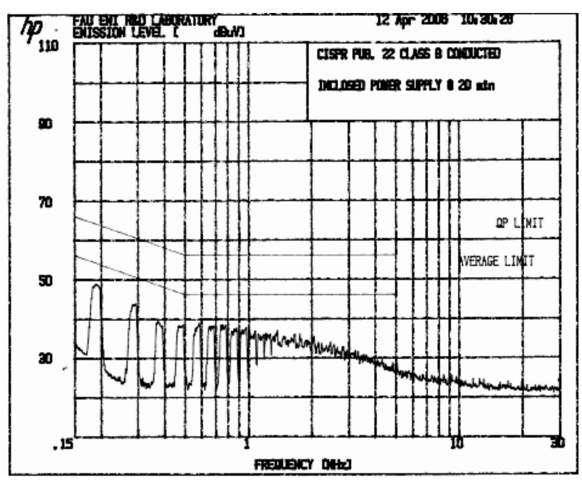


Figure 2: The CP SPS Conducted Emissions for Neutral Line

The following table is the selected conducted emissions versus time of the CP SPS. The data is taken every 5 minutes. It can be seen from Table 1 that the emission is slowly converged to a stable level after 20 minutes. To limit the down time of the EMC laboratory, the maximum time in this study is designed for about 40 minutes.

Table 1
Conducted Emissions and Time Measurements

Freq (MHz)	1 min.	5 min.	10 min.	20 min.	25 min.	30 min.	35 min.	37 min.	40 min.
0.20	62.10	53.50	52.00	50.10	49.10	48.40	47.80	47.80	47.20
0.30	53.10	46.70	45.70	43.90	43.30	43.20	42.70	42.80	42.10
0.39	46.40	42.80	42.30	42.20	41.90	41.40	41.70	41.00	41.00
0.49	42.50	38.50	38.60	38.40	38.90	39.00	38.80	39.00	38.30

Table 2
Amplitude Uncertainty for 20-Minute Warm-Up

Freq. (MHz)			dBμV			AVG (dBμV)	STDEV (dB)
0.20	52.00	51.20	50.10	50.10	50.90	50.89	0.78
0.30	45.50	44.50	43.60	43.90	44.40	44.40	0.71
0.39	43.30	43.10	42.30	42.20	42.30	42.65	0.51
0.49	39.30	39.20	38.70	38.40	38.70	38.87	0.37

From Table 2, after 20 minutes of warm up, the CP SPS emission at 200 kHz is in the range of 50.10-52.00 dBμV. The average value is calculated in μV linear scale and then it is converted to dB later. The standard deviation in dB is the ± variation with respect to the average value. The last two columns of Table 2 are the average and deviation values. For 0.2 MHz, the average of 50.89 dBμV and the standard deviation of 0.78 dB are obtained. This frequency is the worst case among the group of selected frequencies. For other frequencies, the values are also calculated and tabulated in Table 2.

Inter-laboratory Correlation

As per Sections 4.15.1, 5.6.6.1.2 and 5.9.1 requirements [5] for Inter-laboratory correlation, Florida Atlantic University (FAU) EMI R&D laboratory was partner with a lab having ANSI/ISO/IEC 17025 qualification as the second lab. The different in conducted emissions were on the order of 2 dB, 0.6 dB, and 2.7 dB, for peak, quasi-peak and average values, respectively. This is a good correlation. Hence, the results obtained from both laboratories should give similar emission levels to within 3 dB of each other, at least, within the frequencies of observations.

Uncertainty

As required by [5] for system uncertainty, the emission data obtained from the SPS has been analyzed based on [7-8]. In this study, a Gaussian (normal) distribution is assumed as adequately describe the events. Type A evaluation of standard uncertainty is then applied for n independent repeated values a.

The data presented in Table 1 was taken on different days and with the receiving system being warm up for at least 30 minutes, and therefore was considered an independent event.

It is desirable in any experiment to collect as many data points as possible. This concept is to satisfy a central limit value for large *n*. However, for practical purposes, the number of data taken for this study is 5 independent events. The following equations [7] are used to calculate an estimate standard deviation $s(a_j)$ and uncorrelated mean value of the measurand $s(\bar{a})$ which is the same as standard uncertainty $U(x_i)$.

$$s(a_j) = \sqrt{\frac{1}{n-1}\sum_{j=1}^{n}(a_j - \bar{a})^2}$$

$$s(\bar{a}) = \frac{s(a_j)}{\sqrt{n}}$$

In an event of using combined standard uncertainties to describe the measurand, [7], a confidence probability of not less than 95% for a normal distribution and is equated to a coverage factor $k = 2$. However, we viewed that the SPS used has only one variable, i.e., warm-up time to stable. The conducted emission receiving cable was hardwired with the only BNC connector switching between phase and neutral port. At this frequency, the uncertainty is negligible. Hence, the expanded uncertainty was not required. The tabulated $U(x_i)$ is shown in Table 3.

Conclusions

A stable noise source suitable for conducted emission evaluations is needed for quality assurance per ANSI/ISO/IEC 17025-2005. A switching mode power supply (SPS) can provide three values as when a spectrum analyzer is operating in a peak, quasi-peak, and average detection modes. Several types of SPS have been evaluated for its conducted emission characteristics. A cell-phone (CP) SPS was selected for its compact size and minimum coupling to the environment. It was found that after 20 minutes of warm-up, the CP SPS was stable to within 0.37-0.78 dB in the 0.20-0.49 MHz. The result of inter-laboratory correlation was within 3 dB for the three detection modes.

References

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