Theoretical and Practical Aspects Regarding Radiated Emission Testing in Semi-Anechoic Chambers

Livia-Andreea Dina*, Viorica Voicu†, Petre-Marian Nicolae*, and Ionuț Daniel Smărăndescu*
* University of Craiova / Electrical, Energetic and Aero-Spatial Engineering Department, Craiova, Romania,
dina.liviaandreea@yahoo.com, pnicolae@elth.ucv.ro, smarandescu.ionut@yahoo.com
† ICMET Craiova / EEPQ Laboratory, Craiova, Romania, programe@icmet.ro

***Abstract* - This paper presents some theoretical and practical aspects on measurements of radiated emission from a Portable computer. The used Standards are presented and discussed. The measurements were carried out in a Semi-Anechoic Chamber (SAC) in accordance with EN 55022 (CISPR 22) Standard. The test arrangement was in accordance with IEC 61000-4-3 Standard and the following equipment was included: reception antenna, signal generator and emission antenna. The measurements were made at a distance of 3 meters, according to the generic Standard IEC 61000-6-3. The radiated electromagnetic interference (EMI) was assessed in the frequency domain, for the frequency range of 30 MHz – 1 GHz, in compliance with CISPR 22 Standard. The test was performed to verify if the tested item (EUT) - in our case a Portable computer - is operating according to the radiated emission limits imposed by the product Standard of the class in which the equipment is framed: IEC 61000-6-1. Analyzing the values obtained for Quasi-peak during the test period, we noted that none of them exceeded the maximum allowed. The results were in satisfactory agreement with the limits imposed by CISPR 22 Standard, and have demonstrated that the equipment - in our case a Portable computer - works in optimal parameters, passing the radiated emission test.**

Cuvinte cheie: *interferente electromagnetice, măsurători pentru emisii radiate, cameră semi-anechoică, compatibilitate electromagnetică, Laptop.*

Keywords: *electromagnetic interference (EMI), radiated, emission measurements, semi-anechoic chamber, electromagnetic compatibility (EMC), Portable computer.*

I. INTRODUCTION

In these latter days, the increasing number of electronic devices, such as portable computers, personal computers, and others, has contributed to a growth in electromagnetic radiated emissions and electromagnetic interference (EMI) [1], [2].

The poor operation of electrical and electronic devices and equipments, instability, and short lifetime are the causes of a reduced power quality. For portable computers and personal computers, the disturbances can lead to: corrupted files, loosing files and to the destruction of the hardware components [3]. It is helpful to study the electromagnetic compatibility and its risk in the electronic devices, which occurs due to the performance degradation with broadband emissions [1], [4].

Electromagnetic compatibility (EMC) testing is required to demonstrate if the equipment will operate properly in its proposed environment, if it has acceptable safety limits or if it satisfies the required standard levels of immunity and/or emissions.

The limits for the equipment's electromagnetic emissions are certified by the EMC Directive EU 2004/108/CE (which replaces EMC Directive 89/336/EEC), in order to ensure that it will disturb neither radio transmissions and telecommunication, nor other electronic devices. This Directive also addresses to the immunity of such equipment relative to electromagnetic interference.

The equipment designer and manufacturer must consult the Directive in order to make sure that the equipment is not disturbed by radio emissions and does not influence other devices during its operation.

An electronic device (such as portable computers and personal computers) needs to be in compliance with in force EMC norms when it is introduced on the market and/or taken into service [5].

The radiated emission measurements must always state the horizontal distance from the Equipment Under Test (EUT) to the receiving antenna, fact that gives them their uniqueness. We've come from an environment of making measurements at 30 meters in an open space on commercial electronic devices, to an environment of performing measurements at 3 meters [6].

To perform a radiated emission test is not that simple. Radiated emissions tests carried out in an open space (OATS) adds the problem of disturbing signals already found in that environment, signals that can be added over existing signals from the EUT. Fortunately, there are ways to make the difference between these external signals from external sources, such as phones or digital television.

Another approach to these radiated emissions tests is that they are performed in semi-anechoic chambers (SAC) that offer a "clean" electromagnetic environment in terms of interference. In this case, we can only concentrate on the signals captured from the EUT, the external signals not being able to disturb the measurements made.

Assuming that a measurement configuration is consistent with the applied standard, the radiated emissions tests can be performed taking into account some

basic rules that will guide us throughout the measurement process.

The standard one used for measuring the radiated emissions from the Portable computer was CISPR 22, "Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement."

The radiated emission test described in Fig. 1 incorporates a measuring antenna that is placed at a distance of 3 m from the EUT [7].

One can see in the Fig. 2 the scheme of this method, in a much simplified form, but very well expressing the placement of the equipment in the test setup.

The aim of this paper was the verification of the compliance for a Portable computer with the in force standards regarding the radiated emissions, considering the multitude of purposes for which they are used. Given that during the entire period of operation the user is near the Portable computer at a close distance, we considered it necessary to determine the level of electromagnetic radiation to which the user is subjected.

II. Radiated Emission Measurement Standards

A. Standards for Radiated Emission Measuring

The limits and measurement methods that restrict the electromagnetic emission from electric and electronic equipment and that protect the existing radio services are established by CISPR standards.

CISPR standards refer to EMC emission test methods and limits:

•CISPR 16-1, "Specification for radio disturbance and immunity measurement apparatus and methods - Part 1: Radio disturbance and immunity measuring apparatus;"

•CISPR 16-2, "Specification for radio disturbance and immunity measurement apparatus and methods - Part 2: Methods of measurement of disturbances and immunity;"

•CISPR 22, "Information technology equipment - Radio disturbance characteristics - Limits and methods of measurement;"

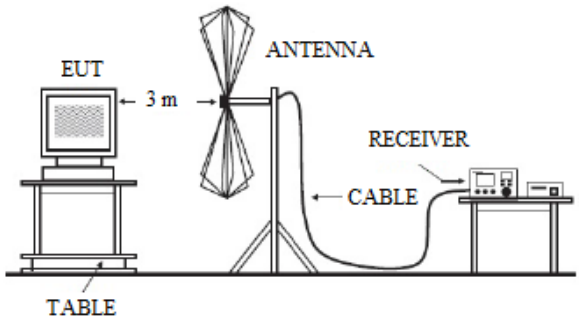

Fig. 1. Setup test for measuring radiated emissions at 3 meters.

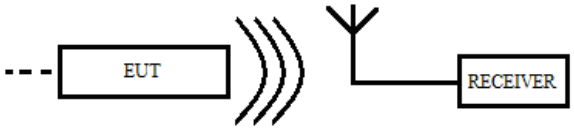

Fig. 2. Radiated emission test method simplified scheme.

•EN 55022, "European limits and methods of measurement of radio disturbance characteristics of information technology equipment."

The above mentioned standards attempt to standardize the products EMC performance, relative to radiated emissions for electrical equipment.

Three-meter measurements are increasingly used world-wide in the measurement processes. The radio-frequency (RF) emissions standard for information technology, telecommunications equipment, portable computers and personal computers is CISPR 22. It has been adopted in the European Union (EU) as EN 55022 and it is incorporated in the Electromagnetic Compatibility Directive (EMCD) [8]. Even though EN 55022 is a product family standard, its test methods are often called up as a basic test method by other emission standards (generic, product, and product-family) [5], [9].

Also, the three-meter measurements have been used by the United States Federal Communications Commission (FCC) for a number of years, especially for measurements of Class B digital devices (portable computers, personal computers and similar devices) [6].

In general, the frequency range for the radiated emission testing is from 30 MHz to 1 GHz. According to CISPR 22 Standard, for this type of equipment (Portable computer) the determination of quasi-peak values is necessary. Paragraph 15.109 (Radiated emission limits) of the FCC Rules says: (a) "Except for Class A digital devices, the field strength of radiated emissions from unintentional radiators at a distance of 3 meters shall not exceed the following values." These values are listed in Table I [2], [6], [10].

Quasi-peak detection is a form of detection where a signal level is weighted based on the repetition frequency of the spectral components making up the signal. The result of a quasi-peak measurement depends on the repetition rate of the signal.

The quasi-peak value is more relevant to the effects of the disturbance. If the perturbation is filtered with a band pass filter, having the bandwidth B and the gain or attenuation A, and the disturbing impulse has the area as in (1) and (2), the values A and B being constant for the measuring apparatus, it is necessary to measure the surface of the impulse (of the integral), which can be achieved by an integration circuit, as in Fig. 3 (where: u_p = disturbance voltage, D = diode, R = line resistance, C = condenser, R_C = equivalent resistance, U_V = quasi-peak voltage, U = reference voltage, t = time) [11].

$$S = \int_0^{\infty} u_{p(t)} dt \tag{1}$$

$$U = 2 \cdot SAB \tag{2}$$

where: S = disturbing impulse area, u_p = disturbance voltage, U = reference voltage, A = filter attenuation, B = filter bandwidth.

B. Standards for Radiated Emission Testing Procedure

The most of electronic devices and equipment are not intentionally designed as radiating antennas, they behaves so accidentally. This is the reason why the direction of the maximum radiation is unknown, and the unit must be checked all around it, at each frequency. The EUT components disposal and any external conducting

elements, such as cables, will modify the positioning, and some layouts will require more space to use. High level emissions are also may change over time if the EUT has periodical functions within it. They may change depending on EUT build state and depending on its operational state. This cannot be predicted in advance, but is well known that if the polarisation of cables is same as the polarisation of the antenna, will be significantly better [12].

In CISPR 22, the measurement distance is considered from the reference point of the antenna to the edge of the EUT. For ensuring predictable results, regardless of the actual ground material, the ground plane is used. It does introduce difficulties into the testing procedure.

A compliant test setup comprises a ground plane from the EUT position to the measuring antenna, and that stretches beyond them, a way of rotating the EUT, a tabletop positioned at 80 cm above the ground plane, and a antenna with the possibility to adjust the height from 1 to 4 m as well as with the possibility to adjust the polarization: horizontally or vertically [12].

Normalised Site Attenuation (NSA) is the parameter that distinguishes a test site used for compliance purposes, from the test site that cannot be used for compliance purposes. This parameter is the result obtained from measuring the attenuation between the EUT and the measuring antenna. The theoretical NSA versus frequency values, for different antenna polarisations and different measurement distances, are contained by CISPR standards, including CISPR 22.

The NSA parameter measured from the test site is compared with the theoretical one. The site can be used for compliance purposes if the difference is less than ±4dB. Fig. 4 shows the theoretical NSA curves for 3 m and 10 m distances. The 3 m measurement distance shows a lower loss than the 10 m measurement distance. Due to the effect of reflection from the ground plane, some differences between horizontal polarization and vertical polarisation can be observed [12].

TABLE I.
CISPR 22 LIMITS OF RADIATED DISTURBANCE VOLTAGES AT THE SUPPLY TERMINALS FOR CLASS B EQUIPMENT

Frequency of Emission (MHz)	Quasi-peak Limits (dBuV/m)
30 - 230	40 (= 100 uV/m)
230 - 1000	47 (= 224 uV/m)

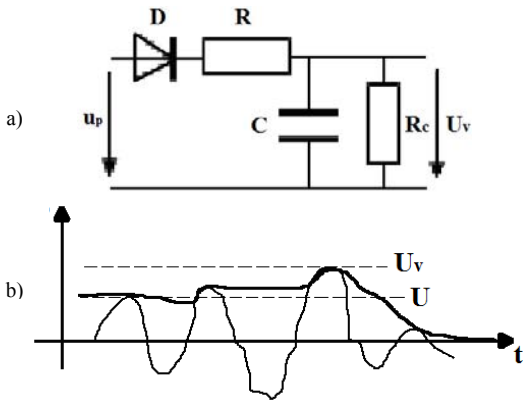

Fig. 3. (a) Integration circuit for Quasi-peak measurement;

(b) Reference voltage and quasi-peak voltage waveforms.

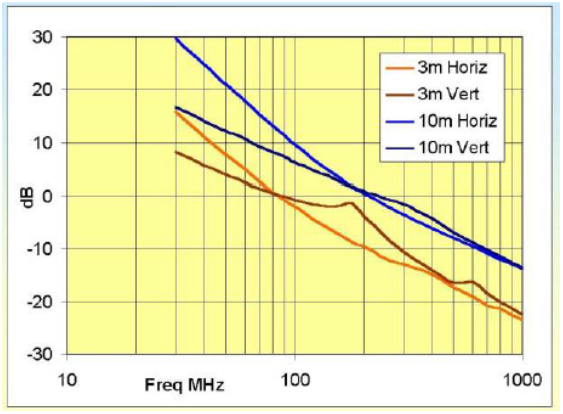

Fig. 4. Theoretical NSA curves for 3 m and 10 m.

The measurement procedure imposed by CIPSR, comprises the requirement to take the worst-case result for the antenna polarized horizontally and vertically, and of the swept in height of the antenna from 1 m to 4 m (for 3 m and 10 m test distances), in order to eliminate the annulment effect of ground plane reflections. The testing procedure must take in consideration the full frequency range of 30 MHz to 1 GHz for standard CISPR tests, with a fixed bandwidth of 120 kHz.

The duration of the test is determined by the frequency step size, the downtime for each frequency, the measuring bandwidth, the response time for the detector and the emission cycle duration for the EUT. Taking into consideration all these factors, this full compliance measurement procedure has become a standard practice at most test laboratories. The total measurement time is optimized by doing an initial series of tests inside the semi-anechoic chamber [12].

Radiated emissions from electronic equipment are not uniform. The most powerful emissions may be released from the rear or front panel or apertures in the shielding. A suitable positioning of the EUT can ensure that worst-case emissions are recorded by the EMI receiver. With the EMI receiver adjusted to view the field of interest, the EUT should be moved through a 360° rotation with at least 45° increments. At each 45° step, the amplitude of the highest and largest signals should be marked. A report should be created with the purpose to correct any problems found in the EUT by the designing engineers. The report must contain some measurement values and some waveforms of the signals [13].

In our case, the test setup was in accordance with IEC 61000-4-3: 2006 + AMD1: 2007 + AMD2: 2010 CSV – "Electromagnetic compatibility (EMC) - Part 4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test." This Standard is applicable to the immunity requirements of electrical and electronic equipment to radiated electromagnetic energy. It establishes the test levels and the required test procedures. The object of this standard is to establish a common reference for evaluating the immunity of electrical and electronic devices when subjected to radiated electromagnetic fields and radio-frequency emissions [14].

The measurements for the Portable computer radiated emissions were made at a distance of 3 meters, according to the generic Standard IEC 61000-6-3: 2006 - "Electromagnetic compatibility (EMC) - Part 6-3: Generic

standards - Emission standard for residential, commercial and light-industrial environments." This part of IEC 61000 for EMC emission requirements is used for electrical and electronic equipment intended for residential, commercial and light-industrial environments. Mandatory levels of emission in the frequency range 0 Hz to 400 GHz are included. The object of this standard is to define the emission test requirements for electronic devices and equipment in relation to transient and continuous, radiated and conducted disturbances [15].

III. Experimental Tests for Radiated Emission

A. Test Configuration and Instruments

The testing procedure was realized in accordance to the EN 55022 (CISPR 22) Standard, and the testing has been done with the software package "EMC 32", the results of the performed measurements aiming to monitor and analyze the emissions radiated by the EUT. The radiated emission limits are given by the CISPR 22 Standard (or the EN 55022 European Norm). The EUT was in this case a Portable computer: Elsaco 8550-20 model. The Portable computer is Class "B" and is intended for use in a residential environment. The technical characteristics of the EUT - Portable computer can be seen in Table II.

The measurements have been performed in a semi-anechoic chamber at a 3 meters distance, and aimed to verify whether this type of equipment is in compliance with the radiated emission standards. The most accurate measurements are made in SAC.

The SAC has special walls to isolate the enclosure from the external electromagnetic field and minimize reflections. The walls are made of metallic plated materials or ferrite and are surrounded by absorbing material (Fig. 5). The enclosure is large enough compared to the EUT, allowing at the same time for a correct control of the field intensities inside it.

The SAC were the radiated emissions tests for a Portable computer were performed is located at ICMET (National Institute for Research and Testing for Electrical Engineering from Craiova, Romania), inside the EMC Laboratory.

TABLE II.
ELSACO 8550-20 TECHNICAL CHARACTERISTICS

Processor	Intel Dual Core
Processor frequency	2000 MHz
Display	15.4 inch
Display type	WXGA
Resolution	1280 x 800 pixels
Video chipset	Intel 945GM
Optical drive	DVD-RW Dual Layer
Network	LAN 10/100/1000 Mbs
Wireless	Intel PRO 3945ABG
Modem	56k V90
Battery	Lithium Ion 6 cells
Power adapter	AC adapter (100/240 V)

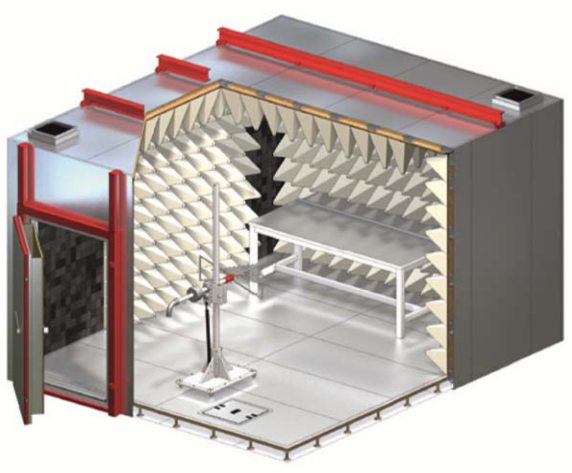

Fig. 5. SAC construction.

The testing configuration was carried out in accordance with IEC 61000-4-3 standard, and included the following equipment:

•Receiver antenna (for measurement): type HL 1000 - a hybrid antenna (biconnical and logarithmic periodical);

•Emission antenna: EMCO 2090 type;

•EMI disturbances receiver: ESCI 3 type – a Rohde & Schwarz EMI Receiver test (for radiated emissions tests the receiver may be also used as a spectrum analyzer).

The Rohde & Schwarz ESCI 3 EMI Receiver is a standard measuring receiver, in compliance with EMC measurements, according to the commercial standards, in the frequency range 9 kHz to 3 GHz. The receiver is compatible with the latest version of CISPR 16-1-1 Standard [2].

The arrangement requirements (shown in Fig. 6) for measuring in compliance with the CISPR 16-4-3 Standard, is mentioning that for the performed measurements in the SAC, the limits required from CISPR 22 Standard apply only when dealing with Quasi-peak values. The Quasi-peak values are more relevant to the effects of the disturbance.

The standard distance of 3 m represents the distance between the place where the supply is positioned and the uniform field area in which the EUT must be placed. During test period, the equipment must be positioned on a nonconductive table, at 0.8 m above ground plane.

Fig. 6. Placing the equipment in the SAC, in compliance with CISPR 16-4-3 Standard.

B. Test Results

The testing procedure was realized in accordance to the EN 55022 Standard (CISPR 22), and has been done with the software "EMC 32".

In order to perform the test, a bilog emission antenna was used as a source for signal generation. The antenna was installed inside the semi-anechoic chamber, in compliance with the test setup imposed by IEC 61000-4-3 Standard. The antenna was positioned at a distance of 3 m from the EUT.

To make the necessary setup the standard test procedure was considered which requires that the radiated emission measurements at 3 m to be performed both with the signal source - antenna positioned in the vertical direction and with the antenna positioned horizontally. Thus, two waveforms of the signal were obtained: Fig. 7 and Fig. 8.

Fig. 7 depicts the field variation in the frequency range in which the measurement was made (30 MHz – 1 GHz), in horizontal polarization.

In Fig. 8 the result of the test concerning the radiated emission from the EUT - Portable computer in vertical polarization is exposed.

The frequency field sweep was analyzed over the entire frequency range with a preset step of 1% and with a measuring time of 1 s for each analyzed frequency.

The situations in which the EMI Receiver has detected significant field level fluctuations, and considered them unsafe, are presented in Table III (in horizontal polarization) and in Table IV (in vertical polarization).

These cases are interpreted individually in order to verify if the recorded value exceeds the value imposed by the standard as Quasi-peak limit.

The frequencies detected with significant signal level fluctuations are plotted by diamond-shaped markers.

The test was performed to verify that the test item – Portable computer is operating according to the radiated emission limits imposed by the product standard of the class in which the tested equipment is included: IEC 61000-6-1 Standard.

The results show that the EUT - Portable computer is having a good behavior since the measured Quasi-peak values do not exceed the maximum limits imposed by the CISPR 22 Standard: 40 dB(µV/m) for the frequency range 30 MHz – 230 MHz, and 47 dB(µV/m) for the frequency range 230 MHz – 1 GHz.

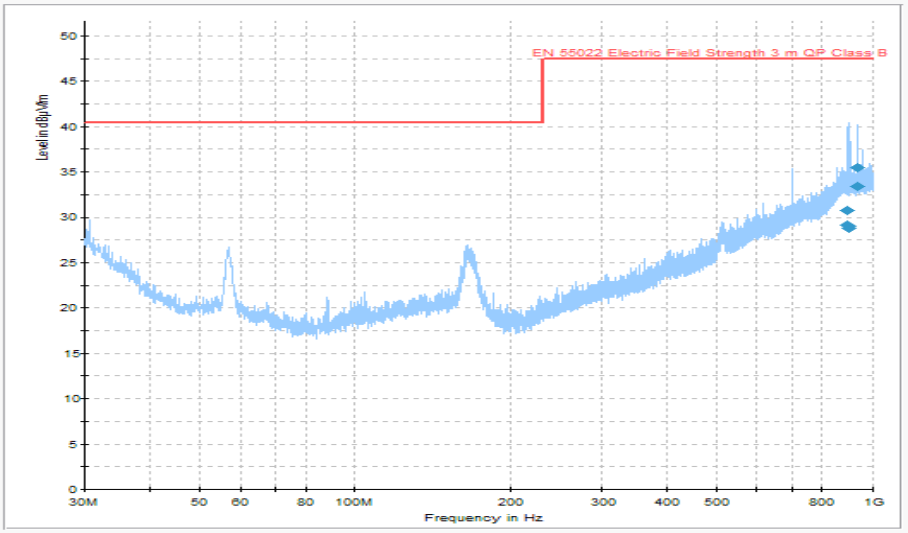

Fig. 7. Portable computer radiated emissions in horizontal polarization.

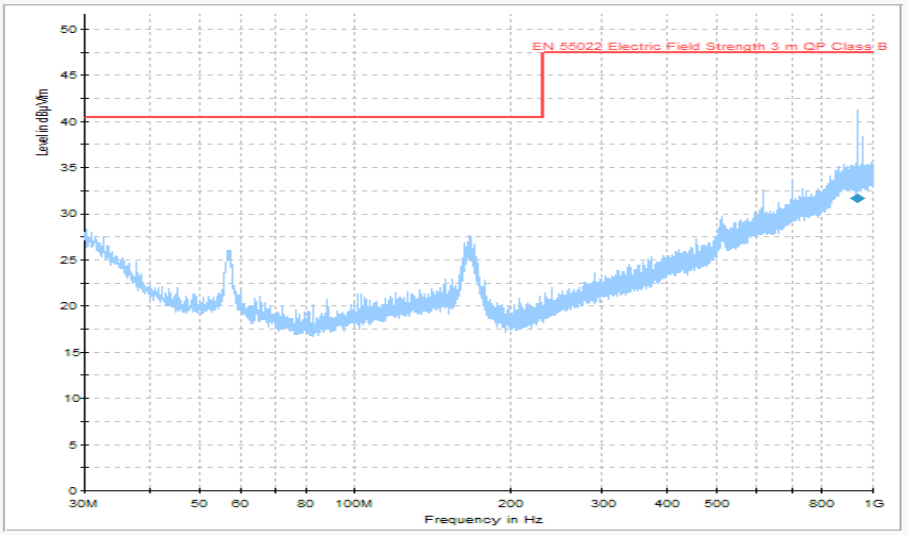

Fig. 8. Portable computer radiated disturbance in vertical polarization.

TABLE III.
FINAL MEASUREMENT DETECTOR IN HORIZONTAL POLARIZATION

Frequency (MHz)	Quasi Peak (dBµV/m)	Meas. Time (ms)	Bandwidth (kHz)	Antenna height (cm)	Turntable position (deg)	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
895.26	29.1	1000	120	400	180	23.6	18.4	47
895.8	30.8	1000	120	250	180	23.6	16.7	47
896.52	28.8	1000	120	250	0	23.6	18.7	47
901.74	29.0	1000	120	250	0	23.6	18.5	47
934.2	35.5	1000	120	400	180	23.8	12.0	47
935.16	33.4	1000	120	400	0	23.8	14.1	47

TABLE IV.
FINAL MEASUREMENT DETECTOR IN VERTICAL POLARIZATION

Frequency (MHz)	Quasi Peak (dBµV/m)	Meas. Time (ms)	Bandwidth (kHz)	Antenna height (cm)	Turntable position (deg)	Corr. (dB)	Margin (dB)	Limit (dBµV/m)
935.22	31.7	1000	120	400	180	23.8	15.8	47

IV. CONCLUSIONS

This paper seeks to highlight some theoretical and practical aspects for radiated emissions testing in semi-anechoic chambers at a distance of 3 meters. Some three-meter measurements for radiated emissions were performed using a Portable computer as testing equipment.

The harmonization of standards has been pursued, so as to make clear both the standard procedure used for testing this type of equipment according to CISPR 22 specifications, and the importance it has in properly fitting the test equipment into a standardized product class.

As a result of the above mentioned conditions, repetitive tests can be performed and, thus, an efficient and economical test method can be carried out compared to outdoor tests (OATS), this being the great advantage of using semi-anechoic chambers.

Analyzing the results of the test report, it has been observed that the Quasi-peak levels imposed by CISPR 22 Standard (40 dBuV/m for the frequency range 30 – 230 MHz and 47 dBuV/m for the frequency range 230 – 1000 MHz) have not been reached or exceeded.

As a result, we can conclude that the tested equipment (Portable computer) works in optimal parameters, and it is in satisfactory agreement with CISPR 22 Standard.

Contribution of authors:
First author – 60%
First coauthor – 10%
Second coauthor – 20%
Third coauthor – 10%

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