Dual Vibrating Intrinsic Reverberation Chamber Used for Shielding Effectiveness Measurements

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Abstract—Two setups for shielding effectiveness measurements of conducting textiles were examined. The first setup was based on IEEE Standard 299 method applied for an anechoic chamber. The second setup was arranged in dual Vibrating Intrinsic Reverberation Chamber. In both setups resonance modes are unavoidable. In the first one they deteriorate final results, while in the second one they improve dynamic range. The second method has the great advantage: oblique incident wave at arbitrary polarizations giving realistic ambient for measurements. A few examples of measurement results are given to illustrate predominancy of the dual VIRC approach over IEEE Std 299 based method.

Keywords—shielding effectiveness measurements; reverberation chamber; IEEE Std 299 method

I. INTRODUCTION

Environment at the present time is overloaded with equipment emitting electromagnetic waves. These emissions create electromagnetic smog, what requires a variety of shielding techniques for susceptible electronic modules, circuits and components. A lot of research is carried out to acquire novel shielding solutions. Properties of new materials can be assessed through numerical modeling or through measurements. For complex shielding materials, e.g. textiles, numerical models become difficult to resolve, and measurement techniques are absolutely necessary.

Shielding effectiveness (SE) of textiles can be measured in different setups. Different methods give different results, because SE depends as well on textile properties as on setup parameters. The correct method is chosen depending on shield application (e.g. frequency range, near or far field region, etc.). For frequencies below 1 GHz very efficient and relatively simple methods based on transmission lines are used (e.g. coaxial, TEM or dual TEM). Whereas for higher frequencies (up to 100 GHz), methods using antennas are applied with more complicated and more time consuming procedures.

I am interested in shielding properties of textiles up to 18 GHz, so I decided to compare well known procedure based on IEEE Standard 299, as noted in [1], with a novel method of dual Vibrating Intrinsic Reverberation Chamber (VIRC). Dual VIRC presented in [2] is a new concept of using two cavities, made of conductive fabrics, which are more effective in mode stirring than conventional reverberation chambers.

Very few experiments were carried out with this new setup, albeit method tends to be very efficient in many kinds of EMC measurements (emission, immunity, SE). The purpose of this work was to check the novel technique in shielding effectiveness measurements. The objectives were achieved by comparing VIRC results with results of IEEE Std 299 method.

II. SHIELDING MEASUREMENT SETUPS

A. Setup for IEEE Standard 299 method

IEEE Standard 299 method is appropriate for SE measurements of any enclosure whose the smallest linear dimension is bigger than 2 meters. The same method can be adapted to SE measurements of small objects like gaskets or flat samples of different materials. For that purpose, the test method requires a shielded enclosure with an open window. Tested objects are mounted in that window, as in Fig. 1.

Following that idea, a setup for textile SE measurements was arranged in an anechoic chamber with adjacent control room, as demonstrated in Fig. 2. There is an open window 60 cm x 60 cm in the wall between the chamber and the room. A hatch with a special fixture for mounting measured textile (Fig. 3) can be fixed in this window. SE of the textile is calculated as a power ratio of electromagnetic field measured without and with the tested material between field source and a receiver:

\[
SE = 10 \log \left( \frac{P_{RX, NO\text{SAMPLE}}}{P_{RX, SAMPLE}} \right).
\] (1)
B. Setup for dual VIRC method

VIRC is an electrically large metallic cavity with high quality-factor (Q), as described in [3]. Boundary conditions inside VIRC are continuously and randomly perturbed by walls movement. When sufficient modes are excited, the field distribution at each location in the working volume of VIRC is a composite of statistically isotropic, randomly polarized and uniformly homogenous plane waves.

VIRC is very effective in mode stirring, enabling measurements over a wide range of frequencies as noted in [4]. A combination of two VIRCs aggregates their Q, creating very powerful setup. One VIRC is used for transmitting, producing high level of EM field strength. The second VIRC is used for detection of low level signals. Because of very high Q of this setup, it is possible to achieve high dynamic range of measurements, using a moderate input power level.

An assembly of dual VIRC setup is relatively simple. VIRCs are build by sewing conductive fabric together, making two cuboid tents. The size of VIRC depends on device under test to be measured and on frequency range as noted in [5]. The bigger the object to be tested and the lower the frequency range, the bigger the VIRC should be. Two VIRCs are combined together with a common wall that forms an interface between them. The hatch with measured textile i.e. “object under test” (OUT) is mounted in the aperture of this common wall.

The wall design and construction should secure good electric connection between OUT and VIRCs. The electromagnetic field is stirred during measurements by moving the walls of both VIRCs. There is no need of any rotating stirrer. Fig. 4 shows the prototype dual VIRC setup with the aperture pointed out by an arrow.

Dimensions of prototype tents are 1.5 by 1.2 by 1 m. VIRCs are made of conductive Shieldex fabric and mounted into two metal frames by means of spiral springs. Each frame is equipped with vertical metal plate to which one of VIRC’ wall is joined. These metal plates enable interconnecting VIRCs together with OUT fixed between them. Two small DC motors are mounted into corners of both frames and attached to quoins of VIRCs. The motors are used to stir VIRCs’ walls.

Two horn antennas were placed in the transmission tent and one horn in the reception tent. The antennas were connected to feed-through connectors installed onto front vertical plates. The measurement setup was completed with cables, a signal generator and a spectrum analyzer. No amplifier was used.

The basic definition of SE measured in an aperture of dual VIRC is the same as for IEEE Std 299 method. Equation (1) is valid for VIRCs when wall losses are dominant i.e. the power transmitted through the aperture or absorbed by OUT is small relative to the power dissipated by the walls and other contents of the chamber. If this is not a case, a more detailed SE equation is recommended, similar to proposed in [7]:

\[
SE = 10 \log \left( \frac{P_{RX, NO\_SAMPLE} \cdot \frac{P_{R, NO\_SAMPLE}}{P_{RX, SAMPLE} \cdot P_{R, SAMPLE}}} {P_{RX, SAMPLE} \cdot P_{R, SAMPLE}} \right)^2. \tag{2}
\]

The fractions represent the power transfer between VIRCs in different directions and in different conditions. The first ratio represents the main power transfer, as in the basic SE definition, both measured with a receiving antenna (RX). The second ratio accounts for the change in the quality factor of the dual VIRC when OUT is mounted on the aperture. The top term represents the power incident onto the aperture with no OUT and the bottom term is the power incident with OUT. Both powers are measured with a reference antenna (R). Equipment configuration within setup is shown in Fig. 5.
III. MEASURING PROCEDURES

I had conducted a few series of measurements of the same textile sample. The same hatch with specialized fixture for textile mounting (with a square aperture of 43 by 43 cm) was used in both setups. The same horn antennas, cables, generator and spectrum analyzer were used in configurations as presented in Fig. 2 and Fig. 5.

Measurements were carried out in frequency range from 1 to 18 GHz. The measurement were conducted in fixed frequencies with a linear step of 200 MHz. Output power of the signal generator was set to 10 dBm and the spectrum analyzer was set to zero span with 300 Hz resolution bandwidth. The spectrum analyzer measured maximum received power over number of sweeping points.

In IEEE 299 setup, for every frequency step, 1000 samples were taken by spectrum analyzer in 0.2 seconds and average value was calculated by personal computer (PC), and then was recorded. While in dual VIRC setup, maximum value of taken samples was recorded, as recommended for measurements in reverberation chambers. In frequency range 1 – 8 GHz 40000 samples were taken in 10 seconds for every frequency step, and in the frequency range 8 – 18 GHz 8000 samples were taken in 2 seconds. Sweep time and number of sweeping points were chosen to acquire stable results, after conducting a few experiments.

Before starting SE measurements of textile sample, the dynamic range of measurement systems had been checked. It was virtually 80 dB for both setups.

Figure 6. Power level of electromagnetic field measured for different combinations of TX and RX antennas polarization in dual VIRC setup: blue line for H pol., green line for V pol., red line for cross-polarized antennas.

Then isotropy and uniformity of waves inside VIRC was examined. Power level of electromagnetic field was measured for different combinations of TX and RX antennas polarization: both H, both V and cross-polarized. Results of measurements were very congruent (as presented in Fig. 6) demonstrating effective field stirring. After confirming good quality of setups, measurements of SE were carried out.

Firstly, OUT was fixed in the aperture of anechoic chamber and some absorbers were placed inside control room in regions of expected reflections. Then measurements were conducted for two antenna polarizations: horizontal (H) and vertical (V). Secondly, some more absorbers were placed inside control room and measurements were repeated for both polarizations. Thirdly, OUT was fixed in the aperture of dual VIRC and measurements were conducted for two orthogonal antenna positions: X and Y. Because of statistically isotropic and randomly polarized character, plane waves inside VIRC can not be described as H or V.

Next, the experiment was carried out with more complicated structure than a textile. Measurements of electronic module installed on perforated metal chassis were done in both setups to check SE of that configuration. The purpose was to acquire solid evidence on the utility of VIRC method.

IV. RESULTS AND ANALYSIS

The measurements results acquired in IEEE Std 299 procedure demonstrate different SE of the textile for V and H polarizations, as can be seen in Fig. 7. This difference is the consequence of non-homogenous structure of textiles. Rapid grows and falls of lines on the graph are created by resonance effects inside control room. For some frequencies there is an apparent discrepancy between the first set of test results and the second set of results. Character of resonance effects was changed by adding some absorbers. Textile SE is deteriorated by these resonance effects. On the contrary, dual VIRC results for orthogonal antenna positions are similar, as can be seen in Fig. 8. In the VIRC case, the resonant modes are well stirred, giving statistically isotropic electromagnetic field inside working volume. Acquired final results are very stable.
New evidence of dual VIRC utility comes to light when electronic module of complicated structure is measured. Because of regular net of holes for inputs/outputs, there are some directions of incident electromagnetic wave for which SE is much lower.

Standard procedure of IEEE 299 gives two results for two arbitral position of antennas that is not likely the worse configuration. Finding antennas position for the worse case could be time-consuming, if ever possible, in IEEE 299 setup. On the contrary, the lowest SE is very easy to find in dual VIRC setup, as the antennas position is irrelevant. The worst case always dominates SE results, as can be seen in Fig. 9.

V. CONCLUSIONS

Comparison of SE measurements demonstrated predominancy of novel approach over IEEE Std 299 method. Dual VIRC creates unlimited set of incident wave conditions, while in IEEE 299 setup incident wave of only one direction and fixed polarization is generated. Object under test in the VIRC setup is exposed to more realistic environment than in IEEE 299 setup. Dual VIRC gives very stable results and facilitates high dynamic shielding effectiveness measurements with relatively simple equipment.

The prototype setup was used from 1 to 18 GHz, giving 80 dB dynamic range with no amplifier. Some tests were carried out for frequencies up to 40 GHz with consistent results, not included in this paper. The low limit for frequency can be extended below 100 MHz by building bigger tents. The only disadvantage of dual VIRC setup is the requirement of very good electric connection between setup and tested objects.

Dual VIRC is simple yet very powerful measurement setup that should gain more attention. More study should be conducted to use it effectively in EMC testing, because this new method can be utilized almost in every laboratory.

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REFERENCES