Measurements of Backscattering from a Dihedral Corner in a Reverberating Chamber

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Abstract ─ In this paper, the backscattering of a dihedral corner is evaluated by measurements accomplished within the reverberating chamber (RC) of the Università degli Studi di Napoli Parthenope, formerly Istituto Universitario Navale (IUN). The obtained results are found in good agreement with those of a previous very accurate model, whose validity was assessed by anechoic chamber measurements.

Index Terms ─ Anechoic chamber, dihedral corner, reverberating chamber.

I. INTRODUCTION

The dihedral corner has been largely used as target in experimental determinations of radar cross section (RCS). Moreover, it is readily applied in a wide variety of complex target configurations. Experimental studies of dihedral corner backscattering have been always accomplished within the anechoic chamber (AC) [1]. The AC is a test-environment in which each direction around the device under test (DUT) is evaluated without any extraneous reflections. In other words, the AC is an artificially simulated controlled environment in which the studies on the DUT can be performed without any reflections or diffraction from the AC walls, i.e., in an ideal environment. The AC is employed for providing antenna parameters but other measurements, such as radiated emission, radiated susceptibility, shielding effectiveness and other electromagnetic compatibility measurements (EMC) are also accomplished in it [1]. Despite of these aspects, the AC is a very expensive test-site due to the large amount of electromagnetic absorbers that are fixed on its walls, floor and ceiling [1].

In the last years, a completely different test-site, i.e., the reverberating chamber (RC) enjoys growing popularity for studies and applications on electromagnetic fields [2-12]. The RC is a metallic chamber in which the input electromagnetic field is randomized by employing different stirring techniques such as mechanical, frequency and source stirring techniques [12]. Nowadays, the RC is become a well-established standard for EMC [13] and it is recently become also standard for wireless applications [14]. Differently from the AC where only a direct link is present between the transmitting antenna and the DUT, within the RC several plane waves incoming from all directions and with own polarizations arrive to the DUT in addition to the direct link. Although from an electromagnetic point of view, the RC appears slightly more complicated with respect to the AC, from an economical point of view, it is more convenient since it is made of aluminum that is essentially much cheaper than the AC absorber. In this paper, a first approach to study the backscattering from a dihedral corner within the RC is accomplished and the obtained results are compared with those of a previous very accurate model, whose validity was already assessed by AC measurements. Although the RC walls are not covered of absorber material, experimental results show that the RC can be used as alternative test facility to the traditional AC measurement procedures for measuring the RCS of dihedral corner. This fact, in addition to its affordability, makes the RC a suitable alternative to the AC for equipping an electromagnetic laboratory with a good performance and not expensive test site facility.

II. MEASUREMENTS OF BACKSCATTERING IN RC

In an RC the field can be expressed in terms of S_{21} scattering coefficient between the two antennas. This is a common approach used to determine the statistical behaviour of the received field within an RC [8]. In particular, the field obtained can be read as a sum of a deterministic component between the transmitting and the receiving antennas and the scattered component associated to reflections and diffraction on the RC walls and stirrers. Let us call such components $S_{21,d}$ and $S_{21,r}$. Hence, S_{21} can be expressed as follows:

$$S_{21} = S_{21,d} + S_{21,r}. \tag{1}$$

In particular, $S_{21,d}$ has zero variance and no zero mean. On the other hand, the real and the imaginary parts of the

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scattered component, i.e., $S_{21,r}$, follow independent zero mean normal distribution with the same variance σ^2. Therefore, it follows that,

$$E\left[S_{21}\right]=E\left[S_{21,d}\right]+E\left[S_{21,r}\right]=E\left[S_{21,d}\right]. \qquad (2)$$

According to (2), the square amplitude of $S_{21,d}$ is equal to the power of direct link component and the variance of $S_{21,r}$ is equal to the power of multipath scattered components [10]. Since we are dealing with the radiation characteristics of a perfectly conducting dihedral corner reflector within the RC, a single but effective sample-based estimator, that takes into account the powers of the direct link and the one of the reflected/diffracted components, must be achieved. Hence, the Rice factor estimator, i.e., $\hat{K}$, is applied. $\hat{K}$ is equal to the power ratio between the direct to the scattered component of the received electromagnetic field, i.e.,

$$\hat{K}=\frac{\left|S_{21,d}\right|^2}{\left\langle\left|S_{21}-S_{21,d}\right|\right\rangle^2}, \qquad (3)$$

where $\left\langle\left|S_{21}-S_{21,d}\right|\right\rangle^2$ is the power of the scattered field component. The $\hat{K}$ factor has been estimated by following the technique developed in [3] in order to improve the accuracy of the backscattering measurements.

III. SIMULATION OF DIHEDRAL CORNER BACKSCATTERING

In this section, a brief explanation of the model employed for the dihedral corner backscattering is summarized. The model used for the simulations is a combination of the improved physical optics (IPO) model and of the physical theory of diffraction (PTD) contribution. It allows predicting very accurately the RCS of the corner in a plane normal to its wedge. The solution of the dihedral corner backscattering is given from the sum of four contributions, in sequence of their quantitative relevance:

a. the backscattering from the faces lighted from the reflected rays;
b. the backscattering due to the direct lighting by the impinging wave;
c. the backscattering due to the lighting of each face by the rays diffracted from the edge of the other one;
d. finally, the PTD correction term.

The first order contribution (a) is the first order term of interaction scattering and the second order contribution (b) is the first order term of the direct scattering, while the contribution (c) is the second order term of the interaction scattering and (d) is the second order term of the direct scattering. The joined IPO and PTD model has been developed and experimentally assessed in [15-16] by comparisons with AC measurements. Representative results of the above-mentioned model are shown in Fig. 1, where the backscattering from dihedral corners with different sizes is reported versus the azimuthal angle. The dihedral face dimensions are $a \times b$ where a is the size of the smallest side. In particular, with respect to the working wavelength, the blue, red, green and black curves are relative to $a/\lambda = 3$, $a/\lambda = 4$, $a/\lambda = 4.5$ and $a/\lambda = 5$, respectively. In the following section, the backscattering measurements from a dihedral corner performed within the RC are compared with the simulated results obtained from the joined IPO and PTD model.

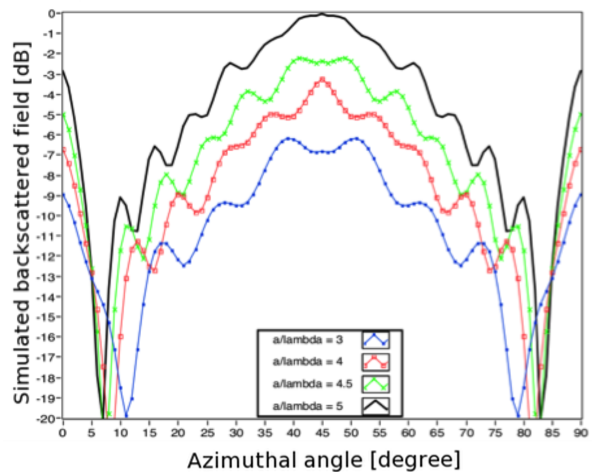

Fig. 1. Simulated dihedral backscattering for different dihedral dimensions. The graph shows the backscattered field (in dB) versus the azimuthal angle (0, 90°). The blue curve is relative to $a/\lambda = 3$; the red curve is relative to $a/\lambda = 4$; the green curve is relative to $a/\lambda = 4.5$; finally, the black curve is relative to $a/\lambda = 5$. The different curves are separated of 6, 4, 2 dB, respectively, from the black one.

IV. EXPERIMENTAL RESULTS

In this section, a meaningful set of experimental results is provided and discussed. Measurements have been conducted at the RC of the Università degli Studi di Napoli Parthenope, formerly Istituto Universitario Navale (IUN). The IUN RC is a 120 m^3 metallic chamber wherein five mechanical stirrers are present. The first two stirrers are volumetric stirrers. They can operate both in step or in continuous mode with a maximum speed of 15 rate per minute (rpm). The horizontal one is placed at the right side of the entrance door; the vertical stirrer is placed opposite to the entrance door. The three flat stirrers can rotate in continuous mode in clockwise or in counter clockwise and with different velocity up to 300 rpm. It is important to note that the stirrer speed control system uses an interface connection, developed in LabVIEW, between the personal computer and the stirrer controller. Through this last one, the desired rpm of the stirrer speed is set up. The first stirrer, S1, is on the wall opposite to the entrance door, the second one, S2, is on the right of the entrance door. Finally, the third stirrer, S3, is on the ceiling of the RC. A sketch of the RC used for the measurements is shown in Fig. 2. Assuming a distance of 0.35 m from walls and stirrers, at minimum usable frequency, the working volume (WV) one considered exhibits an area of about 22 m^2 and a volume of about 70 m^3 [7]. Two Narda Standard Gain Horn working on X-band (8.20 – 12.4 GHz) have been employed, see Fig. 2. The antennas have a shape of four sided pyramids with a rectangular cross-section of 0.078 × 0.059 m^2 area dimensions. Measurements from dihedral corner backscattering have been accomplished by using monochromatic signals at 10 GHz frequency. The dihedron is placed about 1 m from the floor on polystyrene support and it is moved by means of a rotating table (Microcontrole ITL 09) that is managed by LabVIEW. Figure 2 shows a particular of inner of the IUIN RC used for the measurements. For each single measurement, a data set of 501 samples is acquired in 2.00 s, that corresponds to a sample time equal to about 4 ms. In all the experiments all the stirrers are operated together. In particular, the volumetric stirrers are operated at 10 rate for minute (rpm), S1 is operated at 65 rpm, S2 is operated at 45 rpm. Finally, S3 is operated at a 30 rpm. A full calibration of the entire system is *a priori* accomplished to allow obtaining data free of noise due to, for instance, to the cable losses or instrumentation thermal noise. The scattering coefficient S_{21} is measured by making use of the Agilent Technologies Network Analyzer (VNA).

The software used to off-line analyse the acquired data is developed in LabVIEW.

Figure 3 shows the comparison between the backscattering measurement of the dihedral corner with a/λ = 5 performed within the RC and the simulated ones. In particular, the red line is obtained from the RC measurement while the black line is given by simulation. A spherical coordinate system and an azimuthal angle range (0, 90°) have been considered. Two antennas are physically employed for the backscattering measurement. Hence, a pseudo-monostatic configuration with the electromagnetic field in a vertical polarization has been employed. The cross polarimetric separation of the two antennas is equal to 20 dB. Hence, it has no effect on the received dihedral corner backscattering. A fairly good agreement between measurements and simulations is shown in Fig. 3. In particular, two curves, relative to the backscattering of the dihedral corner with a/λ = 5 versus the azimuthal angle, are shown: the AC simulated one (continuous black line with crosses) and the RC measured curve (continuous red line with dots). The good agreement between the two curves witnesses that the RC can be used as alternative test facility to the traditional AC measurement procedures for measuring the RCS of a dihedral corner. It must be noted that these backscattering measurements of dihedral corner within the IUN RC are only a first approach to the RCS measurements in a multipath environment such as the RC.

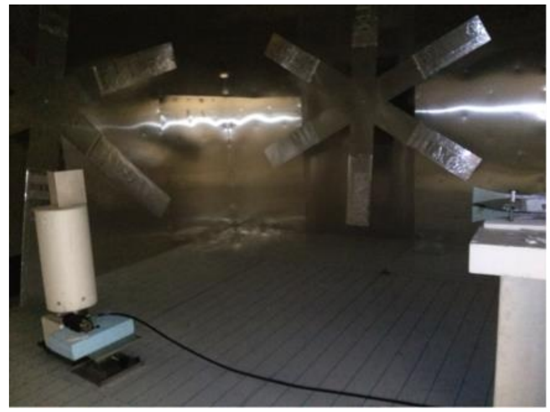

Fig. 2. Particular of the inner IUN RC with the flat S1 and S2 stirrers, the antennas in pseudo-monostatic configuration and with the dihedral corner reflector on the Microcontrole ITL 09 rotating table.

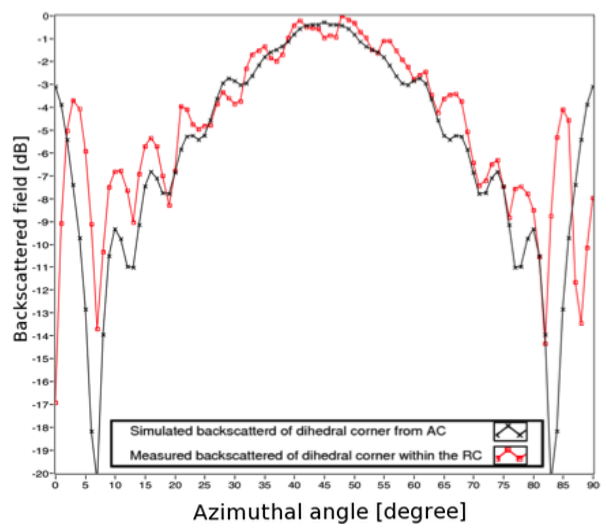

Fig. 3. Comparison between the backscattering measurement from the dihedral corner with a/λ = 5 performed within the RC (red line) and the simulated one (black line), versus the azimuthal angle.

V. CONCLUSIONS

In this paper, an innovative method for the backscattering from a dihedral corner within the RC has been proposed and successfully accomplished. Experiments conducted at the IUN RC have shown that a significant agreement between the measurement results and the simulated ones obtained with a very accurate and reliable model occurs.

Therefore, the RC can become a valid and economical convenient alternative to the well-established AC procedures for RCS measurements.

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