Radar Cross Section Measurements and Simulations of a Model Airplane in the X-band

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Abstract— The objective of this study was to illustrate how different methods of obtaining the Radar Cross Section (RCS) of an object may produce different results. RCS diagrams of a metallic airplane model (length, 0.64 m) were obtained in an anechoic chamber, with a Lab-Volt RCS system, and simulated with a simulation software. The measurements and simulations were carried out at the radar frequency of 9.4 GHz. The resulting RCS diagrams show that although there was a good correspondence between the main features in the RCS diagrams, some differences can still be observed, highlighting the need for different techniques to fully represent the RCS of an object.

1. INTRODUCTION

Radar cross section (RCS) diagrams are usually difficult to interpret due to the fact that they are two-dimensional representations of three-dimensional objects. Moreover, the difficulty in interpreting RCS diagrams is dependent upon the geometry of the object and, sometimes, on the techniques used to measure or calculate the RCS. Measurements are also affected by many external factors, such as instrumental errors, spurious reflections and interferences, which can degrade the quality of the experimental data. In this study, we measured the RCS of an airplane model with a conducting surface using two different experimental set-ups, and also simulated its RCS using commercial electromagnetic simulation software. The comparison of the data obtained shows that differences will arise regardless of the care taken while performing an experiment or carrying out simulations and that these differences should be taken into consideration when interpreting the data.

2. EXPERIMENTAL MEASUREMENTS

The experimental data were collected using two different experimental setups: One inside an anechoic chamber and another in a laboratory room using the Lab-Volt Radar Training System.

The anechoic chamber, is located in the Instituto de Fomento Industrial (IFI/CTA, Brazil). Figure 1 shows the radar antennas used in the measurements. These X-band horn antennas were manufactured by M2SAT (Brazil); each antenna has a gain of 10 dBi, and symmetric radiation patterns with low level of secondary lobes. The radar operated at 9.4 GHz, in a quasi-monostatic configuration and vertical polarization. A HP8360B (HP, USA) synthesized CW generator was use to generate the microwave radiation and the reflected signal was analyzed by a HP8593E (HP, USA) spectrum analyzer. It is estimated that the deviation of the RCS measurements was within 0.7 dB. The model used in the measurements is also shown in Figure 1; it is a scale model of a Boeing 777 with total length of 0.64 m ($\sim 20\lambda$). The body of the model is composed of an epoxy resin and its surface is coated with aluminum (the thickness of the coating is about 10 times larger than the skin depth of the aluminum at this frequency). The distance between the radar antennas and the model was about 6 m.

Electronic Warfare Laboratory (LGE/CTA, Brazil), consisting of interconnected subsystems that allow detailed studies of RCS in a laboratory environment. Measurements were carried out with inverse synthetic aperture radar, operating also at 9.4 GHz at short range, in the presence of noise and clutter. The effects of noise and clutter were removed using time-gating and subtraction techniques during the measurements. For the measurements, the distance between antenna and model was the same one used for the measurements in the anechoic chamber. Figure 2 shows the arrangement of the radar antenna and the model in the laboratory. The model was placed on a Styrofoam pedestal, invisible to radar waves.

Figure 1: Horn radar antennas (transmitting and receiving) (left), and model mounted on a rotating pedestal (right), inside the anechoic chamber.

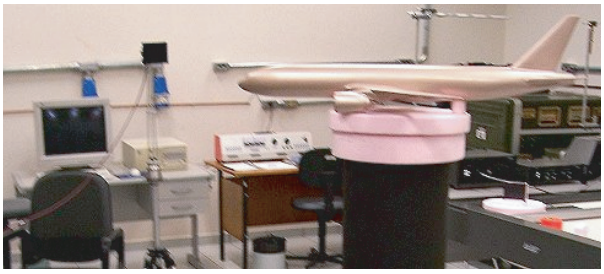

Figure 2: Target mounted on a rotating pedestal and antenna (A) used in the lab-Volt radar training system.

3. RCS SIMULATION

The simulation software CADRCS [3] was used for the simulations. CADRCS uses physical optics combined with ray-tracing and shadowing of objects for the accurate calculation of the RCS of objects greater than radar wavelength [4]. A commercially available CAD model of the Boeing 777 was used in the simulations. The surface of the CAD model was discretized into triangular elements using Rhinoceros modeling tool [6] and imported to the simulation software. A Pentium 4 3.2 GHz PC computer with 4 GB of RAM was used. Figure 3 shows the CAD model used in the simulations, the surface of this model was discretized into 28555 triangular elements. The dimensions of the CAD model (length, wing span) were identical to the model used for the anechoic chamber and Lab-Volt measurements.

4. RESULTS

Both simulations and measurements were performed under the same conditions such as wave polarization and frequency, and distance between radar and object surface. The models were rotated in azimuth with respect to an axis perpendicular to their main symmetry axis. The measurements were obtained in a near-field situation since the distance, r, between the model and the radar antenna did not satisfy the far-field condition, $r > 2d^2/\lambda$, where d is the largest dimension of the model, and λ is the wavelength of the radar [5]. In the simulation, RCS values were calculated at 0.25° intervals; the measurements in the anechoic chamber and with the Lab-Volt system were ob-

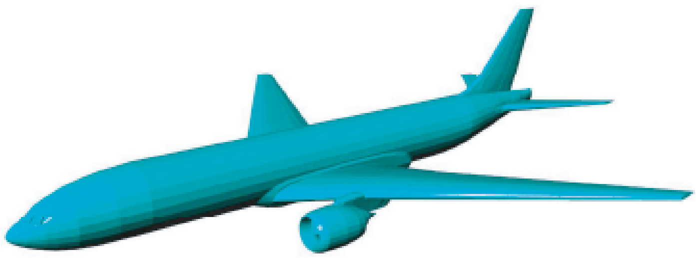

Figure 3: CAD model of the Boeing 777 airplane used in the simulations, length 0.64 m.

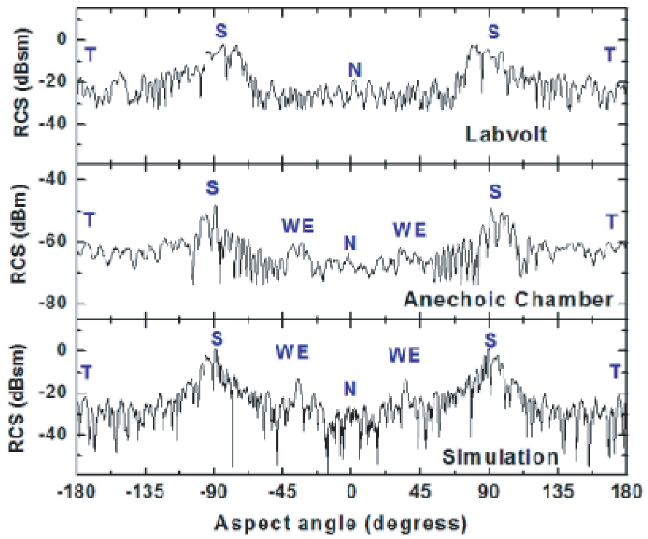

Figure 4: Comparison of RCS diagrams obtained from measurements (Lab-Volt, Anechoic Chamber), and simulations. In the figure, T, S WE, and N indicate that the tail, side, wing edge and nose of the airplane, respectively, were oriented toward the radar antennas. RCS values obtained from simulations and Lab-Volt measurements are displayed in dBsm, and results obtained in the anechoic chamber are displayed in dBm.

tained at approximately at 0.4° and 0.35° intervals, respectively. Figure 4 shows the RCS diagrams obtained from measurements and simulations.

The Lab-Volt Radar Training System, which has been described in detail elsewhere [1, 2], is located in the Of the three diagrams, the one obtained from simulations shows the highest level of detail and symmetry. This was expected, since simulations are not hindered by experimental or instrumental problems. The RCS diagram in this case clearly shows major features of the model, such as the sides of the airplane, corresponding to high reflectivity values, and the wing edge of the airplane. The anechoic chamber RCS diagram also shows these features, with the relative amplitude of the main features being similar to those in the simulation RCS diagram, but one observes that the diagram is not as symmetrical and that lobes corresponding to the same aspect angle have different widths. The RCS diagram obtained with the Lab-Volt system shows the least level of detail, failing the register, for instance, the wind edge, which is a prominent feature of the model; but the diagram in this case shows a good level of symmetry.

Differences between diagrams and the reduced symmetry in a diagram can be the result of many factors such as differences between the CAD model and the actual model, minor misalignments between the antennas and the model and of the model, incorrect positioning of the model on the pedestal, spurious reflections, and instrumental error. Since the diagrams are two-dimensional representations of three dimensional objects it is very difficult to identify sources of problems in the experimental procedures, especially when the experiments were set-up carefully.

5. CONCLUSION

The correct determination of the RCS of an object is a rather difficult task due to the many factors involved in the measurements such as the experimental sources of errors and that can alter significantly the RCS diagram of an object; and once the results are collected the RCS diagram itself is not easily interpreted due to its two-dimensional nature. On the other hand, simulations produce results free from experimental errors and can be carried out taking into account a larger of configurations number, but they depend on high computing power and can be time consuming. The results obtained above suggest that, whenever possible, simultaneous techniques should be used to determine the RCS more precisely.

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