Progress In Electromagnetics Research Letters, Vol. 26, 181–187, 2011

SPHERICAL INDOOR FACILITY APPLIED TO BISTATIC RADAR CROSS SECTION MEASUREMENTS

D. Escot-Bocanegra[1, *], D. Poyatos-Martínez[1], I. Montiel-Sánchez[2], F. M. Sáez de Adana[3], and I. González-Diego[3]

[1]Laboratorio de Detectabilidad y Guerra Electrónica, Instituto Nacional de Técnica Aeroespacial (INTA), Ctra. Ajalvir Km. 4, 28850, Torrejón de Ardoz, Madrid, Spain

[2]Área de Comunicaciones, Navegación y Radar, Instituto Nacional de Técnica Aeroespacial (INTA), Ctra. Ajalvir Km. 4, 28850, Torrejón de Ardoz, Madrid, Spain

[3]Departamento de Ciencias de la Computación, Universidad de Alcalá 28806, Alcalá de Henares, Madrid, Spain

Abstract—A new indoor facility for electromagnetic tests is presented and used here for the specific case of bistatic radar cross section (RCS) measurements. A metallic cube is selected as test case and the results are compared with the predictions obtained with different numerical methods. Good agreement is reported.

1. INTRODUCTION

Most modern radar systems work in monostatic configuration where both transmitter and receiver are located in the same position. Lately a renewed interest in bistatic radar (transmitter and receiver are in different positions) has awakened, due to some of the key advantages of this configuration. Mainly, both object detection and identification can be significantly enhanced through utilization of the additional dimension provided by a bistatic geometry. In this sense, passive radars are bi- or multistatic radar systems that exploit non-radar transmitters of opportunity to detect or identify targets [1]. Similarly, one of the main techniques employed to diminish a target's monostatic radar cross section (RCS) is based on the modification of its shape so that most part of the energy impinging on it is redirected towards directions

Received 22 August 2011, Accepted 23 September 2011, Scheduled 25 September 2011
* Corresponding author: David Escot-Bocanegra (escotbd@inta.es).

different from the source. But, laws of physics cannot be deceived and RCS must have augmented for some bistatic angles [2].

Hence, now great efforts have started to measure bistatic RCS as can be seen, for example, in [3–5]. This paper presents a new indoor measurement facility conceived for conducting various electromagnetic tests and the first bistatic RCS results produced in this system are reported here for the first time.

2. FACILITY DESCRIPTION

The facility presented in this paper has been devised and developed by the Detectability and Electronic Warfare Laboratory (DEWLab), INTA, Spain and built by Orbit/FR-Europe GmbH, Germany, and Alava Ingenieros, S.A., Spain. The DEWLab research group is specially interested in RCS analysis and in near-field to far-field transformations (NFFFT) research for RCS [6, 7], and wanted to extend its test capabilities to perform full bistatic measurements in a wide frequency range. But this system will also allow conducting a full variety of electromagnetic tests: estimation of intrinsic properties of materials, antenna measurements, analysis of radome effects, radar

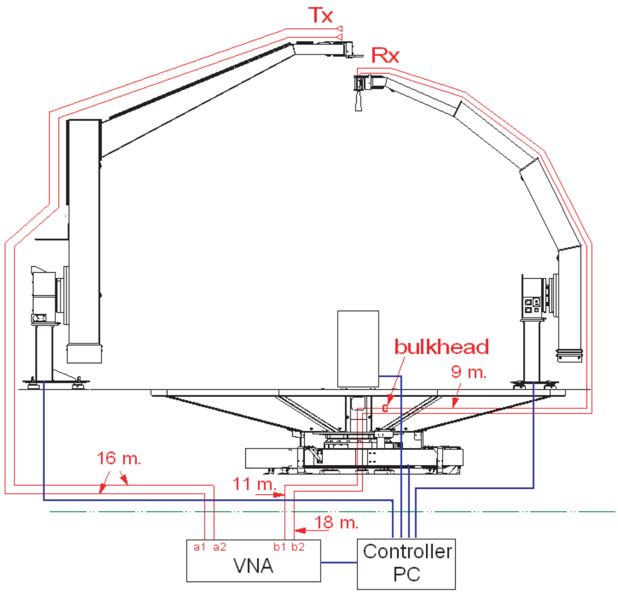

Figure 1. Block diagram. A PC controls the motion and acquires data from the VNA.

absorption tests, etc. The facility, that has been recently delivered, is being set-up and starting to produce the first results [8].

Mechanically, the system consists of two scanning arms driven by two elevation positioners, a turntable and an azimuth positioner. Each arm is governed by one elevation positioner, and the inner arm stands on the turntable, which is moved by the biggest azimuth positioner. Both azimuth positioners are located in a pit below the turntable and the smallest one supports a foam column for target, material or antenna manipulation. The two arms can hold an antenna, and with the use of an extension for the outer one, both antennas can be situated in any point of an imaginary hemisphere and any combination of angles between them and the center can be established. The space available in the laboratory has been optimized and the final center is 88.7 cm from the turntable with 1.7 m scan radius. Two RF cables reach each probe following the sketch presented in Figure 1. With this configuration full polarimetric bistatic measurements can be easily carried out. The instrumental radar used in this facility is the Rhode & Schwarz ZVA50 four-port Vector Network Analyzer (VNA) with reconfigurable receivers, time-domain measurements capability and 1 Hz resolution. The motion and measurement are controlled by a computer. The system can operate from 5.5 to 26.5 GHz by using two sets of two dual linearly polarized probes. The whole facility is housed in an anechoic chamber covered with pyramidal, wedge or flat absorber material to minimize the effect of energy reflections. Further information can be found in [9] and Figure 2 shows a photograph of the

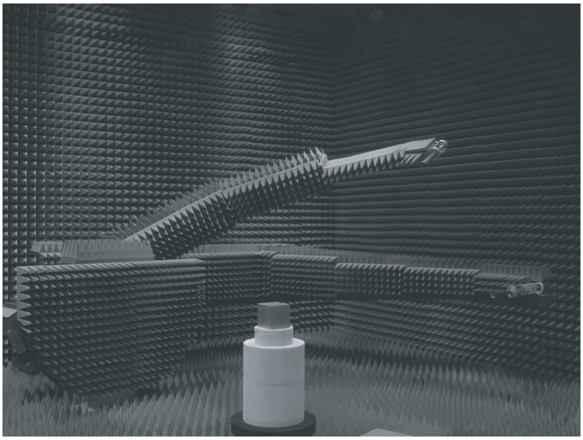

Figure 2. The facility presented in this paper during the measurement of the metallic cube.

facility while being used for testing the metallic cube presented below.

Literature for indoor bistatic facilities is scarce, because the investment for deploying such systems is high and they are only updated or substituted after years of operation, but this facility is an alternative to the similar systems shown in [3] or [5]. In the former, six rails in azimuth provided some bistatic capability in a dome-shaped chamber, but not for every point of the hemisphere. In the latter, a near-field RCS indoor spherical facility was proposed, but bistatic capability was not included. More recently, the chamber employed in [10] could provide bistatic measurements with antennas moving along two fixed rails (one horizontal and one vertical) but other cuts are not possible. Thus, our facility, able to locate two probes at any point of a hemisphere, permits to conduct bistatic angular sweeps that are difficult or impossible to make in other facilities.

3. TEST CASE

A 12 cm metallic cube has been chosen as test case. The metallic cube has been studied in the past and is reported in the literature [11], but this facility allows conducting bistatic angular sweeps in which the transmitter and the receiver are not in the same plane. Thus, with the cube centered in the coordinate system sketched in Figure 3, two cuts are presented in this paper: phi (ϕ) $= 15^\circ, 45^\circ$. For both of them, a probe remains still, transmitting from the +x axis (theta (θ) $= 90^\circ, \phi = 0^\circ$), while the receiving probe moves from $\theta = 0^\circ$ to $\theta = 90^\circ$. The measurements are conducted at 5.8 GHz so that the far-field criterion is accomplished,

$$f < \frac{Rc}{2D^2} \tag{1}$$

where f is the frequency, R the probe-target distance (here 1.7 m), c the speed of light and D the biggest dimension of the target projected onto the plane perpendicular to the line of sight. This facility is an experimental layout to allow researching in near-field to far-field transformations for RCS. More complex targets will be studied when the research advances.

4. MEASUREMENTS

Software gating was employed to enhance the quality of the measurements, meaning that the tests were conducted in the frequency-domain after selecting an appropriate gate in the time/distance-domain to filter out other responses than the coming from the cube. In this sense, a

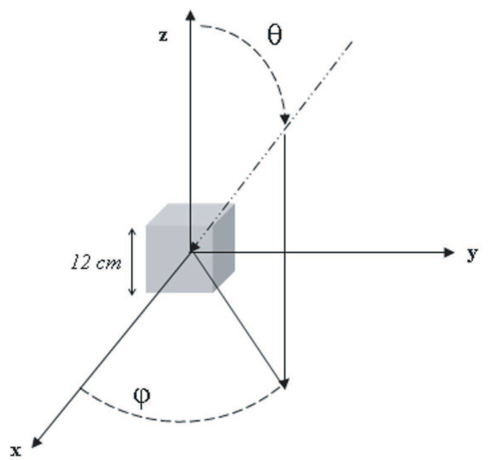

Figure 3. Coordinate system, angles and notation.

Bohmman gate centered in the main peak of the cube's response with a span of 800 mm was chosen. Vector background subtraction was also utilized to improve the signal-to-noise ratio so an identical full angular sweep with no target was conducted before measuring the cube itself. Calibration is accomplished by measuring, for a single bistatic angle, a reference with well-known bistatic RCS. In this case, a 19 cm-diameter metallic sphere was chosen and the measurement was compared with the analytic Mie solution.

5. RESULTS

In Figures 4 and 5, the measurements are plotted together with the predicted results obtained with two different commercial software codes: HFSS v13.0, from Ansys Inc., based on the finite element method (FEM) and MONURBS, a module of the NewFasant v4.3 suite (from NewFasant S.L.), based on the method of moments (MoM) and the multi-level fast multipole algorithm (MLFMA). The aim of this paper is not to discuss the details of the programs but to use them to show that the measurements are correct. However, it must be pointed out that the results presented here are convergent and the simulations were run until the residual error was sufficiently small. It can be appreciated in the figures that both tools, albeit being based on different numerical techniques, produce nearly undistinguishable predictions. There is always some uncertainty when conducting a measurement. This is typically worse when trying to measure low

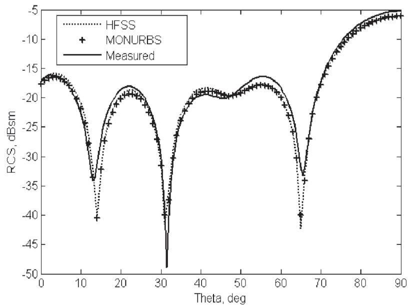

Figure 4. Measured and predicted bistatic RCS for $\phi = 15°$ and theta-theta polarization.

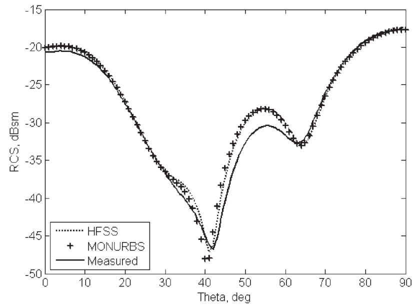

Figure 5. Measured and predicted bistatic RCS for $\phi = 45°$ and phi-phi polarization.

level signals because the background noise is nearer and relative error becomes bigger. Therefore, small discrepancies between predictions and measurements can also be observed, but they are similar or better to those reported in [11].

The bistatic RCS for $\phi = 15°$ and $\theta - \theta$ polarization is presented in Figure 4. Good agreement with respect to the simulations is achieved. It is worth noting that the level of RCS remains around -20 dBsm with three minimums encountered at 14°, 31° and 65° After that, the RCS level smoothly increases until the maximum, for $\theta = 90°$, where the two probes are closer to a monostatic configuration.

Figure 5 depicts the measured bistatic RCS of this target for $\phi = 45°$ and $\phi - \phi$ polarization. Overall, good agreement is achieved. The RCS levels are smaller than in the previous cut and the global minimum is encountered around 40°. From there, again, the RCS increases until $\theta = 90°$.

6. CONCLUSION

A new facility capable of producing full bistatic RCS measurements has been introduced, and the first results have been successfully presented and compared with numerical predictions.

REFERENCES

1. Brown, J., K. Woodbridge, A. Stove, and S. Watts, "Air target detection using airborne passive bistatic radar," *Electronics Letters*, Vol. 46, No. 20, 1396–1397, 2010.

2. Paterson, J., "Overview of low observable technology and its effects on combat aircraft survivability," *Journal of Aircraft*, Vol. 36, No. 2, 380–388, 1999.
3. Chung, B. K., H. T. Chuah, and J. W. Bredow, "A microwave anechoic chamber for radar-cross section measurement," *IEEE Antennas and Propagation Magazine*, Vol. 39, No. 3, 21–26, 1997.
4. Lane, T. L., N. T. Alexander, and C. A. Blevins, "The bistatic coherent measurement system (BICOMS)," *The Record of the IEEE Radar Conference*, 154–159, 1999.
5. Chevalier, Y., P. Minvielle, F. Degery, and P. Brisset, "Indoor spherical 3D RCS near-field facility," *Annual Meeting of the Antenna Measurement Techniques Association, AMTA,* 2007.
6. Leou, J. L. and H. J. Li, "Evaluation of bistatic far-field quantities from near-field measurements," *Progress In Electromagnetics Research*, Vol. 25, 167–188, 2000.
7. Li, N.-J., C.-F. Hu, L.-X. Zhang, and J.-D. Xu, "Overview of RCS extrapolation techniques to aircraft targets," *Progress In Electromagnetics Research B*, Vol. 9, 249–262, 2008.
8. Poyatos-Martínez, D., D. Escot-Bocanegra, E. de Diego-Custodio, I. González-Diego, F. Sáez de Adana, and I. Montiel-Sánchez, "Application of a spherical multi-purpose facility to the selection of the appropriate radome for an on-board pod antenna," *Journal of Electromagnetic Waves and Applications*, Vol. 25, Nos. 8–9, 1243–1252, 2011.
9. Escot, D., D. Poyatos, J. A. Aguilar, I. Montiel, I. González, and F. Saez de Adana, "Indoor 3D full polarimetric bistatic spherical facility for electromagnetic tests," *IEEE Antennas and Propagation Magazine*, Vol. 52, No. 4, 112–118, 2010.
10. Trouve, N., E. Colin-Koeniguer, P. Fargette, and A. De Martino, "Influence of geometrical configurations and polarization basis definitions on the analysis of bistatic polarimetric measurements," *IEEE Transactions on Geoscience and Remote Sensing*, Vol. 49, No. 6, 2238–2250, 2011.
11. Penno, R. P., G. A. Thiele, and K. M. Pasala, "Scattering from a perfectly conducting cube," *Proceedings of the IEEE*, Vol. 77, No. 5, 815–823, 1989.