A Reflection Suppression Technique for Far Field Antenna Measurements

Manuel Sierra Castañer[1], Francisco Cano Fácila[2], Lars Jacob Foged[3], Francesco Saccardi[3], Guilherme Nader Kawassaki[4], Lucas dos Reis Raimundi[4], Stefano Albino Vilela Rezende[4]

[1] Grupo de Radiación. ETSI Telecomunicación. Universidad Politécnica de Madrid. Madrid, Spain, mscastaner@gr.ssr.upm.es

[2]SATIMO. 17, avenue de Norvege. 91140 Villebon-sur-Yvette, France

[3]SATIMO Italy. Via Castelli Romani, 59. 00040 Pomezia (Roma), ITALY

[4] Laboratório de Integração e Testes – LIT, Instituto Nacional de Pesquisas Espaciais – INPE, Av. dos Astronautas, 1758 – Jd. da Granja. 12227-010, São José dos Campos, São Paulo, Brazil

Abstract—This paper presents a reflection suppression technique for far field antenna measurements. The technique is based on a source reconstruction over a surface greater than the antenna itself. To be able to perform the reflection construction the next steps are required: the complete far field antenna pattern is obtained through interpolation of the acquired cuts, the currents are obtained through a holographic technique, the field out of the antenna area is filtered, and the pattern is reconstructed. The algorithm is used with measurements in the LEHA-UPM antenna measurement facilities and in the outdoor far field facility of LIT INPE in Brazil.

Index Terms—antenna measurements; source reconstruction; reflections, far field.

I. INTRODUCTION

Two methods to reduce the unwanted reflection effects in far field antenna measurements are presented: the first method is a modification of the technique explained in [1] for planar and cylindrical near field antenna measurements. The proposed method can be applied to measurements where the AUT is fixed (at least in one axis of rotation) and the antenna probe is moved. This is not the normal case for outdoor system, but it can be applied to the multiprobe StarGate SATIMO systems and Arc Systems. For outdoor systems, or even classical indoor spherical anechoic systems with a poor reflectivity level, this method cannot be applied. However, this paper analysis the problem of the reflections, and a second method to suppress them is presented. Simulations are presented to check the validity of both techniques.

The methods are based on spatial filtering over the plane where the antenna under test (AUT) is placed. To calculate the field in this plane a diagnostic technique is employed: both a holographic technique, based on Fourier Transformation, or a more accurate diagnosis using integral formulation (as INSIGHT©) could be employed.

The algorithms are used with measurements in the LEHA-UPM antenna measurement facilities and in the outdoor far field facility of LIT INPE in Brazil. New measurements are in process and they will be presented during the symposium.

II. REFLECTION SUPPRESION METHOD

If reflected waves are present in antenna measurements, the radiation properties obtained will be perturbed. These same incorrect results are achieved with an equivalent system where reflections can be viewed as direct waves coming from virtual sources (see Fig. 1). Such a replacement is explained in detail via image theory [2], which was also used in [3] to study ground reflections as image current distributions. The identification of the virtual sources is not possible with a conventional diagnostic technique, where the field is only reconstructed over the antenna aperture. However, if the field reconstruction is performed over a surface larger than the antenna dimensions, the aforementioned fictitious sources can be found and cancelled with a filtering process. Thus, the basis of the proposed method is a modified diagnostic technique that provides the reconstructed field in a region whose size in each direction depends on the distance between the AUT and the possible reflective surfaces, which is at least twice as large as that distance, to ensure the correct image identification. In the case of the integral equation method, equivalent currents have to be calculated at a greater number of points. Thus, the number of unknown quantities in the system of integral equations increases; therefore, more time is required to solve the system. On the other hand, modal expansion methods are based on the fast Fourier transform of the PWS, and as a result, the spatial domain, in which the reconstructed field is calculated, and the spectral domain are related as follows:

$$\text{(spectral domain) } k_x = -\frac{\Delta k_x \cdot M_x}{2}, \cdots, \frac{\Delta k_x \cdot M_x}{2}; step = \Delta k_x$$

$$\downarrow$$

$$\text{(spatial domain) } x = -\frac{\pi}{\Delta k_x}, \cdots, \frac{\pi}{\Delta k_x}; step = \frac{2\pi}{\Delta k_x \cdot M_x} \tag{1}$$

$$\text{(spectral domain) } k_y = -\frac{\Delta k_y \cdot M_y}{2}, \cdots, \frac{\Delta k_y \cdot M_y}{2}; step = \Delta k_y$$

$$\downarrow \qquad\qquad (2)$$

$$\text{(spatial domain) } y = -\frac{\pi}{\Delta k_y}, \cdots, \frac{\pi}{\Delta k_y}; step = \frac{2\pi}{\Delta k_y \cdot M_y}$$

where Δk_x and Δk_y are the spectral steps and M_x and M_y represent the total number of samples in each spectral direction, k_x or k_y, respectively. With these relationships, a straightforward procedure to obtain the reconstructed field over a larger surface is to reduce the spectral step sizes, thus increasing the spatial lengths because these parameters are inversely proportional, as deduced from (1) and (2).
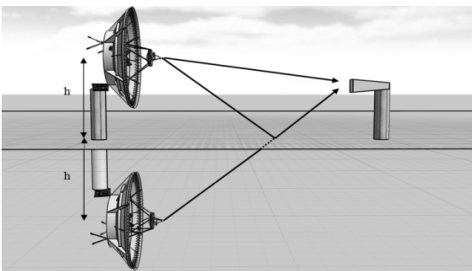
Fig. 1. Reflections in antenna measurements viewed by means of image theory.

This method was used in [1] for planar and cylindrical near field ranges. In order to validate the method for far field methods, firstly, an ideal situation (non real) is analyzed. In this case, it is assumed that the antenna probe rotates over the AUT, and this remains fixed. An array of 9x9 vertical dipoles, uniformly excited, at 900 MHz separated 0.7λ is simulated. The antenna probe is placed at a distance of 80 meters and a plane with a reflection coefficient equal to 0.3 is placed at 8 meters in the transversal direction. Fig. 2 presents the simulated acquired pattern including the reflections and Fig. 3 the reconstructed pattern after the post processing technique.
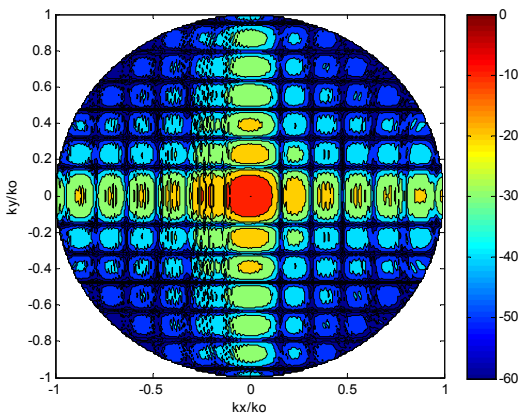

Fig. 2. Disturbed Radiation Pattern.

Fig. 4 presents the source reconstruction applied to the simulated array antenna. It is observed that besides the real antenna the virtual antenna appears at the right distance. This example has been calculated with a complete (half sphere acquisition).
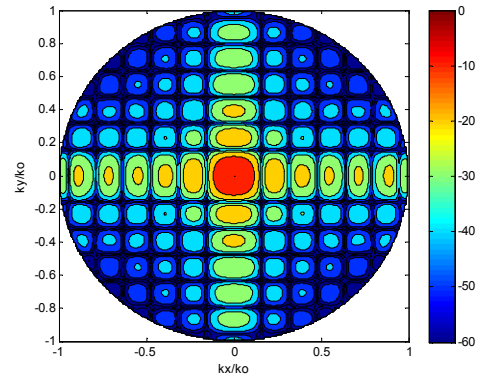

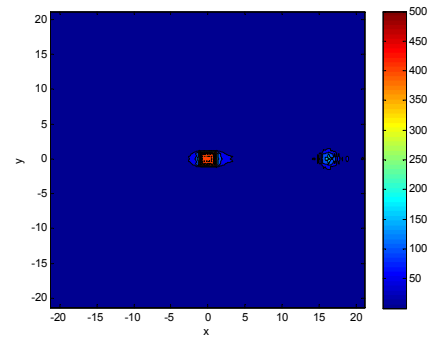Fig. 3. Reconstructed Radiation Pattern after post processing technique.

Fig. 4. Reconstructed sources

III. APPLICATION TO MULTIPROBE ANTENNA MEASUREMENT SYSTEMS

However, in far field antenna measurement systems, it is usually not possible to rotate antenna probe over the AUT (and obviously not in outdoor long distance ranges). With the multiprobe antenna measurement systems, the AUT is rotate only in azimuth. Therefore, the process could be applied for each azimuth position. Fig. 5 shows an example of a SATIMO Stargate system. In this situation, the antenna under test rotates in azimuth and the set of probes take the field in elevation. For each circular acquisition the AUT is fixed and a source reconstruction on each circular acquisition can be performed.
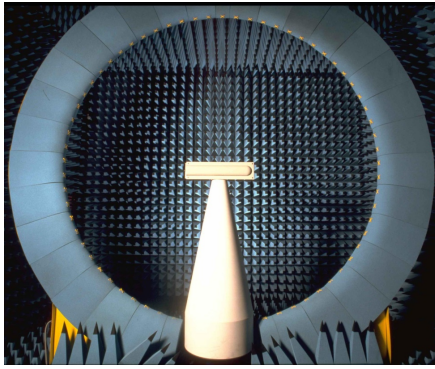
Fig. 5. SATIMO StarGate System

Some simulations also have been performed with a 9x4 array antenna at 9 GHz (with non-separable excitation). In this case, a scatterer with reflection coefficient is equal to -2 is introduced in the horizontal plane, at a distance of 1.5 meters. The antenna probes are in a radius of 6 meters, in order to achieve far field distance. Fig.6 shows the source reconstructions of two orthogonal cuts, assuming that the scatterer is placed in the horizontal plane. As it can be observed, the reflections can be detected and suppressed in the x direction, performing a spatial filtering. In the y direction, these reflections cannot be detected, since they are superposed with the sources coming from the AUT in that plane. Fortunately, the effect of the reflection is higher in the plane of the reflection. Therefore, good improvement is obtained. Fig. 7 and Fig. 8 show the radiation pattern in both planes, from -90 to 90 degrees. In the horizontal plane the filtered radiation pattern is very accurate, cancelling perfectly the reflections, while in the vertical plane the improvement is not complete, although the ripple is cancelled.
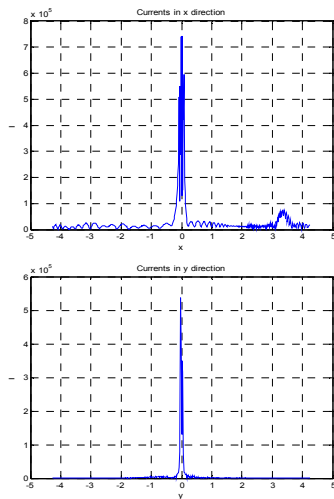

Fig. 6. Source reconstruction in the line of the reflection and in the line normal to the reflection.
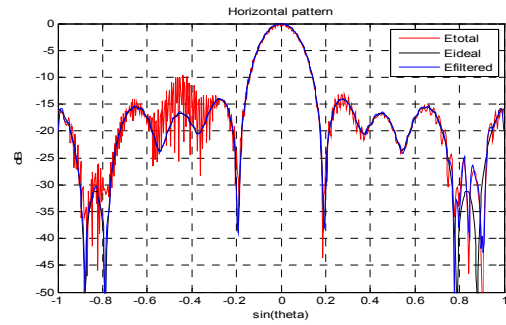

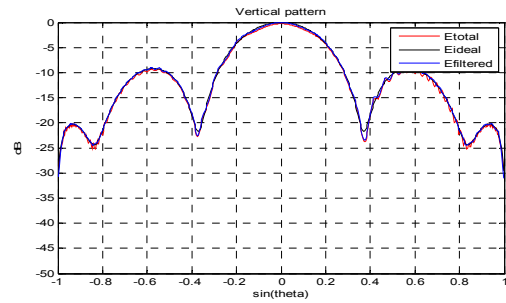Fig. 7. Ideal, corrupted and filtered radiation patterns for horizontal plane.

Fig. 8. Ideal, corrupted and filtered radiation patterns for vertical plane.

IV. APPLICATION TO CLASSICAL FAR FIELD ANTENNA MEASUREMENT SYSTEMS

Unfortunately, this easy process cannot be directly applied to classical far field antenna measurement systems, since the rotation is performed on the AUT. Therefore, the reflection cannot been considered as the image of the AUT for each individual cut, as it was considered before, or in a general case for a planar near field acquisition. However, when an acquisition is performed, the measured far field can be considered as the sum of a direct pattern and a reflected pattern coming from a different angular direction (Fig. 9) for a case where the antenna probe is located at 80 meters and the reflection is at 30 meters. In this situation, if a source reconstruction technique is applied, the AUT and the reflection cannot be directly separated (Fig. 10). However, the result of this source reconstruction is the vectorial sum (Fig. 11) of the sources coming from the direct ray and the sources coming from the reflected ray. These last ones have a phase slope equivalent to the maximum of the reflected pattern in Fig. 9.
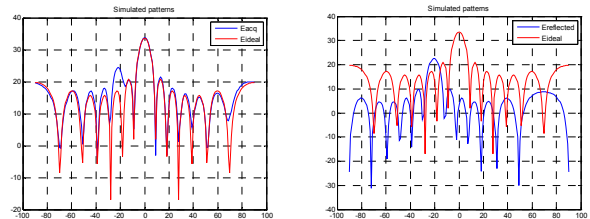

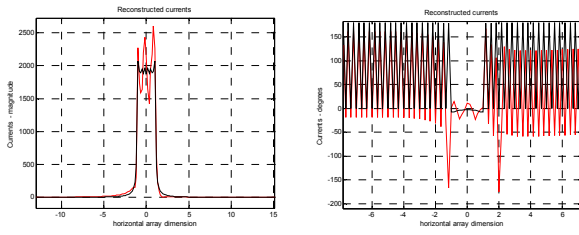Fig. 9. Simulated pattern and individual direct and reflected pattern.

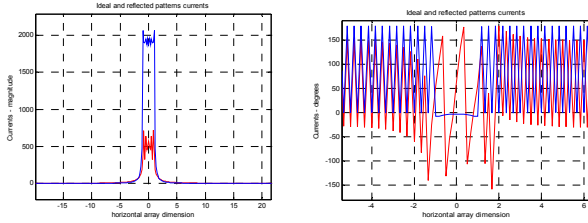Fig. 10. Ideal and corrupted sources (amplitude and phase)

Fig. 11. Sources coming from the direct and from the reflected ray (amplitude and phase).

With one measurement is not possible to extract the ideal measurements, but, if a flip-test is performed, the ideal measurement can be easily process, since the direct currents remain the same, while the reflected currents are the complex conjugate of the first measurement (3). Once the flip-test is performed, the ideal currents can be calculated using (4), where the angle θ of the reflected ray should be known. This can be easily known geometrically, or looking for the maximum of the subtraction of the normal pattern and the flip-test pattern. Fig. 12 shows the results in the application of eq. (4) to the simulated acquisition, and Fig. 13 shows the reconstructed radiation pattern. The main limitation of this process is that expression (4) is not directly solved for the central element, but some techniques for calculating the reconstructed current in this point can be applied.

$$I_{total} = I_{direct} + I_{reflected}$$
$$\approx I_{direct} \cdot \left[1 + \rho \cdot e^{jk_o\left(D_{direct} - D_{reflected}\right)} \cdot e^{jk_o x_i \sin(\theta_{ref})} \right] \qquad (3)$$

$$I_{reconst} \approx I_{direct} \approx 0.5 \cdot \left[I_{acq} + I_{flip} + \frac{j\left(I_{acq} - I_{flip}\right)}{\tan\left(k_o x_i \sin\theta_{ref}\right)} \right] \qquad (4)$$
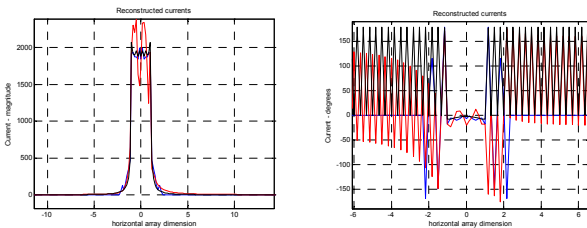

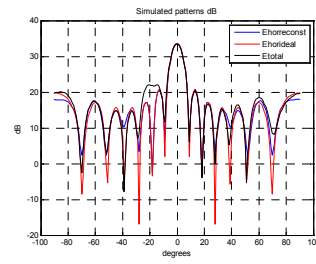Fig. 12. Corrupted, ideal and reconstructed currents (amplitude and phase)

Fig. 13. Corrupted, ideal and reconstructed radiation pattern

V. VALIDATION: MEASUREMENTS IN LEHA-UPM FAR FIELD FACILITY

In order to validate this last procedure, one choke-conical horn at 7.5 GHz has been measured with a large scatterer in one of the sides of the chamber (Fig. 14). Firstly, the antenna probe is measured without scatterer and secondly two acquisitions have been performed (regular and flip test). Fig. 15 shows the measured results, showing a very large effect of the scatterer in the radiation pattern.
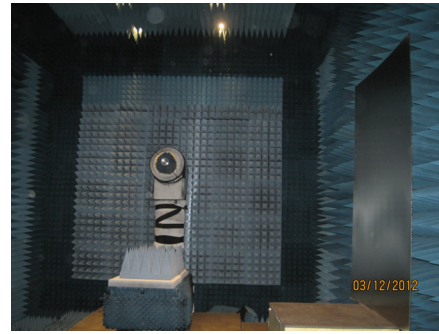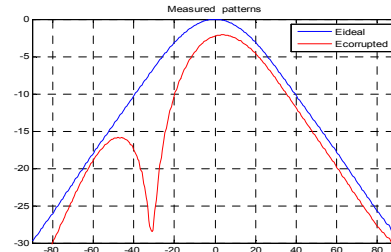

Fig. 14. LEHA-UPM Antenna Measurement System

Fig. 15. Ideal and corrupted measured patterns

When the algorithm is implemented, it is observed that the sources are quite well reconstructed (Fig. 16). However, it is critical the correct determination of the current in the central element. The radiation pattern is recalculated and compared with the correct one (Fig. 17). The improvement is quite good, although it is not correct after 40deg. However, this is a very extreme case due to the higher interference caused by the reflector.
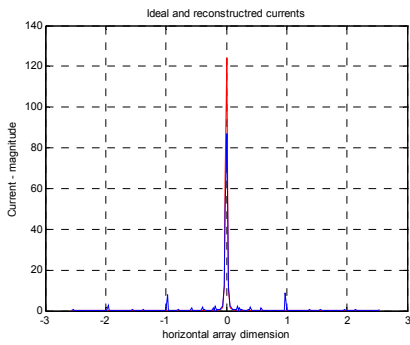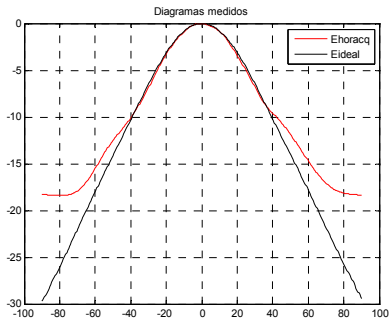
Fig. 16. Ideal and reconstructed currents

Fig. 17: Ideal and reconstructed pattern.

VI. APPLICATION TO MEASUREMENTS IN LIT-INPE FACILITIES (BRAZIL)

Spatial filtering is being applied to LIT-INPE Facilities in Brazil. Fig. 18 shows the far field antenna measurement system, where the AUT is placed in a semi-anechoic room to prevent from rain. In principle, the side trees could create an important reflection. Both techniques have been applied to the measurements. When a flip test is performed, it is observed that the effect of the side reflection is negligible, since both patterns are similar. However, if the source reconstruction process is applied it could be observed some strange currents that appear at both sides. These currents can come from the diffraction created from the semi-anechoic room. In any case, the ripple in the radiation pattern is cancelled.
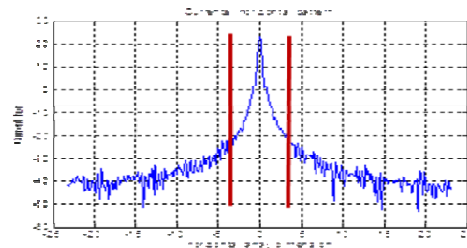

Fig. 18. LIT INPE far field facility.

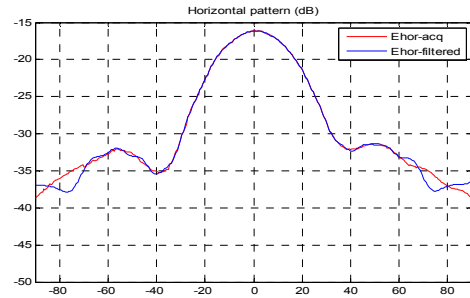
Fig. 19. Reconstructed currents and filtered zone.

Fig. 20. Measured and filtered pattern.

VII. CONCLUSIONS

Spatial filtering has been applied to the reduction of reflections in far field measurements. Two cases have been studied: the first one is the case of the SATIMO multiprobe systems, where the AUT remains fixed during one cut, while the second one is the classical far field antenna measurement. In the first case, the reflections can be easily suppressed, at least in one plane, applying a spatial filtering. In the second case, the reflections cannot be suppressed with only one cut, but if a flip-test is applied (doubling the acquisition time), the reflections can be partially cancelled. This can be applied to reflections in one side wall, but they could be extended to reflections in the ground. The algorithms have been used with measurements, and the results have been explained.

REFERENCES

[1] F. J. Cano-Fácila, S. Burgos, F. Martín, M. Sierra-Castañer, "New Reflection Suppression Method in Antenna Measurement Systems Based on Diagnostic Techniques" IEEE Trans. On Antennas & Propagation, Vol. 59, No. 3, March 2011, pp. 941-949

[2] C. A. Balanis, "Electromagnetic theorems and principles," in Advanced engineering electromagnetic, Ed. New York: Wiley, 1989, ch. 7, sec. 4, pp. 314-323.

[3] R. J. Lytle, "Ground reflection effects upon radiated and received signals as viewed via image theory," IEEE Trans. Antennas Propagat., vol. AP-20, No. 6, pp. 736-741, Nov., 1972.