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5 Author(s) Liliana Anchidin ; Farida Bari ; Razvan D. Tamas ; Laura Pometcu ; Ala Sharaiha View All Authors

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The size of a site for antenna gain measurements is usually correlated with the lower limit of the far-field range; otherwise, near-field to far-field transforms should be performed on data resulting from a field scanning with one or more electrically small probes. The site is typically a reflection free one (e.g., anechoic chamber) or a multi-path site with low correlation between different propagation paths (e.g., reverberation chamber). In this paper, we show that antenna gain can also be assessed in a regular, multi-path environment, mostly in the near-field zone, and with only one probe of a size comparable to the wavelength. We used a data processing technique that we have previously proposed, based on calculating an average transfer function. We compared gain results extracted with our method to results provided by a multiprobe, professional system using an anechoic chamber and near-field to far-field transforms.

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Near-Field Gain Measurements: Single-Probe Distance Averaging in a Multipath Site versus Multi-Probe Field Scanning inside an Anechoic Chamber

Liliana Anchidin* (1), Farida Bari (1), Razvan D. Tamas* (1), Laura Pometcu(2), and Ala Sharaiha(2)
(1) Department of Electronics and Telecommunications, Constanta Maritime University, Romania
(2) Institute of Electronics and Telecommunications of Rennes, France

Abstract

The size of a site for antenna gain measurements is usually correlated with the lower limit of the far-field range; otherwise, near-field to far-field transforms should be performed on data resulting from a field scanning with one or more electrically small probes. The site is typically a reflection free one (e.g., anechoic chamber) or a multi-path site with low correlation between different propagation paths (e.g., reverberation chamber). In this paper, we show that antenna gain can also be assessed in a regular, multi-path environment, mostly in the near-field zone, and with only one probe of a size comparable to the wavelength. We used a data processing technique that we have previously proposed, based on calculating an average transfer function. We compared gain results extracted with our method to results provided by a multi-probe, professional system using an anechoic chamber and near-field to far-field transforms.

1. Introduction

Antenna gain is usually measured inside an anechoic chamber, in an open area test site (OATS) [1], or even in a reverberation chamber [2], [3]. The size of the measuring site should be correlated with the lower limit of the far-field range and the absorbers should be effective even at the lowest operating frequency. Sometimes it might be difficult to set up a measuring site that complies with those limitations, especially when large, low-frequency antennas are characterized, or when measurements are performed *in situ*.

In a previous work [4], we proposed a method to evaluate the gain of an antenna in a multipath environment. We have shown that by computing an average over a set of normalized, transfer functions between the antenna under test (AUT) and the probe antenna the result converges to that corresponding to the free space, single-path scenario. In order to calculate that mean figure the transfer functions measured at different positions are weighted by the current distance between antennas.

Antenna gain can then be extracted from the average transfer function by using the Friis transmission equation; however, that formulation only applies under far-field conditions and by assuming that each antenna is small enough as to be assimilated to a point. In a further paper [5], we have presented a method to process data from near-field measurements with a single probe antenna of a size comparable to the wavelength, in order to extract the gain. We have developed weighting functions to be applied to the near-field data so as to relax the constraints of field zone and probe antenna size. We have found a good agreement between the results provided by our technique and measured data in the far-field zone with the same setup; however, further comparison with more trustful data was needed.

In this paper, we compare measured data provided by our method to results provided by a multi-probe, professional system using an anechoic chamber and near-field to far-field transforms. As opposed to our previous work [5], we used a regular room inside a building as a measuring site, and two different types of antennas were characterized i.e., a narrow band monopole and an ultra-wide band dipole.

2. Distance averaging method

Let us consider a set of two antennas, one of them in transmission mode and the other one in receiving mode. For a given direction of polarization one can define, without loss of generality an axial, equivalent current distribution on both antennas, as shown in figure 1.

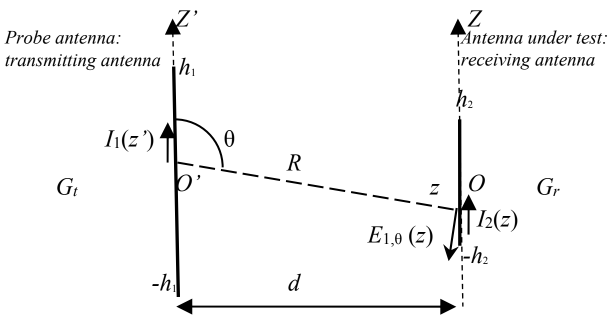


Figure 1. Near-field transmission between two linear dipoles.

An average transfer function can be defined as

$$\overline{|S_{21}|} = \sqrt{\frac{1}{N}\sum_{n}^{N}\left[\frac{d_n}{d_0}\cdot\left|S_{21,n}\right|\cdot\left|F(f,d_n)\right|\right]^2} \qquad (1).$$

where d_n is a set of N distances between antennas, d_0 is the reference distance (usually set at 1 m), and $S_{21,n}$ are the corresponding transfer functions. We denoted by $F(f,d_n)$ the weighting functions for near-field data [5],

$$F(f,d_n)=\frac{V^{\infty}_{0,norm}(f)}{V_{0,norm}(f,d_n)}=\frac{4h_1h_2}{d_n^{\,3}\int_{-h_1}^{h_1}\int_{-h_2}^{h_2}\frac{\exp[-jk_0(R-d_n)]}{R^3}} \quad (2).$$

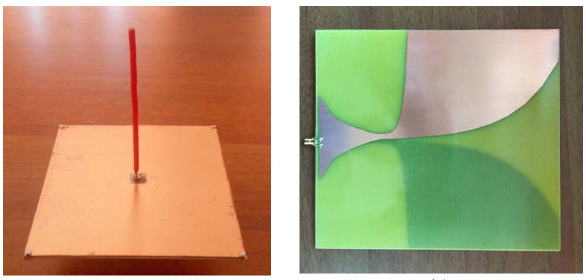
with $V^{\infty}_{0,norm}$ the normalized voltage at the receiving antenna output in the far-field zone, and $V_{0,norm}$ the normalized voltage corresponding to the near-field zone; the other notations are given in figure 1.

The gain of the receiving antenna is then found as

$$G_r=\frac{1}{G_t}\left(\frac{4\pi d_0}{\lambda}\right)^2\frac{R_0}{R_{a_2}}\frac{\overline{|S_{21}|}^2}{|1-S_{22}|^2\left(1-|S_{11}|^2\right)} \quad (3).$$

3. Results

In order to assess the accuracy of our method we measured two antennas, a narrow band monopole and an ultra-wide band Vivaldi dipole. The monopole (figure 2a) was 8.4 cm high, with a ground plane of 10 cm by 10 cm. It operates on two bands, one centered around 800 MHz and the other one around 2.3 GHz. The Vivaldi antenna (figure 2b) has an aperture of 17 cm, and it operates at frequencies of above 500 MHz.



a) b)

Figure 2. Antennas under test: monopole (a) and Vivaldi dipole (b).

Both antennas were firstly measured by using professional multi-probe system inside an anechoic chamber (figure 3) with the lower operating frequency of 800 MHz.

Next we characterized the same two antennas by using our method, based on distance averaging in a multipath environment, that is, a regular room inside an office building (figure 4a).

We employed a probe antenna with a total height of 15 cm (figure 4b), which is comparable to the wavelength over the frequency range of interest.

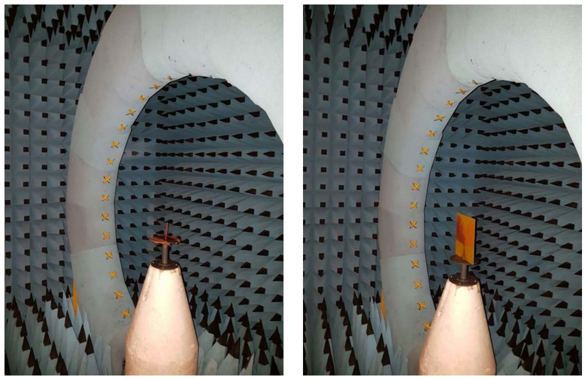
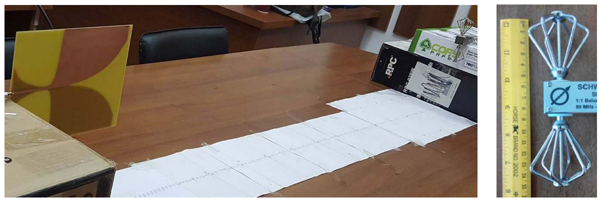


Figure 3. Measuring setup with a multiprobe system, in an anechoic chamber.

Measurements were performed mostly in the near-field zone, as the distances between the two antennas ranged between 15 cm and 60 cm. Compared to our previous work [5], the antennas were successively placed into a matrix of 3 by 6 positions with the aim to improve the accuracy of measurements in that multipath site.



a) b)

Figure 4. Single probe measuring setup for distance averaging in a multipath site (a), and probe antenna (b).

The normalized transfer functions and the resulting average transfer functions are given in figures 5 and 6, respectively.

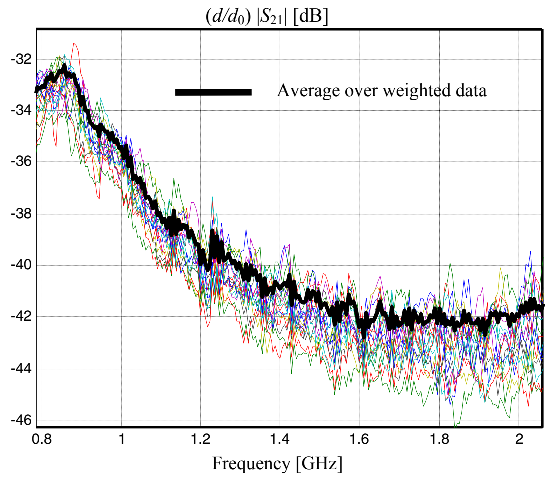


Figure 5. Normalized, transfer factors for the monopole antenna: *d*=15 to 60 cm.

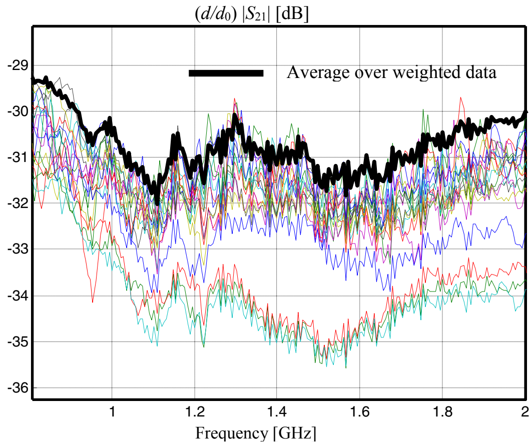


Figure 6. Normalized, transfer factors for the Vivaldi dipole antenna: *d*=15 to 60 cm.

Figures 7 and 8 show the gain variations for θ=90º and φ=0º. Measured results with both methods as well as simulated results are given on the same diagrams.

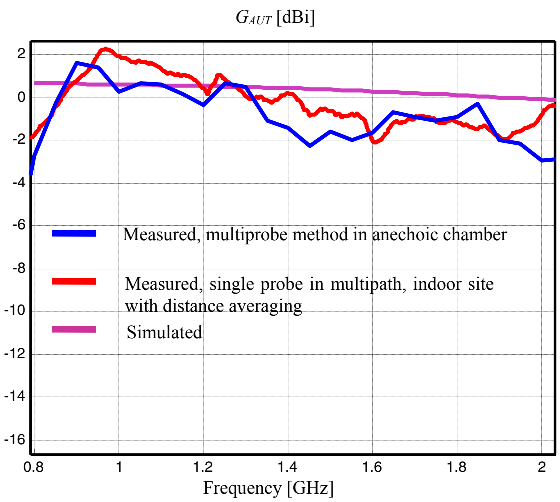


Figure 7. Gain of the monopole antenna.

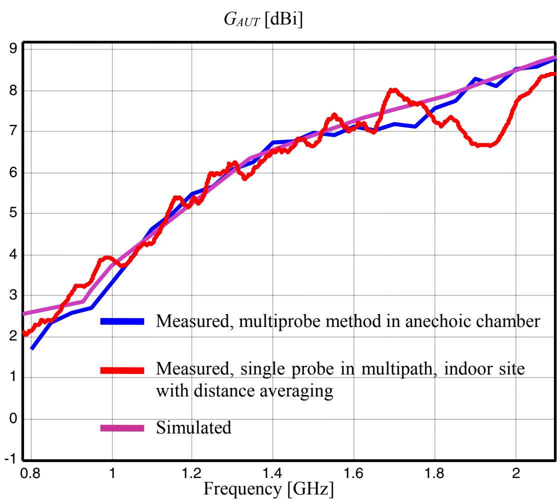


Figure 8. Gain of the Vivaldi dipole antenna.

4. Conclusion

The single-probe, distance averaging method based on weighting functions for measurements in the near-field zone yields accurate results compared to a standard, multi-probe method. It comes out that averaging not only relaxes the field zone constraints but it also significantly removes the effects of the multipath propagation. Discrepancies of no more than 2 dB can be noted between the results provided by the two methods, although at most frequencies they are less than 1 dB. Future work will be focused on developing more appropriate weighting functions derived upon a more realistic basis in order to further improve the accuracy of our method.

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