14 December 2016

Antenna gain measurements in the intermediate-field zone

Liliana Anchidin, Farida Bari, Ana Dumitrascu, Mirel Paun, Daniela Deacu, Sorin Tasu, Alin Danisor, Razvan D. Tamas

Author Affiliations +

Proceedings Volume 10010, Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies VIII; 1001036 (2016) https://doi.org/10.1117/12.2243273

Event: Advanced Topics in Optoelectronics, Microelectronics, and Nanotechnologies 2016, 2016, Constanta, Romania

Abstract

Antenna gain is usually evaluated under far-field conditions. Furthermore, Friis transmission formula can solely be applied when antenna size can be neglected with respect to the distance between the measuring antenna and the antenna under test. In this paper, we show that by applying the distance averaging technique the far-field and antenna size constraints can be overcome. Our method was validated by measuring a monopole

Antenna Gain Measurements in the Intermediate-Field Zone

Liliana Anchidin [1], Farida Bari [1], Ana Dumitrascu[1], Mirel Paun[1], Daniela Deacu[1], Sorin Tasu[1], Alin Danisor[1], Razvan D. Tamas[1]

[1] *Department of Electronics and Telecommunications, Constanta Maritime University, Constanta, Romania*

ABSTRACT

Antenna gain is usually evaluated under far-field conditions. Furthermore, Friis transmission formula can solely be applied when antenna size can be neglected with respect to the distance between the measuring antenna and the antenna under test. In this paper, we show that by applying the distance averaging technique the far-field and antenna size constraints can be overcome. Our method was validated by measuring a monopole antenna and a Vivaldi antenna in an open area test site (OATS).

Keywords: Gain, near-field, intermediate-field, far-field, distance averaging method.

1. INTRODUCTION

In many cases it is impractical or impossible to measure antenna patterns in the conventional far-field range. When the distance to the radiating far-field zone is too long, it may be impractical to move the antenna from the operating place to a measuring facility. In the vicinity of the antenna, the field will include reactive components as well as radiating components. The magnitude of the reactive components decreases rapidly with distance from the antenna so that it can be neglected compared to the magnitude of the radiating components [1]. Figure 1 shows the conventional field zones for an antenna of a total length of *D*. However, the field zones as given in Fig. 1 are not applicable when both measuring antenna and antenna under test have sizes comparable to the wavelength, as every source point on one antenna is seen differently from a given field point on the other antenna.

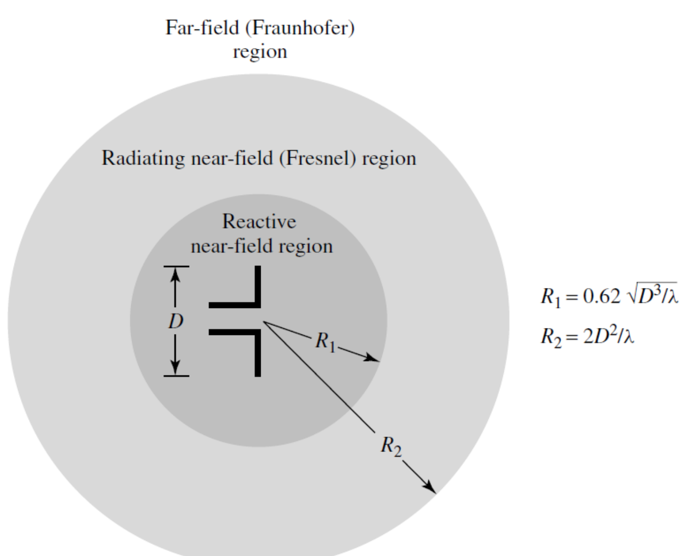

Fig.1 Field regions of an antenna [1]

There are several approaches to extract the gain of an antenna from data measured either in the intermediate or the near-field zone [2], [3], [4]. These approaches usually involve complex post-processing of the measured data.

In this paper, we propose a measuring method based on averaging a normalized transfer function between the two antennas. We show that by multiplying the magnitude of S_{21} by the distance at different measuring positions and by computing an average over that data set, the result is close to free space one. A study case on a monopole antenna and on a Vivaldi antenna is presented.

2. THEORY

For the sake of simplicity we take the case of two linear dipole antennas i.e., an antenna under test of a total length of $2h_1$, and a probe antenna of a total length of $2h_2$, respectively (Fig. 2).

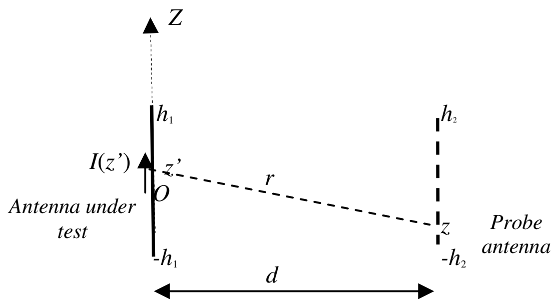

Fig.2 Virtual transmission between a source point on the antenna under test and a field point on the probe antenna

The Fourier transform of the signal received is found as [5]:

$$V_0(\omega, d) \sim jk_0 \int_{-h_1}^{h_1} \int_{-h_2}^{h_2} I_1(z') \frac{\exp(-jk_0 r)}{4\pi r} dz' dz \tag{1}$$

where r is the distance between the current source point and the current field point,

$$r = \sqrt{d^2 + (z - z')^2} \, . \tag{2}$$

The maximal value of that distance is

$$r_{\max} = \sqrt{d^2 + (h_1 + h_2)^2} \tag{3}$$

If

$$d \geq 3(h_1 + h_2) \, , \tag{4}$$

then $d^2 >> (h_1 + h_2)^2$ so we can approximate $d \cong r$.

Consequently,

$$V_0(\omega, d) \sim jk_0 \int_{-h_1}^{h_1} \int_{-h_2}^{h_2} I_1(z') \frac{\exp(-jk_0 r)}{4\pi d} dz' dz \, . \tag{5}$$

Since $\sqrt{1+x}\Big|_{x<<1} \cong 1 + \frac{x}{2}$ then

$$r=\sqrt{d^2+(z-z')^2}\,|_{d^2>>(z-z')^2}=d\sqrt{1+\left(\frac{z-z'}{d}\right)^2}\cong d\left[1+\frac{(z-z')^2}{2d^2}\right]=d+\frac{(z-z')^2}{2d} \tag{6}$$

In that case,

$$V_0(\omega,d)\sim jk_0\frac{\exp(-jk_0d)}{4\pi d}\int_{-h_1}^{h_1}I_1(z')\int_{-h_2}^{h_2}\exp\left[-jk_0\frac{(z-z')^2}{2d}\right]dz\,dz'. \tag{7}$$

A normalized received voltage can be defined as

$$V_{0,norm}(\omega,d)=d\exp(jk_0d)V_0(\omega,d). \tag{8}$$

The normalized received voltage becomes independent on the distance in the far-field region, that is,

$$V_{0,norm}(\omega,d)\sim\frac{jk_0}{4\pi}\int_{-h_1}^{h_1}I_1(z')\int_{-h_2}^{h_2}\exp\left[-jk_0\frac{(z-z')^2}{2d}\right]dz\,dz'. \tag{9}$$

Let

$$F(z',d)=\int_{-h_2}^{h_2}\exp\left[-jk_0\frac{(z-z')^2}{2d}\right]dz. \tag{10}$$

Since

$$\lim_{d_2\to\infty}\frac{1}{(d_2-d_1)}\int_{d_1}^{d_2}F(z',x)\,dx=1 \tag{11}$$

then

$$V_{0,norm}(\omega,\infty)=\lim_{d_2\to\infty}\frac{1}{(d_2-d_1)}\int_{d_1}^{d_2}V_{0,norm}(\omega,x)\,dx\sim jk_0\int_{-h_1}^{h_1}I(z')\,dz'. \tag{12}$$

Hence, we found that by averaging the normalized received voltage over a set of distances one can obtain a result close to the far-field one.

RESULTS

We firstly measured a narrow band antenna, that is, a monopole antenna resonating at around 800 MHz (Fig. 3). Measurements were performed in an open area test site (Fig. 4). In order to apply the distance averaging technique [4], the antenna under test was moved away from the measuring antenna at a distance ranging from 50 cm to 150 cm.

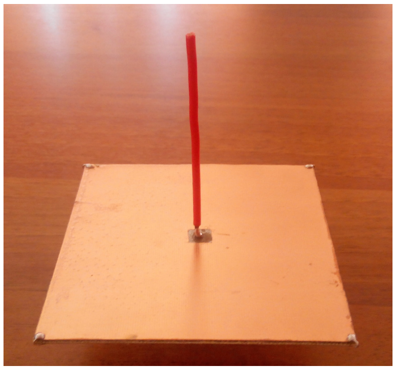

Fig.3 Monopole antenna

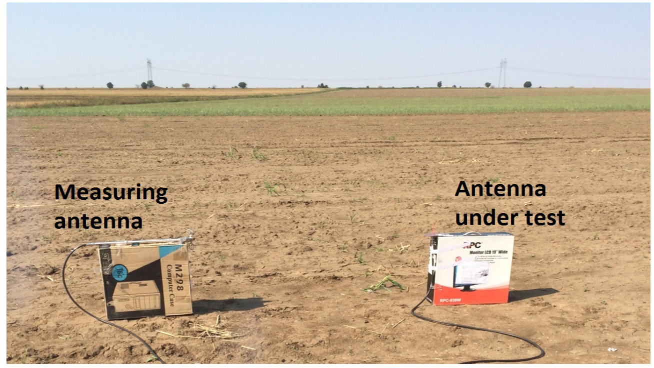

Fig. 4 Open area test site (OATS) measurements: monopole antenna

The normalized transfer function for different distances, defined as $(r/r_0)\ |S_{21}|$, and the average transfer function are given in Fig. 5. We took as a reference distance r_0=1m. By using that average figure the antenna gain is eventually extracted [4] and compared to simulated results (Fig. 6). A good agreement can be noted.

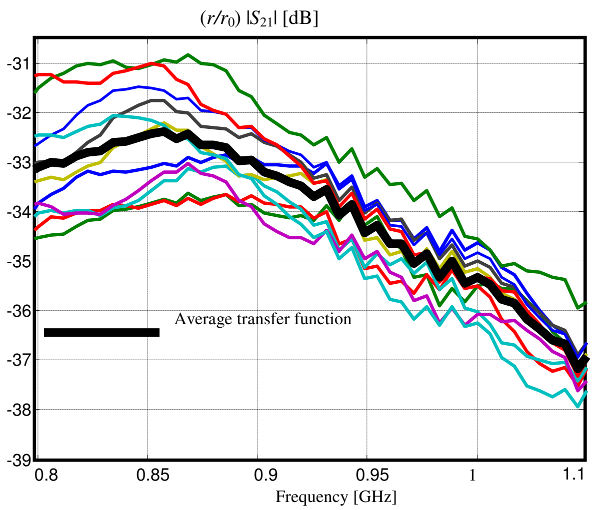

Fig.5 Normalized transfer function: monopole antenna

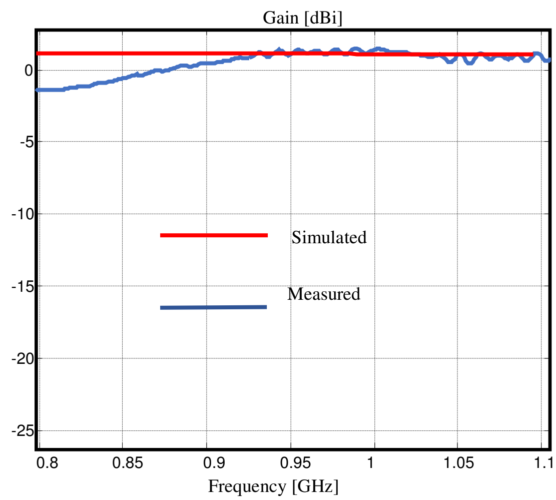

Fig. 6 Monopole antenna gain: simulated and measured

For the second case study we chose an ultra-wide band antenna i.e., a Vivaldi dipole. The OATS setup is shown in Fig. 7.

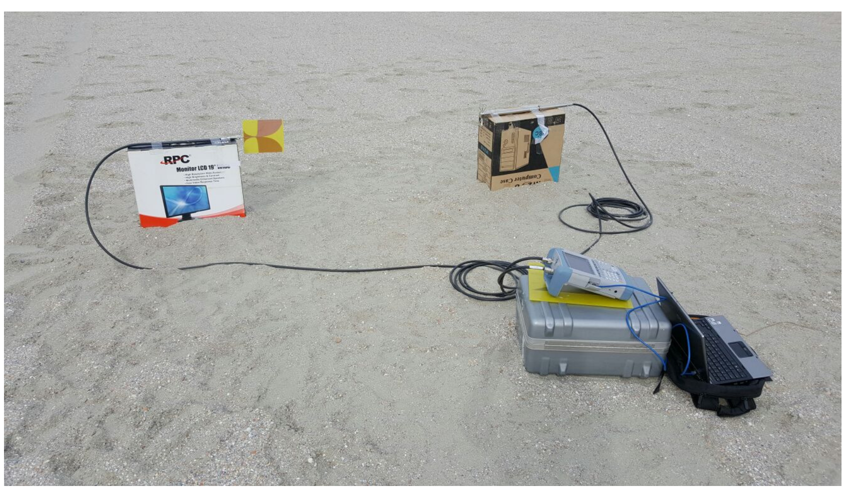

Fig.7 Open area test site (OATS) measurements: Vivaldi antenna

Figure 8 shows the magnitude of the reflection coefficient at the input of the antenna under test, and Fig.9 gives the phase variation of that parameter over the frequency range of interest.

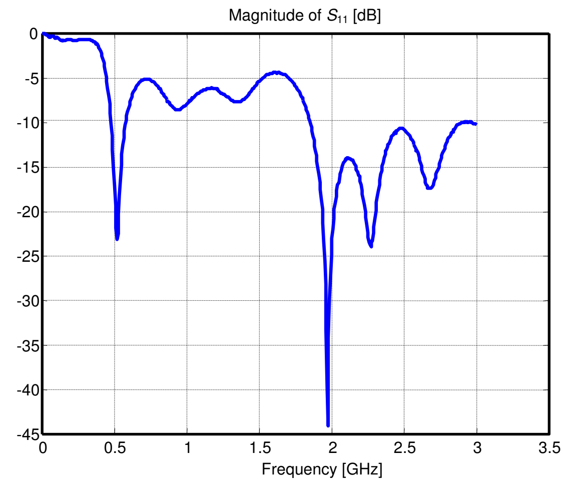

Fig.8 Magnitude of the reflection coefficient at the input of the antenna under test

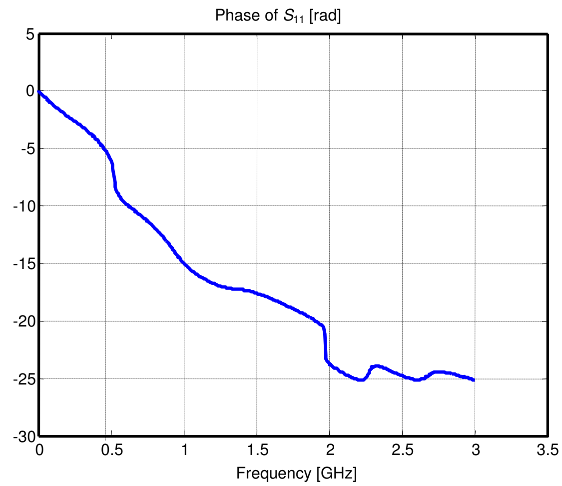

Fig.9 Phase variation of the reflection coefficient at the input of the antenna under test

We measured the normalized transfer function for 11 different distances between antennas, ranging from 50 to 150 cm. The results are given in Fig. 10.

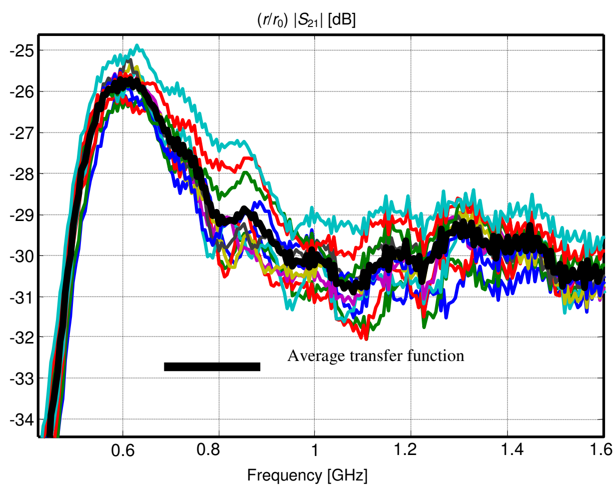

Fig.10 Normalized transfer function: Vivaldi antenna

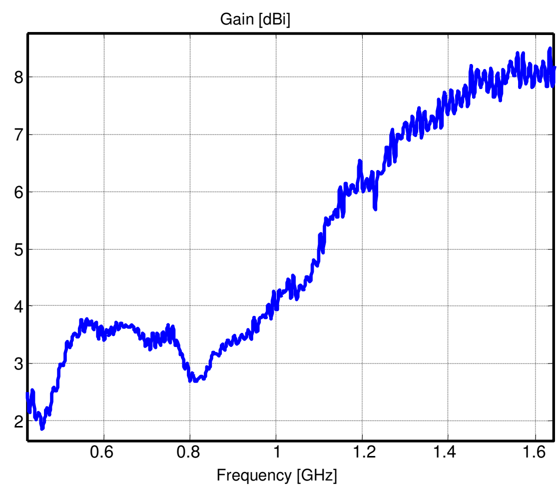

Fig.11 Gain variation: Vivaldi antenna

The gain variation extracted from the average transfer function is shown in Fig. 11.

3. CONCLUSION

We showed that the gain of an antenna can be accurately extracted even when far-field conditions cannot be provided. Our technique consists of calculating an average over a set of values of a normalized transfer function, measured at different distances; we proved that the result of such an average figure converges to the figure that one would obtain in the far-field region, and for infinitely small antennas. We obtained realistic results by testing our method on a monopole, narrow band antenna and on an ultra-wide band antenna (a Vivaldi dipole), respectively.

REFERENCES

[1] Balanis, A.C., [Antenna theory analysis and design], John Wiley & Sons, Inc., New York, 34-36 (2005)

[2] Johnson, R.C., Ecker, H. A., and Hollis J. S., "Determination of far-field antenna patterns from Near-field measurements", Proc. IEEE, 61-12 (1973).

[3] Yaghjian, A. D. "An Overview of near-field antenna measurements", Proc. IEEE 34 (1), 30-45 (1986).

[4] Tamas, R.D., Deacu, D., Caruntu, G., Petrescu, T., "An indoor measuring technique for antenna gain", Proc. International workshop on antenna measuring technology, 219-222 (2013).

[5] Tamas, R.D., Babour, L. Danisor A., Caruntu, G., "An intermediate-field approach of the differential time-domain single-antenna method for electrically large ultra-wide band antennas", Proc. International workshop on antenna measuring technology, 1-4 (2010).