Near-Field Gain Measurements Using the Distance Averaging Method: Linear Scanning versus Matrix Scanning

Liliana Anchidin, Razvan D. Tamas, George Caruntu
Department of Electronics and Telecommunications
Constanta Maritime University
Constanta, Romania
razvan.tamas@cmu-edu.eu

Claudia-Alina Ilie
Department of Telecommunications
University Politehnica of Bucharest
Bucharest, Romania
ilie_claudia01@yahoo.com

Abstract— **Antenna gain can be measured in a multipath site by moving the antenna under test away from the probe antenna at different distances, and by assessing a normalized transfer function as an average figure over the entire data set. In an earlier work, we provided a statistical explanation to the reduction of the multipath effects. Another possible explanation is based on the synthetic aperture principle, by assimilating the set of positions of the probe antenna to an antenna array. In this paper, we compare linear scanning to matrix scanning in order to draw optimal choice criteria for the grid of measuring positions. Measurements were performed on a Vivaldi antenna, in the near-field zone.**

Keywords— ***Antenna gain; multipath site; averaging method; synthetic aperture principle; near-field zone***

I. INTRODUCTION

In a previous work [1], we proposed a method for antenna gain evaluation in a multipath site. Basically, our method aims to reduce the effects of the indirect paths including reflection and diffraction on environing objects by measuring normalized transfer functions at different distances between the antenna under test (AUT) and the probe antenna; eventually, we calculated an average over that data set. The transfer functions are normalized by compensating the effect of the propagation as it would be in the free space, in terms of attenuation and delay.

Further work was focused on assessing the accuracy of our approach by comparing the results to those measured inside an anechoic chamber [2]. We showed that averaging can also relax the field zone constraints by properly defining a set of weighting functions [3], [4], [5].

The theory of the method as presented in our previous work [1] shows how continuously distance-averaged data converges asymptotically to a free space result. It is straightforward that by moving away one of the antennas the effect of the indirect paths statistically cancels out and only the direct path has a constant, deterministic contribution regardless the distance.

In this paper, we provide an alternative insight on the distance averaging method by exploiting the similarity to the concept of synthetic aperture [6], mainly applied in radar signal processing [7]. The synthetic aperture approach provides one with an effective model for optimizing the grid of measuring positions. Broadside directive linear scanning has been previously used in compact range measuring systems in order to remove multipath effects [6]. In this work, we propose an endfire directive scanning approach and we compare linear scanning to matrix scanning. Measurements were performed below the lower limit of the far-field zone. Moreover, instead of using reflectors [6], we applied the distance averaging technique with weighting functions derived as in our previous work [5].

II. THEORY

Let us consider a set of two antennas, one of them in transmission mode and the other one in receiving mode.

An average transfer function can be derived from the scattering parameters $S_{21,n}$ measured for a set of N distances, $\{d_n\}$ between antennas,

$$\overline{S_{21}} = \frac{1}{N}\sum_{n=1}^{N}\left[\frac{d_n}{d_0}\cdot S_{21,n}\cdot F_n(f)\cdot \exp(jk_0 d_n)\right] \tag{1}$$

where d_0 is the reference distance (usually set at 1 m) and $F_n(f)$ are weighting functions that compensate the field zone effect, as defined in [5].

The gain of the receiving antenna is then found from the Friis transmission formula after elementary manipulations by taking into account possible impedance mismatches at both antennas,

$$G_r = \frac{1}{G_t}\left(\frac{4\pi d_0}{\lambda}\right)^2 \frac{R_0}{R_{a2}} \frac{\overline{|S_{21}|}^2}{|1-S_{22}|^2\left(1-|S_{11}|^2\right)}. \tag{2}$$

In (2), R_0 stands for the normalizing impedance (usually set at 50 ohms) and R_{a2} is the radiation resistance of the antenna under test.

Moving one antenna away from the other is actually equivalent to using a linear, highly directive probe array instead of a single probe (usually omnidirectional). It comes out from (1) that the equivalent array is an endfire one [8].

In order to reduce the effect of indirect paths on antenna measurements formation of large side lobes should be avoided. For row, endfire arrays large side lobes usually occur when the spacing between two radiating elements exceeds $\lambda/2$. As an

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example, with a spacing of 10 cm one should expect side lobes at above 1.5 GHz.

We calculated and compared the array factors for two configurations: a row, endfire array of 5 elements with a 10 cm spacing in-between along the *Ox* axis, and an endfire-binomial matrix array of 5 by 3 elements with a 10 cm spacing in-between both along the *Ox* and *Oy* axis, respectively.

Fig. 1 shows the array factor as a function of the azimuth angle for both arrays, at 1.8 GHz.

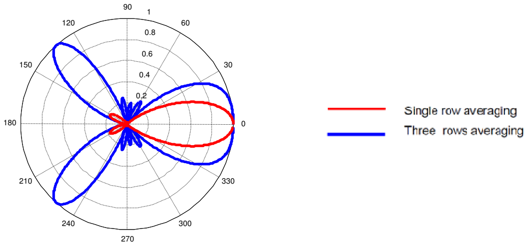

Fig. 1. Array factor for a row configuration with 5 measuring positions, and for a matrix configuration of 5 by 3 positions.

As expected, large side lobes occur at above 1.5 GHz for the 1*D* array with a 10 cm spacing between measuring positions. Conversely, the 2*D* array not only provides a narrower main lobe, but it also exhibits much smaller side lobes, even at above 1.5 GHz.

III. Results

We consider a setup consisting of an antenna under test, a probe antenna, and a vector network analyzer. Measurements were performed in a multipath environment i.e., a regular room inside an office building. The antenna under test was a Vivaldi dipole that operates at frequencies of above 500 MHz. A calibrated, biconical dipole was employed as a probe antenna.

We measured the AUT gain by placing it into two configurations. The first configuration consisted of a row of 5 measuring positions with a distance increment along *Ox* of 10 cm and a minimal distance of 15 cm between the probe and the AUT, as shown in Fig. 2a.The second configuration (Fig. 2b) consisted of a matrix of 5 by 3 positions with a distance increment of 10 cm both along *Ox* and *Oy* axis, and a minimal distance of 15 cm between the probe and the AUT.

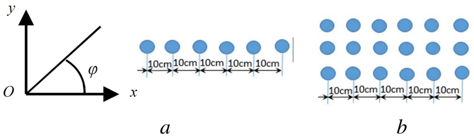

Fig. 2. Scanning configurations: row (*a*) and matrix (*b*).

Fig. 3 shows the gain of the AUT as a function of frequency for θ=90° and φ=0, extracted both with matrix and row configuration. On the same diagram we also show the results provided by a compact range professional system within an anechoic chamber.

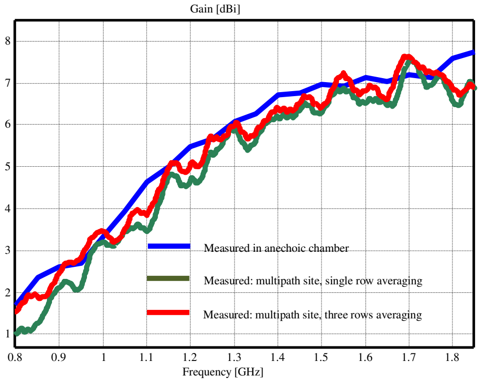

Fig. 3. Gain of the antenna under test for θ=90° and φ=0.

IV. Conclusion

We compared gain results issued from measurements performed in a row configuration of 5 positions, and in a matrix configuration of 5 by 3 positions, respectively.

For each configuration a root mean square error was computed over the frequency range of interest with respect to the data measured with a compact range professional system within an anechoic chamber. The error figure was about 0.5 dB for the row configuration, and 0.2 dB for the matrix configuration, respectively. For the same distance range an endfire-binomial matrix configuration would provide a higher accuracy than an endfire row configuration, even for a distance increment shorter than half-wavelength.

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