Probes Correction for Antennas Near Field Measurement

Chakib Taybi, Mohammed Anisse Moutaouekkil, Rodrigues Kwate Kwate, Bachir Elmagroud and Abdelhak Ziyyat

Abstract The probe is one of the major components building an indoor system for antenna near field measurement. This device allows to collect the distribution of the field radiated by the antenna under test (AUT), and to transform it into available voltage at its output. Thus, because of the response of the probe to other components of the field radiated by the AUT, to the influence of the geometric parameters of this one and to the problems related to the measuring surface. An unwanted error appear between the voltage and the field, and a step of post-processing is therefore necessary to correct this one. In this paper we address the problem for the correction by the technique of the deconvolution, a probe based on an Open Ended Rectangular WaveGuide (OERWG) is used to validate this approach. Thus, the spatial response of the probe is calculated in module and validated by three AUT, an open ridges rectangular waveguide, an open circular waveguide and a dipole antenna. The results obtained show that the calculated reference field and the reconstructed one are confused for the three antennas under test.

Keywords Near field measurement · Near field probe · Waveguide probe · Probes correction · Deconvolution technique spatial response

1 Introduction

The antennas have their fields of application extend to all industries, whether military or civilian [1]. Thanks to the various technological advances, their developments grow up quickly and safely. To ensure both cohabitation without the

C. Taybi (✉) · R. Kwate Kwate · B. Elmagroud · A. Ziyyat
Electronic and Systems (LES) Laboratory, Faculty of Sciences,
Mohammed First University, 60000 Oujda, Morocco
e-mail: c.taybi@ump.ma

M.A. Moutaouekkil
Information Technology Laboratory, National School of Applied Sciences,
Chouab Doukkali University, 24002 El Jadida, Morocco

A. El Oualkadi et al. (eds.), *Proceedings of the Mediterranean Conference on Information & Communication Technologies 2015*, Lecture Notes in Electrical Engineering 380, DOI 10.1007/978-3-319-30301-7_2

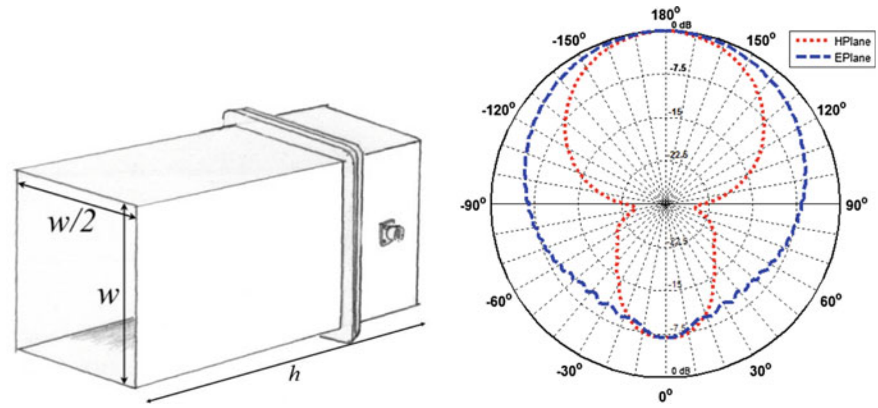

Fig. 1 Architecture and the radiation pattern calculated at a frequency f_o = 10 GHz of an open ended rectangular waveguide

antennas risk, reliable operation and the respect of the international electromagnetic compatibility norms (EMC), it is crucial to know precisely their electromagnetic field. Therefore, various techniques have been developed to implement a setup for measuring the electromagnetic field near the antenna under test (AUT) [2, 3], in order to derive the antenna characteristics such as radiation pattern and gain [4]. Or, for dosimetric investigations such as the calculation of the specific absorption rate (SAR) or security perimeter [5].

Measurements in these systems are mainly based on the use of probe devices, which collects the electric field, the magnetic field, or a combination of both in a fixed point of space [6].

The Open Ended Rectangular Wave Guide (OERWG) Fig. 1, is one of the most probes used in near field antennas measurements, particularly in the planar, cylindrical or spherical systems [7–9], and, in the systems designed to measure SAR [10, 11]. Thanks to their simplicity, robustness and low manufacturing cost.

If a perfect probe should normally measure the local field in a single point and only responds to one of its component, in practice, the OERWG measure the distribution of the field on a finite region of space and also responds to more than one of its components as shown in Fig. 2. Thus, the geometric dimensions of the sensor influence on the measurement [12]. These points are reflected by a difference between, the electromagnetic field radiated by the AUT and the voltage v retrieved by the probe. This difference is calculated in module and represented on Fig. 3 for the OERWG probe at a frequency f_o = 10 GHz and for two distances $d_1 = 0.85\lambda_o$ and $d_2 = \lambda_o$.

To correct this problem, a detailed studies of the influence of various geometrical parameters of the probe on the measure field is presented in [12]. This last one allows, to minimize this perturbation and to approach at best real profiles of fields. However, this geometric study is often followed by a step of post-treatment, generally called, as correction of a probe is necessary to extract the exact distribution of the radiated field by AUT. One of these methods is the deconvolution technique [13].

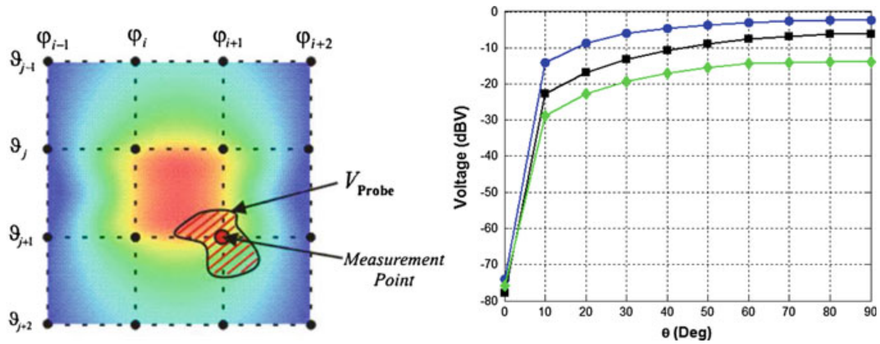

Fig. 2 Measuring surface problem and the selectivity of the probe calculated for a frequency f_o = 10 GHz and a variation of the polarization angle of 0° to 90°

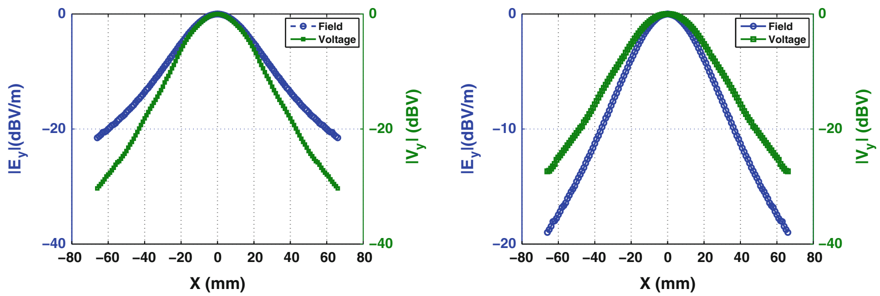

Fig. 3 Error in module between the field *e* and the voltage *v* at the output of the probe for distance $d_1 = 0.85\lambda_o$ and $d_2 = \lambda_o$ and a frequency f_o = 10 GHz

In this work we report on the problem for the correction by the technique of the deconvolution, a probe based on an open ended rectangular waveguide (OERWG) is used to validate this approach. Thus, the spatial response of the probe is calculated in module and validated by three AUT, an open ridges rectangular waveguide, an open circular waveguide and dipole antenna. Our results show that the calculated reference field and the reconstructed field are confused for our test three antennas.

2 Technique of Deconvolution

In this technique, the voltage recovered at the output of the probe $v(x, y, d, f)$, for a distance d and a given frequency f, can be considered as a convolution of the exact distribution of the $e(x, y, d, f)$ with the spatial response of the probe $h(x, y, d, f)$ possibly tainted by the noise $n(x, y, d, f)$ introduced during the measurement.

$$v(x,y,d,f) = e(x,y,d,f) * h(x,y,d,f) + n(x,y,d,f) \tag{1}$$

$$v(x,y,d,f) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} e(x,y,d,f)h(x-x',y-y',d,f)dx'dy' + n(x,y,d,f) \tag{2}$$

The convolution integral is easier to evaluate in the frequency domain, since it is a simple multiplication of two functions Fourier Transforms.

$$V(k_x,k_y,d,f) = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} e(x,y,d,f)h(x,y,d,f)\mathrm{e}^{-\mathrm{j}(\mathrm{k_x x + k_y y})}dk_x dk_y + N(k_x,k_y,d,f) \tag{3}$$

$$V(k_x,k_y,d,f) = E(k_x,k_y,d,f) \times H(k_x,k_y,d,f) + N(k_x,k_y,d,f) \tag{4}$$

The relation of convolution between the exact e field and the voltage v recovered at the output of the probe presented in (2) is similar to the classical formula for the near field probes compensation. Our model replaces the terms vector by those scalars by adding a term of noise mainly present in the practical measures. As a result, the scalar model of near-field measurement can be used for any components of the electric field distribution e_x, e_y, e_z.

The capital letters in (4) denote the spatial Fourier transformed of the field e, voltage v, noise n and the spatial response of the probe h. In practice, the data that represent these functions are available with a limited number of samples, the passage from the spatial domain to the spectral range is provided by the Discrete Fourier Transform (DFT) defined by the (5):

$$D(k_{xp},k_{yq},d) = \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} d(x_m,y_n,d)\mathrm{e}^{-\mathrm{j}(k_{xp}x_m + k_{yq}y_n)} \tag{5}$$

In (5) k_{xp} and k_{yq} are defined by:

$$\left[k_{xp},k_{yq}\right] = \left[\frac{2\pi p}{M\Delta x},\frac{2\pi q}{M\Delta y}\right]_{M\times N} \tag{6}$$

with: $p = 0\ldots, M-1$ and $q = 0\ldots, N-1$.

The function d could be replaced by any set of discrete data obtained from the measurement, the simulation or the post-processing.

The spatial response of the probe is determined from Eq. (4) by an inverse Discrete Fourier Transformation (iDFT) and by changing the AUT by the probe itself as show in Fig. 4, while assuming that the measurement is made without noise. In the fact, the ripples in the quiet zone due to the parasite reflections on domain walls of the anechoic chamber, is minimised by the Least squares filtering

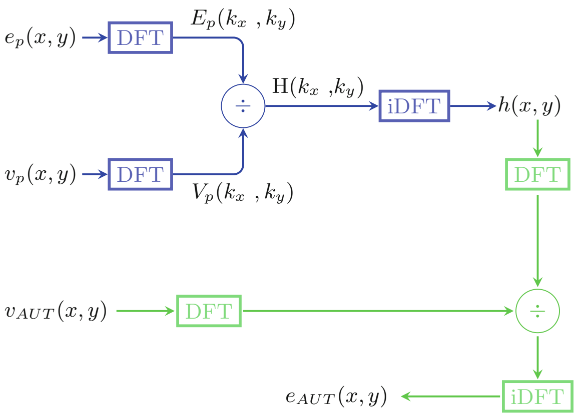

Fig. 4 Exaction (*blue*) and validation (*green*) process of the spatial response

algorithm [13]. The lowercase letter in Eq. (8) which represent the spatial response are obtained by an iDFT of H defined by (7).

$$H(k_x, k_y, d, f) = \frac{V(k_x, k_y, d, f)}{E(k_x, k_y, d, f)} \tag{7}$$

$$h(x, y, d, f) = \text{iDFT}\left[\frac{V(k_x, k_y, d, f)}{E(k_x, k_y, d, f)}\right] \tag{8}$$

Thus, the amplitude of spatial response of the probe OEWG for two distances $d_1 = 0.85\lambda_o$ and $d_2 = \lambda_o$ and for a frequency f_o = 10 GHz is shown in Fig. 5.

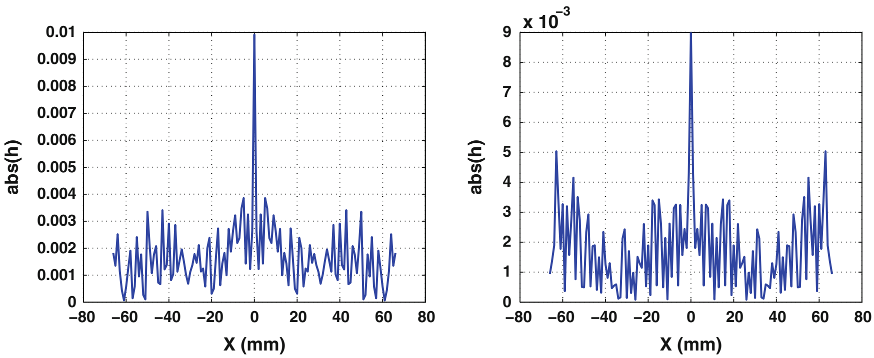

Fig. 5 Module of the spatial response of the probe at a frequency f_o = 10 GHz and a distance $d_1 = 4\lambda_o$ and $d_2 = 5\lambda_o$

3 Results and Discussion

To validate the spatial response represented on Fig. 5, we calculate in this section, the voltage v recovered by the OERWG probe from two AUTs (Fig. 4), The first one is an OERWG loaded by two ridges and the second is a circular waveguide. The radiations patterns of these antennas under test are calculated for a frequency $f = 10$ GHz and they are represented in Fig. 6.

In Figs. 7 and 8, for d_1, d_2 and for f_o, we represent the field reconstructed (e_{rec}) from the voltage v recovered by the probe and the reference field e_{ref} calculated without the AUT. These results show that the reconstructed field from the voltage confused with the reference field for the AUT that have a pattern similar to that of the probe, and good cohabitation with the second type antenna proposed in this study.

To validate the case of AUT that present a wide variation in the diagram relative to the probe, we represent in Fig. 9, for a half wave dipole antenna the reconstructed field from the voltage and the reference field for a frequency $f = 10$ GHz and for both distance $d_1 = 0.85\lambda_o$ and $d_2 = \lambda_o$.

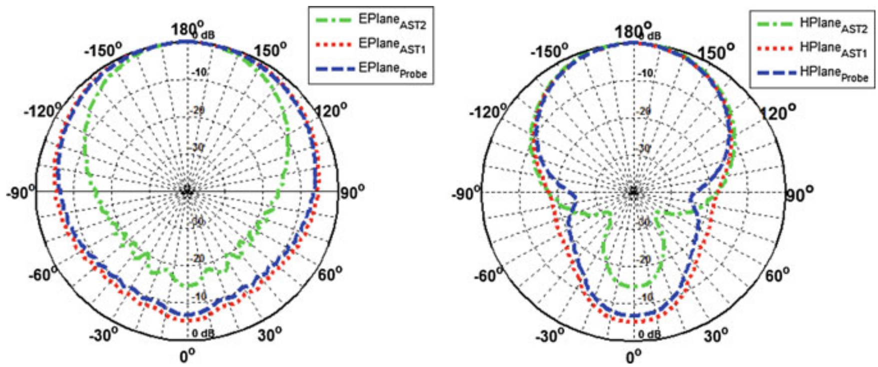

Fig. 6 Radiation pattern of the antenna under test and probe for a frequency $f_o = 10$ GHz

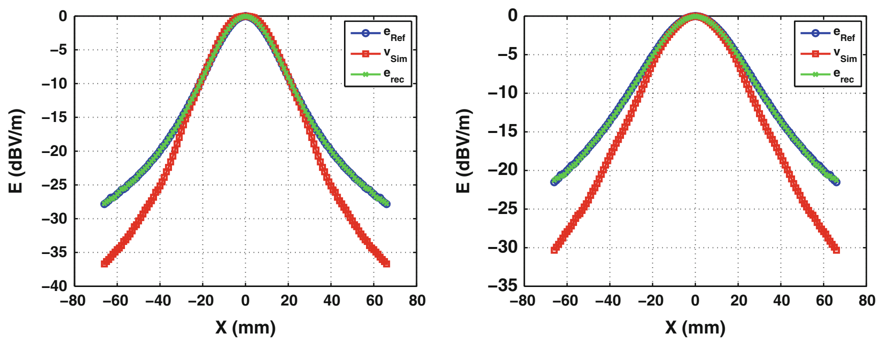

Fig. 7 Comparison between the reconstructed field, the reference field and the voltage at the output of the probe for the ridges OERWG antenna

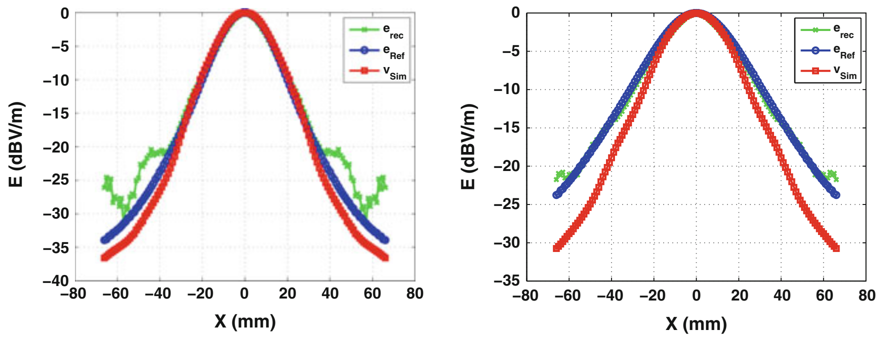

Fig. 8 Comparison between the reconstructed field, the reference field and the voltage at the output of the probe for circular wave guide

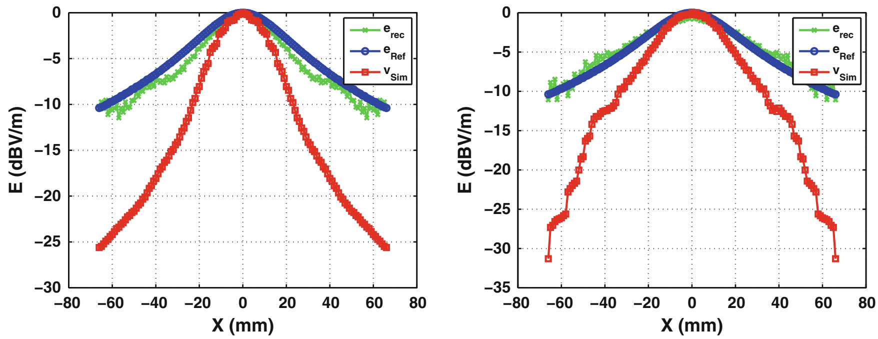

Fig. 9 Comparison between the reconstructed field, the reference field and the voltage at the output of the probe for dipole antenna

4 Conclusion

In this work we studies the correction of the OERWG probe used to measure the tangential component of the electric field. Because of the response of the probe to the other components of the field and the influence of the geometric parameters of this one and to the problems related to the measuring surface, an error appear between the real profile of the field radiated by the AUT and the voltage at the output of the probe. Therefore, a post-processing step is needed to determine the exact distribution of the field. The deconvolution is one of these methods. In our work we reported the fact that the amplitude of the response of the OERWG probe is to determine for two different distances. A test procedure is launched in the latter part of the studies to validate this response. This latter is tested before three antennas under test, a circular guide, a rectangular guide loaded by ridges and a dipole antenna, the results showed a coincidence between the reconstructed eld and calculated without the probe.

References

1. Balanis, C.A.: Antenna Theory: Analysis and Design. Wiley, Canada (2005)
2. Slater, D.: Near-field Antenna Measurement Techniques. Artech House, Boston (1990)
3. Yaghjian, A.D.: An overview of near-field antenna measurements. IEEE Trans. Antennas Propagat. **34**, 30–45 (1986)
4. Johnson, R.C., Ecker, H.A., Hollis, J.S.: Determination of far-field antenna patterns from near-field measurements Proc. IEEE **61**(12), 1668–1694 (1973)
5. Gai-Mai, W.: A new near-field Sar imaging algorithm. In: IEEE 3rd International Conference on Communication Software and Networks (ICCSN) (2011)
6. Moutaouekkil, M.A., Taybi, C., Ziyyat, A.: Caracterisation dune sonde Monople utilise dans la mesure de champ proche. Congers Mediterraneen des telecommunications, Fes (2012)
7. Yaghjian, A.D.: Approximate formulas for the far field and gain of open ended rectangular waveguide. IEEE Trans. Antennas Propagat. **32**, 378–384 (1984)
8. Newell, A.: The effect of the absorber collar on open-ended waveguide probes. In: Antenna Measurement Techniques Association (AMTA), Salt Lake City, Utah, USA, Nov 2009
9. Gregson, S., McCormick, J., Parini, C.: Principales of Planar Near Field Antenna Measurement. IET, London (2007)
10. Qingxiang, Li, Gandhi, O.P., Kang, G.: An open-ended waveguide system for SAR system validation or probe calibration for frequencies above 3 GHz. Phys. Med. Biol. **49**, 4173 (2004)
11. Porter, S.J., Manning, M.I.: A method validates SAR measurement systems. Microwaves RF **44**(3), 68 (2005)
12. Taybi, C., Moutaouekkil, M.A., Kwate, K.R., Elmagroud, B., Ziyyat, A.: Probes characterization for antennas near field measurements. In: 14th Mediterranean Microwave Symposium, IEEE Conference, pp. 12–14. Marrakech, Morocco (2014)
13. Moutaouekkil, M.A.: Least square filtering algorithm for reactive near field probe correction. Progress Electromagn. Res. B, **42**, 225–243 (2012)