

Antenna Characterization without Using Anechoic Chambers or TEM Cells

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ABSTRACT

One of the accustomed procedures to characterize an antenna is evaluating the radiation pattern in an anechoic chamber or at least in a TEM cell. Besides avoiding the reflections, these devices allow a very precise measure of the radiation pattern by isolating the external interference. In this paper an alternative to characterize antennas without using anechoic chambers or TEM cells is discussed. An example of measures obtained by using this method is shared to show the potential of this technique. Additionally the measures are compared with the simulations results obtained with the simulation tool Computer Simulation Technology (CST).

CCS CONCEPTS

• **Hardware** → *Wireless devices*;

KEYWORDS

Antenna Characterization, radiation pattern, antenna simulation.

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1 INTRODUCTION

One important component to optimize the performance of any wireless system is the set of antennas.

There are several useful tools to improve the antennas, as simulators and measurement devices, but usually a complete set of tools to characterize antennas include an anechoic chamber [1] or at least a Transverse Electromagnetic (TEM) cell. These tools are quite expensive ones, and sometimes are not available for small laboratories. In this paper a method to characterize antennas without using

anechoic chambers or TEM cells is discussed. This method, which results good enough to design and optimize antennas, enables small laboratories to work in this area.

The main idea is that: being careful, and utilizing particularly convenient areas, a characterization performed in open space can be precise enough for the optimization of an antenna under development.

This paper describes how this open space characterization was applied in the process of design, simulation and optimization of a SPIDA antenna. We choose to apply this characterization method to a SPIDA antenna, since we aim to optimize it by adjusting some design parameters (e.g. distance of the parasitic elements from the active element).

In Section 2, the design, simulation and fabrication process of a SPIDA antenna is described. In Section 3 the proposed characterization process (without using anechoic chambers or TEM cells) is described. In Section 4 the obtained results are evaluated and finally in Section 5 the main conclusions are summarized.

2 DESIGN, SIMULATION AND FABRICATION OF A SPIDA ANTENNA

The design of this antenna follows the model described in Nilsson [5] and Öström et al [6]. It was originally designed for Wireless Sensor Networks (WSNs), allowing the feature of switched beamforming. It is a simple, cheap and easy to construct antenna, and these characteristics make them suitable for WSNs. The features of these antennas are extensively discussed in [4–6].

In Figure 1 a simulation of the radiation pattern of this antenna is shown, where the alignment of the main lobe with the director element can be observed. This figure was obtained with CST software [3] by introducing a precise model of the fabricated antenna (shown in Figure 3).

In Figure 2 the simulation results for the S_{11} parameter are shown, where the variation of this parameter from 2 GHz up to 3 GHz can be observed. As it can be observed there, the input impedance of this antenna is not well adapted to 50 ohms, in other work of this research project some alternatives to improve this mismatch observed in the input impedance is proposed.

If CST is not available, one alternative can be the free software 4nec2 [8]. Simulations tools have a great value to understand the behavior of the antennas, which are very sensitive to even minimal

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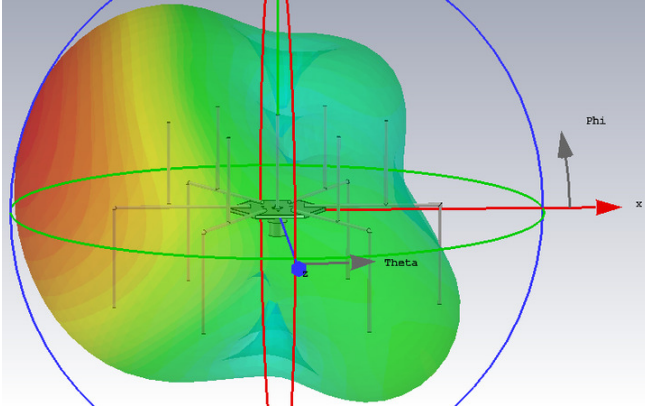


Figure 1: 3D representation of the radiation pattern obtained for the SPIDA antenna with CST simulator for a frequency $f_c=2.4525$ GHz.

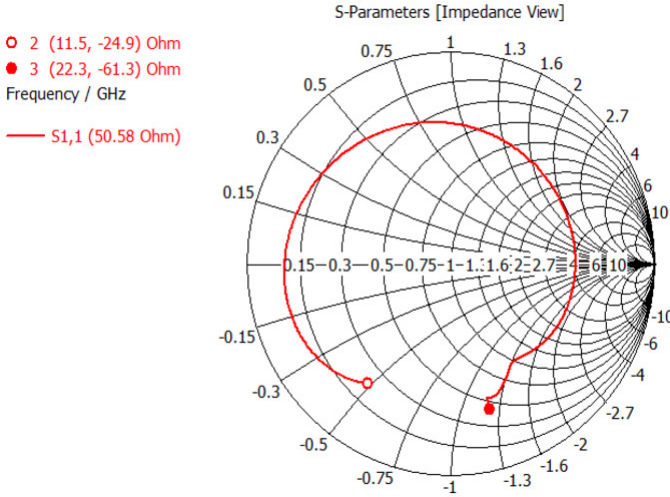


Figure 2: Simulation results of the S_{11} parameter when it varies from 2 GHz to 3 GHz.

modifications. A good simulation work is a crucial task of the antenna optimization process.

In Figure 3, the fabricated antenna is shown. This antenna version has fixed parasitic elements, one director element (isolated and fixed with silicone) and five reflectors (welded). This version of the SPIDA antenna is adequate as an initial version for the characterization of its radiation and input impedance characteristics. In future versions each parasitic element will have a switch, as it is described in [4–6].

For the fabrication of this antenna the dimensions provided in [6] and [5] were strictly followed.

Concerning the fabrication of this antenna, the central hexagon was made with a LPKF ProtoMat S63 circuit board plotter, which simplifies the fabrication process and assures the equality of this

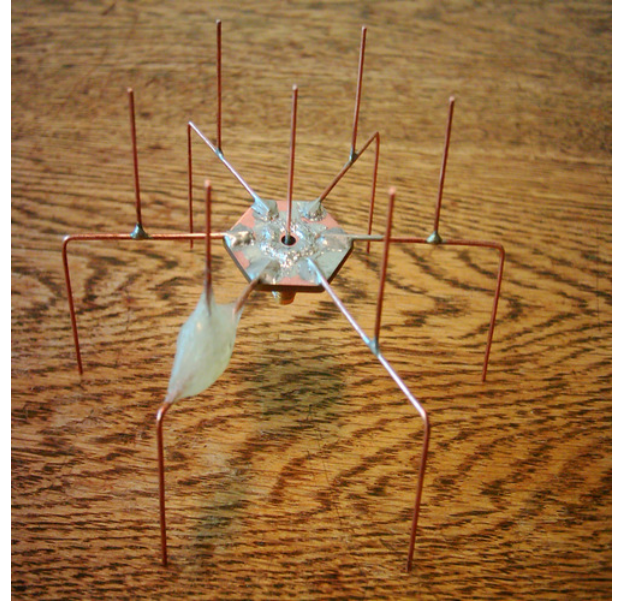


Figure 3: SPIDA antenna fabricated.

piece when a modified version of the antenna is fabricated. For this hexagon, standard 1.6 mm FR4 PCB board of $35 \mu\text{m}$ of copper thickness was used. Both layers of the hexagon were connected with vias of 1 mm^2 of section welded with tin. A SMA connector was welded to the lower copper layer of the hexagon to feed the antenna. All the elements were made with copper wire of 1 mm^2 of section (removing the dielectric shield of the used cable). The active element (the central one) is welded to the central pin of the SMA connector in order to be connected to the central wire of the coaxial cable used for feeding the antenna. The element selected as director is isolated from the rest of the antenna with silicone, as it is shown in Figure 3.

3 CHARACTERIZATION METHOD

In this section the proposed method for the antenna characterization is described. The main motivation is having a procedure to measure the radiation pattern of an antenna when an anechoic chamber or a TEM cell is not available.

Anechoic chambers or TEM cells are able to avoid reflections and interferences. In this work the reflections are minimized by selecting an open space area. For these measures a place near to the sea is used, pointing the transmission in the direction of the sea. In this way the reflection caused by buildings and another reflective objects is avoided. In Figure 4, the open space area selected for the measurements can be observed.

For the characterization of the radiation pattern, besides the SPIDA antenna, a domestic directive WiFi antenna with 6 dBi of maximum gain was used. This WiFi antenna was connected to a RF generator and the SPIDA antenna to a spectrum analyzer. Figure 5 depicts the setup for the measurements, where $d = 3 \text{ m}$ is the distance between antennas and $h = 1.3 \text{ m}$ is the height above the floor.



Figure 4: Open space area where the measures were taken.

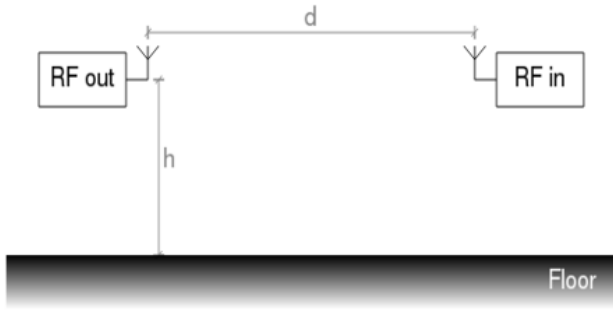


Figure 5: Setup for the radiation pattern measurements.

For the measures of the S_{11} parameter, the Rohde & Schwarz ZVB 8 Vector Network Analyzer (which operates in a range of 300 kHz to 8 GHz) shown in Figure 6 (a) was used. The technique used to take these measures was quite standard, with the only consideration of taking them in an adequate environment. Results are shown in Figure 7.

For the measures of the radiation pattern, the RF Generator Agilent E4438C (which operates in the range of 250 kHz to 3 GHz) ESG Vector Signal Generator shown in Figure 6 (b) was used. The Agilent EXA Signal Analyzer N9010 A (which operates between 9 kHz and 7 GHz) shown in Figure 6 (c) was used as spectrum analyzer. The radiation pattern measures were made in the open space area shown in Figure 4.

The frequency used for these measures was $f_c = 2.4525$ GHz, because this is the central frequency used by the WSN nodes where the SPIDA antenna is used. The transmitted power levels set in the signal generator were 0 dBm and 7 dBm, and the corresponding results for these two power levels were averaged. These power levels are the typical values for WSN nodes.

In order to obtain accurate measurements of the radiation pattern some considerations must be taken into account. Being far away from reflection clusters (except for the floor) and having a link length quite short produce a good relation between the power

arriving to the antenna by the line of sight (direct way) and the power arriving to it through reflections. This leads to place the antennas quite close one from the other. However, there is a minimum distance for the link length, due to the fact that the antennas must work in the far field region. The limit R for the start of the far field region was calculated using (1) [2].

$$R \geq \frac{2D^2}{\lambda} \approx \frac{2 \cdot (0.12m)^2}{0.1223m} \approx 0.24m \quad (1)$$

According to this equation, we can be sure that working at a distance of 3 m, the link is operating in the far field region. Observing the quality of the measures in Figure 8, it is clear that it is not necessary to diminish this link length. Besides this, resin tripods were used to hold the antennas in order to avoid the distortion of the measures that could be caused by using metal tripods.

The effect of the floor as an obstruction can be neglected if it blocks after the 60 % of the first Fresnel radius. Since we place the antenna at a height of 1.3 m, corresponding to the 18th Fresnel radius, this situation can be considered as free space. The surface of the floor used for these measures facilitates scattering and absorption effects, which diminishes the effect of reflections over the floor arriving to the receiver.

As it was previously explained, an open space area is needed to apply this method. To achieve this, we use an area next to the university, taking advantage of the lack of obstacles provided by the sea; but any open space area as countryside or the roof of a building -higher than their neighbors- could be adequate for applying this characterization method.

The results obtained with this characterization method are discussed in the next section.

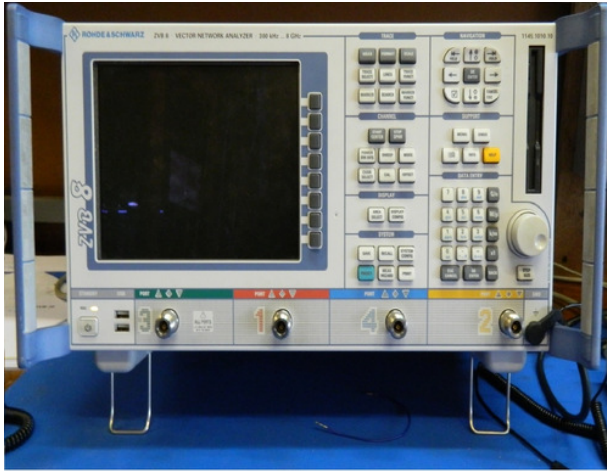
4 RESULTS

In this section the results for the characterization process and the simulations are discussed.

In Figure 7, the measured values for the S_{11} parameter are presented. Comparing the measured results for S_{11} in Figure 7 and the simulated ones in Figure 2, a similar behavior can be observed. Probably by refining the simulation model, a closer performance for both curves could be found, but the focus was put in the radiation patterns, for which the characterization method described in Section 3 was designed.

In Figure 8, the measures of the radiation pattern obtained with the characterization process described in Section 3 were superimposed with the simulation results. We can observe that the measured and simulated curves in both planes (H plane and E plane) are quite similar. This coincidence between the curves and also with the results in the bibliography confirms that the proposed characterization method produces reasonable results, which were enough in our case to optimize the performance of these antennas in later works [7].

As it was previously explained, the measures of the radiation pattern were performed for two levels of transmitted power (0 dBm and 7 dBm), and then averaged to obtain the gain results shown in Figure 8 (a) and (b). Considering the dispersion between measures and simulations in the two cases (H-plane and E-plan), we can say that these are acceptable for most of the purposes. If more regular



(a)



(b)



(c)

Figure 6: Used measuring instruments, (a) Vectorial Analyzer, (b) Signal Generator, (c) Spectrum Analyzer.

and precise curves are needed, the average of more measures for each point can be an alternative to obtain them.

This characterization method was later used for evaluating the performance of different configurations of this antenna, obtaining always a very good matching between simulations and measurements.

5 CONCLUSIONS

In this paper we propose a characterization method for antennas, when anechoic chambers or TEM cells are not available. Considering the coincidence between simulations and measures and also with the results in the existing bibliography, the method shows to

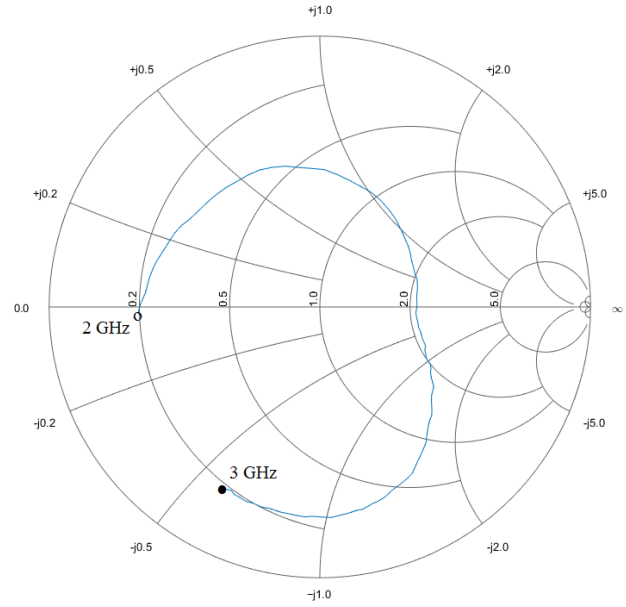


Figure 7: Measured S_{11} parameter.

be an acceptable alternative. More precision in the measures can be achieved by averaging more measures obtained for the same or different transmitted power levels.

This method is a valuable alternative for research groups that do not have resources such as anechoic chambers or TEM cells to work in this area.

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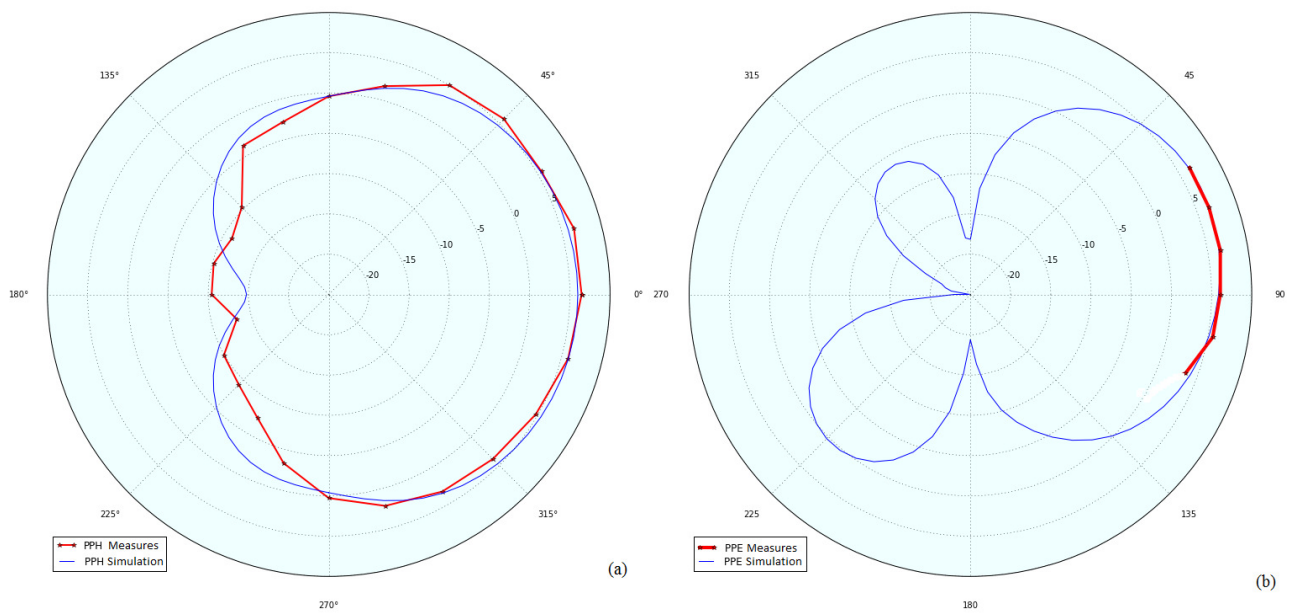


Figure 8: Radiation pattern for the SPIDA antenna, (a) H-plane and (b) E-plane.