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On the Use of a Reliable Low-cost Set-up for Characterization Measurements of Antennas

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Abstract- In this paper, a low-cost time domain-based approach to antenna characterization is presented. The goal is to prove that time domain-based antenna measurements, after appropriate processing, represent an accurate and more practicable alternative to the universally accepted (yet highly expensive) antenna measurements in anechoic chamber, and provide information just as complete. Measurements on two commercial antennas are carried out in the time domain (in a non-controlled environment) and in the frequency domain (in an anechoic chamber): experimental data obtained from the two approaches are compared in terms of Return Loss. Results show that reliable results can be extracted from time domain data, and that a good insight into the antenna characteristics can be obtained even without using highly expensive facilities.

Keywords- time domain reflectometry, antenna characterization, scattering parameter, frequency domain analysis.

I. Introduction

Characterization measurements on electronic devices can be performed either in the Frequency Domain (FD) or in the Time Domain (TD): the advantages and drawbacks related to these two different approaches have been extensively addressed in several other works. Nevertheless, dealing with radiative devices (i.e. antennas) makes the issue more complicated; in fact, the measurement environment can interfere with the radiating antenna, thus altering the results of the measurement [1-3].

Traditionally, measurements of antenna parameters are carried out through expensive instruments, such as a Vector Network Analyzer (VNA), in dedicated facilities (i.e. anechoic chamber): this procedure is universally regarded as the best possible approach to antenna characterization as it undoubtedly provides the best accuracy. Nonetheless, the high costs involved in the execution of this kind of measurements, in many cases, make such procedure virtually impracticable on an every-day basis. For this reason, it is crucial to find alternative ways for characterizing antennas: measurements should be performed more easily; still a good level of measurement accuracy should be preserved.

Indeed, TD-based measurements, after suitable processing, can provide acceptably accurate results with definitely lower related costs. In this regard, the goal of this work is to assess the use of TD approach, and individuate the appropriate conditions that can avoid the use of anechoic chambers

To this purposes, comparative measurements on two commercial antennas are carried out: first in the FD (using a VNA in an anechoic chamber) and then in the TD (more specifically, using a Time Domain Reflectometry instrument in a non-controlled environment). Data obtained in the TD are suitably processed (through the well-known Fourier transformation algorithms), in order to derive the corresponding information in the FD [4], thus guaranteeing an adequate accuracy level without lacking information.

This paper is structured as follows: in Section II, the set-up for each kind of measurement is described. In Section III the results are shown and discussed. Finally, in Section IV conclusions are drawn and the next phases of the activities are addressed.

II. Experimental set-up and proposed approach

A. Antennas Under Test

The antennas considered as test-cases for comparative measurements (Antenna Under Test-AUT) are an Alien ALR-8610-AC antenna and a Clampco Sistemi AP3000 biconical antenna.

The former is an antenna used for Radio Frequency Identification (RFID) applications. No detailed specifications are available for this antenna, except that it is supposed to have -15 dB Return Loss in the operating frequency range (approximately between 865 MHz and 940 MHz). The configuration of the antenna is shown in Figure 1: it is worth mentioning that the truncated edges (indicated in circles in Figure 1) are realized to guarantee circular polarization with only one feed point and to generate two closely-spaced resonance frequencies (that will be addressed later on this paper), between which the antenna is requested to operate [5].

The second antenna considered for the comparative TD/FD measurements is a biconical antenna (Figure 2) generally used with a spectrum analyser for Electromagnetic Compatibility (EMC) measurements. For this antenna, which is designed to operate in a frequency range between 80 MHz and 3 GHz, the Return Loss data (acquired in an anechoic chamber through a VNA) are available from specifications and are used as a reference to which compare the TDR data.

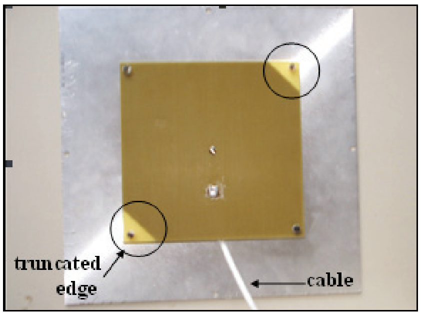

Figure 1. Picture of the RFID antenna under test

Figure 2. Picture of the tested biconical antenna

B. TDR measurement set-up

The instrument used to perform the TDR-based measurements is a Tektronix® Digital Serial Analyzer (DSA8200), equipped with a TDR module (TDR80E04). The rise time of the generated incident pulse is about 17 ps, which corresponds to a frequency bandwidth of about 20 GHz [6]. The maximum number of points that can be acquired in the TD is 4000 (over the considered time window). The corresponding frequency resolution in the FD analysis will be $1/t_{TW}$, where t_{TW} is the duration of the chosen time window.

The TDR-based approach can be briefly described as follows. An electromagnetic step signal is launched into the AUT; part of the signal is reflected back by the AUT towards the step generator. The characteristics of the reflected signal are intrinsically related to the S_{11} of the AUT. The data acquired in the TD are transformed into the FD, and the S_{11} is evaluated. The data processing is performed through the dedicated FD transformation procedure described in [7]. This algorithm takes into account several crucial issues involved in the signal transformation from TD to FD: the time-domain windowing and truncation, the pre-processing operations (such as Nicolson algorithm and zero-padding), and the compensation of parasitic effects through calibration techniques (Short-Open-Load, SOL).

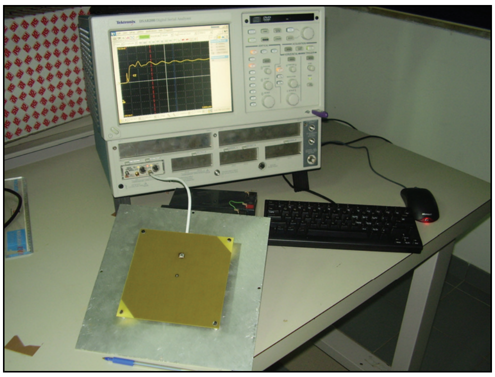

Figure 3.Set-up for the TDR-based antenna measurements

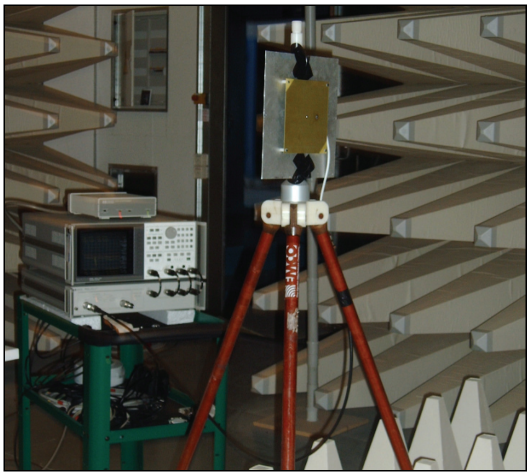

Figure 4. Set-up for the measurement carried out in the anechoic chamber

C. VNA Measurement set-up

As aforementioned, VNA measurements are carried out only on the Alien ALR-8610-AC antenna, for which almost no information was available from specifications.

The VNA used for measuring the reflection scattering parameter (S_{11}) is an HP8753C equipped with the 85047A S-Parameter Test Set. The frequency resolution is set at 1 kHz; the frequency is swept from 820 MHz to 960 MHz. A one port calibration is performed with the Agilent 85052D 3.5mm calibration kit [8].

III. Results and discussion

As can be seen in Figure 3, the TDR measurements are performed in a non-controlled environment (as opposed to the anechoic chamber).

It is important to underline that a crucial point when performing TDR measurements on antennas is to appropriately adjust the measurement parameters. In particular, the length of the acquisition window should be long enough to let multiple reflections die out; on the other hand, a long acquisition window generates noisier measurements. A trade-off is necessary. For the measurements on the ALR-8610-AC the duration of the time window is set at 150 ns, whereas for the biconical antenna it is set at 60 ns.

Furthermore, care must be taken in order to have sufficient dynamic range to characterize the device under test: the dynamic range increases with the number of averages for the acquired waveforms [6]. In the considered measurements the number of averages of the instrument is set at 128.

The calibration standards (namely, a short, an open and a load) are connected and the corresponding waveforms are acquired maintaining the same acquisition window. Once all the waveforms are acquired, they are processed through the transformation algorithm described in [7] and the S_{11} value is extrapolated, in magnitude and phase. For the sake of brevity, in Figure 5 only the TDR waveforms acquired for the Alien ALR-8610-AC antenna are reported.

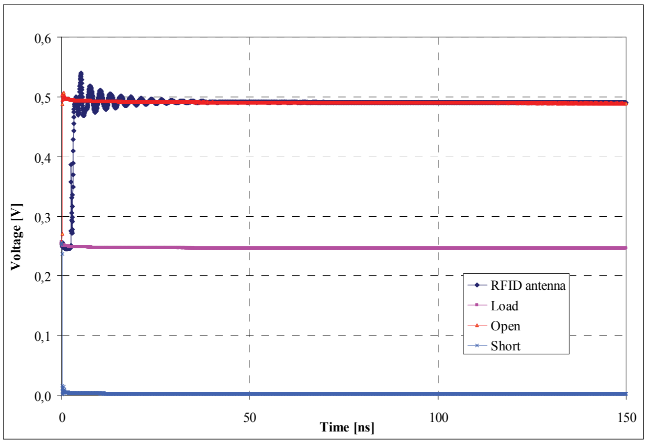

Figure 5. Zoom-in of the TDR waveforms for the ALR-8610 AC and for the calibration measurements

Measurements were repeated in an anechoic chamber: also in this case, systematic errors were taken into account through the same one-port calibration (SOL) procedure [8].

Comparative results between the scattering parameter evaluated from the TDR measurements and the scattering parameter measured through the VNA are shown in Figure 6 and Figure 7.

Referring to Figure 6, it appears that the S_{11} curve obtained from TDR measurement is close to the curve obtained from measurement in the anechoic chamber. In particular, it is important to note that both the resonance frequencies of the antenna, generated by the truncated-edge geometry, are clearly visible not only in the VNA measurement, but also in the TDR measurement. The resonance frequencies estimated by the VNA are approximately at 866 MHz and 899 MHz, whereas the TDR-measured resonance frequencies are approximately at 860 MHz and 903 MHz. As shown in Figure 6b), TDR-based measurements provide an adequate representation of the antenna characteristics also for the phase.

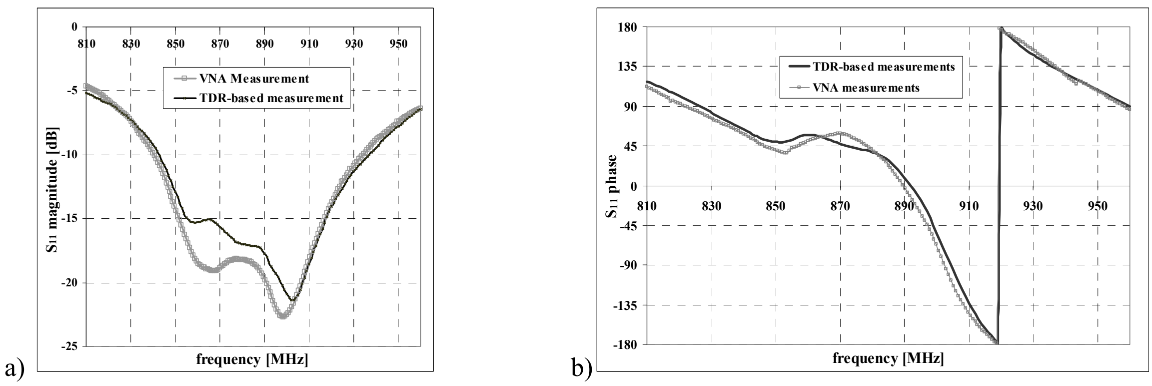

Figure 6. Comparison between the S_{11} obtained through FD transformation of TDR data (black curve) and through VNA measurements in anechoic chamber (grey curve) a) in magnitude), b) phase

As for the measurements on the biconical antenna, in Figure 7 the S_{11} data obtained through the TDR measurements are superimposed to the measurement carried out through a VNA in an anechoic chamber; for the sake of brevity only magnitude information is reported. Also in this case, a good correspondence between results obtained through the two different measurement approaches can be noted. This demonstrates the adequacy of the TDR-approach also for wide-frequency range characterization.
Although the reported comparative analysis is limited to two test-cases only, the proposed method, which involves a TDR set-up and a dedicated transformation algorithm, is an excellent alternative to the use of expensive anechoic chamber and VNA.

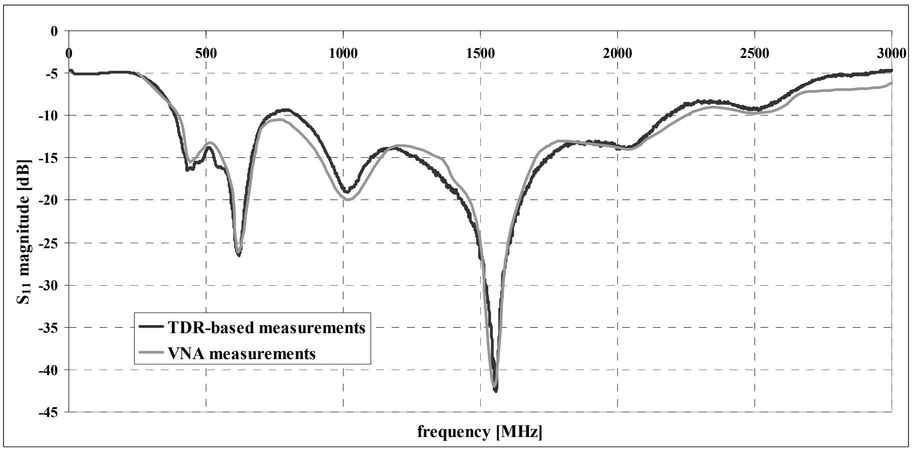

Figure 7. Comparison between the S_{11} (magnitude) for the biconical antenna under test

IV. Conclusions

In this paper an alternative time-domain based approach to antenna characterization has been presented. Comparative measurements of the scattering parameter S_{11} of two commercial antennas have been carried out through the traditional FDR approach in an anechoic chamber and through the TDR approach. Results have shown that TDR-based measurements, together with appropriate post-processing on the data, provide good knowledge on the characteristics of the AUT: this confirms that TD data contain just as much information as FD data. Although retrieving this information requires a good knowledge of TD/FD combined approach, the trade off cost/accuracy of measurement makes TD-based method an attractive alternative to FD-measurements in anechoic chamber. The next step is to provide a rigorous metrological characterization of the proposed method and to extend the TD-based approach to measurements of gain of antennas. Although this may seem rather challenging, the potential of FD/TD combined approach in processing the acquired signals just as if they were acquired in an anechoic chamber, encourage the Authors to pursue this research.

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