A contact-less small antenna characterization through impedance modulation

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Abstract— **In smalls antennas S-parameters measurements are highly influenced by the measurement equipment as well as the environment. In order to avoid this inconvenience, a wireless and non-invasive characterization setup is required. In this paper a novel contact-less measurement setup is developed based on the Radar Cross Section (RCS) measurement method using impedance modulation. A small ($2x2cm^2$) autonomous and self-powered communication device is presented as a system able to change the load impedance of the antenna under test (AUT) to produce impedance modulation. The device contains a microprocessor, a switch able to change between three different load impedances and a 5V battery.**

I. Introduction

Nowadays there is a trend towards the miniaturization of communication systems including the antenna device. Due to the small size of the antenna, the S-parameters measurements are highly influenced by the measurement equipment as well as the environment.

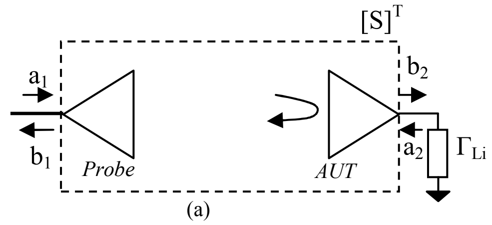
It is well known that changing the load impedance in the antenna feeding it is possible to obtain the characteristic parameters of the antenna, such as S-parameters and gain. Different authors developed a measurement setup using the RCS method [1] [2]. If the load changes with a certain modulation we can analyze the received signal of the modulated scattered fields in order to extract not only a near-field map, as in MST theory [3], but also the characteristic parameters of any antenna.

In this paper a novel contact-less measurement setup through impedance modulation is presented. The theory formulation of the problem and the experimental setup are presented in sections II and III, respectively. In order to validate the setup, three different antenna characterizations have been done and the results are presented in section IV.

II. Formulation

Taking into account the two one-polarization antennas free space system depicted in Fig. 1(a), the resulting scattering matrix $[S]^T$ can be considered as a two port network with a signal flow graph showed in Fig. 1(b). If port 2 of the reciprocal network it is terminated with a reflection coefficient Γ_{Li}, the measured S_{11} is related to S_{ij} as follows:

$$S_{11}^{L_i} = S_{11_{probe}} + \frac{S_{12}{}^2\Gamma_{L_i}}{1-S_{22_{AUT}}\Gamma_{L_i}} \qquad [1]$$



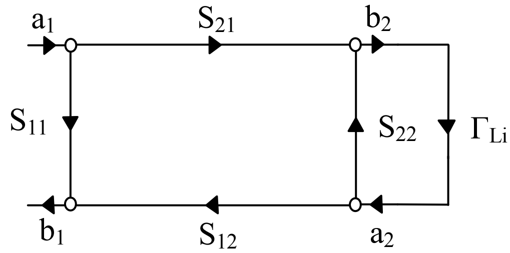


Fig.1 (a) Scattering parameter representation and (b) equivalent signal flow graph.

Where $S_{11probe}$, S_{22AUT} and $S_{11}^{L_i}$ are the return losses of the probe antenna, the Antenna Under Test and the system respectively. Due to the fact that the system is a reciprocal two port network, S_{21} is equal to S_{12} and they are dependent on the gain of each antenna, the polarization coefficient and the distance between antennas. For a complete characterization of the system a double polarization measurement has to be done to obtain the antenna gain but to characterize the reflection coefficient of the AUT only one polarization measurement is needed to extract the S_{22AUT} parameter.

In [1] three unknown have to be solved, $S_{11probe}$, S_{12} and S_{22AUT}. So, a 3x3 equation system is needed to characterize the scattering matrix. Changing the reflection coefficient of port 2 between three known states (short circuit, open circuit and matched load) the scattering matrix is characterized solving the result 3x3 equation system.

III. Experimental setup

A. Switching device

To produce an impedance modulation at a certain frequency, a change between three different load impedances is needed and also the generation of the required frequency modulation. Ideally, a perfect short circuit, open circuit and matched load are needed to cover the maximum different values in the

Smith chart. Finally, the most important aspects it is to perform a good characterization of the load impedances over the frequency range and to obtain differentiated enough load impedances, to generate a better conditioned equation system. Fig. 2 shows the three load impedances used on the switching device characterized between 10 MHz and 2GHz.

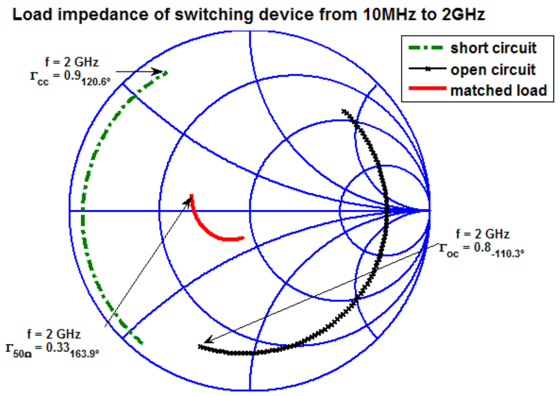


Fig. 2 Load impedance characterization.

The switching device consists of a SP3T switch working from DC to 3.5 GHz able to change the load impedance between three different states, a microprocessor to control the load variation with the required frequency and three different load impedances (open circuit, short circuit and matched load) attached to the switch. A 5V battery is included to realize a self-powered and autonomous system. A complete scheme of the device and the final construction are shown in Fig. 3.

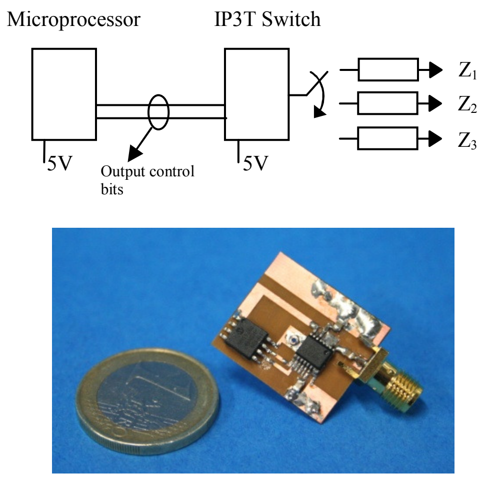


Fig. 3 Communication device scheme and device implementation.

To extract the characteristic parameter of an antenna straightforward from the measurements of the network analyzer, it is necessary to know the correspondence from bit assignation to load impedance. The output of the microprocessor is compounded of two bits that control the input of the IP3T switch. The two bits of control are two square signals with a period of 400ms. Due to the fact that the system only needs three different states and to avoid any ambiguity, the load state is repeated.

Fig. 4 shows a time capture from the network analyzer with the complete measurement setup working. It is easy to identify the load state due to its longer duration. So, there is no ambiguity in the received signal to process it. This facility allows performing the measurements without external trigger. Only the bit assignation has to be previously known in order to extract all the information.

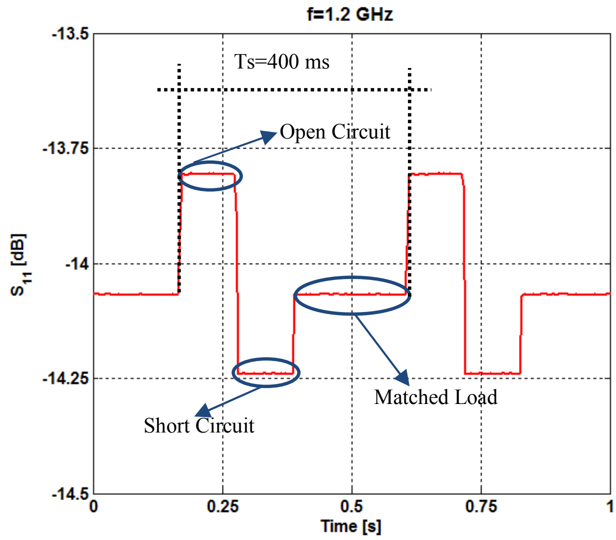


Fig. 4. Time capture from Network Analyzer at 1.2GHz with an open waveguide antenna measurement setup.

B. Measurement setup

The measurement setup is shown in Fig. 5 and is composed of a probe antenna connected to measurement equipment, an AUT and the communication device described in previous section. As measurement equipment an Agilent Network Analyzer E8236 is used in time regime and is monitored by a laptop. The measurement is done inside an anechoic chamber using an electronic calibration procedure to remove the cable contribution. The input reflection coefficient for each switch position over the frequency range of measurement has to be characterized in order to reconstruct the reflection coefficient of the AUT. No external trigger is needed from the communication device to the VNA.

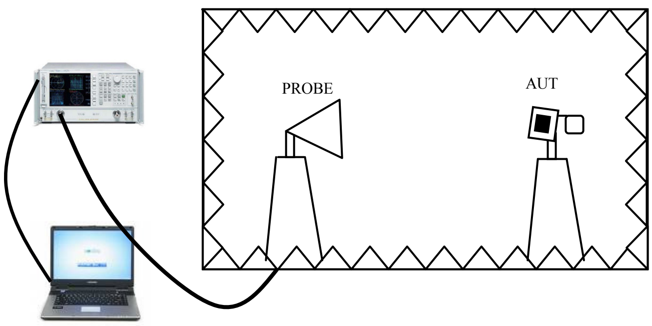


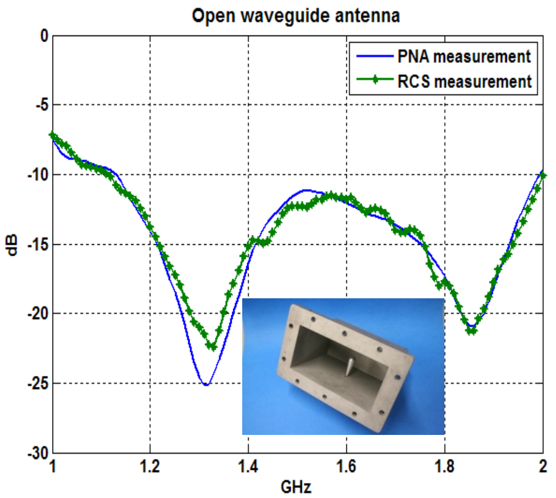
Fig. 5 Measurement setup

V. PRELIMINARY RESULTS

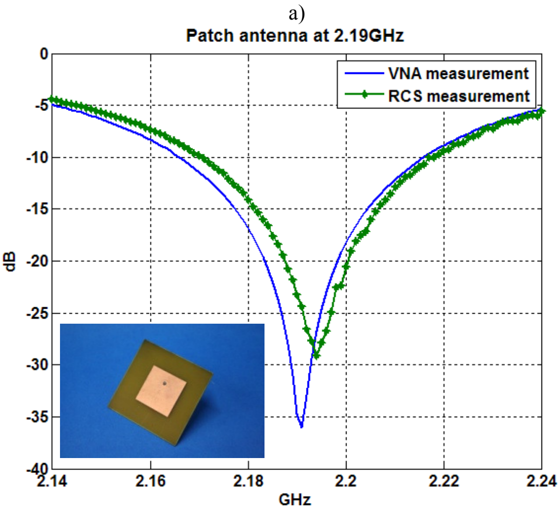
To validate the measurement concept three different standard antennas have been measured. An open waveguide antenna is characterized due to its wideband behavior and good return losses over the frequency range. As a resonant antenna, a patch antenna is measured. Finally, a monopole antenna with small ground plane is characterized. When an antenna has a small ground plane the cable becomes part of the antenna invalidating hence the results. All the measurements have been done with 101 frequency points and 401 time domain points.

The open waveguide antenna is working between 1.1 and 2 GHz, the resonant frequency for the patch antenna is 2.19 GHz and the monopole works at 1.4 GHz with a FBW of 14%. As a probe a ridged antenna between 750 and 2000MHz has been used for the aperture and monopole antenna setup. With the patch antenna setup, a probe with higher frequency range is needed. So, a ridged antenna working from 2 to 10GHz is used.

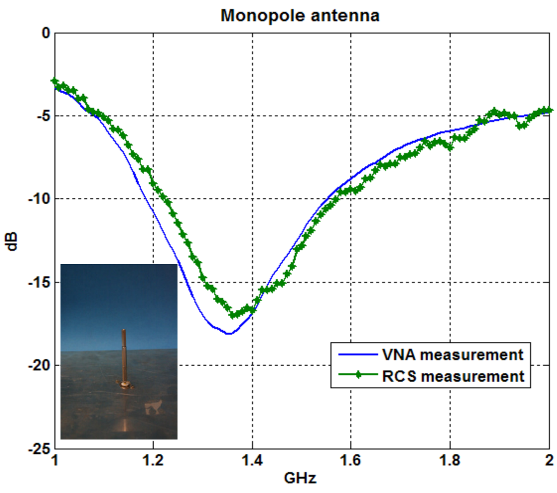
The results obtained from each antenna are shown in Fig. 6. Accurate results are presented between RCS and direct Network Analyzer measurement validating the measurement setup and the switching device presented in this paper.



a)



b)



c)

Fig. 6 Comparison between RCS measurement and direct Network Analyzer measurement for an open waveguide (a), a patch antenna (b) and a monopole antenna (c).

VI. CONCLUSIONS

After validating the method with different antennas an important consideration has to be done. The main goal is to achieve a large dynamic range in the measurement. Most of the dynamic range comes from the return losses of the probe, so a good reflection parameter in the probe is required.

However, a small contact-less, autonomous and self-powered communication device has been constructed and validated in order to characterize small antennas through impedance modulation.

Three reference antennas have been measured and the results are in concordance with direct network analyzer measurements.

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