Rapidly Deployable Portable System for Real-Time Antenna Diagnostics and Characterization

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***Abstract*—In this paper a portable system, based on off-the-shelf components, to perform in-situ fast antenna diagnostics and characterization is presented. In order to perform the antenna evaluation, the operator holds a probe antenna, which is moved in front of the antenna under test (AUT) to acquire the near-field (NF) on an arbitrary surface. During the NF acquisition, an equivalent currents distribution on the aperture of the AUT is continuously reconstructed based on the available samples. Moreover, the far-field (FF) radiation pattern is also computed. In addition to the probe, the system comprises a commercial real-time position tracking system capable of providing the Cartesian coordinates and the rotation angles of the probe, which can be deployed and calibrated in a few minutes. The NF acquisition is accomplished by means of a vector network analyzer (VNA). The obtained results of a test characterizing a horn antenna are discussed, showing good performance.**

I. Introduction

The development of 5G technology involves not only the use of new frequency bands (e.g. 28 GHz), but also the deployment of larger antenna arrays both in base stations and user devices, thus enabling massive MIMO communications and high-capacity point-to-point microwave links [1]. In this context, the capability to perform in-situ fast diagnostics and characterization of the deployed antennas is of great interest. For example, a system based on an Unmanned Aerial Vehicle (UAV) to asses the performance of base station antennas has been recently proposed [2]. In this paper a portable system to perform a fast and accurate evaluation of antennas is presented. To achieve the fast characterization and diagnostics of the Antenna Under Test (AUT), the operator of the system takes measurements of the Near-Field (NF) radiated by the AUT by intuitively moving the probe antenna with their own hand. The probe antenna position is retrieved by a cost-effective high-accuracy positioning system. The diagnostics of the antenna relies on the use of the Sources Reconstruction Method (SRM) to compute an equivalent currents distribution on the aperture of the AUT [3]. The Far-Field (FF) characterization of the AUT is based on the electromagnetic equivalence principle. Once the current distribution on the aperture of the AUT is estimated, the field at any position outside the antenna aperture can be computed. Thus, the AUT radiation pattern is estimated by means of a Near-to-Far field transformation (NF-FF).

II. System Architecture

The system to perform antenna diagnostics and characterization comprises a probe antenna connected to a Vector Network Analyzer (VNA), a positioning system to accurately determine the location of the probe antenna and a conventional laptop to process the acquired data. The block diagram of the system is depicted in Fig. 1.

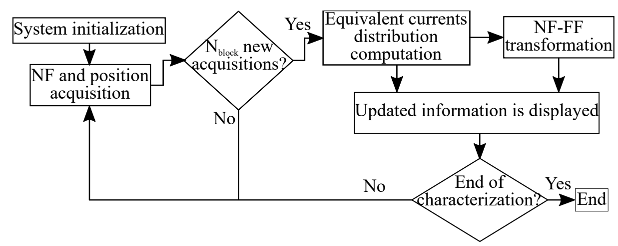

Fig. 1: Block diagram of the system.

The operator performs the characterization of the NF of the AUT by moving the probe antenna in front of its aperture. Meanwhile, the coherent detector and the positioning system are sequentially triggered to acquire data. After N_{block} NF and position samples are acquired, the equivalent currents distribution of the antenna is computed and the FF pattern of the AUT is estimated. The obtained results are displayed on the screen of the data processing laptop so that the operator is able to check the current diagnostics and estimated radiation pattern of the AUT. The locations where data acquisitions were performed are also depicted, so undersampled areas can be detected. The data acquisition continues, updating the currents distribution and radiation pattern displayed in the laptop, until the operator decides that enough data was acquired.

III. Results

The performance of the proposed architecture was assessed by measuring a horn antenna at 32 GHz with the setup shown in Fig. 2. In this case, the detector used to acquire the NF of the AUT was a conventional and bulky laboratory VNA, although a simpler coherent detector or a portable VNA could have been used instead. The positioning system was the motion capture system of Optitrack®. The system was composed of four infrared cameras and reflective markers attached to the probe antenna used to track its position. This motion capture system provides submillimeter accuracy (to apply SRM an accuracy of at least $\lambda/10$ should be achieved). The probe antenna was an open-ended waveguide.

During the measurement of the AUT, a set of $N = 1421$ acquisitions were gathered within a total time of 177 s.

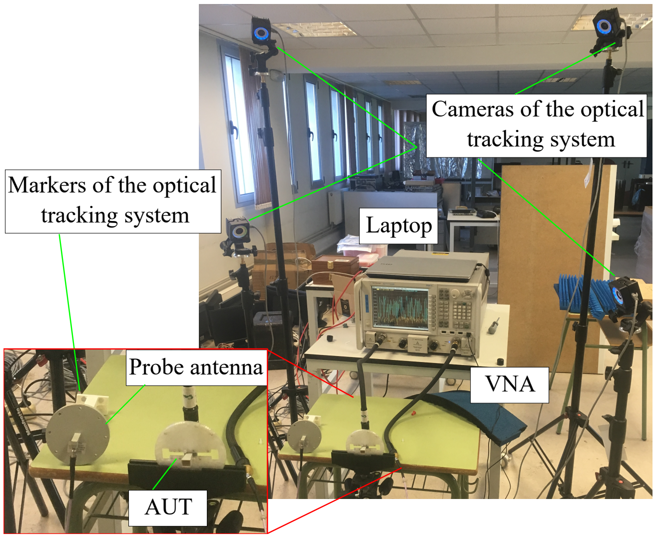

Fig. 2: Measurement setup.

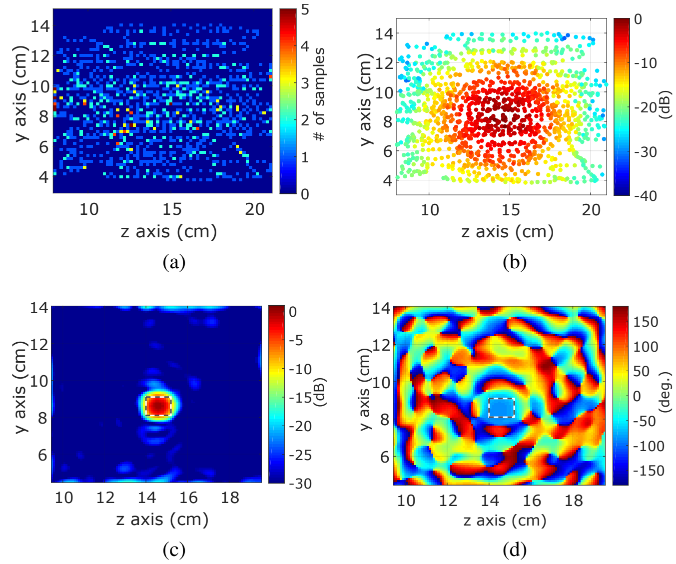

Fig. 3: Heatmap showing where the NF of the AUT was acquired projected in the AUT aperture plane (a); measured NF normalized amplitude (b); magnitude (c) and phase (d) of the equivalent currents distribution of the aperture.

The acquisitions were performed at an average distance of $5.6\,\mathrm{cm}$ from the AUT. The projection of the acquisition positions in the plane of the aperture of the AUT is shown in Fig. 3a. The amplitude of the raw measurements of the NF radiated by the AUT is depicted in Fig. 3b. From the amplitude and phase measurements of the NF radiated by the AUT, its equivalent currents distribution at the aperture was computed using the SRM algorithm. The magnitude and phase of the estimated currents distribution, which provides antenna diagnostics, are depicted in Figs. 3c and 3d respectively. As can be seen, the retrieved equivalent currents are confined within the area of the AUT aperture (3c dashed gray line). In addition, it can be observed that the phase in the area corresponding to the aperture is flat.

Finally, the characterization of the AUT is achieved by means of a NF-FF transformation. The retrieved main cuts of the far-field pattern of the AUT are shown in Fig. 4.

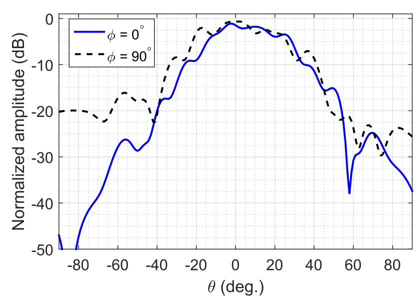

Fig. 4: Estimated main cuts of the AUT far field pattern.

IV. Conclusion

In this paper a portable system which provides in-situ real-time antenna diagnostics and characterization has been presented. The antenna analysis uses NF measurements of the AUT acquired by the operator by moving a handheld probe antenna in front of the AUT aperture. With that information, antenna diagnostics is performed by computing an equivalent currents distribution of the AUT using the SRM and, after that, the FF radiation pattern of the AUT is retrieved by means of a NF-FF transformation. To validate the proposed system architecture the performance of a horn antenna at $32\,\mathrm{GHz}$ was evaluated. Results show that it is possible to accurately obtain a currents distribution of the AUT and its radiation pattern in less than three minutes. Thus, although the system is not expected to provide the same accuracy as measurements performed in an anechoic chamber, it is clearly able to quickly detect the sources of the AUT, including a characterization of its amplitude and phase, which is a very convenient feature to evaluate the performance of large arrays such as the ones involved in the incoming 5G paradigm.

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References

[1] P. Demestichas, A. Georgakopoulos, D. Karvounas, K. Tsagkaris, V. Stavroulaki, J. Lu, C. Xiong, and J. Yao, "5g on the horizon: Key challenges for the radio-access network," *IEEE Vehicular Technology Magazine*, vol. 8, no. 3, pp. 47–53, Sep. 2013.

[2] M. G. Fernandez, Y. A. Lopez, and F. Las-Heras, "On the use of unmanned aerial vehicles for antenna and coverage diagnostics in mobile networks," *IEEE Communications Magazine*, vol. 56, no. 7, pp. 72–78, July 2018.

[3] Y. Alvarez, F. Las-Heras, and M. R. Pino, "Reconstruction of equivalent currents distribution over arbitrary three-dimensional surfaces based on integral equation algorithms," *IEEE Transactions on Antennas and Propagation*, vol. 55, no. 12, pp. 3460–3468, Dec 2007.