Review of Recent Advances and Future Challenges in Antenna Measurement

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Abstract **─** This paper reviews the last advances in Antenna Measurement Field that took place during the previous years in order to analyse the challenges for the antenna measurement community, both industrial and academic, for the future years. The paper begins with an introductory review of the antenna measurement methodologies innovations, continuing with measurement systems technical improvements and concluding with the challenges for the antenna measurement community in the close future.

Index Terms **─** Antenna measurement, field acquisition, post processing techniques.

I. INTRODUCTION

Antenna measurement topic had a large evolution in the decades of 1960 to 1980, with the introduction of compact antenna test ranges and near field measurements [1-3]. Since that moment the progress has been significant, but basically the same far field (including compact antenna test range) or near field techniques, in the three classical configurations (spherical, planar or cylindrical) were used. Conversely, new antenna technologies have been proposed and designed during the last years: wideband small antennas integrated in portable systems, millimeter and submillimeter wave antennas, active antennas and smart antennas, among others.

This revolution in the antenna area has created the necessity of new advances in antenna measurement. Right now, it is really difficult to separate the performance of the antenna with respect the RF system (in the case of small or active antennas); even the antenna itself has to work, and be measured together with the digital signal processors (in the case of smart antennas); the new terahertz bands require an impressive accuracy in the acquisition system to avoid positioning errors; and the measurement of multibeam antennas should be done very fast to reduce the measurement costs. Of course, defense and space markets still require very accurate measurements. The latest advances in antenna measurement research, together with the availability of new technology, faster and more complex to acquire data, to get accurate positioning of the antenna probes and antenna under test (AUT), and the revolution of the capability of computers have allowed to face the antenna measurement challenges created by the new antenna technology.

This paper summarizes some of the most important advances, both in hardware and software, during the last years, and finishes with the new challenges to be afforded by the antenna measurement community in the near future. The paper is divided in the following sections: Section II presents a revision of the last improvements in hardware (antenna measurement systems) and Section III some improvements in software techniques. Section IV does an analysis of the future challenges and, finally, Section V will conclude the paper.

II. ADVANCES IN NEW ANTENNA MEASUREMENT SYSTEMS

New concepts of antenna measurement solutions appeared during the last years. The paper focuses on three concepts: new systems for the measurement of small antennas, systems to cope with problematic of sub-millimeter frequencies and portable solutions for in-situ measurements. In the first case, the new communication systems require small and complex terminals, and the effect of the environment changes the radio electric performance. Reverberation chambers [4-5] emulate an isotropic multipath environment where there is a uniform (or quasi-uniform) distribution of the angle of arrival of the rays over the AUT, allowing the quasi real time measurement of small antennas or MIMO systems. Also, post-processing techniques gives the value of some important parameters for the mobile phone community as sensitivity, total radiated power and MIMO or diversity improvement. Figure 1 shows the measurement of a handset together with a phantom in a Bluetest [6] reverberation chamber.

Another solution to measure these terminals is the multiprobe system. In this case, also, almost real time measurement can be used to measure these devices in free space environment. This was not possible with the classical near field measurements where different

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positioners were acquire the data. Figure 2 [7] shows a Microwave Vision Group (MVG) multiprobe system to measure small antennas or terminals. None of both environments, free space created by anechoic chambers and isotropic created by reverberation chambers, represent really the real life situation. However, their advantage is that they can be reproduced easily.

Fig. 1. Bluetest reverberation chamber (Bluetest copyright).

Fig. 2. Microwave Vision Group System to measure small antennas on terminals (MVG copyright).

Multiprobe technology was proposed in [8] using the Modulated Scattering Measurement Technique (MST). This technique allows the identification of the signal coming from each antenna probe through a different orthogonal low frequency code. Therefore, a passive combiner network can be used, and each individual probe signal in amplitude and phase can be recovered. Of course, this technology can be used for the implementation of classical near field systems (spherical, cylindrical or planar) replacing one of the axes by a multiprobe system. The main advantage of these systems is the reduction of time, since only one dimension scan is required.

The second focus area is the sub-millimeter (and Terahertz) frequency bands. Obviously, if classical near field solutions are employed, the acquisition precision has to be extremely high to be able to transform in a precise way the near field to far field. Nearfield Systems Inc. (NSI) proposed a very high accuracy positioning system for millimeter applications based on the modern robotic technology to precisely position the AUT on the spherical grid [9]. A. Räisänen research group at Aalto University presented a completely different concept [10]. They designed holograms as collimating elements in a Compact Antenna Test Range (CATR) to measure antennas up to 650 GHz. In the amplitude holograms, the transmittance of the hologram T(x,y) relates the transmitted electromagnetic field to the incident electromagnetic field. Also, phase holograms can be designed where the dielectric material of the structure is patterned in the right way. Most of the holograms designed by Aalto University are binarized amplitude ones, where the structure is used to generate a plane wave in the quiet-zone. The main advantages of the holograms include the low manufacturing cost and the possibility of building the CATR at the test site. The main disadvantages of the holograms are the losses and the cross-polar performance. Also, these holograms have narrow frequency band compared with reflector CATR.

The last focus area is related to in-situ measurements. Figure 3 shows the multiprobe StarBot system designed by MVG for the measurement of on-board antennas in airplanes. Figure 4 shows the Portable Antenna Measurement System (PAMS) that takes the form of a gondola suspended from the existing cranes. Astrium GmbH has built it, with support from ESA's Advanced Research in the Telecommunication Systems (ARTES) programme [11]. In Fig. 4, PAMS is shown performing near-field probing along a tilted and planar-oriented scan surface. This solution, together post-processing tools, is very convenient for the measurement of satellite antennas. It is also remarkable the work of some researchers from Politecnico de Torino. They designed an antenna test system using a flying hexacopter equipped with RF transmitter and a telescopic dipole [12]. All these solutions simplify the measurement process, making it closer to the design laboratory or to the final placement of the antenna.

Fig. 3. Microwave Vision Group StarBot system (MVG copyright).

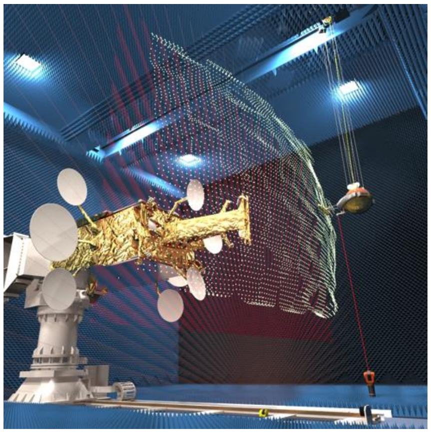

Fig. 4. Portable Antenna Measurement System designed by Astrium GmbH under the ARTES program (ESA).

III. RECENT ADVANCES IN ALGORITHMS FOR ANTENNA MEASUREMENTS

During the last years large improvements have been done in algorithms for the post-processing of the acquired data. Near to far field algorithms have been improved in order to be able to measure in non-uniform grids. Particularly, Fast Irregular Antenna Field Transformation has been developed by Technical University of Munich to be able to process the data acquired with the PAMS system explained in the previous section [13-14]. Also, there has been a large improvement in the reduction of acquisition time. In this sense, it is remarkable the work developed during the last years by University of Salerno and University of Naples Federico II [15], where different acquisition schemes have been optimized for cylindrical or spherical scans depending on the shape of AUT. Pursuing this time reduction, Microwave Vision Group, Technical University of Madrid and Aachen University published a comparison of different methods to perform single cut near field to far field methods [16]. All these improvements mean an important reduction in the measurement time.

Also, there has been a rapid evolution in post-processing tools to improve the results of the measurement. Commercial antenna diagnostic tools, as Insight© (MVG) or Diatool© (TICRA), allow a very accurate source reconstruction technique. Other commercial tools, as Mars© (NSI), Isofilter© (MI-Tech) or MVEcho© (MVG) use the decomposition of the acquired field in cylindrical or spherical modes to filter out echoes and other spurious signals. The translation of the near or far field data to other domains (as modes or currents on the antenna surfaces) allows the engineers to recognize and correct errors in an easiest and fastest way. Obviously, the progress in this field has been supported by a deep study in universities and research centres.

Finally, last improvements in the combination of simulation and measurements allow a more accurate and fast antenna design. In [17], some new concepts in the combination of both tools were presented. All these improvements, combined with the new antenna measurement systems, allow measuring more accurate and faster.

IV. ANTENNA MEASUREMENT CHALLENGES IN A CLOSE FUTURE

The rapid evolution of antenna technology will demand more and more flexibility and reduction in measurement time for the antenna measurements. The antenna industry will demand in-situ, real time, accurate and cost effective measurements. The use and combination of the previous studied techniques and new improvements will allow facing these challenges. In-situ measurements will be required: antenna measurement laboratories will move to the antenna place and not the opposite as we are used to work. The acquisition will be performed using commercial robots, reducing the cost of the measurement equipment. Post-processing techniques will be necessary to substitute the anechoic environments and accurate positioners by less controlled measurement areas. The use of information of positioning of the antenna probe, using laser trackers or other technologies, and the knowledge of AUT geometry, combined with source reconstruction techniques will allow to substitute the high accuracy in the positioning system. This will be completed with the use of post-processing techniques to reduce the effect of reflections or other spurious signals. For larger antennas, unmanned vehicles, with irregular grids, will be used to perform the acquisitions.

A second challenge is the complete integration of the antenna measurement phase in the design and production chain. Simulations and measurements will be combined to optimize the antenna production. Antenna simulation and measurement post-processing platforms will merge in common platforms.

Of course, there will be some specific markets, as space or security, where the classical antenna measurement systems will be used. In this case, the accuracy of the positioning systems will be the most important challenge to improve the accuracy and move to higher frequency bands. Finally, the antenna designers will require the characterization of antennas integrated in the communication systems. In this case, the antenna measurement platforms will have to be able to calculate the quality factors used by the system engineers.

V. CONCLUSION

This document has presented a review of some of the recent advances in the previous years, both in hardware and software technologies. Finally, last section has presented some of the challenges that antenna measurement community will afford during the future years: in-situ measurements, irregular positioning systems, combination of measurements and simulation for making most effective the design process, and measurement of antennas integrated in the whole communication system. The combination of these improvements will make the antenna measurement process easier and most integrated in the antenna or system simulation platforms.

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