Prof. Sarkar's contribution to Antenna Diagnostics and NF-FF Transformation

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***Abstract*—This contribution summarizes one of the numerous contributions to electromagnetics of Prof. Sarkar. In particular, it is focused on the equivalent currents-based techniques for antenna diagnostics and Near-Field to Far-Field (NF-FF) transformation. First, the theoretical background is briefly presented, followed by a review of the main works developed by Prof. Sarkar in this field. Finally, the importance and impact of Prof. Sarkar's work on this topic is highlighted.**

I. Introduction

Prof. Sarkar pioneered several topics in theoretical and applied electromagnetics, ranging from computational electromagnetics to RF channel capacity and MIMO techniques. Part of his research was developed in collaboration with universities, companies, and research centers located worldwide. Some of the authors of this contribution had the opportunity to work with him at his research laboratory at Syracuse, USA, sharing knowledge, points-of-view, and research methodologies. It can be undoubtedly stated that he paved the road to the development of new antenna measurement techniques that have been widely adopted by universities and companies.

II. An Overview of Prof. Sarkar's Contributions

One of the most remarkable contributions of Prof. Sarkar to the antenna measurement community is the development of novel antenna diagnostics and characterization techniques that overcame some of the limitations of existing methods.

More precisely, he set the basis of equivalent currents-based techniques for antenna measurement, which are based on the Electromagnetic Equivalence Principle.

A. Theoretical background

The Electromagnetic Equivalence Principle states that, given an arbitrary distribution of electromagnetic sources ($\vec{J}_1, \vec{M}_1$ in Fig. 1), it is possible to find an equivalent currents distribution ($\vec{J}_{eq}, \vec{M}_{eq}$) on a surface S' enclosing the original sources, so that this equivalent currents distribution radiates the same fields outside that surface ($\vec{E}_2, \vec{H}_2$) as the original sources.

This concept is illustrated in Fig. 1. The upper plot corresponds to the original electromagnetic (EM) problem, where the radiating source is a horn antenna. Next, the horn antenna is enclosed by a surface S'. If the tangential components of the fields radiated by the horn antenna on this surface are known, then, it is possible to directly define an equivalent electric and magnetic currents distribution that radiates the same field outside this surface (as it can be noticed by comparing the two field distributions depicted in Fig. 1).

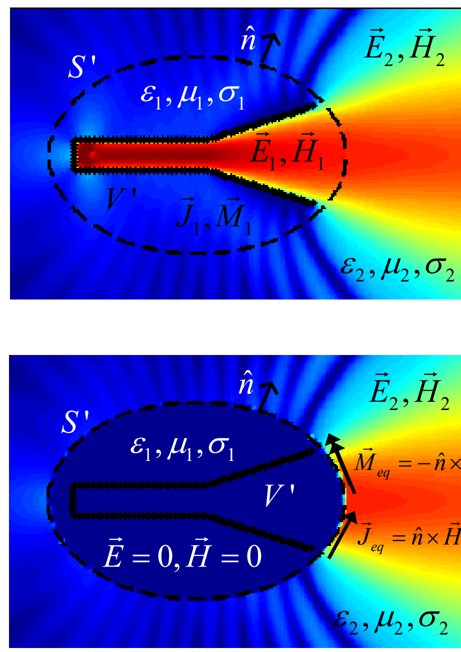

Fig. 1. Illustration of the original and equivalent EM problem.

In practice, the direct acquisition of the tangential field components on S' is not always possible. Thus, they must be calculated from the knowledge of the fields radiated by the sources in another closed surface by means of a Near-Field to Near-Field (NF-NF) transformation.

B. Prof. Sarkar's contributions

In [1], Prof. Sarkar proposed to use an equivalent magnetic currents distribution (Second Equivalence Principle) to perform a Near-Field to Far-Field (NF-FF) transformation. In this case, the measurement or acquisition domain can be an arbitrary geometry (which was a significant advance compared to conventional NF-FF methods requiring the measurement domain to be a canonical surface -planar, cylindrical or spherical-). The reconstruction domain must be a plane covering the antenna aperture. In [2], a similar approach is presented to perform NF-FF transformations, but using an equivalent electric currents distribution.

Another important contribution to the antenna measurement theme is presented in [3], where an iterative method to retrieve the radial component of the electric field in spherical measurement systems is proposed. Following this approach, it has been shown that the radial component, which is related to the evanescent modes, can be retrieved and used to perform NF-NF transformation with decoupled equations involving Cartesian field components, providing diagnostics information.

In [4] Prof. Las-Heras and Prof. Sarkar presented one of the first contributions to the equivalent currents method for phaseless acquisitions. This amplitude-only methods have gained a significant relevance in the last decades, as they have enabled the development and implementation of simpler and less expensive antenna measurement systems. Furthermore, they are especially important at high frequencies, where phase acquisition can be challenging.

Finally, [5] and [6] present practical application examples of the techniques developed by Prof. Sarkar, showing experimental validations of the antenna diagnostics techniques and the NF-FF transformation based on equivalent currents. Fig. 2 illustrates an application example of the non-destructive inspection of an antenna (whose radiating elements are covered by a radome). Thanks to the techniques developed by Prof. Sarkar, it is possible to retrieve a set of equivalent currents on a surface which coincides with that of the radome. From the reconstructed currents, the radiating elements of the antenna can be identified, and their performance can be evaluated. This approach is usually referred to as sources reconstruction method (SRM).

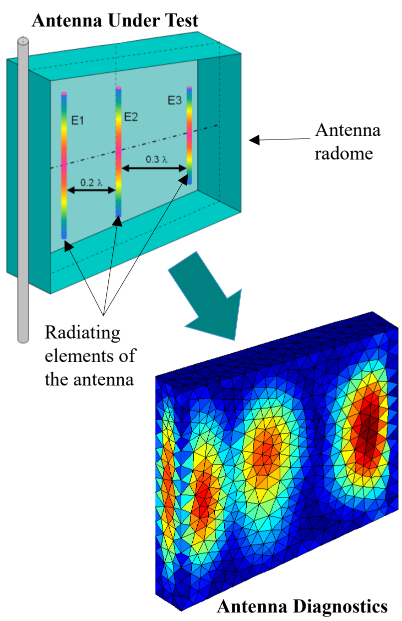

Fig. 2. Example of radome-covered antenna diagnostics by means of the reconstruction of the equivalent currents on a surface fitting the antenna radome [6].

III. Legacy and Impact

The antenna diagnostics and characterization techniques developed by Prof. Sarkar in the 90s and 2000s have had a significant impact in the field of applied electromagnetics, facilitating the development of electromagnetic measurement systems that do not require the usage of a canonical surface. For instance, in [7] the authors present an *in situ* antenna measurement and diagnostics system based on acquiring NF amplitude-only data with a probe antenna mounted on board a UAV. Also, in [8] a handheld antenna measurement and characterization system is presented, where the probe is moved manually in front of the antenna under test. In this case, the system is able to provide antenna diagnostic information and the radiation pattern in real time. The development of this kind of applications has been possible thanks, on the one hand, to the antenna characterization techniques based on equivalent currents developed by Prof. Sarkar, and, on the other hand, to the appearance in the last decade of more compact and accurate microwave and positioning systems.

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