**ECCM 2010**
IV European Conference on Computational Mechanics
Palais des Congrès, Paris, France, May 16-21, 2010

# Two Numerical Techniques for the Electromagnetic Analysis of Multilayered Periodic Structures with Application to the Design of Reflectarray Antennas

R. Florencio[1], R. R. Boix[1], J. A. Encinar [2]

[1] *Department of Electronics and Electromagnetism, College of Physics, University of Seville, Spain, boix@us.es*
[2] *Department of Electromagnetism and Circuit Theory, Polytechnic University of Madrid, Spain, encinar@etc.upm.es*

Current implementations of reflectarray antennas consist of two or three planar arrays of microstrip patches embedded in a grounded multilayered substrate. A feed antenna illuminates the arrays (see Fig. 1) and the individual elements are designed to scatter the incident field with the proper phase to form either a pencil beam radiation pattern [1, 2] or a contoured beam pattern [3, 4, 5]. Reflectarray antennas act as flat reflectors [1], and they combine some of the advantages of reflector and array antennas. On the one hand, they are lighter and easier to manufacture than reflector antennas, and they show improved polarization performance [1]. On the other hand, they are simpler and more efficient than conventional microstrip arrays because they eliminate the complexity and the losses of the feeding network. Narrow bandwidth is the main disadvantage of reflectarray antennas when compared with reflector antennas. Although this narrow bandwidth problem was especially relevant in the case of reflectarrays made of single arrays of patches [1, 3], the problem has been partly alleviated by stacking several arrays of patches, and by using optimization routines which adjust the relative dimensions of the patches in different layers to increase the bandwidth [4]. In the design of a reflectarray antenna, the first step is to define the phase shift that must be chosen for each element of the antenna in order to produce either a collimated beam or a contoured beam (in the case of contoured beams, phase-only synthesis methods have to be used in order to obtain the required phase shift distribution at the different elements) [1, 4]. Once the phase shifts have been determined at several frequencies, the dimensions of the different microstrip patches leading to these phase shifts have to be determined by using an optimization routine that calls a computational electromagnetic technique for the analysis. Since the repeated electromagnetic analysis of each patch in the presence of patches of different dimensions is computationally prohibitive for large reflectarrays with thousands of elements, in the determination of the dimensions of the patches matching the required phases, it is customary to assume that each patch is surrounded by an infinite periodic array of patches of identical dimensions (this is the so called local periodicity assumption) [1]. After the dimensions of the patches have been established, the field reflected on the reflectarray is obtained at several frequencies by electromagnetic simulation, and the radiation patterns of the reflectarray antenna are obtained by means of a 2-D fast Fourier transform of the tangential electric field on the reflectarray aperture [5].

In the whole design process of a reflectarray antenna, the part that demands more CPU time is that related with the optimization of the patches dimensions. For real reflectarrays with thousands of elements where the design of the antenna involves optimization of the dimensions of each element until the phase requirements for polarization and frequency band are fulfilled [4, 5], one may have to analyze hundreds of thousands of problems of electromagnetic scattering by periodic arrays of patches embedded in a grounded multilayered substrate (see Fig. 2). Therefore, a fast and accurate electromagnetic numerical tool is needed for the solution of these problems. The Method of Moments in the spectral domain (MoM-SD) has proven to be one of these tools since it makes it possible to analyze multilayered periodic problems with both efficiency and accuracy. When applying the MoM-SD to the electromagnetic analysis of periodic multilayered problems, two different strategies have been used. The first one is based on the

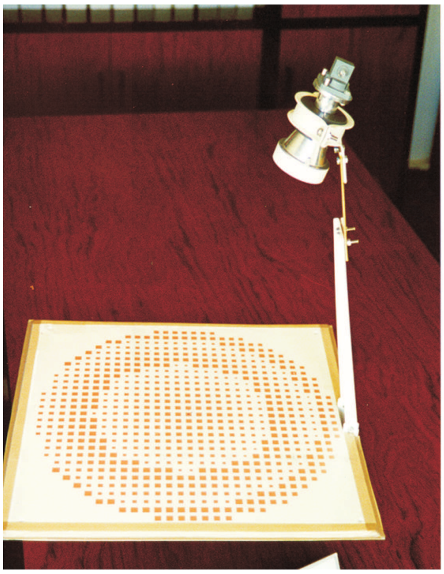

Figure 1: Photograph of a reflectarray antenna fed by a conical corrugated horn.

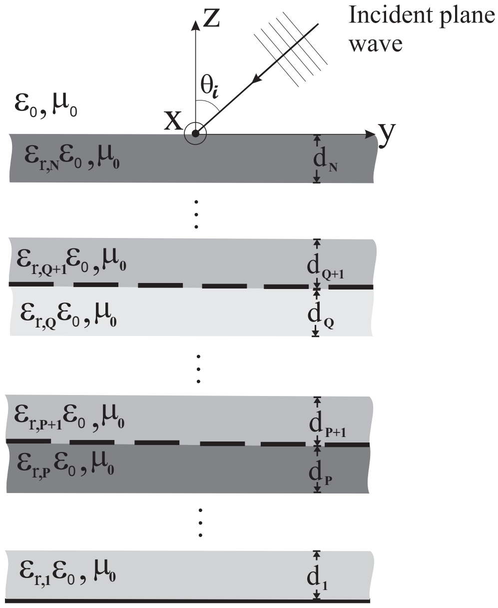


Figure 2: Scattering of a plane wave by a multi-layered substrate containing several infinite periodic arrays of microstrip patches.

use of mathematically complex multilayered Green's functions (MGF), and reduces the analysis of the periodic structure to the summation of double infinite series which may be slowly convergent [6]. The second strategy is based on the generalized (or multi-mode) scattering matrix (GSM) approach , and reduces the multilayered problem to a set of simpler two media problems which are connected by means of a cascading process [7]. The strategy based on MGF is mathematically cumbersome, but it makes it possible to provide stop criteria and acceleration procedures for the double series that have to be summed [8]. The strategy based on the GSM is easy from the mathematical point of view, and makes it possible to separate a complicated problem into a set of much simpler problems. The two strategies will be compared in the conference, and the pros and cons of each strategy will be presented in the context of the design of reflectarray antennas.

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