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THEORETICAL AND EXPERIMENTAL ANALYSIS OF MICROSTRIP PHASED ARRAYS DEPOSITED ON ORIGINAL CONFORMAL SURFACES

Augustin D., Staraj R., Cambiaggio E.

Laboratoire d' Electronique - Université de Nice-Sophia Antipolis
Unité de Recherche Associée au CNRS n° 1400 - 250, rue A. Einstein, 06560 Valbonne, France
Tél. : 92.94.28.10 - Fax : 92.94.28.12

ABSTRACT

This paper deals with the extension of a planar ring array antenna used to produce circular polarisation and to validate an algorithm for a radiation pattern analysis [1]. Now, the theoretical approach and the computer simulation permit us to treat different structures as conformal configurations. We can easily obtain the theoretical 3D-far field radiation patterns of ring arrays lied on inclined planes to constitute pyramidal and octagonal surfaces or simply a "two-slope" array. Our software-tool allows to execute spatial rotations and to choose the phase applied to each radiator to produce a beam deflection. We propose a pyramidal realisation with some experiment results. Besides, we show the predictions of an array placed on an octagonal body. A good accuracy between theoretical and experimental results is observed. Some prospects will be described for future array analysis to improve performances of such computer simulation.

INTRODUCTION

In recent years, conformal microstrip patch arrays have presented a considerable interest, especially in aerospace applications. Most of studies have treated the case of cylindrical solution to produce omnidirectional pattern in the circumferential plane of the cylinder [2]. But, it is interesting to consider other antenna geometries for applications where multi-face arrays as pyramidal or octagonal or other structures, give best results for defined specifications [3]. Figures 1 and 2 present the pyramidal array which consists in four linearly polarised elements and the octagonal antenna composed by eight radiators.

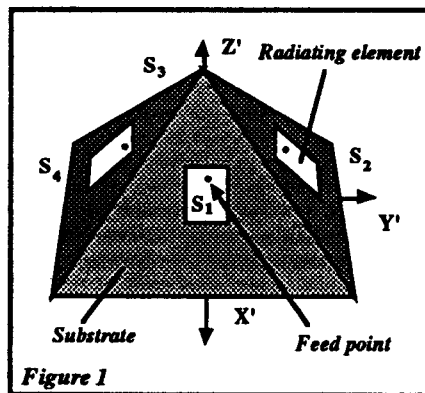


Figure 1
Pyramidal (4 faces) microstrip arrays

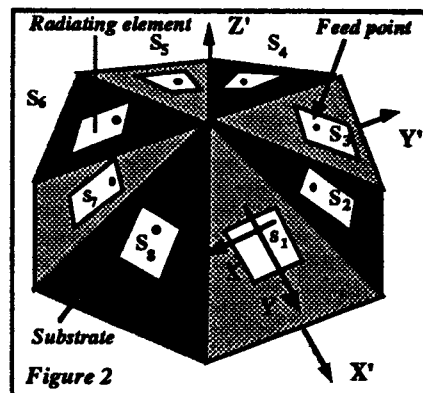


Figure 2
Octagonal (8 faces) microstrip arrays

The aim of this study is to show different radiation characteristics of these conformal antennas thanks to original diagrams. The objective was to develop a computer-tool to easily simulate arrays of microstrip elements printed on inclined surfaces instead of planar ones. In this paper, we will present the theoretical and practical behavior of the radiation patterns of our structures, especially when radiators are sequentially fed to produce a circularly polarised electrical field.

THEORETICAL APPROACH

The objective is to obtain a far electric field in the stationary coordinate system $OX'Y'Z'$, named global (g) system, taking into account all rotated and inclined elements [4]. To reach this result, we determine the initial electric field $E_i(\Theta, \Phi)^*$, radiated by the S_i source in the local (l) system in rotation in space, where (Θ, Φ) are spherical coordinates of the observation points, calculated from spherical coordinates (Θ', Φ') in the g-system. The S_i source, polarised along the OY' axis for the original position before rotation, was taken as the reference. The angular rotations (ρ around the OX' axis and/or Ψ_i around the OZ' axis) effects, are given by the

Eulerian matrix $[P_i]$ for each radiating element S_i . The electrical far field radiated by the i^{th} element (initial field expressed by its components E_Θ and E_Φ) is calculated by analytical functions. The transition between the local coordinate system after rotation and the global coordinate system, where the final result will be obtained, is taken into account in the expression of this field. The final field $E_f(\Theta', \Phi')^*$, for each source after the rotations, expressed in the g-system, is obtained by the product of the initial field with the result of a transformation matrices product. Concurrently, a term FR_i describes the influence of the position (spatial distribution : d-translation and φ_i -angular position), the phase α_i and the amplitude A_i of the exciting current of each element [5] with the expression as follows :

$$FR_i = A_i e^{j[(2\pi/\lambda)d(\cos\varphi_i \sin\Theta' \cos\Phi' + \sin\varphi_i \sin\Theta' \sin\Phi') + \alpha_i]} \quad (1)$$

For n elements, the total field is finally given, in g-system, by:

$$E_{tot}(\Theta', \Phi')^* = \sum_{i=1}^n E_f(\Theta', \Phi')^* FR_i(\Theta', \Phi') \quad (2)$$

* The italic notations is used for field vectors

REALISATION

The square microstrip patches used are linearly polarised and the frequency is located in the C-band. All the identical radiators are probe-fed and their dimensions and feed positions were optimised to obtain a matched input impedance at the resonant frequency of 5 GHz. Different power dividers have been realised by microstrip technology to obtain the desired amplitude and phase shift. The lengths of the different feed lines have been optimised by CAD and we can conclude that the coupling effects are considerably reduced considering the distance between the patches and the conformal disposition. For this article, we propose results with the power divider which sequentially feeds the pyramid radiators. The conformal surfaces are obtained by bending slots which preserve the ground plane continuity. The measurements of the input impedance are quite good.

MEASUREMENTS

Figures 3 gives some notations of the pyramidal array for a realisation with a slope of 30° . A good accuracy is observed as shown figure 4 which compares theoretical and experimental radiation patterns for this array, when elements are sequentially fed to obtain a circular polarisation. Figure 5 presents the theoretical evolution of the E_Φ -component in the circumferential plane versus the variations of the observation-point angle. For the normal direction, the diagram represents the circular polarisation and when the observed point changes, we can see the degradation of the component. Figure 6 represents an original view of the polarisation for each direction (Θ', Φ') . The ellipticity of the polarisation is described by rectangles. These rectangles are a simulation of the ellipses representing the electrical magnitude field in rotation. We can see more easily where a linear or circular polarisation is obtained. Figure 7 gives the theoretical behavior of the radiation pattern in the E-plane versus the slope-angle for the pyramidal antenna when the patches are linearly fed. Figure 8 shows this behavior for the octagonal body when the patches are sequentially fed. Figures 9,10,11 and 12 present the evolution of the radiation pattern versus the choice of the array structure. We represent the theoretical 3D-far field radiated by such ring array.

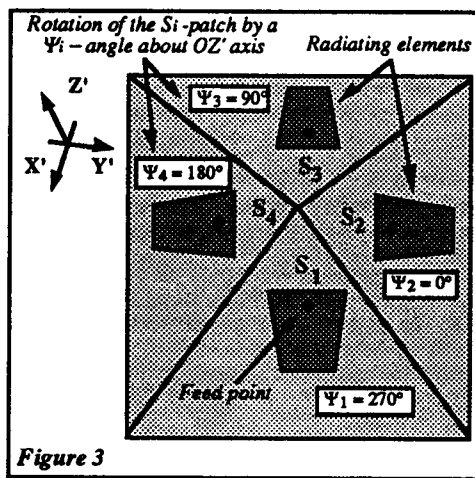


Figure 3

Description of the pyramidal array

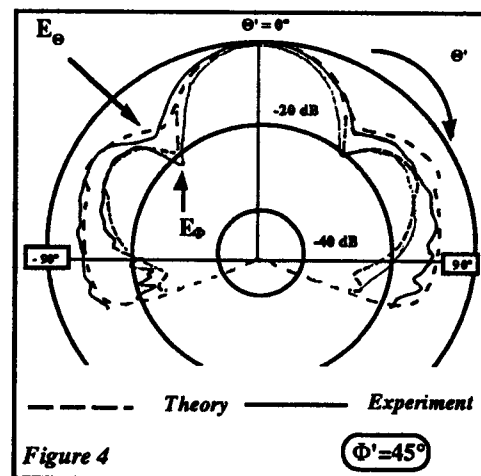


Figure 4

Radiation pattern in the Φ' -plane 45°

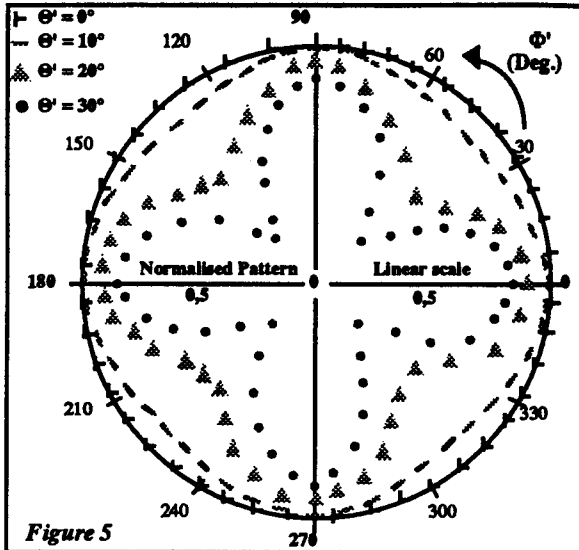


Figure 5 Evolution of the E_{Θ} component in the circumferential plane of the pyramidal array.

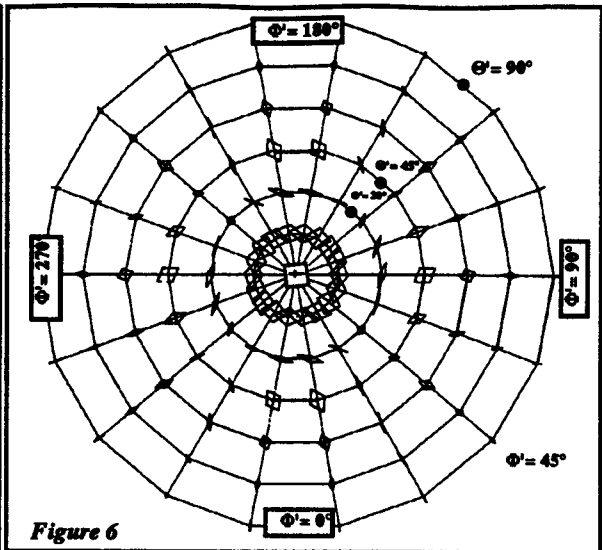


Figure 6 Original view of the polarisation-rectangles for the pyramidal array.

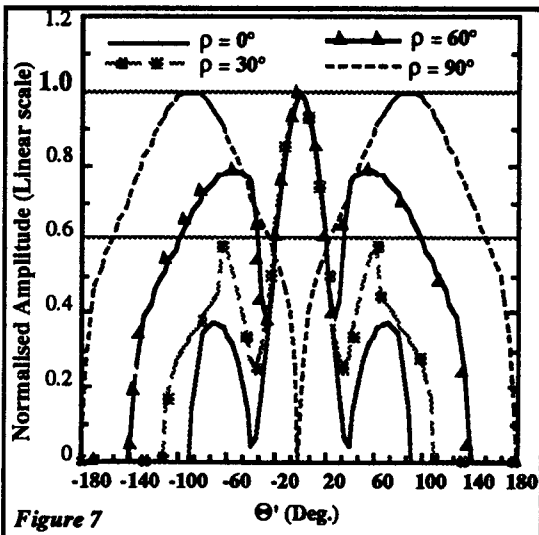


Figure 7 Evolution of E_{Θ} in the E-plane for the pyramidal array versus the variations of the ρ -slope.

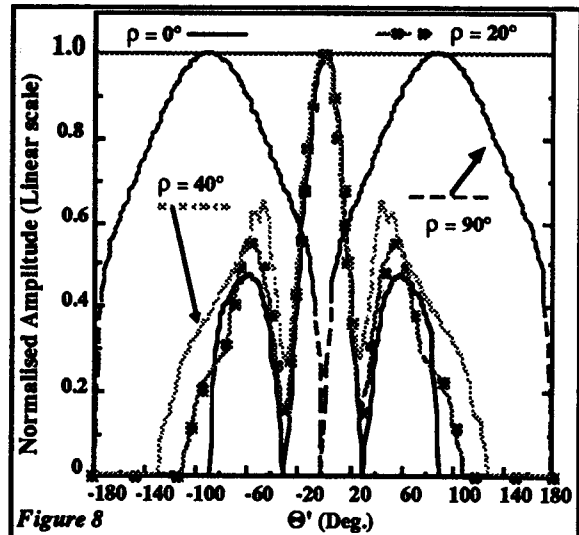


Figure 8 Evolution of E_{Θ} in the 45°-plane for the octagonal array versus the slope of the configuration.

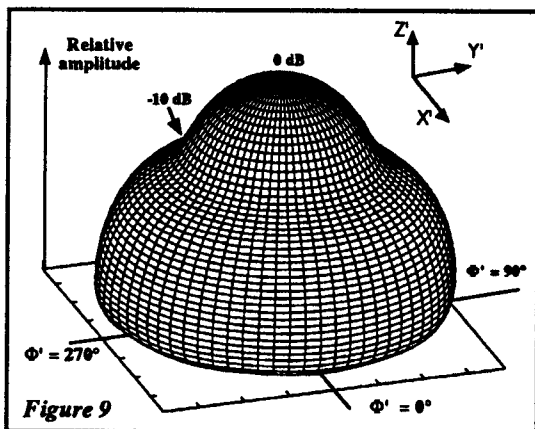


Figure 9 3D-electrical field radiation pattern of the planar ring array.

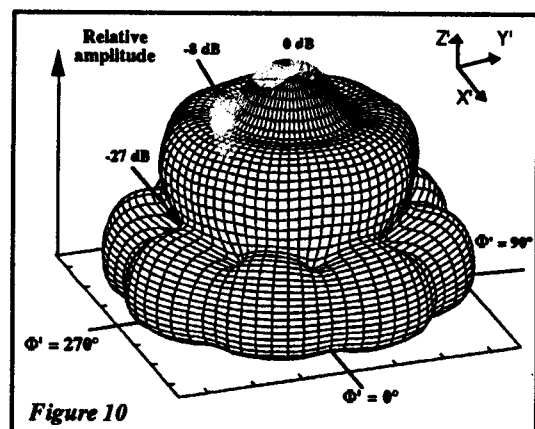


Figure 10 3D-electrical field radiation pattern for a planar ring array with a higher radius.

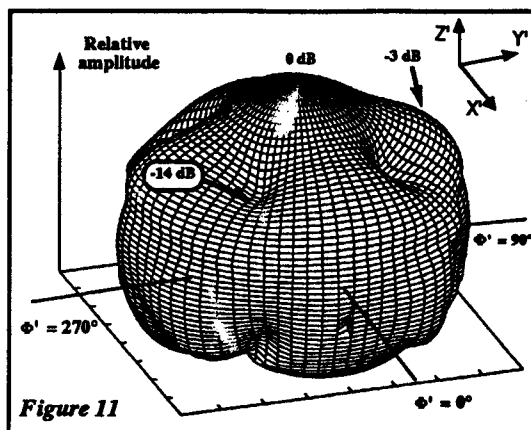


Figure 11
3D-electrical field radiation pattern of the pyramidal array

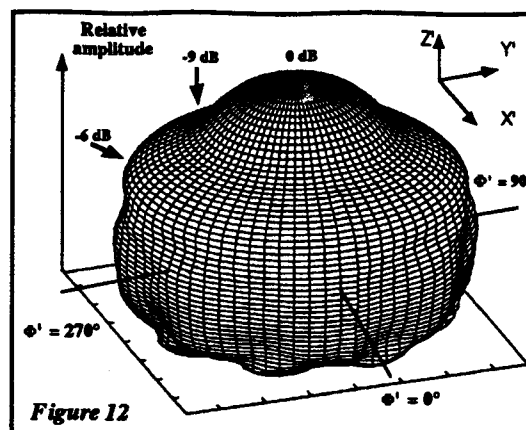


Figure 12
3D-electrical field radiation pattern of the octagonal array

CONCLUSION AND PROSPECTS

The conformal antennas are used increasingly for communications between land and/or spatial mobiles. Their main advantages, in comparison with a planar solution, are their electronical and geometrical capabilities for a spatial tracking motion and the possibility to print them on curved bodies. Our algorithm will be able to arrange, during the last stage, an array of radiating elements where we want in space, thanks to the control of the 3 basic rotations. The analysis approach of the conical structure will also enable to treat the cylindrical configuration. Moreover, it is planned to study a multi-ring array antenna system arranged on different surfaces (figure 13) and thus to increase performances. For a synthesis perspective, we will be able to optimise some parameters as the diameter and the slope of the structures, the rotation angles applied at each source, the number of active radiating elements and the phase shift associated to obtain a beam deflection. For example, this study aims at providing a ripple ratio of the radiation patterns between $[0, -10]$ dB for the relative amplitude, in the total space and close to a defined theoretical model.

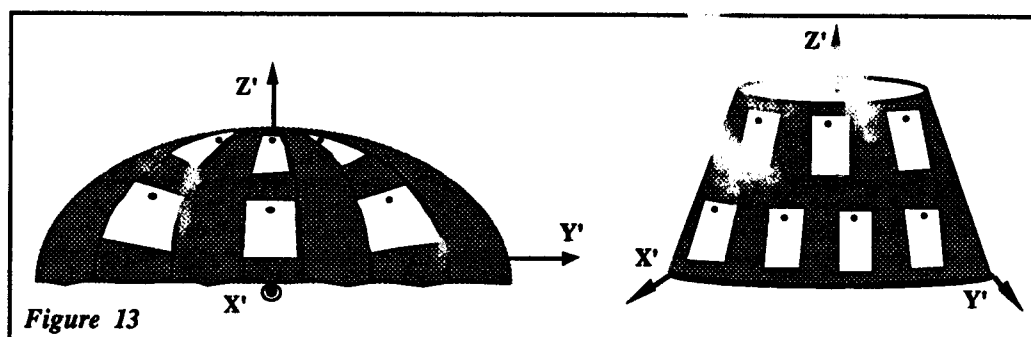


Figure 13
Spherical and conical antennas composed by two ring arrays of rectangular patches

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