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Simulation of Radiation Characteristics for Cylindrical Conformal Phased Array

Rongcang Han
School of Informatics, Linyi Normal University, Linyi 276005, China
E-mail: hanrongcang@lytu.edu.cn

Abstract

FEKO is a 3D simulation tool for the analysis of electromagnetic fields. FEKO can solve the problem of any structural type with a very comprehensive MoM code or other tailored code. In this paper, a radiation pattern for conformal phased array antenna on the surface of a PEC finite cylinder is calculated using FEKO 4.0. The simulation results accord with the true characteristics of conformal array antenna on a finite length cylinder. The results also can meet with which in related reference. So, the simulation can be proved to be correct. Furthermore, the patterns of different scanning angle for this conformal phased array are simulated and some important parameters of the array patterns are given.

Keywords: Conformal Phased Array, Radiation Characteristics, FEKO 4.0

1. Introduction

A conformal antenna is an antenna that conforms to something; in our case, it conforms to a prescribed shape. The shape can be some part of an airplane, high-speed train, or other vehicle (J.A. Ferreira and F. Ares, 1997, 1188). The purpose is to build the antenna so that it becomes integrated with the structure and does not cause extra drag. The purpose can also be that the antenna integration makes the antenna less disturbing, less visible to the human eye; for instance, in an urban environment. A typical additional requirement in modern defense systems is that the antenna not backscatter microwave radiation when illuminated by, for example, an enemy radar transmitter (Lars Josefsson, Patrik Persson, 2006, chapter1).

Conformal antennas are of great interest due to their ability to blend into curved surfaces. Antennas of cylindrical geometry can be analyzed in a number of ways, among which are the finite element method, the auxiliary sources method, the method of moments (MOM), etc. The method of moments can be employed in both spectral and spatial domains. Both solutions work well until the cylinder is electrically small (Alexander Svezhentsev, 2004, 629). Here, we use MOM to simulate the conformal phased array by FEKO 4.0.

2. Radiation Pattern of A Conformal Element Antenna

The specific coordinate and model of a conformal antenna are shown in Figure 1, which is a microstrip antenna described as an element of a conformal phased array. The center of rectangular microstrip antenna on the cylinder at the point (according to cylindrical coordinate system) ($a, 0°, 0$), of which the radius of cylinder is a=0.5λ, the length of cylinder is 4λ. The length of rectangular patch is $2L$ and width is $2\varphi_o a$. The relative dielectric constant for dielectric is ε_r, $\varepsilon_r = 2.33$, the thickness of the substrate is h, $h = 0.05\lambda_g$, where λ_g is the medium wavelength, $\lambda_g = \lambda / \sqrt{\varepsilon_r}$. The microstrip antenna is probe feed; the probe is not in the patch center, but at the point which is $0.125\lambda_g$ away from the center along the direction φ cylindrical coordinate system.

The simulation of the array element is carried out in FEKO 4.0. The simulation results of element patterns are shown in Figure 2 when the cylinder with a radius of 0.5λ. There two radiation patterns at plane E and plane H for conformal element. The behavior of the two patterns shows a good coherence with theoretical results and engineering experiences.

3. Radiation Pattern of A Cylindrical Conformal Phased Array

In order to study the radiation patterns of a conformal phased array antenna, an example in Figure 3 is carried out. The locations of each element are shown in Figure 3. The structure in WinFEKO surroundings of KEKO 4.0 is shown in Figure 4. There are 8 elements of an array on the surface of a cylinder in line. The distance between different elements is 0.5λ. The detailed geometric parameters of the cylinder and the array are shown in Table 1.

When calculating the current element, other elements are regarded as metal scatterers. The point numerical of radiation pattern is the sum of which 8 elements contributed. The result of the array radiation pattern is shown in Figure 5 (a). A numerical result from the reference (Lei XIAO, 2004, 30) is shown in Figure 5 (b). The two curves in Figure 5 coincide with each other. Because of its structural symmetry of the conformal phased array, the antenna patterns in the opposite direction to the same point of view, the pattern shows symmetrically.

Furthermore, the patterns of different scanning angle for this conformal phased array are simulated (see Figure 6). The element excitations of the phased array are identical currents and linear phases, and some important parameters of the array patterns when scanning are shown in Table 2.

Several significant results can be induced from Figure 6 and Table 2. The first side lobe level (SLL1) of the array pattern is higher when the scanning angle rises. With increasing scanning angle, the main lobe of the pattern will be wider; the sidelobe of the pattern will rise gradually. By the inter-element mutual coupling, as well as the combined effect of carrier, the direction of the main beam will appear to deviation while scanning angle equal to 45 degrees. When scanning large angle the array pattern have begun to deteriorate, the main sidelobe has gradually blurred the boundaries of the main beam when scanning angle equal to 60 degrees.

4. Conclusions

In general, a good radiation pattern of a conformal array antenna is simulated with FEKO 4.0. The results show that FEKO 4.0 is a good tool in the simulation of conformal array antennas. The results simulated with FEKO 4.0 can meet with which in related reference and some significant parameters from conformal phased array patterns by simulation are given. This study has great significance to conformal phased array in radar engineering.

References

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Table 1. The parameters of the conformal phased array

Cylinder length	Cylinder radius	Patch dimension	Adjacent distance	Center frequency
4λ	0.5λ	0.5λ*0.5λ	0.5λ	2G Hz

Table 2. Parameters of the array patterns with different scanning angles

Scanning angles (degree)	SLL1 (dB)	3dB beam-width (degree)	Warp of main-beam direction (degree)
0	-13	13	0
15	-12.4	13.5	0
30	-11.8	15	0
45	-10.8	18	1.5
60	-9	22	4.2

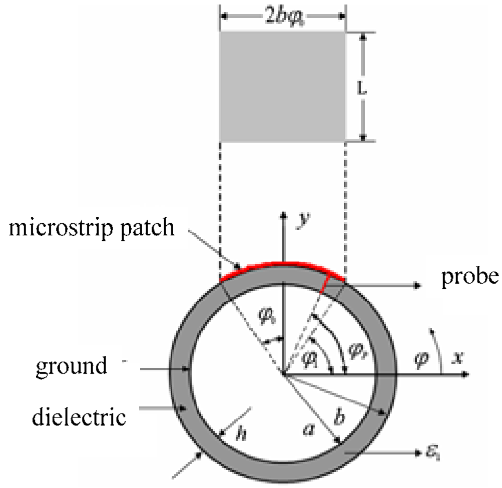
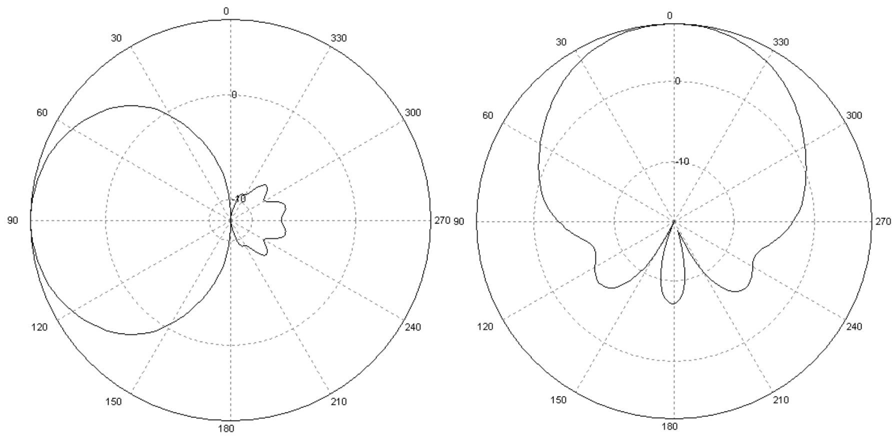


Figure 1. Cross-section diagram of the conformal microstrip antenna



(a) Plane E (b) Plane H

Figure 2. The radiation patterns for conformal element of an array

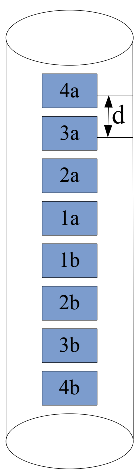


Figure 3. Conformal array of 8 array elements placed on finite length cylinder

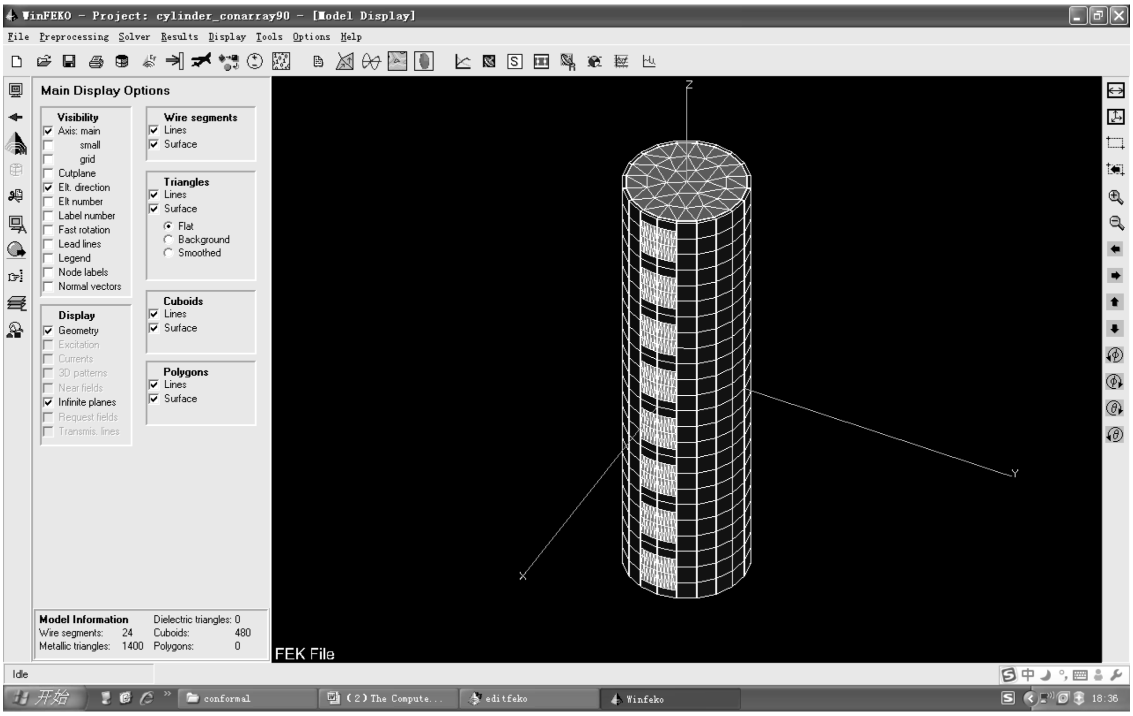
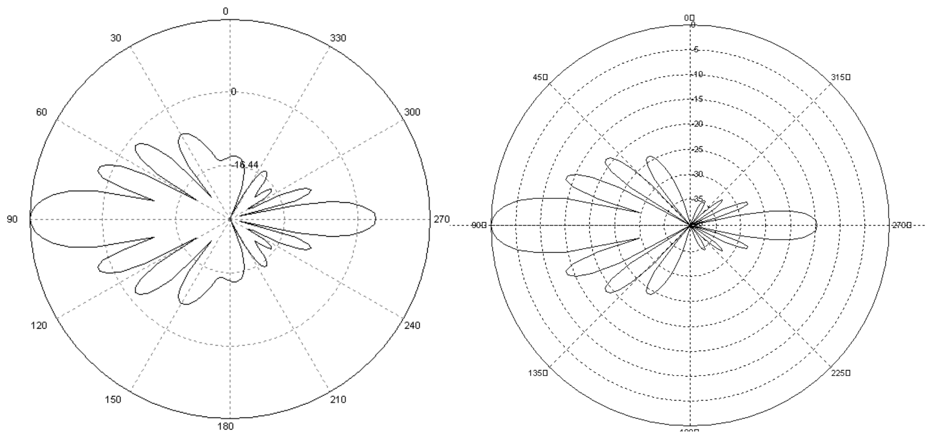
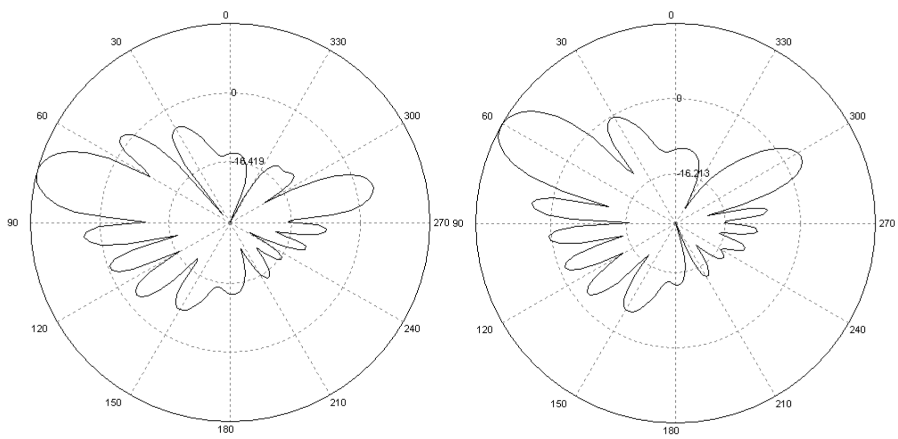


Figure 4. The structure in WinFEKO surroundings of KEKO 4.0

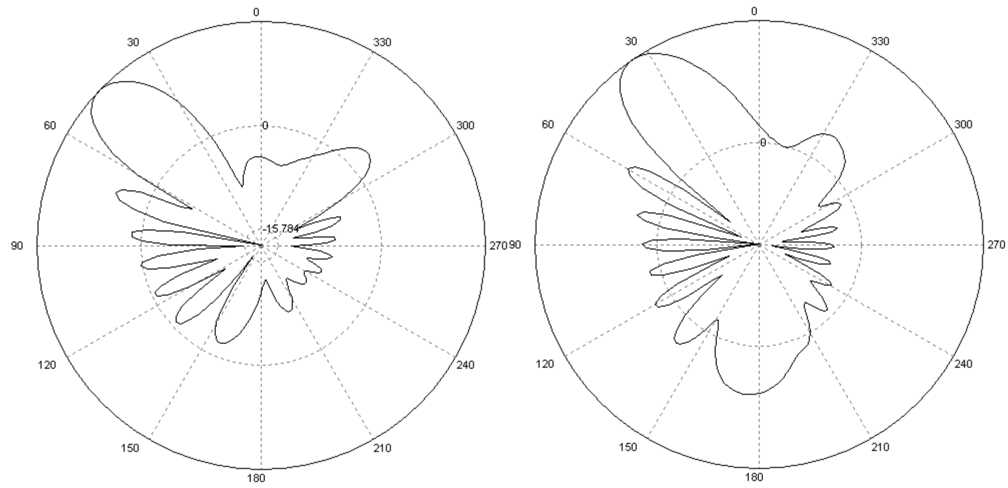


(a) (b)

Figure 5. The results of the array radiation pattern



(a) $SA = 15^{\circ}$ (b) $SA = 30^{\circ}$



(c) $SA = 45^{\circ}$ (d) $SA = 60^{\circ}$

Figure 6. The patterns of different scanning angle (SA) for this conformal phased array