Phase Response of Microstrip Reflectarray Elements of Variable Size

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Abstract:

The microstrip reflectarray antenna is a microstrip patch element planar array, which reflects the incident fields radiating from a feed antenna. Each patch element introduces a phase change to the scattered fields. In this paper, the scattering of the incident plane wave to a microstrip infinite array which performed by similar microstrip patch elements has been investigated. Determination of the reflected fields phase shift is desired. Finite Difference Time Domain (FDTD) method has been employed to calculate the phase shifts. At first, the infinite array configuration is converted to an equivalent unit cell configuration consisting only one radiator element using PEC and PMC walls around it. Then, a TEM plane wave excitation has been introduced for this equivalent waveguide structure and the reflected fields phase shift is determined by discretization of time domain Maxwell's equations and applying FDTD method. Using discrete time Fourier transform, the phase response yields in frequency domain. The phase response versus the microstrip patch size has been determined by using the existing relations for patch resonance dimensions. This method has been used for some elements such as microstrip square patch and microstrip dipole and the results have been compared with results obtained by HFSS software and some presented results in literature obtained from other methods for analyzing these structures.

I. Introduction

A reflectarray combines the features of both a reflector and an array. As shown in figure 1, it utilizes a primary feed to illuminate a secondary-radiating surface. In the reflectarray the secondary surface consists of an array of discrete elements, which receives, and then reradiates the incident primary feed energy rather than a shaped, continuous reflecting surface in a parabolic reflector. An attractive alternative for the secondary surface array is a microstrip planar array. This combination, which is called "Microstrip Reflectarray", has advantages such as low profile, low volume and mass, easy deployability, scannable beam, low manufacturing cost, ability of dual and circular polarization and dual band frequency.

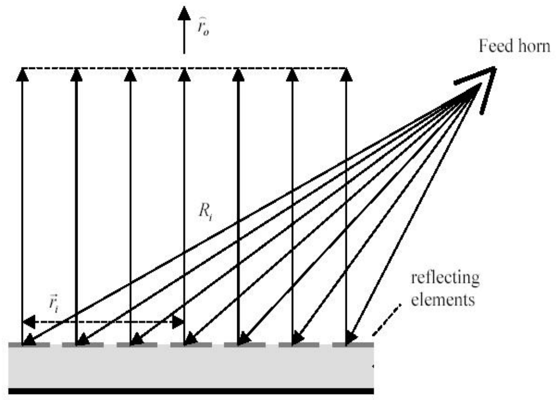

Figure 1. A microstrip reflectarray antenna

The basic design principle requires that the phase φ_i of the field from each element in the reflectarray be chosen so that the total phase delay from the feed to a fixed aperture plane in front of the reflectarray is identical for all elements:

$$\varphi_i - k_0(\vec{R}_i - \vec{r}_i . \hat{r}_0) = \text{constant} \qquad (1)$$

the vectors $\vec{R}_i$, $\vec{r}_i$, $\hat{r}_\circ$, are defined in Figure 1.

A popular microstrip reflectarray is the one which consist of variable size patches [1]. In this method, the phase response curve is required which represents the phase shift in scattered waves from an infinite array versus the variable patch size. A full wave analysis should be used to obtain the required phase response curve. FDTD is a powerful and flexible method to analyze electromagnetic structures and used to determine the phase response of some microstrip reflectarray elements in this paper.

II. Theory

To analyze the microstrip reflectarray which usually consists a large number of patch elements, it is approximated by an infinite array of the same patches. This is a periodic structure can be replaced by an equivalent unit cell waveguide [2]. Figure (2) shows the front view of such an equivalent waveguide. A normal incident wave is assumed to propagate in this unit cell waveguide and insect to the radiating patch on top of a grounded dielectric substrate. An FDTD algorithm with a Gaussian pulse source is used to solve the Maxwell's equations in this waveguide [3].

First order Mur's absorbing boundary condition [4] has applied to simulate the infinite radiation boundary. Solving the discretized Maxwell's equations in waveguide yields the time domain response of electric fields. This has been done twice; once in absence of the microstrip antenna element and second in its presence. The scattered electric fields are calculated and then transformed to frequency domain by discrete Fourier's transform. When the closed form relation of resonance dimensions of antenna elements is available, the phase response versus element size will be obtained easily.

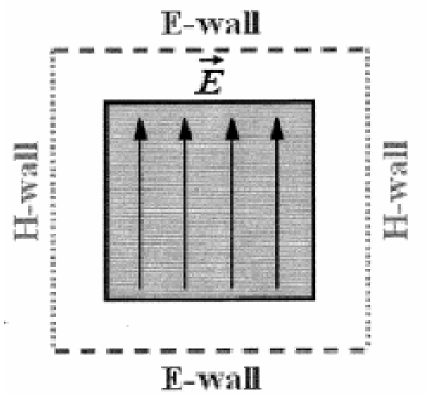

Figure 2- Equivalent unit cell for an infinite array of equal size patches

III. Results

In this paper, microstrip elements such as square patch and dipole have been analyzed by FDTD method. Figure 3 shows the configuration of a unit cell of a microstrip dipole infinite array.

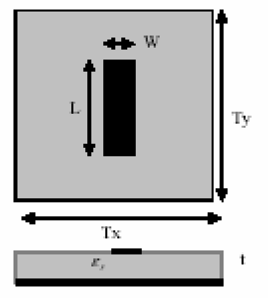

Figure 3- The unit cell of a microstrip dipole infinite array.

The dimensions and characteristics are:

$T_x=T_y=5mm, W=1.5mm, t=0.76mm, \varepsilon_r=2.5,$

f=24 GHz

The phase response of this structure has been represented in Figure 4 and compared with the results obtained by Ansoft HFSS V9 and the results reported in [2] using WGA method and the analysis results of SDIA method [5].

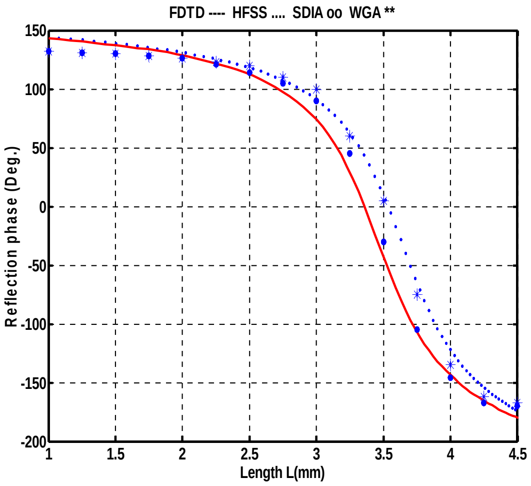

Figure 4- Phase response of a microstrip dipole infinite array

Figure 5 shows the configuration of a unit cell of a square patch infinite array.

The dimensions and characteristics are:

$T_x=T_y=4.28$ mm, t=0.792 mm , $\varepsilon_r=2.94$, f= 28 GHz

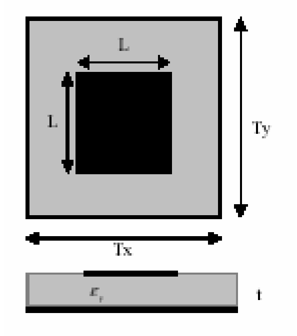

Figure 5- The unit cell of a square patch infinite array

The phase response of this structure has been represented in Figure 6 and compared with the results obtained by Ansoft HFSS V9 and the results reported in [2] using WGA method and the analysis results of CIM method [6].

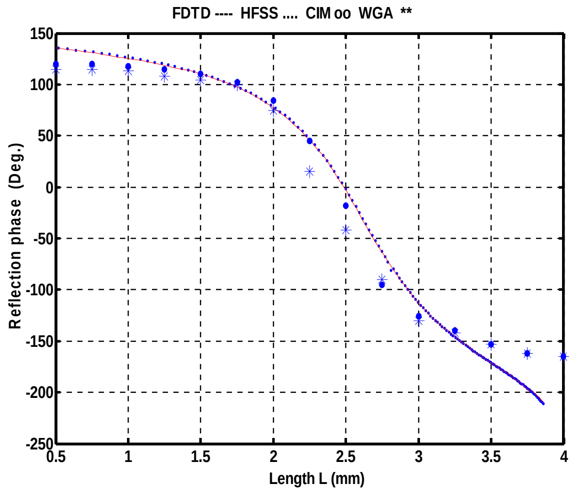

Figure 6- Phase response of square patch infinite array

IV. Conclusion

The simulation results by FDTD method for some element shapes are enough adequate in comparison with some other methods. There is a good agreement

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between FDTD and HFSS results and simulation and experimental results reported in literature. The advantage of this method is clear when a microstrip antenna element is used in a reflectarray which its resonance dimensions versus frequency is available in closed form. In such cases, by running the FDTD program once and using the Fourier's transform the phase response versus frequency will be obtained. Then, phase curve versus antenna resonance dimensions can be obtained without need running the program for each length. For the structures which their resonance dimension-frequency relation is not available in closed form, FDTD method is usable but the running time may go high.

V. References

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