

THE ANALYSIS OF A RECTANGULAR DIELECTRIC RESONATOR ANTENNA USING THE METHOD OF MOMENTS

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Abstract

An aperture-coupled rectangular dielectric-resonator antenna with a very low profile (length-to-height ratio ≈ 6) is analyzed using the method of moments (MoM). The problem formulation is based upon a volume-integral equation technique. Theoretical E- and H-plane patterns obtained from the MoM compare well with measurements and previously published FD-TD results.

I. Introduction

Various configurations of dielectric-resonator antennas (DRAs) have been investigated in recent years using several techniques. The FD-TD method has been applied to analyze and design linearly polarized [1] and circularly polarized [2-3] DRAs of rectangular, "cross", cavity-backed and array [4] configurations. The method of moments (MoM), together with the dyadic Green's function, has been used to analyze hemispherical DRAs [5] and cylindrical DRAs [6]. Previous MoM applications however have been mostly limited to bodies of revolution (BOR) DR geometries.

In this paper, we analyze a low-profile rectangular DRA using a MoM technique based upon a volume-integral equation formulation. The antenna is fed by a microstrip line and, the coupling between the DR and the microstrip feed is through a narrow aperture in a ground plane. This configuration allows the division of the original problem into two half-space problems by application of the equivalence principle and image theory.

II. Formulation

The geometry of the aperture-coupled DRA under consideration is shown in Figure 1. The problem is formulated using the equivalent principle as described in [7] and [8]. The microstrip feedline, denoted by S_C , is replaced by an equivalent surface electric current J_C . The coupling aperture, denoted by S_S , is replaced by an equivalent magnetic current M_S . The dielectric substrate volume is denoted by V_{d1} and the DR by V_{d2} . They are replaced by their equivalent volume electric polarization currents J_{d1} and J_{d2} respectively, which exist in free space.

In this analysis both dielectric volumes are assumed to be homogeneous and lossless and the ground plane is assumed to be infinite. The ground plane separates the problem into two separate sub-problems corresponding to the regions above and below the ground. For

* This research is supported by the Australian Research Council and the Macquarie University International Postgraduate Research Scholarship Scheme.

each sub-problem, the ground plane is removed by using the image theory. The equivalent magnetic current distribution above the aperture, $\vec{M}_s^+$, is given by

$$\vec{M}_s^+ = \vec{E}_s \times \hat{z} \quad (1)$$

where $\vec{E}_s$ is the electric field in the aperture and $\hat{z}$ is the unit vector perpendicular to the ground plane. Below the aperture there is $\vec{M}_s^-$ which, to assure the continuity of the electric field across the aperture, is set equal to $-\vec{M}_s^+$. The total magnetic field just above and below the aperture are set to be equal, to guarantee the continuity of the magnetic field across the aperture:

$$\vec{H}_{\tan}[\vec{J}_{d2}(\vec{r})] + \vec{H}_{\tan}[\vec{M}_s^+(\vec{r})] = \vec{H}_{\tan}[\vec{J}_{d1}(\vec{r})] + \vec{H}_{\tan}[\vec{J}_c(\vec{r})] + \vec{H}_{\tan}[\vec{M}_s^-(\vec{r})], \quad \text{for } \vec{r} \in S_s \quad (2)$$

The other coupled equations are derived as follows [7,8]:

$$\hat{z} \cdot \vec{E}_{\tan}[\vec{J}_c(\vec{r})] - \vec{E}_{\tan}[\vec{J}_{d1}(\vec{r})] - \vec{E}_{\tan}[\vec{M}_s^-(\vec{r})] = \vec{E}_{\tan}^i(\vec{r}), \quad \text{for } \vec{r} \in S_c \quad (3)$$

$$\frac{\vec{J}_{d1}(\vec{r})}{j\omega\epsilon_0(\epsilon_{r1}-1)} - \vec{E}[\vec{J}_c(\vec{r})] - \vec{E}[\vec{J}_{d1}(\vec{r})] - \vec{E}[\vec{M}_s^-(\vec{r})] = \vec{E}^i(\vec{r}), \quad \text{for } \vec{r} \in V_{d1} \quad (4)$$

$$\frac{\vec{J}_{d2}(\vec{r})}{j\omega\epsilon_0(\epsilon_{r2}-1)} - \vec{E}[\vec{J}_{d2}(\vec{r})] - \vec{E}[\vec{M}_s^+(\vec{r})] = \vec{E}^i(\vec{r}), \quad \text{for } \vec{r} \in V_{d2} \quad (5)$$

where ω is the angular frequency, ϵ_0 is the permittivity of free space, and ϵ_{r1} and ϵ_{r2} are the relative permittivity of the substrate and the DR, respectively. For a given incident field in the microstrip feed, the coupled integral equations (2)-(5) are solved for the currents in V_{d1} , V_{d2} , S_c and S_s . Then, the far field is computed.

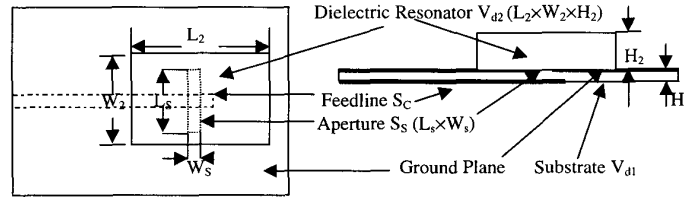


Figure 1. The geometry of DRA under consideration

III. Results

The parameters of the DRA analyzed are listed in the Table 1, where T_s is the distance between the center of the aperture and the end of the microstrip (matching stub length). All dimensions in Table 1 are in millimeters.

L_2	W_2	H_2	L_s	W_s	T_s	H_1	ϵ_{r1}	ϵ_{r2}	Frequency
15.2	7.0	2.6	3.4	1.2	0.8	0.64	10.5	10.8	11.6GHz

Table 1. The parameters of the DRA

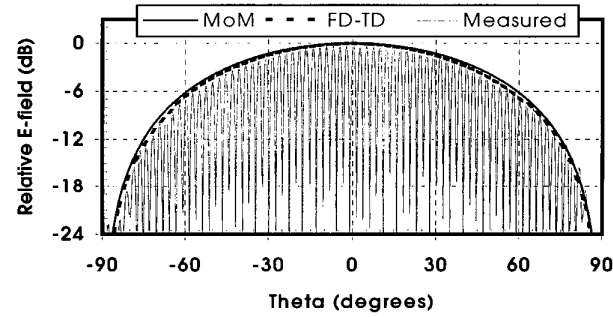


Figure 2. The theoretical and measured far-field patterns of the DRA in the H plane

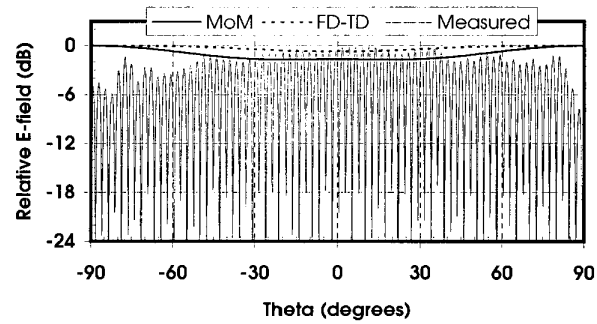


Figure 3. The theoretical and measured far-field patterns of the DRA in the E plane

Figures 2 and 3 show the theoretical (MoM) and measured [1] far-field patterns of the DRA in the E plane and H plane respectively. Also shown in the same figures are the theoretical far-field patterns previously computed using the FD-TD method [1]. Note that the patterns of the test antenna were measured using a spinning linear-polarized horn antenna in order to simultaneously obtain the cross-polarization level. A good agreement between theoretical and measured patterns has been achieved in the H plane.

The difference between the measured and theoretical E-plane patterns must be due to the finite size of the ground plane in the test antenna because an infinite ground plane is assumed in both MoM and FD-TD calculations. Microwave absorbers attached to the ground plane edge of the test antenna may be the reason for the rapid decrease in the measured pattern at about $\theta = \pm 80^\circ$.

IV. Conclusions

A MoM technique has been developed to analyze an aperture-coupled rectangular dielectric-resonator antenna. The computed E-plane and H-plane patterns are compared with those previously obtained by measurements and the FD-TD method. It has been demonstrated that a MoM technique based upon the volume integral equation formulation can be used to design and analyze rectangular DRAs that are excited by an aperture in a ground plane.

V. References

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