COMPARISON OF THREE FDTD MODELING TECHNIQUES FOR COAXIAL FEED

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Introduction

This paper addresses the difficulties reported in numerical modeling of coaxial feed probes [1]. A range of finite-difference time-domain (FDTD) modeling techniques (e. g., gap, magnetic frill and transmission line modeling) was successfully applied for specific applications. We here challenge the same problem for the case of electromagnetically coupled patch antenna (EMCP). This structure has intricate resonance behavior and operates based on two-mode excitation. These two modes have close values of resonant frequency [3] and can be revealed only with precise probe modeling. The following modeling techniques for the probe feed have been implemented and compared with the measurement results: electric gap modeling, sub-cell modeling of inner conductor and very fine discretization of coaxial probe. The results are discussed in the light of advantages and downsides of each technique and the associated computational parameters to obtain a reliable solution.

Antenna Structure

Cross-sectional view of the antenna is depicted in Fig. 1.

Figure 1. Cross-sectional view of the antenna structure.

The antenna is comprised of two stacked patches, separated by a foam layer ($\epsilon_{r\text{-foam}} = 1$). Both patches are etched on a 0.81-mm substrate ($\epsilon_{r\text{-substrate}} = 3.38$, $\tan\delta_{\text{substrate}} = 0.0027$). Another substrate layer is added to the fed-patch, where the two substrate layers are glued to result in the total thickness of 1.74mm, with assumed 0.12-mm glue (electrically modeled as air) layer, modeled with Maloney-Smith method for thin dielectric sheet [4]. The dimensions of interest

are as follows: fed-patch 64mm×68mm, upper patch 72mm×72mm, finite ground plane 100mm×100mm. The radius of the outer conductor of the coaxial probe is 5mm and of the inner conductor is 1mm. For all the simulations reported in this paper, the FDTD problem resulted in a total of 90×90×90 cells.

Numerical Modeling Techniques of the Coaxial Probe

We here present three different modeling techniques of the coaxial probe:

Electric gap modeling. Here, the antenna is excited with a resistive voltage source at the location of the feed. The details of FDTD update equations are given in [4]. This modeling technique is characterized by simplicity in implementation, and for the applications reported in the literature it has shown good agreement with measured data [5].

Sub-cell modeling of inner conductor. Here, the inner conductor of the coaxial probe is modeled using the sub-cell modeling for the thin wire [6]. As mentioned before, the air gap beneath the fed patch is modeled with the thin sheet, and this calls for separate treatment of the updating equations for the thin wire at the junction with the thin air gap. Eq.1 shows the updating of the y-component of the magnetic field H_y . Here, we use the contour path modeling technique [4] of thin wire but we consider the discontinuity of the electric field in the z-direction.

$$H_y|_{i,j,k}^{n+\frac{1}{2}} = H_y|_{i,j,k}^{n-\frac{1}{2}} + \frac{\Delta t}{\Delta z \mu_0} \left(E_x|_{i,j,k-\frac{1}{2}}^n - E_x|_{i,j,k+\frac{1}{2}}^n \right) + \frac{\Delta t}{\mu_0 \frac{\Delta x}{2} \Delta z \ln\left(\frac{\Delta x}{r_0}\right)} \left(E_z|_{i-\frac{1}{2},j,k}^n (\Delta z - \Delta g) - E_z|_{i+\frac{1}{2},j,k}^n (\Delta g) \right) \quad (1)$$

where r_0 is the radius of the inner conductor of the coaxial probe and Δg is the thickness of air gap beneath the lower patch, and the remaining standard FDTD-related notation can be found in [4].

Fine discretization of the inner conductor. Finally, the inner conductor is modeled using the fine discretization of FDTD cells around the coaxial probe, earlier investigated in the context of its effect on calculation of input impedance of a monopole antenna [1]. In this technique, we implement a graded mesh for the region around the feed point in a precise manner to avoid unwanted reflections from the cell junctions.

Results and Conclusion

Figs. 2(a) and 2(b) graph the results for real and imaginary part of input impedance obtained using the three techniques above, along with the measurement results for comparison. In addition, Table I summarizes the computational parameters for each technique. The following can be observed from the presented results:

1. The *electric gap modeling* technique, although simple and straightforward in implementation, results in a 50-MHz shift between the measured and simulated resonance frequency. Further, we note the discrepancy between the model and the measured data around 1.25GHz. Table I suggests that this method calls for a large number of iterations as it converges to the final solution.

(a)

(b)

Figure 2. (a) Real and (b) imaginary part of the input impedance, calculated with three different techniques for the model of coaxial probe shown of the antenna structure in Fig. 1. The measurement data are included as a benchmark for comparison of the three modeling methods.

2. The *sub-cell* modeling of the inner conductor of the coaxial probe demonstrates an improved agreement with the measured data with respect to the previously mentioned technique, both in resonant frequency and in the data at 1.25GHz. Table I demonstrates advantageously smaller number of iterations needed by this technique for convergence to the final result.
3. The *fine discretization of the inner conductor* results in superior matching of input impedance around 1.25GHz with respect to the two methods above, however, Table I shows it is computationally intensive in comparison with the sub-cell modeling technique.

TABLE I.
COMPARISON OF COMPUTATIONAL PARAMETERS FOR THE TECHNIQUES USED TO
OBTAIN RESULTS OF FIG.2.

Technique for modeling the coaxial probe feed	Minimum cell dimension in three coordinates: $\Delta x, \Delta y, \Delta z$ (mm)	Time step Δt (ps)	Number of iterations needed for convergence to the final solution
<i>Electric gap</i>	2, 2, 0.56	1.6661	17000
<i>Sub-cell</i>	1.25, 1.25, 0.56	1.5138	6000
<i>Fine discretization</i>	0.25, 0.25, 0.56	0.5395	12000

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