Characterization of a CPW–MS Transition for Antenna Applications

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Abstract

A full-wave analysis of a Coplanar Waveguide (CPW) to Microstrip (MS) Transition is performed using Finite Difference Time Domain (FDTD) and the High Frequency Structure Simulator (HFSS). The effects from truncating the dielectric substrate around the CPW and microstrip are characterized. Results indicate that decreasing the size of the dielectric substrate does not significantly affect performance.

I Introduction

The general CPW–MS Transition is well covered in the literature [1, 2] and is currently being applied to antenna structures. The antenna structure of interest is a dual-polarized slot–dipole antenna [3]. In this antenna, a coplanar waveguide fed slot antenna is etched into the top of a microstrip fed dipole antenna. In order to feed the antenna from the same side of the substrate, an interconnect which can communicate thru the substrate via electromagnetic coupling is needed. Additionally, the final version of the antenna will operate at high frequencies. Thus, it is necessary that the antenna interconnects have small volume and negligible electrical interference with the rest of the circuit. A transition which satisfies these requirements is a proximity coupled overlay transition [1] between a microstrip and a coplanar waveguide. In this case the electromagnetic coupling occurs in the overlap region between the coplanar waveguide and the microstrip.

As mentioned previously, the volume of the total antenna package at high frequencies is critical. It is necessary to examine the effects of a truncated dielectric on the performance of this transition. Results calculated using FDTD and HFSS are compared for different values of dielectric truncation.

II FDTD Setup

FDTD is a widely-used time–domain full–wave scheme for the characterization of microstrip and coplanar waveguide lines and discontinuities [4, 5]. In FDTD, the propagation of a specific time–dependent function is followed through the structure under test. For the cases discussed below, a Gaussian pulse is chosen as an excitation function due to the fact that it has smooth variation in time. Additionally its Fourier Transform is also a Gaussian function centered at zero frequency. The pulse width of the Gaussian is calculated based on the distance between the excitation and the closest discontinuity [6]. In order to excite the microstrip the vertical electric field under the microstrip is excited. PML absorbing boundary conditions are used in the x–, y– and z–directions as detailed in [7].

Frequency dependent scattering parameters S_{ij} are obtained by probing the vertical electric field [4, 6] at a point between the excitation and the first discontinuity. It should be noted that the FDTD simulation calculates the total field which is the sum of the incident and reflected waveforms along the microstrip. The incident field is obtained by simulating an "infinite" microstrip. By infinite, it is meant that the structure under simulation

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is replaced by a microstrip thru-line terminated on both ends with absorber. In the case studied in this paper, careful attention is paid to the width of the truncated dielectric for the infinite microstrip simulations. To obtain the reflected field the incident field data is subtracted from the total field.

III Results

In this section, results generated using FDTD and HFSS are presented for the frequency range from 5 GHz to 35 GHz. The design frequency of this transition is at $f = 20$ GHz. HFSS is a commercial microwave CAD package that is used to calculate S-parameters and fields of passive high-frequency structures. The setup of the transition in HFSS is straightforward and more information can be found in [8].

Line widths and lengths for the transition structure are shown in Figure 1. Input impedances at the coplanar waveguide and microstrip are 55 Ω. Note that the length of the microstrip is approximately one-quarter of a guided wavelength ($\lambda_{MS_{guide}}/4$) at the design frequency. The parameter D represents the amount that the dielectric is truncated around the coplanar waveguide. In the first case, D is set at 24.5 mils, significantly larger than the $\lambda_{CPW_{guide}}/8$ condition [5]. In the FDTD codes, a mesh of $92 \times 153 \times 54$ is used. This mesh includes the 6 cells of PML added in the x- and z- directions and the 10 cells of PML added in the y- directions, with $\sigma^{Ex}_{max} = 167.0$, $\sigma^{Ey}_{max} = 276.0$, and $\sigma^{Ez}_{max} = 216.0$. These values allow a numerical coefficient of reflection below -50 dB. A Gaussian pulse is applied to excite the microstrip with $f_{max} = 410$ GHz and is placed 40 mils from the discontinuity created by the overlap. S-parameter results are shown in Figure 2. Overall FDTD and HFSS agree well over a large 3 dB bandwidth, which is on the order of 35 percent. Additionally radiation losses are on the order of 2-3 percent over the entire bandwidth. In the next case, the dielectric distance D is truncated to 7 mils around the CPW region. The FDTD setup is identical to that described above. S-parameter results show nearly the same values as those in Figure 1. Finally, the dielectric distance D is truncated to 3.5 mils around the CPW. Referring to Figure 3, we see a 4 dB improvement in S_{11} at the design frequency of 20 GHz. However 3 dB bandwidth is slightly lower and the radiation losses increase to 4-5 percent over the bandwidth.

IV Conclusion

A full-wave analysis of CPW-to-MS transition is performed. The dielectric layer is truncated in order to observe the effect of performance on the transition. It is found that when the dielectric is truncated from 24 mils to 3.5 mils on either side of the coplanar waveguide, S-parameters do not change significantly. Additionally, bandwidth is preserved and radiation losses increase only slightly. It can be concluded that decreasing the size of the transition package will not significantly affect performance.

V Acknowledgments

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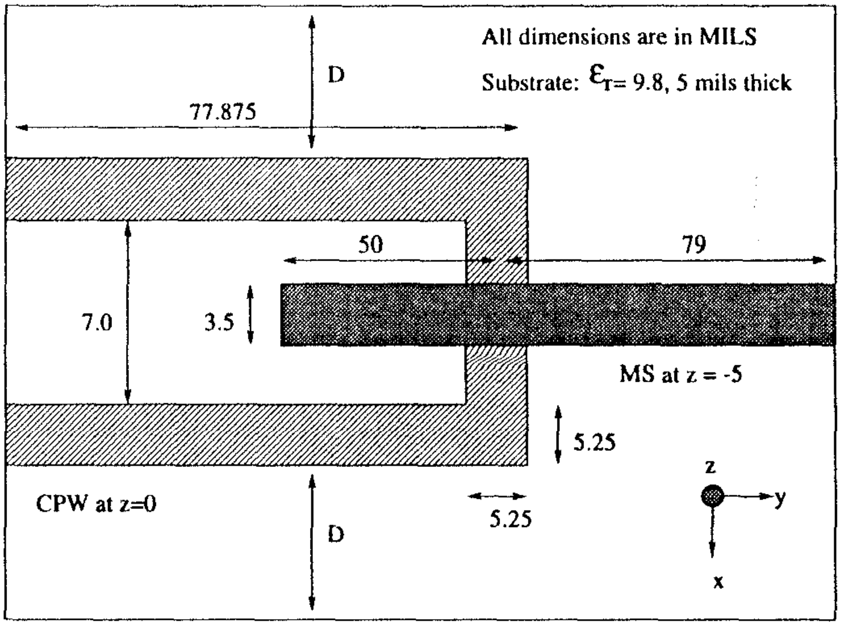

Figure 1: CPW-MS Transition

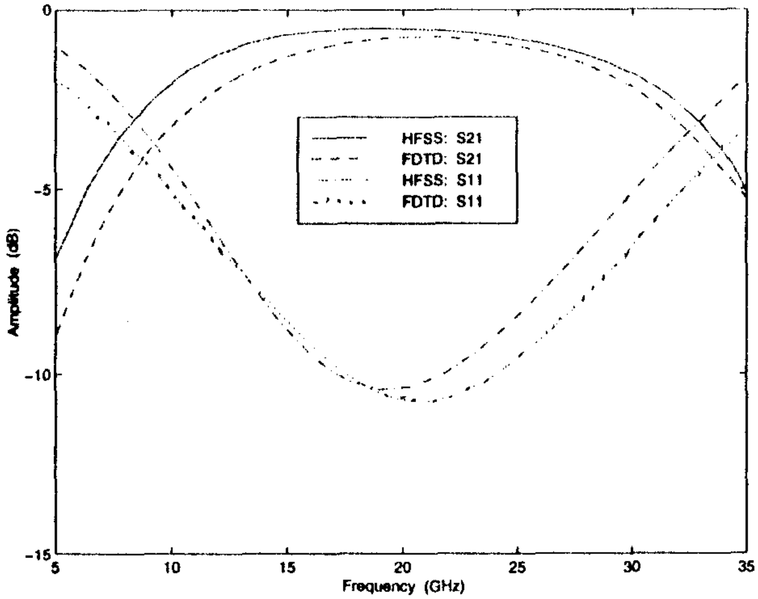

Figure 2: Transition S-parameters for D = 24.5 mils

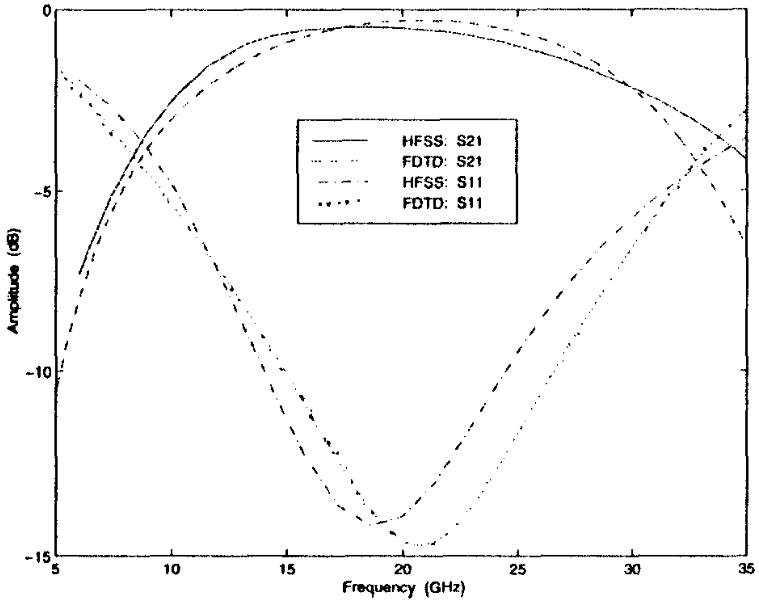

Figure 3: Transition S-parameters for D=3.5 mils