Full Field and Quasi-TEM Time Domain Numerical Analysis of Coupled Microstrip Circuits

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Abstract - Both full field and quasi-TEM time domain analyses of various coupled microstrip line configurations are presented and compared. The full field analysis as well as the quasi-TEM analysis are performed using (different) finite difference time domain algorithms. The first solves Maxwell's equations and the latter solves the multiconductor transmission line (MTL) equations. The capacitance and inductance matrices required for the MTL solution are determined using a previously published electrostatic Green's function technique. The coupled microstrip lines are terminated with resistive loads with values close to the characteristic impedances of the lines. Time domain results show that the quasi-TEM analysis is very qualitatively similar but not the same as the full field analysis. The quasi-TEM analysis requires much less computer resources and may be sufficient for some cases. For more complicated structures only a full field analysis can show some detailed coupling phenomena.

1. Introduction

The use of multiconductor microstrip circuits is common in modern high speed integrated electronics and a common concern is the coupling between the signals on each line. It is well known that a dielectric overlay above the microstrips can act to reduce the far end coupling but increases the near end coupling. This is desirable if one is designing a microwave coupler but undesirable in digital circuits. Other inhomogeneous configurations, such as an air notch [1] and layered substrate [2, 3], have been used recently to reduce this coupling. Time domain modelling of the coupling when the microstrips are loaded and when both the air notch and dielectric overlay exist is considered in this paper.

2. Numerical Methods

The two numerical techniques considered are the direct integration of Maxwell's equations using the FDTD technique and the finite difference solution of the time domain MTL equations as discussed in [4]. The second technique requires the capacitance and inductance matrices valid for the quasi-TEM mode of propagation on the MTL. The capacitance matrix was calculated using the electrostatic Green's function technique described in [1, 3]. The inductance matrix was then calculated by using the standard technique of $\boldsymbol{L} = \boldsymbol{C}_0^{-1}/v^2$ where $\boldsymbol{C}_0$ is the capacitance matrix of the same conductor configuration in free space and v is the free space velocity.

3. Test Problem

The test problem we choose to demonstrate our results is shown in Figure 1. It is the same as the one investigated by Elsherbeni *et al.* [3] where a notch is introduced between coupled microstrips with a dielectric overlay. A Gaussian pulse with a peak value of 1 V and a 10% peak-value width of 150 ps was used to excite the N1 end of the first transmission line via a Thévenin voltage source with source resistance $R_s = 53\ \Omega$. All other ends were terminated with 53 Ω resistances. The microstrips were assumed to be perfectly conducting and the six cases specified in Table 1 were analyzed.

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4. Results and Conclusions

The results using the FDTD and MTL techniques are shown in Figure 2 for case 4. All cases showed similar qualitative features but were quantitatively different (with case 4 showing the largest difference). The far end coupling results show the greatest discrepancy.

The results for cases 1, 4, 5, and 6 using only the FDTD technique are shown in Figure 3. The different peak amplitudes of the pulse at the near end of the passive line agree with the predicted coupling using the static analysis in [1, 3]. The different phase velocities for each configuration can be seen clearly from the figure. The difference in peak value on the active line for the different cases is due to the mismatch between the source and line as well as between the line and load impedances. We chose to use constant R and R_s values for all cases.

Table 1: Parameters for test cases

Case	L	D	ε_{r2}	Case	L	D	ε_{r2}
1	0	0	1.0	4	2.5	2.5	4.7
2	0.5	1.5	1.0	5	0	0	4.7
3	1.5	2.5	1.0	6	2.5	2.5	1.0

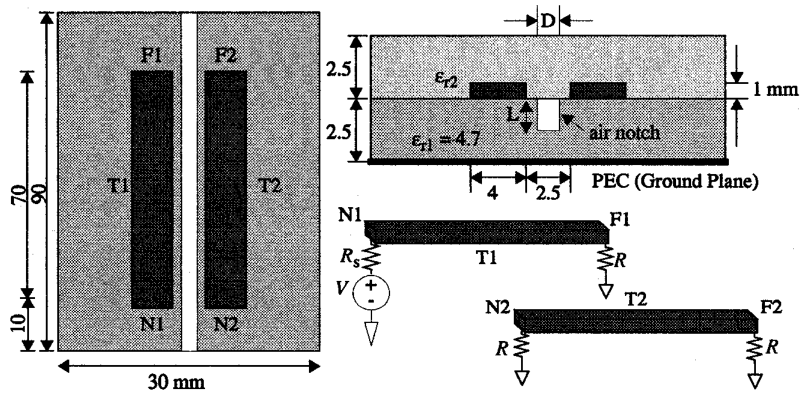

Figure 1 Top View (left), side view (top right), electrical configuration (bottom right)

Acknowledgments

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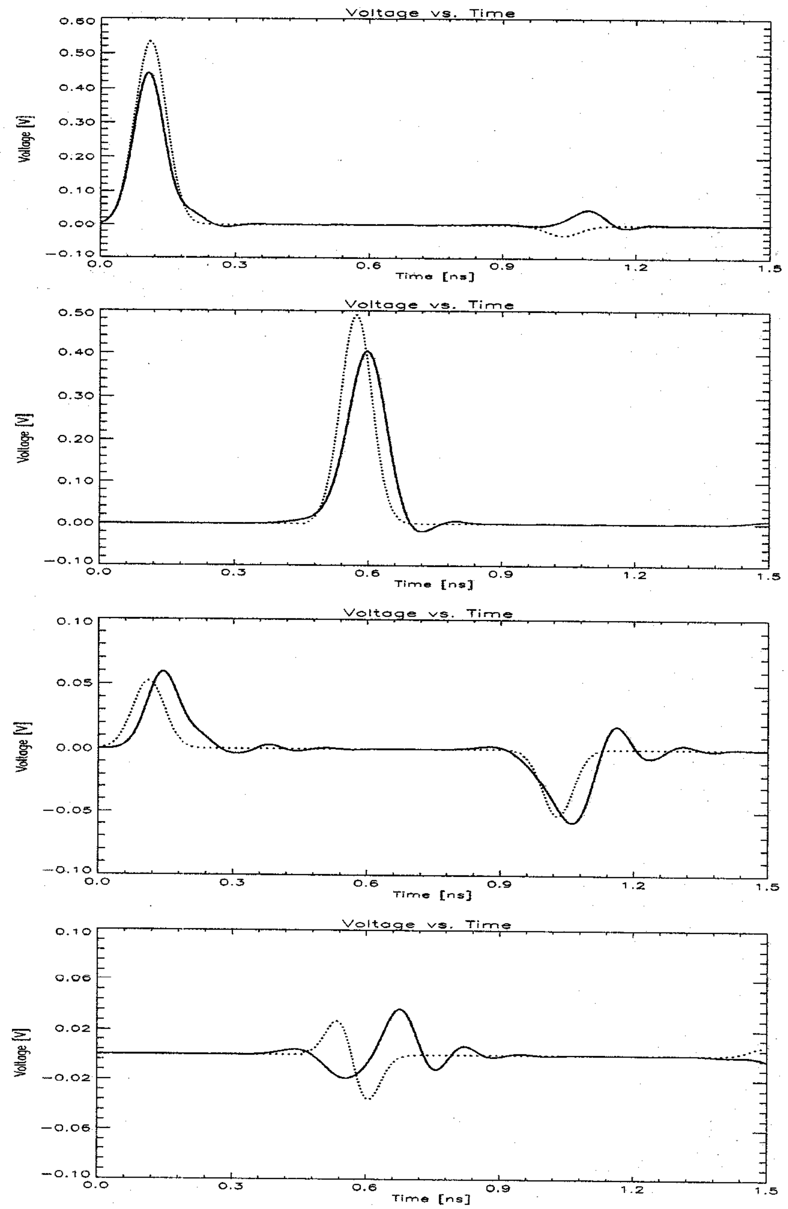

Figure 2 Comparison between FDTD (——) and MTL (·····) solutions for case 4
Top: near end active, second: far end active, third: near end passive, fourth: far end passive
(note: time scale units are [ns])

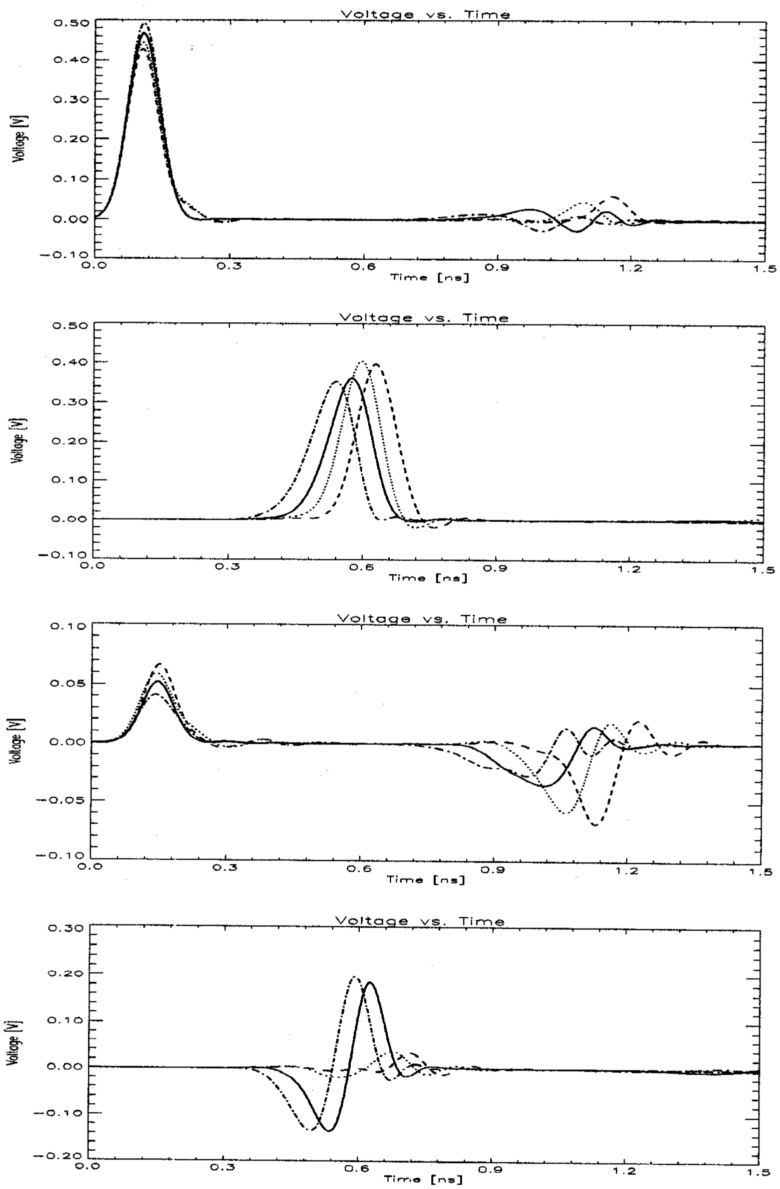

Figure 3 FDTD results for cases 1 (———),4 (·····), 5 (- - - - -), and 6 (- · - · -)
Top: near end active, second: far end active, third: near end passive, fourth: far end passive
(note: time scale units are [ns])