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Full Wave Analysis of Tapered Microstrip Lines Using the Conformal Grids FD-TD Method

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Summary

The miniaturization and ever higher density packing of electronic devices is driving a trend toward three-dimensional configurations. At the same time, the clock rates in digital devices and the operating frequencies are steadily increasing. The tapered microstrip line is often used in such MMICs. Its complex three dimensional structure exerts a strong influence on the MMIC circuit performance. Due to the increase in operating frequencies, it has become necessary to predict the time domain responses as well as the broad band frequency characteristics to directly estimate its performance. Furthermore, time domain analysis has the advantage of being able to obtain the broad band characteristics in a single computer run using Fourier transforms as well as being able to obtain the transient responses itself. The traditional numerical approaches have lacked the versatility to enable such analysis.

The finite-difference time-domain (FD-TD) method [1],[2] is effective for such a three-dimensional time domain problem. However, the traditional rectangular mesh is not suitable for problems where the boundary has an arbitrary configuration, because numerical errors occur at the boundary using stair casing approximation. Consequently, instead of the traditional rectangular mesh, a conformal grids mesh is more appropriate because the boundary condition for an arbitrary angled taper can be calculated precisely[3]-[6]. Furthermore, this approach is suitable for CAD in conjunction with a mesh generator. Such an analysis of a tapered microstrip line in a three-dimensional space and time domain using the conformal grids finite difference approach has not been carried out as far as we know.

In this paper, the full wave analysis of tapered microstrip lines is carried out in the time domain [7],[8]. The method used is the conformal grids FD-TD method. Computed results are compared with those obtained by the experiment and the finite element method. The results agree well. As a result, it is shown that the propagation

characteristics are significantly different from those of stripline or 2-dimensional modeling using magnetic walls.

Fig.1 shows the tapered microstrip line. The relative permittivity ε_r of the substrate is 2.53. The thickness of the substrate is 0.79 mm. The widths of a wide line and a narrow one are 5.32 and 2.66 mm, respectively.

Fig. 2 shows the conformal grids arrangement used in this analysis. The microstrip line is divided by 8 cells in the transverse direction. The discretization in the y direction is uniform.

Firstly, to validate the modeling of a tapered structure by the conformal grids FD-TD method, a two-dimensional case is simulated, which can be precisely predicted by other two-dimensional numerical methods. Fig. 3 shows the reflection coefficient $|S_{11}|$ of a two-dimensional strip line case. $|S_{11}|$ is obtained by the Fourier transforms of the pulse responses in a single computer run. The pulse wave form is a Gaussian pulse. Simulated results agree well with those obtained by segmentation method [9] for a wide band range. Furthermore, the convergence in this analysis is confirmed by the calculation using a finer mesh. The validity of the conformal grids arrangement for a tapered structure can thus be validated.

Next, a tapered microstrip line is simulated similarly in the three-dimensional space. Fig. 4 shows the reflection coefficient $|S_{11}|$ of the microstrip line obtained by this method. In Fig. 4, results obtained by both 3-D FEM software HFSS (Ansoft Corp.) and experiment are also plotted at 10 and 20 GHz. In the HFSS analysis, a shielded model is assumed. The values obtained by each approach agree well with each other. In this case, the radiation is not strong, so the S parameter agrees well in both the open and shielded model. Fig.3 and Fig.4 show that the propagation characteristics of the strip line and the microstrip line are different. Consequently, the microstrip line should be calculated by considering the three-dimensional structure.

Fig. 5 shows the transient field pattern of the pulse propagation. Reflected and transmitted pulse waves affected by the electrical properties of the tapered microstrip line are shown.

Analysis of the other type of taper configurations shown in Fig.6(a) and Fig.6(b) is considered essential. The same approach can be used and these analyses are currently in progress.

All computations were carried out on a HP9000-720 workstation. The memory and CPU time for simulations were about 10MB and 7hrs, respectively. This approach is suitable for CAD in conjunction with a mesh generator. A way to achieve more efficient computation through reduction of required memory and CPU time is currently being investigated.

Acknowledgments

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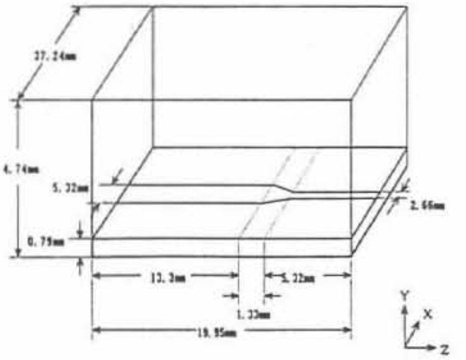

Fig. 1. Tapered microstrip line.

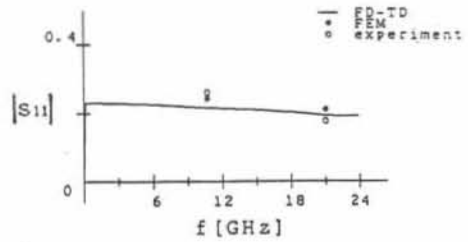

Fig. 4. $|S_{11}|$ vs. frequency by 3D-analysis.

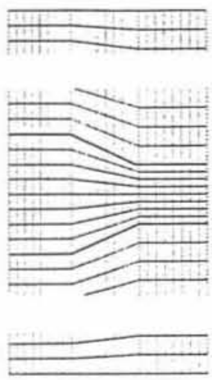

Fig. 2. Conformal grids arrangement.

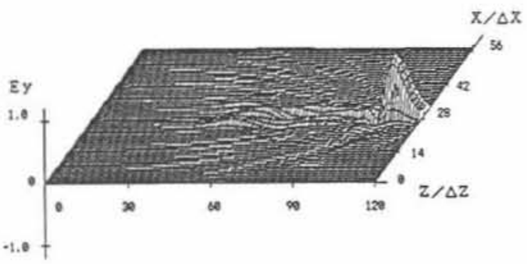

Fig. 5. Propagating wave form.

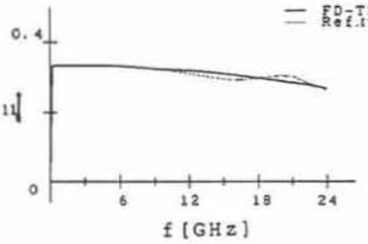

Fig. 3. $|S_{11}|$ vs. frequency by 2D-analysis.

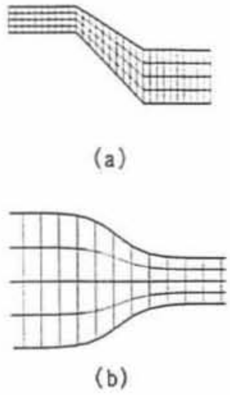

Fig. 6. Tapered microstrip line for other types.