3D Characterization of Air Bridges and Via Holes in Conductor-Backed Coplanar Waveguides for MMIC Applications

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Abstract

A 3D Finite Difference Time Domain (FDTD) Method is used to characterize either an air bridge or two via holes which can be used in a conductor backed coplanar waveguide (CPW) to supress the coupled slotline like mode. The accuracy of the analysis is demonstrated through the comparison of theoretical results obtained using our FDTD method to experimental ones for a via hole ground in a microstrip. It is shown that the via holes discontinuity in a conductor-backed CPW is associated with reflection losses lower than that in the case of an air bridge discontinuity.

Introduction

The use of air bridges and via holes is now a common practice in microwave and mm-wave hybrid and monolithic circuits. Air bridges are indispensable in MMIC design using coplanar waveguides. The side ground planes of the CPW have to be connected in order to supress the propagation of the coupled slotline like mode. Via holes are used in multilayer integrated circuits to connect conductors on differents layers by vertical pathways, and in single layer microstrip circuits to obtain wide band short circuits. Of course air bridges and via holes represent frequency dependent discontinuities associated to the studied transmission lines. In this paper we present a rigorous and efficient full wave analysis for characterising this kind of discontinuities, based on a 3D Finite Difference Time Domain Method. First, a via hole ground in a microstrip transmission line is characterised and the results are compared to those given in [1]. Then two ways, which can be used to supress the coupled slotline like mode in MMIC conductor-backed coplanar waveguides, are analysed : an air bridge and two via holes. In both cases the CPW keeps its technological advantage of easy adaptation to both series and shunt elements connections.

The FDTD Method

The Finite Difference Time Domain Method (FDTD) has been recognized as a powerfull tool for analysing complex guided structures [2]. This method, in a 3D formulation, has been used in our analysis because of its ability to determine accurately and directly in a broad frequency band the structure field solution, by simulating the propagation of a gaussian pulse through each studied structure. The frequency domain parameters are calculated over the whole required frequency range by Fourier transform of the transient results. To obtain discrete approximations to Maxwell's curl equations, the centered difference approximation is used in both time and space first order partial derivative, i.e. the six field components are located respecting the Yee's mesh [3] and the electric field and the magnetic field are alternately calculated in order

CH3277-1/93/0000-0709$01.00

to achieve centered differences for the time derivatives. We consider shielded structures, with electric walls located far enough to not affect the field distribution near the transmission lines (Fig. 1, Fig. 2).

Results and discussion

In order to prove the capability of our method to analyse complex 3D electromagnetic structures, we first simulated a via hole ground in a microstrip line, like that shown in Fig.3. The via hole is considered as a cylinder of of rectangular cross section. The parameters of the structure are: w=2.3 mm, h=0.794 mm, d=0.6 mm, εr=2.32. The variation of the amplitude of scattering parameter S21 as a function of frequency in the [2-14 GHz] band is shown in Fig.5. A very good agreement with the experimental results given in [1] is demonstrated.

Two differents ways to eliminate the unwanted coupled slotline like mode in conductor backed coplanar waveguides are analysed and compared. The side planes of the CPW can be connected either by an air bridge, or by two via holes (Fig.6, Fig.8). When calculating both cases, we studied a CPW having the following parameters, which are adapted for MMIC applications : w=66 μm, g=40 μm, εr=12.8. In order to characterize these discontinuities over a wide frequency band, [0-60 GHz], an excitation pulse sufficiently narrow has been employed : a gaussian pulse having the half width σ=13 ps. The air bridge has a height b=20 μm and a length l=20 μm, while the via holes have each a diameter d=80 μm. In both cases, the distance of each discontinuity from CPW edges was taken x=20 μm.

Fig. 10 shows the incident and the reflected pulse at a reference plane 6 mm far from the air bridge of the CPW shown in Fig.6, while Fig. 11 shows a comparison between the performances for an air bridge and two via holes, through the presentation of the variation of the amplitude of the scattering parameter S11 as a function of frequency in the two cases. It can be seen that the via hole solution gives better transmission properties (even if it can complicate the technological procedure) than the air bridge one. At frequencies as high as 60 GHz, while the via hole solution gives negligible losses, air bridge solution leads to line reflection losses of about 1%. This can considerably influence the circuit performance especially when many air bridges are used.

References

[1] F. Alessandri, M. Mongiardo, R. Sorrentino, "Full-Wave Modeling of Via Hole Grounds in Microstrip by Three-Dimensional Mode Matching Technique", in 1992 IEEE MTT-S International Microwave Symposium Digest, pp 1237-1240.

[2] D.M. Sheen, S.M. Ali, M.D. Abouzahra, J.A. Kong, "Application of the Three-Dimensional Finite-Difference Time-Domain Method to the Analysis of Planar Microstrip Circuits", IEEE Transactions on Microwave Theory and Techniques, vol. 38, no. 7, July 1990, pp. 849-857.

[3] K. S. Yee, "Numerical solution of initial boundary value problems involving Maxwell's equations in isotropic media", IEEE Trans. Antennas Propagat., vol. 14, no. 3, May 1966, pp 302-307.

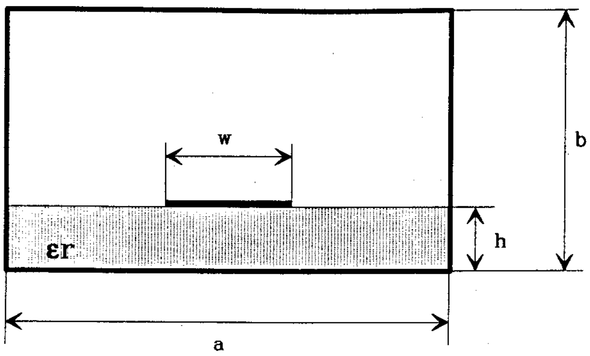

Fig.1 Microstrip transmission line (a=4w,b=4h)

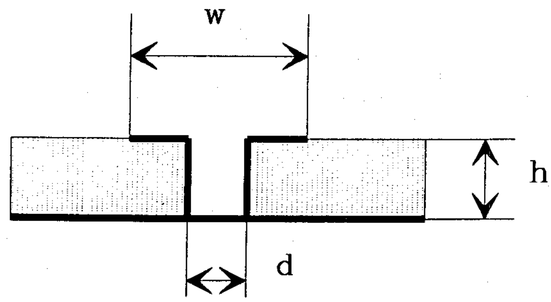

Fig.4 Cross sectional view through the via hole ground in microstrip.

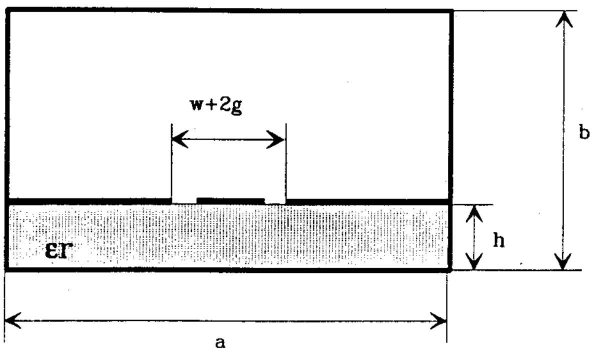

Fig.2 CPW transmission line (a=5h,b=4h)

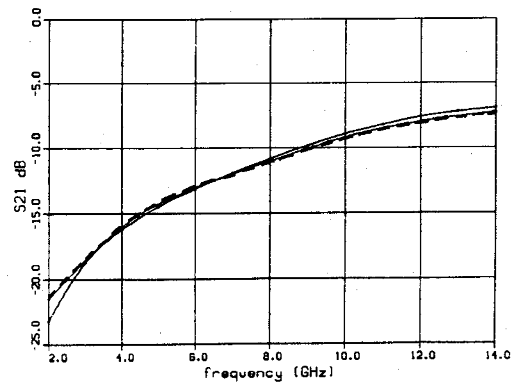

Fig.5 Variation of |S21| for a via hole ground in microstrip as a function of frequency.
——— our results
- - - - - experimental results of ref [1]

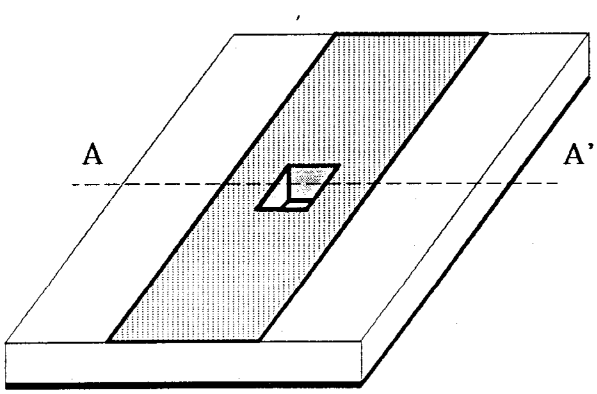

Fig.3 A via hole ground in microstrip

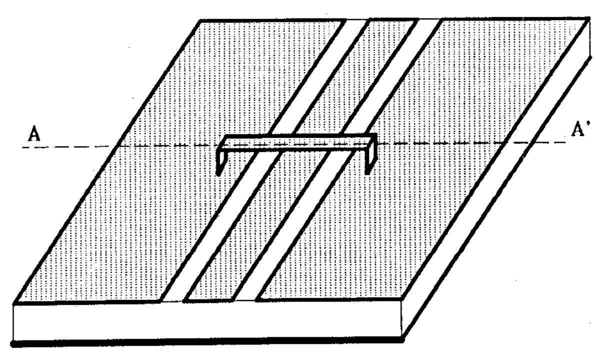

Fig.6 An air bridge on a coplanar waveguide

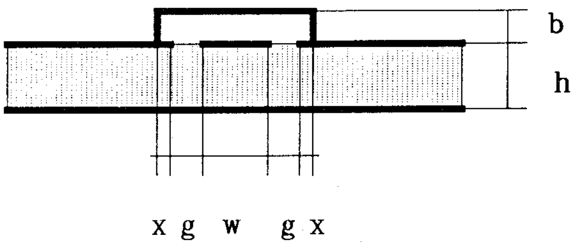

Fig.7 Cross sectional view through an air bridge on a CPW.

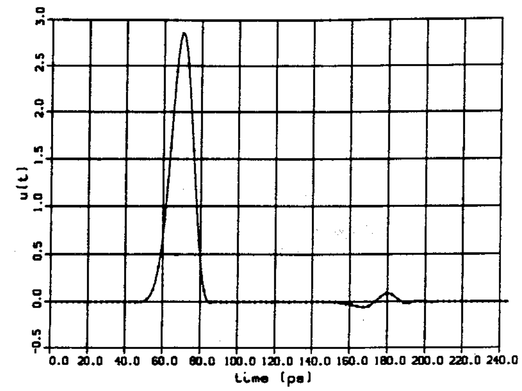

Fig.10 Time domain calculated signal at a reference plane 6 mm far from an air bridge in a conductor-backed CPW.

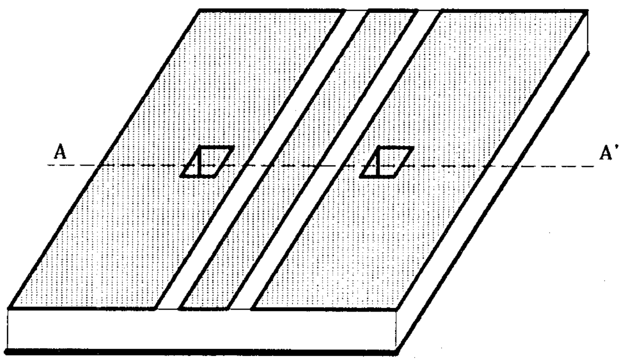

Fig.8 Two via holes in a coplanar waveguide.

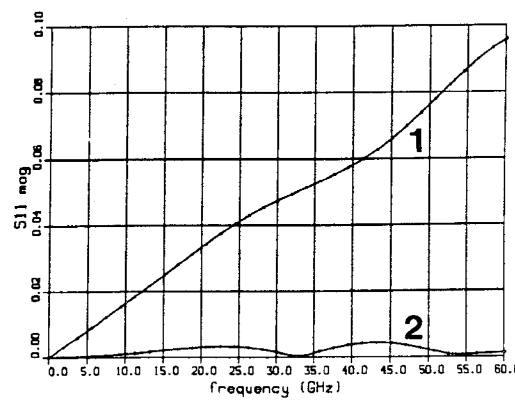

Fig.11 Variation of |S11| as a function of frequency
1 - Air bridge + CPW
2 - Via holes + CPW

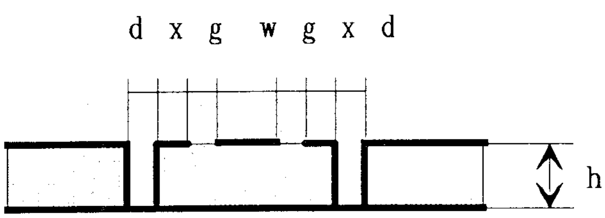

Fig.9 Cross sectional view through two via holes in a CPW.