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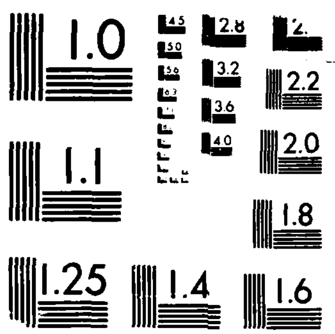

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TIME DOMAIN WAVE PROPAGATION IN MULTILAYERED INTEGRATED CIRCUITS

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prepared by

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TIME DOMAIN ELECTROMAGNETIC WAVES IN MULTILAYERED MEDIA

Principal Investigator: Jin Au Kong

SEMI-ANNUAL PROGRESS REPORT

Under the sponsorship of the ONR Contract N00014–86–K–0533 we have published 7 referenced journal and conference papers and 11 technical reports on time domain electromagnetic waves in multilayer media.

Many integrated circuits contain strip lines at different heights that run parallel or perpendicular to each other. And we have investigated reliable models for these structures. First the capacitances associated with two offset parallel strips at different heights between ground planes are computed using the conformal mapping approach. As an extension, a simplified circuit of parallel-plate lines with transverse ridges is introduced to model two parallel strips with perpendicularly crossing strips on top. We treated it as a distributed circuit consisting of transmission lines segments with periodical capacitive loading. In order to calculate the coupling between two lines, we reduced this structure to two equivalent single line circuits, viz. the even mode and the odd mode circuits. The Laplace transform approach can be easily applied to find out the transient response. The numerical computation carried out for various environments shows that the crossing strips will cause serious trouble for signals with a rise time of less than 50ps to propagate along a distances of 2cm or longer.

Basically, vias in a multilayered integrated circuits are treated like transmission lines with loadings where they encounter holes in ground planes separating different layers. We have modeled a ground plane with a hole and a circular conductor at the center of the hole as a radial waveguide, which in turn is connected to the via, another section of transmission line. Thus by computing the characteristic impedance of the former, we have derived the equivalent load impedance of the via hole. The load impedance is one important parameter in calculating the transient propagation along vias.

The scattering of electromagnetic waves from a randomly perturbed peridic surface is solved using the Extended Boundary Condition (EBC) method. The scattering from periodic surface is solved exactly using the EBC method and this solution is used in the small perturbation method to solve for the scattered field from a randomly perturbed periodic surface. The random perturbation is modeled as a Gaussian random process and the surface currents and the scattered fields are expanded and solved up to the second order. The theoretical results are illustrated by calculating the bistatic and backscattering coefficients. It is shown that as the correlation length of the random roughness increases, the bistatic scattering pattern of the scattered fields show several beams associated with each Bragg diffraction direction of the periodic surface. When the correlation length becomes smaller, then the shape of the beams become broader. The results obtained using the EBC method is also compared with the results obtained using the Kirchhoff approximation. It is shown that the Kirchhoff approximation results show quite a good agreement with EBC method results for the VV and HH polarized backscattering coefficients for small angles of incidences. However, the Kirchhoff approximation does not give depolarized returns in the backscattering direction whereas the results obtained using the EBC method give significiant depolarized returns when the incident direction is not perpendicular to the row direction of the periodic surface.

The analysis of resonance, input impedance and radiation of the elliptic disk, microstrip structure is rigorously formulated, using the Scalar and Vector Mathieu Transforms. With the help of these transforms, the resonance frequencies of the structure can be derived exactly using Galerkin's method and approximately using a perturbational approach. Expressions for the input impedance and the radiation pattern are also obtained.

Theory for quasi-TEM modes propagating in a transversely inhomogeneous (multi-dielectric) longitudinally uniform transmission line, previously derived for time-harmonic waves, is derived for transient signals. It is seen that, while the starting point for the theory is completely different, the result is similar to the time-harmonic theory, and previously derived properties for propagating modes also apply in the transient case. The range of applicability is discussed with a simple example.

Exact image method, recently introduced for the solution of electromagnetic field problems involving sources above a planar interface between two homogeneous media, was originally applied to a restricted pair of medium parameters to obtain a well behaved image located in the 'proper' complex half space. It is demonstrated here with an example that the 'proper' half space limitation can be released to increase the applicability of the exact image theory. However, it is shown that for certain media, numerical difficulties in the field integrals may be encountered, due to crossing of branch cut lines on the complex integration plane. This may occur when the medium where the field is to be calculated is more lossy than the other medium. Methods for the image integration to obtain better convergence for more general media, are discussed.

Simple approximation for diffraction surface currents on a conducting half plane, due to an incoming plane wave, is given in terms of a line current (monofile) in complex space. When compared to the approximation by a current located at the edge, the diffraction pattern is seen to improve by an order of magnitude for a minimal increase in computation effort. Thus, the inconvenient Fresnel integral functions can be avoided in quick calculations of diffracted fields and the accuracy is seen to be good in other directions than along the half plane. The method can be generally applied to problems involving planar metal edges.

We have also proposed a way to account for the effect of complicated geometry from the point of view of continuous transmission line model by letting the coupling between parallel lines in multilayered integrated circuits to be nonuniform. Previously, we devised a scheme that combines the method of characteristics and perturbational series to simplify the computation of the transient response from the coupled transmission line equations. A new transformation for decoupling now enables us to generalize this formulation to calculate the near-end and far-end crosstalks to very high accuracy, given arbitrary positional dependence for both capacitive and inductive coupling coefficients.

The transient response of fundamental sources, such as dipole and line current, was carefully analyzed. With the double-deformation technique, which is a modal technique based on identification of singularities in the complex frequency and wave number planes, we are able to obtain both early and late time response very efficiently. Some results for vertical electric dipole excitation on a two-layer medium have been published. Recently, we have discovered a general scheme of breaking up the integrands so that sources with arbitrary time and space dependence can be incorporated into our formulation without sacrificing convergence.

PUBLICATIONS SUPPORTED BY ONR CONTRACT N00014-86-K-0533 SINCE 1986

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Complex Space Monofilar Approximation of Diffraction Currents on a Conducting Half Plane I. V. Lindell Technical Report No. EWT-RS-112-8706, MIT, 1987

Gaussian Pulse Propagation in Absorbing Media Michael Tsuk, Technical Report No. EWT-RS-115-8708, MIT 1987

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