WAVEGUIDE TREATMENT OF THE SUSPENDED MICROSTRIP LINE WITH TUNING SEPTUMS

USING THE SPECTRAL DOMAIN APPROACH AND THE FINITE-ELEMENT METHOD

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ABSTRACT

The Spectral Domain Approach and the Finite-Element Method are simultaneousely used for deriving the frequency dependence of effective dielectric permittivities and of equivalent characteristic impedances of the technically most relevant modes of the suspended microstrip line with tuning septums.The latter numerical technique helps the former one in the choice of well-behaved basis functions for surface currents on the strip and for tangential fields in the slot.The numerical superiority of the Spectral Domain Approach in modes fields computations is demonstrated.

INTRODUCTION

The extention of practical applications of microwave integrated circuits toward higher frequencies logically exploits the technological advantages of planar microstrip waveguides.As a consequence,designers need an extention of the range of use of the quasi-static solution(deterministic problem)to the hybrid mode solution (eigenvalue problem).In all cases,the latter analysis appears more involved than the former one and can require a big numerical effort.

Recently,an attempt has been made to solve the waveguide treatment of a suspended microstrip line with tuning septums[1] (Fig.1).This new M.I.C. line can play the role between the ordinary microstrip and the suspended substrate geometry[2].It can also substantiate physical explanations about the coupling mechanism of wideband strip-slot couplers[3].

Since the quasi-static solution exists either from the Spectral Domain Approach (S.D.A.)[4] or from the Finite-Element Method (F.E.M.)[5],this paper presents the S.D.A. acting in conjunction with the F.E.M. for solving the tedious eigenvalue problem.

METHODOLOGY

Two ideas govern the study.First,the S.D.A. and the F.E.M. appear quite complementary since the former analysis provides deductive results whereas the latter analysis proceeds from deductive ones.Secondly,considering that the F.E.M. together with the S.D.A. can be formulated as special techniques of the general Moment Method[6],they can generate spurious solutions depending on the fact if the necessary simple basis functions belong or not to the field of the operator of the eigenvalue problem.

In connection to this deconcerting phenomena,it is known that one free boundary point can give rise to one spurious solution.Thus,it will be more marked in the F.E.M. than in the S.D.A.since the first technique uses sub-domain basis while the second uses entire domain basis.In the F.E.M.a lot of free boundary mesh nodes (especially at the dielectric interfaces) can be met in

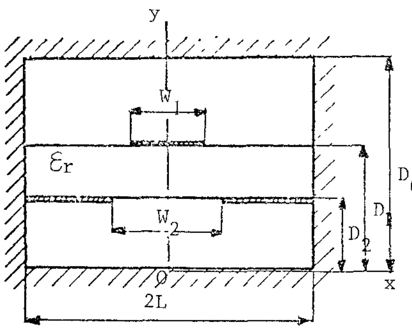

Fig.1. Suspended microstrip line with tuning septums

spite of the mirror symmetry x=0 that must be considered in the line cross section.Alternatly,by applying the S.D.A. to the suspended microstrip line with tuning septums and taking into account the mirror symmetry x=0, the number of free boundary points (at the edge of the strip and at the edge of the slot) cannot overstep two.

Using simultaneously the F.E.M.and the S.D.A.,it becomes possible to select physical and spurious solutions.Finally,this methodology can avoid misinterpretation of the numerical results.

THE FINITE-ELEMENT METHOD

In the F.E.M.,the line cross section is devided into a number of triangular sub-regions and the longitudinal electric and magnetic fields components are uniquely specified in terms of their values at the vertices.

The minimizing equations are written at each vertex and the resulting linear set is,in a matrix form

$$[A(\beta)][u] = \lambda(\beta)\,[B(\beta)][u]$$

where the matrix elements of $[A]$ and $[B]$ together with the eigenvalues $\lambda(\beta)$ are functions of the phase constant β .

A speciale procedure can increase the number of triangles near the sharp tips of the strip and of the slot for good description of the edges fields behavior.

For convergence and also for economy of nodes, a mixture of first and second order polynomials are used as sub-domain basis functions.

THE SPECTRAL DOMAIN APPROACH

The standard computational scheme uses either an impedance representation or an admittance one for matching, in the Fourier domain, the discontinuity and the continuity conditions at the strip interface and at the slot interface.The analysis of the suspended microstrip with tuning septums combines the computational advantages of both the impedance and the admittance representations by introducing the hybrid one.

Relationships between the Fourier transforms (superscript tilda $\sim$) of the tangential electric fields and the surface currents at the strip interface ($y=D_1$) and at the slot interface ($y=D_2$) are written in a matrix form

$$\begin{bmatrix}\tilde{E}_{tan}(D_1)\\ \tilde{J}(D_2)\end{bmatrix} = \begin{bmatrix}H(\beta)\end{bmatrix}\begin{bmatrix}\tilde{J}(D_1)\\ \tilde{E}_{tan}(D_2)\end{bmatrix}$$

The advantages of the present formulation lie in the possibility to approximate more accurately the aperture electric field in the slot together with the surface current distributions on the strip for describing a possible hybrid mode solution.

The choice of well-behaved entire basis functions satisfying the appropriate edge conditions in the Galerkin's procedure reduces both computing time and storage requirements.

COMPARISON BETWEEN THE TWO TECHNIQUES

The comparison has been made on a shielded line , the quasi-static characteristic impedance of its strip mode was previously estimated near 50 ohms. All dimensions of the line can be normalized to the substrate thickness $D=D_1-D_2$ and results can be plotted versus normalized frequency D/λ where λ is the free space wavelength.

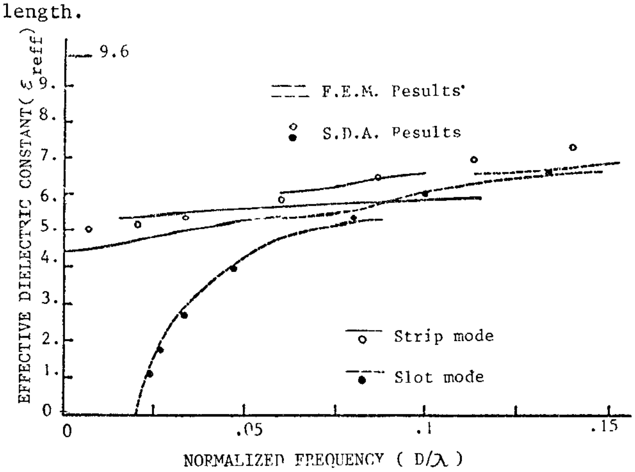

Fig.2. Comparison between F.E.T. and S.D.A results. $\varepsilon_r=9.6$; $D=D_1-D_2$; $D_0=8D$; $D_1=3D$; $D_2=2D$; $W_1=2D$ (strip width) ; $W_2=3D$ (slot width)

Fig.2 gives the effective dielectric permittivities of the strip and of the slot modes the transverse field configuration of which are sketched in Fig.6. The most important point to be made is that in the F.E.M., spurious modes appear still very close to physical ones and their coupling can prevent to deduce both the dispersion characteristics and the associated fields components. As a consequence, the equivalent characteristic impedances have to be considered as unattainable parameters in the F.E.M. Farther the coupling regions the agreement between the two techniques appear very good. In the S.D.A., similar limitations exist but they still take place at very high frequencies.

RESULTS ON FIELDS CONFIGURATION (S.D.A.)

Fields configuration can be partially described in terms of equivalent characteristic impedances by using power flow based definitions. For the strip mode, the power flow is associated with the total longitudinal strip current while for the slot mode, it is associated with the transverse slot voltage.

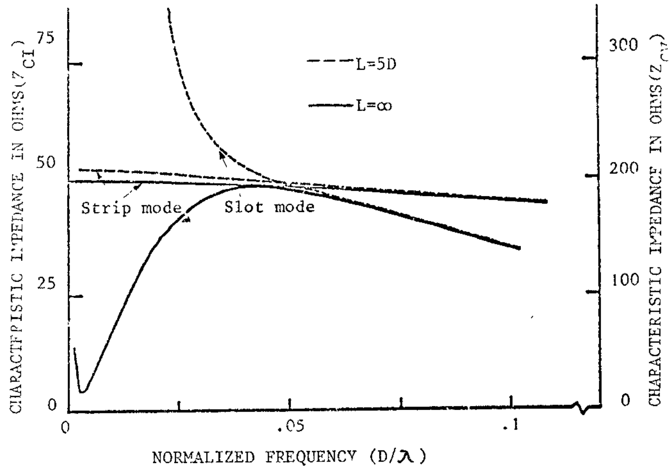

Fig.3.Equivalent characteristic impedances (S.D.A.) $\varepsilon_r=9.6$; $D=D_1-D_2$; $D_0=8D$; $D_1=3D$; $D_2=2D$; $W_1=2D$ (strip width) ; $W_2=3D$ (slot width)

Fig.3 illustrates the lateral closing effect on the two modes fields configurations. As expected, the most important change occurs near the cut-off of the slot mode. Longitudinal electric and magnetic fields variations can be deduced from Fig.6. The TE character of the slot mode near cutoff is clearly demonstrated. Alternatly, the strip mode field configuration appears quite stable in the very large frequency domain of investigation (up to 30 GHz if D=1 mm).

For sake of completeness, Fig.4 and Fig.5 describe the top and bottom closing effect on the strip mode and on the slot mode parameters respectively.

CONCLUSION

The S.D.A. appears less sensible than the F.E.M. in regard to the coupling phenomena between spurious and physical modes. It can be applied for solving the full wave treatment of very complicated strip pattern. The F.E.M. can help the S.D.A. in the choice of well-behaved basis functions.

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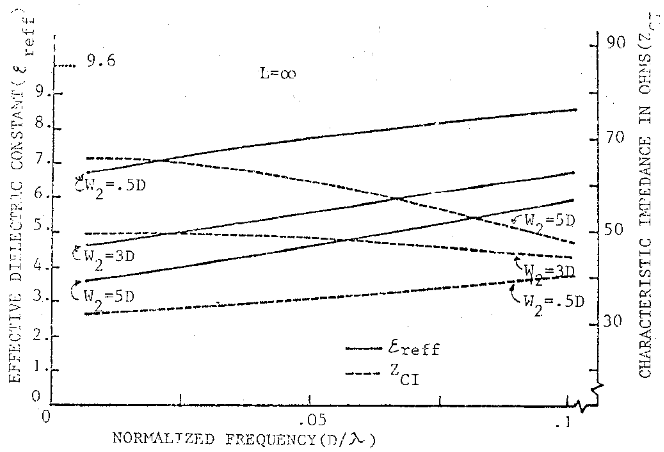

Fig.4. Effective dielectric constant and equivalent characteristic impedance of the strip mode. ε_r=9.6 ; D=D_1-D_2 ; D_0=8D ; D_1=3D ; D_2=2D ; W_1=2D (strip width) ; W_2 (slot width) as a parameter

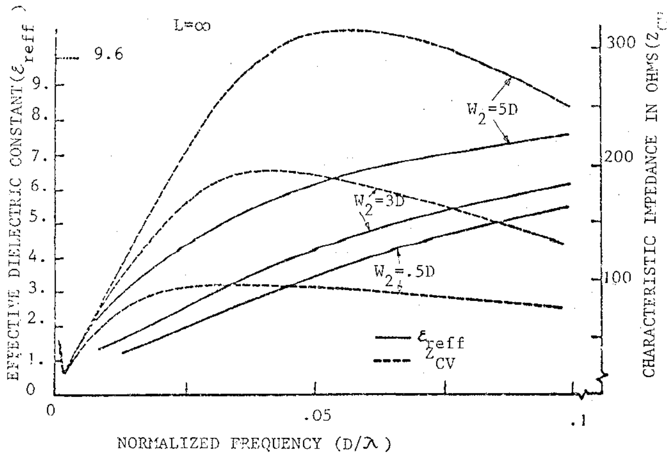

Fig.5. Effective dielectric constant and equivalent characteristic impedance of the slot mode. ε_r=9.6 ; D=D_1-D_2 ; D_0=8D ; D_1=3D ; D_2=2D ; W_1=2D (strip width) ; W_2 (slot width) as a parameter

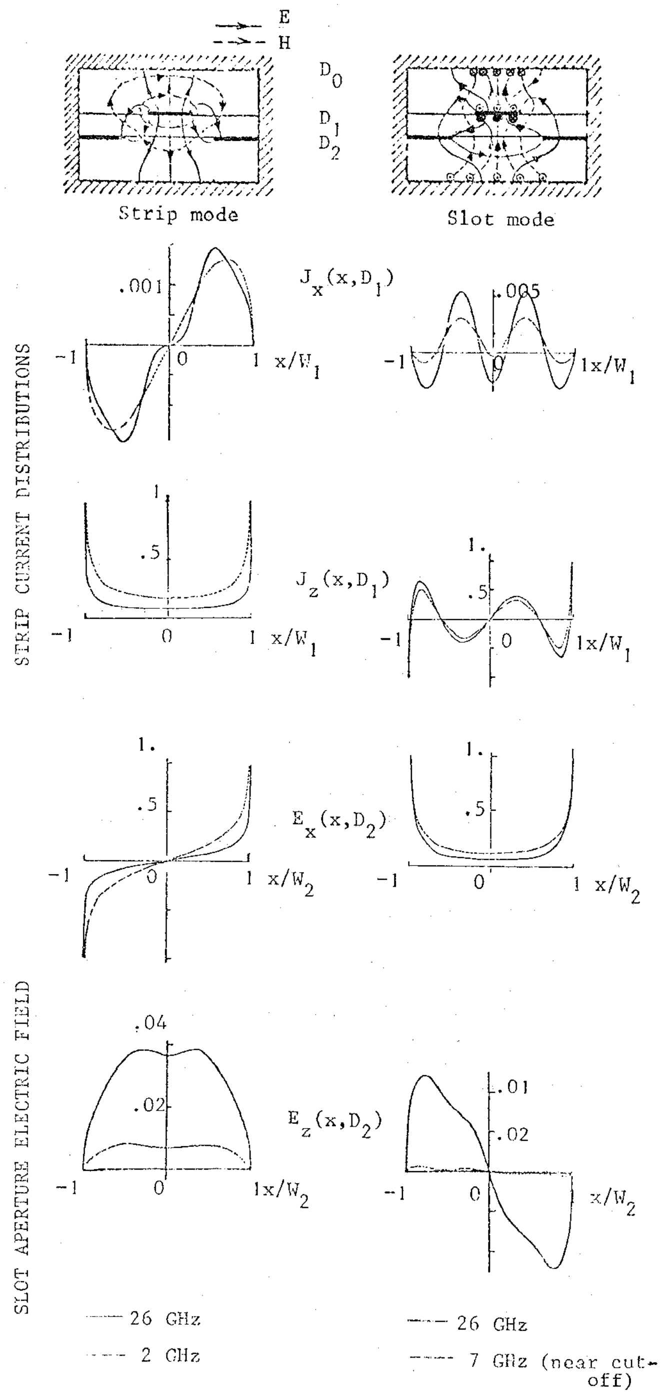

Fig.6. Mode fields components (S.D.A.) ε_r=9.6 ; D=D_1-D_2 ; D_0=8D ; D_1=3D ; D_2=2D ; W_1=2D ; W_2=3D ; L=5D.