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Modeling and Analysis of Anisotropic and Non-linear Structures Using 3D-(SCN) TLM

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ABSTRACT:

The Transmission Line Matrix (TLM) method has been modified to include structures that are non-linear, anisotropic or both. The new development offers the possibility of solving a wide range of problems which include non-linear dielectric, ferrites, plasma and semiconductor regions.

1. THEORETICAL SUMMARY

In the symmetric condensed node(SCN) formulation of the TLM problem, the dielectric properties of the media can be simulated by three open circuited stubs one, for each direction of propagation and the magnetic properties by three short circuited stubs. Losses are simulated by three terminated lines.

A. ANISOTROPIC DIELECTRIC MEDIA

In the modified algorithm the anisotropy of a dielectric media is taken care of by making the characteristic admittance of the open circuit stubs having different values, coresponding to the permitivity values in each direction, i.e if the permitivity of a lossless media is given by the following tensor:

$$\varepsilon = \begin{vmatrix} \varepsilon_{xx} & 0 & 0 \\ 0 & \varepsilon_{yy} & 0 \\ 0 & 0 & \varepsilon_{zz} \end{vmatrix}$$

then, the coresponding normalized admittance will be given by:

$$Y_x = 4\,(\,\varepsilon_{xx} - 1\,)$$
$$Y_y = 4\,(\,\varepsilon_{yy} - 1\,)$$
$$Y_z = 4\,(\,\varepsilon_{zz} - 1\,)$$

Similarly, for anisotropic magnetic media the characteristic impedances of the short circuited stubs have three different values coresponding to the value of the relative permeability in each direction.

B.NON-LINEAR DIELECTRIC MEDIA

In the modified algorithm the non-linearity of the dielectric media is taken care of by making the characteristic admittance of the open circuited stubs at each node a function of the electric field at that node. If the relative dielectric constant $\varepsilon_r(V)$ is now a function of the voltage and the characteristic admittance of each open circuited stub is given by

$$Y(E) = 4\,(\varepsilon_r(V) - 1)$$

The scattering matrix at each node is now also a function of V and following the notation in [1,2] the scattering and connecting processes are given by

$$V^r_k = S(V^i_k)\,V^i_k$$

$$V^i_{k+1} = C\,V^r_k$$

where S(V) is the scattering matrix, V^r and V^i are the reflected and incident voltages and k is the solution time point, while C is the connection matrix.

C.NON-LINEAR REFLECTIVE SURFACES

A similar process is applied to include reflections for non-linear surfaces. In this case the reflection coefficient (E,H) is now made a function of the electric or magnetic fields.

D.NON-LINEAR MAGNETIC MATERIALS

The procedure is identical to that in a above except that short circuited stubs are used and the magnetic field is used to update the permeabilities.

E. NON-LINEAR CONDUCTIVITY

A similar procedure is used with three terminated transmission lines. The conductivity could either be a function of the electric or magnetic fields.

2. EXAMPLES

Many examples have been solved using the above algorithm with no problems in stability. In all the examples continuous input signals were used.

A. DIODE MIXER

A simulation of a diode mixer in a microstrip is shown in Fig. 1. The diode is simulated by a non-linear dielectric region with the non-linear function

$$\varepsilon_r = 2.3 (1 + \tanh (E))$$

Two sinusoidal input signals were applied at 1GHz and 1.6 Ghz . The spectrum of the input and output are shown in Figs 2a and 2b.The mixing effect of the non-linearity is clearly demonstrated.

B. MICROSTRIP ON SAPPHIRE SUBSTRATE

The substrate geometry and coordination of a microstrip on sapphire substrate are shown in Fig. 3. The principal relative permitivity of sapphire are chosen to be $\varepsilon_{xx} = \varepsilon_{zz} = 9.4$ and $\varepsilon_{yy} = 11.6$ the microstrip was with W = 0.4 mm, h = 0.2 mm and with length l = 5.0 mm.
The characteristic impedance of the sapphire microstrip was calculated from the TLM results and shown in Fig. 4. The results are compared with those calculated using rigorous mathematical analysis [3], Fig. 5. Good agreements was obtained between the two sets of results.

3. CONCLUSIONS

The TLM method has been modified to include non-linear and anisotropic media. A wide variety of applications are possible. Non-linearities in dielectric, magnetic and anisotropic media can be simulated. The effects of both propagation and reflection in non-linear media can be simulated.

4. REFERENCES

[1] P.B. Johns, "A symmetrical condensed node for the TLM method", IEEE Transactions on Microwave Theory and Techniques, Vol. 35, 1987, pp. 370-377.

[2] Cheuk-yu Edward Tong and Yoshiyuki Fujino, "An efficient algorithm for Transmission Line Matrix analysis of electromagnetic problems using the symmetrical condensed node", IEEE Transactions on Microwave Theory and Techniques, Vol. 39, August 1991, pp. 1420-1424.

[3] R. P. Owens, J. E. Aitken, and T. C. Edwards, "Quasi-static characteristics of microstrip on an anisotropic sapphire substrate," IEEE Trans. Microwave Theory Tech., vol. MTT- 24, pp. 499-506, Aug. 1976.

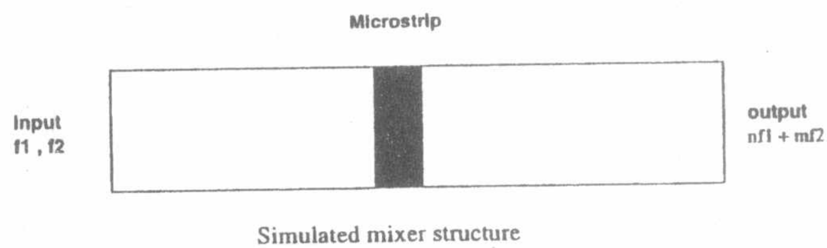

Fig. 1 Simulated mixer structure.

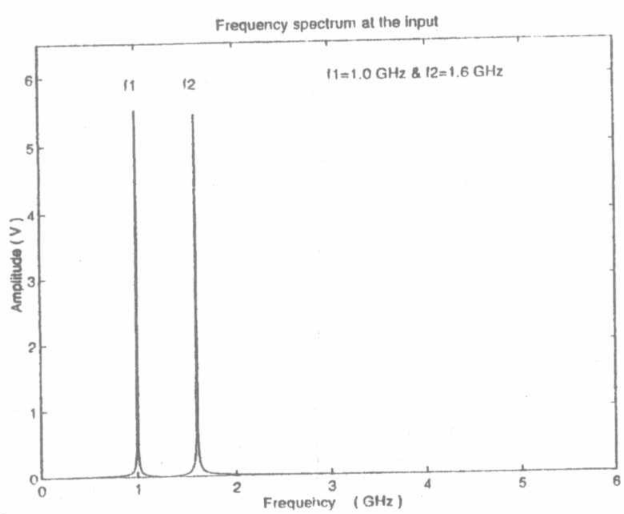

Fig. 2-a Freq. spect. at the input.

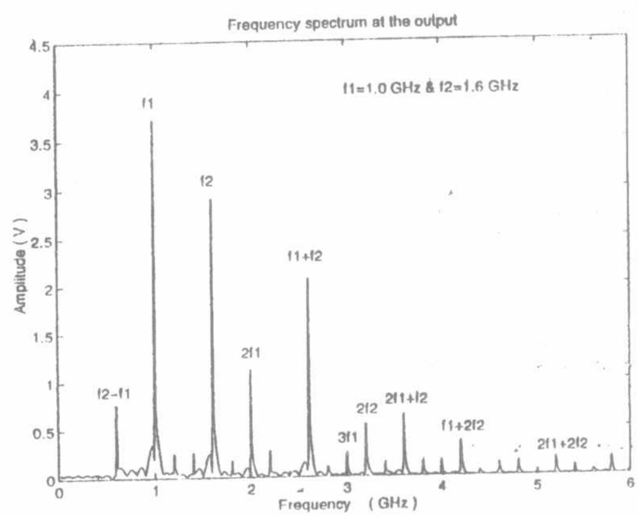

Fig. 2-b Freq. spect. at the output.

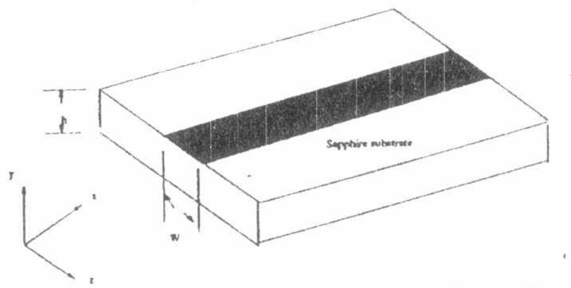

Fig. 3 Microstrip on sapphir substrate.

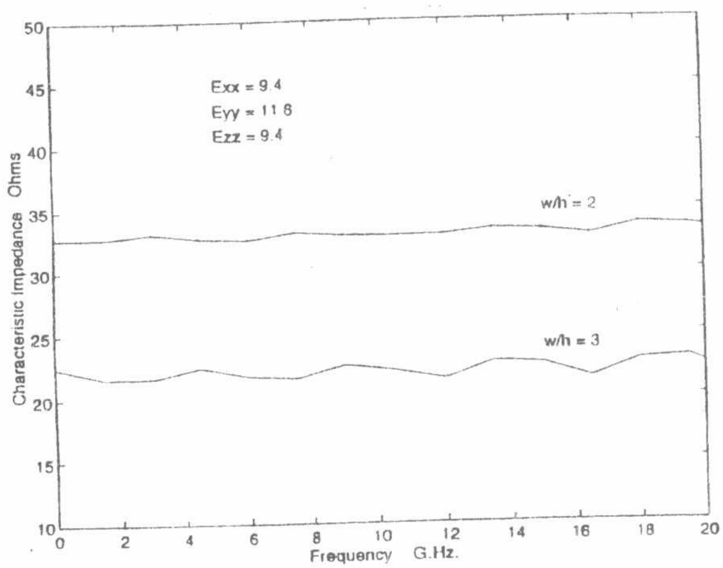

Fig. 4 Result from TLM program.

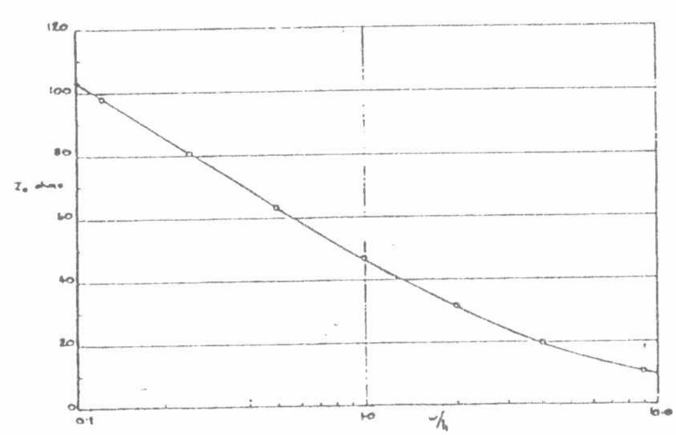

Fig. 5 Result from OWENS et al MTT-24.