THREE-DIMENSIONAL NUMERICAL ANALYSIS OF MICROWAVE CAVITIES USING THE TLM METHOD

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ABSTRACT

The TLM method of numerical analysis provides a solution for six-component electromagnetic fields in three space dimensions and time. The universal program is economical and easy to formulate and all the features of a problem are read in as data. The method has been applied to inhomogeneous lossy cavities and cavities containing microstrip discontinuities.

The time-dependent numerical solution of Maxwell's equations for three field components in two space dimensions using a transmission-line matrix (TLM) has been extensively explored (reference 1 for example). The basic scattering element in the two dimensional matrix consists of a four terminal shunt connected junction of ideal transmission-lines with a fifth line in the form of a stub of variable admittance.

If the voltage on the transmission-lines represents the E field in the propagation medium, the set of Maxwell's equations described in the x-y plane (for example) are,

$$\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y} = \varepsilon' \frac{\partial E_z}{\partial t}$$

$$\frac{\partial E_z}{\partial y} = -\mu \frac{\partial H_x}{\partial t}$$

$$\frac{\partial E_z}{\partial x} = \mu \frac{\partial H_y}{\partial t}$$

when ε' is the complex permittivity.

If, however, a series connected junction is now considered, still with the voltage representing the E field, the set of Maxwell's equations described are,

$$\frac{\partial E_y}{\partial x} - \frac{\partial E_x}{\partial y} = -\mu \frac{\partial H_z}{\partial t}$$

$$\frac{\partial H_z}{\partial y} = \varepsilon \frac{\partial E_x}{\partial t}$$

$$\frac{\partial H_z}{\partial x} = -\varepsilon \frac{\partial E_y}{\partial t}$$

Series and shunt nodes may now be arranged in the x-y, x-z and y-z planes to give a basic three-dimensional scattering element which describes the complete set of Maxwell's equations in three-dimensional space and time.(2) There is a shunt node in each of the co-ordinate planes, the voltages across which represent E_x, E_y and E_z, and a series node in each of the planes with currents representing H_x, H_y and H_z. The three-dimensional geometry of a problem is made up by connecting many such elements together. Boundaries are simulated by introducing reflecting planes or by short-circuiting or open-circuiting individual nodes. The boundaries may be made lossy by using imperfect reflection coefficients(3) or by introducing losses at the nodes. Any of the six field components may be excited by introducing impulses at various points in the network. These impulses travel along the ideal TEM lines and are scattered at the individual two-dimensional nodes according to their appropriate scattering equations. In this way the time domain propagation of all six field components is obtained simultaneously. A solution for any (or all) of the field components is available anywhere within the geometry of the problem. The output consists of a stream of impulse amplitudes corresponding to the output impulse function for the particular field component under consideration. For analysis purposes it is usual to take the Fourier Transform of this function to yield the response to an excitation varying sinusoidally with time.

The method has been used to calculate the resonant frequencies and power decay times of cavities partially filled with lossy dielectric(3), and also to find the dispersion characteristics of microstrip lines. In all cases where comparisons can be made there has been excellent agreement.

The method is illustrated here by calculating the resonant frequencies of cavities containing microstrip with an abrupt change in width. The geometry of the problem and the results are shown in Figure 1. The numerical results are compared with a curve calculated by TEM analysis with a capacitative discontinuity given by Farrar and Adams(4). It is clear that in this problem the effect of dispersion in the microstrip line is far more important than the discontinuity itself.

The TLM numerical method program used for these results and for the other cavities is quite general and describes media of variable permittivity, permeability and losses(conductivity from zero to infinity). All boundaries are read in as data. The computer storage required is basically 12 real numbers per three-dimensional element. The computer time is typically 150s for 200 frequency samples for the cavities of Figure 1. The formulation of the program is relatively easy and the solution of simultaneous equations is not required. The whole program including subroutines has been written in 110 lines of FORTRAN.

The authors believe that a method as general and easy as the TLM technique is quite unique. It is hoped that the method will provide a useful computer-aided design tool for microwave devices to be used in the service of man.

REFERENCES

1. JOHNS, P. B., 'The solution of inhomogeneous waveguide problems using a transmission-line matrix', IEEE Trans., 1974, MTT-22, pp 209-215.

2. AKHTARZAD, S. and JOHNS, P. B., 'Transmission-line matrix solution of waveguides with wall losses', Elec. Lett., 1973, 9, pp 335-336.

3. AKHTARZAD, S. and JOHNS, P. B. 'Solution of 6-component electromagnetic fields in three space dimensions and time by the TLM method', Elect. Lett., 1974, 10, pp 535-537.

4. FARRAR, A. and ADAMS, A. T., 'Matrix methods for microstrip three-dimensional problems', IEEE Trans., 1972, MTT-20, pp 497-504.

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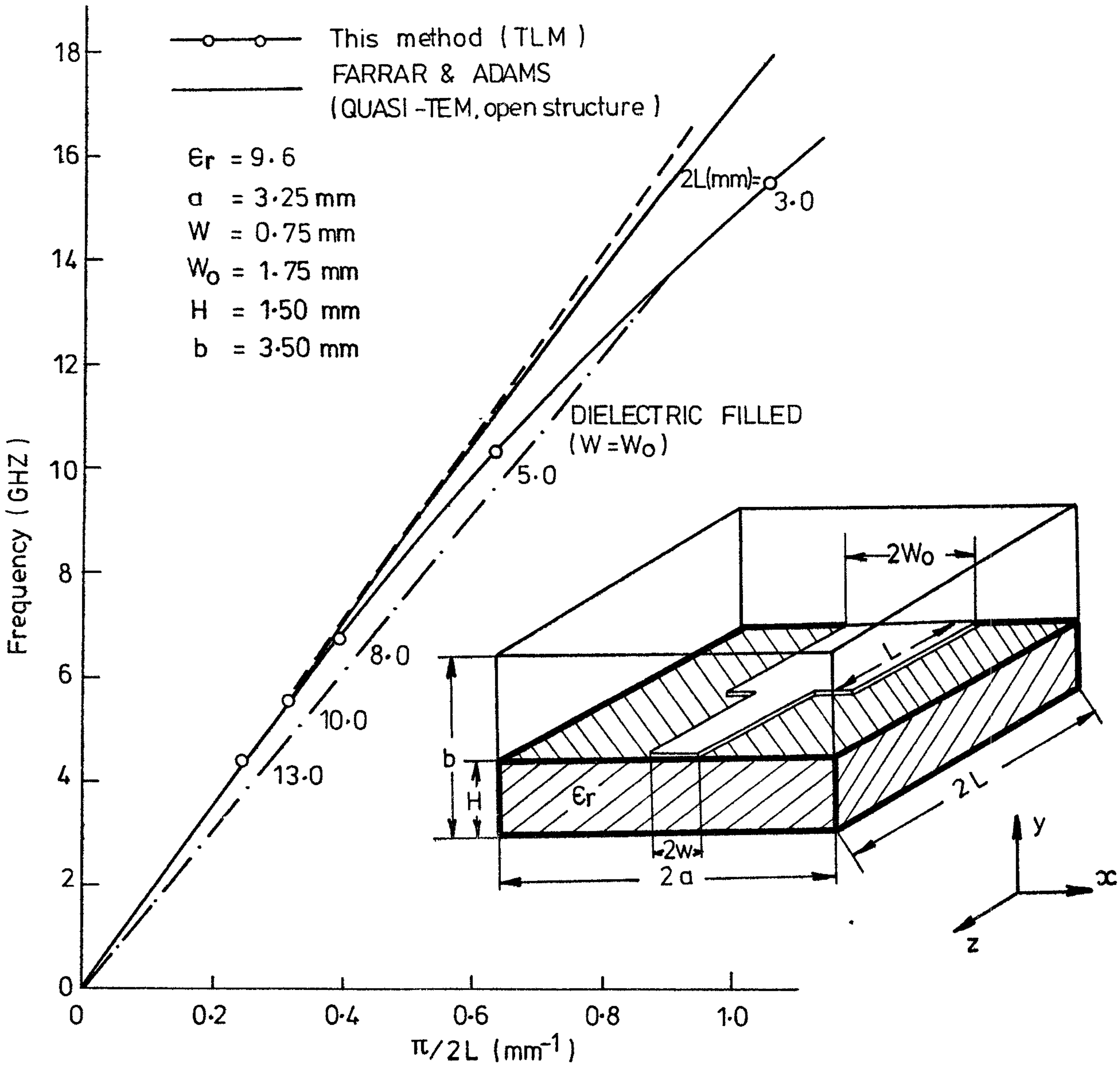

Fig. 1. Dispersion characteristic of microstrip with change in width