An Improved TLM Full-Wave Analysis Using a Two Dimensional Mesh

by

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Abstract

An improved TLM full-wave analysis method based on a novel TLM node is described. Compared to the conventional TLM full-wave analysis, which requires a three dimensional mesh, this method utilizes only a two dimensional transmission line mesh to fully characterize dispersive guided structures. This leads to a significant reduction in CPU time and memory space, and makes the TLM method an even more attractive tool in the analysis of arbitrarily shaped guided structures. Numerical results are given for shielded and suspended coupled dielectric waveguides.

1. Introduction

The transmission line matrix (TLM) method is now widely established as a versatile numerical tool in full-wave analysis of guided structures[1][2]. It involves resonating a section of the guided structure by placing shorting planes along the axis of propagation. The distance L between the shorted planes then equals half of the guided wavelength of the mode at the frequency given by the resonant frequency of the cavity. By changing the distance L, which changes the phase constant $\beta = \pi/2L$, and repeating the calculation of the resonant frequency of the cavity for each β , the entire dispersion characteristic can be obtained. This conventional approach requires a three dimensional mesh and modification of it for each β .

This paper introduces an improved TLM full-wave analysis method based on a novel TLM node. In contrast to the conventional TLM full-wave analysis, this method only involves a two dimensional transmission line mesh and the whole dispersion curve can be obtained in one run of calculation. This leads to considerable reduction of both CPU time and memory space required. In the following, a brief description of this method will be present and some numerical results are given for shielded suspended coupled dielectric waveguide.

2. A new TLM node for full-wave analysis

The new TLM node is shown in Fig.1. It consists of a conventional symmetric condensed node[3][4] and the following relationship between the incident and reflected voltages on the z-axis arms:

$$\begin{aligned} {}_{k+1}V_8^i &= \exp(-j\beta\Delta l)\,{}_kV_4^r \\ {}_{k+1}V_9^i &= \exp(-j\beta\Delta l)\,{}_kV_2^r \\ {}_{k+1}V_2^i &= \exp(+j\beta\Delta l)\,{}_kV_9^r \\ {}_{k+1}V_4^i &= \exp(+j\beta\Delta l)\,{}_kV_8^r \end{aligned} \qquad (1)$$

where ${}_kV_4^r$, ${}_kV_2^r$, ${}_kV_9^r$, ${}_kV_8^r$ and ${}_{k+1}V_4^i$, ${}_{k+1}V_2^i$, ${}_{k+1}V_9^i$, ${}_{k+1}V_8^i$, respectively, are the reflected voltages at time $k\Delta t$ and the incident voltages at time $(k+1)\Delta t$ on the lines 4,2,9,8. $\Delta t = \Delta l/c$, Δl is the

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mesh parameter, c the velocity of light. The derivation of equation (1) is obvious recalling that the z-axis dependent factor of the guided mode is $\exp(j\beta z)$, here β is the phase constant. Thus , if the mode has been established, the reflected or incident voltages along the z-axis at two adjacent nodes have only a phase difference of $\beta\Delta l$ at the resonant frequency. The incident voltages on the lines 2 and 4 at time $(k+1)\Delta t$ are the reflected voltages of the next node along the negative z-axis direction at the time $k\Delta t$, which in turn are identical to the reflected voltages on the lines 9 and 8 except there is an increase of $\beta\Delta l$ in the phase. Similarly, the incident voltages on the lines 9 and 8 at time $(k+1)\Delta t$ are the reflected voltages of the next node along the positive z-axis direction at the time $k\Delta t$, which are also identical to the reflected voltages on the lines 2 and 4 except there is a decrease of $\beta\Delta l$ in the phase. In other word, the z-axis arms of the three dimensional node are directly connected by a non-reciprocal phase shift. The reflected voltages on one z-axis arm at time $k\Delta t$ will propagate along this phase shift and then become the incident voltages on the other arm at time $(k+1)\Delta t$. So the three dimensional node is closed in the z-axis direction and the iteration procedure for the impulse propagation in space need only be carried out in x and y direction. This equivalently reduces the three dimensional line mesh to only a two dimensional mesh and hence reduces considerably the CPU time and memory space required. Furthermore, since β enters the calculation as input data, the whole dispersion characteristic (phase constant versus frequency) can be obtained in one run of calculation. $\beta=0$ will result in the cutoff frequency of the modes.

3. Numerical results

Various checks are made to validate this new TLM node. In the first comparison, the dispersion curve of empty, fully or partially dielectric loaded rectangular waveguide are calculated since those results can be obtained analytically. It was found that the difference between our results and the exact ones are within 1% in all cases provided that the requirement $\Delta l/\lambda \leq 0.1$ is satisfied . Further calculations for more complicated structure are shown in Fig.2. The numerical results of the dispersion characteristic of a shield suspended coupled dielectric guide are present in Fig.2[5]. It is obvious that the TLM method is in good agreement

4. Conclusion

We have present an improved TLM full-wave analysis method which reduces the three dimensional mesh normally required for dispersive structure to a two dimensional mesh. This leads to a drastic reduction of the CPU time and memory space required and enables us to apply the TLM method to analyze large and complicated structure.

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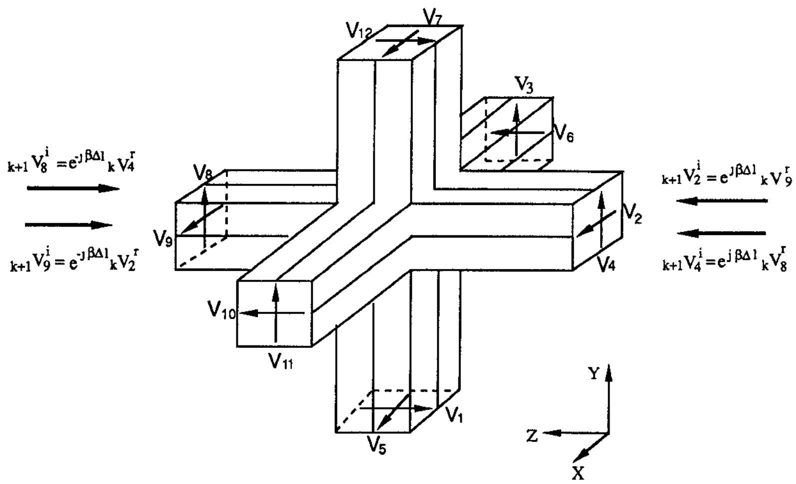

Fig.1 The new TLM node for full wave analysis of guided structure

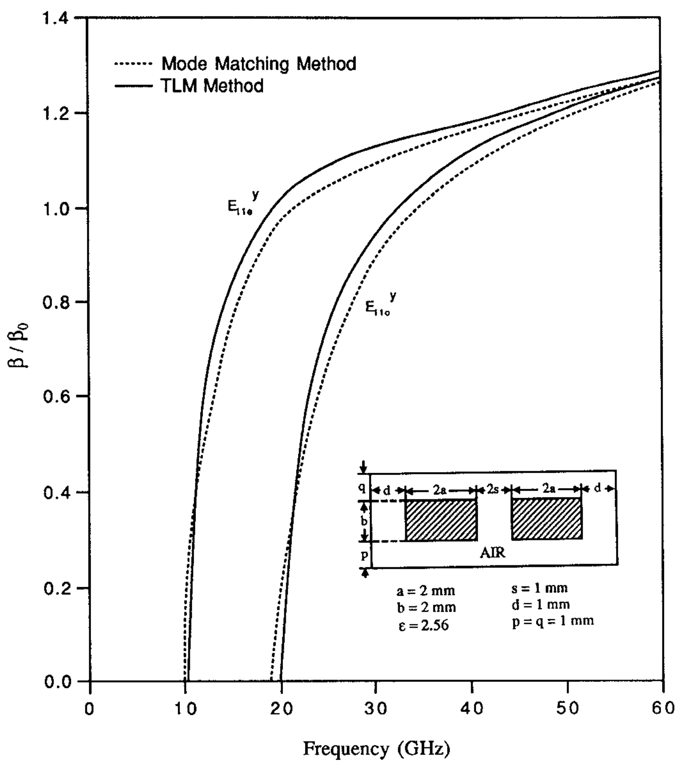

Fig.2 Variation of β / β_0 versus frequency in a shielded suspended coulped dielectric guide