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Transient Analysis of Interline Crosstalk in Tapered Transmission Lines with a Method of Equivalent Cascaded Chain of Subnetworks

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ABSTRACT

The transient analysis of interline crosstalk in tapered transmission lines is presented in this paper. It is considered that the tapered transmission lines are equivalent to a cascaded chain of subnetworks which are made of equal-lengthed short sections of uniform lines. The advantages of this method are that the transient analysis can be implmented easily in computer-aided circuit analysis codes such as SPICE, and any nonlinear loads may be easily incorporated with the existing elements in SPICE. Two types of tapered transmission lines are considered in this paper for comparison. From the numerical results, it is shown that exponential tapered transmission lines is better than straight tapered transmission lines in reducing interline crosstalk.

I. INTRODUCTION

In microwave engineering, tapered transmission lines shown in Fig.1 are widely used for the purpose of impedance matching. Many authors have contributed significantly to the study of tapered transmission lines [1]-[4]. Most papers are considering the ringing effect due to inappropriate impedance matching, little publication has been revealed on the transient analysis of interline crosstalk that may cause signal distortion or fault logic switching severely in tapered transmission lines.The purpose of this paper is to provide a alternative for tapered transmission lines that is simple to implement in standard computer-aided circuit analysis codes such as SPICE. For comparison, two types of tapered transmission lines, exponential tapered transmission lines (ETTL) and straight tapered transmission lines (STTL), are considered in this paper. As shown in Fig.2, it is considered that the tapered transmission lines are equivalent to a cascaded chain of subnetworks which are made of equal-lengthed short sections of uniform lines if the number of the subnetworks is large enough to approximate the tapered transmission lines fully. The model used of each subnetwork is two-wire delay lines model [5] proposed by K.D.Marx and R.I.Eastin. After the inductance or capacitance matrix of each subnetwork is evaluated, each subnetwork can be obtained easily, and the overall tapered transmission lines can be approximated subsequently by cascading total subnetworks. From the numerical results, it is shown that exponential tapered transmission lines is better than straight tapered transmission lines in reducing the interline crosstalk.

II. THEORY

Conside the transmission lines under TEM or quasi-TEM mode assumption, the transmission line equations are given as

$$\frac{\partial}{\partial z}V(z,t)+L\frac{\partial}{\partial t}I(z,t)+RI(z,t)=0 \text{ and } \frac{\partial}{\partial z}I(z,t)+C\frac{\partial}{\partial t}V(z,t)+GV(z,t)=0$$

for two-conductor transmission lines considered in this paper, the 2×2 matrices L, C, R, G are the per-unit-length inductance, capacitance, resistance, and conductance matrices, respectively, that contain the cross-sectional dimensions and properties of the lines. For lossless transmission lines in a homogeneous surrounding medium under considerations, we have $R=G=0$, and

$$LC = \mu\varepsilon = \frac{1}{\upsilon^2}$$

where υ is the propagation speed in the medium, and μ, ε are permeability and permittivity, respectively. After the inductance or capacitance matrix of each subsection is evaluated, each subnetwork using the two-wire delay lines model [5] can be obtained subsequently. The characteristic impedance of i-th subnetwork as shown in Fig.2 is in terms of elements of characteristic admittance matrix

$$Z_i : Z_{\alpha\beta i} = \frac{-1}{Y_{\alpha\beta i}} \quad \text{for } \alpha \neq \beta, \beta \neq 0 \text{ and}$$

$$Z_{\alpha 0 i} = \frac{1}{\sum_{\beta=1}^{2} Y_{\alpha\beta i}}$$

where the characteristic admittance matrix is given by $Y_i = \upsilon C_i$, where C_i is the per-unit-length capacitance matrix of i-th subnetwork. The general subnetwork using two-wire delay lines model with length d and time delay $Td = d/\upsilon$ is shown in Fig.3. After each subnetwork is obtained, the overall tapered transmission lines can be obtained by cascading all subnetworks.

For the exponential tapered transmission lines (ETTL) considered as shown in Fig.1, the spacing between two conductors satisfies the relation $S_L = S_0 \cdot \exp(ETF \cdot L)$, where S_L, S_0 are spacing at z = L and z = 0, respectively. And the condition of exponential tapered spacing between two conductors of ETTL is defined as exponential tapered factor (*ETF*). For $ETF = 0$, it is the case of uniform transmission lines.

III.NUMERICAL RESULTS

As shown in Fig.1, an example consider a #20 gauge (radius = 16 mils) two-conductor transmission lines separated 2cm at Z = 0 and suspended height h = 2 cm above a ground plane with L = 4.674m. A source consisting of a source resistor R_s and a source voltage Vs(t) is connected to a load R_L via a generator conductor. Two other terminations, represented by resistors R_{NE} and R_{FE}, are also connected by a receptor conductor. The subscripts *NE* and *FE* refer to "near end" and "far end", respectively. The objective in the transient analysis of interline crosstalk is to determine the near-end and far-end voltages V_{NE} and V_{FE} which reference to the groune plane. For approximate the ETTL fully, the number of the subnetworks choosed 8 is enough for the *ETF* considered from 0 to 0.5. In this example, delay line length and corresponding time delay of each subnetwork are 58.38cm and 1.95ns, respectively. The input voltage source is a square pulse in order to make the analysis more practical as shown in Fig.4. The crosstalk voltage at near-end in ETTL as *ETF* at 0.1, 0.3, and 0.5, also with the case of straight tapered transmission lines (STTL) keeping same S_L are shown in Figs.5(a), 6(a), and 7(a), respectively. The far-end case are shown in Figs.5(b)-7(b). It is apparent that as *ETF* increases, the overall crosstalk voltage level for both near-end and far-end subsides. It is also noted that the voltage magnitude difference of the peak magnitudes of crosstalk voltage between ETTL and STTL becomes smaller for both near-end and far-end case as *ETF* increases. As the time increases, the voltage magnitude oscillates and damps to zero gradually.

V. CONCLUSION

This paper has presented a method of equivalent cascaded chain of subnetworks for transient analysis of interline crosstalk in tapered transmission lines. The method is easily implemented in SPICE and offers an alternative to the other methods in simulating tapered transmission lines. From the numerical results, this paper revealed that the exponential tapered transmission lines is better than the straight tapered transmission lines in reducing the interline crosstalk if we appropriately choose the value of exponential tapered factor that dominates the crosstalk if we appropriately choose the value of exponential tapered factor that dominates the condition of exponential tapered spacing between two conductors. Further investigations on the tapered transmission lines should take account of nonlinear load and lossy lines case in reducing the interline crosstalk.

VI. REFERENCES

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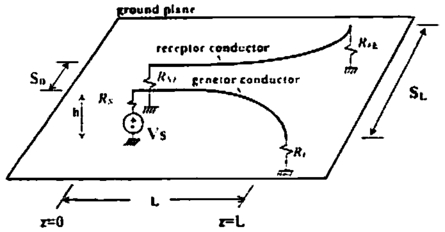

Fig.1 The tapered transmission lines system

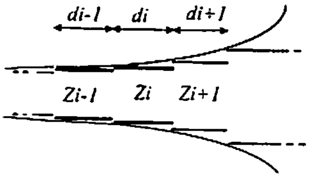

Fig 2(a)

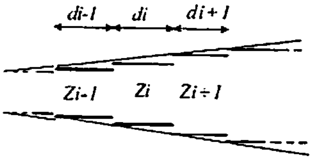

Fig 2(b)

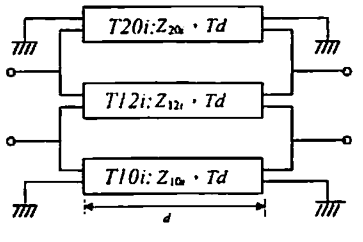

Fig.3 The two-wire delay lines model for *i*-th subnetwork.

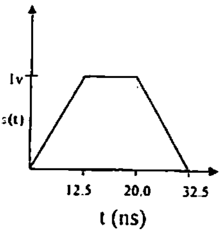

Fig.4 The input voltage source waveform.

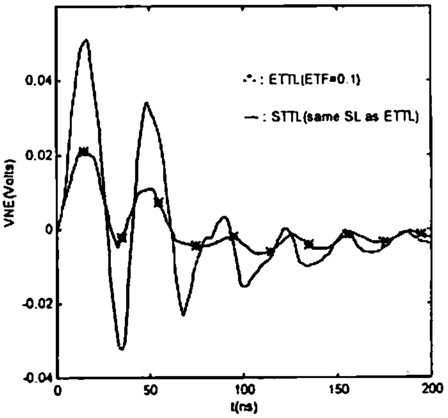

Fig.5(a)

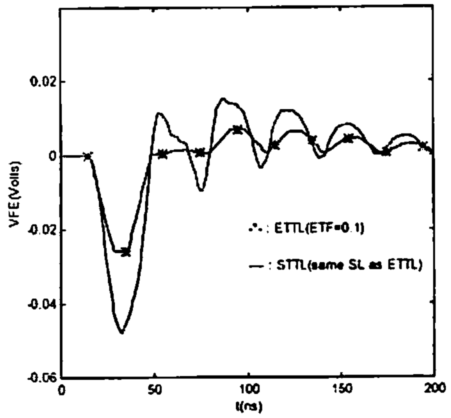

Fig.5(b)

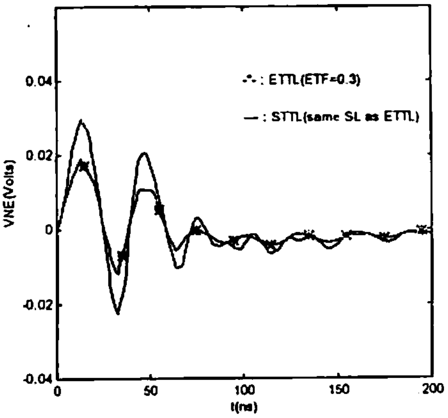

Fig.6(a)

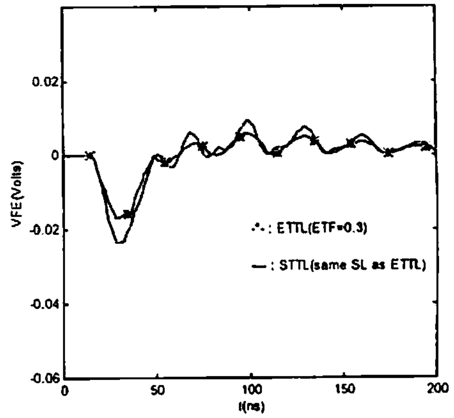

Fig.6(b)

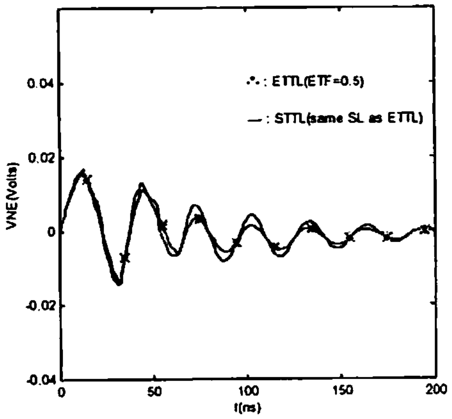

Fig.7(a)

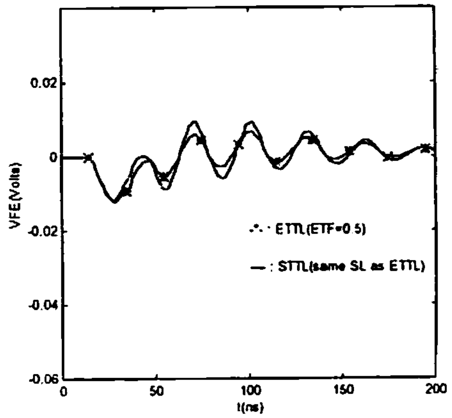

Fig.7(b)