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FAR END CROSSTALK REDUCTION BETWEEN PARALLEL MICROSTRIPLINES USING U SHAPED GUARD TRACE

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ABSTRACT

The increasing demand for high speed electronic circuits leads the printed circuit board designers to face more electromagnetic coupling and radiation problems. The guard shield is one of the methods to minimize the electromagnetic coupling between adjacent microstriplines on a high speed printed circuit board. A novel U shaped guard shield is proposed to reduce far end crosstalk and near end crosstalk. This paper analyses the performance of various guard intervening schemes between two signal lines using FDTD method. The numerical results are verified by Ansoft HFSS simulation results. The U shaped guard traces reduces both near end crosstalk and far end crosstalk by approximately 45% than conventional guard traces.

Keywoeds: crosstalk, microstriplines, U shaped guard trace, FDTD.

1. INTRODUCTION

Now a day's circuit dimensions are becoming reduced and frequency of operations is getting increased in a high frequency system. At this level, interconnects become more vulnerable to signal integrity problems in a high frequency printed circuit board. So designing an interconnect in a proper way to avoid this signal integrity problem is a main issue. Generally microstrip lines are used for chip to chip interconnect on high speed printed circuit board. In parallel microstriplines, crosstalk induces at both near end and far end of victim line when a signal is applying at one end of aggressor line. The near end and far end crosstalk induced by the difference between capacitive coupling and inductive coupling between two lines. Various methods have been proposed to reduce crosstalk and also reported in [1]-[5]. One of the general solution to reduce crosstalk is to provide a guard shield between two lines. The conventional guard trace is not more effective because it could not maintain constant potential throughout the entire line [1]. Alternatively, via stitched guard also used to reduce crosstalk effectively, but it is not suitable for backplane routing [2]. A guard trace with serpentine form have been proposed and published in [4]. In this work, U shaped serpentine guard trace is proposed to reduce both far end crosstalk and near end crosstalk by means of making 45^0 bend rather than 90^0 bend. It helps to reduce excessive inductance and capacitance. Excess capacitance causes the impedance to be lower in the corners than the segments. This can be significant if there are many corners or when signaling at high speeds. In this paper, these structures are analyzed using Finite Difference Time Domain (FDTD) method. FDTD method is one of the popular computational methods using differential time domain numerical modeling technique to calculate electric (E) and magnetic (H) fields. It covers a wide range of frequency over a single simulation run. In this numerical simulation, the entire problem is transformed into a computational domain and E and H fields are calculated using a leap-frog algorithm. From E and H fields, far end crosstalk and near end crosstalk are calculated interms of S parameters by simple numerical formulas. The various microstripline structures are also simulated in the electromagnetic simulation tool Ansoft HFSS [6]. There is a good agreement exists between the simulated and analytical results.

2. PROPOSED STRUCTURE

Figure-1 shows a pair of coupled microstriplines withour guard trace. This can be modeled by uniformly distributed inductance and capacitance. The aggressor line is called as n active line in which signal is applied and the victim line is called as quiet line in which crosstalk voltage is induced. This induced crosstalk voltage depends on the capacitive and inductive coupling ratios.

$$V_{fext} = 1/2\,(\frac{C_m}{C_T} - \frac{L_m}{L_S}).\,TD.\frac{dV_a(t-TD)}{dt} \tag{1}$$

where TD is the propagation time through the transmission line. $V_a(t)$ is applied voltage at the aggressor line [1].

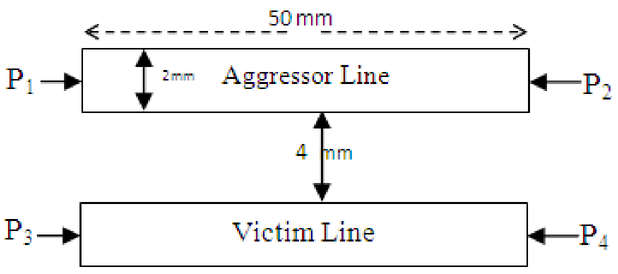

Figure-1. Coupled Microstriplines without Guard.

The inductive coupling is more than capacitive coupling in inhomogeneous microstrip lines. Figure-2 depicts the coupled microstrip lines with guard trace, in which the width of the guard trace is same as that of coupled lines. A general way to reduce crosstalk is to insert a shield between two lines, which is a bare transmission line terminated at both ends. The conventional guard reduces far end crosstalk, but it can not maintain a constant potential throughout the entire line. Figure-3 shows a serpentine guard, in which the combinations of horizontal and vertical sections are repeated along the length of the line. This structure helps to reduce far end crosstalk without increasing inductive coupling.

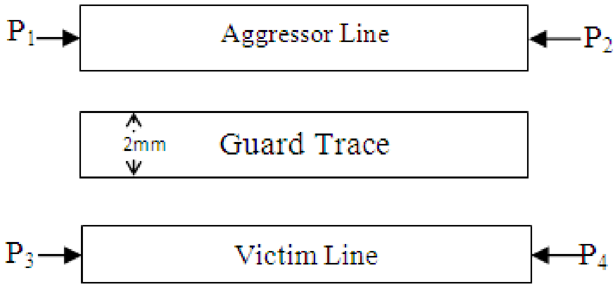

Figure-2. Parallel Microstripline Guard Trace.

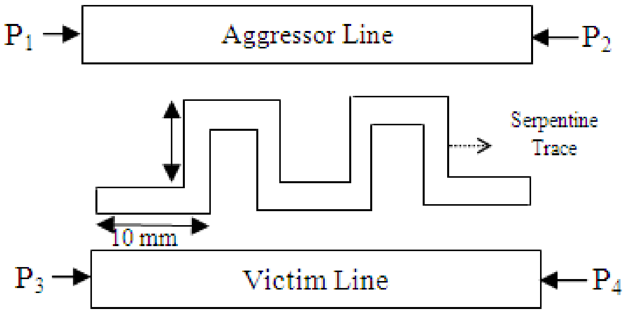

Figure-3. Parallel Microstripline with Serpentine Guard Trace.

Figure-4 shows a proposed U shaped guard trace, in which 45^0 bend is introduced instead of 90^0 bend. It helps to reduce excessive capacitance of the line. Therefore it slightly increases capacitive coupling than 90 bend. Corner effects are more significant than conventional trace.

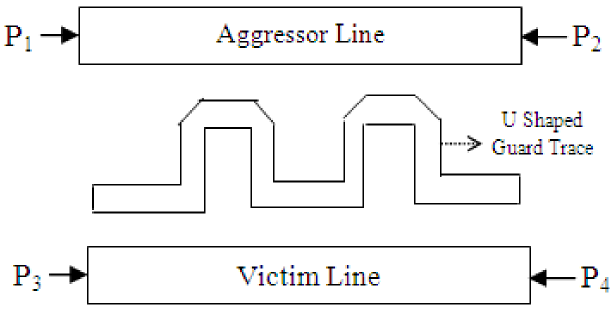

Figure-4. Parallel Microstripline with U shaped Guard trace.

Numerical analysis

The Finite difference time domain method is used to solve 1D, 2D and 3dimentional electromagnetic problems. FDTD method is formulated by modifying Maxwell's curl equations to central difference approximations and then discretized [7]. Consider the following Maxwell's curl equations in time –domain,

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \tag{2}$$

$$\nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t} + \vec{J} \tag{3}$$

These equations give the solution for electric and magnetic fields. In equation (2) $\vec{E}$ represents Electric field and B is magnetic flux density which can be written interms of E and H .

$$\vec{D} = \varepsilon\vec{E} \tag{4}$$

$$\vec{B} = \mu\vec{H} \tag{5}$$

where μ denotes the permeability, ε is the permittivity. The structure is assumed to be lossless and the medium is isotropic and homogeneous. A Yee cell is formed by the cubical elements of dimensions Δx , Δy and Δz in x, y and z directions respectively. The entire computational domain is made up of this Yee cell [7, 8]. The electric and magnetic field components are as follows:

$$H_{x(i,j,k)}^{n+1/2} = H_{x(i,j,k)}^{n-1/2} - \frac{\Delta t}{\mu} \left(\frac{E_{z(i,j+1,k)}^{n} - E_{z(i,j,k)}^{n}}{\Delta y} - \frac{E_{y(i,j,k+1)}^{n} - E_{y(i,j,k)}^{n}}{\Delta z} \right) \quad (6)$$

$$H_{z(i+1/2,\, j+1/2,k)}^{n+1} = H_{z(i,j,k)}^{n} + \frac{\Delta t}{\mu} \left(\frac{E_{x(i+1/2,\, j+1,k)}^{n+1/2} - E_{x(i+1/2,\, j,k)}^{n+1/2}}{\Delta y} - \frac{E_{y(i+1,\, j+1/2,k)}^{n+1/2} E_{y(i,\, j+1/2,k)}^{n+1/2}}{\Delta x} \right) \quad (7)$$

$$E_{x(i,j,k)}^{n+1} = \left(\frac{1 - \frac{\sigma \Delta t}{2\varepsilon}}{1 + \frac{\sigma \Delta t}{2\varepsilon}} \right) E_{x(i,j,k)}^{n} + \frac{\frac{\Delta t}{\varepsilon}}{1 + \frac{\sigma \Delta t}{2\varepsilon}} \left(\frac{H_{z(i,j,k)}^{n+\frac{1}{2}} - H_{x(i,j-1,k)}^{n+\frac{1}{2}}}{\Delta y} - \frac{H_{y(i,j,k)}^{n+\frac{1}{2}} - H_{y(i,j,k-1)}^{n+\frac{1}{2}}}{\Delta z} \right) \quad (8)$$

$$E_{y(i,j,k)}^{n+1} = \left(\frac{1 - \frac{\sigma \Delta t}{2\varepsilon}}{1 + \frac{\sigma \Delta t}{2\varepsilon}} \right) E_{y(i,j,k)}^{n} + \frac{\frac{\Delta t}{\varepsilon}}{1 + \frac{\sigma \Delta t}{2\varepsilon}} \left(\frac{H_{x(i,j,k)}^{n+\frac{1}{2}} - H_{x(i,j,k-1)}^{n+\frac{1}{2}}}{\Delta z} - \frac{H_{z(i,j,k)}^{n+\frac{1}{2}} - H_{z(i-1,j,k)}^{n+\frac{1}{2}}}{\Delta x} \right) \quad (9)$$

$$E_{z(i,j,k)}^{n+1} = \left(\frac{1 - \frac{\sigma \Delta t}{2\varepsilon}}{1 + \frac{\sigma \Delta t}{2\varepsilon}} \right) E_{z(i,j,k)}^{n} + \frac{\frac{\Delta t}{\varepsilon}}{1 + \frac{\sigma \Delta t}{2\varepsilon}} \left(\frac{H_{y(i,j,k)}^{n+\frac{1}{2}} - H_{y(i-1,j,k)}^{n+\frac{1}{2}}}{\Delta x} - \frac{H_{x(i,j,k)}^{n+\frac{1}{2}} - H_{x(i,j-1,k)}^{n+\frac{1}{2}}}{\Delta y} \right) \quad (10)$$

For a linear, isotropic, non-dispersive and homogeneous dielectric with permittivity ε and permeability μ, the time increment has to obey the bound given in equation (11), known as Courant-Freidrichs-Lewy (CFL) Stability Criterion

$$\Delta t < \frac{1}{c\sqrt{\frac{1}{\Delta x^2} + \frac{1}{\Delta y^2} + \frac{1}{\Delta z^2}}} \quad (11)$$

$$c = \frac{1}{\sqrt{\mu \varepsilon}}$$

where c is the velocity of propagation and x, y and z are the minimum cell spacing in the FDTD unit cell. The time step based on each cell is chosen to be the maximum time step that satisfies the Courant condition. The voltage source model is used to simulate source excitation in FDTD method. In this voltage source model, current is replaced by voltage and resistance. This model can be written as

$$E_{z\,i,j,k}^{n+1} = \left[\frac{1 - \frac{\Delta t \Delta z}{2R_s \varepsilon_0 \Delta x \Delta y}}{1 + \frac{\Delta t \Delta z}{2R_s \varepsilon_0 \Delta x \Delta y}} \right] E_{z\,i,j,k}^{n} + \left[\frac{\frac{\Delta t}{\varepsilon_0}}{1 + \frac{\Delta t \Delta z}{2R_s \varepsilon_0 \Delta x \Delta y}} \right]$$

$$\nabla \times H_{i,j,k}^{n+1/2} + \left[\frac{\frac{\Delta t}{R_s \varepsilon_0 \Delta x \Delta y}}{1 + \frac{\Delta t \Delta z}{2R_s \varepsilon_0 \Delta x \Delta y}} \right] V_s^{n+1/2} \quad (12)$$

Where Rs is the internal source resistance and Vs n+1/2 is the voltage excitation. This voltage pulse is given as [9]

$$V_s = e^{-(t-t_0)^2/T^2} \quad (13)$$

where T is the pulse width and to is the time-delay.

The scattering parameters can be obtained by taking the Fourier transform of transient waveforms. A Gaussian pulse is suitable for source excitation because the frequency spectrum of the pulse is also a Gaussian distribution.

RESULTS AND DISCUSSIONS

In order to analyze the crosstalk between microstriplines, various structures namely microstrip with and without guard trace, serpentine guard trace and U shaped guard trace are simulated using FDTD method. These crosstalk models as in Fig [1] - [4] are placed on the glass epoxy material having relative permittivity 4.6 with the thickness of 1.6mm. The ground plane is placed on the other side of the structures. FDTD method is a powerful method, give time domain data for transient analysis. The frequency domain response of crosstalk can be extracted by taking Fourier Transform of time domain data. The numerical results are obtained over the frequency range upto 6 GHz. The physical dimensions mentioned in Fig [1]-[4] are also considered for FDTD simulation. The microstrip structures whose lengths of edges are 15mm*50mm*1.6mm in x, y and z directions respectively. In the FDTD simulation, the space steps Δx , Δy and Δz are chosen to be 0.05mm,0.05mm and 0.265mm respectively. The total mesh dimensions are 50x120x50 in x, y and z directions and the entire computational domain is transformed into 3,000,000 cells. According to the stability criterion, the time step is chosen to be 0.441ps. The resistive voltage source model with 50 ohms resistance is used as a excitation source for obtaining the exact response of measurement with a vector network analyzer.. The first model is with two parallel lines of width 2mm with the spacing of 4mm and the line length is taken to be 50mm. The width of the guard trace is chosen to be 2mm and the length is same as that of aggressor and victim lines. For serpentine microstriplines the vertical segment is chosen as 10mm and horizontal segment is taken as 6mm for analysis. Numerical results of FEXT and NEXT are shown in Figure 5 and 6 for various guard intervening structures. From these simulated results, U shaped guard trace reduce FEXT by more than 15 db and also reduces NEXT by more than 20 dB. These results show that U shaped guard trace performs well in both far end and near end crosstalk reduction. Serpetnine guard trace reduce near end crosstalk like conventional guard trace. There is no variation in the near end crosstalk reduction. But our proposed structure reduce both far end and near crosstalk more than 15% than serpentine guard trace.

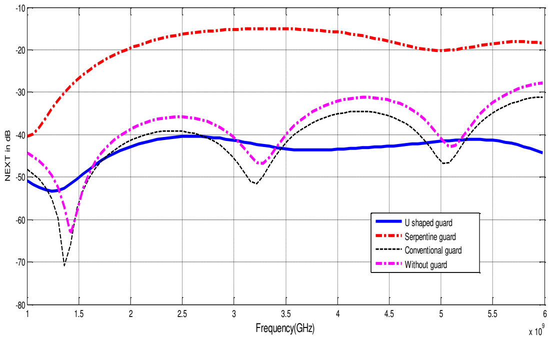

Figure-5. Numerical results of Far end crosstalk for Various Guard intervening schemes.

Figure-7 and Figure-8 show the simulated results of Near end crosstalk and Far end crosstalk for Various Guard intervening schemes, which are obtained from Ansoft HFSS [6]. This simulated results also show that U shaped guard trace reduce near end crosstalk and far end crosstalk more than 45%.

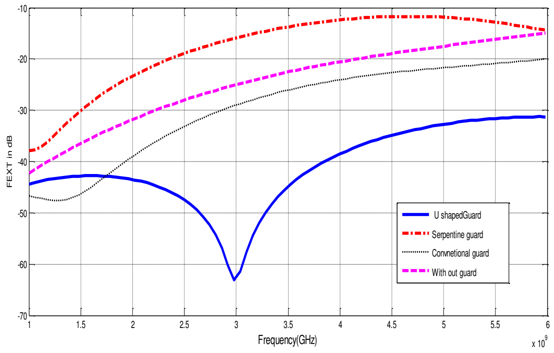

Figure-6. Numerical results of Far end crosstalk for Various Guard intervening schemes.

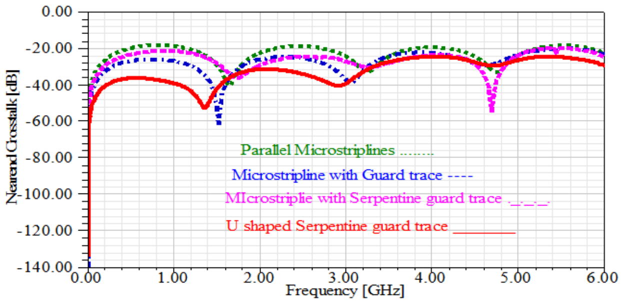

Figure-7. Simulated results of Near end crosstalk for Various Guard intervening schemes.

Figure-7 and Figure-8 show the simulated results of Near end crosstalk and Far end crosstalk for Various Guard intervening schemes, which are obtained from Ansoft HFSS [6]. This simulated results also show that U shaped guard trace reduce near end crosstalk and far end crosstalk more than 45%.

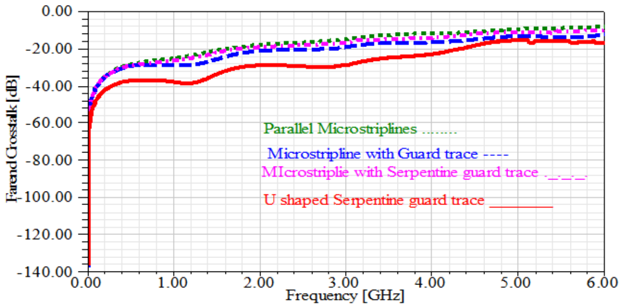

Figure-8. Simulated results of Far end crosstalk for Various Guard intervening schemes.

CONCLUSIONS

The near end and far end crosstalk at a frequency range up to 6 GHz between micrstrip lines with various guard traces on printed circuit board have been analyzed. Simulation results obtained from FDTD and Ansoft HFSS simulation tool have been compared with measured results. Obviously, in this paper, calculations of results with the FDTD method are precise and effective. The results show that NEXT and FEXT for microstriplines with guard trace by using FDTD is very convenient. NEXT and FEXT are important in high performance and high speed circuit board. The U shaped guard trace reduce far end crosstalk more than 40% and increases near end crosstalk by 45% more than other conventional guard traces. There is a good agreement exists between simulation results and numerical results. In order to verify the simulation results, FEXT and NEXT of a U shaped guard trace is to be experimentally validated.

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