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A SYNTHETIC DESIGN OF ELIMINATING CROSSTALK WITHIN MTLS

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Abstract—This paper presents a synthetic concept on eliminating crosstalk within multiconductor transmission lines (MTLs). Firstly, the method of moments (MoM) is used to calculate the per-unit-length (PUL) parameters of transmission lines. Secondly, the crosstalk is predicted using SPICE circuit simulator. Finally, three methods eliminating crosstalk are used synthetically to design the structure of MTLs. According to the results simulated with software, the effect on eliminating crosstalk by the synthetic design is quite satisfactory. Therefore, the concept may be implimented in practical engineering.

1. INTRODUCTION

The MTL is a system consisting of N conductors and a conducting shield or common return conductor and serving to guide electromagnetic waves, which works under surroundings with much electromagnetic interference (EMI), such as the crosstalk from the natural coupling within the MTL, undesirable and sometimes very harmful. It can cause penetration of a signal excited in one simple transmission line (STL) into the near- and far-end load of another STL. Crosstalk may set limits to the dynamic range of circuits, to the frequency band of their application and to the scale of miniaturization. Therefore, the circuit design engineer has to deal with the crosstalk in order that there are the relatively pure signals flowing through the MTLs.

The theory of MTLs has been a subject of many scientific papers in the last decades [1–5], and used in the design of devices with useful coupling, or for estimation of the coupling causing harmful crosstalk. Although the method of predicting crosstalk [1, 6] had been discussed widely in the previous literature and papers, how to eliminate the crosstalk was few investigated. Moreover, these methods were often employed individually. As a result, they are not ideal to eliminate the crosstalk. Ciamulski and Gwarek present a concept and method of eliminating crosstalk between signals propagating in the MTLs, i.e., a proper feeding of input signals and proper matching of both ends of MTL can eliminate crosstalk [7–9]. However, this method is difficult to operate in practical applications for feeding accurately input signals and matching accurately terminal impedances.

This paper presents a new concept eliminating crosstalk that is composed of three methods, that is, terminating optimal impedances, mounting grounded guarding lines, and transforming the structure of microstrip lines to the layout of stripline. Firstly, we extract the PUL parameters of microstrip transmission lines based the MoM. secondly, With the SPICE simulation software, we can simulate and optimize the structure of MTLs in order to obtain the ideal results of eliminating the crosstalk within MTLs. Finally, we obtain the excellent multi-path signals with simulation software, which show that the synthetic design of eliminating crosstalk is a practical operational and effective. For example, the concept of design can be applied to the power dividing networks [10] for eliminating the signal crosstalk within MTLs.

2. PREDICTING THE CROSSTALK

2.1. Calculate PUL Parameters Based on MoM

The MTLs equations [1,4]are given in matrix form as follows:

$$\frac{\partial}{\partial z}\boldsymbol{V}(z,t) = -\boldsymbol{L}\frac{\partial}{\partial t}\boldsymbol{I}(z,t) \tag{1a}$$

$$\frac{\partial}{\partial z}\boldsymbol{I}(z,t) = -\boldsymbol{C}\frac{\partial}{\partial t}\boldsymbol{V}(z,t) \tag{1b}$$

Where

$$\boldsymbol{V}(z,t) = \begin{bmatrix} V_G(z,t) \\ V_R(z,t) \end{bmatrix} \tag{2a}$$

$$\boldsymbol{I}(z,t) = \begin{bmatrix} I_G(z,t) \\ I_R(z,t) \end{bmatrix} \tag{2b}$$

and the PUL parameter matrices are

$$\boldsymbol{L} = \begin{bmatrix} l_G & l_m \\ l_m & l_R \end{bmatrix} \tag{3a}$$

$$\boldsymbol{C} = \begin{bmatrix} (c_G + c_m) & -c_m \\ -c_m & (c_R + c_m) \end{bmatrix} \tag{3b}$$

According to the equations (1a) and (1b), we must first determine the PUL parameters of MTLs. To obtain these parameters, we consider the MoM which has been used widely to deal with numerical solutions of problems in the EM fields [11–13]. In this paper, we consider a parallel six-conductor structure of microstrip transmission lines. As Fig. 1, the lands have identical width w ($w = 2.54\,\mathrm{mm}$) and are assumed to be of zero thickness. The edge-to-edge spacings are denoted as s ($s = 2.54\,\mathrm{mm}$). the board thickness is designated as h ($h = 1.6\,\mathrm{mm}$), the substrate has a relative permittivity of $\varepsilon_r = 4.7$, and the length of transmission lines is 0.25 m. The results of calculation are plotted by 3-dimension form, as follows Figs. 2(a) and 2(b).

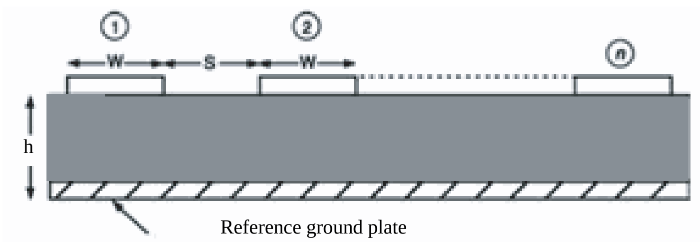

Figure 1. Cross-sectional definition of MTLs parameters.

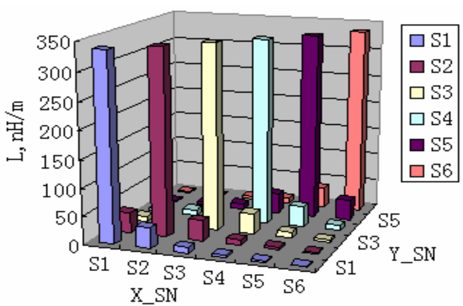

Figure 2a. L matrix of 3-dimension.

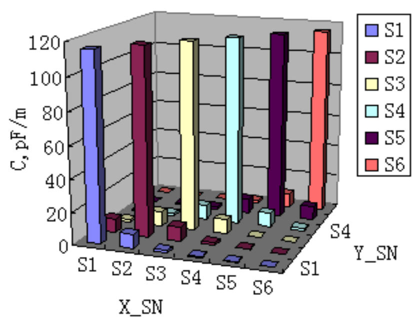

Figure 2b. C matrix of 3-dimension.

According to the above figures, the coupled parameters between the two adjacent conductors are more important than others which are more distant separations one another. Therefore, It is a key factor how to eliminate crosstalk between the adjacent conductors. This problem will discuss in the Section 3.

2.2. Time-domain Analysis on the Crosstalk

To predict the crosstalk within MTLs, we must deal with the equations (1a) and (1b). With the help of PUL parameters extracted from Section 2.1, the time-domain analysis and simulation can be achieved by the SPICE software. In this paper, we excites the MTLs with six-pulse source arrays simultaneously, as follows Fig. 3. The signals rise and fall time was assumed to be 0.5 ns, and durations of 40 ns, 45 ns, 50 ns, 55 ns, 60 ns and 65 ns respectively. The amplitudes were assumed to be 1.5 V, 2 V, 2.5 V, 3 V, 3.5 V and 4 V respectively.

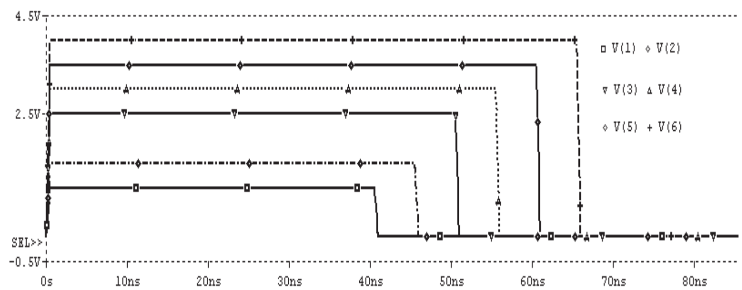

Figure 3. Source exciting signals.

In this paper, the SPICE mode of MTLs is used to predict the crosstalk [14], and the typical waveforms of time-domain simulation are given. In the Fig. 4, the load impedances with 50 ohm are terminated at the far end of the each MTL, and there are not matched resistors at the input signal terminals. From the simulated waveforms, we observe that the rise/fall edges are a little distorted. Similarly, the Fig. 5 shows the distorted waveforms of near end crosstalk which the loads are open and sources are connected with series matched resistors 50 ohm respectively, and Fig. 6 shows the distorted wave-forms of far end crosstalk under the same terminated conditions. Obviously, the crosstalk within MTLs is comparatively terrible.

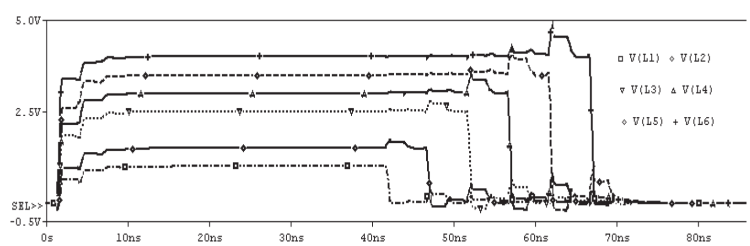

Figure 4. Far end crosstalk: without source matched resistors.

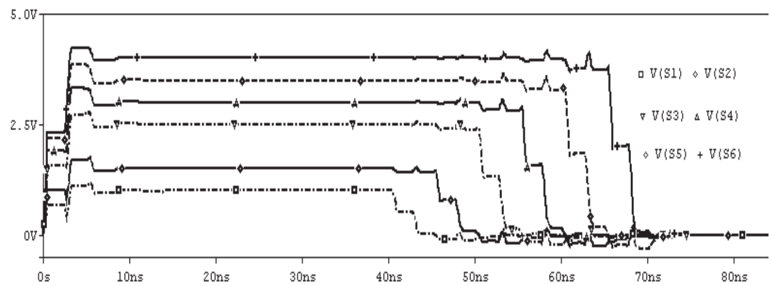

Figure 5. Near end crosstalk: loads are open.

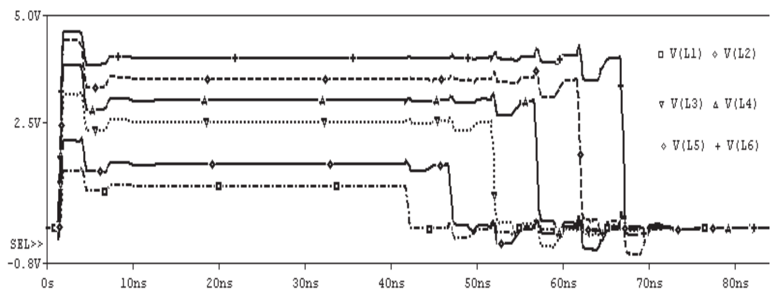

Figure 6. Far end crosstalk: loads are open.

3. ELIMINATING THE CROSSTALK

In this section, we shall discuss the methods on eliminating crosstalk within MTLs in order to improve the transmission quality of signals, which can reduce the crosstalk within MTLs.

3.1. Optimize Terminal Impedances

According to the analysis and simulation in the Section 2, we can observe the phenomenon which the crosstalk would increase sharply when the terminal impedances departure from the MTL characteristic impedance. Therefore, by the optimizing function of SPICE software, we can design the appropriate terminated impedances for reducting the crosstalk within MTLs. Fig. 7 shows the crosstalk is reduced greatly compared with results of Section 2.

3.2. Grounded Guardlines

From Fig. 7, we notice that the rise edges of signals are still distorted for the crosstalk within MTLs. Consequently, we have to explore other

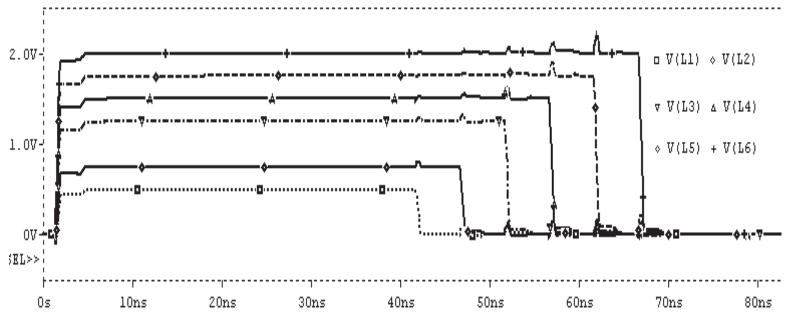

Figure 7. Far end crosstalk: Optimal terminated condition.

approaches to eliminate further the crosstalk.

It is often suggested that using guardlines will significantly decrease cross talk [15, 16]. The guardlines are separate lines that are placed between the aggressor lines and the victim lines that we want to shield. There are three different termination strategies for the guardlines, that is, they are open, terminated and shorted at the ends, respectively. With the EM simulation for the three termination cases, we can see the maximum amount of noise is generated on the guardline if it is left open. And if the guardline is terminated with 50 Ohms on each end, less noise appears. However, the biggest benefit of guardline is when the guardline is shorted on the ends. On the configuration of MTLs with the guardlines which are shorted at each end, as the signal moves down the aggressor line, it will still couple noise to the guardline. But, shorting the ends of the guardline will eliminate near-end noise that would appear along the guardline. Unfortunately, there will still be the buildup of the forward-moving far-end noise on the guardline. As a result, If all we do is short the two ends of the guardline, the far-end noise on the guardline will continue to reflect between the two ends, acting as a potential noise source to the victim line that is supposed to be protected.

Therefore, we may consider adding the vias along the guardlines, namely, the grounded guardlines. An example of the geometry of grounded guardlines is shown in Fig. 8. The grounded guardlines affect the electric- and magnetic-field lines between the aggressor lines and the victim lines, so will always decrease both the capacitance and inductance matrix elements. The spacing between the shorting vias on the guardlines affects the amount of voltage noise generated on the guardlines in two ways. The far-end noise on the guardlines will only build up in the region between the vias. The closer the spacing, the lower the maximum far-end noise voltage that can build up on the guardlines. The more vias, the lower the far-end noise on the guardline.

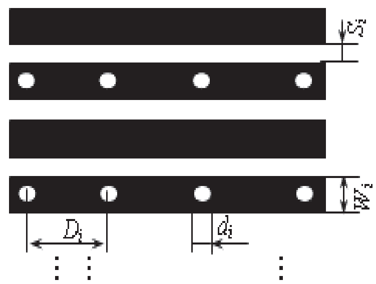

Figure 8. Grounded guardlines.

This will mean lower voltage noise available to couple to the victim lines. We can minimize the amount of far-end noise generated on the guardlines by adding more shorting vias, distributed down the length of the guardlines. These vias will have no impact on the noise directly coupled from the aggressor lines to the victim lines. They will only suppress the noise voltage generated on the guardlines. The amount of coupled noise is related to the reduction in the size of the matrix element due to the presence of the guardlines. By adding multiple vias, we limit the buildup of the noise on the guardlines and this eliminates the possibility of this additional noise coupling to the victim lines. Another role of multiple shorting vias is in generating a negative reflection of the far-end noise which will cancel out the incident far-end noise.

As a rough rule of thumb [16], the shorting vias should be distributed along the guardlines so that there are at least 3 vias within the spatial extent of the signal rise time. This will guarantee overlap of far-end noise and its negative reflection, causing cancellation of noise voltage on the guardlines. In this design of eliminating crosstalk within MTLs, we distribute the 12 shorting vias along the each guardline, spaced at 22-mm intervals. During the analysis and design of grounded guardlines, we can also see the diameters of shorting via have an important effect on the crosstalk decreasing, which is less crosstalk on the victim lines if the diameters are bigger. Accordingly, in this design we choose the diameter of each via is 2.54-mm. According to the above analysis and discussion, we can obtain the time-domain simulation results. A typical simulation result for the crosstalk within MTLs at the far ends is given, as shown in Fig. 9.

Obviously, the simulation result of time-domain waveforms is better than in Fig. 7.

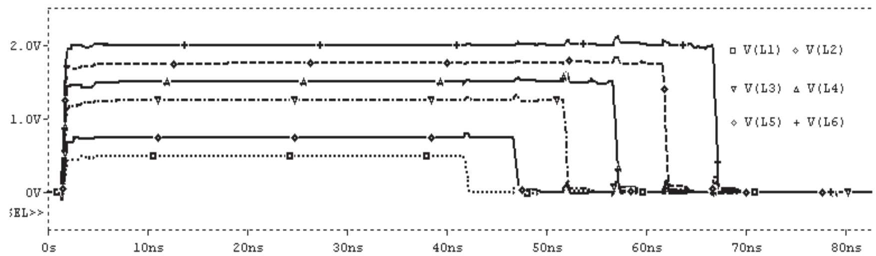

Figure 9. Far end crosstalk: with the grounded guardlines.

3.3. Stripline Configuration

There are several advantages in the stripline structures over microstrip ones, that is, they have an capability of absorbing greatly the fields and resisting the interferences. Moreover, it also eliminates the electromagnetic flux with providing the reference return paths of RF currents. In the stripline case, the relative inductive coupling will not change at all, since inductance is completely independent of any dielectric materials. However the capacitance terms will be affected by the dielectric distribution [16, 18, 19]. According to the results of EM simulation, in the stripline case with homogeneous distribution of dielectric material, the relative coupling capacitance has actually increased from the pure microstrip case, yet the overall far-end noise decreases. Although the guardlines can be used in both microstrip and stripline cross sections, the amount of decreasing crosstalk within MTLs with grounded guardlines in microstrip is not very great, which is seen by comparing the result in Fig. 7 with one in Fig. 9.

Additionally, the guardline in the stripline configuration, offers a very significant amount of isolation over a configuration with no guardline. Consequently, when high isolation is important, the coupled noise to the quiet line will be much less in stripline, and stripline should always be used [16, 20, 21].

Therefore, we may route the sensitive lines in stripline in order to reduce effectually the crosstalk within MTLs. In this design of eliminating crosstalk within MTLs, we layout the six conductor traces with the grounded guardlines into the stripline. The cross section of stripline structures is shown in Fig. 10. The overall design procedure and simulation results will be discussed in Section 3.4.

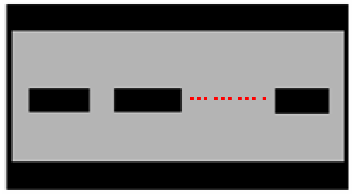

Figure 10. Stripline structures.

3.4. Synthetic Design

According to the above discussions, we improve the design on the structure and layout of MTLs. The structure of microstrip transmission lines is modified into stripline type, and the grounded guardlines added to the every adjacent transmission lines. Based on the above structure and layout, we newly analyze and optimize the MTLs for eliminating the crosstalk. Finally, we obtain the comparatively perfect transmission waveforms within MTLs, as follows Fig. 11. Obviously, the rise edges of signals are improved remarkably compared with Fig. 7.

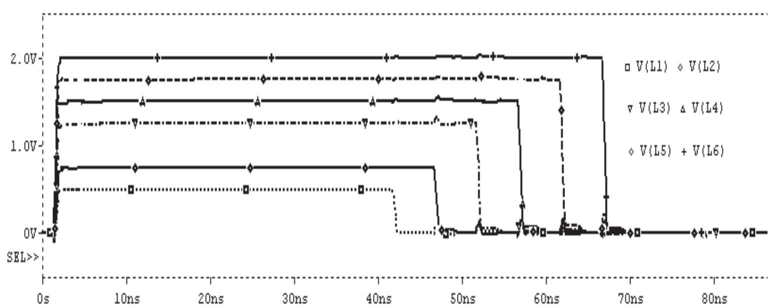

Figure 11. Far end crosstalk: synthetical design.

4. CONCLUSION

The crosstalk within MTLs often degrades the transmission quality of signals, and increases the bit error rate. So, the PCB engineers have to be capable of predicting correctly and eliminating the crosstalk. This paper presents a synthetic concept of design on eliminating crosstalk within MTLs. With the help of new concept, we can attain excellent transmission signals within MTLs, respectively. The validity of synthetic design has been verified using SPICE circuit simulator. Accordingly, the new concept and method might be approached to the practical engineering.

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