Time Domain Analysis of Crosstalk With a Slot Between Microstrip Lines

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Abstract

The crosstalk between microstrip lines placed closely on a printed circuit board is an important issue. Recently, a lack (a slot) formed in a ground plane may be serious problem for the crosstalk or EMI, because of miniaturization of electronic equipment and printed boards, and high-density of circuits. In this paper, we analyzed the influence of crosstalk between two microstrip lines by placing the slot in the ground plane between them in time domain. And, we showed that the near end crosstalk increases as the slot width increases and the far end crosstalk decreases as the slot length increases. Moreover, it seemed that a signal propagating in the line is coupled with the slot, and another the signal propagating in the slot. Next, we analyzed voltages at near and far end by splitting into odd-mode and even-mode excitation. As a result, we showed that the rise times arrived at the far end in the case that the slot length is different are different each other in odd-mode excitation. And, we showed that the near end voltage depends on the slot width in even-mode excitation.

1. Introduction

Recently, with the progress of information processing technology operating speed of electronic devices becomes very fast. Consequently the problem of undesired emission from such fast electronic devices arises. Moreover, electronic devices are becoming small and lightweight. Thus, demands of miniaturizing printed circuit boards (PCBs) in these devices increase.

When two signal lines are closely put on the PCB, the crosstalk is generated between these lines. The crosstalk is caused by electromagnetic coupling or emission from the other sources. By miniaturizing PCBs, those circuits may be constructed on the PCB with multi-layers. A signal line on a layer of the PCB may have some vias with clearance holes to connect to signal lines on another layer. Moreover, when many holes for forming vias are placed in a narrow area, a slot may be formed on a ground plane. It is considered that the undesired influence may be happen to the crosstalk between signal lines if the slot is exist near them.

Many papers have been presented concerning the crosstalk on the PCB in the frequency domain until now [1]. However there is a little researches studied about the crosstalk on the PCB with the slot located along microstrip lines in ground plane as far as the authors know [2]. And so, since the time-domain analysis is an important topic especially for signal integrity in the electromagnetic compatibility field, we analyze them in time domain.

In this paper, we investigate the crosstalk between microstrip lines on the PCB with the slot which is located in the ground plane between lines. Particularly, time-domain analysis of the crosstalk is investigated. Moreover, since two coupling lines can be decomposed into the superposition of an odd-mode excitation and an even-mode excitation, we investigate each transmission line mode. In these investigations, we use the finite-difference time-domain method for analysis.

2. Analysis of the crosstalk

2. 1 The configuration of the microstrip lines and the PCB

The configuration of the microstrip lines and the PCB, top and side view, is shown in Fig. 1. The PCB consists of a dielectric substrate which has thickness T=1.6mm, length L=80mm and width W=96.4mm made by FR4 with relative permittivity 4.8. Two microstrip lines, one line is the generator

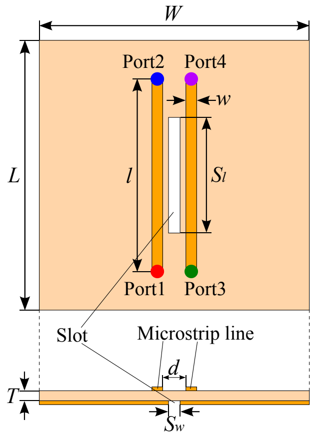
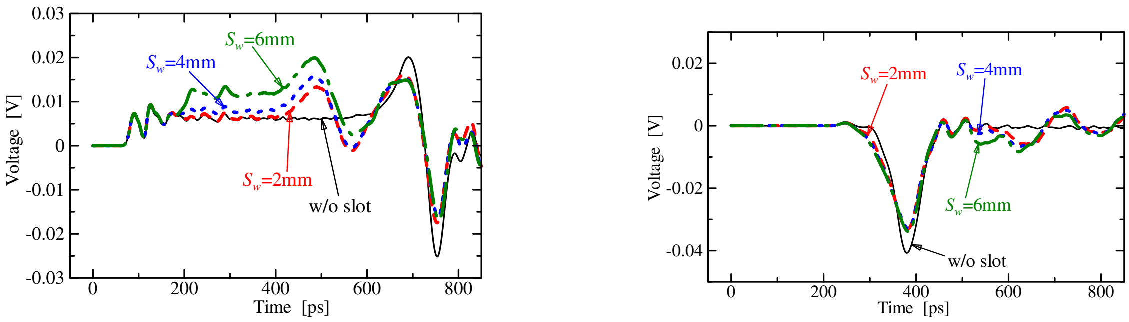


Figure 1: Configuration of microstrip lines and PCB



(a) Near end

(b) Far end

Figure 2: Crosstalks between microstrip lines for various slot width

circuit and the other line is the receptor circuit, which have same width w=2.8mm and length l=50mm are located on the central part of the PCB parallel to each other and separated by d=6mm. Each line has the characteristic impedance of approximately 50Ω if the other line does not exist. A voltage source is connected at Port 1 which has the impedance of 50 *Omega* output and is excited by a step pulse:

$$\left.\begin{array}{ll} V_0 \sin^6(\frac{\pi}{2}\frac{t}{t_0}) & t < t_0 \\ V_0 & t \geqq t_0 \end{array}\right\}$$

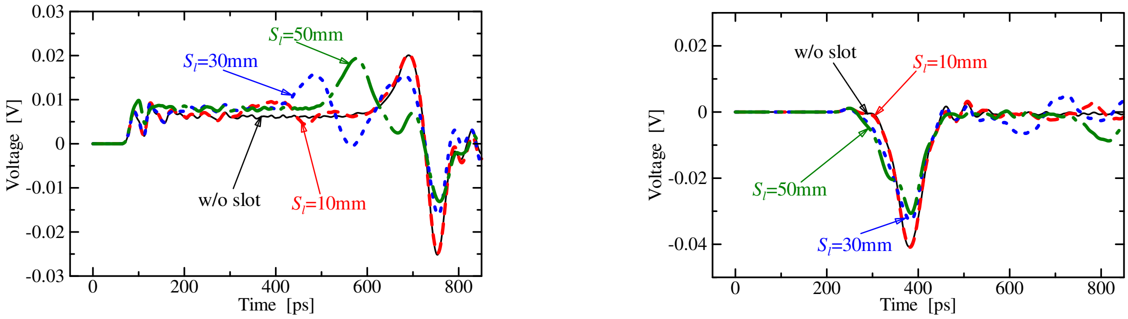
In this paper, we use V_0=1.0V, t_0=30ps. Port 2, Port 3 and Port 4 are terminated 50 Ω resistors. The ground plane is placed on the other side of the PCB. The slot which has the width S_w and the length S_l is located in the center of the ground plane between lines.

2.2 Analysis result of the crosstalk for various slot width

We analyze the near and far end crosstalk for various slot width S_w and length S_l.

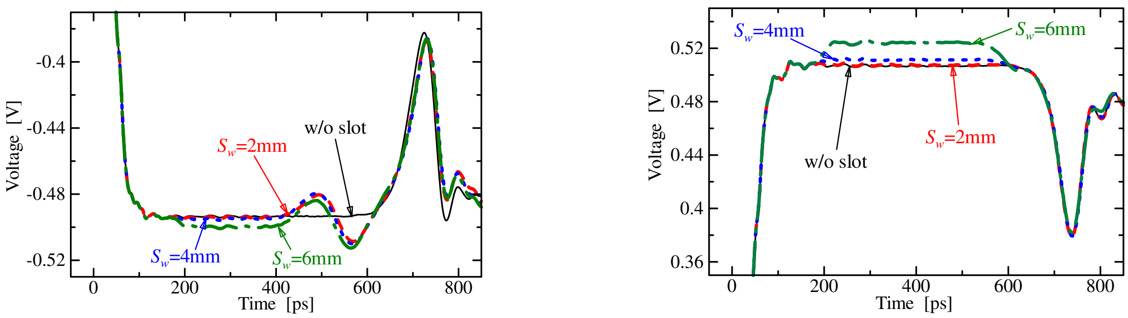
Analysis results of the near and far end crosstalk for S_l=30mm are shown in Fig. 2 (a) and (b), respectively. In Fig. 2 (a), it is shown that the crosstalk between lines increases as S_w increases. For this reason, as the width of the ground plane is narrower, the per-unit-length mutual capacitance between lines increases[]. And, by placing the slot, there is a voltage peak at about 480ps for each case with the slot. It is assumed that the signal propagating in the generator line is coupled with the slot and induces a wave propagating in the slot. So, the wave is observed at Port 3 as the peak after it is reflected at the edge of the slot. A velocity of the wave transmitting in the slot is faster than that of the signal transmitting in the microstrip line because oh the slot placing, between the dielectric substrate and an air. Therefore, the peak is observed earlier than the end of the crosstalk.

In Fig. 2 (b), it is shown that the crosstalk between lines decreases by placing the slot. Small peaks are shown at about 680ps by placing the slot. It is considered that these peaks are caused by multi-reflection waves in the slot.



(a) Near end (b) Far end

Figure 3: Crosstalks between microstrip lines for various slot length



(a) Odd-mode (b) Even-mode

Figure 4: Voltages of odd and even-mode at Port 3 for various slot width

2.3 Analysis results of the crosstalk for various slot length

Analysis results of the near and far end crosstalk for the slot width S_w=4mm are shown in Fig. 3 (a) and (b), respectively. In Fig. 3 (a), the near end crosstalk for the slot length S_l=10mm rises at about 70ps and its voltages becomes in about 0.006V. And after 230ps, the crosstalk voltage increases and it is in 0.008V up to 460ps. After that the voltage becomes 0.006V again. Further, the time range which the crosstalk becomes in 0.008V increases as S_l increases. For example, that time range is 230ps when S_l=30mm and that time range is 400ps when S_l=50mm. The rise time and the time range depend on S_l, and as S_l increases the rise time becomes earlier and the time range becomes larger. This time range corresponds with the time range which the signal propagating in the line passes nearly the slot. Then, the crosstalk increases when the signal passes nearly the slot.

In Fig. 3 (b), the fall time at Port 4 for S_l=10mm is about the same time of the case without the slot. The fall times of the crosstalk for S_l=30mm and 50mm are faster about 30ps than the other cases. In these results, the fall time of the crosstalk at Port 4 is faster as S_l increases. It seems that the time at which the signal is observed at Port 4 is earlier as S_l increases because a velocity of the signal propagating the line becomes fast by the slot. Moreover, the second peak is observed at about 630ps for S_l=30mm. This peak is caused by the multi-reflected wave in the slot.

3. Analysis of even and odd modes

3.1 odd-mode and even-mode

We analyze voltages at the near and far end by splitting into odd-mode excitation and even-mode excitation. The configuration of microstrip lines and the PCB for analysis is same as previous section shown in Fig. 1. In odd-mode excitation, +1V is applied to Port 1 and −1V is applied to Port 3. In even-mode excitation, +1V is applied to Port 1 and Port 3. By adding voltages of odd-mode and even-mode, the voltage at Port 1 is +2V and that at Port 3 is 0V. Moreover, dividing these voltages by 2 respectively, it is considered that Port 1 is +1V and Port 3 is 0V.

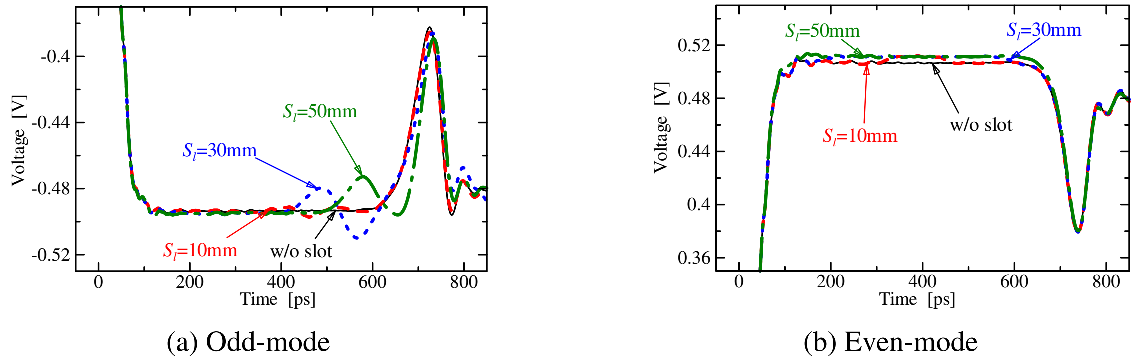


Figure 5: Voltages of odd and even-mode at Port 3 for various slot length

3.2 Analysis results of the voltage for various slot width

Analysis results of the voltage of odd-mode and even-mode excitation at the near end for various slot width S_w are shown in Fig. 4 (a) and (b), respectively. In Fig. 4 (a), a change of the voltage is small regardless of S_w. There is a peak at about 480ps when placing the slot. This is same to the case of the peak in Fig. 2 (a). In Fig. 4 (b), the voltage of even-mode increases as S_w increases. And the voltage increment range is between 180ps to 600ps, which the signal transmits through near the slot in this time range. It is considered that the characteristic impedance of even-mode increases as S_w increases. From these results, it seems that the change of the voltage of even-mode is larger than that of odd-mode to S_w.

3.3 Analysis results of the voltage for various slot length

Analysis results of the voltage of odd-mode and even-mode excitation at the near end for various slot length S_l are shown in Fig. 5 (a) and (b). In Fig. 5 (a), time of peak of each S_l is different each other. It is considered that the wave propagated in the slot reflects on the edge of the slot toward the Port 4. And, the propagation time increases as S_l increases, so the observation time of each peak is different. Since the slot width S_w fixed, it can be seen that the observed voltage is almost same except for the peak. In Fig. 5 (b), the voltage with the slot is larger than that without the slot. And so, in the case with the slot, the voltage rises once, and after several pico-second the voltage rises again.

4. Conclusion

In this paper, we investigated the crosstalk between microstrip lines on the PCB with the slot which is located in the ground plane between the lines. Particularly, time-domain analysis of the crosstalk was investigated by using the FDTD. Moreover, we investigated the transmission line mode splitting into the odd-mode excitation and the even-mode excitation.

First, we showed analysis results of the crosstalk between microstirip lines for various width and length of the slot in ground plane. In the case with the slot of various width, the near end crosstalk increased and the far end crosstalk decreased as slot width increases. In the case with the slot of various length, time range of increasing the near end crosstalk was long and the far end crosstalk decreased as the slot length increases.

Finally, we showed analysis results of the voltage for various width and length of the slot about two transmission line modes, odd-mode and even-mode excitation. In the case with the slot of various width, we showed analysis results of voltages at Port 3. In the case of even-mode excitation, the voltages increased as the slot width increases.

References

[1] Y. Kudo, T. Tobana, T. Sasamori, “A Study of Cross-Talk between Microstrip-Lines on a Printed Circuit Board with Narrow Width, ” Pan-Pacific EMC Joint Meeting, 16S4-3, May 2008.

[2] F. Xiao, K. Murano, Y. Kami, “Analytical Solution for Two Parallel Traces on PCB in the Time Domain with Application to Hairpin Delay Lines, ” IEICE Trans. Commun., vol.E92-B, no.6, pp.1953-1959. June 2009.