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Analysis and Suppression on Simultaneous Switching Noise Coupling Between Multi-Cavities For Multilayer PCBs

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Simultaneous switching noise (SSN) in printed circuit boards (PCBs) or multi-chip module (MCM), commonly known as delta-I or ground bounce noise (GBN), has become major concern of the high-speed digital circuit with low voltage levels and fast edge rates. The power and ground planes constitute the power-bus which is actually a parallel-plate structure. The resonance noise propagating in this structure causes the power integrity (PI) problems for the circuit.

Nowadays, high-integration and high-complexity circuit design makes different DC-level to provide the usage of relative circuits such as digital circuit and RF systems. In this way, many researches focus on the SSN problem in the single power and ground plane. However, the noise coupling in the multilayer structures are also a serious issue in high-speed digital circuits. Slot is widely used in microwave components. The slot is also taken to discriminate different DC-level in the multilayer power/ground planes. Because of the rapid switching current, the switching noise appears in high-speed digital circuits. The SSN not only transmits in its own power and ground plane, but also couples to neighboring power/ground plane through slots. Therefore, the power integrity of circuits is affected. In previous researches, the optimum position method is making slot to suppress the noise instead of adding extra passive elements. This method applied for high level circuit design is inappropriate because the coupling theory accuracy is based on that: (a) slot is smaller relative to the electrical wavelength, (b) slot position should be taken away from the plane edge, and (c) source can not be too close to the slot. Other positions are still affected by resonance. It is hard to find null position in real situation.

This work proposed an approach which was considered that coupled- and slot-effect eliminate SSN in multilayer structure. This approach could cause the potential difference of the slot closing to zero, called “virtual shield”. The effect of “virtual shield” could efficiently eliminate the SSN coupling to the adjacent cavity. The simple approach to reach zero potential difference is obtained by adding short via or decoupling capacitor. The short via was placed at the center of slot edges in the cavity 1 as shown in Figure 1 (a).The dimension of the substrate is 40mm×40mm and its thickness is 0.4mm, and the dimension of the slot is 10mm×1mm. The dielectric constant of the substrate is 4.4. Compared with adding no short via in the cavity 1 and 2, it is seen that the short via eliminates with averagely 10 dB for the first mode as shown in Figure 2(a)-(b). The results demonstrated that the short via could cause the zero-potential-difference to reach virtual shield and eliminate the SSN in multilayer. To suppress the high-order modes could obtain wider suppressive bandwidth by utilizing array short via. Figure 3 shows the measured results for adding array short via. From the measured results shown in this figure, we can find that the SSN is suppressed from dc to 10 GHz with the bandwidth around 10 GHz, and the bandwidth is defined by the insertion loss lower than -20 dB. It means that the slot with array short via efficiently suppresses the noise.

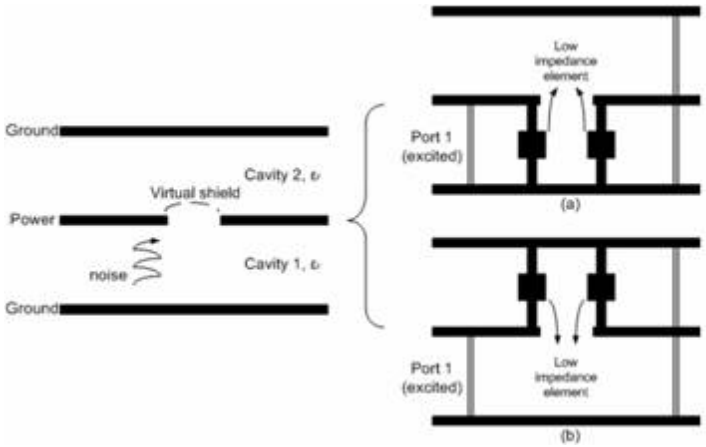

Figure 1. The concept of virtual shield, (a) low impedance elements are placed at cavity 1, and (b) at cavity 2.

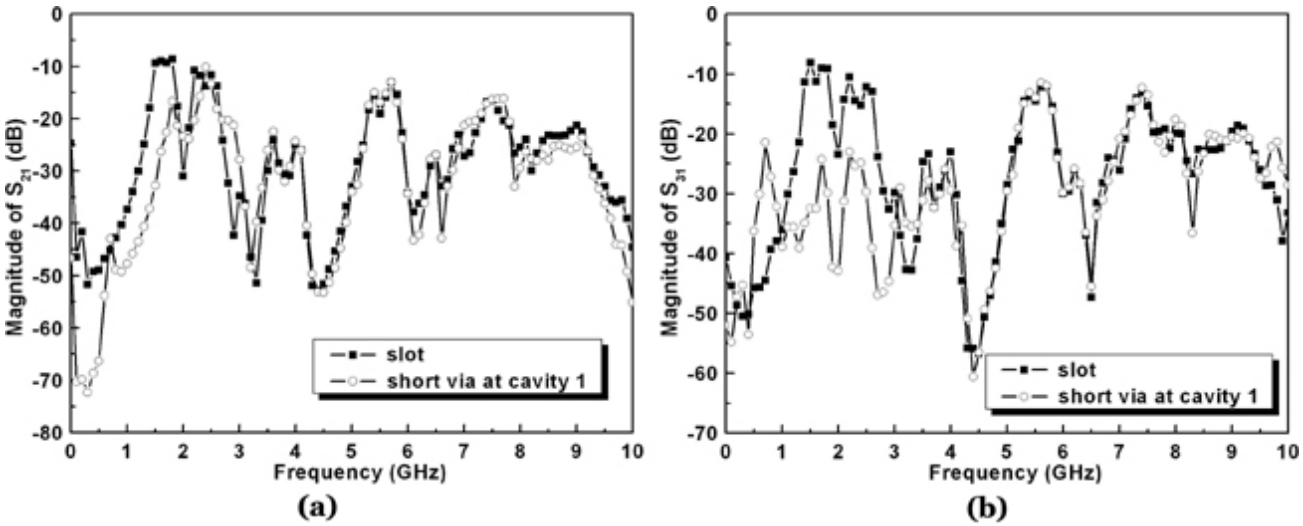

Figure 2. The virtual shield was reached by short via in the case that short via and excited source at the same layer, (a) receiving port at cavity 2, and (b) at cavity 1.

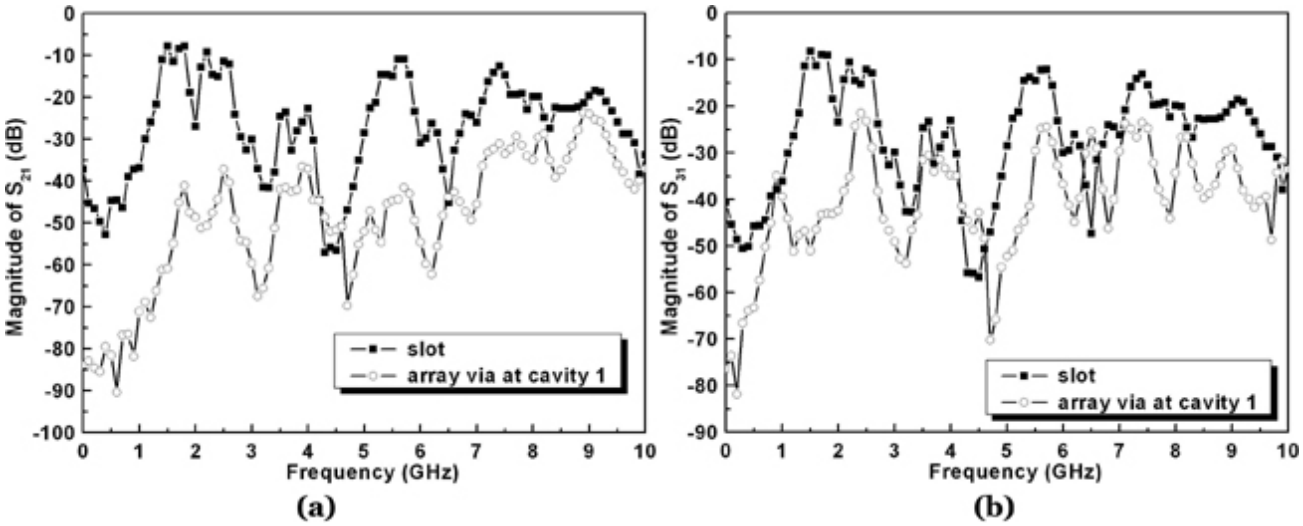

Figure 3. The virtual shield was reached by array short via in the case that short via and excited source at the same layer, (a) receiving port at cavity 2, and (b) at cavity 1.

The eliminated result for receiving port located at the cavity 2 is shown in Figure 4(a), which shows that the switching noise is suppressed from 40 MHz to 5.2 GHz with the bandwidth around 4.16 GHz. The wider-band suppression also could be obtained by adding array short via. Figure 4(b) shows the measured result of the SSN for

the receiving port located at the cavity 1. When the frequency of S31 is between 1.8 GHz to 2.5 GHz, the switching noise at the cavity 1 was still worse after applying suppression method. The reason is that the short via forms a bridge which is connected with the edge of slot. The bridge provides additional propagation path to the port 3 and makes the noise feedback to the cavity 1. In this situation, the elimination behavior will be broken. Therefore, the proposed concept needs to be placed at the same layer as excited port to obtain the efficient switching noise suppression.

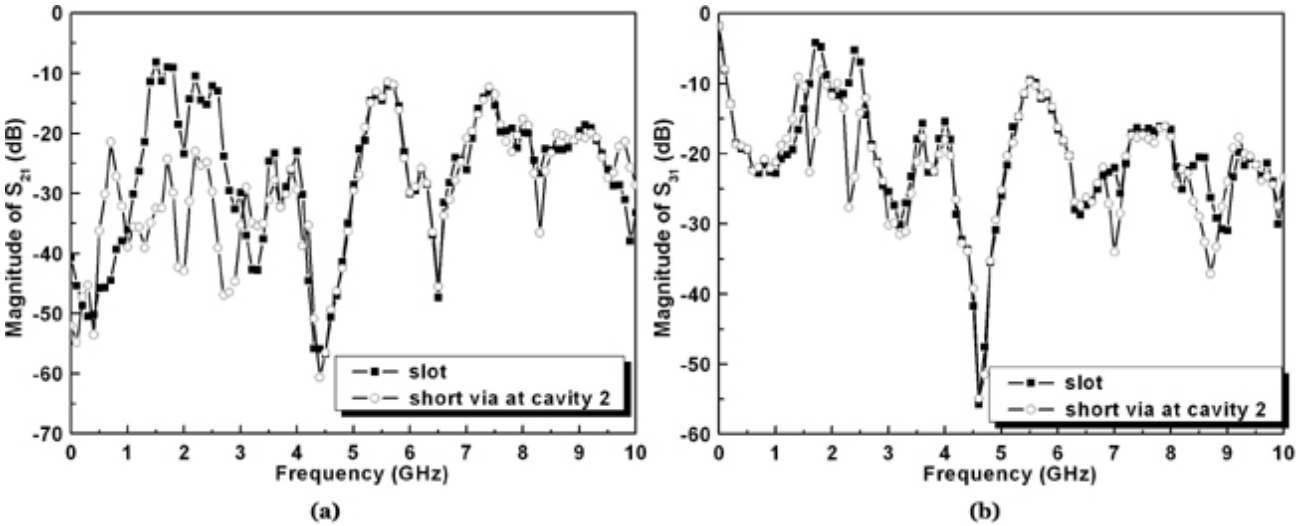

Figure 4. The virtual shield was reached by array short via in the case that short via and excited source at different layer, (a) receiving port at cavity 2, and (b) at cavity 1.