Mitigation of Simultaneous Switching Noise in High Speed Circuit Using Electromagnetic Bandgap Structures with Interdigital Meander Bridge

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Abstract—An interdigital meander-bridge electromagnetic bandgap power/ground planes for suppressing simultaneous switching noise is presented. The effective suppressing bandwidth of interdigital meander-bridge structure is from 880 MHz to 4.91GHz. Although it improves good power integrity, the pads between integrated squares and meander-bridge will destroy signal integrity problem. The performance is determined by maximum eye open and maximum eye width. The results show the present structure is superior to other structure for suppressing simultaneous switching noise and provide a better signal integrity.

Keywords—power integrity, signal integrity, simultaneous switching noise, eye pattern

I. INTRODUCTION

The integration of mixed-signal systems in practical computers is forcing the integration of high-speed digital circuits with analog and radio frequency (RF) circuits. When the signal drivers or the logic circuits of a microprocessor simultaneously switching, the ground bounce noise (GBN) or simultaneously switching noise (SSN) generated from the noisy circuits that can influence power integrity (PI) or the other sensitive RF/analog circuits. Therefore, an effective isolation noise structure is required for improving the PI in mixed-signal systems.

In recent year, the exceptional configurations to mitigate the SSN in printed circuit board (PCB) were discussed by using electromagnetic bandgap (EBG) structures to provide a high impedance surface (HIS) on the power/ground planes. In early periods, these EBG structures used embedded between power and ground planes [1-2], which were increased the cost. Therefore, the planer EBG structures were researched for isolation wide-band SSN, as in [3-4]. These structures comprise two-layer power/ground planes with one of the layers consist of an EBG structure, the other one is continuous metal planes that do not have vias.

This paper proposes the interdigital meander-bridge EBG structure which were designed and measured to observe the improvement for suppressing simultaneous switching noise (SSN) on the power/ground planes. It is organized as follows: section II discusses the design concept and the measurement of interdigital meander-bridge EBG structure. In section III, the interditgil meander-bridge EBG can improved signal integrity quality of single-ended is described.

II. DESIGN AND IMPROVEMENT

A. Design Concept

Fig. 1(a) shows the proposed meander-bridge EBG structure which is applied on a two-layer FR-4 PCB substrate. The thickness of substrate is 0.4 mm and the dielectric constant is 4.4. The dimensions of the PCB are 9×9 cm² and the area of each unit cell is 28.5×28.5 mm². The ground plane is a continuous metal plane and the power plane has nine cells of meander-bridge EBG etched on the power plane. In this proposed structure, the power plane has a periodic pattern that is a two-dimensional (2-D) integrated square and meander-bridge connecting between those squares as shown in Fig. 1(b). Furthermore, a star bridge is used to connect four meander-bridges as shown in Fig. 1(b). The receiving port 1 is all at (15 mm, 75 mm) and the excitation port 2 is at (45 mm, 75 mm).

In multi-layer PCB, the power/ground planes are critical to provide an entire return path, so the signal can reach the destination with minimal distortion. Therefore, the meander-bridge EBG structure should not only supply the wide band-stop but also to suppress the SSN. The interdigital meander-bridge EBG structure is shown in Fig. 2(a). This new structures consists of interdigital pads around each square. The two structures are compared with the low-period coplanar EBG (LPC-EBG) structure proposed in [5] as shown in Fig. 3 and the meander-L bridge structure proposed in [6]. This paper is corroborated experimentally by using vector network analyzer (VNA) and simulated by a 3-D simulator (HFSS).
Figure 1. This paper proposed meander-bridge EBG structures. (a) 2D top view. (b) The geometrical of meander-bridge and the unit cell of star bridge.

Figure 2. The new structures for improving signal integrity. (a) Top view of interdigital meander-bridge structure. (b) The dimensions of interdigital meander-bridge.

Figure 3. The LPC-EBG structures. (a) 9-cell LPC-EBG structure. (b) The unit cell of the LPC-EBG and its corresponding parameters.
B. Improve Ground Bounce Noise

Fig. 4(a) shows the measured $|S_{21}|$ for the discussed meander-bridge EBG power/ground planes. The measurement of the reference board with both integral power and ground planes is also presented in this figure for comparison. Compared with the interdigital structure, the meander-bridge EBG power plane behaves highly efficient SSN elimination in a wide-band range form about 868 MHz to 5.03 GHz (4.162 GHz bandwidth) as shown in Table I.

The bandwidth is defined by $|S_{21}|$ lower than -30 dB. Fig. 4(b) shows the measurement (meas.) and simulation (sim.) insertion loss of the proposed structures and meander-L bridge structure. Excellent agreement between the measurement and simulation from 50 MHz to 6 GHz is seen. From this figure, the suppressed SSN range of meander-L bridge structure is from about 436 MHz to 4.362 GHz (3.926 GHz bandwidth). The key factor of meander-L EBG structure is the meander-L itself, this design can increase the inductance between two integrated squares greatly so that they can suppress the SSN at lower frequencies. But the meander-L structure can not improve the SI problem because this structure will destroy the power/ground planes.

III. SIGNAL INTEGRITY FOR THE MEANDER-BRIDGE EBG POWER PLANES

Fig. 5(a) shows the cross-section of the layer stack-up. The meander-bridge EBG power plane and integrated ground are designed on the second and the third layer, respectively. The length of single-ended trace is 89.6145 mm as shown in Fig. 5(b). They are passing from the top layer to the bottom layer and back to the top layer by two via holes. The trace width is 0.743 mm. The S-parameters for the single-ended structure is simulated by HFSS. Afterward, the eye patterns at the output side are simulated by using pseudorandom bit sequence (PRBS) in Microwave Offices. The bit-sequence swing and the nominal rise/fall time are 1 V and 104 ps, respectively. The data rate of source is 1.6 Gbps. Fig. 6 shows the simulated eye pattern for the proposed structure and other compared structures. The maximum eye open (MEO) and the maximum eye width (MEW) are used as metrics of the eye pattern quality. It is seen that for reference board, MEO = 956 mV and MEW = 623 ps, and the simulated results of compared structures are shown in Table II.

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>Ranges</th>
<th>Bandwidth</th>
</tr>
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<tbody>
<tr>
<td>Without interdigital pads (Meas.)</td>
<td>0.868 ~ 5.03</td>
<td>4.162</td>
</tr>
<tr>
<td>With interdigital pads (Meas.)</td>
<td>0.882 ~ 4.913</td>
<td>4.031</td>
</tr>
<tr>
<td>Without interdigital pads (Sim.)</td>
<td>0.918 ~ 4.875</td>
<td>3.957</td>
</tr>
<tr>
<td>With interdigital pads (Sim.)</td>
<td>0.864 ~ 4.86</td>
<td>3.996</td>
</tr>
<tr>
<td>LPC-PBG (Meas.)</td>
<td>0.868 ~ 3.902</td>
<td>3.034</td>
</tr>
<tr>
<td>Meander-L EBG (HFSS)</td>
<td>0.436 ~ 4.362</td>
<td>3.926</td>
</tr>
</tbody>
</table>
Figure 6. Simulate eye patterns for single-ended trace. (a) The voltage of PRBS source. (b) The reference board. (c) The LPC-EBG structure. (d) The meander-L bridge EBG structure. (e) The meander-bridge EBG structure. (f) The interdigital meander-bridge EBG structure.

Table II. The MEO and MEW for the propose meander-bridge structures and compared structures.

<table>
<thead>
<tr>
<th>Cases</th>
<th>Eye pattern parameter</th>
</tr>
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<tbody>
<tr>
<td>Reference board</td>
<td>MEO (mV) MEW (ps)</td>
</tr>
<tr>
<td>LPC-EBG structure</td>
<td>956 mV 623 ps</td>
</tr>
<tr>
<td>Meander-L bridge EBG structure</td>
<td>804 mV 600 ps</td>
</tr>
<tr>
<td>Meander-bridge EBG structure</td>
<td>732 mV 599 ps</td>
</tr>
<tr>
<td>Interdigital meander-bridge EBG structure</td>
<td>720 mV 610 ps</td>
</tr>
<tr>
<td>Interdigital meander-bridge EBG structure</td>
<td>806 mV 615 ps</td>
</tr>
</tbody>
</table>

IV. CONCLUSION

The interdigital meander-bridge EBG structure for improving the SSN between sensitive RF/analog circuits has been proposed. Compared with the LPC-EBG and meander-L structures, our physical structures have better return paths for high frequencies signal. Because interdigital pads decrease the width of gap between the integrated squares and meander-bridge, the present structure can provide a better SI.
REFERENCES


