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AN EMBEDDED ISOLATION MOAT STRUCTURES WITH WIDE STOPBAND AND LOW PARASITIC EFFECT FOR ELIMINATION SIMULTANEOUS SWITCHING NOISE

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Abstract—In this letter, we use two embedded isolation moats which have different size to obtain the wide stopband elimination performance. The proposed structure is realized by embedding the double isolation moats between power and ground planes. The suppression frequency range of the proposed structure is from 1.2 to 7.2 GHz and the peak noise improvement in time domain is 36%. Furthermore, the proposed structure uses two elimination cells to avoid the parasitic effect generated in the frequency range of several hundred MHz.

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1. INTRODUCTION

A parallel-plate waveguide, which consists of two parallel metal planes and a dielectric substrate, is widely used to modern printed circuit board (PCB) assembly or high-speed packages. However, a cavity formed by the parallel-plate waveguide and the resonance modes can be excited by the simultaneously switching noise (SSN) when the center frequency becomes higher. The resonance noises could produce serious signal integrity (SI) or power integrity (PI) issues [1, 2]. It also induces significant electromagnetic interference (EMI) problems [3].

Several approaches for reducing simultaneously switching noise have been presented. Adding decoupling capacitors between the power and ground planes is an efficient method to eliminate the noise. This method provides a low impedance path leading noise to ground. However, the wideband suppression behavior needs about one hundred capacitors to obtain [2, 3] and decoupling capacitors are not efficiently above several megahertz, due to the effective series inductance of the capacitors. Etching a moat on the power plane to isolate the noise is another approach for avoiding the noise from coupling to the other circuits. In order to escape the EMI problems, a bridge which connects the isolation region and the rest area on the power plane is necessary to provide RF the moat [4]. Nevertheless the SSN could be transferred to outside of the slots through the connecting bridges. Electromagnetic band-gap (EBG) structure exhibits electromagnetic properties that have led to a wide range of applications to filter [5] and antenna [6]. Recently, EBG structure [7] and high-impedance surface (HIS) [8, 9] are widely utilized in SSN suppression between power and ground planes in high-speed circuits. There are many literatures focused on the structure which has lower stopband frequency or broaden the stopband bandwidth. An EBG structure with meander lines is possible to not only extend the bandgap, but also decrease the lower edge of the bandgap [10]. A double-stacked EBG structure was enabled by combining two EBG layers embedded between the power and ground planes [11]. This structure significantly extends the noise isolation bandwidth. However, the undesired resonance in low frequency is induced by EBG and HIS structures. The EMI and SI problems will be taken place by these resonances in high-speed circuit.

In this paper, we propose a new structure with wideband SSN suppression and low parasitic effect in high-speed circuits. The primary conception of this new structure is embedding the isolation moat between the power and ground planes. The proposed structure with 6 GHz stopband covers from 1.2 GHz to 7.2 GHz. Furthermore, the proposed structure does not use many elimination cells to avoid the parasitic effect. This structure is able to not only extend the stopband width, but also decrease the parasitic effect in the low frequency.

2. DESIGN CONCEPT

Our design was realized by combining two isolation moats, which were embedded between power and ground planes. Each moat and ground plane is connected with via to form high-impedance surface structure. The power and ground planes are kept continuous to ensure SI problem, as shown in Figure 1(a). The exciting and receiving port are defined as port 1 and port 2, respectively. Two isolation moats are located around the exciting port to observe the suppression behaviors. Dimension of the two-layer PCB is 90 mm × 90 mm and top view of the proposed structure is shown in Figure 1(b). There are two isolation moats between power and ground planes. The external moat is defined as moat 1, and the other is called moat 2. The corresponding geometrical parameters are denoted as ε_{r1}, ε_{r2}, h_1, h_2, r, L, w, g, where ε_{r1} and ε_{r2} are the dielectric constant of the substrate; h_1 and h_2 are the thickness of the substrate, respectively; r is the radius of the via; g is the gap between two isolation moats; L and w are length and width of the isolation moat, respectively. A series-resonant circuit of the inductor and capacitor can be used to model the equivalent circuit of the proposed structure [1], where capacitance is determined by the patch size and the inductance is dominated by via.

3. RESULT AND DISCUSSION

3.1. Frequency Domain Performance

To demonstrate the proposed structure with efficient suppression behavior, a reference board with power and ground planes keeping continuous is used to compare. Figure 2 shows the simulated S_{21} for the exciting port with individual isolation moat, in which $L_1 = 20$ mm and $L_2 = 12.5$ mm, respectively. All other geometrical parameters are $w_1 = w_2 = 2$ mm, $r = 0.25$ mm, $h_1 = 0.8$ mm, $h_2 = 0.4$ mm, $\varepsilon_{r1} = \varepsilon_{r2} = 4.4$, $g = 1.75$ mm. Below 8 GHz, there are two stopbands for each isolation moat. The full wave simulated results are performed using Ansoft HFSS simulation tool. The bandwidth is defined by the insertion loss less than 20 dB. The bandwidth of the moat 1 is approximately 2.2 GHz, from 1.2 to 3.4 GHz for the first stopband and approximately 1.6 GHz, from 5.2 to 6.8 GHz for the second stopband. The bandwidth of the moat 2 is approximately 2.2 GHz, from 3.5 to 5.7 GHz for the first stopband and approximately

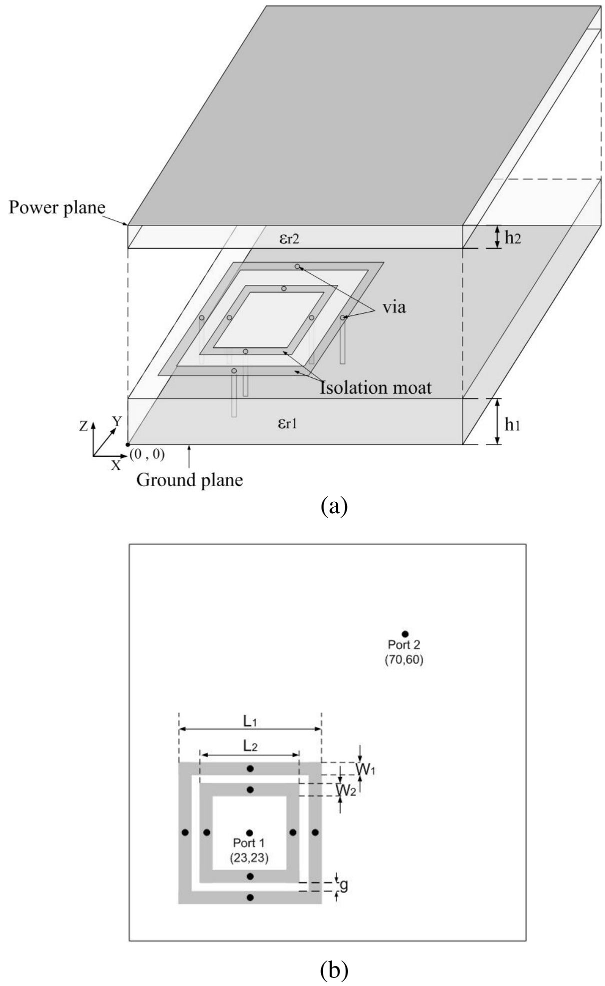

Figure 1. Schematic diagram of the proposed double isolation moat structure. (a) The 3-D view of the structure. (b) Top view of the embedded structure.

1.3 GHz, from 6.3 to 7.6 GHz for the second stopband. Figure 3 shows the suppression results of the two isolation moats individually located around the exciting port and receiving port, respectively. Compared with the reference board, the suppression in a wideband bandwidth is approximately 5.6 GHz, from 1.2 to 6.8 GHz. Figure 4 shows the measured and simulated S_{21} for the proposed double isolation moats structure. The difference between measured and simulated results

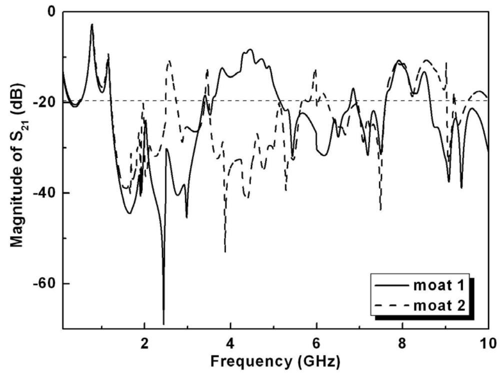

Figure 2. The suppression behaviors for the exciting port with individual isolation moat.

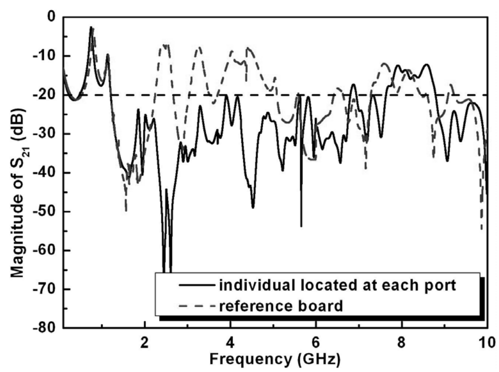

Figure 3. The suppression results of the two isolation moat individual located at each port.

could be resulted from the fabrication accuracy for via dimension and the air gap among the laminated construction. The -20 dB stopband bandwidth of the proposed structure is 6 GHz. Compared with Figure 3, the bandwidth of the proposed structure is wider than 0.8 GHz. It represents that isolation moats placed around exciting port has capability of efficiently eliminating the noise propagation. Because the noises are rapidly suppressed by two isolation moats before that propagated to receiving port.

The traditional approaches, e.g., EBG and HIS structures have excellent omni-direction suppression behaviors. However, it can be clearly observed that undesired multiple resonances exist in several hundred MHz, in which the resonances are caused by the parasitic

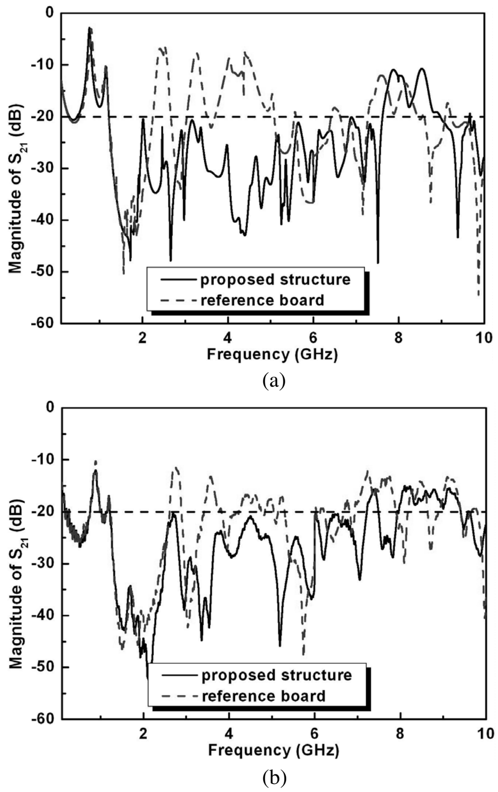

Figure 4. The (a) simulated, (b) measured S_{21} for the proposed double isolation moats structure.

effect of the EBG structures. These peaks have the capability of leading the SI and EMI problems. Compared with the reference board, the undesired resonant frequency does not exist as the frequency is below 1.5 GHz. It means that the proposed structure does not produce significant resonance in low frequency range.

3.2. Time Domain Analysis

A time-domain digital current source is generated and then transformed into a frequency domain response by applying Fourier transform. The input signal is 3.2 Gbps with amplitude of 166 mV and 319 ps edge rate. The time domain analysis of the suppression behavior for the proposed double isolation moat structure are shown in Figure 5. The amplitudes of the proposed structure and the reference board are

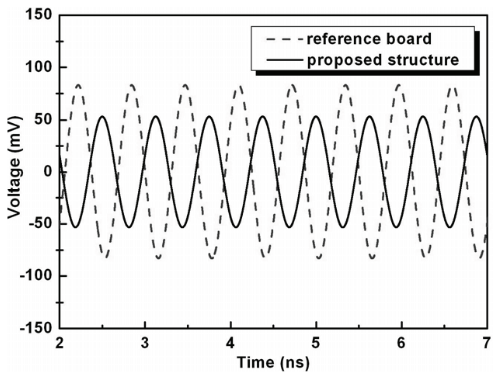

Figure 5. The SSN suppression performance in time domain.

approximately 107.2 mV and 166.6 mV, respectively. Compared with the reference board, the peak noise improvement is approximately 36% for the double isolation moat structure.

4. CONCLUSION

A double isolation moat structure with wide stopband and low parasitic effect is proposed. This concept consists of cascading different dimension of the isolation moats and creating rejection over a wider frequency region. The varied size of the moat structures should be placed around the same port to produce effective SSN suppression. The proposed structure behaves excellent SSN suppression from 1.2 to 7.2 GHz and low parasitic effect in several hundred MHz. The ultra-wide bandwidth SSN suppression using varied dimension of the proposed structure could be obtained.

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