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Serpent Novel Planar Electromegnetic Band Gap Structures of Suppression of Switching Noise in High Speed PCB

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Abstract: We proposed the novel planar miniature and wide band electromagnetic band gap structures with meander plane for power/ground noise suppression in multilayer printed circuit boards. An ultra wide band gap extending from 300 MHz to 10 GHz and beyond is demonstrated by both simulation and measurement and a fine concurrence is observed. In this study a novel method of arranging number of EBG unit cells on both the power ground planes in multi layer PCBs and package is proposed, not only as a means of sufficiently the propagation of power noise but also as a means of minimizing the effect of EBG patterned on a high speed signal. A novel concept of using the EBG structures the reduction of electromagnetic interference is also introduced.

Key words: Electromagnetic Band Gap Structures (EBG), Simultaneous Switching Noise (SSN), Electromagnetic Interference (EMI), Meander Plane (MP), India

INTRODUCTION

The Power Distribution Network (PDN) consisting of both the power plane and a ground plane (P/G) in multilayer Printed Circuit Boards (PCB). The Simultaneous Switching Noise (SSN), Ground Bounce Noise (GBN) AND delta-I noise which mainly occur in high-speed digital systems. The SSN is generated by fast switching devices such as a CPU chip connected to a PDN. It can excite the cavity resonance modes within the parallel-plate waveguide-type P/G planes found in multilayer PCBs and packages. The SSN can lead to significant some problems with Signal/Power Integrity (SI/PI) as well as Electromagnetic Interference (EMI) issues (Swaminathan *et al*., 2004; Wu *et al*., 2004a, b; Lei *et al*., 1999). To build a stable PDN for high-speed digital systems, SSN in multilayer PCBs and packages should be signil cantly suppressed. The problems of SSN have been suppressed by a number of researchers (Swaminathan *et al*., 2004; Wu *et al*., 2004; Lei *et al*., 1999; Kim *et al*., 2008; Hubing *et al*., 1995). The electromagnetic noise in power/ground planes can cause fluctuation or disturbance in the power supply voltage. The Simultaneous Switching Noise (SSN) has become one of the most important concerns (Swaminathan *et al*., 2004; Wu *et al*., 2004a, b).

The Electromagnetic Band Gap (EBG) structures are surrounded in power/ground planes have been introduced as an efficient solution to suppress the power/ground noise in a high-speed PCB board (Wu *et al*., 2005). The main advantages of the EBG structure in the power/ground planes are wideband suppression over the GHz frequency range, high noise rejection level and simple integration in the Printed Circuit Board (PCB). In a previous study on miniaturization, a high dielectric constant material is adopted to effectively increase the patch capacitance (Iglesias *et al*., 2007). However, the usage is constrained by the low reliability and the high cost of the manufacturing process. In the literatures of Lee *et al*. (2005), Chen and Melde (2006) and Abhari and Eleftheriades (2002, 2003), the edge-located via, slit on a patch and a spiral-patterned patch are introduced to attain size reduction without any additional material. The inductance of the EBG unit cell is effectively increased for reduction in the start frequency of the band gap (f_L) which results in the size reduction. However, the stop band bandwidth is decreased by the miniaturization. Considering the wideband spectra of the power/ground noise, it is popular that the EBG structure is miniaturized without degrading the stop band bandwidth.

In this study we propose a Meander Plane EBG (MP-EBG) structure with a significant size reduction and stop band bandwidth enhancement for power/ground noise suppression in the multilayer PCBs. The proposed perforation increases the characteristic impedance (Zo) of the EBG unit cell and improves the wave characteristics below the band gap. It is experimentally verified that the proposed MP-EBG structure achieves both a significant

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reduction in the unit cell size and the desired stop band improvement. Recently, the Electromagnetic Band Gap (EBG) structures have been proposed as a solution capable of sufficiently eliminating SSN. In the initial stage of EBG-related studies, a forbidden frequency band was achieved using mushroom-shaped EBG structures (Kamgaing and Ramahi, 2003; Shahparnia and Ramah, 2004; Wu *et al*., 2004a, b). In this study, a novel array method of locating EBG unit cells partially on both the power and ground planes is proposed for multilayer PCB and packages, it's not only sufficiently eliminates the propagation of SSN but also minimizes the effect of EBG attractive reference planes on high speed PCB signals. The proposed method partially arranges EBG unit cells only near the critical areas. In addition, the proposed structures can use the EBG structures to broaden the forbidden frequency range by incorporating different sizes of EBG unit cells in the P/G planes (Iglesia *et al*., 2007). Electromagnetic Band Gap (EBG) structures, proposed in recent years, have proven effective for noise suppression at frequencies above 1 GHz which the methods mentioned above cannot achieve. EBG structure is a kind of periodic structure that can form High-Impedance Surface (HIS) to prevent the propagation of electromagnetic wave over some frequency range. It was first proposed by sieve piper for application in order to suppress surface wave (Sievenpiper, 1999).

The earlier structures used three layers where the EBG pattern layer with specially designed via is insert between the power plane and the ground plane which makes the fabrication more expensive. Recently the new planar EBG structures were reported for switching noise improvement as in (Wu *et al*., 2005). These novel structures previous multilayer EBG structures used for power plane noise mitigation do not have via holes. In this study, we present planar EBG patterned multi layer PCBs used for noise mitigation. The negative aspect of earlier structures is the limited width of the band gap. The introducing novel structures with meander lines in conjunction with the concept of a super cell, it is possible to not only extend the band gap beyond that was achieved in previous works but also decrease the lower edge of the band gap to approximately 300 MHz without increasing the EBG patch size. It is important to the possibility of electromagnetic leakage through the perforated layer.

PLANAR EBG STRUCTURE DESIGNS AND SSN MITIGATION

The EBG structure design Fig. 1 shows the proposed multi layer power/ground plane with meander line EBG structure. The solid layer can be used for one voltage level AND the EBG-patterned layer is used for the second voltage level. Between these two layers, a uniform substrate material FR-4 with dielectric constant 4.4 and layer thickness of 0.2mm is selected due to its manufacturing ?exibility at our local facilities. The schematics of the unit cell of size 12.2×12.2 mm and its corresponding parameters are shown in Fig. 1. The patch length and width is 12 mm and the gap between the neighboring patches is 0. 2 mm. The width of the meandered line is 0.2 mm. This qualitative model is inspired by the physical behavior of the fields in the patch. It consists of two parts. The first part describes the propagation characteristics between the EBG patch and the continuous power plane, represented by equivalent inductance Lp and capacitance Cp. The second part characterizes the bridge effects between two adjacent unit cells where the gap between the two neighboring unit cells induces the fringe capacitance Cb and the bridge connecting the neighboring unit cells as the inductor Lb. This EBG structure can be conceptually viewed as an electrical ?lter of parallel LC resonator. The center frequency of the stop-band for the EBG structure can be expressed semi quantitatively as $f0 = 1/(2\pi\sqrt{LbCb})$. If the meander line as the connecting bridge (dc link) between adjacent patches, the width of the meandered line is 0.2 mm.

For planar EBG structure, self-resonance plays the main role in the formation of band gap. The surface impedance of the EBG structure is equal to parallel LC resonant circuit. The center frequency and bandwidth of the band gap is determined by the following formulas:

$$Lp = \mu h \tag{1}$$

$$Cp = \varepsilon_r \varepsilon_0 \ (Area/h) \tag{2}$$

where, L and C are the inductance and capacitance of the planar EBG structure, respectively. From the equations, it can be inferred that the stop band bandwidth is inversely proportional to the value of C. However, when the value of C gets much smaller, the center stop band frequency will become higher which is not expected. Increasing the value of L can lower the center stop band frequency and widen stop band bandwidth. If the enlargement of L is much greater than the diminution of C, a planar EBG structure which has lower center stop band frequency and wider stop band bandwidth can be gained. The comparison of unit cell with meander line for proposed edge located via, Slit on patch and Mushroom type. The lower and upper frequency value for proposed method is very high compared to other method. Therefore, the bandwidth is wide.

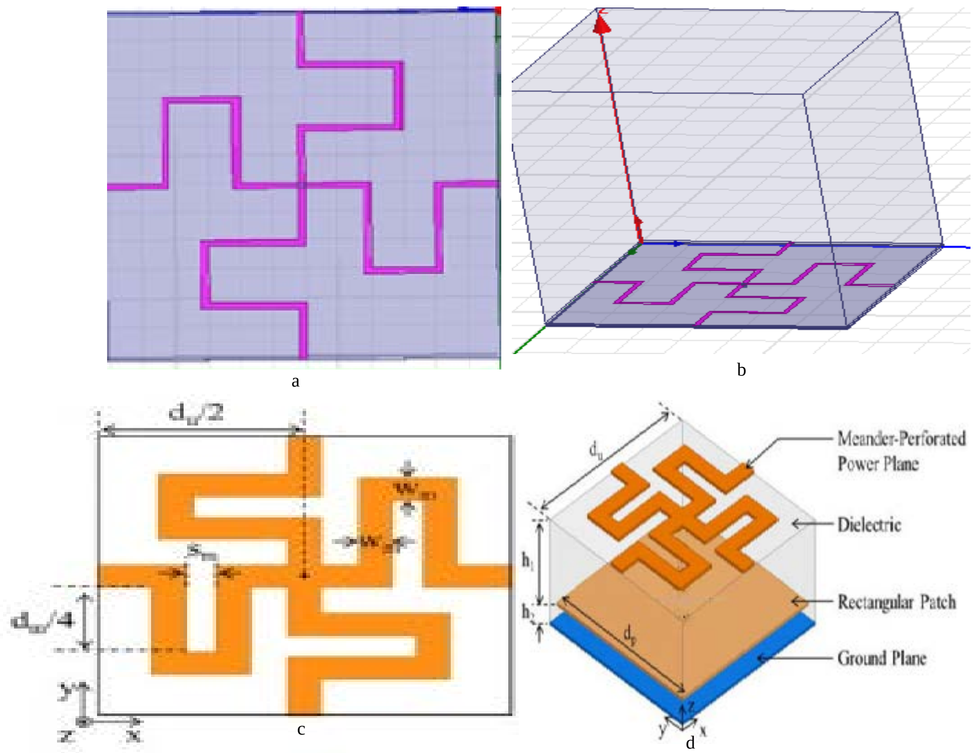

Fig. 1: Proposed EBG structure using a MP: a) Top view with unit EBG cells; b) Perspective view of unit cell structure; C and d) Dimension of unit cell

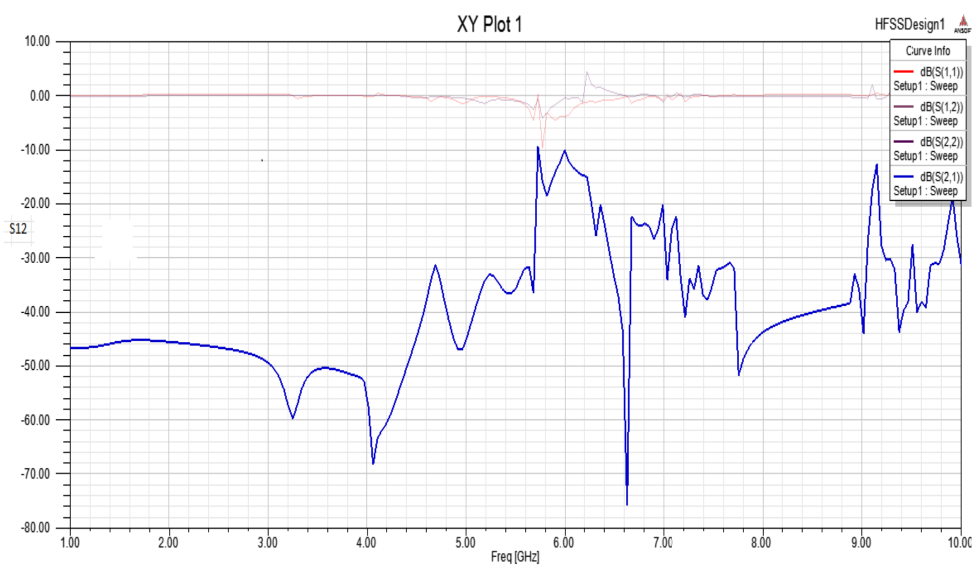

Fig. 2: Comparison of measured S 2 1coefficients for verification of the proposed MPP-EBG structure

The EBG structure can be applied to eliminate the SSN in the power/ground plane pairs. Figure 2 shows the novel EBG structure we designed and its dimensions in detail. We add two ports at the location of interest. Take the

Table 1: Comparison of band gap characteristics (dimension in mm)

Variables	Dm	Dp	H1	H2	Dm	Wm	sm	Fl	fh	BW
MP (Proposed)	12.2	12	0.1	0.1	11.2	0.2	2	3.0	5.7	2.7
Edgelocated via	12.2	12	0.1	0.1	-	-	-	1.38	2.13	0.75
Slit on patch	12.2	12	0.1	0.1	-	-	-	0.92	1.34	0.42
Mushroom type	12.2	12	0.1	0.1	-	-	-	1.58	2.38	0.8

center point (0,0) as the reference point. Then excitation is at the position of Port l (6.1 and 0 mm) and receiver is at the position of Port 2 (6.1 and 12.2 mm) The simulation result of the transmission characteristics between Port 1 and Port 2 is shown in Fig. 2. The result indicates that the valid-30 dB suppression bandwidth is broadened from 300-10 GHz.The proposed EBG power/ground plane pairs significantly eliminate the SSN with an over -30 dB suppression in a broadband frequency rang.shown in Table 1.

CONCLUSION

New types of planar EBG structures for suppression of power/ground noise propagation in high-speed circuits have been proposed. Simulation and measurement show that the EBG patterned power plane incorporating meander lines as a dc link between patches can effectively achieve wide band noise mitigation. By periodically cascading two patches with different topology, an ultra wide band gap for the suppression of SSN propagation extending from 300 MHz to 10 GHz is achieved. When comparison is made with the PCB with solid reference plane, the planar EBG structures introduced here can effectively suppress wave in the PCB. These EBG-based structures can be used to further reduce EMI. It is concluded that acceptable quality of data transmission at high-speed clock rate can be achieved with the super cell EBG-based structure AND signal quality can be further improved if differential signaling is used. In summary, the proposed planar EBG structures not only strongly reduce the power/ground noise propagation for a wide frequency range but also achieve broadband held mitigation for EMI applications. For further we have to design the array of unit cell with meander line EBG structures of suppression for power/ground noise propagation in high speed circuits.

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