NOISE MITIGATION IN HIGH SPEED PCBS USING SPIRAL SHAPED POWER ISLAND EBG STRUCTURES

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Abstract- When a common power supply is used for both analog and digital circuits present in a mixed signal board operating at higher frequency, the noise generated from the high speed digital circuit propagates through the power delivery network (PDN) and affect the performance of sensitive analog circuits. In this paper, power integrity is studied for different EBG cell structures in between 0-10GHz using ADS software. From the simulated results, the straight line EBG provides good suppression for higher frequency, So a Modified Straight Line EBG is designed and examined. By using this in cascaded form the suppression level is maximum of about -65 at 19GHz and minimumof-30dB throughout 8-20GHz. using this in longbride the suppression is maximum of about -65dB at 14GHz and minimum of about -30dB throughout 8-20GHz. By using this EBG in long bridge with via the suppression is maximum of about -72dB at 14GHz and minimum of -30dB throughout 8-20GHz.Finally the long bridge EBG with via is fabricated, measured and the experimental results have good agreement with the simulated results.

Keywords: Electromagnetic bandgap (EBG), Signal integrity (SI), Power integrity (PI).

I INTRODUCTION

A power distribution network (PDN) in multilayer printed circuit boards (PCBs) and electronic packages typically includes both power and ground planes (P/G planes) to supply power to core digital and analog/RF circuits in high-speed systems. However, maintaining stability in such a PDN is often challenging due to simultaneous switching noise (SSN)—a type of power/ground noise. SSN mainly arises in high-speed digital systems when rapid current fluctuations occur within the inductive PDN over a very short time.

This noise is primarily generated by fast-switching components like CPU chips connected to the PDN. The SSN can excite cavity resonance modes within the parallel-plate waveguide structure formed by the P/G planes in multilayer PCBs and packages. These resonant modes propagate through the P/G planes and can interfere with critical signal traces or sensitive analog/RF components, leading to signal and power integrity (SI/PI) degradation.

Therefore, minimizing SSN is essential for achieving a stable PDN in high-speed digital circuits. Numerous researchers have investigated techniques to suppress SSN effectively, and one of the most promising recent approaches involves the use of electromagnetic bandgap (EBG) structures, which have shown strong potential in mitigating SSN within multilayer PCB systems.

This paper proposes a spiral-shaped power island structure Figure 1 that can effectively suppress simultaneous switching noise (SSN) when the power plane drives high speed integrated circuits in a small area**.** In this paper a new EBG is proposed which provides a good noise suppression level. The design specifications are board size 35 x 35mm, number of layers used is 2, substrate used here is fr4,dielectric constant is 4.4.

II DESIGN OF EBG UNIT CELL

Each unit cell of the proposed Electromagnetic Band Gap (EBG) structure consists of a square metallic patch interconnected by bridge lines, forming a periodic lattice on the power distribution plane. These periodic structures inherently exhibit a stopband characteristic in which noise propagation is effectively suppressed due to the parallel resonance between inductive and capacitive components.

An equivalent circuit model of an EBG unit cell on the power plane is depicted in Fig. 2, where the dotted enclosure represents a parallel LC resonant network responsible for generating the stopband behavior. In this model, the inductance (L) is primarily contributed by the bridge lines that connect adjacent unit cells, while the capacitance (C) arises mainly from the gap coupling between the square metallic patches.

Considering the LC resonant circuit, the effect of varying the inductance and capacitance on the stopband bandwidth can be analyzed. For a fixed resonant frequency, a reduction in capacitance or an increase in inductance results in a broader stopband. Hence, to achieve an enhanced and wider noise suppression band, the bridge line inductance should be increased, and the gap-coupling capacitance should be minimized.

This design optimization approach provides an effective means of realizing broadband noise suppression in high-frequency planar power distribution networks.

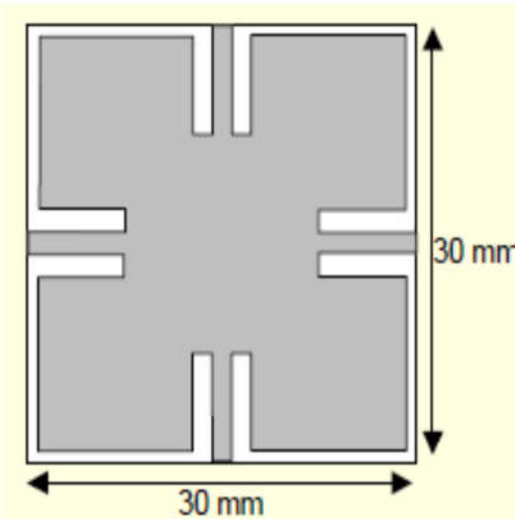


Figure 1.Spiral-shaped power island EBG structure

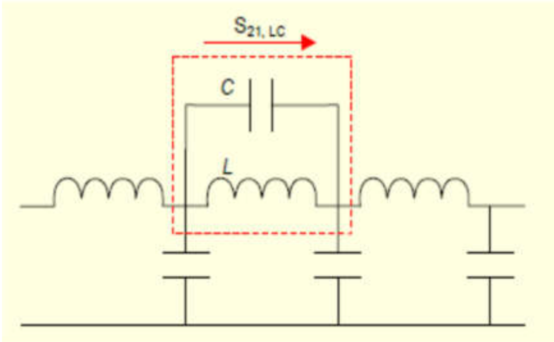


Figure 2.Equivalent circuit model of an EBG unit cell.

III Power Integrity Analysis With Spiral-shaped power island EBG structure

The Spiral-shaped power island EBG structure is examined for cascading, long bridge and with long bridge with via is given below

A. Analysis Of Power Integrity For Spiral-shaped power island EBG Unit Cell

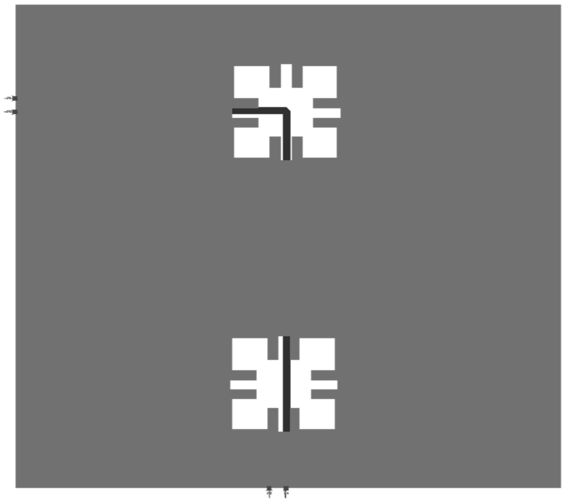


Figure 5 Power Plane With Spiral-shaped power island EBG Cell

Figure 5 illustrates the structure of the spiral-shaped power island EBG cell**,** in which an EBG pattern is etched on the power plane, while a signal trace is designed on the ground plane beneath it. The purpose of this signal trace is to provide a defined path for current flow, enabling controlled propagation of signals while allowing the EBG structure to effectively suppress noise and electromagnetic interference within the circuit.

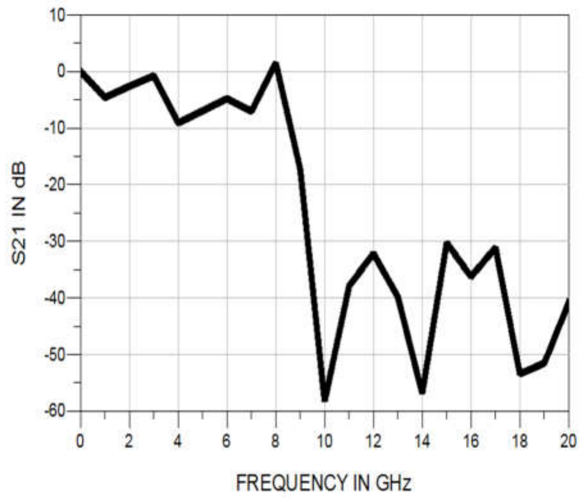


Figure 6.S21 Response Of Spiral-shaped power island EBG cell

Figure 6 illustrates the S21 response of the spiral-shaped power island EBG structure. The measured transmission characteristics indicate a maximum suppression level of approximately –59 dB at 10 GHz, demonstrating the strong noise attenuation capability of the proposed design. Across the frequency range of 8–20 GHz, the structure maintains an attenuation level no lower than –30 dB, confirming its effectiveness in providing wideband noise suppression within high-frequency planar circuits.

B. Design Of Spiral-shaped power island cascading EBG structure

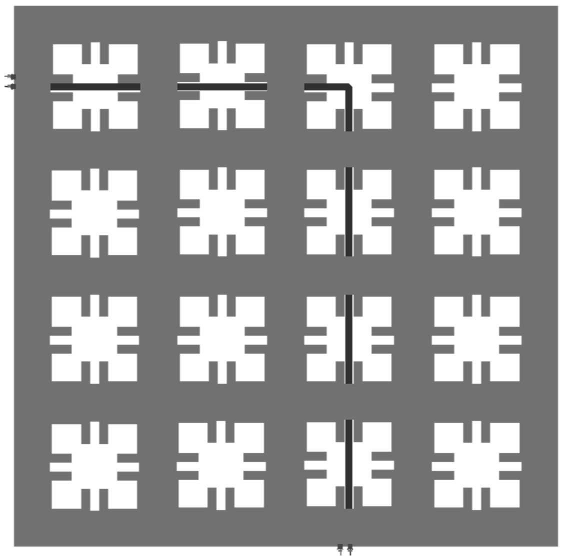


Figure 7 Power Plane Of Spiral-shaped power island cascading EBG structure

Figure 7 illustrates the structure of the power plane incorporating the spiral-shaped power island cascading EBG configuration. In this design, multiple spiral-shaped EBG cells are arranged in a cascaded manner to enhance the overall noise suppression performance. The cascading arrangement effectively increases the attenuation bandwidth and provides improved isolation characteristics. As a result, this structure exhibits superior noise suppression capability compared to other EBG configurations analyzed in this study..

C. Design Of Spiral-shaped power island Long Bridged EBG

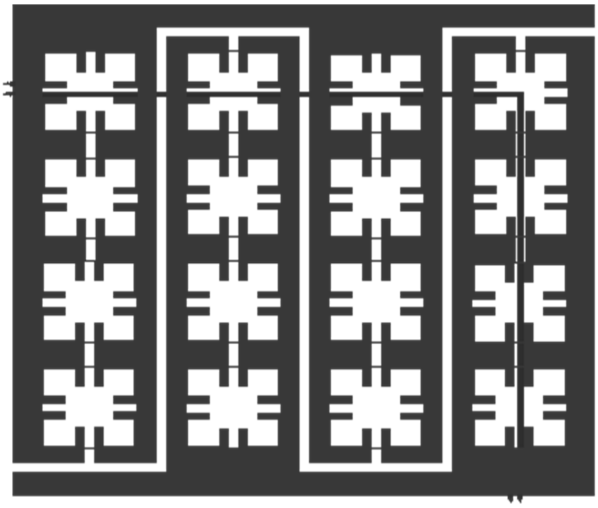


Figure 8 Power Plane Of Spiral-shaped power island Long Bridged EBG structure

Figure 8 illustrates the power plane structure of the spiral-shaped power island long-bridged EBG configuration. In this design, the spiral-shaped EBG cells are interconnected through extended bridge lines, which enhance the inductive coupling between adjacent cells. This configuration effectively broadens the stopband and improves the overall noise isolation performance. Consequently, the long-bridged EBG structure demonstrates superior noise suppression characteristics**,** providing greater attenuation compared to conventional EBG designs.

D. Design Of Spiral-shaped power island EBG In Long Bridge With Vias

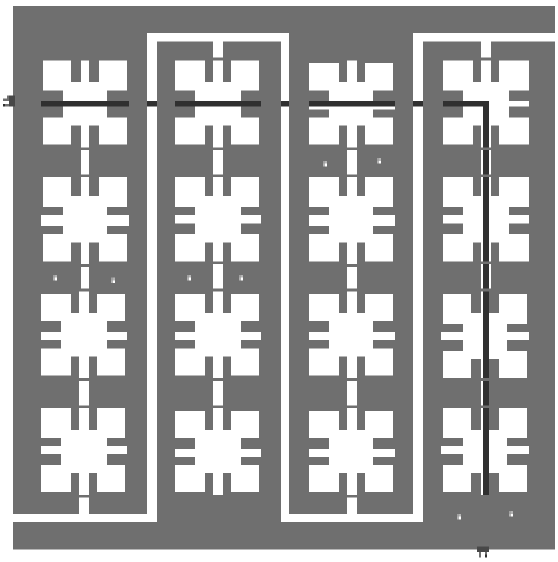
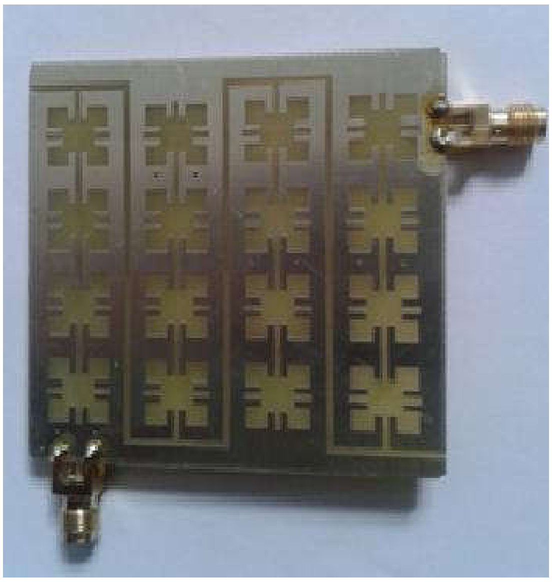


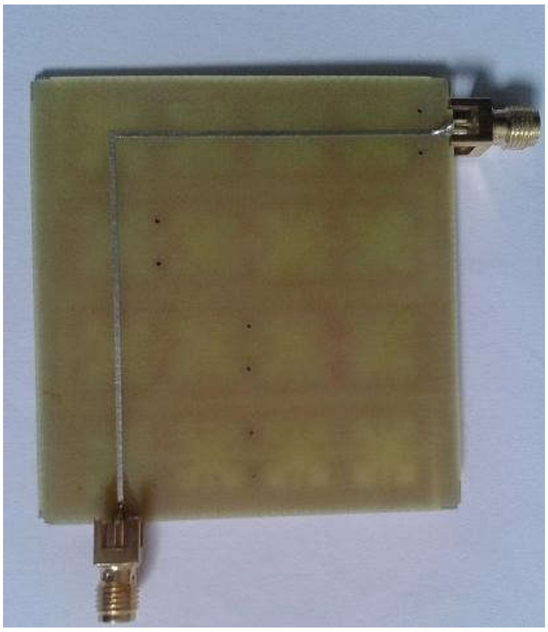
Figure 9 Power Plane Of Spiral-shaped power island Long Bridged EBG With Vias

Figure 9 illustrates the power plane structure of the spiral-shaped power island long-bridged EBG with vias. In this configuration, vertical vias are incorporated into the long-bridged EBG design to further enhance the electromagnetic coupling between the power and ground planes. The addition of vias significantly improves the suppression of simultaneous switching noise by increasing the effective inductance and providing additional current return paths.

The proposed structure was fabricated and experimentally characterized to validate its simulated performance. The photographs of the fabricated prototype are presented below, demonstrating the physical realization of the spiral-shaped power island long-bridged EBG with vias configuration. The measured results confirm the strong noise suppression capability predicted by simulation, highlighting the effectiveness of the proposed design.



a)Topview



(b)Bottomview

Comparison Result

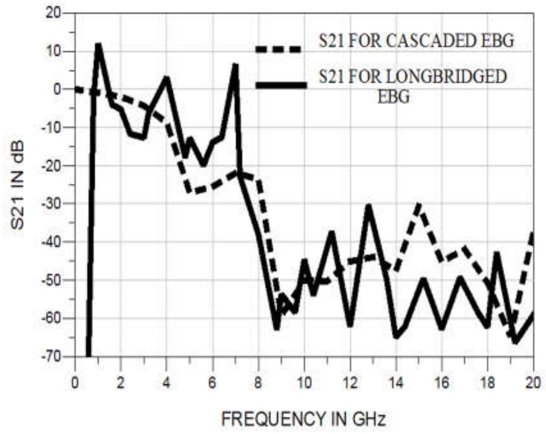


Figure 10 Comparison Of Simulated S21 Response Of Cascaded EBG And Long Bridged EBG

Figure 10 presents a comparison of the S21 response between the spiral-shaped power island EBG structure and the modified straight-line long-bridged EBG structure**.** The comparative analysis highlights the superior performance of the spiral-shaped configuration in terms of noise suppression across a wide frequency range. The S21 response of the spiral-shaped power island EBG structure exhibits a maximum attenuation of approximately –65 dB at 19 GHz, indicating strong suppression of power/ground noise. Across the 8–20 GHz frequency band, the attenuation remains above –30 dB, demonstrating consistent and broadband noise isolation characteristics.

This comparison clearly validates the enhanced effectiveness of the spiral-shaped power island EBG structure over the modified straight-line long-bridged EBG design, confirming its suitability for high-frequency power distribution network applications.

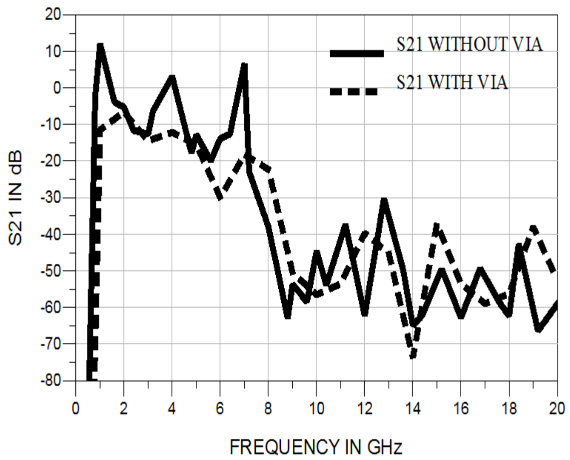


Figure 11 Comparison Of Simulated S21 Response Of Long Bridged EBG And Long Bridged EBG With Vias

From Figure 11, a comparison is made between the power plane of the long-bridged EBG structure without vias and the power plane of the long-bridged EBG structure with vias. The S21 response of the long-bridged EBG without vias exhibits a maximum noise suppression of –65 dB at 19 GHz, whereas the S21 response of the long-bridged EBG with vias shows an enhanced suppression of –72 dB at 14 GHz**.**

The fabricated board was tested, and the measured results were compared with the simulated data to validate the performance. The comparison results are illustrated below. This figure depicts both the simulated and measured transmission coefficient (S21) of the long-bridged EBG structure with vias. The simulated data demonstrate a maximum noise suppression of **–72 dB**, and a strong correlation is observed between the simulated and measured results, confirming the accuracy and reliability of the proposed design.

III. CONCLUSION

A novel Electromagnetic Band Gap (EBG) based performance analysis for noise suppression in high-frequency planar circuits is proposed. In this study, a comparative evaluation of three different noise mitigation strategies is carried out to assess their effectiveness. The experimental results demonstrate that the long-bridged EBG structure with via implementation achieves superior noise suppression, providing an attenuation level of approximately –72 dB across the entire Ultra-Wideband (UWB) frequency range.

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V.

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