A Novel S-Bridged Power Plane With Ultra Wideband Suppression of Ground Bounce Noise Using Open Stub

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Abstract—**In this paper, a novel power plane is proposed using the novel S-shaped bridge electromagnetic bandgap (EBG) structure to isolate the ground bounce noise (GBN) and ultra-wideband suppression of simultaneous switching noise (SSN) in high-speed circuit. The S-shaped bridge effectively increases the inductance between two adjacent unit cells. And the ripples are held down by open stub to get higher attenuation level. The stop-band of -30 dB suppression bandwidth of the design |S31| is from 114 MHz to 8.5 GHz, The results of simulation and experiment will be presented to verify the good performance, and that it covers the entire noise band.**

Keywords—electromagnetic band-gap(EBG); ground bounce noise(GBN);power-to-ground(PGN)plane;open-stub;high-speed circuit; power/signal integrity;

I. INTRODUCTION

In the moden era of developing technology, electronic devices depend on digital electronics and demands not only efficiency but also quality in electric signals, so as to minimize implications during applications. High-speed circuits have fast edge rates,high clock frequencies, and low voltage levels. As a result, the problem of ground bounce noise (GBN) in a wide frequency range, also known as simultaneous switching noise (SSN) arises. The GBN will excite the multiple resonance modes between the power/ground planes, forming resonance noise, as seen in the parallel plates model[1]. There has been many efforts done on the investigation of how to suppress the parallel plate resonance modes [2].[3]. When the noise arises between the power and ground planes, it will cause the signal integrity to be compromised seriously and unwanted electromagnetic interference. This problem can be resolved by connecting decoupling capacitors between the two plates or by using the isolation moat on either the power or the ground plane or by selecting the location of the via ports to eliminate [4].[5].[6], However, such methods only curb the GBN at its target location.

Electromagnetic bandgap structures are periodic structures, and their stopband characteristics can be used to prevent the propagation of electromagnetic waves in a specific frequency range, They has been introduced as a simple, effective, and easy-to-implement isolation approach in printed circuit board (PCB) and package for GBN suppression in the gigahertz range. However the approach is less effective at frequencies higher than 600 MHz due to the parasitic lead inductance of the decoupling capacitors. But it is possible to have an EBG without capacitors. Many EBG structures are limited probably due to parasitic crosstalk between the cells.

Several designs have been presented in an attempt to expand the stop-band width to cover the wide GBN frequency range, which usually goes from 100 MHz to 10 GHz. An L-bridged EBG power plane shows a 4 GHz stopband covering form 600 MHz to 4.6 GHz [6]. A Z-bridged EBG power plane has wider stopband from 260 MHz to 6.76 GHz [7]. A hybrid cell EBG power plane shows a 7.9 GHz stopband covering from 380 MHz to 8.27 GHz [8]. However, their series inductances are not adequate to stop the lower frequency propagation where most GBN sources reside.

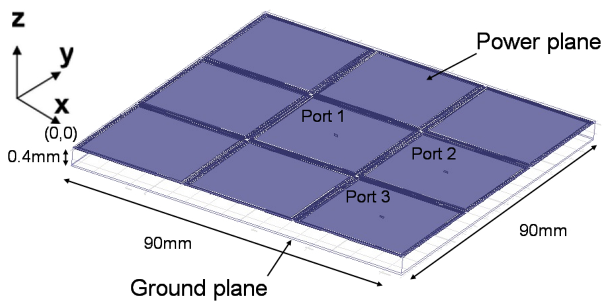

Fig.1, Proposed EBG power and ground plane.

In this paper, a novel S-bridged EBG power plane using open stub, is proposed with ultra-wideband suppression GBN from 114 MHz to 8.5 GHz, almost the whole noise band defined in [9],[10]. Fig.1 shows the proposed S-bridged EBG power planes with nine cells and Port1(45mm,45mm), Port2(45mm,75mm), Port3(75mm,75mm). The features of this new design are the S-bridge, which improve the inductance between two adjacent unit cell so that they can suppress the noise at low frequencies, and the open stub to get higher attenuation levels for the ripples under -30 dB. The proposed EBG power plane aims to lower the stop-band center frequency and broaden the stopband bandwidth so as to subdue the low frequency GBN more efficiently.

II. DESIGN AND ANALYSIS OF THE EBG STRUCTURE

A. Novel S-bridged EBG Power Plane And The Design

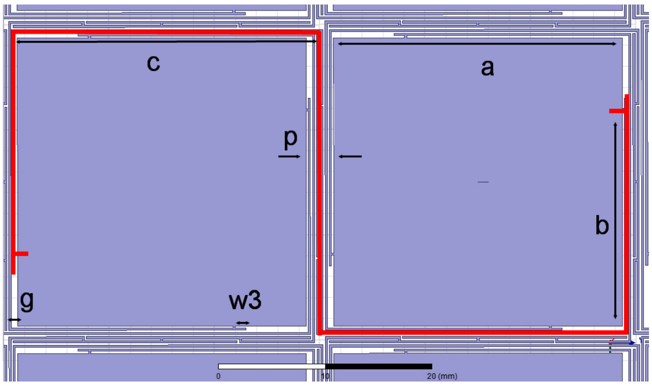

Fig.2(a), connecting two S-bridged EBG cells and the design parameters.

In high-speed circuits, power and ground planes are embedded in multilayer FR4 substrate. Therefore, in a Signal Integrity observation, the planes should not only maintain a continuous source of DC voltage but also a high impedance surface (HIS) to suppress the high frequency noise and wider bandgap bandwidth [9].[10].[11], The SI for the EBG structure is investigated in the time domain using the eye diagram [12]. Fig.2(a) shows the proposed S-bridged EBG power planes and the design parameters. The unit cell of the S-bridged EBG and its corresponding parameter notations is shown in Fig.3(a). Fig.2(b), where, a=30mm, b=20.45mm, c=29.4mm, p=2.6mm, g=0.6mm, w1=7.05mm, w2=6.55mm, w3=1mm, s=0.2mm.

The EBG structure unit can be regarded as an equivalent parallel LC circuit with desired resonance frequency. The frequency of the electromagnetic wave would be prevented from approaching the range of the undesired resonance frequency since the EBG unit possess an infinite impedance in that range. The center frequency of the surface wave band and the width of the bandgap created by EBG can be determined as [13]:

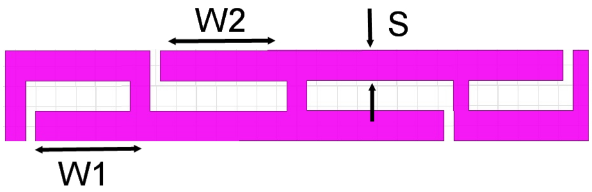

Fig.2(b), the open structure and the design parameters

$$W_0 = \frac{1}{\sqrt{LC}}$$

$$BW = \frac{\Delta W}{W_0} = \frac{1}{\eta}\sqrt{\frac{L}{C}}$$

Where, L is the inductance and C is the capacitance of the periodic structure, η is the wave impedance of the free space. Due to the high damand for a more compact EBG structure, there have already been various existing methods which sought to increase inductance and capacitance in the connecting cells.

The proposed structure has a longer S-bridged, connecting adjacent unit cells together as compared to the conventional S-bridged [14], As a result, the structure contains a greater number of inductors in series, hence there is higher inductance, the lower bound of the GBN suppression stopband is reduced to about 150 MHz, which is lower than the 220 MHz, widening the range of bandgap, hence the range of GBN suppression frequency is greater.

B. EBG Using Open Stub To Suppress

The novel S-bridged EBG structure connecting adjacent unit cells without design of open stub, particular ripples in |S21| from 5.52 GHz to 7.35 GHz and from 10.81 GHz to 12.32 GHz above -30 dB; particular ripples in |S31| from 4.98 GHz to 5.05 GHz and from 7.25 GHz to 7.33 GHz above -30 dB, the ultra-wideband effect is not achieved. Open stubs can overcome these problems. By placing them between adjacent unit cells, they reject the unwanted ripples above -30 dB with three stopband. The stopband of structure is adjusted by w1.w2.w3. As the length of open stub increases, the center frequency of stopband decrease. On the other hand, Fig.2(b), shows the structure that would also increase the circuit size and the insertion loss. Conversely, the open stubs are employed to get higher suppression level of wave propagation in the stopband of the ripples. Simultaneously, the presence of the open stub enable more capacitance and lowering frequency to a greater extent.

III. SIMULATION AND MEASURE RESULT

To confirm the characteristics of the S-bridged structure, the optimized dimensions parameters are as follows above, Fig.4(a), Fig4(b), shows the simulated and measured |S21| from 138 MHz to 7.54 GHz and |S31| from 114 MHz to 8.5 GHz for the proposed design S-bridged EBG with open stub. Simulated and measured |S21| and |S31| have indicated that nice agreements. The energy of the GBN exist mainly at the lower frequency, below 1 GHz, the improvement of the GBN suppression in the lower frequency range is much more practical than in the high frequency range. Hence it would be more useful for the structure to adjust to suppress GBN at the lower frequency range. Fig.3, The EBG patch is kept at the same size of 30mm 30mm.

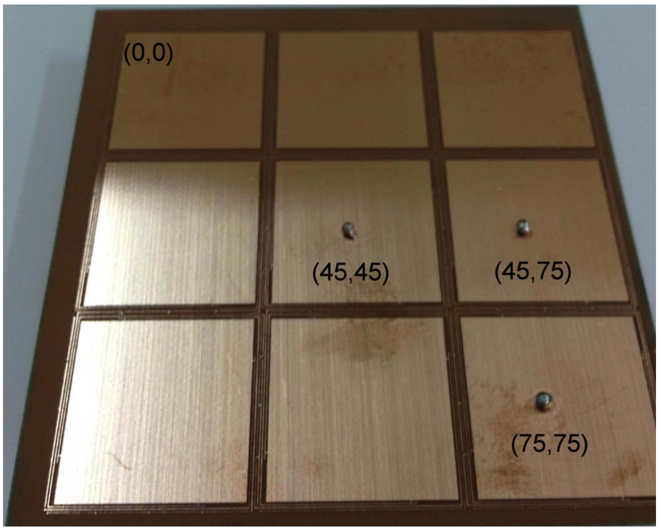

Fig.3, Whole structure of fabricated PCB showing test ports for S parameter measurement.

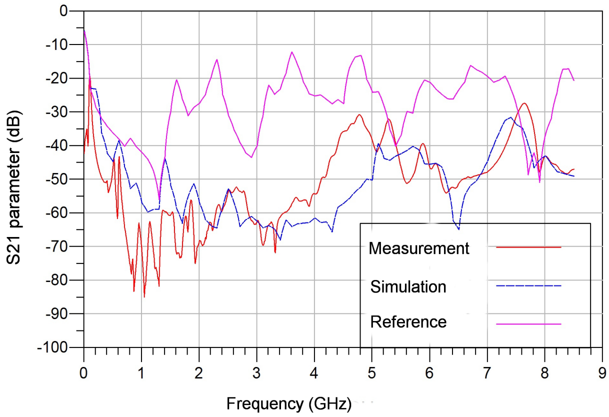

Fig.4(a), Comparison of |S21| between thereference board and the proposed EBG by the simulation and the measurement.

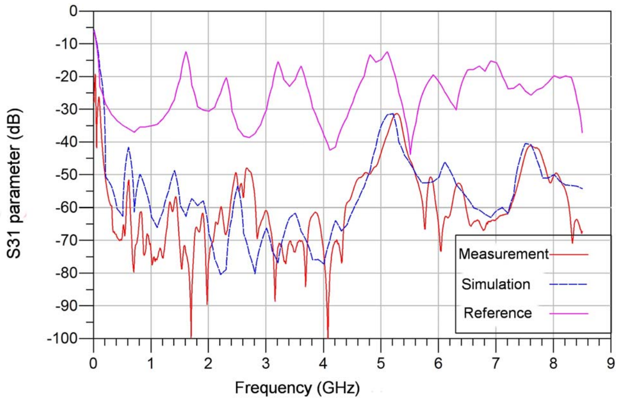

Fig.4(b), Comparison of |S31| between the reference board and the proposed EBG by the simulation and the measurement.

IV. CONCLUSIONS

In this paper, the novel S-bridged EBG structure with the open stub and ultra-wide band, |S31| from 114 MHz to 8.5 GHz with -30 dB bandgap depth is able to provide full coverage for the range of GBN frequency distribution. Hence, this means that ultra-wide suppression of the GBN distributed between power and ground plane is obtained. Compared to previous S-bridged structure, the proposed power plane has high series inductance and structure with open stub to suppression ripples. The proposed structure has only two metal layers that is cost effective, which can be used widely in high-speed circuit.

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