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A NEW UNIPLANAR ELECTROMAGNETIC BANDGAP POWER PLANE WITH BROADBAND SUPPRESSION OF SIMULTANEOUSLY SWITCHING NOISE

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Abstract—A new uniplanar electromagnetic bandgap (EBG) power/ground planes is proposed with broadband suppression of simultaneously switching noise (SSN) from 370 MHz to 4.9 GHz. Meander line bridge is used to increase the inductance between the two neighboring units, which can make the proposed power/ground structure suppress the SSN at low frequencies effectively. Excellent SSN suppression performance is validated both numerically and experimentally. Good agreement is seen. The proposed uniplanar EBG power/ground planes structure can be widely used in high speed integrated circuits.

1. INTRODUCTION

Transient current surges resulted from the simultaneous switching of output buffers in the high speed integrated circuits can create simultaneously switching noise on the chip, package and printed circuit boards. The SSN can arouse significant signal integrity (SI) problems, power integrity (PI) problems and electromagnetic interference (EMI) issues due to the cavity resonance between power and ground planes [1, 2]. With the trend of even faster edge rates and lower voltage levels for the high-speed circuits, the suppression of the SSN is becoming necessary.

In order to suppress the SSN, several methods have been adopted such as island-type power plane structure, resistive termination, shorting vias and adding decoupling capacitors. Most recently, a novel concept of eliminating SSN using a uniplanar electromagnetic bandgap structure was introduced [3, 4]. The uniplanar EBG structures are easily designed and fabricated because specially designed vias and additional inter-plane metal patches that are the basic building blocks of mushroom-type EBG structures are not required here [5].

In this letter, a new uniplanar EBG power/ground planes structure with wideband suppression the SSN from 370 MHz to 4.9 GHz is proposed. The key feature of this new structure is the meander line bridge, which improves the inductance between two neighboring units greatly so that it can suppress the SSN at low frequencies. Good results are obtained by simulation and measurement.

2. DESIGN OF THE NEW UNIPLANAR EBG POWER PLANE

In high speed integrated circuits, power/ground planes are embedded in multilayer FR4 substrate. Therefore, in a SI view, the planes should not only keep continuous to supply the dc voltage but also be as a high impedance surface to suppress the high frequency noise [6]. Figure 1(a) shows the proposed new EBG power plane with nine cells. The unit cell of the new EBG power plane and its corresponding parameters notations are shown in Figure 1(b), where $l = 7.2\,\text{mm}$, $k = 0.5\,\text{mm}$, $g = 0.3\,\text{mm}$, $w = 0.15\,\text{mm}$, $s = 0.3\,\text{mm}$, Figure 1(c) shows the top view photo of fabricated circuit board.

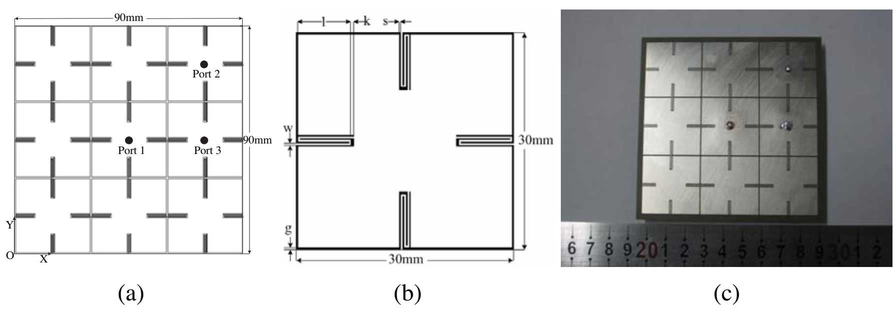

Figure 1. Nine cell EBG power plane. (a) Top view, (b) parameters of a unit cell, (c) photo of fabricated circuit board.

Compared with the traditional and Wu's L-bridged EBG power/ground structures in [3, 4], The key feature is the meander line bridge is used to increase the inductance between the two neighboring units, which makes the proposed power/ground structure suppress the SSN at low frequencies effectively.

As shown in Figure 1(a), three ports from 1 to 3 for the boards are located at (45 mm, 45 mm), (75 mm, 75 mm) and (75 mm, 45 mm), respectively for measurement of the insertion loss ($|S_{21}|$) of the structure. The original point (0, 0) is on the left corner of the EBG power plane as shown in Figure 1(a).

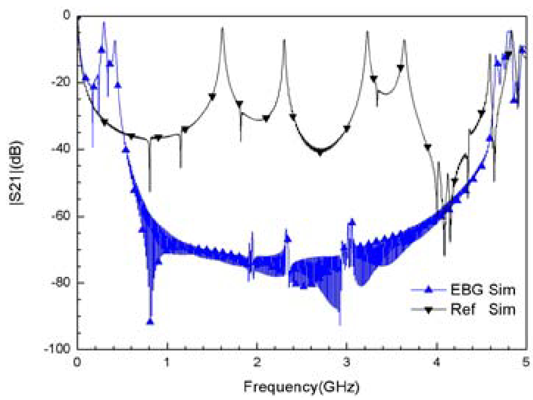

Figure 2. Simulated $|S_{21}|$ of reference board and EBG structure.

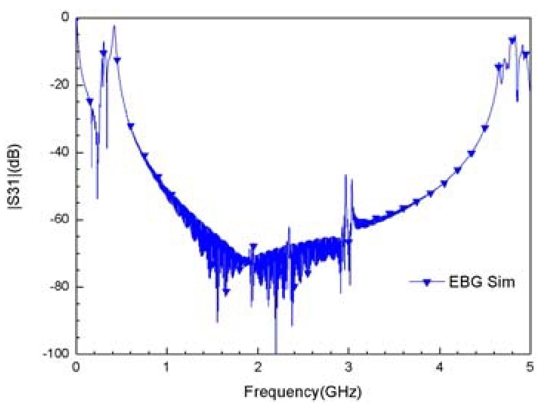

Figure 3. Simulated $|S_{31}|$ of EBG structure.

3. SIMULATIONS AND MEASUREMENTS

The thickness of the substrate is 0.4 mm and the dielectric constant is 4.3. Figure 2 shows the simulated SSN suppression behavior of the designed new EBG power/ground planes, where the noise excitation is located at port 2, and the receiving port is at port 1. The SSN suppression behavior of the reference board with both power and ground planes being solid is also presented in this figure for comparison. Figure 3 shows the simulated SSN suppression behavior of the proposed new EBG power/ground planes when the noise excitation is located port 3, while the receiving port is still at port 1. It is found that the proposed new EBG structure can omnidirectionally eliminate the

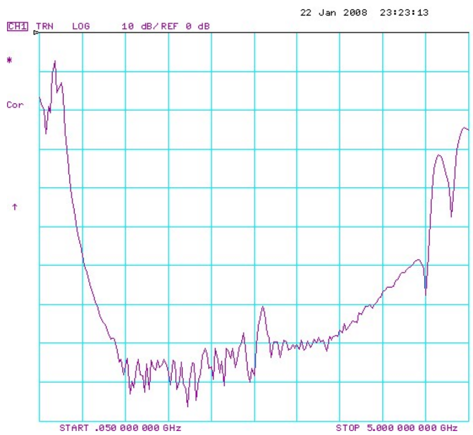

Figure 4. Measured $|S_{21}|$ of EBG structure.

Figure 5. Measured $|S_{31}|$ of EBG structure.

SSN between the power/ground planes. The FDTD method is used to simulate the SSN behavior of the structure [7].

Figures 4 and 5 show the measured *S*-parameters of the fabricated circuit board. Excellent agreement is obtained from dc to 5 GHz between the measurements and simulations. Compared with the reference board, it is clearly seen that the new EBG power plane behaves highly efficient SSN elimination with average 70 dB suppression in a broadband range from about 370 MHz to 4.9 GHz. The bandwidth is defined by the insertion loss lower than −30 dB. Compared with Wu's L-bridged EBG power plane, 230 MHz bandwidth improvement is realized in low frequencies and 300 MHz bandwidth improvement is realized in higher frequencies, the proposed new EBG power plane shows better performance.

4. CONCLUSION

In this letter, a new uniplanar EBG power plane structure is proposed to eliminate the SSN from 370 MHz to 4.9 GHz. Compared with the traditional and Wu's structures, the new EBG power plane structure shows better performance. It is verified by measurements and simulations. The proposed EBG power/ground plane structure can be widely used in high speed integrated circuits.

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