A Novel Uniplanar Compact Photonic Bandgap Power Plane With Ultra-Broadband Suppression of Ground Bounce Noise

Xiao-Hua Wang, Bing-Zhong Wang, Ye-Hai Bi, and Wei Shao

***Abstract*—A novel π-bridged photonic bandgap (PBG) power/ground planes is proposed with ultra-broadband suppression of the ground bounce noise (GBN) in the high-speed printed circuit boards. The S-parameters of the proposed low-period structures show that the novel uniplanar compact photonic bandgap (UC-PBG) structures could omni-directionally suppress the GBN in RF/analog circuits and digital circuits. The high omnidirectionally suppressions of the GBN for the proposed structure are validated both experimentally and numerically in the noise bandwidth from 300 MHz to 6 GHz, almost the whole noise band.**

***Index Terms*—Electromagnetic compatibility (EMC), ground bounce noise (GBN), photonic bandgap (PBG), power/ground (P/G) planes, simultaneously switching noises (SSN).**

I. Introduction

WITH FAST edge rates, high clock frequencies, and low voltage levels, ground bounce noise (GBN) between the power/ground (P/G) planes is becoming one of the major concerns for high-speed integrated circuits. The GBN can excite resonance modes between P/G planes and cause significant signal integrity (SI) problems and electromagnetic interference (EMI) issues [1]–[3]. In other words, this noise can produce false switching in circuits. And with the ever-increasing clock frequencies, the solution imposed by the GBN in high-speed integrated circuits becomes more and more important.

Many research works have contributed to suppress the GBN. Adding decoupling capacitors between the P/G planes is a typical approach to suppress the GBN. But the structures cannot suppress the GBN effectively at frequencies higher than 600 MHz. Recently, the PBG or electromagnetic bandgap (EBG) structures are proposed to eliminate the noise [4]–[10]. Using PBG or EBG structures to form a high impedance surface (HIS), a wider forbidden bandgap bandwidth was achieved in [6]–[8]. However, multilayer substrates with vias are difficult to be implemented. So Wu *et al.* proposed two novel PBG power planes to suppress the GBN in a 3∼4 GHz wider bandwidth in [9], [10], respectively. But the proposed structures still not eliminate the GBN below 6 GHz.

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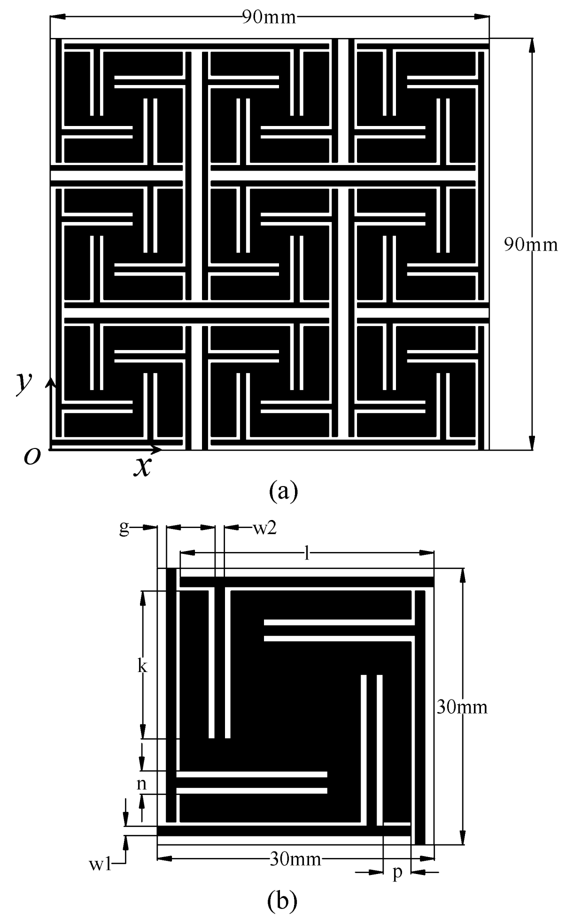

Fig. 1. Nine-cell PBG power plane. (a) Top view. (b) Parameters of a unite cell.

In this letter, a novel low-period π-bridged PBG power planes is proposed with ultra-broadband suppression GBN from 300 MHz to 6 GHz, almost the whole noise band defined in [6], [7]. The key features of this new structure are the π-bridges, which improve the inductance between two neighboring pads greatly so that they can suppress the noise at low frequencies, and the inserts, which change the flow paths of currents so that they can suppress the noise at high frequencies. Good results are obtained by simulation and measurement.

II. Design of the UC-PBG Structure

In high-speed integrated circuits, P/G 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 HIS to suppress the high frequency noise. Fig. 1(a)

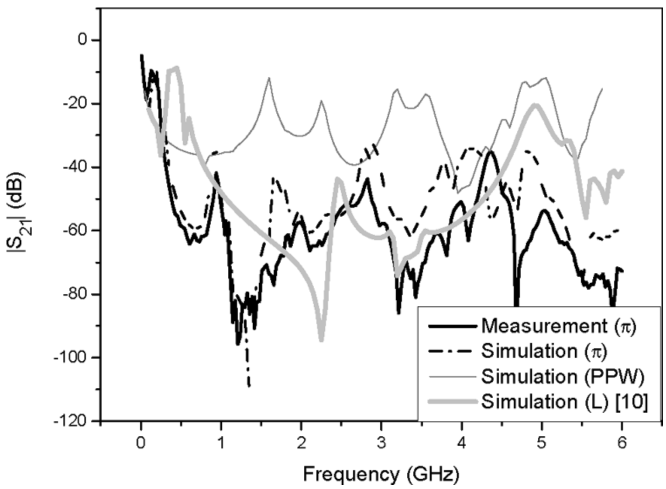

Fig. 2. Comparison of $|S_{21}|$ between the PPW, π- and L-bridged PBG power plane.

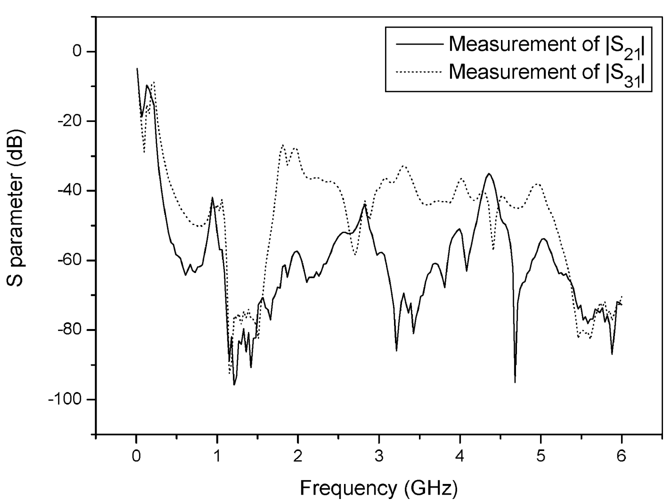

Fig. 3. Measured GBN suppression behavior for noise excitation located at two different locations, Port 2 (74 mm, 74 mm) and Port 3 (74 mm, 45 mm), respectively.

shows the proposed π-bridged PBG power planes with nine cells. And the unit cell of the π-bridged PBG and its corresponding parameter notations is shown in Fig. 1(b), where $w1 = 0.2$ mm, $w2 = 0.2$ mm, $g = 0.3$ mm, $k = 19$ mm, $n = 2$ mm, $p = 7.5$ mm, $l = 28.35$ mm.

Compared with the L-bridged PBG structures proposed by Wu *et al.* in [10], the inductance between the two neighboring pads of the π-bridged PBG structures is five times as large as that of the L-bridged structures when the width of lines is the same. It makes the proposed P/G structures could suppress the GBN at low frequency effectively. And the inserts etched on the power plane change the flow paths of currents. This discontinuity makes the proposed structures could suppress the GBN at high frequencies.

III. Results

Fig. 2 shows the measured and simulated $|S_{21}|$ for the designed π-bridged PBG P/G planes and the simulated $|S_{21}|$ of solid parallel plate waveguide (PPW) and L-bridged P/G planes in [10], where the thickness of the FR4 substrate is 0.4 mm the same as that in [10], and Port 1 and Port 2 are located at (46 mm, 45 mm) and (74 mm, 74 mm), respectively. The HFSS of Ansoft Corporation is used to simulate the structures. And excellent agreement is obtained from dc to 6 GHz between the measurements and simulations. From this figure, we can find that the GBN is suppressed from 300 MHz to 6 GHz with a 5.7-GHz bandwidth, almost the whole noise band defined in [6] and [7]. And the bandwidth is defined by $|S_{21}|$ lower than -30 dB.

Fig. 3 shows the measured GBN suppression behavior for noise excitation port located at two different locations, Port 2 (74 mm, 74 mm) and *Port 3* (74 mm, 45 mm), respectively. The receiving port is all at Port 1. We can find that the GBN is still suppressed in a wide noise band. So the proposed π-bridged PBG structures can omnidirectionally eliminate the GBN between the P/G planes.

IV. Conclusion

In this letter, a novel π-bridged PBG power plane with low-period uniplanar compact structures is proposed to eliminate the GBN from 300 MHz to 6 GHz almost the whole noise band. Compared with the traditional and Wu's structures, our power planes have two key features, the π-bridges and the inserts, which suppress the GBN at low and high frequencies, respectively. The excellent performance of the low-period PBG power planes is verified by measurement and simulation. So the proposed structure can be widely used in high-speed integrated circuits.

References

[1] S. Van den Berghe, F. Olyslager, D. De Zutter, J. De Moerloose, and W. Temmerman, "Study of the ground bounce caused by power plane resonances," *IEEE Trans. Electromagn. Compat.*, vol. 40, no. 2, pp. 111–119, May 1998.

[2] G.-T. Lei, R. W. Techentin, and B. K. Gilbert, "High frequency characterization of power/ground-plane structures," *IEEE Trans. Microw. Theory Tech.*, vol. 47, no. 5, pp. 562–569, May 1999.

[3] T. L. Wu, S. T. Chen, J. N. Huang, and Y. H. Lin, "Numerical and experimental investigation of radiation caused by the switching noise on the partitioned dc reference planes of high speed digital PCB," *IEEE Trans. Electromagn. Compat.*, vol. 46, no. 1, pp. 33–45, Feb. 2004.

[4] R. Abhari and G. V. Eleftheriades, "Suppression of the parallel-plate noise in high-speed circuits using a metallic electromagnetic band-gap structure," in *IEEE MTT-S Int. Dig.*, Jun. 2002, pp. 493–496.

[5] ——, "Metallo-dielectric electromagnetic bandgap structures for suppression and isolation of the parallel-plate noise in high-speed circuits," *IEEE Trans. Microw. Theory Tech.*, vol. 51, no. 6, pp. 1629–1639, Jun. 2003.

[6] T. Kamgaing and O. M. Ramahi, "A novel power plane with integrated simultaneous switching noise mitigation capability using high impedance surface," *IEEE Microw. Wireless Comp. Lett.*, vol. 13, no. 1, pp. 21–23, Jan. 2003.

[7] S. Shahparnia and O. M. Ramahi, "Simultaneous switching noise mitigation in PCB using cascaded high-impedance surfaces," *Electron. Lett.*, vol. 40, no. 2, pp. 98–100, Jan. 2004.

[8] ——, "Electromagnetic Interference (EMI) reduction from Printed Circuit Boards (PCB) using electromagnetic bandgap structures," *IEEE Trans. Electromagn. Compat.*, vol. 46, no. 4, pp. 580–586, Nov. 2004.

[9] T.-L. Wu, Y.-H. Lin, and S.-T. Chen, "A novel power planes with low radiation and broadband suppression of ground bounce noise using photonic bandgap structures," *IEEE Microw. Wireless Compon. Lett.*, vol. 14, no. 7, pp. 337–339, Jul. 2004.

[10] T.-L. Wu, C.-C. Wang, Y.-H. Lin, T.-K. Wang, and G. Chang, "A novel power plane with super-wideband elimination of ground bounce noise on high speed circuits," *IEEE Microw. Wireless Comp. Lett.*, vol. 15, no. 3, pp. 174–176, Mar. 2005.

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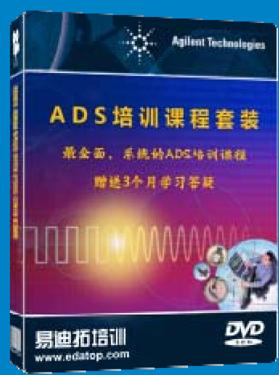

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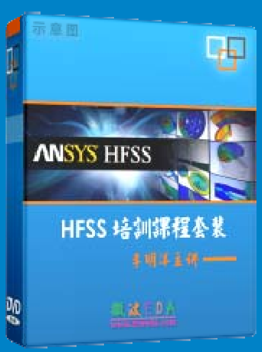

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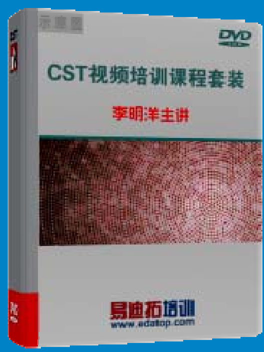

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