Studies of Harmonic Performance on PBG Via Structures

Ming-Sze Tong*, Hyeong-Seok Kim† and Yilong Lu**

Abstract - This paper presents some interesting results regarding the harmonic performance on the photonic band-gap (PBG) structures formed by periodic conducting vias. Study on PBG structures has been one of the major topics in electromagnetics, microelectronics, and communications areas. In most of the studies, the band-gap filtering behavior was fulfilled by a periodic pattern of perforations on the ground planes of microstrip lines. Nevertheless, the PBG characteristics can also be realized using a periodic via-pattern along the transmission-line circuits. Hence, some of the via-typed PBG structures are studied and their frequency characteristics in terms of the scattering parameters are presented. It is found that by varying the length of vias with respect to the period pattern, different harmonic performances are observed.

Keywords: PBG, via, harmonic performance.

1. Introduction

There have been rigorous studies in the area of photonic band-gap (PBG) structures, which are typically formed by periodic arrangement of distributive elements along the direction of guided-wave propagation, so that a band-gap behavior is exhibited within a certain bandwidth. The PBG structures have been successfully applied in microwave area [1]-[3] after being first introduced in the optics area [4]-[5] through proper frequency downscaling.

Most of the PBG structures are constructed using the microstrip-line circuits, and the PBG characteristics are realized through a periodic pattern of perforations on the respective ground planes. However, PBG characteristics can also be realized by using a periodic pattern of via structures on the transmission-line circuits.

To this extent, some of the PBG structures using periodic conducting vias are proposed and studied using a numerical algorithm, the finite difference time domain (FDTD) method [6]. The relationship between the via-lengths with respect to the PBG period and performances on harmonics are examined through frequency spectra of the scattering parameters. Interesting results are observed, which may be deemed as reference guidelines on PBG structures.

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2. Design Procedures and FDTD Setup

In this research, a Blackman-Harris window function is excited at the input port of the structures for broadband computations. All supporting substrates are lossless dielectric materials with $\mu_r = 1$. All conducting strips and the ground plate are assumed to be perfectly electric conductor (PEC) and infinitesimally thin. An unsplit anisotropic perfectly matched layer (UA-PML) technique [7] is employed as the absorbing boundary conditions (ABCs) for effective truncation on the open boundaries. The computational stability is ensured by the Courant condition [8], and a steady state time domain response is extracted for analysis of frequency domain characteristics.

2.1 PBG Structure with Ground Vias on CPW

The first analyzed PBG structure is constructed through introduction of periodic ground vias onto a coplanar waveguide (CPW) circuit. Its configuration is given in Fig. 1, which was very similar to the one proposed in [9].

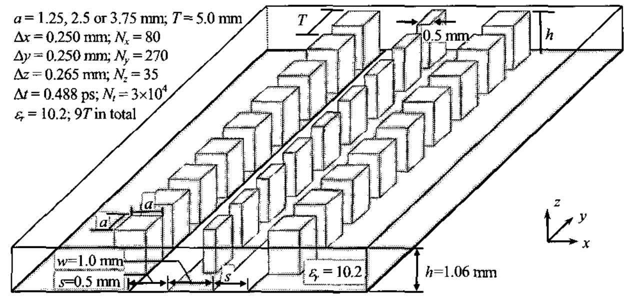

Fig. 1 Configuration of a CPW PBG ground-via structure with series of vias located along the ground planes and the central strip, respectively.

The PBG characteristics are realized by placing periodic vias thoroughly into the substrate and connecting to the conducting plates. Three sets of vias are adopted, where two of them are placed along the two ground planes while the other set is piled along the central strip.

In this layout, the dielectric property of the substrate is $\varepsilon_r = 10.2$. Vias are approximated as PEC rectangular cubes, with a volume of $a \times a \times h$, except along the central strip, where the width of vias are set at 0.5mm. The period of the vias is at $T = 5.0$ mm, and there are totally seven periods along the PBG via structure. Three cases are studied, where the length of vias are set at $a = 1.25$, 2.5, and 3.75 mm, respectively.

2.2 PBG Via Structure on Microstrip Line

Another proposed PBG via structures is on a microstrip-line circuit whose configuration is given in Fig. 2. It is similar to one of the PBG structures presented in [10]-[12], except that this PBG also includes a series of vias underneath the central strip.

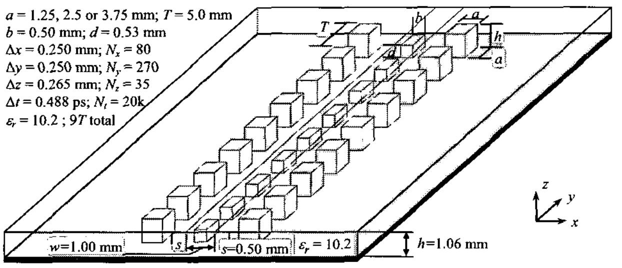

Fig. 2 Configuration of the PBG via microstrip-line structure with vias located along the two sides and beneath the central strip, respectively.

The PBG characteristics are realized by placing periodic vias thoroughly into the substrate and connecting to the conducting plates. Three sets of vias are adopted, where two of them are placed along the two ground planes while the other set is piled along the central strip.

In this layout, the dielectric property of the substrate is $\varepsilon_r = 10.2$. Vias are approximated as PEC rectangular cubes, with a volume of $a \times a \times h$, except along the central strip, where the width of vias are set at 1.0 mm. The period of the vias is at $T = 5.0$ mm, and there are totally seven periods along the PBG via structure. Three cases are studied, where the length of vias are set at $a = 1.25$, 2.5, and 3.75 mm, respectively.

3. Numerical Results

The PBG via structures proposed in the previous section are taken for scattering-parameter analysis. The PBG ground-via structure on CPW line shown in Fig. 1 is studied. The frequency spectra of the structures whose $a = 1.25$, 2.5 and 3.75 mm., corresponding to the ratio of $a / T = 0.25$, 0.5 and 0.75, are obtained in Figs. 3a, 3b and 3c, respectively. It is found that all three cases exhibit a clear PBG behavior between the approximate range of 10 and 13 GHz.

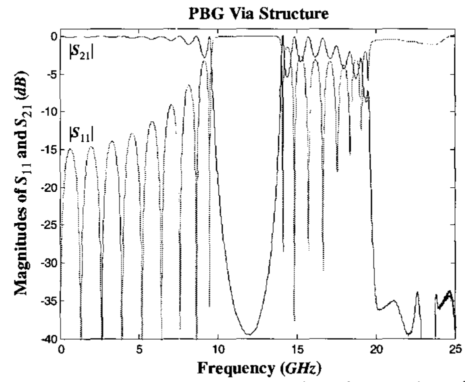

Fig. 3a Frequency dependence of $|S_{11}|$ and $|S_{21}|$ for the CPW PBG ground-via structure with the ratio of $a / T = 0.25$.

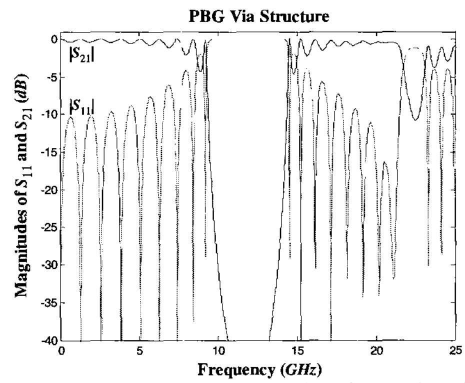

Fig. 3b Frequency dependence of $|S_{11}|$ and $|S_{21}|$ for the CPW PBG ground-via structure with the ratio of $a / T = 0.50$.

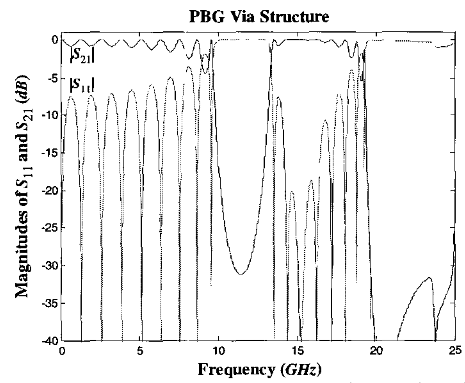

Fig. 3c Frequency dependence of $|S_{11}|$ and $|S_{21}|$ for the CPW PBG ground-via structure with the ratio of $a / T = 0.75$.

Another PBG via structure using ground and central vias on microstrip line whose configuration is shown in Fig. 3 is analyzed. The frequency responses for the sets of vias with the ratio of $a / T = 0.25$, 0.5 and 0.75 are presented in Figs. 4a, 4b and 4c, respectively. Again, a clear band-stop filtering behavior is observed in the range of around 7 GHz. and 12 GHz.

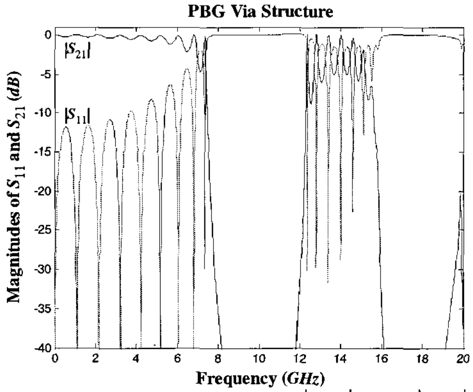

Fig. 4a Frequency dependence of $|S_{11}|$ and $|S_{21}|$ for the micro-strip PBG via structure with the ratio of $a / T = 0.25$.

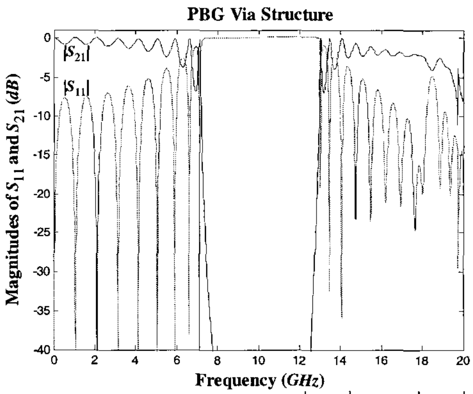

Fig. 4b Frequency dependence of $|S_{11}|$ and $|S_{21}|$ for the micro-strip PBG via structure with the ratio of $a / T = 0.50$.

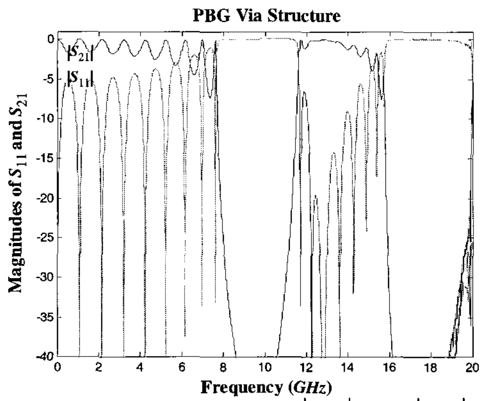

Fig. 4b Frequency dependence of $|S_{11}|$ and $|S_{21}|$ for the micro-strip PBG via structure with the ratio of $a / T = 0.75$.

Results of both analyzed structures have the similarities that the rejection level on the side-lobe band increases when the length-of-via-to-period ratio (a / T) increases, and that the PBG performance on the first harmonics is optimal in terms of $|S_{11}|$ and bandwidth when $a / T = 0.5$. What is also an interesting point is that, although the first-harmonic PBG performance is optimal at $a / T = 0.5$, it does not offer a clear band-gap performance on the second harmonics, i.e. two times of the first harmonics. On the other hand, with $a / T = 0.25$ or 0.75, they suppress both the first and second harmonics. Hence, engineering designers have flexibility to consider whether to choose a PBG structure that concentrates on only the first harmonics or to have a PBG that functions a double harmonic suppression.

4. Conclusion

Harmonic performance on PBG structures, which are formed by periodic conducting vias, was studied using the FDTD method. Results showed good band-stop behavior in all analyzed structures. Additionally, it was found that the PBG performance on the first harmonics is optimal when the length-of-via-to-period (a / T) ratio is at 0.5, while the structures with a / T ratio at 0.25 and 0.75 give rise to suppression on both the first and second harmonics.

Acknowledgement

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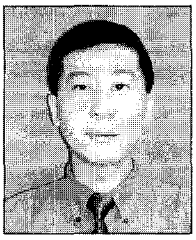

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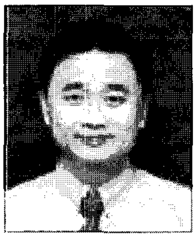

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