Harmonic Suppression and Broadening Bandwidth of Band Pass Filter Using Aperture and Photonic Band Gap Structure

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Abstract

In this paper, we introduced a band-pass filter employed the PBG structure and the aperture on the ground together. The harmonics of band pass filter have been suppressed by employing the PBG structure and the bandwidth of it has been broadened by using the aperture on the ground. The designed PBG cells have three different sizes. The largest cells, the middle cells, and the smallest cells have suppressed the multiple of second harmonics, the multiple of third harmonics, and the multiple of fifth harmonics, respectively. The center frequency has been 2.18 GHz. The bandwidth has been increased from 230 MHz up to 310 MHz(80 MHz, about 35 %) by the aperture and the ripple characteristics in passband have been improved and the harmonic frequencies have been suppressed about 30 dB by the PBG.

Key words : PBG, Band Pass Filter, Aperture, Harmonic Suppression.

Ⅰ. Introduction

PBG structures have been studied in optical communication and have been started to apply in microwave and millimeter-wave circuits recently. PBG structure is a periodic structure where electromagnetic waves of some frequency bands can't be propagated. Many researchers have proposed and demonstrated several PBG structures for microstrip circuits application with filtering characteristics in microwave region[1],[2]. In microwave circuits, the microstrip line bandpass filter has been widely used. But the conventional coupled stripline filter had the harmonic frequencies which degrade the performance of the RF circuits. The extra circuits have been required to suppress them, but extra circuits lead to the insertion loss of filter. PBG structures have been studied to suppress the harmonic frequencies of the band pass filter[3],[4]. In these researches, the harmonic frequencies were suppressed successfully about 20 dB. But characteristic in the pass band were distorted and the bandwidth was varied. Aperture has been applied in order to broaden the bandwidth in microwave strip line filter[5],[6]. The existence of the aperture weakens the signal-to-ground coupling and thus leads to the orientation of field distribution towards the slot interface between the two conductor strips. We suppressed all kinds of harmonics of the band pass filter by combining different sizes of PBG structures without distorting pass band and broadened the bandwidth of filter using the aperture on the ground.

Ⅱ. Design of PBG Cell

The classical filters with PBG structures can be achieved in microstrip technology with the periodic pattern on the ground plane and the conductor microstrip line have a width of 50 Ω on the top plane. The center frequency of the stop band has been determined by the distance between the center of lattices of PBG. We has proposed to fabricate three different PBG structures on the ground plane to suppress harmonics of the filter. The substrate has a dielectric constant of 3.2 with a thickness of 0.76 mm. The conductor strip on the top plane has a width of 1.9 mm, corresponding to a 50 Ω line for conventional microstrip. In order to employ the PBG and the aperture, we designed the fourth order coupled stripline band pass filter. The center frequency and the bandwidth were 2.18 GHz and 230 MHz, respectively. The insertion loss and the attenuation were 2.8 dB and 60 dB, respectively. We made the band pass filter according to the process of Matthaei's theory[7].

We used the PBG structure as shown in reference[8]. $\lambda/4$ Periodic slots were used and the band stop characteristics are shown in reference[9].

The center frequency of the band pass filter is 2.18 GHz. So the harmonic frequencies of the filter are about 4.36 GHz(2nd), 6.54 GHz(3rd), 8.72 GHz(4th), 10.9 GHz (5th), and so on. On the ground plane, the proposed PBG structures with bandstop filters, which have the center frequency of 4.36 GHz(2nd), 6.54 GHz(3rd), 8.72 GHz(4th), and 10.9 GHz(5th) in the rejection band,

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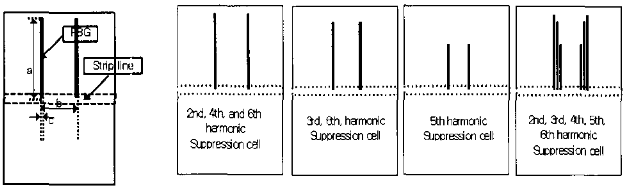
were fabricated. According to the theory[8],[9], the stop band frequency has been related with length a. The length of b and c has been $\lambda/4$ of the stop band frequency and 0.5 mm, respectively. Fig. 1(a) structure suppressed multiple of second harmonics(2nd, 4th, 6th, ···), Fig. 1(b) structure suppressed multiple of third harmonics(3rd, 6th, 9th, ···), and Fig. 1(c) structure suppressed multiple of fifth harmonics(5th, 10th, ···). To suppress all kinds of harmonics of the filter and implement these three stopbands on the single plane effectively, the proposed PBG cells were arranged as shown in Fig. 1(d). As shown in Fig. 1(d), Employing Fig. 1(a), Fig. 1(b), and Fig. 1(c) structure together, we can suppress 2nd, 3rd, 4th, 5th, 6th harmonics of the filter.



(a) (b) (c) (d)

Fig. 1. Proposed PBG structure.

III. Numerical Simulation of PBG

The ansoft HFSS has applied to simulate the proposed structure shown in Fig. 1. The designed PBG cells have three different sizes as show in Fig. 1(d). Fig. 2 shows the measured S-parameters of the proposed PBG structure. Fig. 2(a)~(c) and (d) show the stop band characteristic of the Fig. 1(a)~(c) and (d), respectively. The microstrip width is 1.9 mm, corresponding to a 50 Ω line and the simulated cell sizes are like this;

Fig. 1(a): a=21.65 mm, b=10.82 mm, c=0.5 mm ; The largest cell

Fig. 1(b): a=14.35 mm, b=8.8 mm, c=0.5 mm ; The middle cell

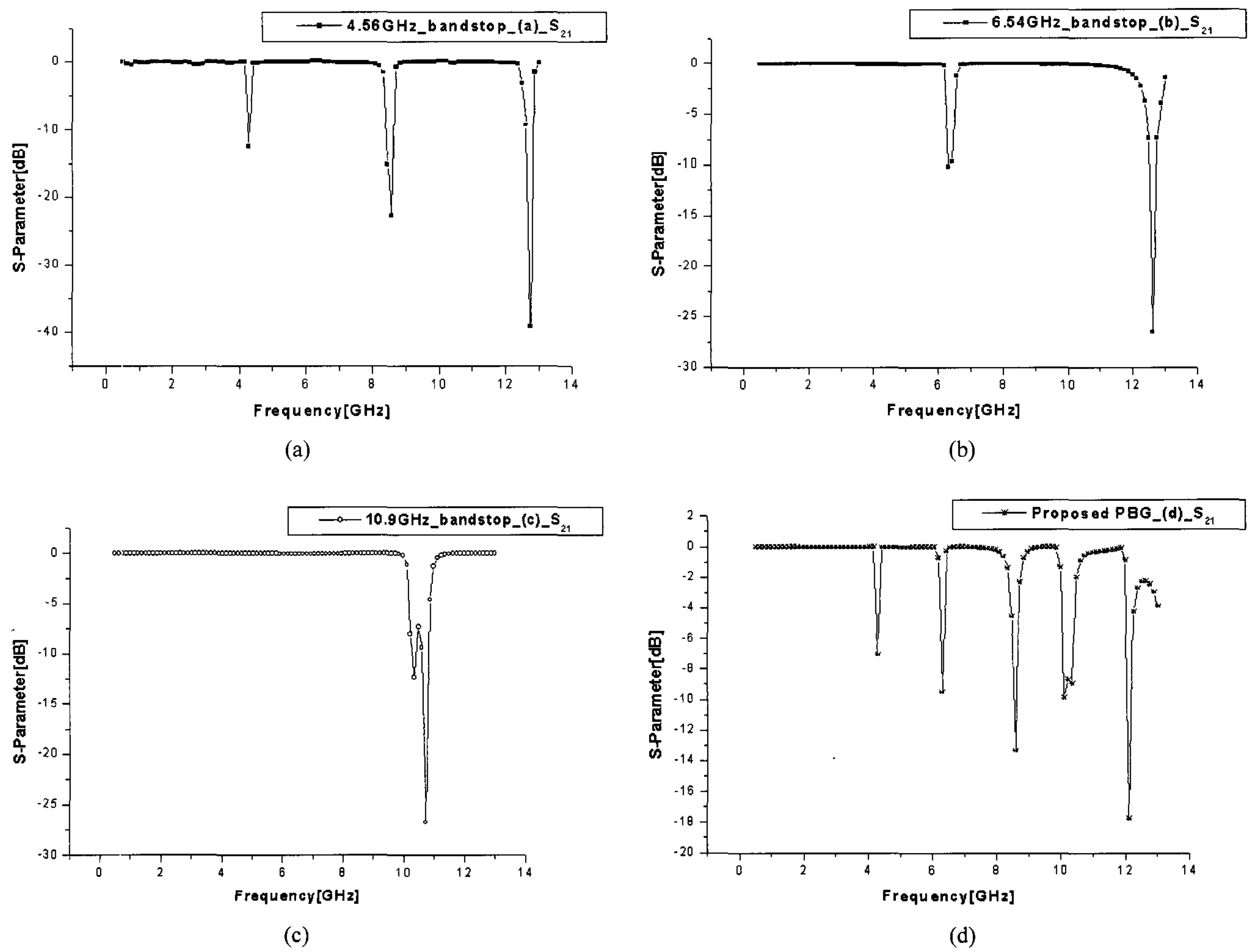


Fig. 2. Frequency response of the proposed PBG cell(simulation).

Fig. 1(c): a=10.7 mm, b=6.82 mm, c=0.5 mm ;
The smallest cell

The largest cells, the middle cells, and the smallest cells have suppressed the multiple of second harmonics, the multiple of third harmonics, and the multiple of fifth harmonics, respectively as shown in Fig. 2, Fig. 1(a) structure suppresses 2nd, 4th, and 6th harmonic frequencies as shown in Fig. 2(a), Fig. 1(b) structure suppressed 3rd, 6th harmonic frequencies as shown in Fig. 2(b), Fig. 1(c) structure suppressed 5th harmonic frequency. As a result, all harmonics are suppressed without increasing cell size as shown in Fig. 2(d).

Ⅳ. Application of The PBG and The Aperture in the Bandpass Filter

Fig. 3(a) shows the schematic of a coupled stripline band pass filter using the proposed PBG structure on the ground plane. Fig. 3(b) shows the results of the proposed PBG band pass filter. For comparison, the insertion loss of a conventional coupled stripline band pass filter was also plotted. The measured transmission coefficients(S_{21}) of a band pass filter are −14 dB, −6.5 dB, −8.5 dB, −9 dB, and −8.5 dB at 4.36 GHz(2nd), 6.54 GHz(3rd), 8.72 GHz(4th), and 10.9 GHz(5th), respectively. The experimental result of the band pass filter on the proposed PBG structure shows about 30 dB suppression of the harmonics of the filter. The largest cells, the middle cells, and the smallest cells have suppressed the multiple of second harmonics, the multiple of third harmonics, and the multiple of fifth harmonics, respectively as we simulated. Using the proposed PBG structure that slots were arranged every $\lambda/4$, we suppressed all harmonics of the filter successfully.

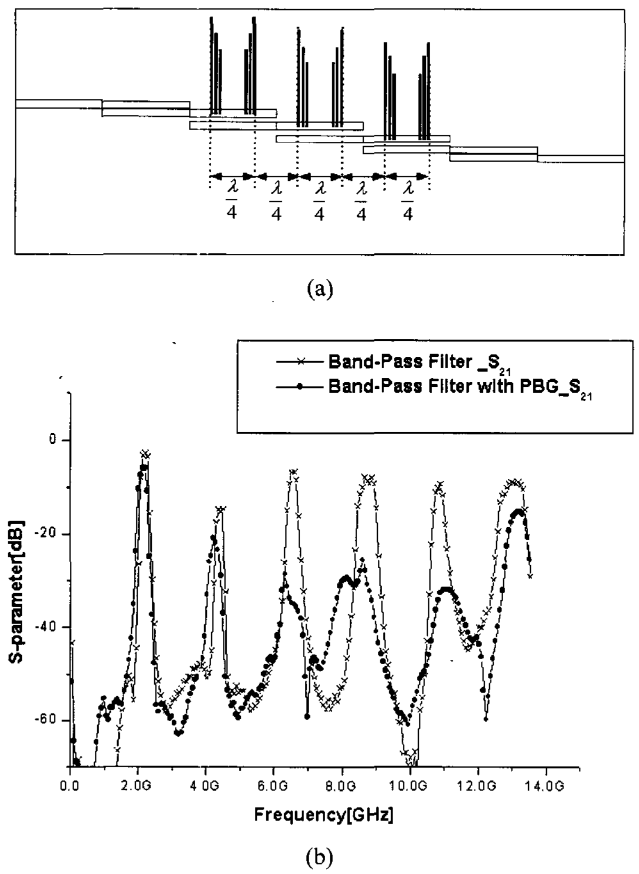


Fig. 3. Employing PBG in the filter.

But there was one problem in employing PBG. As shown in Fig. 3(b), the loss in passband has been increased about 2 dB. In order to compensate the loss, we employed the aperture on the ground as shown in Fig. 4.

Broadening filter bandwidth can be obtained by strong coupling between the coupled lines. Reduction of the strip line width and coupling space between the coupled lines make it possible.

But there has been a limitation on reducing the coupling space between the coupled lines. When the coupling space between the coupled lines is extremely narrow, the sensitivity depending on it can become serious problem and it is very difficult to implement it.

So, the aperture on the ground can be alternative solution instead of narrow coupling space. When the aperture has been fabricated on the ground between the coupled lines, the coupling between strip line and ground plane is decreased and tight coupling between the coupled lines has been obtained by employing the aperture on the ground[6].

In this paper, the aperture has been employed to compensate the loss in passband and broaden the bandwidth without reducing the coupling space. As the aperture area was bigger, the coupling coefficient between the coupled lines was stronger and the bandwidth of the filter was increased. But the strong coupling coefficient has leaded to the low attenuation in the stop band.

Employing PBG and aperture together has been optimized in the limited ground space. In order to

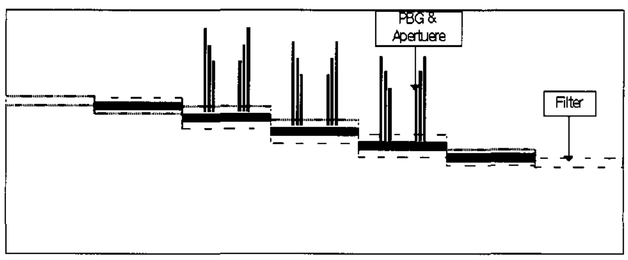


Fig. 4. Bandpass filter employed aperture & PBG.

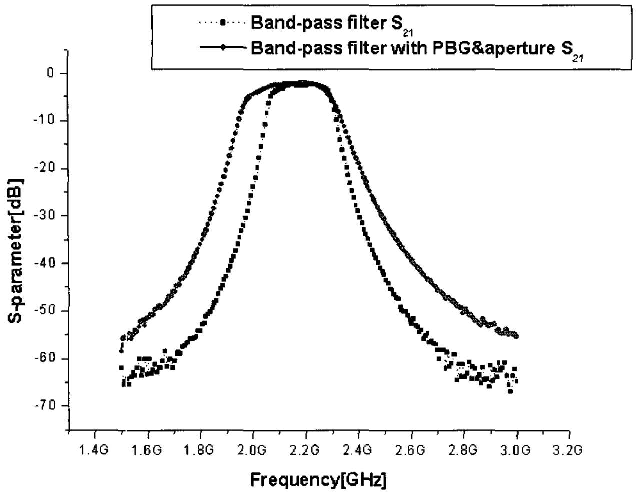


Fig. 5. Frequency response of original filter and aperture & PBG filter(narrow view).

employ these, we made the circuit as shown in Fig. 4. Fig. 4 shows that harmonics of the filter were suppressed by the PBG, and the bandwidth was increased and insertion loss compensated by aperture. The measured results were shown in Fig. 5 and Fig. 6.

Fig. 5 shows that characteristics in the pass band were not distorted. The bandwidth of filter was increased from 230 MHz to 310 MHz(80 MHz, about 34.7 %) and the insertion loss which was occurred by the PBG was compensated from 4 dB to 2 dB by the aperture. The insertion loss employed PBG and aperture together was measured 2.5 dB in the passband. The loss in passband is the effect of SMA connectors and conductor. The loss in passband is comparable to that of a conventional coupled bandpass filter. As shown in Fig. 5, the center frequency moved to the lower frequency band. Because of the slow wave effect by etching the ground, the lengths of striplines in the filter were seen longer, so the center frequency was moved to the lower band.

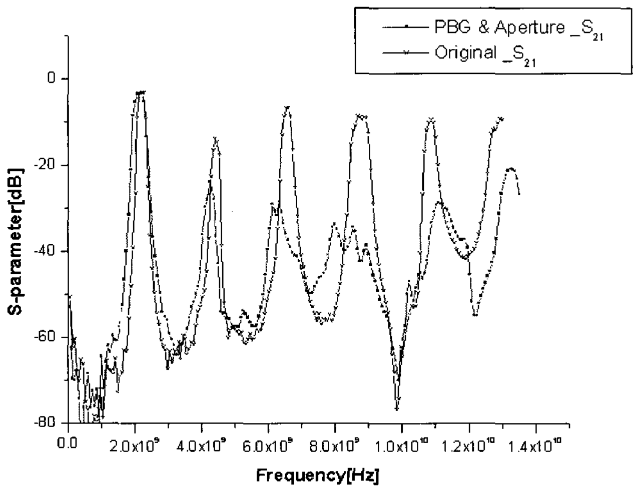


Fig. 6. Frequency response of original filter and aperture & PBG filter(wide view).

Fig. 6 shows the results of the proposed bandpass filter employed PBG and aperture together. Three periodic PBG cells suppressed harmonic frequencies about 20~30 dB and the bandwidth was increased from 230 MHz to 310 MHz(about 34.7 %) by the aperture. The passband loss due to the PBG was compensated by the PBG about 2.2 dB. As the cell number is increased, the PBG effect(harmonic suppression) has been decreased and the aperture effect has been increased. The radiation doesn't occurred in low frequency band but can be occurred in high frequency band.

V. Conclusion

In this paper, we introduced the PBG structure which had suppress harmonics and the aperture which had broaden bandwidth of the band pass filter without increasing the circuit size. According to experiments, the bandwidth has been increased from 230 MHz to 310 MHz(80 MHz, 35 %) by the aperture and all harmonics were suppressed about 30 dB by the PBG. The insertion loss has been improved from 2.8 dB to 2.6 dB by the aperture. It is expected that the proposed PBG structure can be applied in various microstrip circuits to improve their performance by removing harmonic frequencies and broadening the bandwidth.

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