Optimized Etched Hole Size for Suppressing the Periodicity in the Frequency Response in Photonic Bandgap Microstrip Structures

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***Abstract* — Using ideal transmission line model, we find the optimized length for suppressing the periodicity in the frequency response in periodic structure. Optimized length is applied to photonic bandgap (PBG) microstrip structures and we show the existence of optimized etched hole size in ground plane for suppressing the periodicity in the frequency response in PBG microstrip structures and find them.**

I. INTRODUCTION

In recent years, there is interesting of research about photonic bandgap(PBG) structures as microstrip technology. PBG structures are periodic structures where the propagation of waves is not allowed in some frequency band or direction [1]. In microwave or millimeter wave region, they have been used in efficient method of improvement of radiation pattern of antenna [2], increasing the output power efficiency [3], and providing a broad reject band as band stop filter [4]. In microstip technology, PBGs are achieved by drilled in the substrate [5] or etched in the ground plane as an adequate periodic pattern [6][7]. The second method is easier to implement and obtains wider and deeper stopband characteristic [6]. Due to the high confinements of the fields around the conductor strip in the microstip line, it is possible to use a one-dimensional (1-D) periodic pattern instead of 2-D [8].

In general, PBG microstrip structures show a periodicity of frequency response. This is drawback for some applications, for example filter design. In recent research, PBG microstrip structures using network topology was introduced for overcome this drawback [7]. In this paper, we show that PBG microstrip structures with discrete periodic patterns are able to suppress the periodicity in the frequency response as adjusting etched size in ground plane.

II. CONSIDERATION OPTIMIZED LENGTH IN PERIODIC STRUCTURE FOR SUPPRESSING THE PERIODICITY IN THE FREQUENCY THOUGH IDEAL TRANSMISSION LINE

As stated in [9], wave impedance is important role of creation of PBG structures. In microstrip technology, characteristic impedance is like to a part of creation of PBG structures [4]. PBG microstrip structures with etched

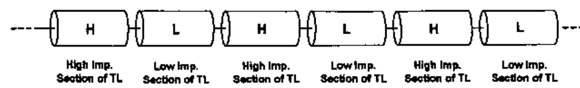

Fig. 1. Ideal transmission line model for a periodic structure.

in ground plane have two part of transmission line. One is normal microstrip line and the other is etched region. Etched region is a sort of a coupled microstrip-slotline [10] as transmission line. A coupled microstrip-slotline has low effective dielectric constant, and realizes high impedance. Therefore PBG microstrip structure with etched in ground plane is a kind of transmission line that has high and low impedance transmission line periodically.

Therefore, we introduced the decision of optimized length of high and low impedance section for suppressing a periodicity in the frequency response by ideal transmission line model and then apply to decision of optimized length of two sections in the PBG microstrip structures. The ideal transmission line has not loss of energy (scattering and radiation loss or conductor loss). So we can model periodic structure easily and find the result of periodic structure easily and fast by ABCD matrix calculation or using schematic CAD software.

A periodic length of PBG structure satisfies the Bragg condition

$$2 \cdot k = k_{Bragg} = 2\pi / a, \qquad \rightarrow a = \lambda_g / 2 \qquad (1)$$

where k is the guided mode wave number, a is the structure period, and λ_g is the guided mode wavelength. In this condition, a length of one period, high and low impedance section, as shown in Fig.1, is $\lambda_g / 2$ ($l_H + l_L = \lambda_g / 2$).

We find the optimized length of high and low impedance section for suppressing the periodicity in the frequency response at periodic structure by adjusting length of each section. As shown in Fig.2, if high impedance section is longer or shorter than lower impedance section, there is creation of second stop region about $2f_o$. If each section of periodic structure, high impedance section and low impedance section, have same length ($l_H = l_L = \lambda_g / 4$, $l_H + l_L = \lambda_g / 2$), second stop region about $2f_o$ is disappeared.

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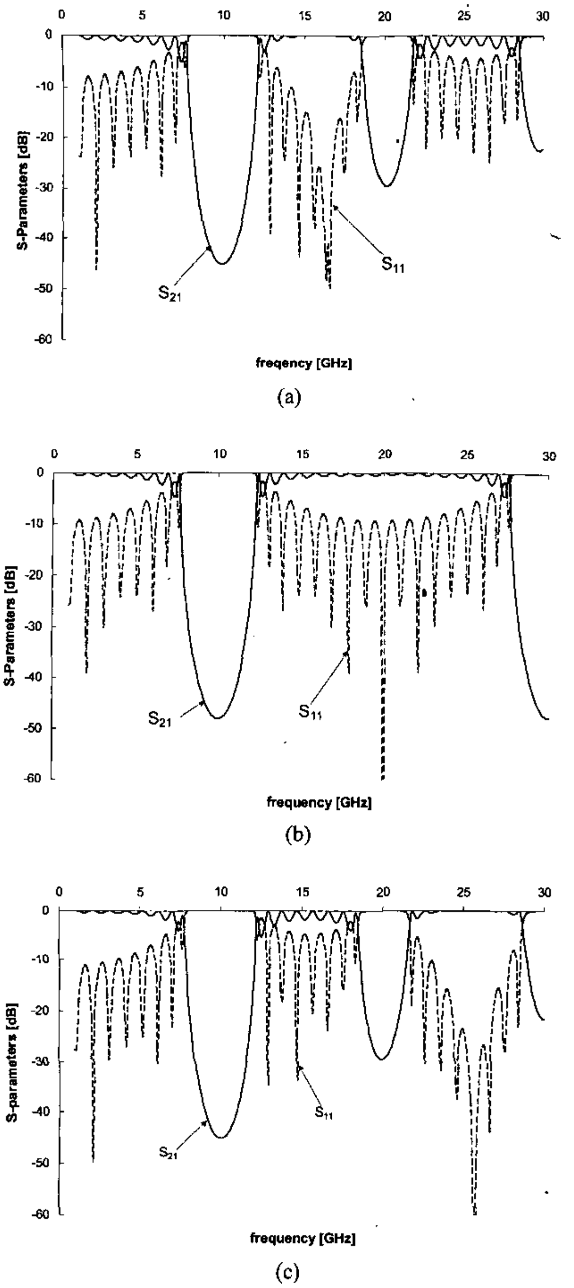


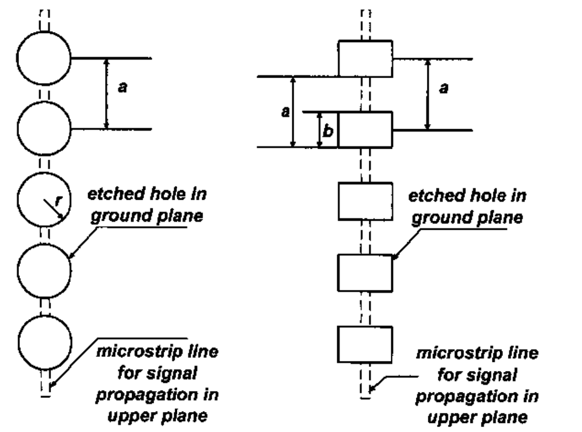
Fig. 2. In case that the length of (a) high impedance section is longer than low impedance section ($l_H > l_L$, $l_H + l_L = \lambda_g / 2$), (b) high impedance section is same to low impedance section ($l_H = l_L = \lambda_g / 4$, $l_H + l_L = \lambda_g / 2$), and (c) high impedance section is shorter than low impedance section ($l_H < l_L$, $l_H + l_L = \lambda_g / 2$) in ideal transmission line model for periodic structures.

III. Optimized Etched Hole Size In Ground Plane In The PBG Microstrip Structures

As stated in [6] for the PBG microstrip structure with circular etched holes, optimal etched hole size is a ratio of r/a of 0.25 for consideration of passband ripple, r being the circle radius and a the structure period. There is a good tradeoff among bandwidth, rejection level, and passband ripple. However they have second stopband region about $2f_o$ in the case of r/a of 0.25[7]. The PBG microstrip structure with etched hole in ground plane has two sections, as shown in Fig.3. Two sections are etched region in ground plane as high impedance section and normal microstrip section as low impedance section, and in our case, low impedance section is obtained by 50Ω microstrip line but it is possible to achieve by using lower impedance than 50Ω and obtain better performance by using difference of high and low impedance. If etched hole radius is 0.25a (r/a=0.25), two section length in the PBG microstrip structure is same in physically. However it's electrical length is different. In etched region, effective dielectric constant is decreased. As effective dielectric is deceased, electrical length is shorter and this condition makes high impedance section is longer than low impedance section. So second stopband region is appeared about $2f_o$. Therefore if etched size has long length than normal microstrip section, it is possible to achieve the PBG microstrip structure with suppressing the periodicity in the frequency response. For same length of high impedance and low impedance section, rigorous analysis is required to etched section. But it's very difficult to calculation and must be considered a coupling and many other conditions at boundary region of high and low impedance section for rigorous calculation for electrical length. So we use an EM simulation and find the optimized length. The period a to have first central stopband frequency of 10GHz roughly results in 6mm for RT/Duroid 6010 substrate ($\varepsilon_r = 10.2$, thickness $h = 0.635$ mm). Its length is considered to require long length at etched region.

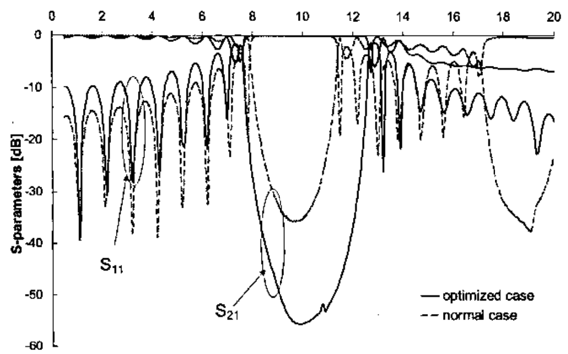
For PBG with circle etched hole, optimized length for suppressing the periodicity in the frequency response about second stopband region, $2f_o$, is 0.35a (r/a=0.35, our case r=2.08mm) approximately, as shown in Fig.4(a). For PBG with square etched hole, optimized length for suppressing the periodicity in the frequency response about second stopband region, $2f_o$, is 0.6b (b/a=0.6, our case b=3.6mm) approximately, b is length of square etched hole, as shown in Fig.4(b).

For circle and square etched hole shape, they cannot use all case for passband ripple. So rectangular shape is attractive for one directional 1-D PBG microstrip

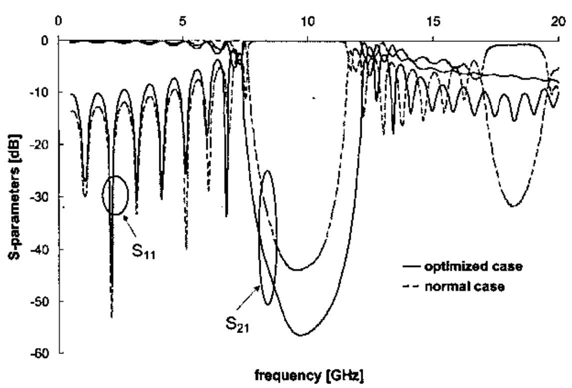


(a) (b)

Fig. 3. Construction of the PBG microstrip structures (a) circular etched and (b) rectangular etched in ground plane.

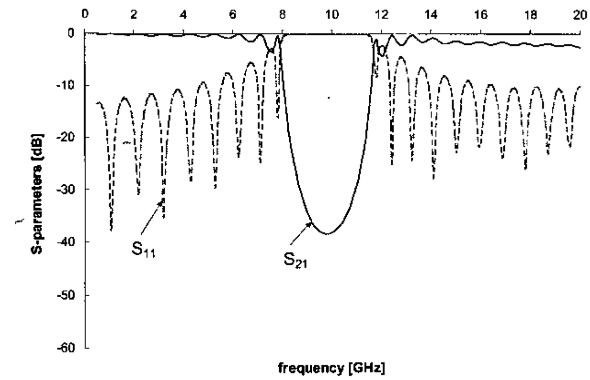


(a)

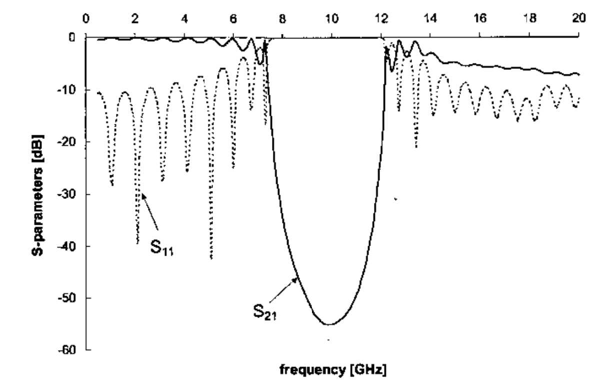


(b)

Fig. 4. Normal (a) circular etched hole in ground plane ($r/a = 0.25$; dotted lines) and optimized circular etched hole($r/a = 0.35$; filled line) and (b) square etched hole in ground plane ($b/a = 0.5$; dotted lines) and optimized circular etched hole($b/a = 0.6$; filled line) for suppressing the periodicity in the frequency response.



(a)



(b)

Fig. 5. Optimized rectangular etched hole in case of (a) $w = 2.5$, $l_H = 3.5$ (b) $w = 3.5$, $l_H = 3.6$.

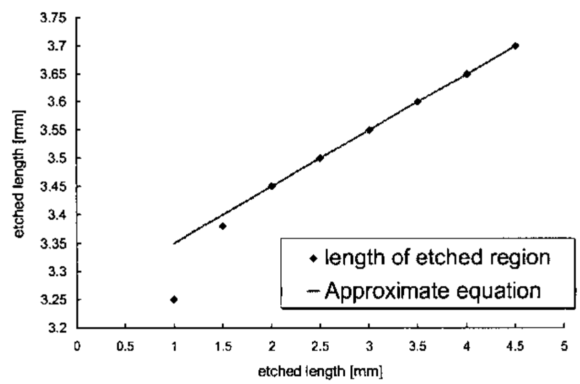


Fig. 6. Relation of optimized length of rectangular etched hole and width of it.

structures. Because they have same length for propagating direction and various width for other direction simultaneously. It is able to be achieved various high impedance by adjusting etched width. However slight shift

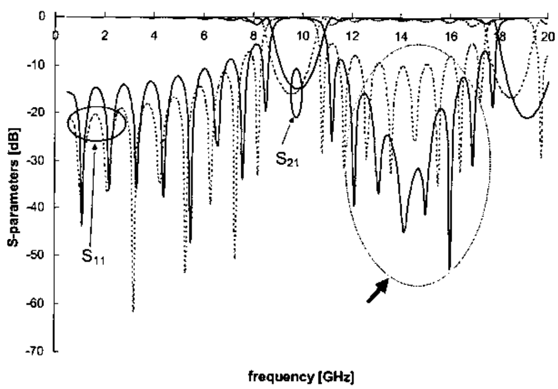


Fig. 7. In case that the length of etched section is longer ($l_H > l_L$, $l_H + l_L = \lambda_g / 2$; filled line) and/or shorter ($l_H < l_L$, $l_H + l_L = \lambda_g / 2$; dotted line) than normal microstrip section in PBG microstrip structures.

of optimized length is existed as shown in Fig.5. Because other mode (e.g. quasi-slot mode) is existed and boundary condition at etched and normal microstrip region is changed in our best knowledge. In this result, we summarize optimized length as follow equation

$$l_H = 0.1w + 3.25 \text{ at } 1.0 \le w \le 4.5 \quad (2)$$
$$a = l_H + l_L = 6 \text{ mm}$$

where l_H is etched hole length, l_L is normal microstrip region length, a is period, and w is etched hole width for our case (dielectric constant is 10.2, thickness of substrate is 0.635mm). Fig.6 shows relation of equation (2) and optimized length.

IV. Additional Discussion

We use the ideal transmission line model and then find the optimized length for suppressing the periodicity in frequency response in one directional 1-D PBG structures. To confirm of usefulness of ideal transmission line model, the length of high impedance section (etched region) of PBG with rectangular etched hole is changed to longer or shorter than low impedance section (normal microstrip region), and than observed characteristic. As shown in Fig.7, if high impedance section is longer than low impedance section, S_{11} is decreased in first and second stopband like Fig.2(a). And if high impedance section is shorter than low impedance section, S_{11} is increased in first and second stopband and decreased in second and third stopband. High impedance section is sorter than low impedance section, and S_{11} is worse in first and second stopband like Fig.2(c). All of above length are electrical length.

Therefore, as using ideal transmission line model, we can roughly observe characteristic of one directional PBG microstrip structures easily and fast.

V. Conclusion

We point out optimized etched hole size in ground plane for suppressing the periodicity in the frequency response in PBG microstrip structures. As using ideal transmission line model, we can observe characteristic of one directional PBG structures and we find optimized length for suppressing the periodicity in the frequency response.

A PBG microstrip structure with suppressing the periodicity in the frequency response is very useful for filter application design, for example band-stop filter.

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