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Application of Electromagnetic Band-Gap (EBG) Structures to Microstrip Line and Antenna Designs

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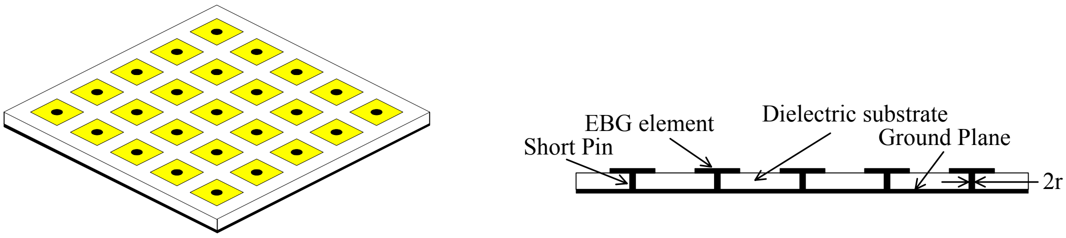
1. Introduction

Electromagnetic band-gap (EBG) structures have been studied by many researchers [1]-[4], because of their unique electromagnetic feature. A mushroom-type EBG structure, which is a typical EBG structure, is composed of periodic structures such a metallic patch with a short pin, as shown in Fig. 1. The new types of EBG structures shown in Fig. 2 and Fig. 3 are proposed and investigated in this study. The EBG structure consists of a ground plane, a dielectric substrate, metallic patch-type elements with short pins and a center conductor of a microstrip-line. The mutual coupling effect on a microstrip array consisting of microstrip antennas (MSAs) and a mushroom-type EBG structure was also investigated in this study.

The properties of the new types of EBG structures and the mutual coupling effect of the MSA array with a mushroom-type EBG structure (MSA-EBG array) were investigated by using an electromagnetic (EM) simulator (IE3D). The results of simulation showed that satisfactory performances were achieved in both the new types of EBG structures and the MSA-EBG array.



(a) Top View (b) Sectional View

Fig. 1. Geometry of a mushroom-type electromagnetic band-gap (EBG) structures

2. New types of EBG structures embedded in microstrip line

The geometry of the test EBG structures, in which a one-dimensional grounded-patch

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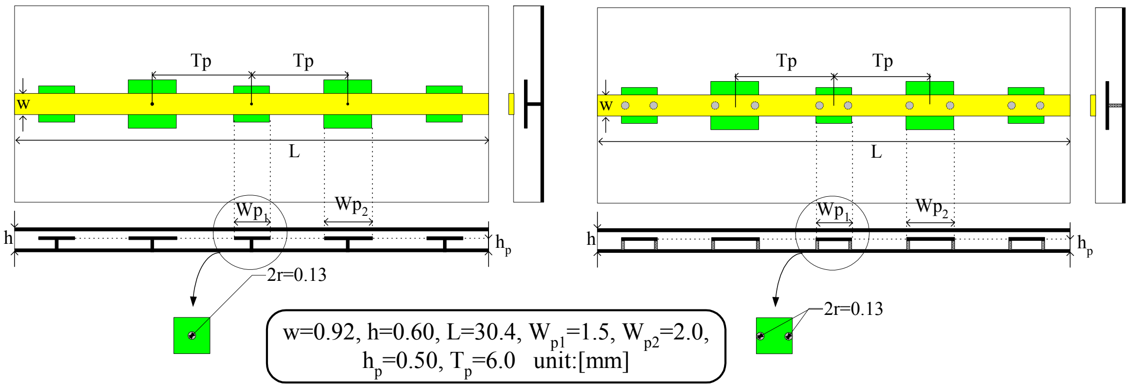
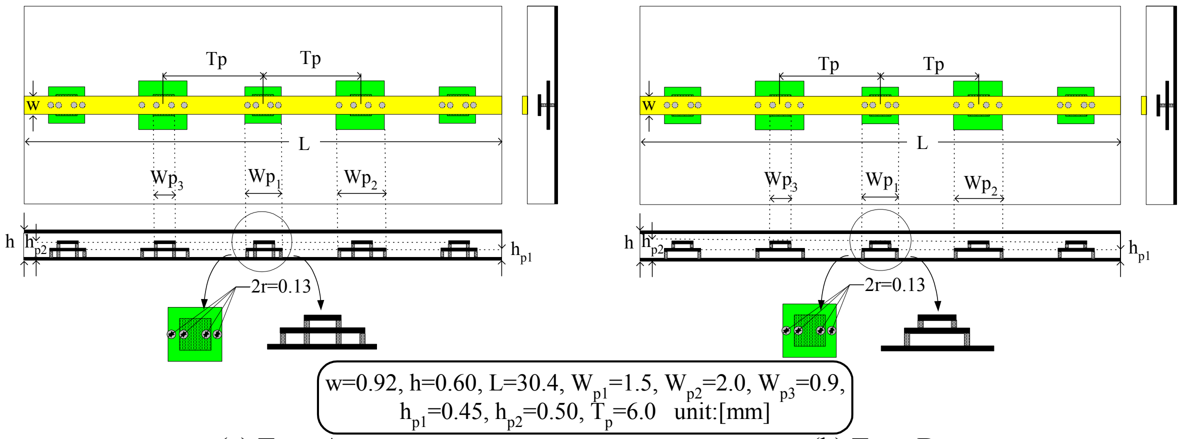


(a) Type I (b) Type II

Fig. 2. One-layer type of EBG structures embedded in a microstrip line (Normal type)



(a) Type A (b) Type B

Fig. 3. Two-layer type of EBG structures embedded in a microstrip line (Stacked type)

array is embedded in a microstrip line substrate, are shown in Fig. 2 and Fig. 3. The microstrip line (Z_0=50Ω) with a width of w=0.92mm was fabricated on a substrate with relative permittivity of $\varepsilon_r = 5.4$ and thickness of h=0.60mm, where Z_0 is characteristic impedance of the microstrip line. Five rectangular patches with two different dimensions, w_{p1}=1.5 and w_{p2}=2.0 mm, were embedded in a substrate just beneath the microstrip line at the period of T_p=6.0 mm, and the height of the patches from the ground plane was set as h_p=0.50 mm in Fig. 2 and h_{p1}=0.45 mm and h_{p2}=0.50 mm in Fig. 3.

Figure 4 shows the frequency characteristics of a transmission coefficient $|S_{21}|$ and a reflection coefficient $|S_{11}|$ for the test EBG structures. It is apparent from this figure that deep and sharpened transmission characteristics ($|S_{21}|$) were obtained for all of the models used in this study. On the other hand, $|S_{11}|$ shows a low insertion loss and small ripples in the passband region for type II, type A, and type B structures. Type B structure demonstrated lower insertion loss and smaller ripples in reflection characteristics as shown in the figure. These results indicate that type B is the most available in these types of EBG structures.

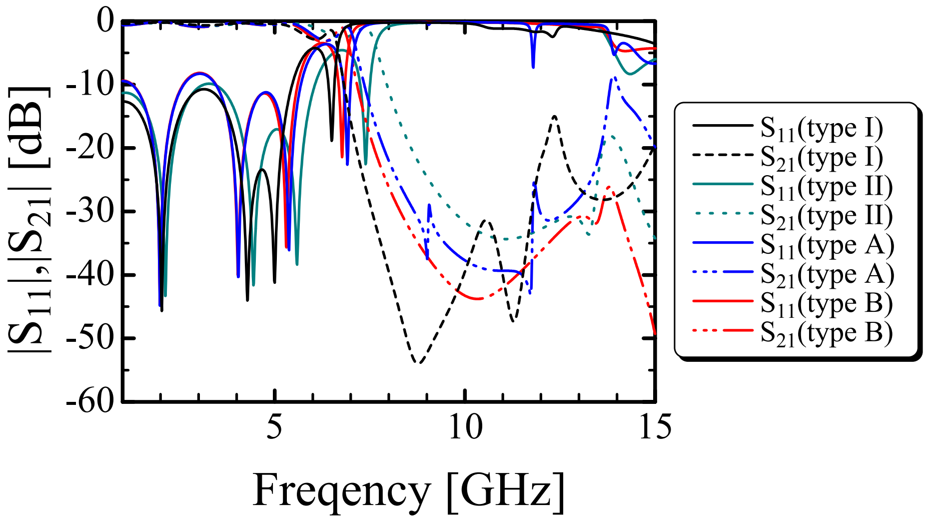


Fig. 4. Reflection and transmission characteristics of EBG structures.

3. Microstrip array with EBG structures

In the design of an array, it is important to estimate the mutual coupling (transmission coefficient) $|S_{21}|$ between microstrip antennas. For this reason, the mutual coupling effects on a microstrip array with a mushroom-type EBG structure (MSA-EBG array) are discussed in this section. The geometry of the test model used here is shown in Fig. 5. Two MSAs and EBG structures are located on the same surface of a grounded dielectric substrate having thickness h and a dielectric constant ε_r. The mutual coupling $|S_{21}|$ for an MSA-EBG array was computed by using an EM simulator. The computed results of an array are shown in Fig. 6 and Fig. 7. As seen in Fig. 6, the mutual coupling $|S_{21}|$ on an MSA-EBG array having three lines of EBG structures is suppressed to below –20 dB.

An MSA-EGB array having one line of EBG structure was selected as a test array for estimating the size effect of a short pin. The mutual coupling $|S_{21}|$ of test MSA-EBG arrays with short pins of various diameters was estimated by using an EM simulator. The results of simulations showed that the mutual coupling $|S_{21}|$ of an MSA array having an EBG structure with a thin short pin (r=0.1mm) is suppressed to below –30 dB, as shown in Fig.7.

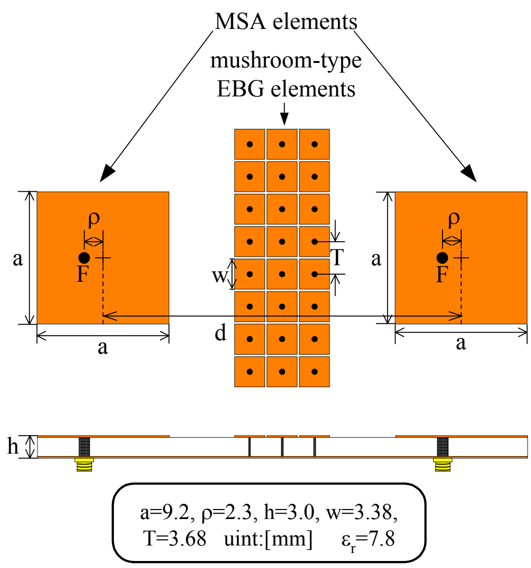


Fig. 5. Microstrip array with mushroom-type EBG structures (MSA-EBG array).

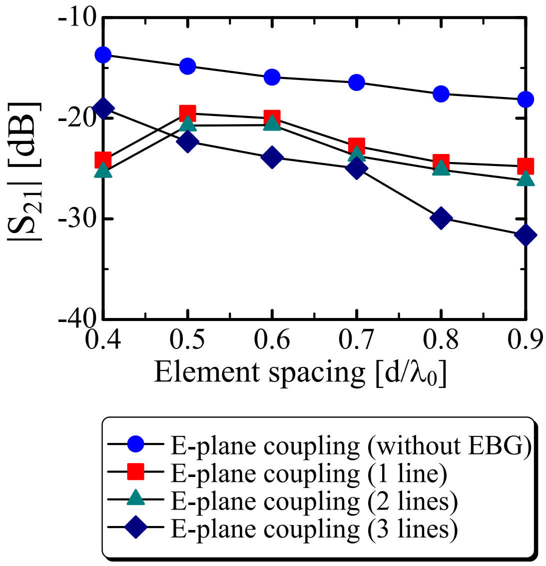


Fig. 6. Mutual coupling $|S_{21}|$ of an MSA-EBG array (r=0.3mm).

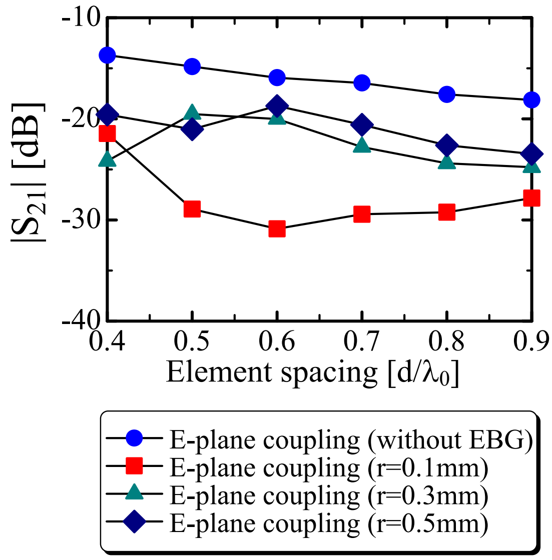


Fig. 7. Mutual coupling $|S_{21}|$ of an MSA-EBG array (One line of EBG structure).

4. Conclusions

New types of EBG structures were proposed, and the performances of the EBG structures were estimated by using an EM simulator in order to establish a design procedure. The results of computation show that the performances of the EBG structures are excellent in terms of both transmission and reflection characteristics. The mutual coupling effect of an MSA-EBG array was also estimated by using an EM simulator. The results of simulations showed that the mutual coupling of the test array is suppressed to below –30 dB. Therefore, the MSA-EBG array is considered to be useful as a high-performance planar array.

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