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AN EFFECTIVE ANALYSIS METHOD FOR EBG REDUCING PATCH ANTENNA COUPLING

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Abstract—This paper presents an effective analysis method for EBG reducing patch antenna coupling. A couple of coaxial probes are used to analyze the mutual coupling reduction range of patch antenna arrays loaded with EBG in this method. Conventional FDTD/PBC algorithm for EBG structures is appropriate only in infinite ground plane and substrate. The gained frequency band-gap by using the algorithm can not be directly used in finite ground plane because of the edge effects. While the proposed coaxial probe method is valid not only in infinite ground plane and substrate, but also for finite ground plane. The method is more suitable for real environments. In order to validate the described method, a two-element microstrip patch antenna array is fabricated and measured. The experimental results are in good agreement with the theoretical data obtained by using the proposed method.

1. INTRODUCTION

EBG structures have gained more and more attention due to their interesting characteristics such as surface wave suppression and in-phase reflection [1–4]. One important application of EBG structures is reducing mutual coupling and eliminating scan blindness for array antennas [5–8]. Before using EBG structures for array antennas, the frequency band-gap of EBG structures must be calculated. Several analysis methods for EBG structures have been reported in [9–11]. Lumped element method has been described in the literature [9]. The results gained by this method are not very accurate because of

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simplified approximation of capacitances and inductances. Periodic transmission line method is presented to analyze EBG structures in [10]. The transmission line method has only been proposed for simple geometries, and it is limited for general geometries. [11] depicts a FDTD/PBC algorithm for EBG analysis. However, the frequency band-gap obtained by this method is only appropriate for infinite ground plane and the results can not be directly used in finite ground plane because of the edge effects.

In this paper, a coaxial probe method is proposed to analyze the mutual coupling reduction of patch antenna arrays loaded with EBG. Compared with FDTD/PBC algorithm, this method is valid not only in infinite ground plane and substrate, but also for finite ground plane. The proposed method considers the edge effects of finite ground plane and it is more suitable for real environments. In order to validate the proposed method, a two-element microstrip patch antenna array is fabricated and measured. It is found that good agreement between experimental and theoretical data is obtained.

2. METHOD DESCRIPTION

The proposed method uses a couple of coaxial probes and the transmission coefficients of S_{21} are measured in two different conditions (with and without EBG between them). By comparing two different S_{21}, we can find that the S_{21} of the probes with EBG is apparently lower than that of the probes without EBG within a special frequency range and the special frequency range is the coupling reduction range. The coupling reduction range also can be used in patch antenna arrays.

A couple of coaxial probes with EBG in finite ground plane, which

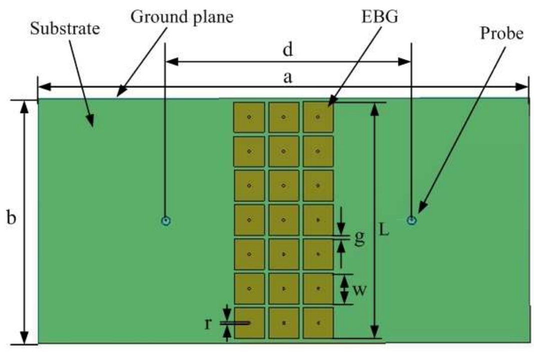


Figure 1. A couple of coaxial probes with EBG in finite ground plane.

is shown in Figure 1, can be used to better understand this method. After the S_{21} with and without EBG are measured, the coupling reduction range can be obtained. If the ground plane and substrate are infinite, enough rows of EBG are needed to make the EBG row length (L) is larger than the probe distance (d), and than electromagnetic simulation software can be used to calculate the coupling reduction range. An example of a mushroom-like EBG structure with infinite ground plane is provided by using FDTD/PBC algorithm and the coaxial probe method. The parameters of the mushroom-like EBG are listed below:

$$w = 6.2\,\text{mm},\ g = 0.8\,\text{mm},\ h = 2\,\text{mm},\ \varepsilon_r = 9.8,\ r = 0.25\ \text{mm} \quad (1)$$

where w, g, and r are the EBG parameters marked in Figure 1, h is the thickness of the substrate and ε_r is the dielectric constant.

The probe distance of d is 50 mm and a 3×11 EBG matrix is inserted between the two probes. The simulated results using two different methods are shown in Figure 2.

Simulated dispersion diagram using FDTD/PBC method is displayed in Figure 2(a) [11]. There is a clear surface-wave band-gap from 3.38 GHz to 4.52 GHz. The transmission coefficients of S_{21} using the proposed method are given in Figure 2(b). There is a coupling reduction range from 3.31 GHz to 4.67 GHz. Comparing Figures 2(a) with (b), we can find that the surface-wave band-gap is fairly similar to the coupling reduction range.

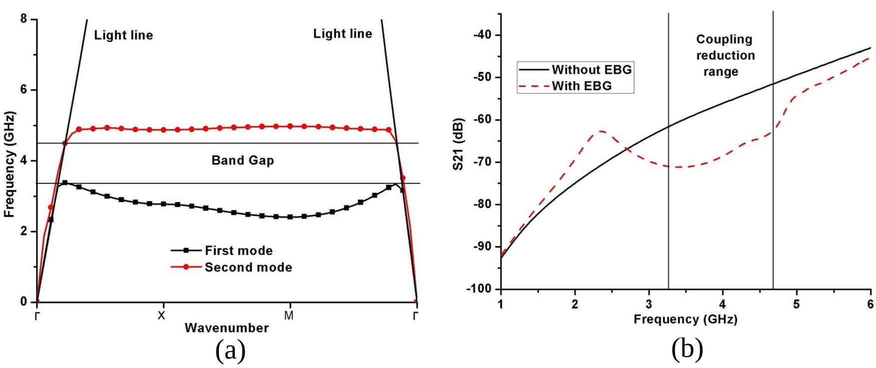


Figure 2. Simulated results using two different analysis methods for the mushroom-like EBG structure in infinite ground plane and substrate. (a) FDTD/PBC algorithm. (b) The proposed coaxial probe method.

3. TWO-ELEMENT PATCH ANTENNA ARRAY

In order to validate the proposed method in finite ground plane, a two-element patch antenna array is designed. Before designing the two-element patch antenna array, the coupling reduction range must be solved to set the antenna sizes. The finite ground plane is designed as shown in Figure 1. The length and width of the ground plane is set as $a = 100$ mm, $b = 50$ mm. The parameters of EBG are the same as formula (1). The probe distance of d is 50 mm and a 3×7 EBG matrix is inserted between the two probes. The simulated coupling reduction range is shown in Figure 3.

The coupling reduction range is from 5.54 GHz to 6.08 GHz and the maximum coupling reduction is 9.1 dB at 5.85 GHz. According to

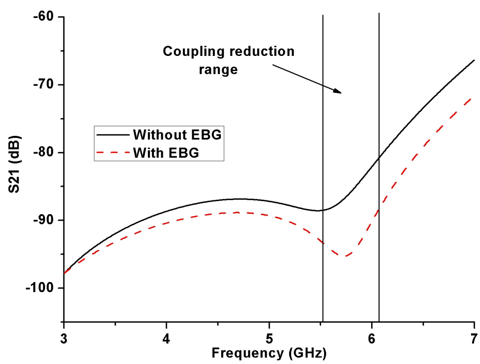


Figure 3. Simulated coupling reduction range using the proposed method in finite ground plane.

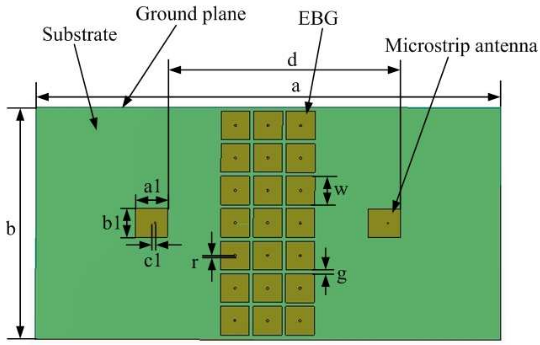


Figure 4. Configuration of the two-element patch antenna loaded with EBG.

the simulated coupling reduction range, a two-element microstrip patch antenna array is designed to work at 5.85 GHz and the configuration of the antenna array with EBG is shown in Figure 4.

The parameters of the patch antenna are $a1 = 7$ mm, $b1 = 6.2$ mm, and $c1 = 0.8$ mm. $c1$ is the distance between the feed probe position and the center of the patch. The simulated S-parameters of the patch antenna array with and without EBG are shown in Figure 5. As shown in Figure 5, the 10-dB bandwidths of the antenna with and without

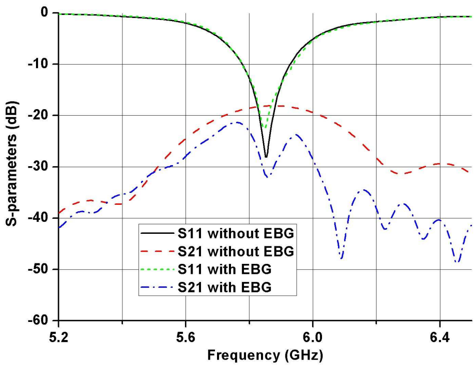
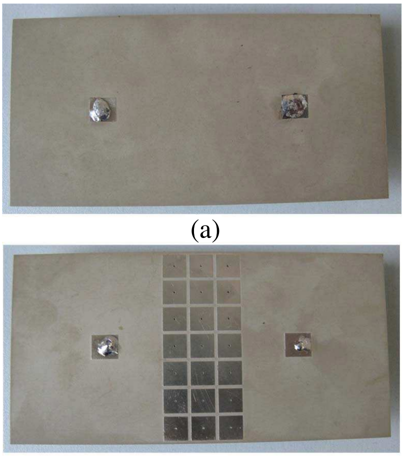


Figure 5. Simulated S-parameters of the two-element patch antenna array with and without the EBG structure.



(a)

(b)

Figure 6. Photo of the fabricated experimental models. (a) Patch antenna without EBG. (b) Patch antenna with EBG.

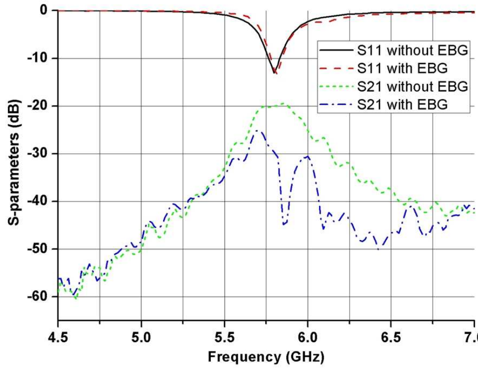


Figure 7. Measured S-parameters of the two-element patch antenna array with and without the EBG structure.

EBG are from 5.76 GHz to 5.93 GHz and from 5.78 GHz to 5.92 GHz, respectively. The coupling coefficient S_{21} of the antenna array with EBG reduces by 3.8 dB all over the work frequency band compared with the antenna array without EBG. The maximum coupling reduction of 16.3 dB is obtained at 5.85 GHz.

Experimental models are fabricated and measured. The photo of the fabricated experimental models is shown in Figure 6 and the measured data are shown in Figure 7. The measured 10-dB bandwidths of the antenna with and without EBG are from 5.78 GHz to 5.84 GHz and from 5.76 GHz to 5.83 GHz, respectively. The coupling coefficient of the antenna array with EBG reduces by 8.3 dB all over the work frequency band and the maximum coupling reduction of 25.3 dB is observed at 5.86 GHz. It is found from the experimental data that the EBG structure can evidently reduce the patch antenna mutual coupling within the coupling reduction range obtained by the proposed method.

4. CONCLUSION

An effective analysis method for EBG reducing patch antenna coupling is proposed in this paper. Compared with FDTD/PBC algorithm, the proposed method is valid not only in infinite ground plane and substrate, but also for finite ground plane. An experimental model is fabricated to validate the described method. The measured results show that the EBG structure can evidently reduce the patch antenna mutual coupling within the coupling reduction range gained by the proposed method.

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