Comparative Results of Microstrip Reflectarray With/Without PBG Ground Plate[1]

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Abstract In this paper, the microstrip reflectarray with/without PBG ground plate are designed and compared. The results show that incorporating PBG structure into reflectarray does not improve the gain as said in reference, but obviously suppress the back-lobe as expected. These facts are discussed in mechanism

I. Introduction

The microstrip reflectarray [1] is attractive alternative of conventional parabolic reflector antenna in some applications because of its compactness , lightweight and low manufacturing cost. A standard microstrip reflectarray consists of a feed as primary radiator and an array of patch elements printed on a grounded dielectric substrate. Each element is slightly different from one nearby, whose role is introducing proper phase shift to convert a spherical wave illuminated from feed into a backward plane wave re-radiated. Many papers were presented to enhance the performances of microstrip reflectarray [2-5], among them the ref. [5] reported that the gain can be enhanced by incorporating a PBG structure into reflectarray as shown in Fig 1, where the PBG structure consists of a 2-D periodic perforations on the ground plate. However, further simulated results by the authors show that does not really enhance the gain, though the back-lobe of reflectarray can be suppressed obviously. These results have been verified by experimental data, and also theoretically explained here.

II. PBG Structure in Reflectarray

The photonic bandgap structure is a new class of periodic medium in which the electromagnetic wave propagation is prohibited for the certain frequency bands. This property has been effectively applied to the printed antenna, as well as to the waveguide and integrated circuit. A significant advantage of PBG structure is that can suppress the surface wave along the substrate possibly excited, then improve the bandwidth, efficiency, and radiation pattern.

Most researches on PBG structure were focused on 1-D and 2-D structures, because they are easier to be fabricated by means of periodically drilling holes in the substrate or etching patterns in the ground plane [7]. On the other side, the 3-D PBG structure with complete bandgap for all directions is inconvenient to be employed due to its greater thickness and more complicated fabrication.

Various kinds of 2-D PBG structure are developed for different applications. Due to the easy fabrication and integration with the radiator, the type of etching ground plane is more popular than that of drilling substrate. Furthermore, two current kinds of co-planar metallic structure surrounding the radiator are attractive for the antenna with single radiator only, one is named as

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mushroom-like PBG [8] consisting of smaller square patches each shorted to the ground plate with via; another is uni-planar compact PBG [9] consisting of smaller shaped patches without via. However, for reflectarray application, a traditional PBG structure simply consisting of square hole in the ground plane under the substrate with the same period of the radiator array [5] is a reasonable design. Where each periodic cell may be considered as a normal patch element loaded by a reactance resulted from the hole in ground plane, and then results in an offset of resonant frequency from the design one, which corresponding to the change in gain.

In this paper, the same period of the reflectarray and the PBG structure is proposed as 0.6 λ_0 by 0.6 λ_0 (λ_0 is wavelength in free space); The side-length of square hole is 3.9 mm for designed frequency of 10 GHz; the permittivity and thickness of dielectric substrate are 2.33 and 1.57 mm respectively. These data coincide with that in [5], thus the simulated phase curves of reflection coefficient vs. patch length for the cases of with and without PBG ground plate are very close to that provided in [5] too. According to these curves, two 37-element (quasi-circular) reflectarray (Fig.3) of microstrip patches with (curve 1) and without (curve 2) PBG structure were designed for 10 GHz, and a broadband tapered slot-line radiator is used as a feed [10-11]. Thus, the directivity (gain) and back-lobe level (in dBi) for each sample are simulated and tested in both cases of with and without PBG ground plate. The results are summarized below.

III. Comparison and Discussion

Table 1 lists the simulated results of directivity and back-lobe vs. frequency for a 37-element reflectarray mentioned above, where:

Case # 11--- designed and also constructed according to a PBG perforated ground plate,

Case #10--- designed according to a PBG perforated ground plate, but constructed from a solid ground plate;

Case # 00--- designed and also constructed according to a solid ground plate,

Case # 01--- designed according to a solid ground plate, but constructed from a PBG perforated ground plate,

Table.1 Simulated performances of reflectarray at different frequencies (in 4 cases)

Frequency (GHz)		9.50	9.75	**10.0**	10.25	10.5
Directivity / Back-lobe (dBi)	Case # 11	14.6 /-2.3	16.1 /-12.0	**16.8 /-9.2**	14.7 /-6.3	14.0 /-4.0
	Case # 10	14.7 / 1.8	14.9 / -1.3	16.7 / 2.4	16.3 / 2.3	16.0 / 1.6
	Case # 00	15.6 / 2.3	16.0 / -0.1	**17.4 / 3.0**	15.6 / 0.9	14.7 / 1.3
	Case # 01	16.1 /-10.9	16.3 / -6.1	14.3 /-2.5	12.7 /-2.1	12.7 /-1.9

(denote the ‘yes’ as ‘1’ and ‘no’ as ‘0’ for the digits; the first digit means if designed with PBG, and the second one means if constructed’ with PBG.)

The comparison between # 00 and # 01 seems a great difference in directivity, that means a unbalanced estimation for a reasonable design (using the left curve in Fig.2) of normal reflectarray and an unreasonable construction with perforated plate (corresponding to the right curve in Fig.2).

If the comparison is made between two reasonable designs of reflectarray #11 and # 00, the conclusion becomes less difference, even the directivity of normal one # 00 is slightly higher than the PBG one # 11 at 10 GHz, due to the cause discussed later; however, the PBG suppresses back-lobe obviously.

As shown in Fig.2 that the curve for solid plate (without PBG) is always on the right side of the curve for perforated plate (with PBG). Hence, when the design for cases # 11 and # 00 under the condition of same size of initial patch, and then the sizes of subsequent square patches are always different, where the patch size of # 00 is larger than that of # 11. Usually, the effective aperture of element is proportional to the patch size, thus the effective aperture of # 00 is greater than that of # 11 for each element of the reflectarray, When the effective aperture of each element can really sum up without overlap over the whole aperture, then the efficiency of reflectarray will reach the greatest on the operated frequency. Nevertheless, once the effective apertures of adjacence are overlapping, due to the close mutual coupling, the phase shift will be deteriorated from the correct value and then the gain of reflectarray will drop down.

If a reflectarray with PBG structure, designed in case # 11 according to the phase curve (left) of Fig.2, is replaced its perforated ground plate by solid one (case # 10) only, then the gain of the reflectarray becomes smaller at the designed frequency. However, it is not a measurable comparison in the gain, because the phase shift used in case # 10 is not correct.

Ⅳ. Conclusion

Introducing PBG structure (etching a periodic pattern in the ground plane) into reflectarray can not always improve the gain, but the backlobe of reflectarray can be improved obviously. In order to enhance the gain of reflectarray , some other approaches need to be incorporated into the design of reflectarray to increase the aperture efficiency of reflectarray.

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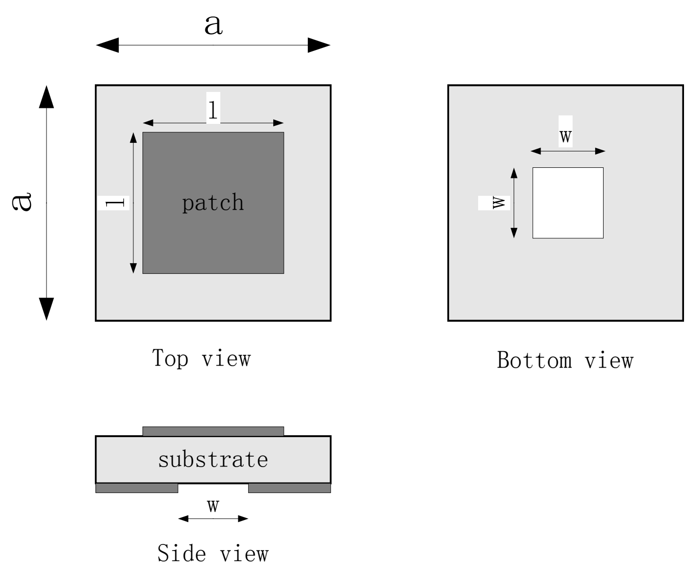


Fig.1 The unit cell of reflectarray with PBG structure

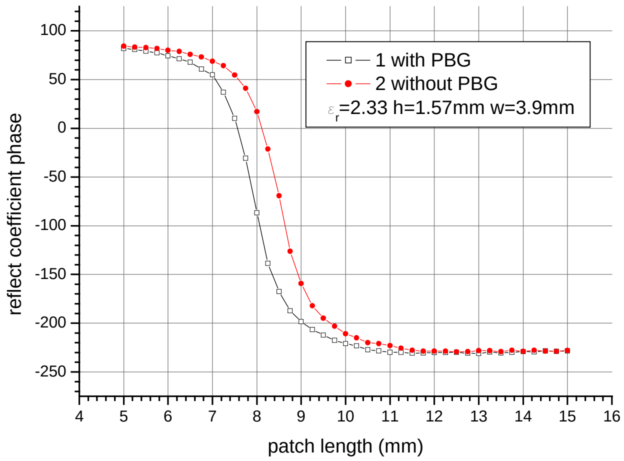
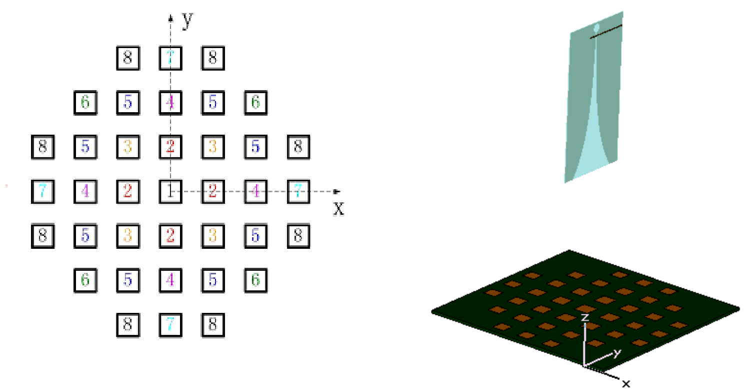


Fig.2 The reflect coefficient phase curve of variable patch size with and without PBG



(a) (b)

Fig.3 37-element reflectarray configuration (a)sketch map (b)perspective view