2006-01-01

Investigation on Annular-ring Patch Antenna with EBG Structure

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INVESTIGATION ON ANNULAR-RING PATCH ANTENNA WITH EBG STRUCTURE

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ABSTRACT

An annular-ring loaded circular patch antenna with slot-ring array of EBG cells on the ground plane is presented. A comparison is made between the annular ring loaded patch on a conventional PEC groundplane and the same patch on a groundplane with a 2x2, a 4x4 and a 6x6 slot-ring EBG array. It was found that the annular-ring patch antenna with a 4 x 4 slot-ring array in the ground plane is superior in the overall performance (gain, impedance and axial-ratio bandwidth). The array of EBG was found to improve gain by 3.5dB and increase the bandwidth of input impedance by about 60% (from 56MHz to 85MHz) and the bandwidth of axial ratio increased by about 70% (from 14MHz to 24MHz).

1. INTRODUCTION

The annular-ring patch antenna [1, 2] has been very popular due to its small size and low profile. In [3], the circular patch antenna coupled to the annular-ring with a cross-slot in the ground plane just at the back of the radiator was shown to significantly reduce the antenna size. But if the dimensions of the antenna become small, its performance, such as the gain and bandwidth, are degraded. Electromagnetic Band Gap (EBG) structures [4-6] have been reported to improve performances in antenna application by suppressing surface waves and limiting diffraction effects at the edges of the truncated ground plane.

In this paper, the different slot-ring array EBG structures are designed to improve the gain and both impedance and axial-ratio bandwidth of the circularly polarized antenna.

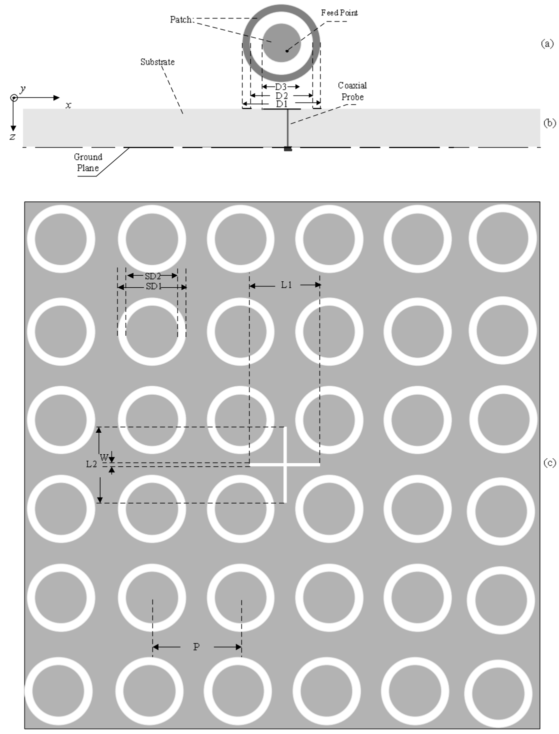

Figure 1 *The geometry of the proposed annular-ring patch antenna*
a) annular-patch (b) substrate (c) with a 6 by 6 slot-ring EBG ground plane

The performance of several annular-ring patch antennas are simulated and presented in this paper.

2. DESIGNS OF SLOT-RING EBG GROUND PLANE AND ANNULAR-RING ANTENNAS

Fig.1 shows the geometry of the circular patch antenna loaded with concentric annular-ring slots and with an unequal cross-slot in the ground plane. These structures are printed on the substrate of FR4 material with a thickness of 1.52mm, the permittivity of 4.1, loss tanδ of 0.018. The unequal cross-slot can reduce antenna patch size for a given operation frequency. In this paper, the orthogonal cross-slot with unequal lateral lengths, L1 and L2, is centred with respect to the patch. By adjusting the lengths of the two arms of the cross-slot, the resonant frequency of the proposed annular-ring patch antenna is separated into two near-degenerate resonant modes with equal amplitude and 90 degree phase difference. So, circular polarization antenna can be achieved.

TYPE	Feed Point (x, y)	BW1 (MHz)	BW2 (MHz)
Antenna 1	(-4mm, 4mm)	54	14
Antenna 2	(-4.5mm, 4.5mm)	69	20
Antenna 3	(-3.8mm, 3.8mm)	85	24
Antenna 4	(-4.8mm, 4.8mm)	77	22
	Min Axial (dB)	Centre Frequency (GHz)	Gain (dBi)
Antenna 1	0.65	1.610	0.5
Antenna 2	0.60	1.550	3.3
Antenna 3	0.53	1.568	4.0
Antenna 4	0.64	1.548	3.2

Table 1 *The comparison of the performances for four annular-ring patch antennas.*
BW1: Impedance Bandwidth; BW2: Axial Ratio Bandwidth
Antenna 1: Annular-ring patch coupling circular patch without EBG
Antenna 2: Annular-ring patch coupling circular patch with a 2x2 slot-ring array EBG
Antenna 3: Annular-ring patch coupling circular patch with a 4x4 slot-ring array EBG

At the same time, by reversing the cross-slot in reference with the feed point, either left- or right-hand circular polarization can be obtained.

The proposed antenna dimensions were optimized, so that D1=35.0mm, D2=28.0mm, D3=17.0mm, L1=28.2mm, L2=32.0mm, slot line width w=1.0mm. A 50 ohm input impedance coaxial probe is used as a feed line. The ground plane size used in all the simulations is 240mm×240mm. The EBG periodic length P=40.0mm. The parameters SD1=30.0mm and SD2=22.0mm finally define the annular-ring slot EBG structure. In order to fairly compare the four different antennas, different feed point locations were optimized to take into account all the different impedance scenarios. They are listed in Table 1.

3. SIMULATED RESULTS

The annular-ring patch antennas with a 2x2, a 4x4 and a 6x6 slot-ring array EBG structure in the ground plane were designed and numerically evaluated. The results for the proposed antenna are simulated using the Finite Element method. The simulated input impedance and axial ratio bandwidth for the antennas with and without EBG are compared in Fig. 2 and Fig. 4, respectively. The performances in terms of impedance and axial ratio bandwidth, minimum axial ratio peak, centre frequency and gain of these antennas are listed in the Tab.1.

Comparing the four antennas, it is evident that the proposed antenna with a 4 by 4 slot-ring array EBG achieves the greatest improvement in the gain, impedance and axial ratio bandwidth. In fact, for the Antenna 3 with a 4 by 4 slot-ring array on the ground plane, the input impedance bandwidth below 10dB return loss is about 85MHz (from 1.515GHz to 1.60GHz); the axial ratio bandwidth below 3dB is 24MHz (from 1.555GHz to 1.579GHz). But for the antenna without EBG, the impedance bandwidth is only 54MHz (from 1.592GHz to1.646GHz); the axial ratio bandwidth is 14MHz (from 1.605GHz to 1.619GHz).

As the only difference between all the antennas under test is just the presence or the number of elements of the EBG arrays, all the improvements resulted are exclusively due to the effect of the EBG structure.

In fact, it is believed that the surface waves

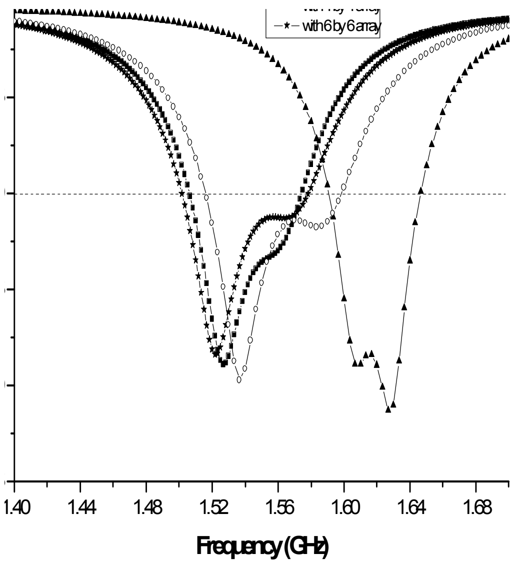

Figure 2 *Comparison of S11 for the four antennas*

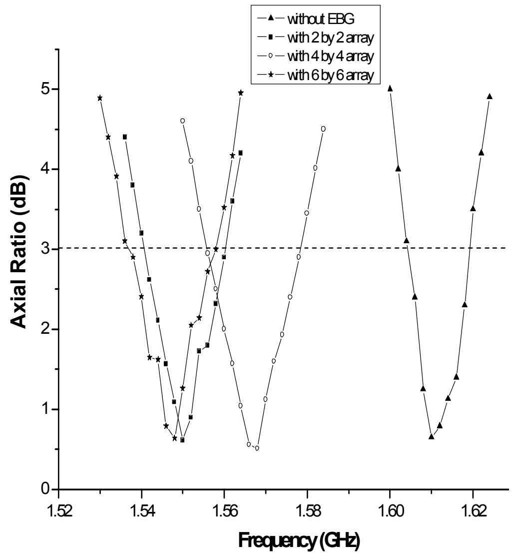

Figure 3 *The comparison of axial ratio for four antennas*

suppression together with diffraction effects reduction aid and reshape the radiation pattern in such a way that different cuts appear more symmetric. In addition to that, as surface waves are reduced, more energy is conveyed in the boresight direction. The results for the Antenna 4 with a 6 by 6 slot-ring array EBG might be surprising as they confirm a reduced performance when compared with the Antenna 3 (4 by 4 slot-ring array EBG). However, this phenomenon, also observed in [7], confirm that EBG loaded ground plane have to be designed appropriately together with the antenna under test and more cells is not always the best solution. For the proposed antenna, the radiation patterns at XoZ plane and YoZ plane at 1.568GHz are plotted in Fig.4 and 5, respectively. Figure 4 shows a comparison of the Smith charts of the four antennas investigated. Also from this, the Antenna 3 results the most effective as its locus is tighter and indicates more sharply a better axial ratio feature. The gain at the centre frequency of 1.568 GHz for the annular-ring patch antenna with a 4 by 4 slot-ring EBG is 4.0dBi. The gain at the centre frequency of 1.610GHz for annular-ring patch antenna is 0.5dBi (without EBG), so the proposed antenna can increase the gain over 3.5 dB compared to the antenna without EBG structure. Cross polarization levels are illustrated against co-polar components in Figs. 5 and 6.

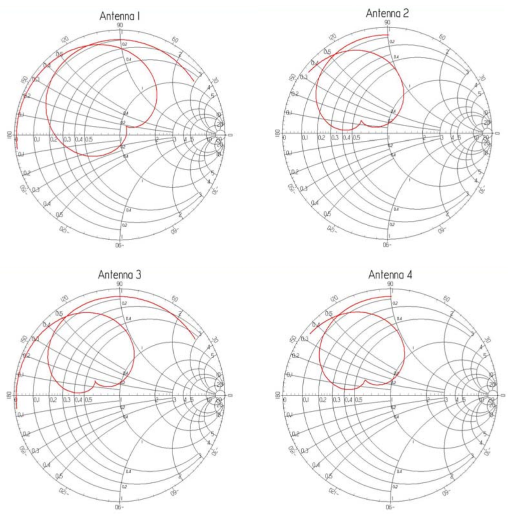

Figure 4 *Smith Charts for the four antennas in the frequency range 1-2GHz.*

4 CONCLUSIONS

In this paper, a circular-patch antenna loaded by an annular ring and placed on a slot-ring EBG structure is investigated and developed. A complement slot-ring EBG structure is used to increase the performances of the annular-ring patch antenna. The simulated results show that an annular-ring patch antenna with a 4 by 4 slot-ring array EBG structure is better than other array sizes. The improvement in gain, impedance bandwidth and axial ratio bandwidth are significant. They are better that 3.5dB increase in gain, approximately 60% wider bandwidth (from 56MHz to 85MHz) and the bandwidth of axial ratio improves by about 70% (from 14MHz to 24MHz).

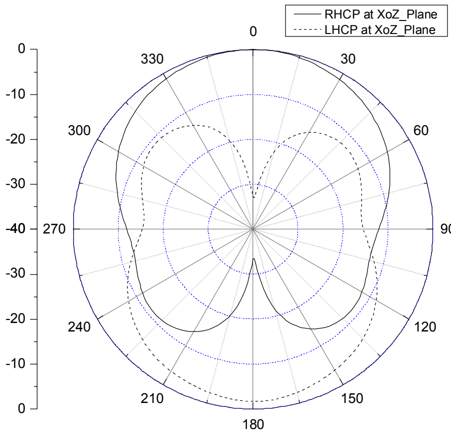

Figure 5 *The radiation patterns of annular-ring patch antenna with a 4 by 4 array slot-ring EBG Radiation Patterns at YoZ-Plane at 1.568GHz.*

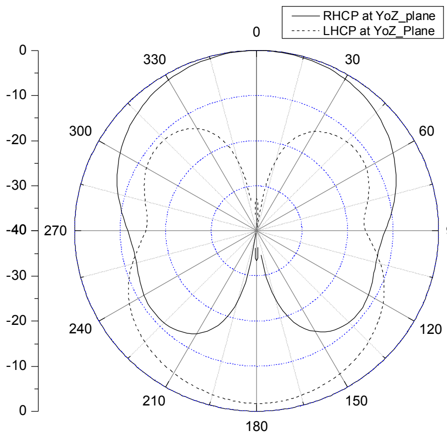

Figure 6 *The radiation patterns of annular-ring patch antenna with a 4 by 4 array slot-ring EBG Radiation Patterns at XoZ-Plane at 1.568GHz.*

ACKNOWLEDGEMENT

Authors would like to thank Science Foundation Ireland for supporting this work.

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