Metallic EBG structures for directive antennas using rectangular, cylindrical and elliptical shapes

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Metallic EBG Structures for Directive Antennas using Rectangular, Cylindrical and Elliptical Shapes

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This paper presents different designs of directive antennas using Electromagnetic Band Gap (EBG) structures. The EBGs consist of periodic structures of metallic wires. In this study, periodic structures in cartesian, cylindrical and elliptical coordinates are considered. Experimental results of antennas using these different geometries and a monopole as an excitation source are presented, and their performances are compared.

Introduction

Electromagnetic Band Gap (EBG) structures are periodic structures, which offer passbands and stopbands to electromagnetic waves [1]. Recently, different techniques have been proposed for designing high-gain antennas with a single feed by using the proprieties of EBG structures [2-7]. Rectangular [2-3], cylindrical [4-6] and elliptical structures [7] have been proposed. In [2], a method based on the Fourier transform has been proposed to obtain the proprieties of the EBG structures in the angular domain and then to predict the radiation patterns of the EBG antenna. In [3], frequency and pattern responses of the EBG structures excited by electromagnetic waves from the interior of these structures have been used to analyze the antenna performances. Using a cylindrical EBG structure, an antenna with high directivity in the elevation plane and wide horizontal beam, has been also presented [4]. In [5], a method has been proposed for designing EBG structures composed of multiple layers of cylindrical periodic surfaces, and in [6], these structures have been applied for base station antennas. In addition, a design of an EBG antenna with elliptical geometry has also been proposed in [7].
In this paper, experimental results of directive antennas with three different configurations of EBG structures composed of metallic wires are presented. Structures with different rectangular, cylindrical and elliptical shapes are considered. The impedance and directivity performances of these three antennas are compared.

Rectangular Structure

Figure 1(a) presents the geometry of a rectangular EBG antenna. The EBG structure is composed of a 2-D periodic structure of metallic wires, excited at its center by a monopole. The structure is used at its first resonant frequency. The antenna is designed using the method presented in [3]. Note that metallic reflectors are added to focalize the radiation in one side. As an example, Figure 1(b) presents the measured and simulated radiation pattern in the H-plane (xoy plane) at 2.63 GHz. The half-power beamwidth is 15.3° in the H-plane. The measured directive gains are between 19 dBi (at 2.61 GHz) and 20.2 dBi (at 2.65 GHz). In addition, an impedance bandwidth ($S_{11} < -10\ dB$) from 2.61 GHz to 2.65 GHz is achieved, which represents a fractional bandwidth of 1.5%.

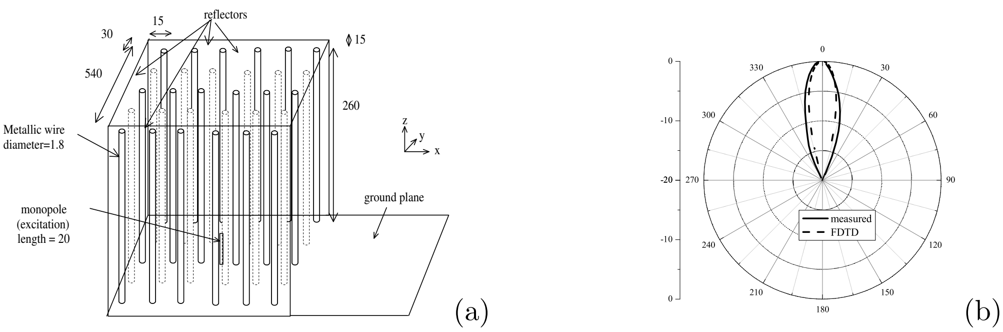


Figure 1: (a) Geometry of a rectangular EBG antenna (dimensions in mm) (b) Simulated and measured radiation patterns in the H-plane at 2.63GHz.

Cylindrical Structure

Figure 2(a) presents the geometry of the Cylindrical EBG (CEBG) antenna. The CEBG structure has been designed using the method presented in [6-7]. The radius of the first cylindrical layer and the period between layers are equal to 45 mm. The wires length and diameter are 200 mm and 1.5 mm, respectively. The monopole length is 30 mm. Defects are applied to the structure to allow directive radiation in the direction of the defects, at the stopband of the CEBG. The defects consist of removing wires: 3 wires are removed from the first layer, 5 from the second, 7 from the third, and so on. As an example, Figure 2(b) presents the measured and simulated radiation pattern in the H-plane at 2.17 GHz. A bandwidth ($S_{11} < -10\ dB$) from 1.74 GHz to 2.31 GHz (a fractional bandwidth of 28%) is achieved. The half-power beam widths in the H-plane are 47.8° and 37.9° at 1.77 GHz and 2.17 GHz, respectively. The measured gains are 12.2 dB and 15.8 dB at 1.77 GHz and 2.17 GHz, respectively.

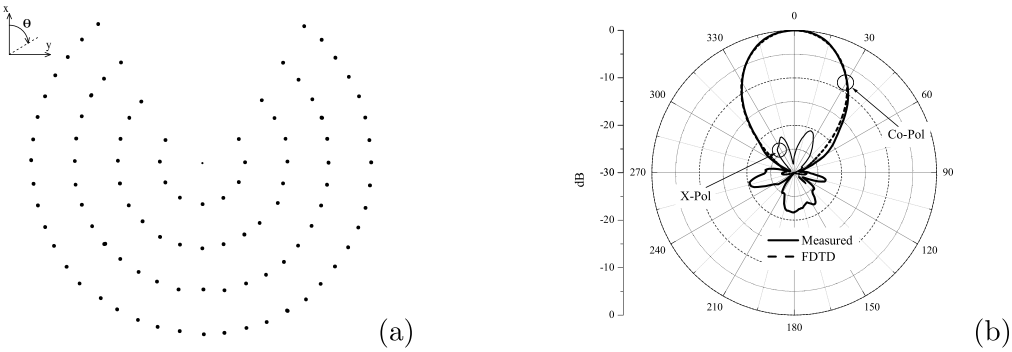
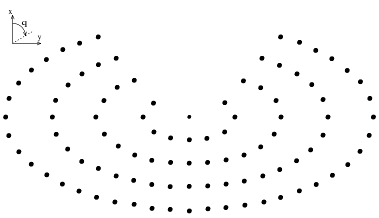
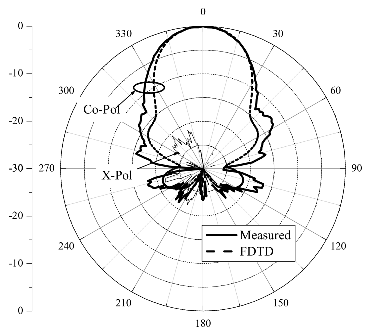


Figure 2: (a) Geometry of a CEBG structure with defects (b) Simulated and measured radiation patterns in the H-plane at 2.17GHz.

Elliptical Structure

Figure 3(a) presents the geometry of an Elliptical EBG (EEBG) antenna [7]. This Elliptical EBG is designed by conserving the elliptical period between wires. The semi-major and semi-minor axis of the first ellipse are equal to 64 mm and 32 mm, respectively, and they correspond to the radial periods in the two axis. The position of the different wires have been calculated numerically. The wires length and diameter are 270 mm and 1.8 mm, respectively. The monopole length is 32 mm. A bandwidth ($S_{11} < -10\ dB$) from 1.76 GHz to 2.29 GHz (a fractional bandwidth of 26%) is achieved. The half-power beam widths in the H-plane are 48° and 37.7° at 1.77 GHz and 2.17 GHz, respectively. As an example, Figure 3(b) presents the measured and simulated radiation pattern in the H-plane at 2.17 GHz. The measured gains are 11.6 dBi and 12.6 dBi at 1.77 GHz and 2.17 GHz, respectively


(a)



(b)

Figure 3: (a) Geometry of an EEBG structure with defects (b) Simulated and measured radiation patterns in the H-plane at 2.17GHz.

Comparison

The antenna aperture taper efficiency is an important tool for evaluating the performance of directive antennas, and it is calculated using the equation [8] :

$$e = Gain/(10\log(4\pi A/\lambda^2)) \tag{1}$$

where A is the area occupied by the antenna in the zoy plane. Using this equation, Tab. 1 presents the performances of the different EBG antennas in terms of bandwidth, gain and efficiency.

Shape	Bandwidth (%)	Gain (dBi)	Area (mm^2)	Efficiency (%)
rectangular	1.5	20.2	540*260	94.4
cylindrical	28	15.8	360*200	94.32
elliptical	26	12.6	512*270	64.3

Tab. 1: Performances of the different EBG antennas.

The gain and efficiency for rectangular, cylindrical and elliptical structures are measured at 2.65 GHz, 2.17 GHz and 2.17 GHz, respectively. From these results, it can be seen that the cylindrical EBG antennas present the same efficiency as the rectangular ones but with a greater bandwidth. The elliptical EBG antennas present the lowest efficiency. Elliptical and cylindrical EBG antennas have similar bandwidth.

Conclusion

Experimental results of directive antennas using EBG structures of metallic wires have been presented. Periodic structures with rectangular, cylindrical and elliptical shapes have been studied, and their performances in terms of bandwidth and directivity have been presented and compared.

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