Circular Patch Antenna with 1D-EBG for X-Band

Amina Bendaoudi and Rafah Naoum

Laboratory of Telecommunication and Digital Signal Processing
University of Sidi Bel Abbès, 22000, Algeria
{amina_nes,rafah.naoum}@yahoo.fr

Abstract. This paper presents unidimensionnel electromagnetic band gap structure (1D-EBG) uses the circular patch antenna as an excitation source. Moreover, this paper presents a comparison between circular and square excitation source. The proposed model is simulated using Ansoft HFSS software and various antenna parameters are measured. Since, the resonance frequency of this structure is 12 GHz; these antennas are suitable for X-band [8.2 GHz; 12.4 GHz] and military applications. The results show the possibility of using a circular patch antenna as the excitation source with unidimensionnel electromagnetic band gap instead of a square patch antenna according to the same resonance frequency and with a reflection coefficient equal to -17.73dB and a directivity of 21.2dB.

Keywords: Circular patch antennas, Resonant EBG, Bragg Mirror, Directivity.

1 Introduction

The extensive, rapid and explosive growth in wireless communication technology and communication systems is prompting the extensive use of low profile, low cost, less weight and easy to manufacture antennas. All these requirements are efficiently realized by microstrip antennas. The applications of microstrip antennas are wide spread because of their advantages due to their conformal and simple planar structure [1], [2]. But the major disadvantage of microstrip antennas is its low directivity and do not have a good radiation patterns.

In the last decade, periodic EBG structures were the focus of much attention due to their promising applications in microwave circuit and antenna design. These EBG periodic structures exhibit wide band pass and band rejection properties at certain microwave frequencies. This unique property has been utilized in enhancing the performance of microstrip antennas and circuits [3-4]. The EBG can forbid the propagation for electromagnetic waves whatever their direction of propagation. The introduction of a defect within a structure 1D-EBG can open a frequency band of transmission and improves the reflection and the directivity significantly.

In reference [5], has been shown that an antenna can provide values of directivity exceeding 15 dB in the presence of an excitation source square patch type and thus allows to overcome the problem of power system required complex for feeding a network of patches. In this paper, we use a structure consisting of a Bragg mirror

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placed on top of a circular patch antenna. Therefore, the following work is divided into five sections: the first section is devoted to give an overview of the circular patch antenna. Second section gives a preface of the unidimensionnel electromagnetic band gap (1D-EBG) structure. Third section discusses the 1D-EBG design with a circular patch antenna as a probe. Forth section demonstrates the results of the paper as a whole and a comparison between both structures: square patch antenna with 1D-EBG and circular patch antenna with 1D-EBG is presented. Finally, a brief conclusion is presented in the fifth section.

2 The Design of Circular Patch Antenna

Patch antennas play a very significant role in today's world of wireless communication systems. A microstrip patch antenna is very simple in the construction using a conventional microstrip fabrication technique. The most commonly used microstrip patch antennas are rectangular and circular patch antennas [6]. Microstrip antenna can be defined as a structure that has a conducting patch printed on a grounded microwave substrate [7].

The resonant frequencies of the circular patch can be analyzed conveniently using the cavity model [8], [9], [10]. The cavity is composed of two perfect electric conductors at the top and bottom to represent the patch and the ground plane, and a cylindrical perfect magnetic conductor around the circular periphery of the cavity. Using the synthesis procedure as mentioned in [11], the resonant frequency of a circular patch can be computed as:

$$f_0 = \frac{c \cdot J_{mn}}{2\pi \, r \sqrt{\varepsilon_r}} \tag{1}$$

Where

r = radius of circular patch antenna.

ε_r= dielectric constant.

J_{mn} = mth zero of the derivative of the Bessel function or order n.

For dominant mode TM_{11}, J_{mn} = 1.84118 [12] which is extensively used in all kind of microstrip antennas.

3 Unidimensionnel Electromagnetic Band Gap Structure (1D-EBG)

The 1D-EBG are composed of a stacks periodic dielectric or metallic structures, it have properties of frequency filtering which is illustrated by changes depending on the frequency coefficients of reflection through a material EBG illuminated by a plane wave at normal incidence.

3.1 Creation of a Bragg Mirror

A multi-layered structure will be created, that almost completely reflects a perpendicular incoming wave for one specific frequency (f_0). Therefore, an adjustment to every layer is necessary in order to obtain a destructive interference of the transmitted waves. Every layer has to be λ/4 thick if the multi-layered structure is an alternation between layers of air and layers of a dielectric material [5].

The formulas which represent the thicknesses of the air layer and the layer of dielectric are the following:

$$e_{air} = \frac{c}{4\, f_0} \tag{2}$$

$$e_{diel} = \frac{c}{4\, f_0\, \sqrt{\varepsilon_r}} \tag{3}$$

Where c is the celerity of light in vacuum.

3.2 Creation of a Resonant Cavity

The introduction of a defect in this structure (figure 1) results in a narrow transmission peak within the band gap. A defect layer of air is introduced, λ_0 thick, the wavelength corresponding with the center frequency f_0 of the band gap. This structure forms a resonant cavity, similar to the Fabry-Perot cavity [5].

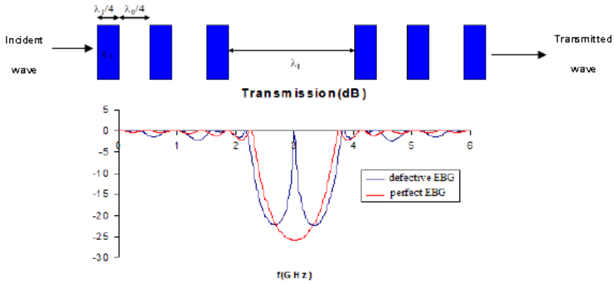


Fig. 1. Multi-layered structure with a defect and its transmission for axial incidence

4 Introduction of an Excitation Source

The 1D cavity is formed on one side a perfect plan E (ground plane of the antenna) and the other side of the Bragg mirror. The cavity has a thickness λ / 2 and the Bragg mirror is composed of 3 layers of relative dielectric permittivity ε_r = 2.6 and a thickness λ / 4. The dielectric layers are separated by layers of air, also thick λ / 4 is the wavelength for which the antenna operates. Here this corresponds to a frequency of 12GHz (figure 2).

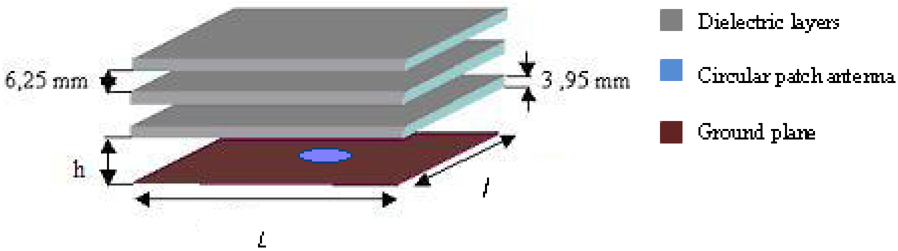


Fig. 2. Antenna and 1D-EBG

However, the antenna having finite dimensions, the resonant frequency of the cavity depends on the transverse dimensions of the EBG material. The calculation of the latter can be approximated by the formula [13]:

$$f_0 = \frac{c}{2\pi}\sqrt{\left(\frac{n\pi}{l}\right)^2 + \left(\frac{m\pi}{L}\right)^2 + \left(\frac{p\pi}{h}\right)^2} \quad (4)$$

Where
n,m,p = indices of the cavity mode.
L,l,h =cavity dimensions.
This cavity has the following dimensions: *l*= *L*= 100 mm, *h*= 12.73 mm and should work on the mode 111.

5 Results and Discussion

Using the commercial code Ansoft's *HFSS (*High Frequency Structure Simulator), a bi-periodic structure considered infinite in the lateral directions has been simulated at normal incidence [14]. The version used is version 10.1 HFSS is a software package for electromagnetic modeling and analysis of passive, three dimensional structures. It presents a comprehensive and meticulous description of the process of modeling a circular patch antenna with 1D-EBG structure in HFSS. Plots of S-parameter values will be calculated and compared with simulation; square patch antenna with 1D-EBG structure, which is performed in reference [5].

5.1 Reflection Coefficient

The same design procedure, which was used for square patch with 1D-EBG in [5], is used in circular patch with 1D-EBG. The square and circular patch antenna use the same substrate (ε_r = 2.33, h = 1.57 mm) and a power source coaxial.

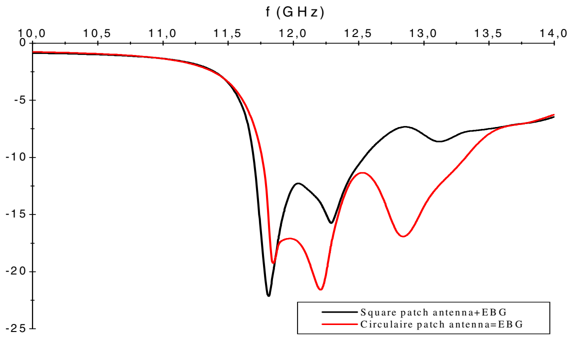


Fig. 3. Simulated reflection coefficient (in dB)

The figure 3 shows the graph of reflection coefficient both structures: square patch antenna+1D-EBG and circular patch antenna+1D-EBG. From the reflection coefficient curve it is clear that the circular patch antenna+1D-EBG have less reflection -17.73dB and operating frequency at 11.92 GHz compared with square patch antenna+1D-EBG has the minimum value is obtained at 11.8GHz and the minimum value obtained is -24dB, we confirm that this study structure is able to use in X-band applications. The antenna shows a wide band behavior between 11.92 GHz and 12.2 GHz.

5.2 2D-Directivity

Two figures below represent the directivity of the two structures in two different planes (Phi = 0 ° and phi = 90 °).

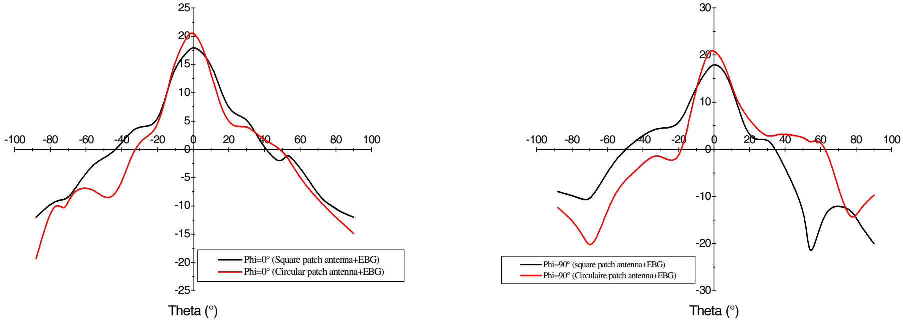
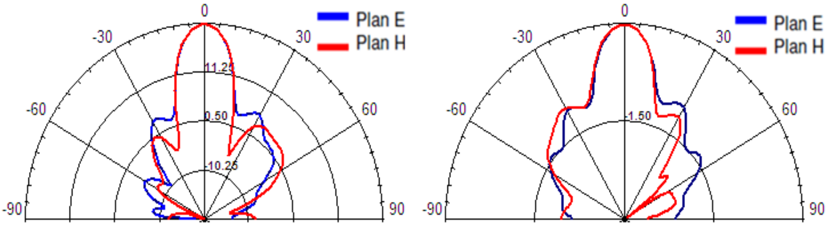


Fig. 4. Simulated directivity (in dB)

The maximum directivity gain obtained from the graph is 21.2 dB for circular patch antenna with 1D-EBG structure. Note that with the directivity EBG becomes narrower. Consequently, the maximum directive gain increases by about 18 dB to 21dB, a 3dB increase therefore. We notice the appearance of side lobes, but they are small enough.

5.3 Radiation Pattern

The figure 5 shows the radiation pattern of the two structures. It is clear from the graph that the radiation is not distributed but directed along a single direction. The Half-Power BeamWidth (HPBW) in the E-plane is 58deg and 66deg in the H-plane. Directional radiation patterns make this structure a good candidate for the antennas used for applications of X-band.



(a) (b)

Fig. 5. The radiation pattern at 12GHz for:
a) Circular patch+1D-EBG ; b) Square patch+1D-EBG

Table 1 shows the obtained simulated results. As shown in the table, the results obtained from square patch with 1D-EBG are very close to those obtained from circular patch with 1D-EBG.

Table 1. Comparison table between square patch+EBG and circular patch+EBG

	Square patch+1D-EBG	Circular patch+1D-EBG
Optimal frequency	11.8 GHz	11.92 GHz
Reflection coefficient	-24 dB	-17.73 dB
Maximal directivity	18.4 dB	21.2 dB
E-Plane HPBW	62deg	58deg
H-Plane HPBW	38deg	66deg

6 Conclusion

In this paper, circular patch antenna with 1D-EBG has been studied and compared with square patch. From the simulation results, we can see that the directivity gain can be improved by changement of the excitation type (shape of the patch antenna) and using circular patch antenna with 1D-EBG, we could obtain a more directional radiation pattern than that obtained using square patch antenna with 1D-EBG. Moreover, we proved the ability of using circular patch antenna with 1D-EBG with same performance of square patch antenna with 1D-EBG approximately.

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