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Microstrip Antenna with Different Settings of EBG Structures for Applications in 5G Technology

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ABSTRACT

This work analyzes the influence of an EBG structure in a microstrip antenna that operates at frequency of 28 GHz, 5G technology. The proposed EBG structure is configured in three ways, by varying the radius of the cylindrical element in the dielectric substrate, in order to compare the data obtained for each configuration and the standard antenna. It was observed the behavior of the radiation characteristics from the proposed changes, yielding variations in gain, bandwidth and impedance matching.

Keywords: Microstrip antenna, EBG, bandwidth, gain, impedance matching.

1. INTRODUCTION

The antennas are capable devices of radiate or receive radio waves and play an important role in communication systems. Among the various types of antennas, one of the most used types due to their characteristics for application in modern communication systems are the microstrip antennas [1]. Among the advantages of microstrip antennas, can highlight: ease of molding the planar and non-planar surfaces, simple construction, low cost, versatility in terms of the resonance frequency, polarization, radiation pattern and impedance. These kinds of antennas have some disadvantages, such as low efficiency, low power, low directivity and small bandwidth (of a few percent) [2].

To solve the problem referring to the narrow bandwidth of microstrip antennas, some techniques have been described in the literature. One would be the use of forbidden band structure (EBG - Electromagnetic Band Gap and PBG - Photonic Band Gap) present on the substrate of the antenna.

PBG structures are those that present periodicity in form and where the propagation of electromagnetic waves in certain frequency bands are not allowed (forbidden bands) [3]. This type of structure was originally researched in the optical region [4, 5], but due to the fact that this structure has its properties applicable to a broad frequency spectrum, searches in the microwave region have been observed in recent years, and in this region, these structures receive the EBG terminology (Electromagnetic Band Gap) [6]. These types of structures allow an increase in the bandwidth of the device, however there is a frequency offset to a large value, since the introduction of forbidden bands, there is a decrease in the effective dielectric constant. Therefore, the dielectric constant needs to be calculated for the antenna to be resized.

According to homogenization theory, relative permittivity depends of the polarization [7]. For electromagnetic waves propagating in the xy-plane, p polarized waves are those in which the electric field is polarized perpendicular to the z-axis and s those in which the electric field is parallel to the z-axis.

The values of ε_{eq} equivalent permittivity for each polarization are:

For s polarization;

$$\varepsilon_{eq} = \beta\left(\varepsilon_1 - \varepsilon_2\right) + \varepsilon_2 \quad (1)$$

For p polarization;

$$\frac{1}{\varepsilon_{eq}} = \frac{1}{\varepsilon_1}\left[1 - \frac{3\beta}{A_1 + \beta - A_2\beta^{10/3} + O\left(\beta^{14/3}\right)}\right] \quad (2)$$

where

$$A_1 = \frac{2/\varepsilon_1 + 1/\varepsilon_2}{1/\varepsilon_1 - 1/\varepsilon_2} \quad (3)$$

$$A_2 = \frac{\alpha\left(1/\varepsilon_1 - 1/\varepsilon_2\right)}{4/3\varepsilon_1 + 1/\varepsilon_2} \quad (4)$$

being β the ratio of the area of the cylinders on the cell, ε_1 and ε_2 are the permittivity in medium 1 (cylindrical element) and medium 2 respectively, α is a constant equal to 0.523 and O represents the origin of the system considered.
This paper sets out to analyze the behavior of a standard rectangular patch antenna fed by microstrip line, designed for a resonance frequency of 28 GHz and compare this elementary model with a proposed EBG structure, being made a change in this structure, radius of the cylindrical elements of the periodic structure in order to analyze the return loss, bandwidths and gains.

2. DESIGN

For the standard antenna used in this work was adopted a rectangular patch structure fed by microstrip line designed for 28 GHz frequency. The dielectric substrate used is RT / duroid 6010LM with relative permittivity (ε_r) of 10.2, tangent losses (tg δ) of 0.0023 and thickness of 0.254 mm. Fig. 1 shows the geometry of the standard antenna, where the dimensions are W = 2.26 mm, L = 1.57 mm, y = 0.585 mm, z = 0.84 mm and w = 0.16 mm.

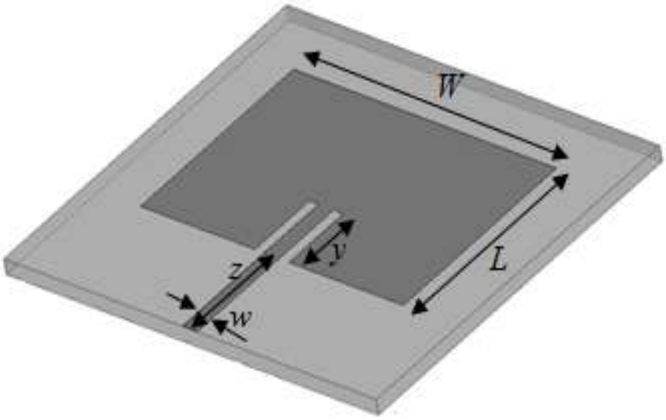

Figure 1. Geometry of the standard antenna.

The proposed EBG structure consists of a rectangular grid with twelve cylindrical elements (filled with air). The periodicity (or network constant) shows value of 1 mm. In this periodic structure are performed three variations on the radius of the cylinder within the substrate. The values used for the radius of the cylinder are 0.2, 0.3 and 0.4 mm. Figure 2 shows the antenna with the air cylinder in the substrate.

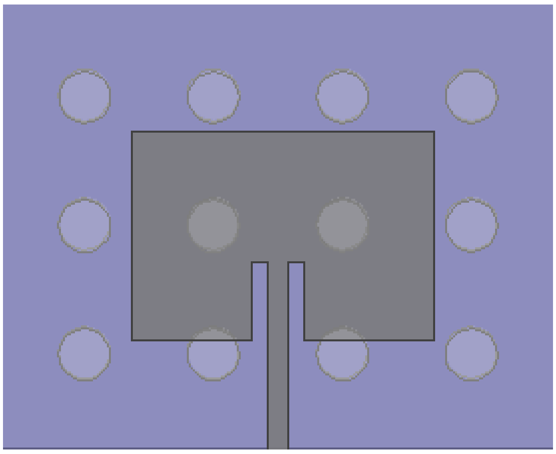

Figure 2. Antenna with EBG structure.

After modeling the antenna pattern and the proposed settings for the EBG structure, simulations were performed in order to obtain comparative data for: return loss, bandwidth and gain. The results of the simulations will be described in the next section.

3. RESULTS

For the standard antenna and for the proposed settings for the EBG structure described in the previous section, simulations to obtain values of return loss versus frequency were carried out and values of bandwidth and radiation pattern to obtain the gain. All these values were compared in order to verify the characteristics of all the settings.

Fig. 3 shows the values of return loss as a function of operating frequency for the standard antenna and the proposed settings for the EBG structure. Can see the shift in the operating frequency of the antenna when using the EBG structures where as the radius of the cylinder increases, the operating frequency of the antenna also continues to rise, since the decrease of dielectric constant. The values of return loss, the operating frequencies and the widths of absolute bands for the standard antenna and other configurations are shown in table 1.

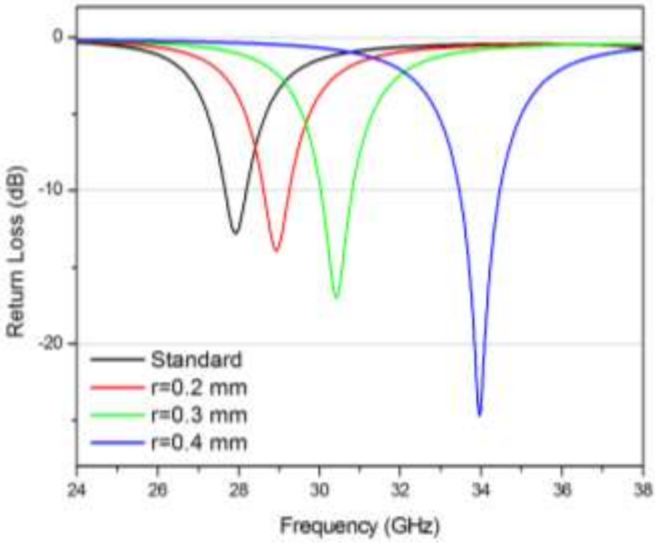

Figure 3. Return loss of the standard antenna and proposed settings.

Table 1: Values of return loss, operating frequencies and bandwidth for the standard antenna and proposed settings

Structure	Return Loss (dB)	Frequency (GHz)	Bandwidth (MHz)
Standard antenna	-12.8	28	525
EBG with r = 0.2 mm	-13.9	28.9	632
EBG with r = 0.3 mm	-17	30.4	760
EBG with r = 0.4 mm	-24.7	34	998

Given the decrease in dielectric constant, their values were calculated for the EBG structures and the antenna has been resized so that the answer is a frequency of 28 GHz to any setting. Table 2 shows the values of the permittivity, as well the new dimensions as a function of radius of the air cylinder in the structure.

Table 2: Permittivity and dimensions of the new antennas as function of the radius of the air cylinder

r (mm)	ε	*W*(mm)	*L*(mm)	*y*(mm)	*z*(mm)	*w*(mm)
0	10.2	2.26	1.57	0.585	0.84	0.16
0.2	9.5	2.34	1.62	0.603	0.87	0.16
0.3	8.5	2.46	1.78	0.632	0.92	0.16
0.4	6.6	2.76	2.11	0.692	1	0.16

The antennas were simulated again and the response of frequency for any setting is 28 GHz. Fig. 4 shows the return loss versus frequency, where it can be seen that with the increase of the radius of the air cylinder, there is an increase of the bandwidth, as well of the impedance matching.

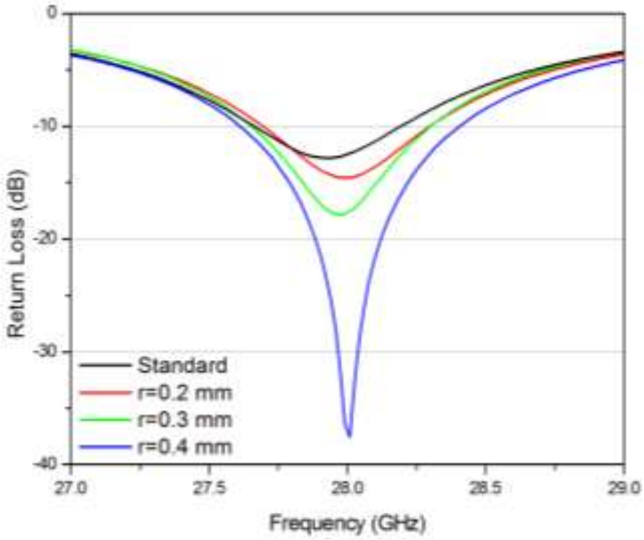

Figure 4. Return loss of the new proposed antenna designed for 28 GHz.

Fig. 5, 6, 7 and 8 show the radiation pattern in 2D and 3D of the standard antenna and proposed settings. The standard antenna has a gain of 5.096 dB. The EBG structures with radius 0.2 mm, 0.3 mm and 0.4 mm has the following gains, respectively: 5.128 dB, 5.275 dB and 5.838 dB. With these values, it observed an improvement in the antenna gain for any proposed configuration of the EBG structure, and the setting of radius r = 0.4 mm presented the best gain.

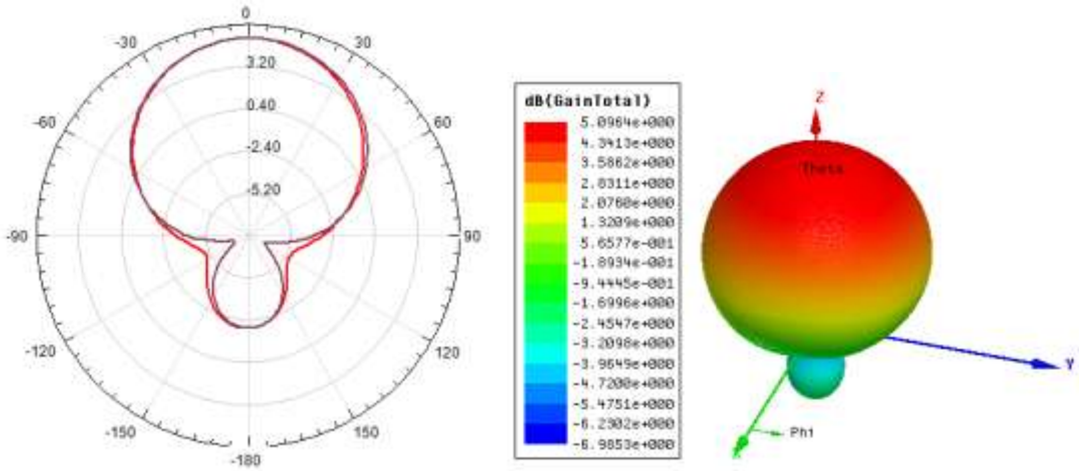

Figure 5. Radiation pattern of the standard antenna.

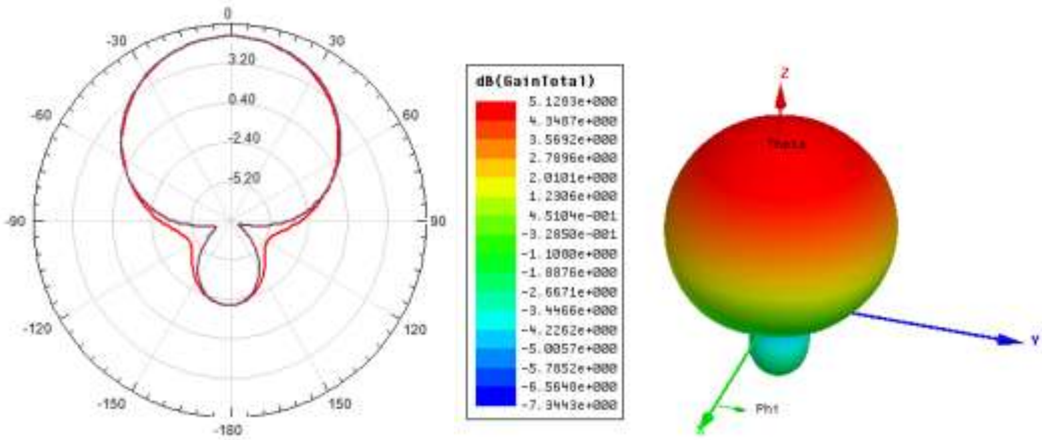

Figure 6. Radiation pattern of the configuration with r=0.2 mm.

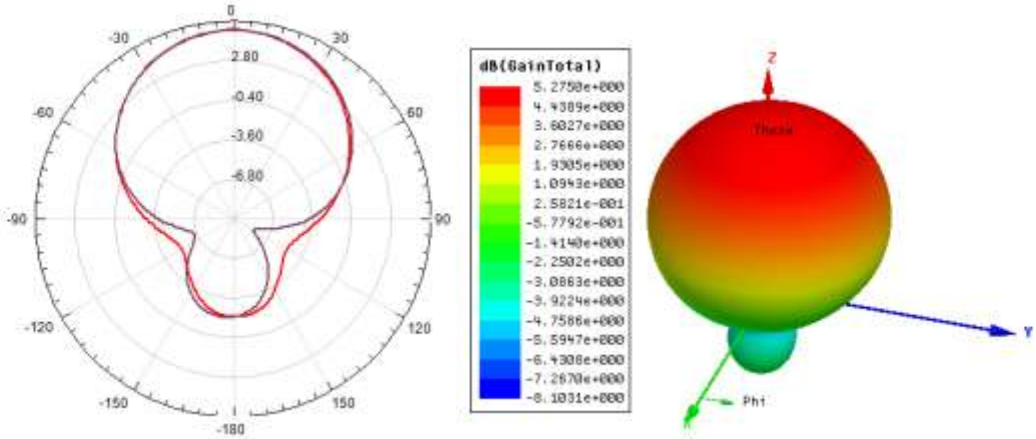

Figure 7. Radiation pattern of the configuration with r=0.3 mm.

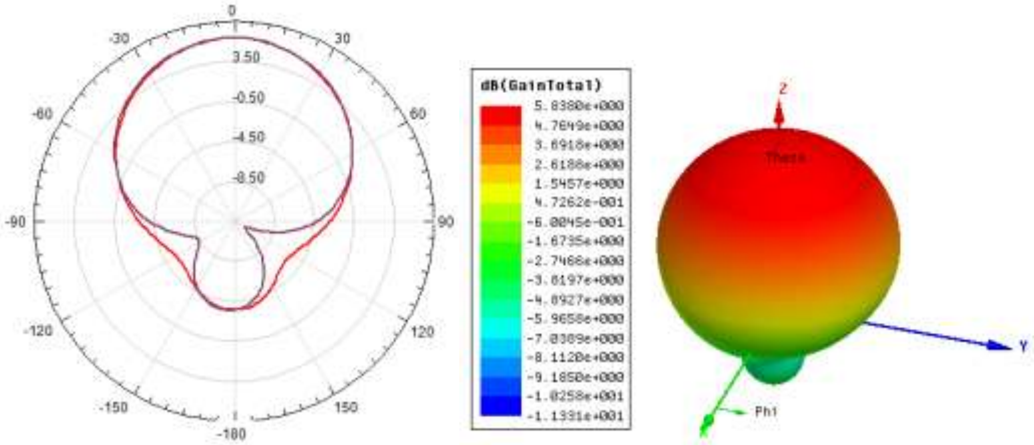

Figure 8. Radiation pattern of the configuration with r=0.4 mm.

4. CONCLUSIONS

In this paper a microstrip antenna was designed to operate at 28 GHz and its radiation properties were analyzed. An EBG structure was proposed and three different settings of the cylindrical elements of the periodic structure have been analyzed in order to obtain comparative data with the model of the standard antenna, such as return loss, bandwidth and gain.

Therefore, there is an improvement in bandwidth for all proposals of EBG structure in comparison with the model of the standard antenna. Another feature of the proposed configurations has been the displacement at the operating frequency, where when the radius of the cylinder in substrate increases, the operation frequency also increases. Thus, from the calculation of permissiveness for EBG structures, antennas were resized for the frequency of 28 GHz, obtaining a better impedance matching and bandwidth for proposals structures.

The antenna gain increased for all proposals configurations related to the standard antenna. The configuration with the cylinder of radius 0.4 mm had the highest gain, with a value of 5.838 dB.

In short, it was noticed the improvement in radiation properties when the EBG settings are used, showing the potential of these structures for use in 5G technology.

5. ACKNOWLEDGMENT

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