Using mushroom EBG in microstrip array antenna to reduce Side Lobe Level

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Abstract: Metamaterial is type of material that isn't in nature and it is manufacture by combination of multi material with together and by combination of their specification , the resulting metamaterial contain negative ξ_r, μ_r. One kind of metamaterial is EBG that we use it in our paper and discussion about its effect on microstrip antenna. EBG has a band gap in specific frequency that causes not propagation in this frequency. using EBG in antenna, band gap specification cause reduction in surface field that means side lobe level will decrease. Really in microstrip array surface wave that is propagate in substrate cause side lobe in pattern. Our antenna work at 10 Ghz. After designing the array with 4 element and designing EBG in 10 Ghz , the periodic structure of EBG has been embedded around the antenna . Combination of antenna and EBG led to decrease surface and SLL about 2.5 dB.
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1. Introduction

In today's world of globalization, increased use of wireless technology in communication has led to a different antenna is also required. With upgraded technology, telecommunication system going to miniaturization in volume, so it's inevitable to use antennas with smaller structures and more flexibility forms. Customary antennas because of their giant dimensions have replaced with microstrip antennas and combination of their arrays.

Besides, in the most applications such as radar antenna it is required to minimize the ratio of side lobe magnitude to main lobe magnitude to raise radiation of energy in main desirable direction. Many different methods were presented such as Taylor and Chebysheff distribution on elements [1].

In this paper it has been tried to improve SLL with utilization of EBG metamaterial structure in antenna. In section one, a 2*2 microstrip array antenna in 10 Ghz has been designed and all dimensions were determined, then the features of pattern were described after simulation.

In second section, EBG structure is designed in 10 Ghz and some features is noted.

In last section designed EBG is located beside of antenna elements. Finally these situations in term of SLL are compared with structure without EBG.

SECTION ONE: Designing of microstrip array antenna

In this section, designing of microstrip antenna with transmission line feeding network was accomplished. The main reference of this paper is [1]. Finding antenna dimension essentially needs three parameters: resonance frequency fr=10 Ghz, substrate height h=0.1588cm, dielectric constant which in this paper RT/druid 5880 was used so $\varepsilon_r = 2.2$. With attention to Balanis equations, antenna dimension as follows:

$$w = \frac{c_0}{2fr}\sqrt{\frac{2}{\varepsilon_r + 1}} = 1.186cm$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2} = 1.972$$

$$\Delta L = 0.412h\left(\frac{(\varepsilon_{reff} + 0.3)(w/h + 0.262)}{(\varepsilon_{reff} - 0.258)(w/h + 0.8)}\right) = 0.081cm$$

$$L = \frac{\lambda}{2} - 2\Delta L = 0.906cm$$

Which c_0 is light velocity y in free space (3×10^8) , λ is wavelength in 10 Ghz frequency, w and L are antenna's patch dimensions, figure (1) shows this antenna:

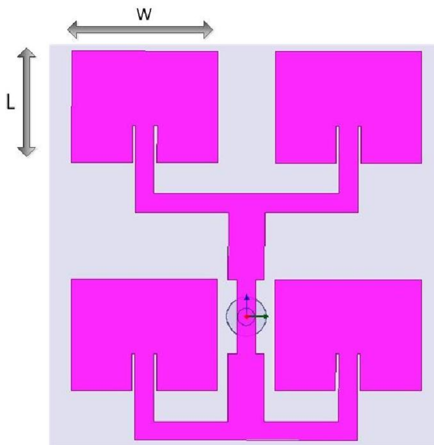

Fig (1): microstrip array antenna in 10Ghz

After simulation, antenna pattern in $\varphi = 90^{\circ}$ plane was shown in figure (2), which has 12.6267db dB gain and -12.6985db SLL.

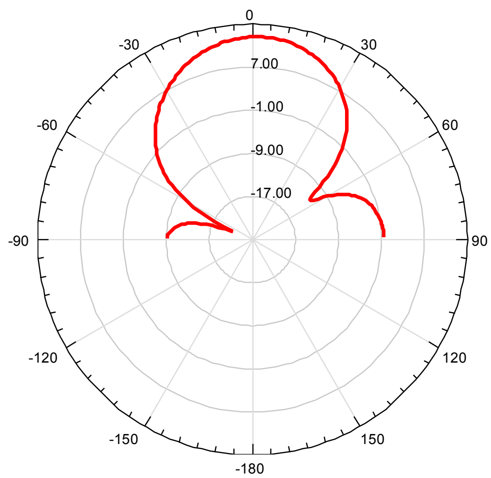

Fig (2): pattern of microstrip array antenna

2. EBG Designing in 10 Ghz Frequency

Here, a kind of metamaterial that is called EBG[1] has been presented. These kind of metamaterial structures have been constructed from same and periodic units besides each other. Each unit is a combination of conductor and dielectric, so that it is equal to LC circuit. Serial and parallel combination in one unit cell has been presented in figure (3). For four kinds of metamaterials (DSP[2], MNG[3], ENG[4] and DNG[5]). [5]

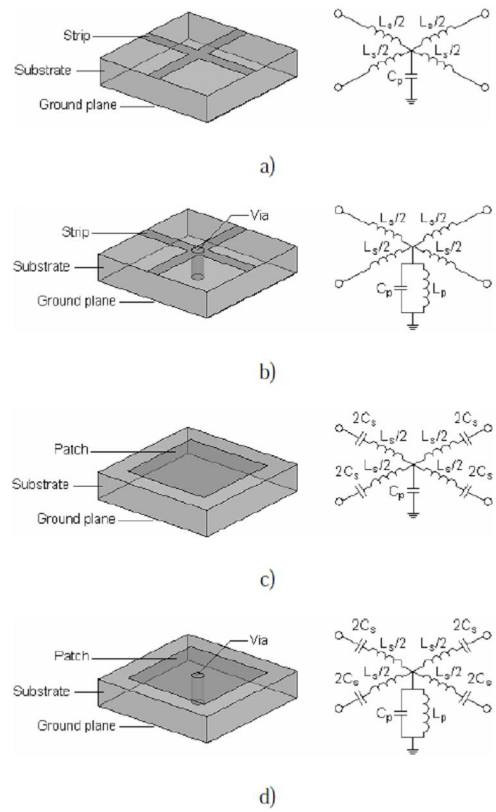

Fig (3): Possible mushroom structure, combination of conductor and dielectric: DPS(a), ENG(b) ,MNG (c), DNG(d)

Figure (3), (a) is a DSP material with serial inductance and parallel capacitance. Figure b) in addition of serial inductance it required parallel inductance. Third figure presented MNG metamaterial. In fact a conductor with flat surface on dielectric will indicate a serial capacitance and inductance also parallel capacitance. In the last figure, a flat plane on dielectric has been connected to ground plane with via. Because of connection between serial inductance and capacitance with adjacent cell and the connection of parallel structure to ground, materials with DNG quality was produced (the latest EBG well known as mushroom EBG).

Due to the periodic structure and its how to put together those have two important features:

1) EBG structure with special dimension cause to special frequency band so that waves can't propagate in this band neither angles nor polarization.
2) In this distinguished frequency band, EBG surfaces have zero reflected phase.

These two features led to use mushroom EBG as dam against wave propagation. EBG will destroy incident wave in frequency which it was designed, so

[1] Electromagnetic Band Gap
[2] DPS (Double Positive)
[3] MNG (Mu Negative)
[4] ENG (Epsilon Negative)
[5] DNG (Double Negative)

there is not wave forward of EBG, this subject will extended in next section.

In this section we used equations that mention in [6] to design EBG dimensions in 10 Ghz frequency. As it is shown from figure (4) we can equivalent a combination of two EBG to LC circuit. According to patch dimension L and C magnitudes are found.

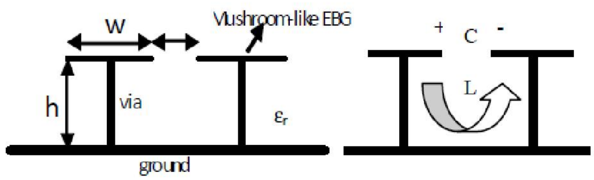

Fig (4): Equivalent a combination of two EBG to LC circuit

2.1. Dimensions in 10 Ghz frequency is as follows:

$$L = \mu_0 h$$

$$c = \frac{w\varepsilon_0 (1+\varepsilon_r)}{pi} \cos^{-1}\left(\frac{w+g}{g}\right)$$

As it was shown in figure (4) w is patch dimension in EBG and g is the space. With h=0.1588cm and with use of this formula $L = 1.9955 * 10^{-9}$H. base of the $2\pi * f = \frac{1}{\sqrt{Lc}}$, magnitude of $C = 0.1268 * 10^{-12}$ F is calculated. Then EBG patch dimension is $w = 62 * 10^{-4} mm$ and distance between cells is $g = 15 * 10^{-4}$m.

SECTION TREE: embedding EBG in antenna

Designed EBG has been located around antenna to decrease surface field .Two rows of EBG were embedded both sides of antenna, these EBG led to decrease part of waves which radiated from main patch antennas and propagate on the surface of that.

In fact, surface waves led to appear side lobes or cause to bigger magnitude. Embedded EBG around antenna it has been led to band this surface wave propagation.

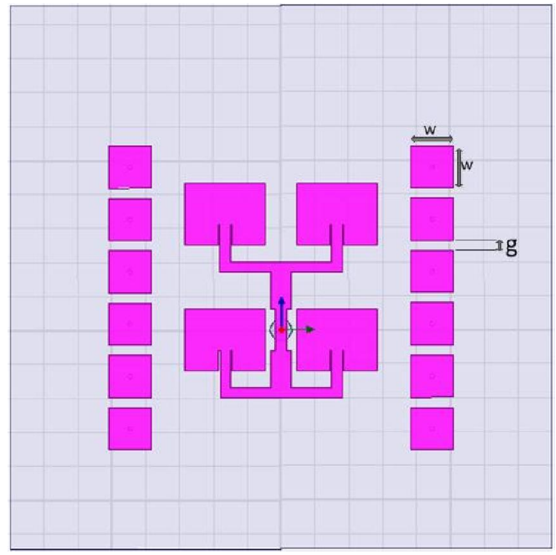

Fig (5): embedding EBG in antenna

The output pattern of this combination has been illustrated in figure (6)

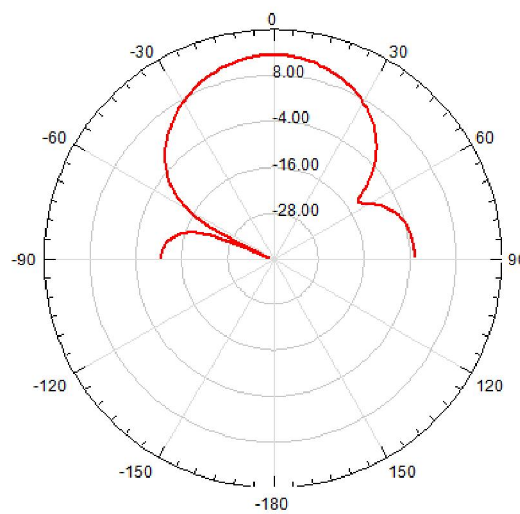

Fig (6): pattern of antenna with embedded EBG

3. Discussions

Two row of EBG have been located around antenna, so these structure cause to improvement in SLL almost 2.5 dB, and it increase gain measurement. Table 1 will present details.

Table (1): last results

	Gain	SLL
Main antenna	12.62 dB	-12.69db
Antenna with EBG	13.29 dB	-15.24dB
Change value	0.67 dB	2.5

SLL reduction and gain enhancement will justify as follows:

1) SLL reduction is because of EBGs features, that it eliminates surfaces waves due to antenna patch edges.
2) Another point of view, no feeding EBG cause to parasetic effects. One of those is gain enhancement that happened in this paper.

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