The Study on the Effect of Electromagnetic Band Gap on Microstrip Array Antenna at 28 GHz

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***Abstract*— A microstrip patch array antenna with Electromagnetic Band Gap (EBG) structure 28 GHz is presented. The antenna objective is to achieve the high directivity. Rogers Duroid RT5880 is chosen to be based substrate with a dielectric constant εr is 2.2 and the thickness is 0.254 mm. Uni-planar electromagnetic Band-Gap (EBG) scheme is presented for size reduction, the proposed structure can be considered as an ameliorated uni-planar compact EBG (UC-EBG) in a fractal from the conventional shape which significantly enlarges the fringe capacitance to compress the overall size of the unit cell. The Computer Simulation Technology Microwave Studio 2016 software has been used. By selecting optimum parameters, the simulated return loss of proposed antenna during design frequency (28 GHz) is -40.491 dB at 28.03GHz it is before addition of EBG and 48.751 dB after the addition of EBG is. In addition, the value of directivity is also increased after addition of EBG, which is 17.01 dBi and the achieved bandwidth is 960 MHz. Antenna with a higher gain and bandwidth is good for that is satellite communication and for next generation.**

***Index Terms*— Microstrip, Electromagnetic band gap (EBG) structure, 28 GHz, Mushroom Shaped EBG, Fractal EBG.**

I. INTRODUCTION

The frequency for 5G was started from 10 GHz to 86 GHz [1]. The proposed antenna frequency design was operated at 28 GHz. The speed of the data it is one of the features of 5G, to achieve that features the antenna needs to have high directivity and a look like a pencil beamforming radiation pattern [2,3]. The requirement of the features comes with numerous of a challenge, where all features must meet technological design issues and commercial criteria which are low cost, small size, radiation efficiency, antenna gain, broadband performance, and much more.

The reason of why the Microstrip Array Antenna is at 28-GHz because of the famous microstrip patch's basic features which are low cost, easy to manufacture and it has a simple structure. Therefore, the antenna parameters are easy to be designed. Next, the array design permits the antenna to achieve tremendous expansion.

From the previous studies [4], the performance of using the Electromagnetic Band Gap (EBG) on Microstrip Antenna is to overcome the limitations of constricting bandwidth, low gain, excitation of the surface waves. Other than that, EBG also can reduce the mutual coupling among radiating patches and suppress the side lobes and the back lobes of the antenna [5]. The unique properties of the structure, it is famous use in research areas usually in radio frequency design. Many exciting phenomena appear when periodic structures interact with electromagnetic waves, which include band pass, band stop and frequency band gap. The example periodic structure review application for EBG is guiding wave, reflector, photonic crystal and photonic bandgap. Other than that, wave propagation, noise reduction for the high speed electronic device and mutual coupling effect reduction [6,7,8]. Recently there is a significant increase in utilizing EBG structures in antenna community. By increasing the coupling area of the adjacent metal patches, loading the lumped parameters [9]. However, there remain some disadvantages, such as single-band, narrow bandwidth, integrating difficulties, etc.

This antenna was developed from a single patch to 8-Element patch array antenna and operates at 28 GHz. Material that has been used for this design is Rogers Duroid RT5880 the dielectric constant which is ε_r 2.2, and the height of the dielectric constant is 0.254 mm. There are some advantages of the patch which are low profile design, feed line and matching network can be fabricated simultaneously, light weight and comfortable, low fabrication loss and countless more.

II. DESIGN OF ANTENNA AND EBG

A. Antenna Design

The antenna was designed from the single patch which is using basic equation According '*Antenna Theory: Analysis and Design'* [10], the calculations of the dimension of a single patch are presented below;
Calculation of the patch Width, *Wp*:

$$W_p = \frac{c}{2fr\sqrt{\frac{\varepsilon_r+1}{2}}} \tag{1}$$

Substitute $c = 3 \times 10^8$, fr =28 GHz and εr= 2.2; W=4.42 mm
Calculation of the actual length of antenna, *L*:

$$L = L_{eff} - 2\Delta L \tag{2}$$

Substitute $Leff$=3.73 mm, ΔL=0.13 mm; L= 3.47 mm

Figure 1 illustrates the front and the back of the single patch antenna. All parameters are calculated manually by using the equations [10].

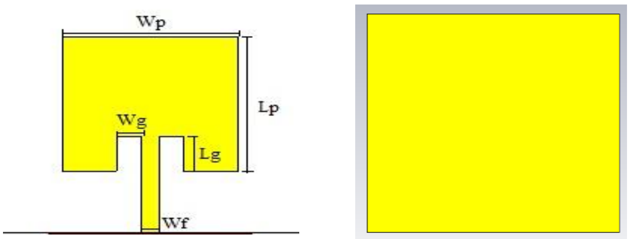

Figure 1 The front view of and back view of a single patch antenna

The single section of the quarter-wave transformer has an equal length with the quarter-wave in microstrip and its characteristic of impedance is Z_1, should be given by:

$$z_1 = \sqrt{z_0 z_{in}} \quad (3)$$

where Z_0 the characteristic impedance of the 50 ohms is line and Z_{in}, is the input impedance of the rectangular patch

The width *W2* of the quarter-wave transformer can be located by an equation *Wd*, to calculate the value of Z_1, from an equation of the Z_1. The equation all the same because of using the same feed but with a difference value of the ohm on every feed. The highest the value of ohm, the smallest size of the feed antenna.

$$\frac{W1}{h} = \begin{Bmatrix} \frac{8C^A}{e^{2A}-2} for \frac{W1}{h}<2 \\ \frac{2}{\pi}\left[B-1-\ln(2B-1)+\frac{\varepsilon_e}{\varepsilon_r}\left\{\ln(B+1)+0.39-\frac{0.61}{\varepsilon_r}\right\}\right] for \frac{W1}{h}>2 \end{Bmatrix} \quad (4)$$

$$A = \frac{Z_0}{60}\frac{\sqrt{\varepsilon_r+1}}{\sqrt{2}} + \frac{\varepsilon_r-1}{\varepsilon_r+1}\left(0.23+\frac{0.11}{\varepsilon_r}\right) \quad (5)$$

$$B = \frac{377\pi}{2Z_0\sqrt{\varepsilon_r}} \quad (6)$$

Table 1 shows the design of feed antenna from single patch up to 8-Element. Except for the length feed of 100 ohms. This is because the length feed is needed to be measured by using a pick point in CST and separated by a spacing element, therefore the length feed is designed. Each of the patch antennae is separated by 10.7143 mm.

Table 1
Design of feed antenna

Design of feed	Length of feed(mm)	Width of feed (mm)
50 ohm	1.9581	0.7826
70 ohm	1.9873	0.4569
100 ohm	2.0201	0.2276

As shown in Figure 2, the 8-Element of the microstrip array antenna. The antenna is using feed that is designed by using a formula above.

B. Electromagnetic Band Gap (EBG) Design

The Fractal EBG structure is a normal rectangular antenna with slots. The objective is to design an EBG structure at 28 GHz. Figure 3 below shows the conventional of 2D EBG which is known as Fractal EBG.

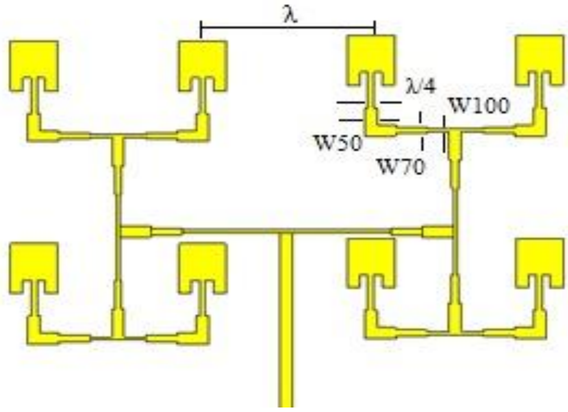

Figure 2 The front view of 8-Element Patch Array Design

The material for designing the EBG is Rogers Duroid RT5880 with thickness is 0.254mm and the material of the patch is copper with the thickness is 0.0035mm. the design and simulation completed by computer simulation tools (CST).

LC filter can explain the operation mode of EBG. The parameters *L* (inductance)is the result for the current flow through the vias and the *C* (capacitance) is the effect of the gap between the patches. The patch width *Ws*, substrate thickness *h*, gap width *g* and dielectric constant *εr*, the inductance *L*, capacitance *C* and resonance frequency are related in the equations below [11,12,13]:

$$L = \mu_0 h \quad (7)$$

$$C = \frac{Ws\,\varepsilon 0(1+\varepsilon r)}{\pi}\cosh^{-1}\left(\frac{Ws+g}{g}\right) \quad (8)$$

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \quad (9)$$

In this Structure two slots at the upper and bottom of EBG was designed. One slot is designed at the right and left of the EBG. The EBG is added with vias at the centre of the EBG.

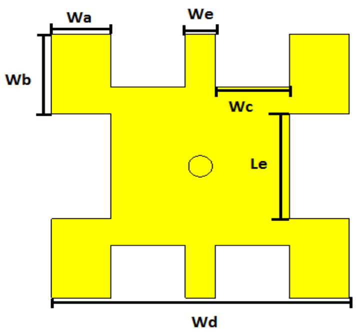

Figure 3 The conventional Fractal EBG

Table 2
Dimension of the conventional fractal EBG

Parameters	Fractal EBG surface (mm)
Wa	1
Wb	1.5
Wc	1

Wd	3
We	0.5
Le	1.5

To achieve 28 GHz resonate frequency, the EBG was designed again with only two slots, below are the second design of fractal. The fractal EBG has a dimension of 1 mm X 1 mm without vias.

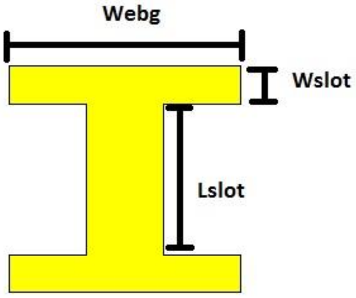

Figure 4 The modified Fractal EBG

Table 3
Dimension of the modified fractal EBG

Parameters	Fractal EBG surface (mm)
Webg	1
Wslots	0.3
Lslots	0.7

C. Integration of Microstrip Array Antenna With EBG

The modified EBG had been choice due to the simple design and easy to fabricate and work with. The microstrip array antenna with electromagnetic band gap was integrated to increase the gain and reduce the side lobe of the antenna

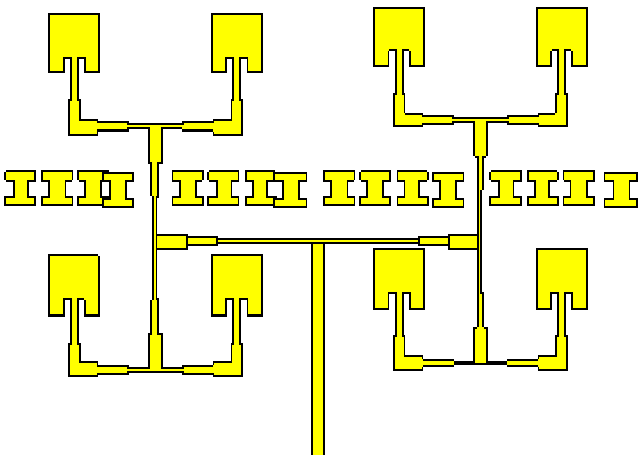

Figure 5 The integrated microstrip array with modified Fractal EBG

III. Result And Discussion

A. Return loss and Bandwidth

The result for microstrip array antenna and EBG had shown some improvement on return loss

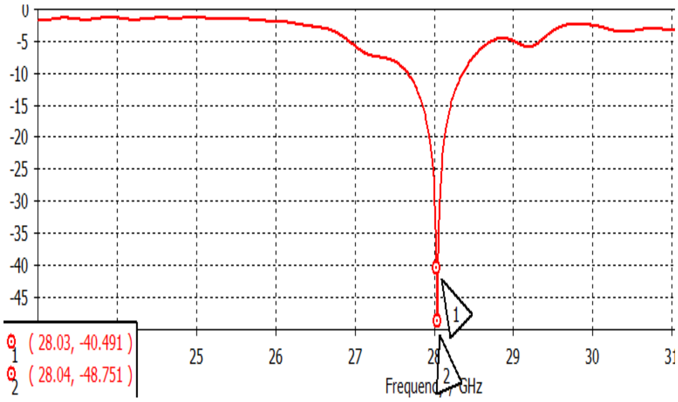

Figure 6 The return loss for an integrated antenna with and without EBG

From the figure 6 shows the result for return loss for integrated antenna and EBG, the marked as number 1 is the return loss result for Microstrip array antenna was -40.491 dB at 28.03 GHz, but when it integrated with EBG the result had been good result which is -48.751 dB at 28.04 GHz and it marked as number 2 in the figure. And both for bandwidth is 960 MHz.

Result for conventional and modified EBG is:

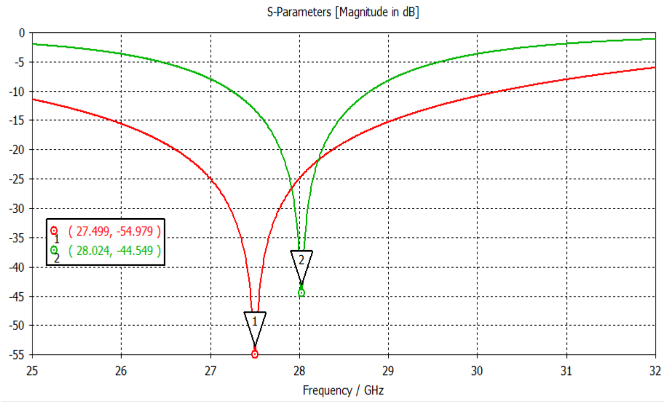

Figure 7 The return loss conventional EBG and modified EBG

The red color line represents fractal EBG design 1 and green color line represent fractal EBG design 2. Thus, the best result is fractal with two slots only. The result for design 2 was resonated -44.54 dB at 28 GHz. The first design, the EBG were resonated at 28 GHz is -54.97 dB. Design 2 was chosen because of the frequency that resonates at 28 GHz same as Microstrip antenna resonate. But the result for both EBG still has a good result because still below -10 dB.

B. Directivity and Sidelobes

The Directivity is a fundamental of an antenna parameter. It is a measure of how directional an antenna radiation pattern is. An antenna that radiates equally in all directions would have effectively zero directionality, and the directivity of this type of antenna would be 1 (or 0 dB).

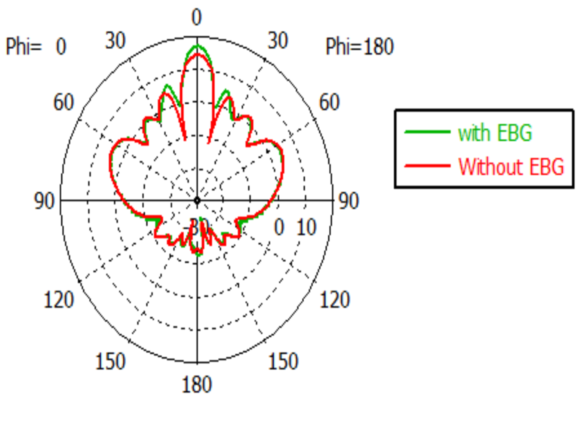

Figure 8 The comparison radiation pattern with and without EBG

Figure 8 shows a comparison of radiation pattern between microstrip array 4x2 with EBG and without EBG. It shown that the main lobe of microstrip array 4x2 with EBG is higher than without EBG, this is because the gain of the antenna also increases. However, the side lobe does not show much different between microstrip array 4x2 with EBG and without EBG. This is because the EBG is not placed in the right place, this is mean the radiation from the antenna is not filter by EBG structure. The result for directivity before without EBG is 14.37 dBi, after put the EBG the result had been increasing to 17.01 dBi.

Table 4
The summarize for the result

8th Element of Array	Without EBG	With EBG
Directivity	14.37 dBi	17.01dBi
Return Loss	-31.662 dB	-48.751 dB

The previous studies about integrated the EBG into antenna had been proved by this project. The modified fractal EBG give a good result for return loss and the directivity.

IV. Conclusion

This research is presented in the study on the effect of EBG on microstrip array antenna at 28GHz is achieved. The 8-element patch array antenna with EBG is chosen which gives a high gain of 17.01 dBi at 28 GHz, while without EBG is only 14.37 dBi. The return loss also has been improved from the previous from -31.62 dB to -48.75 dB. The radiation pattern has been effected by the integration with the EBG, the structure of EBG giving a side effect for the sidelobe antenna. In the future, the antenna will improve more on the sidelobes.

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