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Compact MIMO Antenna with Electromagnetic Band Gap (EBG) Structure

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***Abstract*— In this paper, a compact MIMO antenna consisting of four single element antennas operating at 28 GHz is proposed using Rogers RT5880 with ε_r=2.2 and tanδ=0.0009. In order to make this antenna more compact, distance between radiating elements was reduced, however this increased the isolation between them. To achieve high isolation EBG structures are placed between patches. Initially the spacing between radiating elements was 1.4 ƛ and the mutual coupling was above 29 dB but when we reduced the size with distance between antennas to 0.75 ƛ the isolation decreased and with EBG structure, this high isolation is achieved. By using EBG structure isolation is increased by factor of 10.3%, and the operating frequency and of this antenna is from 26.99 GHz-29.49GHz.**

Keywords—Multiple Input Multiple Output (MIMO), Electromegnatic bang gap (EBG), Mutual Coupling (MC)

I. INTRODUCTION

In this era wireless communication has become an important part of our life and play a major role. Historically, wireless technology developed from the first generation (1G) to fourth generation (4G) and every technology was better than its previous one. With the fast evolution in wireless communication, the usage of wireless systems is also increasing day by day due to which congestion in a network occurs, to avoid it wireless communication community is focusing on 5G technology which will improve the quality of communication as it has higher transfer speeds and lower network latency. In wireless communication, antennas are considered as basic part of the system. There are various types of antennas for different applications. In recent years, several types of antennas are being studied and designed for 5G. In the field of antennas MIMO play a major role because it can send and receive more than one signal simultaneously over the same channel. After the designing of antennas mutual coupling between radiating elements remained an issue and to reduce it many techniques were and are being used.

Recently a lot of work has been developed to study the techniques for improvement of isolation between radiating elements. In [1] two types of antennas, four U-slits and four L-slits are etched and these antennas are placed orthogonally to reduce mutual coupling, with the operating frequency band is from 2.6-2.8 GHz and better isolation is achieved but it has very complex structure and greater size. The metal strip reflector is used between two coplanar strip line staircase-shaped radiating elements in [2] to enhance isolation and the operating frequency band is from 3.1-10.6 GHz but the drawback is that this occupy greater area. Slot technique is used to improve isolation between the patches in [3], its operating frequency band is from 3-4.5 GHz but it resides in larger area. To further suppress the mutual coupling a parasitic T-shaped strip between radiating elements is employed in [4], it has greater area. The frequency band is from 3.08-11.8 GHz. In [5] better isolation is achieved but the area covered by the antenna is much greater. The proposed work is improved from [1]- [5] as it is well isolated with a compact size.

This work is about reduction of size and mutual coupling between radiating elements, for this a 4x4 MIMO antenna with EBG structure is designed at frequency of 28 GHz. This paper is organized in a manner that section **II** covers antenna design and section **III** cover detailed parametric analysis. Likewise, Section **IV** addresses about simulated results and conclusions in section **V**.

II. ANTENNA DESIGN

The single microstrip patch antenna is designed and then converted into a 4x4 MIMO (multiple input multiple output) antenna. We reduced the size of the substrate to such an extent that our required results are achieved at that specific point and after reduction of size the center to center distance is 7.5(0.75ƛ), so the antenna size is decreased about 30% width wise. Reduction of size caused mutual coupling between the closely placed patches. So, in order to suppress that mutual coupling, we used a Z-type EBG (Electromagnetic Band Gap) structure [6] on the substrate and between the patches to increase isolation of the antenna as shown in Fig. 1.

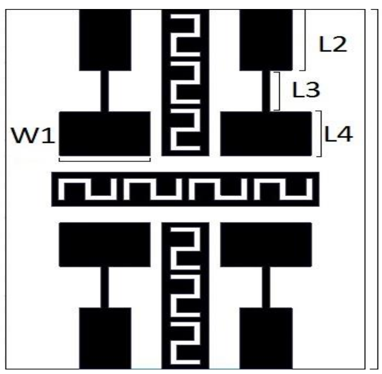

Fig. 1. MIMO Antenna with EBG

The EBG (Electromagnetic Band Gap) structure on the substrate between the patches was designed to increase isolation between the patches and the width of slot of is 0.3 *mm* and as shown in Fig.2 are of different length which are given in table below. A single column of EBG consisting of three Z-type structures shown in Fig.2 is placed vertically in between patches their lengths are equal to the total length of single element antenna and also a structure consisting of four Z-type structures are placed horizontally in between patches and its length is 12.42 mm.

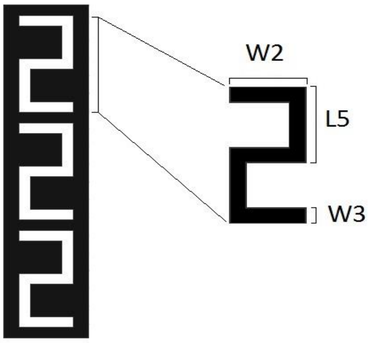

Fig. 2. EBG structure

Table I. Design Parameters of the Antenna

Parameters	Symbol	Value (λ)
Length of substrate	L1	2.18
Width of substrate	Sw	1.57
Length of patch	L4	0.26
Width of patch	W1	0.39
Length of transformer	L3	0.25
Width of transformer	Tw	0.03
Length of feeding line	L2	0.36
Width of feeding line	Fw	0.22
Width of single EBG structure	W3	0.02
Length of single EBG Structure	L5	0.14
Width of single EBG structure	W2	0.13

III. Parametric Analysis

A detailed parametric analysis is carried out to have a better understanding that what is the effect on parameters if we change the length or width of patch or EBG structure. By applying optimetrics following results are achieved

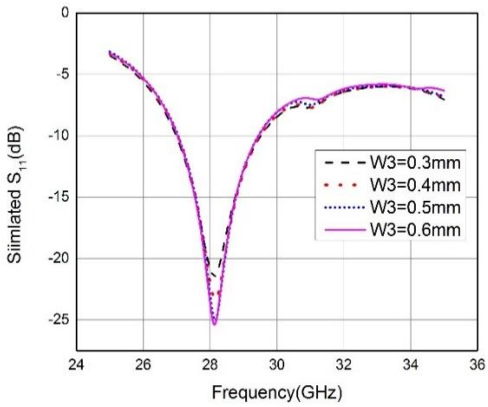

Fig. 3. Simulated S11 for Parametric Analysis of EBG

Table II. Optimetrics on EBG(S_{11})

Width of EBG (mm)	Return Loss (dB)
0.3	-20
0.4	-22
0.5	-23
0.6	-24

The results shown in Fig. 4 and Fig. 5 show that if we change the length if the patch and width of patch then what will be the effect of this change on results.

The optimetrics on length show that if the length is changed there is a slight change in return loss otherwise our antenna does not under go any major changes and operates on our desired frequency as the graph shows in Fig. 4 below

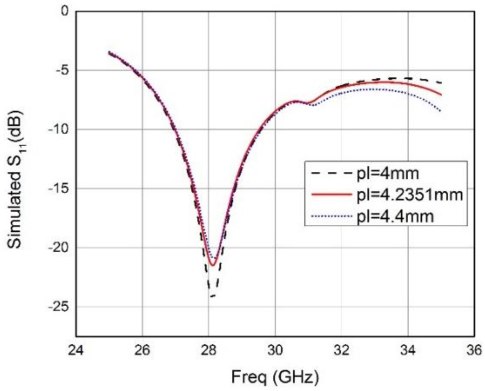

Fig. 4. Simulated Results of Patch Length

The optimetrics on width in Fig. 5 show that if the width of patch is changed the operating frequency is changed but return loss remains the same. Antenna does not operate at our desired frequency on any width other than 2.8mm.

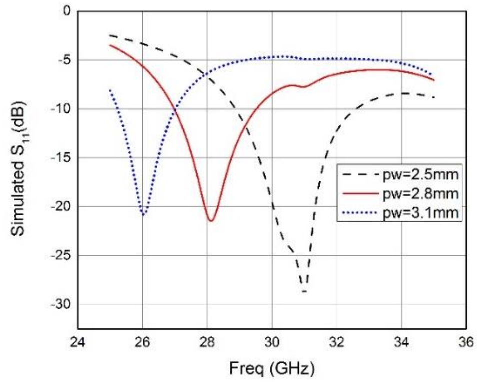

Fig. 5. Simulated Results of Patch Width

After performing this analysis, we selected the most suitable parameters of EBG and the patch at which our required results are achieved at our operating frequency

IV. Results

Results shown in Fig.6 shows that without EBG(Electromagnetic Band Gap) the S_{11} is slightly better than the one with EBG(Electromagnetic Band Gap) as S_{11} without EBG(Electromagnetic Band Gap) is almost -26 dB and S_{11} with EBG(Electromagnetic Band Gap) is almost -20 dB less than the limit -10 dB but we designed the EBG (Electromagnetic Band Gap) structure in order to increase isolation decreased by reduction of size then isolation between closely placed patches is better with EBG(Electromagnetic Band Gap) than without EBG(Electromagnetic-Band-Gap).

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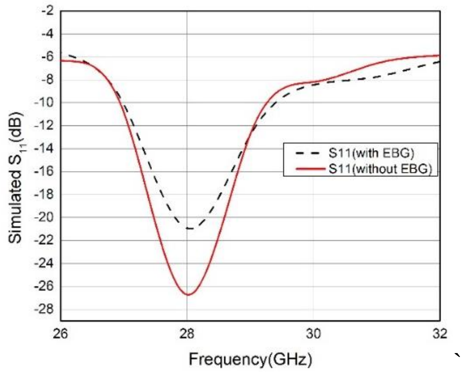

Fig. 6. Simulated S11 of MIMO with and without EBG

While S_{12}, S_{13}, S_{14} in Fig. 7 shows that isolation is increased by using an EBG (Electromagnetic Band Gap) structure between patches because without EBG (Electromagnetic Band Gap) the peak value is almost -26 dB and with EBG the value is -29 dB, so the required isolation is achieved.

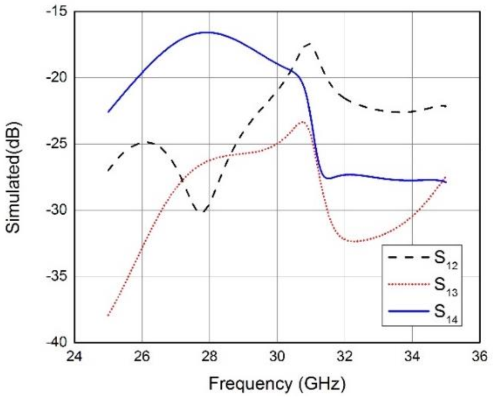

Fig. 7. Simulated S_{12}, S_{13}, S_{14} of MIMO with EBG

Radiation patterns of MIMO antenna are shown in the Fig. 8 The radiation pattern along YZ and ZX plane are achieved. These radiation patterns indicate that this antenna is directional in nature as its major lobes are in one direction and minor lobes are in other directions and the major lobe show the direction of the antenna and this is because of more than one radiating element being used.

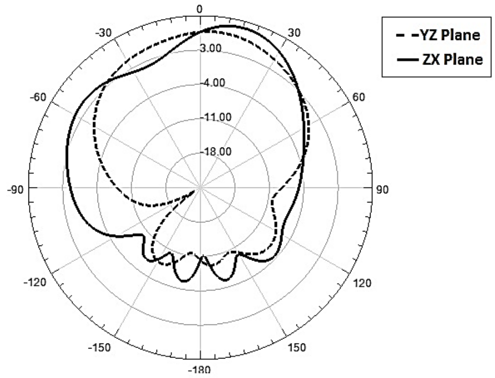

Fig. 8. Radiation Pattern in YZ plane

V. CONCLUSION:

In this research, a MIMO antenna is designed and discussed. In this antenna, a z-type EBG structure is placed between patches to reduce mutual coupling. After the simulation the mutual coupling is reduced up to -29 dB, and high gain of 8.6 dBi is achieved. It covers 2.5 GHz of bandwidth, and the frequency band ranges from 26.99 – 29.49 GHz with high isolation.

Table III. Comparison between Reviewed papers and our proposed work

Reference	Technique	Gain(dBi)	BW(GHz)	Size (λ^3)
[1]	U-slit etched and L-slit etched PIFAs	3	2.6 - 2.8 and 3.4 - 3.6	13.2×6.60x0.90
[2]	Open L-shaped slot and a narrow slot on the ground plane	4.2	3.1 - 10.6	3.01x3.01x0.07
[3]	Two coplanar strip line fed staircase-shaped	5.2	3.1 - 10.6	2.35x2.83x0.15
[4]	A parasitic T-shaped strip between the radiating elements	3	3.08 - 11.8	3.63x3.63x0.15
[5]	Rectangular slots on each side of the ground plane	4.9	2.7 - 3.6	4.71x9.43x0.28
Work Proposed	EBG structures between radiating elements	8.67	26.99 - 29.49	2.46x1.58x0.08

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