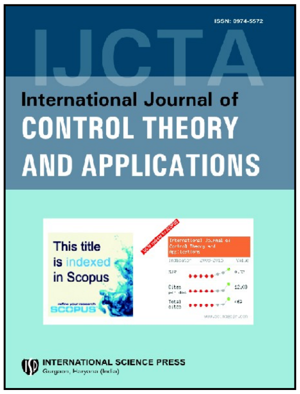

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A CPW Fed Monopole Antenna with Uniplanar EBG and Rhombic CSRR Exhibiting Multiband Characteristics

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Abstract: In this article, the design and analysis of a compact coplanar waveguide (CPW) fed multiband monopole antenna loaded with electromagnetic bandgap structures (EBG) is presented. By placing complementary split ring resonators (CSRR) the proposed antenna study extended for operating over the frequency range of Bluetooth / IMT – E (2.4–2.484 /2.5-2.65 GHz), (WLAN 802.11 group with 5 different frequency ranges 2.4 GHz, 3.6 GHz**,** 4.9 GHz**,** 5 GHz, 5.9 GHz) for personal wireless communication systems. Other frequency bands beyond Ultra Wideband 11.73 – 12.75 GHz are used for RADAR and fixed satellite communication systems are also covered under the designed antenna model. The introduction of Uniplanar EBG structure in combination with Rhombic CSRR resulted in significant decrease of surface waves, thereby providing an increase in gain of proposed antenna compared with simple monopole.

Keywords: Coplanar waveguide (CPW), Electromagnetic Bandgap (EBG), Multiband, Rhombic CSRR

1. INTRODUCTION

Researchers are focusing on achieving ultra wideband characteristics of antenna and also focusing on the design of triple and multiband antennas with moderate bandwidth and gain. Different novel structures are been proposed and profound interest in advanced structures and materials in recent years. Three major categories of such materials are i) Photonic Crystals ii) Electromagnetic Band-gap (EBG) structures [1] and iii) Metamaterials. Primary goal of this paper is to concentrate on second category mentioned above, namely EBG structures.

The issue associated with planar monopole antennas emerges in guiding the plane waves by a plane between two media: conductor-dielectrics or dielectrics-dielectrics. The Electromagnetic energy between the interfaces transforms into surface waves. Generally, the higher the permittivity of dielectrics and thicker the substrate, the influence of surface waves is stronger. Another major problem is that the electromagnetic waves radiated into substrate and reaching the air-dielectric interface at angles more than $\theta_c = \sin^{-1} \varepsilon^{-1/2}$ are reflected completely [2-3]. The power which is transformed into surface waves does not contribute to the main radiation pattern of the antenna, but it is scattered off the edges of the ground plane which leads to ripples in radiation pattern, increased back radiation, depreciation of gain and low polarization purity which are undesirable for practical applications.

These problems can be justified by assimilating EBG while designing an antenna [4-5], which ultimately results in increase of gain that can be obtained by reducing backward radiation [6]. Added to that, EBG contributes in reduction of mutual coupling which strongly elevates the performance of antenna arrays [7-9]. Although there exists different EBG's like 2-D, 2.5-D [11], 3D, a uni-planar unit cell EBG structure is chosen in this paper for simplicity and ease of fabrication.

The proposed antenna consists of combination of uni-planar EBG structure along with a pair of complementary split ring resonators (CSRR) for which the excitation is provided by a common micro strip line. The reflection coefficient and Frequency bands of operation are dependent on the physical dimensions of CSRR pairs. EBG's are embedded on the ground plane which alters the performance characteristics of antenna. In this work, simple monopole antennas characteristic are compared with a model which is incorporated with uniplanar EBG structures. EBG structures suppress the surface waves, which results in enhanced gain, improvement in return loss and radiation pattern**.** The antenna works for all bands of 802.11 i.e.; 2.4 GHz, 3.6 GHz, 4.9 GHz**, 5** GHz**,** 5.9 GHz**.** It is suitable for WLAN and Wi-Max applications. Interesting factor is that this antenna works beyond UWB range which is desirable for RADAR and other satellite Communication applications.

In metamaterials, magnetic response can be attained by using a common constituent that is a Split Ring Resonator (SRR). It can be categorized as a structure that has negative values of permittivity and permeability [12].SRR consists of a highly conductive metallic Ring in which one or more slots (gaps) can be made by different non conductive materials or other dielectrics. If the ring is placed in the presence of a varying magnetic field ,an electric current is induced in the metal ring which results in charge accumulation across the gaps. Electric field due to the charge counteracts the circular current which in turn leads to energy storage in the neighborhood of the gaps and concentration of magnetic field energy is observed in the region enclosed by ring. Hence it acts as a resonator resulting in reduction of mutual coupling among the elements. It can be understood in terms of a resonant LC circuit which couples to a magnetic field and can be distinguished by the effective capacitance of the slits and effective inductance of loop defined by the ring.

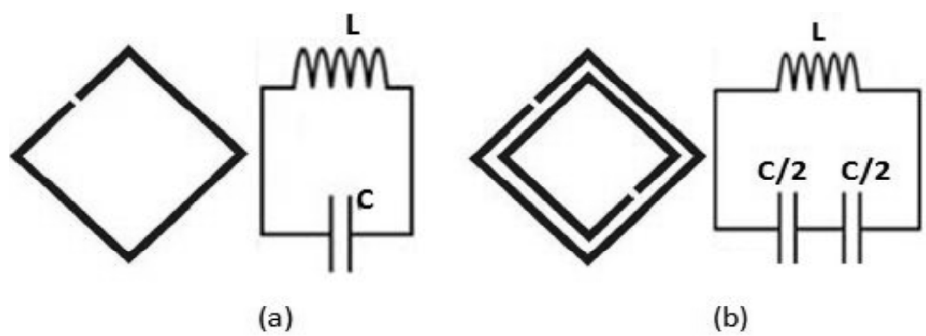


Figure 1: Rhombic SRR with its equivalent circuit (a) Single SRR (b) Complementary SRR

2. ANTENNA TOPOLOGY & DESIGN CONSIDERATIONS

Three prototypes of antennas namely configurations A, configuration B, configuration C are designed with CPW feed and variation in position of EBG have been studied. Configuration 'C' as shown in Fig.1 (a) comprises of printed circular monopole antenna of radius 'R' fed by a CPW and coupled with a pair of CSRR's. The CPW feed consists of ground planes having width $'W'_1$ and $'W'_2$, Length 'L_s' and a signal line of Width 'S' and length L_s+ t with symmetric gaps 'S_g' between the ground planes and signal line. The antenna is printed on a Taconic substrate having thickness h and dielectric constant ε_r.

Fig 1(a) shows the geometry of a Coplanar Waveguide (CPW) antenna with Length 'L' and Width 'W' and L = W= 50 mm. The Radius 'R' of the circular patch is 12.5mm with length of feed line as 'L_s' = 22.5 mm and width S = 5mm. The circular patch having radius 'R' = 12.5 mm with Length of feed line 'Ls' = 22.5mm and ground plane spread over both sides of the feed line with a feed gap 't' = 0.2mm, length L_s and Width $W_1 = W_2 =$ 22.2 mm. In configuration B, a unit cell EBG is placed on the center of the patch with dimensions as tabulated. The design parameters & dimensions are common for all the configurations specified.

A pair of rhombus shaped SRR's with Thickness 'c' and the distance of separation as 'd'. Small slits are made complementary to each other with the gaps g_1 and g_2 which were printed on the other side of the substrate with one of the vertex of SRR is l_1 =10mm & vertex of other SRR at l_2 =6mm from ground.

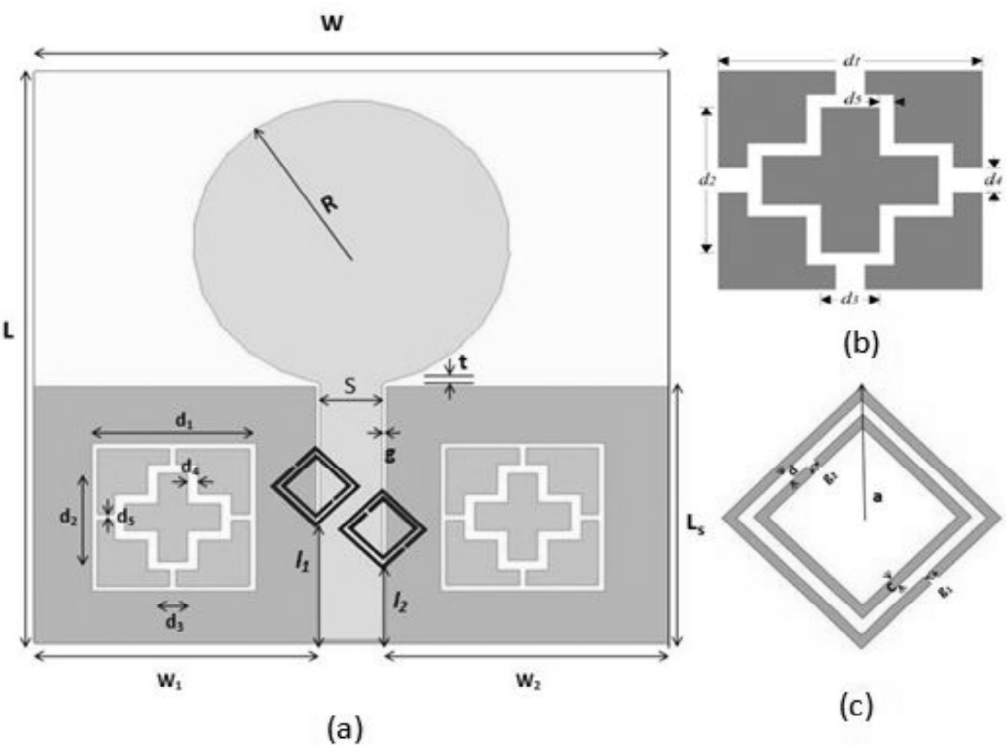


Figure 2: Schematic of a printed circular monopole with EBG on ground plane (Config. C): (a) Top view with CSRR on bottom metallization (b) Uni-planar unit cell EBG structure (c) Unit cell Rhombic CSRR

Dimensions of Rhombic CSRR are tabulated and parametric analysis is done on the split gaps 'g_1' and 'g_2'. The geometry and dimensions of Uni-planar unit cell EBG are tabulated. In configuration C, a simple Unit cell of EBG structure is incorporated on either side of the feed line at the center of the ground planes. The change in return loss, gain & other antenna parameters is validated by considering the Uniplanar Unit cell EBG structure on both ground planes and patch as shown in configuration D.

Table 1
Dimensions for Fig. 1(b)

attribute	*Units(mm)*
d_1	12
d_2	7.58
d_3	2.34
d_4	0.39
d_5	0.85

Table 2
Dimensions for Fig. 1(c)

Attribute	*Units(mm)*
g_1	0.25
g_2	0.25
a	2.5
c	0.5
d	0.6

3. RESULTS AND ANALYSIS

The return loss of all the Configurations A, B, C, D are depicted in Fig. (3). Simulation results imply that when EBG structures are placed, the return loss significantly reduced when compared to the antenna without EBG. Among the three configurations B, C, D consisting of EBG's on different portions of the antenna, Incorporation of EBG on ground plane has significant effect. Hence the bandwidth for Configuration 'A' and Configuration 'C' are compared separately such that the increase in operating ranges of antenna is more distinct.

Fig. (3) Shows the comparison of return loss curves of a simple monopole antenna and antenna loaded with EBG structures on the ground plane. From Fig. 3 it is evident that a bandwidth of about 3.24 GHz in the range of

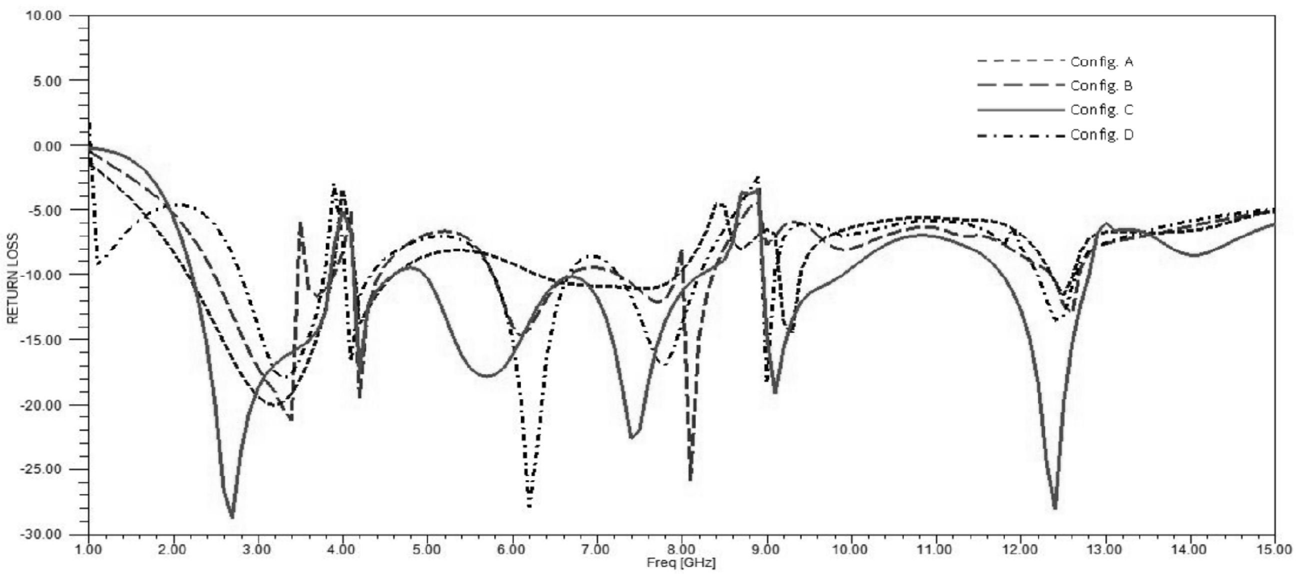


Figure 3: Reflection coefficient for Config. A, B, C, D

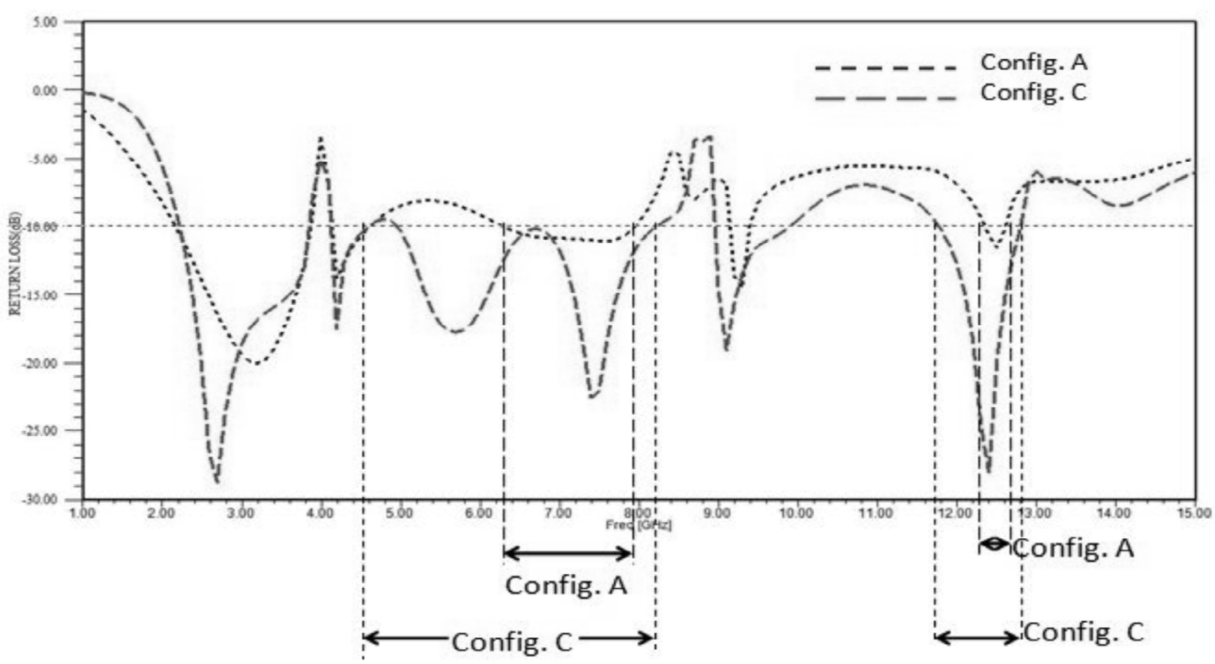


Figure 4: Comparison of B.W of CPW fed circular monopole with and without EBG structure

4.94-8.18 GHz and 880 MHz in the range of 11.75-12.79 GHz is obtained for Configuration ‘C’ whereas a minimal bandwidth of 1.04 GHz and 220 MHz are obtained for Configuration ‘A’. The reflection coefficients obtained are -28.49 dB and -20.02 for configuration ‘C’ and Configuration ‘A’ respectively. The bandwidth obtained for Configuration ‘C’ is almost 3.5 times more than the bandwidth of Configuration ‘A’.

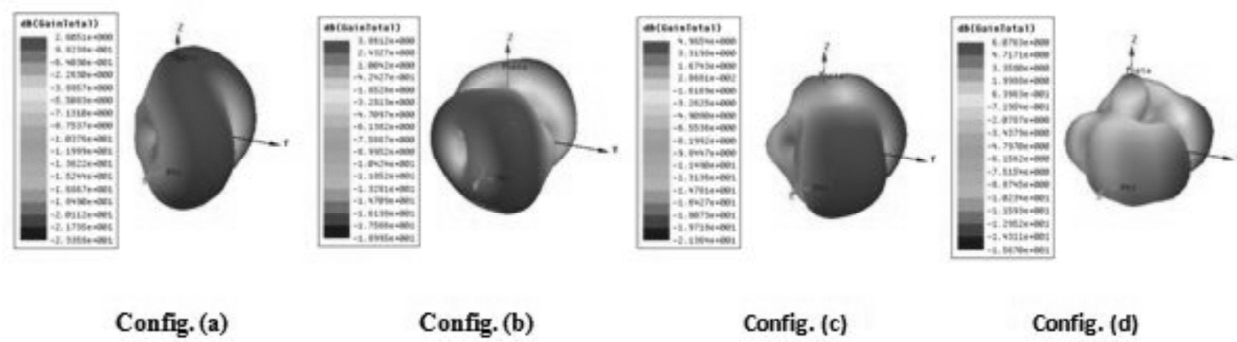
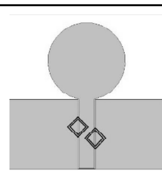
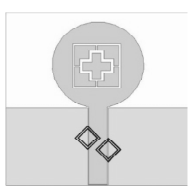
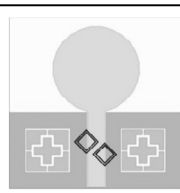
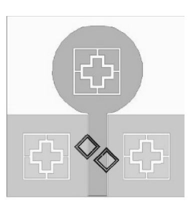


Figure 5: Gain patterns for different Configurations

Gain of the antenna is the key parameter while deciding the performance of the antenna. Simulated results show that there is a significant increase in gain of 3.47 dB by the Integration of 1-D unit cell EBG structure on patch antenna. This implies that minimization of surface waves is achieved

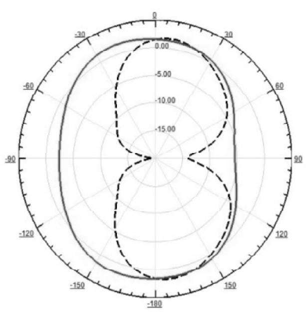
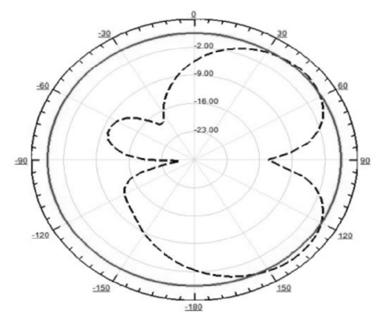
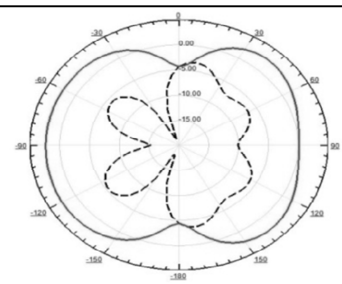
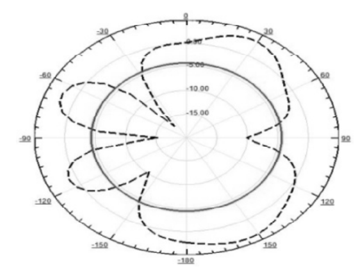
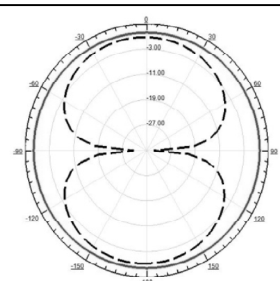
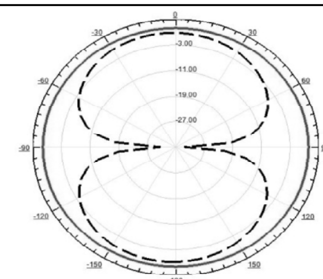
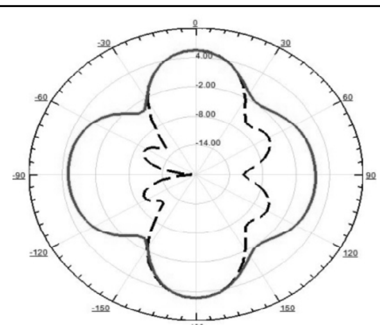
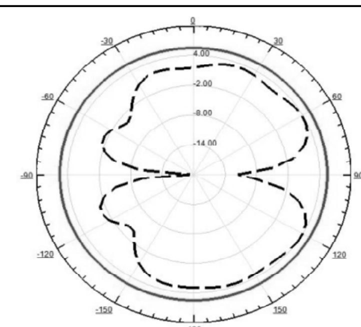
Table 3
Different Configurations of Antennas

Antenna Topology & EBG position	*Different Configurations*	*Operating Bands (GHz)*	*Gain(dB)*	*S_{11}(dB)*
Configuration A Without EBG		2.15 – 3.83 4.10 – 4.53 6.31 – 7.92 9.17 – 9.35 12.31 – 12.58	2.605	-19.936
Configuration B EBG on patch		2.48 – 3.41 3.57 – 3.83 4.10 – 4.37 5.71 – 6.59 7.23 – 7.90 7.96 – 8.32 12.28 – 12.56	3.861	-25.45
Configuration C EBG on ground		2.24 – 3.81 4.06 – 8.15 8.92 – 9.82 11.72 – 12.75	4.965	-28.39
Configuration D EBG on ground & patch		2.74 – 3.81 4.01 – 4.28 5.74 – 6.64 7.19 – 8.16 12.18 – 12.61	6.076	-27.77

The overall performance parameters of the designed antennas are tabulated in Table 3. The corresponding resonant frequenices and the average gain parameters are tabulated and presented in that table. The simulated Radiation patterns at different frequencies are shown in Table 4. The modelled antennas are showing omni directional pattern in the H-plane and directive pattern in the E-plane.

3.1. Radiation Patterns

Table 4
Radiation Patterns of different Configurations

Phi 0 & 90	*Configuration*	*Theta 0 & 90*
	Config. A	
	Config. B	
	Config. C	
	Config. D	

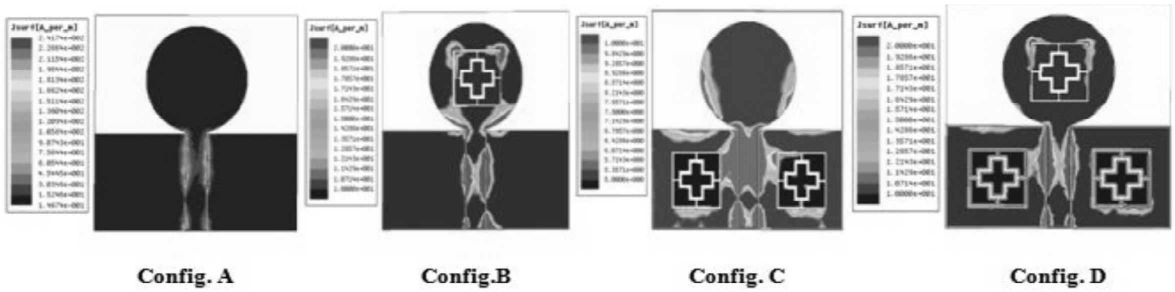


Figure 6: Current Distributions

The current distributions of simple monopole are not much elegant in config. A. when EBG's are placed on patch the intensity of current flowing through the feed line increased. In Config. C, current flow through the signal line and reaching the patch is observed. When EBG's are placed on both patch and ground the current flow through EBG and Signal line is visible.

4. PARAMETRIC ANALYSIS

For better understanding of the obtained result, parametric Analysis is done for the gaps of CSRR g_1 & g_2

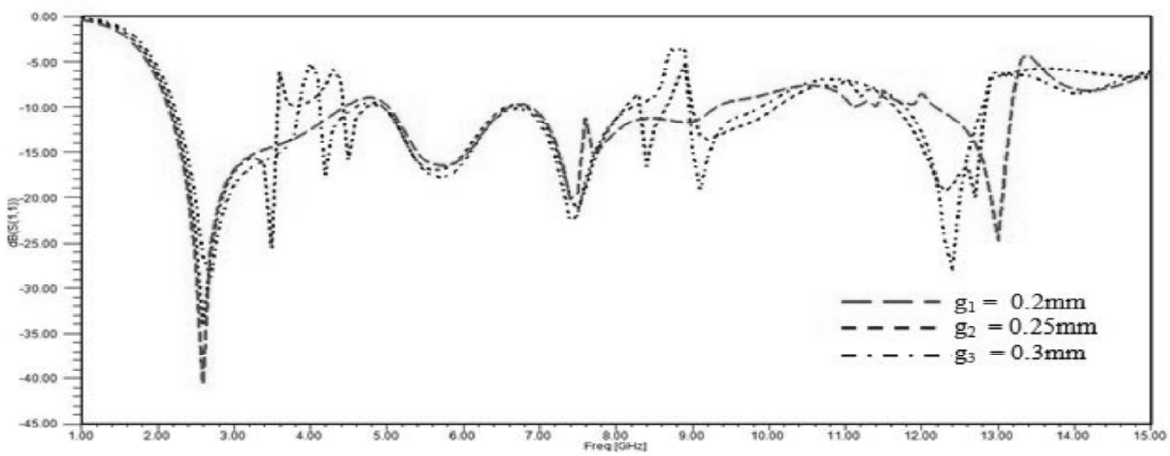


Figure 7: Parametric analysis for gap g_1

A variation of 0.05 is made in the slits of the complementary split ring resonator (CSRR) is made and a notable decrease in returnloss is achieved up to -40 dB. It also altered the operating bands of the antenna

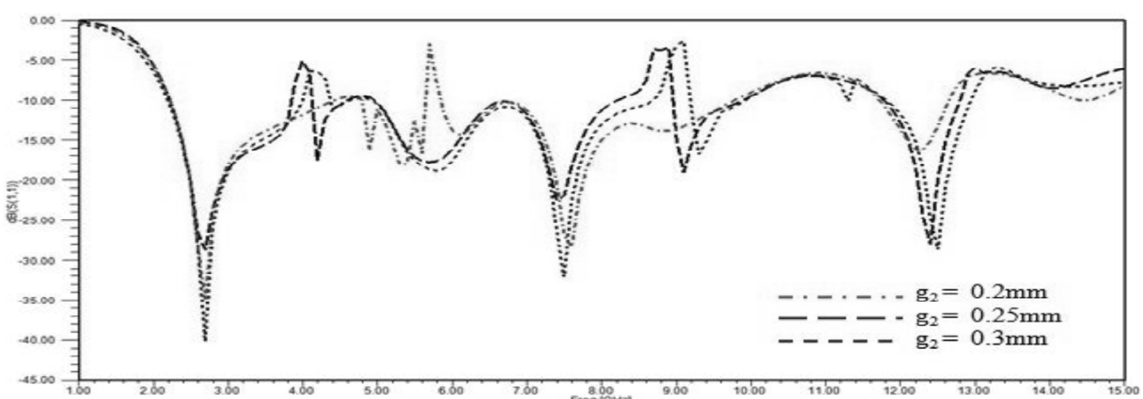


Figure 8: Parametric analysis for gap g_2

Similarly, parametric analysis is done for another slit gap g_2 and frequency vs. return loss curve is plotted. The change in parameters g1 and g2 are providing notch bands in the operating band and showing some significant change in overall operating band.

4. CONCLUSION

This work has provided analysis of uniplanar electromagnetic band gap (EBG) structures that are incorporated in microstrip antennas to reduce the surface waves and mutual coupling resulting in increased antenna performance. A rhombic split ring resonator has been used in this work to obtain the desired operating bands at some of the communication band application. The results obtained with the proposed model are accelerating the applicability of this model in desired communication band applications with gain more than 6 dB and directivity more than 6.5 dB.

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