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Research paper

Electromagnetic Bandgap Structured CPW Fed Circular Monopole Antenna with Bandwidth Enhancement for Wideband Applications

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Abstract

A circular monopole antenna with coplanar wave guide feeding is constructed with the combination of Electromagnetic Band Gap structure for the improvement of bandwidth. A plus shaped defected ground is etched on the ground plane to obtain the EBG characteristics in the proposed antenna model. A complete analysis with respect to reflection coefficient, VSWR, impedance, radiation pattern, current distribution, gain and efficiency are presented in this work. The proposed model occupying the dimension of 50X50X1.6 mm on FR4 substrate with dielectric constant of 4.3. Antenna operating in the dual band of 1.5-3.6 GHz (GPS, LTE, Bluetooth and Wi-Fi applications) and 4.8-15 GHz (WLAN, X-Band and Satellite communication applications) with bandwidth of 2.1 and 10.2 GHz respectively. A peak realized gain of 4.8 dB and peak efficiency more than 80% are the key features of the current design.

Keywords*: Bandwidth Enhancement, Coplanar Waveguide Feeding (CPW), Electromagnetic Bandgap (EBG), Monopole, Wideband.*

1. Introduction

Researchers are focusing on achieving ultra wideband characteristics of antenna and 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 Bandgap (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 and 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 the DGS based EBG. EBG's are embedded on the ground plane which alters the performance characteristics of antenna. In this work, simple monopole antennas characteristic is 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 and 5.5 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 oth**e**r satellite Communication applications.

2. Antenna Design

The circular shaped radiating element was taken on the feedline based on the following formula. Here 50-ohm impedance is chosen at the feed point to construct the model. A plus shaped defected ground is etched on the ground plane which acts as the electromagnetic bandgap structure for the current model. The placement of the EBG improving the bandwidth and providing additional resonant frequencies to operate without changing the overall length. The overall dimensions of the antenna is around 50X50X1.6mm on FR4 substrate material of permittivity 4.3 and loss tangent 0.02.

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$$R_1 = \frac{F}{\sqrt{1+\frac{2h}{\pi\varepsilon_r F}\left[\ln\frac{\pi F}{2h}+1.7726\right]}} \quad \text{------(1)}$$

2.

$$F = \frac{8.791\times10^9}{f_r\sqrt{\varepsilon_r}} \text{ ----- (2)}$$

where ' f_r ' is the resonant frequency of the antenna, ' ε_r 'is the relative permittivity of the dielectric material and *'h'* is the thickness of the dielectric layer.

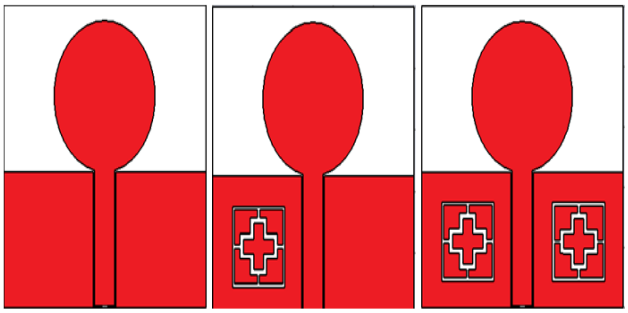

Fig 1:. EBG Antenna Iterations, (a) CPW Fed Circular Monopole, (b) Single EBG, (c) Double EBG

The length L=50 mm, width W=50 mm, width of the feed Wf=5 mm, width of the ground plane Wg=22.2 mm, feed gap t=0.2 mm, radious of the patch R=12.5 mm.

3. Results and Discussion:

The results obtained from the current model are presented in this section. Fig 2 shows the reflection coefficient of the antenna model 1, model 2 and the proposed design. Antenna model 1 is resonating at 5 GHz with bandwidth of 6.9 GHz and impedance bandwidth of 72.4%. antenna model 2 resonating at dual band of 2 to 5.8 GHz and 8 to 13 GHz with bandwidth of 3.2 GHz and 5 GHz respectively. The proposed antenna model is resonating at dual wideband at 1.5 to 3.6 GHz and 4.8 to 15 GHz with bandwidth of 2.1 GHz and 10.2 GHz respectively. The same can be witnessed from Fig 3, where the reflection coefficient and the VSWR are plotted in the single figure for analysis.

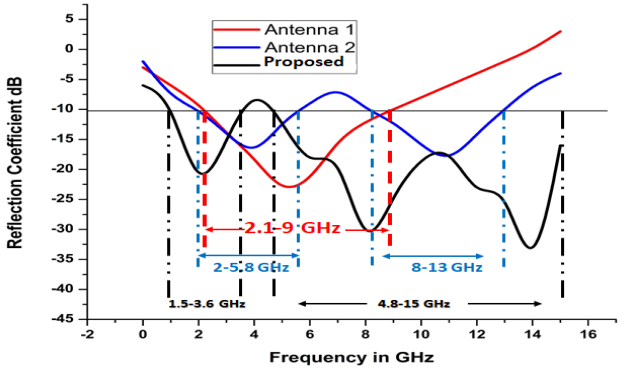

Fig 2.: Frequency Vs Reflection Coefficient of Antenna Iterations

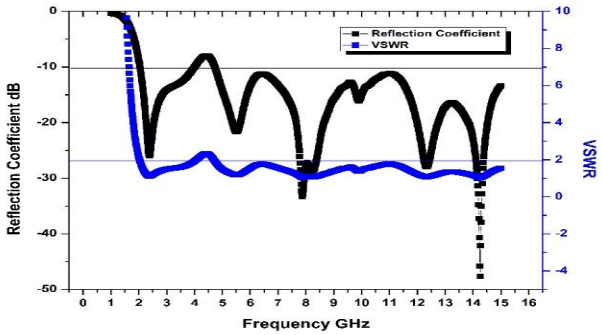

Fig 3:. Proposed Antenna Reflection Coefficient and VSWR

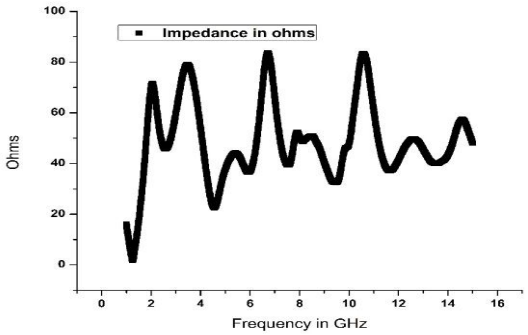

Fig 4:. Frequency Vs Impedance

The impedance characteristics of the antenna in the operating band can be observed from the Fig 4. Throughout the operating band the impedance is varying in and around 50 ohms, which gives the information regarding good impedance matching.

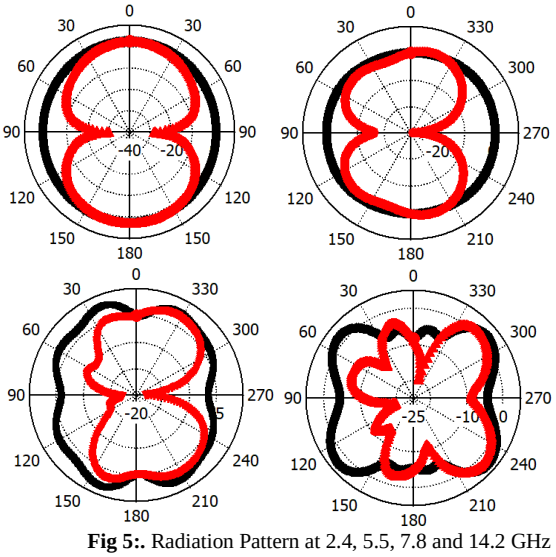

Fig 5:. Radiation Pattern at 2.4, 5.5, 7.8 and 14.2 GHz

The radiation characteristics of the antenna at different operating bands are presented in the Fig 5. Omni directional pattern in H-plane for lower bands and quasi omni for higher bands can be observed in H-plane. Monopole like pattern at 2.4 and 5.5 GHz and disturbed pattern at 7.8 and 14.2 GHz can be observed in E-plane.

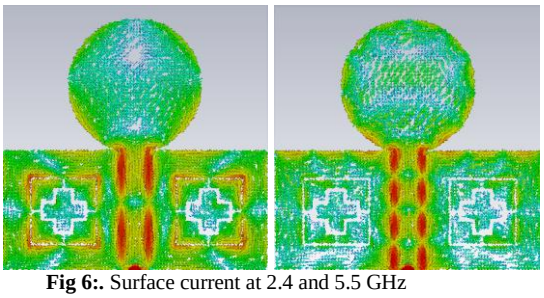

Fig 6:. Surface current at 2.4 and 5.5 GHz

The surface current distribution and the time domain analysis are presented in Fig 6 and Fig 7. The current distribution over the feed line is more when compared with radiating structure. At low operating band of 2.4 GHz, we can observe the current intensity is concentrated on the edges of the EBG structure also. The intensity is less on EBG due to rejection of certain radiation at 5.5 GHz. The time domain analysis of the proposed antenna with respect to the input signal and its response is presented in Fig 7. The analysis is presented here with normalized amplitude on the y-axis as shown.

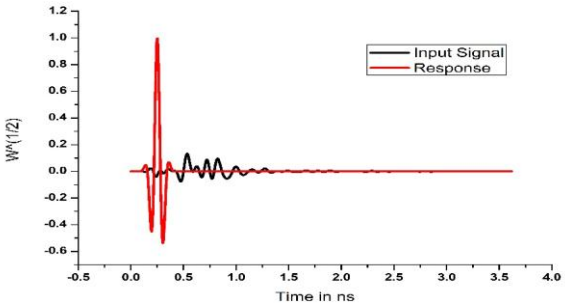

Fig 7:. Time domain analysis

The gain parameter with respect to the operating frequency is presented here in Fig 8. A peak realize gain of more than 4.8 dB and an average gain of 3.4 dB can be observed here. The efficiency of the antenna is also observed in simulation and measurement.

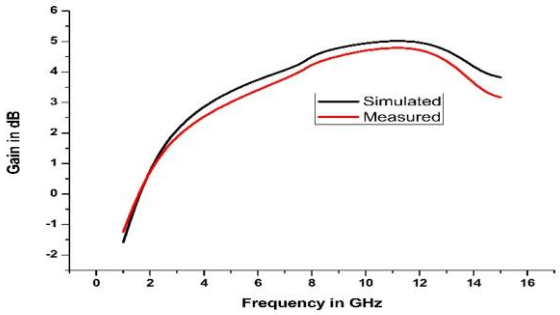

Fig 8:. Frequency Vs Gain

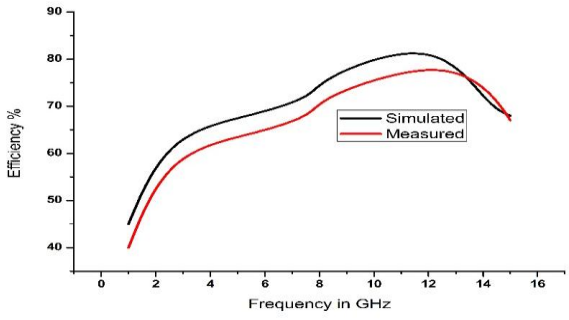

Fig 9:. Frequency Vs Efficiency

Fig 9 shows the overall efficiency of the antenna in the operating band. It can be observed that an efficiency of more than 80% achieved at 12 GHz in the case of simulation and 76% in the case of measurement.

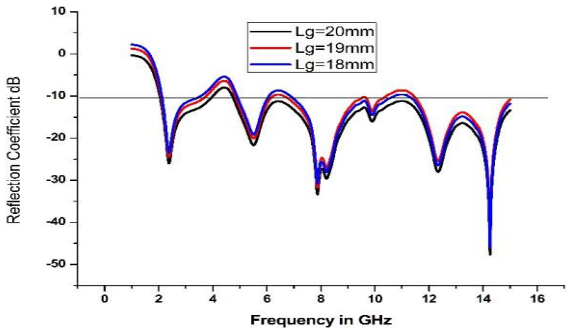

Fig 10:. Parametric analysis with change in 'Lg'

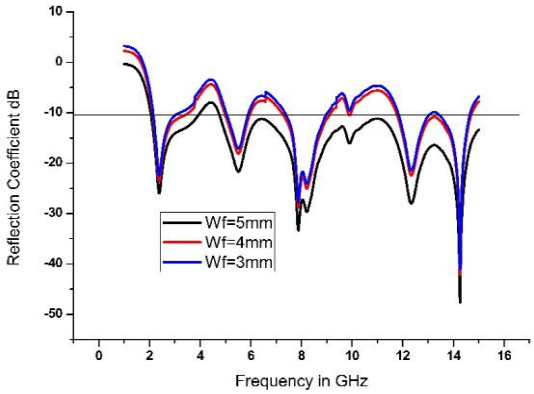

Fig 11:. Parametric analysis with change in 'Wf'

The parametric analysis of the antenna with respect to the length of the ground and width of the feedline was performed. The optimized dimensions are finalized before fabrication of the antenna model. Fig 10 and 11 shows the parametric analysis results for the optimization of the dimensions 'Lg'=20 mm and 'Wf'=5 mm.

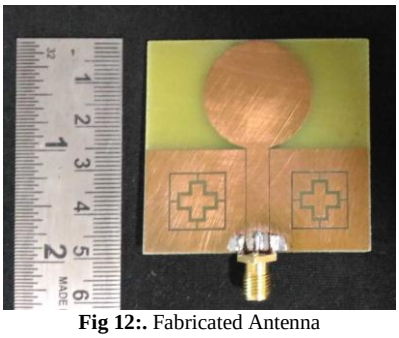

Fig 12:. Fabricated Antenna

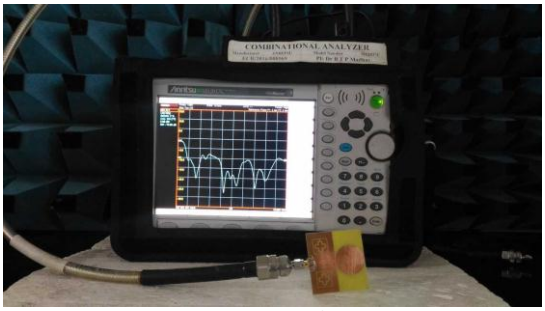

Fig 13:. Measurement of S_{11} on VNA

The prototyped antenna on FR4 can be observed from Fig 12 and the measurement of reflection coefficient can be observed from Combinational analyzer in VNA mode.

4. Conclusion

A compact dimension of 50X50X1.6 mm based EBG structured antenna is designed and the analysis is presented in this work. The proposed antenna operating in the dual band with wide bandwidth in the operating bands, which covers the most of the wireless communication applications like GPS, PCS, UMTS, Bluetooth, LTE, Wi-Fi and WLAN applications at lower side. Antenna covering Radar and satellite communication applications at higher operating bands. Antenna processing average gain of 3.4 dB and average efficiency of 72%. The measured results are providing excellent correlation with the simulation results for validation.

5. Acknowledgements

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