Gain Enhancement Modelling of Coplanar Waveguide fed Circular Monopole Antenna with EBG Placement

Raghavaraju Aradhylula, T V Rama Krishna, B T P Madhav

Abstract: A circular monopole antenna with coplanar waveguide feeding is designed for wideband applications. Different electromagnetic bandgap structures are placed beneath the antenna ground plane to improve the gain and the radiation efficiency. The depicted model occupies the dimension of 50X50X1.60 mm on FR4 substrate with dielectric constant of 4.3. Aerial 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 2.10 and 10.20 GHz respectively. The final novel antenna design provides good correlation with simulation results.

Keywords- bandwidth enhancement, coplanar waveguide feeding (CPW), monopole.

I. INTRODUCTION

The microstrip patch antenna with high gain is very significant in the transceiver module for wireless communication system. Microstrip-patch antenna suffers with low radiation, narrow bandwidth, small power handling capability, poor polarization purity, high Q and spurious feed radiation. Continuous efforts are going on with numerous novel methods to improve the performance of the antennas like array designs, substrate removal techniques, frequency selective surfaces (FSS) and electromagnetic bandgap (EBG) structures etc. The antenna can improve the gain, but the compactness of the model will be in the problem. Substrate removal techniques can provide small improvement in the gain, but spurious radiations will cause degradation in the bandwidth performance characteristics. Surfaces having frequency selectivity capability and the electromagnetic band-gap structures are the best choice to provide good radiation characteristics with development in the gain [1-2].

This article providing the simulation and the experimental validation of different EBG structures on the circular monopole antenna to improve the impedance characteristics and the gain. Researchers put attention on achieving ultra wideband characteristics of antenna and focusing on the design of triple and multiband antennas with moderate bandwidth and gain [1]. Different novel structures are being proposed and intense interest is shown in making structures and materials in modern decades [2]. Three significant categories of such materials are i) photonic crystals ii) electromagnetic band-gap structures and iii) metamaterials. The EBG structures will allow the electromagnetic waves to pass in different alternative directions other than the conventional guiding and provides stop band characteristics with filtering structures. The EBG structures can solve the problems like surface and leaky waves and provide good radiation efficiency [3-4]. The impedance matching characteristics can be improved with the placement of spiral EBG structures in the antenna design. We know that the period of the EBG lattice should be the half wavelength in general at stop band frequency [5]. In practical cases, there is a problem in the accommodation of large structures of EBG’s. Researchers investigated many compact structures of EBG’s like spiral like EBG, fork like EBG, UC-PBG and mushroom like ENB to provide compactness in the structure [6].

II. ANTENNA DESIGN

The circular shaped radiating element was taken on the feed line 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 depicted model occupies the dimension of 50X50X1.60 mm on FR4 substrate has a value dielectric constant of 4.30.and loss tangent 0.020.

\[ R = \sqrt{\frac{F}{1+\frac{2h}{\pi \varepsilon r F} \left[ \ln \left( \frac{\pi F}{2h} \right) + 1.7726 \right]}} \]  
\[ F = \frac{8.791 \times 10^6}{f \sqrt{\varepsilon _r}} \]

where “f” is the resonant-frequency of the antenna, “\( \varepsilon _r \)” is the relative-permittivity of the dielectric material and “h” is the small thickness of the dielectric layer. Two types of EBG structures are examined here for gain enhancement. The first structure consisting of square shaped conductive elements separated by equal amount of distance between them on FR4 substrate. This EBG structured design is placed exactly below the antenna structure. Fig 1(a) shows the circular monopole antenna with CPW feeding. Fig 1(b) shows the antenna placed on the EBG structure of dimension 58X58X0.8 mm.

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fig 1(c) presents the EBG layer 1, which is placed below the antenna with distance of 0.1 mm. Square shaped elements acting like band-gap structures to notch the operating band of the antenna from 4-8 GHz. fig 1(d) shows the EBG layer 2, which is also acting as band gap structure with quad band notching. The dimensions of the antenna are presented in Table 1.

**Table1: Parameters Of The Proposed Antenna Model**

| Parameter | Dimension (mm) |
|-----------|----------------|
| R         | 12.5           |
| Wf        | 5              |
| L         | 50             |
| W         | 50             |
| h         | 1.6            |
| Wg        | 22.2           |
| t         | 0.2            |
| Lg        | 20             |
| W1        | 13             |
| W2        | 8              |
| L1        | 13             |
| L2        | 8              |
| Le1       | 10             |
| We1       | 10             |
| Le2       | 10             |
| We2       | 10             |
| Le        | 58             |
| We        | 58             |

**III. RESULTS & ANALYSIS**

In order to provide design criteria the prototyped antenna model is tested with combinational analyzer for reflection coefficient and VSWR parameters and the radiation characteristics are examined in the anechoic chamber. fig2 shows the characteristics of VSWR for the antenna without EBG and with EBG of 2 different structures under the antenna model. Antenna model 1 of without EBG is providing notch band between
4 to 5 GHz with bandwidth of 2 GHz at first resonant band and 10 GHz at second resonant band. The antenna model 2 of EBG layer 1 is notching wideband from 4 to 8 GHz and providing bandwidth of 2 GHz at first band and 5 GHz at second band. The antenna model 3 of EBG layer 2 is notching quad band. The notch bands are between 2 to 3 GHz, 4 to 5 GHz, 6 to 8 GHz and 11 to 12 GHz with operating bands at 1.6 GHz (GPS), 3.6 GHz (Wi-Fi), 5.8 GHz (WLAN) and 10.6 GHz (Satellite Applications).

The designed antenna model dimensions are optimized before the fabrication and presented here in Fig 3 and 4. The width of the feed line dimensions are verified for optimized dimension and found the best suitable value at 5 mm. When dimensions are below 5 mm then antenna is not in the operating range.

The radius of the patch is also varied from 10.5 to 12.5 mm and found the best performance characteristics at 12.5 mm. After doing the parametric analysis, we realized that for the radius value of below 12.5 mm there is no resonance in the antenna operating band. The radiation patterns of the antenna in three conditions are presented from Fig 5 to 7. The gain of the antenna can be three-dimensional radiation characteristics here.
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(a) E-Plane, (b) H-Plane, (c) 3D-Pattern

![Fig.7: Radiation pattern at 1.6 GHz for EBG Layer2, (a) E-Plane, (b) H-Plane, (c) 3D-Pattern](image)

The radiation characteristics are analyzed in anechoic chamber with turn table mechanism setup. The designed antenna without EBG is providing peak realized gain of 2.39 dB with monopole like pattern in E-plane and quasi omni directional in H-plane. The antenna model with EBG layer 1 providing the peak gain of 4.83 dB and antenna model with EBG layer 2 providing the peak gain of 5.83 dB as shown in Fig 6(c) and 7(c).

![Fig.8: Radiation Pattern Measurement In The Anechoic Chamber](image)

![Fig.9: Surface current distribution of the antenna, (a) Without EBG, (b) With -EBG layer1, (c) With- EBG layer2](image)

The surface current distribution of the antenna model with EBG and without EBG are presented in Fig9. The current density is focused at feed line in the first case, but in the EBG based cases the current is at lower and the upper parts of the radiating element also. The gain characteristics of the antenna with and without EBG is presented in fig 10. Here we can observe the peak realized gain and the average gain over the operating bands and the improvement in the gain parameter with the placement of EBG structures.

![Fig.10: Frequency Vs Gain plot](image)
The prototyped antenna of circular monopole with plus shaped defected ground on FR4 substrate can be observed from fig 11. The measurement of reflection coefficient for the designed antenna on anritsu combinational analyzer is presented in Fig 12. The designed electromagnetic band gap structures of layer 1 with square shaped conductive structures can be observed from Fig 13. To prepare this layer, we have used conductive copper tapes on the 0.8 mm thickness substrate.

Another EBG structure of cross shaped conductive layer is presented in Fig 14. These two structures are placed beneath the antenna in two cases and examined the bandwidth and the gain. The measured radiation pattern and the gain are presented in Fig.7 and Fig.10. The placement of EBG structures below the antenna for measurement are presented in Fig 15 and 16.

IV. CONCLUSIONS

In this paper the design and analysis of circular monopole antenna with plus shaped defected ground structure discussed. Square shaped electromagnetic band-gap structured elements are placed beneath the designed antenna to improve the gain of the antenna. Two EBG structures are designed and examined in this work. The first EBG layer 1 providing peak realized gain of 4.830 dB and the second EBG layer 2 providing peak realized gain of 5.480 dB.

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