



Enhancement of Gain of Printed T Monopole Antenna Using Uniplanar EBG for ISM Band (2.4GHz) Applications

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ABSTRACT: A novel and simple printed T monopole antenna with EBG Structure is proposed. The antenna comprises T-shaped monopoles of different sizes, which generate resonant modes for the desired 2.4GHz frequency range. The proposed antenna has a low profile and can easily be fed by using a 50 microstrip line. Prototypes of the proposed antenna designed for WLAN operations in the 2.4GHz bands have been constructed and tested. Good radiation characteristics of the proposed antenna have been obtained. Effects of varying the monopole dimensions and the ground-plane size on the antenna performance have also been studied. To introduce uniplanar EBG Structure for enhancement of gain of the antenna is been done. Effects of varying EBG Structure and antenna performance have also been studied using HFSS Software.

KEYWORDS: Uniplanar EBG Structure , Monopole antennas, Printed antennas, Microstrip antennas, WLAN operations, Gain of the Antenna.

I. INTRODUCTION

PRINTED monopole antennas having the hook-like radiating strip [1], straight radiating strip [2], inverted-F radiating strip [3], [4], and so on have been applied in the wireless local area network (WLAN) operations. These printed monopole antennas are very suitable to be integrated on the circuit board of a communication device, leading to the attractive features of occupying very small volume of the system and decreasing the fabrication cost of the final product. In addition, with the use of this kind of printed monopole antennas, a concealed antenna for the system can be obtained; that is, there are no protruded portions in appearance for the antenna. This characteristic can avoid the possible damages of the protruded antennas, such as the protruded monopole antennas used for notebook computers [5], due to catching on things.

Recently Electromagnetic Band Gap (EBG) structure have been introduced and various types of EBG structures have been implemented in different applications such as reduction of surface waves, reduction of mutual coupling between two planar antennas. Since an EBG structure has a filtering behavior, it can be used to design antennas with stop band characteristics [4]. The paper starts with the design of simple monopole antenna. The uniplanar like EBG structure have been used in the same plane of monopole antenna for wide band response. The EBG structure is introduced around the antenna to increase gain of the antenna and suppression of surface wave. The Square like uniplanar EBG structure is designed. The antenna radiates over the frequency band of 2.4 Ghz , which include different applications like ISM Band (industrial, scientific and medical applications), WiFi and Bluetooth, Cell phones, GPS, Microwave Oven and Satellite Radio.

Recently, there are rapid developments in wireless communications, and in order to satisfy the IEEE 802.11 WLAN standards in the 2.4 GHz (2400–2484 MHz). For the available designs, the printed monopole antennas reported in [1]–[3] are capable of single-band operation only, and the printed dual-band inverted-F monopole antenna shown in [4] requires a shorting pin for ground connection, which increases the antenna complexity and the fabrication cost as well.



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In this paper, we demonstrate a novel and simple dual-band design of the printed monopole antenna. Simply by loading a horizontal conducting strip to a T-shaped or top-loaded monopole antenna (see Fig. 1), be easily obtained. The proposed monopole antenna looks like two stacked T-shaped monopoles, and is referred to as the T monopole antenna in this study. Details of the antenna design are described, and prototypes of the proposed antenna for WLAN operations in the 2.4GHz bands have been constructed and tested.

II. RELATED WORK

In [6] authors proposed for WLAN applications: The designed for full natural resonance in a single band, e.g., the 2.4GHz band, and uses a matching network to for artificial resonance at a second band. The natural impedance of the monopole in second band is set in a range that produces an efficient antenna with substantial range in both of the first and second bands.

In [7] authors proposed for monopole antenna with EBG: In this paper, a new compact ultra wideband circular monopole antenna with an acceptable band-rejection characteristic is investigated. This rejection band is created by means of an electromagnetic band-gap (EBG) structure. The EBG structure that is used here is a mushroom-like structure. An equivalent circuit model is employed to investigate the stop band characteristic of the EBG. The operation frequency band is 3.1–10.6 GHz with a rejection band of 0.7 GHz around 5.5 GHz. Accurate and high rejection is achieved. The proposed model is implemented, and the measured results are in good agreement with simulated ones.

In [8] authors proposed EBG Structure and Ground with Slots: In this paper a low cost, simple and small size ultra wide band circular monopole antenna is designed. The notch band is created by multiple number of slots in the ground plane. The proposed antenna is designed on the FR-4 substrate of height 1.6 mm. The antenna is designed with ground plane of dimension 50 x 55 mm and is fed by 50 ohm microstrip line. It is found that the EBG design approach in the ground plane is a good candidate for frequency rejection of wide range. The antenna achieves an operational bandwidth of 1.5 Ghz (1.5 Ghz to 3 Ghz) which included ISM band (1.8 and 2.4 Ghz), WiFi / Bluetooth (2.4 Ghz), Satellite Radio (2.3 Ghz), and GPS (1.575 Ghz).

In [9] authors proposed Triple band gap Uni-Planar EBG structure: A triple-band electromagnetic band gap (EBG) structure for antenna applications is presented in this paper. The idea proposed in this the paper is etching several properly shapes in the metal surface of the uni-planar compact EBG (UC-EBG) cell to introduce three band gaps separately. These band gaps are represented by three different equivalent circuits, from which the resonant frequencies can be estimated. An in-house developed computational code based on FDTD method was used to analysis the dispersion properties of the structure. Formulas for investigating the central frequencies of the three bandgaps are also presented corresponding to the equivalent circuits. An array with size of 4 \times 5 of EBG cell was numerically simulated and experimentally measured to verify the accuracy of the band gaps.

In [10] authors proposed Monopole with Periodic EBG structure: A novel printed monopole antenna with dual wideband is presented for simultaneously satisfying wireless local area network (WLAN) and worldwide interoperability for microwave access (WiMAX) applications. The antenna structure consists of a rectangular monopole with a microstrip feed line for excitation and a trapezoid conductor-backed plane for band broadening. The measured 10 dB bandwidth for return loss is from 1.9 to 4.32 GHz and 5.1 to 7.18 GHz, covering all the 2.4/5.2/6.0 GHz WLAN bands and 2.5/4.0/6.2 GHz WiMAX bands.

III. ANTENNA DESIGN CONSIDERATIONS

As shown in Fig. 1, the proposed antenna can be considered as two stacked T-shaped monopoles, both operated as quarterwavelength structures, and is easily fed by a 50 microstrip line of width w_f in this study. Both of the two T-shaped monopoles and the microstrip line are printed on the same side of the dielectric substrate (in this study, the FR4 substrate of thickness 0.8 mm and relative permittivity 4.4 was used.). On the other side of the dielectric substrate, a ground plane of length L and width W is printed below the microstrip feed line.

In this design, the larger T-shaped monopole comprises a vertical strip (width w and height h_1) in the center and a horizontal strip (width w_1 and length $2l_1 + w$) on the top. This larger T-shaped monopole controls the first or lower

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operating band of the proposed antenna. This arrangement was found to be effective in obtaining a wider impedance bandwidth of the antenna's upper operating band, and the bandwidth enhancement results are demonstrated in the following section.

To achieve the desired band operations, for example, the WLAN operations in the 2.4 GHz bands, we can adjust the parameters, (h_1 , l_1 , w_1 , w) of the T-shaped monopoles for controlling, respectively. The proper parameters can be obtained with the aid of the commercially available software Ansoft HFSS (High-frequency structure simulator). In addition, it should be noted that the ground-plane dimensions can also affect the resonant frequencies and operating bandwidths of the two operating bands. Thus, the ground-plane dimensions should also be taken into account in determining the proper parameters for the proposed design to achieve the desired band operation.

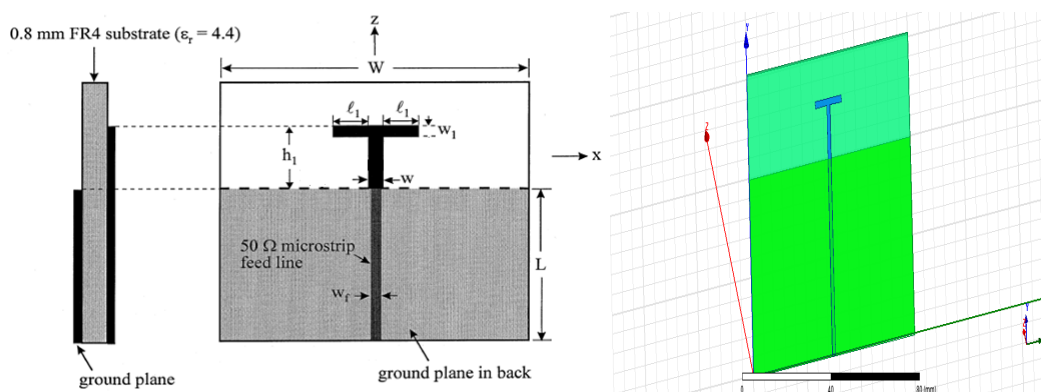


Fig. 1. Geometry of the proposed printed T monopole antenna and HFSS design.

A. Effects of Various Monopole Parameters:

A reference antenna (the antenna shown in Fig. 1 without the lower horizontal strip) was first tested, whose measured and simulated return loss is shown in Fig. 2(a). In this case, the widths (w_1 and w) of the larger T-shaped monopole were chosen to be the same as that ($w_f=1.5\text{mm}$) of the $50\ \Omega$ microstrip line for convenience. The height (h_1) of this reference antenna was chosen to be 14.5 mm (only about 12% of the wavelength at 2450 MHz), and the two protruded portions of the horizontal strip on the top were of the same length ($l_1=5.3\text{mm}$). The ground plane of length 50 mm and width 75 mm was first used in the study. From the obtained results, it is clearly seen that a resonant mode covering the 2.4 GHz WLAN band was excited. Reasonable agreement between the measured data and the simulated results is obtained. This resonant mode has a 10 dB impedance bandwidth of 405 MHz (2130–2535 MHz).

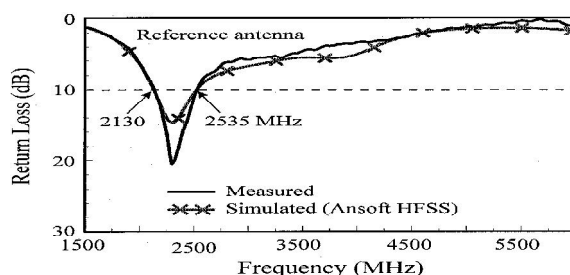


Fig. 2. Measured and simulated return loss for the proposed antenna

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B.Radiation pattern:

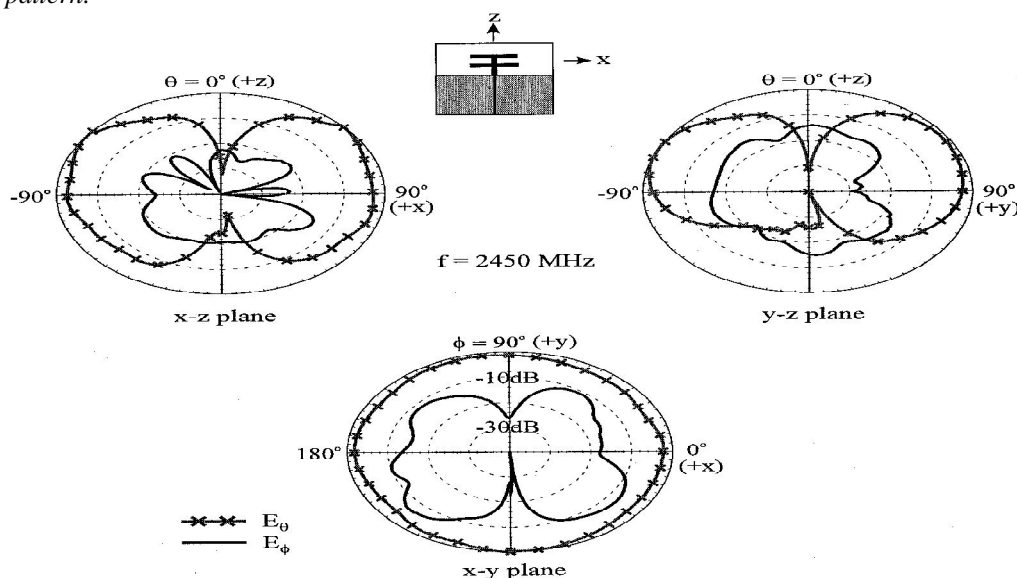


Fig. 3. Measured radiation patterns at 2.4 GHz for antenna

IV.EBG STRUCTURE DESIGN AND ANALYSIS

An EBG structure can be described as a lumped element circuit with distributed capacitors and inductor. This electrical LC-circuit forms frequency selective surface impedance. From the Uniplanar EBG as shown in Figure 4, the gaps between the conductor edges of two adjacent cells introduce equivalent capacitance C . In addition, the narrow strips, connected the two patches, introduce equivalent inductance L . Thus, it can be described using the equivalent LC circuit, as shown in Figure 4. The center frequency f_c of the bandgap is defined as follows

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

The inductor and the capacitor is due to the gap effect between the adjacent patches. They can be approximated by the following expressions

$$L = \mu_0 h \quad (2)$$

$$C = \frac{W\epsilon_0(1+\epsilon_r)}{\pi} \cosh^{-1}\left(\frac{W+g}{g}\right) \quad (3)$$

where h and ϵ_r are the substrate height and the dielectric constant, and W and g are the width and the gap of the EBG, respectively. The establishments of the band gaps depend on the creation of components capacitors and inductors. These elements can be combined together into the equivalent circuit to determine the corresponding center frequency of the band gap. In the proposed structure, these band gaps can be represented by three different equivalent circuits. From (1),(2),(3) equation we can calculate EBG cell size and gap between the cell.

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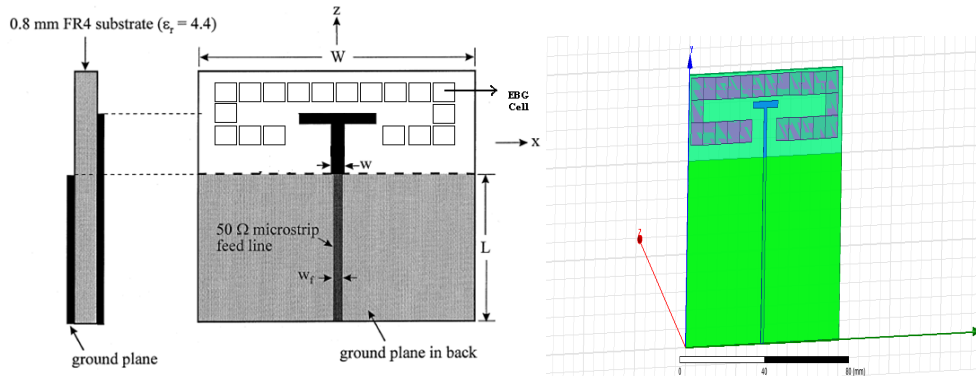


Fig. 4. Geometry of the proposed printed T monopole antenna with EBG structure and HFSS design.

V. SIMULATION RESULTS

A. Graphs:

The S11 graph (frequency graph) of the monopole antenna with EBG shown in Fig. 5, in which resonance frequency is exactly 2.4GHz and this is matching with our design frequency range. The return loss is -21 dB and reflection is very less. The VSWR value 1.86 and this is less than 2. The ideal case of the VSWR is equal to 1.

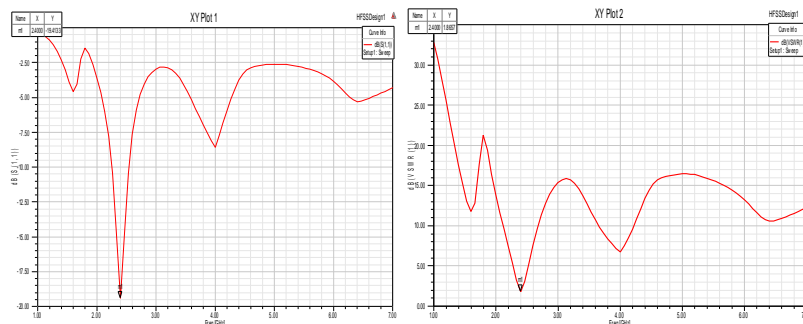


Fig 5. Graph of S11 and VSWR after introducing EBG Cell

Figure 6 shows the measured radiation pattern for frequency of 2.4GHz with the simulated results depicted together as comparison. From the results, it should be noted that both results are coincided each other qualitatively. It seems that the radiation pattern of proposed antenna has the characteristics that comply to omnidirectional pattern with no major lobe and minor lobe. This is one of characteristic advantages of monopole antenna compared to the conventional microstrip antenna that has unidirectional radiation pattern.

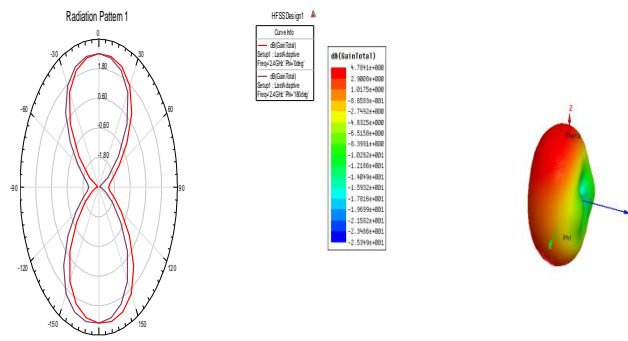


Fig 6. Graph of Radiation pattern and gain after introducing EBG Cell



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It can be also noted that the surface wave of the patch antenna alone is already small compared to the direct source field. From this, the gain enhancement of the EBG antenna is not only due to the reduction of the surface wave but it is mainly due to the coupling between the patch antenna and the EBG structure. The gain of the Antenna increase from 3.50 dB to 4.78 dB after introducing uniplanar EBG structure.

B.Comparison of T Monopole Antenna with and without EBG cell

DESIGN	WITHOUT EBG	WITH EBG
FREQUENCY	2.4GHz	2.4GHz
RETURN LOSS	-21dB	-21dB
VSWR	1.4	1.3
GAIN	3.50 dB	4.78 dB
SUBSTRATE	FR4	FR4

Table I

VI. CONCLUSION AND FUTURE WORK

In this paper an approach to design the uniplanar EBG structure in antenna has been proposed. The design is simply placing the planer EBG structure near to the radiating part of monopole antenna for create band gap creating, which increase the overall Gain of antenna. A gain of the monopole antenna is increased from 3.50dB to 4.78 dB is achieved by using uniplanar EBG structure with proper gap between the cell. A novel printed double-T monopole antenna have been demonstrated. Constructed prototypes suitable for WLAN operations in the 2.4 GHz bands have been studied, and good antenna performances of the operating frequencies across both of the 2.4 GHz bands have been obtained. Large effects of varying monopole parameters andground-plane sizes on the antenna's resonant frequencies and impedance bandwidths have also been seen. For future work, using array of monopole can be implemented for more gain and improve the bandwidth of the monopole antenna also.

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