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Design of Multiband Antenna Operation Based on Electromagnetic Band Gap (EBG) Structure

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Abstract: *This paper present a triple band, low profile microstrip antenna for radio altimeters, IEEE INSAT/super extended C band and X band applications. Here triple band operation is achieved by mushroom-like electromagnetic band gap (EBG) structure. The proposed antenna operates over radio altimeter band (4.1-4.4 GHz), extended C band from (6.7-7.1 GHz) and X band from (9.1- 10.5 GHz).An antenna is simulated on FR-4 substrate and overall dimension is 42x34x1.6 mm^3. High-Frequency Structure Simulator (HFSS) software tool was used for the simulation.*

Keywords: *Multiband antenna, Electromagnetic band gap (EBG), Rectangular microstrip antenna, C band, X band, Radio altimeter.*

I. Introduction

In recent years, Wireless technology has been ahugedevelopment, which required the convenience of efficient modules that can be functioned at instant at low power consumption. With the growth of wireless communication systems, there is an enormous requisite for antennas which are suitable to operate in multiband operation in wireless communications, such as cell phones, aerospace, radars and sensor networks. Printed microstrip patch antenna become the highly demanding antenna because of their applications, which has some advantages like lightweight, low profile properties, cost and operating in high - frequency range [1]. However, the general microstrip antenna has some disadvantages such as low efficiency, narrow bandwidth, and surface wave losses [2]. There are many printed antennassuch as monopole, dipole, and slot with dual or multiband structure have been presented [3-6]. Three radiating elements with strip were used to achieve a WLAN and WiMAX frequency band of operations [3]. A customized U-shaped in the ground plane and composite form of the slot etched on the radiating patch, dual band frequency was obtained [4]. Defective ground structure (DGS) and L-shaped strips and cross-shaped strip line were used to achieve a dual-band and bandwidth enhancements [5]. A slot antenna was presented to achieve dual-band (2.4-2.485 GHz and 5.15-5.825) using narrow slots at corner region on radiating patch [6]. To investigated dual-band operation slot antenna for LTE/WWAN operation obtained by tapered open-slot is fed by 50 ohms vertical feed line with two parallel protruded feeding structures [7]. Using annular slot and annular patch stacked together,

slot/patch antenna was presented for dual-band operation at 2.5 and 3.5 GHz [8]. However, these antennas have complex structures, small bandwidth and not purely tunable characteristics. Recently different techniques have been established such as electromagnetic band gap (EBG) structure [9-11]. To advance the functionality of high frequency, suppress the surface wave and improve the antenna parameter of the printed antennas using EBG mushroom-like structure [9]. By using a different shape of EBGstructures are placed on conducting ground plane, antenna bandwidth and the gain were improved [10]. Novel metamaterial based EBG was introduced to achieve dual-band antenna at frequencies 2.4 GHz and 5.0 GHz [11].

In this paper it is proposed to obtain a triple band operation using mushroom-like EBG structures for radio altimeters, IEEE INSAT/super extended C band and X band applications. The demonstration of a multiband antenna using EBG is showcased in section II. Section III shows the simulated results of the proposed antenna.

II. Antenna Design

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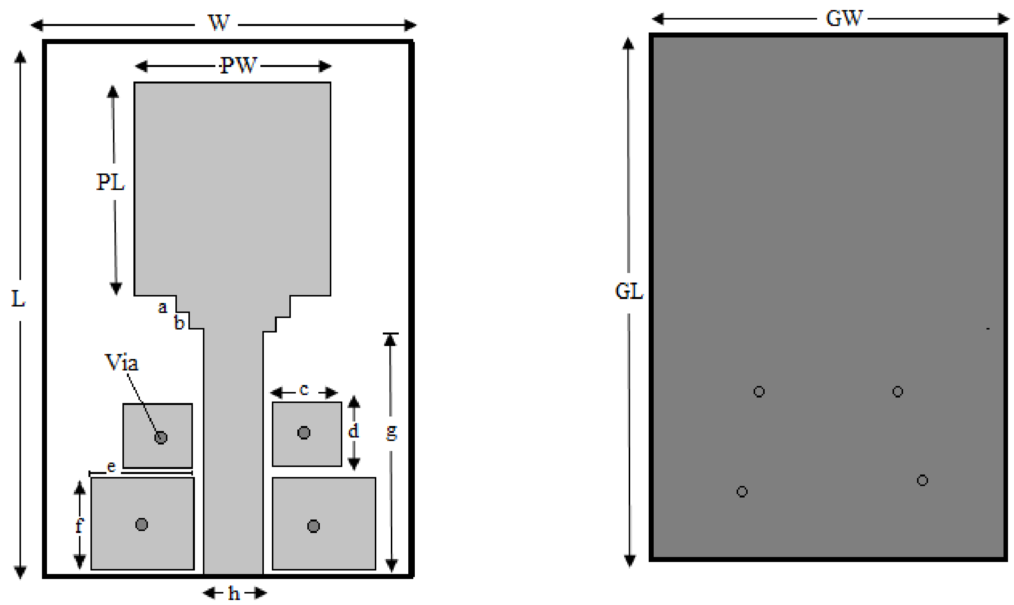


a) Top View b) Bottom View

Figure no 1: Geometry and dimension of proposed antenna a) Top View b) Bottom View

The design and geometry configuration of the antenna is shown in Fig 1. The proposed antenna was simulated on FR 4 substrate relative permittivity (ε_r) of 4.4, loss tangent (tan δ) of 0.02 and height of 1.6 mm. The overall size of an antenna is 42 x 34 mm^2. A Width of the micro-strip feed line is 'h' is fixed at 2.2 mm in arrange to attain 50Ω impedance. The mushroom-like EBGconfiguration was composed of a ground plane with different size square patch on top of an inserted via, which connects the middle of the square patch and the ground plane.

Table no 1: Proposed antenna parameters after optimization

Parameter	L	W	PL	PW	GL	GW	a
Unit (mm)	42	34	16	15	42	34	4
Parameter	b	c	d	e	f	g	h
Unit (mm)	1	6.1	6.1	9.25	9.25	22.2	3

The resonance frequency of the mushroom-like EBG structure is determined [12].

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

L is the inductor effect and *C* is the capacitance effect in EBG structure.

The inductor *L*is because of the currents flowing through the vias and the bottom plate. Here the inductance *L*depends on the height of the substrate h and can be given by

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

The capacitor *C* is because of the gap effect between the adjoining patches and it is calculated [9].

$$C = \frac{k\varepsilon_0(1+\varepsilon_r)}{\pi}\cosh^{-1}\left(\frac{k+g}{g}\right) \qquad (3)$$

Where *k* is the width of the mushroom-like EBG, *g* is the gap of the mushroom-like EBG, *h* is the substrate thickness.

The proposed antenna resonates at three frequencies 4.3 GHz, 6.9 GHz and 9.3 GHz respectively. The width and the gap dimension of mushroom- like EBG are obtained from the above equations. The optimized parameter of the proposed antenna is shown in table 1.

III. Simulation Results

The proposed antenna is simulated by using the High-Frequency Structure Simulator (HFSS) software tool. Fig.2 show the simulated return loss with mushroom-like EBG cells and without EBG cells.

Simulated return-loss characteristics shows, without mushroom-like EBG structure cell, the only rectangular shape radiating patch shows one resonant frequency of 10 GHz. It gives only X band frequency applications. Presenting four mushroom-like EBG structure cells exhibits three resonant frequencies of 4.3 GHz, 6.9 GHz, and 9.3 GHz. The -10-dB bandwidth of 300 MHz from (4.1-4.4 GHz), 400 MHz from (6.7-7.1 GHz) and 1400 MHz from (9.1- 10.5 GHz) respectively, which is used to radio altimeters, IEEE INSAT/super extended C band and X band applications.

The radiation pattern states to the directional need of the strength of fields from the antenna. The simulated radiation pattern E-field co and cross polarization at 4.3 GHz, 6.9 GHz, and 9.3 GHz have been presented are shown in Fig. 3. It shows the radiation patterns bidirectionalcharacteristics at E-plane and gain of the proposed antenna at E-Plane is0.5 dB, 3.49 dB and 2.82 dB at 4.3, 6.9 and 9.3 GHz respectively. The operative bandwidth of the proposed antenna with good radiation patterns existed to be about 300 MHz from (4.1-4.4 GHz), 400 MHz from (6.7-7.1 GHz) and 1400 MHz from (9.1- 10.5 GHz) which are reliable with the requirement of the radio altimeters, IEEE INSAT/super extended C band and X band applications.

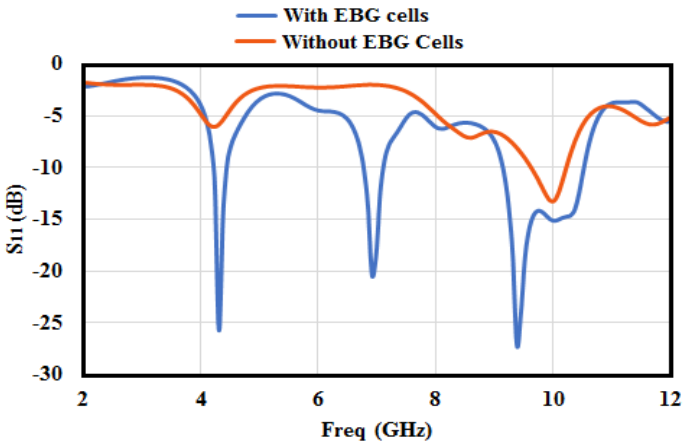
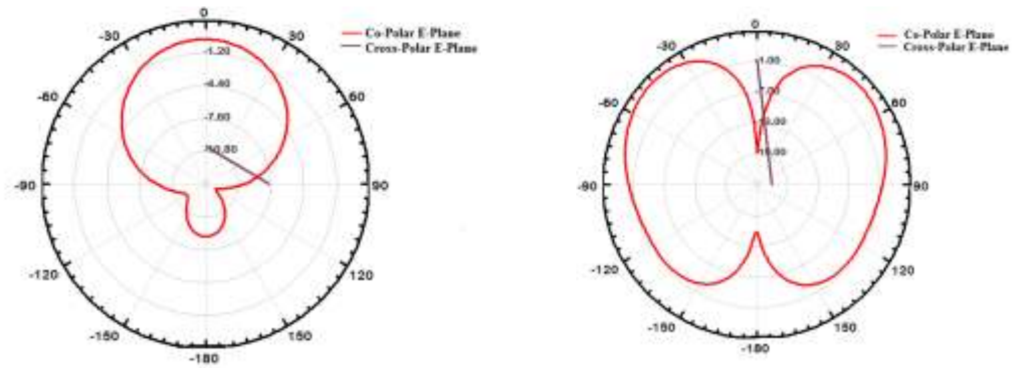
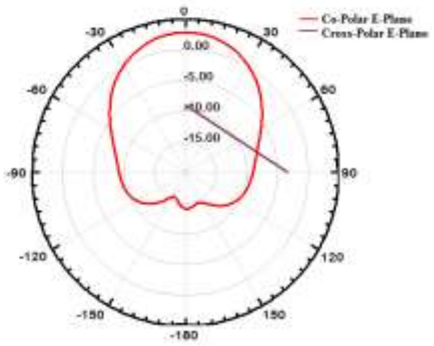


Figure no 2: Simulated return-loss characteristics effect of EBG cells



(a) (b)



(c)

Figure no 3: Radiation patterns for the proposed antenna with copolar and cross-polar at resonant frequencies (a) 4.3 GHz (b) 6.9 GHz and (c) 9.3 GHz

IV. Conclusion

A triple- band, small size, low profile microstrip patch antenna is simulated on FR 4 substrate for radio altimeters, IEEE INSAT/super extended C band and X band applications by using mushroom-like EBG structure cells. Simulated results show that the antenna is accomplished of operating at 4.1-4.4 GHz for radio altimeters, 6.7-7.1 GHz for IEEE INSAT/super extended C band and 9.1- 10.5 GHz for X band applications. The antenna has a small size 42 x 34 mm^2 and realizes triple band operation with appropriate impedance matching and radiation patterns.

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