A Novel Hexagonal Boundary Fractal Antenna with Band Notch Characteristics

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Abstract—A novel coplanar waveguide (CPW) fed hexagonal shaped antenna for Ultra Wide Band (UWB) applications with WLAN band-notch characteristics is proposed in this work. The proposed antenna covers the entire UWB bandwidth of 3.1 to 10.6 GHz with band rejection in the range 5.1 to 5.9 GHz. The rejection in WLAN range reduces interference between ultrawide band and WLAN band. Band rejection is achieved by etching rectangular slot on the radiating element.

Keywords—Ultra Wide Band, Band notch, WLAN, CPW, Fractal Antenna

I. INTRODUCTION

Ultra Wide Band (UWB) systems can be characterised by a system with relatively large bandwidth. As per FCC standardisation, UWB is allocated a frequency range of 3.1 to 10.6 GHz for its operation with a power emission level of -41.3 dBm/MHz. IEEE 802.15.3 standardisation group was formed to establish a standard for high speed communication based on UWB. UWB band is divided into lower (3.1 to 5.15 GHz) band and upper (5.875-10.6 GHz) bands. Due to baseband nature of signal transmission, UWB system have potentially low complexity and low cost. Other advantages includes high data rate, low power consumption, resistant to multipath and jamming. Several applications of UWB antennas are EM measurement, wireless communications, radars, medical imaging, localisation and wireless sensor networks. Particular UWB antenna is selected based on the requirements [1] - [3].

UWB can coexist with other communication systems. Traditional narrow bands like WLAN, X bands overlap with UWB. In order to avoid interference, band stop performance is needed. There are different techniques like tuning stub, insertion of shaped slots, using parasitic element, implementing fractal geometry to notch any unwanted frequencies [4]. Band rejection in the range 4.7 to 5.9 GHz can be obtained by embedding spur lines on the ground plane [5]. UWB antenna with hilbert curve slots on radiating element is used for WLAN/WiMAX applications is proposed in [6]. CPW fed UWB antenna with dual notch band is reported in [7]. Here split ring slot in radiator and slots in ground plane are used to achieve rejection. A partial annular slot is embedded at lower portion of annular ring shaped radiating patch to cover entire UWB band with rejection at WLAN band is considered [8]. Circular boundary Sierpinski carpet fractal with band notch is achieved by etching meandered slot from radiator. Band rejection obtained is 5.15 - 5.825 GHz [9]. Fractal antennas are based on the concept of a fractal, which is a recursively generated geometry that has fractional dimensions. A fractal antenna is capable of operating at many different frequencies simultaneously.

In this work hexagonal boundary fractal antenna for WLAN applications is proposed. Band rejection in the WLAN range of 5.1 to 5.9 GHz is achieved by etching slots on the radiating element. The proposed system covers entire UWB bandwidth and desired radiation patterns are obtained.

This paper is organized as follows. Section II describes antenna design and section III gives parametric study. In section IV simulation results are discussed. Finally section V draws the conclusion. Antenna is designed and investigated using high frequency structure software (HFSS).

II. ANTENNA DESIGN

The geometrical configuration of proposed antenna is shown in Fig.1. An FR4 substrate with relative permittivity of 4.4, a loss tangent of 0.02 and a thickness of h=1.59 mm is used for the proposed antenna. The substrate is having a cross section of 40x38 mm. The proposed antenna uses a CPW fed hexagonal boundary sierpinski carpet fractal structure. The 50 ohm CPW fed structure consists of the CPW transmission signal strip line with a signal strip width 2.6 mm. A partial ground plane is used for this structure. The length of the ground plane Lg and the width of the ground plane Wg are important design parameters, where Lg= 18.14 mm and Wg=17 mm.

Initiator for this hexagonal boundary carpet fractal is a hexagonal shaped antenna. First iteration of this fractal antenna is obtained by etching out central hexagon of 6mm size,which is one third size of the initiator. Next iteration is obtained by subtracting additional four hexagons of one third size of center hexagon. Band rejection in WLAN frequency range is obtained by etching a slot combined by circles and rectangles.

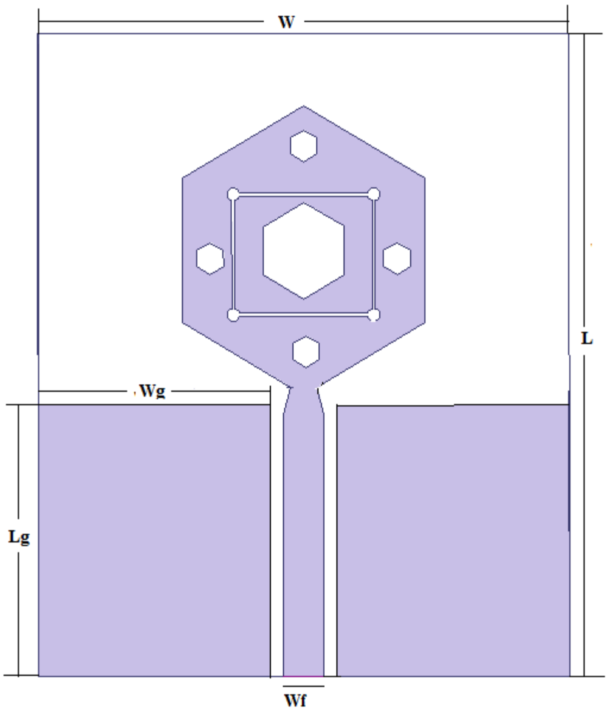

Fig. 1. Antenna structure

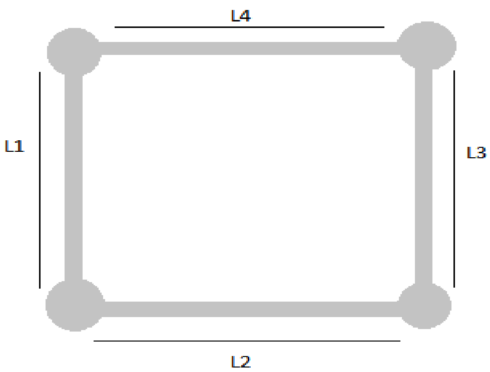

Fig. 2. Slot for band rejection

III. PARAMETRIC STUDY

Parameter study of the slot etched on the patch is performed. The antenna has a rectangular slot of width Ws. Length of this slot is denoted by Ls which is a combination of L1,L2,L3 and L4. From the four corners of this slot, four circles are also etched. This combinational slot is responsible for the band rejection in the region 5.1- 5.9 GHz. When total length of slot Ls is 29.4 mm, band rejection is obtained in the range 4.5 GHz to 4.9 GHz. As length of slot Ls is increased from 29.4 mm to 31.8 mm, band notched region shift towards higher frequency side. Variation of frequencies with changing length is shown in Table.I. Matching over the band also increases with increase in length. An optimum slot length of 31.4 mm is selected for achieving the desired band rejection.

Length of slot (Ls)	Band Rejection
29.4 mm	4.5 GHz - 4.9 GHz
29.8 mm	4.8 GHz - 5.5 GHz
30.8 mm	4.9 GHz - 5.7 GHz
31.4 mm	5.1 GHz - 5.9 GHz
31.8 mm	5.2 GHz - 6 GHz

TABLE. I

PARAMETERIC STUDY ON LENGTH

Width of slot is also a significant design parameter. When width of slot is selected as 0.2 mm, desired band rejection in the range 5.1 GHz to 5.9 GHz is obtained. Slot width is adjusted while fixing the length of rectangular slot as 31.4 mm and radius of circle as 0.4 mm. As slot width Ws is increased from 0.2 mm to 0.4 mm, notch band shift towards lower frequency side. An optimum slot width of 0.2 mm gives the desired band rejection. Table.II gives the variation of notch band when width of the slot is changed.

Length of slot (Ls)	Width of slot (Ws)	Band Rejection
31.4 mm	0.2 mm	5.1 GHz - 5.9 GHz
31.4 mm	0.3 mm	4.8 GHz - 5.5 GHz
31.4 mm	0.4 mm	4.3 GHz - 4.7 GHz

TABLE II
PARAMETERIC STUDY ON WIDTH

Radius r of circular slot also determines notch region. When radius of circle is selected as 0.6 mm, band notch is obtained in the region 4.4 to 4.9 GHz. As the radius is decreased from 0.6 mm to 0.3 mm, band rejection region is shifting towards higher frequency. Table.III shows the parametric study on radius of circular slot. An optimum radius of 0.4 mm is selected for the required notch characteristics.

The optimised parameters are Ls =31.4 mm, Ws= 0.2 mm and r = 0.4 mm.

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Width of slot (Ws)	Radius of circular slot (r)	Band Rejection
0.2 mm	0.6 mm	4.4 GHz - 4.9 GHz
0.2 mm	0.5 mm	4.9 GHz - 5.7 GHz
0.2 mm	0.4 mm	5.1 GHz - 5.9 GHz
0.2 mm	0.3 mm	5.2 GHz - 6.1 GHz

TABLE III
PARAMETERIC STUDY ON RADIUS OF CIRCULAR SLOT

IV. RESULTS AND DISCUSSION

Antenna is investigated using high frequency structure software (HFSS) version 15 based on finite element method (FEM). The simulated results are discussed below.

A. Return Loss

Simulated return loss curve of proposed antenna is given in Fig. 3. Simulated result shows that, the proposed antenna provides a sharp band notch of 5.1 to 5.9 GHz. Impedance bandwidth range from 3 GHz to 11 GHz and the bandwidth covers entire UWB band. Return loss upto -33.18 dB is obtained at 10.4 GHz which shows better impedance matching. Better return loss values are obtained at other resonant frequencies also. Hence the proposed system can perform in the entire UWB band and avoids the interference from the WLAN systems operating in 5.1-5.9GHz.

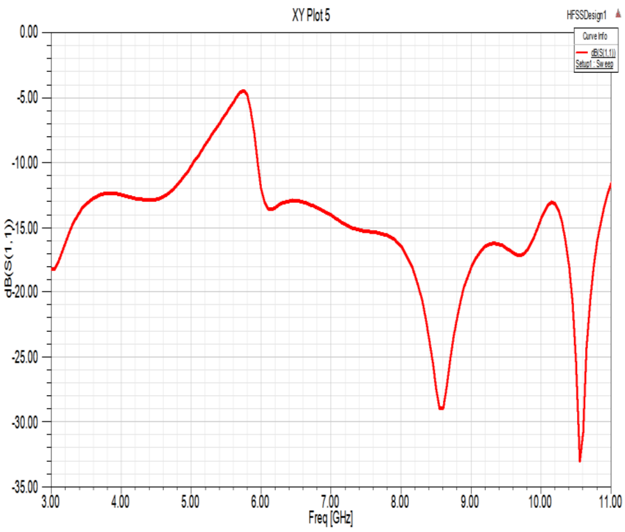


Fig. 3. Return Loss of proposed antenna

B. Radiation Pattern

Radiation patterns at E plane and H plane are analysed at 3 different frequencies. Nearly omnidirectional radiation patterns are obtained for H plane at frequencies 6.2 GHz, 8.6 GHz and 10.5 GHz.

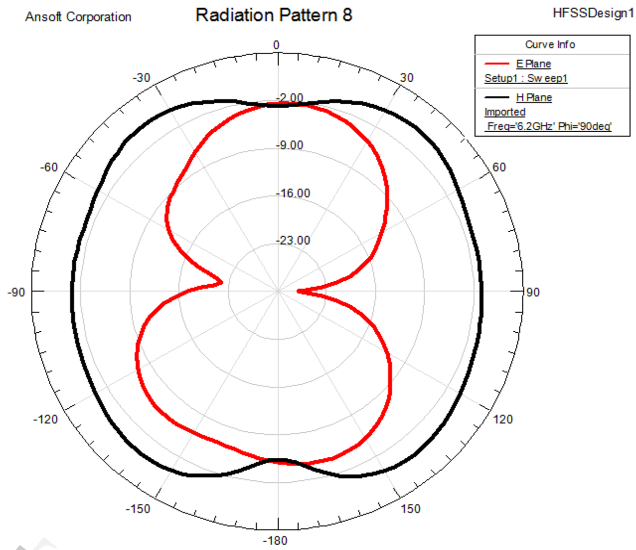


Fig. 4. Radiation Pattern at 6.2 GHz

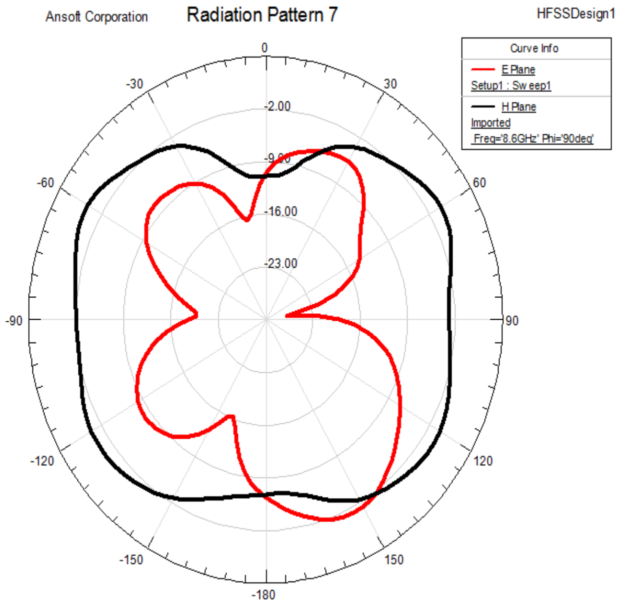


Fig. 5. Radiation Pattern at 8.6 GHz

It is noticed from the radiation patterns of proposed fractal antenna, dipole like radiation characteristics are obtained for the E Plane. There is slight distortions in the E plane characteristics due to band rejection function.

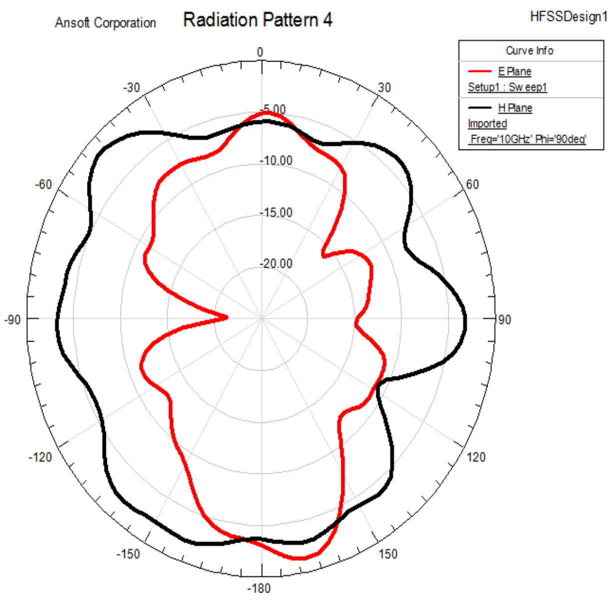
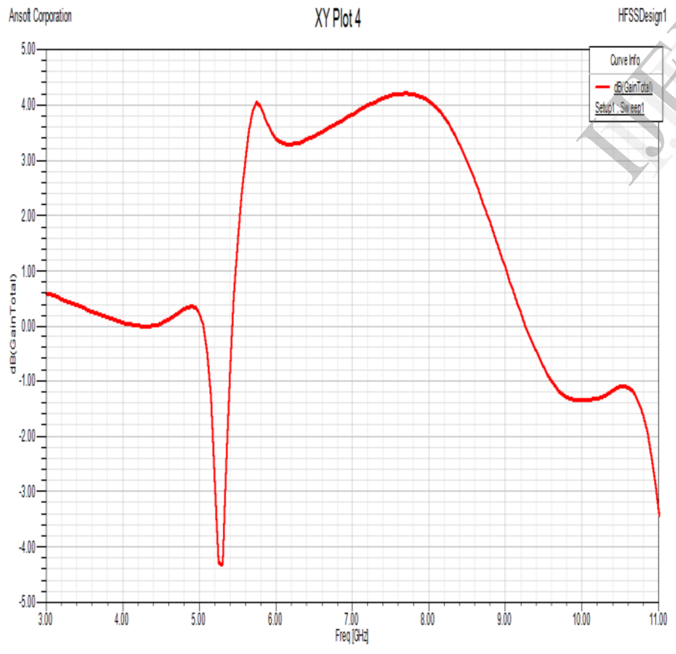


Fig. 6. Radiation Pattern at 10.5 GHz

C. Gain

Simulated gain of the proposed hexagonal boundary



fractal antenna is shown in Fig.7. Simulated result shows that gain is relatively flat over the entire UWB band and maximum gain upto 4.1 dB can be achieved around 8 GHz. There is a significant reduction of gain in the WLAN band as expected.

The proposed antenna can perform well in the UWB band with a rejection in the 5.1 to 5.9 GHz.

Fig. 7. Gain

V. CONCLUSION

A novel CPW fed Hexagonal boundary carpet fractal antenna with band notch characteristics has been proposed in this paper. Antenna has simple and easy to fabricate structure. The designed antenna covers entire UWB bandwidth of 3.1 to 10.6 GHz. By etching a rectangular shaped slot, interference to 5.1 to 5.9 GHz band assigned for IEEE 802.11a and HIPERLAN/2 is reduced. Gain upto 4.1 dB is achieved and omnidirectional radiation patterns are obtained over the required bandwidth.

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