Design of a Novel UWB Hexagonal Patch Antenna having Three Notched Band Features

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Abstract-A UWB hexagonal patch antenna with three band-stop features is suggested in this article having a hexagonal shaped radiator fed with microstrip line with "I", "C" and Inverted "U" shaped slots to attain the band notch characteristics. The dimensions of the suggested antenna are 30mm×28mm×1.6mm. The design is printed on FR4 substrate of permittivity 4.6 and loss tangent 0.02. The antenna reports a substantial bandwidth from 2.65 GHz to 11.3 GHz. Out of this 8.65 GHz range, the VSWR is less than 2 except at three notch bands for WiMax system (3.3 to 3.7 GHz), WLAN system (5.15 to 5.85 GHz) and ITU (7.95 to 8.4 GHz). The proffered antenna has a stable gain in the entire range of 8.65 GHz except the notch bands. The radiation pattern of this antenna is nearly omni-directional.

Keywords-Ultra-Wide Band, ITU Frequency Band, WLAN, VSWR, WiMAX, HFSS.

I. Introduction

Ultra wideband (UWB) is a rapidly emerging technology with enhanced features for example low power utilization, high data rate, minimal effort and enhanced resolution of multipath [I]. This is a peerless and unrivalled technology for implementation in high speed and short range transmission. It is highly recommended for its utilization in the field of medical such as high precision cancer detection [ii]. High resolution ground penetrating radar also uses UWB technology. In 2002, the Federal Communication Commission (FCC) in America completely transformed and revolutionized it by approving the unlicensed utilization of UWB range from 3.1 to 10.6 GHz [iii]. Since then, an elevated and enlarged number of research labs, academic institutions and governmental agencies have been trying to amplify the latent potentials of this technology and actualize it into reality. Its maximum power is restricted to -41dBm/MHz. UWB implies time shifting mechanism to broadcast binary data having rate in million pulses per second. In this 7.5 GHz bandwidth, several narrow band systems pre-exist. Interference problems emanate from these narrow band systems. UWB system is affected by WiMax(3.3 to 3.7 GHz), WLAN (5.15 to 5.35 GHz and 5.72 to 5.8 GHz) and ITU (7.95 to 8.4 GHz).One solution, to get rid of interference problem, is to use filter but it may add up to the expenditure and increase the multifaceted nature and sophistication of the system [iv]; a simpler technique which could be implied is the use of antenna in order to overcome this conundrum. There are varied methods and techniques employed with a specific end goal to accomplish the objective of band notching. One being the use of parasitic element in order to stop the undesired range of frequencies [v-vi]. Another method being the introduction of fractal geometry in the designing of antenna which notches specific frequencies and thus enlists itself in the category of notching techniques [vii]. Yet another method could be acquired where band notch UWB antenna is outlined by utilizing split-ring resonator. The dimensions of the rings determine notch frequency [viii]. Additionally, open loop, closed loop, open-circuited and short-circuited coplanar waveguide resonators are used to design band notch UWB antenna [ix-x]. Apart from the above mentioned procedure, yet again, Computer auto-design technique is one of the procedures in which optimization process is used to design band stop antenna [xi-xii]. Last but not the least, Cuts or slots of various geometrical shapes are driven in the radiator to achieve band notch characteristics. Current flows mainly on the surface of patch feeding line and ground plane and thus, cuts in these portions trap the current. The dimensions of the cuts are proportional to the notch frequency and its bandwidth [xiii-xiv]. This paper is based on slot technique of band notching which uses CST Microwave Studio Suite for simulation. Triple stop band characteristic has been achieved by introducing 'I' shaped and 'C' shaped slots and an inverted 'U' shaped cut in the radiating element. The excitation given here is microstrip line in nature.

II. Antenna Design

UWB monopole antennas employ various geometrical shapes but in our propounded design, hexagonal geometrical structure has been brought into service. The desired antenna is formulated on FR-4 substrate. Its thickness (h) is taken to be 1.6 mm so as to achieve the relative permittivity (ε_r) of 4.6. The dimensions of the substrate are 30 x 28*mm*. The dimensions of the ground plane are 8 x 28*mm*. It also has a slot in the top mid of ground which has a length of 3.5mm and width of 3.3mm. The desired antenna is provided with a 50 Ω micro strip feed which has a length of 8mm and width of 3mm. The length of each side of the hexagon is 10 mm. The resonating range of this antenna varies from 2.65 to 11.3 GHz. Different slots are exploited to stop various bands to side-step interference. WiMax band (3.3 *to* 3.7 *GHz*) is thwarted by 'I' shaped slot of dimension 12.5 *mm* x 0.3*mm*. 'C' shaped slot having length 18.7 mm and width 0.5mm is made use of to stop the band in the range of 5.15 *to* 5.8 *GHz* used for WLAN application. The ITU frequency band (7.95 *to* 8.4 *GHz*) has been stopped by inverted 'U' shaped slot of dimension 12.28 *mm* x .60*mm* in feeder line and lower portion of the patch. Notch frequency and substrate permittivity determine dimensions of the slots. At notch frequencies, length of the slots is quarter wavelength or half wavelength. The following postulates define length of the slots (*Ls*) [15].

$$Ls = c/(4f_n\varepsilon_c) \quad (1)$$

or

$$Ls = c/(2f_n\varepsilon_c) \quad (2)$$

Whereas

$\varepsilon_c = \sqrt{(\varepsilon_r + 1)/2}$.

ε_c is the relative dielectric constant of FR-4 substrate
Ls is length of slot in mm,
C is the speed of light and its value is 3 x 10^8 *m/s* and
f_n is notch frequency in Ghz.

The above equations are used to determine the dimensions of the design. By careful analysis and parametric study of the proposed model, the final structure of the antenna is obtained which is displayed in illustration 1. The length of 'I' shaped slot is 12.5mm and its width is 0.3mm. The length of 'C' shaped slot is 18.7 mm and its width is 0.5mm. The inverted 'U' shaped slot is 12.28 mm long and its width is 0.6mm. The other parameters are recorded in Table 1.

TABLE I
DIMENSIONS OF THE VARIOUS PARAMETER OF THE NOVEL ANTENNA DESIGN

Parameters	Value(mm)	Parameters	Value(mm)
L	30	L_1	1
W	28	L_2	7
H_1	6	L_3	1
H_2	10	L_4	12.5
H_3	5.5	L_f	3
H_4	6		
H_5	5.5	L_g	3.5
H_6	8	W_g	3.3

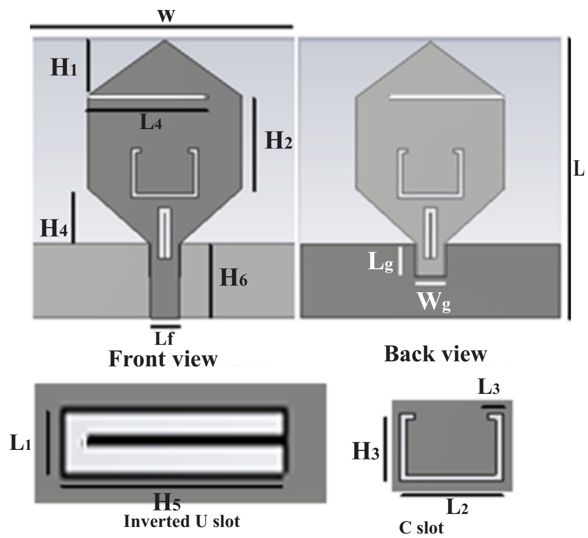


Fig. 1. Design of Novel Hexagonal Antenna

III. DISCOURSE/DEBATE ON FINDINGS

In this portion, the findings of UWB monopole antenna with triple notch bands are put forward. The S_{11} (*dB*) characteristic of the suggested antenna is displayed in Fig. 2. This graph reveals the wideband behavior of the antenna in which 2.65 to 11.3 GHz portion of S_{11} (*dB*) is less than -10dB which stands perfectly in line with the criterion set by FCC.

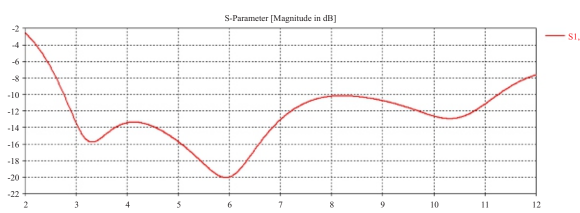


Fig. 2. S_{11}(dB) of the novel Antenna covering the whole UWB Band

Fig. 3 shows the VSWR plot without notched characteristics.

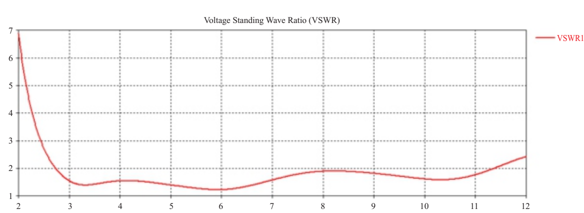


Fig. 3. VSWR plot of the novel antenna

Fig. 4 shows the notched characteristics of the antenna at three different communications bands and from VSWR plot it is clear that the three bands centered at 3.48, 5.52 and 8.15 GHz have been halted by the antenna.

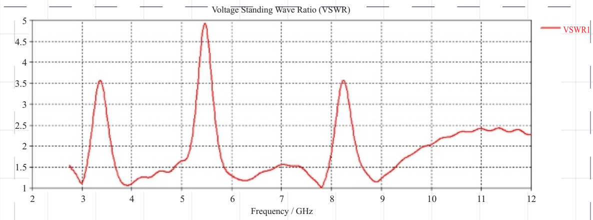


Fig. 4. VSWR plot of the antenna with triple stop band features

In the entire 8.65 GHz bandwidth $VSWR \leq 2$ except at notch bands.

Fig. 5, Fig. 6 and Fig. 7 represents the stepwise return loss of the proposed antenna with three notch bands. Fig. 8 is showing all the results in one plot.

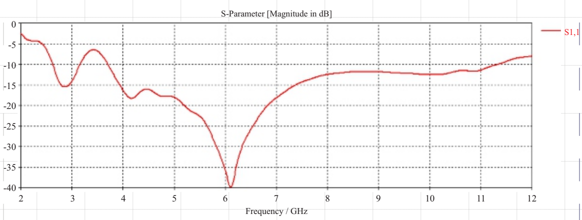


Fig. 5. S_{11}(dB) of the antenna with first notch of WiMAX band.

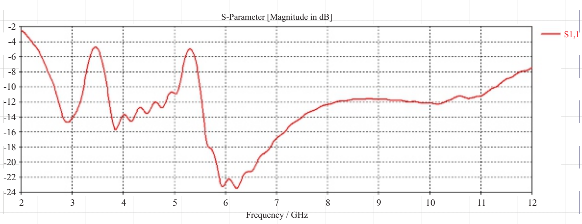


Fig. 6. S_{11}(dB) of the antenna with first and second notch of WiMAX and ISM bands.

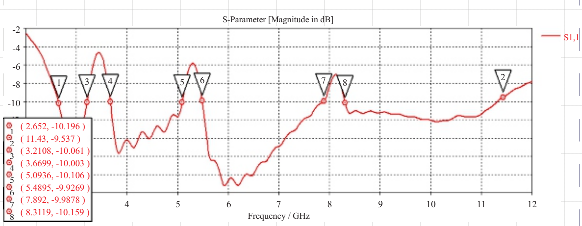


Fig. 7. S_{11}(dB) of the antenna with first, second and third notch of WiMAX, ISM and ITU bands.

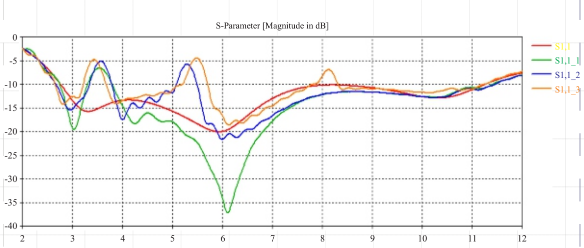
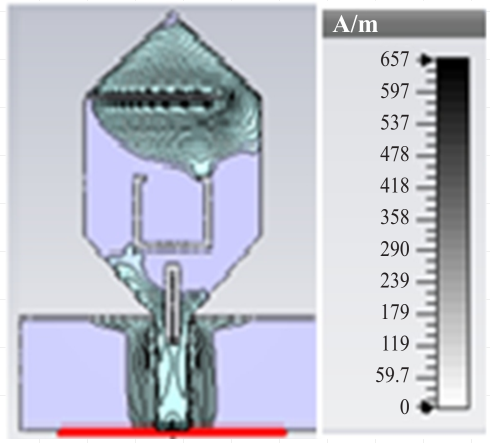
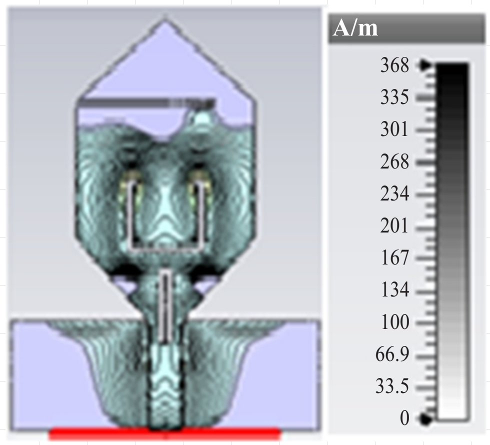


Fig. 8. Progressive S_{11}(dB)of the proposed antenna with all three notches.

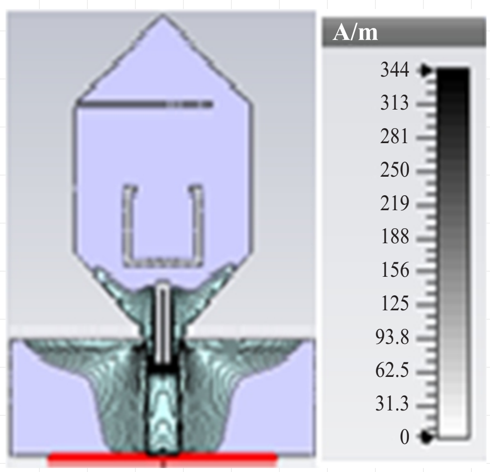
To discuss notching characteristics of the simulated antenna, the surface current circulations at various bands are depicted in Fig. 9(a), (b) and (c).



(a)



(b)

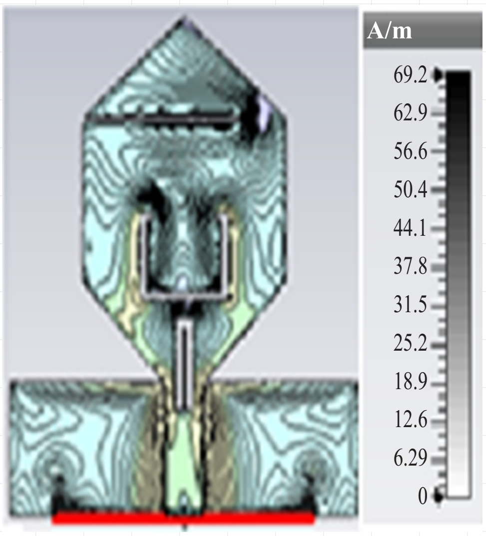


(c)

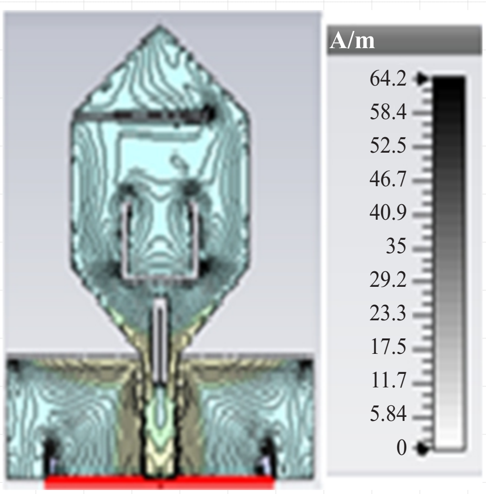
Fig. 9. Current circulations at stop bands of (a) 3.48GHz, (b) 5.52GHz and (c) 8.15GHz

While Fig. 10 (a) and (b) highlights the current circulations at 4.5 GHz and 7 GHz which are considered as present in pass bands.

The results presented in Illustration 9 and 10 signify that energy is concentrated around the slot and does not radiate into the space. At stop band, the current circulation is dominant in the area encapsulating the slots which enhances near field radiation counteracted and thus enhanced power is bounced back to the incoming terminal. This way the band notching characteristics of antenna can be achieved [xvi]. While current distribution at pass bands show that slots have negligible effect on the radiations.



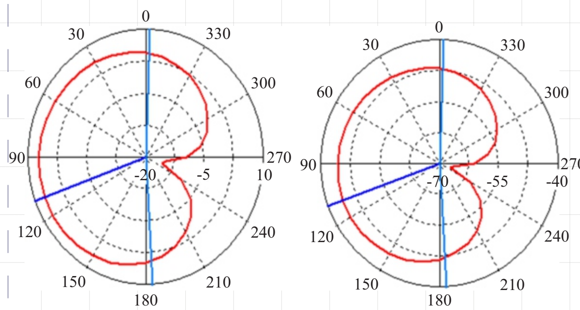
(a)



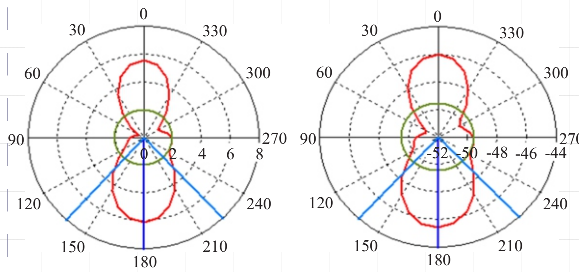
(b)

Fig. 10. Current circulations at pass bands of (a) 4.5GHz and (b)7GHz

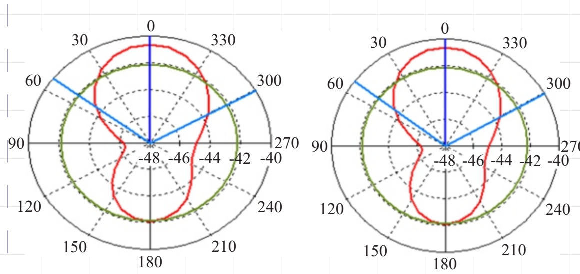
The radiation pathways at varied frequencies are displayed in Fig. 11. Fig. 12 describes the gain of the antenna. The gain increases with increase in frequency. However, there is a sharp decrease in gain at notch bands. The 3-dimensional (Directivity) radiation pattern of the propounded antenna is displayed in Fig. 13 with 6.8dBi at 9 GHz of directivity.



(a) E & H plane at 3.48 Ghz



(b) E & H plane at 5.52 Ghz



(c) E & H plane at 7 Ghz

Fig. 11. Radiation pattern (E and H-plan) at (a) 3.48GHz, (b) 5.52 GHz and (c) 7GHz

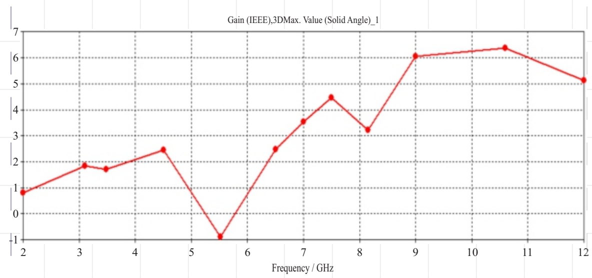


Fig. 12. Gain versus Frequency plot

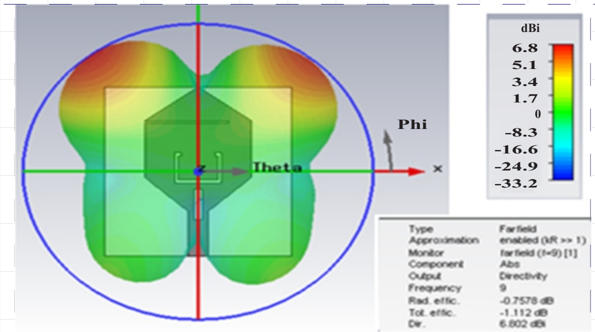


Fig. 13. The 3-dimensional (directivity) radiation pattern

IV. Conclusion

A monopole antenna with triple stop bands features for UWB application has been propounded. This 30 x 28 mm^2 antenna operates in the whole UWB range barring three stop bands. These three stop bands at 3.48 GHz, 5.52 GHz and 8.15 GHz have been actualized by the introduction of slots in radiator and micro-strip feeding line. 'I' shaped slot in radiator stops WiMax band. 'C' shaped cut in the radiator notches WLAN. Inverted 'U' shaped cut in radiator and feeding line blocks the ITU band. The length of cuts is half or quarter of guided wavelength of central frequency of notch bands. The simulated findings confirm the suitability of proposed antenna for UWB communication system to evade interference with above mentioned three narrow bands.

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