IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 10, Issue 4 Ver. III (July – Aug. 2015), PP 09-15
www.iosrjournals.org

A Planar Ultra-Wideband Antenna with Multiple Band-Notch Characteristics

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Abstract: *In this paper a compact planar ultra-wideband (UWB) antenna with notch characteristics is presented which excites multiple notches at different frequencies across the band of operation. Required notch frequencies are obtained with the help of T shaped slots and inverted L-shaped metallic filter element. The notch frequency is varied with the help of slot on patch and ground plane. The proposed antenna has overall dimensions of 22mm×23 mm ×1.6mm. The proposed antenna operates in the FCC defined UWB frequency range (3.1-10.6 GHz). The proposed geometry was designed and optimized with the help of ie3D software. The optimised (through ie3D) results of the geometry have been validated by a prototype and found nearly good results.*
Index Terms: *Ultra-wideband antenna, Microstrip Antenna, Notch Filter*

I. Introduction

The U.S Federal Communication Commission (FCC) authorized the UWB frequency range from 3.1-10.6 GHz that is unlicensed in Feb 2002. Hence, important research activities can be conducted in this range which can be used for academic and industrial fields [1]. UWB antennas have many challenges in design including radiation stability, compact size, low manufacturing cost, and electromagnetic interference. Interference is mainly because of overlap in the frequency range of FCC with various existing wireless communication systems, viz. WiMAX, IEEE 802.16 system at 3.5GHz (3.3-3.7GHz) and wireless local area network (WLAN) IEEE 802.11a system which uses 5.2/5.8GHz (5.15-5.825GHz) [2]. Therefore, to avoid the interference, notch filters find great significance. Notch filters are introduced internally to minimize the space and cost significantly instead of adding them externally [2].

There are several works reported by researchers on introducing notch frequencies in the band of operation [2-7]. Some of them are achieved by using U-shaped [3], H-shaped slot and C-shaped [5] slot in the patch or radiating ground plane one can achieve the notch filter [3-5]. Instead of using different shaped slots, few of the researchers used complementary split ring resonator (CSRR) [5], complementary spiral loop resonator (CSLR) and the addition of parasitic elements for notch band filter design [6, 7]. The resonance frequency can be varied by adjusting the slot dimensions for all these methods. Most of these methods need changing the geometry parameters of an antenna. Hence, without any change in the antenna geometry, band notch structures using capacitively loaded loop resonator (CLL) was achieved in [2]. CLL element has characteristics of a high-quality factor and compact size. But it can be tough to put CLL element in slot antenna itself. Also, it has drawback that area of CLL element may vary with frequency.

So, in this design, a compact planar UWB antenna with multiple notch characteristics is presented. The proposed antenna was designed to excite single, dual, triple, and four independent notches at various frequencies across the band of operation. The details of these designs have been presented in the subsequent sections. The paper is organized as follows. The antenna geometry and its optimised dimensions are presented in Section 2. Optimization procedure is also presented in the later part of this section. Section 3 covers the experimental results and discussions. Finally, the work is concluded in Section 4.

II. Antenna Geometry With Single Notch Frequency

The antenna consists of the finite ground plane on the backside of the substrate and radiating element & filter (metallic strip) elements on the front side of the substrate. Figure 1 shows basic geometry of the proposed UWB antenna with single notch characteristics. However, if no notch characteristics are required, then the metallic strip (on right side of the radiator) has to be removed. The FR4 epoxy resin material is used as substrate with dielectric constant of 4.4 with height of the substrate (h)=1.6mm. The overall dimensions of the antenna are 22mm×23mm×1.6mm. Microstrip feeding is used for the excitation of the geometry. All the parameters of the optimized geometry are represented in Table 1

Table 1: Dimensions of the geometry

Parameter	L	W	l_f	w_f	l_t	w_t
Value(mm)	14.0	7.0	6.0	3.0	3.2	0.8

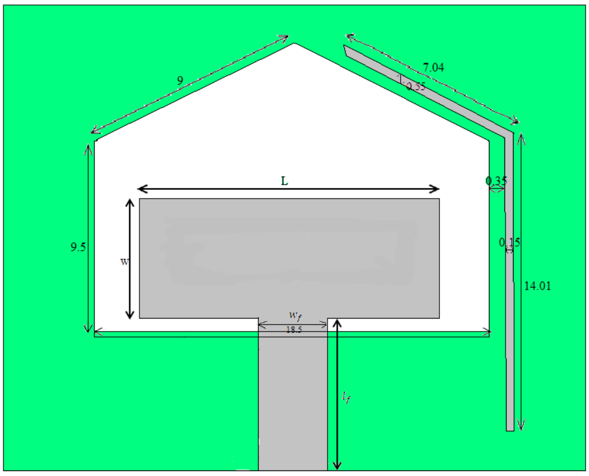


Fig. 1: UWB antenna geometry (all values are in mm)

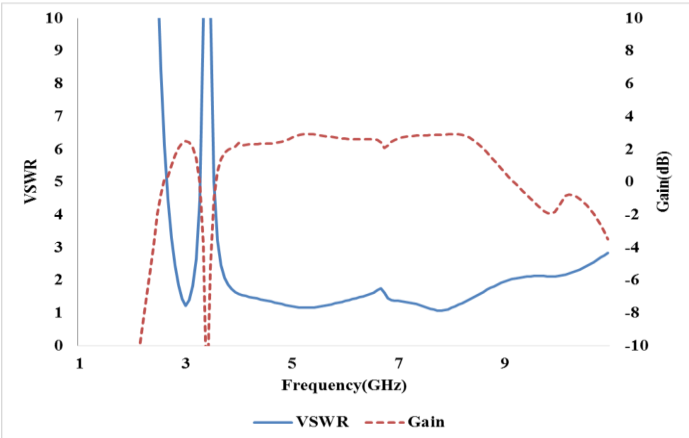


Fig. 2: VSWR vs. frequency plot of antenna geometry shown in Figure 1.

2.1 Two Notches

In order to excite the two notches, the single slot (U-shaped) about (22mm length and 0.5mm width) is introduced on radiating patch (pl. ref. Figure 3). The introduced slot excites a notch at 3.5 GHz and other at 4.4 GHz. It is observed that notch frequency is obtained by varying width and length of the slot on the radiator patch.

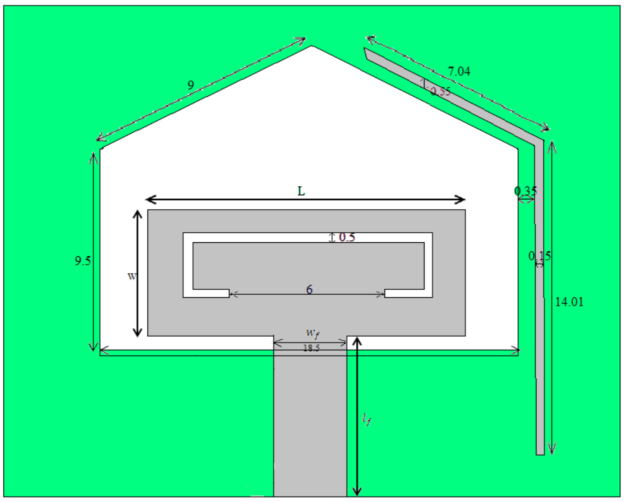


Fig. 3: Introduction of single notch using a metallic patch

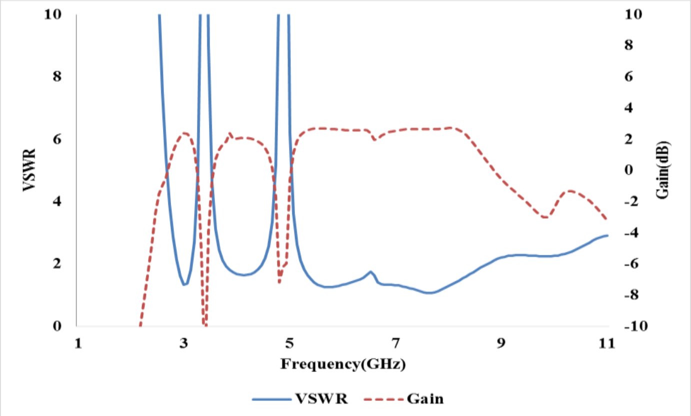


Fig. 4: VSWR, and gain vs. frequency plot of the geometry shown in Figure 3.

2.2. Three Notches Geometry

For three notch characteristics, one can achieve using the same antenna geometry with two slots (pl. ref. Figure 5) on the metallic patch of lengths 22mm and 16mm respectively. The VSWR characteristics of the antenna are shown in Figure 6. In Figure 6, it may be noticed that the third notch is excited at about 7GHz without disturbing the first two notches (at 3.5GHz and 4.4GHz).

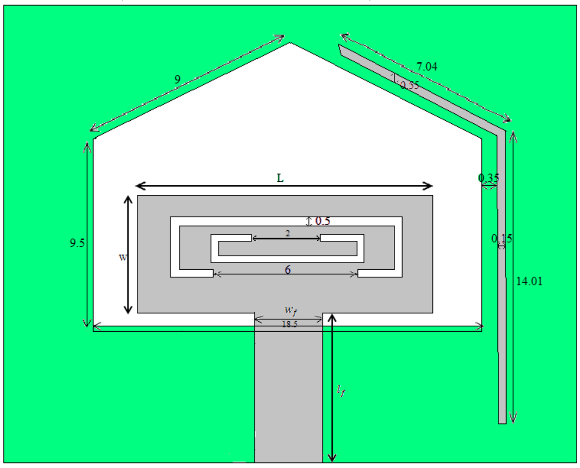


Fig. 5: UWB antenna with three notch characteristics.

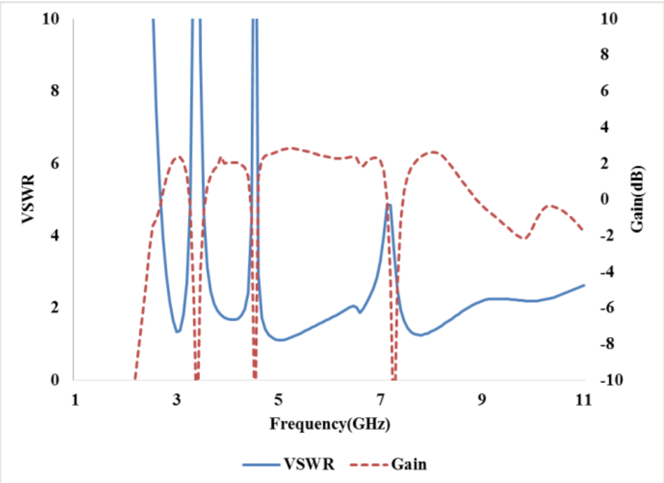


Fig. 6: VSWR and gain vs. frequency plots of the geometry shown in Figure 5.

2.3. T Shaped Slot on Ground Plane for Four Notches

In this effort we tried to excite four notches. For this two T-shaped slots (1mm width and 3mm length) have been introduced on the ground plane (Figure 7). The effects of these T- shaped slots on antenna characteristics are presented in Figure 8. From the Figure 8, it may be noted that the fourth notch appears at

9.8GHz. Like previous approaches, here too the first three notches (3.5GHz, 4.4GHz, and 7GHz) remain unaltered.

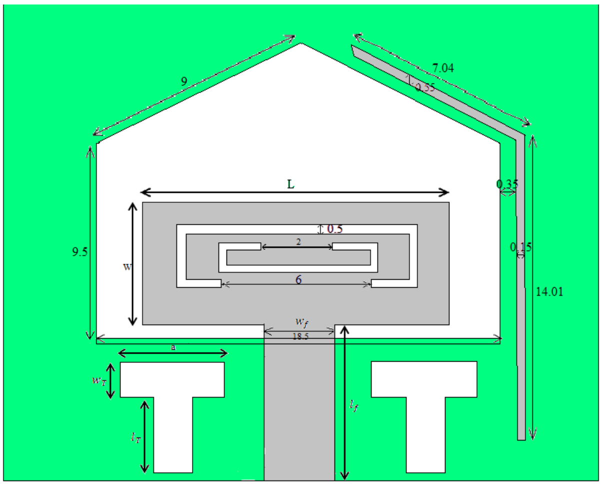


Fig. 7: The antenna geometry for exciting four notches

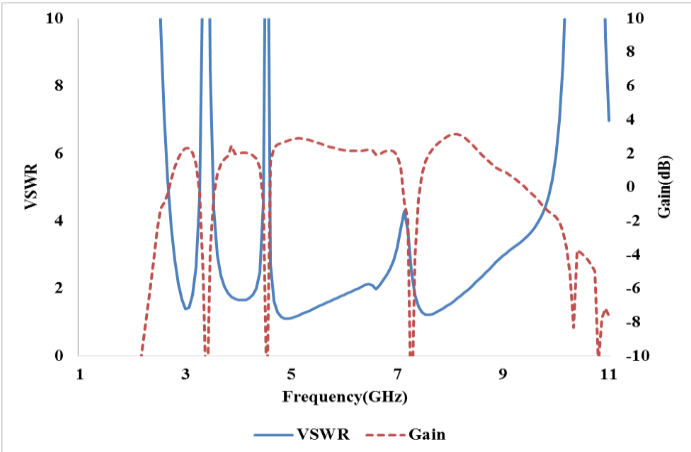


Fig. 8: VSWR and gain total vs. frequency plots of the geometry shown in Figure 7.

2.4 T Shape Notches with Filters

In yet another approach, we introduced T shaped slot with inverted L- filters as shown in Figure 9. All these dimensions are depicted in Table 2. Filters (metallic strips) are placed on the front side of the substrate. With these geometry parameters the notch characteristics are obtained at 3.5 GHz, 4.4 GHz, 7 GHz, and at 7.7 GHz. By introducing the additional L-shaped strips (filters), the notch frequency of 9.9GHz that was obtained in the earlier approach (Section 2.3), can be tuned to 7.7 GHz.

Table 2: Dimensions of the optimised geometry shown in Figure 9

Parameter	L	W	l_f	w_f	l_t	w_t	a	b	c	D	e	g
Value(mm)	14	7	6	3	3.2	0.8	5.25	0.5	4.75	6.75	1.5	1.75

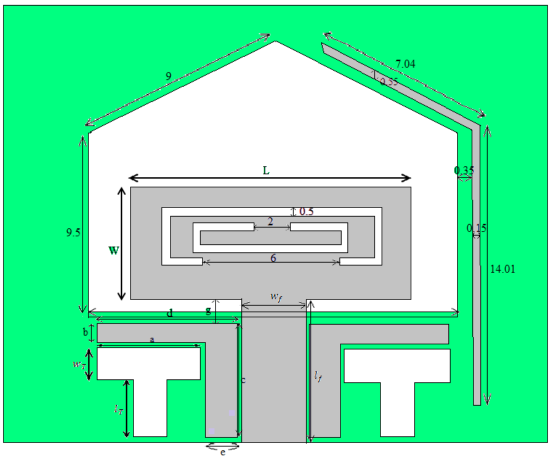


Fig. 9: Four bands notch optimised antenna

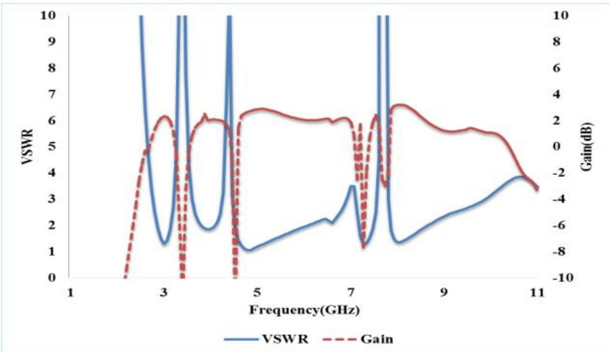
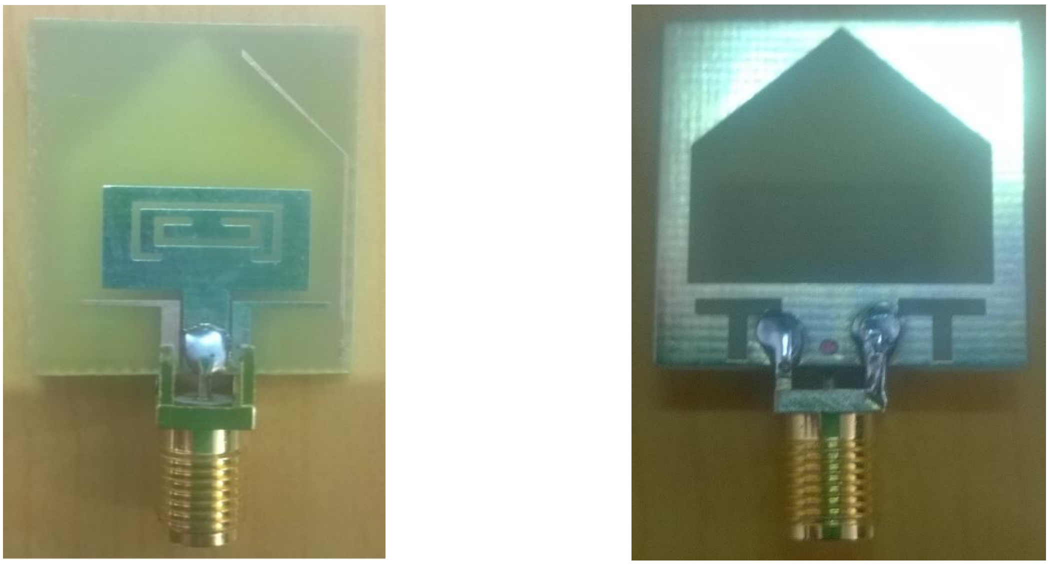


Fig. 10: VSWR and gain total vs. frequency plots of the optimised geometry shown in Figure 9.

III. Experimental Validation And Discussions

The final geometry shown in Figure 9 with its optimized dimensions presented in Table 2 was fabricated and tested. The FR4 glass epoxy substrate was used for fabrication of designed geometry with dielectric constant of 44, and a thickness of 1.6 mm. A photograph of the fabricated prototype shown in Figure 11, and its S_{11} measurement setup is shown in Figure 12. The input characteristics comparisons of measured and simulated values are presented in Figure 15. From Figure 15 it may be noted that the measured results are fairly agreed with the simulated values. The radiation patterns are presented at several frequencies in the operating bands of frequencies (excluding notches) to represent the proper working of the antenna at desired bands of frequencies.



(a) (b)

Fig. 11: Fabricated prototype (a) Front side (b) Back side.

Fig. 12: Photograph of the measurement setup.

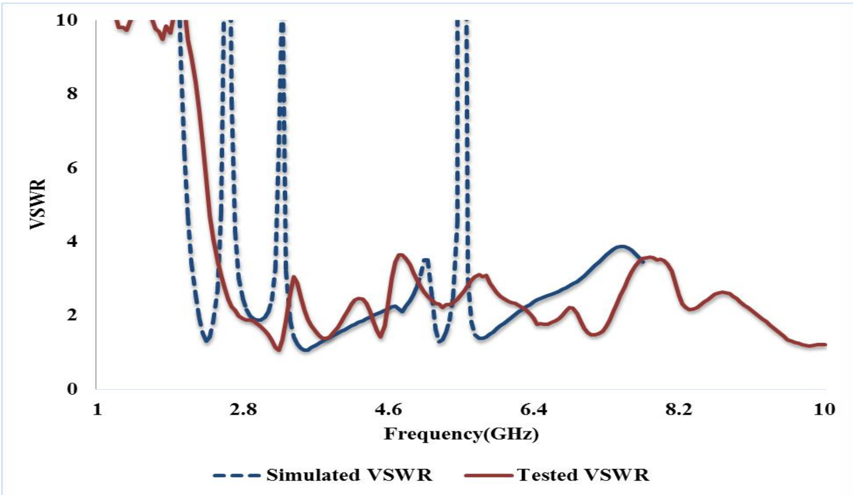
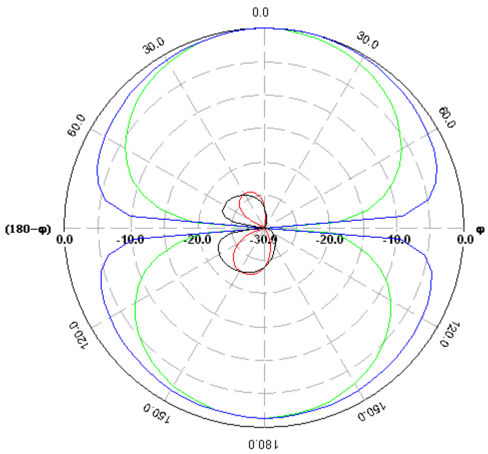
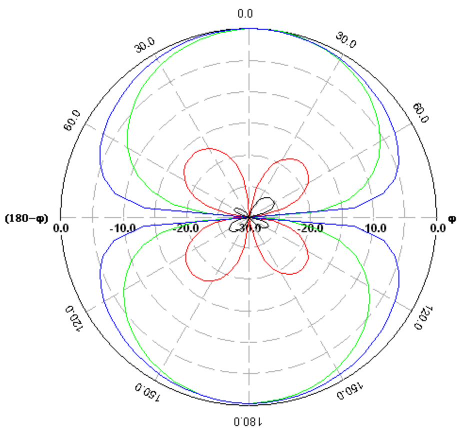


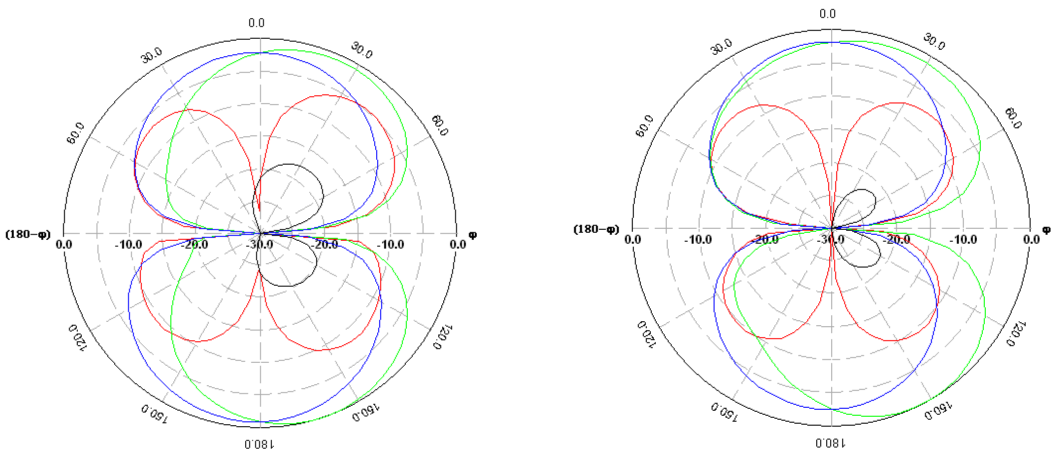
Fig. 13: VSWR vs. frequency comparisons of measured and simulated data.



(a) 3 GHz



(b) 4.7 GHz



(c) 7.4 GHz (d) 8 GHz

Fig. 14: E and H plane radiation patterns at different frequencies in operating bands. Note: Blue curve: H-Co. Poln.; Gree curve:E-Co. Poln.; Red curve: E-Cross Poln.: Black curve: H-Cross Poln.

IV. Conclusions

An ultra-wideband (UWB) antenna with multiple notch characteristics antenna has been presented. Designs are demonstrated that one, two, three, and four notches in the bands of operation can be excited. Also, fine tuning of notch characteristics can be achieved by varying either length or width of these metallic filters. The fabricated prototype was measured and compared with the simulated optimized results. A fair matching with the measured data was observed. The antenna presented here is a good candidate for eliminating any unwanted or disturbing frequency in the desired band. The further study includes the modeling to understand the modes of notch band characteristics.

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