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A Planar Microstrip Antenna with Enhanced Triple-Bands Notched Characteristics for UWB Applications

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Abstract- A compact printed ultra-wideband (UWB) monopole antenna with triple band-notched characteristics is presented. The antenna consists of a square patch and a modified grounded plane. In order to realize Triple band notched bands characteristics, a T-shaped Stripinsert in the square slot of the radiation patch and a pairs of U-shaped parasitic strips beside the feed line is used. To remit the potential interference with coexisting wireless systems operating over 3.3–3.6 GHz, 5.15– 5.35 GHz, or 10.12-10.3 GHz bands, the overall dimensions of the proposed antenna are 31mm×26 mm ×1.6mm.The measured and simulated results are introduced and show that the proposed compact antenna has a stable and omni directional radiation patterns across all the relevant bands.

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Abstract- A compact printed ultra-wideband (UWB) monopole antenna with triple band-notched characteristics is presented. The antenna consists of a square patch and a modified grounded plane. In order to realize Triple band notched bands characteristics, a T-shaped Stripinsert in the square slot of the radiation patch and a pairs of U-shaped parasitic strips beside the feed line is used. To remit the potential interference with coexisting wireless systems operating over 3.3–3.6 GHz, 5.15–5.35 GHz, or 10.12-10.3 GHz bands, the overall dimensions of the proposed antenna are 31mm×26 mm ×1.6mm.The measured and simulated results are introduced and show that the proposed compact antenna has a stable and omni directional radiation patterns across all the relevant bands.

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I. Inroduction

With the definition and acceptance of the ultra-wide-band (UWB) impulse radio technology in the USA [1], there has been considerable research effort put into UWB radio technology worldwide. However, the non-digital part of a UWB system, i.e., transmitting/receiving antennas, remains a particularly challenging topic. In 2002 [1]UWB communication systems have attracted considerable attention due to the advantages of high-speed data rate and extremely low spectral power density, since the Federal Communications Commission (FCC) first approved the frequency band from 3.1 to 10.6 GHz for commercial UWB applications. Since then, the Probable design and implementation of UWB system has become a highly competitive topic in both industry and academy communities of telecommunications. In particular, the antenna ofultra-wide bandwidth is the key component of the UWB system and has attracted significant research power in the past few years [2]. In [3], The FCC approved the frequency range for causing the interference to the existing wireless communication systems ,such as the IEEE 802.16 Wi MAX system at 3.5 GHz (3.3-3.7 GHz) and the IEEE 802.11a wireless local area network (WLAN) system at 5.2/5.8 GHz (5.15-5.825 GHz) and dedicated short-range communication (DSRC) for IEEE 802.11p.

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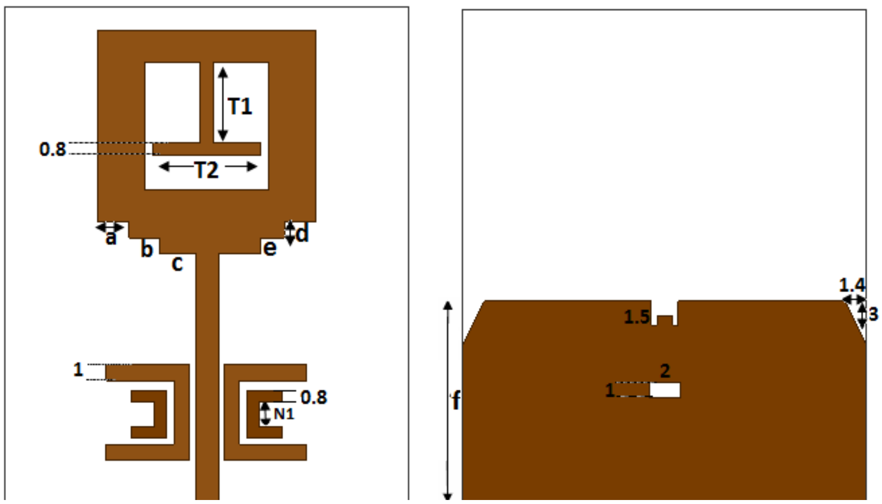
In the literature, various techniques have been applied in the UWB antenna to achieve the single band-notched function. The widely used methods are etching slots on the patch or on the ground plane, i.e., such as Challenges of the feasible UWB antenna design include the wide impedance matching, radiation stability, low profile, compact size, and low cost for consumer electronics applications. For some UWB applications which does not require overall compact size of the transmitter or receiver, appropriately designed band pass filters or spatial filter such as a frequency selective surface (FSS) above the antenna can be used to suppress the dispensable bands [4].However for the UWB systems which demand a compact, less complex and low cost design, frequency band rejection function may be employed in the antenna itself, which includes embedding optimal shaped slot in the radiating patch or in the ground plane. The main problem of the frequency rejected function design is the difficulty of controlling width of the band-notch in a limited space. Furthermore, strong couplings between two band-notched characteristic designs for adjacent frequencies are obstacles to achieving efficient dual band-notched UWB antenna. [5] Many techniques have already been proposed to design band-notched antennas, for example, `L' shaped slot and a twisted `J' shaped slot , Square Aperture Strip , by etching two round shape slots, U-shaped slot, and by adding Strip like parasitic strip, U shaped antenna,[5-12]And most of the techniques is like the adding Strip and elements and integrate with the feed line of the antenna like Capacitive Loaded Line Resonators (CLLRs), SCRLH resonator structure, band rejected elements, self-complementary structure.[13-21]. And Most of the MIMO antenna technique also evolved for this Notch performance [22] adding two capaciti veloaded loops (CLLs) close to the micro-strip feed line, [23] T-shaped Strip-loaded ring-resonator (SLRR) [24] embedding a Strip that is located to the hollow center of feed [25] ground plane and a T-shaped exciting Strip [26, 27] monopole antenna with notches at four frequencies is presented. Notch characteristic satdesired frequencie sare obtaine dusing smaller ctangular metallic strips. [28]A T-shaped Strip embedded in the square slot of the radiation patch and a pair of U-shaped parasitic strips beside the feed line is used [29].

In this paper, a compact, micro strip fed, monopole UWB antenna with triple band notched characteristics is presented. This work adds perturbation in the surface current density of the radiating element and the feed element. Initially a reference antenna is designed, which exhibits radiating characteristics in the frequency band 3-11 GHz. The proposed antenna structure is simulated using the An soft High Frequency Structure Simulator (HFSS), A T-shaped Strip in the radiation patch and four U-shaped Strips beside the feeding line are used to realize triple-band-notch characteristic. The parametrical analyses of these filtering structures are carried out The simulation and measurement both indicate triple bands rejection with central frequencies of 3.6 and 5.5 GHz,10.2GHz respectively, and excellent notched band characteristics.

II. Configuration of Proposed Tipple Band Nothced Antenna



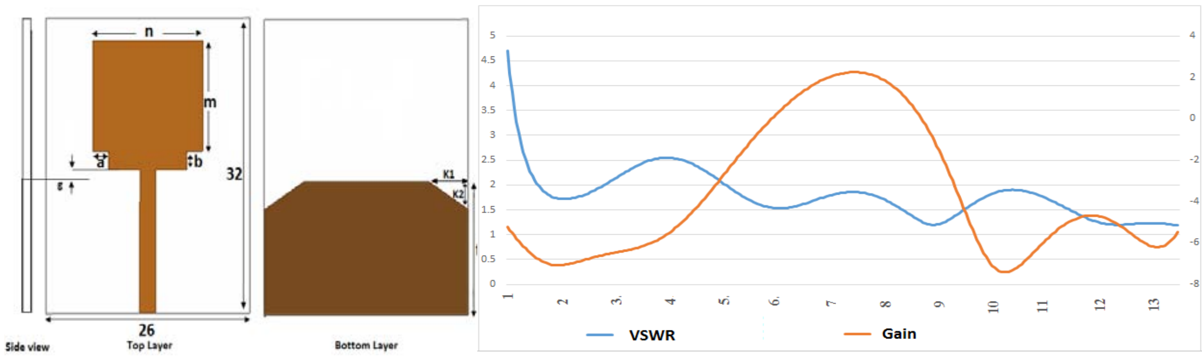
(a) Top view (b) Ground

Fig. 1: Geometry of proposed triple band notched UWB antenna.

In this design, the micro strip line fed triple band notch planar antenna consists of rectangular radiating patch and a partial rectangular ground plane is proposed shown in Figure 1. The patch with a dimension of m x n *is* printed on the top side PCB substrate while the partial ground plane having a side length fis printed on the bottom side. The proposed antenna has a compact size of *31x26*and is printed on 1.6mm thick Fr4 dielectric substrate with dielectric constant 4.4 and loss tangent 0.02. It is composed of a 50Ω micro strip feed line, a planar radiating patch with two round shape Strip and rectangular ground plane with a pair of C-shaped Strip to band stop function.

A. Uwb Monopole Antenna

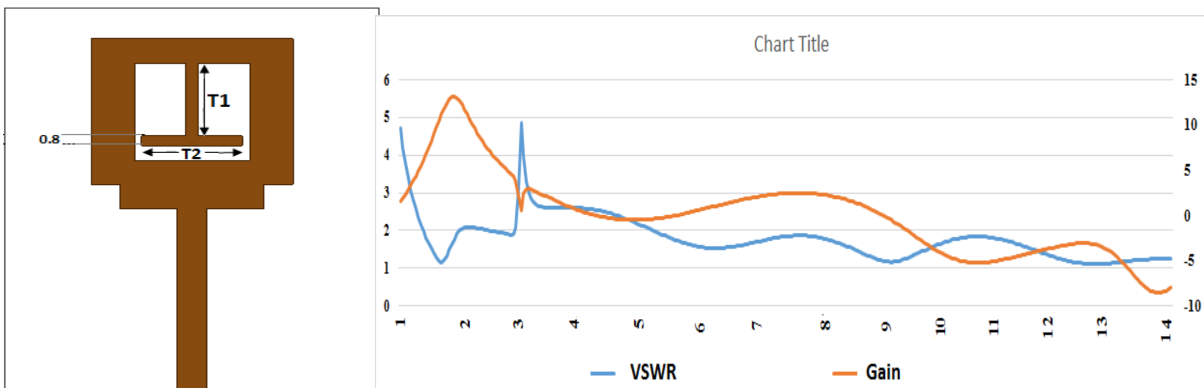
The evolution process for the compact UWB antenna.UWB monopole antenna the designed antenna of optimized dimensions is implemented with a low-cost on Fr4substrate shown in fig 2. To improve the bandwidth of the antenna, the partial ground plane is modified by cutting triangular shape slots at its top edge. The width of the micro strip feed line is chosen as 1.4 mm to achieve the characteristic cimpe dance of 50. The dimensions of the designed antenna after optimization are as follows: a= 2mm, b=2mm, s=15.5, f=11.5mm, m=12mm, n=14mm, g=1mm, K1=8mm, K2=3mm.



(a) (b)

Fig. 2: Configuration Parameters of The UWB antenna (a) Monopole Antenna (b)Comparison of VSWR and Gain of the Monopole Antenna.

B. Single Band Notched Uwb Antenna



(a) (b)

Fig. 3: (a) Geometry of the Single Band Notched UWB Antenna (b) Simulated VSWR of Single Band Notch UWB Antenna and Gain vs frequency

To reduce the interferences from the Wi MAX systems, the band-notched function is desirable in the UWB system. By inserting a T-shaped $\lambda/4$ open Strip in the micro strip feed line. The notch frequency given the dimensions of the Wi MAX band-notched feature can be postulated as formula [22]

The length of the U-shaped slot can be calculated by,

$$li = \frac{c}{4f_i\sqrt{\frac{\varepsilon_r+1}{2}}}$$

Where c and ε_{eff} are the speed of light in free space and the approximated effective dielectric constant, respectively.

C. Dual Band Notched Uwb Antenna

Then for wideband isolation there is a fork shaped a Strip introduced into the ground plane of the antenna, due to that mutual coupling get reduced.Fig.1. shows the proposed triple band notched UWB antenna. For more specifications of antenna dimensions of a Strip and the more branches get added and enhance the isolation but there is effect on impedance bandwidth. Fig. 4 shows the decreasing in mutual coupling of the antenna due to Strip structure. So the fork Strip here not only performs the role of an isolator, but also acts as a compensating radiator for the UWB antenna [6]. In wireless communication application occurs in UWB such as WLAN IEEE802.11a and HIPERLAN/2 WLAN operate at 5.15-5.35 GHz and 5.725-5.825GHz respectively. In order to reduce the electromagnetic interference, the stop band filter 5-6 GHz is often required for UWB system. However, the UWB systems with extra filter circuits are more complex and expensive.

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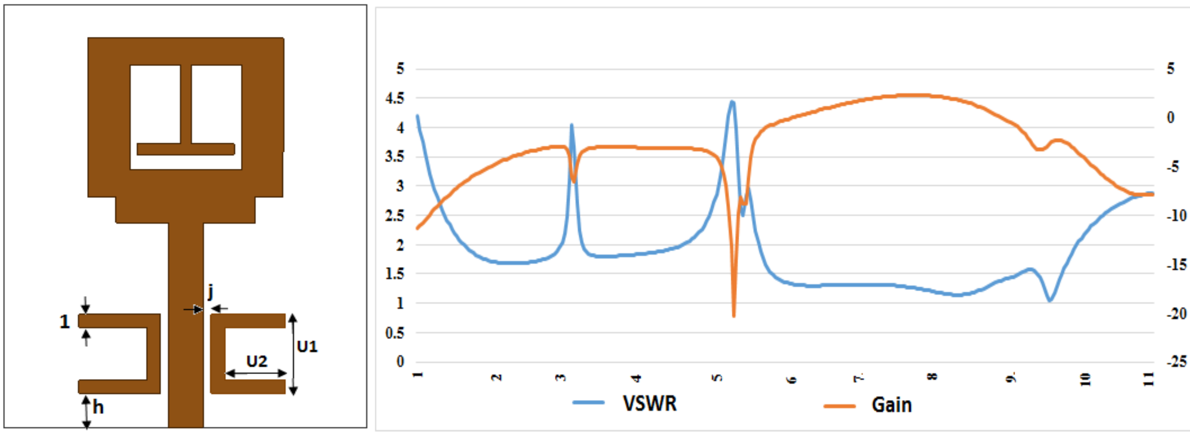


(a) (b)

Fig 4: (a) Geometry of the Dual Band Notched UWB Antenna (b) Simulated VSWR of Single Band Notch UWB Antenna and Gain Vs frequency

D. Triple Band Notched Band Antenna

For the triple band notch, the insertion of C-shaped resonating element along the symmetrically to feed line of the antenna with respect to the Dual band notch Element. The triple notch create at the 10.12-10.3GHz among the VSWR of the antenna. To minimize the potential interferences between UWB system and WiMAX system, the antenna with dual notched bands becomes necessary. Here a λ/4 C-shaped slits is integrate on antenna to achieve a triple band-notch antenna which is shown in fig 5. By adjusting the ground plane and the c-shaped Strip in the UWB antenna the triple band notched is investigated. These results can readily account for the triple band- notched characteristics.

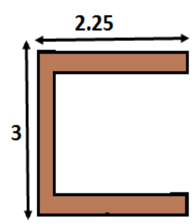


Fig. 5: C-Shaped Strip

To achieve triple band notch characteristics, three resonant elements are placed above the ground plane to generate three notches separately in the Wi MAX, the lower WLAN and the (ITU) 10.2GHzbands shown in fig 6.To create a band notch among the antenna for WLAN and WIMAX the T-shaped for WLAN and two C-shaped Resonating element add in the UWB antenna for the WLAN (3.5GHz) Wi MAX (5.5GHz) and ITU (10.2 GHZ) respectively. The band notch characteristics of the proposed antenna can be controlled by properly adjusting the parameters of these resonant elements placed at the Side of the feed as shown in Fig. 1.

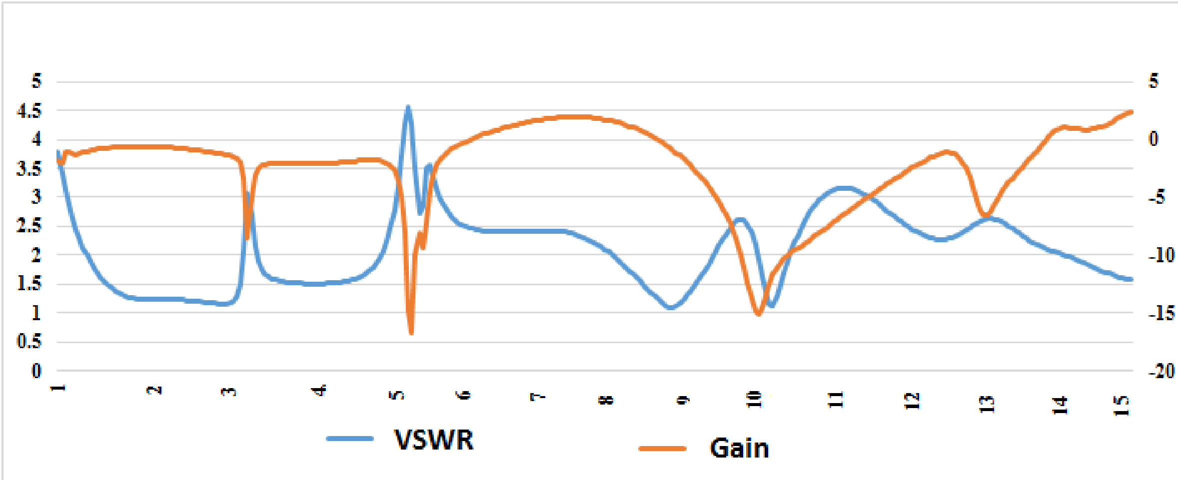
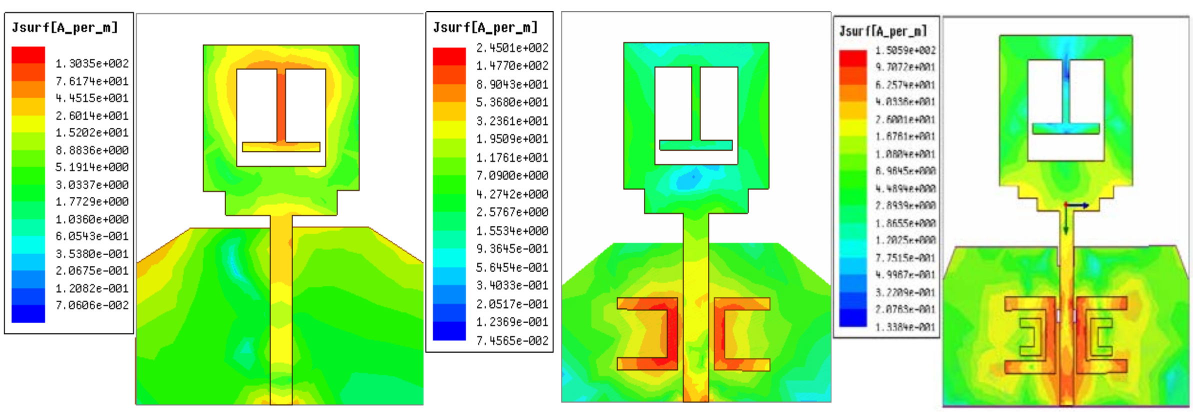


Fig. 6: Simulated VSWR of Single Band Notch UWB Antenna and Gain Vs frequency

As can be seen, the current distributions are mainly concentrated in the signal line and near the gap between the radiator and the ground plane. These sensitive locations therefore have been selected for the band-notched elements in this presented work.The mechanism of frequency rejection could be illustrated and discussed using current distributions along the radiating element. Fig.7 is the cases of wave radiation at frequencies of 3.2 GHz and 5.25 GHz and 10.2 GHz, respectively. It is seen that the current concentrates along curved edges and two sides of patch.



(a) (b) (c)

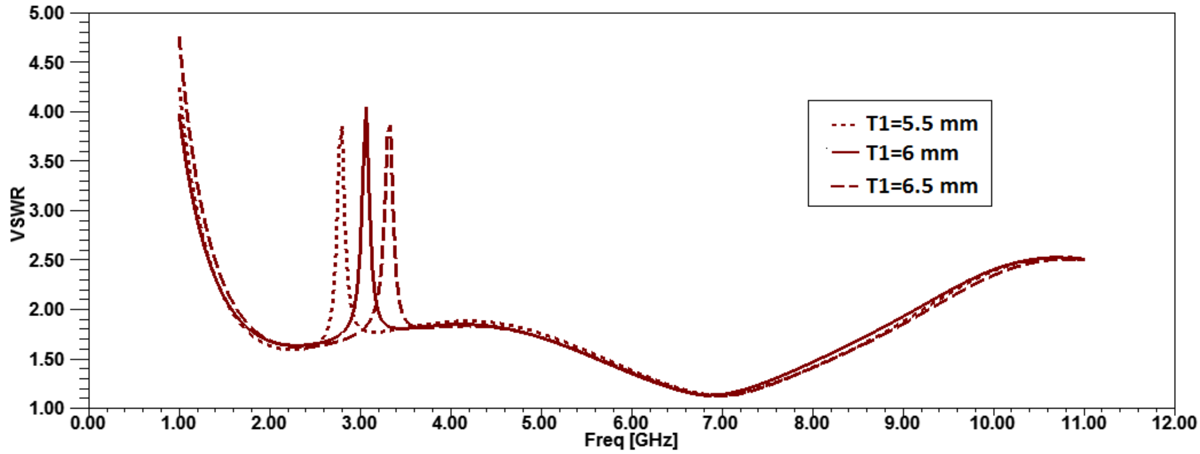
Fig. 7: Simulated Current Distribution at (a) At 3.2GHz (b) At 5.25GHz(c) At10.2GHz

As a result, the antenna can achieve radiate wave at those frequencies. Fig. 7(b) is the case of rejected frequency at 5.25 GHz. It can be observed that the current only concentrates around c-shaped slit and strongly concentrates at the small gap on the top c-shaped slit. There is no current distribution at the other parts of patch. This operational antenna can be considered as transmission line as the mode published and postulated in [7, 9].

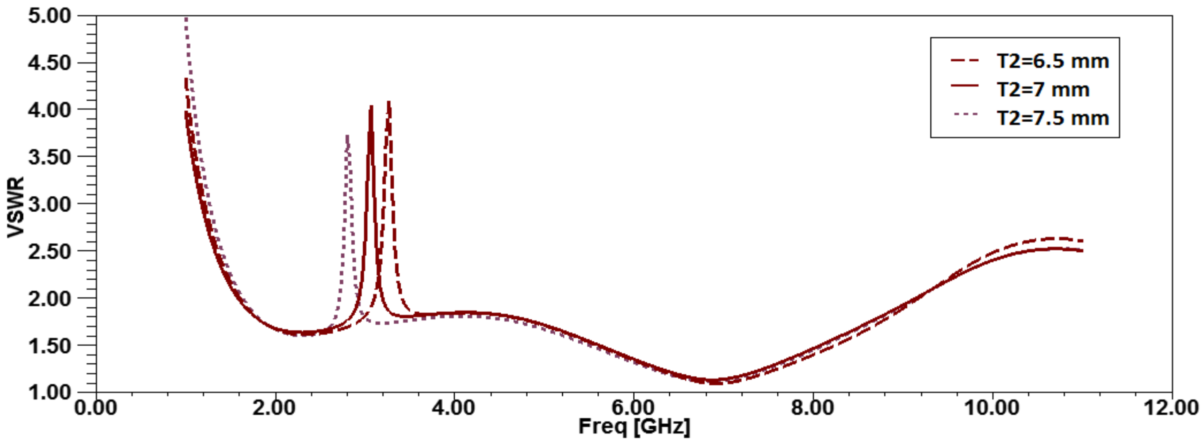
III. Parametric Analysis

a) The Effect of T1 and T2.

A parametric study of the triple band-notched UWB antenna has been conducted by computer simulation to explore how the dimensions of the different resonant elements affect the performances of band notches. Therefore, we need to investigate the individual resonant effects based on length, width, and position. Basically, the length and width of the each resonator acts as the inductance, and the distance between the adjacent arms acts as the capacitance. The couplings between the resonators and the main radiator act as the filter to create a notch band at certain frequency as explained in detail in [18, 19]. Several aspects were considered to optimize the final design like the overall impedance bandwidth of the antenna, the bandwidth of the notched bands, and the level of band rejection at notched frequency. The Impedance bandwidth of the antenna shown in fig 8.



(a)



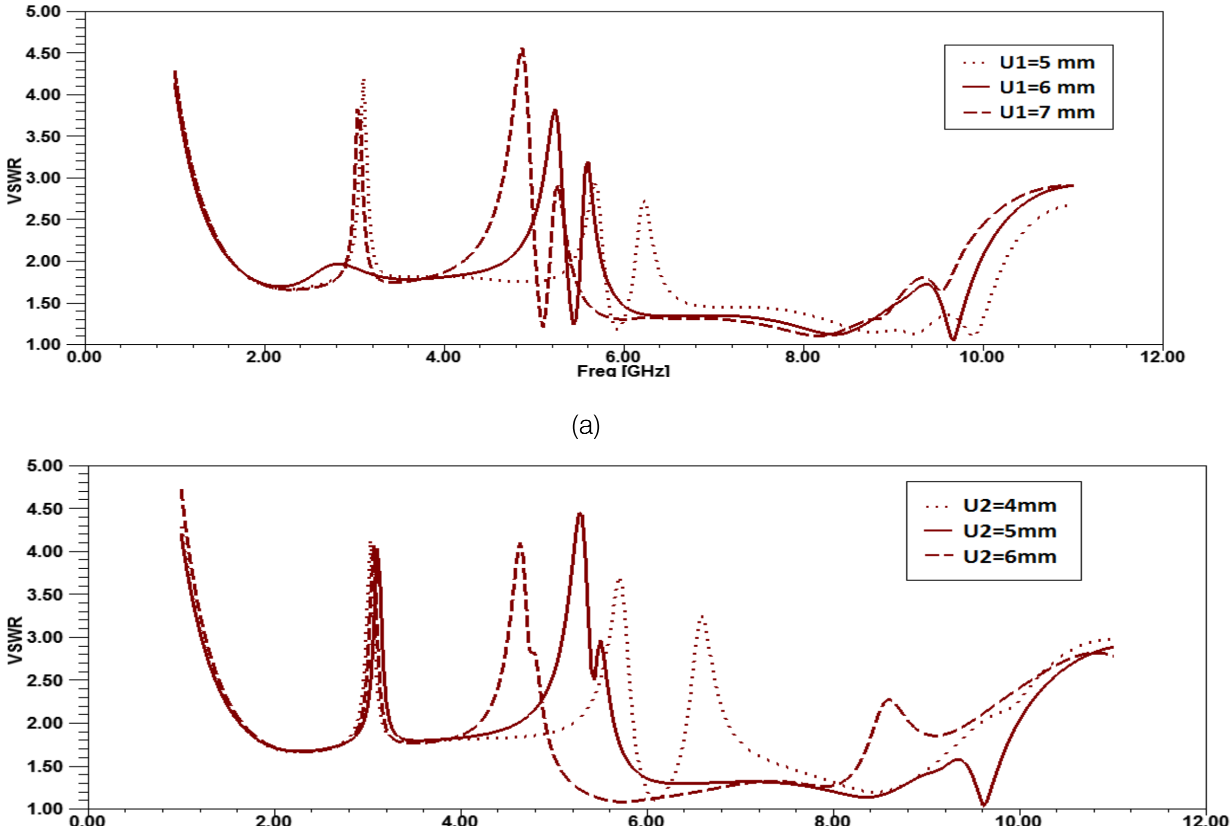
(b)

Fig. 8: Simulated band-rejection characteristics of the proposed antenna with dual notched bands in case of different (a) T1 and (b) T2

The impedance bandwidth of the antenna shown in above fig.8, which is varies with the dimension of T-shaped strip as the length increases the notch band is increases.

b) The Effect of U1 and U2

A Parametric study is accomplished based on realizing UWB characteristics. To enhance impedance bandwidth and create a band stop function, a Strip is connected to the U-shaped feed line that is located between inserted UWB Antenna. While by adjusting he dimension of U1 and U2 result in the Variation of VSWR of the UWB antenna which shown in fig 8. As we increase the U1 and U2 change in VSWR occurs as in higher frequency. The VSWR shift towards the higher frequency which shown in fig 9 (a) and (b).Obviously, the undesired frequency rejection band of 5.1 to 5.9 GHz is achieved by embedding C-shaped slit into the patch while the other frequencies in UWB are little affected. As this work provides a new design of UWB with triple band rejections.



(a)

(b)

Fig. 9: Simulated band-rejection characteristics of the proposed antenna with dual notched bands in case of different (a) U1 and (b) U2

c) *The Effect Of N1*

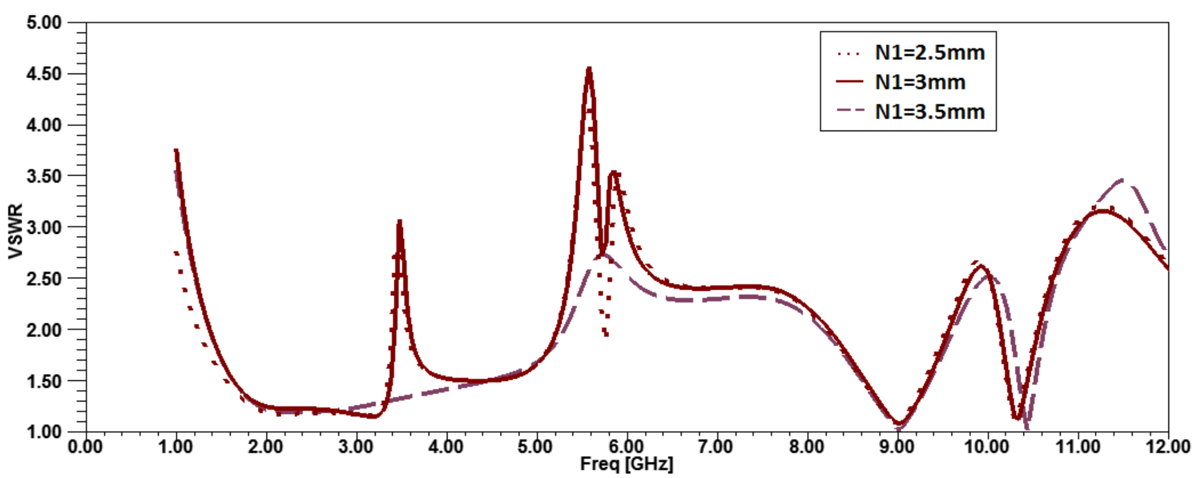
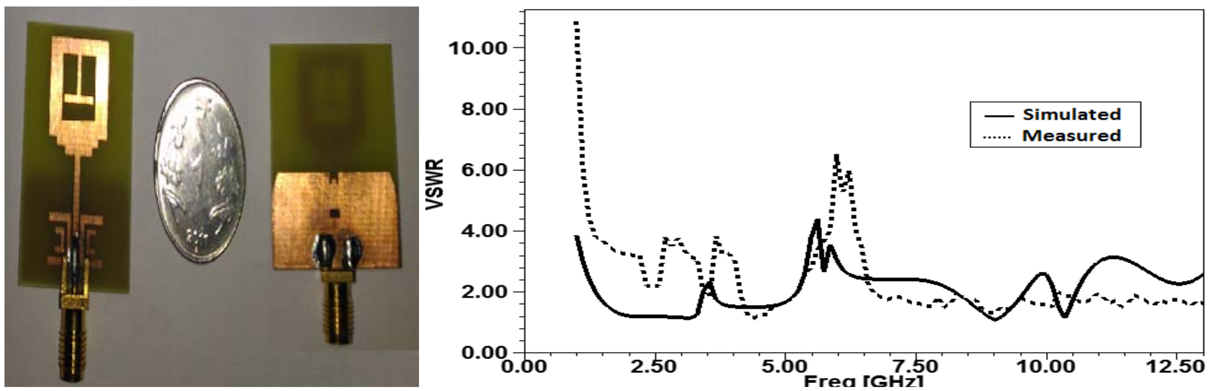


Fig. 10: Simulated band-rejection characteristics of the proposed antenna with dual notched bands in case of different N1

Finally by inserting slot in the ground plane of the UWB antenna and the by adding the C-shaped Strip add in the UWB antenna results in the notch at the higher Band at 10.1-10.3GHz.While we increase the dimensions of N1 the change in impedance bandwidth of the antenna which shown in fig 10. Sizes of these parameters have a serious impact on the position and bandwidth of this notch band. The optimize value of the N1 is taken as 3mm for the better notch at 10.2 GHz which having the third band notch in this design.

IV. Results and Discussions

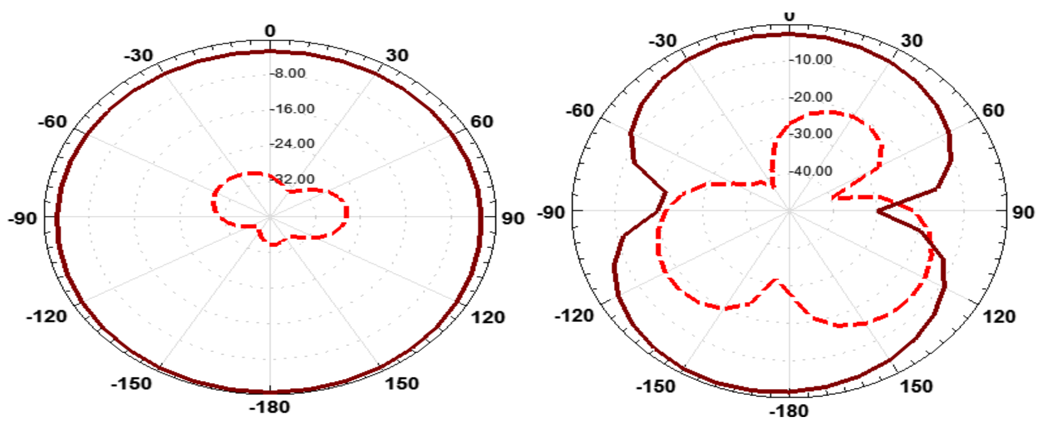


(a) (b)

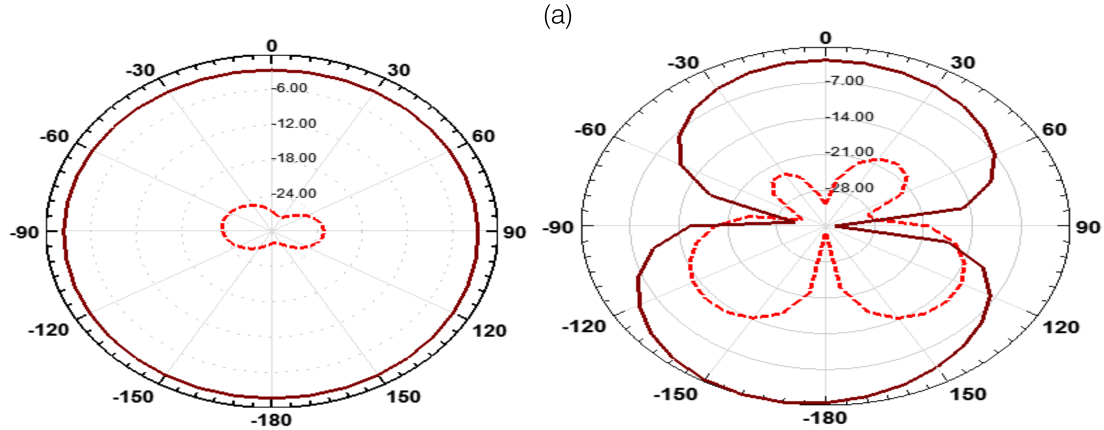
Fig.11: (a) Prototype of Antenna (b) Simulated and Measured Results

The designed antenna has an impedance bandwidth of 3-13 GHz covering commercial UWB band (3.1–12.6 GHz) and rejects the frequency band of 3.3-3.6 GHz, 5.15-5.35 GHz, and 10.1-10.25GHz to eliminate electromagnetic interference (EMI) problems in the UWB communication.The measured and simulated VSWR of the proposed triple band notch antenna is shown in Fig. 11.The comparison between the simulated results using commercial high frequency structure simulator (HFSS) and the results from the measurement of the fabricated antenna using a ROHDE N SCHWARZ ZVL Vector Network Analysers.Fig.11 shows the simulated and measured VSWR for the proposed antenna as well as the baseline antenna. By introducing T-shaped and C-shaped elements, tri-band-notched properties are obtained.

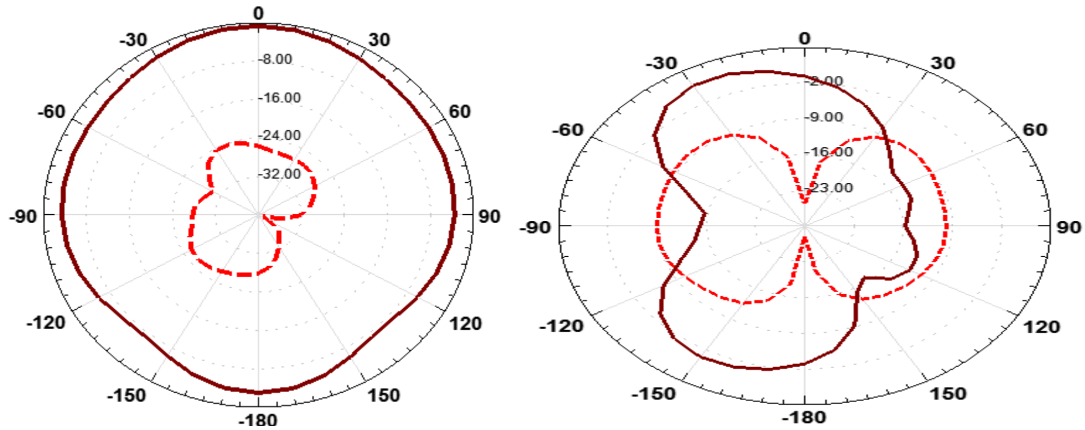
V. Radiation Mechanism



(a)



(b)



(c)

--------- Cross Polarization Co Polarization

Fig. 12: Simulated far-field radiation patterns; *(left)* H (x-z)-plane and *(right)* E (y-z)-plane at (a) 3.24 (b) 4.22, and (c) 9.12 GHz

The Simulated radiation patterns of antenna 3 at frequencies 3.24 GHz, 4.22 GHz and 9.12 GHz are illustrated in Figure 12. The radiation pattern is bidirectional in *E*-plane (*yoz* -plane) and omni directional in *H*-plane (*xoz* -plane) at 3.24 GHz and 4.12 GHz. It can be regarded as a monopole which features a doughnut-shaped pattern at the fundamental mode. As the frequency increases, the radiation pattern in *H*-plane (*xoz* -plane) is quasi-omni directional, and the cross-polarization component becomes larger at 4.22 GHz. At 9.12 GHz, as the higher-order modes exist, the pattern in the *H*-plane (*xoz* -plane) is similar to the shape of a four-leaved clover, and the cross-polarization component is large. Figure 8 gives the measured peak gains and the radiation efficiency of the antenna from 3.24 GHz-13 GHz. It can be seen that sharp gain drops of the antenna with notch bands occur both in 3.4-3.7 GHz and 5.15-5.825 GHz and 10.1-10.3GHz bands. As discussed in the last section, with the increase of frequency, the efficiency of the antenna is deceased for the dielectric loss and conductor loss. In addition, it can be observed that the measurement decreases sharply in the notched band.

VI. Conclusion

In this Paper the triple band notched at Wi MAX (3.23-3.85GHz), WLAN (5.15-5.85GHz) and ITU at (10.1-10.3GHz) UWB antenna has been successfully implemented and discussed. A VSWR <2 impedance band of 2.8–13 GHz has been obtained.The triple band notched characteristics are obtained by inserting T-shaped Strip and Two C-shaped Strip adding symmetrically along the Feed line of the UWB antenna.The length of each slot has been taken about Quarter of guided wavelength. The antenna is fabricated, and the measured results show good agreement with the simulated ones. The simulated results State that the antenna has a stable far field radiation pattern in *H*- and *E*-planes all over the UWB. Steady gain has been detected, apart from the notched frequency. The proposed antenna is appropriate for practical UWB applications.

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