**An Ultra-Wideband Antenna with Single Band and Dual Band Elimination Characteristics**

ABSTRACT New efficient and accurate analytic models of ultra-wideband (UWB) microstrip antennas are introduced to design small printed parabolic shape monopoles with single and dual band notch antennas shaped with rectangular cavities and corrugated edges for wireless applications. Two UWB antennas are made with parabolic shape radiator by using FR4 substrate (3.5 -14.25 GHz) and making half circular patch with four semicircle slot cut at the edges of radiator (3.5-13 GHz).Single notch is designed by making a plus shape cavity( 5-7.5 GHz), with C shape at the end of arms of plus sign cavity( 6.5-7.3 GHz), double parabolic cut at edges of cavity(6.1-7.1 GHz), double parabolic cut at edges of cavity with parabolic cavities at both ends of monopole radiator (6.1-7.5 GHz), by etching a thin line cavity (5.1-6.2 GHz) and inverted C shape cavity (3.1-4 GHz). These single notch antennas are used to cut C Bands and Satellite downlinks X bands. Dual notch bands is also achieved by including thin rectangular cavity and inverted C-shaped cavity (3.4-4 GHz and 4.8 – 5.9GHz). Band notch characteristics is also designed to eliminate the interference with existing bands of Wi-Max and WLAN. Dual band notch antenna is fabricated and tested for S parameters, VSWR. The designs are applicable in short range, high data speed wireless within the frequency band from (3.1 to 13 GHz and 3.5 to 14.25 GHz). These microstrip antennas along with single and dual band-notch in UWB systems are also compact with multifunctional features reducing the number of antenna in wireless devices. Also useful in wireless networks having a wide radiation pattern and in biomedical diagnosis. These antennas are light weighted, robust and also give low cost of production.

INDEX TERMS UWB, Monopole, parabolic antenna, WiMAX, WLAN, Notch antennas, Slot, Small antenna

1. INTRODUCTION

With the advancement in impulse technology, requirement of low power communication systems and use of Ultra Wide band (UWB) is the most suitable frequency band for short-range wireless communication. UWB technology is used with high data transmission using wide bandwidth. It is also a suitable technology for reducing fading generated by multipath.

Federal Communication Commission (FCC) [1] allows us to use ultra-wideband (UWB) from 3.1 to 10.6 GHz for commercial purposes. Many types of UWB antenna designs have been suggested.

remove

Ultra-Wideband (UWB) wireless technology is preferable for short range, very high data rate wireless applications , UWB Radars and highly secured networks. It has high performance in adverse weather and lightning conditions giving good precision with low output power requirement. UWB technology gives good noise immunity and it can be used to penetrate the materials easily. UWB communication works at very low energy levels in case of short range and gives high bandwidth. In Wireless Communication Systems it can be used in LAN & PAN, Short Range Radios. It is also useful in Military Communications, Surveillance and vehicular Radars. It has good immunity to multipath fading at very high data rates. In sensing applications it is used in medical imaging. Despite of its useful applications UWB also suffers from interference with other radio-based technologies.

Give the range of these bands

Already existing bands of WIMAX/ WLAN [8,9] and other C bands interferes with the UWB frequency band [6,7] (3.1–10.6 GHz).Hence band notch generation at these interfering bands can completely eliminate the interference in case of critical applications. Here we have experimented with different designs of UWB antenna and the notch antennas, which rejects the one and two bands.

For planar monopole UWB antennas notch band are designed by many methods. Different techniques used are by changing the length of a slot [2,3,6,7-10]on the ground plane and the length of parasitic elements. Split ring resonators and parasitic elements [8] etched on the antenna tuning stubs are also used to design band notch antennas. Additional frequency notch-bands (WiMAX/WLAN) [1,2,3] created by inserting the cavity of approximately half of the length of parabolic diameter near the outer [4]edge and one inverted C[5] cavity near the feed lines.

In these designs we have achieved the reduction in size of the antenna as compared with the earlier designs available in the literature.

The detail design of UWB is discussed in point no 3 where design no A to I elaborates the parabolic structure in monopole and the different cavities formed inside antenna to achieve notch bands single band and dual bands. For simulation and optimization Ansys HFSS is used. In point no 4 fabrication of dual band rejection antenna is discusses. Point 5 discusses about observation and results. Parametric analysis is done in 6 and point no 7 discusses about advantages and limitation with this structure. Point 8 concludes the design.

Ansys HFSS is a 3D electromagnetic (EM) simulation software for designing and simulating high-frequency electronic products such as antennas, antenna arrays, RF or microwave components, high-speed interconnects, filters, connectors, IC packages and printed circuit boards.

No.

UWB ANTENNA DESIGN AND DEVELOPMENT STAGES FROM UWB TO DIFFERENT NOTCH BAND STRUCTURES

UWB antenna should be small, with omnidirectional pattern with good time domain characteristics and are required to have good impulse response [11,7] with minimal distortions. These antennas are of circular [12,13,9], square, elliptical [8,14,15], pentagonal, and hexagonal disc [11]. Elliptical and circular discs provide UWB characteristics for commercial applications [11] Planar monopoles are reported [6,8,14,16] to provide impedance bandwidth with satisfactory radiation pattern.

In the design a half parabolic radiator is fed by microstrip feed line (MSL). The MSL excites the slot of antenna with an impedance matching. Ground plane is printed on the opposite of the PCB. FR-4 [6,5,12,8,14,16] substrate glass epoxy is found to be a popular plastic laminate grade with good strength to weight ratios. FR4 has zero water absorption characteristics and is an electrical insulator. It has high mechanical values [5,8], good for both dry and humid conditions. That is the reason it is used in variety of electrical and mechanical applications.

Note: length, width, thickness

Near zero

Substrate in the antenna is of 26mm x27mm x 1.6mm, Patch of (Circle Radius)13mm; Patch Rectangle=13mmx3mm; Ground=11.5mmx27mm Ground Cut=4mmx3mm.Half parabolic disc and 50-ohm micro strip feed line are on the same side of FR-4 substrate. Substrate thickness is 1.6 mm and a relative permittivity is 4.7 with a loss tangent, tan δ = 0.02.

A parabolic radiator designed over a rectangular partial ground plane (**table 1**). The antenna is then gradually changed from structure **A** to the band-rejection antenna structure **I.** In antenna A there is a 50-ohm MSL [3,6,7] on the side of the FR4 substrate. Antenna structures from **A** to **I** improves impedance matching. Radiating discs shapes are modified successively. The design parameters of the antennas are labelled in Antenna A (mm). These antenna structures can cover wide frequency bands.

**Antenna A and F** cover in full GHz bands from 3.5 -14.25 GHz and 3.5 GHz to 13 GHz respectively. **Antenna C** covers a notch band (6.5 to 7.3 GHz)inUWB band. In design of Antenna A having half circular patch with radius of 13mm. and it connected with 13mm x 3mm rectangular feeding line[3]. It is BW 3.5 GHz to 13.6GHz and attenuation is s11= -21dB.It VSWR value is 1.1, which is less than 2.

Unify all like that: 3.5-13 GHz

**Antenna F** having half circular patch with radius of 13mm. this half circle path is slot cutting with four half circle with radius of 3mm each. Antenna F having BW 3.5GHz to 13GHz and attenuation is S11= -42dB. Its VSWR value is 1.8 which is less than 2.

Unify the symbol

**Antenna B** having half circular patch with radius of 13mm. this half circle patch is slot cutting PLUS-design (+), with dimension 12mmx16mm and width of the dimension is 4mm. Antenna B is used for BW of 3.2GHz-13.2GHz which can cover a large bandwidth and offers low attenuation with S11= -39dB.It’s VSWR value is 4 which is greater than 2.It is having notch at 5GHz to 7.5GHz.

**Antenna C** having half circular patch with radius of 13mm. this half circle patch is slot cutting ‘PLUS-design’ (+) with dimension 12mmx16mm and 4mm width. The ‘PLUS’ shape is further slot cut to the end of each side with half circle with the radius of 2mm each. Antenna C is used for BW of 3.2GHz-14.2GHz which can cover a large bandwidth and offers low attenuation with S11= -24. 5dB.Its VSWR value is 2.5 which is greater than 2.it having notch at 6.5GHz to 7.3GHz.

**Antenna D** having half circular patch with radius of 13mm. this half circle patch is slot cutting ‘PLUS-

design’ (+) with dimension 12mmx16mm and 4mm width. The ‘PLUS’ shape is made with a slot cut to the end of each side with half circle with radius of 2mm each and this half circle is further slot cut with reverse circle with radius of 1mm.Antenna D is used

for BW of 3.1GHz-14.3GHz which can cover a large bandwidth and offers low attenuation with S11= -15. 5dB.Its VSWR value is 3 which is greater than 2.it having notch at 6.1GHz to 7.1GHz.

**Table 1: Selected Antennas**

**Antenna E** having half circular patch with radius of 13mm. this half circle path is slot cutting with two half circle with radius of 3mm each. this half circle patch is slot cutting ‘PLUS’ design with dimension 12mmx16mm and 4mm width. The ‘PLUS’ shape is made with a slot cut to the end of each side with half circle with radius of 2mm each and this half circle is further slot cut with reverse circle with radius of 1mm.Antenna E is used for BW of 3.3GHz-13.6GHz which can cover a large bandwidth and offers low attenuation with S11= -29dB.Its VSWR value is 3 which is greater than 2.5.it having notch at 6.1GHz to 7.5GHz.

**Antenna G** has half circular patch with radius of 13mm. This circular patch further slot cut by a straight line[2] with dimension 5mmx13mm.Antenna G is used for BW of 3.2GHz-15.0GHz which can cover a large bandwidth and offers low attenuation with S11= -16dB.Its VSWR value is 3 which is greater than 2.it having notch at 3.1GHz to 4GHz.

What: length, width, thickness

**Antenna H** has half circular patch with radius of 13mm.This circular patch further slot cut by inverted C shape [6,7,12] with dimension 8mmx3mm.Antenna H is used for BW of 4GHz-15.0GHz which can cover a large bandwidth and offers low attenuation with S11= -16dB. Its VSWR value is 2.1 which is greater than 2.it has notch at 3.1GHz to 4GHz.

What: length, width, thickness

**Antenna I** has half circular patch with radius of 13mm.This circular patch slot cut by a straight line with dimension 0.5mmx13mm and also in inverted C shape with dimension 8mmx3mm.

Antenna I is used for BW of 3GHz-12.0GHz which can cover a large bandwidth and offers low attenuation with S11= -16dB. Its VSWR value is 3.2 which is greater than 2.it is having notch at 3.1GHz to 4GHz. Its VSWR value is 5.1 which is greater than 2.It is having another notch at 4.8 GHz to 5.9GHz.

In this work rejection of the WiMAX (3.3–3.6 GHz), WLAN (5.15–5.82 GHz) bands[2] and X band Satellite Communication bands rejection are shown[8,15,2].

|  |  |  |  |
| --- | --- | --- | --- |
| **UWB** | **A** | Circle patch radius =13  Rect.strip patch=13X3(In mm) | A diagram of a circle with a red dot  Description automatically generated |
|  | **F** | Circle patch radius =13  Small circle patch R=3  Rect. strip patch=13X3  (In mm) | **A diagram of a funnel  Description automatically generated** |
|  | **B** | Circle patch radius =13  ‘PLUS’ design =12X4  (In mm) | **A drawing of a cross  Description automatically generated** |
| **single** | **C** | ‘PLUS’ design =12X4  ‘PLUS’ radius =2  (In mm) | A drawing of a cross  Description automatically generated |
| **band** | **D** | ‘PLUS’ design =12X4  ‘PLUS’ outer radius =2  ‘PLUS’ inner radius =1  (In mm) | A drawing of a cross with text and symbols  Description automatically generated |
| **notch** | **E** | ‘PLUS’ design =12X4  ‘PLUS’ outer radius =2  ‘PLUS’ inner radius =1  Small circle radius=2  (In mm) | **A drawing of a bat  Description automatically generated** |
| **antenna** | **G** | Circle patch radius=13  Cutting line=0.5X13  (In mm) | **A drawing of a half circle  Description automatically generated** |
|  | **H** | Circle patch radius=13  H-Shape size=3X8  (In mm) | **A diagram of a measuring device  Description automatically generated** |
| **dual**  **band**  **notch**  **antenna** | **I** | Circle patch radius=13  Cutting line=0.5X13  H-Shape size=3X8  (In mm) | **A drawing of a basketball hoop  Description automatically generated** |

**III. FABRICATION AND TESTING OF DUAL BAND REJECTION ANTENNA:**

Figure 1 shows the dual band antenna fabrication using FR4 substrate. Parabolic radiator is shown in figure 1 a and ground plane in figure 1 b. S parameters and VSWR are analysed using Network Analyzer figure 1 c. In the anechoic chamber radiation patterns as shown in Figure 5 are observed (figure 1 d).

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Figure 2 shows the results obtained by VNA for S parameters and VSWR parameters.

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A close-up of a piece of metal

Description automatically generated(a)

(b)

**

(c)

**A close-up of a device

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(d)

**Figure 1. Fabrication of dual band rejection at WIMAX and WLAN (a) Patch Side Antenna Design G, (b) Ground Side Antenna Design G, (c). Testing with VNA,(d). Measuring radiation in anechoic chamber**

Place a coin or scale to show the size of the antenna.

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(a)

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(b)

**Figure 2. Testing with VNA (a) Antenna Testing Result (S Parameter) (b) Antenna Testing Result (VSWR)**

**IV.OBSERVATIONS AND RESULTS**

Simulation results of antenna A , F and B,C,D,G,H,I (table 1) are shown in table 2.The table shows S parameter, VSWR, attenuation and bandwidth of band reject and passband.

For antenna A ( 3.5 -14.25 GHz) and Antenna F (3.5 GHz to 13 GHz) VSWR ≤ 2.In the band rejection modes, VSWR > 2 for Antenna B,C,D,E (X band Satellite bands 6-7.5 GHz), Antenna G (WLAN)[6,7] 5.1 to 6.2 GHz Antenna, H- shows strong rejections.

Thus, the strong rejections are in range for antenna B, C, D, E more than 15 dB. Similarly for antenna G (-16dB) and H (-14dB). In the dual rejection mode in Antenna, I it is more than 10 dB. Figure 3 (a- d)

It is possible to draw the shapes using well-known drawing programs such as : Origin lab, GraphPad Prism.

**TABLE 2: Simulation results of antenna A , F and B,C,D,G,H,I**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Type | Antenna | Bandwidth | Notch | s11(reflection coefficient) | VSWR | Gain |
| UWB | antenna A | 3.5 -14.25 GHz | -- | -21dB | 1.1  (<2) | 4.1 |
|  | antenna F | 3.5 GHz to 13 GHz | -- | -42dB | 1.8  (<2) | 3.9 |
|  | antenn A | Rejected BW | Notch | S11 | VSWR | Gain |
|  | antenna B | 5 to 7.5 GHz(including military X Band) | -4dB | -39dB | 4.0  (>2) | 3 |
| single | antenna C | 6.5 to 7.3 GHz | -7.1dB | -24.5dB | 2.3  (>2) | 5 |
| band | antenna D | 6.1 to 7.1 GHz | -6.5 | -15.5dB | 3  (>2) | 4 |
| notch | antenna E | 6.1 to 7.5 GHz | -7.1 | -29dB | 2.5  (>2) | 4 |
| antenna | antenna G | 5.1 to 6.2 GHz | -5.1 | -16dB | 3.5  (>2) | 3 |
|  | antenna H | (WIMAX)3.1 to 4 GHz | -4.1 | -14dB | 2.1  (>2) | 2 |
| dual  band  notch  antenna | antenna I | (WIMAX)3.4 to 4 GHz  And  (WLAN)4.8 to 5.9 GHz | -5  And  -4.2 | -18dB | 3.2  (>2)  5.1  (>2) | 3 |
|  |  |  |  |  |  |  |

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**(d)**

**Figure 3. S parameter and VSWR of UWB and notch antennas:(a) Design A, B, C, D, E and F (S Parameter),(b) Design G, H and I (S Parameter), (c) Design A, B, C, D, E and F (VSWR), (d) Design G, H and I (VSWR)**

Figure 3 shows the comparative simulation results of S parameters and VSWR parameters. Antenna A, B, C, D, E and F S parameters are shown in figure 3 a, VSWR in figure 3 c. For design G, H, I the S parameters shown in figure 3 b and VSWR is plotted in figure 3 d.

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Description automatically generated with low confidenceCurrent density plots are obtained for the dual band rejection antenna shown in figures 4 a-h. High current density is found at the feed line and at the bottom in ground plane.Radiation patterns and gain of antenna are plotted in figure 5a,b and figure 6 a-d.

It is possible to draw the shapes using well-known drawing programs such as : Origin lab, GraphPad Prism.

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**(f)**

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Description automatically generated **(g)**

**(h)**

**Figure 4. Current density plots of dual band notch antenna for WIMAX and WLAN (a) 0 degree,(b),(c),(d) 90 degree, (e)170 ,(f)180 degree,(g) 270 degree (h) 350 degree**

A graph with a heart in the center

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**(a)**

A red circle with numbers

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**(b)**

**Figure 5 Electric fields patterns at (a) 12 GHz at o degree and 90 degree (b) 5GHz**

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**(a)**

A red and yellow sphere with black text

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**(b)**

A graph with a heart drawn on it

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**(c)**

A red and yellow colored object

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**(d)**

**Figure 6. Gain total at (a), (b) 3D Gain at 5GHz frequency (c) 12GHz at 90 degree 3 notches are shown (d) 3D gain at 12 GHz**

**V. PARAMETRIC ANALYSIS AND COMPARISION:**

***A.*** As looking into the rapid development of communication [27] we need to design tuneable antennas. Coming to the advanced design of the antenna which consisted of an inductor between the slot length or at the power feedline to the antenna can be done through a small sized rectangle [28]. The inductor controls the frequency of the antenna while using it. The omega () is the frequency factor that is responsible for the change in frequency of the inductor. Also a zig zag pattern of rectangles gives us the exact shape like an inductor but instead of making a zig zag rectangle, only a simple rectangle can be placed by assigning it as a lumped port RLC. Addition of parasitic elements gives notched frequency band and an open-end slit of the antenna structure and a tuning stub which can control notched band [24]. Tuning stubs in the slots in the ground plane and in feed line are reported to give dual band and triple band notch antennas [28].

Several simple and tunable filtering systems are integrated on the monopole. It can also be attached to the ground plane or to the feeding line. Step etching techniques [29] on the ground plane is also used. Using metamaterials, [21] resonant structures are introduced in the monopole to achieve special electromagnetic performances.

Recent research also shows that two notch bands [27, 30] can be controlled by a single varactor diode. For this PIN diodes and varactor diodes are used. Capacitance tuning of the varactor diode   
is done by changing the reverse bias voltage across the diode [27, 30, 31]. Main radiator via a single varactor diode [27,30] is connected or varactor diode can be connected across the gaps [30]. Tunable band-notched characteristics of final structure are measured by VSWR characteristics.

RLC equivalent circuits are drawn to analyze the performance of the antenna at different frequencies and under different conditions. UWB antenna band can be achieved by the large number of independent resonances overlapped [17]. These are concatenation of RLC components. Input impedance is matched [17] for Antenna A and F (Figure 7 a) over the entire bandwidth. notching structures [17] are designed by a series of RLC circuit which is connected in parallel with the input impedance in case of notched band centered at 3.5 GHz [17] such as Antenna H and I (Figure 7 b) for single notch antenna in earlier experiments[17].

Resonating frequency is given by-

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**(a)**

**TABLE 3:**

**Characteristics of the Antennas with their application**

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**(b)**

**Figure 7 (a)Equivalent circuit UWB antenna [Fig 2b[17]] (b)Single band rejection equivalent circuit [Fig 3[17]]**

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(For the resonant frequency ,relative permittivity and slot length L ). In the proposed design the slots are of much smaller lengths which is an added advantage with the design.

2-Two nested structures of C-shaped slots and two independent C-shaped slots are also used for generation of dual band-notched frequencies thus making tuning of antenna more simple [20].

***B. Comparison with earlier designs***

Earlier designs also triple-notch UWB circular monopole antenna in WiMAX, WLAN and X-Band downlink satellite communication bands have been presented [17, 18].

Table 3 shows the comparision of the antennas proposed with earlier designed antennas in entire UWB range with single band and dual band rejection ranges.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sl.l no | Size of an antenna and structure | Substrate used | Applications | Bands of frequency rejections |
| 1 | Parabolic structures in monopole [23] size is 90mm x 85mmx 1.6mm | FR4 epoxy substrate | Dual band rejections | WIMAX  WLAN |
| 2 | **Table 2** **Antenna I** half circular patch with radius of 13mm. slot cut by a straight line with dimension 0.5mmx13mm and also in inverted C shape with dimension 8mmx3mm Circle patch radius=13  Cutting line=0.5X13  H-Shape size=3X8  (In mm)  With ground plane | Substrate FR4 | **Dual band rejections** (WIMAX)  (WLAN) | 3.4 to 4 GHz  4.8 to 5.9 GHz |
| 3 | Circular patch and circular arc slot is designed annular ring patch and a partial ground plane with a rectangular slot[24] | Substrate FR4 | Dual band rejections WLAN & DSRC systems (dedicated short-range communication) | WLAN and at 5.5 GHz |
| 4 | **antenna B**  **antenna C**  **antenna D**  **antenna E**  **antenna G**  **antenna H**  (size mentioned in table 1 all in mm not exceeding 12- 13 mm radius) | Substrate FR4 | Single band rejections  including military X Band **(antenna B)**  (WIMAX)(**antenna** **H**) | 5 -7.5 GHz(B)  6.5 -7.3 GHz(C)  6.1 -7.1 GHz(D)  6.1 -7.5 GHz(E)  5.1 -6.2 GHz(G)  3.1 - 4 GHz(H) |
| 5 | Structure in z-shape [22] dimensions 38 mm × 35 mm × 1.57 mm.  with ground plane | Roger5880 substrate | UWB,wireless communications applications, microwave imaging | 2.8–22.7 GHz |
| 6 | **TABLE 2 Antenna A**  Circle patch radius =13,  Rect. strip patch=13X3( mm)  **Antenna F**  Circle patch radius =13mm, Small circle patch R=3mm  Rect. strip patch=13X3( mm)  With ground plane | Substrate FR4 | Entire UWB bandwidth | 3.5-14.25 GHz  3.5 – 13 GHz |

The table is not clear, format the table more clearly.

Mushroom like structure cavity [18] and several other structures [20] such as etching in shapes of C, L, T, H, U, E and half-circle slots are also made either on the radiation patch or on the ground plane. Parasitic strips [20, 18] are also used for dual band-notched functions [20].

1-The proposed UWB antenna with band rejection re configurability differs than the earlier designs as it works in the four modes-full UWB mode, individual Wi-Max rejection mode, WLAN rejection mode, Satellite X rejection modes and dual rejection modes (Wi Max and WLAN).

2-The proposed monopole antennas are designed using a ground plane in UWB bands, single notch and dual notch bands. A ground plane prevents interference of the outside circuitry [21] due to adverse effects caused by surface waves [21]. By using the ground plane emission of electromagnetic signal is maintained in the horizontal plane.

2- In the design efficient band rejections are obtained by cavities of different shapes such as rectangular and plus shape cavity, inverted C shape, combination of plus shape cavity with etched in shape of arc at the edges of square shape cavity. All cavities are gradually changed and tested in simulation for notch bands mentioned in table 1. The basic design is of parabolic monopole structure with ground plane. All cavities are etched on that parabolic patch.

Radiation patterns for the UWB and notch bands are shown in figures 5 .E field at 12 GHz and 5GHz showing notch below 0 dB. Gain is more than 15dB at 12 GHz. Except the notch E field shows strong omnidirectional gain more than 5 dB.

Size reduction: The most of the work is found on the wide bandwidth in UWB or the notch double and triple bands antennas in UWB [17, 18, 19,22] . The designs are in either EBG or complicated structures. Here in this research all antennas UWB to single notch and double notch shows drastic size reduction and all antennas are achieved step by step by modifying the previous structure using a single parabolic structure which is a cost reduction as compared to other available designs in literature.

**VI.ADVANTAGES AND LIMITATION:**

***A. Advantages***

Printed monopoles are found useful in many portable [21] devices which are integrated with the Radio Frequency circuits. Because of loses due to the presence of surface waves in dielectric materials substrate material of low dielectric constant is recommended for such devices.

1-The proposed design in UWB has found its importance in medical imaging and Radar surveillance. Different designs including UWB antennas with single notch and dual band notch antennas in simplified way has been structured. Both UWB antennas A and F have wide bandwidth 3.5 to 14.25 GHz ‘A’ and 3.5 to 13 GHz ‘F’. First UWB frequency bands with single notch is simulated at different frequencies by cutting slots of different shapes. Then dual frequency band rejection is simulated coming in between the UWB transmission. Keeping the design simple and basis structure same our aim is to incorporate the notch bands gradually changing the slot dimensions inside the parabolic patch. It has single notch as well as dual notch characteristics giving high VSWR more than 3 at all notch frequencies clearly (figure 3).

Hence the proposed antenna is suitable for the high-performance UWB systems which can reject the waves of WiMAX/WLAN and X band waves of downlink satellites. The UWB antenna is preferable for the very high data rate, short range wireless applications and UWB Radars and highly secured networks.

2-The Proposed antennas are in single notch structure ‘B’ (5 to 7.5 GHz (including military X Band)) , ‘C’ (6.5 to 7.3 GHz), ‘D’ (6.1 to 7.1 GHz), ‘E’ (6.1 to 7.5 GHz), ‘G’ (5.1 to 6.2 GHz) and in ‘I’ dual notch (WIMAX 3.4 to 4 GHz, WLAN 4.8 to 5.9 GHz). The basic design in monopole has UWB pattern from 3.5 to 14.5 GHz. First antenna design is made UWB which is a parabolic structure in monopole, second design is circular patch with slots in the shapes of circular arcs at the edges. In order to achieve notch at different frequency bands parabolic monopole antenna design is gradually changed by cutting slots in rectangle and arcs at the edges of rectangular slots as visible in B,C, D,E and H for single bands. We achieve different notch frequencies (table 2). Similarly Dual band notch are also achieved by inserting slots of rectangular shape and inverted C shape in the same basic parabolic monopole structure(table 2). This makes the designs a unique proposal of antennas where single structure can be explored for multiple functions in UWB including single notch and dual notch frequency bands.

3-As discussed proposed design in monopole is simpler and smaller in design and dimensions than earlier available [18] designs.

4- Its bandwidth is ranging from 3.5 GHz to 14.25 GHZ. Peak gain exceeds 4dB at 12 GHz. Antenna can exhibit omnidirectional radiation patterns E fields as shown in figure 5 shown at 12 GHz and 5GHz. Antenna shows high gain and radiation efficiency in UWB frequency band and rejections at notched frequencies. Dual band Antenna gain and efficiency decreases at around 5 GHz and 3.5 GHz Figure 6 . Gain total at 12GHz at 90-degree notches are shown.

5- The antenna designed is light weight and small in size. It has symmetric radiation patterns and satisfactory gain. It is suitable for different UWB applications[20].We successfully obtained both IEEE 802.16 WiMAX system and IEEE 802.11a WLAN system dual band rejections in Antenna I.

As in 5G Communication will need massive MIMO antenna system to match high data rate.UWB-MIMO is a suitable application where 2 such monopoles [18, 32] or four monopoles [29] can be connected 90 degree apart to achieve isolation among monopoles. Decoupling strips with the slotted ground plane [18] for diversity applications are used.Circular shaped and rectangular shaped monopoles [31, 32] gives good multiband characteristics. These antennas are suitable [31] for satellite services and Land mobile navigation services. Hence band notched re configurability in (UWB) and UWB-MIMO design will lead to high data rate antennas which are switchable and tunable [24,28]at the desired notched frequencies.

UWB antennas [23] are also found suitable for imaging in the biomedical systems as the bandwidth of antenna ranges from 3.5 GHz to 14.25 GHz.The bandwidth is also required for outdoor and indoor wireless communication systems [24]. We experimented with the different designs of UWB antenna and the notch antennas, which rejects the one and two bands. The Proposed Ultra-Wideband (UWB) wireless technology similar to other UWB antennas is preferable for the very high data rates[26], short range wireless applications and UWB Radars [22]and highly secured networks [26].It has good noise immunity and signals can penetrate the variety of materials. UWB communication uses very low energy levels for short range [22]. UWB can be used in LAN & PAN, Short Range Radios [17, 19, 22] and Military Communications.

## **Limitations**

The antenna is designed for single, dual or UWB range bandwidth. To incorporate further band rejections of undesired signals future experiments can be performed in this design. Group delay and ringing effects are there in ground plane. To remove these difficulties new metamaterial geometries are found suitable[21]. The antenna is fixed at the designed single or dual notch characteristics which can be made tunable further incorporating the changes in design as a tunable antenna.

**VII. CONCLUSION**

In this paper, a compact parabolic monopole antenna is presented and designed over a partial ground plane. The structure is low cost, planar wideband. UWB antenna with band-rejection can work in four modes – full UWB, individual WiMAX or WLAN rejection or Satellite X band rejection and dual rejection (WiMAX and WLAN). The full operating band works from 3.5 to 14.25 GHz. The antenna is of low-cost FR4 substrate and has been tested for band rejections which are found about 16 and 10 dB in WiMAX and WLAN bands.

The range of X band

Future scope lies in analyzing this design for triple band and multiple band notch antennas in wireless applications.

**REFERENCES**

[1] M. Sharma, Y.K. Awasthi, Singh Himanshu, Kumar Raj, Kumari. Sarita "Compact printed high rejection triple band-notch UWB antenna with multiple wireless applications" *Engineering Science and Technology, an International Journal*, 2016

[2] R. Chandel, A.K. Gautam, K. Rambabu, ‘Tapered fed compact UWB MIMO diversity antenna with dual band-notched characteristics’, *IEEE Trans Antennas Propagation* 2018;66(4):1677–84.

[3] X.L. Sun., L. Liu, S.W. Cheung, T.I. Yuk, ‘Dual-band antenna with compact radiator for 2.4/5.2/5.8 GHz WLAN application’, *IEEE Transactions on Antennas and Propagation,* Vol. 60, pp. 5924-5931, 2012. <https://doi.org/10.1109/TAP.2012.2211322>

[4] K. P. Ray, "Design Aspects of Printed Monopole Antennas for Ultra-Wide Band Applications", *International Journal of Antennas and Propagation*, 2008

[5] M. I. Khan, M. I. Khattak , G. Witjaksono, Z. U. Barki, S. Ulla, I. Khan and M. L. Byung, ‘Experimental Investigation of a Planar Antenna with Band Rejection Features for Ultra-Wide Band (UWB) Wireless Networks’, *Hindawi International Journal of Antennas and Propagation* ,Vol 2019, Article ID 2164716, <https://doi.org/10.1155/2019/2164716>

[6] T. R. Muthu, A. Thenmozhi, ‘Design of frequency reconfigurable antenna for cognitive radio applications’, *Optoelectronics and Advanced Materials – Rapid Communications*, Vol. 15, No. 5-6, May-June 2021, p. 260 – 270

[7] K. G. Thomas, M. Sreenivasan, *IEEE Transactions on Antennas and Propagation* 58(1), 27 (2010)

[8] D.K. Raheja, B.K. Kanaujia, S. Kumar, ‘Compact four-port MIMO antenna on slotted-edge substrate with dual-band rejection characteristics’, *Int J RF Microw Comput Aided Eng* 2019;29(7):e21756

[9] G. Srivastava, BK. Kanuijia, ‘Compact dual band-notched UWB MIMO antenna with shared radiator’, *Microw Opt Technol Lett.* 2015;57(12):2886-2891.

[10] S. U. Rahman, Q. Cao, Y. Wang, Ullah H. “Design of wideband antenna with band notch characteristics based on single notching element”, *Int Journal RF Microwave Computer Aided Eng*, October 2018

[11] [K. Siwiak](https://www.wiley.com/en-us/search?pq=%7Crelevance%7Cauthor%3AKazimierz+Siwiak), [D. McKeown](https://www.wiley.com/en-us/search?pq=%7Crelevance%7Cauthor%3ADebra+McKeown), “Ultra-wideband Radio Technology”, 2nd Edn, ,2004

[12] W. Wei, L. Y.Bo, W. R.Yuan, S. C. Bo, and C.T.Jun, ‘Band-Notched UWB Antenna with Switchable and Tunable Performance’, *Hindawi Publishing Corporation International Journal of Antennas and Propagation,* Volume 2016, Article ID 9612987, 6 pages <http://dx.doi.org/10.1155/2016/9612987>

[13] L. WT, Y.Q. Hei, H. Subbaraman, X.W. Shi., R.T. Chen, ‘Novel printed filtenna with dual notches and good out-of-band characteristics for UWB-MIMO applications’, *IEEE Microw Wirel Compon Lett.,* 2016; 26(10):765-767

[14] D.K. Raheja, B.K. Kanaujia, S. Kumar, ‘Low profile four-port super-wideband multiple-input-multiple-output antenna with triple band rejection characteristics’, *Int J RF Microw Comput Aided Eng*. 2019;e21831

[15] Z. Tang, X. Wu, J. Zhan, S. Hu, Z. Xi, Y Liu., ‘Compact UWB-MIMO antenna with high isolation and triple band-notched characteristics’, *IEEE Access,* 2019;7: 19856–65

[16] Md. S. Alam, A. Abbosh, "Reconfigurable band‐rejection antenna for ultra‐wideband applications", *IET Microwaves*, *Antennas & Propagation*, 2017

[17] N. Jaglan, B. Kanaujia , S.D. Gupta, S. Srivastava, “Triple Band Notched UWB Antenna Design Using Electromagnetic Band Gap Structures”, *Progress In Electromagnetics Research C*, Vol. 66, 139-147, 2016

[18] N. Jaglan,  S.D. Gupta,  E.. Thakur, D. Kumar ,  B. K. Kanaujia,  S. Srivastava , “Triple band notched mushroom and uniplanar EBG structures based UWB MIMO/Diversity antenna with enhanced wide band isolation”[*AEU - International Journal of Electronics and Communications*](https://www.sciencedirect.com/journal/aeu-international-journal-of-electronics-and-communications), [Vol. 90](https://www.sciencedirect.com/journal/aeu-international-journal-of-electronics-and-communications/vol/90/suppl/C), June 2018, Pages 36-44

[19]- N. Jaglan,  B.K. Kanaujia ,  S D. Gupta  and  S. Srivastava**,** “Dual Band Notched EBG Structure based UWB MIMO/Diversity Antenna with Reduced Wide Band Electromagnetic Coupling”**,** *Journal of RF-Engineering and Telecommunications,* ISSN: 2191-6349

[20]- J. Xu,D.-Y. Shen, G.-T. Wang, X.H. Zhang, X.-P. Zhang and K. Wu , “A Small UWB Antenna with Dual Band-Notched Characteristics”, *International Journal of Antenna and Propagation, Hindawi*, Volume 2012 | Article ID 656858

[21]**-** R. Cicchetti,E. Miozzi and  O. Testa,“Wideband, Multiband, Tunable, and Smart Antenna Systems for Mobile and UWB Wireless Applications”, [*International Journal of Antennas and Propagation*](https://www.hindawi.com/journals/ijap/), [2017](https://www.hindawi.com/journals/ijap/contents/year/2017/)

[22] S. [Ullah](https://pubmed.ncbi.nlm.nih.gov/?term=Ullah%20S%5BAuthor%5D),  C. [Ruan](https://pubmed.ncbi.nlm.nih.gov/?term=Ruan%20C%5BAuthor%5D),  M S.  [Sadiq](https://pubmed.ncbi.nlm.nih.gov/?term=Sadiq%20MS%5BAuthor%5D), [T.Ul Haq](https://pubmed.ncbi.nlm.nih.gov/?term=Haq%20TU%5BAuthor%5D) and [W. He](https://pubmed.ncbi.nlm.nih.gov/?term=He%20W%5BAuthor%5D) “High Efficient and Ultra Wide Band Monopole Antenna for Microwave Imaging and Communication Applications”, [*Sensors*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6982843/), 2020 Jan,20(1):115

[23] M. Hayouni, N. Dakhli, F. Choubani, T H. Vuong, and J. David, “ A Planar Parabolic Patch Antenna for UWB Applications” , *Progress In Electromagnetics Research Symposium Proceedings,* Marrakesh, Morocco, Mar. 20–23, 2011 377

[24] R. Azim and M T. Islam, “Compact planar UWB antenna with band notch characteristics for WLAN and DSRC”, *Progress In Electromagnetics Research*, Vol. 133, 391–406, 2013

[25] Y. [Wang](https://ieeexplore.ieee.org/author/37086308154),  T. [Huang](https://ieeexplore.ieee.org/author/37086922390),  D. [Ma](https://ieeexplore.ieee.org/author/37086920745),  P. [Shen](https://ieeexplore.ieee.org/author/37086917777),  J. Hu, W. [Wu](https://ieeexplore.ieee.org/author/37292827500), “Ultra-wideband (UWB) Monopole Antenna with Dual Notched Bands by Combining Electromagnetic-Bandgap (EBG) and Slot Structures”, IEEE explore 2019, *IEEE MTT-S International Microwave Bio Conference* ((IMBIOC)

[26] V. Sorathiya ,   A. G. Alharbi,   S. Lavadiya, “Design and investigation of unique shaped low-Profile material-based superlative two-element printed ultrawideband MIMO antenna for Zigbee/WiFi/5G/WiMAX applications**”,** [*Alexandria Engineering Journal*](https://www.sciencedirect.com/journal/alexandria-engineering-journal), [Volume 64](https://www.sciencedirect.com/journal/alexandria-engineering-journal/vol/64/suppl/C), 1 February 2023, Pages 813-831

[27]- M. E. Yassin, H. A. Mohamed, E. A.F. Abdallah, H. S. El-Hennawy, “Semi-Circular Stubs UWB Monopole Antenna with Tunable Dual Band-Notch Characteristics” March 2022,[*International Journal of Microwave and Optical Technology*](https://www.researchgate.net/journal/International-Journal-of-Microwave-and-Optical-Technology-1553-0396) 15(2):169-177

[28]- S S, [Pillalamarri](https://www.researchgate.net/profile/Syam-Pillalamarri?_sg%5B0%5D=CBSg6H-uQAaPLEd2dRKhsX7noiJGKyibS5nt0m7gXLjv8oxhhTmcr5j5ZC6NAwP793KVWoI.RUilwXgBPseXlUrzqI1KGt-MwBqhI2er7fbRLy79zX5LtmYKOxB8bWU4i09YbbMk4VOOw1GwcTY2dfLCuLOOKA&_sg%5B1%5D=MuiPEGNlU3Eudi2nd1TTjiB75F9ACBwkKQsUKDsgo1IiMbAiU9mxGx5avLfOJmIugoZU3Aw.cshSROOqLMW9OoykMHe5tSXaKAbsufBE8dHRj_jkLYe3S1wxHL1sE1FagED2Zw_JLDG5h_O7-zszC6xGLxhpFw),  S K. Kotamraju,  B. T. P.etal. Madhav, “Parasitic Strip Loaded Dual Band Notch Circular Monopole Antenna with Defected Ground Structure”, August 2016, [*International Journal of Electrical and Computer Engineering*](https://www.researchgate.net/journal/International-Journal-of-Electrical-and-Computer-Engineering-2088-8708)6(4):1742-1750,

[29]- W. Naktong, A. Ruengwaree,“Four-Port Rectangular Monopole Antenna for UWB-MIMO Applications”, *Progress In Electromagnetics Research B,* Vol. 87, 19-38, 2020

[30]- C. Zhang, Z. Zitong , Y. Jie , X. Pei1 , L. Zhu and L. Gaosheng , “A miniaturized microstrip antenna with tunable double band-notched characteristics for UWB applications”, *Scientific Reports.* Aug 2022.

[31]- S. Modak, S. Daasari, P P. Shome, T. Khan, “Switchable / Tunable Band-Notched Characteristics in UWB and UWB-MIMO Antennas: A Comprehensive Review”,[*Wireless Personal Communications: An International Journal*](https://dl.acm.org/toc/wpco/2023/128/3)*,*[Volume 128](https://dl.acm.org/toc/wpco/2023/128/3) [Issue 3](https://dl.acm.org/toc/wpco/2023/128/3) Feb 2023 pp 2131–2154

[32] R. R. Saravanakumar, “Circular tooth based low profile 1x2 superlative MIMO antenna with high gain and isolation for fixed satellite service, and land mobile navigation applications” [*Physica B: Condensed Matter*](https://www.sciencedirect.com/journal/physica-b-condensed-matter), [Volume 650](https://www.sciencedirect.com/journal/physica-b-condensed-matter/vol/650/suppl/C), 1 February 2023, 414490 [21]

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