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Design of Dual Band Notched Compact Planar Rectangular patch Antenna for Ultra-Wide Band Application

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ABSTRACT

A dual band-notched compact ultra wideband antenna is presented, with a modified rectangular patch and truncated ground plane. To generate single and dual band-notched characteristics, we use two inverted U-shaped slots, instead of changing the patch or feedline shapes. By properly adjusting the dimensions of these elements, two controllable notch resonances are achieved. The simulated results shows that the proposed dual band-notched monopole antenna offers a very wide bandwidth from 3 to 12 GHz, defined by less than -10dB return loss, with two notched bands, covering all the 3.3 to 3.7GHz WiMAX and 5.1 to 6GHz WLAN2. Impedance, radiation and efficiency characteristics of the antenna are also discussed. The proposed antenna is simulated using CAD FEKO 6.2 suit electromagnetic simulator using MoM (Method of Moment).

Keywords: Patch antenna; Ultra wideband; Radiating patch; Truncated Ground plane; Method of Moment; Dual-band notch

1. INTRODUCTION

In recent years, design of ultra-wideband (UWB) antennas has received an increasing attention after adoption of frequency band from 3.1 to 10.6 GHz for UWB applications by the Federal Communication Commission in 2002. Various kind of planar broadband antennas have been studied and reported for UWB applications [1-4]. Many of them have large radiation patch connected with the microstrip-fed line [4-5].

There are several techniques are defined to obtain the notched band characteristics such as tuning stub technique[6], designing of different shaped slots on the microstrip Antenna patch[7-8], design using parasitic elements of various geometries[9-10] or by fractal geometry of an antenna[11]. simple and commonly used approach is to incorporate slots or parasitic strips into the antennas' radiator, such as L-shaped slots , U-shaped slots [12] and I-shaped parasitic strips [13], which are known as half-wavelength or quarter-wavelength resonator structures.

In this paper, a simple and compact microstrip line-fed planar UWB antenna with dual band-notched characteristics at 3.5 GHz and 5.5 GHz is proposed. The dual band-notched characteristic can be achieved by embedding the inverted U-shaped slot in the radiating patch and another inverted U-shaped slot in the truncated ground plane to obtain band-notched properties for WiMAX(3.3-3.7GHz) and WLAN(5-6GHz). The notch frequencies can be done by adjusting the total length of the inverted U-shaped slots to be approximately half the guided wavelength of the required notch frequency. The appropriate efficiency and stable radiation patterns are obtained. Moreover, the simulated results have a good agreement with our requirements.

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2. ANTENNA CONFIGURATION

For to obtain the notched band property firstly primitive antenna is taken. The antenna consists of a rectangular radiation patch and a partially modified ground plane with corner notches on both to achieve a broad bandwidth. Two inverted U-shaped slots are designed to achieve a notched bandwidth. These two inverted U-slot comprises of one vertical arm and one horizontal arm, the U-slot width is uniform along its length except at the bend. These two slots are placed on rectangular radiating patch(for WiMAX) and on truncated ground plane(for WLAN2). Distance between the radiating patch and truncated ground plane of the substrate is properly selected and fixed at 1 mm, to achieve required bandwidth of the ultrawideband function.

3. ANTENNA DESIGN AND PARAMETRIC STUDY

3.1. Full Band UWB Monopole Antenna Design

Fig. 1 shows the configuration primitive antenna with pair of notches at lower corner edges of rectangular patch and a truncated ground plane having pair of notches.

The proposed antenna, has the dimension of 25 mm X 33 mm (Wsub X Lsub), is constructed on FR4 substrate with thickness of 1.6 mm and relative dielectric constant of 4.4 having loss tangent (tan δ) of 0.02. The width Wf of the micro strip feed line is fixed at 2.8mm. On the upper surface of the substrate, a rectangular patch with size of Wp X Lp is printed. The rectangular patch has a distance of to the ground plane printed on the back surface of the substrate. By cutting the two notches L1 X W1 and L2 X W2 of suitable dimensions at the monopole's two lower corners, it is observed that much enhanced impedance bandwidth can be achieved for the proposed antenna. This thing occurs because of two notches affects the electromagnetic coupling between patch and ground plane.

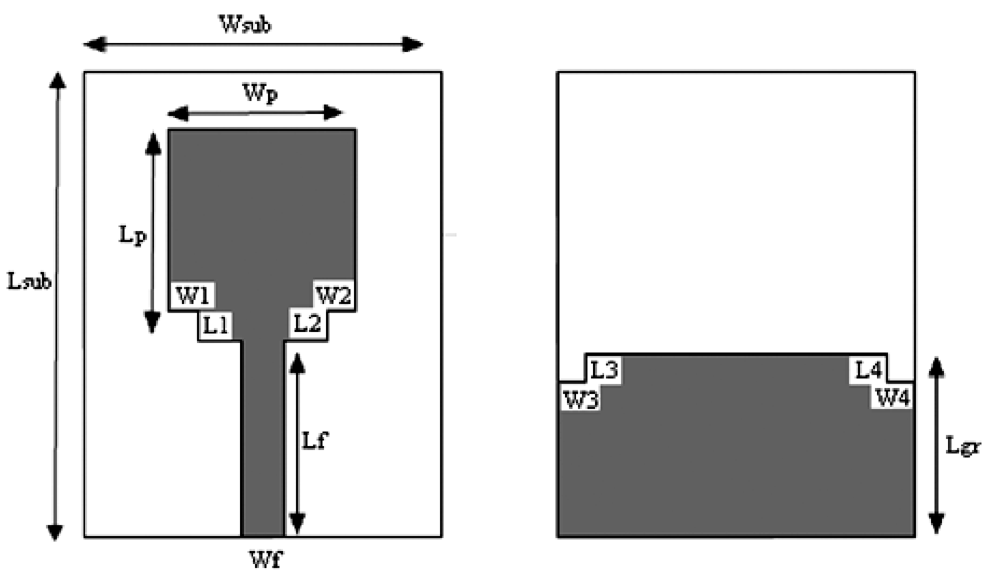


Figure 1: Configuration of primitive antenna

In addition to this, to obtain the more enhanced bandwidth the pair of notch is obtained on the ground plane of L3 X W3 and L4 X W4 , Also the gap 'g' between patch and ground plane along with position of microstrip feedline is obtained by the way of simulation . This parameter is important to determine the sensitivity of impedance matching as shown in fig. 2 the obtained VSWR<2 obtained from parametric analysis for gap 'g' between patch and ground plane. This shows that there is a good impedance matching between the microstrip transmission line and the corner notched rectangular radiating element. The notched structure and partial ground plane with multiple rectangular slots improve the impedance matching and the bandwidth of the primitive antenna.

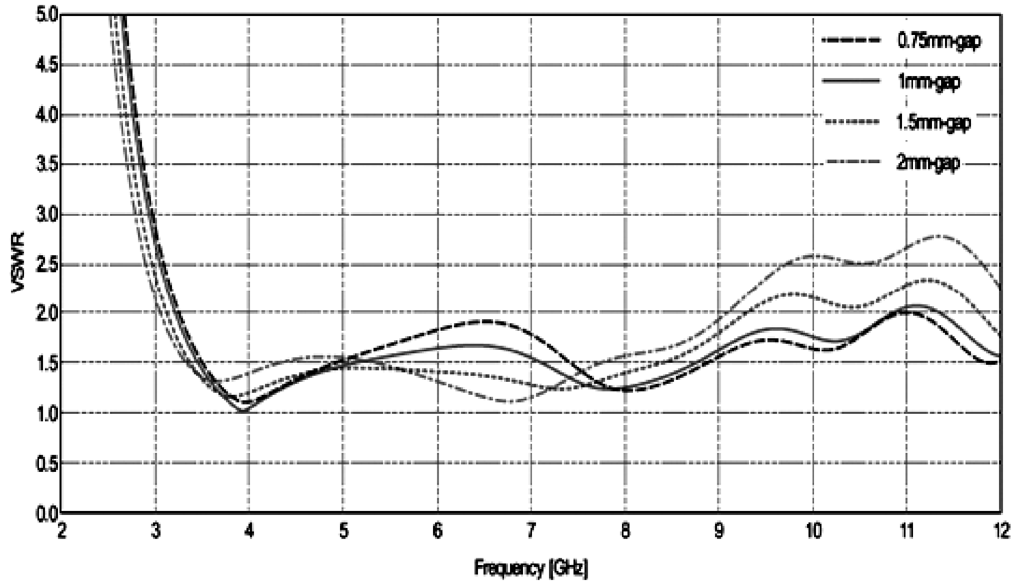


Figure 2: Simulated VSWR with gap variation between radiating patch and ground plane

The optimized dimensions of proposed antenna are as follows: Wsub = 25mm, Lsub = 33mm, Wp = 13mm, Lp = 15mm, Wf = 2.8mm, L1 = L2 = L3 = L4 = 2mm, W1 = W2 = W3 = W4 = 2mm, Lf = 14mm, Lgr = 13mm and g = 1mm. This is found that using these dimensions the antenna satisfies requirements of UWB antenna from 3.2 GHz to 12 Ghz.

3.2. Single and Dual Band-Notched UWB Monopole Antennas

The truncated ground plane of the proposed antenna is an effective part of the antenna. The current distribution on the modified (defected) ground plane affects the impedance characteristics of the antenna. As a result, by inserting a pair of corner notches at the ground plane and carefully adjusting their parameters, additional resonances can be excited and hence much enhanced impedance bandwidth may be achieved.

The proposed antenna structure is simulated using method of moment (MoM) software, CADFEKO Version 6.2[15]. Once the UWB bandwidth is achieved, to obtain notched band properties of the proposed antenna, current distribution of an antenna plays an important role which is the advantage of method of moment analysis where we can analyze actual antenna radiation. Due to which, While performing the simulation it is observed that the antenna has maximum current distribution on the patch at 3.5GHz for designing of the stop band structure. To achieve the stop band function of an antenna next we proposed a inverted U-shaped slot of half wavelength ($\lambda/2$) in rectangular radiating patch as shown in fig.3.

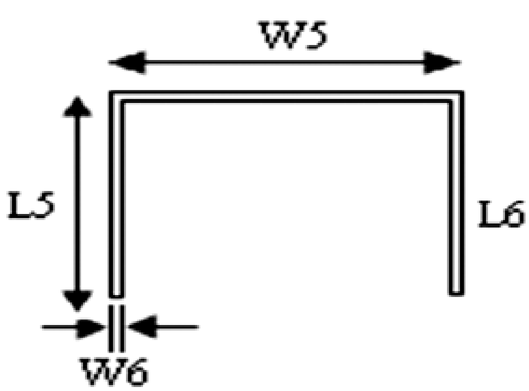


Figure 3: Inverted U-slot for WiMAX

The exact position of the slot is identified by observing the current distribution of the patch. Fig. 4 shows current distribution at 3.5GHz before and after the implementation of inverted U slot. From figure it is observed that after the implementation of this slot the antenna has notched the band from the 3.3 to 3.7GHz.

The slot length is calculated as:

$$f_{notch} = \frac{C}{2L_{slot} * \sqrt{\in reff}} \quad (1)$$

$$\in_{reff} = \frac{\in_r + 1}{2} \quad (2)$$

Where Lslot is the length of the slot; åeff is the effective dielectric constant; c is the speed of light.We can use (1) and (2) to predict the length of the slot resonator, then, optimize the parameter Lslot with full wave simulation. The half wavelength of the slot resonators is short at both ends. The adjustment of the band-notched frequency can be done by varying the lengths of the slots. However, the widths of the slot also affect the notched bandwidth. At the desired notch frequency, the current distribution is around the U-shaped slots.

The parametric analysis is done to obtain the notched band characteristics for WiMAX using this inverted U-slot in the radiating patch by varying the gap between the radiating patch and U-slot, also by varying the

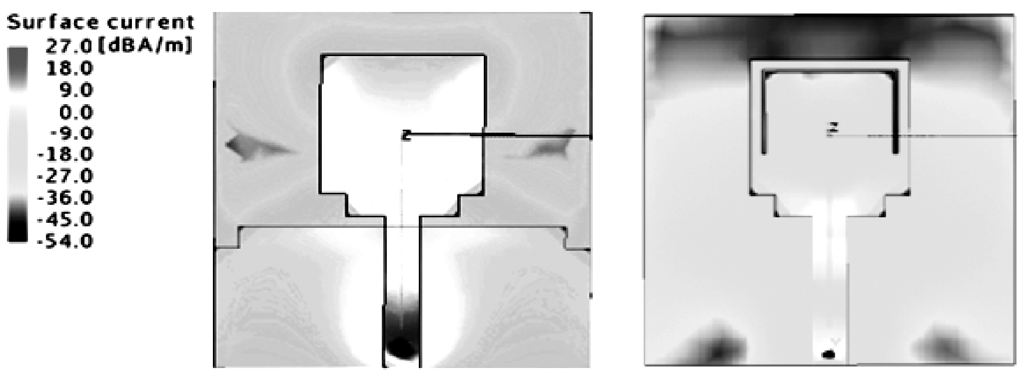


Figure 4: Current distribution at 3.5GHz before and after the implementation of inverted U-slot.

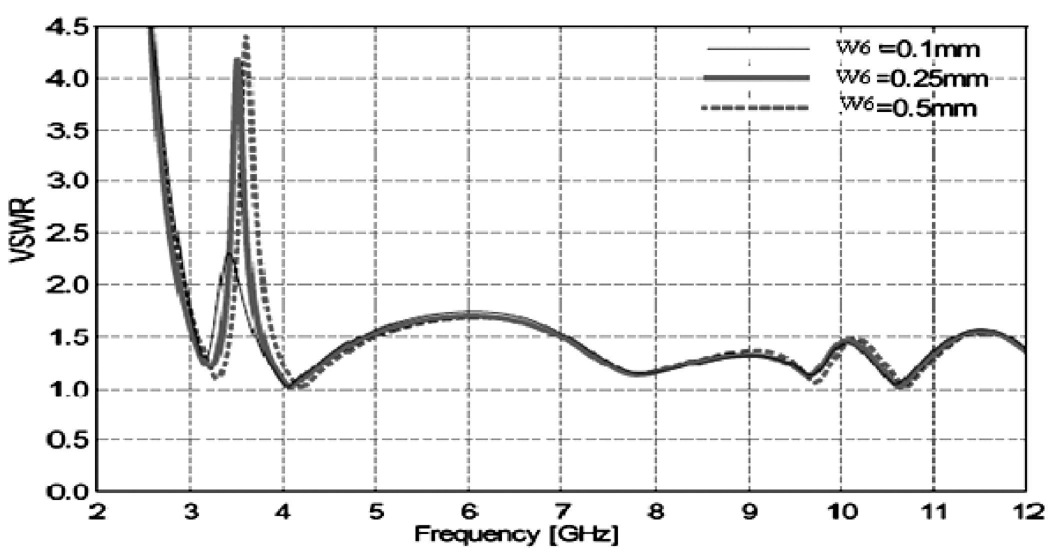


Figure 5: Parametric analysis done by varying slot width for WiMAX

slot width W6(i.e. Sw) and length. Fig. 5 represents the parametric analysis done by varying slot width (W6) the peak obtained is varying. And it found that at W6=0.25mm obtained peak is at 3.5GHz which meets our requirements.

The optimized dimensions of proposed inverted U-slot are as follows: L5=L6=8mm, W5=11mm, W6=0.25mm and gap between radiating patch and slot is 1mm obtained by the way of simulation. The results shows that using these dimensions the antenna satisfies requirements of WiMAX band notching function from 3.3 GHz to 3.7 Ghz.

Same procedure is followed to notch the another narrowband system known as WLAN2 to avoid its interference from the UWB system. The position of another inverted U-shaped slot as shown in fig.6 is identified by observing the current distribution of radiating antenna after notching the band of WiMAX. It is observed that the current is more at the truncated ground plane.

The slot length and width is also calculated through half wavelength dimensions. Fig.7 shows the parametric analysis done for to obtain the notched band property for WLAN2 by varying the slot width i.e.Sw (W8) of inverted U-slot in the ground plane.

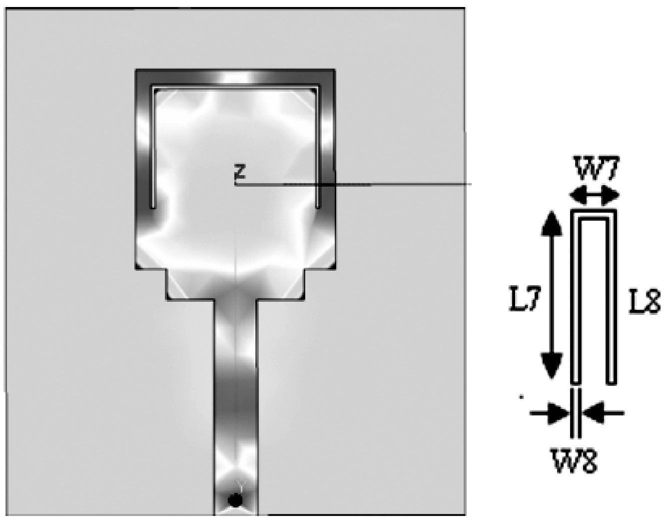


Figure 6: Current distribution at 5.5GHz and Inverted U-slot for WLAN2

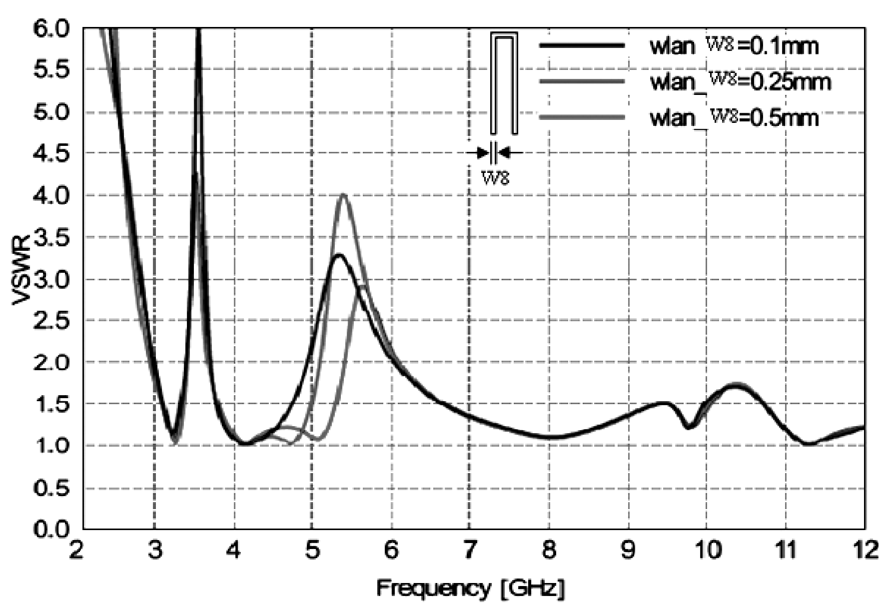


Figure 7: Parametric analysis done by varying slot width for WLAN2

The optimized dimensions for WLAN2 band notch using inverted U-shaped slot are as follows: L7=L8=8mm, W7=1.5mm, W8=0.25mm and gap between radiating patch and slot is 1mm obtained by the way of simulation. The results shows that using these dimensions the antenna satisfies requirements of WiMAX band notching function from 3.3GHz to 3.7 GHz as well as for WLAN2 band from 5.1 to 6 GHz Fig. 8 shows the configuration of proposed design of an antenna. Which exhibits the dual band notch properties for WiMAX and WLAN2 band.

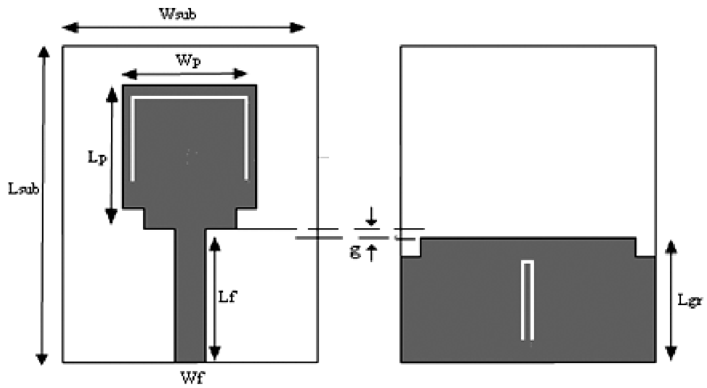


Figure 8: Configuration of proposed antenna

4. RESULTS AND DISCUSSIONS

The results and discussion are divided into two parts which consist of optimized results and time domain analysis and experimental results and discussion. In Section 4.1, optimized results including the simulated final results of reflection coefficient, VSWR, radiation patterns and efficiency of the proposed antenna will be discussed. On the other hand, in Section 4.2, the time domain analysis where electric probe is placed at different positions to investigate the transmitted and received pulse signals.

4.1. Full Band UWB Monopole Antenna Design

Based on the optimized parameters of the proposed dual band-notched planar rectangular UWB antenna with truncated ground plane. We obtained the bandwidth of an antenna rages from 3GHz to 12GHz. Fig. 9 and 10 shows the reflection coefficient <-10dB and VSWR<2 obtained after the inserting two inverted U-slots, one in the rectangular radiating patch and another on the truncated ground plane. Which leads to obtain the proper impedance bandwidth.

It can be seen that the simulated impedance bandwidth for reflection coefficient< -10dB is from 3 to 12 GHz, except the bands of 3.3-3.7GHz (required for WiMAX) and 5.1-6GHz (required for WLAN2). While

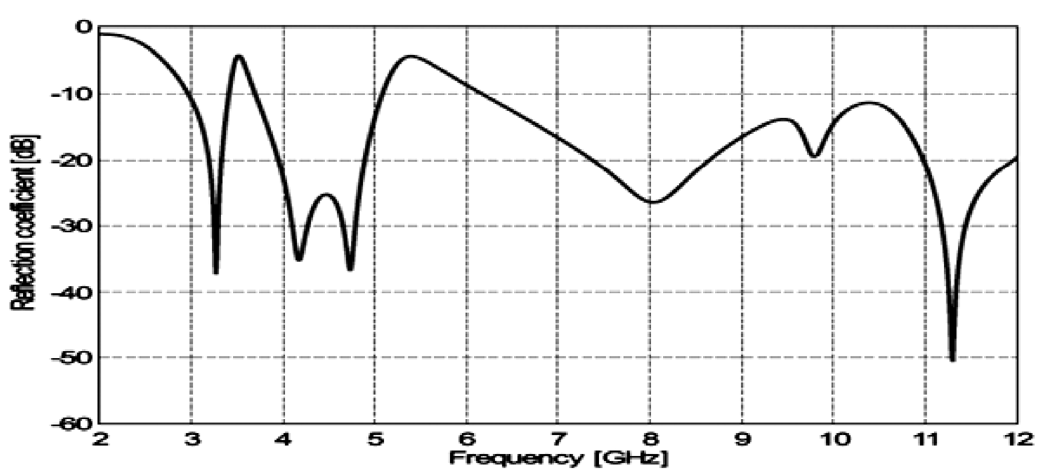


Figure 9: Simulated reflection coefficient <-10dB

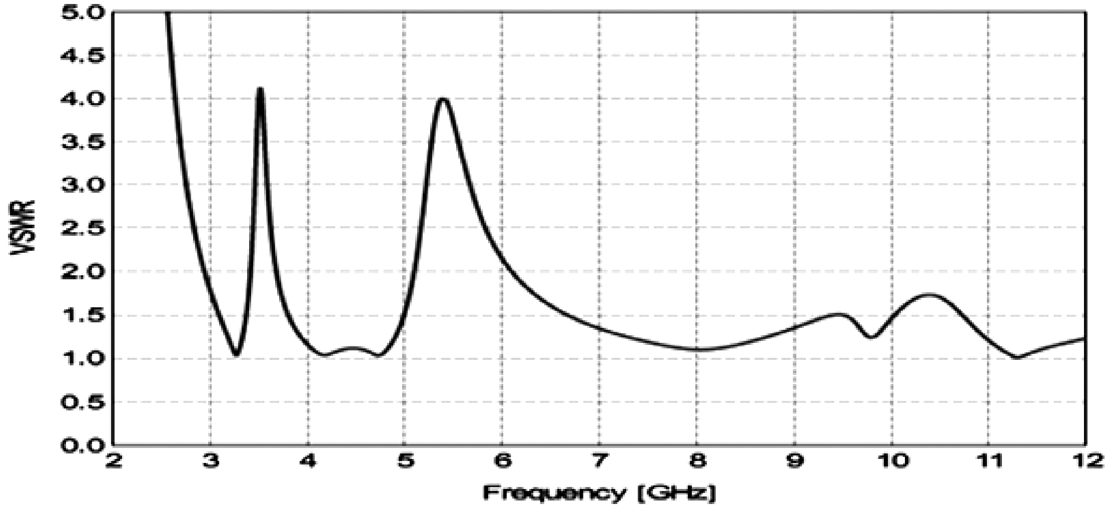


Figure 10: Simulated VSWR < 2

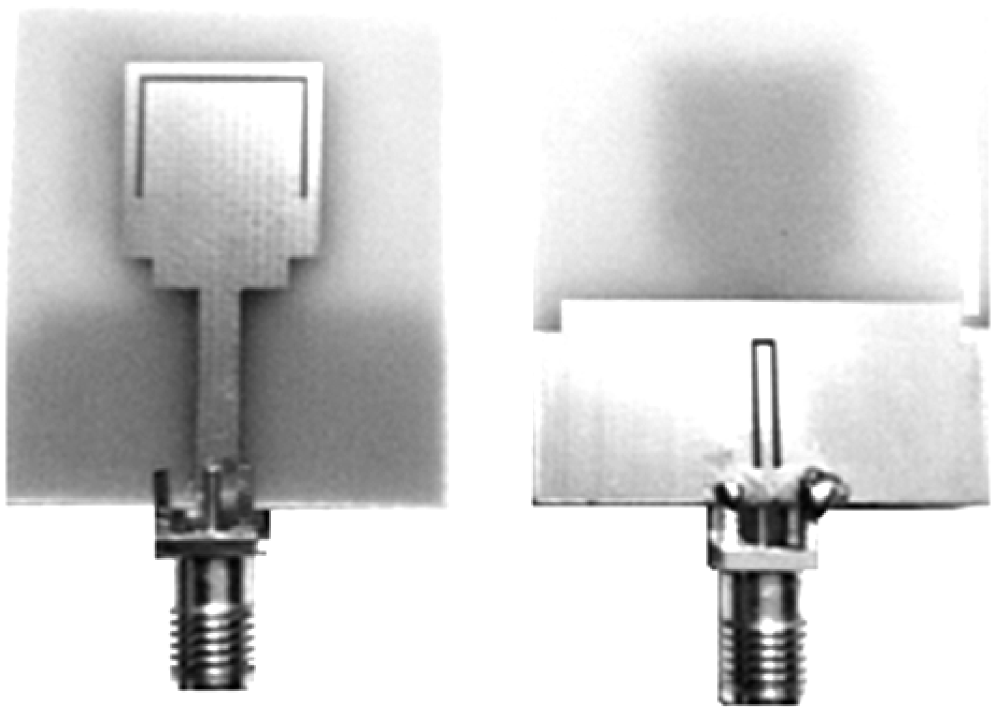


Figure 11: prototype of an proposed system

designing by the way of simulation it is also clearly seen that by using this filtering structure, the lowest frequency of the antenna is significantly decreased from 3.2 to 3 GHz.

After performing the designing and parametric analysis of an antenna. The proposed system is fabricated using FR4 substrate having thickness is of 1.6mm. Fig. 11 shows the manufactured prototype of an antenna.

This proposed system is measured on using Agilent Technologies handheld RF vector network analyzer (N9916A) having a range of 30KHz to 14GHz in open air medium. From figure 12 it is observed that the proposed system meets the requirement of dual band notching properties at 3.5GHz and 5.5GHz.

Fig. 13 shows simulated co-polarization and cross polarization obtained across the E-plane and H-plane. As the micro strip patch antenna has the advantage of its smaller cross polarization[1]. Our antenna fulfills such requirements of polarization. The antenna has shown similar characteristics in case of reflection coefficient and VSWR to get dual notched bands.The simulated efficiency of an antenna is decreased at the

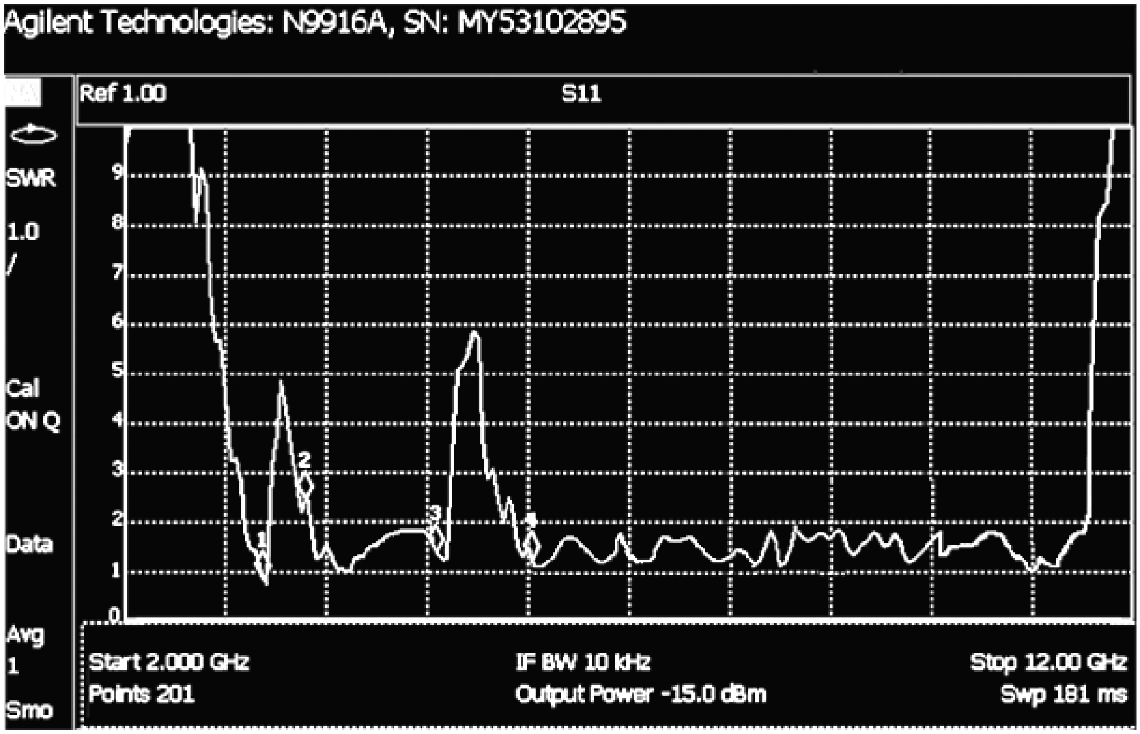
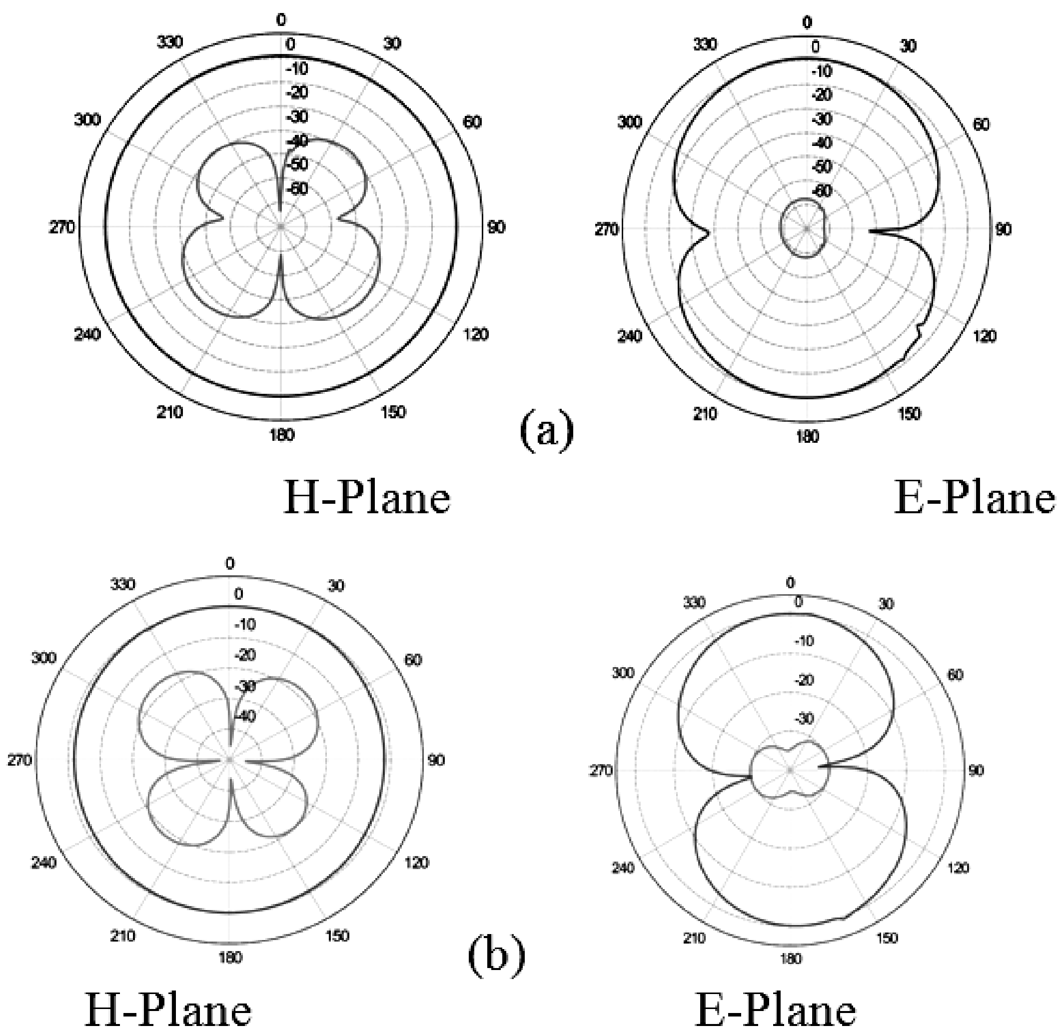


Figure 12: Measured VSWR < 2 obtained after the inserting two inverted U-slots.



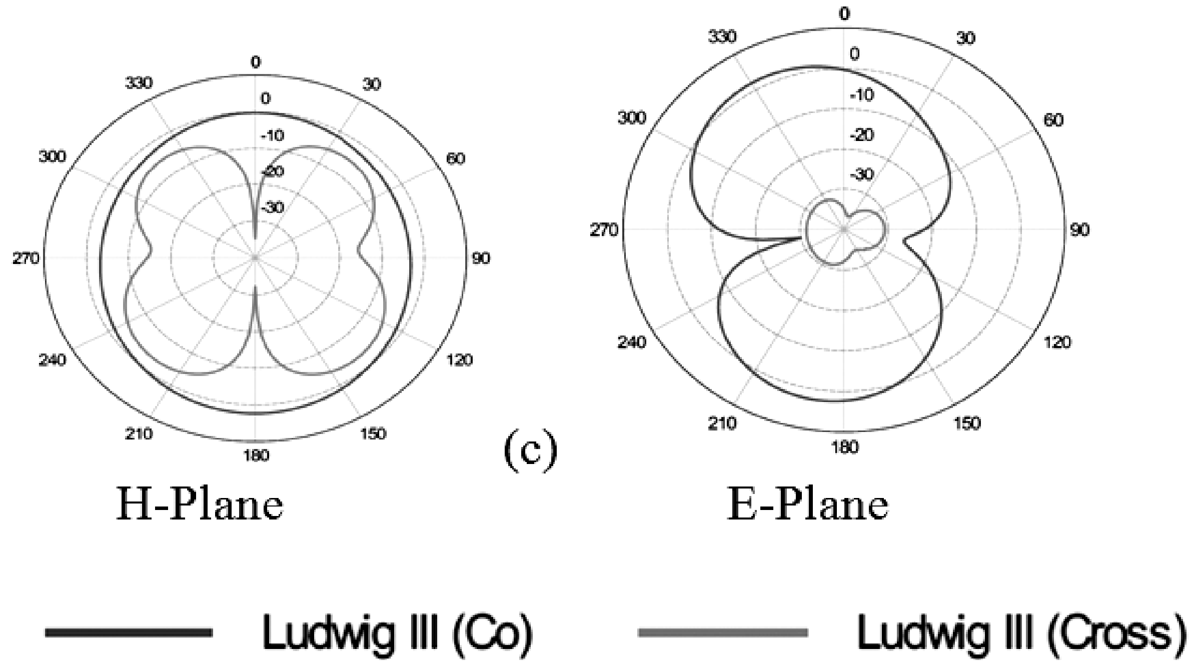


Figure 13: Simulated radiation patterns of the dual band-notched antenna at the frequencies of (a) 3.1, (b)5, and (c)7.5 GHz.

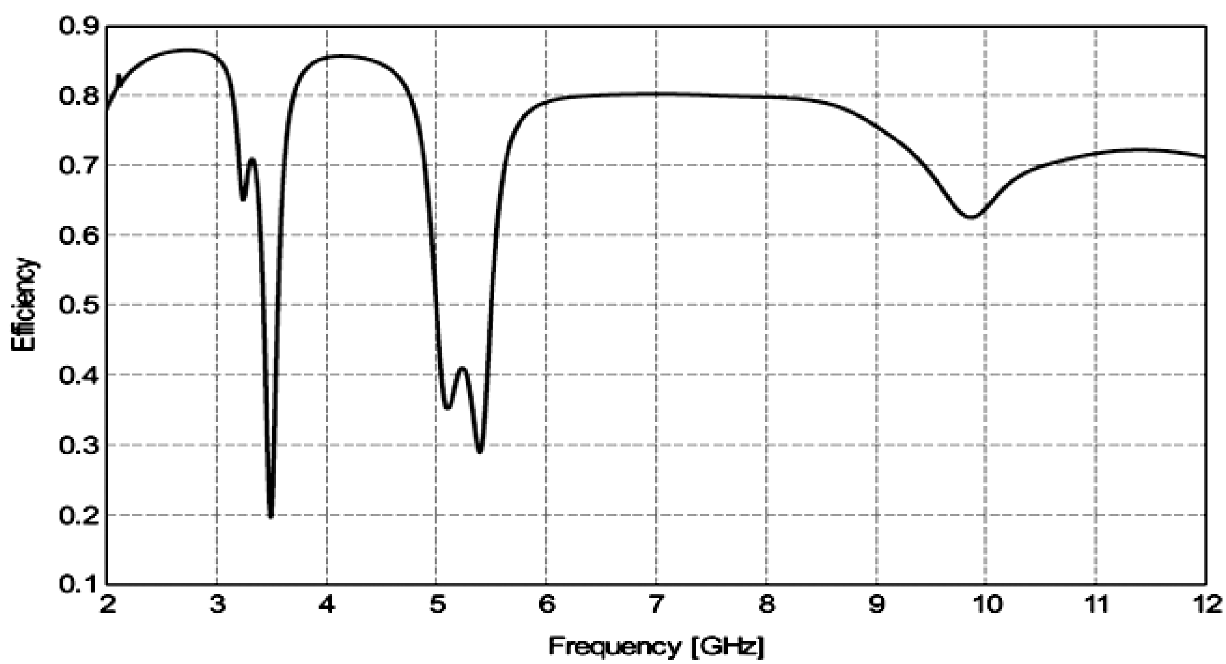


Figure 14: Simulated efficiency of an antenna

higher edges of frequency due to the lossy substrate and it is upto 70%. Fig. 14 shows the graph of frequency versus efficiency of an antenna obtained by performing simulation.

The figure indicates that the realized dualband-notched antenna has good efficiency flatness except in two notched bands. Therefore, these two inverted U-shaped slots will not have negative effect on the radiation performance of the antenna, in UWB band.

4.2. Time Domain Analysis

As UWB antennas are inspired by transient pulse (such as Gaussian pulse), waveform response provides constructive recognition on antennas time-domain performance is favourable. Therefore, waveform response

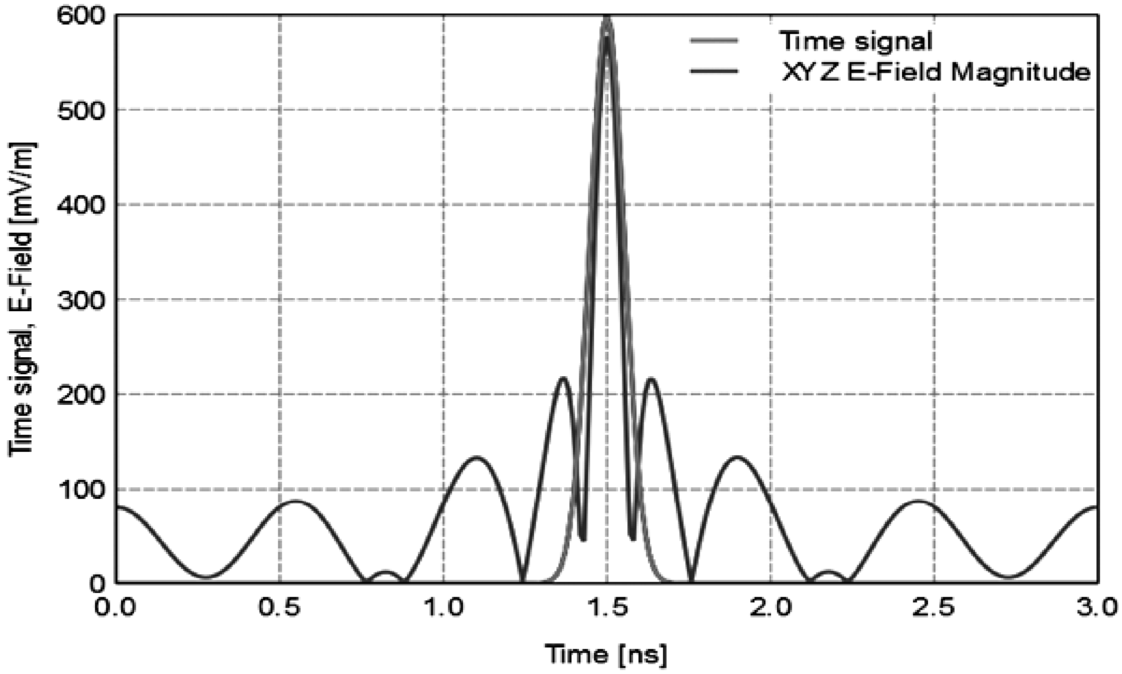


Figure 15: Time domain analysis for transmitted and received pulse

of the antenna is demonstrated in this section for comparison. In order to validate the efficiency of the antenna, the pulse base signal is excited with Gaussian pulse. It can be related to the dispersion of receive signal compared to transmitter signal. Figure 15 shows the radiated E field which is virtually place probe in simulation to study the effect of radiated signal.

From this figure, the antenna is fixed at azimuth angle of 90^o, It is proved that the proposed antenna has good potential in transmitting UWB signals with minimum distortion. Furthermore, the time domain UWB pulse signal received by the electric probe shows stable performance where the received pulse signal is almost identical to the transmitted pulse signal.[15-17]

5. CONCLUSION

A dual band notched compact planar rectangular radiating patch antenna with truncated ground plane is presented. By introducing the corner notches on both at rectangular radiating element and at partial ground plane, a wideband impedance matching is achieved. To mitigate the potential interference between the UWB systems and narrowband systems such as WiMAX (3.3-3.7GHz) and WLAN (5.1-6GHz), two inverted U-shaped slots are added for band rejection. The simulated results shows that the antenna not only has dual notched bands over an ultra-wide operation band but also have a good radiation pattern. The proposed planar antenna is easily integrated with RF/microwave circuits for low cost manufacturing and suitable for various UWB applications.

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