Higher Isolated Dual Band Notched UWB MIMO Antenna With Fork Stub

D.D.Katre
Department of Electronics & Telecommunication,
Amrutvahini college of Engineering,
Sangamner 422608, India
durgeshkatre19@gmail.com

R.P.Labade
Department of Electronics & Telecommunication,
Amrutvahini college of Engineering,
Sangamner 422608, India
rplabade@gmail.com

***Abstract*—In this paper, dual band notch Multi-input Multi-output (MIMO) System of two U-shape patch antennas has been evolved for the UWB application. Spacing between two elements of antennas is $0.270\lambda_0$ at 3.1GHz for the UWB operation. To enhance isolation and increase bandwidth impedance, a fork shaped stubs added in the ground plane of the antenna. Due to interference with WIMAX (3.3-3.7 GHZ) and WLAN (5.2-5.8 GHz) on UWB dual band notch function is perform. For achieving the dual band notch characteristics, trekking slots cut in the patch with a feed and C-shaped strip are placed adjacently to the feed line of the antenna. Due to a fork shaped stubs in ground planes, reducing of mutual coupling between elements $S_{21} \leq$ -20dB. Peak gain, Efficiency of antenna also investigated and it shows that the proposed MIMO antenna has pleasant characteristics of UWB application.**

Index terms— Band-notched ultra-wideband (UWB) antenna, high isolation, Diversity antenna, multiple-input multiple-output (MIMO), MIMO antenna, UWB antenna.

I. INTRODUCTION

In contemporary years, ultra-wideband (UWB) communication systems depict massive act in the wireless world because of their lots of advantages like widespread impedance matching, radiation stability, low profile, compact size, and low cost [1]. To assistance of several multimedia services, have higher data rates of wireless communication system. The necessity of high bit error rates (BER) wireless communication with high channel capacity and reliability, multiple-input multiple-output (MIMO) system is a desired method. In the multifunctional wireless communication application, MIMO antenna system should have compact structure and high isolation [2]. Numerous techniques had proposed to enhancing isolation between the elements of an MIMO antenna because MIMO antenna system requires high isolation. The function of MIMO antenna depends on the inter-element spacing, aperture area, radiation pattern of single antenna element, array geometry and number of antenna elements. However, designing MIMO antenna over wide bandwidth is challenging tasks due to the tradeoff between inter-element spacing and mutual coupling. Mutual coupling and radiation patterns are governed by electrical separation between elements, which varies significantly from frequency of wide bandwidth. Larger inter-element spacing results of lower mutual coupling, but the size of the antenna becomes large which is not suitable for compacts systems. Decrease in interelement spacing makes an antenna system compact but increases mutual coupling due to increase in surface wave coupling between the elements [3-5].

UWB technology enables a distinct inclusive of WPAN (Wireless Personal Area Network Communication Technologies) applications, and UWB system has been reported to be resistant against fading effects, which is frequency selective and does not affect the entire occupied bandwidth [3, 4]. There have already been some local wireless communication protocols, such as Wireless Local Area Networks (WLAN, 5.2-5.8 GHz) and Worldwide Interoperability for Microwave Access (WiMAX, 3.3-3.7 GHz), which overlap with the ultra-wide operating band. This will cause interference with UWB MIMO and other local wireless system; this is especially true to UWB systems, for it works in an extremely low power level. [6] To overcome the challenges mentioned above, many methods have been proposed. These decoupling schemes can be divided into three major categories. The first method is using UWB diversity antennas [4]–[6]. The principle of this process is analogous to that of dual-polarized antennas. Due to the orthogonality of gain patterns of the antenna elements, low coupling between the elements can be achieved. Moreover, the MIMO antennas for UWB systems using this method usually have a compact size. The second method employs decoupling structures [7]–[10], such as treelike structure [7], and parasitic trek lines [10]. The antennas adopting this method could obtain a high isolation performance. However, as decoupling structures usually have a complex realizing form, the size of the antenna is hard to realize miniaturization. The third method is used widely, and it can be treated as a hybrid method that combines the former two methods [3], [11]–[14]. By using UWB diversity antennas and decoupling structures between the antenna elements at the same time, compact size and low mutual coupling usually can be achieved [15]. Another one UWB antenna consists of the radiation patch connected through a via with the strip placed beneath the patch for high isolation [16].Due to dense multipath propagations in UWB technology in indoor environment cause for Inter Symbol Interference (ISI). Thus, to turn this drawback into an advantage, multiple antennas or MIMO techniques can be employed to exploit such rich scattering environments. The more important are that the applications of UWB are limited to the short distance communication with very low transmission power allowed by the FCC. Hence, using MIMO together with UWB helps in extending the communication range as well as offers higher link reliability [17].

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In this letter, two U- Shaped monopoles intended for UWB MIMO antenna with separation of λ/4. Section II shows, for increasing impedance bandwidth the fork shaped stub added in the ground plane of the antenna, effect of the stub in ground also investigated. After that Dual band notch characteristic is obtained by trekking slots and C- shaped strip added in the adjacent of the feed. Section III shows that, the simulated impedance bandwidth, mutual coupling between elements and radiation performance of antenna. Peak gain and efficiency of the antenna are also scrutinized. The calculated envelop correlation coefficient by S- Parameter is 0.65. The simulation results are obtained in CAD-FEKO 7.0 EM Simulation Software.

II. Configuration Of Proposed Dual Band Nothced MIMO Antenna

The proposed UWB MIMO antenna is made up of 60mm × 35mm thickness of 1.6mm with dual notch band function on FR4 substrate of dielectric constant 4.4 and loss tangent of 0.02. First, two symmetric U-shaped cut patches itched on top side of an antenna with distance between a feed is 0.270 λ0 and for increasing the isolation there should be added the fork shaped stub on the ground plane of the antenna. For dual band notch operation for WIMAX (3.3-3.7GHz) trekking a slot cut on the patch with feed of the antenna and for WLAN (5.2-5.8GHz) C shape strip added to the feed line shown in Fig.1.

A. Approach of MIMO Antenna

The element for UWB MIMO antenna is chosen as a traditional U-shaped monopole antenna with naturally wideband. Initially, the antenna is designed on a FR4 substrate (ε_r= 4.4, tan δ = 0.02) with total size of 30mm × 35mm × 1.6mm. The initial geometry and dimensions are shown in Fig.2.

The rotated cross shaped monopole antenna is used as the reference antenna. The rotated cross monopole patch consists of three parts: the vertical rectangular patch (A) and two rotated rectangular patches (B and C), which has a rotated angle of *α.* Due to rotation of patches B and C there is increasing bandwidth. The substrate Ws × Ls , having patches A ,B,C with sizes Wa × La (for A) , Wb × Lb (for B and C) all are fed to the 50 Ω micro strip feed line of Wf × Lf. Due to reduction in patch size of area D in less current region and after that slot of W1×L1, W2×L2 , there is not extent change in the VSWR which shown in Fig.3.

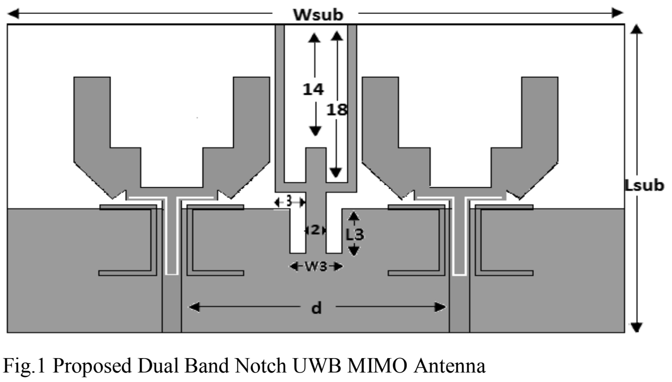


Fig.1 Proposed Dual Band Notch UWB MIMO Antenna

Design Parameters of UWB MIMO antenna is as follows:

Wsub	Ws	Ls	Wa	La	Lg
60	30	50	9	28	14
Lsub	**Bx**	**By**	**W1**	**L1**	**d**
35	5	10	12	8	26
Wb	**Lb**	**Wf**	**Lf**	**g**	-
13	27	2.5	15	1	-
W2	**L2**	**Ls2**	**Wm**	**Lm**	-
6	5	35	60	35	-

All the parameters of the antenna are in mm.

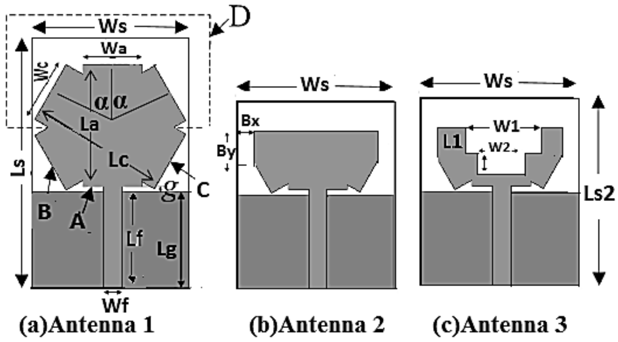


Fig.2. Design of Single Element UWB Antenna

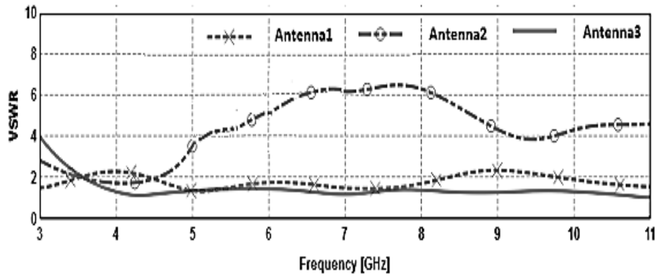


Fig.3 Simulated VSWR Of Antenna 1,2,3.

The geometry of the proposed MIMO antenna is illustrated in Fig. 1. The MIMO antenna printed of two symmetric U-shaped branch 30mm × 50mm × 1.6mm on FR-4 substrate with partial ground plane and micro strip-fed through ports 1 and 2.The spacing between of antenna elements λ/4(0.270 λ_0) over UWB. Different types of MIMO antenna systems have been proposed for UWB applications. The designed systems show good impedance characteristics in the frequency band of 3.1-10.6 GHz, Thus fulfilling the FCC requirements for UWB communications. These systems also have very low mutual coupling and correlations, so they provide good diversity performance. These MIMO Antennas is composed of identical stepped patch elements. In Fig.8 reflection coefficient of UWB MIMO antenna is presented, there has $S_{11}\leq$ -20 dB isolation which resonant at 3.7, 4.7 and 6.4 GHz all over UWB (3.1-10.6GHz).

B. Effect of Ground and Stub

For better isolation over wideband stub in ground proposed for the UWB antenna elements. Due to the inserting stub in ground plane of antenna there is increased in isolation over UWB. Edge to edge separation between elements is d (0.270λ0).

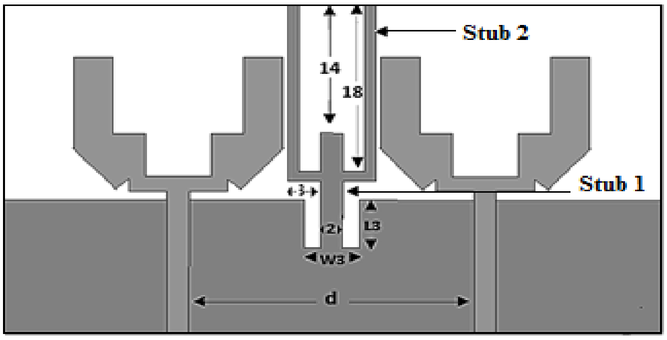
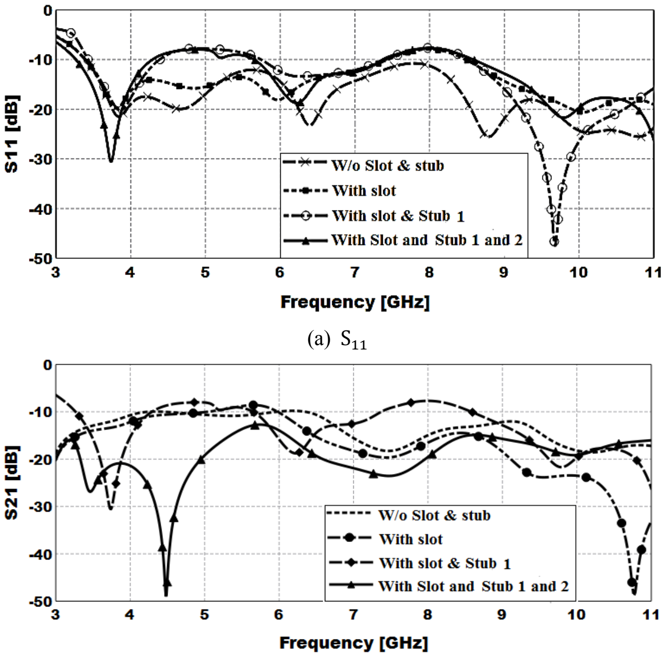


Fig.4. UWB MIMO Antenna With Fork Stub In Ground

There is extent effect on the spacing between two symmetric elements on impedance performance of antenna. Before introducing stub branch in ground square slot of width W3=5mm and Length L3=5mm which has been detach from the ground plane and stub of 2×12 mm put over, which have less effect on current distribution of ground plane.

After that, a stub branch 1 and branch 2 added for the reducing of mutual coupling of antenna elements. Due to insertion of a stub like structure in the ground plane side increasing in wideband isolation and hence reduce mutual coupling of antenna. The current among the stub distributed over stub branch 1 and stub branch 2 and all over the reducing of mutual coupling takes place.

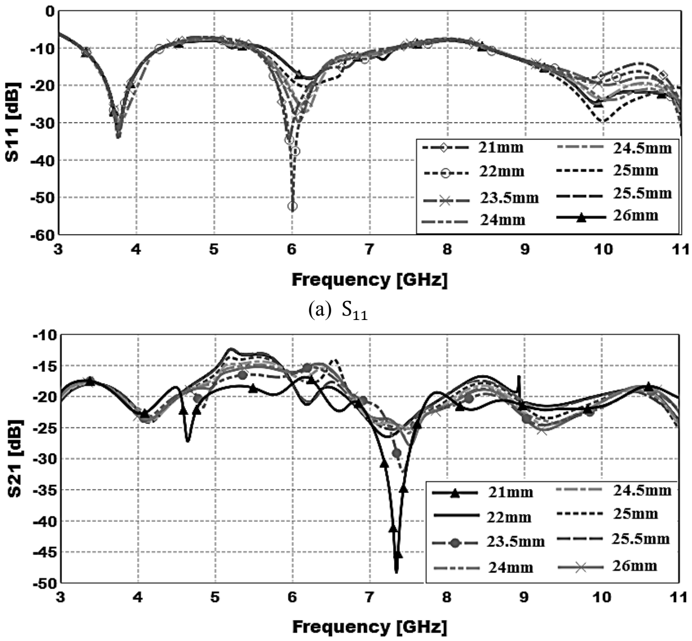
Performance affection of stub on impedance bandwidth shown in Fig. 5(a) and Fig. 5(b) shows mutual coupling of antenna with ground $S_{21} \leq -12$ dB, stub with branch 1 $S_{21} \leq -22$ dB and stub with branches 1& 2 $S_{21} \leq -25$ dB. Due to symmetric shape of MSA S22 parameter is as same as S11. In Fig. 4, shows the geometry of proposed antenna with the slot L3 × W3, stub 1 and stub 2.



(a) S_{11}

(b) S_{21}

Fig.5 Simulated (a) S_{11} (b) S_{21} Parameter of Ground Slot and Stub



(a) S_{11}

(b) S_{21}

Fig.6. Effect of spacing between two elements (varying d)

C. *Effect of Spacing*

On the other hand, due to consequence of separation of interelements in antenna in order to reducing mutual coupling effect. Due to placement of elements in ame substrate there is net flow of curent may effect on other element while one port is excited and other is terminated with the 50 Ω load. The proposed antenna having d =0.272 λ_0. As shown in Fig.6 variation of spacing in antenna element which affect on the impedance bandwidth and mutual coupling of the antenna.

D. *Design Approaches of Dual Band-Notched UWB MIMO Antenna*

Fig.1. shows the proposed dual band notched UWB antenna i.e. firstly two U-shaped monopoles selected as MIMO antenna shown in Fig. 1. Then for wideband isolation there is a fork shaped a stub introduced into the ground plane of the antenna, due to that mutual coupling get reduced. For more specifications of antenna dimensions of a stub and the more branches get added and enhance the isolation but there is effect on impedance bandwidth. Fig. 5 shows the decreasing in mutual coupling of the antenna due to stub structure. It can be seen that the mutual coupling is obviously reduced over the entire band, and the operating frequency of the MIMO antenna extends lower. So the fork stub here not only performs the role of an isolator, but also acts as a compensating radiator for the MIMO 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.

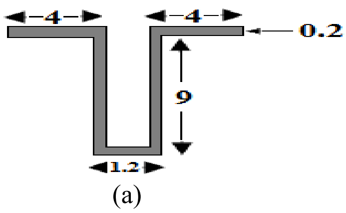


Fig. 7. Geometry and dimensions of the proposed dual band-notched UWB MIMO antenna, (a) slot view for 3.5 GHz and (b) strip view for 5.5 GHz. (Unit: mm).

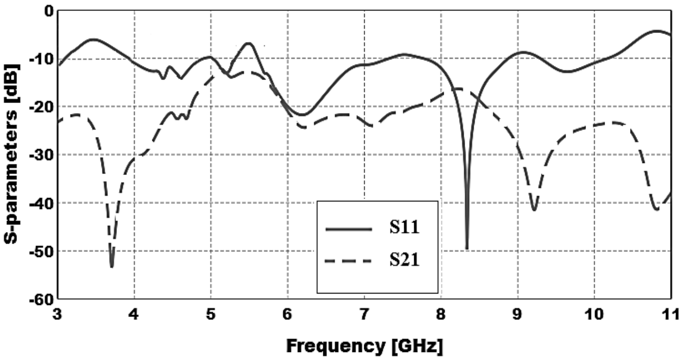


Fig. 8 Simulated S_{11}& S_{21} parameter of proposed Dual band notched UWB antenna

To remedy this problem, the UWB antenna with build-in frequency notch structure is often chosen. Most of the techniques have been employed for frequency rejection in UWB antenna designs including using radiating patches with embedded narrow slits of a half wavelength [18].Fig. 7 shows the Slot for WIMAX (3.3-3.7GHz) and strip view for the WLAN (5.2-5.8 GHz).

$$l_i = \frac{c}{2f_i\sqrt{\frac{\varepsilon_r+1}{2}}} \qquad i = 3.5,\ 5.5\ \text{GHz} \qquad (1)$$

III. Result And Discussion

A. S-Parameter

The simulation results of proposed dual band notched UWB MIMO antenna shown in Fig.8 Simulated result shows that the impedance bandwidth S_{11} ≤-10dB across UWB excluding S_{11} ≥ -10dB across band notch of (3.3–3.7 GHz and 5.15–5.85 GHz), is achieved. Fig shows that the mutual coupling between two symmetric elements is reduced while the stub adds in the ground plane of the antenna.

B. Radiation Characteristics

Like measurement of radiation pattern with either port 1 or 2 is excited and other port 2 and 1 terminated with load of 50 Ω. In x-y plane the radiation pattern is omnidirectional pattern while in x-z plane is eight shaped pattern which is also mirror images of each other with port 1 or port 2 excitation of symmetric element on same substrate and other is terminated with matched load and this type of radiation pattern satisfy the UWB operation.

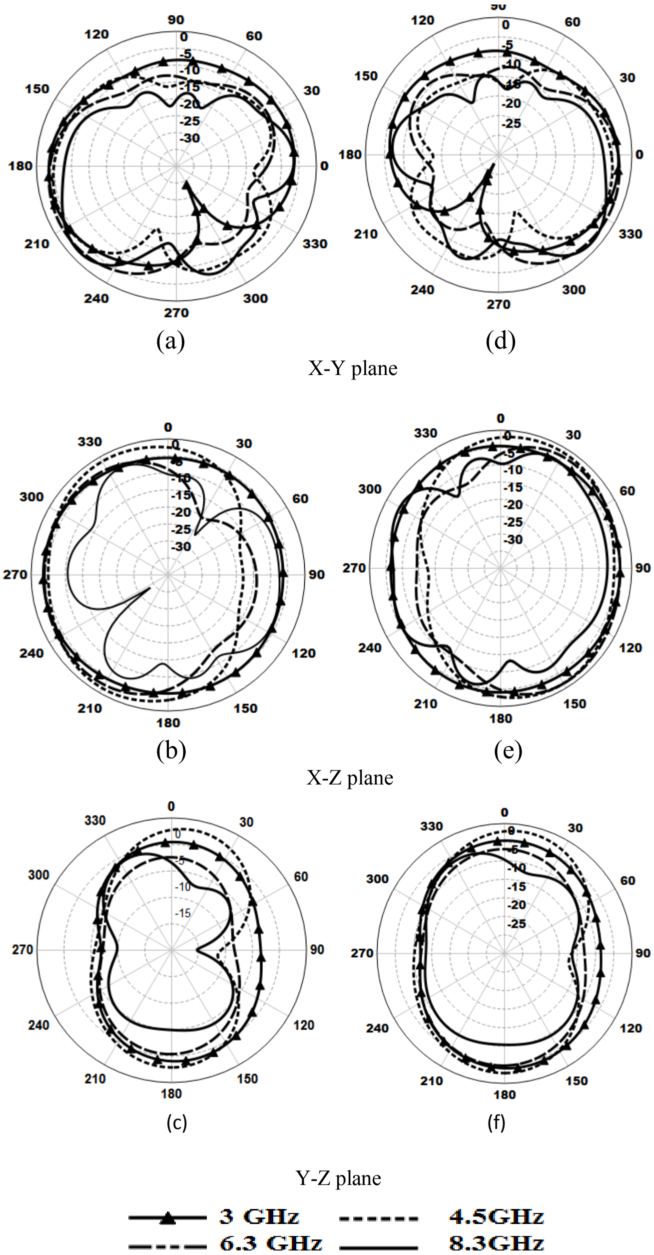
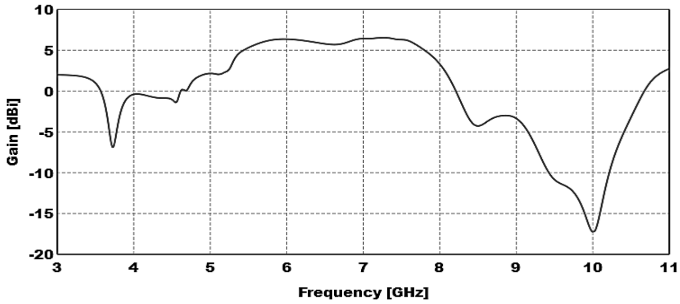


Fig.9. Simulated 2D Radiation Pattern at 3, 4.5, 6.3 & 8.3 with (a), (b), (c) at Port 1And (d), (e), (f) at Port 2.

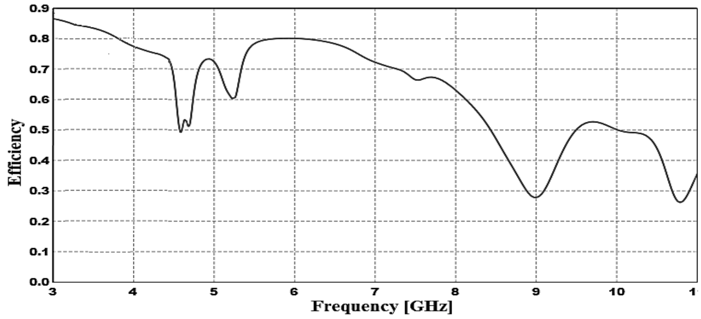
C. Diversity Performances

Pattern diversity is used to reduce the channel fading produced by multipath environments. The envelope correlation coefficient is an important parameter to judge the diversity performance of antenna.
Correlation coefficient is calculated using *S* parameters [19],

$$\rho_e = \frac{|S_{11}{}^*S_{12} + S_{21}{}^*S_{22}|^2}{(1 - |S_{11}|^2 - |S_{21}|^2)(1 - |S_{22}|^2 - |S_{12}|^2)} \qquad (2)$$



(a)



(b)

Fig.10. (a) Simulated Gain & (b) Efficiency of proposed antenna

The calculated ECC at 5.2, 6.3 and 8.3 GHz are 0.65, 0.57 and 0.49, respectively, which mean very low antenna correlations and can meet the diversity demands. ECC across UWB is 0.67 which is also suitable for Good diversity performance.
The diversity gain is,

$$G_{app} = 10\sqrt{1 - |\rho_e|} \quad (3)$$

The calculated diversity gain is more than 6.63 dB throughout the frequency band 3.1 GHz-10.6GHz.The simulated peak gain and radiation efficiency shown in Fig.10. From Fig. peak gain of proposed UWB MIMO antenna is 3dBi. And efficiency of the antenna is 75 % across the UWB. By using the proposed technique, the gain and the radiation efficiency are decreased dramatically in the notched bands, while good radiation performance is achieved over the other frequency band of operation.

IV. CONCLUSION

A dual band-notched UWB MIMO antenna with range of 3.0-11GHz with high isolation has been achieved and studied for wireless communication system which demands high data rates. For enhancing isolation a fork shaped stub added in ground plane of the antenna which provides the $|S_{21}| \leq$ -20dB. The dual band notch characteristics have performed with the trekking slot in the radiation patch with feed and C-shaped strip added in adjacently to the feed line of the antenna.

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