DESIGN OF MINITURISED MIMO ANTENNA WITH W-LAN BAND NOTCHED FOR ULTRA WIDE BAND (UWB) APPLICATIONS

Numan Ahmad[1], Shahid Bashir[1*], Shahid Rauf[1]

ABSTRACT

A miniaturized Multi-input Multi-output (MIMO) antenna is proposed for Ultra-wideband (UWB) applications having capability to mitigate interference with the WLAN (5.15GHZ-5.85GHZ) operating band. A 'spider' shape structure is etched on the ground as a decoupling structure to obtain impedance matching as well as desired isolation. W-LAN notched band in the entire Ultra Wide band is obtained by etching a couple of straight line on the ground plane. A very compact UWB-MIMO antenna with overall dimension of 20×20 mm² has been proposed which is smaller than most of other MIMO antennas designed for UWB. Impedance bandwidth for the proposed MIMO antenna is 2.9-11.1GHz with -10dB refection coefficient and isolation better than -16.5dB in the total Ultra Wide band is achieved.

KEY WORDS: *MIMO antenna, UWB, W-LAN, Notched band, Mutual coupling*

INTRODUCTION

High speed transmission, low power consumption, high security and wide bandwidth make ultra-wideband a promising technology (Oppermann et al. 2005).In 2002 Federal Communications commission (FCC) released (3.1-10.6GHz) spectrum for Ultra Wideband applications (Choi et al. 2004). However, challenges like multipath fading between the transmitter and the receiver in the communication channel, can be faced by the UWB system. Multiple-input-multiple-output (MIMO) is promising technique, to deals with the multi path fading (Bolin et al. 2005). Channel capacity of various systems can be increased using MIMO technology because of transmitting data over multiple channels (Wallace et al. 2003). Spectral efficiency and capacity of any system is increased by use of several antennas at the receiver side (Hussain and Sharawi 2015). Besides this, mutual coupling rebate the achievement of two or more antennas in MIMO system. However, isolation enhancement in MIMO antennas design for UWB is a very challenging assignment.

Until now, various techniques have been reported to enhance isolation of different MIMO antennas. Several decoupling structures were used to reduce the mutual coupling like, floating parasitic (Khan et al. 2014), T shaped (Kang et al. 2015), comb shaped , EBG structures (Li et al. 2015) metal strips (Tang and Lin 2014) and wideband neutralization line (Zhang and Pedersen 2016). W-LAN band correlate in the entire UWB, which degrade the performance of the existing UWB system. Nonetheless, MIMO antenna carrying the strength to neglect the interference with the present wireless communication system like W-LAN (5.15-5.85GHz) was designed. Recently, an L shaped (Babu et al. 2016), C-shaped (Tripathi et al. 2014), slot with an arc shaped (Chacko et al. 2013) and a couple of split-ring resonator (SRR) slot (Siddiqui et al. 2015) methods have been suggested to realize band-notched characteristics.

In this paper, a compact Ultra wide band MIMO antenna with characteristic of W-LAN band notched for UWB is proposed and analyzed. A pair of symmetric antennas was placed parallel to each other to realize a simple design. Moreover, a 'Spider' shape and inverted 'T' shape decoupling structures is etched on the ground plane between two antenna elements to create an extra path for current to reduce mutual coupling and matched the two antennas. A pair of "line strips" on the T shape is introduced for W-LAN (5.15-5.85GHz) notch band.

ANTENNA DESIGN

Size of miniaturized UWB-MIMO antenna with W-LAN band notched is presented in Fig.1. The planned antenna with overall size of 20×20×0.8 mm³is printed on substrate (FR-4) having dielectric constant value 4.4 and substrate height of 0.8mm which is compact as compared to most of the UWB antennas having a single resonator. The dimension of radiating patch is 3.5mm×4.8mm and that of feed is 1.5mm×3mm. Distance between two

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antennas is choose as 10mm in UWB-MIMO.

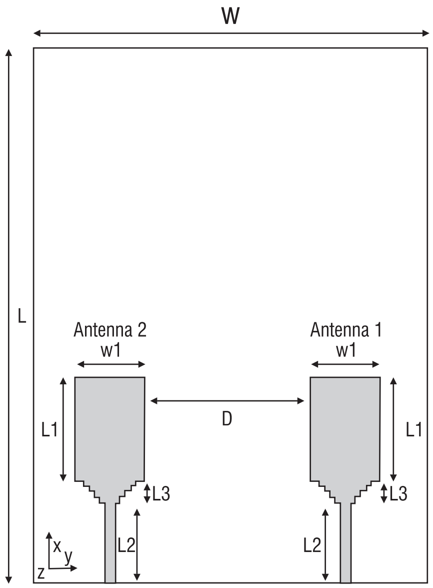


Fig. 1 Front view of MIMO antenna

“Spider shaped”, “inverted T shaped” defects in the ground is used for isolation and matching of the proposed MIMO. “Spider shape” is basically the combination of cylinder, upper boxes lower box, central box and long rectangular box defects in the ground of the antenna as illustrated in Fig 2. Numerical simulations in this paper were carried out in High Frequency Structure Simulator (HFSS).

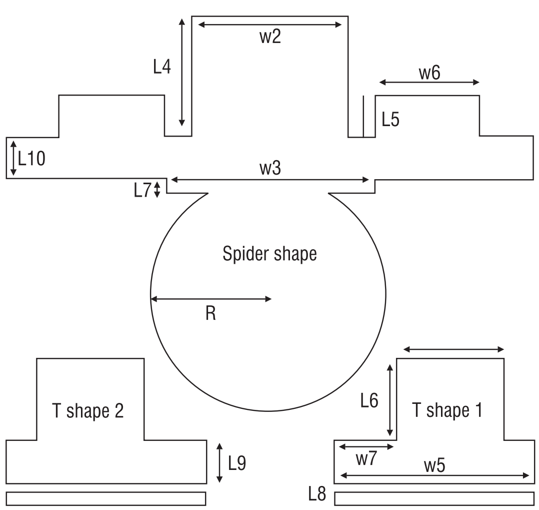


Fig. 2 Back view of MIMO antenna

The antenna parameters are given in the following Table1 with all values in millimeters (mm).

Table 1. Antenna Design Parameters

W	20	W4	4	L9	2
L	20	L4	4.3	L10	1.5
W1	3.5	W5	8	R	4.2
L1	4	L5	2	D	10
W2	6	W6	4		
L2	3	L6	3.5		
W3	8	L7	1		
L3	0.8	L8	0.2		

Simulation result of design evolution of UWB MIMO antenna is presented in Fig. 3. A single UWB antenna carrying a rectangular radiating patch structure is compared with the stairs case shape in the lower part of the radiating patch. S11 result shows, that a good impedance matching is achieved in the upper UWB from 9GHz to 11GHz, because size of the radiating patch is further reduced due to stairs from 4.8mm to 4mm which result an acceptable matching in upper UWB. Four stairs at the left and right side of the radiating patch, having 0.2mm fixed size along x-axis and declining from 1.5mm to 0.9mm respectively from stair 1 to stair 4 along y-axis.

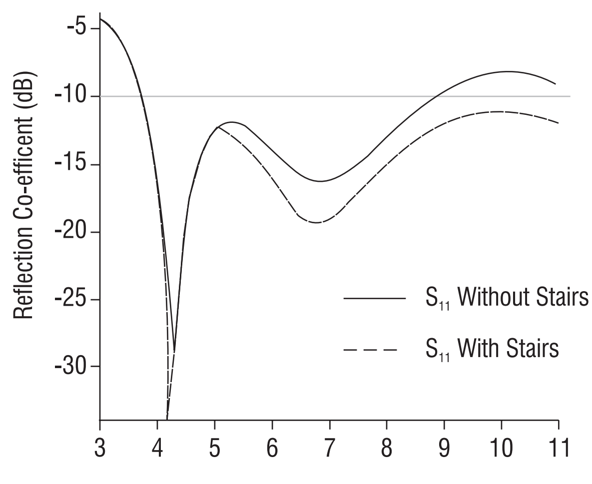
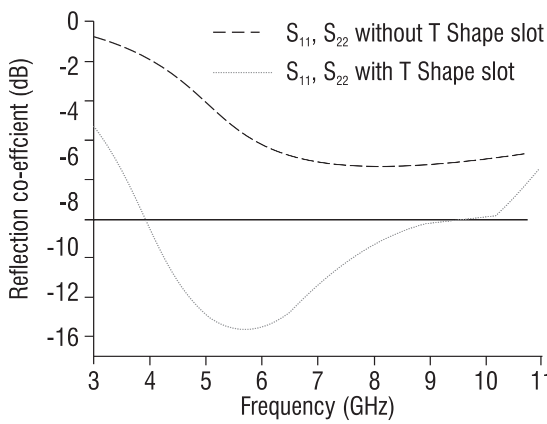


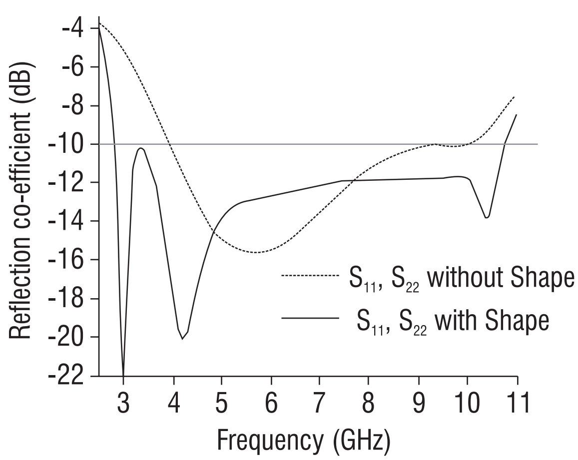
Fig. 3 Simulation result with and without stairs

Inverted T shaped and spider shaped slots in the ground of the MIMO antenna has significant effect on impedance matching. Simulation result in Fig. 4 shows that after T shape slot, proposed antenna is matched in the total UWB except 3.1-4.2GHz band. To further match the two antennas in the final MIMO design a spider shaped slots were introduced in the ground plane. MIMO antenna completely satisfied the condition of impedance matching as well as mutual coupling (S11 and S22< -10dB, S12 and S21< -15dB) as a result of spider shape slot as demonstrated in Fig.4 and Fig.5. Fig. 5 (a) presented the effect of isolation with and without the spider shape in term of S_{21} and S_{22} for antenna 2 while Fig. 5(b) defines the mutual coupling for antenna 1. A pair of straight line strips is etched on the T shape for W-LAN band notched in the whole UWB as illustrated in Fig.7.

To consider the impact of spider shape and a pair of lines, an overall surface current distribution at frequency 4.4GHz is shown in Fig.6. As can be seen a large magnitude current induced in these strips created an extra coupling path as a result, reverse current was produced which canceled out the response of initial coupling.

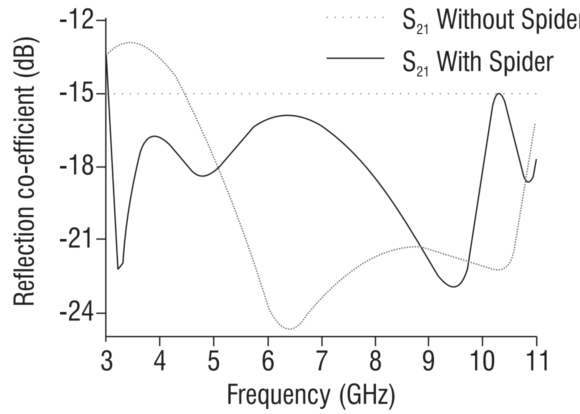


(a)

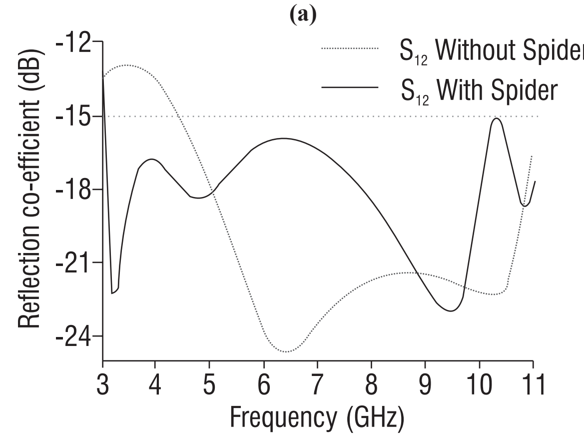


(b)

Fig. 4 scattering parameters with and without (a) T shape slot (b) spider shape

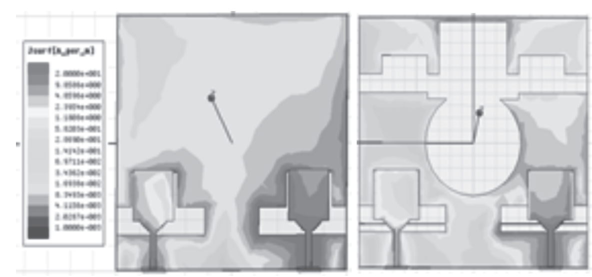


(a)



(b)

Fig. 5: Effect of Spider shape on Mutual coupling (a) antenna2 (b) antenna1

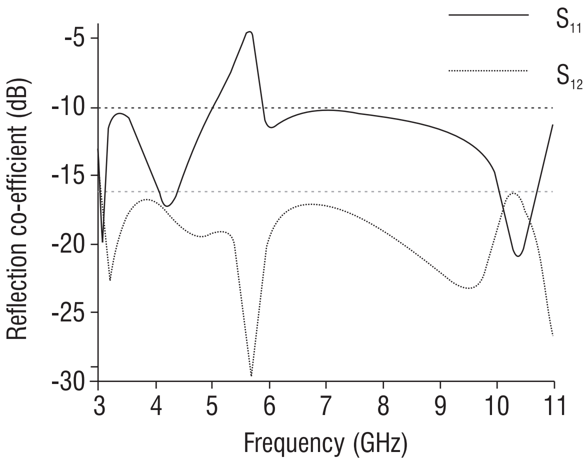


(a) (b)

Fig.6 Surface Current distribution at 4.4GHz (a) without spider and pair of lines (b) With spider and pair of lines

RESULTS AND DISCUSSION

S-parameter of the antenna1 and antenna 2 in the proposed MIMO against frequency is illustrated in Fig.7. Simulated results showed that impedance matching (S_{11} and S_{22}) of the antenna is below -10dB from 2.9GHz to 11.1GHz except notch at W-LAN band for stopping interference. Mutual coupling (S_{21} & S_{12}) of the compact MIMO antenna is better than -16.5dB for the total UWB, registered MIMO a suitable candidate for UWB applications.



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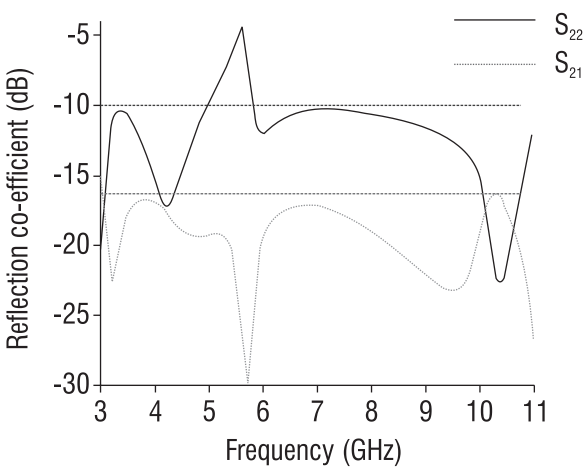
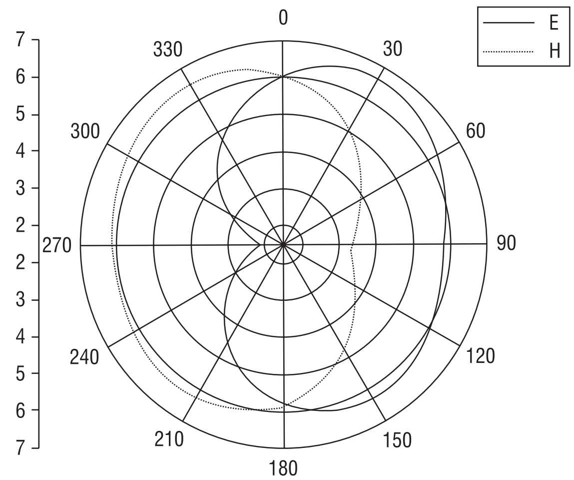


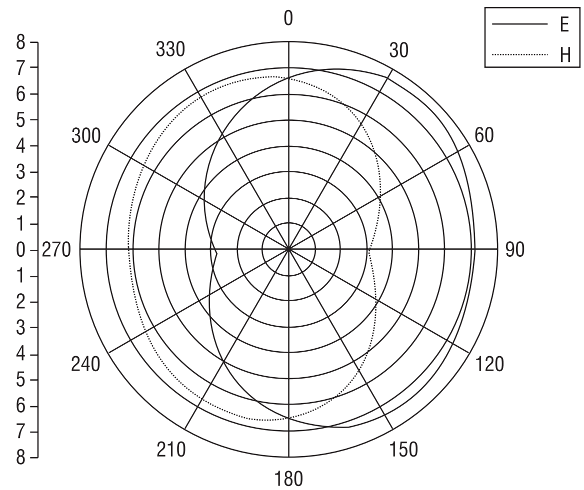
(b)

Fig.7 S-parameters (a) antenna 1 (b) antenna 2

2D and 3D radiation patterns of the proposed design are shown in Fig.8 and Fig.9. 2D radiation pattern at 3.6GHz, 4GHz, 6.6GHz and 9.6GHz in H-plane (YZ) and E-plane (XZ) are given in Fig.8. In H-plane the radiation pattern is close to omnidirectional, which shows that our proposed antenna attained a uniform and broad coverage for UWB system. MIMO antenna comprised of two symmetric resonators having the same radiation pattern at port 2 and port 1**.** Fig.9 illustrates 3D radiation pattern of MIMO antenna at 3.6GHZ, 5.6 GHz, 6.6GHz and 9.6GHz respectively. The radiation pattern maintains its donut shape at all of these frequencies.Furthermore, peak gain against various frequencies is plotted in Fig 10. Peak Gain is in the range from 1.5 to 5.16dBi in the overall UWB except at the 5.5GHz notched band where it is -3.32dBi.



(a)



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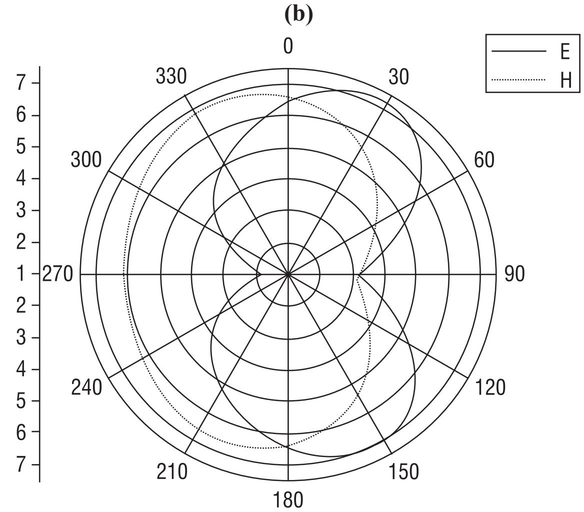

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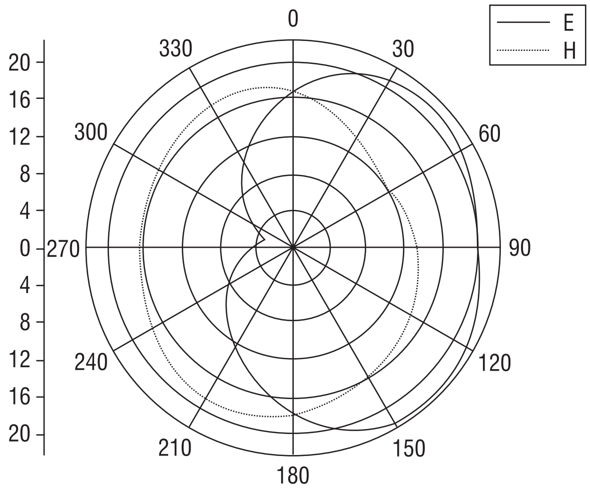
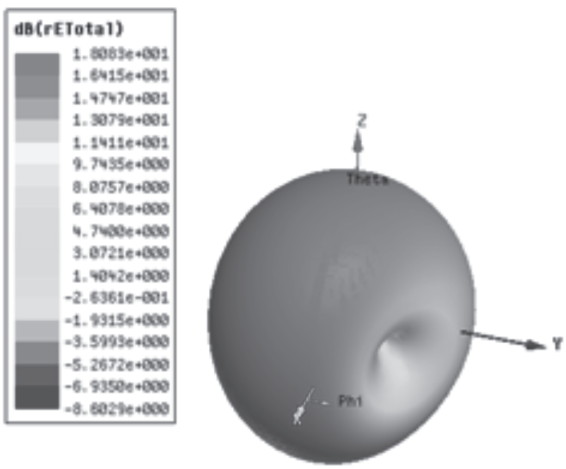


(d)

Fig. 8 2Dimensional radiation pattern (a) 3.6GHz (b) 4GHz (c) 6.6GHz (d) 9.6GHz in E (black line) and H plane (blue line)



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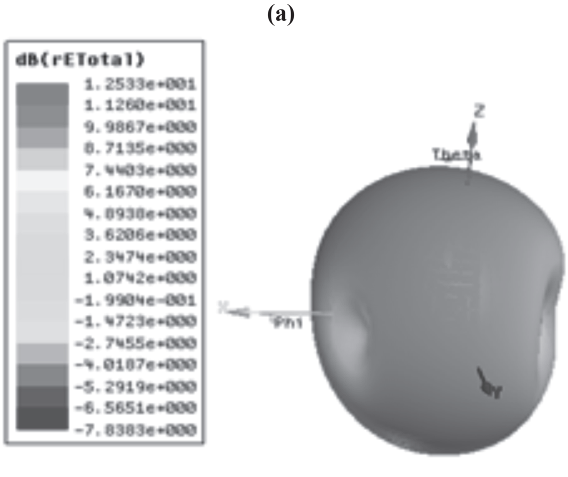

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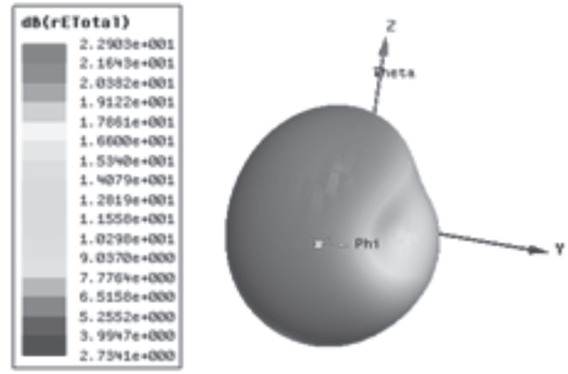

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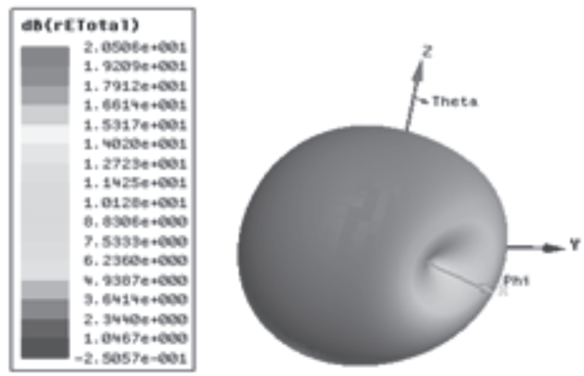

(d)

Fig. 9 3D radiation patterns (a) 3.6GHz (b) 5.6GHz (c) 6.6GHz (d) 9.6GHz

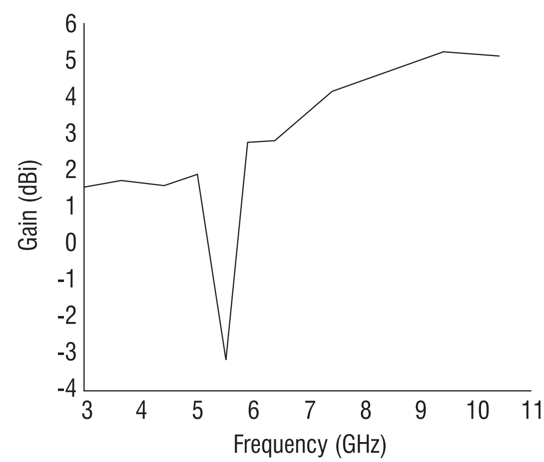

Fig.10 Peak gain versus frequency for proposed MIMO Antenna

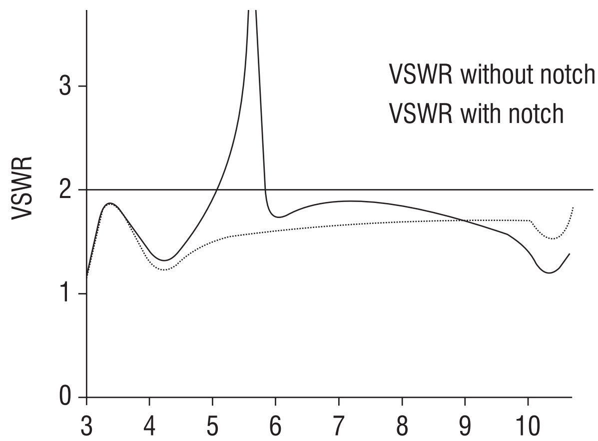

Fig.11 VSWR

Table 2. Comparison of proposed and other MIMO antennas design for UWB

Reference	Size(mm)	Bandwidth (GHz)	Isolation (dB)
[6]	38.5x38.5	3.1-10.6	-15
[7]	26x31	3.1-10.6	-25
[8]	60x40	3-6	-20
[9]	30x40	3.1-10.6	-15
[11]	22x36	3.1-10.6	-15
[12]	40x25	3.1-10.6	-15
Proposed antenna	20x20	2.9-11.1	-16.5

Voltage standing wave ratio (VSWR) for the final UWB MIMO antenna design is demonstrated in Fig.11. From this result, it is evident that the value of the VSWR is less than 2, from 3GHz to 11GHz with sharp notch on W-LAN.

CONCLUSION

UWB MIMO antenna with compact size having the characteristic of WLAN notched band is shown in this paper. Two symmetric antennas with parallel combination are employed in the design. Impedance matching of -10dB and mutual coupling better than -16.5dB in total UWB (3.1–10.6 GHz) have been achieved by creating T shapes inverted slots and a spider shape in the ground plane. A sharp rejection band is obtained by creating a pair of lines through the inverted T shaped slots on the ground. Along with, isolation and matching, omnidirectional radiation pattern of the proposed MIMO antenna is achieved. The value of VSWR less is than 2 and a peak gain for the entire UWB is also investigated. All of the above mentioned parameters make the proposed antenna a suitable candidate to overcome the problem of multipath fading.

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