ISSN: 0975-766X
CODEN: IJPTFI
Research Article
Available Online through
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DESIGNING OF COMPACT UWB-MIMO ANTENNA TO SUPPRESS THE FREQUENCY INTERFERENCE WITH WIMAX &WLAN SYSTEMS

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Received on 06-08-2016 *Accepted on 10-09-2016*

Abstract

A Ultra-wideband(UWB) multiple input multiple output antenna with a compact size of 22 × 36 mm^2 at frequency range 3.1-10.6 GHz to overturn the frequency 5.15-5.85 GHz and 3.3-3.8 GHz interfering with WLAN and WIMAX systems is designed for medical applications. The UWB MIMO antenna consists of two triangular monopole antenna elements and a T-shaped ground stub. A vertical slot is cut on the middle of the T-shaped ground stub to reduce the mutual coupling. Also it consists of two strips on the ground plane to suppress the WIMAX & WLANS systems creating a notched band frequency. measurements are used to study the antenna performance in rapports of impedance matching, isolation between the two input ports, radiation pattern, antenna gain, surface current distribution and envelope correlation coefficient(ECC), total active reflection coefficient(TARC). Outcomes show that the antenna can function from 3.1 to additional 11 GHz with a notched band in 5.15–5.85 GHz and 3.3-3.8 GHz. The mutual coupling observed is less than −15 dB with ECC less than 0.1.

Keywords: Band notch, multiple-input-multiple-output (MIMO), Isolation, Frequency interference, ultra-wideband (UWB).

1. Introduction

Multiple input multiple output (MIMO) technology has the advantage of increased channel capacity without needing additional [1]. A MIMO communication system needs using many antennas fixed in the transmitter and receiver with a smaller amount of coupling between them. For handheld devices, the space is restricted and installing MIMO antennas with less coupling is at all times a tough task. Innumerable MIMO antennas have been studied for its use in handy devices in various wireless systems such as the LTE [2] and WLAN [3]. Research showed that MIMO technology used in UWB system would give more channel capacity. Also various techniques were used to reduce coupling between the antenna elements in MIMO antennas [4], [5]. The UWB frequency from 3.1 to 10.6 GHz interferes with the WLAN and WIMAX band from 5.15 to 5.85 GHz and 3.3-3.8 GHz. To overcome this problem, it is needed to design the UWB antenna with the band-stop characteristics [6]. In MIMO [7] antennas with the notched characteristics were studied to quash the frequency interference from the WIMAX & WLAN systems. Two heptagonal single pole elements were orthogonally placed on the substrate for low coupling between the two input ports. A slot was made on each of the antenna elements to suppress the WLAN band. Though, the two antenna elements didn't have a common ground plane, making the antenna challenging for use. In [8] a compact dual band notched UWB MIMO antenna with the high isolation was considered. The [7] slot antennas were used for the UWB applications with the strip to assure high isolation. The slots were fixed on the input feeding structure to create a notched band. On the other hand, for creating this type of the structure we need large size. A dual notch band was intended for an UWB MIMO antenna using dependent strips and slots on the antenna elements. This antenna had a dense size of 27 × 30 mm^2.

In this article, we intend to design an UWB MIMO band-notched antenna that is much smaller than shown in [8]. It has a compact size of 22 × 36 mm^2, which is 14% smaller in electric size compared to the design in [7]. A strip on the ground is required to create the estimated notched band with the efficacy of 7%, which is much smaller than all of those in [8],[7]. The measured results obtained by simulation proved that the antenna has a decent impedance matching, great isolation and good diversity performance all over the UWB with notched band characteristics in 5.15–5.85GHz and 3.3-3.8GHz. The isolation between the two monopole antennas is -12.53 dB (S_{21}).

2. Methodology

2.1 Antenna Design

After understanding the need for designing of the compact MIMO antennas for UWB and WLAN [3], we have calculated the size of parameters of the micro strip patch and the dimensions of the substrate. We designed antenna [7] for the required frequency range using HFSS software. We compared the antenna characteristics by varying the ground dimensions, antenna patch shapes and sizes (dimensions).

Design Equations

Designing of T-Stub:

$f_r = \frac{144}{l1+l2+g+\frac{A1}{2\pi l1\sqrt{\varepsilon_{re}}}+\frac{A2}{2\pi l2\sqrt{\varepsilon_{re}}}}$, Calculated f_r =4.4 GHZ, l_1 = L, l_2 = l_r,

g = lf1 + lf2 − LG1, A1 = $\frac{LG1WG1}{2}$+ $\frac{LG2WG2}{2}$ + (L −LG1 − LG2) (WG1 + ws/2), A2/l_2 = lr,

$\varepsilon_{re} = \frac{(\varepsilon_r+1)}{2}$, ε_{re}=effective dielectric constant

Where l_1 and l_2 indicate the length of the ground plane and the radiation patch and g denotes the gap between them.A1 and A2 denote the area of the ground plane and the radiation patch. l_1, l_2, g, A1 and A2 are in mm.

2.2 Antenna geometry

The MIMO antenna has a very small size of 22×36 mm^2. The UWB antenna can be of any shape such as rectangular, elliptical, circular which do not have significant differences in their performance. The antenna proposed here uses the triangular shaped radiators. The resonant frequency of a planar monopole antenna can be estimated by the below formulae,

$$fL = \frac{7.2}{\{(L+r+p)\times k\}} GHZ$$

Where fL = 3.15 (lower band edge frequency)

*p = 1cm (*length of the 50Ω feed line)

L =S (height of the planar monopole antenna)

r = S/2π (effective radius of the cylindrical monopole antenna)

S = side length of the planar square monopole antenna

In this case the value of lower band frequency is 3.15 Hz and by using the values of the other parameters the value of L is obtained. The factor *k* can be assumed of having the similar significance as of $\sqrt{\varepsilon_{eff}}$ i.e. k =1.15 (In this case).

L = S = l_r = 8.06 mm

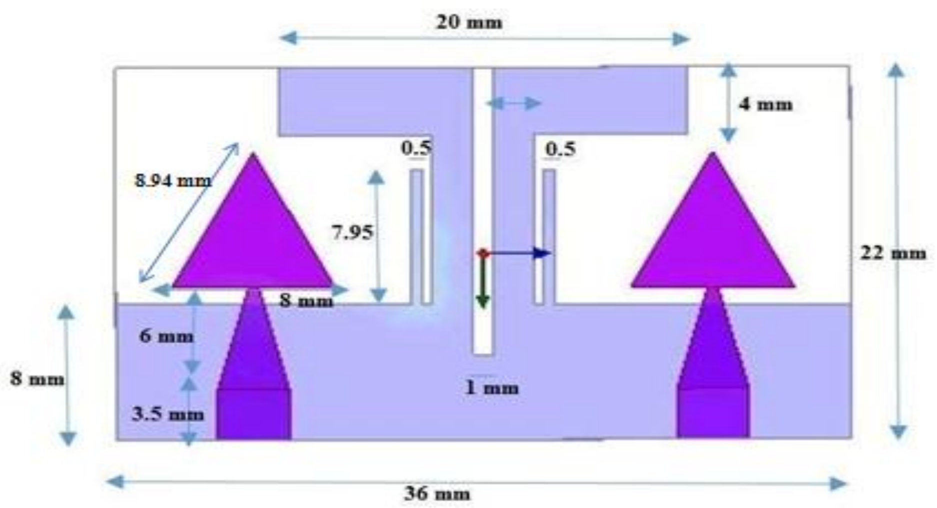


Fig.1 Geometry of antenna (dark gray: antenna patch, light gray: ground).

The impact of the T shaped ground stub extended vertically between the two elements is to provide impedance matching. A rectangular slot is cut upright on the T shaped ground for obtaining the good isolation [9] between the ports. Strip 1 and strip 2 are placed adjacent to the T stub to supress the WLAN and WIMAX band interfering with the UWB. They act as open end slots, which serve as λ/4 resonators at the band stop frequency of WLAN and WIMAX.

Two ports of the antenna have same impedance due to symmetrical structure. The antenna is designed using HFSS on a Rogers R4350B substrate with the values of dielectric constant, loss tangent and thickness as 3.5, 0.004 and 1.6 mm respectively.

3. Results

3.1 S Parameters

It can be observed that the bandwidth of the antenna with and without the ground slot are almost the same and are from 2.8 GHz to more than 11 GHz. A wide band of isolation is attained with the T shape because of two reasons. One is, the first branch acts as the reflector which reduces the mutual coupling by separating the radiation patterns of the two elements. The number of branches is inversely proportional to the mutual coupling. The other mechanism is that as the branches increase, more resonances are introduced, which is provided by a monopole of one branch or a quarter wavelength slot formed by two neighbouring branches.

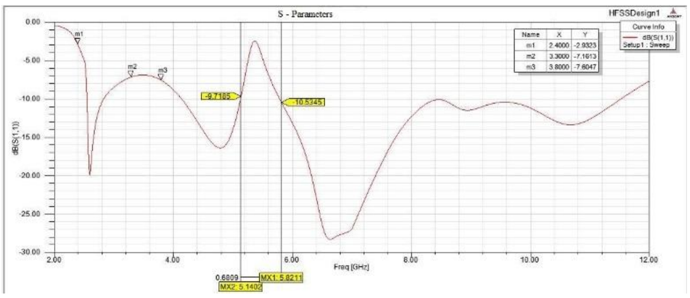


Fig.2 S_{11} parameters of MIMO antenna.

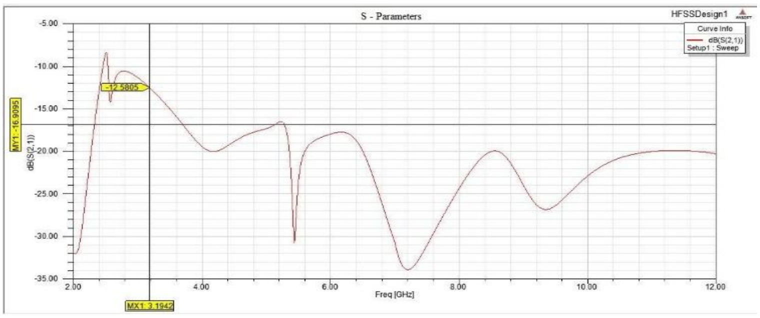
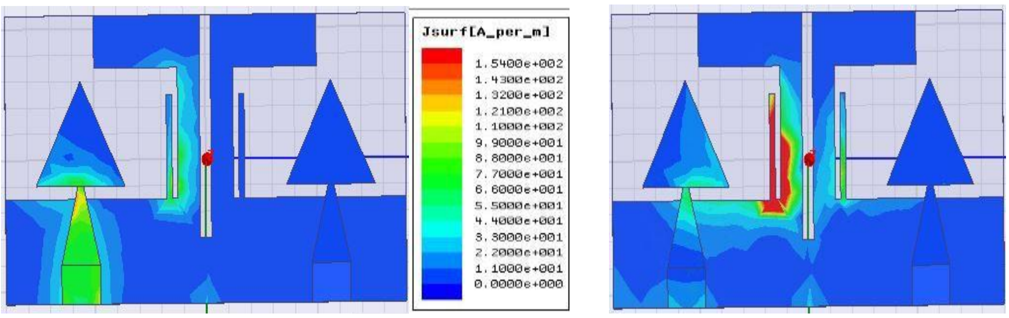


Fig.3 S_{21} parameter of MIMO antenna.

The above graph is obtained after simulating the antenna structure in the figure using HFSS software. The S_{11} graph crosses the 10 dB line twice at frequencies 2.4GHz and 10.61GHz thus covering the required frequency band of ultra-wide band spectrum. And between the frequencies 5.15 to 5.85 and 3.3 to 3.8 GHz is notched i.e. in the WLAN frequency and the WIMAX is notched which was the ultimate aim of the work. Because of this notching, the interference between the UWB and WLAN, WIMAX frequencies are attained.

3.2 Surface Current Distribution



(a) (b)

Fig.4 Surface Current distribution at (a) 4 GHZ (b) 5.4 GHZ.

The surface current distribution of triangular antenna is shown in Fig.4 (a) and Fig.4 (b). As seen from the above current distributions we can see the distribution of current which shows clearly that at the WLAN frequency range of 5.4 Hz the antenna elements are isolated. Port 1 is excited and port 2 is terminated to a load of 50 ohm.

3.3. Radiation Performance

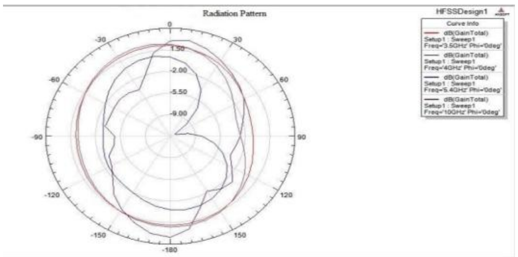


Fig.5(a)

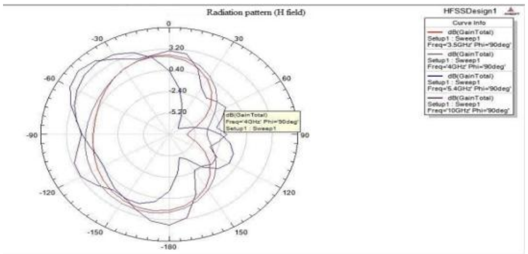
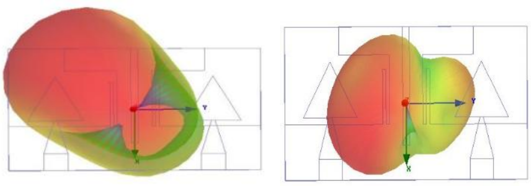


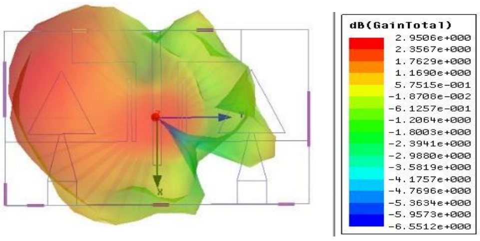
Fig.5(b)

Fig. 5(a) 2-D radiation patterns at 4GHZ, 5.4GHZ, 10 GHZ in (E plane) and Fig. 5(b) in (H plane).

The 2D radiation patterns with port 1 excited and port 2 terminated with 50-Ω load in the E-plane and H-plane is shown above. The gain at 4 GHz is 0.25dB and the gain at 5.4 GHz is 0.1 and the gain at 10 GHz is 5.1 db. We notice that, with an increase in frequency the gain increases at 4 GHz and when it reaches 5.4 GHz gain reduces showing the band notch characteristics.



(a) (b)



(c)

Fig.6 3D radiation patterns at (a) 4 GHz, (b) 5.4 GHz, and (c) 10 GHz.

The resulting 3D pattern looks kind of like a globe with the antenna beneath and energy radiating outward. With port 2 terminated with a 50-Ω load and port 1 excited, the simulated 3D radiation patterns at the frequency of 4 GHz, WLAN reject frequency of 5.4 GHz and the frequency of 10 GHz are shown in Fig. 6. Due to the symmetrical structure of the MIMO antenna, the radiation patterns with port 2 excited and port 1 terminated with a 50-Ω load are the same. Fig. 6(a) and (c) shows that the patterns are slightly directional at about $\theta = 270^{\circ}$. The power is radiating toward the left of the x–z plane because port 1 is feeding the antenna on the left. Similarly power would be radiating towards right for antenna on the right, thus attaining pattern diversity. At the WLAN frequency of 5.4 GHz, the radiation pattern in Fig. 6(b) indicates the power is much reduced.

3.4. Envelope Correlation Coefficient

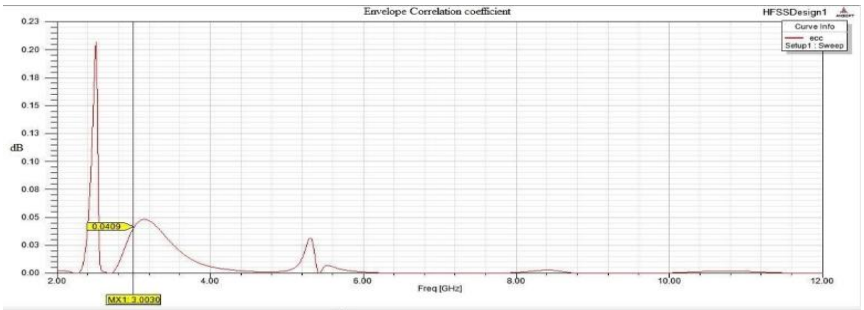


Fig.7 Envelope Correlation Coefficient (ECC).

In a MIMO antenna array system envelope correlation coefficient "ρ" shows the effect of different propagation paths of the RF signals that reach the antenna elements. ECC varies from 0 to 1. For a good MIMO antenna performance this value must be zero. In this work, the measured value of ECC is very small value approximating it to zero.

3.5. Total Active Reflection Coefficient (TARC)

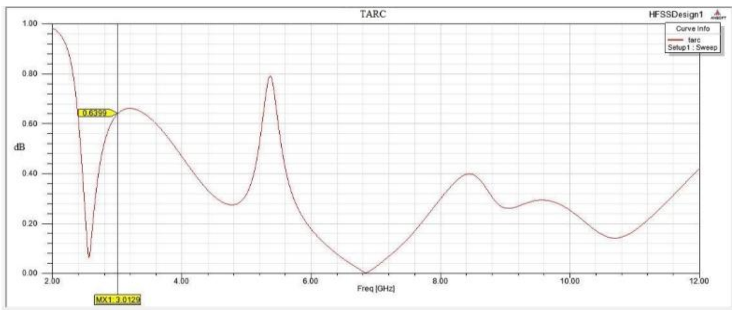


Fig.8 Total active reflection coefficient (TARC).

While computing the radiation performance of MIMO antenna systems, TARC indicates the total incident power to the radiated power. The total active reflection coefficient (TARC) is the square root of the sum of all incident powers at the ports minus the radiated power, divided by the sum of all incident powers at the ports of an N-port antenna. The TARC should lie in the range of 0 to 1, where 0 indicating zero reflections and 1 indicating full reflections from the antenna elements. TARC is found to be less than 1.

3.6. Diversity Gain:

Diversity gain is the increase in signal-to-interference ratio due to some diversity scheme.

Diversity gain is usually expressed in dB. It is found to be 10 dB.

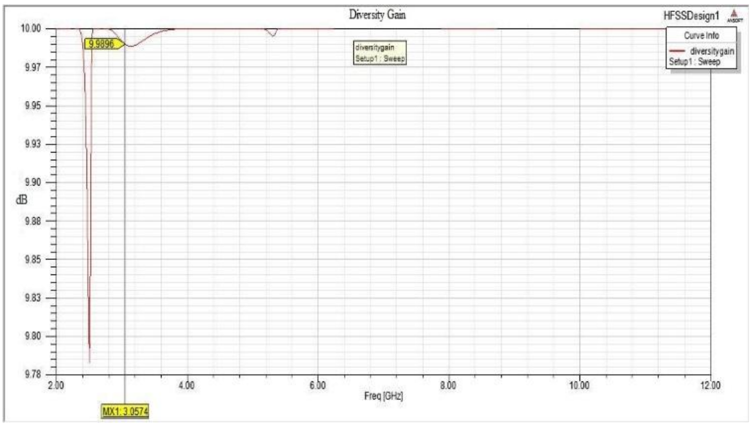


Fig.9 Diversity gain.

4. Discussion

4.1. Effects of T Shaped Ground Stub

The T shaped ground stub in the MIMO antenna provides better impedance matching for the antenna and enhances isolation by reflecting radiation from the radiators. This T shape is chosen for compactness. The antenna has a low cutoff frequency (for $S_{11} < -10$ dB) of about 4 GHz (which is higher than 3.1 GHz required for the UWB). Hence it serves to bring down the frequency to 2.8 GHz instead of 4 GHz by generating a resonance at 5 GHz with the T stub. Coupling (S_{21}) between the two input ports is almost less than −15 dB.

4.2. Effect of Ground Slot

The ground slot cut on the T-shaped ground stub enhances isolation. The impedance bandwidths of the antenna with the ground slot and without the ground slot are the same which is from 2.8 GHz to greater than 11 GHz. Though, without the ground slot, the mutual coupling between the two input ports of the antenna is greater than −15 dB in the frequency range less than 5 GHz [6], [8]. With the use of ground slot, a resonance at 2.6 GHz is generated, resulting S_{21} below -15dB.

4.3Effects of Strips

Without the strips, the antenna provided good impedance matching lower than -10dB and low mutual coupling whose value is lower than -15 dB in the entire UWB. The two thin strips are used to provide a band stop characteristics for the antenna at WLAN and WIMAX. Hence the stop band can be adjusted by varying the length l_t and width w_t of the strips. It is observed that as the strip length l_t increases from 7 to 9 mm, the excluded (notched) frequency decreases from 6.2 to 5 GHz, while S_{21} remains same across the UWB. As the strip width w_t increases from 0.3 to 0.9 mm, the upper edge of the stop band remains same at 5.85 GHz, but the lower edge shifts thereby increasing the stop bandwidth.

5. Conclusion

MIMO Antenna is used as a reason of increasing the channel capacity without requiring additional power or frequency spectrum. It requires numerous antennas installed in the transmitter and the emitter region with less coupling between them which is a great challenge due to the restricted space in compact devices. Research studies show that MIMO technology used in UWB system provide superior channel capacity when compared to other narrow band systems. Hence mutual coupling reduction was carried out in UWB and also notching of WIMAX and WLAN region was discussed. UWB signals can penetrate through obstacles, which find application to image organs of human body. It has high precision ranging at centimeter level based on the ultra-short pulse characteristics, which is suitable for the localization and detection in medical applications. Also it has low electromagnetic radiation with less energy consumption. Hence it finds application in medical monitoring, medical imaging etc.

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