Designing and Analysis of MIMO Antenna for UWB Applications

Rhea Nath[1] , Pramod Singh[2]

[1]*Electronic Communication, Mtech Student Meerut Institute of Engineering and Technology, UP Technical University (India)*

[2]*Associate Professor, Meerut Institute of Engineering and Technology (India)*

ABSTRACT

The presentation paper focus on the implementation of UB antenna with monopole structure including a Microstrip patch for various applications. There over all dimension of this system of UWB MIMO antenna is 32x32x1.6 cum. This antenna is a two ports MIMO antenna that operates within a frequency range of 2.3 to 10.07 GHz. A Defective Ground Structure (DGS) is proposed to minimize isolation between the antenna elements. Better isolation between the antenna ports could provide a mutual coupling of -29dB.

Keywords*: MIMO, Microstrip, UWB, Diversity, Mutual Coupling.*

INTRODUCTION

Because of inherited advantage, such as, high data rate in the limited range, low power and easy fabrication, for the last so many years, UWB is taken into consideration as one of the best techniques in present context. The limitation of maximum emission of 4.31 dB/MHz with 3.1 – 10.6 GHz have been fixed by FCC. In wireless connectivity between portable consumer device, such as, with the help of UWB technology printers, digital cameras and computers with high data transfer rate is possible within such short range of connectivity [1]. The fundamental advantages in UWB communication system is the low power and high data transfer rate interference immunity. However, due to low power transmission limits the operations of UWB systems within a short range communication [1]. MIMO technology use multiple antennas at its both terminals i.e. transmitter and receiver ends for significant enhancement of the performance of transmission and channel capacity without losing additional energy and bandwidth [2]. In the case of wireless communication, a big problem like multipath fading appears when signal with different amplitudes and phases combine destructively at the receiver end, such as, spatial diversity, time diversity etc. can be solved.Diversity MIMO antenna both in the base station and mobile terminal is to increase the transmission capacity and reliability of the system without increasing both the bandwidth and power consumption that improve a great deal in spectrum efficiency. The MIMO performance determine the correlation of received signal by antenna elements [3].

Why UWB and MIMO used together?

The MIMO system can increase the overall performance of antennas. The antenna designer has to design absolute compact UWB MIMO antenna with least mutual coupling and also reduced correlation factor between the antenna elements keeping in view to overall new challenges like, reduction in mutual coupling and also the correlation between the antenna elements.

By introducing MIMO technology in to the UWB spectrum, enhancement in channel capacity to a large extent, robust and coverage radius is noticed [4]. To have an improved communication system, multiple antennas are equipped at both the terminals i.e. receiver as well as transmitter. This is in contradictory to the conventional communication system with only one antenna at each end i.e. transmitter and receiver ends.

Because of extremely low permissible transmitted power of -41.3 dB/MHz, UWB technology is restricted to short range communication. To overcome this restriction, MIMO technology in combination with UWB technology is considered to be one of the best solutions. While implementing this MIMO technique for both portable and compact devices, one more obstacle arises out of poor isolation and strong mutual coupling in compact antenna elements, but compact size of wireless devices limits this approach. Therefore, there appears a tough challenge to decrease mutual coupling and increase isolation between the antenna elements.

Challenge in MIMO antenna.

Designing of MIMO antenna for its usage in portable wireless communication devices with its compact size to reduce mutual coupling between the antenna elements is of course, a challenging task. Mutual coupling arises due to minimal spacing of antenna. Placement of multiple antennas into a single, compact and slim body of wireless devices and making it resonant for a different wireless communication applications into a single device is a toughest challenging job. As the antenna elements are firmly coupled with each other, maintaining isolation characteristic between them is indeed a challenging task.

Why Microstrips are used?

For accommodation of multiple constraints of communication system, a demand for Microstrip patch antenna having more than one port is felt necessary. This arrangement consequent upon the compact antenna size, overall cost effectiveness, with a higher channel capacity and enhancement in space diversity. It is an established fact that power dissipation result in high coupling degradation of antenna. Therefore, for designing multiple port antennas a high level precaution is an essential requirement. In addition, the antenna should be compact in size [7]. The wireless multimedia technology increase the reliability and capacity requirement of wireless communication. Therefore, the MIMO system has been considered as one of the best reliable and promising technology because it is well suited for fulfilling all the requirements like, high capacity, high data rates, high reliability etc. The most advantageous factor rest with MIMO system is that without increasing transmitted power and bandwidth, the system can improve capacity and reliability requirement. The MIMO system can use a host of antenna from different diversity scheme. The draw-back of the system is the use of multiple antennas in the system which in turn can increase the size of the system and also deteriorate the isolation between the antenna elements, thus causing distortion in radiation patter and also degrade the channel capacity.

In an attempt to reduce mutual coupling effects between the antenna elements in MIMO system, a number of experimental works have been conducted. Some of them are spacing between antennas and slit added in the ground plane is divided by slots [7][8].

Design and Analysis:

Construction of proposed antenna –

The construction of the proposed antenna s made on a FR4 substrate having a dimension of 32x32 sqmm and thickness of 1.6mm. Two concentric circles having radius of 5.5mm and 3.5mm are considered as outer circle and inner circle respectively. The area of circle is 95.07sqmm and that of the other circle is 38.50sqmm respectively. By subtracting the inner circle are from the outer circle area, we can obtain the area of ring equal to 56.576 sqmm. The area of arc measuring 28.28sqmm was obtained by dividing the ring area measuring 56.57 sqmm by 2. The width of the ring is 2mm. Here the antennas contribute two arc shaped radiating elements. Similarly, another arc shaped structure having same dimension is constructed and is placed on the ground facing the first arc. Both the arc shaped structure are placed perpendicular to the ground and are also supported individually rod shaped material of equal width of 1.3mm. Here the antenna is constructed by both the arc shaped radiating structure taken together. A rod like stud introduced diagonally between the two arcs shaped elements describing an angle of 45 degree to the ground with one end attached to the ground and the other remains open. The idea behind the insertion of the rod like stub is to enhance the isolation between the two antenna elements. Such structure is known as monopole structure. It is said to be partially grounded as the ground plane does not cover the whole structure. The present structure is said to be monopole structure antenna since the ground plane is not parallel to the proposed antenna.

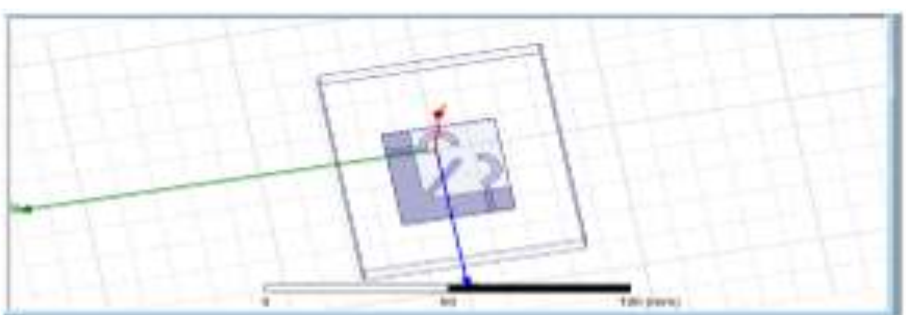

Figure 1.1: Structure of proposed antenna

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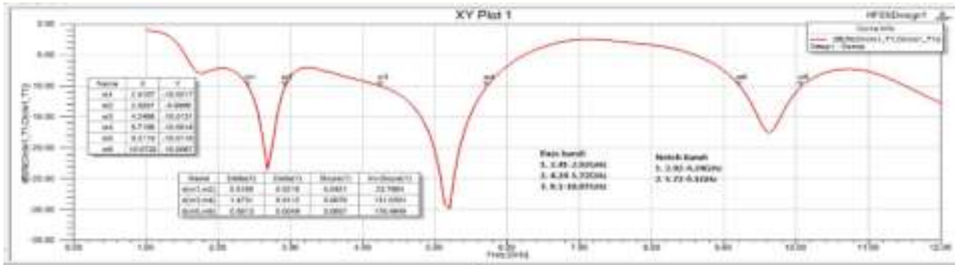

Figure 1.2: Graphical representation of return loss of the proposed antenna

The return loss in the communication system can be defined as a power loss because of reflection or returned due to discontinuity in the transmission line. Due to mismatch at the terminal load or insertion of a device in the transmission line, discontinuity occurs. Normally, this is expressed in terms of ratio in decibel (i.e. dB).

$$R_L \text{ (dB)} = 10 \, log_{10} \frac{P_i}{P_r}, \qquad \text{Equation (1)}$$

Where, R_L(dB) is the return loss in decibel unit, P_i = incident power and P_r = reflected power.

Band	Bandwidth	Applications
Pass Band	2.41 – 2.92 GHz	Bluetooth,Wi-Fi,S-Band,Satellite,Celluar phone
Pass Band	4.24 – 5.72 GHz	WLAN,C-Band,Radar
Pass Band	9.1 – 10.07 GHz	Radar
Notch Band	2.92 – 4.24 GHz	Satellite,Sirius,XM Radio,Cellular Phone
Notch Band	5.71 – 9.1 GHz	C-Band Satellite Uplink,C-Band ISM Radar

Table 1: Application of bandwidth range

The return loss plot in graphical representation is to find location of bandwidth. A total number of five bands are used in the proposed antenna. Three out of five bands are pass bands and the remaining two are notch band. Since our consideration in respect of UWB range is restricted within the frequency range of 3.1 GHz – 10.6 GHz, only two pass bands and two notch bands are in the operating range of interest of UWB. The three pass bands used are in different frequency range of 2.41 – 2.92 GHz, 4.24 – 5.72 GHz and 9.1 – 10.6 GHz and the two notch bands used are in different frequency range of 2.92 – 4.27 of 5.27 – 9.1 GHz.

Since the proposed antenna is a UWB-MIMO antenna, focus is made on the entire UWB frequency range from 3.1 to 10.6 GHz as a matter of consideration. While taking into account the operation frequency range of proposed antenna, only two pass bands and two notch bands are put in active use. The portion of plot in vertical scale above the value of -10dB representing the application of notch band and the portion of plot in vertical scale below the value of -10dB representing the application of pass band in the proposed antenna. A frequency band of 3.1 to 10.6 is taken into consideration in this case as the proposed antenna is within the UWB range. While designing the proposed antenna within UWB range, two pass bands and two notch bands are used within the given range. Two pass bands within the frequency range of 4.2 – 5.72 GHz & 9.1 – 10.07 GHz are applied and also on the other hand two notch bands within the frequency range of 2.92 – 4.24GHz and 5.72- 9.1 are applied.

Mutual Coupling – Mutual Coupling is known as electromagnetic interaction between the elements of antenna in array. The current so developed in each element in array due to electromagnetic interaction depends upon their own excitation and also the contribution of adjacent antenna element as well.

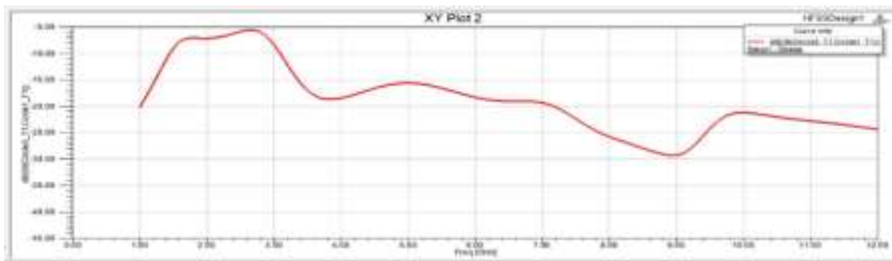

Figure 1.3: Graphical representation of Mutual Coupling

Normally, no interference of any kind should be between the antenna elements, even if there is any that should be eliminated at any cost. In order to avoid interference between the antenna elements, an attempt is initiated by providing isolation between the antenna elements. While applying isolation technique in an attempt to enhance the special gap between the antenna elements, a stub is required to be inserted between the antenna elements which in turn could eliminate the interference between the two antenna elements. In the proposed antenna as well a rod shaped stub was introduced placing diagonally between the antenna elements describing an angle of 45 degree to the ground plane. Since the proposed antenna is a UWB-MIMO antenna, its operation is within UWB frequency range. In the graphical chart, the portion below the value of -15dB on the vertical scale represent decrease in mutual coupling between the antenna elements. Hence, the mutual coupling is less (i.e. > -15dB) in the proposed UWB MIMO antenna.

Radiation Pattern

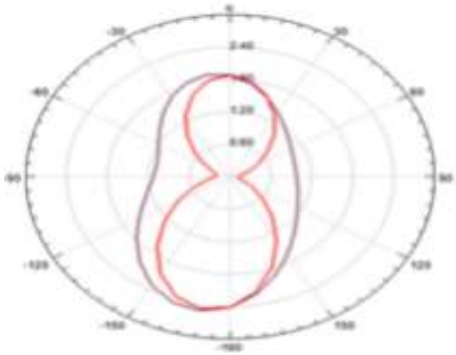

Figure 1.4 E-Plane and H-Plane pattern

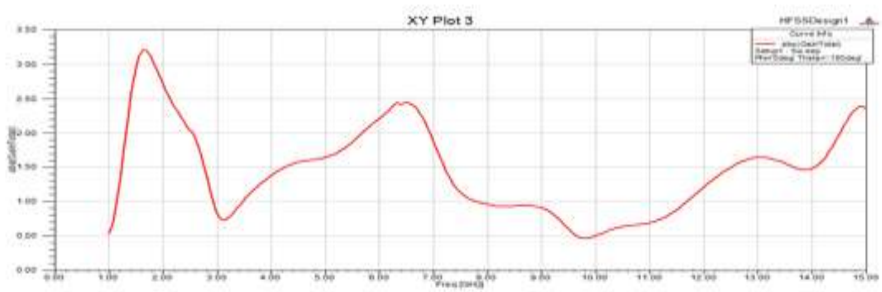

Figure 1.5 : Gain vs frequency plot

It can be concluded from the above figure that the proposed antenna has an omni-directional radiation pattern covering a frequency range within the UWB frequency range (i.e. 3.1 to 10.6 GHz). Both simulation and the experimental results are closely agreeable to each other showing that the proposed antenna is feasible for UWB applications.

SL No.		Size of the antenna (mm^2)	Impedance Bandwidth (GHz)	Isolation (dB)
1	Lee et al (2012) [10]	86.5x55	1.9 – 10.6	≥15
2	Rajagopalan A (2007) [11]	125x125	3.6 – 8.5	15
3	Gao P et al (2014) [12]	48x48	2.2 -12	≥15

4	Chen Y (2008) [13]	45x62	3.5 – 10.5	18
5	Chac BT et al (2013) [14]	50x50	2.76 – 10.75	≥15
6	Seec TSP (2008) [15]	45x37	3.1 – 5.0	20
7	Wong K et al (2003) [16]	48x115	2.3 – 7.7	≥20
8	Hong S et al (2008) [17]	80x60	2.27 – 10.2	≥20
9	This Work	32x32	2.3 – 10.07	≥25

Table 2 : Comparison of UWB-MIMO antennas in respect of dimensions ,isolation and bandwidth are as follows:

(a) (b)

Figure 1.6: Fabricated Prototype – (a) Top view of proposed antenna, (b) Bottom view of proposed antenna

For the purpose of verification of the proposed antenna design, the fabrication of an UWB MIMO antenna done on low cost FR4 substrate as is shown in figure 1.6 above. The antenna so design and fabricated is measured on Aglent 83752A. The size of the proposed antenna as measured is 32mm x 32 mm.

Figure 1.7: Graph plot at 2.34 GHz of proposed fabricated antenna

Figure 1.8: Graph plot at 2.65GHz of proposed fabricated antenna

Figure 1.9: Graph plot at 3.5 GHz of proposed fabricated antenna

Figure 1.10 : Graph plot at 4.57 GHz of proposed fabricated antenna

Figure 1.11: Graph plot at 8.57 GHz of proposed fabricated antenna

Figure 1.12: Graph plot at 9.17 GHz of proposed fabricated antenna

Figure 1.13: Graph plot at 9.4 GHz of proposed fabricate antenna

Figure 1.14: Operational view of proposed antenna in lab

As because the simulated and experimented results both agrees closely with each other, hence, the proposed antenna is proved to be a good candidate within UWB operational range.

Results: The antenna presented here is the proposed antenna having a frequency bandwidth of 1.6 GHz. In normal terms, the bandwidth having a minimum frequency of 0.5 GHz considered to be a UWB MIMO antenna. In the proposed antenna both pass bands and notch bands are applied within the range of 4.24 – 5.72 GHz & 9.1 – 10.7 GHz for pass bands and 2.92 – 4.24 GHz & 5.72 – 9.1 GHz for notch bands respectively are within the range of UWB. The interferences and so other hindrances causes by other applications are within the range of 2.92 to 9.1 GHz.

Conclusion and future of work

Conclusion: The a proposed antenna as has been presented here is a compact UWB MIMO with a frequency bandwidth of 1.6 GHz. The proposed antenna's structural design provides an isolation between the antenna element greater than -25dB that is much less than the prescribed isolation gap of -15dB. As such, the structural design of proposed antenna is able to achieve an antenna with less mutual coupling, less interference which result in an efficient antenna. From the above comparison Table it can easily derive that the proposed antenna is an compact UWB MIMO antenna having less mutual coupling and less interference in the UWB operating range. Hence, it can be concluded that the proposed is an efficient UWB MIMO antenna.

Future Work: The present work of this antenna may further be extended to design a 4 port to 6 port UWB MIMO antenna system in order to increase channel capacity so as to adapt high date rate applications.

Considering this structure as a foundation one, other such structures based on this may be constructed in an attempt to have a more reduced mutual coupling.

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