Designing and Analysis of MIMO Antenna for UWB Applications

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Abstract: *In this presented paper the focus is made on implementation of ultra bandwidth antenna with monopole structure for numerous applications. This antenna includes a Microstrip patch. The overall system dimension of the UWB MIMO antenna is 32 x 32 x 1.6* mm^3 *It is two ports multiple input multiple output antenna operates in at a bandwidth of 1.6 GHz.. A defective ground of structure (DGS) for increasing isolation between the antenna elements is proposed. A mutual coupling of -29 dB is obtained with better isolation between the two antenna ports.*

Key Words*: MIMO, Microstrip, UWB, Diversity, Mutual Coupling.*

Introduction:

What is UWB ?

Because of are inherited advantages, such as, low power, high data rate in the limited range and easy fabrication, for the last several years. UWB is considered to be one of the best technologies of search hot spot. FCC have fixed the limitation of maximum emission of 41.3 dBm/Mez with 3.1 – 10.6 GHz. UWB technology enable to offer very high data transfer rate within a short range by connecting portable consumer devices, such as, printers, digitals cameras and computers, wireless with each other [1].

What is MIMO ?

In UWB communication system the low power and high data rate interference immunity are the fundamental advantages. However, the low transmitted power limits the UWB system only to operate in short range communication [1].

Multiple Input Multiple Output (MIMO) technology involves multiple antennas in use at both the transmitter and receiver to significantly enhance the performance of date transmission and channel capacity without sacrificing additional energy and bandwidth [2].

In the case of Wireless Communication multiple fading is appeared to be a big problem when at the receiver end Signal with different amplitudes and phases combine destructively, such as, spatial diversity, time diversity etc. can be solved.

Diversity MIMO antenna (in the base station and mobile terminal) to increase the system's transmission capacity and reliability without increasing bandwidth and power consumption that improve the spectrum efficiency in great deal. The performance of the MIMO antenna determine the correlation of the signals received by antenna elements [3].

Why UWB & MIMO used together ?

The overall performance of antenna can be increased by MIMO system, but to overcome new challenges like, reduction in mutual coupling and correlation between the antenna elements [3], antenna designer has to go through the challenges in designing of UWB MIMO antenna with absolutely compact with least mutual coupling and also reduced correlation factor between the elements of antenna.

While extending MIMO technology to the UWB regime, in UWB indoor communication system again to a large extent in the channel capacity, robust and coverage radius is noticed [4].

These systems are equipped with multiple antennas at both the transmitter ends and receiver ends to improve communication systems. This is in contrast to conventional communication systems with only one antenna at the receiver end.

Due to extremely low allowable transmitted power i.e. -41.3 dBm/MHz, UWB technology is limited to short range communications. To overcome this limitation, the combine effects of both the MIMO techniques with UWB technology is found to be one of the best solutions.

However, the MIMO technique, while implementing for both portable and compact devices, one more hindrance arises out of poor isolation and sturdy mutual coupling between closely packed antenna elements, but wireless device of compact size limits this approach. Therefore, there appears a good challenge to enhance the isolation or to reduce mutual coupling [6].

Challenge in MIMO antenna

The designing of MIMO antenna in respect to its usages in a portable wireless communication device to reduce the mutual coupling between the antenna elements is indeed a challenging task. Mutual coupling do occur due to finite spacing of the antenna. Placing the multiple antennas into the body of a single compact and slim wireless terminal devices and making it resonant for the different wireless communication applications that are integrated into a single device is an utmost challenging job. Since the antenna elements are strongly coupled with each other, the additional challenging task is to maintain the isolation characteristic between the antenna elements.

Why Microstrip is used ?

To accommodate the multifunction constraints of communication systems, there felt an essential demand/need for Microstrip patch antenna having more than one port. Consequently, this leads to compact antenna size, overall cost effectiveness, with higher channel capacity and space diversity enhancement. It is a well known fact that due to power dissipation there result a high coupling degradation of antenna. Therefore, high precaution is required to design multiport antennas. Additionally, the antenna should be compact in size [7].

The reliability and capacity requirements of wireless communication systems is increased by wireless multimedia technology. Therefore, the MIMO system has been proved to be one of the most suitable and promising technology for this because it is well suited for all the requirements like, high capacity, high data rate, high reliability etc. One main advantage rests with the MIMO system is that it can improve capacity and reliability requirements without increasing transmitted power and bandwidth. MIMO system can also utilize several antennas for different diversity scheme. However, use of multiple antennas in the system increase the size of the system is a drawback of the system and also worsen the isolation between the antennas elements, therefore, causing distortion in radiation pattern and thus, decrease channel capacity.

Many experimental work have been conducted to reduce the mutual coupling effects between the antennas elements in MIMO system. Some of these are; spacing between antennas and slits added in the ground plane is divided by slots [7][8].

Design and Analysis:

Construction of proposed antenna;

The proposed antenna is constructed on a FR4 substrate with dimension equal to 32 x 32 sq.mm and thickness of 1.6 mm. Two concentric circles, one with a radius of 5.5mm considered as outer circle and the other with a radius of 3,5mm as inner circle. The area of both the outer and the inner circles are 95.07sq.mm and 38.50sq.mm respectively. By subtracting the area of inner circle from that of outer circle, we can obtain the area of ring equal to 56.57sq.mm. Again, by dividing the area of ring by 2 we get the area of arc measuring 28.28 sq.mm. The width of the arc is 2mm. Here, two arc-shaped radiating elements constitute the antenna.

Another similar arc shaped structure of same dimension is constructed and is placed on the ground before the first arc facing each other. Both the arc shaped structure are placed perpendicular to the ground and both are supported individually by rod shaped material of same width of 1.3mm. The width of the arc is measuring 2mm. Here, both the arc shaped radiating structure together constitutes the antenna.

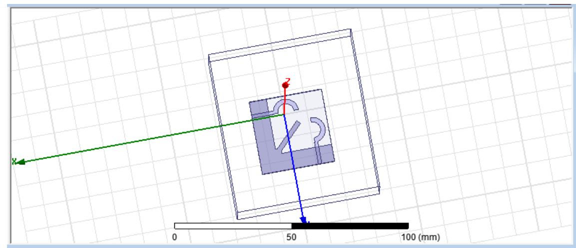

Figure 1.1 : Structure of proposed Antenna

A rod like stub is inserted diagonally between the two arc-shaped elements constituting an angle of 45^o to the ground with one end attached to the ground and the other remains open. The insertion of the stub here is to enhance the isolation between the two antenna elements. It is a monopole structure. The ground plane will not cover the whole structure and as such, can be said to be partially grounded. Since the ground plane is not parallel to the proposed antenna, this structure is said to be a monopole structured antenna.

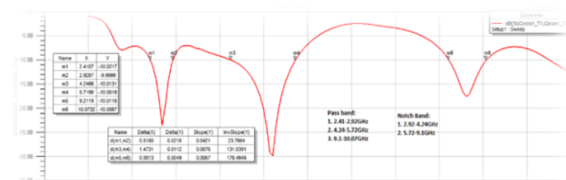

Figure 1.2 : Graphical representation of return loss of the proposed Antenna

In the communication systems, the Return Loss can be defined as the loss of power due to signal reflection or returned by a discontinuity in the transmission line. The discontinuity occurs due to a mismatch in terminal load or with a device introduced in the transmission line. This is normally, expressed in terms of ration in decibel (dB).

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

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

Band	**Bandwidth**	**Applications**
Pass Band	2.41 – 2.92 GHz	Bluetooth, WiFi, S-Band, Satellite, Cellular 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	5.72 – 9.1 GHz	C-Band Satellite Uplink, C-Band ISM Radar

Table-1: Applications in bandwidth range

The Return Loss plot in graphical is meant to find bandwidth. In the proposed antenna, a total number of five bands are used. Out of this five bands, three are pass band and the other two are notch bands. Since we are considering UWB frequency range (3.1 GHz – 10.6 GHz), only two pass bands and two notch bands are in the operating range of UWB. The three pass bands used here are in the frequency range of 2.41 – 2.92 GHz, 4.24 – 5.72 GHz and 9.1 – 10.07 GHz and the two notch bands used are in the frequency range of 2.92 – 4.27 GHz and 5.72 – 9.1 GHz. Since the proposed antenna here is a MIMO UWB antenna, we are taking into consideration a frequency range of 3.1 – 10.6 GHz only. Taking into account the range of the proposed antenna, only two pass bands and two notch bands are in active use. In the proposed antenna, the plot representing portion above the value of -10 dB in the vertical scale is due to the application of notch band and the plot representing the portion below the value of -10 dB is due to the application of pass band. In this case a frequency band of 3.1 – 10.6 GHz is being considered as because we are using in the range of UWB. While designing the proposed antenna within the frequency range of 3.1 – 10.6 GHz, we use two pass bands and two notch bands within the range of interest. Here, two pass bands are applied between the range of 4.2 – 5.72 GHz and 9.1 – 10.07 GHz and also two notch bands between the range of 2.92 – 4.24 GHz and 5.72 – 9.1 GHz are applied.

Mutual Coupling:

Mutual coupling can be defined as the electromagnetic interaction between the antenna elements in array. The current so developed in each element of the antenna of an array depends both on their own excitation and also the contributions of the adjacent antenna elements.

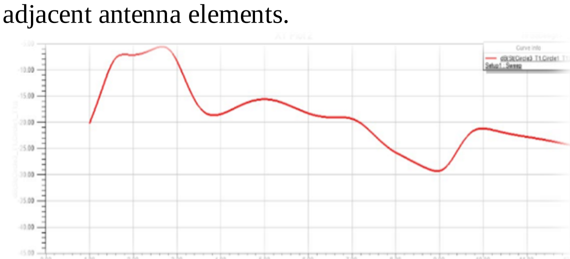

Figure 1.3: Graphical representation of Mutual Coupling

Generally, there should be no interference between the antenna elements, if even found that should be eliminated. In an attempt to avoid interference between the antenna elements, isolation is provided between them. While applying isolation technique with the insertion of stub between the antenna elements, the space between the elements is enhanced which in turns eliminates the interference between the two antenna elements. In the proposed antenna, we inserted a rod like stub diagonally placed between the antenna elements with an angle of 45^{o} to the ground surface. As the proposed antenna is a MIMO UWB antenna, the operation of interest is within a frequency range of 3.1 – 106 GHz. In the graphical representation, the portion below the value of -15 dB in the vertical scale in the plot represent reduction in the mutual coupling. \Hence, the proposed MIMO UWB antenna is less in mutual coupling (> - 25dB).

Radiation Pattern

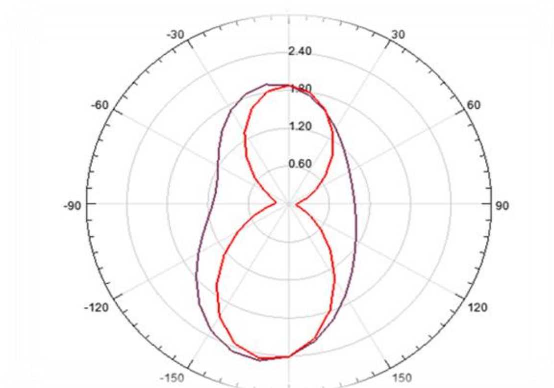

Figure 1.4: E-plane & H-plane pattern

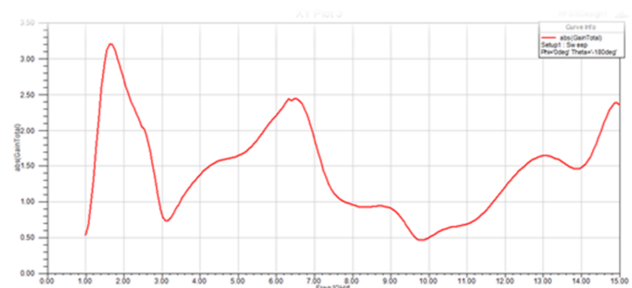

Figure 1.5: Gain Vs. Frequency Plot

From the above, it can be drawn that the radiation pattern of the proposed antenna is omni-directional and can cover a frequency range within the UWB frequency range (i.e. 3.1 to 10.6 GHz). The simulation and experimental results are closely agreeable showing the feasibility of the proposed antenna for UWB applications.

Comparison of UWB – MIMO antennas in respect of dimensions, isolations and bandwidths are as follows:

Sl. No.		Size of the Antenna (mm^2)	Impedance Bandwidth (GHz)	Isolation (dB)
1.	Lee et al (2012) [10]	86.5 x 55	1.9 – 10.6	≥ 15
2.	Rajagopalan.A (2007) [11]	125 x 125	3.6 – 8.5	15
3.	Gao P et al (2014) [12]	48 x 48	2.5 – 12	≥ 15
4.	Chen Y (2008) [13]	45 x 62	3.5 – 10.5	18
5.	Chac. BT et al (2013) [14]	15 x 50	2.76 – 10.75	≥ 15
6.	Seec TSP (2008) [15]	45 x 37	3.1 – 5.0	20
7.	Wong K et al (2003) [16]	48 x 115	2.3 – 7.7	≥ 20
8.	Hong S et al (2008) [17]	80 x 60	2.27 – 10.2	≥ 20
9.	This work	32 x 32	2.3 - 10.07	≥ 25

(a) (b)

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

For verification of the present approach of antenna design , the fabrication of UWB MIMO antenna on low cost FR4 substrate as shown in figure 1.6 is made The antenna so designed is measured on Aglent 83752A .The size of the UWB MIMO antenna is 32 mm x 32mm

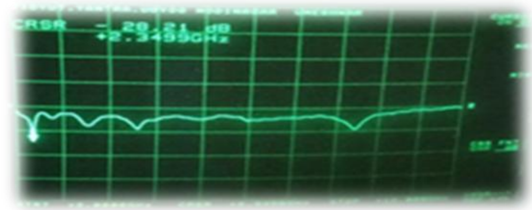

Figure 1.7: Graph plot at 2.34 GHz on proposed fabricated antenna

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

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

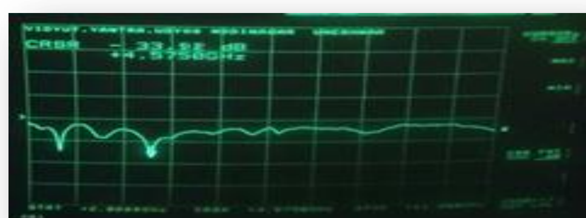

Figure 1.10: Graph plot at 4.57 GHz on proposed fabricate antenna

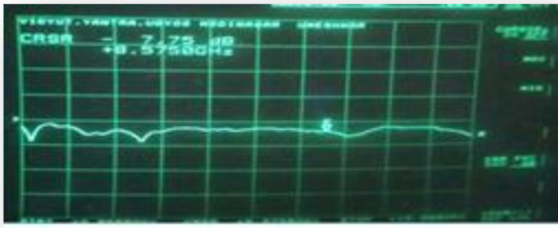

Figure 1.11: Graph plot at 8.57 GHz on proposed fabricated antenna

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

Figure 1.13 : Graph plot at 9.4GHz on proposed fabricated antenna

Figure 1.14: Operational view of proposed antenna in Lab.

Both the tested and simulated results of the proposed antenna agrees closely with each other and, hence, the proposed antenna is a good candidate within the operational range of UWB.

Result:

The proposed antenna presented is having a bandwidth of 1.6 GHz. Normally, the bandwidth with a minimum frequency of 0.5 GHz is considered to be a UWB MIMO antenna. The pass bands applied are within the range of 4.24 – 5.72 GHz and 9.1 – 10.07 GHz which lie in the range of UWB. The notch bands applied are within the range of 2.92 – 4.24 GHz and 5.72 – 9.1 GHz. This hinders the interference causes by other applications within the frequency range of 2.92 to 9.1 GHz.

Conclusion and future work:

Conclusion:

The proposed antenna presented here is a compact UWB MIMO antenna having a bandwidth of 1.6 GHz. The structural design of the proposed antenna provide an isolation greater than -25 dB which is much below than the specified isolation gap of -15 dB. As such, could obtained an antenna with less mutual coupling and hence, less interference resulting an efficient antenna. It can be derived from the above comparison table that the proposed antenna is a compact antenna with less mutual coupling and reduced interference operating in the UWB range, hence, can be concluded as a efficient UWB MIMO antenna.

Future work:

The work of this antenna may further be extended to four-port to six-ports MIMO antenna systems in an attempt to increase channel capacity for high data rate applications.

For a better diversity performance, the reconfigurable antenna elements may be used.

Different other structures based on this structure, may be attempted to further reduce the mutual coupling.

Reference:

[1].Chun-Xu Mao and Qing-Xin Chu, Senior Member, IEEE, " Compact Coradiator UWB-MIMO Antenna With Dual Polarization''IEEE Transactions on Antenna and Propagation,Vol.62,NO.9,September 2014

[2]. Jian Ren*, Dawei Mi, and Ying zeng Yin , "Compact Ultrawideband MIMO Antenna with WLAN/UWB Bands Coverage," Progress In Electromagnetics Research C, Vol. 50, 121–129, 2014

[3]. Andreas F. Molisch., Jeffrey R. Foerster.: Channel Models For Ultra wideband Personal Area Networks,Vol. 10. IEEE Wireless Communications (2003) 14-21.

[4] .Wasim Q. Malik., David J. Edwards.: Measured MIMO Capacity and Diversity Gain With Spatial and Polar Arrays in Ultra wideband Channels,Vol. 55. IEEE Transactions On Communications (2007) 2361–2370.

[5]. Federal Communication Commission (FCC), "Revision of part 15 of the commissions rules regarding ultra-wideband transmission systems," ET Docket 98–153, FCC 02–48, First Report and Order, Apr. 2002.

[6]. A. Najam, Y. Duroc, and S. Tedjni , "UWB-MIMO Antenna with Novel L Stub Structure", Progress In Electromagnetics Research C, Vol. 19, 245–257, 2011

[7].Sara Mahmoud, W. Swelam, and Mohamed H. Abd El Azeem Arab Academy for Science, Technology and Maritime Transport, Cairo, Egypt , "A Compact Highly Isolated Two Ports Microstrip Antenna Based on Defected Ground Structure for WLAN/WiMAX

Application'', Progress In Electromagnetic Research Symposium (PIERS), Shanghai, China, 8–11 August 2016
[8].Fitri Yuli Zulkifli and Eko Tjipto Rahardjo , "Compact MIMO Microstrip Antenna with Defected Ground for Mutual Coupling Suppression'', Progress In Electromagnetics Research Symposium Proceedings,Marrakesh,Morocco,Mar.20–23,2011
[9]. Singh, H. S., B. R. Meruva, G. K. Pandey, P. K.Bharti, and M. K. Meshram, "Low mutual coupling between MIMO antennas by using two folded shorting strips," Progress In Electromagnetics Research B, Vol. 53, 205–221, 2013.
[10]. Lee, J.M.; Kim K.B.; Ryu H.K.; Woo, J.M(2012)., "A Compact Ultrawideband MIMO Antenna With WLAN Band-Rejected Operation for Mobile Devices", Antennas and Wireless Propagation Lett., IEEE, vol.11, 990-993,2012
[11] Rajagopalan A., Gupta G., Konanur A.S., Hughes B., Lazzi G. Increasing channel capacity of an ultrawideband MIMO system using vector antennas. IEEE Trans. Antennas and Propagation 2007; 55 (10) 2880-2887
[12]. Gao P.; He S.; Wei X.; Xu Z.; Wang N.; Zheng Y (2014). Compact Printed UWB Diversity Slot Antenna With 5.5-GHz Band-Notched Characteristics, Antennas and Wireless Propagation Lett., IEEE , vol. 13,pp 376-379,2014
[13]. Chen Y., Lu W.J., Cheng C.H., Cao W., Li Y. Printed diversity antenna with cross shape stub for ultra-wideband applications. Proceedings of 11th IEEE International Conf. Communication Systems, (813-816), Nov. 2008
[14]. Chacko, B.P.; Augustin, G.; Denidni, (2013) T.A. Uniplanar Spolarisation diversity antenna for ultrawideband systems, Microwaves, Antennas & Propagation, IET,vol 7 ,pp 851-857,2013
[15]. See T.S.P., Swee A.M.L., Chen Z.N. Correlation analysis of UWB MIMO antenna system configurations. Proceedings of IEEE International Conf. Ultra Wideband, (105-108), Sep. 2008
[16]. Wong K.L., Su S.W., Kuo Y.L. A printed ultra-wideband diversity monopole antenna, Microwave and Optical Technologies Let., Vol. 38, No. 4, 2003, (257-259)
[17]. Hong, S.; Chung, K.; Lee, J.; Jung, S.; Lee, S.; Choi, J(2008) "Design of adversity antenna with stubs for UWB applications". Microwave. Opt. Technol. Letters., vol 50,pp 1352– 1356,2008