RESEARCH ARTICLE OPEN ACCESS

UWB - MIMO Antennas Using A High Isolation Techniques

Rhea Nath[1] , Pramod Singh[2]

[1] *Electronic Communication, M.Tech Student Meerut Institute of Engineering and Technology, UP Technical University (India)*
Email id: nathrhea48@gmail.com[1]
[2]*Associate Professor, Meerut Institute of Engineering and Technology (India)*
Email Id: pramod.singh@miet.ac.in[2]

Abstract:

The UWB MIMO antenna as presented in this paper is for UWB applications. MIMO system can improve the channel capacity by engaging multiply antenna at both transmitter and receiver ends without extra power and bandwidth. To have a better antenna performance, reduction in mutual coupling and enhancement in isolation is essential. are preferable for their low profile, simple and inexpensive to manufacture, mechanically robust, comfortable to planer and non-planer surfaces, compatible with MMIC designs, Microstrip patch antennas are very versatile in regard to resonant frequency, polarization, pattern and impedance [2]. MIMO antenna technology can considerably improve speed in data transmission and channel capacity. MIMO antenna in UWB application can increase data transmission range [3].

1.Introduction:

In late 1990's engineers and researchers had shown great interest on MIMO antenna system. Considering such channel is a classic for wireless network communication, MIMO system find the solution for narrow bandwidth and the bottleneck in case of wide band for information access [4], to meet the demand for high data rate transmission at low cost and low power consumption. The UWB communication system has been examined in recent past. UWB in the wireless communication sector has turned into a burning topic. The feasibility in respect of UWB design have the challenges that includes wide impedance matching, radiation stability, low profile, compact size and cost effectiveness. As a solution to the problem and also further improvement in capacity and link quality, multiplexing gain and diversity gain are considered to be the milestones.

For high date rate transmission in short range wireless communication, UWB technology is proved to be a very capable technology [5]. UWB radio is considered to be a good candidate for low power and low cost design. The applications of UWB system is …… because of very low power transmission [6]. To make best possible use of radiated and received power as a success of UWB communication system [4] for feasibility in future commercial sector as well, solution to the problem is more challenging. As a result of relentless research, MIMO system is proved to be one of the best solutions. This imparts firmness in UWB linkage and improvement in data transmission rate. Designing MIMO antennas in UWB applications faces some stiff challenges as well. The invent of Printed Circuit technology in Microstrip patch antennas become versatile because of cost effectiveness and easy fabrication. However, the design of first Microstrip antenna structure in 1970 had a major drawback of narrow impedance bandwidth [3], more substrate height, use of DGS and parasite patches etc.

(A)Challenges:

Challenging mainly lies in decreasing the mutual coupling and correlation between the elements of antenna system [8]. As a solution to these problems, some useful techniques have been presented. Eventually, it was considered that UWB MIMO antenna system is efficient within a bandwidth of 3.1 – 10.6 GHz with regard to diversity, radiation, size etc. Some of the advantages of UWB MIMO antennas are –

1. Reduction in multipath fading
2. Low power requirement
3. UWB radio system can transmit pulses of very short duration, accurately and efficiently.

Two major challenges in designing MIMO antenna in UWB application are maximizing antenna elements and enhancing the isolation between the elements that, otherwise, reduce the mutual coupling between the antenna elements. [9]

(B) Why UWB is used:

With the release of frequency bandwidth (3.1 – 10.6 GHz) by FCC, a new technology has been employed with least interference called UWB. This unlicensed service technology can be used by any one, any time and everywhere. UWB in addition to its Ground Penetration Radar (GPR) applications can also extend for communication and radar applications. UWB devices can operate with a series of very short electric pulses resulting transmission within very wide bandwidth. UWB signals can transverse at high speed with low power consumption. All these features altogether make it usable for various applications, such as, positioning, geo-location, radar sensor and more.

Important properties

Followings are some of the important properties:

1. **Linear Phase and Constant Group Delay in directivity** – The Constant Group Delay if remain constant, restrict spreading of pulse waveform in time domain.

2. **Low Return Loss on UWB bandwidth** –`Any mismatch between the antenna end and the circuitry end degrade the overall dispersion characteristic because of multipath fading arises between the feeding cables.

3. **Constant directivity over UWB -** The constant directivity can avoid the ripples of frequency transfer function in some specified direction and can reduce degradation in dispersion characteristic.

(C) Why MIMO is used?
It is a wireless technology with multiple transmitters and multiple receivers for more data to transfer at the same time. MIMO technology adopt multipath phenomenon like, radio wave when transmitted information after being bounced by different objects reaches receiving antenna multiple time through different angles with slight time variation.

Figure 1: : MIMO Technology uses multiple radios to transfer more data at the same time

With the use of smart transmitters and receivers with spatial dimension by exciting multipath behaviour of MIMO technology which in turn increases the performance and range of the antenna and also to transmit and receive multiple signal streams of data at the same time.
MIMO antenna able to combine flow of arriving data streams via different paths at different times for signal capturing power at receiver. Spatial diversity technology used by smart antenna is to put in use of surplus antennas to receiver diversity to increase range.

(D) Benefit

1. Effects of multipath and fading arises when attempt to obtain high data through put rate in limited bandwidth channel. MIMO system is useful in modern wireless standards with ability to maximize date input in adverse conditions like, interference, multipath and fading. The development of MIMO Orthogonal Frequency Division Multiplexing (OFDM) communication system is a main motive for transmission of high data rate over a long distance.

2. Superior Data Rae, Range and Reliability
The use of multiple antennas at both the transmitter and receiver ends offers superior data rate, range and reliability without any bandwidth or power transmit. This MIMO system able to send multiple date streams by creating multiple independent channel.

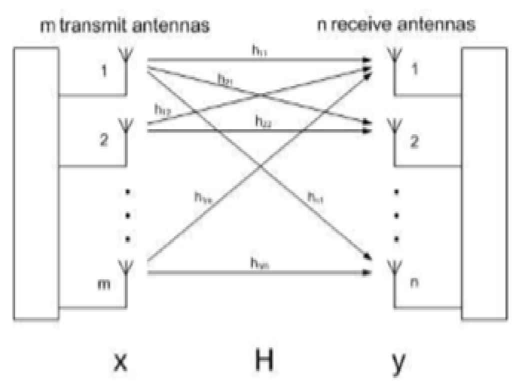


Figure 2: General MIMO

There are MIMO like, 2x2, 3x3 & 4x4 supported by 2, 3 & 4 independent data streams respectively. These streams are combined by dynamic digital beam-forming and MIMO receiver process to increase reliability and range.

2. Literature Survey

Two identical monopole antenna elements having a comb-line like structure on the ground plane altogether constitutes a UWB MIMO antenna. Such structural design UWB MIMO antenna is for improving impedance matching and isolation enhancement.

An antenna with impedance bandwidth > 3.1 – 10.6 GHz, mutual coupling between the two ports < -25dB and envelope correlation coefficient across the band < 0.001 along with a comb-line electromagnetic band-gap structure, altogether is to improve mutual coupling and isolation enhancement is proposed, figure 3[10]. To have a compact MIMO antenna for portable wireless devices at the lower frequency band of 2.4 GHz, such as, WLAN is practical problem. Such system prefer antenna with directional gain. To achieve high isolation between the antenna elements and maintain wide bandwidth is major challenge.

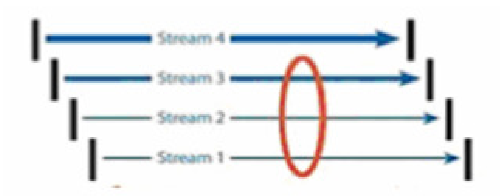


Figure 3: Stream combining for enhanced reliability

For consideration of polarization diversity, as a proposed work tri monopole antenna structure focusing mainly on mutual coupling and casting effects. The increase in capacity is attributable to polarization diversity instead of pattern diversity [13]. To attain UWB frequency range an attempt is made by splitting the Square Ring Slot of Microstrip Square Ring Slot Antenna and feeding network is optimized [14]. For designing of a monopole antenna with reconfigurable features [15], a RF switch (PIN diode) is inserted at feeding point.

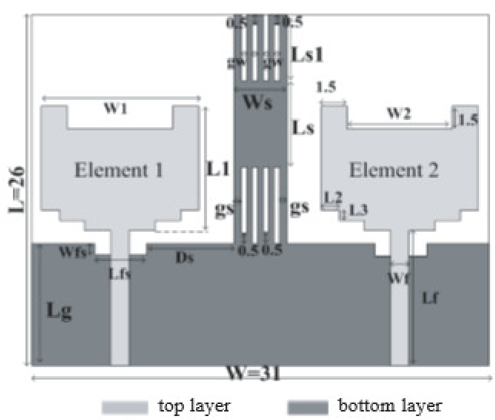


Figure 4 : Geometry of MIMO antenna with comb like structure

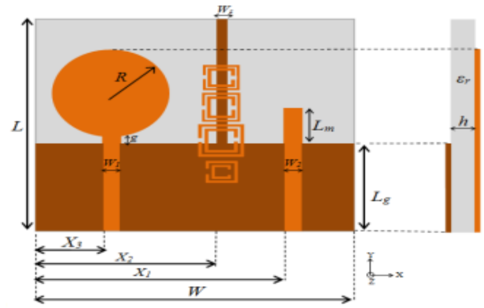


Figure 5: MIMO Antenna System with SRR And Stub

In this work MIMO antenna operates on two frequencies, that means, it works on two antenna elements, one of which is circular monopole antenna which operates in UWB range that is 3.1GHz to 10.6GHz and other monopole antenna centered at 5.45GHz. The antenna elements are isolated by placing Stub and array of Split Ring Resonators (SRR) of different size and it is found that using these two methods provide high isolation between the antenna elements that is > 20 dB and increases the efficiency of the antenna here. Shown in figure 5 [23].

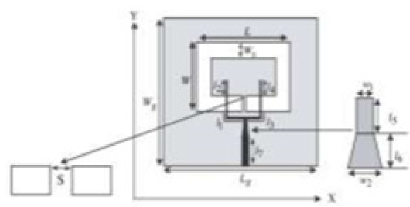


Figure 6: Geometry of Split Square Ring Slot Antenna

To have better efficiency of the MIMO system, simultaneous use of multiple antennas at both the ends of transmitter and receiver is required. This greatly influences the researchers in their work on MIMO technology in UWB applications. This equation (1) below shows that how the MIMO channel spectrum efficiency increases;[16] [17]

$$C = Blog(1+ S/ N) \qquad \text{equation …..(1)}$$

Where "C" is channel capacity "B" is bandwidth, "S" is signal power l. "N" is the power of Additive White **G**aussian Noise (AWGN). From the above equation it can be drawn that channel capacity can be increased with the improvement in SNR or increasing signal bandwidth. With the help of MIMO systems channel capacity can be enhanced. It can be drawn from the equation (1) that the capacity of MIMO increases with the increase of antenna at both the transmitter and receiver ends.

$$C_{MIMO} = \log [\det (I_{MR} + \frac{S_{INR}}{M_T} HH^H)] \qquad \text{equation(2)}$$

Where M_T & M_R are no. of transmitter and receiver respectively. IMR, the identity matrix. MR x MR and H is a MT x MT matrix.

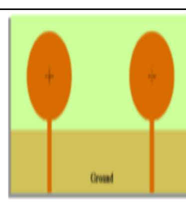
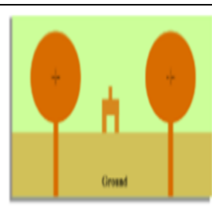
Two antennas are used; one step-tapered slot antenna (S-TSA) and the other a square monopole antenna with an inverted H-shaped slot with high isolation. The E-field because of its orthogonal property, improves the isolation between the two ports. In this case, an UWB operational band (3.1 – 10.6 GHz) and an isolation of 30dB between the two ports is achieved [18].

To achieve a compact MIMO antenna applications in the frequency range from a lower frequency end such as, WLAN (i.e. 2.4 GHz) and also in the range of \UWB (3.1 GHz to 10.6 GHz), two antenna with open L-shaped slot antenna is used which reduces the mutual coupling of between the antennas elements at a low frequency as low as WLAN (2.4 GHz) with a narrow slot inserted to the ground plane. Such antenna gains an impedance bandwidth of 2.0 GHz to 10.6 GHz with a mutual coupling as low as 20dB in case of WLAN and 18 dB throughout UWB applications [10].

For a dual polarized antenna, a structure of double slot system is used. An antenna so designed with an impedance bandwidth of 7.7% between both the ports with port isolation better than 30 dB within the LTE frequency band of 2.5 GHz – 2.7 GHz, that led to achieve a highly isolated compact dual polarized patch antenna [12].

Below Table showing Comparison between the characteristics of antenna with and without stub

Performance comparisons of antennas with and without stub.[22]

Parameters		
Layout		
Constituent elements	Circular disc	Circular disc
Feeding Configuration	Parallel	Parallel
Impedance bandwidth (GHz)	3.1 – 10.6	3.1 – 10.6
Gain Variation(dBi)	3.5	2.5
Total efficiency	>75%	70 – 80%
Group delay (ns)	2.2	1
Isolation (dB)	>11	>15
Correlation Coefficient (dB)	< -15	< -9.5
TARC	< -10	< -9.5
Size (mm^2)	43x80	40x68

Comparison between the high isolation technique

Techniques	Isolation (dB)	Radiation Pattern	Bandwidth (GHz)	Gain variation	Size (mm^2)
Inverted shaped stub	15	Omni-directional	3.1 – 10.06	<2.5	40x68
Fork shaped structure	17	Omni-directional	4.4 – 10.7	<2.5	40x68
Cantor set Fractal UWB structure	20	Omni-directional	4.5 – 10.6	<2.5	40x68
Stepped impedance resonator	23	Omni-directional	3.1 - 10	<2	35x40
Closely-Packed UWB-MIMO Diversity	26	Omni-directional	3.1 – 5.15	<2	48x25
Multiple ground slits	12	Omni-directional	0.7	<2.5	60x100
Tree like structure	20	Omni-directional	3.1 – 10.6	<3.1	35x40

3. Conclusion:

This paper focus on the basic and important concept of MIMO antenna for UWB applications. Further, it discussed challenges for designing MIMO antennas for UWB applications. It also provides performance comparison among MIMO antennas.

4. Future Scope:

For MIMO, focus can be made on improvement channel capacity by decreasing correlation coefficient and increasing isolation between the antennas elements result in increasing overall performance of MIMO antennas. [1]

So far, the research work is only confined in the field of radiation pattern and S-parameters, but no attempt was made on performance evolution which is necessary to MIMO antennas mostly on Quad Band Operation, incorporation several applications together into a slim body on portable devise with different resonant on multiple frequencies is very challenging. Now work is required to be concentrated in this field as well. [20]

Researchers should focus their future findings for an appropriate general model that can integrate the influences on the antenna elements and their ground of applications. Such model is a useful device in deriving general guiding principles for MIMO antenna systems [21]

Further different types of stubs and array of Split Ring Resonators (SRR) of different size can be used to gain high isolation and low mutual coupling between antenna elements.

References

[1] M.Jusoh, M.F.Jamlos, M.R.Kamarudin, and F.Malek "A MIMO Antenna Design Challenges for UWB Application", 2012.

[2]Hong-Kyun Ryu and Jong-Myung Woo "Design of Ultra-wideband MIMO Antenna for Mobile Handset Applications'' PIERS Proceedings, Moscow, Russia, August 19–23, 2012

[3] Constantine A. Blains "Antenna Theory: Analysis And Design" 3rd edition, John Wiley and sons, 2005.

[4] Kasra Payandehjoo and Ramesh Abhari, "Employing EBG structures in multiantenna systems for improving isolation and diversity gain", IEEE antennas and wireless propagation letters, vol.8, pp.1162-1165, Nov2009.

[5] Keith R.Carver and James W.Mink, "Microstrip Antenna Technology", IEEE Transactions on antennas and propagation, vol.29, no.9, pp.2-24, Jan1981.

[6] Guan-Yu Chen, Jwo-Shiun Sun and YD Chen, "Characteristics of ".UWB antenna and wave propagation", International Symposium on Intelligent Signal Processing and communication systems, pp.713-716, Dec2005.

[7] Kasra Payandehjoo and Ramesh Abhari, "Employing EBG structures in multiantenna systems for improving isolation and diversity gain", IEEE antennas and wireless propagation letters, vol.8, pp.1162-1165, Nov2009.

[8] Shuai Zhang and Zhinong Ying, "UWB MIMO/Diversity antennas with a tree like structure to enhance wideband isolation", IEEE antennas and wireless propagation, vol.8, pp.1279-1282, Nov2009.

[9] M.C. Greenberg, L.L. Virga, "Characterization and design methodology for the dual exponentially tapered slot antenna" IEEE Antennas and Propagation Society International Symposium, vol.1, pp. 88 - 91, July 1999, Atlanta, GA.

[10] Narges Malekpour and Mohammad A. Honarvar "Design of High-Isolation Compact MIMO Antenna for UWB Application" Progress In Electromagnetic Research C, Vol. 62, 119–129, 2016

[11]. Jian Ren*, Dawei Mi, and Yingzeng Yin, " Compact Ultra wideband MIMO Antenna with WLAN/UWB Bands Coverage „Progress In Electromagnetic Research C, Vol. 50, 121–129, 2014

[12]. 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.

[13]. Liang Dong , Hosung Choo , Robert W.Heath, and Hao Ling "Simulation Of MIMO Channel Capacity With Antenna Polarization Diversity""" IEEE Transaction Vol4 no.4 july 2005.

[14]. Sadat, S., M. Fardis, F. G. Geran, and G. R. Dadashzadeh, "A compact Microstrip square-ring slot antenna for UWB applications," Progress In Electromagnetic Research, Vol. 67, 173– 179, 2007.

[15]. Ghanem, F., J. R. Kelly, and P. S. Hall, "Switched UWB to narrowband planar monopole antenna," European Conference on Antennas and Propagation, 12–16, Barcelona, Apr. 2010.

[16]. See, T. S. P., A. M. L. Swee, and Z. N. Chen, "Correlation analysis of UWB MIMO antenna system configurations," Proceedings of the 2008 IEEE International Conference on Ultra-wideband (ICUWB2008), Vol. 2, 2008.

[17]. Abou-Rjeily, C., "Pulse antenna permutation and pulse antenna modulation: Two novel diversity schemes for achieving very high data-rates with unipolar MIMO-UWB communications," IEEE Journal on Selected Areas in Communications, Vol. 27, No. 8, Oct. 2009

[18] Lihong Wang, Lina Xu, Xinwei Chen, Rongcao Yang, Liping Han, and Wenmei Zhang "A Compact Ultra wideband Diversity Antenna With High Isolation""", IEEE antenna and wireless propagation letter,VOL.13,2014

[19] Yanshan Gou ,Shiwen Yang Quanjiang Zhu and Zaiping Nie,"""A Compact Dual- Polarized Double E-Shaped Patch Antenna With High Isolation" , IEEE Transaction on antenna and propagation ,Vol 61,no.8 , august 2013

[20] H. Chih-Chun, L. Ken-Huang, S. Hsin-Lung, L. Hung-Hsuan, and W. Chin-Yih, "Design of MIMO antennas with strong isolation for portable applications," in Antennas and Propagation Society International Symposium, 2009. APSURSI '09. IEEE, 2009, pp. 1-4.

[21]. Dirk Manteuffel Wireless Communications, University of Kiel Kaiserstrasse 2, 24143 Kiel, Germany Manteuffel@tf.uni-kiel.de „„MIMO Antenna Design Challenges"", 2009 Loughborough Antennas & Propagation Conference 16-17 November 2009, Loughborough, UK

[22]. A . Najam ,Y. Duroc and S. Tedjni "UWB-MIMO Antenna With Novel Stub Structure'' progress in electromagnetic research C,Vol.19,245-257,2011

[23]. Rajashekar G P, Usha Rani M A, "Design of MIMO Antenna with High Isolation using Split Ring Resonator", International Research Journal of Engineering and Technology (IRJET) Volume: 04 Issue: 05 | May -2017