MIMO Antenna for UWB Applications

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Abstract
In this paper an ultra-wideband MIMO antenna for various applications is presented. For this purpose planar Microstrip antenna is used because of compact size, conformal shape, easy and inexpensive to manufacture using printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs and when the particular patch shape and mode are selected, Multiple-input multiple-output (MIMO) antenna technology can significantly improve data transmission speed and channel capacity, when MIMO antenna is used in UWB application then it increase the high data transmission range.

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

1. INTRODUCTION

For sending bulk of digital data over a wide frequency range for a short distance with least power consumption, we use a wireless technology known as Ultra wideband (UWB). UWB radio can carry signals through doors, walls, hills and other obstacles and also carry a huge amount of data over a maximum distance of 230 feet at very low power. It can be compared with another short range wireless technology known as Bluetooth, a standard form to connect handheld wireless devices with other similar devices which needs line of sight communication at comparably high power level. For high date rate and short range transmission, UWB communication is widely used. The UWB spectrum released in April, 2002 by the Federal Communication Commission (FCC) in the United States for working in the rage of frequencies from 3.1 GHz to 10.6GHz with a low power spectral density (PSD) not exceeding -41.3dBm/MHz UWB. .

Microstrip patch antennas become very versatile due to ease of making and lower cost with the help of modern printed-circuit technology. The structure of first Microstrip antenna was first designed by Munson and Howel in 1970 however its concept was first given by Deschamps in 1953. Despite of having several advantages these structures exhibit a major drawback of narrow impedance bandwidth [3]. There are various methods to reduce these problems like use of high dielectric constant substrate, increasing height of the substrate, use of parasitic patches and use of DGS etc.

Multiple-Input Multiple-Output (MIMO) technology uses several transmitters and receivers together to exchange more data at the same time. An important feature of MIMO technology is reaching of transmitted message at the receiving end repeatedly due to reflections of signal from wall, ceilings and several other obstacles [4]. MIMO enable the antennas to add signals coming from different paths and at different instants to increase receiver signal capturing capacity effectively. Thus this technology makes the antennas work smarter. These smart antenna systems use spatial diversity technology where spare antennas are put to good use. With the use of several antennas enables MIMO wireless technology to noticeably increase the capacity of the given channel. It is possible to augment the throughput of the channel with every pair of antennas added to the system. When MIMO and UWB are used together then it increases the efficiency of the system.

Thus with the help of MIMO we can simultaneously reduce multipath fading and increase transmission capacity [5], [6]. This type of multipath fading poses a great problem in wireless communication where signals with different amplitudes and phases overlap with one another and in a destructive fashion at the receiver. The solution to this problem is diversity technology, such as, spatial diversity, time diversity and polarization diversity, etc. MIMO technology can be used to improve the spectrum efficiency enormously without increasing bandwidth and power consumption. Using this technique capacity of communication link can be increased without change in signal to noise ratio levels with the help of various uncorrelated antennas. The MIMO intended for UWB system is appropriate in many applications when working with both the MIMO-UWB together. The salient consideration that are made on the antenna parameters are –

- **(i)** The desired frequency range must cover entire UWB range.
- **(ii)** Omni-directional radiation pattern is desired.

(iii) The minimum radiation efficiency should be 70%

(iv) The gain over the UWB bandwidth that is to be evenly distributed

(v) The envelop correlation

(vi) The diversity gain [29].

II. Why UNB-MIMO is together used:

Both for high data rate and short range communication systems, the UWB system has proved to become more promising. Because of the restriction imposed on the transmit power, UWB communication are the best suited one for short range communication. Design of ultra wide band antennas has become challenging because of the tough constraint, that often clash in achieving a wide impedance bandwidth alongwith high radiation efficiency, uniform gain and compact size. Although MIMO antenna system has capability to improve the overall antennas performance but in addition to these advantages subject there are new challenges also such as, reducing the mutual coupling and the correlation between the elements [25]. A UWB indoor communication systems registered huge gain in the channel capacity, robustness and converge radius [26]. UWB MOMO systems are prepared with multiple antennas at both the transmitting and the receiving ends in order to get better communication performance as compared to conventional communication systems where only one antenna each on both the transmitting and receiving ends.

The drawbacks of the conventional methods are surmounted by the use of spatial diversity methods in MIMO technology. The transmission of data from one M terminal (i.e. transmitter antenna) to other N terminal (i.e. receiver antenna) supported by the receiver terminal. These types of systems are used in wireless communication in order to enhance the capacity. It provides increase in data throughput considerably and link range without extra bandwidth or power. The two main advantages of MIMO system in regard to diversity gain and spatial multiplexing (SM) are used to study of the effect of increase in bit rate antennas. The effect of spatial correlation must be reduced in MIMO system in order to obtain better system performance.

However, the advantages of UWB are to use low power and high data interference immunity in communication system. The UWB systems are limited to short range communication due to low power constraints but problem can be reduced with the help of MIMO technology in UWB. It increases data rate and also overcome multipath fading. MIMO has been proved to be a competent technology to improve channel capacity, with no extra power or bandwidth. Although the installation of multiple antenna elements in a limited space causes mutual coupling between antennas. Thus MIMO UWB systems have the advantage of reducing multipath fading and increasing transmission capacity but we have to work on mutual coupling problem [11 – 13].

Challenges in Designing MIMO antennas:

In modern wireless communication system, high data rate and channel bandwidth must be at highest priority. In the field of MIMO antennas the main area of work for researchers is to improve channel capacity, bandwidth, gain, and polarization diversity while reduce coupling between antenna elements.

Further, these systems also requires that the multiple element antenna (MEA) should be miniaturized so that they can get fit in the compact and robust equipments that are for use and support multiband operation for the equipment reusability in the different parts of the globe. Still there is a lot of scope for designers in the development of novel antenna systems for new generation networks to come, by enhancing the impedance and multiband resonance. With the use of radiation pattern diversity the correlation coefficient can be reduced MIMO antenna performance can be improved. Thus the major challenge in MIMO antenna design is reduction of mutual coupling between the antennas elements. As antenna elements are placed in close proximity in MIMO, problem of mutual coupling may arise. This inter element spacing decides the phase difference between the wave radiated by the elements which may cause constructive or destructive interference. Theoretically we know that the gain increases with increase in number of antenna elements, but on increasing number of elements mutual coupling also increases. This introduces high coupling coefficient and lower data rates [27]. To integrate various antenna elements in a single compact wireless device and tune them to operate at multiple resonant frequencies for different applications is challenging task. The main challenge in this design is to maintain low mutual coupling and high isolation between closely spaced antenna elements.

According to Shannon's channel capacity theorem,

$$C = B\log(1 + \frac{S}{N}) \quad (1)$$

Where 'C' is channel capacity 'B' is bandwidth, 'S' is signal power l. 'N' is the power of additive white Gaussian noise (AWGN). From the above equation it is clear that channel capacity can be increased with the improvement in SNR or increasing signal bandwidth. It is not simple to increase SNR of a communication channel. With the help of MIMO systems this problem of increasing the channel capacity can be reduced.

It is quiet difficult job to integrate compact sized antenna elements with low mutual coupling coefficient. It can be done by understanding the fundamental principles of antenna correlation on one hand and the interaction between an antenna and a finite size ground plate on the other hand. This approach can be used to solve the above mentioned problem [28]. Researchers have proposed many MIMO antennas to reduce the mutual coupling for UWB systems [19 – 23].

In order to reduce the mutual coupling between the two elements and to increase the isolation, a comb-line structure acting as an electromagnetic band-gap structure was proposed [11]. At the lower frequency end, such as WLAN (2.4 GHz) band, the problem is to get a compact MIMO antenna for portable wireless devices. The antenna required for such systems must have directional gain. The vital challenge is to keep high isolation between the antenna elements and to maintain wide bandwidth needed for UWB simultaneously [12].

Unique characteristics of UWB system:

The UWB technology has tremendous capabilities than proves it to be far ahead from its other counterparts for solution of wireless communication systems. The characteristics of this technology are illustrated below:

- As in UWB system there is no need of modulation or demodulation of carrier, so this system does not need component such as, mixers, filters, amplifiers and local oscillators etc. So, UWB system can be said to has an inherent capability in integrating low cost, low power IC processes.
- Due to extremely high impedance bandwidth UWB systems have capability to provide data rate upto hundreds of Mbps or even several Gbps for a range of 1 to 10 meters [30].
- Although there are various existing narrow band applications in 3.1 to 10.6 GHz frequency range but UWB system working at quiet low power density level not proved to be threatening [31].
- Due to lower power density level the UWB system are not only of non-interfering operation but also have low probability of detection and interception. Thus UWB technology proved to be very impressive in secure communication systems.

Thus from the above discussion it is clear that the UWB technology provides wide bandwidth with simple circuit at lower cost and lower power density levels. Due to lower power density the UWB operation proved to be non-interfering and non detectable and this is very important for secure communication

III. Literature Survey:

Recently, a lot of work has been done with regard to MIMO-UWB antenna. A. Najam, Y. Duroc, and S. Tedjni proposed two circular disc patch antenna elements operating over the entire UWB range. Here isolation between two elements is regularly below 15 dB with the help of Y shaped stub as shown in Fig.(1). By insertion of stub the size of antenna can also be reduced. In a different work, Chun-Xu Mao and Qing-Xin Chu proposed that to provide higher isolation between two ports we can etch 'T' shaped slot in the antenna structure. Here dual polarization can also be achieved by exciting pentagon shaped antenna with perpendicular feed. This proposed antenna exhibit good impedance matching; outstanding isolation, and dual polarization characteristics [6].

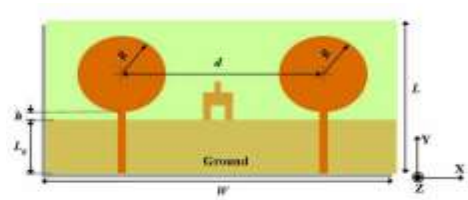

Fig. (2). Layout of UWB MIMO Antenna [4]

In a separate work, an investigation on the effect of different two elements antenna system configuration formed by mutually coupling and correlation for MIMO application where designed of a two suspended UWB plate antennas operating at 3-6 GHz are done and installed on a finite system ground plane. The envelop correlation between the two antennas from S-parameter is analyzed such that an optimized configuration is achieved as shown in Fig.(2) [7]. To consider polarization diversity, a work is proposed where a tri monopole antenna structure is used and the focus is made on mutual coupling and casting effects using the computational electromagnetic solver numerical electromagnetic code. The capacity increase is mainly attributable to polarization diversity instead of pattern diversity [8]. By splitting the Square Ring Slot of Microstrip Square Ring Slot Antenna (MSRSA) and optimizing the feeding network, UWB frequency range can be attained as shown in Fig.(3) [9]. In another approach we can insert RF switches (PIN diode) at the feeding point to design a monopole antenna with reconfigurable features [10].

In a different work UWB-MIMO antenna system having two identical monopole antenna elements a to provide wide impedance bandwidth and enhanced isolation, a comb-like structure on the ground plane is used. This type of antenna covers entire UWB range with a better isolation than -25dB. As this MIMO antenna is proficient to achieve an envelope coefficient of less than 0.001, so we can say that it is good for portable UWB communication systems [11].

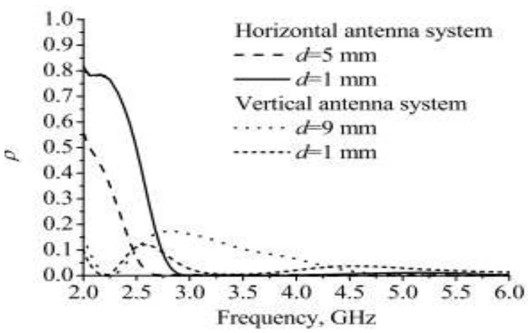

Fig.(2). Correlation for Horizontal and Vertical Antenna System

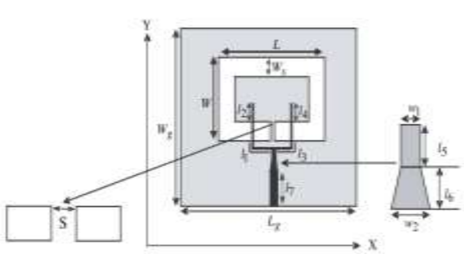

Fig. (3). Geometry of Split Square Ring Slot Antenna

For the application of WLAN/UWB compact MIMO antennas with two open L-shaped slot antenna is used. This reduces the mutual coupling of antennas at a low frequency i.e. 2.4 GHz, a narrow slot is also added to the ground plane. This antenna has an impedance bandwidth larger than 2 – 10.6 GHz, low mutual coupling of less than 20dB in the WLAN band and 18dB through UWB applications [12].

To achieve a dual polarized antenna, a double slot structure system is used. An antenna having an impedance bandwidth of 7.7% for both the ports has been designed. The port isolation as measured remains better than 30dB within the LTE bandwidth of 2.5 – 2.7 GHz, which led to obtain a notable Compact Dual polarized shaped patch antenna with high isolation [13].

Two antennas are being used; one is step-tapered slot antenna (S-TSA) and the other is a small square monopole antenna with an inverted H-shaped slot with high isolation. Because of orthogonality of E-field, the isolation between of two ports is improved. Here, the antenna can operate at a bandwidth range of 3.1 to 10.6 GHz, and the isolation between the two ports is better than 30dH [14].

The MIMO requires multiple antennas, both at transmitter and receivers ends that work simultaneously to achieve the required result efficiently. This achievement greatly influence the researchers focus to work on MIMO technology in UWB applications, when both MIMO and UWB work together it can easily overcome multipath propagation with non-line-of sight (NLOS), and achieve the accurate result easily. By increasing the spectrum efficiency of the channel using Equation (1) as below, the MIMO antenna enhance channel capacity [15] [16].

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

Suppose M_T and M_R are the number of transmitters and receivers, respectively. While I_{MR} is the identity matrix, M_R x M_R and H is a M_T x M_T matrix. From Equation (1), as the number of antenna both in transmitter and receiver are increased, the capacity of MIMO is also increased.

However, to increase the efficiency and effectiveness of MIMO, MIMO needs to overcome the problems, as very low mutual coupling, low correlation, high diversity gain, and low total active reflection coefficient (TARC). [17, 18]. Design of two identical patch elements on a single substrate is done. Antenna is now achieved to supply a UWB frequency resonant of 3.1GHz to 10.6 GHz. MIMO antenna is now accessible to have an optimum inter-element spacing with minimum reflection coefficient of -10dB, low mutual coupling less than -15dB and low correlation coefficient as well [24].

Future Scope:

Researchers can make their future research work upon UWB MIMO positioning effect, which improves the mutual coupling parameter. This type of model might be constructed for development of universal guidelines for UWB-MIMO antenna systems incorporated on miniature terminals [1].

In case of MIMO, work can be done to enhance the channel capacity by reducing the correlation coefficient in one hand and increasing the isolation between the antennas on the other resulting in overall increasing the performance of MIMO antennas.

So far, the research is mainly focus in the field of S-parameters and radiation pattern, but no stressed is given on the study of performance evaluation. So a necessity is felt to work in the field of performance evaluation researches that design the MIMO antennas at most on Quad Band operation, integrated several applications into a thin body on a handheld device having different resonant on multiple frequencies is quite difficult. So further work need to be considered in this field [27].

Researchers in their future work will focus on finding an appropriate general model that can combine the influences on the part of antenna elements and common ground of the application. Such a model might be an useful device to derive the general guiding principles for MIMO antenna systems integrated on miniature terminals [28].

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