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A Review of Enhancement in the Isolation between Elements of UWB-MIMO Antennas

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Abstract

The Federal Communication Commission (FCC) has officially assigned an unlicensed frequency range of 3.1–10.6 GHz bandwidth having very low radiated power levels for use in commercial applications. But the Ultra Wide Band UWB system faces problems such as Signal fading and Multipath Environments thus not suitable for large distances and can be used for short distances only. Thus the solution of the existing challenges is MIMO (Multi- Inputs and Multi- Outputs). MIMO Technology provides high data rates and increased range and are more reliable.UWB – MIMO can be combined together to extend the communication range and reliability of link. The UWB-MIMO technology eliminated Multipath and signal fading problems. Apart from these benefits, UWB-MIMO is also facing challenges for joint implementation of both UWB and MIMO. These challenges are modulation schemes of UWB-MIMO, designing of compact and suitable UWB antenna array, efficient as well cost effective RF circuits. The designing of multiple antennas in small space is a big challenge .So the antenna patterns of MIMO need to be de-correlated .And another challenge for UWB-MIMO is to enhance the isolation(Isolation must be high) between antenna elements. In this paper some methods are proposed to achieve increased isolation in UWB MIMO antennas.

Keywords: UWB-MIMO; FCC; antenna; MIMO

1. Introduction

ULTRAWIDEBAND (UWB) is a fast growing technology that makes use of wide frequency bands to transmit signals at very low energy levels. It has reliable applications in short-range high-data-rate transmission, in radar imaging and cancer sensing, etc. Since the authorization from the Federal Communications Commission (FCC) in the US for the unlicensed use of 3.1–10.6 GHz spectrum for applications with low power emission in the year 2002, UWB systems have attracted much attention. Like other wireless communication systems, UWB systems also suffer from multipath fading. It is very well-known that Multiple-Input-Multiple-Output (MIMO) technology can be used to provide multiplexing and diversity gain for improvements in the capacity and link quality of wireless systems . UWB systems using extended bandwidths already have high data rates, so MIMO technology can be used for faded countermeasure by diversity gain. The basic concept behind the use of MIMO Antennas is to deploy multiple antenna elements to transmit or receive signals with different fading characteristics. Since there is least possibility that all the signals at receiver end will experience deep fading at same time, the system reliability can be increased by accurate selection/combination of the received signals. However, installation of multiple antenna elements on small space available in portable devices will cause high mutual coupling and as a result degrade the diversity performance. Thus, the main challengein employment of MIMO technology in portable devices is - the designing of small MIMO antennas having low mutual coupling. In this paper some methods are proposedfor the reduction of mutual coupling between the elements and for increasing the isolation factor between the antenna elements.

2. UWB Systems

Ultra-wideband (also known as UWB ultra-wide band and ultraband) is a radio technology that uses very low energy for short range, high bandwidth communications over a large portion of the radio spectrum. UWB has traditional applications in non-cooperative radar imaging. Most recent applications target sensor data collection, precision locating and tracking applications.

The Federal Communications Commission (FCC) allocated the bandwidth of 7.5GHz that is from 3.1 GHz to 10.6GHz to UWB applications which is largest spectrum allocation by FCC.

Ultra-wideband was formerly known as pulse radio, but the FCC and the International Telecommunication UnionRadio communication Sector (ITU-R) currently defined UWB as an antenna transmission for which emitted signal bandwidth exceeds the lesser of 500 MHz or 20% of the arithmetic center frequency. Thus, pulse-based systems in which each pulse that is transmitted occupies the UWB bandwidth (or an aggregate of at least 500 MHz of narrow-band carrier; for example, orthogonal frequency-division multiplexing (OFDM)) can access the UWB spectrum under the rules. Pulse repetition rates may be either low or very high. Pulse-based UWB radars and imaging systems tend to use low repetition rates (typically in the range of 1 to 100 Mega pulses per second).

Differing from traditional narrow band radio system such as transmission of signal by modulating the amplitude, phase or frequency of the sinusoidal waveforms, UWB transmits the information by generation of radio energy waves at particular time instances in very short pulses form thus occupies very large bandwidth and enables time modulation. Because of transmission of non-successive and very short pulses, UWB Radio propagation is able to provide high data rates in an order of several hundred megabytes per second. Hence the power consumption of the UWB is very low compared to other traditional methods. The dominating applications by use of UWB are WBAN, WPAN, RFIDs, and sensor networks. The IEEE standard of UWB for high data rates is 802.15.3a and 802.15.4a for low data rates. The challenges faced by the UWB system are: I) Signal fading and II) Multipath. The solutions for these challenges are to combine UWB with MIMO technology where MIMO stands for Multi-Input and Multi-output. The MIMO technology exploits multipath to provide high data rates and thus simultaneously provides increase in the range and becomes reliable without consuming extra radio frequency.

3. MIMO System

MIMO (multiple Input, Multiple Output) is an antennabased technology for wireless communications where multiple antennas are used at both the transmitter (source) end and the receiver (destination). The antennas at each end of the communications circuit are combined for minimization of errors and optimization of data speed. MIMO is one of various forms of smart antenna technology; the others are MISO(multiple Inputs, single output) and SIMO(single input, multiple outputs).

In conventional wireless communications, where a single antenna is used at the source, and a single antenna is used at the destination. In some of the cases, this gives rise to problems with multipath effects. When an electromagnetic field (EM field) meet with obstructions such as hills, buildings, and utility wires, the wave fronts gets scattered, thus they may take various paths to reach the destination. The late arrival of scattered portions of the signal causes problems such as distortion, fading, cut-out and intermittent reception (picket fencing) of signal.

In digital communications systems like wireless communication it may cause a reduction in speed of data and an increased number of errors. The use of two or more antennas that provides transmission of multiple signals (one for each antenna) at both the source and the destination, eliminates the problem caused by multipath wave propagation.

MIMO uses number of antennas and considerably increases the capacity of the channel. Shannon's law defines the maximum rate at which error free data can be transmitted over a given bandwidth in the presence of noise.It is

Capacity=BW log2 (1+SNR) Hertz

Where BW is bandwidth in Hertz and SNR is signal to noise ratio.

The traditional way to achieve more data rates is by increasing the signal bandwidth. But increasing the signal bandwidth of a communication channel by increase of the symbol rate of modulated carrier makes it susceptible to multipath fading. MIMO Communications channel provides a solution to the multipath challenge by using multiple signal paths. In effect MIMO systems use a combination of multiple paths and multiple antennas to gain knowledge of the communications channels. By using spatial dimensions of communications link, system can achieve higher data rates than traditional single-input and single-output channel.

If we use N number of spatial streams the achieved channel capacity is as follows

Capacity=NBW log2 (1+SNR)

This channel capacity by MIMO is N times greater than SISO. Thus the multiple antenna configurations can be used to overcome the drawbacks of multi-path and fading to achieve high data rates throughout the system in limited-bandwidth channels

MIMO technology has aroused interest because of its applications in digital television (DTV), wireless local area networks (WLANs), metropolitan area networks (MANs), and mobile communications.

a. UWB-MIMO System ULTRAWIDEBAND

ULTRAWIDEBAND (UWB) technology have become one of the most reliable and promising technologies for its inherent advantages, such asHigh-Speed data transmission rate, high security, low costs, and low power consumption. Although, in order to mitigate its interference to other systems, the Federal Communications Commission (FCC) assigned an unlicensedfrequency range of 3.1–10.6 GHz bandwidth with a very low radiated power level (less than41.3dBm/ MHz) for commercial use in applications of UWB systems. The problem of signal fading in multipath environments is very serious for UWB system, which will decrease performance of UWB system. Multiple-input multiple-output (MIMO) technology utilizes multiple antennas at both the transmitter and receiver ends that have been adopted to improve the quality of communication and increases the system capacity. Thus, MIMO technology can be used as an effective and efficient technology to solve the multipath-fading problem in systems.

The Advantages UWB-MIMO is:-

- Interference Suppression or Mitigation
- The higher data rate can be achieved with the help of multiple antennas
- It helps in achieving reduction in BER (Bit Error Rate) by application of advanced signal processing algorithms on the received data symbols by multiple antennas.
- Improved link quality is achieved.
- Extended coverage

- Lower susceptibility of tapping by unauthorized persons due to use of multiple antennas
- MIMO offers high QoS (Quality of Service)

The challenges faced by UWB-MIMO systems are:-

- MIMO based systems cost higher compare to single antenna based system due to increased hardware and advanced software requirements.
- UWBMIMO channel modeling.
- The optimization of UWB-MIMO modulation schemes
- The hardware resources increase power requirements; hardware complexity is higher compare to single antenna based system.

b. ***Techniques of Enhance Isolation And Reduce Mutual Coupling***

There are three technique of enhance isolation and reduce mutual coupling which are given below:

Using Decoupling and Matching Networks (DMN)

The achievement of High isolation and low mutual coupling is achieved by method of decoupling and matching networks. The far field radiation patterns and the scattering parameters of the antenna system can be used to calculate envelope correlation by assuming a uniform propagation channel which can be written for a reciprocal and symmetrical antenna system as:

$$\rho_e = \frac{|2Re\{S_{11}^{*}S_{12}\}|^2}{(1-|S_{11}|^2-|S_{12}|^2)^2}$$

From the equation above, it is clear that by change in the magnitude and phase of either S11or S12, the correlation factor between the two antennas can be decreased. In practice, this can be achieve by using a matching network for connection of the antennas. From the point of view of system, it is important to consider the value of 1| S11| 2 |S12| that is taken into account of effective radiated power by the antenna system, and can be maximized by minimizing | S11| and | S12|. Thus, the two matching networks are used at both sides to minimize S11 and S12. And a decoupling network is used to make S11 in quadrature with S12 i.e., S12 is purely imaginary and the real part of mutual impedance Z12 is equal to zero. This can be achieved by use of a lossless decoupling network. In UWB-MIMO (Ultra-wide Multiple Input Multiple Output) Systems it can be noticed that a lot of work is presented to get better isolation using DMNs. However, this technique is not tractable for UWB-MIMO systems. To design matching networks and to realize for wideband, multiband and ultra-wideband MIMO systems are difficult. Thus, this technique is not employed yet for UWB-MIMO systems in the literature to the best of our knowledge

Using Defected Ground Structure (DGS)

The (DGS) defected ground structure also has capability to provide a band stop effect by the combination of inductance and capacitance. The defects on the ground plane store a fraction of propagating energy which can be designed in terms of simple equivalent reactive circuit. DGS have been applied to antenna designs for suppressing harmonics and cross polarization of a patch antenna, and for increasing the isolation between antenna elements. A defected ground structure (DGS) consists of concentric circular rings having different configurations as presented and its stop band characteristics are examined. Later, this DGS is being employed for reducing mutual coupling between two cylindrical dielectric resonance antennas. About 5 dB suppression has been obtained near the operating frequency around 3.3 GHz. Other variants of this technique can be embedding of slits or meander lines in the ground plane. In the ground plane structure consisting of five pairs of slits etched into the middle of a ground plane of two closely packed planar inverted-F antennas is proposed. These slits are interleaved with metal strips and these strips could be thought of as capacitors. At the same time, some inductance is introduced along the central small connecting strip. Therefore, the structure behaves as a band stop filter based on a parallel resonator. As a result, such a pattern etched onto the ground plane effectively suppresses mutual coupling. A significant improvement up to 20 dB in isolation is observed in the case of monopole antennas.

Using Electromagnetic Band Gap (EBG) Structures

The electromagnetic band gap (EBG) behaves as a high impedance surface. This structure constitutes of an array of metal protrusions on a flat metal sheet. They can appear as mushrooms or thumbtacks protruding from the surface. If the protrusions are small compared to the wavelength, their electromagnetic properties can be defined using lumped circuit elements. The long conducting path linking them together provides the inductance and proximity of the neighboring metal elements provides the capacitance. They behave as parallel resonant LC circuits and acts as electric filters for blocking the flow of currents along the sheet. This is the origin of the high electromagnetic surface impedance. In this way, EBG structures carry the ability of suppressing surface wave's propagation in a frequency band which makes them useful to improve the ports isolation in printed antennas. InUWB-MIMO Systems this technique is widely used for narrowband MIMO systems, yet it has some drawbacks. The method is not reliable for wideband systems due to a large number of mushroom-like EBG structures that will be required to cover the wide range of frequencies. In conclusion, antennas will require largerarea forembedding these structures for UWBMIMO systems. Later, an intricate process is required forfabrication of such structures. There are some methods of decoupling which are given below:

- The method of Decoupling is introduced for the improvement in isolation between two radiating elements
- Four planar Micro strip lines having open ended fed λ/4 slot to excite the fundamental radiating antenna mode over a prescribed frequency range for achieving enhance isolation between two radiating elements.
- SRR (Split Ring Resonator) is used to improve the isolation between the two radiating patches
- Three open ended slots are used as a decoupling structure for enhancing the isolation between antenna elements
- Using H-shaped DGS Defected Ground Structure (DGS):
- T–shaped decoupling structure in ground plane is extruded which improved the isolation in the MIMO antenna
- Electronic band gap (EBG) and co-design approach structures are used to improve isolation of antenna that offers better diversity performance

Table-I: Comparison table of proposed antenna with existing reference.

Size(mm2)	**Isolation (dB)**	**ECC**	**Reference**
140×120	15	<0.1	[2]
52.8×52.8	14	<0.25	[4]
77×79	20	-	[7]
54.98×76	12	<0.026	[12]

Above Table-I shows Isolation Improvements comparison of reference papers.

4. Conclusion

By getting a little overview of UWB and MIMO, it makes easier in understanding the idea of implementation of MIMO technique in UWB communications systems. As per rules of FCC, extremely low power is being allowed for transmission, i.e. – 41.3 dBm /MHz, and it obstruct the development of UWB communication systems having higher data rates and covering longer distances. To overcome this obstacle, MIMO technique is consideredasone of the solutions for improvementin reliability and the capacity of UWB systems. However, a number of challenges are raised to shape this solution physically. In this paper, we discussed about methods how to reduce the mutual coupling between the antennas and thus leading to enhancement in the isolation between the antennas in UWB-MIMO.

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