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Enhancing the isolation between Elements of UWB-MIMO Antennas

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Abstract : *The Federal Communication Commission (FCC) officially assigned an unlicensed frequency range of 3.1–10.6 GHz bandwidth with a very low radiated power levels for commercial applications. But the UWB system faces the problems of signal fading and multipath environments, suitable for short distances only .The solution for this challenges are MIMO (Multi- inputs and Multi- outputs). MIMO Technology provides high data rates and increases in range and reliability.UWB – MIMO combined together extending the communication range and link reliability. The UWB-MIMO technology elimininates Multipath problems and signal fading. Apart from benefits, UWB-MIMO also facing challenges for joint implementation of UWB-MIMO. These challenges are UWB-MIMO modulation schemes,design of compact and suitable UWB antenna array,efficient and cost effective RF circuits.The designing multiple antennas in small space is big challenge.So the antenna patterns of MIMO need to decorrelate .And another challenge for UWB-MIMO is enhance the isolation between antenna elements.In this paper we propose some methods to increase the isolation in UWB-MIMO antennas.*

Keywords – *Décor relation, Isolation between the elements, Multipath, Signal fading, UWB-MIMO,*

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I. Introduction

ULTRAWIDEBAND (UWB) is a rapidly growing technology which makes use of wide frequency band to transmit signals at low energy level. It has promising applications in short-range high-data-rate transmission, 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 2002 , UWB systems have attracted much attention. Like other wireless communication systems, UWB systems suffer from multipath fading. It is well-known that multiple-input-multiple-output (MIMO) technology can be used to provide multiplexing gain and diversity gain to improve the capacity and link quality, respectively, of wireless systems . UWB systems using huge bandwidths already have high data rates, so MIMO technology can be used for fade countermeasure through diversity gain. The basic concept of MIMO is to use multiple antenna elements to transmit or receive signals with different fading characteristics. Since it is unlikely that all the received signals will experience deep fading at the same time, the system reliability can be increased by proper selection/combining of the received signals. However, installing multiple antenna elements on the small space available in portable devices will inevitably cause severe mutual coupling and significantly degrade the diversity performance. Thus, one of the main challenges to employ MIMO technology in portable devices is the design of the small MIMO antennas with low mutual coupling. In this paper we propose some methods to reduce the mutual coupling between the elements and increase the isolation between the antenna elements.

II. UWB Systems

The Federal Communications Commission (FCC) allocated the bandwidth of 7.5GHz that is from 3.1 GHz to 10.6GHz to UWB applications this is largest spectrum allocation by FCC. UWB is a radio transmission technology which occupies an extremely wide bandwidth exceeding the minimum of 500MHz or at least 20% of the centre frequency is revolutionary approach for short-range high-bandwidth wireless communication. Differing from traditional narrow band radio system transmitting the signal by modulating the amplitude ,frequency or phase of the sinusoidal waveforms, UWB system transmit information by generating radio energy at specific time instants in the form of very short pulses thus occupy very large bandwidth and enabling time modulation. Due to transmission of non –successive and very short pulses, UWB radio propagation provides high data rates in the order of several hundred megabytes per second. The power consumption of the UWB is very low compared to traditional methods. The dominants applications of UWB are WBAN, WPAN, RFIDs, and sensor networks. The IEEE standard for UWB is 802.15.3a for high data rates and 802.15.4a for low data rates. The challenges faced by the UWB system is i) signal fading ii) Multipath. The solutions for these challenges combine UWB with MIMO technology. MIMO stands for multi-input and Multi-output. The MIMO technology exploits multipath to provide high data rates and simultaneously increases the range and reliability without consuming extra radio frequency.

III. MIMO SYSTEM

Multiple-input multiple output (MIMO) technology is a wireless technology that uses multiple transmitters and receivers to transfer more data at the same time. MIMO technology takes the advantage of a radio –wave phenomenon called multipath where transmitted information bounces off walls ceilings, and other objects, reaching the receiving antenna multiple times via different angles. MIMO technology leverages multipath behavior by using multiple smart transmitters and receivers with an added spatial dimension to dramatically increase performance and range. MIMO allows multiple antennas to send and receive multiple spatial streams at the same time. MIMO uses number of antennas, and then it 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

$$Capacity=BW \log_2 (1+SNR) \text{ Hertz}$$

Where BW is bandwidth in Hertz and SNR is signal to noise ratio. In traditional way to achieve more data rates is by increasing the signal bandwidth. Unfortunately increasing the signal bandwidth of a communications channel by increasing the symbol rate of modulated carrier increases its suspectabilitily to multipath fading. MIMO Communications channel provides an interesting solution to the multipath challenge by requiring multiple signal paths. In effect MIMO systems use a combination of multiple antennas and multiple paths to gain knowledge of the communications channels. By using spatial dimensions of communications link, MIMO system can achieve significantly higher data rates than traditional single-input and single-output channel. If we use N number of spatial streams the channel capacity is as follows

$$Capacity=NBW \log_2 (1+SNR)$$

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

IV. UWB-MIMO SYSTEM

ULTRAWIDEBAND (UWB) technology has become one of the most promising technologies for its inherent advantages, such as high-speed transmission rate, high security, low cost, and low power consumption. However, in order to mitigate its interference to other systems, the Federal Communications Commission (FCC) officially assigned an unlicensed 3.1–10.6 GHz bandwidth with a very low radiated power level (less than-41.3dBm/ MHz) for commercial applications of UWB systems. Therefore, the problem of signal fading in multipath environments is quite serious for UWB system, which will deteriorate performance of UWB system. Multiple-input multiple-output (MIMO) technology that utilizes multiple antennas at both the transmitter and receiver has been adopted to improve the communication quality and increase the system capacity. Thus, MIMO technology can be used as an efficient technology to solve the multipath-fading problem in systems.

The Advantages UWB-MIMO is

- Interference mitigation or suppression
- Higher data rates
- Improved link quality
- Extended coverage
- Reduce the analog hardware equipments.

The challenges faced by UWB-MIMO systems are

- UWB-MIMO signaling trade-offs
- UWBMIMO channel modeling
- the optimization of UWB-MIMO modulation schemes
- design of compact and suitable UWB antenna arrays
- efficient and cost-effective UWB-MIMO RF circuit design,

Among these challenges, the design of compact and suitable UWB diversity antennas is difficult. The significance of antenna in a wireless communication system cannot be avoided. Antenna is one of the critical elements to be miniaturized along with the other circuit elements. The design of antenna faces a lot of challenges itself in this race. As devices are going to be more compact, therefore the antennas must be positioned within the available space. So the implementation of multi-antenna structures becomes more challenging in the very limited space provided by the small terminals. Another challenge is the enhancement of isolation between the access ports of MIMO antennas. The main aim of this paper is focused on to reduce the mutual coupling and how to increase isolation between the antenna elements .In this paper we proposed some methods to reduce mutual coupling and increase the isolation between the antenna elements. This paper also describes some of our proposed designs and structures of the different types of MIMO antennas for UWB applications exploiting spatial, polarization and pattern diversities, and a solution to enhance the isolation with reduced size of antenna.

V. Techniques to reduce mutual coupling and to enhance isolation

The mutual coupling has a significant effect on MIMO channel capacity in rich scattering environments. The degree to which coupling induced correlation degrades MIMO channel capacity. Another problem resulting from an increase in mutual coupling is the subsequent decrease of the array's radiation efficiency due to impedance mismatch. So the reduction of mutual coupling becomes very important. Similarly, poor isolation also degrades the array's radiation efficiency due to the leakage of transmitted power from the excited antenna to the port of non-excited antenna. In this paper we propose some methods to reduce the mutual coupling and enhancing the isolation.

Those methods are

- Using Decoupling and Matching Networks (DMN)
- Using Electromagnetic Band Gap (EBG) structures
- Using neutralizing line
- Using Defected Ground Structure (DGS)
- Using spatial and angular variations
- Inserting stubs
- Using heterogeneous elements

5.1 Using Decoupling and Matching Networks (DMN):

The achievement of low mutual coupling and good isolation is achieved by using decoupling and matching networks. The envelope correlation can be calculated from the far field radiation patterns as well as from the scattering parameters of the antenna system .Assuming uniform propagation channel. The envelope correlation can be written as in for a reciprocal and symmetrical antenna system:

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

From above equation, it is clear that by changing the magnitude and phase of either S_{11}or S_{12}, the correlation between the two antennas can be decreased. In practice, this can be achieved by using a matching network for connecting the antennas. From the system point of view, it is also important to consider the value of $1 - |S_{11}|^2 - |S_{12}|^2$ that takes into account the effective radiated power by the antenna system, and it is maximized by minimizing $|S_{11}|$ and $|S_{12}|$. Thus, two matching networks can be used at both sides to minimize S_{11} and $S_{12.}$ While a decoupling network can be used to make S_{11} in quadrature with S_{12} i.e., S_{12} is pure imaginary and thus the real part of mutual impedance Z_{12} is equal to zero. This can be achieved by using a lossless decoupling network. In UWB-MIMO Systems it can be noticed that lot of work has been presented to get better isolation using DMNs. However, this technique is not tractable for UWB-MIMO systems. The matching networks to design and to realize for multiband, wideband and ultra wideband MIMO systems are enough difficult. Thus, this technique is not employed yet for UWB-MIMO systems in the literature to the best of our knowledge.

1.2 Using Electromagnetic Band Gap (EBG) structures:

The electromagnetic band gap (EBG) structure behaves as a high impedance surface. This structure consists of an array of metal protrusions on a flat metal sheet. They can be appears as mushrooms or thumbtacks protruding from the surface. If the protrusions are small compared to the wavelength, their electromagnetic properties can be described using lumped circuit elements like capacitors and inductors. The proximity of the neighboring metal elements provides the capacitance, and the long conducting path linking them together provides the inductance. They behave as parallel resonant LC circuits, which act as electric filters to block the flow of currents along the sheet. This is the origin of the high electromagnetic surface impedance. Because of its unusual impedance, the surface wave modes on this structure are very different from those on a smooth metal sheet. In this way, EBG structures have the ability of suppressing surface waves propagation in a frequency band which makes them very 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 constraints. The method is not viable for wideband systems because a large number of mushroom-like EBG structures will be required to cover the wide range of frequency. As a result, antennas will require large area to embed these structures for UWBMIMO systems. Further, an intricate process is required to fabricate such structures. They involve an intricate fabrication process with cells shorted to the ground through vias.

5.3 Using neutralizing line:

The technique of using neutralizing line is based on the concept to neutralize two antennas operating in the same frequency band to enhance the isolation. This is uses a suspended neutralization strip line physically connected to the antenna elements. This line samples a certain amount of the signal on one antenna element and delivers to the other antenna element in order to cancel out the existing mutual coupling, thus increasing total efficiency. In other words, an additional coupling path is created to compensate for the electrical currents owing on the PCB from one antenna to another. In UWB-MIMO Systems this technique is very attractive and has provided good results, yet it is not employed to UWB MIMO antennas so far. It could be very difficult to couple the elements operating over the wide range of bandwidth in such a way that they cancel out mutual coupling.

5.4 Using Defected Ground Structure (DGS):

The defected ground structure (DGS) is also able to provide a band stop effect due to the combination of inductance and capacitance. The defects on the ground plane store a fraction of propagating energy and that can be modeled in terms of a simple equivalent reactive circuit as was explained in detail in. DGS has been applied to antenna designs to suppress harmonics, cross polarization of a patch antenna, and to increase the isolation between antennas. a defected ground structure (DGS) consisting of concentric circular rings in different configurations is presented and its stop band characteristics are examined. Later, this DGS is being employed to reduce mutual coupling between two cylindrical dielectric resonator antennas. About 5 dB suppression has been obtained near the operating frequency around 3.3 GHz. Other variants of this technique could 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. In it has been demonstrated that meander line embedded ground plane provides better isolation as compared with silted ground plane. Recently, a combination of two techniques, i.e., DGS and EBG, is presented in. A silted pattern is etched on the ground plane and three mushroom photonic band gap (PBG) are etched on each wall. Using two techniques together, isolation between the ports of closely-packed antenna elements is increased by 30 dB.

5.5 Using spatial and angular variations:

The technique of using spatial and angular variations relative to the antenna elements of array is very commonly used to reduce mutual coupling. It is well demonstrated that by increasing the space between the radiating elements decor relates them and even the spacing greater than or equal to $\lambda/2$ gives mutual coupling less than -20 dB, where λ is free space wavelength at the center frequency. However, the spacing becomes less than $\lambda/2$ in the case of compact MIMO antennas for portable devices, thus it requires considering the mutual coupling effects to be compensated. Therefore, in addition to separating the radiating elements by some distance, positioning of the radiating elements at different angles with respect to each other helps to reduce mutual coupling by exploiting the diversity in polarization. Being very simple technique, it has not some specific constraints relating to the bandwidth but with size of the antenna.

VI. Conclusion

Taking a little overview of UWB and MIMO, it makes easier to understand the idea of implementing MIMO technique in UWB communications systems. As per FCC rules, extremely low power is being allowed to be transmitted, i.e. – 41.3 dBm /MHz, and it impedes the development of UWB communication systems with higher data rates or covering longer distances. To overcome this bottleneck, MIMO technique has been considered to be one of the solutions that will improve the reliability and the capacity of UWB systems. However, a number of challenges arise to shape this solution physically. In this paper, we discussed about methods how to reduce the mutual coupling between the antennas and enhancing the isolation between the antennas in UWB-MIMO.

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