MIMO-OFDM COMBINATION-THE KEY TO IMPROVE *BER* PERFORMANCE OF OFDM SYSTEM

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ABSTRACT : *Orthogonal Frequency Division Multiplexing (OFDM) is under too intense consideration for latest research in wireless transmission due to high spectral efficiency. The quick growth of mobile wireless communication technology is the key for providing the latest demand for reliable communication even in high speed as per the latest definition of term mobile. OFDM system eliminates long equalizer's need. The efficient hardware implementation can be realized using Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) combination in transmitter side and receiver side respectively. Different types of diversity such as frequency, code and spatial are used now a days. Antenna diversity has gained as a one of the promising technique for enhancing Bit Error Rate (BER) performance. Multiple Input Multiple Output(MIMO) transmission has better BER performance compare to Single Input Single Output(SISO) with same bandwidth and transmission rate. The combination of MIMO with OFDM is used now a day for improved performance. MIMO with OFDM provides both spectral efficiency and robustness against noise. In this given paper BER of MIMO with OFDM is analyzed with different modulation schemes and different numbers of antennas.*

Key Words: Orthogonal Frequency Division Multiplexing (OFDM), Inverse Fast Fourier Transform(IFFT), Fast Fourier Transform(FFT), Bit Error Rate(BER), Multiple Input Multiple Output(MIMO), Single Input Single Output (SISO)

1. INTRODUCTION :

Wireless communication system has become one of the most recent areas in the field of telecommunications, as the data rates of wireless system increases to higher and higher values both equalizer and rake receiver become very much complex for practical use. *OFDM (Orthogonal Frequency Division Multiplexing)* is one the way of overcoming such problem. In this approach the data stream is split into large numbers of sub streams each of which is modulated onto different carriers. If only a single frequency carrier is used, then the symbol duration has become very small in order to achieve the required data rate and the system bandwidth become too much high. For example GSM having the data rate up to 200Kbps uses bandwidth of 200 KHz while the IEEE 802.11 system with data rate of up to 55Mbits/s uses bandwidth of 20MHz. The delay dispersion of a wireless channel depends upon the wireless environment. If in the given system the duration of symbol becomes too much small, then the data length of the equalizer becomes too much long. The computation effort of such equalizer is very long and the probability of instabilities increases very much. TDMA makes the symbol duration very small. *CDMA* uses band spreading thus uses rake receiver with few fingers in addition to the equalizer. *OFDM* on other hand increases the symbol duration on each of the carrier. OFDM is particularly uses multicarrier communication technique in which the concept is to divide the complete signal bandwidth into a large number of subcarriers. The divided information is transmitted on each of such divided subcarriers. The frequency spacing between subcarriers is selected in such a fashion that the subcarriers are completely orthogonal to each other mathematically. OFDM has gained too much interest for very high data rate wireless communications even at the speed of 200 Km/sec due to its robustness to frequency selective fading and very high spectral efficiency. Communication system which uses multiple transmitters and multiple receivers are often called Multiple Input and Multiple Output (MIMO) systems. In short it is known as MIMO system. It provides high data reliability and higher data rates for any kind of system. More number of antennas at transmitter end means more number of times information is being sent and more number of antenna at the receiver end means that one antenna has not received the information correctly due to wireless channel than another antenna can receive it correctly. MIMO system takes the advantage of spatial diversity that is obtained by spatially separated antennas in multipath environment.

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2 BASICS OF MIMO-OFDM AND THEIR COMBINATION

OFDM dates back some 40 years; a patent was applied in midst of 1960[1].The work is very old but due to VLSI technology, its practical implementation is realizable in the new era of digital communication. The practical implementation of the concept of IFFT and FFT made this possible in today's era. The OFDM splits the information into N parallel streams which are then transmitted by modulating N distinct carriers called sub carriers or tones. OFDM increases the symbol duration which makes decoding comparative easy at the receiver end.

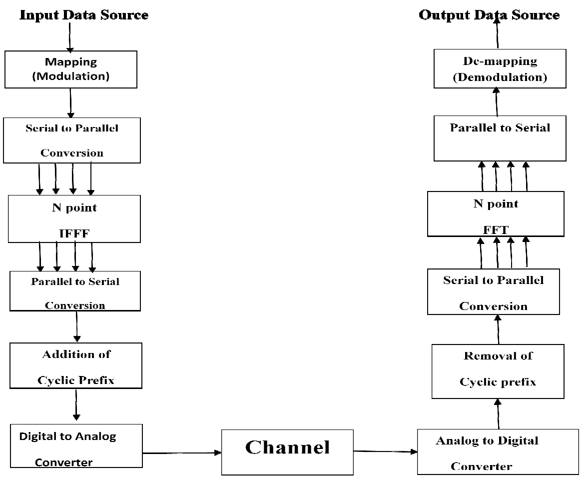

Figure1 Block diagram of OFDM Transmitter & Receiver

In order for the receiver to be able to separate the signals carried by different sub carriers, they have to be orthogonal to each other mathematically as shown below.

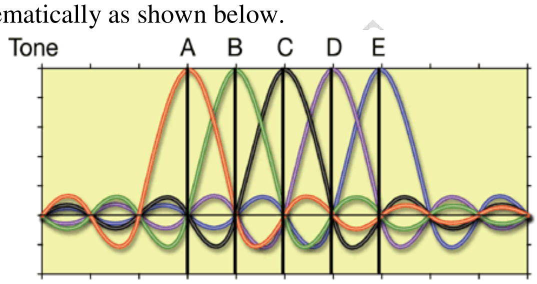

Figure 2 Orthogonal Tones in OFDM

Parallel bits are mapped to serial bits , after IFFT cyclic prefix is being done to prevent Inter Carrier Interference (ICI). The Digital to Analog (D/A) conversion is being done and data is transmitted. The receiver part is just reverse of the transmitter one. Analog to Digital (A/D) conversion is being done and then cyclic prefix is being removed then serial to parallel is being done followed by FFT and parallel to serial conversion. At last demapping is being done. Conventional FDMA can achieve this by having a large spacing between the carriers. This however waste precious spectrum. A much narrow spacing of sub carrier can be achieved. Orthogonality means two signal are independent of each other in a specified time interval and do not interact with each other. *OFDM* significantly reduces receiver complexity in wireless broadband multi-antennas system. OFDM is very popular now a day. Currently OFDM technology is used in *Wireless Local Area Networks (IEEE 802.11a, IEEE802.11g), Digital Video Broadcasting (DVB) and Digital Audio Broadcasting(DAB)etc.[2].*

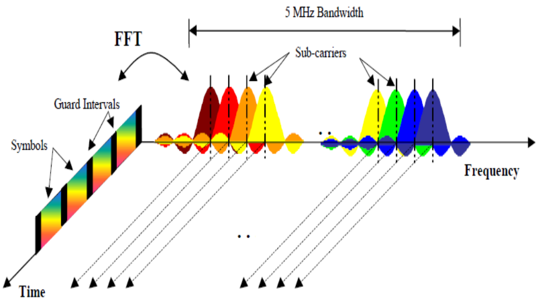

Figure 3 OFDM symbols in time and frequency domain

MIMO system is also known by name of Multiple *Element Antennas (MEA).* The MEA or MIMO system is usually used in three different modes. These are beam forming, diversity and spatial multiplexing. Spatial multiplexing which incorporates MEA at the transmitter end for transmission of different parallel data streams containing the information. The original data stream is multiplexed into various parallel streams. Each parallel stream is sent through transmit antenna element. The wireless or wire line channel mixes up these data stream so as each of the receive antenna element sees a combination of information. If the wireless channel is well behaved the received signals represents linearly independent combinations. In the case perfect appropriate digital signal processing at the receiver end can separate the data stream. A fundamental condition here is that the number of received antenna is at least as large as the number of transmitted data stream [3].If we have one transmit and one receive antenna, the concept is known as Single Input Single Output (SISO).If one number of antenna is used for transmitting information and more than one antennas are at the receiver side, the concept is of Single Input Multiple Output (SIMO).The Multiple Input Single Output (MISO) concept is the concept where multiple antennas are at the transmitting end and single antenna is there at the receiver end of the system. The concentration of this paper is on Multiple Input and Multiple Output (MIMO) where at both the end of transmitter and the receiver multiple antennas are used. *MIMO* is an advanced physical layer method which uses multiple antenna at both at transmitter as well as at the receiver side. Antenna diversity offers robustness and gain over single antenna system [4]. Diversity provides the receiver end with several replicas of the transmitter signal and is therefore very powerful tool to combat fading and interference for further processing at the receiver end [5]. We can also say that multipath and mobility make channel disperse not only in time domain but also in domain of frequency. [6] So we must take care of it while designing the system like we have use the concept of cyclic-prefix

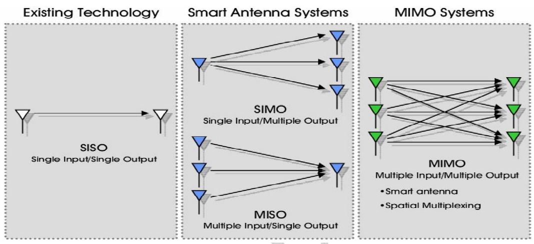

Figure 4 SISO, SIMO, MISO and MIMO concept

In MIMO, the data is fed to different antennas at the transmitting end and it is passed through the air channel and received by different antennas. If channel matrix is given as H, x is transmit signal vector and n is the noise vector, the received signal vector y is given by

$$y = Hx + n$$

The concept is shown in the figure below.

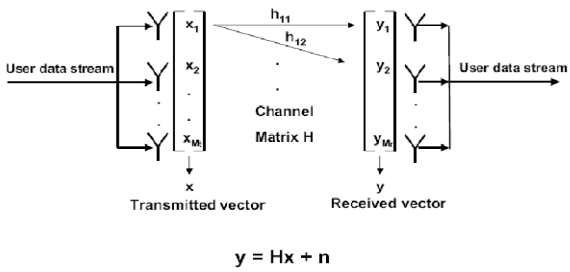

Figure 5 MIMO concept with Channel Matrix and Noise

The combination of MIMO & OFDM as explained in earlier in this paper gives higher data rates with low BER. In other words, MIMO –OFDM is produced by using different combinations of multiple transmit and multiple receive antennas in an OFDM system has becoming a practical alternative to single carriers system or SISO transmission. As we keep on increasing the number of transmit antennas / number of receive antennas the BER reduces. *OFDM* drastically reduces complexity of receiver as far as decoding is concern in wireless broadband multi-antenna system [7]

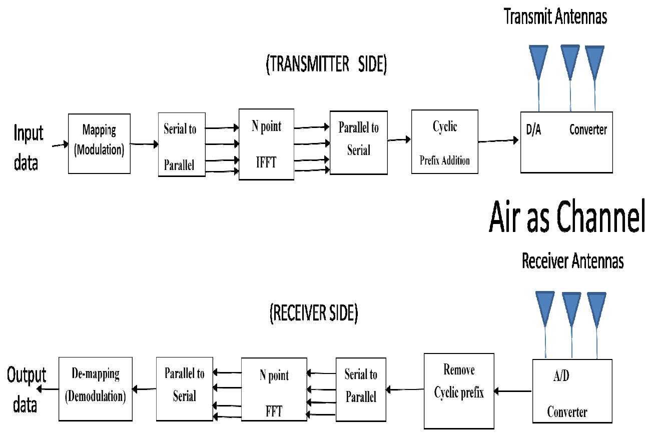

Figure 6 OFDM and MIMO concept with 3 Tx / Rx Antennas

The number of transmit antennas or receiving antennas can be more than three or even two each. The requirement of number of antennas is based on BER requirement at desirable Eb/No (Bit energy/Noise power) in the given system. Disadvantages of OFDM are high sensitivity to time and carrier offset and synchronization. High Peak to average power ratio (PAPR) is another big drawback for OFDM technology, which needs large back-off in the transmitter amplifier to minimize non linear distortion at the transmitting end. [8]

3 RESULTS AND DISCUSSION

Table 1 Parameters under consideration

S.N.	Technical parameter	Type
1	Channel Type	AWGN
2	OFDM Sub carriers	1024
3	Oversampling Rate	4
4	Modulation Scheme	BPSK/QPSK/16 QAM/64QAM
5	No. of iterations	10000

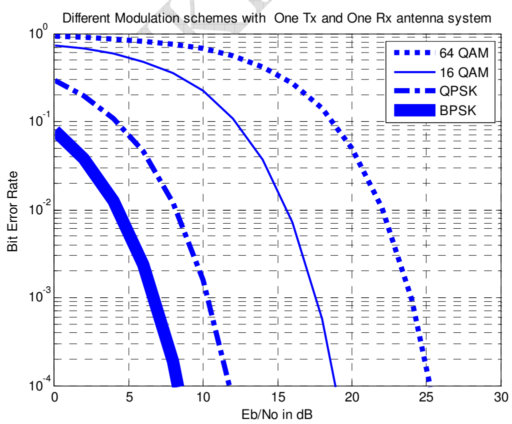

Figure 7 BER plot for One Tx /One Rx for all modulation schemes under consideration

The figure already given is of different modulation schemes of M ary QAM for OFDM system in which the BER of BPSK is least and increasing order like of QPSK then 16 QAM and 64 QAM has highest BER of all in the Schemes in this picture for one transmit and one receive antenna. It will be clear from the readings that as we increase the no of transmit/receive antennas. The BER gets reduced in all cases of M ary

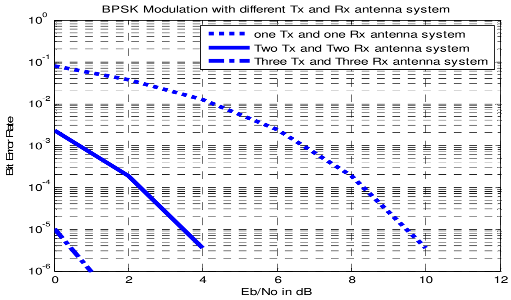

Figure 8 BER plot for different Tx /different Rx for BPSK

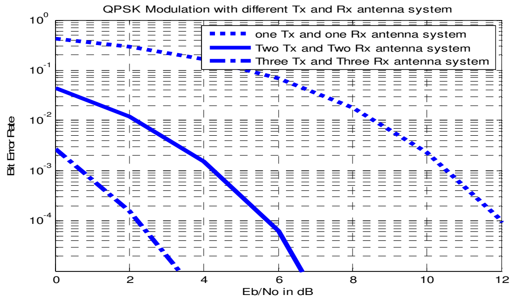

Figure 9 BER plot for different Tx /different Rx for QPSK

As shown in figure 8 and figure 9 that for BPSK / QPSK modulation, if we increase the number of transmit and receive antennas the BER gets reduced for a given Eb/No. The same explanation holds true for 16 QAM and 64 QAM as shown in as shown in figure10 and figure 11.

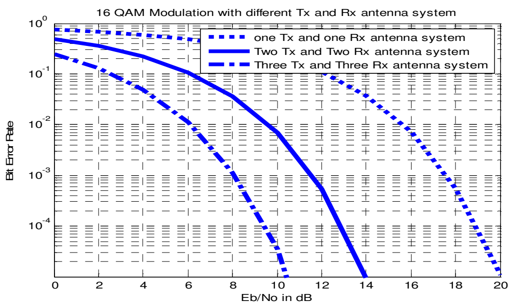

Figure 10 BER plot for different Tx /different Rx for 16 QAM

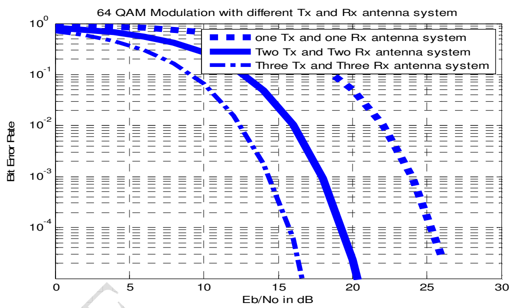

Figure 11 BER plot for different Tx / different Rx for 64 QAM

It will be clear from the readings that as we increase the number of transmit antennas / the number of receive antennas. The BER gets reduced in all cases of M ary for a given Eb/No. The BER reduces as we go from 1 X 1 (1Tx and 1 Rx) to 3 X 3 (3Tx and 3 Rx) scenario.

4 . CONCLUSION

In this paper we have performed the experiments and analyzed the concept in MATLAB. BER is more in case of 64 QAM compare to 16 QAM and QPSK also 16 QAM has more BER compare to QPSK keeping all condition same and channel same using OFDM technology. If we are going for higher order QAM, then MIMO is one of the best solution to reduce BER. As we increase the number of received antenna keeping the transmit antenna and channel same BER reduces also if we increase the no of transmit antennas and then increase the received antenna BER further reduces. The antennas cost and the small hardware cost for processing of received signals should be considered for the cost factor in case of MIMO in OFDM system.

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