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Design & Implementation of MIMO-OFDM Transmitter Section for Wireless Communication

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Abstract

The major limitations to Mobile and Fixed Wireless Communication growth is the disadvantages of traditional wireless communication System due to the limitations of available frequency resources, Bandwidth, channel capacity, complexity, reliability, transmission data rate, physical areas and communication channel between transmitter and receiver. This paper address such a Compatible advance MIMO Transmission system incorporated with OFDM framed in WLAN standard to deal with data signals of BPSK/ QPSK/16QAM/64QAM/256QAM constellation in MIMO communication modes for establishing wireless communication link. The system is designed for FPGA devices of the Xilinx family and the performance of MIMO is checked over SISO/MISO for reliability of communication, compatibility, Data rate, BER and optimized resource utilization to handle the traffic of multiuser though multiple channels, to ensure the transmission and reception of quality signals even in the failure of any channel.

Keywords: *MIMO,OFDM,WLAN, BPSK,QPSK,16QAM,64QAM,256QAM,SISO,MISO, Transmitter, Receiver, Antenna, FPGA,BER,SNR.*

1. Introduction MIMO System

The Demand of users of Mobile and Fixed Wireless Communication is constantly growing and need the tether less connectivity, higher data rates, good voice quality and higher channel capacity. In early days the mobile were used mostly for voice communication, but now it is utilized as a multimedia device. The wireless data transmission gives us every opportunity to get all feasible, necessary access to the world wherever we are and wherever we need from.

The users of the wireless communication demands for higher data rates, good voice quality and higher network capacity restricted due to limited availability of radio frequency spectrum, Bandwidth, Channel Capacity, physical areas and transmission problems caused by various factors like fading and multipath distortion [1]. The Wireless communication is divided into mobile communications and fixed wireless communications. The demand for wireless communication is constantly growing and need the tether less connectivity [2].

To improve the performance of fading channels, diversity techniques are used. Diversity techniques are used to overcome the fading problem and to improve the performance of the radio channel without increasing the transmitted power or bandwidth and improves the SNR [10].

Among the various diversity techniques, spatial diversity is best suitable for the wireless communication. Multi-input-multi-output (MIMO) wireless communication uses spatial diversity techniques [3].

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Alamouti suggested new transmit diversity techniques to provide the same diversity order as that of Maximum Ration Combining (MRC) by using two transmit antenna and one receive antenna [4] as shown in figure (1). Transmit diversity is more cost effective than receive diversity for base station, to improve the reception quality of all the remote units under the base station.

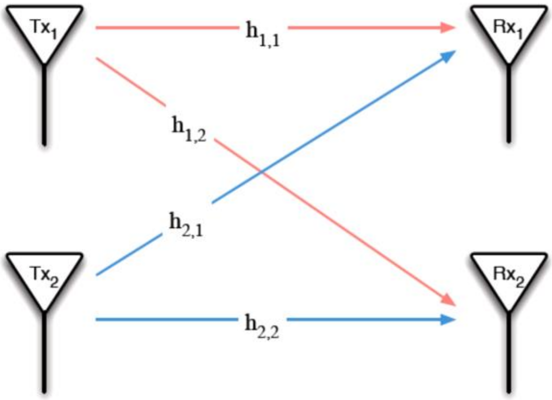

Figure 1. Communication Channel in 2x2 MIMO Systems

Thus, by employing Alamouti's scheme for multiple transmit and receive antenna the diversity can be achieved to improve the performance of radio wireless communication channel [4]. The algorithm is developed for implementing Alamouti scheme considering 2 Transmit and 2 Receive Antenna (Known as MIMO system of 2x2 size) along with the OFDM and different constellation in SISO/MISO/MIMO Communication modes for wireless communication using FPGA. The performance of the transmission system is observed for various parameters like Data link, Physical resource utilization. The operation of the system has been realized through simulation results.

This paper is organized as follows. Section 2 Basic conceptual Block diagram MIMO System, Section 3 described the operation of MIMO-OFDM-WLAN Transmitter Section designed to transmit the two signals, Section 4 the simulation results MIMO Transmitting antenna array, Section 5 discusses about the performance analysis and Section 6 about results and conclusion.

2. Conceptual MIMO System

The overall conceptual block diagram of MIMO communication system is shown in figure (2) which has the following four elements.

- MIMO-Transmitter Section (MIMO-TX)
- MIMO-Antenna Array (N and M) with RF Combiner and High Power Amplifier.
- MIMO-Channel (H)
- MIMO-Receiver Section (MIMO-RX)

The input data applied to MIMO-TX section which encodes the data in Alamouti STBC code with OFDM and IEEE 802.11a data packet transmission. The Encoded data are transmitted by MIMO Antenna arrays system through a MIMO Channel towards receiving antennas. At the Receiver end, the received signal is decoded, synchronize for timing and frequency, to recover the original transmitted data at the receiver.

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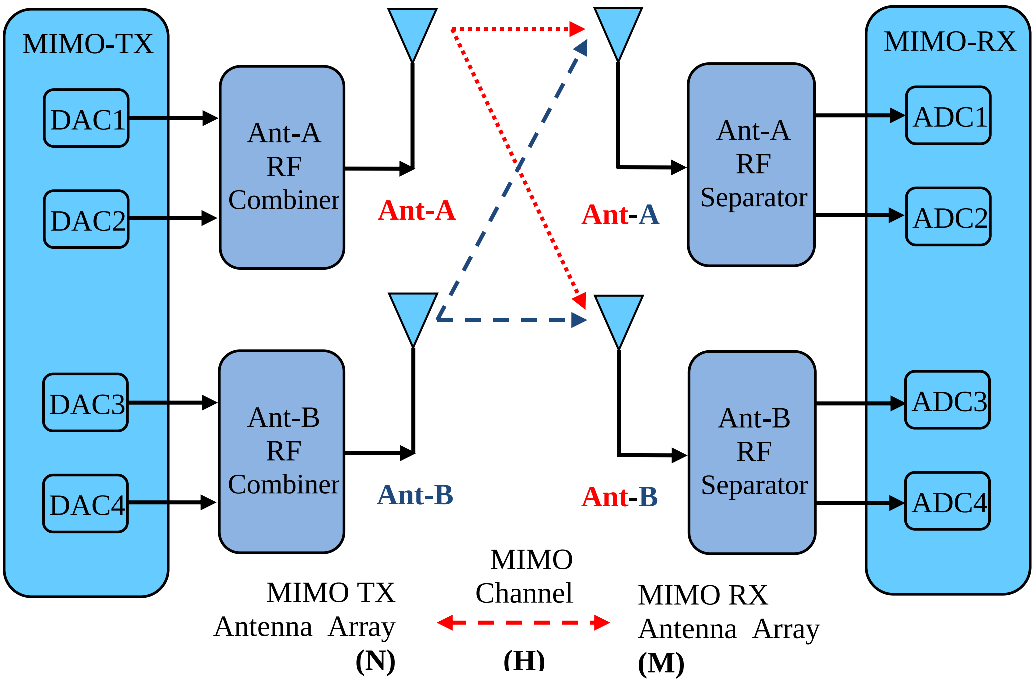

Figure 2. Conceptual 2x2 MIMO Systems

This system can be configured for SISO,MISO and MIMO communication system with OFDM modulation for IEEE 802.11a WLAN standards. The Users data to be transmit is processed by Transmitter Section for transmitting signals by TX Antennas arrays (N) in either SISO,MISO and MIMO communication mode. The radiated signals are received by the corresponding RX Antenna Array (M) through a communication channel. The communication link is established between MIMO-TX and MIMO-RX, and examine for reliability of Connections, Bit error rate, data rates etc. The SISO and MISO system is employed for examining the performance of this systems with MIMO and to investigate the advantages of MIMO over MISO and SISO. The system is classified as MIMO-OFDM-WLAN Transmitter and MIMO-OFDM-WLAN Receiver section[9].

This paper address the Design and implementation of MIMO-OFDM-WLAN Transmitter Section as follows.

3. MIMO-OFDM-WLAN Transmitter Section

The figure (3) shows the proposed block diagram of MIMO-OFDM Transmitter for IEEE 802.11a WLAN standards [5] [6]. As seen from the figure, the random data inputs are processed through various functional blocks, to prepared the signals for transmission by transmitting antennas arrays for a selected communication system. The overall operation of MIMO-OFDM-WLAN transmitter of figure (3) is as follows.

3.1 Random Bit Generator

The Data bits are generated by random data bit generator which is a logical block used to output start pulse when Transmitter starts. To check the performance of the system, the continuous data bits are required to form a data packet, so the internal random data generators is implemented. However, Instead of this block, the users data bits can also be used as a Data Input to the transmitter section.

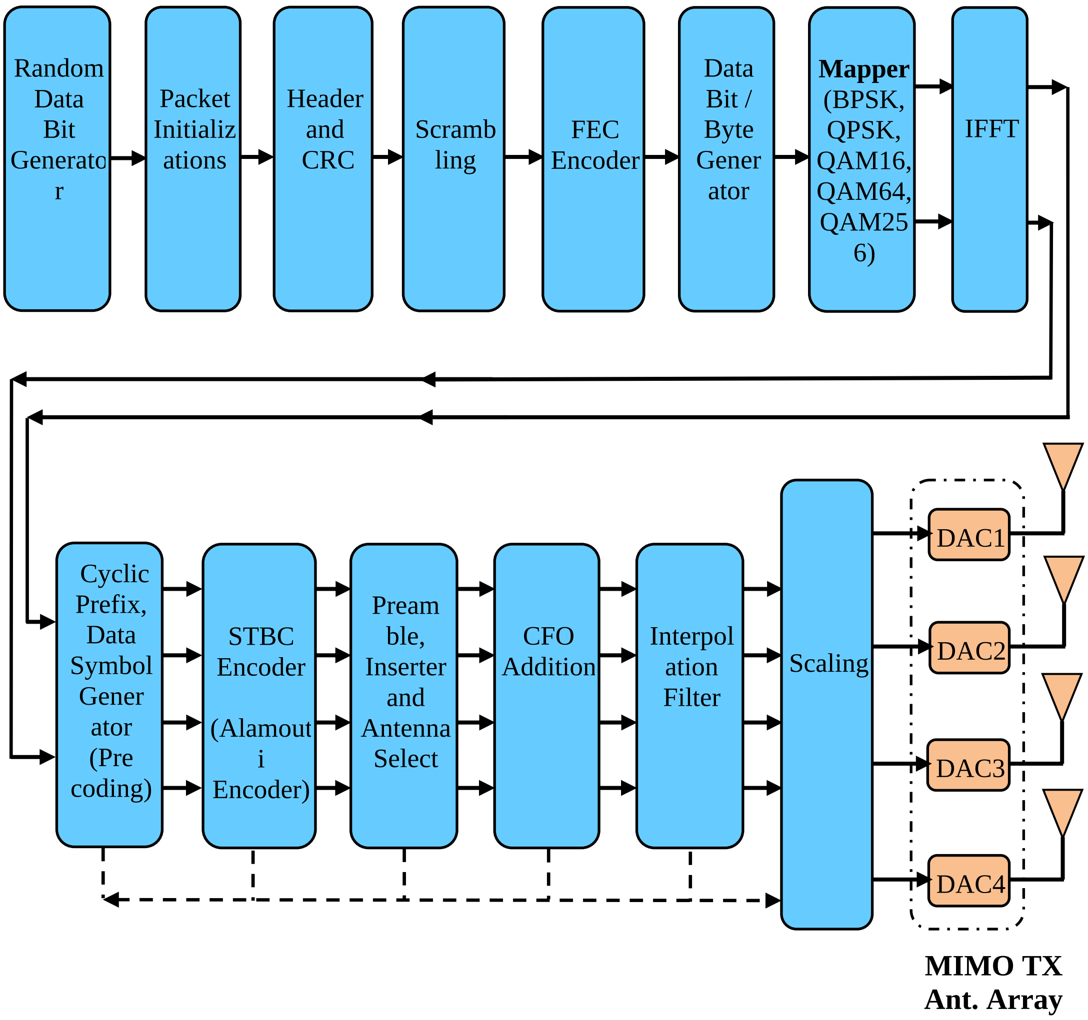

Figure 3. MIMO-OFDM-WLAN Transmitter Section

3.1 Random Bit Generator

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3.2 Packet Initializations

The data input to be transmit is framed into a Packet known as Data Packet. We have implemented OFDM Transmitter/ Receiver loosely based on IEEE 802.11a WLAN standards for SISO,MISO and MIMO communication system. The function of this block to Initialize data packet formation for a selected communication systems. The data packet consists of Preambles (long and short), Antenna Training symbols, Header, Base Rate, CRCs, Error Correcting codes, Cyclic Prefix, OFDM Data payload. The data packets are formed for SISO/MISO/MIMO modes.

Therefore, for the applied data input, data packet frame is defined for a preselected parameters and other control signals which will required for further processing blocks of the selected communication systems.

3.3 MIMO Signal Transmission Analysis

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This blocks functions for (1) Packet Header CRC (2) Scrambling (3) FEC Encoder (4) Data Bit/Byte Generator (5) Mapper.

The Packet Initialization blocks signals are applied for MIMO signal Transmission analysis to proceed the data inputs through above said blocks. This is a very important block of the Transmitter section which functions concurrently. The header contains the information of Base Rate and CRC redundant bits added in signal. The base rate carries the information of type of modulation used for OFDM Data. The users data are processed for packet header, CRC, scrambling and FEC Error correcting Encoder. The Error Correcting Codes (ECC) are added in data inputs which will help the Receiver section to correct the error in received data. The FEC of 1/2,2/3,3/4 and 1(No coding) coding rates are implemented. These data bits are mapped through a RAM to generate Data Bytes as Payload of Data Packet. This data bits are modulated by BPSK/QPSK /16QAM/64QAM/256QAM modulation schemes. This finally outputs two data signals which are being used for transmission as data inputs Data_Tx_I and Data_Tx_Q by other proceeding sections.

3.4 Inverse Fast Fourier Transformation (IFFT) Analysis

The IFFT module converts the complex frequency values into complex time values for transmission. The two data inputs Data Tx_I and Tx_Q are applied to IFFT analysis to output corresponding signals Xk_I and Xk_Q with other synchronizing control signals required for further processing elements of Transmitter sections. We have selected to used Pipelined, streaming I/O architecture as our data is continuous and this offers a high throughput.

The Xilinx fast Fourier transform 7.1 is configured for inverse fast Fourier Transform (IFFT) of Pipelined, Streaming I/O, Transform length 64, Target clock frequency 80MHz, phase factor width 24, Scaled, convergent rounding, output ordering-Bit/Digit reverse order, input data timing 3 clock cycle offset. 1 Number of stages using block RAM, Recorder buffer-Block RAM, Optimize options- used 3 multiplier structure for resource optimization, Butterfly arithmetic used CLB logic.

3.5 Data Symbols Generator

The function of this block to generate data symbols S1 and S2 with their real and imaginary parts for the applied IFFT inputs Xk_I and Xk_Q of valid IFFT Vout signal. The CPs of CP length are prefix to OFDM symbols. This stage is also known as STBC pre-coding as this stage prepared the data symbols for Alamouti Encoder. The even and odd samples of input data Xk_I and Xk_Q are separated to produce data symbols. The two complex data symbols S1 and S2 are generated as first Symbol S1: S1_I and S1_Q and second symbol S2 : S2_I and S2_Q with Packet done control signal for indicating the other blocks.

3.6 Alamouti STBC Encoder

The two complex Data symbols S1 and S2 for a selected antennas are applied for Alamouti's Space Time Block encoding [4]. MIMO uses space time coding described by an Alamouti code which is belonging to a class of Space-Time Block Codes (STBC). The Space-Time refers to coding across space & time. Coding across space by using multiple transmit and receive antennas, and across time by using multiple symbol periods. Alamouti code operates on blocks of input bits described by a code matrix which defines what is to be sent from the transmit antennas during transmission of a block. These two symbols are first directly transmitted by two transmitting antennas and then in next time these symbols are swapped and also complex conjugated [7].

3.7 Preamble Insertion and Antenna Select modes

The next step in data processing is addition of Preambles symbols to data packet which are used by the receiver for Packet detection, AGC, Carrier frequency offset estimation and symbol timing estimation. The Preamble symbols are subdivided as Short Training Symbols (STS) and Long Training Symbols (LTS). The task of this block is to generate the preambles, insert them in appropriate data signal. The preamble added Data signal output is prepared for transmission for a SISO / Alamouti MIMO Antenna select logic modes.

3.8 MIMO RF Analysis

The last stage of MIMO Transmission is preparing the packetized data prior to RF Transmission known as MIMO RF Analysis. This blocks functions for (1) CFO Addition (2) Interpolation Filter (3) Scaling (4) DACs (5) MIMO TX Antennas

The final data packet formed for a given data inputs for OFDM,WLAN and SISO/MISO/ MISO communication modes is processed for MIMO RF Analysis consist of these various blocks.

The CFO analysis plays an important role for RF transmission, to enables the receiver to recover the error-free symbols. The first block of MIMO RF analysis is CFO additions which generates separate CFOs for Antenna-A and Antenna-B inputs. The Input signals to be transmitted are slightly shifted by a small frequency offset (CFO), so as to reduce the effect of mismatch of carrier frequencies and frequency offset. Thus to recover the interference free received symbol from noisy channel. The CFO must be known to Transmitter and Reciver. So the preambles of the data packet structure of IEEE 802.11 are used by the receiver for carrier frequency offset estimation to reduce the ICI.

The CFO added data inputs of transmitting antennas are passed through interpolation filter and scaled for the RF antnnas through DACs. The output of transmitter is complex symbols which are combined in RF combiner part of Radio Board to generate single complex symbol for single transmitting antenns. In our designed we have not implemented RF Combiner and Tx antenna array section. The complex outputs of Antenna-A (as Ant_A_I and Ant_A_Q) and of Antenna-B (as Ant_B_I and Ant_B_Q) are directly used for channel estimation and correspondingly, these outputs are fed to respective two Receiving antennas of MIMO Receiver Sections.

In this way, the data input are preapared for MIMO Transmission using BPSK/QPSK/16QAM/64QAM/256QAM modulation scheme with 1/2,2/3,3/4,1 coding rates for OFDM and IEEE 802.11a WLAN system, with the facility of selceting the SISO/MISO/MIMO communication modes for the compariosion to prove that the MIMO is superior over ther two modes [8].

4. Simulation Results of MIMO-OFDM-WLAN Transmitter Section

The interpolated outputs are scaled for the given Payload, Preambles, Antennas configurations. The Digital to Analog converter block of respective input signals converts the scaled outputs into analog form. The final outputs of a MIMO transmitter for two complex symbols S1 and S2 are Ant A-I , Ant A-Q, Ant B-I and Ant B-Q. These signals are transmitted by MIMO Antenna Arrays.

The RF Part of MIMO shall include the DACs , RF Combiners, RF Power Amplifiers to drive the MIMO Ttransmitting antennas arrays of size 2 TX and 2 RX antennas for the applied four signals S1(Ant A_I,Ant A_Q) and S2(Ant B_I,Ant B_Q). Figure (4) shows the actual Transmitting signals being transmitted by the MIMO Transmitter in Alamouti MIMO modes.

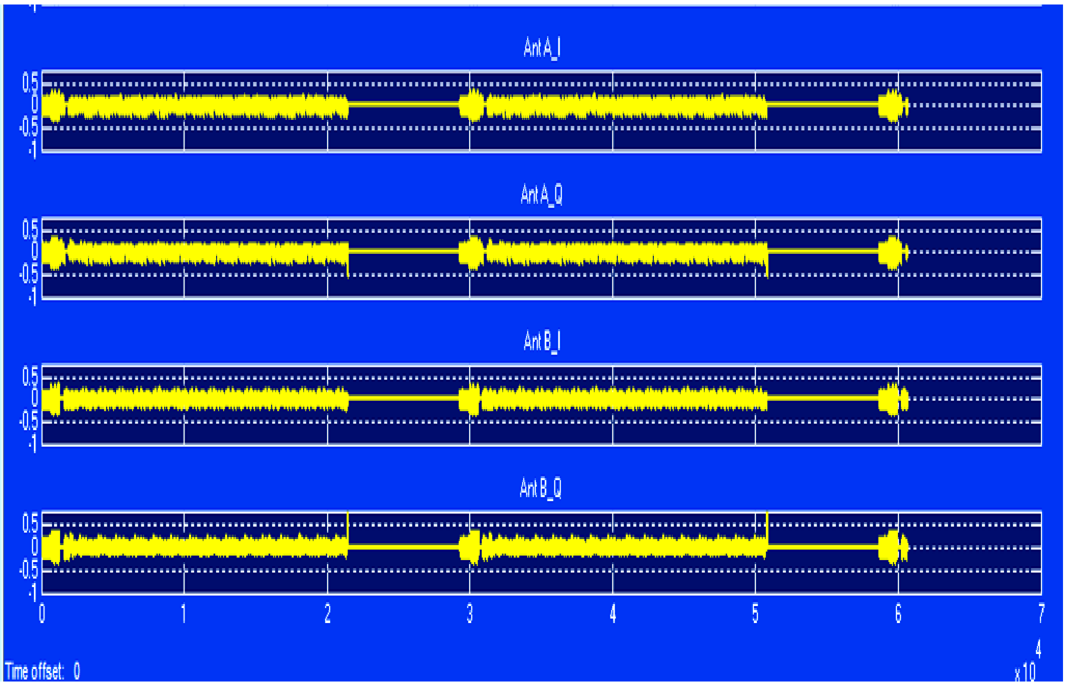

Figure 4. MIMO TX Antenna- Transmitting Signals

Thus the Outputs signals Ant A-I , Ant A-Q, Ant B-I And Ant B-Q are the actually signals going to transmitting antennas as a Transmitting Signals for a selected SISO /MISO/ MIMO modes of communication. The results shows that the input Signals S1 and S2 are being transmitted as S1(Ant A_I,Ant A_Q) and S2(Ant B_I,Ant B_Q) through MIMO Transmitting antenna array towards MIMO receiver section.

5. Performance Analysis

5.1. Bit Error Rate (BER) Analysis of MIMO Communication System

The BER plot of MIMO communication system with BPSK/QPSK/16QAM/ 64QAM/ 256QAM modulation schemes and 1/2 coding rates for 1024 OFDM WLAN is shown in figure (5).MIMO link is established for all the types of modulation schemes. However, the noise level of the system is different for different types of modulation systems, which can be reduced by appropriately adding error correcting codes and other parameters of the systems. The BPSK,QPSK,16QAM has less noise level and able to recover the transmitted signal from most noisy channel with minimum noise, but there data rates are low. The 64QAM and 256QAM able to produce higher data rates, but has more effect of the noise than lower order modulation. However, by managing the noise level of the system by other means, MIMO with 64QAM or 256QAM can be used for long distance communication with higher data rates.

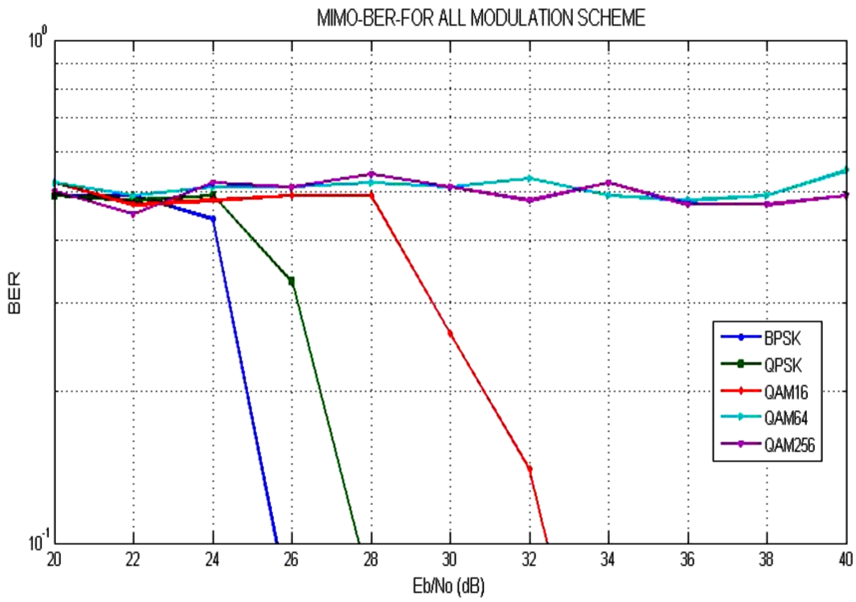

Figure 5. BER Plot for MIMO Communication System

The similar experiment of SISO and MISO system is carried out. The average BER of SISO/MISO/MIMO is 0.202/0.182/0.194 respectively which shows that the BER of MIMO is better than BER of SISO and comparable with MISO which also has its limitations.

In MIMO system, if BPSK with 2/3 CR, QPSK with 2/3 CR,16QAM with 2/3 or 1/2, 64QAM with 3/4 and 256QAM with 2/3 coding rate schemes are used, then the noise level of the system is optimized to have minimum BER value. Thus we have a robust MIMO communication link.

5.2. Data Rate of MIMO Communication System

Considering Users data modulated by 64QAM with 3/4 FEC coding transmitted over MIMO channel of 20MHz in OFDM long / Short GI produces data rate (throughput) of 108 Mbps/120 Mbps and for 40MHz channel 180 Mbps/216 Mbps respectively. The required each channel bandwidth is suppose to choose to accommodate users data. The signal bandwidth is 16.66 MHz /33.32 MHz for 20MHz/40MHz respectively. Thus 64QAM-3/4 CR-OFDM-IEEE 802.11a WLAN-MIMO communication system employing a two spatial stream (2TX and 2 Rx) able to provide data rate of 108-216 Mbps in 20-40MHz channel bandwidth.

5.3. Spectral Efficiency of MIMO Communication System

The Spectral efficiency of 8 bits/s/Hz for 20MHz channel bandwidth and 7.2 bits/s/Hz for 40MHz channel bandwidth.

The maximum spectral efficiency for maximum data rates of SISO and MIMO system for different modulation schemes and coding rates are tabulated. The spectral efficiency of 256QAM SISO for 20MHz / 40MHz is 4 / 3.6 bits/s/Hz, whereas the same in MIMO is 8 / 7.2 bits/s/Hz respectively.

The maximum achievable Spectral efficiency for SISO is 4 bits/s/Hz and for MIMO is 8 bits/s/Hz in 20MHz channel bandwidth. Therefore the lower channel bandwidth (20MHz) has higher spectral efficiency and higher channel bandwidth (40MHz) has lower spectral efficiency. However, the data rates are higher for higher bandwidth and vice-versa.

Thus the Spectral efficiency of MIMO is double of SISO for 20MHz / 40MHz channel bandwidth. Hence MIMO shall be preferred over SISO communication systems.

5.4. FPGA Resource utilization

The FPGAs Resources utilization for single chip is optimized to 28.18% on target device. Therefore, the target device can have three chips of a system designed. The 24 users can be multiplexed on a single chip. Therefore, the target device can be used to provide the services to 72 users.

6. Conclusion

The users data modulated by BPSK modulation with 2/3 FEC coding, QPSK modulation with 2/3 FEC coding, 16QAM modulation with 2/3 FEC coding, 64QAM modulation with 3/4 FEC coding and 256QAM modulation with 2/3 FEC coding schemes as a first choice, transmitted by this MIMO-OFDM-WLAN transmitter sections, produces the received signal almost same as the transmitted signals with negligible noise. Observed the robust communication link between transmitter and Receiver.

As MIMO systems employs multipath channel, So MIMO is better than MISO and SISO communication systems. However, the performance of system SISO/MISO limited by channel conditions. The MIMO system performs better than MISO as well as SISO for a long distance LOS communication link. The system is compatible with input signal of any type of modulation scheme with different coding rates. The Data rates and Spectral Efficiency of MIMO system is almost doubles of SISO system. So MIMO communication link is most robust than SISO.

The Communication System designed is a universal system can be configured for SISO,MIMO and MIMO transmission modes of communication included with OFDM and IEEE 802.11a WLAN standards. The MIMO transmitter section offers most robust communication link.

Thus MIMO is future communication system that overcomes the limitation of traditional SISO system and proves better than MISO communication mode. The signals are transmitted and received even in a failure of some of channels.

Therefore, this is a Compatible MIMO Transmission system with OFDM and IEEE 802.11a WLAN standards suitable to provide the service to Real field users.

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