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Implementation of MIMO-OFDM System using ML decoder

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***Abstract*— The traffic in wireless networks has been showing an exponential growth over the last decade. In order to meet the demand, and support a continuation of this growth, bandwidth efficient, high data rate and multipath fading free communication system is required. Orthogonal frequency division multiplexing (OFDM) system with multiple input multiple output (MIMO) configuration fulfils the above demands. In the process of generation of MIMO-OFDM signal, binary data is passed through a turbo encoder and the output of the turbo encoder is modulated using Quadrature Amplitude Modulation (QAM). The QAM output is passed through Inverse Fast Fourier Transform (IFFT) to produce OFDM signal and this signal is transmitted using Space Time Block Codes (STBC) for MIMO implementation. In this project, the MIMO-OFDM signal is detected by using maximum likelihood (ML) method in which Viterbi Algorithm is used. This project presents how the OFDM signal is generated at the transmitter and detected at the receiver using ML method. Results are simulated using MATLAB software.**

Keywords—MIMO-OFDM,Maximum-likelihood reciver,PAPR

I. INTRODUCTION

Communication is the process of transferring information from one place to another. The information may need to travel hundreds or thousands of miles via channel to reach the destination.

A great change in communication systems was observed with introduction of wireless communications. Wireless communication was initially implemented in analog domain and now it is in both analog and digital. This can be implemented using both single and multiple carriers. In single carrier systems desired signal is transmitted using single carrier, whereas in multicarrier systems desired signal is split into narrowband signals and each signal is modulated with different carriers. Multicarrier systems are less affected by inter-symbol interference and multipath fading and preferable in high data rate systems. Orthogonal Frequency Division Multiplexing (OFDM) is one of the multicarrier systems.

In the present scenario (4G), demand emerges for high-speed, high-quality digital mobile portable reception and transmission. Multiple-input multiple-output orthogonal frequency division multiplexing (MIMO-OFDM) technology is one of the most attractive candidates for fourth generation (4G) mobile radio communication. It effectively combats the multipath fading and improves the bandwidth efficiency. At the same time, it also increases system capacity so as to provide a reliable transmission.

It is expected that the next generation wireless cellular systems provide users with rapid access to high quality multimedia applications to support high speed packet data services. To obtain this, MIMO technologies are considered extensively to improve spectral efficiency which provides better capacity with the increase in number of antennas without any increase of bandwidth or transmit power[1][2].

As OFDM is capable to transmit high quality signal even in the multipath fading channel, it is the most popular technique in wireless communication systems. But OFDM systems suffer from Inter-Carrier Interference (ICI) and High Peak to Average Power Ratio (PAPR). The reasons for ICI are frequency and phase offsets, Doppler shift etc., and causes loss in orthogonality between subcarriers. Amplitude fluctuations occur due to coherent addition of subcarriers, and lead to increase in Peak to Average Power Ratio (PAPR). High PAPR demands large dynamic range for ADC and DAC, degrades power amplifier efficiency, causes in-band distortion, out of band radiation due to clipping and spectral broadening respectively. Several techniques have been proposed for reduction of PAPR. PAPR can be reduced either by decreasing the peak power (clipping, partial transmit sequence, selective level mapping etc.,) or increasing the average power (Tone injection, Tone reservation etc.,). In this work SLM is considered as it reduces PAPR significantly without loss of any information.

The integration of MIMO and OFDM techniques provides a preferred solution for the high rate wireless technologies because of its high spectral efficiency, robustness to frequency selective fading, increased diversity gain and enhanced system capacity.

Maximum Likelihood (ML) and Maximum A Posteriori (MAP) decoders are the most preferable decoders for the detection of OFDM signal at the receiver. In this work ML is considered because it provides the optimum MIMO detection performance [3]. Viterbi algorithm uses Maximum Likelihood principle for detection in two ways 1) Hard Decision Viterbi Algorithm (HDVA) or Conventional Viterbi Algorithm and 2) Soft Output Viterbi Algorithm (SOVA) which uses reliability values for detection.

II. BLOCK DIAGRAM

This block diagram shows the entire implementation of the MIMO-OFDM system and also says the working of the transmission part and receiving part. It mainly consists of turbo encoder and decoder, slm and sldm, fft and ifft, and serial to parallel converter, two receivers and two transmitter Antennas.

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Transmitter:

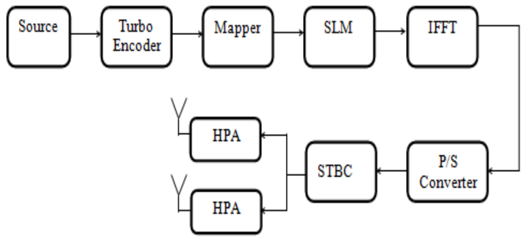

Fig: Proposed MIMO OFDM transmitter

Receiver:

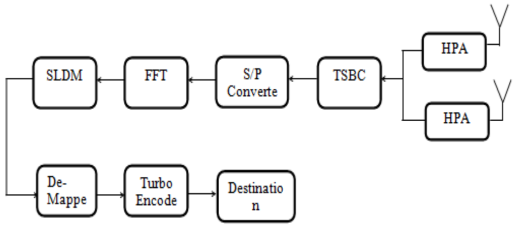

Fig: Proposed MIMO OFDM receiver

III. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING(OFDM)

Orthogonal frequency division multiplexing (OFDM) is a form of Multicarrier modulation technique in which high data stream is split into lower data streams and each stream is transmitted through a different carrier signals and all sub-carrier are orthogonal to each other. Figure shows the block diagram of multi carrier modulation.

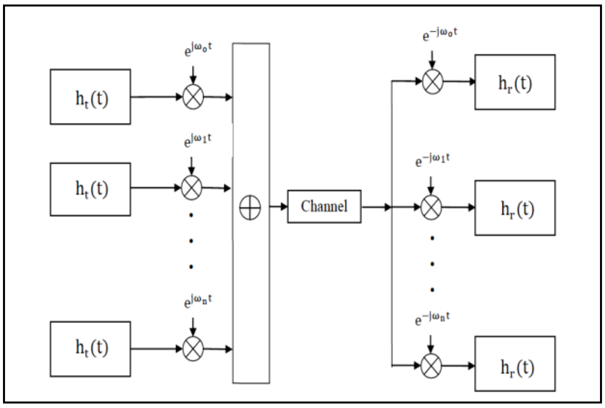

Fig: Block Diagram of Multi carrier modulation system

A. Basic block diagram of OFDM system

The basic principle of OFDM is to split a high rate data stream into lower rate data streams that are transmitted simultaneously over a number of orthogonal subcarriers. Because the symbol duration increases for lower rate parallel subcarriers, the relative amount of dispersion in time caused by multipath delay spread is decreased. Inter symbol interference is eliminated almost completely by introducing a guard time in every OFDM symbol. In guard time the symbol is cyclically extended to avoid Inter-Carrier Interference (ICI).

Basic block diagram of OFDM system is shown in figure

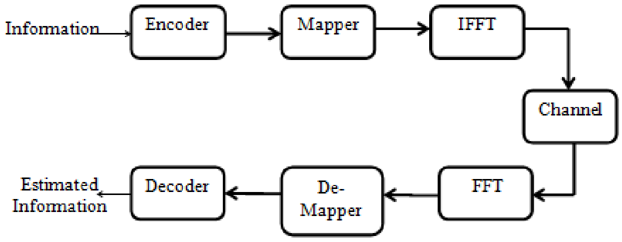

Fig: OFDM System

B. Inter–Symbol Interference (ISI)

Inter-symbol interference (ISI) is a form of distortion of a signal in which one symbol interferes with subsequent symbols. This is an unwanted phenomenon as the previous symbols have similar effect as noise, thus making the communication less reliable. ISI is usually caused by multipath propagation or the inherent non-linear frequency response of a channel causing successive symbols to 'blur' together. The presence of ISI in the system introduces error in the decision device at the receiver output. Therefore, in the design of the transmitting and receiving filters, the objective is to minimize the effects of ISI and thereby deliver the digital data to its destination with the smallest error rate possible.

C. Inter – Carrier Interference (ICI)

Presence of Doppler shifts, frequency and phase offsets in an OFDM system causes loss in orthogonality of the sub-carriers. As a result, interference is observed between sub-carriers. This phenomenon is known as inter-carrier interference (ICI).

D. Quadrature Amplitude Modulation (QAM)

Potential bit rate can be improved by combining both Amplitude Shift Keying (ASK) and Phase Shift Keying (PSK). Ability of equipment to distinguish small differences in phase limits the potential bit rate. This combined modulation technique is known as Quadrature Amplitude Modulation (QAM). It is possible to obtain higher data rate using QAM. It may be noted that M-ary QAM does not have constant energy per symbol, nor does it have constant distance between possible symbol values. Fig 3.5 shows the constellation diagram for 16QAM signal.

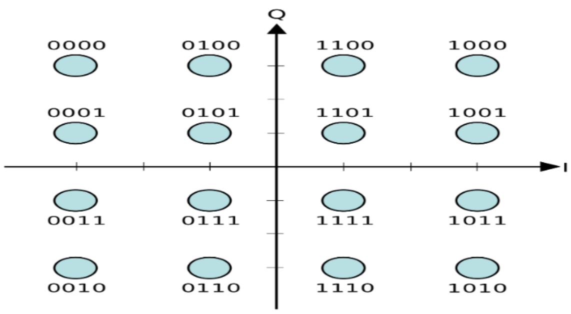

Fig. Constellation diagram for 16QAM

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Constellation diagram provides a graphical representation of the complex envelope of each possible symbol state. The X-axis of the constellation diagram represents the in-phase component of the complex envelope, and the Y-axis represents the quadrature component of the complex envelope. The distance between the signals on a constellation diagram indicates how different the modulation waveforms are, and how well a receiver can differentiate between all possible symbols in the presence of noise.

IV. MULTIPLE INPUT MULTIPLE OUTPUT (MIMO)

The simplest form of MIMO configuration is SISO which is effectively a standard radio channel in which transmitter functions with single antenna so does the receiver. In this there is no need for diversity or additional processing. However interference and fading will influence the system and so is limited in its performance.

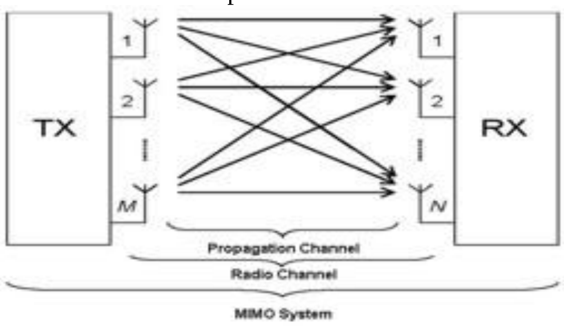

Fig: MIMO system

A. *Equations*

T A narrow band flat fading system with MIMO configuration can be modeled as

$$Y = HX + n$$

Where Y and X are the receive and transmit vector H and n are the channel matrix and the noise vector respectively.

Referring to information theory, the ergodic channel capacity of MIMO systems where perfect instantaneous channel state information is known of both the transmitter and receiver.

$$C_{perfect\_CSI} = E[\max_{Q;t_r(Q)\leq 1} log_2 \det(I + \rho HQH^H)]$$

$$= E[log_2 \det(I + \rho DSD)](4$$

Where $( )^H$ denotes Hermitian transpose, is the transmit SNR ie., ratio of transmit power to noise power. The optimal signal covariance $Q=VSV^H$ is obtained by singular value decomposition of H. $UDV^H=H$ and an optimal diagonal power allocation matrix

$S= diag(s_1, s_2, \ldots, s_{min}(N_t, N_r), 0, \ldots, 0)$

If only the statistical channel state information at the transmitter is known, then the ergodic channel capacity will decrease as Q can only be optimized in terms of average mutual information as

$$C_{statistical\_CSI} = \max_Q E[log_2 \det(I + \rho HQH^H)]$$

If there is no information about CSI at the transmitter to maximize channel capacity under worst case statistics the signal covariance Q as $Q=1/N_t$ and is selected accordingly

$$C_{no\_CSI} = E\left[log_2 \det\left(I + \frac{\rho}{N_t} HH^H\right)\right]$$

V. DETECTION USING VITERBI ALGORITHM

Viterbi decoders are used to decode convolution coding, which has been used in deep space communications as well as wireless communications. The Viterbi algorithm is to find a maximum likelihood sequence of state transitions, consistently a path, in a trellis by assigning a transition metric to possible state transitions.

A. *RSC Encoder*

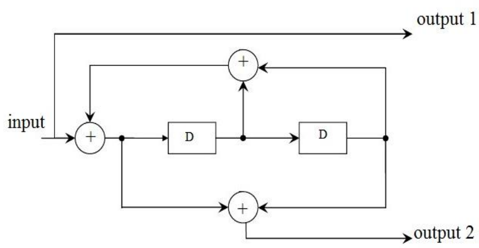

Fig: RSC Encoder

B. *Viterbi Algorithm*

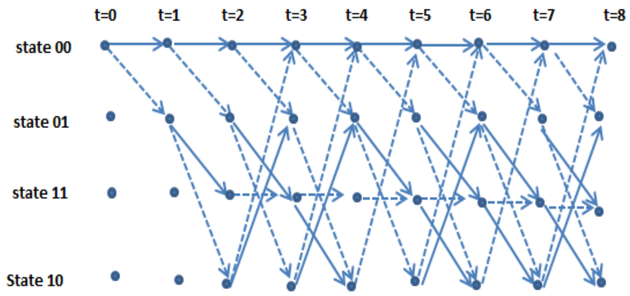

Fig: Trellis diagram for RSC encoder

The four possible states of the encoder are depicted as four rows of horizontal dots. There is one column of four dots for the initial state of the encoder and one for each time instant during the message. The solid lines connecting dots in the diagram represent state transitions when the input bit is a zero. The dotted lines represent state transitions when the input the input bit is a one. There is a correspondence between the arrows in the trellis diagram and finite state machine discussed above.

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VI. SIMULATION RESULTS

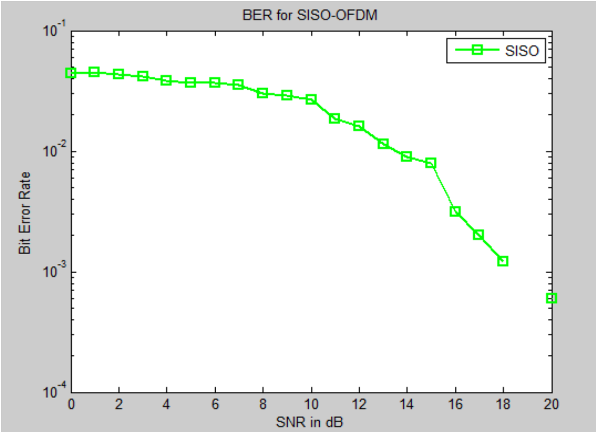

Fig: SISO OFDM

The above figure represents bit error rate comparison between SISO OFDM for 256 carriers. From the figure, it is concluded that BER performance for SISO OFDM is better.

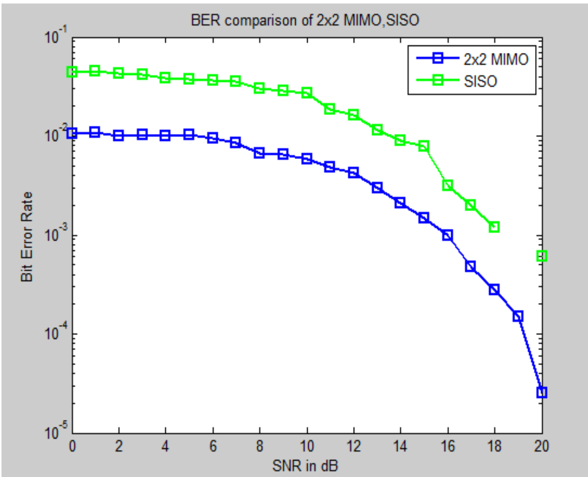

Fig: Comparison of MIMO and SISO OFDM

The above figure represents bit error rate comparison between SISO and MIMO OFDM for 256 carriers. From the figure, it is concluded that BER performance for MIMO OFDM is better.

Here in this MIMO OFDM, 2X2 MIMO configuration is used in which data is transmitted through two transmitting antennas at transmitter and received data through two receiving antennas at receiver.

With SLM the threshold power required at the power amplifier is reduced. It improves the power amplifier efficiency. This improvement in the power amplifier efficiency reduces signal clipping and spectral broadening.

This improves the BER performance. Hence OFDM with SLM gives better BER performance over OFDM without SLM.

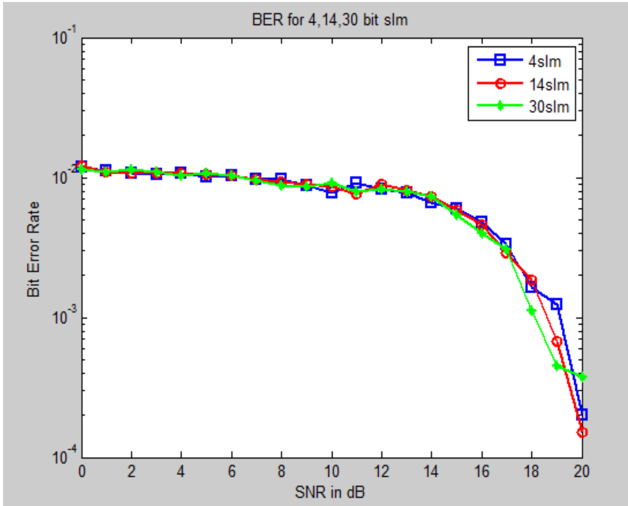

Fig: MIMO using 4, 14, 30 SLM techniques

Using different SLM techniques like 4 slm, 14 slm, and 30slm.

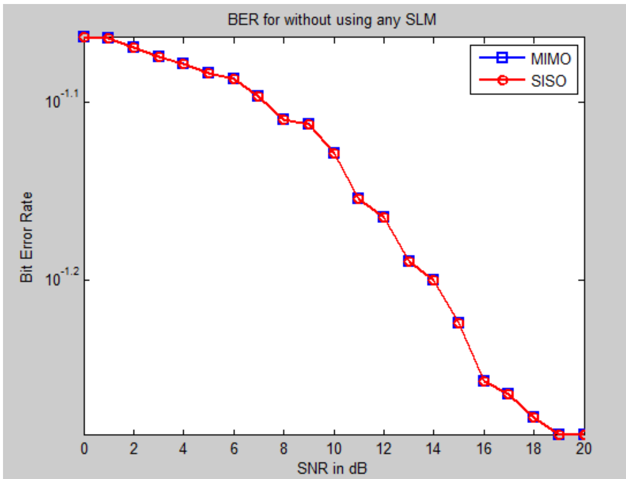

Fig: Without using SLM techniques

Without using any SLM techniques the observed output for the SISO and MIMO OFDM system and in this the input which is sent without any blocks between the transmitter and receiver.

VII. CONCLUSIONS

In this paper we proposed an algorithm for the MIMO-OFDM with ML decoder. In the process of generation of MIMO-OFDM signal, binary data is passed through a turbo encoder and the output of the turbo encoder is modulated using Quadrature Amplitude Modulation (QAM) and this signal is decoded by using maximum likelihood (ML) method in which Viterbi Algorithm. Results are simulated by using the MATLAB software.

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