ENERGY EFFICIENT SYSTEM USING MIMO-OFDM

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Abstract— Energy efficient wireless system is now days is a keen area of Interest for the researchers and scientist in the field of digital communication which is highly depends upon the coding system, bit-error-rate, coding system, power of transmission, signal quality etc. In this paper we demonstrate a method by using Alamouti Codes for OFDM system with Linear MMSE detection techniques. The orthogonal principle introduced in OFDM helps to avoid Inter Symbol Interference while Alamouti provides signal security with reducing errors especially at high Sound to Noise ratio regime. We have introduced White Gaussian Noise to check the effect on our designed system ,also channels assumed to be with low-correlation coefficient among the channels. In this paper we have used 2×2 MIMO architecture with low correlation coefficient to study the effect of high SNR on energy efficiency i.e. consumption level of energy per bit at high SNR.

Index Terms— Alamouti Codes, BER, CSI, Energy Efficiency, MIMO, OFDM.

INTRODUCTION

The demand of high-speed communication has become prominent in last decade, which leads the wireless communication to next level i.e.4G/5G.The main concern of the scientists and researchers is to fulfill the expectation regarding high-speed data transfer, min. BER, less energy consumption etc. or in the other way we can say that a good communication system depends upon basically on two factors i.e. Spectrum efficiency and Energy Efficiency.

Spectrum efficiency means that how efficiently a spectrum or bandwidth should be distributed among the users simultaneously so that there should be minimum interference and the system should not get overloaded at any time instant.

On the other hand Energy Efficiency means that the system should consume minimum energy as far as possible in transferring the data or bits .Continuous investigation is going to reduce the energy consumption as in [1] by applying different architectures for wireless communication.

In this paper we have design an architecture using MIMO-OFDM (Multi Input Multi Output-Orthogonal Frequency Division Multiplexing) with Alamouti codes to improve the Bit Error Rate (BER) and hence it will result in improving energy efficiency. The energy efficiency is expressed as in [2] which is as follows

$$\eta_{ee} = \frac{B\log_2\left(1+\frac{P}{BNo}\right)}{P} \qquad (1)$$

Here P means transmitter power, B means

Band -Width of the system and No is the White Gaussian Noise power.

II. SYSTEM MODEL

In the designing of aforesaid architecture we have to take some system parameters mentioned in TABLE I, these parameters are in accordance with [3] which will be helpful to compare the results, also the symbol rate R_s can be related to data rate as $R_d = \log2(N)\, R_s$. Where N denotes the order of modulation for ex:- in 16-QAM , N=16 .

Then after deciding system parameters there are other two important factors i.e. XPD(cross-polar discrimination) & CPR(co-polarization ratio) which will be helpful in designing the channel coefficient matrices, as in [4] for co-located antennas the XPD and XPR are numerically equal with XPD lower than XPI, now the angle of polarization for reception is assumed to be $\pm 45^0$which is mentioned as in [5].In this paper we are applying physical-statistical models mentioned as in [6] which assume to neglect the errors by using empirical approach.MIMO architecture consists of multiple antennas at transmitter side as well as at receiver side. Hence there exist several channels according to the configuration of the antennas i.e. for 2×2 MIMO there would exist 4 channels. MIMO channels can be represented as in [7]

$$Y = Hx + W \qquad (2)$$

Where Y is $N_r \times 1$ matrix known as received symbol matrix after transmission, x is $N_t \times 1$ matrix known as transmitted symbol matrix , H is $N_r \times N_t$matrix known as channel coefficient matrix, W is $N_t \times 1$ matrix known as noise matrix.Alamouti Codes comes under the classes of Orthogonal Space Time Block Codes (OSTBC) which are very efficient for 2×1 MISO system and 2×2 MIMO system. The main advantage of Alamouti code is that it does not require CSI (Channel State Information) at transmitter side.

Due to the use of Alamouti Codes the equation (2) can be written as follows

$$Y'' = \begin{pmatrix} h11 & h12 \\ h21 & h22 \\ h12^* & -h11^* \\ h22^* & -h21^* \end{pmatrix} \begin{pmatrix} x1 \\ x2 \end{pmatrix} + \begin{pmatrix} w1 \\ w2 \\ w1^* \\ w2^* \end{pmatrix} \quad (3)$$

here x1 and x2 are two transmitted symbols, w1, w2, represents the AWGN noise components with w1*,w2* are the complex conjugate of w1 and w2 respectively.

The derivation of (3) is mentioned in Appendix A. OFDM *Block*is known as Orthogonal Frequency Division Multiplexing which is especially used in *LTE system*. It performs as a modulator as well as a multiplexer also. In OFDM each signal is transmitted over a different carrier frequency and each carrier frequency is orthogonal to each other such that the dot product of any two signals is zero. However still the problem of ISI(Inter-Symbol-Interference) persist in OFDM to remove this problem we use OFDM with CP(Cyclic Prefix)[8] , although due to CP the length of OFDM symbol increases and hence symbol duration increases but still it has advantage of time and frequency acquisition in wireless communication. In this section we design a model using MIMO-OFDM with Alamouti Codes, the basic idea behind using the Alamouti code at transmitter side is that it is an orthogonal code and hence it is compatible with OFDM, secondly it does not require CSIat transmitter side.

In this paper we have use 16-QAM (Quadrature Amplitude Modulation) as a modulation part in OFDM, at transmitter side 16-QAM is then converted into orthogonal signals using IFFT(Inverse Fast Fourier Transform) , after IFFT the CP is added which results in avoiding the ISI at transmitter, then the resultant signal together with CP is transmitted serially by using Alamouti code .

At the receiver side in detection stage we use linear MMSE (Minimum Mean Square Error) method to detect the symbol generated by OFDM and transmitted using Alamouti Codes, after this serially received symbols are parallel converted and an FFT (Fast Fourier Transform) process is done at receiver side after this demodulation using 16-QAM demodulation is done and the signals are correctly decoded.

At high Sound to Noise Ratio (SNR) regime the MMSE approaches ZF, mentioned as in [9] hence the detection equation will be as follows

$$x_{mmse} = \left[H^H H + I/SNR \right]^{-1} HY \quad (4)$$

Where ,x_{mmse}represent the correct detection of symbols.x1 and x2 which are transmitted using Alamouti Codes, H^H represent Hermitian of Channel Matrix.

III. SIMULATION AND RESULT

The Energy Efficiency depends on various factors and hence it's expression changes from model to model.

As per [1] the energy efficiency means that the system should consume min. energy as much as possible in transferring the bits , the smaller the value the more energy efficient the system is and it is given by

$$\eta_{ee} = \frac{P_t T_t}{N_{good}} \quad (5)$$

Where P_t represent total power transmitted, T_t represent total transmission time, N_{good} represent total no. of successfully received bits.

Here in this paper the formula mentioned in equation (5) is modified as follows

$$\eta_{ee} = \frac{P_t T_t}{(1-BER) * Notb} \quad (6)$$

Where P_t represent total power transmitted, T_t represent total transmission time, BER represent Bit Error Rate, $Notb$ represent no. of bits transmitted.

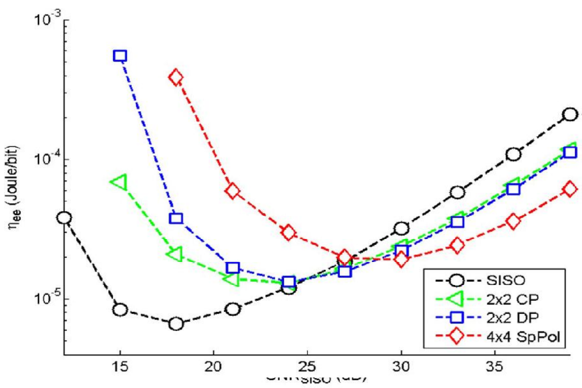

Figure 1:Energy Efficiency using Packet Erasure Method.

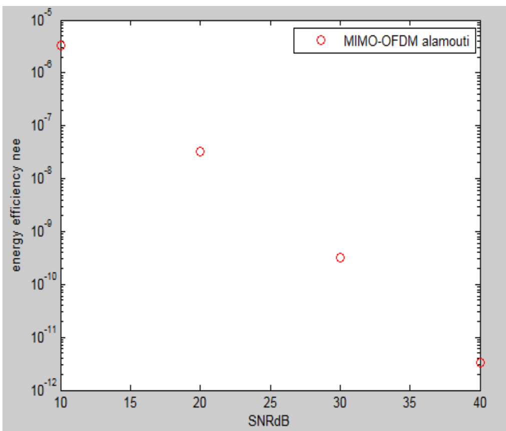

Figure 2:Energy Efficiency using MIMO-OFDM with Alamouti

Table.1: SYSTEM PARAMETERS FORSIMULATION

Parameters	Value
Carrier frequency ,f_c	400 MHz
FFT-point	1024
Bandwidth BW	10 MHz
Useful symbol duration	22.472µs
Modulation	16-QAM
White Noise, N_o	-174dBm/Hz
Signal detection	Linear MMSE
Power of transmission P_t	5000 mW
Symbol rate R_s	1 million/sec

The results of Fig.(1) is based upon packet erasure scheme which is mentioned in [1] applied to different configuration like Single Input Single Output(SISO),2×2 MIMO,4×4 MIMO we can compare this result from Fig.(2) which is the output of our proposed model which clearly specifies that this new approach of MIMO-OFDM with alamouti codes makes the system to consume less energy especially at high SNR regime or in other words this approach is more energy efficient at high SNR.

CONCLUSION

Although in this paper the system becomes more energy efficient by using Alamouti with OFDM and also the BER decreases by using 16-QAM as a part of modulator in OFDM. This paper also shows the 2×2 MIMO gives better result than 4×4 MIMO, but still there are lot of work in future because as configuration of MIMO increases from 2×2 to 4×4, 8e×8 the designing of alamouti codes becomes cumbersome and hence it will lead further exploration in future work to make system less complicate and more energy efficient or in other words a trade-off between complexity and energy efficiency is to be done.

APPENDIX A

The steps for calculation 2×2 Alamouti Codes is as follows: Let at 1st time instant x1 and x2 be transmitted symbol from Transmitter1(Tx1) and Transmiter2(Tx2) respectively, then the channel equation according to (2) will be

$$Y1= \begin{pmatrix} h11 & h12 \\ h21 & h22 \end{pmatrix} \begin{pmatrix} x1 \\ x2 \end{pmatrix} + \begin{pmatrix} w1 \\ w2 \end{pmatrix} \quad (7)$$

Or this can be written in expanded form as

Y1(1)= h11x1+h12x2 + w1 (8)

Y2(1)= h21x1+h22x2 + w2 (9)

Where Y1(1) & Y2(1) represent received symbol at 1st a time instant at Receiver1(Rx1) and Receiver2(Rx2) respectively.

Y1 represents total received symbol matrix of 2×1 dimension at time instant 1st.

Again at 2nd time instant –x2* and x1* be transmitted symbol from Transmitter1(Tx1) and Transmiter2(Tx2) respectively ,then the channel equation according to (2) will be

$$Y2= \begin{pmatrix} h11 & h12 \\ h21 & h22 \end{pmatrix} \begin{pmatrix} -x2^* \\ x1^* \end{pmatrix} + \begin{pmatrix} w1 \\ w2 \end{pmatrix} \quad (10)$$

Where x2* and x1* are the complex conjugate of x2 and x1 respectively . In the expanded form the above matrix can be written as

Y1(2) = -h11x2* + h12 x1* + w1 (11)

Y2(2) = -h21x2* + h22 x1* + w2 (12)

Where Y1(2) & Y2(2) are the received symbol at Rx1 and Rx2 respectively at time instant 2nd. Y2 represents total received symbol matrix of 2×1 dimension at time instant 2nd

Taking complex conjugate of equation (11) & (12) We have,

Y1(2)* = h21*x1- h11*x2 + w1* (13)

Y2(2)* = h22*x1- h21*x2 + w2* (14)

Now rearranging equation (13)& (14) in matrix form we have,

$$Y2^*= \begin{pmatrix} h12^* & -h11^* \\ h22^* & -h21^* \end{pmatrix} \begin{pmatrix} x1 \\ x2 \end{pmatrix} + \begin{pmatrix} w1^* \\ w2^* \end{pmatrix} \quad (15)$$

on combining equation (7) &(15) we have

$$Y'' = \begin{pmatrix} Y1 \\ Y2^* \end{pmatrix} = \begin{pmatrix} h11 & h12 \\ h21 & h22 \\ h12^* & -h11^* \\ h22^* & -h21^* \end{pmatrix} \begin{pmatrix} x1 \\ x2 \end{pmatrix} + \begin{pmatrix} w1 \\ w2 \\ w1^* \\ w2^* \end{pmatrix}$$

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