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European Journal of Advances in Engineering and Technology, 2014, 1(1): 54-60

Research Article ISSN: 2394 - 658X

MIMO-OFDM in Rayleigh Fading Channel with LDPC

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ABSTRACT

This research paper investigates the Ergodic capacity of MIMO-OFDM system in Rayleigh Fading Channel to increase the Ergodic Capacity of the system. Orthogonal Frequency Division Multiplexing (OFDM) is multicarrier modulation technique for transmission of signals over wireless channel. OFDM, using multiple sub carriers divides the available spectrum into number of sub orthogonal sub channels. Multiple input multiple outputs (MIMO) using multiple transmitting and receiving antennas for high data rate transmission with limited bandwidth are used. OFDM is combined with MIMO to increases the capacity of the system. MIMO-OFDM is popular technique for high data transmission because of usages of multiple carriers. One of the challenging problems of OFDM is Peak to Average Power Ratio (PAPR). In this it has been attempted to minimize the value of PAPR so that Ergodic Capacity of the system increases. For Reducing the value of PAPR we have used Coding Technique Low Density Parity Check Coding (LDPC).Further analysis by using 64 QAM with LDPC, using this Quardature Amplitude Modulation Spectral Efficiency increases. For investigating the systems performance Matlab has been used, mostly focusing on four Parameters Ergodic capacities, Signal to Noise Ratio, Bit Error Rate, Number of Transmitting Antennas. This will allow future wireless system to have high data rates. By reducing the number of guard bands the spectral efficiency can be increased in future.

Key words: MIMO, OFDM, LDPC, General Block Interleave, Bernoulli Random Binary Generator, Convolution Block, 64 QAM, SNR, BER and Rayleigh channel

INTRODUCTION

Orthogonal Frequency division Multiplexing (OFDM) technique with Multiple Input Multiple Output (MIMO) systems has been an area of interesting and challenging research in the field of broadband wireless communication. Multiple input multiple output (MIMO) system using multiple transmit and receive antennas are widely recognized as the vital breakthrough that will allow future wireless systems to get more data rates with limited bandwidth and power resources[1]. The multiple antennas have been used to increase diversity to combat channel fading. Hence, A MIMO system can give two types of gains: spatial multiplexing or capacity gain and diversity gain. The advantage of MIMO diversity to overcome the fading then it is needed to send the same signals through the different MIMO antennas. To use MIMO concept for increasing capacity different set of data is sent at the same time through the different antennas without the automatic-repeat request of the transmission [3]. The advantages of OFDM make it a good scheme for high-speed transmission links. One major difficulty is OFDM's high Peak to Average Power Ratio (PAPR). When N signals are combining with the same phase; they produce a peak power that is N times the average power. These higher peaks cause saturation in the power amplifiers; leading to inter modulation products among the subcarrier and disturbing out of band energy. It becomes worth while reducing PAPR towards this end there are many proposals such as clipping, coding and peak windowing. Reduction of PAPR comes at a price of performance degradation; mainly in terms of rate and BER. This paper finds to use the LDPC codes as powerful coding techniques for IEEE 802.11 x OFDM standards which are combined with PAPR scheme [6]. LDPC codes can be out a better solution first to overcome the disadvantage of OFDM modulations and second to keep a robustness regarding the BER performances. Low density parity check (LDPC) codes were developed by Robert Gallager. LDPC codes are set to be used as a standard in Digital Video Broadcasting (DVB-S2) and 4G mobile communications. The other advantage of LDPC codes is that they are highly parallelizable in hardware. Their minimum distance (dmin) increases proportionally with an increase in the block length. Therefore in addition to using channel coding for better error performance, the technique used for modulating the coded signal is also very important as it transforms the signal waveforms and enables them to better withstand channel distortions. The great numbers of QAM modulation techniques are currently in use out of which 64 QAM are known to be the best. As stated above; channel coding ads redundancy to the uuencoded signal and thus increases the bandwidth in the process. Therefore a modulation technique is needed which is spectrally efficient and also has good error performance. And much research has been done on the concatenation of LDPC codes with 64 QAM modulation techniques. Also; the earlier studies reveal that uuencoded signal has error in the performance of system. It needs to be established is 64 QAM with channel coding, specifically LDPC codes to remove error from the signal.

SYSTEM MODEL

In this section, this paper describes communication system model. The system model used is shown in Fig.1.The data to be send over the channel was randomly generated and was in the encoded form. This information is coded by using LDPC codes. After the coded information sequence has been obtained; it is applied to digital modulator which may 64 QAM modulation techniques. This modulated carrier is transmitted over the Rayleigh fading channel in the presence of AWGN (Additive White Gaussian Noise). The received information is passed through demodulator and LDPC decoder where the errors are detected and corrected. After that analyse that how much BER reduces by using LDPC encoder with various modulation techniques. If BER reduces then our performance is good and result is better than the previous result. The number of blocks used in the model has been described in detail below.

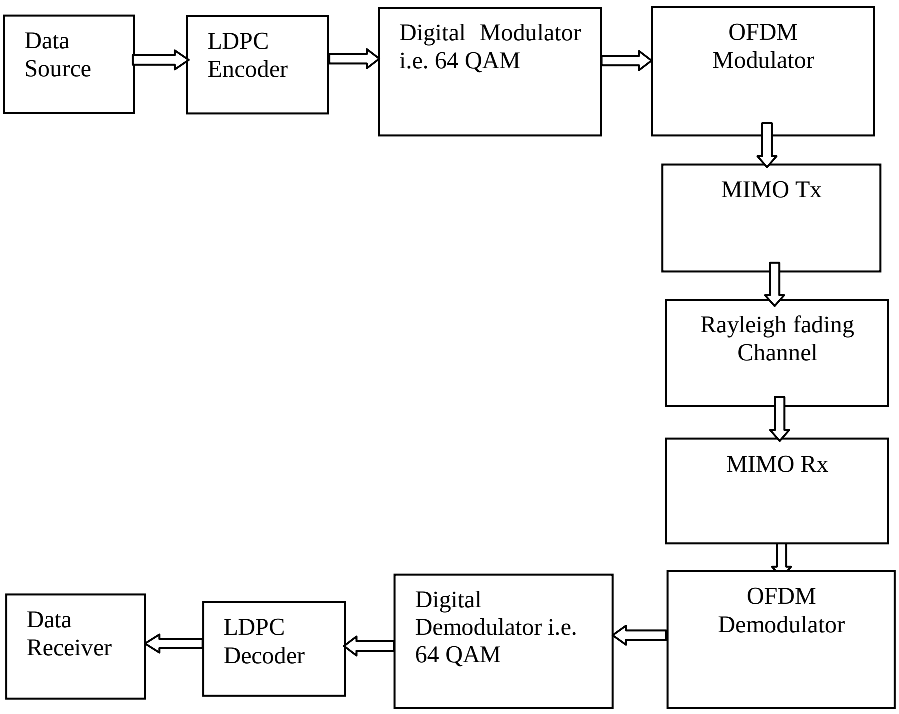

Fig. 1: Block diagram MIMO-OFDM SYSTEM

III LDPC CODE

In 2001, T.J Richardson, A. Shokrollahi, and R. Urbanke find that the performance of LDPC codes is close to the Shannon limit. It has been further demonstrated by simulations that LDPC codes of block length 10^7 approach the Shannon limit within 0.0045dB. Their excellent forward error correction properties, their minimum distance (dmin) increases proportionally with an increase in the block length. As the name suggests; LDPC codes are characterized by a parity check matrix which is sparse. Therefore a sparse matrix is one in which the number of 1's is very less as compared to the number of 0's. Due to the sparse property of the matrix; the size of the matrix can be increase without an increase in the number of 1's, which means that it can gain better distance properties without increasing the decoding complexity. Then LDPC codes are presented graphically by Tanner graphs in which they are two types of nodes; check nodes and bit nodes. This graphical presentation helps to easily understand the decoding algorithm of LDPC codes. Unlike other code which are decoded by ML (Maximum Likelihood) detection; LDPC codes are decoded by iterative decoding algorithm known as message passing algorithm. The decoding can be hard decision or soft decision. At the time when these codes were made; they were ignored partly because of the parallel develop of concatenated codes and also because the hardware at that time could not support such a complex decoder design. But today's world with the rapid development of Digital Signal Processing and Very Large Scale Integration these codes can be effectively implemented and hence they are set to be the codes of the coming wireless generations.

In order to find that some mathematically result about Low Density Parity Check code; the channel model considered here are known symmetric binary input channel. To this it mean a time discrete channel; for which the input is a sequence of binary digits 0 and 1; and the output is corresponding sequence of letter from a discrete or continues alphabet. If a symmetric binary input channel use without coding a sequence of binary digit would be send through the channel and receiver would guess the send symbol one at time from the received symbol. If coding were use; however; the coder would first take sequence of binary digits carry the data from the source and would map these sequence into longer redundant sequence called code words.

Here it define the rate R of such codes and if code word of length n. Then there are 2^{nR} possible sequences from the source that are mapped into n-length code words. Thus only a fraction $2^{-n(1-R)}$ of different n-length sequence can be used as code words. At the receiver; the decoder with its knowledge of which sequence are code words can separate the send n-length code words from the channel noise. Thus the code words are mapped back into the nR information digits. The decoding scheme describe in LDPC avoid the intermediate decision and operate directly with a probability of input symbol conditionals on the corresponding received symbol. Then code describes here with special example of parity check codes. Therefore code words of parity-check code are formed by combining a block of binary message digits with block of check digit. Each check digit is the module 2 sum of a pre-specified set of message digits.

This formation rule for the check digits can be presented conveniently by parity check matrix; as shown in equation 1. The matrix presents a set of linear homogeneous module 2 equation called parity-check equations and set of code words is a set of solution of this equation. To call the set of digits contained in a parity check equation a parity check set. Take example the first parity check set in equation 1 is the set of digit.

$$n(1-R)\begin{bmatrix}1 & 1 & 1 & 0 & 1 & 0 & 0\\ 1 & 1 & 0 & 1 & 0 & 1 & 0\\ 1 & 0 & 1 & 1 & 0 & 0 & 1\end{bmatrix} \tag{1}$$

The use of parity check code makes coding relatively simple implement. Also if a typical parity check code of long block length is used on a BSC, and if the code rate is between critical rate and channel capacity then probability of decoding error will be almost as small as that for best possible code of that rate and block length.

Low Density Parity Check code is codes specified of matrix containing mostly 0's and relatively flow 1's. Therefore in particular, (n, j, k) low density code is a code of block length n with matrix like that in equation 1; where each column have a small fixed number j of 1's and each row have a small fixed number k of 1's. And this type of matrix has the check digit appearing in diagonal form as in equation 1.

However for coding purpose in equation presented by this matrix can always be solve to give the check digit a explicit sum of information digit.

QAM

Quadrature amplitude modulation (QAM) is created by changing both the phase and amplitude of signal. The bits are map to two analogue signals by changing the amplitude and phase. Then two analogue signals are out of phase with each other by 90◦; making them orthogonal. Depend on structure of the constellation diagram; various types of QAM exist. The QAM having a rectangular structure are denoted by rectangular-QAM; likewise circular symmetry constellations are called circular-QAM. And each constellation performs deferent under different channel conditions. Then rectangular-QAM is much simple to modulate and demodulate due to its regular structure; which is created by amplitude modulations in phase and Quadrature. The other hand; circular-QAM has the advantage of performing best in channels effected by phase noise. Too furthermore; with help of digital signal processing this is now possible to implement such schemes. Thus basically Quadrature amplitude modulation (QAM) can be viewed as a combination of ASK and PSK. That mean the digital information is carried in both the phase and the amplitude of the carrier signal. The baseband equivalent representation; u_m (t) the QAM signal can be expressed as

$$u_{m=\left(A_m^I+jA_m^Q\right)g(t)} \quad m=1, 2, 3....M \tag{2}$$

A_m^I And A_m^Q € {±1Δ, ±3Δ……± (√M-1) Δ}

(Δ is a constant whose value is determined by the average transmitted power) are preferred to the in phase (I) and Quadrature (Q) amplitudes corresponding to the M possible symbols in the two-dimensional space, as shown for 64-QAM in Fig. 2; take example. The function g (t) is a real-valued signal pulse whose shape influences the spectrum of the transmitted signal. The u_m (t) in (1.15) can also be represented in polar form as

$$u_m(t) = A_m\, e^{j\theta_m} \quad m=1, 2..........M \tag{3}$$

Where A_m and θ_m denote the amplitude and phase of the m symbol, and are given by

$$A_m = \sqrt{(A_m^I)^2 + \left(A_m^Q\right)^2} \tag{4}$$

$$Q_m = tan^{-1}\frac{A_m^I}{A_m^Q} \tag{5}$$

The baseband signal described and can be expressed as a band pass signal, $s_m(t)$, which is chosen from one of M possible signalling waveforms.

$$S_m(t) = Re\{u_m(t)e^{j2\pi f_c t}\} = A_m g(t)\cos(2\pi f_c t + \theta_m) \tag{6}$$

The modulator output frequency is often lower than the desired transmission frequency; the modulator frequency must be up-converted to the appropriate radio frequency (RF) for transmission. “64-QAM” results when 64 =M for M-ary QAM. Then QAM transmits K =log2M bits of information during each symbol period. For 64-QAM; there are 64 possible symbols each containing 6 bits. The mapping of the bits into symbol is frequently done in accordance with the Gray codes which help to minimize the several of bit errors occurring for every symbol error. Because Gray-coding is a bit assignment where the bit patterns in adjacent symbol only differs by one bit; this code ensures that a single symbol in error likely corresponds to a single bit in error. Then rectangular constellation of a Gray-coded unfiltered 64-QAM signal is shown in Fig. 2.

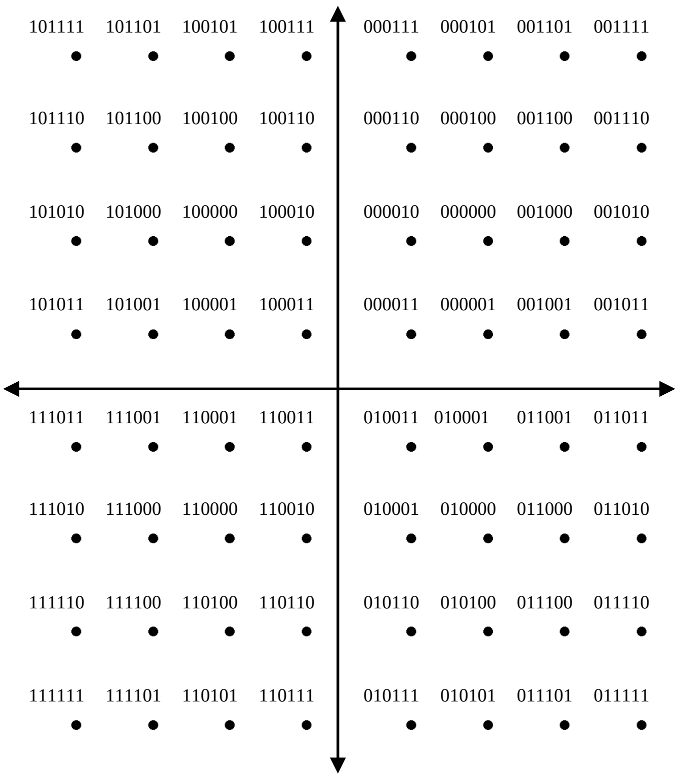

Fig. 2 Cancellation diagram for 64 QAM

Then modulation of the System shall be Quadrature Amplitude Modulation (QAM) with 64 points in the constellation diagram. Thus constellation diagrams present the signal transmitted in the wireless communication system. And as shown in Fig. 2; the constellation points in Quadrant 1 shall be converted to Quadrants 2; 3 and 4 by changing the three MSB (i.e. Ik and Qk) and by rotating the q LSBs. Prior to modulation; the I and Q signals shall be square-root raised cosine filtered.

RESULTS AND DISCUSSION

It uses the SIMULINK toolbox for the purpose to design coding for MIMO-OFDM system in Rayleigh fading channel. .And design MIMO –OFDM by using LPDC encoder and 64 QAM modulations. It uses LDPC encoder to overcome the PAPR value and hence increasing the Ergodic capacity.

Here measure Ergodic capacity with different value of SNR by using different number of antennas. When it compare these to our base paper result it find out our Ergodic capacity value is large as compare to base paper's value. At number of transmitting antenna i.e. Nt = 9 the Ergodic capacity value is equal to 90. Where in base paper its value up to 70 at SNR=20. And as respectively the different number of antenna n=1,3,5,7 and 9 the Ergodic capacity increase at different SNR values as shown in figs below.

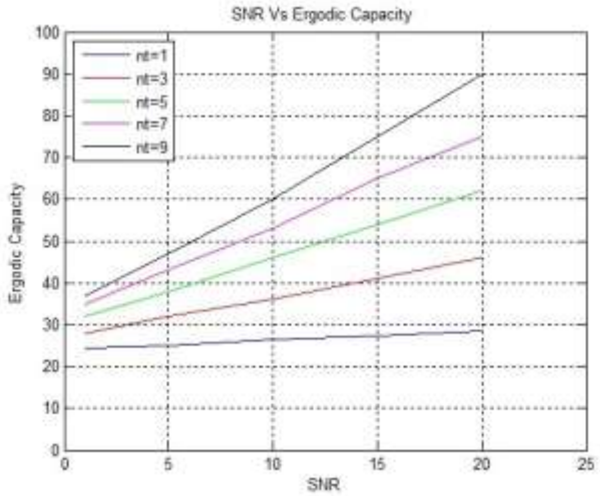

Fig. 3 SNR Vs Ergodic Capacity with Different Number of Antennas

Fig. 4 BER v/s SNR with LDPC

Table 1 SNR and Ergodic Capacity

S No	Ergodic Capacity at nt =1	Ergodic Capacity at nt =3	Ergodic Capacity at nt =5	Ergodic Capacity at nt =7	Ergodic Capacity at nt =9
1	24.33	27.89	32	35.10	36.94
2	24.45	29.30	33.32	36.84	39.103
3	25.25	30	35.01	39.02	41.95
4	25.32	31.23	36.24	40.99	44.13
5	25.45	32.12	37.89	43.05	44.89
6	25.50	32.45	39.31	44.09	49.45
7	25.51	33.14	40.58	46.54	51.01
8	25.83	33.85	42.25	48.75	53.95
9	25.91	34.47	44.05	50.81	56.68
10	26.00	35.11	46.21	53.01	60
11	26.11	36.26	48.01	55.05	62.35
12	26.52	38.14	49.85	57.87	65.45
13	26.84	39.25	51.05	60.02	69.23
14	27.13	40.01	52.37	62.95	71.50
15	27.89	41.14	54.15	65.20	74.47
16	28.49	42.23	55.58	67.01	77.25
17	28.78	43.15	57.47	69.05	80.03
18	29.45	44.37	59.21	70.02	83.57
19	29.53	45.25	60.11	73.02	86.65
20	29.79	46.17	62.27	74	90

Here draw a graph between BER and SNR by using LDPC encoder and BER reduces up to 10^{-29}. This is better than previous result.

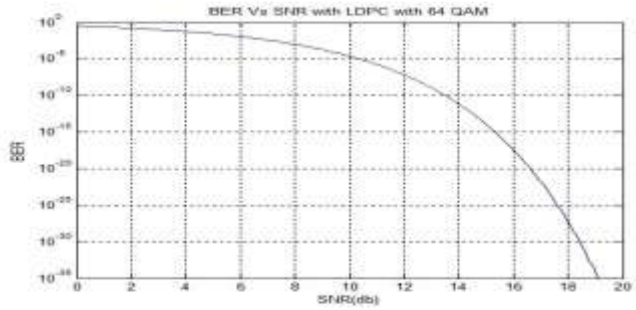

Fig. 5 BER v/s SNR with LDPC and 64 QAM modulations

Here draw a graph between BER vs. SNR by using LDPC encoder and 64 QAM. BER reduces up to 10^{-35}. This is better than previous result.

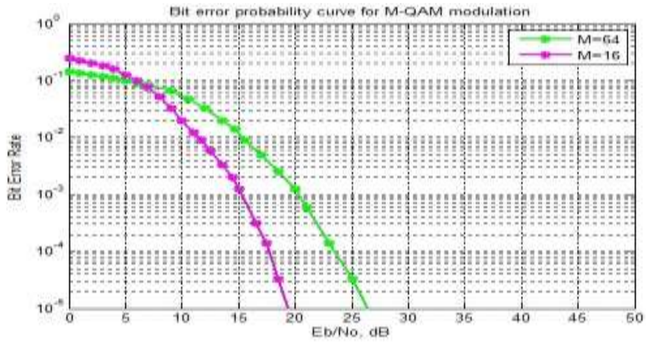

Fig. 6 Comparisons between 64 QAM modulations and 16 QAM modulations

The above Fig. explains that 64 QAM modulations have more spectral efficiency as compare to 16 QAM modulations. Therefore, used 64 QAM modulations techniques. It give the information that our Ergodic capacity is more than 250 when Nt =30.

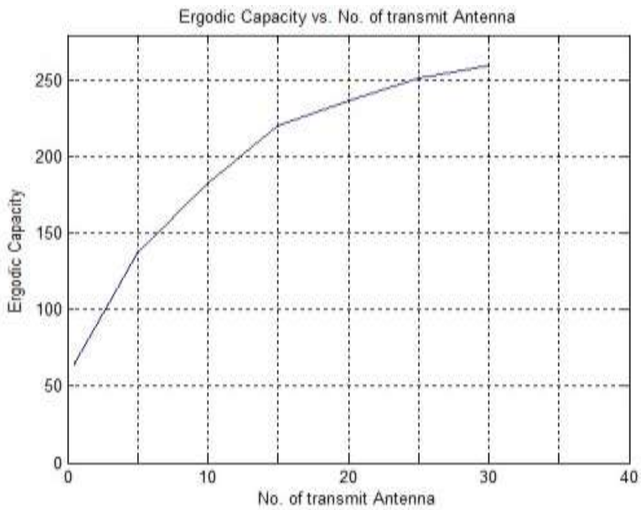

Fig. 7: Ergodic capacity vs. different number of antenna

CONCLUSION

MIMO-OFDM system is used for high speed data transmission in a Wireless Broadband Communication system. Multiple Transmitting and Receiving antennas are used to combat channel fading. Here the design for MIMO-OFDM system is developed in Rayleigh fading channel, which increases the Ergodic capacity of system by reducing PAPR problem. PAPR is biggest problem of OFDM which limits the Ergodic capacity of system. To overcome this problem LDPC encoder is used with interleaved convolution block. To increase the spectral efficiency of the system 64 QAM modulation is used. As the number of transmitting antennas is increased Ergodic capacity of the system increases.SNR has high values by using LDPC and 64 QAM as compared to previous results. BER value decreases and ergodic capacity increases. This system will provide the High data rate for future wireless systems. In this limitation of the outage capacity, we may try to work on increasing outage capacity by using other parameters; we may also combine the adaptive modulation to increase the data rates. This will allow future wireless system to have high data rates. By reducing the number of guard bands the spectral efficiency can be increased in future.

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