Enhancement of Quality of Service of MIMO-OFDM

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ABSTRACT
Orthogonal frequency division multiplexing is a promising technology for high data rate transmission in wide band wireless system for achieving high downlink capabilities in a future cellular system. This paper demonstrate, how to improve the capacity of the system and transmission quality of orthogonal frequency-division multiplexed (OFDM) along with multi-input multi-output (MIMO) used with adaptive modulation can effectively eliminate fading in wireless channels. To minimize the overall transmit power, greedy algorithm approach was proposed for the optimal bit and power allocation strategy, the performance of adaptive bit and power allocation MIMO-OFDM system based on greedy algorithm is completely studied and the performance comparison among greedy algorithm, chow algorithm and average algorithm is represented. The analysis and the simulation are considered in two stages. First stage involves single-input single-output (SISO) OFDM system. This is compared with the performance of fixed OFDM transmission where a constant rate is applied to each subcarrier. Second stage involves MIMO-OFDM and we compared the performance of MIMO-OFDM system under different antennas numbers.

General Terms
Measurement, Performance, Design, Experimentation, Theory, Verification.

Keywords
Greedy Algorithm, MIMO-OFDM, Adaptive Modulation, Dynamic Allocation.

1. INTRODUCTION
In poor wireless channels, the continuously changing channel gain makes the wireless channel capacity change accordingly.
In the traditional communication systems, the radio transmission system scheme is dead against the worst conditions. But the channel is not always stay in the bad state, this conservative idea greatly reduce the spectral efficiency of system [1]. Up to now, many adaptive bit and power allocation algorithm have been put forward. In this paper, a modified adaptive bit and power allocation algorithm based on greedy algorithm is put forward [2-3], [7-9].

The target of this algorithm is to minimize the transmission power under a given fixed system performance. In the algorithm, first the bit and corresponding power are allocated to each sub-carrier according to SNR channel condition in the receiver, and then the residual power is allocated to the sub-carriers, which can use them most efficiently. In this way, this algorithm is efficiency while calculation is less complex. We introduced the model of adaptive bit and power allocation strategy for MIMO-OFDM system also adaptive bit and power allocation based on greedy algorithm for MIMO-OFDM system as well as margin adaptive quadrature modulation (MAQM) schemes. We derive the spectral efficiency for average allocation and adaptive allocation using greedy algorithm in the algorithm first the bit and then corresponding power are allocated to each subcarrier according to signal to noise ratio (SNR) channel condition in the receiver and then the residual power is allocated to the subcarriers. In this way this algorithm is efficiency while calculation is less complex.

2. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING
Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission technique used in applications catering to both wired and wireless communications [4-6]. However, in the wired case, the usage of the term Discrete Multi-Tone is more appropriate. The OFDM technique divides the frequency spectrum available into many closely spaced carriers, which are individually modulated by low-rate data streams. In this sense, OFDM is similar to frequency division multiplexing access (FDMA). The bandwidth is divided into many channels, so that, in a multi-user environment, each channel is allocated to a user. However, the difference lies in the fact that the carriers chosen in OFDM are much more closely spaced than in FDMA (1 kHz in OFDM as opposed to about 30 kHz in FDMA), thereby increasing its spectral usage efficiency. The orthogonality between the carriers is what facilitates the close spacing of carriers. The orthogonality principle essentially implies that each carrier has a null at the center frequency of each of the other carriers in the system while also maintaining an integer number of cycles over a symbol period. The motivation for using OFDM techniques over time division multiplexing access (TDMA) techniques is twofold. First, TDMA limits the total number of users that can be sent efficiently over a channel [10-12]. In addition, since the symbol rate of each channel is high, problems with multipath delay spread invariably occur. In stark contrast, each carrier in an orthogonal frequency division multiplexing (OFDM) signal

has a very narrow bandwidth (i.e. 1 KHz); thus the resulting symbol rate is low. This results in the signal having a high degree of tolerance to multipath delay spread, as the delay spread must be very log to cause significant inter-symbol interference (e.g. > 500usec).

3. GREEDY ALGORITHM

To improve the capacity of the system and transmission quality OFDM along with MIMO is used with adaptive modulation to effectively eliminate the fading effect in wireless channels. The optimum bit and the power allocation strategy is based on the greedy algorithm. A greedy algorithm is any algorithm that follows the problem solving met heuristic of making the locally optimal choice at each stage with the hope of finding the global optimum. Greedy algorithms are simple and straightforward. They are short sighted in their approach in the sense that they take decisions on the basis of information at hand without worrying about the effect these decisions may have in the future. They are easy to invent, easy to implement and most of the time quite efficient. Many problems cannot be solved correctly by greedy approach. Greedy algorithms are used to solve optimization problem.

4. ADAPTIVE MODULATION

Most OFDM systems use a fixed modulation scheme over all carriers for simplicity. However each carrier in a multiuser OFDM system can potentially have a different modulation scheme depending on the channel conditions. Any coherent or differential, phase or amplitude modulation scheme can be used including BPSK, QPSK, 8PSK, 16QAM, 64QAM, etc. Each modulation scheme provides a tradeoff between spectral efficiency and the bit error rate. The spectral efficiency can be maximized by choosing the highest modulation scheme that will give an acceptable bit error rate (BER) [8]. In a multipath radio channel, frequency selective fading can result in large variation in the received power of each carrier. For a channel with no direct signal path this variation can be as much as 30 dB in the received power resulting in a similar variation in the SNR. Using adaptive modulation the carrier modulation is matched to the SNR, maximizing the overall spectral efficiency.

In systems that use a fixed modulation scheme the carrier modulation must be designed to provide an acceptable BER under the worst channel conditions. This results in most systems using BPSK or QPSK. These give a poor spectral efficiency (1-2 bits/s/Hz) and provide an excess link margin most of the time. Using adaptive modulation, the remote stations can use a much higher modulation scheme when the radio channel is good. Thus as a remote station approaches the base station the modulation can be increased from 1 bits/s/Hz (BPSK) up to 4-6 bits/s/Hz (16QAM - 64QAM), significantly increasing the spectral efficiency of the overall system. Preliminary results show that for a cellular network the system capacity can potentially be doubled using adaptive modulation. In adaptive OFDM i.e. AOFDM, adaptive transmission scheme is employed according to channel fading condition with OFDM to improve the performance. Firstly we have investigated the OFDM system performance of un coded adaptive modulation using quadrature amplitude modulation (QAM) and phase shift keying (PSK). To further enhance the system, we employ convolutional coding to OFDM system. Adaptive modulation systems invariably require some channel state information at the transmitter. Adaptive modulation systems improve rate of transmission, and/or bit error rates, by exploiting the channel state information that is present at the transmitter. Especially over fading channels, which model wireless propagation environments, adaptive modulation systems exhibit great performance enhancements compared to systems that do not exploit channel knowledge at the transmitter.

5. SPREADING FACTOR COMPARISO-N WITH DIFFERENT DATA RATE

Ultra Wide Band (UWB) devices operate in a huge bandwidth of 7.5 GHz, lasting from 3.1 GHz to 10.6 GHz. Basically, two different approaches to the use of this bandwidth have been proposed. The first approach relates to single band system. In this approach, the information is directly modulated into a sequence of impulse-like waveform. Each pulse has a very small duration of less than 1 ns, and it occupies the entire available bandwidth of 7.5 GHz. The second approach involves multiband OFDM system. The whole 7.5 GHz UWB bandwidth is divided into 14 different sub-bands of 528 MHz to comply with the FCC’s UWB definition. In each sub-band, orthogonal frequency multiplexing (OFDM) with 128 sub-carriers is applied to modulate the transmit signal.

In this work, the implementation of UWB system is processed following the standard proposal IEEE 802.15-03/268r3 that is based on the second approach. The reason of using this proposal is due to the advantages of the multiband OFDM system. In this system, the information can be processed over a smaller bandwidth comparing to that in the first approach. As a result, this approach reduces the complexity of the design and the power consumption, lowers the cost, and improves spectral flexibility and worldwide compliance. In addition, this approach includes the use of lower-rate ADCs and thus simplifies the digital complexity.

5.1 UWB Multiband Tx and Rx

A UWB multiband OFDM system is separated into two systems: a transmitter and a receiver. These systems comprise from two components, a baseband and a radio frequency (RF) as shown in Figure 1 and Figure 2. The performance of the implemented UWB systems is justified based on the baseband components. In the transmitter, the baseband component consists of the following blocks: data scrambler, convolutional encoder and puncturer, bit inter-leaver, constellation mapping, and inverse FFT. The baseband component of the receiver, in general, consists of the same blocks of the baseband in the transmitter but in a reverse order.

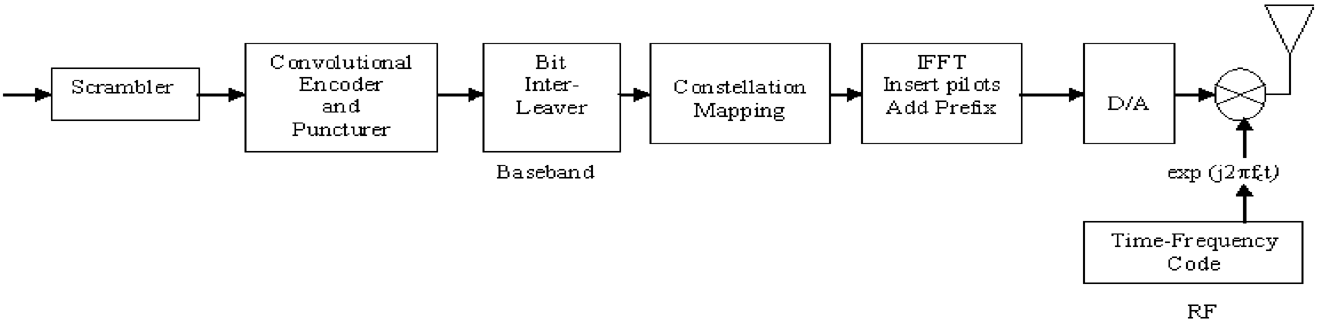


Fig 1: UWB multiband OFDM Transmitter

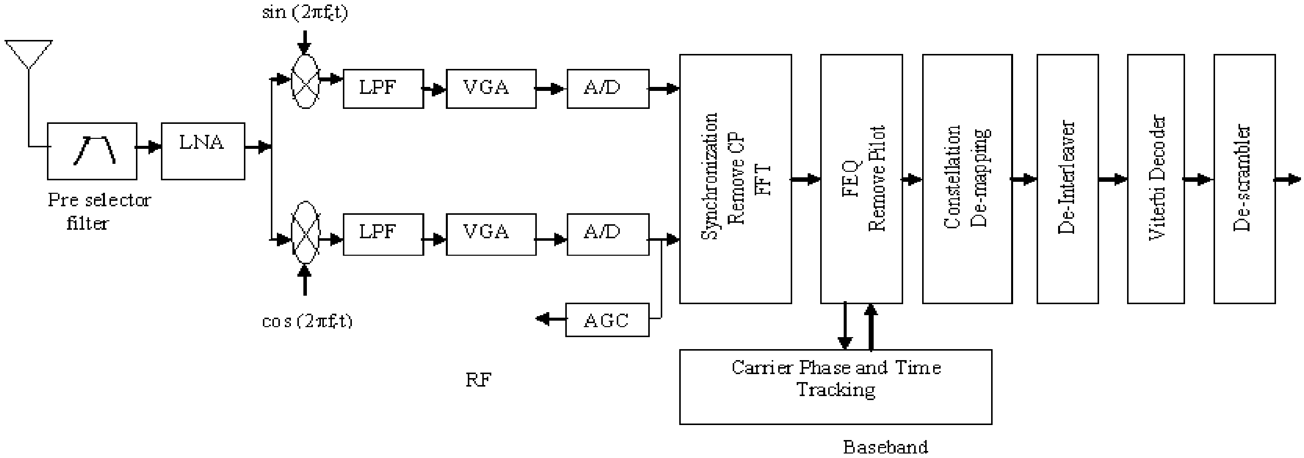


Fig 2: UWB multiband OFDM Receiver

In general, the UWB multiband system supports 10 different data rates of 53.3, 55, 80, 106.7, 110, 160, 200, 320, 400, and 480 Mbps [2]. The convolutional encoder supports 5 different coding rates of 1/3, 11/32, 1/2, 5/8, and 3/4. The convolutional code with rate 1/3 is the mother code. The other coding rates can be obtained by puncturing the mother code. The puncturing simplifies the implementation of the convolutional encoder. Viterbi decoding algorithm is employed to decode the convolutional encoded stream. In the UWB system, each OFDM symbol contains 128 sub-carriers, in which 122 sub-carriers carry 100 data, 12 pilots, and 10 guards which are modulated using quadrature phase shift keying (QPSK); the other 6 sub-carriers are reserved for nulls. The UWB system also exploits frequency diversity and temporal diversity to obtain different quality of performance by employing frequency spread and time spread. The higher the spreading gain factor is the more diversity, thus the better the performance of the system. For data rates less than or equal to 80 Mbps, denoted Low Rate, the system obtains an overall spreading gain factor of 4 with factor of 2 from each spread. For the data rates from 106.7 Mbps to 200 Mbps, denoted Middle Rate, the overall spreading gain factor for the system is 2; there is no frequency spread. For the data rates greater than 200 Mbps, denoted High Rate, the system has neither frequency nor time spread. The data rate dependent modulation parameters are listed in Table 1, which summarizes the technical parameters of UWB multiband OFDM systems.

Table 1. Rate-dependent parameters

Data rate (Mb/s)	Modul-ation	Coding rate (R)	Conjugate symmetric input to IFFT	Time spreading factor	Overall spreading gain	Coded bits per OFDM symbol (N_{CBPS})
53.3	QPSK	1/3	Yes	2	4	100
55	QPSK	11/32	Yes	2	4	100
80	QPSK	1/2	Yes	2	4	100
106.7	QPSK	1/3	No	2	2	200
110	QPSK	11/32	No	2	2	200
160	QPSK	1/2	No	2	2	200
200	QPSK	5/8	No	2	2	200
320	QPSK	1/2	No	1 (No spreading)	1	200
400	QPSK	5/8	No	1 (No spreading)	1	200
480	QPSK	3/4	No	1 (No spreading)	1	200

The UWB multiband OFDM system presented above is a single input single output (SISO) system, which consists of one transmit antenna and one receive antenna. In the next section, UWB systems employing multiple input single output (MISO) and multiple input multiple output (MIMO) schemes are presented.

6. ADAPTIVE MODULATION MODEL

Consider a channel with m TX and n RX and N channels. At the TX N sub band channels transmit signals X with the period T. The signal is converted from frequency to time domain using IFFT. Assume a length G equal to the discrete-time channel impulse response M. At the RX these signals are converted into the frequency domain using FFT from which the G samples are removed. In addition, b*sqrt(p) and

1/sqrt(p) are the proportion factor for adaptive bit and power allocation. Character of channels is assumed to be known at the transmitter and receiver. If the time delay of symbols transmitted over wireless channels is near or over the period of transmitted symbols, frequency selective fading incurs when the symbols are transformed into frequency domain. Based on the character of OFDM, it can be regarded as flat fading in narrow band period of each sub-channel for OFDM system. The scheme of adaptive modulation model for MIMO- OFDM system is shown in below Figure 3.

Dynamic bit and power allocation based on greedy algorithm:

i. Find the bit with least cost to increment
ii. Choose the subcarrier with index n.
iii. Allocate m bit for the sub-carrier.
iv. Compute the incremental power of that sub-carrier.

7. DYNAMICS BIT AND POWER ALLOCATION

In general, we can evaluate a system from two sides, which are quality of service (QoS) and cost of service (CoS). QoS can be represented by BER and rate of system, and CoS can be represented by total transmission power. Based on adaptive modulation margin adaptive (MA) principals, that is, under the constrain of given bit rate and the target BER requirement, this method can adaptively adjust the transmit power of each sub-carrier to minimize the transmit power of the system. In single user case, different bits and modulations are allocated for each sub-carrier according to the channel state of each sub-carrier. Since the power needed for transmitting definite bits is independent each other, it is approved that the optimal bit allocation is greedy allocation.

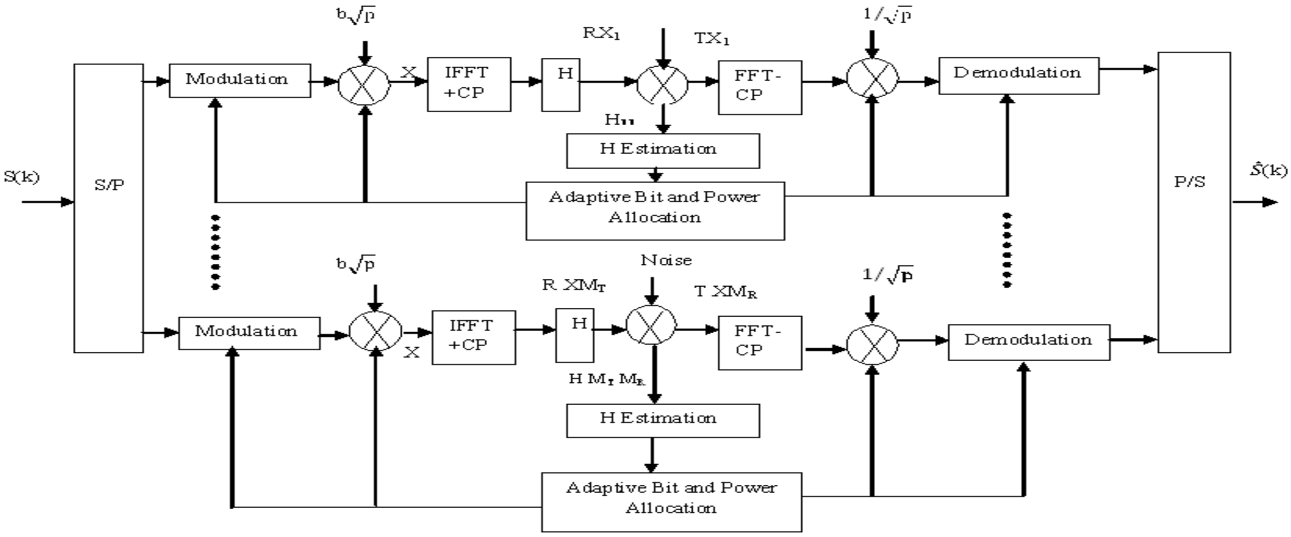


Fig 3: The scheme of adaptive modulation model for MIMO OFDM system

8. FLOW GRAPH FOR OFDM TX AND RX

The following Figure 4 & Figure 5 as flow graphs for OFDM Tx & Rx respectively.

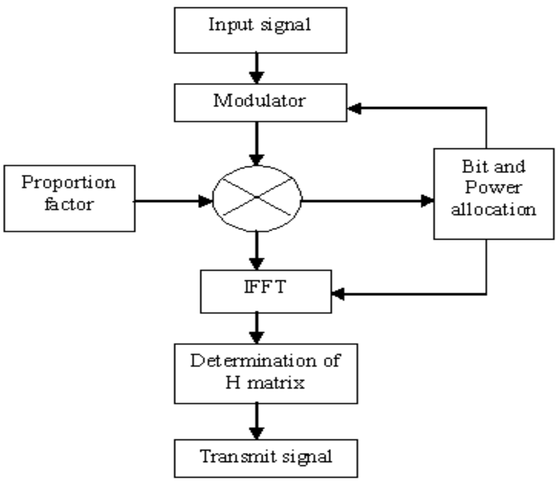


Fig 4: OFDM Transmitter

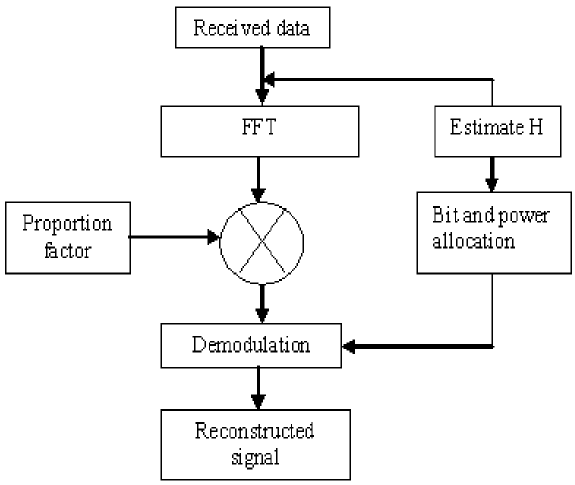


Fig 5: OFDM Receiver

9. BIT ERROR RATE

In any phase modulation scheme the information is expressed in terms of phase of the carrier. Phase of the carrier signal is shifted according to the input binary data. Two-state n phase shift keying (PSK) is called BPSK where the phase of the radio carrier is set to 0 or π according to the value of the incoming bit. Each bit of the digital signal produces a transmit symbol with duration Ts, which is equal to the bit duration Tb. Four-state or quadric phase PSK is called QPSK, in which two bits are combined and the radio carrier is phase-modulated according to the four possible patterns of two bits. Transmitting a symbol takes twice as long as a bit (Ts = 2 x Tb) which means that the bandwidth efficiency of QPSK is twice that of BPSK. Bit error rate (BER) of a communication system is defined as the ratio of number of error bits and total number of bits transmitted during a specific period. It is the likelihood that a single error bit will occur within received bits, independent of rate of transmission. There are many ways of reducing BER. Here, we focus on channel coding techniques. The performance of digital receiver is measured by a parameter called the Bit-Error Ratio (BER). The bit error rate (BER) tells the fraction of the bits which are wrongly detected, i.e.

$$BER = \frac{\text{No. of bits in error}}{\text{Total bits transmitted}} = \frac{\text{Wrong bits per sec}}{\text{Data rate in bits per sec}}$$

For a satisfactory performance BER has to be less than$10^{-9.}$ A channel in mobile communications can be simulated in many different ways. The main considerations include the effect of multipath scattering, fading and Doppler shift that arise from the relative motion between the transmitter and the receiver. In our simulations, we have considered the two most commonly used channels: the Additive White Gaussian Noise (AWGN) channel where the noise gets spread over the whole spectrum of frequencies and the Rayleigh fading channel. Coded and uncoded BPSK & QPSK schemes have been simulated using the Serenade Symphony tool. BER has been measured by comparing the transmitted signal with the received signal and computing the error count over the total number of bits. For any given modulation, the BER is normally expressed in terms of signal to noise ratio (SNR). convolutional coder takes a binary input sequence and outputs a convolutionally encoded binary sequence according to the specified parameters of the model, in which every K input bits are encoded into N output bits. The rate of the coder is given by the ratio K/N.

10. CYCLIC PREFIX IN OFDM

The spectrum required is first chosen based on the input data and the modulation scheme used (typically Differential BPSK, QPSK or QAM). Data to be transmitted is assigned to each carrier that is to be produced. Amplitudes and phases of the carriers are calculated based on the chosen scheme of modulation. The required spectrum is then converted back to its time domain signal by employing Inverse Fourier transform algorithms like the inverse fast Fourier transform.

The next step is that of adding a guard period to the symbol to be transmitted. This ensures robustness against multipath delay spread. This step can be achieved by having a long symbol period, which minimizes inter symbol interference. The level of robustness can be further increased by the addition of a guard period between successive symbols. The most popular and effective method of doing this, is the addition of a cyclic prefix**.** A cyclic prefix is a copy of the last part of the OFDM symbol, which is prep ended to the transmitted symbol shown in Figure 6. This makes the transmitted signal periodic and does not affect the orthogonality of the carriers. Further, this also plays a decisive role in avoiding inter-symbol and inter-carrier interference.

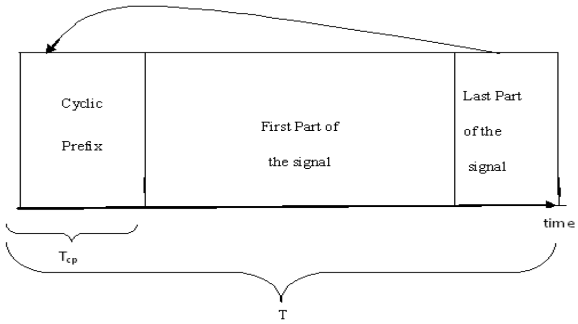


Fig 6: The Cyclic Prefix is a copy of the last part of the OFDM signal

11. USE OF MIMO OFDM SYSTEM

In radio, multiple-input and multiple-output, or MIMO, is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology.

MIMO technology has attracted attention in wireless communications, because it offers significant increases in data throughput and link range without additional bandwidth or transmit power. It achieves this by higher spectral efficiency (more bits per second per hertz of bandwidth) and link reliability or diversity (reduced fading). Because of these properties, MIMO is an important part of modern wireless communication standards such as IEEE 802.11n (Wi-Fi), 4G, 3GPP Long Term Evolution, Wi-MAX and HSPA + MIMO OFDM system is presented in below Figure 7.

Wi-MAX is a type OFDM system development in this era.Where Wi-MAX 2 supports upto 1 Gbps data rate for trasmission of signal in this module of system.

- 20 MHz bandwidth, MIMO-OFDM mobile Wi-MAX transceiver (PHY-layer).
- Exceeds the Wi-MAX Forum Radio Conformance Tests.
- Current Wi-MAX IPs targeting mobile terminals operate at 10 MHz.
- The 20 MHz channel bandwidth will be introduced in Wi-MAX 2.

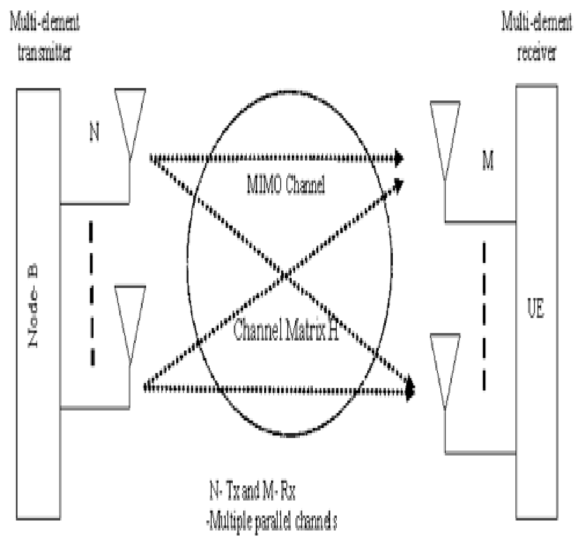


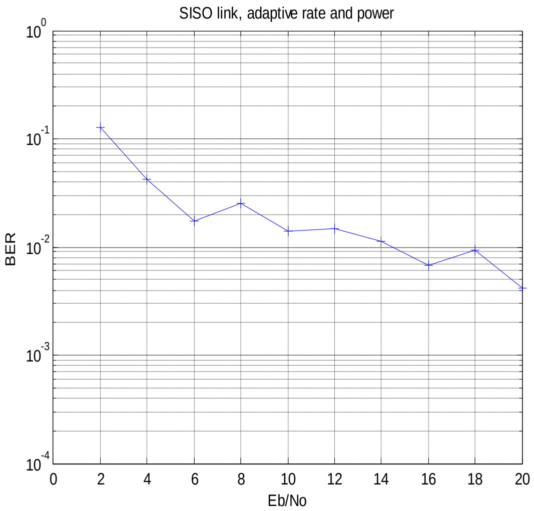
Fig 7: MIMO-OFDM system

GEDOMIS® is currently hosting a mobile Wi-MAX transceiver featuring a 2x2 MIMO-OFDM configuration and a high channel bandwidth of 20 MHz. The physical layer algorithms of the transceiver were modeled in Matlab.

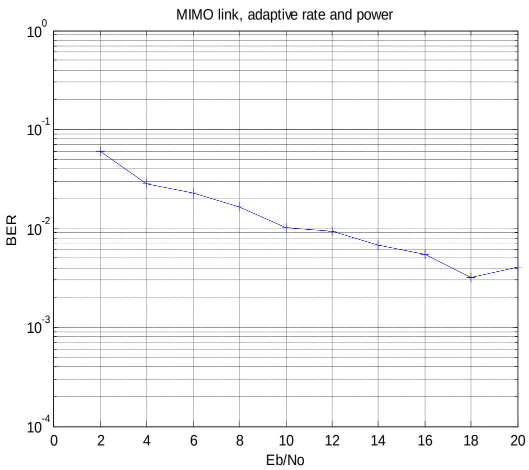
12. RESULTS AND DISCUSSIONS

In our simulation schemes, the sub-carrier of OFDM symbol is N = 64; cyclic prefix is CP = 16. The receive antennas and transmit antennas are different combinations of $N_t = \{1, 2, 4\}$ and $N_r = \{1, 2, 4\}$. The bits allocated for each OFDM symbol is B = 128. In this paper, adaptive modulation is used, which order is $M = 2^c$, c = {0, 2, 4, 8}. The channel model is multi-path Rayleigh fading channel; power delay distribution is exponential distribution, which is {1, exp (-1), exp (-2)}, and noise variance is σ □ $= 1*10^{3}$.

Results are analyzed in four phases. In the first phase, it compared the SISO and MIMO for adaptive rate and power. The result is presented in Figure 8. This is to ascertain that MIMO-OFDM performs better performance than its counterpart in terms of BER and signal to noise ratio.



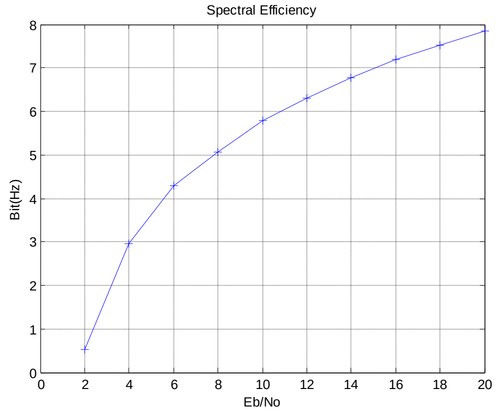
(a) SISO



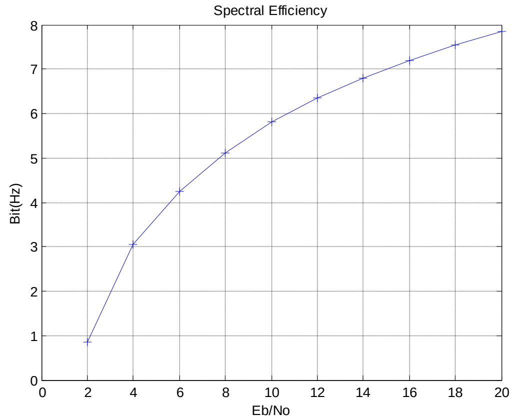
(b) MIMO

Fig 8: Adaptive rate and power for (a) SISO and (b) MIMO

In the second phase, it compares the spectral efficiency of SISO and MIMO-OFDM to prove that, our novel method enhances the spectral efficiency in MIMO as compared to SISO. This is depicted in below Figure 9.



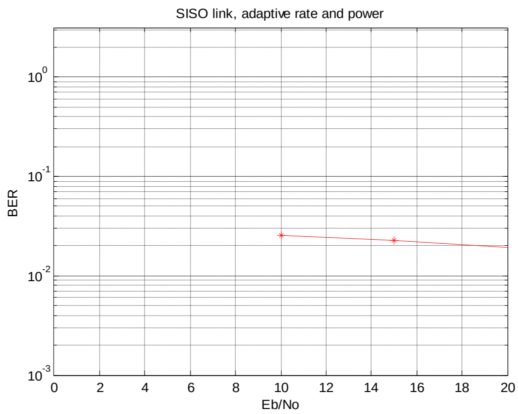
(a) SISO



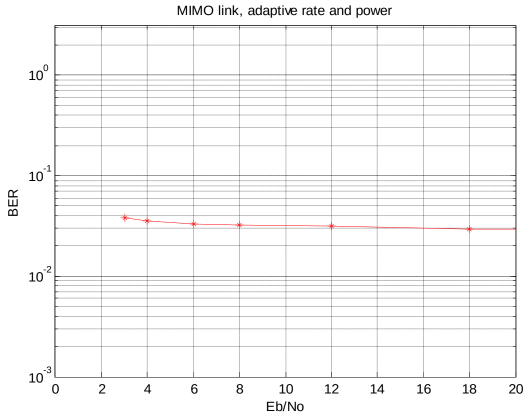
(b) MIMO

Fig 9: Spectral efficiency for (a) SISO (b) MIMO OFDM

In the third phase, it compare SISO & MIMO, for adaptive rate & power with chow and greedy algorithm. This result is presented in below Figure 10. This is to ascertain in both the cases shows that chow algorithm which has constant BER than greedy algorithm.



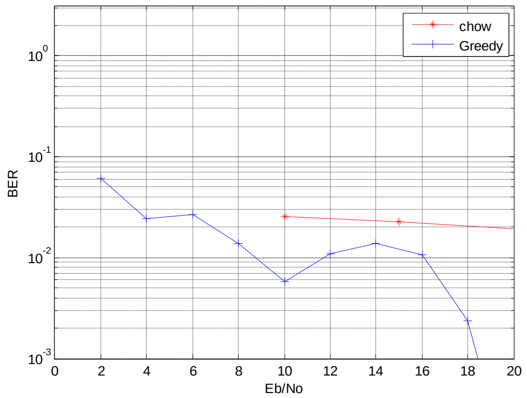
(a) SISO



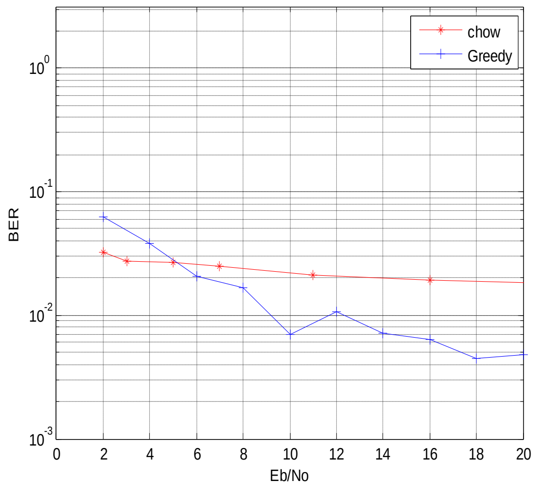
(b) MIMO

Fig 10: SISO & MIMO link, adaptive rate and power with chow & greedy algorithm

In the final phase, it applies chow and greedy algorithm to both SISO and MIMO-OFDM system. Results show that chow algorithm shows a constant BER in both the cases, while BER performance of greedy algorithm varies with signal to noise ratio making it more adaptive for fading channels, strategically enhancing the QoS of mobile communication system shown in below Figure 11.



(a) SISO OFDM



(b) MIMO OFDM

Fig 11: Application of chow & greedy algorithm for (a) SISO (b) MIMO OFDM

13. CONCLUSION

The combination of adaptive modulation, MIMO technology and OFDM technology can effectively resist various fading in wireless channel and at most improve the capacity of system as well as performance As compared to SISO technology. It is proved that whatever in BER or in spectral efficiency, the performance of adaptive bit and power allocation for MIMO-OFDM system using greedy algorithm is clearly superior to that of system using average bit and power allocation algorithm. The main goal of the research around these topics will be finding low complexity and power efficient algorithms which increases the quality of service (QoS). 4G systems adopting this novel technology will not only be characterized by a higher data rate than existing wireless systems, but also will be specified as having higher mobility and better link quality attracting huge customers.

14. ACKNOWLEDGMENTS

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