BER Analysis for Quadrature Amplitude Modulation in MIMO-OFDM System

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ABSTRACT

The transmitter is a 4x4 MIMO antenna mode with Quadrature Amplitude Modulation (QAM) scheme is used to increase the SNR and to decrease the BER of the system. Here channel coefficient is evaluated and BER, PER, FER and capacity of the channel is improved. Here 10000 bits are given as input. As this whole system operates under Orthogonal Frequency Division Multiplexing (OFDM) scheme, various sub-carriers are allocated in the range of 8, 16 or 32. Also here, the relays are used perform the switching operation. The two types of relaying schemes used here are Amplify-and-Forward relay and Decode-and-Forward relay. Then the channel used here is Rayleigh fading channel and Additive White Gaussian Noise (AWGN) is added to the channel to minimize the effect of random processes that occur naturally. The channel coefficient and also the channel capacity is analyzed to illustrate the growth of the individual channels. Based on the relaying schemes the outputs from different channels are combined using Maximal Ratio Combining (MRC) or Equal Ratio Combining (ERC). At last proper demodulation is performed and the signal reaches the destination where proper PDFs and CDFs are used to analyze BER and SNR. The system runs under an algorithm called Water-Filling algorithm which is a method of power optimization algorithm to obtain high throughput and to improve the performance.

Keyword: *QAM, relay, MRC, EGC, Fading, BER, SNR*

1. INTRODUCTION

Wireless communication was introduced in the 19th century and wireless communication technology has developed over the subsequent years. It is one of the most important mediums of transmission of information from one device to other devices. In this technology, the information can be transmitted through the air without requiring any cable or wires or other electronic conductors, by using electromagnetic waves like IR, RF, satellite, etc. In the present days, the wireless communication technology refers to a variety of wireless communication devices and technologies ranging from smart phones to computers, tabs, laptops, Bluetooth Technology, printers. The wireless communication system which permits user to communicate even from remote operated areas. There are many devices used for wireless communication like mobiles. Cordless telephones, Zigbee wireless technology, GPS, Wi-Fi, satellite television and wireless computer parts. Current wireless phones include 3 and 4G networks, Bluetooth and Wi-Fi technologies.

1.1 Multipath propagation

In wireless telecommunications, multipath is the propagation phenomenon in radio signals reaching the receiving antenna by two or more paths. Causes of multipath include atmospheric ducting, ionospheric reflection and refraction, and reflection from water bodies and terrestrial objects such as mountains and buildings. Multipath causes multipath interference including constructive and destructive interference, and phase shifting of the signal. Destructive interference causes fading. Where the magnitudes of the signals arriving by the various paths have a distribution known as the Rayleigh distribution, this is known as Rayleigh fading.

1.2 MIMO

MIMO (multiple input, multiple output) is an antenna technology for wireless communications in which multiple antennas are used at both the source (transmitter) and the destination (receiver). The antennas at each end of the communications circuit are combined to minimize errors and optimize data speed. MIMO is one of several forms of smart antenna technology. In conventional wireless communications, a single antenna is used at the source, and another single antenna is used at the destination. In some cases, this gives rise to problems with multipath effects. When an electromagnetic field (EM field) is met with obstructions such as hills, canyons, buildings, and utility wires, the wave fronts are scattered, and thus they take many paths to reach the destination. The late arrival of scattered portions of the signal causes problems such as fading, cut-out (cliff effect), and intermittent reception (picket fencing). In digital communications systems such as wireless Internet, it can cause a reduction in data speed and an increase in the number of errors. The use of two or more antennas, along with the transmission of multiple signals (one for each antenna) at the source and the destination, eliminates the trouble caused by multipath wave propagation, and can even take advantage of this effect. MIMO technology has aroused interest because of its possible applications in digital television (DTV), wireless local area networks (WLANs), metropolitan area networks (MANs), and mobile communications.

1.3 OFDM

Multiple input, multiple output-orthogonal frequency division multiplexing (MIMO-OFDM) is the dominant air interface for 4G and 5G broadband wireless communications. It combines multiple input, multiple output (MIMO) technology, which multiplies capacity by transmitting different signals over multiple antennas, and orthogonal frequency-division multiplexing (OFDM), which divides a radio channel into a large number of closely spaced sub channels to provide more reliable communications at high speeds. The combination of MIMO and OFDM is most practical at higher data rates. MIMO-OFDM is the foundation for most advanced wireless local area network (wireless LAN) and mobile broadband network standards because it achieves the greatest spectral efficiency and, therefore, delivers the highest capacity and data throughput. OFDM enables reliable broadband communications by distributing user data across a number of closely spaced, narrowband sub channels. This arrangement makes it possible to eliminate the biggest obstacle to reliable broadband communications, inter symbol interference (ISI). ISI occurs when the overlap between consecutive symbols is large compared to the symbols' duration. Normally, high data rates require shorter duration symbols, increasing the risk of ISI. By dividing a high-rate data stream into numerous low-rate data streams, OFDM enables longer duration symbols. MIMO-OFDM is a particularly powerful combination because MIMO does not attempt to mitigate multipath propagation and OFDM avoids the need for signal equalization. MIMO-OFDM can achieve very high spectral efficiency even when the transmitter does not possess channel state information (CSI). When the transmitter does possess CSI (which can be obtained through the use of training sequences), it is possible to approach the theoretical channel capacity. CSI may be used, for example, to allocate different size signal constellations to the individual subcarriers, making optimal use of the communications channel at any given moment of time. More recent MIMO-OFDM developments include multi-user MIMO (MU-MIMO), higher order MIMO implementations (greater number of spatial streams), and research concerning massive MIMO and cooperative MIMO (CO-MIMO) for inclusion in coming 5G standards.

1.4 FADING CHANNEL

In wireless communications, fading is variation of the attenuation of a signal with various variables. These variables include time, geographical position, and radio frequency. Fading is often modeled as a random process. A fading channel is a communication channel that experiences fading. In wireless systems, fading may either be due to multipath propagation, referred to as multipath induced fading, or due to shadowing from obstacles affecting the wave propagation, sometimes referred to as shadow fading. The terms slow and fast fading refer to the rate at which the magnitude and phase change imposed by the channel on the signal changes. The coherence time is a measure of the minimum time required for the magnitude change or phase change of the channel to become uncorrelated from its previous value. Slow fading arises when the coherence time of the channel is large relative to the delay requirement of the application. In this regime, the amplitude and phase change imposed by the channel can be considered roughly constant over the period of use. Slow fading can be caused by events such as shadowing, where a large obstruction such as a hill or large building obscures the main signal path between the transmitter and the receiver. The received power change caused by shadowing is often modeled using a log-normal distribution with a standard deviation according to the log-distance path loss model. Fast fading occurs when the coherence time of the channel is small relative to the delay requirement of the application. In this case, the amplitude and phase change imposed by the channel varies considerably over the period of use.

2. BER ANALYSIS USING QAM

The usage of Space Shift Keying (SSK) in the existing system produced high BER and low SNR. This is overcome by using Quadrature Amplitude Modulation (QAM) instead of SSK. This in turn increases the performance of the overall system. In this system power optimization is employed using water-filling algorithm to increase the overall throughput. The channel employed here is Rayleigh fading channel which provides effective communication. The relaying schemes are used to increase the coverage area and to provide lossless data transmission between the source and the destination.

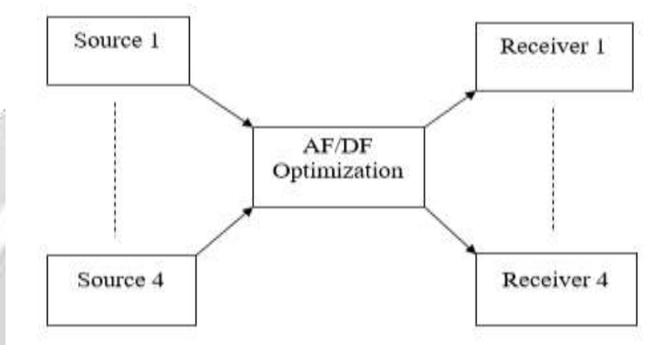

Fig-1: Overall system

The overall system consists of 4x4 Multiple Input Multiple Output (MIMO) antenna, which has 4 transmitter antennas and 4 receiver antennas. The diversity combining technique is used between the transmitter and the receiver to have an efficient transferring of information. Moreover the channel capacity and the channel coefficient are computed to identify the channel performance.

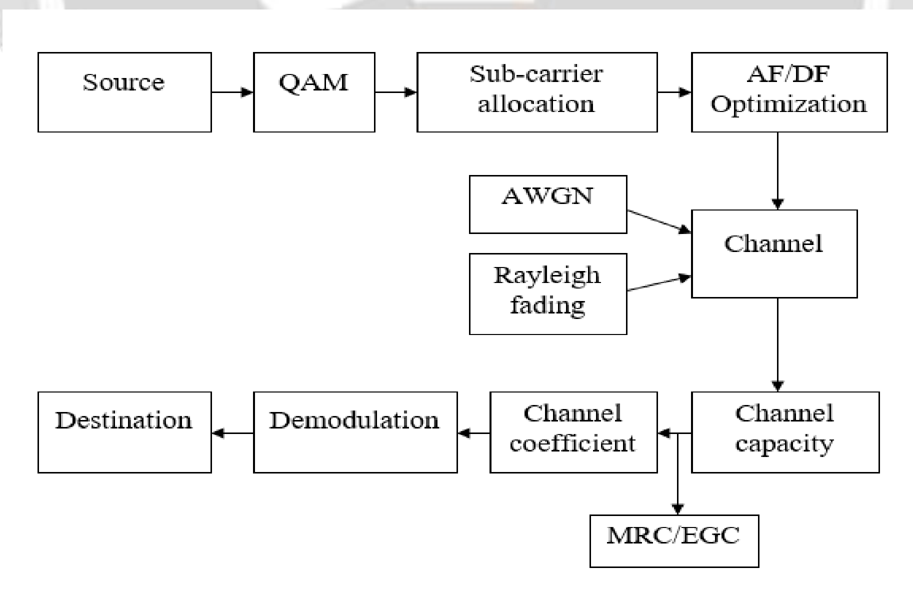

Fig -2: Process of BER analysis using relay

2.1 Source

The overall system consists of 4x4 Multiple Input Multiple Output (MIMO) antenna, which has 4 transmitter antennas and 4 receiver antennas. The diversity combining technique is used between the transmitter and the receiver to have an efficient transferring of information. Moreover the channel capacity and the channel coefficient are computed to identify the channel performance.

2.2 QAM

Quadrature amplitude modulation (QAM) is both an analog and a digital modulation scheme. It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme.

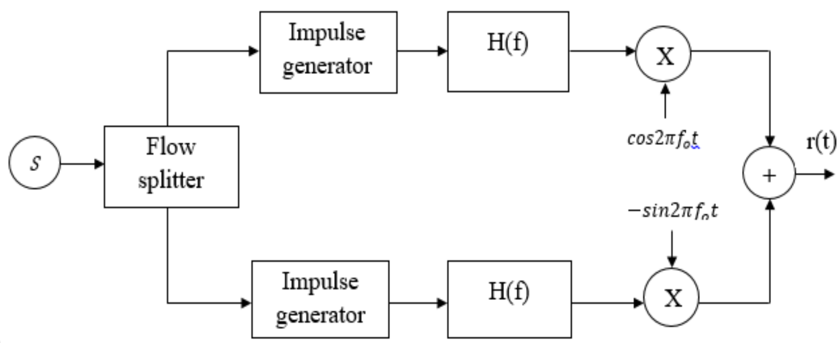

Fig-3: QAM transmitter

The two carrier waves of the same frequency, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carriers or quadrature components. The modulated waves are summed, and the final waveform is a combination of both phase-shift keying (PSK) and amplitude-shift keying (ASK), or, in the analog case, of phase modulation (PM) and amplitude modulation. It is worth noting that as the amplitude of the signal varies any RF amplifiers must be linear to preserve the integrity of the signal.

Fig-3 shows that, at first the flow of bits to be transmitted is split into two equal parts: this process generates two independent signals to be transmitted. They are encoded separately just like they were in an amplitude-shift keying (ASK) modulator. Then one channel (the one "in phase") is multiplied by a cosine, while the other channel (in "quadrature") is multiplied by a sine. This way there is a phase of 90° between them. They are simply added one to the other and sent through the real channel.

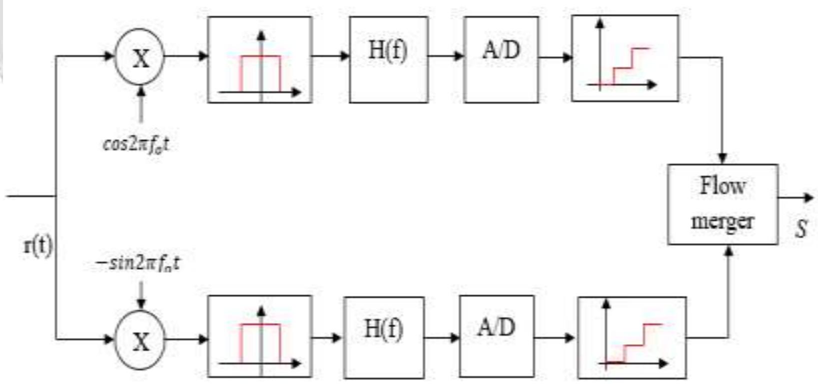

Fig-4: QAM receiver

The receiver in fig-4 simply performs the inverse operation of the transmitter. Multiplying by a cosine (or a sine) and by a low-pass filter it is possible to extract the component in phase (or in quadrature). Then there is only an ASK demodulator and the two flows of data are merged back.

2.3 Sub-carrier allocation

The sub carriers are allocated based on Orthogonal Frequency Division Multiplexing (OFDM) scheme. Orthogonal frequency-division multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. OFDM is a frequency-division multiplexing (FDM) scheme used as a digital multi-carrier modulation method. A large number of closely spaced orthogonal sub-carrier signals are used to carry data on several parallel data streams or channels. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth.

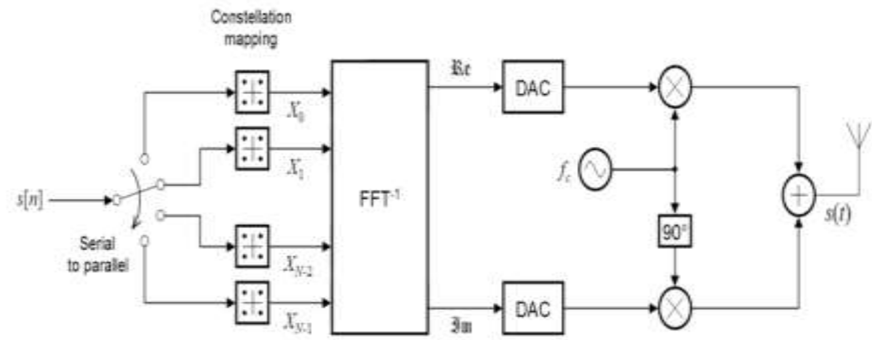

Fig-5: OFDM transmitter

From fig-5 it is found that by inverse multiplexing, serial stream of binary digits these are first de-multiplexed into N parallel streams, and each one mapped to a (possibly complex) symbol stream using some modulation constellation (QAM, PSK, etc.). Note that the constellations may be different, so some streams may carry a higher bit-rate than others. An inverse FFT is computed on each set of symbols, giving a set of complex time-domain samples. These samples are then quadrature-mixed to passband in the standard way. The real and imaginary components are first converted to the analogue domain using digital-to-analogue converters (DACs); the analogue signals are then used to modulate cosine and sine waves at the carrier frequency, respectively. These signals are then summed to give the transmission signal.

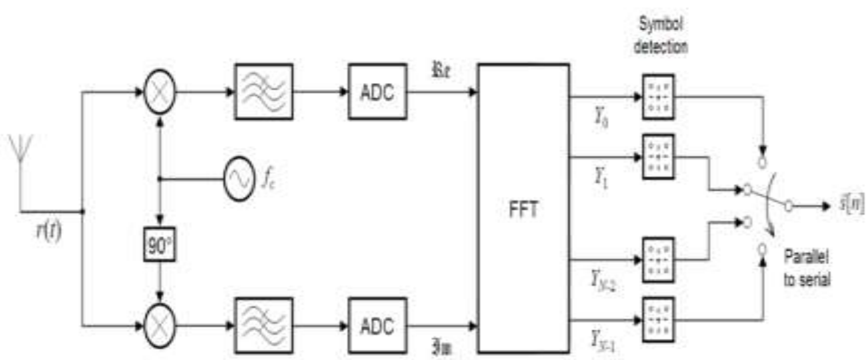

Fig-6: OFDM receiver

Fig-6 shows that the receiver picks up the received signal, which is then quadrature-mixed down to baseband using cosine and sine waves at the carrier frequency. This also creates signals centered on two times of the carrier frequency, so low-pass filters are used to reject these. The baseband signals are then sampled and digitized using analog-to-digital converters (ADCs), and a forward FFT is used to convert back to the frequency domain. This returns N parallel streams, each of which is converted to a binary stream using an appropriate symbol detector. These streams are then re-combined into a serial stream, which is an estimate of the original binary stream at the transmitter.

2.4 AF/DF Optimization

Relays that receive and retransmit the signals between base stations and mobiles can be used to increase throughput extend coverage of cellular networks. The simplest cooperative relaying network consists of three nodes, namely source, destination, and a third node supporting the direct communication between source and destination denoted as relay. If the direct transmission of a message from source to destination is not (fully) successful, the overheard information from the source is forwarded by the relay to reach the destination via a different path. Since the two communications took a different path and take place one after another, this implements the concept of space diversity and time diversity. Amplify and forward (AF) allows the relay station to amplify the received signal from the source node and to forward it to the destination station. AF requires much less delay as the relay node operates time-slot by time-slot. Also, AF requires much less computing power as no decoding or quantizing operation is performed at the relay side.

Decode and forward (DF) overhear transmissions from the source, decode them and in case of correct decoding, forward them to the destination. Whenever unrecoverable errors reside in the overheard transmission, the relay cannot contribute to the cooperative transmission. Here the relay decodes the source message in one block and transmits the re-encoded message in the following block. In practice, a cooperative system should be a narrow band one, or guard interval between transmitted symbols should be used to avoid intersymbol interference due to relays.

2.5 Channel

Rayleigh fading channel is used for the communication, which is a frequency selective channel and along with that AWGN also added as a noise. Rayleigh fading is a statistical model for the effect of a propagation environment on a radio signal, such as that used by wireless devices. Rayleigh fading models assume that the magnitude of a signal that has passed through such a transmission medium (also called a communication channel) will vary randomly, or fade, according to a Rayleigh distribution — the radial component of the sum of two uncorrelated Gaussian random variables. Rayleigh fading is viewed as a reasonable model for tropospheric and ionospheric signal propagation as well as the effect of heavily built-up urban environments on radio signals. Rayleigh fading is most applicable when there is no dominant propagation along a line of sight between the transmitter and receiver. Rayleigh fading is a small-scale effect. There will be bulk properties of the environment such as path loss and shadowing upon which the fading is superimposed. How rapidly the channel fades will be affected by how fast the receiver and/or transmitter are moving. Motion causes Doppler shift in the received signal components. The Rayleigh propagation model is most applicable to instances where there are many different signal paths, none of which is dominant. In this way all the signal paths will vary and can have an impact on the overall signal at the receiver.

2.6 Channel capacity

Channel capacity is the tight upper bound on the rate at which information can be reliably transmitted over a communications channel. The capacity over AWGN is expressed as,

$$C = Blog_2\ (1+\gamma)$$

where gamma is the signal to noise ratio at the receiver. If the capacity should be estimated over a fading channel, the SNR (or gamma) becomes a random variable.

2.7 Channel coefficient

The channel splits into multiple sections where each section has some growth. It is used to analyze the parameters that cause the growth of the channel. The channel coefficient matrix is expressed as,

$$\mathbf{H}_l = \begin{bmatrix} H_{11}^l & H_{12}^l & \cdots & H_{1M}^l \\ H_{21}^l & H_{22}^l & \cdots & H_{2M}^l \\ \vdots & \vdots & \ddots & \vdots \\ H_{N1}^l & H_{N2}^l & \cdots & H_{NM}^l \end{bmatrix}$$

2.8 Diversity combining

Diversity combining is the technique applied to combine the multiple received signals of a diversity reception device into a single improved signal. When the required signal is combination of several waves (i.e. multipath), the total signal amplitudes may experience deep fades (i.e. Rayleigh fading) over time or space. The major problem is to combat these deep fades, which results in system outage. The most popular and efficient technique for doing so is to use some form of diversity combining. Its basic principle is to create multiple independent paths for signal and combine them in an optimum or near optimum way.

2.8.1 Maximal ratio combining

Maximal ratio combining (MRC) is used when DF is applicable. The received signals are weighted with respect to their SNR and then summed. Fig-7 shows the working of MRC technique. Here the resulting SNR yields $\sum_{k=1}^{N} SNR_k$ where SNR_k is the SNR of the received signal k.

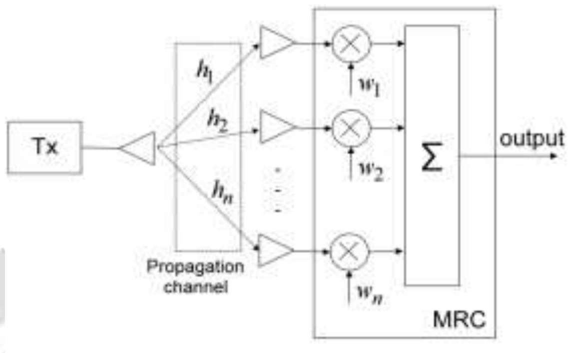

Fig-7: Maximal ratio combining

2.8.2 Equal gain combining

Equal gain combining (EGC) is used when AF is applicable It is a simplified version of MRC. All the received signals are summed coherently with equal gain. The proposed system integrates the technique of adaptive relaying in a CR based environment and also consider the power allocation at the relaying and the distribution of the subcarriers to the relay. The problem now is how to allocate optimally the power at the transmitters (S and R) to reach high capacity using ARP and without causing harmful interference to the primary user from the cognitive transmitters. The solution for this problem is proposed by an algorithm based on the sub gradient method. For simplicity, first the subcarrier is selected and assumed that the relay uses the same sub-carrier for receiving (from S) and for transmission (to D) in second time slot, besides we used random selection of carrier from S-R to R-D and compared the performances of both schemes.

2.9 Demodulation

The QAM demodulator is very much the reverse of the QAM modulator. The signals enter the system, they are split and each side is applied to a mixer. One half has the in-phase local oscillator applied and the other half has the quadrature oscillator signal applied.

2.10 Destination

Similar to the transmitter 4 antennas are used at the receiver. The receiver receives the information by cross over the listed modules and reach the destination here we compare the communication with source it is good or not. BER is analyzed only at the destination.

3. WATER FILLING ALGORITHM

The proposed algorithm is water filling algorithm, which is used for power optimization. Water filling algorithm is a general name given to the ideas in communication systems design and practice for equalization strategies on communications channels. As the name suggests, just as water finds its level even when filled in one part of a vessel with multiple openings, as a consequence of Pascal's law, the amplifier systems in communications network repeaters, or receivers amplify each channel up to the required power level compensating for the channel impairments. Since the water filling algorithm is a power optimization algorithm it plays an important role in allocating the power to the sub channels. Due to the usage of relay, more power is consumed by each channel, so optimum usage of power is important for effective communication. Thus to optimize the power, we use this algorithm to allocate power to each channel. Due to this power optimization strategy, throughput can be increased easily. Here the total power is sub-divided and a sufficient amount of power is allocated to each and every channel. Then each channel is checked for its power available. Once the power of the channel is consumed, then the power is reallocated to the channel. Likewise the power allocation to the channel is performed iteratively.

After sorting the CSNR from largest to smallest, we begin to apply the water-filling procedure as shown in fig-8 to the set of sub channels to allocate overall available energy. After execution of the water-filling algorithm, we compare the energy so obtained for the first sub channel to the second. If it does not exceed, then the overall procedure ends, and the resulting distribution for the input energies coincides with that achievable via the standard water-filling procedure. On the contrary, when it is greater then, we clip to, reduce the available total energy by, and start a second water-filling procedure. This last procedure operates only on the remaining sub channels of index ranging from 2 to and attempts to allocate to them a total energy equal. More in general, at the beginning of the iteration of the algorithm, we have and therefore, we proceed to apply the water-filling procedure only to the last sub channels with the overall energy set to. If the energy so obtained for the input of the channel is less (or equal) than, then the procedure stops; in the opposite case, is clipped to, is reduced by, and a new iteration of the water-filling algorithm is started over the last sub channels.

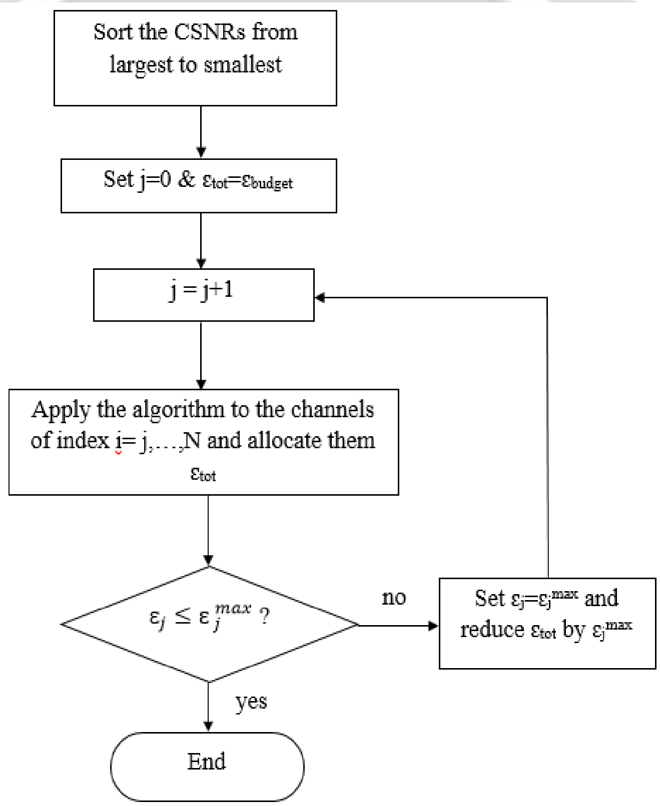

Fig-8: Flowchart of water filling algorithm

4. RESULTS AND DISCUSSION

The expected results of our system is produced by means of simulations using MATLAB software. This gives four types of graphs. They are,

- Performance evaluation of 8, 16, 32, and 64- QAM.
- Plot of MRC and EGC techniques.
- Plot of power optimization.
- Plot of matched and random pairing.

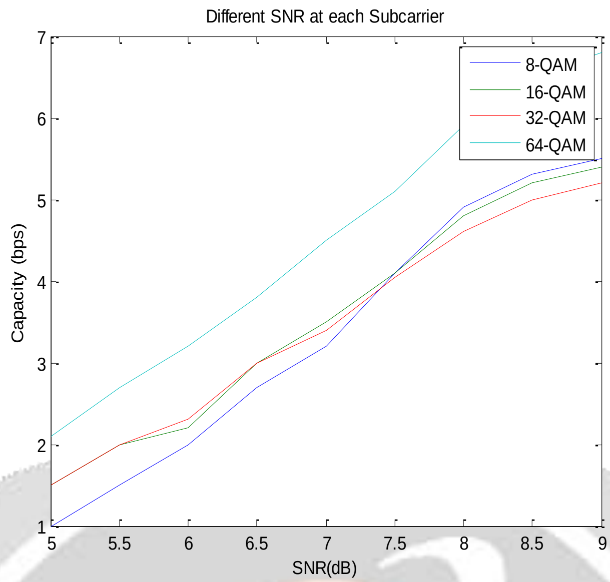

Fig-9: Performance plot of types of QAM

Fig-9 compares the different types of QAM with their capacity and SNR achieved by them. Here the common thing is that as the SNR increases the capacity also increases. This graph also infers that when the number of subcarriers increases the capacity and the SNR also increases correspondingly. Generally the SNR should be high for effective communication. Here the communication will be more effective for 64 - QAM when compared to the other types of QAM.

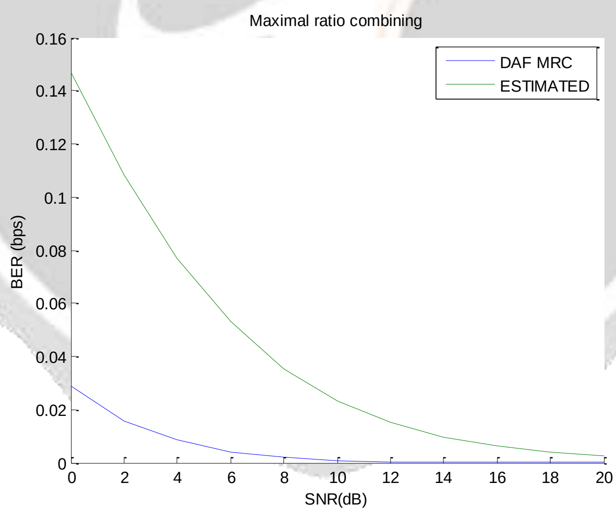

Fig-10: Plot of MRC

Fig-10 shows that the practical value of MRC is compared with the estimated value. This technique also achieves a signal to noise ratio more than 20 dB. MRC technique has a normal bit error rate of 0.03 bps at the start and gradually decreases as the signal to noise ratio increases. It yields better results than the estimated values.

From fig-11, this technique approximately achieves a signal to noise ratio of 20 dB. The estimated EGC is compared with the practically achieved result. Here this technique has a normal bit error rate of 0.14 bps at the start and gradually decreases as the signal to noise ratio increases. Moreover this graph produces a high signal to noise ratio as compared to the estimated result. And also the bit error rate is decreased more than the estimated value.

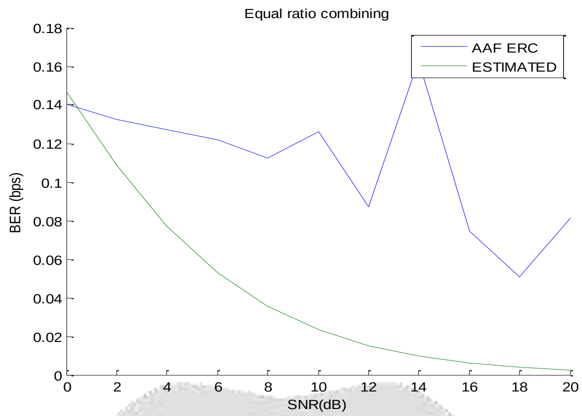

Fig-11: Plot of EGC

Power optimization technique can be analysed using the plot of power in fig-12. Here the power allocated for each subcarrier is compared. Also the estimated values are compared against the practical values. This graph shows that the power for each subcarrier increases as the number of bits per sub carrier increases.

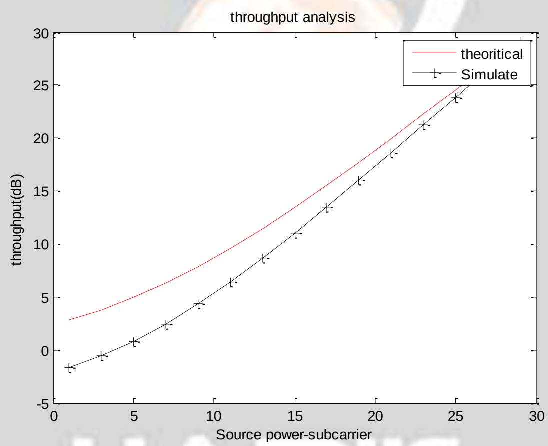

Fig-12: Plot of power optimization

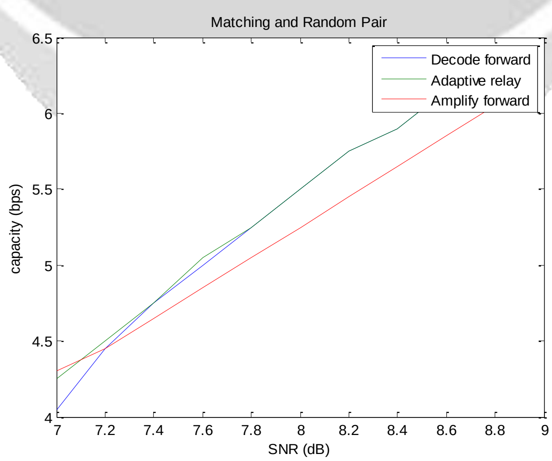

Fig-13: Plot of matched and random pairing

Fig-13 shows the graph of pairing. This graph gives the relationship about how much of the information has been transmitted and how much has been received. Matched pairing implies that the transmitted information has been received fully. Whereas random pairing depicts that the transmitted information has not been received fully. This is helpful in finding the data loss at the receiver. This also depicts that the matched pairing occurs when MRC technique is employed and random pairing occurs if EGC technique is employed.

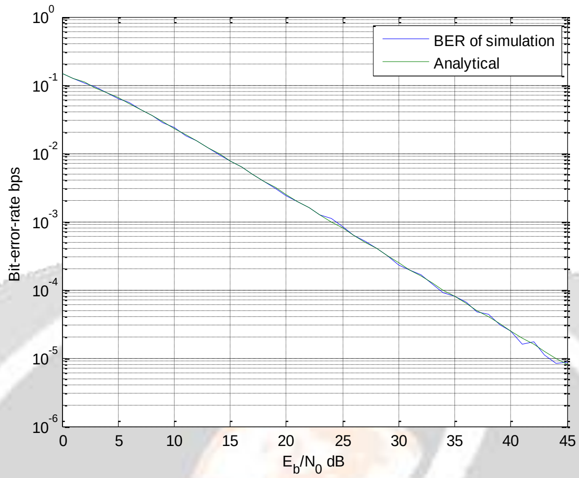

Fig-14: Plot of BER vs. SNR

Fig-14 is the final graph of the overall system which compares the bit error rate with the signal to noise ratio achieved. Here the Quadrature Amplitude Modulation technique is used, which produces high performance by increasing the signal to noise ratio and decreasing the bit error rate. This system is constructed to achieve a high SNR of approximately 45 dB.

5. CONCLUSION

The proposed system concludes that the various disadvantages faced by employing spatial modulation technique is been overcome by using QAM technique. Due to this the BER is reduced drastically upto 10^{-5} and which inturn increases the SNR of the system upto 45 dB. Also the throughput of the system has also been increased due to the application on the power optimization algorithm. Also here a near optimal power allocation algorithm in cognitive radio OFDM-based with adaptive relaying protocol is presented. The complexity of this algorithm is that we allocate jointly the power in source and relay by ensuring the interference constraint and choose the type of relay in an adaptive way. This algorithm distributes jointly the power in source and relay so that no excessive interference is introduced to the primary user. The proposed algorithm achieves a near optimal performance, which depends largely on the pairing technique.

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