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Improving the QAM Performance by using RSBC, Alamouti STBC and Interleaving over Rayleigh Fading Channel in Wireless Communication Applications

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Abstract: The aim of the paper is to improve the performance of QAM which is, one of the widely used modulation technique in the digital wireless communication that founds applications in DVB-T, DVB-C, modems, HSPA, LTE, LTE-A, microwave, and satellite systems, over a fading channel. Quadrature amplitude modulation (QAM) is a widely used method for transmitting digital data over the bandpass channels. In a communication channel, fading is one of the major issues among all, which degrades the performance of the systems to a great extends therefore it is necessary to reduce the effect of fading in order to improve the performance of the system in terms of bit error rate. Since the errors are introduced by the transmission medium we need to use a method that can be used to detect the errors and correct the errors. In order to achieve this, the error detection techniques and error correction techniques are used. These techniques increase the bandwidth requirement, but they provide reliable communication. An Almouti 2 X 2 STBC diversity technique is use to scale down the effect of fading whereas for error detection and correction the Reed-Solomon codes are used and the error rate is improved by the Interleaver. The model is implemented and investigated using Simulink (MATLAB) simulation. Firstly the performance of the QAM is analyzed over a fading channel then the performance of QAM along with RSBC, Alamouti STBC and Interleaving is compared with it, to comment on the benefits of the applied techniques.

Keywords: Bit error probability, DVB-T, LTE, LTE-A, QAM, RSBC, STBC, and Interleaver.

I. INTRODUCTION

In the today's world most digital communication systems are highly band-limited because the usable spectrum resources are severely congested. As a result, system architects must consider the bandwidth-efficient modulation technique as the highest priority in the assigned channel. Nevertheless, in many applications (such as phone modems, microwave terrestrial links, satellite communications, wireless mobile communications, etc.), the bandwidth is limited, and the objective is to transmit with the highest possible data rate in the given bandwidth. The demand of high data rates in digital wireless applications continues to grow at an exponential rate. The limited availability of spectrum makes achieving high data rates in digital wireless communications challenging objective. Therefore it is very necessary to make the efficient utilization of the available bandwidth which is possible by choosing an appropriate modulation technique.

The Modulation is the process of transforming an incoming stream of information into a format that is suitable for transmission over a medium. Digital modulation consists of mapping the information bits into an analog signal for transmission over the channel. The main factors or elements for choosing any digital modulation technique are they should have a high rate of data transmission with high spectral and power efficiency i.e. minimum bandwidth requirement and low transmission power is needed, should be capable of handling channel impairments i.e. minimum probability of bit error and its implementation should requires low power and cost. Most of the times fulfilling all these requirements are not possible always and therefore technique must be chosen that gives the best desired result. More importantly, digital modulation offers a number of advantages over analog modulation, including higher spectral efficiency, powerful error correction techniques, resistance to channel impairments, more efficient multiple access strategies and better security and privacy. For all these reasons, systems currently being will or proposed for wireless applications are all digital systems.

Specifically, high-level digital modulation techniques such as M-QAM allow much more efficient use of spectrum than is possible with analog modulation. M-ary Quadrature Amplitude Modulation (M-QAM), simply known as QAM, is

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employed in many digital communication systems, including 16-QAM, 64-QAM, and 256-QAM in DOCSIS, an international telecommunications standard to provide high-speed Internet access over cable TV. Other applications of QAM lie in broadband digital cellular standards, such as LTE, WiMAX, as well as public safety standards, such as TETRA, and TV white spaces, such as cognitive WRAN.

When the modulated signals are transmitted over a channel the transmitted signal is distorted because of nonlinearities and imperfections in the frequency response of the channel. The Other sources of signal degradation during the transmission through the channel are noise and interference which is the basic limitations in the digital communication systems design. There are various sources of noise, internal as well as external to the system. Although noise is random in nature, it may be described in terms of its statistical properties such as the average power or the spectral distribution of the average power. The performance of a communication link is degraded by many transmission impairments including fading, delay spread, doppler spread, co-channel and adjacent channel interference, noise, and receiver implementation losses. Other than the inter symbol interference (ISI) that occurs via channel filtering it can also arise when the signal is transmitted over a multipath fading channel. This type of channel is existed in all kind of mobile and wireless communication application.

In a multipath fading, the signal arrives at the receiver end by following a multiple path. These paths are generally existed due to the signal reflection from the ground, buildings, hills, and other large structures. They can also arise from signal diffraction caused by the corners of the buildings or sliding across rooftops. They also can arise by signal scattering from objects like trees, lamp posts, vehicles, etc. Where each of the signal paths results in to a randomly delayed, phase-shifted and attenuated copy of the signal transmitted. These multipath signal copies are combine at the receiver, giving rise to the received signal whose envelope can be described by a rayleigh fading process (i.e. no line-of-sight path), or by the rice fading process (i.e. one line-of-sight path), or a Nakagami fading process. Also, since the multipath copies arrival times are random, especially in case of a mobile environment, these multipath components might overlap the next symbol or bit that causes the inter symbol interference. Such kind of ISI is not possible to eliminate by the pulse shaping precept by the Nyquist criterion for zero ISI, but can be reduced by the equalization. All these effects are collectively called as a fading. A kind of fading channel that have an inter symbol interference is called a frequency-selective fading channel whereas a channel that exhibits least inter symbol interference is called as the flat fading channel.

The Fading causes a very low instantaneous received signal-to-noise ratio (SNR) or carrier-to-noise ratio (CNR) when the channel exhibits a deep fade, delay spread causes inter symbol interference (ISI) between the transmitted symbols, and a large Doppler spread is indicative of rapid channel variations and may necessitate a receiver with a fast convergent algorithm. Receiver implementation losses include carrier frequency offset, sample clock frequency offset, symbol timing errors, and channel estimation errors. Co-channel interference, adjacent channel interference, and noise are additive impairments that degrade the bit error rate performance by reducing the SNR or CNR.

The Diversity techniques are widely used to reduce the effects of multipath fading and improve the reliability of transmission without increasing the transmitted power or sacrificing the bandwidth. Because the transmission channel causes the errors in the transmitted bit stream, it is therefore needed to incorporate the error detection techniques. If the errors have been detected by the receiver, then it can ask for the retransmission. In order to reduce the rate of such retransmission the error correction techniques is needed. In order to reduce the redundancy in the signal the source coding techniques are employed in communication. Since the errors are introduced by the transmission medium, we need to find a method that can be used for either detection of the errors or correction of the errors or both. In order to achieve this, the error detection techniques and error correction techniques are used. Utilising these techniques causes the bandwidth need to grow up but end at the better communication or transmission.

In digital communication system, an important design parameter is the Bit Error Rate (BER). To achieve a good BER (to reduce the bit errors as much as possible), the Signal to Noise Ratio (SNR) should be high. The ratio E_b/N_o is the fundamental measure of signal quality which is closely related to the SNR. SNR and E_b/N_o, are related by the formula $E_b/N_o= S/N_o\,R$ where E_b is the energy per bit or the bit energy, N_o is the noise power density in watts/Hertz. The total noise in a signal with bandwidth of B is given by $N = N_o \times B$. Hence, $E_b/N_o= (S/N)\,(B/R)$. The BER can be reduced by increasing the E_b/N_o, value, which can be achieved either by increasing the bandwidth or by decreasing the data rate or bit rate or transmission rate R.

The performance of a digital communication system is measured in terms of the Bit Error Rate (BER). BER is measured in terms of the ratio of the number of bits in error as a percentage of the total number of bits received. BER = number of bits received in error / total number of bits received. Depending on the application, the BER requirements vary. For applications such as banking, a very high BER is required, of the order of 10^{-12} i.e., out of 10^{12} bits only one

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bit can go wrong (even that has to be corrected or a retransmission requested). For applications such as voice, a BER of 10^{-4} is acceptable. BER is dependent on the modulation technique used. The performance in terms of the BER also is dependent on the transmission medium.

Thus in this paper we have chosen QAM as the one of the modulation technique that found applications in digital wireless communication systems like DVB-T, DVB-C, modems, HSPA, LTE, LTE-A, operating over rayleigh fading channel whose performance will be analysed first in terms of bit error rate and then by using a diversity technique along with the source coding and channel coding we will analyse the change in the bit error rate performance of the QAM modulation technique so that it can be effectively used in the various applications.

Radio signals generally propagate according to three mechanisms; reflection, diffraction, and scattering. Reflection is occurs when the plane waves are incident upon any surface with dimensions that are very large when compared to the wavelength. Whereas diffraction arises as per the Huygen's principle whenever there is any object between the transmitting and receiving antennas, secondary waves are get generated that arises behind the obstructing body. The scattering is occurred due to the reflection of the plane waves when incident on the object, whose dimensions are on the order of a wavelength or less. As a result, energy of the waves gets radiated in the various directions. In a terrestrial environment, the multiple signals are present as a result Multipath signals are received i.e. different variations of the signals is propagated in the environment that reaches to the receiver from the transmitter through various paths.

In addition, the movement of transmitter or receiver or the surrounding clutter in it results in the amplitude or phase changes in the overall received signal for the small amount of time that causes the fading. The main effects of the multipath fading are rapid variations in the strength of a signal when travelled over a small distance or interval of time. On different multipath signals due to variations in the doppler shifts results into a random frequency modulation. Multipath propagation delays result into the echoes or time dispersion. The problem can be solved by following two different ways firstly by adding margin to the fading on the transmitter but it is not considered to be an effective solution for this, therefore another method that can be used is to receive the two or more variations of the signal at the receiver ensuring the correlation between them. So, the system performance in fading channels is improved by the diversity technique.

Rather than receiving and transmitting the required signal using one channel, we use the multiple copies of the required signal that are transmitted over the different channels. In order to provide a diversity, gain, the space-time block coding utilizes the high algebraic structure. The multiple transmit & receiver antennas increase the diversity, which results in high SNR.

The QAM is one of the digital modulations type or scheme that provides the greater rate of transmission for the wireless communication systems along with the high spectral efficiency and for that it is not necessary to increase the bandwidth of the channel. QAM, combined with other schemes, has gained great attention in overcoming detrimental channel impairments. QAM is widely used because it comprises of amplitude as well as phase, that helps in correcting the QAM signal when get corrupted. The Quadrature Amplitude Modulation (QAM) is simply a combination of AM and PSK, in which two carriers out of phase by $90^0$are amplitude modulated. The 16-QAM is used in various applications such as DVB-C (digital video broadcasting—cable), modems and microwave digital radio. The 16-QAM or other higher-order QAMs (64-QAM, 256-QAM) are more bandwidth efficient than BPSK, QPSK, or 8PSK and are used to gain high-speed transmission.

The performance of Quadrature Amplitude Modulation (QAM) scheme is measured by estimating its probability of error produced by noise and interference induced in the channel. Because of the fading in a wireless communication system during transmission leads to an error at the receiver end. The number of errors that are likely to occur in the system is expressed as the bit error rate (BER). The bit error ratio or bit error rate (BER) is the number of bit errors corresponding to the total number of transferred bits in a studied time interval. The BER is given as the ratio between the Errors and the total Number of Bits, whereas the bit error probability indicates the value of the expectation for the bit error rate. The bit error rate, which is the approximation of the bit error probability is said to be accurate in the long time interval and for a high number of bit errors.

In this paper, we analyze the performance of QAM scheme which is degraded due to multipath fading by employing various schemes and coding techniques like reed-soloman block coding, interleaving, and almouti STBC. For that, we calculate the probability of bit error rate of Quadrature Amplitude Modulation (QAM) over Rayleigh fading and additive white Gaussian channels with Reed-Soloman block coding, interleaving and almouti STBC. For the above analysis, a QAM modulation technique that has 16, 64 etc. constellation points are used along with reed soloman block coding whose order depends on the order of QAM selected, matrix interleaving, and almouti STBC of order the order of 2 X 2. While the model is developed and analysed by Simulink MATLAB software with relevant toolboxes.

II. MAIN CONSTITUENTS OF THE SYSTEM.

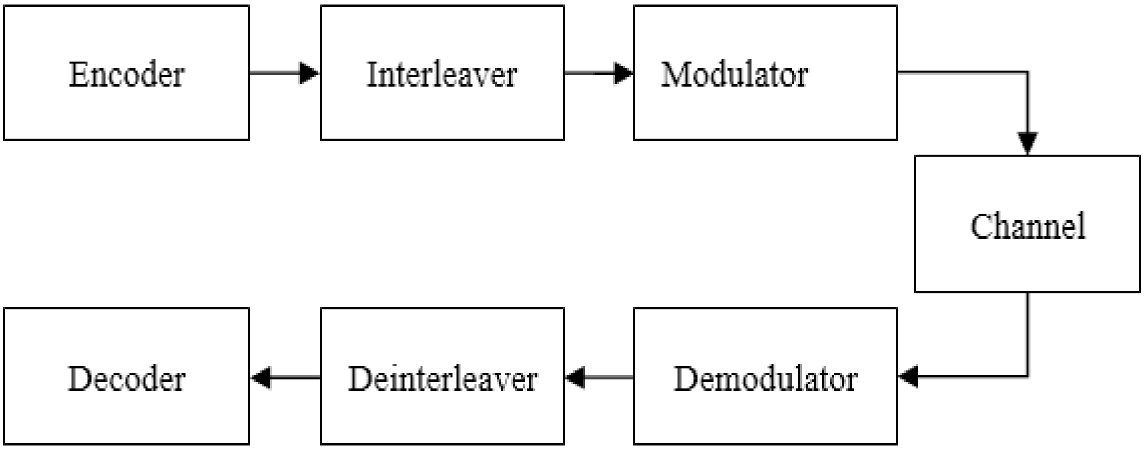

Fig. 1. Block diagram of the basic system.

Figure 1 shows the generalized block diagram representation of the system which basically consists of transmitting and receiving section. On the transmitter side there is encoder which encodes the incoming bits of stream, followed by an inter leaver that rearranges the stream of bits that helps in spreading the burst error which is then applied to the modulator that modulates the signal which is then transmitted through the channel. On the receiver side the received signal is first demodulated and applied to the de inter leaver which spreads the burst error followed by the decoder that finally decodes the signals, results into an original stream of data bits.

III. SIMULATION & ANALYSIS

The different models are developed by using Simulink simulation tool in Matlab which is a graphical tool making it more popular in building and simulation of the models because of its simplicity of implementation and ease of analysing options available when compared with the Matlab. The process of simulation begins with simple implementation of model to observe the effect of AWGN and rayleigh channel on the signal constellation for the case 16-QAM is considered, other orders of QAM can also be considered.

The model is build up by using the four major blocks are random integer generator which acts as a source, QAM baseband modulator, AWGN and rayleigh channel, and scopes to observe the effect of two different channels on the performance or on the signal constellation points in a scatter plot. Simulating the above model will give the scatter plot. The aim of building this model is to show the effect of AWGN and rayleigh channel on the transmitting signals. The next model which is build up is to know the effect of rayleigh channel on the bit error rate.

In this the model is simulated with a single rayleigh channel path to see the effect on the bit error rate value which is then simulated for the multipath. The model is build up by using random integer generator, QAM modulator and demodulator, rayleigh channel and error rate calculation block to know how much errors are generated during the signal travels from source to demodulator.

The simulation is performed on the models by setting up various block parameters as per the simulation requirements. In order to improve the bit error rate reed solomon block coding, almouti space time block coding and interleaving techniques is introduced in the model instead of utilising all of them at a time we will add each technique associated blocks into the model step by step and see its effect on the error rate value.

The reed solomon encoder and decoder blocks are used in the next model to observe the changeover in the error rates. By setting up appropriate parameter values of the blocks for the simulation of model will give the resultant for bit error rate value.

After that interleaver and deinterleaver blocks are introduced in the model that actually used to spread the any kind of burst error in the data sequence observing the simulation result for it and the final model is build up with the use of Almouti 2 X 2 STBC in the existing model and obtaining the final bit error rate value that can be compared with the previous model bit error rate values.

IV. RESULT AND CONCLUSION

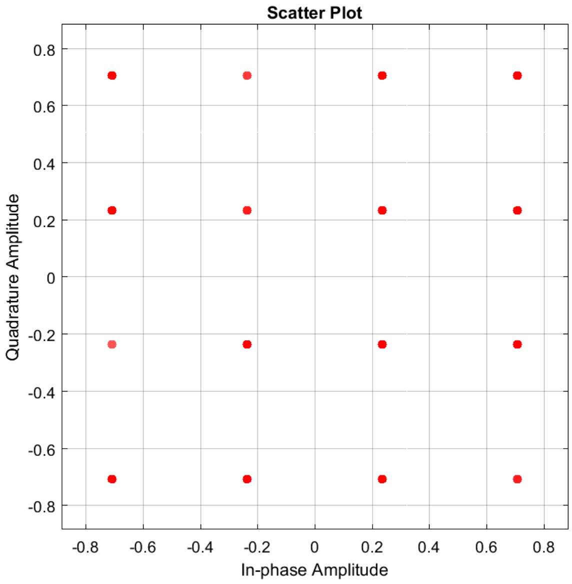

Figure 4.2 The signal constellation with 16 precisely located points.

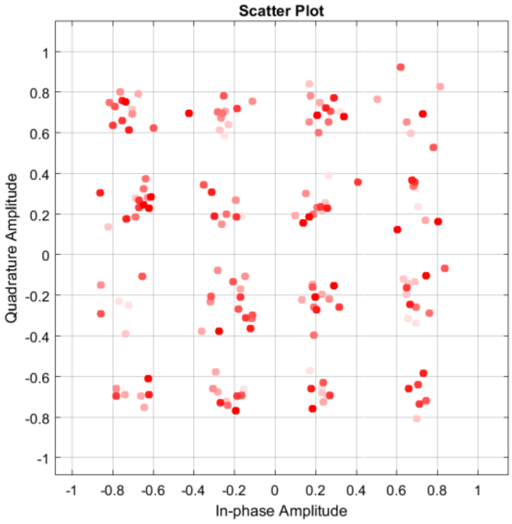

Figure 4.3 A small cluster of points caused by the noise.

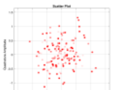

Figure 4.6 Scatter plot showing the Spreading of the signal constellation points due to Rayleigh Fading.

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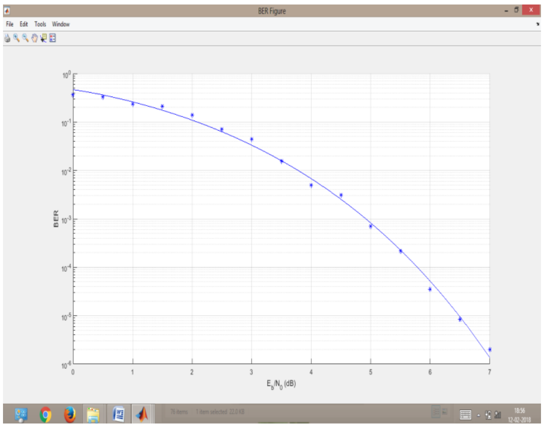

Figure 4.9 Plot for the 16-QAM in Rayleigh fading channel.

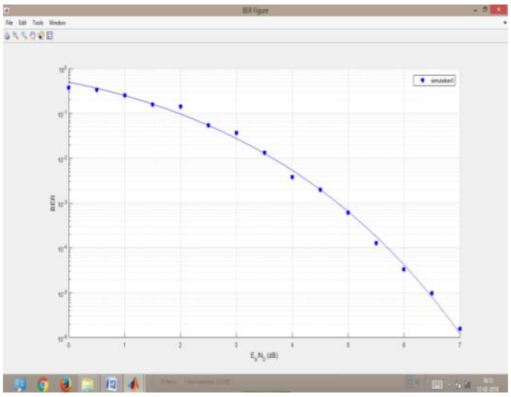

Figure 4.12 Plot for the 16-QAM in Rayleigh channel model comprising of Rayleigh fading block, AWGN block, math function block.

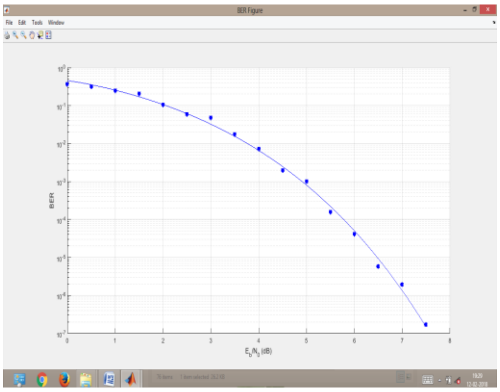

Figure 4.15 Plot for the 16-QAM in Rayleigh channel with RS encoder and decoder.

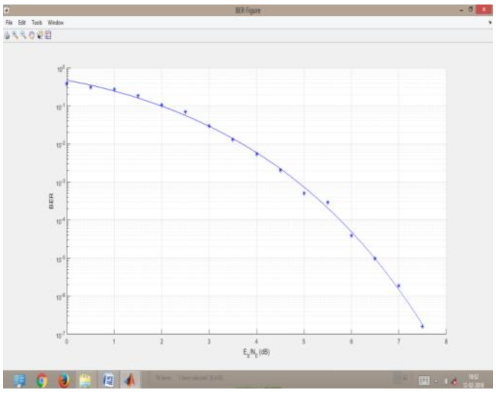

Figure 4.18 Plot for the 16-QAM in Rayleigh channel with RS encoder & decoder and interleaver.

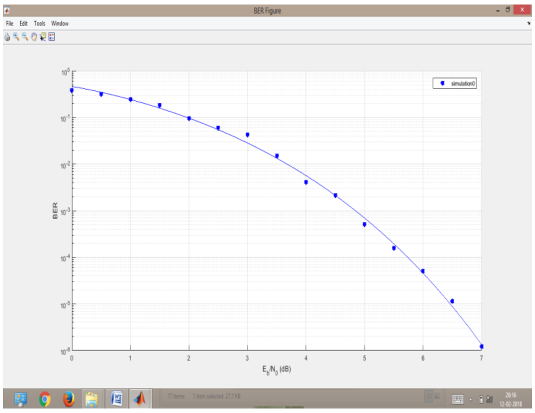

Figure 4.22 Plot for the 16-QAM in Rayleigh channel with RS encoder & decoder, interleaver and STBC.

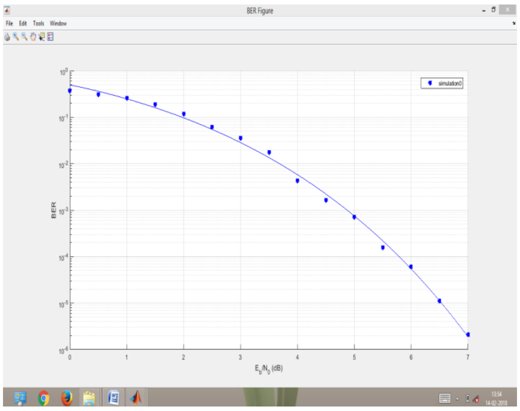

Figure 4.25 Plot for the 64-QAM in Rayleigh channel model comprising of Rayleigh fading block, AWGN block, math function block.

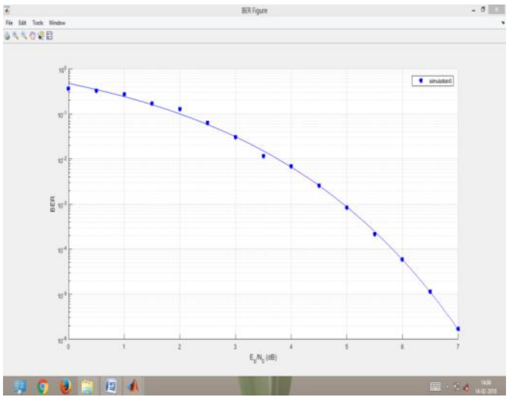

Figure 4.28 Plot for the 64-QAM in Rayleigh channel with RS encoder & decoder, interleaver and STBC.

The figure 2 and figure 3 shows the scatter plot in which the constellation points are place at a correct position while due to the presence of additive white gaussian noise in the channel the constellation points spread up resulting into the formation of small clusters around the constellation points indicating the possible position of a constellation point on a scatter plot after the signal is subjected to AWGN channel. The simulation shows the effect of AWGN on signal when the signal is transmitted over it. In the next case a similar kind of simulation is performed but this time instead of AWGN channel, a channel assumed to be rayleigh channel for that a rayleigh fading block is used. The Multipath Rayleigh Fading Channel block is used to implement the multipath rayleigh fading channel. The block is used to model mobile wireless communication systems. The simulation of a simulink model shows how the signal constellation points are spread up when signal is subjected to rayleigh channel results into formation of a cluster of points shown in figure 4. In the next Simulink model the efforts has been made to obtain the BER performance for the QAM in rayleigh fading channel. Prior to developing BER results for QAM in rayleigh fading channel with multipath component, it is worthwhile to investigate the characteristics of the rayleigh channel using the simple model with single path. The simulation result shows the bit error rate of 0.2186 also the same result can be visualise in terms of graphical representation as a plot between BER vs. Eb/No shown in figure 5. The plot BER vs. Eb/No is obtained by using the BERTool application. The Simulink model simulates the communication system whose performance wants to study, while BERTool manages a series of simulations using the model and collects the BER data. The result obtained here is for the simple rayleigh channel model, from which it is clear that the rayleigh channel affects the modulated signal.

The model shown modified to investigate the effect of rayleigh fading channel with multipath component. A simulink model allows the BER performance in the presence of multipath to be readily estimated. This capability, provided by simulink, is important since estimation of BER in the presence of multipath is not easily obtained analytically. figure 6. provides BER results for QAM in rayleigh fading channels respectively. The simulation results into the bit error rate 0.06053 which is quite low as compared to the bit error rate in the previous case this is due to the multipath component with ideal conditions and block parameters assumed for simulation. The first effort made in reducing the BER is utilizing the RS codes; a simulink model is developed for that, simulating the model shows the improvement in the BER as compared to the previous case. The associated result is shown in figure 7, from which it is very clear that the bit error rate is improved to 0.03681 when the result is compared with the bit error rate without the enclosing the reed solomon code. In the next case the model is modified with addition of interleaver/deinterleaver blocks in order to further improve the bit error rate for QAM the corresponding model simulated which shows that the bit error rate value of 0.02886, the bit error rate is reduced to some extent, the associated BER plot is shown in figure 8. Finally the model is developed with the almouti STBC technique, the effort is made in order to reduce the bit error rate further. When the model is executed shows the result as per the expectation with further reduction in the value of bit error rate for QAM to about 0.009623 also can be seen from the BER plot shown in figure 9. All the above simulation results are completely associated with the quadrature amplitude modulation having sixteen constellation point but the same techniques can be employed to other higher order QAM. For the case the simulation for 64-QAM is conducted, that result into the similar kind of results as expected shown in figure 10 and figure 11. Thus from the above simulation result and response it is evident that it is possible to reduce the bit error rate to great extent by employing RS coding, interleaving and diversity techniques in applications based on quadrature amplitude modulation transmission.

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