DOI: 10.21917/ijct.2011.0040

BER PERFORMANCE COMPARISON OF MULTIPLE ANTENNA USING SPACE TIME BLOCK CODED OFDM SYSTEM IN MULTIPATH FADING ENVIRONMENT

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Abstract

Present wireless communication systems uses FDMA, TDMA and CDMA techniques and are facing various issues like multipath fading, time dispersion which leads to inter symbol interference (ISI), lower bit rate capacity and less spectral efficiency. In a conventional terrestrial broadcasting, the transmitted signal arrives at the receiver through various paths of different lengths. Hence multiple versions of the signal interfere with each other and it becomes difficult to extract the original information. The use of Space Time Block Coded (STBC) Orthogonal Frequency Division Multiplexing (OFDM) technique provides better solution for the above issues. In this paper, we study the Bit Error Rate (BER) performance of STBC OFDM system employing BPSK, QPSK and QAM modulations. As STBCs have been derived from Generalized Complex Orthogonal Designs (GCOD), the norms of the column vectors are the same (e.g., Alamouti Code). We present an analysis of how multiple transmitting antennas and one receiving antenna produces reduced BER at lower value of SNR. From the simulation results, we observed that the BPSK allows improved BER performance over a noisy channel at the cost of maximum data transmission capacity. But the use of QPSK and QAM allows higher transmission capacity at the cost of slight increase in the probability of error.

Keywords:

Generalized Complex Orthogonal Design, Space Time Block Code, Alamouti Code, OFDM, Antenna Diversity

1. INTRODUCTION

To improve the BER performance of a wireless transmission system in which the channel quality fluctuates, it suggested that the receiver should be provided with multiple received signals generated by the same underlying data. These suggestions are referred as diversity which exists in different forms such as temporal diversity, frequency diversity and antenna diversity. Temporal diversity includes channel coding in conjunction with time interleaving which involves redundancy in time domain. Frequency diversity means transmission of different frequencies which provides redundancy in frequency domain. Antenna diversity can be viewed as redundancy in spatial domain and implemented by using multiple antennas at both transmit side (base station) and the receive side (mobile units).

Space time coding refers channel coding technique for transmissions with multiple transmit and receive antennas. STBCs are simple, but effective tool to obtain transmit diversity in MIMO communication channel. Orthogonal STBCs designed for more than two antennas can achieve full diversity order but they have code rate less than unity. It is known that the BER performance of orthogonal STBCs can be simply obtained from existing analytical results for receive diversity maximal ratio combining (MRC) with the same diversity order by appropriately scaling the SNR.

In [7], a two antenna system at both the transmitter and receiver side employing STBC using 4 PSK and 16 QAM was simulated. But the SNR in range of 19dB is required to achieve BER of 10^{-2} over AWGN channel. In [8], A wireless communication system employing simple diversity technique using one transmitting antenna and two receiving antenna with BPSK modulation was simulated. But the SNR in the range of 28dB is required to achieve BER of 10^{-5} over Rayleigh faded channel. In [9], a system with two, three, and four transmit antenna at the transmitter employing STBC using PSK and QAM modulations over Rayleigh faded channel has been studied. In all the above systems, the BER performance with maximum of 4 antenna diversity has been simulated and only single orthogonality has been provided by STBC to achieve system security.

In this paper, we simulate and compare the BER performance of STBC OFDM system using BPSK, QPSK and QAM modulation schemes with 2, 4 and 8 transmitting antennas. The combination of STBC and OFDM provides double orthogonality to the transmitting signal and improves security during transmission of data.

The paper is organized as follows: Section 2 provides the system model. In Section 3, we present the orthogonalization in multipath channels using STBC. Section 4 discusses about orthogonalization in multipath channels using OFDM and in section 5, we present and discuss the simulation results. Conclusions are given in Section 6.

2. SYSTEM MODEL

Consider a wireless communication system with ‘n’ transmitting antennas and ‘m’ receiving antennas. Assume that the m × n channel matrix (H) is static for the code length which has ‘p’ time slots. The entries of H , (h_{ij}’s) are independent complex Gaussian random variables (i.e., the fade amplitudes are Rayleigh distributed). The m × 1 receive vector, y_t at time slot‘t’ can be expressed using Eq. (1).

$$y_t = Hx_t + n_t \qquad (1)$$

where x_t is the transmitted n×1 complex symbol vector at time t, and n_t is the m×1 noise vector with independent zero mean complex Gaussian random variables with variance No/2.

For a code length p, the transmitted code block X is given by $X=[x_t, x_{t+1}, x_{t+2,\ldots\ldots}, x_{t+p}]^T$,where$[.]^T$ represents the transpose operation. The corresponding received code block Y can be expressed using Eq. (2).

$$Y = \sim X + n \tag{2}$$

where $\sim$ is the block diagonal channel matrix given by Eq. (3).

$$\sim = \begin{pmatrix} & 0 & \ldots 0 \\ 0 & & \ldots 0 \\ 0 & 0 & \ldots H \end{pmatrix} \tag{3}$$

and the noise block n is given by $n = [n_t, n_{t+1}, n_{t+2,\ldots\ldots}, n_{t+p}]^T$. If $s(l) = Ve^{j\Phi l}$, $l = 1,2,\ldots k$ are the complex symbols taken from BPSK, QPSK or QAM signal set to be transmitted in p time slots, the transmitted code block X can be expressed in the form given by Eq. (4).

$$X = Av \tag{4}$$

where v is a 2k × 1 vector, given by Eq. (5).

$$v = [v_{1I}, v_{2I}, \ldots\ldots v_{kI}, v_{1Q}, v_{2Q}, \ldots\ldots v_{kQ}] \tag{5}$$

where v_{lI} and v_{lQ} respectively are real and imaginary parts of the l^{th} complex symbol, s(l). A is the np × 2k complex matrix which performs the space time coding on v**.** Now $A = [A_1, A_2, \ldots\ldots A_p]$, where A_i performs the linear operation at time slot i. Using this the received code block Y given in Eq. (2) becomes

$$Y = H_{eq}v + n \tag{6}$$

where $H_{eq} = \tilde{H}A$ is a mp × 2k equivalent channel matrix. For example, for Alamouti code with one receive antenna (i.e., n=k=p=2 and m=1), A, H_{eq}, and v are given by the following Eqs. (7) to (11).

$$A = \begin{pmatrix} 1 & 0 & j & 0 \\ 0 & 1 & 0 & j \\ 0 & -1 & 0 & -j \\ 0 & -j & 0 & -1 \end{pmatrix} \tag{7}$$

$$A_1 = \begin{pmatrix} 1 & 0 & j & 0 \\ 0 & 1 & 0 & j \end{pmatrix} \tag{8}$$

$$A_2 = \begin{pmatrix} 0 & -1 & 0 & -j \\ 1 & 0 & -j & 0 \end{pmatrix} \tag{9}$$

$$H_{eq} = \begin{pmatrix} h1 & h2 & jh1 & jh2 \\ -h2 & h1 & jh2 & -jh1 \end{pmatrix} \tag{10}$$

$$v = [x_{1I}, x_{2I}, x_{1Q}, x_{2Q}] \tag{11}$$

At the receiver, linear combining is performed. We assume that the channel matrix H is perfectly known to the receiver. We use the form of optimum decision metric for the orthogonal STBCs presented in[1], and is given by Eq. (12).

$$\tilde{Y} = R(H_{eq}^{*'}Y) = \Lambda v + \tilde{n} \tag{12}$$

where R(z) denotes the real part of z, Λ is a 2k × 2k diagonal matrix and $\tilde{n} = R(H_{eq}^{*'}n)$ where *' denotes the Hermitian operator. Hence, the optimal receiver, is taking the real and imaginary values from $\tilde{Y}$ and performing symbol by symbol detection. From (12), the decision metric for the l^{th} complex symbol is given by

$$Z(l) = \tilde{Y}(l) + j\tilde{Y}(l+k), \quad l=1,2,..k \tag{13}$$

The system model and the decision metric presented above are valid for STBC OFDM from both GCOD's as well as from COD's[3] – [4]. In [2], the equivalence of the above decoding to receive diversity MRC has been shown for equal-weight STBCs. The overall transmission system model is shown in Fig.1.

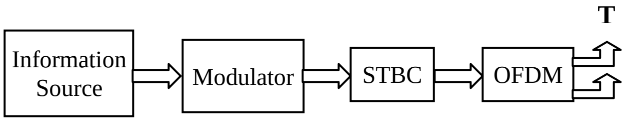


Fig.1. STBC OFDM transmitter

3. ORTHOGONALIZATION IN MULTIPATH CHANNELS USING STBC

The Alamouti code is the first STBC that provides full diversity at full data rate for two transmit antennas. A block diagram of the Alamouti space time coder is shown in Fig.2. The information bits are first modulated using a digital modulation scheme. The encoder takes the block of two modulated symbols S1 and S2 in each encoding operation and send it to the transmit antennas according to the code matrix S which is generated as given Eq. (14).

$$S = \begin{pmatrix} S1 & S2 \\ -S2* & S1* \end{pmatrix} \tag{14}$$

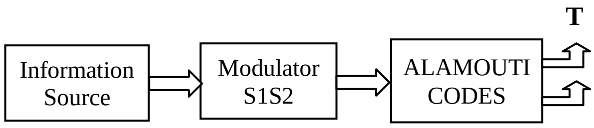


Fig.2. Alamouti space time encoder

The first and second row represents the first and second transmission period respectively. During the first transmission, the symbols S_1 and S_2 are transmitted simultaneously from antenna one and antenna two respectively. In the second transmission period, the symbol $-S_2^*$ is transmitted from antenna one and the symbol S_1^* from transmit antenna two. It is clear that the encoding is performed in both time (two transmission intervals) and space domain (across two transmit antennas).

The pioneering work of Alamouti has been a basis to create OSTBCs for more than two transmit antennas. Similar to the case of two transmit antennas, the encoder takes the block of four modulated symbols S1,S2,S3 & S4 in each encoding operation and send it to the transmit antennas according to the code matrix S_1 given in Eq. (15).

$$S_1 = \begin{pmatrix} S1 & S2 & S3 & S4 \\ -S2 & S1 & -S4 & S3 \\ -S3 & S4 & S1 & -S2 \\ -S4 & -S3 & S2 & S1 \end{pmatrix} \tag{15}$$

Using COD, the transmission matrix is given by the Eq. (16).

$$S = \begin{pmatrix} S1 & S2 & S3 & S4 \\ -S2 & S1 & -S4 & S3 \\ -S3 & S4 & S1 & -S2 \\ -S4 & -S3 & S2 & S1 \\ S1* & S2* & S3* & S4* \\ -S2* & S1* & -S4* & S3* \\ -S3* & S4* & S1* & -S2* \\ -S4* & -S3* & S2* & S1* \end{pmatrix} \tag{16}$$

Similarly the encoder takes the block of eight modulated symbols S1, S2, S3, S4, S5, S6, S7 & S8 and generates the transmission matrix S as given by the Eq. (17).

$$S_1 = \begin{pmatrix} S1 & S2 & S3 & S4 & S5 & S6 & S7 & S8 \\ -S2 & S1 & -S4 & S3 & -S6 & S5 & S8 & -S7 \\ -S3 & S4 & S1 & -S2 & S7 & S8 & -S5 & -S6 \\ -S4 & -S3 & S2 & S1 & S8 & -S7 & S6 & -S5 \\ -S5 & S6 & -S7 & -S8 & S1 & -S2 & S3 & S4 \\ -S6 & -S5 & -S8 & S7 & S2 & S1 & -S4 & S3 \\ -S8 & S7 & S6 & S5 & -S4 & -S3 & -S2 & S1 \end{pmatrix} \tag{17}$$

Using COD, the transmission matrix is given by the Eq. (18).

$$S = \begin{pmatrix} S1 & S2 & S3 & S4 & S5 & S6 & S7 & S8 \\ -S2 & S1 & -S4 & S3 & -S6 & S5 & S8 & -S7 \\ -S3 & S4 & S1 & -S2 & S7 & S8 & -S5 & -S6 \\ -S4 & -S3 & S2 & S1 & S8 & -S7 & S6 & -S5 \\ -S5 & S6 & -S7 & -S8 & S1 & -S2 & S3 & S4 \\ -S6 & -S5 & -S8 & S7 & S2 & S1 & -S4 & S3 \\ -S8 & S7 & S6 & S5 & -S4 & -S3 & -S2 & S1 \\ S1* & S2* & S3* & S4* & S5* & S6* & S7* & S8* \\ -S2* & S1* & -S4* & S3* & -S6* & S5* & S8* & -S7* \\ -S3* & S4* & S1* & -S2* & S7* & S8* & -S5* & -S6* \\ -S4* & -S3* & S2* & S1* & S8* & -S7* & S6* & -S5* \\ -S5* & S6* & -S7* & -S8* & S1* & -S2* & S3* & S4* \\ -S6* & -S5* & -S8* & S7* & S2* & S1* & -S4* & S3* \\ -S8* & S7* & S6* & S5* & -S4* & -S3* & -S2* & S1* \end{pmatrix} \tag{18}$$

If the channel coefficients h1 and h2 of Rayleigh channel h can be perfectly estimated at the receiver, the decoder can use them as channel state information. The received signal Y may be written as shown in Eqs. (19) and (20).

$$y1 = s1*h1 + s2*h2 + n1 \tag{19}$$

$$y2 = -s2*h1 + s1*h2 + n2 \tag{20}$$

The received signal may be written equivalently as shown in Eqs. (21) and (22).

$$y1 = h1s1 + h2s2 + \tilde{n}_1 \tag{21}$$

$$y2 = -h1*s2 + h2*s1 + \widetilde{n2} \tag{22}$$

Thus the Eqs. (21) and (22) can be written as given in Eqs. (19) and (20).

$$\begin{pmatrix} y1 \\ y2 \end{pmatrix} = \begin{pmatrix} h1 & h2 \\ h2* & -h1* \end{pmatrix} \begin{pmatrix} S1 \\ S2 \end{pmatrix} + \begin{pmatrix} \tilde{n}1 \\ \tilde{n}2 \end{pmatrix} \tag{23}$$

H is termed as the equivalent virtual MIMO (Multi Input Multi Output) channel matrix of the Alamouti STBC scheme and is given by Eq. (24)

$$H = \begin{pmatrix} h1 & h2 \\ h2* & -h1* \end{pmatrix} \tag{24}$$

Similarly for the four transmit case, the channel transfer matrix is given in Eqs. (25).

$$H = \begin{pmatrix} h1 & h2 & h3 & h4 \\ h2 & -h1 & -h4 & h3 \\ h3 & h4 & -h1 & -h2 \\ h4 & h3 & -h2 & h1 \\ h1* & h2* & h3* & h4* \\ h2* & -h1* & -h4* & h3* \\ h3* & h4* & -h1* & -h2* \\ h4* & h3* & -h2* & h1* \end{pmatrix} \tag{25}$$

For eight transmit antenna, the channel transfer matrix is given in Eqs. (26).

$$H = \begin{pmatrix} h1 & h2 & h3 & h4 & h5 & h6 & h7 & h8 \\ h2 & -h1 & -h4 & h3 & -h6 & h5 & h8 & -h7 \\ h3 & h4 & -h1 & -h2 & h7 & h8 & -h5 & -h6 \\ h4 & h3 & -h2 & h1 & h8 & -h7 & h6 & -h5 \\ h5 & h6 & -h7 & -h8 & -h1 & -h2 & h3 & h4 \\ h6 & -h5 & h8 & h7 & h2 & -h1 & -h4 & h3 \\ h7 & -h8 & h5 & -h6 & -h3 & h4 & -h1 & h2 \\ h8 & h7 & h6 & h5 & -h4 & -h3 & -h2 & -h1 \\ h1* & h2* & h3* & h4* & h5* & h6* & h7* & h8* \\ h2* & -h1* & -h4* & h3* & -h6* & h5* & h8* & -h7* \\ h3* & h4* & -h1* & -h2* & h7* & h8* & -h5* & -h6* \\ h4* & h3* & -h2* & h1* & h8* & -h7* & h6* & -h5* \\ h5* & h6* & -h7* & -h8* & -h1* & -h2* & h3* & h4* \\ h6* & -h5* & h8* & h7* & h2* & -h1* & -h4* & h3* \\ h7* & -h8* & h5* & -h6* & -h3* & h4* & -h1* & h2* \\ h8* & h7* & h6* & h5* & -h4* & -h3* & -h2* & -h1* \end{pmatrix} \tag{26}$$

4. ORTHOGONALIZATION IN MULTIPATH CHANNELS USING OFDM

OFDM signals are generated digitally and the signal consists of a sum of subcarriers that are modulated using BPSK or QPSK or QAM. The relationship between all the carriers must be controlled to maintain the orthogonality of the carriers [6]. After modulating the input data digitally, the resulting spectrum is converted back to its time domain using Inverse Fourier Transform (IFFT). The IFFT converts a number of complex data points, of length power of 2, into the time domain signal of the same number of points. Fig. 3 shows the block diagram of OFDM transceiver and each block is discussed in the following sub sections.

4.1 SERIAL TO PARALLEL CONVERSION

In OFDM each symbol typically transmits 40-4000bits, so a serial to parallel conversion is needed to convert the input data to be transmitted in each OFDM symbol. The data allocated to each symbol depends on the modulation scheme and the number of subcarriers. For example, for a subcarrier modulation of QPSK each subcarrier carries 2 bits, and so for a transmission using 100 subcarriers, the number of bits per symbol would be 400.

4.2 MODULATION

The modulation scheme is a mapping of data words to a real (In phase) and imaginary (Quadrature) constellation, also known as an IQ constellation. For example, 32 PSK (Phase Shift Keying) has 32 IQ points in the constellation. The number of bits that can be transmitted using a single symbol is equal to $\log_2 M$, where M is the number of points in the constellation, thus 16-PSK transfers 4 bits per symbol. Each data word is mapped to one unique IQ location in the constellation. The resulting complex factor I+jQ, corresponding to an amplitude of $\sqrt{I^2 + Q^2}$ and a phase of < (I+jQ), where $j=\sqrt{-1}$. If we increase the number of points in the constellation, it does not change the bandwidth of the transmission, thus using a modulation scheme with a large number of constellation points, allow to improve spectral efficiency. For example, 256-QAM has spectral efficiency of 8 b/s/Hz, compared with only 1 b/s/Hz for BPSK. However the greater number of points in the modulation constellation, the harder are to demodulate at the receiver. As the IQ locations become spaced closer together, a small amount of noise will cause error in the transmission.

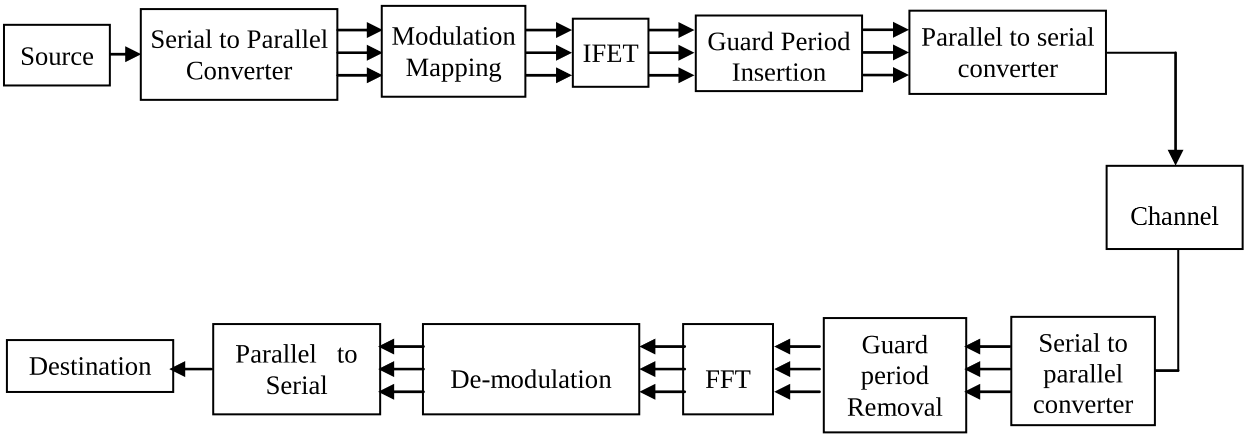


Fig.3. OFDM Transceiver

4.3 INVERSE FOURIER TRANSFORM

An IFFT is used to convert the signal to the time domain allowing it to be transmitted [5]. The IFFT drastically reduce the amount of calculations by exploiting the regularity of the operations in IDFT. Using the radix-2 algorithm, an N-point IFFT requires only (N/2) $\log_2 N$ complex multiplications. For a 16-point transform, for instance, the difference is 256 multiplications for the IDFT versus 32 for the IFFT, a reduction by a factor of 8. This difference grows for large number of subcarriers. The number of multiplications in the IFFT can be reduced even further by using a radix-4 algorithm.

4.4 GUARD PERIOD AND CYCLIC EXTENSION

One of the most important advantages of OFDM is its robust to multipath delay spread, and that is achieved by dividing the input stream in N_s subcarrier, the symbol duration is made N_s times smaller, which also reduces the relative multipath delay spread, relative to the symbol time, by the same factor. Guard time is introduced to each symbol to eliminate ISI. The component from one symbol cannot interfere with the next symbol. Guard time consists of no signal at all. In this case, we will have another problem which is Inter Carrier Interference (ICI). ICI is the cross talk between different subcarriers, which mean they are no longer orthogonal. To eliminate ICI, OFDM symbol must be cyclically extended in the guard time. This ensures that the delayed replicas of the OFDM symbol always have an integer number of cycles with in FFT interval, as long as the delay is smaller than the guard time. As a result, all multipath signals with delay smaller than the guard time cannot cause ICI.

4.5 CHOICE OF OFDM PARAMETERS

The choice of OFDM parameters is a trade of between various conflicting requirements. Usually there are three main requirements: bandwidth, bit rate, and delay spread. The delay is spread based on the guard time; the guard time should be about four times the root mean squared delay spread. This value depends on the type of modulation used. Higher modulation scheme is more sensitive to ICI and ISI. When the guard time is set, the symbol duration can be fixed. To minimize the lose in SNR caused by the guard time, it is desirable to have the symbol duration much longer than the guard time. Longer symbol duration means more subcarriers with smaller subcarrier spacing that leads to more sensitivity to phase noise and frequency offset, also the problem of peak to average power ratio will rise. A practical design choice is to make the symbol duration at least five times the guard time.

After we set the guard time and symbol duration, the number of subcarriers may be determined by the required bit rate divided by the bit rate per subcarrier. The bit rate per subcarrier is defined by the modulation scheme. For example, let us say if we want to design a system with the bit rate of 25Mbps, tolerable delay spread of 250ns and bandwidth of 25MHz. Having delay spread of 250ns suggest that 1000ns = 1 μs is a safe value for the guard time. The OFDM symbol duration should be 6 times the guard time (6μs), so the guard time loss is smaller than 1dB. The subcarrier spacing = 1/(6-1)μs = 200KHz. We can determine the number of subcarrier needed by looking at the ratio between the required bit rate and OFDM symbol rate. To achieve 25Mbps each OFDM symbol has to carry 25Mbps × 6µs = 150 bits of information. To do this there are several options, one is to use 16-QAM with coding rate ½ to get 2 bits per symbol per subcarrier. In this case, 75 sub carriers are needed to get the required 150 bits per symbol. Another option is to use QPSK with coding rate ¾ , which gives 1.5 bits per symbol per subcarrier. In this case, 100 sub carriers are needed to reach the 150 bits per symbol. However 100 subcarriers means a bandwidth of 100/5 µs = 20MHz, and hence fulfills all the requirements.

4.6 OFDM RECEIVER

The demodulation of an OFDM signal is performed exactly the same manner. In the receiver, FFT is used to estimate the amplitude and phase of each subcarrier. The FFT performs the same operation as the matched receiver for the single carrier transmission, except for a bank of subcarriers. From this we can say that in AWGN, OFDM will have the same performance as a single carrier transmission. However, most propagation environments suffer from effects of multipath propagation. For a given bandwidth, the symbol rate for a single carrier transmission is very high, where as for OFDM signal it is N times lower, where N is the number of subcarriers used. The lower symbol rate leads to low ISI. Also using guard period at the start of each symbol removes any ISI shorter than its length. If the guard period is long enough, all the ISI can be removed. Multipath propagation results in frequency selective fading that leads to fading of individual subcarriers. Forward error correction is used in OFDM to compensate for the subcarrier from severe fading. The performance of the OFDM system will be determined by the noise seen at the receiver.

4.7 OFDM SIMULATION PARAMETERS

Table.1 shows the simulation parameters of an OFDM system. An 800-carrier system was used. Each user should have multiple carriers so that if several carriers are lost due to frequency selective fading, then the remaining carriers will allow the lost data to be recovered. However, using a big number of carriers will degrade the system performance due to the sensitivity of OFDM to frequency stability errors. The greater the number of carriers a system uses, the greater it requires frequency stability. The modulation method used is PSK; BPSK gives 1 bits/Hz spectral efficiency and is the most durable method, however system capacity can be increased using QPSK(2 bits/Hz) and 16 QAM (4 bits/Hz), but at the cost of a higher BER.

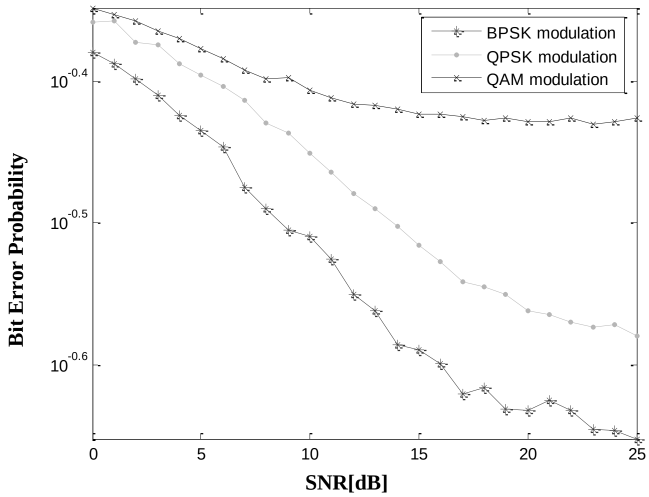
Table.1 OFDM system parameters considered for the simulation

Parameter	Value
Carrier Modulation used	BPSK, QPSK, 16QAM
FFT Size	2048
Number of carrier used	800
Guard time	512 sample (25%)

5. RESULTS AND DISCUSSION

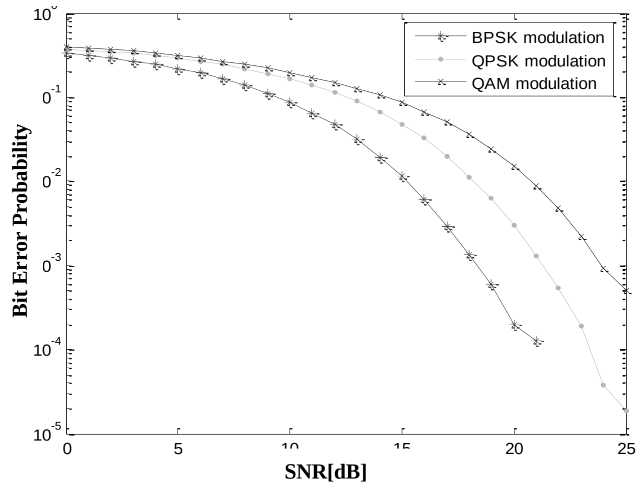
In this section, we present some simulation results that illustrate the BER performance of STBC OFDM system using BPSK, QPSK and QAM modulations. Using the parameters of the transmission matrix S (from Eq.s 14, 16 and 18), we simulate the BER performance of two, four and eight antenna systems at the transmitter and the simulation parameters are as shown in Table.1.

Two Antenna Systems

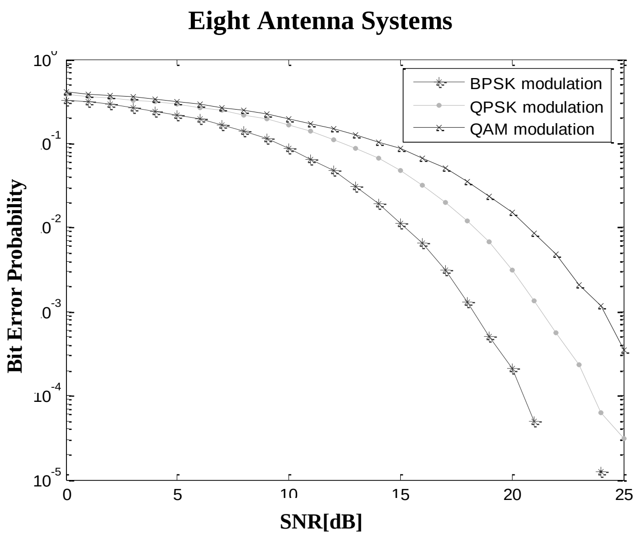


(a) Two Antenna Systems

Four Antenna Systems



(b) Four Antenna Systems



(c) Eight Antenna Systems

Fig.4(a, b &c). BER performance of STBC OFDM system

Fig. 4 shows the BER performance of STBC OFDM system over Rayleigh fading channel using BPSK, QPSK and QAM modulation techniques. The symbol rate has been decided for these three modulation schemes with randomly generated data. We noticed that for all modulation schemes, as Eb/No increases BER reduces. It is also observed that the STBC OFDM system with QPSK and QAM modulation schemes can tolerate transmission with a SNR in excess of 20-25dB. At BER of 10^{-3}, SNR of 18.5dB, 21.5dB and 24dB are required using BPSK, QPSK and QAM modulations, respectively. The results further show that the BER rapidly increases as the SNR drops below 10dB. This is because of the fact that QPSK uses two bits per symbol and 16 QAM uses four bits per symbol. Hence QPSK and QAM are easily affected by noise. Therefore STBC OFDM system with QPSK and QAM requires larger transmit power. In the case of STBC OFDM system with BPSK, the BER is less for low SNR as compared to QPSK. Thus BPSK allows the BER to be improved in a noisy channel at the cost of transmission data capacity. In all two, four and eight antenna systems, the bit error probability is less in the case of BPSK modulation, because BPSK constellation has more area for correct decision boundary compared to QPSK and QAM constellations.

6. CONCLUSION

In this paper, we presented an analysis, and simulated the BER performance of STBC OFDM system employing BPSK, QPSK and QAM modulation techniques with two, four and eight transmitting antennas. The results show that because of the larger diversity order (8^{th} order) S transmission matrix, the system performs better than 4^{th} and 2^{nd} order antenna diversity. It also shows that the STBC OFDM system with BPSK scheme performs better on Rayleigh fading channel. Therefore, STBC OFDM system with BPSK modulation technique will be a suitable one for high capacity 4G wireless communication in future.

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