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Research Article
Performance Enhancement of OSTBC Applied OFDM Modulation for Wireless Communication Systems

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Abstract
Background and Objective: Multi-Input Multi-Output (MIMO) systems combined with Orthogonal Frequency Division Multiplexing (OFDM) gained a wide popularity in wireless applications due to the potential of providing increased channel capacity and robustness against multipath fading channels. **Methodology:** This study distinguishes than the previous study on showing the best code between Alamouti code and OSTBC (Tarokh code) after applying them in multicarrier modulation OFDM and comparing the two combined schemes with some studies that are made previously. **Results:** More of this, point out the adequate length of IFFT about OFDM and the order of the constellation for PSK and QAM modulation that given a good performance (low BER) in two combined system. **Conclusion:** The channel assumed is rayleigh fading that modeled wireless channel, Maximum Likelihood (ML) is used for detection the data at the receiver side.

Key words: MIMO, alamouti, OSTBC, OFDM, BER, rayleigh fading

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

The MIMO (OSTBC)-OFDM are adopting in present and future wireless communication systems such as IEEE 802.11, IEEE 802.16, which these systems are also known by their commercial designations: Wifi Wimax, respectively and adopting also in LTE (4th generation of mobile communication) are some examples[1].

These standards take advantage offered by Orthogonal Frequency Division Multiplexing (OFDM) and Orthogonal Space Time Block Code (OSTBC) to combat fading channel phenomenon when the signal power drops significantly and gives rise to high bit error rate[2]. The OFDM integrates several functions, including multi subcarriers for transmitted data (Nsc), Inverse Fast Fourier Transform (IFFT) is performed on each data symbol block carried by Nsc, cyclic prefix of length Nc is added, although these parallelization already reduces the impact of Intersymbol interference (ISI) and fading channel and OSTBC providing replicas of transmitted signal over space and time see matrice g_2 (code Alamouti) and matrice g_4 (code Tarokh). Therefore, the receiver that has multiple antenna having multiple copies of the transmitted signal going through independent path that is compensate fading effect.

Many studied the OFDM and OSTBC separately and proposed many solutions by combined them, which the subject of our study distinguish of previous study on shows the effect of time diversity order offered on matrice code proposed by Alamouti[3] and Tarokh code[4] will applied them with OFDM modulation and we will also see the significant role plays by IFFT parameter (in OFDM) on these two codes for determine BER. More of this evaluates the performance system (Alamouti-OFDM and Tarokh OFDM) under different order constellation of modulation. To achieve a satisfactory performance (low BER) in STBC-OFDM for wireless channel need to search suitable parameters (Order of time diversity, IFFT length, order of constellation for the modulation used).

Multiple antennas used at the transmitter and at the receiver known as MIMO system can implement OSTBC as method of coding the data for provides spatial diversity and time diversity. One of the most popular transmit diversity schemes has been proposed by Alamouti[3], which uses two transmit antennas and one receive or two receive antenna. Space Time Block Codes (STBCs) it is a coding technique designed for use with MIMO systems to improve the performance by maximizing the diversity gain or coding gain by coding across multiple antennas over multiple symbol durations and used also for increase data rate. Initially, STBC was analyzed by Alamouti[3], which further was modified by Tarokh *et al*.[4] using ML technique. Furthermore, transmit diversity has been studied extensively for combating the fading channels because of its simple implementation using multiple antennas at the transmitter end. The first bandwidth efficient transmit diversity scheme was proposed by Wittneben[5,6] with the delay diversity scheme proposed by Seshadri and Winters[7], which further was modified by Foschini[8] giving multilayered space time architecture. Alamouti's proposed a coding scheme for two transmit antennas in[3] and one or two receive antennas. The STBC is a simple scheme that achieves a full diversity order and to improve the reliability of the transmission that obtained by the coded data from the space and the time.

Tarokh *et al*.[4] proposed orthogonal space time block coding which generalizes Alamouti's transmission scheme for more than two transmit antenna with the rate less than one and is able to achieve the full spatial diversity promised by the multiple transmit and receive antennas. These generalized codes are amenable to a very simple decoding algorithm ML based on linear processing at the receiver. It is a set of practical signal design techniques to which approaches the information theoretic capacity limits of MIMO systems.

Orthogonal space-time block coded OFDM (OSTBC-OFDM) is a popular physical-layer scheme for multi-input multi-output communications over frequency selective fading channels, offering diversity gains in a convenient way. Owing to its low encoding and decoding complexities[9,10].

For example, Alkhawaldeh[11] proposed a wideband channel estimator for full rate full diversity selection system with more than two transmit antennas in conjunction with OFDM technology.

Afghah *et al*.[12] investigate a new method for turbo codes and concatenating them as outer code with Alamouti's space-time block coding scheme as inner code to achieve the benefits of both techniques including acceptable diversity and coding gain.

In this study, we attempt to derive the optimum OSTBC-OFDM system by analyzing and comparing the performance of OSTBC-OFDM systems in wireless environment. The comparative present study of orthogonal STBC. The Alamouti code with OFDM and Tarokh code with OFDM in different length of IFFT for BPSK and QAM modulation and comparing each of these associations on different M-constellation of modulation. So that it compared performance of two codes of our study with some study investigated previously as[12-14].

MATERIALS AND METHODS

System model: An orthogonal space-time block code for M transmit antennas is a linear code that satisfies the following orthogonality property:

$$XX^H = I_M \sum_{i=1}^{k} |X_i|^2 \quad (1)$$

where, I_M is the M×M identity matrix. Orthogonal space-time block codes are an important family of linear space-time codes that achieve full diversity, while decoupling the ML detection of the transmitted symbols such that each transmitted symbol is detected separately from the other transmitted symbols.

The first orthogonal space-time block code is a rate-one space-time block code for two transmit antennas developed by Alamouti[3] and Tarokh *et al.*[4] constructed orthogonal space-time block codes for real and complex alphabets for arbitrary number of antennas. In particular, Tarokh constructed real orthogonal space-time block codes with rate-one for any number of transmit antennas and complex orthogonal space-time block codes with rate 1 for 2 antennas, rate ¾ for 3 and 4 antennas and rate ½ for more than 4 antennas.

OSTBC: Alamouti[3] proposed the scheme composed by 2 transmit antenna and one or two receive antenna and the output of the encoder proposed in this study as following coding orthogonal matrix of size T×N which (g_2: Is matrice code for alamouti code and g_4: Is matrice code for Tarokh code). Figure 1 shows the data transmission of the source to the channel until arrival to the receiver side:

$$g_2 = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix} \quad (2)$$

$$g_4 = \begin{pmatrix} x_1 & x_2 & x_3 & x_4 \\ -x_2 & x_1 & -x_4 & x_3 \\ -x_3 & x_4 & x_1 & -x_2 \\ -x_4 & -x_3 & x_2 & x_1 \\ x_1^* & x_2^* & x_3^* & x_4^* \\ -x_2^* & x_1^* & -x_4^* & x_3^* \\ -x_3^* & x_4^* & x_1^* & -x_2^* \\ -x_4^* & -x_3^* & x_2^* & x_1^* \end{pmatrix} \quad (3)$$

When, the input symbols to the alamouti encoder are divided into groups of two symbols each. The signal at a given symbol period, the 2 symbols are in each group $[x_1, x_2]$ are transmitted simultaneously from the two antennas. The

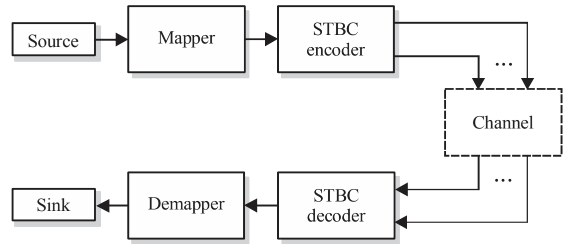

Fig. 1: Space time encoder and decoder

signal transmitted from antenna 1 is x_1 and the signal transmitted from antenna 2 is x_2. In the next symbol period the signal $-x_2^*$ is transmitted from antenna 1 and the signal transmitted x_1^* is transmitted from antenna 2:

$$\begin{bmatrix} r_1^j \\ r_2^j \end{bmatrix} = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix} \begin{bmatrix} h_{j1} \\ h_{j2} \end{bmatrix} + \begin{bmatrix} n_1^j \\ n_2^j \end{bmatrix} \quad (4)$$

The received signal is given by:

$$R = X_N H + N \quad (5)$$

where, $R = \left[r_t^j\right]_{T\times M}$ is the received signal matrix of size T×M and whose entry r_t^j is the signal received at antenna j at time t, t = 1, 2,...., T, j = 1, 2, ..., M; $N = [n_t^j]_{T\times M}$ is the noise matrix and $X_N = [x_t^i]_{T\times N}$ is the transmitted signal matrix whose entry x_t^i is the signal transmitted at antenna i at time t, t = 1, 2, ..., T, i = 1, 2, ..., N. The matrix $H = \left[h_{i,j}\right]_{N\times M}$ is the channel coefficient matrix of size N×M whose entry $h_{i,j}$ is the channel coefficient from transmit antenna i to receive antenna j. The entries of the matrices H and N are independent.

The ML estimate at the decoder by decoder by performing $\underset{X_N}{\min} \|R - X_N H\|_F^2$. Where $\|.\|_F$ is the frobenius norm. The OSTBCs have a very simple and decoupled ML decoding algorithm.

The illustrate this by an example. Consider the OSTBC proposed by alamouti for N = 2 and defined as:

$$X = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix} \quad (6)$$

The fading coefficients denoted by h_{j1} (t) and h_{j2} (t) are assumed constant across the two consecutive symbol transmission periods and they can be defined as:

$$h_1(t) = h_1\,(t+T) \quad (7)$$

$$h_2(t) = h_2\,(t+T) \quad (8)$$

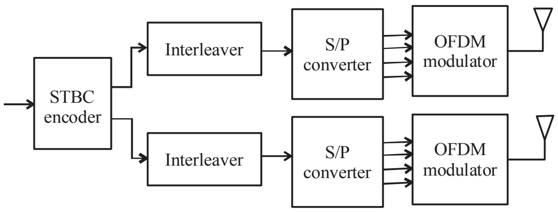

Fig. 2: Block of transmitter for STBC-OFDM

The receiver receives r_1 and r_2 denoting the two received signals over the two consecutive symbol periods for time t and t+T. The received signals can be expressed by:

$$\begin{bmatrix} r_1 \\ r_2 \end{bmatrix} = \begin{bmatrix} x_1 & x_2 \\ -x_2^* & x_1^* \end{bmatrix} \begin{bmatrix} h_1 \\ h_2 \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \end{bmatrix} \tag{9}$$

The maximum likelihood decoder chooses a pair of signals $(\hat{x}_1, \hat{x}_2)$ (from the signal constellation to minimize the distance metric over all possible values of $\hat{x}_1$ and $\hat{x}_2$:

$$\hat{X}^{(p)} = \underbrace{\text{argmin}}_{x^{(p)} \in \{\pm 1\}^N} \left\| R^{(p)} - HX^{(p)} \right\|_F^2 \tag{10}$$

where, p space time block index.

OSTBC applied with OFDM: Ansari and Rajatheva[15], it consider in following the OSTBC-OFDM system model under consideration in the first subsection when it used the simple STBC of Alamouti scheme with 2 transmit antenna and 2 receive antenna as illustrated in Fig. 2.

The matrix of the employed space time codes is defined by $T \times N_t$, after the block of OFDM modulation is denoted by the length of Inverse Fast Fourier Transform (IFFT) and the total signal provide from this block is composed in K-sub carriers.

Furthermore, assuming that n, (n = 1, 2, ..., T_s) is time slots for OFDM modulation and $S_{u,k}[n]$ denotes a coded symbol provide transmitted from uth (u = 1, 2, ..., N_t) antenna at the Kth sub carrier. Collectively it transmit kT_sN_t symbols in a code word from N_t antennas and across T_s consecutive OFDM slots, respectively.

After, a coded symbol provide (from OSTBC-OFDM) transmit at the channel H (flat rayleigh fading) according to Kavitha *et al.*[16] it assume the channel matrix of receive/transmit antenna pairs during the 1st and 2nd symbol/subcarrier intervals of Alamouti code as follow:

$$H^1 = \begin{bmatrix} h_{11}^1 & h_{12}^1 \\ h_{21}^1 & h_{22}^1 \end{bmatrix} \tag{11}$$

$$H^2 = \begin{bmatrix} h_{11}^2 & h_{12}^2 \\ h_{21}^1 & h_{22}^2 \end{bmatrix} \tag{12}$$

In the above equation, h_{vu}^k denotes the channel fading coefficients between the vth receive antenna to the uth transmit antenna one during the kth symbol/subcarrier intervals. Then, the MIMO channel is quasi-static if $H^1 = H^2$.

Tarokh *et al.*[17], the model of the resultant received signal can be formulated as following:

$$y_{v,k} = \sum_{u=1}^{N_t} H_{vu}[k] X_{u,k}[n] + n_{v,k}[n] \tag{13}$$

where, $n_{v,k}[n]$ is the additive complex gaussian noise.

After applied over this signal received the maximum likelihood detection rule defined as following:

$$D_{ML} = \sum_{u=1}^{N_t} \sum_{k=0}^{K-1} \left| y_{vk}[n] - \sum_{u=1}^{N_t} H_{vu}[k] X_{uk}[n] \right|^2 \tag{14}$$

RESULTS AND DISCUSSION

After taken benefits discovery by OSTBC[3,4] from the order of diversity that presented by their code matrices g_2 and g_4 for Alamouti and Tarokh successively and the OFDM that considered robustness against fading channel for high data rate of wireless standards. Such as many studied combined OSTBC-OFDM for achieve minimum BER[13,14]. We try across this study to contribute in the same subject to obtain a good BER performance. By combined 2 codes Alamouti and Tarokh with OFDM, which the simulated result are done in Matlab for determine Bit Error Rate (BER) vs Signal To Noise Ratio (SNR) that are considered 2 parameters at the receiver provides a good measure of the received signal quality.

In this section (divided into 4th sub-sections), simulation results are presented in following after:

- Fixed the type of modulation BPSK and observe BER with various IFFT length (OFDM) for two codes (Fig. 3, 4)
- Fixed the IFFT length at 1024 and varied order constellation of PSK and QAM modulation for two codes (Fig. 5-8)
- We compared the BER performance of two codes in 512, 1024 IFFT length for BPSK and QPSK and in 1024 IFFT length for 4-QAM (Fig. 9-11)
- We made a comparison between our proposed methods (Alamouti and Tarokh) codes-OFDM with other methods[12-14] in Fig. 12 and 13

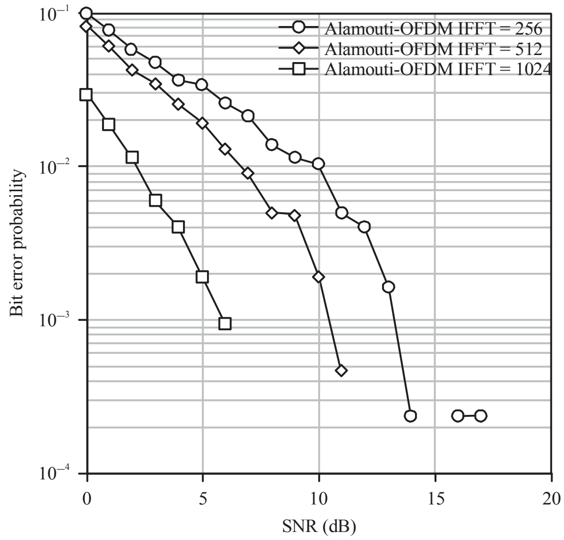

Fig. 3: BER vs for BPSK Alamouti-OFDM in 3 case of IFFT length (Nsc = 64 and CP = 12)

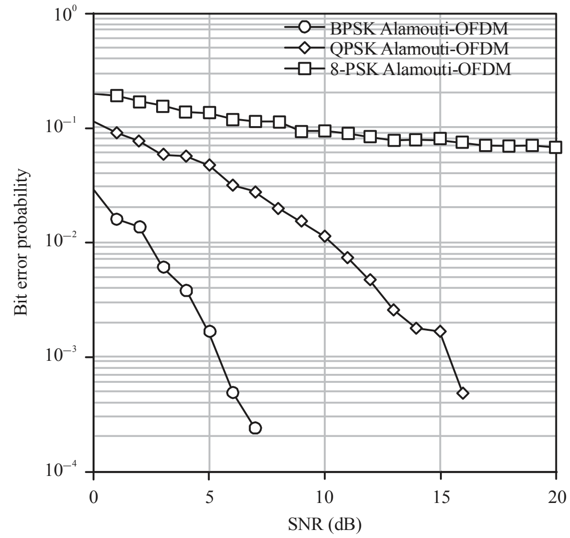

Fig. 5: BER vs SNR for Alamouti code-OFDM in different constellation of PSK modulation

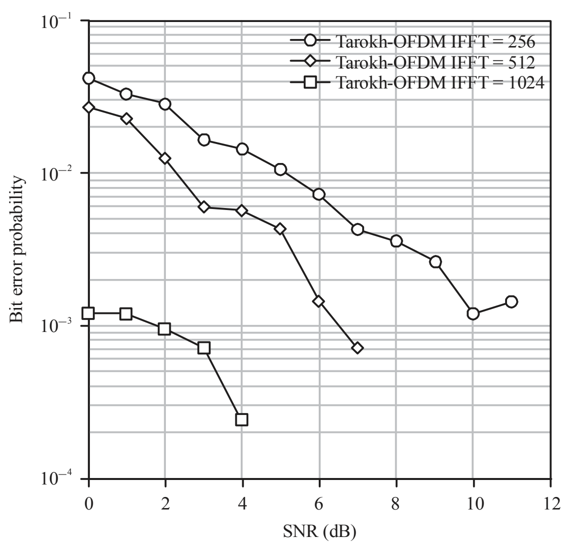

Fig. 4: BER vs for Tarokh-OFDM in 3 case of IFFT length (Nsc = 64 and CP = 12)

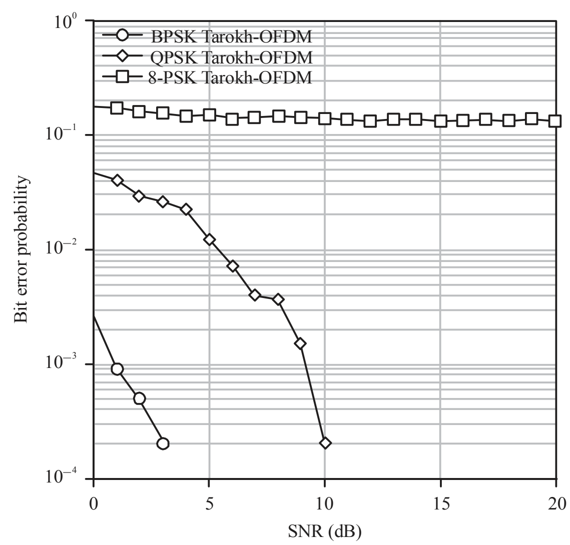

Fig. 6: BER vs SNR for Alamouti-OFDM and Tarokh code OFDM in different constellation of PSK modulation

The channel assumed across simulation result is rayleigh fading channel that represent real environment of wireless channel. When BER is calculated by applied ML rule (Eq. 14) over the signal received (Eq. 13) the new vector generated by ML detection compared it with the first vector randomly generated. Following results of BER provided shows the structure of the simulation system used. As seen in system model described in the previous section by using two transmit and two receive antenna it was also considered Nsc as the number of subcarriers, CP as the cyclic prefix length added over the OFDM symbol. The parameters of all the OSTBC-OFDM studied are summarized in following below:

Modulation type	QAM and PSK
Code matrix of OSTBC	g_2 and g_4
Number of antenna	2,2
Channel	rayleigh fading
Number of subcarriers	64
Length of IFFT	256, 512 , 1024
Cyclic prefix	12
Code rate	1, ½
Receiver	maximum likelihood

Table 1: BER obtained in certain values of SNR

	Alamouti-OFDM			OSTBC (Tarok Code)-OFDM		
	BPSK			BPSK		
IFFT	256	512	1024	256	512	1024
SNR = 4	$10^{-1.4}$	$10^{-1.5}$	$10^{-2.4}$	$10^{-1.8}$	$10^{-2.3}$	$10^{-3.7}$
SNR = 6	$10^{-1.5}$	$10^{-1.9}$	10^{-3}	$10^{-2.2}$	$10^{-2.8}$	0
	1024					
IFFT	BPSK	QPSK	8-PSK	BPSK	QPSK	8-PSK
SNR = 4	$10^{-2.4}$	$10^{-1.3}$	$10^{-0.9}$	0	$10^{-2.7}$	$10^{-0.9}$
SNR = 10	0	10^{-2}	10^{-1}	0	$10^{-3.8}$	$10^{-0.9}$
	1024					
IFFT	4-QAM	8-QAM	16-QAM	4-QAM	8-QAM	16-QAM
SNR = 4	$10^{-1.5}$	$10^{-0.7}$	$10^{-0.6}$	$10^{-1.8}$	$10^{-0.7}$	$10^{-0.6}$
SNR = 10	$10^{-2.2}$	$10^{-0.8}$	$10^{-0.7}$	$10^{-2.8}$	$10^{-0.8}$	$10^{-0.7}$

Table 2: Same BER arrived in two codes at SNR value different

		Alamouti-OFDM	Tarokh-OFDM
IFFT	BER	SNR	SNR
256	$10^{-2.4}$	11	7
	10^{-3}	13	10
512	$10^{-2.4}$	8	5
	10^{-3}	10, 5	6, 5
1024	10^{-3}	6	2

Table 1 shows a comparison between Tarokh code and Alamouti code in SNR = 4 and SNR = 10 and for different constellation order of modulation PSK and QAM successively.

It is clear from result presented in this table that Tarokh code is best on BER given than the Alamouti-code when BPSK, QPSK and 4-QAM used as modulation (In all IFFT utilized) except that with Alamouti in IFFT 256 BER has reached $10^{-3.7}$ but with Tarokh code BER has reached just 10^{-3} (Fig. 5, 6).

It can be observed that two codes have same BER performance when we increased the order constellation of modulation as 8-PSK, 8-QAM and 16-QAM, respectively. Then the 2 codes lose their performance against the channel fading and the noise added in the receiver. It considered normally for higher constellation of modulation as demonstrated from theory of digital modulation[18]. At this case, it is necessary added the channel coding as turbo codes or convolution codes before, the data passed the fading channel for leading the performance of two codes in acceptable values of for high constellation modulation.

Effect of IFFT-length on Alamouti-OFDM and Tarokh-OFDM: It has been shown from Fig. 3 and 4 that the increase of IFFT length on the process of simulation, clear influence of IFFT length appeared over 2 codes, the BER decreases in 2 codes when we increase the length of IFFT. But there are other observation if comparing BER produced (in the same IFFT length) in two codes as shows result in above Table 2.

Table 2 shows that Alamouti code arrived the same BER that Tarokh code but needs more value for SNR. Then, Tarokh code gained in performance 3-4 of SNR value compared with Alamouti. This is reason to say Tarokh performed good that Alamouti at this case.

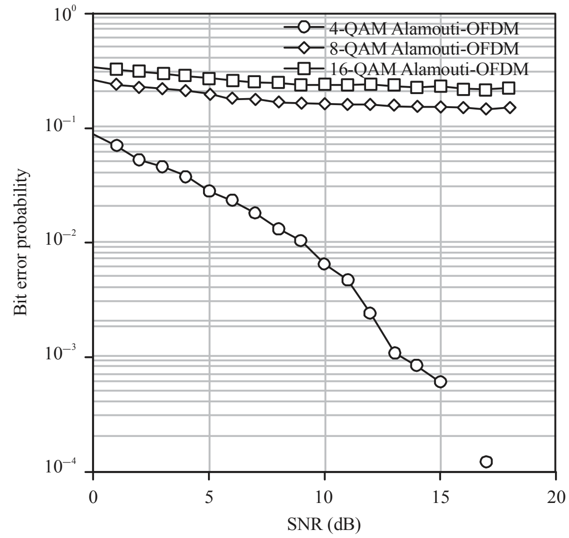

Fig. 7: BER vs SNR for Alamouti-OFDM in different constellation of QAM modulation (IFFT = 1024)

Effect of constellation order for PSK and QAM modulation on Alamouti-OFDM and Tarokh-OFDM: For the case of IFFT length constant, that equal 1024 and this we varied the constellation order of modulation PSK for 2 codes. The result is shown in Fig. 5 and 6. As observed the performance of two codes is decreases with the increase the constellation order, the BER performance in QPSK modulation is decreased a little comapred than 8-PSK that loss significant performance as shown in Fig. 5 and 6. Then, the performance degrades as more bits per symbol are transmitted that is proved by the theory of digital modulation[18].

After fixed the IFFT length in 1024 and varied the order of constellation about QAM modulation for two codes. The result is shown in Fig. 7 and 8. It can be observed that the BER of 2 codes is best just for 4-QAM modulation but 2 system combined losses significant performance after we increased the constellation order for 8-QAM and 16-QAM successively for the same reason said already after we have seen the BER performance of M-PSK. Applied high constellation order of modulation over the data generated the symbol provided carry more bits than low constellation order of modulation that because the performance is degrades in 8-QAM and 16-QAM.

So that, each type of modulation PSK or QAM and with their order of constellation has its own value of BER. Because each type of modulation performs differently in the channel fading (modeled in the simulation as rayleigh distribution that

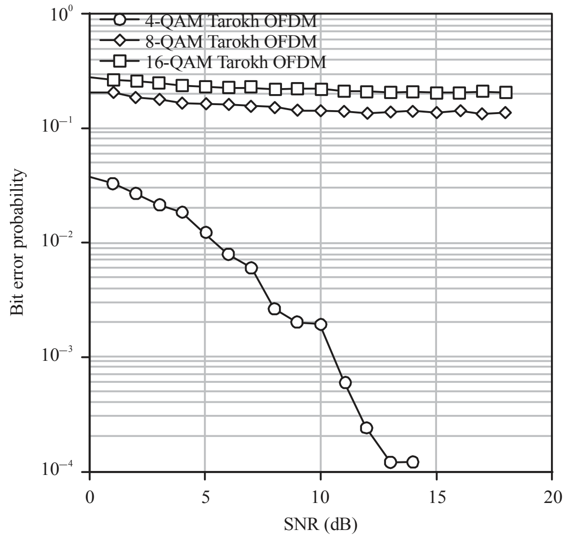

Fig. 8: BER vs SNR for Tarokh code-OFDM in different constellation of QAM modulation (IFFT = 1024)

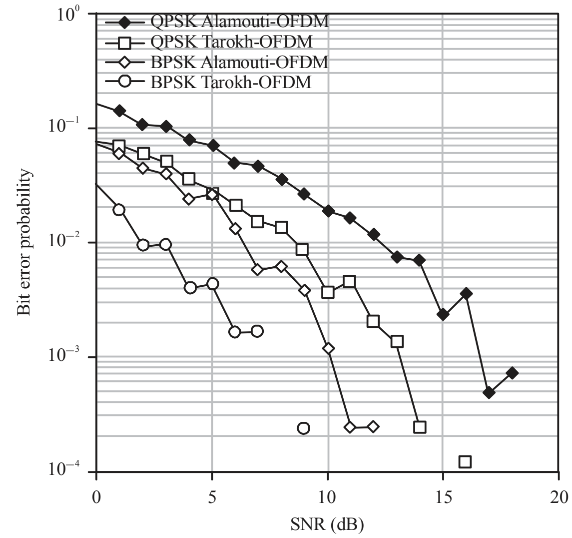

Fig. 10: Comparison of BER between Alamouti-OFDM and Tarokh code-OFDM at BPSK and QPSK (IFFT = 512)

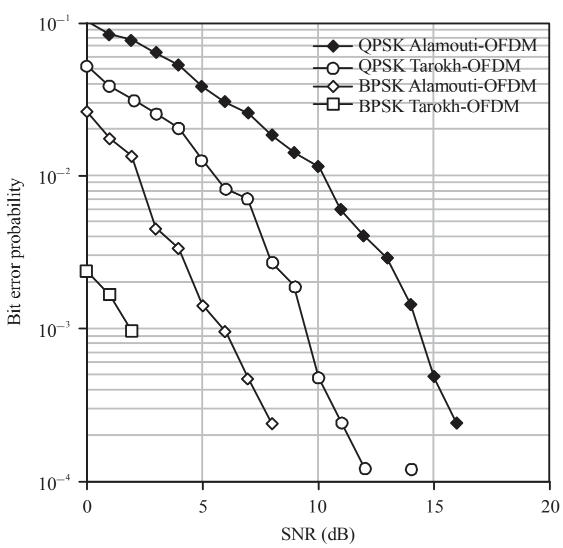

Fig. 9: Comparison of BER between Alamouti-OFDM and Tarokh code-OFDM at BPSK and QPSK (IFFT = 1024)

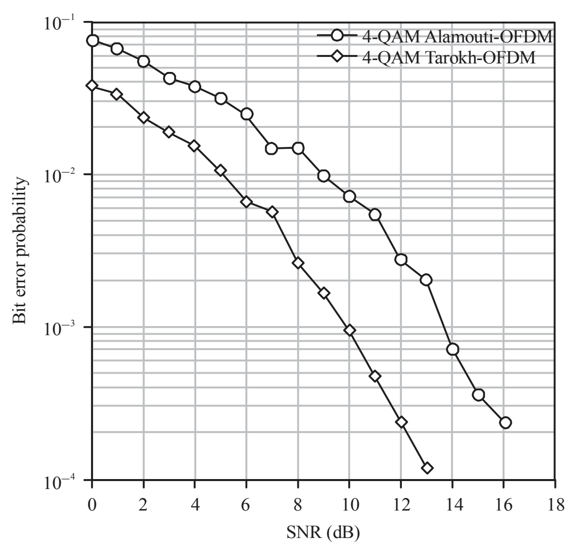

Fig. 11: Comparison of BER between Alamouti-OFDM and Tarokh code-OFDM at 4-QAM modulation (IFFT = 1024)

present real environment of wireless channel) and in the presence of noise added over the signal received (modeled in the simulation as AWGN signal expressed by n in Eq. 13). High order modulation schemes (in 8-PSK, 8-QAM and 16-QAM) able to carry high data rates this leading the performance of two codes inefficiencies (or not robust) from the fading channel and in the presence of noise as obtained in OSTBC simulation results[19,20].

Comparison between Alamouti-OFDM and Tarokh-OFDM: In Fig. 9-11 a comparison of BER performance was presented between Alamouti-OFDM and Tarokh-OFDM at different IFFT length for BPSK and QPSK modulation (in Fig. 9 for IFFT = 1024 and in Fig. 10 for IFFT = 512). As the same comparison was also done for 4-QAM modulation presented in Fig. 11 (IFFT = 1024).

All results (Fig. 9-11) of this comparison demonstrate that Tarokh-OFDM performs better than Alamouti-OFDM for IFFTused (512 and 1024) and for BPSK, QPSK and 4-QAM. This is explained by high order of temporal diversity utilizes from matrices code code g_4 used through Tarokh code which Tarokh code divided the generated symbols obtained from

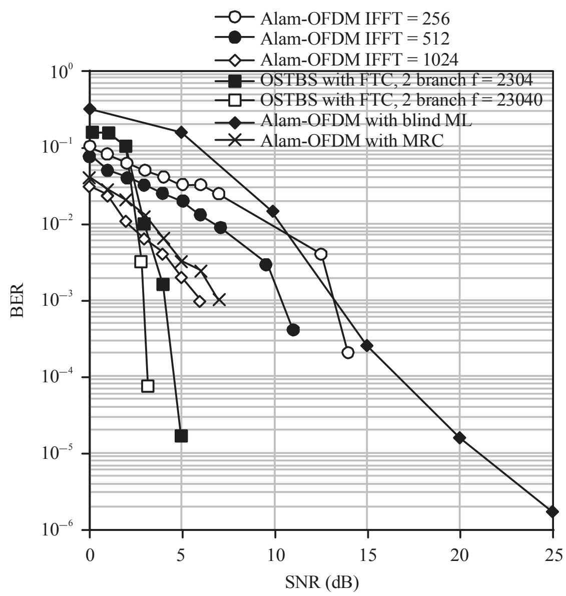

Fig. 12: BER comparison between proposed method Alamouti-OFDM and other methods[12-14]

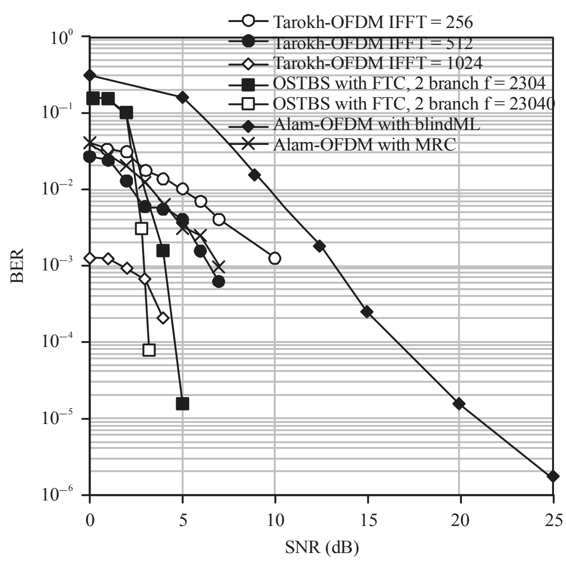

Fig. 13: BER comparison between proposed method Tarokh-OFDM and other methods[12-14]

(BPSK, QPSK and 4-QAM) in 4 groups and transmitted these over height times slots as show in g_4 (Tarokh code), compared to alamouti code that transmitted 2 blocks in two time slots as shows in g_2 (Alamouti code). As proved by simulation result provided[19] when the authors studied the performance of various matrices codes as g_2, g_3 and g_4 of OSTBC with different order of modulation at different cases.

Comparison between proposed methods and other methods: All results presented in Fig. 12 and13 used BPSK modulation. The OSTBC code for 2 transmit and 2 receive antennas, rayleigh channel is applied as model of fading wireless channel, these assumptions let us a made this comparison under a same condition.

From Fig. 12 and 13 an important comparison was presented between these proposed methods Alamouti and Tarokh codes applied them with OFDM for BPSK modulation and other methods[12-14]. When in Fig. 8, the authors used OSTBC[12] (Alamouti matrice g_2) only concatenated with Fast Turbo Codes (FTC) at different frame length (f = 2304 and f = 23040)[12] as shows in Fig. 8. Figure 4 presented a new method of blind[13] Maximum Likelihood (ML) as detection for Alamouti-OFDM under multi path rayleigh channel (L = 4) and in Fig. 8 when the authors used Alamouti-OFDM with MRC (Maximum Ratio Combining) as type of receiver diversity under multi path rayleigh channel[14].

First comparison, with OSTBC-fast turbo codes[12] when the authors used different frame length. It can be seen from Fig. 12 and 13, these proposed methods (Alamouti and Tarokh codes)-OFDM considered best just for SNR = 0, 1, 2 successively as shown in Fig. 12 and 13. But for SNR $\geq$3, BER decreased rapidly by OSTBC-fast turbo codes and until $10^{-4.9}$ for SNR = 5. The used of channel coding fast turbo codes gives to OSTBC more robustness against the effect of fading channel (modeled by Rayleigh Model) and reduction of time decoding compared with classical turbo codes as discussed[12].

Second comparison, BER performance of proposed methods (Alamouti and Tarokh) codes with OFDM present great improvement especially for low SNR (SNR<10) compared with Alamouti-OFDM used blind ML as shown in Fig. 12 and 13. The reason is multi path from rayleigh channel that has four tap (L = 4) and the number of sub-carriers (Nsc = 16) about OFDM applied by authors over the data[13], unlike our proposed methods the number of sub-carriers used in simulation results is 64 and multi path channel that has one tap (L = 1). But it is shown in Fig. 12 and 13 that Alamouti-OFDM blind ML is continued to performed until arrive at BER = $10^{-5.8}$ in SNR = 25. However, the blind ML detection in Alamouti-OFDM suffers from low SNR. We study best for high SNR when blind ML detection appeared their efficiency against the multi path rayleigh channel as discussed[13].

Third comparison, between proposed method Alamouti-OFDM with Alamouti-OFDM used MRC diversity receiver[14] as shown in Fig. 12. These proposed method (in IFFT = 1024) has a little difference compared with Alamouti-OFDM used MRC and considered worst in BER presented when we used

512, 256 as IFFT length except that for SNR = 11 (IFFT = 512) and for SNR = 14 (IFFT = 256) our proposed method have BER = $10^{-3.2}$ and $10^{-3.7}$ that appeared in Fig. 12. Such as the two methods have same diversity order (g_2 matrice code) then, the difference between two methods it comes by high IFFT length used by our proposed method and by MRC receiver diversity which used in Alamouti-OFDM[14].

As other comparison between proposed method (Taokh-OFDM) with Alamouti-OFDM used MRC diversity receiver[14]. Our proposed method (Tarokh-OFDM) out performs than Alamouti-OFDM with MRC in BER resulted as shown in Fig. 13 when we used IFFT length 1024 and 2 methods have almost the same BER when we used IFFT 512. It is shown also from Fig. 13 that Alamouti-OFDM with MRC considered a good by BER provided compared it by Tarokh-OFDM when we used 256 as IFFT length. Then, little improvement provided by Tarokh-OFDM after we have seen first comparison between Alamouti-OFDM (proposed method) and Alamouti-OFDM used MRC it comes by the more of diversity order provided by (g_4).

After the comparison between proposed methods and other methods[12-14]. It can say that IFFT length, type of codes used with OFDM (for our study) and method of detection, parameters used by other methods are all important factors for saying our combined system Alamouti and Tarokh with OFDM is good or other. So, that the quality of transmission data from rayleigh fading channel it depends on the method applied over the data and parameters used over these methods and depends also on SNR value.

CONCLUSION

The performance in term of BER resulted from the 2 combination system Alamouti-OFDM and OSTBC (Tarokh Code)-OFDM. Which the results founded we are given the suitable parameters (length of IFFT) about multicarrier modulation and constellation order of PSK and QAM modulation. Those enhance the performance of BER through two codes. Further, the temporal diversity presented from OSTBC (Alamouti and Tarokh code) generally has significant affect from OFDM (safe with BPSK, QPSK and 4-QAM) over diversity presented across two codes but Tarokh code has more significant comparing with Alamouti code (in BPSK, QPSK and 4-QAM) as interpreted previously and two codes become inefficiencies in BER introduced when 8-PSK, 8-QAM and 16-QAM are used.

About the comparison made between our study and other methods. The improvement of BER performance it depends on method applied over the data, the parameters used by these methods and also SNR value has important influence across these methods for say which methods are good in the term of BER provided against the rayleigh fading channel.

Then, the BER performance of proposed methods (Alamouti and Tarokh) codes with OFDM it can be preferred in some scenarios with use a low constellation order of modulation and high IFFT about OFDM modulation.

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