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Study of the Alamouti-OFDM system using ZP technique and training symbols in multi path selective fading channel

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ABSTRACT

In this paper, we propose a modified Alamouti code matrix and it associated with zero padding orthogonal frequency division multiplexing known as Alamouti- ZP OFDM. The zero padding (or zeros samples) are adopted over the OFDM symbols that construct also the encoded symbols of the Alamouti matx. Training symbols are applied for the channel estimation. Furthermore, the ML decoding algorithm is used to get output bits which the BER can be measured. The selective multi path fading is used as model for wireless channel to evaluate the performance provided by the proposed system. The performance of the proposed approach is evaluated based on BER parameter. For that, the system is simulated in two profiles of paths (i.e. 3 paths and 6 paths), of which the spread delays are taken (in millisecond and in microsecond), respectively. Different data streams are simulated and compared. And the BER performance are compared also for IFFT lengths of 512 and 1024 and the BER results presented for all parameters of paths number, and spread delays. The simulation results show that the presented system performed good, while the spread delays of multi path channel are great (microseconds or milliseconds) and even increased the data simulated from increasing the parallel of the data streams transmitted in the system study. So, the system could keen their effectiveness against of fading channel and ISI phenomenon. And finaly, it is shown that increasing IFFT samples in the simulation process the improvements are more enhanced of the approach proposed.

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1. INTRODUCTION

Wireless application systems are widely studied in the many research paper from considering multi carrier modulation known by orthogonal frequency division multiplexing (OFDM) transmission as an attractive method which able to transmit high bit rate where it has been proposed in the most research work applied for the wireless network applications [1, 2]. As the OFDM system in **[**3, 4] has shown reducing the effect of Inter Symbol Interference (ISI) in the dispersive Rayleigh fading environment when the symbol duration transmitted must be larger than the delay spreading**.** However**,** OFDM transmission equipped with N_t transmit antenna and N_r receive antennas such as known MIMO-OFDM systems constitutes the layer physic of the most modern wireless standards as WiFI, WiMax, UMTS, LTE and either for the next generation of mobile communication [5, 6)] which has presented great benefits in wireless channels which a fading phenomenon has been reduced by the setting a series of techniques, data rate has improved, and BER performance has also enhanced [7, 8].

Then, coding across the multiple input multiple output MIMO-OFDM combination system has become required for reliable transmission after the famous code of Alamouti that proposed in [9]. Such as Alamouti-OFDM wireless system has been widely studied in the many research [10,11] for the wireless communication systems which the Alamouti code provided full diversity order, full data rate, and it yields low complexity detection by using maximum likelihood (ML) [9]. However, the receiver has the more chance to retrieve the data that could affect by fading effect. So, to ensure more reliable transmission and combating efficiently a frequency selective multi path Rayleigh fading the estimation channel is needed [12, 13] and many methods have been shown in that issue for either MIMO-OFDM or Alamouti-OFDM systems [14, 15] Among estimation methods used we found training sequence based estimation schemes and zero padding which the different studied proposed has a difference in how to employ training scheme [16].

The main contribution of this paper consists of a study for new scheme of Alamouti – ZP OFDM wireless system and adopted over the system sequence symbols training. The novelty is to propose a new Alamouti matrix based on the original matrix published in [9]. The new matrix includes three transmission times instead of conventional matrix [9] which includes two transmission times. The symbols encoded in new Alamouti matrix constructed by the OFDM sysmbols expressed as k subcarriers. Furthermore, over those symbols the zero padding (ZP) samples have adopted in 1-st and laste of OFDM symbols to provide the efficiency of system against interference intersysmbole and fading channel. The training symbols are transmitted in 3rd transmission time in the proposed matrix. ML decoding is applied in the reception to get the output bits which the system studied can be performed in terms of the bit error rate (BER) parameter versus several signal to noise ratio (SNR) values.

In the paper, we present a detailed wireless system of Alamouti –ZP OFDM which we have provided general a scheme to show all process used in this work and detailed a mathematical modelisation of system have been presented. Then, in the section of simulation results the numerical values of parameters systems simulated have been presented and the BER performances have been discussed at different parameters of the system. Furthermore, we have finished the work by conclusion about simulations results and performance resulted by the combined wireless system Alamouti- ZP OFDM.

2. SYSTEM MODEL DESCRIPTION

2.1. GI-OFDM (CP-OFDM or ZP-OFDM)

A modulation OFDM multi carrier includes a key parameter known as guard interval (GI). It is used to combat the phenomenon of fading multi path channel for wireless systems. Without GI samples in OFDM symbols the delayed for muti path channel and the transmitted OFDM symbols could interfere with each other [17]. For that, Samples duration of GI introduced in OFDM symbols should longer than or equal to the maximum delays of multi path channel to provide more efficiency against to intereference inter symbol (ISI). There are mainly two ways to introduce GI [17]. First is known by cyclic prefix (CP), in the CP-OFDM, the last samples of OFDM symbol are re-introduced to the starting of the OFDM symbol. Other way to add the GI is known by zero padding (ZP), and in the ZP-OFDM filling up GI with zeros either in starting of the OFDM symbol or in ending of OFDM symbol. There are a lot of works made for that as presented in [18,19]. In this presented work we propose to add the ZP (zeros samples) in the first and last of OFDM symbol respectively as schown in Figure 1 (c). The three situations for OFDM symbols are presented in figure 1.

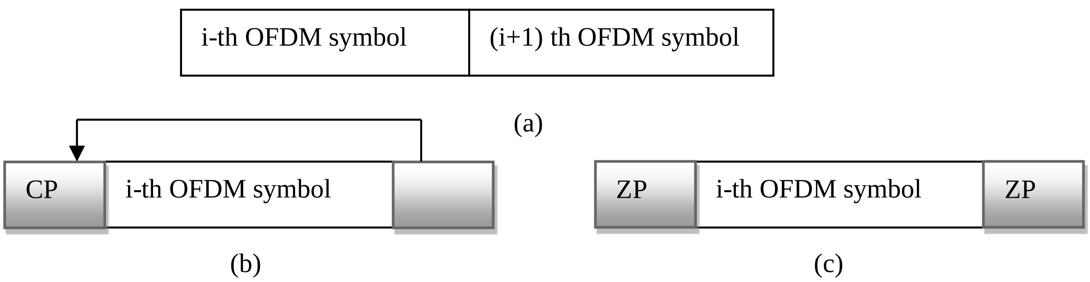

Figure 1**.** OFDM Symbol

(a). OFDM symbol without GI, **(b).** OFDM symbol with GI as CP, **(c).** OFDM symbol with GI as ZP

2.2. Proposed Alamouti-ZP OFDM method

The proposed Almaouti – ZP OFDM wireless system consist of series of blocks shown in the two following figures that presented as two chains, one consists of the transmission block, and the other consists of the reception block as presented in Figures 2 and 3 respectively.

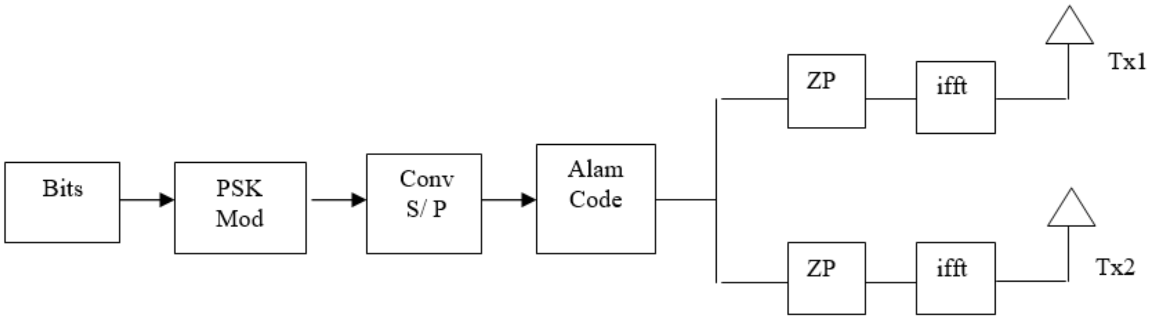

Figure 2. The steps of emission process of the proposed Alamouti-ZP OFDM system

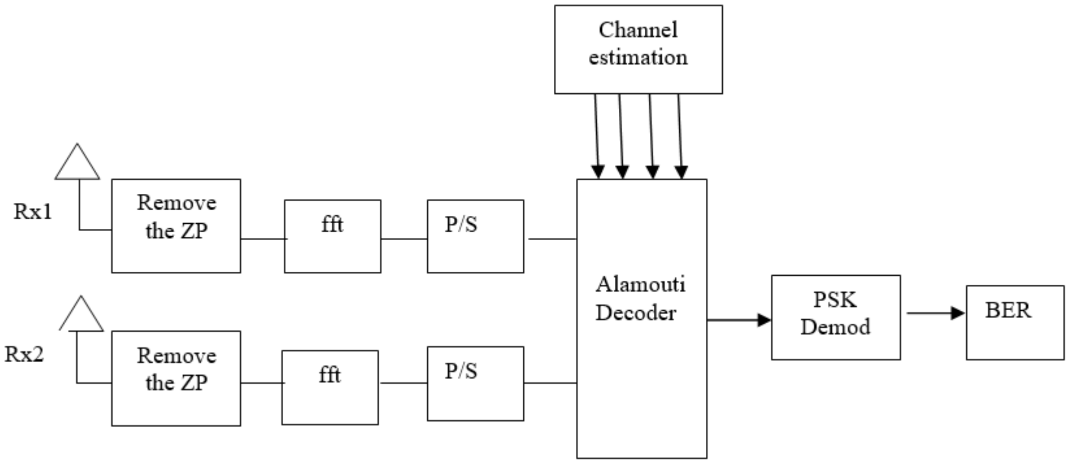

Figure 3. The steps of reception process of the proposed Alamouti- ZP OFDM system

2.2.1. Transmission side

First, we consider data binary sequence $s_{1,} s_2, \ldots., s_m$ passed to the PSK modulation which mapped these binary bits to the complex symbols $x_1, x_2, \ldots, x_m$ where the symbols are generated as BPSK and QPSK constellations. Then, it fed into serial parallel block (S/P) that provide L parallel data streams each of these data streams consist by k symbols.

After that, we divided these data into two chains (corresponding to the two antennas used and presented also from Alamouti matrix) which the data given is processed as following.

In this step, we construct Alamouti matrix code from arrival parallel data streams or the matrix code wills having (2×2) size, the rows define the transmission period and the columns define the transmission antenna. The Alamouti matrix in the first will write as:

$$\mathrm{X} = \begin{bmatrix} \mathrm{X}_{1,\mathrm{k}}^1 & \mathrm{X}_{2,\mathrm{k}}^2 \\ (-\mathrm{X}_{2,\mathrm{k}}^1)^* & (\mathrm{X}_{1,\mathrm{k}}^2)^* \end{bmatrix} \tag{1}$$

In these symbols $X_{t,k}^n$, n: denotes the transmit antenna number, t: represent the time of transmission, k: number of PSK symbols modulation constitue the OFDM symbol.

To add the guard interval (GI), we have inserted zeros padding (ZP) into encoded symbols presented (in Eq. 1).

Furthermore, at each transmission period the new encoded symbols will present as $V_1 = [zeros\ \boldsymbol{X(k)}\ zeros]$, and $V_2 = [zeros\ \boldsymbol{X(k)}\ zeros]$ respectively. Where, the Eq. 1 can represented as following:

$$\mathrm{V} = \begin{bmatrix} \mathrm{V}_1^1(\mathrm{M}) & \mathrm{V}_2^2(\mathrm{M}) \\ (-(\mathrm{V}_2^1(\mathrm{M}))^* & (\mathrm{V}_1^2(\mathrm{M}))^* \end{bmatrix} \quad (2)$$

M: Represent the number of samples constitue the symbol V that consist by k symbols of PSK modulation with the samples of zeros added. That means that the symbols of matrix (eq. 1) are extended by inserting ZP (Zero Padding) samples.

After that, we have extended the matrix of Eq. 2 that corresponding and similar to original Alamouti code [9]. The third transmission is added and it is used to transmit the training symbols that helping to separate a series of transmission of encoded symbols and help to identify the effect of fading over the samples passed through multi path wireless channel. Therefore, the matrix of Eq. 2 can be shown as following:

$$V = \begin{bmatrix} V_1^1(M) & V_2^2(M) \\ \left(-V_2^1(M)\right)^* & (V_1^2(M))^* \\ T_3^1(M) & T_3^2(M) \end{bmatrix} \quad (3)$$

To generate the final OFDM signal from encoded symbols presented in matrix of Eq. 3, the IFFT operation is performed over all symbols shown in the matrix respectively for generating OFDM frames presented by N samples in time domain.

And we applied the IFFT operation in the previous matrix. We will obtain the new matrix C presented as:

$$C = \begin{bmatrix} C_1^1(N) & C_2^2(N) \\ (-C_2^1(N))^* & (C_1^2(N))^* \\ T_3^1(N) & T_3^2(N) \end{bmatrix} \quad (4)$$

$C(N)$ are The OFDM symbols introduced by IFFT process which N are the number of temporal samples in each symbol. And $T(N)$ are the training symbols having N samples in the time domain.

As presented in matrix C: 1st time of transmission, the symbols $C_1^1(N)$ and $C_2^2(N)$ are transmitted by 1st and 2nd antenna respectively. Then, in the 2nd time the symbols $(-\mathrm{C}_2^1(\mathrm{N}))^*$ and $(C_1^2(N))^*$ are transmitted by 1st and 2nd antenna respectively. After that, in the third time the training symbols $T_3^1(N)$ and $T_3^2(N)$ are transmitted from 1st and 2nd antenna respectively.

2.2.2. Wireless Rayleigh selective fading channel

The proposed wireless system is implemented in selective multi path fading channel as presented in [20]. That modeled by H matrix which related the paths between the two transmit antennas and the two receive antennas. Each path has a gain and their corresponding spread time and having the same length as each symbol transmitted, the channel simulated in this study can modeled by the following matrix:

$$\mathrm{H} = \begin{bmatrix} {h_{11}}^l(\tau, N) & {h_{12}}^l(\tau, N) \\ {h_{21}}^l(\tau, N) & {h_{22}}^l(\tau, N) \end{bmatrix} \quad (5)$$

Each path of h_{ij} has $l\ tap$ and their corresponding τ of delay time represented from N samples.

2.2.3. Reception side

In the reception side, the resulting Alamouti- ZF OFDM signal is expressed as follows:

$$y^j = \sum_{t=1}^{T} \sum_{i=1}^{N_t} \sum_{l=1}^{L} \sum_{n=1}^{N} h_{ij}^l(\tau, N) * C_{t,N}^i + W_{t,N}^j \quad (6)$$

$j = 1,2$ corresponds to the two receiver antennas used and that corresponding to the two columns presented from the Alamouti code given in section of transmission side.

Basically, to recover the signal transmitted the inverse operations of transmission side will be performed in the receiver. For that, we can write the received signal of Eq. 6 as following:

$$\begin{aligned} &1^{st}\text{ instant: } y_1^j[k] = \textstyle\sum_{l=1}^{L}(h_{j1,k}^l X_{1,k} + h_{j2,k}^l X_{2,k}) + W_k^j \\ &2^{nd}\text{ instant: } y_2^j[k] = \textstyle\sum_{l=1}^{L}(-h_{j1,k} X_{2,k}^* + h_{j2}^l X_{1,k}^*) + W_k^j \end{aligned} \tag{7}$$

The subscript K of the two above equations denotes the subcarriers number.

And W_k^j : represent the additive noise added over the two received signals in the two antennas used $(j = 1,2)$ which taken length same as k subcarrier number.

Furthermore, these parallel symbols presented by k subcarriers are converted to the serial symbols as presented in the following equations:

$$\begin{aligned} &1^{st}\text{ instant: } y_1^j = \textstyle\sum_{l=1}^{L}\left(h_{j1}^l x_1 + h_{j2}^l x_2\right) + w^j \\ &2^{nd}\text{ instant: } y_2^j = \textstyle\sum_{l=1}^{L}\left(-h_{j1}^l x_2^* + h_{j2}^l x_1^*\right) + w^j \end{aligned} \tag{8}$$

And for decoding Alamouti code and see the performance of that wireless system provided, we have applied the ML detection on those signals received according to [9] and we have generalized the two decision statistics presented in chapter 3 of [21] for the multipath Rayleigh channel used which are constructed based on linear combination of the received signals in that part of processing. $\tilde{x}_1$ And $\tilde{x}_2$ are introduced by the two equations in the following where the two decision statistics are given:

$$\tilde{x}_1 = \sum_{j=1}^{N_r}\sum_{l=1}^{L}(h_{j1}^l)^* y_1^j + h_{j2}^l (y_2^j)^* \tag{9}$$

$$= \sum_{i=1}^{N_t}\sum_{j=1}^{N_r}\sum_{l=1}^{L}\left|h_{ji}^l\right|^2 x_1 + \sum_{j=1}^{N_r}\sum_{l=1}^{L}(h_{j1}^l)^* w_1^j + h_{j2}^l (w_2^j)^* \tag{10}$$

$$\tilde{x}_2 = \sum_{j=1}^{N_r}\sum_{l=1}^{L} h_{j2}^* y_1^j - h_{j1}\left(y_2^j\right)^* \tag{11}$$

$$= \sum_{i=1}^{N_t}\sum_{j=1}^{N_r}\sum_{l=1}^{L}\left|h_{ji}^l\right|^2 x_2 + \sum_{j=1}^{N_r}\sum_{l=1}^{L}\left(h_{j2}^l\right)^* w_1^j - h_{j1}(w_2^j)^* \tag{12}$$

The maximum likelihood decoding rules for the two independent signals x_1 and x_2 are given by

$$\hat{x}_1 = arg \underbrace{min}_{\hat{x}_1 \in S}\left[\left(\sum_{j=1}^{N_r}\sum_{l=1}^{L}\left(\left|h_{j1}^l\right|^2 + \left|h_{j2}^l\right|^2\right) - 1\right)|\hat{x}_1|^2 + d^2(\tilde{x}_1, \hat{x}_1)\right] \tag{13}$$

$$\hat{x}_2 = arg \underbrace{min}_{\hat{x}_2 \in S} \left[\left(\sum_{j=1}^{N_r} \sum_{l=1}^{L} \left(\left| h_{j1}^l \right|^2 + \left| h_{j2}^l \right|^2 \right) - 1 \right) |\hat{x}_2|^2 + d^2(\tilde{x}_2, \hat{x}_2) \right] \tag{14}$$

3. RESULTS AND DISCUSSION

3.1. Simulation setup

Some studies have considered MIMO-ZP OFDM based on training sequence such as [15, 16, and 22]. These studies had taken their applications in the selective fading environment of the mobile channel. And a fewer study had applied Alamouti with ZP OFDM, in this work we propose a new Alamouti matrix constitue by three times of transmission and two transmit antennas. The BPSK and QPSK modulation constulations are adopted respectively over binary data generated as described in the model sytem section. The proposed Alamouti matrix has associated with ZP OFDM used training symbols as pilot to identify the channel estimation in the reception**.** This system applied in wireless multi path channel or these channels have been simulated as three and six paths that each channel has a different delay time and power (Table 2 and Table 3). And the ML detection technique is used to recover the symbols and finaly the sequences binary had received. Based on it the system studied can be tested from the BER parameter. The BER results provided in this section allows the analysis effectivness of system against conditions of fading multi path channel.

The measured performance is presented in this section. The measure provided is to calculate the Bit Error Rate (BER) versus a series of Signal to Noise Ratio (SNR) values taken between [0 to 20] dB where the BER have been plotted versus SNR values at different parameters as presented in simulation results.

The system is tested for data binary having 3200 bits and it is modulated by PSK modulation. Then, the PSK symbols converted into parallel data having l streams (or the subcarriers used is 64* 50 data parallel streams = 3200 bits). Then, the matrix of Alamouti is constructed which we have taken each of parallel streams as encoded symbol and put it according to Alamouti matrix. For training symbols, the matrix Alamouti coding is extended to third transmission time presented by elements T in the matrix as have been presented in the past section (system model). Then, the OFDM process (IFFT) are applied to generate the signal in the time domain and transmit it by the two antennas used.

The main simulation parameters based on the Alamouti – ZP OFDM system are presented in Table 1.

Table 1. Parameters for simulated Alamouti- ZP OFDM

Parametres	**Specifications**
System model	Novel Alamouti code- ZP OFDM
Sequence length	3200 bits
Data parallel length	3200 bits, 6400 bits, and 9600 bits
Modulation type	BPSK, and QPSK
Time transmission	3 times of transmission
Number of transmit antenna	2
Number of receive antenna	2
Channel	Multi path selective fading channel
Number of subcarriers	64
IFFT length	512, and 1024
ZP length	12 samples
Receiver	ML decoding

For the wireless channel implemented in the simulation two profiles are proposed. Which the parameters simulated for these two profiles is modeled as Rayleigh fading multi path channel and they are presented in the following two tables:

Table 2. Powers and delays spread for wireless multi path channel, 03 Paths (in ms and μs)

Paths	1	2	3
Gain (power)	0	-2.5	-3
Delays (ms)	0	1e-3	3.5e-3
Delays (μs)	0	1e-6	3.5e-6

Table 3. Powers and delays spread for wireless multi path channel, 06 Paths (in ms and μs)

Paths	1	2	3	4	5	6
Gain (power)	0	-2.5	-3	-3	-4	-6
Delays (ms)	0	1e-3	3.5e-3	5e-3	5.6e-3	7e-3
Delays (μs)	0	1e-6	3.5e-6	5e-6	5.6e-6	7e-6

Analysis of the system proposed are observed in different situations, which the BER performances of system are compared at different parameters. Such as, for different paths number (Figures 4 and 5), Different data capacity transmitted is presented and compared in (Figures 6 and 7). Two situations of multi path channel are compared where spread delays in ms and μs respectively (Figures 8 and 9).

3.2. BER Performance results

3.2.1. Effects of paths number for Rayleigh fading channel

In the two following figures (Figures 4 and 5**)** the simulations of the BER performance for the Alamouti-OFDM system are compared between the 03 paths and the 06 paths for the multi path channel implemented in the simulation. The delays spread of these wireless paths are taken in the microsecond. And this BER comparison is presented also for the two constellations of BPSK (Binary phase-shift keying) and for QPSK (Quadrature phase-shift keying) respectively. And as well as, the IFFT length = 512 and other IFFT length = 1024 are simulated for Figures 4 and 5 successively. It can be seen from the BER curves presented that the system has the same BER performance for the two paths number simulated both in BPSK constellation, and in QPSK constellation and for the IFFT_L $= 512$, or for the IFFT_L $= 1024$.

Thus, the approach proposed keep the same BER performance even 06 paths are used which it will probably the system has affected by more transmission error than where 03 paths are used. Consequently, the two notions of training symbol and zeros padding have given the system more robustness against selective multi path fading channels. As further comment, the increasing of the SNR values provided the system more performance or more decreasing of BER in all parameters simulated in Figures 4 and 5 successively. In **[23]** performance in different paths number is studied and compared with different case for OFDM system applied in selective channel.

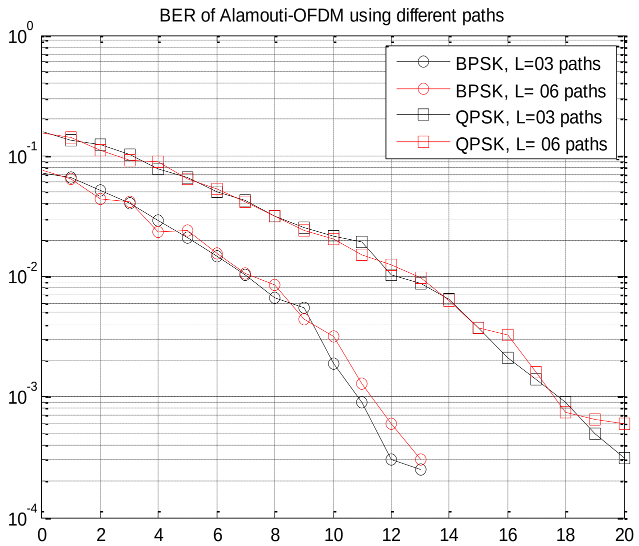

Figure 4. BER comparison of Alamouti- ZP OFDM
($k = 64$, $IFFT\_L = 512$), *delays in microseconds*

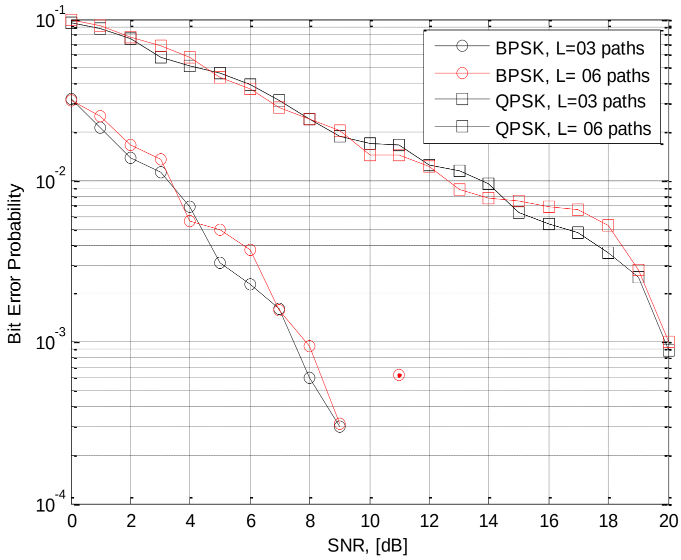

Figure 5. BER comparison of Alamouti- ZP OFDM
($k = 64, IFFT\_L = 1024$) *and delays in microseconds*

3.2.2. Effects of data length

In Figures 6 and 7 the system of Alamouti – ZP OFDM have simulated for different data binary length for 3200 bits (64carriers*50 parallel data), for 6400 bits (64carriers*100 parallel data), and for 9600 bits (64 carriers* 150 parallel data) which we have used in that comparison $03\ paths$. And IFFT_L $= 512$ is used in Figure 5, IFFT_L $= 1024$ is used in Figure 6**.** From the BER curves presented in that comparisons, it can be seen that the BER performance is remain the same even the data binary is increased. So, the approach proposed is performed well at the multi path selective channel even the system transmit more data binary.

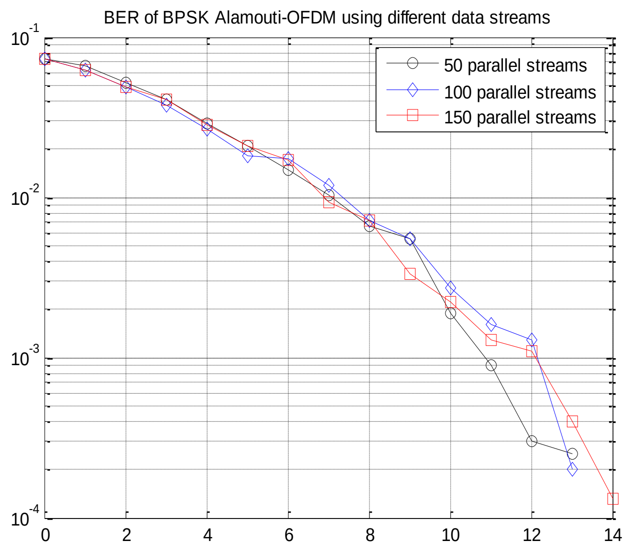

Figure 6. BER comparison of Alamouti- ZP OFDM in different parallel data streams
(BPSK, $k = 64, IFFT\_L = 512$) *and (L= 03 paths, delays in microseconds)*

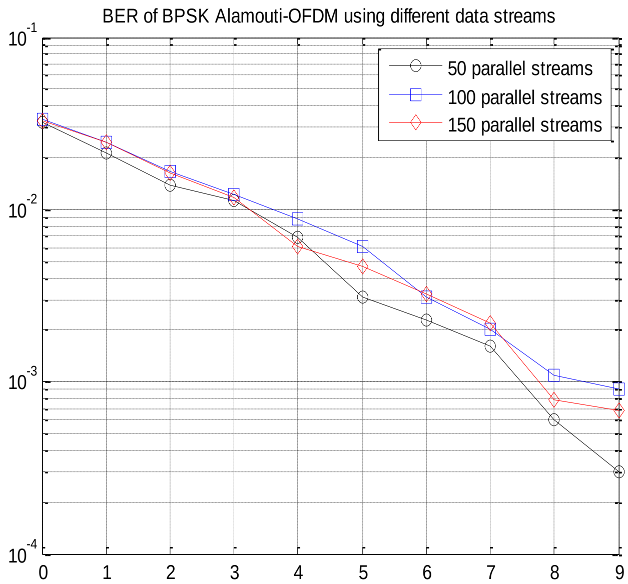

Figure 7. BER comparison of Alamouti- ZP OFDM in different parallel data streams
(BPSK, $k = 64$*,* $ifft\_L = 1024$*) and for (L= 03 paths, delays in microseconds)*

3.2.3. Effects of delays spread (ms and μs) for 3 paths and 6 paths

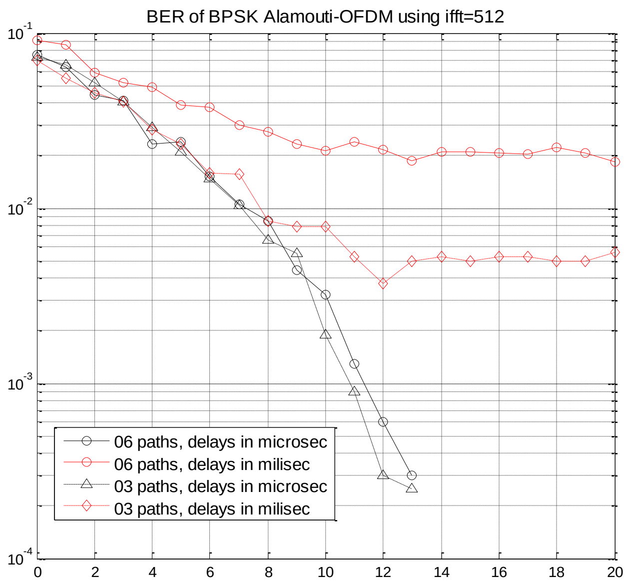

Figure 8. BER comparison of Alamouti- ZP OFDM using two types of delays
(BPSK, $k = 64$*,* $IFFT\_L = 512$*) and for (L= 03 paths, L= 06 paths)*

Figure 8 shows a BER comparison of the Alamouti-OFDM system after used 03 paths and 06 paths in the simulation which a comparison has presented between spreading delays of microsecond and millisecond respectively. While, the IFFT length simulated for that comparison is 512 samples.

It has been shown from the curves of BER plotted in Figure 8**,** that increasing spreading delays from μs to ms the BER has increased. As simulated, greater spread delays provided in wireless channel could generate probably more interference ISI between consecutive symbols transmitted. That interpreted by greater BER parameter as schown in Figure 8.

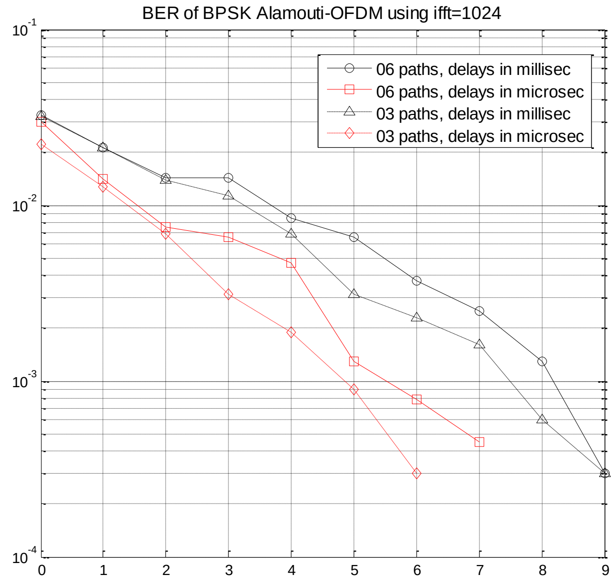

Figure 9. BER comparison of Alamouti- ZP OFDM using two types of delays
(BPSK,$k = 64$, $IFFT\_L = 1024$) and for (L= 03 paths, L= 06 paths)

In Figure 8 the curves of BER compared are the same of BER compared in Figure 9 but for Figure 9 we have used IFFT length 1024 samples. In that comparison, it can be seen the same observation that has made in Figure 7 where the BER introduced by the Alamouti- ZP OFDM system is increased in milliseconds spread delays compared to microseconds spread delays for the two paths number (L=3 paths, and L= 6 paths) simulated. That's came from the great probability of the interference phenomenon affected the symbols received through multi path channel and which make difficult to detection by ML criterion to find a right position in complex constellation for symbols passed in selective fading channel. As example the authors in [24, 25] has been considered important analysis for different wireless models in terms of the study the effect of spreading delays.

Now, as comparison between the BER performances presented in Figure 8 and in the Figure 9 when spread delays used is (ms):

As seen in the two figures (Figure 8 and Figure 9), greater BER values has been presented when IFFT length 512 samples is used as compared to the BER presented when IFFT length 1024 samples is used in the simulation of the proposed method.

For example: In IFFT (length) $= 512$ samples: the BER haven't arrived 10e-3 and 10e-2 for 03 paths and 06 paths respectively where the system stopped to performed more in SNR=10dB for 06 paths and in SNR= 13 dB for 03 paths. It can be clear for SNR $= (12$ to $20)$ dB, no improvement in BER simulated by the system at the two profiles of multi path presented.

And in IFFT (length) $=$ 1024 samples: the BER have exceed the BER performance of 10e-3 which arrived 10e-3.6 at SNR=9, for 03 paths and 06 paths successively.

As result of that comparison, a greater IFFT length simulated more improvement of wireless system Almaouti – ZP OFDM has provided in term of BER. Or if the system will affected by greater spread delays (as ms) it is better to use greater IFFT length (as 1024 samples).

3.2.4. Effects of IFFT length

In the two last following figures, we have compared the BER performance of the Alam-OFDM system in two IFFT lengths (512 and 1024) such as 03 paths and 06 paths are employed either in Figure 10 and Figure 11 respectively which we have compared two IFFT lengths for spread delays millisecond and microsecond. It is shown that increasing the IFFT length (samples) the BER performance is improved as well as for millisecond and microsecond spread delays as presented in the curves plotted. Therefore, the IFFT_L $=$ 1024 samples give the system more gain in the SNR.

For example: in Figure 10 it can be seen that at the BER of 10^{-2} the system in IFFT 1024 is better about 4dB and 6dB than the system with IFFT 512 in the spread delays of microseconds and milliseconds respectively.

And in Figure 11 it can be clear also at the BER of 10^{-2} the system in IFFT 1024 is better about 4dB than the system with IFFT 512 in the delays microseconds but for milliseconds delays the BER of 10^{-2} is arrived at SNR=1.8 dB about using IFFT_L $= 1024$ and didn't arrived 10^{-2} even SNR is increasing until 20dB, for the last case the IFFT_L $= 512$ samples is considered not sufficient to recompense the probability error affected the system by the long delays used (milliseconds) and for 06 paths. So, more IFFT samples are simulated more improvement in performance of the proposed wireless system have been provided. As well as, the IFFT length effect has studied for OFDM system in [26].

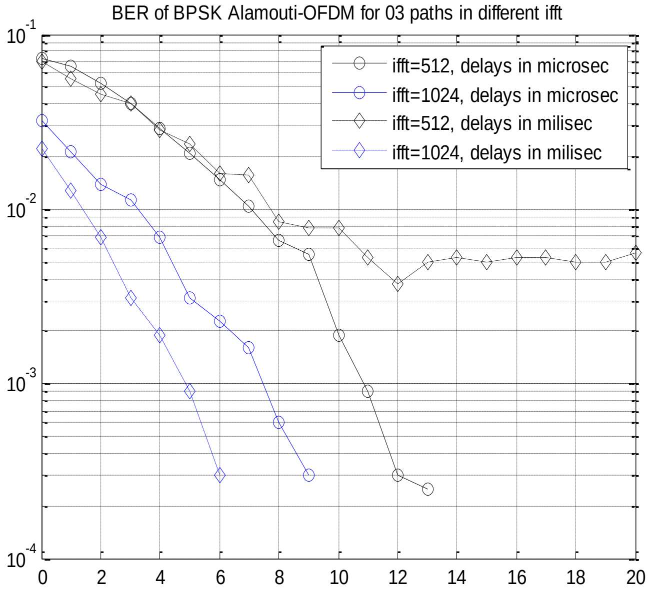

Figure 10. BER comparison of Alamouti- ZP OFDM using two IFFT lengths
$(BPSK, k = 64\ and\ L = 03\ paths)$

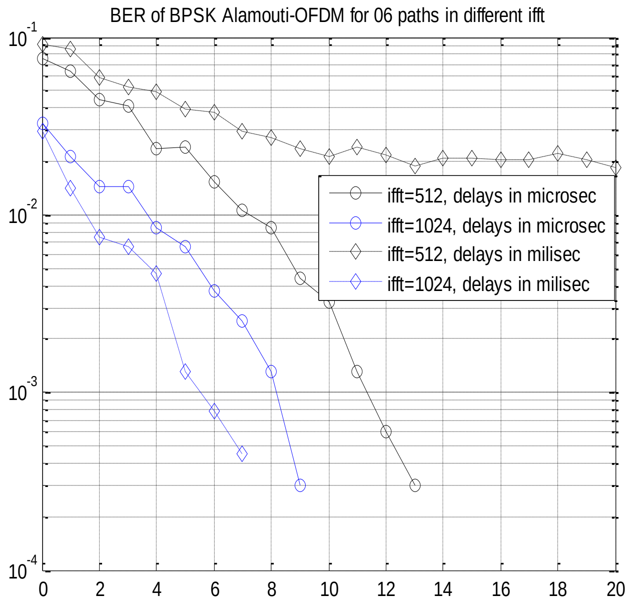

Figure 11. BER comparison of Alamouti- ZP OFDM using two IFFT lengths
$(BPSK, k = 64\ and\ L = 06\ paths)$

3.2.5. BER performance numerical results

Table 4. BER Comparative results for Alamouti –ZP OFDM in 3 paths

SNR (dB)		4	6	8	10	12
Spread delays	IFFT	BER	BER	BER	BER	BER
In μs	512	$10e-1.5$	$10e-1.8$	$10e-2.3$	$10e-2.7$	$10e-3.5$
	1024	$10e-2.7$	$10e-3.6$	//	//	//
In ms	512	$10e-1.5$	$10e-1.8$	$10e-2.1$	$10e-2.2$	$10e-2.4$
	1024	$10e-2.2$	$10e-2.7$	$10e-3.4$	//	//

We present in the following a BER comparison between using IFFT length (512 and 1024) and between spread delays (ms, and µs) used in the wireless Alamouti- ZP OFDM:

As comparison between ifft length:
1-st, at (spread delays μs): $BER = 10^{-2.7}$ have obtained for $SNR = 4\ (ifft = 1024)$, but it have obtained for $SNR = 10\ (ifft = 512)$. Improvement in the system about 6 dB when $ifft = 1024$ have been simulated.
2nd, at (spread delays ms): the system reached $BER = 10^{-2.2}$ *at SNR* = *4* $(ifft = 1024)$ but same BER have resulted at $SNR = 10\ (ifft = 512)$. then the system have been enhanced about *6 dB* when the $ifft = 1024$ have been simulated.

As comparison between spread delays:
1-st, in ifft = 512: it can be clear from BER values of the table.3; same BER have presented in the two spread delays when ($SNR = 2\ to\ 6\ dB$). and better BER performance have provided by spread delays μs when $(SNR = 10\ and\ 12)dB$ respectively.
2nd, in ifft = 1024: The best BER performance have presented in the system studied from spread delays μs than ms for $SNR = (4\ to\ 6)\ dB$.

4. CONCLUSION

In this work, we have presented a wireless system consist of combination between a new Alamouti matrix proposed associated with ZP-OFDM and which the training sysmbols are adopted in the system and transmitted in the 3-rd transmission time over the matrix. The ML algorithm technique is applied to decode the received data after that the BER performance can be calculated. So, the system proposed has been evaluated for the frequency selective multi path Rayleigh fading channel. Furthermore, the system has analysed in BER parameter in function of different situations.

From the simulation results, some points can be concluded about the system proposed are:

- When spread delays of multi paths are in μs, the system has almost the same performance either 3 paths or 6 paths are simulated (see Figure 4 and Figure 5).
- Increased the data simulated, the system has presented same performance as seen in Figures 6 and 7.
- Important degradation in the performance of the system simulated when spread delays is used (in ms) and IFFT length is 512 (Figure 8) against to the spread delays (in ms) and IFTT length is 1024 (Figure 9).
- A better improvement have been shown for the system studied when IFFT length used is 1024 samples compared to the IFFT length 512 samples (Figure 10 and Figure 11).

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