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Enhanced Linear Equalization using PSO in FBMC MIMO Systems

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Abstract

Communication systems with high data rate and higher transmission capacity through the wireless channel are important for researchers. Filter bank based multicarrier (FBMC) modulation with offset quadrature amplitude modulation (OQAM) makes researchers interested due to its advantages compared to orthogonal frequency division multiplexing (OFDM). It is a type of modulation technique that can overcome the Inter-Symbol Interference (ISI). The paper indicates that OFDM, FBMC-QAM, multiple-input multiple-output (MIMO) transmission layouts, and channel estimation layouts study same logic. Also, MIMO receiver design is realized for FBMC such as ZF and MMSE techniques.
A novel hybrid algorithm named particle swarm optimization (PSO) hybrid with ZF and MMSE techniques (PSO-MMSE) and (PSO-ZF) is proposed and put upon for the first time in MMSE and ZF signal detection in MIMO systems. Finally, PSO-ZF and PSO-MMSE, the two methods are better in terms of simulation and reduces complexity. These techniques are proved to provide very high performance when compared with the traditional detectors in which numbers of users are very high as compare to transmitting antenna. From the simulation results, it is clear that PSO-MMSE and PSO-ZF improve the results by 10% than traditional detection technique and bit error rate BER reached to a level of 10^{-5}.

Keywords: FBMC, OFDM, MMSE, ZF, PSO

1. Introduction

Wireless communication systems are used OFDM that is popular technology in many application [1-6]. FBMC system has developed in recent years and it has been a replace to OFDM [7]. In widespread application, a cyclic prefix (CP) required to use for OFDM in a practical multipath delayed channel. On the contrary, FBMC doesn't need CP because of the advantage characteristic of the pulse shaping in stability opposite to multipath delay, which compared to general CP-OFDM and obtained a rise in spectral performance [8]. Also, interference of narrowband and guard band degradation between the channels is obtained FBMC many advantages because better stopband attenuation is enhanced with FBMC than OFDM. Because of between the adjacent pulses occur overlap in the space of frequency, FBMC symbols include interference. In addition transmission signal with overlap/sum is generated in the multiple FBMC symbols in time domain so, ISI has occurred in the transmission signal. In literature mentioned interferences named as intrinsic interference. (OQAM) is used to preserve the orthogonality of neighboring pulses in the conventional FBMC, in which real detection is demodulated using each real-valued symbol [9]. But the FBMC system based on OQAM is not appropriate to cooperate with conventional MIMO techniques [10-13], owing to the available intrinsic interference [14]. For this reason, QAM based FBMC is getting attractive to a researcher to eliminate the restrictions of OQAM and to design used QAM symbols a new prototype filter. QAM-FBMC structure is improved to transfer QAM symbols to cope with the defects of OQAM-FBMC. Among QAM symbols placed null data to reduce intrinsic interference in FBMC symbol assignment design. However, the receiver has high complexity and because of high residual interference performance of BER is reduced [15].

By designing two different prototype filters, the orthognality condition is met. In this technic QAM symbols can be obtained without any attenuation in performance of BER and without adding CP. When we use the two different prototype filters in QAM symbols transmitting, attenuation the side lobe of the prototype filter in the conventional QAM-FBMC is significantly larger than OFDM. Owing to QAM-FBMC has smoothness response in the time domain. Therefore, QAM-FBMC must have a new prototype filter with a good condition about side lobe must have a confident performance with regard to BER in practical studies [16].
This paper intends into five sections. The current section gives an introduction of 5G technologies and several kinds of literature for linear equalization techniques. In the second section, FBMC system is introduced and described. The third section describes channel and system modeling for FBMC MIMO system through equalization techniques with and without PSO optimization. Simulation results and analysis are offered in Section Four. While the final Conclusion is offered in Section V.

2. FBMC-OQAM system

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Recently, researchers fascinated loads of attention in FBMC and to develop this modulation so many equalizations and synchronization methods have been improved. But mostly the improvements are involved single-input-single-output (SISO) systems. Equation (1) expressed the transmitted signal of FBMC-OQAM system in discrete time.

$$s[m]=\sum_{k=0}^{M-1}\sum_{n\in Z}a_{k,n}g[m-nM/2]e^{j\frac{2\pi}{M}k(m-\frac{D}{2})}e^{jQ_{k,n}} \quad (1)$$

In equation (1), even number of subcarriers is M, in real field g[m] is the prototype filter. The delay term is D/2 that attached to the length L_g of g[m]. After this selections w,e obtain D = KM−1 and L_g=KM, where the overlapping factor is K. $a_{k,n}$ is the transmitted symbols with real or the imaginary parts of QAM symbols. $Q_{k,n}$ = π2(n+ k)−πnk is an additional phase term. Equation (1) can be modified as equation (2).

$$s[m]=\sum_{k=0}^{M-1}\sum_{n\in Z}a_{k,n}g[m] \quad (2)$$

Owing to OQAM-FBMC works real-valued symbol in transmit and receive processing, end of this to transform complex-to-real and real-to-complex values, OQAM uses pre-processing and post-processing as seen in Figure 1, respectively. OQAM-FBMC is ensured the orthogonality with the pulse shape of the prototype filter and the state in the real value of OQAM.

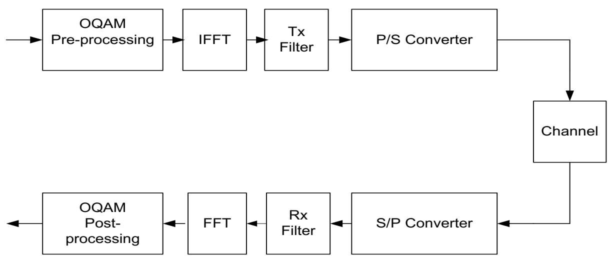

Fig. 1. OQAM FBMC block diagram.

Supposing the best channel, in the receiver m is number of subcarrier, k is time instant in the equation (3) can be formulated the demodulated symbol.

$$\begin{aligned} d_{m,k} &= \sum_{n=-\infty}^{\infty}\sum_{k=-\infty}^{\infty}\sum_{m=0}^{M-1}d_{m,k}\gamma_{m,k}[n]\gamma^{*}_{m,k}[n] \\ &= d_{m,k}+\underbrace{\sum\sum d_{m,k}\sum_{n=-\infty}^{\infty}\gamma_{m,k}[n]\gamma^{*}_{m,k}[n]}_{\text{◆ntrinsic interference}} \end{aligned} \quad (3)$$

The orthogonality condition must be obtained in the real field to realize a symbol with real valued in OQAM-FBMC as follows in equation (4).

$$R\left\{\sum_{n=-\infty}^{\infty}\gamma_{m,k}[n]\gamma^{*}_{m,k}[n]\right\} \quad (4)$$

$$R\left\{\sum_{n=-\infty}^{\infty}\gamma_{m,k}[n]\gamma^{*}_{m,k}[n]\right\}=R\left\{\gamma_{m,k}[n]*\gamma^{*}_{m,k}[-n]\right\} \quad (5)$$

$$=\delta_{m,m'}\delta_{k,k'} \quad (6)$$

Eguation (4,5) describes the real part of a complex-valued discussion with R{·} and the operator * points out the linear convolution in equation (5) .

As h[n] is multipath fading channel and w[n] is additive white Gaussian noise (AWGN), equation(7) formulates the received signal y[n].

$$y[n]=h[n]*s[n]+w[n] \quad (7)$$

$$\sum_{u=0}^{T-1}h[\tau_u]s[n-\tau_u]+w[n] \quad (8)$$

In Equation 8, the multipath delay is τ_u and the number of multipath delays is *T*. As the m subcarrier at k time instant, imaginary values of ISI and inter-carrier interference (ICI) are available in the demodulated symbol. If channel state information (CSI) is known well at the receiver, the zero forcing (ZF) equalizer is utilized in the real-valued symbol detection and used symbol as follows in Equation 9.

$$d_{m,k}=R\left\{\frac{r_{m,k}}{H_m}\right\} \quad (9)$$

H_m indicates channel frequency response (CFR) of h[n] as seen in Equation (9).

The schematic of an FBMC transceiver is presented in Figure 2, where the signal blocks that are different appear in grey-shaded color. As seen in the figure, FBMC requires additional filter banks. with Fast Fourier Transforms (FFT) can be used to be able to realize the framework of FBMC modulation/ and polyphase filtering [17]. Comparing the transceiver complexity of FBMC with OFDM-based solutions, latest research results have shown that the additional complexity required for implementing the subcarrier filtering is only moderate, amounting to a 30% raise at the transmitter and to a factor of two at the receiver [18].

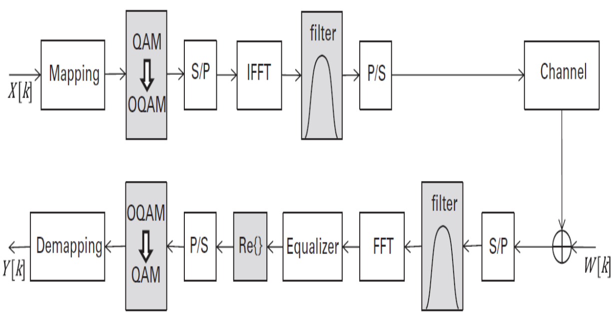

Fig. 2. FBMC transceiver block diagram.

Figure 3 shows the frequency response of a section of FBMC on basis of PHYDYAS prototype filter with(filter oversampling factor) L=4, where the frequency spacing between subcarriers is taken as unity. It is observed that odd index (even index) sub-carriers do not overlap with each other. They overlap with neighbors only. That is considered the main characteristic of the FBMC system[19].

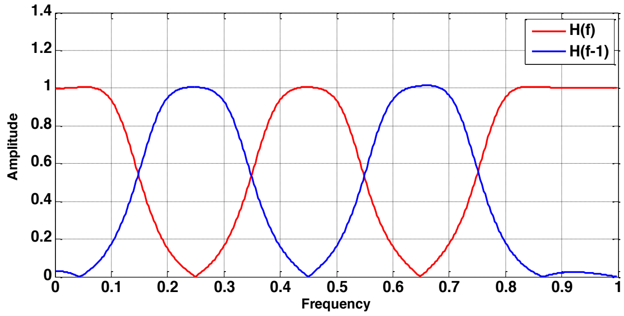

Fig. 3. Frequency response of a section of FBMC system

The method of choosing the prototype filter is the main thing that distinguishes FBMC from OFDM. The OFDM system uses a rectangular window filter whereas the FBMC system uses a filter designed with the pulse shaping standard. The spectral leakage problem is solved in OFDM. Because of using a well-formed filter in FBMC, the side-lobe levels are lower than in OFDM. The bandwidth for all the sub-channels can be saved. The results in avoiding ICI and ISI is displayed in Figure 4 and Figure 5 respectively. The (number of overlapping symbols) M=16, (filter oversampling factor) K=4 and the filter length is 63 (KM-1).

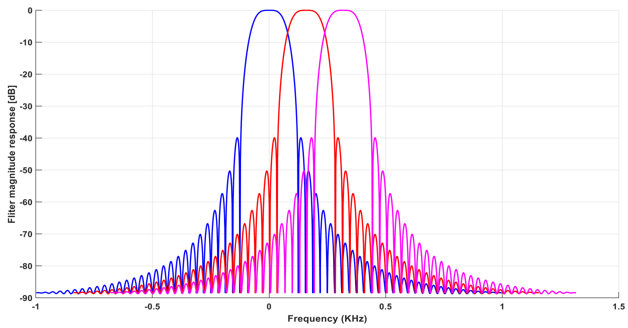

Fig. 4. Subcarriers overlapping between FBMC

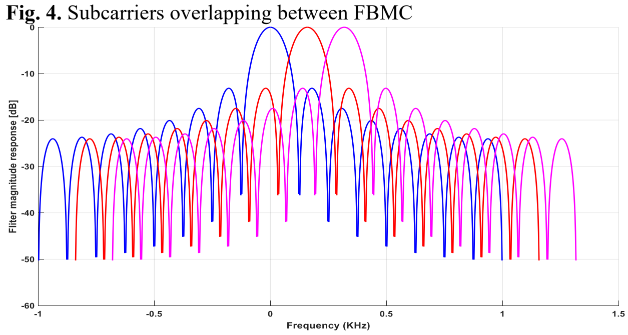

Fig. 5. Overlapping between OFDM subcarriers

3. ZF and MMSE equalizers performance in FBMC MIMO system

For every time slot, the N transmitting antennas give the block of data this is described as:

$$A_i(t) = [a_{i1}(t) \ldots\ldots a_{iN}(t)]^T \qquad (10)$$

$A_i(t)$ describes the whole data block which is transferred in only one slot of time t. $[a_{i1}(t) \ldots\ldots a_{iN}(t)]$ are the data which is got from the N streams of data where i^{th} defines the index. Also, each $A_i(t)$ is influenced by the channel type which is Rician fading along with time-variant. The matrix for 2*2 transmitting antennas is showed as:

$$H(t)=\begin{bmatrix} h_{11}(t) & h_{12}(t) \\ h_{21}(t) & h_{22}(t) \end{bmatrix} \qquad (11)$$

The first row in equation (11) describes the channel coefficients of 1st transmit antenna signal which is received at 1st and 2nd received antennas, these coefficients are h_{11} andh_{12}. Additional noise can be added to the signal as presented in equation (12):

$$N = [n_i \cdots\cdots\cdots\cdots n_n]^T \qquad (12)$$

It is seen that the IFFT of the data streams produced by QAM modulator is then fed to synthesis prototype filter. Next, the data streams are transmitted with one chosen antenna for every stream. The channel influences the signal by adding AWGN.

$\hat{x}_1(t)$, $\hat{x}_2(t)$ indicates the transmitted symbols on the receive antenna of the same number along with multipath and ISI. This is clearly understood in the following equations:

$$\hat{x}_1(t) = h_{11}a_{i1}(t) + h_{21}a_{i2}(t) \qquad (13)$$

$$\hat{x}_2(t) = h_{12}a_{i1}(t) + h_{22}a_{i2}(t) \qquad (14)$$

a) Zero-forcing(ZF)

MIMO systems are a popular candidate for next-generation communication technology. Independent data streams are realized in MIMO systems utilized space multiplexing. Convenient signal processing techniques are used the data streams at the receiver such as linear receivers like Zero Forcing (ZF) which has only sub-optimal performance but provide important computational complexity reduction with tolerable performance degradation. Channel state information (CSI) is necessary to proper operate in these receiver structures [20]. Also, zero forcing equalizer is simple linear equalization algorithm for MIMO receiver which depends on the way of calculating of pseudo-inverse for the frequency response of the channel. The algorithm is practical heavily in MIMO which knowing the channel lets recovery of the two or more streams which can reduce intersymbol interference (ISI) to zero when noise is free in a channel. In this case, we will get an advantage when ISI is important compared to noise. Equation (11) is explained channel matrix H, noise vector n and received vector y and transmitted symbols x.

$$y = Hx + n \qquad (15)$$

In true sense, it provides an overall response at its output for the symbol that is being detected and forces the response from all other symbols to zero. As well as Nt equals Nr, therefore, H will be a full rank square matrix whose inverse exists. Applying the inverse response of the channel on equation (15) we will get:

$$y(t)H^{-1}(t) = A_i(t) + NH^{-1}(t) \qquad (16)$$

Now, to extract the data symbols using ZF equalizer, a matrix W_{ZF} is required which satisfies the condition $W_{ZF}G = I$. This condition is implemented using a pseudo inverse as:

$$W_{ZF} = [H^H H]^{-1} H^H \qquad (17)$$

Where H^H is hermition transpose operator for matrix H, $[H^H H]^{-1}$ is the pseudo inverse of multiplication for matrix H.

In equation (17), $[H^H H]^{-1}$ can be expanded using wolfram Mathimatica program, for simplicity it is shown in the case of 2×2 which is:

$$[H^H H]^{-1} = \begin{bmatrix} |h_{11}|^2 + |h_{21}|^2 & h_{11}^* h_{12} + h_{21}^* h_{22} \\ h_{12}^* h_{11} + h_{22}^* h_{21} & |h_{12}|^2 + |h_{22}|^2 \end{bmatrix}^{-1} \quad (18)$$

In equation (18), the off-diagonal terms are non-zero. The ZF equalizer works on trying to remove the interfering terms when it performs the equalization.

The covariance matrix of the noise affecting the system is calculated as:

$$E[(NH^{-1})^H . NH^{-1}] = N(H. H^H)^{-1} \quad (19)$$

b) MMSE Analysis

The MMSE equalization method is considered one of the most optimal methods to find a balance between interference cancellation and noise reduction. In fact, MMSE does not totally reduce the noise, as an alternative, it makes a relation between removing the ISI and noise power of the received signal by exploiting the mean square sense. Similar to the ZF equalizer the equalization matrix for MMSE equalizer can be represented as:

$$W_{MMSE} = \left[H^H H + \sigma_g^2 I\right]^{-1} H^H \quad (20)$$

Given equation (17) and (20) showed each of equalizers is almost the same except the term of σ_g^2 which represent SNR hence the equation (20) formulated as:

$$W_{MMSE} = \left[G^H G + \frac{1}{SNR} I\right]^{-1} G^H \quad (21)$$

MMSE receiver is a technique of linear detector that reduces to minimum value of the mean squared error between the transmitted symbols. MMSE detector is utilized to reduce both interference and noise. So it is understood that the MMSE detector tries to enhance the balance between mitigating interference and reducing noise. Therefore MMSE detector is outperformed ZF detector when noise is available in the channel.

C) PSO algorithm:

PSO is an evolutionary algorithm that is originated study of the fish and birds flock movement behavior. The flying birds are either spread or move simultaneously before they find the position where they can locate food.

While their search for food from a single place to another, there always exists a bird that smells the food faster than the others so it will have better food resource information. Finally, birds will finally form a group to the position where food may be found. Solution swarm in the PSO is placed into comparison with the birds swarm. The progress for the solution swarm is equivalent to the birds moving from one position to another; the finest solution is the same as the good information collected by the birds.

As a result of that the of PSO has several advantages like its ease and is easily implemented, the algorithm may widely be applied in many applications. PSO concept is illustrated in details in [21]. Each individual, named particle, of population, named swarm, changes its path toward its prior best position, and in the path of the earlier best position reached by any element from its zone. PSO fundamental algorithm is consisting of two steps:

1) The positions, $x^i(k)$ and velocities, $v^i(k)$ of the primary population for particles are at random formulated for the i^{th} particle at the time k, where i is present particle number in the swarm, $i \in \{1,2, \ldots\ldots, S\}$ and S is swarm size.

2) Calculate updated velocities for the whole particles at time k +1 as given:

$$v^i(k+1) = w. v^i(k) + c_1. r_1 (p^i(k) - x^i(k)) + c_2. r_2 (p^g(k) - x^i(k)) \quad (22)$$

Where, r_1 along with r_2 are distributed random variables in [0:1] range. Fitness function shows which particle will have the finest position value $p^i(k)$ over the recent swarm, and also updates the best position $p^g(k)$ for the current for all the previous swarm moves. The three terms in the equation are presenting the present movement, element own memory, and swarm influence. These parameters are added using three weights, specifically, inertia factor, w, self-confidence factor, c_1, and swarm confidence factor, c_2, correspondingly. Velocity updates here are affected together by best global and local at the present population.

3) The position of each particle is reorganized using its velocity vector at the time k +1 as:

$$x^i(k+1) = x^i(k) + v^i(k+1) \quad (23)$$

The three steps of the update of velocity, position renew, and calculating the fitness are repetitive until a preferred convergence condition is met. Given that objective function f with an optimum global solution in n-dimension domain R^n is clear as

Given f: $R^n \longrightarrow R$

$$f(X_1, X_2, X_3, \ldots\ldots, X_n) = f(x) \quad (24)$$

Where: X_i is the search variable where n elements represent the free variables set of the given function, R^n is definite as search space where each element is called a nominee solution available in search space.

The PSO purpose is to locate the best solution X^*so as to function $f(X^*)$to be maximum or minimum in the defined search space. The PSO is a search technique which generates a cluster of particles. Each particle gives a solution at search space. All particles fly to move in search space which is multidimensional where it changes its position according to its own gained experience and that of its neighbors. Every particle takes attention of its best location at search space which shows best solution that reached so far and is named p^i (k). The best generally fitness value for swarm which is the finest place that obtained by the whole swarm particles so far is named $p^g(k)$.

In accordance to what is described above, any particle's position is affected by best position visited by it p^i (k) which is its personal experience and the location of finest element in its swarm $p^g(k)$ (the experience of swarm particles). In each step, PSO updates the velocity of each particle. The acceleration of a certain particle to the best position is achieved in accordance with random numbers that have been generated. The particle's velocity with the position is reorganized by means of equations (22) and (23).

d)PSO signal detection in MIMO FBMC:

An important step to implement PSO is to define a fitness function; this is the link between the optimization algorithm and the real-world problem. Each optimization problem has a certain fitness function. The particle`s coordinates are used to return a fitness value to be given to the current location. The velocity of the particle is changed according to the relative locations of pbest and gbest. Once the velocity of the particle is determined, it simply moves to the next position. After applying this technique for each particle, it is repetitive until reaching the maximum iteration number.

Equation (10) is described as the transmitted symbols from the data sequence $\{a_{i1}(t) \ldots\ldots a_{iN}(t)\}$ of size N which passed to channel. The detector choose optimal N_{Tx}transmitted symbol vectors from the existing data.

Taking the assumption that the additive noise is Gaussian and white, the ZF and MMSE problem may be described as the minimum of squared Euclidean distance to a certain target vector y over N_{tx}dimensional finite discrete search set:

$$X = \arg_{x \in A_{TxN}} \min \|y - Hx\|^2 \tag{25}$$

Where y is the received symbol at the output of the pth receiver, while H may be expressed as the pth row of the channel transfer function.

The optimal ZF and MMSE detection schemes need to examine all A_{TxN} symbol combinations (b is the number of bits per symbol). The problem may be resolved by computing all possible x and detecting the x value that gives the minimum value like in (25). Therefore, computational complexity increases exponentially by increasing $N_{Tx} * N_{Rx}$.

The proposed MIMO detection algorithm based on standard continuous PSO [22] is described below:

Initialize the particle size (swarm) by taking the initial solution guess. Initialize the algorithm parameters.

Fitness of each particle is calculated using (5):

$$f = \|y - HX\|^2 \tag{26}$$

The fitness of a solution is represented by the minimum Euclidean distance for every symbol. Find the global best performance 'gbestd' in the population that represents the least value of Euclidean distance found so far. Take the values of personal best 'p^i (k)' for each bit along with its previous values.

e) MIMO CHANNEL CAPACITY

With a MIMO system consisting of Nt transmit antennas and Nr receive antennas, the channel matrix is written as

$$H = \begin{pmatrix} h_{11} & \cdots & h_{1Nt} \\ \vdots & \ddots & \vdots \\ h_{Nr1} & \cdots & h_{NrNt} \end{pmatrix} \tag{27}$$

Together with the fact that the determinant of a unity matrix which is equal to 1, expressed respectively as:

$$C = E_H = \left\{ \sum_{i=1}^{k} \log_2(1 + \frac{\rho}{n_T} \lambda_i) \right\}$$

$$= E_H = \left\{ \sum_{i=1}^{k} \log_2(1 + \frac{\rho}{n_T} \sigma_i^2) \right\} \tag{28}$$

In equation (28), λi represent the eigenvalues of the diagonal matrix Λ and σ_i^2 are the squared singular values of the diagonal matrix Σ . When every Nt transmitted signal are received, the MIMO channel maximum capacity is reached by the same set of nr antennas without interference.

With optimal combining at the receiver and receive diversity only (n_t = 1), the capacity of the channel can be expressed as:

$$C = E_H\{1[\log_2(1 + \rho \,.\, x_{2nR}^2)]\} \tag{29}$$

Where x_{2nR}^2 is a chi-distributed random variable with 2nR degrees of freedom, If there are Nt transmit antennas and optimal combining between Nr antennas at the receiver, the capacity can be written as:

$$C = E_H \left\{ n_T \left[\log_2 \left(1 + \frac{\rho}{n_T} . \; x_{2nR}^2 \right) \right] \right\} \tag{30}$$

When the channel is known at the transmitter, the maximum capacity of a MIMO channel may be achieved by using the water-filling principle on the transmit covariance matrix. The capacity is then given by:

$$C = EH\{ \sum_{i=1}^{k} \log 2 \left(1 + \epsilon \frac{\rho}{nT} \lambda i \right) \}$$

$$C = EH\{ \sum_{i=1}^{k} \log 2 \left(1 + \epsilon \frac{\rho}{nT} \sigma i2 \right) \} \tag{31}$$

4. Simulation results

This section provides the simulation parameter as presented in table 1. At SNR of 20 dB for 2×2, 4×4, 8×8, 16×16 and 32×32 respectively in MIMO FBMC systems, the BER performance of all the equalization structures in order to verify the behavior of them under multi MIMO scenario.

Table 1. Parameters N *N MIMO (N= 2, 4, 8,16,32)

Parameters	Value
No. of Sub-Carriers	128
Frame Size	16
Eb/N0	0-30dB
Channel length	Tx*Rx
Channel	Rician over AWGN
antenna size	(2×2),(4×4),(8×8)(16×16) and (32×32)
Scheme	MIMO-FBMC
Equalizers	ZF, MMSE
Mapping	16-OQAM
Bit Type	In-Phase and Quadrature
Pop size	50
Iteration	100
C_1	2
C_2	2
W_{max}	1
W_{min}	0.3

Figure 6 and 7 shows the BER curves of the receiving antennas plotted against Eb/No for a 2 *2, 4*4, 8*8, 16*16 and 32*32 MIMO FBMC system with ZF and MMSE equalizers. Consider different data stream for separate antennas in transmission schemes. The BER curves results are for five antenna arrangements. First, a 2×2 transmit and receive antenna array is used. In the second case a 4 × 4 array is used and in the third case an 8 × 8 antenna array are used. Finally, the two cases 16 × 16 and 32 ×32 antenna array is used. It is observed that as the number of antennas is increased , the BER drops significantly. The solid lines in the following figure show that the PSO algorithm after applying it for both equalizers (ZF and MMSE), the performance of bit error rate in relation with Eb/No was much better than using the conventional ZF and conventional MMSE(dashed lines in both figures). It should be taken into account that PSO-MMSE equalizer performance is well known to always better than PSO-ZF.

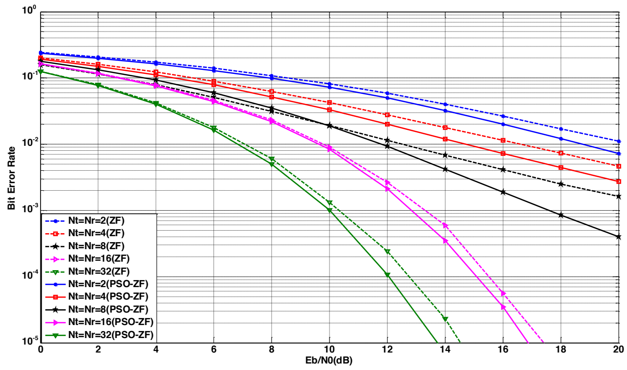

Fig. 6. BER VS Eb/No FBMC-MIMO schemes for conventional ZF and PSO-ZF

The impact of increasing the number of antennas between the transmitter and receiver on spectral efficiency is investigated in Figure 8. It can be understood that accompanied by the growth in the antenna arrays, the capacities of FBMC MIMO system arise. Also, the increase in antenna arrays reduces the mutual interference between the source and the destination, which is the cause of getting why the average capacity increases. Figure 8 shows the results of the channel capacity FBMC MIMO system, without optimization as a function of SNR. It can be seen that the capacity increases with an increase in the number of elements of the antenna array. This result confirms that the FBMC MIMO system is more efficient than traditional SISO system and that as the number of antennas in the array increases, so does the transmission throughput. Figure 8 also shows the simulation results with PSO optimization. There is a consistent increase in channel capacity for the MIMO channel. This increase is most significant in MIMO 8x8 system because it has more antennas in the array. The results in table 2 confirm that the efficiency of PSO to improve both spectral efficiency and BER performance. This means that a simple methodology can produce satisfactory results with reduced computational complexity.

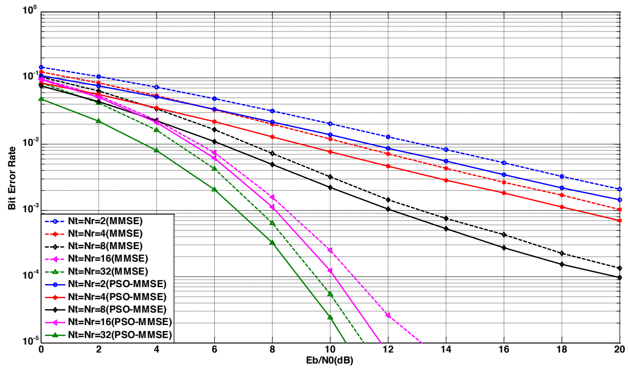

Fig. 7. BER VS Eb/No FBMC-MIMO schemes for conventional MMSE and PSO-MMSE

Table 2. Proposed system with and without PSO optimization.

FBMC System	Capacity performance(bps/Hz) (SNR=20)		BER Performance at (SNR=10)			
	Without optimization	With optimization	Without optimization		With optimization	
			MMSE	ZF	MMSE	ZF
MIMO 2×2	9	9.05	0.02092	0.08119	0.01384	0.07237
MIMO 4×4	25.8	29	0.0119	0.0426	0.007727	0.03324
MIMO 8×8	51.25	59	0.003214	0.01922	0.002226	0.01922
MIMO 16×16	101.6	118.8	0.000249	0.009032	0.000123	0.00832
MIMO 32×32	201.2	237.2	$5.4*10^{-5}$	0.001325	$2.4*10^{-5}$	0.00101

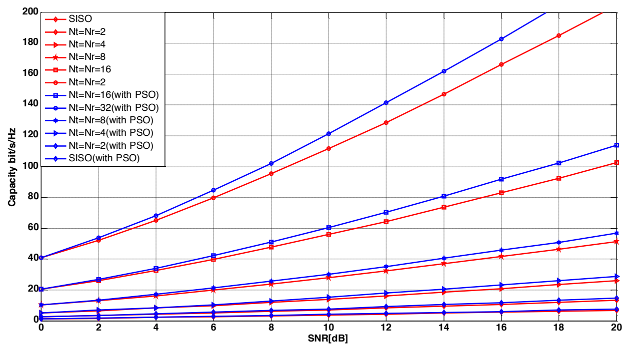

Fig. 8. Channel capacities of FBMC MIMO system

- **<u>Complexity analysis:</u>**

The complexity of the MIMO system defined as a number of floating point operations(FLOPS) such as additions, multiplications are required to compute the transmitted vector x [23, 24]. Table 3 shows the complexity analysis of the ZF, MMSE, PSO-ZF and PSO-MMSE approaches, in terms of a number of transmitting and receiving antennas are used to detect the signal.

Table 3 estimates the complexity of various detectors in MIMO system with dimensions of Nt = Nr = {4,8,16,32} for 16 QAM. This table shows that the PSO-MMSE algorithm is more complex than the other algorithms however, PSO-MMSE gives better results than others.

Table 3. Complexity analysis for proposed equlizers in FBMC system

Algorithm	Equation(Flops)	Value of complexity			
		N=4	N=8	N=16	N=32
ZF	$2(N_r^2 N_t)+ N_r^3+N_t N_r$	208	1600	12544	99328
MMSE	$2(N_r^2 N_t)+ N_r^3+N_r^2 + N_t N_r$	224	1664	12800	100352
PSO-ZF	I(Pop size) $2(N_r^2 N_t)+ N_r^3+N_t N_r$	1040000	8000000	62720000	496640000
PSO-MMSE	I(Pop size) $2(N_r^2 N_t)+ N_r^3+N_r^2 + N_t N_r$	1120000	8320000	64000000	501760000

5. Conclusion

To sum up we have talked about the MIMO system and the FBMC modulation schemes and saw their effect on the channel and how we used them to overcome the ISI. we have described the FBMC and how it can improve the prototype filters in order to have better efficiency.

This paper deals with Computational Intelligence in MIMO detection. In this work, a novel algorithm is proposed called PSO based MMSE and ZF equlizers for MIMO systems with increased number of antennas. The analysis says that by properly selecting the PSO parameters the algorithm can converge quickly. The performance of the algorithm shows that it is a good choice for MMSE and ZF signal detections where the receiver search time is reduced in detecting the symbols which are the vantage characteristics of a receiver.

Also MIMO is used at the transmitter and at the receiver simultaneously to increase the channel capacity and the data rate. Instead of MIMO-OFDM, here we are using MIMO-FBMC to reduce BER and providing a higher quality of signals and faster processing of data. The addition of CP in the OFDM technique reduces spectral efficiency and bandwidth. By using the FBMC the spectral efficiency can be increased because of the absence of CP addition. The sidelobes produced as a result of multiplexing is also being removed by using filter banks and reducing ISI. The BER value is being reduced from 0.51 to 0.74 dB by using the PSO algorithm in both equalizers. As a result, the demand for the future generation can be satisfied with a high data rate with reduced error.

The best antenna configuration is found by using the PSO algorithm which gives the highest capacity. The simulation results show that the PSO algorithm is a powerful and efficient optimization technique in the field of antenna arrays optimization. This also results in increasing the data throughput in the MIMO system.

The results show 12.8% enhancement in the capacity of a channel for the 4x4 MIMO system, 15.1% enhancement is also achieved for the 8x8 MIMO system, also 16.9% enhancement for the 16x16 MIMO system and 17.8% for a 32x32 MIMO system is a result. These results are preliminary, however, they are quite satisfactory because of the wide variety of parameters offered by the tool.

The results of the simulated system show that the MIMO FBMC system with PSO is better in performance. MMSE minimizes the deep fading as well as ISI leading to better BER than ZF algorithm.

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