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A NEW BIO- INSPIRED METHOD OF PAPR REDUCTION IN FILTER BANK MULTICARRIER MODULATION (FBMC) SYSTEM

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Abstract

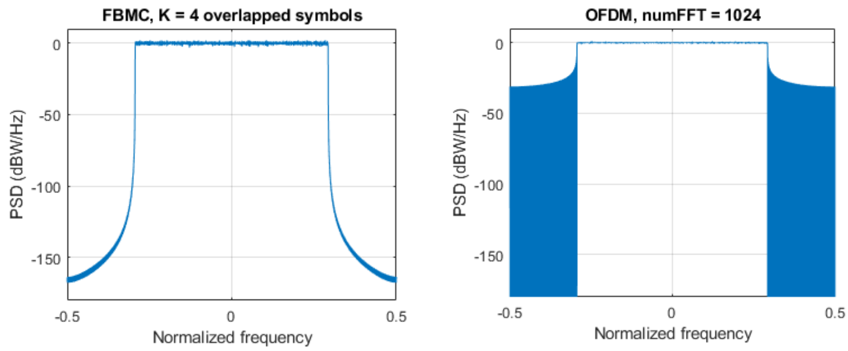
This paper presents a novel bio-inspired technique for peak-to-average power ratio (PAPR) reduction in filter bank multicarrier (FBMC) modulation systems. The approach extends on the survival of the fittest approach to fit the value of PAPR at the affordable level in multicarrier systems like FBMC. In the proposed technique the out-of-band interference has been investigated at sensible PAPR. The Complementary Cumulative Distribution Function (CCDF) has been computed as a measured parameter for PAPR in the proposed technique. The proposed Genetic algorithm method is shown to agree with substantial PAPR lessening and increases the viability of FBMC as a replacement modulation system for Orthogonal Frequency Division Multiplexing (OFDM).

Keywords: CDF, FBMC, Genetic algorithm (GA), OFDM, PAPR.

1.Introduction

The demand for advanced and more efficient improved wireless communication services for 5G, Internet of Things (IoT), and for multimedia such as tactile internet, virtual reality, a 4K video streaming, multiplayer gaming, etc. are expanding every day. This application creates an important demand for higher data rates, lower latency, and bigger network capacity. Higher energy efficiency has turned into a preference in advanced communication systems since more user gadgets are presently battery operated. Currently orthogonal frequency division multiplexing (OFDM) modulation scheme has widely utilized multicarrier modulation technique which highlights most of the modern high-speed data wireless communication systems over frequency selective fading channels [1, 2].

OFDM has been enjoying its domination in wired broadband and wireless communication as the most attractive signalling method. IEEE 802.16 and IEEE 802.11, Long Term Evolution (LTE) advanced and Third Generation Partnership Projects (3GPP) are examples of these standards. However, it is noted that OFDM leads to low spectrum efficiency and out-of-band (OOB) leakage as shown in Figs. 1(a) and (b). Filter bank multi-carrier (FBMC) is an alternate communication system that resolves the problems that occurred in OFDM by utilizing quality filter banks that avoid the entry and exit of noise.



(a) PSD of FBMC **(b) PSD of OFDM**

Fig. 1. The existence of high-power spectral efficiency in FBMC.

The FBMC has many advantages such as bandwidth flexibility, high spectrum efficiency, and low OOB leakage [3-5]. FBMC is an efficient and robust to multipath fading channels. Therefore, for future generation communication, especially 5G, FBMC systems have been regarded as a potential candidate. Various types of FBMC communication system include filtered multi-tone based FBMC (FMT-FBMC), cosine modulated multi-tone FBMC (CMT-FBMC), offset quadrature amplitude modulation based FBMC (OQAM-FBMC) [6-9].

Due to the use of pulse shaping filters, they have lower spectral side lobes as compared to OFDM. From the above-mentioned schemes, FMT-FBMC is intermediate to single carrier and multi-carrier methods inline communication or transmission. It adds spectrum management, duplexing, and unbundling as unusual advantages. In CMT-FBMC, symbols of subcarrier are pulse amplitude and vestigial side band modulated. Synthesis filter-bank of CMT-FBMC is used to set a band-limit of Pulse Amplitude Modulated (PAM) symbols to vestigial side band signals and then modulate them to various frequency bands.

In OQAM-FBMC operation, QAM based symbols are in-phase and quadrature components are staggered by T/2 (T is time period) symbol period. Unlike in FMT-FBMC, a significant overlap in OQAM-FBMC among adjacent bands is allowed. The orthogonality among the subcarriers allows the received symbols to be free of Inter-Symbol-Interference (ISI) and Inter-Carrier Interference (ICI).

The orthogonality is attained by quadrature components of the subcarrier symbols and time staggered in-phase and designing good frequency localization property of pulse shaping filters [10-12]. Based on an earlier analysis of FMT-FBMC, CMT-FBMC, and OQAM-FBMC, it is observed that OQAM-FBMC is exceptionally preferable to the other two.

Although in FBMC there are several merits, still facing some challenges which need due consideration [13]. Since FBMC is a multicarrier transmission and communication technology and uses a filtering process with no inclusion of cyclic prefix (CP) to the symbol, therefore, FBMC is the worst in PAPR ratio as compared to OFDM. To utilize FBMC as technical characteristics, minimizing the PAPR of OQAM-FBMC is very important.

Researchers in the past decade have proposed several methods for reducing PAPR in OFDM such as partial transmit sequence (PTS) [14], selective level mapping (SLM) [15], tone reservation technique [16], and various algorithms are also proposed such as chicken swarm optimization (CSO) [17], and particle swam optimization (PSO) [18], and so on. In considering the certain correlation between the OFDM communication technology and OQAM-FBMC technology, it is logical for researchers to research or study how to utilize various PAPR reduction techniques of OFDM signals to minimize the PAPR of FBMC signals. However, the difference between the two systems is that the signals of OFDM are not dependent while a signal in OQAM-FBMC is overlapped with the adjacent data block signal, that is the reason, the conventional methods for PAPR reduction of OFDM cannot be working efficiently for OQAM-FBMC [19]. Therefore, various modified SLM and PTS based techniques have been proposed recently in [20-23] for the PARP reduction in OQAM-FBMC. Moreover, some hybrid schemes like SLM and tone reservation (TR), multi-data PTS-TR based give a better PAPR reduction as compared to a single method [24-25].

Zhao et al. [26] explored the overlapping structure of OQAM-FBMC by proposing hybrid techniques combined with upgraded PTS and clipping filtered based methods. Another approach to increase the efficiency of OQAM-FBMC is by using the multiple input multiple output (MIMO) technique in OQAM-FBMC. For future wireless communication systems, MIMO OQAM-FBMC has therefore considered a very promising potential for physical layer technique because of its high spectral efficiency and reliability. However, the combination of OQAM-FBMC to MIMO is more complex as compared to the OFDM [27].

This paper proposes a novel SLM-DCT based genetic algorithm technique for PAPR reduction in the FBMC. The SLM –DCT technique is combined with a genetic algorithm for MIMO based OQAM-FBMC for a significant reduction in PAPR. The CCDF curves depict the performance of the proposed technique is better than the existing state of the art techniques.

The rest of the paper is formulated as follows: the system model of OQAM-FBMC for PAPR reduction is presented in Section 2. SLM scheme is presented in Section 3. Section 4 combines the SLM scheme with DCT. In Section 5, a hybrid scheme of SLM-DCT with GA for PAPR reduction is proposed. Simulation results are presented in Section 6.

2. System Model

The system model of the OQAM/FBMC communication system is presented in Fig. 2. At the transmitter, the complex inputs (real and imaginary) symbols are staggered by T/2 in the time domain. We define the input sequence $c_k(m)$ as

$$c_k(m) = \begin{cases} a_k\left(\frac{m}{2}\right), & m \text{ is even,} \\ b_k\left(\frac{m-1}{2}\right), & m \text{ is odd.} \end{cases} \quad (1)$$

where the symbols c_k (m) are up-sampled by $K/2$ and passed through a bank of filters (pulse shaped filters) and modulated with K number of subcarrier modulators, in which carrier frequencies are $1/T$ spacing apart. $a_{k,}, b_k$ denote the number of data symbols to input and m is number of data blocks.

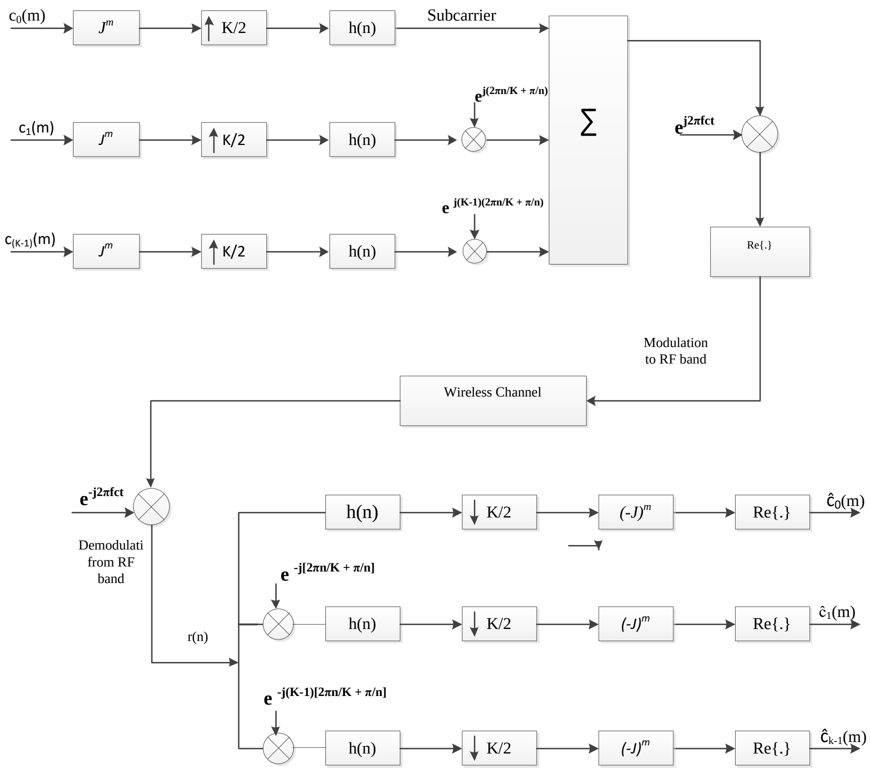


Fig. 2. proposed system model of OQAM-FBMC front end back end.

Suppose *Ts* be the sampling interval length, therefore $T_s = T/K$. The modulated signal of OQAM/FBMC in discrete time is

$$s(n) = \sum_{k=0}^{K-1} \left[h(n) * \sum_{m=-\infty}^{\infty} j^m d_k(m)\delta(n - \frac{mK}{2})\right] e^{jk\left(\frac{2\pi n}{2}+\frac{\pi}{2}\right)}$$
$$= \sum_{k=0}^{K-1} \sum_{m=-\infty}^{\infty} j^m d_k(m)\delta(n - \frac{mK}{2})\, e^{jk\left(\frac{2\pi n}{2}+\frac{\pi}{2}\right)}$$
$$= \sum_{k=0}^{K-1} \sum_{m=-\infty}^{\infty} j^{k+m} d_k(m)\delta(n - \frac{mK}{2})\, e^{j\frac{2\pi kn}{K}},\ -\infty < n < \infty \tag{2}$$

where $h(n)$ denotes the symmetric and real pulse shaping filter, d_k is the response of the prototype filter and * denotes the linear convolution. The $h(n)$ has only non-zero values within the interval $-\alpha K/2 \leq n \leq \alpha K/2$ where $-\alpha K/2 \leq n \leq \alpha K/2$ is the impulse response of the designed filter. $2n/K-\alpha \leq m \leq 2n/K+\alpha$ is the summation of m interval of Eq. (2). Equation (2) can be rewritten as

$$s(n) = \sum_{k=0}^{K-1} \sum_{m=\ulcorner 2n/K \urcorner -\alpha}^{\llcorner 2n/K \lrcorner +\alpha} j^{k+m}\, d_k(\mathrm{m}) h(n - mK/2) e^{j\frac{2\pi kn}{K}} \tag{3}$$

where $\llcorner\ \lrcorner$ and $\ulcorner\ \urcorner$ represent the next larger and smaller integers respectively. From Eq. (3), α determines the number of data symbols to input. After the modulation FBMC modulated signal s(n) passes through a D/A converter and transmitted after the modulation to RF band. Then the baseband signal $s(t)$ is a continuous-time version signal

$$s(t) = \sum_{k=0}^{T-1} \sum_{m=\ulcorner 2n/T \urcorner -\alpha}^{\llcorner 2n/T \lrcorner +\alpha} j^{k+m}\, d_k(\mathrm{m}) h(n - mT/2) e^{j\frac{2\pi kn}{T}} \tag{4}$$

Here, $h(n)$ is a discrete form and here $h(t)$ is the continuous-time version of the $h(n)$, and T denotes the symbol period.

At the receiver, the received signal should be equals to the transmitted signal for an ideal channel. The signal passed through A/D (analog to digital) converter after the demodulation from the RF band. Then $r(n)$ received signal demodulated by utilizing K subcarrier demodulators and passed through a bank of filters (matched filters). After that filtered signal $\hat{c}_k\,(m)$ is down-sampled by K/2 are

$$\hat{c}_k\,(m) = \Re\left\{(-j)^{k+m} \sum_{n=-\infty}^{\infty} r(n) h(\frac{mK}{2} - n) e^{-j\frac{2\pi kn}{K}}\right\} \tag{5}$$

Equation (5) is rewritten as

$$\hat{c}_k\,(m) = \Re\left\{(-j)^{k+m} \sum_{n=\frac{m-\alpha}{2}K}^{\frac{m+\alpha}{2}K} r(n) h(\frac{mK}{2} - n) e^{-j\frac{2\pi kn}{K}}\right\} \tag{6}$$

where $\Re$ denoted real part. $\hat{a}_k(m)$ and $\hat{b}_k(m)$ are the real and imaginary parts of the mth symbol on the kth subcarrier, respectively. The recovered symbols (QAM) $= \hat{a}_k(m) + j\hat{b}_k(m)$ are

$$\hat{c}_k\,(m) = \begin{cases} \hat{a}_k\left(\frac{m}{2}\right), & m \text{ is even} \\ \hat{b}_k\left(\frac{m-1}{2}\right), & m \text{ is odd} \end{cases} \tag{7}$$

where

$$\hat{a}_k = \sum_{m'=-\infty}^{\infty} \sum_{k'=0}^{K-1} \sum_{n=-\infty}^{\infty} h(mK-n) \times \left\{a_{k'}(m') h(n - m'K) cos\left[(k' - k)\left(\frac{2\pi n}{2} + \frac{\pi}{2}\right)\right] - b_{k'}(m') h\left(n - m'K - \frac{K}{2}\right) sin\left[(k'-k)\left(\frac{2\pi n}{K} + \frac{\pi}{2}\right)\right]\right\} \tag{8}$$

and

$$\hat{b}_k = \sum_{m'=-\infty}^{\infty} \sum_{k'=0}^{K-1} \sum_{n=-\infty}^{\infty} h\left(mK - n + \frac{K}{2}\right) \times \left\{a_{k'}(m')h(n - m'K)sin\left[(k' - k)\left(\frac{2\pi n}{2} + \frac{\pi}{2}\right)\right] - b_{k'}(m')h\left(n - m'K - \frac{K}{2}\right)cos\left[(k' - k)\left(\frac{2\pi n}{K} + \frac{\pi}{2}\right)\right]\right\} \quad (9)$$

3. The peak to Average Power Ratio (PAPR) using the SLM Technique

The main drawback of the FBMC system is high PAPR which reduces the power amplifier efficiency [28]. The complex symbols are sending by utilizing FBMC which are modulated at different subcarriers resulting in a high PAPR. PAPR is defined in the FBMC system as the peak amplitude squared divided by the RMS value squared i.e. ratio of peak power to the average power [29].

In general, PAPR can be written as

$$PAPR\ (S_k) = \frac{\max\{|S_k|^2\}}{E[|S_k|^2]} \quad (10)$$

where S_k is the kth signal and E[.] represents the expected value of S_k. In signal processing, PAPR is normally expressed in decibels (dB) and can be written as

PAPR (dB) = 10log10 (PAPR).

The PAPR reduction efficiency is calculated by CCDF, which is the measure of the probability that PAPR exceeds some value of the threshold.

CCDF = probability (PAPR > X_0).

where X0 is the threshold.

Various SLM schemes are used to reduce PAPR such as conventional SLM, Trellis SLM, and Dispersive SLM. The following equation shows the PAPR performance of the FBMC signal at an interval of *T*.

$$PAPR_{s(t)} = \frac{max_{0\le t\le T}|s(t)|^2}{\frac{1}{T}\int_0^t |s(t)|^2} \quad (11)$$

4. Select Level Mapping (SLM) and Discrete Cosine Transform (DCT)

The SLM scheme was first described by Bäuml et al. [30]. SLM is an interesting technique because it is productive and simple. To generate *N* groups in the SLM scheme, the input data sequences are multiplied by each of the phase- sequences to produce different PAPR signals, possibly over different paths (*U*) with remaining input symbols. The signal with lower PAPR is selected and then transmitted. The conventional SLM algorithm block diagram is shown in Fig. 3.

$$x_u(t) = \frac{1}{\sqrt{N}} \sum_{k=0}^{k=N-1} X_k B_{u,k} e^{j2\pi\Delta f t}, \quad 0 \le t \le NT \quad (12)$$

where u = 1, 2, 3 .,…, *U* and *N* is the number of subcarriers.

Least PAPR is selected for transmission among the modified data blocks. Selected mapping PAPR reduction depends upon the architecture of phase sequences and the number of paths *U* (number of phase sequences).

In the OFDM system, the conventional SLM attains a high efficiency as in OFDM there is no overlapping between the symbols. On the other hand, FBMC constructs high PAPR because of overlapping in adjacent symbols. To overcome the PAPR problem, the discrete cosine transform is used in this scheme after the SLM. DCT transform is utilized to reduce the autocorrelation of the input sequence which in turn reduces the PAPR problem and no side information is needed to be transmitted to the receiver.

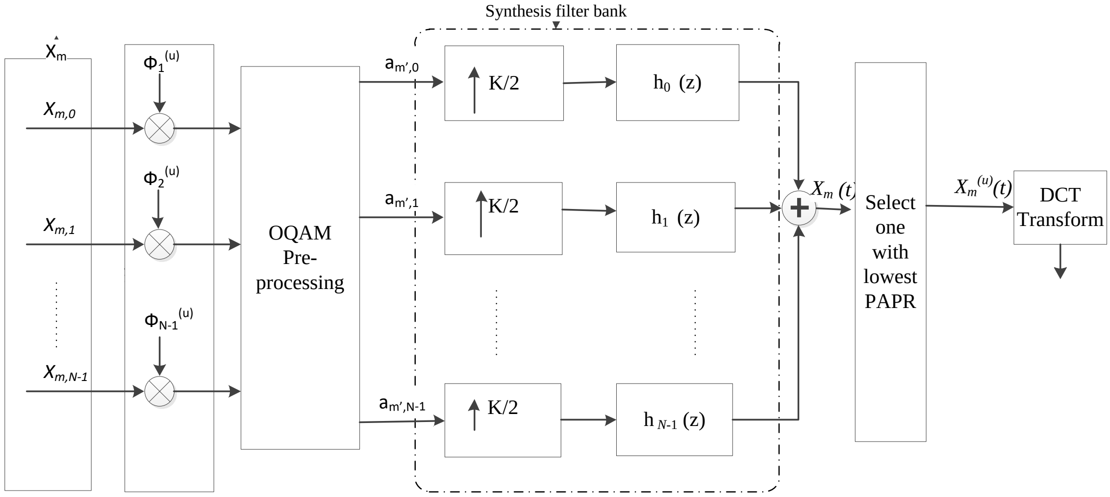


Fig. 3. SLM based DCT for PAPR reduction.

The DCT of one-dimensional formal expression of length N is given as (taking real part only)

$$X_c(k) = \sum_{n=0}^{N-1} x(n) \cos \frac{\pi(2n+1)k}{2N}, \; k = 0 \; \dots\dots\dots. \; N-1 \tag{13}$$

Inverse Discrete Cosine Transform (IDCT) is thus defined as:

$$x(n) = \alpha(k) \sum_{c=0}^{N-1} X_c(k) \cos \frac{\pi(2n+1)k}{2N}, n = 0 \dots\dots\dots\; N\text{-}1 \tag{14}$$

where α(k) is defined as:

$$\alpha(k) = \begin{cases} \frac{1}{\sqrt{N}} & \text{for} \quad k = 0 \\ \frac{2}{\sqrt{N}} & \text{for} \quad k \neq 0 \end{cases} \tag{15}$$

The matrix form of X_c is given as:

$$X_c = C_N \mathrm{x} \tag{16}$$

where C_N is a DCT transform with $N \times N$ matrix and X_c and x are both vectors with dimensions $N \times 1$. The row or column of DCT matrix C_N is an orthogonal vector matrix. This property of the DCT transform is used to reduce the PAPR of FBMC.

5. Genetic Algorithm (GA)

The GA is one of the developmental optimizing techniques developed by John Holland and his students in the 1960s and 1970s. We propose an enhanced GA to reduce the high PAPR of FBMC systems with the SLM-DCT technique.

For applying variable to variable crossover in GA for FBMC systems, first, increase the values of an original FBMC signal in 8 elements, then for calculating PAPR of 8 elements, it ascends the values for PAPR for every 8 elements which are called a gene. Then we have two sets of parents after selecting from half of the above genes.

After that loop begins firstly with picking a crossover point randomly and from this crossover point, it exports several rows and columns. Secondly sent from parent I to child and parent II to a child I, this composes a matrix on putting child I, child II in the new functions. In the mutation process, put the elements in one row by randomly flipping all the elements of the matrix. Until the number of iterations finished, repeat these two processes until the iterations are finished.

5.1. GA for reduction of PAPR

In GA we find a set of phases suitable for minimizing PAPR of transmitting FBMC signal. These are referred to as phase factors. The payload of SLM and SLM-DCT techniques is reduced by searching small sets instead of the whole set as in conventional SLM. These small sets are formulated just like a biological population, which is defined by N chromosomes and C genes. Now N is the population size and C is the number of sub-blocks. Whatever is the value of C, it is referred to be a phase factor in SLM-DCT, and the solution is done randomly for the initial population. Mathematically this can be formulated as:

$$\omega = (\omega_h - \omega_l)i - \omega_l \quad (17)$$

where ω_h and ω_l refer to the highest and lowest value in the variable range and i refers to random values between 0 and 1. Thus the values-1 and 1 are used for ω_h and ω_l respectively. Then we calculate PAPR values for each chromosome by multiplying SLM and SLM-DCT sequences with a set of phase factors. The PAPR values obtained are known as cost values and are arranged from minimum to maximum. A chromosome with a small cost value is muted with another small cost value chromosome to construct a new population.

The next step in the proposed GA combines the muted chromosomes to create children chromosomes. The Optimization problem is formulated by modifying one or more genes to serve a new population to further run the algorithm. The maximum possible value is chosen to limit the cost value. If the cost value becomes less than the maximum possible limit or the number of iterations exceeds the maximum number of iterations, the loop is terminated. Thus, the optimization problem of PAPR is solved by searching for the optimal phase factor ω to obtain minimum PAPR

Optimization problem in GA is formulated by modifying one or more genes to serve a new population to run the PAPR reduction algorithm using SLM-DCT sequences. The maximum possible value is chosen to limit the fitness function (Δf). If Δf becomes less than the maximum possible limit or the number of iterations exceeds the maximum number of iterations, the loop is terminated. Thus, the optimization problem of PAPR is solved by searching for the optimal phase factor ω of Eq. (17) to obtain minimum PAPR.

5.2. Pseudo-code

//# Initialize all parameters

```
p1, p2(population) c1, c2 (Chromosomes)
max_symbol=1e3, Maximum limit
Step 1.
let t = 1 (no of iterations)
while (t  ≤ max_symbol)
generate FBMC signal
calculate PAPR of the signal
max_symbols = 1e3
for j = 1:1024 (population size)
for i = 1:4 (no of chromosomes ( A T G C ))
//# -B and B are the variable range, x is the transmitted signal
if(x(i, j)  <=  -B)
xc(i, j) = -B
else if (x(i, j) >= B)
xc(i, j) = B
else xc(i, j) = x(i, j)
end
end
end
else if
(x(I, j) ≥ B )
fil =  filter(b, a, xc)
y=fil
calculate PAPR2
PAPR_sum(nsymbol) = min (PAPR2)
for j=1:1024
for i=1:4
if(x(i,j) <= -B)
xc(i,j)=-B
elseif (x(i,j)>=B)
xc(i,j)=B;
else xc(i,j)=x(i,j)
end
end
end
fil= filter(b,a,xc)
y=fil;
calculate PAPR3
PAPR_sum_DCT(nsymbol) = min (PAPR3)
end
end
Step 2
//# proposed GA for SISO and MIMO FBMC
```

```
nt=1;nr=1 (no of transmit and receive antenna)
p1 = rand(1,10)
p2 = rand(1,10)
crossoverpointindex1 = 2
crossoverpointindex2 = 6
c1 = [p1(1:crossoverpointindex1)
p2(crossoverpointindex1+1:crossoverpointindex)p1(crossoverpointindex2+1:end)
]
c2 =
[p2(1:crossoverpointindex1)p1(crossoverpointindex1+1:crossoverpointindex2)
p2(crossoverpointindex2+1:end)]
chd = [c1 ;c2]
disp(chd)
z=sum(chd)
z=max(z)
If z<(maximum limit)
Calculate PAPR
end
Goto Step 2
Change the no of transmit and receive antennas
```

6. Simulation Results

Figure 4 shows the PAPR reduction using SLM-DCT based genetic algorithm in SISO FBMC. From Fig. 4, it can be seen that the PAPR of the original FBMC signal is 6.8 dB, the PAPR of SLM based FBMC is 4.4 dB while it further reduced to 2.85 dB using SLM-DCT. The PAPR using SLM based GA is 1.9 dB, while SLM-DCT based GA counts PAPR of 1.8 dB which is least from all these techniques.

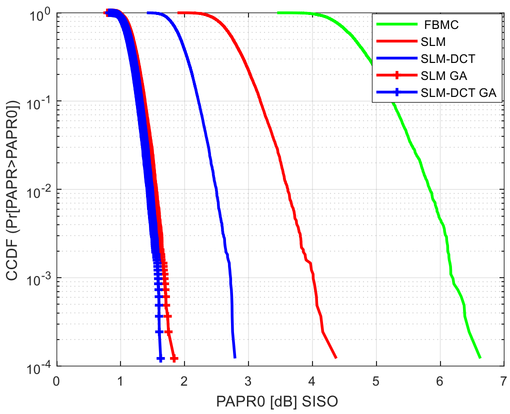


Fig. 4. PAPR reduction of SISO FBMC.

Figure 5 shows the PAPR reduction using SLM-DCT based genetic algorithm in 2×2 MIMO FBMC. The figure shows the original FBMC signal is having a PAPR of 6.4 dB. SLM reduces the PAPR to 2.2 dB. Reduction of PAPR using

SLM-DCT is about 1.4 dB and SLM based GA further reduces the PAPR to 0.95 dB, while SLM-DCT based GA lowers PAPR further to 0.9 dB.

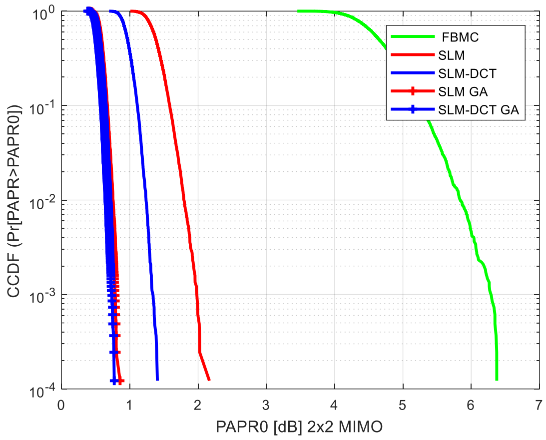


Fig. 5. PAPR reduction of 2×2 MIMO FBMC

Figure 6 shows the PAPR reduction using SLM-DCT based GA in 3×3 MIMO FBMC. It is seen from the figure that the original FBMC is having a PAPR of 6.8 dB. SLM reduces it to 1.4 dB. SLM-DCT reduces it to 1 dB. SLM based GA reduces it to 0.8 dB, while SLM –DCT based GA reduces it to 0.75 dB.

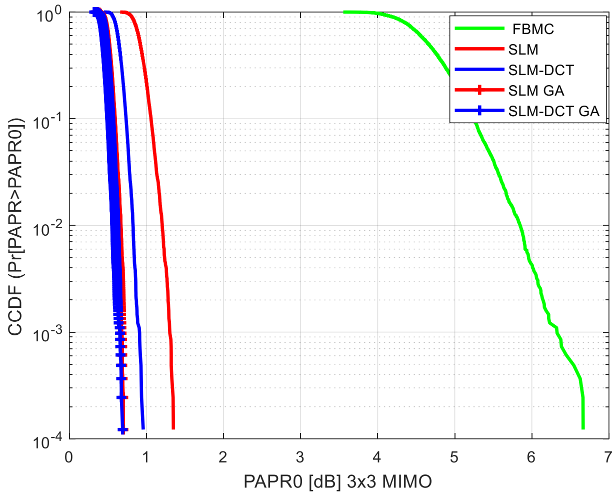


Fig. 6. PAPR reduction of 3×3 MIMO FBMC.

Figure 7 shows the PAPR reduction using SLM-DCT based GA in 4×4 MIMO FBMC. The figure shows the original FBMC signal is having a PAPR of 7 dB. SLM reduces it to 1 dB. SLM-DCT reduces it to 0.7 dB, while SLM based GA signal further reduces it to 0.5 dB and it is seen that PAPR of SLM-DCT based GA signal in FBMC is least and is almost 0.4 dB.

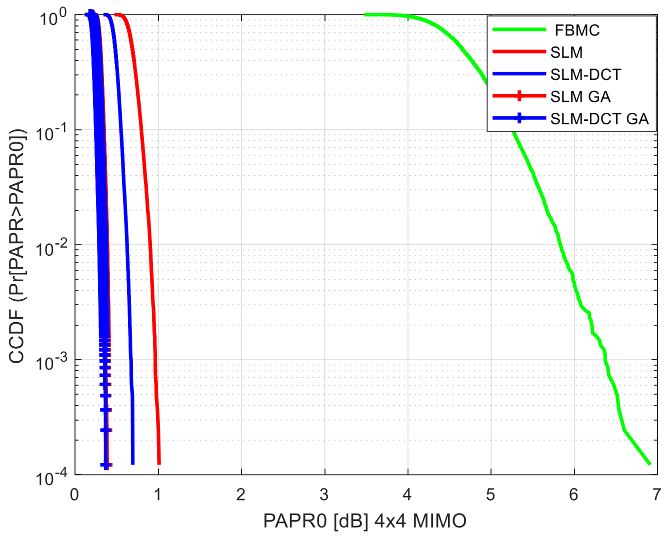


Fig. 7. PAPR reduction of 4×4 MIMO FBMC.

The above results are more precisely tabulated in Table 1.

Table1. PAPR comparison of various techniques.

Type of Signal	Pure FBMC	SLM	SLM-DCT	SLM based GA	SLM-DCT based GA
SISO-FBMC	6.8 dB	4.4 dB	2.85 dB	1.9 dB	1.8 dB
2×2 MIMO-FBMC	6.4 dB	2.2 dB	1.4 dB	0.95 dB	0.9 dB
3×3 MIMO-FBMC	6.5 dB	1.4 dB	1.0 dB	0.8 dB	0.75 dB
4×4 MIMO-FBMC	7.0 dB	1.0 dB	0.8 dB	0.5 dB	0.4 dB

The original FBMC signal is having the peak power of 6.8 dB. After the incorporation of MIMO with 2×2, 3×3,4×4 combinations, the peak power of FBMC signal changes to 6.4 dB, 6.5 dB, and 7 dB, respectively. Thus 4×4 FBMC is having highest peak power. SLM-DCT based GA significantly reduces the peak power for all the three MIMO configurations. Table 1 precisely specifies the numerical values for reduced PAPR using proposed techniques.

7. Comparison with the State of Art Techniques

References [14-18] have used several techniques for PAPR reduction in OFDM systems and [25, 26] used FBMC systems, these include PTS, SLM, tone reservations and PSO etc. Authors have done PAPR reduction on OFDM, FBMC systems and Table 1 shows the improvement in PAPR reduction. The state of art techniques has been compared with the proposed technique and Table 2 clearly shows that proposed technique has much better improved results.

Table 2. Evaluation of proposed-work with several works on PAPR reduction.

Techniques	system	PAPR in dB	References
PTS Scheme Based on Tree for PAPR Reduction	OFDM	6.2 at w = 8	[14]
G-MSLM: derived general form of modified SLM	OFDM	7.8 at M= 114	[15]
Tone Reservation for OFDM Systems by Maximizing Signal-to-Distortion Ratio	OFDM	6.6	[16]
PAPR Reduction Technology Based on CSO Algorithm in CO-OFDM System	OFDM	CSO-5.0 PSO-3.4	[17]
Binary honeybee mating partial transmit sequence to improve OFDM	OFDM	Gradient Descent-6.82 GA-6.6 BHBM-6.3	[18]
Hybrid PAPR Reduction Scheme for FBMC/OQAM Systems	FBMC	1) PAPR reductions for different schemes with V=4, c=8 and A=2.4. PTS-8.8 dB Hybrid-7.1 dB M-Hybrid-7 dB 2) Hybrid scheme, with V = 4 and V = 8 PTS-8.7 dB (v=4), PTS-7.7 dB (v=8) Hybrid-7.2 dB(v=4), Hybrid-6.1 dB(v=8) M-Hybrid-7 dB (v=4), M-Hybrid-5.9 dB (v=8)	[25]
Using a Joint Optimization Scheme	FBMC	CCDFs of the FBMC/OQAM signal with the IBPTS-ICF joint optimization scheme, V = 4 CPTS-11 dB, Conventional clipping-8.2 dB, IBPTS-8 dB, IBPTS-ICF-3.8 dB	[26]
Proposed technique	FBMC	1) PAPR reduction of 2×2 MIMO FBMC: SLM-2.2 dB, SLM-DCT-1.5 dB, SLM-GA-0.9 dB, SLM-DCT-GA-0.8 dB 2) PAPR reduction of 4×24 MIMO FBMC: SLM-1.0 dB, SLM-DCT-0.7 dB, SLM-GA-0.5 dB, SLM-DCT-GA-0.5 dB	

8. Conclusion

In this paper, a new Bio inspired (Genetic Algorithm) based PAPR reduction in FBMC Systems is proposed. In the proposed, scheme combined spatial domain and frequency domain methods of PAPR reduction have been used with a genetic algorithm. Based on simulation results, it has been observed that the proposed scheme is convergent in a real sense providing better PAPR reduction results. Moreover, the proposed scheme has been integrated with massive MIMO systems which makes it an ideal candidate for 5G and IoT networks.

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Appendix A

Computer Programme

A. 1. Introduction

In the 1960s and 1970s, John Holland and his students created a number of developmental optimization approaches, including the GA. With the SLM-DCT approach, we propose an upgraded GA to lower the high PAPR of FBMC systems The pseudo code for the PAPR reduction in FBMC is given in section 5.2. using GA.

A. 2. Flow chart for the PAPR reduction

Matlab-2017 software is used for the PAPR reduction in FBMC using GA. Each estimation convenience. The main flow chart of the programme is shown in Fig. A-1.

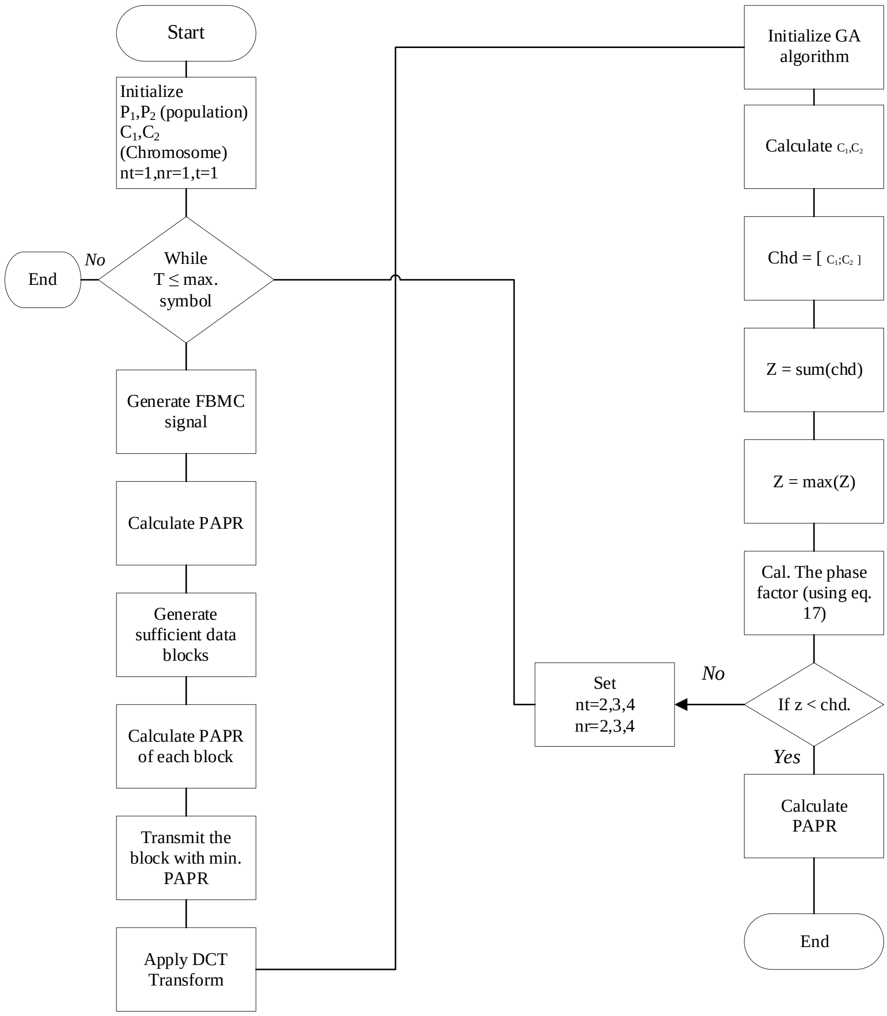

Fig. A-1. Flow chart for PAPR reduction.