# Optimization of PAPR in MB-OFDM UWB Signals Using SM-HOA Technique

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***Abstract***

***In wireless communication systems some require high data rate which can be greater than 100Mb/s which is a short range. Here ultra-wideband (UWB) systems can be used as it has high channel capacity. The spectrum available in UWB is used in orthogonal frequency division multiplexing systems with multi band (MB-OFDM) for various applications in communication. The major barrier in communication system is high peak average power ratio (PAPR) due to the disturbances caused in transmitting components which are nonlinear in nature. It is very much essential to reduce the PAPR to maximum extent in MB-OFDM UWB signals. In this paper, Hybrid optimization technique is considered by combining Grey-wolf and firefly algorithm for PAPR reduction. The noise reduction is performed for the UWB signals and results need to be analysed. In this paper the evaluation of proposed algorithm is shown by calculating the error rate per bit (BER) and PAPR. The obtained results are compared with other optimization techniques. Our results demonstrated hybridization of optimization technique is a promising technique for the transmission of MB-OFDM UWB signals compared to genetic algorithm, firefly optimization and grey wolf optimization-based MB-OFDM UWB signal transmission.***

***Keywords:*** *OFDM, UWB Signals, Firefly Algorithm, Grey wolf Optimization, PAPR, BER*

## 1. Introduction

In wireless communication systems short distance for transmission of data with high speed are given more importance in present scenario. The ultra-wide band (UWB) technology meets the requirement among the users [1]. In-order to use the entire bandwidth effectively which is available in UWB spectrum, OFDM systems is designed with multi-bands which is said to be MB-OFDM [2]. As the range of bandwidth increases, the number of sub-channels also increases this phenomenon leads to increase in peak average power ratio (PAPR). The major task is to reduce PAPR as the high PAPR limits the capacity of the channels which is occurred by High power amplifiers (HPA). The distortions present in OFDM systems are linear and nonlinear. Most of the signal interference problem in signals is caused by nonlinear distortions. The variations like increase or decrease in bit error rate depend on the interference which occurs in in-band and out-band. If the in-band interference increases the BER also increases and vice-versa. The inter-modulation and signal constellation are caused due to in-band interference and the spreading of spectral via channels is caused due to out-band interference. If there are no distortions in the transmitting signals, the PAPR can be reduced. The major interest in to come up with new techniques for reducing of PAPR, one of such technique is clipping and which is easy and simple to implement [3]. This is one of the initial techniques which is a nonlinear process. It helps in reducing the in-band and out-bands interferences. Performance of filtering processed by clipping helps in reduction of peaks that are reproduced, in [4] turbo codes are generated so that clipping effect can be reduced. Many techniques have been introduced for reduction of PAPR, in [5] a tunable predistorter based on Rapp's SSPA model is been proposed. Further optimization techniques were introduced by which the process helps in obtaining the best solution for reducing the PAPR. In this paper, combination of two optimization techniques is performed for find optimal value of PAPR in MB-OFDM ultra-wideband signals and the results are matched with other optimization techniques such as, firefly algorithm [6], grey-wolf algorithm [7], Grasshopper algorithm [8]. The results are evaluated using MATLAB tool and the performance measures calculated are PAPR and BER. These factors show the efficiency level of the techniques which are used.

## 2. Multi Band UWB System

The use of ultra-wideband technology has been increased in wireless communication systems as it has short range, flow rate of data is high, consumes lower power and provides bandwidth which is required for the system [9]. Standard Institution like Federal Communication Commission (FCC) recognises UWB technology having a bandwidth range of greater than 500MHz or it provides minimum of twenty present of the center frequency on which the operations of the concern systems perform. Major range of applications are mobile communications, GPS systems, Satellite communications, United states Navy services (USNS) etc in which most of them uses high range of bandwidth which are not having license. The band width range above 7.5GHz are not having permission to use which is been stated by FCC. So, FCC controls the emission of power in UWB devices to reduce the threshold limit of noise that is considered by other technologies which use the same band range. One of the main advantages is cost function, which is free for UWB user, rather than being expensive using other technology for similar band range. In [10], it is given that -40dBm W/MHz or 10nW/MHz of spectrum is the max power that is been limited in UWB devices and is very less when compared with wireless local area networks with a limit of 10mW/MHz. Some of the standard working committee projection reveal that UWB in present trend have a mini speed requirement of 110Mbps with a distance to cover is 10m. The speed is very high when compared to current Bluetooth technology with a max speed limit of 1Mbps. The channel capacity as shown $ChannelCapacity = B.W * log2(1+SNR)$ [12] states that due to decrease in power, SNR goes down, so Bandwidth should be very large for high channel capacity which is the advantage of UWB which has a minimum B.W of 500MHz. The power and the range is given by Friss transmission equation as shown which states that the $Power\ received \propto 1/Range2$**.**

As the power function is not directly proportional to range, the ranges used for different coding techniques can be extended to larger distance. In current conditions the wireless USB uses UWB for transmitting data that assures a speed of 480Mbps. It is the future standard for Bluetooth as seen by Bluetooth Special Interest group IEEE 802.15.1

### A. Single Band Technology

The difference of single band and multiband is shown in Fig1 and Fig 2. The transmission of single carrier with a limited bandwidth range is shown in below fig 1. In [12] the single carrier transmission proposal was used in Motorola and Path Cerva based DS-CDMA technology. In which the direct sequence transmission is performed.

### B. Multi Band OFDM

Multiband is simply dividing the original given band into several sub-bands. The multiband concept in UWB is as shown in below fig 2.

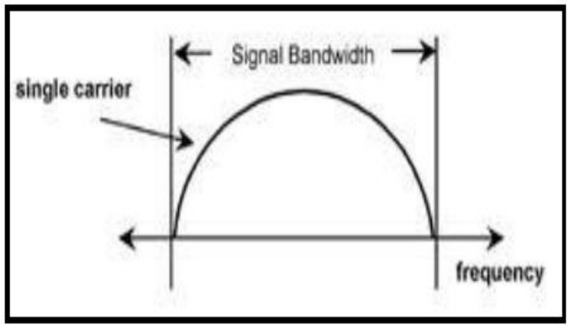


Fig: 1 Single Carrier Transmission

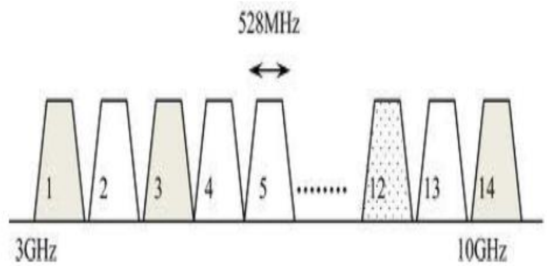


Fig:2 Multiband in UWB

The 7.5GHz of band is subdivided into smaller bands and each sub-band is of 528MHz wide according to FCC definition for UWB, minimum bandwidth requirement of 500MHz. It is of two types pulse-based transmission or OFDM based transmission.

**3. UWB Signals in MB-OFDM**

The equation which states the UWB signals in MB-OFDM can be shown as,

$$d_n = \frac{1}{N}\sum_{s1=0}^{N-1} D_{s1} \exp\left(\frac{j2\pi mn}{N}\right); n = 0,1,2, \ldots\ldots N-1$$

where $D_{s1}$ is the $s1^{th}$ symbol of QAM and for which the N values considered to be 128 [6]. The total length of the samples that are taken to be of L=165 in which the MB-OFDM symbol are designed with placements of the data blocks. To obtain the proposed length zero prefix position with 32 number of samples and the guard interval for every 5 samples. The design of MB-OFDM UWB signals is shown in below Fig 3.

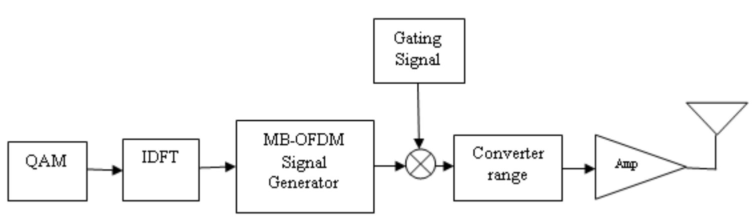


Fig 3. Transmitting side of MB-OFDM UWB signal [3].

The final $k^{th}$ position of MB-OFDM symbol is given by

$$u_{k,l} = \begin{cases} 0 & 1 < l \leq 32 \\ d_{l-33} & 32 < l \leq 160 \\ 0 & 160 < l \leq 165 \end{cases}$$

Then the equation of Multi Band OFDM signal is given as

$$u(t) = \Re((\sum_{k=-\infty}^{\infty} \sum_{l=1}^{L} u_{k,l}\, h_{rect}(t - kT_{OFDM} - (l-1)\Delta t)\exp(-j2\pi f_c t))$$

In this a rectangular frequency response $h_{rect}$ is a filter which is been bounded by $\pm 1/(2\Delta t)$, $T_{OFDM} = L\,\Delta t = 312.5$ nanoseconds is the MB-OFDM symbol period, $\Delta t = 1/(N\Delta f) \approx 1.9$ nanoseconds, and the complex number has real and imaginary parts, where the real part is denoted by $\Re$.

As said in [2] a specific time-frequency code is provided for MB-OFDM signals with a fourteen number of bands center frequencies for the signal hop's. Some of the gate functions are used for simulating the time-frequency code which is have a single range of frequency. These gate functions are multiplied as $g(t); T = bwT_{OFDM}, \tau = wT_{OFDM}$ where $b$ represents the band number, the periodic signals in each band is **w.** The function for periodic gating is given as $g(t; T, \tau) = \sum_{k=-\infty}^{\infty} R(t - kT;\, \tau)$ where $R(t;\tau) = \begin{cases} 1 & 0 \leq t < \tau \\ 0 & otherwise \end{cases}$ and $T > \tau$

**4. Proposed Hybridization for PAPR reduction**

**A. Firefly Optimization**

Fireflies are unisex with the goal that each individual firefly will be pulled into different fireflies paying little mind to their opposite sex. The attractiveness and brightness are correlated to each other and are directly in proportional with each other, and they both lessening as their separation increments. Along these lines for any two blazing fireflies, the less splendid one will attract the more brilliant one. A specified firefly will be moving randomly which will be considered as a sharp fly for obtaining optimal result. The firefly brightness will be controlled based on the availability of flies.

The attractiveness concept in firefly is related with the intensity of light or brightness of the neighbour flies, the following is developed as the variation of attractiveness $\beta$ with the distance $r$ by

$$\beta = \beta_0 e^{-\gamma r^2} \tag{4}$$

Where $\beta_0$ is attractiveness at r=0

The firefly $i$ is attracted to another more brighter firefly j and move towards j and the sane is determined by

$$x_i^{t+1} = x_i^t + \beta_o e^{-\gamma r_{ij}^2}(x_j^t - x_i^t) + \alpha_t \epsilon_i^t \tag{5}$$

Where the second term $\beta_o e^{-\gamma r_{ij}^2}(x_j^t - x_i^t)$ is concern based on the attraction. The third term i.e. $\boldsymbol{\alpha_t \epsilon_i^t}$ is randomization with $\boldsymbol{\alpha_t}$ being the randomization parameter, and $\boldsymbol{\epsilon_i^t}$ is a vector of random numbers drawn from a Gaussian distribution or uniform distribution at time $t$.

**B. Grey Wolf Optimization**

This optimization technique is based on the hunting nature of the wolf and the leadership way of behaving among the wolves which exist in nature. In this process initially four wolves are considered for obtaining the leadership qualities in search of prey. The names are termed as alpha, beta, delta, and omega respectively. The algorithm follows the administration skills and the general chasing concept of the grey wolves. In [9], the behaviour of wolves that are considered initially forms of chain of commands by its own individual level of authority. The hunting begins first by searching for the prey. Secondly the prey is been encircled, finally when the prey is stuck in within the boundary of wolves then prey gets attacked. After performing the three steps the final optimal solution is obtained. In this algorithm best agents need to identify and are denoted as $P(\alpha), P(\beta)\ and\ P(\delta)$. The velocities are termed as Eq. (6), Eq. (7), and Eq. (8)

The equations can be shown as:

$$V_\alpha = |C.P_\alpha(t) - P(t)| \quad (6)$$

$$V_\beta = |C.P_\beta(t) - P(t)| \quad (7)$$

$$V_\delta = |C.P_\delta(t) - P(t)| \quad (8)$$

The positions are updated as Eq. (9), Eq. (10), and Eq. (11):

$$P_1 = P_\alpha - B.V \quad (9)$$

$$P_2 = P_\beta - B.V \quad (10)$$

$$P_3 = P_\delta - B.V \quad (11)$$

Where B and C are the vector coefficients which are calculated as Eq. 10 and Eq. 11

$$B = 2b.r_1 - b \quad (12)$$

$$C = 2.r_2 \quad (13)$$

**C. Hybridization of Optimization Techniques**

The grey wolf optimization and Firefly optimization is combined to form a better search of agents to obtain the best position, to obtain the best PAPR value [11].

Here we consider the velocities of the grey wolf as,

$$R_\alpha = \frac{|C.P_\alpha(t) - P(t)|}{d_{max}} \quad (14)$$

$$R_\beta = \frac{|C.P_\beta(t) - P(t)|}{d_{max}} \quad (15)$$

$$R_\gamma = \frac{|C.P_\gamma(t) - P(t)|}{d_{max}} \quad (16)$$

where $d_{max} = (U_B - L_B) * \sqrt{Dim}$

Dim= Signal Length

Then the velocity is updated w.r.t. firefly and is given as,

$$V_\alpha = \beta_0 e^{-\gamma R_\alpha^m} \quad (17)$$

$$V_\beta = \beta_0 e^{-\gamma R_\beta^m} \quad (18)$$

$$V_\gamma = \beta_0 e^{-\gamma R_\gamma^m} \quad (19)$$

Here we consider $\beta_0 = 2, m = 2, \gamma = 1$. Now the positions are considered according to Eq. (9), Eq. (10), and Eq. (11).

**Algorithm for SM-HOA**

The SM-HOA algorithm given as,

Step1: Initialise input data $I_x = I_1 I_2 I_3 \dots \dots \dots \dots . I_n$

Step2: Converting of SB of data to PB

Step3. The phase rotation process of bits is done, and hybrid optimization technique is applied

Step4. Consider the agents for search (wolves) and the process of search is based with respect to fireflies

Step5: Fitness function is evaluated

Step6: Find the best position with respect to the velocities given as $V_\alpha, V_\beta$ $and$ $V_\delta$

Step7: Update the position

Step8: Again, evaluate the fitness function after updating of positions

Step9: further update the position of $V_\alpha, V_\beta$ $and$ $V_\delta$ w.r.t. fireflies

Step10. Best solution needs to be identified

Step11. PAPR signal with minimum value is determined.

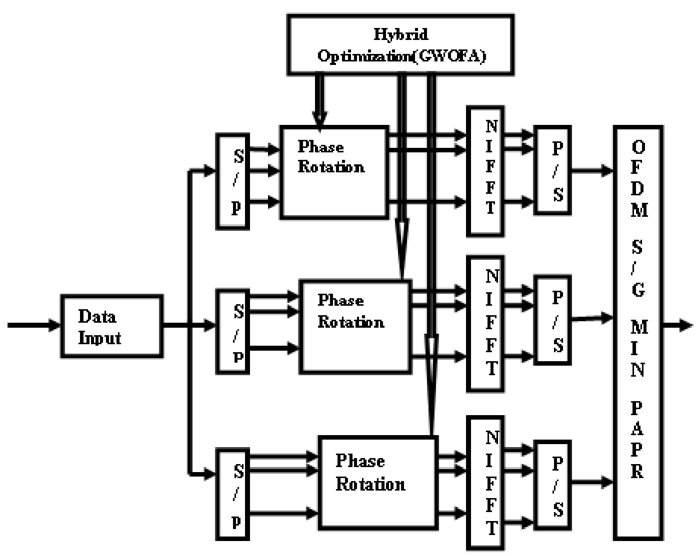


Fig 4. SM-HOA Model [11]

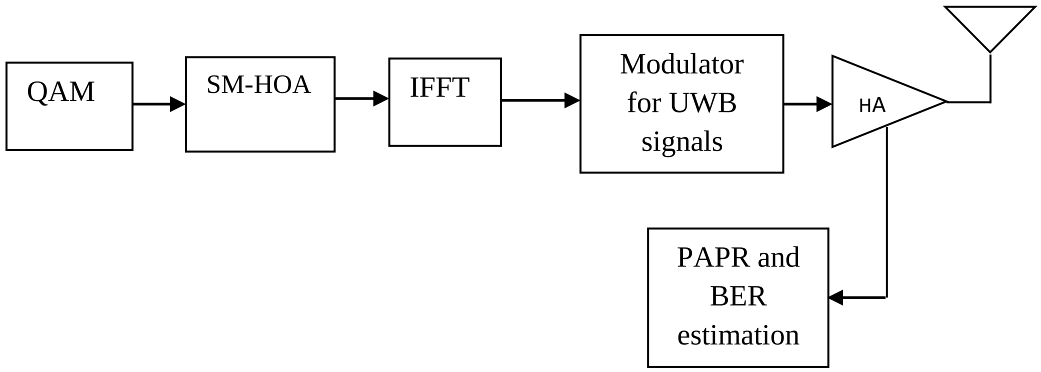


Fig 5. Proposed MB-OFDM-UWB hybrid system.

## 5. Results and Discussion

The results obtained using proposed technique is evaluated and shown in this section. Various techniques are been compared with the proposed hybrid optimization techniques. In this we consider multi band model for transmitting and receiving the information in OFDM system. CCDF metric is mostly used metric for evaluating the performance of PAPR. CCDF is the cumulative distribution function which judges the value of PAPR in OFDM signals for a given limit of threshold.

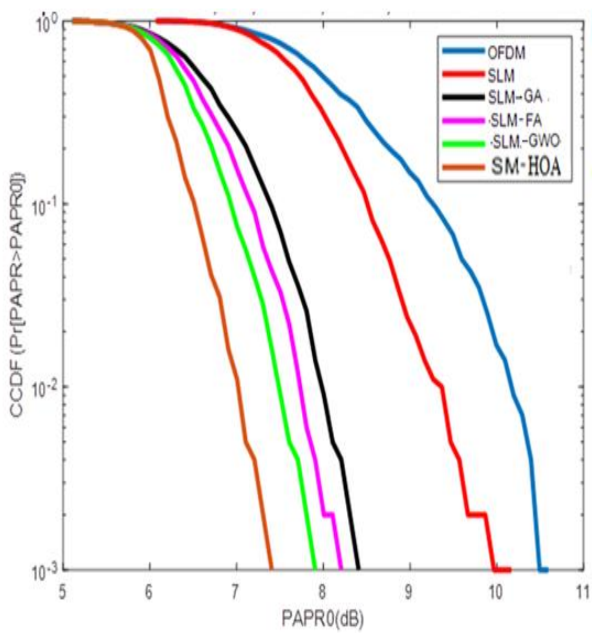


Fig 6. PAPR for M=2

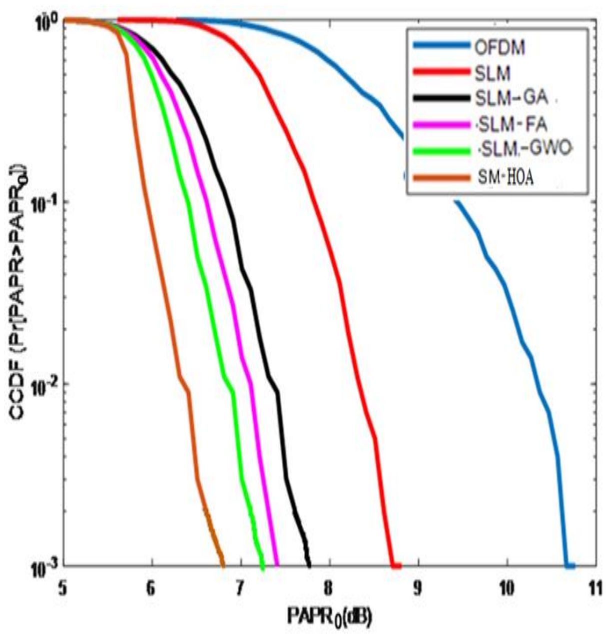


Fig 7. PAPR for M=4

The results shown prove that the proposed approach has good consideration for reducing the PAPR when compared with other approaches. The values of PAPR does not exceed 8.90 dB for SLM, 7.05 dB for SLM-GA, 6.62 dB for SLM-FA, 6.05 dB for SLM-GWO and 5.5 dB for SM-HOA. From fig 6 we can observe the values.

Here we consider different values and 'M' and simulate the results, as shown below.

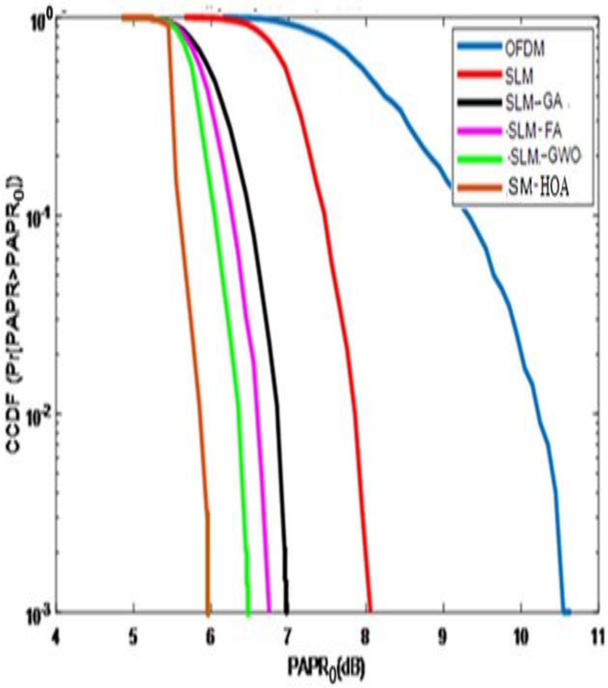


Fig 8. PAPR for M=8

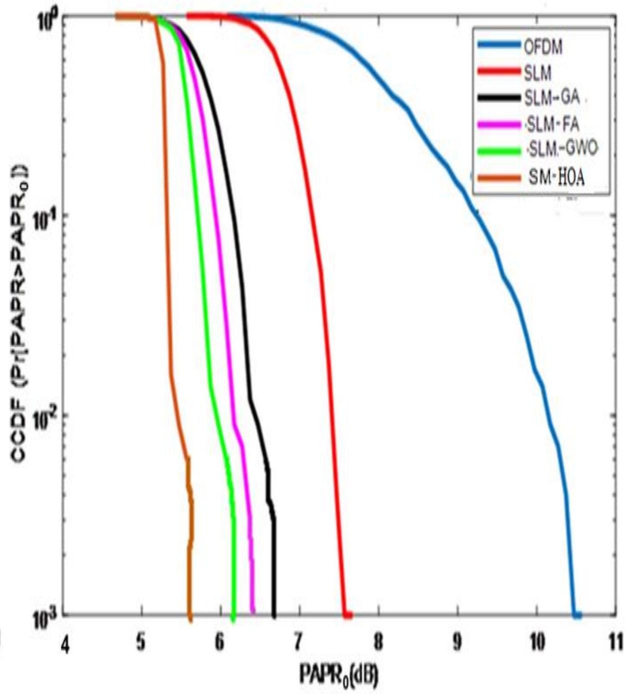


Fig 9. PAPR for M=16

For M=8 the results obtained using various techniques is shown in fig 8. As the size of M increases the PAPR gradually decreased, but the as the M size increases the system complexity will be increased.

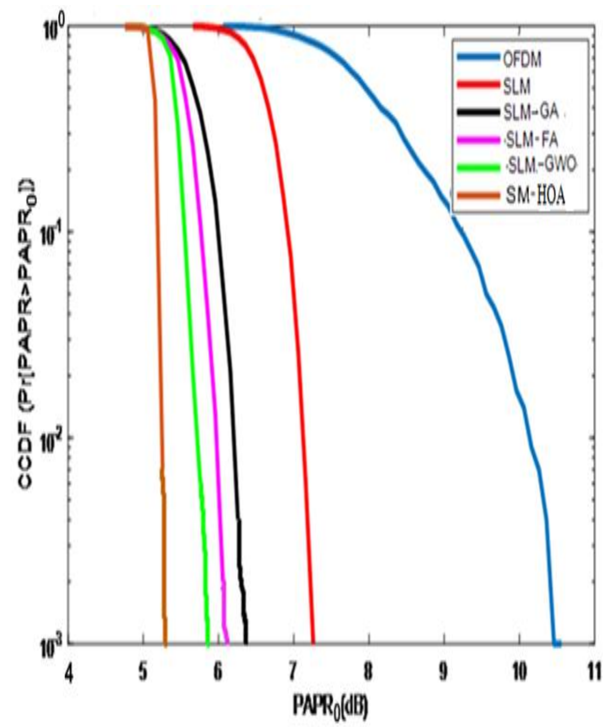


Fig 10. PAPR for M=32

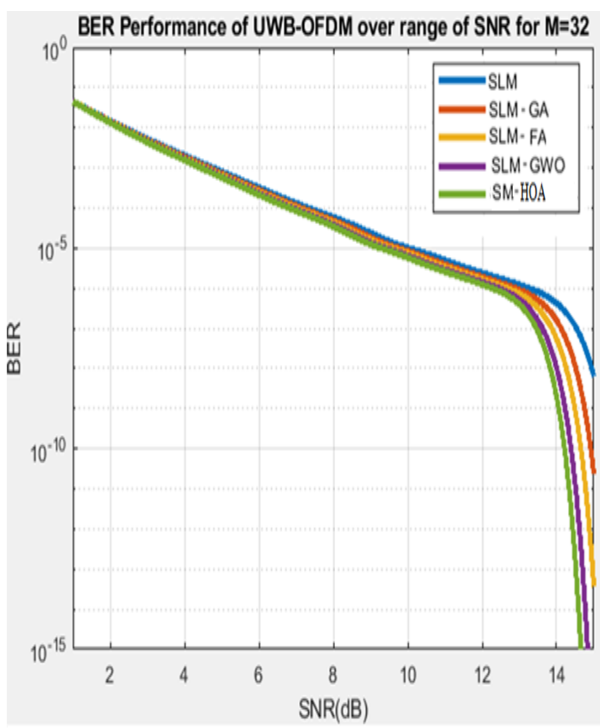


Fig 11. SNR vs BER for M=32

In this paper the analysis is done until M value is 32. Further the increase in value of M the steady PAPR value will be achieve. From our analysis it is observed that the PAPR is reduced using hybrid optimization technique in MB-OFDM UWB system.

Here, from the above results, the system BER and PAPR both are been balanced without disturbing the functionality of the MB-OFDM system. The proposed techniques maintain a cordial way of dealing the distortions in the signals. The gains and power achieved are in controllable stage. The side information is been restricted by applying channel coding. The data integrity is been preserved by which the rate of data flow will be reduced. The proposed technique has a good reduction in PAPR without degrading the Bit error rate which is shown in the above results.

Table 1. Comparison of PAPR using various techniques.

| **Technique/M=** | **2** | **4** | **8** | **16** | **32** |
|---|---|---|---|---|---|
| SLM | 10.13dB | 8.78dB | 8.14dB | 7.75dB | 7.28dB |
| SLM-GA | 8.34dB | 7.68dB | 6.96dB | 6.62dB | 6.21dB |
| SLM-FA | 8.14dB | 7.49dB | 6.80dB | 6.40dB | 6.05dB |
| SLM-GWO | 7.84dB | 7.17dB | 6.46dB | 6.12dB | 5.70dB |
| **SM-HOA** | **7.34dB** | **6.67dB** | **5.96dB** | **5.62dB** | **5.20dB** |

We considered SNR as 9dB, the proposed technique SM-HOA having zero-bit error rate for SNR more than 9dB. The proposed techniques give a promising value of PAPR, without degrading the BER. The BER obtained using proposed technique is low near all SNR values when compared with other techniques. Table 2 gives the values of SNR by considering 12dB for various 'M' values.

Table 2. BER vs SNR for 10dB using various techniques.

| **Technique/M=** | **2** | **4** | **8** | **16** | **32** |
|---|---|---|---|---|---|
| SLM | $10^{-6}$ | $10^{-6.2}$ | $10^{-5.5}$ | $10^{-5}$ | $10^{-4.9}$ |
| SLM-GA | $10^{-7}$ | $10^{-6.3}$ | $10^{-5.7}$ | $10^{-5.5}$ | $10^{-5.1}$ |
| SLM-FA | $10^{-8}$ | $10^{-6.5}$ | $10^{-5.9}$ | $10^{-5.8}$ | $10^{-5.2}$ |
| SLM-GWO | $10^{-12}$ | $10^{-7}$ | $10^{-6}$ | $10^{-5.9}$ | $10^{-5.3}$ |
| **SLM-GWOFA** | $10^{-15}$ | $10^{-7.5}$ | $10^{-6.2}$ | $10^{-6}$ | $10^{-5.5}$ |

## 6. Conclusion

In wireless communication system short range transmission have given more importance for which UWB signals are consider. In this paper, MB-OFDM UWB signals are considered and the most common problem is high PAPR. To reduce the PAPR so many techniques have been implemented and four techniques, namely, SLM-GA, SLM-FA, SLM-GWO, SM-HOA are implemented and evaluated. The proposed hybrid optimization is good in terms of PAPR and BER. Irrespective to the level of computational complexity and performance of BER, the proposed Hybrid optimization technique is said to be a promising technique for PAPR reduction in MB-OFDM UWB signals. Further hybridization of different optimization techniques can be applied for reducing the PAPR. Any of the best combination can provide low PAPR.

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