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# PAPR and BER Reduction on Improving Performance for Filtered-OFDM using MSM and PSO

**M. Selvakumar, B. Sudhakar**

***Abstract:*** ***Filtered-Orthogonal Division Multiplexing (F-OFDM) is one of the capable alternative candidate modulation methods for 5G communication systems. F-OFDM utilizes the allocated spectrum by having lower side-lobes, which leads to higher spectral efficiency. However, it experiences an elevated peak-to-average power ratio (PAPR). This influences the radio frequency components' operation mode, such as the power amplifier and the digital-to-analog converter. Also, high PAPR builds the amplifiers to exertion in non-linear regions and enhance the Bit Error Rate (BER). Moreover, Large PAPR guides to spectral spreading and band distortion. Selective Mapping (SLM) provides enhanced PAPR reduction without the data rate loss and also exclusive of the signal distortion. Though, SLM has elevated computational complexity additionally. Numerous procedures have been suggested in the research for OFDM. In this thesis, a modified-SLM using Discrete Sine Transform (DST) is recommended to lessen the PAPR of filtered-OFDM. The idea of a Discrete Sine Transform is de-correlating the data in a sequence by compressed a large amount of signal energy into a few transform coefficients; consequently it provides an improved diminution in PAPR. Furthermore, the BER performance of the system has been enhanced by applying an optimization algorithm called Particle Swarm Optimization (PSO). This proposed model results illustrate that the proposed Modified Selective mapping using Discrete Sine Transform (MSLM-DST) technique can provide a PAPR reduction of about 4.4 dB. Moreover, the PSO improved the system performance as it significantly reduces the BER of the system.***

***Keywords:*** ***Filtered Orthogonal Division Multiplexing (F-OFDM), Particle Swarm Optimization (PSO), Peak-to-Average Power Ratio (PAPR), Discrete Sine Transform (DST), Bit Error Rate (BER) and Selective Mapping (SLM).***

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## I. INTRODUCTION

FOFDM is the one among the OFDM based candidate modulations for upcoming 5G systems. However, as in all multicarrier modulations (MCM), high PAPR is the main drawback of this modulation as the transmitted signals is the superposition of multiple independent and orthogonal sub-carriers. Lower PAPR is an essential waveform design principle for the 5G new waveforms to be capable of meeting the 5G requirements and of improving the power efficiency, so the PAPR should be reduced.

It has become imperative to have an adequate PAPR reduction technique with less computational and hardware complexity, consequently, propose a modified selective mapping using Discrete Sine Transform to lessen the PAPR of filtered-OFDM. However, employing a single technique has disadvantages that may affect the performance of some other system parameters like Bit Error Rate, so applied the PSO algorithm that will advance the BER concert of the system.

This paper is planned to written up as follows. Section 2 studies filtered OFDM. Peak-to-average power ratio is conversed in Section3, and Section 4 presents the proposed work. The obtained results are discussed and investigated in section 5, and chapter 6 discussed the conclusion

## II. FILTERED OFDM

In F-OFDM, the allocated bandwidth could be split up as many the number of sub-bands; each one sub-band is independently modulated by means of classical OFDM modulation [1], Sub-band-based separating is then applied to stifle the between sub-band impedance, F-OFDM additionally gives noteworthy decreases on the gatekeeper band utilization, prompting progressively effective range usage [2]. It is the augmentation of the exemplary OFDM with an extra sub-band channel and adaptability in changing the parameters like transmission time interval, length of cyclic prefix, and subcarrier spacing [3]. The filter bandwidth is planned for an assured sub-band, but it is avoidably equal to 1 PRB. In this way, Filtered OFDM is proficient of surmount the drawbacks of OFDM while keep hold of the reward of it. The critical properties of F-OFDM are as follows [2] [4].

i. By sub band based filtering, the global synchronization requirement is relaxed, and it can support inter-sub band asynchronous transmission.

ii. The consumption of the guard band can be minimized to a least level by suitably designing filters to restrain the OOB emission.

iii. Optimized numerology is able to apply in each sub band to suit the demands of specific types of services.

iv. Having OFDM as its center waveform, which permits F-OFDM to appreciate the attractive properties of OFDM and empower the quick use of all current OFDM-based models.

v. F-OFDM is good with MIMO, and furthermore its PAPR can be effectively diminished utilizing traditional decrease strategies

All in all, the new presentation prerequisites looked by the 5G waveform can be satisfied by F-OFDM, and the general range effectiveness can be improved.

### A. Filtered-OFDM Transceiver

As illustrated in the Fig.1, the F-OFDM transmitter produce the OFDM signal based on the allocated block of successive subcarriers in a numeral successive OFDM symbols.

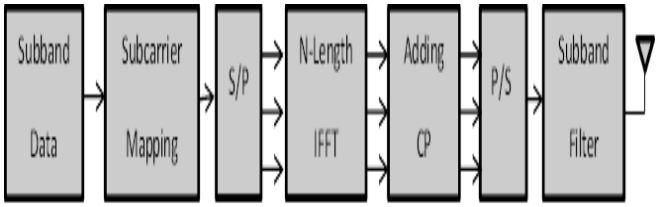


**Fig.1. F-OFDM Transmitter**

In order to understand the transmitter and receiver side processes we have to characterize the F-OFDM symbol mathematically. Starting from discrete time representation of OFDM symbol:

$$x(n) = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} c_k e^{j2\pi kn/N} \quad (1)$$

Where N is the quantity of subcarriers. The F-OFDM signal is then gotten by passing the sign x(n) through an approoriately planned range forming channel to restrain the certain amount of band emissions, we get :

$$\tilde{x}(n) = x(n)*f(n) \quad (2)$$

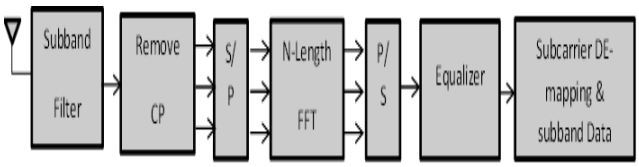


**Fig.2. F-OFDM Receiver**

## III. PEAK AVERAGE POWER RATIO (PAPR)

All OFDM-based systems have high PAPR as the transmitted signals are the superposition of multiple sub-carriers through an IFFT process. Essentially, F-OFDM messages additionally comprise of numerous free and symmetrical sub-transporters and have the issue of high PAPR, which is successfully one of the main usage drawbacks of the OFDM-based frameworks. Besides, the PAPR could be increased by the sub-band filter during the F-OFDM order.

### A. PAPR Definition

The PAPR measurement on the continuous time base-band OFDM signal, x (t) is stated as the proportion connecting the highest instantaneous power with the average power, which is

$$\mathrm{PAPR}(x(t)) \triangleq \frac{\max\limits_{0 \le t \le Kt_s} |x(t)|^2}{\frac{1}{Kt_s}\int_0^{Kt_s} E\left\{|x(t)|^2\right\} dt}. \quad (3)$$

Where E [•] means the expecting significance. In the event that the x (t) signal is inspecting at the Nyquist Rate t=n, with whole number n, the discrete-time baseband OFDM signal x (n) can be composed as:

$$x(n) = \frac{1}{\sqrt{K}} \sum_{k=0}^{K-1} X(k) e^{j2\pi \frac{k}{K} n}, \quad n = 0, 1, \ldots, K-1, \quad (4)$$

Furthermore, the PAPR as far as discrete-time baseband OFDM sign can be communicated as:

$$\mathrm{PAPR}(x(n)) \triangleq \frac{\max\limits_{0 \le n \le K-1} |x(n)|^2}{\frac{1}{K}\sum_{n=0}^{K-1} |x(n)|^2}. \quad (5)$$

By and large, the PAPR of the discrete OFDM signal is lesser to the PAPR of the nonstop OFDM flags by 0:5 ~ 1 dB [5]. Henceforth, the connection between PAPRs is given by:

$$\mathrm{PAPR}(x(n)) <= \mathrm{PAPR}(x(t)) \quad (6)$$

The above power qualities can likewise be portrayed as far as their magnitudes by characterizing the Crest Factor (CF), the one characterized as the proportion between greatest amplitude of OFDM signal x (t) and the root-mean-square (RMS) [13]. The CF is characterized as:

$$CF = \frac{max|x(t)|}{E[||x(t)|^2|]} = \sqrt{PAPR} \quad (7)$$

PAPR is an arbitrary variable since it is an element of the info information, and the information is irregular variable. This is performed by figuring the complementary cumulative distribution function (CCDF) utilizing equation (7) for various PAPR values as follows:

$$\mathrm{CCDF} = \Pr(\mathrm{PAPR} > \mathrm{PAPR0}) \quad (8)$$

The Cumulative Distribution Function (CDF) is the most consistently utilized parameters that are utilized to quantify the effectiveness of some PAPR procedure. The CCDF encourages us to gauge the likelihood with the purpose of PAPR of specific information square surpasses the given limit [6].

### B. Selective Mapping Technique

In SLM, the basic idea is to deliver a great deal of OFDM signals, all of them talking to comparable data square, and a short time later transmitting the one with the most decreased PAPR.

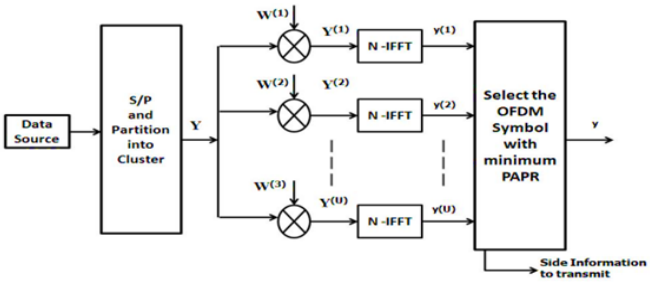


**Fig.3. Selective Mapping (SLM) Technique for PAPR Reduction**

The input data is apportioned into a data block Y of length N. subsequently these data block is multiplied factor through factor by means of phase sequence $W^{(u)}$

$$W^{(u)} = [W_{u,0},\ W_{u,1},\ \ldots,\ W_{u,N-1}]^T \qquad (9)$$

for u=0, 1…, U

Resulting into U modified data blocks $Y^{(u)} = [Y_{u,0}, Y_{u,1}, \ldots, Y_{u,N-1}]^T$ (10)

Where, $Y_{u,k} = Y_k W_{u,k}$ for k=0, 1…., N-1 (11)

Subsequent to that, the N-point IFFT of every data block $Y^{(u)}$ is taken; the resulting OFDM signal is given as:

$$y^u(n) = \frac{1}{N}\sum_{k=0}^{N-1} Y_k W_{u,k} \exp\left(\frac{j2\pi kn}{N}\right) \qquad (12)$$

*For* n=0, 1… U-1

Among the OFDM data bocks $Y^{(u)}$(n), u=0, 1, … , U-1, just lone with the least PAPR is chosen regarding the transmission and the comparing chosen stage factor likewise transmitted to collector as side data. A lot of work has been recommended as an adapted SLM to decrease the computational complexity as well as to diminish or eliminate the side information sent out [7].

## IV. PROPOSED TECHNIQUES

F-OFDM is one among the OFDM-based candidate modulations for upcoming 5G systems. However, as in all multicarrier modulations, high PAPR is the main problem of this modulation as the transmitted signals is the superposition of multiple independent and orthogonal sub-carriers. Lower PAPR is an essential waveform design principle for the 5G new waveforms to be capable of meeting the 5G requirements and of improving the power efficiency, so the PAPR should be reduced. The conventional PAPR reduction approaches applied in the traditional OFDM have some advantages and disadvantages, which affects the overall system performance. Therefore, it is an interesting issue of how to correctly choose and extend the PAPR reduction methods in the traditional OFDM to the new modulation schemes. This work propose a technique of PAPR reduction for F-OFDM, a frequency domain modified selective mapping technique using discrete sine transform DST. Furthermore, offer an optimization algorithm called PSO is used in the system for the reduction of BER and overall improvement of the system.

### A. Modified Selective Mapping Using Discrete Sine Transform

In SLM initially the sub band information are partitioned into sub obstructs all including the comparative information and afterward everybody ought to duplicate by various phase sequences. The sub-block that gives the base PAPR is a short time later picked. The SLM diagram is specified in Fig.4.

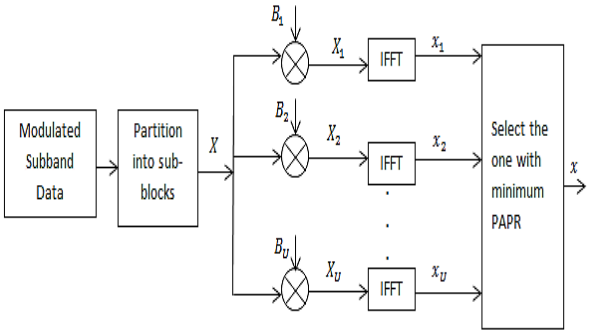


**Fig.4. Block diagram of selective mapping**

Adjusted sub band information X in the wake of parceling are duplicated by phase vectors {B1, B2, . . . , Bu}to give the changed sub- blocks {X1, X2, . . . , Xu} to be additionally handled by IFFT. Out of these altered information obstructs the one that gives the least PAPR is chosen and passed on. PAPR decline in SLM depends upon number and plan of stage groupings U, Greater number of stage courses of action gives more PAPR decline. In the wake of applying SLM, the baseband F-OFDM signal comprising of N sub- carriers becomes

$$x_u(t) = \frac{1}{\sqrt{N}}\sum_{m=0}^{N-1} A_m B_{u,m} e^{j2\pi kt/T} \qquad (13)$$

Where x (t) is the modified data block. u = 1, 2. . . U is the number of sub-block and $A_m$ is the symbol of the $m^{th}$ sub-carrier, while T is the duration for symbol. At the recipient side a reverse process is executed to make progress the inventive information.

Multicarrier signs are able to build during composite exponential capacities; however this isn't the main premise. DST gives a lot of sinusoidal capacities that can be utilized to execute multicarrier adjustment plans, for example, F-OFDM. It straightly changes the time space information into the recurrence area by rep-despising the information as a whole of sines. Mathematically they can be described as:

$$X(t) = \sqrt{\frac{2}{N}}\sum_{n=0}^{N_s-1} a_n b_n \sin\left(\frac{n\pi t}{T_s}\right) \qquad (14)$$

DST is like DFT however of genuine capacities as it were. It has the property of information pressure that is practical for PAPR decrease; by de-associating the first information and compacting the sign vitality in a smaller number of change coefficients. The compaction assists with diminishing the PAPR of the first sign. The principle bit of leeway of DST is that it doesn't need some side data for the collector.

The computational unpredictability of DST is likewise not as much as that of Fourier changes. SLM attains superior PAPR excluding at the cost of larger complexity.

Therefore via joining the features of the both techniques, a better PAPR reduction is achieved.

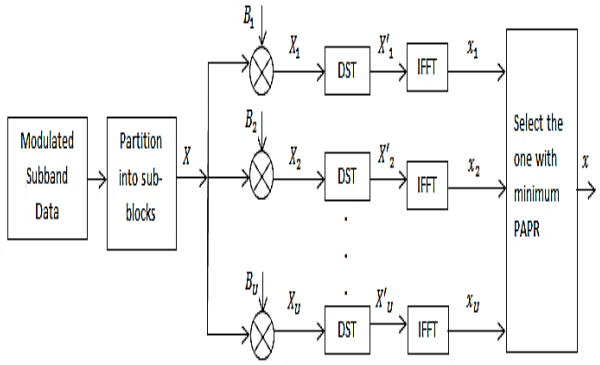


**Fig.5. Block diagram of proposed Modified Selective Mapping**

In the proposed modified SLM, the modulated sub band data subsequent to the partitioning into sub-blocks, be once more altered by DST prior to applying IFFT on every sub-block $\{X'_1, X'_2, \ldots, X'_u\}$ to give the modified sub-blocks $\{x_1, x_2, \ldots, x_u\}$. This transform de-correlate the data in a sequence by compressing great quantity of signal energy keen on little transform coefficients so this provides an enhanced lessening while a high PAPR signal is practical at the input. The proposed scheme is represented in block diagram is shown in Fig. 5. Since each sub-block is transformed before IFFT, the complexity of the method boost to (UN log N) where N log N is the complexity of transform and the number of sub-blocks by U.

### B. Particle Swarm Optimization (PSO) For Bit Error Rate Reduction

This algorithm inspired by the flocking and schooling patterns of birds and fish. In this paper, PSO is given as an improvement of the BER of the system.

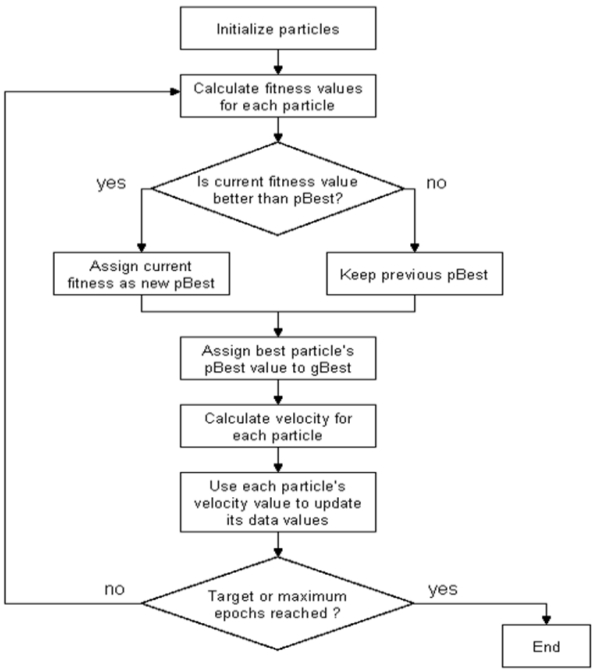


**Fig.6. Flow diagram illustrating PSO algorithm**

## V. RESULTS AND DISCUSSION

We design an F-OFDM transceiver based on LTE standard, as listed in table 5.1 below. And we will examine the performance of the filtered OFDM by means of peak-to-average power ratio, power spectral density and bit error rate.

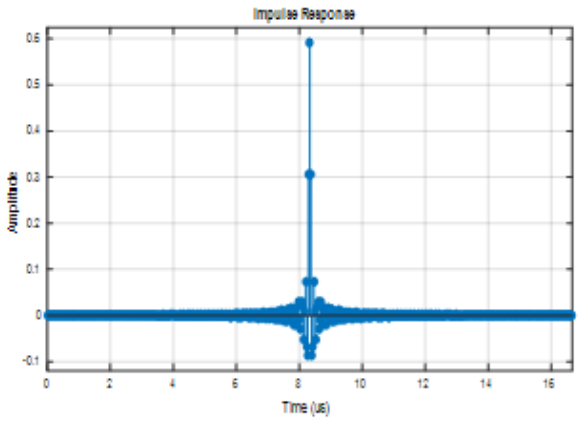


**Fig.7. Filter impulse response**

**Table I: Simulation Parameters**

| Parameters | Value |
|---|---|
| Number of FFT points | 1024 |
| Number of data subcarriers in sub band | 600 |
| Subcarrier spacing(KHz) | 15 |
| Cyclic prefix length in samples | 72 |
| Channel Bandwidth (MHz) | 10 |
| Modulation | 64QAM |
| Sampling frequency (MHz) | 30.72 |
| Channel model | AWGN |
| Filter type | FIR |
| Filter length | 513 |

In F-OFDM, the time domain sub band OFDM signal is passed through a well-designed filter to advance the out-of-band radiation of the sub band signal. As the channels pass band compares to the sign's transmission capacity, just a pair of subcarriers close to the edging are influenced. The between image impedance acquired is limited because of the channel configuration using windowing with delicate truncation. The drive reaction and greatness reaction of the channel utilized is represented in Fig. 7 and Fig.8, individually.

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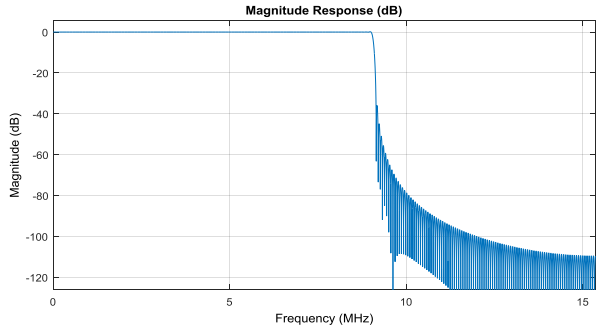


**Fig.8. Filter magnitude response**

Comparing the figures 9 and 10 of the power spectral densities for F-OFDM and OFDM modulations, respectively, it's clear that F-OFDM has lower side lobes. This allows higher utilization of the allocated spectrum, leading to increased spectral efficiency.

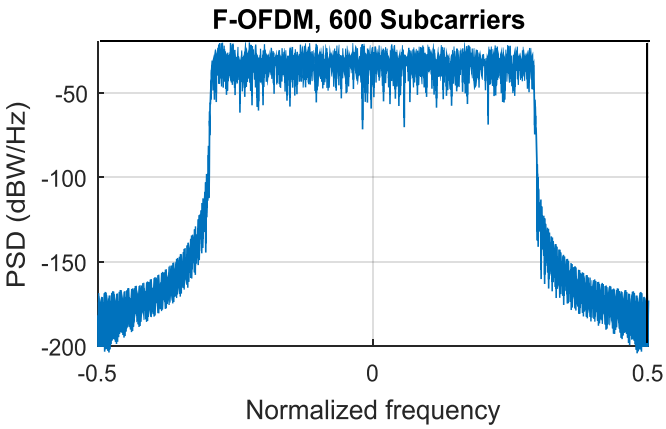


**Fig.9. Power spectral density (PSD) for F-OFDM signal**

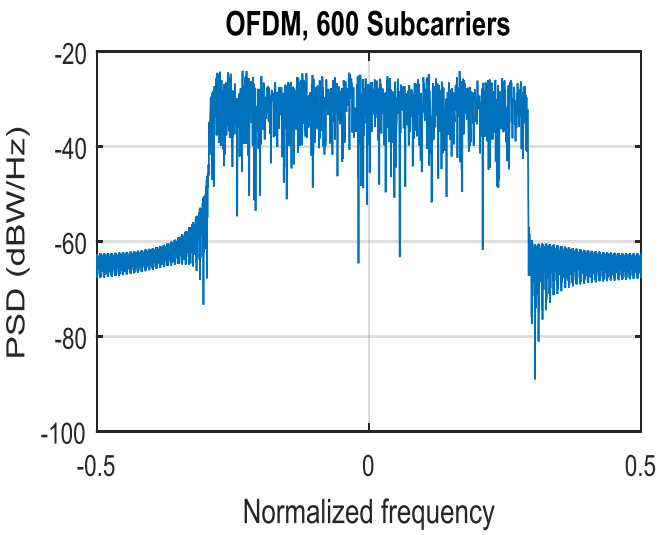


**Fig.10. Power spectral density (PSD) for OFDM signal**

When it comes to the Peak average power ratio we get from the simulation that: PAPR for OFDM = 9.721 dB, where PAPR for F-OFDM = 11.371 dB which determines that the F-OFDM has a high PAPR than OFDM which may restrict it to be applied in 5G systems, this makes necessary to reduce the PAPR. Also, as the Fig.11 shows, the F-OFDM has a cumulative distribution function of about 4.6dB above the average power.

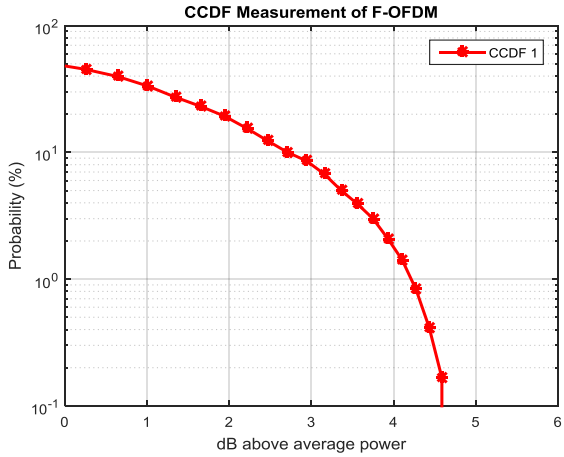


Fig.11. CCDF of F-OFDM

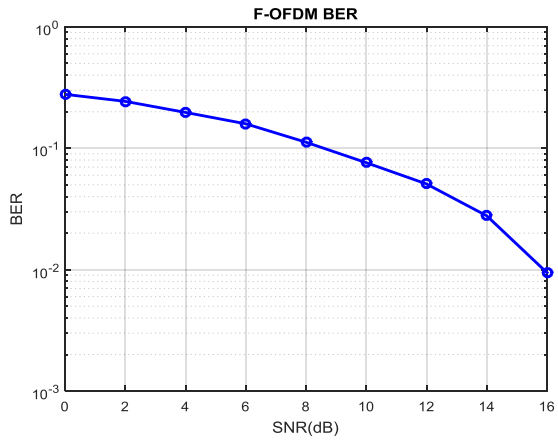


**Fig.12. BER of F-OFDM**

Fig.12 shows the BER graph of F-OFDM. From that it could shows that F-OFDM system acquired a high BER.

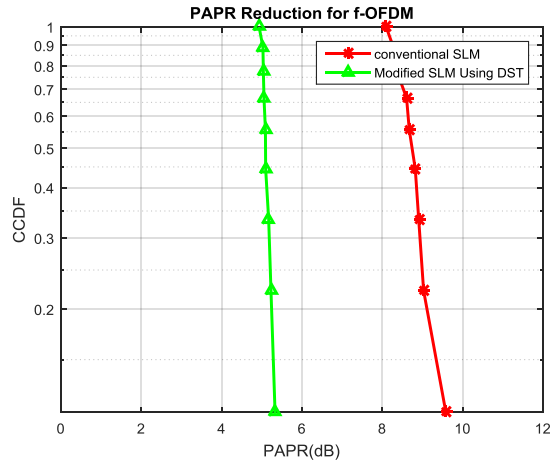


**Fig.13. PAPR of F-OFDM Using Both SLM and MSLM-DST**

The PAPR resultant graph of applying both the conventional SLM with number of blocks U=4 and the modified SLM using DST is shown in Fig. 13, observe that PAPR is about 10.2dB when the existing SLM is used.

But in the case of the proposed MSLM-DST, it gives a PAPR around 5.8dB. So, it could shows that the SLM combined with DST reduces the PAPR on the subject of 4.4 dB.

As in Fig. 12, the F-OFDM has a high BER, which debases the concert of the system. To overcome this, we apply the PSO algorithm for reducing the BER to get better overall performance of this system. The fig.14 shows a comparison between the BERs before and after the optimization process. There is a significant reduction of BER when used the PSO optimization algorithm.

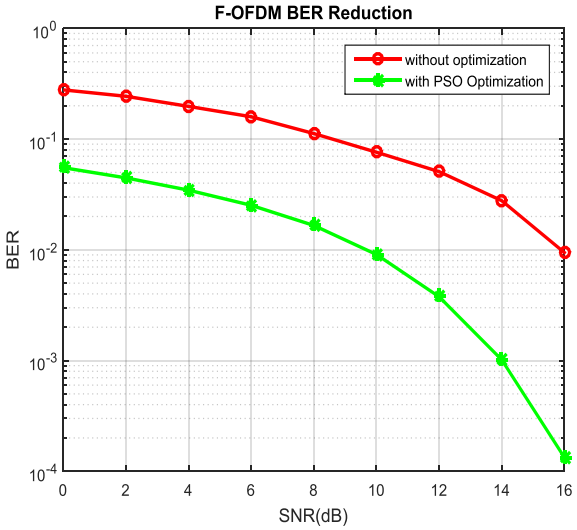


**Fig.14. BER of F-OFDM with and without optimization**

## VI. CONCLUSION

Filtered-OFDM is one among the OFDM-based alternative entrant modulation schemes towards 5G communication systems. We design an F-OFDM system and compare it with OFDM, and from results, we got that F-OFDM have lower side lobes, which a better spectral efficiency than OFDM, but it suffers from a higher PAPR than OFDM. In this Paper, a modified frequency domain technique is projected to lessen the PAPR for filtered-OFDM. A modified SLM technique is projected to combine the conventional SLM with DST and the transform is applied subsequent to every IFFT block in SLM. By applying the DST at the output of every IFFT block lessen the autocorrelation of the signal and as well denses the signal energy in certain amount of transform coefficients leading to better PAPR reduction. The proposed scheme coalesce the features of the both SLM and the transform and provides a better lessening in the PAPR than the conventional SLM. Furthermore, by pertain the PSO algorithm; the F-OFDM achieves a considerable decrease in BER. Therefore, from the results, it is obvious that the technique and the algorithm which have been engaged in the report give a better reduction in both PAPR and BER.

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