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Implementation of Fountain coded PTS schemes for PAPR reduction in OFDM System

Ghatage Surajkumar Sadashiv[1], Dr. J. A. Shaikh[2]

PG Student, Electronics PVPIT, Budhgaon, India[1]

Professor, Electronics, PVPIT, Budhgaon, India[2]

Abstract: Orthogonal Frequency Division Multiplexing (OFDM) is considered to be a promising technique against the multipath fading channel for wireless communications. However, the main drawback of OFDM system is the high Peak to Average Power Ratio (PAPR) of the transmitted signals system which leads to power inefficiency in RF section of the transmitter. Many PAPR reduction schemes have been proposed to overcome this problem. This paper present different PAPR reduction techniques and conclude an overall comparison of these techniques.

Keywords: Bit error rate (BER), Multicarrier, Orthogonal frequency division multiplexing (OFDM), Peak to average power ratio (PAPR).

I. INTRODUCTION

High capacity and variable bit rate information transmission with high bandwidth efficiency are just some of the requirements that the modern transceivers have to meet in order for a variety of new high quality services to be delivered to the customers. Because in the wireless environment, signals are usually impaired by fading and multipath delay spread phenomenon, traditional single carrier mobile communication systems do not perform well. In such channels, extreme fading of the signal amplitude occurs and Inter Symbol Interference (ISI) due to the frequency selectivity of the channel appears at the receiver side. This leads to a high probability of errors and the system's overall performance becomes very poor [13]. Techniques like channel coding and adaptive equalization have been widely used as a solution to these problems. However, due to the inherent delay in the coding and equalization process and high cost of the hardware, it is quite difficult to use these techniques in systems operating at high bit rates, for example, up to several Mbps. An alternative solution is to use a multi carrier system. Orthogonal Frequency Division Multiplexing (OFDM) is an example of it and it is used in several applications such as asymmetric digital subscriber lines (ADSL), a system that makes high bit-rates possible over twisted-pair copper wires. It has recently been standardized and recommended for digital audio broadcasting (DAB) in Europe and it is already used for terrestrial digital video broadcasting (DVB-T) [7]. The IEEE 802.11a standard for wireless local area networks (WLAN) is also based on OFDM [12].

OFDM is a technique for transmitting data in parallel by using a large number of modulated sub-carriers. These sub-carriers (or sub-channels) divide the available bandwidth and are sufficiently separated in frequency (frequency spacing) so that they are orthogonal. The orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period. This is shown in fig. 1.1. Due to this orthogonality condition, the spectrum of each carrier has a null at the center frequency of each of the other carriers in the system.

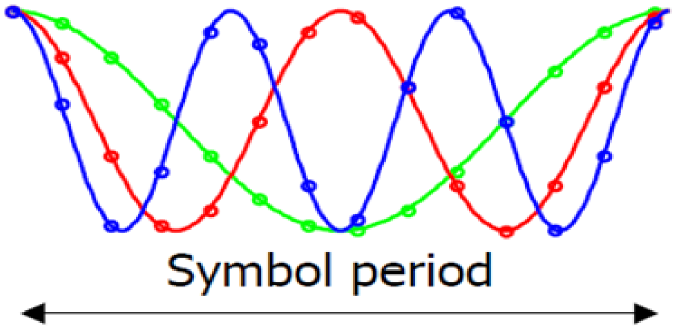


Fig 1.1: Orthogonality condition

This orthogonality results in no interference between the carriers, although their spectra overlap. This can be seen from the fig. 1.2 and 1.3. Fig. 1.2 shows the single subcarrier spectra and fig. 1.3 shows the 8 subcarrier spectra.

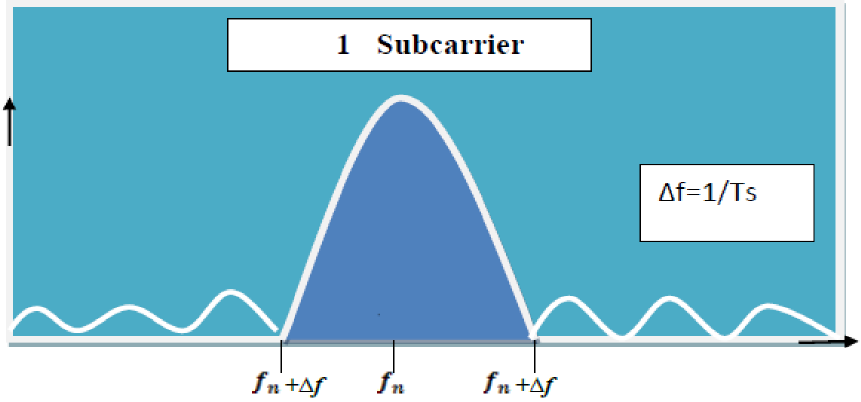


Fig 1.2: Single Subcarrier spectra

From fig. 1.3, it can be observed that spectrum of each carrier has a null at the center frequency of each of the other carriers in the system. The separation between carriers is theoretically minimal so there would be a very compact spectral utilization.

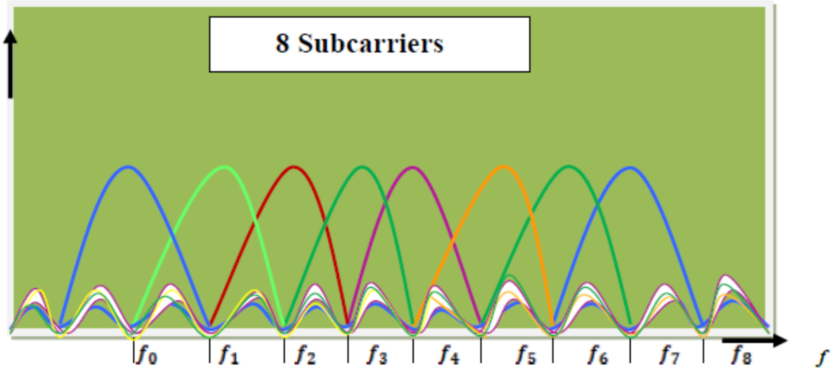


Fig 1.3: 8 Subcarrier spectra

To check the orthogonality among different signals, some sample signals and their DFT spectra are shown in fig. 1.4. This program generates a matrix of the sample signal vectors x_i in each row, and then computes the product of itself and its transpose, which checks the orthogonality among the signal vectors. Running this program yields the result as shown in fig.1.

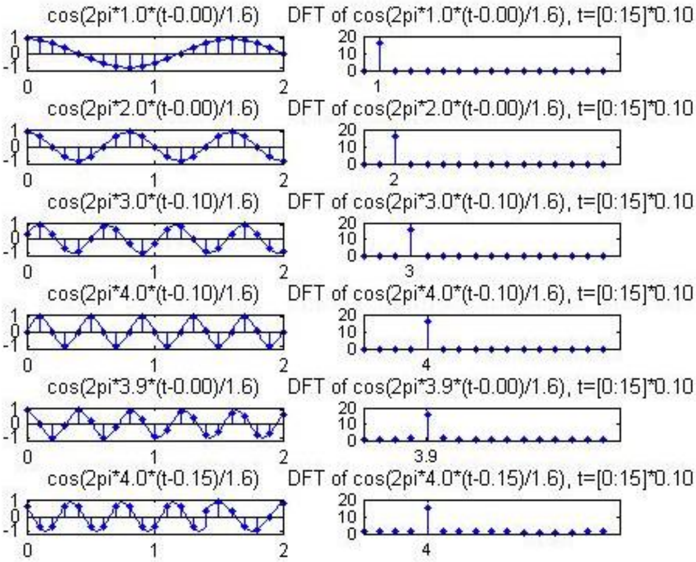
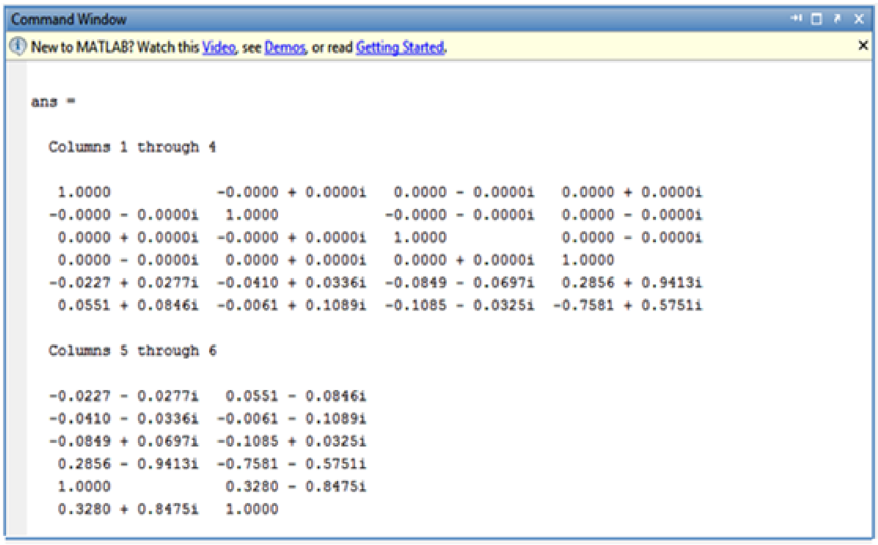


Fig 1.4: Sinusoidal signals with different frequencies/phases and their DFTs.

From fig. 1.5, it can be seen that, the upper 4 x 4 sub-matrix is a diagonal (identity) matrix, which implies that the first four signals $x1$, $x2$, $x3$, and $x4$ (with radian frequency of an integer times the fundamental frequency) are orthogonal to each other regardless of some delay. In contrast, all the entries in the fifth/sixth rows and columns are not zero, which implies that the four signals $x1$, $x2$, $x3$, $x4$ and the last two signals $x5$, $x6$ are not mutually orthogonal since the frequency of $x5$ is not a multiple of the fundamental frequency and $x6$ has a discontinuity as can be seen from fig. 1.4



```
ans =

  Columns 1 through 4

   1.0000             -0.0000 + 0.0000i   0.0000 - 0.0000i   0.0000 + 0.0000i
  -0.0000 - 0.0000i   1.0000             -0.0000 - 0.0000i   0.0000 - 0.0000i
   0.0000 + 0.0000i  -0.0000 + 0.0000i   1.0000              0.0000 - 0.0000i
   0.0000 - 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   1.0000
  -0.0227 + 0.0277i  -0.0410 + 0.0336i  -0.0849 - 0.0697i   0.2856 + 0.9413i
   0.0551 + 0.0846i  -0.0061 + 0.1089i  -0.1085 - 0.0325i  -0.7581 + 0.5751i

  Columns 5 through 6

  -0.0227 - 0.0277i   0.0551 - 0.0846i
  -0.0410 - 0.0336i  -0.0061 - 0.1089i
  -0.0849 + 0.0697i  -0.1085 + 0.0325i
   0.2856 - 0.9413i  -0.7581 - 0.5751i
   1.0000              0.3280 - 0.8475i
   0.3280 + 0.8475i   1.0000
```

Fig 1.5: Orthogonality test result.

OFDM bandwidth utilization is shown in fig. 1.6. OFDM systems are attractive for the way they handle ISI, which is usually introduced by frequency selective multipath fading in a wireless environment. Each sub-carrier is modulated at a very low symbol rate, making the symbols much longer than the channel impulse response. In this way, ISI is diminished. Moreover, the effects of ISI can completely disappear if a guard interval is included in between a series of successive OFDM symbols. The multipath delay must be greater than this guard interval. Despite the fact that each sub-carrier has a modest data rate, a high data rate can be reached overall by employing a lot of sub-carriers. Since ISI has little to no impact on OFDM systems, a receiver-side equalization is not required. The modulation and demodulation of the signal in the OFDM system uses Inverse Fast Fourier Transform/Fast Fourier Transform (IFFT/FFT) algorithms. The system's resilience to multipath channel errors depends on the length of the IFFT/FFT vector. This vector's time period was selected to ensure that is significantly longer than the multipath signal's received maximum echoes' delay duration. First, the required spectrum is selected depending on the input data and modulation strategy, and then OFDM is generated. Some data is designated to transmit on each carrier that will be created. Following that, the necessary carrier amplitude and phase are determined based on the modulation technique (usually differential BPSK, QPSK, or QAM). This spectrum is then transformed into a time domain signal using the IFFT. A cyclic time domain signal is converted via the FFT into its equivalent frequency spectrum.

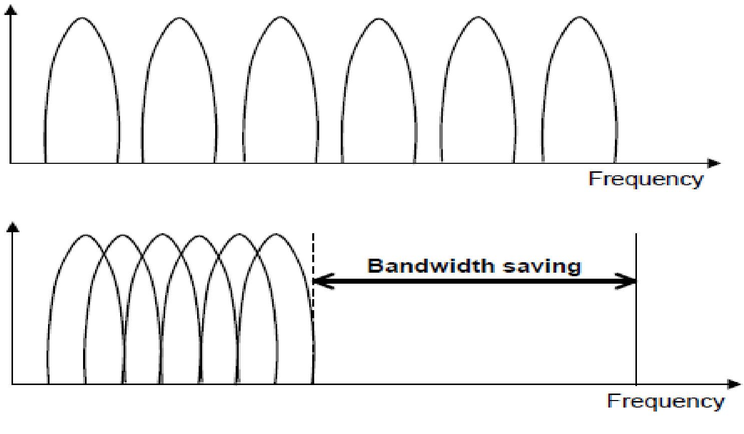


Fig 1.6: Bandwidth utilization

OFDM System Model 1.2
Fig. 1.7 provides a block diagram of an OFDM transmitter and receiver in a streamlined design. Here, a channel encoder receives input data symbols that are then mapped to the BPSK/QPSK/QAM constellation.
To get the time domain OFDM symbols, one uses the IFFT. The following are examples of time domain symbols:

x n = IFFT Xk x n = 1/N _(k=0)0 n N-1 (1.1) ; (N-1) Xk e (j2 kn/N)
where N is the number of subcarriers and Xk is the transmitted symbol on the kth subcarrier.

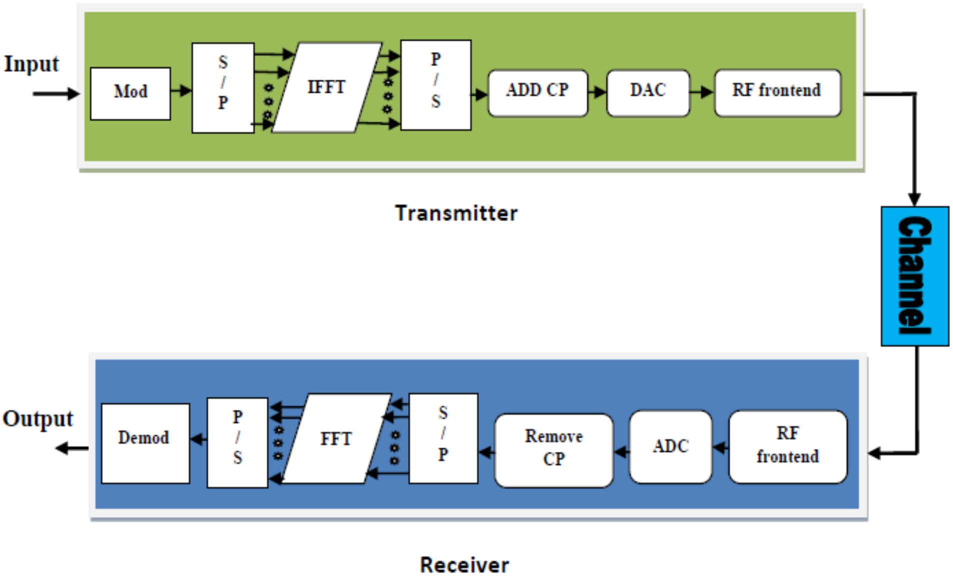


Fig 1.7: OFDM transmitter and receiver

Cyclic prefix (CP) is used to cyclically lengthen the time domain signal in order to prevent Inter Symbol Interference (ISI) from the former OFDM symbol. In order to model the linear convolution of a frequency selective multipath channel as circular convolution, which may then be translated to the frequency domain using an FFT, CP functions as a repetition of the symbol's end. Simple frequency domain processing, like channel estimation and equalization, is possible using this method. The baseband digital signal is converted into an analog signal using a digital to analog converter (DAC). This process is carried out in the DAC block of fig. 1.7. The analog signal is then sent in advance of the RF frontend. After receiving the analog signal, the RF frontend executes operations. . The signal is amplified by a Power Amplifier (PA), up converted to RF frequencies using a mixer, and finally sent via antennas. The received signal is transformed to base band at the receiver side by the RF frontend. The Analog to Digital Converter (ADC) digitizes and resamples the analog signal. The analog signal is digitalized and re-sampled using the ADC. For the sake of simplicity, the frequency and time synchronization blocks are not depicted in Fig. 1.7. The signal's CP is eliminated in the frequency domain.

In addition to offering greater bandwidth efficiency, immunity from multipath fading and impulse noise, resistance to frequency selective fading, and resistance to impulse noise, OFDM is a desirable multicarrier transmission technology for wireless and wired networks because it eliminates the need for sophisticated equalizers and the physical implementation of digital signal processors.
However, there are still some difficult problems in the design of the OFDM systems.

1.3 Benefits and Drawbacks of the OFDM System
The following is a list of some of OFDM's benefits and drawbacks:

1.3.1 Advantages of OFDM
Among the advantages of an OFDM system are the following:
Using FFT to implement modulation and demodulation techniques with OFDM is computationally efficient.
The OFDM signal is more resilient to delay spread and offers robustness in multipath propagation environments.
Compared to single carrier transmission methods, OFDM is more robust to frequency selective fading.
The OFDM system offers good defense against impulsive parasitic noise and co-channel interference.
In the OFDM system, pilot subcarriers are employed to prevent frequency and phase shift mistakes.
Complex receiver algorithms are not necessary.
enables a high data rate.

1.3.2 OFDM's drawbacks
The following list includes some of an OFDM system's drawbacks:
High peak to average power ratios (PAPR) of the transmitted signal plague the OFDM signal.
Carrier frequency offset has a significant impact on OFDM.
When different emitters share subcarriers, synchronization is challenging.

Applications of OFDM, 1.4
Due to its various advantages, OFDM has been adopted for a number of technologies, including:
Services for asymmetric digital subscriber lines (ADSL).
4G Digital Audio Broadcast (DAB), Wi-Fi Wi-MAX IEEE 802.20, and DVB throughout Europe.

1.5 Purposes
This subsection contains a list of the project's goals. These objectives are met by this project:
detailed knowledge of digital communication.
recognizing the function of OFDM in systems for high-speed data communication.
to research the mathematical theory behind each OFDM modulation operation.
to use MATLAB software to create a traditional OFDM system.
to evaluate the outcomes and assess how they differ from expected outcomes.
to comprehend the OFDM system's restrictions and look for a workaround.
to use MATLAB software to apply the suggested PAPR reduction strategy and to assess the outcomes.

II. LITERATURE REVIEW

One data stream is transmitted using OFDM over a number of slower subcarriers. A unique instance of multi carrier transmission is this. In contrast to single carrier systems where the entire link fails if the signal fades or is interfered with, a multicarrier system will only be affected by a small subset of its subcarriers. In the middle of the 1960s, publications introduced the concepts of parallel data transmission and frequency division multiplexing [3, 4]. "Synthesis of band-limited orthogonal signals for multichannel data transmission" was researched and written about by Robert W. Chang [3]. "Performance of an efficient parallel data transmission system" was investigated and described by Burton R. Saltsburg.

[4]. These research looked at the fundamentals of orthogonal multiplexing for simultaneous transmission of multiple data messages across a transmission medium with a linear band restriction at the highest data rate possible without inter-channel and inter-symbol interferences. The early stages of OFDM's development were well under way when Mosier R. announced "Kineplex, a bandwidth efficient binary transmission system" in 1958. In a conventional parallel data system, the total signal frequency range is divided into N non-overlapping frequency sub-channels. After each sub channel has been modulated with a distinct symbol, N sub channels are frequency multiplexed. It would make sense to eliminate spectral channel overlap in order to reduce inter-channel interference, but doing so leads in a poor utilization of the available spectrum. The advice from to handle with It was inefficient to employ parallel data and FDM with overlapping sub channels in the middle of the 1960s. A high-efficiency multicarrier transmission method uses "Orthogonal frequency" carriers, which are the subject of the majority of study. These oscillators in a carrier bank created these analog-heavy carriers. The analogy approach was quite challenging, and adding more subcarriers was not practical. Furthermore, it was imposing limitations on receiver design. Weinstein and Ebert were able to resolve this problem.

Following the application of the Discrete Fourier Transform (DFT) to parallel data transmission systems as part of the modulation and demodulation process, Weinstein and Ebert published their work as "Data transmission by Frequency Division Multiplexing using the DFT" in 1971 [5]. The digital implementation of the OFDM system on a special-purpose computer performing the FFT and the removal of the coherent demodulators and banks of sub carrier oscillators, which are frequently needed in FDM systems, were both made easier to understand thanks to this study. First, OFDM was used to examine high-speed modems, digital mobile communications, and high-density recording.

Botaro Hirosaki presented a system titled "An Orthogonally multiplexed QAM system using DFT" that utilized the OFDM techniques for multiplexed QAM. Digital audio broadcasting (DAB), high-bit-rate DSL (HDSL, 1.6 Mbps), asymmetric digital subscriber lines (ADSL, up to 6 Mbps), and wideband data transmission over FM radio channels were all uses of OFDM in the 1990s. The PAPR issue and its remedies have been the subject of numerous studies. A lot of fundamental and modern knowledge is available online and in the IEEE database. The authors of "OFDM PAPR reduction by switching null subcarrier and data subcarriers" (K.T. Wong, B. Wang, and J.C. Chen) suggest reducing PAPR in OFDM by switching null and data subcarriers [1]. The innovative PAPR reduction technique described in this paper lowers the PAPR of the OFDM system while delivering a number of additional advantages. However, this technique has a very high level of computational complexity. "Dynamic null-data subcarrier switching for OFDM PAPR reduction with low computational overhead" is the name of a novel technique created by S. Ahmed and M. Kawai to lessen computational complexity [2]. This novel approach reduces the PAPR of the OFDM system requirement with only a modest processing power requirement.

The foundations of OFDM, its limitations, and its applications are covered in numerous books. See "OFDM for wireless Multimedia Communication" by R. Van Nee and R. Prasad, available from Artech House [11], for the basics. Each step required to create an OFDM symbol is detailed in this book, along with a description of the OFDM theory. Also provided are an analysis of the PAPR issue and several solutions.

This book provides a theoretical justification for and demonstration of the use of IFFT and FFT in OFDM. Important terms like the amount of subcarriers, modulation method, guard band, cyclic prefix, zero padding, etc. are covered in this book. The book "MIMO-OFDM Wireless Communication with MATLAB" by Yong Soo Choo, Jaekwon Kim, Won Young Yang, and Chung-Gu Kang [12] contains instructions on how to build an OFDM system using Matlab software. The OFDM theory and its use are discussed in this book. Each step required to build the OFDM system in Matlab is also covered.

III. ILLUSTRATIONS

3.1PAPR and the need to lower PAPR

3.1.1 When these sinusoids are in phase at the IFFT input, the OFDM signal, which is created by superimposing numerous individual sinusoidal subcarriers, would have a high amplitude. As a result, these sinusoids are added constructively to create a big amplitude that corresponds to a high PAPR at the IFFT output. When N is the number of carriers, the peak amplitude of an OFDM signal may be N times greater than that of a single carrier system [6].

3.1.2High Power Amplifier (HPA)

The OFDM signals will experience nonlinear distortion, spectral spreading, in-band distortion, and inter modulation interference across the OFDM subcarriers when their peak amplitudes reach or exceed the saturation region of a power amplifier at the transmitter and a low noise amplifier at the receiver [8]. The bit error rate (BER) at the receiver is reduced by all of these. Utilizing pricey power amplifiers with a wide saturation region is one straightforward option. However, these power amplifiers would be ineffective since high peak amplitudes occur erratically. In addition, design considerations like the price and battery life of devices limit high peaks.

Large PAPR also necessitates the need for a DAC with a sufficient dynamic range to handle the high peak of the OFDM signals. Despite the fact that a high precision DAC provides high PAPR with a tolerable level of quantization noise, it may be quite expensive for the system's specified sampling rate. A low precision DAC, on the other hand, would be less expensive, but it will have significant quantization noise, which lowers the Signal to Noise Ratio (SNR) when the dynamic range of the DAC is raised to support high PAPR. Furthermore, a large number of subcarriers in OFDM signals have a Gaussian distribution, which means that peak signals rarely occur and hence uniform quantization by ADCs is not preferred.

If clipped, it will disrupt the communication systems with in-band distortion and out-of-band radiations (adjacent channel interference) [8]. Therefore, the optimum course of action is to lower the PAPR prior to the transmission of OFDM signals through nonlinear HPA and DAC [9]. The following is a possible mathematical expression for an OFDM signal's PAPR:

$$\mathrm{PAPR}[x_n] = \frac{\max\limits_{0\le n<N} |x_n|^2}{E[|x_n|^2]} \qquad (3.1)$$

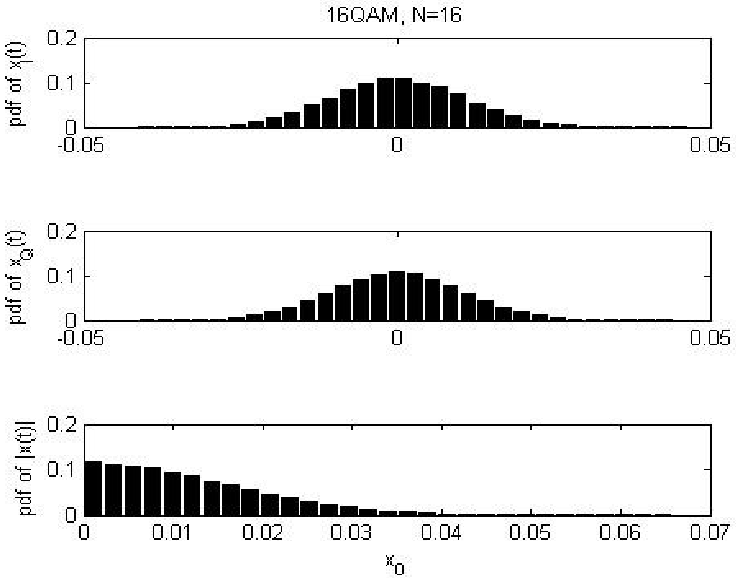
Where E {.} denotes average power.
PAPR can be expressed in ‘dB’ as follows,
PAPR (dB) = 10 $\log_{10}$PAPR(x_n) (3.2)

For a sufficient number of subcarriers, it can be assumed that the real and imaginary components of the time-domain complex OFDM signal (after IFFT at the transmitter) have asymptotically Gaussian distributions, even though the input signals of N-point IFFT have independent and finite magnitudes and are uniformly distributed for QPSK and QAM by the central limit theorem. Then, a Rayleigh distribution is followed by the amplitude of the OFDM signal.

According to its continuous-time version, Fig. 3.1 displays the individual time-domain QAM-modulated subcarrier signals for N = 8 and their sum. Figure 3.1 makes the PAPR properties of the OFDM signal clear. In general, it is anticipated that as the number of subcarriers rises, the PAPR will become important. The distributions of total, including their real and imaginary components, are shown in Fig. 3.2 for N=16, further illuminating the PAPR properties of the OFDM signal.

Fig 3.1: Time-domain OFDM signals

1. Fig. 3.2 shows that the real and imaginary parts of OFDM signal follow a Gaussian distribution while OFDM signal follows a Rayleigh distribution [11].



2. Fig 3.2: Magnitude distribution of OFDM signal

3. 3.2 Various PAPR reduction strategies:
4. 4. Various theories and hypotheses about how to determine the distribution of the PAPR have been documented, and there are many different ways to lower the PAPR. There are two types of schemes: "signal distortion" schemes and "signal scrambling" schemes. These methods enhance the transmit signal power, the BER, the data rate loss, the computational complexity, the distortion, the channel side information, etc. in order to reduce the PAPR.

5. By distorting the signal before amplification, "signal distortion" schemes lower high peaks. Amplitude clipping, filtering, and companding are some specific methods. However, "signal distortion" techniques may result in significant in-band and out-of-band noise, which would impair system performance. For instance, clipping can result in both in-band distortion like self interference and out-of-band radiation like nonlinear distortion into OFDM signals, despite being computationally straightforward. Additionally, the receiver must estimate the difficult-to-measure location and size of the transmitter's clipping operator.

6. The methods for signal scrambling For the PAPR reduction, use various scrambling sequences to scramble each OFDM symbol. Some specific methods include selective mapping (SLM), low complexity phase weighting, block coding, excess power reduction coding, interleaving, active constellation extension, tone reservation (TR), tone injection (TI), and selective mapping of partial tones.

7. Clipping, filtering and peak window:
8. When the transmitter's power amplifier's saturation level is below the signal span, the signal is automatically clipped. The position and size of the transmitter's clipping operation are two factors that the receiver must estimate and which are challenging to get. However, clipping reduces the BER and spectral efficiency of systems by introducing both in-band distortion, such as self interference, and out-of-band radiation, such as nonlinear distortion, into OFDM signals.
9. Peak windowing strategies, which are better clipping techniques, reduce out-of-band radiation by attenuating peak signals using narrowband windows like the Gaussian window. After clipping, filtering can lower out-of-band radiation. Additionally, clipping may result in some peak re-growth, causing the signal to occasionally surpass the clipping level.

Repeated clipping and filtering operations can be employed to limit peak re-growth at the cost of increased computational complexity in order to achieve a desired PAPR.
10. Interleaving technique:
11. A group of interleavers are utilized in the interleaving strategy to lower the PAPR of multicarrier signals. A device that reorders data blocks is known as an interleaver. Different interleavers are used to permute data blocks from the original data block to create a series of changed data blocks. It is then decided which changed data block has the lowest PAPR to transmit. The receiver just needs to be aware of the interleaver being used at the transmitter in order to reconstruct the original data block.

IV. METHODOLOGY

Selected Mapping (SLM): Using the same number of various phase sequences, which each represent the same data as the original data block, the transmitter creates a collection of candidate data blocks that are sufficiently diverse from one another. The transmission is chosen from those with the lowest PAPR. As side information, the recipient should receive information on the chosen phase sequence. This image shows the SLM-OFDM transmitter. fig. 4.4.

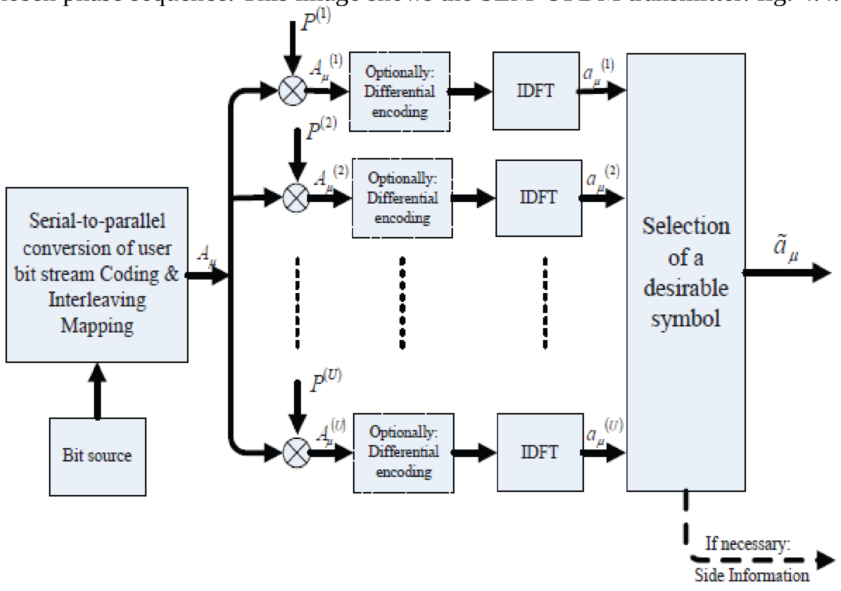


Fig 4.4: Block diagram of SLM technique.

Before the IDFT and just after creating the alternate OFDM signals, differentially encoded modulation might be used. Differential demodulation must be put into practice at the receiver immediately following the DFT.
Tone Reservation (TR): TR is another strategy that has been suggested to lower PAPR. The major goal of this technique is to reduce PAPR by maintaining a limited number of tones. This can be a convex problem that can be properly formulated and addressed. The number of reserved tones, where they are located, how complex they are, how much power is permitted on the reserved tones, etc., all affect how much of the PAPR is reduced.
The additive strategy for reducing PAPR in the multicarrier communication system is described in this method. It demonstrates that conserving a small percentage of tones results in significant PAPR minimization, always employing a straightforward technique at the system's transmitter without adding any additional complexity at the receiver end. Since there are just a few tones (N), reserving them for PAPR reduction could result in a non-negligible portion of the bandwidth being used, which would lower the data rate.
The benefits of the TR technique include its simplicity, lack of side information requirements, and lack of additional receiver operations. The TR approach includes the addition of the time domain signal and data block. A data block depends on the time domain signal of the original multicarrier signal to minimize the high peak. This time domain signal can be simply approximated at the system's transmitter and stripped away at the receiver.
In the TR technique, the cancellation signal is chosen from the frequency domain reserved subcarriers in a way that reduces the PAPR of the TR sent signal. To eliminate the tone reserved subcarriers at the receiver and reduce distortion, the symbol is demodulated in the frequency domain at the receiver tone by tone.
Partial Transmit Sequence (PTS): By applying the proper rotation factors to subcarrier sub blocks, the transmitter creates its transmitting signal with a low PAPR. In contrast to PTS, which only performs scrambling rotations to subcarrier sub blocks, SLM applies independent scrambling rotations to all subcarriers. In fig. 4.5, the PTS-OFDM transmitter is shown with the indication that one PTS can always be left unroasted.

Tone Injection (TI): The basic idea behind tone injection is to expand the constellation so that a single data point can be mapped into a variety of possible points in the expanded constellation. Tone injection is used to reduce PAPR by replacing a basic constellation point with a new point in the expanded constellation, which is equivalent to injecting a tone with the proper frequency and phase into the original signal.

The receiver simply has to know how to map the redundant constellation on the primary constellation; TI does not need the additional side information. The TI approach, in contrast to the TR technique, injects signal while using the same frequency range as the information-carrying signal and also boosts the power of the sent signal.

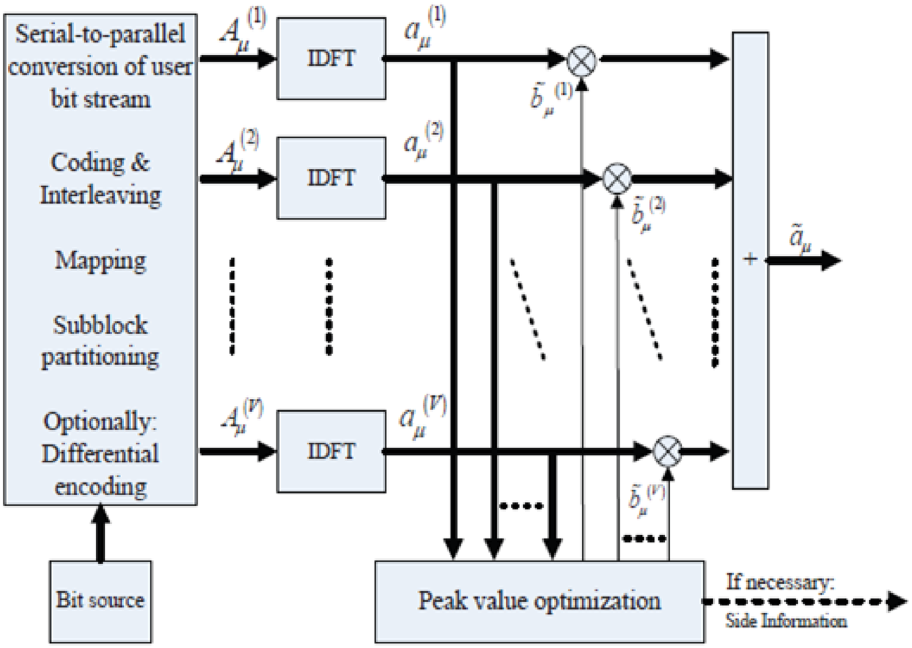


Fig 4.5: Block diagram of PTS technique.

Active constellation extension: In order to lower the data block's PAPR, some of the outer signal constellation points of the data block are dynamically expanded outside of the original constellation. Many different constellation schemes, including QAM, MPSK, and QPSK, which allow for increased margin for data points that are near the outer edges of the constellation without raising the likelihood of error for other data symbols, can be used with the active constellation extension approach. Additionally, channel side information and data rate hit information are not required. The transmitted signal's power does, however, rise as a result of these alterations.

Coding: By choosing the right code word for transmission, coding techniques are utilized to lower the PAPR. As an illustration, block coding relies on sequences that can both repair errors and reduce peak power. The data sequence is encased in a bigger sequence, and only those larger sequences with low peak powers are employed. Using a block code, the data is encoded. A new sequence is communicated that includes some of the data symbol sequence that corresponds to the code word in order to lower the PAPR. The error-correcting code could fix any mistakes that are intentionally introduced. As a result, PAPR reduction sacrifices some of the code's ability to repair errors.

3.3 Evaluation standards for diverse plans

These standards must be used to compare and contrast different approaches:
The PAPR reduction was successful.
complexity of the transmitter's computations.
complexity of the receiver's computations.
how much channel side information (CSI) must be sent between the transmitter and receiver.
any prerequisite information required by the transmitter.
Combination/synergy with various PAPR reduction methods is necessary or conceivable.
CDF, or Cumulative Distribution Function
One of the most often utilized criteria for assessing the effectiveness of any PAPR reduction method is the CDF. In most cases, the Complementary CDF (CCDF) is utilized in place of the CDF to quantify the likelihood that the PAPR of a particular data block exceeds a predetermined threshold.

F(z)=1-exp(z) (3.3) is the formula that describes the CDF of the amplitude of a signal sample z.
The PAPR's CCDF is provided by,

P(PAPR>z) = 1 - P(PAPRz) (3.4).
=1- 〖F(z)〗 N is equal to 1-(1-exp(-z))N.

V. RESULT

Simulation Outcome
The complementary cumulative distribution function (CCDF) of PAPR for OFDM with null-data subcarrier switching method and OFDM without any PAPR reduction is shown in Fig. 5.1. The maximum PAPR for an OFDM system without using any PAPR reduction techniques is 8.8 dB, whereas the PAPR value for a null-data subcarrier switching mechanism cannot be higher than 7.1 dB. As a result, PAPR is reduced when using the null-data subcarrier switching approach.

Simulation settings:

Modulation Applied: 16-QAM
Two subcarriers were switched.
100 FDM symbols are used.

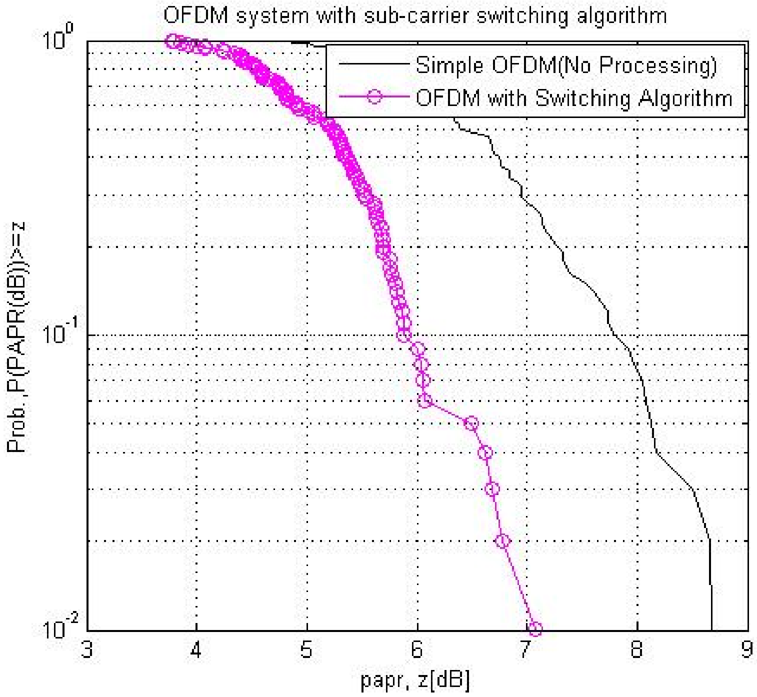


Fig 5.1: CCDF plot showing PAPR reduction capability of sub-carrier switching method.

The complementary cumulative distribution function (CCDF) of PAPR for OFDM with and without null-data subcarrier switching, and for OFDM with dynamic switching is shown in Fig. 5.2. Figure 5.2 shows that the maximum PAPR for an OFDM system without using any PAPR reduction techniques is 9.5 dB, but that the PAPR values for dynamic switching and null-data subcarrier switching are limited to 8 dB and 8.8 dB, respectively. As a result, as compared to the simple switching method, the dynamic switching method exhibits PAPR reduction with very little computational overhead.

Simulation settings:
Modulation Applied: 16-QAM
2 subcarriers were exchanged.
100 OFDM symbols total.
52 data subcarriers are present.
12 null subcarriers are present.

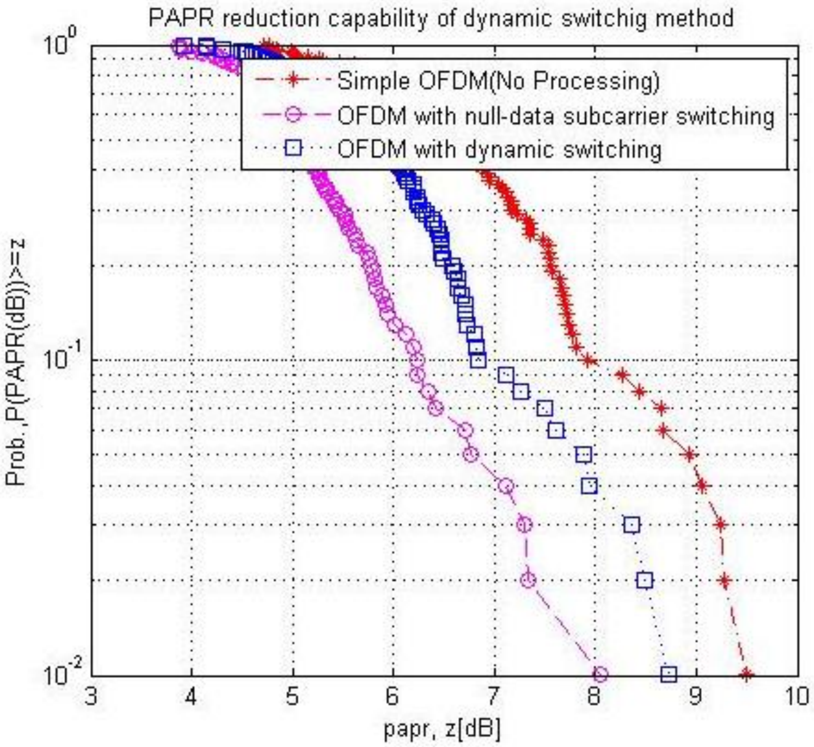


Fig 5.2: CCDF for PAPR reduction capability of dynamic switching method.

Fig 5.3 shows the OFDM signal in time domain. Random bit stream is generated in the MATLAB tool to construct the OFDM signal.

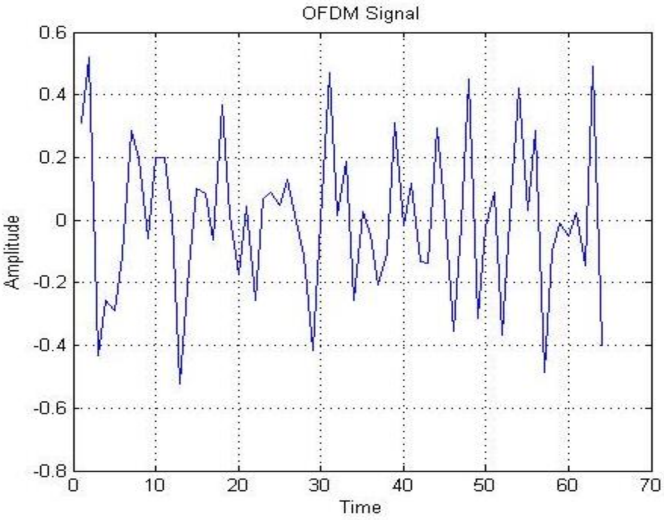


Fig 5.3: Time domain OFDM signal.

Figure 5.4 compares the null-data subcarrier switching approach, the suggested method, and the complementary cumulative distribution function (CCDF) of PAPR for OFDM without any PAPR reduction. Figure 6.4 shows that the highest PAPR for an OFDM system without using any PAPR reduction techniques is 10.8 dB, while the PAPR values for the proposed approach and the null-data subcarrier switching method are respectively limited to 9 dB and 9.1 db. Because of its minimal computing overhead, the suggested method has nearly the same PAPR reduction properties as the null-data subcarrier switching method. Remember that the proposed technique and the null-data subcarrier switching method have 66 and 1128 searching operations, respectively. This indicates that the proposed method is superior to the null-data subcarrier switching method., The proposed strategy reduces the computational load by 94.15% while achieving about the same amount of PAPR reduction.

The PAPR reduction capability is decreased if this proposed method is used with the dynamic switching method, but for P=2, the maximum number of searching operations needed will only be 17, which represents a 98% reduction in computational load.

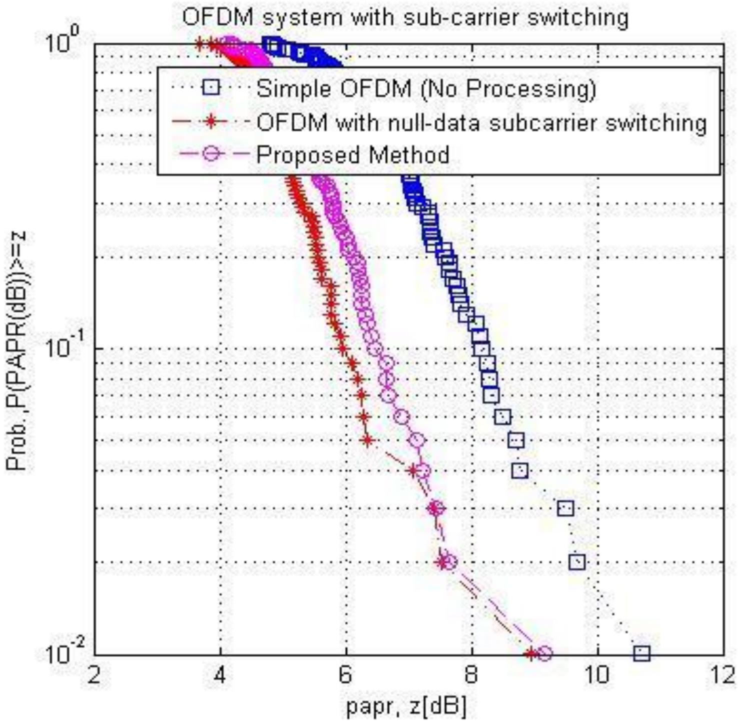


Fig 5.4: CCDF plot showing PAPR reduction capability of proposed method

The CCDF of PAPR for OFDM without any PAPR reduction, the suggested approach paired with dynamic switching, and the null-data subcarrier switching method are all shown in Fig. 5.5. Figure 6.5 shows that the maximum PAPR for an OFDM system without using any PAPR reduction techniques is 9.2 dB, but that the PAPR values for the proposed approach and the null-data subcarrier switching method cannot be higher than 7.8 dB and 8.5 dB, respectively. As a result, the suggested method exhibits PAPR reduction features with a roughly 98% reduction in computational load.

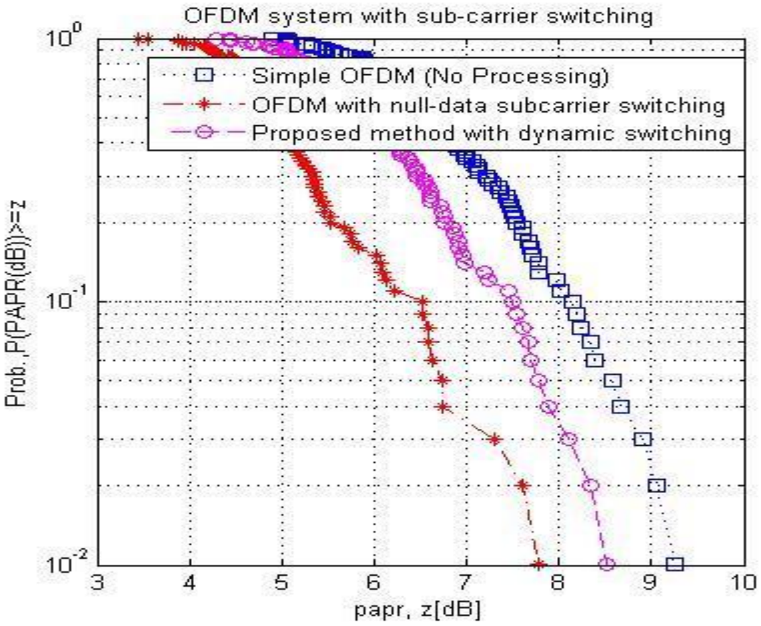


Fig 5.5: CCDF plot for proposed method combined with dynamic switching method

Fig. 5.6 shows the CCDF of PAPR for OFDM without any PAPR reduction, the null-data subcarrier switching method, proposed method and proposed method combined with dynamic switching method.

The highest PAPR for an OFDM system without using any PAPR reduction techniques is 8.8 dB; however, the PAPR values for the proposed method and the null-data subcarrier switching method cannot be higher than 6.9 dB and 7.2 dB, respectively. The proposed method's maximum PAPR when used with the dynamic switching methodology is 7.9 dB. As a result, the suggested method exhibits PAPR reduction features with a roughly 98% reduction in computational load

Fig 5.6: CCDF plot for proposed method and other switching methods.
Table 5.7 shows the trade-off between PAPR and computational time reduction for null-data subcarrier switching, proposed method and proposed method combined with dynamic switching method.

Table 5.7
Trade-off between PAPR and computational time

Method Used	PAPR Reduction (%)	Reduction in computational time (%)
Null-data subcarrier switching	26	--
Proposed	23.5	92
Proposed combined with dynamic switching	12	98

The simulation tool in MATLAB 7.11 was used to get the results in Table 5.7. The comparison plot of BER vs. Eb/N0 is shown in Fig. 5.8. Since there are more switching possibilities in the null-data subcarrier switching method than in the suggested approach, the error probability is higher in the null-data subcarrier switching method. Figure 5.8 indicates that the suggested approach's BER performance is substantially identical to that of the null-data subcarrier switching method.

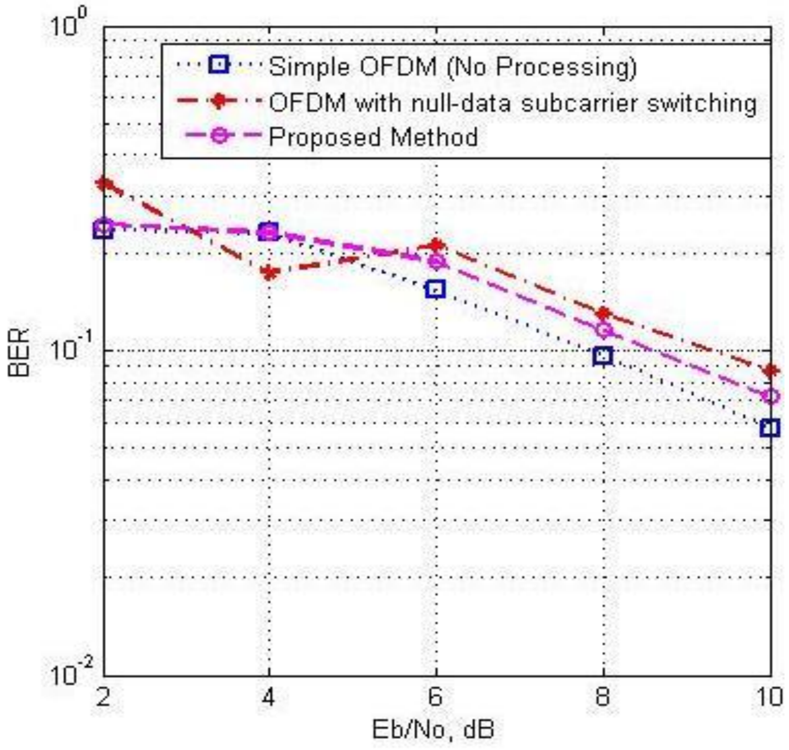


Fig 5.8: Comparative plot of BER Vs Eb/N0

VI. CONCLUSION

One of the usual options for high speed data transmission across a communication channel, OFDM is a particularly alluring method for multicarrier transmission. It offers a number of benefits, but it also has one significant disadvantage: a very high PAPR. Numerous methods have been researched to lower the PAPR number. In chapter 6, a brand-new technique called "Computationally efficient null-data subcarrier switching scheme" is put forth to lower the PAPR of multi-carrier OFDM systems by switching null subcarriers with data subcarriers. This CSI-free preprocessing algorithm is compatible with the majority of current OFDM standards and can be used in conjunction with many other PAPR reduction techniques. Without sacrificing PAPR reduction ability, the suggested technique significantly reduces the computational workload.

In Mat lab, a communication system based on OFDM is used. The PAPR reduction capabilities and the BER performance of the suggested strategy are also demonstrated using simulation results. Comparing the proposed method to the null-data subcarrier switching method, the proposed method achieves roughly the same PAPR reduction with a very small computational overhead. It still has the benefit of being free of side information. The suggested method can be utilized in conjunction with currently available low computational overhead techniques to greatly minimize computational overh

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