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IOT and DSP (combination of hardcore Virtex-5 FPGA and soft core DSP processor) OFDM System PAPR Reduction Using Artificial Intelligence Algorithm

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ABSTRACT

Orthogonal frequency division multiplexing (OFDM) is extensively applied in the downlink of narrowband Internet of Things (IoT). However, the high peak-to-average power ratio (PAPR) of OFDM systems leads to a decrease in transmitter efficiency. Therefore, the researchers proposed the artificial neural network (ANN) based PAPR reduction schemes. However, these schemes have the disadvantages of high complexity or cannot overcome the defects of traditional schemes. In this Synopsis, a novel PAPR reduction scheme based on neural networks (NNs) is proposed for OFDM systems. This scheme establishes a PAPR reduction module based on NN, which is trained using the low PAPR data obtained by the PTS method. To overcome the defect of poor BER performance of the SCF scheme, a recovery module is introduced at the receiver, to recover the distorted signal. To realize the improvement of BER performance and the reduction of PAPR simultaneously, the **Virtex-5** two modules are jointly trained based on multi objective optimization.

Keywords: OFDM, IDFT, ISI, PAPR, Cyclic Prefix, Amplitude Clipping & Filtering, SLM, PTS, Cumulative Distribution Function (CDF), MATLAB.

I. INTRODUCTION

Wireless Communication have experienced a fast growth and promises the better performances of the system. Multi-carrier phenomenon is considered to be one of the major developments in the wireless communication and is a widely adopted technique for digital data transmission because of its advantages. In advance wireless communication techniques need for high-speed data transmission has become utmost priority. In this era of multicarrier modulation (MCM), OFDM is an efficient technique in which high data rate is achieved and thus becoming important standard in wireless communication and a much better candidate for recent technology. OFDM is highly adopted modulation technique in many advance wireless technologies as it provides high spectral efficiency, robustness against multiple fading and avoid inter symbol interference using cyclic prefix concept and converts the frequency selective fading into flat fading which reduces the equalizer complexity at the receiver side. OFDM signals can be efficiently modulated and demodulated using Inverse Fast Fourier Transform (IFFT) and Fast Fourier Transform (FFT) respectively.

Today, OFDM has grown to be the most [1] current announcement system in highspeed infrastructures. OFDM is becoming the chosen modulation technique [2] for wireless transportations. OFDM can offer large data rates with [3] sufficient robustness to radio channel impairments. As the most promising technique, OFDM is used in various field of communication like digital video broadcasting (DVB), wireless local area network (WLAN) and digital audio broadcasting (DAB).[5] It is a multi-carrier modulation technique. Because of its simplicity, it is much easier to use single carrier transmission scheme but the major problem of single carrier modulation is inter symbol interference. Orthogonal frequency division multiplexing (OFDM) came into existence to remove the shortage of single carrier transmission in case of having high data rate. OFDM is good for high-speed digital communication. OFDM modulation technique is used in 4G mobile system. One of the major drawback of OFDM system is high peak to average power ratio (PAPR) in time domain and form large amplitude wave form. High PAPR push the power amplifier into non-linear area result in in-band and out-ofband distortion. This PAPR should be least for powerful transmission. Number of techniques are used to overcome the Peak to average power ratio in OFDM system. In this paper we present different techniques that can be used to minimize high PAPR problem in OFDM system.

II. OFDM ADVANTAGES

OFDM has been used in many high data rate wireless systems because of the many advantages it provides.[1]

• Immunity to selective fading: One of the main advantages of OFDM is that is more resistant to frequency selective fading than single carrier systems because it divides the overall channel into multiple narrowband signals that are affected individually as flat fading sub-channels.

• Resilience to interference: Interference appearing on a channel may be bandwidth limited and in this way will not affect all the sub-channels. This means that not all the data is lost.

• Spectrum efficiency: Using close-spaced overlapping sub-carriers, a significant OFDM advantage is that it makes efficient use of the available spectrum. Resilient to ISI: Another advantage of OFDM is that it is very resilient to inter-symbol and interframe interference. This results from the low data rate on each of the sub-channels.

• Resilient to narrow-band effects: Using adequate channel coding and interleaving it is possible to recover symbols lost due to the frequency selectivity of the channel and narrow band interference. Not all the data is lost.

• Simpler channel equalisation: One of the issues with CDMA systems was the complexity of the channel equalisation which had to be applied across the whole channel. An advantage of OFDM is that using multiple sub-channels, the channel equalization becomes much simpler.

OFDM disadvantages

Whilst OFDM has been widely used, there are still a few disadvantages to its use which need to be addressed when considering its use.

• High peak to average power ratio: An OFDM signal has a noise like amplitude variation and has a relatively high large dynamic range, or peak to average power ratio. This impacts the RF amplifier efficiency as the amplifiers need to be linear and accommodate the large amplitude variations and these factors mean the amplifier cannot operate with a high efficiency level.

• Sensitive to carrier offset and drift: Another disadvantage of OFDM is that is sensitive to carrier frequency offset and drift. Single carrier systems are less sensitive.

III. CONCEPT AND PROCESS

Orthogonal Frequency Division Multiplexing (OFDM) is one of the modulation types used for current wireless and telecommunications systems. This system used the technique of encoding digital data on multiple carrier frequency and becomes a popular method for wideband digital communication. It is widely used to produce high data rates and combating multipath fading in wireless communication technology. OFDM is already used over the world to attain high data rates which is needed for data intensive applications. It has been used in wireless network, audio broadcasting and 4G mobile communication technology. This modulation format already been used in the WIFI arena (802.11a, 802.11ac, etc.). OFDM use the Cyclic Prefix (CP) which will reduce the overall spectral efficiency. OFDM based on the idea of modulating each data stream on subcarriers and dividing high-bit-rate data stream into several lower bit-rate data. Conventional OFDM makes use of Fast Fourier Transform (FFT) as its basic block. Multicarrier modulation knowing as schemes which able to provide high data rate. Figure 4 shows the frequency response for OFDM which exhibits strong sidelobes due to rectangular windowing. OFDM is a wideband modulation technique which is able to handle with the issues of the multipath reception by transmitting many narrowband overlapping digital signals in parallel in one wide band. It is very useful for communication over channels with frequency selective fading. Nevertheless, it is difficult in handling selective fading in the receiver because of the complicate architecture of the receiver. Besides that, flat fading is easy to combat compared to the frequency selective fading by the use of simple error correction and equalization schemes.

IV. OVERVIEW OF PAPR

OFDM is one of the many multicarrier modulation schemes, which provides high spectral efficiency, low implementation complexity, less susceptibility to echoes and non linear distortion. Owing to these advantages of the OFDM system, it is greatly used in various communication systems. But the main problem one faces for implementing this system is the high peak to average power ratio of this system. A large PAPR increases the difficulty of the analog to digital and digital to analog converter and reduces the efficiency of the radio frequency (RF) power amplifier [3,6]. Regulatory and application constraints can be implemented to reduce the peak transmitted power which in turn reduces the range of multi carrier transmission. This lead to the hindrance of spectral growth and the transmitter power amplifier is no longer confined to linear region in which it must operate. This has a injurious effect on the battery lifetime. Therefore in communication system, it has been observed that all the potential benefits of multi carrier transmission can be out - weighed by a high PAPR value [3].

The peak to average power ratio(PAPR) is the major drawback of OFDM system which decrease the performance of the transmitted signal. The large peak to average power ratio(PAPR) push the power amplifier to work in nonlinear area which result in band and out of band distortion. When subcarriers with large number are out of phase, a significant PAPR can cause the transmitter's power amplifier to run within a non-linear operating region. This cause significant signal distortion at the output of the power amplifier. In addition, the high PAPR can cause saturation at the digital to analog converter, leading to saturation of the power amplifier. PAPR also causes intermodulation distortion between the sub-carriers and distorts the transmit signal constellation. Therefore, the power amplifier must operate with a large power back-off, approximate to that of PAPR which lead to insufficient operation. Therefore it is necessary to overcome the PAPR of the transmit signal in MIMO-OFDM systems.[5]

There are a number of techniques to deal with the problem of PAPR. Some of them are amplitude clipping, clipping and filtering, partial transmit sequence (PTS) and „interleaving". These techniques achieve PAPR reduction at the expense of transmit signal power increase, bit error rate (BER) increase with data rate loss and computational complexity increase [3].

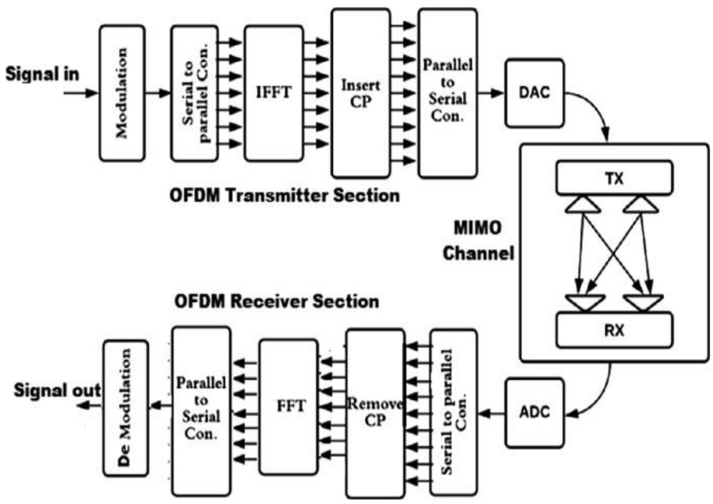

Fig. 1 Shows the MIMO OFDM Transmission System.

Practical communication systems are usually peak power limited. An OFDM signal consists of a large number of independently modulated subcarriers, which on coherent addition may produce a high instantaneous peak with respect to the average signal level. High power amplifiers (HPA's) are used to amplify the time domain OFDM signal to the desired power level. In order to deal with the large fluctuations in the envelope of OFDM signal, HPA's are required to have a large linear range. Such HPA's are costly, bulky and difficult to design. If an HPA with limited linear range is utilized for amplification, it may operate near saturation and can cause out-of-band (OOB) radiations and in-band distortion. The OOB distortion/noise is a major concern, especially in wireless communications, where large differences in signal strength from a mobile transmitter impose stringent requirements on adjacent channel interference (ACI) [8]. To accommodate large envelope fluctuations of the OFDM signal, the digital to analog converter (DAC) and analog to digital converter (ADC) are also required to have a wide dynamic range, which further increases the cost and complexity of the OFDM system. The recent interest in the application of OFDM to present and next generation wireless communication networks has triggered the development of numerous schemes to combat this problem.

V. PROBLEM DEFINITION

Being a multicarrier modulation scheme, OFDM brings all key profit of a multicarrier scheme but unlike single carrier modulation schemes, it suffers from the problem of ICI. Explore the existing ICI cancellation schemes and perform a comparison of CIR and BER performances. The PAPR is an important parameter that must be taken into consideration while designing an ICI cancellation scheme for the OFDM system of practical applications use. Therefore, investigation of PAPR performance of OFDM systems utilizing ICI cancellation schemes is also considered as another area to be explored in this research paper. Final aim of this review paper is to suggest a joint scheme for simultaneous PAPR reduction in OFDM systems.

PAPR REDUCTION TECHNIQUES

Nowadays, reducing PAPR has become pivotal for the multicarrier systems. Various PAPR reduction techniques have been introduced so far for the MCM systems. The fundamental classification for minimization of PAPR can be done as follows:

• Distorted Signal Techniques

• Non-Distortion based Signal Techniques

The techniques causing power loss and distortion in the original signal after processing it with reduction technique, are termed as signal distortion techniques. These schemes are responsible for initiating the spectral regrowth phenomenon in multicarrier systems. This in turn, deteriorates the spectrum causing distorted signals. While, if the PAPR is reduced using the reduction methods in order that the original signal remains unaffected and there occurs no loss of power, are called as non-distorted signal techniques. Some of them are discussed below:

• Clipping and Filtering

• Companding

• Selected Mapping (SLM)

Tone Reservation (TR)

• Tone Injection (TI)

• Active Constellation Extension (ACE)

• Partial Transmit Sequence (PTS)

VI. PARTIAL TRANSMIT SEQUENCE (PTS) TECHNIQUE

The Partial Transmit Sequence (PTS) technique is a popular method used to reduce the Peak-to-Average Power Ratio (PAPR) in multicarrier communication systems such as Orthogonal Frequency Division Multiplexing (OFDM). High PAPR is a critical issue in OFDM systems, as it leads to non-linear distortion in power amplifiers, reducing system efficiency and performance. PTS provides an effective way to address this issue without significantly affecting the system's performance or complexity.

Key Concepts of PTS:

1. **Partitioning the Data**:

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- The input data block is divided into multiple subblocks, often referred to as "partitions" or "subcarriers."
- These subblocks are independently phase-rotated using a set of phase factors.

2. **Phase Optimization**:
    - Each subblock is assigned a phase factor from a predefined set.
    - The goal is to optimize these phase factors to minimize the PAPR of the combined OFDM signal.
3. **Combination**:
    - The subblocks are combined after applying the optimal phase factors.
    - The combined signal is then converted to the time domain using an Inverse Fast Fourier Transform (IFFT).
4. **Search for Optimal Phase Factors**:
    - A search algorithm (e.g., exhaustive search, iterative methods, or heuristic algorithms) is used to determine the best phase factors that minimize the PAPR.
    - The complexity of the search increases with the number of subblocks and the size of the phase factor set.

Steps in the PTS Technique:

1. **Input Signal Division**:
    - The input frequency-domain OFDM symbol is divided into VVV disjoint subblocks: X1,X2,...,XVX_1, X_2, ..., X_VX1,X2,...,XV.
    - Each subblock contains a subset of the input data, and their sum reconstructs the original input signal.
2. **Phase Factor Multiplication**:
    - A phase rotation factor bvb_vbv is applied to each subblock XvX_vXv.
    - The phase factor set is typically limited to values like {1,−1,j,−j}\{1, -1, j, -j\}{1,−1,j,−j}.
3. **Signal Combination**:
    - The modified subblocks are summed to form the time-domain OFDM signal.
4. **PAPR Calculation**:
    - The PAPR of the resulting signal is calculated.

- The search for the optimal phase factors continues until the minimum PAPR is achieved.

5. **Transmission**:
    - The OFDM signal with the minimum PAPR is transmitted.

Advantages of PTS:

- **Effective PAPR Reduction**: Significant PAPR reduction can be achieved without distorting the transmitted signal.
- **Flexibility**: PTS can be applied to various multicarrier systems.
- **Nonlinear Effects Mitigation**: Reduces distortion caused by the power amplifier's nonlinearities.

Disadvantages of PTS:

- **Computational Complexity**: The search for optimal phase factors can be computationally intensive, especially with a large number of subblocks.
- **Side Information Overhead**: The receiver needs to know the phase factors applied at the transmitter, requiring the transmission of additional side information.
- **Latency**: The optimization process introduces processing delays.

Variants and Enhancements:

To address the computational complexity and overhead, various improved PTS schemes have been proposed:

- **Iterative PTS (IPTS)**: Reduces the search space using iterative techniques.
- **Simplified PTS (SPTS)**: Limits the phase factor set to reduce complexity.
- **Hybrid PTS**: Combines PTS with other PAPR reduction techniques like clipping or tone reservation.
- **Artificial Intelligence-based PTS**: Uses machine learning or heuristic algorithms to optimize phase factors efficiently.
-

VII. PROPOSED METHODOLOGY

Partial Transmit Sequence (PTS) Technique and AI-Based PAPR Reduction

The Partial Transmit Sequence (PTS) technique is a powerful method for reducing the Peak-to-Average Power Ratio (PAPR) in multicarrier systems such as OFDM. PTS reduces PAPR by dividing the input signal into multiple subblocks, applying phase rotation to each subblock, and combining them to minimize signal peaks. However, the conventional PTS technique suffers from high computational complexity due to the exhaustive search for optimal phase factors. To address this, Artificial Intelligence (AI)-based approaches, such as machine learning and heuristic optimization, are increasingly integrated with PTS. AI techniques can predict or optimize the phase factors more efficiently by leveraging training data or using advanced algorithms like genetic algorithms, particle swarm optimization, or deep learning models, significantly reducing complexity while achieving effective PAPR reduction.

Process Flow for PTS with AI-Based PAPR Reduction:

1. **Input Signal Partitioning**:
   - Divide the input frequency-domain OFDM signal into VVV disjoint subblocks X1,X2,...,XVX_1, X_2, ..., X_VX1,X2,...,XV, ensuring the sum reconstructs the original signal.
2. **AI-Driven Phase Factor Prediction**:
   - Train an AI model (e.g., a neural network or optimization algorithm) using historical or simulated OFDM data to learn the relationship between input signals and optimal phase factors.
   - Use the AI model to predict or generate the phase factors {b1,b2,...,bV}\{b_1, b_2, ..., b_V\}{b1,b2,...,bV} for each subblock, minimizing computational complexity compared to exhaustive search.
3. **Phase Factor Application**:
   - Apply the predicted phase factors bvb_vbv to each subblock XvX_vXv to rotate their phases.
4. **Signal Combination**:

- Combine the phase-rotated subblocks to form the modified time-domain signal: X′=∑v=1VbvXvX' = \sum_{v=1}^{V} b_v X_vX′=∑v=1VbvXv.

5. **PAPR Calculation and Refinement**:
   - Compute the PAPR of the modified signal. If needed, iteratively refine the AI model or use a hybrid approach to further optimize phase factors.
6. **Transmission**:
   - Transmit the PAPR-reduced OFDM signal along with any necessary side information about phase factors for receiver decoding.

Integrating AI with PTS not only reduces computational overhead but also enables adaptive and real-time optimization for varying communication scenarios, making it highly suitable for next-generation wireless communication systems like 5G and beyond.

VIII. RESULT AND SIMULATION

Software Key Features Algorithms for designing the concrete band of communications systems, including antecedent coding access coding, interleaving modulation, access models. MIMO equalization and synchronization.

• GPU-enabled Arrangement tar for computationally accelerated algorithms such as Turbo, LDPC, and Viterbi decoders Alternate accommodation tools, including eye diagrams, constellations and access drop functions

• Graphical apparatus for comparing the apish bit absurdity amount of an arrangement with analytical results.

• Access models, including AWGN. Multipath Rayleigh Fading. Rician Fading.MIMO Multipath Fading, and LTE MIMO Multipath Fading

• Basal RF impairments, including nonlinearity, actualization noise, thermal noiseand actualization and abundance offsets

• Algorithms accessible as MATLAB function MATLAB Arrangement objects, and Simulink blocks

• Abutment for fixed-point clay and C and HDL cipher generation

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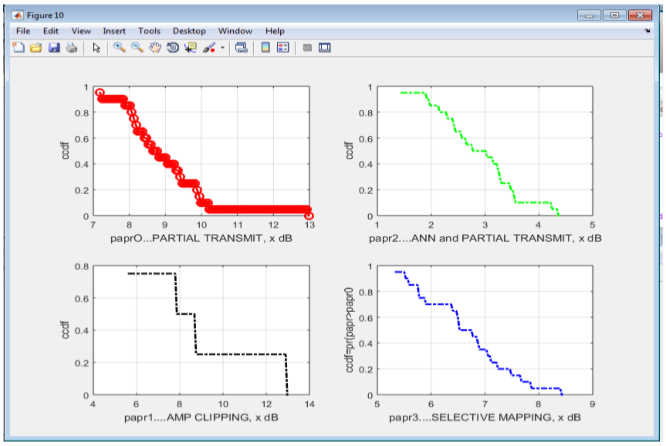

Fig. 2 Comparison of PAPR reduction methods.

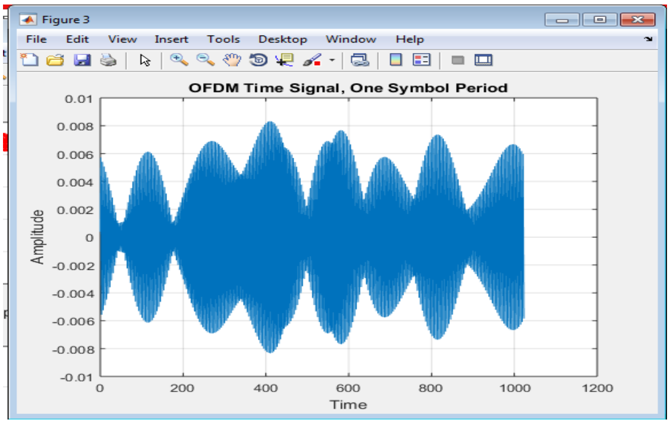

Fig. 3 Signal Symbol period.

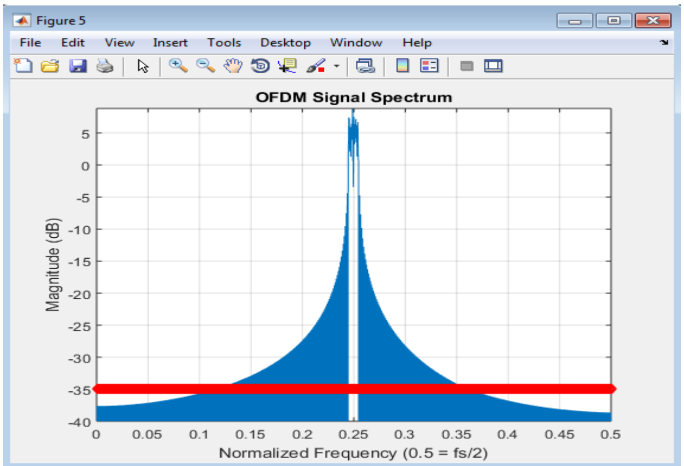

Fig. 4 OFDM signal Spectrum.

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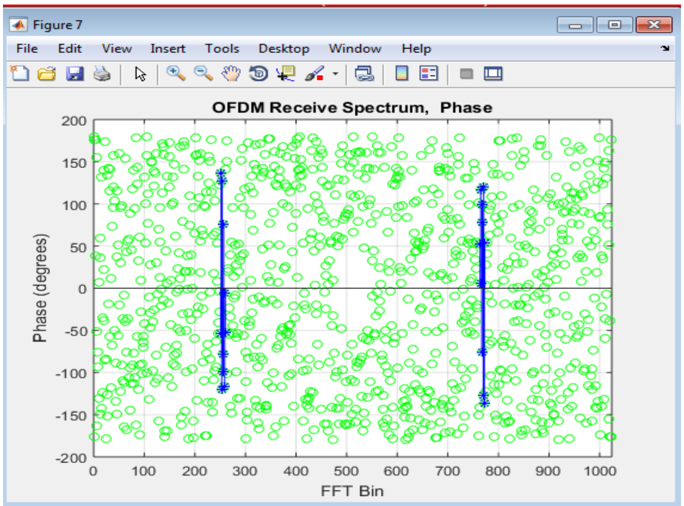

Fig. 5 Receiving Signal.

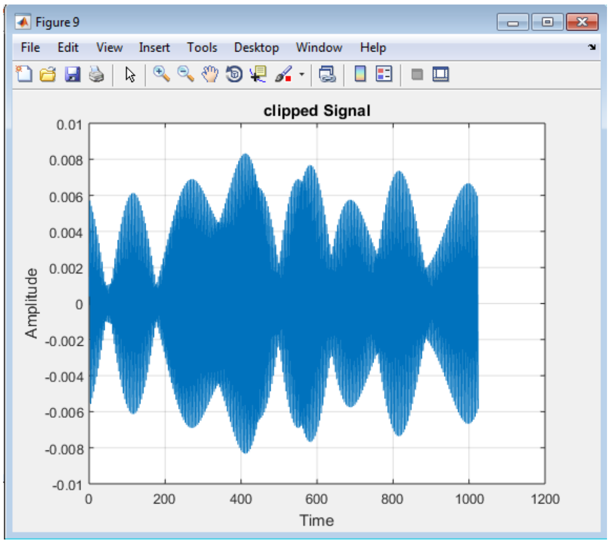

Fig. 6 signal.

IX. CONCLUSION

OFDM is very much attractive scheme for multicarrier transmission as it is known as mimo and has better spectral efficiency, simple deployment of receiver section and high speed data transmission up to 100mbps over a communication channel. Every scheme has pros and cons so its main disadvantage is a very high PAPR. In this project different techniques are elaborated to overcome this problem but as in some techniques we get reduced PAPR then at the same time high BER is there which is not a useful for conventional system. PTS scheme is the most straightforward approach to lessen the PAPR however huge number of iterations is required to restrict out-of-band radiation and to accomplish wanted PAPR level.

OFDM is a very attractive technique for multicarrier transmission and has become one of the standard choices for high – speed data transmission over a communication channel. It has various advantages; but also has one major drawback: it has a very high PAPR. In this project, the different properties of an OFDM System are analyzed and the advantages and disadvantages of this system are understood. The bit – error – rate is also plotted against the signal – to – noise ratio to understand the performance of the OFDM system. We have also aimed at investigating some of the techniques which are in common use to reduce the high PAPR of the system.

From the comparison curve of the SLM and PTS techniques, we could infer that PTS is more effective in PAPR reduction.

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