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Modelling and Simulation of OFDM and Implementation of PAPR Reduction Techniques

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Abstract: *OFDM, (Orthogonal Frequency Division Multiplexing) is a technic which use large subcarriers that orthogonal each other. The concept of OFDM is to split serial data with high bit rate into parallel data with lower bit rate. OFDM has advantage of simple equalization and intercell interference. Although OFDM is the most commonly efficient method of transmission, a drawback emerges from the mode of transmission which is the PAPR (peak to average power ratio) thus resulting in high complexity in analog to digital converter and digital to analog converter and reduction of RF amplifier efficiency. Some of the PAPR Reduction techniques are Amplitude clipping which states that a threshold value of the amplitude is set in this process and any sub-carrier having amplitude more than that value is clipped or that sub-carrier is filtered to bring out a lower PAPR value. In Partial Transmit Sequence Transmitting only part of data of varying sub-carrier which covers all the information to be sent in the signal. Selective Mapping In this a set of sufficiently different data blocks representing the information same as the original data blocks are selected. Selection of data blocks with low PAPR value makes it suitable for transmission. The results indicate that the proposed algorithm can significantly enhance the performance of OFDM systems by reducing the high PAPR without introducing distortion or requiring additional optimization algorithms. Over all this Project Offers a practical and efficient solution to address the high PAPR issue, improving the performance of OFDM - Based wireless communication Systems.*

Keywords*: Partial Transmit sequence, Selective mapping, PAPR, Amplitude Clipping*

I.INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier modulation technique. Multi-carrier transmission is a method devised to deal with frequency selective channels. In frequency selective channels different frequencies experience disparate degrees of fading. The problem of variation in fading levels among different frequency components is especially aggravated for high data rate systems due to the fact that in a typical single carrier transmission the occupied bandwidth is inversely proportional to the symbol period. The basic principle of multicarrier transmission is to translate high rate serial data stream into several slower parallel streams such that the channel on each of slow parallel streams can be considered flat. Parallel streams are modulated on subcarriers. In addition to that, by making symbol period longer on parallel streams the effect of the delay spread of the multi-path channel, namely inter-symbol interference (ISI), is greatly reduced. In multi-path channels multiple copies of the transmitted signal with different delays, which depend on characteristics of the material from which the transmitted signal has been reflected, are received at the receiver. The delay spread of a channel is a measure of degree of multi-path effect - it is equal to the difference between arrival times of the first and the last multi-path components. Due to the fact the length of the symbol period of each parallel stream scales proportionally to the number of subcarriers used the percentage of overlap between two adjacent symbols due to delay spread and resulting from its inter-symbol interference (ISI) also decreases proportionally to the number of subcarriers.

II.FUNCTIONAL OVERVIEW

OFDM is a specialised FDM having the constraint that the sub-streams in which the main signal is divided, are orthogonal to each other. Orthogonal signals are signals that are perpendicular to each other. A main property of orthogonal signals is that they do not interfere with each other. When any signal is modulated by the sender, its sidebands spread out either side. A receiver can successfully demodulate the data only if it receives the whole signal. In case of FDM, guard bands are inserted so that interference between the signals, resulting in cross-talks, does not occur. However, since orthogonal signals are used in OFDM, no interference occurs between the signals even if their sidebands overlap. So, guard bands can be removed, thus saving bandwidth. The criteria that need to be maintained is that the carrier spacing should be equal to the reciprocal of the symbol period. In order that OFDM works, there should be very accura synchronization between the communicating nodes. If frequency deviation occurs in the sub-streams, they will not be orthogonal any more, due to which interference between the signals will occur.

1.Quadrature Amplitude Modulation(QAM):- Data Rate Enhancement:- QAM allows us to transmit multiple bits per symbol by varying both amplitude and phase. In OFDM, each subcarrier is modulated using QAM, enabling efficient utilization of available bandwidth. Higher-order QAM (e.g., 16QAM or 64QAM) achieves higher data rates. Robustness and Tolerance:- QAM provides robustness against noise and interference. Even if some subcarriers experience fading or interference, others remain unaffected due to orthogonality. This resilience ensures reliable communication in challenging environments. Spectral Efficiency:- OFDM divides the available spectrum into orthogonal subcarriers. QAM modulation on each subcarrier allows simultaneous transmission of multiple data streams. Spectral efficiency is improved, as more information can be transmitted within the same bandwidth. Compatibility with Digital Systems: QAM is widely used in digital communication systems. OFDM leverages this familiarity, making it easier to integrate with existing technologies. QAM in OFDM:- In OFDM, QAM is used to modulate individual subcarriers. Each subcarrier carries a separate data stream, and the combined set of subcarriers forms the OFDM signal. The QAM modulation on each subcarrier allows efficient utilization of the available bandwidth. For example, 16QAM uses 16 different amplitude and phase combinations to represent 4 bits per symbol, while 64QAM represents 6 bits per symbol. Orthogonal Subcarriers:- OFDM subcarriers must be orthogonal (statistically unrelated) to avoid interference. Orthogonality ensures that the integral of the product of two subcarriers over time is zero.

2.Quadrature Phase Shift Keying(QPSK):- Quadrature phase shift keying (QPSK) is a digital modulation technique that transmits data at a constant frequency while varying the phases of the carrier signal. QPSK is one of the fundamental modulation schemes used in orthogonal frequency division multiplexing (OFDM) systems. QPSK uses four phases (0°, 90°, 180°, and 270°) to represent data symbols. Each QPSK symbol corresponds to two bits (since there are four possible phase angles). The use of QPSK in OFDM provides several advantages: Spectral Efficiency: QPSK achieves a good balance between data rate and spectral efficiency. It transmits two bits per symbol, which is efficient for OFDM subcarriers. Robustness to Fading: QPSK results in a constant amplitude signal, which reduces the impact of amplitude variations due to fading. Simple Demodulation: QPSK demodulation is straightforward, making it suitable for efficient OFDM receivers. Low Complexity: QPSK modulation and demodulation circuits are relatively simple compared to higher-order modulation schemes. Customized Demodulation: To ensure good data recovery, the OFDM demodulator is custom-designed for the specific symbol sets used during modulation. The combination of QPSK modulation and OFDM provides an effective solution for reliable wireless communication

III. METHODOLOGY

Orthogonal Frequency Division Multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequencies. The main advantage of OFDM is its robustness against channel impairments such as multipath propagation and frequency-selective fading. Here is a detailed explanation of the OFDM methodology, covering each step from data preparation to reception.

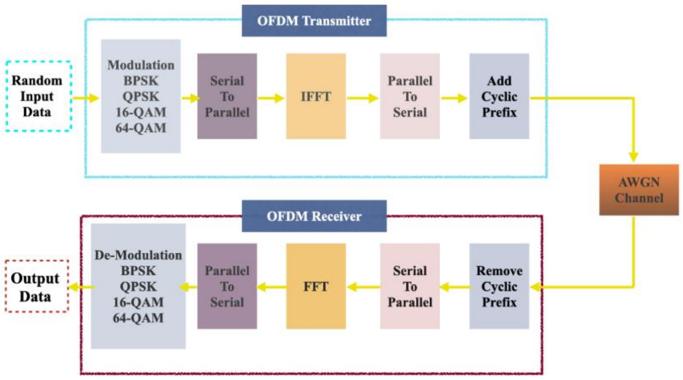

Fig.1 OFDM Block Diagram

Input Data Stream: Consider a high-speed serial data stream that needs to be transmitted. Parallel Sub-Streams: This high-speed serial data stream is divided into multiple parallel sub-streams. The number of parallel sub-streams is typically equal to the number of subcarriers in the OFDM system. Assume we have a serial data stream: 1011001110001010 If we want to divide this stream into 4 parallel sub-streams, we can split it as follows: Serial data stream: 1011001110001010 Parallel sub-stream 1: 1011 Parallel sub-stream 2: 0011 Parallel sub-stream 3: 1000 Parallel sub-stream 4: 1010

Choosing a Modulation Scheme: Common modulation schemes used in OFDM include QPSK (Quadrature Phase Shift Keying), 16-QAM (16-point Quadrature Amplitude Modulation), 64-QAM, and others. The choice of modulation scheme affects the data rate and the robustness of the transmission. For example, QPSK maps each pair of bits to one of four possible complex symbols, while 16-QAM maps each group of 4 bits to one of 16 possible complex symbols. Mapping Bits to Symbols: The binary data from the parallel streams is grouped according to the number of bits per symbol required by the chosen modulation scheme. For instance, in QPSK, every 2 bits are mapped to one complex symbol. In 16-QAM, every 4 bits are mapped to one complex symbol. Consider a parallel data stream 10111000 and using QPSK modulation: Bits: 10 -> Symbol: -1 + j (assuming a specific QPSK mapping) Bits: 11 -> Symbol: -1 - j Bits: 10 -> Symbol: -1 + j Bits: 00 -> Symbol: 1 + j

Inverse Fast Fourier Transform (IFFT) in transmitter: The IFFT (Inverse Fast Fourier Transform) is used in OFDM to convert the frequency domain representation of the modulated data into the time domain. This step is crucial because OFDM transmits data over multiple orthogonal subcarriers simultaneously in the time domain.

Adding Cyclic Prefix (CP) in transmitter: The primary purposes of adding a cyclic prefix (CP) are to: Improve robustness against multipath interference. Prevent inter-symbol interference (ISI). Multipath interference occurs when transmitted signals reflect off various objects and take different paths to reach the receiver. This can cause delayed versions of the signal to arrive at different times, leading to ISI. The CP helps to mitigate these issues. Why Use a Cyclic Prefix? Guard Interval: The CP acts as a guard interval. It allows the receiver to sample the incoming signal without ISI, as the ISI affects only the cyclic prefix and not the actual data. Circular Convolution: Adding a CP ensures that linear convolution (which occurs in a multipath channel) behaves like circular convolution. This property simplifies the equalization process at the receiver and maintains the orthogonality of subcarriers.

AWGN (Additive White Gaussian Noise) Channel: The purpose of using an AWGN channel model in OFDM systems is to simulate the effect of noise on the transmitted signal. This helps in analyzing the performance of the system in the presence of noise, which is a common real-world condition. Process: In an AWGN channel, the transmitted signal is corrupted by additive white Gaussian noise. This type of noise is characterized by having a constant spectral density (hence "white") and a normal distribution in amplitude (hence "Gaussian"). The primary parameters used to describe an AWGN channel are the signal-to-noise ratio (SNR) and the noise power spectral density.

Removing Cyclic Prefix: In Orthogonal Frequency Division Multiplexing (OFDM) systems, the cyclic prefix (CP) is added to each OFDM symbol to mitigate the effects of channel delay spread, inter-symbol interference (ISI), and frequency-selective fading. However, before demodulating and decoding the data, the cyclic prefix needs to be removed from each received OFDM symbol.

FFT (Fast Fourier Transform): In Orthogonal Frequency Division Multiplexing (OFDM) systems, the Fast Fourier Transform (FFT) is a crucial operation performed at the receiver to convert the received time domain signal back to the frequency domain. This process is essential for demodulating the transmitted data symbols. Demodulation in OFDM involves extracting the phase information from received complex symbols and decoding this information back into binary data. This process enables the receiver to recover the original transmitted symbols and decode the information carried by each subcarrier. Peak to Average Power Ratio (PAPR) in OFDM: An OFDM signal consists of several independently modulated sub-carriers, which can give a large PAPR when added up coherently. When N signals are added with the same phase, they produce a peak power that is N times the average power of the signal. So OFDM signal has a very large PAPR, which is very sensitive to non-linearity of the high-power amplifier.

Effect of High PAPR: High PAPR corresponds to a wide power range which requires more complicated analog-to digital (A/D) and digital-to-analog (D/A) converters in order to accommodate the large range of the signal power values. Therefore, high PAPR increases both the complexity and cost of implementation. Researchers have suggested several techniques to reduce PAPR over the years [21] [22] [23] [24] [25]. This research work presents the simulation study and analysis three PAPR reduction techniques in this section. a) Clipping and Filtering Technique’s)SelectedMappingTechnique. c) Partial Transmit Sequence Technique.

Clipping and Filtering Technique: Clipping is a way of reducing PAPR by simply limiting the maximum amplitude of the OFDM signal, such that all signal values are limited to the threshold. Clipping the OFDM signal before amplification is a simple method to limit PAPR. However clipping may cause large out of band (OOB) and in band interference as it is a nonlinear process which results in the system performance degradation.

SELECTIVE LEVEL MAPPING(SLM) In the SLM, the input data sequences are multiplied by each of the phase sequences to generate alternative input symbol sequences. Each of these alternative input data sequences is made the IFFT operation, and then the one with the lowest PAPR is selected for transmission.

Partial Transmit Sequence Partial Transmit Sequence is one of the most important technique for reducing PAPR in OFDM systems. Main idea of PTS is data blocks are divided into non-overlapping sub-block with independent rotation factor. The fundamental idea of this technique is sub-dividing the original OFDM symbol data into sub-data which is transmitted through the sub-blocks which are then multiplied by the weighing value which were differed by the phase rotation factor until choosing the optimum value which has low PAPR.

IV.RESULTS

Generally In Figure-1 indicates Generation of Random signals and with that signals we are doing mapping and then by applying modulation(figure-3).After modulation we are performing IFFT and adding cyclic prefix to reduce ISI and then Adding AWGN channel (figure-6) which means that Additive White gaussian Noise in order to check the performance of BER and SNR and then removal of cyclic prefix it tends to frequency signal and that signal converted to Time domain signal by Applying FFT and at last by performing demodulation in order to receive the signal Properly. Due To independent Sub carriers PAPR problem Arises and to reduce PAPR we are using three reduction Techniques Amplitude clipping(Figure-14) and Partial Transmit sequence(Figure-15) , Selective mapping(Figure-17) and at last we plot all the Over all performance of PAPR Reduction Techniques.

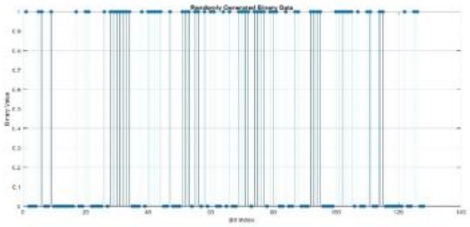

Fig1.Generation of Random signals

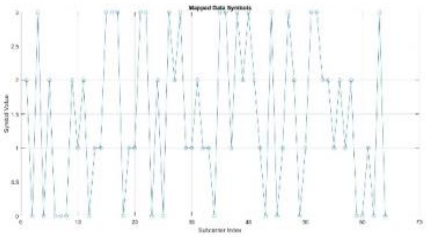

Fig2.Mapped Data symbols

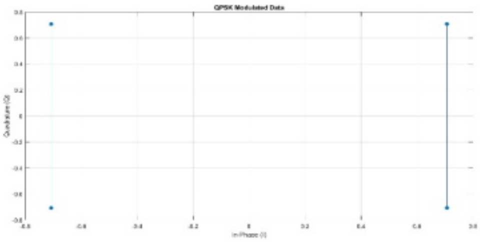

Fig3.QPSK Modulated Symbols

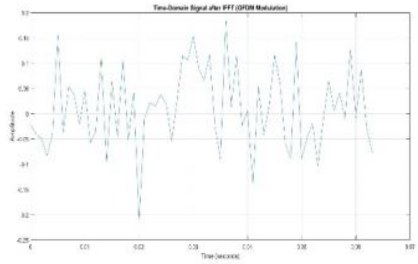

Fig 4. Time domain after IFFT

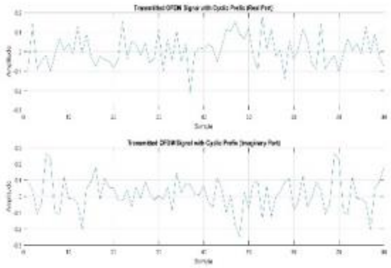

Fig5. Addition of cyclic prefix

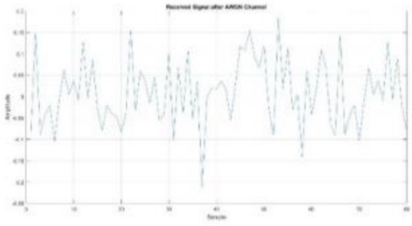

Fig 6. Signal After AWGN channel

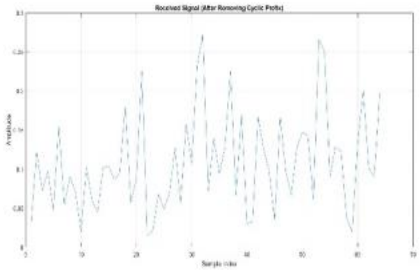

Fig 7. After Removal of Cyclic Prefix

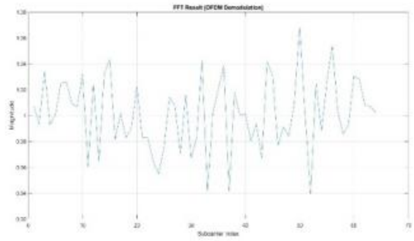

Fig 8. After FFT (Demodulation)

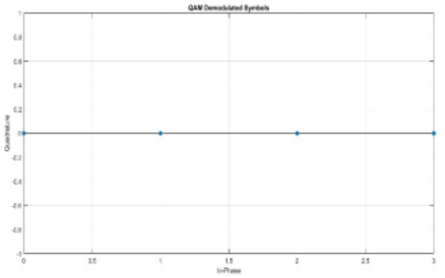

Fig 9. Demodulation Symbols

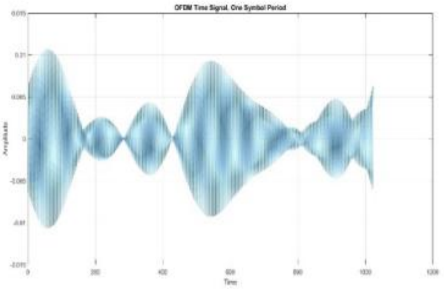

Fig 10. OFDM Time signal ,One symbol Period

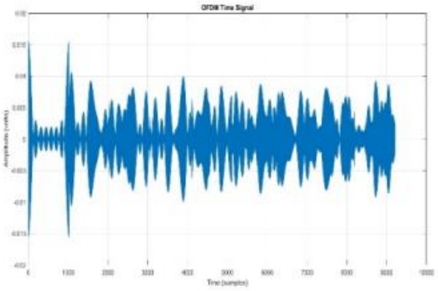

Fig 11. OFDM Time Signal

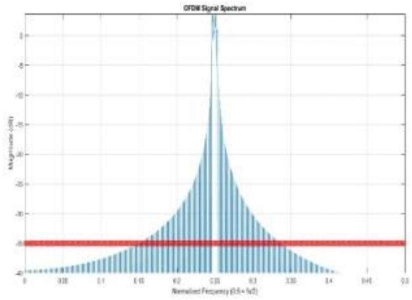

Fig 12. OFDM Signal Spectrum

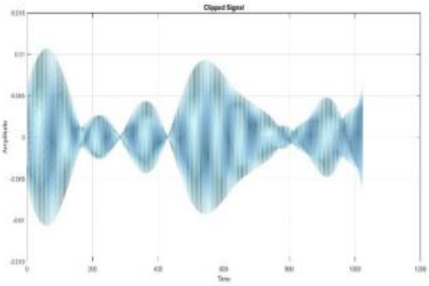

Fig 13. Before Clipping

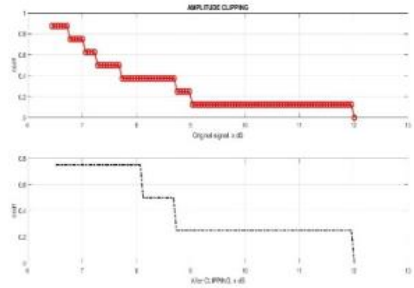

Fig 14. Amplitude Clipping

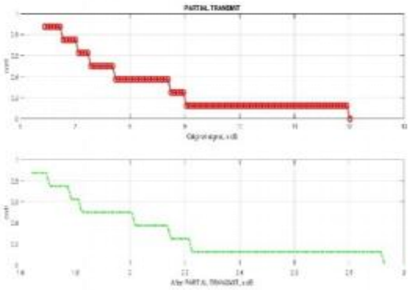

Fig 15.Partial Transmit Sequence

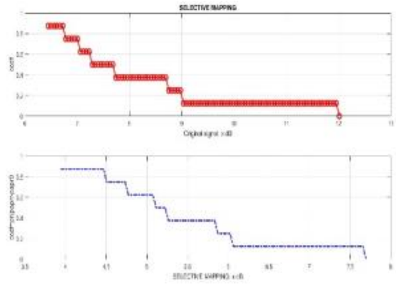

Fig 16. Selective Mapping

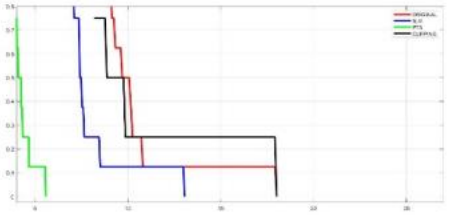

Fig 17. OverAll Performance of PAPR Reduction Techniques

CONCLUSION & FUTURE SCOPE

OFDM is similar to Frequency division multiplexing but the difference lies in modulation and demodulation of signals. The basic priority is to minimization of Inter-symbol Interference, cross-Talk and PAPR Reduction. The different PAPR reduction schemes are applied accordance with the technology. OFDM has several interesting properties that suit its use over Wireless channels and hence many Wireless standards have started to use OFDM for modulation and multiple accesses. It is also concluded that OFDM when combines with MIMO plays a very important role in next generation mobile communication system because of high demand in data speed and to compensate the growing capacity in limited spectrum. One of the drawback of MIMO-OFDM is its hardware implementation is very complex and its circuit require a high power which make it costly and its size is also large as compare to traditional antennas. This article provides the comprehensive details about the OFDM System and different PAPR reduction techniques which also gives an opportunity to the researcher and academician who wants to work in this field. OFDM is similar to FDM but the difference lies in modulation and demodulation of a signals. The basis priority is to minimization of ISI, Cross-talk and PAPR. The different PAPR schemes are applied accordance with the technology. Different Papr Reduction techniques are used like Selective mapping, Partial Transmit Sequence and Amplitude Clipping which used to reduce High PAPR. Basic requirements of practical PAPR techniques include the compatibility with the family of existing modulation schemes, high spectral efficiency, and low complexity. Even though various techniques were introduced to reduce the PAPR in OFDM, none of the techniques proves to be a perfect solution. The corresponding reduction technique has chosen for various system requirements. In future even more PAPR reduction technique can be introduced.

5G Networks: OFDM is a cornerstone of 5G technology, used in both the downlink and uplink. It supports higher data rates, lower latency, and more efficient spectrum use. 6G Networks: Future 6G systems are likely to continue leveraging OFDM, with enhancements to support even higher frequencies (terahertz bands), massive MIMO (multiple-input multiple- output), and new applications such as holographic communications and pervasive connectivity.

Massive IoT: As IoT devices proliferate, OFDM can help manage the spectrum efficiently and handle the diverse requirements of massive machine-type communications (mMTC). Low-Power Wide-Area Networks (LPWAN): OFDM variants can be tailored to meet the low power and wide coverage needs of LPWAN technologies.

Massive MIMO: Combining OFDM with massive MIMO techniques can significantly increase spectral efficiency and capacity. Beam-forming: Advanced beam-forming techniques using OFDM can improve signal quality and coverage, especially in dense urban environments.

Vehicular Communications: OFDM is essential for Vehicle-to-Everything (V2X) communications, supporting applications like autonomous driving, traffic management, and infotainment. High-Speed Trains and Aircraft: Enhanced OFDM can provide reliable, high-speed internet access to passengers on fast-moving platforms.

Higher Throughput: OFDM continues to evolve in Wi-Fi standards, enabling higher throughput and better performance in dense environments.

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