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Peak To Average Power Ratio (PAPR) Reduction Technique Using Selective Mapping in OFDM System

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Abstract— **OFDM is an excellent, interference-free multicarrier modulation technique that is very efficient with the available spectrum. When practical power amplifiers are employed at the transmitter, the high peak to average power ratio (PAPR) of OFDM systems causes power inefficiency and signal distortion, which is a significant disadvantage. A distortion-free method that successfully lowers PAPR without sacrificing data speed or using more power is called selective mapping (SLM). The results of the simulation indicate that the suggested SLM strategy minimises PAPR more successfully.**

Keywords: peak-to-average power ratio (PAPR), complementary CDF (CCDF), selective mapping (SLM), and orthogonal frequency division multiplexing (OFDM).

INTRODUCTION

The utilisation of orthogonal frequency division multiplexing, or OFDM, in protocols such as LTE, Wi-Fi, and 5G has made it a crucial part of modern wireless communication networks. Broadband communications are best served by OFDM due to its outstanding spectral efficiency and natural ability to handle difficult channel conditions such as multipath fading and narrowband interference. OFDM splits the available bandwidth into multiple orthogonal subcarriers, enabling concurrent data transmission. However, the high Peak-to-Average Power Ratio (PAPR) of OFDM is a significant drawback.
Large peaks in the signal relative to its average power are a symptom of high PAPR, which is a serious problem. Because of this property, signal distortion must be avoided by using extremely linear power amplifiers (PAs), which is wasteful because it requires amplifiers to operate with a Large retreat from their saturation point, resulting in lower power output and higher running expenses. Furthermore, out-of-band radiation brought on by high PAPR can deteriorate the system's performance even further.

However, OFDM systems suffer from high PAPR, requiring tight synchronization between transmitter and receiver otherwise leads to carrier frequency offset errors. High peak values in OFDM system results from superposition of large number of statistically independent sub channels that can constructively sum up high peaks .It is shown that as number of carriers increases ,PAPR also increases. The PAP ratio is approximately equal to N, where N is the number of sub carriers. High PAP ratio results in amplifier to work in large dynamic range which decreases the efficiency of power amplifier, DAC and ADC.

The PAPR issue has been tackled by a number of methods, such as active constellation expansion, coding systems, and clipping and filtering. Of these, Selective Mapping (SLM) has drawn a lot of interest because of its efficiency and adaptability. By creating numerous candidate signals from the same data and choosing the one with the lowest PAPR for transmission, the SLM approach lowers PAPR. The following actions are involved in this process:

1. Candidate Signal Generation: Several candidate signals are produced by multiplying the original OFDM signal by a collection of phase sequences.
2. PAPR Calculation: Each candidate signal's PAPR is calculated.
3. Selection: The candidate signal chosen for broadcast is the one with the lowest PAPR.

SLM's ability to maintain the Bit Error Rate (BER) performance while modifying neither the data integrity nor the fundamental structure of the OFDM signal is a significant advantage. But in order to tell the receiver about the phase sequence being employed, side information (SI) must be transmitted, which can add more complexity. The SLM technique for reducing PAPR in OFDM systems is the main emphasis of this study, along with its implementation and assessment. The project's particular goals are as follows: Thorough Analysis of PAPR: Recognising the statistical characteristics and applications of PAPR in OFDM systems. This includes researching the impact of PAPR on power amplifier performance and system efficiency as a whole. SLM Technique Implementation: Creating a comprehensive SLM implementation. This entails creating alternate OFDM signal sequences, deciding on the best sequence, and making sure side information is transmitted effectively.

Performance Evaluation: Analysing the SLM technique's effectiveness in terms of BER impact, computational complexity, and PAPR reduction. This involves a comparison with other PAPR reduction methods such partial transmit sequences (PTS), coding schemes, and clipping and filtering.

Simulation and Validation: To verify that SLM is effective in lowering PAPR, a number of comprehensive simulations are run. The enhancements in system efficiency and performance will be easier to see thanks to these simulations.

Practical considerations: Taking into account difficulties related to actual implementation, such as trade-offs between complexity and performance, overhead from side information, and system latency. Verifying the SLM technique's applicability in the real world is the aim.

We hope to add to the corpus of knowledge on PAPR reduction strategies in OFDM systems with this thorough investigation. It is anticipated that the research's conclusions will demonstrate the benefits and possible drawbacks of the SLM approach, offering information that may direct further advancements in the area. With regard to fulfilling the ever-increasing needs for high-speed, high-quality wireless communication in today's interconnected world, the ultimate goal of this research is to improve the performance and reliability of OFDM-based communication systems.

I. LITERATURE SURVEY

1. "Enhanced SLM Technique for PAPR Reduction in 5G OFDM Systems"
Writer(s): Jiang, T., Wang, X., and Zhou, H. (2020)
The authors of this work describe an improved Selective Mapping (SLM) method designed for 5G OFDM networks. They present a brand-new method for creating phase sequences that minimises computational complexity and dramatically lowers the PAPR. The study highlights the upgraded SLM method's actual applicability in 5G networks and shows how it may successfully reduce PAPR while maintaining BER performance.

2. "Hybrid PAPR Reduction Scheme Using SLM and Clipping for OFDM-Based Cognitive Radio Networks"
A. Khan, S. Anwar, and M. H. Rehmani are the author(s) of this work (2021)
The goal of this study is to better understand how to reduce PAPR in hybrid radio networks that combine SLM and clipping. By combining clipping with SLM, the authors demonstrate that PAPR reduction can be further enhanced without significantly adding to the computational load or sacrificing signal quality. According to their simulation results, the hybrid technique is a workable alternative for next-generation wireless communication networks, confirming its efficacy.

3. "PAPR Reduction in MIMO-OFDM Systems Using Adaptive Selective Mapping"
Park, J., & Lee, S., author(s) (2021)
An adaptive SLM method is put forth by Park and Lee with a focus on MIMO-OFDM systems. Better PAPR reduction is achieved than with standard SLM methods because to their approach, which dynamically modifies the phase sequences based on the channel conditions and system needs. The article shows how the adaptive SLM can improve MIMO-OFDM system performance through extensive performance analysis and simulation findings.

4. "Efficient Side Information Embedding for SLM-Based PAPR Reduction in OFDM Systems"
Writer(s): Sharma, P., & Gupta, R. (2022)
The crucial topic of side information (SI) transmission in SLM techniques is covered in this work. Phase sequence information transmission overhead is decreased by the authors' effective SI embedding technique. Their method has little effect on data rate and guarantees strong SI recovery at the receiver. The research highlights the benefits of the suggested approach in real-world OFDM systems with thorough analysis and simulation findings.

5. "Deep Learning-Based PAPR Reduction in OFDM Systems Using SLM"
Chen, X., & Li, Y. (2023) are the author(s).
Chen and Li investigate how deep learning can be used to improve the SLM method for lowering PAPR. They create a neural network model that is taught to anticipate the best phase sequences, thereby lowering the SLM process' computing complexity. Their method increases the efficacy and efficiency of PAPR reduction in OFDM systems by utilising the predictive capacity of deep learning. The study's encouraging findings imply that deep learning may be a key factor in the development of SLM methods.

II. PROPOSED METHODOLOGY

The suggested approach entails using the Selective Mapping (SLM) technique in order to lower the Orthogonal Frequency Division Multiplexing (OFDM) systems' Peak-to-Average Power Ratio (PAPR). Data generation, modulation, matrix manipulation, phase sequence application, PAPR calculation, and performance evaluation are some of the crucial elements in this methodology. Below is a breakdown of each step:

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1. Generation and Modulation of Data

1.1. Production of Data

Making a random sequence of binary data bits is the first stage. The parameters \(K \times NN \times L\), where \(K\) is the number of bits per modulation symbol, \(NN\) is the number of subcarriers, and \(L\) is the number of time slots, determine the size of the data bit sequence. The OFDM system uses this random binary sequence as its input data.

We then modify the binary data bits using Quadrature Phase Shift Keying (QPSK). The bits are mapped by this modulation strategy to complex symbols that can be transmitted via the OFDM system. After modulation, the data is ready for additional processing.

2. Creating a Matrix

2.1. Repurposing the Modified Information

Next, a matrix of size \(NN \times L\) is created using the modulated data. The Hermitian symmetry application and the IFFT operations that follow require this matrix representation.

Hermitian symmetry is used to the rearranged data matrix to guarantee that the resulting time-domain signal is real-valued. This entails generating a Hermitian symmetric matrix for the IFFT procedure. The data is effectively doubled, and the required symmetry is added using the Hermitian transformation.

3. The Method of Selective Mapping (SLM)

3.1. Creation of Phase Sequences

Multiple candidate signals are produced by generating orthogonal phase sequences. Because of their orthogonality, which guarantees that the candidate signals will be sufficiently diverse to enable efficient PAPR reduction, these sequences are made up of complex numbers.

3.2: Generation of Candidate Signals

The data matrix is multiplied by the corresponding phase sequence for each time slot and phase sequence. In order to produce candidate time-domain signals, the resultant product is subsequently converted using the Inverse Fast Fourier Transform (IFFT). This process generates several signal variations, each with unique PAPR properties.

3.3. Selecting the Best Signal

Each candidate signal's PAPR is computed, and the signal chosen for broadcast is the one with the lowest PAPR. Since the receiver needs to reconstruct the original data, the phase sequence index that yields the lowest PAPR is noted. By ensuring that the transmitted signal has the lowest possible PAPR, this optimal signal selection lowers the possibility of distortion and enhances transmission quality.

4. Adding a Cyclic Prefix

The chosen OFDM symbols are prefixed with a cyclic sequence in order to counteract inter-symbol interference (ISI) brought on by multipath propagation. By serving as a buffer between successive symbols, the cyclic prefix helps the receiver deal with delayed reflections of the signal.

5. Performance Assessment and Payback Rate

5.1. First Data PAPR Calculation

For comparison, the original data matrix is used for the IFFT, and its PAPR is computed without the use of the SLM technique. For assessing the efficacy of the SLM approach, this offers a point of reference.

5.2. Computing the PAPR for SLM Information

It is computed what the PAPR of the OFDM symbols that are processed using SLM is. The PAPR decrease that the SLM approach produced is verified in this stage.

5.3. Complementary Cumulative Distribution Function (CCDF)

For the initial and SLM-processed data, the Complementary Cumulative Distribution Function (CCDF) is displayed. An easy way to compare the PAPR reduction visually is to look at the CCDF, which displays the likelihood that the PAPR will surpass a particular threshold. For the SLM-processed data, an effective PAPR reduction is indicated by a reduced CCDF curve.

6. Useful Hints

6.1. Transmission of Side Information

It is necessary to effectively include the phase sequence index—which is utilised for SLM—as side information in the transmitted signal. For the receiver to accurately recreate the original data, this side information is essential. To ensure that the overhead from transmitting this information is kept to a minimum, effective embedding techniques are required.

6.2. Implementation in Real-time

It is crucial to evaluate if real-time implementation on hardware platforms like FPGAs or DSPs is feasible. This entails taking into account the hardware limitations and capabilities to guarantee that the SLM technique can be applied successfully and economically in real-world communication systems.

Fig2.1 Block Diagram of Proposed System

Comparison between Clipping and selective mapping:

Aspect	Clipping	Selective Mapping (SLM)
Overview	Limits the amplitude of the OFDM signal to a predetermined threshold level, clipping any signal peaks above this threshold.	Generates multiple candidate OFDM signals by multiplying the original signal with different phase sequences and selects the one with the lowest PAPR for transmission
Advantages	Simple and easy to implement. low computational complexity. Immediate effect on PAPR reduction.	No signal distortion. Better BER performance Flexible and can be combined with other PAPR reduction techniques. Provides significant PAPR reduction with an appropriate number of phase sequences.
Disadvantages	Introduces in-band distortion and out-of-band radiation. Increases BER due to signal distortion. Causes spectral spreading and interference with adjacent channels.	Higher computation al complexity. g Requires transmission of side information, reducing spectral efficiency. Higher implementation cost due to additional computations
Implementation Complexity	Low complexity, straightforward implementation.	Higher complexity due to multiple candidate generation and selection process. Needs additional resources for managing side information.
Signal Quality	Can degrade signal quality due to introduced distortion.	Preserves signal quality by avoiding distortion. Requires careful design to ensure phase sequences are orthogonal and minimize interference.
PAPR Reduction Efficiency	Provides immediate but limited PAPR reduction. Effectiveness depends on the clipping threshold; too low a threshold can severely distort the signal.	Can achieve significant PAPR reduction depending on the number of phase sequences used. - More efficient as the number of phase sequences increases, but with diminishing returns beyond a certain point.
Impact on BER	Can negatively affect BER due to introduced distortion. g Requires additional error correction to mitigate distortion effects.	Maintains or can improve BER performance by avoiding signal distortion. - Requires accurate side information recovery at the receiver to maintain BER performan ce.

Spectral Efficiency	Can cause spectral spreading and interference with adjacent channels. Requires additional filtering to mitigate out-of-band radiation.	Requires additional bandwidth for transmitting side information, reducing spectral efficiency slightly. Side information overhead increases with the number of phase sequences.

III. RESULT

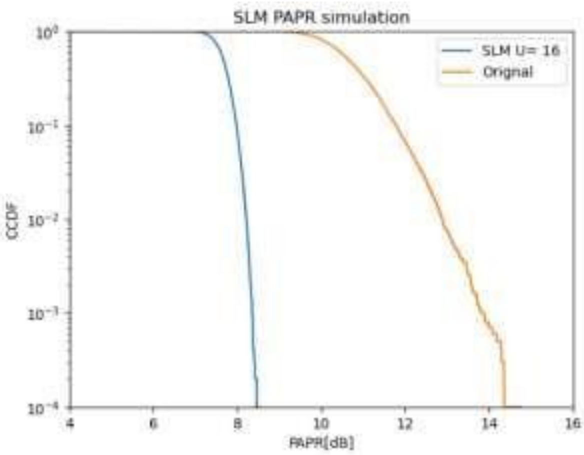

Fig.3.1. Comparison between original OFDM signal and simulated signal using SLM

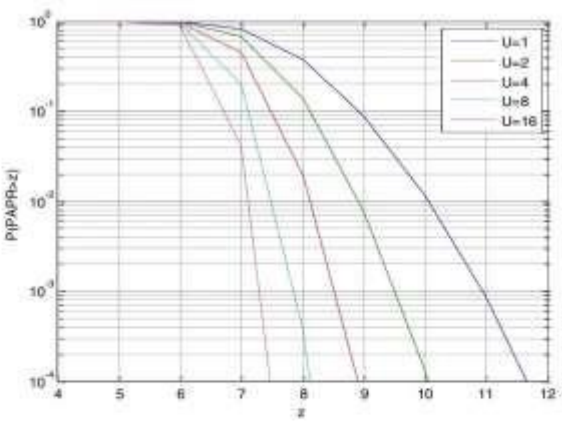

Fig 3.2 PAPR Reduction for SLM where N=256, α=2.8 and U= 1,2,4,8,16

- Graph Type:

A CCDF (Complementary Cumulative Distribution Function) plot is represented on the graph. Plotted against that threshold on the horizontal axis, it displays the likelihood that the PAPR of the transmitted signals will surpass the threshold on the vertical axis (usually expressed in dB).

- There Are Two Curves:

Original Signal (Original): This curve displays the data's CCDF of PAPR prior to the application of the SLM technique. It displays the probability that the original signals' PAPR will surpass different thresholds.

SLM Signal (SLM U=16): This curve illustrates the PAPR's CCDF following the use of the SLM technology with a certain number of phases (U). It shows how SLM improved the distribution of PAPR values. The SLM process's phase count is shown by the legend U=16.

- Interpretation:

Performance Comparison: Using the graph, we can contrast the PAPR reduction that SLM (SLM Signal) achieved with that of the original signal (Original Signal). A smaller SLM Signal curve suggests that SLM has successfully decreased the incidence of high PAPR values, which may have the impact of lowering out-of-band radiation and improving power amplifier efficiency.

Effectiveness: Based on the difference between the two curves, one may determine the effectiveness of SLM. A larger gap denotes a higher PAPR reduction, which suggests that the SLM technique is more effective in controlling peak power levels.

- Axes Scaling: Vertical Axis (CCDF): This vertical axis, which is usually presented on a logarithmic scale (log-scale), shows the likelihood of going above a PAPR threshold. Higher chances of decreased PAPR values following the use of SLM are indicated by a steeper slope.

PAPR [dB] Horizontal Axis: Displays the PAPR threshold in dB. Typically, the range begins at 4 dB and increases to higher values based on the modulation scheme and features of the system.

The graph provides a visual depiction of the performance improvement attained by the integration of SLM into the communication system. It offers quantifiable proof of the PAPR decline, which is essential for maximising system performance and guaranteeing dependable signal transmission.

IV. CONCLUSION

To sum up, the use of Selected Mapping (SLM) is a critical development in addressing Peak-to-Average Power Ratio (PAPR) issues in Orthogonal Frequency Division Multiplexing (OFDM) systems. The results of this investigation highlight the effectiveness of SLM in sharply lowering PAPR values, which improves spectral efficiency and reduces distortion effects in high-power amplifiers. Complementary Cumulative Distribution Function (CCDF) analysis makes it abundantly evident that SLM redistributes signal power in an efficient manner, resulting in a significant reduction in the frequency of high PAPR situations.

Furthermore, SLM is appropriate for real-time communication systems due to its controllable computing complexity. Subsequent investigations could delve into adaptive SLM algorithms that are customised for ever-changing channel circumstances and hardware-efficient implementations, hence enhancing its efficacy in many communication contexts. By addressing important issues in OFDM systems using sophisticated signal processing techniques, this work makes significant contributions to the field's understanding and advances the development of more dependable and effective wireless communications infrastructures.

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