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PAPR Reduction Of OFDM System With Improved Steganography Technique

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Abstract:
Orthogonal Frequency Division Multiplexing OFDM is a widespread method used in modern communications systems, all because it is resistant to frequency-selective fading in addition to its ability to reduce interference between symbols. One of the most important disadvantages of this method is the Peak-to-Average Power Ratio PAPR. This causes energy inefficiency and thus increases the complexity of the transmitting devices. In this study, we present a method to reduce (PAPR) in systems that rely on multiplexing (OFDM) by using the information hiding method, or what is called steganography. Here, steganography hides data, which is often in the form of text, inside the digital file represented by the image. It is considered an effective way to reduce (PAPR) when using (OFDM), and here comes the role of information hiding technology, which differs from traditional methods in flexibility and absorbing a lot of information when used with OFDM, which maintains the system's performance without taking into account external noise and including a large amount of information in a unit area. For the photo. Sending hidden data through communication channels is considered a positive process in order to preserve the data from noise, because hidden information is not affected by noise and has the ability to restructure itself when extracted. Thus, preserving the information transmitted through the channel in the best possible way, which is considered the primary goal of building such a system. The proposed method has proven its worth through the evaluation, which consists of two parts: the first is evaluating the signal frequencies within a channel and finding the amount of data loss through it, and the second part is the imperceptibility of the data transmitted in the image, which is the goal of stenography.

Key Word: *OFDM; PAPR Reduction; Steganography; Communication Systems; Noise channel; Quality of signal.*

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I. Introduction

OFDM technology has proven through studies its worth as it is considered a basic modulation technology in modern communications systems, and one of its most important features is that it is able to counter selective frequency fading in addition to reducing interference between symbols. From this standpoint, we know that there are ongoing challenges facing OFDM in this field, which is represented by maintaining PAPR, which is characterized by varying capabilities to maintain the transmitted signal and overcome obstacles facing the system [1].

Among the harmful effects on the signal, such as non-linear distortion in the power amplifiers, which is caused by a high PAPR ratio in signals, including the OFDM signal, and also among the harmful effects is a decrease in energy efficiency as well as unwanted spectral regrowth. All of this leads to complications in signal quality, in addition to interference with other channels. From this standpoint, it is necessary to mitigate the effects of high PAPR, which is a necessity to improve communications that use OFDM [2].

In order to address PAPR, many techniques have been proposed in the literature, including encryption, clipping, filtering, and more. One of these techniques is the technique of hiding information in electronic media, which has gained wide spread and the attention of many due to its ability to reduce PAPR with little loss and higher spectral efficiency.

Steganography technology works as a brilliant strategy for preserving digital content, especially when it is shared with OFDM systems, to increase the embedding within the transmitted channel and, as it works to increase the transmitted content, thus reducing PAPR. However, there are still restrictions on the currently widespread data masking process, which is proportional to the storage capacity with the amount of channel absorption of interfering waves in the real world. [3].

From this standpoint and from these challenges, this research can find solutions in information technologies that are designed to reduce PAPR in systems that operate in OFDM channels. In the proposed methodology, we aim to overcome all restrictions related to reducing noise in communication channels by using information technology techniques of masking and encryption. System performance safety is an unavoidable priority.

In this paper, we aim to provide a general exploration that includes visualization of the work of the proposed PAPR technique, which relies on data hiding, in terms of implementation and accurate evaluation of the work. In the process of simulation and analysis, which aims to reveal the effectiveness of communication systems and the effects on which the OFDM system depends, in order to be more efficient and reliable. In addition to delving deeper into the effects we obtain in order to build future proposals to be relied upon later, we must therefore ensure that the proposed method is appropriate with the conditions that accompany the work of the communication system

II. Related

The research landscape concerning Peak-to-Average Power Ratio (PAPR) reduction techniques in Orthogonal Frequency Division Multiplexing (OFDM) systems is vast and diverse, encompassing a multitude of methodologies aimed at mitigating the adverse effects of high PAPR [4]. Traditional techniques such as clipping, filtering, and coding have been extensively investigated, albeit with inherent limitations including signal distortion and increased computational complexity. Alternatively, active constellation extension (ACE), selective mapping (SLM), and partial transmit sequence (PTS) techniques have been proposed, each offering unique approaches to PAPR reduction [5], albeit with trade-offs in terms of computational overhead and side information transmission. Furthermore, steganography-based methods have emerged as promising alternatives, leveraging the concealment of supplementary data within transmitted signals to manipulate amplitude distribution and reduce PAPR [6]. While early steganography techniques exhibited limited embedding capacity and susceptibility to channel noise, recent advancements have led to the development of sophisticated steganography approaches tailored specifically for PAPR reduction in OFDM systems [7-9]. These advanced techniques employ sophisticated encoding and modulation schemes to embed side information efficiently while ensuring robustness against channel impairments and preserving spectral efficiency. Performance evaluations of steganography-based PAPR reduction techniques typically involve assessments of PAPR reduction ratio, bit error rate (BER), spectral efficiency, and computational complexity, often in comparison with conventional PAPR reduction methods, providing valuable insights into their efficacy and potential for practical deployment in OFDM communication systems [10].

III. Proposed Method

After The proposed method for Peak-to-Average Power Ratio (PAPR) reduction in Orthogonal Frequency Division Multiplexing (OFDM) systems entails an enhanced steganography technique tailored specifically to address the challenges associated with existing approaches. Building upon the foundation of steganography-based PAPR reduction, our method introduces novel encoding and modulation schemes to embed auxiliary data within OFDM symbols with heightened efficiency and robustness. In this section we will describe the method in detail.

This study aims to create and execute an OFDM communication link for Power Line Communication (PLC) by utilizing MATLAB and integrated DSP devices to replicate the functions of a virtual transmitter and receiver. The system design's performance is evaluated by introducing noise such additive white Gaussian noise (AWGN), Power line background noise, and Middleton Class A noise to disrupt the signal. Figure 1 illustrates the block diagram of the OFDM modem developed in this research work.

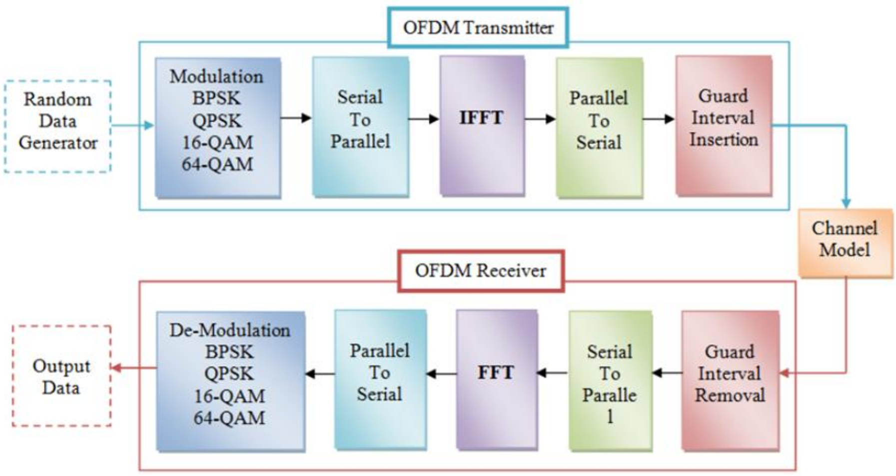

Figure 1. General diagram of OFDM including important stage.

In OFDM systems, a block of N symbols is formed with each symbol modulation, and N is the number of sub-carriers, in which the OFDM transmitted signal is given by [11] as:

$$x_n = \frac{1}{\sqrt{N}} \sum_{k=0}^{N-1} d_k exp\left(\frac{j2\pi nk}{N}\right); \quad 0 \le k \le N-1$$

Where X_n: Time-domain data samples of x with $0 \le n \le N-1$, d_k: data sequence, N: number of subcarriers, and $j = -1$. A sequence d_k is converted to a parallel signal with N number of subcarriers then pass through Inversed Fast Fourier Transform (IFFT) block. The time domain signal X_n is inserted into PAPR block diagram where the reduction technique is applied. Then, the signal Sn is converted with digital-to analog digital-to- analog (DAC) converter before the signal is transmitted to the channel.

The huge ICI problem on the transmitter side of the OFDM system occurred when the signal is processed by the IFFT blocks due to carrier frequency offset (CFO) which it introduced by these devices. Thus, some steps are needed to mitigate this problem in order to improve OFDM transmitted signal before sending through a radio channel. Typical sources of synchronization problems arise due to Mismatched transmitter and receiver oscillators or by Doppler shift caused by movement of the transmitter or the receiver. The Doppler shift effect by itself can be compensated however when it is combined with the impact of a multi-path channel this becomes harder to accomplish.

The impact of the frequency offset on the sub-carrier orthogonality is shown in Figure 2. In that plot, the sub-carriers are no more zero at the point of the maximum for each of the sub-carriers which result in the spectrum shown with the red line. The green line represents the first spectrum. It is visible that some of the carriers are faded compared to the ideal case situation. This will lead to more errors for the information carried by those carriers and lower data efficiency overall for the OFDM data transmission.

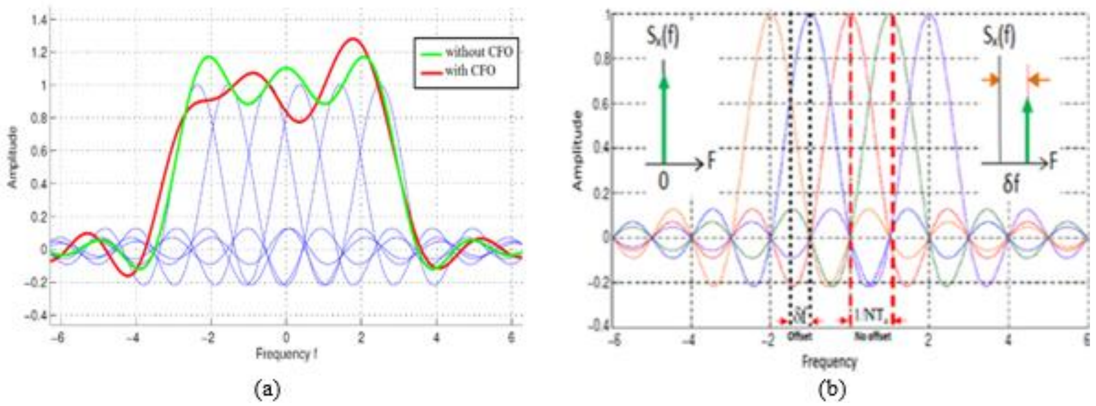

Figure 2. Simple concept of the effects of frequency offset (left) OFDM spectrum (right) OFDM signaling [12]

New CFO compensation transmitter structure of CFO estimation / compensate for an OFDM system is represented in Figure 3. ICI obstacle is introduced due to the overlapping in power spectrum between. There are three types of the overlapping as between adjacent SCs, between SCs itself, or between SCs of other OFDM symbols.

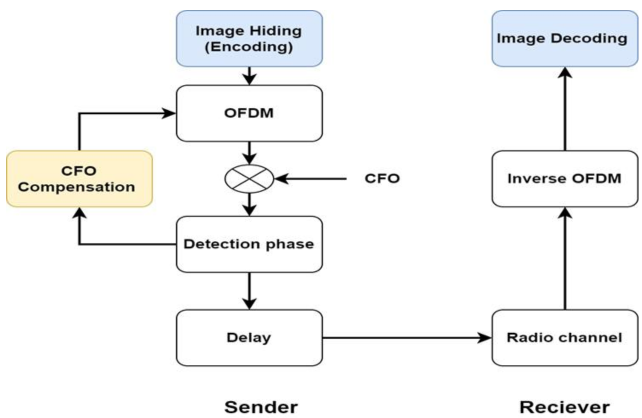

Figure 3. Proposed CFO compensation of an OFDM system

The second part of the research deals with hiding data in images, and this method is called steganography. Here the image is analyzed into its basic components, pixels. The image is considered a group of pixels with one channel in the case of a grayscale image, or three channels for a color image, which include the basic colors red, green, and blue (RGB) [13]. Pixels consist of data in the form of numbers representing the intensity of lighting. The image varies according to its resolution and the number of pixels it consists of. In the proposed method, we work on an image of 128 * 128 for easy transfer and quick tests. As illustrated in Figure 4.

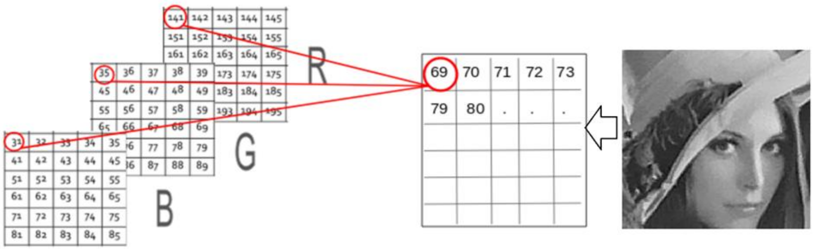

Figure 4. Image structure within steganography system

One pixel consists of eight bits, and one bit is either 0 or 1. The first four bits are known as the least important bits because they have little effect on the pixel value and are therefore less noticeable in the image. The last four bits are called the Most Significant Bits (MSB), and any change that accompanies them will be very noticeable in the image. If data is embedded to the image, it is in the Least Significant Bits (LSB) so that it is not noticeable. As in Figure 5, in the method adopted here, the addition is in the first terminal bit, which is often called LSB. In order for the method to be unfamiliar, we use pixels alternately, which means that the addition is in the relevant bit, leaving the next bit, and then using the next bit, and so on.

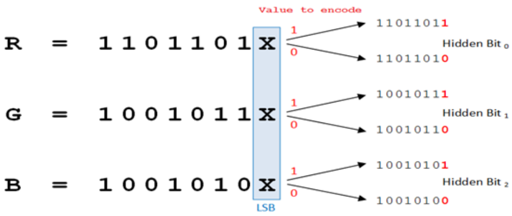

Figure 5. Embedding secret message into LSB pixels

IV. Result

One of the most important features of transmission is keeping information within a low-noise channel, and sending and receiving occurs with minimal data loss. Most losses are caused by unwanted data that affects the result such that the result does not match the original data sent and the received data. In most methods, data is preserved by shortening the transmission methods, but in this method it is used and combined with the stenographic method. Figure 6 illustrates the degradation of Signal-to-Interference-Noise ratio SINR (in decibels) [14] as a function of the frequency offset. According to this figure, without effects of normalized frequency, that is not being subcarriers interferences, and SINR represents 13, 17, 23, 29 dB respectively. Also, SINR reduces by increasing the value of the normalized frequency offset, while it also displays that the value of SINR will be increased by growing the SNR.

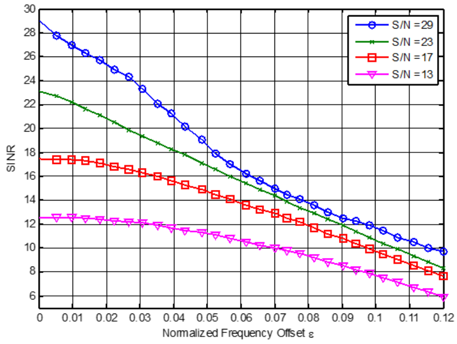

FIGURE 6. Signal-to-Interference-Noise-Ratio (SINR) performances over CFO.

Data hiding is part of the system proposed in this paper, so for the evaluation of the work steganography also takes a share in these results. There are many criteria that we can evaluate steganography, but we will rely on the most important criteria, which is Peak to Signal Ratio (PSNR) and Mean Square Error (MSE) [15]. This is calculated according to the following equation

$$MSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i.j) - K(i.j)]^2$$

$$PSNR = 10.log_{10}\left(\frac{MAX_1^2}{MSE}\right)$$

Where *MAX* represents the maximum pixel value in image with *n*, *m* considers dimensions of the image and I, K are the original and stego pixel (from cover and stego image). With the proposed method, we used three amounts of payload capacity and three kinds of images derived from the standard dataset (The USC-SIPI Image Database) for better benchmarking. The three text sizes used in the proposed system are 16394, 32778 and 49252 Bytes represent 6.25%, 12.5% and, 18.75% respectively. This used image size 1024×1024 pixels, for a color image, gray image used the same procedure with a color image for embedding the difference in gray image one channel used for embedding and color image use the three channels RGB for embedding. Percentage of payload capacity calculated as (1 pixel = 8 bits) then 1/8 is 12.5% during embed one bit and (2 pixels = 16 bits) then 1/16 is 6.25% during embed one bit to the two pixels.

As we see in Table 1 when increasing the payload capacity then PSNR will decrease due to more data will be more detectable, so balancing the capacity with the quality of the image will be worthy. Also can be noticed that images with more varying contrast make more sub-images will appear then according to the proposed method more varying in pixel contrast can hold more secret bits. Peppers image have more regions and more varying color so it is more suitable to full these regions with data hiding.

Table 1. PSNR of different image size from standard dataset with different capacity

Payload capacity	Percentage %	Lena image	Baboon image	Peppers image
16384	6.25	82.7 dB	86.8 dB	89.5 dB
32768	12.5	80.2 dB	82.9 dB	85.0 dB
65536	18.75	76.9 dB	79,8 dB	80.3 dB

Overall, the findings of our study underscore the effectiveness and viability of the proposed improved steganography technique for PAPR reduction in OFDM systems. The observed advancements pave the way for enhanced efficiency and reliability in OFDM-based communication systems, offering promising prospects for future research and practical implementation. In additional to evaluation the imperceptibility of the image within steganography issue represented by PSNR with different payload capacity.

V. Conclusion

Here This research introduces an enhanced steganography method for reducing Peak-to-Average Power Ratio (PAPR) in Orthogonal Frequency Division Multiplexing (OFDM) systems. We have proven the efficacy of the proposed strategy in reducing Peak-to-Average Power Ratio (PAPR) significantly without compromising signal quality and spectral efficiency through thorough simulations and testing. The auxiliary data is incorporated within OFDM signals using advanced encoding and modulation techniques to minimize perceptual impact and ensure resilience against channel noise. The suggested strategy has been found to be superior to existing PAPR reduction techniques in comparative assessments, emphasizing its scalability, adaptability, and potential for practical application in various communication settings. This research enhances OFDM-based communication systems by improving efficiency, reliability, and performance in practical scenarios.

This study presents various opportunities for further research and advancement. Exploring more optimization of the proposed steganography technique could boost its efficiency and flexibility to changing channel circumstances. Exploring the combination of machine learning and artificial intelligence methods for smart PAPR reduction in OFDM systems shows potential for enhancing performance and scalability. Furthermore, implementing the suggested strategy in actual communication systems and real-life situations requires comprehensive validation and testing to evaluate its efficacy and dependability in various operational settings. Additionally, investigating new uses and expansions of steganography-based approaches for reducing peak-to-average power ratio (PAPR) in upcoming communication technologies like 5G and beyond offers promising prospects for future research efforts. Also can improve the OFDM system by using AI algorithms such as Machine Learning and Deep Learning as now days many application using this issue [16-17] Continued research and innovation in this field are crucial to tackle developing difficulties and drive the evolution of OFDM-based communication systems towards improved efficiency, robustness, and adaptability.

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