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ACE-PI: PAPR Reduction in OFDM Systems Using Constellation Extension with Peak Insertion

Chhavi Bansal, Aabhas Mathur, Hemant Dhabhai

Abstract: *In this study, a proposal is offered in order to calculate the Bit Error Rate with the Signal to Noise Ratio. Here in this paper, it is illustrated that by comparing this analysis among the other mechanisms effective results can be obtained. By applying the ACE scheme in which the clipping technique block is replaced with Peak Inversion (PI) and butter worth band-pass filter is added after the ACE constraint block for generating less distortion and more smoothing. As, it has been concluded from a survey that among different PAPR reduction techniques, PI found to be an effective technique which can reduce PAPR to an extent by incorporating a relatively high impulse. The MATLAB is used for analyzing the enhanced ACE scheme that offers better results in terms of both PAPR and BER.*

Keywords: *Peak Inversion (PI), Bit Error Rate, PAPR, ACE.*

I. INTRODUCTION

Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation technique which segregates the accessible spectrum into subcarriers, among every subcarrier attaining a low rate data stream. As illustrated in figure 1, to achieve the orthogonality, proper spacing is attained by the subcarriers and the pass-band filter shape. By offering an established, scalable, adaptive mechanism for wireless communications, OFDM will play a significant role in appreciating Cognitive Radio (CR) idea. In each OFDM signal by applying a guard band the Inter-symbol interference (ISI) is fully decreased. To evade the inter-carrier interference (ICI) the applied guard band is regularly enlarged. In the wireless communication method, the benefit of OFDM scheme is that the channel fading is vigorous. By raising the count of subcarriers the frequency selective fading (FSF) is decreased. By selecting the coherence bandwidth that is higher than the subcarrier spacing of the channel, the flat channel will influence every subcarrier Therefore, no channel equalizer is required. Nowadays, the OFDM is applied in several wireless applications [1]. It is utilized in various WLAN standards, 3GPP-LTE, Wireless Metropolitan Area Networks, Asymmetric Digital Subscriber Line, power line communications and Digital Video Broadcasting (DVB). The WLAN standards are for instance HIPERLAN-2, IEEE 802.11a. Even though the OFDM has various merits, it also has a key demerit that is high Peak-to-Average Power Ratio (PAPR). Non-linear nature of the high PAPR in the transmitter results in degraded power effectiveness of the network [2].

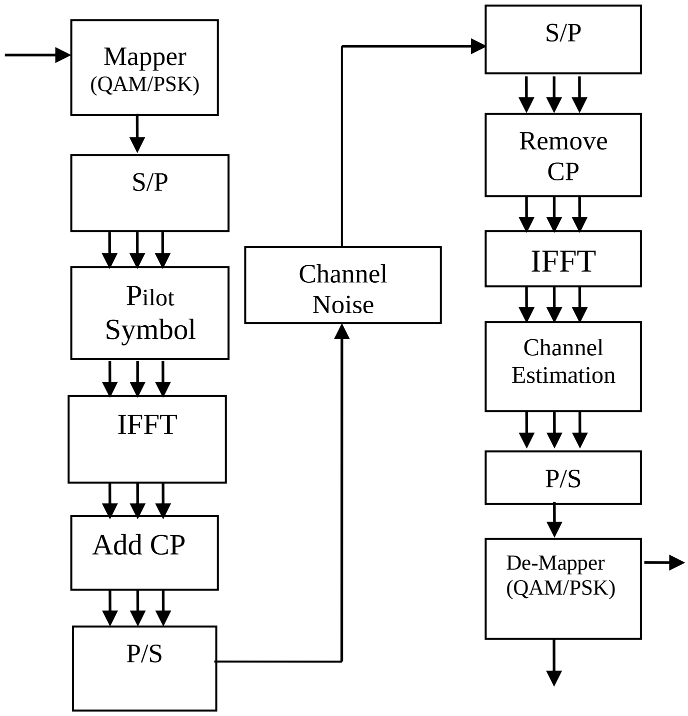

Figure 1: Model of OFDM [3]

The requirement of high rate data transmission occurs with the development in the practice of the wireless communication channel. OFDM is utilized to broadcast the data on high rate. In the wireless channels, OFDM is assumed as an efficient scheme [3]. The wireless channels should depend upon the selective and the time variance. The OFDM is an effective method that creates the assets of flexibility and multicarrier modulation. It is a technique for digital multi-carrier modulation that applies various independent subcarriers. An earlier modulated signal is altered into other signals that have great frequency and bandwidth. FDM is applied in several areas such as DAB, DVB. With the high transmission rate, the data is broadcasted by the OFDM. The issue of multipath interference and frequency

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fading is resolved by OFDM. For data transmission, the orthogonal subcarriers are utilized by the OFDM [4].

The data is broadcasted parallel by the orthogonal subcarriers. The wireless channels are divided into sub-channels that posses the assets of narrowband frequency and non-selective. In OFDM, the channel equalization is attained by using the Pilot method. By evaluating the significance of channel transfer factor, the channel equalization could be obtained with the help of the pilot symbols. With the help of IFFT and FFT, the OFDM can be executed digitally [5].

OFDM is operated with the decomposition of the variety of the current spectrum into several orthogonal sub-channels. Decomposition can cause occurrence of flat fading in all narrowband sub-channels. The utilization of the OFDM takes place during wireless communication; therefore, there is requirement of improvement in the OFDM. To construct it in a more effective and optimized way, several researchers are putting effort on this method. The number of subcarriers such as orthogonal subcarriers, narrow-band subcarriers etc. are broadcasted parallel by the OFDM. Due to the accessible bandwidth, the decomposition of these subcarriers has occurred. The subcarriers should be alienated in a way that the spectral can be utilized. The overlapping of the sub-channels is permitted by the OFDM in terms of frequency as it directs to the increase in the transmission rate. At the receiver end, the multipath interference is controlled very effectively by the OFDM. The FSF and ISI i.e. Inter Symbol interference is introduced by the OFDM. It is utilized in the fourth generation of wireless communication. The multipath fading is resisted in the network. The bandwidth of the network is also enhanced. Based on the FDMA mechanism, OFDM is operated and use it in a more exact and efficient way [6].

II. DEVELOPMENT OF OFDM SYSTEM

The procedure of OFDM development is alienated into three classes that are discussed as follows:

- FDM
- OFDM
- Multicarrier Communication

A. FDM (Frequency Division Multiplexing)

FDM is a mechanism that is applied to avoid the overlapping of the signals to its neighboring signal. The non-overlapping frequency range to every signal of the several channels is allocated by the FDM method. A guard band is applied to distinguish the signals of the several channels. The signals that are contiguous to one another the guard band is located within them [7]. The foremost disadvantage of the FDM mechanism is that the digital filters are not available in this mechanism due to which the signals that are nearer to their neighboring signals cannot be filtered.

B. Multicarrier Communication

With the help of a single channel, it is impossible to broadcast the streams with high data rates. That's why the signals are decomposed into subcarrier signals to broadcast the data with higher rates. To broadcast the data on the channel or the system, the signals are called as unique signals. A de-multiplexer is utilized at the receiver end which is applied to demodulate the signals. Afterward to achieve the real data, the demodulated signals are kept together to get the real signals [8]. To broadcast the data on the channel many subcarriers are utilized by the OFDM mechanism. The data is broadcasted on many or diverse channels. To the neighboring signals, the carriers of the signals are orthogonal or sovereign. To obtain carriers, they must be located accurately at the null modulation spectra of contiguous signals.

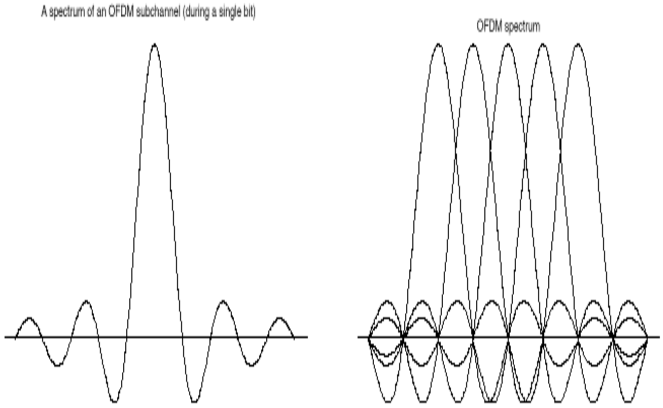

Figure 2: Spectrum in OFDM [8]

C. Principle of Orthogonality

The unavailable bandwidth over the channel is reduced as possible in the multi-carrier system. By decreasing the frequency space within the carriers, the reduction is likely to happen. If the carriers are in orthogonality to each other, the constricted space along with the carriers is achieved [9]. The time-averaged integral product for a couple of signals must be zero to be orthogonal. The orthogonality for a couple of signals can be numerically stated as:

$$\frac{1}{T}\int_{t_1}^{t_2+T} f_k(t) \times f_l(t)dt = 0 \; if \; k \neq l \quad \ldots (1)$$

Where $f_k(t)$ and $f_l(t)$ are any two signals over a time period $[t_1, t_1+T]$, T is a signal time interval. For ortho-normal, the integral product with average time of two should be one.

Mathematically, ortho-normal of two signals can be written as-

$$\frac{1}{T}\int_{t1}^{t1+T} f_k(t) * f_l(t)dt = 1 \quad if \; k{=}l \qquad \ldots (2)$$

By applying equation (1) and (2), orthogonality for OFDM system is written as-

$$\frac{1}{T}\int_0^T e^{j2\pi f_k t} * e^{-j2\pi f_l t}\, dt = \frac{1}{T}\int_0^T e^{j2\pi kt} \times e^{-j2\pi lt}\, dt = \frac{1}{T}\int_0^T \frac{e^{j2\pi(k-l)t}}{T} dt \qquad \ldots(3)$$

By resolving equation (3), we get-

$$\frac{1}{T}\int_0^T e^{j2\pi f_k t} \times e^{-j2\pi f_l t} = \begin{cases} 0 & \forall\, k \neq l \\ 1 & \forall\, k = l \end{cases} \quad \ldots (4)$$

Taking the discrete samples with the sampling instances at $t = nT_s = {}^{nT}/_{N}, n =$ 0,1,2…..N-1.

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Equation (4) can be expressed in the discrete-time domain as-

$$\frac{1}{N}\sum_{n=0}^{N-1} e^{\frac{j2\pi k}{T}nT_s} * e^{-\frac{j2\pi k}{T}nT_s} = \frac{1}{N}\sum_{n=0}^{N-1} e^{\frac{j2\pi(k-l)}{N}n} = \begin{cases} 0 & \forall\, k \neq l \\ 1 & \forall\, k = l \end{cases} \quad \ldots (5)$$

Orthogonality

If integral of multiple of two periodic signals on single period is equivalent to zero, then it is said to be orthogonal. For the case of continuous-time:

$$\int_0^T \cos(2\pi n f_0 t)\cos(2\pi m f_0 t)\, dt = 0 \ldots\ldots \quad (6)$$

For the case of discrete time:

$$\sum_{k=0}^{N-1} cos\left(\frac{2\pi kn}{N}\right) cos\left(\frac{2\pi km}{N}\right) dt = 0, \ldots\ldots \quad (7)$$

Where, m ≠ n in both cases.

D. Sub–Carriers

In the OFDM method, each subcarrier is a sinusoid among frequency which is a count diverse of the main frequency [10]. Each subcarrier will be treated such as a Fourier array section of the composite flag. The subcarrier waveform will be illustrated as–

$$s(t) = \cos(2\pi f_c t + \theta_k) \quad \ldots (8)$$
$$= a_n cos(2\pi f_0) + b_n \sin(2\pi f_0 t) \quad \ldots (9)$$
$$= \sqrt{a_n^2 + b_n^2} \quad \ldots (10)$$
$$\cos(2\pi n f_c t + \varphi_n) \quad \ldots (11)$$

where, $\varphi_n = tan^{-'}\left(\frac{b_n}{a_n}\right)$

The total of the subcarriers is the nth baseband OFDM signal:

$$S_B(t) = \sum_{n=0}^{N-1}\{a_n\, cos(2\pi n f_0 t) - b_n\, sin(2\pi n f_0 t)\} \ldots\ldots (12)$$

E. Inter–Symbol Interference

When an individual image interferes with images, the Inter-symbol interference (ISI) bends the signal. Accordingly constructing the correspondence minimum solid as the previous images have a relative impact as noise is an unwanted sensation. Generally, the multipath propagation is used to generate ISI or the reaction of the inherent nonlinear frequency of a channel getting on progressive images to blur collectively. At the result of the receiver in the decision devices, error is produced by the existence of ISI [11] in the mechanism. Consequently, the aim is to decrease the impacts of ISI in the arrangement of the sending and the receiving channels and therefore with the minimum possible errors the superior information is transmitted to its target.

F. Inter-Carrier Interference

In subcarriers' orthogonality, the occurrence of Doppler shifts and frequency and phase offsets in an OFDM method origins loss. Due to which within the subcarriers the interference has experimented. This happening is called as inter-carrier interference [12] (ICI).

G. Cyclic Prefix

In an OFDM image, the Cyclic Prefix or Guard Interval is an intermittent extension of the previous section which is added to the façade of the signal at the transmitter and is evacuated at the receiver earlier than demodulation.

The two important benefits of the cyclic prefix are-

- It performs as a guard interim and it removes the inter-symbol obstacle from the last image.

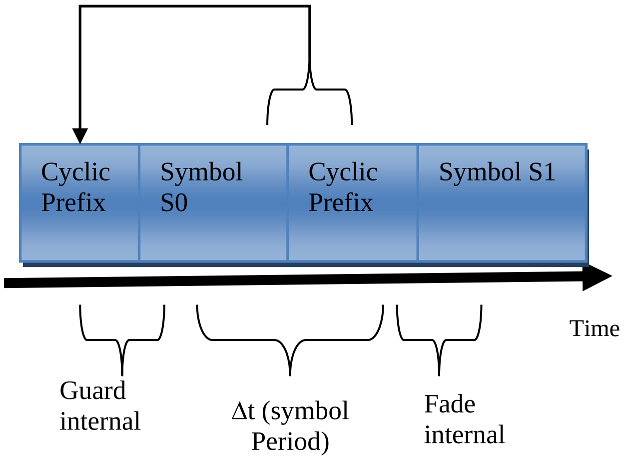

Figure 3: Cyclic Prefix In data packet

- To permit the linear convolution of a frequency–selective multipath channel to be formed as circular. However, it performs as a duplication of the end of the symbol

H. Inverse Discrete Fourier Transform

The familiar QPSK information images are persistent onto the orthogonal sub-carrier by summiting potential with OFDM in frequency domain. Nonetheless, switch of signal on divert is achievable in the accurate time space. For which the IDFT is implemented that alters the OFDM motion from frequency domain to time space. Being a linear alteration, the IDFT can be easily linked to the network and at the receiver end. DFT can be linked to improve the first information in frequency domain at the receiver end. To obtain the time space similarity of the OFDM signal from its frequency components is actualized, thus, the principle of Fourier transform is orthogonal in environment [13]. Generally, in observation as a substitute of DFT and IDFT, the Fast Fourier Transformation is actualized for N-information signal structure considering the lower component versatile temperament of the network.

III. PRESENT WORK

The problems like the transmitted signals from high Peak-to-Average Power Ratio (PAPR) are occurred in the OFDM mechanisms. This problem can be resolved by various mechanisms offered by the diverse researchers as that directs to the increment in the complexity of the system, higher Bit error rate (BER) and transmitted signal power, etc.

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Also, there is a problem of disturbance in the adjacent channel because of using of clipping technique for power reduction at the initial stage. The high data rates in the communication systems cause an issue in the current communication mechanisms, particularly inter-symbol interference (ISI) in fading channels. To deal with such problem, many solutions were proposed, as coding schemes were used to reduce the ISI and reducing the BER in the communication system. But still, improvements can be done, however, by not only using the coding schemes in the OFDM communication but this can be more improved by introducing the equalization approach in the present systems. This will reduce the variation in the signal at the receiver end and more BER and ISI will be reduced. Therefore, an Active Constellation Extension (ACE) mechanism has been projected that offers improved outcomes in case of several performance parameters such as PAPR and BER. In the proposed model, the equalization approach that can be recommended will be improved by ML equalizer. Novel ACE scheme introduced peak inverse and butter worth band pas filter so that the PAPR can be decreased to an extent by incorporating a relatively high impulse.

IV. RESULT AND DISCUSSION

The graph of figure 1 shows the errors on several Signals to noise ratio values that are 0 to 33. Here in this figure, the BER calculates from the 0 value of the SNR to the 33 value of the SNR. The Bit Error rate decreases gradually on diverse SNR values and it lies below the 10^{-7} value.

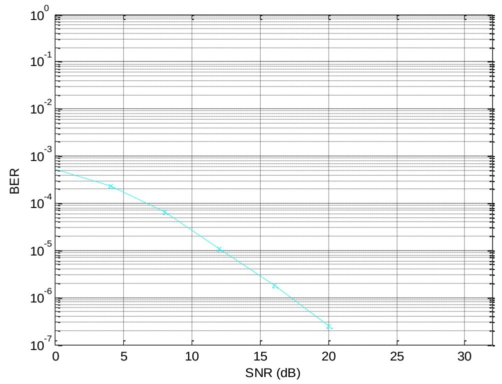

Figure 4: Proposed Bit Error Rate on different SNR values

The graph in figure 5 depicts the PAPR corresponding to the proposed work. The observed value is 4.36 (dB). The y-axis in the graph shows the value of complementary cumulative distribution function and x-axis calibrates the data in the form of PAPR.

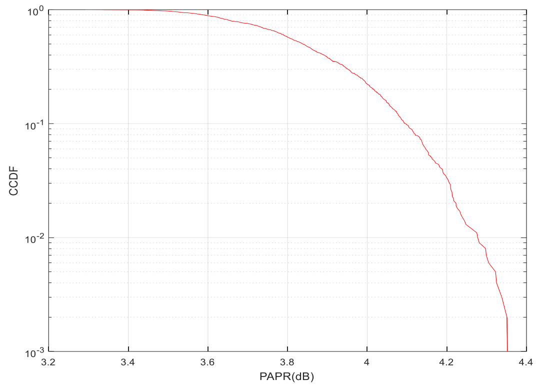

Figure 5: PAPR achieved of Proposed ACE algorithm

V. CONCLUSION

The problems like the transmitted signals from high Peak-to-Average Power Ratio (PAPR) are occurred in the OFDM mechanisms. This problem can be resolved by various mechanisms offered by the diverse researchers as that directs to the increment in the complexity of the system, higher Bit error rate (BER) and transmitted signal power, etc. Therefore, an Active Constellation Extension (ACE) mechanism has been projected that offers improved outcomes in case of several performance parameters such as PAPR and BER. Also, there is a problem of disturbance in the adjacent channel because of using of clipping technique for power reduction in the initial stage. So the author has suggested that by applying the ACE scheme the PAPR can be decreased to an extent by introducing a relatively high impulse. The MATLAB is used for analyzing the enhanced ACE scheme that offers better results in terms of both PAPR and BER.

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Chhavi Bansal is pursuing her Masters of technology in the field of digital communication at Aravali Institute Of Technical Studies, Udaipur. She got practical training from The Studio And Transmitting Center All India Radio, Udaipur, India and gained deep knowledge in digital electronics. She has completed Bachelors of technology in the field of Electronics and Communication from Geetanjali Institute of Technical Studies, Udaipur, India. Her work is focused on the wireless communication, OFDM systems.

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