A Hybrid Method Using Carrier Interferometry and Partial Transmit Scheme for PAPR Reduction

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***Abstract* - Communication is one of the important aspects of life. With the advancement in age and its growing demands, there has been rapid growth in the field of communications. Signals, which were initially sent in the analog domain, are being sent in the digital domain, even single–carrier waves are being replaced by multi– carriers. Multi–carrier systems like Carrier Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM) are now–a–days being implemented commonly. In the OFDM system, orthogonally placed sub–carriers are used to carry the data from the transmitter end to the receiver end. Presence of guard band in this system deals with the problem of Inter Symbol Interference (ISI) and noise is minimized by larger number of sub–carriers. But the large Peak – to – Average Power Ratio (PAPR) of these signal have some undesirable effects on the system. In this paper we have focused on learning the basics of an OFDM system and have undertaken various methods to reduce the PAPR in the system so that this system can be used more commonly and effectively.**

***Keywords* - OFDM, IDFT, ISI, ICI, PAPR, Cyclic Prefix, CCDF, CI, Companding, PTS.**

I. INTRODUCTION

With the ever growing demand of this generation, need for high speed communication has become an utmost priority. Various multicarrier modulation techniques have evolved in order to meet these demands; few of them are Code Division Multiple Access (CDMA) and Orthogonal Frequency Division Multiplexing (OFDM) etc. Orthogonal Frequency Division Multiplexing is a frequency – division multiplexing (FDM) scheme utilized as a digital multi – carrier modulation method. A large number of closely spaced orthogonal sub – carriers is used to carry data. The data is divided into several parallel streams of channels, one for each sub – carriers. Each sub – carrier is modulated with a conventional modulation scheme (such as QPSK) at a low symbol rate, maintaining data rates similar to the conventional single carrier modulation schemes in the same bandwidth.

OFDM is a Multicarrier Transmission technique which divides the available spectrum into many carriers each one being modulated by a low data rate stream. OFDM is similar to Frequency Division Multiple Access (FDMA) in the multiple user access is achieved by sub-dividing the available bandwidth into multiple channels, which are then allocated to users. OFDM uses the spectrum much more efficiently by spacing the channels more closely. This is achieved by making all the carriers orthogonal to each other

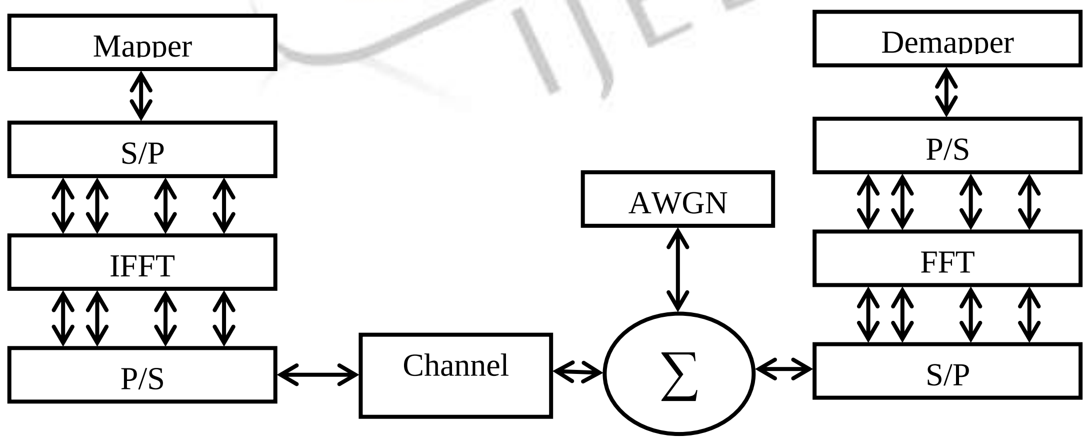

Fig.1: Block Diagram of OFDM

Orthogonal Frequency Division Multiplexing is a special form of multicarrier modulation which is particularly suited for transmission over a dispersive channel. In this technique the different carriers are orthogonal to each other, that is, they are totally independent of one another. This is achieved by placing the carrier exactly at the nulls in the modulation spectra of each other.
OFDM is one of the many multicarrier modulation techniques, which provides high spectral efficiency, low implementation complexity, less vulnerability to echoes and non – linear distortion. Due to these advantages of the OFDM system, it is vastly used in various communication systems. But the major problem one faces while implementing this system is the high peak – to – average power ratio of this system. A large PAPR increases the complexity of the analog – to – digital and digital – to – analog converter and reduces the efficiency of the radio frequency (RF) power amplifier . Regulatory and application constraints can be implemented to reduce the peak transmitted power which in turn reduces the range of multi carrier transmission. This leads to the prevention of spectral growth and the transmitter power amplifier is no longer confined to linear region in which it should operate. Thus in communication system, it is observed that all the potential benefits of multi carrier transmission can be out - weighed by a high PAPR value. There are a number of techniques to deal with the problem of PAPR. But PAPR reduction achieved at the cost of transmit signal power increase, bit error rate (BER) increase, data rate loss, computational complexity increase, and so on.

A. PAPR

PAPR is the ratio between the maximum power and the average power of the complex passband signal s(t), that is,

$$\text{PAPR}\{s(t)\}=\frac{\max|s(t)|^2}{E|s(t)|^2}$$

High Peak-to-Average Power Ratio has been recognized as one of the major practical problem involving OFDM modulation. In general the high PAPR results values from the nature of the modulation itself, where multiple subcarriers/sinusoids are added together to form the signal to be transmitted. When N sinusoids add, the peak magnitude would have a value of N, where the average might be quite low due to the destructive interference between the sinusoids. High PAPR signals are usually undesirable for the analog circuitry. High PAPR signals would require a large range of dynamic linearity from the analog circuits which usually results in expensive devices and high power consumption with lower efficiency (for e.g. power amplifier has to operate with larger back-off to maintain linearity).

PAPR reduction techniques vary according to the need of the system and are dependent on various factors. PAPR reduction capacity, increase in power in transmit signal, losing data rate, complexity of computation and increase in the bit-error rate at the receiver end are various factors which are taken into account before adopting a PAPR reduction technique of the system.

RELATED WORK

Khan, Muhammad Ajmal [1] has proposed PAPR reduction technique using biased subcarriers. A known time-domain reference sample (D_{ref}) is used to bias the subcarriers at the transmitter, and the same bias is used at the receiver to recover the sequence of original subcarrier samples. A closed-form analytical expression for complementary cumulative distribution function for PAPR has been derived and is illustrated as a function of the introduced bias. The effectiveness of the proposed technique is evaluated both analytically and numerically. Analytical and simulation results confirm that significant reduction in PAPR can be achieved. For example, it is shown that nearly 9.45-dB reduction in 0.1% PAPR can be achieved for a 16-QAM orthogonal frequency division multiplexing system with 1024 subcarriers. Numerical results show that the average bit error rate performance of the proposed system does not degrade relative to the original system. It is found that the proposed technique has the lowest complexity among the various available techniques for PAPR reduction.

Ye, Chen, Zijun Li [2] in this paper, a novel segmental partial transmit sequence (S-PTS) scheme is proposed for the peak-to-average power ratio (PAPR) reduction in offset OQAM-OFDM systems. OFDM systems overlapped with the neighbourhood subcarriers, the orthogonality can still be preserved through the staggered QAM (SQAM) technique. Therefore, the problem will appear when a large number of subcarriers are necessary. The main aim of this method is to divide the overlapped OQAM-OFDM signals into a number of segments and the proposed method is compared with tradition PTS scheme and it is found that the S-PTS method may provide better PAPR reduction with lower computational complexity.

Kang, Sungyong [3] has proposed a power-concentrated subcarrier method for use in OFDM systems to reduce PAPR of the OFDM signal without increasing system complexity or side information. The PAPR can be reduced by simply inserting a power-concentrated subcarrier (PCS) to replace the zero in the end of the signal spectrum at the zero padding stage. The simulation is performed with a conventional CO-OFDM transmission system with a PCS under dispersion and a nonlinear effective fibre to estimate PAPR using complementary cumulative distribution function (CCDF), error vector magnitude (EVM), and bit-error-rate (BER) characteristics. After a 2000-km transmission, the conventional CO-OFDM had an optimal fibre launch power of −6 dBm from the BER characteristics. In contrast, the proposed CO-OFDM with a PCS improves transmission performance in terms of log (BER) as much as −0.67 by an increased fiber launch power of −1 dBm with 60% concentrated-power of the PCS.

J.H.Lee [4] proposed PAPR reduction by utilizing companding and precoding approaches for OFDM system. This high PAPR value gives non linearity at transmission to make complex design. Thus, it is required to reduce the PAPR for lesser complexities, higher stability and efficiency. In the multi-path-propagation systems OFDM gives better option but on the other hand it also carries high peak average ratio (PAPR) at the transmitter end. Moreover, in this paper, comparison of μ-law companding and A-law companding approaches are also described to notice the effect on PAPR value. In this work several PAPR approaches has been discussed and distinct precoding matrices are utilized for PAPR reduction. The result indicates that the proposed approach is efficiently reduced the PAPR values.

Yoshizawa, Ryota [5] have proposed a new peak-to-average power ratio (PAPR) reduction technique for orthogonal frequency-division multiplexing (OFDM) signals based on the trellis structure. OFDM systems have been developed for high data rate communications. In the IEEE 802.11 standard, the carrier frequency can go up as high as 2.4 GHz or 5 GHz. Researchers tend to pursue OFDM operating at even much higher frequencies. The proposed approach is capable to choose the series individually from given information series. In addition, suitable constellation labelling for presented approach has been developed to improve its PAPR reduction capability. It is demonstrated that presented approach may attain good error rate as compared to traditional existing systems.

Talele, Shilpa [6] presented the PAPR reduction technique with change in few parameters of subcarriers, OFDM symbols. OFDM is multiplexing scheme which divide data stream to share the bandwidth available. Narrowband channel is called subcarrier which transmit phase or amplitude modulated data signal. Orthogonally technique can reduce interference between subcarrier and increase spectrum efficiency utilization. OFDM receiver requires frequency synchonization to Inter-Carrier Interference (ICI). The experiment result indicates that PAPR performance is enhanced with increase in number of transmitting antennas. But only few distinctions in PAPR reduction for number of subcarriers and when OFDM symbols are varied, there is recognizable reduction in PAPR. Therefore, separate subcarriers have minimum effect on PAPR performance compared to OFDM symbol variation.

Cuteanu, Victor [7] has explained the OFDM, which is one of the modulation techniques widely used in the broadband wireless technology. Orthogonal frequency division multiplexing (OFDM) is used to achieve high data-rate communications. One of the main problems of this technology is the high peak-to-average power ratio of transmission signal due to the superposition of many subcarriers. This paper presents a new hybrid peak-to-average power ratio reduction technique, which combines a selective mapping method with the clipping method. The paper presents the performance and advantages of the new technique and compares it with other existing methods.

Manasseh, Emmanuel [8] addressed the challenges regarding the provision of channel state information as well as reducing peak-to-average power ratio (PAPR) of a multiple input multiple output orthogonal frequency multiplexing (MIMO–OFDM) system. The mean squared error (MSE) of the channel estimate is adopted as the optimization criterion to design pilot symbols for channel estimation in MIMO–OFDM systems with null subcarriers. Authors explained the designing the placement and power distribution to the pilot symbols for multiple transmits antennas to minimize the MSE of the least square (LS) channel estimates. To reduce interference of the pilot symbols transmitted from different antennas, an algorithm to guarantee that pilot symbols are disjoint from any other transmitter pilot set is proposed. To efficiently reduce the PAPR of the MIMO–OFDM signals, a method that mixes dummy symbols and phase information of the pilot symbols is presented. Simulation results based on IEEE 802.16e are presented to illustrate the superior performance of the proposed channel estimation method over the existing standard and the partially equi-spaced pilot symbols. It is demonstrated in this paper that, by mixing the dummy symbols and phase information of the pilot symbols, the PAPR of the MIMO–OFDM signals can significantly be reduced.

Ogunkoya, Funmilayo [9] proposed pilot-assisted (PA) PAPR reduction technique in O-OFDM using multiple LED (Light emitting diode). By using the PA approaches, additionally PAPR reduction may be attained with the amalgamation of increased P and G(P is number of iterations and G is number of filter used).This pilot assisted approach is relied on the data symbol phase rotation with P number of iterations of pilot symbol to attain reduction in PAPR approach. A result indicates exchange among various LEDs hardware complexity and the PA approaches to attain required PAPR reduction. The performance of comparison with existing system with G= 16, result indicates that PA approach has ability of minimizing G to 3 to attain the same PAPR of approx. 11 dB using P = 5 at CCDF of 10^{-3}.

Kaur, Gurleen [10] proposed PAPR reduction techniques in wavelet based OFDM. Wavelet based OFDM has an upper edge over Fast Fourier transform (FFT) based OFDM in terms of orthogonality and bandwidth usage. Though these qualities are an advantage, the fluctuations in input signal's envelope cause a hike in Peak to Average Power ratio (PAPR). The results are analyzed using clipping, companding, double companding and hybrid techniques. Better results have been found using these techniques compared to simple FFT and wavelet based OFDM.

Minn, Hlaing, and Daniel Munoz et al. [11] have explained the various pilot designs for channel estimations of OFDM systems. This design is required less plot overhead as compare to existing designs and also provides the estimation. The performance analyses and simulation results provides the benefit of proposed design.

Khojastepour, Mohammad A. Amir et al. [12] have presented a novel approach for channel estimation in OFDM system. Sparse channel estimation refers to estimating the time domain channel impulse response. In this work, the problem is formalized and drives the essential condition on the different number of pilots. Moreover, suboptimal solution has been presented which is improved OFDM channel. The work in this paper explained that training overhead can be severely minimized while maintaining the same accuracy as the current state of the art techniques.

PROPSED METHODLOGY

Orthogonal frequency division multiplexing (OFDM) is a promising solution for high data rate transmission infrequency-selective fading channels [7]. A major drawback of OFDM at the transmitter side is the high peak-to-average power ratio (PAPR) of the transmitted signal. High peaks of OFDM signals occur when the sinusoidal signals of the subcarriers are added constructively. These high peaks necessitate using larger and expensive linear power amplifiers. Since high peaks occur irregularly and infrequently, this means that power amplifiers will be operating inefficiently.

A. *OFDM system using CI coded companding transform:*

Assume an input data bit stream having bit rate R bps where bits are mapped to some constellation points by using digital modulation method. Suppose N be the number of constellation points and it is stored from an interval of Ts = NIR. Now assuming pseudo-orthogonal spreading codes for kth information symbol is defined as

$$\beta^k = (e^{j0}, e^{j\Delta\theta k}, e^{j2\Delta\theta k}, \ldots\ldots, e^{j(N-1)\Delta\theta k})$$

Where,

$$\Delta\theta_k = 2\pi k/N$$

Now, CI coded information signal is given to IFFT having size M in order to produce CI OFDM symbol that may be given as:

$$S[n] = \sum_{i=0}^{M-1}\sum_{k=0}^{N-1} a_k\, e^{j\frac{2\pi}{N}ki} e^{j\frac{2\pi}{M}ni} \quad , 0 \le n < M$$

After IFFT, the resultant signal is converted to serial and then linear non-symmetrical companding transform with single inflexion point is performed, that is given as

$$x[n] = \begin{cases} \frac{1}{u}. s[n] if \ |s[n]| \le v \\ u. s[n] if \ |s[n]| > v| \end{cases}$$

Where, $0 \le u \le 1$ is the peace wise slope parameter and 0<v<max {|s[n]|} is the threshold level.
At the receiver end, receiver signal may be given as

$$r[n]=y[n]+w[n]$$

Where w[n]= AWGN noise component in discrete form.
Initially CP is eliminated and it is fed to the inverse linear non-symmetrical companding transform that may be given as

$$\tilde{s}[n] = \begin{cases} u. r[n] if n \in \varphi 1[l] \\ \frac{i}{u}. r[n] if n \in \varphi 2[l] \end{cases}$$

$$\varphi_1 = \{\forall |s[n]| \le v$$
$$\varphi_2 = \{\forall |s[n]| \le v$$

After equalization, the symbols are converted from parallel to serial format. Finally output data bit stream is obtained by demodulating the signal using QAM demodulation.

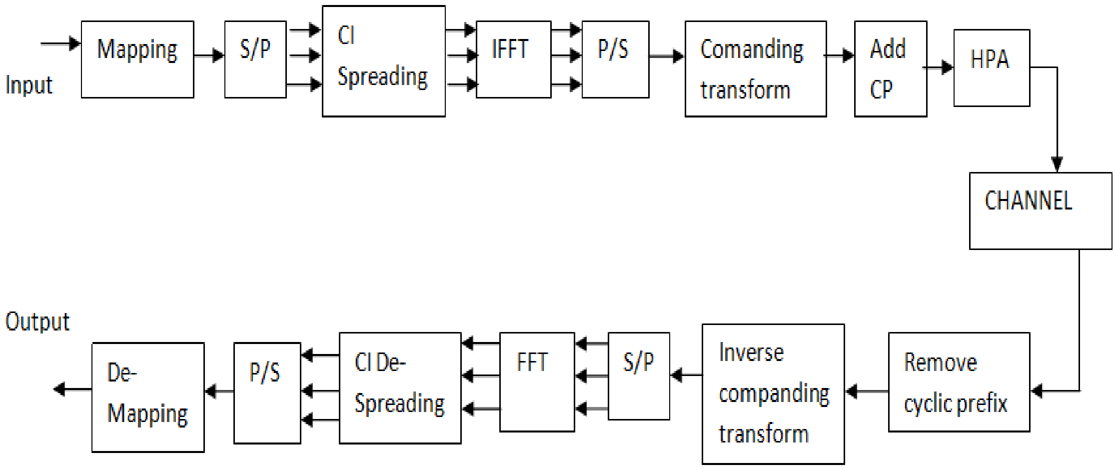

Fig.2: Block Diagram of OFDM system using CI coded companding transform

In the improved PTS scheme

- We divide the 2-point inverse fast Fourier transform (IFFT) into two parts.
- We transform the input symbol sequence partially, using the first stages of IFFT (L operations), into an intermediate signal sequence.
- Then the intermediate signal sequence is partitioned into a number of intermediate signal sub-sequences.
- Then, the remaining stages of IFFT (N-L operations) are applied to each of the intermediate signal sub-sequences and the resulting signal sub-sequences are summed after being multiplied by each member of a set of rotating vectors to yield distinct OFDM signal sequences.
- We then select the one with the lowest peak to average power ratio (PAPR) among these OFDM signal sequences for transmission.
- This selected modulated signal is then taken through companding transform and then passed through the channel.
- On the other side, then inverse companding transform is performed on the received signal. Then converted from serial to parallel, and then applied FFT on it.
- This signal is converted to serial and then demapped to get the resultant signal.
  The new PTS OFDM scheme must reduce the computational complexity to a great extent.

RESULTS ANALYSIS

In this paper, PAPR performance is examined and simulation was done on MATLAB for 10000 symbols.

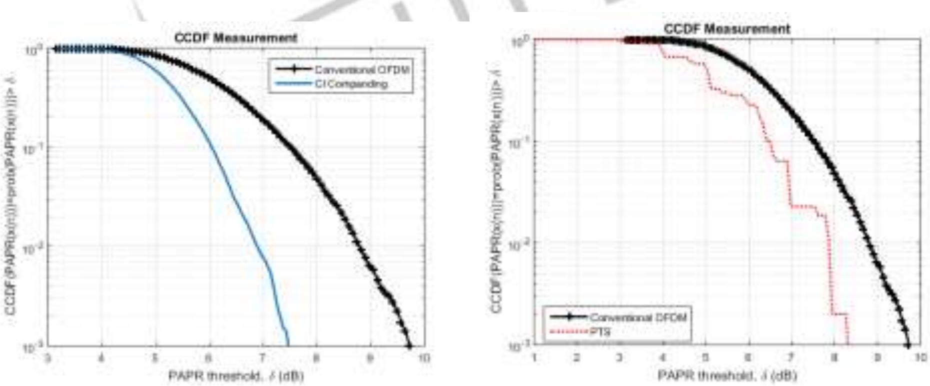

Fig 4.1 CCDF Measurement graph between conventional OFDM, CI Companding and Partial Transmit Scheme based OFDM

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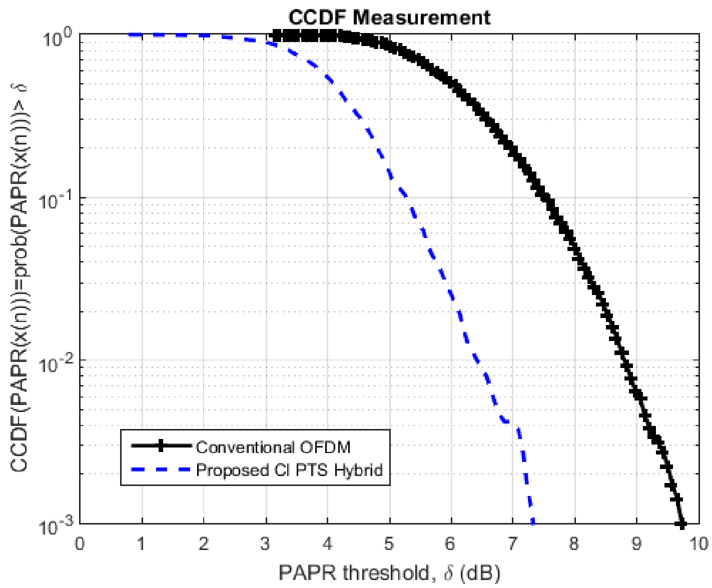

Fig 4.2 CCDF Measurement graph between conventional OFDM and Proposed Hybrid method based OFDM.

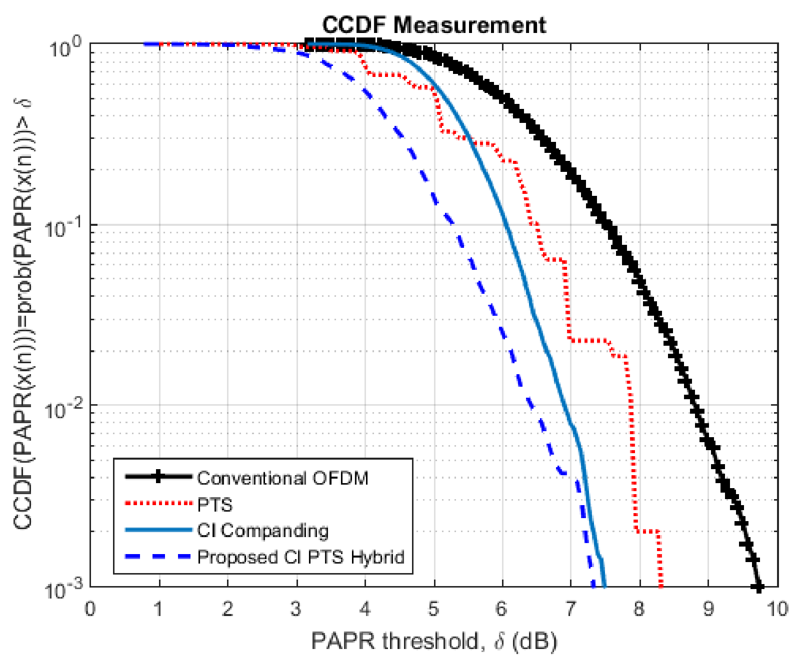

Fig 4.3 Final comparison of CCDF Measurement graph of proposed hybrid technique with individual techniques.

Figure 4.2 shows the CCDFs of the PAPR of signal and two distinct PAPR reduction method of OFDM system. It is noted that the proposed CI-PTSOFDM system, has reduced the PAPR to 7.231 from 9.779 for conventional system.Figure 4.3 represents the performance of the proposed system in combination with the existing systems taken into consideration for comparison and simulation purpose.

CONLCUSION

In this paper, CI coded companding transform merged with PTS has been presented which decreases PAPR extensively which has enhanced the performance of OFDM system. The results shows that the presented approach may operates better with reduced back off value of non-linear power amplifier that improves the efficiency of amplifier. More so, some back off value decreases the dynamic range of amplifier that reduces the cost and its complexity. The proposed design CI-PTS OFDM is used for attaining high efficiency and low complexity. The proposed approach is using FFT which assures the half FFT for similar sub carrier. With proposing CI-PTS FFT/IFFT, difficulties of simple CI/OFDM and simple PTS scheme has been decreased considerably.

The future work may involve hardware implementation of the proposed system in order to make the system deployable in industry for communication purposes.

REFERENCES

[1] Khan, Muhammad Ajmal, and Raveendra K. Rao. "Low-Complexity PAPR Reduction Technique for OFDM Systems Using Biased Subcarriers."*Canadian Journal of Electrical and Computer Engineering* 39, no. 1 (2016): 19-25.

[2] Ye, Chen, Zijun Li, Tao Jiang, Chunxing Ni, and Qi Qi. "PAPR reduction of OQAM-OFDM signals using segmental PTS scheme with low complexity."*IEEE Transactions on Broadcasting* 60, no. 1 (2014): 141-147.

[3] Kang, Sungyong, Jaehoon Lee, and JichaiJeong. "PAPR reduction technique by inserting a power-concentrated subcarrier for CO-OFDM."*Optics Communications* 350 (2015): 119-123.

[4]J.H.Lee"PAPRReductionofOFDMSignalsUsingaReducedComplexity PTSTechnique",*IEEE Signal Processing Letters*,Vol. 11, No. 11, November 2014.

[5] Yoshizawa, Ryota, and Hideki Ochiai. "A novel trellis-based PAPR reduction technique for OFDM signals." In *2014 IEEE International Symposium on Information Theory*, pp. 1563-1567.

[6] Talele, Shilpa A., Aarti G. Ambekar, and DeepshikhaHinger. "Novel PTS Technique to PAPR Reduction for STBC MIMO-OFDM using Four Transmitting Antennas." In *IJCA Proceedings on International Conference on Computer Technology*, vol. 1, pp. 25-30.

[7] Cuteanu, Victor, and AlexandruIsar. "PAPR reduction of OFDM signals using selective mapping and clipping hybrid scheme." In *Signal Processing Conference (EUSIPCO), 2012 Proceedings of the 20th European*, pp. 2551-2555.

[8] Manasseh, Emmanuel, Shuichi Ohno, and Masayoshi Nakamoto. "Combined channel estimation and PAPR reduction technique for MIMO–OFDM systems with null subcarriers." *EURASIP journal on wireless communications and networking* 2012, no. 1 (2012): 1-15.

[9] Ogunkoya, Funmilayo B., Wasiu O. Popoola, and SinanSinanović. "PAPR reduction in optical OFDM with grouped LEDs." In *Communication Systems, Networks and Digital Signal Processing (CSNDSP), 2016 10th International Symposium on*, pp. 1-6.

[10]Kaur, Gurleen, Naresh Kumar, and B. S. Sohi. "PAPR reduction technique on wavelet based OFDM system by employing multi-level wavelet transform." In *Signal Processing, Computing and Control (ISPCC), 2015 International Conference on*, pp. 215-219.

[11] Minn, Hlaing, and Daniel Munoz. "Pilot designs for channel estimation of OFDM systems with frequency-dependent I/Q imbalances."*Communications, IEEE transactions on* 58, no. 8 (2010): 2252-2264.

[12] Khojastepour, Mohammad A. Amir, Krishna Gomadam, and Xiaodong Wang. "Pilot-assisted channel estimation for OFDM systems using theory of sparse signal recovery." In *Acoustics, Speech and Signal Processing, 2009.ICASSP 2009. IEEE International Conference on*, pp. 2693-2696.