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Low complexity algorithm for PAPR reduction in OFDM system adopting SUI channel model

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Abstract:*-Orthogonal frequency Division Multiplexing (OFDM) is an attractive technology in Wireless Communication. High Peak-to-Average Power Ratio (PAPR) is one of the challenging issues in OFDM systems. High PAPR force the High Power Amplifier (HPA) to operate in its linear region with wide dynamic range, with poor power efficiency.*

Index words: OFDM, Peak-to-Average Power Ratio (PAPR), SLM, High Power Amplifier (HPA).

I. INTRODUCTION

In olden days people used to communicate with distant counterparts by make usage of traditional approaches like sending the information with birds, sending people as ambassador to convey the information. Most of the researchers termed 21st century as Communication arena due to the high end technological advancement in this area which makes communication fast and reliable. The intense research classified communication into two categories a) wire based communication b) wireless based communications. Wire based communications is considered as most useful tool in world wars to convey information from one end to another in 1940's and optical fiber plays a crucial role in wire based communication mechanism and after completion of war the dominance of United States of America (USA) and Union of Soviet Socialist Republics (USSR) over the world makes the research on communication so fast that in two decades communication research grows from daily life communication to satellite communication and this development mainly because of wireless communication.

Modern wireless communication started an innovative revolution in mankind daily life, where advanced wireless communications had following applications

(i) High speed internet
(ii) High quality multimedia
(iii) High definition streaming videos

Wireless communications are broadly classified into three different categories namely i) Conventional communication systems such as FDMA, TDMA which mainly has two drawbacks one is low data rate and low spectral efficiency. ii) Existing communication systems like CDMA are suitable for mobile and radar communication but the main drawback is drawback is data rate (speed). iii) Future generation communication models such as OFDM are used in Applications like 3G, 4G, LTE, WIFI, and WIMAX.

Orthogonal frequency division multiplexing is considered as highly successful communication model compares to conventional communication models because of low sensitivity to multipath propagation and eminent spectral efficiency. Orthogonal frequency division multiplexing too suffers from some drawbacks, high peak to average power ratio is main drawback which occurs due to the insufficiency power distribution by high power amplifier which results in in-band and out-band distortion. Digital communication are comprised of two communication representations pass band representation and base band representation, pass band represents continuous mode of communication while base band represents digital mode of communication. In our proposed work we present the base band representation of orthogonal frequency division multiplexing signal with N sub carriers as follows

$$x(t) = \frac{1}{\sqrt{N}}\sum_{k=0}^{N-1} X_k e^{j2\pi\frac{k}{Nt_s}t}, \qquad 0 \le t \le Nt_s \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

N represents number of sub carriers,t_s=Sampling time ,,X represents the frequency domain of orthogonal frequency division multiplexing symbols such as X=[X_1, X2.........X_{N-1}]^T,T=Nt_s =symbol duration.When the number of sub carriers is large then it can be treated as complex Gaussian process by the central limit theorem, this complex Gaussian process technically called as Peak to average power ratio. In order to resolve this issue several theories are proposed in the literature. One of such theory proposed in the literature is µ-law Companding; it reduces the Peak to average power ratio impact on orthogonal frequency division multiplexing in small amount. To overcome the drawback of µ-law Companding in our proposed work we present the Non-linear companding transform technique for efficient results.

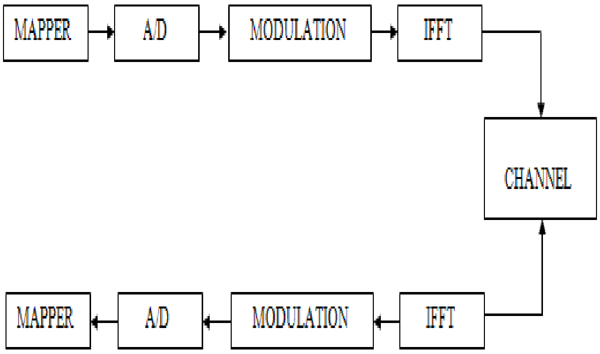

Figure 1.1: OFDM block diagram

Orthogonal frequency division multiplexing (OFDM) has been attracted many research organizations related to high speed communication area due to its many attractive features like Orthogonality, acceptable to all types of scenarios like SISO, MIMO, MISO AND SIMO, no inter carrier interference and on the other hand it has so many drawbacks namely delay, distortion and finally peak to average power ratio.

The input given to the orthogonal frequency division multiplexing (OFDM) has been taken in two different ways namely (i) OFDM sub carriers and (ii) OFDM symbols. Here the following diagram shows that in frequency domain it is termed as OFDM sub carriers and while in the time it is termed as OFDM symbols.

II. ORTHOGONALITY

The conventional algorithms namely clipping, clamping and filtering when compare with the orthogonal frequency division multiplexing the main difference one can find is its orthogonal approach where the amplitude of sub carriers should be at exactly 90 degrees. Without applying any external parameters like filters etc one can easily know the distortions in OFDM by simply checking the orthogonal approach it clearly give the statistics whether the OFDM signal is in normal mode or abnormal mode.

Orthogonal frequency division multiplexing too suffers from some drawbacks, high peak to average power ratio is main drawback which occurs due to the insufficiency power distribution by high power amplifier which results in in-band and out-band distortion. Digital communication are comprised of two communication representations pass band representation and base band representation, pass band represents continuous mode of communication while base band represents digital mode of communication. In our proposed work we present the base band representation of orthogonal frequency division multiplexing signal with N sub carriers as follows.

A. GUARD INTERVAL

Actually when number of samples is more for analysis then the complexity increases gradually then division of the samples has became mandatory in the high speed communications area. Generally in OFDM we make use of two guard intervals namely cyclic prefix and zero-pad suffix respectively. While the most popular one is the cyclic prefix and it too has some disadvantages like it consumes some power and removal of cyclic prefix at the receiver end have becomes a challenging task in some scenarios. While come to zero pad suffix it cant be applicable at all scenarios and its zero consumption of power some times pose problem of detachment with the respective subcarriers, The cyclic prefix technique and zero pad suffix technique representations are as shown below respectively.

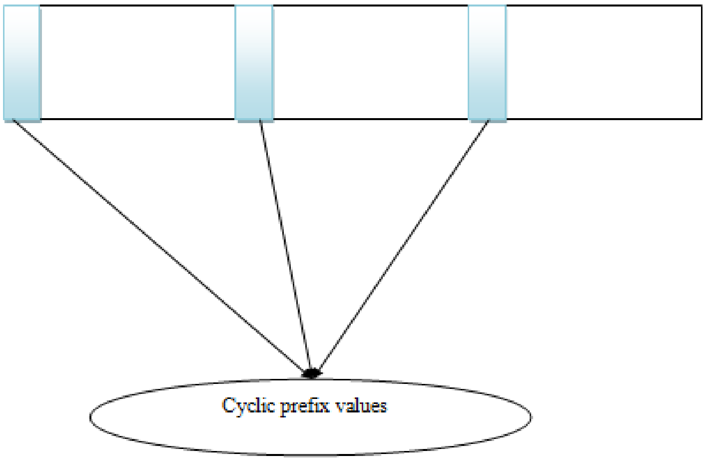

Figure: 2.1 .Cyclic prefix representation along with the sub carriers

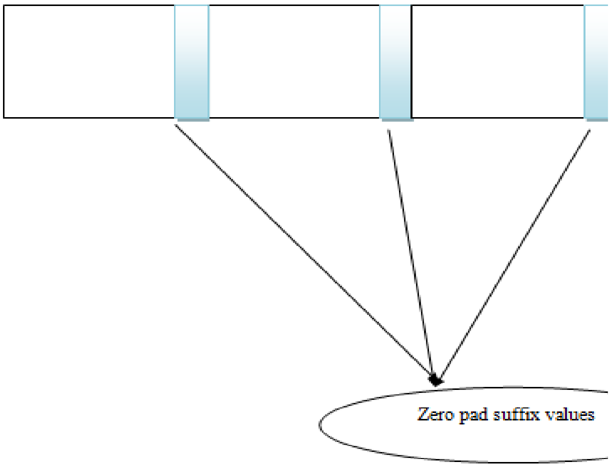

Figure: 2.2. Zero-pad suffix representation along with the sub carriers

The zero pad suffix technique is advance than the cyclic prefix and it has many advantages over the cyclic prefix technique but it cannot be applied in all conditions and due to its zero power consumption approach it has serious problems of losing its attachment with the subcarriers in transmission. Then the subcarriers recovering at the receiver pose serious issue. Orthogonal frequency division multiplexing too suffers from some drawbacks, high peak to average power ratio is main drawback which occurs due to the insufficiency power distribution by high power amplifier which results in in-band and out-band distortion. Digital communication are comprised of two communication representations pass band representation and base band representation, pass band represents continuous mode of communication while base band represents digital mode of communication. In our proposed work we present the base band representation of orthogonal frequency division multiplexing signal with N sub carriers as follows.

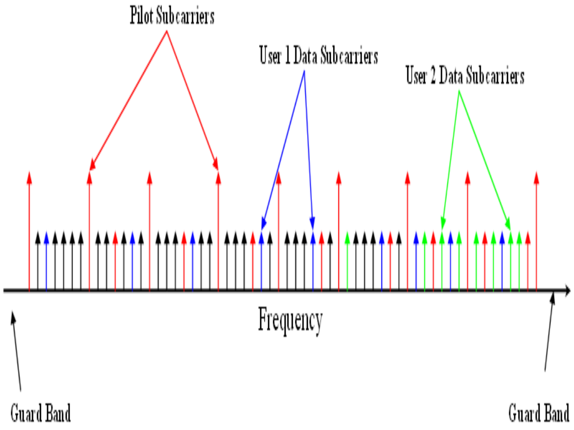

Figure: 2.3. PILOT SYMBOL

In the conventional methods PAPR reduction has been done based on the statistics acquired from the pilot symbol, usage of multiple guard intervals, multiple pilot symbols creates the abnormal power distribution which creates complexity. So due to this drawbacks companding and finally weighted schemes came into existence.

Orthogonal Multicarrier Modulation is one such innovative approach which is considered as promising method for data transmission over multiple channels with necessary frequency selective fading. Compare to all works reported in the literature the proposed Orthogonal Multicarrier Modulation is simple in implementation mainly because of usage of inverse fast Fourier transform (IFFT).The respective block diagrams of convolution scheme and proposed weighted scheme of the orthogonal frequency division multiplexing system. The data carriers which carrier the data stream is modulated in nature is transformed by using the IFFT transformation technique and the conventional block which we make use in the proposed scheme to reduce the Peak to average power ratio (PAPR) of Orthogonal frequency division multiplexing(OFDM) signal.

$$b = \{b^0, b^1, \dots \dots \dots, b^{U-1}\} \quad (1)$$

Where U is the size of B, and bu, 0 ≤ u ≤ U − 1, is the uth phase rotation vector, which is defined as

$$b^u = [b_0^u, b_1^u, \dots \dots, b_{N-1}^u]^T \quad (2)$$

With$b_k^u = e^{j(2\pi i/W)}$, i = 0, 1…., W − 1. In this paper, we adopt W = 2 for simplicity. For convenience, denote $b^{m,u} = [b_0^{m,u}, b_1^{m,u}, \dots \dots, b_{N-1}^{m,u}]^T$ as the phase rotation vector used by the mth OFDM/OQAM symbol$S^m(t)$,. Usually, B is assumed to be known at both the transmitter and the receiver. After $s_k^m(t)$ is generated as in (3), AS-I generates $s_k^{\sim m}(t)$ by multiplying the corresponding element in the selected phase rotation vector, i.e.,

$$s_k^{\sim m}(t) = s_k^m(t) b_k^{m,u} \quad (3)$$

Then, the new OFDM/OQAM symbol $S^{\sim m}(t)$ is expressed as

III. METHODOLOGY

ALTERNATIVE-SIGNAL METHOD

A. AS-I Algorithm

Inspired by the SLM method, the AS-I algorithm reduces the PAPR by optimally choosing one phase rotation vector from a given set for each OFDM/OQAM symbol. Over different OFDM/OQAM symbols, the phase rotation vectors might be different. Denote the set of candidate phase rotation vectors as:

$$S^{\sim m}(t) = \sum_{k=0}^{N-1} s_k^m(t) b_k^{m,u} \quad (4)$$

Thus, the PAPR reduction problem with the AS-I algorithm for the mth OFDM/OQAM symbol$S^m(t)$, m = 0, 1. . . M − 1, can be formulated as

$$(P1): \min_{b^{m,u}} \max_{mT \le t \le (m+K+1/2)T} \left| \sum_{k=0}^{N-1} s_k^m(t) b_k^{m,u} \right|^2 \quad (5)$$

Note that we adopt the peak power as the design metric throughout this paper. This is because the PAPR reduction should come from the peak power reduction rather than the average power increasing. Given the finite dimensionality of B, exhaustive search is adopted here to search the optimal$b^{m,u}$. For each$S^m(t)$, the complexity of searching the optimal bm,u is on the order of O(U), i.e., for each $S^m(t)$, we take U searches. Thus, the complexity for all$S^m(t)$, m = 0, 1. . . M − 1, is on the order of O(UM).

Remark 1: After obtaining the PAPR-reduced OFDM/OQAM signal $\hat{s}(t)$, the transmitter should send side information to the receiver about which phase rotation vector is selected for $S^m(t)$, m = 0, 1, . . . , M − 1. Obviously, log2(U) bits are needed for such side.

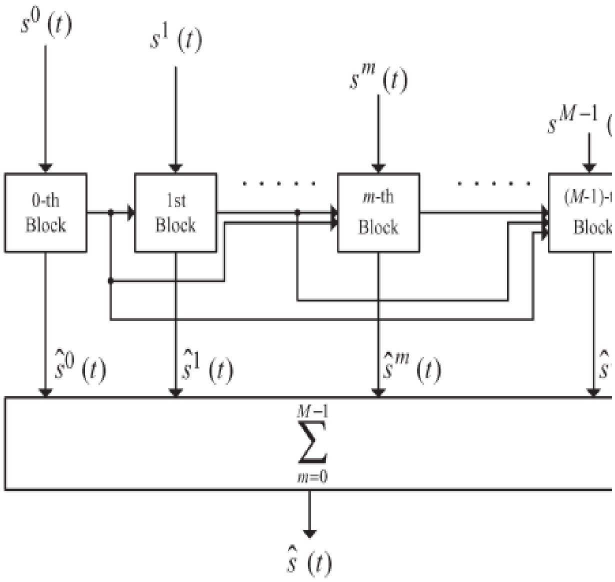

Fig. 2.4: Structure of the AS-S algorithm.

Information transmission [11] of each OFDM/OQAM symbol and, thus, M log2(U) bits for all the M symbols in total. At the receiver, if the side information is correctly received, the original data matrix X can be thus successfully recovered. We will illustrate the PAPR reduction performance achieved by the AS-I algorithm in Section II. As we will discussed later, the AS-I algorithm does not perform well enough since it ignores the structure of the OFDM/OQAM signals, i.e., the correlation among adjacent OFDM/OQAM symbols, whereas reducing the PAPR of $S^m(t)$ independently is strictly suboptimal. To improve the PAPR reduction performance, the AS-J algorithm is proposed in the following to fully explore the intersymbol correlations.

B. AS-J Algorithm

For each OFDM/OQAM symbol $S^m(t)$, the AS-J algorithm first chooses one phase rotation vector from the given B; then, it applies a joint PAPR reduction scheme among all the M OFDM/OQAM symbols. Similarly, after s ˜m k (t) is generated, as we did in the AS-I algorithm, the PAPR reduction problem could be formulated as

$$(P2): \min_{b^{0,u},b^{1,u},\ldots\ldots\ldots,b^{M-1}} \max_{mT\le t\le\left(m+K-\frac{1}{2}\right)T} \left|\sum_{m=0}^{M-1}\sum_{k=0}^{N-1} s_k^m(t)b_k^{m,u}\right.$$

Subject to: $b^{m,u}\epsilon B, m = 0,1,\ldots\ldots, M-1$ (6)

It is easy to check that the complexity of exhaustive searching to solve Problem (P2) is on the order of O(U M), which makes the exhaustive search method impractical. Similarly, the number of bits for the side information is equal to M log2(U). It is earlier shown that the AS-I algorithm is simple but performs badly, whereas the AS-J algorithm performs well but bears high complexity. To balance the PAPR reduction performance and the complexity, the AS-S algorithm is proposed in the following.

C. AS-S Algorithm

The main idea of the AS-S algorithm is shown in Fig. 3, which shows that the AS-S algorithm adopts a sequential optimization procedure. In the mth block, by taking into account the previous OFDM/OQAM symbols, i.e., $S^0(t)$,

$S^1(t)$, . . . , $S^{m-1}(t)$, we reduce the peak power of $S^m(t)$. A detailed illustration of the proposed algorithm is described as follows.In the zeroth block, we multiply $S^0(t)$ by different phase rotation vectors and choose the one with the minimum peak power, which is denoted as $S^{\sim 0}(t)$. Then, $S^{\sim 0}(t)$ is sent to the first block to solve the following problem:

$$\min_{b^{1,u}} \max_{2T \le t \le 4T} \left| \hat{S}^0(t) + \sum_{k=0}^{N-1} s_k^m(t) b_k^{m,u} \right|^2 subjecttob^{1,u} \epsilon B \quad (7)$$

The optimal phase rotation vector is denoted as $b^{1,u*}$, and the new generated symbol is cast as:

$$\hat{s}^1(t) = \sum_{k=0}^{N-1} S_k^1(t) b_k^{1,u*} \quad (8)$$

Next, $\hat{s}^0(t)$ and $\hat{s}^1(t)$ are both sent to the second block to calculate the new symbol$\hat{s}^2(t)$. We repeat the given procedure until the (M − 1)th block. Thus, AS-S is a sequential optimization procedure. Specifically, in the mth block, m = 1, 2. . . M − 1, the optimization problem could be cast as follows:

$$(P3): \min_{b^{m,u}} \max_{(m+1)T \le t \le (m+1)T} \left| \sum_{l=0}^{m-1} \hat{s}^l(t) + \sum_{k=0}^{N-1} s_k^m(t) b_k^{m,u} \right|^2 subjecttob^{m,u} \epsilon B \quad (9)$$

Note that Γ is a key parameter that significantly affects the PAPR reduction performance and will be discussed in Remark 2. In Problem (P3), the search complexity for each symbol $\hat{s}^m(t)$ is on the order of O (U), and the complexity for all the M symbols is on the order of O (UM). Similarly, the number of bits to transmit the side information is also equal to M log2 (U). Remark 2: We plot the amplitudes of h (t − mT) and $S^m(t)$ in Fig. 4, where the parameters of the prototype filter are the same as those in [2], [4], and [5]. It can be seen that the large-amplitude samples of h (t − mT) are located within {(m + K/2 − 1/2) T ≤ t ≤ (m + K/2 + 1/2)T }. For h (t − mT − T/2), its large-amplitude samples are located within {(m + K/2) T ≤ t ≤ (m + K/2 + 1) T}. According to (5) and (6), we could obtain that the large-amplitude samples of $S^m(t)$ are located within {(m + K/2 − 1/2) T ≤ t ≤ (m + K/2 + 1) T}. Intuitively, to obtain a good PAPR reduction performance, the large-amplitude samples of $S^m(t)$ should be included in the optimization duration {(m + 1) T ≤ t ≤ (m + Γ) T} in Problem (P3), i.e., Γ should satisfy Γ ≥ K/2 + 1. Furthermore, since $S^m(t)$ only spans over {mT ≤ t ≤ (m + K + 1/2) T}, it follows that Γ ≤ (K + 1/2). Thus, we conclude that K/2 + 1 ≤ Γ ≤ (K + 1/2) is a good choice.

Thus, the AS-S algorithm is summarized as follows:

Step 1: Initialization: m = 1. Multiply$S^0(t)$) by different phase rotation vectors and denote the one with the minimum peak power as$\hat{S}^0(t)$. Then, $\hat{S}^0(t)$is sent to the first block.

Step 2: In the mth block, solve Problem (P3), and the new symbol is denoted $S^{\sim m}(t)$. Send$S^{\sim 0}(t)$., $S^{\sim 1}(t)$., . . . , $S^{\sim m}(t)$to the next block.

Step 3: Set m = m + 1, if m ≤ M − 1, go to 2); otherwise, calculate $\hat{s}(t) = \sum_{m=0}^{M-1} \hat{s}^m(t)$ and output the value.

IV.RESULTS AND DISCUSSION

Experiments are performed under 1024 symbols and 64 sub carriers with proposed AS-I, AS-J and AS-S methods. From figure1 it can be seen that AS-J methods out performs about 2.8 -3 (dB) when compared against AS-S method. However AS-S shows better performance at L=3 as shown in figure 3. As an improvement task this method is compared against the Iterative clipping transform and the results are tabulated in figure 4.

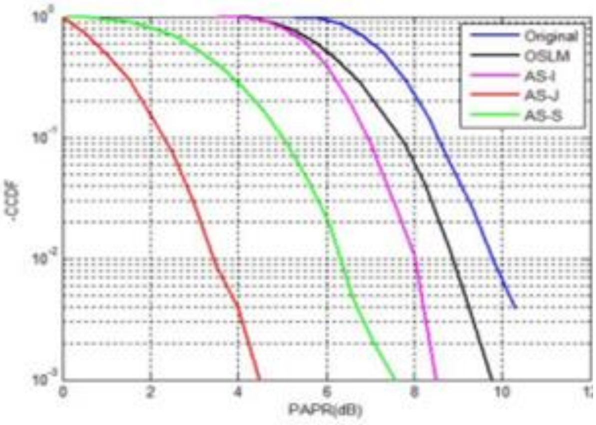

Figure 1: PAPR performance analysis proposed approaches.

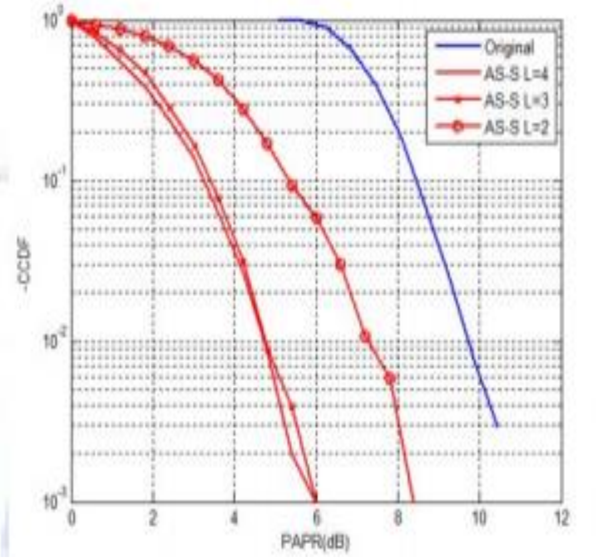

Figure 2: PAPR performance analysis proposed approaches under different 'U' values

It is found that the Iterative transform is outperforming than AS-I, AS-S methods but fall short of 1.2dB than AS-j method.

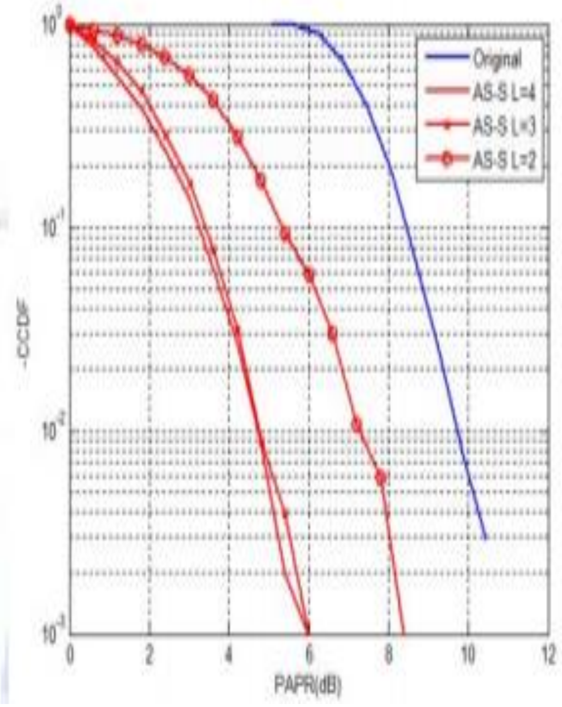

Figure 3: PAPR performance analysis of 'AS-S' under different 'L' values

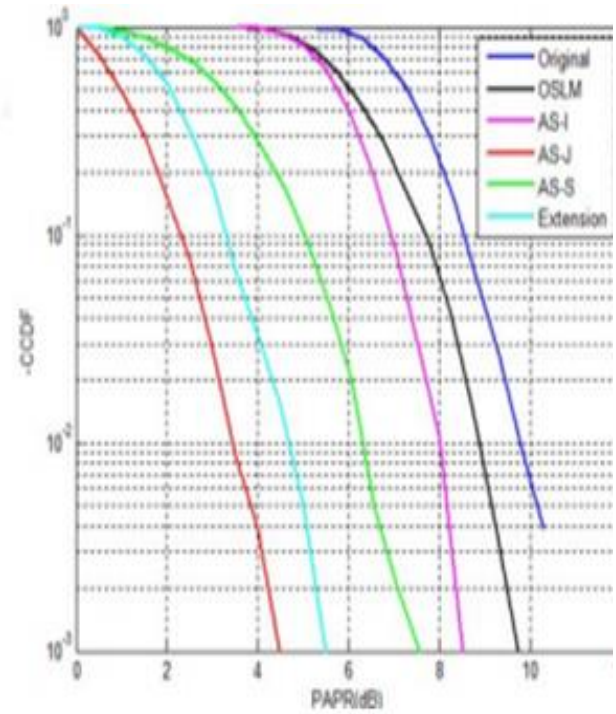

Figure 4: PAPR performance analysis of different methods including an extension of Iterative clipping TRANSFORM

V. CONCLUSION

The importance of multi-carrier communication system has been established in the present communication era. The merits and demerits of OFDM system along with its implication are discussed in first chapter. Multi-carrier communication system especially OFDM has been evolved as one of such potential candidate which are bandwidth efficient and robust to multipath channel condition (frequency selective fading). The research activities in OFDM have grown tremendously during last two decades. Due to its advantageous features like high spectral efficiency, easy equalization and robustness to frequency selective fading channel, the OFDM has been adopted by many broadband wireless communication standards like DAB, DVB-T, IEEE 802.11, 802.16 and UWB communication systems. Besides so many advantageous and favourable features, there exist some major drawbacks of OFDM which must be resolved for getting all the advantages. Therefore, for overall improvement in the performance of OFDM system, it is required to handle all these issues separately. This thesis presents brief review of major problems of OFDM system with their existing solutions. The main focus of work was to provide an appropriate solution to each and every major problem like high PAPR, timing synchronization, frequency synchronization and ICI reduction. After the review of different concerns and their solutions, following conclusions drawn:

1. Development of a suitable timing offset estimator,
2. Algorithm enumeration for frequency offset estimation,
3. Establishment of methods for PAPR reduction,
4. Induction of new pulse shape in OFDM receiver for ICI reduction.

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