Efficient Technique for Both PAPR and OBPL decline in OFDM-Based System

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Abstract – *Most of leading technologies in the area of communications is wireless technology. It offers well-organized data transmission and upward the concept for 4G and 5G communications. For multiplexing signal groups, the wireless technology adopted Orthogonal Frequency Division Multiplexing (OFDM). The OFDM-based system is structured in multi-carrier transmission which gains high spectral efficiency. The OFDM system limited by its problem of high PAPR and OBPL, both of these two problems occurred at transmission end. PAPR is Peak to Average Power Ratio, caused due superimpose of carriers and OBPL is Out-of-Band Power Leakage, occur due side-lobe in modulated data.*

Many literatures are providing solution to fix both PAPR and OBPL. In this paper, Signal Set Expansion (SSE) of OFDM symbol is added with suppressing signal for dual decline in PAPR and OBPL without impacting the BER performances. Like so, the amount of PAPR and OBPL reductions can be appreciably improved than the system that of performance offered by two separate individual optimization techniques i.e., individually performing PAPR reduction and OBPL reduction. In addition, this dual decline procedure offers additional flexibility. Finally analyze Bit Error Rate (BER) versus Signal to Noise Ratio (SNR) for three different channels.

Keywords: 4G, 5G, PAPR, OBPL, SSE, BER and SNR.

I. INTRODUCTION

OFDM (Orthogonal Frequency Division Multiplexing) is multi-carrier transmission which makes better utilization of available spectrum resources. OFDM scheme is adopted in majority of offered broadband communications principles like WiFi, IEEE 802.22 WRAN, etc. OFDM provide high spectral efficiency and it is advanced multiplexing system that achieve high data rate. The challenges made in OFDM system are Peak-to-Average Power Ratio (PAPR), Out-of-Band Power Leakage (OBPL) and frequency offset. Both PAPR and OBPL reduction is theme of this paper. PAPR occurred due to superimpose of multiple carriers with different phase and amplitudes which leads sudden increase in peak power. This increased peak power i.e., PAPR causes Power Amplifier (PA) to operate in non-linear region. Hence PAPR limit power efficiency and hikes in cost of device. OBPL is result of excess side lobes in spectrum. There are many different techniques for limiting both PAPR and OBPL individually and jointly in OFDM-Based systems [10]-[13].

Input signal to Power Amplifier (PA) is operate within its operating limits for proper operation of PA. The input signal with high PAPR, PA operates in non-linear region. It results non-linear distortion and interference between adjacent carriers called Inter-Carrier-Interference (ICI). To limit PAPR there are many algorithms proposed in literature. Such as Clipping Method [5]-[6] limit signal amplitude, which is above reference level and passes bellow reference level. It causes inband distortion, leads fall in Bit Error Rate (BER). Selective Mapping (SLM) [1]-[4], selects least PAPR symbol among set of symbols which are differed by phase. Partial Transmit Sequence (PTS) [7]-[9], Input data sequence portion into sub-block and assigned different phase weights, summed signal will have least PAPR. Both SLM and PTS offer complex design and cost effective.

Both high PAPR and non-linear operation of PA results large side lobes cause leakage in power called Out-of-Band power leakage. Due to OBPL, rapid rise in transmission power. There are many algorithms proposed in literatures for limiting OBPL. These algorithms are classified according to two categories time domain and frequency domain. Windowing method [14] is Time domain approach, selects particular portion signal. Whereas inserting guard band [14] between sub-carriers and Advanced Carrier Cancelation [15] are frequency domain approaches. Even these approaches providing better reduction in OBPL, they limited by their own limitations.

There are some methods to dual decline in PAPR and OBPL such as SLM with MCS [16], active point modification [17], Signal Set Spreading out with Advanced Carrier Cancelation [18]. In this paper, a method discussed for dual decline of PAPR and OBPL in OFDM-based systems. This method is combination of both Signal Set Expansion (SSE) and Suppressing Alignment (SA). The main object of SSE is to limit PAPR. SSE is iterative procedure for huge reduction in PAPR and it does not hold any side information sequence. SA proposed for dual decline in PAPR and OBPL. SA utilized CP to avoid interference between adjacent symbols OFDM signal. The proposed SSE-SA algorithm efficiently works to reduce OBPL occurred due to huge side-lobes and high PAPR.

The paper arrangement as follows: Sect.-II, System model is introduced. In Sect.-III, proposed method introduced. In Sect.-IV simulation results are discussed for different channels such as Rayleigh fading channel, Additive White Gaussian noise channel and SUI-3 channel. Finally, In Sect.-V provided conclusion.

Notations: $[.]^H$ and $[.]^T$ is conjugate transpose and transpose of a matrix. ker(.) and arg(.) are kernel and argument values, here $[.]^H$ and ker(.) are deals with complex numbers. E [.] expected value or mean value, $\|.\|_2$ and $\|.\|^\infty$ are norm-2 and uniform norm.

II. SYSTEM MODEL

The proposed system model is shown in fig-1, consisting transmitter and receiver over single channel. The digital generated input bits are mapped to complex symbols by using M ary Phase Shift Keying (MPSK Now these complex symbols are divided into N symbols using Serial-to-Parallel (S\P) convertor block. Both SSE and SA are discussed in next section. By using N subcarriers apply IFFT on data sequence. Along these lines, the OFDM transmitter/collector combine should control their transmissions with the end goal that insignificant impedance is caused to this nearby client. Give the aggregate number of subcarriers a chance to be N, where the subcarriers traversing the neighboring client band, Insert L samples on both end of data sequence to avoid ISI called as CP denoted as C_p and followed by parallel-to-serial convertor. To relieve the impacts of ISI, a CP of length L tests, which is thought to be bigger than the most extreme defer spread of the channel, is added to the begin of the OFDM symbol.

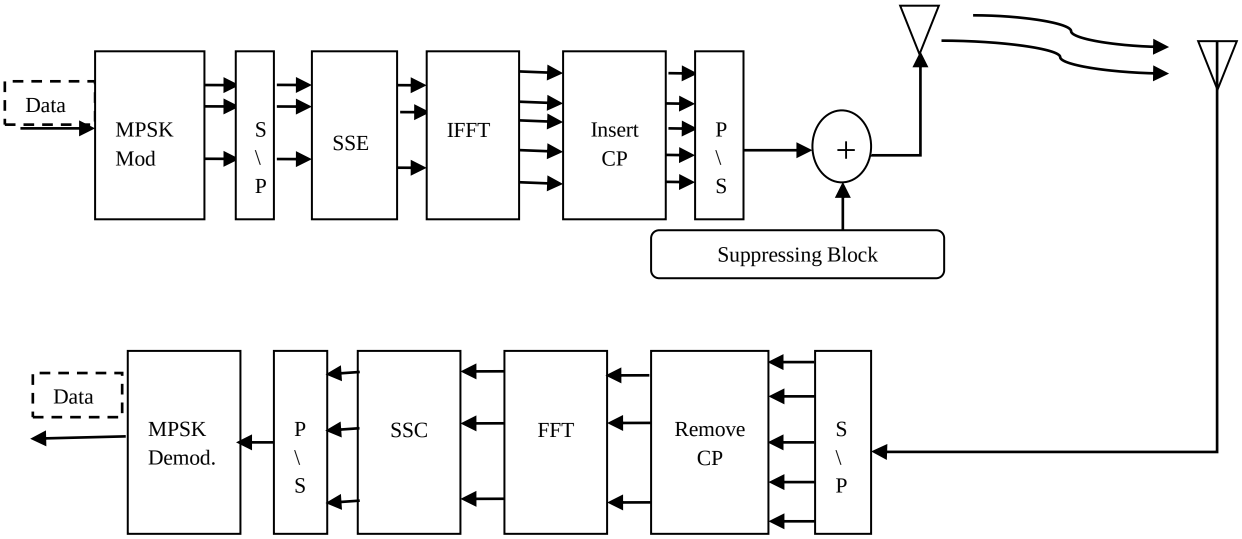

Fig-1: Block diagram of proposed system model

III. PROPOSED METHOD

A. Signal Set Expansion (SSE)

Let input sequence X=[X_0, X_1…., X_{N-1}] ^{T} in FD, where N is number of subcarriers to modulate input data sequence. X is complex data and its IFFT is x = [x_0, x_1 …, x_{N-1}]. Therefore IFFT defined in time interval between $t \in [0, T_0]$ given by

$$x(t) = \frac{1}{N}\sum_{n=0}^{N-1} X\left(e^{jwn}\right) e^{\frac{j2\pi nt}{T_0}} \qquad (1)$$

Where T_0 is period of OFDM symbols.

The Peak-to-Average Power Ratio (PAPR) of OFDM sequence defined as, ratio of maximum instantaneous power to average power, and it is given by

$$PAPR[x(t)] = \frac{||x(t)||_\infty^2}{\frac{1}{N+L}||x(t)||_2^2} \qquad (2)$$

The basic idea behind signal set expansion, map the expanded sequence from the original sequence to limit PAPR. The modulator that modulates symbols at rate M bits\symbol and that contains 2^M group of points in its constellation diagram. These points are mapped to modulation that modulates (M + p) bits\symbol and it contains 2^{M+p} constellation points. Therefore every symbol in original data is coupled with $2^{M+p}/2^M$ points in expanded data. For example, for QPSK, M=4 (constellation points p, q, r, s) and let p=1. It expanded to 3 symbols and 8 constellation points (p1, p2, q1, q2, r1, r2, s1, s2), shown in fig-2. Select each expanded points producing 2^N combinations. Change phase between expanded symbols, compute PAPR for each combination and select least PAPR for transmission. Phase difference in extended data between two points which is associated to original signal constellation point is θ. Where θ=π/4, 3π/4, 5π/4, 7π/4.

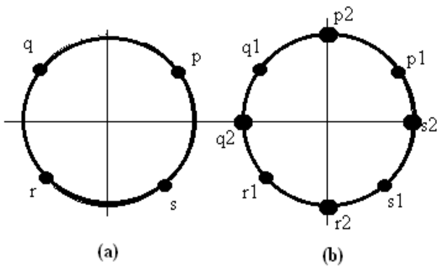

Fig-2: Symbol mapping QPSK to 8-PSK

Then OFDM symbol $X(e^{jwn})$ can modified to $X'(e^{jwn})$ which given by

$$X'\left(e^{jwn}\right) = \arg(\min(PAPR[X(e^{jwn})])) \ (3)$$

Computing PAPR for different combinations leads computational complexity. To avoid complexity, divide OFDM symbols in three groups, shown if figure-3. Length of each group is L/2, N-L, and L/2 respectively. Apply SSE on 1st and

3rd group, consisting only L-subcarriers and remaining (N-L) subcarriers carry information. Therefore, by reducing combinations, complexity will be limited.

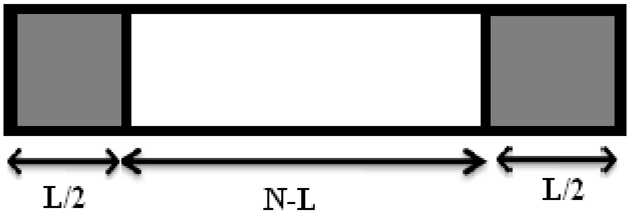

Fig-3: Symbol structure in SSE

B. Suppressing Alignment (SA)

The key idea to design suppressing block: 1) to limit OBPL and 2) avoid interference to original information signal i.e., receiver can collect all information send by transmitter. The suppressing signal, $S = [S_1, S_2 \ldots, S_{N+L}]^T$ whose length is same as OFDM signal, given by

$$S = PC \qquad (4)$$

Where P and C are OPBL reduction matrixes with length of (N+L)×L and L×1 respectively. To design both of these matrixes we need to know state of channel, simply Channel State Information (CSI). The transmitted signal given by

$$t = C_p F^{-1} d + PC \qquad (5)$$

Consider channel whose transfer function $H = [h_0, h_1 \ldots h_l]$, where H is toeplitz matrix and additive noise n. Then data at receiver r, given by

$$R = Ht + n \qquad (6)$$

Receiver end signal given as

$$y = F\overline{C}_p Ht + n = F\overline{C}_p H C_p F^{-1} d + F\overline{C}_p HPC + n \quad (7)$$

Where C_p and $\overline{C}_p$ are add CP and remove CP respectively. From (7), second term denotes interference caused by suppressing block. P designed in such way that, this interference equals to zero.

$$F\overline{C}_p HPC = 0 \qquad (8)$$

To satisfy (8) condition, P is null space of $\overline{C}_p H$ and matrix P can chosen such that span (P) = ker ($\overline{C}_p H$). Hence dimension of $\overline{C}_p H$ = N. By considering Singular Value Decomposition (SVD), $\overline{C}_p H$ can written as

$$\overline{C}_p H = u \sum v^T \qquad (9)$$

where u is orthogonal and ∑ is an diagonal, they contains singular value of $\overline{C}_p H$. v is orthogonal, written as $v = [v_1 \ldots v_{N+L}]$. Then P can expressed as

$$P = [v_N \ \ v_{N+1} \ldots v_{N+L-1}] \qquad (10)$$

Let consider spectrum of (5),

$$S_t = FFT_\zeta(C_p F^{-1} d + PC) \qquad (11)$$

Interference caused in adjacent bands can written as

$$I = FFT_I(C_p F^{-1} d + PC) = FFT_I(C_p F^{-1} d) + FFT_I(PC) \quad (12)$$

In (12) 1st term represents OBPL from original data and 2nd OBPL from S. To avoid OBPL,

$$C = \arg\min \| FFT_I(C_p F^{-1} d) + FFT_I(PC) \|_2 \quad (13)$$

Therefore solution for C is given by

$$C = -(F_s^H F_s + \lambda I)^{-1} F_s^H F_d \qquad (14)$$

Proper value of λ, we can fix dual decline in PAPR and OBPL [19], where $F_s = FFT_I(C_p F^{-1} d)$, $F_d = FFT_I(PC)$ and λ is Lagrange Multiplier (LM).

VI. PERFORMANCE DETERMINATION

Here, we present simulations of proposed method for dual decline in PAPR and OBPL. These simulations can evaluate performance of proposed method.

A. PAPR reduction

The simulation results of PAPR plotted in terms of Complementary Cumulative Distribution Functions (CCDF). Fig-4 shows results of CCDF for PAPR with comparing conventional OFDM.

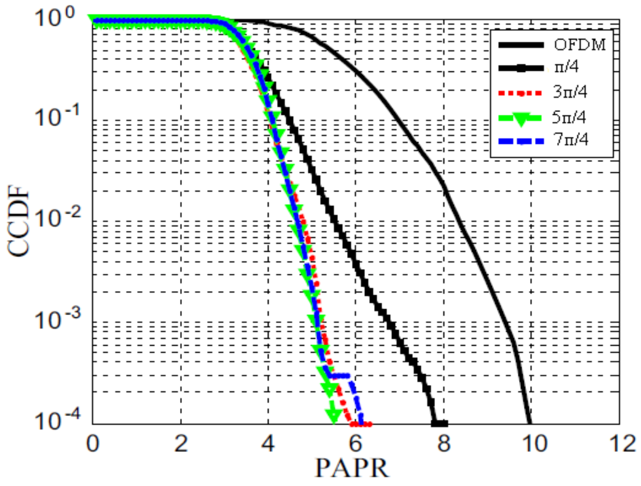

Fig-4: PAPR decline for SSE (N=16)

It compares original conventional OFDM over proposed scheme for different values of θ and N. As θ changes, PAPR can change. The PAPR calculated for different values of phase difference θ = π /4, 3π/4, 5π/4, 7π/4 and N = 16, 64 subcarriers, shown in fig-4 and fig-5.

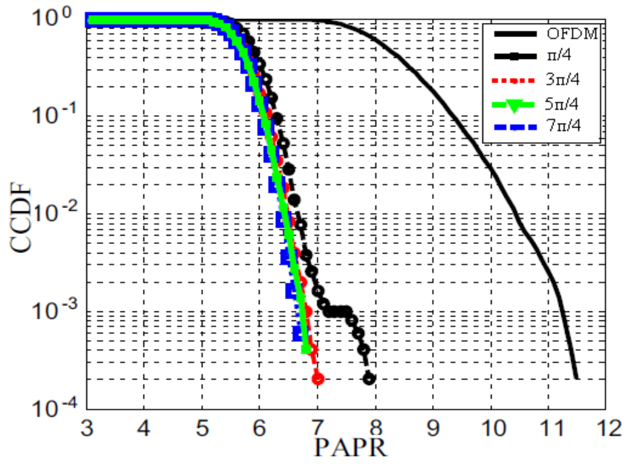

Fig-5: PAPR decline for SSE (N= 64)

To limit impact on BER performance, the optimum value of θ is 3π/4. I.e., at θ = 3π/4 gives more reduction in PAPR than other range of values. Figure-4 shows CCDF for N = 16. The amount of PAPR reduction is 4.2dB for θ = 3π/4 and 2.5dB for θ=π/4. In figure-5, N=64, reduction in PAPR will be 4.8dB and 6.3dB for θ = 3π/4 and π/4 respectively.

B. OBPL reduction

Fig-7 shows tradeoff between OBPL and PAPR. The value LM λ in (14), [0:1]. Optimum value of LM can reduce both PAPR and OBPL. There for λ=0, SA deal with only OBPL reduction and λ=1, SA can reduce only PAPR. It is necessary to select optimum value of λ=0.5. OBPL caused due to side lobes, in (12), OBPL occurred in both information and suppressing signal are must limited. Fig-7 shown power exists in side lobes for proposed SSE-SA approach.

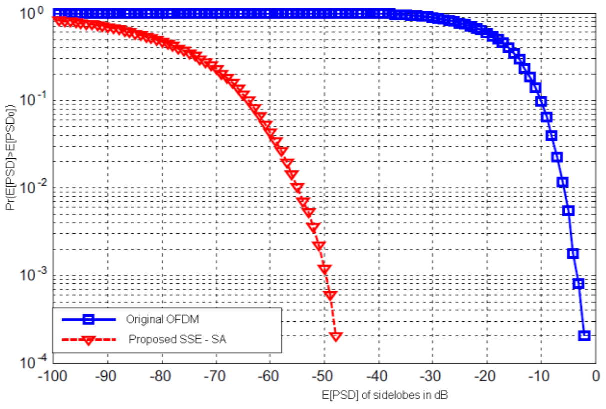

Fig-7: Side lobe power for proposed SSE-SA

Fig-8 shows optimum PAPR reduction for proposed SSE-SA approach, great reduction in PAPR can be achieved.

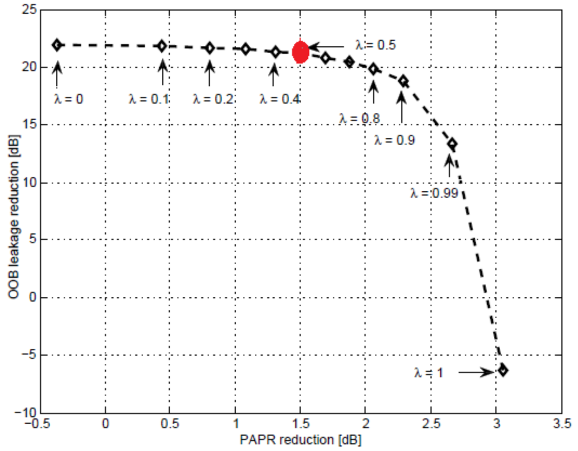

Fig-6: Tradeoff between PAPR and OBPL

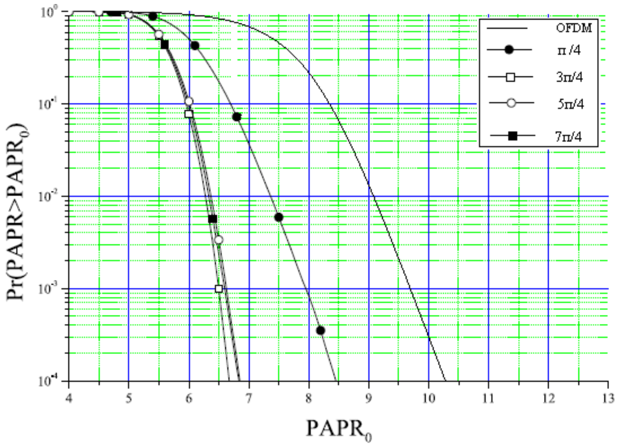

Fig-8: PAPR reduction for proposed SSE-SA

V. CONCLUSION

In this paper work, we proposed an efficient technique for dual decline in PAPR and OBPL. This approach is combines SSE-SA, which provides great reduction in PAPR as compared with conventional OFDM. In addition, it does not affect spectral efficiency due to CP. The suppressing signal constructed in such way that it cannot create any interference to information data. The computer simulations show that great decline in both OBPL and PAPR achieved for optimum values of phase difference (θ) and LM (λ).

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