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Designing a Novel PTS Method to Reduce Peak to Average Power Ratio in OFDM

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Abstract: ***Most of the wireless standards used these days, heavily rely on Orthogonal Frequency Division Multiplexing (OFDM). Peak to Average Power Ratio (PAPR) is one of the known key acknowledged confines of OFDM. Reduced PAPR at OFDM transmitter helps power amplifier to operate in stable mode and reduction in complexity of digital to analog converter (DAC). Several PAPR reduction techniques have been evolved from different principles such as signal scrambling techniques, such as Partial Transmit Sequence (PTS), signal distortion techniques such as Clipping, etc. Reducing PAPR degrades bit error rate (BER) or computational complexity. PTS is one of the best methods of PAPR reduction. There is large scope of betterment of PTS to get a best PAPR reduction technique. In this paper we have concentrated on PTS scheme by exploring PTS and its variants evolved over a period of time. We proposed a novel PTS with best performance balancing PAPR and BER performance. Design and development of scheme is done using a graphical programming environment LabVIEW (Laboratory Virtual Instrumentation Engineering Workbench) and real time environment validation is done with software defined radio – NIUSRP2922, which is National Instruments Universal Software Radio Peripheral. The paper has three sections in first section, Introduction, the OFDM fundamentals and PAPR are defined in design perspective, in second section conventional and proposed PTS schemes have been explained. The third section consists of result and conclusion.***

Keywords **:** ***OFDM, PAPR, PTS, ACF, LabVIEW, NI-USRP***

I. INTRODUCTION

A. OFDM:

OFDM utilizes frequency spectrum almost 50% more than conventional frequency division multiplexing and has excellent performance in multipath fading channel. Figure 1 Shows Time and Frequency domain representation of OFDM signal. It uses the concept of Cyclic Prefix (CP) which adds last few bits of symbol as prefix to symbol, to prevent Inter Symbol Interference. CP is required to maintain the Orthogonality but it costs a part of spectrum [1]. OFDM can transmit bulk of data over Radio waves and it is one of the most known prominent multicarrier multiplexing accesses Technique [2].

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Mathematically OFDM is expressed as equation (i)

$$x(t) = \sum_{k=0}^{N-1} X_k e^{j2\Pi kt/T} \qquad 0 \le t \le T \qquad \text{(i)}$$

OFDM acted as backbone in numerous deployments such as Digital Audio Broadcasting: DAB/EUREKA, DAB+, Digital Radio Mondale, HD Radio, T-DMB and ISDBTSB Terrestrial Digital Video Broadcasting: DVB-T and ISDBT, Mobile TV: DVB-H, T-DMB and ISDB-T, Wireless PAN, ultra-wideband (UWB) IEEE 802.15.3a, Wireless LAN radio interfaces: IEEE 802.11a, g, n and HIPERLAN/2, Wireless MAN: broadband wireless access standard, IEEE 802.16e, the mobile broadband wireless access standard IEEE 802.20, 4G Long Term Evolution (LTE): Evolved UMTS, Terrestrial Radio Access (E-UTRA). And now it has been considered as a strong candidate for 5G mobile phone standards [3] [4]. Figure 2 shows conventional Block schematic of OFDM Transmitter and Receiver

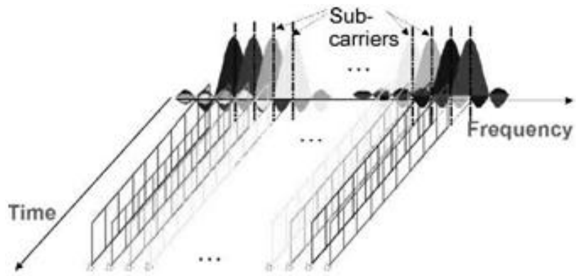

Figure 1: Time and Frequency domain representation of OFDM signal

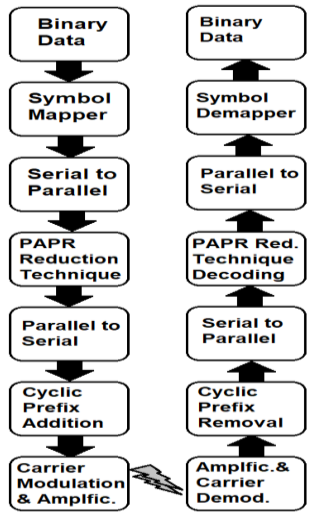

Figure 2: Block schematic of OFDM Transmitter and Receiver

B. OFDM SIGNAL DESIGN:

We have taken the IEEE 802.11a/g Wireless Local Area Network design specifications into consideration for basic signal design and implementation in LabVIEW Platform. The OFDM symbol structure consists of a serial block of N modulated symbols ordered from serial original data bits and converted to a parallel block to generate the N frequency domain OFDM symbols. A time-domain OFDM signal is generated by adding N OFDM symbols modulated onto the N orthogonal sub-carriers [5][6]. Figure 3: shows bandwidth of designed OFDM signal. Figure 4 shows OFDM Symbol Construction in LabVIEW, which includes data source, serial to parallel conversion, zero padding, Inverse Fast Fourier Transform (IFFT) and Zero Padding. The Figure 5 shows Cyclic Prefix in OFDM signal, here 8 symbols of end signal are prefixed to the signal, 96 source data bits are mapped with 48 data symbols using QPSK, then 16 zeros are padded, theses 64 bits are then transformed with IFFT and finally last 8 symbols are prefixed into signal making 72 symbols in one OFDM symbol.

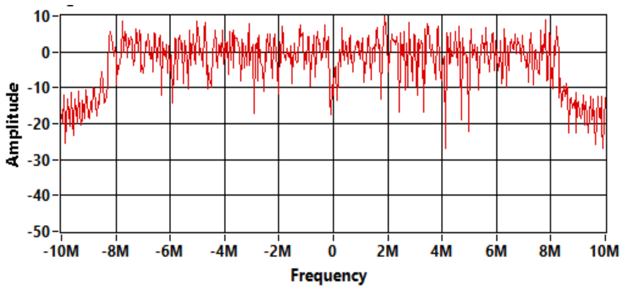

Figure 3. IEEE 802.11a Signal Bandwidth

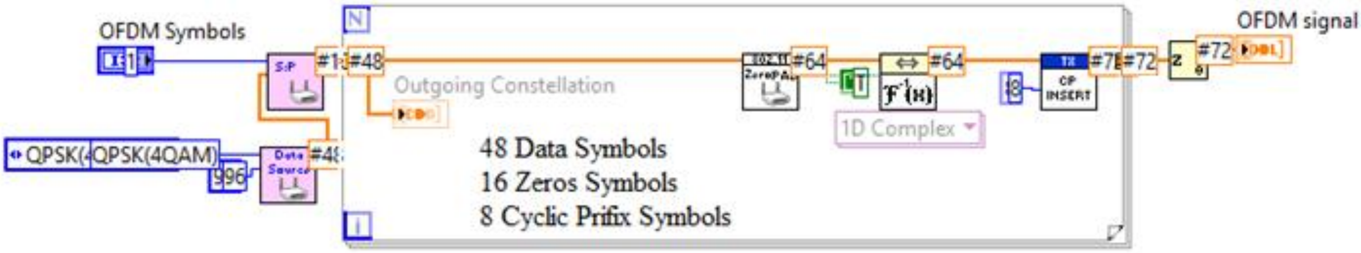

Figure 4: OFDM Symbol Construction in LabVIEW

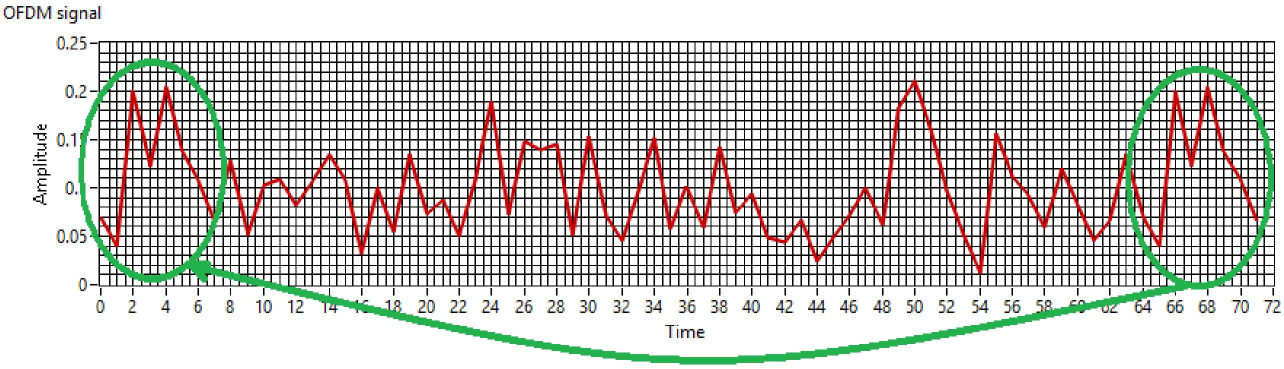

Figure 5: Cyclic Prefix in OFDM Symbol

C. PAPR:

The OFDM system deployment becomes costlier because of its High PAPR which causes when a large number of subcarrier get summed-up together creating often large peaks compared to single carrier systems [7]. PAPR has noise like amplitude, with a very large dynamic range and it is more sensitive to carrier frequency offset and drift as compared to single carrier systems Mathematically PAPR can be defined as shown with equation (ii) and (iii). Figure 6 shows LabVIEW tool to measure PAPR of OFDM signal.

$$PAPR = \frac{\max |x(t)|^2}{E[|x(t)|^2]} ....(ii)$$

PAPR in dB can be calculated as

$$PAPR_{dB} = 10\log_{10}(PAPR)..............(iii)$$

High PAPR in OFDM signal creates a conflict in High Power Amplifier (HPA) threshold value and Peak signal value. Power consumption of HPA of transmitter increases as the high peaks go into the saturation region of the HPA, making non-linearity in signal amplification.

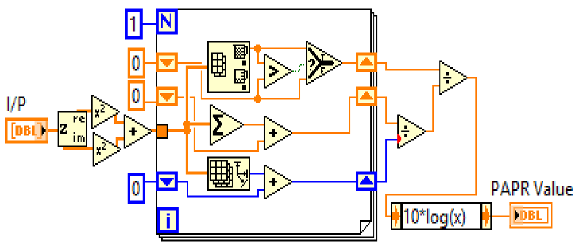

Figure 6: PAPR Measurement using LabVIEW

This creates in-band distortion and out-off-band distortion resulting increased BER at the receiver and spectral re-growth respectively. This effect not only increases the power consumption of HPA but also increases complexity at ADC and DAC [7]. Choosing wide band power amplifier increases cost of system and it will be waste of cost as high peak in signal is probable event may occur less frequently. PARP value is proportional to number of subcarriers equation

(iv) shows value of PAPR is function of N subcarriers

$$PAPR_{dB} = 10\log_{10}(N).......(iv)$$

For instance if number of subcarriers are 52, as like in IEEE 802.11a/g the instantaneous PAPR value may be expected as much as 17 dB, which is most unlikely event.

Actual instantaneous PAPR goes up to 09 dB for this standard. By reducing PAPR in OFDM Transmission Power Amplifier Efficiency Improves, signal distortion & BER can be reduced, by reducing 1 dB of PAPR approximately 6-9% transmission power can be minimized [8].

These reasons lead a strong motivation to reduce the PAPR further in OFDM systems. Present methods are good but not best.

D. CCDF

The complementary cumulative distribution function (CCDF) is used to know how often the random variable- here PAPR, is above a particular level. CCDF computes the power from a time domain signal it is also known as tail distribution or exceedance. The CCDF curve shows the amount of time a signal spends above the average power level of the measured signal, or equivalently, the probability that the signal power will be above the average power level. Performance of transmitted signal is evaluated with CCDF tool for different PAPRs of the signal [9].

II. CONVENTIONAL AND PROPOSED METHOD PARTIAL TRANSMIT SEQUENCE

A. Conventional PTS

The PTS is a most preferred probabilistic scrambling scheme for PAPR reduction [10]. A generalized block diagram of PTS scheme [11] is as shown in Figure 7.

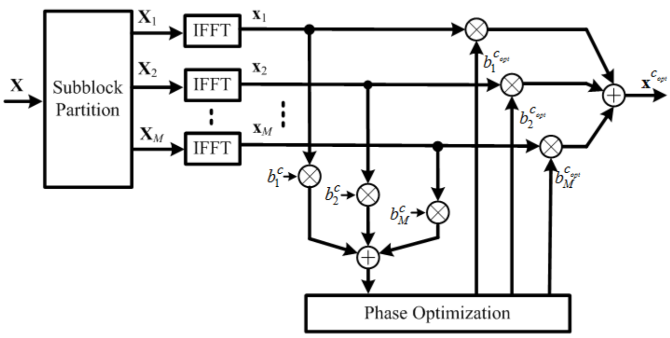

Figure 7: Conventional PTS scheme

As shown in 8 partitioning of input data block X is done into M disjoint sub-blocks and multiplied with by phase rotation factor set to achieve low peaks with phase scrambling technique. These set will give multiple copies of data set with varying PAPR, the candidate having least PAPR will be chosen as signal to transmit and identity of corresponding phase rotation sequence as side information [12][13].

B. Proposed Method

The proposed method is a novel approach of reducing PAPR based on SLM, PTS and ACF techniques, which gave us improved results. The results are evaluated for various modulation schemes of IEEE 802.11a/g WLAN standard with CCDF at transmitter and BER at receiver. The proposed algorithm is as shown in Figure 8.

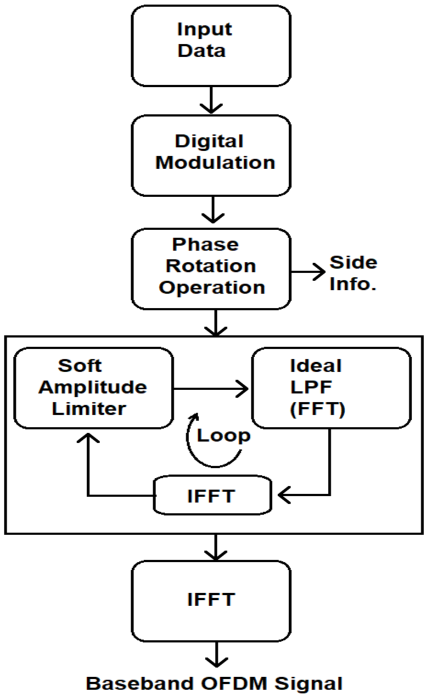

Figure 8: Proposed Method

The algorithm is designed and developed with LabVIEW platform, and for real environment validation it is deployed over software defined radio, the test bed of same is illustrated with Figure 9 as follows.

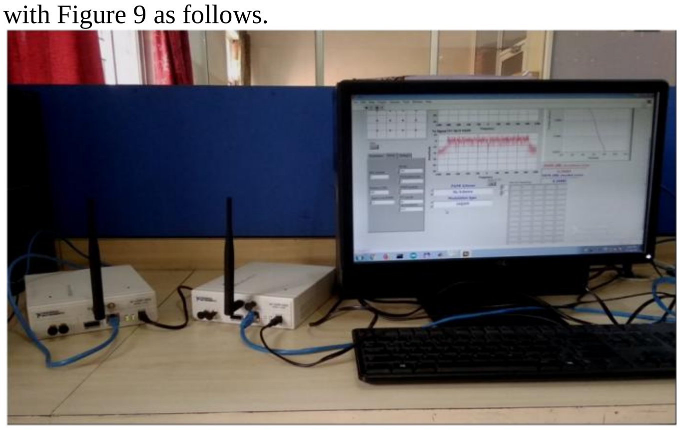

Figure 9: Test Bed with Software Defined Radio- NI USRP 2922

C. Mathematical Model of Proposed Technique:

Let x_v represents v^{th} disjoint block of signal set x, the IFFT of these v disjoint blocks is represented by X_v and X represents summation of these disjoint blocks i.e. one OFDM symbol as shown in equation (v)

$$X = \sum_{v=1}^{V} IFFT\{x_v\} = \sum_{v=1}^{V} X_v......(v)$$

The ***N*** replications of OFDM symbols with ***v*** disjoint blocks is used to form a matrix, this matrix is then multiplied with phase rotation factors matrix of size (***N***x***v***) to reduce highly uncorrelated data caused by IFFT. Let X_{SET} represent the resultant matrix (***N***x***v***) of this multiplication as shown in equation (vi).

$$X_{SET}=\left[\begin{bmatrix} X_{11} & X_{12} & ..... & X_{1N} \\ X_{21} & X_{22} & .... & X_{2N} \\ .. & .. & ..... & .. \\ X_{v1} & X_{v2} & ..... & X_{vN} \end{bmatrix}^{T} \begin{bmatrix} e^{j\phi 11} & e^{j\phi 12} & ..... & e^{j\phi 1N} \\ e^{j\phi 21} & e^{j\phi 22} & .... & e^{j\phi 2N} \\ .. & .. & ..... & .. \\ e^{j\phi v1} & e^{j\phi v2} & ..... & e^{j\phi vN} \end{bmatrix}\right]^{T} ..(vi)$$

$\boldsymbol{X_{SET}}$ has N replications of signal $\boldsymbol{X}$, one of these N signals is selected for minimum PAPR. The copy of $\boldsymbol{X}$ with least PAPR is shown in equation (vii) with $\boldsymbol{Y}$. whereas the $\boldsymbol{b_v}$ shows index number of X with minimum PAPR as shown in equation (viii)

$$Y=\arg\min_{X_v^{SET}}(\max_{v=1,2,...V}|X_{v,n}^{SET}).......(vii)$$

$$bv=\arg\min_{[v]}(\max_{v=1,2,...N}|X_{v,n}^{SET}).......(viii)$$

Repeated Amplitude clipping and filtering is performed on Y to a predefined amplitude level A, the resultant signal is stored in Z as shown in equation (ix). This seems similer to conventional amplitude clipping and filtering but rather different in actual with the fact that it is done post phesor rotation and hence selection of value of A is quite different than as that of the conventional scheme. This causes least in-band distortion or out-of-band radiation in signal.

$$Z=\begin{cases} Y, & if\,Y\le A \\ A, & if\,Y>A \end{cases}...........(ix)$$

Z along with b_v is sent to recover the original signal at the receiver. The receiver has a similar set of phase rotation factors, so only information (indices) of these phase sequence needed to be sent from the transmitter side.

III. RESULT AND CONCLUSIONS

OFDM signal with no PAPR reduction scheme, with PTS scheme and proposed scheme are comparatively evaluated for BPSK, QAM, 16 QAM and 64 QAM modulation techniques figure 10,11,12 an 13 are comparative analysis of said schemes for BPSK, QAM, 16QAm and 64 QAM respectively.

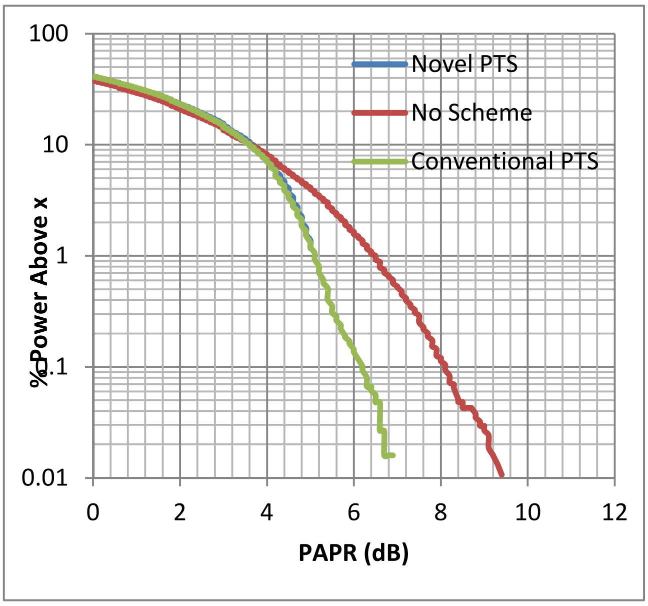

Figure 10: CCDF plot for BPSK implementation

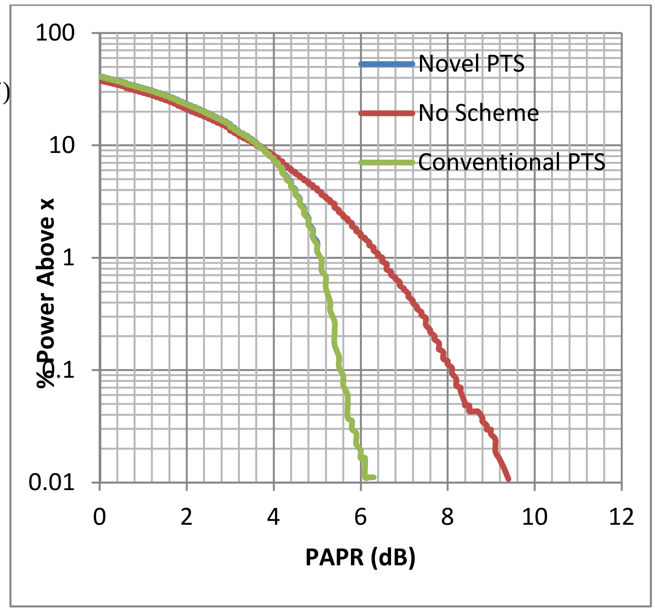

Figure 11: CCDF plot for QAM implementation

The proposed method is derived from PTS & ACF and has optimum BER with the lowest PAPR. The proposed method could successfully reduce PAPR value below 6dB with approximately the same BER performance as that of the signal without any scheme applied. The proposed method has been validated by simulation as well as test bed setup of Software-

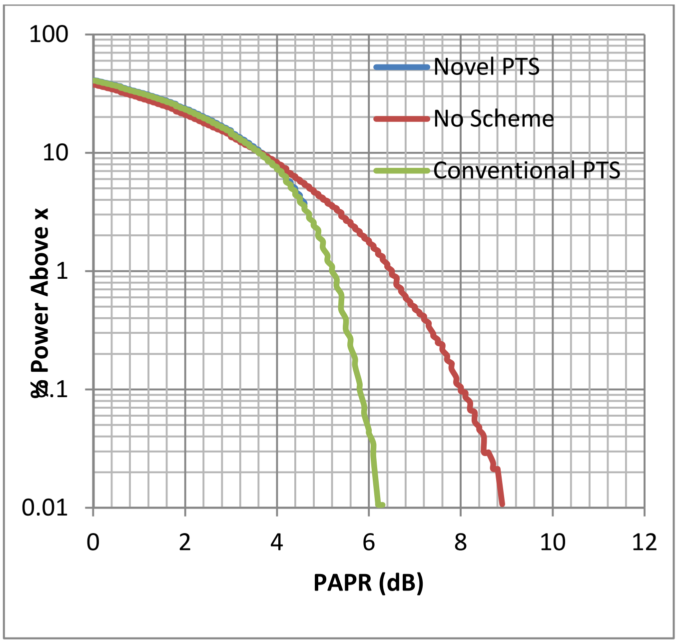

Figure 12: CCDF plot for 16-QAM implementation

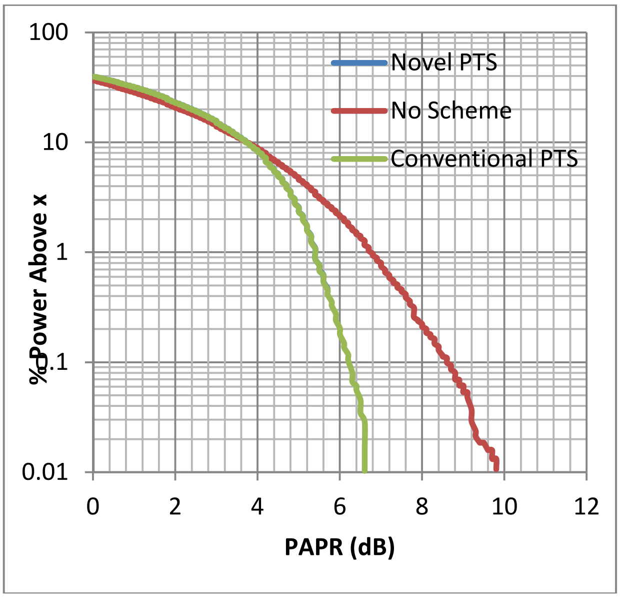

Figure 13: CCDF plot for 64-QAM implementation

Defined-Radio NI USRP 2922. Table 1 shows the comparative analysis of PAPR values of OFDM signal with no scheme, conventional PTS scheme and proposed PTS scheme for various modulation techniques with which we may conclude proposed method is improved version of existing PAPR reducing techniques. Proposed PAPR scheme further may be tested on other OFDM standards such as DVB, IEEE 802.16m, IEEE 802.20 and others.

Table 1: Comparative analysis of PAPR values of OFDM signal

PAPR SCHEMES	PAPR Value (Max) in dB) for Different Modulation Techniques			
	BPSK	4-QAM	16-QAM	64-QAM
No Scheme	9.6	9.4	8.9	9.8
Proposed Scheme	5.1	5.1	4.7	5.7
Conventional PTS	6.8	6.2	6.3	6.6

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