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PERFORMANCE EVOLUTION ANALYSIS OF DCT PRECODED OFDM WITH PIECEWISE LINEAR COMPANDING FOR WIMAX

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Abstract*— *Orthogonal FDM (OFDM) is a thrilling method for typical applications those require huge degree of data rates. Because of the excessive PAPR, the complexity of HPA and in addition DAC moreover will growth. For the reduction of PAPR in OFDM several strategies are to be had. Among them Companding is an appealing low multifaceted way for the OFDM alerts PAPR diminishment. As of overdue, a Piecewise linear companding approach is prescribed going for limiting companding contortion. In this paper, an aggregate Piecewise linear companding (PLC) method and Discrete Cosine Transform (DCT) approach is relied upon to reduce PAPR of OFDM to a top notch extent. Simulation outcomes suggests approximately show off this new proposed method acquires noteworthy PAPR lower even as keeping up improved overall performance in the Bit Error Rate (BER) in comparison to piecewise linear companding approach without PSD overall performance degradation.

Keywords*— *OFDM; PAPR; Discrete Cosine Transform; Companding Distortion; Piecewise linear companding.

I. INTRODUCTION TO OFDM

Orthogonal FDM is an adjustment arrangement that is being utilized by many of the latest wireless and additionally telecommunications standards. A substantial number of nearly dispersing sub-carrier signals those are orthogonal to each other are utilized to convey information on a several parallel information paths or channels. Significant preferences of OFDM is that the Receiver has low complexity,discovers applications which require high information rate applications, give invulnerability to ISI by utilizing cyclic prefix than single carrier systems, no requirement for utilizing bank of oscillators. It permits synchronous transmission of subcarriers over a typical channel, in this manner making effective utilization of accessible range, brings about high Spectral Efficiency. Because of its antagonistic advantages, it finds the applications in Digital Audio Broadcasting (DAB), IEEE 802.11(Wireless LAN), MBWA (IEEE802.20), DSL and ADSL Modems, DRM and Wireless Metropolitan Area Networks (WMAN) and in addition DVB-T.

A couple of systems are developed to address the problem of PAPR in OFDM signals [1, 11]. In these techniques, companding plans secure thought in light of their versatility and straightforwardness. The possibility of µ-law companding framework was at first introduced in [5]. Later on, Exponential Companding (EC) was made in [6], which can upgrade diminishment of OFDM's PAPR by adjusting the scattering (conveyance) of OFDM signs while keeping normal power remains reliable. Starting late, another nonlinear companding strategy is proposed [7] which changes the Gaussian distribution motion into linear. This nonlinear companding system reduces the PAPR of OFDM signal to a weakness of high computational multifaceted nature. By then Two Piecewise Companding (TPWC) methodology proposed in [8] which pack broad signal amplitudes and develop minimal ones by using two particular piecewise limits. In all above companding systems, it diminishes PAPR by making companding curving. Starting late, a piecewise linear companding strategy was explored in [9] to lessen the reduction in companding distortion. The DCT Precoded structure is better than anything diverse precoders in terms of complexity in lessening PAPR and moreover it gives change in BER execution of the basic OFDM at the same BER [10].

In this, the paper is off evolved with the preface of the subject in zone 1. Portion 2 displays a problem or drawback of OFDM (i.e.) PAPR. Section 3 explains the DCT Transform processing. Territory 4 offers signal preparing steps to realize a PAPR diminish by method for joining PLC Transform and DCT. MATLAB simulated outcomes are introduced in area 5 ultimately the paper concluded in 6.

II. CONCEPTION OF PAPR PROBLEM

Predominantly, M number of data symbols those are independent are going to mapping by using available baseband modulation schemes. In a general sense, OFDM signal is described as the sum of these M modulated symbols of independent nature. Thus oversampled OFDM symbols in time-domain $Y=[y_0, y_1, ..., y_{LM-1}]^T$ can be

$$y_n = \frac{1}{\sqrt{ML}} \sum_{k=0}^{M-1} Y_k . e^{j2\pi \frac{kn}{ML}}, \quad 0 \le n \le ML-1, \,.........(I)$$

Where time index ranging from $n = 0,1,..., LM-1$. Usually, Up-sampling factor ($L \ge 4$) is used to precisely portray the PAPR. For ensuring the Nyquist criteria $(L-1)M$ zeros are infused in the centre of the OFDM signal of M length vector, i.e.

$$Y_e = \left[Y_0, Y_1, ..., Y_{\frac{M}{2}-1}, \underbrace{0, ..., 0}_{M(L-1)}, Y_{\frac{M}{2}}, ..., Y_{M-1} \right]^T . \quad (2)$$

We can say that $y = IFFT_{LM}\{Y_e\}$. By taking these into consideration, real and imaginary parts of the OFDM signal $|y_n|$, it approaches a Rayleigh distribution

$$f_{|y_n|}(y) = \frac{2y}{\sigma_y^2} e^{-\frac{y^2}{\sigma_y^2}} \qquad y \geq 0. \qquad (3)$$

As from (3), now the CDF of $|y_n|$ is related as

$$F_{|y_n|}(y) = \Pr ob\{|y_n| \leq y\} = \int_0^y \frac{2y}{\sigma_y^2} e^{-\frac{y^2}{\sigma_y^2}} dy = 1 - e^{-\frac{y^2}{\sigma_y^2}}, \quad y \geq 0 \qquad (4)$$

With this the Peak to Average Power Ratio of OFDM is

$$PAPR_Y = \frac{\max_{n \in [0, LM-1]} \left\{ |y_n|^2 \right\}}{E\left\{ |y_n|^2 \right\}}. \qquad (5)$$

It is necessary to consider the PAPR of OFDM system as an arbitrary variable and characterize the statistical depiction adapted by the Complementary CDF (CCDF), expressed as the likelihood that the PAPR of signal (x) surpasses a relegated level $\gamma_0 > 0$, i.e.

$$CCDFY(\gamma_0) = \Pr ob\{PAPRY > \gamma_0\} = 1 - (1 - e^{-\gamma_0})^N \quad (6)$$

The piecewise linear companding technique (PLC) is explained [9] in Fig. 1,

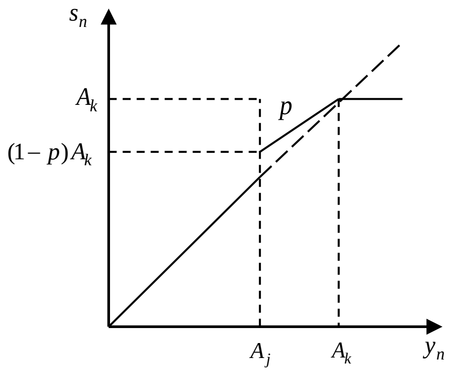

Figure 1. Schematic of PLC Transform

III. DISCRETE COSINE TRANSFORM

The DCT decorrelates the data sequence such as the Hadamard transform. This transform is applied to decrease the autocorrelation of the input sequence before the IFFT operation is applied. In brief we review the DCT in this section. The one-dimensional DCT of length N can be formulated as following:

$$X_c(k) = \alpha(k) \sum_{n=0}^{N-1} x(n) \cos\left[\frac{\pi(2n+1)k}{2N}\right], \qquad (10)$$

For $k = 0, ..., N-1$

Similarly, the inverse transformation can be formulated as

$$x(n) = \sum_{k=0}^{N-1} \alpha(k) X_c(k) \cos\left[\frac{\pi(2n+1)k}{2N}\right], \qquad (11)$$

For $n = 0, ..., N-1$

For both Equations (10) and (11) $\alpha(k)$ is defined as

$$\alpha(k) = \begin{cases} \frac{1}{\sqrt{N}}, & for \quad k = 0 \\ \frac{2}{\sqrt{N}}, & for \quad k \neq 0 \end{cases} \qquad (12)$$

Equation (10) can be expressed in matrix form as

$$X_c = C_N x \qquad (13)$$

Where X_c and $\mathbf{x}$ are both vectors of dimension $N \times 1$, and C_N is a DCT matrix of dimension $N \times N$. The rows (or column) of the DCT matrix, C_N are orthogonal matrix vectors. The basic idea behind the use of this DCT is that it can reduce the peak power of OFDM signals by using orthogonal property of the DCT matrix.

IV. STRATEGY OF PROPOSED TECHNIQUE

In this section, a crossover companding strategy (DFT precoding OFDM with PLC) is proposed to diminish the Problem caught in OFDM sign by method for joining DFT and PLC. To start with the approaching information changed through making utilization of Discrete Fourier Transform, after which this changed over data is actualized as contribution to IFFT sign preparing module. The OFDM framework with proposed approach is demonstrated in Figure 2.

The proposed system processing steps are given below:

Step1: Firstly DCT transform is applied to the sequence X i.e.

$$Y = HX$$

Where H is the Precoding matrix given in (12) as

$$H = \begin{bmatrix} p_{00} & \cdots & p_{0(N-1)} \\ \vdots & \ddots & \vdots \\ p_{(N-1)0} & \cdots & p_{(N-1)(N-1)} \end{bmatrix} \qquad (13)$$

Step2: Apply IFFT to DCT transformed signal, $y = ifft(Y)$, where $Y = [Y(1) \;\; Y(2) \;\; .... \;\; Y(N)]^T$

$$y_n = \frac{1}{\sqrt{NL}} \sum_{k=0}^{N-1} Y_k . e^{j2\pi\frac{kn}{NL}}, \quad 0 \leq n \leq NL-1 \qquad (14)$$

Step3: Apply Piecewise Linear Companding transform to y, i.e. $s(n) = C\{y(n)\}$

$$s(n) = C\{y(n)\} = \begin{cases} y(n) & |y(n)| \leq A_i \\ my(n) + (1-m)A_c & A_i < |y(n)| \leq A_c, \\ sgn(y(n))A_c & |y(n)| > A_c \end{cases} \qquad (15)$$

Now it is transmitted into Channel.

Step4: Apply Piecewise Linear Decompanding transform to the received signal $r(n)$, i.e. $\hat{y}(n) = C^{-1}\{r(n)\}$

$$\hat{y}(n) = C^{-1}\left(r(n)\right) = \begin{cases} r(n) & |r(n)| \le A_i \\ \left(r(n) - (1-m)A_c\right)/m & (1-m)A_c < |r(n)| \le A_c, \\ sgn(r(n))A_c & |r(n)| > A_c \end{cases} \quad (16)$$

Step5: Apply FFT transform to the signal $\hat{y}(n)$, i.e. $\hat{Y} = fft(\hat{y})$, where $\hat{y} = [\hat{y}(1)\ \ \hat{y}(2)\ \ ....\ \ \hat{y}(N)]^T$

Setp6: Apply inverse DCT transform to the signal $\hat{Y}$, i.e. $\hat{X} = H^{-1}\hat{Y}$.

Then the signal $\hat{x}$ is demapped to bit stream.

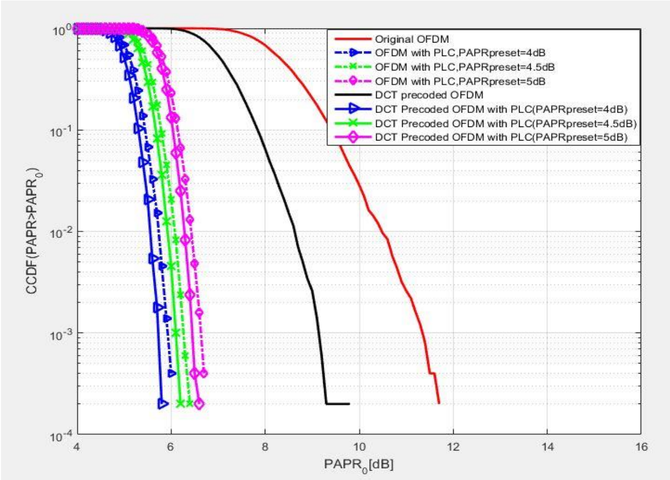

Fig.3. CCDF plot of proposed system along with conventional systems with 4-QAM

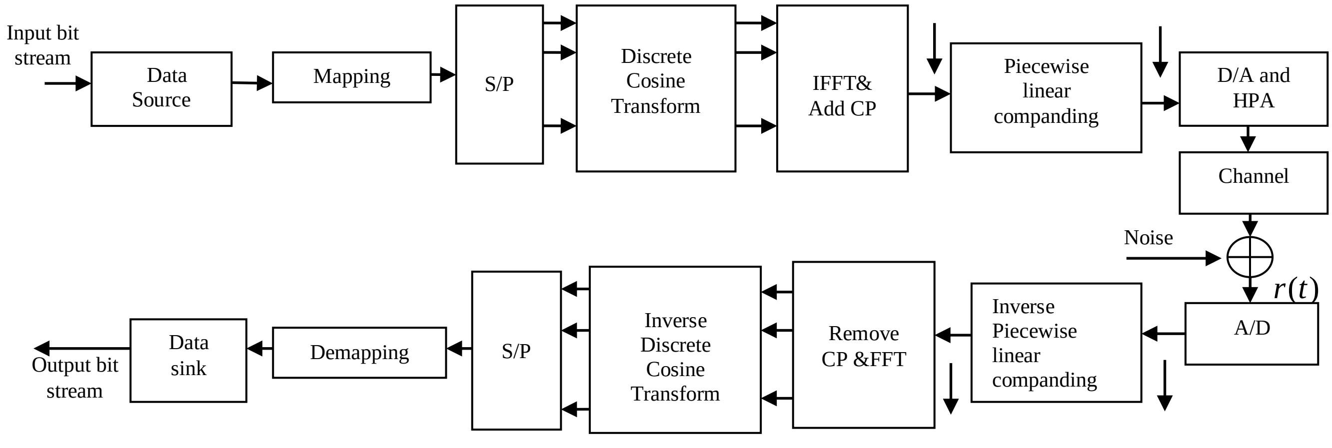

Fig.2 Block diagram of the Proposed Method (DCT Precoded OFDM with Piecewise Linear Companding).

V. SIMULATION RESULTS

MATLAB simulated results are conferred to assess the execution of the proposed procedure with reference to the Peak to Average Power Ratio diminishment, BER and also PSD execution. In this number of subcarriers to be taken are 256 and the over-sampling factor should be 4 with reference to the specifications of WiMAX (IEEE 802.16). M-ary QAM (M=4, 16, 64, 256) is adopted as mapping strategy here.
This SSPA model is formulated by

$$|y(t)| = \frac{|x(t)|}{\left(1+\left(\frac{|x(t)|}{Z_{sat}}\right)^{2k}\right)^{\frac{1}{2k}}} \quad (17)$$

Where Z_{sat} is the level of saturation, and knee factor *(k)* = 2.

A. Reduction in PAPR Capabilities

The PAPR improved characteristics of the proposed method along with the existing systems are simulated by using CCDF allowing 4-QAM, 16-QAM and 64-QAM are used as the mapping methodologies are depicted in the Figures 3,4 and 5.

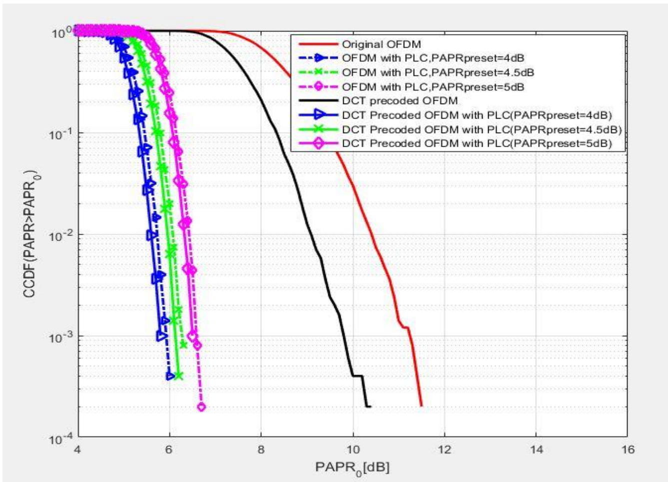

Fig.4. CCDF plot of proposed system along with conventional systems with 16-QAM

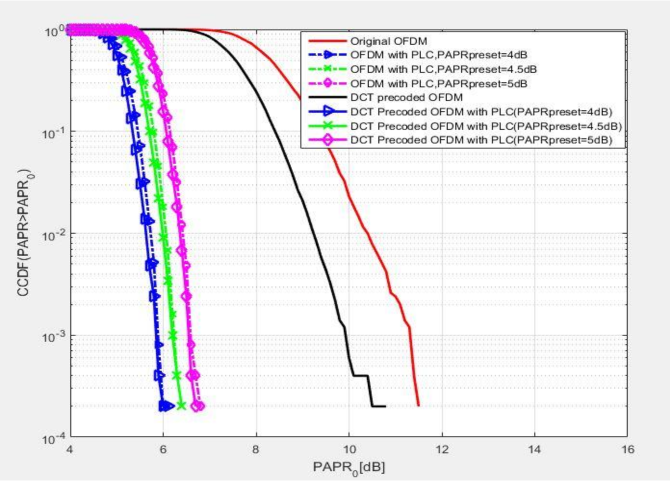

Fig.5. CCDF plot of proposed system along with conventional systems with 64-QAM

Table-1 tabulates the PAPR estimations for this proposed framework in comparison with existing systems over M-QAM (M=4, 16, 64)

TABLE I: PAPR VALUES

	4QAM	16QAM	64QAM
OFDM	9.4007	8.0096	7.7353
OFDM with PLC (X=4dB)	5.1565	5.0881	5.162
OFDM with PLC (X=4.5dB)	5.4893	5.4152	5.4758
OFDM with PLC (X=5dB)	5.8127	5.7745	5.861
DCT Precoded OFDM with PLC (X=4dB)	5.08	5.07	5.0563
DCT Precoded OFDM with PLC (X=4.5dB)	5.4644	5.4	5.4196
DCT Precoded OFDM with PLC (X=5dB)	5.79	5.78	5.8477

B. Improvement in Bit Error Rate Statistics

The proposed system's improved BER performance be depicted here along with the available existing system over M-ary QAM (M=4, 16) under Additive WGN Channel and figured in Figure-6 and 7. From this, the loved comment is that the BER execution is enhanced with FOUR-QAM regulation, with the current proposed strategy.

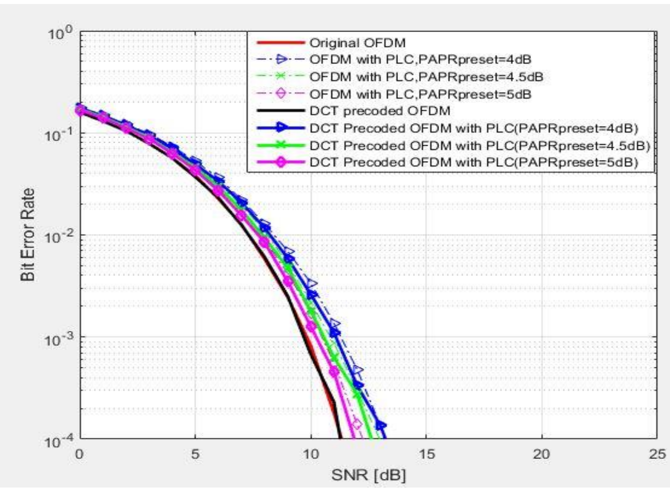

Fig.6. Proposed system's Enhanced BER in comparison with existing system using 4-QAM over AWGN Channel.

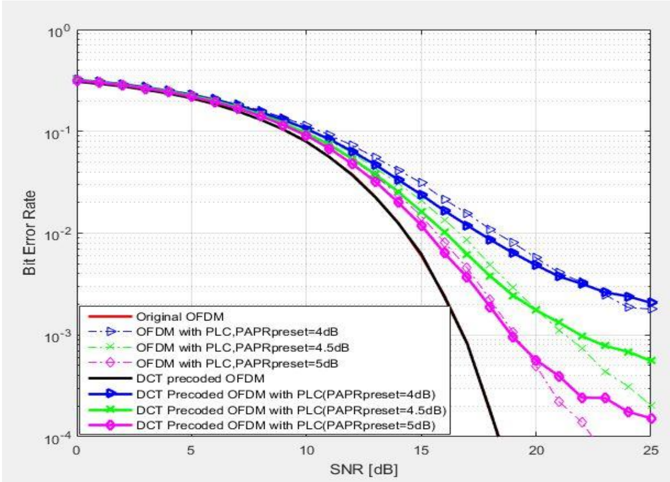

Fig.7. Proposed system's Enhanced BER in comparison with existing system using 16-QAM over AWGN Channel.

Fig.8, Fig.9 delineates the BER execution with 4-QAM, 16QAM as mapping alongside SSPA going through an AWGN channel. Significant perception from these is that the BER execution of this proposed strategy with Solid State Power Amplifier is adequate as well.

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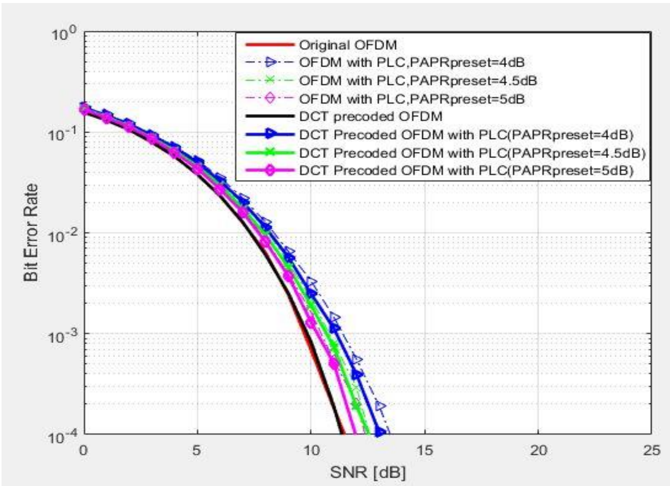

Fig.8. Proposed system's Enhanced BER in comparison with existing system using 4-QAM over AWGN Channel including SSPA.

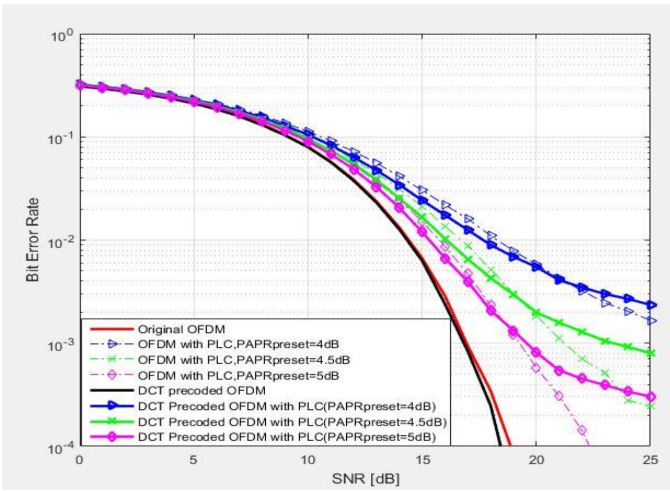

Fig.9. Proposed system's Enhanced BER in comparison with existing system using 16-QAM over AWGN Channel including SSPA.

Fig. 10-15 delineate the Bit Error Rate execution of this proposed strategy under SUI channels [11, 12], those are the Standardized Multi path fading channels as per Stanford University Interim.

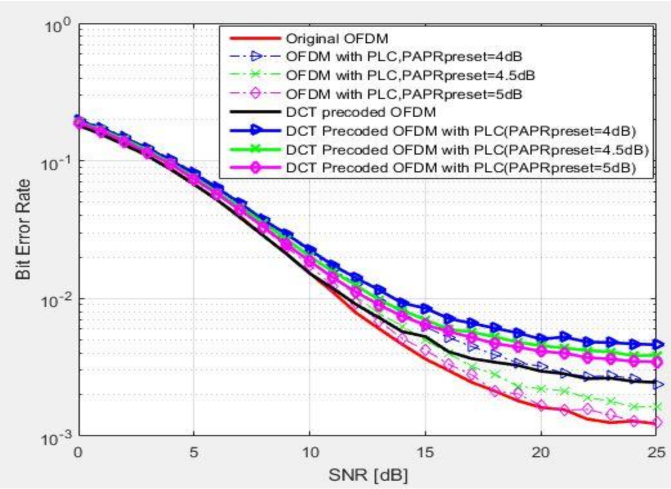

Fig.10. Proposed system's Enhanced BER in comparison with existing system using 4-QAM under SUI -1 Channel.

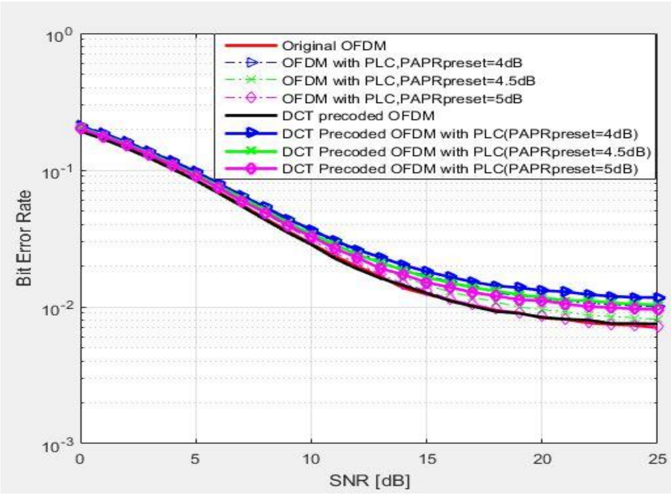

Fig.11. Proposed system's Enhanced BER in comparison with existing system using 4-QAM under SUI -2 Channel.

SUI channels as per the Tree densities present are tabulated in following Table.

TABLE-2 SUI CHANNELS TERRAIN CHARACTERISTICS

Terrain Type	Environment	SUI Channels
A	Moderate to Heavy amount of Obstruction (Hilly)	SUI-5,6
B	Medium amount of obstruction	SUI-3,4
C	Flat Terrain	SUI-1,2

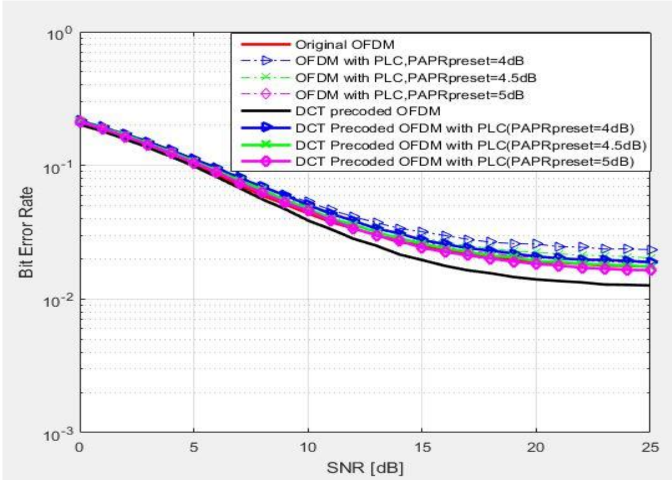

Fig.12. Proposed system's Enhanced BER in comparison with existing system using 4-QAM under SUI -3 Channel.

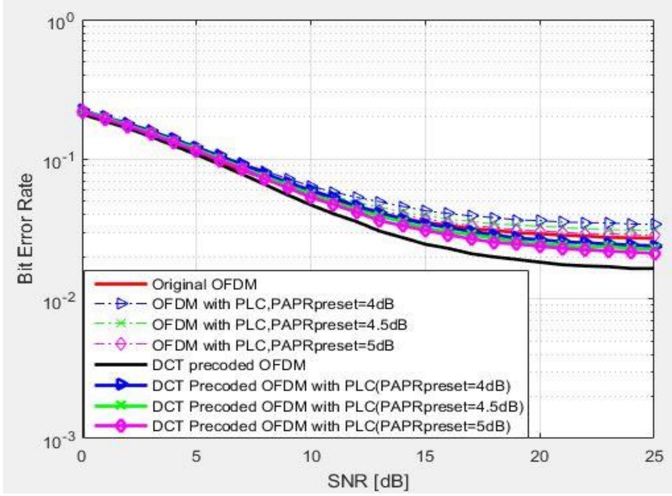

Fig.13. Proposed system's Enhanced BER in comparison with existing system using 4-QAM under SUI -4 Channel.

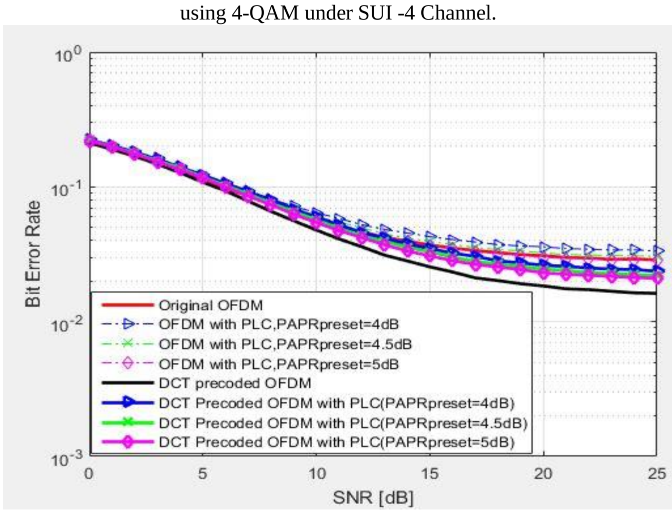

Fig.14. Proposed system's Enhanced BER in comparison with existing system using 4-QAM under SUI -5 Channel.

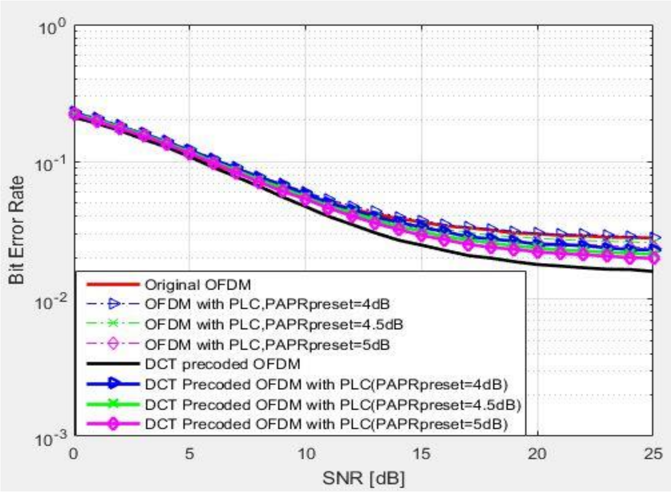

Fig.15. Proposed system's Enhanced BER in comparison with existing system using 4-QAM under SUI -6 Channel.

SUI-1 and SUI 2 have low delay spread because these two channels represent the terrain type C which is characterized by low tree density. Hence there are few obstructions in the signal propagation from a Source (Transmitter) to a Destination (Receiver). The other terrain types have moderate to high delay spread. All these contributing to the value of **K** -factor of the channel.The worthwhile observations from the results obtained from Figure 8 that this proposed strategy enhances the BER improvement over SUI Channels.

C.PSD PERFORMANCE

The proposed system's improved Power Spectral Density performance be depicted here along with the available existing system over M-ary QAM (M=4, 16, 64) and figured in Figures-16, 17 and 18.

VI. CONCLUSION

In this paper, a hybrid companding transform (DCT Precoded OFDM with PLC) is proposed aiming at reducing PAPR in OFDM signals and the Simulation results are compared with the existing Piecewise linear companding (PLC) technique. The PAPR is reduced by 0.7dB when considering the preset value as 4dB. The BER performance under an AWGN channel using 4-QAM is improved by 0.2dB and maintaining the same performance in 16QAM.This method shows improved performance over SUI -3 to SUI-6 channels. The PAPR reduction as well as the improvement in BER performance is achieved without sacrificing the PSD performance.

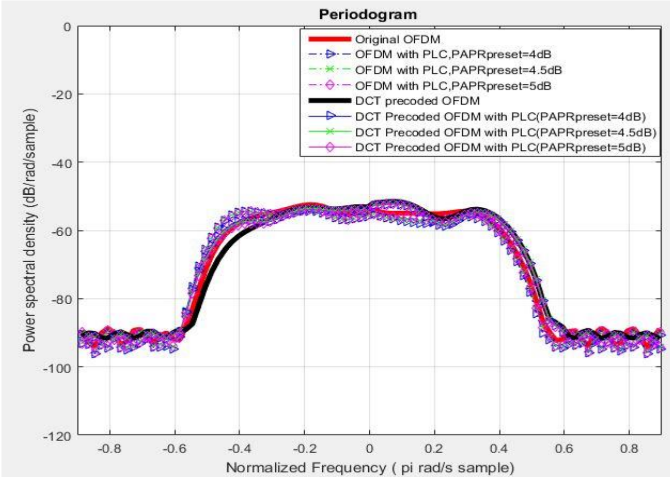

Fig.16. Performance of PSD for the Proposed system with conventional systems with 4-QAM

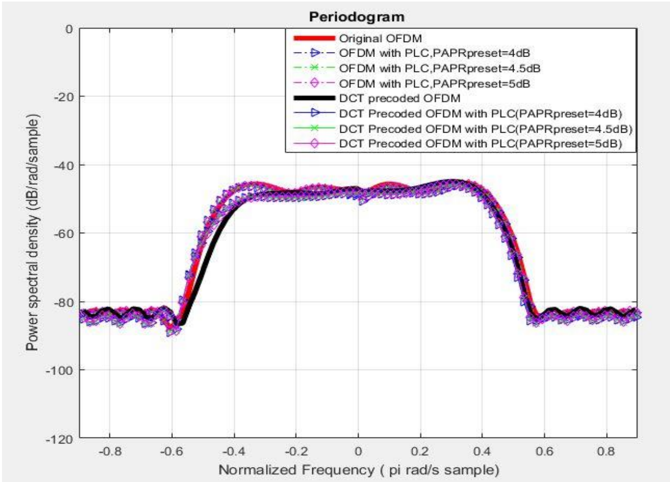

Fig.17. Performance of PSD for the Proposed system with conventional systems with 16-QAM

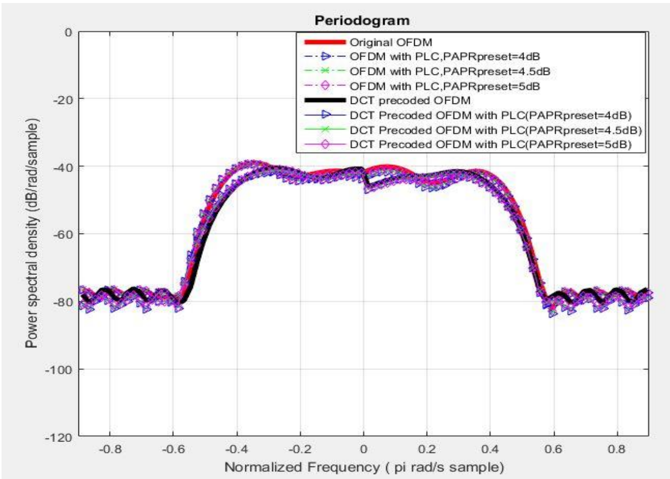

Fig.18. Performance of PSD for the Proposed system with conventional systems with 64-QAM

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