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THE BER PERFORMANCE OF OFDM SIGNAL THROUGH MULTIPATH CHANNELS (AWGN, RAYLEIGH & RICIAN) BY USING CLIPPING

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ABSTRACT

To transmit vast digital data over radio waves OFDM is the best digital modulation method. The time domain OFDM signal, that is, addition of different orthogonal sinusoids, tends to high peak to average power ratio (PAPR) which is critical to OFDM system. Clipping is the method to limit the PAPR of an OFDM signal before amplification, but in which hoist the enormous bit error rate of the received OFDM signal. The continuous function of OFDM transmission is measured by enumerating the probability of bit error rate versus signal noise ratio (SNR) beneath multipath channel models (Rician, Rayleigh and AWGN). The simulation result has demonstrated the performance of OFDM signal, underneath various channel models. We can conclude that AWGN channel is the best model when compared to Rayleigh and Rician channels.

Key words: AWGN, BER, OFDM, PAPR, Rayleigh, Rician and SNR

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1. INTRODUCTION

The performance of wireless systems can be evaluated by considering the transmission characteristics, constraints of multipath channels. The disadvantage of high PAPR is experiential in OFDM system due to Inverse Fast Fourier Transform (IFFT) operation. The intensity dynamic range of transmitting signal is because of inherent properties of multicarrier transmission system [1]. When a high dynamic sequence of OFDM signals is transmitted through a non-linear amplifier the OFDM signal causes significant distortion. To diminish the

PAPR, the number of techniques has been proposed [2]. Here, the clipping method provides significant improvement in PAPR reduction with a surge in Bit Error Rate.

The data transmission efficiency over wireless channels is carried out by calculating BER which is the function of SNR at the receiver. All the wireless channel models are function of distance between the sender and the receiver, the channel gain and the path loss exponent. There are different standard probabilities distributed functions which are time-variant parameters. This paper mainly deals with frequently used distributions. There are Rayleigh, Rican and AWGN wireless channel models. The detection of the signal is done by various replicas of receiving signals.

2. FUNDAMENTAL OF OFDM SYSTEM AND FADING CHANNELS

2.1. ODFM System

The sum of N independent sub-carriers of same bandwidth forms the OFDM signal, which can be easily implemented by the Inverse Fast Fourier Transform operation as shown in figure1. Here, assume $S^i = \{S^i(l)\}_{l=0}^{M-1}$ as the frequency domain complex data sequence, after PSK/QPSK modulation scheme over the l^{th} sub-carrier, $l = \{0, 1, 2\ldots N-1\}$to be transmitted in the i^{th} OFDM symbol. After that the time-domain signal $s^i = \{s^i(m)\}_{m=0}^{M-1}$ is given by equation(1).Where l and m are the frequency and time indices of OFDM signal respectively.

$$s^i[m] = \frac{1}{\sqrt{N}} \sum_{l=0}^{M-1} S^i[l] e^{j\frac{2\pi}{N}mn} \quad 0 \le n \le M-1 \qquad (1)$$

The frequency-domain QPSK/PSK modulated sequence $S = \{S(m)\}_{m=0}^{M-1}$ are not dependent and identically distributed (IID) random sequences and because of central limit theorem operation, samples acquire very large magnitudes, low amplitude of samples are enough to operate an amplifier in the linear region.

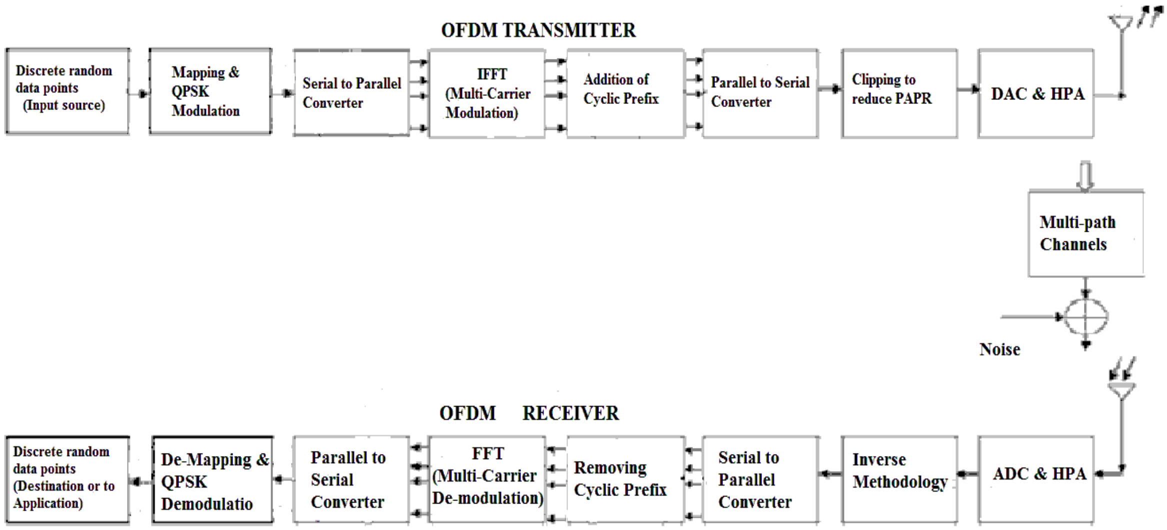

Figure 1 OFDM signal transmission and reception block diagram

This results in the well-known PAPR problem of OFDM systems. In common, the PAPR ($\mathcal{P}$) of the time-domain sequence s = {s[n]} is defined as the ratio between the maximum instantaneous power and its average power [3] as shown below equation (2)

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

Where, E {·} denotes a statistical average value. In the literature, the most frequent way to measure the PAPR is to find the probability in which PAPR exceeds a desired threshold v_{th}. This is characterized by the Complementary Cumulative Distribution Function (CCDF) is a random variable as shown below equation (3)

$$CCDF\left[PAPR\left(s^i(n)\right)\right] = Prob[PAPR\left(s^i(n)\right) > v_{th}] \quad (3)$$

2.2. Fading Channels

The wireless channels face various fading phenomena at the time of signal transmission known as a communication channel. In the real modern world environment, the radio propagation effects the multi-path signals generated by the fading channels. Multiple signals are received by the receiver due to multiple signal propagation paths and the resultant received signal is the vector sum of all transmitted signals from an OFDM transmitter. Which are arriving from any direction and incident of angle. In multipath environment, some signals assistance the nature of constructive path and some others nature of destructive path [4].

2.2.1. Rayleigh Fading

Let us consider a simple communication channel as shown in below figure2. It consists of an input signal s (t) which passes through a wireless channel whose channel coefficient is given as an impulse response h (t). The output signal is represented as y(t).

Figure 2 Simple wireless communication channel

From the definition of superposition theorem the multipath response is equal to the sum of individual responses.

Therefore, $h(t)=a_0\,\delta(t-T_0)+ a_1\,\delta(t-T_1)+ a_2\,\delta(t-T_2)+\ldots\ldots a_L\,\delta(t-T_L)$ (4)

It can be written as, $h(t) = \sum_{i=0}^{L-1} a_i\delta(t-\tau_i)$ (5)

Where a_i and τ_i are the attenuation and delay of the i^{th} path respectively. After modulation the received pass band signal over a wireless communication channel is

$$y(t) = \sum_{i=0}^{L-1}[Re\{a_i s(t-\tau_i)\}e^{j2\pi fc(t-\tau_i)} \quad (6)$$

From equation (6), after narrow band assumption $s(t-\tau_i) \cong s(t)$ the complex channel coefficient depends on the attenuation and propagation delay respectively (a_i, τ_i) as shown in below equation7.

$$h = \sum_{i=0}^{L-1} a_i e^{-j2\pi f_c \tau_i} \quad (7)$$

When only unintended paths exist between the source and destination without line of sight path, then the received signal will be the vector sum of whole scattered and reflected signals. The signal amplitude lost due to several signals at the various phases because of multipath propagation environment. These phase changes are the result of different distance travelled along with distinct paths. As a result the received signal amplitude has intense fluctuations which are random variables. The Rayleigh distribution is a familiar distribution for fast fading.

The assumption made here is that the similar attenuation is maintained by all signals at unlike phases. The random variable “a” corresponds to signal amplitude and σ^2 corresponds to variance of in-phase and quadrature components. The distinguishing part of a sequence or cycle over the time of the received signal is typically held to be uniformly distributed on (0,2π) [5].

Now let us consider $x = a\cos\Phi$ and $y = a\sin\Phi$ then the amplitude distributed function is given as $F_{A,\emptyset} = \frac{1}{\pi} e^{-a^2} |J_{xy}|$. Where $|J_{xy}|$ is a Jacobin coefficient for polar conversion.

$$|J_{xy}| = \begin{vmatrix} \frac{\partial x}{\partial a} & \frac{\partial y}{\partial a} \\ \frac{\partial x}{\partial \emptyset} & \frac{\partial y}{\partial \emptyset} \end{vmatrix} = \begin{vmatrix} \cos\emptyset & \sin\emptyset \\ -a sin\emptyset & a\, cos\emptyset \end{vmatrix} = \qquad (8)$$

$$\therefore F_{A,\emptyset}(a,\emptyset) = \frac{1}{\pi} e^{-a^2} a = \frac{a}{\pi} e^{-a^2} \qquad (9)$$

The marginal distribution of a random variable is

$$\mathrm{F_A(a)} = 2ae^{-a^2} \qquad (10)$$

2.2.1.1. Bit Error Rate

Bit error rate is an important parameter to analyses the performance of any communication system. If a system is affected by noise, then the reliability of the system decreases and the performance of the system also decrease. For any simple wireless communication, the received signal

$$\mathrm{y = h.s + n} \qquad (11)$$

The receiver power is given by $|h|^2 s^2$. Where s^2 is the transmitted signal power, the Channel coefficient $h = ae^{j\emptyset}$, $|h| = a$. Now the SNR with fading is given by

$$(SNR) = \frac{s^2 a^2}{\sigma^2} \qquad (12)$$

$$BER_{BPSK} = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \qquad (13)$$

$$BER_{BPSK} = Q\left(\sqrt{SNR}\right) \qquad (14)$$

$$BER_{BPSK,RAYLEIGH} = Q(\sqrt{a^2\, SNR}) \qquad (15)$$

$$Average\ Bit\ Error\ Rate = \int_0^\infty Q\left(\sqrt{SNR}.a\right).F(A).da \qquad (16)$$

$$= \int_0^\infty Q(\sqrt{SNR}.a^2)\, 2ae^{-a^2} da \qquad (17)$$

After simplification the average bit error rate for Rayleigh distribution is given below equation 18

$$BER = \frac{1}{2}(1 - \sqrt{\left(\frac{SNR}{2+SNR}\right)} \quad (18)$$

2.2.2. Rician Fading

It occurs when Line of Sight (LOS) is present away with the Non- Line of Sight (NLOS) path in between the source and destination, i.e. the received signal is a combination of both straight and scattered multipath signals. Here' we modelled a narrow band broadcast channel by considering a sinusoidal transmitted carrier

$$s(t) = Re\{e^{j2\pi f_c t}\} \quad (19)$$

A Rician multipath channel can be expressed for received signal as shown below equation 20

$$v(t) = C.Re\{e^{j2\pi f_c t}\} + S^L r_l \cos(\omega_c t + \emptyset_l) \quad (20)$$

Where, the amplitude of the line of sight component is represented as C. r_l and $\emptyset_l$ are the amplitude and phase of the l^{th} reflected wave respectively, L identifies the number of reflected and scattered waves. The derivation of rician fading is related to Rayleigh fading. Where we go for the calculation of probability density function of the received OFDM signal and observed the random process I(t) and Q(t) at particular instant of time t_0.The joint pdf is given as

$$f_{p,\theta}(p,\theta) = \frac{\rho}{2\pi\sigma^2} \exp\left(-\frac{(\rho^2 - 2.C.\rho.cos\theta + C^2)}{2\sigma^2}\right) \quad (21)$$

Here σ^2 is an average scattered and reflected power which is given by $0.5C^2$.Where C is the dominant component. The pdf of the magnitude is obtained from the integral. Where robust LOS signal component exists, then we found the distribution to be Rician, the probability density function is given by equation 23.

$$f_\rho(\rho) = \int_0^{2\pi} f_{\rho,\theta}(\rho,\theta) d\theta \quad (22)$$

$$= \frac{\rho}{\sigma^2} \exp\left(-\frac{\rho^2 + C^2}{2\sigma^2}\right) I_0\left(\frac{C.\rho}{\sigma^2}\right) \quad (23)$$

Where, σ is the standard deviation of in-phase and quadrature phase components. The amplitude of the dominant path signals and the zero-order modified Bessel function are represented by C and I_0 respectively. Generally the dominant path significantly makes less than the depth of fading in terms of BER and Rican fading results in the better functioning than Rayleigh fading. An occurrence of line-of-sight (LOS) components depends on the size of the cell site and environments. If there is smaller cell site, there is a chance to higher the probability of LOS path. Rician probability density function said to be a Rayleigh pdf if there is no dominant path between source and destination. When C is large associated with standard deviation σ, the distribution is approximately Gaussian distribution. Thus, all the properties of Rician distribution cover Gaussian and Rayleigh distributions.

2.2.3. AWGN Channel

The transmitted signal affected by the noise when a transmitted signal passes through the channel. The channel contains an unvarying frequency spectrum over specific frequency band. Based on the assumption that the in-phase and quadrature phase components are statistically independent [6].

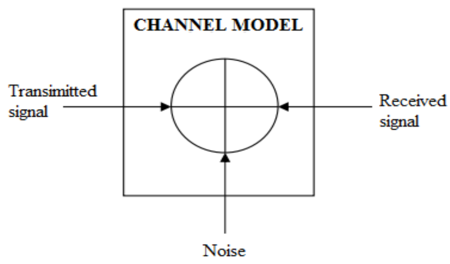

Figure 3 Communication channel model

Where, wide sense stationary Gaussian noise process has null mean and double-sided power spectral density $N_O/2$ (power per unit frequency). Zero-mean Gaussian noise is completely characterized by its variance, this is the simple method to use and recover the received signals and it is the best design of optimum receiver. The performance of any modulation scheme can be measured by bit error probability P_b also referred as BER. In a slow flat fading channel the BER performance of any digital modulation scheme can be calculated by the following equation 24

$$P_b = \int_s^{\infty} P_{b,AWGN}(\gamma) P_{df}(\gamma) d\gamma \tag{24}$$

The probability of error of a specific modulation system is represented as $P_{b,AWGN}$ with specific signal-to-noise ratio $\gamma = h^2 \frac{E_b}{N_o}$.Where, h is the gain of the channel, E_b/N_0 represents the bit energy to the noise power density of a non-fading AWGN channel ratio. The random variable h^2 represents an instantaneous power and the probability density function P_{df} which is a function of γ of the fading channel

For M-ary PSK the BER of AWGN channel is given as

$$BER_{MPSK} = \frac{2}{max(log_2 M, 2)} \sum_{k=1}^{max(\frac{M}{4},1)} Q\left(\sqrt{\frac{2E_b log_2^M}{N_0}} sin \frac{(2k-1)\pi}{M}\right) \tag{25}$$

For coherent detection of binary PSK equation M=2 shrinks to $BER_{BPSK} = Q\left(\sqrt{\frac{2E_b}{N_0}}\right)$ (26)

$$Q(s) = \frac{1}{\sqrt{2\pi}} \int_s^{\infty} exp\left(-\frac{y^2}{2}\right) \tag{27}$$

The equation can be rewritten as

$$BER_{BPSK,AWGN} = \frac{1}{2} erfc\left(\sqrt{\frac{E_b}{N_0}}\right) \tag{28}$$

3. CLIPPING

The simplest method in OFDM system for PAPR reduction is clipping. In this method high peaks of OFDM signals are pruned prior to passing through power amplifier. This method is called clipping. With clippers we can reduce the signal high peaks to threshold level (v_{th}), if the signal crosses above v_{th} then clipper limit the signal up to predetermined level otherwise clipper passes the signal contently. The clipped signal is given by equation (29)

$$y[n] = \begin{cases} -v_{th} & if\ s[n] < -v_{th} \\ s[n] & if\ -v_{th} \leq s[n] \leq v_{th} \\ v_{th} & if\ s[n] > -v_{th} \end{cases} \quad (29)$$

Where, an OFDM signal is denoted by s[n], the clipping level is denoted by v_{th}. The clipping is a non-linear method that causes out-of-band and in-band distortions to the transmitted OFDM signal [7]. Where in-band distortion can degrade the performance of bit error rate and out-of-band distortion causes interference of the adjacent channel to the band pass signal. Here, the figure (3) and figure (4) shows the simulation results of an OFDM signal without and with clipping respectively.

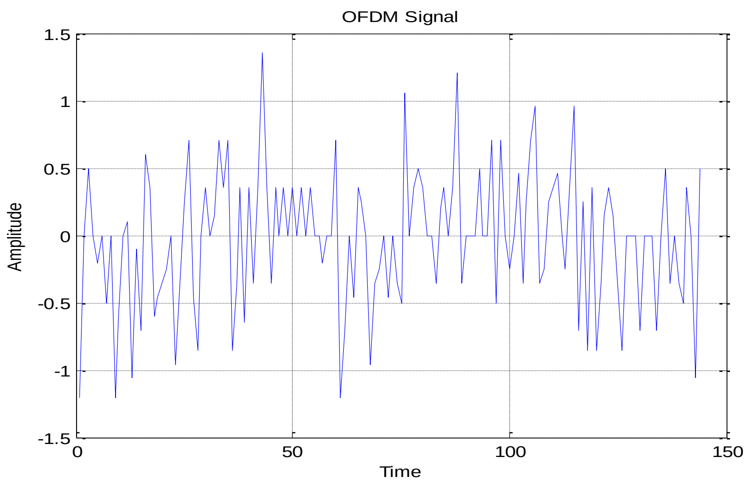

Figure 4 OFDM signal without clipping at N=1024

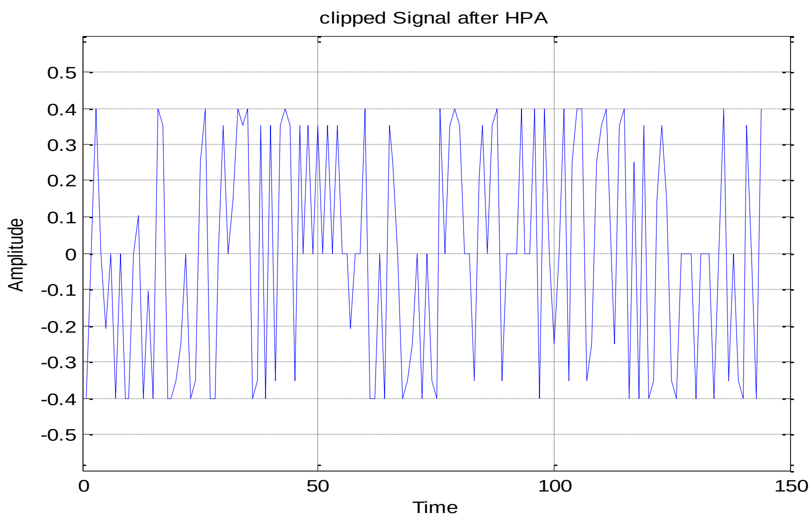

Figure 5 OFDM signal with clipping at N=1024

Basically, in slicing the high peaks of signal amplitude are removed, which reduces the peak power of the transmitted OFDM signal. Hence, PAPR is reduced in transmitted OFDM signal after peak power reduction.

4. SIMULATION RESULTS

In this section, discusses and presents all the results obtained out comes with the computer simulation program coded in MATLAB7.5. At this point, wireless communication system analytical approach is done by considering the Rician, Rayleigh and AWGN fading channels. The simulations are conducted for the transmitted OFDM signal with clipping and without clipping.

In Figure6, there is two curves represent a comparison between the OFDM signal transmission without and with clipping. Where, we observed after clipping there is an obvious drop in the PAPR of the OFDM signal. Figure5 illustrates the PAPR is nearly 12dB for the unclipped signal at CCDF of 10−1. PAPR is decreased to 10dB after applying clipping algorithm to the OFDM signal for the same values of CCDF.

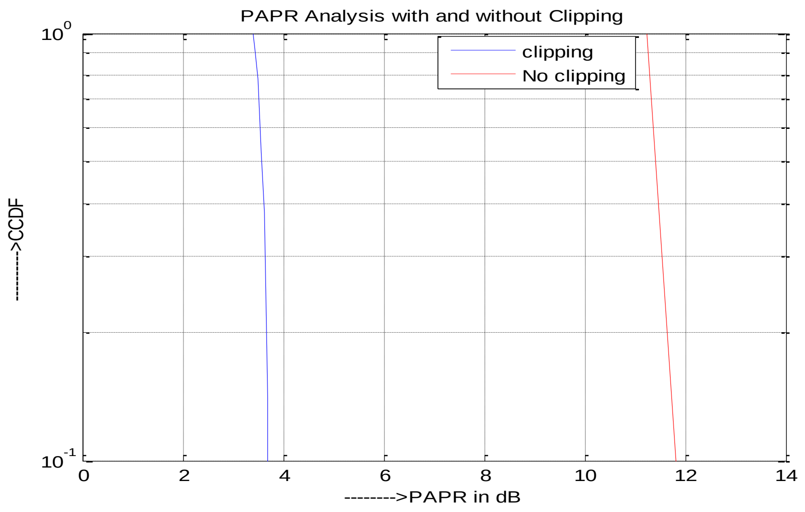

Figure 6 PAPR reduction without and without clipping

In this contrast, the bit error rate performance is degraded poorly as shown in Figure7 as it gets better when the OFDM signal propagated through the AWGN channel. The performance of BER for the clipped and unclipped OFDM signal with respect to the signal to noise ratio (SNR) is related to the BER as shown in figure 7. It is observed that clipped OFDM signal has a high bit error rate than compared to unclipped OFDM signal when propagating through any channel. It is clear that the OFDM system performance is degraded with clipping method. The BER of the clipped signal is 0.02754 at 4 dB SNR and the BER of the unclipped signal is 0.0000156 at 4 dB SNR for AWGN channel.

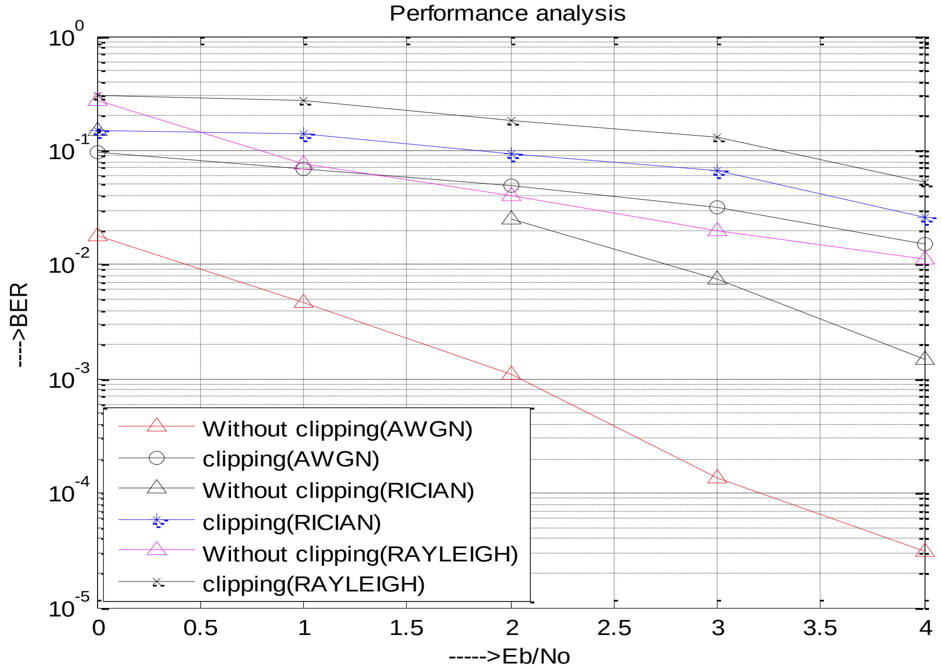

Figure 7 BER performance without and with clipping through AWGN, rayleigh & rician channels

From table1, we observed that the Rician fading channel is better than the Rayleigh fading channel because there exist line of sight and non-line of sight paths in between the source and destination that is the received signal covers both the direct and scattered multipath signals from wireless environment. Simulation results in figure 7 shows the performance of the OFDM system over AWGN and fading (Rayleigh & Rician) channels with clipping technique. From the results, we have noticed that the BER performance is improved by using AWGN channel and outperforms when compared to Rayleigh & Rician channels from the following table1.

Table 1 Comparison of bit error rate for different channels

Type of the Channel	Bit error rate value without clipping	Bit error rate value with clipping
AWGN Channel	0.0000156	0.02754
RICIAN channel	0.0060630	0.03852
RAYLEIGH Channel	0.0110620	0.07703

5. CONCLUSIONS

Hence, we conclude that the efficient multi-carrier digital modulation technique is OFDM. Due to high data rates and efficient spectrum utilization, which is suitable for both wired and wireless communications. Where, the negative aspect of OFDM is high peak to average power ratio due to IFFT operation at the transmitter.

At transmitter the power amplifier operated at saturation because of the high peaks of OFDM signal which causes non-linear distortion and spectral spreading. With the intention to reduce the effects of high PAPR in OFDM system, clipping is a better technique. The peaks of the OFDM signals are clipped by applying the clipping method, where PAPR reduces significantly by 10 dB, but the enormous increase in Bit Error Rate of received signals. From the results, we have perceived that the performance of BER is better using AWGN channel and outperforms when compared to Rayleigh and Rician channels.

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