Volume 3, Issue 6, June 2013 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Performance Analysis of Synchronization on Orthogonal Frequency Division Multiplexing Communication System

Namisha Rani*, Mohit Mehta
Department of Electronics & Communication Engineering
Punjab college of Engineering & Technology, Lalru, India

Absract - Orthogonal frequency division multiplexing signal suffer from high peak to average power ratio. This high peak to average power ratio results in the operation of the power amplifier in saturation region. Orthogonal frequency division multiplexing signals may also result in out band distortion due to overlapping of side lobes. Thus guard band is inserted to reduce the out band radiation. Cyclic prefix and zero padding are methods to insert guard interval Orthogonal frequency division multiplexing signal. In this paper these guard interval techniques has been studied and analyzed in detail and bit error performance of Orthogonal frequency division multiplexing system with 64 point Fast Fourier Transform has been analyzed for different values of cyclic prefix. From the study it has been concluded that bit error rate performance in an Additive White Gaussian Noise channel is less as compare to the Raleigh fading channel as the length of cyclic prefix is increased. Crest factor is an important parameter for calculation of peak to average power ratio which is equal to square root of peak to average power ratio. In this Paper, simulation have also been carried out for the measurement of crest factor for clipped, clipped & filtered Orthogonal frequency division multiplexing signal. Clipping is most widely technique for peak to average power ratio reduction. But it results in clipping distortion which can be filtered out by using pulse shaping filter. This Paper also presents the bit error rate performance of the clipped and clipped & filtered techniques. Results shows that clipping ratio has significant effect on peak to average power ratio, smaller the clipping ratio the greater is the peak to average power reduction effect. Results also show that bit error rate performance decreases as clipping ratio decreases.

Keywords: Cyclic Prefix, Guard Interval, OFDM, PAPR

I. INTRODUCTION

Wireless communications is regarded as the most important development with wide range of applications. Advances and development in this field aim for fast and reliable communication. Multi Input Multi Output- Orthogonal frequency division multiplexing (MIMO-OFDM) system provides high data streams of radio links. MIMO system uses orthogonal frequency division multiplexing (OFDM) as modulation technique [1]. OFDM is a multicarrier transmission scheme which facilitates high data rate transmission and provides with spectral efficiency. OFDM has been proposed in various wireless communication standard such as IEEE 802-11a standard for wireless Local Area Network (WLAN), IEEE-16a Standard for wireless Metro politician Area Network (WMAN), digital audio/video broadcasting systems in Europe. Single carrier transmission scheme is not useful for a high data rate wireless transmission because such transmission requires a high complexity equalizer to deal with the inter-symbol interference problem. Multiple carriers can be used for high rate data transmission to overcome the frequency selectivity of the wideband channel experienced by single-carrier transmission. An OFDM signal can have a high peak-to-average power ratio (PAPR) at the transmitter, which causes signal distortion such as in-band distortion and out-of band radiation due to the nonlinearity of the high power amplifier (HPA) and a worse bit error rate (BER) [2]. Advantages of OFDM system has many advantages such as High spectral efficiency, Simple implementation by Fast Fourier transform (FFT), Low receiver complexity, Robust ability for high data rate transmission over multipath fading channel, High flexibility in terms of link adaptation, Low complexity multiple access schemes such as orthogonal frequency multiple access (OFDMA). Disadvantages of OFDM system like Relatively higher peak to average power ratio (PAPR) compared to single carrier system, which tends to reduce the power efficiency of the RF amplifier, Sensitive to frequency offsets, timing errors and phase noise [3].

This paper is organized in the following way:Section 2 gave the overview of OFDM. Section 3 explain the detail of OFDM Parameters. In this section we also explained the different parameters like guard interval,. Complementary Cumulative Distribution Function (CCDF), measurement of crest factor using CCDF plots. In next Section explained the simulation result shown that BER performance analysis for OFDM system with 16-QAM and varying CP. Finally, in section 5 explained the conclusion of best results for better understanding of the mentioned system.

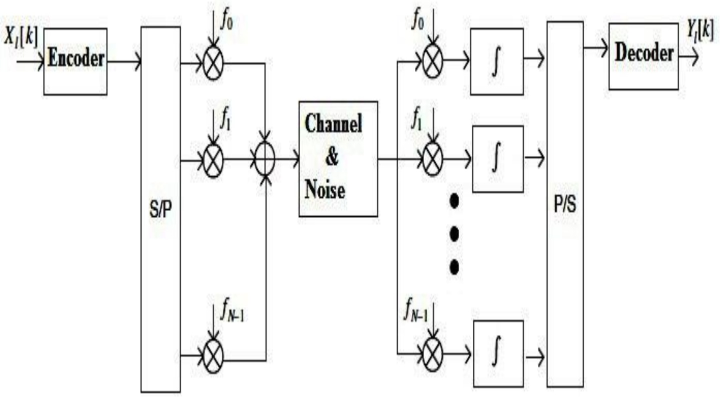
II. BASICS OF OFDM

OFDM is a method of digital modulation in which a signal is split into several narrowband channels at different frequencies. The technology was first conceived in the 1960s and 1970s during research into minimizing interference among channels near each other in frequency.

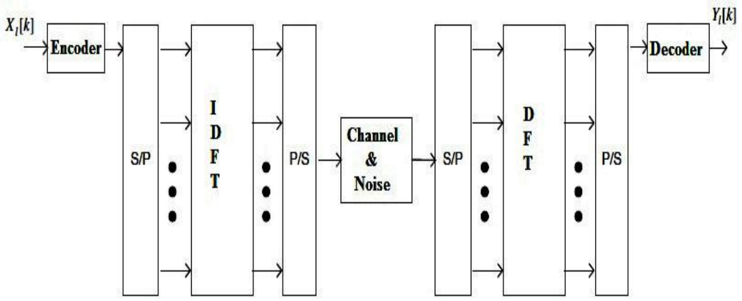
A. *OFDM Transmission Scheme:*

Orthogonal frequency division multiplexing (OFDM) transmission scheme is similar to the FMT transmission scheme only in the sense that it employs multiple subcarriers. Fig 1 shows the overview of OFDM transmission scheme. OFDM does not use individual bandlimited filters and oscillators for each subchannel and the spectra of subcarriers are overlapped for bandwidth efficiency. On the contrary in FMT scheme the wideband is full divided into N orthogonal narrowband subchannels. The multiple orthogonal subcarrier signals, which are overlapped in spectrum, can be produced by generalizing the single-carrier Nyquist criterion in equation (1) into the multi-carrier criterion.

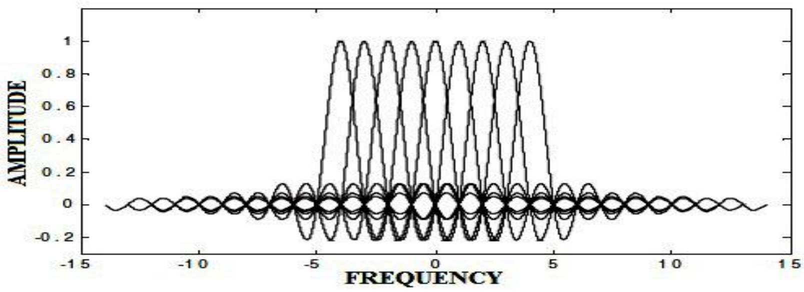
$$\sum_{i=-\infty}^{\infty} G\left(f - \frac{i}{T} \right) = T \qquad (1)$$



(a) Overview of OFDM Transmission scheme



(b) IDFT/ DFT implementation of OFDM scheme



(c) The spectrum of OFDM signal

Fig 1 Structural and spectral characteristics of OFDM Transmission scheme

Practically, discrete Fourier transforms (DFT) and inverse DFT (IDFT) processes are useful for implementing these orthogonal signals. Fig 1(b) shows the IDFT/DFT implementation of OFDM scheme. The DFT and IDFT used can be implemented efficiently by using fast Fourier transform (FFT) and Inverse Fast Fourier Transforms (IFFT). Fig 1 (c) shows the spectrum of OFDM signal. The spectrum of the OFDM signal can be considered as the sum of the frequency shifted sinc functions in the frequency domain, all subcarriers being of the finite duration T.

III. OFDM PARAMETERS

A. *Guard Interval:*

Orthogonality can be defined for two signals if the integral of the products for their common (fundamental) period is zero. Mathematically it can be defined as:

$$\frac{1}{T_{sym}}\int_0^{T_{sym}} e^{j2\pi f_k t} e^{-j2\pi f_i t} dt = \frac{1}{T_{sym}}\int_0^{T_{sym}} e^{j2\pi\frac{k}{T_{sym}}t} e^{-j2\pi\frac{i}{T_{sym}}t} dt$$

$$= \frac{1}{T_{sym}}\int_0^{T_{sym}} e^{j2\pi\frac{(k-i)}{T_{sym}}t} dt \qquad = \begin{cases} 1, & \forall \text{ integer } k=i \\ 0, & \text{otherwise} \end{cases} \tag{2}$$

In equation (2) the time-limited complex exponential signals $\{e^{j2\pi f_k t}\}_{k=0}^{N-1}$ is considered which represent the different subcarriers at $f_k = k / T_{sym}$ in the OFDM signal, where $0 \le t \le T_{sym}$. Equation (2) can be written in the discrete time domain taking the discrete samples with the sampling instances at $t = nT_s = nT_{sym} / N$, n = 0, 1, 2... N-1 as:

$$\frac{1}{N}\sum_{n=0}^{N-1} e^{j2\pi\frac{k}{T_{sym}}nT_s} e^{-j2\pi\frac{i}{T}nT_s} = \frac{1}{N}\sum_{n=0}^{N-1} e^{j2\pi\frac{k}{T_{sym}}\frac{nT}{N}} e^{-j2\pi\frac{i}{T_{sym}}\frac{nT_{sym}}{N}}$$

$$= \frac{1}{N}\sum_{n=0}^{N-1} e^{j2\pi\frac{(k-i)}{T_{sym}}n} \qquad = \begin{cases} 1, & \forall \text{ integer } k=i \\ 0, & \text{otherwise} \end{cases} \tag{3}$$

Orthogonality is an essential condition for the OFDM signal to be ICI-free.

B. *OFDM Guard Interval:*

An OFDM signal may incur out-of-band radiation, which causes non-negligible adjacent channel interference (ACI). It is clearly seen from Fig 2 that the first side lobe is not so small as compared to the main lobe in the spectra. Therefore, OFDM scheme places a guard band at outer subcarriers, called virtual carriers (VCs), around the frequency band to reduce the out-of band radiation [3]. The OFDM scheme also inserts a guard interval in the time domain, called cyclic prefix (CP), which mitigates the inter-symbol interference (ISI) between OFDM symbols [4].

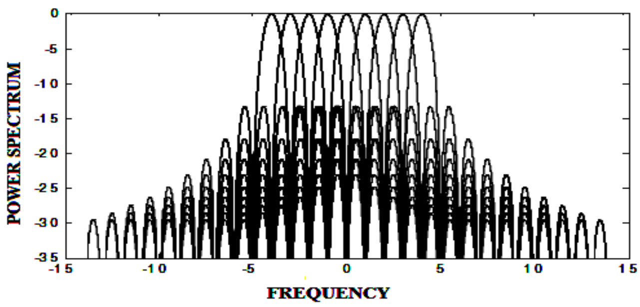


Fig 2 Power spectrum of OFDM signal (dB)

The OFDM guard interval can be inserted in two different ways. One is the zero padding (ZP), that pads the guard interval with zeros. The other is the cyclic extensions of the OFDM symbol with cyclic prefix (CP) or cyclic suffix (CS) [5].

C. *BER of OFDM Scheme:*

The analytical BER expressions for M-ary QAM signaling in AWGN and Rayleigh channels are respectively given as

$$P_e = \frac{2(M-1)}{M\log_2 M} Q\left(\sqrt{\frac{6E_b}{N_o}\cdot\frac{\log_2 M}{M^2-1}}\right) \tag{4}$$

For AWGN channel and for Rayleigh fading channel its

$$P_e = \frac{M-1}{M\log_2 M}\left(1-\sqrt{\frac{3\gamma\log_2 M/(M^2-1)}{3\gamma\log_2 M/(M^2-1)+1}}\right) \tag{5}$$

Where γ and M denote $\frac{E_b}{N_o}$ and the modulation order, respectively [6]. Q(.) is the standard Q function defined as

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_{x}^{\infty} e^{-t^2/2} dt \tag{6}$$

If N_{used} subcarriers out of total N (FFT size) subcarriers (except $N_{vc} = N - N_{used}$ virtual subcarriers) are used for carrying data, the time-domain SNR, SNR_t, differs from the frequency-domain SNR, SNR_f ,[2] as:

$$SNR_t = SNR_f + 10\log\frac{N_{used}}{N}[dB] \tag{7}$$

D. *CCDF Measurement Of OFDM Signals:*

Compared with single-carrier systems, OFDM systems are known to have a high PAPR (Peak-to-Average Power Ratio) because the transmit signals in an OFDM system can have high peak values in the time domain since many subcarrier components are added via an IFFT operation. Decreasing the SQNR (Signal-to-Quantization Noise Ratio) of ADC (Analog-to-Digital converter) and DAC (Digital-to-Analog Converter) while degrading the efficiency of the power amplifier in the transmitter the high PAPR is considered one of the most detrimental aspects in the OFDM system. In the uplink the efficiency of power amplifier is critical due to the limited battery power in a mobile terminal hence the PAPR problem is more important.

E. *Peak-to-Average Power Ratio (PAPR):*

PAPR is the ratio between the maximum power and the average power of the complex pass band signal $\tilde{s}(t)$ [7], that is,

$$PAPR\{\tilde{s}_I(t)\} = \frac{\max\left|\mathrm{Re}(\tilde{s}_I(t)e^{j2\pi f_c t}\right|^2}{E\{\left|\mathrm{Re}(\tilde{s}_I(t)e^{j2\pi f_c t}\right|^2\}} = \frac{\max\left|\tilde{s}_I(t)\right|^2}{E\{\left|\tilde{s}_I(t)\right|^2\}} \tag{8}$$

The above power characteristics can also be described in terms of their magnitudes (not power) by defining the crest factor (CF) as

Passbandcondition: $CF = \sqrt{PAPR}$

Basebandcondition: $CF = \sqrt{PMEPR}$

F. *CCDF Plots:*

A CCDF curve shows how much time the signal spends at or above a given power level. The power level is expressed in dB relative to the average power. A CCDF curve is basically a plot of relative power levels versus probability. Mathematically CCDF can be explained with a set of data having the probability density function (PDF). To obtain the Cumulative Distribution Function (CDF), the integral of the PDF is computed. Then inverting the CDF results in the CCDF. It concludes that the CCDF is the complement of the CDF or CCDF = 1 – CDF.

G. *Measurement Of Crest Factor Using CCDF Plots:*

An OFDM signal with N subcarriers exhibits the maximum power when every subcarrier component coincidently has the largest amplitude with identical phases. The maximum power becomes larger as N increases and the probability that maximum-power signal occurs decreases as N increases.

Clipping And Filtering:

In PAPR reduction schemes clipping, being considered the simplest, limits the maximum of transmit signal to a pre-specified level. Clipping has some disadvantages which are listed as follows:

BER performance degradation occurs because of the in-band signal distortion caused by Clipping. *Out-of-band radiation* is caused by clipping imposing out-of-band interference signals to adjacent channels. The out-of-band signals caused by clipping can be reduced by filtering it may affect high-frequency components of in-band signal (aliasing) when the clipping is performed with the nyquist sampling rate in the discrete-time domain. But if clipping is performed for the sufficiently-oversampled OFDM signals (e.g., $L \geq 4$) in the discrete-time domain before a low-pass filter (LPF) and the signal passes through a band-pass filter (BPF), the BER performance will be less degraded [8]. *Peak re-growth* is the problem faced by the system when filtering the clipped signal is used to reduce out-of-band radiation. The signal after filtering operation may exceed the clipping level specified for the clipping operation [9]. A PAPR reduction scheme using clipping and filtering is shown in Figure 4.9 where L is the oversampling factor and N is the number of subcarriers. In this scheme, the L-times oversampled discrete-time signal $x'[m]$ is generated from the IFFT ($X'[k]$with $N\cdot(L-1)$ zero-padding in the frequency domain) and is then modulated with carrier frequency f_c to yield a pass band signal $x^p[m]$. Let $x_c^p[m]$ denote the clipped version of $x^p[m]$, which is expressed as:

$$x_c^p[m] = \begin{cases} -A & x^p[m] \le -A \\ x^p[m] & |x^p[m]| < A \\ A & x^p[m] \ge A \end{cases} \tag{9}$$

Or

$$x_c^p[m] = \begin{cases} x^p[m] & \text{if } |x^p[m]| < A \\ \dfrac{x^p[m]}{|x^p[m]|} \cdot \mathrm{A} & \text{otherwise} \end{cases} \tag{10}$$

where A is the pre-specified clipping level. Note that Equation (10) can be applied to both baseband complex-valued signals and passband real-valued signals, while Equation (9) can be applied only to the passband signals. Let us define the clipping ratio (CR) as the clipping level normalized by the RMS value s of OFDM signal, such that

$$CR = \frac{A}{\sigma} \tag{11}$$

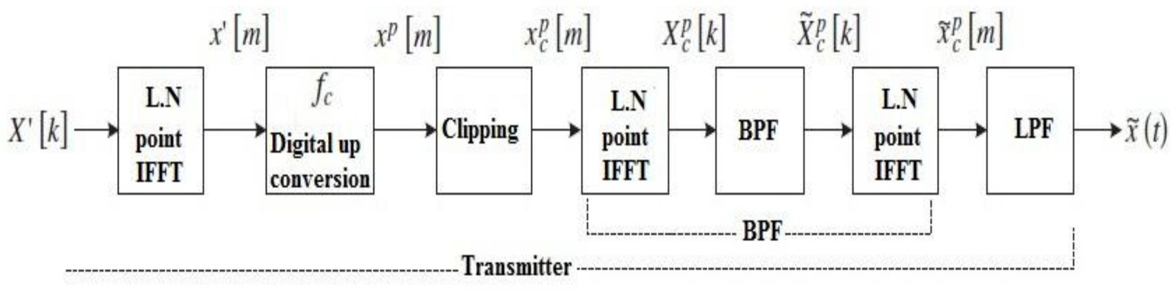


Fig. 3 Block diagram of a PAPR reduction scheme using clipping and filtering

The values of parameters used in the QPSK/OFDM system for analyzing the performance of clipping and filtering technique are shown in Table 1.

Table 1 Parameters used for simulation of clipping and filtering

Parameters	**Value**
Bandwidth, BW	1 MHz
Sampling frequency, $f_s = BW.L$ with Oversampling factor, L = 8	8 MHz
Carrier frequency, f_c	2 MHz
FFT size, N	128
Number of guard interval samples (CP)	32
Modulation Order	QPSK
Clipping ratio (CR)	0.8, 1.0, 1.2, 1.4,1.6

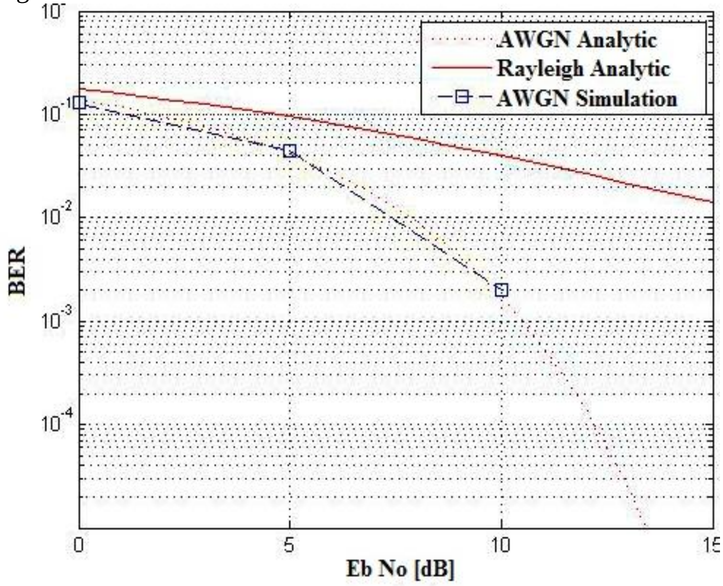
It has been known that $\sigma = \sqrt{N}$ and $\sigma = \sqrt{N/2}$ in the baseband and pass band OFDM signals with N subcarriers, respectively. In general, the performance of PAPR reduction schemes can be evaluated in the following three aspects [10]:

- In-band ripple and out-of-band radiation that can be observed via the power spectral density (PSD).
- Distribution of the crest factor (CF) or PAPR, which is given by the corresponding CCDF.
- Coded and uncoded BER performance.

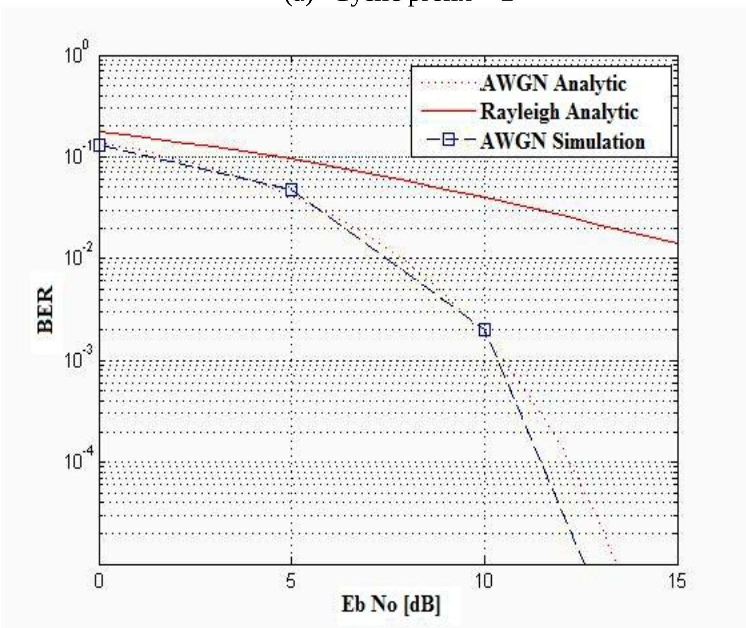
IV. RESULTS

A. *Simulation results of Guard Interval*

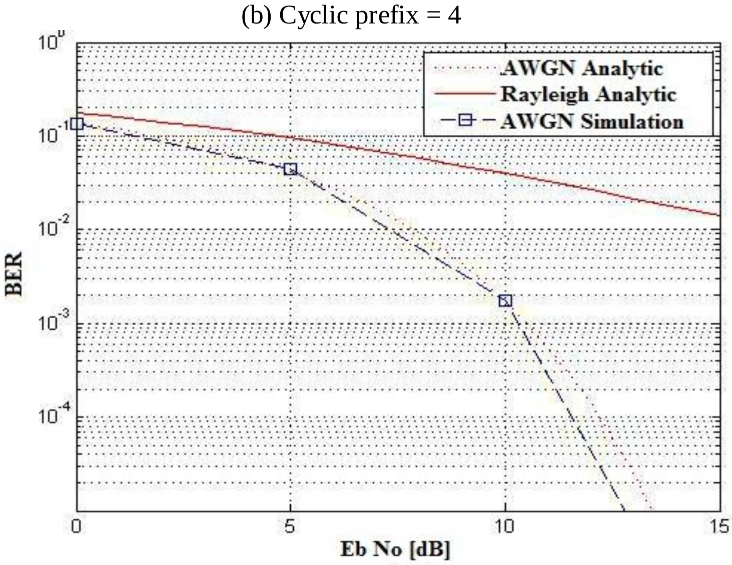
The effect of ISI (inter symbol interference) can be simulated as the length of a guard interval (CP or ZP) varies. The BER performance of an OFDM system with 64-point FFT (N=64) and varying guard interval in the AWGN or a multipath Rayleigh fading channel is presented in the below simulation results. The BER performance with CP of length 16 samples, as shown in Fig 4(d) , is consistent with that of the analytic result in the Rayleigh fading channel. This implies that the OFDM system is subjected to a flat fading channel as long as CP or ZP is large enough. Table 2 shows the effect of ISI on BER performance at different SNR with different length of GI in AWGN channel. The effect becomes significant as the length of GI decreases.



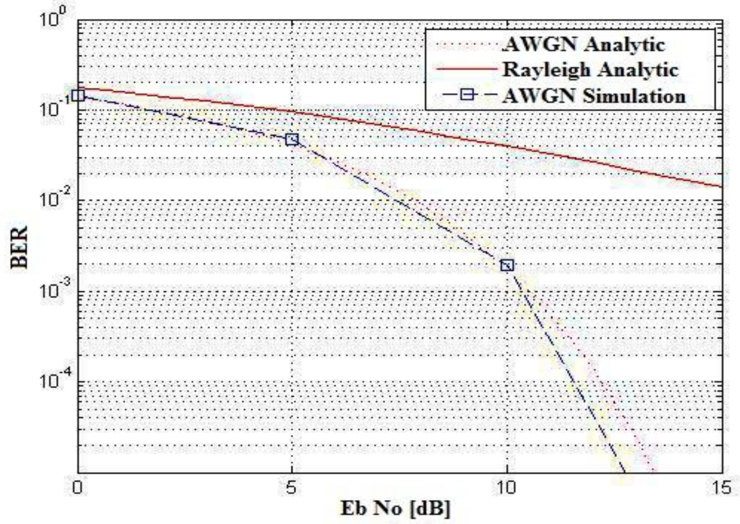
(a) Cyclic prefix = 2



(b) Cyclic prefix = 4



(c) Cyclic prefix = 8



(d) Cyclic prefix = 16

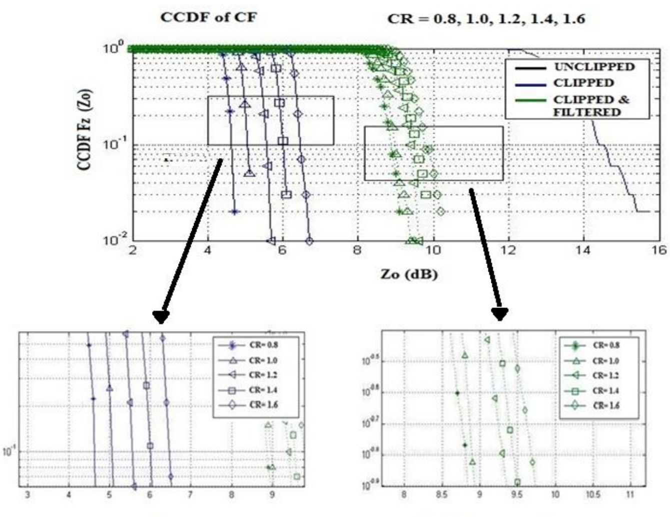
Fig 4 BER performance for OFDM system with 16-QAM and varying CP

Table 2 BER at different SNR with different CP for AWGN channel

Cyclic prefix length	CP-2	CP-4	CP-8	CP-16
Signal power	9.377 e-002	4.688e-002	2.344e-002	1.172e-002
BER at 0	0.1285	0.1308	0.1354	0.1432
BER at 5	0.0447	0.04815	0.04384	0.04688
BER at 10	0.001979	0.01987	0.001728	0.001946
BER at 15	0.0	6.944	1.736	1.389

B. *Simulation Results For Measurements Of Crest Factor:*

Simulation has been done using MATLAB in order to obtain the CCDFs of Crest Factor for the clipped OFDM signal and Clipped & Filtered OFDM signal. Crest factor being the square root of PAPR facilitates in determining the PAPR distribution. The PAPR distribution and the BER performance are shown with Fig 5 and Fig 6 respectively. Performance of OFDM signal is analyzed using different values of Crest ratio. The performance of signal after clipping and after clipping & filtering are presented.



(a) Clipping (b) Clipping and Filtering

Fig 5 PAPR Distribution of OFDM signal

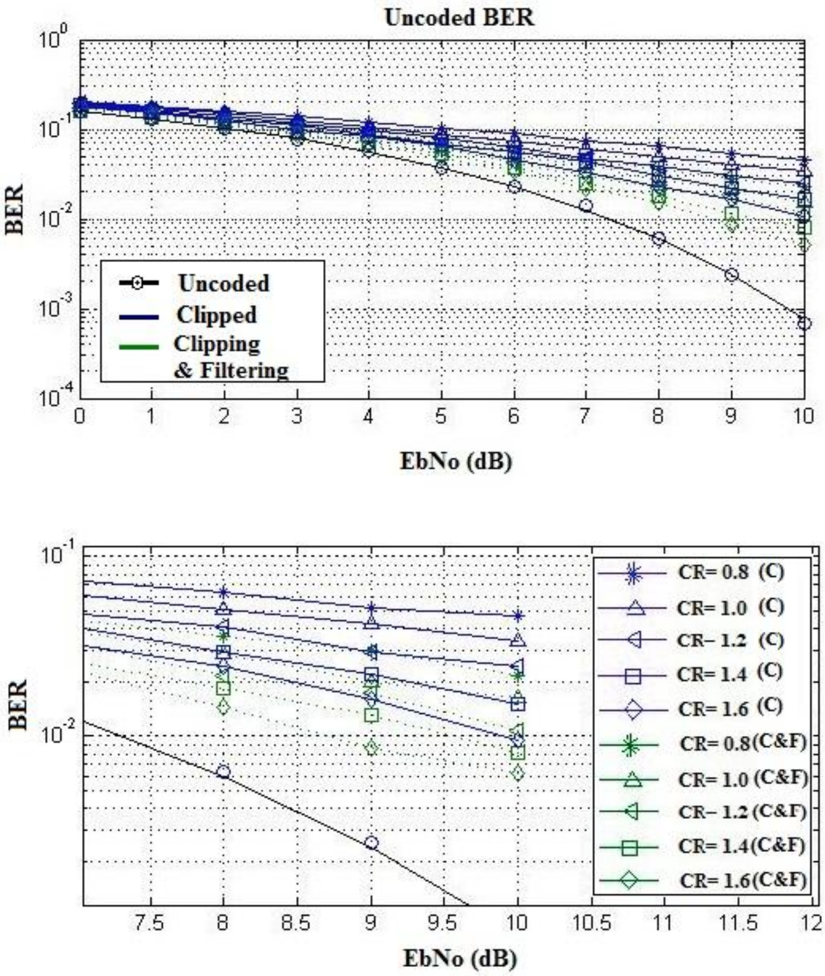


Fig 6 BER Performance of OFDM signal

V. CONCLUSION

In this paper investigations are done on different parameters of Orthogonal frequency division multiplexing system with different experimental values in order to conclude the best results for better understanding of the mentioned system. Bit Error Rate performance of the system is analyzed by varying the guard interval in different fading environments. The effect of Inter Symbol Interference is significant in Rayleigh as compared to Additive White Gaussian Noise and becomes more significant with the decreasing Guard Interval. Crest Factor being the square root of peak to average power ratio of an Orthogonal frequency division multiplexing signal can be used to define peak to average power ratio distribution. Clipping and filtering are the techniques used to reduce peak to average power ratio in a Orthogonal frequency division multiplexing system. It is shown by the Complementary Cumulative Distribution Functions of crest factor that the peak to average power ratio values decreases after clipping whereas increases slightly after filtering. The significance of Clipping Ratio is also shown. Variation in the clipping ratio affects the bit error rate and the peak to average power ratio distribution of the Orthogonal frequency division multiplexing signal.

REFERENCES

[1] Evegenii Krouk, Sergei Semnov , "*Modulation and coding techniques in wireless communications*", 2011.

[2] E. Costa, M. Midro, and S. Pupolin, "*Impact of amplifier nonlinearities on OFDM transmission system performance*," IEEE Communication Lett., vol. 3, pp. 37–39, Feb. 1999.

[3] Hongwei Yang, "*A road to future broadband wireless access: MIMO-OFDM- Based air interface."* IEEE Communications Magazine, vol 43, pp 53-60,Jan. 2005.

[4] Peled, A. "*Frequency domain data transmission using reduced computational complexity algorithms*." IEEE ICASSP, 5, pp 964–967, 1980.

[5] Xiaojing Huang, "*Effect of DC offset on OFDM system with zero padded suffix*." IEEE, 2006.

[6] Proakis, J.G. Digital Communications, fourth edition, McGraw-Hill, New York, 2001.

[7] Palicot, J. and Lou€et,Y. "*Power ratio definitions and analysis in single carrier modulations.*" EUSIPCO, Antalya, Turkey, Sep. 2005.

[8] Ochiai, H. and Imai, K. "*On clipping for peak power reduction of OFDM signals"*. IEEE GTC, vol. 2,pp. 731–735, Dec. 2000.

[9] Han, S.H. and Lee, J.H. "*An overview of peak-to-average power ratio reduction techniques for multicarrier transmission*." IEEE Wireless Communication , 12(2), pp 56–65, 2005.

[10] Li, X. and Cimini, L.J. "*Effects of clipping and filtering on the performance of OFDM.*" IEEE Communication .Letter, 2(20), pp 131–133, 1998.

[11] Richard Van Nee and Ramji Prasad *"OFDM for Wireless Communication",* Artech House, 2.

[12] Simon Litsyn , Gerhard Wunder, *"Generalized bounds on the crest factor distribution of OFDM signals with applications to code design.*", IEEE symposium of Information theory , pp 992-1006, March 2004.

[13] Wonhoon Jang, Nuno Borges Carvalho, *"Crest factor reduction through scaling and recovering by frame in OFDM communications systems*." IEEE, 2011.

