BER Analysis of OFDM Systems with Varying Frequency Offset Factor over AWGN and Rayleigh Channels

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Abstract

The progressively escalating demand for tremendously high rate data transmission over wireless mediums needsresourcefulconcord of electromagnetic resources considering restrictions like power incorporation, spectrum proficiency, robustness in disparity to multipath propagation and implementation complication. Orthogonal frequency division multiplexing (OFDM) is a favorable approach for upcoming generation wireless communication systems. However its susceptibility to the frequency offset triggered by frequency difference between local oscillator of transmitter and receiver or due to Doppler shift results to Inter Carrier Interference. This delinquent of ICI results inworsening performance of the wireless systems as bit error rate increaseswith increase in value of frequency offset. In this paper simulation results aredemonstratedfor analyzing the effect of varying frequency offset factor on system's error rate performance.

Index Terms—*Bit Error Ratio (BER), Inter-Carrier Interference (ICI),Additive white Gaussian Noise (AWGN), Carrier Frequency Offset (CFO).*

I. INTRODUCTION

The intensification in number of mobile users desires for wireless technologies that can deliver data at high speeds in a spectrally crucial manner. However, supporting such high data rates with appropriate robustness to radio channel impairments involvesjudicious excerpt of techniques. Orthogonal frequency division multiplexing (OFDM) is a multicarrier multiplexing technique, in which data is transmitted over several parallel frequency sub channels at a lower rate. It has been standardized in several wireless applications such as Digital Video Broadcasting (DVB), HIPERLAN, IEEE 802.11 (Wi-Fi), and IEEE 802.16 (WiMAX) and isused for wired applications as in the Asynchronous Digital Subscriber Line (ADSL),Digital Audio Broadcasting (DAB) and power-line communications [1,2].One of the foremost reasons to use OFDM is to step-up the robustness against narrowband interference or frequency selective fading. As every technique has its inadequacies, this technique also has problem of being sensitive towards frequency mismatch. This mismatch in frequency can either arise because of variation in local oscillator frequencies of transceivers or due to Doppler shiftinitiating carrier frequency offset. TheCFO upshots in loss of orthogonality of the subcarriers which causes ICI. This paper isoutlined in way that Section II expresses the basic description and issues of OFDM system succeeded by the system portrayal and interference scrutiny and Mathematical description of ICI is given in Section III succeeded by simulation results in Section IV. The conclusion of paper is given in Section V.

II. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING

OFDM is a distinct case of multi-carrier modulation. The dictum of OFDM is to split a single high-data rate stream into a number of lesser rate streams that are transferred simultaneously over some narrower sub channels which are orthogonal to each other. Henceforward it is not only a modulation technique nevertheless a multiplexing technique too. The merits of this technique that make it a desired choice over other modulation techniques are its extraordinary spectral efficiency, easier implementation of FFT, lower receiver intricacy, robustness for high-data rate transmission over multipath fading channel, high controllability for link adaptation are few benefits to list. However, it has two elementary impairments: 1) higher peak to average power ratio (PAPR) as paralleled single carrier signal [3]. 2) Susceptibility to phase noise, timing and frequency offsets that acquaint with ICI into the system. The carrier frequency offset is instigated by the disparity of frequencies amongst the oscillators at the transceivers, or from the Doppler spread due to the relative motion between them. The phase noise arises mainly due to imperfections of the LO in the transceiver. The timing offset emerges due to the multipath delay spread and because of it not only inter-symbol interference, but ICI also transpires. However, ICI influenced by phase noise and timing offset can completely be compensated or fixed. But the manifestation of frequency offset due to the Doppler spread or frequency shift resulting in ICI is arbitrary, henceforth only its impact can be lessened. Many diverse ICI mitigation schemes have been extensively reconnoitered to fray the Inter-Carrier Interference in OFDM systems, comprising frequency-domain equalization [4], time-domain windowing [5], and the ICI self-cancellation (SC) schemes[6]-[12], frequency offset estimation and compensation techniques[13] and so on. Amidst the schemes, the ICI self-cancellation scheme is a modest method for ICI minimization. It is a two-phase approach that uses redundant modulation to overpower ICI with ease for OFDM [18].

III. SYSTEM DEPICTION AND ICI ANALYSIS

Figure1 portraits a distinctive discrete-time base-band equivalent OFDM system model. As presented, a stream of input bit stream is first mapped into symbols using BPSK modulation. The symbols are modulated using IFFT on N-parallel subcarriers succeeding the serial-to-parallel (S/P) conversion. With cyclic prefix (CP) appending, the OFDM symbols are sequential using parallel to serial (P/S) conversion and referred to the channel. At the receiver, the received symbols are recaptured by S/P transformation, CP removal, FFT transformation, P/S conversion and are demapped with equivalent scheme to obtain the anticipatednovel bit stream [14][17][18].

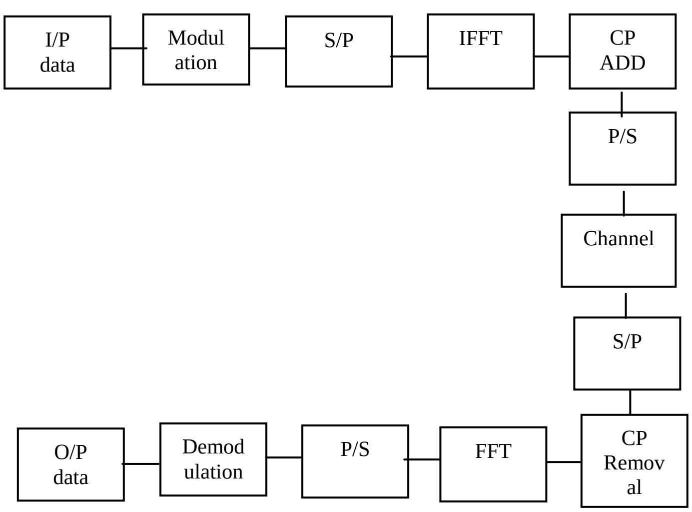

Fig. 1 OFDM Transceiver

In OFDM systems, the transmitted signal in time domain can be exhibit as:

$$x(n) = \frac{1}{N}\sum_{k=0}^{N-1} X(k)e^{j\frac{2\pi kn}{N}} \qquad (1)$$

Where x (n) represents the nth sample of the OFDM transmitted signal, X (k) symbolizes the modulated symbol for the kth subcarrier and k = 0, 1... N -1, N is the total quantity of OFDM subcarriers.

The received signal in time domain is specified by:

$$y(n) = x(n)e^{j\frac{2\pi n\epsilon}{N}} + w(n) \qquad (2)$$

Where ϵ is the normalized frequency offset known by $\epsilon = \Delta f.NTs$ in which Δf is the frequency difference which is either due to variance in the local oscillator carrier frequencies of transmitter and receiver or due to Doppler shift and T_s is the subcarrier frequency and w (n) is the Additive White Gaussian Noise acquainted in the channel.The outcome of this frequency offset on the received symbolstream can be implicit by considering the received symbol Y (k) on the kth subcarrier. The received signal at subcarrierindex kcan be stated as

$$Y(k) = X(k)S(0) + \sum_{l=0,\ l\neq k}^{N-1} X(l)S(l-k) + W(k)$$
(3)

Where k = 0, 1… N-1 and X (k) S (0) is the wanted signal and $\sum_{l=0\ l\neq k}^{N-1} X(l)S(l-k)$ is the ICI component of acknowledged OFDM signal.

ICI component S (l-k) can be given as:

$$S(l-k) = \frac{\sin(\pi(l+\epsilon-k))}{N\sin(\pi(l+\epsilon-k)/N)}\exp(j\pi\left(1-\frac{1}{N}\right)(l+\epsilon-k)$$
(4)

IV. RELATED WORK

A simulation is directed to evaluate performance of system for input specifications given in Table 1.

Table I : Input Parameters for Simulation

Input Parameters	
Parameters	**Values**
Carrier frequency	2.3 GHz
Bandwidth	10 MHz
Modulation	BPSK
No. of Bits	51200
No. of Symbols	50
Data Sub-Carriers	512
Subcarrier Frequency	10.94 KHz
Cyclic Prefix	256
OFDM Symbol Length	1280
Symbol Time	91.4 µ sec
FFT Size	1024
SNR (dB)	0:2:12
Offset ϵ	0-0.2
Channel	AWGN, Rayleigh
Noise	AWGN

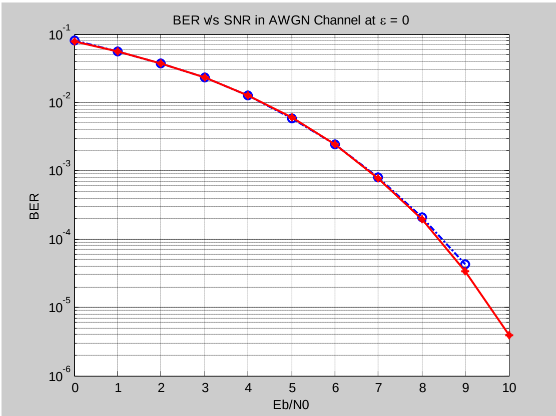

Fig. 2 BER Performance of OFDM at 0 Frequency Offset in AWGN Channel.

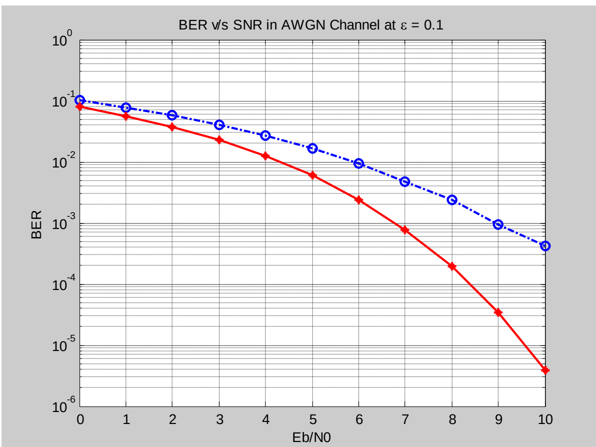

Fig. 3 BER Performance of OFDM at 0.10 Frequency Offset in AWGN Channel.

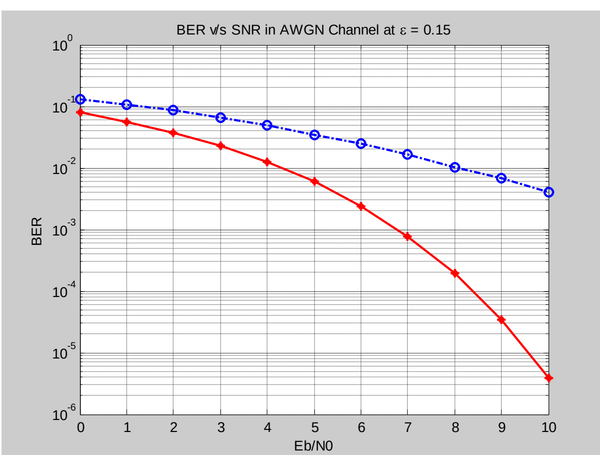

Fig. 4 BER Performance of OFDM at 0.15 Frequency Offset in AWGN Channel.

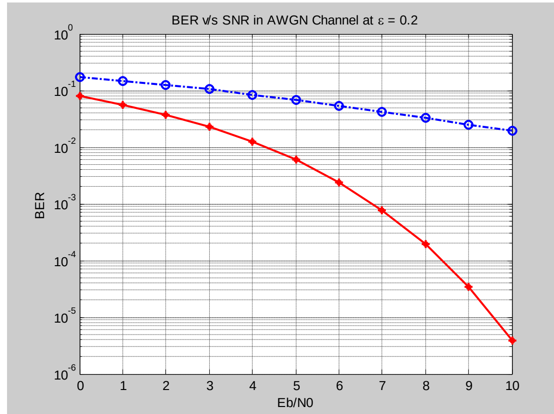

Fig. 5 BER Performance of OFDM at 0.20 Frequency Offset in AWGN Channel.

Figure 2 to Figure 5 illustrates that as the value of frequency offset is increasing, correspondingly the bit error rate performance of standard OFDM system is degrading in AWGN channel.

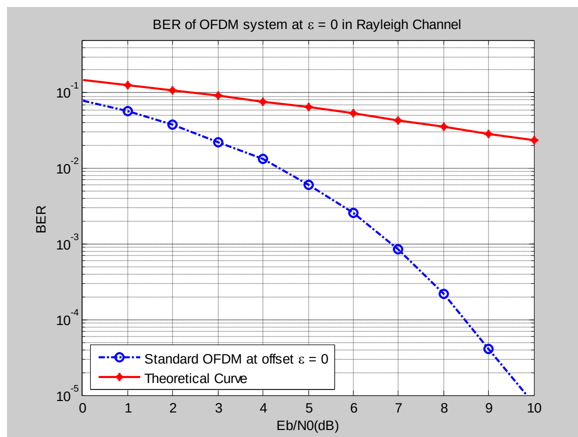

Fig. 6 BER Performance of OFDM at 0 Frequency Offset in Rayleigh Channel.

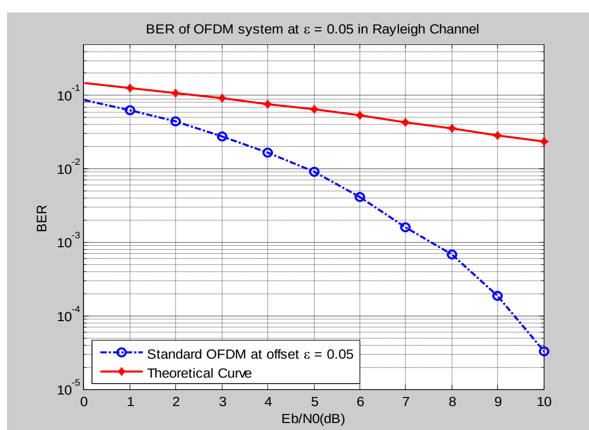

Fig. 7 BER Performance of OFDM at 0.05 Frequency Offset in Rayleigh Channel.

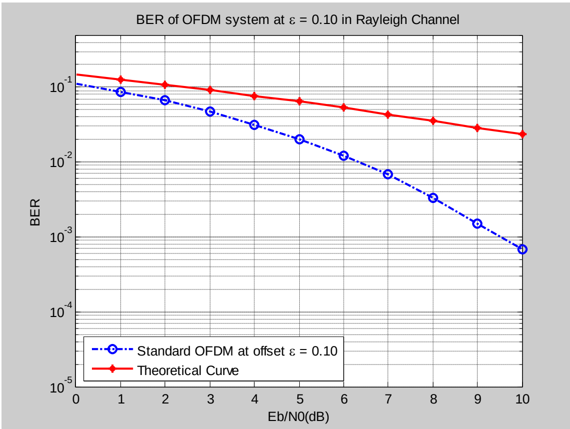

Fig. 8 BER Performance of OFDM at 0.10 Frequency Offset in Rayleigh Channel.

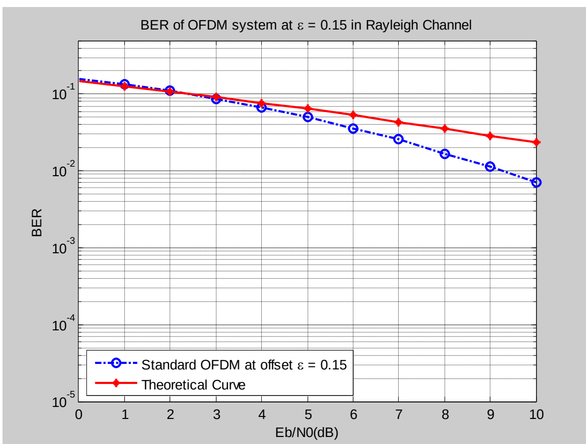

Fig. 9 BER Performance of OFDM at 0.15 Frequency Offset in Rayleigh Channel.

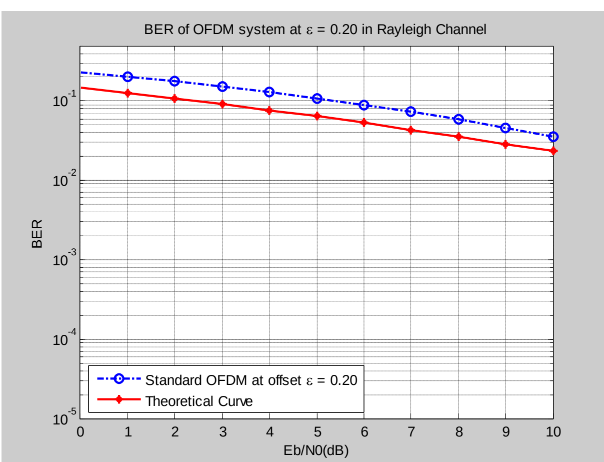

Fig. 10 BER Performance of OFDM at 0.20 Frequency offset in Rayleigh Channel.

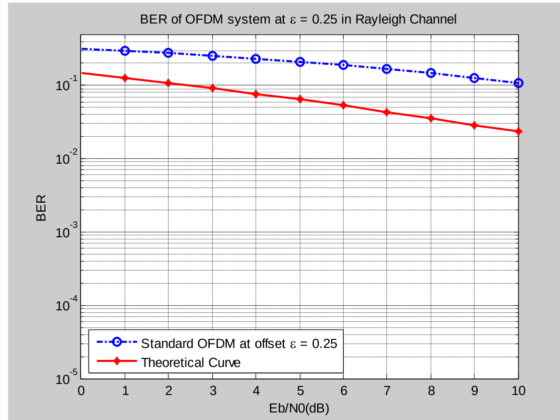

Fig. 11 BER Performance of OFDM at 0.25 Frequency Offset in Rayleigh Channel.

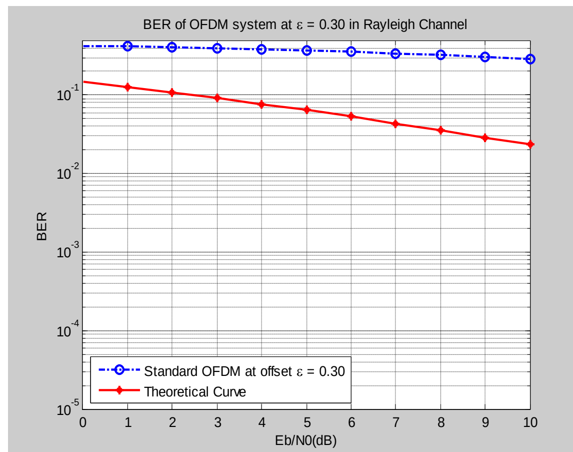

Fig. 12 BER Performance of OFDM at 0.30 Frequency Offset in Rayleigh Channel.

Figure 6to Figure 12depicts that the bit error rate performance of standard OFDM system is degrades in Rayleigh channel degrades at higher values of frequency offset.

It can be undoubtedly seen that OFDM system with BPSK modulation for Channel Bandwidth of 10 MHz and subcarrier 512, BER of 10^{-5}can be accomplished for both lower and higher values of SNR in case there is no offset in the system. But as the offset gets introduced either due to frequency dissimilarity or due to Doppler shift system's performance starts deteriorating in terms of BER of the system. This is because the ICI component gets introduced as soon as offset occurs. It is this Inter Carrier Interference that is responsible for performance degradation of system.

It can be seen from figure 2 to figure 12 that frequency offset factor deteriorates the system's performance. The effect is much worse at higher values of offset in both channel as compared to the lower ones.

An efficient, simple and effective technique is required to mitigate its effect.

V. CONCLUSION

This paper scrutinises the effect of varying frequency offset factor on OFDM system's performance. The offset gets introduced either due to frequency dissimilarity or due to Doppler shift system's performance starts deteriorating in terms of BER of the system. This is because the ICI component gets introduced as soon as offset occurs. It is this Inter Carrier Interference that is responsible for performance degradation of system. . An efficient, simple and effective technique is required to mitigate its effect.

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