Estimating the Preamble and Carrier Offset in Asymmetric Channel for Synchronization in Broadband Signal Processing

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Abstract: ***In multipath fading the signal is transmitted through free space channel which has its significance characteristics in the time and frequency domain. At the receiver side we need a perfect synchronization model so that we can achieve better spectral efficiency and BER. More over Synchronization will vary according to the channel, traffic pattern and the path loss component of the different environment like urban, sub urban etc. A dynamic receiver should successfully receive and demodulate data with effective BER analysis. In which Timing synchronization is used to determine the arrival of data burst and the symbol boundaries whereas frequency synchronization is used to synchronize local oscillator to a carrier frequency. But in multipath the synchronization is very difficult. In this research paper, A transceiver model has been simulated using Matlab and performance evaluation has been done for uplink and downlink transmission with the effect of different environment includes AWGN channel, multipath channel, and SUI channel model. In this paper Multicarrier modulation OFDM has been used for broadband wireless environment with its standard FFT size. In second stage, simulations are done for synchronization considering with preamble, the carrier frequency offset and phase noise is estimated at the receiver. With our analysis frequency selective fading environment increases the robustness to narrowband interference and offers high spectra with equalization strategies.***

Keywords: OFDM; AWGN; FFT; BER; SUI; Channel; UL;DL; Synchronization; SYMBOL; Constellation

1. Introduction

Orthogonal frequency division multiplexing (OFDM) system is widely used and emerging broadband wired and wireless communication systems such as digital subscriber lines (DSL), wireless LAN (802.11), digital video broadcasting (DVB), and now WiMAX (802.16), 3G LTE and fourth generation cellular systems. We specify some standard of WiMAX in Table 1

OFDM is the modulation technique for high speed data modulation. OFDM is a type of multichannel modulation as shown in Fig 1 and Fig.2, which divides a given channel into many parallel sub channels or subcarriers, so that multiple symbols are sent in parallel. In this research article we use one of the type of OFDM that we will describe the discrete Fourier transform (DFT) with a cyclic prefix. The DFT (implemented with a fast Fourier transform (FFT)) and the cyclic prefix have made OFDM both practical and attractive to the radio link designer. The primary advantage of OFDM is its high. spectral efficiency and robustness to multi-path fading. However, to ensure the ISI-free and ICI-free detection at the receiver, an accurate synchronization with precise timing information is needed. Timing synchronization is used to determine beginning of a data and the symbol boundaries whereas frequency synchronization is used to synchronize local oscillator to a carrier. The OFDM transmitter is composed of three parts: assemble OFDM frame, create OFDM signal by performing IFFT, and add cyclic prefix (guard interval used to cancel inter symbol interference). Then the short and long preamble will be added at the beginning of the data burst for synchronization and equalization purpose.

At the receiver, an accurate synchronization must be performed first. Then complimentary operations with the transmitter are applied in the reverse order. The frequency domain channel equalizer (FEQ) is a one-tap equalizer. Its training data is the long preamble for downlink and short preamble for uplink. [1][2][6][8].

A. **FFT Logic**

A fast Fourier transform is an efficient algorithm to compute the discrete Fourier transform (DFT) and its inverse []3[5]. This is applied to discrete data so the transforms are done by summing instead of integration. The Fast Fourier Transform is a representation used in computer codes. Let x_0, ..., x_{N-1} be complex numbers. The DFT is defined by the formula.

$$X(k) = \sum_{j=1}^{N} x(j)\omega_N^{(j-1)(k-1)}$$

$$x(j) = (1/N)\sum_{k=1}^{N} X(k)\omega_N^{-(j-1)(k-1)} \quad \text{..........1}$$

$$\omega_N = e^{(-2\pi i)/N} \quad \text{........2}$$

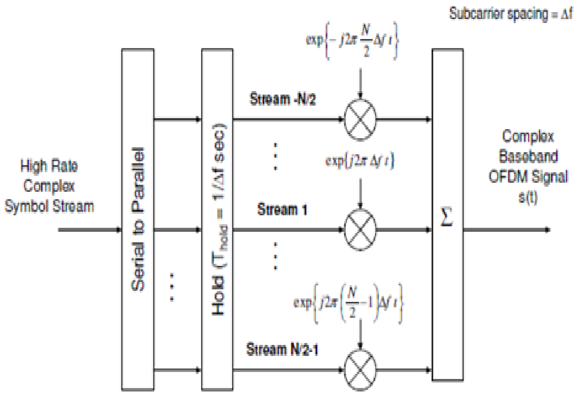

Figure 1: Ofdm conceptual block

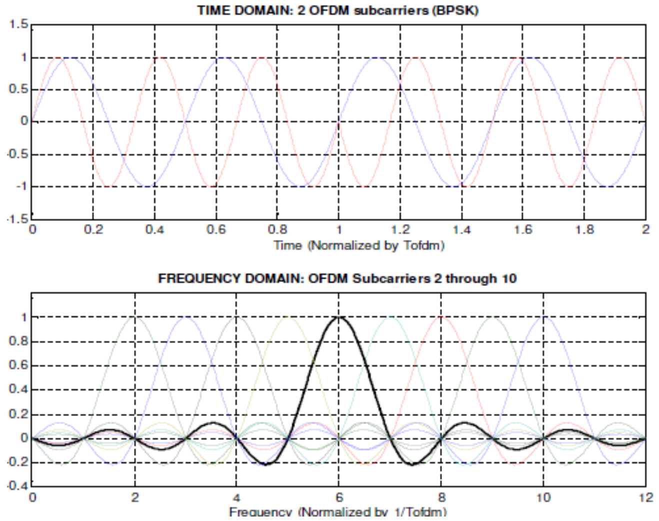

Figure 2: OFDM Signal Analysis

B. IFFT Logic

The inverse Fourier transform simply inverts the operation i.e. it converts from frequency domain back to time domain representation
of the signal

C. Bit Error rate (BER)

BER is the number of error the bits occurs within one second in the transmitted signal. [2]

$$\text{BER}=\frac{\text{NUMBER OF BITS PER SYMBOL}}{\text{TOTAL NO OF BITS TRANSMITTED}}$$

Table 1.1: Standerd of WiMAX

Transmission scheme	Single carrier only	Single carrier, 256 OFDM or 2048 OFDM	Single carrier, 256 OFDM or scalable OFDM with 128, 512, 1024, or 2048 subcarriers
Modulation	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM
Gross data rate	32Mbps–134.4Mbps	1Mbps–75Mbps	1Mbps–75Mbps
Multiplexing	Burst TDM/TDMA	Burst TDM/TDMA/ OFDMA	Burst TDM/TDMA/ OFDMA
Duplexing	TDD and FDD	TDD and FDD	TDD and FDD
Channel bandwidths	20MHz, 25MHz, 28MHz	1.75MHz, 3.5MHz, 7MHz, 14MHz, 1.25MHz, 5MHz, 10MHz, 15MHz, 8.75MHz	1.75MHz, 3.5MHz, 7MHz, 14MHz, 1.25MHz, 5MHz, 10MHz, 15MHz, 8.75MHz

2. Proposed System Model

In this section, the performance of the system model is analyzed for the parameters like number of subcarriers: 256 size of the IFFT/FFT: 256, length of the cyclic prefix: 32 symbols, pilot subcarriers: 8, preamble is sent at the beginning to estimate the channel (i.e. uplink, short preamble; downlink, long preamble) bandwidth of channel: 2.4GHz channel model: AWGN channel, h = [1 0] Multipath channel, h = [1 0 0 0 0 0.5 0 0.2];SUI channel, h = [−0.5038−0.6725−0.2833 − 0.3782 − 0.1593 − 0.2127].

Implementation of synchronization model is done with 3 stages during the transmission of OFDM symbol with channel. For an OFDM system, only phase and amplitude can be changed since frequency must to be kept orthogonal. BPSK, Gray-mapped QPSK, 16-QAM, and 64-QAM are consider for simulation. The OFDM transmitter is composed of three parts: assemble OFDM frame, create OFDM signal by performing IFFT, and add cyclic prefix (guard interval used to cancel inter symbol interference). Then the short and long preamble will be added at the beginning of the data burst for synchronization and equalization purpose.

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We design our algorithm as per the generated OFDM data and this data is modulated and mapped with the help of constellation

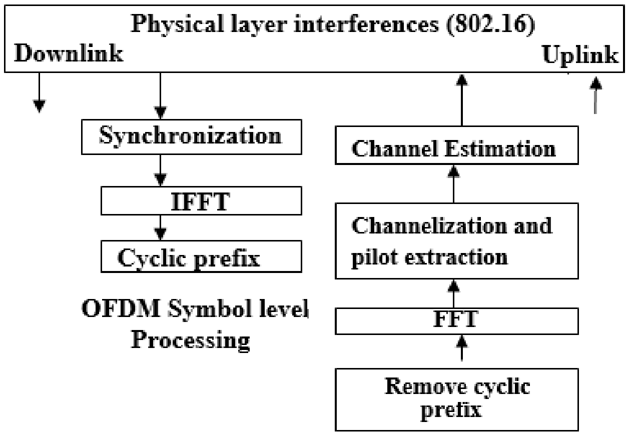

Figure 3: WiMAX System model for Physical layer

We propose the new model for better synchronization with supportive equation as shown Fig 4. We simulated the simulation with the help of MATLAB in three different simulation stages which specify the implementation of the algorithm.

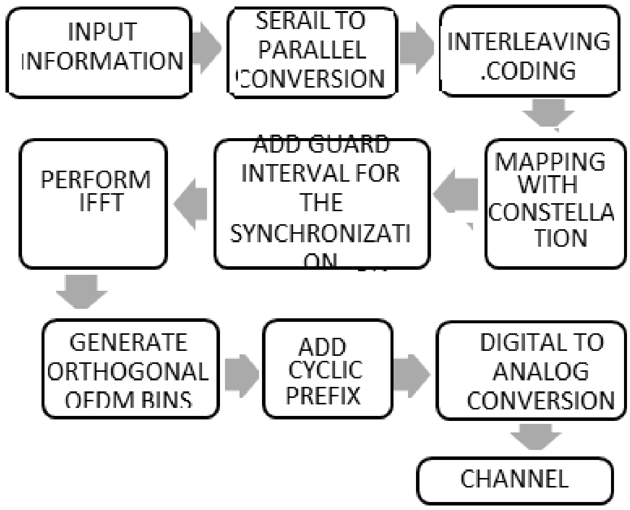

Figure 4: (a) Proposed Block diagram

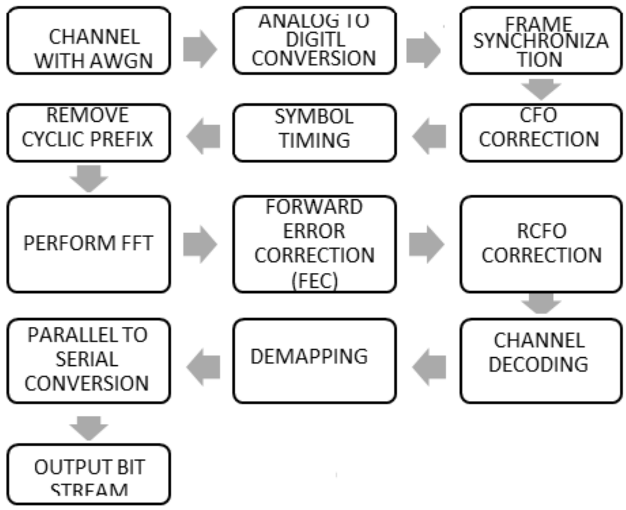

Figure 4: (b) Proposed block diagram

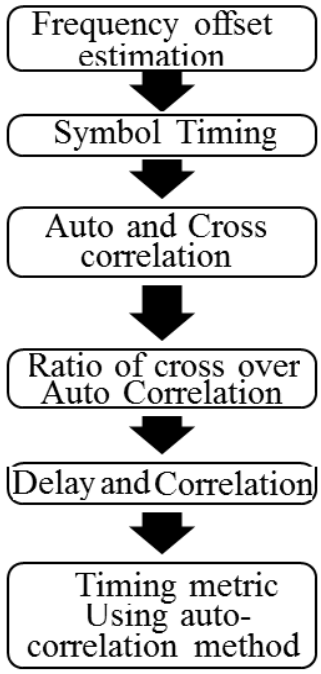

Figure 5: Down link implementation

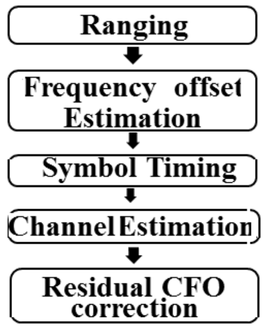

Figure 6: Uplink Implementation

3. Algorithm

Simulation 1: Generating Long preamble (combination of first symbol and second symbol OFDM with cyclic prefix). In simple This long preamble is combination odd and even subcarriers which are used for the packet detection, symbol detection and estimation of CFO with fine synchronization.

$P_{(SHORT)} = \sqrt{2}\ \sqrt{2}\mathrm{conj}\ (P_{ALL}(k))$ k mod 4 = 0

0 k mod 4 ≠ 0

$P_{(ALL)} = \sqrt{2}\ \sqrt{2}\mathrm{conj}\ (P_{ALL}\ (k))$ k mod 2 = 0

0 k mod 2 ≠ 0

$P_{ODD}(k) = \sqrt{2}\ \sqrt{2}\mathrm{conj}\ (P_{ALL}\ (k))$ k mod 2 = 0

0 k mod 2 ≠ 0

Simulation 2:
In this stage we simulated the Carrier Frequency Offset (CFO), Symbol Timing and Sampling Clock Frequency. To measure the frequency offset in time domain, it is necessary to track and measure the phase slope. With preamble's replicate structure, repeated time segments in time series can be used to estimate the phase factor. a 64 bit delay register is used to calculate the auto-correlation and cross-correlation of the receiver signal. Symbol timing is the estimate timing and frequency offset using the same time domain training sequence. In their method, the time domain OFDM symbol used for training consists of two identical.

Simulation 3
Implementation of synchronization model is done with 3 stages during the transmission of OFDM symbol with channel. For an OFDM system, only phase and amplitude can be changed since frequency must to be kept orthogonal. BPSK, Gray-mapped QPSK, 16-QAM, and 64-QAM are considered for simulation. The OFDM transmitter is composed of three parts: assemble OFDM frame, create OFDM signal by performing IFFT, and add cyclic prefix (guard interval used to cancel inter symbol interference). Then the short and long preamble will be added at the beginning of the data burst for synchronization and equalization purpose.

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International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Impact Factor (2012): 3.358

Simulation 4

Effect of High Power Amplifier (HPA)

In Fig 7, numerical simulation results are presented to investigate the nonlinear effects of HPA on an OFDM system. HPA nonlinearity may have bad influence on OFDM signals mainly on two aspects:

a. Out-of-band distortion, which will cause the OFDM power spectrum distortion, i.e. the spectral spreading of the amplified signal and introduce adjacent channel interference (ACI). Requirements on ACI for RF systems are very strict especially for large number of subscribers; therefore, it is of great importance to decrease the out-of-band distortion.
b. In-band distortion, which may disturb the OFDM constellations. PSD is utilized to evaluate the effects of AM/AM distortions on OFDM signals. Fig.4.11 shows the time domain waveform of a typical OFDM signal before passing through the HPA along with spectral representation of the data into the time domain using an Inverse Fast Fourier Transform for baseband OFDM modulation.

Fig.14 shows the result in this section, effects of HPA on an OFDM system. HPA nonlinearity may have bad influence on OFDM signals mainly on two aspects:

c. Out-of-band distortion, which will cause the OFDM power spectrum distortion, i.e. the spectral spreading of the amplified signal and introduce adjacent channel interference (ACI). Requirements on ACI for RF systems are very strict especially for large number of subscribers; therefore, it is of great importance to decrease the out-of-band distortion.
d. In-band distortion, which may disturb the OFDM constellations. PSD is utilized to evaluate the effects of AM/AM distortions on OFDM signals. Shows the time domain waveform of a typical OFDM signal before passing through the HPA along with spectral representation of the data into the time domain using an Inverse Fast Fourier Transform for baseband OFDM modulation.

To prevent overlapping of the data at the receiver cyclic prefix is inserted whose duration is one fourth of the total OFDM symbol duration. At the receiver side, firstly the data is received through linear receivers followed by a linear combiner. This linear combiner is designed in such a way that the output SNR is maximized at each instant of time. Then this data is converted again to the digital domain by passing it through an analog to digital converter. Cyclic prefix, data is again converted into serial to parallel by a serial-to-parallel converter. These parallel bit streams are demodulated using Fast Fourier Transform (FFT) to get back the original data by converting parallel bit streams into serial bit streams

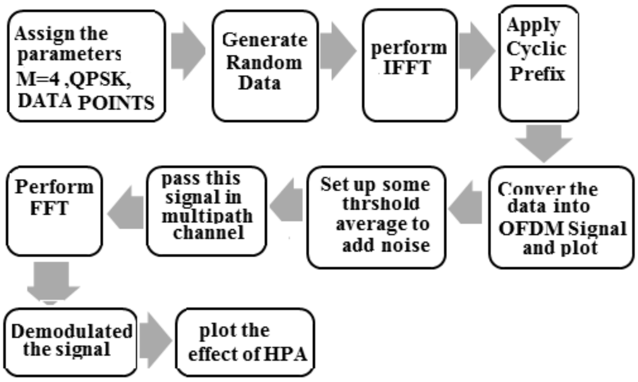

Figure 7: Effect of HPA

4. Results

Complete simulation has been done in the corresponding figures with proposed algorithm.

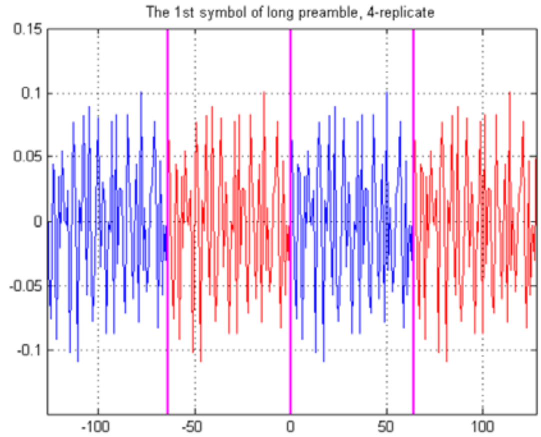

Figure 8: Generating Preamble OFDM symbol

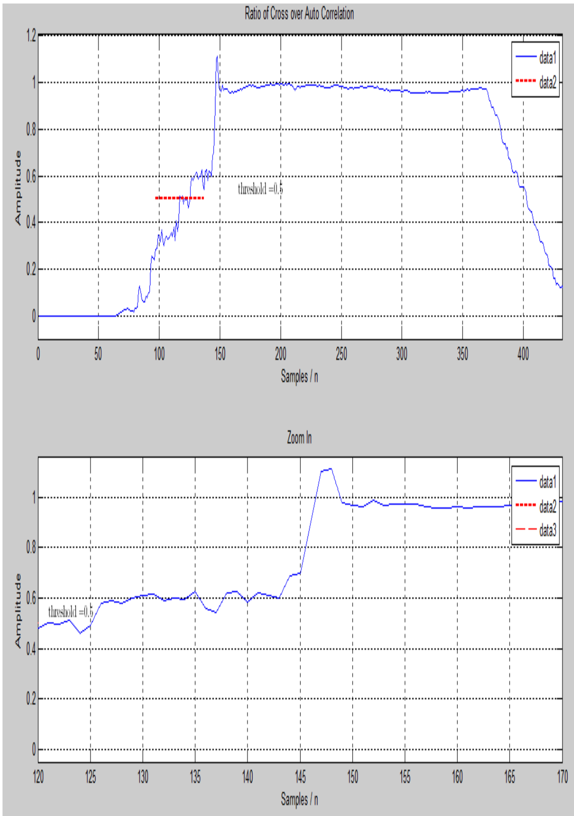

Figure 9: Ratio cross over auto correlation

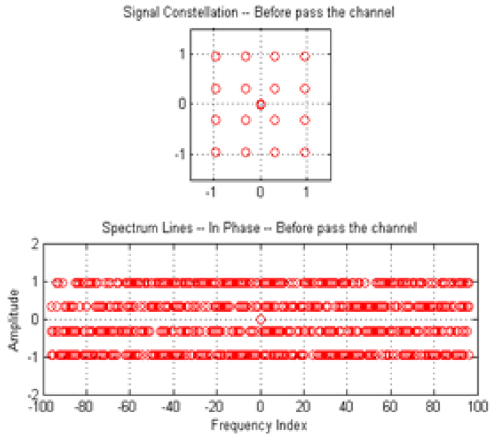

Figure 10: 16 QAM Constellation with spectrum

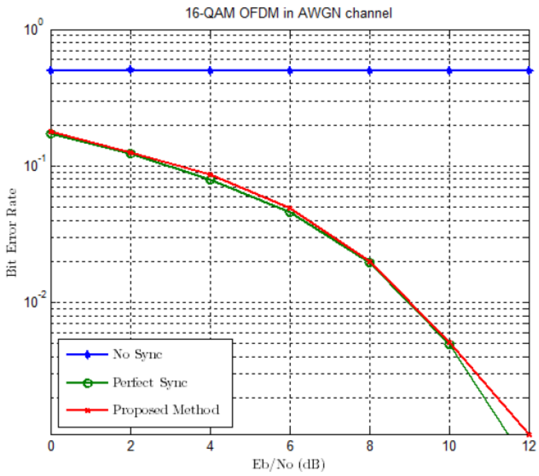

Figure 11: Effect of BER in AWGN Channel

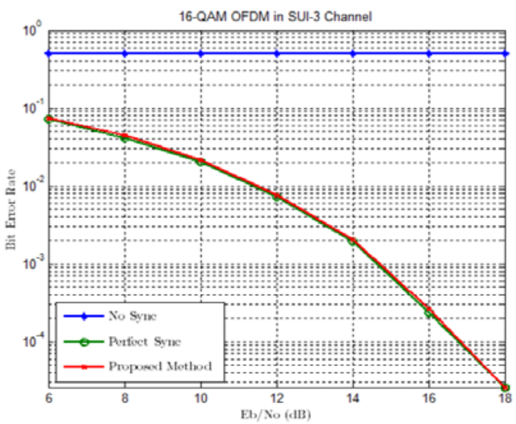

Figure 12: Effect of BER in SUI Channel

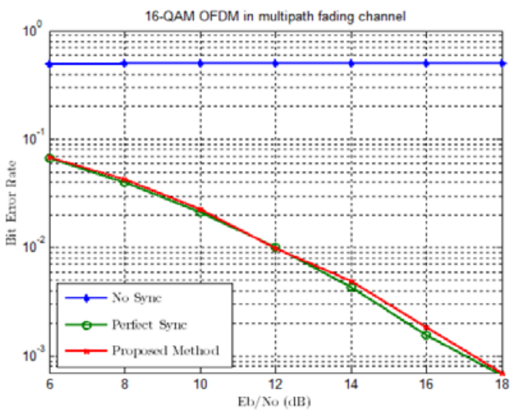

Figure 13: Effect of BER in Multipath Fading Channel

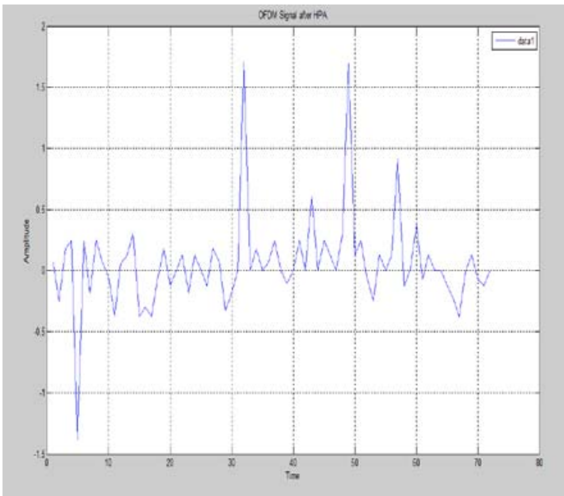

Figure 14: Effect of High Power Amplifier on OFDM

5. Conclusion

In this research article we present a method to accurately estimate the necessary timing and frequency adjustments to allow the receiver to correctly process the samples of the OFDM waveform in synchronization from the transmitter to the receiver side. As OFDM demodulation is extremely sensitive to synchronization impairments. In fact, a single synchronization error introduces huge error that the resulting performance is unacceptable for any sort of applications. Therefore, a perfect synchronization is very important for OFDM-based receivers. So we designed a algorithm which is based on the frequency offset, CFO compensation and symbol timing with the help of auto and cross correlation in Long preamble for which we generate a timing metric for auto-correlation method. Finally system level simulation has been done for a transmitter-channel-receiver model for WIMAX in Matlab. Simulation has performed for the BER using QAM with no synchronization and perfect synchronization with the effect of different channel.

6. Acknowledgement

At the outset I must admit and acknowledge that the present paper is the outcome of the continuous motivation and inspiration of my mentors, who have been instrumental initiating me into research. Working with them have been excruciating at times as my supervisor and guide are hard task masters.

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