Frequency Offset Estimation of WiMAX using Repeated Preamble

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Abstract—**Wide area network for cellular communications, are implemented by towers .The main advantage of WiMAX is that it supports movement from one place to another. However this WiMAX faces the mismatch in frequency during transmission which in turn leads to inter carrier interference and loss of orthogonality in the carriers used for transmission. Thus CFO estimation and compensation needs to be carried out for these systems to increase the efficiency of data transmission. The CFO estimation technique used here is a data aided technique that makes use of a preamble to attain the estimate. The preamble has been designed using optimized GCL sequences which increases the accuracy of CFO estimation.The method used for phase compensation in this method is phase rotation.**

Keywords-WiMAX,CFOestimation,repeatedpreamble,WLAN,GCL

I. INTRODUCTION

In telecommunication, need for reducing cost per bit has driven efficient utilization of available frequency spectrum. Efficient modulation techniques play important role in achieving this goal of cost reduction. For any system to achieve next generation standard's data rate, it has to transfer the information at faster speeds. For sending more data in a given time, data carrying symbol period needs to be as small as possible; this poses challenges for developers to face channel effects and hardware complexities. If all bandwidth is used as a single big resource, symbol duration should be kept low to pack more data in a unit time. However if the same large bandwidth resource is divided into number of small resources, then the large amount of incoming data stream can be sent onto many small streams simultaneously for a longer time. This is similar to passing one big stream of water through a shower faucet, into number of small streams at the output. The modulation scheme that achieves this is known as Orthogonal Frequency Division Modulation (OFDM) technique. In OFDM technique, the data is sent over small streams of Orthogonal (not interfering) frequencies termed as subcarriers. This division of frequency domain into many orthogonal subcarriers has benefits of combating the channel in a simpler way as compared to the conventional systems. OFDM modulation technique, divides high speed data streams into number of low speed data streams, for increasing symbol time. Dividing the available frequency resource into Orthogonal frequencies also improves spectral efficiency[1-2].

To improve coverage and achieve same or improved data transfer rate as IEEE 802.11 standards, a new standard group was formed by IEEE in 1999. This new study group was named as Worldwide Interoperability for Microwave Access (WiMAX) and published its first standard IEEE 802.16 in December 2001[9-10] which delivered point to multipoint Broadband Wireless transmission in the 10–66 GHz band, with only a line-of-sight (LOS) capability. WiMAX uses OFDM modulation. One of the major issues faced by the WiMAX is the loss of orthogonality of subcarriers due to frequency mismatch between the transmitter and receiver carrier frequency known as the CFO. This in turn reduces the efficiency of the system. With a carrier frequency of 5.2 GHz the CFO of a system lies within 40ppm.

The most efficient means of CFO estimation is the data aided method[4].The preamble can be used for CFO estimation as it experiences the same impairments as that of the symbol being transmitted. In this paper we make use of a repeated preamble which is more efficient compared to the existing preamble. The repeated preamble can thus be used for both timing and frequency synchronization.

The synchronisation in WiMAX can be divided into 2 parts: timing synchronization and frequency synchronization[5]. Frequency synchronization is necessary to maintain the local oscillator frequency of transmitter and receiver similar for coherent detection.Timing synchronization is essential to avoid intersymbol interference. The synchronization can be achieved by data aided technique which makes use of a preamble or the non data aided or blind technique which makes use of a cyclic prefix for CFO estimation .In this paper we make use of the data aided technique which makes use of the preamble . The advantage of this method when compared to the blind method of estimation is that the preamble sequence is known to both the transmitter and receiver and helps to detect the starting point of data during data transmission [4].

Timing synchronization in wireless networks consists of two parts: coarse timing synchronization and fine timing synchronization The aim of coarse synchronization is to find the beginning of the frame being transmitted and fine synchronization looks forward to find the beginning of the OFDM symbol in the packet being transmitted.

Frequency synchronization aims to remove the frequency mismatch between the transmitter and receiver. The transmitter generally transmits the data at a carrier frequency obtained from the local oscillator frequency. Due to mismatch in the local oscillator frequency the receiver experiences a frequency offset known as the carrier frequency offset. The reasons for the frequency mismatch includes Doppler effect in cases where the system is in movement, phase shift experienced by the system due to channel effect and error in the frequency generated by the local oscillator[8].

II.SYSTEM MODEL

WiMAX system can be divided into two parts : WiMAX transmitter and WiMAX receiver. The figure1 shows a WiMAX system used for transmission and reception of the signal.

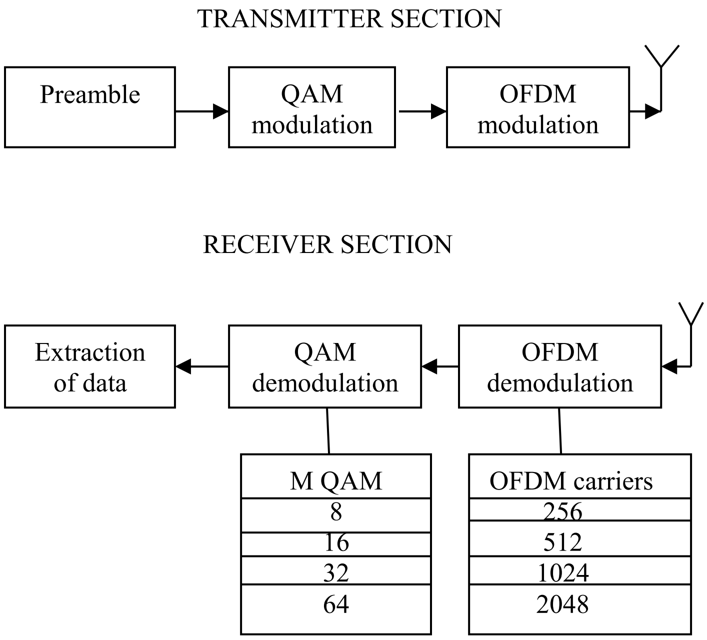

Fig1.Wimax system model

The M array QAM modulation can take any of the values shown above in fig1.The OFDM carriers used will vary depending on the Wimax specifications.In this paper we make use of the IEEE 802.16 specification of Wimax which makes use of FFTof size of 256.In the Wimax system the input data is transmitted along with the preamble.The data is then modulated by means of QAM and mapped to the different subcarriers by means of OFDM modulation.The cyclic prefix is added to the above data to avoid intersymbol interference. After the modulation the serial data is transmitted At the receiver the reverse process of the transmitter section is carried out which involves cyclic prefix removal followed by demodulation to extract data.

III.PREAMBLE STRUCTURE

The preamble consists of the short preamble and long preamble. The short preamble has 320 samples .This includes four identical sequence of a short pulse and cyclic prefix, The long preamble also consists of 320 samples which includes two identical sequence of long pulse and cyclic prefix. The figure 2 below shows the preamble structure.

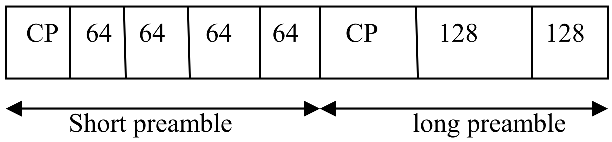

Fig2.Preamble Structure

In short preamble in order to obtain the four identical parts choose only those subcarriers that are multiples of four.The samples of short preamble are given by

$$P_4(k) = \begin{cases} 2^*P_{ALL}(k) & \text{if kmod4 =0} \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

After generating the four identical samples we add the cyclic prefix which corresponds to the last 64 bits of the short preamble. In long preamble to obtain two identical parts we choose only those subcarriers which are multiples of 2.The samples of the long preamble are given by

$$P_2(k) = \begin{cases} \sqrt{2}^*P_{ALL}(k) & \text{if kmod2 = 0} \\ 0 & \text{otherwise} \end{cases} \qquad (2)$$

In these equations the $P_{ALL}(k)$ is taken according to the IEEE 802.16-2004 OFDM physical layer specifications and is given by

$$P_{ALL}(-100,100) = \begin{cases} 0 & \text{if k =0} \\ \pm 1 \pm j & \text{otherwise} \end{cases} \qquad (3)$$

The short and the long preamble are arranged as per the 256 IFFT structure as shown in the fig 3 below. The above P_{ALL} sequences are then modified as given below to obtain the GCL sequences

$$P_{GCL}(-100,100) = a_k\, b_{(k)\mathrm{mod}(m)} \quad k=0,1......N-1 \qquad (4)$$

Where a_k ,k=0,1.....N-1 is a zadoff-chu sequence of length $N=sm^2$ where m and s are arbitrary positive integers.b_k ,k=0,...,m-1 be any sequence of m complex numbers having the absolute value equal to 1 and (k)mod(m) means taking a modular m operation

The above GCL sequences[11-14] are then optimised using the matlab function fmincon based on the interior reflective newton method and arranged into 256 IFFT structure for CFO estimation. The main advantage of using GCL sequence over other sequence is that it has a lower PAPR ratio and higher correlation value when compared to the standard frequency domain values given by $P_{ALL\ (-100,100)}$ defined above in equation 3.The advantage of a low PAPR system is that we can maximise the estimation for the same given transmit power and the power boost requirement will also be comparatively less as a system is power boosted by taking the difference between the systems PAPR and preamble's PAPR[3].

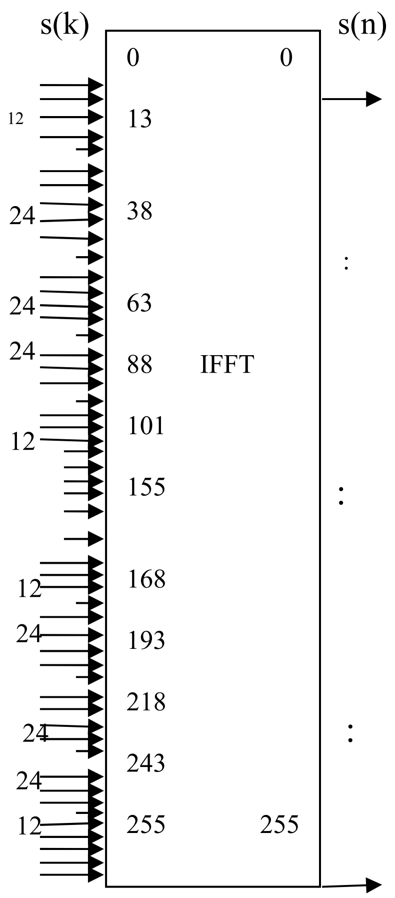

Fig3: 256 IFFT structure

The IEEE 802.16 with 256 IFFT size has 192 data 8 pilot tones and 56.The subcarriers 13,38,63,88,168,193,218,243 corresponds to pilot tones. There are 56 nulls from 101to156 and 192 data carriers to transmit data in between the null and the pilot tones

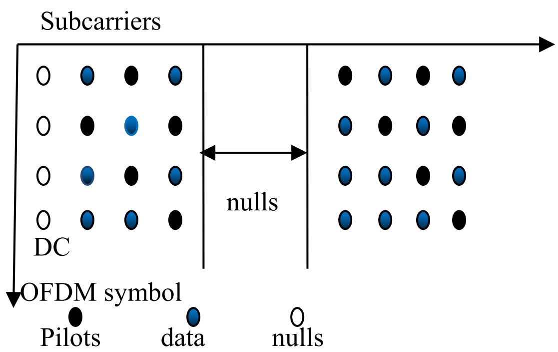

Fig 4:Arrangement of data on subcarriers

IV. CFO ESTIMATION AND COMPENSATION TECHNIQUE

There are several methods for CFO estimation[6-8] .In this paper CFO is estimated by taking the correlation between the symbols in the preamble. The CFO is added to the input signal x(n) as given below

X(n) = x(m).*exp(i*2*pi*(0:m-1)*CFO); (5)

Where m is the number of data symbols being transmitted
The CFO is estimated from the input signal by finding out the correlation of the signal transmitted. The input signal contains a preamble at the beginning used for CFO estimation.The simulations are performed on a preamble with 640 samples where 320 samples corresponds to short preamble and the remaining belongs to long preamble

The CFO is estimated from the short preamble mentioned above using the equation given below:

$$z(m) = \sum_{m=0}^{L-1} r_m^* \, r_{m+L} \qquad (6)$$

$$y(m) = angle(z(m))/2\pi \qquad (7)$$

$$offset1 = y(m)*4/256 \qquad (8)$$

where the value of L refers to the number of samples in short preamble.In the above equation we multiply by the factor 4 so that we choose only those subcarriers which are multiples of 4 as the short preamble has 4 identical parts.

The CFO is estimated from the long preamble with two sets of identical symbol of 128 sample each using the equation given below:

$$Z(m) = \sum_{m=0}^{L-1} r_m^* \, r_{m+L} \qquad (9)$$

$$Y(m) = angle(z(m))/2\pi \qquad (10)$$

$$offset\ 2 = y(m)*2/256 \qquad (11)$$

In the above equation we multiply by the factor two so that we choose only those subcarriers which are multiples of two as the long preamble has two identical parts. The numerical value in the Z(m) equation above corresponds to the corresponding sample in the long preamble with 320 samples.

The final CFO is estimated by taking the average of offset1 and offset2 and is given by

$$CFO = (offset1 + offset2)/2 \qquad (12)$$

The CFO compensation is done to the entire WiMAX packet based on the assumption that the entire packet experiences the same CFO as the preamble .The CFO compensation is carried out by the equation given below using the technique of phase rotation

$X(m)_{compensated} = x(m).*exp(- i*2*pi*(0:m-1)*CFO);$

V. RESULTS

To study the correlation properties of preamble simulations are done using Matlab2013a.The short preamble has 4 peaks on each side corresponding to the four identical parts and the long preamble has 2 peaks on each side corresponding to the 2 identical parts .The correlation plot of standard preamble in fig5,fig6 and optimised GCL sequence based preamble in fig7,fig8 given below shows that the GCL sequence based preamble has a higher correlation value .The magnitude plot of the standard preamble in fig9and optimised GCL sequence based preamble in fig10 indicates that GCL based preamble has average magnitude nearest to peak magnitude. The MSE curve of the CFO estimation using both the preambles are given in fig 11and fig12

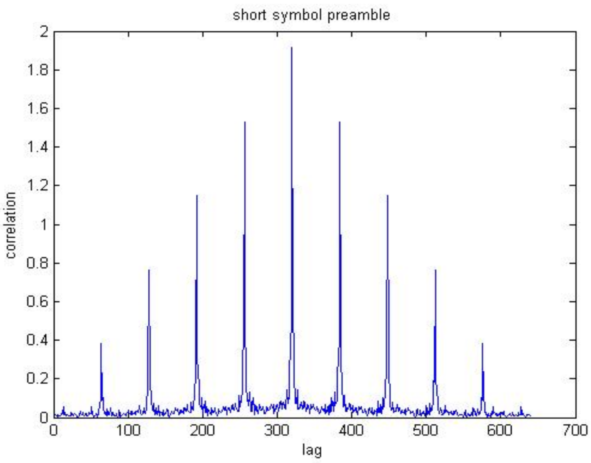

Fig 5:correlation of short preamble symbols of standard preamble

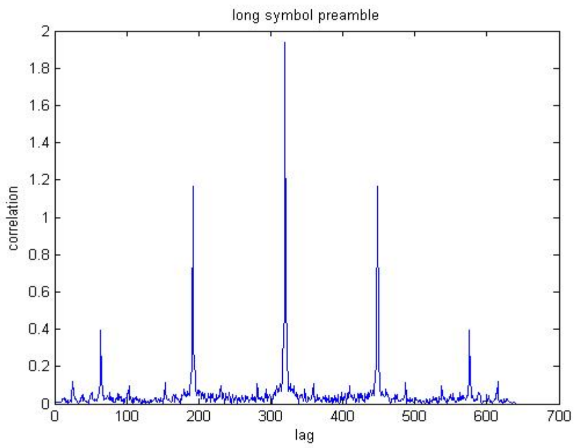

Fig 6:correlation of long preamble symbols of standard preamble

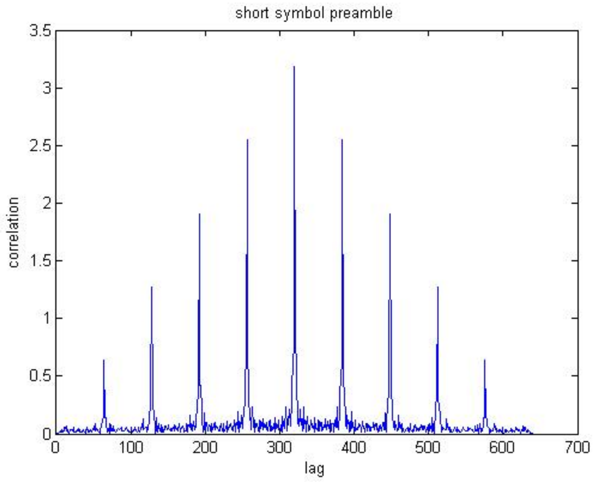

Fig 7:correlation of short preamble symbols of optimised GCL sequence based preamble

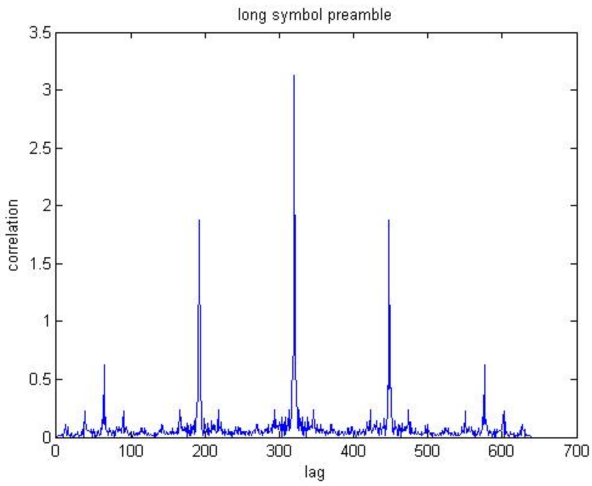

Fig 8:correlation of short preamble symbols of optimised GCL sequence based preamble

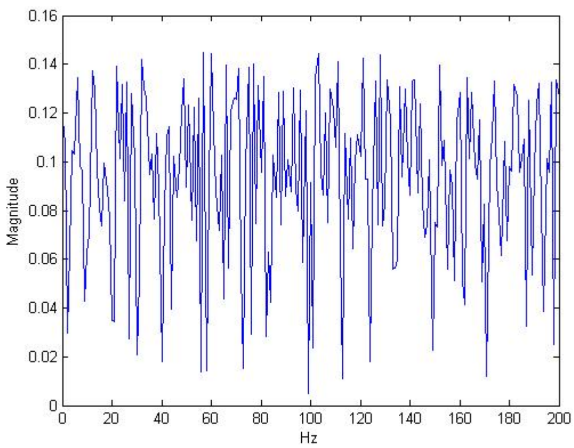

Fig9:Magnitude plot of standard preamble

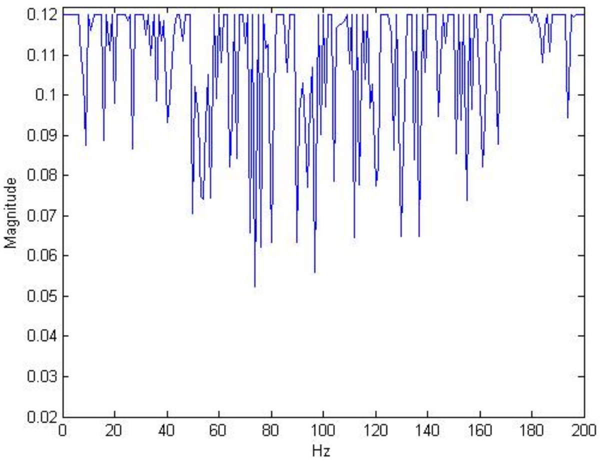

Fig10:Magnitude plot of optimised GCL sequence based preamble

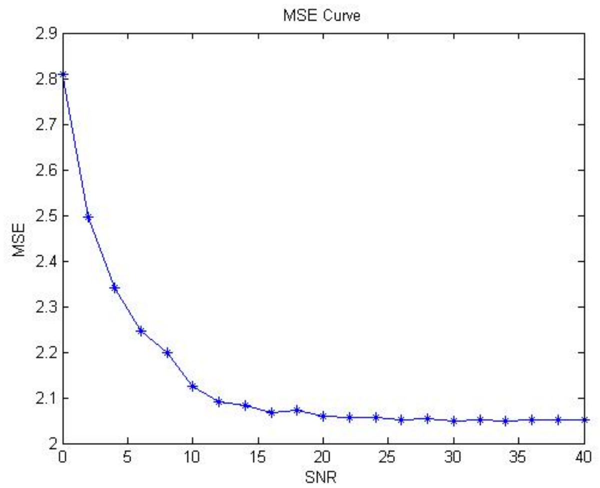

Fig11:MSE curve of standard preamble

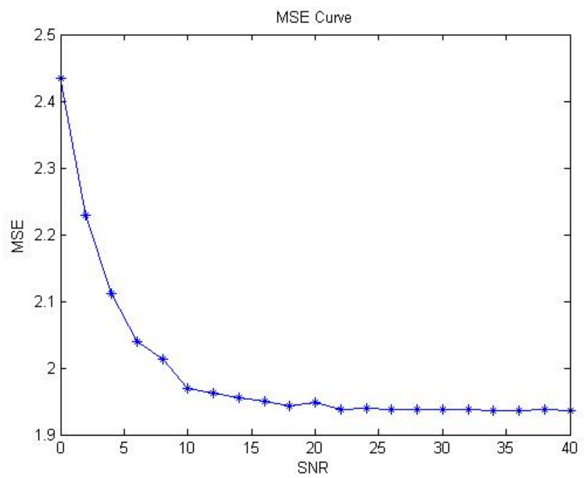

Fig 12 : MSE curve of optimised GCL preamble

VI. CONCLUSION

The MSE curves indicates that the CFO estimation using the optimized GCL sequence based preamble is more accurate compared to the standard preamble. The optimized GCL sequence based preamble also has a reduced PAPR ratio and an improvement of 2dB over the standard preamble which increases the efficiency of the system.

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