Channel Estimation for Wimax System Based On Comb Type Pilot Arrangement in AWGN Channel

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Abstract— **WiMAX (Worldwide Interoperability for Microwave Access) is a wireless networking system which provides wireless broadband to fixed and mobile terminals. Channel estimation is an essential problem in WiMAX system. But still Performance evaluation with channel estimation is required because amplitude and phase shift causes error in wireless channel.[2] While considering the Channel estimation for Wimax system it is important that, A good choice of the pilot pattern should match the channel behavior both in time and frequency domains[1]so Pilot-aided channel estimation has been used. These Pilot Assisted estimation techniques are mainly classified with block type and comb type pilot arrangements.**

In this paper, the channel estimation of WiMAX system for comb type arrangement under AWGN channel conditions is discussed. Here, mainly two algorithms Least Square and Least Mean Square are tested with Linear and Spline interpolation. Simulation will be carried out using MATLAB as a testing environment. BER versus SNR curves are used for comparing the results.

Keywords- **WiMAX, OFDM, AWGN, Channel Estimation, Comb-type arrangement, Interpolation.**

I. INTRODUCTION

Worldwide Interoperability for Microwave Access is a promising technology that was predicted to be the great leap toward broadband metropolitan area wireless network. This technology is specified in IEEE std. 802.16TM, in which the Orthogonal Frequency Division Multiplexing (OFDM) and Orthogonal Frequency Division Multiplexing Access (OFDMA) are used as modulation methods. There are two different standards, IEEE Std. 802.16d-2004 and IEEE std. 802.16e-2005 for fixed and mobile environment respectively.

WiMAX is designed to cover wide geographical areas serving large number of users at low cost and provides a wireless alternative to wired backhaul and last-mile deployments. It supports higher bandwidth than the existing wireless technologies and a coverage radius up to 20 or 30 miles away from the base station. WiMAX provides LOS, Near Line of sight & Non line of sight coverage with the greatest range covered in case of Line of sight and least distance covered in case of Non Line of Sight conditions.

The wireless-MAN-OFDMA PHY specified in the IEEE 802.16d/e standard is designed for non-line of sight (NLOS) operation in the frequency bands below 11 GHz and channel bandwidths of no less than 1 MHz (typically 5-25 MHz)[4].The intention of the standard is to enable vendors to manufacture the interoperable equipment's in order to ensure the interoperability between the vendors.[5]

It is well known that the wireless channel causes an arbitrary time dispersion, attenuation, and phase shift in the received signal. The use of orthogonal frequency-division multiplexing and a cyclic prefix mitigates the effect of time dispersion. However, it is still necessary to remove the amplitude and phase shift caused by the channel if we want to apply linear modulation schemes, such as the ones used in WiMAX.

OFDM technique is widely adopted in those systems due to its robustness against Multipath fading and simpler equalization scheme. In major of applications, for retaining the orthogonality of subcarriers and overcome intersymbol interference (ISI), a cyclic prefix (CP) is inserted instead of simply inserting guard interval. If the maximum delay of the Multipath channel does not exceed the CP length, the OFDM system would be ISI free by removing the guarding interval. For WiMAX systems, its delay spread is typically over several micro-seconds which are longer than the guarding interval. Hence, it is very difficult to maintain the system BER performance for non-line-of-sight (NLOS) channels at high data rate transmission.

As all prior knowledge about the channel conditions are not available and channel conditions may vary over time.so these channels needs to be estimated and updated on regular basis. In communication systems, channel estimation methods may be classified as blind, semi-blind or pilot-aided [13].Blind algorithms do not require any training data and exploit statistical or structural properties of communication signals. Pilot-aided

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methods on the other hand rely on a set of known symbols interleaved with data in order to acquire the channel estimate. Semi-blind methods combine a blind criterion with limited amount of pilot data, which improves both effective data rates and convergence speed. They also benefit from a larger sample support since both pilot and data are used for channel estimation [1]

The Pilot subcarriers are used for carrying pilot symbols. The pilot symbols are known as 'priori' and can be used for channel estimation and channel tracking.[7] .Pilot-based approaches are widely used to estimate the channel properties and correct the received signal. There are two types of pilot arrangements for Training-based (Pilot Assisted) Channel estimation Technique on the basis of arrangement of inserting pilot tones into OFDM symbol [6] a) Block-type pilot arrangement. b) Comb-type pilot arrangement.

The comb-type pilot channel estimation consists of algorithms to estimate the channel at pilot frequencies, and to interpolate the channel coefficients that belong to the pilot sub carriers using linear interpolation or spline interpolation to obtain the Channel Frequency Response (CFR) at the data sub carriers. The comb type channel estimation at the pilots can be based on LS, Least Mean-Square (LMS), which has been suggested in order to increase the performance of the estimation process.

This paper introduces an end to end WiMAX Physical layer system model including comb type channel estimation with interpolation approaches. Results are monitored with inserting AWGN in the channel model.

II. BACKGROUND

Wireless communication systems have different subcarriers at the channel transfer function and these subcarriers are appears unequal in both frequency and time domains. Therefore, a dynamic estimation of the channel is necessary.

Comb-type pilot channel estimation is introduced to satisfy the need for estimating and equalizing when the channel changes even from one OFDM block to the subsequent one. It is thus performed by inserting pilot tones into certain subcarriers of each OFDM symbol, where the interpolation is needed to estimate the conditions of data subcarriers. The arrangement of pilots in comb type estimation is shown in Fig .1-[9]

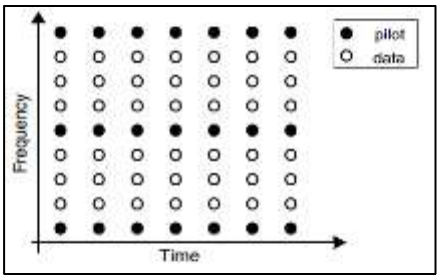

Fig 1 : Comb Type Pilot Estimation

A dynamic estimation of channel is necessary before the demodulation of OFDM signals since the radio channel is frequency selective and time-variant for wideband mobile communication systems .The equalizer minimizes the effect of the wireless channel and allows subsequent symbol demodulation. Both, the equalizer or channel estimator can be applied to compensate for the attenuation and phase shift introduced by the channel [8]

The WiMAX forum has two different system profiles: first based on IEEE 802.16-2004, OFDM PHY, called fixed system profile; second based on IEEE 802.16e-2005 scalable OFDMA PHY, called the mobility system profile[12]The IEEE 802.16 PHY layer model is simulated using MATLAB. Models for PHY layer of IEEE 802.11b/a (Wi-Fi) also referred to complete the simulation.

A) Fixed and Mobile WiMAX:

In fixed Wimax the FFT size is fixed at 256.Wimax has three classes of subcarriers. Out of 256 subcarriers ,192 subcarriers used for carrying data, 8 used as pilot subcarriers for channel estimation and synchronization purposes, and the rest used as guard band subcarriers. Fixed WiMAX uses orthogonal frequency division multiplexing (OFDM) modulation technique. The OFDM parameters used in WiMAX are as shown below in table 1 [11]

TABLE I
OFDM PARAMETERS USED IN WIMAX

Sr. No	Parameter	Fixed WiMAX OFDM-PHY	Mobile WiMAX Scable OFDMA-PHY			
1	FFT size	256	128	512	1024	2048
2	Number of used data subcarriers	192	72	360	720	1440
3	number of Pilot subcarriers	8	12	60	120	240
4	Number of null guard band subcarriers	56	44	92	184	368
5	Channel bandwidth (MHz)	3.5	1.25	5	10	20
6	Subcarrier frequency spacing	15.625	10.94	10.94	10.94	10.94
7	Useful symbol time (microseconds)	64	91.4	91.4	91.4	91.4
8	Guard time assuming 12.5% (microseconds)	8	11.4	11.4	11.4	11.4
9	OFDM symbol duration (microseconds)	72	102.9	102.9	102.9	102.9
10	Number of OFDM symbol in 5 ms frame	69	48	48	48	48
11	Cyclic prefix or guard time	1/32,1/16,1/8,1/4				

IEEE 802.16e-2005 is referred to as mobile WiMAX. In Mobile WiMAX, the FFT size is scalable from 128 to 2,048. Here, when the available bandwidth increases, the FFT size is also

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increased such that the subcarrier spacing is always 10.94 kHz. This mobile Wimax uses as OFDMA modulation technique. A combination of OFDM with FDMA, called OFDMA, OFDMA adds multiple accesses to OFDM by allowing several subscribers to transmit simultaneously on every OFDM symbol of different carriers. Mobile WiMAX has a 2.3, 2.5and 3.5 GHz spectrum and this mobile Wimax System is defined such that user can travel at speeds between 0- 120 km/h.

In OFDMA, Inverse Fast Fourier Transform is used to transform the data sequence into time domain. After the IFFT block, a system chooses a cyclic prefix (CP) such that it is larger than the maximal expected delay spread. This delay spread is inserted to avoid inter-symbol and inter-carrier interferences. After that the signal is transmitted. The Waveform arriving at the base station is given by the superposition of signals from all active users, which experience their individual fading channels & complex additive white Gaussian noises. Demodulation is inverse process of OFDMA modulation process,[4]

B). Channel Estimation for Comb type pilot arrangement

Channel estimation is an important issue in any OFDM system for demodulation and decoding. The function of channel estimation is to form an estimate of the amplitude and phase shift caused by the wireless channel. [3]

Comb type channel estimation in can be performed by either inserting pilot tones into all of the subcarriers of OFDM symbols with a specific period or inserting pilot tones into each OFDM symbol. We are performing this channel estimation in two steps:

- The first step is to estimate the channel frequency coefficients at the pilot symbols positions using Least Square and Least Mean Square technique in Wimax Model.
- Using the estimates of the channel frequency coefficients, we then interpolate over channel frequency coefficients corresponding to the data symbols in Wimax Model.

The comb-type pilot channel estimation consists of algorithms to estimate the channel at pilot frequencies and to interpolate the channel. The estimation of the channel at the pilot frequencies for comb-type based channel estimation is done using LS and Least Mean-Square (LMS). And expected that LMS has been shown to perform better than LS. The interpolation of the channel for comb-type based channel estimation is done with considering linear interpolation, spline interpolation. To analyze this comb type estimation firstly we need to study whole WiMAX System simulation.

III. WiMAX SYSTEM SIMULATION

We simulate Wimax End to End model using MATLAB 2009b. The simulation is made with combination of 3 sub models i.e. WiMAX Transmitter model, WiMAX Receiver model and Channel Estimation model. The Entire simulated Wimax End to End model is shown in figure 2.

Fig 2 : WiMAX End to End Model

In WiMAX transmitter setup, Channel coding part is composed with 3 major steps- randomization, Forward Error Correction (FEC) and interleaving. FEC is done in two phases through the Reed-Solomon and Convolutional Code After the interleaving process, the data is given to suitable modulation process to create an OFDM symbol. To ensure proper implementation, the end-to-end system was modeled in accord with the standard for this specific configuration. Additional functions such as Inverse Fast Fourier Transformed (IFFT) and cyclic prefix is added to the OFDM Symbol ensure compatibility. In this simulation we used QPSK modulation. Also Additive White Gaussian Noise (AWGN) is added in the channel.

The receiver implementation is an inversion of all the transmitter functions with addition of channel estimation. As channel estimation function have a large impact on receiver performance. So the channel estimation functions were modeled in this simulation. A receiver model was constructed such that it reverses all of the elements of the transmitter. First extract the data symbols from the OFDM waveform. Then demodulated waveform, deinterleave decode (first Viterbi, then Reed Solomon) and finally reverse the bit scrambling operation of the transmitter to calculate Bit Error Rate.

The channel estimation based on comb type pilot arrangement is studied through different algorithms for both estimating channel at pilot frequencies and interpolating the channel. The estimation of channel is based on Least Square and Least Mean Square algorithm while the channel interpolation can be done using linear interpolation & spline interpolation.[10]

The effect of linear interpolation approach and spline interpolation approach based on LS and LMS are investigated. Also both estimation algorithms are compared with considering linear,& spline interpolations. All test cases were simulated using QPSK which is the type of modulation

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supported by WiMAX. All the simulations were carried out on the same number of frame base to get a result.

IV. RESULTS & DISCUSSION

We have simulated the proposed scheme of WiMAX communication system in comb type pilot arrangement using Matlab with specifications mentioned in table 2

TABLE II
PARAMETERS FOR SIMULATION

Parameters	Value
No. of Subcarriers in FFT	256
Guard Interval (G)	¼ from symbol period
Channel Bandwidth	1.25 Mhz to 28 Mhz
Sampling Frequency	1.72 Mhz to 32 Mhz
Cyclic Prefix length	64
Modulation	QPSK
Channel Model	AWGN
Range OF SNR	0 to 16

With considering the model shown in fig 2 and the specifications given in table 2; the performance at different cases with addition of AWGN for measuring bit error rate versus SNR are verified. The whole simulation takes less than 5 minutes on a regular PCS with MATLAB version of (R2009b) Figures 3 to 7 shows the actual performance.

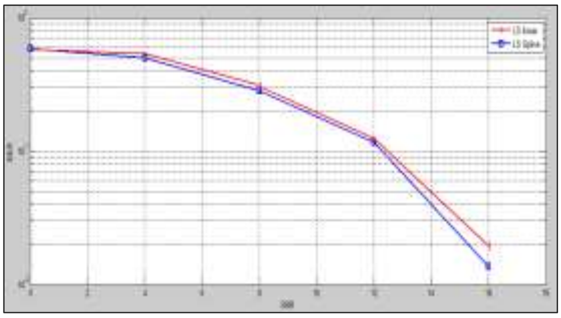

Fig 3: LMS with linear & Spline interpolation

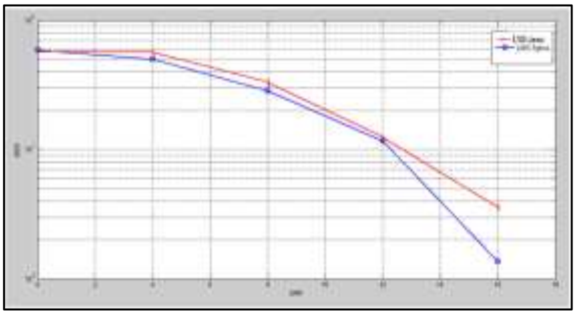

Fig 4: LMS algorithm with linear & Spline interpolation

Figure 3 & 4 demonstrate the Bit Error Rate vs Signal to Noise Ratio graph for the Least Square algorithm and Least mean Square algorithm with both linear, Spline interpolation respectively. The graph shows that as SNR increases the Bit Error Rate decreases for both the interpolations. As BER is less so from figure 3 And 4 we analyses that Spline interpolation performs better than that of the linear interpolation for both the algorithms.

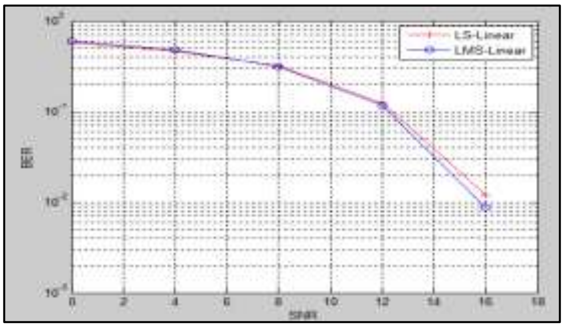

Fig 5: LS & LMS algorithm with linear interpolation.

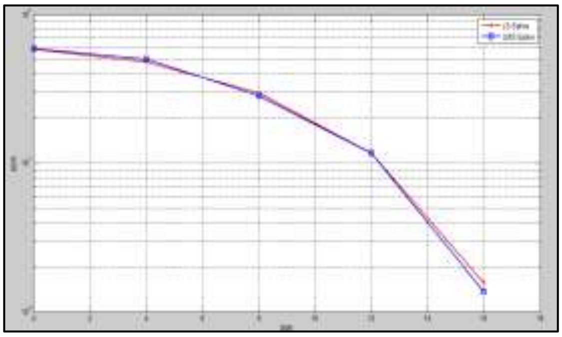

Fig 6: LS & LMS with spline interpolation

In fig. 5 we compared performance between LMS algorithms & LS algorithm with linear interpolation and in fig. 6 same is done with spline interpolation. Here also if SNR increases then BER decreases i.e. LMS estimator has less bit error rate than LS estimator algorithm. Hence in both cases we observe that at higher SNR LMS algorithm works better than LS algorithm.

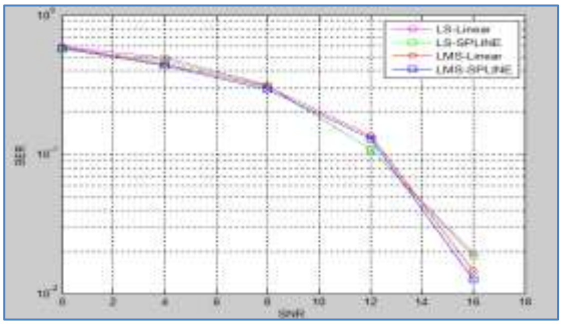

Fig 7: LS and LMS with Linear, Spline interpolation

Fig 7 gives final analysis of paper. In this figure we compared both LS estimation algorithm and LMS estimation Algorithm with linear and Spline interpolation. Here we found that in all cases bit error rate is decreases with increase in signal to noise ratio. The LMS linear interpolation has less bit error rate than LS linear interpolation. It is also shown from figure 7 that the performance of combination of estimation techniques usually

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ranges from the best to the worst as follows, LMS Spine to LS linear .Finally with considering all the graphs we analyze that LMS spline interpolation technique works better than all cases under AWGN conditions.

V. CONCLUSION & FUTURE WORK

In this paper, we found that with adding AWGN in channel conditions, higher order interpolation technique (spline) gives better performance than lower order interpolation technique (linear). Least Mean Square channel estimation algorithm works better than that of Least Square Algorithm. And mainly the combination of LMS, Spline interpolation has less bit error rate than any other combinations and it less bit error rate. So we analyses that LMS spline interpolation technique is best suitable channel estimation technique under AWGN Channel conditions.

In future also we can work on this model with following some possible recommendations. The algorithm will be tested with considering Fading Effect on the channel.. We can extend this work for other interpolation techniques such as second order, low-pass etc. At different velocities also we can evaluate the performance.

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