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PERFORMANCE EVALUATION OF MOBILE WIMAX USING SLIDING WINDOW MMSE EQUALIZATION

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Abstract: *WiMAX is introduced by the Institute of Electrical and Electronic Engineers (IEEE) which is standard nominated 802.16d-2004 (used in fixed wireless applications) and 802.16e-2005 (mobile wireless) to provide a worldwide interoperability for microwave access.). IEEE 802.16e-2005 has been urbanized for mobile wireless communication which is based on orthogonal frequency division multiplexing (OFDM) technology and this enables going towards the 4G mobile in the future.*

In a usual OFDM broadband wireless communication system, a guard interval using cyclic prefix is included to avoid the inter symbol interference (ISI) and the ICI. This guard interval is necessary to be at least equal to, or longer than the maximum channel delay spread. This method is very simple, but it reduces the transmission efficiency.

To compensate affect of ICI by applying equalizers at receiving side is an active research area. Zero forcing (ZF) and Minimum mean square error (MMSE) are mainly two equalization algorithm. Unfortunately, the MMSE method requires the inversion of an N × N ICI matrix, where N is the number of subcarriers. When N is large, the computational complexity can become prohibitively more. Utilizing the fact that ICI energy is clustered in adjacent subcarriers, MMSE equalization is made localized.

The aim of this paper is the performance evaluation of 802.16e OFDM-PHY system using sliding window MMSE channel equalizers at the receiver side for different doppler frequency. The Bit Error Rate (BER) of the wireless communication channel using Recursive sliding window Minimum Mean Square Error (MMSE) equalizer is analyzed. The simulation includes BER versus Energy to noise ratio (E_b/N_0) at various doppler frequencies for performance predictions.

Keywords: *OFDM, ISI, ICI, MMSE Equalizer, ZF, BER, Mobile WiMAX.*

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INTRODUCTION:

Worldwide Interoperability for Microwave Access (WiMAX) is based on wireless metropolitan area networking (WMAN) standards developed by the IEEE 802.16 group and adopted by both IEEE and the ETSI HIPERMAN group [1]. It provides very high data throughput over long distance in a point-to multipoint and line of sight (LOS) or non-line of sight (NLOS) environments. WiMAX can provide seamless wireless services up to 20 or 30 miles away from the base station [2].

The IEEE 802.16e-2005 forms the basis for the WiMAX solution for mobile applications and is often referred to as mobile WiMAX [3].

OFDM technique is widely adopted in those systems due to its robustness against Multipath fading and simpler equalization scheme. In most of applications, for retaining the orthogonality of subcarriers and overcome 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 [4]. For WiMAX systems, its delay spread is typically over several microseconds which are longer than the guarding interval.

Therefore, it is very challenging to maintain the system Bit Error Rate (BER) performance for NLOS channels at high data rate transmission also for mobile WiMAX. Doppler Effect degrades system performance. Both, the equalizer or channel estimator can be applied to compensate for the attenuation and phase shift introduced by the channel [5]. Equalization and channel estimation is simple for OFDM systems but it needs careful consideration due to their implementation limitations to accomplish the trade-off between complexity and accuracy.

INTER CARRIER INTERFERENCE (ICI):-

Radio channel are arbitrary, fast varying and inaccuracy prone. In a wireless system the variation/oscillation in the received signal is called fading. The aim of the wireless system design is to overcome different types fading and offer consistent and competent transmission. Generally there are two types of fading [6]:

- **Large scale fading**: It is the instability in the average signal strength over a large distance and is caused by earthly change. This occurs when a mobile travel from a lake to hilly area or from an open area to a high buildings area. Large scale fading can be mitigated by controlling the transmit power.

- **Small scale fading**: Occurs as a effect of the fluctuations in the received signal strength over a little distance and is caused by multipath and Doppler's shift. Doppler shift refers to the alteration on frequency of the signal because of comparative motion between the transmitter and the receiver.

The Doppler shift is the variation in frequency and wavelength of a wave for an observer moving comparatively to the source of the waves. In multipath fading channel, different Doppler shift on every of the multipath components guide to random frequency modulation as long as there is relative motion between the base station and the mobile, Doppler shift is given by [6].

$$f_d = (v/\lambda)cos\,\theta$$

where: Above Equation refers to the relation between the Doppler shift and the mobile velocity as well as the spatial angle between the direction of mobile motion and the wave arrival.

The Doppler shift introduces a different type of interference in OFDM i.e. ICI [7]. OFDM separated the spectrum into narrowband subcarriers and they are closely spaced simply because they are orthogonal. One of the requirements for orthogonality is to preserve the subcarrier spacing exactly the reciprocal of the symbol period [7]. The frequency shifts thus varying the subcarrier spacing which results in the loss of orthogonality. This loss of orthogonality creates interference between the signals which is called as ICI [7]. Since the subcarriers in OFDM are usually very narrow hence the OFDM system becomes very sensitive to ICI. ICI destroys the orthogonality of the OFDM system which is overcome by the use of cyclic prefix method.

Researchers have proposed various methods to combat the ICI in OFDM systems:

- **Frequency Domain Equalization**
- **Time Domain Windowing**
- **Pulse Shaping.**
- **ICI Self Cancellation**

Equalizer at receiver side to improve the performance in time selective channel is allowed in Mobile WiMAX [8]. Equalizer in wireless communication is adaptive traversal linear filter which is designed as channel compensator. The value of weight of equalizer is adjusted according to equalization algorithm. ZF and MMSE equalization algorithm are two most popular algorithms [9].

SYSTEM MODEL

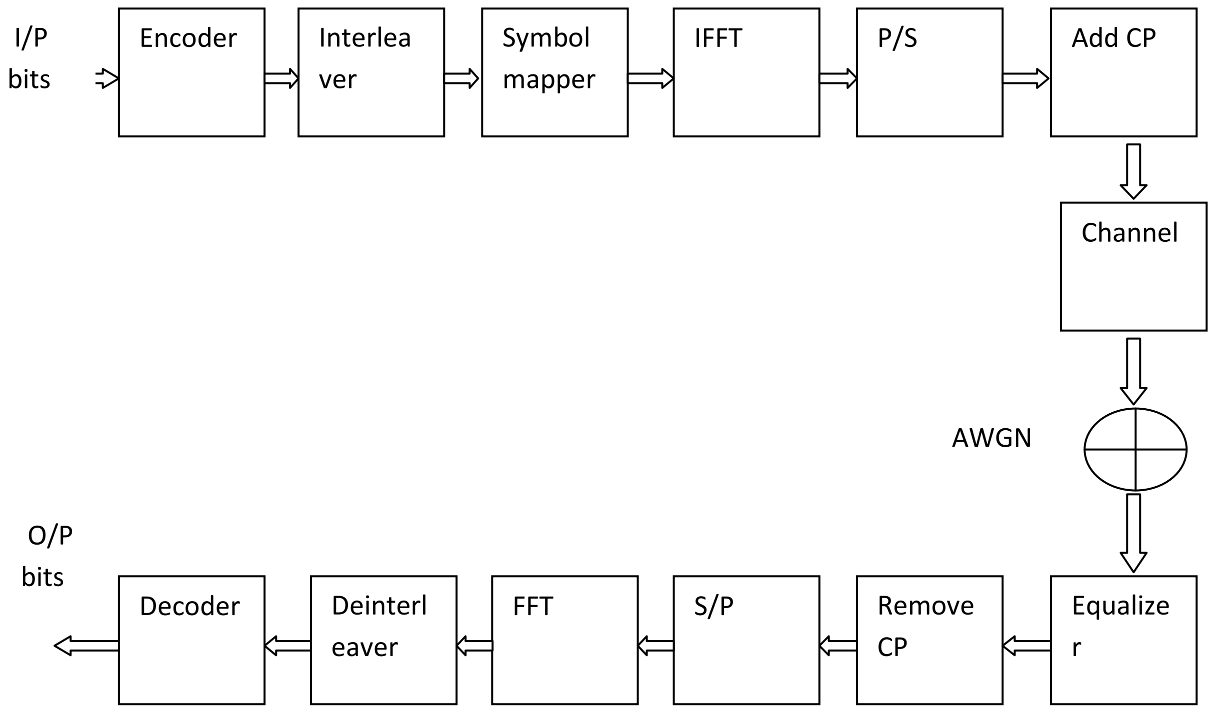

Fig.1.OFDM based physical layer system of mobile WiMAX

The OFDM system model is

$$Y = HX + w \tag{1}$$

Where, $Y= [Y_0,Y_1,\ldots,Y_{N-1}]^T$ are the received OFDM subcarriers.

$X= [X_0,X_1,\ldots,X_{N-1}]^T$ are the transmitted OFDM subcarriers.

$w= [w_0,w_1,\ldots,w_{N-1}]^T$ are the additive white Gaussian noise.

$$\text{And } H= \begin{bmatrix} H_{0,0} & H_{0,1} & \ldots H_{0,N-1} \\ H_{1,0} & H_{1,1} & \ldots H_{1,N-1} \\ H_{N-1,0} & H_{N-1,1} & \ldots H_{N-1,N-1} \end{bmatrix} \tag{2}$$

As equalizers are compensator for channel distortion so the equalizer output is given by:

$$X= GY \tag{3}$$

Where, G is the N-by-N equalizer matrix which minimizes the cost function $E\left\{\left|X-\hat{X}\right|^2\right\}$ and the solution is, $G = [R_{xy}R_y]^{-1}$ (4)

The resulting MMSE is then given by :

$$MMSE = Tr(Rx- R_{xy}R_y\, R_{yx})^{-1} \tag{5}$$

Where, $R_{xy} = \sigma^2_x H^H$, (6)

$$R_y = \sigma^2_x HH^H + \sigma^2_w I_N \quad , \qquad (7)$$

Where R denotes covariance matrix, the superscript H denotes complex conjugate transpose and $\mathbf{I}_N$ is the N-by-N identity matrix

Then (3) can be rewritten as

$$G = H^H(HH^H + I_N) \qquad (8)$$

Likewise (4) becomes MMSE=σ^2_xTr(1-GH) (9)

SLIDING WINDOW MMSE EQUALIZER:

Using the fact that ICI energy is concentrated in adjacent sub channels, the complexity of the frequency domain equalization can be significantly reduced without much performance degradation. The MMSE equalizer is too complex to be implemented, especially when *N* is large. Using the fact that the ICI power is localized to the neighborhood of a desired sub channel, only a few neighborhood sub channels can be used for equalization without much performance penalty [10]. If the ICI channel memory has length *q*, the correlation length among each data subcarriers is at most 2*q*. Recursive Sliding window MMSE equalizer employs a much smaller window of size (2*q* + 1) × (2*q* + 1)

More specifically, the channel matrix $\mathbf{H}m \in \mathcal{C}(2q+1)\times(2q+1)$ in sliding window MMSE equalizer becomes

$$\mathbf{H}_m = \begin{bmatrix} h_{m-q,m-q} & \dots h_{m-q,m+q} \\ h_{m,m-q} & \dots h_{m,m+q} \\ h_{m+q,m-q} & \dots h_{m+q,m+q} \end{bmatrix} \qquad (10)$$

The problem is to find the equalizer coefficient vector $\mathbf{g}_m = [g_{m,0}, \dots, g_{m}, q-1]$

From (7), the MMSE solution is

$$g_m = R_{XmYm} R_{Ym}^{-1} \qquad (11)$$

And, by considering the same assumption as in the previous section, the solution for MMSE equalization is given by:

$$R_{XmYm} = E\{x_m \mathbf{y}_m^H\} \qquad (12)$$

$$= \sigma_x^2 h_m^H$$

Where $\mathbf{h}_m$ is the mth column of the matrix H_m

Also $R_{Ym} = E\{ y_m y_m^H \}$

$$= \sigma_x^2 H_m H_m^h + \sigma_w^2 I_q. \qquad (13)$$

After inserting (12) and (13) into (11), the *q*-tap equalizer vector g_m becomes

$$g_m = h_m^{H}(H_m H_m^{h} \frac{\sigma_w^2}{\sigma_x^2} Iq)^{-1} \quad (14)$$

Similarly, $$\text{MMSE} = \sigma_x^{2} \sum_{m=0}^{N-1} (1 - g_m h_m) \quad (15)$$

By choosing an appropriate number q, the complexity of the equalizer can be reduced significantly.

RESULTS AND ANALYSIS

Simulation results of the proposed equalizers with application to IEEE 802.16e mobile WiMAX standard are evaluated. The input data is encoded with 64- state rate-1/2 binary convolutional code (BCC) with polynomials in octal notation $(133,171)_8$, 16-QAM modulation is used with 256 subcarriers. The channel considered for simulation is COST-TU with 12 numbers of taps. The normalized Doppler frequency f_dT_s= 6.82% and 13.64% is applied one by one. At receiver side MMSE equalizer is applied with 5 numbers of taps and 11*11 sized windows is being used for channel estimation. For analyzing performance of proposed algorithm between BER and E_b/N_0 at various f_dT_s are shown.

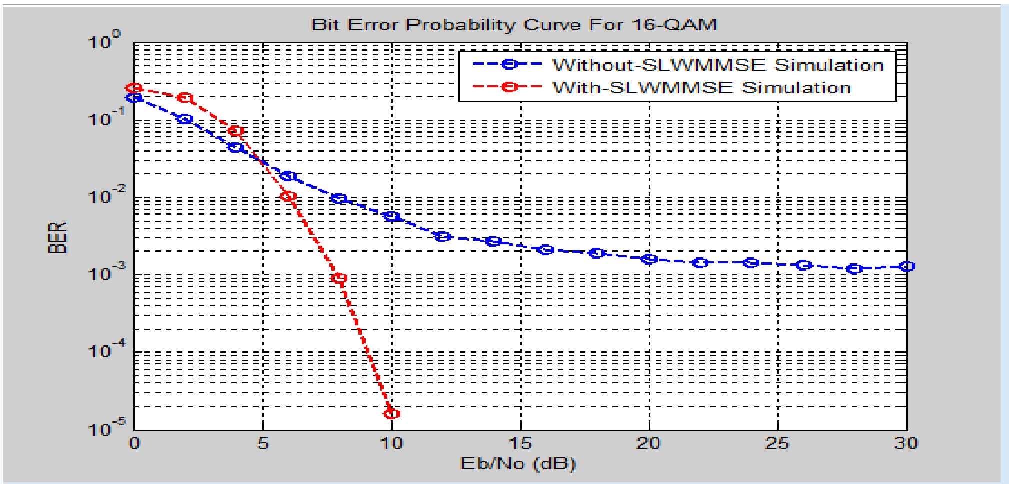

Fig.2. BER of OFDM based physical layer mobile WiMAX with and without sliding window MMSE equalization for f_dT_s= 6.82%.

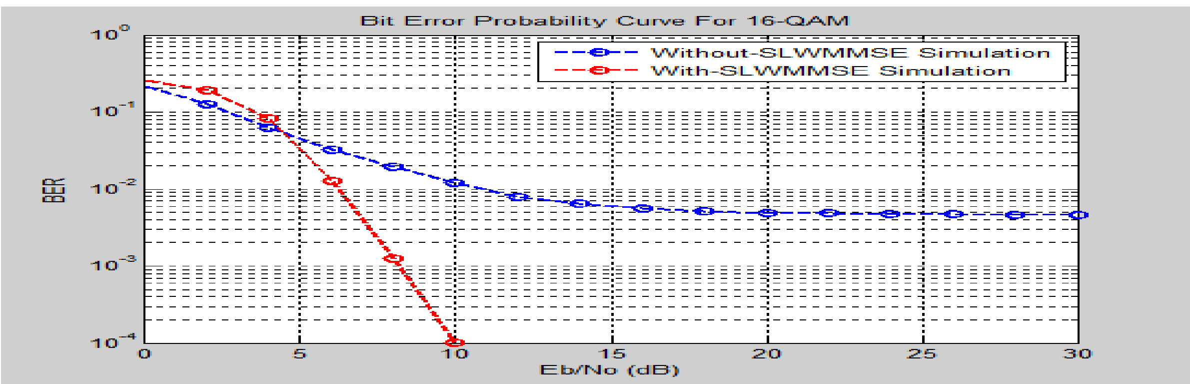

Fig.3. BER of OFDM based physical layer mobile WiMAX with and without sliding window MMSE equalization for f_dT_s= 13.64%.

By analyzing the result this can be concluded that SLW MMSE equalizer offers same BER at low values of E_b/N_0 for different f_dT_s . At E_b/N_0=10dB the proposed SLWMMSE equalizer gives BER $1.63*10^{-5}$, $1.02*10^{-4}$ at f_dT_s =6.82%, 13.64% respectively. This is because higher value of f_dT_s introduces more ICI in the system.

Due to energy concentration property of ICI the proposed SLW MMSE used 5 numbers of taps without performance degradation.

CONCLUSION

As demand for high speed communications under different mobile scenarios rises, the ICI problem of OFDM systems become an important issue. Iterative equalization and decoding of the wireless mobile coded OFDM system is considered. Complexity reduction compared to the MMSE equalizer is achieved due to the energy concentration property of ICI. Computational efficient recursive sliding window MMSE based equalizer are derived which provides excellent performance and complexity trade-off. The performance of the equalizer has been evaluated over the COST-TU channel model with application to WiMAX. The results suggest that iterative processing at the receiver end allows full exploitation of both temporal and frequency diversity available in a spectrally efficient system.

This is concluded that OFDM based physical layer of mobile WiMAX system applying recursive sliding window MMSE equalization at receiver side having 5 number of tap with 64 state BCC encoding scheme, QAM-16 modulation with 256 subcarrier, with COST –TU channel having 12 number of taps and applying f_dT_s =6.82%, 13.64% one by one gives reduced BER as compared to other techniques. As the normalized Doppler frequency increases, the performance of proposed algorithm degrades due to higher ICI in the system.

FUTURE WORK

The proposed coded-OFDM signal reduces the BER with recursive sliding window MMSE equalization at receiver side. Thus future work is with MIMO system.

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