An Interleaving And Channel Sensing Approach For 802.16 WiMAX Systems

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Abstract- *This paper focuses on mitigating one of the most serious challenges of WiMAX systems which BER degradation. The reason for BER degradation can be attributed to the random nature of wireless channels, mobility of users causing Doppler Shifts and changing scenario of Interacting Objects (IOs). Since WiMAX uses multicarrier modulation like OFDM, hence it becomes impractical to expect a frequency flat nature of the wireless channel along the entire band of the frequency.[3] The proposed technique presented in this paper utilizes the channel state information (CSI) of the channel to decide a threshold for multiple sub-carriers and suppress the ones whose strength is below the particular threshold. It has been shown that the proposed technique attains better results compared to conventional WiMAX systems*

Keywords- WiMAX, Channel State Information (CSI), Signal to Noise Ratio (SNR), Bit Error Rate (BER), Probability of Error (P_e), Channel Sounding, Sub-Carrier Suppression.

I. INTRODUCTION

Wired communication becomes infeasible in terms of cost, maintenance and complexity as the distance and number of users under consideration increases. It is very difficult to use wired communication over long distances which makes wireless communication is necessary. The term ‘wireless’ is used for the telecommunication systems in which some form of energy is used to transfer information without the use of wires. In our day to day life wireless technology plays a very important role. WiMAX has evolved as the key choice for high speed broadband access rendering last mile connectivity. It utilizes OFDM to attain high data rates. The implementation of WiMAX through it’s block diagram is shown below.**[21]**

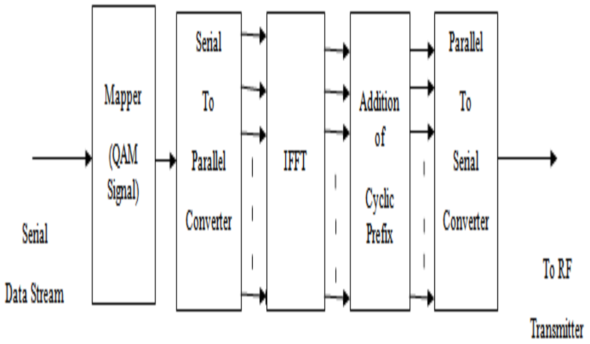

Fig.1 Block Diagram of WiMAX Transmitter

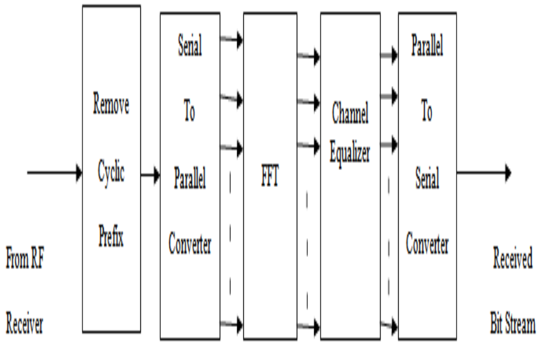

Fig.2 Block Diagram of WiMAX Receiver

The main features of IEEE 802.16/WiMAX technology are the following:

- (Carrier) frequency <11 GHz. For the moment, the frequency bands considered are 2.5 GHz, 3.5 GHz and 5.7GHz.
- OFDM. The 802.16 is (mainly) built with the Orthogonal Frequency Division Multiplexing (OFDM) transmission technique known for its high radio resource use efficiency.
- Data rates. A reasonable number is 10 Mb/s. Reports have given more ambitious figures going up to 70 Mb/s or even 100 Mb/s. These values would be in a

very good state of the radio channel and for a very small cell capacity, making these values too optimistic for the moment.

- Distance. Up to 20 km, a little less for indoor equipments.

II. FREQUENCY SELECTIVE CHANNELS

Wireless channels suffer from the drawback of frequency selectivity as well as Doppler shifts due to mobile users. Distortions occur in the received signal due to non flat nature of the channel. An equalizer tries to estimate the channel transfer function and reverse its effects. **[5]**The channel frequency response has to be necessarily flat to satisfy distortion less transmission but a practical channel never satisfies such a frequency flat nature. This causes some of the carriers in the system in getting suppressed by the wireless channel and thereby degrading the Signal to Noise Ratio (SNR) of those affected carriers. A direct consequence of the above is degraded BER performance of the system. A practical frequency selective channel is shown in figure.3 **[22]**

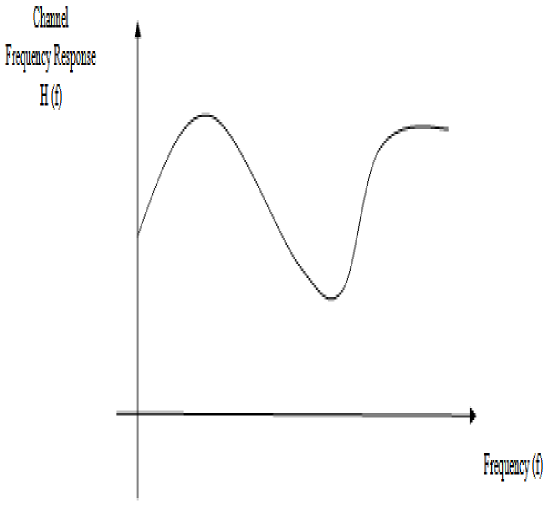

Fig.3 Frequency Response of a Practical Frequency Selective Channel

It can be clearly seen from the frequency response of the channel that the channel behaves differently for different frequencies.

III. INTERLEAVING

The Interleaving is technique in which burst errors are avoided using permutation of bits. The interleaver can be thought to be a block that is used to permute the bits of the input data stream. he permutation or randomization of the data bits is useful for avoiding or reducing the chances of burst errors. The concept can be understood by considering a random data stream of bits x(n). In such a case, the chances of burst errors or errors with a sudden upsurge in error rate can occur. It is often very difficult to recover the actual bits in case burst errors occur. The interleaver maps the bits into another stream of bits y(n) such that it spreads out the bits with continuous repetition into a spread out bit stream. In this case, due to the permutation, the chances of burst errors get reduced.

Mathematically it is given by:

$$x(n)\xrightarrow{I}y(n) \qquad \textbf{(1)}$$

Here,

I is the interleaving action
x(n) is the original bit stream
y(n) is the interleaved bit stream

To revert the effect at the receiving end, the process of de-interleaving is used which is the opposite process of interleaving. The de-interleaver process is opposite to the interleaver process to give back the original bit stream. Mathematically,

$$y(n)\xrightarrow{DI}x(n) \qquad \textbf{(2)}$$

Here,

DI is the de-interleaving process giving back the de-interleaving process.

The interleaving and non-interleaving process are opposite processes or opposite block pairs. The interleaver spreads out the data bits in such a manner so as to decrease the chances of burst or group errors. The most common structure of the interleaver is the block interleaver, which has a mapping as:

$$Y = r(x) \qquad \textbf{(3)}$$

$$x = C(Y) \qquad \textbf{(4)}$$

Here,
r stands for row wise write
c stands for column wise read
x is the input data stream
Y is the output data stream

IV. PROPOSED SYSTEM

The methodology for the proposed system can be understood as:

Sub-Carrier Suppression using CSI of the channel

Consider a discrete impulse response of the channel given by $\mathrm{h(n)}$. We will obtain the frequency response of the channel using the FFT i.e.

$$\mathbf{H(f) = FFT\,[h(n)]} \quad \textbf{(5)}$$

A random binary message stream needs to be generated which would eventually modulate by the sub carriers to generate the composite signal.

Let the message signal be $\mathrm{X_i}$, now the composite signal needs to be analyzed under three different cases:

1. The data bits are modulated by all the sub carriers those would be used for modulation. The strength sub carriers are different due to the frequency selective nature of the channel.
2. Sub carriers are categorized into two categories viz. good and poor sub carriers based on their strength. Sub carriers having strength greater than the average can be considered as good sub carriers while the ones having less strength are considered as poor sub carriers. Finally, poor sub carriers are suppressed and will not be utilized for modulation.
3. Modulated data by sub carriers are having constant strength which indicates an ideal channel of flat frequency response.

The output of the channel is obtained by convolving the composite signal with impulse response of the channel. This convolution is done for all the three cases discussed above. After convolution random sequence will be generated and random noise to be added to the signal when it is passed through the channel. In order to analyze the effect of these sub carriers at the output the scatter plots of the signals are obtained. The scatter plots can be analyzed on the basis of three types of signal i.e. the signals having high strength, average strength & weak strength.

The scatter plots depict the signaling points of the signal.

Subsequently the received signal has to be obtained using

$$\mathrm{X'}_i = \mathrm{FFT[x'(u)]}$$

Finally, the BER or Probability of Error needs to be analyzed for three cases again i.e.

1) When all the sub carriers are utilized for modulation.
2) When poor sub carriers based on a threshold value are suppressed.
3) When all sub carriers are utilized for modulation and all the sub carriers have equal strength due to ideal nature of the channel

It should be noted hare that the BER Curve should fall the earliest for the ideal channel case since for the ideal channel, S/N would be highest among all the cases considering all the sub carriers. Although it’s not a practical case exhibiting frequency selectivity of the channel, still it helps in a comparative analysis with the degradations with respect to a frequency selective channel.

The BER curve utilizing all non-ideal sub carriers should fall the slowest with respect to the SNR as some sub carriers would have extremely weak signal strength thus resulting into very low values of S/N. An earlier fall is expected from the system where poor sub carriers are suppressed since the sub carriers which have the least SNRs are not utilized for modulation. Thus the BER performance would not be as poor the above step. It is important to validate the results obtained from the graphs with the corresponding mathematical relation for BER. Coherent results are expected from the scatter plots and the BER curves.

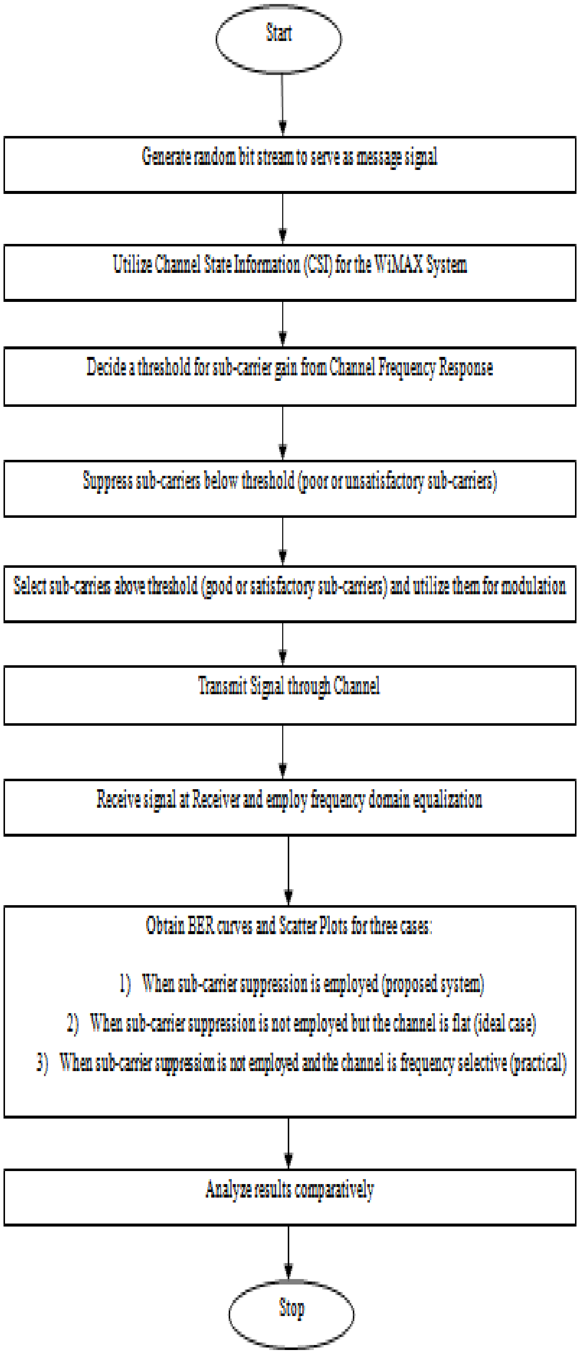

Fig.4 Flowchart of Proposed System

During the entire process, we assume the channel to be quasi-static or Wide-Sense Stationary. But it is crucial to emit bursts of RF signals in the channel with a repetitive time period $\mathbf{T_{rep}}$ which should be less than the time before which the channel changes (T-hat).The condition can be described as

$$T_{rep} < \hat{T} \quad (6)$$

So the sounding can be described as

$$\tilde{s}(t) = \sum_{i=0}^{t} s\,(t - i\,Trep) \text{ with } Trep < \hat{T} \quad (7)$$

So, knowing the sub-channel gain**,** poor sub-carriers can be identified based on the minimal value of the acceptable of the system. If we do not make the distinction of the poor sub-carriers, then the overall performance of the WiMAX system would be dominated by the poor sub-carriers. So after identifying the poor sub-carriers, these subcarriers are suppressed (tone-suppression) to improve the BER performance of the system.

The proposed system would achieve a BER performance that can be compared with the BER performance of an ideal flat channel and a frequency selective channel which does not employ any technique.

The probability of error**[23]** is estimated under three cases:

1. When the channel is ideal:
2. When all the sub-carriers are used for modulation:

$$\text{BER} = \frac{\textbf{Error in a bit}}{\textbf{Total no.of bits Transmitted}} \quad (8)$$

3. When poor sub-carriers or tones are suppressed among all sub carriers:

Let the strength of the sub carrier be defined as A. The sub carriers can be categorized as,

$A \geq T \rightarrow \text{good subcarrier}$
$A < T \rightarrow poor\ subcarrier$

V. RESULTS

The system is simulated on MATLAB.

Figure 5 depicts the sub-carrier gain of an ideal channel for WiMAX systems. It should be noted though that such a channel is practically non-existent and only a frequency selective channel exists practically.

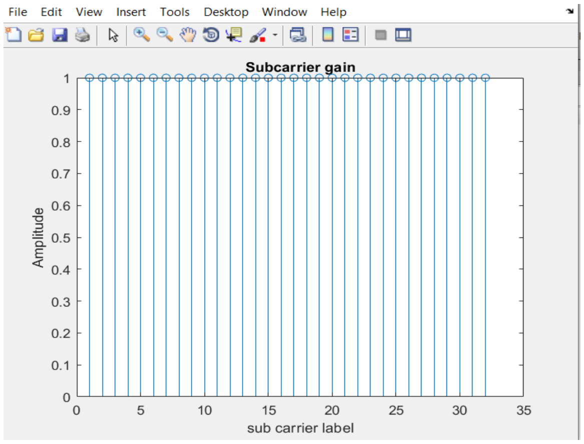

Fig.5 An Ideal Channel (FLAT)

Figure 6 below depicts the sub-carrier gain of a practical (frequency selective) channel for WiMAX systems

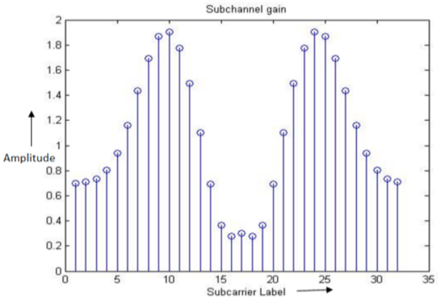

Fig.6 Non-Ideal Channel (Frequency Selective)

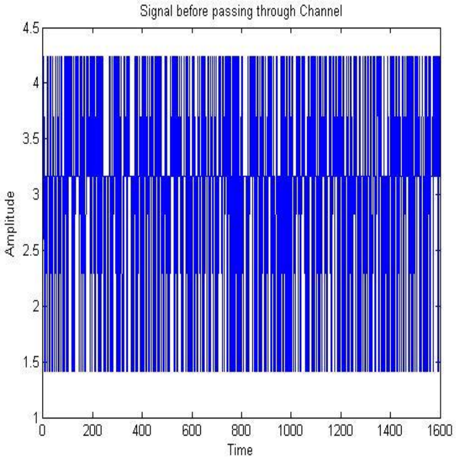

Fig.7 Original time-domain signal

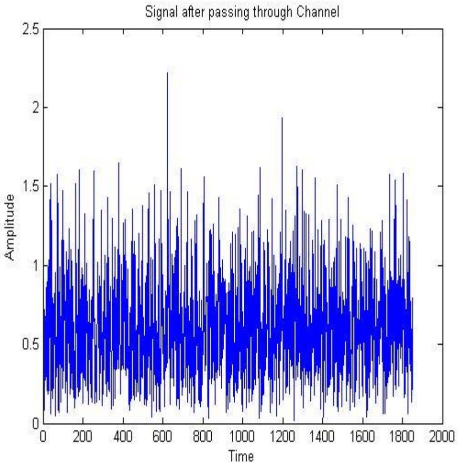

Fig.8 Time-domain signal after passing through frequency selective channel

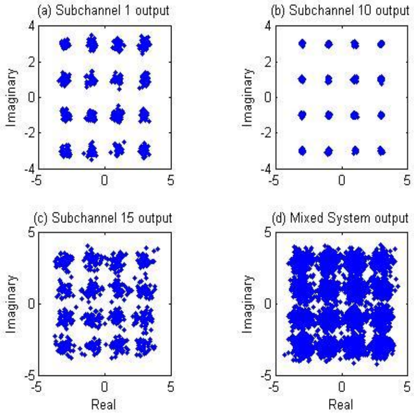

Fig.9 Obtained Scatter Plots for WiMAX System

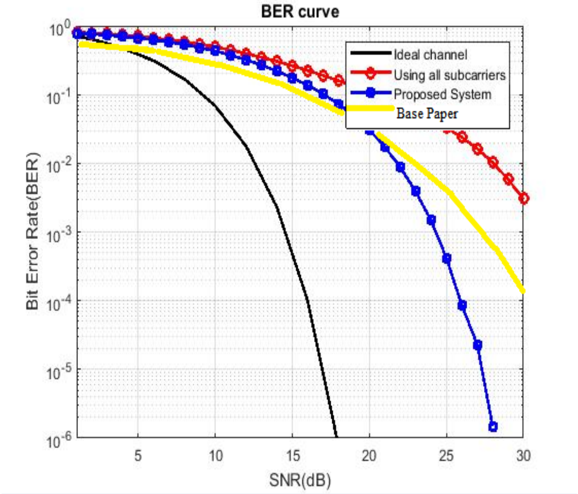

Figure9 Comparative BER Performance of WiMAX System

VI. CONCLUSION

It can be concluded from the previous discussions and obtained results that the proposed system achieves better

BER performance compared to the conventional WiMAX system because of sub barrier suppression below threshold. Here the chosen threshold has been chosen as 60% of the maximum sub-carrier gain of the channel. Finally it has been shown that the proposed system attains better BER performance compared to a conventional WiMAX system. The BER performance of the system is further validated through the scatter plots which indicate that the sub-carriers with higher strength show less deviation whereas the ones with lower strength shown more deviation from ideal behavior. The overall scatter indicates that the unsatisfactory subcarriers dominate the overall system scatter and thus should be suppressed in order to improve the performance of the system.

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