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CHANNEL ESTIMATION FOR MOBILE WIRELESS COMMUNICATION SYSTEM USING DISCRETE WAVELET TRANSFORM

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Abstract: Channel estimator is the key component of the receiver in wireless system. It estimates the channel transfer function by extracting the channel's information from pilots in the transmitted signal, so that we can recover the useful data. The difficulty in channel estimation is caused by the complexity of the channel and the white Gaussian noise added to the received signal. The proposed research aims to use Discrete Wavelet Transform to reduce the noise before taking care of the interpolation. WiMAX IEEE 802.16e_2005 standard is the reference model to implement the concepts.

Keyword: Channel Estimation, WIMAX, Discrete Wavelet Transform (DWT).

1. Introduction

In wireless system, the receiver needs a channel estimator to find out the channel transfer function. There are generally two methods: using preamble and pilots. The first method is adding training symbols before the transmission data so that the receiver can estimate the channel in the very first time and consider the channel will be unchanged for the next moment while the received data are useful information. This method quite good when the channel changes slowly, but if either the transmitter or the receiver is moving, Doppler Effect occurs, the channel changes quickly and causes a great degrade in this method. The second method is to assign known data symbol call pilot into data stream with some kinds of pattern. By extracting pilots out of the received data, we can estimate the channel transfer function, usually the frequency response. This method can update the channel on-the-go and adapt with the fast fading channel. In practical system, the combination of these two methods is preferred, for example we can see this in IEEE 802.11b/g, 802.16 system. This work herein using the second one. Based on scattered pilots in the transmitted signal, the estimator calculates the transfer function at the pilot – positions and interpolates the whole channel by some common ways: linear, cubic-Spline etc. then the useful data can be recovered. However, the result is not as good as expected because white Gaussian noise is added to the data and pilots as well, cause the mismatch channel and therefore, lowers the performance of the whole system. The deeper the signal is buried in noise, the more challenge for the estimator to extract the information about channel, and of course the system suffers a huge amount of errors. The proposed research aims to use Discrete Wavelet Transform to reduce the noise before performing the interpolation. The Mobile WiMAX IEEE 802.16e_2005 standards will be used in simulation as reference model.

2. Mobile Wireless Communication System

2.1. Overview of OFDMA

OFDMA (Orthogonal Frequency Division Multiple Access) is the enhancement of existing OFDM technology. OFDMA divides a signal into sub-channels (groups of carriers), with each sub-channel being allocated to a different subscriber. Each subscriber can be treated separately independent of location, distance from the base station, interference and power requirements [1]. In one OFDMA symbol, each sub-channel includes groups of 14 – carriers, named clusters, which are permutated randomly for recovering information's ability. Figure 1 illustrates a spectrum of one symbol storing 2 subscribers' data.

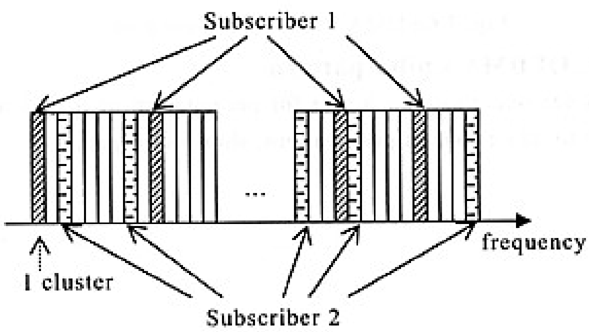

Fig. 1 Spectrum of one OFDMA symbol

The OFDMA PHY system is very complicated with many modes, procedures as well as rules. Briefly, it has some main parts in Transmitter and Receiver as shown in Figure 2 and Figure 3.

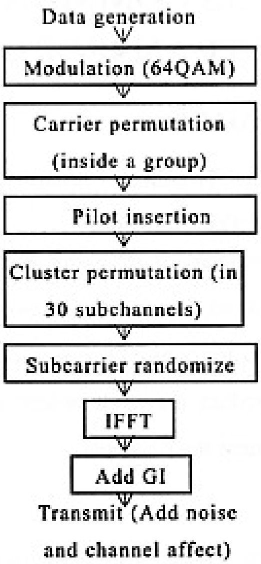

Fig. 2 OFDMA_PHY's Transmit part

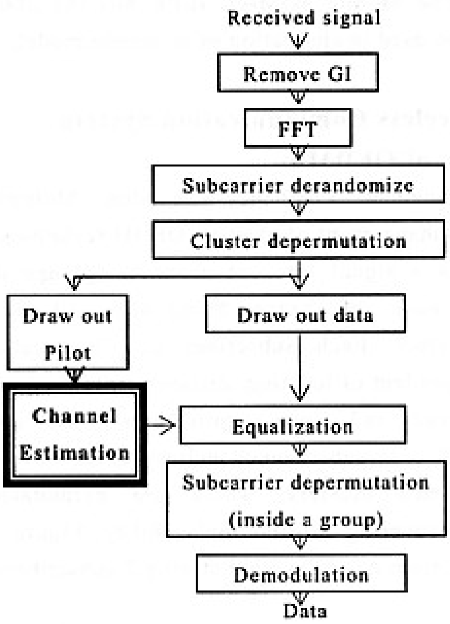

Fig. 3 OFDMA_PHY's Receiver part

2.2. OFDMA's pilot pattern

Since one cluster is a unit for permutation, it is also a unit to take a look at pilot pattern, shown in Figure 4.

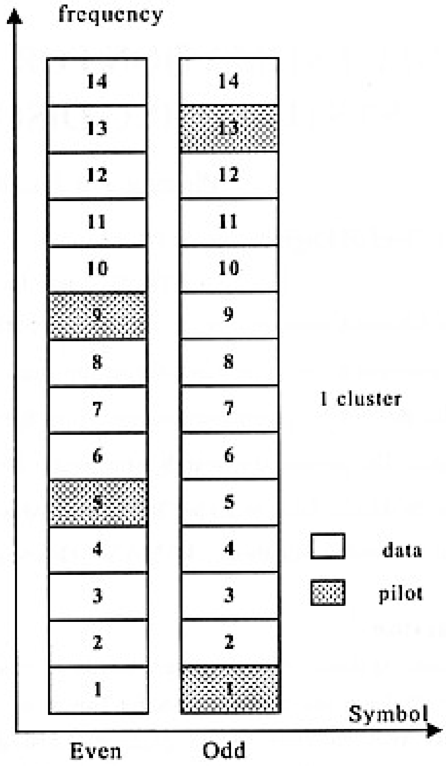

Fig. 4 OFDMA's pilot pattern

3. Channel Estimation

The Channel Estimation find out the information of environment which affected transmit signal.

Assume the transmit data and pilots are X(n) and $X_p(k)$, respectively, k is the specific position in OFDM symbol.

The signal coming to the receiver is:

$Y(n) = X(n).H(n) + N(n)$

With:

H(n): Frequency response of the channel

N(n): additive white Gaussian noise

$n = \{1, N\}$

Extract the data correspondent with transmitted pilots: $Y_p(k)$

Easily to see that if there's no noise added to the transmit signal, the transfer function of the channel at pilot-points will be:

$H_p(k) = Y_p(k)/X_p(k)$

Then, interpolate the whole channel function for every data points by some usual methods: linear, cubic-Spline, etc.

$H\_est(n) = interpolate(1:N , H_p(k) , method)$.

And next recover the useful information simply by:

$X\_est(n) = Y(n) / H\_est(n)$

When the signal is buried in noise, the performance depends on the SNR (Signal to Noise Ratio). We can only get a fair result if SNR is appropriate high. With a medium SNR, the channel function can not be calculated exactly even at the pilot-points, so that the interpolated function is far from the real channel, resulting the degrading in recovering original data.

4. Discrete Wavelet Transform (DWT)

4.1. Overview

Nowadays, the Wavelet Transform is used widely in signal analysis, especially in image processing, and is opening a new promising for multimedia applications. A part of it, the Discrete Wavelet Transforms (DWT), has been proved to be a superior noise reducing method. When taking DWT to the input signal, it will split signal into two parts: a low-pass coefficients (approximation) and a high-pass coefficients (detail). By repeating the DWT in the next low-pass coefficients, the smaller separations are obtained [2]. DWT for a noise filter is not a new method but up till now, it has been used mainly in image processing. This time, it is joined in telecommunication. So, we will use DWT to filter out the noise with a call in mind that the channel function in a very short time containing some hundreds point of data is equivalent to a very low frequency signal. Then high-pass coefficients are applied thresholds to remove noise and the last thing is taking the IDWT (Inverse DWT) to obtain the transfer function that quite fits the real channel.

Three main reasons that DWT have efficiency are:

· DWT makes power concentrated on a few of coefficients.

· After transformation, no affect qualification of input signal because of DWT's Conservation energy ability.

· An invertible transform.

4.2. Haar wavelet

In this simulation, Haar wavelet is utilized due to its simplicity.

The approximation sub-signal (low pass):

$$A_n = \frac{y_{2n-1} + y_{2n}}{\sqrt{2}} \qquad \text{(Eq. 1)}$$

The detail sub-signal (high pass):

$$D_n = \frac{y_{2n-1} - y_{2n}}{\sqrt{2}} \qquad \text{(Eq. 2)}$$

Invert Haar wavelet Transform:

$$y_{n-1} = \frac{A_{n/2} + D_{n/2}}{\sqrt{2}} \qquad y_n = \frac{A_{n/2} + D_{n/2}}{\sqrt{2}} \qquad \text{(Eq. 3)}$$

5. Channel Estimator

As said in section 2 and 3, Channel Estimator receives a set of pilots at correspondent points. First, it is filtered by DWT - IDWT couple with a threshold clipping high pass where most noise is existing. After that, pilot values are purely channel information - in ideal case, so interpolations will be done.

5.1. Time interpolation

Looking to figure 5, at the 1st, 13th position in even symbol and the 5th, 9th position in odd one, pilot values will be estimated basing on corresponding neighbour pilot positions. The middle symbol has average value while the border's has copy value of the nearest one.

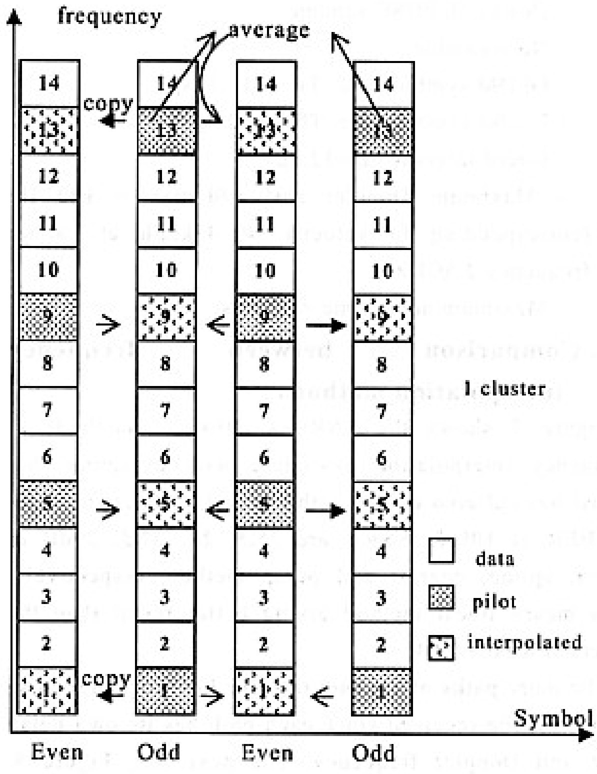

Fig. 5 Time interpolation

5.2. Frequency interpolation

After taking time interpolation, each cluster has 4 pilots and 10 positions unknown. Some simple interpolation methods are introduced in [3]:

- Nearest neighbour interpolation

- Linear interpolation
- Cubic-Spline interpolation
- Piecewise cubic Hermite interpolation

Figure 6 shows the block diagram of the proposed Channel Estimator.

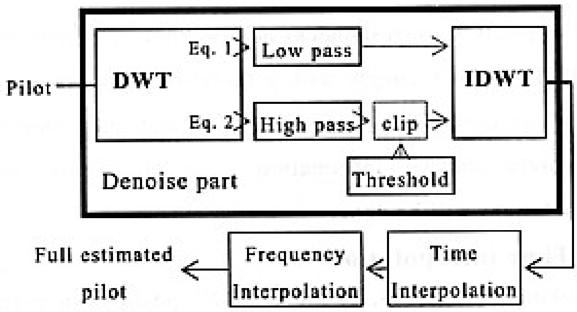

Fig. 6 Channel Estimator

6. Simulation results

Following are the parameters used in the simulation:

- OFDMA 1024 FFT
- Downlink PUSC scheme
- No preamble
- OFDM symbol time: Ts = 115.2µs;
- Useful symbol time: Tb = 102.4µs;
- Guard interval Tg =12.8µs;
- Maximum Doppler shift: fd_max = 100 Hz (corresponding to velocity of 43km/h at carrier frequency 2.5GHz)
- Maximum delay time = 12.8µs;

6.1. Comparison between frequency interpolation methods

Figure 7 shows the SNR vs. BER of methods at frequency interpolation procedure with assuming that signal has suffered only 1 path channel transfer function. At BER of 10E-2, SNR's are 25.5, 27, 27.5, 29dB in linear, spline, nearest and pchip method, respectively. This means linear method giving better result than the others at least 1.5dB.

The more paths of channel transfer function, the worse signal will be received since each path has its own delay time and Doppler frequency. The next one, Figure 8, signal will be defeated by 2 paths channel transfer function. Each path has its own delay time's value randomly between 0 and maximum delay time. In this case, linear also produces better result about 1.4dB comparing 25.5dB with 26.9, 27 and 29dB of the others.

6.2. The results of DWT filter

The efficiency of DWT over against without DWT before performing interpolation is figured out in two cases. Figure 9 and Figure 10 show results supposing that channel transfer function has 1 path and 2 paths, respectively. When BER is 10E-2, proposed method's denoising is at 22dB SNR, better 4.5dB in first case and 21.5dB SNR, reduces 4.5dB SNE in next case as comparison with no denoising.

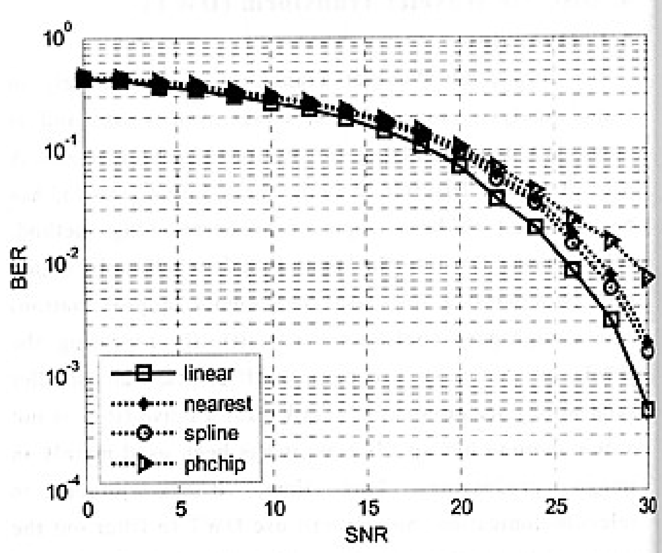

Fig. 7 Compare between all frequency interpolation methods when channel transfer function has 1 path

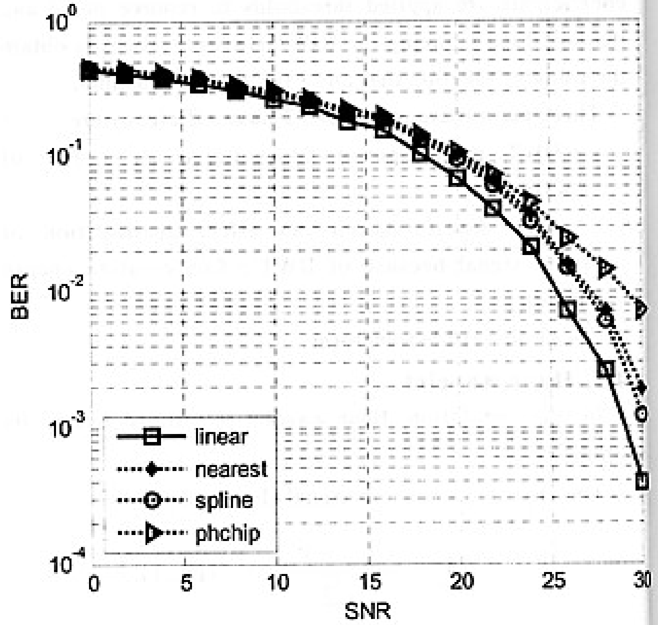

Fig. 8 Compare between all frequency interpolation methods when channel transfer function has 2 paths

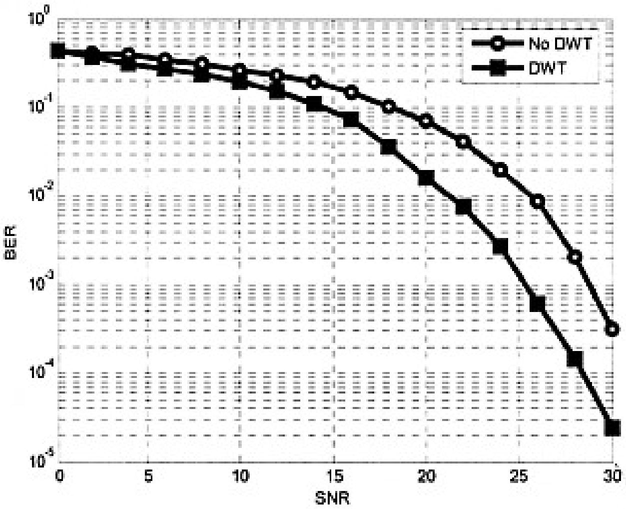

Fig. 9 Compare between with and without DWT denoise when channel transfer function has 1 path

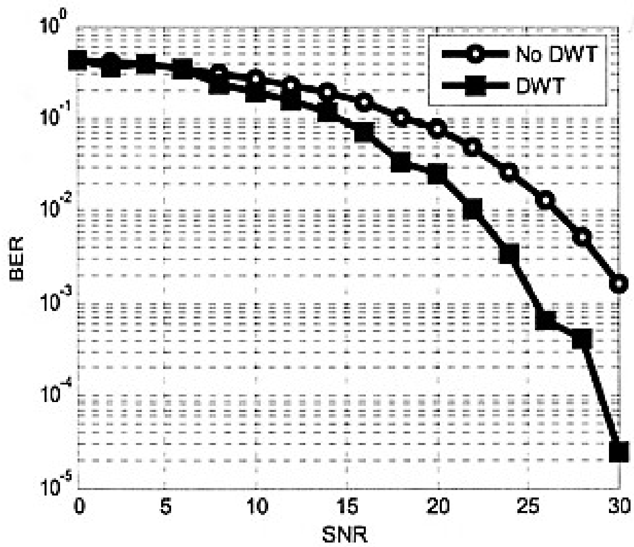

Fig. 10 Compare between with and without DWT denoise when channel transfer function has 2 paths

7. Conclusion

In frequency estimation, linear interpolation makes better results than others about 1.4dB at 10E-2 BER. Moreover, it is also the easiest and simplest interpolation method.

There are many kinds of noise filter, but in this case, using DWT to be a filter is very simple. Let's see DWT with Haar function. Obviously, it doesn't need high computation, just simply plus and minus, and after all, multiplying with a scale coefficient.

Channel estimation is difficult because of channel complexity itself and Gaussian noise. My proposed method is using DWT reducing noise before estimating the channel. The simulation results show that its performance is higher about 4.5dB SNR when BER is 10E-2.

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