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DISCRETE WAVELET TRANSFORM - BASED CHANNEL ESTIMATION ALGORITHM FOR MIMO-OFDM SYSTEM

K.Sakru Naik[#1], V S R kumari [*2]

[#]M.Tech Student, Department of Electronics and Communication Engineering, Sri Mittapalli College of Engineering, Thummalapalem, Guntur Dt, Andhra Pradesh, India

[*] HOD, Department of Electronics and Communication Engineering, , Sri Mittapalli College of Engineering, Thummalapalem, Guntur Dt, Andhra Pradesh, India

ABSTRACT

This paper proposes a Discrete wavelet transform (DWT) based channel estimation method for orthogonal frequency division multiplexing (OFDM) systems. Wavelets based systems provide better spectral efficiency because of no cyclic prefix requirement, have very narrow side lobes and also exhibit improved BER performance. Meanwhile, channel estimation in wavelet based multicarrier systems still remains a big challenge. In this work an investigation into the performance of discrete wavelet transform based multicarrier system using zero forcing equalization in time domain is presented. The results produced were then compared to that of conventional FFT-based OFDM system. The proposed system shows superior BER performance.

Keywords: Channel Estimation; MIMO-OFDM; DFT, WDT.

1. INTRODUCTION

Orthogonal frequency division multiplexing (OFDM) has become a popular technique for transmission of signals over wireless channels. OFDM has been adopted in several wireless standards such as digital audio broadcasting (DAB), digital video broadcasting (DVB-T), the IEEE 802.11a Local area network (LAN) standard and the IEEE 802.16a metropolitan area network (MAN) standard. OFDM is also being pursued for dedicated short-range communications (DSRC) for road side to vehicle communications and as a potential candidate for fourth-generation (4G) mobile wireless systems.

OFDM converts a frequency-selective channel into a parallel collection of frequency flat sub channels. The subcarriers have the minimum frequency separation required to maintain

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orthogonality of their corresponding time domain waveforms, yet the signal spectra corresponding to the different subcarriers overlap in frequency[3]. Hence, the available bandwidth is used very efficiently. If knowledge of the channel is available at the transmitter, then the OFDM transmitter can adapt its signaling strategy to match the channel. Due to the fact that OFDM uses a large collection of narrowly spaced sub channels, these adaptive strategies can approach the ideal water pouring capacity of a frequency-selective channel.

In practice this is achieved by using adaptive bit loading techniques, where different sized signal constellations are transmitted on the subcarriers[1, 7]. OFDM is a block modulation scheme where a block of N information symbols is transmitted in parallel on N subcarriers. The time duration of an OFDM symbol is N times larger than that of a single-carrier system. An OFDM modulator can be implemented as an inverse discrete wave let transform (IDWT) on a block of N information symbols followed by an analog-to-digital converter (ADC).

To mitigate the effects of inter symbol interference (ISI) caused by channel time spread, each block of N IDWT coefficients is typically preceded by a cyclic prefix (CP) or a guard interval consisting of G samples, such that the length of the CP is at least equal to the channel length. Under this condition, a linear convolution of the transmitted sequence and the channel is converted to a circular convolution. As a result, the effects of the ISI are easily and completely eliminated. Moreover, the approach enables the receiver to use fast signal processing transforms such as a wave let implementation for OFDM implementation. Similar techniques can be employed in single-carrier systems as well, by preceding each transmitted data block of length N by a CP of length, while using frequency- domain equalization at the receiver [2].

In this paper, we focus on DWT-based channel estimation method. This algorithm can make good compromise between performance and computational complexity[5]. Most of the published work on DWT-based channel estimation assumes each path delay is an integer multiple of the sampling interval in multipath channel. However, it is difficult to ensure this condition in real system because of the complexity and incomprehensibility of the transmission channel.

In non sample- spaced multipath channels, the channel impulse response will leak to all taps in the time domain. In propose a method to reduce leakage power by calculating energy increasing rate. Another approach is also proposed by extending the LS estimate with a symmetric signal of its own. Based on these two methods, we propose a new method to solve the problem of energy leakage[2].

2. MIMO-OFDM SYSTEM MODEL

A Wavelet based OFDM system with beam former and MIMO configuration is explained in this section. Figure 1 shows the transmitter and receiver part respectively with k=8 number of sub-carriers as an example. We consider this system is in a multiuser environment of k interfering users, where kth user decorated with Mk number of antennas is communicating with a base station equipped with N number of antennas[1].

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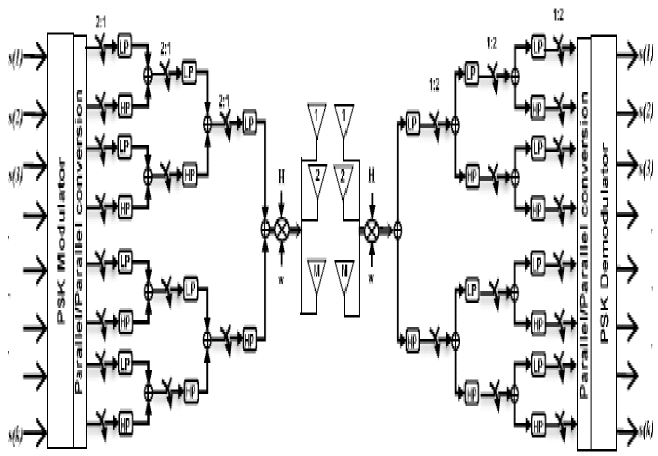


Fig: 1 WOFDM Transmitter and Receiver

On the transmitter side, first a binary phase shift keying (BSPK) modulator is used for mapping s(k) data stream to the symbol stream x(n). After the mapping process a parallel-to-parallel (P/P) converter reshapes the modulated data stream x(n). Into, for example, N = 8 parallel data streams. This P/P converter makes sure that N=2^n, where n is an integer, so that the transmitter can perform inverse discrete wavelet transform (IDWT) and produce one final sequence in n stages. Sequential two x(n) symbol streams are up-sampled by the up-sampling factor 2, filtered by the wavelet filter g(n) or h(n), respectively, and then summed. Output streams are up-sampled by 2, filtered and summed again[4,6,10].

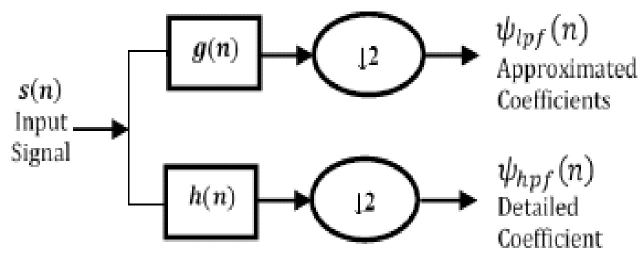
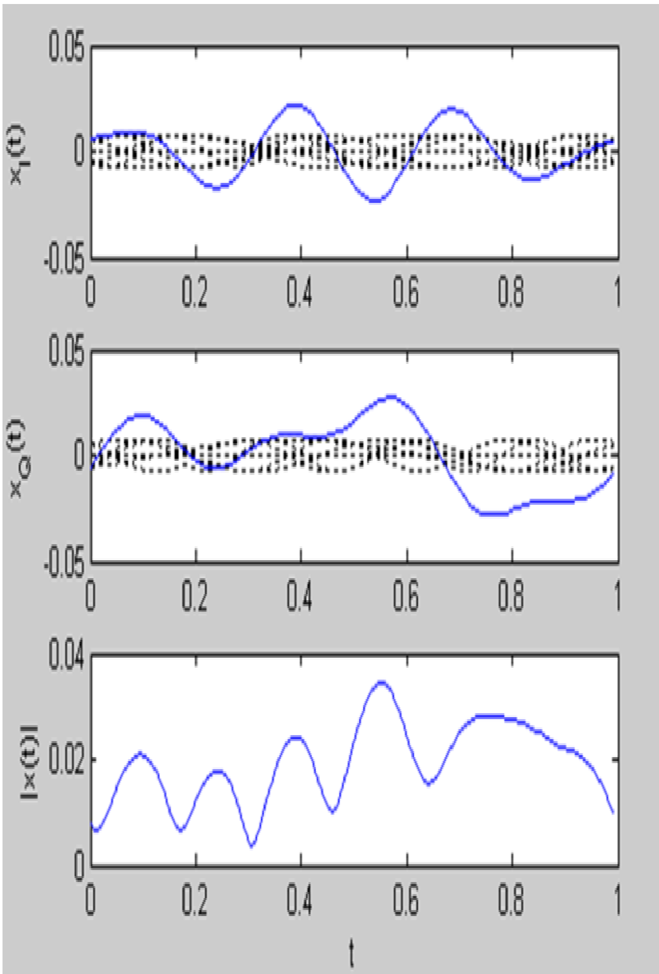


Fig: 2 Block Diagram of Wavelet Decomposition

3. MIMO-OFDM MODEL

It is assumed that the system has *NT* transmitter antennas and *NR* receiver antennas. The total number of the subcarriers is *N*. At the sending end, the data stream is modulated by inverse wave let transform (IWT) and a guard interval is added for every OFDM symbol to eliminate ISI caused by multi-path fading channel. The receiver performs opposite operations[3, 8].



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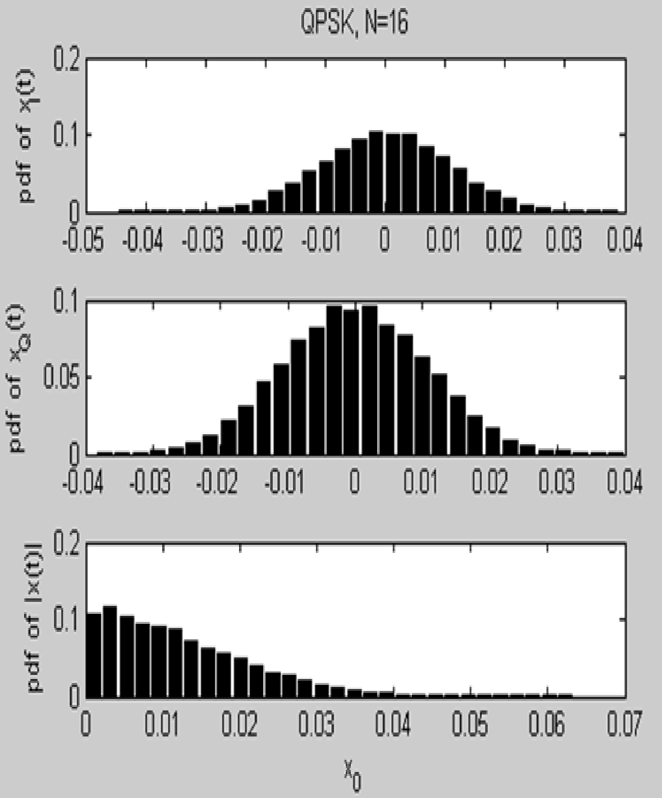

Fig: 3 OFDM SIGNAL

Least-square estimation:

If the channel and noise distributions are unknown, then the least-square estimator (also known as the minimum-variance unbiased estimator)is $\mathbf{H}_{\text{LS-estimate}} = \mathbf{Y}\mathbf{P}^H(\mathbf{P}\mathbf{P}^H)^{-1}$ where $()^H$ denotes the conjugate transpose. The estimation Mean Square Error (MSE) is proportional to Tr(PP^H)^-1where tr denotes the trace. The error is minimized when PP^H is a scaled identity matrix. This can only be achieved when N is equal to (or larger than) the number of transmit antennas. The simplest example of an optimal training matrix is to select P as a (scaled) identity matrix of the same size that the number of transmit antennas.

MMSE estimation:

If the channel and noise distributions are known, then this a priori information can be exploited to decrease the estimation error. This approach is known as Bayesian estimation and for Rayleigh fading channels it exploits that vec (H) ~CN (0, R), vec (N) ~CN (0, S). The MMSE estimator is the Bayesian counterpart to the least-square estimator and becomes

Vec(HMMSE-estimate)= (R^1+(P^TX1)^H.S^-1(P^TX1))^-1(P^TX1)^H.S^-1Vec(Y)

Where X denotes the Kronecker product and the identity matrix I has the dimension of the number of receive antennas.

The estimation Mean Square Error (MSE) is tr (R^-1+(P^T X I)^Hs^-1(P^T X I))^-1 and is minimized by a training matrix P that in general can only be derived through numerical optimization. But there exist heuristic solutions with good performance based on water filling. As opposed to least-square estimation, the estimation error for spatially correlated channels can be minimized even if N is smaller than the number of transmit antennas. Thus, MMSE estimation can both decrease the estimation error and shorten the required training sequence. It needs however additionally the knowledge of the channel correlation matrix R and noise correlation matrix S. In absence of an accurate knowledge of these correlation matrices, robust choices need to be made to avoid MSE degradation [4, 8].

MMLS Channel Estimation: LS algorithm is the simplest channel estimation. It is assumed that $H^{\wedge}_{ls}$ is the estimate of the channel impulse response H .The LS estimate of the channel in frequency domain on subcarrier k can be obtained as:

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$H^{\wedge}_{ls}(k) = Y(k)/X(k) = H(k)+(W(k) / X(k))$; 0<= k <=N-1

Where,

H(k)- Channel at pilot subcarriers

X(k)-Input at the k^{th} pilot subcarrier

Y(k)-Output at the k^{th} pilot subcarrier

4. BER CALCULATION:

As an example, assume this transmitted bit sequence: 0 1 1 0 0 1 0 1 1, and the following received bit sequence: 0 0 1 0 1 0 1 0 0 1, the number of bit errors (the underlined bits) is in this case 3 (5). The BER is 3 incorrect bits divided by 10 transferred bits, resulting in a BER of 0.3 or 30%. In a noisy channel, the BER is often expressed as a function of the normalized carrier-to-noise ratio measure denoted Eb/N0, (energy per bit to noise power spectral density ratio), or Es/N0 (energy per modulation symbol to noise spectral density). For example, in the case of QPSK modulation and AWGN channel, the BER as function of the Eb/N0 is given by:

BER=1/2 erfc($\sqrt{Eb/No}$)

5. SIMULATION RESULT ANALYSIS

Packets are distributed in time and frequency domain as described before, but the packets which are transmitted back to back through same group of 4 sub channel are corrupted due to slowly time varying nature of fading. We maintain coherence time to be more than that of the packet transmission time through a sub channel, and the channel condition is fed back for each packet. We simulated block fading channel with number of sub-bands N = 4 and the coherence bandwidth equivalent to 16 subcarriers (M = 16). QPSK is used as modulation scheme. Thus, 128 × 2 bits per OFDM symbol is transmitted through a sub channel.

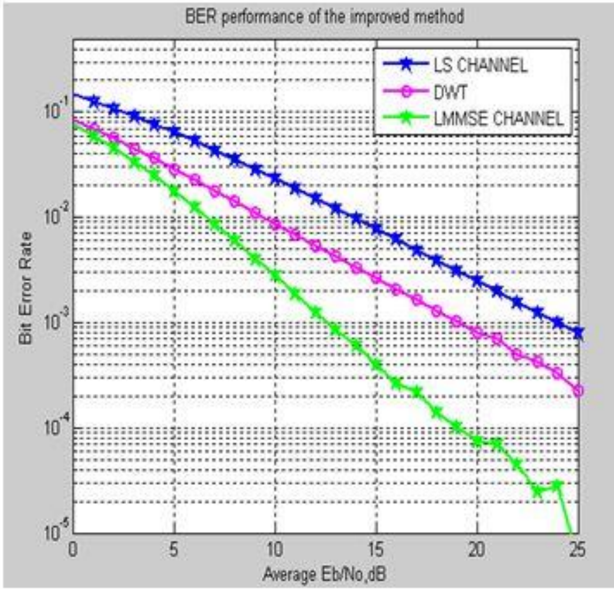

Fig4: BER Performance

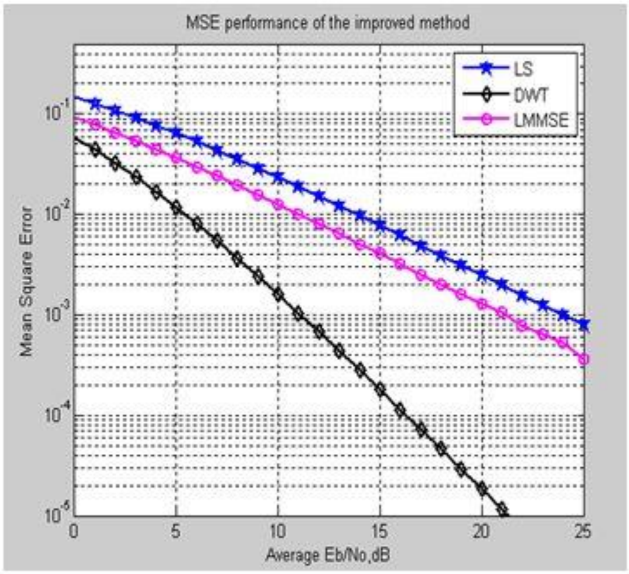

Fig5: MSE performance

To conclude, we present a case of DWT compressed signal transmission over OFDM channels where binary channel state information is available at the transmitter, but retransmission is not allowed**.** Where we are arranged in

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descending order of priority and mapped over the channels starting with the good ones. The coefficients with lower importance level, which are likely mapped over the bad channels, are discarded at the transmitter to save power without significant loss of reception quality.

6. CONCLUSION

We present a case of DWT compressed signal transmission over OFDM channels where binary channel state information is available at the transmitter, but retransmission is not allowed**.** Where we are arranged in descending order of priority and mapped over the channels starting with the good ones [3]. The coefficients with lower importance level, which are likely mapped over the bad channels, are discarded at the transmitter to save power without significant loss of reception quality.

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