Finding the Optimum Level of Wavelet Decomposition for Reducing Noise in Wireless Communication

Omar, S.F., 1Salman Yussof and 2Islam, T.

1College of Information Technology, Universiti Tenaga Nasional.
2Faculty of Computer Science and Engineering, PSTU, Bangladesh, PhD Fellow, Engineering Faculty, University Kebangsaan Malaysia.

Abstract: This paper presents an experiment to find the optimum level of wavelet decomposition for time-frequency analysis in wireless communications. Wavelet decomposition is used in many applications to reduce noise in transmitted signals in wireless communications. However, there are problems to obtain optimum level of wavelet decomposition for reducing noise in practice. This work is shown in the design of finding optimum level of wavelet decomposition including signal to noise ratio (SNR) in computers based simulations. Numerical results obtained from analysis and simulations shows how very good performance is obtained with optimum level of wavelet decomposition. The model of finding optimum wavelet decomposition has the advantages of flexibility, efficiency, and accuracy of using wavelet transformation in wireless communications.

Key words: Optimum level, wavelet decomposition, noise reduction, wireless communication.

INTRODUCTION

Wavelet transform leads to improvement in the signal to noise ratio (SNR) compared to Fourier Transform for signal analysis in wireless communication (Chik et al., 2010). However, the usual modulation technique is implemented using Fourier transform. The use of Fourier transform in signal processing is only able to reveal the information from time domain to frequency domain of the modulated signal. The transmitted signal is affected with noises and electric interference during signal transmission in communication system.

Wavelet transform shows better performance to reduce noise with proper wavelet decomposition in signal processing (Zhang et al., 2001; Rajbhandaril et al., 2009, 2010). Many researchers concentrate on using wavelet transform as robust technique in modulation of wireless communications. Wavelet Packet Modulation (WPM) offers much lower side lobes in transmitted signal than Orthogonal Frequency Division Multiplexing (OFDM). Implementation of wavelet transformation is able to reduce inter carrier interference (ICI) and narrowband interference (NBI) in wireless communication (Moreira et al., 1996; Moeneclaey et al., 2001). Inter carrier interferences and other noises reduce the performances of data transmission in the application of communication engineering (Gautier and Lienard, 2006). Wavelet based multicarrier modulation is introduced as a robust technique for OFDM in a wireless communications with narrowband interferences and multipath channel interferences. A bit error rate (BER) analysis and performance comparison in the work of Silveira et al. (2009) shows how wavelet-coded transmission systems is better than Fourier based transmissions when applied over Rayleigh fading channels and noisy channels. Vetterli and Kovacevic (1995) applied wavelet to detect the phase changes, and used the likelihood function based on the total number of detected phase changes as a feature to classify M-array PSK signal. In wireless modulation technique, the performance is increased with simultaneous analysis of time and frequency domain with wavelet transform.

Though wavelet-based modulation and demodulation criteria shows better performance in signal processing, there are problems to find the optimum level of wavelet decomposition for use in wireless communications. There is a need for the development of wavelet-based wireless communication with efficient channel estimation and equalization methods to enable these systems to reach their maximum performance. In wireless communication, the performance is improved for reducing noise and fading criteria with time frequency analysis simultaneously with optimum wavelet transform. The main problem in the design of a communications system with wavelet transform is to deal with noisy channel and multi-path fading, which causes a significant degradation in terms of both the reliability of the link and the data rate (Jamin and Mahonen, 2005).

This research focuses on the reduction of noise and interference through de-noising criteria of wavelet decomposition. However, the level of wavelet decomposition must be chosen carefully. De-noising with very high level wavelet of decomposition reduces too much noise which can eliminate the transmitted information. On the other hand, using low level of wavelet decomposition may cause the de-noising to be ineffective. In this study, the idea of finding optimum level of wavelet decomposition is presented through justifications of SNR
obtained from Matlab simulations. In this research, simulation and analysis with Matlab wavelet tools will be conducted to find the optimum level of wavelet decomposition for the de-noising purpose. The aim of the research is to identify the optimum level of wavelet decomposition to get better performance for reducing noise in wireless communications.

**Methodology:**

In the research work, the simulation of wavelet decomposition for different level is performed using Matlab 2009. The optimum level of wavelet decomposition is obtained based on the noise reduction performance for modulation and demodulation technique in wireless communications. The metric used to measure the noise reduction is the signal-to-noise ratio (SNR).

The simulation is conducted in the wavelet analysis including Daubechies (Db) wavelet decomposition with level of 2, 4, 6, 8 and 10. After de-noising of noisy signal using different wavelet decomposition, noise-free signals are recorded sequentially to get precise level in wireless communications. SNR is measured for each level of wavelet decomposition. In this study, optimum level is obtained by comparing SNR for successive simulation with different level of haar wavelets and db wavelet decompositions.

SNR generically means the dimensionless ratio of the signal power to the noise power contained in a recording (Xu et al., 1994). SNR parameterizes the performance of optimal signal processing systems when the noise is obtained in signal processing. The noise, \( N(t) \) seen with transmitted signal, \( s(t) \) has a stochastic description in communication technology.

When the signal is deterministic, its power \( P_s \) is defined as

\[
P_s = \frac{1}{T} \int_0^T s^2(t) dt
\]

where \( T \) is the duration of an observation interval of the signal. Moreover, the signal's root mean squared (rms) value equals the square-root of its power.

When the signal is a stationary stochastic process, its power is defined as the value of its correlation function \( R_s(\tau) \) at the origin.

\[
R_s(\tau) = E[s(t)s(t + \tau)]; \quad P_s = R_s(0)
\]

Here, \( E[.\] denotes expected value. The noise power, \( P_N \) is related to its correlation function.

\[
P_N = R_N(0)
\]

Thus, SNR is determined according to the power ratio of transmitted signal, \( s(t) \) and noise, \( N(t) \) in signal processing.

\[
SNR = \frac{P_s}{P_N}
\]

In the study SNR is estimated through the parameter of mean value and standard deviation taken from the residual options in wavelet tools. SNR is considered as the reciprocal of the coefficient of variation and defined as the ratio of mean to standard deviation of a signal or measurement.

\[
SNR = \frac{\mu}{\sigma}
\]

Where \( \mu \) is the signal mean or expected value and \( \sigma \) is the standard deviation of the noise.

The parameters of histogram, cumulative histogram, auto-correlation and FFT spectrum are considered in the study to get precise decomposition level. Figure 1 shows the block diagram of using wavelet decomposition for de-noising performance including the parameters of histogram, mean, variance in the receiver portion.

Wavelets decomposition is selected in such a way that it looks similar to the patterns of the signal. A good approach to find a solution to this problem is done by searching a function, which is suitable to approximate both the analyzed signal envelope and frequency content of the signal. The wavelet Transform has been computed and the coefficients are recorded in the numerical model. These extracted coefficients are used to get
FIG. 1: Flow-chart of wavelet decomposition for signal de-noising.

After getting number of peaks of coefficient in wavelet decomposition, the mean value and variance of received signal is taken for M-array quadrature amplitude modulation (QAM) mapping in modulation and demodulations.
RESULT AND DISCUSSION

Wavelet transformation shows an important role with noise reduction performance in wireless communications (Mallat, 1999; Zhang and Howard Fan, 2000). The orthogonal criteria of the DWT based modulations technique is much better than that for the FFT based modulation technique. Though wavelet decomposition with higher level is better to reduce noise, this criteria also discards the message signal during data transmission (Gautier et al., 2007). Alternatively, low level decomposition is not sufficient to reduce noise effectively from the transmitted signal in communication technology.

In these discussions, the simulations have been done for db wavelet using wavelet tools of MATLAB version 2009. Example of 6 level wavelet decomposition is presented in Fig 2. Figure 2 shows the noisy synthetic signal as S and de-noised signal, D_s including approximation coefficients and details coefficients obtained from numerical simulations.

![Fig. 2: Practice of 6 level wavelet decomposition.](image)

The signal to noise ratio (SNR) for different wavelet decomposition is measured for additive white Gaussian noise (AWGN) channel, flat fading channel (FFC), and selective fading channel. All simulation results of different wavelet decompositions are provided as a function of signal-to-noise-ratio (SNR) defined as the ratio of signal power to noise power and expressed in dB.

The parameters of histogram, cumulative histogram, autocorrelation and FFT spectrum are obtained as the results of simulation to get precise decomposition level. Every simulation is done with different level of db wavelet decomposition and the parameters of histogram are recorded. Example of simulation results is shown in Fig. 3.
The results of simulation for different level of db wavelet decomposition are shown in table 1. It is clearly seen that 8 level wavelet decomposition has much better performance than the 2, 4 or 6 level wavelet analysis in signal processing. But for 8 level wavelet decomposition the mean value of the signal has been reduced effectively. As a result, the SNR performance is not very good for eight level wavelet de-noising in numerical evaluations. Though signal mean value is higher in de-noised signal for two level db wavelet decomposition, the presence of noises is more than high level decomposition. According to SNR performance, two level decomposition is not very effective to obtain in demodulation technique of wireless communication. The efficiency of wavelet transform in modulation and demodulations is shown with increasing the SNR and decreasing the required value of BER. In this channel, in addition to AWGN all frequency components of signal will be affected by a constant attenuation and a linear phase distortion, which has been chosen to have a Rayleigh distribution. According to simulation results, the SNR of 6 level decomposition shows better performance to reduce noises with reliable outcomes in this study. Thus, six level wavelet decomposition is considered as the best wavelet decomposition for de-noising in these numerical simulations.

### Table 1: SNR for different wavelet decomposition.

<table>
<thead>
<tr>
<th>Wavelet</th>
<th>Level</th>
<th>Mean</th>
<th>Standard deviation</th>
<th>Signal to noise ratio (SNR) in db</th>
</tr>
</thead>
<tbody>
<tr>
<td>Db</td>
<td>2</td>
<td>2.43</td>
<td>0.83</td>
<td>4</td>
</tr>
<tr>
<td>Db</td>
<td>4</td>
<td>2.97</td>
<td>0.95</td>
<td>5</td>
</tr>
<tr>
<td>Db</td>
<td>6</td>
<td>3.1</td>
<td>0.816</td>
<td>6</td>
</tr>
<tr>
<td>Db</td>
<td>8</td>
<td>3.13</td>
<td>1.2</td>
<td>4</td>
</tr>
</tbody>
</table>

### Conclusion:

Optimum level of wavelet decomposition shows better performance in noisy and multipath fading channel in wireless communications. The new idea of using wavelet transform is demonstrated as dynamic time-frequency scheme to enhance the performance of multicarrier modulation and demodulation system. The research concentration also reduces the presence of noises and interferences during data transmission through wireless communications. The optimum wavelet decomposition level is obtained by measuring the SNR for reducing noises in wireless transmission system. Our future research would be inspired by the use of wavelet decompositions for error detection and correction using wavelet transform in data transmission system.
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REFERENCES


