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Comparative Analysis of Different Wavelets in OWDM with OFDM for DVB-T

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ABSTRACT

To increase the data rate of wireless medium with high performance, orthogonal frequency division multiplexing (OFDM) is used which is a powerful technique that uses an Inverse Fast Fourier Transform (IFFT) at the transmitter to modulate a high bit-rate signal onto a number of carriers. The problem with this technique is that it is inherently inflexible and requires a more complex IFFT core. This paper provides an analysis of a technique for both designing wavelets and to measures respective performances, called Orthogonal Wavelet Division Multiplex (OWDM), an alternative to OFDM, which uses a Discrete Wavelet Transform (DWT) instead of using the IFFT to generate the output and has a lower computational complexity and increases flexibility. The three of the more common wavelet families are investigated with increasing order to ascertain which wavelet transform is the most suited for use in an AWGN channel and measures the performance in terms of Bit Error Rate (BER) and Signal to Noise Ratio (SNR) for AWGN channel in comparison with OFDM and illustrates the next level analysis of new system comparing different wavelets. It is also able to increases the spectral efficiency and decreases the bit error rate as compare with OFDM. Performance of BER, evaluation of SNR and the design of OWDM are synthesized through computer simulations using MATLAB.

Keywords: OWDM, OFDM, IFFT, DWT, Wavelet Modulation, SNR, BER.

1 INTRODUCTION

With the advent of 4G wireless communication systems, bandwidth is a precious commodity and service providers are continuously met with the challenge of accommodating more users with in a limited allocated bandwidth. In other words, the next generation of wireless systems is supposed to have a better quality and coverage, to be more powerful and bandwidth efficient, and be deployed in diverse environments. The phenomenon which makes reliable wireless transmission difficult is time-varying multi-path fading. OFDM is a technique widely used in wireless communication systems due to its high data rate transmission capability with high bandwidth efficiency and also its robustness to multi-path fading without requiring complex equalization techniques [1-3]. OFDM has been adopted in a number of wireless applications including Digital Audio Broadcast (DAB), Digital Video Broadcast (DVB), and Wireless Local Area Network (WLAN) standards such as IEEE802.11g and Long Term Evolution (LTE) [4-7].

The objective of this paper is to identify how the new OWDM system can be compared with the existing OFDM system so simulation were first run using OFDM as the RF modulation front-end. Following this, the OFDM block was replaced with the OWDM block with same tests run. This paper is to investigate three of the more common wavelet families with increasing order to ascertain which wavelet transform is the most suited for use in an AWGN channel and compare the performance of OWDM with OFDM in terms of BER and SNR for an AWGN environment with DVB-T parameters of 3/4 rate convolutional encoding, 64-QAM modulation and 1/32 Guard Interval.

2 ORTHOGONAL WAVELET DIVISION MULTIPLEXING (OWDM):

Wavelet modulation is modulation scheme to make use of wavelet transformations corresponding to the data being transmitted. The advantage of wavelet transform than other transforms such as Fourier transform is discrete both in time as well as scale [15-16]. OWDM using the discrete wavelet transform is a multiplexing transmission method in which data being assign to wavelet sub bands having different time and frequency resolution. The main advantage of using OWDM is that it is a very flexible system and it can offer a high degree of side lobe suppression. By analyzing the wavelets, it can be seen that there is an overlap of the frequency response between the sub channels resulting in a certain amount of aliasing. By increasing the order of the wavelets, the effect of aliasing can be decreased and therefore the orthogonality between the sub bands. In DWT -OWDM, the modulation and demodulation are implemented by wavelets rather than by Fourier transform. Wavelet based system establishes a small bit error rate probability than that of the Fourier

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transform based system.

When performing a frequency analysis of a signal, often, if there is minimal variation in time, Fourier transform with appropriate windowing will provide accurate information. If however, there are fast fluctuations in the time domain or the time domain contains information that is relevant to how the frequency domain information is reacting, a time-frequency analysis is necessary. There are several mechanisms that can be used to do this but the most common three are the Short-Time Fourier Transform (STFT) that works by sweeping a window over the time-domain signal and presents a three dimensional spectrograph; the wavelet transform and wavelet packets. The wavelet transform maps a time function into a two dimension function of α instead of w - frequency, where α is called the scale and is the translation of the wavelet function along the time axis. The continuous waveform transform of a signal s (t) can be defined as [15].

$$CWT(a,\tau)=\frac{1}{\sqrt{a}}\int s(t).\psi\frac{(t-\tau)}{a}dt$$ ....

..... (1)

Where CWT is the Continuous Wavelet Transform, t is the time, Ψ (t) is the basic (or mother wavelet) and the $\psi(t-\tau)/a\sqrt{a}$ is the baby wavelet made by either stretching or compressing the mother wavelet.

3 Proposed System:

The use of filters in the wavelet domain has been predominantly used for multi-resolution analysis of time varying signals. The big difference between OFDM and OWDM is that in OFDM, the FFT performs sub band decomposition with a specific number of sub bands at well defined intervals. Whereas OWDM, it is possible to dynamically allocate the number of sub bands and the bandwidth of each sub bands.

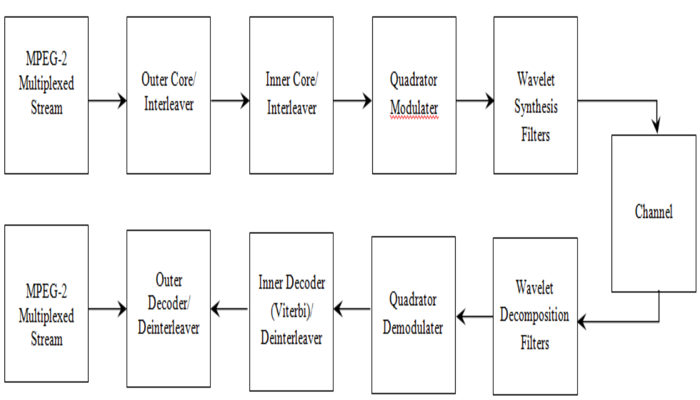

Fig. 1.0 Proposed System Block diagram

4 Simulation & Results:

Now the system is simulated, the effect of showing different wavelets in the OWDM as compares with OFDM and analysis their response to Additive White Gaussian Noise (AWGN). Proposed model was considered taking in a binary sequence, 64-level Quadrature amplitude modulation (64-QAM) on the stream, buffer up the results into a fixed symbol size and then pass the buffer through the OWDM modulator. The overall buffer size was set to 2048 symbols as per the DVB-T 2K system and only 2 levels of decomposition were used at this time. The decision to present the results without coding was to demonstrate the error correction capabilities of the wavelet transform themselves. To compare the different wavelets, the buffered Quadrature modulated block (containing the same information for each trial) was passed through the different wavelet filters. The output from the filter was passed through the AWGN channel with decreasing Signal to Noise Ratio (SNR) and then demodulated. At the output of the receiver, the decoded bit stream was compared to the transmitted bit stream and from this result an overall bit-error-rate (BER) can be calculated.

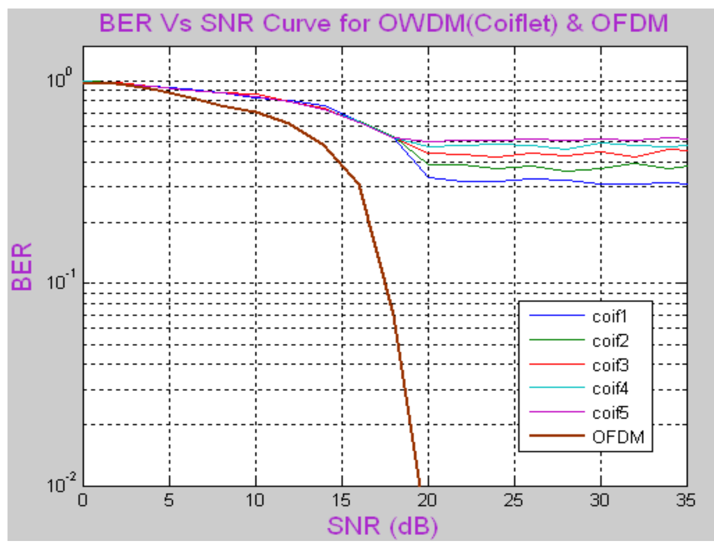

Fig. 2.0 Comparison of Signal to Noise Ratio against Bit Error Rate for increasing order of Coiflet wavelet with OFDM.

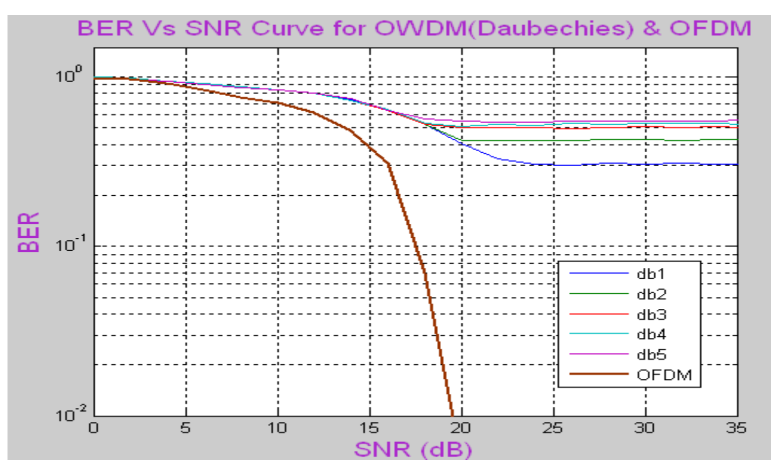

Fig. 3.0 Comparison of Signal to Noise Ratio against Bit Error

Rate for increasing order of Daubechies wavelet with OFDM.

Figures 2.0 and 3.0 depicts the results of simulating the OWDM with different wavelet filters and comparing the Bit Error Rate (BER) at the output of the QAM demodulator against the channel Signal to Noise Ratio (SNR). Figure 2.0 represents the Coiflet family and figure 3.0 represents the Daubechies family. From figures 2.0 and 3.0, it can be seen that there is a definite difference in the resilience to AWGN as seen in a terrestrial channel. The first observation that can be seen in these figures is that as the order of the filters decrease, the resilience to noise increases.

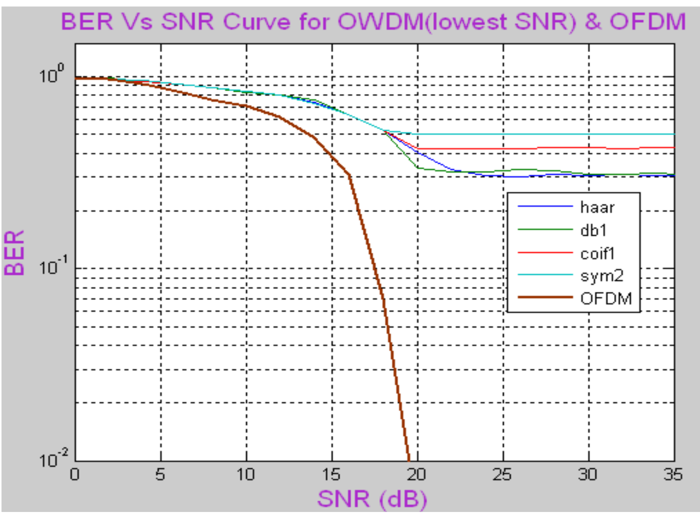

Fig. 4.0 Comparison of Signal to Noise Ratio against Bit Error Rate for lowest SNR curve for wavelet family with OFDM.

Fig. 4.0 shows the relationship of the BER to the SNR for the different wavelet transforms where the different trace lines in Fig. 4.0 depict the three different families of wavelet tested and the Haar wavelet taken from the curves in figures 2.0 and 3.0. It can be seen that the least resilient wavelet family is the Symlet followed by the Coiflets, then the Daubechies. As the order of the wavelet increases, the tolerance to noise decreases and this is consistent for all three wavelet families. The top trace in Fig. 4.0 is Symlet wavelet representing the weakest wavelet for use in OWDM and the bottom trace in the waveform is the first-order Daubechies (Haar) wavelet.
From Fig. 4.0, it can be seen that, if the families are to be considered independently, as the order of the filter increases, their resilience towards noise decreases. Looking at the curves in Fig. 4.0, it can be seen that the Daubechies family (including the Haar) outperforms both the Coiflets and the Symlets. From the results shown in Fig. 4.0, it can be seen that, even at high levels of SNR, there are still errors at the receiver. The reason for this is that, because AWGN is essentially random, the amount of noise added to the upper and lower subbands differs. As reconstruction of the transmitted signal is a function of both subbands, distorting either means it is no longer possible to attain perfect reconstruction of the transmitted signal even with very low SNRs.

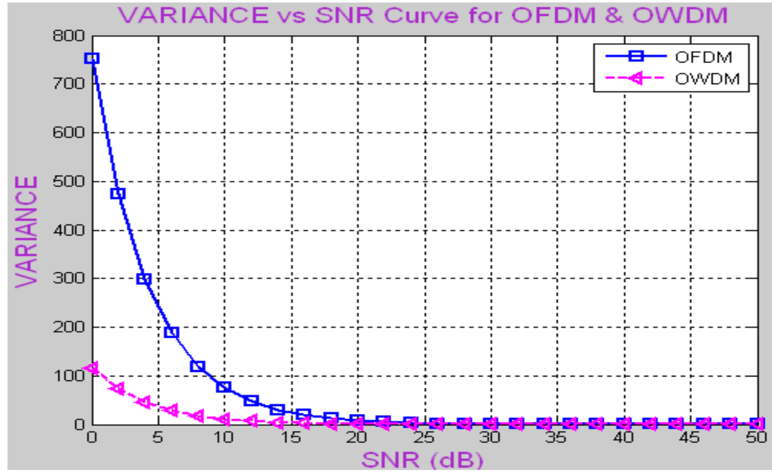

Fig. 5.0 Comparison of Signal to Noise Ratio against Variance between OFDM & OWDM.

Figure 5.0 shows the effects of adding AWGN to a DVB-T compliant OFDM and OWDM transmission. Simulation has shown that OFDM suffers from noise and only attains a BER less than 2 $x10^{-4}$ for SNR greater than 16dB. When the OFDM block in Figure 1.0 is replaced with the proposed system using the same SNR value, it can be seen from Figure 5.0 that the output from the synthesis filters are very similar when compared to the OFDM system. Examining these results further, a measurement of the variance versus the SNR of each received plot as depicted in Figure 5.0 shows slight increases in performance in the OWDM system and thus the two systems can be considered to be comparable. From above discussion it has been shown that OWDM is lower computational complexity, increases flexibility and low multi-path propagation loss than OFDM. While signals in OFDM systems overlap just in the frequency domain, DWT-OFDM signals overlap in the time domain as well so savings in bandwidth can be achieved.

4 Conclusion

In this paper we have demonstrated a set of simulations and comparison as well as evaluation has been succeeded of different wavelet families of OWDM with OFDM. From these results, it is suggested that the Haar wavelet is the most suited for OWDM because of the higher resilience to noise in a channel followed by the Daubechies family, while the Symlet wavelet is the least suited. These results indicate that in OWDM, the lack of orthogonality between the sub-bands has improved the resilience to noise owing to the increase in effective bandwidth of each sub-band. The results showed that there were some OWDM schemes which BER outperformed that of OFDM and Haar wavelet achieved the best BER performance compared to other wavelets

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and OFDM as well. From these results, it can be seen that there is a direct similarity between OFDM and OWDM when considering multi-path interference and AWGN. This is a good start in proving the potential of this technology but it should be stressed that this work is still in its infancy and there is still a significant amount of work that is needed before formally proposing this method as an alternative to OFDM but it is hoped that the results presented here are sufficient to convince the academic community that there is merit in this research. The system presented has no error correction coding, although in a practical system, coding would be included. In this paper, no error correction codes have been incorporated. However, these codes can be considered later on.

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