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Implementation of Discrete Wavelet Transform Using QPSK Modulation In OFDM Transmission

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Abstract

OFDM has gained much popularity in the field of wireless communication because of its ability to transfer the data at higher rate, high bandwidth efficiency and robustness to multipath and delay. The BER performance of conventional FFT-OFDM system is compared with DWT-OFDM system and DCT-OFDM system in an AWGN environment. Wavelet transform are implemented in a new design for orthogonal frequency division multiplexing. The new structure was tested and compared with conventional Fast Fourier Transform – based orthogonal frequency division multiplexing. Simulation results were generated using MATLAB platform. The proposed system has increased spectral efficiency, reduced inter symbol interference and inter carrier interference and improved bit error rate performance compared with other systems.

Keywords: Additive White Gaussian Noise, Discrete Wavelet Transform, Orthogonal Frequency Division Multiplexing, Quadrature Phase Shift Keying.

Introduction

Every transmission has some information to be protected. It can be an image, text or any other signal. This paper focuses on the transmission of an image. For a signal to travel in a channel, assuming it to be a safe transmission, the information should be processed in such a way that it is immune to the noise present and other hindrances. Here, the image to be protected is turned into logical bits. Most of the basic forms available are suitable for any process to be applied on for the record. OFDM has been a well known technique for the past several years, where anybody can have an access due to its work nature. OFDM is a multicarrier modulation scheme that divides the input data into bands on which modulation is performed and multiplexed into the channel at different carrier frequencies so that information is transmitted on each of the sub carriers, in such a way that the sub channels are free of distortion. DWT-OFDM has also been a combination for the past few years and turns out to be a successful format[3]. After all these process, the transformed analog signal can be transmitted in to an AWGN channel. The system is programmed using MATLAB software.

The systematic arrangement of this paper is as follows; Section 2, gives an overview of the binary image and a modulation technique called QPSK. Section 3 introduces discrete wavelet transforms and its definitions. Section 4, shows the proposed work of OFDM based on wavelet transform. The simulation results of MATLAB are put up in Section 5. The final section draws the conclusion.

Binary Image and Modulation

A binary image is used as the input image. The binary image with its extreme level has the pixel values of 0 and 1 alone considering black and white. Any other value before has been quantized to either one of these. Its chosen because the processing is simpler and any image undergoing processing, can be represented in binary form. It has only two information, a background and an object on it. The storage size is small and can be applied on all basic image processing machine. For this model to process successfully the size of the image is standardized, as matrix $m \times n$ with the consideration that the channel is noisy. The matrix to be processed is pulled out in the form of a column matrix and arranged as streams of input bits where N is total number of bits in the input stream. The input should be sent through the channel and should be received as with least errors as possible. So this message signal is in need of modulation. Variety of modulation schemes such as QPSK, QAM, M-PSK have been used in the development OFDM[2]. As a first step the input stream is modulated using QPSK. As a matter of fact, QPSK is an extended version of binary PSK where a symbol consists of two bits and there is two orthonormal basis functions, therefore four dibits are possible. The constellation of QPSK puts each dibit in each quadrant and every point lies in a circle with equal distance. This uses the bandwidth efficiently double the time of BPSK and sends four bits in a symbol.

$$\text{Bit\_seq}(i)=\{1010101\ldots.\} \text{ for } 0\leq i\leq N \quad (1)$$

$$\text{Oddbits}(i)=\{1111..\} \text{ for } 0\leq i\leq N/2+1 \text{ if N is odd , for } 0\leq i\leq N/2 \text{ if N is even.} \quad (2)$$

$$\text{Evenbits}(i)=\{1111..\} \text{ for } 0\leq i\leq N/2 \quad (3)$$

As the input stream approaches the mapper it divides them into odd and even bits. The QPSK uses local oscillator where the carrier frequency is f_c and t is bit period where $t=2*(1/f_c)$. During the separation of odd and even bits, the logical value zero is converted into -1. When a dibit leaves a remainder of zero when it is divided by 2 it is converted to an even bit and the remaining are considered to be odd bits. Therefore the bits are equally or unequally divided into two groups.

$$\text{Odd seq}=A*\text{odd bits}*\sin(2\pi f_c t) \text{ for } -E_m \leq A \leq +E_m \quad (4)$$

$$\text{even seq}=A*\text{even bits}*\cos(2\pi f_c t) \text{ for } -E_m \leq A \leq +E_m \quad (5)$$

The quadrature phase shift keying of odd and even sequence is the QPSK modulated output, M.If the even and odd bits are independent of each other at the input to the modulator, the QPSK modulated signal is considered as two independent BPSK modulated signals with orthogonal carriers[9]. The output is in terms of symbols.

Modulated output

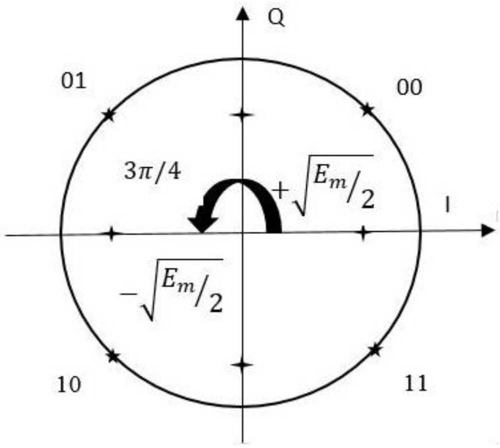
$$M_n(t) = \sqrt{\frac{2E_m}{T_m}} \cos\left(2\pi f_c t + (2n-1)\frac{\pi}{4}\right) \; n = 1,2,3,4 \tag{6}$$

The four phases $\pi/4$, $3\pi/4$, $5\pi/4$, $7\pi/4$are derived from $M_1(t)$,$M_2(t)$,$M_3(t)$,$M_4(t)$respectively. The distance between the origin and the presence of symbol is $\sqrt{E_m}$, that is the radius of imaginary circle connecting all symbols around the origin. Modulated output has various phases on which the symbol lies. In QPSK, n represents phases (4 phases)

Signal constellation coordinates$\left(\pm\sqrt{E_m/2}\,,\pm\sqrt{E_m/2}\right)$

Table 1: QPSK Constellation

Bit pair	Signal coordinates	Phase shift
00	$\left(+\sqrt{E_m/2}\,,+\sqrt{E_m/2}\right)$	$\pi/4$
01	$\left(-\sqrt{E_m/2}\,,+\sqrt{E_m/2}\right)$	$3\pi/4$
10	$\left(-\sqrt{E_m/2}\,,-\sqrt{E_m/2}\right)$	$5\pi/4$
11	$\left(+\sqrt{E_m/2}\,,-\sqrt{E_m/2}\right)$	$7\pi/4$



Discrete Wavelet Transform

Wavelet is a small part of a wave. More information can sent through a finite bandwidth by this technique. Discrete wavelet transform (DWT) algorithms have become standards tools for processing of signals. Wavelet is a finite one and its orthogonality was employed over both scale and time[7]. It analyzes the signal with different resolutions at different frequency bands by decomposing the signal into an approximation containing coarse and detailed information. The former is the high-scale, low frequency component of the signal whereas the detail is its reciprocal. The transform and its inverse is about averaging and differencing. There are different types of filters like Haar, Daub4, Daub6 [11] on which FDWT can be performed. Matrix multiplication and linear equation are two methods by which it can be done.

The Daubechie4 wavelet transform can be extended to multiple levels as many times as the signal can be divided by 2. Thus the extension level of Daubechie4 (Daub4) is lengthy, so the first level of Daub4 is taken into consideration. Consider 'm' is the incoming signal containing 'n' no of symbols. For 1-level Daub4 transform the mapping is $m \xrightarrow{D_1} (t^1|f^1)$ where t^1 is the 1st trend sub signal and f^1 is the 1st fluctuating sub signal for they have 'n/2' elements each. In this analysis, a signal is broken down into trendy and fluctuating sub signals that are used to reconstruct the original signal later.

Every value of t_k of $t^1 = (t_1, t_2 \ldots\ldots t_{n/2})$ is equal to scalar product $t_k = m.P_k$ (7)

Similar to equation 7,

Every value of f_k of $f^1 = (f_1, f_2 \ldots\ldots f_{n/2})$ is equal to scalar product $f_k = m.Q_k$ (8)

where $P^1{}_k$ is first level scaling signal and $Q^1{}_k$ is first level wavelet function.

Let the scaling numbers be $s_1 = \frac{1+\sqrt{3}}{4\sqrt{2}} s_2 = \frac{3+\sqrt{3}}{4\sqrt{2}} s_3 = \frac{3-\sqrt{3}}{4\sqrt{2}} s_4 = \frac{1-\sqrt{3}}{4\sqrt{2}}$ (9)

$$P_1^1 = s_1 \quad s_2 \quad s_3\, s_4 \quad 0 \;\ldots\; 0 \tag{10}$$

$$P_2^1 = 0\; 0\; s_1 \quad s_2 \quad s_3\, s_4 \quad \ldots \quad 0 \tag{11}$$

$$P_{n/2}^1 = s_3 \quad s_4 \quad 0 \ldots 0 \quad s_1 \quad s_2 \tag{12}$$

First level scaling signal of Daub4 $P^1{}_k = s_1 P^0{}_{2k-1} + s_2 P^0{}_{2k} + s_3 P^0{}_{2k+1} + s_4 P^0{}_{2k+2}$ (13)

which satisfy the properties $s_1^2 + s_2^2 + s_3^2 + s_4^2 = 1$ and $s_1 + s_2 + s_3 + s_4 = \sqrt{2}$

Let the wavelet numbers be $w_1 = \frac{1-\sqrt{3}}{4\sqrt{2}} w_2 = \frac{\sqrt{3}-3}{4\sqrt{2}} w_3 = \frac{3+\sqrt{3}}{4\sqrt{2}} w_4 = \frac{-1-\sqrt{3}}{4\sqrt{2}}$ (14)

$$Q_1^1 = w_1 \quad w_2 \quad w_3\, w_4 \quad 0 \;\ldots\; 0 \tag{15}$$

$$Q_2^1 = 0\; 0\; w_1 \quad w_2 \quad w_3\, w_4 \quad \ldots \quad 0 \tag{16}$$

$$Q_{n/2}^1 = w_3 \quad w_4 \quad 0 \ldots 0 \quad w_1 \quad w_2 \tag{17}$$

1st level wavelet signal of Daub4 $Q^1{}_k = w_1 Q^0{}_{2k-1} + w_2 Q^0{}_{2k} + w_3 Q^0{}_{2k+1} + w_4 Q^0{}_{2k+2}$ (18)

which satisfy the properties $w_1^2 + w_2^2 + w_3^2 + w_4^2 = 1$ and $w_1 + w_2 + w_3 + w_4 = 0$

First level of Daub4 inverse transform $m = t^1 + f^1$ (19)

where $t^1 = (m * P_1^1)P_1^1 + (m * P_2^1)P_2^1 + \cdots + \left(m * P_{\frac{n}{2}-1}^1\right)P_{\frac{n}{2}-1}^1 + \left(m * P_{n/2}^1\right)P_{n/2}^1$

(20)

$$f^1 = (m * Q_1^1)Q_1^1 + (m * Q_2^1)Q_2^1 + \cdots + \left(m * Q_{\frac{n}{2}-1}^1\right)Q_{\frac{n}{2}-1}^1 + \left(m * Q_{n/2}^1\right)Q_{n/2}^1 \tag{21}$$

This paper deals with OFDM transmission, so the inverse DWT is used. P_k^l is an average of values of m, Q_k^l is the difference of operation on the values of m. The P_k^l is a combination of elementary scaling signals which are short lived. These short lived trends signals live for only four time-units which are measured by the trend values. In the same way, the combination of elementary wavelets forms detail signal. These wavelets live for only four time-units. The relative contribution of each wavelet is measured by the fluctuation value. From the properties, it is found that all the Daub4 wavelets have energy 1.

DWT Based OFDM Transmission

The implementation of OFDM-DWT modulator is as follows. The transform employed in the transmission part is Inverse Daubechie4. The output of QPSK and its corresponding length of zeros are given as the input for this transform. The output is the modulated and transformed signal ready for transmission. DWT based OFDM signals overlap both in time and frequency domains, so there is no call for CP as in the case of a DFT-OFDM pair[5]. Therefore, during this transformation, the spectral containment of the channel is improved. It has the heavy possibility of being more powerful and more efficiency in bandwidth with high data rate[11]. The system is designed to work when transmission is through the AWGN channel.

Simulation Results

The DWT based OFDM using QPSK modulation is designed with MATLAB program and the simulation results are as follows,

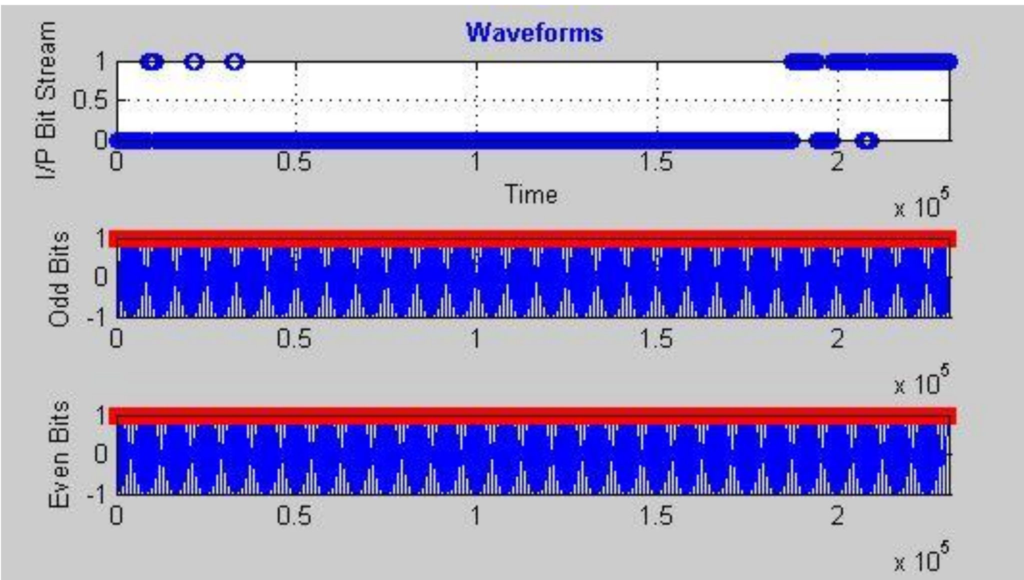


Figure 1: Simulation Results of Input ,Odd And Even Bits

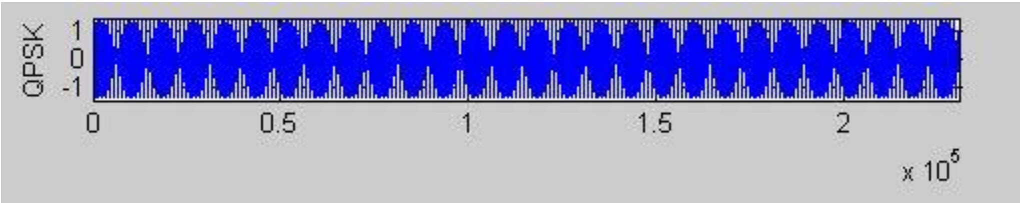


Figure 2: Simulation result of modulated signal

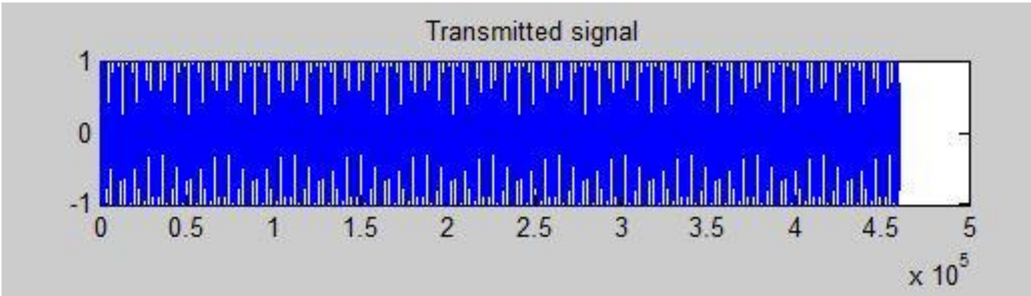


Figure 3: Simulation output of transmitted signal

Figure 1 represents the input stream of logical bits from binary image and the mapper dividing them into odd and even bits. Figure 2 represents the QPSK modulated output. Figure 3 is the transformed output ready for transmission by Daub4 based OFDM. This signal is transmitted over the AWGN channel.

Conclusion

Simulation results show that DCT based scheme yields the lowest average bit error rate for AWGN channel. Whereas, out of all mother wavelets used Haar and Daubechies wavelet based scheme yields low BER than FFT-OFDM for an AWGN channel. Although the theory of wavelet transform has been well-evolved and documented over the past years, the use of wavelets in the communication is still in the early age of the development. Future work may include the implementation of forward error correction techniques such as convolution codes. An efficient channel estimation algorithm may be included for performance evaluation of DCT-OFDM and DWT-OFDM working.

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