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Original Article

Wavelet Transform Application Based on Matlab Simulation

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Abstract: Multiple Input Multiple Output (MIMO) and Orthogonal Frequency Division Multiplexing (OFDM) techniques are combined to provide the spectrum efficiency and high data rate improvement that it was required for 4G, 5G wireless systems. Discrete Wavelet Transform (DWT) is presented as an alternative for Fast Fourier Transform (FFT) since there is no necessity for Cyclic Prefix (CP) due to the overlapping properties of DWT. By a simple replacement of the FFT with DWT in MIMO-OFDM system, an improvement of performance has been detected which leads to a new system scenario MIMO-OFDM based on DWT. In this thesis, the two systems are simulated with particular parameters and the performance of Bit Error Rate (BER) is evaluated to determine the different types of wavelets in various channel conditions with separate modulation methods (8, 16, 32-QAM). Therefore, MIMO-OFDM system based on DWT algorithm will be compared with MIMO-OFDM system based on FFT algorithm by using MATLAB simulation software. And besides, We would like to refer to use Neural Network algorithms to replace Wavelet transform in the next research.

Keywords: MIMO, OFDM, DWT, FFT, ANN.

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1. Introduction

The areas of wireless communication have been significantly challenging in the last years. Over time, several generations have passed to improve the speed and capacity while maintaining an appreciable quality of service. The combination of Multiple Input Multiple Output system with Orthogonal Frequency Division Multiplexing (MIMO-OFDM) has a potential to increase spectral efficiency so it represents an important research area. An OFDM system divides the high data rate serial number into parallel streams with low data rates. The method of conventional MIMO-OFDM based on FFT requires the insertion of the Cyclic Prefix (CP) to combat the effects of the Inter Symbol Interference (ISI) which it will increase the consummation of the bandwidth and reduce the spectral efficiency. To overcome the limitation of this problem, an approach of MIMO-OFDM based on Wavelet Transform is proposed as an alternative of the conventional MIMO-OFDM. A MIMO-OFDM system used DWT algorithm is simply implemented by the replacement of the FFT/IFFT with DWT/IDWT blocks and there is no need to add CP due to the properties of Wavelet Transform [1] offers a high suppression sides lobes and provides the analysis of the signal in both time and frequency domain. The Bit Error Rate (BER) according to Signal Noise Ratio (SNR) performance of this method is better than the conventional MIMO-OFDM [2, 3]. Bit error rate (BER) is a measure of the number of bit errors that occur in a given number of bit transmissions. It is usually expressed as a ratio.

At present, we is continuing to test with the Artificial Neural Network (ANN) algorithms suit to replace DWT and reduce the complexity.

2. Implementation of dwt-based MIMO-OFDM and FFT-based MIMO-OFDM

2.1. The MIMO-OFDM system with Fourier transform

Asma Bouhlela *et al.* [4] have presented a model design of MIMO-OFDM using Fast Fourier Transform (FFT), which is used to translate from the Time-domain signal into a Frequency-domain. The Inverse DFT and DFT are essential parts in the implementation of a MIMO-OFDM. MIMO-OFDM based on FFT has many benefits to improve performance, to increase the spectrum efficiency, to save the power and to reduce the effects of the Multipath Fading channel.

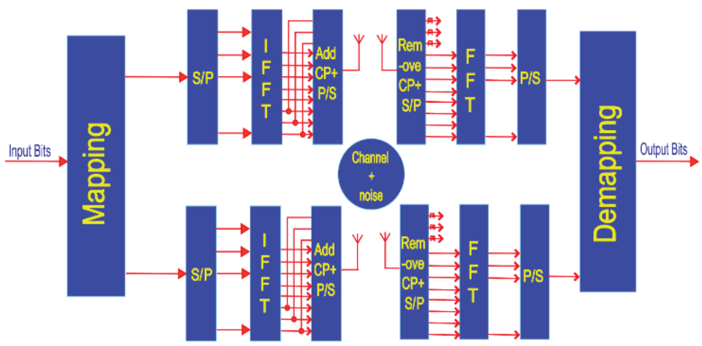

Figure 1. MIMO-OFDM transceiver based on Fourier transform

For this system, we consider N_{tx} transmit antennas, N_{rx} receive antennas, n OFDM symbols, and K subcarriers. Datastream is first mapped into complex symbols according to the type of modulation techniques. The transmitted symbols vector is expressed as:

$$S[n,k] = [S_1(n,k) \dots S_{N_{tx}}(n,k)]^T,$$

$$k = 0,1, \dots K - 1 \quad (1)$$

Where $S_i[n,k]$ is the symbol, which is transmitted at the n^{th} symbol, k^{th} subcarrier, and i^{th} antenna.

By applying the Inverse Fast Fourier Transform (IFFT), the symbol vectors are turned into OFDM symbol:

$$S_n[m] = \frac{1}{\sqrt{kN_{tx}}} \sum_{k=0}^{K-1} S[n,k]\, e^{i\frac{2\pi m}{k}} ,$$

$$m = 0,1, \dots, k \quad (2)$$

To avoid Inter-symbol Interference Symbol (ISI) in addition to the Inter-Carrier Interference (ICI) a Cyclic Prefix (CP) is added before the transmission of each symbol and then signal vectors are fed though the i^{th} transmitter antenna [5]. In [6], CP is removed from signal vector at q^{th} receiver and Fast Fourier Transform (FFT) is applied. Then the received signals vector can be expressed as:

$$Y_q[n,k] = \sum_{i=1}^{N_{tx}} H_i[n,k] * S_i[n,k] + W_q[n,k] \quad (3)$$

$H_i[n,k]$ is the channel impulse response vector and $W_q[n,k]$ is the Additive White Gaussian Noise (AWGN).

2.2. The MIMO-OFDM system with Wavelet transform

The transceiver of the MIMO-OFDM system based on Wavelet transform is as shown in figure 2 as in [7].

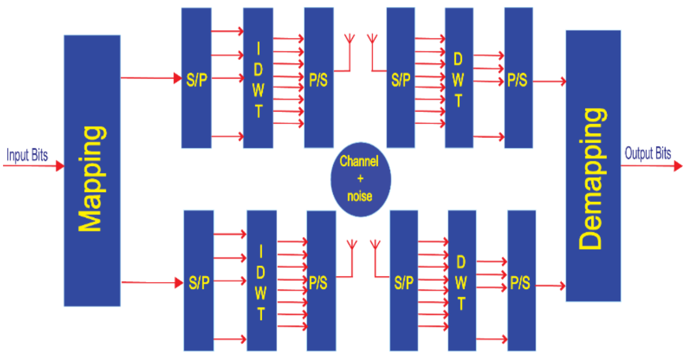

Figure 2. MIMO-OFDM transceiver based on Wavelet transform

After modulation of the data stream using as a constellation diagram, mapped symbols will be carried over by the Wavelet carriers. The Wavelet carriers are nothing but the IDWT coefficients: detailed coefficients and approximate coefficients. Those coefficients are obtained from the mother wavelet $\psi(t)$ expressed as:

$$\Psi_{j,k}(t) = 2^{\frac{-j}{2}} \Psi(2^{-j}t - k) \quad (4)$$

Where j is the scaling index

k is the position on the time axis

To obtain the finite numbers of scales, scaling function $\phi\,(t)$ is used. IDWT-OFDM symbol now can be considered as the weight of Wavelet and scale carriers, as expressed in the following equation.

$$S(t) = \sum_{j,k} W_{j,k}(t) * \Psi_{j,k}(t) + \sum_k a_{j,k} * \phi_{j,k}(t) \quad (5)$$

Where $w_{j,k}$ are sequences of wavelet

$a_{j,k}$ are approximation coefficients

On the other hand, the reverse process is simulated using DWT in the receiver. The signal will be processed to the demodulator for data recovery.

The implementation of the MIMO-OFDM based on DWT is obtained by a simple replacement of FFT/IFFT blocks with DWT/IDWT and an elimination of CP pending and removing in the transmitter and receiver part.

3. Results and discussion

The simulation result is carried out for both the MIMO-OFDM system based on FFT and DWT algorithms under Additive White Gaussian Noise (AWGN) and Rayleigh Flat Fading channel. Therefore, the receiving signal is:

$$y(t) = h(t)x(t) + n(t) \tag{6}$$

Where *x(t)* is transmitted signal

n(t) is AWGN

h(t) is the Flat Fading channel parameter.

The simulation parameters are listed in table 1.

Table 1. Simulation Parameters

	MIMO-OFDM with FFT	**MIMO-OFDM with DWT**
Variables	Matrix values	
Modulation method	8-QAM, 16-QAM, 32-QAM	8-QAM, 16-QAM, 32-QAM
N	32	32
n_S	1000	1000
CP	4	0
wv	-	db1, db2
d (N x n_S)	32 x 1000	32 x 1000
X_m (N x n_S)	32 x 1000	32 x 1000
xx	1 x 32000	1 x 32000
X_k	32000 x 1	64000 x 1
U_k	32000 x 1	64000 x 1
uu	1 x 32000	1 x 64000
U_m (N x n_S)	32 x 1000	32 x 1000
d' (N x n_S)	32 x 1000	32 x 1000

3.1. The result of the MIMO-OFDM system based on FFT/DWT in AWGN channel

The comparison is made of the MIMO-OFDM system with FFT between the QAM points of 8, 16, 32 over the AWGN channel. The performance gain is wide from 16-QAM systems to the 32-QAM systems. The higher points systems will have bigger SNR values. The higher performance gains are also observed when the SNR increases, as shown in figure 3.

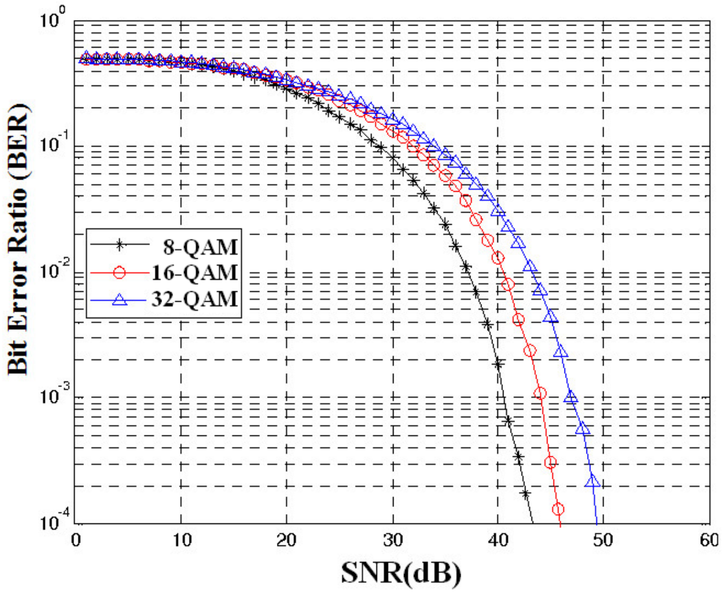

Figure 3. BER vs. SNR curves in case of the MIMO-OFDM based on FFT in the AWGN channel

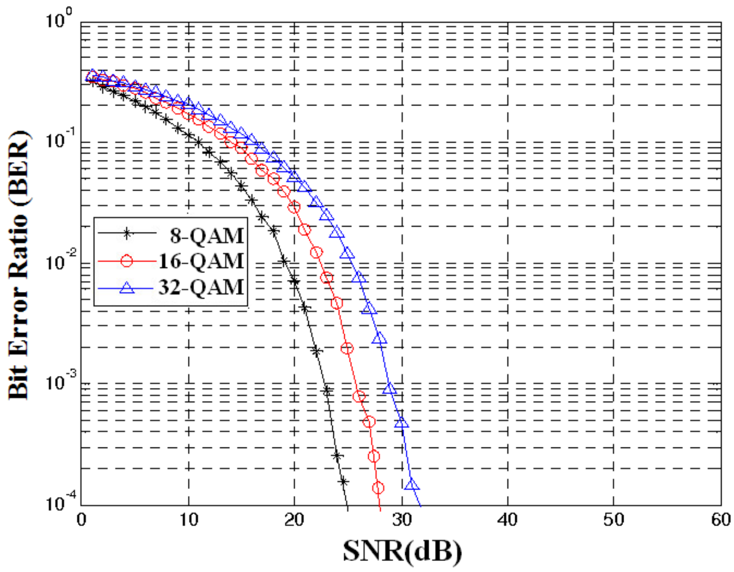

Figure 4. BER vs. SNR curves in case of the MIMO-OFDM based on DWT in the AWGN channel

Figure 4 shows the results for the MIMO-OFDM system based on DWT that uses QAM points of 8, 16 and 32 over the AWGN channel.

The performance gains obtained from 8-QAM, 16-QAM, and 32-QAM is broad. The performance gains are also observed when the SNR increases. In the MIMO-OFDM system based on DWT, the BER performance at 16-QAM is better than the system using 32-QAM.

As the results of figure 3, 4 show us that the performance of the MIMO-OFDM system using DWT algorithm is better than the MIMO-OFDM system with FFT using the same QAM modulation way.

3.2 The result of the MIMO-OFDM system based on FFT/DWT in Rayleigh Flat Fading channel

In this section, the channel model used is the Flat Fading channel, where the bandwidth of the transmitted signal is smaller than the coherence bandwidth of the channel. Then, all frequency components of the transmitted signal undergo the same attenuation and phase shift in transmission through the channel. In this simulation, the value of the Doppler frequency is 500 Hz. The BER performance of the MIMO-OFDM system based on FFT with 8, 16, 32-QAM is shown in Figure 5. The performance is reduced as the number of constellation mapping points increased from 8 to 16 points. This section has clearly shown that the performance of the FFT-based MIMO-OFDM system is affected by Doppler frequency as well as the value of QAM constellation points. The MIMO-OFDM system with FFT simulated in the Flat Fading channel performs is better at the lower Doppler frequency as compared to its performance at the higher Doppler frequency.

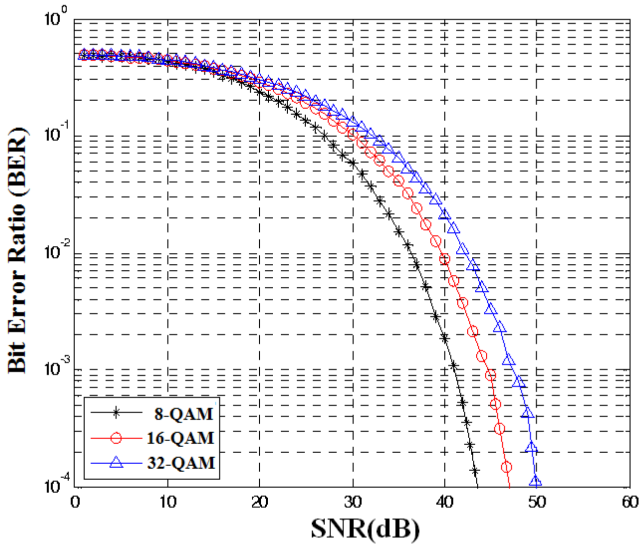

Figure 5. BER vs. SNR curves in case of the MIMO-OFDM based on FFT in the Rayleigh Flat Fading channel.

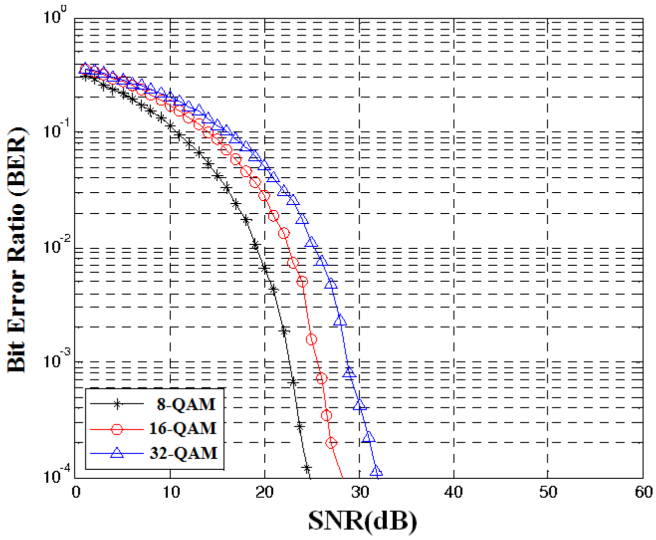

Figure 6. BER vs. SNR curves in case of the MIMO-OFDM based on DWT in the Rayleigh Flat Fading channel.

The MIMO-OFDM system with DWT is also affected by Doppler frequency as well as the value of QAM constellation points. The MIMO-OFDM system with DWT simulated in the Flat Fading channel is better at the lower Doppler frequency (500Hz) as compared to its performance at the higher Doppler frequency. Figure 6 shows the BER performance of the MIMO-OFDM system based on DWT using QAM 8, 16 and 32 constellation mapping points over Flat Fading channel.

From two of figures, it clearly shows that the performance of the MIMO-OFDM system with DWT is better than the FFT-based MIMO-OFDM system at the same QAM points.

4. Discussion

This paper presents the performance analysis of the MIMO-OFDM system based on FFT and DWT in AWGN and the Flat Fading channel and carried out according to the SNR.

The results in terms of BER show that the DWT-based MIMO-OFDM system is more efficient rather than the traditional MIMO-OFDM system. The performance gain of the system using 4-QAM is better the systems that use 16-QAM and 32-QAM since the SNR value is bigger then systems using more constellation points. The results indicated that DWT is a good alternative way to FFT but at the cost of higher complexity of equalization.

In the next time, we will propose a blind signal detection approach based on ANN as in [8], [9] for MIMO-OFDM systems when the channel is not known to the receiver. Neural networks have offered state of the art solutions in many other domains than classifications. Since we can view the detection as an act of classification, we can choose one of the techniques as a classifier. Training a neural network involves many hyper-parameters controlling the size and structure of the network and the optimization procedure which can help achieve better detection over large-scale systems.

6. Conclusions

In this paper, we presented some of the results in terms of BER performance of MIMO-OFDM by using FFT and DWT. We can see that the DWT algorithm gave better qualities than FFT at the same number of constellation points of the QAM modulation and the transmitter power. However, an approaching with DWT is conduct more complexity than FFT. And we supposed that the channel was known at the receiver. So, we propose to use ANN algorithms for MIMO-OFDM in the next our research.

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