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Doppler reduction using Sliding Window technique in WP-OFDM system

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Abstract: This letter presents a new Wavelet Packet (WP) OFDM system using a Sliding Window (SW) technique. The SW is used to increase signal orthogonality and thus reduces the Doppler frequency effect in the received data. This is done by reducing the round-off error and long correlation time of the received data. Simulation results show that the proposed system offers significant BER gains over the standard WP-OFDM system without SW under flat fading and the Additive White Gaussian noise (AWGN) channel.

Keywords: Wavelet Packet, Sliding Window (SW), FFT, Doppler frequency

Classification: Science and engineering for electronics

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1 Introduction

The effect of the lost in signal Orthogonal frequency division multiplexing (OFDM) system in multipath environment are the Intersymbol Interference (ISI) and Intercarrier Interference (ICI) occur [1]. Therefore, this will effect the detection of the signal at the receiver.

OFDM system based on Wavelet packet modulation (WPM) has emerged as the efficient multicarrier scheme. The orthogonality between the subcarriers follows the orthogonal characteristic of Wavelet transform. Besides, it provides bandwidth efficiency as compared to the DFT based OFDM systems [2]. Wavelet packet decompositions generate set of self and mutually orthogonal waveforms which could also be used for synchronous orthogonal multiplexing for wireless communication system [3].

In the WP-OFDM the signals are orthogonal if they are mutually independent of each other. The orthogonality have a property that allows multiple information signals to be transmitted perfectly over multipath channel without interference, and the loss of orthogonality results in blurring between these information signals and degradation in communications.

Salih in [4] presents that the Sliding Window (SW) technique for FFT based OFDM (IEEE 802.11a) that enhances the transmitted signals orthogonality and reduces Doppler frequency effect under flat fading and the AWGN channels.

This letter proposes a new WP-OFDM system based on SW that improves the transmitted signals orthogonality. The aim is to further increase the signal orthogonality in WP based OFDM using the SW technique presented in [4]. This reduces the Doppler frequency effect and to improve the system performance o under multipath Rayleigh fading and the AWGN channel. The main difference between this work and [4] is the utilization of WPT instead of FFT, with the aim to have a different OFDM system.

2 WP-OFDM system with Sliding Window (SW)

The proposed WP-OFDM system with SW block diagrams is illustrated in Fig. 1. The SW technique is placed in the transmitter in between the FFT and IDWPT blocks. In receiver, the inverse SW technique is placed in between WPT and IFFT blocks. The output from the FFT is of length N, and the data serve as the input to the SW block. Then they are fed to the IWPT block. The data then are converted into serial sequence for transmission via a fading channel. In the receiver, the reverse processes are carried out.

The use of SW technique offers the following to the WP-OFDM system:

1. It reduces the round-off error that may occur in any bit at the receiver due to the channel effect. For example, if an error occurs at any received bit, part of its energy is spread to the other adjacent bits due to mixing property of SW technique, which does addition operation at the transmitter side and subtraction operation at the receiver side.

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2. It reduces the long correlation time of the received data, thus reduces processing time. A shorter correlation period also helps to mitigate the frequency offset effect and the round off error. The frequency offset results in phase rotation or shifts of the sampled signals causing reduced correlation between the received signal and the transmitted waveform. The longer the correlation period, the larger is the phase shift and the poorer the correlation.

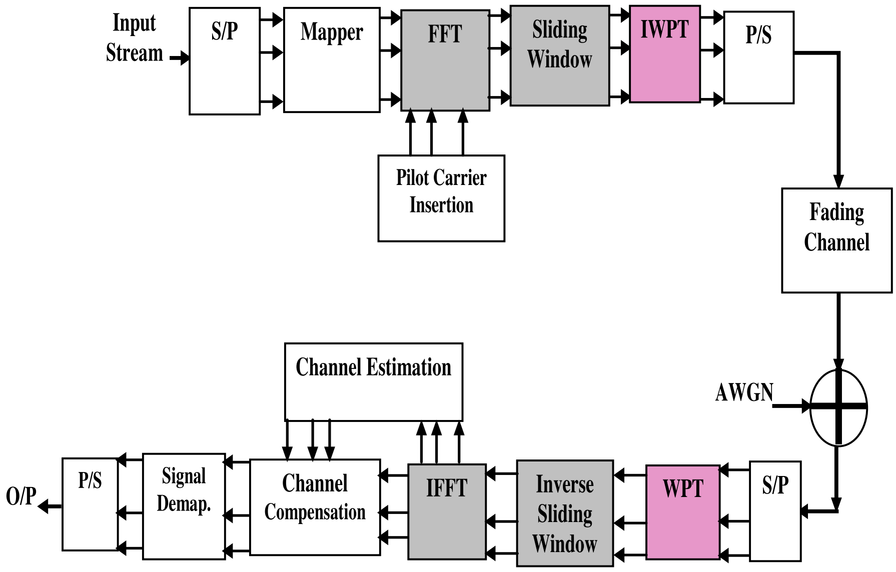

Fig. 1. The Block Diagram for the proposed system model.

3 The analysis of model

In the transmitter, the output of the FFT is added with the pilot carriers and zero padding, thus in the frequency domain the signal is resented as follows:

$$x_N = FFT\{x_k\} = \frac{1}{N}\sum_{k=0}^{N-1} x_k e^{-j2\pi nk/N}, \qquad n = 0, \ldots, N-1 \tag{1}$$

where x_k is data symbol of the k^{th} subcarrier and N is the number of sub-carriers.

This vector signal will be entered to SW block. The readers may refer to [4] for the details for SW technique.

The output signal from SW will be processing to Inverse Discrete Wavelet Packet Transform (IDWPT) in transmitter,

$$X_n = IDWPT(\bar{x}_n) \tag{5}$$

The impulse response of the channel can be formulated in vector form as [5]

$$h_n = [h_1 h_2 \ldots\ldots\ldots h_n] \tag{6}$$

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The received signal from the channel can be expressed as [5]

$$y_n = X_n * h_n + w_n \tag{7}$$

where $*$ denotes linear convolution

The linear convolution channel converts with ISI to a form of circular convolution without ISI.

$$y_n = X_n \otimes h_n + w_n \tag{8}$$

Where $\otimes$ denotes the circular convolution, and w_n is zero mean complex Gaussian independent random variable representing AWGN.

Then the signal will be entered to DWPT process. The wavelet packet waveforms have the property in both time and frequency domain.

The received signals in this step will become as in Eq. (9).

$$\bar{y}_n = DWPT(y_n) \tag{9}$$

The outputs of WPT block will be entered to ISW block, to become:

$$\begin{aligned} y_1 &= \bar{y}_1 \\ y_2 &= \bar{y}_2 - y_1 \\ y_3 &= \bar{y}_3 - y_2 \\ y_4 &= \bar{y}_4 - y_3 \\ &\ldots\ldots \\ y_{n-1} &= \bar{y}_{n-1} - y_{n-2} \\ y_n &= \bar{y}_n - y_{n-1} \end{aligned} \tag{10}$$

The Inverse Fast Fourier Transform (IFFT) is used to convert the frequency domain signals to time domain signals.

$$Y_n = IFFT\ \{y_k\} = \sum_{k=0}^{N-1} y_k\ e^{j2\pi nk/N}, \qquad n = 0, \ldots, N-1 \tag{11}$$

Following the IFFT is the zero padding (1: P) remover, where P: is numbers of the pilot carriers.

In the last step is found the channel frequency response will be used to compensate the channel effects on the data, and the estimated data can be found using the following equation:

$$\text{Estimation of data}\,(k) = H^{-1}_{estimate}(k) * \text{Received data}(k),\ k = 0, 1, \ldots.., N-1 \tag{12}$$

4 Simulation results

In this section, the simulation results are presented which show the performance comparison of WP-OFDM with SW and the WP-OFDM system without SW technique. The performance results of the systems are taken using AWGN and Flat Fading channel using the OFDM parameters as listed in Table 1. The bit rate used in this simulation is 54 Mbps.

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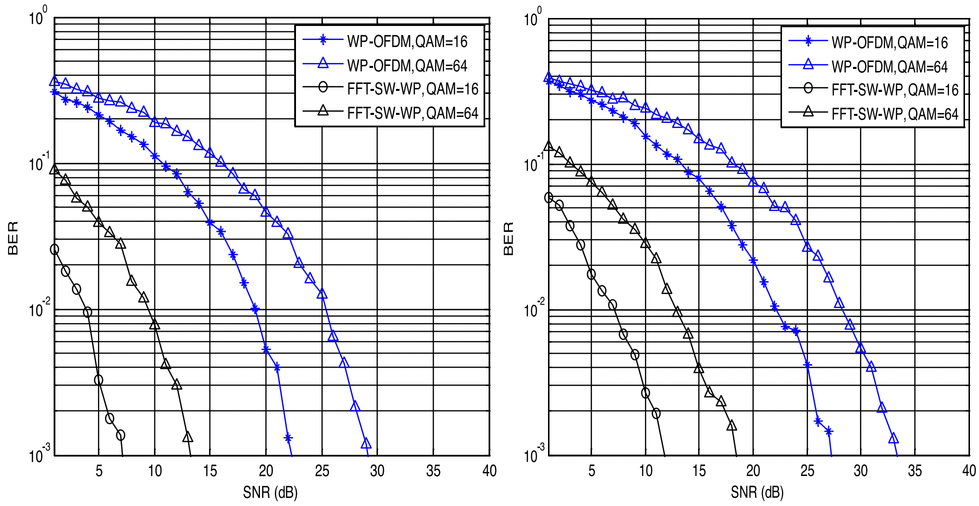
Table I. Simulation Parameters.

Parameter	WP-OFDM
Modulation (QAM)	16, 64
Doppler Frequency	200 Hz
Number of Pilot sub-carriers	4
Widow Size (N)	64
Data Rate	54 Mbps
Number of effective sub-carriers	48
Cyclic Prefix	8 bit
Wavelet	Haar
Channel	AWGN
	Flat Fading+ AWGN



a b

Fig. 2. BER performance for models at, a-AWGN channel (QAM=16, 64) b-Flat fading channel (QAM=16, 64, Doppler frequency=200 Hz.

4.1 The performance of proposed model

The BER performance of the WP-OFDM with FFT based SW using QAM=16 and 64 constellation mapping points over AWGN channel is shown in Fig. 2-a. It is found that the proposed model of WP-OFDM with FFT based on SW (FFT-SW-WP) technique has a BER $= 10 - 3$ at SNR $= 7.5$ dB (QAM=16) and at SNR $= 13.5$ dB (QAM=64), while the standard model has the BER high at same point in the AWGN channel. A wide span gain is observed between the performances of these models, so the proposed model is better and more significant than the standard system.

While the Fig. 2-b shows the BER performance of the WP-OFDM system based SW using QAM=16, 64 constellation mapping points over Flat Fading channel. This figure clearly shows that the performance of WP-OFDM system based SW technique is better than the standard WP-OFDM system at same QAM points. The Doppler frequency considered here is 200 Hz. It can be seen from Fig. 2 that there exist a wide difference in BER curves between the models where the gain at BER $= 10^{-3}$ is about 12 dB (QAM=16) and

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at SNR=18 dB (QAM=64).

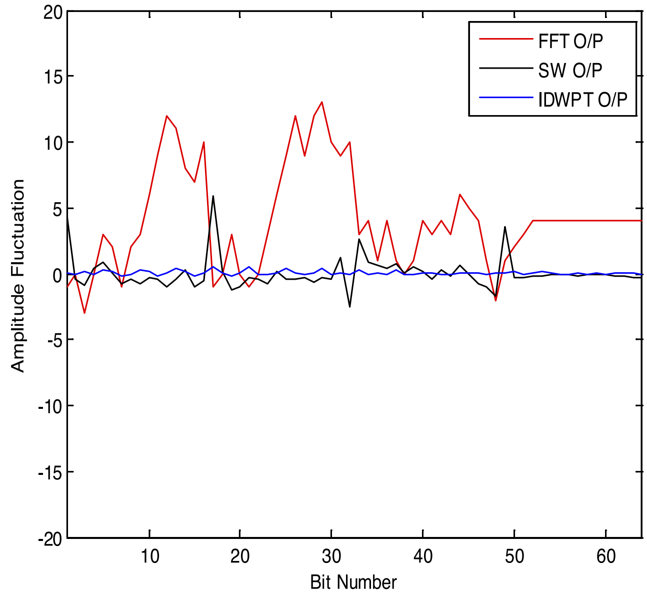

Fig. 3. The Signal Shape of the Transmitter Side.

4.2 The signal shape of the transmitter side

It can be seen in Fig. 3 that the signal shape after FFT block fluctuates while the output of SW block is less. The effect of SW technique is to smooth the transmitted signal. Since the Doppler frequency will cause a left or right shift (fluctuates) in received data, the output signal from the IDWPT will be less affected by Doppler frequency.

5 Conclusion

In this letter, the sliding window technique is used in WP-OFDM system to improve signal orthogonality. The SW has been included to reduce the Doppler frequency effect, thus improves the performance of WP-OFDM system.

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