

Simulated Assessment of Orthogonal Wavelet Division Multiplexing (OWDM) for Future Wireless System

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Abstract- Orthogonal Wavelet Division Multiplexing (OWDM), is a progressive multi-carrier modulation method that use discrete wavelet transforms (DWT) in place of Fast Fourier transforms (FFT) to improve upon OFDM. It enhances spectral efficiency and robustness against interference by eliminating the need for a cyclic prefix (CP), offering better performance in frequency-selective fading channels, reducing Inter-Symbol Interference (ISI). In this paper, we implement and investigate the performance of OWDM in wireless scenario. The simulated outcomes reveal the supremacy of OWDM over conventional OFDM.

Keywords – OFDM, OWDM, CP, ICI, BER, WLAN.

I. INTRODUCTION

The demand for reliable and high-speed mobile wireless communications is rapidly growing. OFDM based wireless system promise to offer high data rate over large areas to a large number of users where broadband is unavailable. However, at destination, the reliability of orthogonal frequency division multiplexing (OFDM) is limited due to the time-varying nature of the channel. Thus, inter-carrier interference (ICI) occurs and therefore increases inaccuracies in channel tracking. However, it can efficiently be avoided at the price of power loss and bandwidth (BW) enlargement by implanting a cyclic prefix (CP) guard interval before each block of parallel data symbols. But this guard band reduces the spectral efficiency of the OFDM system [1].

Newly, it was discovered that discrete wavelet division multiplexing (OWDM) is capable of decreasing the inter symbol interference (ISI) and ICI. OWDM can also support considerably greater spectrum efficiency than OFDM. In OWDM technique, the sub-bandwidth division is attained by means of the inverse discrete wavelet-based transforms, whereas conventional OFDM uses IFFT [2-3]. Further key difference is that OWDM symbols overlap in both time and frequency domains, whereas OFDM symbols overlap only in frequency domain. Consequently, inserting cyclic prefix (CP) to the OWDM symbol frame does not have any effect on the bit error rate (BER) performance. The key advantage of OWDM compared to OFDM is that OWDM is more band-width (BW) efficient than OFDM [4]. In this paper, the FFT-OFDM is replaced by wavelets-OFDM (OWDM) in order to further decrease the level of interference and increase spectral efficiency. The simulated outcomes revealed that proposed Multiwavelet design attains much lesser bit error rates (BER), rises signal to noise power ratio (SNR), and therefore, can be an alternative to the conventional OFDM. The proposed OWDM system was modeled, tested, and its performance was evaluated and compared.

II. OWDM System Structure

OWDM is considered a promising technique for next-generation communication systems where high throughput and reduced latency are required [5]. The core components and implementation of OWDM includes

- **Transmitter (Modulator):** It uses Inverse Discrete Wavelet Transform (IDWT). The QAM-modulated data is up-sampled and passed through synthesis filter banks (Low Pass and High Pass) to generate the composite signal.
- **Receiver (Demodulator):** It uses Discrete Wavelet Transform (DWT). The received signal is passed through decomposition filter banks and down-sampled to recover the original data stream.
- **Wavelet Families:** In this system common wavelets used for optimization include Haar, Daubechies, Symlet and Biorthogonal. Biorthogonal wavelets are often preferred for 5G applications due to their linear phase and design flexibility.

Key advantages of OWDM compared to Conventional OFDM (C-OFDM) include [6]:

- **Superior Efficiency:** By removing the cyclic prefix, OWDM increases bandwidth and power efficiency, which is crucial for 5G and future communication systems.
- **Reduced Interference:** OWDM significantly reduces Inter-Carrier Interference (ICI) and ISI due to the superior localization of wavelet functions in both time and frequency.
- **Better Performance:** It offers better Bit Error Rate (BER) and Peak-to-Average Power Ratio (PAPR) performance compared to traditional OFDM.
- **Flexibility:** It acts as a highly flexible, channel-optimized alternative to OFDM for various wireless applications.

In conventional OFDM, a redundant Cyclic Prefix (CP) is inserted to each symbol to avoid Inter-Symbol Interference (ISI). This consumes up to 20–25% of total bandwidth. However, wavelet filters have better "time-frequency localization". OWDM can uphold signal integrity without a CP, instantly reclaiming that lost bandwidth for actual data [7]. OFDM uses rectangular windows, which cause high "side lobes" in the frequency spectrum. This creates interference for users in adjacent frequency bands. However, wavelet functions (like Daubechies or Meyer) naturally taper off at the edges. These filters permit for much tighter spacing between users, which is critical for the crowded 6G spectrum. The major drawback of OFDM is high PAPR, which drains mobile battery life and requires expensive, inefficient power amplifiers. However, because wavelets decompose signals into different scales, the resulting peaks are often less extreme. Wavelet Packet Modulation (WPM) create signals that are "kinder" to battery-powered IoT devices [8]. Conventional OFDM struggles with the Doppler Shift (e.g., a user in a high-speed train), which destroys the orthogonality of subcarriers. However, the multi-resolution nature of wavelets permits the system to be more resilient to frequency shifts. Research is focused on finding specific wavelet shapes that remain orthogonal even under extreme doppler conditions [9]. The OWDM transceiver is illustrated in Figure 1.

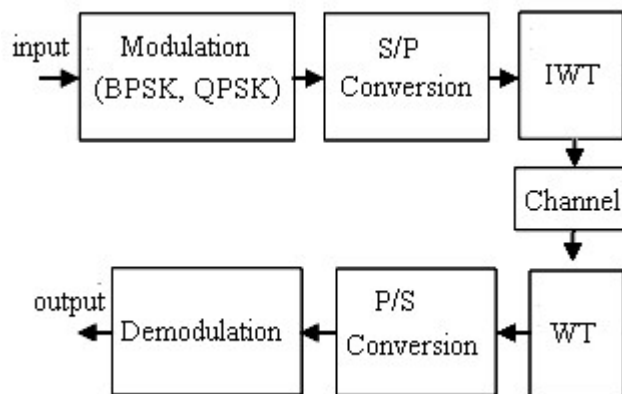


Figure 1. OWDM Transceiver

Unlike Fourier transforms, which are standardized and predictable, the choice of a Wavelet Basis can act as an additional layer of security. Wavelet transform is equivalent to filtering a signal with a low pass and high pass filter bank, while the IWT is equivalent to combining a low pass and high pass signal into one signal. Due to the overlapping nature of wavelet properties, the wavelet based does not need cyclic prefix to deal with delay spreads of the channel. As a result, it has higher spectral containment than that of Fourier-based OFDM.

The incoming signal is first converted from serial to parallel form and then modulated. There is up sampling of signal in each iteration of inverse wavelet packet transformation (IWPT). Now the signal is decomposed one with HPF and the other with LPF [10]. The outputs of HPF and LPF branches are then subsequently added.

The wavelet coefficients are the representation of signals in scale and position or time. The scale is related to the frequency. Low scale represents compressed wavelet which means that the signal is rapidly changing, or the signal is in high frequency. On the other hand, high scale represents stretched wavelet which means that the signal is slowly changing, or the signal is in low frequency.

III. Simulated Results

Orthogonal Wavelet Division Multiplexing (OWDM), also known as Wavelet Packet Modulation (WPM), is a multicarrier communication technique proposed as a flexible, lower-complexity alternative to traditional Orthogonal Frequency Division Multiplexing (OFDM). The conventional OFDM (FFT-OFDM) and OWDM system are developed, analyzed, and simulated in MATLAB.

The simulated results of conventional OFDM and OWDM are shown in the figures 2 to figures 4.

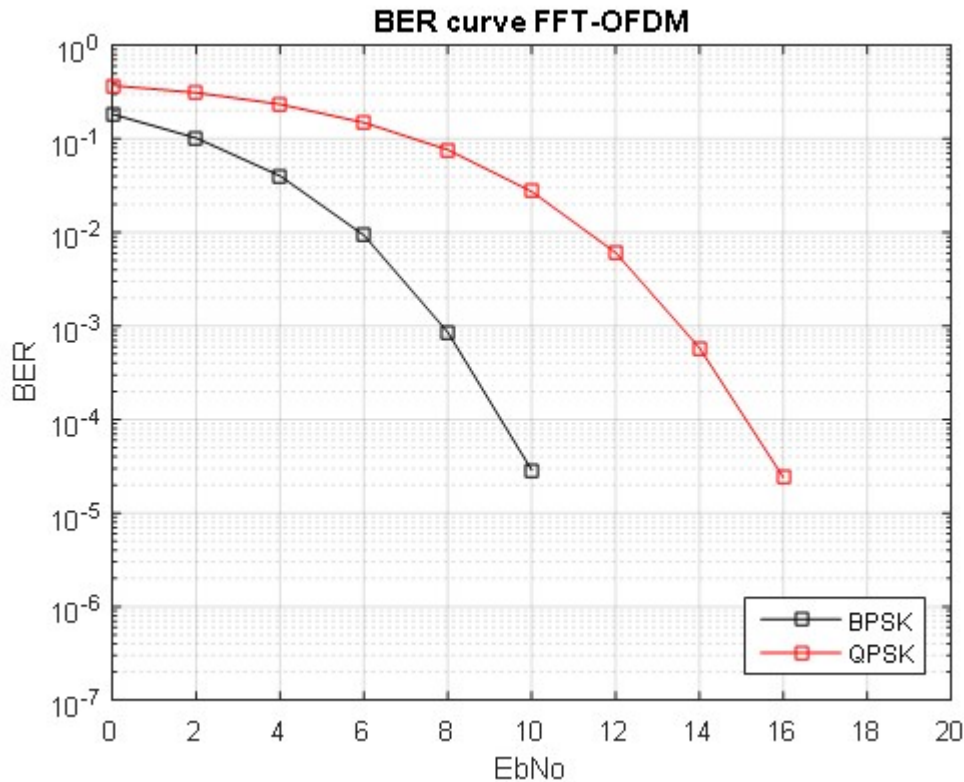


Figure 2. BER of OFDM Transceiver

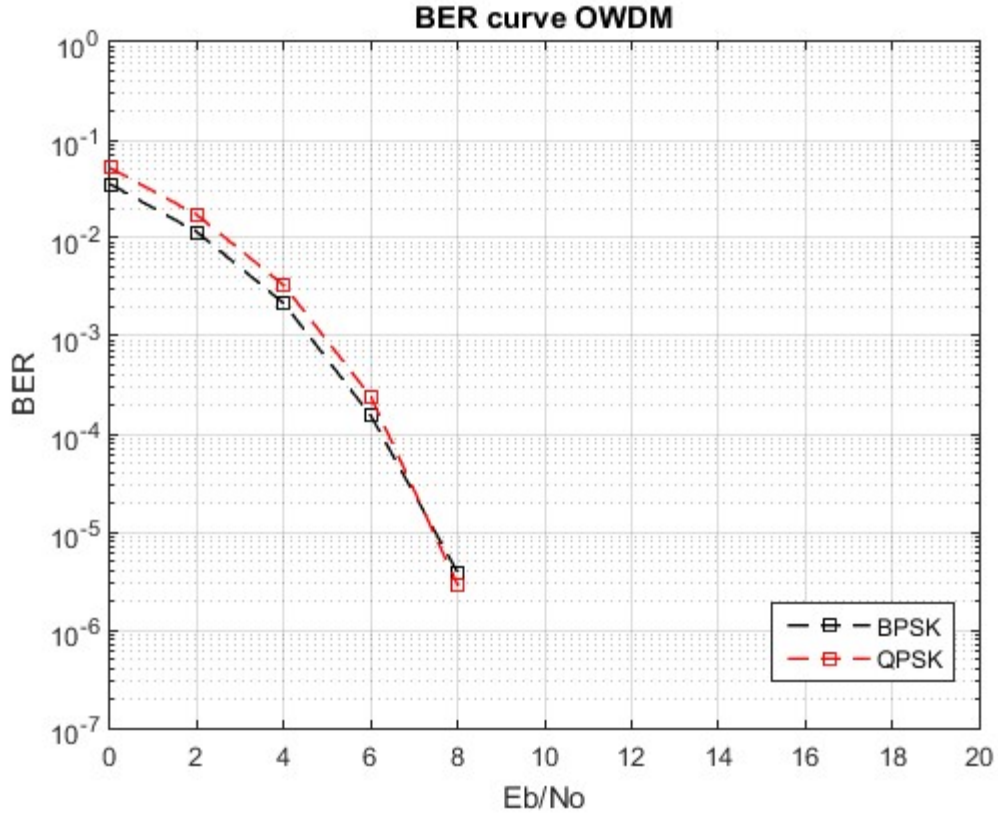


Figure 3. BER of OWDM Transceiver

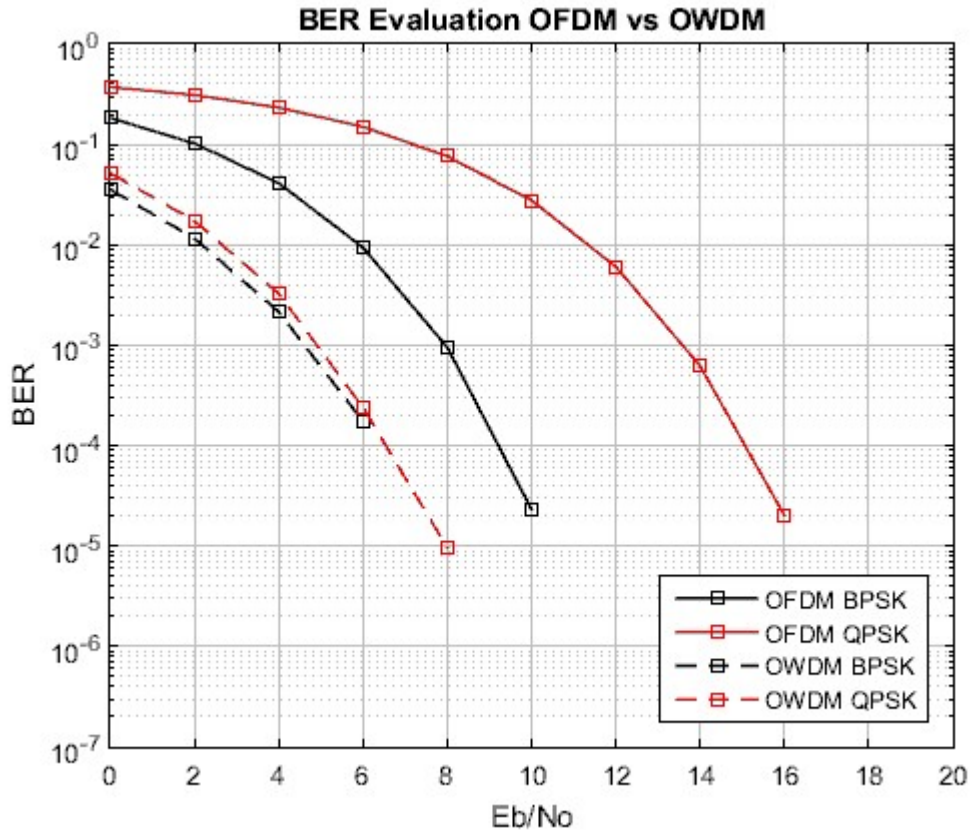


Figure 4. Comparative BER of OFDM vs OWDM Transceiver

The performance of conventional OFDM is compared with OWDM system. The assessment of performance of developed system is bit error rate versus signal-to-noise ratio (BER vs. SNR).

BER performance of conventional OFDM with M-PSK over Rayleigh channel is given in figure 2. The result reveal that when we increase the value of E_b/N_0 , the BER reduces and also results reveal that, although using a higher M-PSK is better for high-capacity transmission, the points on the constellation are very close to each other which makes the transmission less robust to error with the same SNR.

The simulated BER result for the OWDM system with M-PSK modulation over Rayleigh channel are shown in figure 3. The comparative result for M-PSK modulation of conventional OFDM and OWDM is shown in figure 4. The outcomes reveal that there is an improvement of BER, when we use wavelet Transform rather than Fast Fourier Transform.

IV. CONCLUSION

In this paper, OFDM and OWDM wireless system is implemented and the BER performance of the developed system is evaluated. The simulated outcomes reveal that the OWDM out-performs over traditional OFDM in terms of E_b/N_0 for the same bit error rate (BER).

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