ISSN: 2277-9655
Impact Factor: 1.852

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Removal of Cyclic Prefix in Adaptive OFDM for Dynamic Spectrum Access using DWT and WT

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Abstract

Spectrum has valuable resource in wireless communication. In wireless communication some spectrum is waste due to uses of cyclic prefix (cp) in FFT multicarrier sampling. In place of FFT used DFT and wavelet transform function for removal of cyclic prefix. Wavelet based OFDM, particularly using DWT and WPT-OFDM as bstitutions for Fourier- based OFDM with the focus on impulse noise effects. We begin by constructing the models of the inverse and forward transforms. We explain in detail each model and study the BER performance in two scenarios when varying the Poisson recurrence parameter a from small to large. The wavelet based SOFDM (DWT-SOFDM and WPT-SOFDM) are assumed to have other normal bases and perfect reconstruction properties. Results show that a large values of limits the impact of impulsive noise on the system. We also found that the WPT-SOFDM platform is superior in BER to others.

Keywords: DWT and WT.

Introduction

The large number of wireless mobile users, high speed data transmission, and the global demand for multimedia services such as data, speech, audio, video, and image were the motivations to develop new system with improved Quality of Services (QoS)[4]. In the early 2000s, the Third Generation (3G) systems were introduced in Japan. To realize a wireless mobile communication, radio-wave propagation is a complicated phenomenon. Unlike wired networks in which the channel is free from interference, a wireless channel is unpredictable due to impairments from random time varying phenomena induced by signal reaction, direction and scattering and relative motion transmitter and receiver. In order to overcome the complexity and obtain low cost system, Discrete Fourier Transform (DFT) has been applied as part of the modulation and demodulation processes[5,6]. In OFDM system, FFT/IFFT is one of the fundamental components in its block. The IFFT operation is a simple way to modulate data onto orthogonal sub-carriers. Multi-carrier CDMA (MC-CDMA) also is an attractive scheme for the high-speed wireless data communication. However, MC-CDMA exists severe multiple-access interference (MAI) in a frequency-selective fading uplink channel. NIAI can be mitigated by multi-user detection (MUD), but the complexity is high. Compared with MCCDMA, OFDMA does not exhibit MAI within a single cell. So complexity of OFDMA system is much lower than that of MC-CDMA. DFT-SOFDM, which is proposed for 3GPP LTE, is the combination OFDMA with single-carrier with Frequency domain equalization (SC-FDE)[12], the later technique was proposed by Sari in 1994[16]. It reduces peak-to average power ratio (PAPR) relative to OFDMA, and also can employ one-tap frequency-domain equalization. But DFT SOFDM does not consider the deep fading subcarriers that can dramatically degrade the BER performance. Alternative methods are to use wavelet transforms replacing IFFT and FFT[10]. By using these transforms, the spectral containment of the channels is better since they are not using CP. They can be considered as Discrete Wavelet Transform OFDM (DWT-OFDM) or Wavelet Packet Transform OFDM (WPT-OFDM). Both transforms employ Low Pass Filter (LPF) and High Pass Filter(HPF) operating as Quadrature Mirror Filters satisfying perfect reconstruction and orthonormal bases properties. The transforms use filter coefficients as approximate and detail in LPF and HPF respectively. The approximated coefficients is sometimes referred to as scaling coefficients, whereas, the detailed is referred to wavelet coefficients [3]. Sometimes these two filters can be called sub band coding since the signals are divided into sub-signals of low and high frequencies respectively. The purpose of this paper is to view the effects of impulse noise on the wavelet-based OFDM particularly using DWT and WPT-OFDM as substitutions for Fourier-based OFDM. A recent work has focused on the effect of impulse noise when wavelet packet division multiplexing (WPDM) is used [8]. Some discussions are related to the performance comparison between OFDM and Time Division multiplexing (TDM). However, there is no indication of comparative study and performance using DWT and WPT as alternative replacement of FFT[11]. Although the studies in [9] provides strong analysis of impulsive noise and its effect on the performance of OFDM system, the discussion is mainly for the application in the power line communications (PLC). To make better use of spectrum, cognitive radio transceivers need to transmit over multiple non-contiguous frequencies "holes." It is therefore natural to choose multi-carrier-based technologies for the physical layer. In a DSA network, the subcarriers located in the vicinity of an incumbent user need to be deactivated to avoid interference to the incumbent users[9].

The rest of paper is organized as follows. In Section II, the system model for SOFDM and DSA, The Section III SOFDM-DWT and WT. IN section IV gives simulation results followed by a conclusion in Section V.

System Model

SOFDM, assuming there are N subcarriers, the transmission of the Kth symbol corresponds to (using complex baseband notation)[1]

$$s^{(k)}(t) = b^{(k)}\sqrt{\frac{E_b}{N}}\sum_{i=0}^{N-1}\beta_i^{(k)}e^{j2\pi i\cdot\Delta f t}g(t) \quad (1)$$

Where $b^{(k)}$ is the kth information symbol (assumed 1 or 1 for ease of presentation) and $\beta_i^{(k)}$ is the ith value in symbol 's spreading sequence; i.Δf is the frequency position of the ith carrier component; and g(t)is a rectangular waveform of unity height which time-limits the code to one symbol duration T_s. It is crucial to note that selection of $\Delta f == \frac{1}{Ts}$ ensures subcarrier orthogonality over the time-limited duration of interest, i.e., over symbol duration T_s. It is also important to note that, to maintain the orthogonality among all the spread information symbols, the spreading code for each information symbol should be orthogonal. The transmitted signal at one SOFDM symbol at carrier frequency is

$$S_{NC-OFDM}(t) = \sqrt{\frac{E_b}{N}}\sum_{k=0}^{N-1}b^{(k)}\sum_{i=0}^{N-1}\beta_i^{(k)}e^{j2\pi(f_c+i\cdot\Delta f)t}g(t) \quad \ldots (2)$$

OFDMA usually has two schemes for allocating subcarriers to each user, which is depicted in Fig 1. It is clear that the second scheme is much more advantageous than the first, especially in frequency-selective fading channels. This is due to a deep narrow-band fade can affect only a few of sub-carriers in each sub-carriers group [12]. This paper will adopt the second scheme for establishing sub-carriers groups. considers the synchronous uplink of the system employing N sub-channels and accommodating a maximum number of U active users. Each user transmits symbols on a set of L=N/U assigned sub-channels. For the sake of simplicity, we consider only one user u with subcarriers group. The user u (1 < u < U)[15] transmits the stream of symbols s' $S^U=[S^{UO}, S^{ui}, , ^{Slj} 1]^T$, with the superscript (.)T meaning transpose operation. Vector S" is converted into frequency domain by a L-point DFT processor: $S^u=F_{i*} s^u$.

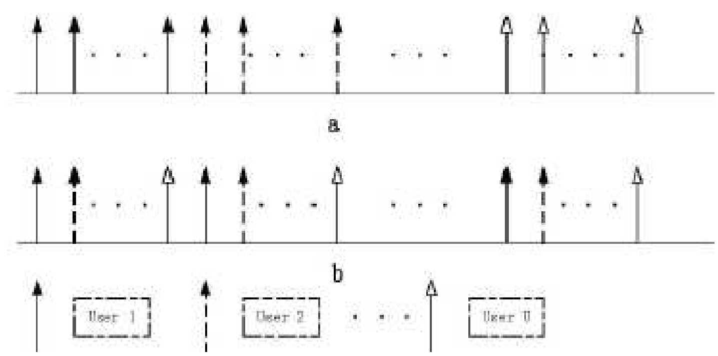

Figure 1. Two schemes for establishing sub-carriers group

Wavelet Based-SOFDM

Wavelet transforms have been considered as alternative platforms for replacing IFFT and FFT. By using the transform, the spectral containment of the channels is better since it does not. One type of wavelet transform is namely as Discrete Wavelet Transform OFDM (WT-SOFDM)[10]. It employs Low Pass Filter (LPF) and High Pass Filter(HPF) operating as Quadrature Mirror Filters satisfying perfect reconstruction and orthonormal bases properties. The transform uses filter coefficients as approximate and detail in LPF and HPF respectively. The approximated coefficients is sometimes referred to as scaling coefficients, whereas, the detailed is referred to wavelet coefficients [3]. Sometimes these

ISSN: 2277-9655
Impact Factor: 1.852

two filters can be called subband coding since the signals are divided into sub-signals of low and high frequencies respectively. This section discusses the alternative way to replace the conventional SOFDM using WT. We will first explain the WT-OFDM implementation model and follow with the discussion that this platform satisfies the orthonormal bases and perfect reconstruction properties. The transceiver of WT-SOFDM is shown in Fig. 2[8]. In the top part, the transmitter first uses a digital modulator (i.e 16-*QAM*) which maps the serial bits into symbols converting *dk* into *Xm*, within *N* parallel data stream *Xm*(*i*) where *Xm*(*i*)*j*0 · *i* · *N* -1. The main task of the transmitter is to perform the discrete wavelet modulation by constructing orthonormal wavelets. Each *Xmi* is first converted to serial representation having a vector *XX* which will next be transposed into *CA[17]*. This mean that *CA* not only its imaginary part have inverting signs but also its form is changed to a parallel matrix. Then, the signal is up-sampled and filtered by the LPF coefficients or namely as approximated coefficients. Since our aim is to have low frequency signals, the modulated signals *XX* perform circular convolution with LPF filter whereas the HPF filter also perform the convolution with zeroes padding signals *CD* respectively. Note that the HPF filter contains detailed coefficients or wavelet coefficients. Different wavelet families have different filter length and values of approximated and detailed coefficients. Both of these filters have to satisfy orthonormal bases in order to operate as wavelet transform.

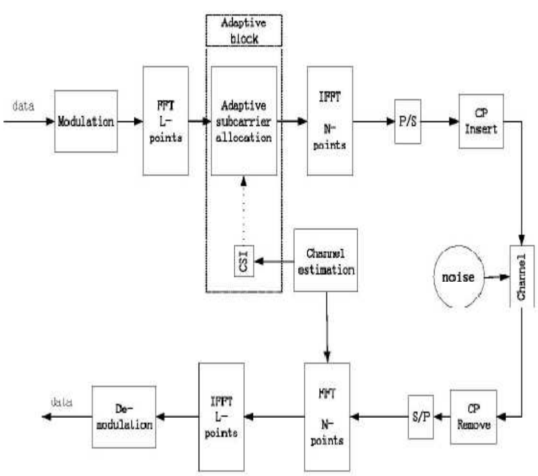

Figure 2. A simplified block diagram of WT-SOFDMA

Simulation Results

In this section, we compare the performance of the FFT-SOFDM and WT-SOFDM. All of the transformed models in FFT-, DWT- and WPTOFDM systems used the parameters as shown in Table I. The number of samples for the subcarriers *N* is 64, and the number of samples for the symbols *ns* is 1000.

Variable	FFT-SOFDM	WT-SOFDM
N	64	64
Ns	1000	1000
Cp	8	0
D	64*1000	64*1000
Xm	64*1000	64*1000
Xk	1*64000	1*64000
Uk	1*64000	1*64000
Um	64*1000	64*1000
D^1	64*1000	64*1000

Table 1 shows that parameter of result evaluation.

Figure 3 shows that performance comparison of SNR and bit error rate for FFT in SOFDM

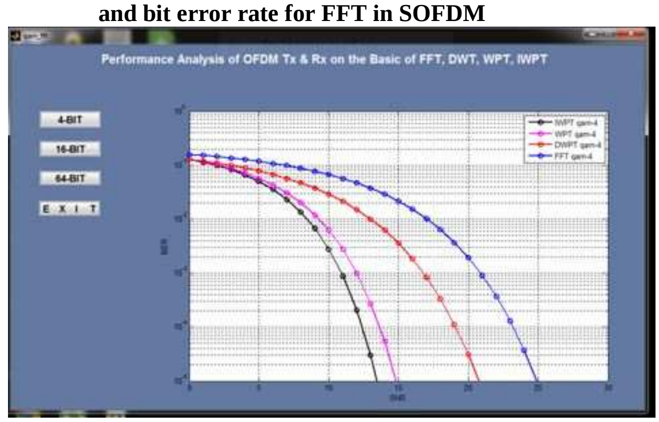

Figure 4shows that performance comparison of SNR and bit error rate for 4 bit SOFDM

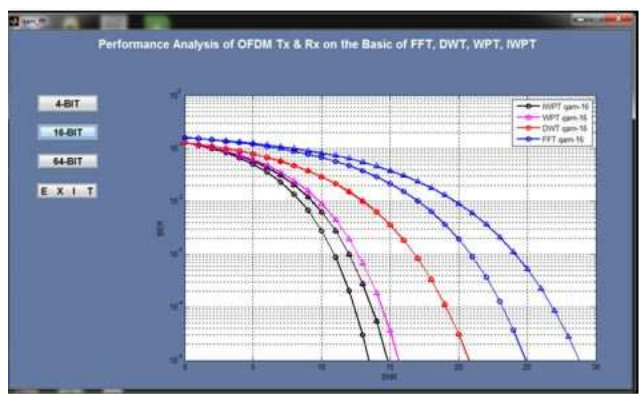

Figure 5 shows that performance comparison of SNR and bit error rate for 16-bit SOFDM

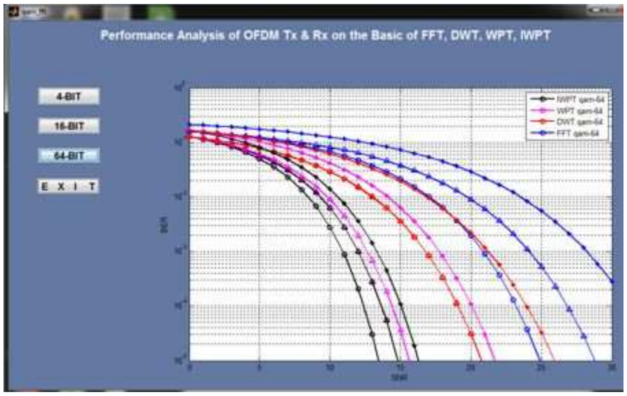

Figure 6 shows that performance comparison of SNR and bit error rate for 64-bit SOFDM

Conclusion

WT-SOFDM ,WPT-SOFDM and IWPT-SOFDM as substitutions for FFT-SOFDM, with focus on the effects of impulse noise AND removal of cyclic prefix. Performance in terms of BER was also obtained while varying the Poisson distribution parameters. Our results showed that impulse noise has less impact on the system when its recurrence parameter *a* is large. The BER performance of the WPT-SOFDM system is shown to be superior to others.

Simulation results over realistic channel models and dynamic spectrum access scenarios confirm the theoretical performance analysis presented in the paper.

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ISSN: 2277-9655
Impact Factor: 1.852

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