Double Rate OFDM System in Time Varying Channel

Dr. A.Y.Hassan
Department of Electrical Engineering
Benha Faculty of Engineering, Benha University
Ashraf.fahmy@bhit.bu.edu.eg

***Abstract*—This paper introduces a new way to increase the transmission rate of data in Orthogonal-Frequency-Division-Multiplexing (OFDM) system. The data rate is doubled by doubling the number of the subcarriers in the OFDM signal. The bandwidth of the OFDM signal and the OFDM-symbol rate are not changed. Complex Exponential Subcarriers (CESs) are used instead of Real Sinusoidal Subcarriers (RSSs). Two different complex symbols are transmitted simultaneously through each pair of conjugate symmetry subcarriers instead of one complex symbol in the conventional OFDM system. The modulation order on each subcarrier is reserved without any change. The time-domain samples of the proposed OFDM symbols are complex. The real and imaginary parts of these symbols are re-modulated with two orthogonal pulse-shapes. The used pulse-shapes are chosen to be Hilbert-transform pair. Different types of pulse-shapes are proposed for using with the proposed OFDM system.**

***Keywords*—Orthogonal Frequency Division Multiplexing; exponential carriers; orthogonal pulse shapes; Bandwidth efficiency; inter-symbol interference.**

I. INTRODUCTION

OFDM is widely used in many communication systems [1]. Actually, the revolution in the applications of the cellular phones, Internet, and satellite communications in the last few years increases the demand on high-data-rate communication systems [2]. OFDM is a wide-band communication system, which supports high-data-rate transmissions [3]. OFDM is used for many telecommunications and wireless standards [4]. OFDM is used in wireless local area network standards such as 802.11a, 802.11n, 802.11ac and more [5]. It is also chosen for the cellular telecommunications standard LTE / LTE-A, and in addition to this, it is adopted by other standards such as WiMAX and many more [6]. OFDM is adopted for a number of broadcast standards too. It is used in Digital Audio Broadcasting (DAB) and Digital Video Broadcast (DVB) standards [7].

OFDM can transfer data with high rates by dividing the high-rate data stream into lower-rate data streams. The low-rate streams modulate orthogonal subcarriers with smaller bandwidth. This technique constructs flat fading sub-channels inside a frequency selective fading channel. Therefore, OFDM is suitable for multipath fading channels and it can resist Inter-Symbol Interference (ISI) signal appeared in this type of channels [8]. On the other hand, OFDM system is affected by another type of interference called Inter-Carrier Interference (ICI). This interfering signal is produced when the orthogonality between the subcarriers is lost [9]. The orthogonality between the subcarriers is lost due to two main sources. The first source is the relative motion between the transmitter and the receiver. This motion produces a Doppler-frequency shift, which changes the frequencies of the subcarriers in the OFDM signal [10]. The second source of missing orthogonality between subcarriers is the miss-synchronization between the local oscillators in the transmitter and the receiver.

In this work, the data transmission rate in OFDM systems is doubled without increasing the bandwidth of the OFDM signal or increasing the order of the modulation in each modulated subcarrier. Actually, the total transmission rate in the OFDM system depends on three factors. The first is the number of the used subcarriers. The second factor is the modulation order used in each sub-channel. The third factor is the OFDM symbol rate. The proposed improvement in the transmission rate depends on the first factor. The data-rate is doubled in the proposed OFDM system by doubling the number of the used orthogonal subcarriers in the same bandwidth. The proposed system uses the same symbol rate and the same modulation order as the conventional OFDM system.

In the conventional OFDM system, the used subcarriers are real-sinusoidal signals. The maximum number of these subcarriers is equal to half the number of the samples in the OFDM symbol. However, in the proposed system, the used subcarriers are complex-exponential signals. The maximum number of these complex subcarriers is equal to the number of samples in the OFDM symbol. Therefore, the number of the subcarriers in the proposed OFDM system is twice the number of the subcarriers in the current used OFDM systems.

When the CESs are used instead of RSSs, the produced time-domain samples of the OFDM signal are complex numbers [8]. The proposed system uses the real and imaginary parts of these samples to modulate two orthogonal pulses [11]. The real part of the OFDM samples modulates a specific pulse, however the imaginary part modulates the Hilbert-transform of this pulse.

The paper is organized as followed. Section (2) gives a brief revision on OFDM system. Section (3) describes the idea of the proposed OFDM system. It gives the mathematical model of the modulated signal and the structure of the modulator and the demodulator for the proposed system. Different shaping pulses and their Hilbert transform pairs are

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