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Orthogonal Frequency Division Multiplexing (OFDM)

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Abstract
Orthogonal Frequency Division Multiplexing (OFDM) is a multi carrier modulation technique which divides the available spectrum into many carriers. OFDM uses the spectrum efficiently compared to FDMA by spacing the channels much closer together and making all carriers orthogonal to one another to prevent interference between the closely spaced carriers. The main advantage of OFDM is their robustness to channel fading in wireless environment. The objective of this project is to design and implement a baseband OFDM transmitter and receiver on FPGA hardware. This project concentrates on developing Fast Fourier Transform (FFT) and Inverse Fast Fourier Transform (IFFT). The work also includes in designing a mapping module, serial to parallel and parallel to serial converter module. The design uses 8-point FFT and IFFT for the processing module which indicate that the processing block contain 8 inputs data. All modules are designed using MATLAB programming language.

***Keywords**: Orthogonal frequency, Multiplexing.*

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1. Introduction

Orthogonal Frequency Division Multiplexing (OFDM) is one of the latest modulation techniques used in order to combat the frequency-selectivity of the transmission channels, achieving high data rate without inter–symbol interference. The basic principle of OFDM is gaining a wide spread popularity within the wireless transmission community. Furthermore, OFDM is one of the main techniques proposed to be employed in 4th Generation Wireless Systems. Therefore, it is crucial to understand the concepts behind OFDM. In this paper it is given an overview of the basic principles on which this modulation scheme is based. Due to the spectacular growth of the wireless services and demands during the last years, the need of a modulation technique that could transmit high data rates at high bandwidth efficiency strongly imposed. The problem of the inter–symbol interference (ISI) introduced by the frequency selectivity of the channel became even more imperative once the desired transmission rates dramatically grew up. Using adaptive equalization techniques at the receiver in order to combat the ISI effects could be the solution, but there are practical difficulties in operating this equalization in real-time conditions at several

Mb/s with compact, low-cost hardware. OFDM is a promising candidate that eliminates the need of very complex equalization.

In a conventional serial data system, the symbols are transmitted sequentially, one by one, with the frequency spectrum of each data symbol allowed to occupy the entire available bandwidth. A high rate data transmission supposes very short symbol duration, conducing at a large spectrum of the modulation symbol. There are good chances that the frequency selective channel response affects in a very distinctive manner the different spectral components of the data symbol, hence introducing the ISI. The same phenomenon, regarded in the time domain consists in smearing and spreading of information symbols such, the energy from one symbol interfering with the energy of the next ones, in such a way that the received signal has a high probability of being incorrectly interpreted. Intuitively, one can assume that the frequency selectivity of the channel can be mitigated if, instead of transmitting a single high rate data stream, we transmit the data simultaneously, on several narrow-band sub channels (with a different carrier corresponding to each sub channel), on which the frequency response of the channel looks "flat".

2. Theory

This project will focus on Orthogonal Frequency Division Multiplexing (OFDM) research and simulation. OFDM is especially suitable for high-speed communication due to its resistance to ISI. As communication systems increase their information transfer speed, the time for each transmission necessarily becomes shorter. Since the delay time caused by multi path remains constant, ISI becomes a limitation in high-data-rate communication [1]. OFDM avoids this problem by sending many low speed transmissions simultaneously. For example, figure 1 shows two ways to transmit the same four pieces of binary data.

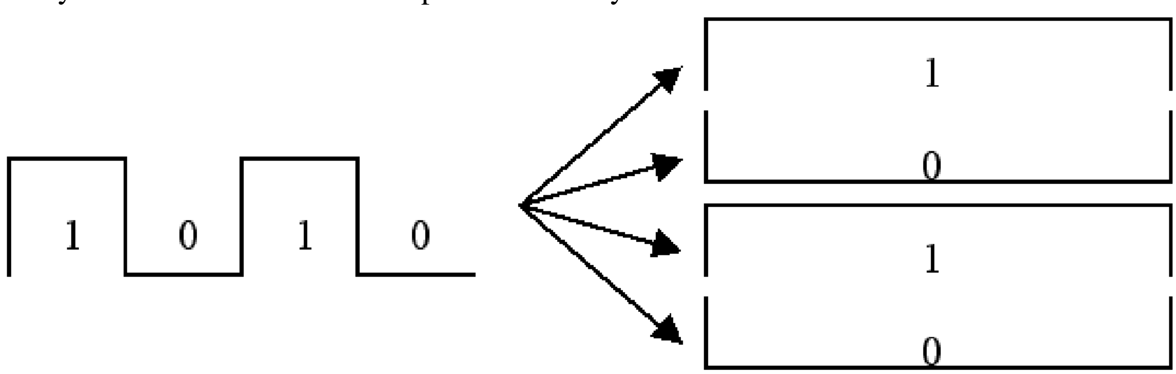


Fig. 1: Traditional vs OFDM Communication

Suppose that this transmission takes four seconds then, each piece of data in the left picture has duration of one second. On the other hand, OFDM would send the four pieces simultaneously as shown on the right. In this case, each piece of data has duration of four seconds. This longer duration leads to fewer problems with ISI. Another reason to consider OFDM is low-complexity implementation for high-speed systems compared to traditional single carrier techniques [2].

3. Significance

With the rapid growth of digital communication in recent years, the need for high-speed data transmission has increased. New multicarrier modulation techniques such as OFDM are currently being implemented to keep up with the demand for more communication capacity. Multicarrier communication systems "were first conceived and implemented in the 1960s, but it was not until their all-digital implementation with the FFT that their attractive features were un-ravelled and sparked widespread interest for adoption in various single-user and multiple access (MA) communication standards" [2]. The processing power of modern digital signal processors has increased to a point where OFDM has become feasible and economical. Examining the patents, journal articles, and books available on OFDM, it is clear that this technique will have an impact on the future of communication. Since many communication systems being developed use OFDM, it is a worthwhile research topic. Some examples of current applications using OFDM include GSTN (General Switched Telephone Network), Cellular radio, DSL & ADSL modems, DAB (Digital Audio Broadcasting) radio, DVB-T (Terrestrial Digital Video Broadcasting), HDTV broadcasting, HYPERLAN/2 High Performance Local Area Network standard, and the wireless networking standard IEEE802.11 [1] [3] [4].

4. Simulation Design

This project consists of research and simulation of an OFDM communication system. Figure 2 shows a simplified flowchart of the MATLAB simulation code.

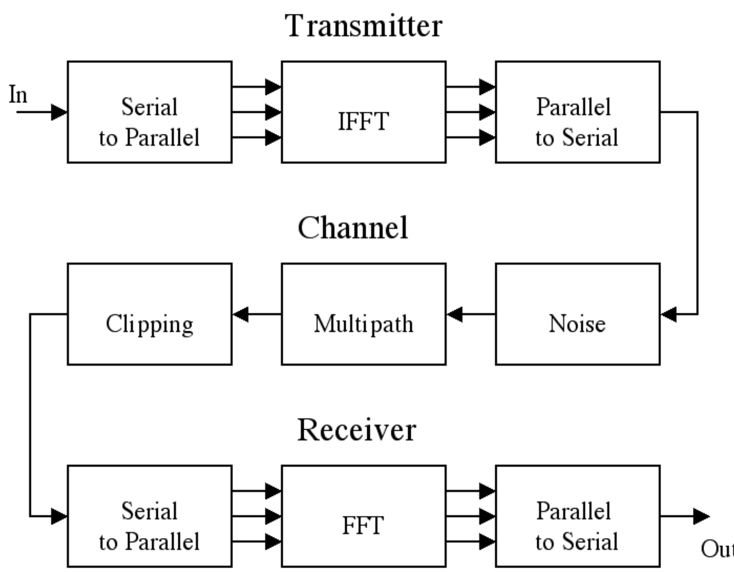


Fig. 2: OFDM Simulation Flowchart

Simulation Outputs

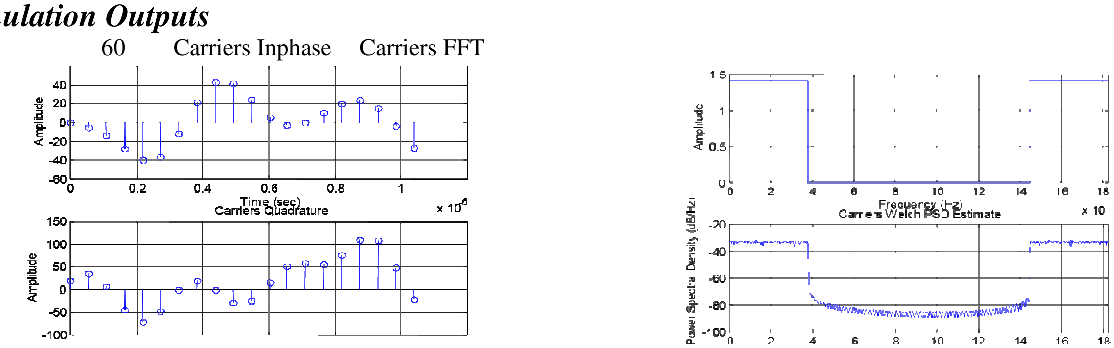
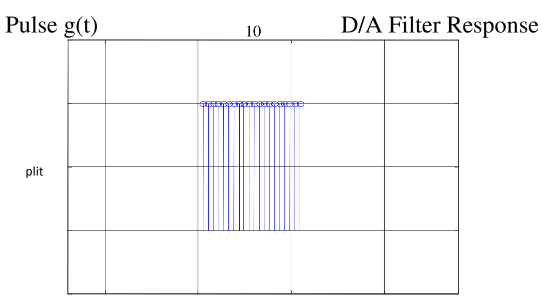
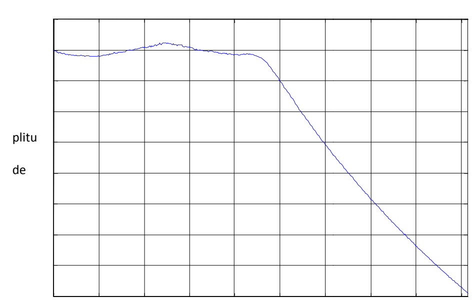


Fig. 3: Time and frequency response signal





-50Time (sec)510x 10-8-800 24 6Frequency (Hz)810121416x 10186

Fig. 4: Pulse shape g(t)

Fig. 5: D/A filter response

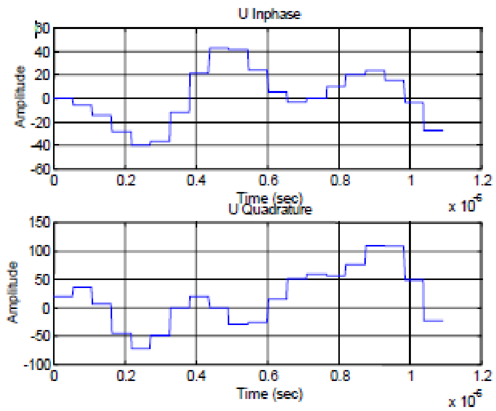


Fig. 6: Time response of signal U

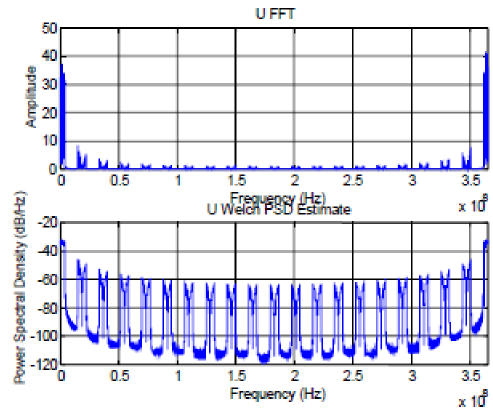


Fig. 7: Frequency response Signal U at (C)

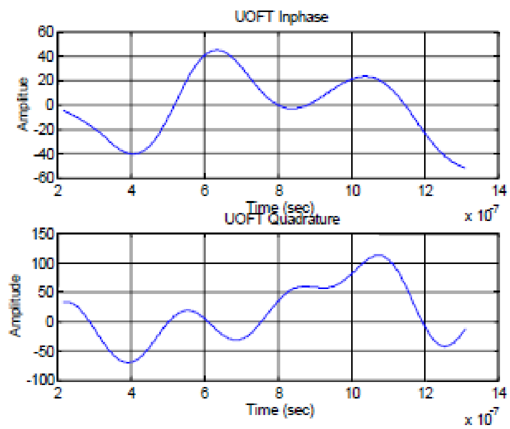


Fig. 8: Time response of signal

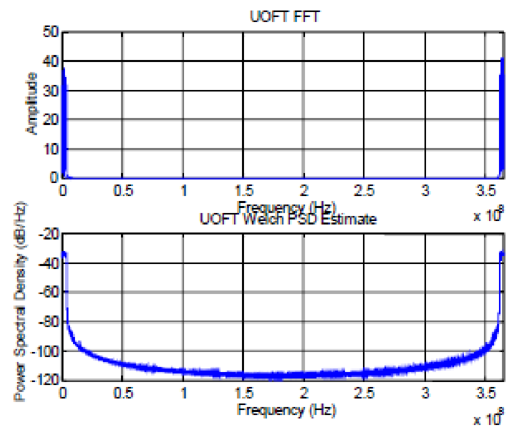


Fig. 9: Frequency response UOFT at (D)

5. Advantages of OFDM

OFDM has several advantages over single carrier modulation systems and these make it a viable alternative for CDMA in future wireless networks. Following are the advantages of OFDM:

- *Multipath delay spread tolerance*

OFDM is highly immune to multipath delay spread that causes inter-symbol interference in wireless channels. Since the symbol duration is made larger (by converting a high data rate signal into N, low rate signals), the effect of delay spread is reduced by the same factor. Also by introducing the concepts of guard time and cyclic extension, the effects of inter-symbol interference (ISI) and inter carrier interference (ICI) can be removed completely.

- *Immunity to frequency selective fading channels*

If the channel undergoes frequency selective fading, then complex equalization techniques are required at the receiver for single carrier modulation techniques. But in the case of OFDM the available bandwidth is split among many narrowly spaced subcarriers. Thus the available channel bandwidth is converted into many narrow flat fading sub channels. Hence it can be assumed that the subcarriers experience flat fading only, though the channel gain/phase associated with the subcarriers may vary. In the receiver, each subcarrier just needs to be weighted according to the channel gain/phase encountered by it. Even if some subcarriers are completely lost due to fading, proper coding and interleaving at the transmitter can recover the user data.

- Chance to cancel any cannel if is affected by fading.
- *Flexibility*: Each transceiver has access to all subcarriers within a cell layer.
- *Easy equalization*: OFDM symbols are longer than the maximum delay spread resulting in flat fading channel which can be easily equalized.
- High spectral efficiency.
- Resiliency to RF interference.
- Lower multipath distortion.

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