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EFFICIENT IMPLEMENTATION AND ANALYSIS OF OFDM USING FPGA

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Abstract: This project will focus on Orthogonal Frequency Division Multiplexing (OFDM) research, simulation, and efficient implementation. 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 multipath remains constant, ISI becomes a limitation in high-data-rate communication. OFDM avoids this problem by sending many low speed transmissions simultaneously. The detailed simulation of the OFDM system with 16 QAM will be implemented .The transmitter and receiver will be implemented using FPGA. All Modules are designed using VHDL programming language.

Keywords: Orthogonal Frequency Division Multiplexing (OFDM), Field Programmable Gate Array (FPGA), Hardware Description Language (HDL), Inverse Fast Fourier Transform (IFFT), Fast Fourier Transform (FFT), and Signal top Noise Ratio (SNR).

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INTRODUCTION

In this project we are efficiently implementing OFDM Transmitter & receiver by using FPGA.

What is OFDM?

OFDM is multicarrier modulation technique which divides the available spectrum into many carrier .The actual and now communication schemes tends to use OFDM system in order to provide high data rates , for transmitting large amount over a radio wave less ISI interference . OFDM uses FFT algorithm on both transmitter and receiver.

Concept of OFDM -

In this new information age, high data rate and strong reliability features our wireless communication systems and is becoming the dominant factor for a successful deployment of commercial networks. MIMO-OFDM (multiple input multiple output orthogonal frequency division multiplexing), a new wireless broadband technology, has gained great popularity for its capability of high rate transmission and its robustness against multi-path fading and other channel impairments.

OFDM [1] is becoming a very popular multi-carrier modulation technique for transmission of signals over wireless channels. It converts a frequency-selective fading channel into a collection of parallel at fading sub channels, which greatly simplifies the structure of the receiver. The time domain waveforms of the subcarriers are orthogonal (*sub channel* and *subcarrier* will be used interchangeably hereinafter), yet the signal spectral corresponding to different subcarriers overlap in frequency domain. Hence, the available bandwidth is utilized very efficiently in OFDM systems without causing the ICI (inter-carrier interference). By combining multiple low-data-rate sub carriers, OFDM systems can provide a composite high-data-rate with long symbol duration. That helps to eliminate the ISI (inter-symbol interference), which often occurs along with signals of a short symbolduration in a multipath channel. Simply speaking, we can list its pros and cons as follows [2].

1.1 Advantage of OFDM systems are:

- High spectral efficiency
- Simple implementation by FFT (fast Fourier transform)

- Low receiver complexity
- Robustability for high-data-rate transmission over multipath fading channel
- High flexibility in terms of link adaptation
- Efficient use of spectrum
- Resistant to frequency selective fading
- Eliminates ISI (Inter Symbol Interference)

1.2 Disadvantages of OFDM systems are:

- Sensitive to frequency offsets, timing errors and phase noise;
- Relatively higher peak-to-average power ratio compared to single carrier system, which tends to reduce the power efficiency of the RF amplifier.
- High Synchronism accuracy .

1.3 OFDM System Model

The principle of OFDM is to divide a single high-data-rate stream into a number of lower rate streams that are transmitted simultaneously over some narrower sub channels. Hence it is not only a modulation (frequency modulation) technique, but also a multiplexing (frequency-division multiplexing) technique. OFDM starts with the “O", i.e., orthogonal. That orthogonality differs OFDM from conventional FDM (frequency-division multiplexing) and is the source where all the advantages of OFDM come from. The difference between OFDM and conventional FDM is illustrated in Figure 1.1.

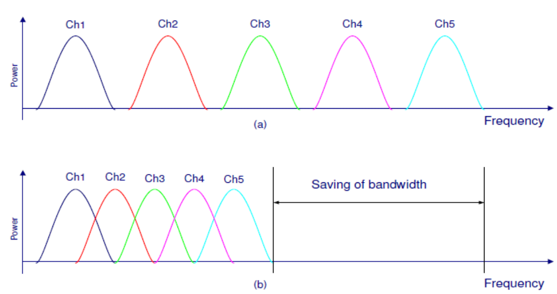


Figure 1.1: Comparison between conventional FDM & ODM

2. Literature summary and related work:

It is well known that Chang proposed the original OFDM principles in 1966, and successfully achieved a patent in January of 1970. OFDM is a technique for transmitting data in parallel by using a large number of modulated sub-carriers. These sub-carriers divide the available bandwidth and are sufficiently separated in frequency so that they are orthogonal. The Orthogonality of the carriers means that each carrier has an integer number of cycles over a symbol period.

In 1971, Weinstein and Ebert proposed a modified OFDM system [12] in which the discrete Fourier Transform (DFT) was applied to generate the orthogonal subcarriers waveforms instead of the banks of sinusoidal generators. Their scheme reduced the implementation complexity significantly, by making use of the inverse DFT (IDFT) modules and the digital-to-analog converters. In their proposed model, baseband signals were modulated by the IDFT in the transmitter and then demodulated by DFT in the receiver. Therefore, all the subcarriers were overlapped with others in the frequency domain, while the DFT modulation still assures their Orthogonality.

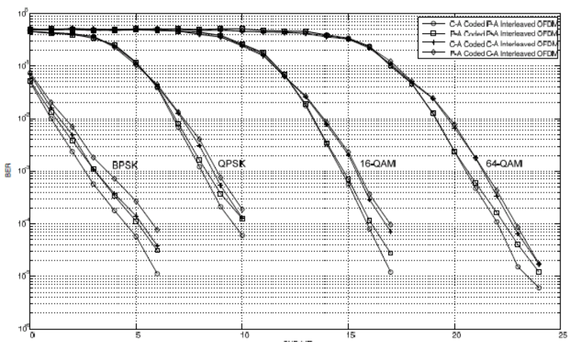
OFDM systems are much more sensitive to synchronization errors than single carrier systems. Several approaches have been proposed for estimating the time and frequency offset either jointly [3],[4] or individually. Current System-on-Chip (SOC) platforms provide wide range of programmable processors and ASIC components .These components provide user, a flexibility & reduction of cost of implementation. ASIC are not suitable were flexibility is required. By implementing the OFDM using FPGA, performance can be increased.

In 2004 C. Ebeling, C. Fisher, G. Xing, M. Shen & H. Liu [5] proposed The RaPiD implementation has about six times the performance/cost of a DSP implementation, while an ASIC has about six times the performance/cost of RaPiD.

In 2008 S.Haene, D. Perels & A Burg [6] proposed that A real-time MIMO-OFDM physical layer transmitting at a peak data rate of 216Mbit/s over 20MHz bandwidth was prototyped and characterized through measurements. Real-time operation of the system on an FPGA was achieved by diligent selection and optimization of the employed transceiver algorithms for the FPGA implementation and by careful design of the corresponding transceiver hardware architecture.

In 2011 P. J. Lobo, F. Pescador, G. Maturana & M. C. Rodríguez [7] proposed that it could be possible to integrate the whole system (i.e. receiver and gateway) in a single platform with one DSP and the FPGA, especially considering that current versions of the DSPs. A combined SoC that includes both the communications and video peripherals would be perfectly fit for the task. Other functional combinations are possible, such as a receiver and gateway without video decoding capabilities or even a system with just the gateway functionality. In the latter case, a smaller and cheaper processor could be used.

In 2012 Z. Iqbal, S Nooshabadi & Heung-No Lee [8] proposed that OFDM gives an efficient way to design the IEEE 802.16 system for FPGA. A special double-buffering design method is used to implement the interleaver with minimum memory requirement and initial latency. The data rate of the standard is doubled with the help of efficient design methodologies and optimization. This approach can also be used to design other high-speed communication systems or to improve their speeds.BER performance four systems Vs modulation is as shown in figure 2.1



There are few more works which implemented the OFDM in FPGA for different applications. Ludovico de Souza et al [9] shows that FPGA implementation of 802.11 wireless modem is possible. Another work by Y. Kim et al [10] shows the implementation of IEEE 802.11 wireless LAN which support both OFDM & DSSS “Direct Sequence Spread Spectrum”; which is implemented using combination of FPGA & ARM7 processor. Moisés Serra [11] designed the OFDM transmitter having specifications: 64-IFFT, 16 QAM, 36Mbits/s.

3. OFDM Transmitter

The model considered for the implementation of the OFDM transmitter is theshown in the Fig. 3.1, and basically consist of the following blocks:

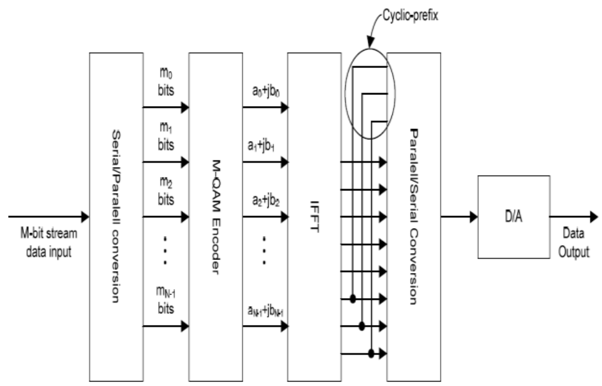


Fig. 3. 1 OFDM transmitter

The serial to parallel converter receive the M serial bits to be transmitted, and those bits are divided into N sub-blocks of mn bits each sub-block. Those Nsub-blocks will be mapped by the constellation modulator using Gray codification, this way an + jbn values are obtained in the constellation of the modulator.

The M-QAM encoder converts input data into complex-valued constellation points, according to a given constellation, 4QAM, 16-QAM, 32-QAM and so on.The amount of data transmitted on each subcarrier depends on the constellation; 4QAM and 16QAM transmit two and four data bits per subcarrier, respectively. Which constellation to use depends on the quality of the communications channel. In a channel with high interference a small modulation scheme like BPSK is favorable, since the required signal to noise ratio (SNR) inthe receiver is low, whereas in a interference free channel a larger constellations more beneficial due to the higher bit rate.

It is necessary to specify how the constellation will be mapped to implement that block. However, independently of the format of the constellation, the block encoder can be made by consulting a conversion table, implemented with aLUT that exists in LCs of FPGAs. It is important to notice that in that mapping block, bits are converted into complex symbols (phasors) having the information of the constellation in itsI, Q components. The Inverse Fast Fourier Transform (IFFT) transforms the signals from the frequency domain to the time domain; an IFFT converts a number of complex data points, of length that is power of 2, into the same number of points but in the time domain. The number of subcarriers determines how many sub-bands the available spectrum is split into.

4. OFDM Receiver

The blocks of the OFDM Receiver are shown in the Fig. 4.1, and those blocks are:

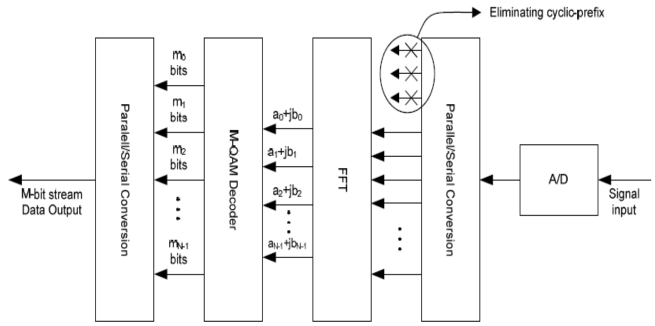


Fig. 4.1OFDM receiver

The demodulation can be made by DFT, or better, by FFT, that is it efficient implementation that can be used reducing the time of processing and the used hardware. FFT calculates DFT with a great reduction in the amount of operations, leaving several existent redundancies in the direct calculation of DFT. At the decoder, a mapped symbol (point) of the transmitted constellation may have changed due to the additive noise in the communications channel, a mis-adjustment in the sampling time at the receiver, or several other unwanted causes.

5. Proposed work & Objectives

Proposed work:-

In a paper titled" A Novel implementation of OFDM using FPGA" by M.A. Mohamed, A.S. Samarah, M.I. Fath Allah, it is mentioned that a base band OFDM transmitter and receiver can be successfully developed using VHDL codes and then it can be implemented using FPGA. We are going to implement the project with the use of FFT which takes only one cycle to give the output, which is fast as compare to previous approaches as it takes 16 cycles to give output.

Objective:-

This project will emphasis on Orthogonal Frequency Division Multiplexing (OFDM) research, simulation, and efficient implementation. OFDM 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 multipath remains constant, ISI becomes a limitation in high-data-rate communication [15]. OFDM avoids this problem by sending many low speed transmissions simultaneously. For example, Figure 4.1 shows two ways to transmit the same four pieces of binary data. 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 [16]

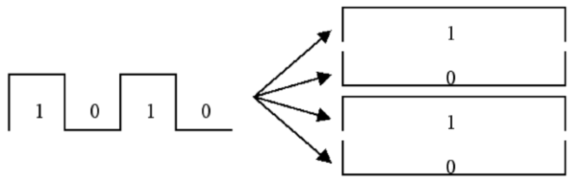


Figure:5.1 Traditional Vs OFDM Communication

6. Desired implementation

The methodology and desired implementation of project is basically divided into four stages. Every stage starts with study of related topic followed by design, implementation, test & analysis as shown in fig.7.

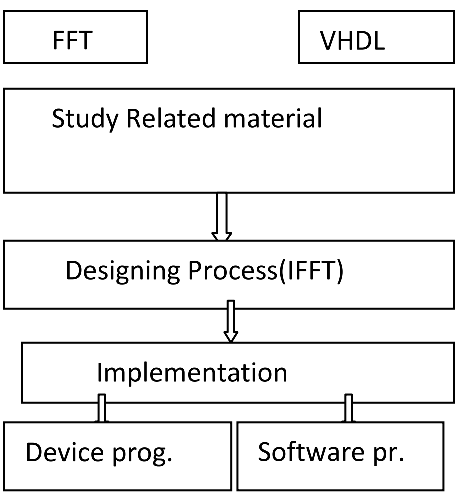


Figure 6.1 Flowchart for methodology desired implementation for project

7. RESULT & DISCUSSION

The expected results for each component in an OFDM uplink/downlink system will be shown using VHDL simulator and implemented using FPGA. Serial to parallel converter is used to convert the data from the serial form to the parallel form to introduce it to IFFT and programmed using VHDL language. In the receiver the inverse blocks for those of the transmitter will be obtained.

8. CONCLUSIONS AND FUTURE SCOPE

We are expecting that the simulations results follow closely the theoretical results.

Mobile devices than earlier, so high data rate connectivity is required after in OFDM technology. The future scope of this technology is tremendous and a lot of research is currently going on to further improve data services for the users.

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