OFDM Transceiver Implementation on FPGA

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Abstract— This paper describes the review work on Orthogonal Frequency Division Multiplexing (OFDM) Transceiver Design and Implementation on FPGA hardware. Orthogonal Frequency Division Multiplexing (OFDM) is a spectrally more effective multi-carrier modulation technique which divides the allotted spectrum into many sub-carriers which are orthogonal to one another and due to which the interference is reduced to the more extent. Implementation on FPGA adds the more flexibility to the system. The no of advancements in OFDM have been proposed in the recent years to reduce the complexity and power consumption of the transceiver and to increase the total throughput while maintaining the performance [6].

Key words: OFDM, DQAM, QAM, FFT, IFFT, IEEE FPGA, 802.11 standards

I. INTRODUCTION

With the advancements in the technology there is need to have a high speed data transmission in digital communication. OFDM is a combination of both the modulation technique as well as multiplexing technique and provides high speed data transmission for digital communication. In OFDM the available bandwidth spectrum is effectively divided into the no of sub –carriers which are orthogonal to one other.

In recent communication services data rate, bandwidth used, the bit error rate (BER), are the parameters that is considered to produce a reliable wireless communication system [7]. OFDM system minimizes the inter-symbol interference and fading effect and also provides higher data rates while transmitted over the guided(optical) or wireless channel. Among the standards that are using OFDM are the IEEE 802.11a,g &n and for Wireless Local Area Networks (WLANs), IEEE802.16 for Metropolitan Access, Wi-Fi, Worldwide Interoperability for Microwave Access (WiMAX) [10].

To implementation of the design FPGA is preferred since it allows more flexibility in design and also with the use of FPGA one can achieve higher computing speed than which achieved by using digital signal processors (DSPs) and general purpose processors (GPP). In recent years, Field-Programmable Gate Arrays (FPGAs) have become an important component for implementing high performance, high throughput digital signal processing (DSP) for digital communication systems. FPGAs consist of look-up tables, memory, registers, multiplexers, and the modern FPGAs also include dedicated circuitry for fast adders and multipliers [9].

The implementation of OFDM using fast fourier transform (IFFT/FFT) has advantage that sub channel receiver filters which need to be tuned, are not required (unlike conventional FDM). Orthogonal frequency division multiplexing (OFDM) is a very efficient and effective technique to overcome the inter symbol interference (ISI) and inter carrier interference (ICI) problem, these are the some fundamental problems for any communication systems [11].

To understand how the OFDM works, it is needed to first understand the concept of orthogonality. The any two signals/functions 〖a〗_m (t) and 〖a_n〗^* (t) are said to be orthogonal with respect to one other over the interval a<t<b if they satisfy the condition as shown below equation 1.

$$\int_a^b a_m(t) a_n{}^*(t) dt = 0 \text{ , n} \neq \text{m} \ldots\ldots\ldots\ldots (1)$$

Orthogonality can also be defined as the two signals existing over the same time interval independent of each other and do not interfere with each other. Orthogonality can be achieved with the help of Inverse Fast Fourier Transform (IFFT) module at the transmitter side. Orthogonality is a property that allows us to transmit multiple signals over a common channel without interfering with each other thereby making better spectrum utilization by removing the guard bands which are previously required in FDM. The signal is detected without interference at the receiver side. Loss of orthogonality results in blurring between the information signals transmitted and degradations in communications [12].

In general way the two periodic signals are said to be orthogonal when the time integral of their product over one period, is equal to zero. So the Orthogonality of subcarriers is one of the important factors in the OFDM system. If it is not maintained then errors may procured in the received information.

Present work is divided into the no of sections as follows: section II presents the review on related work; section III presents the OFDM general transceiver architecture and explanation of it; section IV includes the application part and last section V concludes the all.

II. LITERATURE SURVEY

The concept of using parallel data transmission by means of frequency division multiplexing was first published in 1960 [7]. The idea was to use parallel data streams of data and FDM with overlapping sub channels to avoid the use of high-speed equalization and to overcome the impulsive noise and multipath distortion problems and also to fully use the available bandwidth. The initial applications of such technique were in the military communications. After that they are adopted in telecommunication field. In the 1980s, OFDM has been used in high speed modems, digital mobile communications and high-speed recordings.

The no of fast modems were developed for telephone networks. In 1990s, OFDM has been adopted for wideband data communications, wireless multimedia communication, wireless LAN [1] high-bit-rate digital subscriber lines (HDSL), asymmetric digital subscriber lines (ADSL), digital audio broadcasting (DAB) and digital audio broadcasting (DVB) broadcasting.

A basic OFDM system consists of a quadrature amplitude modulation (QAM) or PSK modulator/demodulator, a serial to parallel / parallel to serial converter, and an IFFT/FFT module. The iterative nature of the FFT and its computational order makes OFDM ideal for a dedicated architecture outside or parallel to the main processor [8]. The Mapper and Demapper are the basic blocks used for modulation and demodulation in the OFDM. According to the requirement of the design, designer can select any one modulation scheme for mapping at the transmitter and reverse of the same at the receiver end. Commonly used modulation schemes are BPSK, QPSK, 16-QAM or 64-QAM [6]. Among these 64-QAM is preferred for OFDM [1], because if we used higher order QAM then it results into the increase in BERs. So the 64-QAM maintains the trade-of between the speed and the BERs. These factors also vary with the type of FPGA used.

Many methods are proposed to implement OFDM with good flexibility and performance in accordance with the requirement of the design. The table 1 below shows some ways to implement OFDM using different basic blocks according to requirement of the designer. Table also shows that different authors used different platform for the implementation and they observed the BERs, The requirements of the designer can be a parameters like BER (Bit Error Rate), performance, throughput, cost etc.

III. OFDM GENERAL BLOCK DIAGRAM

The block diagram of the OFDM transceiver consists of no of core blocks as shown in the Fig 1. The main blocks are Serial to Parallel Convertor, Modulation, and IFFT at the transmitter end and FFT, Demodulation and parallel to serial convertor at the receiver end.

Publication year and Author	**Method used/Blocks used**	**Result/conclusion**	**Software/Implemented on**
[1] 2013/ IJCET Yojna Bellada	16-QAM mapper /demapper used. Zero padding is used for time and frequency synchronization. Memory based FFT radix-4 butterfly unit for DIT FFT is considered.	BER performance varies between 9.01 to 0.0001	Matlab-7.8.0 (only for BER performance) Xilinx (Verilog) Spartan-3 an FPGA board.
[2] 2013/ IEEE Akash Mecwan	64-QAM. 64 point FFT and IFFT used. Modules are designed using system generator in MATLAB.	Colour image of 27 * 27 is sent and properly received	MATLAB 2010a and Virtex-5 board of Xilinx.
[3] 2013/ IJSCE Nasreen Mev	Scrambler/Descrambler RS encoder/decoder, Convolution encoder/decoder, Interleaver/ Deinterleaver, Constellation mapper/demapper, OFDM with 64-Sub-Carriers-QPSK-FFT radix 22 algorithm.	Bits are transmitted and received and error checking corresponding to blocks.	Quartus-II and Modelsim Simulation tool
[4] 2014/ IJETAE Pratibha Mane	Modulation- QPSK,MSK Designed using MATLAB/SIMULINK visual modelling tool set and implemented on spartan6 FPGA device.	BER- 0.000001 Combination of OFDM with MIMO results in less BER. Support data rates up to 600mbps.	MATLAB 2008b Xilinx 12.3 Modelsim-6.5 Spartan6 FPGA device.

Table 1: comparative study of various implementation of OFDM on FPGA

The image of any specification is taken for the transmission. The pixel values corresponding to the image are extracted and sent in the form of data stream as an input to the transmitter block.The data stream received is converted to the parallel form using the serial to parallel convertor block. The no of output bits of parallel data depends upon the modulation scheme we are going to use in the next block then the parallel data is processed by the modulation block. Further the data is processed by the IFFT block which is the most important block of the transmitter side. IFFT block also provides the orthogonality. The exactly reverse action is carried out at the receiver end.

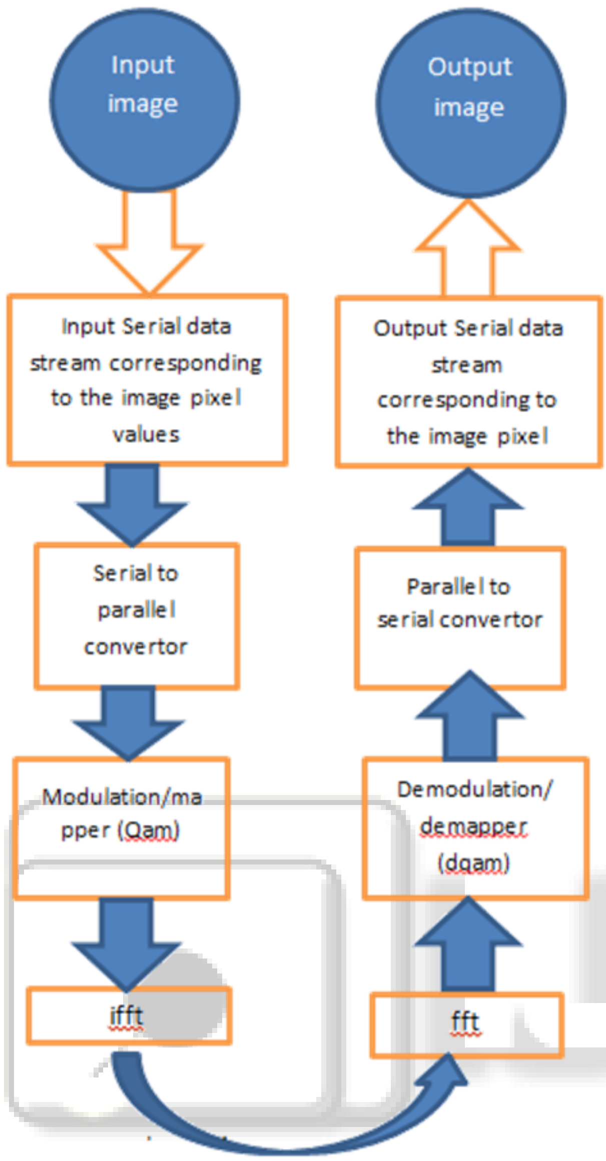

Fig. 1: OFDM general block diagram

IV. APPLICATIONS

OFDM has been widely used in following area:

1) OFDM preferred as the leading physical-layer interface in wireless communications environment.
2) Mobile communications.
3) HDTV-Digital Video Broadcasting (DVB) and Digital audio broadcasting (DAB).
4) OFDM based multiple access technology OFDMA is also used in several 4G and mobile broadband standards.
5) Mobile-WiMAX.
6) The wireless LAN (WLAN) radio interface.
7) IEEE802.11a, g, n, ac.
8) ADSL and VDSL broadband access.
9) Power Line Communication (PLC).Etc.

V. CONCLUSIONS

The main objective of this paper is to study all the important processing blocks of OFDM system. Among all the block modulation/demodulation and IFFT/FFT blocks are of great importance. IFFT/FFT provides the necessary processing of signal frequency domain to time domain and vice versa and it also provides orthogonality to the signal. IFFT/FFT is used instead of other conversion schemes because of the advantage of high computational capability and less computational time of the former. For modulation QAM is preferred over the other modulation schemes. Specifically 64-QAM is used, because if we use higher point QAM for higher throughput it results in increase in BERs.

VI. REFERENCES

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