VHDL Design OFDM System using FFT/IFFT

Patel Kajalben Ramanbhai[1] Prof. S. P. Patil[2]
[1]Student [2]Assistant Professor
[1,2]Department of Electronics & Telecommunication Engineering

Abstract— Orthogonal Frequency Division Multiplexing (OFDM) is a multi-carrier system where data bits are encoded to multiple sub-carriers, while being sent simultaneously. This results in the optimal usage of bandwidth. A set of orthogonal sub-carriers together forms an OFDM symbol. To avoid ISI due to multi-path, successive OFDM symbols are separated by guard band. This makes the OFDM system resistant to multi-path effects. The main advantage of this transmission technique is their robustness to channel fading in wireless communication environment. The main focus of this project is to design 8-point IFFT and FFT blocks which are used in transmitter and receiver blocks of OFDM system. The methodology used is the 8-point IFFT/FFT (DIT) with radix-2 butterfly algorithm. The design unit also consists of modulation and demodulation for mapping technique. The design has been coded in VHDL. The timing simulation and synthesized results are performed and the design is analyzed by using Xilinx ISE 13.2 tools.
Key words: FFT, IFFT, OFDM, QAM & VHDL

I. Introduction

The OFDM is the modulation scheme having multicarrier transmission techniques here the available spectrum is divided into many carriers each one being modulated at a low rate data stream. The spacing between the carriers is closer and the carriers are orthogonal to one another preventing interferences between the closely spaced carriers hence OFDM can be thought of as a combination of modulation and multiplexing techniques[9], each carrier in a OFDM signal has very narrow bandwidth so the resulting symbol rate is low which means that the signal has high tolerance to multi path delay spread reducing the possibility of inter symbol interference (ISI)which is the requirement for today's communication systems. OFDM used in the field of wireless and wired communication systems. This is reflected by the adoption of this technique in applications such as digital audio/video broadcast (DAB/DVB), wireless LAN (802.11a and hiperlan2), broadband wireless (802.16) and XDSL.

OFDM is similar to FDM but much more spectrally efficient by spacing the sub-channels much closer together (until they are actually overlapping). This is done by finding frequencies that are orthogonal, which means that they are perpendicular in a mathematical sense, allowing the spectrum of each sub-channel to overlap another without interfering with it as shown in Fig 1. In Fig. 2 the effect of this is seen, as the required band width is greatly reduced by removing guard bands (which are present in FDM) and allowing signals to overlap.

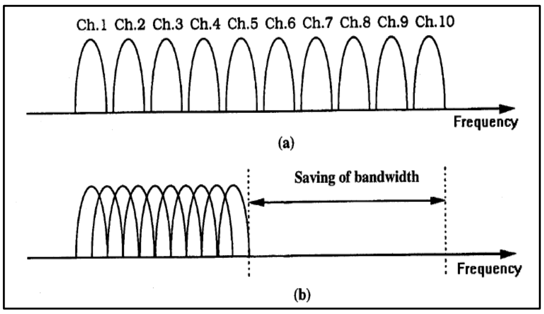

Fig. 1: (a) Spectrum of FDM showing guard bands (b) Spectrum of OFDM showing overlapping subcarriers

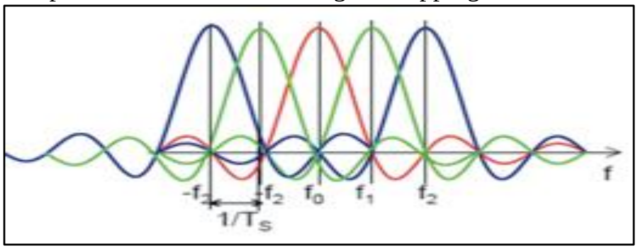

Fig. 2: Spectrum overlap in OFDM

The OFDM transmitter and receiver contain Inverse Fast Fourier Transform (IFFT) and Fast Fourier Transform (FFT), respectively[6]. The IFFT/FFT algorithms are chosen due to their execution speed, flexibility and precision [3]. For real time systems the execution speed is the main concern.

The IFFT block provides Orthogonality between adjacent subcarriers. The Orthogonality makes the signal frame relatively secure to the fading caused by natural multipath environment. As a result OFDM system has become very popular in modern telecommunication systems. The main objective of this paper is to design IFFT/FFT blocks for OFDM, because these are main blocks for modulation and demodulation in OFDM transmitter and receiver [2]. The OFDM signal is generated by implementing the Inverse Fast Fourier Transform (IFFT) at the transmitter which is used to convert frequency domain to time domain and Fast Fourier Transform (FFT) which is used to convert time domain to frequency domain at the receiver side is implemented.

II. OFDM MODEL

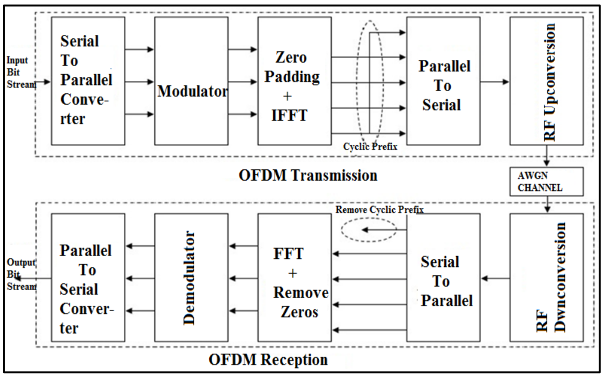

Fig. 3: Block Diagram of OFDM system

The detailed block diagram of OFDM transmitter & Receiver system is shown in the Fig 3.

A. Serial to Parallel Converter

The input serial data stream is formatted into the word size required for transmission, e.g. 4 bits/word for QAM, and shifted into a parallel format. The data is then transmitted in parallel by assigning each data word to one carrier in the transmission.

B. Modulation & Demodulation of Data

The data to be transmitted on each carrier is then differentially encoded with previous symbols, and then mapped into a QAM format and for Demodulation inverse process of Modulation is used.

C. IFFT/FFT

The IFFT transform a spectrum Frequency domain into a time domain signal and For FFT inverse process of IFFT.

III. IMPLEMENTATION

Implement the OFDM Sub block and finally interconnect all of them together to form complete OFDM circuit. The simulation results in XILINX ISE 13.2 software of Modulator, Demodulator, FFT and IFFT block are shown in Fig. 6, 7, 8, 9 respectively. The functioning of each block is explained as follows:

A. 16-QAM

Presented system uses QAM modulation so 16 constellation points are used. To have different constellation values data is divided in groups of 4 bits each and convert that binary code to gray code for better accuracy. Upper two bits are used for imaginary number and lower two bits are used to denote real number.

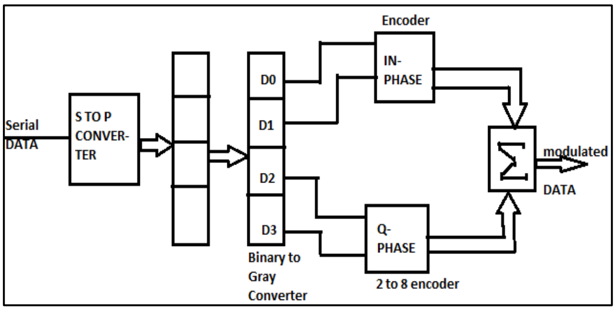

Fig. 4: 16-QAM Block Diagram

Bit combination	Gray Code	Constellation value	Nature of value
0000	0000	-3j-3	Complex
0011	0010	-3j+3	Complex
0100	0110	-j+3	Complex
1011	1110	J+3	Complex
1101	1011	3j+1	Complex
0111	0100	-j-3	Complex
1000	1100	j-3	Complex

Table 1: Some Bit combinations and corresponding constellation

Different bit combinations and corresponding constellation are shown in Table 1. In above modulation scheme, bit combination (D3D2 or D1D0) 00 corresponds to -3, 01 corresponds to -1, 11 correspond to 1, 10 correspond to 3.

To achieve this, a separate process is written in VHDL code. “Case” statement is used to check the combinations. As constellation is complex number, two different arrays are required to store real part and imaginary part separately. In the process for constellation mapping, case statement checks the bit combinations and according to bit combinations one of the 4 values (-3,-1, 1, 3) is assigned in imaginary or real output respectively .Output of 16-QAM block applied to IFFT block.Fig.6. shows the simulated output of 16-QAM block.

B. 8-Point IFFT

Implementation of butterfly diagram is done in this algorithm using VHDL. Radix-2 Decimation-in-time (DIF) IFFT is implemented in this algorithm & Simulated this algorithm using Xilinx ISE 13.2 tools.

C. 8-Point FFT

In Fig.5 the basic butterfly unit for the radix-2 8-point FFT algorithm is shown.

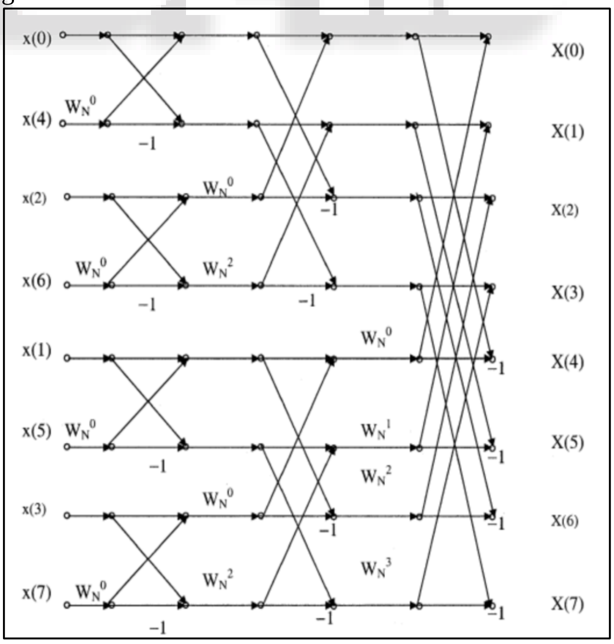

Fig. 5: Block Diagram of OFDM system

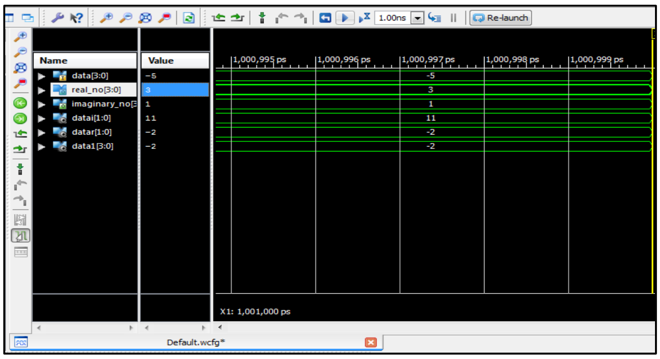

Fig. 6: Simulation result of 16-QAM modulator

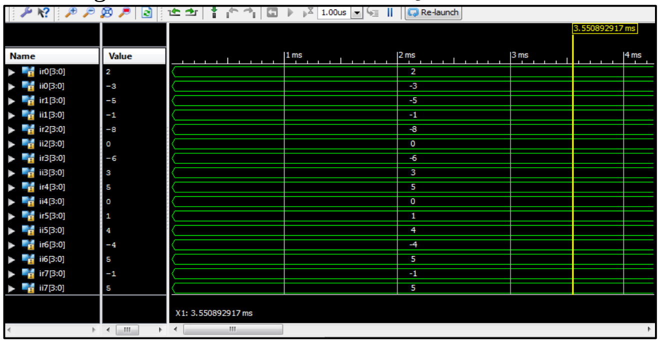

Fig. 7: Input to IIFT

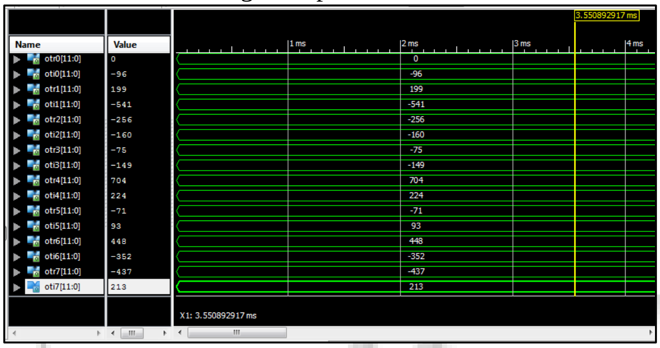

Fig. 8: Output to IFFT & Input to FFT

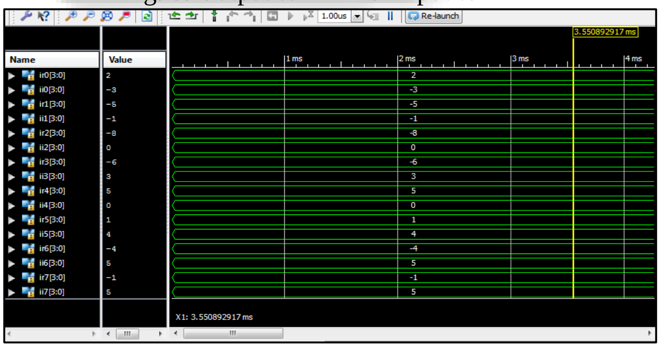

Fig. 9: Output to IFFT

IV. CONCLUSION

Design 8-point FFT & IFFT to implement for communication application like OFDM system using VHDL language. The different blocks of OFDM system such as QAM Modulator, 8-IFFT, 8-FFT and Demodulator is designed on Xilinx project navigator. These blocks are simulated on XILINX 13.2 ISE Design Suite, tested for different data value.

V. FUTURE WORK

Design OFDM transmitter and receiver using 8-point FFT/IFFT. This is very basically implementation and lots of resources are used. This work is extended to implement 8-point FFT/IFFT at efficient ways and utilize the hardware.

REFERENCES

[1] Zhiwei Tang and Dongqin Sheng “Implementation of OFDM Based on FPGA”The third research of institute of public security, Shanghai, China-2012 International Conference on Image, Vision and Computing (ICIVC 2012)

[2] Manjunathi akkannavar, Ashwini Desai, ”Design and Implementation of OFDM’, International Journal of Engineering and Advanced Technology (IJEAT) volume-1 Issue 6, August 2013.

[3] K.Hari Krishna, T.Rama Rao, Vladimir A Labay, “FPGA Implementation of FFT Algorithm for IEEE 802.16e (Mobile WiMax)”.International Journal of Computer Theory and Engineering, Vol. 3, No.2, April 2011.

[4] Horosaki B., “An orthogonally multiplexed QAM system using the DFT,” IEEE Trans. Comm. Vol. COM-29, pp. 982-989, July 1981.

[5] Khan, A.U.,Al-Akaidi, M.M. ; Khan, S.A.; Khattak, S. “Performance analysis of a 64-point FFT/IFFT block designed for OFDM technique used in WLANs” IEEE Xplore - Conference Publications > Multi Topic Conference, 2003

[6] Shaminder Kaur, Rajesh Mehra, “FPGA Implementation of OFDM Transceiver using FFT Algorithm” International Journal of Engineering Science and Technology (IJEST).

[7] R.Van Nee, R. Prasad Publication by Artech House, “OFDM for wireless Multimedia Communications.”, e-book.

[8] Yufeng Shao, Nan Chi, Jingyuan Fan, and Wuliang Fang ‘‘Generation of 16-QAM-OFDM Signals Using Selected Mapping Method and Its Application in Optical Millimeter-Wave Access System‘’ IEEE photonics technology letters, vol. 24, no. 15, august 1, 2012.

[9] R. Van Nee, R. Prasad, “OFDM for Wireless Multimedia Communications,” Artech Hause Publishers, 2000, ch. 1, pp. 20–25.

[10] Manushree Bhardwaj1, Arun Gangwar2, Devendra Soni3’’A Review on OFDM: Concept, Scope & its Applications’’ IOSR Journal of Mechanical and Civil Engineering (IOSRJMCE) ISSN : 2278-1684 Volume 1, Issue 1 (May-June 2012), PP 07-11

[11] Michael Bernhard, Joachim Speidel ’’Implementation of an IFFT for an Optical OFDM Transmitter with 12.1 Gbit/s’’

[12] W. Shieh, H. Bao, and Y. Tang, “Coherent optical OFDM: theory and design,” Opt. Express, vol. 16, no. 2, pp. 841–859, 2008.

[13] J.W.Cooley andJ. W. Tukey, “An Algorithm for the Machine Calculation of Complex Fourier Series,” Mathematics of Computation, vol. 19, no. 90, pp. 297–301, 1965.

