

# High Speed and High Reliable OFDM System with Radix 4

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**Abstract:** As one of the most promising techniques for wireless applications including digital audio broadcasting, digital video broadcasting and wireless local area networks, orthogonal frequency division multiplexing is becoming a focus of interests and attentions of worldwide researches. On comparing all the networks and communication system prevailing today in this scientific world, OFDM system stands first among all those networks and systems. Hence forth this system has been in focus of all the intellectuals around the world in using as well as in making that further comfortable to the requirements of the current updates of the world. These flaws can be abated by using the radix 4 technologies in IFFT and FFT blocks of OFDM system. The radix 4 technology can able to process the signal with many sample points eventually could able to give accurate discretized and quantized values of the signal to next block process the signal successively in the OFDM system both in transmitter and receiver side of the system. Hence forth this radix 4 technology could able to decrease the high bit error rate and computational complexity in processing the signal.

**Keywords:** M sim, FPGA kit, radix 4, OFDM, IFFT and FFT

## 1. Introduction

As one of the most promising techniques for wireless applications including digital audio broadcasting, digital video broadcasting and wireless local area networks, orthogonal frequency division multiplexing is becoming a focus of interests and attentions of worldwide researches. Among all the communication systems and networks prevailing in the current scientific trend named as GSM, WCDMA and many others, OFDM system stands ahead of others in all the aspects of wielding the system in optimized way. However, it has some demerits like more computational complexity in processing the signal throughout its entire system as well as high bit error rate and this drawback hampers the optimized way to use it effectively, henceforth it is necessary to alleviate all these flaws and drawbacks of this system.

To abate all the demerits many techniques have been introduced to upgrade at least as many blocks as possible in the OFDM system. Those techniques are named as Coding, companding, clipping and filtering, constellation extension, tone reservation and injection, selected mapping, partial transmit sequence and many other schemes. Unfortunately all the above mentioned techniques couldn't alleviate and upgrade the present OFDM system as much as we required and therefore we deduced that switching to RADIX 4 from RADIX 2 in both the IFFT and FFT blocks at the transmitter and receiver of the OFDM system would be the very good solution to this problem than anything else.

At the transmitter side of the system IFFT block is present, it converts the digital input of the system into its discrete signal to be converted into analog signal utterly in DAC block comes next to it and then analog signal is transmitted through the channel towards the receiver. Here the accuracy of the signal depends on conversion of the digital input into the discrete signal at transmitter henceforth we can say RADIX 4 could able to give more accurate discrete value of the signal than the RADIX 2 as it computes with more no of samples points in the signal.

The same wise at the receiver FFT block converts the analog signal into the discrete signal, and the accuracy at this side depends on this conversion therefore with RADIX 4 technique FFT at the receiver could able to maintain the accuracy in the conversion. The accuracy achieved at both the transmitter and the receiver of OFDM system builds the reliability of the system; thereby this system also reduces the computational complexity in processing the signal.

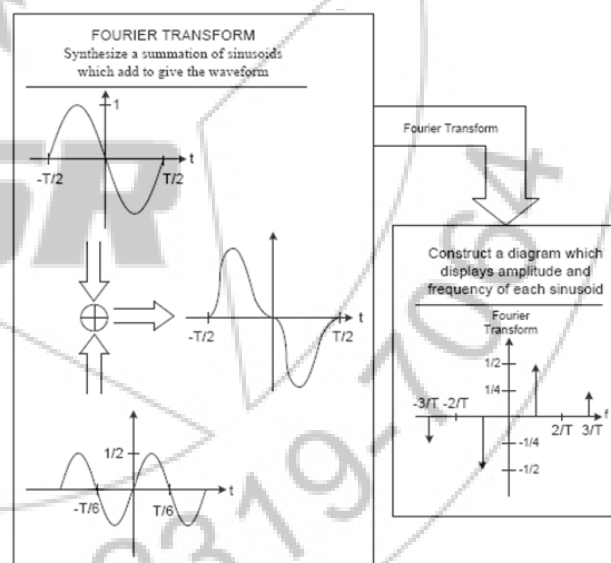


Figure 1: Overview of the Fourier Transform

Application using frequency analysis of discrete-time signals in digital signal processor is the most convenient method especially in general-purpose digital Computer or specially designed digital hardware. Frequency analysis is performed on a discrete-time signal  $\{x(n)\}$  by converting the time-domain sequence to an equivalent frequency-domain presentation. A straightforward representation of the Fourier transform is illustrated in Figure. From the figure, it shows the essence of the Fourier transform of a waveform is to decompose or separate the waveform into a sum of sinusoids of different frequency.

## 2. Overall Design

The basic idea of OFDM is to divide the available spectrum into N orthogonal sub channels. The digital baseband blocks of an OFDM transceiver, is illustrated in Figure.

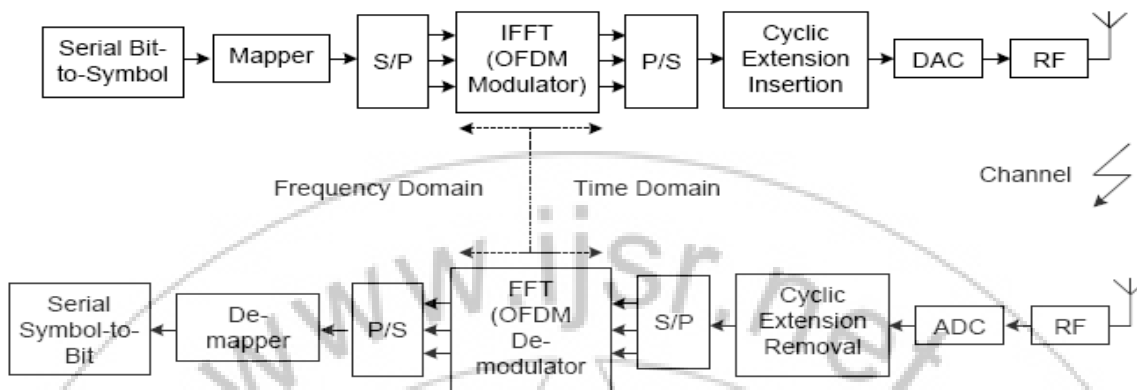


Figure 2: Simplified Transceiver block of OFDM system

### A. Blocks of OFDM system

The OFDM transceiver block contains a mapper / demapper, a serial to parallel (S/P) converter / parallel to serial (P/S) converter, a digital to analog converter (DAC), an analog to digital converter (ADC), a cyclic insertion/removal and a FFT/IFFT. In the sub block of OFDM transmitter, mapper block converts the data to signal located in the frequency domain where each sub-channel is assigned one signal.

The final block of OFDM transmitter is to insert a cyclic extension to remove the effect of inter-symbol interference (ISI) and inter-channel interference (ICI). The OFDM receiver block is also described in Figure. After down-conversion and analog-to-digital conversion the cyclic extension is removed. The data is fed into FFT block as a parallel input after going through serial to parallel converter. FFT block is used to demodulate the N sub-carriers of the OFDM signal and transformed back to the frequency domain.

### B. Mapping and De-mapping

Input data is converted to complex valued signal points by the mapper block. These data signals are converted to signal based on the constellation, e.g. BPSK or 64-QAM. Figure 2.4, represents the BPSK, QAM and 16-QAM constellation plot where the in-phase (I) axis corresponds to the real part and the quadrature (Q) axis corresponds to the imaginary part of the output signal. The amount of data transmitted on each sub-carrier is 12 dependants on the type of constellation. For example BPSK and 16-QAM transmit one and four data bits per sub carrier.

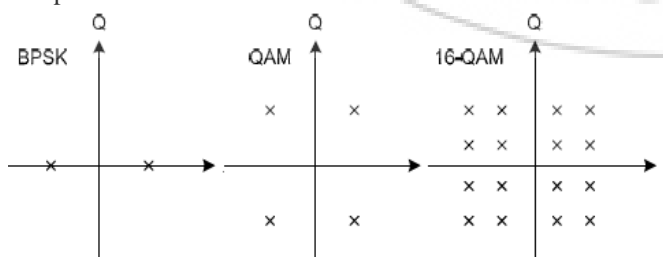


Figure 3: Typical Constellations for wireless system applications

### C. IFFT and FFT block

The Fast Fourier Transform (FFT) converts the signals from time domain representation to frequency domain representation and consequently the IFFT performs the reverse operation. Signals are processed in frequency domain due to simplified computation as compared to the time domain computation, e.g. convolution in the time domain becomes multiplication in the frequency domain.

The sub-carrier can be separated again with FFT algorithm even though the spectrum is overlapped because IFFT is a linear operation. The orthogonality of subcarriers in OFDM can be maintained and individual sub-channel is completely separated by the FFT at the receiver when there are no inter-symbol interference (ISI) and inter-carrier interference (ICI) introduced by transmission channel distortion.

### D. RADIX 4 FFT Algorithm

When the number of data points N in the DFT is a power of 4 (i.e.,  $N = 4^v$ ), we can, of course, always use a radix-2 algorithm for the computation. Let us begin by describing a radix-4 decimation-in-time FFT algorithm briefly. We split or decimate the N-point input sequence into four sub sequences,

$$X(4n), x(4n+1), x(4n+2), x(4n+3), n = 0, 1 \dots N/4-1.$$

$$X(p, q) = \sum_{l=0}^3 [W_N^{lq} F(l, q)] W_4^{lp}$$

$$F(l, q) = \sum_{m=0}^{(N/4)-1} x(l, m) W_{N/4}^{mq}$$

$$p = 0, 1, 2, 3; \quad l = 0, 1, 2, 3; \quad q = 0, 1, 2, \dots, \frac{N}{4} - 1$$

The radix-4 butterfly is depicted in a more compact form that each butterfly involves three complex multiplications, since  $W_N^0 = 1$ , and 12 complex additions.

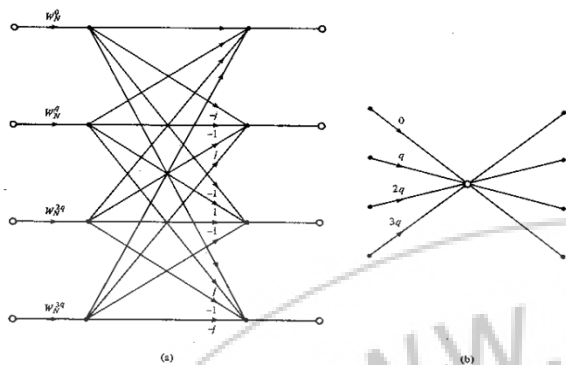


Figure 4: Radix 4 butterfly daigram

A 16-point, radix-4 decimation-in-frequency FFT algorithm is shown in Figure. Its input is in normal order and its output is in digit-reversed order. It has exactly the same computational complexity as the decimation-in-time radix-4 FFT algorithm

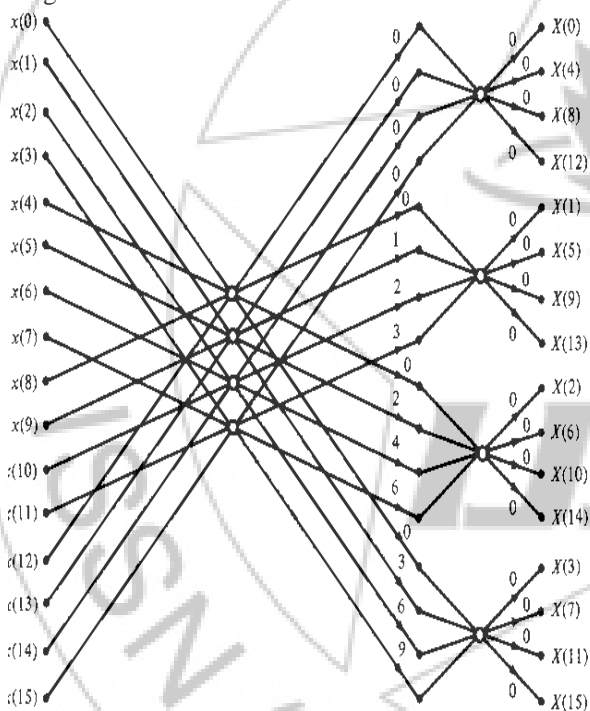


Figure 5: Sixteen-point, radix-4 decimation-in-frequency algorithm with input in normal order and output in digit-reversed order

### 3. Software Design of OFDM System with RADIX 4

#### A. Software versions

This documentation was written to support Model Sim SE 5.7c for UNIX and Microsoft Windows 98/Me/NT/2000/XP. If the Model Sim software you are using is a later release, check the README file that accompanied the software. Any supplemental information will be there. Although this document covers both VHDL and Verilog simulation, you

will find it a useful reference even if your design work is limited to a single HDL.

#### B. Model sim's Graphic Interface

While your operating system interface provides the window-management frame, Model Sim controls all internal-window features including menus, buttons, and scroll bars. The resulting simulator interface remains consistent within these operating systems:

- SPARCstation with Open Windows, OSF/Motif, or CDE
- IBM RISC System/6000 with OSF/Motif
- Hewlett-Packard HP 9000 Series 700 with HP VUE, OSF/Motif or CDE
- Linux (Red Hat v. 6, 7 or later) with KDE or GNOME
- Microsoft Windows 98/Me/NT/2000/XP

Because ModelSim's graphic interface is based on Tcl/Tk, you also have the tools to build your own simulation environment. Easily accessible preference variables and configuration commands, simulator preference variables, and graphic interface commands give you control over the use and placement of windows, menus, menu options and buttons.

#### C. Using the Wave Window

Using time cursors in the wave window any of the previous lesson simulations may be used with this part of the lesson, or use your own simulation if you wish.

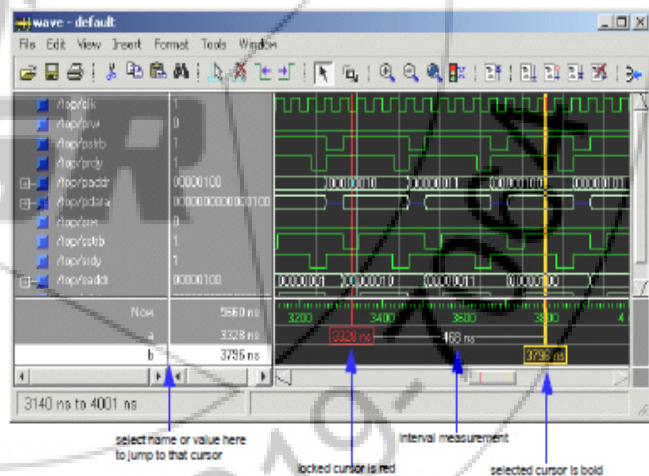


Figure 6: Wave Window

When the Wave window is first drawn, there is one cursor located at time zero. Clicking anywhere in the waveform display brings that cursor to the mouse location. You can add cursors to the waveform pane by selecting Insert > Cursor (or the Add Cursor button shown below). The selected cursor is drawn as a bold solid line; all other cursors are drawn with thin lines.

#### 4. Results

The design and implementation of Radix4 single-path delay feedback pipelined FFT/IFFT processor on an FPGA has been presented. The description was made by VHDL in

Xilinx ISE on Virtex-5 family and the functionality was verified by Model sim Xilinx Edition

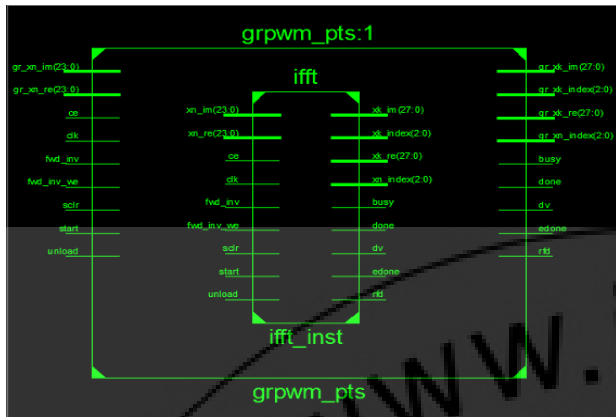


Figure 7: IFFT simulation results

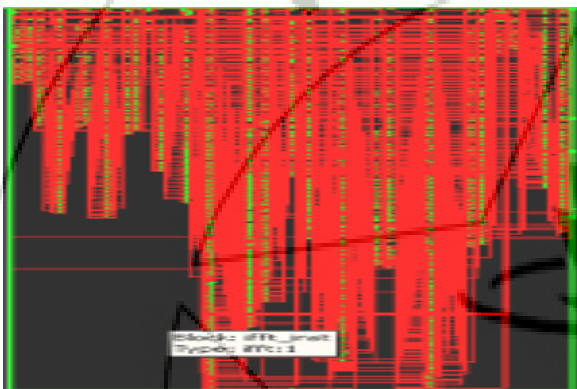


Figure 8: M sim model result

## 5. Conclusions

The outputs from the VHDL described architecture are validated against the standard FFT in Mat lab. And in forth we have inflicted benefits in the existing OFDM system to extend it towards our proposed system of OFDM with optimized accuracy, reliability and precision in the transmission of the data eventually by reducing the bit error rate as well as by increasing the no of samples in the signal in order to process the signal very precisely and to appraise the value of the signal very closely as it would be.

## 6. Future Enhancement

Future works on this project can be done in increasing the number of radix further to optimize the reliability and other features of the system acting as boon.

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