



OFDM Transceiver Design using C

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Abstract

The aim of this paper is to design a baseband orthogonal frequency division multiplexing (OFDM) [1]-[2] transceiver including 8 point Fast Fourier Transform (FFT), 8 point Inverse Fast Fourier Transform (IFFT) [3] core processor, DPSK modulator[4], demodulator serial to parallel and parallel to serial converter blocks in C language.

The main challenge is to derive the algorithm for Fast Fourier Transform (FFT) and Inverse Fast Fourier Transform (IFFT). There are many algorithms available that can implement FFT and IFFT.

Index Terms— Fast Fourier Transform; asymmetric digital subscriber lines (ADSL); discrete multi tone(DMT); sinc function;

I. Introduction

The race for the next generation wireless network is on again with OFDM challenged by CDMA2000 and WCDMA. The growing use of streaming media and other high speed application may allow OFDM-based device to win in the race for 4G (4th generation mobile) dominance. However it will be several years before the next generation mobile will be out on the market. NTT-DoCoMo and Hewlett-Packard are jointly developing technology for 4G mobile and expected to commercialize it by year 2010. NTT-DoCoMo tested the 4G mobile system and is able to transmit at a staggering rate of 20 MBPS up and 100 MBPS down using OFDM architecture [5].

Many wired and wireless standards bodies have adopted OFDM for a variety of applications. OFDM is the basis for the global standard for asymmetric digital subscriber line (ADSL) and for digital audio broadcasting (DAB) in the European market. In the wireless network space, OFDM is the heart of IEEE 802.11a, 802.11g, and HiperLAN/2.

The wireless network industry has been growing significantly over the past year. There are many established and startup companies developing high-speed wireless network products to provide wireless multimedia applications. The high data rates and robust communications of OFDM enable the implementation of wireless LANs (local area network) and MANs (metropolitan area network)

The main problems in the OFDM transceiver implementation are overflow and signed bit issues. This is due to the limited number of bits allocated for the output. Overflow occurred when the output bits are not sufficient to represent the correct value. In order to overcome this problem, number of bits used to represent the OFDM signal has been increased from 8 to 17 bits (1bit to represent sign, 8 bits to represent integer and decimal parts each). OFDM has been chosen for several current and future communication systems. The modulation and demodulation equations of OFDM resemble the IDFT and DFT equations. We try to exploit these similarities in designing transceiver.

The expected contributions of this proposed approach is that:

- Amplitude modulation block is implemented using DPSK modulation
- 8 point IFFT core is implemented using decimation in frequency (DIF) algorithm.
- Cyclic prefix is appended at the end of the bits to be transmitted.
- Appended cyclic prefix is removed at the receiver side.
- 8 point FFT core is implemented using decimation in frequency (DIF) algorithm

- Amplitude demodulation block is implemented using DPSK demodulation

II.Literature survey

OFDM can be viewed as a collection of transmission techniques. When this technique is applied in wireless environment, it is referred as OFDM. In the wired environment, such as asymmetric digital subscriber lines (ADSL), it is referred as discrete multi tone (DMT). In OFDM, each carrier is orthogonal to all other carriers. However, this condition is not always maintained in DMT. OFDM is an optimal version of multi carrier transmission schemes.

OFDM started in the mid 60's, Chang[2] proposed a method to synthesis band limited signals for multi channel transmission. The idea is to transmit signals simultaneously through a linear band limited channel without inter channel (ICI) or inter symbol interference (ISI).

After that, Saltzberg performed an analysis based on Chang's work and he conclude that the focus to design a multi channel transmission must concentrate on reducing crosstalk between adjacent channels rather than on perfecting the individual signals.

In 1971, Weinstein and Ebert made an important contribution to OFDM. Discrete Fourier transform (DFT) method was proposed to perform the base band modulation and demodulation. DFT is an efficient signal processing algorithm. It eliminates the banks of sub carrier oscillators. They used guard space between symbols to combat ICI and ISI problem. This system did not obtain perfect orthogonality between sub carriers over a dispersive channel. It was Peled and Ruiz in 1980 who introduced cyclic prefix (CP) that solves the orthogonality issue. They filled the guard space with a cyclic extension of the OFDM symbol. It is assume the CP is longer than impulse response of the channel.

III.OFDM Carriers

As fore mentioned, OFDM is a special form of Multi Carrier Modulation (MCM) and the OFDM time domain waveforms are chosen such that mutual orthogonality is ensured even though sub-carrier spectra may over-lap. With respect to OFDM, it can be stated that orthogonality is an implication of a definite and fixed relationship between all carriers in the collection. It means that each carrier is positioned such that it occurs at the zero energy frequency point of all other carriers. The sinc function, illustrated in Figure1 exhibits this property and it is used as a carrier in an OFDM system.

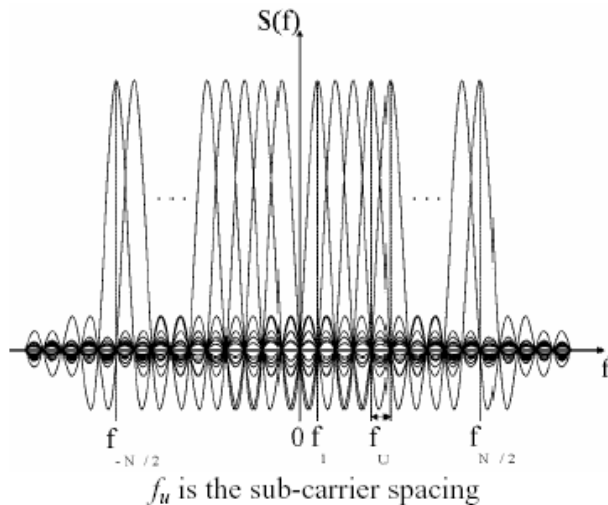


Figure 1. OFDM sub carriers in the frequency Domain.

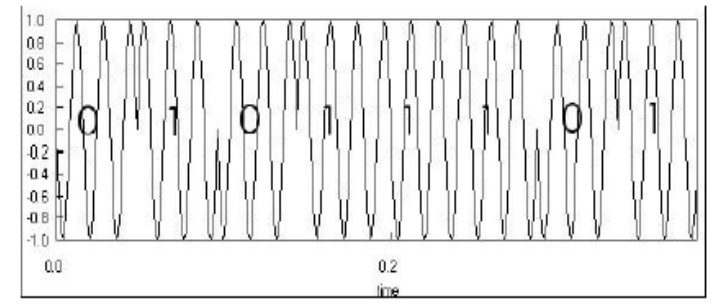


Figure 2. Binary Phase-Shift Key (BPSK) representation of “01011101”.

A. Generation of OFDM Signals

To implement the OFDM transmission scheme, the message signal must first be digitally modulated. The carrier is then split into lower-frequency sub-carriers that are orthogonal to one another. This is achieved by making use of a series of digital signal processing operations.

The message signal is first modulated using a scheme such as BPSK, QPSK, or some form of QAM (16QAM or 64QAM for example). In BPSK, each data symbol modulates the phase of a higher frequency carrier. Figure 2 shows the time domain representation of 8 symbols (01011101) modulated within a carrier using BPSK. In the frequency domain, the effect of the phase shifts in the carrier is to expand the bandwidth occupied by the BPSK signal to a *sinc* function. The zeros (or “nulls”) of the *sinc* frequency occur at intervals of the symbol frequency.

B.Implementation of 8-points inverse fast Fourier transform (IFFT) and fast Fourier transform (FFT)

Here we discuss the approach and method that is chosen to design the core processing block in an OFDM transmitter. The computational time between DFT and FFT is faster using FFT method because the number of multiplications and additions operation in FFT is less compared to DFT method as shown in Table 2.2. The FFT and IFFT operation are almost identical except for scaling and conjugation of the twiddle factor. Thus, it is assumed the computational time between FFT and IFFT is same. There are two methods to implement the OFDM transmitter [9], namely structural method and direct computation method. Both methods will be discussed in the following section.

C.Algorithm of an 8-point Inverse Fast Fourier Transform (IFFT)

The core processing block in an OFDM transmitter is the Inverse Fast Fourier Transform. The IFFT can be implemented using 2 methods, structural method or direct mathematical method. Structural method implements a single butterfly computation.

In the direct method, the final output is derived from the input directly. In a structural method, the single butterfly and summation has to be carried out 12 times for an 8-point IFFT. The multiplication and summation has to be carried out, although the twiddle factor has value of 0 or 1. This introduces redundancy in the implementation. For example, the implementation of structural approach is $X=(0)a+(1)b$, where in the direct mathematical approach, the implementation is simply $X=b$. Multiplication of the twiddle factor is skipped to avoid redundancy in and reduce computation time. Thus, this method is optimized.

In the Figure 3, it is shown that there are 3 stages in an 8-point IFFT. Stage 1 accepts the input data directly. The Figure 4.4 shows the computation in Stage 1. It is shown the even samples and odd samples are processed separately. The outputs of Stage 1 are feed as the inputs of the Stage 2. Stage 2 computation take place and this process repeats at the final stage, Stage 3.

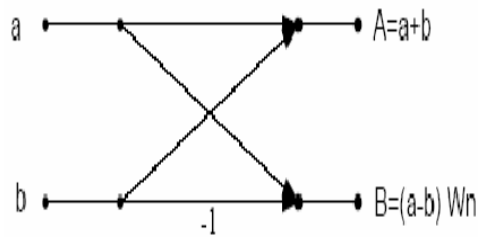


Figure 3 Single Butterfly Flow Chart in IFFT

IV.Simulation results

The following results are obtained for the character set “MCE E&C.”

Firstcase: Errorless transmission

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Turbo C++ IDE
Enter the data with 8 character
MCE E&C.

Entered data in binary
0 1 0 0 1 1 0 1 0 1 0 0 0 0 1 1 0 1 0 0 0 1 0 1 0 0 1 0 0 0 0 0 0 1 0 0 0 1 0 1
0 0 1 0 0 1 1 0 0 1 0 0 0 0 1 1 0 0 1 0 1 1 1 0
press any number to continue
1

DPSK modulated signal is given as follows
1 1 0 1 1 1 0 0 1 0 0 0 0 0 1 1 1 1 0 0 0 0 1 1 0 0 0 0 0 1 1 1 1 1 0 0 0 0 1 1
0 1 0 0 0 1 1 1 1 0 0 0 0 0 1 1 0 1 0 1 1 0 0 0

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Figure 4. Output of DPSK modulation in binary

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press any number to continue
1

output of serial to parallel convertor
0 0 1 1 1 0 1 1
1 1 0 0 0 0 0 1
1 1 0 0 0 0 1 1
1 1 1 0 0 0 0 0
1 1 0 0 0 0 1 1
1 1 1 0 0 0 1 0
1 1 0 0 0 0 0 1
0 0 0 1 1 0 1 0

```

Figure 5. Output of serial to parallel converter

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press any number to continue
1

Binary output of IFFT block

Real value

sign bit integer value decimal value
1 11100100 00100000
0 00010001 00110101
0 00001111 01000000
0 00001100 11001010
1 11111101 01100000
0 00001100 11001010
0 00001111 01000000
0 00010001 00110101

press any number to continue
1

Imaginary values

sign bit integer values decimal values
0 00000000 00000000
1 11111001 11001010
1 11110110 11100000
1 11111000 01001010
0 00000000 00000000
0 00001000 01001010
0 00001010 11100000
0 00000111 11001010

```

Figure 6.Binary output of IFFT block

V Discussion and Conclusions

OFDM transceiver is designed successfully using C language. FFT and IFFT have been chosen to implement instead of the Discrete Fourier Transform (DFT) and Inverse Discrete Fourier Transform (IDFT) because they offer better speed with less computational time.

The main problems encountered in this implementation were overflow and signed bit issue. This is due to the limited number of bits allocated for the output. Overflow occurred when the output bits are not sufficient to represent the correct value. In order to overcome this problem, number of bits used to represent the OFDM signal has been increased from 8 to 17 bits (1bit to represent sign, 8 bits to represent integer and decimal parts each). C language is used for implementation because of the availability of several cross compilers like Reads51, TMS320C30(DSP).

Amplitude modulation and demodulation blocks can be implemented using QAM or QPSK techniques.

Hardware implementation of transceiver can be done by converting the C code to assembly code using cross compilers and downloading the assembly code to a floating point supporting processor.

Higher point FFT and IFFT core processing blocks can be implemented instead of 8 point FFT and IFFT core processing blocks to increase the efficiency and reduce the time required to transmit the data.

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