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An Optimal Technique for Software Defined Radio Using Modem

R.Sathya , D.Vennila

Abstract**—** This paper presents a software-defined radio (SDR) system with reconfigurable architecture for wireless communications. SDRs used for different Standards, and different operational modes. For simplicity, two operational modes, quadrature amplitude modulation (QAM) and quadrature phase shift keying (QPSK) of OFDM baseband transceivers are implemented. The interoperability and adaptability among these operational modes of this OFDM System is discussed. OFDM Transmitter and Receiver output is simulated by using XILINX software (Spartan 3E). The volder's algorithms are used in proposed system. The main advantage of volder's algorithm is complexity and Number of logic gates are reduced. The main purpose of volder's algorithm is using only one adder and one subtractor. The QAM and QPSK both modes employ radix-2 decimation-in time fast Fourier transform (FFT) algorithms. The OFDM transceivers are gives interoperability, adaptability, low complexity and interference is avoided.

Index Terms - SDR,OFDM,IFFT,QPSK,FFT,QAM, Volder's algorithm,VHDL.

I. INTRODUCTION

Due to rapid growth of wireless and multimedia communication, there is a tremendous need for high-speed data transmission. Telecommunication industry provides variety of services ranging from voice to multimedia data transmissions, in which speed ranges several Kbps to Mbps. Existing system, may fail to support high speed efficient data transmission. To improve the speed and maximum amount of data transmission Orthogonal Frequency Division Multiplexing (OFDM) system may be used [1].

Orthogonal Frequency Division Multiplexing (OFDM) was first developed in the 1950's [2]. OFDM is a method of encoding digital data on to a numerous carrier frequencies. It has developed into a very popular scheme for wideband digital communication systems. Many researchers shown OFDM can be used in applications such as audio broadcasting [4], digital television [5], power line networks, wireless networks and 4G mobile communications.

II. OVERVIEW OF OFDM TECHNIQUE

Orthogonal Frequency Division Multiplexing (OFDM) is a modulation scheme having multicarrier transmission technique [2]. In OFDM, spectrum is divided into abundant carriers each one being modulated at lower data rates. Fig.1 shows spectrum of Frequency Division Multiplexing (FDM). In FDM subcarriers are non-overlapping, hence requires more bandwidth. Fig.2 shows spectrum of OFDM overlapping subcarriers. Saving of bandwidth in OFDM is shown in Fig.2. OFDM is analogous to FDM but much more spectrally effective by positioning the sub-channels much closer together. This is done by selecting the frequencies that are orthogonal and by letting the spectrum of each sub channel to overlay another without interfering with it.

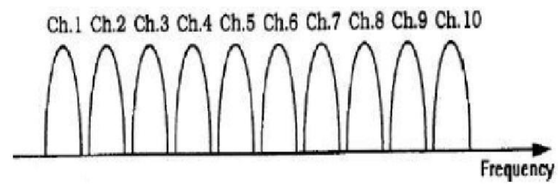

Figure 1 Spectrum of FDM non-overlapping subcarriers

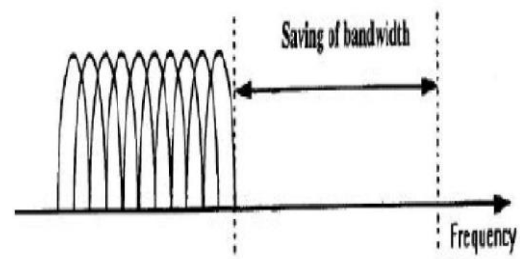

Figure 2 Spectrum of OFDM overlapping subcarriers

III. EXISTING OFDM TRANSCEIVERS FOR SDR

Now a days, digital processors (DSPs) based on reconfigurable logic devices (FPGAs and CPLDs) are taking relevance in the digital communications world. The software defined radio was created to obtain both permanent communications inside different bands of the radio and microwave spectrum with a single device and adaptability as opposed to new innovations of components and equipment. Basically, one is to transfer to software many of the functions that have been taking place in hardware. As semiconductor devices are shrinking, the rate of new Services introduced will soon exceed the rate of miniaturization in electronic packaging. What is needed is a flexible, universal radio platform for receive and transmit which can be programmed to steer to any band, tune to channel of any bandwidth, and receive any modulation-all within reasonable physical constraints, including size, weight, power consumption.

Currently, Wireless Sensor Networks (WSN) used in 2.4

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GHz ISM band like Zig-Bee, Wi-Hart are getting interference from the other systems like WLAN, Bluetooth etc. No efficient modulation is employed so for adjusting the interference from other systems for a WSN. Interference makes the sensor units to transmit data at higher power level which is not efficient for a battery powered device in a sensor networks.

3.1 OFDM Transmitter

In an OFDM system, the transmitter blocks contain the IFFT modules as shown in below Figure 3. The FFT processor must finish the transform within 312.5ns to serve the purpose in the OFDM system. Our FFT architecture effectively fits into the system since it has a minimum required time period of 10.827ns. An OFDM carrier signal is the sum of a number of orthogonal sub carriers, with baseband data on each subcarrier sub-carrier being independently modulated commonly using some type of quadrature amplitude modulation (QAM) or (PSK).

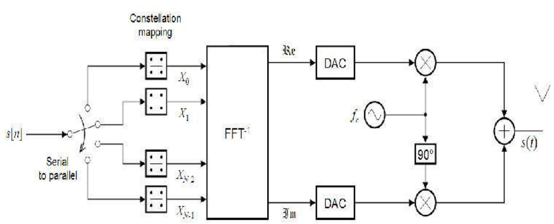

Figure 3 OFDM Transmitter

This composite baseband signal is typically used to modulate a main RF carrier. $s[n]$ is a serial stream of binary digits. By inverse multiplexing, these are first de-multiplexed into N parallel streams, and each one mapped to a (possibly complex) symbol stream using some modulation constellation (QAM, PSK, etc.).

3.2 OFDM Receiver

In an OFDM system, the receiver blocks contain the FFT modules as shown in below Figure 4. The receiver picks up the signal $r(t)$, which is then quadrature mixed down to baseband using cosine and sine waves at the carrier frequency. This also creates signals centered on $2fc$, so low-pass filters are used to reject these. The baseband signals are then sampled and digitized using analogue-to-digital converters (ADCs), and a forward FFT is used to convert back to the frequency domain.

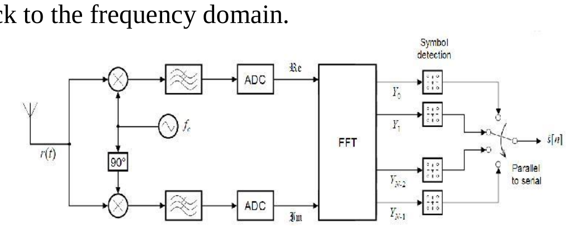

Figure 4 OFDM Receiver

IV. PROPOSED OFDM TRANSCEIVER FOR SDR

While programmable devices serve as the heart of the hardware platform within SDR systems, the software based transceiver enjoys its flexibility and adaptability for many applications. For example, certified software components compliant with 802.11 Wi-Fi standards are guaranteed to be interoperable with other modules. These standards deal with the physical layer and data link layers defined by the international standards organization open systems interconnect (ISO-OSl). Hence, the interoperability among different operational modes in wireless networks is achieved via software modules with relatively low cost on development.

For example, IEEE 802.16 and 802.11 n standards define a large set of modulation and coding schemes to facilitate this goal. Moreover, adaptive modulation schemes can be used to minimize the required antenna sizes of the link, while still being able to transport high capacities. This may reduce antenna front end equipment costs. The software modulation and demodulation modules of DSP based architecture can be efficiently updated and switched to meet this new design requirement. CORDIC (CO-ordinate Rotation DIgital Compute), also known as the digit-by-digit method and Volder's algorithm, is a simple and efficient algorithm to calculate hyperbolic and trigonometric functions.

4.1 Volder's Algorithm

The modern CORDIC algorithm first described by jack E.volder.it was developed at the aero electronics department of convair to replace the analog resolver in the B-58 bomber's navigation computer. The CORDIC subroutines for trigonometric and hyperbolic functions can share most of their code. CORDIC is particularly well-suited for handheld calculators, in which low cost and thus low chip gate count is much more important than speed.

Volder's algorithm equation (4.1) & (4.2) is,

$$(\;) = \;() - \;() - \quad (4.1)$$

$$(4.2)$$

$$(\;) = \;() + \;() - $$ in above equation, $= 0, = 0$

$$(-1) - (0)$$

Substitute $(-1) = (0)$ in above equation, $= 0, = 1$

$$(0) = -1$$

$$(0) = (1)$$

The volder 's algorithm using only one adder and one subtractor.

Application of CORDIC uses simple shift-add operations for several computing tasks such as the calculation of trigonometric, hyperbolic and logarithmic functions, real and complex multiplications, division, square-root calculation, solution of linear systems, eigen value estimation, singular value decomposition, QR factorization and many others.

V.DESIGN OF OFDM TRANSMITTER AND RECEIVER

The proposed OFDM system consists of an OFDM baseband transmitter and an OFDM baseband receiver. This chapter gives details on the complete architecture of the proposed design and elaborates further on the design and implementation of the transmitter portion of the project. The transmitter gets its input from the serial port of the host PC.This board does not have a serial port therefore we used an HSMC to santa Cruz daughter board. The daughter board contains altera standard HSM connector and serial port.Serial communication format is (8 bit data+ start bit + stop bit).The 1 byte data from RS 232 receiver is stored in a FIFO. Data from FIFO is given (bit by bit) to the transmitter module. Architecture of the proposed OFDM system (transmitter high lighted). The modulated output from the transmitter is fed into another FIFO and then taken out into the RS232 Transmitter (byte by byte) the prepares the data serial communication over the RS232 interface by adding start and stop bits.

5.1 COMPLETE OFDM SYSTEM

The complete OFDM system contains transmitter and receiver. The transmitter blocks consists of scrambler, Reed Solomon encoder, Interleaver, IFFT, Addition of CP, ect. The receiver blocks consists of De-scrambler, Reed Solomon decoder, De-Interleaver, FFT, Removal of CP, ect.

5.1.1 Scramble and Descramble

Data bits are given to the transmitter as inputs. These bits pass through a scrambler that randomizes the bit sequence. This is done in order to make the input sequence more disperse so that the dependence of input signal's power spectrum on the actual transmitted data can be eliminated. At the receiver end descrambling is the last step. Descrambler simply recovers original data bits from the scrambled bits.

5.1.2 Reed-Solomon Encoder and Decoder

The scrambled bits are then fed to the Reed Solomon Encoder which is a part of Forward Error Correction (FEC).Reed Solomon coding is an error-correction coding technique. Input data is over-sampled and parity symbols are calculated which are then appended with original data. A Reed Solomon code is represented in the form RS (n, k), where

$$n=2m-1 \qquad (5.1)$$

$$k=2m-1-2t \qquad (5.2)$$

$$t=n-k/2 \qquad (5.3)$$

Here m is the number of bits per symbol, k is the number of input data symbols (to be encoded), n is the total number of symbols (data + parity) in the RS codeword and t is the maximum number of data symbols that can be corrected. At the receiver Reed Solomon coded symbols are decoded by removing parity symbols. Calculate the n, k and t using equation (5.1),(5.2) & (5.3).

5.1.3 Convolutional Encoder and Decoder

Reed Solomon error-coded bits are further coded by Convolutional encoder. This coder adds redundant bits as well. In this type of coding technique each m bit symbol is transformed into an n bit symbol; m/n is known as the code rate. This transformation of m bit symbol into n bit symbol depends upon the last k data symbols, therefore k is known as the constraint length of the Convolutional code. Viterbi algorithm is used to decode convolutional encoded bits at the receiver side.

5.1.4 Interleaver and De-Interleaver

Interleaving is done to protect the data from burst errors during transmission. Conceptually, the in-coming bit stream is re-arranged so that adjacent bits are no more adjacent to each other. The data is broken into blocks and the bits within a block are rearranged. As far as De-Interleaving is concerned, it again rearranges the bits into original form during reception.

5.1.5 Constellation Mapper and De-Mapper

The Constellation Mapper basically maps the incoming (interleaved) bits onto different sub-carriers. Different modulation techniques can be employed (such as QPSK, BPSK, QAM etc.) for different sub-carriers. The De-Mapper simply extracts bits from the modulated symbols at the receiver.

5.1.6 Inverse Fast Fourier Transform and Fast Fourier Transform

This is the most important block in the OFDM communication system. It is IFFT that basically gives OFDM its orthogonality. The IFFT transform a spectrum (amplitude and phase of each component) into a time domain signal. It converts a number of complex data points into the same number of points in time domain.

5.1.7 Addition and Removal of Cyclic Prefix

In order to preserve the sub-carrier orthogonality and the independence of subsequent OFDM symbols, a cyclic guard interval is introduced. The guard period is specified in terms of the fraction of the number of samples that make up an OFDM symbol. The cyclic prefix contains a copy of the end of the forthcoming symbol. Removal of cyclic prefix is then done at the receiver end and the cyclic prefix free signal is passed through the various blocks of the receiver.

VI. SIMULATION RESULTS

Figure 5 Simulation Results of Scrambler

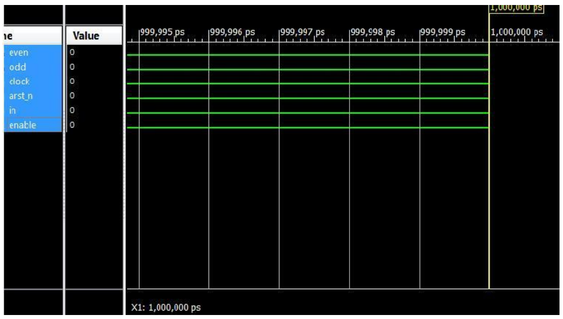

Figure 6 Simulation Results of Convoutional encoder

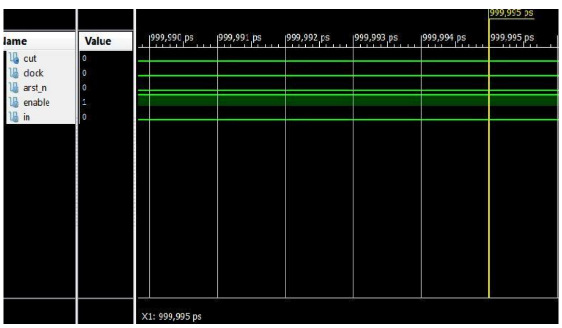

Figure 7 Simulation Results of De-scrambler

VII. CONCLUSION

This paper presents a SDR system using OFDM transceiver. Both the interoperability and adaptability among QPSK and 64-QAM operational modes of the OFOM systems is discussed. OFDM Transmitter and Receiver output is simulated by using XILINX software. Additionally, differences and similarities in data carrying capabilities between QPSK- and 64 QAM of OFDM systems and the associated clock cycles required to demodulate data using FFT programming methods are provided. Higher execution speed is achieved by using this method. The trade off of this optimization is a larger program memory requirement of verilog code. Programming of FFT code and the QPSK-OFDM combination come with a resulting cost associated with an increase in clock cycles, which must be taken into consideration.

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