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Design of DS-CDMA Transceiver using BPSK Modulation/Demodulation

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Abstract: Code Division Multiple Access (CDMA) uses spread spectrum technology where each user is assigned a code and allows multiple users to be multiplexed over the same physical channel. Where as the time division multiple access (TDMA) divides access by time, while frequency-division multiple access (FDMA) divides it by frequency. CDMA is a form of "spread-spectrum" signaling, since the modulated coded signal has a much higher bandwidth than the data being communicated. Now, the Spread spectrum is used in the commercial applications such as, mobile handsets, internet and satellite applications. By using Spread spectrum communication we can achieve the secure communication. In this paper the pure digital BPSK modulation technique is used to implement the CDMA Transceiver. The whole system is implemented only in the digital form, so cost is reduced. This design will makes whole system as a system on chip. All the modules functionality is verified with Modelsim simulation results. Xilinx ISE tools are used for FPGA synthesis. Spartan 3E development board is used for FPGA implementation.

Key words: Code Division Multiple Access (CDMA) · Binary Phase Shift Key (BPSK) · Direct Sequence Spread Spectrum (DSSS) · FPGA · TDMA · FDMA

INTRODUCTION

Over the past five to ten years, communication systems have been developing rapidly especially in the wireless and cellular network arena [1]. As user demand grows, conventional communication systems such as time-division-multiple access (TDMA), frequency-division-multiple access (FDMA) and space-division-multiple-access (SDMA) are becoming inadequate for some application in today's communication requirements. Consequently, a new system called code-division-multiple-access (CDMA) is proposed to replace the abovementioned systems. This new system utilizes the spread spectrum technique where the message signals can occupy both the time and frequency domains simultaneously, thus the system capacity is significantly increased.

The CDMA is a digital modulation and radio access system that employs signature codes (rather than time slots or frequency bands) to arrange simultaneous and continuous access to a radio network by multiple users. Contribution to the radio channel interference in mobile communications arises from multiple user access, multipath radio propagation, adjacent channel radiation and radio jamming. The spread spectrum system's performance is relatively immune to radio interference. Cell sectorisation and voice activity used in CDMA radio schemes provide additional capacity compared to FDMA and TDMA. However, CDMA still has a few drawbacks, the main one being that capacity (number of active users at any instant of time) is limited by the access interference. Furthermore, Near-far effect requires an accurate and fast power control scheme. The first cellular CDMA radio system has been constructed in conformity with IS-95 specifications and is now known commercially as CDMA one.

Today widely used data communication scheme is Spread Spectrum communications. It has many features that make it suitable for secure, multiple accesses and many other properties that are needed in a communication system. Spread Spectrum is a means of transmission in which the signal occupies a bandwidth in excess of the minimum necessary to send the information. The band spread is accomplished by means of a code, which is independent of the data and synchronized reception with the code at the receiver is used for dispreading and subsequently data recovery. It was originally developed for the military under a covering of privacy [2].

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The purpose of coding is to transform an information signal so that it looks more like noise. In the receiver, the incoming signal is decoded and the decoding operation provides resistance to interference and multi path fading. The spreading or dilution of energy in spread spectrum systems over a wide bandwidth results in several possible advantages, short-range interferences-free overlays on their emissions and resistance to interference, from other emissions and low detestability. The low spectral density needed for spread spectrum communication systems, as well as ability of some of these systems.

Technical Work Preparation: The following are the important stages of DS- CDMA system used for transmission and reception of I/O signals:

Spread Spectrum: In Spread Spectrum communication occupancy of bandwidth is high, as a result power spectral density is lower and in the channel the signal looks like noise. The Spreading is done by combining the data signal with a code (code division multiple access) which is independent of the transmitted data message [2]. Spread Spectrum communication is secure communication, without knowing the spreading code, it is (nearly) impossible to recover the transmitted data. There are a couple of Spread Spectrum Techniques which can be used.

Direct Sequence Spread Spectrum: In a DS-SS scheme, the original message symbol (+1 or -1) is multiplied by sequence of codes. These are referred to as the spreading codes. A PN sequence is a binary sequence that exhibits randomness properties but has a finite length and is therefore deterministic. Synchronization is achieved using PN sequence between transmitter and receiver. PN generators are based on Linear Feedback Shift Registers (LFSR). The block diagram of DS-CDMA Transmitter is shown in the Figure 1.

CDMA uses correlation property to receive the signals exactly. In hardware implementation the correlation can be designed multiplier and accumulate (MAC). At the receiver, the same PN sequence which is used in the transmitter is correlated with incoming signal. The Block diagram of the DS-CDMA receiver is shown in Figure 2.

In this paper the pure digital modulation technique is used. In DS-CDMA transmission and reception of the signal can be done using digital modulation technique like BPSK. The BPSK modulation and demodulation is designed purely in digital. The phase accumulator

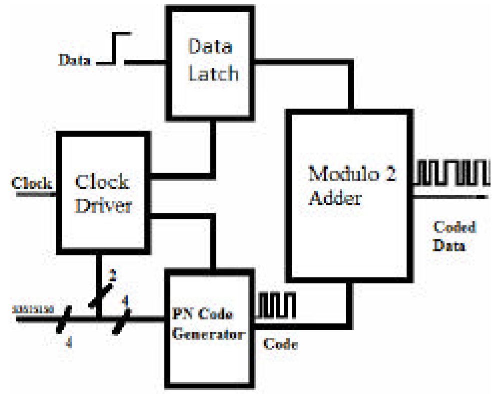

Fig 1: DS-CDMA Transmitter [ref 2]

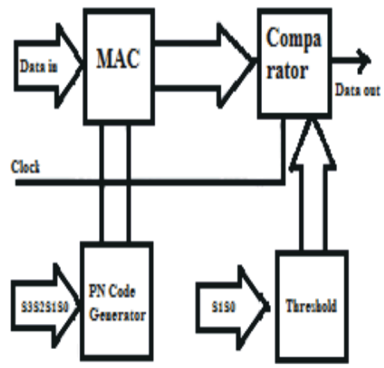

Fig 2: DS-CDMA Receiver [ref 2]

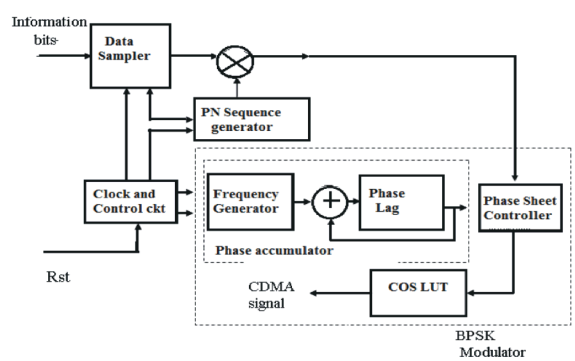

Fig 3: Modified DS-CDMA Transmitter [ref 3]

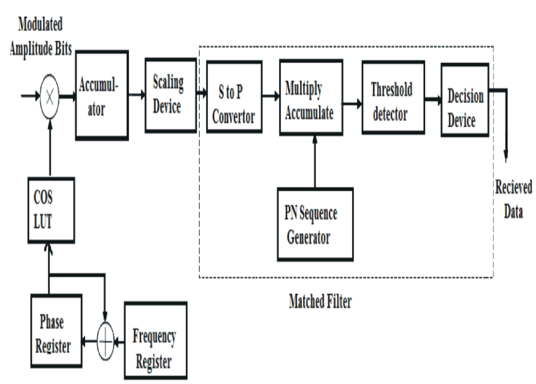

Fig 4: Modified DS-CDMA Receiver [ref 3]

Table 1: Specification of the CDMA Transceiver

S.No.	Component	Description
1.	Type of PN sequence	ML / gold code
2.	PN sequence length	64 in case of ML sequence, 128 in case of gold sequence
3.	Type of modulation	BPSK
4.	Type of demodulation	Coherent BPSK demodulation with 15 output
5.	Type of correlator	Matched filter
6.	Type of signal synthesis	ROM based Direct digital frequency synthesis
7.	front end design entry	VHDL
8.	Backend synthesis	Xilinx Spartan 3E FPGA
9.	Threshold type	constant threshold value, adjustable

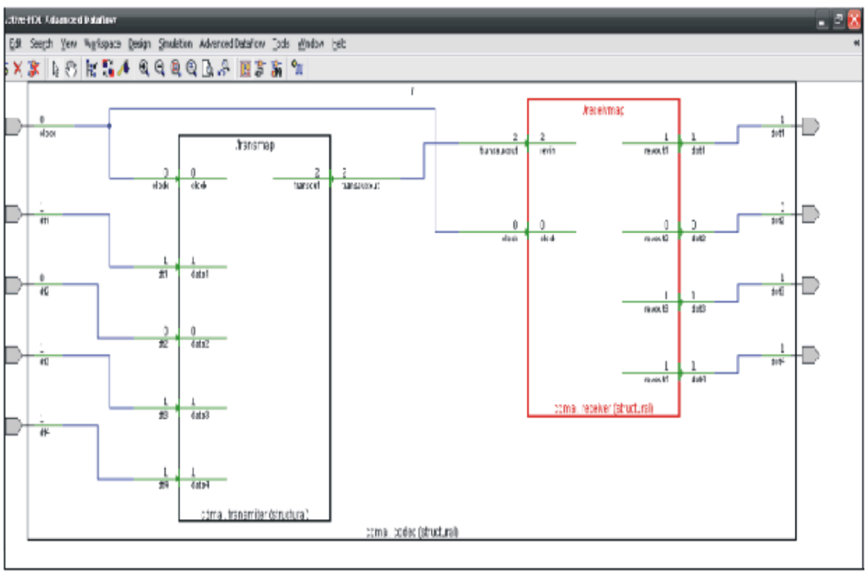

Fig 5: Block diagram of Transceiver

consists of phase increment register, adder and phase register. The phase increment register stores the instantaneous phase increment values. The accumulated phase also is represented by 6 bits, which limits the maximum phase by 111111 and addition by 1 to maximum value causes the phase to become 000000. This is expected and desired since the Look up Tables are programmed to consider 63 as highest phase value and phase increment by one results next cycle of waveform. Since 6 bits are used to represent the 0E to 360E the increment in digital phase value by one causes effective increment of 5.625E (results by dividing 360E with 64 maximum possible combinations of 6 bits). This also implies that outputs can't have more that 64 samples for one cycle. The phase shifter block shifts the instantaneous phase produced by phase accumulator, according to the spreaded bits. Since in DDFS with 6 bit phase representation 32 (100000) corresponds to 180E phase, the phase shifter adds the 32 (100000) when symbol '1' is given and adds 0 (000000) when symbol '0' is given. Phase shifter is implemented by using 6 bit adder. The block diagram of the modified DS-CDMA transmitter shown in the Figure 3.

The DS-CDMA Transmitter is implemented using pure digital architecture. The Direct Digital Frequency Synthesis (DDFS) technique with phase shifting provision is used for the signal generation.

The Figure 4 shows the block diagram of modified DS-CDMA Receiver. Digital coherent BPSK demodulator principle is used in this paper for receiving the DS-CDMA signals. The BPSK demodulator produce 15 (-7 to 7) digital words, unlike in conventional BPSK demodulator which produces only two symbols ('1' and '0'). This is necessary due to the low power spectral density of DS-CDMA signals and it is only possible to detect the information bits after correlation. The accumulator in the receiver corresponds to the integrator in the analog equivalent. The accumulator accumulates the outputs of multiplier for one symbol duration and outputs at the beginning of next symbol. The symbol timing recovery issues are not addressed in this paper, hence the is used.

The Scaling circuit scales input value to 4 bit signed number range, i.e., -7 to +7. The PN sequence generator is same as the one which is discussed in transmitter, except in the output type. In the transmitter side the output of PN sequence generator continuously produces PN sequence on one bit output. But in the receiver side, since the complete PN sequence is required every time for correlating with the outputs of BPSK demodulator it is provided as a parallel vector. Another difference is the ‘1’ of PN sequence is provided as +1 and ‘0’ is provided as -1, which is the required form for correlator. Matched filter based correlator is used in this paper for receiving the DS-CDMA signals. The correlator accepts the demodulator outputs and multiplies with length PN sequence which is a sequence of +1 and -1. The outputs of multipliers are accumulated to produce the correlator output. The magnitude of the correlator output peaks whenever exact match occurs between the PN sequence and BPSK demodulator outputs. The output of the matched filter is given to the threshold detector, for detecting the information bits. The threshold detector compares the magnitude of the correlator output with the threshold value. If the magnitude of the correlator output is higher than the threshold value, then it rises a flag indicating that one bit is detected. If the sign of the correlator output is positive, then it will be interpreted as ‘1’. Otherwise it will be declared as ‘0’. This is the detected information bit.

The transceiver is combination of transmitter and receiver. The transmitter transmits one bit signal with four users at the transmitter end. The receiver gets the input Rvin from the transmitter output and decodes it to produce the output. Block diagram of Transreceiver is shown below.

RESULTS AND DISCUSSION

In direct sequence spread spectrum, each bit in the original signal represented by multiple bits in the transmitted signal, using spreading code (PN code). The spreading code spread the signal across a wider frequency band in direct proportion to the number of bits used. Therefore a 10 bit spreading code spreads the signal across a frequency band (i.e. 10 times) greater than a ‘1’ bit spreading code.

One technique with direct sequence spread spectrum is to combine the digital information stream with the spreading code bit stream using EXORing. Simulated waveform of transmitter is shown in Fig 6 below.

At the receiver end, the incoming signal is multiplied by same spreading code which is used in transmitter to recover the original signal. Simulated waveform of receiver and Transreceiver is shown below in Fig 7 and Fig 8 respectively.

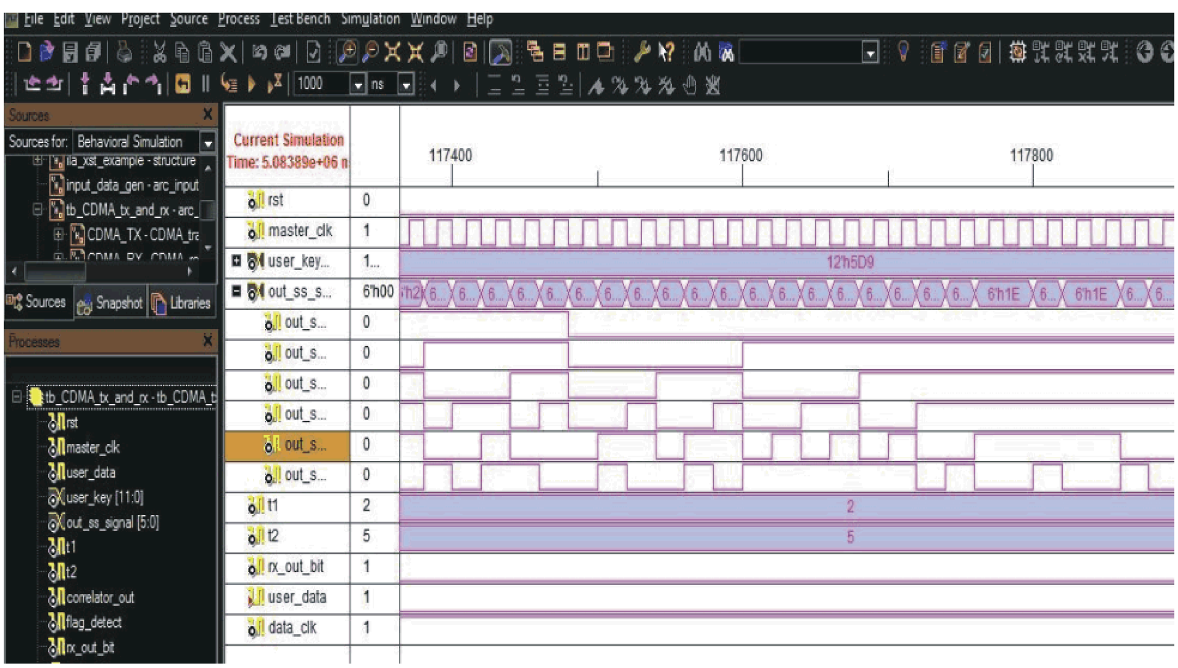

Fig. 6: Simulation result of CDMA Transmitter

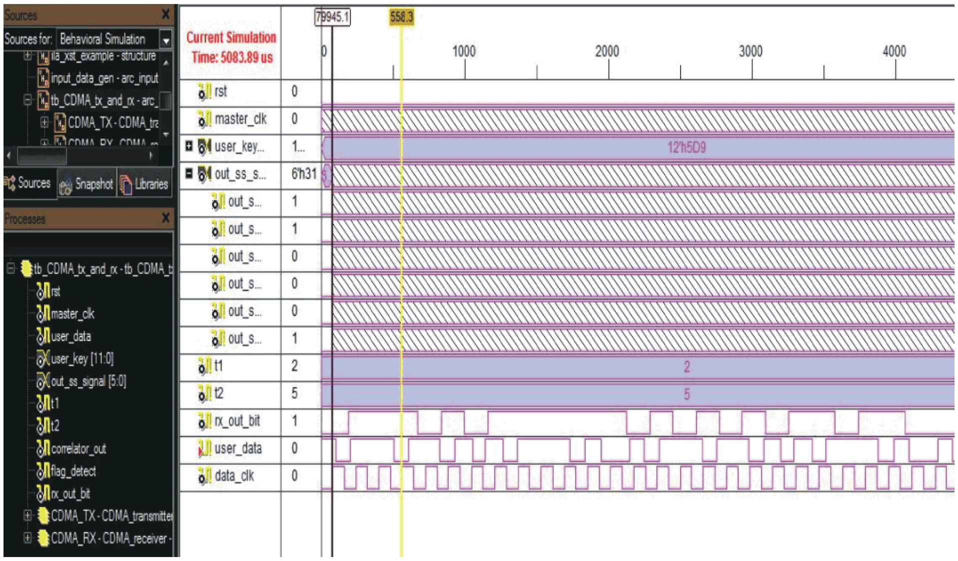

Fig. 7: Simulation result of CDMA receiver

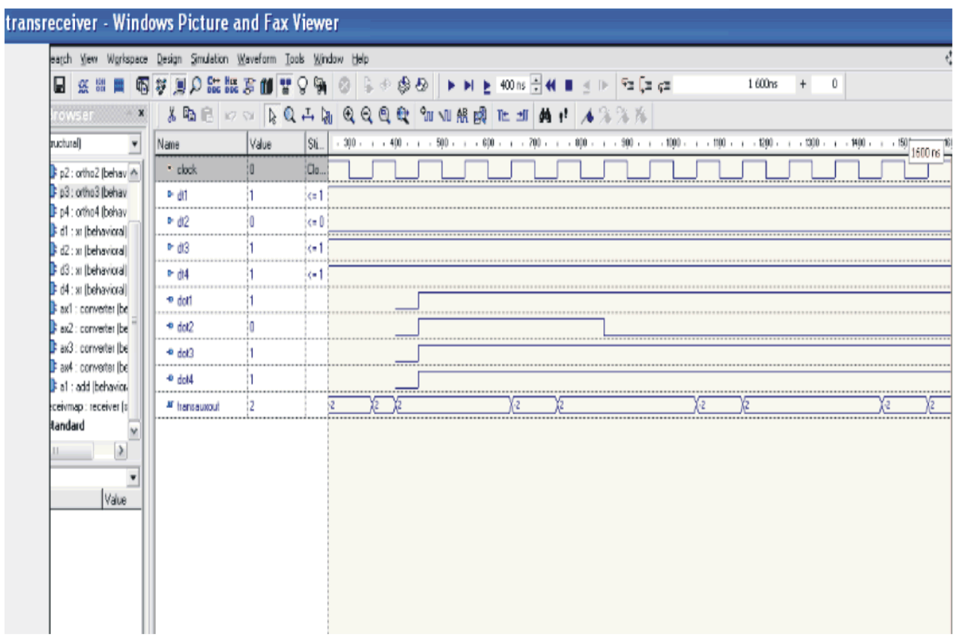

Fig. 8: Simulation result of CDMA Transceiver

CONCLUSION

The BPSK modulation and demodulation is implemented in pure digital form. The Code Division Multiple Access (CDMA) Transmitter and Receiver is successfully designed and integrated together to implement Transreceiver (shown in Fig 8) on Front end tool Modelsim and synthesized by the Xilinx tool and finally implemented on the Spartan board kit.

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