Implementation of Chaotic UWB Systems for Low Rate WPAN

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Abstract *– In order to support ultrawide-band signal generation for low rate WPAN, several types of signal generation mechanisms are suggested such as Chaos, Impluse, and Chirp signals by the activity of IEEE 802.15.4a. The communication system applied chaos theory may have ultrawide-band characteristics with spread spectrum and immunity from multipath effect. In order to use the advantage of chaotic signal generation, we introduce the system implementation of communication and networking systems with the chaos UWB signal. This system may be composed of mainly three parts in hardware architecture : RF transmission with chaotic signal generation, signal receiver using amplifiers and filters, and 8051 & FPGA unit. The most difficult part is to implement the chaotic signal generator and build transceiver with it. The implementation of the system is devidced into two parts i.e. RF blocks and digital blocks with amplifiers, filters, ADC, 8051 processor, and FPGA. In this paper, we introduce the system block diagram for chaotic communications. Mainly the RF block is important for the system to have good performance based on the chaotic signal generator. And the main control board functions for controlling RF blocks, processing Tx and Rx data, and networking in MAC layer.*

Keywords: Ultrawide-band, Chaotic Oscillator, Low Rate WPAN

1 Introduction

The UWB (Ultrawide band) technology has dramatically attracted interesting in recent several years. The UWB systems have several advantages compared to legacy communication systems such as spreading effect similar to noise-like signal and resistance to severe multipath environment. As a result of activity in IEEE WPAN working groups [1] (IEEE 802.15.3a, IEEE 802.15.4a), standards are proposed to apply both of high speed and low speed applications.

The signal generation of UWB signals can be categorized in vearious ways according to IEEE 802.15.4a proposals. First, the impulse generators are the most well known technologies which use in nanosecond pulse width in time domain. Second, chirp signals, used in radar system for decades, can be applied to generate the UWB signals. Third, the chaos behavior is used to make an oscillators by electrical circuits as well as theory.

According to the chaos theory, one of the interesting chracteristics of implementing oscillators is that it may generate pure noisy singal, which can not be repeated without knowing exact system parameters, similar to spread spectrums. From 1980's, there are several research papers are published realted with electronic circuits using chaos attraction. Among them, the Chua has introduced a extensively analyzed results of chaotic circuits and system with Chua's oscillator [2]. However, it is impracticable to the real systems implementing the wanted properties. In order to overcome this drawback, self-excited oscillating systems for chaos generators are suggested using ring oscillating systems with Filters and a nonlinear device [3]. These results enabled us to control the parameters of chaotic oscillators, especially for wideband applications. In paper [4], the practical implementation of chactic oscillators is introduced according to the theory of [3], which shows the possibility to make ultrawide band spectrums. With these theoretical backgrounds, direct chaotic communication systems are introduced in [5]. This paper presented the experimental results of implementing wireless communication systems using direct modulation and demodulation of chaotic signals without up and down frequency converters.

Our main contributions of this paper is that chaotic oscillator for ultrawide band between 3.1-4.9GHz is implemented with two differential amplifiers, and chaotic UWB communication systems with PHY and MAC functions as a prototype. In this paper, we introduce the direct communication systems with ultrawide band chaotic oscillators generating 3.1-4.9GHz spectrum. First, the chaotic UWB system blocks are explained. Secondly, the chaotic RF blocks are investigated more deeply considering subfucntions. And then, the experimental results of implementing the systems are measured and finally we state concluding remarks.

2 Chaotic UWB System

Chaotic UWB system is composed of four blocks: Transmitter, Receiver, Antenna, 8051 & FPGA processing. For transmitting the modulated data, chaotic oscillator generates continuous noisy-like signals and modulated directly with the data according to the signal strobe form 8051&FPGA processing block. And then the signal is amplified to have maximum power output satisfying the FCC regulations. The Tx and Rx data paths are selected by the switch and passed through wideband antenna. The BPF (Band Pass Filter) actually rejects the unwanted frequency for the received signal. In the receiver block, the signal is amplified using two stages of LNA (Low Noise Amplifier) to increase the signal level and relatively reduce the noise level. Then the detector converts the power level into the voltage level in order to enable the ADC to digitize accepted signal. Finally 8051 & FPGA block process digital logic and system control functions.

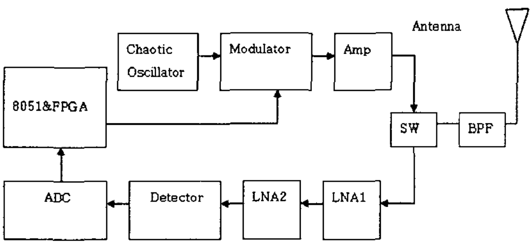

Figure 1. Chaotic UWB system block diagram

3 Chaotic RF Blocks

For low rate WPAN system, Chaotic UWB systems need several technical requirements. Since FCC in USA has established the UWB signal regulation, the bandwidth should be satisfied by their specifications at least. Therefore, the bandwidth for the chaotic UWB is selected between 3.1-4.9GHz. And the maximum power level is set below -43.0dBm/MHz. And they should support the link transmission rate 1kbps and aggregate transmission rate 1Mbps for the networking of the system

3.1 Chaotic Oscillator

According to the ring oscillator implementation [3], chaotic oscillator should be comprised of at least one nonlinear device and a Filter to form a feedback loop. In order to make ultrawide band signal, however, it is not easy to control the peak spectral element in the oscillator. In Figure 2, Chaotic UWB oscillator is implemented with differential amplifiers working as nonlinear device, and Band Pass Filter selecting the resonant frequencies. In order to control the chaotic properties of the system, three variable capacitors are adjusted to produce wanted spectrum.

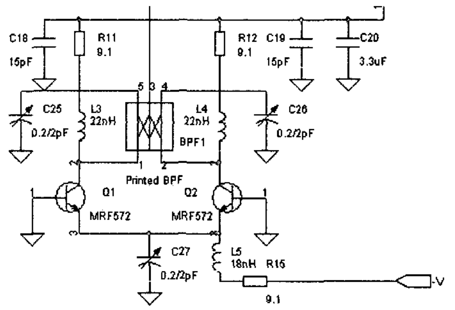

Figure 2. Chaotic UWB oscillator

After tuning the variable capacitors, chaotic UWB spectrum is given as following Figure 3. For the BPF, since we used 9 order filters, there are several peaks arising in band period and shaping frequency band. However, spectrum itself is not uniformly distributed.

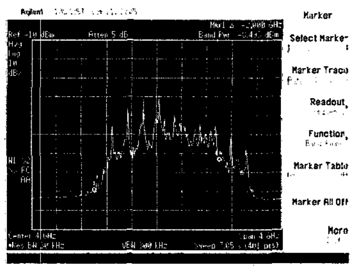

Figure 3. Power spectrum of chaotic UWB oscillator

If the waveform is measured in time domain, it does not show any sinusoidal component in each time, but abruptly changes phases as time going on. This effect forms a fundamental characteristic of chaotic signals which can be considered noisy like spectrum.

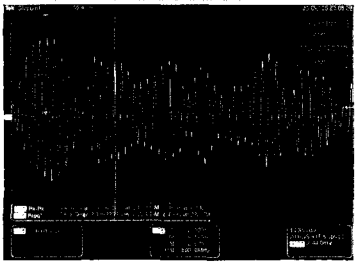

Figure 4. Waveform of chaotic UWB oscialltor

3.2 Modulation

Since our system basically applies the ON/OFF keying modulation and demodulation, if there are continuous 0 sequences, it may have a difficulty in finding the time synchronization for bit data. Therefore, we use simple coding scheme i.e. "1010" sequence for "1" data, and "1000" sequence for "0" data. Direct modulated sequence is captured in Figure 5. Considering the ON state, the peak value is not constant because chaotic signal itself does not have regular amplitude level.

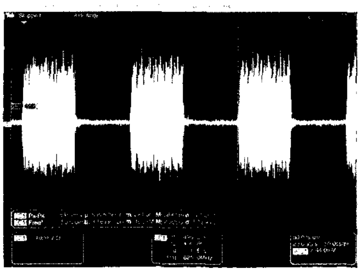

Figure 5. Modulated signal of chaotic signal

3.3 Band Pass Filter

One of the important components in receiving signal is the BPF rejecting unwanted spectrum component. In order to build wideband receiver, 9th order BPF is implemented. The simulated power spectrum of filter is given in Figure 6. The simulated results show that insertion loss is 3.5dB.

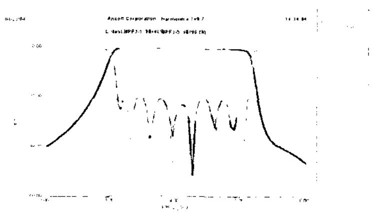

Figure 6. Simulation of BPF power spectrum

3.4 LNA Blocks

Received signal should be amplified and suppress the noise to have enough gain. The gain of the LNA b:ock is set about 32 dB and the noise figure is 1.9dB using two stage LNAs. The simulated LNA power spectrum is shown in Figure 7.

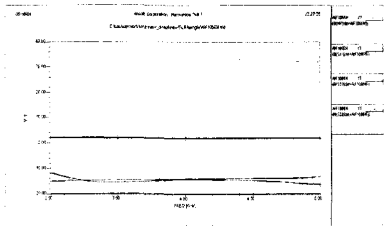

Figure 7. Simulation of LNA power spectrum

4 System Implementation

In implementing the chaotic UWB system, it is separated with two boards: one contains RF blocks, and the other contains Digital control block including ADC, 8051 processor and FPGA.

The implemented chaotic UWB RF blocks are presented in Figure 8. The antenna, designed by ETRI, has devised to operate in UWB band (3.1-11.5GHz). BPF is implemented with 9th order inter digital filter on the epoxy substrate as FR4. The switch, which changes Tx and Rx mode by the signal from the FPGA, uses HMC232LP4 produced by Hittite company. For two stage LNAs, MGA-86576 by Agillent and HMC315 by H:ttite are connected by a cascade. Finally the Detector, which converts the power signal into voltage signal, is AD8318 by Analog Devices, which operates between 0.001-8GHz frequency band, and in the range between -60~-5dBm power levels at 3.6GHz frequency.

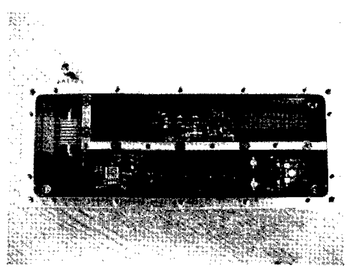

Figure 8. Implementation of Chaotic UWB RF blocks

The digital control blocks perform digital data converting, system control, and data processing for PHY/MAC. For the operation of system, we do not use OS and the tasks are achieved by the interrupt handling procedures of 8051 processor. The MAC function follows the IEEE 802.15.4

standard. The overall integrated system is demonstrated in Figure 9

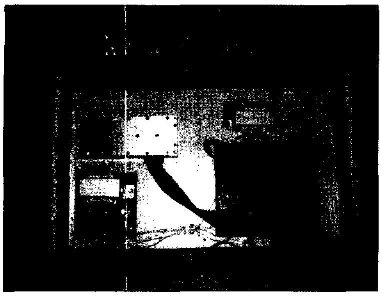

Figure 9. Chaotic UWB system

4.1 Experimental Results

The system performance is basically measured by Packet Error Rate (%) according to interesting parameters, such as distance, interference, and so on. Transmission distance is determined by the sensitivity of the system. Since the maximum power level of detector is -65dBm, this sets the power limits of the system. After all, the measured bottom power level of the system is about -45dBm. With these system parameters, if we measure the Packet Error Rate by the distance, maximum 2.8 m transmission can be achieved.

5 Conclusions

This paper presents the implementation of chaotic UWB systems for wireless communications. The main contributions of this paper are implementation of chaotic oscillator with 3.1-4.9GHz and building the RF blocks considering the ultrawide band operations. However, since the RF components are not optimized for the chaotic UWB communications, relatively the transmission range is short, which is further study field.

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