FPGA Implemention of UWB-IR Receiver for In-body to Out-of-body Communication Performance Evaluation

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Abstract

For designing an optimized transceiver structure of ultra wideband (UWB) transmission in in-body to out-of-body communications, it is necessary to make the transceiver structure be easily adjustable in order to realize a good communication performance in an experimental environment. For this purpose, we first implement our develop UWB-impulse radio (IR) receiver structure for the in-body to out-of-body communication in a field programmable gate array (FPGA) board, and evaluate the fundamental performance of the FPGA-implemented UWB-IR receiver by a biological-equivalent liquid phantom experiment. The FPGA configuration results indicate that our FPGA realization of the UWB-IR receiver has accomplished quite few FPGA slices without any communication performance degradation. Moreover, the evaluation result in the liquid phantom experiment shows that the FPGA-implemented UWB-IR receiver can achieve a bit error rate (BER) of 10^{-3} up to a communication distance of 70 mm with ensuring a high data rate of 2 Mbps.

1. Introduction

Wireless body area networks (BANs) are attracting much attention as a promising technology in health care and medical applications [1][2]. The in-body to out-of-body communication plays an important role in wireless BANs because it can transmit various vital signals and image/video data from the inside of human body to the outside medical equipment. Some typical applications include wireless cardiac pacemaker and wireless capsule endoscope. The former requires a highly realiable communication performance for vital signal monitoring, and the latter requires a higher data rate for real-time image transmission. In order to fulfill the above requirements, we have developed an ultra wideband (UWB)-impulse radio (IR) transceiver for the in-body to out-of-body transmission [3], but the optimization of the transceiver structure remains to be accomiminished. In this paper, we aims to implemen the UWB-IR receiver structure in a field programmable gate array (FPGA) board, which can make us be easily to investigate various demondulation schemes so as to realize an optimized receiver structure. With the FPGA-implemented UWB-IR receiver, we experimentally evaluate the communication performance of our UWB-IR modulation/demodulation scheme in a biological-equivalent liquid phantom.

2. FPGA Implementation of UWB-IR Receiver Structure

The transmitter employs a multi-pulse position modulation (MPPM) scheme with several UWB-IR pulses. The pulses have a time width in the order of tens of nanoseconds and a frequency band from 3.4 to 4.8 GHz, i.e., the UWB low-band. The receive employs energy detection (non-coherent detection) scheme for demodulating the MPPM signal because of its low power consumption. The detailed transmiter and receiver structures are shown in [3], and the optimized energy detection period was experimentally found to reach a good demodulation performance. Fig. 1 shows the overview of the FPGA configuration for implementing the UWB-IR receiver. The impleanted UWB-IR receiver mainly consists of three components, that are a memory module, a synchronization module and a detection module. In the memory module, the received signals are converted into squared values to calculate the energy and are then stored in shift registers. The synchronization module estimates the symbol timing by using the received UWB-IR signals based on the cross-correlation between the received signal and the pulse detection intervals. Since the binary MPPM chooses one from two location assignments for bit information of “0” and “1”, the detection module calculates two kinds of energies of the received signal for the corresponding pulse locations at the symbol timing estimated in the synchronization module. According to the comparison result between the two energies, the detection module determines the transmitted bit information.

The circuit design of the UWB-IR receiver structure was developed in Verilog-HDL language, and the developed circuit was configured on Xilinx Virtex-6 FPGA board (XC6VLX204T-1FFG1156FPGA). Table I shows the

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results of the FPGA configuration. As can be seen from Table I, our FPGA realization of the UWB-IR receiver requires quite few FPGA slices. So, the implemented UWB-IR receiver can be realized with extermely simple structure.

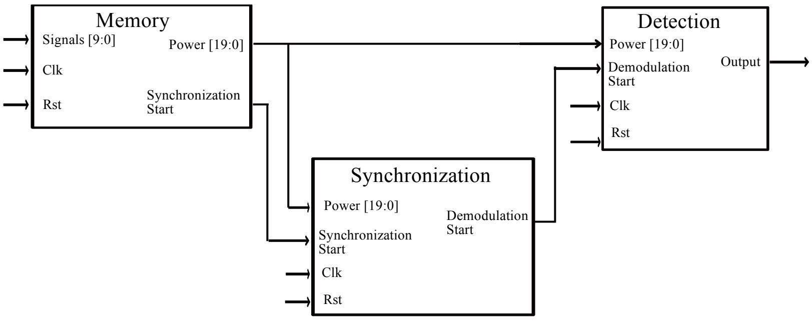

Fig. 1 Overview of FPGA configuration.

Table I FPGA configuration results

Slices	Available	Used
Registers	301440	10049 (3%)
LUTs	150720	17918 (11%)
LUT-FF-pairs	77794	2711 (10%)
IOB	600	71 (11%)
BUF	32	2 (6%)
DSP48E1	768	1 (0.1%)

3. Performance Evaluation Experiment with Liquid Phantom

We then performed experiments for evaluating the fundamental performance of the implemented UWB-IR receiver. For this purpose, we measured the bit error rate (BER) performance of the UWB-IR transceiver in a biological-equivalent liquid phantom simulating a human body. Fig. 2 shows the measurement setup with the liquid phantom. A loop-type UWB low-band antenna was inserted in the liquid phantom and connected to the UWB-IR transmitter at outside of the phanotom through a semirigid cable. The receiving antenna was a planar UWB low-band antenna. It was placed on the phantom surface and connected to the FPGA-implemented receiver through a RF frontend consisting of an amplifier, a frequency down-conveter and a low pass filter. We measured the BER performance as a function of distance between the transmitting and receiving antennas, and show the results in Fig. 3. For comparison, we also show the results for a simulated receiver developed in C language in Fig. 3. Note that the FPGA-implemented receiver performs only fixed-point calculation, whereas the simulated receiver deals with floating-point calculation. As a result, we can see from Fig. 3 that the difference between the both receivers is significantly small, so it is concluded that our FPGA implementation of the UWB-IR receiver has been successfully realized without any BER performance degradation. Furthermore, as seen from Fig. 3, the BER performance of approximately 10^{-3} is accomplished at the distance of around 70 mm with the data rate of 2 Mbps. The achievable BER performance of around 10^{-2} to 10^{-3} means that it is possible to obtain an error-free BER if we adapt an adequate forward error correction code. This error-free BER satisfies the requirement for almost all in-body to out-of-body communication in medical applications. Therefore, the FPGA-implemented UWB-IR receiver can establish a reliable communication link up to 70 mm at a date rate of 2 Mbps in the biological-equivalent liquid phantom.

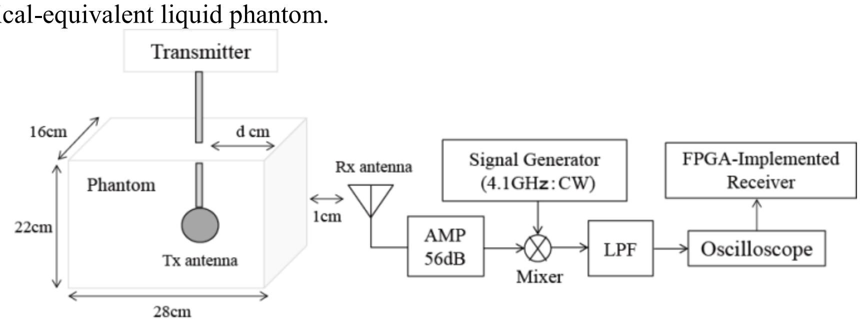

Fig. 2 Phantom experiment setup.

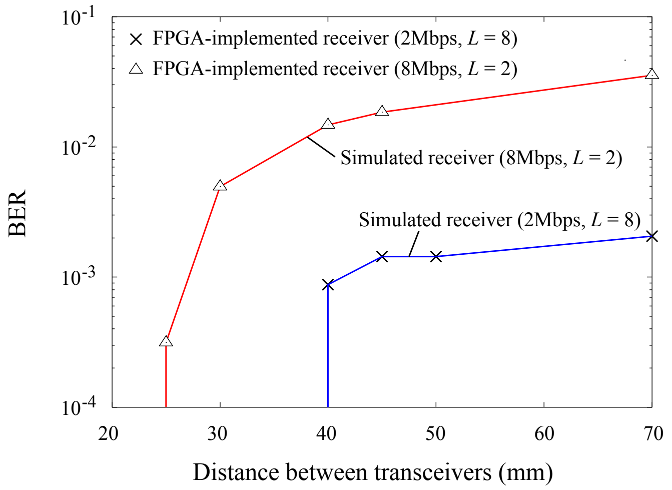

Fig. 3 BER performance for FPGA-implemented receiver.

4. Conclusion

This study has implemented our previously developed UWB-IR receiver structure in an FPGA board, and has evaluated the fundamental performance for the FPGA-implemented UWB-IR receiver by a liquid phantom experiment. The result of the FPGA configuration indicates that our FPGA realization of the UWB-IR receiver has accomplished quite few FPGA slices without any BER performance degradation. Additionally, the FPGA-implemented receiver can achieve a BER performance of 10^{-3} up to a communication distance of 70 mm with ensuring a high data rate of 2 Mbps. Such an FPGA-implemented receiver provides a significant convenience for optimizing the receiver structure in an experimental environment. Our future subject is to further improve the transceiver performance in actual in-body to out-of-body communication environment with the FPGA-implemented receiver.

References

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