A Software Defined Radio for Time of Flight Based Ranging and Localization

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1. INTRODUCTION

Time of Flight (ToF) ranging methods are quite complicated ranging methods, but their precision and ability for mitigating the effects of multi-path propagation are superior compared to power decay (received power) measurement methods. Due to the strict timing requirements of the ToF methods, precise timing should be done in hardware, which on the other hand limits the use of Software Defined Radio (SDR) platforms.

The main idea in this work is to do the necessary changes to the SDR hardware (the FPGA), so it can support precise timing needed for ToF measurements.

2. APPROACH

Two Way Ranging (TWR) methods can be efficiently implemented because they do not require strict time synchronization of the stations involved in the ranging procedure, or generally in positioning procedure. Since in TWR methods one station serves as an active reflector, it is needed to implement the active reflection functionality in the SDR's FPGA. The second functionality needed is a mechanism that would record the reflected signal, from the distant station, and transfer the data to a personal computer, for further processing of the received signal. Of course, precise time measurement between the transmission of the ranging signal, and recording of the reflected copy, should be implemented in hardware since precise measurement of this time is not possible in software.

In this work, the USRP N210 software defined radios (from Ettus Research) are used. They use a Gigabit Ethernet interface to connect on a personal computer. The data from the A/D converter and to the D/A converter is transfered using this interface. The latency, from sampling to transferring the data to the PC is 1-2 ms in the best case.

Because of the huge latencies, a special hardware, in the FPGA of the SDR, for data buffering, is required. This hardware consists of block ram memories for the sequence that should be sent for ranging and also for receiving the reflected sequence. Control logic and a synchronizer are also implemented, for detecting the ranging sequence. A numerical controlled oscillator (NCO) and CORDIC processor are inserted both in the RX and TX datapath, for fine tuning of the frequency. After the ranging sequence is sent from the first station, it is reflected from the second station and received and stored in the RAM of the first station. The received sequence is then transfered to a PC, where the precise calculation of the distance is performed.

The system consists of a few USRP N210 radios, used as anchor nodes, and one USRP N210 used as a mobile node. The positions of the anchor nodes should be known in advance, if absolute positioning is required. The anchor nodes serve as active reflectors, so they do not need a PC for data processing. Different analog frontend daughterboards can be used, but the maximum bandwidth of the available boards is 40 MHz. The sampling rate of the A/D and D/A converters is 100 MSps, for I and for Q channels.

3. CONCLUSIONS

Since the main processing is done on a PC, different algorithms can be tested and compared. With fine tuning of the parameters of the system, the expected accuracy for ranging and positioning is estimated to be below 1 m. The ranging procedure takes quite short time, since the ranging sequence used is not longer than 1024 chips. Due to the short measurement time, averaging can be used, for further improving the ranging precision.