Ultrasonic Communication through Solid Channels with OFDM

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Background, Motivation, and Objective

Using ultrasonic signal for communication is an alternate solution when electromagnetic waves are not feasible for carrying the information through the channel. Ultrasonic signal can be used to conduct communication in different channels such as solid, gas and liquid. A practical scenario for using the ultrasonic signal for communication is in nuclear facilities. The nuclear reactors are sealed and shielded with reinforced concrete with pipes goes in and out for heat exchange. This arrangement blocks electromagnetic waves for communication. Ultrasonic transducers can be attached to these pipes for communication purposes. In this study, we focus on ultrasonic communication through solid channels. Orthogonal Frequency-Division Multiplexing (OFDM) is used to improve the performance of the communication in solid channels such as plates, pipes, and blocks.

Statement of Contribution/Methods

For this study, a Software Defined Ultrasonic Communication (SDUC) platform is designed and implemented to conduct an array of ultrasonic communication experiments. A ZYNQ System-on-Chip (SoC) with both ARM A9 processor and FPGA is used as the main controller. In this system, Digital Down Converter (DDC) and Digital Up Converter for signal modulation and demodulation are based on FPGA within the ZYNQ SoC. The ARM processor running Linux based operating system is used to transmit and receive the baseband signal to and from the FPGA accelerators. Power amplifier on the transmitter side and low-noise amplifier on the receiver side are utilized to improve the Signal-Noise-Ratio (SNR) of the communication. The ultrasonic communication is conducted by guiding the ultrasonic wave into a metal plate though oblique angle wedges. By this arrangement, Rayleigh surface wave or LAMB wave can be generated to carry the information through the solid channels. The characteristics of different wave modes in a metal plate are studied to improve the performance of the communication. An anti-multipath communication technique called OFDM is used to obtain better communication quality and a higher bit rate.

Results/Discussion and Conclusions

With the SDUC system that we have built, we can conduct experiments for ultrasonic communication. The system can also scan the frequency response of the channel setup. OFDM is used to improve the communication quality. In the test configuration, the ultrasonic signal is transmitted through a 50 cm long solid aluminum bar with oblique angle wedges, and a solid plexiglass cylinder. Piezoelectric transducers with the center frequency of 2.5 MHz are used to transmit and receive the OFDM ultrasonic waves in the cylinder. The bit rate of this test can reach up to 1.5 Mbps. The result shows that OFDM ultrasonic communication can offer higher bit rates and lower bit error rates compared to other modulation methods.