A Data Communication System Using Ultra Wideband (UWB) Technology

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Abstract

The main objectives of this project are to broaden basic knowledge of UWB wireless communications systems, and in particular, gain in-depth understanding of circuit design and performance of UWB systems. Using an input source of a data stream, a UWB based transmitter modulates the input signal into a UWB pulsed signal. A hardware-based receiver is to be designed to reconstruct the received UWB signal. The results of solving design issues and system performance will be discussed.

Keywords: Ultra Wideband, high data rate, wireless communications systems.

1. Introduction

Since its inception in the early 1960’s, UWB technology was primarily known for military applications1. In recent years, extensive research and development efforts have been put into exploiting this technology for commercial applications. Due to its high bandwidth for data communications, together with its immunity to multipath and low power transmission characteristics, Ultra Wideband (UWB) technology has attracted more and more researchers’ attention on its potential applications in communications. These applications include high data rate communications systems, medical imaging, and object detection2,3. Investigations have been conducted on the issues related to different aspects of UWB technology such as interference with other networks2, and pulse optimization techniques3.

The reason for the slow progress in UWB technology stems from the FCC regulations on its use. In 2003, the FCC finally allotted bandwidth, in the range of 3.1 to 10.6 GHz, for UWB in commercial markets (previously, only military was allowed to use UWB at given frequencies). The primary concern of the FCC was interference issues with GPS systems and other devices operating near the 3 GHz frequency range4. With the lift of this regulation, some companies have begun work on UWB based data communications systems, as well as other fields of interest. UWB could be used in solving the last mile problem of present data communications systems. This research project’s goal is to examine the basic principles of UWB technologies through the creation and testing of primitive circuit boards.

2. Design Methodology

In our design, a radar system, based on McEwan’s patent5 and Staderini’s UWB tutorial6, is modified to accomplish the data transfer. Figure 1 shows our transmitter design. The transmitter consists of an oscillator, pulse generator, a power amplifier, and an antenna. The oscillator generates a pulse train that determines the Pulse Repetition Rate (PRR). The pulse generator produces transmission pulses whose width primarily determines the bandwidth of the transmitted signal. The pulses are modulated by the digital information signal. Because this is a conceptual design, we used generic electronic parts to build a system with the PRR at 3.5 MHz. The transmission pulse width is designed at 8.3 ns, which spreads the modulating signal to a bandwidth at approximately 120 MHz. It is worth mentioning that the relative low PRR poses a limit on the transmitted data rate. This is due to the fact that sampling rate of our receiver is based on the PRR. Detailed analysis is provided in the following paragraphs.
Figure 2 shows our designed receiver. The receiver is comprised of an antenna, a delay line, a sampling circuit, an integrator, and an instrumentation amplifier (also acting as a bandpass filter). From the antenna, the signal is sent to the sampling circuit. Our circuit is designed to sample 10,000 samples per period of the received signal, and the integrator averages these samples to reconstruct the message signal. Because we use a delayed copy of the pulse train from the transmitter as our sampling pulses, the relatively low PRR limits our transmission data rate.

Once the message signal is detected, it is then sent to the instrumentation amplifier. The amplifier is constructed to act as a bandpass filter as well as an amplifier. The filter will remove the high frequency contents of the reconstructed signal, hence leaving the low frequency baseband message at the output of the amplifier.

Even though the prototype can only be used for low data rate transmission, the concept is demonstrated with this design. The results are presented in the next section. The circuits can be scaled to accommodate higher data rate by increasing PRR and reducing number of samples for signal reconstruction. These strategies will be discussed in a later section.
3. Results

Figure 3 shows the unmodulated UWB pulse train. A repetition rate of 3.44 MHz is achieved. This frequency can be increased by replacing the feedback capacitor in the oscillator segment of the transmitter. However, by changing this capacitor, it was found that the output signal became distorted. For testing purposes, the repetition rate was kept at a manageable frequency.

![UWB pulse train](image)

UWB bandwidth is primarily determined by the transmission pulse width. Figure 4 illustrates the pulse shapes achieved by this system. A bandwidth of approximately 120 MHz is accomplished. While the bandwidth can be further increased by reducing the pulse width, it was decided to use a smaller bandwidth for the sake of concept demonstration.

![UWB monopulse](image)
This pulse train is modulated by the information signal for transmission. Figure 5 shows the UWB signal modulated by a 10 Hz ramp signal. The smearing of the pulses indicates the modulation, while the center pulse is synchronized by the oscilloscope.

Figure 5. Transmitted UWB signal

Figure 6 shows the modulated signal and the unmodulated UWB spectrum. When modulation is added to the transmitting signal, the bandwidth of the system can be viewed as covering a very wide span.

Figure 6. Spectrum of the modulated vs. unmodulated pulse train
Figure 7 shows a screenshot of the transmitted and recovered signal. As can be observed, an unfiltered version of the transmitted ramp pulse train is recovered. Clear transitions of the received signal corresponding to the transmitted signal can be extracted by filtering out the high frequency components of the recovered signal. This process is trivial and can be accomplished by the previously described instrumentation amplifier.

Figure 7. Original data signal (top) versus the recovered ramp function at the output of the receiver (bottom)

4. Conclusions and Future Work

While the system as a whole did not perform as originally expected, the primary goal of this senior project has been fulfilled by the successful implementation of this point-to-point UWB system. A good understanding of the theory of operation of a basic UWB system has been gained through this experiment. Because of the selection of generic electronic parts and limited layout and tools experience, as well as time limitations, the data rate and the operating frequency range are not as high as expected, nor is the spectrum spread as wide as we had originally planned. With simple hand-made dipole antennas, which heavy loss is expected, a 10 feet transmission range is achieved, which is adequate for testing the basic operations of UWB. For a first-run system on a topic such as UWB, which has much research left to be done, this project is a great start. This project, as a whole, has been a tremendous educational experience and provided us with the knowledge and tools needed to further our potential as engineers.

For future work, two transceivers have been purchased from Time Domain Corporation that will allow further research into UWB. These transceivers are programmable to allow for multiple applications including data communications. Software is already included that will aid in determining key factors in radio communications, such as signal to noise ratio, bit error rate, and signal strength. Work with these transceivers will link this project to the next step in our investigation of UWB.

5. Acknowledgements

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6. References


6. Enrico M. Staderini, “Everything you always wanted to know about UWB radar…: a practical introduction to the ultra wideband technology,” (Online Symposium for Electronics Engineers).