Flood Level Monitoring System using Magnetic Induction Antennas

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ABSTRACT

As weather patterns are becoming more unpredictable, there is a need to develop countermeasures to prepare for such disasters. This project focuses to improve and organize communication for Search and Rescue teams. This device reads and collects water levels. Collected data is sent wirelessly via Magnetic Induction antennas connected to software-defined radios. Data collected from the sensors is modulated onto a carrier wave. The receiver demodulates the wave to acquire the initial sensor readings. We established direct wired communication which shows data is being transmitted and received. We modulated and demodulated the signal using Amplitude Modulation(AM). We implemented the Magnetic Induction antennas and monitored the behavior. Results suggest that data can be sent and received successfully from one serial device to another with minimal interference. The device is cost-effective, durable, and transmits data over long distances, allowing it to replace current water level sensors. This research study serves to inform the general public, housing developers, and public safety officials about the advantages of using this product.

INTRODUCTION

- Hurricane Harvey caused major flooding across many areas of Houston, Texas. Search and Rescue teams had difficulties assessing and prioritizing areas based on the amount of flooding and relied on good samaritans for help.
- We created a device using Arduino and two sensors which collects water levels both directly and through non-contact. We researched a method of transmitting this asynchronous data wirelessly and over long distances while maintaining data integrity using LabVIEW software.
- Data transfers needed to occur over Radio Frequencies (RF), so we used a software defined radio to establish communications.
- USRP (Universal Software Radio Peripheral) is a device we used to transmit and receive data on RF. Figure 1 below shows the block diagram of this device.

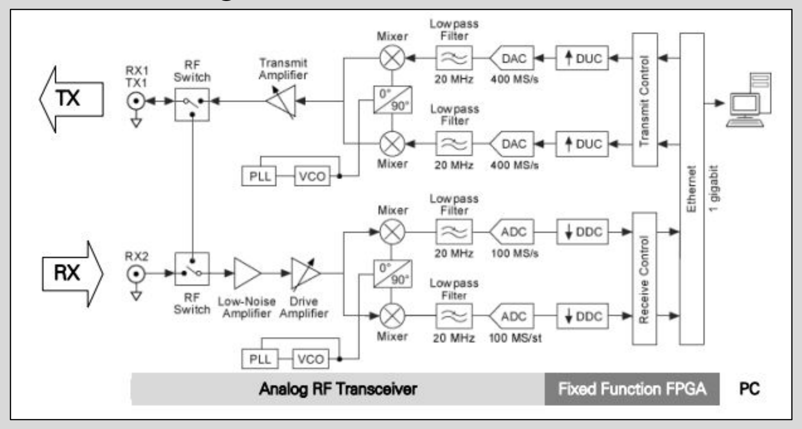
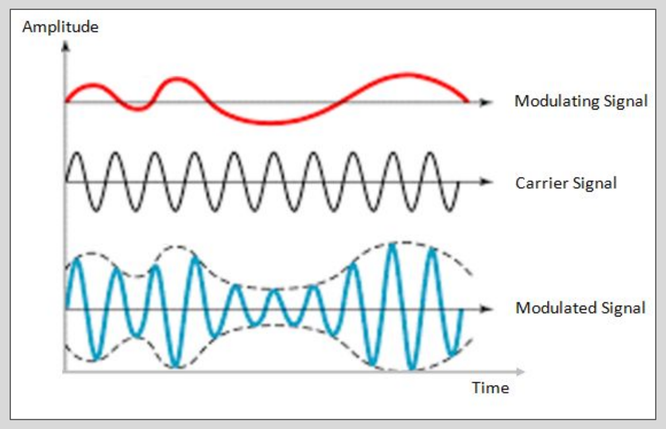


Figure 1: Block Diagram of the USRP
Major components of this software radio peripheral is the transmitter and receiver nodes. This device allows data to be transmitted along radio frequencies and has the capabilities to support wireless transmission with the Magnetic Induction Antennas.

- Magnetic Induction antennas are low frequency which allows for long distance communication. Also, Magnetic Induction antennas have the capabilities to work above ground and underwater.
- In order for asynchronous data, such as water level readings, to be transmitted, this data has to be modulated with another constant signal.
- Modulation is a technique used to manipulate a constant waveform in a way such that the signal can be demodulated or extracted to obtain a stream of data. Figure 2 displays an example of how modulation works.

Figure 2: Example of Signal Modulation
Data Signal (red) is obtained, and a Carrier Signal is generated with fixed amplitude and frequency. Data Signal is modulated with the Carrier Signal using a formula which forms the final Modulated Signal which is sent and demodulated at the other end. For Amplitude Modulation, the formula is A=C+M(t), where A is the new amplitude, C is the Carrier Signal, and M(t) is the Data Signal.



- There are many types of modulation techniques (i.e. Amplitude Modulation, Frequency Modulation, Phase-shift Key Modulation etc.). Amplitude Modulation works best at low frequencies.

RESULTS

- Data from the direct contact sensor was collected using LIFA toolkit in Labview. LIFA is a LabVIEW package which allows Labview to collect and display Arduino data.
- Figure 3 shows a sample collection of Arduino data in Amplitude vs Time.
- For modulation to occur, a Carrier Wave needs to be generated which is used to modulate the data collected by the Arduino sensor. The Carrier Wave is a sine wave with an amplitude of 1 as shown in Figure 4.

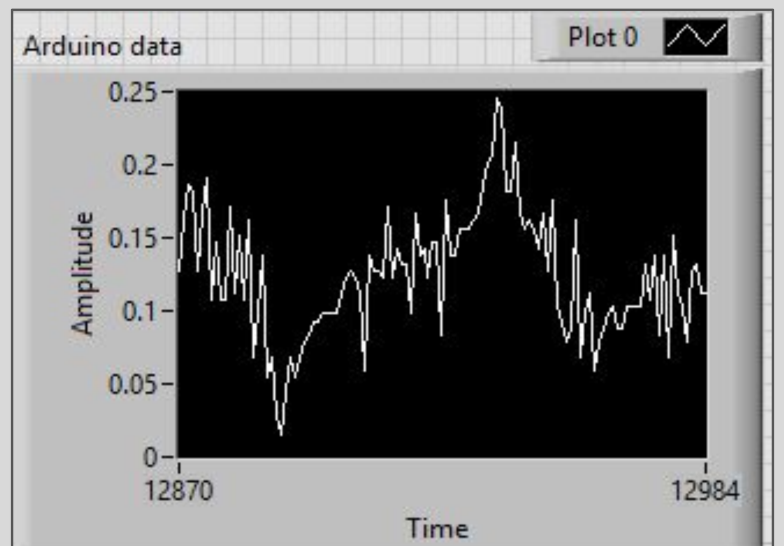


Figure 3: Sample of Arduino Water-Level Sensor data
This figure displays readings from the Arduino Water-Level sensor. The graph compares Amplitude (in Volts) versus Time. The data is asynchronous, which means that it needs to be modulated before being sent.

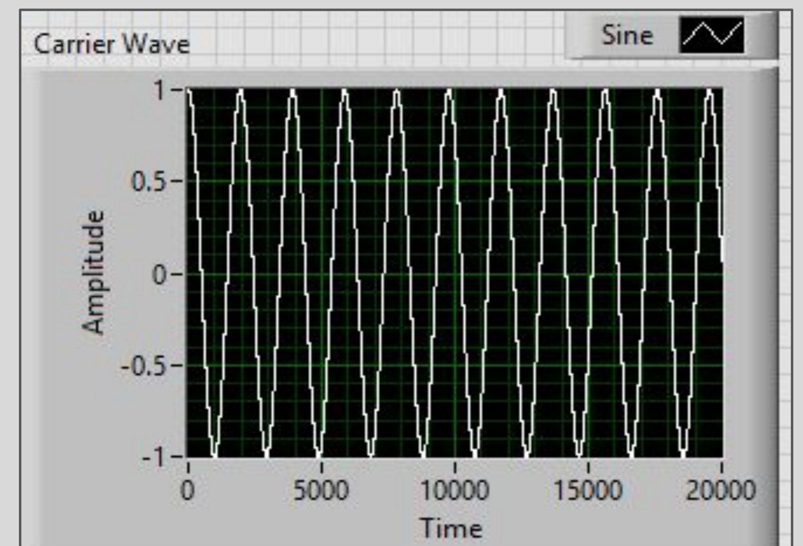


Figure 4: Example of Fixed Carrier Signal
This figure displays a Carrier Wave with a fixed Amplitude and Frequency. The data collected from the Arduino sensor is combined with this Carrier Wave through Modulation, then the Modulated Signal is sent wirelessly.

- For Amplitude Modulation, the data collected from the Arduino is combined with the Carrier Wave, and the amplitude of the Carrier Wave is altered depending on the sensor data. There is no phase change, and this modulated signal is shown in Figure 5.
- A significant part of the flood level detection system was establishing communication between two USRPs. For assurance, a generic asynchronous wave was transferred to establish connection. This wave is displayed in Figure 6.

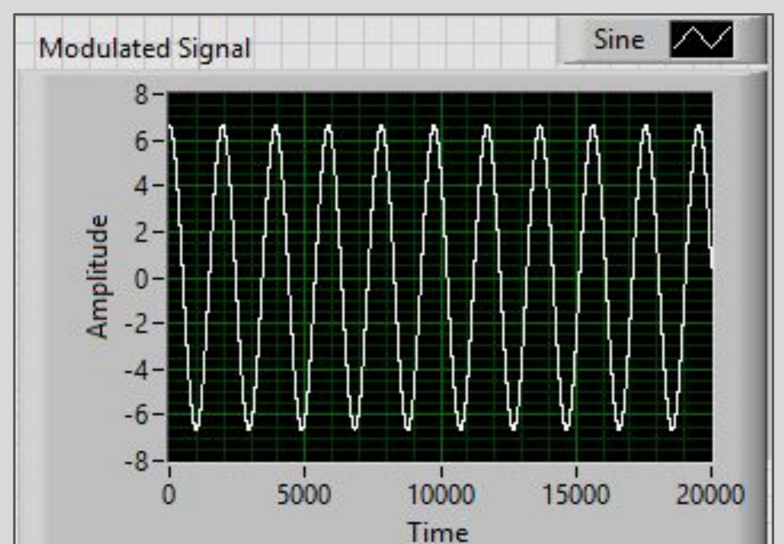


Figure 5: Modulated Signal
This figure shows the modulated waveform. As shown, the amplitude of the graph changes as the sensor values change. This displays how Amplitude Modulation functions.

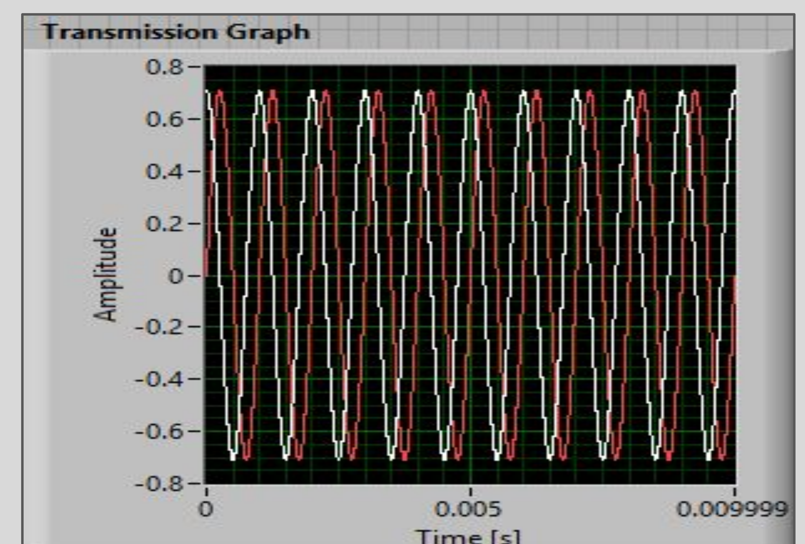


Figure 6: General Transmitted Asynchronous Wave
This figure displays a wave with fixed amplitude and frequency being transmitted. This was used as a test to establish communication between the two USRP devices.

- Figure 7 represents the signal that is read by the second USRP when no data is been transferred. The device appears to receive static noise when no transmission signal is sent.
- Figure 8 represents the signal being read by the receiving USRP when a sine wave is transferred on the same channel. For a signal to be picked up, both devices must share the same carrier frequency and channel.

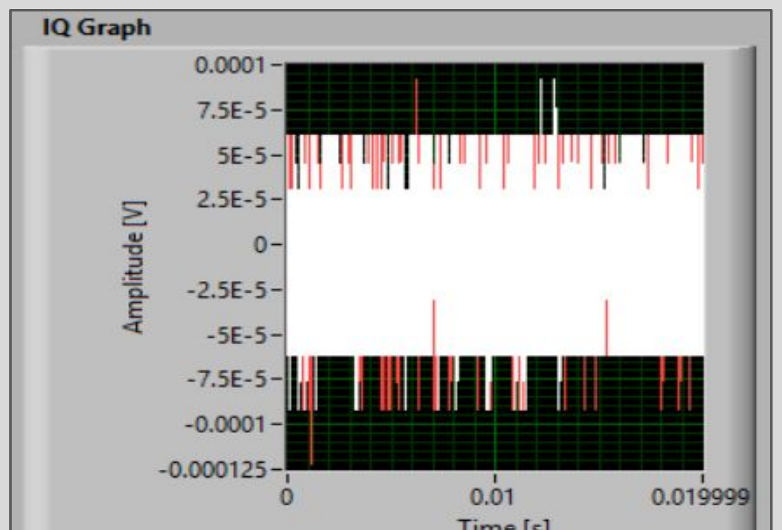


Figure 7: Static Waveform without Transmission Signal
This figure shows the waveform received when no wave is transmitted. Since there was no waveform sent, the device is picking up noise in the form of static.

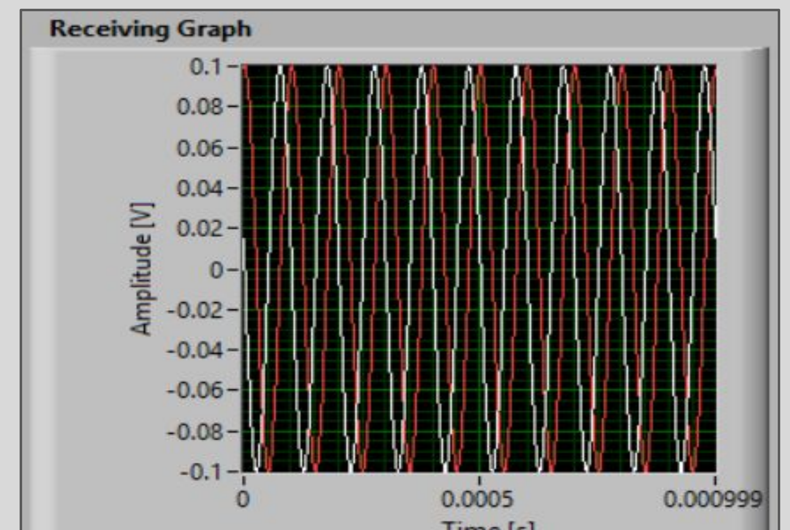


Figure 8: General Received Asynchronous Wave
This figure displays what is received from Figure 6. This proved that the two USRP devices were communicating with each other as intended.

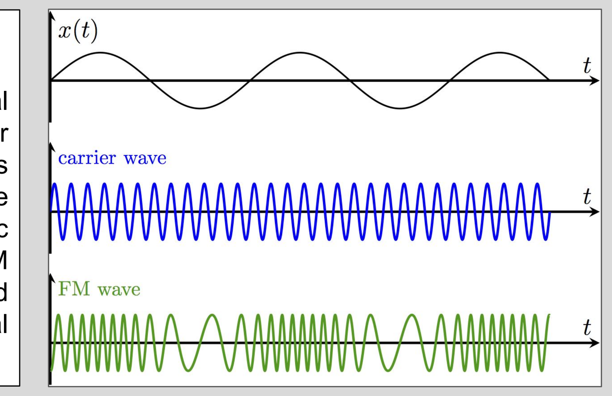
RESULTS SUMMARY:

The data was collected in Labview using the NI Labview Interface for Arduino. The data displays how an increase in water levels constitutes a voltage increase in the sensor. The voltage readings from the sensor ranged from 0 to 3.5 volts. Data was modulated with a Carrier Wave, which consisted of a sine wave with a frequency of 1 kHz and an amplitude of 1 volt. The amplitude of the modulated signal ranged between 1 volt and 8 volts, with the frequency matching the Carrier Wave frequency. When testing for communication between the USRPs, a signal with an IQ rate of 200 kHz was sent across using the USRP N210. The waveform received on the USRP 2920 had the same frequency and the phase shift between the IQ signals was also analyzed to be 90 degrees, but the amplitude was significantly lower. Once direct communication was established, Magnetic Induction Antennas were placed to mimic wireless communication.

METHODS

- The two sensors that were used were direct and non-contact sensors. The primary sensor functioned as a continuous water-level reading sensor, and the second sensor was used when water was mixed with different mediums like mud.
- An Arduino board was used to collect the information from both of the sensors, and that information was collected using Arduino IDE and Labview.
- Labview has a better User Interface and has several example programs to guide the user in MI communication.
- The technique that was used to transfer the signal from one USRP to another was amplitude modulation. Figure 9 shows an example of modulation.

Figure 9: Example of Frequency Modulation (FM)
As described in the Introduction, a Data Signal needs to be masked or modulated onto a Carrier Wave in order to be sent wirelessly. This example shows Frequency Modulation where the Carrier Wave is altered based on specific frequencies of the data signal. The final FM wave/Modulated Signal is then sent and demodulated to obtain the original Data Signal that was collected.



- The primary benefit of AM modulation over any other type of modulations is that it is the most effective when transmitting low frequency signals over long distances.
- Both modulations use a carrier wave which is usually a sine wave at a set frequency which is then combined with the data signal to form the modulated signal.
- The major difference between both modulations is that amplitude modulation adjusts the amplitude whereas frequency modulation adjust the phase.
- The formulas used to represent amplitude modulation are:

$C(t) = C\sin(\omega_c + \phi_c)$,
Where C = carrier amplitude, ϕ_c = Phase of carrier signal.

$M(t) = M\cos(\omega_m + \phi_m)$,
Where M = amplitude of the analog information signal, ϕ_m = Phase of analog information signal.

$A(t) = (C + M(t)\cos\omega_m)\sin\omega_c$,

$A(t) = C\sin\omega_c + M(t)\cos\omega_m\sin\omega_c$,

- We used LabVIEW as a low frequency radio transmitter and receiver to establish communication with Magnetic Induction Antennas.

CONCLUSION

- The Arduino microcontroller was a cheap alternative to other designs and had the capabilities to collect and transmit data.
- LabVIEW allowed us to merge the collected water-level data with a fixed Carrier Wave to further transmit and receive a modulated waveform both directly wired and wirelessly.
- Using LabVIEW and Amplitude Modulation, water levels collected from an Arduino device can be transmitted and received from one USRP to another USRP using Magnetic Induction Antennas.

FURTHER RESEARCH:

- Further research needs to be directed towards using Advanced Encryption Standard to encrypt any of the data that is being transmitted or received.
- Since homeowners should have remote access to water-level readings in and around their homes, more research needs to be put into creating an app which allows authorized users to have access to the data.

REFERENCES

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