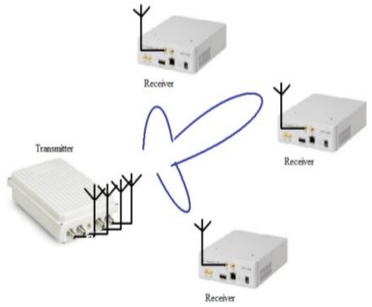
Directional Signal Transmission in Wireless Data Communications

Yuqing Lin, Jeewan Thapa Magar, Natalia Harrow
Mentor: Dr. Yun Ye
LaGuardia Community College CUNY

Abstract

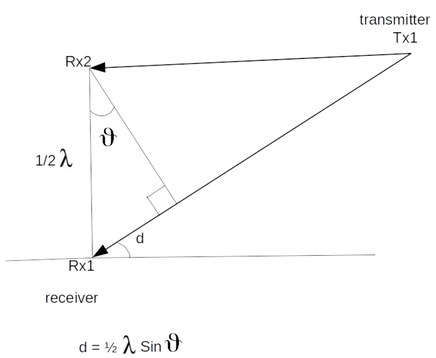
Traditionally, in wireless data communication electromagnetic radio waves are emitted from omni-directional antennas by the transmitter and only a tiny portion of the radio waves arrive at the receiver, resulting in poor energy efficiency. To improve the performance of the wireless communication system, we explore directional signal transmission using multiple antennas, a more effective alternative. We investigate the angle of arrival estimation in precoding and study the effect of different receiver movements on the accuracy of beam steering, using Universal Software Radio Peripheral (USRP) E310 and GNU Radio applying Principal Component Analysis (PCA) method. We use a motion sensor to record the actual movement of the receiver and then demonstrate the effectiveness of our PCA method.



Methodology

Angle of Arrival(AOA)

Angle of arrival measurement or degree of arrival (DOA) is a method for determining the direction of propagation of radio frequency wave. In order to implement this method, an antenna array is required on the receiver side.Since signal transmitted by a transmitter would arrive to the elements of the antena array in different time frames, base on this delays, AOA could be calculated.



$d = \frac{1}{2} \lambda \sin \vartheta$

Project Implementation

The project implementation started with simulation and experimental platform setup. We studied the basis of beamforming mechanisms while setting up the software simulation base on GNURADIO and hardware experimental platform and familiarizing with system architecture including radio transceiver equipped with antenna arrays.

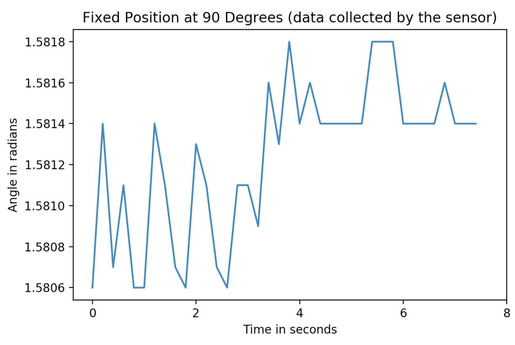
- **USRP Portion**

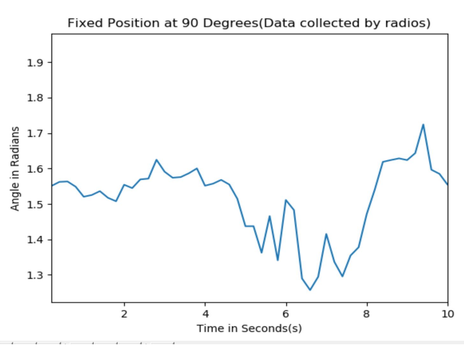
  USRP E310 offers a portable stand-alone software defined radio platform designed for field deployment. The flexible 2x2 multiple input multiple output transceiver which allow us to analyze signal sources from a frequency range of 70 MHz – 6 GHz.We program these two radios to gather the direction between them by using Gnuradio companion apply PCA method.

- **PhidgetSpatial Precision 3/3/3**

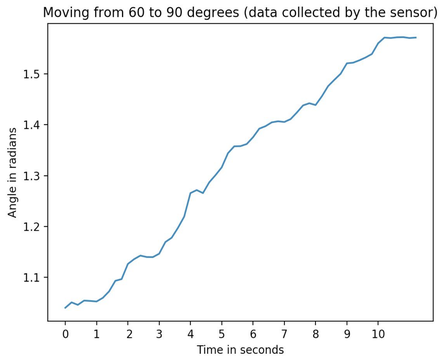
  PhidgetSpatial is a motion sensor that we used to analyze the receiver's movement. We wrote several Python programs that let us calculate an angle, acceleration and velocity of the receiver using the data gather through the sensor.

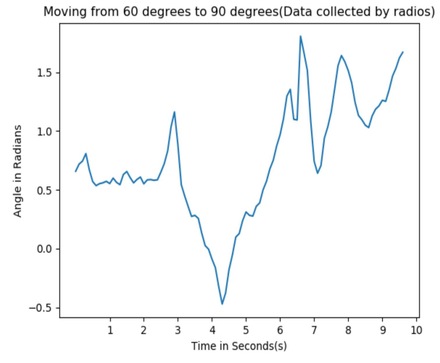
Results





Mean Squared Error: 0.0126





Mean Squared Error: 0.342

When the transmitter was in motion, the mean squared error (MSE) was 0.3418 -- much greater than the MSE of 0.0125 in the fixed position. These uncertainty were mainly caused by signal distortion and interference during the signal transmission.

Conclusion

Through the analysis of the experimental results of the AOA method and comparison to the data collected by the sensor, we were able to recognize the challenges in implementing directional signal transmission. As our results revealed, directional signal transmission between the radios in motion is particularly challenging as it is vulnerable to interference. Our data shows that the signal being transferred between the devices in motion results in significantly higher mean squared error than the signal transmission between both radios remaining in fixed positions.

We hope that the challenges and advantages of directional signal transmission in wireless data communication will be further studied, followed by discussion on how to improve the system design based on our observations.

References:

Ettus Knowledge Base contributors, "Streaming processed data from the E31x with GNU Radio and ZMQ," *Ettus Knowledge Base,* https://kb.ettus.com/index.php?title=Streaming_processed_data_from_the_E31x_with_GNU_Radio_and_ZMQ&oldid=3207 (accessed April 18, 2018).

WHITING, Sam et al. Time and Frequency Corrections in a Distributed Radio Network Using Gnu Public Radio. **Proceedings of the GNU Radio Conference**, [S.l.], v. 2, n. 1, p. 8, sep. 2017. Available at: <https://pubs.gnuradio.org/index.php/grcon/article/view/38>. Date accessed: 18 apr. 2018.

angles = [59.60, 60.21, 59.93, 60.41, 60.37, 60.31, 60.72, 61.45, 62.64, 62.83, 64.54, 65.08, 65.48, 65.32, 65.31, 65.69, 67.01, 67.49, 68.60, 69.87, 72.52, 72.86, 72.52, 73.73, 74.54, 75.42, 77.02, 77.79, 77.81, 78.05, 78.81, 79.78, 80.06, 80.49, 80.61, 80.53, 80.85, 81.59, 82.40, 82.64, 82.44, 83.42, 84.57, 85.28, 85.96, 87.14, 87.21, 87.48, 87.80, 88.19, 89.40, 90.04, 89.99, 90.07, 90.09, 89.99, 90.04]

static90 = [90.56, 90.61, 90.57, 90.59, 90.56, 90.56, 90.61, 90.59, 90.57, 90.56, 90.60, 90.59, 90.57, 90.56, 90.59, 90.59, 90.58, 90.62, 90.60, 90.63, 90.61, 90.62, 90.61, 90.61, 90.61, 90.61, 90.61, 90.63, 90.63, 90.63, 90.61, 90.61, 90.61, 90.61, 90.62, 90.61, 90.61, 90.61]

Through the analysis of the experimental results of the AOA method compared to the data collected by the sensor, we concluded that the signal transmission is challenging to directional signal transmission as it is particularly vulnerable to interference. Data error rate will be calculated using the received data and the original data. Comparison with traditional signal transmission will be quantified. The impact of channel conditions and receiver mobility on system performance will be studied, followed by discussion on how to improve the system design based on the observation.

fter analysing the experimental results of the AOA method and comparing them with the data collected by the sensor, we concluded that when the transmitter is in motion the signal is more vulnerable to interference.

and The next steps of the project will consist of on-site testing and data analysis. The task in the final phase is to analyze the experimental results, and to reveal the advantages and challenges in implementing directional signal transmission.