Locate Radio Transmission Source Via Trilateration

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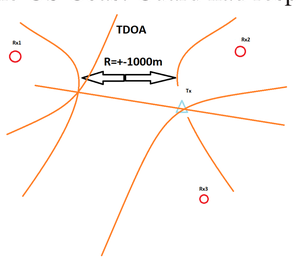
Technical Objectives

1. GPS module must be used to acquire the latitude and longitude of each receiver's location.
2. Capture the digitized 99.9 MHz FM signal in Riverside, CA across multiple synchronized receivers.
3. Calculate the correlation of FM data and acquire time difference.
4. FM signal source position must be established via combining the hardware and software.

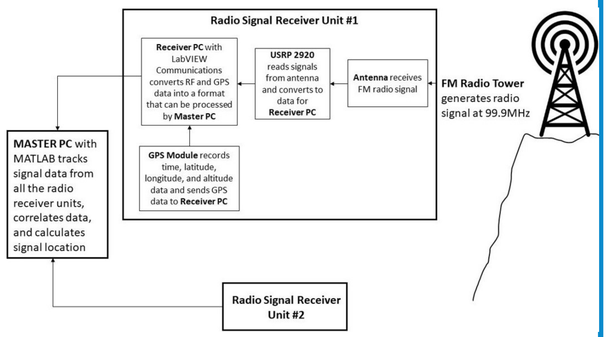
Introduction

The Trilateral FM Signal Locator is a system that determines the location of the source of an FM radio signal. The system is capable of recording radio signal and GPS data in order to mathematically calculate the approximate geographic location of a signal source. Our Project aims to solve the problem of Search and Rescue scenarios within the US Navy as well as other branches of the U.S. Armed Forces, commercial operations, and civilian recreational activities. In 2013, according to the US Department of Transportation, over $384 million in property had been lost and 54000 working hours had been spent in response to the nearly 18000 cases the US Coast Guard had responded to.



This project greatly simplifies and cuts the cost of such endeavors by comprising of two subsystems that work in tandem, receiving the same signal and comparing the Time Difference of Arrival between the two.

Materials & Methods

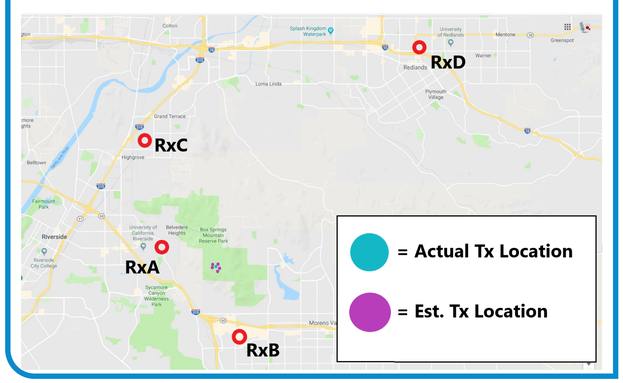


The following methods were used:

- Difference and Approximate Derivative: **diffX=[X(2)-X(1),X(3)-X(2),...,X(n)-X(n-1)]**
- Detrend: Remove a trend from a vector
- Cross-Correlation: **E[A(n+m)*conj(B(n))]=E[A(n)*conj(B(n-m))]**
- Time Difference Of Arrival(TDOA): **Δt=Δt2-Δt1**
- Super Relevant Correlation Data

Results 2

Here we can visually see the scale of the experiment and the placement of the receivers and compare the estimated locations of Tx to its true location.



Results 1

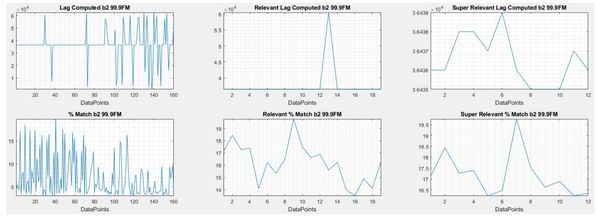
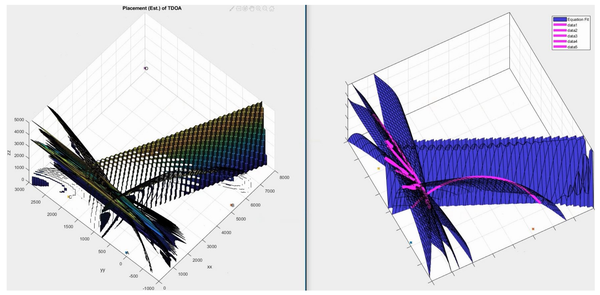


Figure 1: Super Relevant Correlation Data

Test	Distance Error (meters)
1	132.97
2	193.45
3	161.37
4	112.48
5	151.57
Arithmetic Mean	150.368

Table 1: Error Across Tests

Super Relevant Correlation Data provides very precise results of correlation. This works across multiple tests across multiple receiver comparisons, showing that this method is a very good way of sifting through irrelevant data.



After, a weighted average taking into account the % match and correlation for all Super Relevant Correlation Data of each TDOA comparison is applied. This single correlation value is converted to distance, and possible 3-D paraboloids of where the transmitter can be are found. Since it is very unlikely all paraboloids will intersect at the same location due to measurement device biases, random noise due to the environment, and the resolution possible due to the sample rate of the RF samples taken, some sort of method to find the space where the transmitter is most likely to be must be found. Here the line of intersect equation is found between each parabola. Then the points resulting in shortest distance between each line of intersect is found. The center of these points results in a prediction of the transmitter location with an estimate
(150, σ = +/- 27) meters from actual Tx Location.

Conclusion

In developing this system, we have shown that using RF analysis via measuring Time Difference of Arrival has allowed us to consistently determine the location of an FM signal source over long distances with the aid of GPS. It is our aim that this will lead to the development of smaller-scale systems that can aid in search-and-rescue operations on land and at sea.

References

[1] Kaune, Regina. (2012). Accuracy Studies for TDOA and TOA Localization, 2012 15th International Conference on Information Fusion, Singapore, Singapore, 9-12 July 2012. IEEE.

[2] Wei, X., Wang, L., Wan, J. (2006). A New Localization Technique Based on Network TDOA Information, 2006 6th International Conference on ITS Telecommunications, Chengdu, China, 21-23 June 2006. IEEE.

Future Research

- Significantly greater accuracy might be attainable if a Kalman Filter was implemented. Instead of requiring 4 receivers, only 2 would be needed.
- Real-Time Implementation with the use of GNU Radio or standard Lab View
- Combine with Triangulation to produce more sources of useful data, leading to greater accuracy

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