Russell Silva
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Weekly Report #3 - Work Done This Week on the Project Proposal

I focused all of my work on the literature review since I believe this section needed the most work. In the future, my work should be more dispersed among other critical sections, given that the literature review should be included in the work allocation of the whole research team.

I tried to incorporate ideas from the literature review organization discussed such as the cons of approaches of references and pros of approaches of references. In addition, some ideas such as “clock drifts and bulk delays can be mitigated by implementing cross correlation with virtual sources on a software level (e.g. GNU Radio Blocks)” can be expanded upon; however, going further into the functionality of such approaches would be more warranted in the proposal’s technical section. Moreover, the literature review should be as informative as possible, while maintaining a certain degree of conciseness.

II ii. Literature Review

Transmitted signals at antenna array elements can be quantized at receivers to provide signal strength, phase difference, or time arrival information to be used in a Watson-Watt, Phase Interferometry, or Time Difference of Arrival (TDOA) system respectively ([1] , [2], [16], and [22]). Phase based measurements can be skewed by multipath effects in the environment by constructive and destructive interference for line of sight signals [2]. TDOA systems are not as susceptible to multipath effects; however, obtaining precise positioning from close proximity transmitters in TDOA is difficult because nanosecond synchronization is required to compare lightspeed propagated signals. This flaw in time difference of arrival can be mitigated by subsample interpolation at signal correlation peaks [22].

Although lightspeed propagation substantially helps with obtaining real time results, it adversely affects the collection of synchronized data at antenna array elements in the radio frequency direction finding systems mentioned. More intensive hardware synchronization can be avoided by using a time-modulated array to switch between antennas in a direction finding system [21], shown in Figure 1 [21]. Conversely, coherent receivers running on a single clock signal can correct synchronization errors from clock drift and other delays by incorporating a signal generator input to each channel [20]. In addition, clock drifts and bulk delays can be mitigated by implementing cross correlation with virtual sources on a software level (e.g. GNU Radio Blocks) [23].

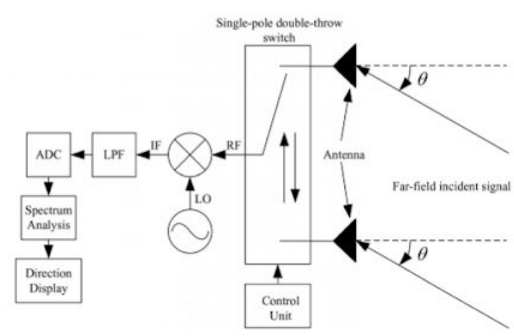

Figure 1: Time Modulated Array Setup

A phase interferometry system with real time operation on multiple receivers without an apparent phase offset correction/controlled noise source system was able to identify an angle of arrival within ± 2.5 degrees for all emitter distances from 1 km to 100 km [1]. The error threshold from this system is less than the ± 5 degree angle of arrival threshold error determined in the time-modulated approach in [21].

The phase interferometry system in [1] was primarily developed to handle UHF frequencies for airborne sources. Because the frequency of this system was relatively high for phase interferometry, antennas were spaced at distances larger than half the wavelength of transmitted signals. Thus, the system was optimized to handle phase ambiguity, which is explored more in the technical section of this proposal. Testing protocols and optimization were handled in Matlab and C, modeling the effects of antenna spacings on AOA accuracy under worst-case conditions. In the hardware setup, three antennas were used to resolve phase ambiguities and determine the azimuthal AoA in a synchronized three channel system with RF mixers driven by a common local oscillator. The block diagram is shown in Figure 2.

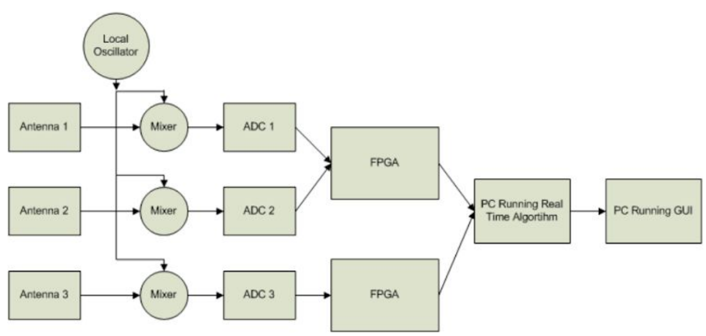

Figure 2: Block diagram for Phase Interferometry in Guerin, Jackson, and Kelly [1]

Ma, Hui and Kan [2] proposes a 3D indoor passive tag localization method with an accuracy of a few centimeters in a multi-frequency identification system. The paper leveages nonlinear backscatter which exploits nonlinear elements in passive devices to generate second or higher-order harmonics for an uplink response. This paper introduces a novel approach in mitigating multipath interference, defined as the occurrence when radio waves reach a receiver via two or more paths. This causes a constructive and destructive interference of the signal, as well as phase induced error (Figure 1). In order to combat multipath interference, a phase error threshold is used within a HMFCW ranging algorithm to find an optimal frequency combination that generates an undistorted line of sight path.

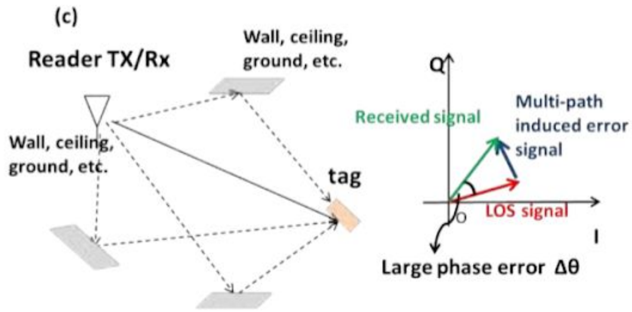

Figure 3: Dense indoor multi-path induced phase error [2].

Direction Finding Implementations using RTL software defined radios have proved to be promising alternatives to more expensive options by achieving up to 3.5m accuracy in TDOA [22] and by having an extensive hobbyist base with multiple Github repositories such as this one [24]. This project is demoed here.

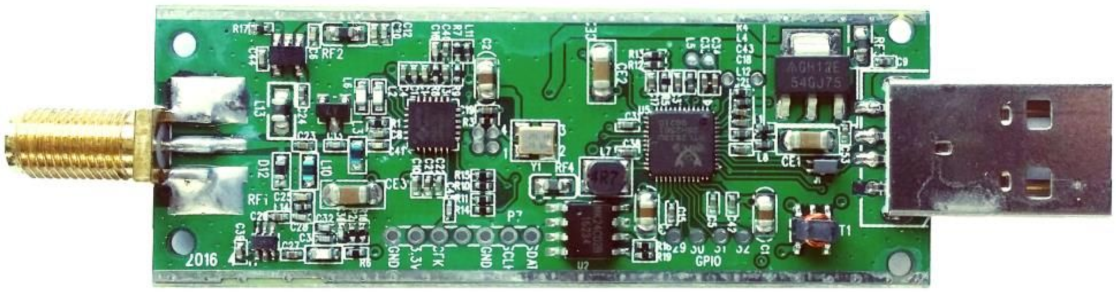

Figure 4: RTL-SDR (RTL2832U). Image Credit: rtl-sdr.com

VIII. References

[1] D. Guerin, S. Jackson, and J. Kelly, “Passive Direction Finding: A Phase Interferometry Direction Finding System for an Airborne Platform,” Oct. 10, 2012. https://web.wpi.edu/Pubs/E-project/Available/E-project-101012-211424/unrestricted/DirectionFindingPaper.pdf.

[2] Y. Ma, X. Hui, and E. Kan, “3D Real-time Indoor Localization via Broadband Nonlinear Backscatter in Passive Devices with Centimeter Precision,” Oct. 3, 2016. https://dl.acm.org/citation.cfm?id=2973754.

[3] “Sub-1 GHz and 2.4 GHz Antenna Kit for LaunchPad and SensorTag,” May 3, 2016. http://www.ti.com/tool/CC-ANTENNA-DK2.

[4]: “CC1310 LaunchPad Default Antenna,” Nov. 14, 2016. https://e2e.ti.com/support/wireless_connectivity/proprietary_sub_1_ghz_simpliciti/f/156/t/554880.

[5] “CC1310 LaunchPad Design,” Jul. 28, 2016. https://e2e.ti.com/support/wireless_connectivity/proprietary_sub_1_ghz_simpliciti/f/156/p/532331/1938371.

[6] “CC1310 SimpleLink Ultra-Low-Power Sub-1 GHz Wireless MCU,” http://www.ti.com/lit/ds/symlink/cc1310.pdf.

[7] “CC1310 IQ Samples,” http://www.ti.com/lit/an/swra571/swra571.pdf.

[8] “CC13XX Antenna Diversity,” http://www.ti.com/lit/an/swra523b/swra523b.pdf.

[9] “Crystal Oscillator and Crystal Selection for the CC26XX and CC13XX Family of Wireless MCUs,” http://www.ti.com/lit/an/swra495f/swra495f.pdf.

[10] “The Raspberry Pi UARTS,” https://www.raspberrypi.org/documentation/configuration/uart.md.

[11] “UART vs SPI vs I2C,” http://www.rfwireless-world.com/Terminology/UART-vs-SPI-vs-I2C.html.

[12] Řeřucha, Š., Bartonička, T., Jedlička, P., Čížek, M., Hlouša, O., Lučan, R. and Horáček, I. (2015). The BAARA (Biological Automated Radiotracking) System: A New Approach in Ecological Field Studies. PLOS ONE, 10(2), p.e0116785.

[13] Weiser, A. W., Orchan, Y., Nathan, R., Charter, M., Weiss, A. J., & Toledo, S. (2016). Characterizing the Accuracy of a Self-Synchronized Reverse-GPS Wildlife Localization System. 2016 15th ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN). doi:10.1109/ipsn.2016.7460662

[14] B. Porat and B. Friedlander, “Fractionally-Spaced Signal Reconstruction Based on the Maximum Likelihood”, Proc. IEEE Workshop on Higher-Order Statistics, July 1997.

[15] A. Smith, H. Balakrishnan, M. Goraczko, and N. Priyantha. Tracking moving devices with the Cricket location system. In Proceedings of MobiSys, pages 190–202, 2004.

[16] D. Zhang, J. Ma, Q. Chen and L. M. Ni, "An RF-Based System for Tracking Transceiver-Free Objects," *Fifth Annual IEEE International Conference on Pervasive Computing and Communications (PerCom'07)*, White Plains, NY, 2007, pp. 135-144.

[17] Wescott, Tim. “Sampling: What Nyquist Didn’t Say, and What to Do About It.” 20 June 2016, www.wescottdesign.com/articles/Sampling/sampling.pdf.

[18] Wolff, Christian. “Radar Basics.” *Radar Basics - In-Phase & Quadrature Procedure*, www.radartutorial.eu/10.processing/sp06.en.html.

[19] National Instruments. “What Is I/Q Data?” *What Is I/Q Data?*, 30 Mar. 2016, www.ni.com/tutorial/4805/en/.

[20] Bartolucci, Marco, et al. “Synchronisation of Low-Cost Open Source SDRs for Navigation Applications.” *2016 8th ESA Workshop on Satellite Navigation Technologies and European Workshop on GNSS Signals and Signal Processing (NAVITEC)*, 2016.

[21] He, Chong, et al. “Direction Finding by Time-Modulated Array With Harmonic Characteristic Analysis.” *IEEE Antennas and Wireless Propagation Letters*, vol. 14, 2015.

[22] Krüger, S W. “An Inexpensive Hyperbolic Positioning System for Tracking Wildlife Using off-the-Shelf Hardware.” May 2017.

[23] Whiting, Sam, et al. “Time and Frequency Corrections in a Distributed Network Using GNURadio.” 2017.

[24] “Tejeez/rtl_coherent.” *GitHub*, 6 July 2016, github.com/tejeez/rtl_coherent.

[25] “RTL-SDR Blog silver dongle first impressions, compared to NooElec blue dongle”https://medium.com/@rxseger/rtl-sdr-blog-silver-dongle-first-impressions-compared-to-nooelec-blue-dongle-4053729ab8c7

[26] “VIDEO TUTORIAL: INSTALLING GQRX AND RTL-SDR ON A RASPBERRY PI”https://www.rtl-sdr.com/video-tutorial-installing-gqrx-and-rtl-sdr-on-a-raspberry-pi/