Russell Silva
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Report #4 – Bulk and Phase Offsets between RTL SDR Datastreams. Installation and Modification of GNU Radio OutOfTreeModules for Direction Finding.

Overview

I commenced work last week on coding the framework for collecting long discrete blocks of data from each RTL SDR, correcting for bulk offsets between each data block, and inputting sample snapshots into autocorrelation/MUSIC code all from a Bash shell script. The progress of this implementation was halted by an inconsistency of cross correlation results for sampling lengths of more than five seconds. While trying to find the source of this issue, I continued project development on GNU Radio. Continuous alignment between RTL SDR datastreams was observed from cross correlation functions within Sample Offset blocks and standard GNU Radio blocks.

Cross Correlation of Discrete Blocks

A method was constructed to synchronize samples within discrete files that were composed of minute long sampling lengths. Based on the sampling rate (1 Msps), each file would have 60,000,000 samples and would be of 120 Megabyte size. It is important to note that the sampling rate of the RTL SDR cannot be lowered below 900 Ksps [1]. To test the synchronicity of each entire discrete file, cross correlation was performed at the beginning and end of each file. Unfortunately, the tail end of the cross correlation (with applied channel delays) had significant unpredictable sampling offset at each cross-correlation test. Successful channel synchronicity was only guaranteed for 5 seconds of sampling or less. Further tests will be done to try to isolate the source of the problem, such as testing the cross-correlation time offsets and peaks for multiple windows across each of the files to see if there is a relationship between sampling offset and time. The problem can either stem from a buffering problem with the rtl_sdr executable pipe or the binary to complex reading of the files (see numpy.fromfile [2]).

Installation of GNU Radio Packages

Since the source of the above problem was not localized by Friday, project development was continued on GNU Radio during the weekend. Last semester we left off with several problems with GNU Radio which mainly included the Raspberry Pi’s incompatibility with cross-correlation and MUSIC blocks and the steep learning curve of GNU Radio. After perusing the OutOfTreeModules FAQ [3] and a myriad of forum posts, cross-correlation blocks (et. al Whiting) and ETTUS MUSIC blocks (et. al Collins) were successfully installed and simulated on GNU Radio. Some steps of this process included performing mass automated file changes [4] (both repositories have the same project name) and installing an unlisted dependency (sudo apt-get install swig). A careful installation and setup procedure (that will be performed again from a vanilla Raspbian system for validation) will be included in the AMRUPT repository during the documentation period.

Sample Offset Correction GNU Radio

A flowchart like the one shown in Figure 1 (bottom of document) was used to monitor the cross-correlation peak of two channel delays separated by a bulk delay. Figure 2 shows the output of this flowchart. Afterwards, I used a sample offset block with an integrated delay block to attempt to correct for this bulk delay. Before applying this block, I modified the block's C++ code to include a system call to turn on the noise source. The first five iterations of are discarded to allow time for the noise source to turn on. Once all the user specified iterations are completed (at least 15 recommended), the noise source is turned off. The cross-correlation peaks are outputted to the console (Figure 3) and the median out of these peaks is used in the delay block. The median of the cross-correlation peaks did not change overtime when testing this block, regardless of noise-to-antenna/antenna-to-noise RF switching.

The only consideration at this point is that the bulk delays determined by the GNU Radio flowchart FFT does not match the bulk delays determined by the sample offset block. Results from both functions are nonvarying overtime, which adds to the perplexity of this issue. My initial guess is that the flowchart FFT is not completely accurate (some testing results have shown it to be on the other side of the x-axis). Further testing (see phase offset testing section) will be implemented to undoubtedly determine the correct procedure.

Phase Offset Testing

Please watch Sam Whiting's and Travis Collins' GRCon talks which can be found here and here respectively. Both discussions go over procedures to remove phase offsets between receiver channels. It is arguable that this procedure is necessary for Whiting's system (makes no mention of an interconnected noise source and uses an FM station to correct for bulk offsets [5]) and Collins' system (does not correct for bulk delays), but not for ours since phase offsets can be debatably corrected by solely applying a bulk offset correction. However, it is questionable whether a cross-correlation with a noise signal would be enough to correct for phase offsets (a noise signal has random phase fluctuation).

An experiment will be devised to see if a phase offset correction will be necessary in our system. A common signal generator will be used to feed in a sinusoid to two receivers at once. In order for the sinusoids to have zero phase from each other, the signal will be split by a one to two SMA connection and the lengths of the wires/components will be the exactly the same. If there is a constant phase offset for the duration of the entire test, and if a different phase offset is observed at each test, a phase correction procedure with a known location beacon will be implemented.

Resources and relevant Forum Posts

[1] https://wiki.spench.net/wiki/RTL2832U
[2] https://docs.scipy.org/doc/numpy-1.13.0/reference/generated/numpy.fromfile.html
[3] https://wiki.gnuradio.org/index.php/OutOfTreeModules
[4] https://superuser.com/questions/324428/find-and-replace-command-for-whole-directory

[5] https://github.com/jakapoor/AMRUPT/blob/master/Literature/General_radio_direction_finding/Angle%20of%20Arrival%20Methods/GNU%20Radio%20-%20Whiting.pdf
[6] https://coherent-receiver.com/getting-started

Figures:

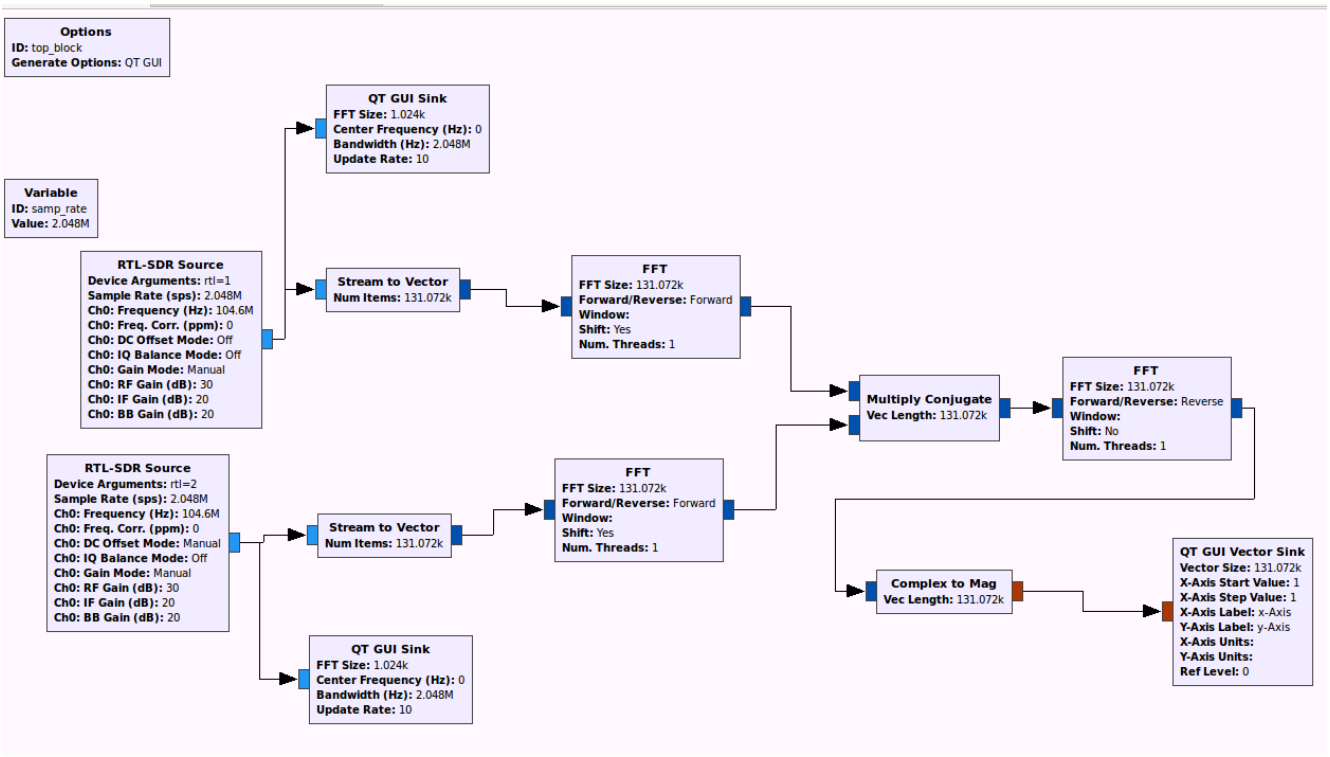

Figure 1: Cross Correlation Function using Standard GRC Blocks [6]

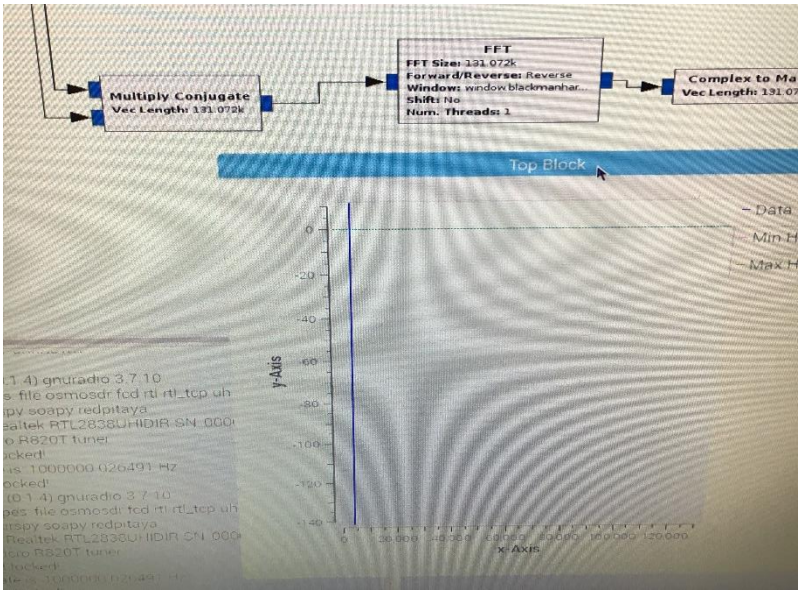

Figure 2: Cross Correlation Function Output

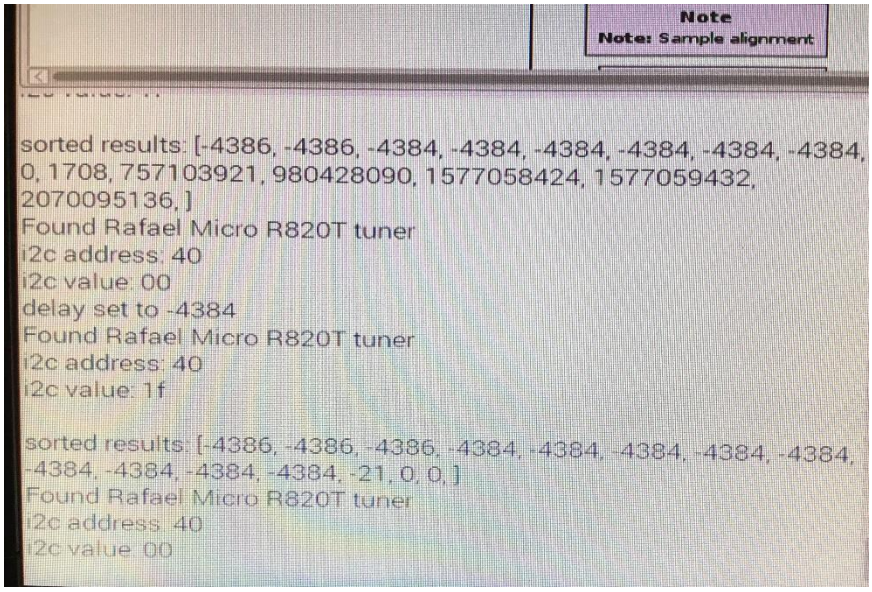

Figure 3: Sample Offset Block Equivalent Results for Sample Offset Initiation and Manual Reinitiation (after long period of time)