Updated GNSS IF Recorder Report
Larry Wurtz, Phd
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Following is an updated status report on work regarding the GNSS IF recorder pelican case. The objective since the first status report dated 2 July 2020 was to complete the GPS L1 satellite acquisition algorithm and develop an initial algorithm to track satellites after acquisition. There are many books and journal papers describing GNSS satellite tracking. Many of them were tried and were found to be non-functional with real IQ data. Tracking in the presence of noise revealed that GNSS satellite tracking is more than science and has some art involved.

The GNSS IQ recorder mounted in a pelican case uses two RF front-ends for GNSS IQ data capture. One RF front-end consists of a MAX2769C for down conversion for GPS L1. A MAX2771 RF front-end will be used to capture all other GPS and Galileo bands. To date, the GNSS IQ recorder has been used to collect a one second sampling of 2-bit IQ data for GPS L1 at a 16.368 MHz sample rate with an input 2.5 MHz notch filter. As construction of the GNSS IQ recorder continues, much longer record times for up to two simultaneous GNSS bands will be performed. For now, algorithms are being developed using a one second collection of GPS L1.

The satellite acquisition algorithm was implemented with a fast parallel FFT / IFFT method typical of most GPS receivers. The number of acquisitions was increased from two to four per satellite to overcome navigation bit transitions during a sampling period. The delta frequency search was reduced from a common 500 Hz to 50 Hz for improved track lock time. PRN code acquisition accuracy is to 0.0625 chips. From the four acquisitions for each satellite, a voting scheme based on PRN code variance, rather than signal power level, was implemented to determine if a satellite is present and strong enough to track. Figures 1, 2, and 3 show the acquisition metrics for satellites 2, 6, and 19; all of which were determined to be acceptable for submission to the tracking algorithm.

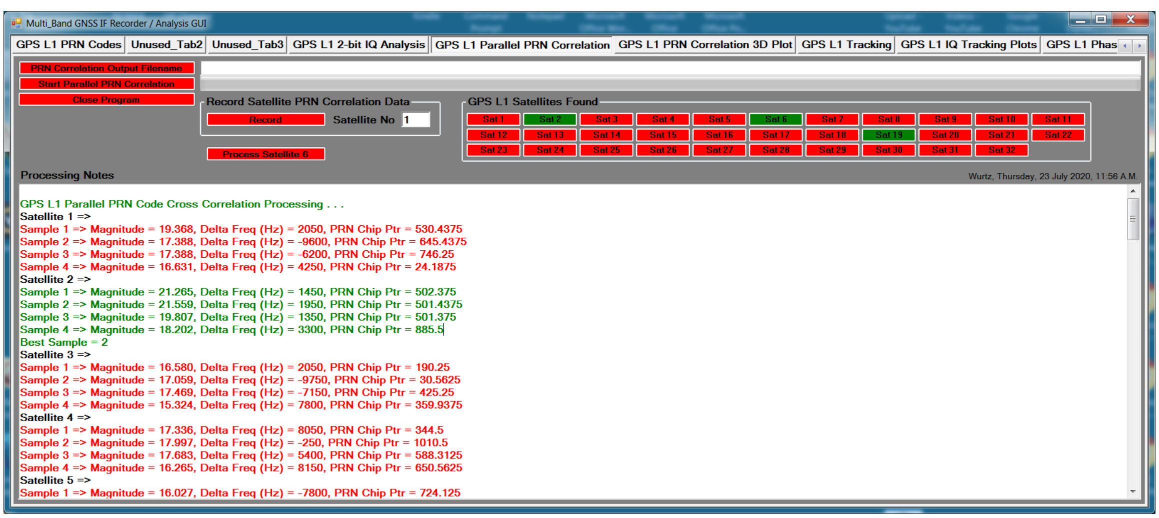

Figure 1. GPS L1 satellite 2 acquisition metrics

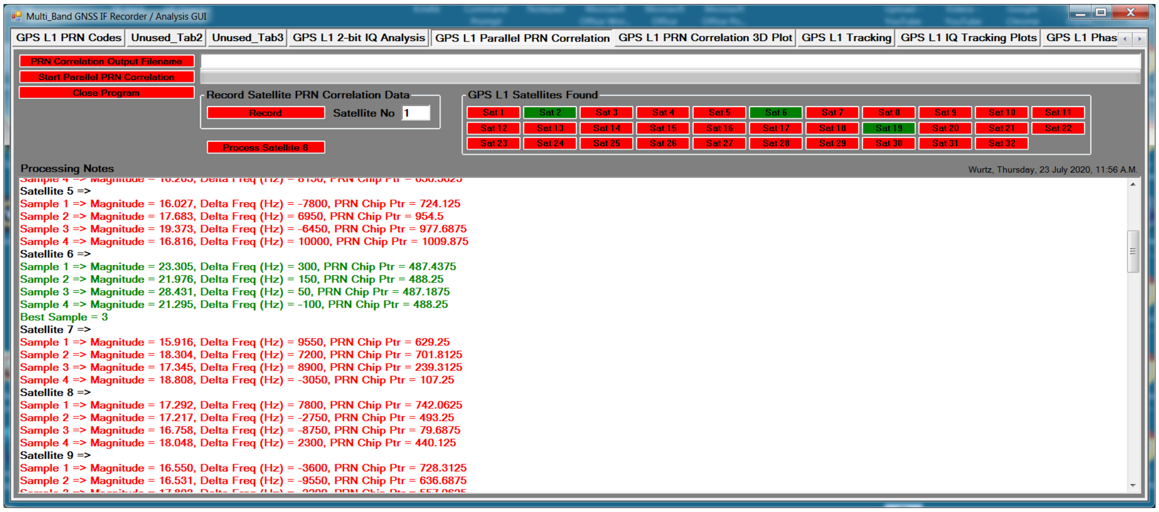

Figure 2. GPS L1 satellite 6 acquisition metrics

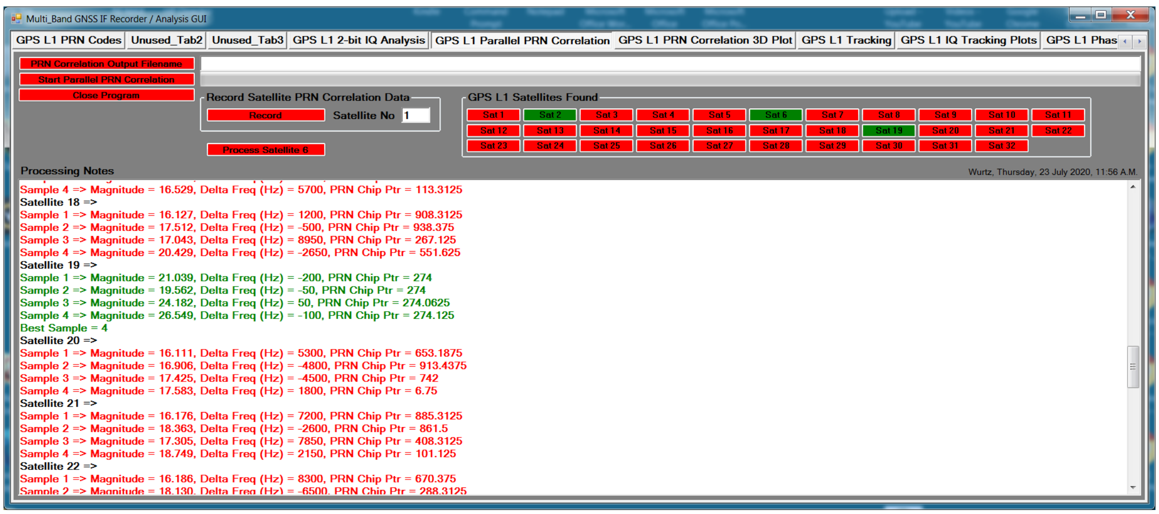

Figure 3. GPS L1 satellite 19 acquisition metrics

Figures 4, 5, and 6 show the PRN code correlation 3D plots commonly reported in many books and papers. Other than looking impressive, these plots do show that cross and auto correlations of satellite PRN codes, or "Golden Codes", are extremely effective for satellite identification and spectrum spreading.

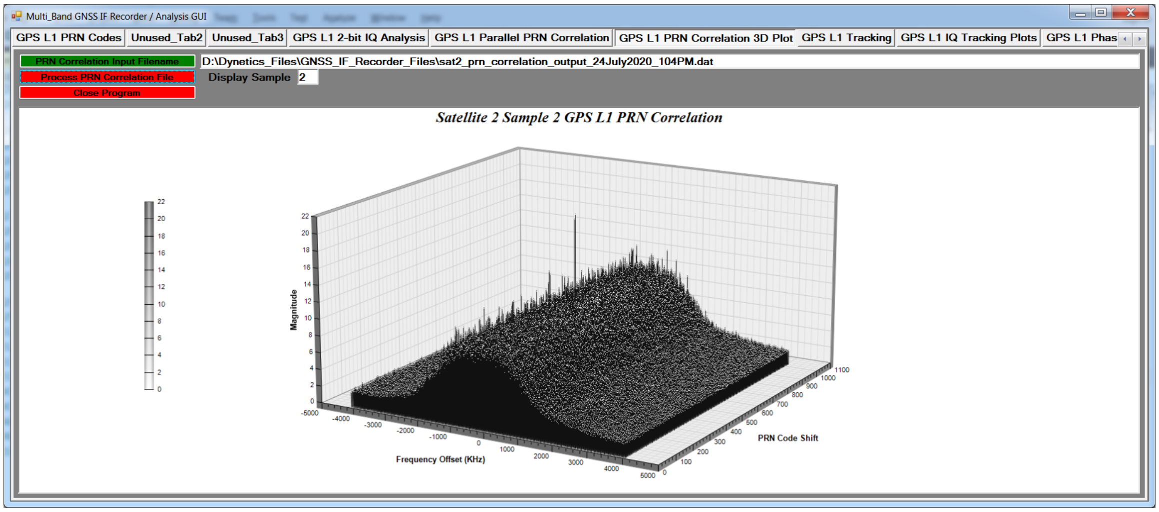

Figure 4. GPS L1 satellite 2 PRN code correlation

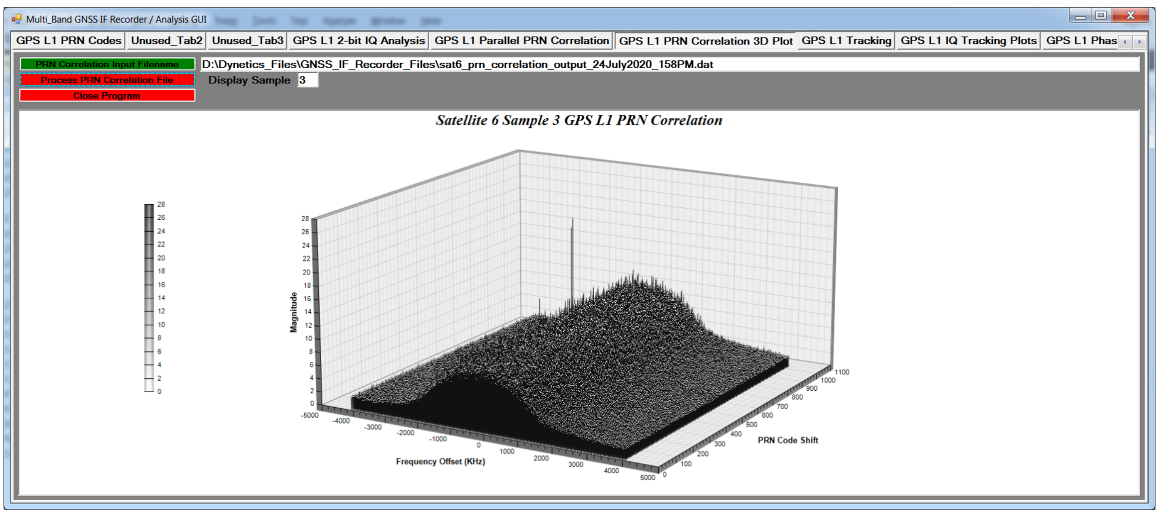

Figure 5. GPS L1 satellite 6 PRN code correlation

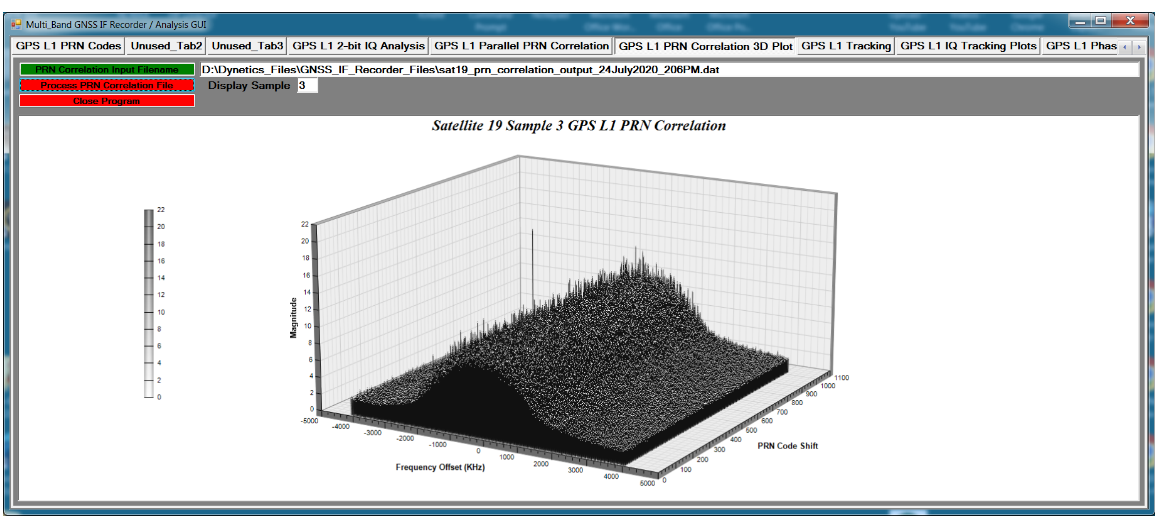

Figure 6. GPS L1 satellite 19 PRN code correlation

The first version of tracking algorithm is based on an early-late code tracking loop for PRN code alignment with non-coherent discriminator. The carrier phase tracking loop is based on a costa-loop controlling phase error to a NCO. The phase tracking loop uses an arc-tangent discriminator with 2nd order loop filter. The 2nd order carrier loop filter supports an adjustable damping coefficient, 0.7 for this case, and adjustable loop bandwidth. During the initial phase of tracking, the carrier loop bandwidth is set to 50 Hz and tightens to 5 Hz for improved noise rejection when tracking has full lock. Future versions of the carrier tracking algorithm will involve higher order loop filters and perhaps a Kalman filter. It would also be very good to have input from an external IMU for improved lock performance. Future versions of the tracking algorithm will wipe-off the 50 Hz navigation BPSK modulation from the carrier phase tracking loop.

Figures 7, 8, and 9 report performance of the initial tracking algorithm. Full lock is completed within 60 msecs from data start. At full lock, carrier loop bandwidth drops from 50 Hz to 5 Hz for improved noise rejection. Carrier phase offset is within +/- 1 degrees. The reader will have to zoom in to see the details. Because IQ data is recorded and post-processed, the software can be modified to essentially operate in reverse to recover full lock metrics back to the beginning of recorded data.

Because the initial tracking algorithm implements an early-late PRN code tracking loop, many papers provide in-phase and quadrature-phase performance plots. If the code tracking loop and carrier tracking loop are in lock, the remaining 50 Hz BPSK navigation modulation is shifted to the in-phase leg of the tracking loop. Figures 10, 11, and 12 do indeed show most energy in the in-phase arm of tracking and that lock has been established. It's from processing the in-phase and quadrature-phase energy levels that lock decisions are made.

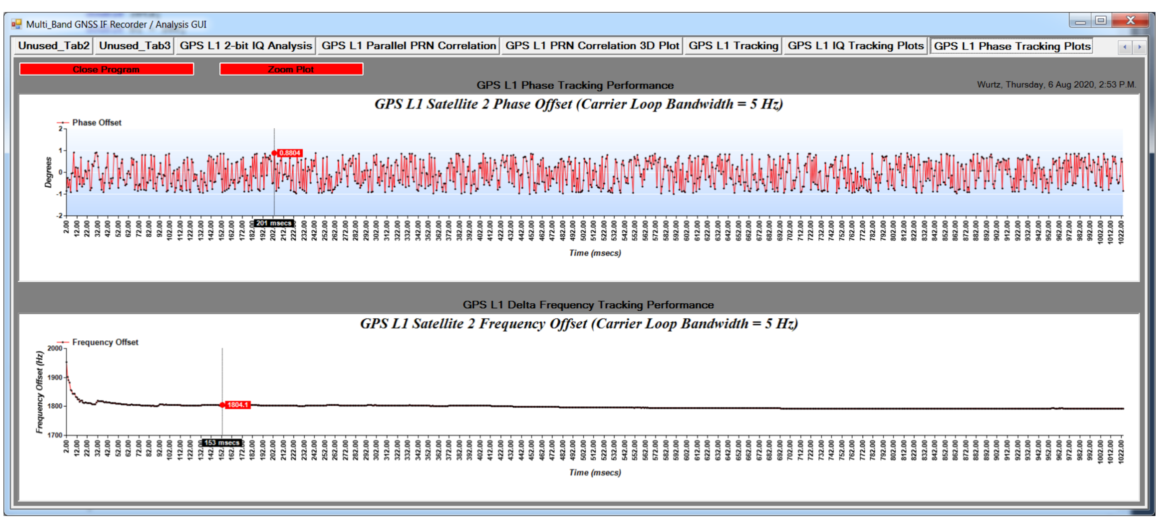

Figure 7. GPS L1 satellite 2 carrier offset and delta frequency offset

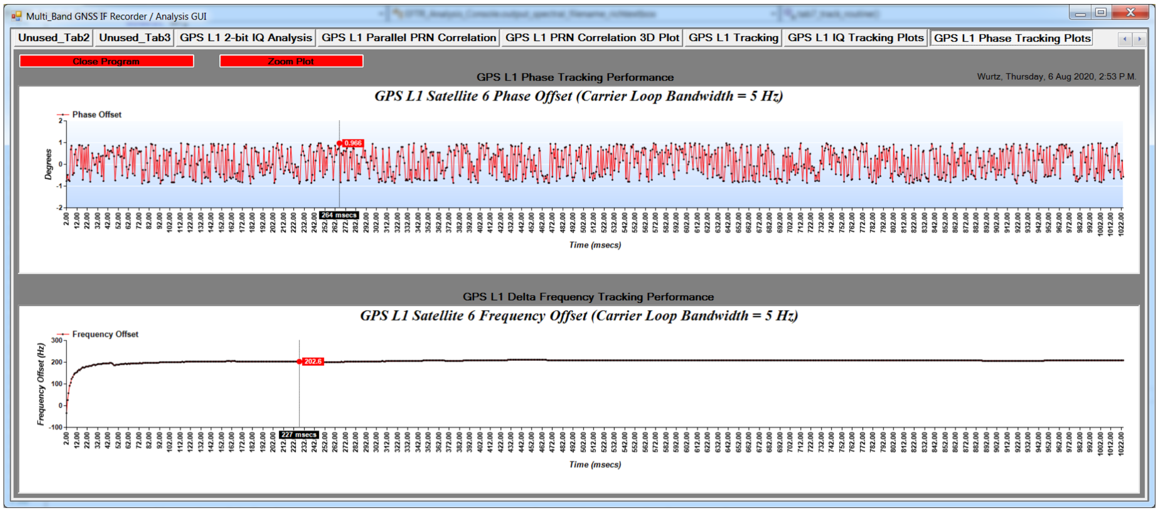

Figure 8. GPS L1 satellite 6 carrier offset and delta frequency offset

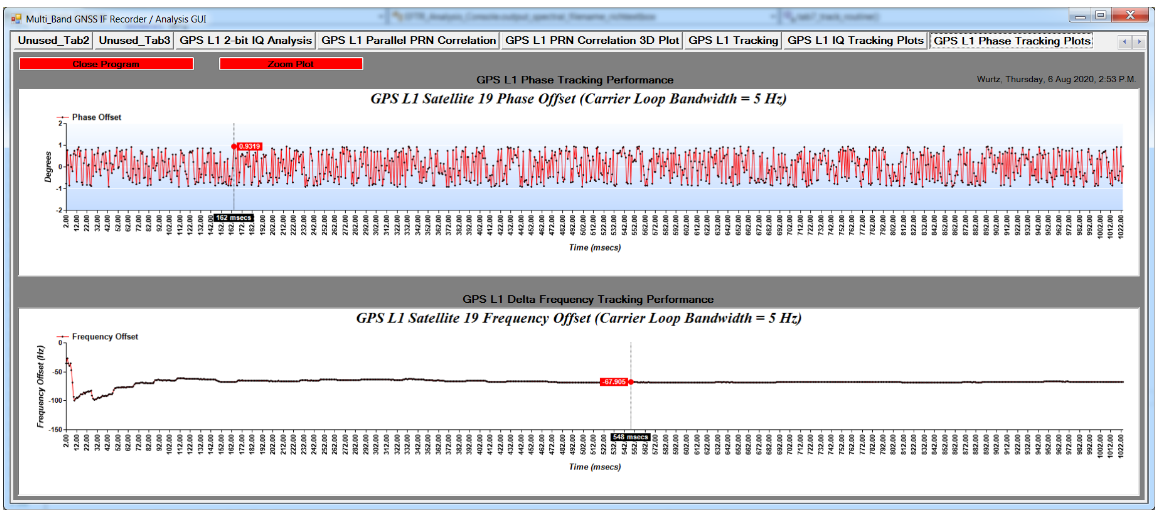

Figure 9. GPS L1 satellite 19 carrier offset and delta frequency offset

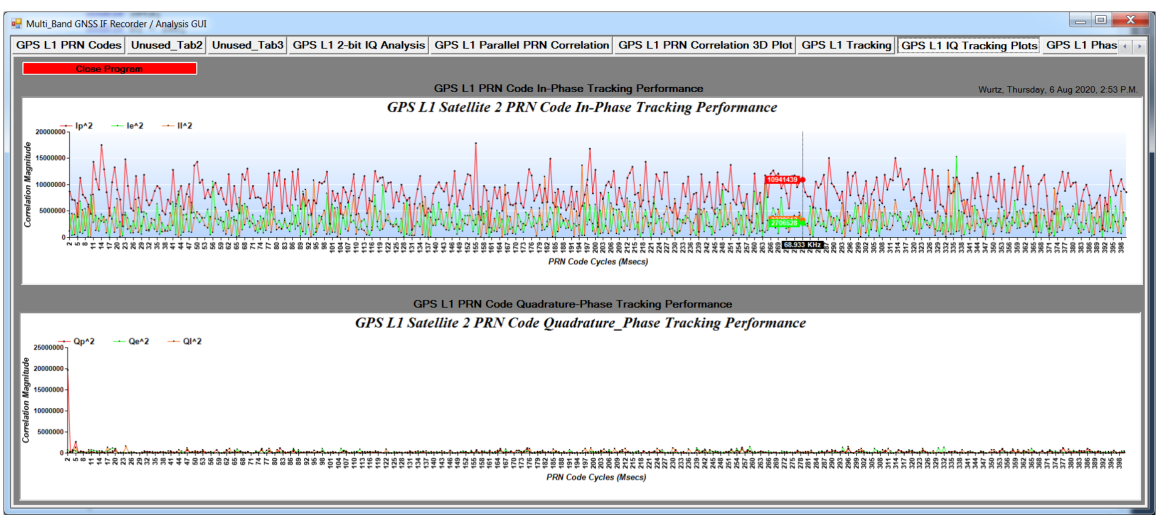

Figure 10. GPS L1 satellite 2 in-phase and quadrature-phase signal levels

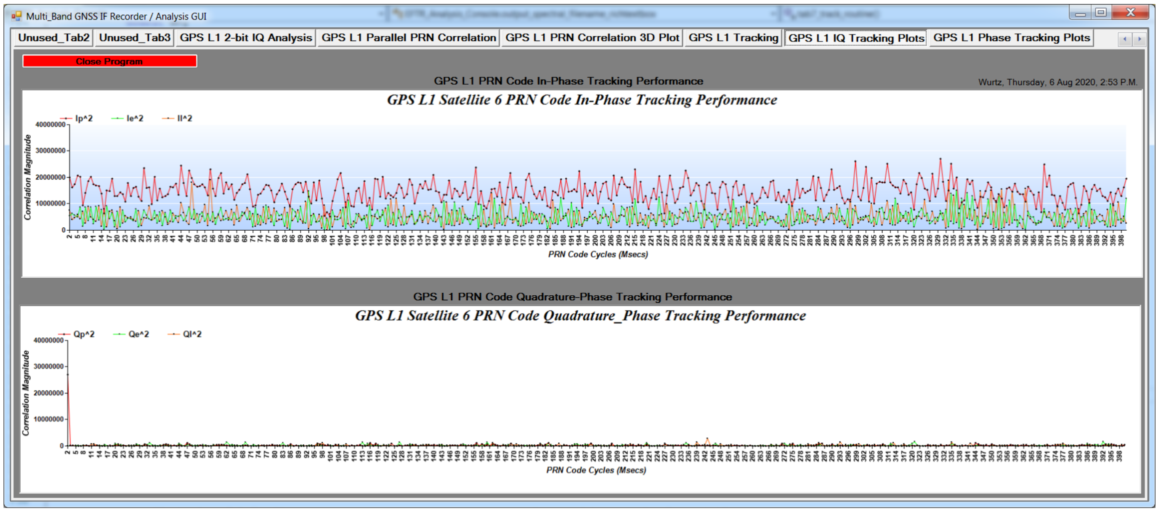

Figure 11. GPS L1 satellite 6 in-phase and quadrature-phase signal levels

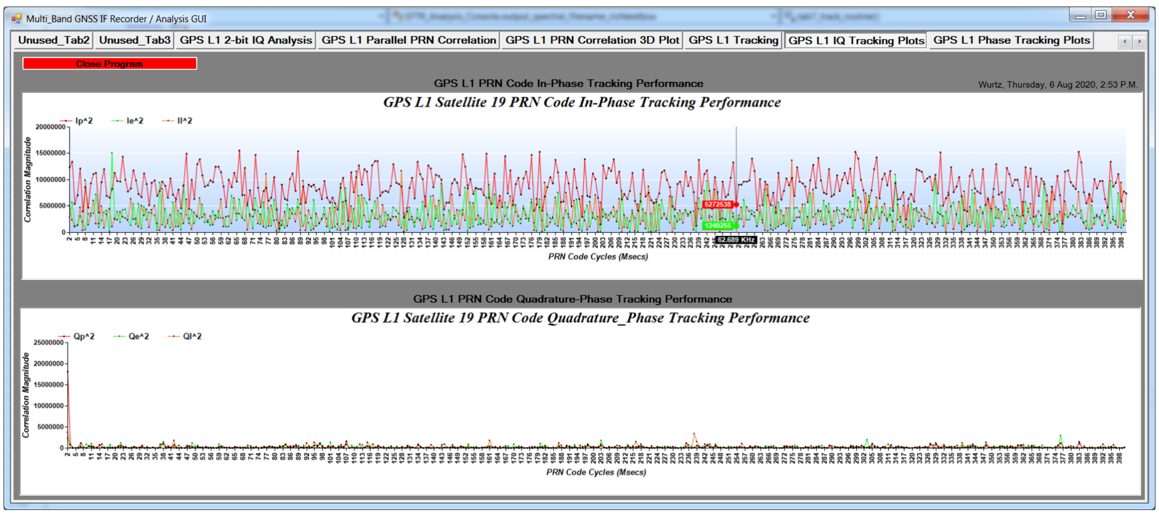

Figure 12. GPS L1 satellite 19 in-phase and quadrature-phase signal levels

The next phase of this work is to extract and process the 50 Hz navigation data for ephemeris metrics. First, the GNSS IF recorder pelican case will take it's next evolution to enable the recording of very long GPS L1 data streams via gigabit Ethernet to a host PC. Much more than the current one second recording will be needed to process navigation data. Eventually, this work will include to the recording and analysis of other GPS and Galileo bands. All of the developed GNSS processing algorithms can be implemented on a Xilinx Zync platform.

Figures 13 and 14 show the next evolution of GNSS IF recorder antenna. With this antenna setup, we will avoid the loss of signal due to blockage from buildings and trees that hindered the first one second recording of GPS L1.

Figure 13. Next GNSS IF recorder antenna

Figure 14. Next GNSS IF recorder antenna