Initial GNSS IF Recorder Analysis
Larry Wurtz, Phd
2 July 2020

Following is a very short discussion of GPS L1 data analysis using a MAX2769C as a RF front-end. Figures 1 and 2 show the MAX2769C placed in a pelican case of portability. The circuit board to the right with blue ADC board attached buffers MAX2769C 2-bit IQ output to Ethernet packets which are recorded by a host PC. 2-bit IQ data is at an IF of 4.092 MHz and sampled at 16.368 MHz. A UBlox ANN-MB series active GNSS antenna was used with the MAX2769C RF front-end.

The first recording event was focused on quickly gathering data for analysis to determine if the MAX2769C was even a candidate for RF down conversion. Perhaps more time should have been given to antenna placement in that the laboratory building completely blocked the line-of-sight to most GPS satellites. Figure 3 shows the GPS satellite

Figure 1. GNSS IF Recorder - top view

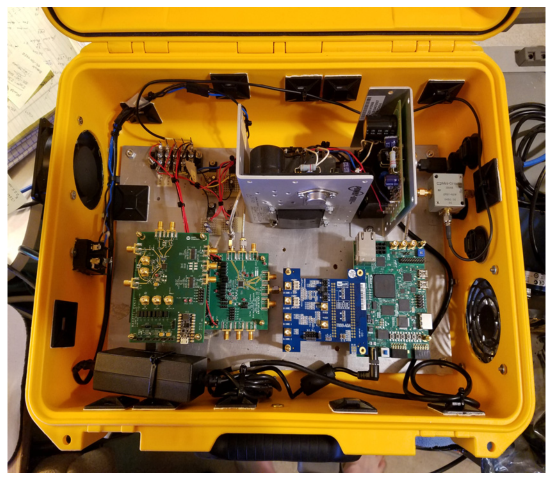

Figure 2. GNSS IF Recorder - Inside view

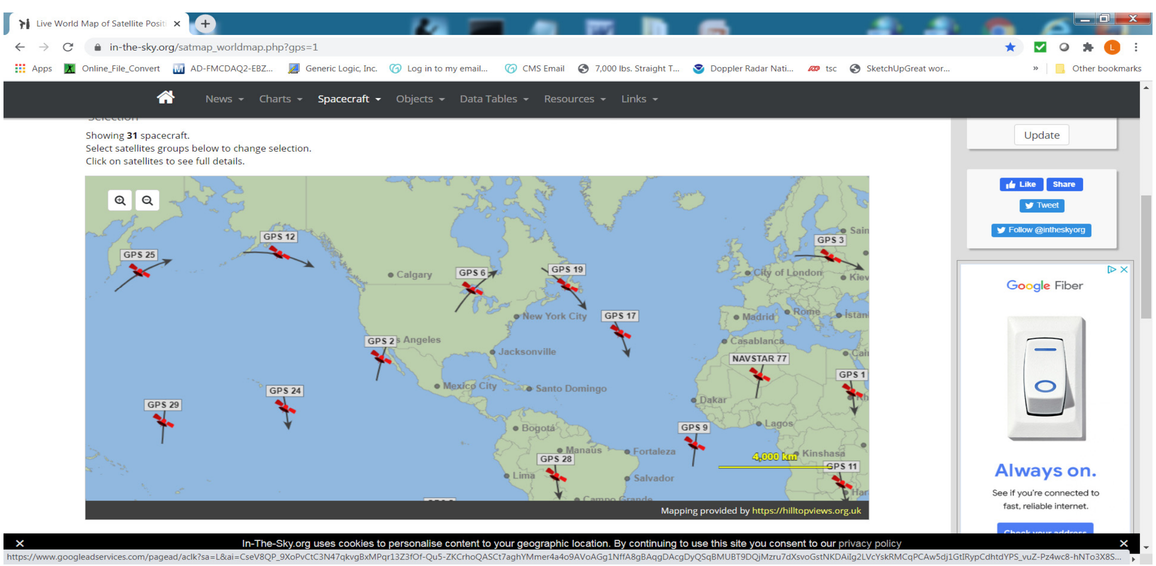

Figure 3. GPS Satellite Position during Data Capture

positions when data was recorded.

Figure 4 shows a FFT of the first 65536 samples of recorded 2-bit IQ data. As expected, the spectrum is centered at an IF of 4.092 MHz and demonstrates a 2.5 MHz bandpass filtration as were the configuration settings of the MAX2769C. 90% of the GPS L1 information spectrum is within a 2 MHz band centered at 1575.42 MHz. The GPS L1 signal levels are in the -125 to -110 dBm range at the receiver antenna. Along with the spread spectrum from the PRN codes, visual identification of GPS signals from spectral plots would not be possible. Figures 5 and 6 report the 1023 chip pseudorandom noise (PRN) codes generated and used to identify each satellite's data stream in the collected data.

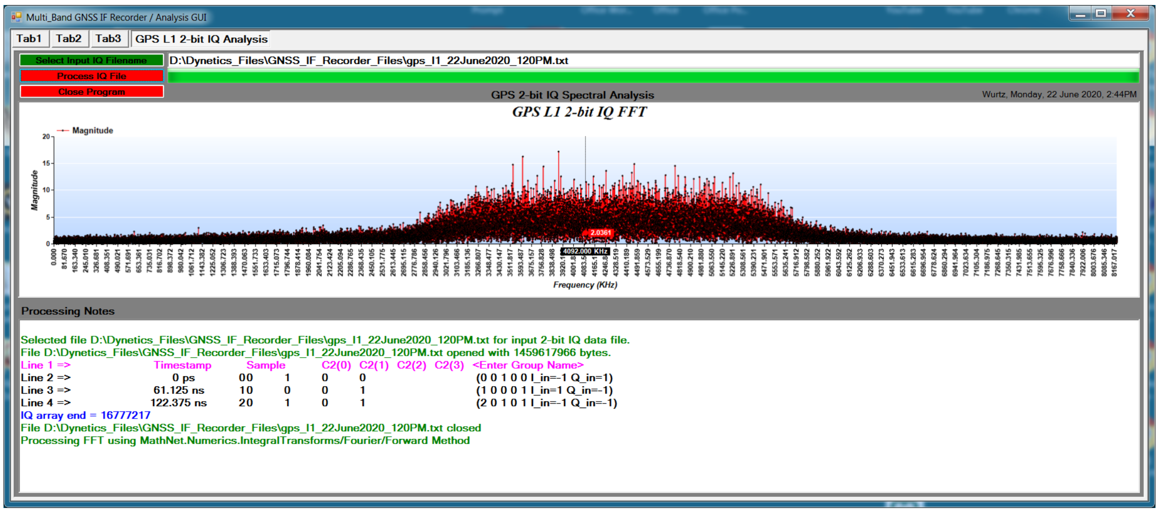

Figure 4. FFT of sampled 2-bit IQ data from MAX2769C

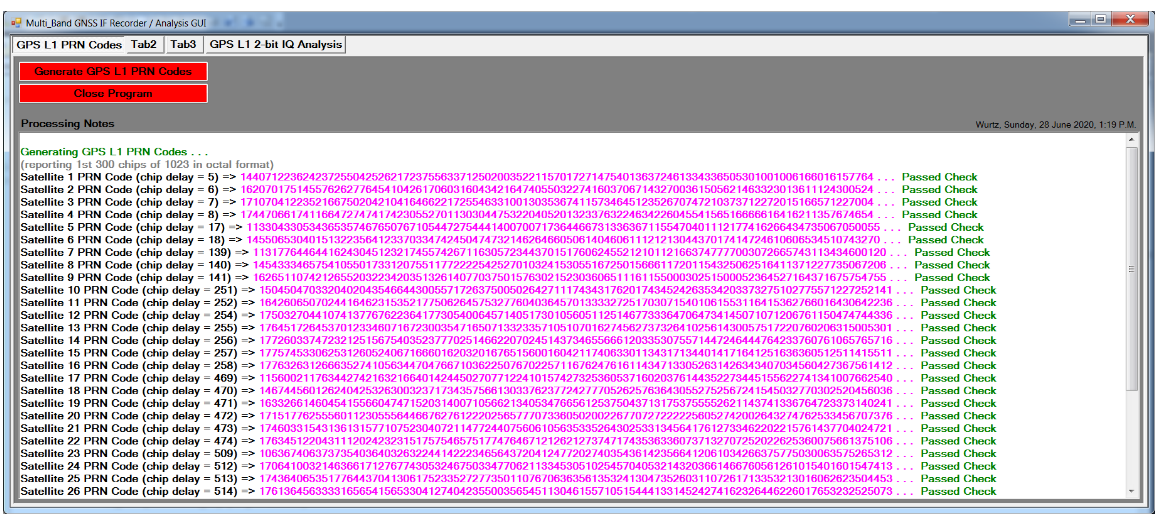

Figure 5. PRN codes for GPS Satellites 1 through 26

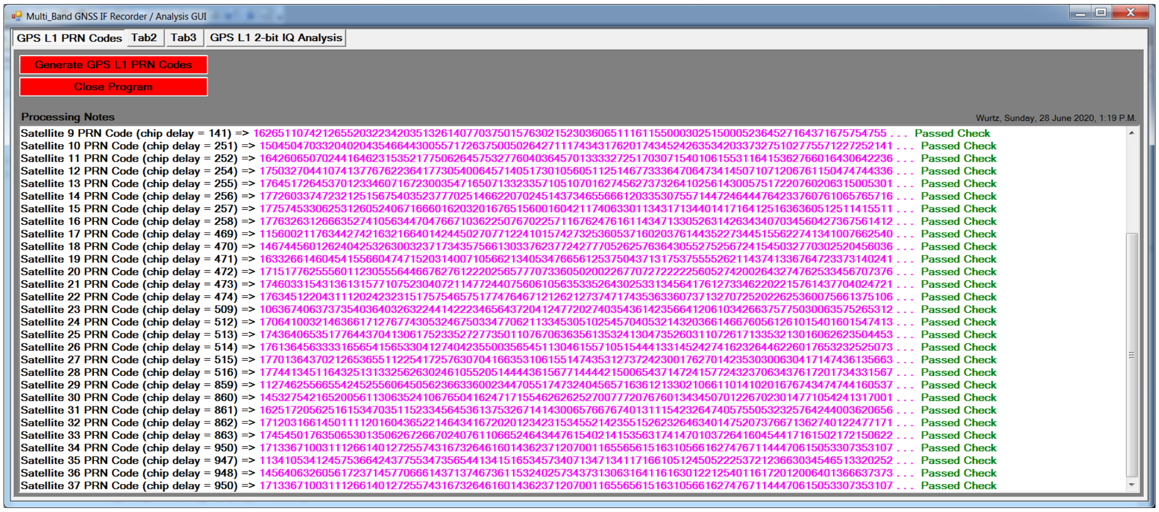

Figure 6. PRN codes for remaining GPS Satellites

The first step in data analysis is to acquire the GPS satellites. The acquisition phase requires a great deal of processing time in that each 1023 chip PRN code must be convolved across the collected data for one PRN code period of 1 msec for L1 at the 16.368 MHz sample rate following by a set of frequency shifts from the 4.092 MHz IF to account for Doppler effects between the satellite and receiver velocities. A number of papers report that increments of 500 Hz is sufficient to account for the Doppler effects.

A parallel acquisition search algorithm was used to cross and auto-correlate each satellite PRN code for one PRN code cycle across the collected data. Table 1 reports correlation results for a sampling of satellites. As expected, satellites 6 and 19 are strong since each is almost directly above the receiver. All other GPS satellites are weak either due to line-of-sight blockage or distance from the receiver. The next record event will have the antenna elevated for better satellite reception. Figures 7, 8, and 9 show the associated PRN plots for Satellites 6, 19, and 2, respectively.

Satellite No	Largest Magnitude from Correlation	PRN code shift	Doppler shift +/- 500 Hz
2	17.878	501.500	-1499 Hz
6	26.270	487.375	0 Hz
19	21.430	273.938	0 Hz
13	14.749	775.875	+27973 Hz
17	14.274	267.375	-109893 Hz
3	13.932	546.250	+36464 Hz
12	14.129	592.875	-417592 Hz

Table 1. Sampling of searched GPS Satellites for L1 Band

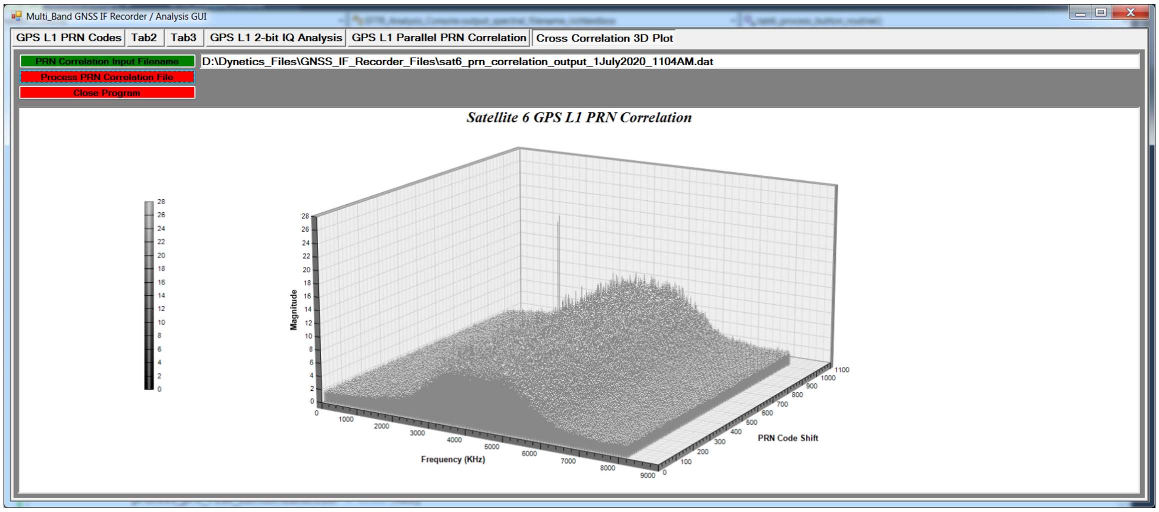

Figure 7. Plot of PRN Correlation for Satellite 6

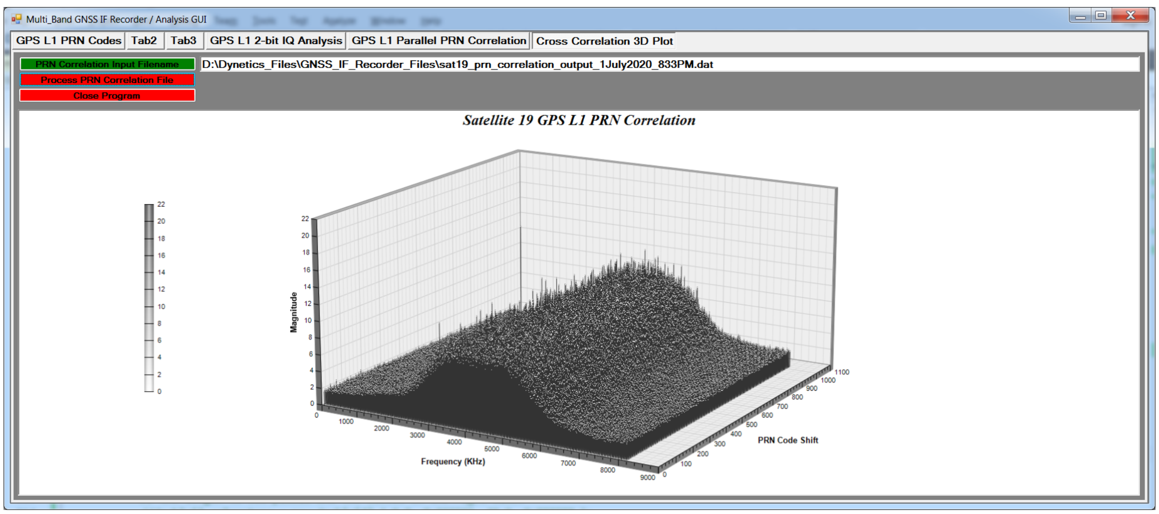

Figure 8. Plot of PRN Correlation for Satellite 19

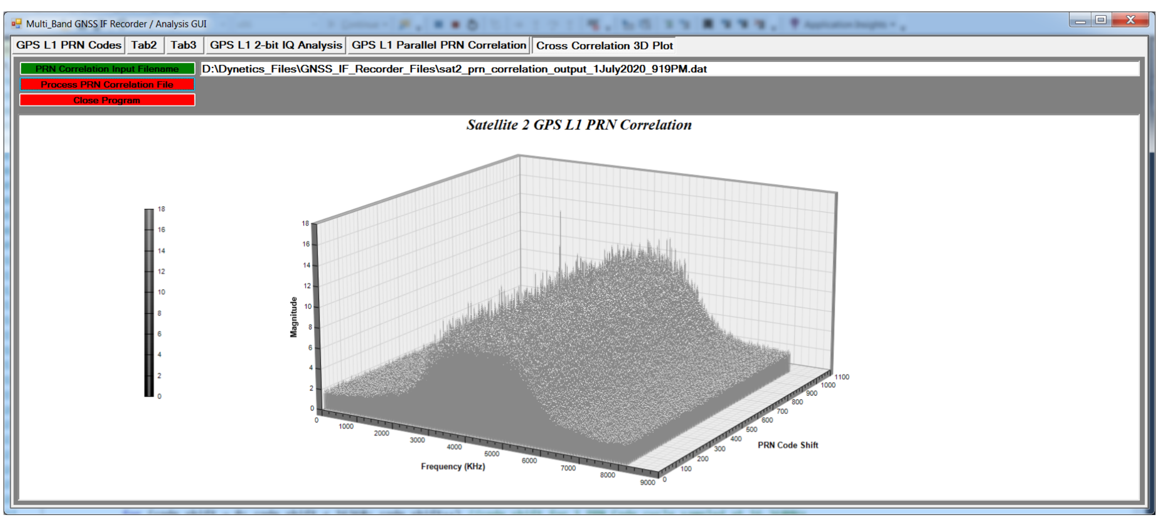

Figure 9. Plot of PRN Correlation for Satellite 2

The next phase of this analysis/research will continue with IF carrier and code tracking to retrieve navigation data for generation of ephemeris data. Eventual research will include comparative algorithms to enhance processing performance, anti-spoofing techniques, collection of multiple GPS and Galileo bands for improved position accuracy and satellite availability.

Continued IQ data collection will include the multi-band MAX2771 RF front-end receiver along with collections of bit resolutions ranging from 2 to 12 bits.