Senior Design Project in Electrical Engineering

GNSS SOFTWARE DEFINED RADIO (SDR)

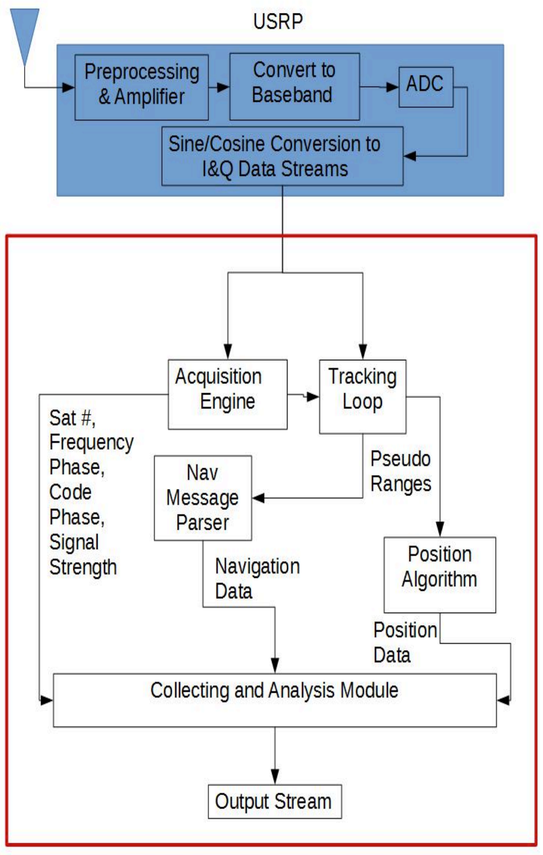
Signal Evaluation & Analysis of New Global Navigation Satellite Systems (GNSS)

1/c Carlos Palenzuela, 1/c Marek Pilarski

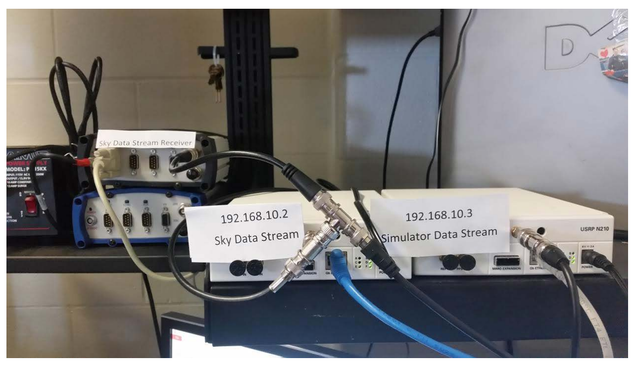
Advisor: CDR Seals, Dr. Hartnett, & Dr. Crilly Sponsor: USCG NAVCEN (Liaison: LT Mendoza)

PROJECT BACKGROUND

The US Air Force manages and services the US Global Positioning System (GPS). Recently, the Air Force has developed new GPS signals including L1C, L2C, and L5. The Coast Guard Navigation Center (NAVCEN) is interested in having the ability to monitor these signals. Our Global Navigation Satellite System (GNSS) receiver uses a Universal Software Radio Peripheral (USRP) as the front end of the receiver. The USRP is versatile in that it can receive signals on a wide range of frequencies. The USRP will receive and pass the GPS signal to a computer. The computer will process all the data and display all the signal analysis information.



Block Diagram of Radio Front End & Software Defined Receiver



Universal Software Radio Peripheral (USRP) for our antenna and simulator.

PROJECT REQUIREMENTS

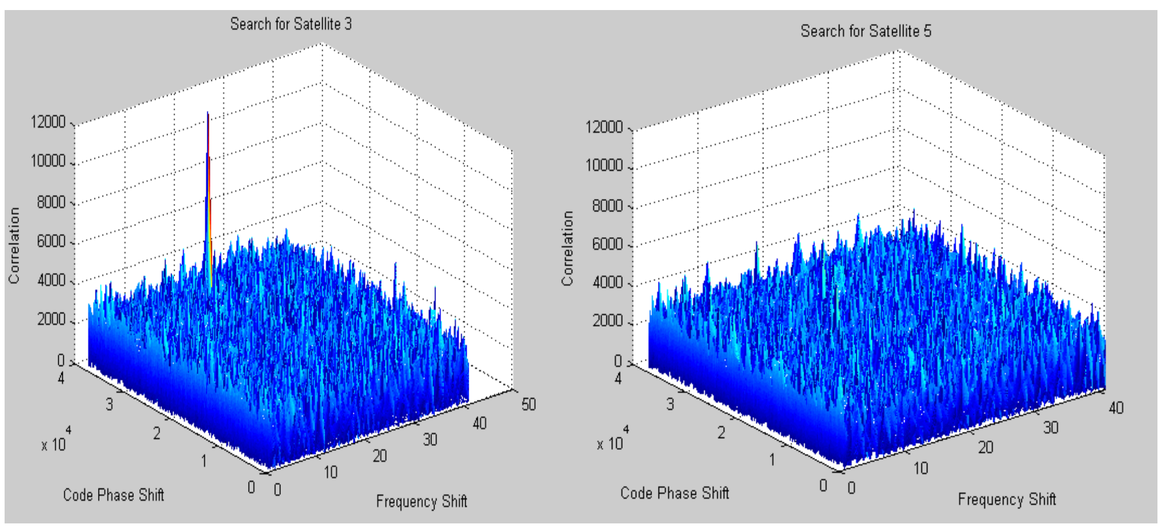
- **Software Defined – The receiver must have a small front end, and all processing must be done inside the computer.**
- **Customizable – Must have an easy and common logging suite.**
- **Signal Analysis – Receiver must be able to analyze L1C, L2C, and L5 GPS signals, all accessed from an easy to use GUI.**

PROJECT DELIVERABLES

The Project Goals:

- **Operational RF front end**
- **Operational satellite acquisition engines**
- **Operational tracking loops**

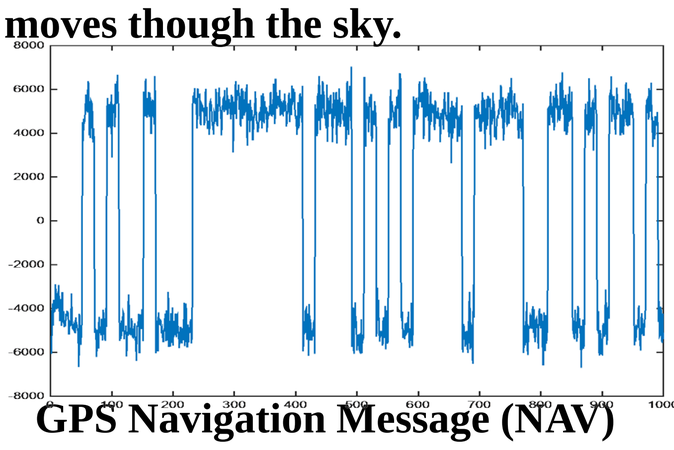
RESULTS FROM ACQUISITION MODULE



Left: There is a strong correlation in codes when looking for satellite 3, as shown by the large spike. This means that satellite 3 is in the sky. Right: There is no correlation in codes when looking for satellite 5, and there is no spike in this graph. This means that satellite 5 is not visible to our antenna.

RESULTS FROM TRACKING

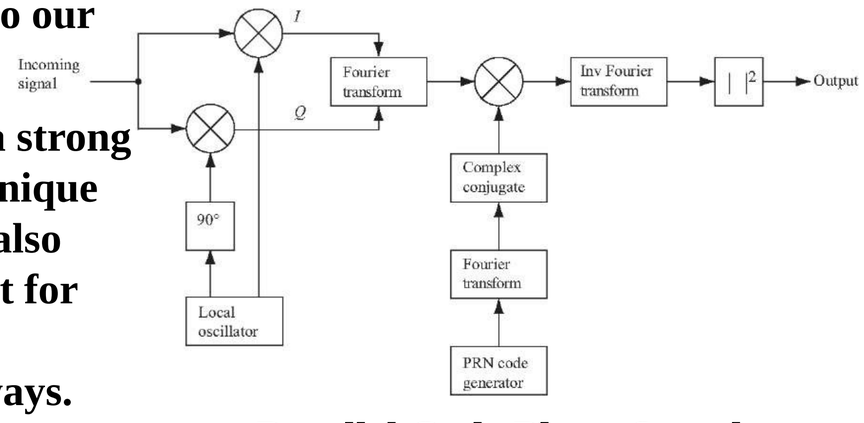
In the Tracking Loop, we use data from acquisition to find the message that the satellite is sending. We do this by taking an estimation of the frequency and code shift from acquisition, and using it to wipe the PRN Code and Carrier wave from the GPS signal. After that, all that is left are the navigation bits. Throughout the loop, we continuously update the frequency and code phase in order to account for Doppler shift as the satellite moves though the sky.



GPS Navigation Message (NAV) output from the tracking loop

RESULTS

When searching for satellites, we are looking for a strong correlation between the received signal, and the unique code for the satellite we are looking for. We must also search over multiple shifts in frequency to account for the movement of the satellites. We wrote three algorithms that will accomplish this in different ways. One will search through each combination of frequency and code shift. Another will search through all the different frequencies in parallel, and the final one will search through all the code shifts in parallel. Using test data, we were able to find multiple satellites and confirm our algorithms were working. Next we obtained real GPS data from the USRP. We confirmed that our acquisition engines were working by comparing the satellites our engines found to the ones that our NovAtel ProPak found in the sky. In every instance, we found every satellite that the NovAtel found. Next we wrote a tracking code to extract the navigation data from the satellites, and plotted it, showing what the navigation data looks like. The data bits can give us the information about the satellite, which we use to get position.



Parallel Code Phase Search Algorithm Block Diagram

Engine Name	32 Satellite Search Time (s)
Serial Search	1700
Parallel Frequency Space Search	207
Parallel Code Phase Search	24

Comparison of the time it took for each engine to search through all 32 satellites of the GPS constellation. The fastest one was Parallel Code Phase Search, which took 24 seconds.