ASSIGNMENT 9 – GPS SIGNAL ACQUISITION

Assigned : 17 November 2019
Due : 6 December 2019, 10 PM
Students may work in assigned teams of 2 on this assignment.

OBJECTIVES

- Understand and implement the acquisition process using raw signal samples captured by a rooftop GPS receiver front end.
- Use visibility prediction code developed earlier in the class to accelerate the acquisition process.

OVERVIEW

This assignment pulls together concepts and tools from prior modulation and visibility prediction assignments, and adds a new element of working with actual GPS sampled data collected on the roof of the Engineering Center. The primary goal is to acquire GPS signals from a short set of raw data captured by the NT1065 GNSS RF front end. The recorded data set has been reformatted into a MATLAB binary file that you easily load. The file contains 37 ms of 2-bit complex samples. The complex samples correspond to the sampled signal $s_{l,k}$ shown in Figure 1. You will construct the open loop carrier wipeoff and code correlation functions needed to compute a complex correlator output for a specified C/A code at a given delay and carrier frequency against the measured samples as shown in Figure 2. You will then use this code to evaluate the output over an appropriate acquisition search grid. The final goal is to identify which satellite signals are present in the recorded data and estimate their code delays (modulo 1ms) and Doppler frequencies.

The data set was collected by D.K. Lee on August 28, 2018, at about 16:29 UTC.
The approximate location is N 40.0, W 105.15, Height 1629 m.
The nominal sampling frequency is 6.625 MHz.
The nominal IF frequency is (negative) -60 kHz.

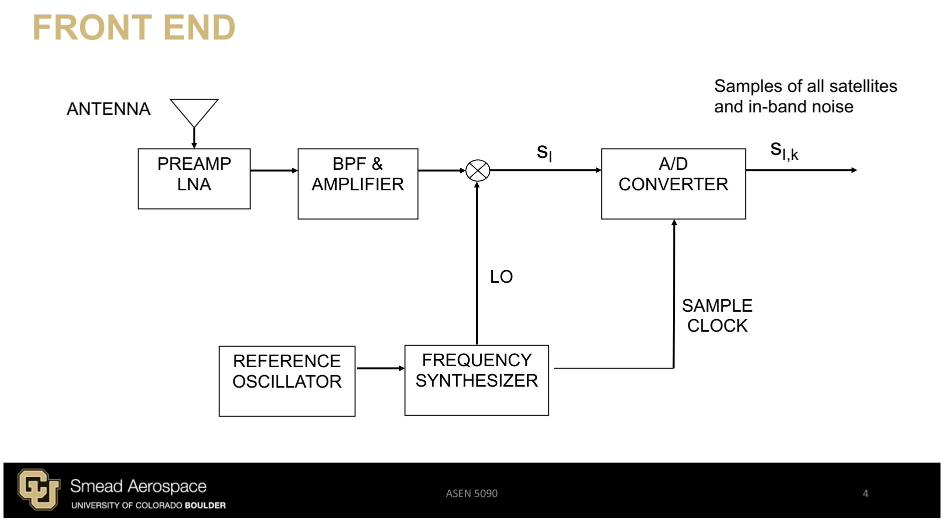

Figure 1. Block diagram of sampling receiver

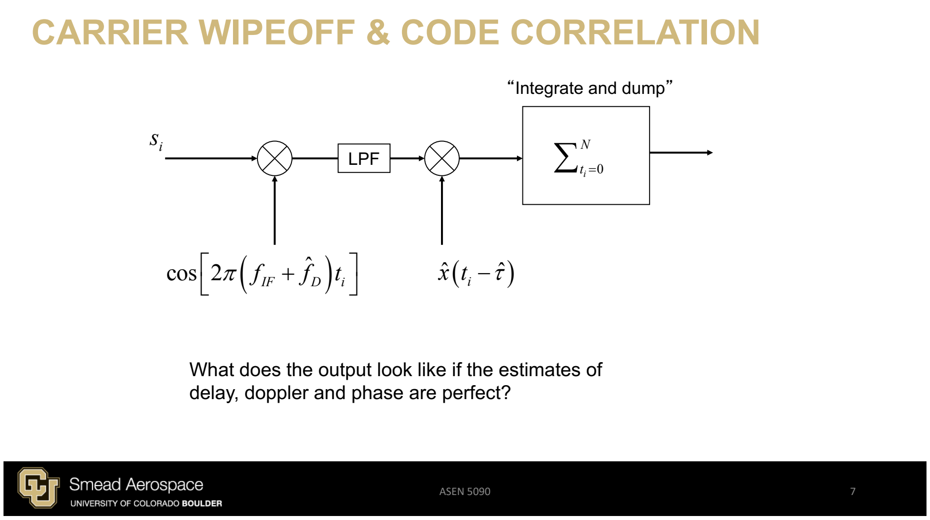

Figure 2. Block diagram of carrier wipeoff and code correlation functions.

https://www.gpsworld.com/launchpad-multi-frequency-gnss-rf-front-ends/

NT1065_USB3

Multi-band multi-system 4-channel coherent GNSS RF front-end based on NT1065 "Nomada" IC.

Features

- 4 coherent GNSS channels
- IF bandwidth up to 32MHz for each channel
- Acquisition of wideband signals up to 64 MHz (such as Galileo E5) with 2 coherent channels
- Built-in 2-bit ADC
- USB3 interface (up to 800 Mbit/s)
- Ability to connect 4x CRPA

EXERCISES

1. **Visibility Prediction**
   Use your code from HW3 and an appropriate almanac file to predict which satellites should be visible at the specified location and time. Show their locations on a sky plot (plotAzEl). As a check, you should find that PRNs 2 and 12 are both visible above 60 deg elevation.

2. **Carrier wipeoff and code correlation**
   Calculate and check the complex correlator output for PRN02 at a specified delay value (τ) and a Doppler value of (f_D).
   - Load the sample data set – this is the received signal s_R.
   - Create a time vector at intervals of Δt_s corresponding to 1ms worth of samples:
     $$t = [t_1 \quad t_2 \quad \cdots \quad t_n]$$
   - Create a vector of the corresponding PRN2 C/A code values (+1/-1) for each element of time vector:
     $$x = [x_1 \quad x_2 \quad \cdots \quad x_n]$$
   - Create a vector of the corresponding IF carrier phase for the given time vector and Doppler.
     $$\theta_i = 2\pi(f_{IF} + f_D)t_i, \quad \theta = [\theta_1 \quad \theta_2 \quad \cdots \quad \theta_n]$$
   - Construct the complex correlator output for a specified delay value (τ) by shifting the starting index into the sampled data by $\tau/\Delta t_s$, multiplying with the code and a complex representation of the carrier, and summing:
     $$S(f_D, \tau) = \sum_{i=1}^{n} s_R\left(i + \frac{\tau}{\Delta t_s}\right) x_i \, e^{-j\theta_i}$$

   You can check your code by first using an ideal input signal (s_{CHECK} instead of the actual received signal s_R)
   $$s_{CHECKi} = x_i(cos\theta_i + jsin\theta)$$
   Look at the correlator output when the selected delay and Doppler match and when they don't.
   As another check, for the start of the sample data file, for PRN02 I get the following results:
   ```
   DOP=0    DELAY=  9 samples    S = -67.4585 +99.0478j
   DOP=1kHz DELAY= 2943 samples  S =  1598.8 - 391.3j
   ```
   (This assumes that the sampled data is just shifted forward, not circularly wrapped. You'll get a slightly different (but also OK) answer if you select just a 1ms section of data and circularly shift it.)

3. **Create a search grid in delay and Doppler and find PRN02**
   - Set up the *delay* axis of the grid in steps corresponding to the sample interval.
   - Set up the *Doppler* axis of the grid in steps of 1kHz / (integration time in msec).
   - Compute and display a 3D mesh plot of the magnitude of $S(f, \tau)$ for PRN02 using 1ms of data.
   - The peak of the plot corresponds to the PRN02 delay and Doppler.
     Report the value of the delay (in samples and in meters), and the Doppler (in Hz).
   - For the peak Doppler bin, plot the magnitude of S as a function of tau.
   - For the peak delay bin, plot the magnitude of S as a function of Doppler.
4. **Find at least 3 additional satellites and generate the same plots and results.**
5. Increase the integration time to 2ms or more and repeat the acquisition process for 2-3 of the satellites. You might try choosing satellites with lower correlation peaks to see if the longer integration time improves the results, or see if you can acquire a satellite expected to be visible that did not seem to have a peak with just 1ms of data. Describe your results.

Grading – Provide clear responses to each of the exercises including plots, discussion, and code.
Total assignment is worth 50 points.