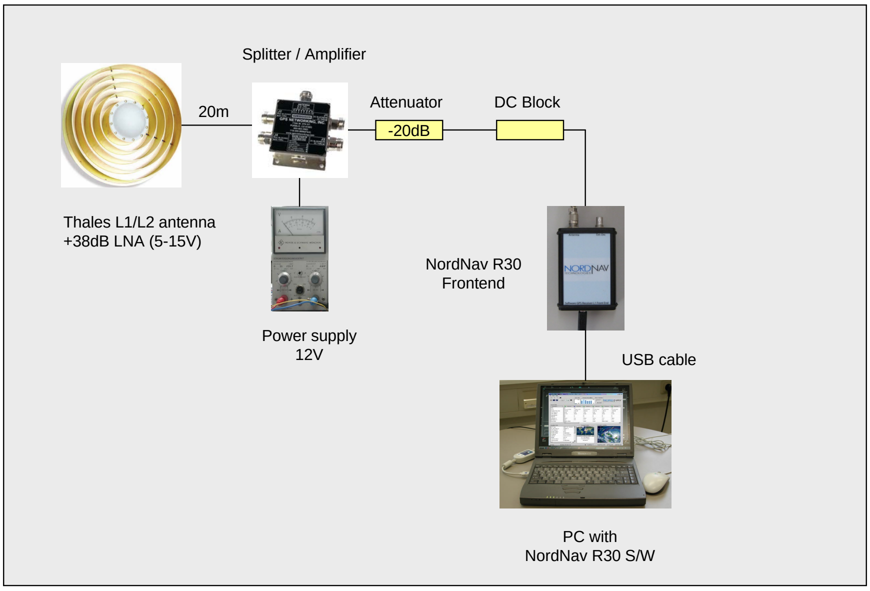
Exercise 4 – C/A Code Acqusition

Description

The exercise illustrates the GPS C/A code signal search and acquisition using a software radio approach. A GPS receiver frontend is used to record down-converted and digitized radio frequency signals. C/A code chip sequences for individual PRNs are generated based on shift registers as defined in the GPS signal specification. After modulation on a synthesized carrier at the intermediate frequency, the recorded signal and the code replica are correlated to acquire GPS satellite signals. A frequency search is performed to identify the proper Doppler shift and a Fourier transform is used to determine the code offset relative to the start of the data set.

Test Setup



Equipment

- NordNav R30 frontend and receiver software
- Bias-tee and regulated power supply
- Dual-frequency GPS antenna with low noise amplifier
- R/F and USB cables
- Attenuator

Tasks

Data collection

- Operate the NordNav software receiver; note the time-to-first fix and the tracked satellites
- Use the NordNav receiver to record a short (few secs) set of compressed R/F samples (4-bit sampling
- Convert the data into a single-byte-per-sample format using the NordNav control software

Note: the R30 frontend employs an intermediate frequency of 4.1304 MHz and a sampling rate of 16.3676 MHz. The resulting files will have a size of 1 GB /min.

Analysis and discussion

- How many data have to be recorded/processed for
  - for C/A code acquisition? for detecting navigation bits and navigation data frame?
  - for positioning?
- Write a Matlab function `code=CA(prn)` to compute the 1023 chips C/A Gold code sequence for any of the PRNS 1 to 32. Use numerical values +1 and –1 to represent logical 0s and 1s, respectively.
  - Compute the auto-correlation for shifts of 0 to 1022 chips to validate your code-sequences. Verify that the correlation result is always one of the four values 1, -1/1023, -65/1023, or +63/1023.
  - Plot the auto-correlation function of PRN1 and the cross-correlation of PRN1 and PRN2

  Hint: in Matlab, a shifted copy of the code can be obtained using the statement `shifted_code = [code(shift+1:1023) code(1:shift)]`. The correlation for integer delays can be computed via the dot product `(shifted_code*code')/1023`.
- Read the data corresponding to one C/A code period and generate a histogram of the sampled values
  - What is the range of values obtained with 4 bit sampling?
  - How many bytes/samples do you need to read to cover the specified time interval?
  - Create a vector `t` of sampling times corresponding to the stored data points

  Hint: use the following Matlab code to read n bytes from the beginning of the file
  ```
  fid = fopen(fileName, 'rb');
  fseek(fid, 0, 'bof');
  signal = fread(fid, n, 'int8')';
  ```
- Select a PRN of your choice that was tracked by the NordNav receiver during your data take
- Remove the intermediate frequency and approximate Doppler from the signal by mixing it with a carrier replica from the numerically controlled oscillator
  - What is the possible/expected range of Doppler shifts for a terrestrial receiver
  - Select a Doppler offset f_D as an integer multiple of a 250 Hz (or 125 Hz) search bin width
  - Generate a sine and cosine wave ($\sin(2\pi f_\mathrm{NCO} t_i)$, $\cos(2\pi f_\mathrm{NCO} t_i)$) at the NCO frequency $f_\mathrm{NCO} = f_\mathrm{IF} + f_\mathrm{D}$ for all sampling epochs t_i
  - Compute the in-phase and quadrature components $I(t)$ and $Q(t)$ by (epoch-wise) multiplication of the signal with the sine and cosine wave.
- Correlate the “Doppler-free” signal with the C/A code replica
  - Generate a C/A code replica by sampling the C/A code at the sampling frequency ($f_\mathrm{sample} = 16.3676\ \mathrm{MHz}$) over a full C/A code period.

    Note: the resulting vector must have the same length as the signal and the I/Q vectors
  - Use a complex Fourier transform to compute the correlation function for all delays t_i:
    `corrAmp = abs(ifft(fft(I+j*Q).*conj(fft(CAcodeReplica))));`
- Repeat the above steps for the Doppler search grid
  - generate a surface plot showing the correlation “mountain” as a function of Doppler offset and time delay
  - compare the Doppler shift with the value measured by the NordNav receiver

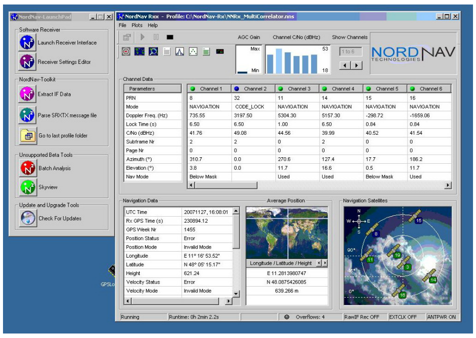
- plot the correlation amplitude versus Doppler offset and correlation versus time delay around the peak correlation.
- How wide is the correlation function in each direction and what are the consequences for the acquisition process in a GPS receiver?

References

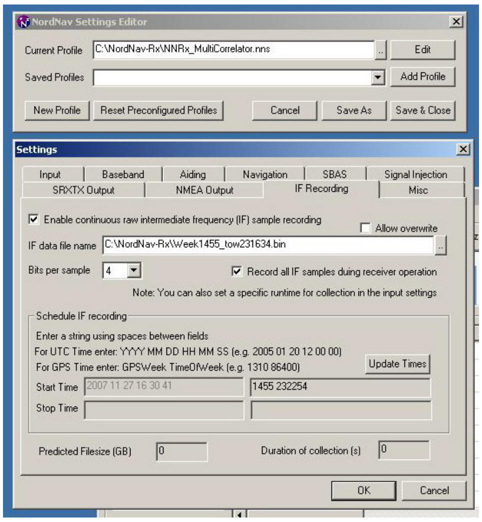
1. Misra P., Enge P.; Global Positioning System (GPS): Theory and Applications; Ganga-Jamuna Press (2001).
2. Navstar GPS Space Segment / Navigation User Interfaces; ICD-GPS-200, Revison C; 25 Sept. 1997; Arinc Research Corp., El Segundo (1997).
3. Borre K., Akos D.M., Bertelsen N., Rinder P., Jensen S.H.; A Software-Defined GPS and Galileo Receiver; Birkhäuser (2007).

Instructions

- Connect the frontend to the roof-top antenna and the PC running the NordNav software receiver
- Start the NordNav launch pad and activate the “Receiver settings editor” using the corresponding button in the launch pad. Create a new profile “NNRx_Team<A/B/C>.nns”.
    - Select 6 channels in the “Baseband” tab
    - Any other options (TBC)
- Activate the software receiver using the “Launch Receiver Interface” button in the launch pad and monitor the signal search and start of navigation. Take a note of tracked satellites, signal strengths and Doppler offsets



- Activate the receiver settings editor in the “File” menu and select your profile



- Select the “IF Recording” tab and enter a file name (*.bin) for recording
- Enable recording
- Select 4 bit sampling
- Switch to the “Input” tab and enter a receiver runtime of, e.g., 0.1s

- Start the receiver; deactivate recording after completion
- Launch the “Extract I/F Data” tool and convert raw data samples to 1-byte integer format (*.sim)