Radar Exercises: Doppler, Sampling, Pulse Compression

1. The Poker Flat ISR operates at 450 MHz. The echo from the ionosphere is produced by reflection from ion sound waves. A typical phase speed for these waves is 3 km/s. What is the Doppler frequency shift in Hz caused by reflection off these waves? This represents the approximate width of the Doppler spectrum.

2. The Nyquist theorem states that we must sample a signal at a rate of at least twice its highest frequency in order to recover it. For part 1, this so-called "Nyquist rate" is about 20 kHz, meaning we need samples of I and Q from the target at a rate of 20kHz. What is the maximum target range at which we can obtain independent samples of I and Q at this rate? How does this compare with the altitude of the ionosphere?

3. Range resolution is controlled by the length of the transmitted pulse. The optimal detection strategy involves correlating the received signal with a replica of the signal we transmitted (called "Matched Filtering"). In the script given, the two vectors of 1's represent identical uncoded radar pulses. Running the script plots the so-called "range ambiguity function" for the pulse, which is computed by correlating the pulse with itself. The origin represents the target location, but there is also received power at ranges other than 0, hence there is "range ambiguity" associated with any single detection. Try the following:

   a) First let's try a shorter pulse. Replace pulse2 with the following
   pulse2 = [0,0,0,0,1,1,1,1,1,0,0,0]
   This represents a pulse that is 40% shorter. Rerun the script. What effects do you see compared to the original pulse?

   b) Now replace pulse2 with the folloing coded version of the pulse,
   pulse2 = [1,1,1,1,1,-1,-1,1,1,-1,1,-1,1]
   Each element represents a "bit" or "baud" whose signe we can control. This code is called a "13-baud Barker code." The sign changes can be implemented in hardware by flipping the phase of the transmitted signal 180 degrees for these bauds. Rerun the script now. What have we achieved with this coding?

   c) The range ambiguity is generally defined as the "full-width at half-maximum" (FWHM) of the main peak of the matched filter output. Compare the range ambiguity of the uncoded and coded pulses based on this definition. The ratio of these quantities is referred to as the "pulse compression ratio". What costs have we paid for the improved in range resolution from pulse coding?