Exercises for Introduction to Radar

1. The Poker Flat ISR operates at 450 MHz. The ionospheric echo 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 (or kHz) 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 twice its highest frequency in order to recover it. For part 1, the so-called "Nyquist rate" is about 20 kHz, meaning we need to sample I and Q from our target at a rate of 20kHz. What is the maximum target range at which we can obtain independent measurements of I and Q at this rate? How does this compare with the altitude of the ionosphere?

3. The focusing power of a dish antenna depends on the ratio of its diameter d to the wavelength λ. This dimensionless quantity is referred to as the "electrical length" of the antenna, and its inverse gives the beamwidth in radians. The Millstone Hill fixed antenna has a diameter of 68 m and operates at 440 MHz. What is the beamwidth in degrees?

4. Range resolution is controlled by the length of the transmitted pulse. The optimal detection strategy for radar 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 a "range ambiguity" associated with any single detection.

   a) In the script, replace pulse2 with the following coded version of the pulse,
   [1 1 1 1 1 -1 -1 1 1 -1 1 -1 1];
   Each element represents a "bit" or "baud". This code is called a "13-baud Barker code." The changes in sign can be implemented in hardware by flipping the phase of the transmitted signal 180 degrees for these bauds. Running the script again should give you two ambiguity functions. What have we achieved?

   b) Suppose the pulse length is 130 μs (micro-seconds), such that each baud has length 10 μs. What is the length in kilometer of the uncoded pulse? What is the length of each baud?

   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 improvement in range resolution from pulse coding?