Lab 9: Radar Range Equation

Materials:

- Time Domain P410 radar
- MRM RET software
- USB 2.0 A to Micro-B cable.
- Targets
- Tape measure

Introduction:

In this laboratory we will explore the radar range equation. The radar range equation relates the range of the radar to the characteristics of the radar, the target, the antennas and the environment. In its simplest form, the equation can express the received power as

$$P_r = \frac{P_t G}{4\pi R^2} \cdot \frac{\sigma}{4\pi R^2} \cdot A_e \qquad (1)$$

where

- P_r is the received signal power
- P_t is the transmitter power radiated by an isotropic antenna (radiates uniformly in all directions)
- G is the gain of the transmit antenna (due to directionality.)
- R is the range from the radar to the target in meters
- σ is the radar cross section (RCS) of the target. The radar cross section determines the power density returned to the radar for a particular power density incident on the target.
- A_e is the effective area of the receiving antenna.

The first term on the right hand side of equation (1) is the power density at range R from the antenna. A portion of that energy is reflected (reradiated) back at the radar. The reradiated power density is expressed by the second term in equation (1). The power received by the radar is given as the product of the incident power density times the effective area of the receiving antenna, A_e.

The RCS (σ) depends on the characteristic dimensions of the object compared to the radar wavelength. For this experiment we will use a sphere, since it has a simple RCS due to having the same shape no matter from what aspect it is viewed. We will measure the received signal power and verify that it drops proportional to $1/R^4$ as range increases. We will also measure the received signal power for different shaped objects to verify different RCS for different shaped objects.

When the radar configuration and the target type do not change, but only target distance changes the radar range equation can be expressed

$$P_r = \frac{K}{R^4} \tag{2}$$

where K is a constant factor that can be determined through experiment.

Experiment:

For this experiment we will determine the received signal power for a sphere at different ranges, and for different targets at a fixed range.

1. Apply power to the MRM, start MRM RET and connect to the MRM.
2. Set the **Transmit Gain** to 0 so that received signals due to close targets are not saturated.
3. Set the **Scan Start** time to the value calculated in Experiment 2. Set the **Scan Stop** time to give a maximum range of approximately 2.5 meters.
4. Take a background scan with no target present. Log the data and note the file name.
5. Place a sphere at a distance of approximately 1 meter from the face of the antenna. Measure the actual distance with a tape measure. Take a scan with the target in place and log the data. Name this file “target_1m.csv” or equivalent.
6. Repeat step 5 with a target at distances of 1.5 meters and 2 meters.
7. In Matlab open the *Experiment2.m* file and save the file as *Experiment3.m*
    a. Change the code so that it will open and save the data from the background scan and each target scan into appropriately named variables.
    b. Plot 1 scan from the background and each target overlaid in one figure. Discuss the similarities and the differences in this figure.
    c. Form and plot the difference scans for each of the target locations. Verify the target locations match with the measured values.
8. Determine the received signal power for each of the targets. The maximum signal value will be proportional to the received voltage. By squaring this voltage, we have an estimate of the signal power. Plot this value for each target versus the range. It should decrease as range increases by $1/R^4$. Comment on how your measurements behave with respect to range.
9. The MRM measurements are inherently noisy. This noise is due to a variety of sources including thermal noise and other reflections in the range bin of interest. One method of reducing some of the effects of the noise is to average measurements over several scans. Form the average of 10 difference scans for each target. Plot these scans and repeat step 8. Do the average received powers better follow the predicted performance?

10. We will now explore the change in received signal power due to target differences. Form a background scan (no target present) and scans with four targets: large sphere, small sphere, metal plane, corner reflector. In each case log the scans, form and plot the difference scans, and determine the received signal power for each target. Record the received signal powers.

Questions:

1. How closely did your measurements of received signal power follow the $1/R^4$ prediction? How could you improve these results?
2. Based on your measurements of signal power as a function of target range, what would you predict the received signal power to be at a range of 10m? 30m? How could you increase the received signal power?
3. How did the received signal power vary with respect to the different targets? Did the received signal powers vary as you expected?

Turn in:

3, 7b, Plots from MRM Plotter for 8, 9, 10 & Matlab code (commands) for 9.