RCS Homework 7: Phenomenology

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The calibration of radar using a static target like a radar tower is a standard practice. To calibrate the radar, the RCS of a static object, typically a water tower, is calculated then compared against the data collected from the radar. This data is then compared to adjust the results from the radar to be more accurate.

In this experiment, the radar cross section of the target, a 33m tall, 10m in diameter steel water tower, 3.47 nautical miles from the radar lab is used. First, the RCS of the target is calculated using a function created in MATLAB called “cylinder_rcs.m”. This function, however, simplifies the target to be floating cylinder, with no foundation or conical roof. With the given values in Figure 1:

Variable:	Data:
Water Tower Height	33 meters
Water Tower Radius	5 meters
Water Tower Distance	3.47 nautical miles
Water Tower Direction	Southeast
Water Tower Material	Steel
Water Tower Reference	Radar Lab
Radar Frequency	9.4 GHz
Incident Angle Varied	-90˚ - 90˚

Figure 1: Variables for the experiment.

The MATLAB “cylinder_rcs.m” function only accounts for incident angle, bistatic angle, frequency, tower height, and tower radius. Inputting this data, the function the Geometric theory of diffraction to calculate the RCS of the cylinder. This results in an RCS as seen in Figure 2 and plotted in Figure 3:

Vertical RCS: 0.004193+0.18356i
Horizontal RCS: 2.6576e-05+0.079623i

Figure 2: MATLAB function RCS results.

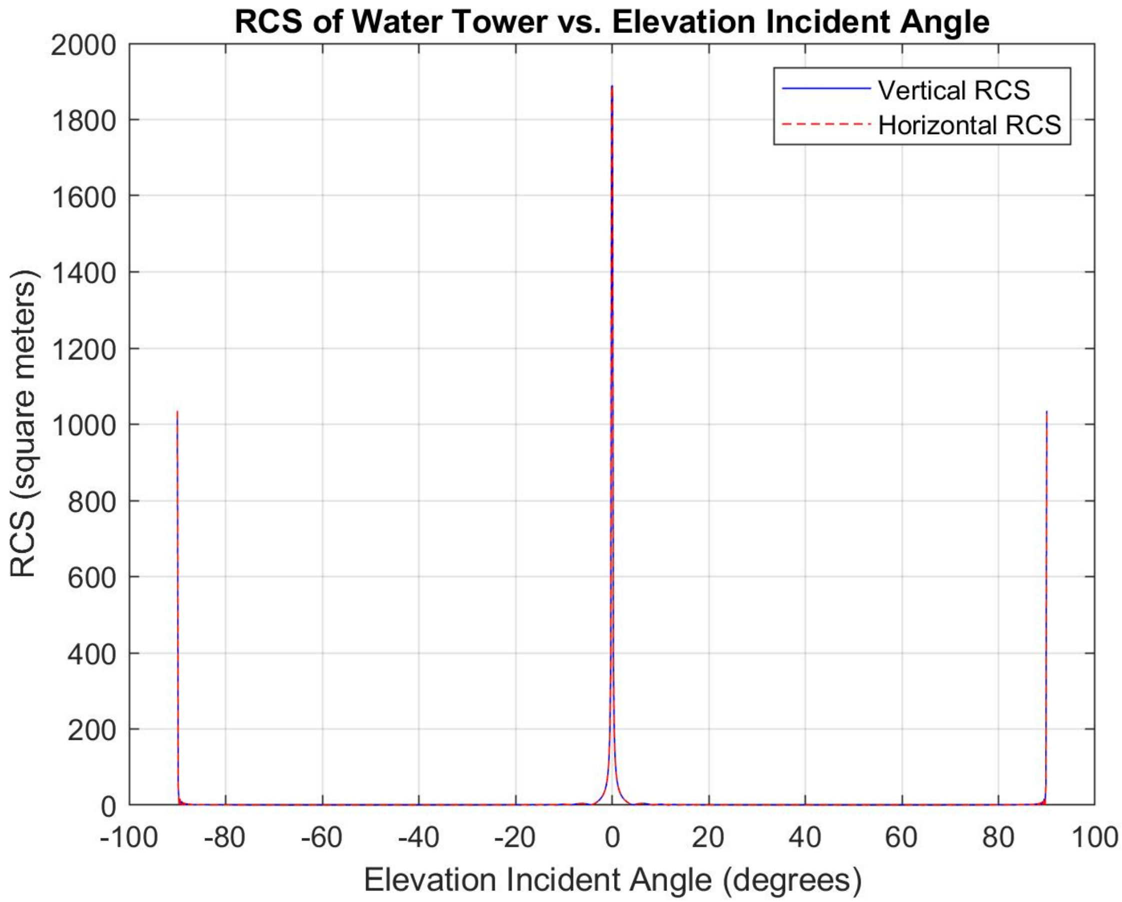

Figure 3: RCS plotted over variable incident angle.

The data displays several RCS reflections at -90˚, 0˚, and 90˚. This demonstrates that the water tower is a good calibration target when the radar waves hit the target head on. The reflect points at 90˚ and -90˚ shows that the water tower acts as a good target when the edge's of the radar emission reflect off of it.

For a target to be good for radar calibration, it must be static, have a stable RCS, be large, have a consistent material, have specific angular reflections, be geometrically simple, be safe and cheap. Since the water tower demonstrates all of these characteristics, we can conclude that the water tower has good characteristics to be a radar calibration target.

Due to the simplicity of the MATLAB function, reducing the target to a floating cylinder, several assumptions are made that reduce the models effectiveness. To improve the model, the water tower can be thought of as a series of rectangles to represent the foundations, a cone to represent the roof, a cylinder to represent the body, and a half sphere to represent the bottom of the water tank. By combining these simple shapes, the RCS of the water tower can be more accurately calculated.

Other considerations would be the environment. Considering variables like the weather, atmospheric pressure, humidity, temperature, radar elevation, foliage, obstacles like buildings and power lines, and other EMF sources would increase the model's accuracy.

Since water can absorb electromagnetic waves, water in the atmosphere in the form of humidity or weather like snow, fog, or rain the signal strength will be reduced. Water can also cause reflections that further muddle the target's RCS. A tertiary effect of weather on RCS return is how water on a surface or target changes the dielectric of the surface. This not only changes the RCS of the target but also the clutter around the target. Setting a new noise level.

The location of the radar is also a significant variable. The location of the radar relative to the target can be broken down into x, y, and z directions. If the radar is farther or closer to the target, the signal strength can decrease or increase respectively as determined by the radar range equation. If the radar also moves in the plane, changing what direction the radar faces the target can also change the RCS. This is because as the radar is translated across the z-axis, the environment and clutter changes, as well as, the profile of the target. Requiring new environmental and target models to calculate the RCS of the target. If the radar translates up or down into the y direction, all aspects of the target and environment change. This is most apparent if the radar is directly above the target. In this case, if the radar was above the target, the water tower would be a circle from the reference of the radar, making the cylindrical target model inappropriate. The clutter like buildings would also have much greater reflections since their relative cross-section will be much larger than the targets. Lastly, the ground would also be a factor, reflecting energy back to the radar. These are just some of the variables to consider when changing the location of the radar relative to the target.

In conclusion, the calibration of a radar on a static object like a water tower is an effective way to calibrate a radar system. However, the MATLAB function "cylinder_rcs.m" used to calculate the RCS of the water tower makes several assumptions that reduce the models accuracy. Methods to increase the models accuracy can be implemented. Other variables like the environment, clutter, and radar location would also significantly change the accuracy of the model and must be defined to accurately calibrate a radar system.

Code Appendix:

```
% Parameters for the water tower
a = 5;
h = 33;
freq = 9.4e9;
biangle = 0;

% Range of elevation incident angles (from -90 to +90 degrees in radians)
angles = linspace(-pi/2, pi/2, 1000);

% Initialize arrays for RCS data
RCS_ver = zeros(size(angles));
RCS_hor = zeros(size(angles));

% Calculate RCS for each incident angle
for i = 1:length(angles)
   [RCS_ver(i), RCS_hor(i)] = cylinder_rcs(angles(i), biangle, freq, a, h);
end

% Plotting the RCS
figure;
plot(rad2deg(angles), abs(RCS_ver), 'b-', rad2deg(angles), abs(RCS_hor), 'r--');
xlabel('Elevation Incident Angle (degrees)');
ylabel('RCS (square meters)');
legend('Vertical RCS', 'Horizontal RCS');
title('RCS of Water Tower vs. Elevation Incident Angle');
grid on;
```