ECE 278C Assignment 7: Short Baseline Sensing Systems

Abstract

In this assignment, the backward propagation method is used to perform simulation, analysis and estimation of the geolocation of a single target in the active sensing mode. The data collection procedure and the reconstruction method are discussed. I find that the range estimation from each receiver-transmitter pair produces an ellipsoid, and that the intersection of these ellipsoids aligns exactly with the location of the target. I find that the target region can be shrunk to reduce computation time once I have confirmed the location of the reflective target.

1. Introduction

In Assignment 6, I saw that overlaying the range profiles from 241 data points on a receiving aperture accurately reconstructs a source region because the sources naturally arise at the intersections of the rings from the individual range profiles. In this assignment, I extend that concept to reconstruct a source region characterized by only a single target point. For this task, only two data points (receivers) are needed.

In Assignment 6, the aperture data was gradually gathered by transmitting an FMCW wave at a point on the aperture and measuring the reflected wave at that same point. I characterized this measured wave entirely based on its phase shift, and backward propagated this wave out-and-back to every point in the source region. This caused peaks to arise in the reconstructed source region only at points where the length of the out-and-back backward propagation exactly cancelled the phase shift from the forward propagation. Therefore, the reconstructed source region from any given data point on the aperture was characterized by a ring of constant radius. By repeating this process for every data point on the aperture and overlaying the resulting rings, the source region was accurately reconstructed.

In this assignment, I transmit the FMCW wave just one time from the origin and measure the reflected wave's phase shift at two receivers on opposite sides of the x axis. Because the out-and-back forward propagation starts at the origin and ends at the receivers, I backward propagate the wave from the receivers out to every point in the source region and back to the origin. I find that the resulting range profile is characterized by an ellipsoid instead of a ring, as the endpoints of the out-and-back propagation are fixed at different locations. By overlaying the ellipsoids from the two receiver/transmitter pairs, the target location is determined with high precision. The following sections discuss the data measurement and backward propagation procedures.

2. Data Collection

I orient my transmitter at the origin and place the receivers at $(-5\lambda_0, 0)$ and $(5\lambda_0, 0)$. I place the target location at $(9\lambda_0, 15\lambda_0)$. Therefore, the distance to the target from the transmitter is $r_0 = 17.5$ with a bearing angle of $theta = 59$ degrees. I transmit an FMCW wave with $N = 128$ step frequencies corresponding to 128 wavelengths centered around $\lambda_0 = 1$.

I obtain the data at a receiver by forward propagating Green's function from the origin to the target and back to the receiver for each of the 128 wavelengths. I measure the phase shift for each of these waves and store these 128 complex numbers as $g_1(n)$ for the first receiver and as $g_2(n)$ for the second receiver.

3. Reconstruction

I sequentially back propagate the data in $g_1(n)$ and $g_2(n)$ one wavelength at a time until the reconstruction embodies the sum of all 128 range profiles of the two overlapping ellipsoids. I perform the reconstruction over a large $30\lambda_0$ by $30\lambda_0$ source region to capture the entire shape of the final range profile. Figure 1 shows the gradual reconstruction as the number of back propagated wavelengths, n, increases. Figure 2 shows the corresponding spectrum.

I see that the range profiles gradually add together to create a peak at the target location. Moreover, I see that the spectrum grows longer radially as n increases, which aligns with my observations of the spectra of range profiles in Assignments 5 and 6.

To better show the information gained from the reconstruction spectrum, I repeat the process with the same transmitter/receiver/target set up but I define the source

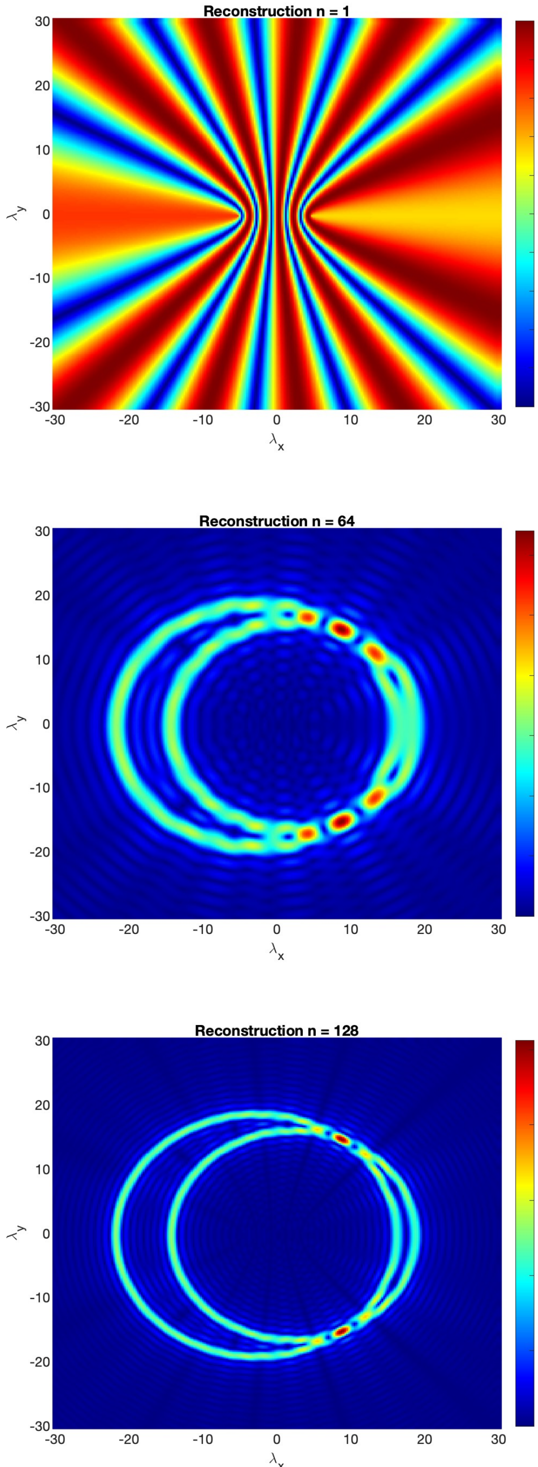

Figure 1. Sum reconstruction for $n = 1$, $n = 64$, and $n = 128$ from the top

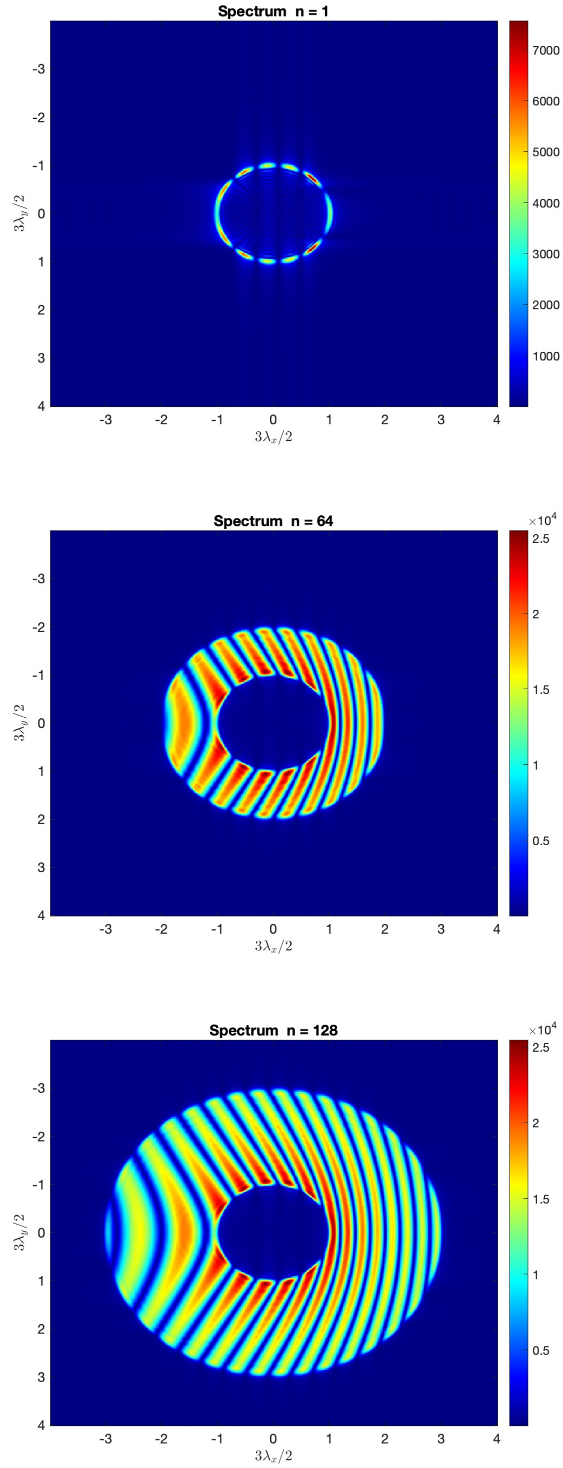

Figure 2. Sum reconstruction spectrum for $n = 1$, $n = 64$, and $n = 128$ from the top

region to be only $10\lambda_0$ by $10\lambda_0$ centered around the target. Figure 3 shows the gradual reconstruction as n increases and Figure 4 shows the corresponding spectrum.

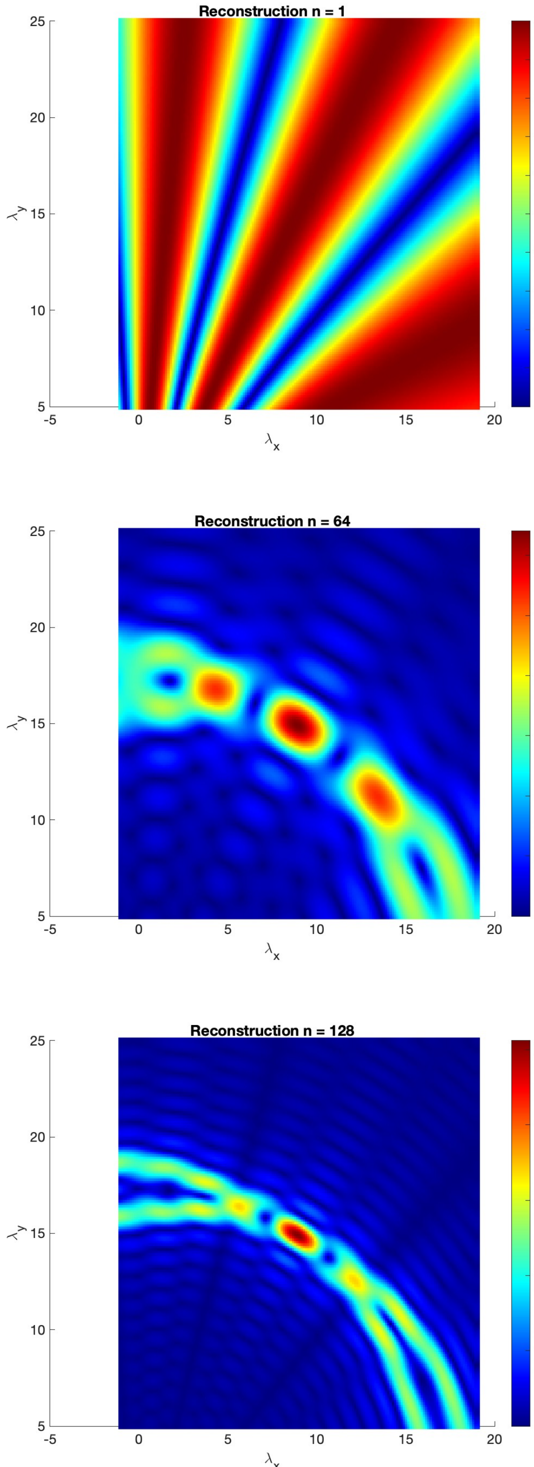

Figure 3. Sum reconstruction for $n = 1$, $n = 64$, and $n = 128$ from the top

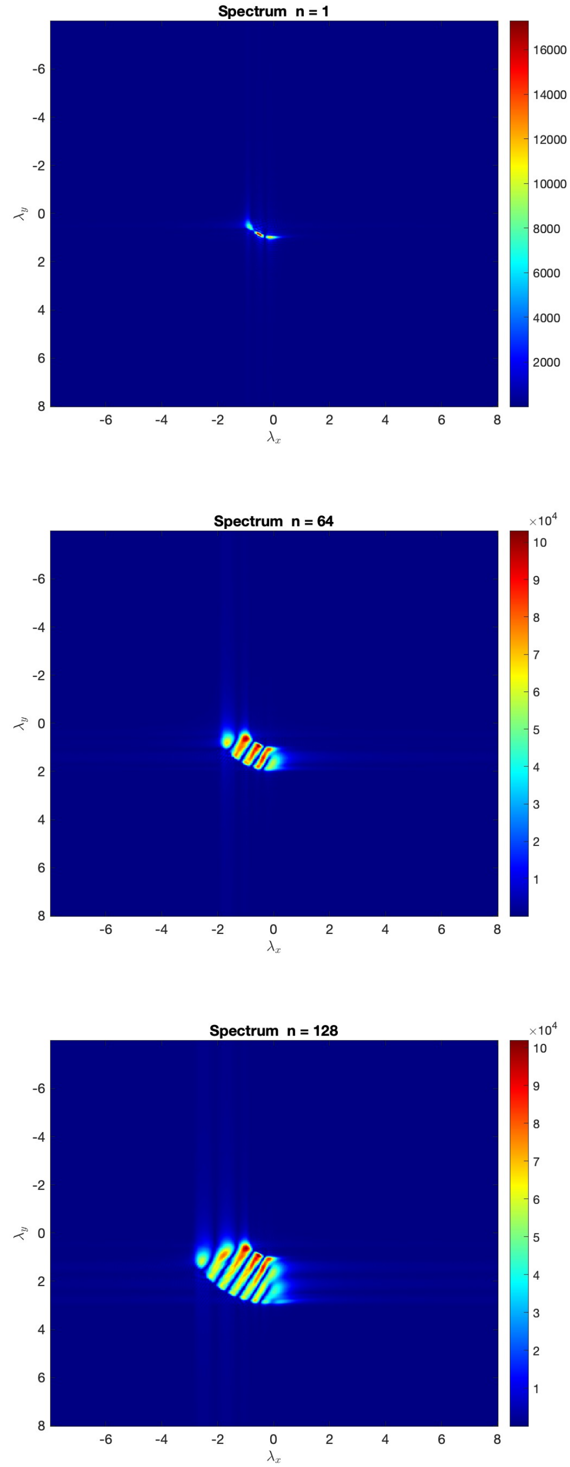

Figure 4. Sum reconstruction spectrum for $n = 1$, $n = 64$, and $n = 128$ from the top

I notice that the spectrum now reflects the bearing angle of the target location. This is because I measured the spectrum on a more localized region around the target location, so the plane waves that comprise the spectrum mostly propagate from the receiver locations, which closely align with the bearing angle. The smaller target region also allowed the code to run much faster, so I was able to increase the sampling frequency from $\lambda_0/4$ to $\lambda_0/8$ for the reconstruction process and provide more accuracy for the target location estimation. I see that the peak in the reconstruction clearly arises at $(9\lambda_0, 15\lambda_0)$.

4. Conclusion

I have shown that the range estimation procedure using backward propagation can be used to estimate the geolocation of a single target with only one transmitter and two receivers. I saw that the choice of target region allowed me to zoom in on the target estimation, while the choice of sampling frequency delayed computation but improved the accuracy of the estimation. I also saw that the range profile is extremely accurate when using the wideband operating mode; in this assignment I transmitted an FMCW wave using 128 operating wavelengths and found that the bandwidth of the range profile was thin enough to be confident in the target location estimation. The benefit of using this reconstruction method is that the separation distance of the receivers does not matter. In other words, as long as there are two receivers and a fixed transmitter the target estimation will be extremely accurate!