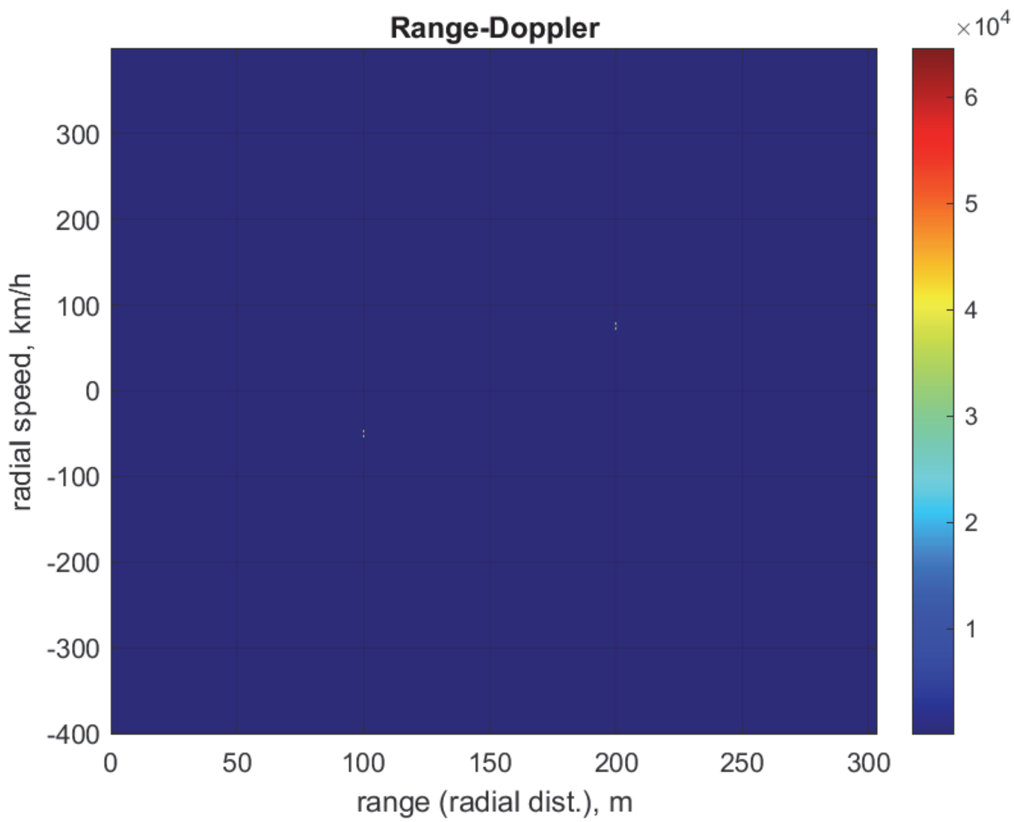
Test case example with 2 targets, with additional instructions & insights.

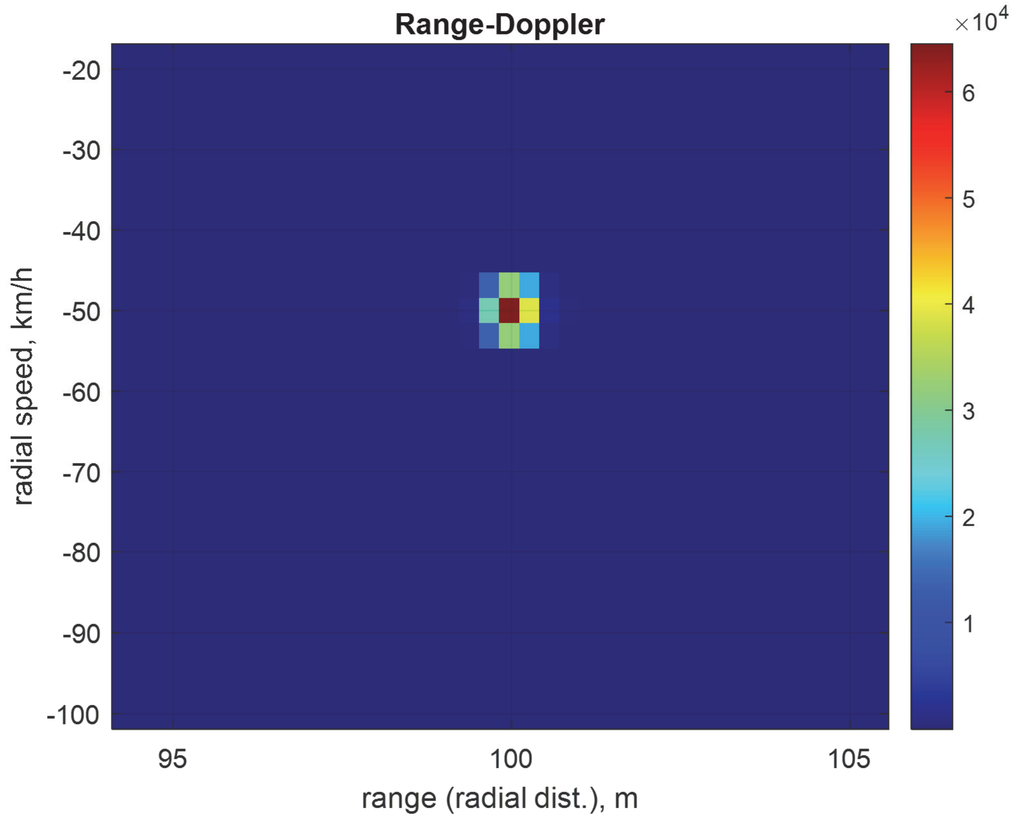
- Target 1 with range (radial distance) 100 m, relative radial velocity -50 km/h (incoming), azimuth -60 degrees.
- Target 2 with range (radial distance) 200 m, relative radial velocity +75 km/h (outgoing), azimuth +45 degrees.

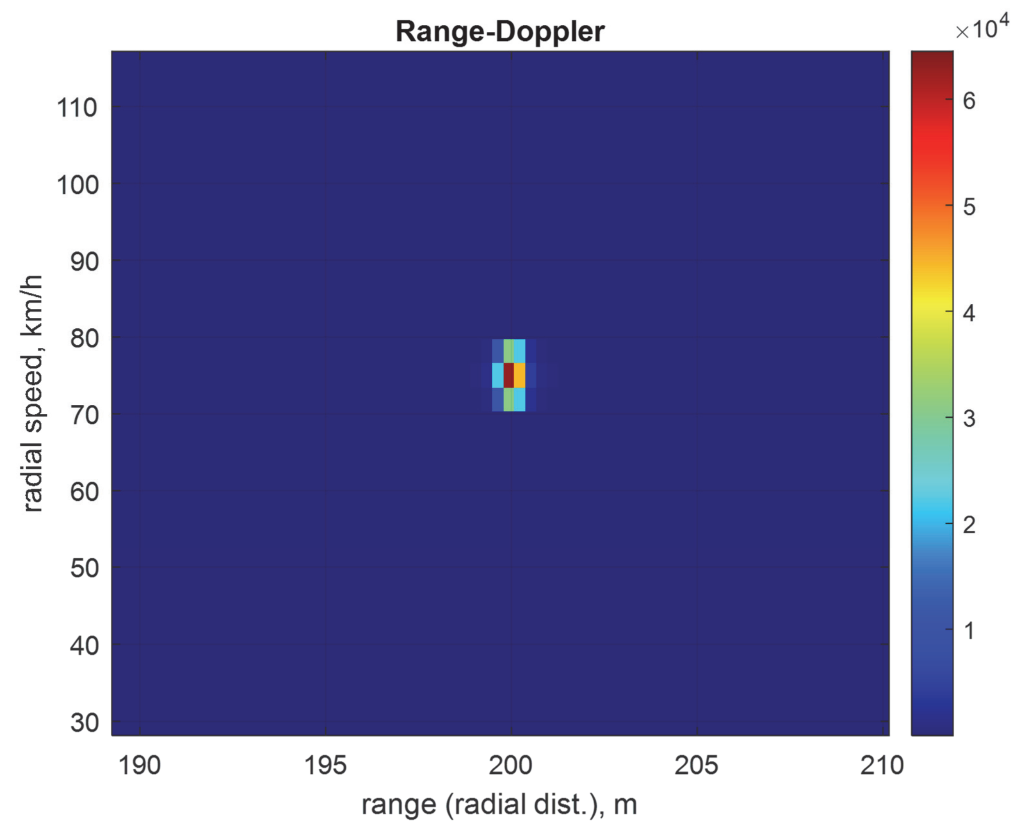
Note: an azimuth of 0 degree is in front of the radar system (car, automotive system). A negative azimuth is left of the frontal direction, and a positive azimuth is right of the frontal direction. The axis of the radar sensors (receiver antennas) is perpendicular to the frontal direction axis.

First, "Range-Doppler" 2-D plots are obtained for each sensor (each receiver antenna) by computing 2-D FFTs from all the chirps signals received at each sensor. The plot below shows the resulting Range-Doppler 2-D plot for the first sensor.



If zooms are performed centered at the two clusters with higher magnitudes, we obtain the following plots, where we can verify that the correct range (radial distance) & relative radial velocity are found for each target (100 m with -50 km/h, 200 m with +75 km/h):

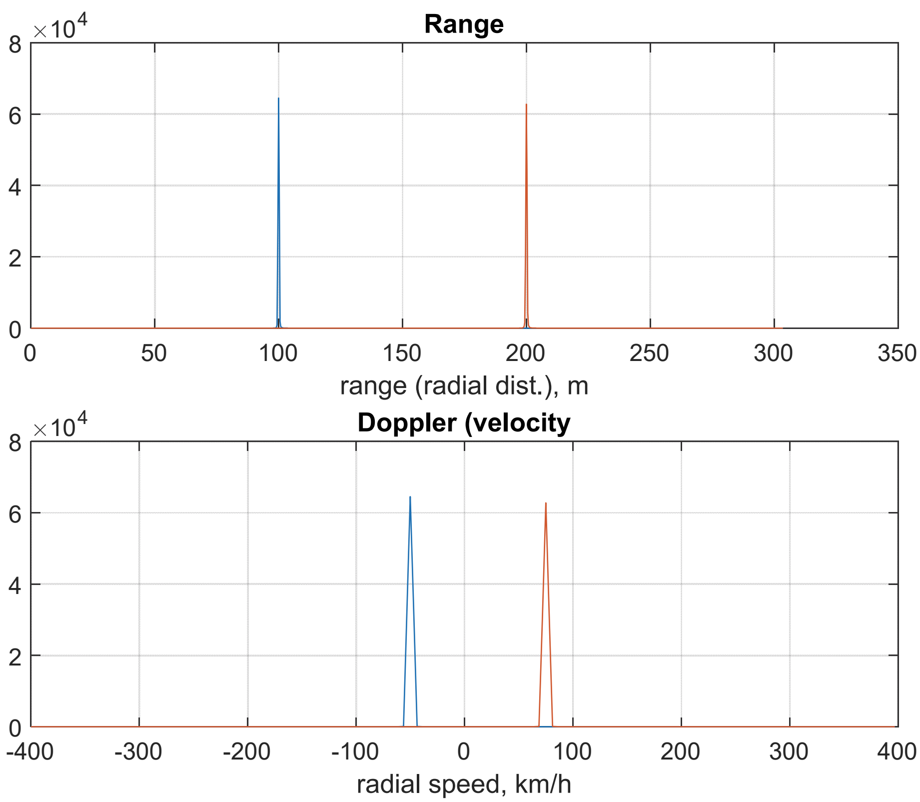

Range-Doppler
×10^4
radial speed, km/h
range (radial dist.), m
-20
-30
-40
-50
-60
-70
-80
-90
-100
95
100
105
6
5
4
3
2
1


Range-Doppler
×10^4
radial speed, km/h
range (radial dist.), m
110
100
90
80
70
60
50
40
30
190
195
200
205
210
6
5
4
3
2
1

Next, for each detected target, we want to show "1-D FFT slices" in the vertical (velocity) and horizontal (range) directions of the Range-Doppler 2-D plot, to show more clearly the measured values. The resulting magnitude plots will be much more accurate (visually) than the Range-Doppler 2-D plot.

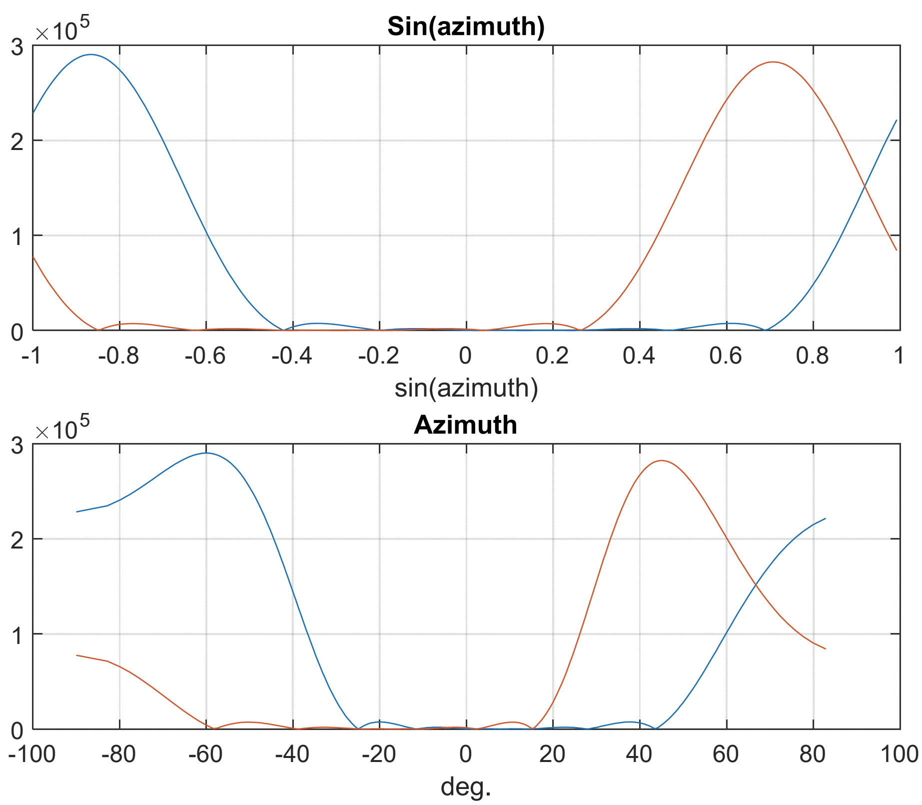
Note: the similar magnitude for the two targets in the 2-D Range-Doppler plot comes from using the same amplitude for the echo from each target in the synthetic signal generated for the simulations. Since both targets produce similar peak values in the 2-D Range-Doppler plot, a simple method detecting the maximum magnitude values can be used to detect the peak locations. However, to avoid cases where the maximum detected values actually come from the same peak (same cluster) in the 2-D Range-Doppler plot, some additional criterion was added to verify that the detected maximum magnitude values are sufficiently far from each other in the 2-D Range-Doppler plot (i.e., they come from different clusters). The thresholds for this additional criterion were adjusted by trial and error, with a different threshold for each dimension.

Below the results for the first target (in blue) are plotted on the same figure as the results for the second target (in red). Again, we can verify that the resulting range and velocity measurements are correct (100 m with -50 km/h, and 200 m with +75 km/h).

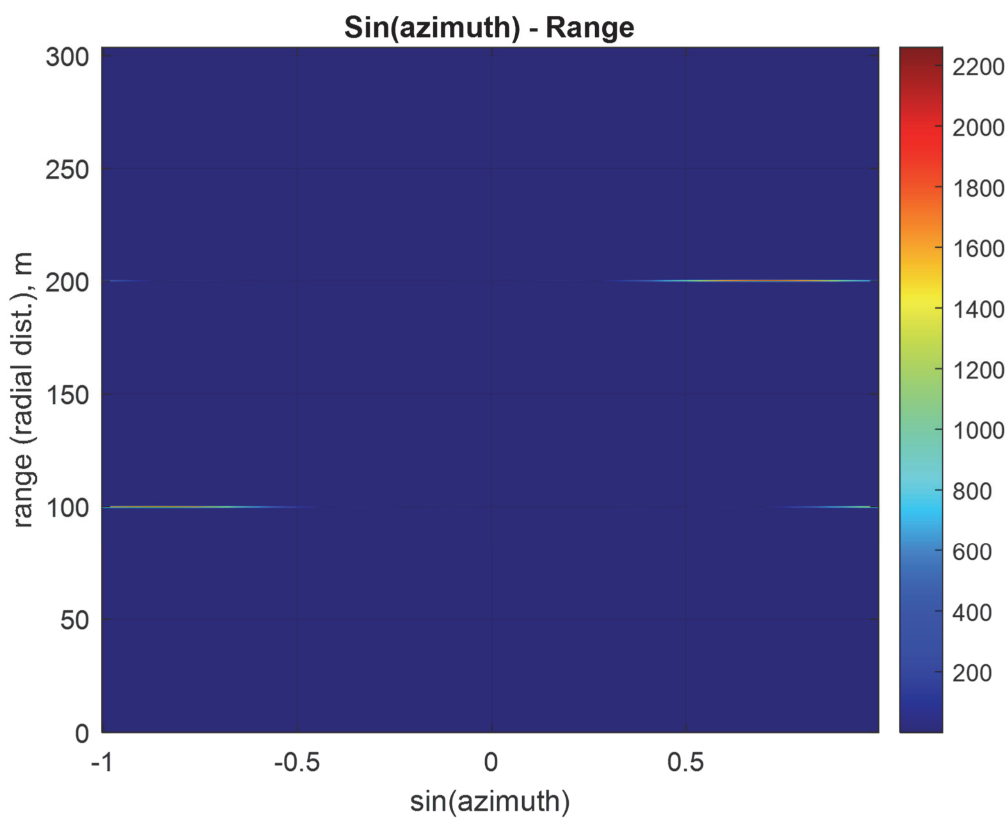


Next we consider computing the azimuth information (targets' Direction of Arrival, DOA), from the 2-D Range Doppler data of all sensors (which becomes a 3-D cube of data). This is done with a 3rd FFT in the dimension of the different sensors. But it is not required to compute these FFTs for all the elements in the Range-Doppler 2-D data. Instead, the FFTs along the sensor dimension can be computed only at the detected locations of "peaks" (or clusters) in the Range-Doppler 2-D data from the first sensor. For instance, the FFTs along the sensor dimension can be computed for only two positions in the Range-Doppler 2-D data in the current example, because it has only 2 targets. This greatly reduces the computational complexity.

The resulting FFT magnitudes for each target are displayed below in the same plots (target 1 in blue, target 2 in red). The natural x-axis from -1.0 to 1.0 (1st subplot below) obtained at this stage corresponds to sin(azimuth), so a non-linear inverse sine (arcsine) operation can be done on the x-scale to display the results with a scale in degrees (2nd subplot below). We can verify from this plot that the detected azimuths correspond to the correct azimuths of the two targets (-60 degrees and 45 degrees).



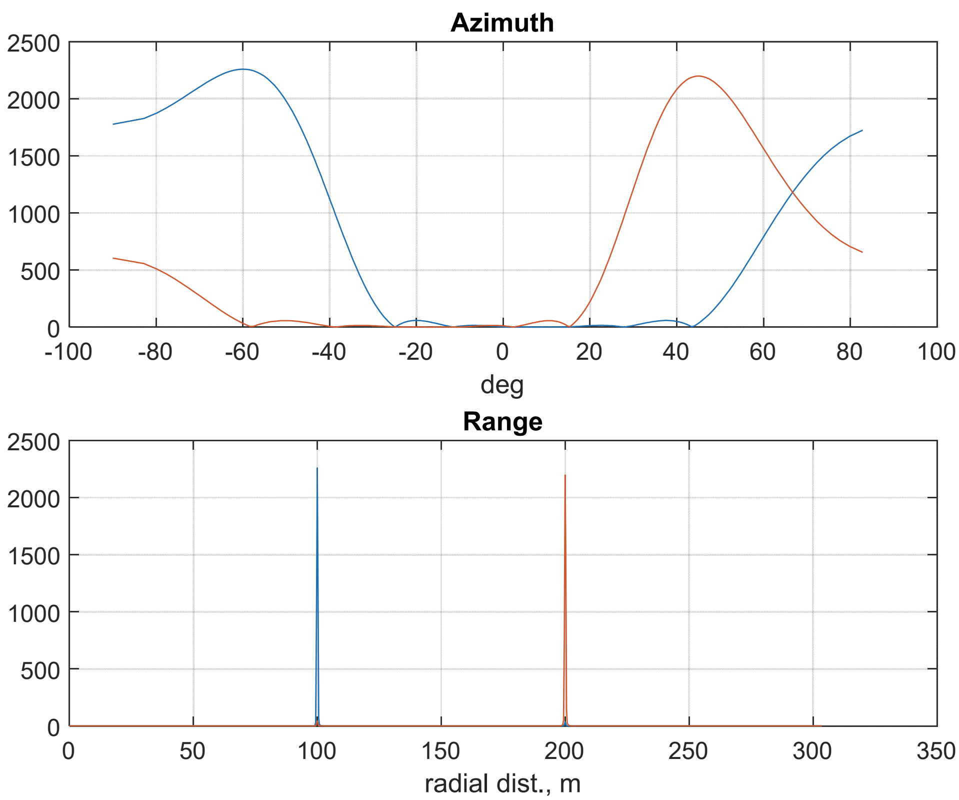
Next, instead of computing a Range-Doppler 2-D plot for a given sensor, we compute instead an Azimuth-Range 2-D plot. This is done for example if we are not interested in the velocity information. This can be computed by using any received chirp (i.e., a single chirp instead of all the received chirps during the radar scan period). To produce the plots below, the first received chirp signal was used, at all sensors.



Next, for each detected target, as was done earlier for the Range-Doppler 2-D plot, we want to show "1-D FFT slices" in the vertical (range) and horizontal (azimuth) directions, to show more clearly the measured values. The resulting magnitude plots will be much more accurate than the Azimuth-Range 2-D plot.

This requires again detecting the location of the maximum magnitude values in the Azimuth-Range 2-D plot (and making sure again that the detected maximum values don't belong to the same target, i.e., they come from different clusters).

The resulting "1-D FFT slices" (magnitudes) are plotted below on the same figure for both targets (target 1 in blue, target 2 in red). We can verify that the correct azimuth and range values are detected (-60 degrees with 100 m, and 45 degrees with 200 m).



Finally, for visualization, it is sometimes instructive to produce a “bird’s eye” plot, which shows the strength of the detections (or more simply, the location of each detected target) as viewed from the sky. This can be done either by:

- Using a polar plot of the azimuth and range information;
- Using a cartesian plot of the azimuth and range information converted to x-y coordinates.

To produce the plots below, the 2nd approach was used. But in retrospect, perhaps the 1st approach would have been easier…