Homework 6 submission

ECET 512 — Wireless Systems

Drexel UNIVERSITY

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1 Submitted files

For this assignment, this report and the archives outlined below were created or added to and submitted.

1.1 SRC Folder

+ *"main.m"*: The MATLAB script will run a simulation that accomplishes the goal of the homework. It plots a mobile user moving along a trajectory within a one cell area with a single base station. It plots the user moving and then the output of the antenna array for each frame based on user position.

+ *"ulaSteering.m"*: This MATLAB function takes as its parameters the user position, base station position, the number of array elements, the frequency of the signal, and the spacing between elements as fractions of a wavelength. The output is the steering vector as well as a symbolic function representing the beamforming spectrum.

1.2 DOC Folder

+ *"steering_video.avi":* This is a video that shows the mobile user moving through the single cell space within the area trackable by a uniform linear antenna array.

+ *"steering_DOA_video.avi":* This is a video that shows the output of the antenna array shown by its beamforming spectrum as the user moves through the single cell space. Showcases the same simulation as *steering_video.avi*

+ "*DOAEstimation.png*": This photo shows the plot of the DOA estimation for an array with inter-elements spacing of half a wavelength and ten array elements.

+ "*DOAOtherWavelengths.png*": This photo shows the plots of the beamformer output for ten options for inter-element spacing.

+ "*DOAStandstill.png*": This photo shows a snapshot of the user animation at the starting position.

2 Code execution

The MATLAB programming language was used to create the simulations for this homework. To run the simulations, simply run the "*main.m"* script the problem. It shows a mobile user traveling through a single cell and then plots the output of a uniform linear antenna array corresponding to the same simulation. It then determines the output of the array for the user in its starting position for different inter-element spacing.

3 Homework Solution

3.1 MATLAB Movies

To view the movie illustrating the movement of the mobile user, refer to the flicks found in the DOC archive.

3.2 Beamformer output with spacing lambda/2

This problem asked to follow the algorithm for the Bartlett beamforming technique for determining the direction of arrival of a user's uplink signal. The code presented in *ulaSteering.m* uses the samples of each array element of a user's position to predict the direction of arrival of the signal based on the magnitude and phases of the incoming signal. It took as its parameter the position of the users, which can be a single point or a collection of previous points. It also expected the frequency of the signal, the number of array elements, the center of the base station, as well as the inter-element spacing of each element represented as a fraction or fractions of a wavelength. The program simulates the placing of the elements starting at the base station center and placing the next element the corresponding spacing away below the previous one. Imagine the array as extending below the base station center. Since the spacing was rather small, and the cell radius large for the simulation I decided not to plot the exact positions on the array elements on the plot. What was plotted though was naturally the user moving through the space that could be detected by the array (the fourth quadrant of the cell space) and took measurements. A snapshot of the user in its first position is seen in Figure 1.

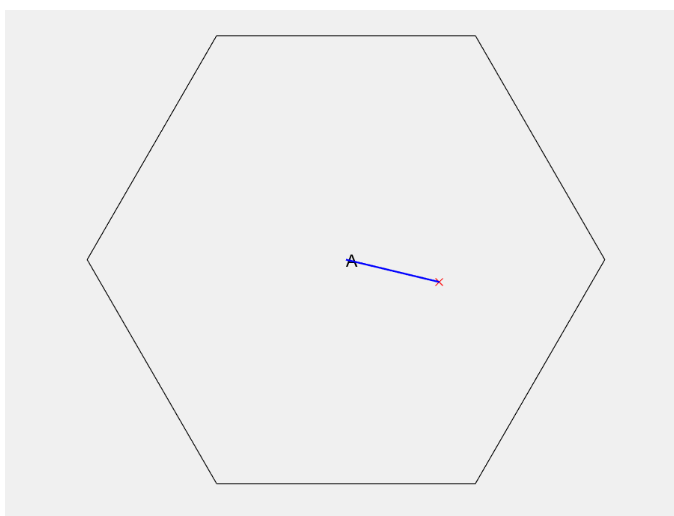

Figure 1: Snapshot of the user in its first position used for the simulation Figure generated in MATLAB R2019a.

After the simulation of the mobile user moving, the position data is run through again for the plotting of the spectrum. The output of the program after going through the necessary steps is shown in another accompanying movie, and I have provided a snapshot of that movie conveniently at the first frame so that it matches up with the previous figure. See this snapshot in Figure 2.

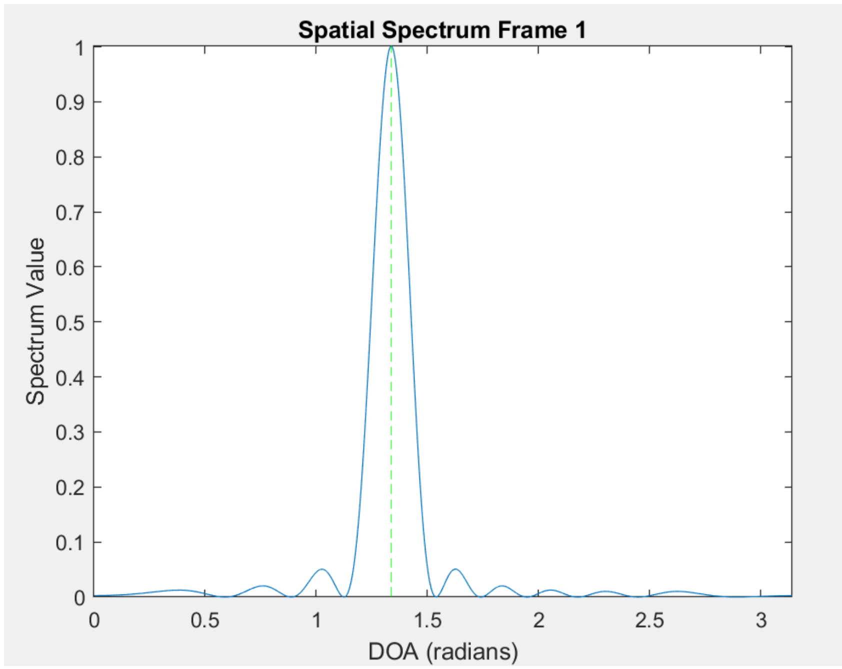

Figure 2: Plot showing a snapshot of the beamformer output evolving as the user moves through the cell space. Figure generated in MATLAB R2019a.

As the movie plays out, the peak of the spectrum moves according to the incoming estimated direction of the uplink signal. The plot also shows a vertical line corresponding to the true direction of arrival which matches up rather closely to what is predicted. Note that this algorithm tends to act funky when the user is in other quadrants of the cell when the direction of arrival goes negative or beyond 180 degrees. I suppose a limitation of the linear configuration is that you would need four in each cardinal direction to compensate for this effect since this configuration has similar responses to users in front or behind it. So, more would be necessary for proper locating. On another note, this snapshot shows the output for the inter-spacing of half a wavelength where the next part will show for different spacings.

3.3 Beamformer output with other spacings

The next part of the program evaluates the DOA of the uplink signal for the first position in the simulation for inter-element spacings of one tenth a wavelength all the way up to a full wavelength spacing. A collection of subplots are given below in Figure 3 that illustrates the output of the spectrum for each space.

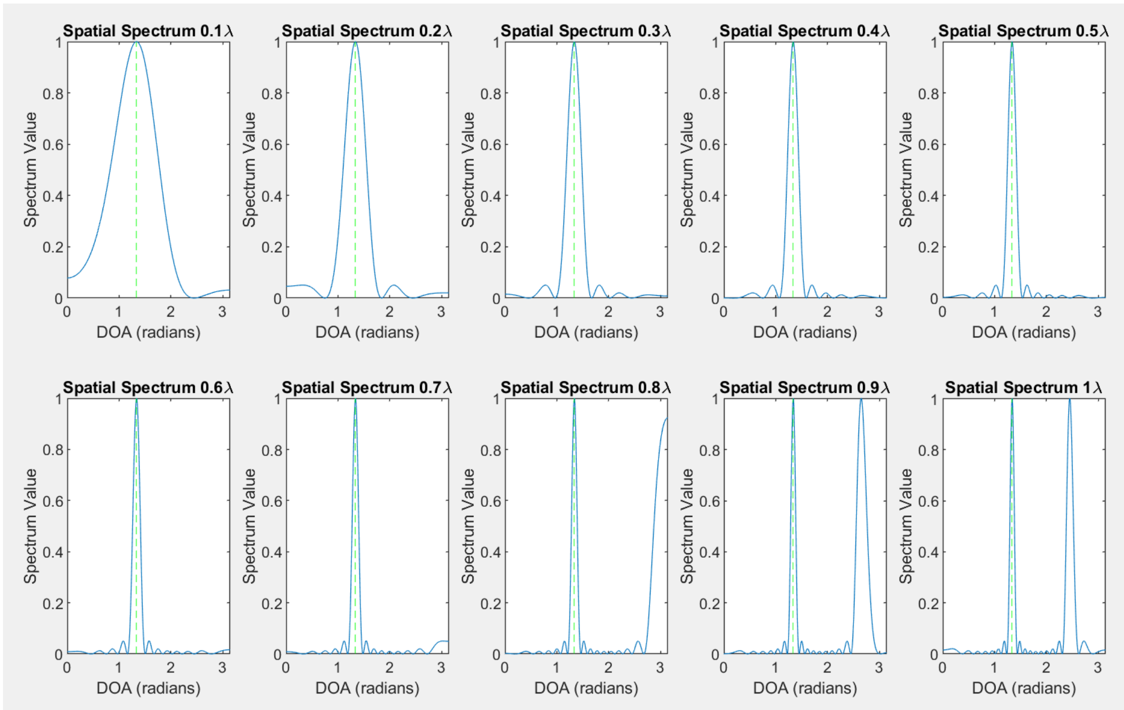

Figure 3: Plots showing the output of the beamformer for various inter-element spacings. Figure generated in MATLAB R2019a.

As is clearly seen in the plot, the output of the spectrum shape seems to change as the inter-element spacing does. The estimation peak becomes more and more narrow. At a certain point, around half a wavelength, the integrity of the prediction starts to fail as another peak begins to form to the right seemingly due to the spatial equivalent of aliasing that would occur in this sampling approximation. It seems that the equivalent Nyquist limit for the antenna arrays is around half a wavelength before things go a bit out of control. This is seconded by the given article as it also mentions that the half wavelength spacing is as good as it gets. Smaller wavelength fractions show a more prominent peak that has fewer sidelobes than the higher order spacings which probably has to do with the wave the interference pattern shifts depending on the electrical distance between receivers. This is why the amount of rippling seems to become greater as the spacing becomes closer to a wavelength. The final result is that another signal seems to pop up on the graph at what is about a 90-degree separation from the first one.