Communication System Assignment 6a

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Exercise 6a.1: Zero Forcing Beamforming

The Vandermonde and Butler matrix implemented in the previous assignment 5 could generate beams without inter-beam interferences but only with certain beam directions.

The zero forcing beamforming technique however can solve this constraint by forcing the product of beamformer matrix and steering vectors equal to an identity matrix, to eliminate the inter-beam interference with generated beams pointing to different directions.

Several examples have been simulated in this section.

1. Uniform Linear Array with M=2, ϑ=0°, 40°

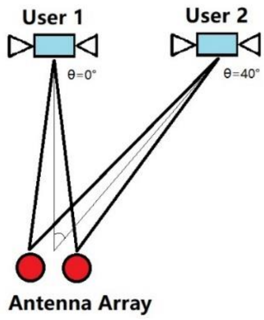

Figure 1.1: The Schematic of the ULA System

The gain of the ULA with M=2, ϑ=0°, 40° as shown in Figure 1.1, has been plotted in Figure 1.2 respectively in the Cartesian coordinate with the unit of decibel and in polar coordinate.

The pointing directions cannot be correctly presented with the antenna array of only 2 elements, this phenomenon can be improved by increasing the number of elements within the array.

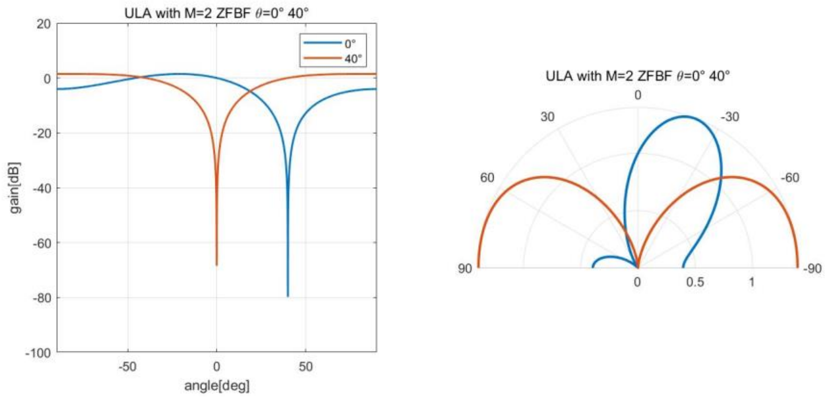

Figure 1.2: Gain of the ULA

2. Uniform Linear Array with M=4, ϑ=0°, 40°

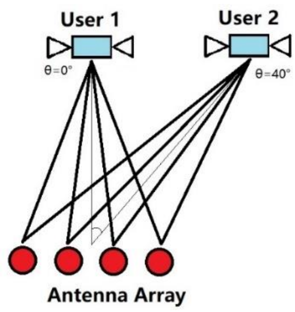

Figure 1.3: The Schematic of the ULA System

The gain of the ULA with M=4 and with the same angles as in part 1 as shown in Figure 1.3, has been plotted in Figure 1.4 respectively in the Cartesian coordinate with the unit of dB and in polar coordinate.

The beams have been pointing to the correct directions in this situation but with more side lobes.

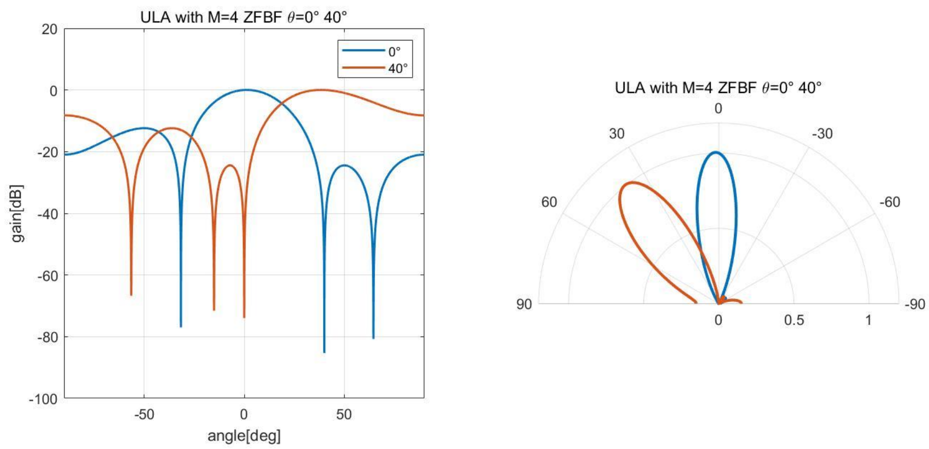

Figure 1.4: Gain of the ULA

3. Uniform Linear Array with M=8, ϑ=0°, 40°

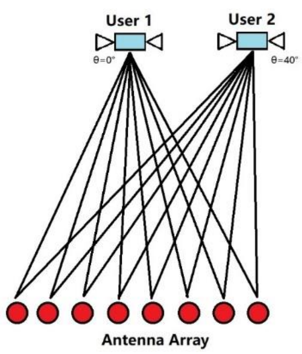

Figure 1.5: The Schematic of the ULA System

The gain of the ULA with M=8 and with the same angles as in part 1 (as shown in Figure 1.5) has been plotted in Figure 1.6 respectively in the Cartesian coordinate with the unit of dB and in polar coordinate.

The gain of the main lobe become more concentrated with a larger number of elements and have now much lower side lobe levels.

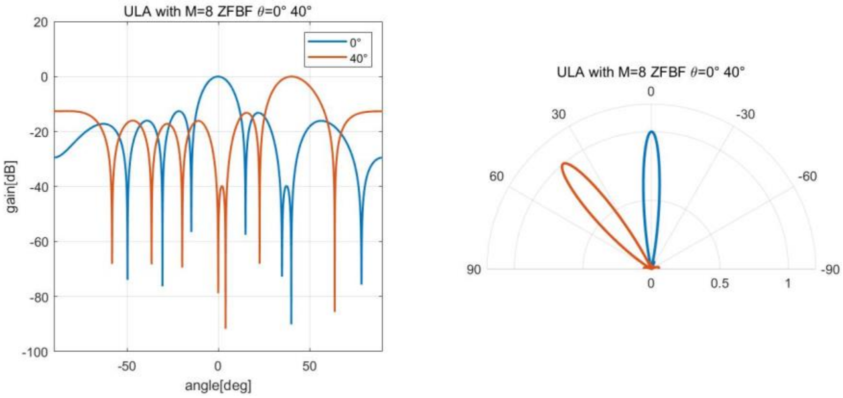

Figure 1.6: Gain of the ULA

4. Uniform Linear Array with M=8, ϑ=30°, 60°

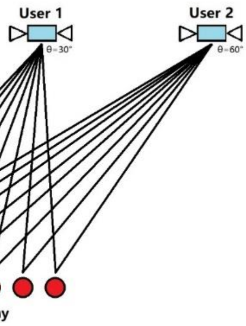

Figure 1.7: The Schematic of the ULA System

The gain of the ULA with M=8, ϑ=30°,60° as shown in Figure 1.7, has been plotted in Figure 1.8 respectively in the Cartesian coordinate with the unit of dB and in polar coordinate.

The behavior of the beam with a larger angle is worse than the small angles. As shown in Figure 1.8, when ϑ=60°, the side lobes become larger than the condition of ϑ=30°.

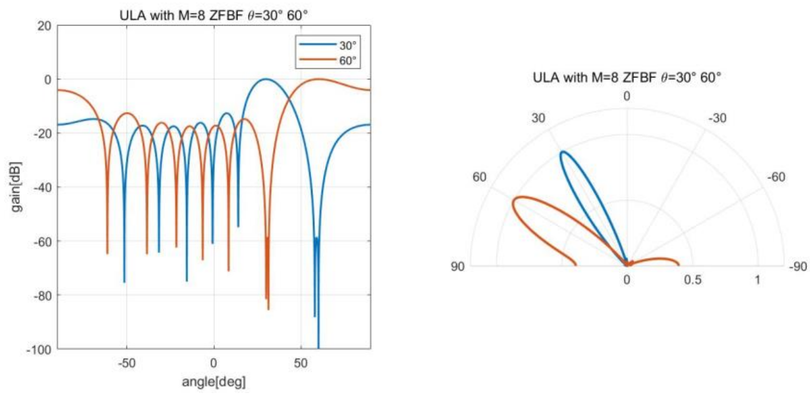

Figure 1.8: Gain of the ULA

Exercise 6a.2: Hybrid Beamforming

In this section, a hybrid array with M=8, ϑ=0°,20°,45°,-15°,-50°, as shown in Figure 2.1 has been simulated.

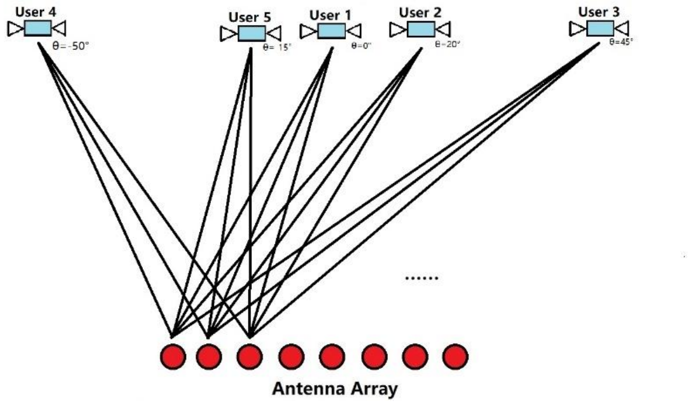

Figure 2.1: The Schematic of the ULA System

As shown in Figure 2.2, the gain of the hybrid array has been respectively plotted in the Cartesian coordinate with the unit of decibel and in polar coordinate.

With the increasing of the element number, the ZFBF technique can still solve the interferences between the beams.

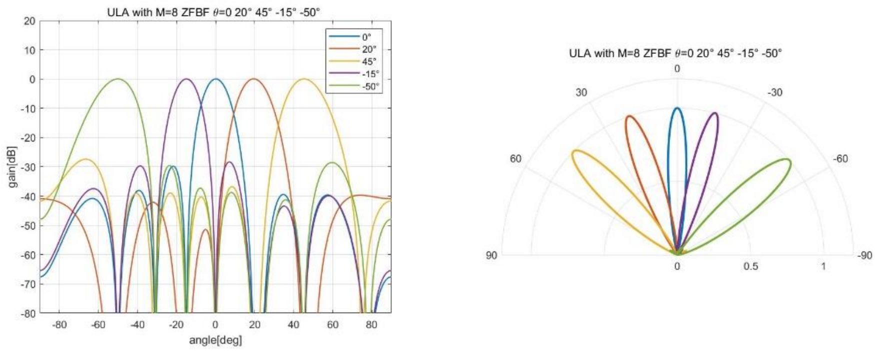

Figure 2.2: Gain of the ULA

Exercise 6a.3: Uniform Planar Array

The uniform planar array gains have been analyzed in this section with the sizes of each array as 2×2, 4×4 and 8×8.

At the mention of the MATLAB code, when using the instruction of 'scatter' and 'scatter3', the code will run very long time due to the massive iterations of the angles to plot the scatter points one by one. This problem of the run speed can be efficiently improved when using the vectors in the 'scatter' and 'scatter3' instructions rather than using a single element. Another approach to improve the code speed is to set the size of the matrix in previous in order to allocate the memory in advance and reduce the time of changing the memory of the matrixes sizes every time in the circulation.

The final version of the MATLAB code has been implemented with each angle step of 0.015, and has plotted 43,995×105=4,619,475 points in each figure using the instruction of 'scatter' and 'scatter3'.

1. Uniform Planar Array with $M_x \times M_y = 2\times 2$

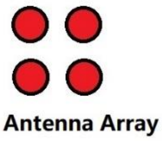

Figure 3.1: The Schematic of the 2×2 UPA System

The schematic of the UPA system is as shown in Figure 3.1. The Gain of the 2×2 UPA has been plotted in Figure 3.2, with the maximum gain at $\vartheta=0°$.

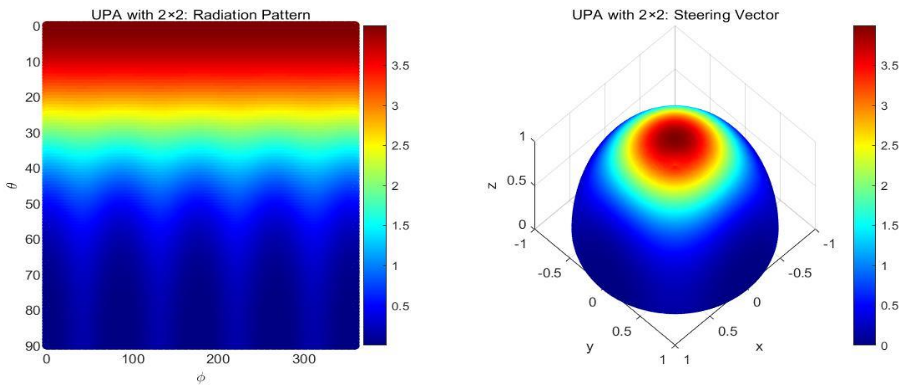

Figure 3.2: The 2D and 3D Plot of the UPA Gain

2. Uniform Planar Array with $M_x \times M_y = 4\times 4$

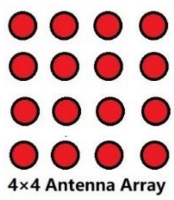

Figure 3.3: The Schematic of the 4×4 UPA System

The schematic of the UPA system is as shown in Figure 3.3. The Gain of the 4×4 UPA has been plotted in Figure 3.4, with the maximum gain at ϑ=0°, and the max-gain area is thinner than the situation with less elements while the value of the maximum gain becomes larger.

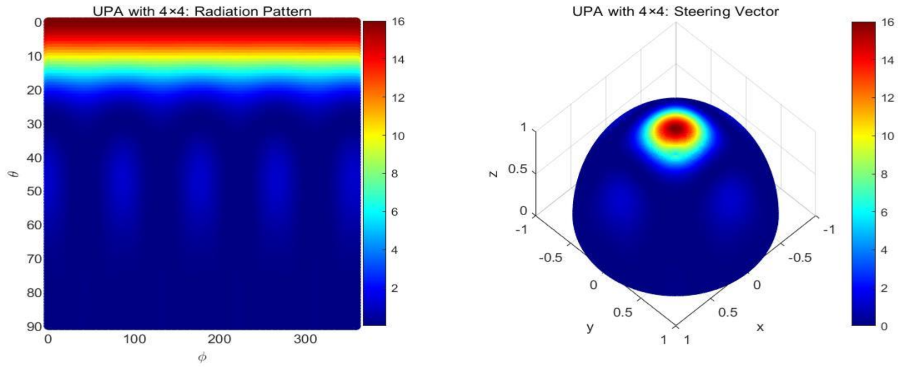

Figure 3.4: The 2D and 3D Plot of the UPA Gain

3. Uniform Planar Array with M_x×M_y=8×8

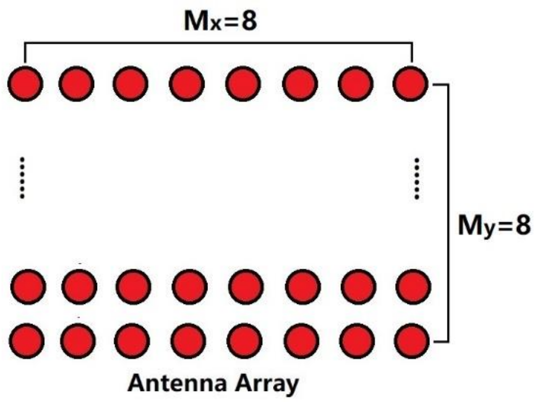

Figure 3.5: The Schematic of the 8×8 UPA System

The schematic of the UPA system is as shown in Figure 3.5. The Gain of the 8×8 UPA has been plotted in Figure 3.6, with the maximum gain at ϑ=0° and the range of the maximum gain has been much thinner but with much higher value.

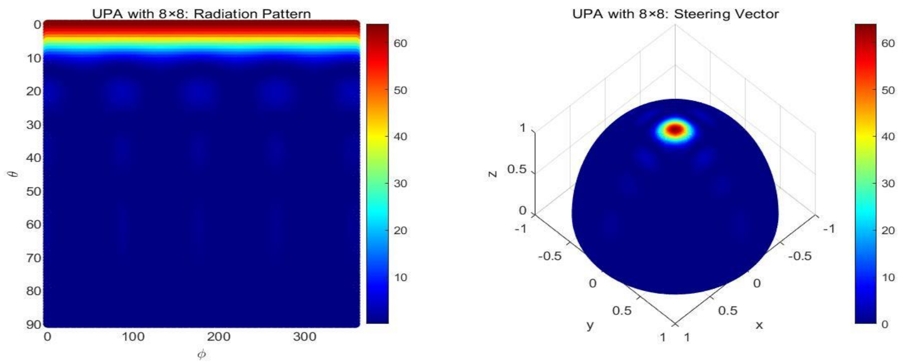

Figure 3.6: The 2D and 3D Plot of the UPA Gain

Exercise 6a.4: Conventional Beamforming of UPA

In this section, the gains of the 8×8 UPAs with different pointing directions have been plotted, respectively with the angles as shown in the table below.

The implemented of the MATLAB code is with each angle step of 0.02 in this section and finally plotted 24,885×79=1,965,915 points in each figure, thus the plots have less resolutions than in exercise 3.

No.	ϑ_0	φ_0
1	30°	0°
2	30°	30°
3	30°	90°
4	60°	0°

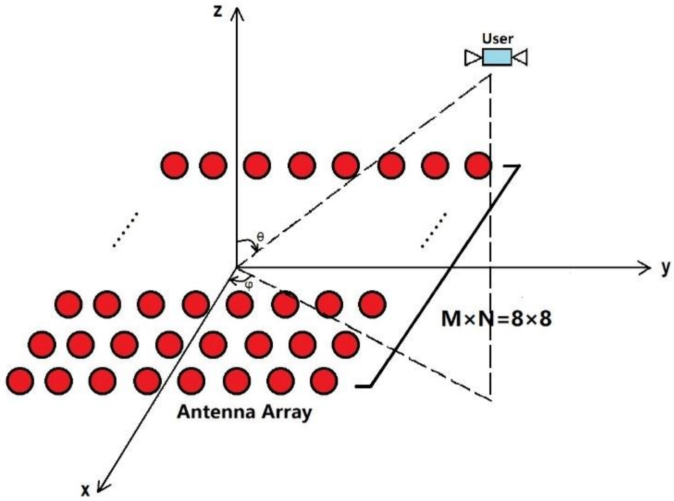

Figure 4.1: The Schematic of the 8×8 UPA System

The schematic of the UPA system with generic pointing angles is as shown in Figure 4.1. The 2D and 3D plots of the gains are as shown in Figure 4.2, 4.3, 4.4 and 4.5 with different angles, where the maximum gain appears at the set pointing angles.

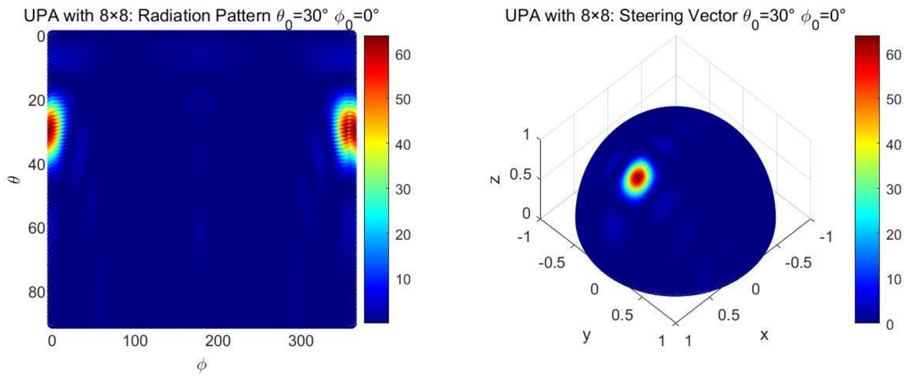

Figure 4.2: The 2D and 3D Plot of the UPA Gain

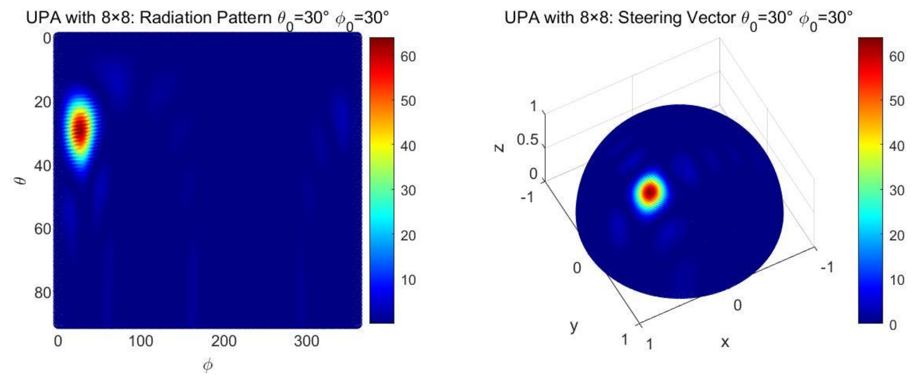

Figure 4.3: The 2D and 3D Plot of the UPA Gain

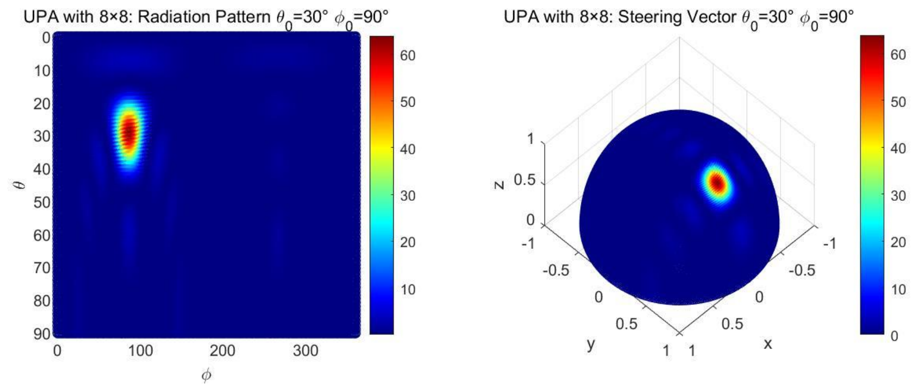

Figure 4.4: The 2D and 3D Plot of the UPA Gain

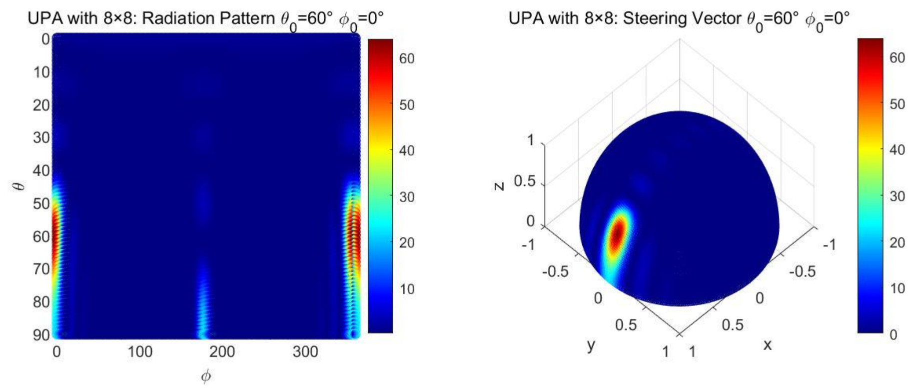

Figure 4.5: The 2D and 3D Plot of the UPA Gain