EE401 ACT
Coursework Part-A:
Multipaths Spatiotemporal SIMO Wireless System

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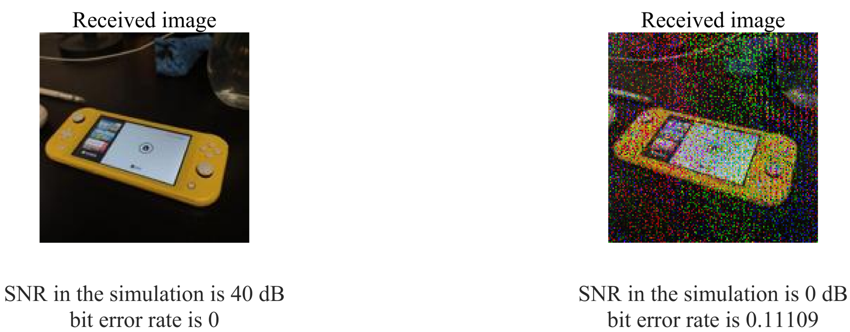
Individual Set-up

This coursework utilizes principles in ACT lecture notes [1]. Based on my name, $X = 20, Y = 8$. The three images chosen for the three transmitters (T_xs) are shown in Figure 1. Please read the html function guide in "Wrappers" folder for a clear implementation structure.

Figure 1: Three T_x images



(a) (b)

Figure 2: Task 1 received images and bit error rate

1 Task 1

In this task, each of the three images was transmitted via a SISO system. The wireless system had four parts: 1)P-N codes were applied to symbols of each image. 2)Symbols were simultaneously transmitted through 3 wireless channels. 3)To receive the desired signal, correlations were calculated between received symbols of different delays and the desired signal's P-N code. Estimation of channel delay was the delay that produces the largest correlation. 4) the Desired signal was separated.

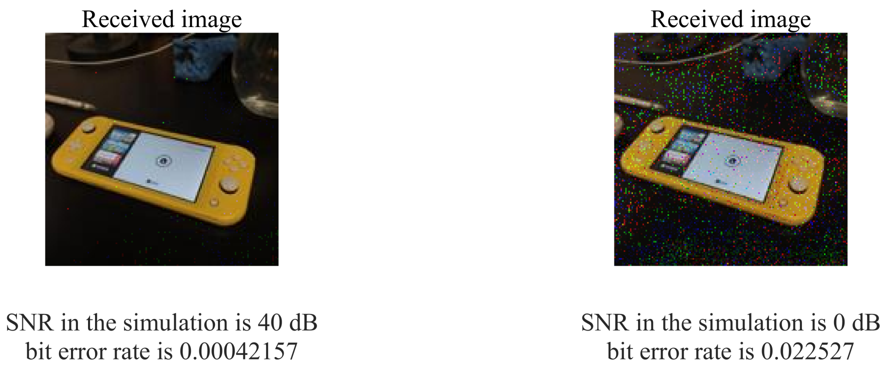
For smaller noise power, the received symbols are separable. Therefore using gold sequence, receiver (R_x) receives the noiseless image (Figure 2 (a)).

When noise power was larger, the SISO system's performance was poor (Figure 2 (b)). SISO system has only one path (no diversity), therefore there was no way of removing noise. To solve this problem, task 2 made use of the diversity of multi-path.

2 Task 2

In this task, the desired user transmitted the image with three paths (MISO system), which provided diversity. The best receiver for this set-up: a RAKE receiver with Maximal-ratio combining (MRC) was designed for reception of the desired image. The reception has four procedures: 1)Path delay was estimated. 2)Path fading coefficients were either given or estimated using a histogram (a trial). 3)P-N code was used to separate the three paths. 4)Combine three paths using MRC to reconstruct user images.

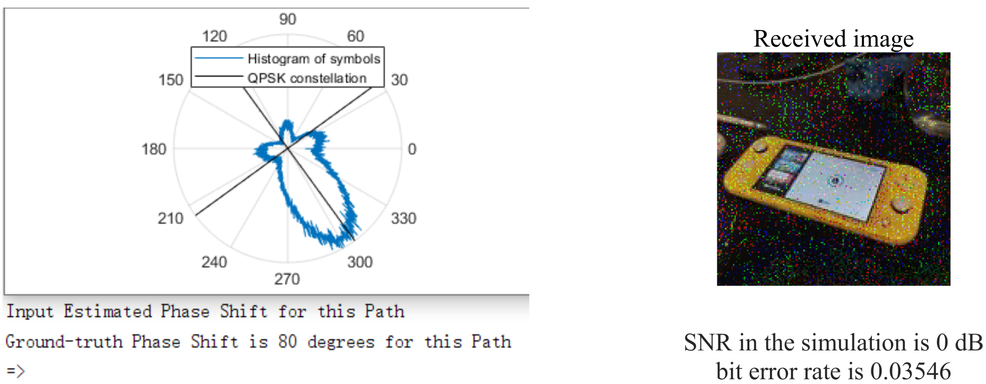
From Figure 3 it can be observed that the RAKE MRC receiver made use of channel diversity to optimize SNR.



(a) (b)

Figure 3: Task 2 received images and bit error rate

For practical reception problems, path fading coefficients may not be known. Estimating the amplitudes of fading coefficients was easy while estimating the phase was difficult. An attempt was made to estimate fading coefficients' phase by observing histograms. This method works by manually inputting the estimated phase (Figure 4 (a)). Self-correlation may help automatically identification of rotation angle. With right phase estimation, good result was obtained (Figure 4 (b)).



(a) (b)

Figure 4: Task 2 histogram β estimation

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Ground Truth Delays:
 0 7 13
Delay Estimates:
 0 11 13
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(a)

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Ground Truth Delays:
 2 5 11
Delay Estimates:
 2 5 11
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(b)

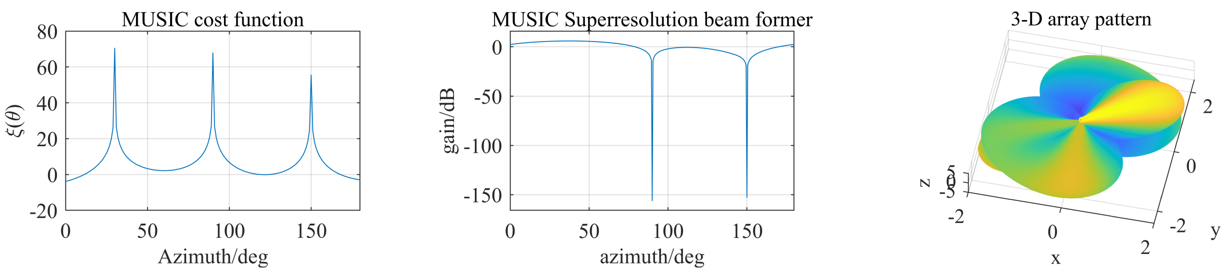
Figure 5: (a) Delay estimate when X=20, Y=8. (b) Delay estimate when X=20, Y=6.

It was also observed that delay estimate using P-N code correlation was not always accurate in multi-user system (Figure 5). This might be the reason why MRC did not significantly lower SNR. In this task, since different users' signals exist, desired user's gold sequence might correlate with other users' symbols. This sometimes generates wrong delay estimation. In task 3, a beam-former was applied to suppress other users' symbols. Without other users, accurate delay estimates could be obtained using correlation.

3 Task 3

3.1 Space-time Decoupled

For space-time decoupled estimation, three steps were used: 1)Use the MUSIC algorithm [2] to estimate direction of arrival (DOA) (Figure 6 (a)), 2)Use super-resolution beam-forming to receive desired user's signal (Figure 6 (b) (c)), 3)Use correlation with gold sequence to estimate path delay.



(a) (b) (c)

Figure 6: Task 3 MUSIC super-resolution

Multi-receiver achieved perfect reception under each noise level (Figure 7).

(a) (b)

Figure 7: Task 3 space-time decoupled reception

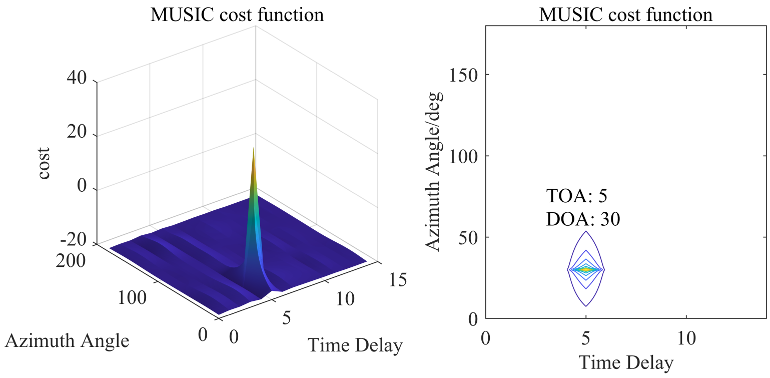


Figure 8: Task 3 STAR MUSIC cost function

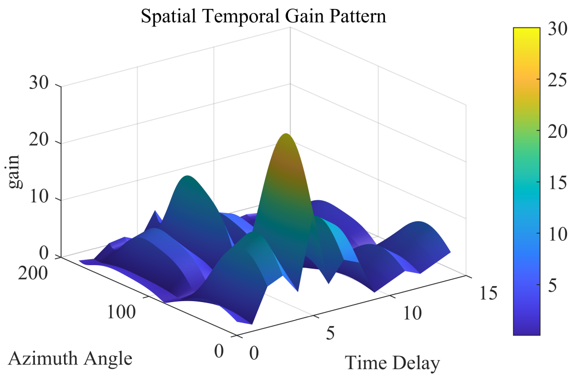


Figure 9: Task 3 STAR array gain pattern

3.2 Space-time Integrated

For spatial-temporal reception, there are three steps: 1)Extend received symbols, 2)Implement spatial-temporal MUSIC algorithm on spatial-temporal array manifold (STAR) (Figure 8), 3)Use STAR array pattern to receive desired signal (Figure 9). For joint space-time reception, the total number of signal paths can be more than the number of R_xs [3]. Paths that overlay in space or time domain can also be separated now [3].

(a)

(b)

Figure 10: Task 3 joint space-time reception

Joint space-time reception also achieved perfect reception under each noise level (Figure 10).

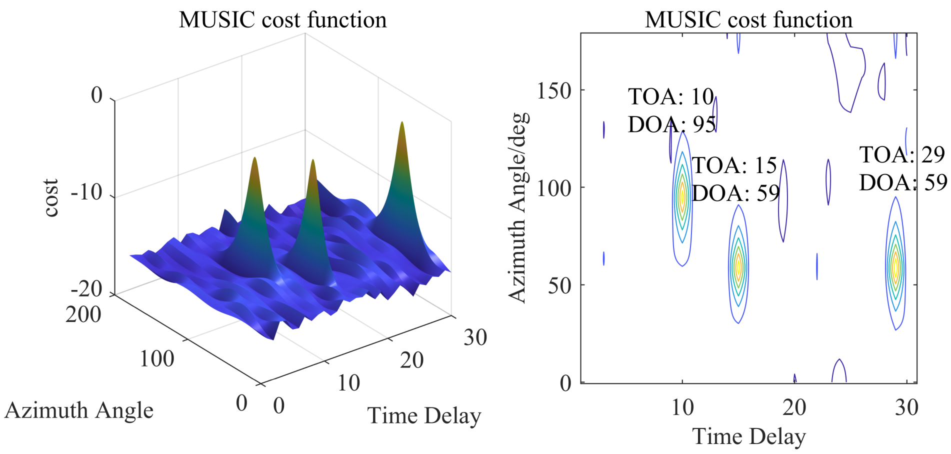


Figure 11: Task 4 STAR MUSIC cost function

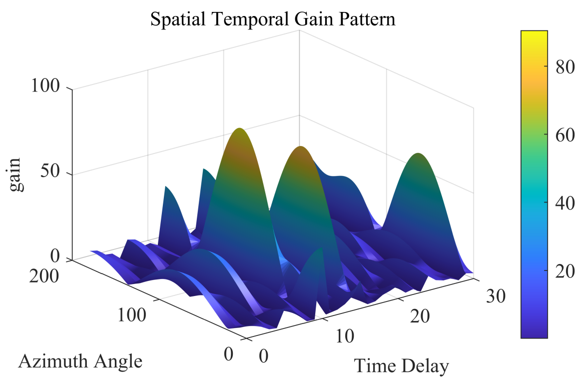


Figure 12: Task 4 STAR array gain pattern

4 Task 4

The principle of task 4 is similar to task 3. In task four, the desired signal had three paths. To obtain DOA and delay estimates from the STAR MUSIC cost function, a threshold was first implemented to remove the floor in the cost function. Afterward, differentials were calculated to identify all three peaks (Figure 11). This method works without a pre-known number of paths.

The received message in task 4 was: "Haozhe, congratulations! You have completed the mission!!!!!"

References

[1] A. Manikas, "Advanced communication theory lecture notes," *Imperial College London*, 2021. [Online]. Available: https://skynet.ee.ic.ac.uk/notes/notes.html

[2] R. Schmidt, "Multiple emitter location and signal parameter estimation," *IEEE transactions on antennas and propagation*, vol. 34, no. 3, pp. 276–280, 1986.

[3] A. Manikas and L. Huang, "Star channel estimation in ds-cdma communication systems," *IEE Proceedings-Communications*, vol. 151, no. 4, pp. 387–393, 2004.