Network System Capstone
@CS.NYCU

2025.02.27 Lab1 Analog Beamforming

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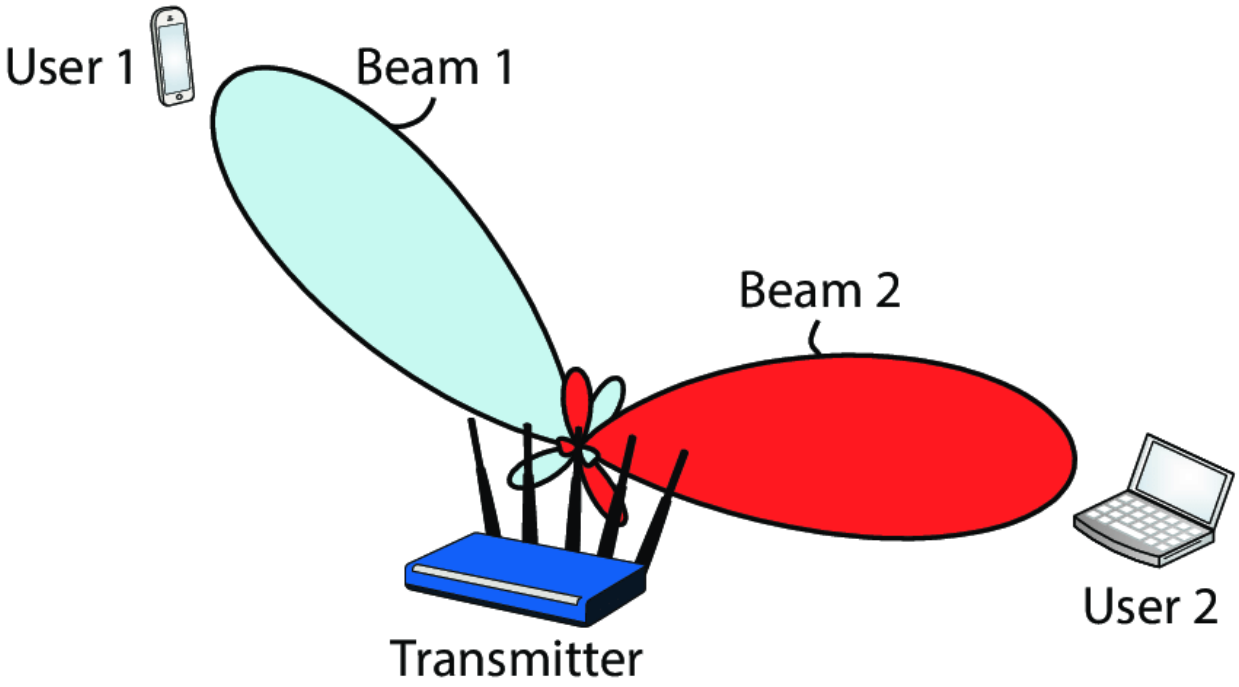
Deadline: 2025.03.13 23:59

Agenda

- Overview
- Topology & Parameters
- Tasks
- Report & Result
- Submission

Overview – Beamforming

In this lab, we are going to write a Matlab program that simulates analog beamforming



Overview – Ewa function

- Reference

- uniform.m: Generates a uniformly spaced linear array configuration for antenna elements

- steer.m: Computes the phase shifts needed to steer an antenna array's beam in a specified direction

- scan.m: Evaluates the array's radiation pattern by scanning over a range of angles

Overview – Ewa function (cont.)

- Reference

- friis_equation.m: Calculates the received power or path loss using the Friis transmission equation

- dtft.m: Computes the Discrete-Time Fourier Transform of an input sequence

Topology and Parameters

- Carrier frequency: 24GHz
- Tx/Rx locations
  - 1 Tx: [0, 0]
  - 2 Rx: random $[x_1, y_1]$ $[x_2, y_2]$
- Power
  - P_{tx}: 20 dBm
  - N_0: -88 dBm
- Number of antennas
  - Tx: 16-antenna Tx with linear phased array
  - Rx: 1-antenna
- Number of beams (codebook size)
  - [0:10:180]

Tasks

- Modify bf.m and finish the tasks below

1. Simulate beam scanning
2. Calculate Rx power and SNR
3. Calculate interference power and SINR of two concurrent beams

Task 1: Simulate Beam Scanning

1. TODO: Calculate AoD
   - Hint1: Find the actual angle θ_1 and θ_2 for user 1 and user 2

2. TODO: Find the beam with the closest beam angle
   - Hint1: Scan all feasible beams [0:10:180]
   - Hint2: Identify the optimal beam θ_1^* and θ_2^* for user 1 and user 2
     - i.e., the direction that maximizes the gain

Task 2: Calculate SNR

1. TODO: Identify the Tx gain of users 1 from the optimal beam θ_1^*
   - Assumption: The resolution is 360, meaning the 180-degree range is divided into 360 angles
   - Hint1: Find Tx gain based on this resolution

2. TODO: Calculate the Rx power and SNR_{dB} for user 1
   - Assumption: The Rx gain is 1
   - Hint1: Use Friis' free space model with identified Tx gain to get pathloss
   - Hint2: Convert the power value to dBm

Task 3: Calculate SINR

1. TODO: Identify the Tx gain of users 2 from the optimal beam θ_2^*
   - Assumption: The resolution is 360, meaning the 180-degree range is divided into 360 angles
   - Hint1: Find Tx gain based on this resolution

2. TODO: Calculate the interference power and $SINR_{dB}$ for user 1
   - Assumption: The Rx gain is 1
   - Hint1: Use Friis' free space model with identified Tx gain to get pathloss
   - Hint2: Convert the power value to dBm

Report and Result Format

Report (50%)

- In PDF format
- Explain how you implement your lab step by step for each commit version
- Briefly explain how each answer was obtained
- Maximum of 4 pages

Result (30%)

- In PDF format
- Numerical results, figures and your observations
- Maximum of 3 pages

Notice: The example outputs and figures are for reference only

Result – Task1

Task1

Q1: What are the values of θ_1 and θ_2?

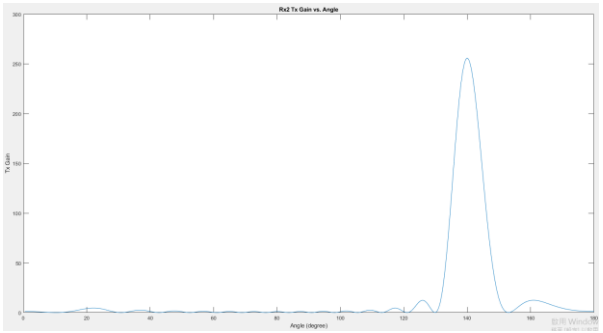
- Example output:

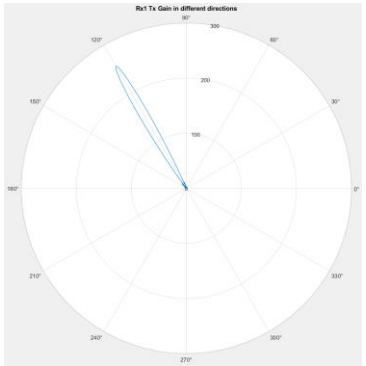
```
Task1: Calculate AoD
Rx1 Actual Angle: 122.573342 degree
Rx2 Actual Angle: 144.019546 degree
```

Result – Task1 (cont.)

Q2: Plot 4 figures showing the optimal beam θ^* with the maximal Tx gain for both user 1 and user 2

- Figure 1: Cartesian plot for user 1(x axis: angle in degree, y axis: Tx gain)
- Figure 2: Cartesian plot for user 2(x axis: angle in degree, y axis: Tx gain)
- Figure 3: Polar plot corresponding to figure 1
- Figure 4: Polar plot corresponding to figure 2
- Example figures:





Result – Task2

Task2

Q1: What are the Rx power and SNR of user 1?

- Example output:

```
Task 2: Calculate Rx power and SNR
Rx1 power: -31.479814 dBm
Rx1 SNR: 56.520186 dB
```

Result – Task3

Task3

Q1: What are the interference power and SINR of user 1?

- Example output:

```
Task 3: Calculate SINR of two concurrent beams
Rx1 interference power: -66.778165 dBm
Rx1 SINR: 35.265695 dB
```

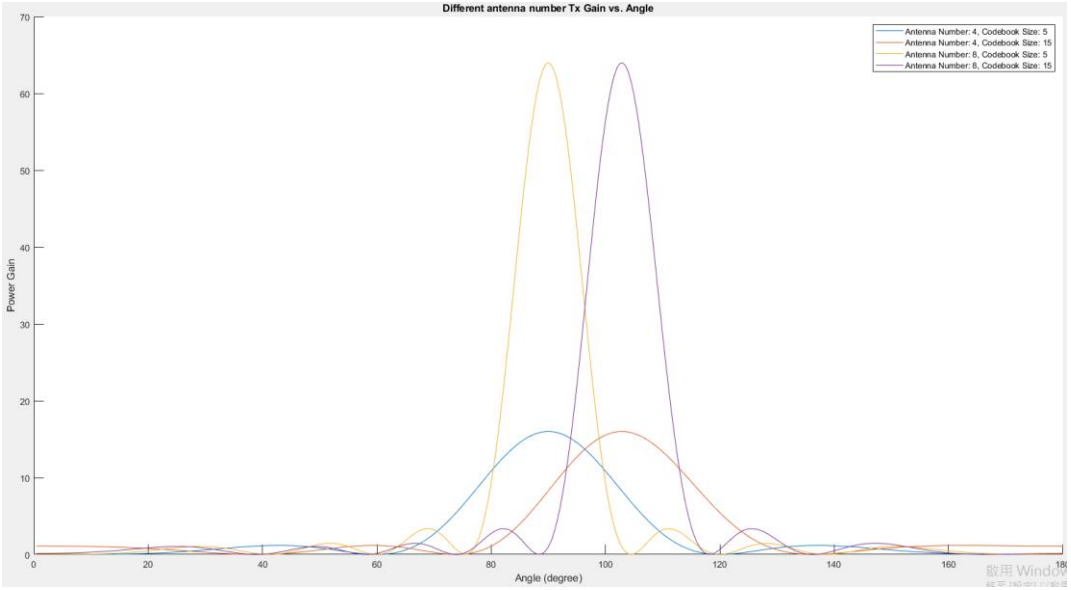
Result – Comparison

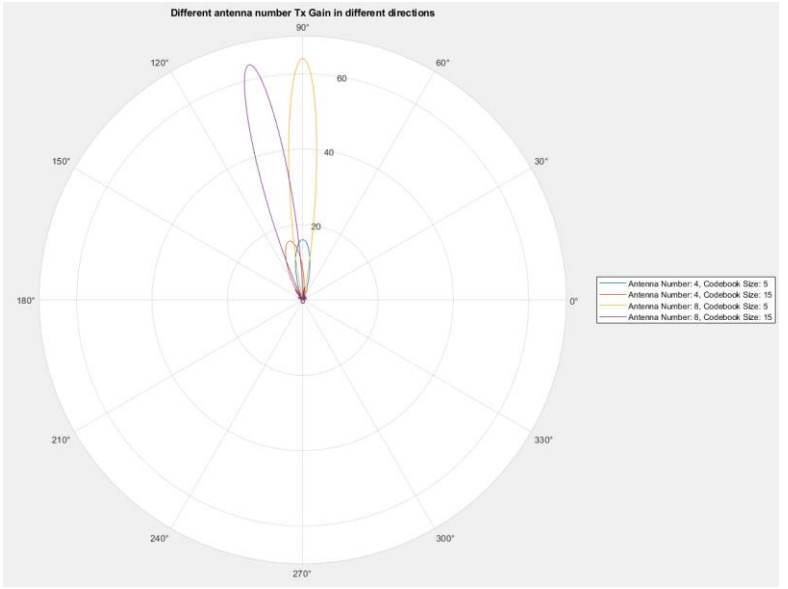
Comparison

- Plots of the optimal beam θ* for user 1 and 2 under different antenna number (4 or 8) and codebook size ([0:5:180] or [0:15:180])
  - 2 figures includes with 4 lines each:
    - Figure 1: Cartesian plot (x axis: angle in degree, y axis: Tx gain)
    - Figure 2: Polar plot corresponding to figure 1
    - Line 1: 4 antennas, codebook size [0:5:180]
    - Line 2: 4 antennas, codebook size [0:15:180]
    - Line 3: 8 antennas, codebook size [0:5:180]
    - Line 4: 8 antennas, codebook size [0:15:180]
- Answers from 20 random runs for tasks 1 to 3
  - Example output:

```
Avg Rx1 Power: -38.327834 dBm
Avg Rx1 SNR: 49.672166 dB
Avg Rx1 Interference power: -78.362215 dBm
Avg Rx1 SINR: 26.068541 dB
```

Result Comparison Example



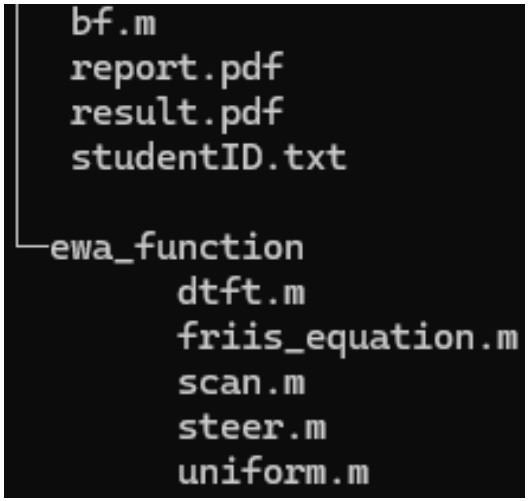



```
--- Tx Antennas: 4 ---

--- Codebook Size: 5 ---
Calculate Rx1 power and SNR
Receiver1 power: -52.757763 dBm
Receiver1 SNR: 35.242237 dB

Calculate SINR of two concurrent beams
Receiver1 interference power: -66.729634 dBm
Receiver1 SINR: 13.939576 dB

--- Codebook Size: 15 ---
Calculate Rx1 power and SNR
Receiver1 power: -52.758080 dBm
Receiver1 SNR: 35.241920 dB

Calculate SINR of two concurrent beams
Receiver1 interference power: -67.727494 dBm
Receiver1 SINR: 14.928817 dB
```

```
--- Tx Antennas: 8 ---

--- Codebook Size: 5 ---
Calculate Rx1 power and SNR
Receiver1 power: -46.737163 dBm
Receiver1 SNR: 41.262837 dB

Calculate SINR of two concurrent beams
Receiver1 interference power: -72.203068 dBm
Receiver1 SINR: 25.353071 dB

--- Codebook Size: 15 ---
Calculate Rx1 power and SNR
Receiver1 power: -46.738492 dBm
Receiver1 SNR: 41.261508 dB

Calculate SINR of two concurrent beams
Receiver1 interference power: -66.554919 dBm
Receiver1 SINR: 19.785401 dB
```

Submission

- Modify studentID.txt
- Replace <Your_Student_ID> with your own studentID
- File structure:



- Notice: You will get penalty with wrong file structure and naming

Commit to GitHub

- Add all modified and new files to the staging area

```
# git add <FILENAME>
$ git add .
```

- Record changes to the repository

```
# git commit -m "<COMMIT_MESSAGE>"
$ git commit –m "Initial commit"
```

- Upload to GitHub

```
$ git push
```

Due

- **Mar. 13 (Thu.) 23:59, 2025**
- Don’t need to submit to E3
- Commit **your files** to your GitHub repository
  - Should have at least **3 commits** (Initial, work in progress, final)
  - One version should be at least **1 day** after another
- **Notice: You will get penalty with wrong file structure and naming**

Grading Policy

- Grade
  - Code correctness – 20%
  - Report – 50%
  - Result – 30%
- Late Policy
  - (Your score) * 0.8D, where D is the number of days overdue
- Cheating Policy
  - Academic integrity: Homework must be your own – cheaters share the score
  - Both the cheaters and the students who aided the cheater equally share the score