EE677: MIMO Wireless Communications **EE Dept. IITK**

MATLAB Assignment-2

Massive MIMO capacity lower bound for 2-cell systems (10 marks) *Oct. 2023*

Assume a uniform linear array with $d_H = 1/2$, wherever required.

1. Plot the function $g(\varphi_0^0, \varphi_0^1)$ by varying the interfering UE angle φ_0^1 from $-\pi$ to π. Assume desired UE fixed at and angle of $\varphi_0^0 = \pi/4$. Plot the function for $M = 1, 100, 1000$ in the same figure.

2. We consider deterministic LoS and Random NLoS massive MIMO system with 1 user in each cell of two-cell model with MRC processing. Recall that their lower bounds on UL SE are given respectively as

$$\mathrm{SE}_0^{LoS} = \log\left(1 + \frac{p\beta_0^0 M}{p\beta_1^0 g(\varphi_0^0, \varphi_1^0) + \sigma^2}\right)$$
$$\mathrm{SE}_0^{NLoS} = \log_2\left(1 + \frac{M-1}{\bar{\beta} + \frac{1}{\mathrm{SNR}_0}}\right).$$

   Plot these bounds in the same figure by varying M from 10 to 100. Fix the SNR of desired UE at $\mathrm{SNR}_0 = 0$ dB and strength of inter-cell interference as $\overline{\beta} = -10$ dB. Plots should be averaged over different independent UE angles. Pick φ_0^0 and φ_1^0 such that they are uniformly distributed from 0 to 2π.

   Useful information: Recall that the NLoS bound is derived by assuming $\mathbf{h}_i^0 \sim \mathcal{N}_{\mathbb{C}}(\mathbf{0}_M, \beta_i^0 \mathbf{I}_M)$ for $i = 0, 1$, which is uncorrelated Rayleigh fading channel. To plot this lower bound, this information is, however, not required. It will be required in the next question where we plot the actual (average) SE.

3. Compare the above lower bounds with the deterministic and average SE given below for deterministic LoS and Random NLoS massive MIMO channels, respectively.

$$\mathrm{SE}_0^{LoS} = \log\left(1 + \frac{p\|\mathbf{h}_0^0\|^2}{p\frac{|(\mathbf{h}_0^0)^H \mathbf{h}_1^0|^2}{\|\mathbf{h}_0^0\|^2} + \sigma^2}\right)$$
$$\mathrm{SE}_0^{NLoS} = \mathbb{E}\left\{\log\left(1 + \frac{p\|\mathbf{h}_0^0\|^2}{p\frac{|(\mathbf{h}_0^0)^H \mathbf{h}_1^0|^2}{\|\mathbf{h}_0^0\|^2} + \sigma^2}\right)\right\}$$

   Key information required to plot the above expressions:

   - For the NLoS case, plot SE_0^{LoS} after averaging it over independent angles for desired and interfering UE, which are uniformly distributed between 0 to 2π.
   - Recall for NLoS case, we assume $\mathbf{h}_i^0 \sim \mathcal{N}_{\mathbb{C}}(\mathbf{0}_M, \beta_i^0 \mathbf{I}_M)$ for $i = 0, 1$, which is uncorrelated Rayleigh fading channel. The β_i^0 values can be derived with $\overline{\beta} = -10$ dB. The SE_0^{NLoS} should be obtained by averaging it over multiple channel realizations.

Plots for Q2 and Q3 should be provided in the same figure. You could combine their code also in the same program. Please code each case separately as a function.

Learning from Q2 and Q3: With the lower bounds in Q2, we avoid averaging, which we have to do in Q3. This is one of the main objective of deriving these lower bounds.

4. Consider the lower bound on the UL SE for NLoS massive MIMO channels for K users in each cell of two-cell model with MRC.

$$\mathrm{SE}_0^{NLoS} \geq K \log_2 \left(1 + \frac{M-1}{(K-1) + K\bar{\beta} + \frac{1}{\mathrm{SNR}_0}} \right).$$

Plot this bound by varying K for $M/K = 1$, $M/K = 2$, $M/K = 4$ and $M/K = 8$ in the same figure.

Please read this carefully.

- Each one of you have to individually do all assignments. You can discuss with your friends but you will have to completely write your own code.
- Copying also means sharing your code with some else for them to copy. We will not differentiate between the two acts, and both such cases will be awarded zero. Our decision will be final.

Please follow these Coding instructions:

- Properly comment your code.
- The code should execute and generate the desired output.
- Your submission should be self-contained (should include all the files required for running it).
- Avoid hard-coding the values of the variables for specific configurations. The code should be generic.

Please follow these submission instructions.

- Deadline is 15th of Oct., 11:59 pm. Please start coding it at the earliest, and don't wait for the deadline to approach.
- All codes should be in one .zip/.rar folder. Please do not submit separate files.
- Upload your properly commented in the drive link which will be provided later. Name your code as rollno.zip.
- Please submit one final zip file.
- Please do not mail your file to me.