EE321: Communication Systems **EE Dept. IITK**

MATLAB Assignment-3

Frequency and phase offset estimation *April 2025*

The objective of this assignment is to implement frequency and phase offset estimation algorithms. You will see that we will implement the third question of the tutorial.

1. Transmitter modeling with pilot and data
   (a) Generate a 16-bit pilot sequence $p[n] \in \{0, 1\}$ for $n = 1, \ldots 16$, and modulate it using QPSK modulation scheme.
   (b) Generate a 584-bit data sequence $d[n] \in \{0, 1\}$ for $n = 17, \ldots 600$, and modulate it using QPSK modulation scheme.
   (c) Form one packet by appending pilot QPSK symbols before data QPSK symbols. Denote the pilot and data QPSK symbols as $b[k]$ for $k = 1, \ldots, 300$.
2. Frequency and phase offset modeling:
   (a) Recall that samples at symbol-rate are with frequency and phase offset are modeled as follows:

$$y[k] = b[k]e^{j(\Gamma k+\theta)} + N[k], \quad k = 1, \ldots, K$$

   where T is the symbol time, and $N[k]$ is discrete-time complex WGN with variance $\sigma^2 = N_0/2$ per dimension.
   (b) Introduce in $b[k]$ frequency offset of $\Gamma = 2\pi\Delta f T$ with $\Delta f = 10^4$ Hz and $T = 1$ μsec, and a phase offset of $\theta = 30^\circ$.
   (c) Add complex AWGN $N[k]$ noise to above transmit stream. MATLAB generates complex AWGN noise such that each of its component has unit variance. Change the variance to observe an SNR of 30 dB.
   (d) Plot $y[k]$. Write observation about the constellation in a word document.
3. Frequency and phase offset estimation and compensation:
   (a) Obtain ML estimates of Γ and θ based on the observation $(\mathbf{y} = y[1], \ldots, y[K])^T$ for $k = 1, \ldots 8$, by using the algorithm developed in the third tutorial question. Assume that receiver knows the QPSK pilot sequence $b[k]$ for $k = 1, \ldots, 8$, which it uses for estimating Γ and θ.
   (b) Compensate Γ and θ from received stream as follows:

$$\tilde{y}[k] = y[k]e^{-j(\Gamma k+\theta)}. \quad k = 1, \ldots, K$$

   (c) Plot $\tilde{y}[k]$. Write observation about the constellation in a word document.
   (d) Now vary the SNR from 10 to 30 dB in steps of 5 dB. Write observation about the constellation $\tilde{y}[k]$ for each SNR in a word document.

(e) Compile the values of estimates of Δf and θ at different SNR values in a table in the word document

Please follow these Coding instructions:

- Properly comment your code.
- 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. Code should be generic.

Please follow these submission instructions.

- Deadline is Aprl. 10th, 11:59 pm.
- All codes and documents should be in one .zip/.rar folder, and submit one zip file.
- Name your code as rollno.zip. and upload your properly commented in drive link below. `https://tinyurl.com/d4wjyvcp`
- Please do not mail your file to us.

Please also read this carefully.

- Each one of you have to individually do all the reading and MATLAB 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 two acts, and both such cases will be awarded zero. Our decision will be final.