# EE 332: Digital Communication Assignment-2

Prachi Bindal
220102071

IQ file :63

## Methodology

### 1. Symbol Rate Estimation

- Let the received signal be: $r(t) = s(t-\tau) \cdot e^{j(2\pi \Delta f t + \theta)}$ with $s(t) = \sum a_n p(t-nT)$
- $r(t) \cdot r^*(t) = |s(t-\tau)|^2 = \sum_{n,m} a_n a_m^* p(t-nT)p(t-mT) \rightarrow |r(t)|^2 = \sum |a_n|^2 p^2(t-nT)$ $\xrightarrow{\text{On taking fourier transform}}$ $\mathcal{F}\left\{|r(t)|^2\right\} = \sum \frac{|a_n|^2}{T} G\left(f - \frac{n}{T}\right)$

  Hence the Peak occurs at 1/T, -1/T ,0... and so on and we can find the symbol rate

### 2. Samples Per Symbol:

Samples per Symbol is directly sampling rate / Symbol rate

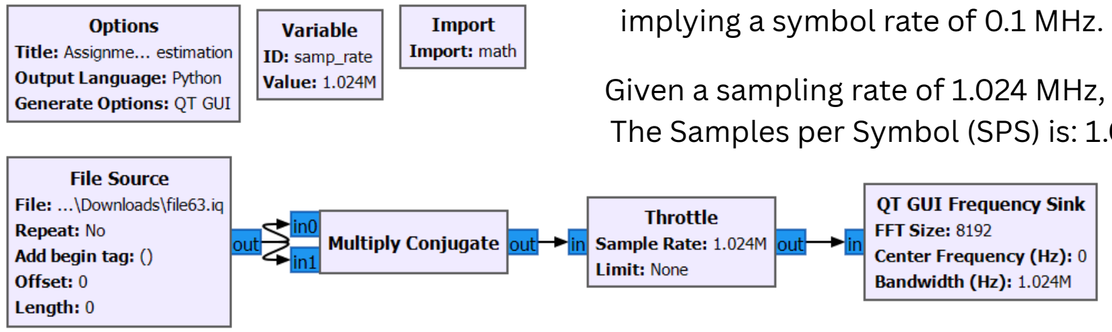
### 3. Frequency offset Estimation

- By raising the signal to appropriate power q, $r(t)^q = \left(\sum a_n p(t-nT)\right)^q \cdot e^{j(2\pi \Delta f t + \theta)q} \rightarrow r(t)^q = \sum a_n^q \, p^q(t-nT) \cdot e^{j(2\pi q \Delta f t + q\theta)} + \text{cross terms}$

  the modulation effect is removed (assuming |an| is going to be constant), and spectral peaks appear at 1/T +qΔf

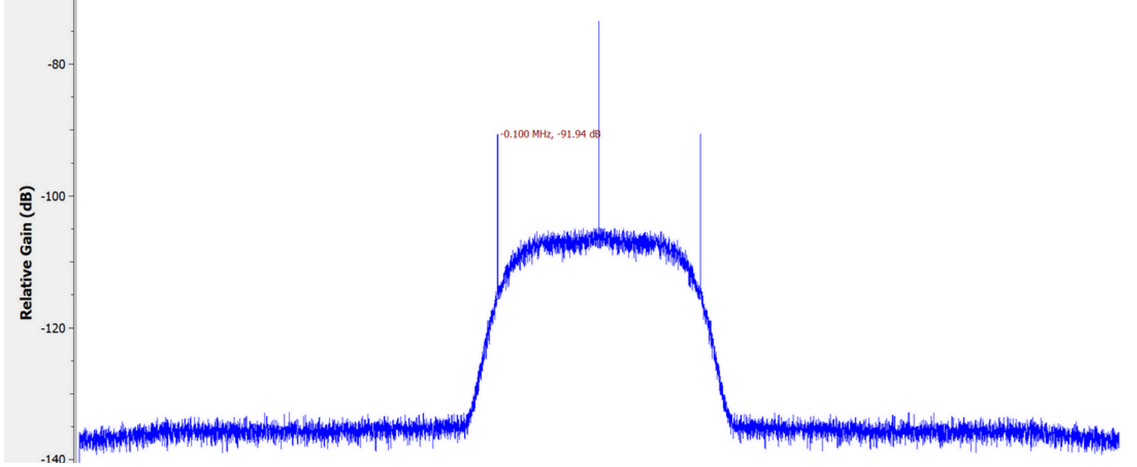
### 4. Modulation Type

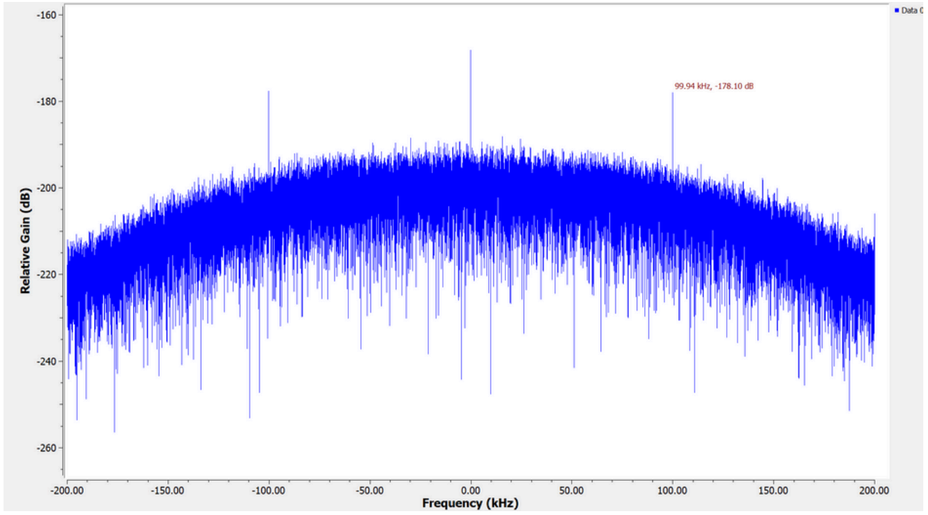
To identify the modulation scheme, one sample was taken from every N symbol samples to minimize the impact of inter-symbol interference (ISI). and Costa's Loop is used to cancel frequency offset. The resulting points were then used to analyze the constellation diagram



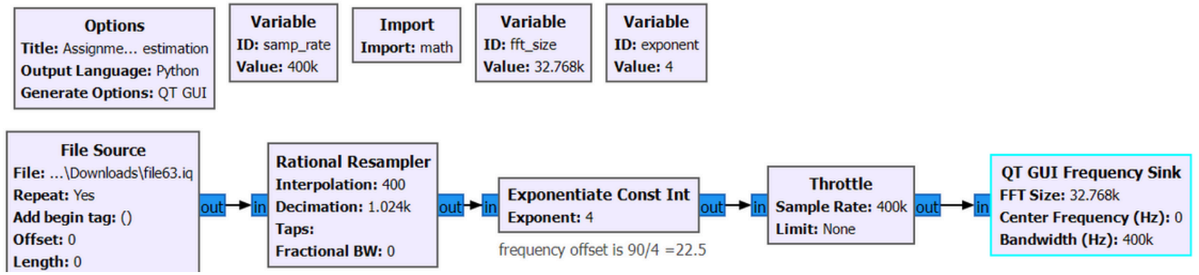

The spectral peak occurs at 0.1 MHz, implying a symbol rate of 0.1 MHz.

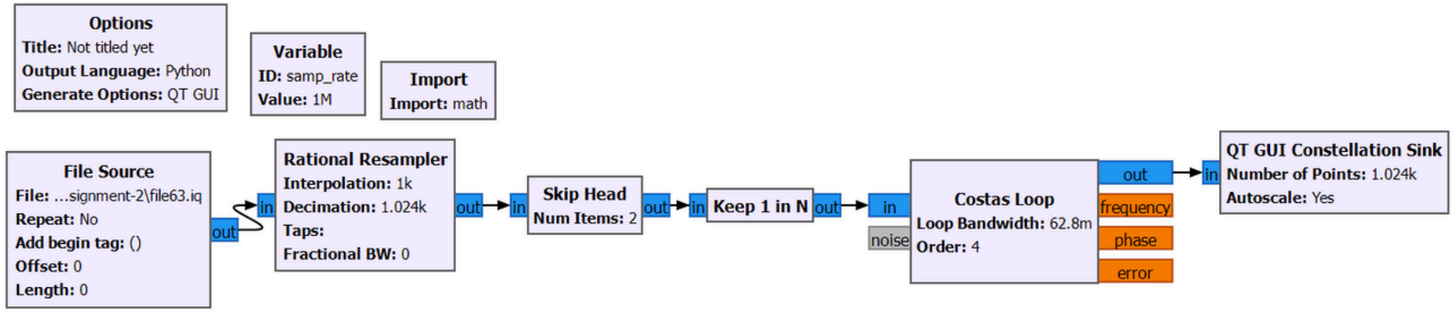
Given a sampling rate of 1.024 MHz,
The Samples per Symbol (SPS) is: 1.024/0.1=10.24≈10



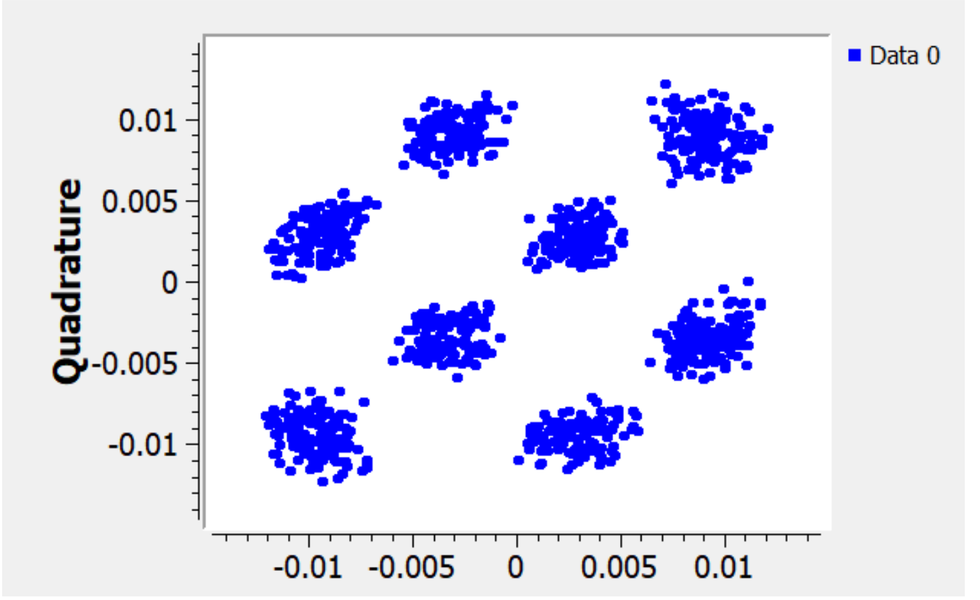



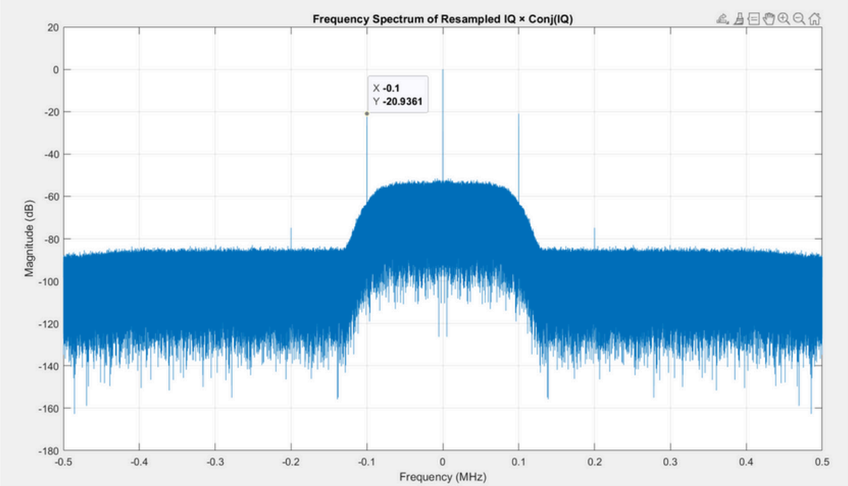

A spectral peak was observed at 100.09 kHz, slightly offset from the expected 100.00 kHz.
Thus, the frequency offset is: Δf = (100.09 - 100)/4 = 90/4 = 22.5hz

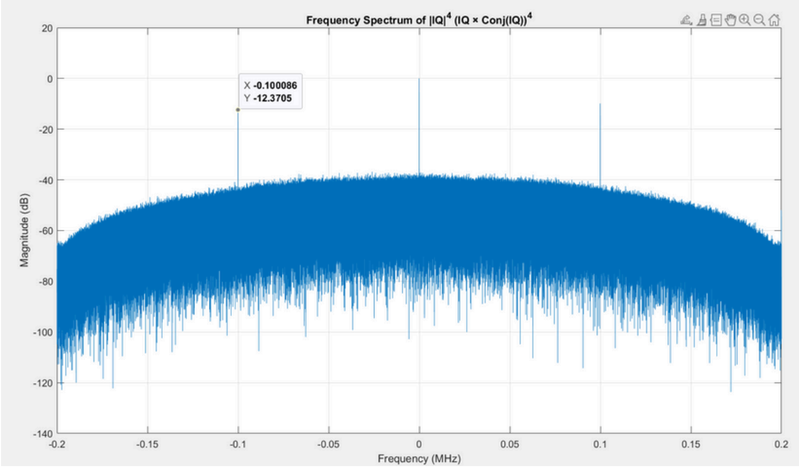



Based on the constellation diagram, the modulation scheme is identified as 8-QAM.






Based on the MATLAB analysis, the resulting frequency spectrum reveals a frequency offset of approximately 21.5 Hz, which closely aligns with the 22.5 Hz offset obtained from GNU Radio.

# Results

- Symbol Rate: 0.1 MHz
- Samples per Symbol (SPS): 1.024/0.1=10.24≈10
- Frequency Offset (Δf): (100.09−100)/4=90/4 Hz=22.5 Hz
- Modulation Scheme: 8-QAM