# Simulation Results (Week-1)

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## 1 Team details


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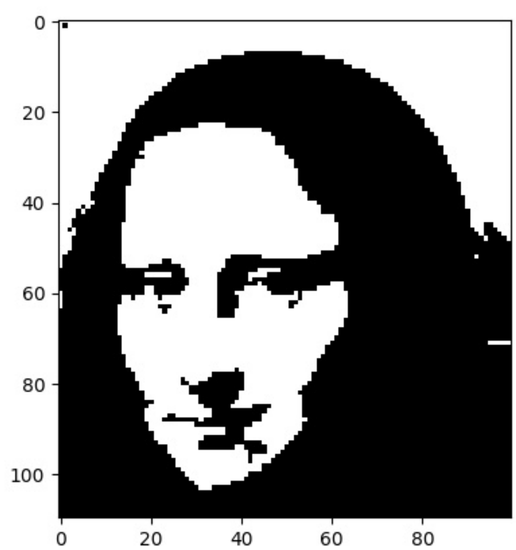
## 2 4-QAM simulation

- **Original Image**:



- **BER values for different values of $E_b/N_0$:**
  Note that the values of the bit error rate and $Q(\sqrt{2\frac{E_b}{N_0}})$ are approximately equal and the BER decreases with an increase in $\frac{E_b}{N_0}$.

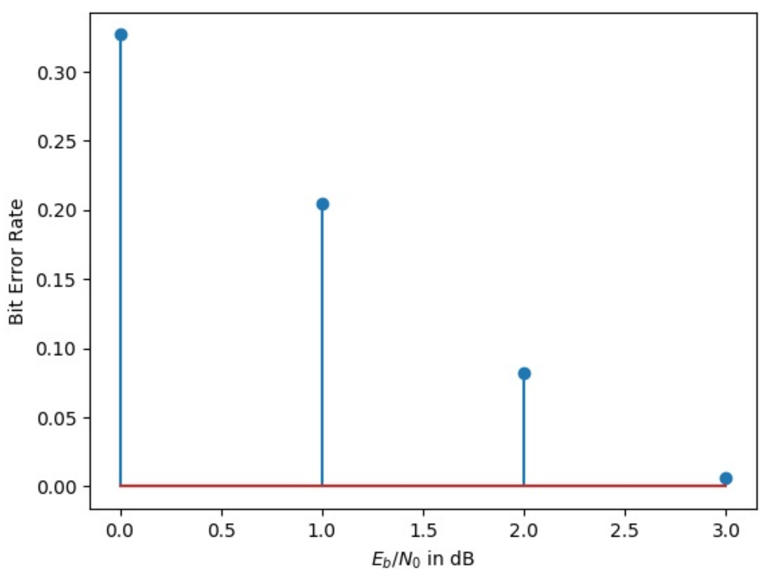
```
shaik-mastan@shaik-mastan-HP-Laptop-15-da1xxx:~/IDP$ python -u "/home/shaik-mastan/IDP/EE18BTECH11039_EE18BTECH11010.py"
For E_b/N_0 = -10 dB
No. of incorrectly demodulated bits: 3678
Bit Error rate: 0.33436363636363636
Q-function: 0.32736042300928847

For E_b/N_0 = -5 dB
No. of incorrectly demodulated bits: 2399
Bit Error rate: 0.21809090909090909
Q-function: 0.2132280183576204

For E_b/N_0 = 0 dB
No. of incorrectly demodulated bits: 858
Bit Error rate: 0.078
Q-function: 0.0786496035251425

For E_b/N_0 = 5 dB
No. of incorrectly demodulated bits: 69
Bit Error rate: 0.006272727272727273
Q-function: 0.00595386714777868
```

- **Plot of BER v/s $\frac{E_b}{N_0}$**



## 3 Demodulated Images

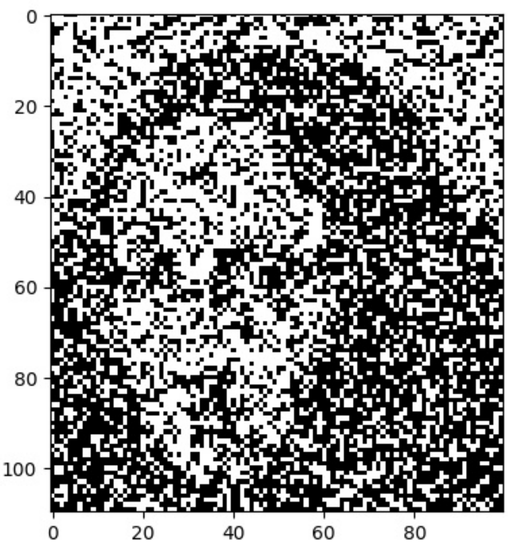



Figure 1: Demodulated image for $E_b/N_0 = -10\ dB$

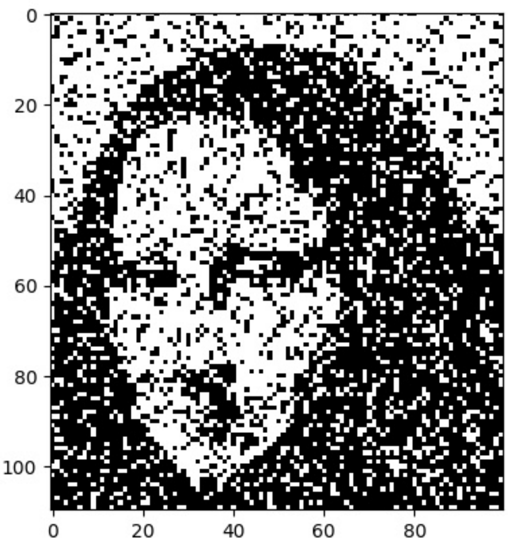


Figure 2: Demodulated image for $E_b/N_0 = -5\ dB$

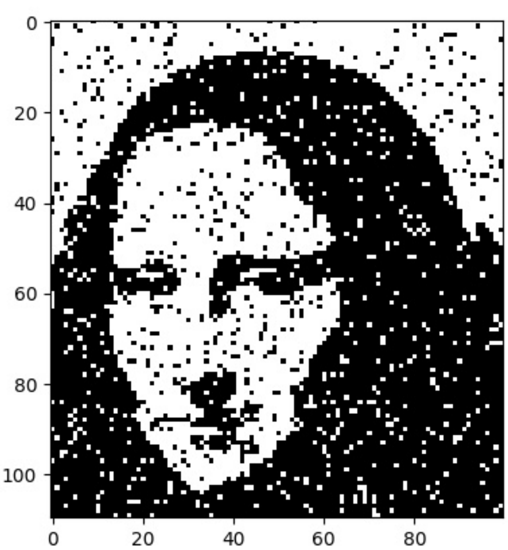


Figure 3: Demodulated image for $E_b/N_0 = 0\ dB$

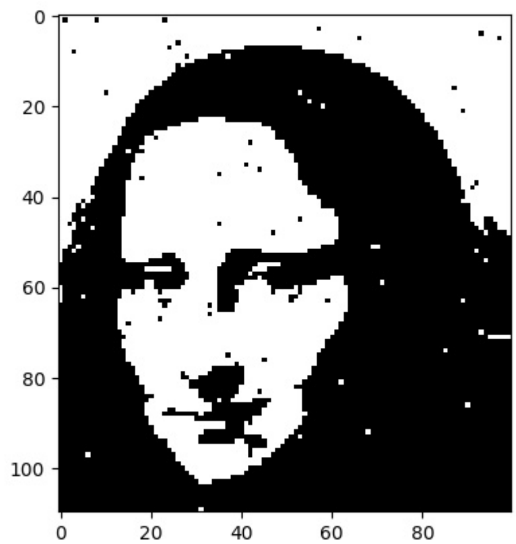



Figure 4: Demodulated image for $E_b/N_0 = 5\ dB$

# 4 Explanation of the code

This section is about the significant variables used in the program.

- img - The matrix which is used to store the pixel values.
- s - The vector which is used to store the signal values generated for the image bits.
- S_space - The vector which is used to store the unique M-QAM symbols.
- bit_array - The vector which is used to store the bits corresponding to the symbols in S_space. This vector is used in the demodulation scheme later in the program.
- Eb_N0_dB - The list which is used to store the given values of $\frac{E_b}{N_0}$ in dB.
- Eb_N0 - The list which is used to store the given values of $\frac{E_b}{N_0}$ in the decimal scale.
- w - The vector which is used to store the AWGN of $\mu = 0$ and $\sigma^2 = f_s \frac{N_0}{2}$.
- r_sym - The vector which is used to store the signal space co-ordinates of r.
- dist - The vector which is used to store the distance of the signal space co-ordinates from the received vector. These distances are used to find the minimum distance required for demodulation.
- demod - The vector which is used to store the demodulated bits based on the minimum values in dist.

In the attached program, the signal is modulated according to the given instructions. The 'M' signal space co-ordinates are stored in a vector, which will be used for demodulation. Upon integrating (manually), we get energy of each signal as T, which means $E_b = \frac{T}{2}$. The given $\frac{E_b}{N_0}$ values are converted from dB to decimal scale and the corresponding $N_0$ is generated. With this given value of $N_0$, the AWGN values are generated and added to s.

For demodulation scheme, the received signal is represented as signal space co-ordinates. The distance between r and the M-QAM symbols are computed. The QAM symbol which gives the minimum distance is stored and the corresponding bit values (two bits) are stored in the demod vector.