## 0.1 Evaluation Parameters

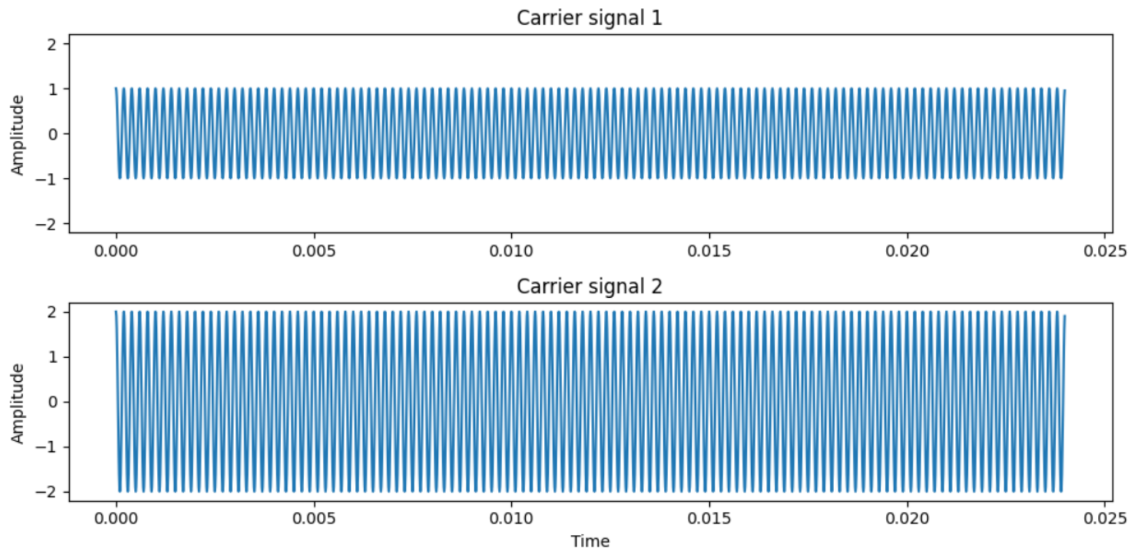
We choose f, f1, f2 which are the frequency of carried signal have the value of $5000Hz$, $5000Hz$ and $10000Hz$, respectively. $Spb = 100$ is determined by the number of samples per bit used for the modulation scheme.

## 0.2 Simulate Modulation

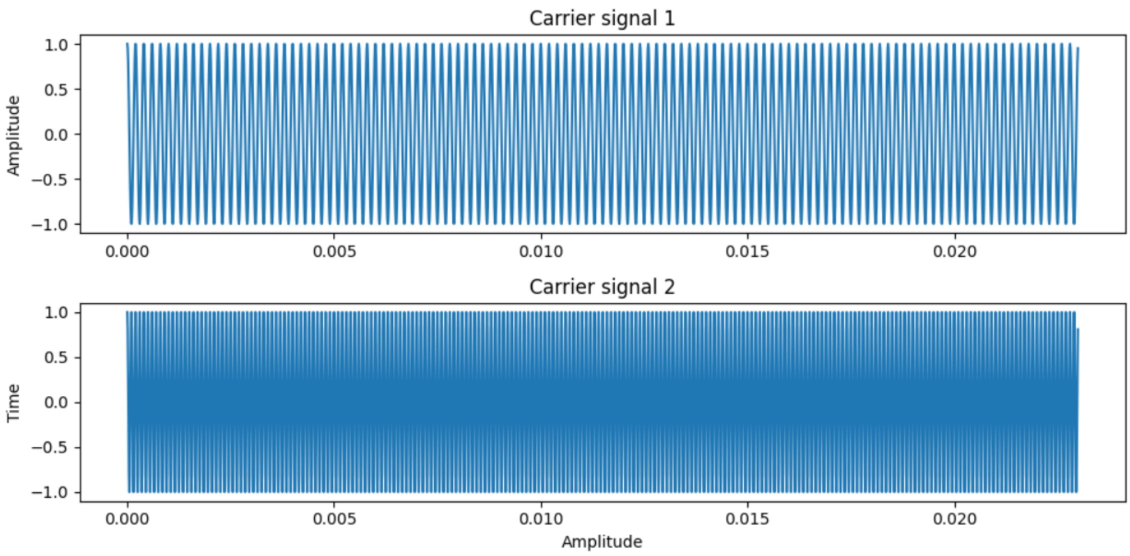
- Generating and plotting the Carrier Signals:

- For ASK modulation, 2 carrier signals is $cos(2\pi fx)$ and $2cos(2\pi fx)$. If the binary data is 0, the carrier signal is $cos(2\pi fx)$, and if the binary data is 1, the carrier signal is the other.
- For FSK modulation, we choose 2 signals $cos(2\pi f_1 x), cos(2\pi f_2)x$. If the binary data is 0, the carrier signal is $cos(2\pi f_1 x)$, and if the binary data is 1, the carrier signal is the other.
- For PSK modulation, we choose 2 signals $cos(2\pi fx), cos(2\pi fx + \pi)$. If the binary data is 0, the carrier signal is $cos(2\pi fx)$, and if the binary data is 1, the carrier signal is the other.

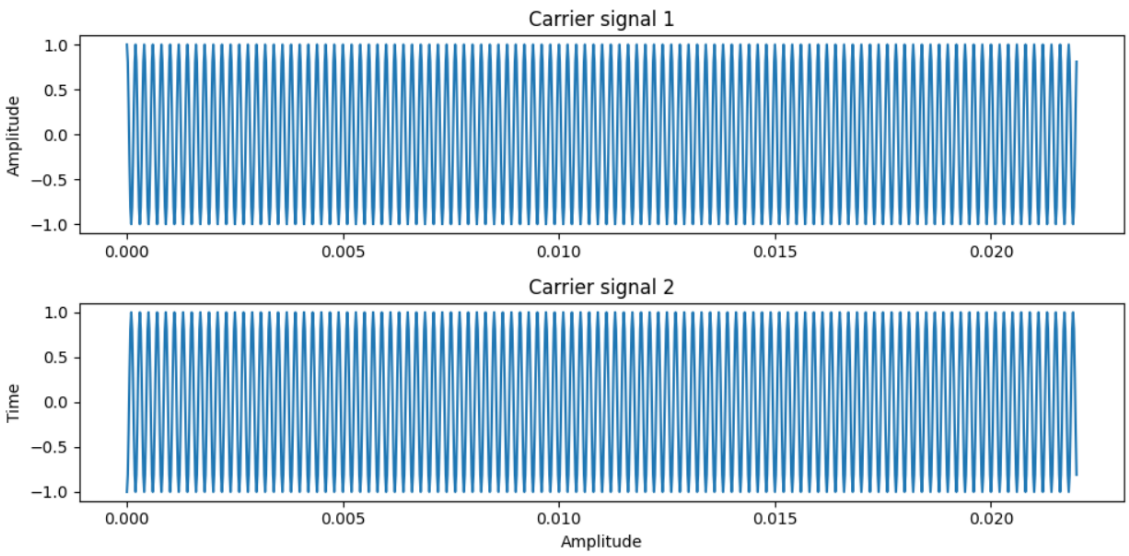
These carrier signals are then plotted to visualize the waveform.




**Hình 0.1:** ASK carrier signal

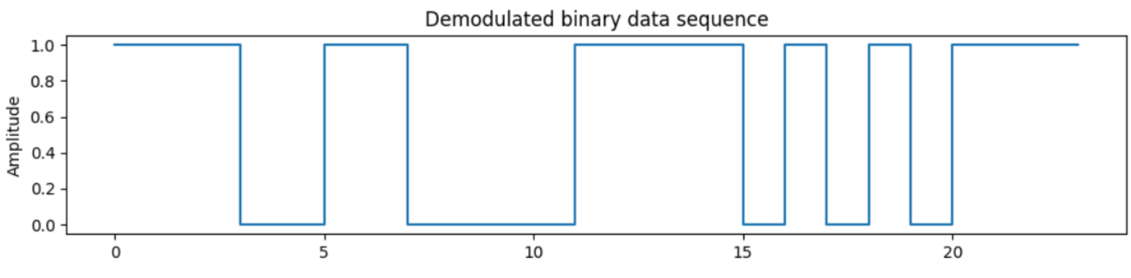



**Hình 0.2:** FSK carrier signal



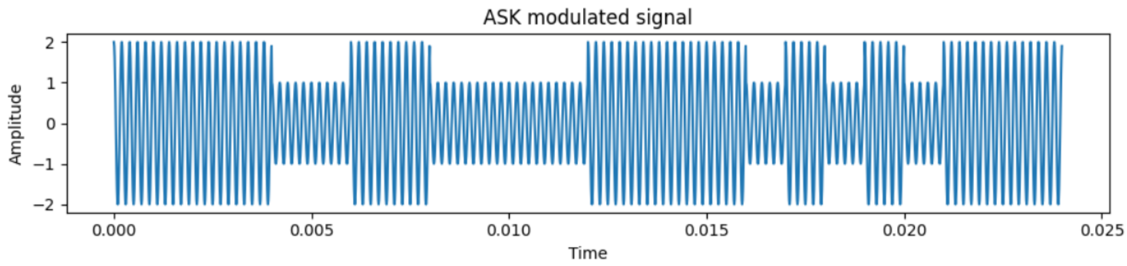

**Hình 0.3:** PSK carrier signal

- Generating and Plotting the Binary Data Sequence: The next step is to generate a random binary data sequence, which consists of 1s and 0s. We use stream bit random with length between 20 and 30. The binary data sequence is then plotted to visualized the pattern of data.

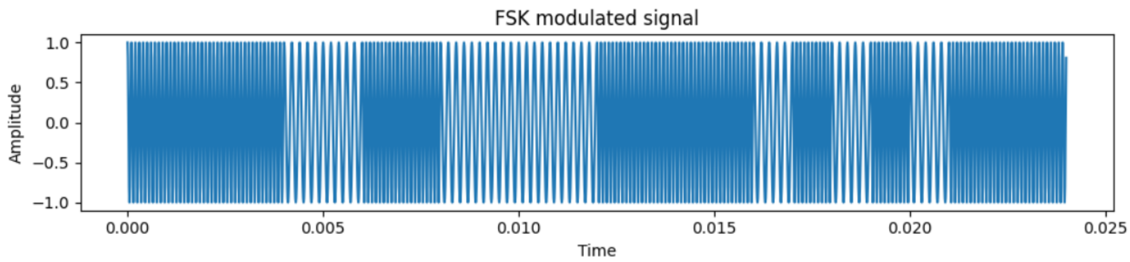



**Hình 0.4:** Binary data sequence

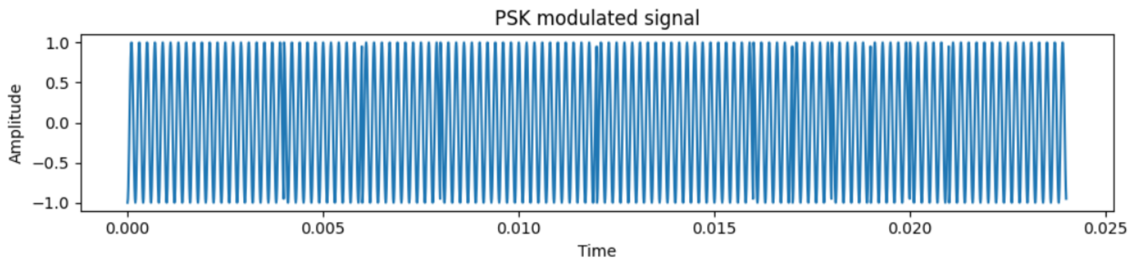
- Performing Modulation and Plotting Modulated Signal: The final step is to perform the modulation of the binary data sequence using carrier signals with the help of mathplotlib library.




**Hình 0.5:** ASK modulation



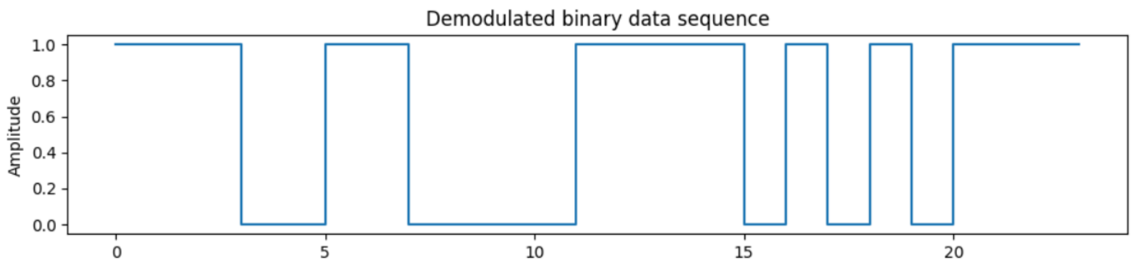

**Hình 0.6:** FSK modulation




**Hình 0.7:** PSK modulation

## 0.3 Simulate Demodulation

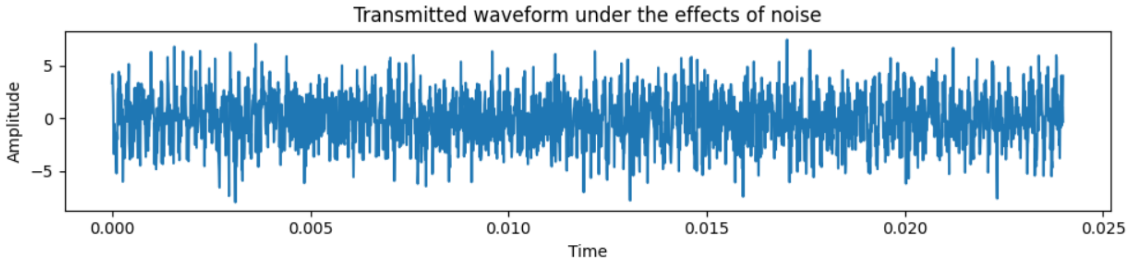
The method in demodulation is to correlate the modulated signal with the carrier signals.The correlation is performed using the Maximum Likelihood Criterion to determine the most likely value of the demodulated binary data based on the modulated signal and the carrier signals. This will define whether the demodulated binary data is 0 or 1.



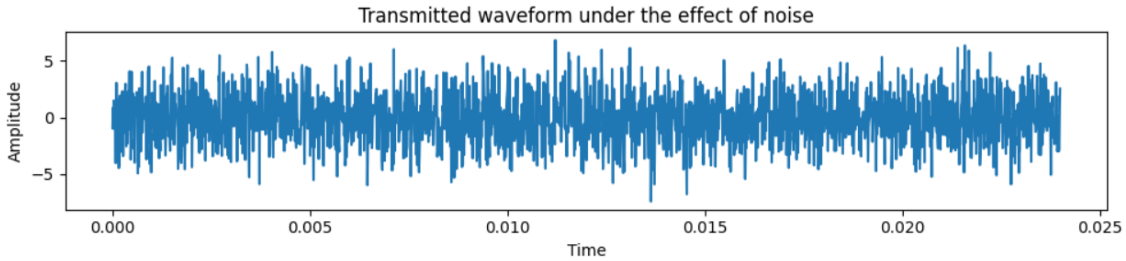

**Hình 0.8:** Demodulated binary data sequence

## 0.4 Modulation and demodulation under effects of noise

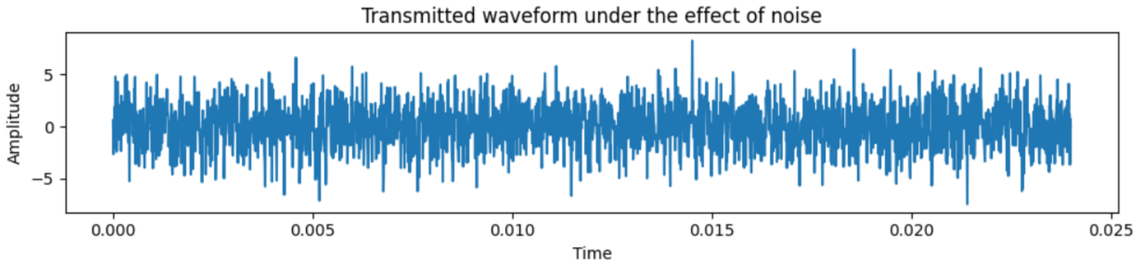
The noise is added to the transmitted waveform as $r(t) = s(t) + n(t)$, where $s(t)$ is the transmitted waveform and $n(t)$ is the Gaussian noise. In this project, we choose $N = 0$ and $standard\ deviation = 1$



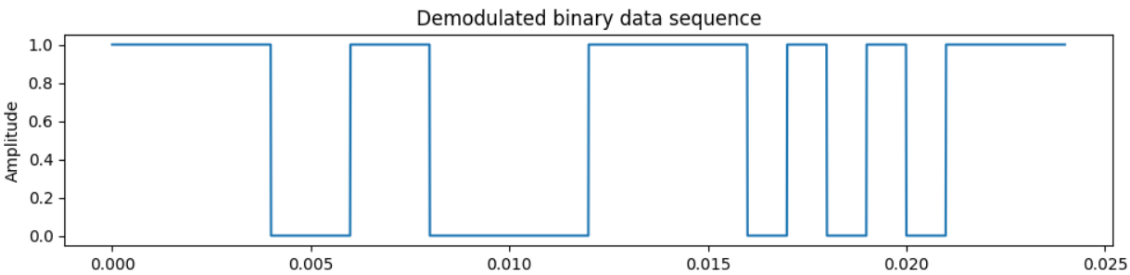

**Hình 0.9:** ASK transmitted wave under effect of Gaussian noise



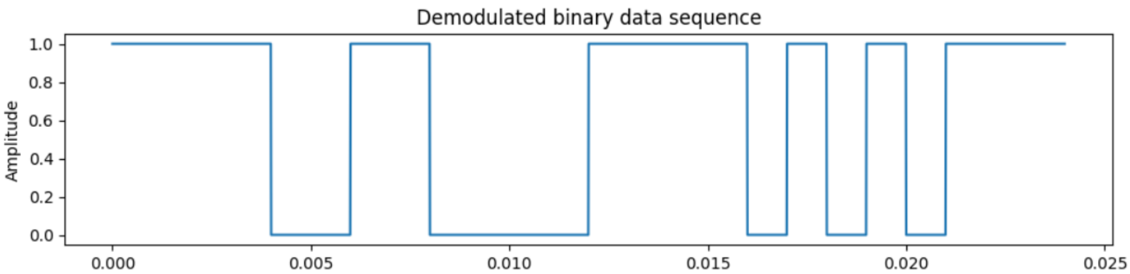

**Hình 0.10:** FSK transmitted wave under effect of Gaussian noise



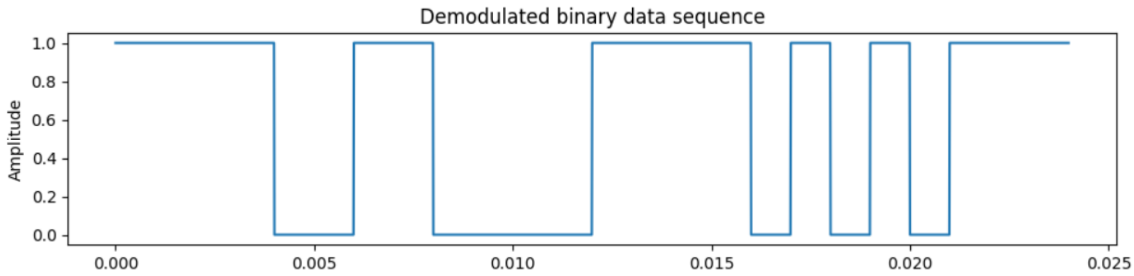

**Hình 0.11:** PSK transmitted wave under effect of Gaussian noise




**Hình 0.12:** ASK Demodulated binary sequence under effect of Gaussian noise



**Hình 0.13:** FSK Demodulated binary sequence under effect of Guassian noise




**Hình 0.14:** PSK Demodulated binary sequence under effect of Gaussian noise

## 0.5 Compute the Error rate

The error probability is calculated by comparing the original binary data sequence with the demodulated binary data under the effect of noise. The number of difference bits between the input and output bits divided by the total number of input bits represent the bit error rate.

Bit error rate: $BER = \frac{1}{n}\sum_{i=1}^{n}(u[i] \neq r[i])$, where n is the total number of bits.

From the above experiment:

- ASK demodulation:It can be seen that there are no difference between the input binary sequence and the demodulated signal after adding the noise (when t =100ms), therefore the $BER = 0\%$
- FSK demodulation: $BER = 0\%$
- PSK demodulation: $BER = 0\%$