

MPSK Modulation and Demodulation

The aim of the experiment is to reconstruct a transmitted image, modulated by MPSK scheme, at the receiver. The 'M' in the M-PSK represents the maximum number of possible symbols (For Example: BPSK: $M = 2$, QPSK: $M = 4$). The maximum likelihood decoder will be used at the receiver to recover the symbols. To model a channel for transmission AWGN noise will be added to transmitted signal before processing at the receiver.

The symbol error rate (SER) vs $\frac{E_s}{N_0}$ (in dB) and bit error rate (BER) vs $\frac{E_b}{N_0}$ (in dB) will be plotted (where E_s is the symbol energy, E_b is the bit energy and $N_0/2$ is the AWGN noise variance) and will be compared with the theoretical value, .

The MPSK symbols are generated as

$$s_i = \sqrt{E_s} \cos \left[\frac{2\pi(i-1)}{M} \right] + j \sqrt{E_s} \sin \left[\frac{2\pi(i-1)}{M} \right] \quad i = 1, 2, \dots, M$$

The probability of symbol error is given by

$$P_s = 2Q \left[\sqrt{\frac{2E_s}{N_0}} \sin \left(\frac{\pi}{M} \right) \right]$$

and that of bit error is given by

$$P_b = \frac{2}{\log_2 M} Q \left[\left(\sqrt{\frac{2E_b}{N_0} \log_2 M} \right) \sin \left(\frac{\pi}{M} \right) \right]$$

where E_b is the energy per bit.

The relation between E_s and E_b is given by

$$E_s = E_b \log_2(M)$$

Note that we are using the baseband transmission for simulation.

Following are the steps to be followed for the simulation experiment.

1. Read the image cameraman.png. You can get the image by clicking [here](#). The image is of size 256×256 . Use suitable python package for reading the image (imageio, opencv etc).

2. Convert the pixel values to bits and map to MPSK symbols. Make sure to use same number of bits for all the values. Plot the constellation diagram of the MPSK symbols.
3. Set an SNR value for the transmission and generate a complex Gaussian noise with enough number of samples for the required SNR. Here $\frac{E_s}{N_0}$ can be considered as the SNR. Since each value of SNR is generated by varying the noise power you can take $E_s = 1$.
4. The received signal which is the combination of MPSK symbol and the noise samples shall be passed through an ML decoder to do the demapping. The constellation diagram of the received signal shall be plotted.
5. Convert the demapped symbols to bits and then to pixel values. Also find the SER and BER.
6. Reconstruct the image.
7. Iterate the above steps for SNR (in dB) values from -10 to 10 with increments of 1 and plot the SER and BER separately. Also plot the theoretical SER and BER value for MPSK Modulation. Compare them.
8. Iterate all the above steps for $M = 2, 4, 8$.