Results

1 Task – 1

Impulse Train Representing BPSK symbols

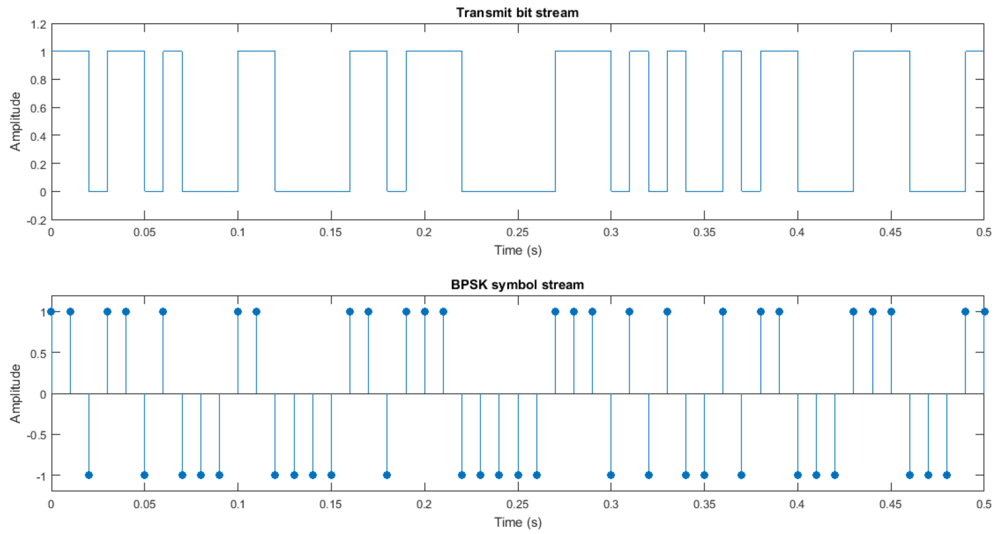
A random bit sequence was generated with length L = 1000 and mapped into BPSK symbols using the following rule.
$$a_k = \begin{cases} 1 & b_k = 1 \\ -1 & b_k = 0 \end{cases}$$

Impulse train is generated which represents the BPSK symbols and given by the following equation.

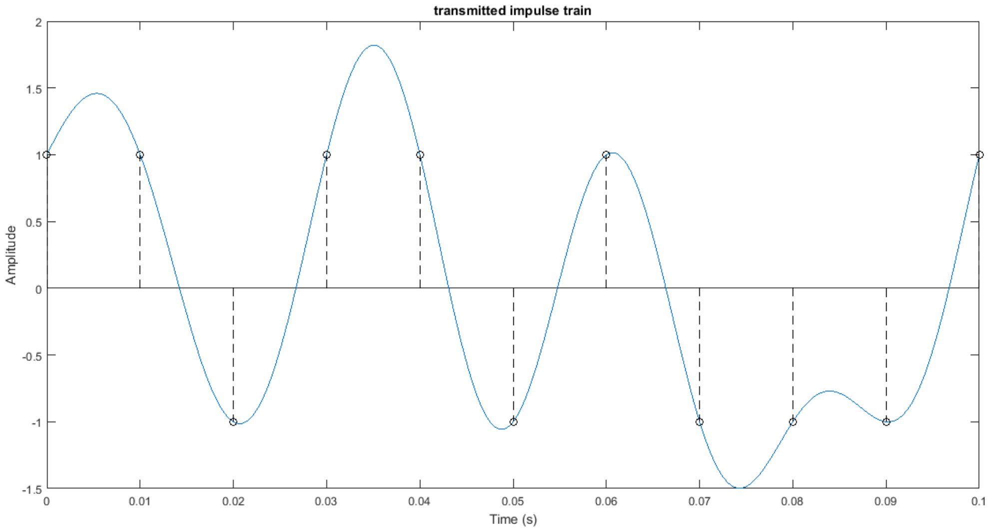
$$x(t) = \sum_{k=0}^{L-1} a_k \, \delta\,(t - k\,T_b)$$

The bit duration - Tb = 0:1 s.

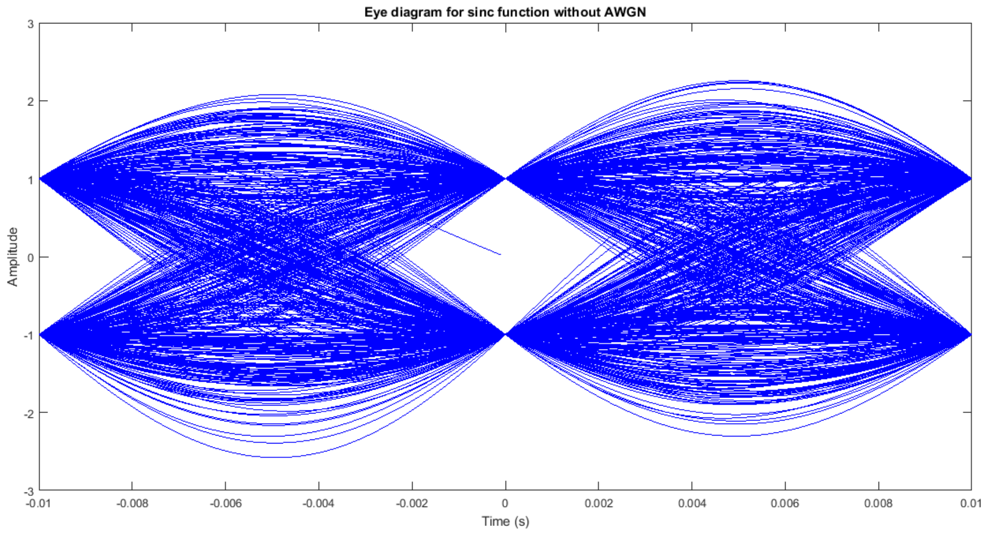
1.1 Impulse train representing with BPSK symbolling



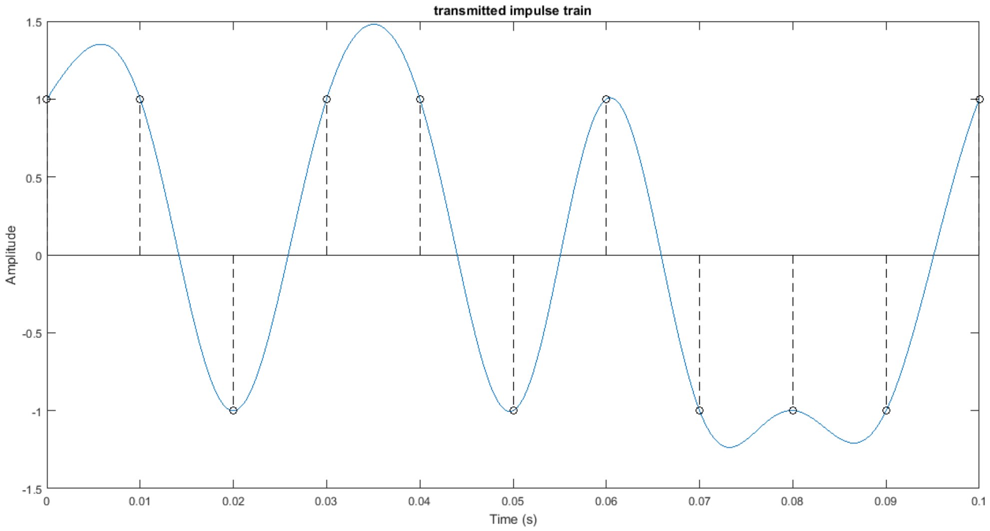
1.2 Received signal using Sinc function



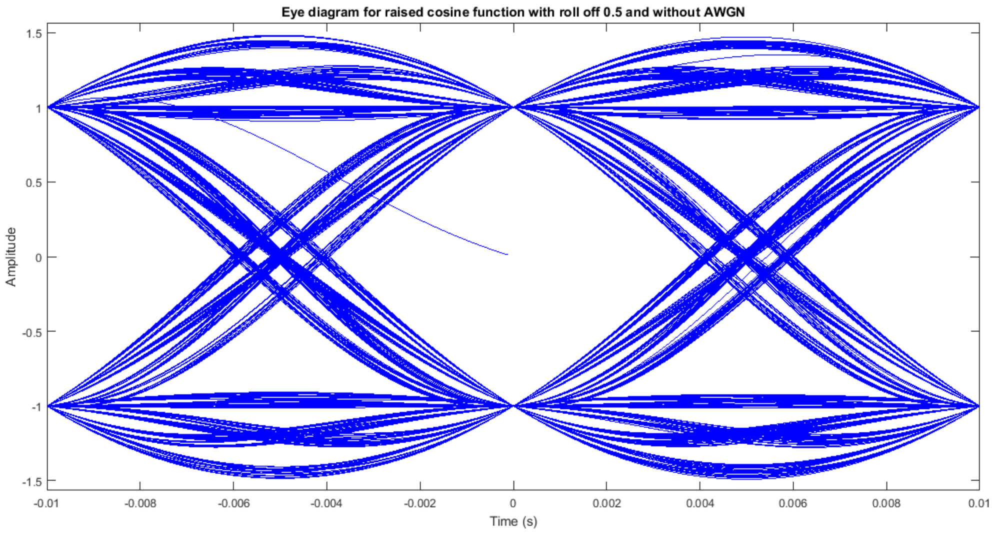
1.3 Eye Digram – Sinc Function



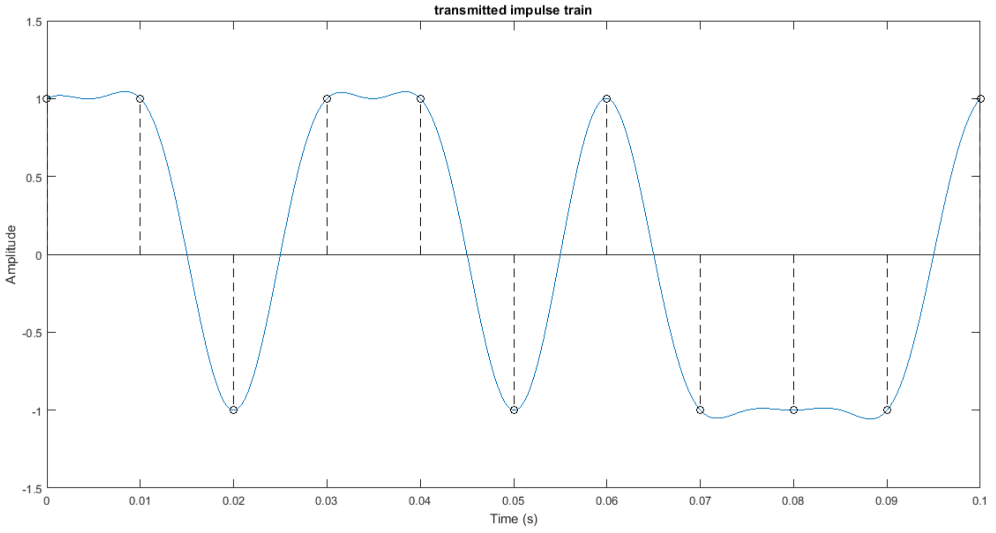
1.4 Received signal using Raised Cosine Function (roll-off = 0.5)



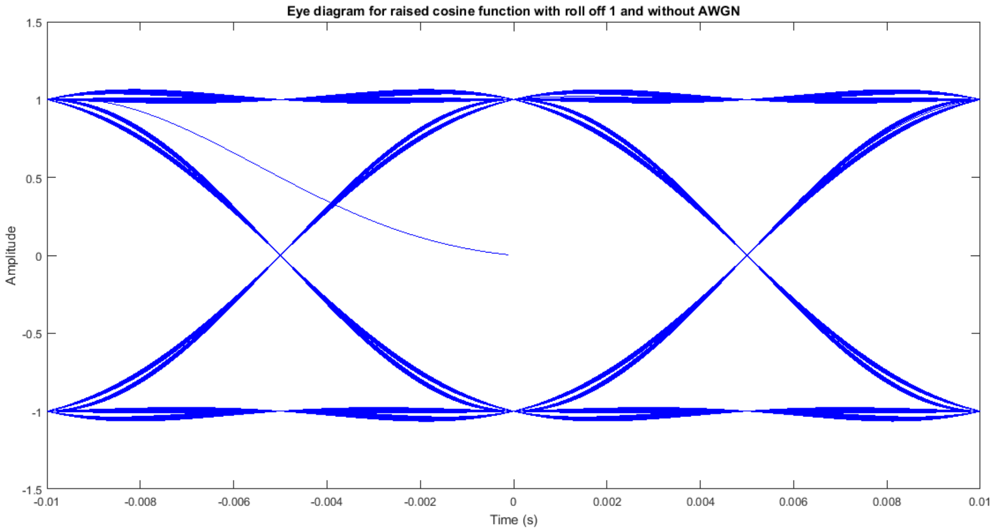
1.5 Eye Diagram – Raised Cosine Function with roll-off 0.5



1.6 Received Signal using Raised Cosine Function with roll-off = 1



1.7 Eye Diagram – Raised Cosine Function with roll-off 1



1.8 Comparison of the robustness of the systems

Sinc pulse has the lowest robustness. Maximum orizontal distance is of the eye is smallest. Therefore length the error free sampling region is small. The slope of the eye is steep. Therefore system is sensitive to delays in sampling time.

Width at the corner of the eyes is large. Therefore large timing jitters are there.

Robustness of raised cosine filter with r=1 is the highest. It has a large maximum horizontal distance in the eye. Therefore length of error free sampling region is high. Slope of eye is small. Therefore system is less sensitive to timing delays. Width at the corners of the eye is small. Therefore the timing jitters are small.

Robustness of the raised cosine filter with gain roll of factor 0.5 is lower than that of raised cosine filter with gain roll of factor 1 and higher than that of sinc pulse

2 Task – 2

In this step, Additive white Gaussian Noise (AWGN) is added to the transmitted signal with Eb=N_0=10dB and Eb is the average bit energy and N0 is the noise power spectral density. Considering equiprobable symbols, we can calculate the average bit energy as

$$E_b = \frac{1}{2}\left(1^2 + (-1)^2\right) = 1$$

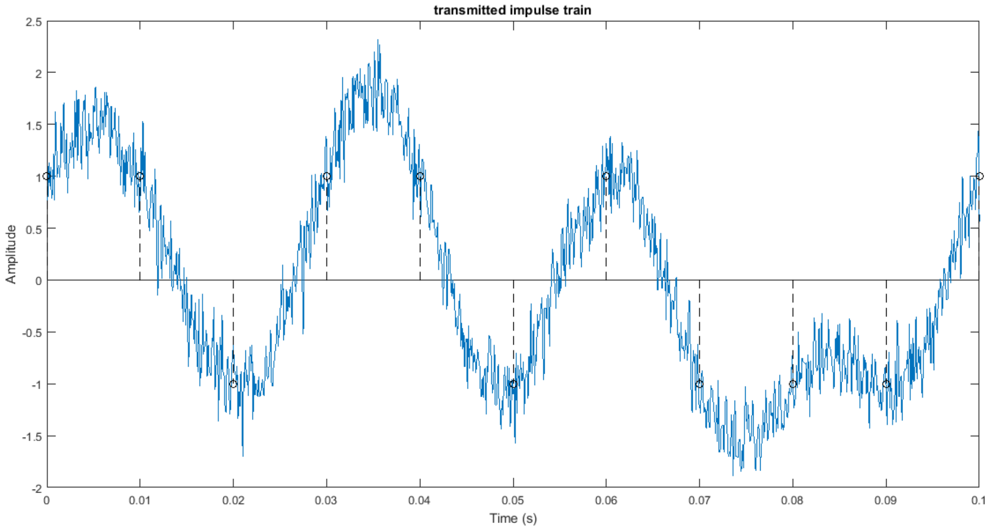
follows.

According to the average bit energy, N_0 is calculated as,

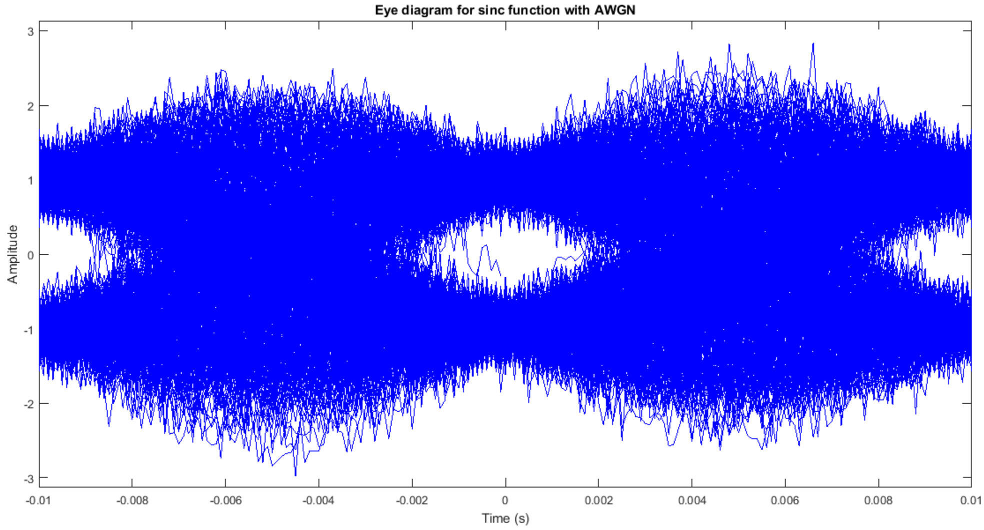
$$N_0 = E_b\, 10^{-0.1\,\gamma}$$

γ is Eb=N_0 in dB.

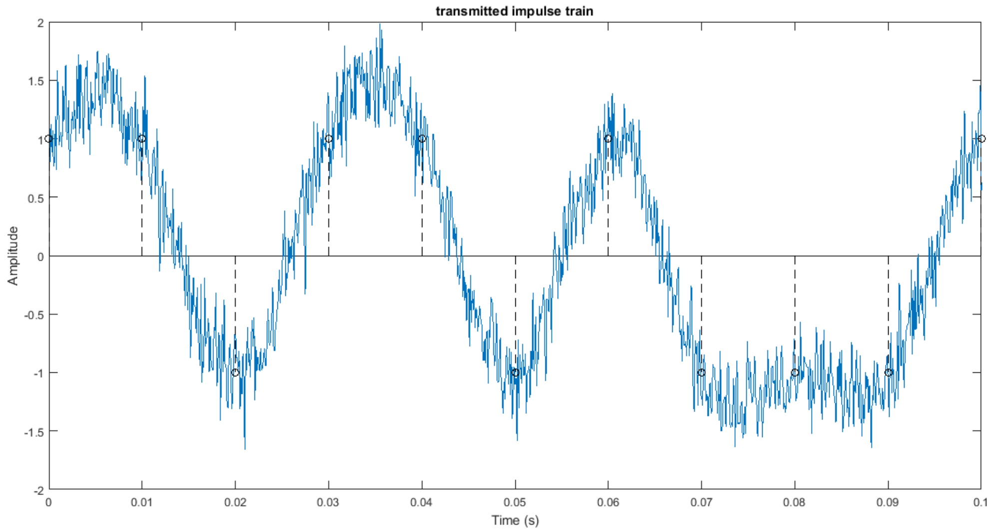
2.1 Received Signal with AWGN using Sinc Function



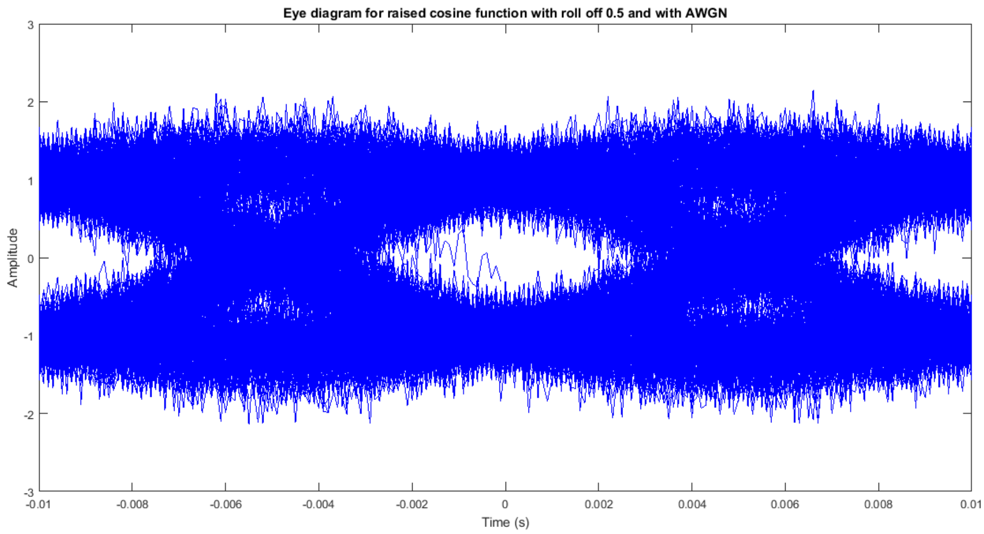
2.2 Eye Diagram with AWGN – Sinc Function



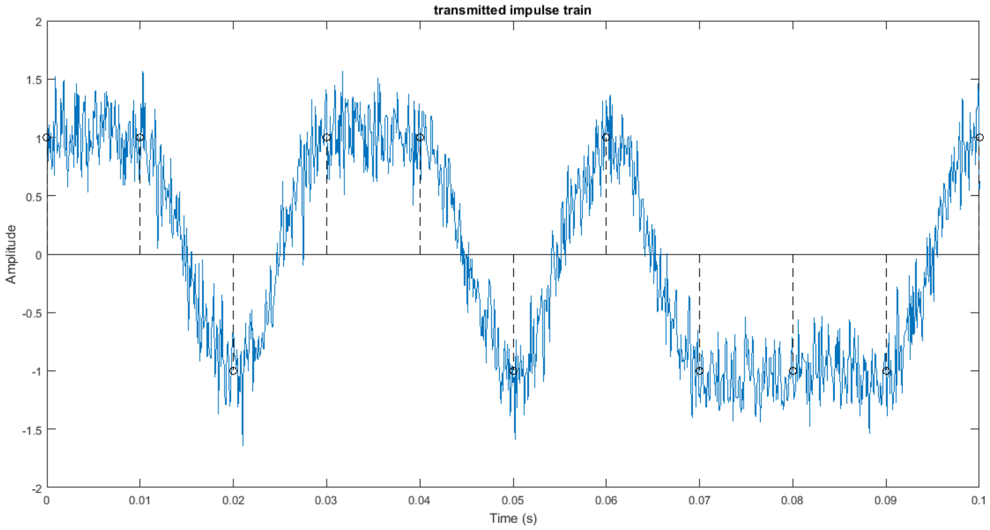
2.3 Received Signal with AWGN using Raised Cosine Function with roll-off 0.5



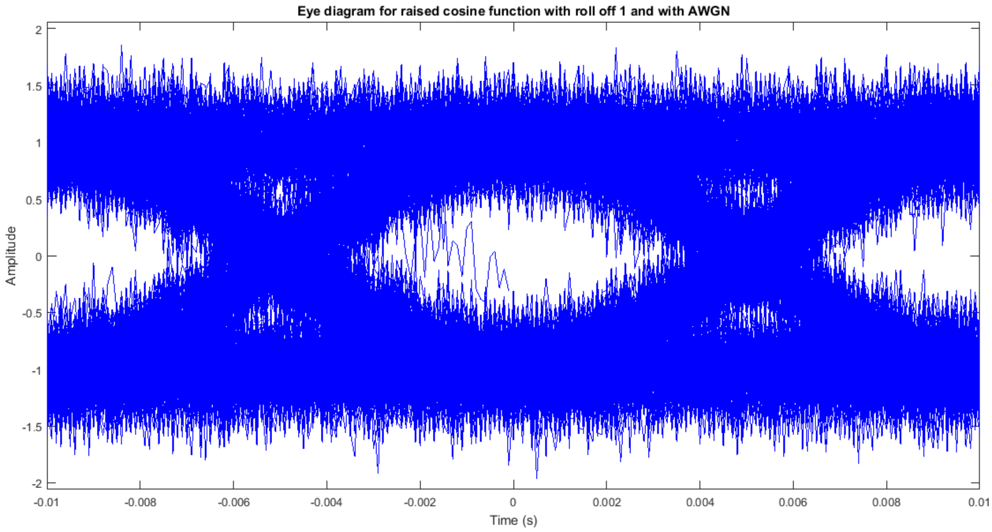
2.4 Eye Diagram with AWGN - raised Cosine Function with roll-off 0.5



2.5 Received Signal with AWGN using Raised cosine with roll-off 1



2.6 Eye Diagram with AWGN - Raised cosine with roll-off 1



2.7 Comparison of the Robustness of the systems

Adding AWGN has increased the width of eye corner significantly and ha has reduced both horizontal and vertical maximum openings in all the 3 systems.
But still the system with rolling factor 1 is the most robust system as it still has the highest error free sampling region with lowest slope and lowest width of the eye with respect to noise, sampling time and synchronization errors.
The system with roll off factor 0.5 is more robust than the system utilizing sinc function as it has a high error free sampling area with a low slope and a lower width at the eye corner when compared.

3 Task – 3

In this task, the system is extended to a 4-PAM system. The real bit sequence is mapped to a 4-PAM symbols using the following rule.

$$a_k = \begin{cases} \dfrac{-3\,d}{2} & b_k = 0 \ and \ b_{k+1} = 0 \\ \dfrac{-d}{2} & b_k = 0 \ and \ b_{k+1} = 1 \\ \dfrac{d}{2} & b_k = 1 \ and \ b_{k+1} = 1 \\ \dfrac{3\,d}{2} & b_k = 1 \ and \ b_{k+1} = 0 \end{cases}$$

d is the distance between two symbols. In this, the value of d was set to 1.

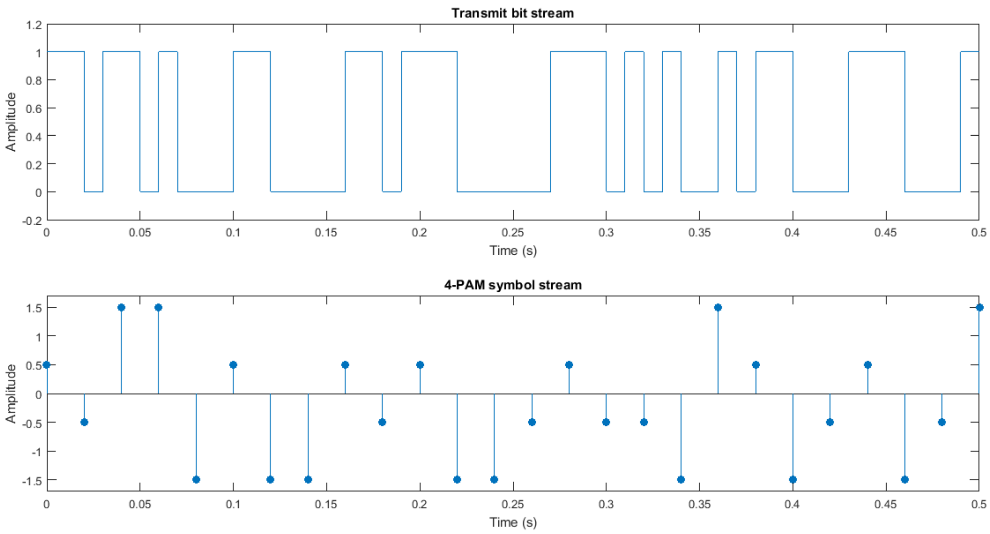
Impulse train is generated which represents the 4-PAM symbols are given by the following equation.

$$x(t) = \sum_{k=0}^{L/2-1} a_k\, \delta\,(t - 2\,k\,T_b)$$

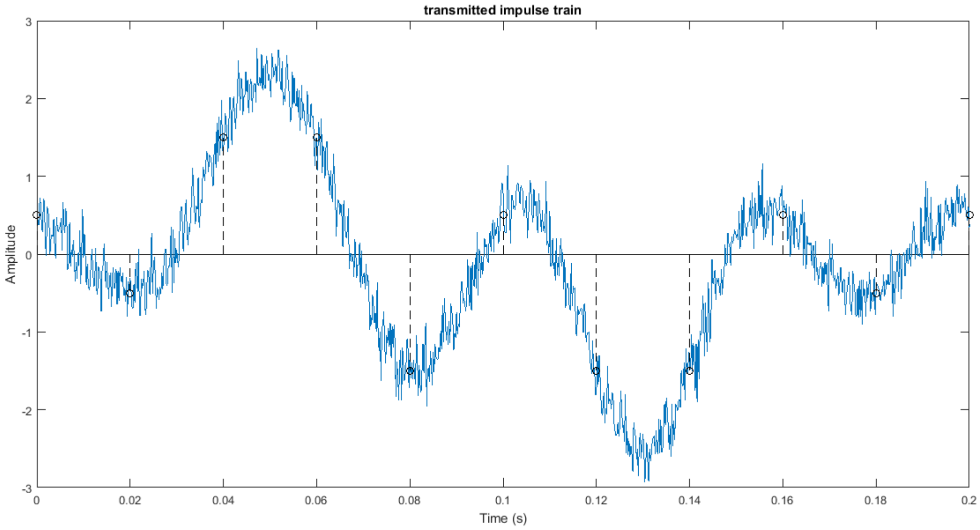
Transmitted signal is generated by convolving the impulse train with the pulse shaping filter. AWGN is added to the transmitted signal as in the BPSK system. The average bit energy of the 4-PAM system is as follows.

In this case d = 1, Eb = 1.

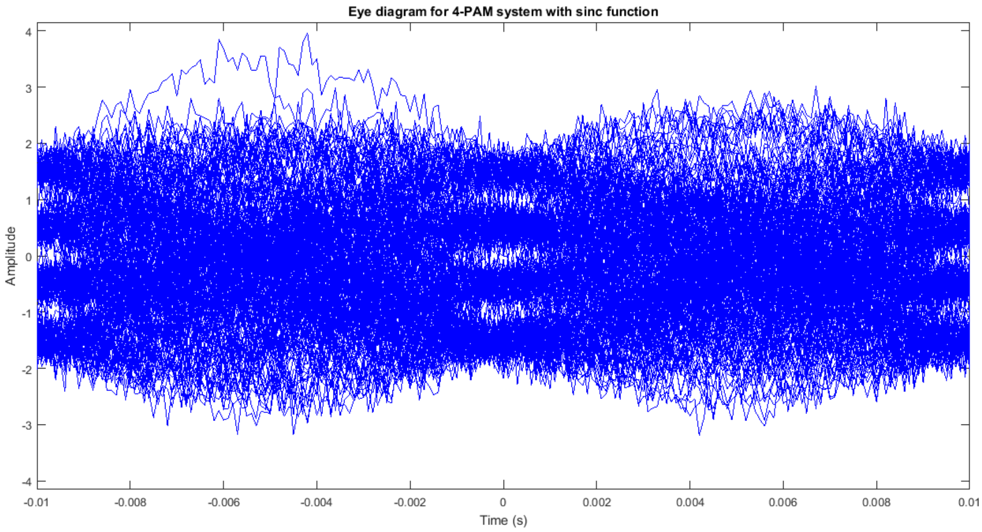
3.1 Impulse Train Representing 4-PAM symbols



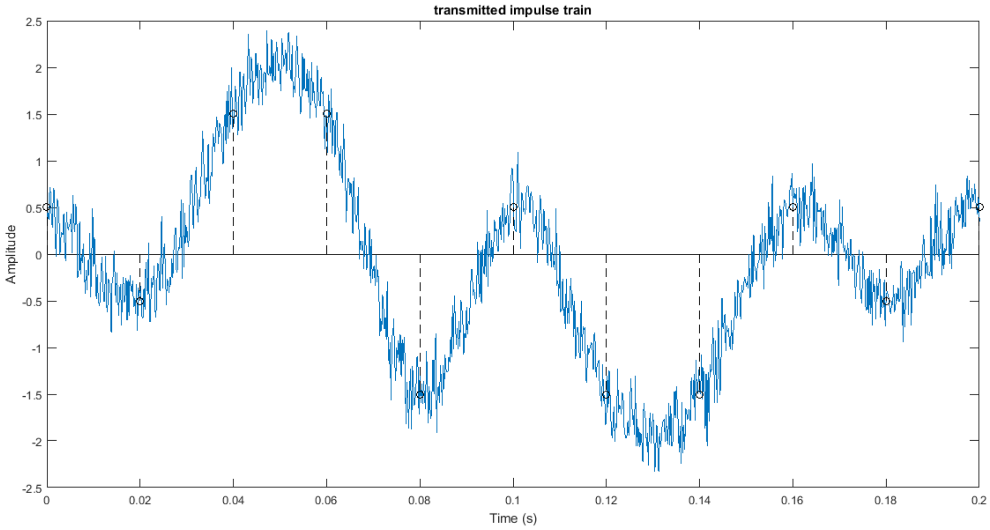
3.2 Received Signal with AWGN using Sinc Function



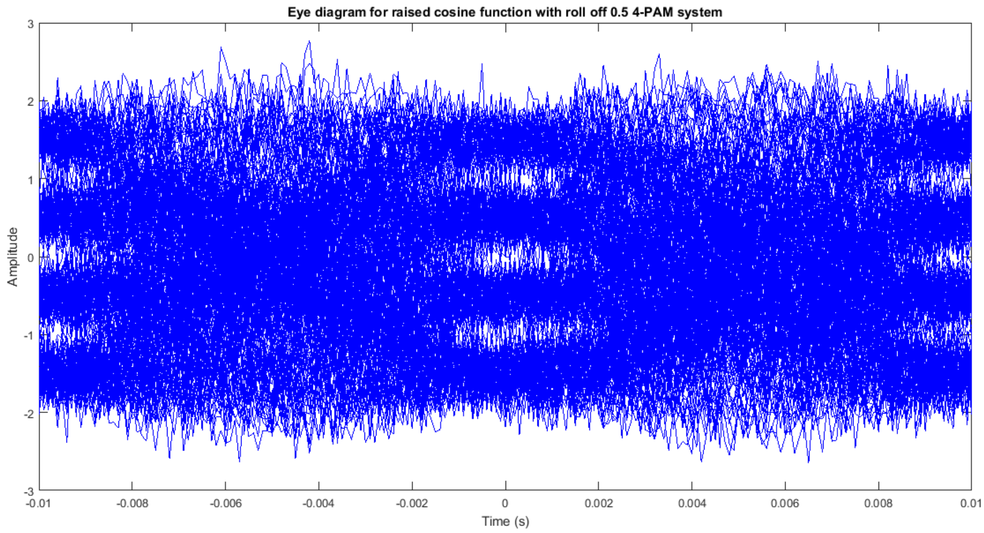
3.3 Eye Diagram with AWGN – Sinc Function



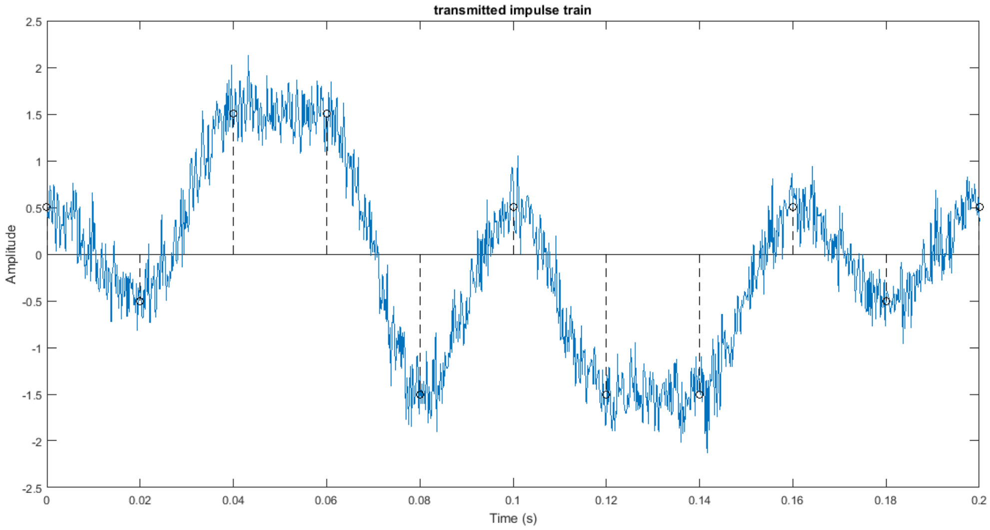
3.4 Received Signal with AWGN using Raised Cosine Function with roll-off 0.5



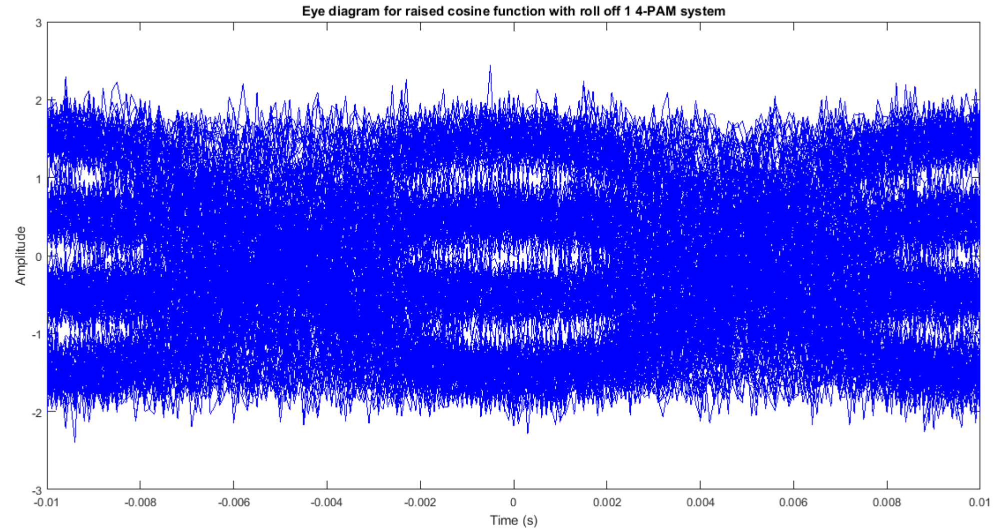
3.5 Eye Diagram with AWGN - raised Cosine Function with roll-off 0.5



3.6 Received Signal with AWGN using Raised cosine with roll-off 1



3.7 Eye Diagram with AWGN - Raised cosine with roll-off 1



3.8 Comparison of the Robustness of the systems

Adding AWGN has increased the width of eye corner significantly and has reduced both horizontal and vertical maximum openings in all the 3 systems.
But still the system with rolling factor 1 is the most robust system as it still has the highest error free sampling region with lowest slope and lowest width of the eye with respect to noise, sampling time and synchronization errors.
The system with roll off factor 0.5 is more robust than the system utilizing sinc function as it has a high error free sampling area with a low slope and a lower width at the eye corner when compared.