İSTANBUL MEDİPOL UNIVERSITY

EECD1212913: DIGITAL COMMUNICATION LABORATORY

Lab report No:.4: Digital modulation techniques

Professor: Huseyin Arslan

Student Name: Salim Mohd Yahya
Student Number: D3230014
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Introduction

The lab introduces Nyquist and non-Nyquist filters applied in wireless communications and how they affect transmission and processing of the sent and received symbols. The following setup among others was applied.

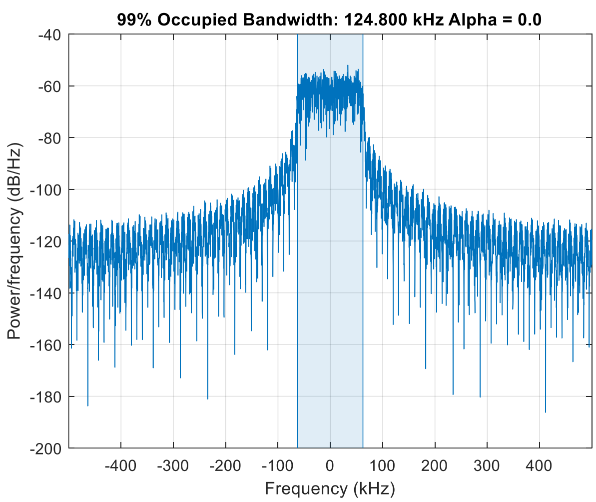
4	RadioID: *(found using findPlutoRadio command)*	sn:10447354119600060d001800cf281e583b	sn:104473dc599300131200210082672a4170

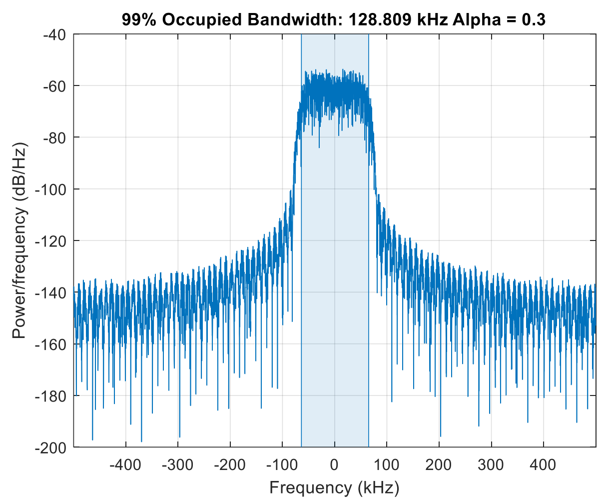
Nyquist Filtering

Question 2
Occupied Bandwidth Observation for different Roll off factors.

From the power spectrum, it can be noted that the occupied bandwidth of the signal increases with increasing Roll off factor, this is theoretically expressed as B = (1+ Roll off factor) *R, where R is symbol rate

The power spectrum records a increasing bandwidth with increasing Roll off factor as shown in the figures





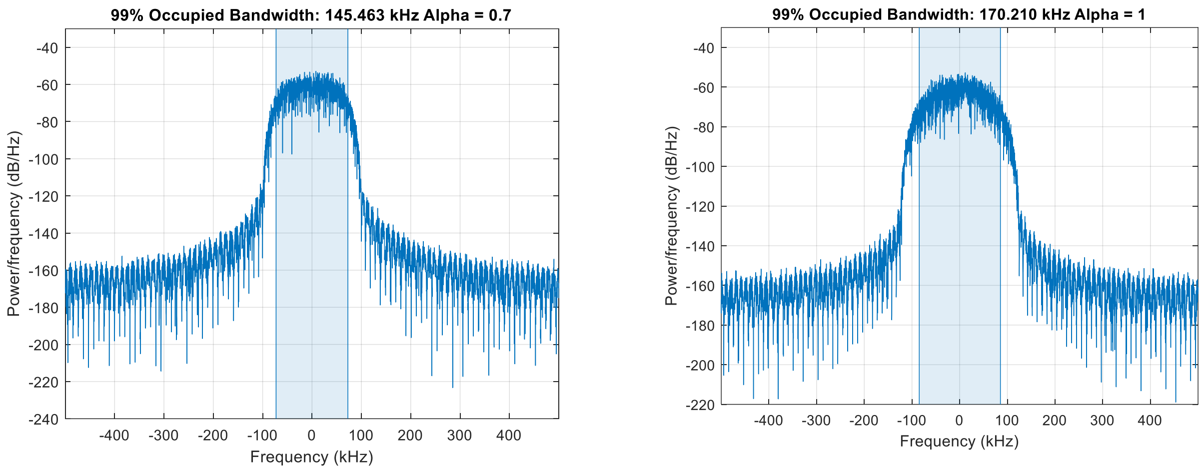
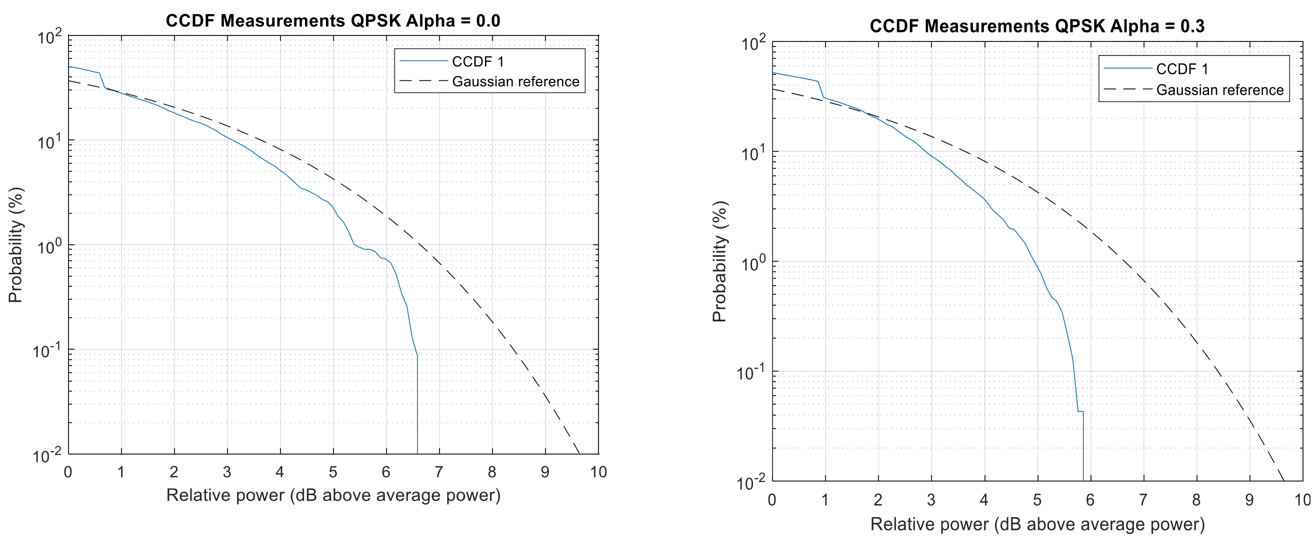


Figure 1 OBW for different Roll off factors

Question 2

CCDF Observations for different Roll off factors

CCDF plots show higher PAPR for lower Roll off factors because of sidelobes and hence higher dynamic ranges while higher Roll off factors suppress sidelobes and hence the signal experience smaller dynamic range and hence lower PAPR. It is highly likely to find symbols with relative power higher than the average of 6dB when Roll off factor is 0.0 while for Roll off factor = 1, the probability of even finding symbols with power higher than average of 2dB is significantly lower.



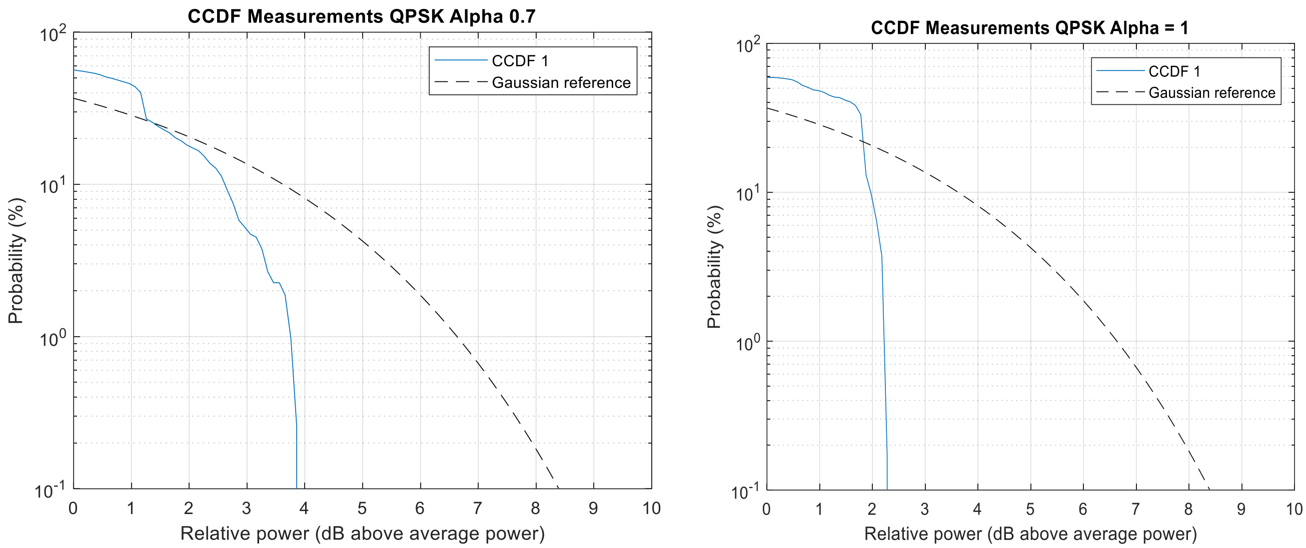
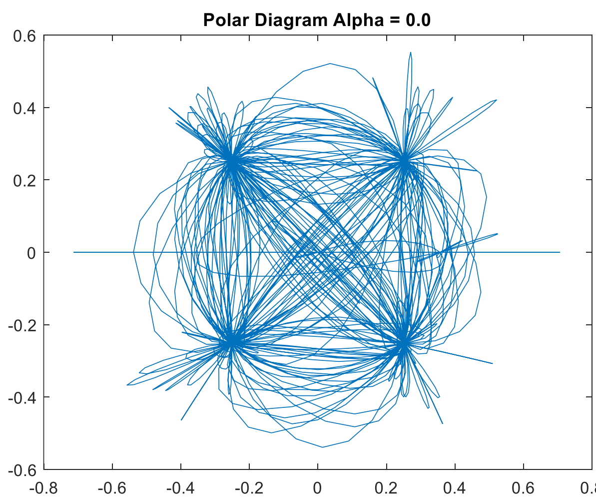


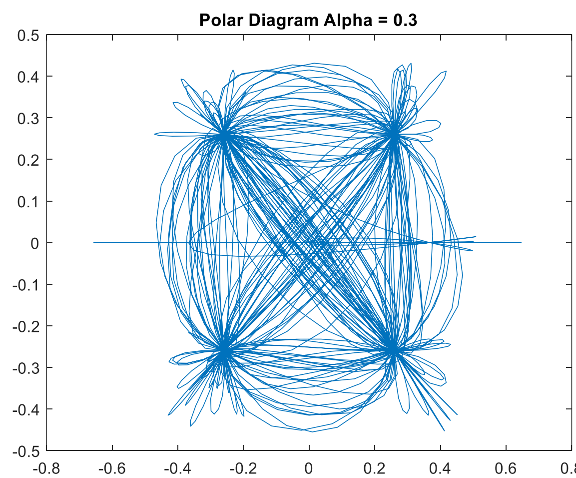
Figure 2 CCDF for Different Roll off factors

Question 2

Polar Diagrams Observations for Different Roll off factors

The polar diagrams show high dynamic ranges at low Roll off factors compared to high Roll off factors, the transitions from one point to the other in the constellation highlight the dynamic nature of the transitions. The zero crossings are dominant with lower Roll off factors as compared to higher ones.





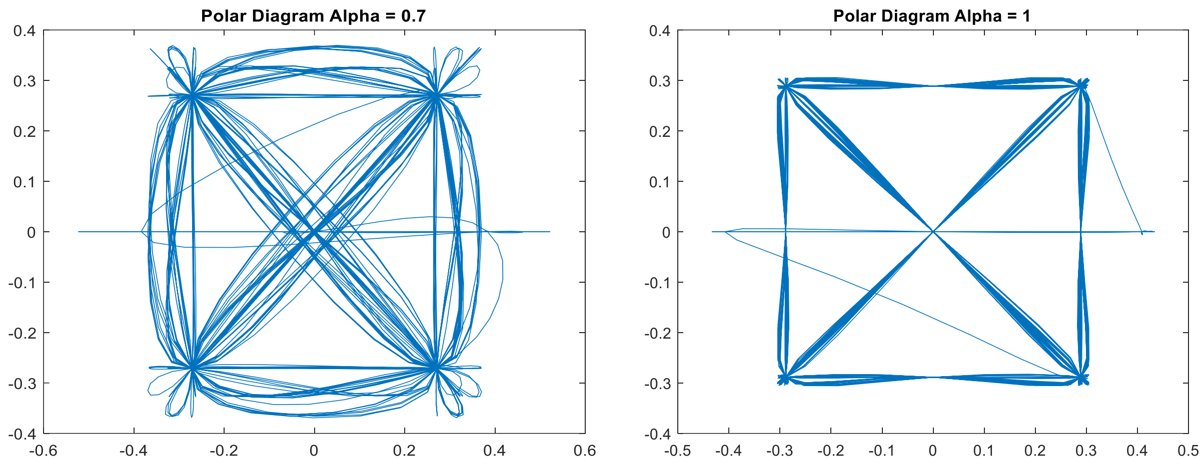
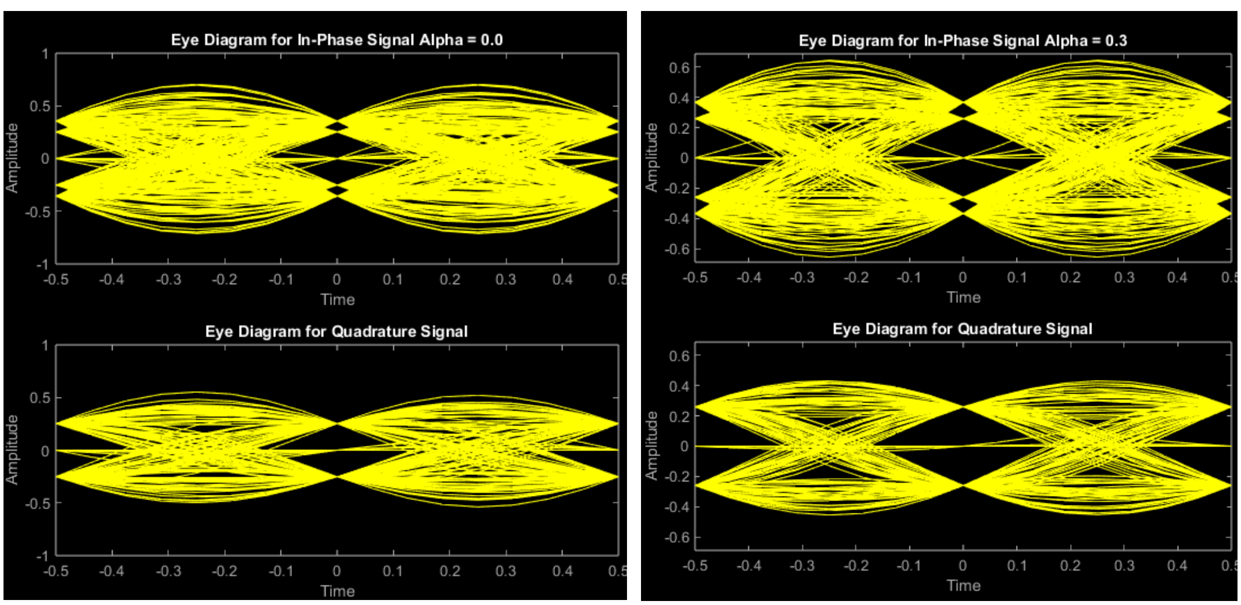


Figure 3 Polar diagrams for different Roll off factors

Question 2

Eye diagrams for different values of Roll off factor

The clarity of the transitions in the eye diagrams show less susceptibility to noise and jitter as well as ISI for larger Roll off factors as compared to lower Roll off factors. The heights of the eye for Roll off factor = 1 are high compared to Roll off factor = 0.3 or 0.7 signifying noise robustness. The robustness of the symbols against timing jitter is also notable when considering the width of the eyes of higher Roll off factors compared to lower Roll off factors.



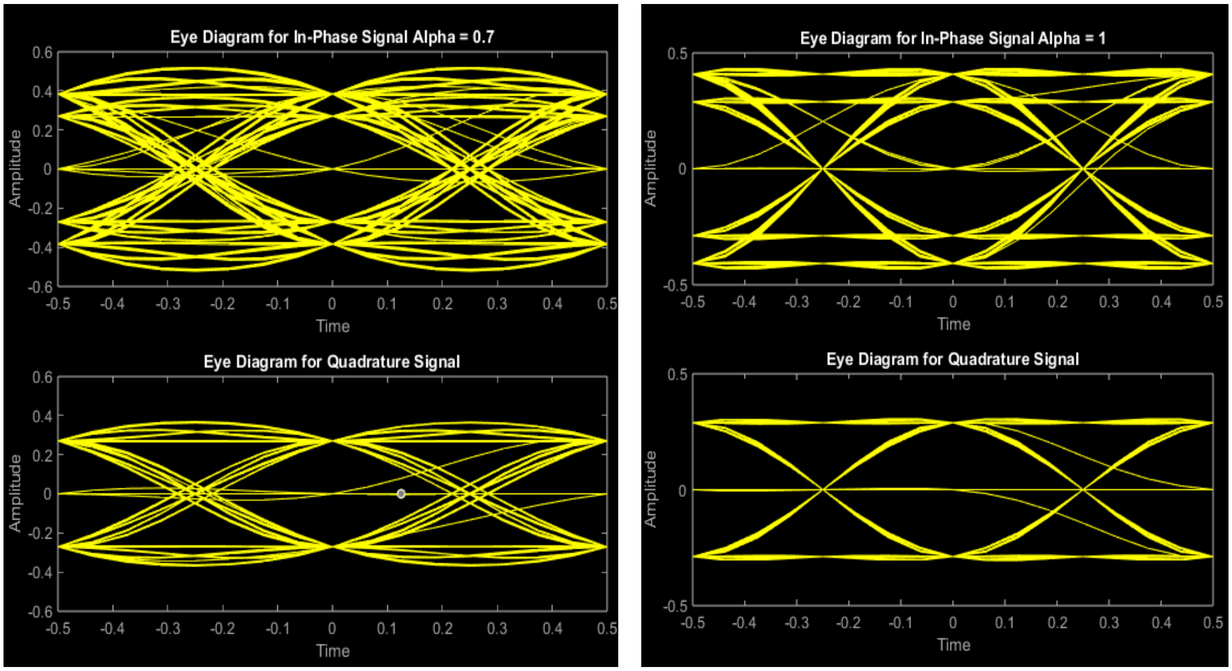


Figure 4 Eye Diagrams for different Roll off Factors

Question 3

As figure 5 shows, when rectangular filter is used, the signal occupies infinite bandwidth in the frequency domain, the diagram shows how the signal power maintains a significant magnitude over the whole frequency band. This is different from those observed in question two where a peak is observed at the central frequency and the signal power dies exponentially on each side of the peak.

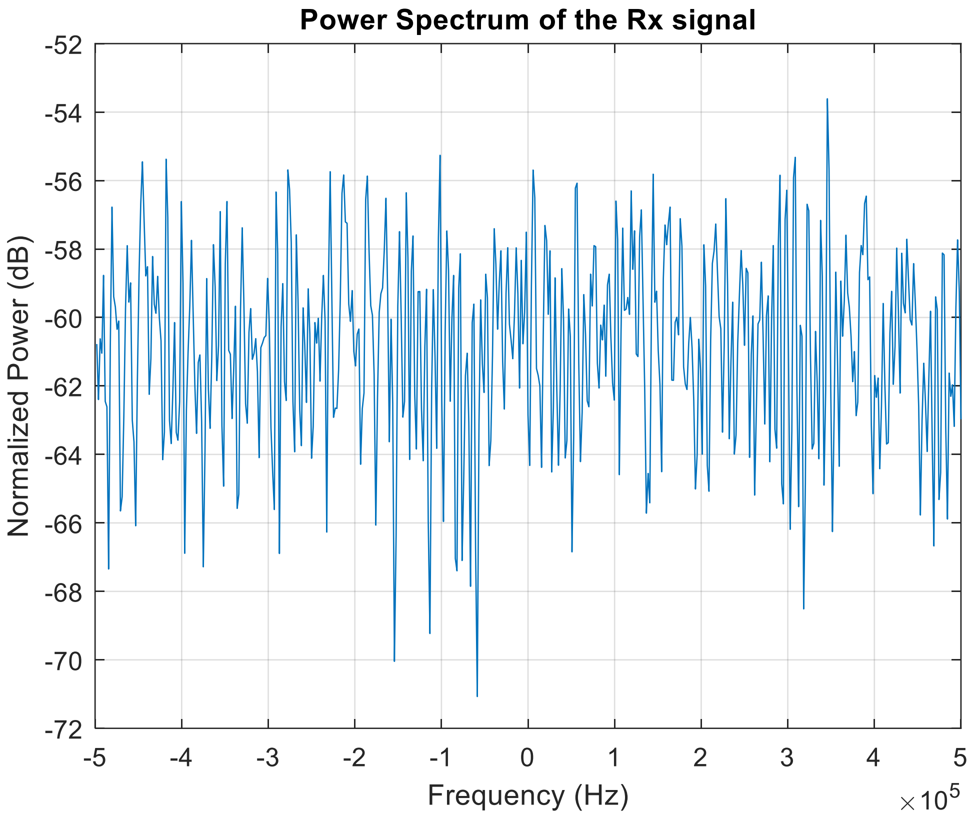


Figure 5

Question 4

As instructed in the question, sampling was done with an offset of 1, this means that when downsamping the sampling will take place at a position less than the required position by 1, thus we expect displaced constellation points from the ideal position. The EVM's of these pointsare expected to decrease with increasing Roll off factor.

This serves as a good example of how sampling is affected by distortion of a signal which can take place due to noise, equipment impairments, or the channel.

The impact of the offset is more pronounced than in lower Roll off factor and less systematic as compared to large Roll off factor.

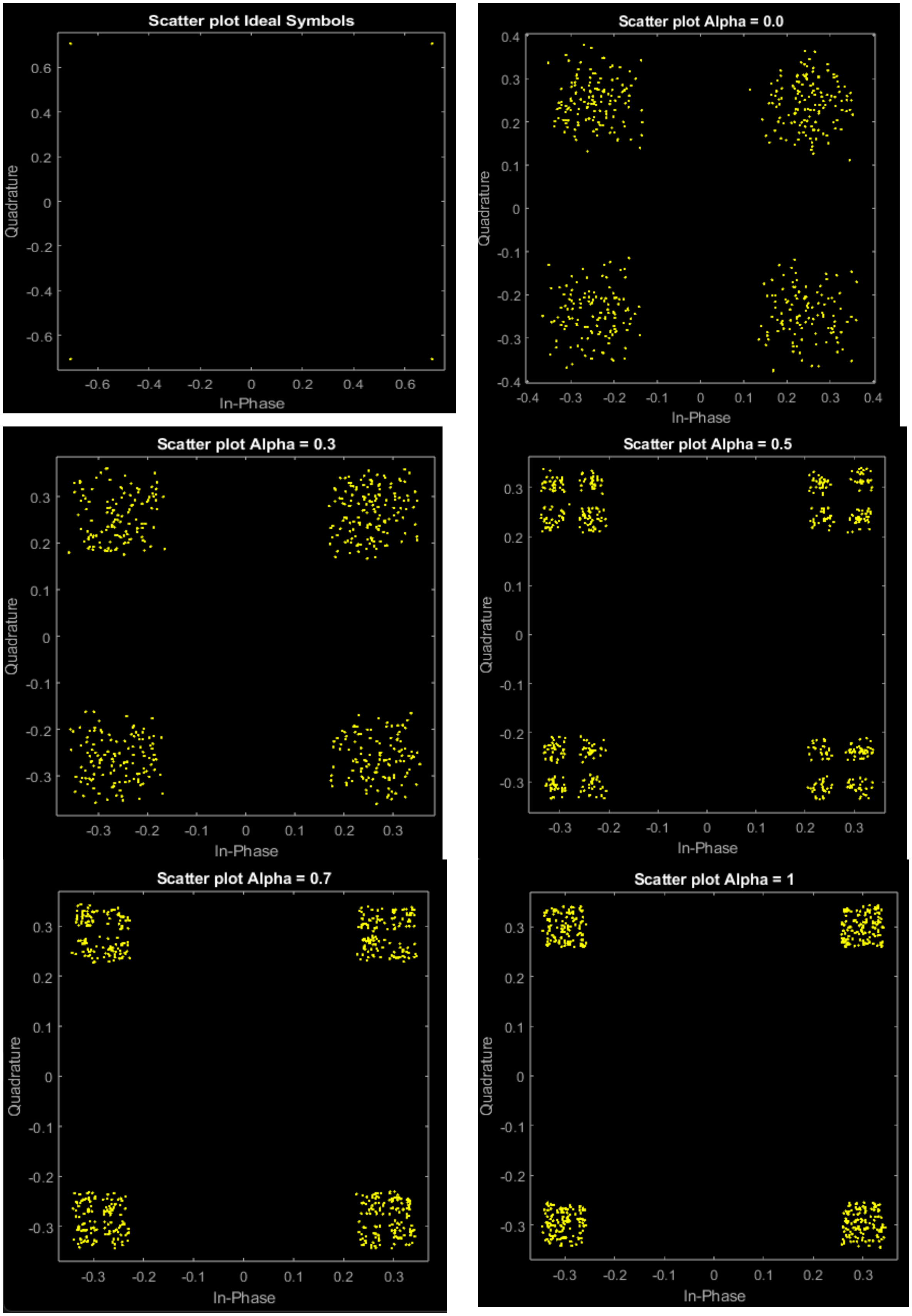


Figure 6 Constellation diagrams for different Roll off Factors with sampling offset of 1

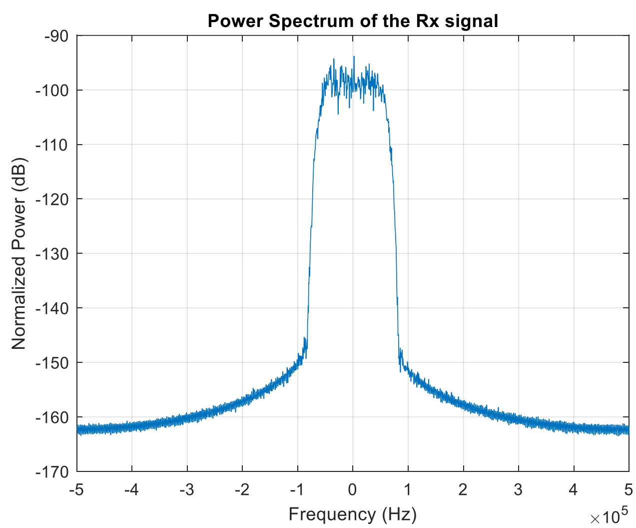
Question 6

The SNR calculated from the obtained rms EVM was 10.572.

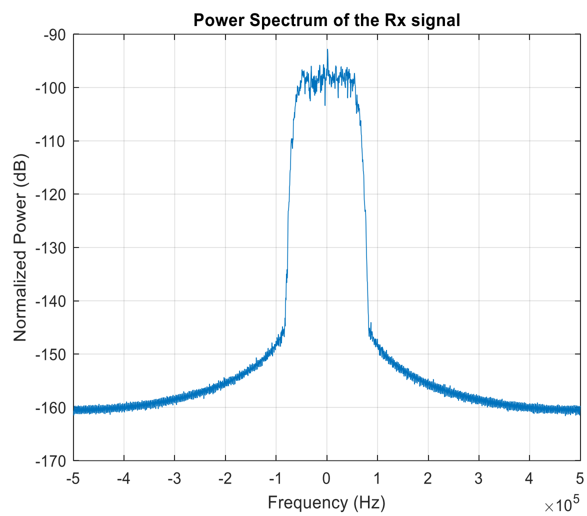
Question 7

A frame was generated using root raised cosine filter (RRC) with match filtering enabled, then SNR was calculated using the obtained EVM measurement. The value of SNR calculated was now 13.5823. From the observation it can be deduced that the advantage of match filtering is to improve the SNR of the received signal.

Question 8



Unmatched Filtering

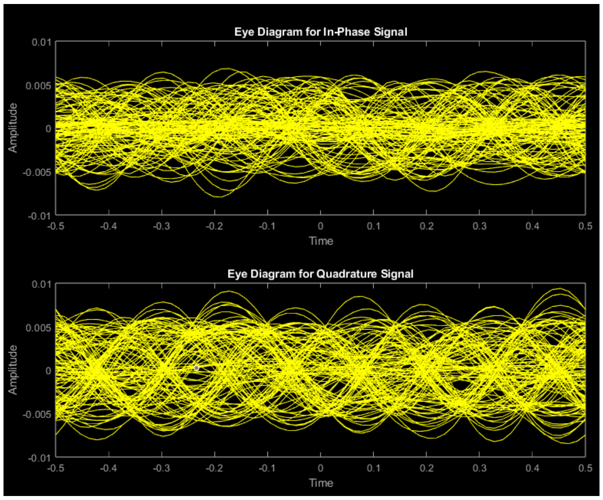


With matched filtering

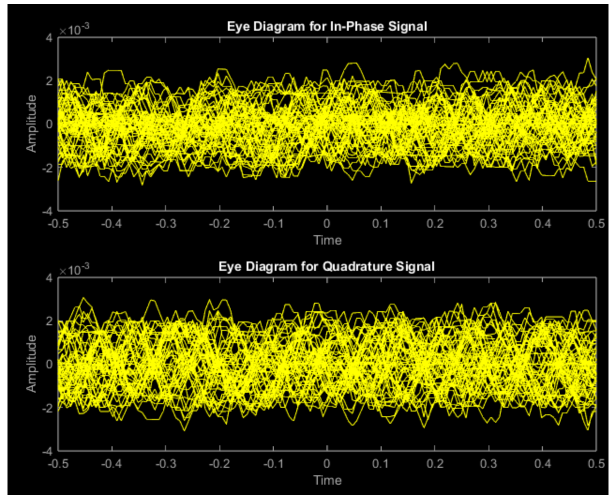
Figure 7 Matched vs Unmatched Filtering Power Spectrums

Question 9

It can be observed that without matched filtering, the SNR becomes highly impacted and results in eye diagrams without clear sampling points. As observed in the figure, the eye diagram is highly distorted for unmatched filter showing that RRC is not a Nyquist Filter.



Matched filtering



Un matched Filtering

Figure 8 Matched vs Unmatched Eye Diagrams

Gaussian Pulse Filtering

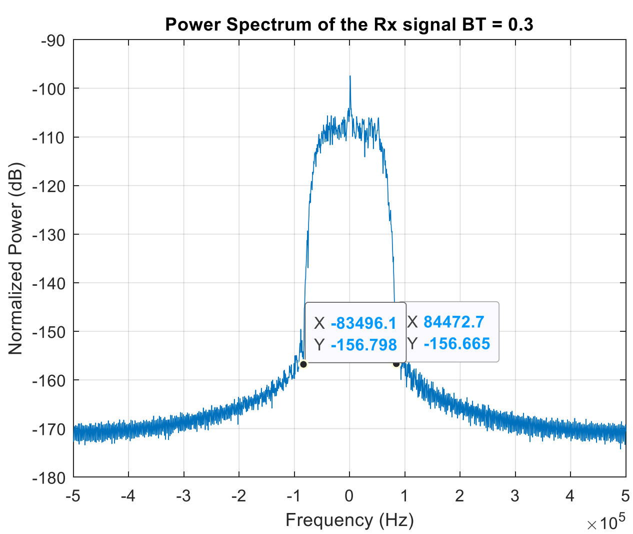
Question 10

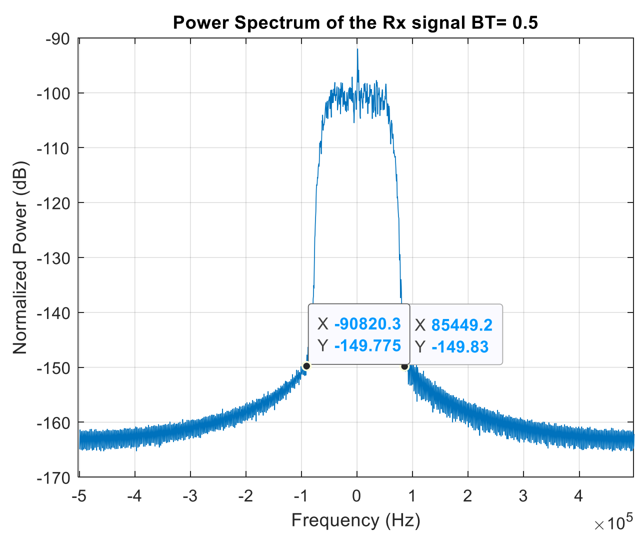
Observations based on Power Spectrum Analysis.

The power spectrum for different BT product shown depict higher peak received power increasing BT (0.3<0.5<0.7) roughly -109dB, -100dB and -99dB respectively.

The bandwidth occupied by the received signal also increases with increasing BT, as seen in the data points, null to null bandwidth can be roughly estimated to 168 MHz, 176MHz and 178MHz for BT of 0.3, 0.5 and 0.7 respectively.

Side band suppression can also be observed to be increasing with increasing values of BT, this can be observed by considering the thickness of the tails of the spectrum plot





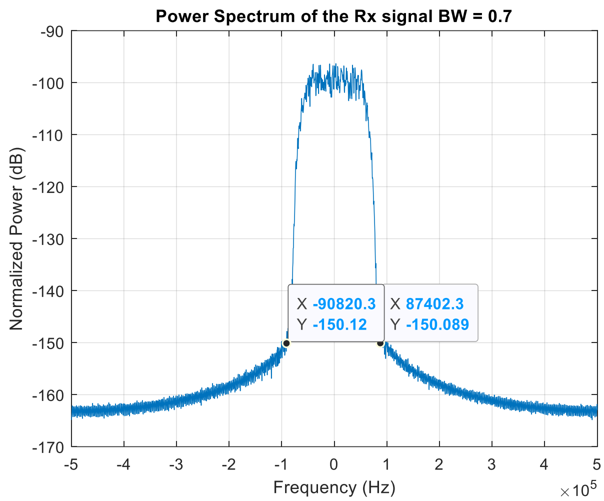


Figure 9 Occupied Bandwidth for Different BT

Observation based on Constellation Diagram

Constellation diagram for BT = 0.3, shows that it is impossible to detect symbols without errors, the 0.5 appear a little rotated but detectable while that of 0.7 also suffers a little rotation but with better separability of symbols as compared to those of 0.5 and 0.3 this shows that with increasing BT product,

It can be deduced that Inter-symbol interference is huge when BT value is small and gets reduced with increasing BT at the expense of bandwidth as observed in the spectrum analysis.

This also shows that the Gaussian filter is not a Nyquist filter as the bandwidth it occupies causing ISI with neighboring symbols.

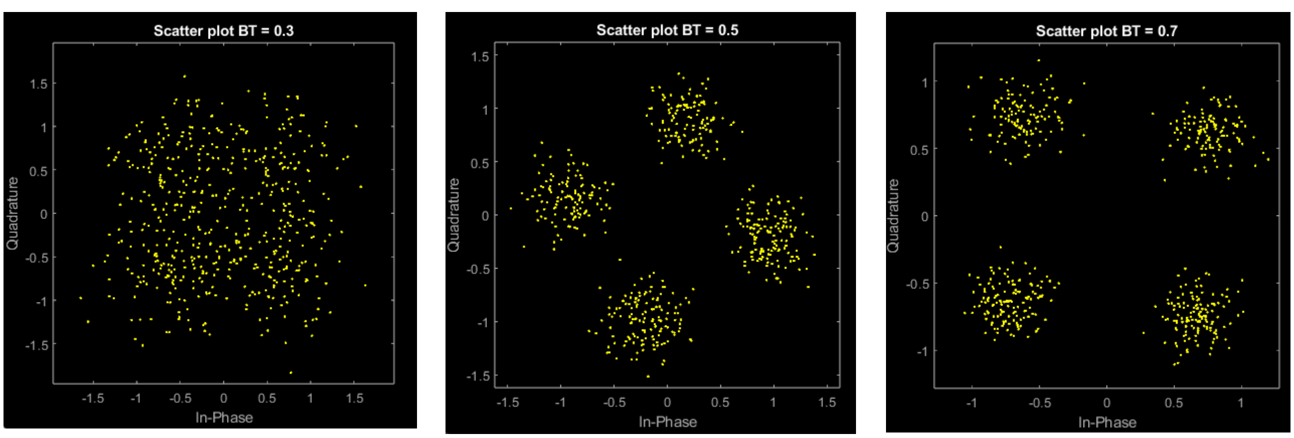


Figure 10 Constellation Diagrams for Different BT values

Conclusion

The lab provides a great insight into understanding how filters affect transmitted symbols and the consequent processing of the same.