1 Objectives

The objective for this lab is to construct a sequence of shaped pulses and examine the role of pulse shape on intersymbol interference and the effect of noise.
During this lab we will look at 4 difference types of line code:

- Polar
- On-Off
- Bipolar
- Differential

2 Procedure

For this lab we designed the system seen in Figure 1. There are four specific subsystems that are used. The first is seen in Figure 2. This system takes the input of an On-Off Binary signal and generates a Polar signal that goes from negative one to one. This is done with a lookup table where zero corresponds to negative one and one corresponds to one. The second subsystem is seen in Figure 3. In this subsystem, a running sum is used to keep track of if we are on an odd or even one, uses a look up table to correspond odd ones to a value of one and even ones to correspond to a value of negative one and then uses a multiplier to keep zeros as zeros. The third and final encoder subsystem is one for the differential line code. This is seen in Figure 4 and uses a running sum and lookup table to take the binary input and output a differential line code. The last subsystem just contains a Eye Diagram and Spectrum Analyzer.

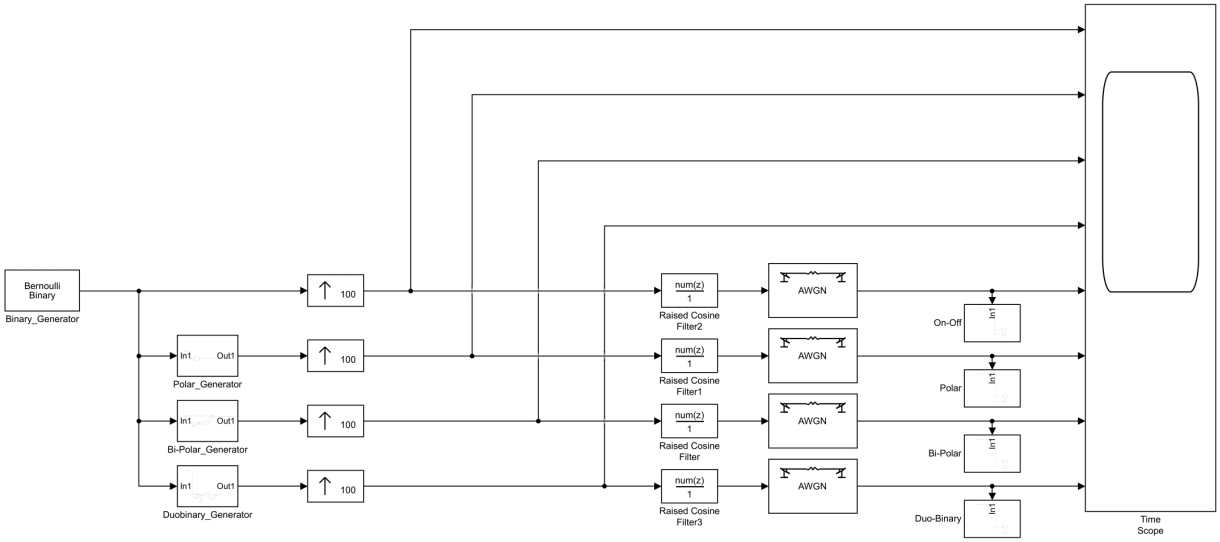


Figure 1: Simulink Program created to work with Line Codes

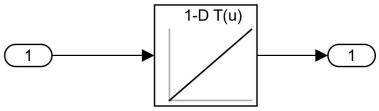


Figure 2: Polar Encoder

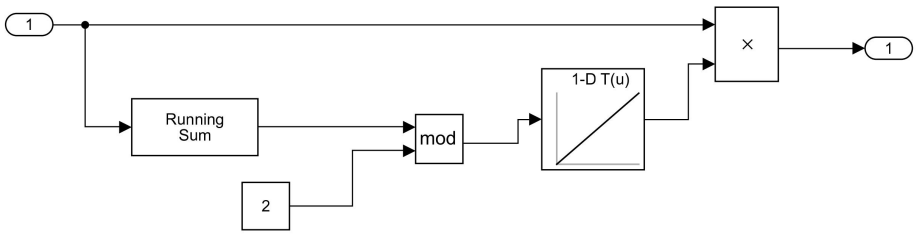


Figure 3: Bipolar Encoder

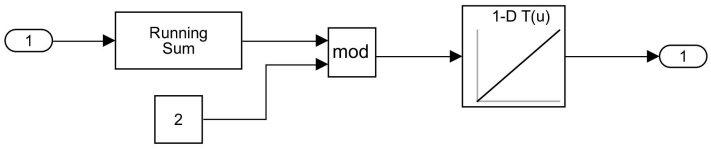


Figure 4: Differential Encoder

2.1 Pulse Types

During this lab we will be using a variety of pulse shapes. Below are the different pulse shapes that I used.

2.1.1 Raised Cosine Pulse

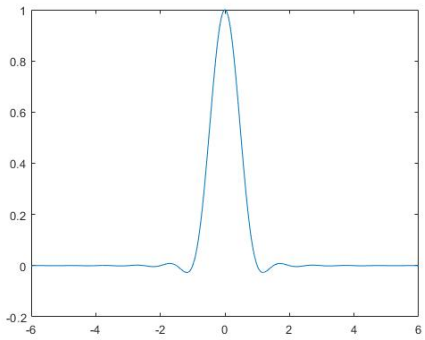
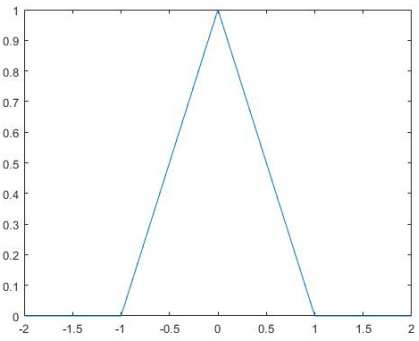
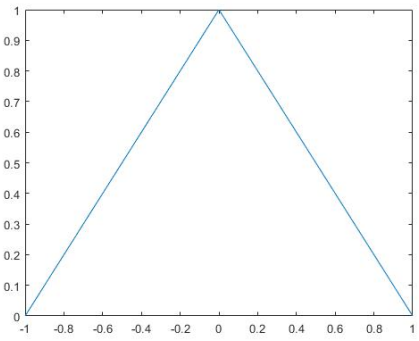


Figure 5: Raised Cosine Pulse

2.1.2 Triangle Pulse



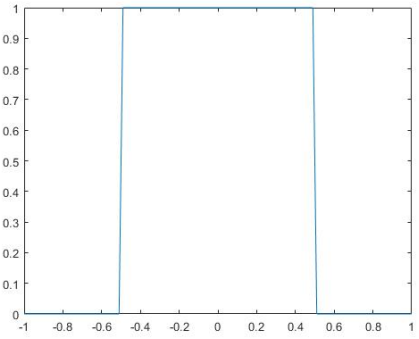
(a) Triangular Half Width Pulse



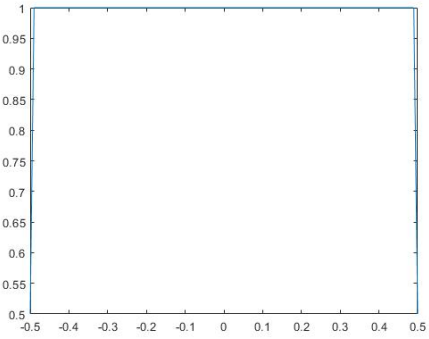
(b) Triangular Full Width Pulse

Figure 6: Triangular Pulse

2.1.3 Rectangle Half Width



(a) Rectangular Half Width Pulse



(b) Rectangular Full Width Pulse

Figure 7: Triangular Pulse

2.1.4 Sinc

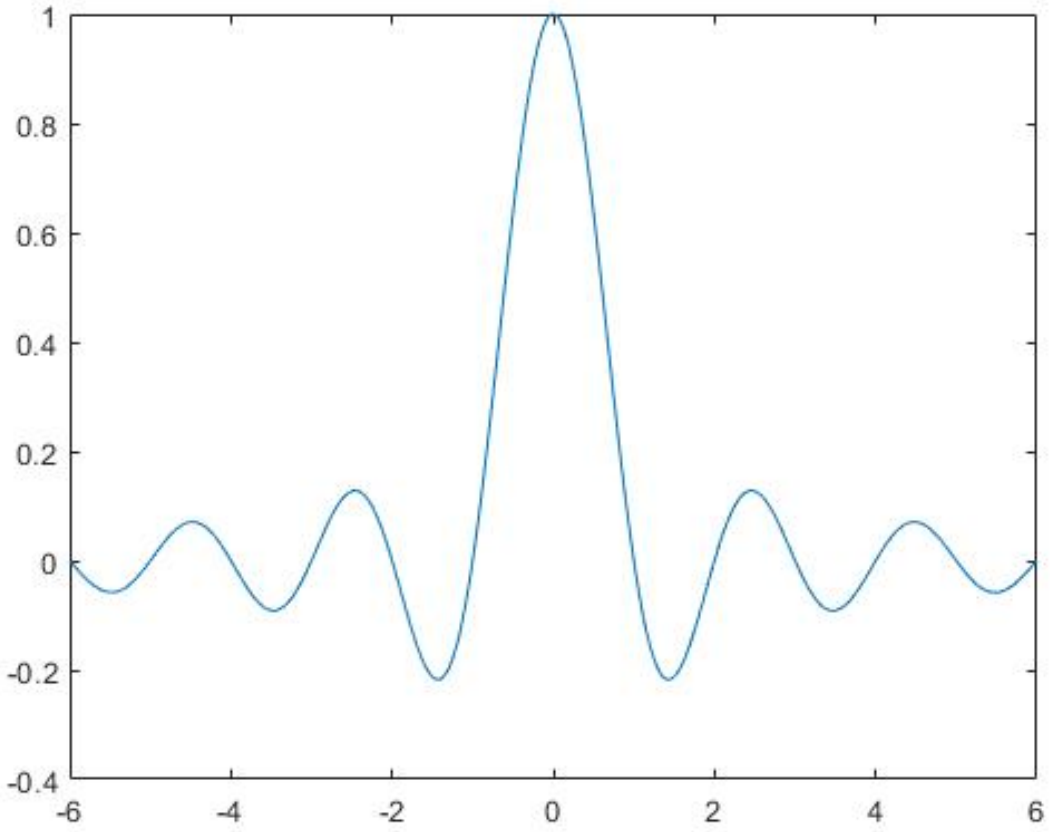


Figure 8: Raised Cosine Pulse

2.1.5 Sinc Squared

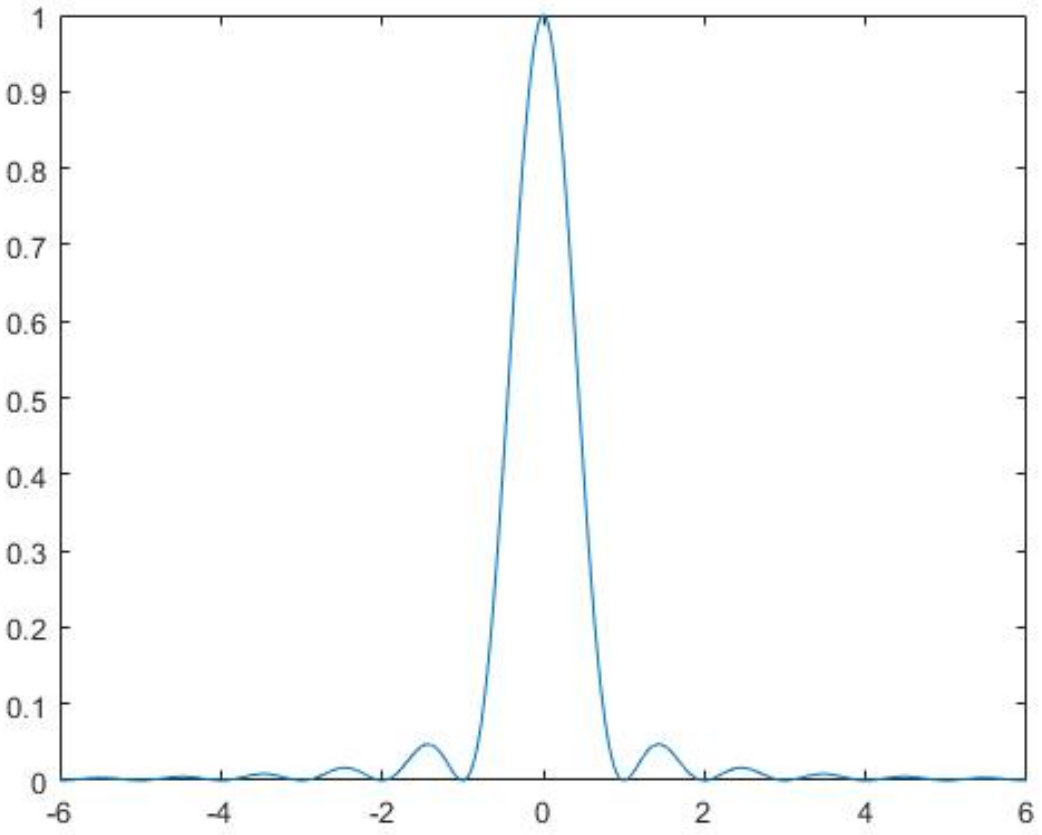


Figure 9: Raised Cosine Pulse

2.1.6 Sin Pulse

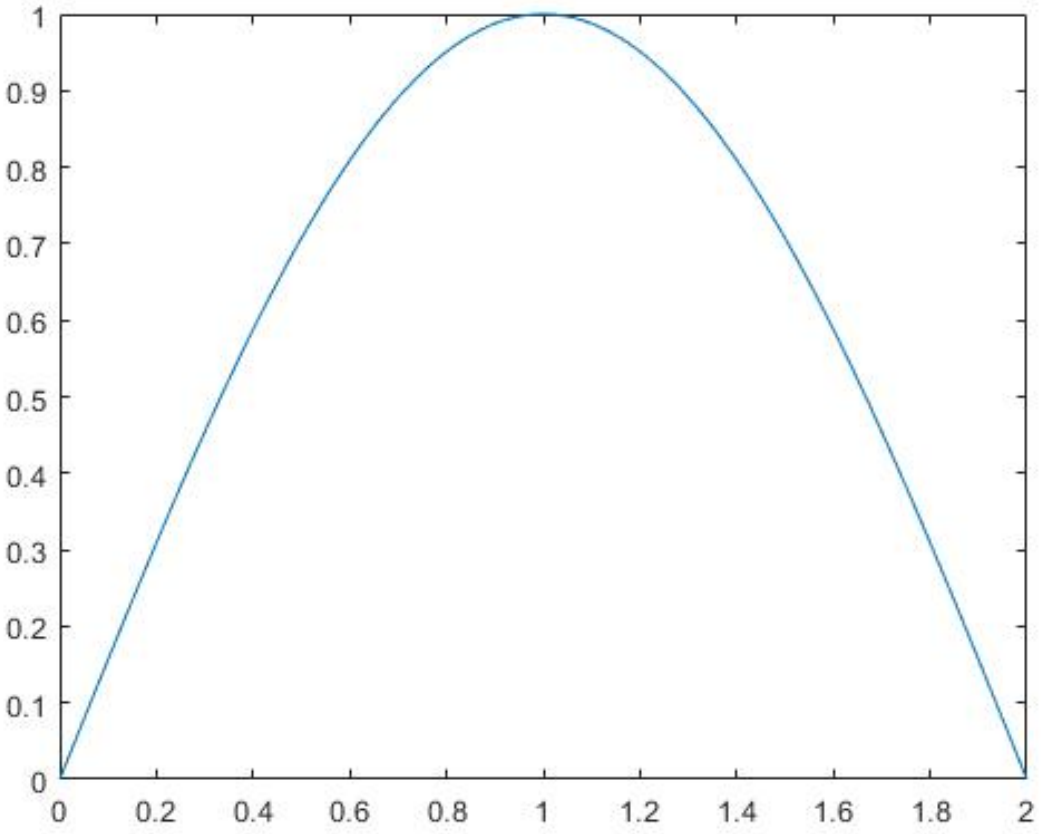


Figure 10: Raised Cosine Pulse

3 Results

3.1 On-Off

3.1.1 Time Signal

The following images or for On-Off encoding with the various pulse shapes. They are presented with the On-Off encoded binary stream, the generated signal when convoluted with a shaped pulse and the received signal with noise in the channel.

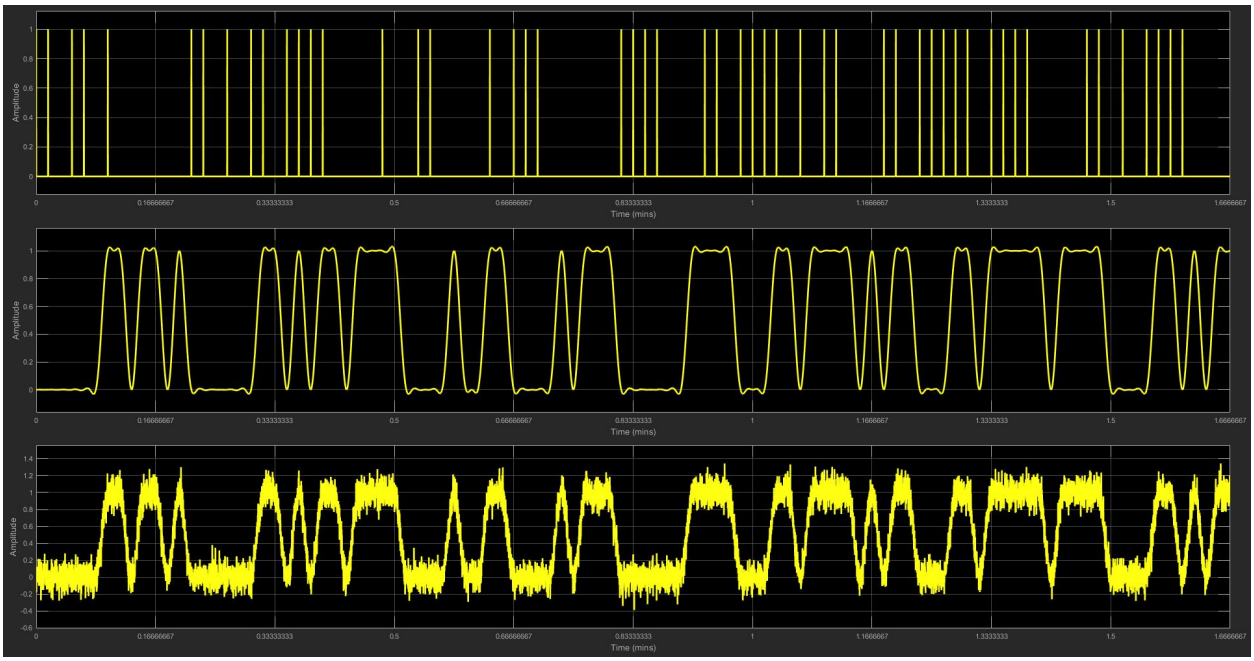


Figure 11: On-Off encoding with a Raised Cosine Shaped Pulse

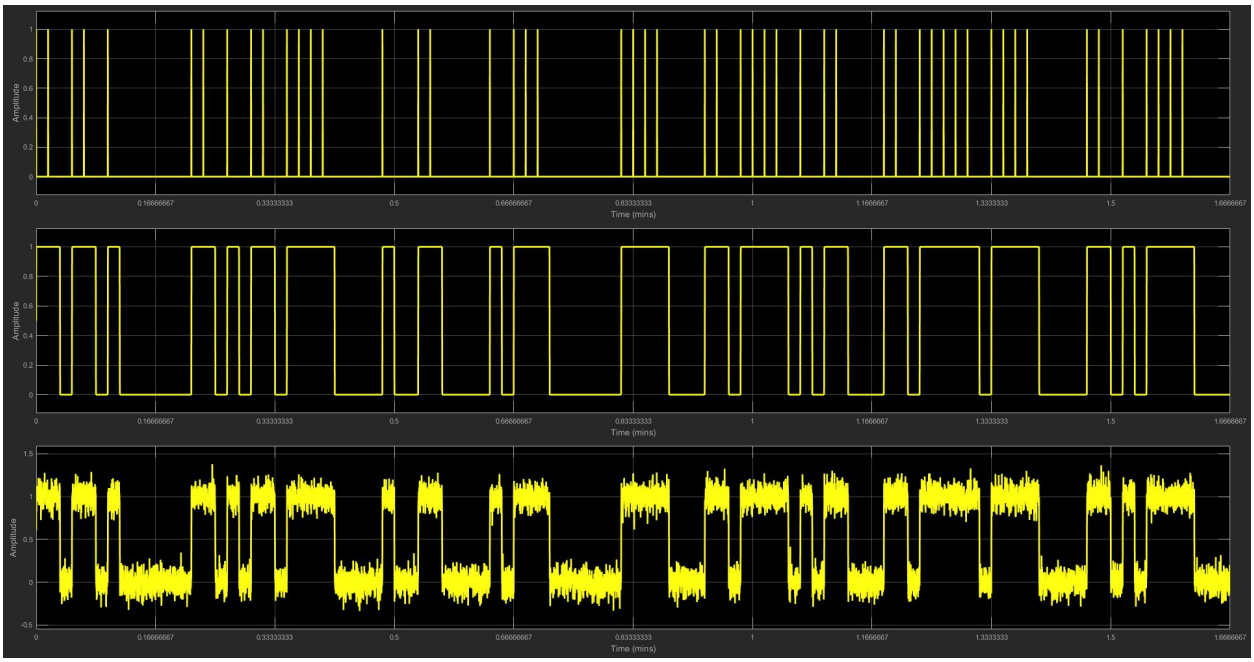


Figure 12: On-Off encoding with a Full Width Rectangle Shaped Pulse

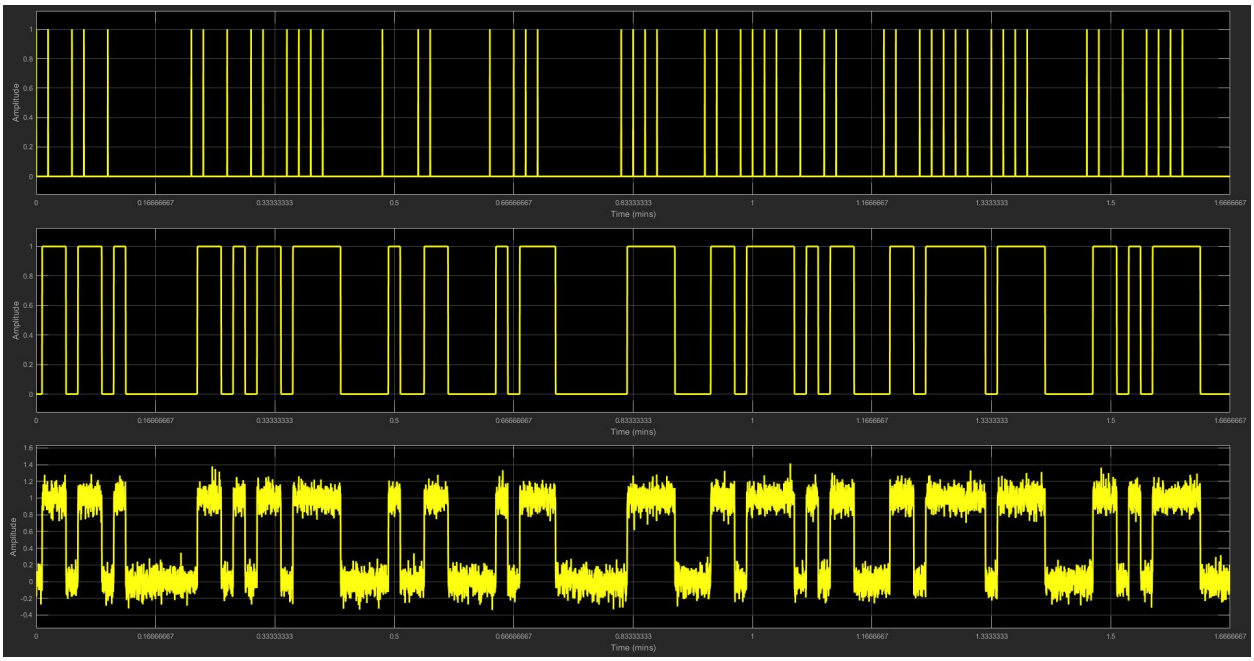


Figure 13: On-Off encoding with a Half Width Rectangle Shaped Pulse

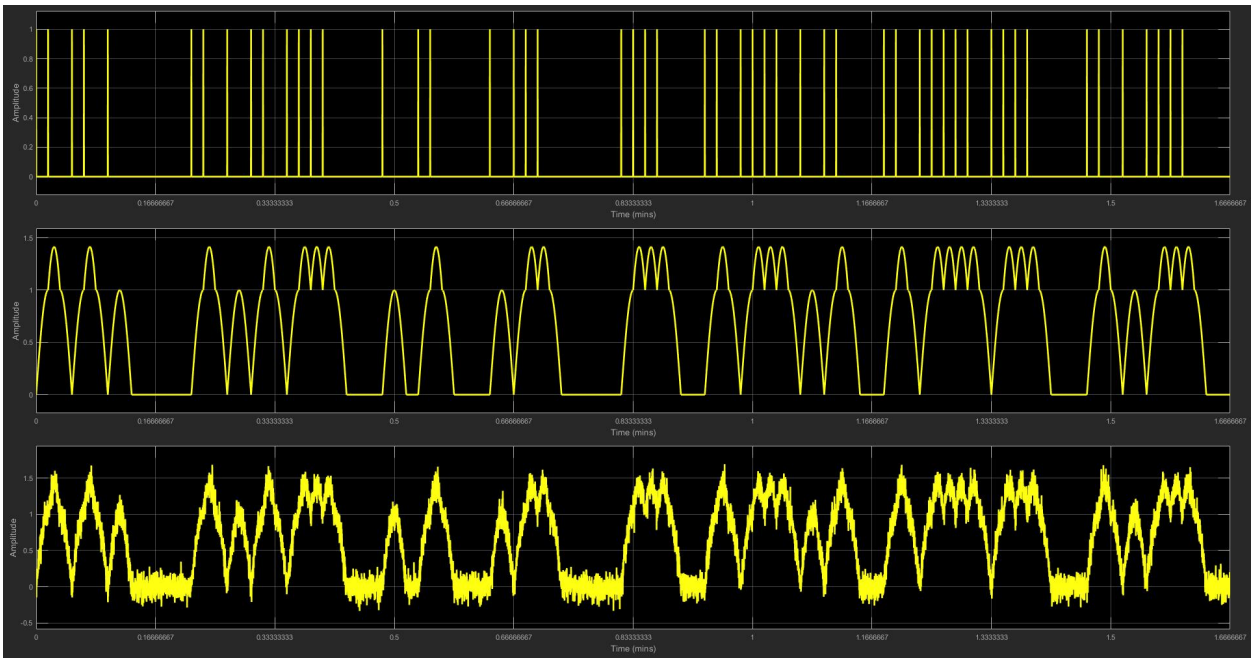


Figure 14: On-Off encoding with a Full Width Rectangle Shaped Pulse

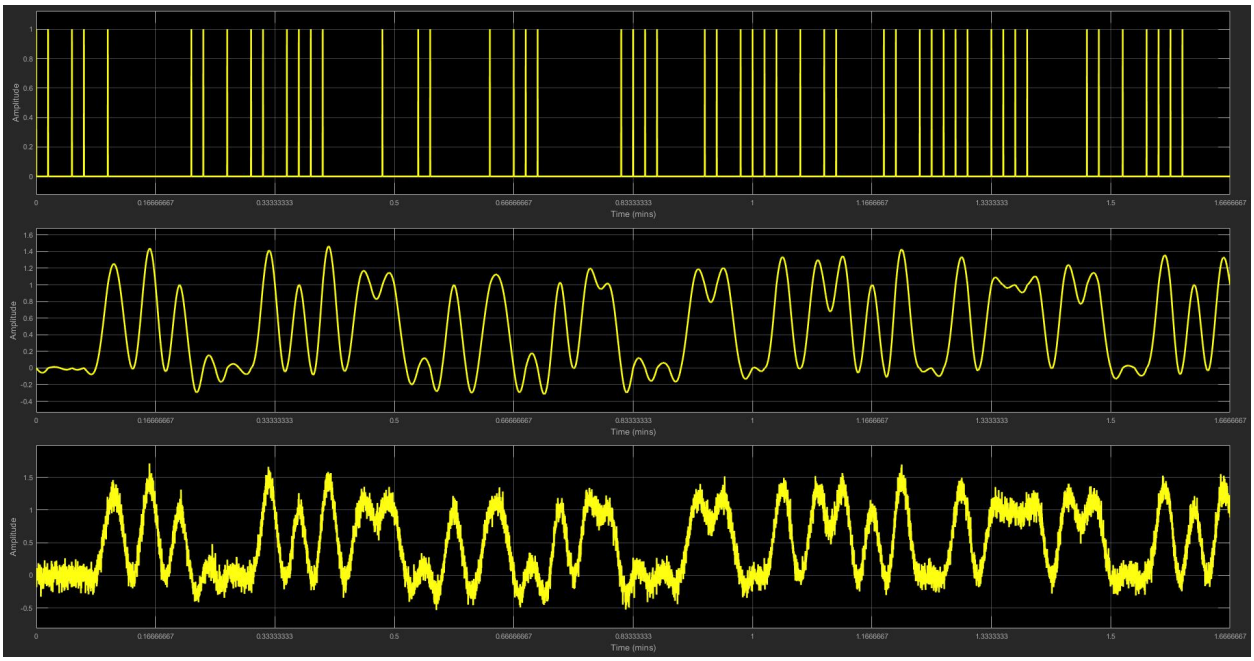


Figure 15: On-Off encoding with a Sinc Shaped Pulse

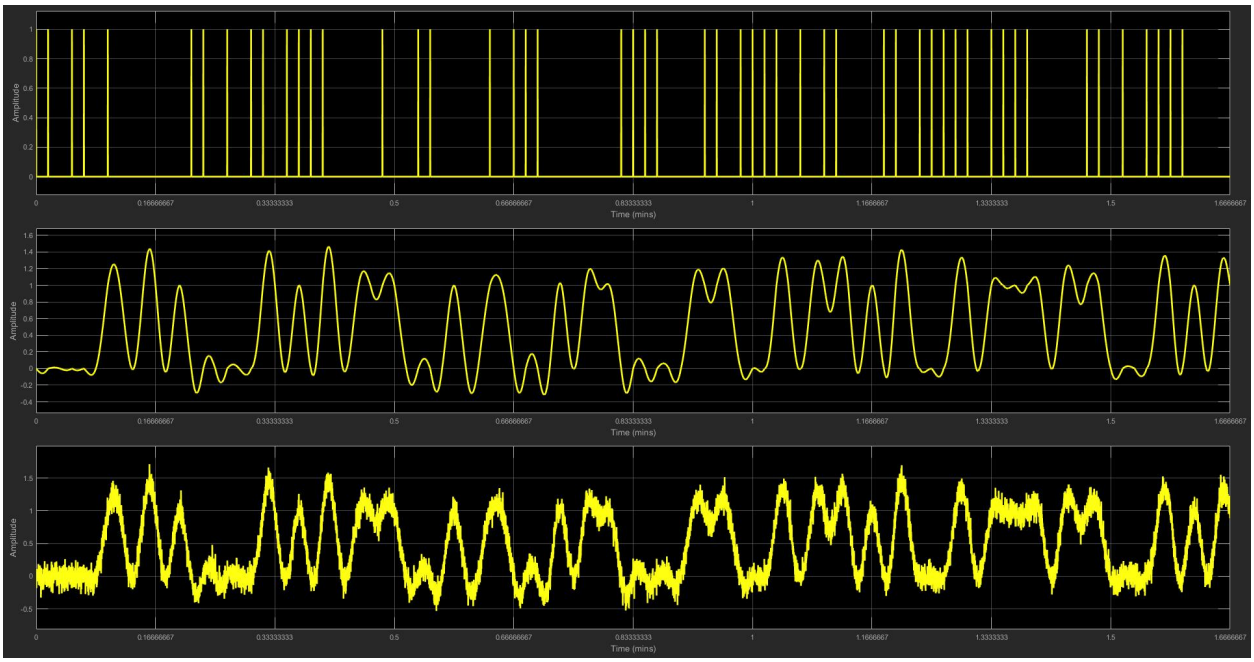


Figure 16: On-Off encoding with a Sinc Squared Shaped Pulse

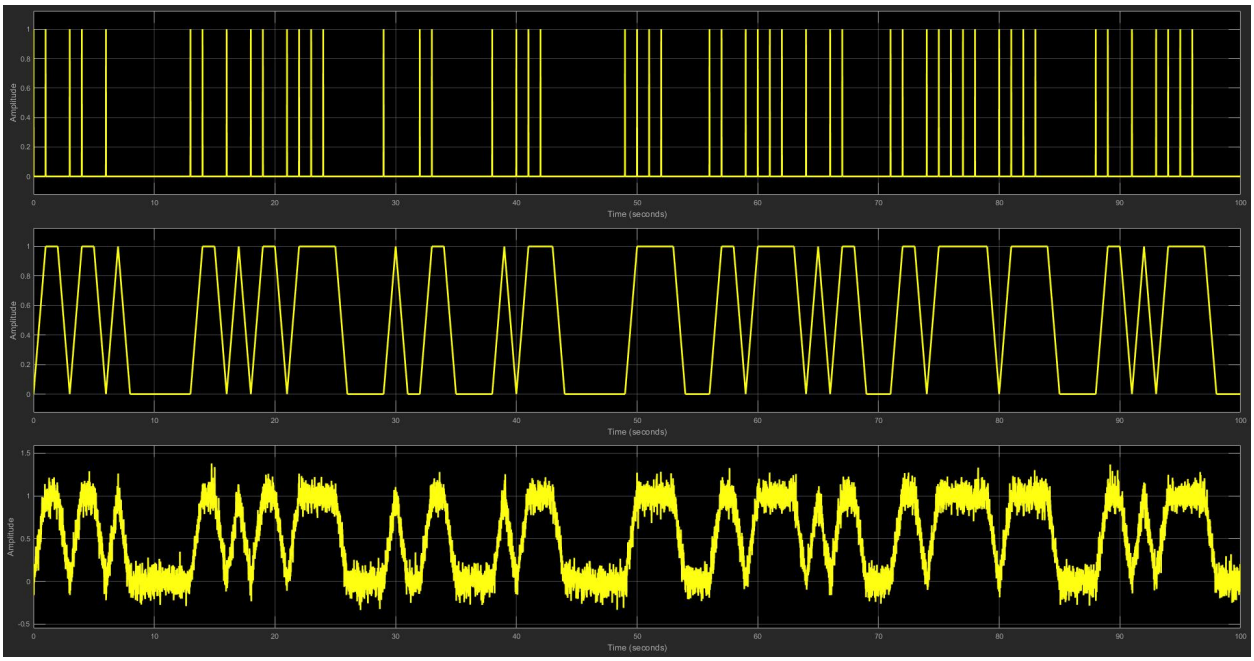


Figure 17: On-Off encoding with a Full Width Triangle Shaped Pulse

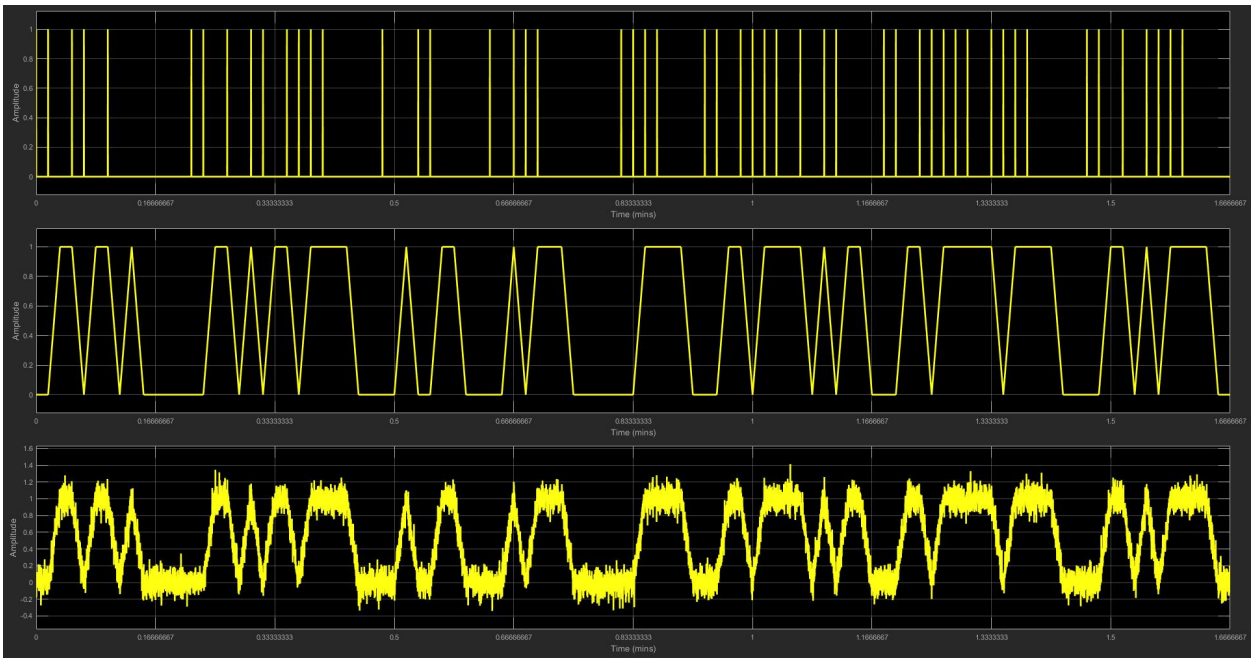


Figure 18: On-Off encoding with a Half Width Triangle Shaped Pulse

Something that should be noted is that the apparent difference between full width and half with shaped pulses for both Rectangle and Triangle shaped pulses have an identical waveform. The difference is the half width is a delayed signal.

3.1.2 Eye Diagrams

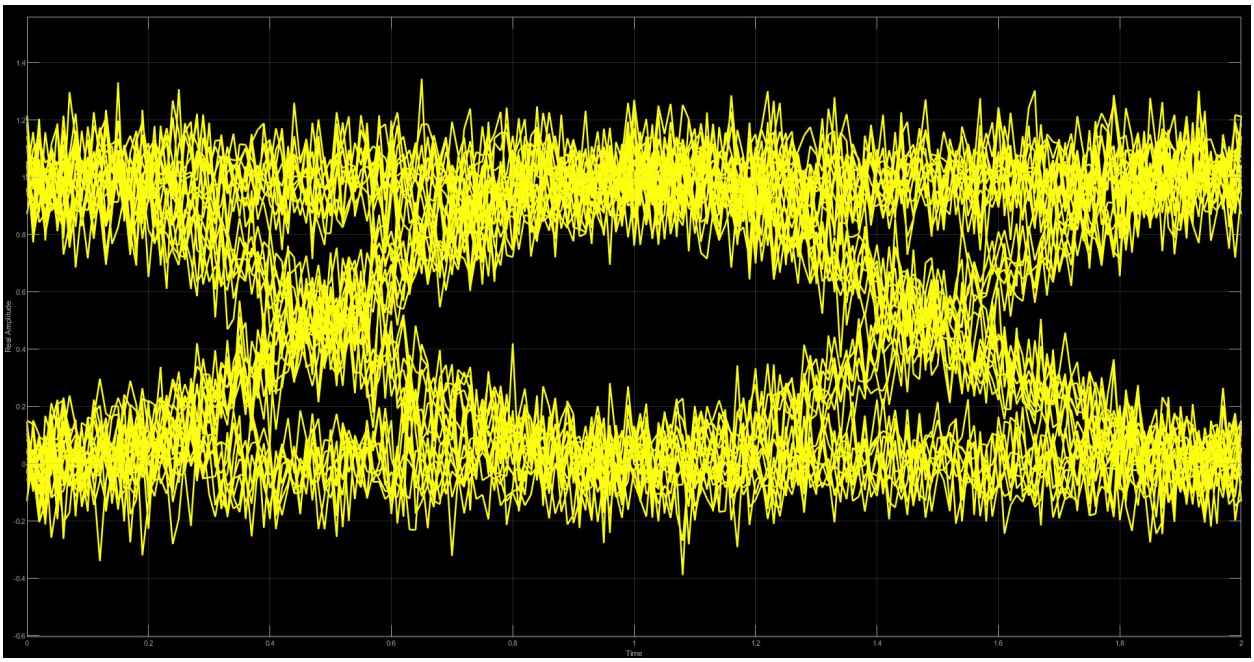


Figure 19: Eye Diagram for On-Off encoding with a Raised Cosine Shaped Pulse

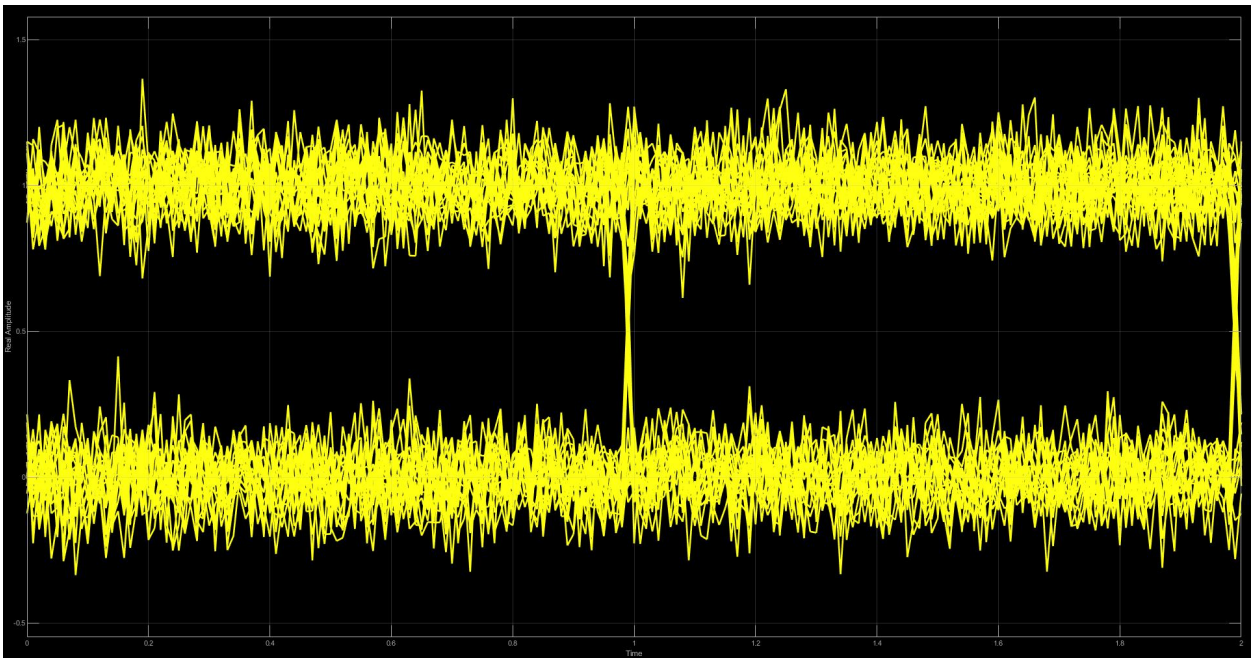


Figure 20: Eye Diagram for On-Off encoding with a Full Width Rectangle Shaped Pulse

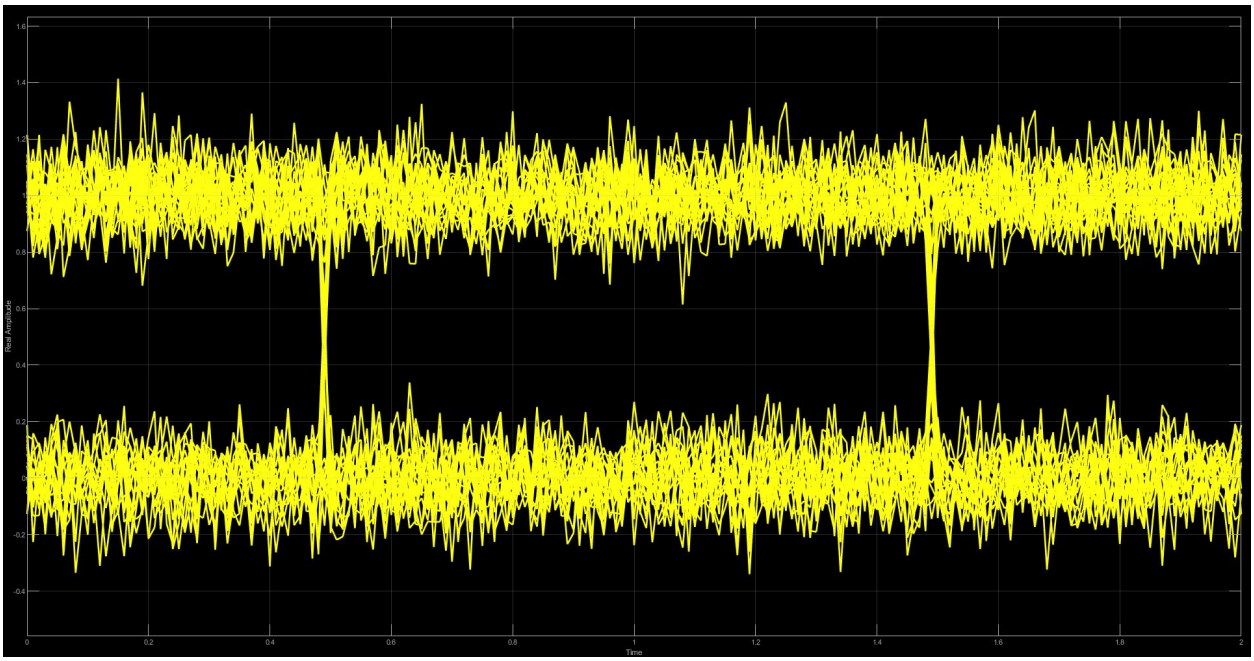


Figure 21: Eye Diagram for On-Off encoding with a Half Width Rectangle Shaped Pulse

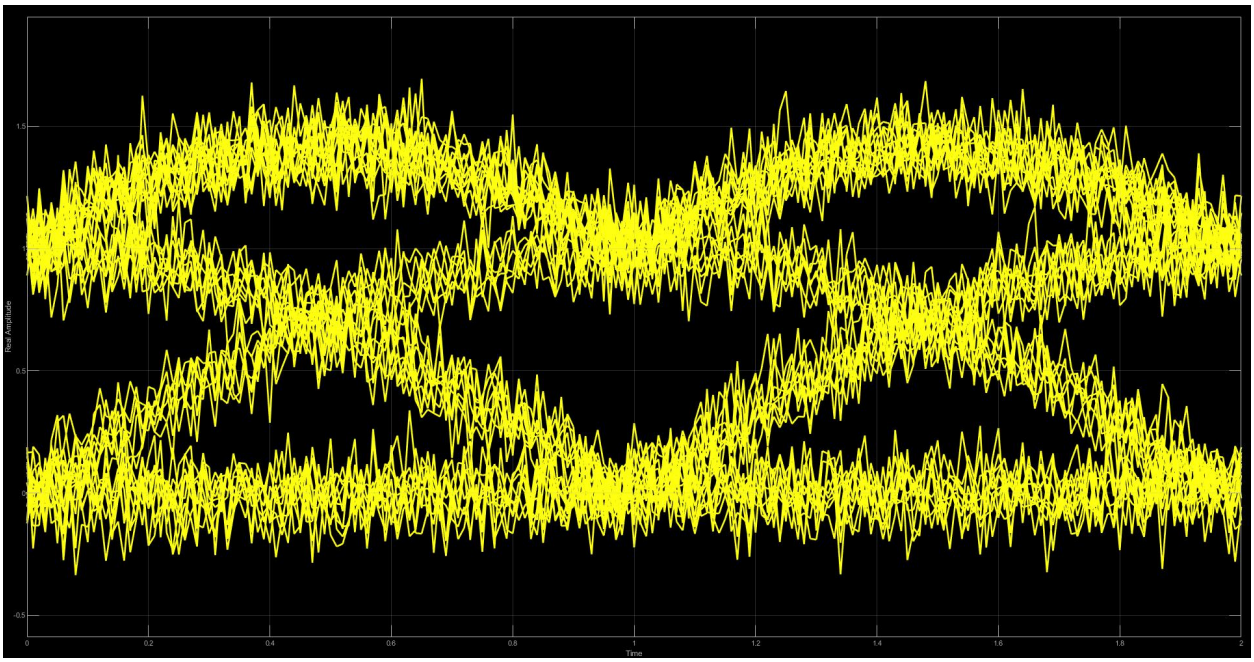


Figure 22: Eye Diagram for On-Off encoding with a Full Width Rectangle Shaped Pulse

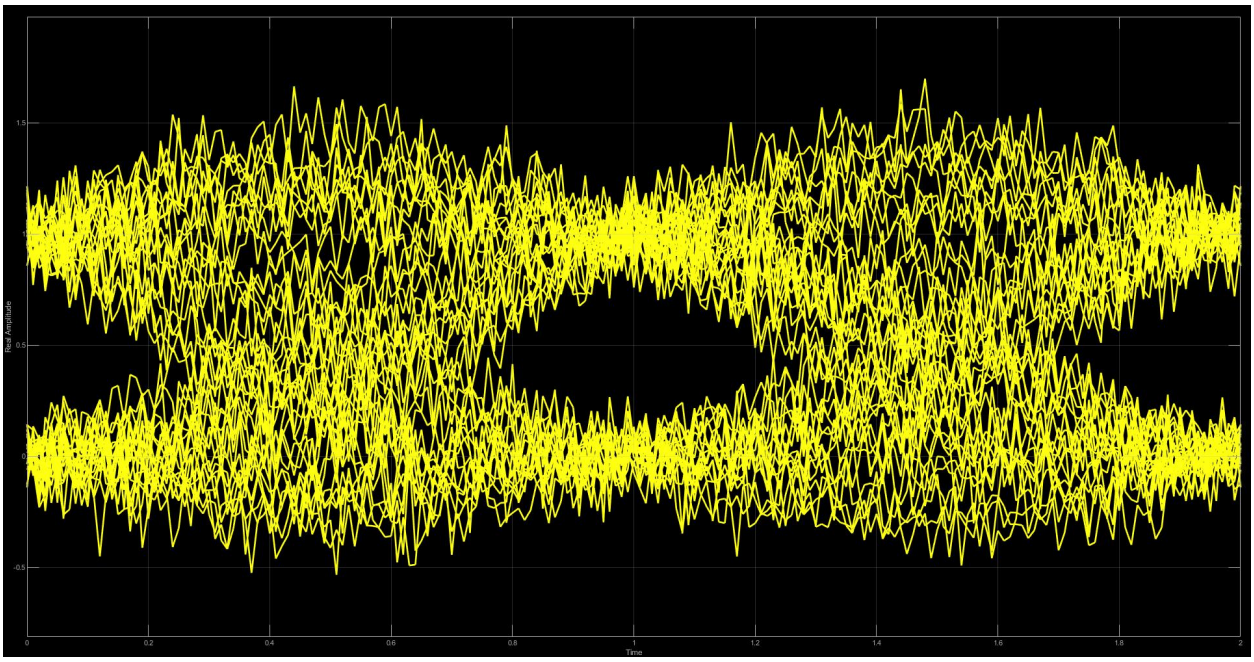


Figure 23: Eye Diagram for On-Off encoding with a Sinc Shaped Pulse

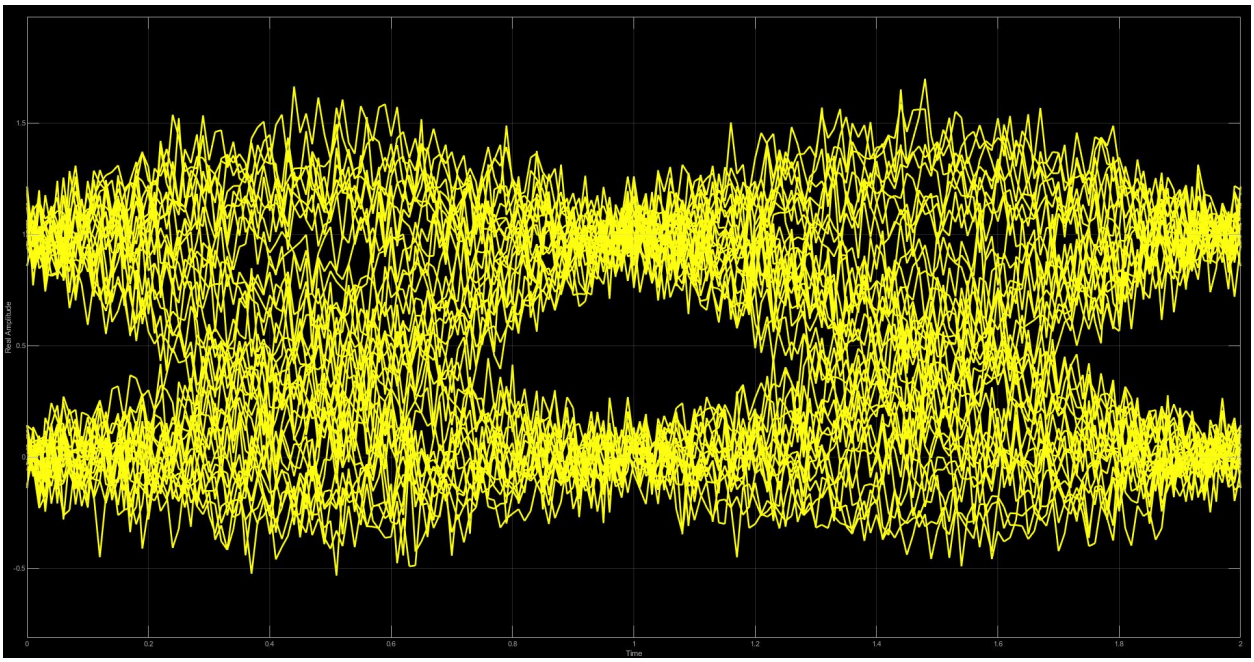


Figure 24: Eye Diagram for On-Off encoding with a Sinc Squared Shaped Pulse

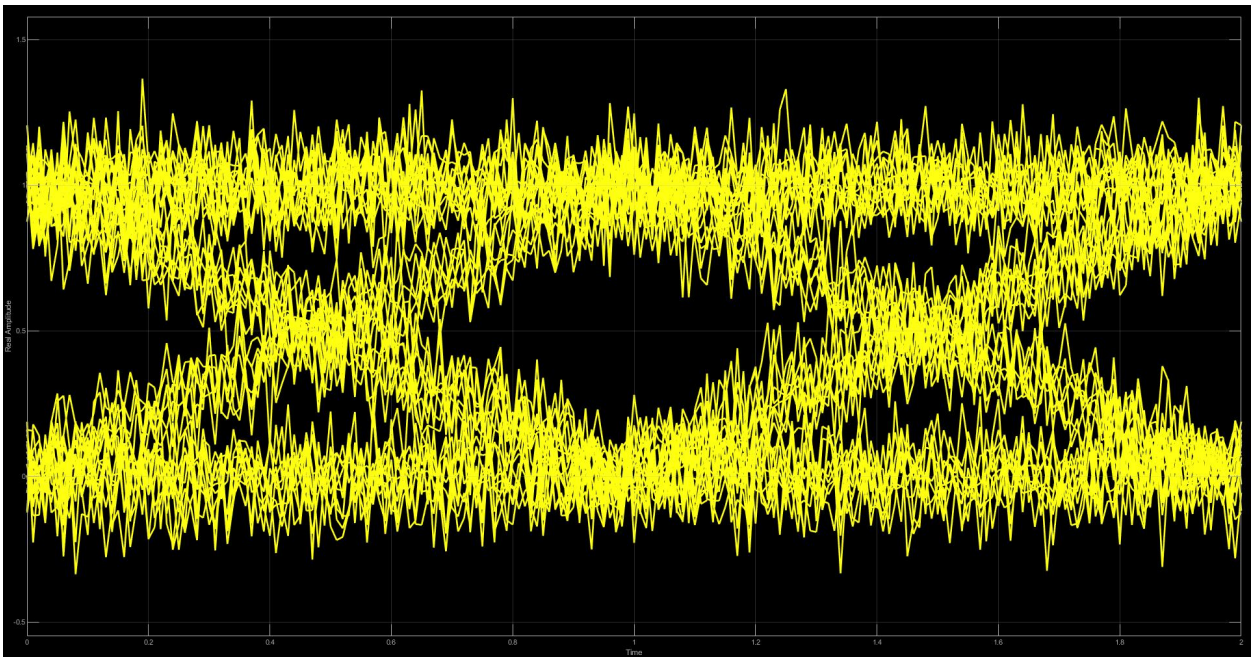


Figure 25: Eye Diagram for On-Off encoding with a Full Width Triangle Shaped Pulse

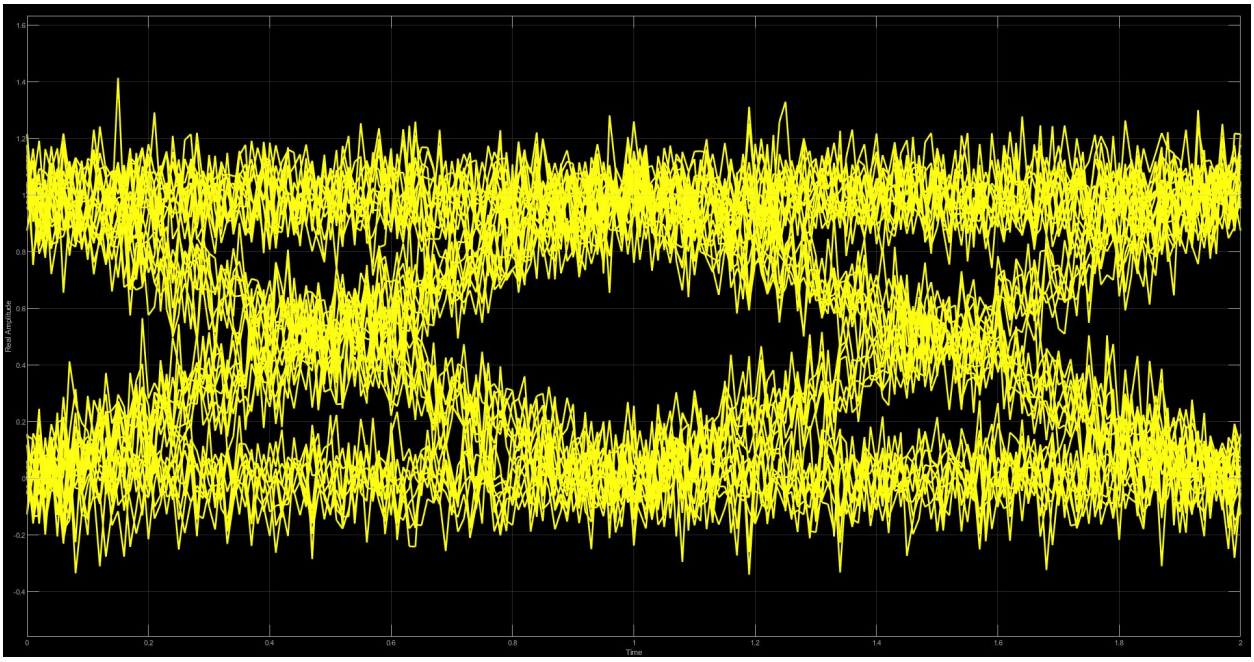


Figure 26: Eye Diagram for On-Off encoding with a Half Width Triangle Shaped Pulse

When looking at the eye diagrams, it can be seen in the full and half width rectangle pulses that in the half width shaped pulse the decision instant is offset by half the period of the signal.

3.1.3 Spectrum

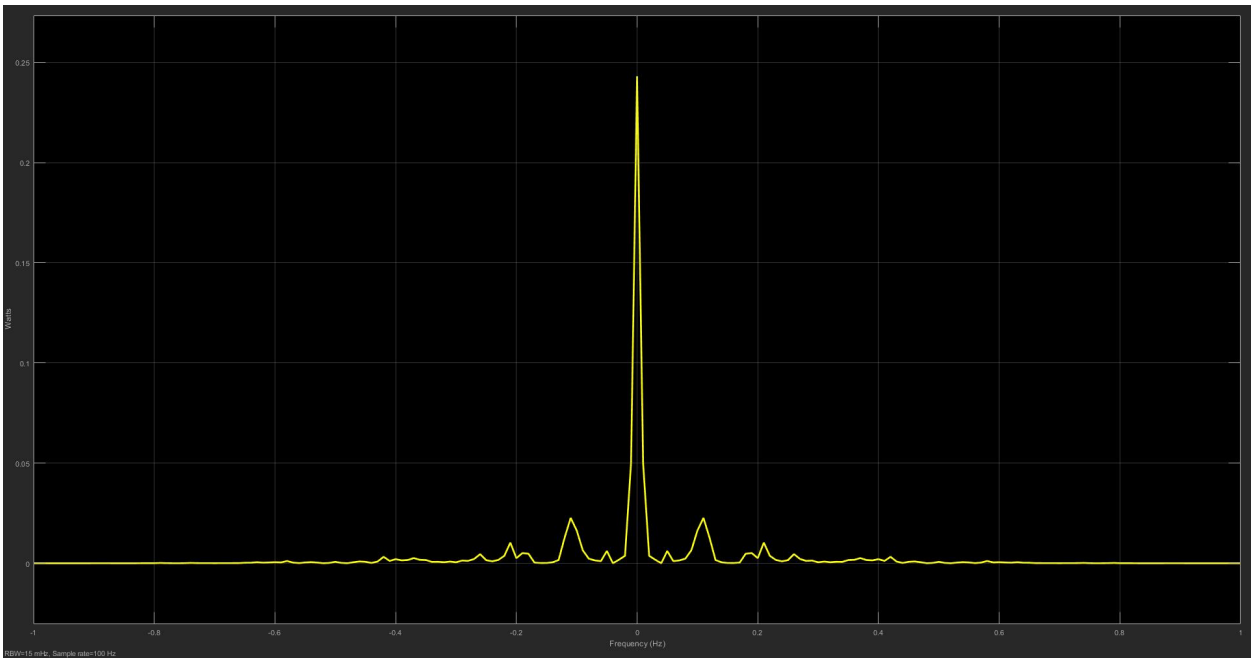


Figure 27: Spectrum for On-Off encoding with a Raised Cosine Shaped Pulse

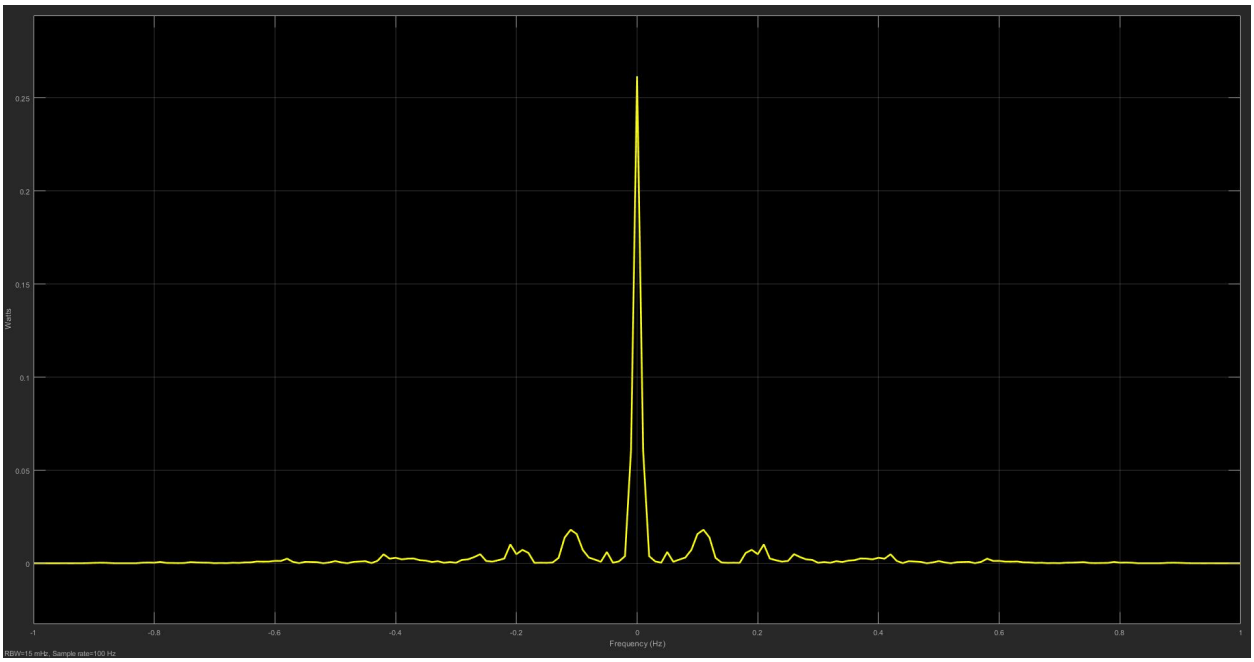


Figure 28: Spectrum for On-Off encoding with a Full Width Rectangle Shaped Pulse

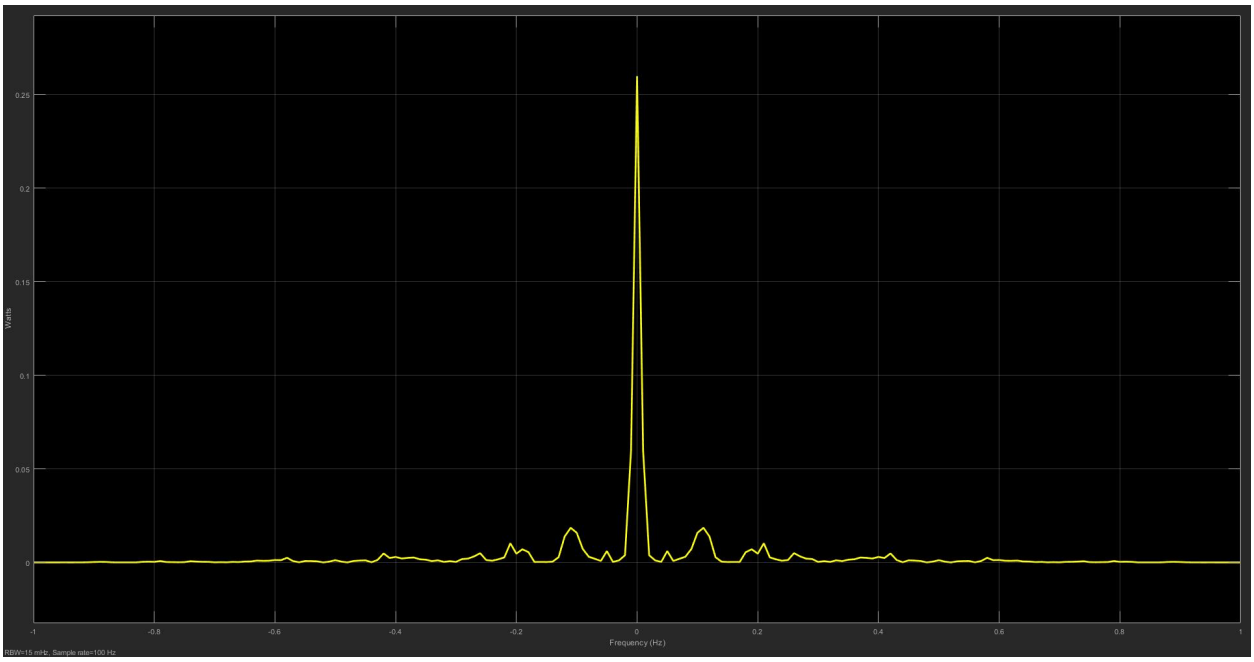


Figure 29: Spectrum for On-Off encoding with a Half Width Rectangle Shaped Pulse

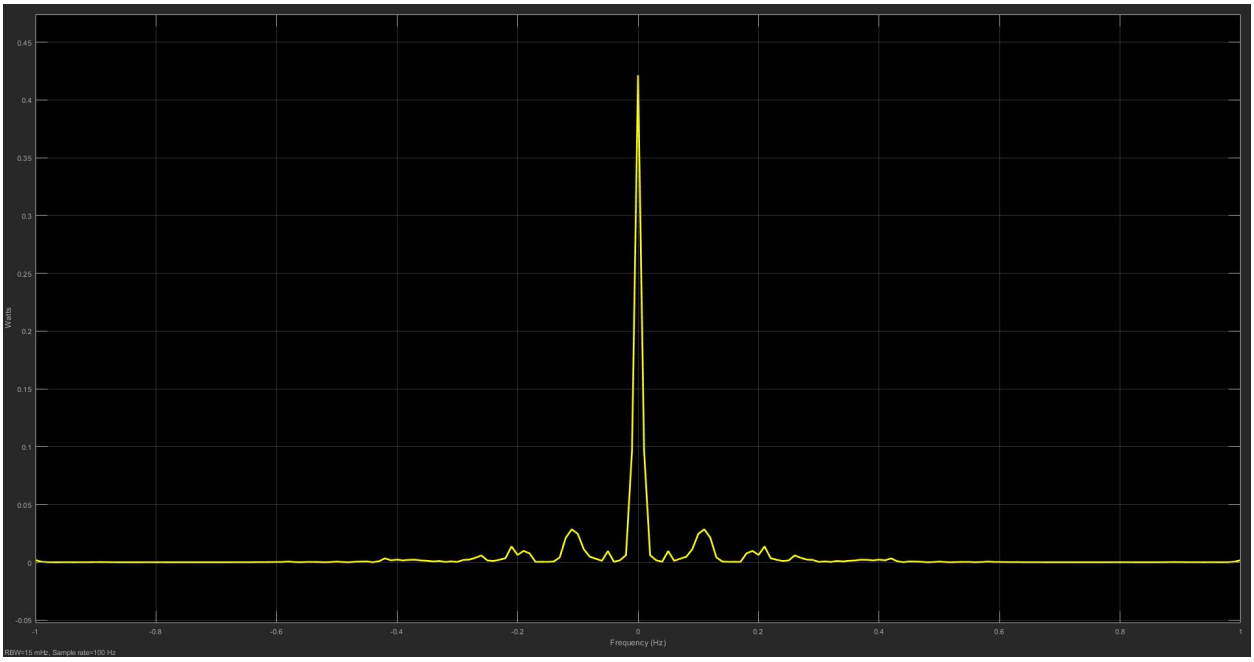


Figure 30: Spectrum for On-Off encoding with a Sin Shaped Pulse

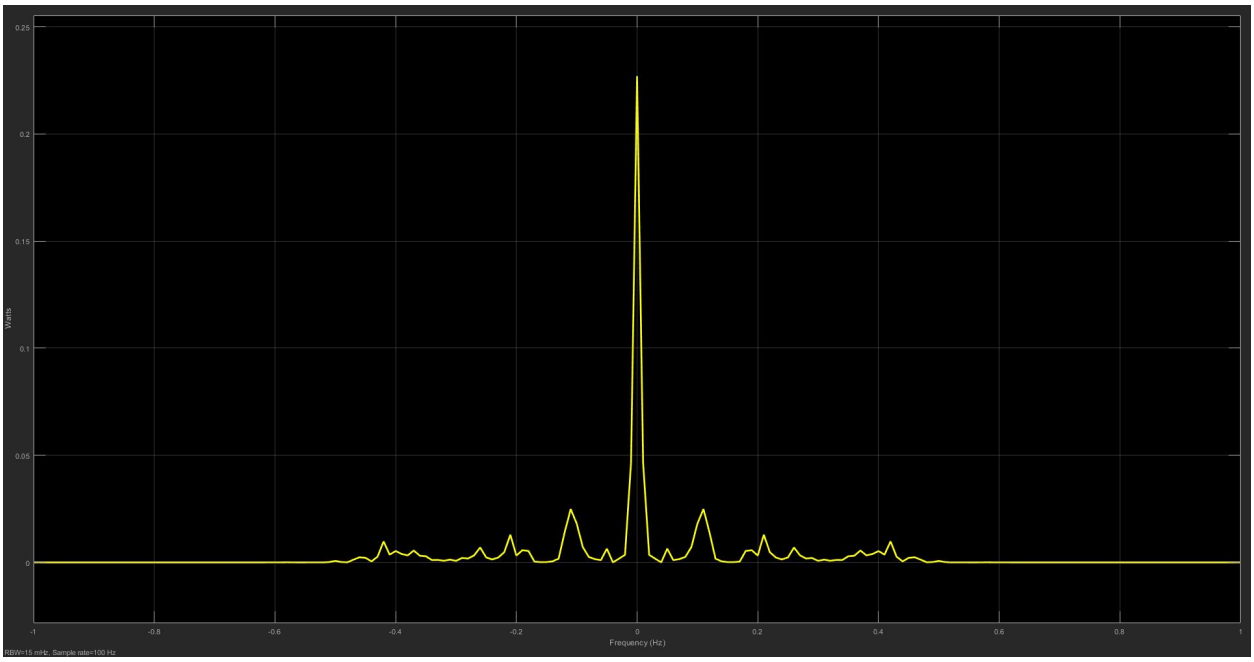


Figure 31: Spectrum for On-Off encoding with a Sinc Shaped Pulse

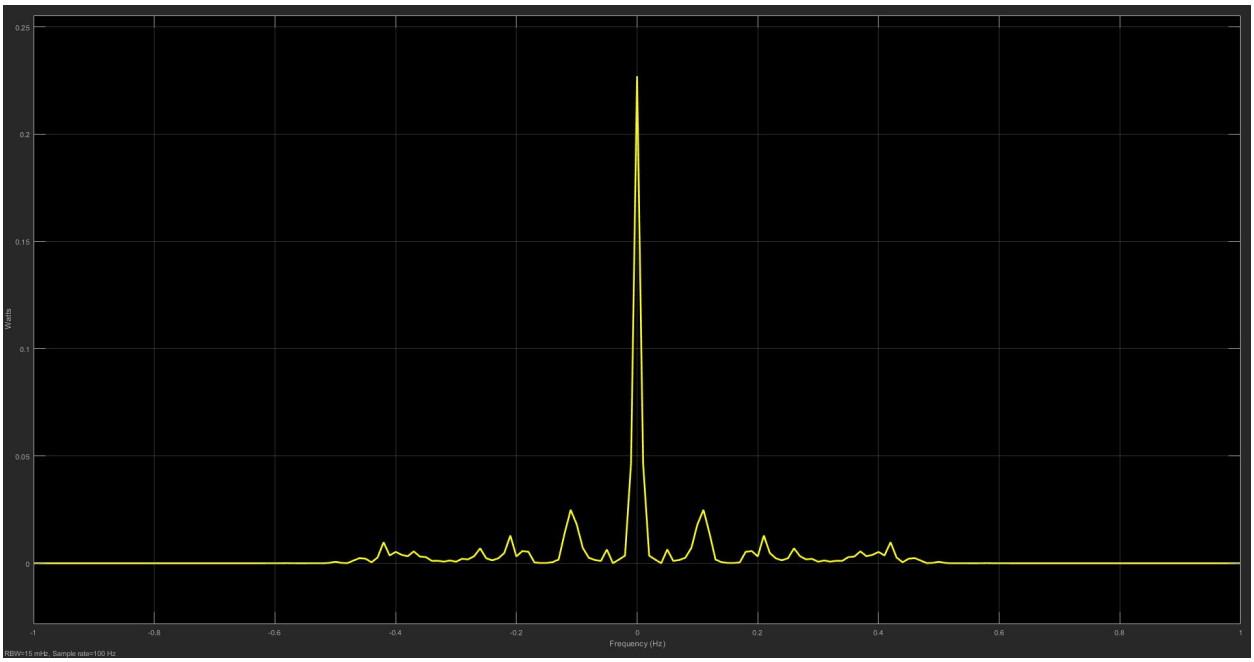


Figure 32: Spectrum for On-Off encoding with a Sinc Squared Shaped Pulse

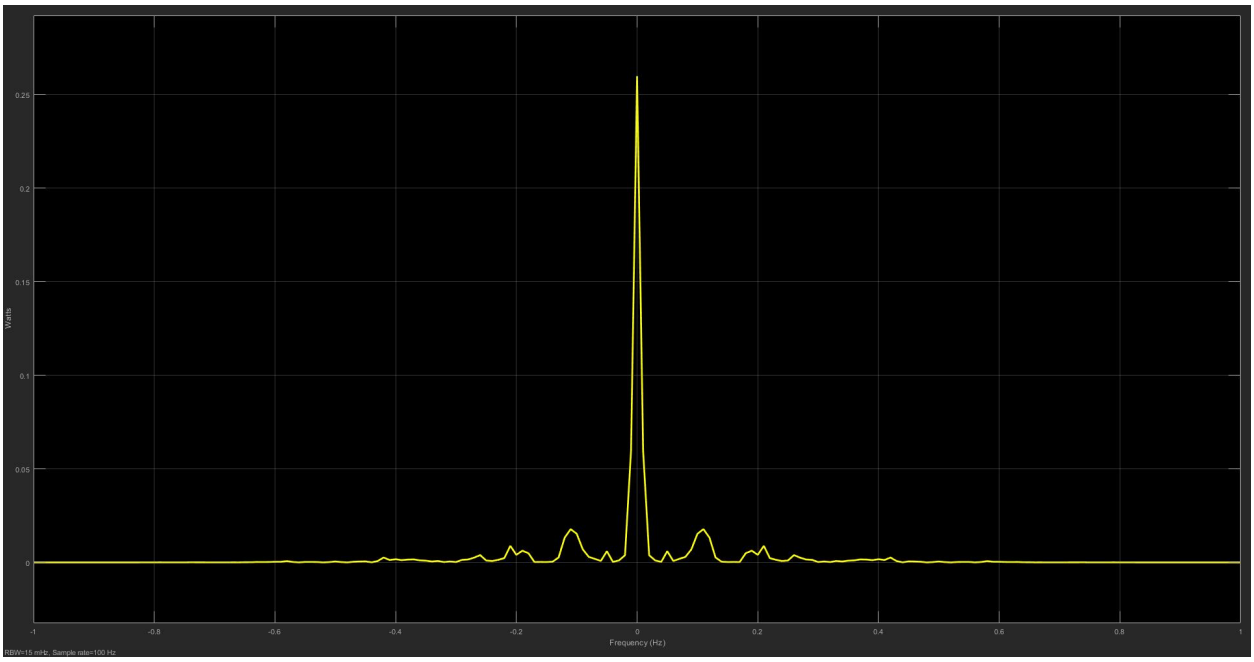


Figure 33: Spectrum for On-Off encoding with a Full Width Triangle Shaped Pulse

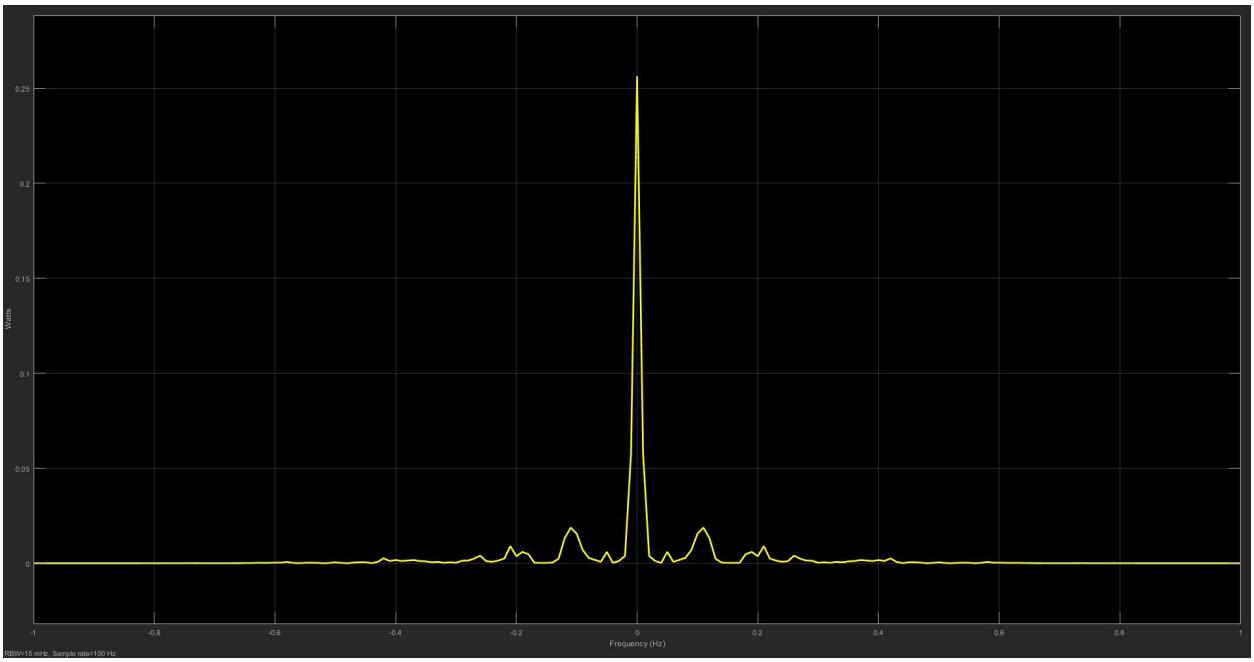


Figure 34: Spectrum for On-Off encoding with a Half Width Triangle Shaped Pulse

3.2 Polar

3.2.1 Time Signal

The following images or for Polar encoding with the various pulse shapes. They are presented with the Polar encoded binary stream, the generated signal when convoluted with a shaped pulse and the received signal with noise in the channel.

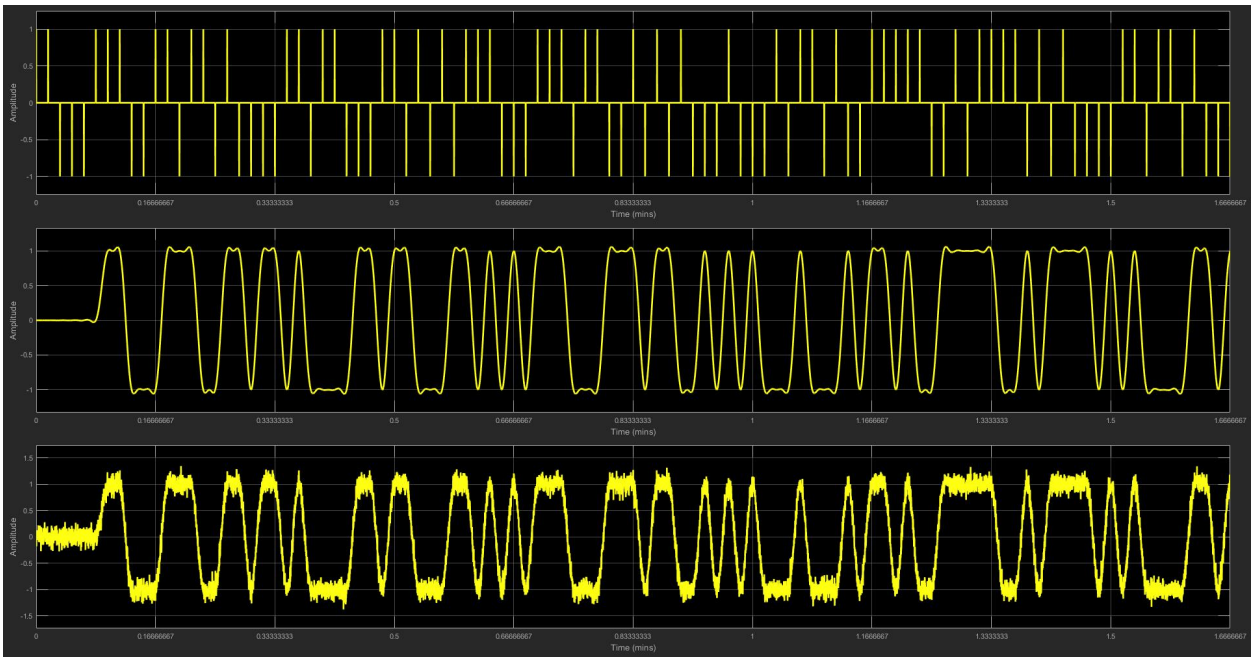


Figure 35: On-Off encoding with a Raised Cosine Shaped Pulse

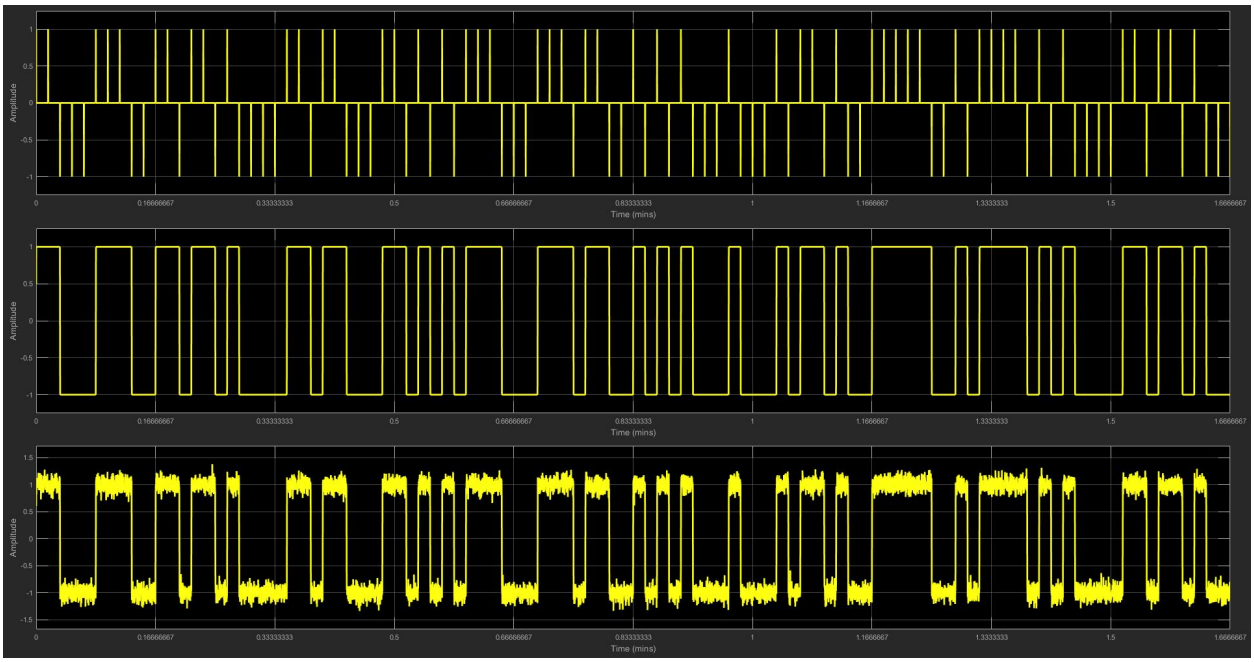


Figure 36: On-Off encoding with a Full Width Rectangle Shaped Pulse

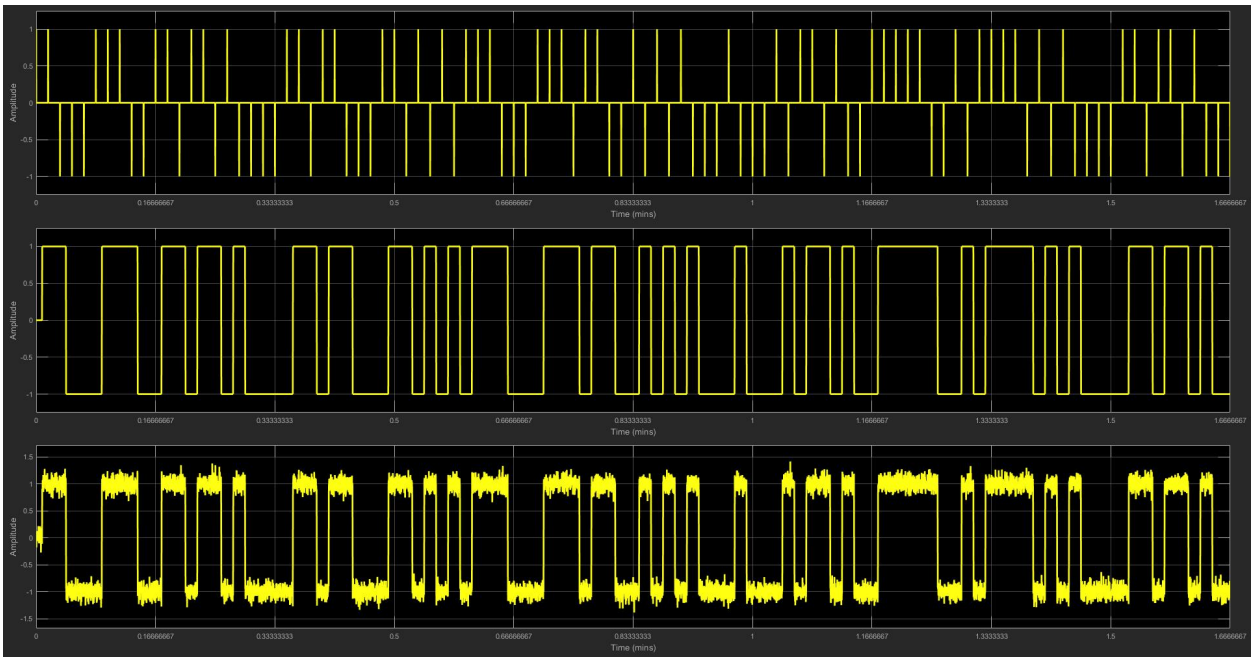


Figure 37: On-Off encoding with a Half Width Rectangle Shaped Pulse

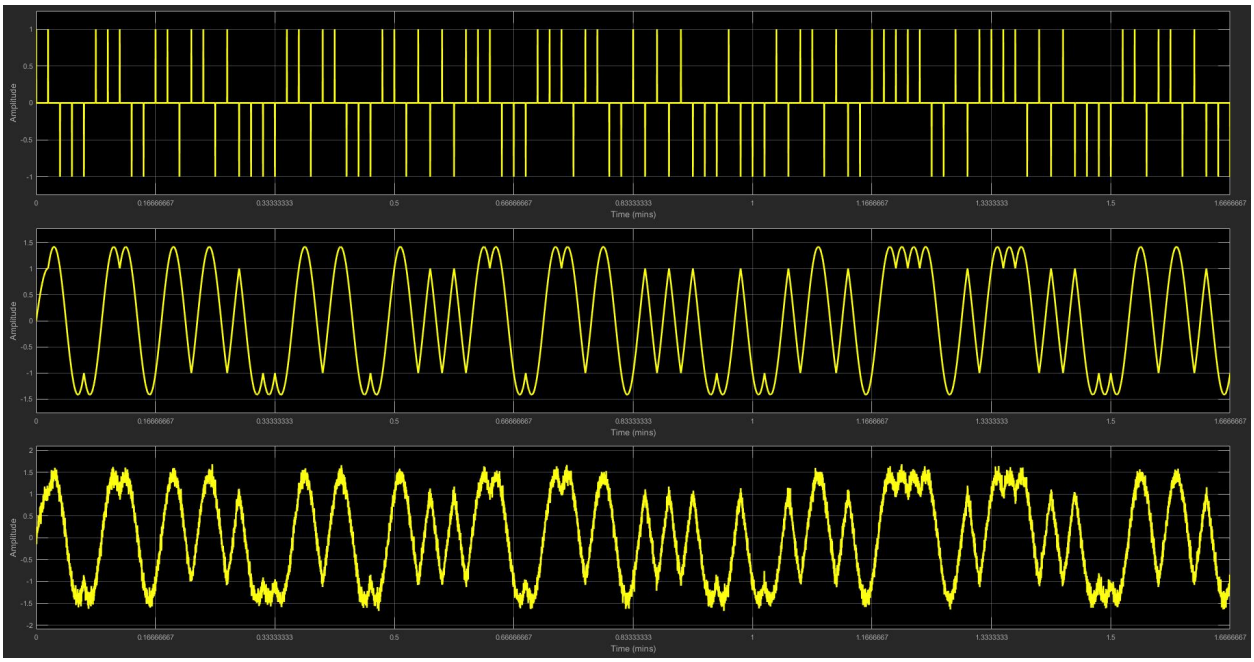


Figure 38: On-Off encoding with a Full Width Rectangle Shaped Pulse

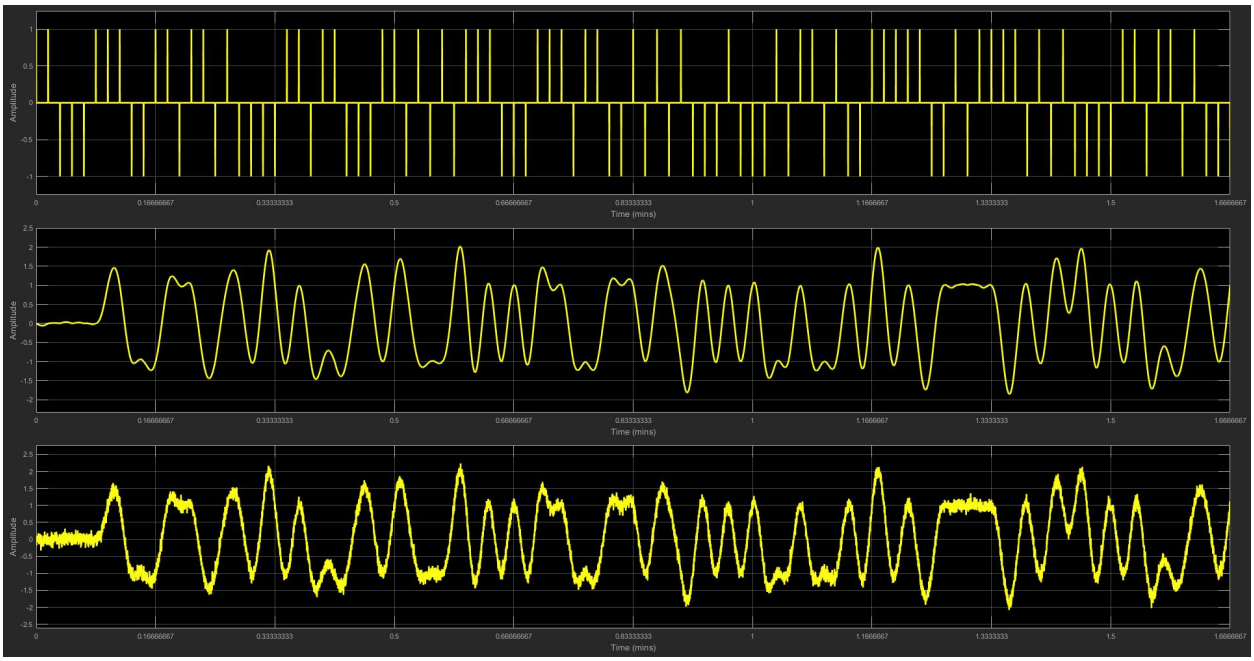


Figure 39: On-Off encoding with a Sinc Shaped Pulse

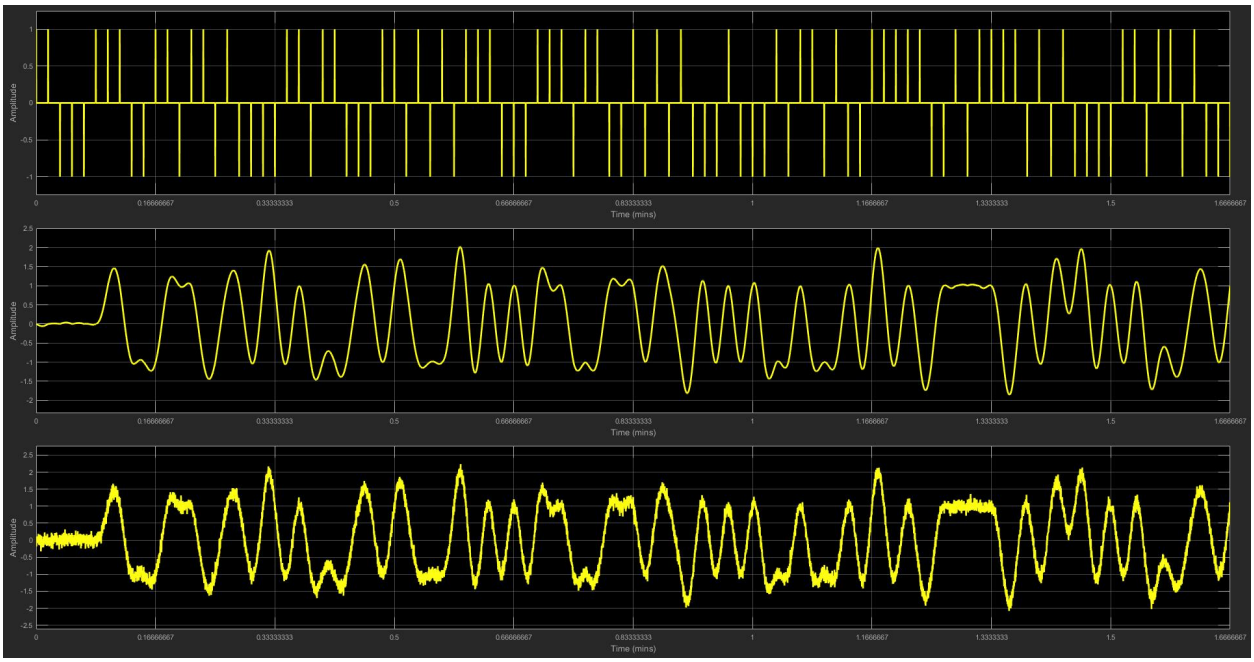


Figure 40: On-Off encoding with a Sinc Squared Shaped Pulse

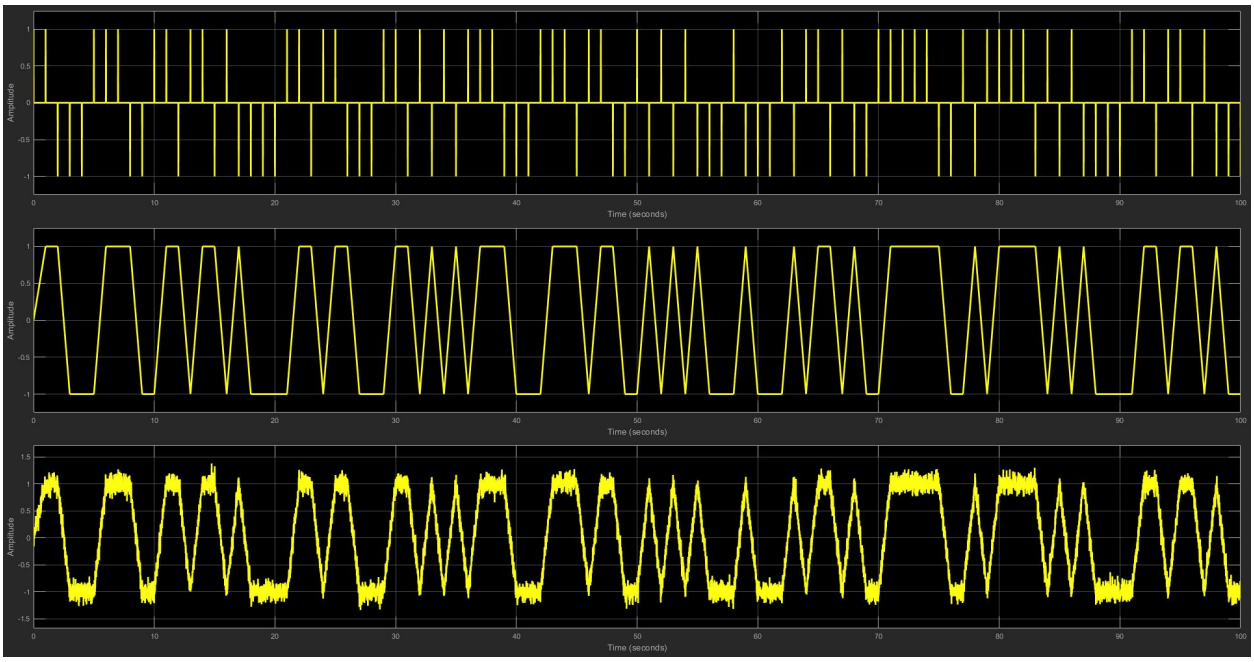


Figure 41: On-Off encoding with a Full Width Triangle Shaped Pulse

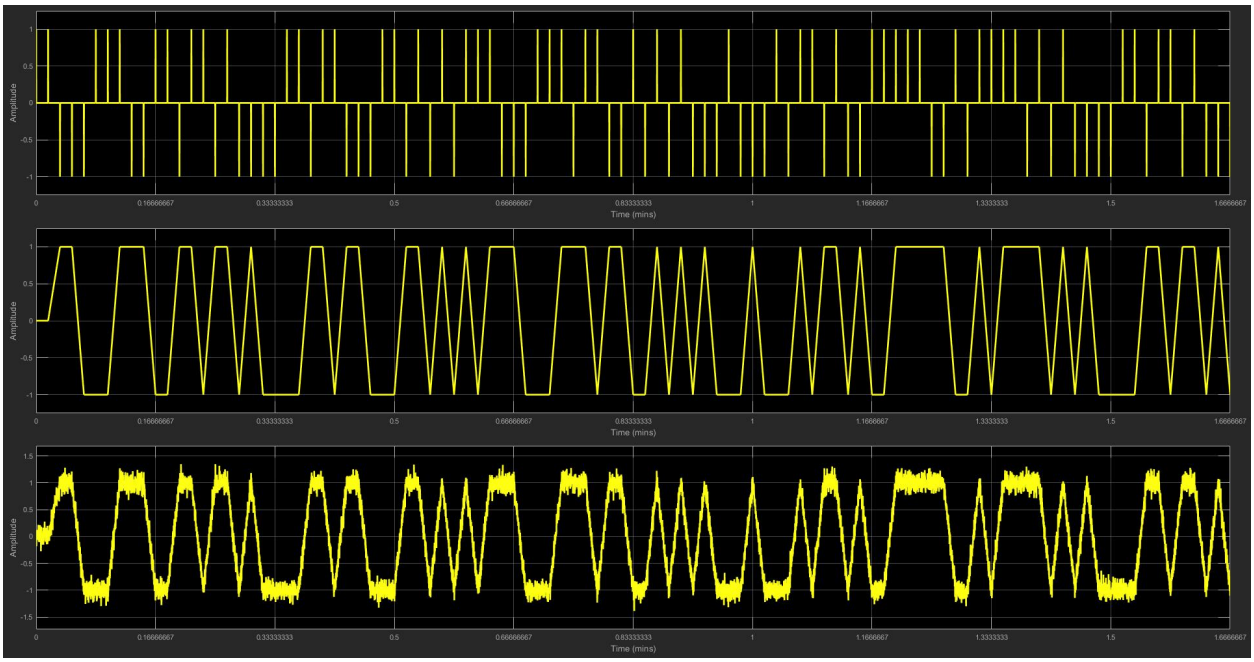


Figure 42: On-Off encoding with a Half Width Triangle Shaped Pulse

Something that should be noted is that the apparent difference between full width and half with shaped pulses for both Rectangle and Triangle shaped pulses have an identical waveform. The difference is the half width is a delayed signal.

3.2.2 Eye Diagrams

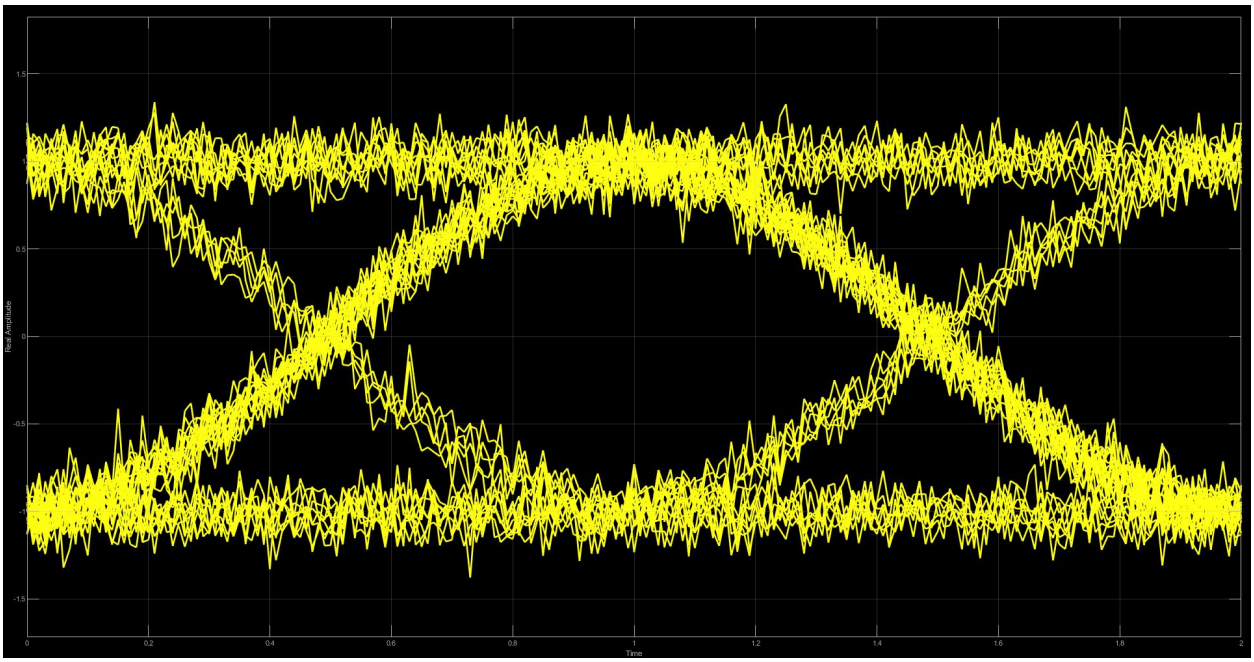


Figure 43: Eye Diagram for Polar encoding with a Raised Cosine Shaped Pulse

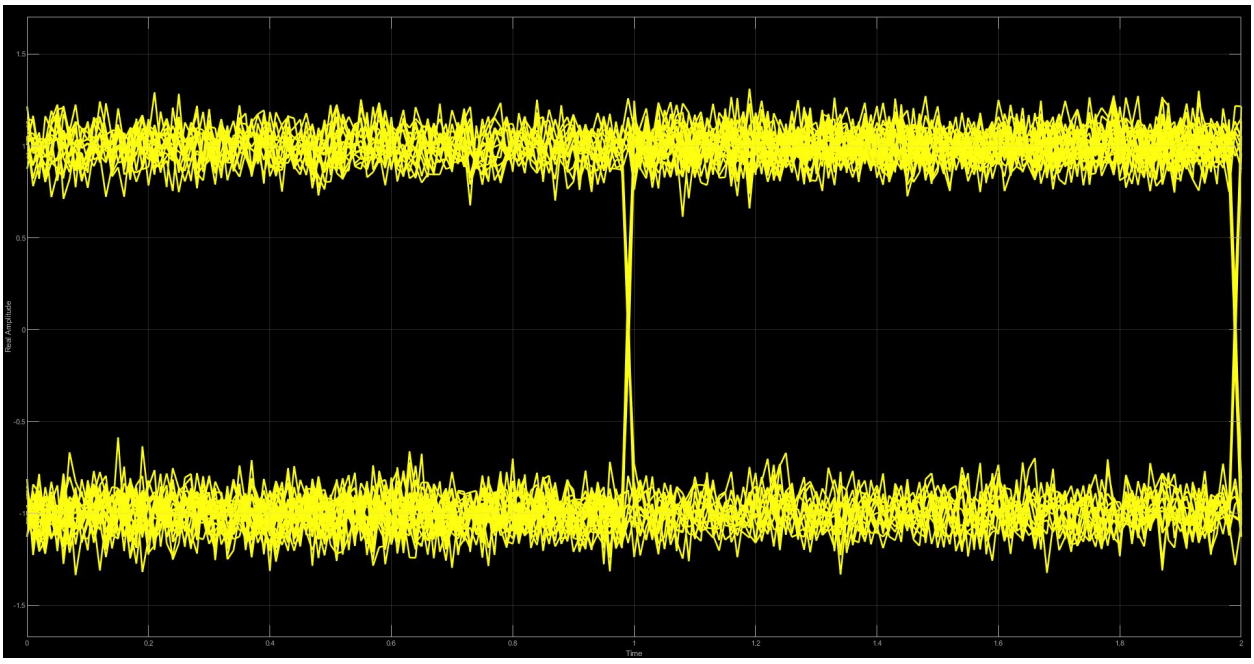


Figure 44: Eye Diagram for Polar encoding with a Full Width Rectangle Shaped Pulse

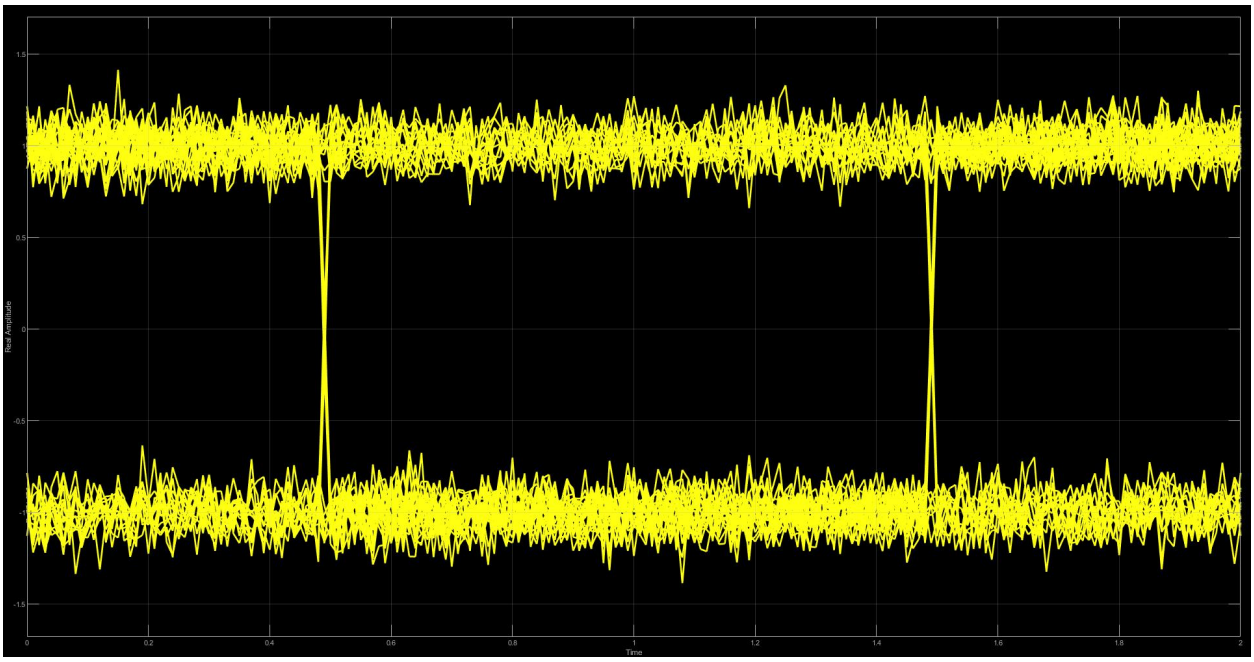


Figure 45: Eye Diagram for Polar encoding with a Half Width Rectangle Shaped Pulse

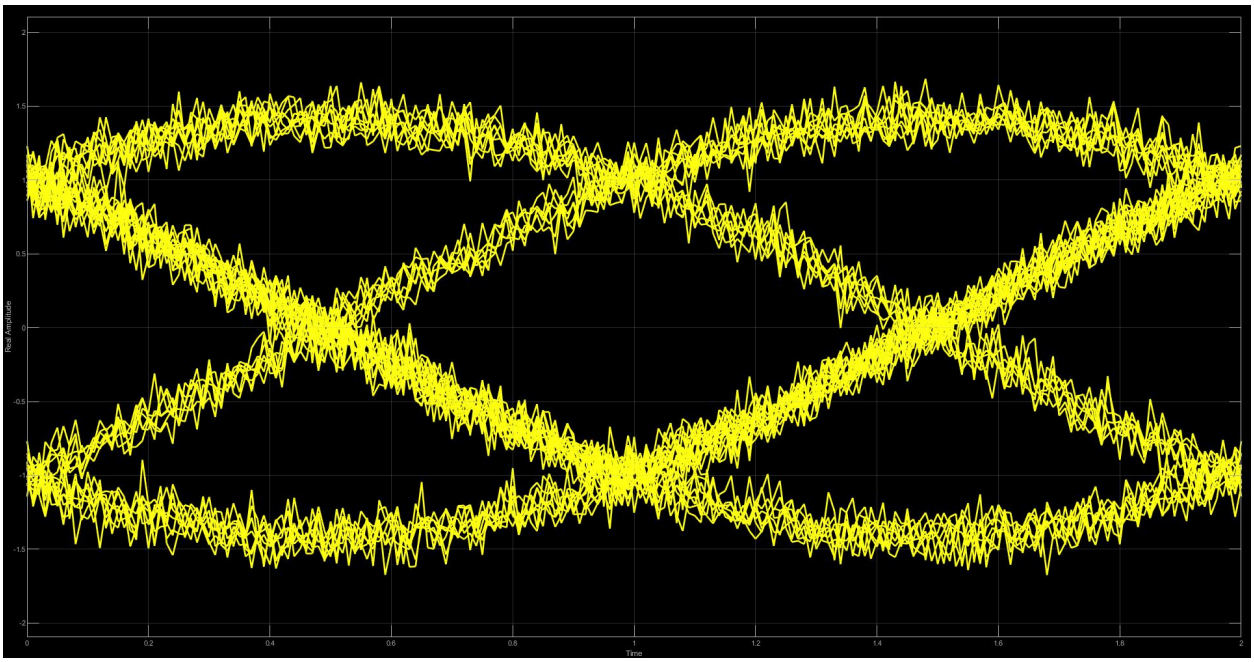


Figure 46: Eye Diagram for Polar encoding with a Full Width Rectangle Shaped Pulse

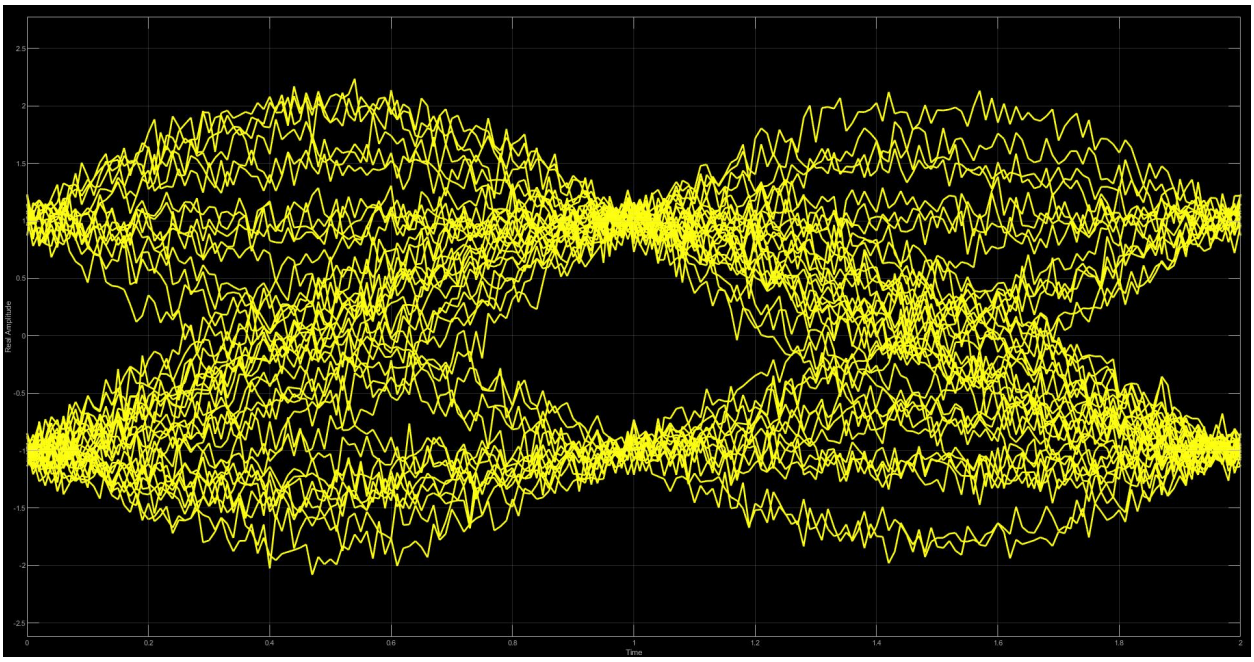


Figure 47: Eye Diagram for Polar encoding with a Sinc Shaped Pulse

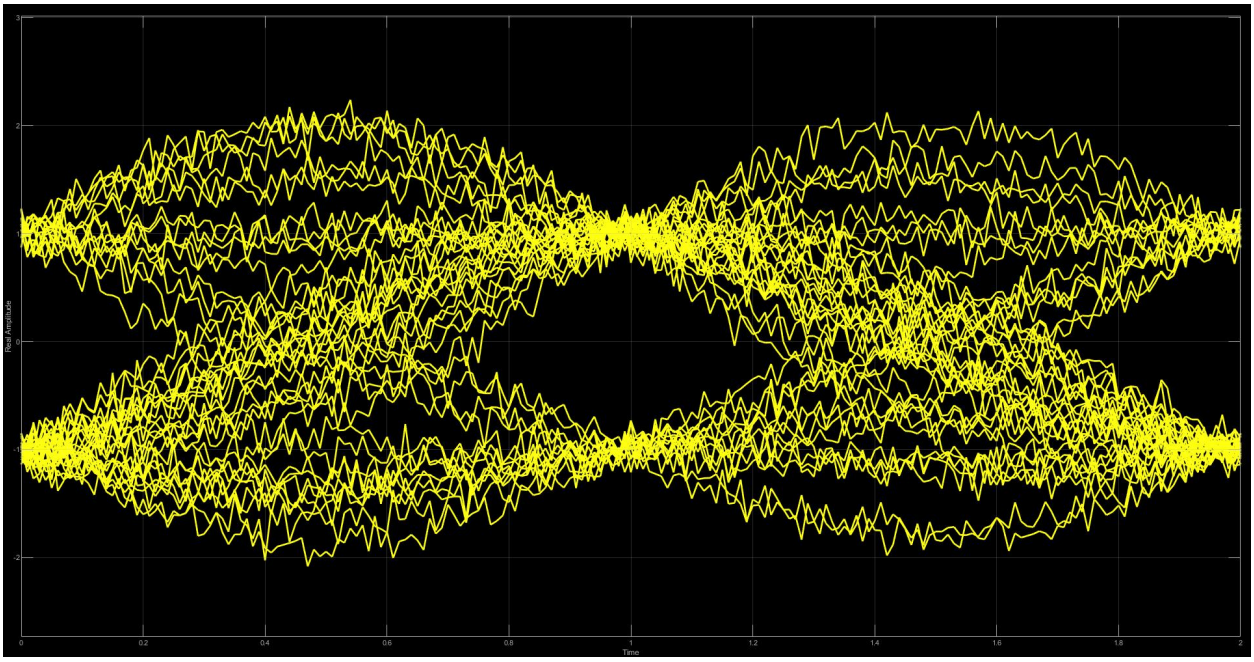


Figure 48: Eye Diagram for Polar encoding with a Sinc Squared Shaped Pulse

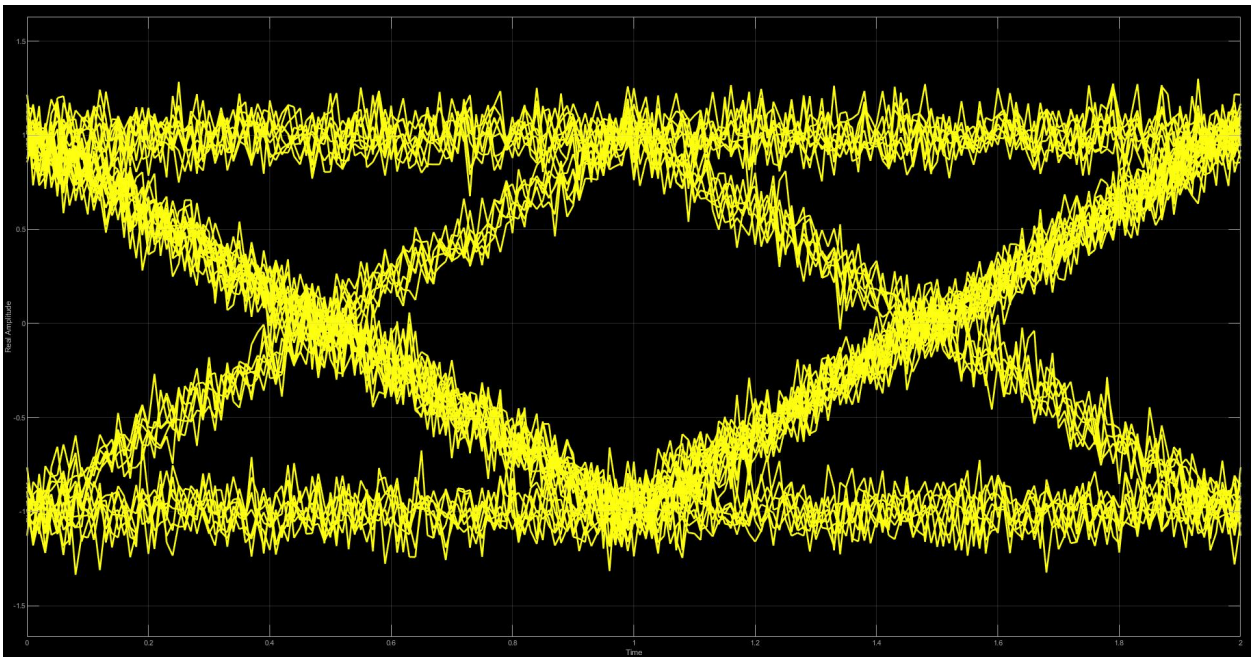


Figure 49: Eye Diagram for Polar encoding with a Full Width Triangle Shaped Pulse

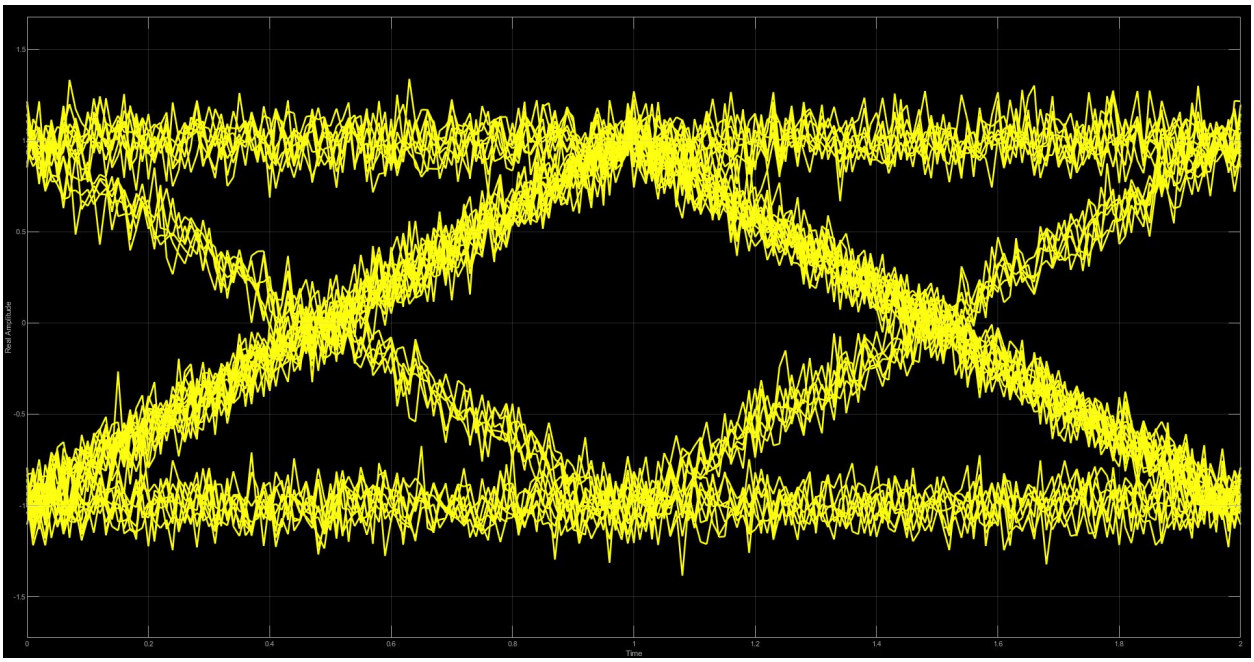


Figure 50: Eye Diagram for Polar encoding with a Half Width Triangle Shaped Pulse

When looking at the eye diagrams, it can be seen in the full and half width rectangle pulses that in the half width shaped pulse the decision instant is offset by half the period of the signal.

3.2.3 Spectrum

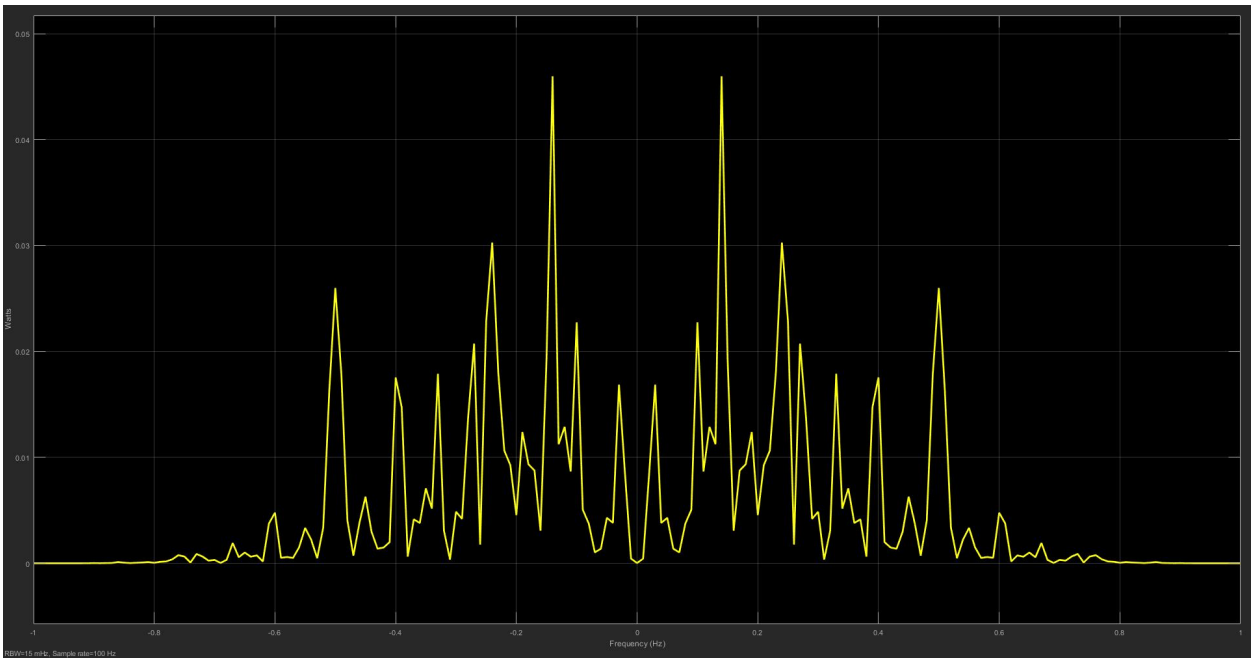


Figure 51: Spectrum for Polar encoding with a Raised Cosine Shaped Pulse

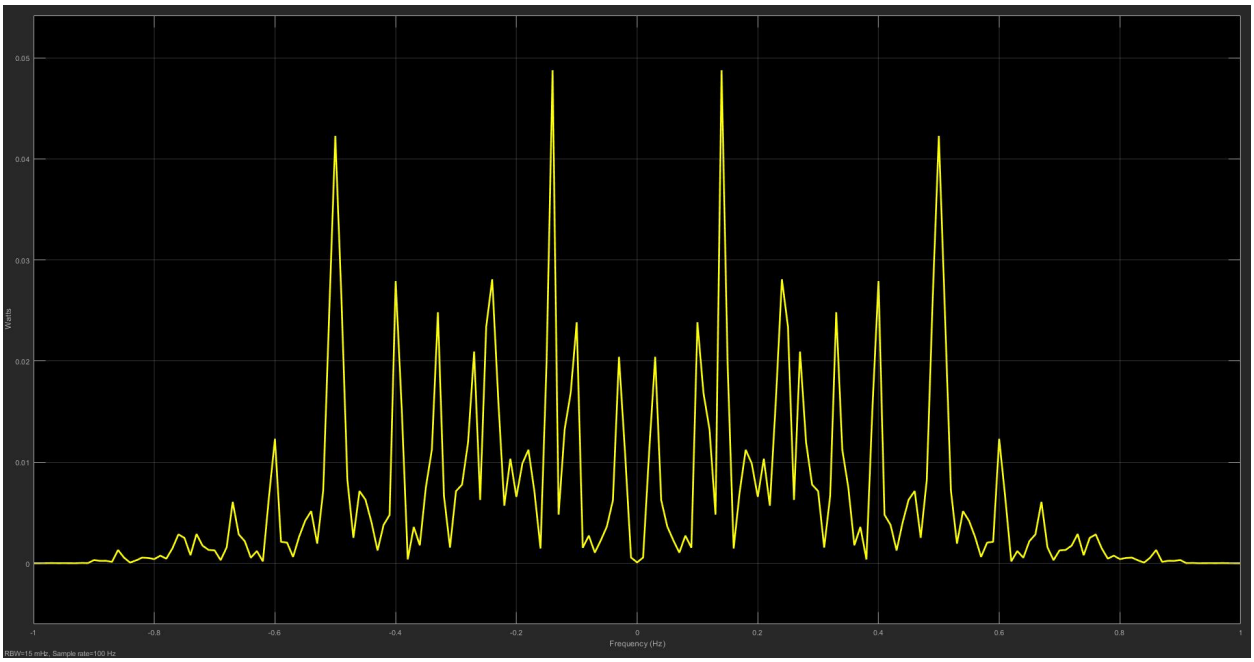


Figure 52: Spectrum for Polar encoding with a Full Width Rectangle Shaped Pulse

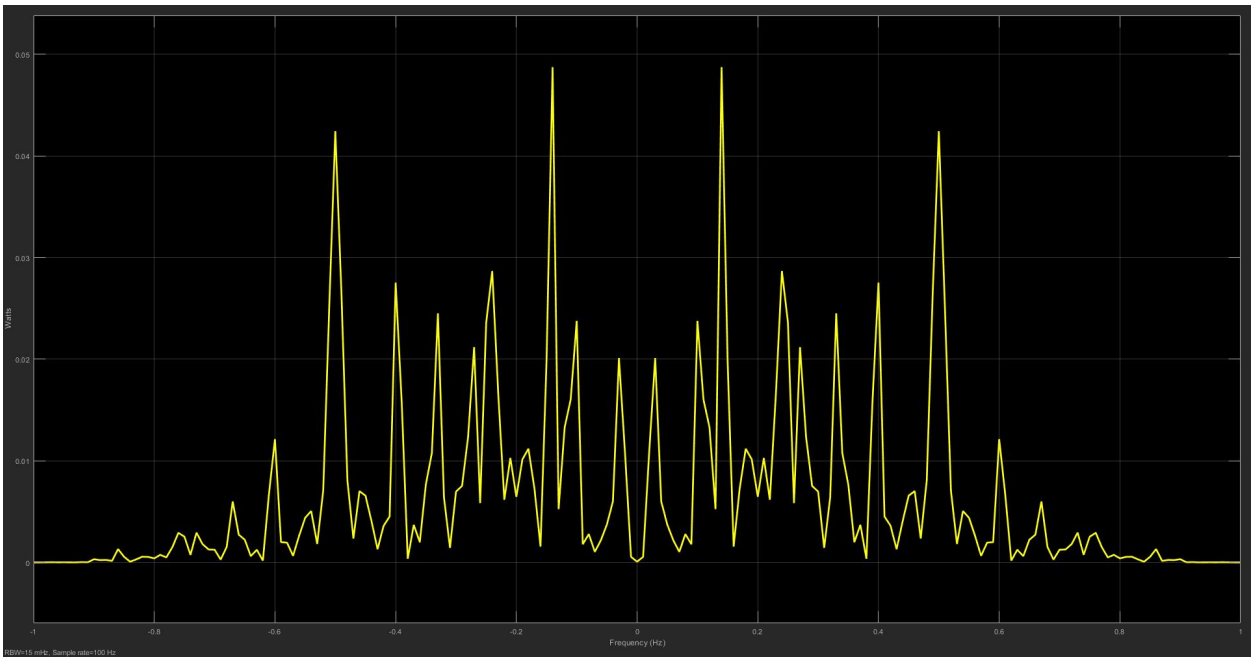


Figure 53: Spectrum for Polar encoding with a Half Width Rectangle Shaped Pulse

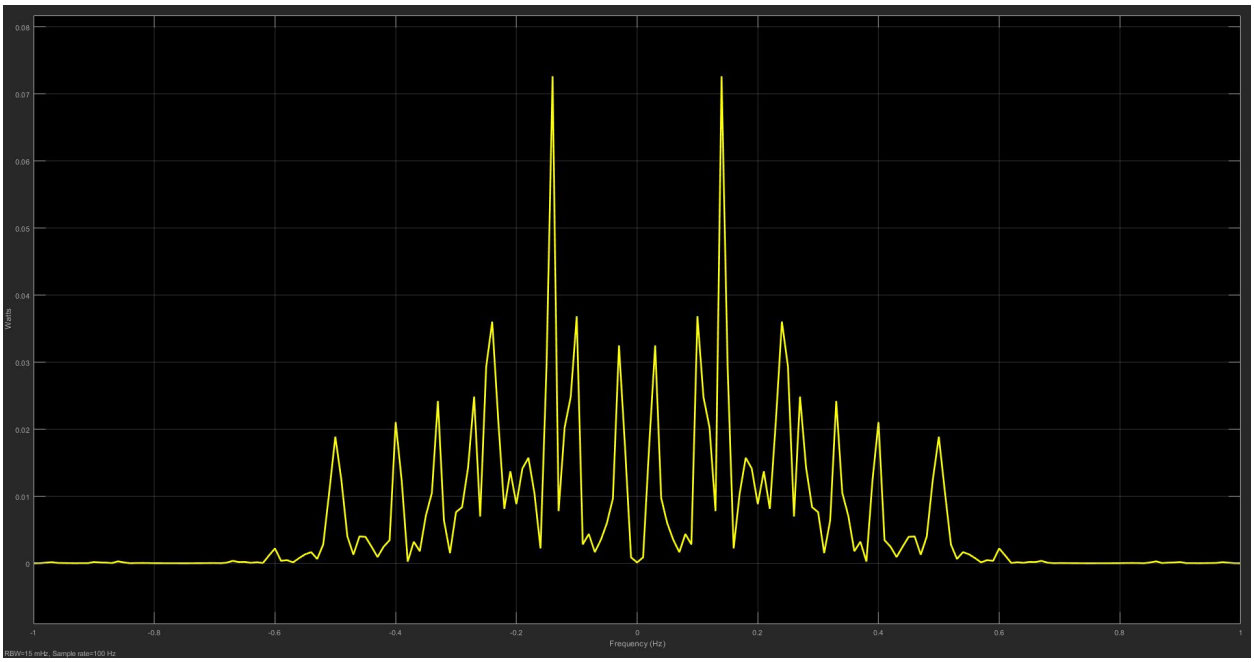


Figure 54: Spectrum for Polar encoding with a Sin Shaped Pulse

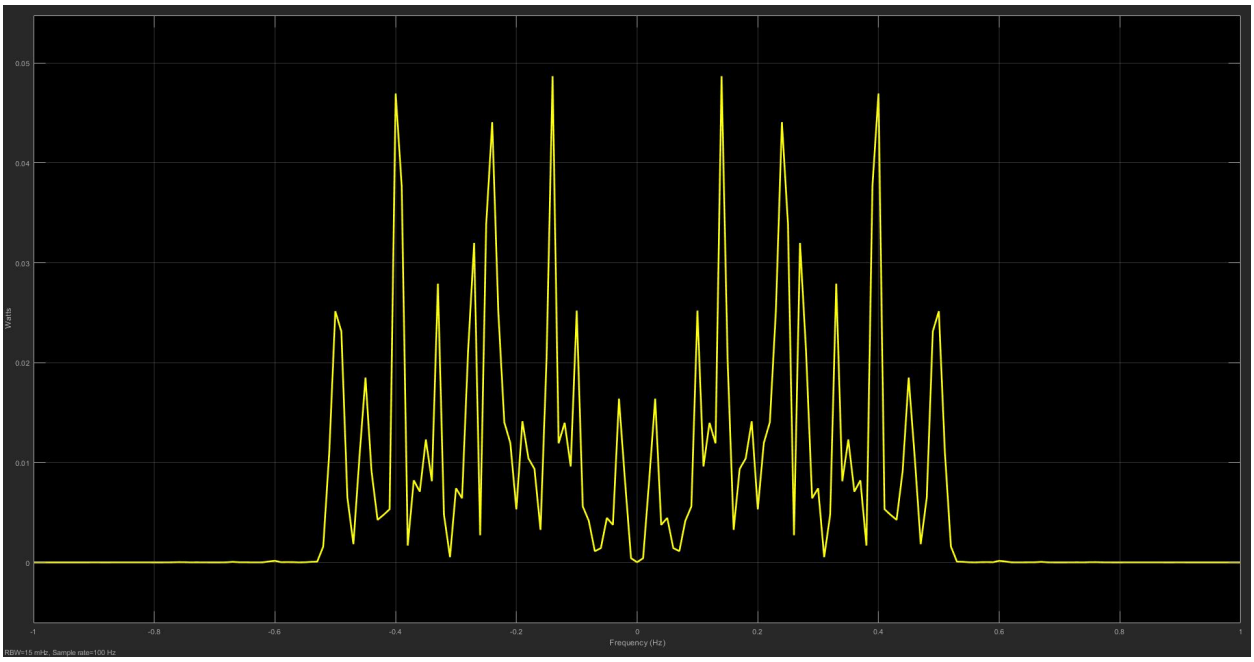


Figure 55: Spectrum for Polar encoding with a Sinc Shaped Pulse

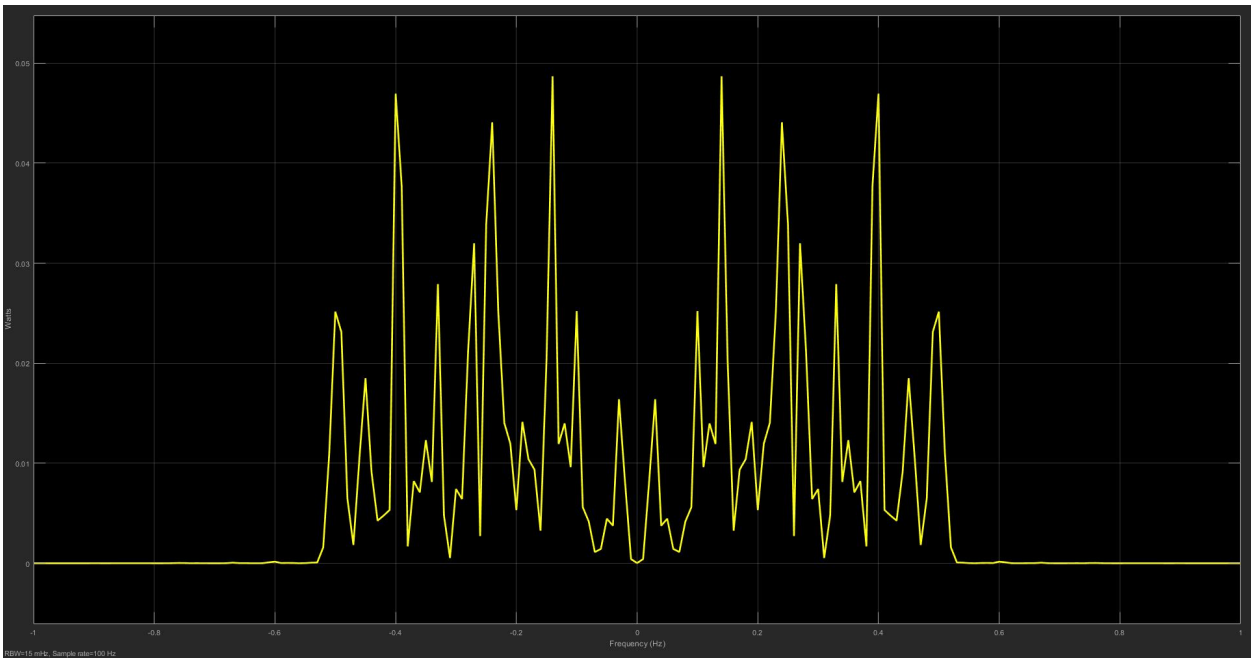


Figure 56: Spectrum for Polar encoding with a Sinc Squared Shaped Pulse

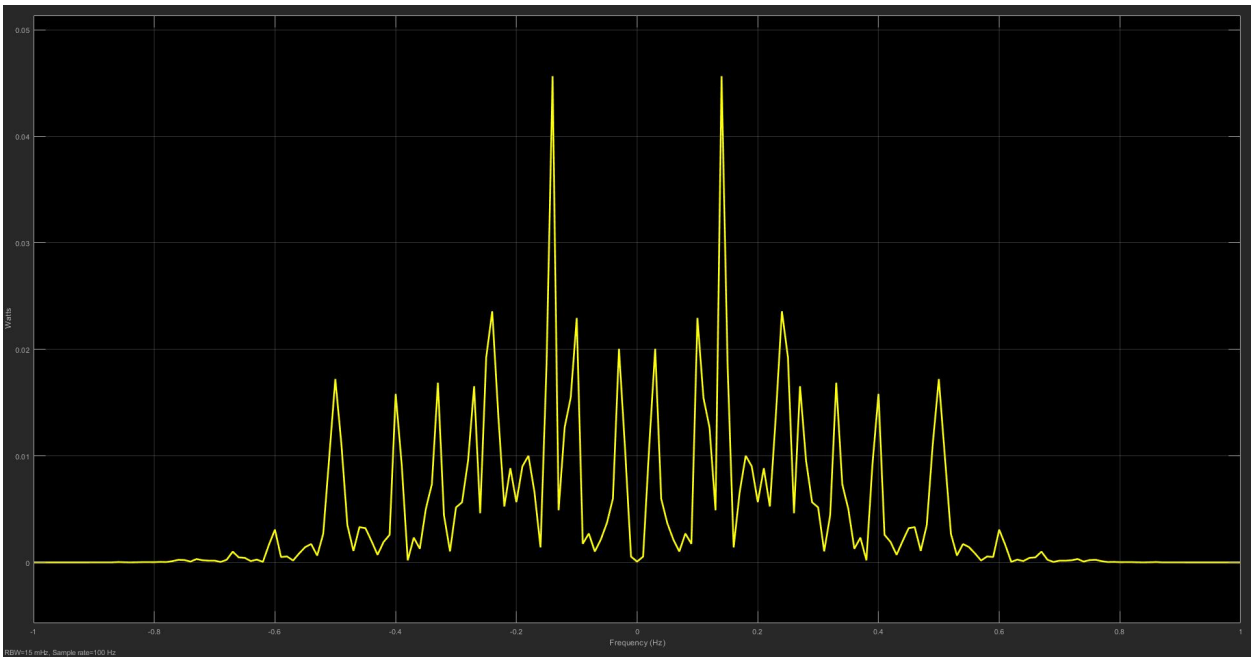


Figure 57: Spectrum for Polar encoding with a Full Width Triangle Shaped Pulse

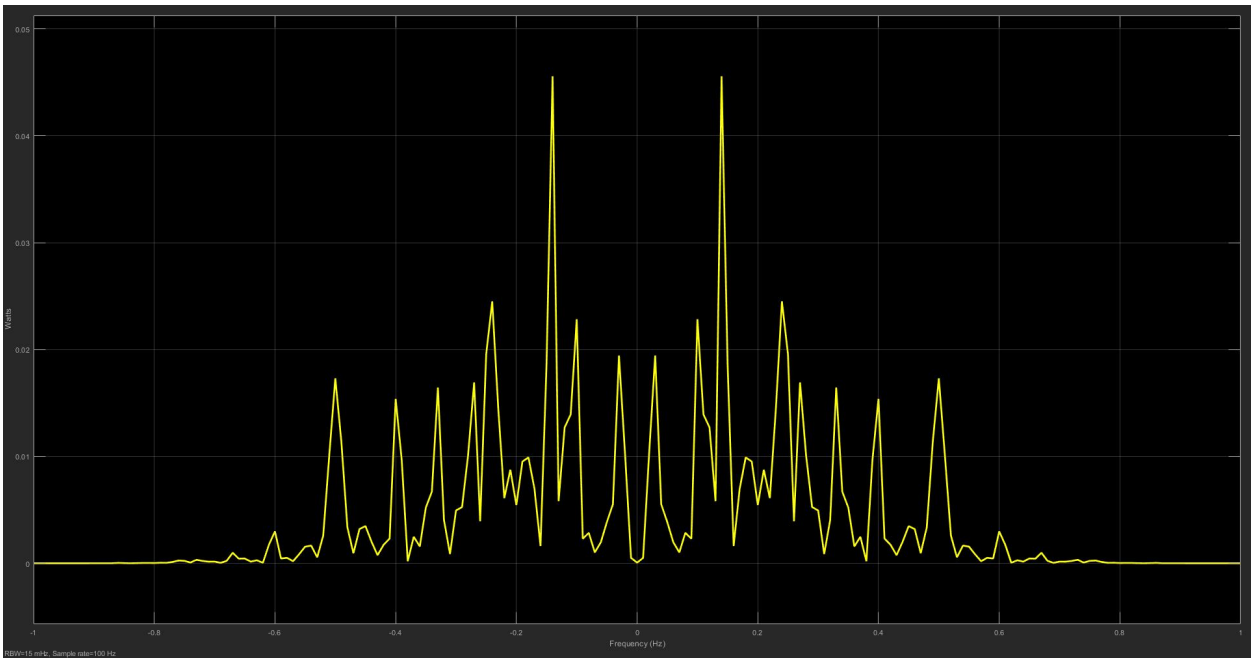


Figure 58: Spectrum for Polar encoding with a Half Width Triangle Shaped Pulse

3.3 Bipolar

3.3.1 Time Signal

The following images or for Bipolar encoding with the various pulse shapes. They are presented with the Bipolar encoded binary stream, the generated signal when convoluted with a shaped pulse and the received signal with noise in the channel.

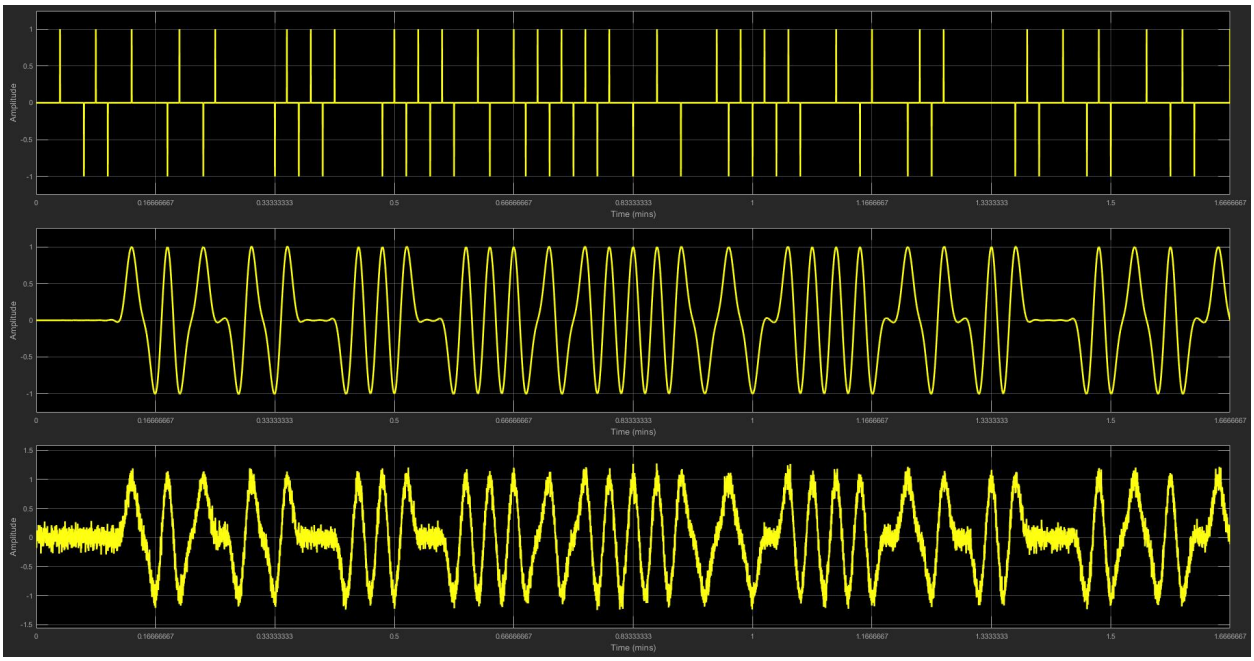


Figure 59: Bipolar encoding with a Raised Cosine Shaped Pulse

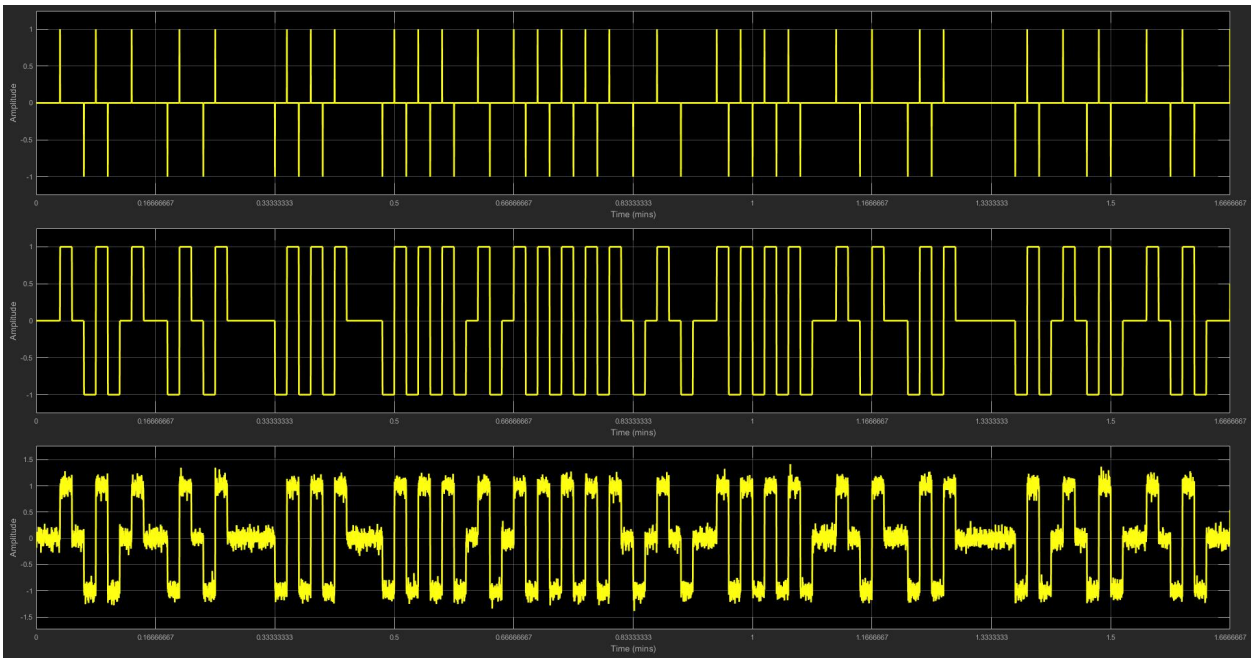


Figure 60: Bipolar encoding with a Full Width Rectangle Shaped Pulse

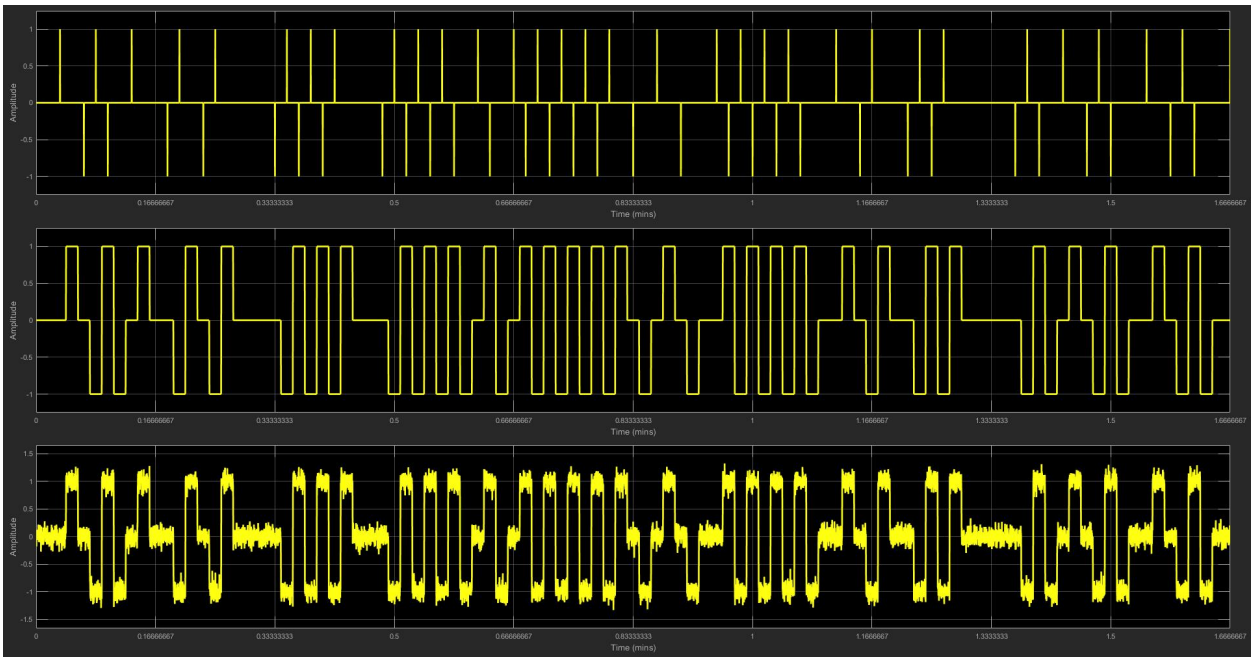


Figure 61: Bipolar encoding with a Half Width Rectangle Shaped Pulse

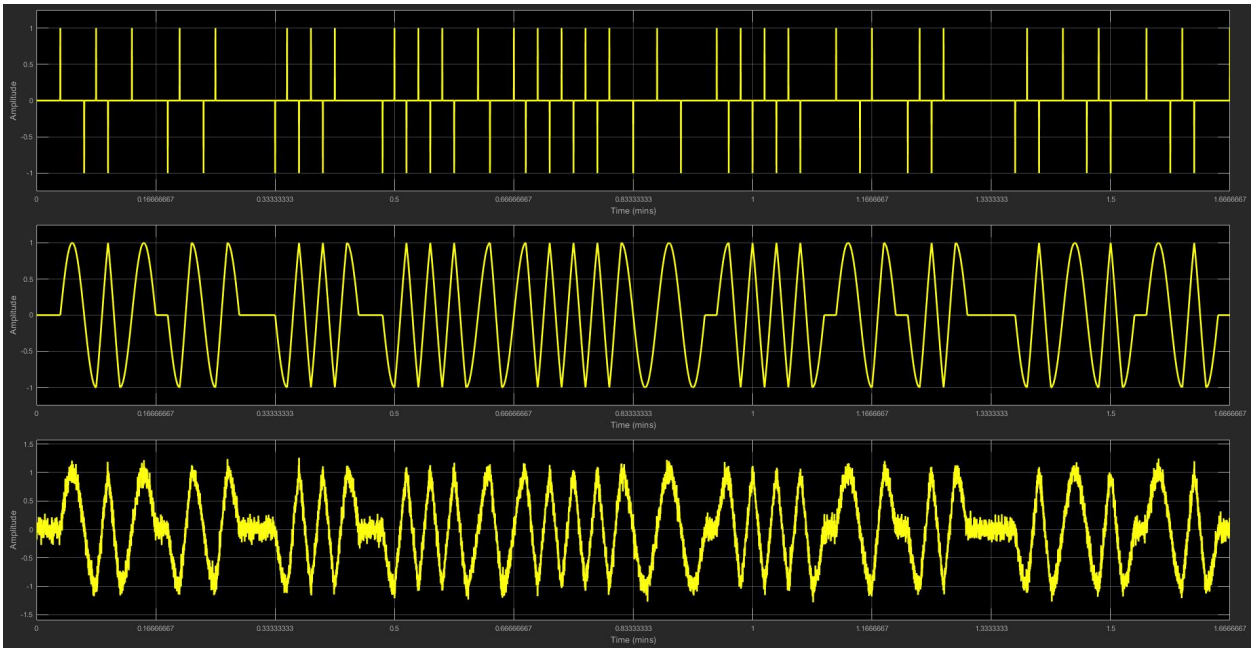


Figure 62: Bipolar encoding with a Full Width Rectangle Shaped Pulse

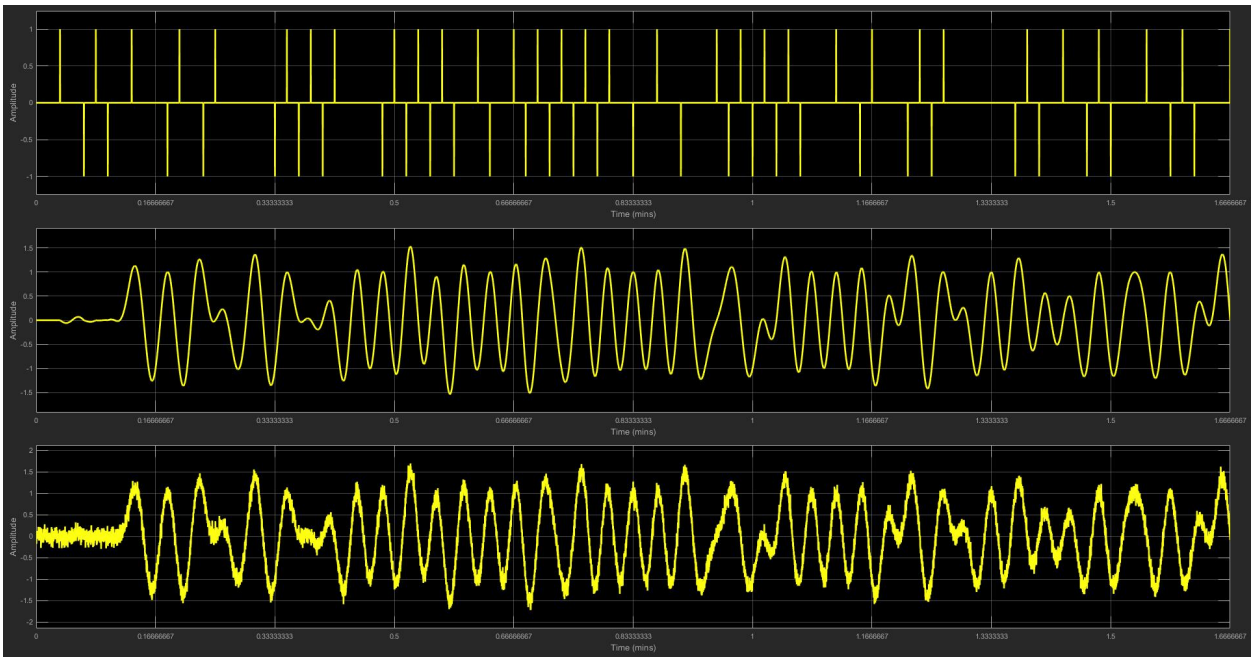


Figure 63: Bipolar encoding with a Sinc Shaped Pulse

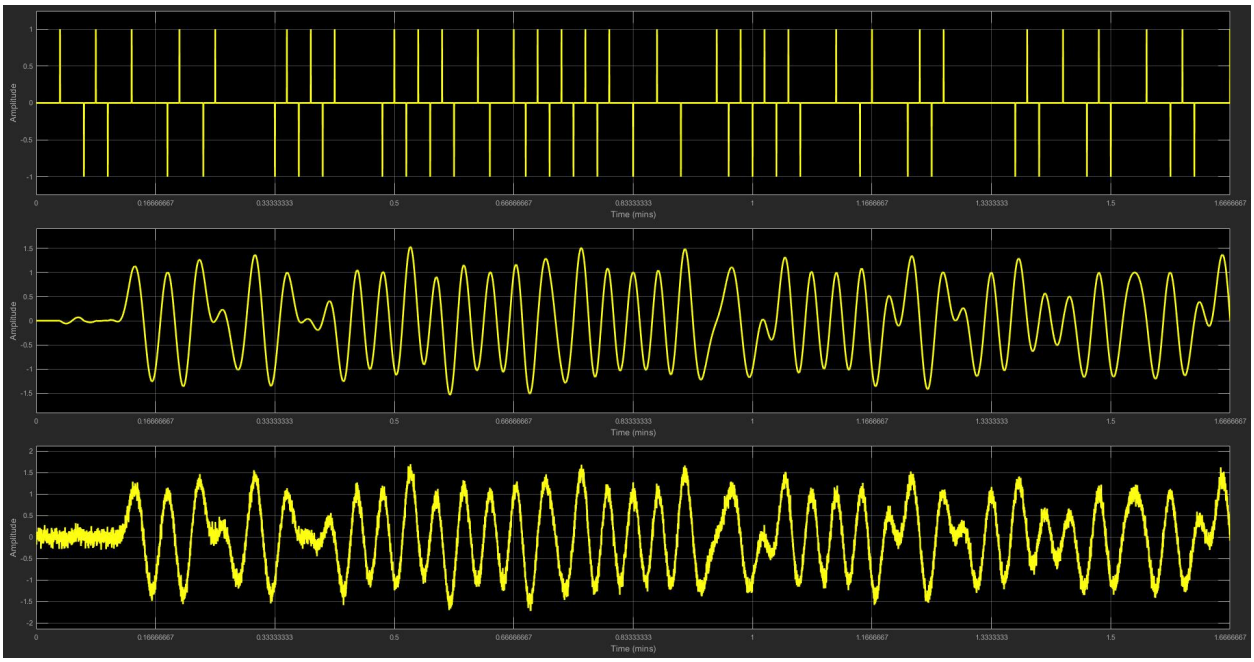


Figure 64: Bipolar encoding with a Sinc Squared Shaped Pulse

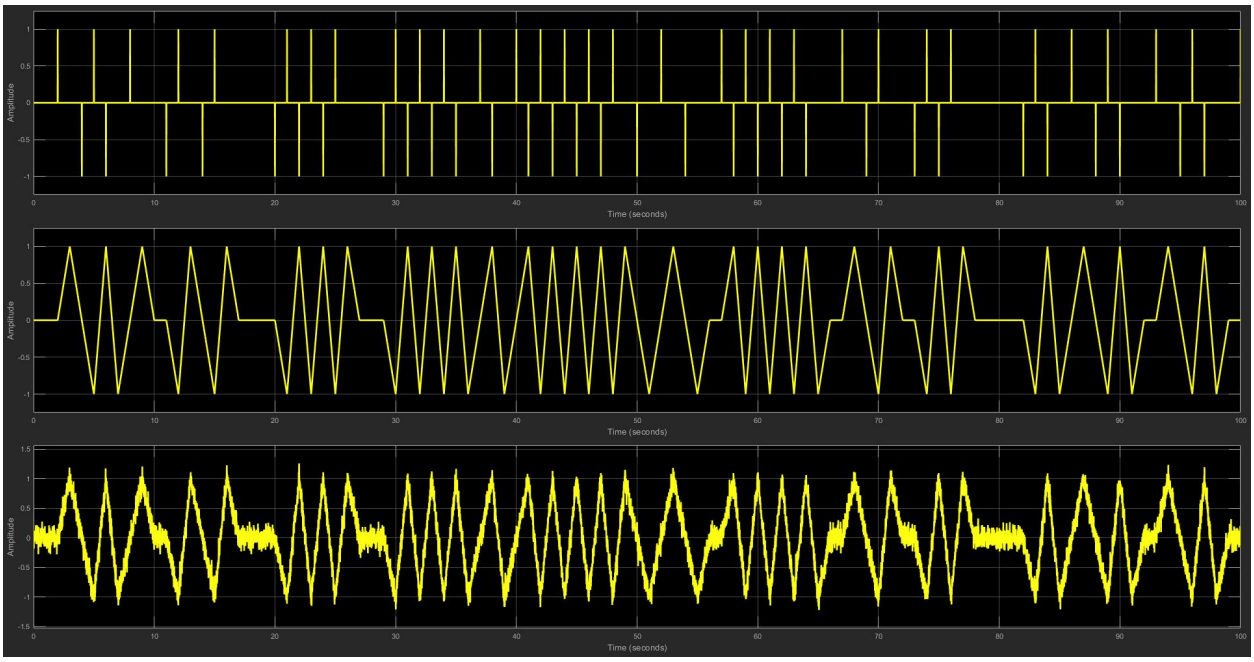


Figure 65: Bipolar encoding with a Full Width Triangle Shaped Pulse

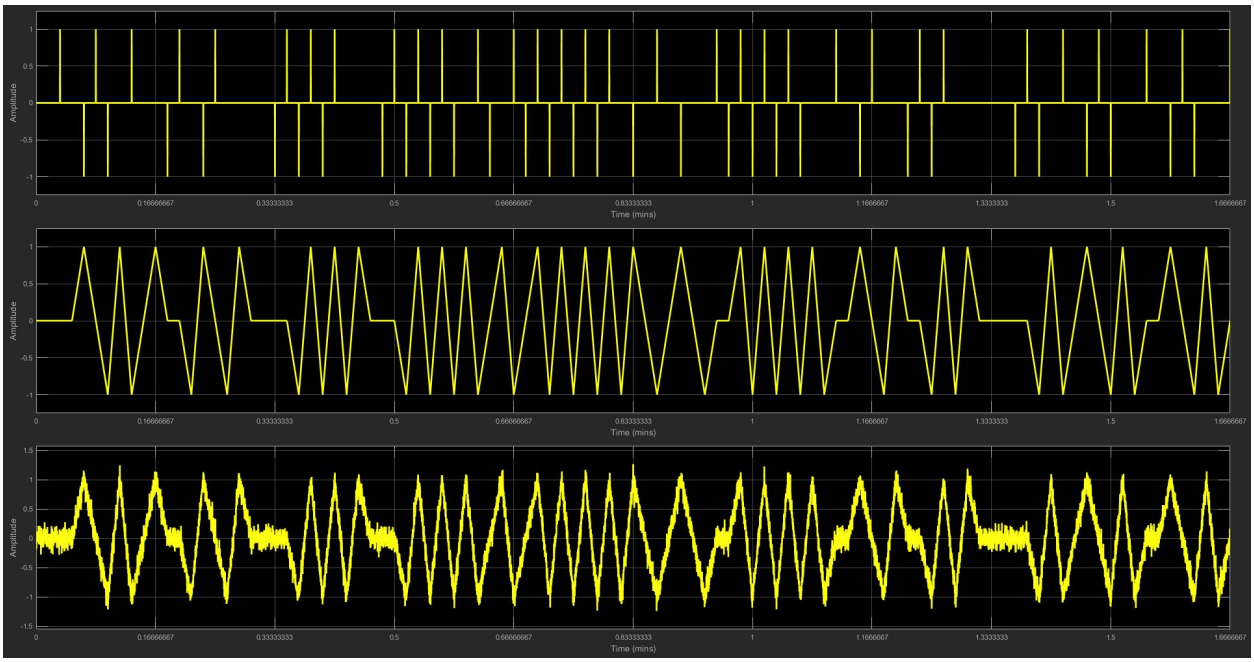


Figure 66: Bipolar encoding with a Half Width Triangle Shaped Pulse

Something that should be noted is that the apparent difference between full width and half with shaped pulses for both Rectangle and Triangle shaped pulses have an identical waveform. The difference is the half width is a delayed signal.

3.3.2 Eye Diagrams

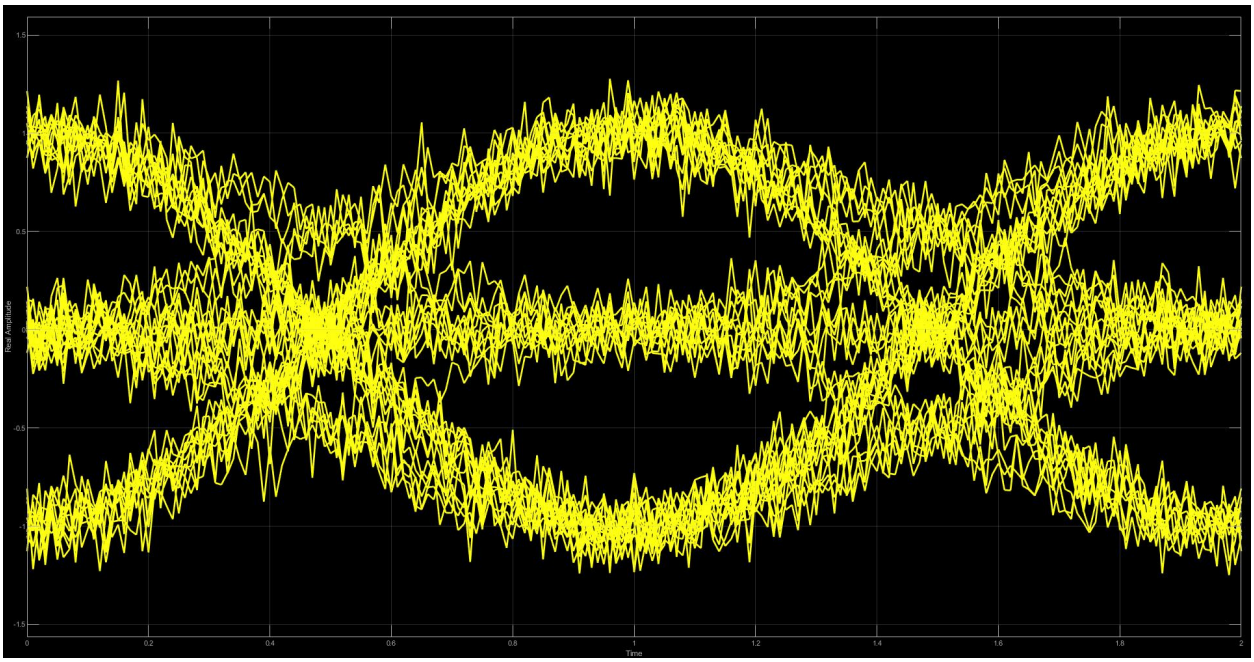


Figure 67: Eye Diagram for Bipolar encoding with a Raised Cosine Shaped Pulse

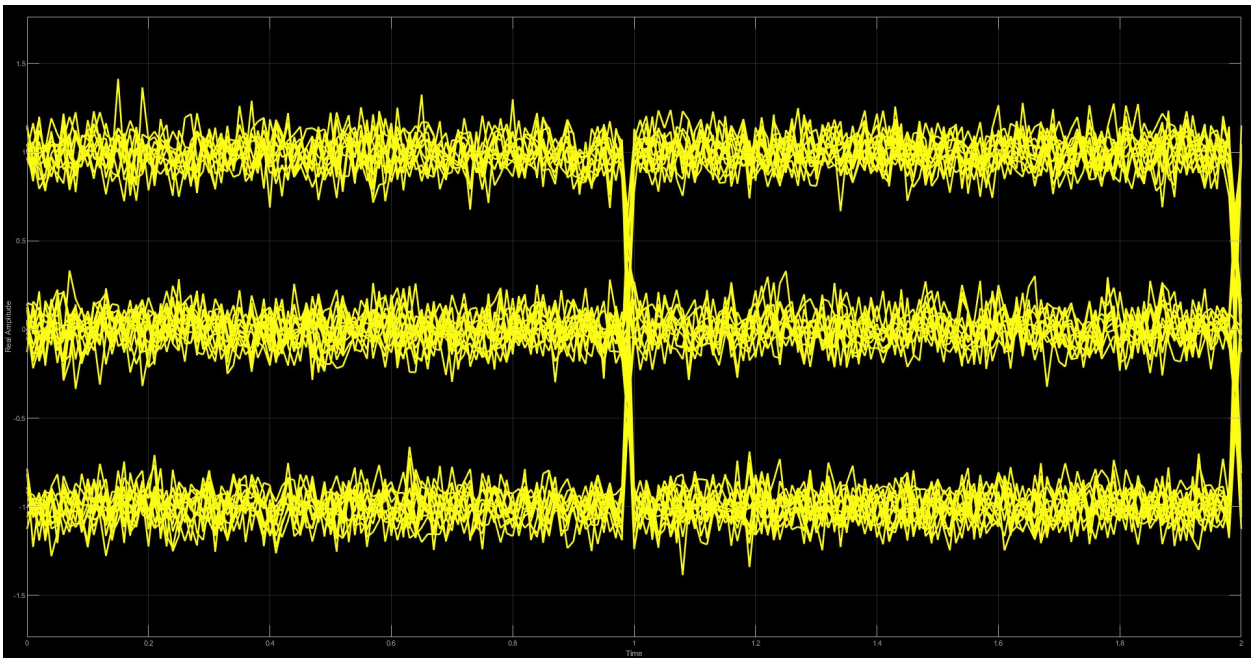


Figure 68: Eye Diagram for Bipolar encoding with a Full Width Rectangle Shaped Pulse

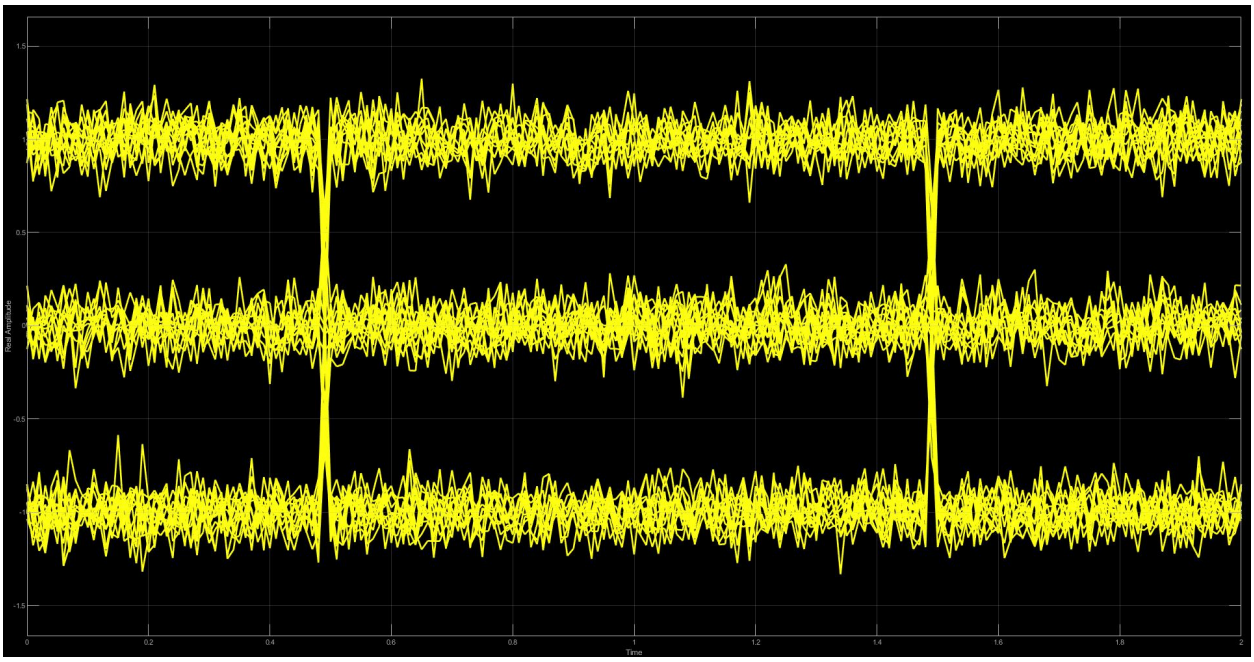


Figure 69: Eye Diagram for Bipolar encoding with a Half Width Rectangle Shaped Pulse

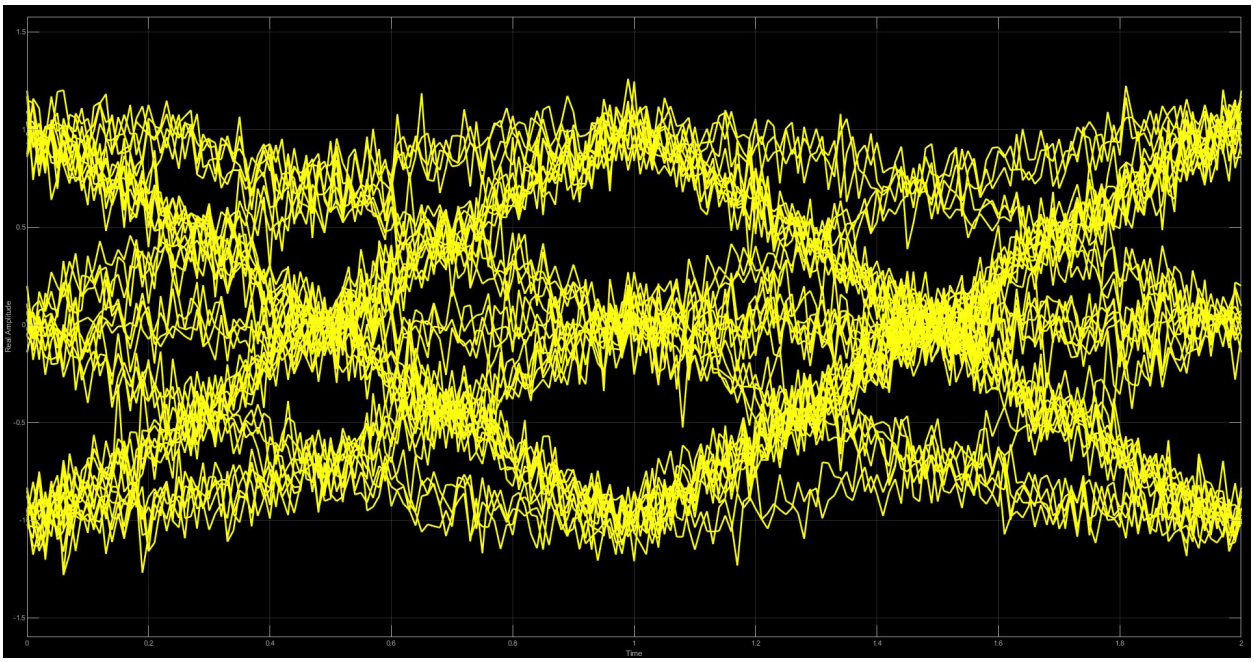


Figure 70: Eye Diagram for Bipolar encoding with a Full Width Rectangle Shaped Pulse

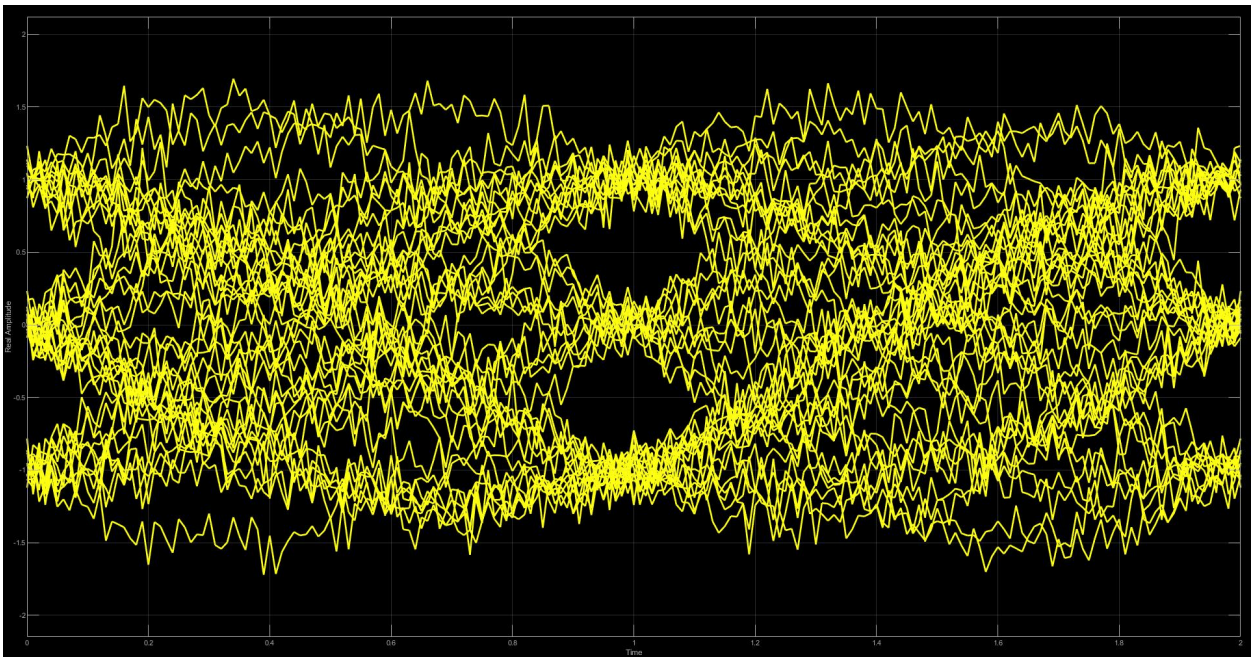


Figure 71: Eye Diagram for Bipolar encoding with a Sinc Shaped Pulse

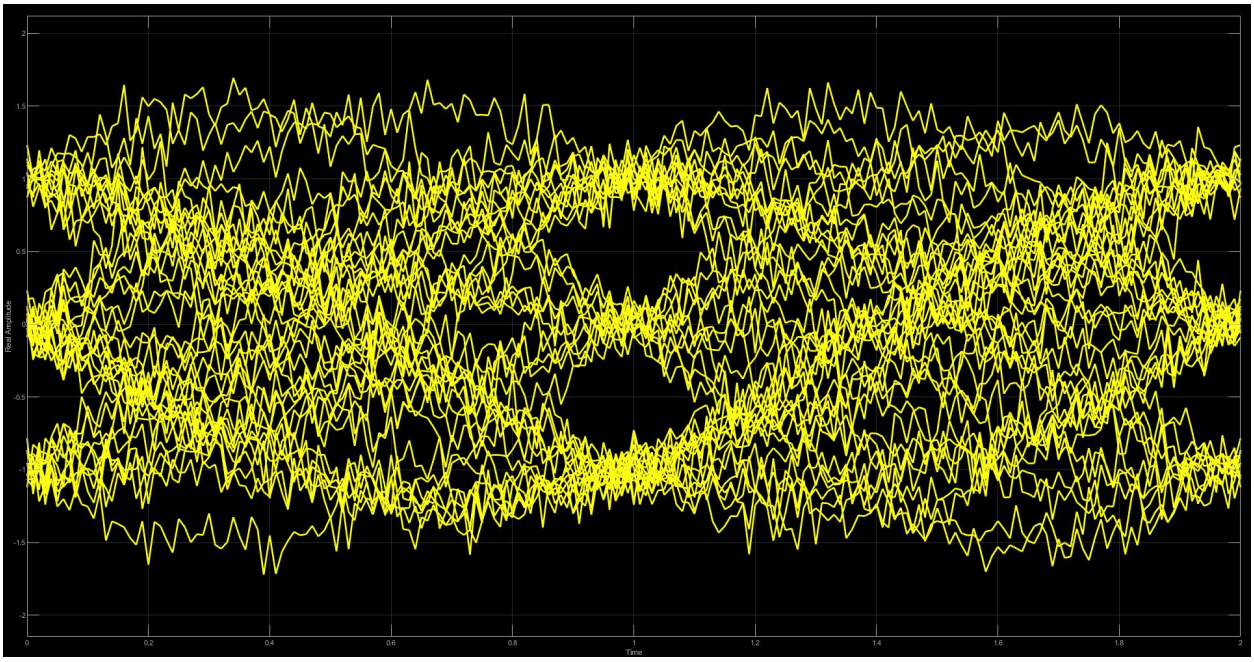


Figure 72: Eye Diagram for Bipolar encoding with a Sinc Squared Shaped Pulse

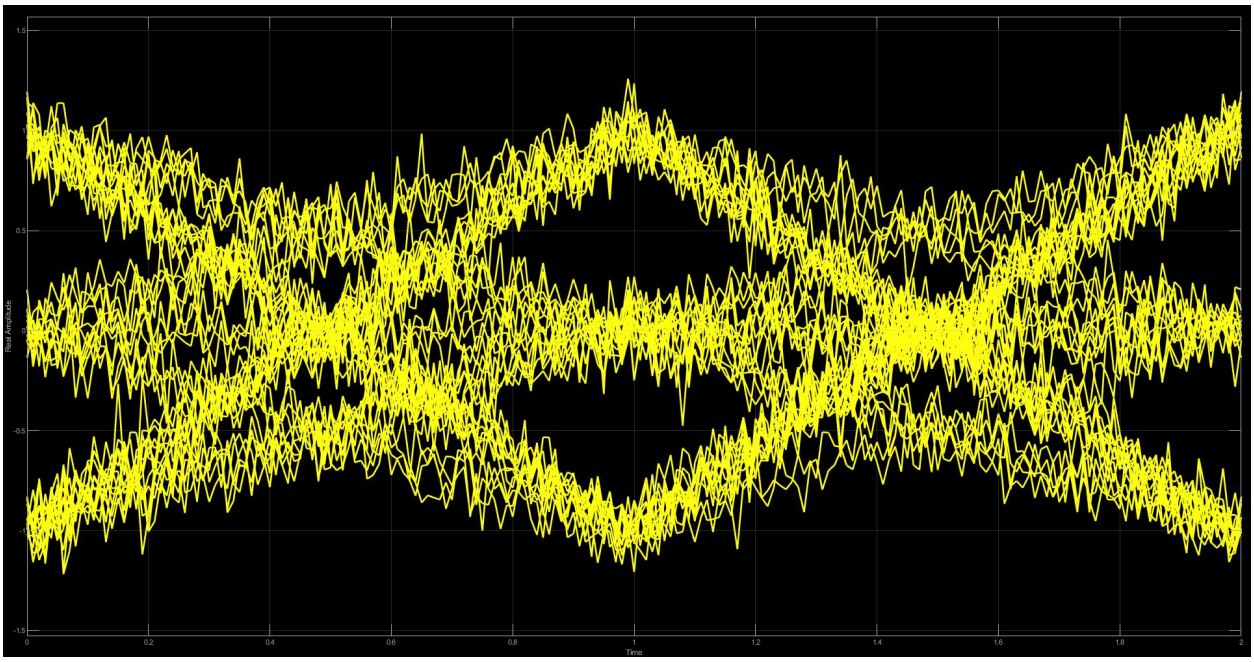


Figure 73: Eye Diagram for Bipolar encoding with a Full Width Triangle Shaped Pulse

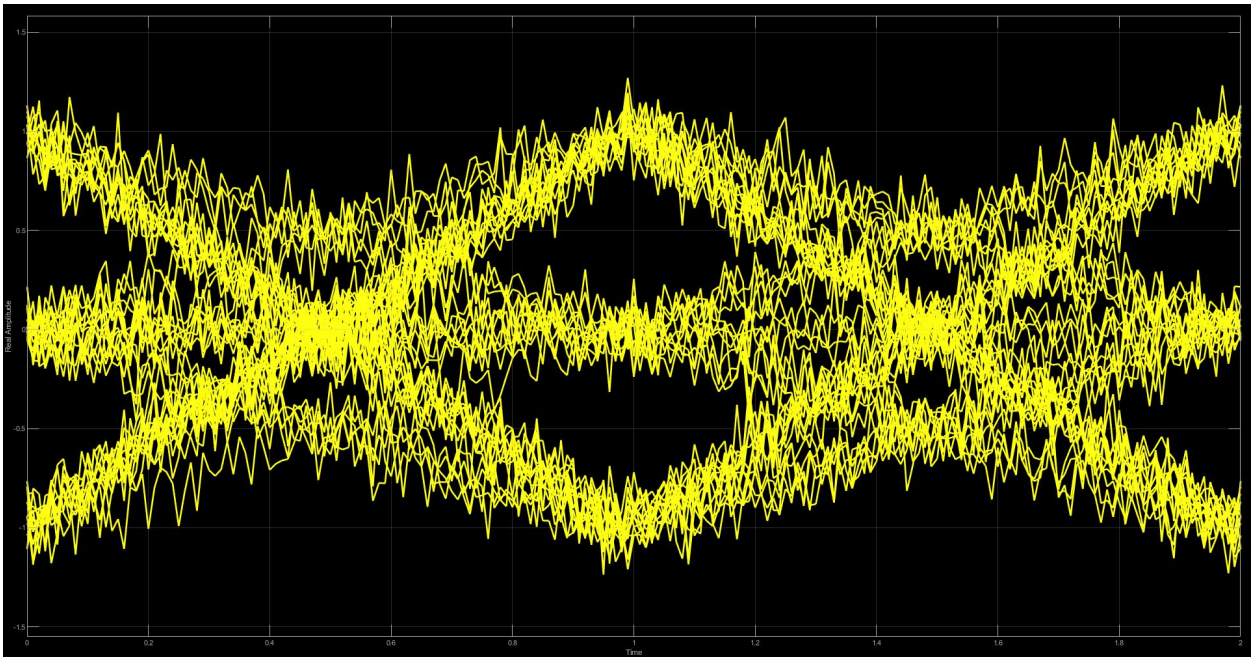


Figure 74: Eye Diagram for Bipolar encoding with a Half Width Triangle Shaped Pulse

When looking at the eye diagrams, it can be seen in the full and half width rectangle pulses that in the half width shaped pulse the decision instant is offset by half the period of the signal.

3.3.3 Spectrum

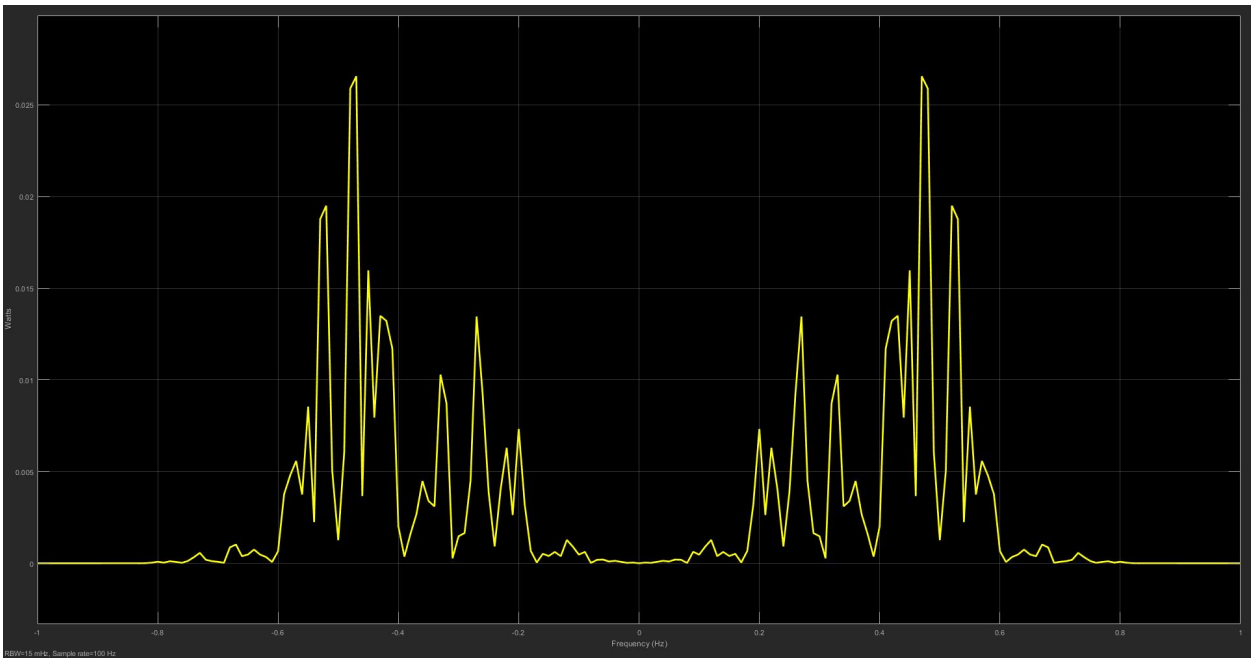


Figure 75: Spectrum for Bipolar encoding with a Raised Cosine Shaped Pulse

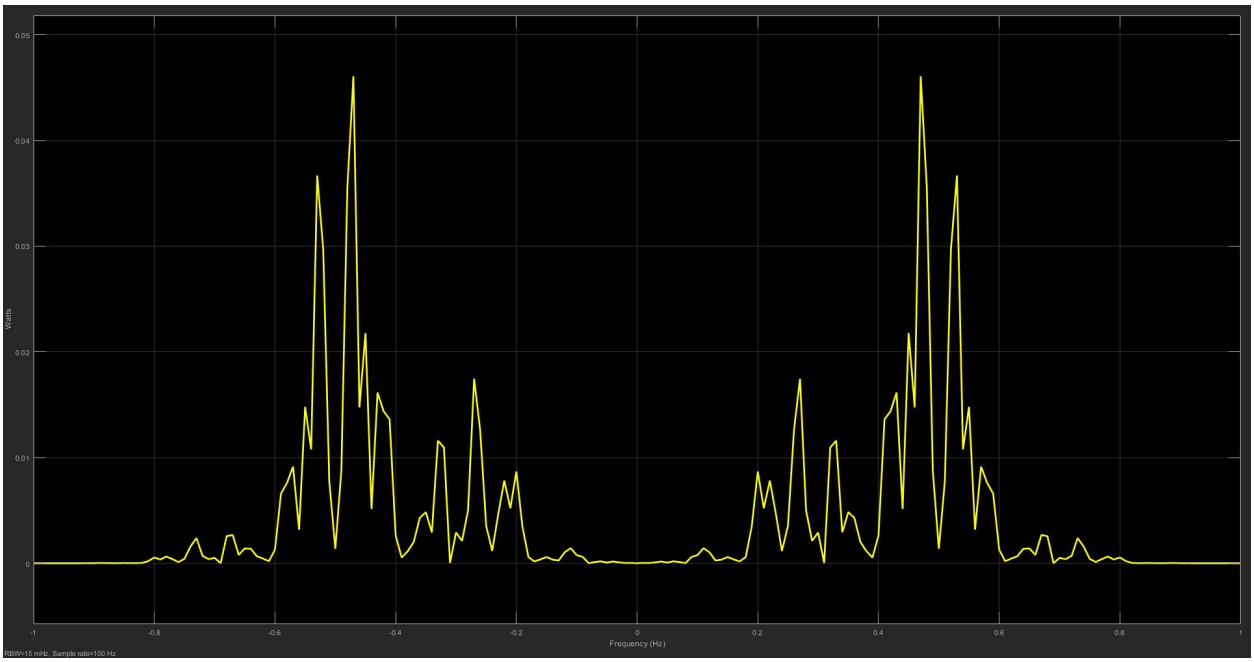


Figure 76: Spectrum for Bipolar encoding with a Full Width Rectangle Shaped Pulse

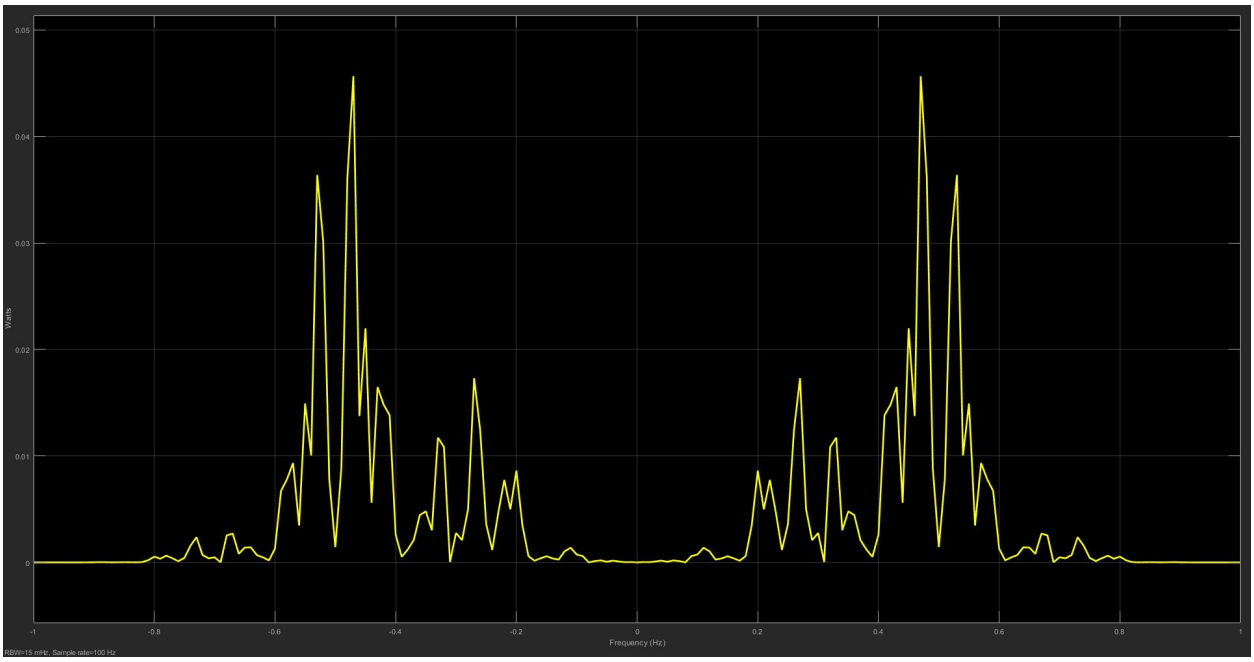


Figure 77: Spectrum for Bipolar encoding with a Half Width Rectangle Shaped Pulse

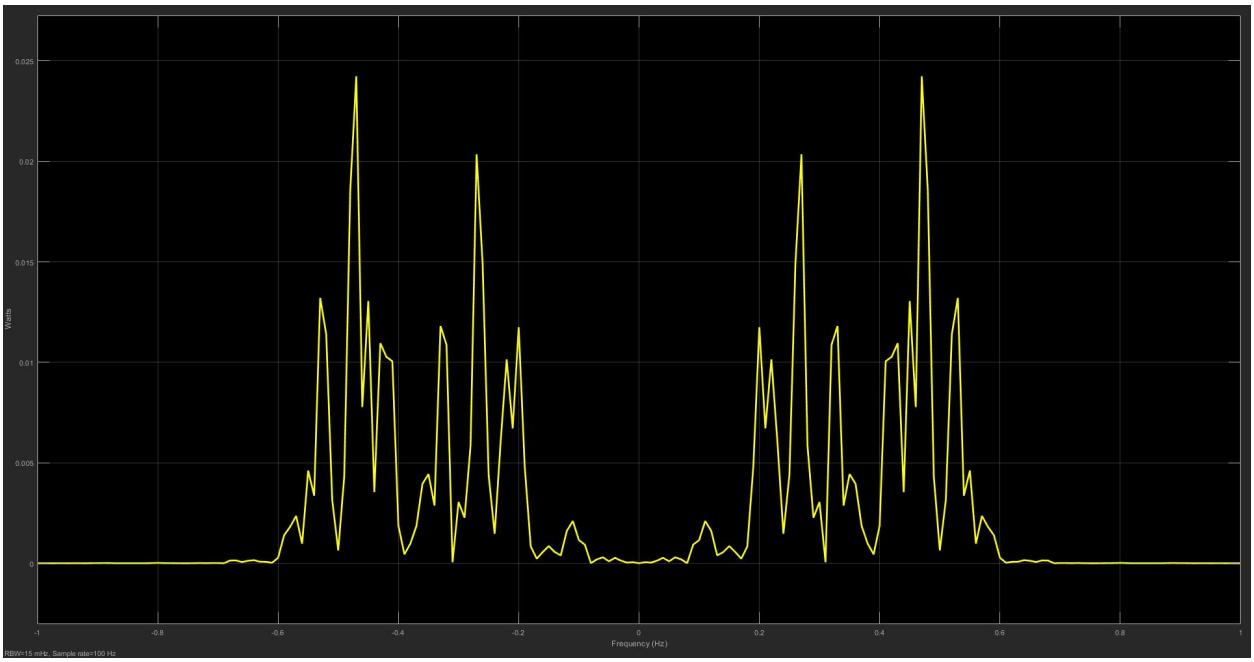


Figure 78: Spectrum for Bipolar encoding with a Sin Shaped Pulse

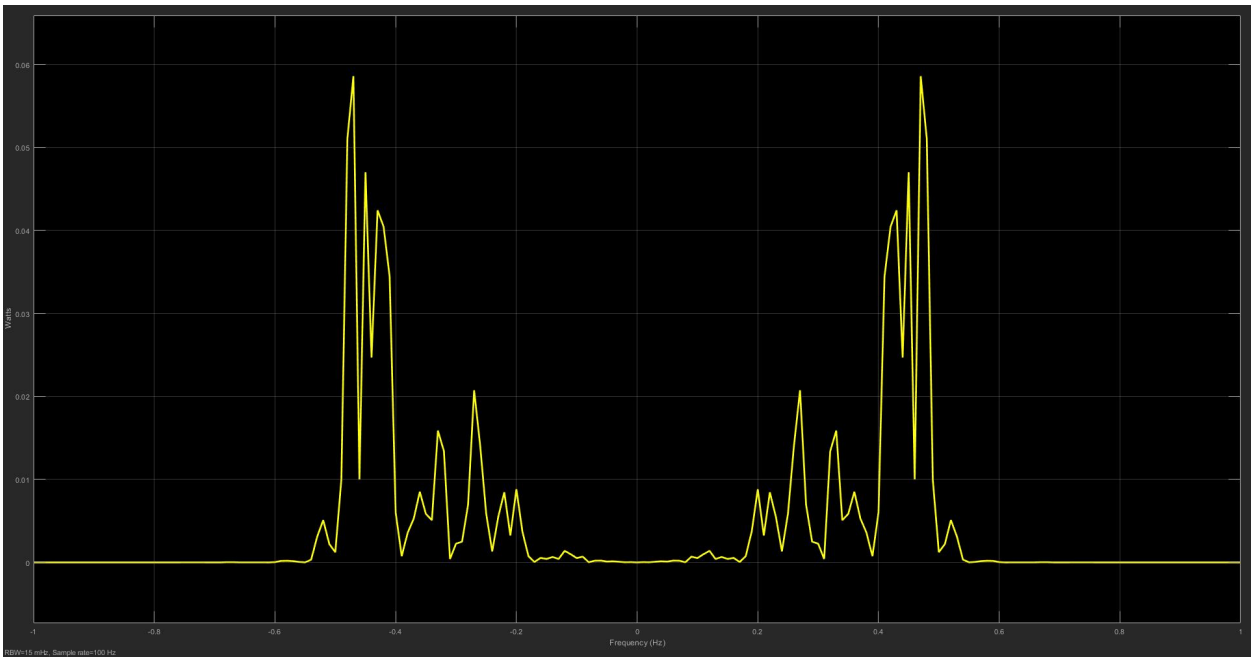


Figure 79: Spectrum for Bipolar encoding with a Sinc Shaped Pulse

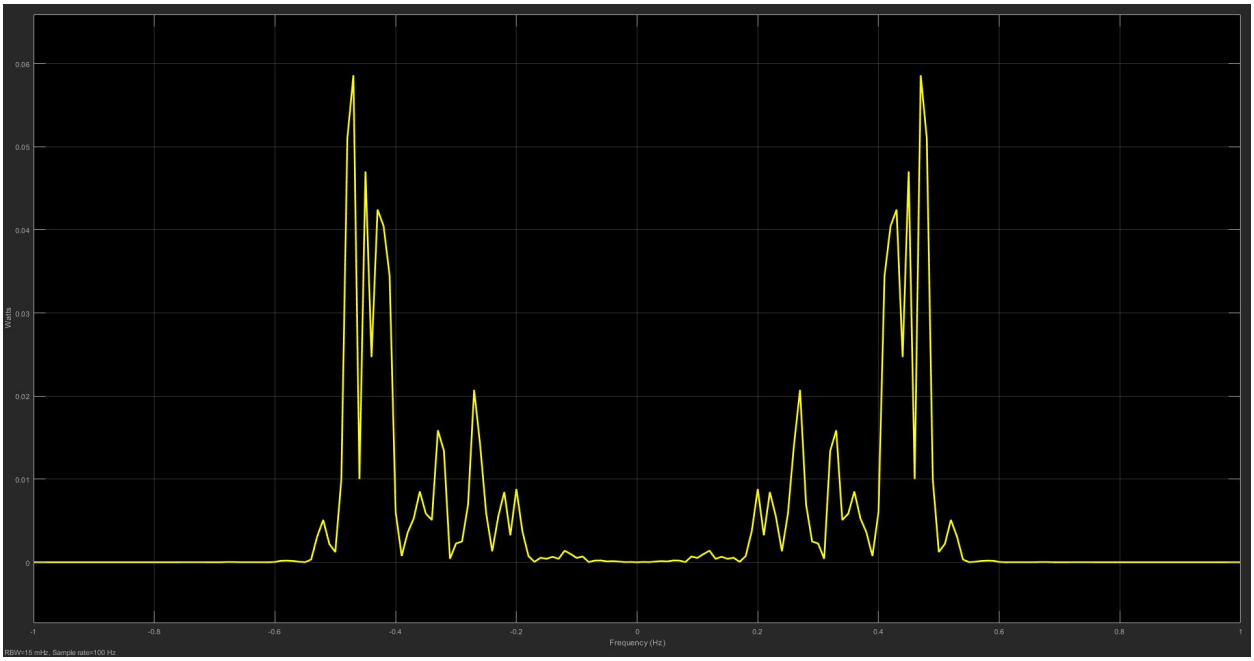


Figure 80: Spectrum for Bipolar encoding with a Sinc Squared Shaped Pulse

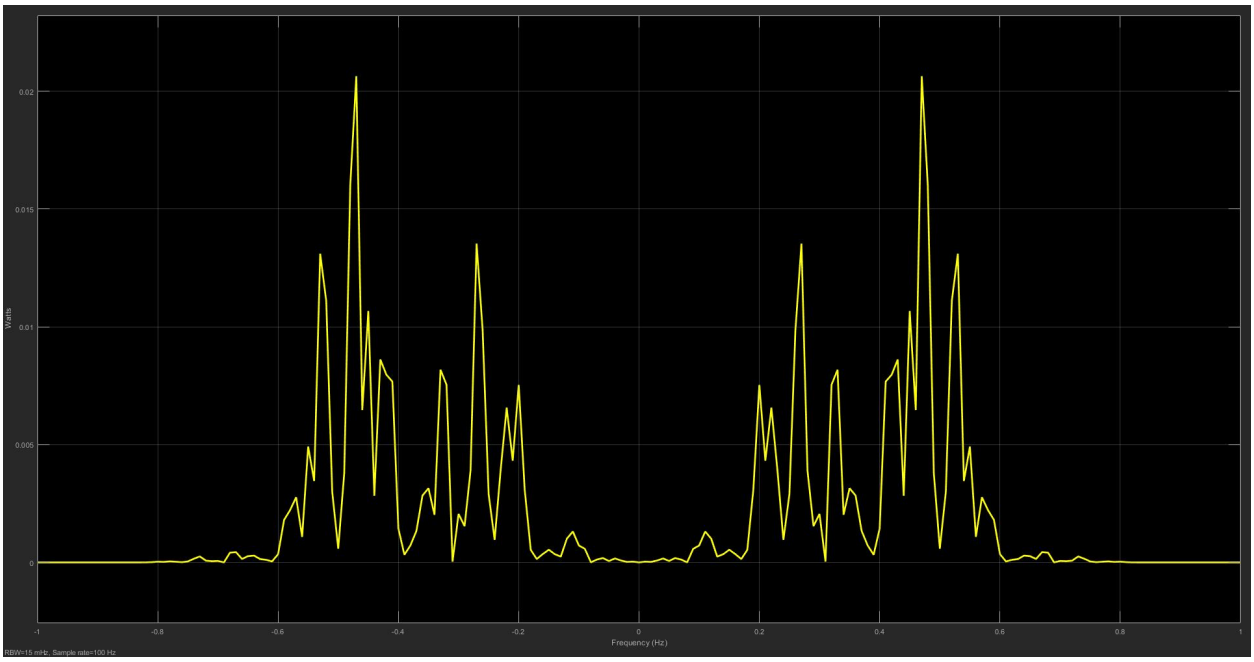


Figure 81: Spectrum for Bipolar encoding with a Full Width Triangle Shaped Pulse

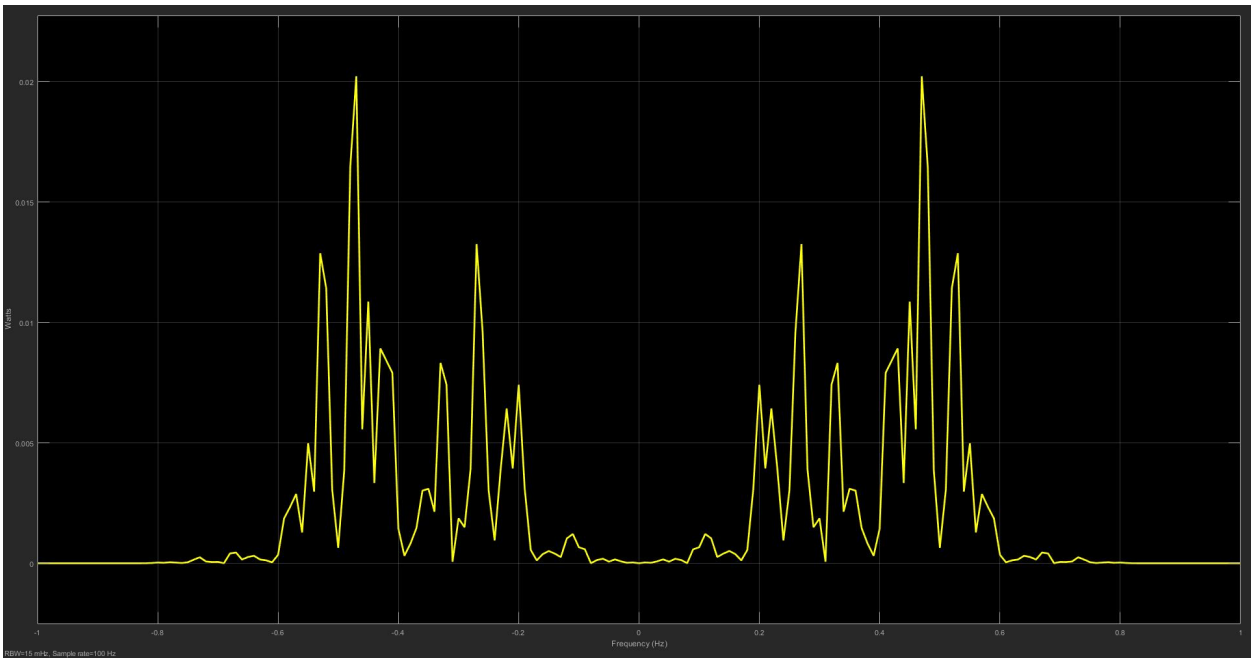


Figure 82: Spectrum for Bipolar encoding with a Half Width Triangle Shaped Pulse

3.4 Differential

3.4.1 Time Signal

Below is the time signal for Differential encoding.

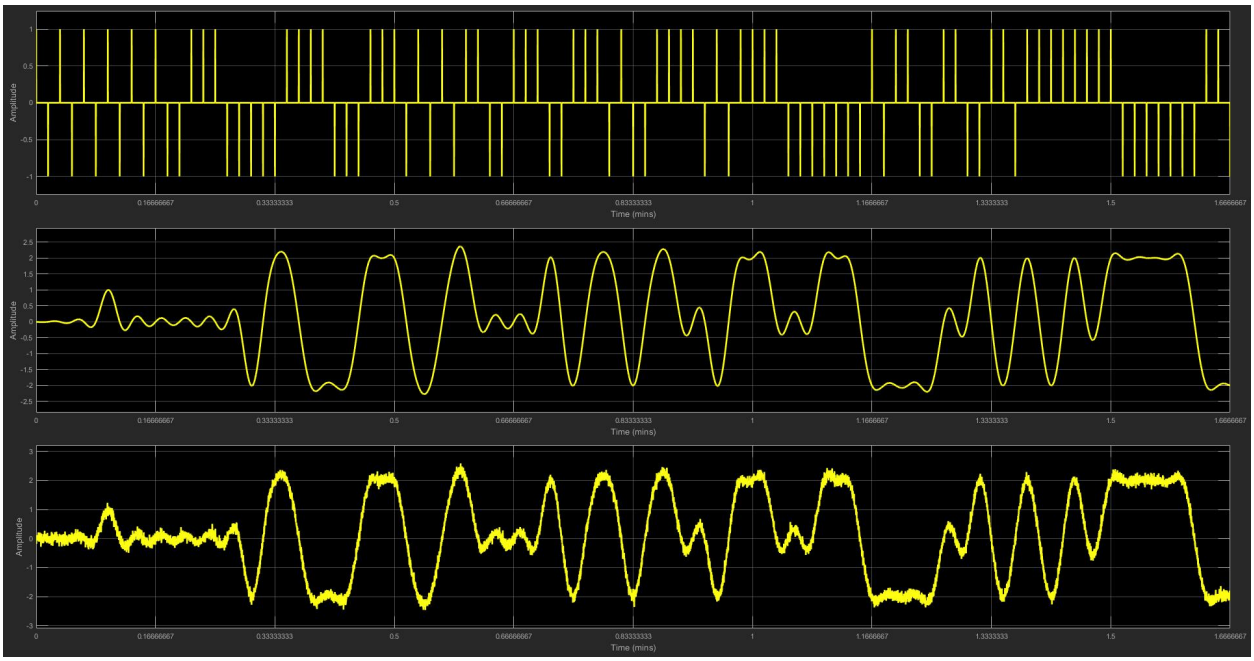


Figure 83: Differential encoding with the Duobinary Shaped Pulse

3.5 Eye Diagram

Below is the Eye Diagram for Differential encoding.

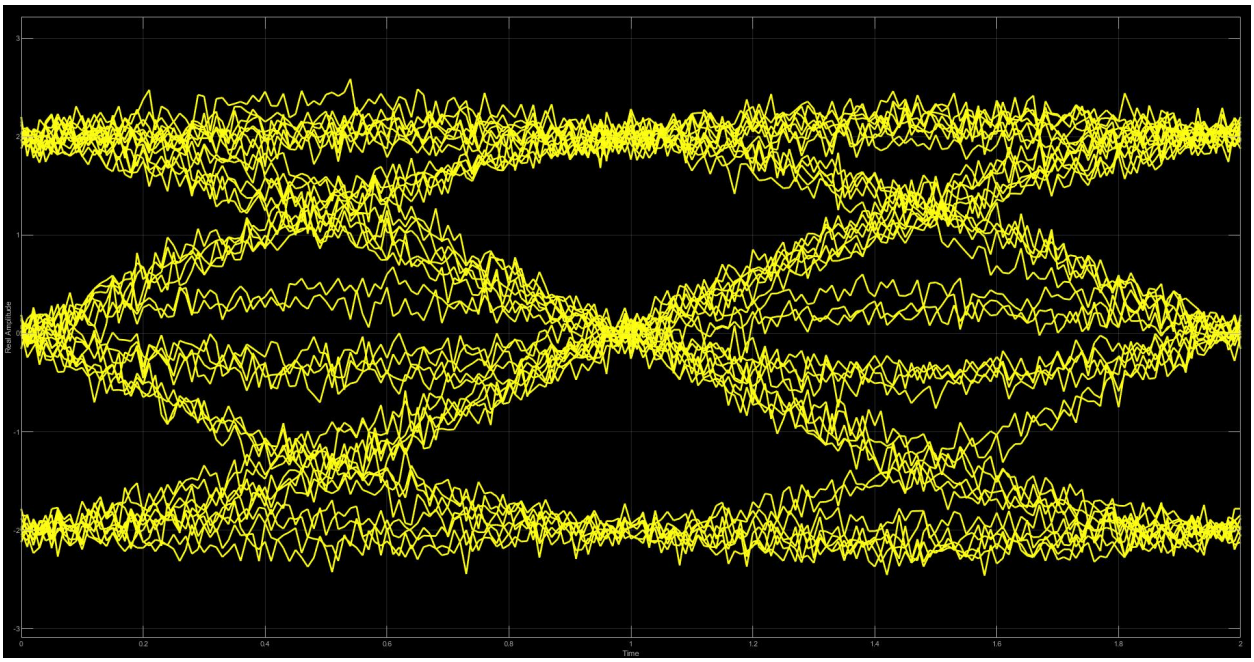


Figure 84: Eye Diagram for Differential encoding with the Duobinary Shaped Pulse

3.6 Spectrum

Below is the Spectrum for Differential encoding

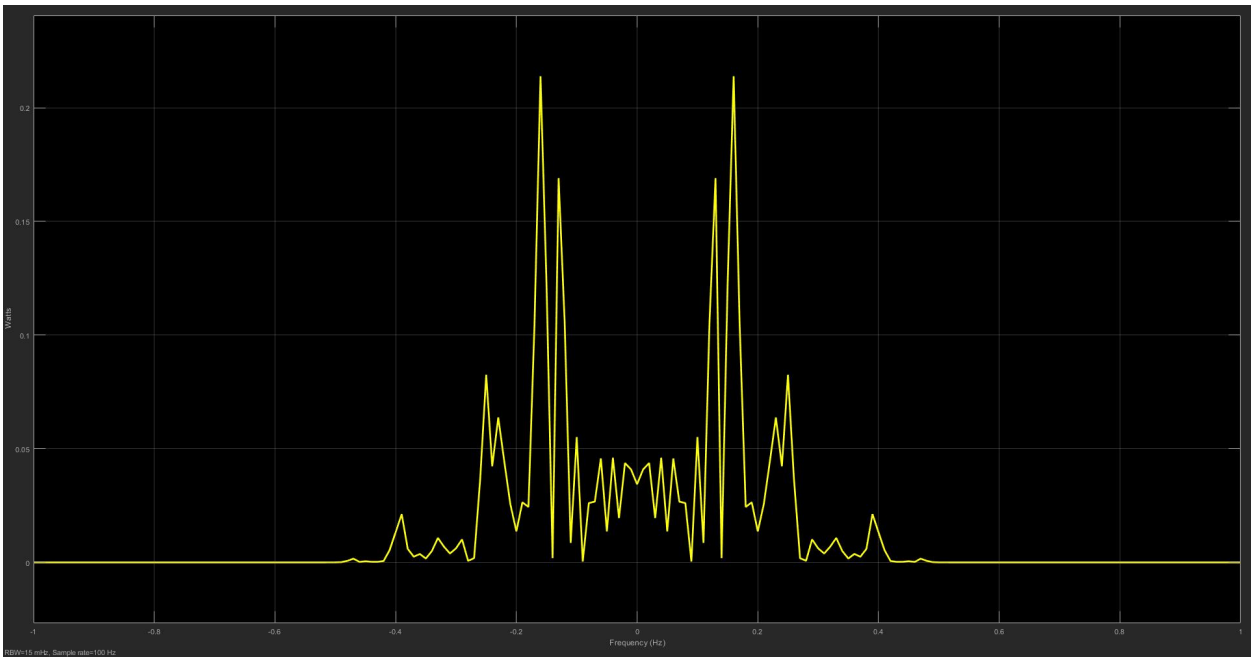


Figure 85: Spectrum for Differential encoding with the Duobinary Shaped Pulse

4 Summary

The goal for this lab was to computationally analyze the different pulse shapes and what their effects are different types of line codes. On-Off line coding is simpler than the other line codes, but it looking at the spectrum that it produces, there is a large DC component to the signal. Polar line encoding removes this DC component, but Bipolar encoding does the same and requires less power to transmit. As for the different pulse shapes, Raised Cosine, Sinc and Sinc Squared are a good middle ground between the narrow bandwidth of Sin Pulses, and the large noise tolerance that the Rectangle and Triangle Pulse off. The Differential line code can only be used with the Duobinary pulse shape. The advantage that differential line code offer over the other the types of line code is that it has a nice error detection scheme built in.