Department of Electrical & Electronics Engineering

Abdullah Gül University

EE3001 Lab 7

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Submitted by:

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Grade: / 100

OBJECTIVE

The objective of this lab exercise is to present amplitude shift keying modulation and demonstrate its application through the design of a transmitter and receiver device using NI LabVIEW with the NI USRP 2900 platform. Other than that, this lab helps to introduce digital communications through the usage of Amplitude-Shift Keying (ASK), the simplest form of digital modulation. Specific objectives include examining symbol mapping, pulse shaping, matched filtering, threshold detection, pulse synchronization, transmitter design, receiver design, phase synchronization, and alignment of receiver and transmitter bit streams. Along these objectives, participants will gain experience and comprehension of ASK modulation, digital communication algorithms, and phase synchronization applications.

BACKGROUND

In the background section of lab report, my purpose is to deliver a complete overview of the experiment conducted, along with the essential theoretical foundation and background information. The purpose of this part is to allow the transmitter to understand the scientific background of experiments and their objectives.

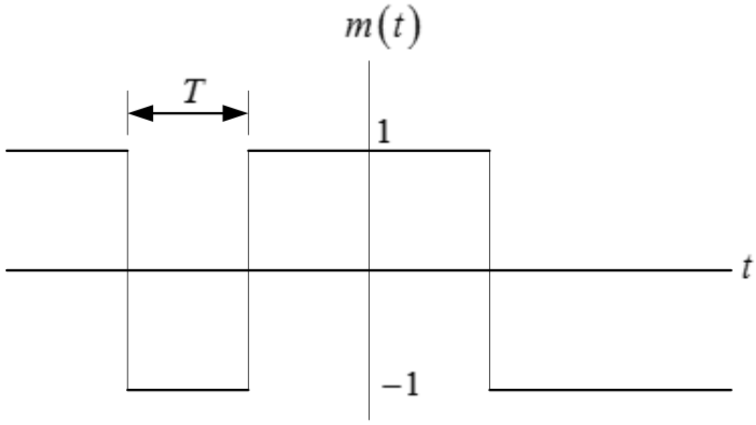

Figure.1 Binary Message Waveform

In the polar NRZ format, a binary 1 is characterized by a pulse of amplitude “1” and a binary “0” by amplitude pulse of -1. Each pulse has duration of T seconds. Hereby, the symbol rate is $1/T$. The ASK formula is:

$$g_{ASK} = A[1 + m(t)]\cos(2\pi f_c t),$$

Where,

$f_c = Carrier\ Frequency$

$A = Carrier\ Amplitude$

$$g_{ASK} = 2A\cos(2\pi f_c t),$$

$$g_{ASK} = 0,$$

Depending on whether the corresponding message bit is a 1 or a 0

The outlining scientific principles and theories that form the basis of our experiment has been begun. This includes explaining the relevant theories, laws, and equations conducting the investigation. The experiment emphases on symbol mapping and bit value symbols, which are fundamental ideas in data transmission and coding. Symbol mapping refers to the process of giving symbols to specific bit patterns, while bit value symbols define the value of a bit within a symbol. These concepts play a crucial part in different communication systems and coding structures.

Bit Value	Symbol
0	$-1+j0$
1	$1+j0$

Table.1 ASK Symbol Mapping

In this lab project, symbols are transferred along pulses, the form of which plays a crucial role in shaping the bandwidth of the transmitted signal will be observed. In order to transition from symbols to pulses, we will firstly attach 1 "$L-1$" zeroes after every symbol. Hereby, higher upsampling factor L simplifies the digital-to-analog conversion in the transmitter, although demanding faster digital processing. For aim, $L = 20$ will be entered. The upsample function shows the execution of this operation efficiently.

$$T_x = \frac{T}{L}$$

or a sample rate of

$$\frac{1}{T_x} = L\frac{1}{T},$$

If we operate the upsampled signal to a filter with an impulse response $g_{Tx}[n] = g_n$, where g_n is a rectangular pulse of unit amplitude and length L samples, each symbol at the filter output will be denoted by a rectangular pulse. $Figure$ 2 illustrates the effect of upsampling and filtering: waveform (a) represents the symbol sequence existing in every T seconds, waveform (b) exhibits the symbol sequence after upsampling, and waveform (c) shows the upsampled symbol sequence post-filtering by the pulse-shaping filter. Remarkably, waveform (c) look like a discrete-time version of the polar NRZ message waveform described in Figure 1. A key advantage of this sequence of steps in generating the message waveform is that the impulse response $g_{TX}[n]$ of the pulse-shaping filter need not be rectangular.

At the end, the background section delivers a thorough comprehension of the experiment by illuminating the scientific principles, describing the experimental setup, and presenting the related theoretical derivations and operations. The usage of equations in images confirms their accurate depiction and conservation along the report, contributing to the general clarity and reliability of the information showed.

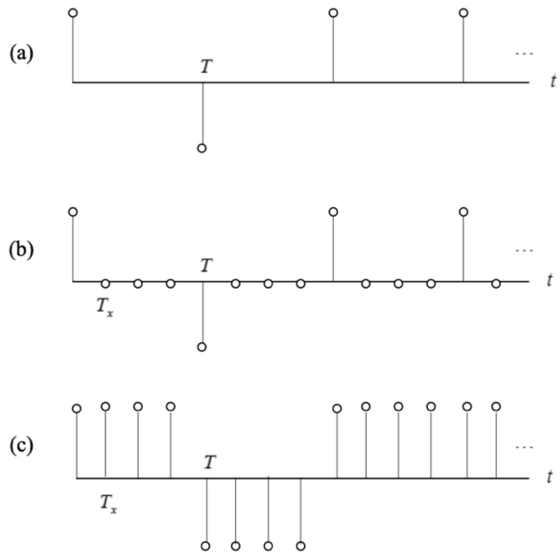

Figure.2 (a) Symbol sequence, (b) Upsampled symbol sequence, (c) Filtered upsampled symbol sequence.

The provided ASKRxTemplate.gvi file attends as a template for the receiver, offering six interface functions throughout USRP diagram. In order to ensure, the receiver takes two frames of data upon each implementation, the receiver computes the number of samples in a frame based on message length, symbol rate, and actual IQ rate from the front panel inputs. This number is then doubled and used as the input for Fetch Rx Data.

After fetching the data, it undergoes processing. Firstly, it passes through a fifth-order Chebyshev bandpass filter with high and low cutoff frequencies of 110 kHz and 90 kHz, respectively. The sampling frequency for this filter is obtained from the reciprocal of the "dt" component of the waveform returned by Fetch Rx Data, designated as 1/T.

Subsequently, the real part of the filtered complex array is extracted to acquire the envelope, simulating a full-wave rectifier. This envelope then passes through a matched filter, produced using MT Generate Filter Coefficients with modulation type set to ASK. The "matched samples per symbol" parameter is computed from the actual IQ rate (1/T) and symbol rate.

For picturing, the output of the matched filter is linked to a Convolution function, which feeds into the Cluster Properties function for show on the Baseband Output graph. Additionally, an eye diagram is executed to depict the baseband output signal, with the horizontal axis scaled to exhibit one or two symbol times.

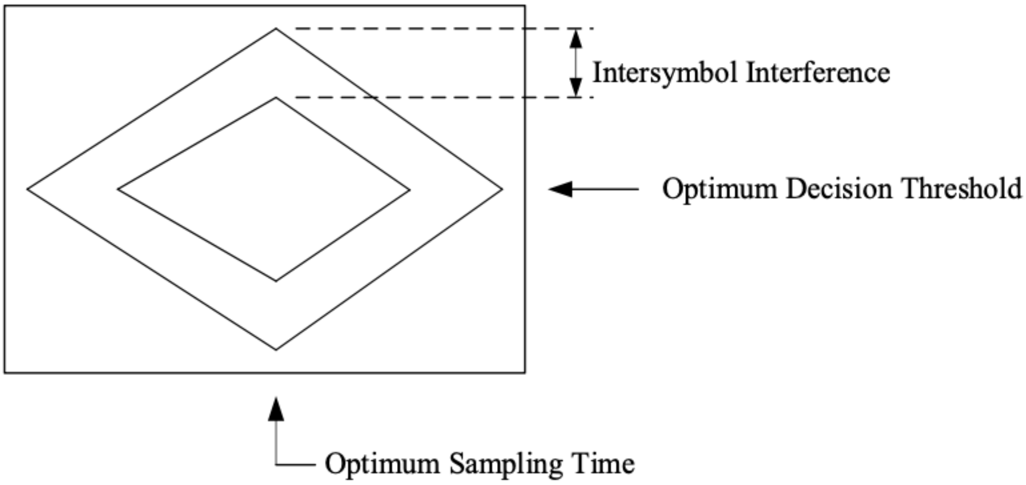

Figure.3 Stylized Eye Diagram

Figure 3 demonstrates an eye diagram, a representation of a baseband signal with its horizontal axis scaled to represent one or two symbol times. This diagram proposals signal quality, timing synchronization, and the presence of intersymbol interference.

In the receiver template, the Modulation Toolkit function MT Format Eye Diagram is delivered to enable eye diagram generation. The baseband output waveform is linked to the "waveform" input, while the symbol rate (Hz) is obtained from the front panel control. The "eye length" parameter is set to 2 to confirm sufficient visualization.

Additionally, PulseAlign(real) is located on the block diagram to align the baseband waveform, with the calculated M samples per symbol connected to the "receiver sampling factor" input. Once aligned, the waveform can be sampled using Decimate (single shot) with the decimating factor set to M.

In order to determine each received sample represents a 1 or a 0, comparison with a threshold is necessary. The Mean DBL function calculates this threshold, and the comparison result is the receiver's digital output, presented as a Boolean array. Conversion to an integer array using a Boolean to Integer function finishes the building of the ASK receiver.

RESULTS

- PRELAB RESULTS FOR TRANSMITTER AND RECEIVER

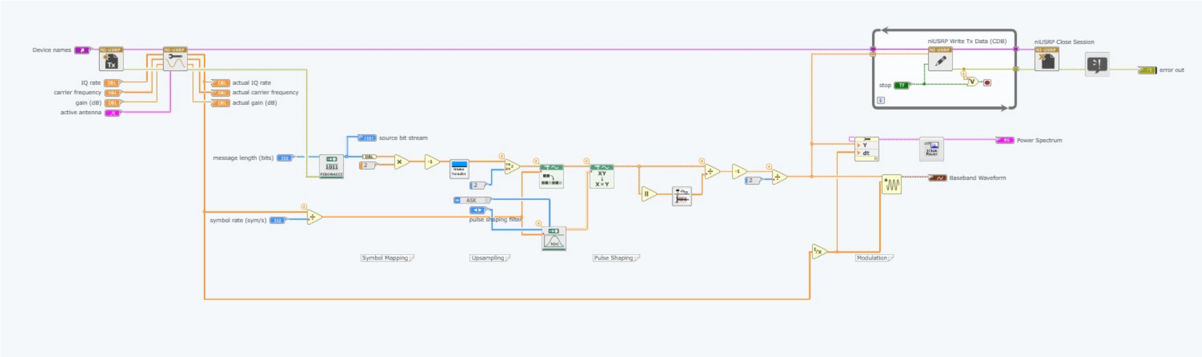

Figure-3 Transmitter Diagram,

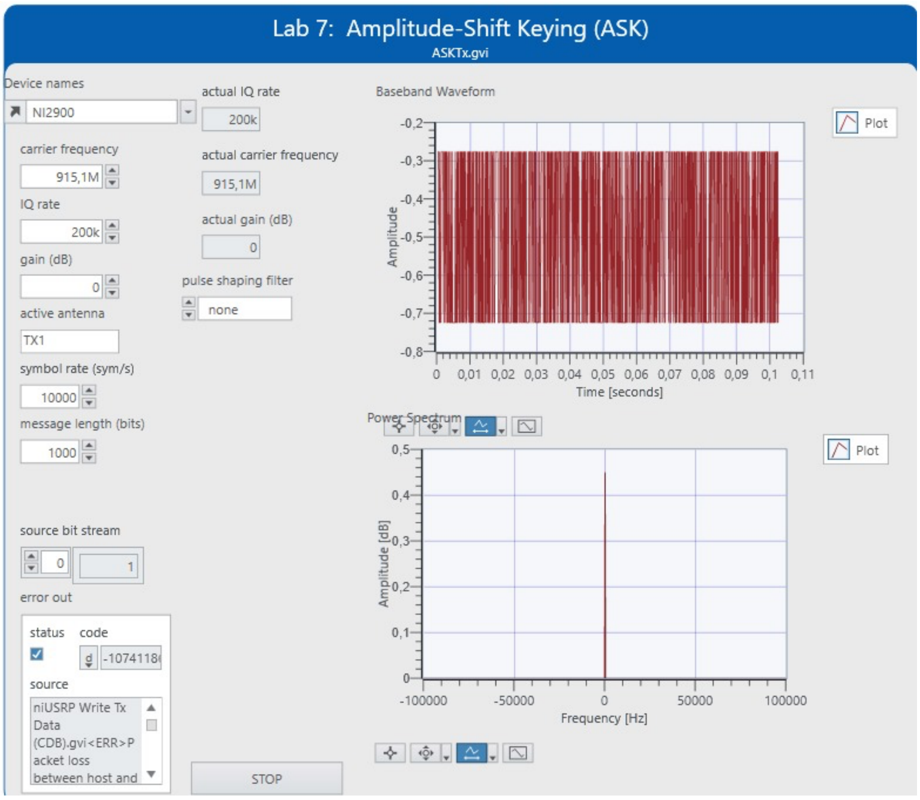

Figure-4 Transmitter Panel

Combine hardware setup, transmitter configuration, signal spectrum observation, and pulse shaping filter modification. Connect a loopback cable and attenuator between the TX 1 and RX 2 connectors of the USRP, link it to your computer, and power it. Open LabVIEW, access the prelab transmitter, and configure it with specific parameters: Carrier Frequency (915.1 MHz), IQ Rate (200 kHz), Gain (0 dB), Active Antenna (TX1), Symbol rate (10,000 symbols/s), Message Length (1000 bits), and select "None" for the pulse shaping filter. Execute the transmitter, then observe the signal spectrum after transmission, measuring the null-to-null bandwidth and assessing the spectral roll off rate. Print a copy of the spectrum.

Modify the pulse shaping filter to "Root Raised" for a root-raised-cosine filter, re-run the program, observe the spectrum again, measure the null-to-null bandwidth, and print another copy for comparison.

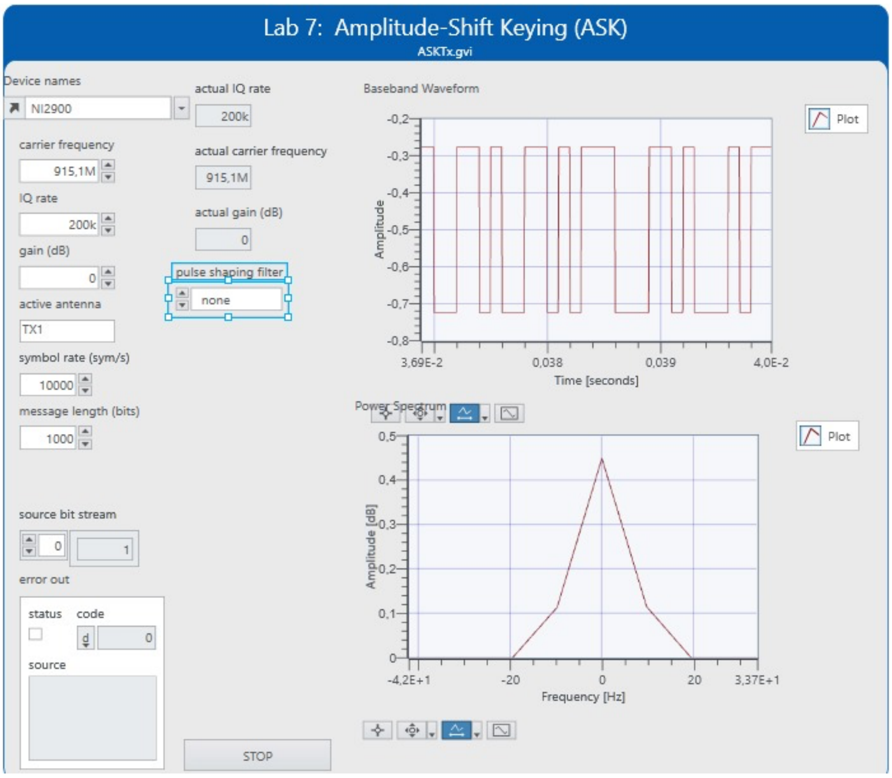

Figure-5 Transmitter Pulse Shaping Filter (None)

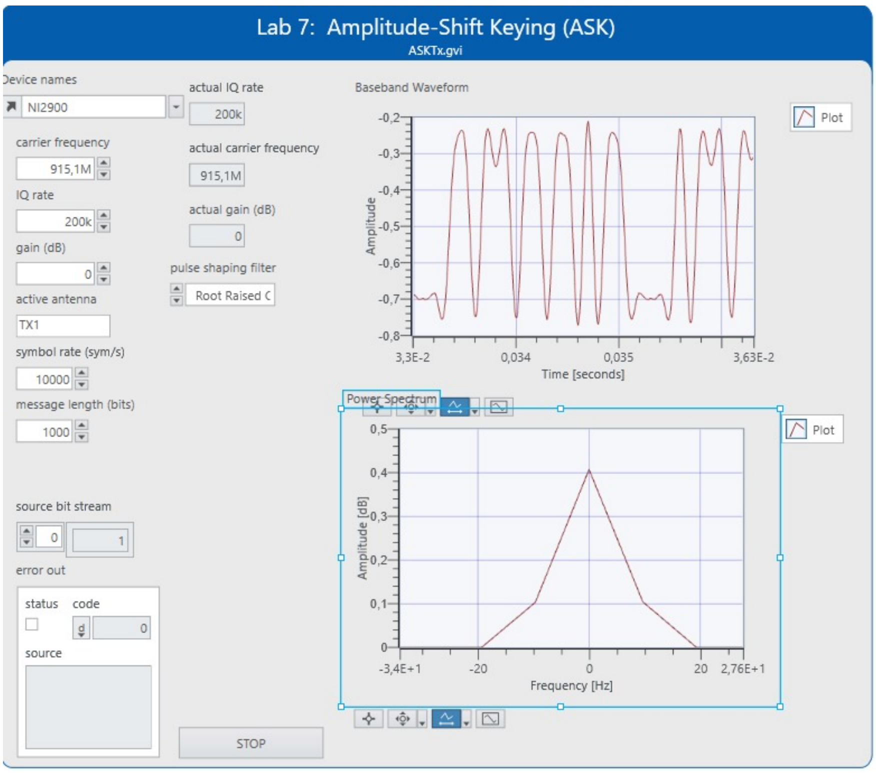

Figure-6 Transmitter Pulse Shaping Filter (Root-Raised Cosine Filter)

Ensure the receiver is configured with Carrier Frequency (915.0 MHz), IQ Rate (1 MHz), Gain (0 dB), Active Antenna (RX2), Symbol rate (10,000 symbols/s), Message length (1000 bits), and no pulse shaping filter. Run the transmitter, then the receiver. Use horizontal zoom to view individual pulses on the demodulated waveform, checking if they resemble triangular pulses. Analyze the eye diagram, noting the optimum sampling time and presence of intersymbol interference. Change both transmitter and receiver pulse shaping filters to "Root Raised" for root-raised-cosine filters. Run transmitter and receiver, observe baseband output, and eye diagram. Comment on changes in the eye diagram, specifically regarding reduction of intersymbol interference. For pulse synchronization effect, connect "aligned waveform" output of PulseAlign(real) to MT Format Eye Diagram. Re-run transmitter and receiver, observing the eye diagram to determine the new optimum sampling time.

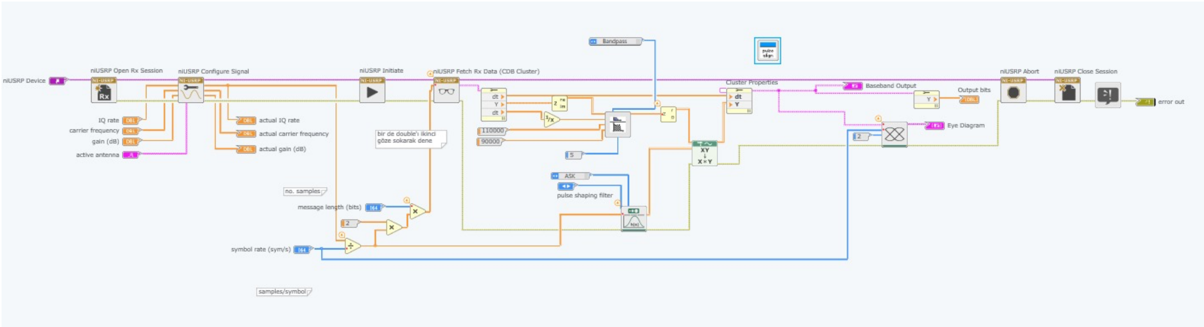

Figure-7 Without Pulse Aligned Receiver Diagram

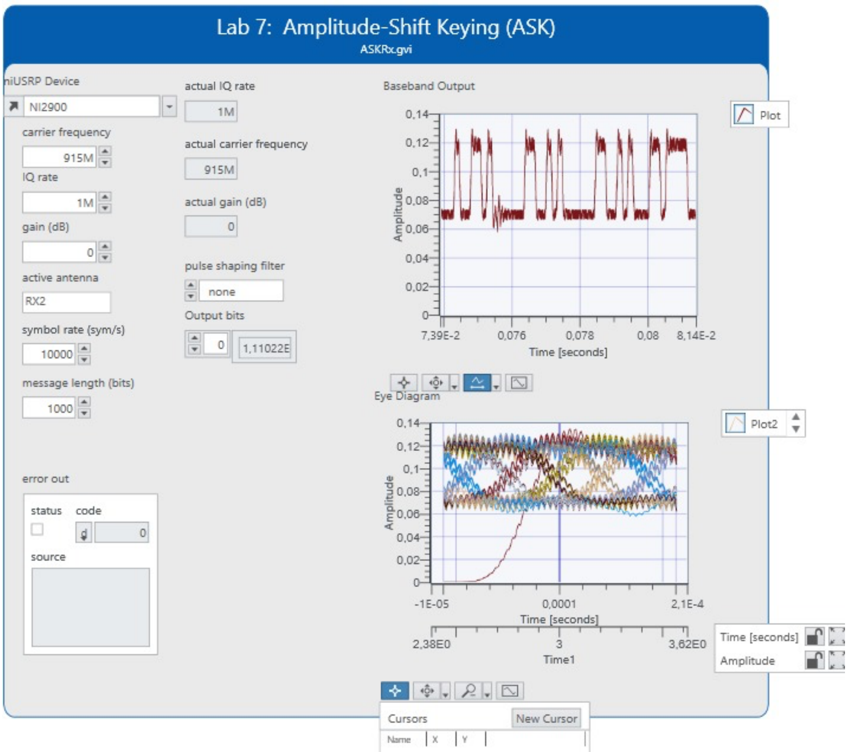

Figure-8 Without Pulse Aligned Receiver Panel

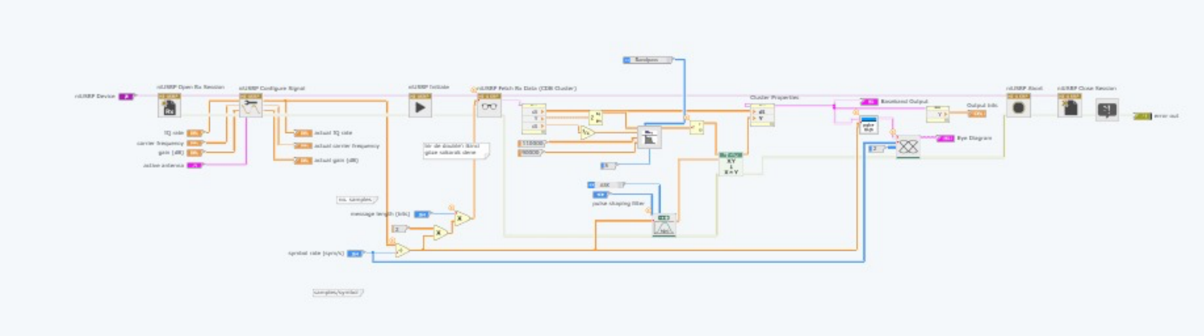

Figure-9 Pulse Aligned Receiver Diagram

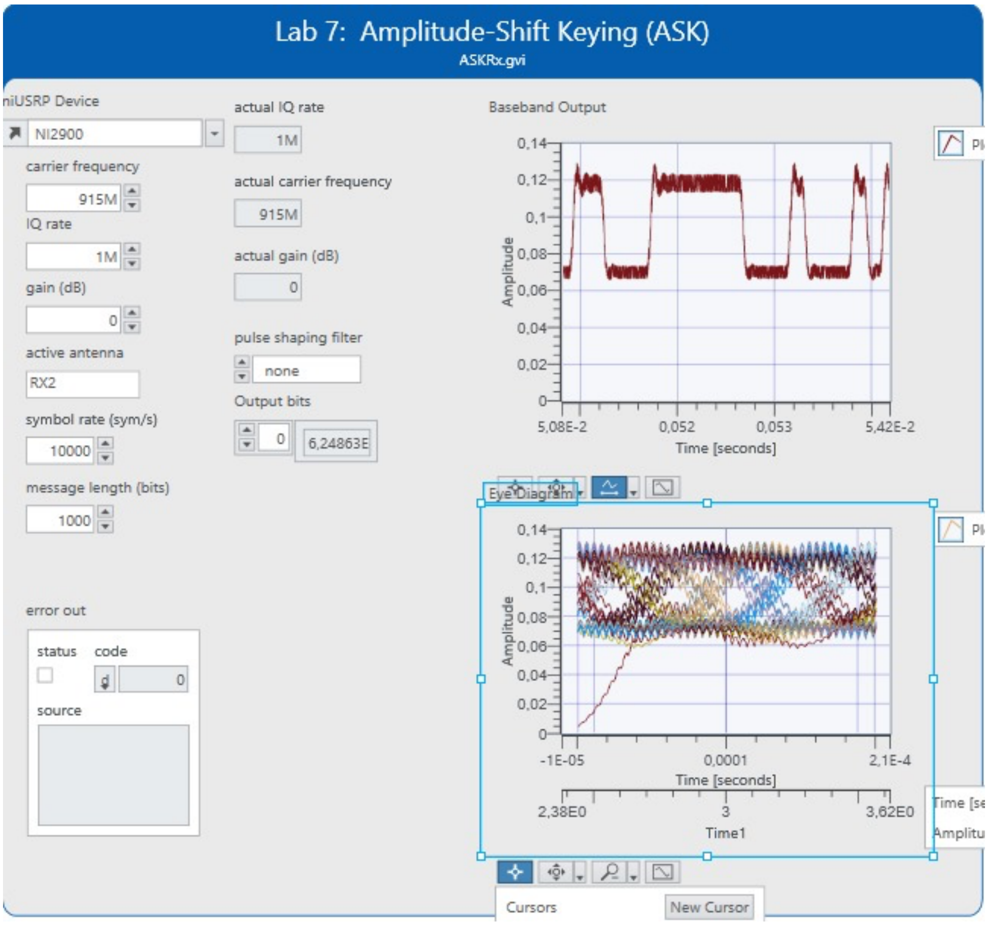

Figure-9 Pulse Aligned Receiver Panel

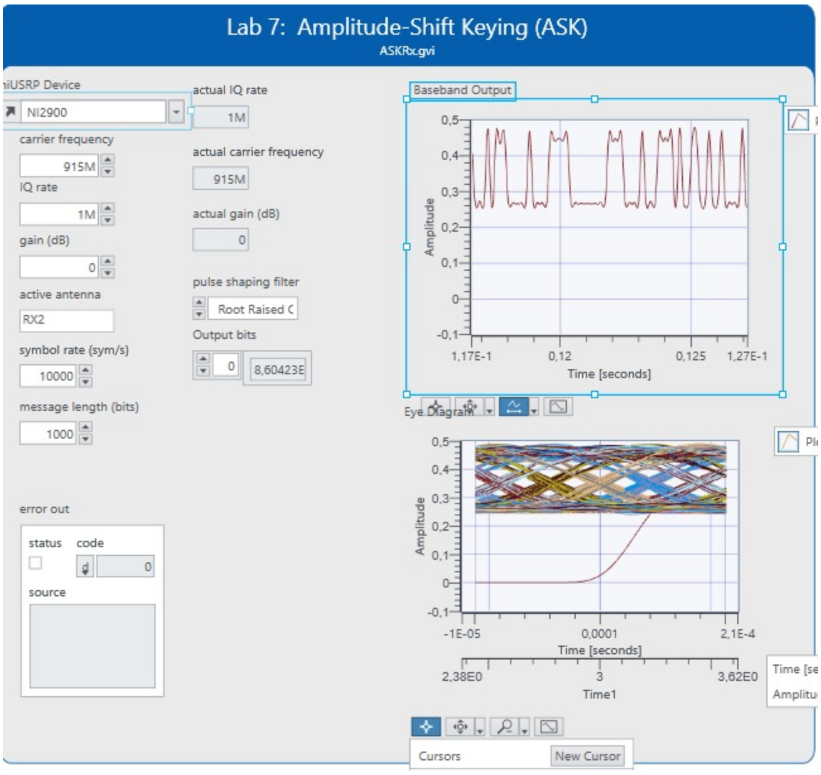

Figure-10 Receiver Pulse Shaping Filter (Root-Raised Cosine Filter)

CONCLUSIONS

Through the exploration of Amplitude Shift Keying (ASK) modulation in Lab 7, facilitated by NI LabVIEW and the NI USRP 2900 platform, I have gained important informations related with this modulation technique. The design and implementation of both transmitter and receiver systems have gave me precious practical knowledge in the development of communication systems.

While initially challenging, altering the transmitter frequency was successfully achieved by changing concepts from previous labs and adjusting our approach accordingly. Each task presented genuine learning occasions, enhancing my comprehension in executing NI LabVIEW, USRP 2900, and basic telecommunications concepts.

The examination of phase synchronization has been particularly imporant. Now, I am not only understands its vital role in signal synchronization but also possesses real life experience in employing it within the LabVIEW.

In summary, the Lab 7 project has been an invaluable educational journey, giving me with a comprehensive understanding of ASK modulation, NI LabVIEW, USRP 2900, and the implementations of phase synchronization. It has provided me with valuable abilities and insights that will provide me endeavors within the telecommunications industry.