EEP3010

Communication System Lab

To study the generation of quadrature phase-shift keying(QPSK) modulated signal using arbitrary waveform generator, MATLAB, and IQ modulator

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By:

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Experiment #6

Abstract:

The generation and characterization of BPSK/QPSK modulated signals is a fundamental topic in digital communication systems. Binary Phase Shift Keying (BPSK) and Quadrature Phase Shift Keying (QPSK) are widely used modulation schemes due to their simplicity and robustness in noisy environments. BPSK and QPSK signals are generated by modulating a carrier signal with binary and quadrature data, respectively. The modulated signals are then transmitted over a communication channel, where they are subject to noise and interference. The receiver then demodulates the received signal and recovers the original data.

The performance of BPSK/QPSK signals is characterized using various parameters such as Bit Error Rate (BER), Signal-to-Noise Ratio (SNR), and Error Vector Magnitude (EVM). These parameters provide insight into the quality of the transmitted signal and the effectiveness of the modulation scheme. In addition, BPSK/QPSK signals can be visualized using constellation diagrams, which provide a graphical representation of the signal's amplitude and phase at different points in time. The constellation diagram is a useful tool for analyzing the performance of the modulation scheme and identifying any distortions or impairments in the transmitted signal. In summary, the generation and characterization of BPSK/QPSK modulated signals are essential topics in digital communication systems. Understanding the performance of these modulation schemes is crucial for designing reliable and efficient communication systems that can operate in noisy environments.

Phase shift in quadrature In the modulation technique known as keying, the transmitted signal is made up of four distinct sinusoids that have the same frequency and amplitude but are phase-shifted. Every sinusoid has a 90° phase shift. It can also be seen as a mixture of I phase and Q phase from two BPSK. The I and Q phases are orthogonal to one another and both have two separate amplitude levels (+1 and -1) or phase levels (0° and 180°). These sinusoids send four symbols that are translated from two bits of data. The bandwidth efficiency is higher compared to QPSK, but the bit error rate also rises. The bandwidth efficiency is the same as QAM, but the bit error rate is lower.

Objective:

In this experiment our main objective are:

- To generate I and Q phase data for QPSK modulation.
- Perform different types of pulse shaping and observe in the oscilloscope.
- Observe the frequency response, constellation diagram , IQ diagram, eye diagram, channel power and EVM for different pulse shaping techniques in Signal Analyzer.

Experimental Procedure:

The necessary equipment required for this part of experiment is :

- N9010A Signal Analyzer/89601 Vector Signal Analysis Software with Oscilloscope (Digitizer)
- AFG3021B Function Generator (2 set)
- DPO2024 Oscilloscope, 200 MHz
- ME1100 dream-catcher training kit

- A PC with MATLAB/LABVIEW
- 2 × BNC(m)-to-BNC(m) coaxial cable, 1.0 m
- 4 × SMA(m)-to-BNC(m) coaxial cable, 1.0 m
- 3 × SMA(m)-to-SMA(m) coaxial cable, 0.18 m
- 3 × USB cable

Part A: Generating I and Q phase data signal for QPSK modulation

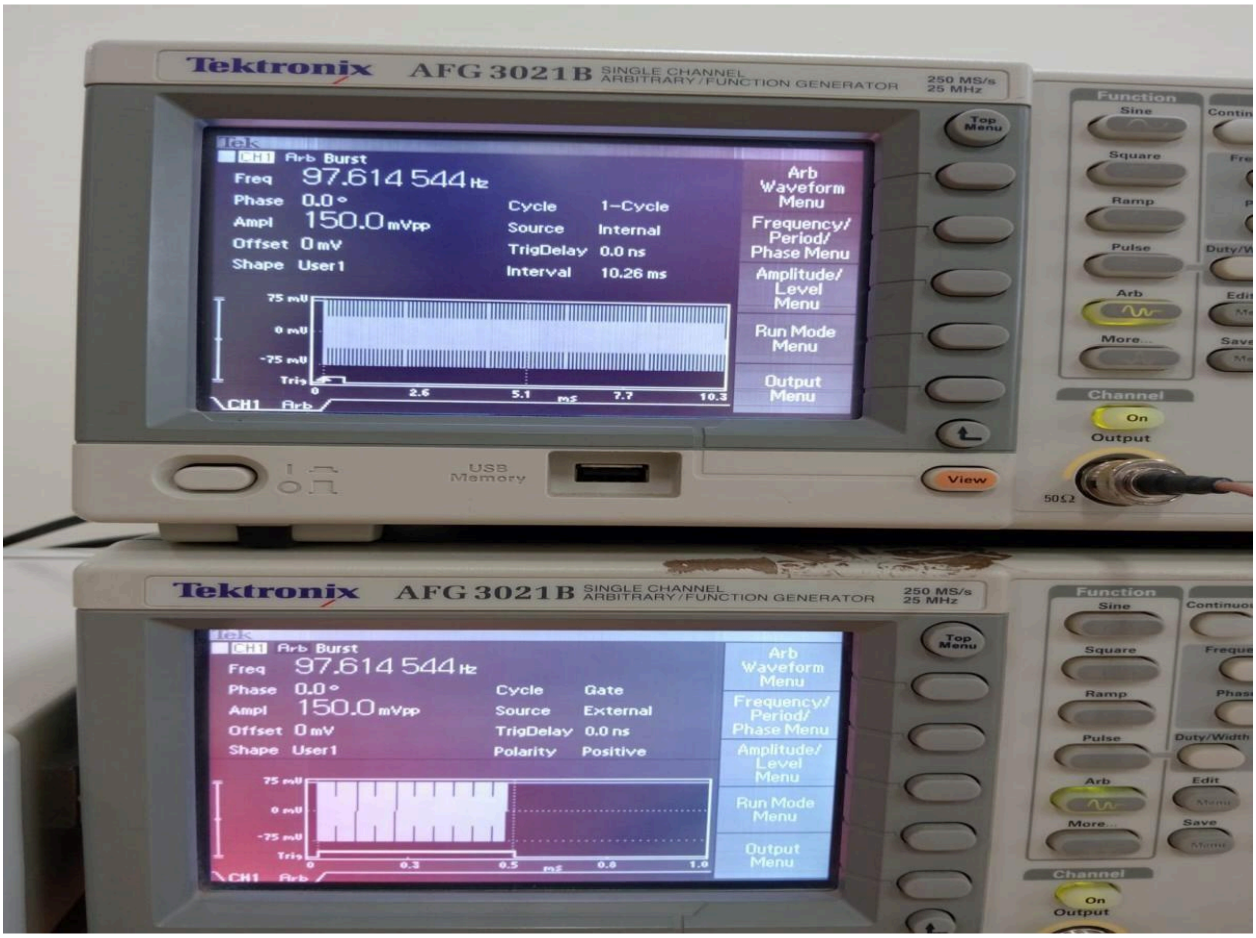
- Generate I and Q phase data through the PRBS process. For this generator polynomial X12 + X11
  + X8 + X6 + 1 is used to get an array of length 212. First half array used for I data and rest for Q.
- Upsample the data arrays i.e. insert seven 0s after every bit or element in the array. Design rectangular filter and root raised cosine filter with different roll off factor and perform convolution to get the desired pulse shape in the data
- Store the data in a .csv file and load it in the function generator. Select arbitrary waveform with appropriate trigger interval and burst frequency according to the sample size. Observed different pulse shaping data in the oscilloscope

Part B: Modulating and analyzing QPSK modulated signals

- Give the I and Q data signals to IQ modulator and a sinusoidal carrier of frequency 50 MHz and -3 dBm amplitude at LO port. Connect the output RF port to a signal analyzer.
- Observe the IQ diagram, constellation plot, eye diagram, frequency spectrum, channel power and error vector in the signal analyzer for different types of pulse shaping

Test Results:

Values of BFs and TIs for users



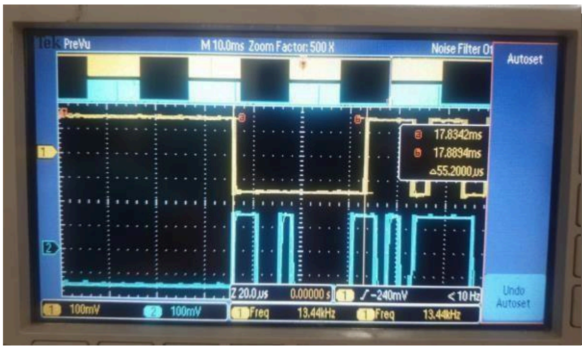
Burst Frequency and Trigger interval are added for I and Q- User1

Burst Frequency and Triggered interval are added for I and Q- User2 RRC(0.25)

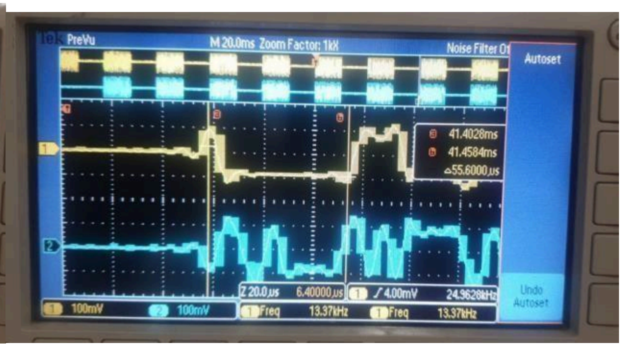
Burst Frequency and Triggered interval are added for I and Q- User3 RRC(0.5)

Burst Frequency and Triggered interval are added for I and Q- User4 RRC(0.75)

We observe the outputs of I and Q after passing through different filters.



i)Rectangular Filter

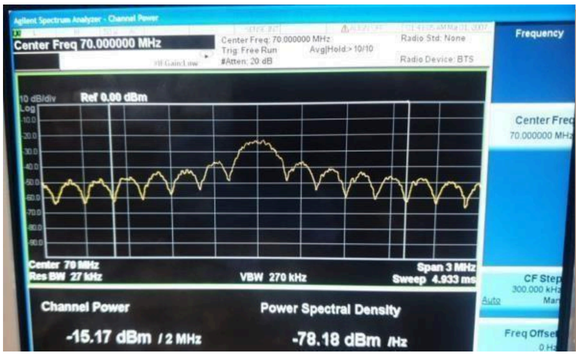


ii)Root Raised Cosine Filter(roll off = 0.25)

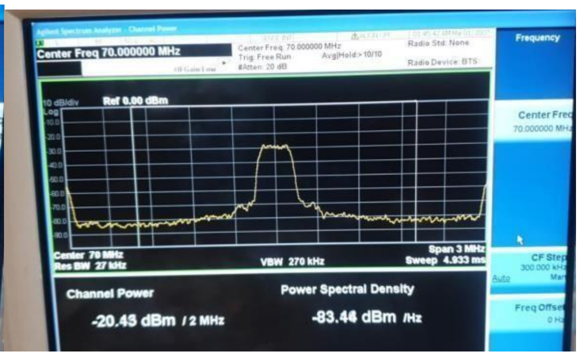
iii)Root Raised Cosine(roll off = 0.5)

iv)Root Raised Cosine Filter(roll off = 0.75)

The PSD of the above signals are:



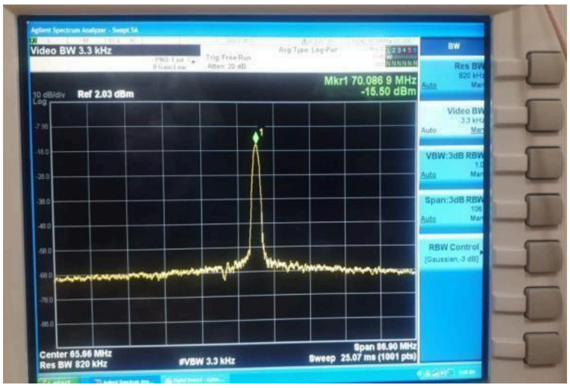
i)Rectangular Filter



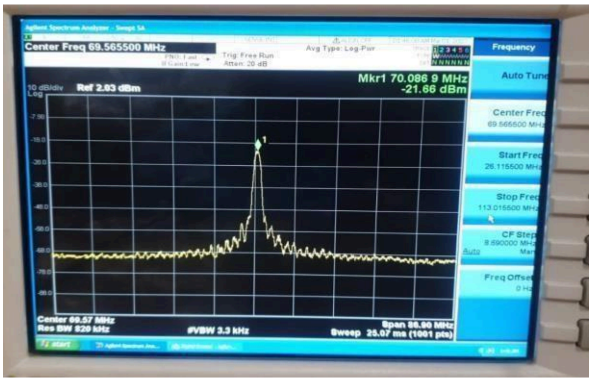
ii)Root Raised Cosine Filter(roll off = 0.25)

iii)Root Raised Cosine(roll off = 0.5)

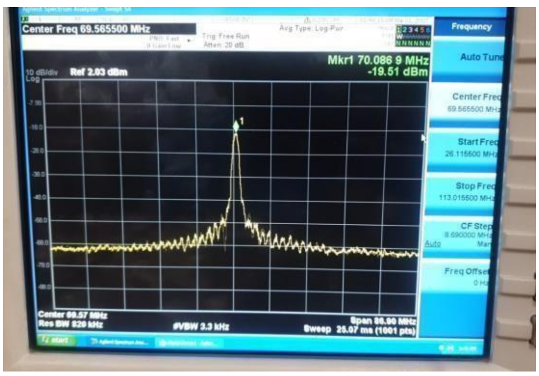
iv)Root Raised Cosine Filter(roll off = 0.75)



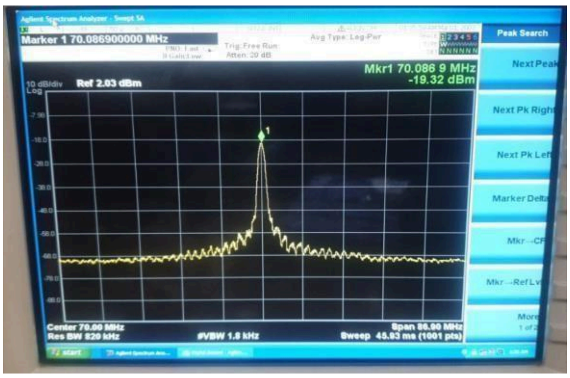
i)Rectangular Filter



ii)Root Raised Cosine Filter(roll off = 0.25)

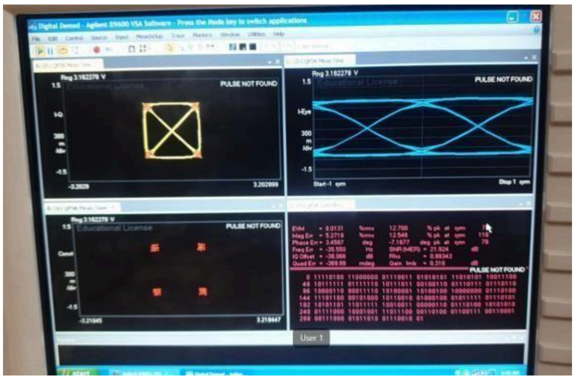


iii) Root Raised Cosine(roll off = 0.5)

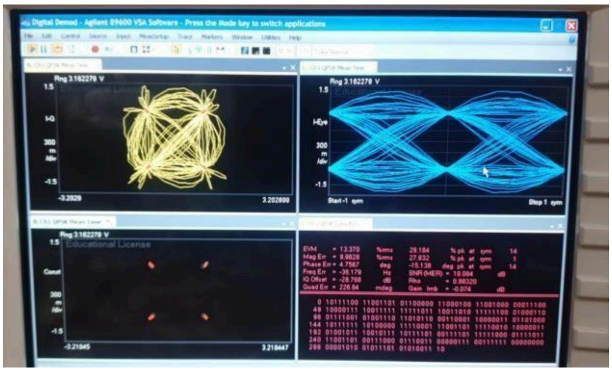


iv)Root Raised Cosine Filter(roll off = 0.75)

The eye diagram and the constellation plots obtained for different filters as follows:

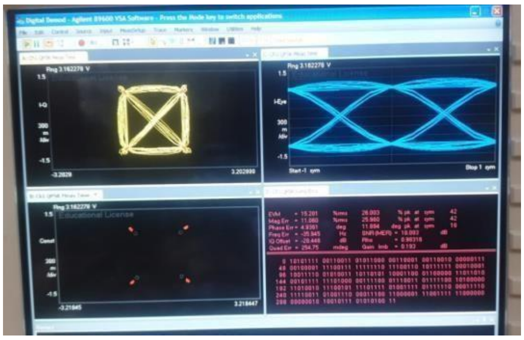


i) Rectangular Filter



ii)Root Raised Cosine Filter(roll off = 0.25)

iii)Root Raised Cosine(roll off = 0.5)



iv)Root Raised Cosine Filter(roll off = 0.75)

Filter	Number of Samples	Burst Frequency (Hz)	Trigger Interval (ms)
Rectangular Pulse Filter	16391	97.614544	10.24
RRC pulse(alpha = 0.25)	16560	97.618358	10.35
RRC pulse(alpha = 0.50)	16481	97.087379	10.30
RRC Pulse(alpha = 0.75)	16448	97.276265	10.28

Users	Occupied BW (kHz)	Total Power (dBm)	EVM (% rms)
1- rectangular	1800	16.8	16.906
2- RRC(0.25)	236.72	21.1	21.907
3- RRC(0.5)	263.44	20	24.426
4- RRC(0.75)	297.20	19.8	27.119

Here occupied bw for rectangular filter is higher than RRC but lower the EVM which is tradeoff for rectangular filter which will be discussed in discussion and conclusion.

Discussion:

- The QPSK signals that have passed through the filter are visible in the first section of the test results. In the first figure, convolution with a rectangular filter is depicted, as a result, steep edges can be seen. In contrast, in the second diagram, the data stream appears to be more shaped like a sine. The signal is less susceptible to ISI when it passes through the raised cosine filter.
- The signal spectrum of a QPSK signal will be widened and spread out when it passes through a rectangular filter, which is known as spectral spreading. Intersymbol interference (ISI) can result from this spectral spreading, which lowers the

  communication system's overall performance. Additionally, the rectangular filter's edges will severely attenuate the signal's high-frequency components, which could lead to data loss.
- On the other hand, the signal spectrum will be shaped in a more controlled way when a QPSK signal is passed through a raised cosine filter, minimizing the effects of ISI and reducing spectral spreading. In comparison to rectangular filters, the raised cosine filter is a type of finite impulse response filter that transitions from one state to the next smoothly. This frequency selectivity helps to reduce the impact of narrowband interference and improve the overall performance of the communication system.
- When a QPSK signal is passed through a rectangular filter, the signal will be broadened and its eye diagram will become more distorted. The signal will have larger eye openings, but the level of intersymbol interference (ISI) will also increase. On the other hand, when a QPSK signal is passed through a raised cosine filter, the signal will be more tightly controlled and its eye diagram will be more defined. The raised cosine filter reduces the spectral spreading and minimizes the effects of ISI, leading to a more clear and easily recognizable eye pattern.
- With a higher roll-off factor, the spectral shaping will be more sharp, resulting in a narrower main signal bandwidth and less spectral spreading, which will lower the ISI. This can be seen in the signal's eye diagram, which will have levels that are clearer and more distinct.
- A lower roll-off factor will lead to looser spectral shaping, a wider main signal bandwidth, and greater spectral spreading, all of which will increase ISI. This can be seen in the eye diagram of the signal, which will have more overlapping levels.

- When a rectangular filter is used, a QPSK signal's constellation diagram will display points that are more dispersed than they would be in an ideal QPSK signal. This is due to the fact that the rectangular filter will result in ISI, which can lead to errors in the demodulated signal.
- The constellation diagram will display points that are closer together and more densely packed when a QPSK signal is run through an RRC filter as opposed to one that is rectangular. This is due to the fact that the RRC filter has a more gradual transition between symbols, which lowers the amount of ISI and enhances the demodulated signal's quality.

Calculations

Calculations:

$$\text{Burst frequency} = \frac{\text{Transmission rate of data}}{\text{Total length of data}}$$

$$\text{Trigger Interval} = \frac{1}{\text{Burst frequency}}$$

User 1 16391

$$BF = \frac{200 \times 10^3 \times 8}{16391} = 97.614544 \text{ Hz}$$

$$TI = \frac{1}{BF} = \frac{1}{97.614544} = 10.24 \text{ ms}$$

User 2 16560

$$BF = \frac{200 \times 10^3 \times 8}{16560} = 96.618357 \text{ Hz}$$

$$TI = \frac{1}{BF} = \frac{1}{96.618357} = 10.35 \text{ ms}$$

User 3 16480

$$BF = \frac{200 \times 10^3 \times 8}{16480} = 97.087378 \text{ Hz}$$

$$TI = \frac{1}{BF} = 10.30 \text{ ms}$$

User 4 16448

$$BF = \frac{200 \times 10^3 \times 8}{16448} = 97.276264$$

$$TI = \frac{1}{BF} = \frac{1}{97.276264} = 10.28 \text{ ms}$$

Conclusions:

The constellation diagram in Fig. 4 demonstrates that the modulated signal consists of four distinct waves with equal amplitudes and 90° irc phase shifts. This denotes that the signal being sent is QPSK. The channel power and spectral density of the rectangular pulse are the lowest. Moreover, as the roll-off factor increases, the power spectral density of root increased cosine pulses drops. As seen in Table 1, this. Higher roll-off factor rectangular and RRC pulses have bigger bandwidths, which results in a greater distribution of energy. Therefore, because of the channel's bandwidth restriction, this pulse's energy loss is greater. Various eye diagrams result from varied pulse shapes. Rectangular pulse shape has a smaller jitter and a finer eye with a big opening and width. The eye opening likewise grows as the roll-off factor does The frequency spectrum of rectangular pulse is wider and that of

The RRC pulse is narrow and the same can be seen from the plots. Also the bandwidth of RRC is proportional by roll-off factor and plots also verify the same. As seen from Table 3, the EVM of rectangular pulse is minimum and increases with roll-off factor for RRC pulse. The signal to noise ratio is best for rectangular pulse and decreases with increase in the roll-off factor for RRC pulse.

The data signal consists of sharpened 1’s and 0’s, and the sharpness decreases and takes the shape of waveform on decreasing alpha.Moreover, the channel power increases on decreasing alpha from 1 to

0.75. Similar thing happens to Power Spectrum Density. The opening of the eye also increases which represents the proper difference between the different possible waveforms in the signal.

References:

- Lab Manual For Experiment #6.
- Principles of communication systems – S.Haykin.
- Communication system Notes.