Part I

Software Defined Radio (SDR)

Workshop 4: Digital Modulation with SDR and Simulink

Objective: Constructing a digital modulation and demodulation scheme using Simulink

Outcome: After successfully completing the experiment, the student will be able to

1. Identify the structure of a digital modulation/demodulation scheme
2. Identify impact of noise and hardware imperfection for a digital modulation/demodulation scheme

Equipment and Components Required:

1. Laptop or PC with following Software
   - Matlab and Simulink version R2019b or later
   - MathWorks DSP Systems Toolbox
   - MathWorks Communication System Toolbox
   - MathWorks Signal Processing Toolbox

4.1 Introduction

Digital modulation is a process that maps the binary data bits into symbols to convey the information. The digital modulation schemes can be mainly categorized based on the property of the carrier signal that is used for modulation.

1. Schemes based on amplitude of the carrier signal
2. Schemes based on phase of the carrier signal
3. Schemes based on both amplitude and phase of the carrier signal

Additional resources:-

- https://www.youtube.com/watch?v=CCOX2tvgM80

Basic digital modulation schemes are

1. Amplitude Shift Keying (ASK)
   - Amplitude of the carrier signal will be changed based on the bit pattern
   - Bandwidth requirements is low
   - Vulnerable to interference
2. Frequency Shift Keying (FSK)
   - Frequency of the carrier signal will be changed based on the bit pattern
   - Bandwidth requirements is high compared to ASK
3. Phase Shift Keying (PSK)
   - Phase of the carrier signal will be changed based on the bit pattern
   - Scheme is complex
   - Robust against interference

Fig. 4.1 illiterates ASK, FSK and PSK modulation schemes.

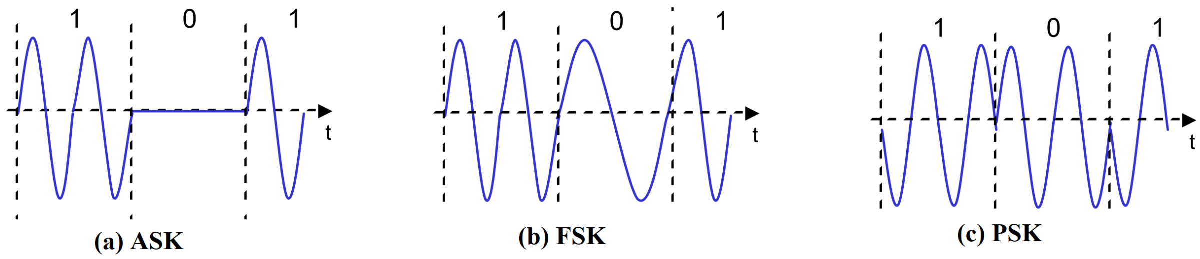

Figure 4.1: Binary ASK, FSK and PSK representation.

4.1.1 Signal Constellation

Signal constellation is representation of each signal as a vector in a Euclidean space. Fig 4.2 shows the constellation diagram for the BPSK and QPSK modulation schemes.

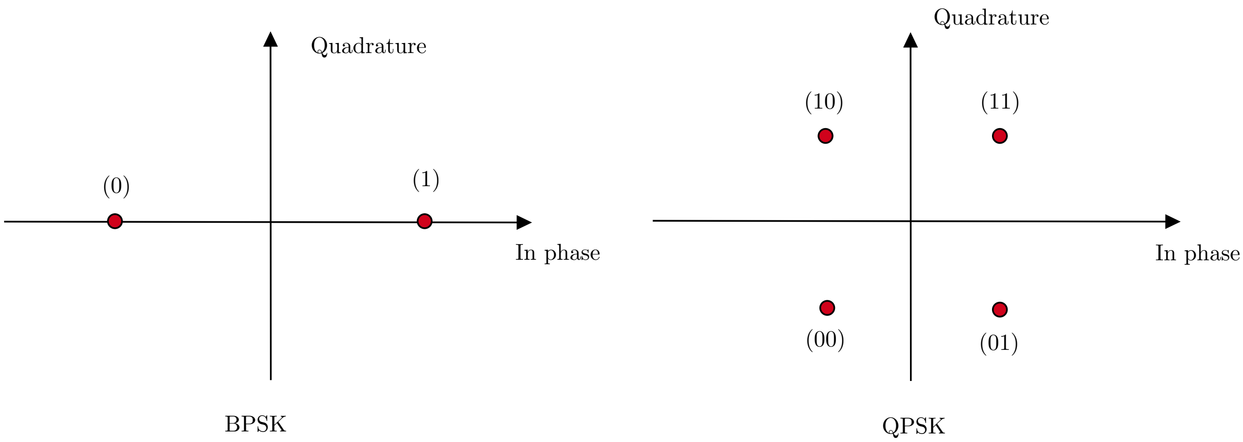

Figure 4.2: Constellation diagrams for BPSK and QPSK modulation.

In the transmission phase, the binary data are grouped in to groups of bits. The these bit groups are assigned to the appropriate symbols. E.g., For QPSK 10101101111011 $\rightarrow$ 10 10 11 01 11 10 11. In the receiver, this process is reversed (de-mapping). The received signal constellation is used for de-mapping. Here, decision boundaries are used to determine the received symbol (Fig. 4.3).

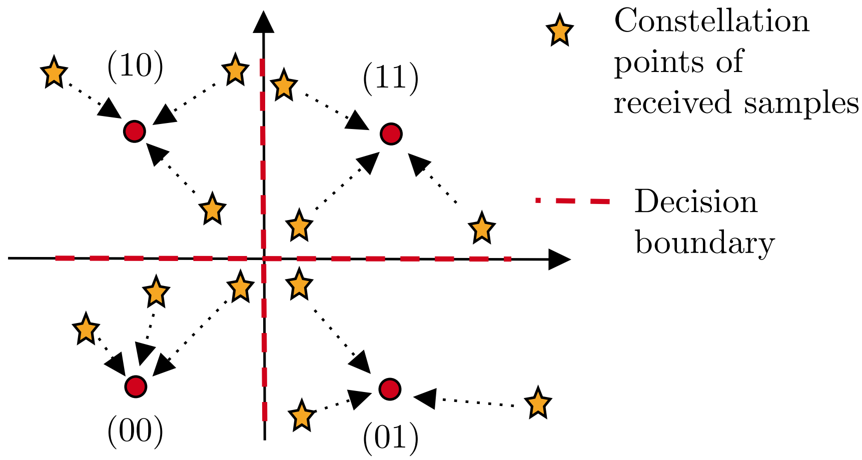

Figure 4.3: Decision boundaries for QPSK modulation.

4.2 Laboratory Experiment:-QPSK Modulation and De-Modulation with SDR (Graded)

This lab is based on the "Software Defined Radio using MATLAB Simulink and the RTL-SDR" book from https://www.desktopsdr.com.

Task 1. *Open "QPSK_map_demap.slx" (available in Moodle) file. Identify the blocks and their functionalities. In this model, how many bits are mapped to a symbol? What are the data rate and frame rate?*

Task 2. *Open "QPSK Modulator Baseband" block and then click on view constellation (Fig. 4.4) and draw the constellation diagram.*

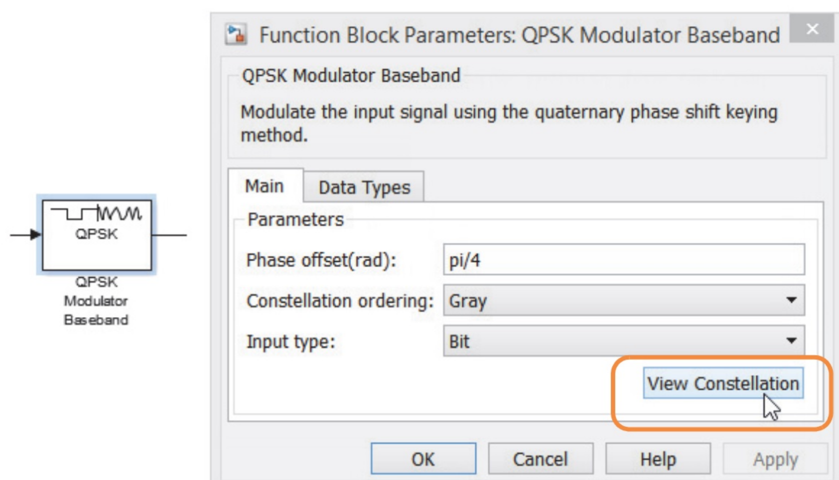

Figure 4.4: View constellation Window.

Task 3. *Open "QPSK Demodulator Baseband" block and inspect the parameter and verify that these parameters are corresponding to the parameter of the modulation block. Then, run the simulation and observe the results. Comment on the results. (In the constellation diagram, the red plus sign is the reference point and the blue circle is the received symbol).*

Task 4. *Open "QPSK_map_demap_IQ.slx" (available in Moodle) file. Identify the blocks and their functionalities. Write down the functionalities of each blocks.*

Task 5. *Run the simulation and observe the constellation diagram and Time scope. Right click on constellation diagram and then click on configuration properties and change Symbol to display as 1. To view one symbol at a time, click on step forward button (Fig. 4.5), it will enable you to view one symbol at a time. Now again click on step forward button to see the next symbol.*

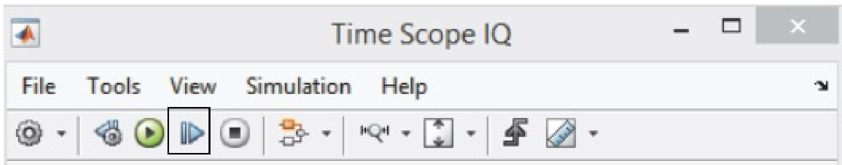

Figure 4.5

Next, we move on to a more challenging scenario. Recovering symbols with noise.

Task 6. *Open "QPSK_constellation_noise.slx" (available in Moodle) file. Identify the blocks and their functionalities. What are the differences in this model compared to the model given in task 1?*

Task 7. *Open "AWGN Channel" block and inspect the parameters. Set the value E_b/N_o as 10 dB. Run the simulation and observe the constellation diagram. Compare the results with task 1. Change the E_b/N_o value and comment on the impact of this value to the results. (Hint:- To get a quantitative measurement for error, enable error vector measurement by clicking signal quality button (Fig. 4.6)).*

Task 8. *What is measured by Error vector measurement? Change the E_b/N_o as 20 dB, 10 dB, 0 dB, −10 dB, −20 dB. Comment on your answer.*

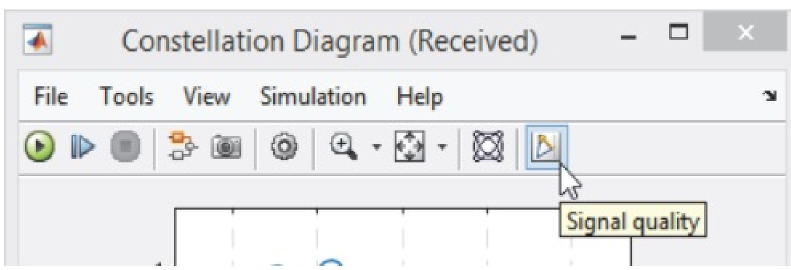

Figure 4.6

In the above, we have assumed ideal condition in the de-modulation process. However, in practical , there are many things that need to be considered. One challenge is the local oscillator of the receiver is not frequency and phase lock to the carrier. This problem can be categorized as

1. Frequency of the local oscillator is slightly different compared to the frequency of the carrier signal.
2. Phase of the local oscillator is different from the phase of the carrier signal (both has the same frequency)
3. Frequency of the carrier signal and local oscillator are changing time to time.

Due to carrier de-synchronization, constellation points do not appear in the correct location and this results in incorrect symbol detection. Carrier synchronization can be done in two different ways, (a) carrier synchronization after the demodulation or (b) carrier synchronization at the demodulation. Other than carrier synchronization, the symbol timing synchronization also needs to be done. It also has a significant impact on symbol identification process. Here, we assumed that the symbol timing synchronization is already done and carrier synchronization is yet to be performed.

Task 9. *Open "QPSK_synch_demod.slx" (available in Moodle) file. Identify the blocks and their functionalities.*

Task 10. *Open the constellation diagram of the receiver and run the simulation. Observe constellation diagram pattern change with time.*

Task 11. *To observe the waveform in time domain, open the RRC Samples Time Scope.*

Task 12. *To observe the frequency adjustment of the local oscillator, open the VCO frequency Time Scope block. How long it has taken to stabilize? Change the frequency error by typing* $f_e = 250$ *in Matlab command window. Change the value to a larger value and observe the synchronization process. Comment on your answers.*

Task 13. *Include an "AWGN Channel" block to the system given in task 9. Then, run the simulation. Comment on your observations compared to the task 9.*

Task 14. *Demos from www.desktopSDR.com*

- *Coarse Frequency Synchronisation*
- *Timing and Phase Synchronisation*

EN2130: Communication Design Project
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Task Sheet

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Date:

Task 1.

Task 2.

Task 4.

Task 6.

in this model AWGN nosie chanel added to mo

Task 7.

now in the constallation diagram recieved samples are mapped away from the referance
points becouse nosice getting added to samples when they transsmittting through the
AWGN channel it changes the phase and amplitudes of the original samples

when Eb/no valuse increased received samples more close to referance points with less error
when Eb/no value decreased received samples more splited away from referance points with more error

Task 9.

Task 12.

approximatly 11 ms

when we increasing the fe the time it takes to stablize is increasing

Task 14.