Digital Communication IA2 MINI PROJECT

QPSK (Quadrature Phase Shift Keying)

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Digital Modulation

Coherent Techniques

Phase synchronized locally generated carrier needed at the receiver to recover information signal.

Non-Coherent Techniques

No phase synchronized local carrier needed.

Binary Modulation

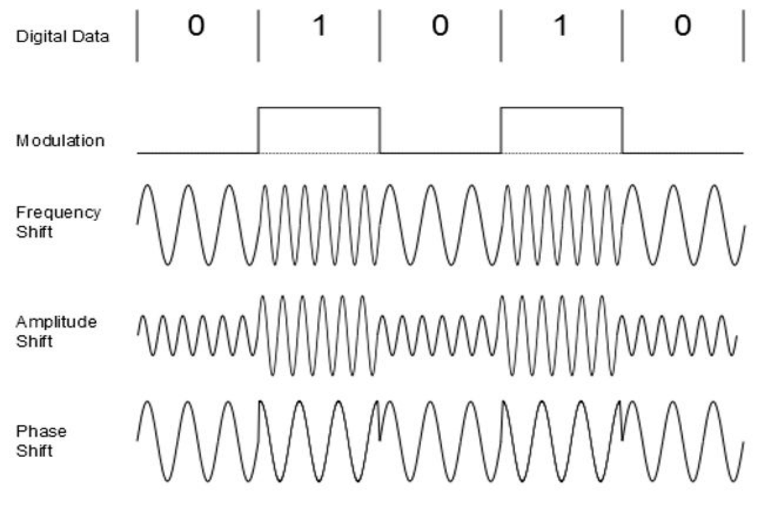
- Amplitude (ASK)
- Frequency (FSK)
- Phase (PSK)

M- ary Modulation

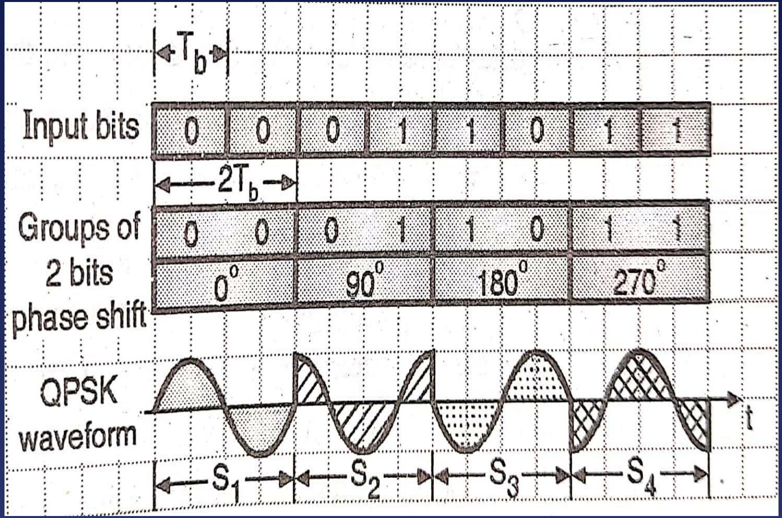
- Quadrature (QPSK)
- Minimum (MSK)

Digital Modulation

Binary Schemes



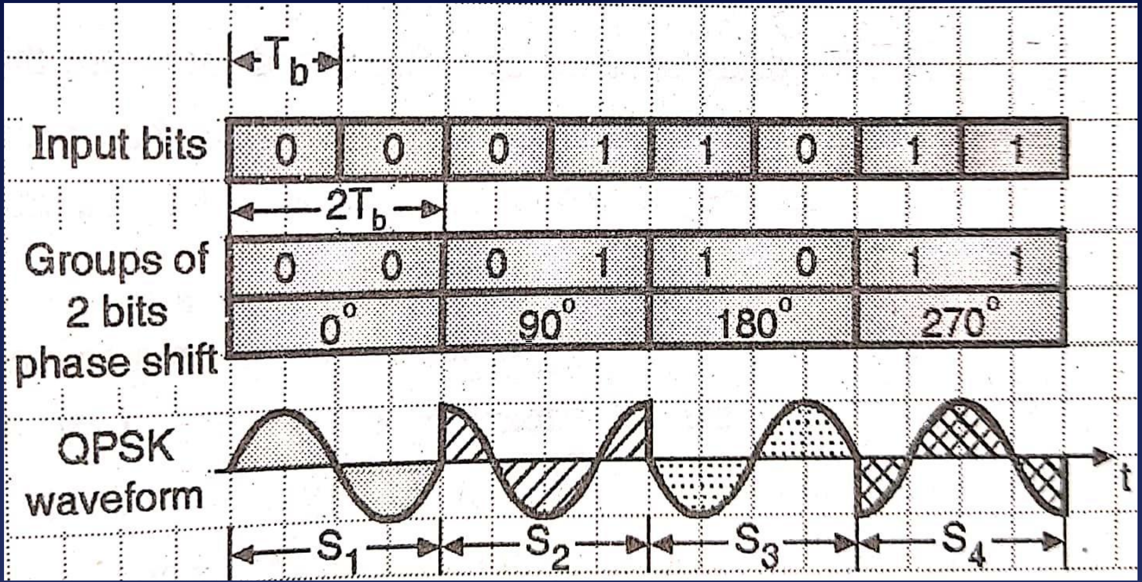
M-ary Schemes



Introduction to Quadrature Phase Shift Keying

1. ASK and BPSK → 2 level Modulation Techniques as they can represent only 2 states of the digital data (0 or 1).
2. So, Bit rate = Baud rate.
3. The maximum bit rate which can be achieved using ASK, BFSK or BPSK does not meet the requirements of data communication systems as telephone voice channel has limited BW.
4. We can increase the bit rate by using Multilevel modulation techniques.
5. Here, the data groups are divided into groups of 2 or more bits & each group of bits is represented by a specific value of amplitude, frequency or phase of the carrier.
6. QPSK is an example of such multilevel phase modulation.
7. In QPSK system, two successive bits in a bit stream are grouped together to form a message and each message is represented by a distinct value of phase shift of the carrier.

Waveforms & Grouping



For Eg.
'00011011'

Symbol	Phase
00	0°
01	90°
10	180°
11	270°

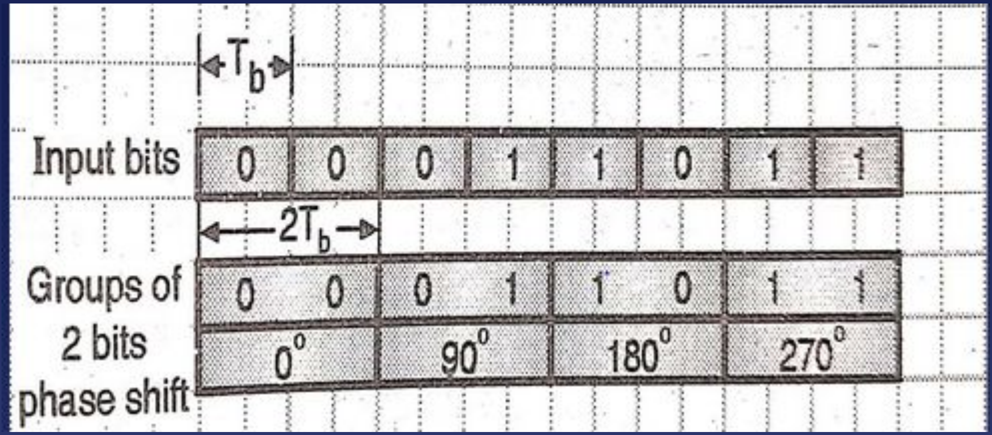
1. Each symbol or message contains 2 bits.
2. Symbol duration **Ts = 2*Tb.**
3. If symbols are transmitted , then we have to transmit the carrier at respective phase shifts.

Symbol Transmission Rate

As 2 successive bits are grouped together to form a symbol, the QPSK signal changes will occur at the **symbol rate which is half the bit rate.**

So, Symbol time (Ts) = 2Tb

Symbol rate (fs) = fb/2



Mathematical Representation

A QPSK signal can be represented mathematically as:

$$V_{QPSK}(t)=\sqrt{2P_1}\cos\left[\omega_c t+(2m+1)\frac{\pi}{4}\right]$$

For m = 0, 1, 2, 3…

By substituting the values of m from 0 to 3 we get the messages as

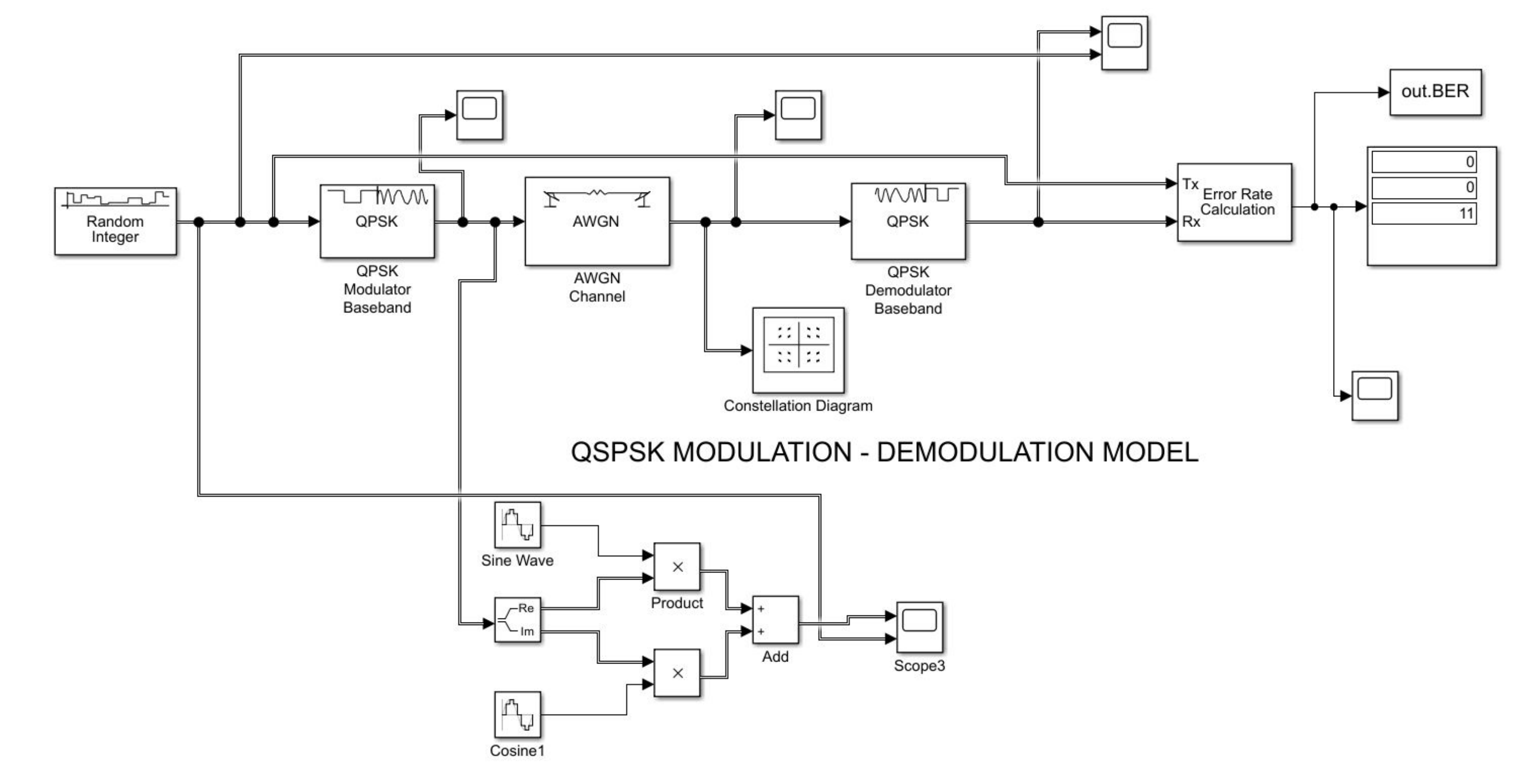
$$V_{QPSK}=s_1=\sqrt{2P_1}\cos\left[\omega_0 t+\frac{\pi}{4}\right]\ldots \text{ for } m=0$$

$$V_{QPSK}=s_2=\sqrt{2P_1}\cos\left[\omega_e t+\frac{3\pi}{4}\right]\ldots \text{ for } m=1$$

And similar for the values of m=2 and 3

We can now substitute the value Ps in terms of Symbol energy and Symbol time as **Ps = E/T.**

Block Diagram in Simulink



Elements In Block Diagram

1. **QPSK Modulator Baseband**: Modulates using the quadrature phase shift keying method. The output is a baseband representation of the modulated signal.

2. **QPSK Demodulator Baseband**: Demodulates a signal that was modulated using the quadrature phase shift keying method.

3. **Scope**: Display waveforms generated during simulation.Allows you to adjust the amount of time and the range of input values displayed.

4. **Random Integer**: Generates uniformly distributed random integers in the range [0, *M*-1], where *M* is specified by the Set size parameter. Use this block to generate random binary-valued or integer-valued data.

5. **Error Rate Calculation:** Compares input data from a transmitter with input data from a receiver. It calculates the bit error rate as a running statistic.

Elements In Block Diagram

6. **AWGN Channel:** Adds White Gaussian Noise to the input signal. It inherits the sample time from the input signal.

7. **Constellation Diagram :** Displays the signal as a two-dimensional xy-plane scatter diagram in the complex plane at symbol sampling instants.A constellation diagram is a representation of a signal modulated by a digital modulation scheme such as quadrature amplitude modulation or phase-shift keying.

8. **Sine & Cosine wave:** Modulator Baseband block has the inherent property of showing output in complex form.In order to observe the phase shift ,we need sinusoidal waveform.
For that the complex waveform is divided into Real and Imaginary part.

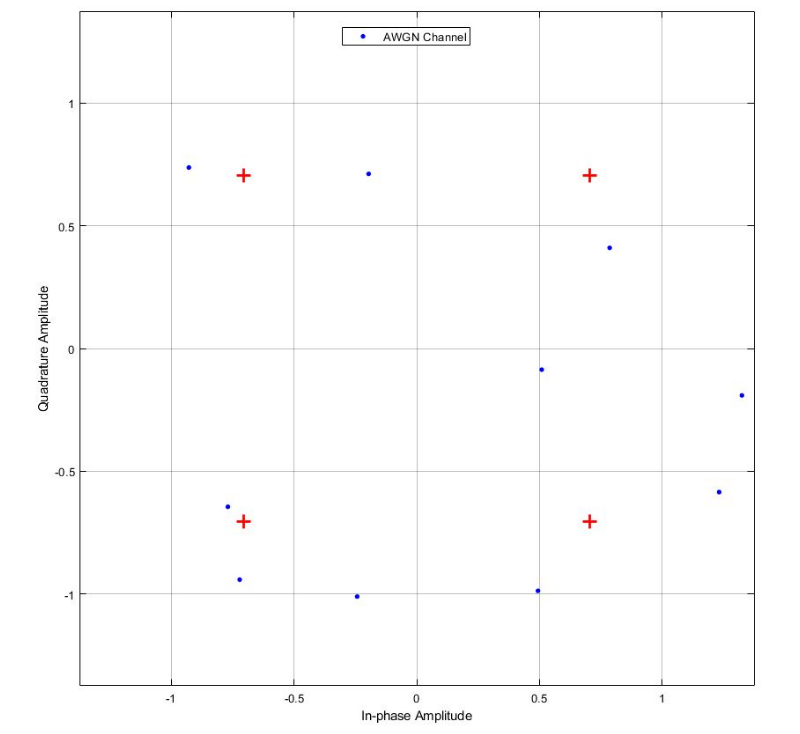
9. **Product,Adder:**Multiplier is used to obtain the product of the trigonometric functions with real and imaginary part which is then added together using adder.

Constellation Diagram

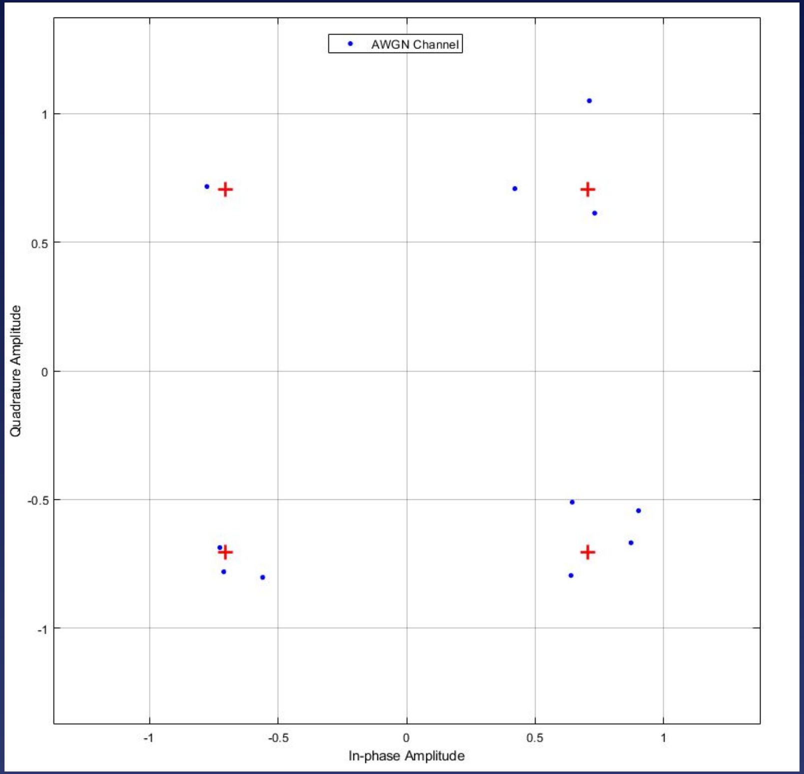
Observations

For SNR(Eb/No)=0

- When SNR =0 it results into low quality sound due to distortion.
- Red dot - Phase Shift
- Blue dots - Noise
- Here the blue dots are not concentrated as noise is introduced between the symbols because of AWGN channel.



Constellation Diagram

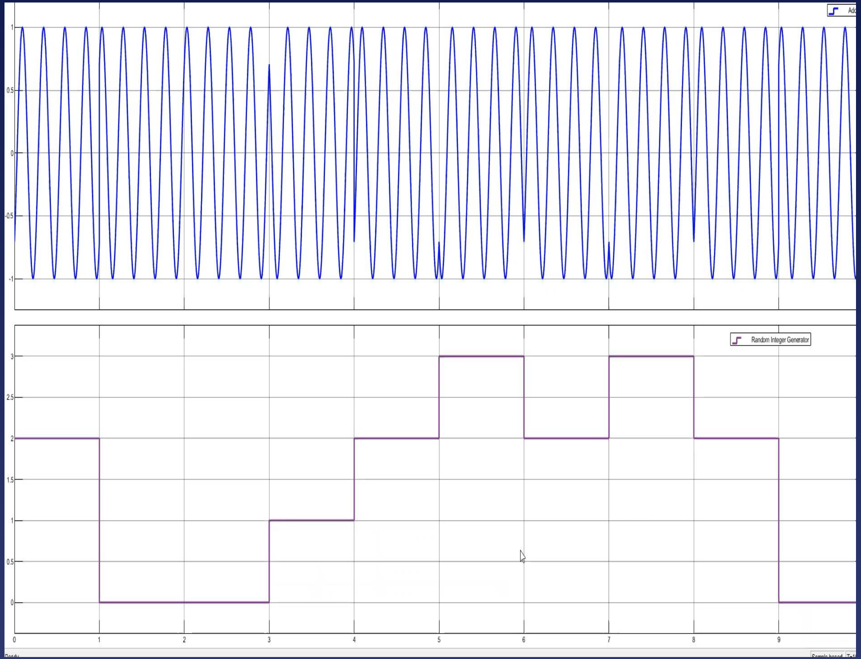


For SNR= 10

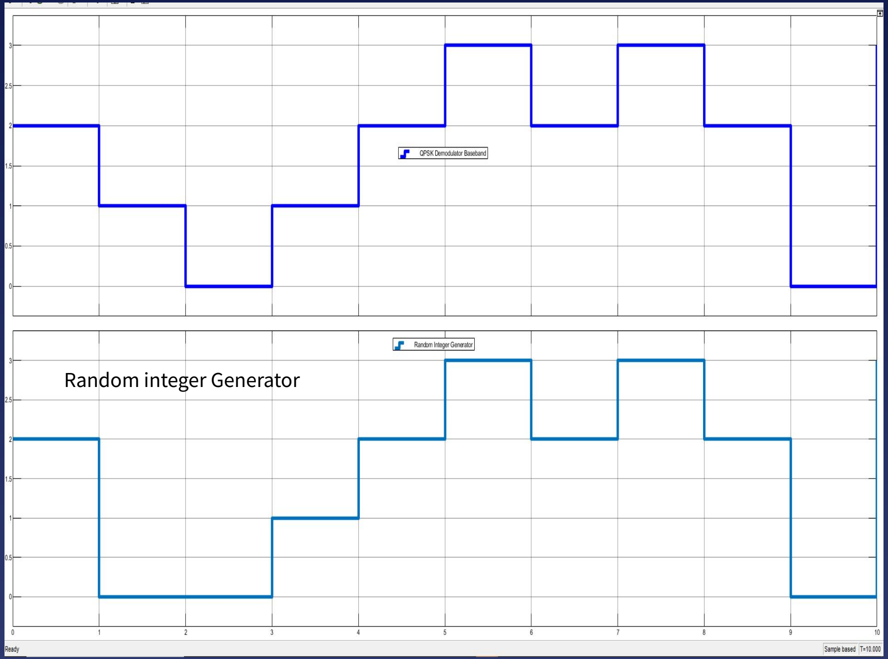
- By observing we can see the noise signals (blue dots) are nearby and concentrated
- This will result in good audio quality of the signal.
- We can conclude that more the SNR ratio,better the quality of audio signal and less noise distortion.

Output Waveforms

Phase Diagram



Demodulator Baseband



Calculations

Formula :

$$BER = \frac{\text{Errors}}{\text{Total Number of Bits}}$$

When SNR = 10

Total no. of bits = 11 → generated by random integer generator.

Total no. of error bits = 0

$$\therefore \quad BER = \frac{\text{Total no. of error bits}}{\text{Number of total bits}} = \frac{0}{11} = 0$$

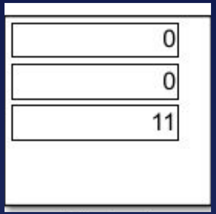
when SNR = 00

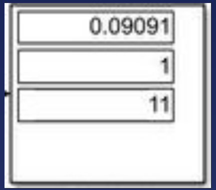
Total no. of bits = 11

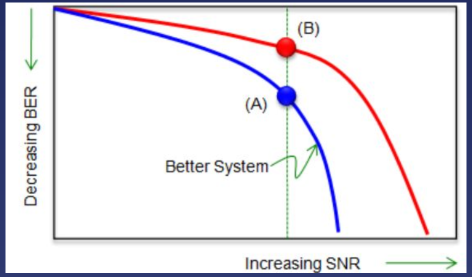
Total no. of error bits = 1

$$\therefore \quad BER = \frac{1}{11} = 0.0909$$

Display Output:







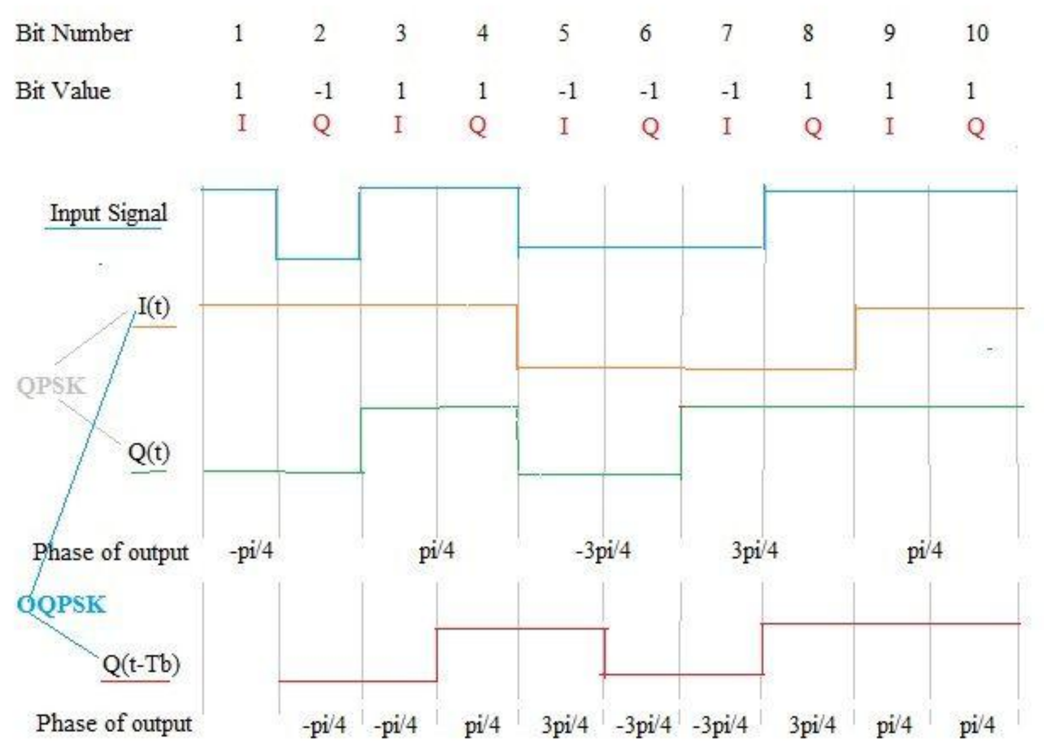
QPSK Transmitter

Offset QPSK Transmitter

- Offset Quadrature Phase Shift Keying is referred as OQPSK
- In OQPSK, after splitting the bit stream into odd & even, 1 bit stream is made offset by 1 bit period with respect to the other.After this, the direct and shifted bit streams are fed to the mixers.
- be(t) and bo(t) cannot change simultaneously
- Phase changes of +/- 90 exist.
- Amplitude variation are of the **order of 3 dB**

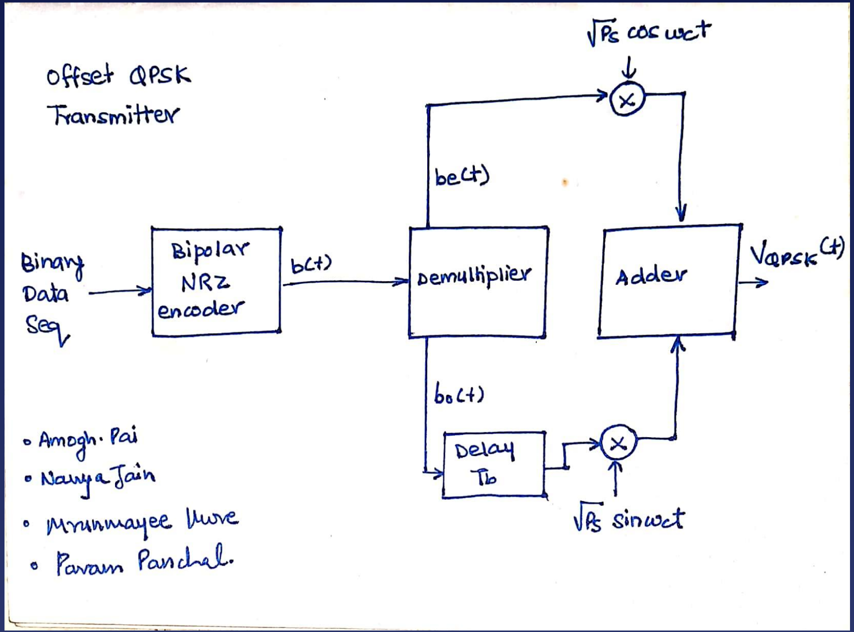
Non-offset QPSK Transmitter

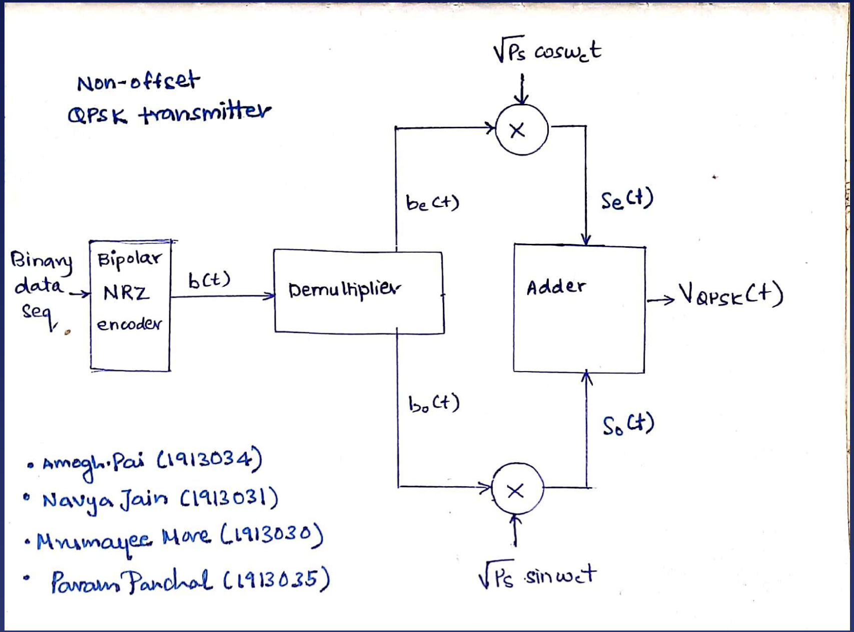
- Non-offset Quadrature Phase Shift Keying is referred as QPSK.
- In QPSK, first input bit stream is split into two bit streams referred as odd and even. These streams are applied simultaneously to the mixers.
- be(t) and bo(t) can change simultaneously
- Phase changes of +/- 90° and +/-180°.
- Amplitude variations are of the **order of 30dB**



QPSK and OQPSK Time Domain Waveforms

Transmitter Block diagrams for OQPSK and QPSK



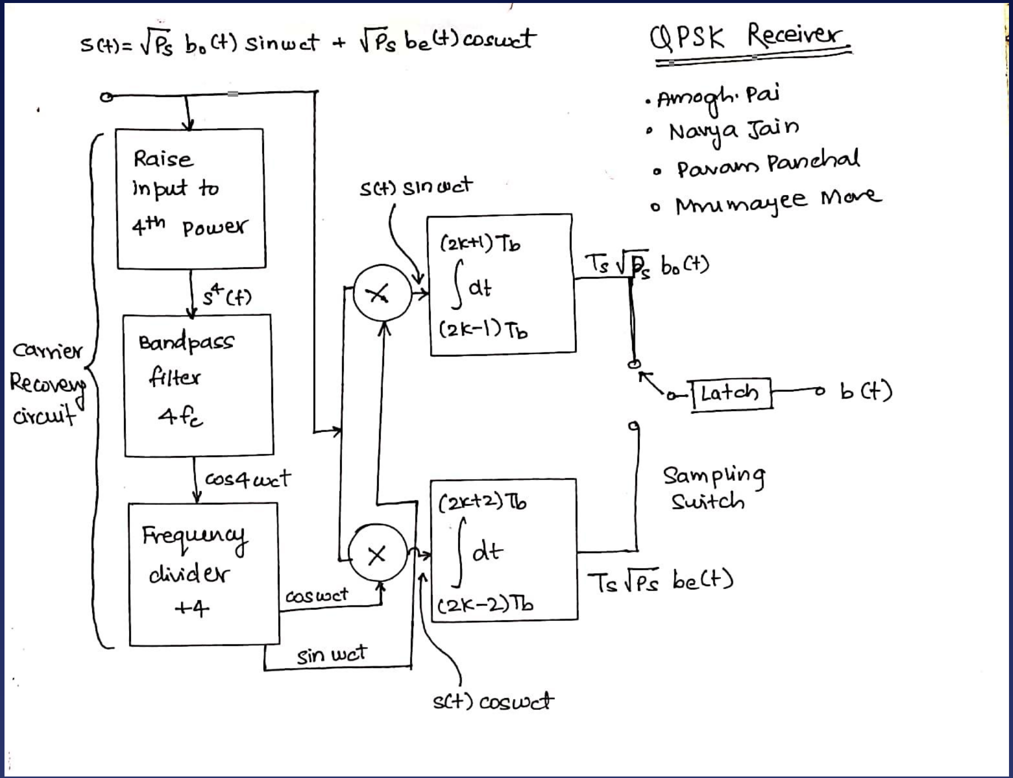


Receiver Operations

- Let us represent the received QPSK signal by s (t) instead of V_{QPSK} (t). The received QPSK signal s (t) is raised to fourth power i.e. s^4 (t).
- This signal → filtered by using a bandpass filter with a center frequency of 4* $\omega_c t$. The output of bandpass filter → $\cos 4\,\omega_c t$.
- A frequency divider which divides the frequency at the filter output by 4 ,generates the 2 carrier signals **$\sin \omega_c t$, $\cos \omega_c t$**.
- The incoming signals (t) is applied to 2 synchronous demodulators which are made of a multiplier (balanced modulator) followed by an integrator. Each integrator integrates over a 2-bit interval of duration **Ts = 2Tb**
- One synchronous demodulator uses cos $\omega_c t$ as carrier signal and the other one uses sin $\omega_c t$ as a carrier signal.
- The input to the upper integrator is given by,

$$s(t) \times \sin \omega_c t = b_o(t)\sqrt{P_s}\,\sin^2 \omega_c t + b_e(t)\sqrt{P_s}\,\sin \omega_c t\,\cos \omega_c t$$

QPSK Receiver



- Synchronous detection technique is used.
- Hence it is necessary to locally generate the carriers cos(t) and sin(ot).
- The technique for carrier regeneration is similar to the one employed for BPSK system.

Applying to upper integrator, which integrates over symbol period $T_s = 2T_b$

$$\text{Integrator o/p} = \int_{(2k-1)T_b}^{(2k+1)T_b} s(t) \times \sin \omega_c t \, dt$$

Substituting respective values & by using appropriate formulas,

we get $\text{Integrator o/p} = b_o(t)\sqrt{P_s}\, T_b$

- Similarly we can prove that output of the lower integrator is given by **be(t)*√Ps Tb.**

- Thus at the output of the two integrators we obtain the bit streams be(t) and bo(t).

- We need to use bit synchronizers in QPSK receiver .
- Uses of Bit Synchronization
  - Used to establish the beginning and end of the bit intervals of each bit stream.
  - To operate the sampling switch.
- At the end of each integration time for each integrator, the integrator output is sampled.
- The samples are taken alternately from the 2 integrator outputs, at the end of each bit time Tb, and these samples are then held in the latch for the bit time Tb.
- Each individual integrator output is thus sampled at intervals of **2 Tb**. At the output of the latch we get the signal b (t).

QPSK Spectrum

The Power Spectral Density(PSD) of an NRZ bipolar signal with each bit extending over a period Tb as :

$$S(f) = P_s T_b \left[\frac{\sin(\pi f T_b)}{(\pi f T_b)} \right]^2$$

This is the PSD of signal b (t). In QPSK, this signal b (t) is divided into even and odd bit streams i.e. be (t) & bo (t) resp. Each symbol in these bit streams a period of Ts = 2Tb seconds. Therefore their PSD are given by:

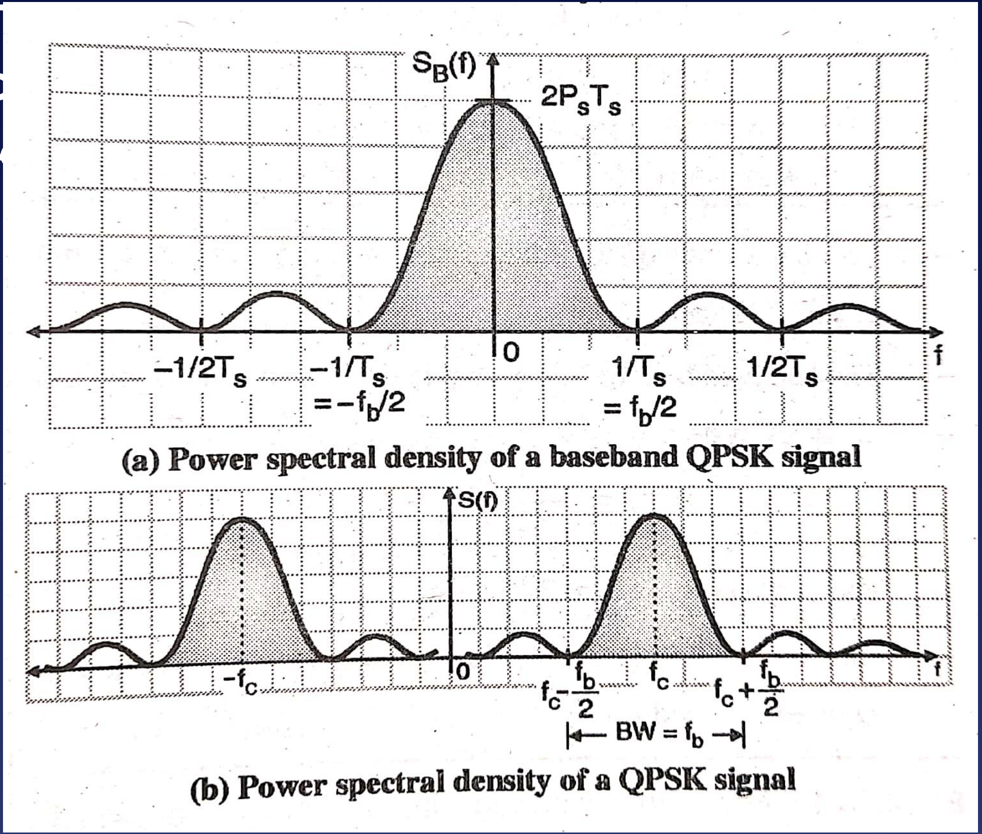
$$S_e(f) = P_s T_b \left[\frac{\sin(\pi f T_s)}{(\pi f T_s)} \right]^2$$

$$S_o(f) = P_s T_b \left[\frac{\sin(\pi f T_s)}{(\pi f T_s)} \right]^2$$

As bo (t) and be (t) are statistically independent, the PSD of a QPSK signal is given by,

$$S_B(f) = S_e(f) + S_o(f)$$

$$= 2 P_s T_b \left[\frac{\sin(\pi f T_s)}{(\pi f T_s)} \right]^2$$



- Hence the Bandwidth of the QPSK system can be obtained from the Figure of the PSD.
- We find that the BW of the QPSK system is half that of the BW of the BPSK system, i.e
- **BW_{QPSK} = 2fb/2 = fb**
- This is a major advantage of multilevel modulation, wherein the BW is significantly reduced

Error Probability

Rate of occurrence of an error in a hypothetical infinite repetition of the procedure.

General formula for Pe:

$$P_e = \frac{1}{2}\,\mathrm{erfc}\left\{\frac{\gamma_{max}^2}{8}\right\}^{1/2}$$

$$\gamma_{max}^2 = \frac{2}{N_o}\int_0^T P^2(t)\,dt$$

For QPSK, the probability of error is given by:

$$P_b = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) \text{ or } P_e = \frac{1}{2}\,\mathrm{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right)$$

E= Energy of each symbol

Eb= Energy of one bit

No= power per Hz

QPSK- Pros and Cons

ADVANTAGES

- Very good noise immunity.
- Baud rate = 0.5 * bit
- Therefore more effective utilization of effective bandwidth of the transmission channel.

DISADVANTAGES

- Generation and detection is complex.
- Not Power efficient modulation technique compared to other techniques since more power is required to transmit two bits.

APPLICATIONS

- Satellite transmission
- Video Conferencing
- Cellular Phone Systems
- Cable modems
- Other forms of digital communication over RF carrier

References

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Thankyou