DIGITAL CARRIER MODULATION & DEMODULATION TECHNIQUES

Multiple Choice Type Questions

1. Which one is not a digital modulation technique [WBUT 2015]
   a) PCM b) delta modulation c) DPCM d) PAM

Answer: (d)

2. Which multiplexing technique transmit digital signal? [WBUT 2015]
   a) FDM b) TDM c) WDM d) both (a) and (b)

Answer: (b)

3. In a Delta modulation system, the granular noise occurs when the modulating signal [WBUT 2015]
   a) increases rapidly b) remain constant
   c) decreases rapidly d) none of these

Answer: (a)

4. For generation of FSK the data pattern must be given in [WBUT 2016]
   a) RZ format b) NRZ format
   c) split-phase Manchester d) polar-quaternary format

Answer: (b)

5. In QPSK the transmission bandwidth required is [WBUT 2016]
   a) f_b b) $2f_b$ c) $f_b/2$ d) $4f_b$

f_b = bit rate

Answer: (c)

6. To avoid slope overload in delta modulation the maximum value of signal amplitude will be [WBUT 2016, 2018]
   a) $s\ f_s$ b) $w\ f_s$ c) $s\ f_s/w$ d) f_s/w

where s=step size f_s= sampling frequency w =signal frequency

Answer: (a)

7. Which one is Digital modulation? [WBUT 2016, 2018]
   a) AM b) FM c) PCM d) PAM

Answer: (c)

8. QAM Modulation needs a phase shifter of phase shift [WBUT 2016]
   a) $\pi/6$ b) $\pi/4$ c) $\pi/3$ d) $\pi/2$

Answer: (d)

9. Bandwidth of QPSK as compared to that BPSK is [WBUT 2018]
a) Double b) Half c) Same d) Zero

Answer: (b)

10. FSK system is presently used in communication of data through satellite. The technique uses [MODEL QUESTION]
a) some frequency signal for transmission of ONE, & no signal for transmission for ZERO
b) constant frequency signal for ZERO & no signal for ONE
c). one set of frequencies for ONE, & another set of frequencies of ZERO
d) pulses are transmitted through satellite & frequency etc. has no relevance

Answer: (a)

11. The message bit sequence input to a DPSK modulator is 1, 1,0, 0, 0, 1, 1. The carrier phase during the reception of the first two message bits is π, π. Thecarrier phase in remaining four message bits is [MODEL QUESTION]
a) π, π, 0, π b) 0. 0, π, π
c) 0. π, π, π d) π, π, 0, 0

Answer: (d)

12. The modulating technique which is most affected by noise is [MODEL QUESTION]
a) PSK b) ASK c) DPSK d) FSK

Answer: (d)

13. Which of the following gives maximum probability of error? [MODEL QUESTION]
a) ASK b) FSK c) PSK d) DPSK

Answer: (a)

14. Differential encoding is used in [MODEL QUESTION]
a) FSK b) PSK c) ASK d) DPSK

Answer: (d)

15. What is effective to reduce cumulative error? [MODEL QUESTION]
a) PCM b) DPCM c) Delta sigma modulation d) ADM

Answer: (b)

16. The bit rate of a digital communication system is 34 Mbps. The modulation scheme is QPSK. The band rate of the system is [MODEL QUESTION]
a) 68 Mbps b) 34 Mbps c) 17 Mbps d) 85 Mbps

Answer: (c)

17. For a voice grade signal, the signal to noise ratio of DPCM is [MODEL QUESTION]
a) worse than standard PCM b) better than standard PCM
c) same as standard PCM d) none of these

Answer: (a)

18. A BPSK system transmits 1000 bits/sec. The transmission rate in baud is [MODEL QUESTION]
a) 1000 baud b) 500 baud c) 2000 baud d) none of these
Answer: (a)

19. A carrier recovery circuit is not needed with [MODEL QUESTION]
a) BPSK b) QPSK c) DPSK d) QAM
Answer: (c)

20. If the sampling is done at 60 KHz, the bit rate in DM is [MODEL QUESTION]
a) 60 Kbps b) 480 Kbps c) 120 kbps d) None of these
Answer: (a)

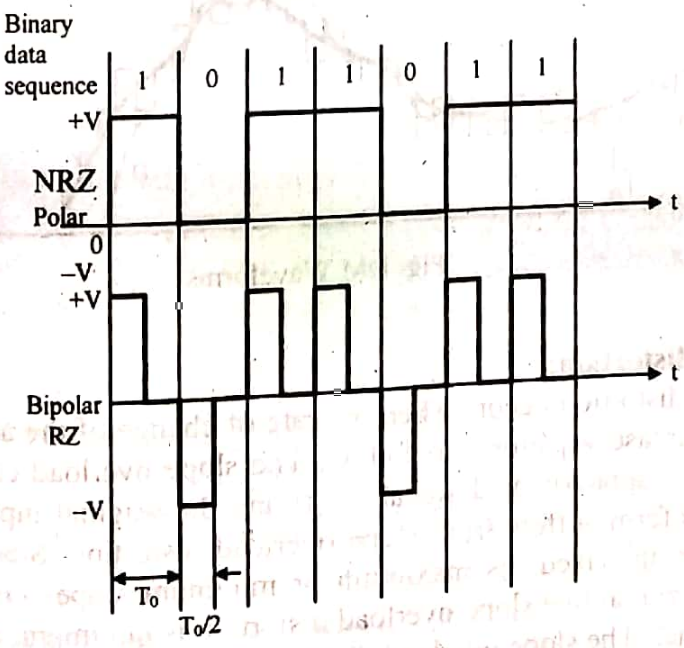
21. Which of the following gives minimum probability of error [MODEL QUESTION]
a) ASK b) FSK c) PSK d) DPSK
Answer: (c)

Short Answer Type Questions

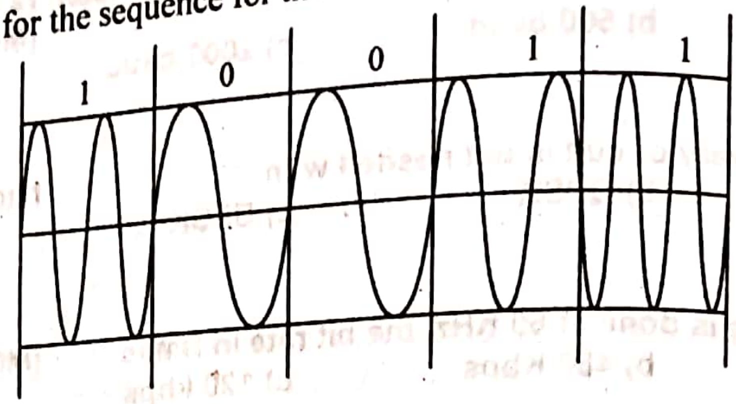
1. a) Encode the bit sequence 1011011 in the NRZ-polar and RZ-bipolar format.
b) Sketch the FSK waveform for the sequence for the bit 10011. Assume that $f_{c1} = f_{c2} = \frac{2}{T_b}$, T_b being the bit duration. [WBUT 2013]

Answer:

a) Bit sequence is
1011011



b) FSK waveform for the sequence for the bit 1 0 0 1 1



2. What is the slope overload distortion and granular noise in Delta Modulation? How are they removed? **[WBUT 2013]**

OR,

What are the drawbacks of delta modulation and how can it be overcome? Explain with suitable diagram. **[WBUT 2016]**

Answer:

1. Granular noise:

As shown in Fig , the m'(t) waveform is a staircase approximation to the analog signal m(t). For this staircase waveform, there will be an initial transient period labeled A. When modulator reaches steady state, the staircase waveform around the analog waveform as shown at B. This hunting produces granular noise. The granular noise occurs when the step size is two large compared to small variations in the input signal. This can be observed at point B. Here, input is slowly increasing but the staircase waveform remains horizontal. The granular noise can be reduced by keeping step size small.

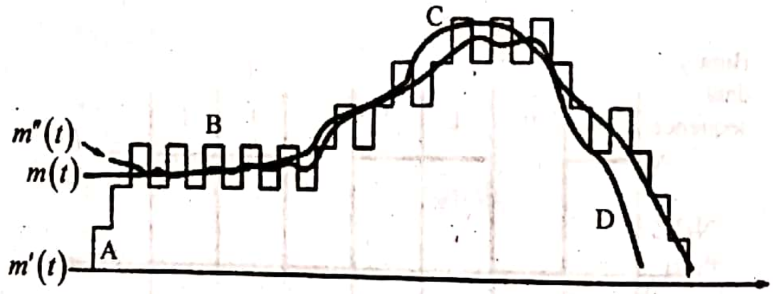


Fig: DM Waveforms

2. Slope overload distortion:

The slope overload distortion occurs when the rate of change of the analog waveform is too high for the staircase waveform to follow. The slope overload causes a large error between the staircase approximated signal, m'(t) and the original input signal, m(t). At point C and D waveform suffers from slope overload distortion. Since the step size of delta modulator remains fixed, its maximum or minimum slopes occur along straight lines. In case of horizontal line slope overload distortion is minimum, and it is maximum along the vertical line. The slope overload distortion can be minimized by increasing the step size. But increase in step size increases granular noise. To solve this problem the delta modulation process is modified and known as adaptive delta modulation.

3. What is continuous phase FSK? How is a CPFSK signal generated? What is the advantage of CPFSK? **[WBUT 2014, 2017]**

Answer:

1st Part:

Discrete spectral components present in the multi-oscillator continuous phase FSK scheme can be reduced substantially by incorporating memory in the modulated waveform's phase. This scheme is called Continuous Phase Frequency Shift Keying (CPFSK).

2nd Part:

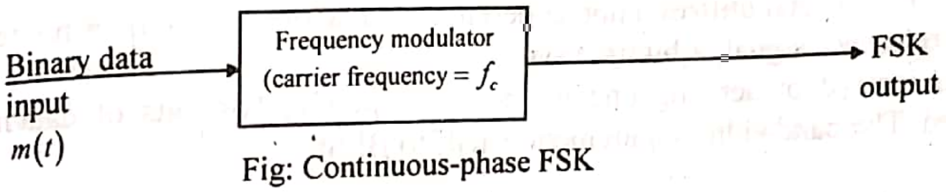


Fig: Continuous-phase FSK

The continuous-phase FSK signal is generated by feeding the data signal into a frequency modulator. This FSK signal is represented by

$$s(t) = A_c \cos\left[\omega_c t + D_f \int_{-\infty}^{t} m(\lambda)\, d\lambda\right]$$

or, $$s(t) = \mathrm{Re}\left\{g(t)e^{j\omega_c t}\right\}$$

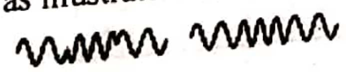
where $$g(t) = A_c e^{j\theta(t)}$$

$$\theta(t) = D_f \int_{-\infty}^{t} m(\lambda)\, d\lambda \qquad \text{for FSK}$$

and $m(t)$ is a baseband digital signal. Although $m(t)$ is discontinuous at the switching time, the phase function $\theta(t)$ is continuous because $\theta(t)$ is proportional to the integral of $m(t)$. If the serial data input waveform is binary, such as a polar baseband signal, the resulting FSK signal is called a binary FSK signal. Of course, a multilevel input signal would produce a multilevel FSK signal. We will assume that the input is a binary signal in this section and examine the properties of binary FSK signals.

3rd Part:

The FSK transmitted signal can have either discontinuous phase or continuous phase, depending on the signal design, as illustrated below:



Continuous phase, shown on the right, is desirable, since the high frequency components are reduced. This is important for a bandlimited channel and particularly important when the channel is nonlinear.

4. a) What is line coder?
b) Compare BPSK, BFSK and QPSK and draw the constellation diagram of these. **[WBUT 2015]**

Answer:

a) Line coder in a digital communication system is a circuit which converts standard logic levels to a form more suitable for line transmission.

b) 1st Part:

BPSK modulation technique is a technique that offers several advantages over other modulation techniques that is it has the simplest of the system design, and it has power efficiency to be optimum.

The binary FSK signal utilizes a non coherent demodulator, which does not require either a derived reference signal or bit time synchronization.

In QPSK, instead of sending one bit per time period, two bits of data/message are transmitted. The bandwidth requirement is half to BPSK.

2nd Part:

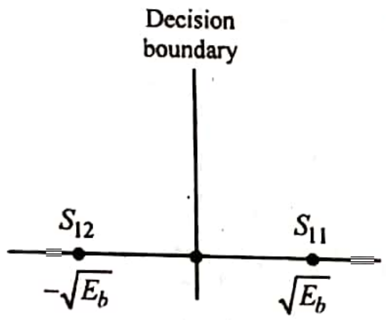


Fig: Constellation diagram of BPSK

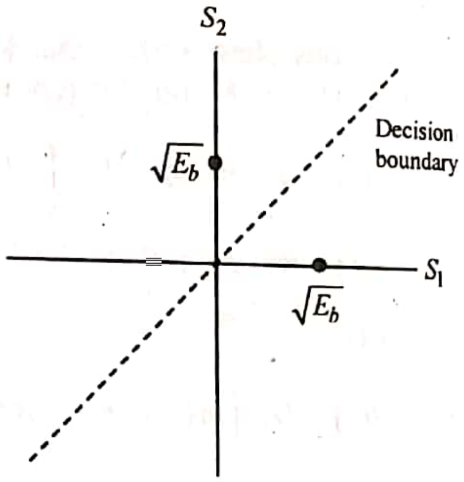


Fig: Constellation diagram of BFSK

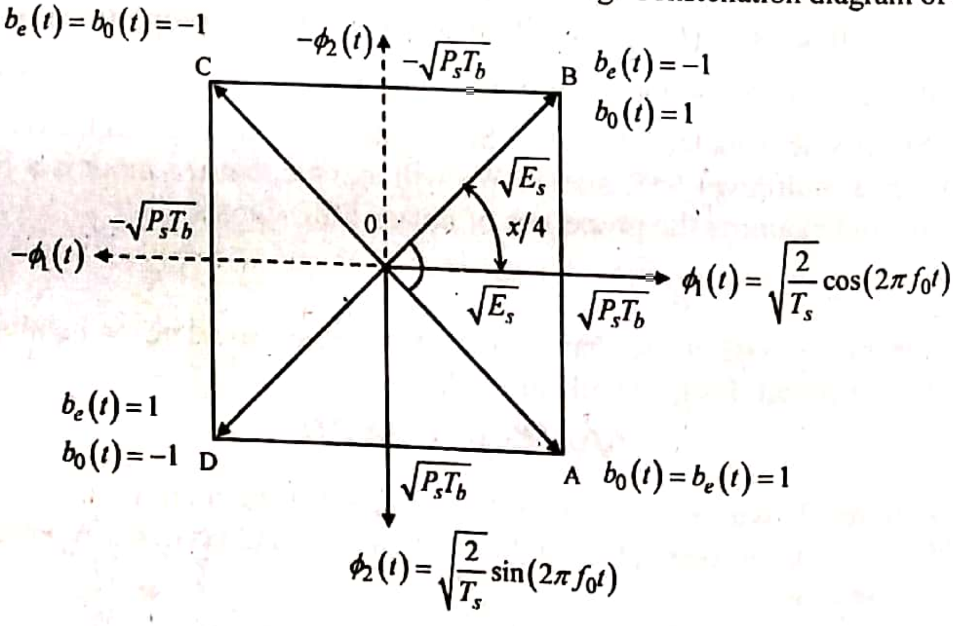


Fig: Constellation diagram of QPSK

5. Explain differential pulse code modulation with proper diagram. **[WBUT 2017]**

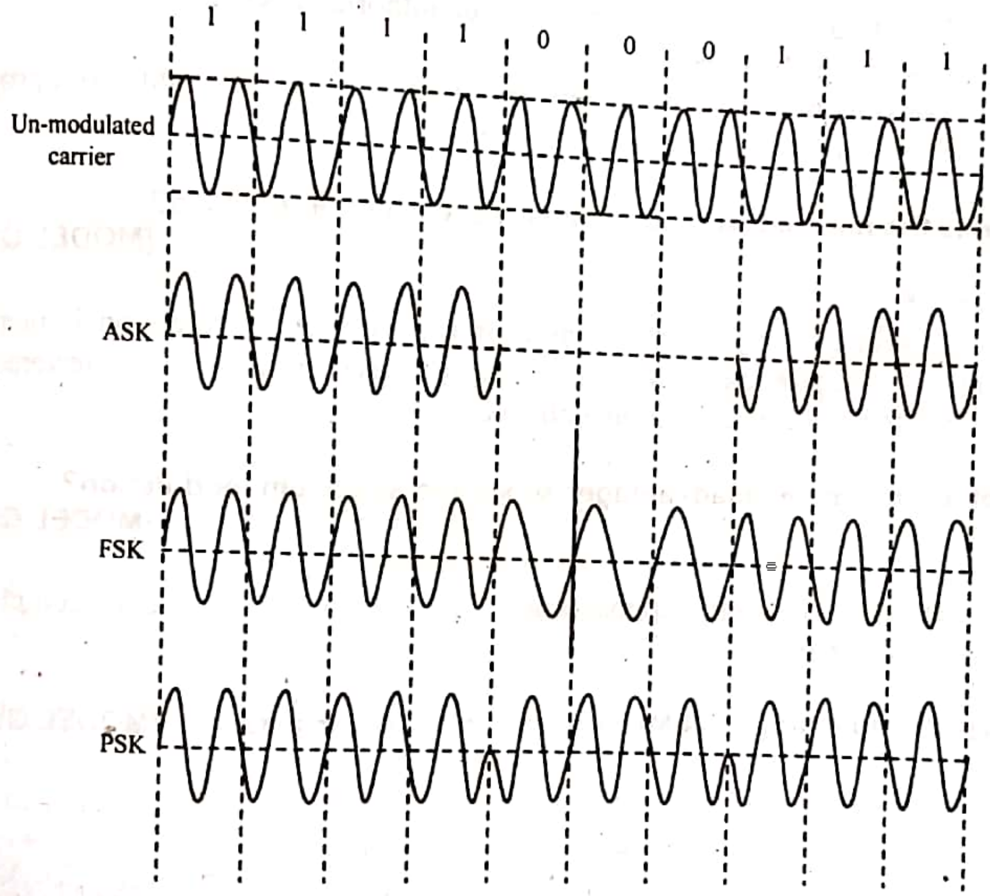
Answer:

Refer to Question No. 8(c) of Long Answer Type Questions.

6. Draw ASK, FSK, PSK signal to transmit data stream 1111000111. What is complementary error function? **[WBUT 2018]**

Answer:

1st part:



2nd part:

The complementary error function denoted by *erfc*, is defined as:

$$erfc(x) = 1 - erf(x)$$

$$= \frac{\sqrt{2}}{\pi}\int_x^{\infty} e^{-t^2}\,dt = e^{-x^2}\,erfc(x)$$

which also defines *erfc* x, the scaled complementary error function which can be used instead of *erfc* to avoid arithmetic underflow. Another form of $erfc(x)$ for non-negative x is known as Craig's formula, after its discover,

$$erfc(x),\ (x \geq 0) = \frac{2}{\pi}\int_0^{\pi/2} \exp\left(\frac{-x^2}{\sin^2\theta}\right) d\theta$$

This form is valid only for positive values of x, but it can be used in conjunction with $erfc(x) = 2 - erfc(-x)$ to obtain $erfc(x)$ for negative values.

7. What are the characteristics of spread spectrum modulation? **[MODEL QUESTION]**

Answer:
The following are the characteristics of spread spectrum modulation
(i) It is a kind of double modulation technique
(ii) Pseudo noise codes are used for modulation
(iii) They are resistant to jamming
(iv) They are difficult to intercept for an unauthorized person
(v) They are easily hidden
(vi) They provide a measure of immunity to distortion due to multipath propagation
(vii) They have asynchronous multiple access capability

8. What is the main advantage of spread spectrum techniques? **[MODEL QUESTION]**

Answer:
This is its ability to reject interference. It can combat an intentional interference or jamming by a hostile transmitter. It can also reject unintentional interference due to another user transmitting in the same channel.

9. What are the main disadvantages of spread spectrum modulation? **[MODEL QUESTION]**

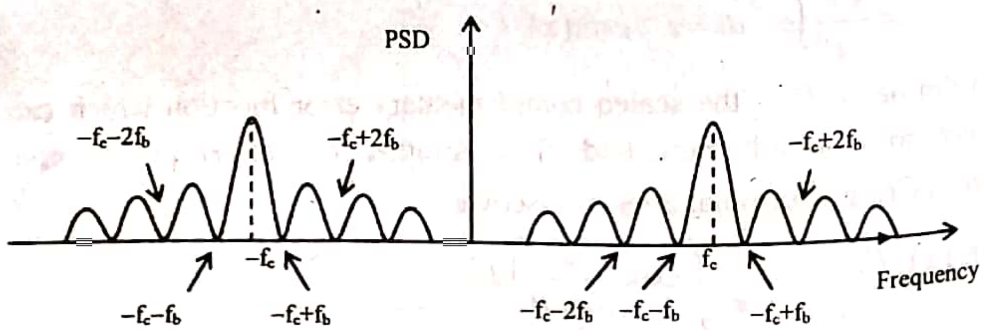
Answer:
These are (i) increased transmission bandwidth (ii) system complexity and (iii) processing delay.

10. State the advantages of M-ary modulation techniques. **[MODEL QUESTION]**

Answer:
M-ary modulation techniques require less bandwidth than binary modulation schemes. M-ary modulation utilizes the channel more efficiently.

11. Compare the bandwidths of QPSK and BPSK. **[MODEL QUESTION]**

Answer:
The power spectral density of a BPSK signal is shown in the diagram below:

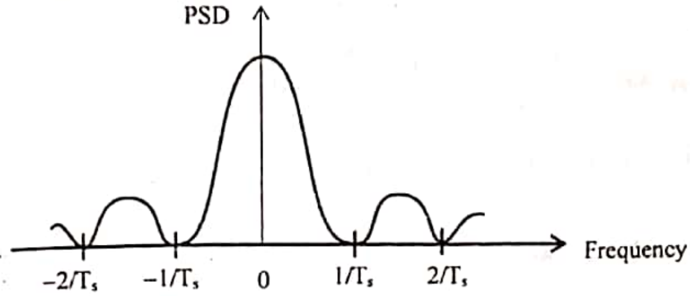


In the above PSD vs. frequency diagram of BPSK signal it is seen that the main lobe for PSD is centered around carrier frequency f_c and extends from $f_c - f_b$ to $f_c + f_b$.

Thus the bandwidth = $(f_c + f_b) - (f_c - f_b) = 2f_b = \frac{2}{T_b}$

Hence the minimum bandwidth of BPSK signal is equal to twice of the highest frequency contained in the baseband signal.

The plot of PSD of QPSK signal is shown in the diagram below:



Here T_s is the symbol duration. We know, $T_s = 2T_b$ where T_b is the bit duration.

From the above figure it is clear that the bandwidth $BW = \frac{2}{T_s} = \frac{2}{2T_b} = \frac{1}{T_b} = f_b$

Thus the bandwidth of QPSK is half of the bandwidth of BPSK.

12. Compare the noise performances of various digital modulation schemes.
[MODEL QUESTION]

Answer:

The noise performances of various digital modulation schemes are expressed in terms of the probability of error, P_e. In fact, in all cases, P_e is a function of E_b/N_o where E_b is the bit energy and N_o is the noise power spectral density. P_e for various digital modulation techniques is summarized below:

Digital Modulation	Error probability, P_e
Coherent binary PSK	$\frac{1}{2} erfc\left(\sqrt{E_b / N_o}\right)$
Non-coherent binary ASK	$\frac{1}{2} \exp\left(-E_{av} / 2N_o\right)$
Non-coherent binary FSK	$\frac{1}{2} \exp\left(-E_b / 2N_o\right)$
Differential phase shift keying (DPSK)	$\frac{1}{2} \exp(-E_b / N_o)$
Coherent binary FSK	$\frac{1}{2} erfc\sqrt{E_b / 2N_o}$
Coherent QPSK	$\frac{1}{2} erfc\left(\sqrt{E_b / N_o}\right)$
Coherent MSK	$\frac{1}{2} erfc\left(\sqrt{E_b / N_o}\right)$

The error rates of all the systems decrease monotonically with increase in E_b/N_o. For a given value of E_b/N_o, coherent PSK gives the smaller probability of error than any other schemes. MSK has exactly the same error rate performance as QPSK.

13. Determine the bandwidth and baud for an FSK signal with a mark frequency of 32KHz and space frequency of 24KHz and a bit rate of 4Kbps. [MODEL QUESTION]

Answer:

Peak frequency deviation $\Delta f_c = \frac{|f_m - f_s|}{2} = \frac{|32-24|}{2} = 4KHz$

Minimum bandwidth, $B = 2(\Delta f_c + f_b)$

Here $f_b = 4\text{Kbps}$

Hence $B = 2(4000+4000) = 2\times 8000 = 16KHz$

Since with FSK, baud is equal to the bit rate, we obtain baud = 4000

Long Answer Type Questions

1. a) What is the disadvantage of delta modulation? What method is used to overcome the problem which arises in delta modulation? [WBUT 2014, 2018]

Answer:

1st Part:

Delta modulation suffers from two types of quantization noise, namely, (1) Slope overload distortion and (2) granular noise. The figure below shows the generation of slope overload distortion and granular noise in DM.

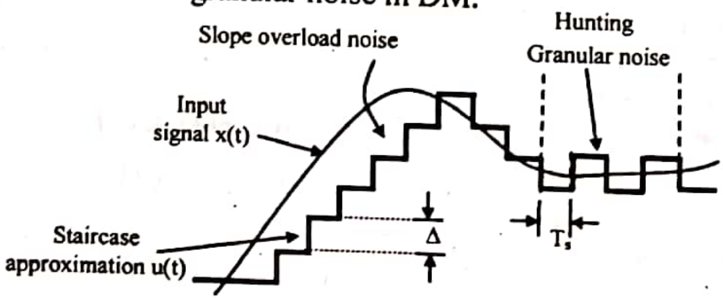


Fig: Generation of slope overload noise granular noise

When the analog signal changes rapidly the staircase signal cannot approximate it. The step size of the staircase signal becomes too small to follow the rate of rise of the input signal $x(t)$. Thus there is a large error between the staircase approximated signal $u(t)$ and the original input signal $x(t)$. This error or noise is known as slope overload distortion.

When the original analog signal has a relatively constant amplitude the step size becomes too large compared to small variations in the input signal $x(t)$. This causes the staircase approximation $u(t)$ to hunt around a relatively flat segment of the input waveform. The error thus generated between the input and staircase approximated ... granular noise.

2nd Part:

Adaptive Delta Modulation:

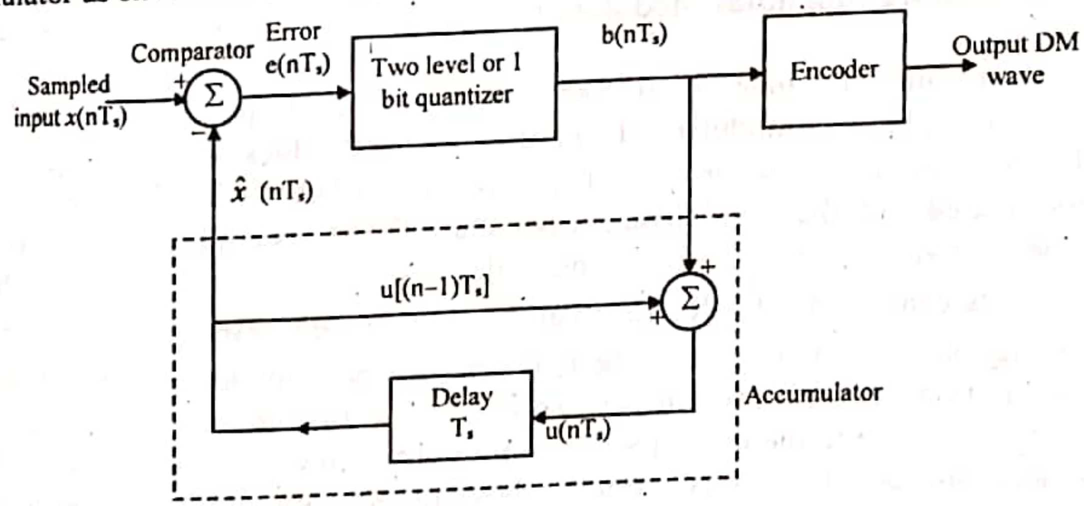
To overcome the quantization errors due to slope overload distortion and granular noise in Delta Modulation, the step size may be varied automatically depending on the amplitude characteristics of the analog input signal. When the signal changes very rapidly the step size is increased. If the signal is varying very slowly the step size is reduced. Thus the step size is adapted to the level of the input signal. Such a digital pulse modulation system is called adaptive delta modulation (ADM). An adaptive delta modulator can take continuous changes in step size or discrete changes in step size. If a given string of bits contain equal number of 1s and 0s, it is assumed that the staircase is oscillating about a slowly varying analog signal. In such cases, the step size is reduced. On the other hand, if there is an excess of either 1s or 0s within the given string of bits it would indicate the staircase is trying to catch up with a rapidly changing analog signal. In such cases the step size is increased.

b) Draw and explain the block diagram of transmitter and receiver of a delta modulator? **[WBUT 2014, 2016, 2018]**

Answer:

Delta Modulation Generation

Delta modulation transmitter consists of a summer, a two-level quantizer and an accumulator as shown in the diagram below:



The summer in the accumulator adds quantizer output ($\pm\delta$) with the previous sample approximation.

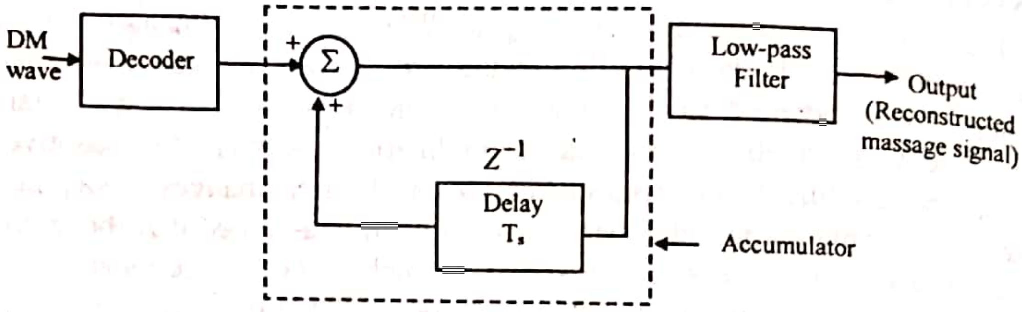
Thus $u(nTs) = u\left[(n-I)Ts\right] \pm \delta = u\left[(n-1)Ts\right] + b(nTs)$

The previous sample approximation $u\left[(n-1)T_s\right]$ is restored by delaying one sample period T_s. The sampled input signal $x(nT_s)$ and staircase approximated signal $\hat{x}n(T_s)$

are subtracted in the summer to get error signal $e(nT_s)$. Depending on the sign of $e(nT_s)$, one bit quantizer generates an output of $+\delta$ or $-\delta$. In case of $+\delta$, binary 1 is transmitted and in case of $-\delta$, binary 0 is transmitted.

Delta Modulation Reception

The block diagram of a DM receiver is shown in the figure below:



The receiver consists of an accumulator and a low pass filter. The accumulator generates the staircase approximated signal output and is delayed by one sampling period T_s. The output of the delay line is then added to the input signal. If the input is binary '1' then it adds $+\delta$ to the previous delayed output. If the input is binary '0' then it adds $-\delta$ i.e. δ is subtracted from the delayed signal. The low pass filter smoothes the staircase signal to reconstruct the original message signal $x(t)$. The low pass filter has the cut off frequency equal to the highest frequency in $x(t)$.

2. Explain Quadrature Amplitude Modulation. **[WBUT 2014, 2018]**

Answer:

Quadrature amplitude modulation (QAM) combines both phase and amplitude modulation. If the phase is modulated to have n distinct values and the amplitude is modulated to have m distinct values, then the system is nm-QAM system. It is the carrier that is so modulated with the input signal. A popular 8 QAM system has a QPSK system associated with two different carrier amplitudes. As there are 8 different states, $2^k = 8$, $k = 3$ bits can be encoded for each baud symbol to be transmitted. In addition to the carrier being phase shifted by 90° to be fed to the balanced modulator 2 for obtaining four-phase conditions, two bit combination words are also first converted into four-level dc voltages, which come to the modulators as inputs. The scheme is shown in Fig.1. The converters used are usually D/A converters whose outputs are equally spaced voltage levels — the magnitudes in the four spaces are related to the different combinations of the two input bits. Obviously, the output levels must precisely be obtained for combining in the linear summer to produce the desired amplitude and phase. The QPSK diagram of Fig. 2 may be extended for the 8 QAM amplitude phasor diagram. This is known as constellation diagram and is shown in Fig. 2. The two amplitude levels are A and A' and the phases are as in Fig. 2.

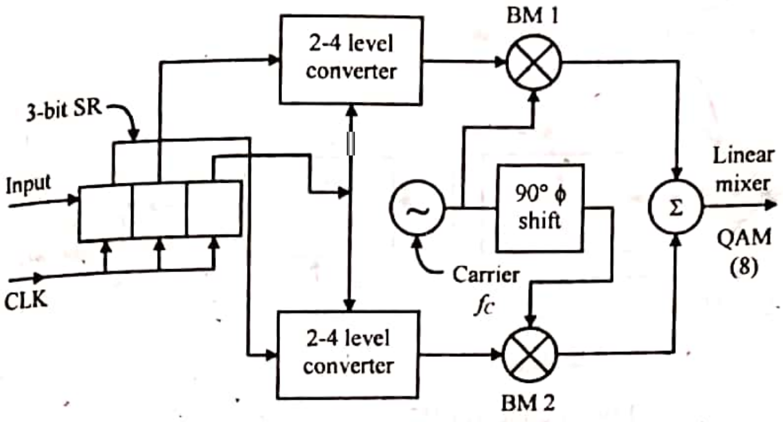


Fig: 1 QAM modulation scheme

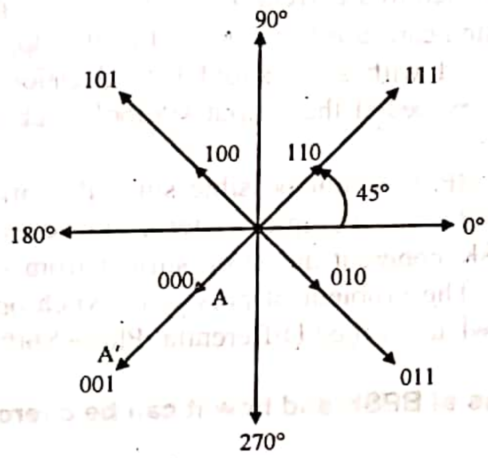


Fig: 2 The constellation diagram

Table 1 shows the amplitudes and phase shifts corresponding to the three-bit information

Table 1 QAM amplitudes and phase-shifts

3-bit word	Amplitude	Phase (°)
000	A	225
001	A'	225
010	A	315
011	A'	315
100	A	135
101	A'	135
110	A	45
111	A'	45

3. a) Explain coherent detection of BPSK signal with proper diagram.
[WBUT 2014, 2018]

Answer:

Only coherent detection of BPSK signal is possible. A coherent BPSK detector is shown below:

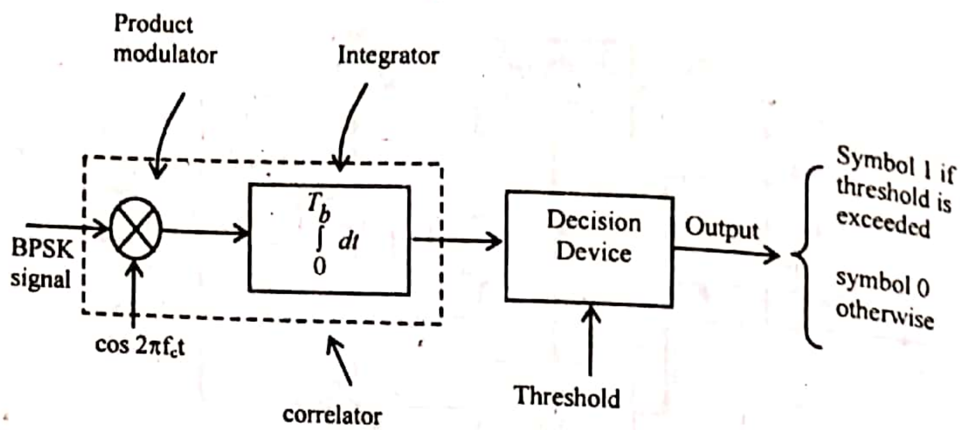


Fig: A coherent BPSK Detector

Here the BPSK signal is applied to a correlator consisting of a product modulator and an integrator. A locally generated carrier $e(t) = \cos 2\pi f_c t$ is also applied to the correlator. The correlator output is compared with a threshold in a decision device. If the threshold voltage (usually 0 volt) is exceeded the output symbol is chosen as 1; otherwise it is chosen as 0.

Non-coherent detection of BPSK is not possible since the envelope of a PSK wave is same for both symbols 1 and 0 and a single carrier frequency is used for the modulation process unlike BFSK. BPSK coherent detection suffers from synchronization problems for both phase and timing. The problem of providing synchronous carrier for detecting BPSK signal is avoided in what is called Differential Phase Shift Keying or DPSK.

b) What are the drawbacks of BPSK and how it can be overcome?

[WBUT 2014, 2018]

Answer:

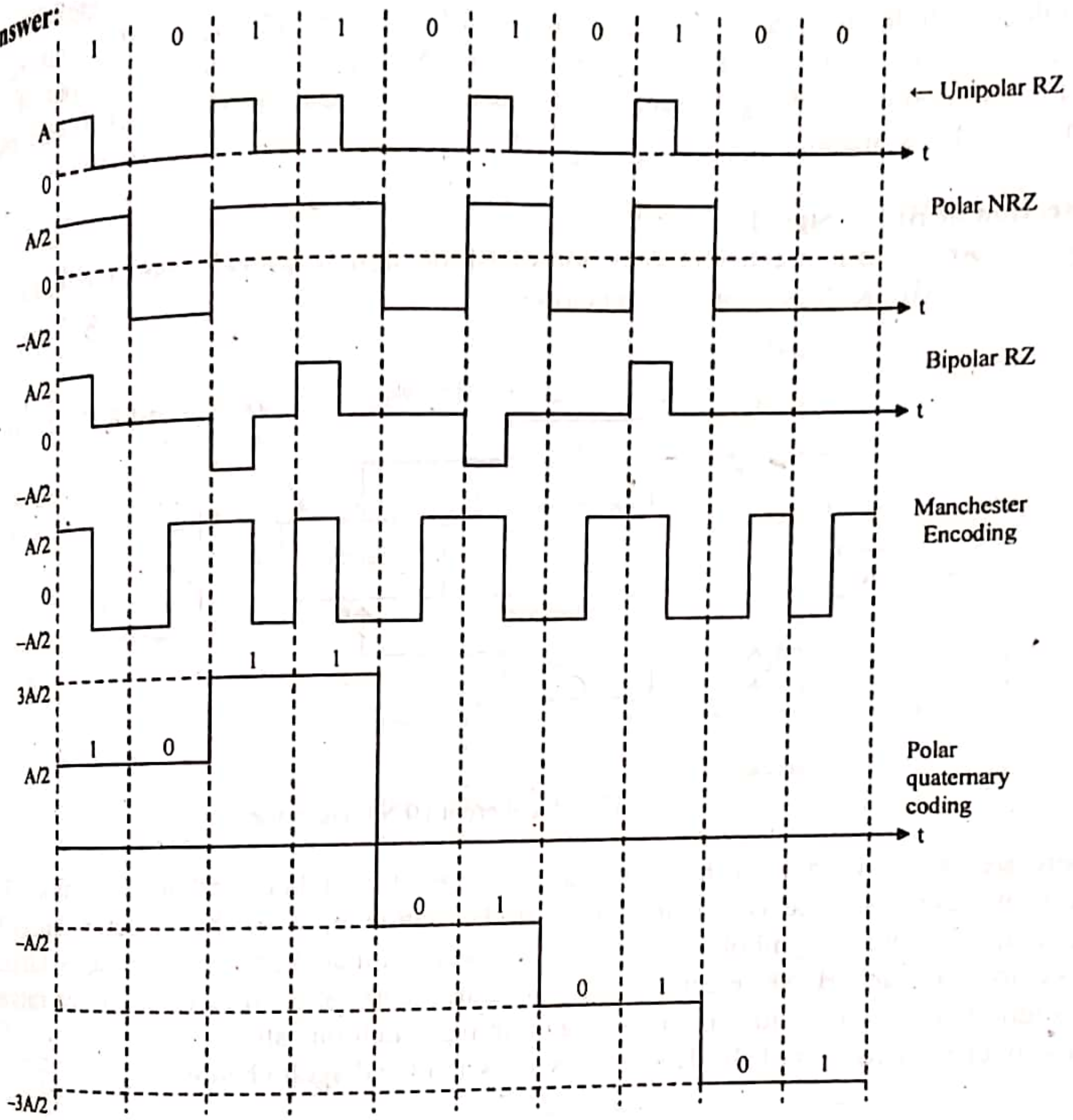
In a coherent BPSK receiver the carrier is regenerated by squaring the input BPSK signal $b(t)\sqrt{2P_s}\cos 2\pi f_c t+\theta)$ If the received signal is $-b(t)\sqrt{2P_s}\cos(2\pi f_c t+\theta)$, then also the squared signal remains the same. This means that the recovered carrier is unchanged even if the input signal has changed its sign. Thus it becomes impossible to determine whether the received signal is b(t) or –b(t). This results in ambiguity in the output signal. This problem has been solved in QPSK. BPSK also suffers from inter-symbol interference (ISI) and inter channel interference, which can be solved to some extent by using filters.

c) Draw the waveform for the following digital data 1011010100

i) Polar NRZ
ii) Bipolar RZ
iii) Manchester coding
iv) Polar quaternary coding
v) Unipolar RZ.

[WBUT 2014, 2018]

Answer:



4. Draw the block diagram for generation and detection of the BFSK signal and explain it. [WBUT 2015]

Answer:

Generation of BFSK Signal

Binary FSK signals can be generated by using a Frequency Modulator as shown in the diagram below: -

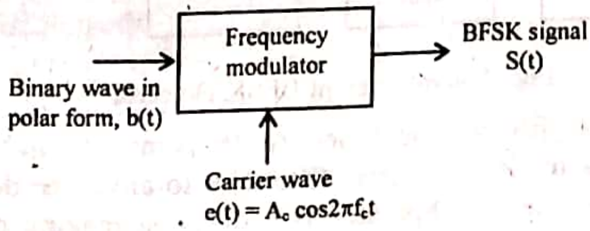


Fig: A BFSK Transmitter

Here the digital signal in polar form b(t) and a carrier wave e(t) are applied to a Frequency Modulator (say a Voltage Controlled Oscillator, VCO). As the modulating voltage changes from one level to another (say +5V to −5V), the output of the frequency modulator changes from one frequency f_1 to another frequency f_2 and thus generates BFSK signal.

Detection of BFSK Signal

Both coherent and non-coherent detection of BFSK signals are possible. A coherent or synchronous BFSK detector is shown below:

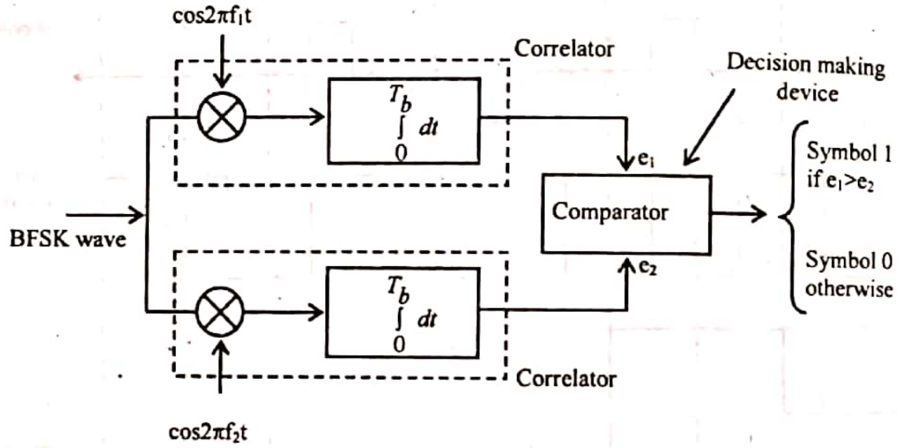


Fig: A coherent BFSK Detector

There are two correlators each consisting of a product modulator and an integrator. The decision-making device is a comparator. If the output $e_1 > e_2$ the detector makes a decision in favour of symbol 1. If $e_1 < e_2$, the decision making device decides in favour of symbol 0. Such BFSK receivers are also called correlation receivers. Since this is coherent detection it requires both phase and timing synchronization.

Non-coherent detection of BFSK signals is shown in the diagram below:

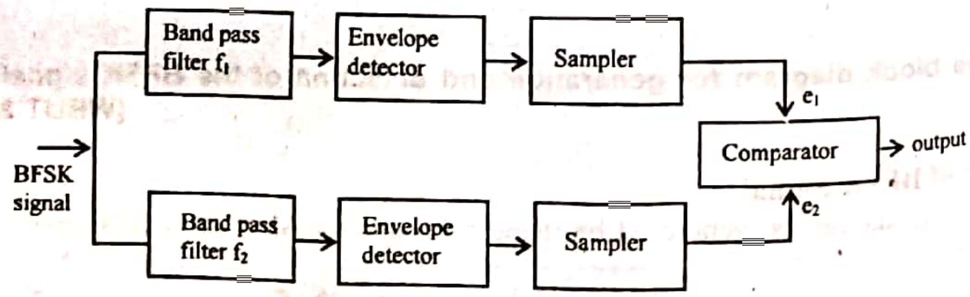


Fig: A non-coherent BFSK Detector

There are two band pass filters, one tuned to frequency f_1 and the other tuned to frequency f_2. The outputs of the band pass filters go to envelope detectors followed by samplers and comparator. Here comparator is a decision making device. It decides in favour of symbol 1 if $e_1 > e_2$ and in favour of symbol 0 if $e_1 < e_2$.

5. a) With suitable block diagram explain the working principle of QPSK Tx and Rx.
[WBUT 2015]

Answer:

Quadriphase or Quadrature Shift Keying (QPSK)

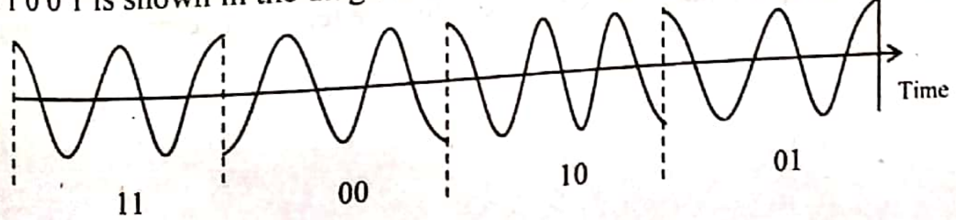
QPSK is a digital modulation technique in which two successive bits in the data sequence are grouped together so as to achieve better bandwidth efficiency. As the bits are grouped together to form symbols, the bit rate or signaling rate (f_b) is reduced which reduces the bandwidth of the channel.

QPSK may be treated as an M-ary PSK modulation scheme in which M = 4. In QPSK the combination of two successive bits results into four distinct symbols. As one symbol changes to next symbol, the phase of the carrier changes by 90° or $\frac{\pi}{2}$ radians. Each symbol is called a dibit. As an example, the four dibits may be 00, 01, 10, 11 in natural coded form or 00, 10, 11, 01 in Gray encoded form. The four dibits or symbols and their corresponding signals and phase shift in the Gray encoded form may be represented as shown below.

Input Successive bits	Symbol	Signal	Phase Shift in carrier
00	S_1	$s(t)=A_c\cos\left(2\pi f_c t-\frac{3\pi}{4}\right)$	$-\frac{3\pi}{4}$
10	S_2	$s(t)=A_c\cos\left(2\pi f_c t-\frac{\pi}{4}\right)$	$-\frac{\pi}{4}$
11	S_3	$s(t)=A_c\cos\left(2\pi f_c t+\frac{\pi}{4}\right)$	$+\frac{\pi}{4}$
01	S_4	$s(t)=A_c\cos\left(2\pi f_c t+\frac{3\pi}{4}\right)$	$+\frac{3\pi}{4}$

for $0 \le t \le T$ where T=symbol duration

A QPSK signal waveform for a binary sequence 1 1 0 0 1 0 0 1 is shown in the diagram below:



Generation of QPSK Signals

QPSK signals can be expressed as

$s(t) = A_c\cos\phi(t)\,2\pi f_c t - A_c\sin\phi(t)\sin 2\pi f_c t$

where $A_c\cos\phi(t)$ forms the in-phase component and $A_c\sin\phi(t)$ forms the quadrature component. Thus QPSK signals can be generated based on the in-phase and quadrature components as shown below:

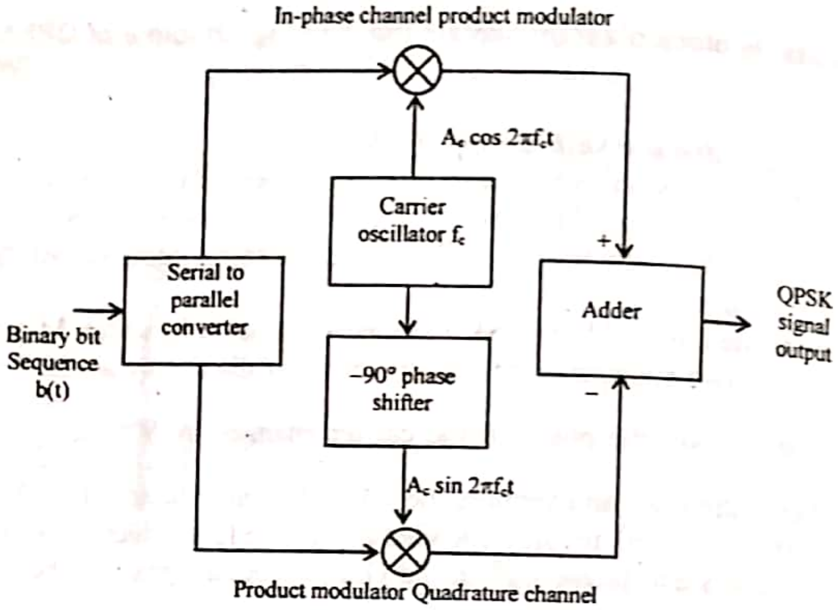


Fig: A QPSK Transmitter

The converter converts each successive pair of bits of the incoming binary bit sequence as two separate bits with one bit applied to the in-phase channel and the other bit applied to the quadrature channel. The output of the serial-to-parallel converter in the in-phase channel is applied to one product modulator along with the in-phase carrier $A_c \cos 2\pi f_c t$. The output of the serial to parallel converter in the quadrature channel is applied to the other product modulator along with a quadrature carrier signal $A_c \sin 2\pi f_c t$ produced by a −90° phase shifter. The outputs of the two product modulation are added in a summer circuit to obtain the QPSK signal.

As signaling interval $T = 2T_b$ where T_b is the bit duration, for a given bit rate $f_b = \frac{1}{T_b}$, a QPSK system requires half the transmission bandwidth of corresponding BPSK system. QPSK is also called quaternary phase shift keying, the term 'quaternary' meaning 4.

Detection of QPSK Signals

Coherent detection of QPSK signal is shown in the block diagram below.

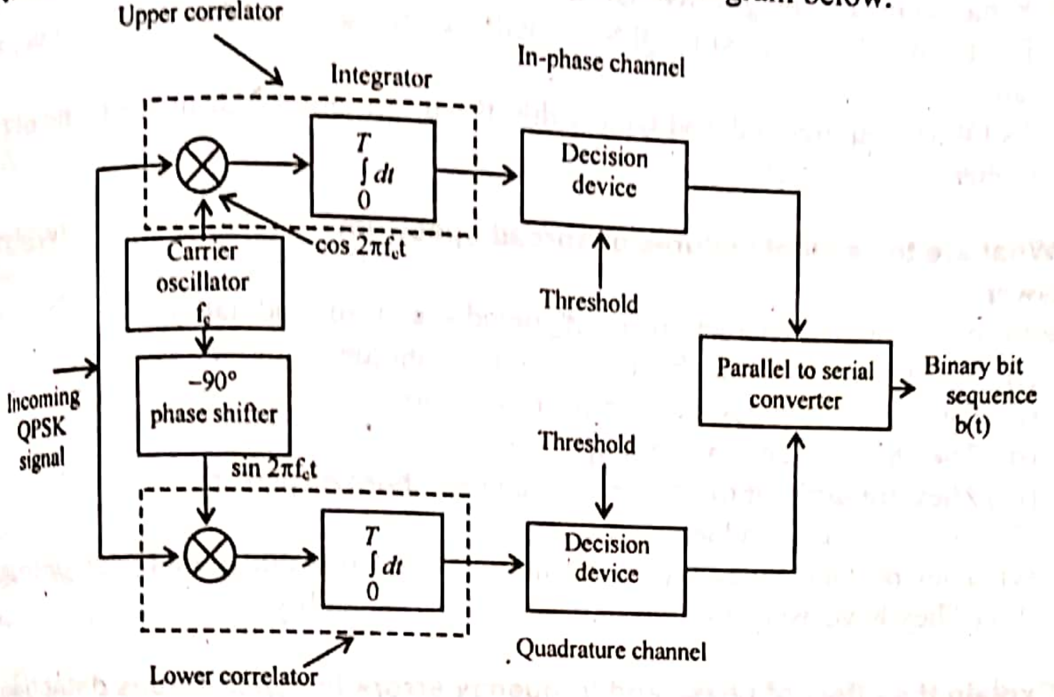
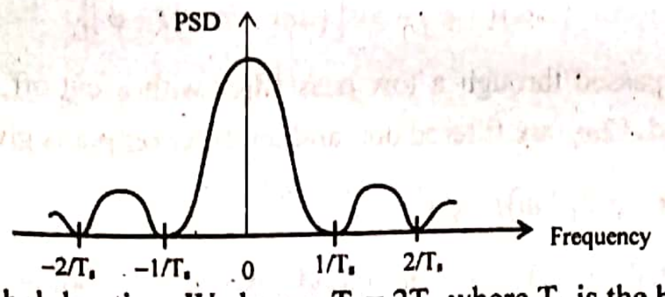


Fig: Block diagram of a coherent QPSK receiver

The detection scheme uses a pair of correlators connected in parallel. The cosine of the carrier phase is computed by the upper correlator and the sine of the carrier phase is computed by the lower correlator. The two decision devices compare the sign of the two correlator outputs. This enables unique resolution of the four transmitted phase angles. Interleaving of the decisions made by the two decision devices in the in-phase and quadrature channels is made by the parallel to serial converter which results in the reconstruction of the binary data stream.

Power Spectral Density Plot of QPSK Signal

The plot of PSD of QPSK signal is shown in the diagram below:



Here T_s is the symbol duration. We know, $T_s = 2T_b$ where T_b is the bit duration. From the above figure it is clear that the bandwidth

$$BW = \frac{2}{T_s} = \frac{2}{2T_b} = \frac{1}{T_b} = f_b$$

Advantages of QPSK

QPSK has some advantages over BPSK.

1) The bandwidth required in QPSK is half as compared to BPSK for the same bit error rate.
2) As QPSK requires reduced bandwidth, the information transmission rate of QPSK is higher.

b) What are the salient features of spread spectrum? **[WBUT 2016]**

Answer:

The following are the characteristics of spread spectrum modulation

(i) It is a kind of double modulation technique
(ii) Pseudo noise codes are used for modulation
(iii) They are resistant to jamming
(iv) They are difficult to intercept for an unauthorized person
(v) They are easily hidden
(vi) They provide a measure of immunity to distortion due to multipath propagation
(vii) They have asynchronous multiple access capability

6. Explain the effect of phase and frequency errors in synchronous detection. **[WBUT 2016]**

Answer:

The frequency and phase of the local oscillator signal in synchronous detection must be identical to the transmitted carrier. Any discrepancy in frequency and/or phase causes a distortion in the detected output at the receiver. Let us examine the nature of distortion caused by phase or frequency discrepancy.

Let a modulated signal reaching the receiver signal be $f(t)\cos\omega_c t$. Assuming, a locally generated signal with frequency and phase error equal to $\Delta\omega$ and ϕ, respectively, the product of the two signals, in the synchronous detector yields,

$$e_d(t) = f(t)\cos\omega_c t \cdot \cos\left[(\omega_c + \Delta\omega)t + \phi\right]$$

$$= \frac{1}{2}f(t)\left\{\cos\left[(\Delta\omega)t + \phi\right] + \cos\left[(2\omega_c + \Delta\omega)t + \phi\right]\right\}$$

When this signal is passed through a low pass filter with a cut-off frequency ω_m, the terms centered around $\pm 2\omega_c$ are filtered out, and the filter output is given by

$$e_o(t) = \frac{1}{2}f(t)\cos\left[(\Delta\omega)t + \phi\right] \qquad \text{....(1)}$$

The baseband signal $f(t)$ is multiplied by a slow-time varying function $\cos\left[(\Delta\omega)t + \phi\right]$ that distorts the message signal $f(t)$. Let us consider the following special cases:

(i) When the frequency error $\Delta\omega$, and phase error ϕ are both zero, then Eqn. (1) yields,

$$e_o(t) = \frac{1}{2} f(t)$$

i.e., there is no distortion in the detected output.

(ii) When there is only the phase error, i.e.,

$\Delta\omega = 0$, but $\phi \neq 0$

Then Eqn. (1) yields,

$$e_o(t) = \frac{1}{2} f(t)\cos\phi$$

which shows that the output is multiplied by $\cos\phi$. When ϕ is time independent, there is no distortion; rather, there is only attenuation. The output is maximum when $\phi = 0$, and minimum when $\phi = 90°$. However, in general, ϕ randomly varies with time due to random variation of propagation media (ionosphere). This causes undesirable distortion in the detected output.

Quadrature Null Effect:
The detected output is zero when $\phi = 90°$. This is called a quadrature null effect, because the output signal is zero when the local carrier is in phase quadrature with the transmitted carrier.

(iii) When there is only the frequency error, i.e.,

$\Delta\omega \neq 0$ and $\phi = 0$

Then Eqn. (1) yields

$$e_o(t) = \frac{1}{2} f(t)\cos(\Delta\omega)t$$

Here, the multiplying factor $\cos(\Delta\omega)t$ is time-dependent, and causes distortion in the detected output. The error $\Delta\omega$ is usually small, and hence a message $f(t)$ is multiplied by a slow varying sinusoidal signal. This is a more serious distortion. Hence frequency error should be avoided.

(iv) When both errors are non-zero, i.e., $\Delta\omega \neq 0$ and $\phi \neq 0$, Eqn. (1) itself provides the detected output. In this case, the constant phase error provides attenuation, and the frequency error causes distortion in the detected output. This, we get an attenuated and distorted output in the receiver.

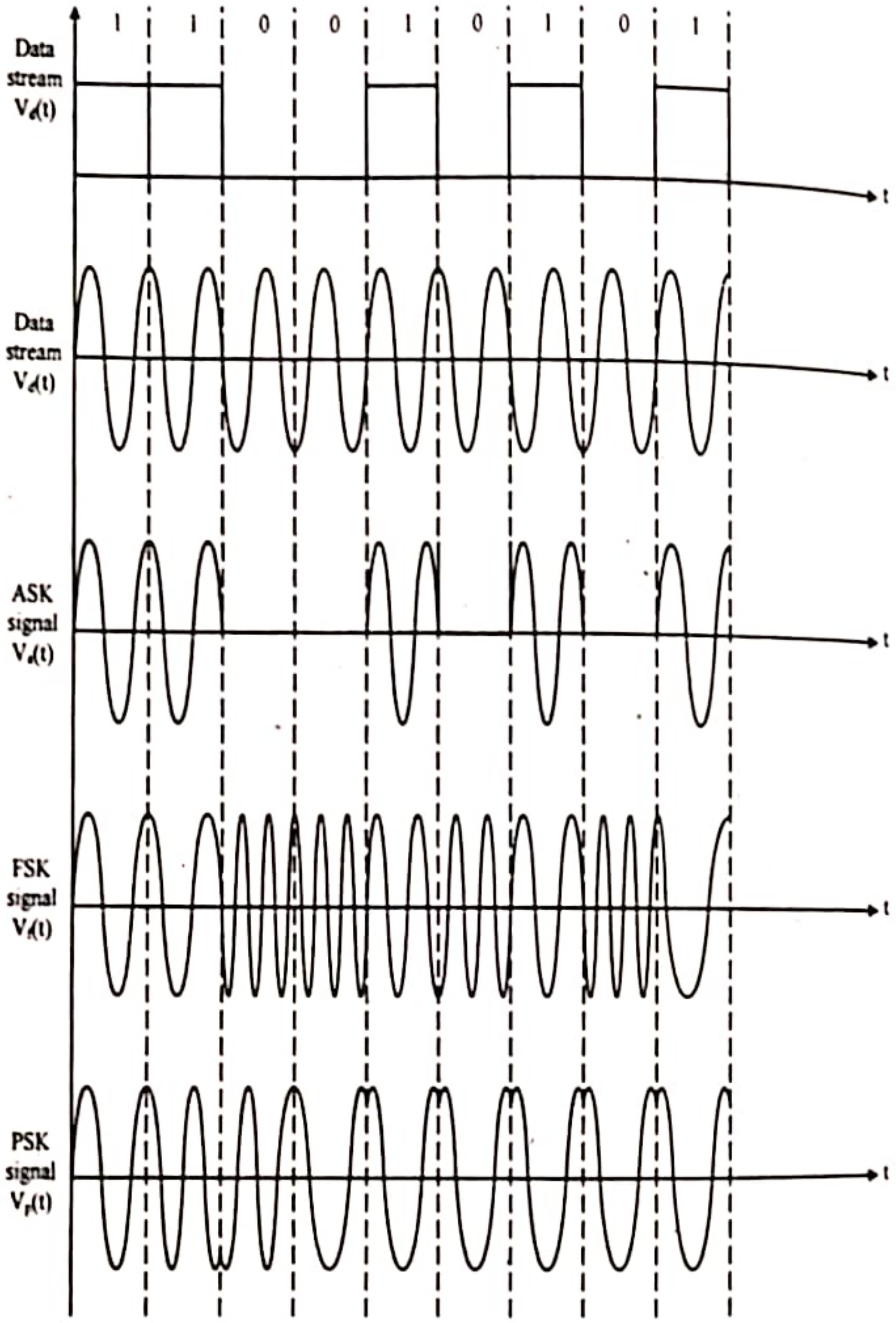
7. a) Explain with proper diagram the detection of BPSK signal. [WBUT 2016]
b) What are the drawbacks of BPSK and how can it be eliminated?
c) Draw ASK, FSK, PSK signals to transmit data stream 110010101.

Answer:

a) *Refer to Question No. 3(a) of Long Answer Type Questions.*

b) *Refer to Question No. 3(b) of Long Answer Type Questions.*

c)



8. Write short notes on the following:

a) Adaptive Delta Modulation [WBUT 2013]

b) BPSK mod and demod [WBUT 2013]

c) DPCM [WBUT 2016]

Answer:

a) Adaptive Delta Modulation (ADM):

The block diagram of ADM is shown below in fig below.

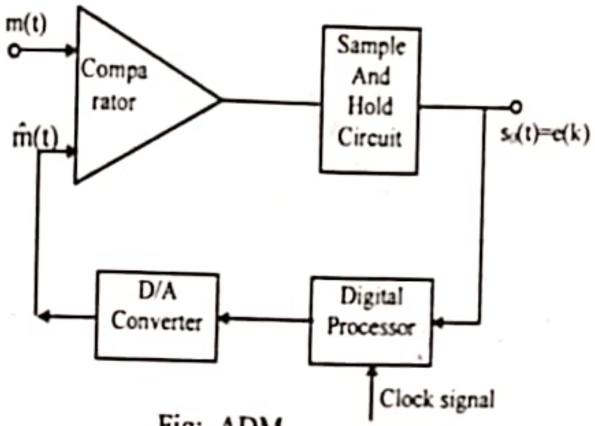


Fig: ADM

In this method, the processor has an accumulator and at each active edge of clock waveform, generates a step S which diminishes the accumulator.

The algorithm to generate step S is as follows:

In response the k^{th} active clock edge the processor generates a step equal in magnitude to step generated in response to

(k - l)st clock edge. This step is added or subtracted from the accumulator to movė rh(t) towards m(t). If the direction of the step at clock edge k is the same as at edge k-1 then the processor increases the magnitude of the step by amount So and if the directions are opposite then the magnitude of step size So is decreased by processor.

Advantages of Adaptive Delta Modulation over ordinary Delta Modulation

Adaptive delta modulation has certain advantages over ordinary delta modulation. These are

i) The signal to noise ratio is better in ADM because of the reduction in slope overload distortion and granular noise.
ii) The dynamic range of ADM is wider than ordinary DM because of the variable step size.
iii) Utilization of bandwidth is better in ADM than simple DM.

b) BPSK mod and demod

Figure 1 shows one kind of circuit used for generating BPSK, a standard lattice ring modulator or balanced modulator used for generating DSB signals. the carrier sine wave is applied to the input transformer T_1 while the binary signal is applied to the transformer enter taps. The binary signal provides a switching signal for the diodes. When a binary 0 appears at the input, A is + and B is $-$, so diodes D_1 and D_4 conduct. They act as closed switches, connecting the secondary T_1 to the primary of T_2. The windings are phased so that the BPSK output is in phase with the carrier input.

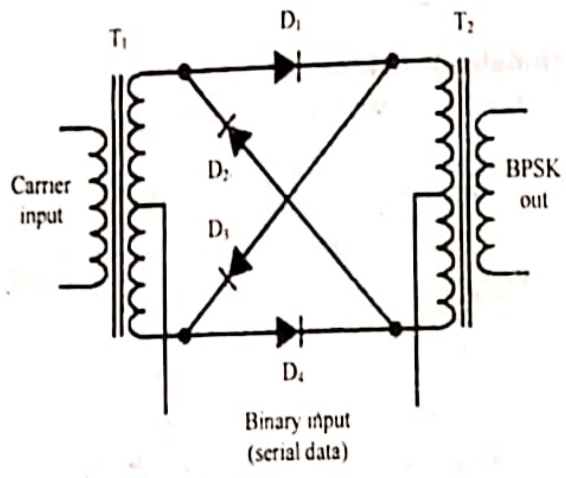


Fig: BPSK Modulator

When a binary 1 appears at the input, A is –ve and B is +ve, so diodes D_1 and D_4 are cut off while diodes D_2 and D_3 conduct. This causes the secondary of T_1 to be connected to the primary of T_2 but with the interconnections reversed. This introduces a 180° phase-shift carrier at the output.

Demodulation of a BPSK signal is also done with a balanced modulator. A version of the diode ring or lattice modulator can be used, as shown in Fig. 2. This is actually the same circuit as that in Fig. 1, but the output is taken from the center taps. The BPSK and carrier signals are applied to the transformers. IC balanced modulators can also be used at the lower frequencies. The modulator and demodulator circuits are identical to the doubly balanced modulators used for mixers. They are available as fully wired and tested components for frequencies up to about 1 GHz.

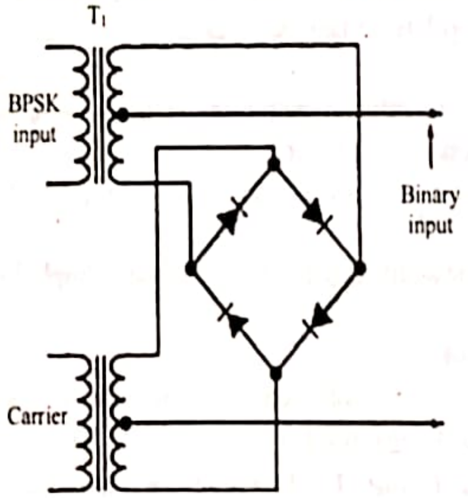


Fig: BPSK Demodulator

c) Differential Pulse Code Modulation (DPCM)

In a typical PCM system, there are successive samples taken in which there is little difference between the amplitudes of the two samples. In such a case several identical

PCM codes are transmitted which are redundant. The figure below illustrates the redundant information in PCM system.

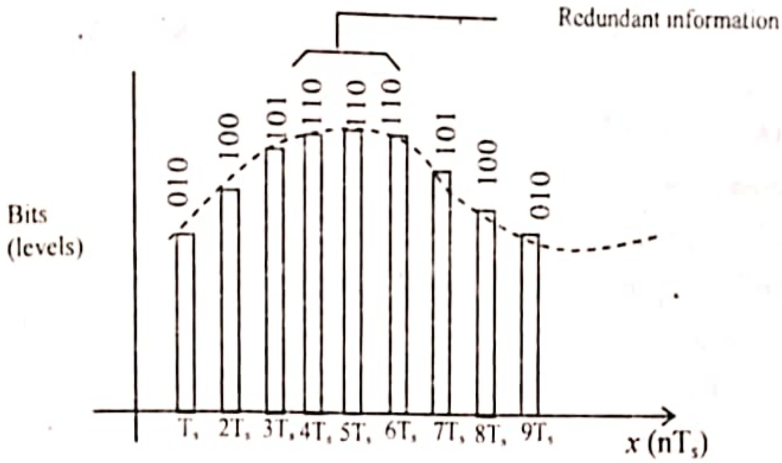


Fig: Redundant information

Here 3 bit (8 levels) PCM is used. The successive samples at $t = 4T_s$, $t = 5T_s$ and $t = 6T_s$ have the same value 110 and are redundant. If this redundancy is reduced, the overall bit rate will decrease and the number of bits required to transmit one sample will also be reduced. This type of digital pulse modulation scheme is known Differential Pulse Code Modulation (DPCM).

With DPCM, the difference in the amplitude of two successive samples is transmitted rather than the actual sample. Because the range of sample differences is typically less than the range of individual samples, fewer bits are required for DPCM than conventional PCM. For example, let at sample time k, the sample value = m(k). At sample time (k-1), the sample value = m(k-1). Instead of transmitting m(k) at time k we can transmit the change m(k) – m(k-1) at time k. It is obvious that m(k) – m(k-1) will be smaller than the sample value m(k) or m(k-1). Let us suppose ($V_H - V_L$) is such that 8 bits are required to have $2^8 = 256$ levels. But the difference m(k) – m(k-1) may extend over only $\pm 2\Delta$ (i.e., Δ, $-\Delta$, 2Δ and -2Δ) so that only four levels are there which will require only 2 bits.

DPCM Transmitter

DPCM works on the principle of prediction, which states that the value of the present sample can be predicted from the past samples. The diagram below shows a DPCM transmitter using predictor.

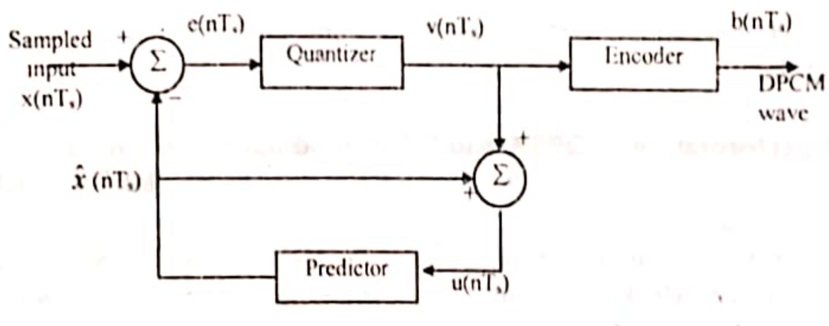


Fig: A DPCM Transmitter

Let a baseband signal x(t) is sampled at the rate $f_s = \frac{1}{T_s}$ to produce a correlated sequence denoted by x (n T_s) where n have integer values. The input to the quantizer is the output of the summer and is given by

$$e(nT_s) = x(nT_s) - \hat{x}(nT_s)$$

where $\hat{x}(nT_s)$ is the prediction output of $n(T_s)$ and

e(n T_s) is called a prediction error.

$v(nT_s) = e(nT_s) + q(nT_s)$ where $q(nT_s)$ is the Quantization error.

Also $u(nTs) = \hat{x}(nTs) + v(nTs)$

$= \hat{x}(nT_s) + e(nT_s) + q(nT_s)$

But $\hat{x}(nT_s) + e(nT_s) = x(nT_s)$ and hence

$u(nT_s) = x(nT_s) + q(nT_s)$

Thus u(nT_s) is nothing but the quantized version of x(nT_s). Also u(nT_s) is independent of the prediction filter characteristics.
The encoder encodes v(nT_s) and produces DPCM waves denoted by b(nT_s).

DPCM Receiver
Figure below shows the block diagram of a DPCM receiver.

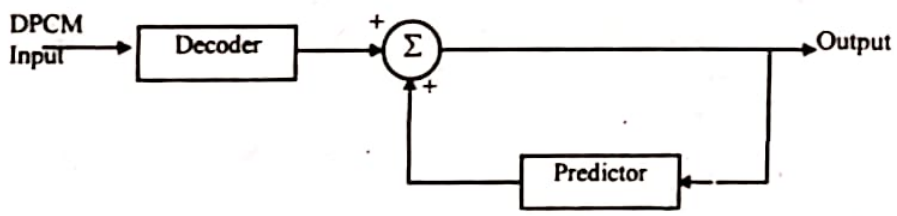


Fig: A DPCM Receiver

The receiver consists of a decoder to reconstruct the quantized error signal from the incoming DPCM signal. The quantized version of the original input is reconstructed from the decoder output using a predictor. The prediction filter output and quantized error signals are summed up in a summer circuit to give the quantized version of the original signal.
The prediction filter used in the DPCM transmitter and DPCM receiver can be realized by using a tapped-delay-line filter.

9. Compare the performance of QPSK and DPSK modulation schemes.
[MODEL QUESTION]

Answer:
DPSK does not require any carrier for detection at the receiver end. DPSK is viewed as a non-coherent version of BPSK. Therefore the complicated circuitry for generation of local carriers is not required in DPSK.

The bandwidth requirement of DPSK and QPSK is the same and is equal to $1/T_b$ where T_b is the bit duration. But the bit error rate (BER) of DPSK is more than that of QPSK. The BER of DPSK is given by

$$\left.\text{BER}\right|_{\text{DPSK}} = \frac{1}{2}\exp(-E_b/N_0)$$

Where E_b = bit energy and N_0 = noise power spectral density.
But the BER of QPSK is given by

$$\left.\text{BER}\right|_{\text{QPSK}} = \frac{1}{2}\,erfc(\sqrt{E_b/N_0})$$

Obviously

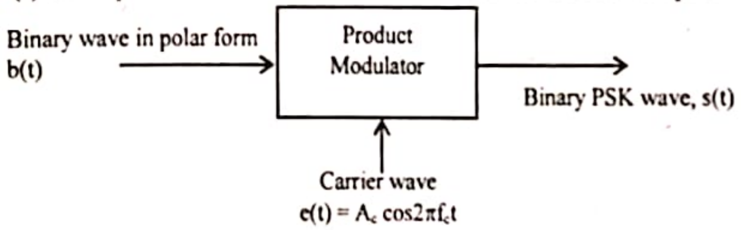
$$\left.\text{BER}\right|_{\text{QPSK}} < \left.\text{BER}\right|_{\text{DPSK}}$$

Thus the noise performance of DPSK is inferior to that of QPSK.
Moreover, as DPSK uses two successive bits for its reception, error in the first bit creates error in the second bit. Thus error propagation effect is more in DPSK than in QPSK.

10. a) With neat block diagram, explain the generation & detection of the BPSK signal. [MODEL QUESTION]

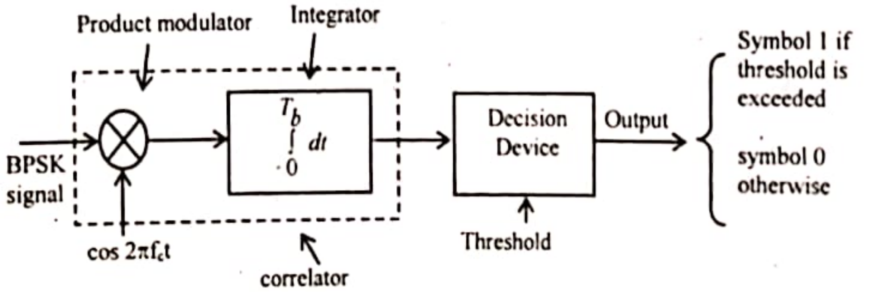
Answer:

Generation of BPSK Signal:
BPSK signal can be generated by a product modulator as shown below. Here the binary signal wave b(t) is in polar form whereas in the ASK this is in unipolar form.



A unipolar binary data sequence can be converted to bipolar NRZ signal by using a bipolar NRZ level encoder.

Detection of BPSK Signal
Only coherent detection of BPSK signal is possible. A coherent BPSK detector is shown below:



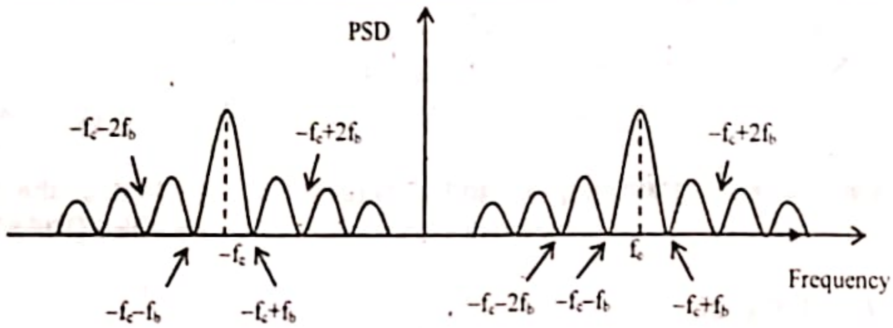
Here the BPSK signal is applied to a correlator consisting of a product modulator and an integrator. A locally generated carrier $e(t) = \cos 2\pi f_c t$ is also applied to the correlator. The correlator output is compared with a threshold in a decision device. If the threshold voltage (usually 0 volt) is exceeded the output symbol is chosen as 1; otherwise it is chosen as 0.

Non-coherent detection of BPSK is not possible since the envelope of a PSK wave is same for both symbols 1 and 0 and a single carrier frequency is used for the modulation process unlike BFSK. BPSK coherent detection suffers from synchronization problems for both phase and timing. The problem of providing synchronous carrier for detecting BPSK signal is avoided in what is called Differential Phase Shift Keying or DPSK.

b) Discuss Powers Spectral Density (PSD) of BPSK Signal. **[MODEL QUESTION]**

Answer:

The power spectral density of a BPSK Signal is shown in the diagram below:



Note that the shapes of PSD of the BPSK signal and binary ASK(BASK) are similar except that there is no impulse at the carrier frequency in BPSK. It may be noted that BPSK is a non-linear modulation scheme whereas BASK is a linear modulation scheme. BPSK has the advantage that it has superior performance over BASK in a noisy environment for a given peak power.

c) What are the drawbacks of BPSK? **[MODEL QUESTION]**

Answer:

In a coherent BPSK receiver the carrier is regenerated by squaring the input BPSK signal $b(t)\sqrt{2P_s}\cos(2\pi f_c t+\theta)$ If the received signal is $-b(t)\ \sqrt{2P_s}\cos(2\pi f_c t+\theta)$, then also the squared signal remains the same. This means that the recovered carrier is unchanged even if the input signal has changed its sign. Thus it becomes impossible to determine whether the received signal is b(t) or –b(t). This results in ambiguity in the output signal. This problem has been solved in QPSK. BPSK also suffers from inter-symbol interference (ISI) and inter channel interference which can be solved to some extent by using filters.

d) A BPSK modulator has the carrier frequency 70 MHz and input bit rate is 10 Mbps. Determine the maximum and minimum frequencies of the modulated signal. **[MODEL QUESTION]**

Answer:

BPSK output $= \sin(2\pi f_a t)\sin(2\pi f_c t)$

where f_a = maximum fundamental frequency of binary input

f_c = carrier frequency.

Here $f_a = \frac{f_b}{2} = \frac{10}{2} = 5MHz$ where f_b = input bit rate.

So, BPSK output

$$= [\sin 2\pi(5\text{MHz})t][\sin 2\pi(70\text{MHz})t]$$

$$= \frac{1}{2}\cos 2\pi(70-5\text{MHz})t - \frac{1}{2}\cos 2\pi(70\text{MHz}+5\text{MHz})t$$

Hence minimum lower side frequency (LSF)

$= 70 - 5 = 65$MHz

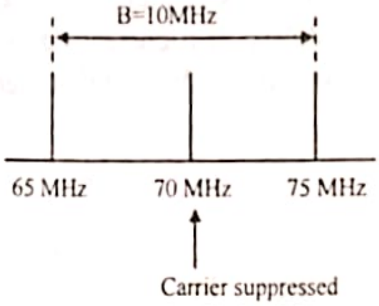
Maximum upper side frequency (USF)

$= 70 + 5 = 75$MHz

Hence the minimum Nyquist bandwidth (f_N) is.

$$f_N = 75 - 65 = 10MHz$$

The baud, f_b = 10 megabaud.

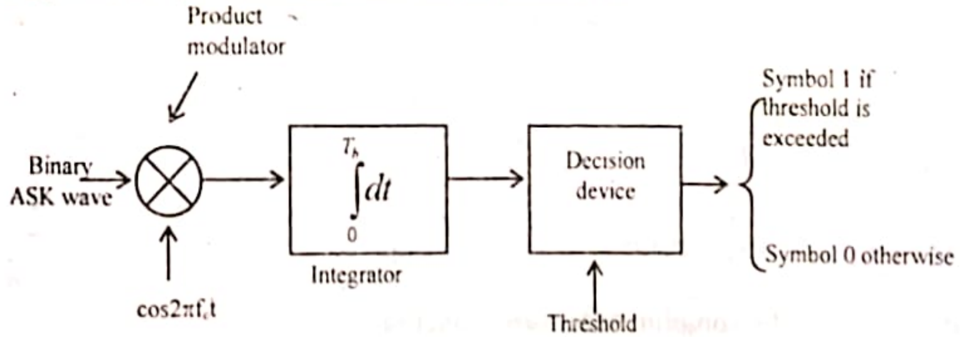


11. a) What is coherent detection technique? Describe ASK demodulation through coherent detection. **[MODEL QUESTION]**

Answer:

In coherent detection technique, a local carrier is used for detection. The local carrier is generated at the receiver which is phase-locked with the carrier at the transmitter. The received signal is heterodyned with the local carrier to generate the baseband signal.

The coherent detection of ASK is shown in the block diagram below. In coherent detection, a locally generated signal of the same frequency and phase as the transmitted signal is applied to a product modulator as shown below.



The integrator integrates the output signal of the product modulator over a bit interval, T_b and the output of the integrator is compared with a preset threshold in a decision device. It makes a decision in favour of symbol 1 if the threshold is exceeded and in favour of symbol 0 otherwise.

A synchronous or coherent detector should have two forms of synchronization viz. phase synchronization and timing synchronization. Phase synchronization is necessary because it ensures locking in phase of the locally generated carrier wave with the transmitted signal. Timing synchronization is necessary because it ensures proper timing of the decision making operation in the receiver with respect to the switching instants.

b) Calculate the probability of error of QPSK signal. **[MODEL QUESTION]**

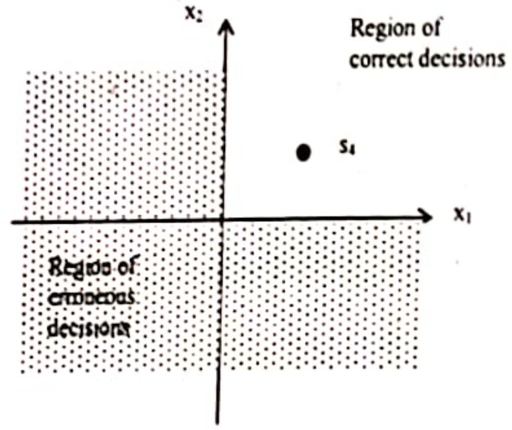
Answer:

Let the received signal $x(t)$ is given by

$$x(t) = s_i(t)+w(t) \quad \text{for} \quad 0 \le t \le T \text{ and } i = 1,2,3,4$$

where $w(t)$ is the sample function of white Gaussian noise of zero mean and power spectral density $N_o/2$ and $s_i(t)$ is the signal vector.

The probability of a correct decision, P_c, equals the conditional probability of the joint event $x_1>0$ and $x_2>0$ given that signal $s_4(t)$ was transmitted.



$$\text{Hence } P_c = \int_o^{\infty} \frac{1}{\sqrt{\pi N_o}} \exp\left[-\frac{(x_1-\sqrt{E/2})^2}{N_o}\right] dx_1 \times \int_o^{\infty} \frac{1}{\sqrt{\pi N_o}} \exp\left[-\frac{(x_2-\sqrt{E/2})^2}{N_o}\right] dx_2$$

The first integral on the right hand side is the conditional probability of the even $x_1>0$ and the second integral is the conditional probability of the even $x_2>0$, both given that signal s_4 (t) was transmitted

$$\text{Let} \quad \frac{x_1-\sqrt{E/2}}{\sqrt{N_o}} = \frac{x_2-\sqrt{E/2}}{\sqrt{N_o}} = Z$$

$$\text{Then} \quad P_c = \left[\frac{1}{\sqrt{\pi}} \int_{-\sqrt{E/2N_o}}^{\infty} \exp(-z^2)dz\right]^2$$

From the definition of the complimentary error function

$$\frac{1}{\sqrt{\pi}} \int_{-\sqrt{E/2N_o}}^{\infty} \exp(-z^2)dz = 1-\frac{1}{2}erfc\left(\sqrt{\frac{E}{2N_o}}\right)$$

$$\text{Thus} \quad P_c = \left[1-\frac{1}{2}erfc\sqrt{\frac{E}{2N_o}}\right]^2 = 1-erfc\left(\sqrt{\frac{E}{2N_o}}\right)+\frac{1}{2}erfc^2\left(\sqrt{\frac{E}{2N_o}}\right)$$

The average probability of symbol error for coherent QPSK is

$$P_e = 1 - P_c = erfc\left(\sqrt{\frac{E}{2N_o}}\right) - \frac{1}{2}erfc^2\left(\sqrt{\frac{E}{2N_o}}\right)$$

In the region where $\left(\frac{E}{2N_o}\right) >> 1$ we may ignore the second term on the right hand side

and then $P_e \cong erfc\sqrt{\frac{E}{2N_o}}$

In QPSK system, there are two bits per symbol which means that the transmitted signal energy per symbol is twice the signal energy per bit i.e. $E = 2E_b$ and hence

$$P_e \cong erfc\sqrt{\frac{E_b}{N_o}}$$

This is the expression for probability of error of QPSK.

c) A 16–QAM modulator has a carrier frequency of 70MHz and input data rate of 10Mbps. Calculate the minimum double-sided Nyquist bandwidth and the symbol rate. **[MODEL QUESTION]**

Answer:

There are four channels I, I′, Q and Q′ in 16–QAM modulator.

The bit rate of the I, I′, Q and Q′ channels is equal to one–fourth of the input bit rate, f_b.

Here $f_b = 10$Mbps and $f_c = 70$MHz.

$$f_{bI} = f_{bI'} = f_{bQ} = f_{bQ'} = \frac{f_b}{4} = \frac{10Mbps}{4} = 2.5Mbps.$$

So, the fastest rate of change and highest modulating frequency presented to either balanced modulator in 16–QAM is

$$f_a = \frac{f_{bI}}{2} = \frac{f_{bI'}}{2} = \frac{f_{bQ}}{2} = \frac{f_{bQ'}}{2} = \frac{2.5Mbps}{2} = 1.25MHz.$$

The output wave from the balanced modulator is

$$\sin(2\pi f_a t)\sin(2\pi f_c t)$$

$$= \frac{1}{2}\cos 2\pi(f_c - f_a)t - \frac{1}{2}\cos(f_c + f_a)t$$

$$= \frac{1}{2}\cos 2\pi(68.75MHz)t - \frac{1}{2}\cos 2\pi(71.25MHz)t$$

Hence the double-sided Nyquist bandwidth is

$$f_N = 71.25 - 68.75 = 2.5MHz$$

The symbol rate = Nyquist bandwidth = 2.5 mega baud.

12. a) With the help of block diagram, explain working principle of ASK modul and demodulator.
b) Draw ASKS, FSK and BPSK signal to transit data stream – 10100011.

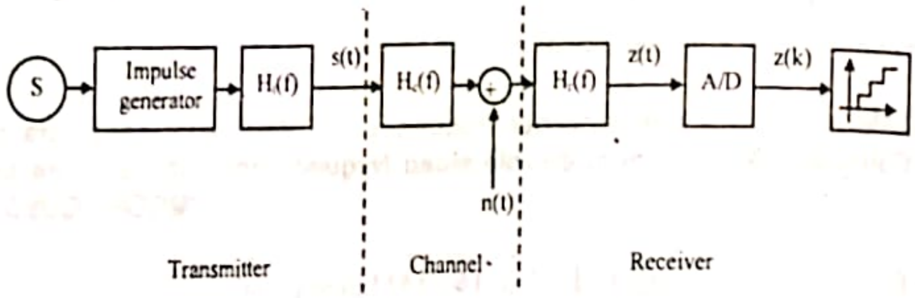
[MODEL QUESTI

Answer:

a) ***Amplitude-shift keying (ASK)*** is a form of digital modulation technique wl represents digital data as variations in the amplitude of a carrier.

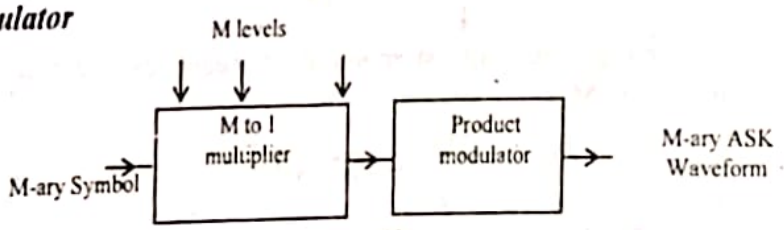
The simplest and most common form of ASK operates as a switch presence of a ca wave to indicate a binary one and its absence to indicate a binary zero. This typ modulation is called **on-off keying.**

The ASK modulation technique is generally used to transmit digital data over opt fiber. For LED transmitters, binary 1 is represented by a short pulse of light and binary by the absence of light. Here is a diagram showing the ideal model for a transmiss system using an ASK modulation:

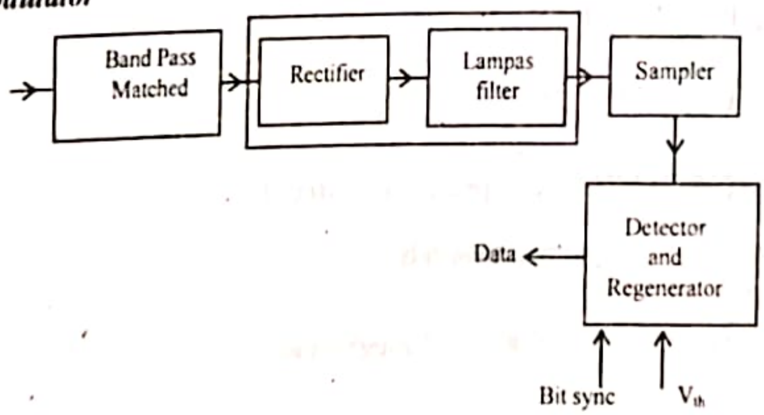


It can be divided into three blocks.
First one represents the transmitter transmits the digital signals.
Second one is a linear model of the effects of the channel.
Third one shows the structure of the receiver.

BASK Modulator



BASK Demodulator



b)