Digital Modulation Schemes

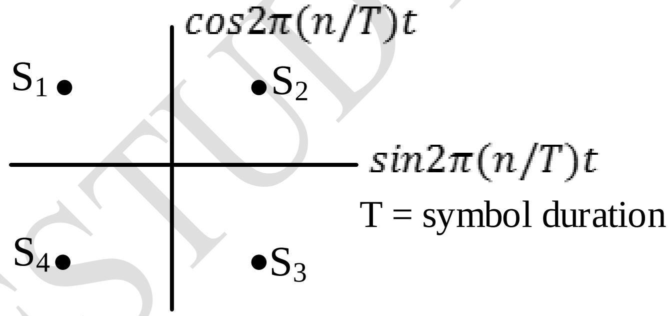
1. In binary data transmission DPSK is preferred to PSK because
   (a) a coherent carrier is not required to be generated at the receiver
   (b) for a given energy per bit, the probability of error is less
   (c) the 180^0 phase shifts of the carrier are unimportant
   (d) more protection is provided against impulse noise

[GATE 1989: 2 Marks]

Soln. Differential phase shift (DPSK) is non coherent version of the PSK. It is differentially coherent modulation method. DPSK does not need synchronous (Coherent) carrier at the demodulator. The input sequence of binary bits is modified such that the next bit depends upon the previous bit

Option (a)

2. For the signal constellation shown in the figure, the type of modulation is



[GATE 1991: 2 Marks]

Soln. The given constellation has four signals which are 90^0 apart with the adjacent signal

These waveforms correspond to phase shifts of 0^0, 90^0, 180^0 and 270^0 as shown in the phase diagram.

The type of modulation is QPSK

3. Quadrature multiplexing is
   (a) the same as FDM
   (b) the same as TDM
   (c) a combination of FDM and TDM
   (d) quite different from FDM and TDM

[GATE 1998: 1 Mark]

Soln. Quadrature carrier multiplexing (QCM) enables two DSBSC modulated waves, resulting from two different message signals to occupy the same transmission bandwidth and two message signals can be separated at the receiver.

It is also called Quadrature Amplitude Modulation (QAM) so it is quite different from FDM and TDM

Option (d)

4. The message bit sequence to a DPSK modulator is 1,1,0,0,1,1 . The carrier phase during the reception of the first two message bits is π, π. The carrier phase for the remaining four message bits is
(a) π, π,0, π
(b) 0,0, π, π
(c) 0, π, π, π
(d) π, π,0,0

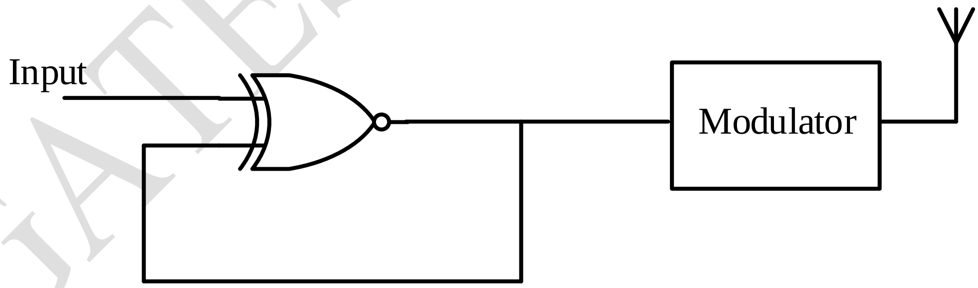
[GATE 1998: 2 Marks]

Soln. Message bits sequence 1 1 0 0 1 1

Let, Logic $1 \rightarrow 0^0$

Logic $0 \rightarrow \pi$

Ref. bit = 0



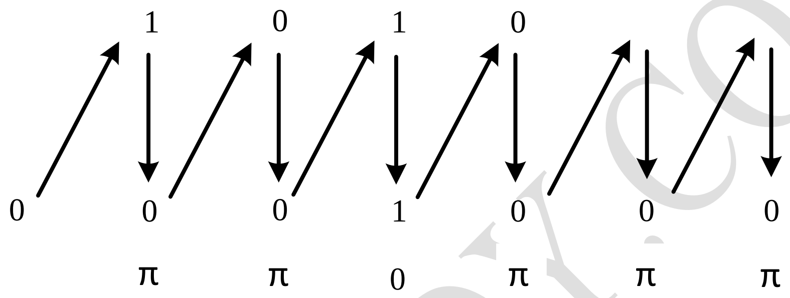
Ex NOR

A	B	Y
0	0	1
0	1	0
1	0	0
1	1	1

$Y = A \odot B$

$= AB + \bar{A}\bar{B}$

(output is 1 when both input are same)



Remaining message bits are

0 π π π

Option (c)

5. The bit steam 01001 is differentially encoded using ‘Delay and Ex OR’ scheme for DPSK transmission. Assuming the reference bit as a ‘1’ and assigning phases of ‘0’ and ‘π’ for 1’s and 0’s respectively, in the encoded sequence, the transmitted phase sequence becomes
(a) π 0 π π 0
(b) 0 π π 0 0
(c) 0 π π π 0
(d) π π 0 π π

[GATE 1992: 2 Marks]

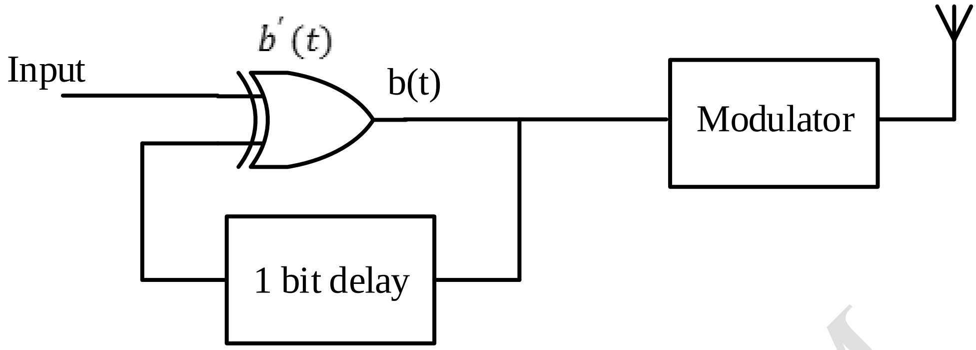
Soln.

EX-OR

A	B	Y
0	0	0
0	1	1
1	0	1
0	0	0

$Y = A \oplus B$

Output is 1 when both input are different



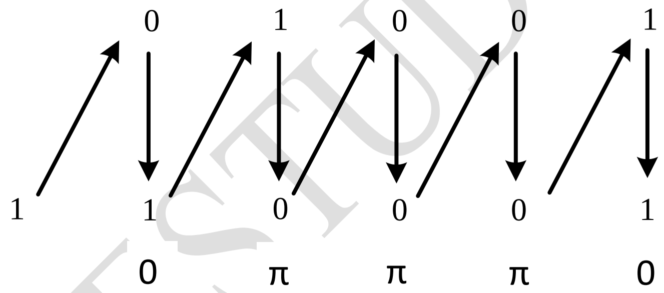
Bit stream

0 1 0 0 1

Ref. bit 1

Logic 0 → π

Logic 1 → 0



Option (c)

6. A video transmission system transmits 625 picture frames per second. Each frame consists of a 400 x 400 pixel grid with 64 intensity levels per pixel. The data rate of the system is
   (a) 16 Mbps
   (b) 100 Mbps
   (c) 600 Mbps
   (d) 6.4 Gbps

[GATE 2001: 2 Marks]

Soln. Frames per sec = 625

Pixels per frame $= 400 \times 400$

64 intensity levels per pixels

Can be represented by bits per pixel

Data rate $= 625 \times 400 \times 400 \times 6 = 600\ Mbps$

Option (c)

7. The bit rate of digital communication system is R kbit/s. The modulation used is 32-QAM. The minimum bandwidth required for ISI free transmission is

(a) R/10 Hz
(b) R/10 KHz
(c) R/5 Hz
(d) R/5 KHz

[GATE 2013: 1 Mark]

Soln. In an ideal Nyquist channel, bandwidth required for ISI (Inter Symbol Interference) free transmission is

$$W = \frac{R_b}{2}$$

Here modulations is 32 QAM

i.e. $2^n = 32\ \ or\ \ n = 5\ bits$

Signaling rate is

$$R_b = \frac{R}{5}\ kbps$$

Where R is bit rate

Min. bandwidth

$$W = \frac{R_b}{2} = \frac{R}{5 \times 2} = \frac{R}{10} KHz$$

Option (b)

8. For a bit-rate of 8 kbps, the best possible values of the transmitted frequencies in a coherent binary FSK system are

(a) 16 KHz and 20 KHz
(b) 20 KHz and 32 KHz
(c) 20 KHz and 40 KHz
(d) 32 KHz and 40 KHz

[GATE 2002: 1 Mark]

Soln. Given

Bit rate = 8 kbps

The transmitted frequencies in coherent BFSK should be integral multiple of 8 i.e. the option

32 KHz & 40 KHz is the choice.

Since both frequencies are multiple of 8

Option (d)

9. An M-level PSK modulation scheme is used to transmit independent binary digits over a band-pass channel with bandwidth 100 KHz. The bit rate is 200 kbps and the system characteristic is a raised-cosine spectrum with 100% excess bandwidth. The minimum value of M is _______

[GATE 2014: 2 Marks]

Soln. Bandwidth $(B) = \frac{R_b}{log_2 M}(1+\alpha)$

Or, $100\ KHz = \frac{200\times10^3}{log_2 M}$

Or, $log_2 M = 4$

Or, M = 16

10. In a baseband communication link, frequencies upto 3500 Hz are used for signaling. Using a raised cosine pulse with 75% excess bandwidth and for no inter symbol interference, the maximum possible signaling rate is symbols per sec is

(a) 1750
(b) 2625
(c) 4000
(d) 5250

[GATE 2012: 1 Mark]

Soln. For raised cosine spectrum transmission bandwidth is given as

$B_T = \frac{R_b}{2}(1+\alpha)$

Where α – Roll off factor

R_b – bit rate

$B_T = \frac{R_b}{2}(1+\alpha)$

Where R_b – maximum signaling rate

Or, $3500\ Hz = \frac{R_b}{2}(1 + 0.75)$

Or,

$$R_b = \frac{3500 \times 2}{1.75} = 4000\ bps$$

Option (c)

11. Coherent orthogonal binary FSK modulation is used to transmit two equiprobable symbol waveforms $s_1(t) = \alpha \cos 2\pi f_1 t$ and $s_2(t) =$ a$\cos 2\pi f_2 t,$ where $\alpha\ is\ 4\ mV$. Assume an AWGN channel with two-sided noise power spectral density $\frac{N_0}{2} = 0.5 \times 10^{-12}\ W/Hz$. Using an optimal receiver and the relation.

$$Q(v) = \frac{1}{\sqrt{2\pi}} \int_{v}^{\infty} e^{-\frac{u^2}{2}} \text{du}, \quad \text{the bit error probability}$$

For a data rate of 5000 kbps is

(a) $Q(2)$ (c) $Q(4)$
(b) $Q(2\sqrt{2})$ (d) $Q(4\sqrt{2})$

[GATE 2014: 2 Marks]

Soln. For coherent FSK modulation probability of error

$$(P_e) = \frac{1}{2}\ erfc\ \left[\frac{E_b}{2N_0}\right]$$

Given

Data rate $R_b = 500\ kbps = 500 \times 10^3\ bps$

$$\frac{N_0}{2} = 0.5 \times 10^{-12}\ W/\ Hz$$

$$\alpha = 4 \times 10^{-3} V$$

$T_b = \frac{1}{Rb} = \frac{1}{500 \times 10^3} = 2 \times 10^{-6}\ sec$

Signal energy $E_b = T_b \times signal\ Power$

$= 2 \times 10^{-6} \times \frac{A^2}{2}$

$= 2 \times 10^{-6} \times \frac{\alpha^2}{2}$

$= 2 \times 10^{-6} \times \frac{(4\times10^{-3})^2}{2}$

$= 10^{-6} \times 16 \times 16^{-6}$

$E_b = 16 \times 12^{-12}$ Joules

$$Here \qquad P_e = \frac{1}{2}\, erfc\left[\sqrt{\frac{16 \times 12^{-12}}{2 \times 10^{-12}}}\right]$$

$$= \frac{1}{2}\, erfc\left[\sqrt{8}\right] = \frac{1}{2}\, erfc\left[\frac{4}{\sqrt{2}}\right]$$

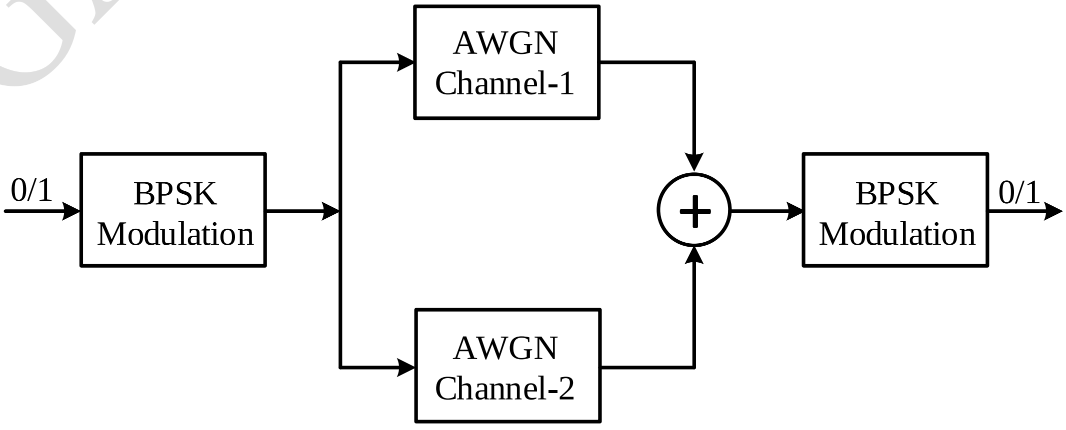
Note,

$$\frac{1}{2}\, erfc\left[\frac{y}{\sqrt{2}}\right] = Q(y)$$

$P_e = Q(4)$

Option (c)

12. Let $Q(\sqrt{\gamma})$ be the BER of a BPSK system over an AWGN channel with two-sided noise power spectral density $N_0/2$. The parameter γ is a function of bit energy and noise power spectral density.
A system with two independent and identical AWGN channels with noise power spectral density $N_0/2$ is shown in the figure. The BPSK demodulator receives the sum of outputs of both the channels.



If the BER of this system is $Q(b\sqrt{\gamma})$, then the value of b is________

[GATE 2014: 2 Marks]

Soln. Given,

Bit error rate (BER) of BPSK system with AWGN channel $= Q\sqrt{\gamma}$
additive white Gaussian Noise (AWGN) with power spectral density $N_0/2$
γ parameter is function of bit energy and Noise power spectral density.

Demodulator receives the output of both channels.

$$So,\ \ BER = Q\left(\sqrt{\gamma + \gamma}\right)$$

$$= Q\left(\sqrt{2\gamma}\right)$$

$$= Q\left(\sqrt{2}\,\sqrt{\gamma}\right)$$

By comparing we find

$$Q\left(\sqrt{2}\,\sqrt{\gamma}\right) = Q\left(b\sqrt{\gamma}\right)$$

$$So, b = \sqrt{2}$$

13. A BPSK scheme operating over an AWGN channel with noise power spectral density of $N_0/2$, uses equiprobable signals

$$S_1(t) = \sqrt{\frac{2E}{T}}\sin(\omega_c t) \quad and \quad S_2(t) = \sqrt{\frac{2E}{T}}\sin(\omega_c t)$$

Over the symbol interval (0, T). If the local oscillator in a coherent receiver is ahead in phase by 45^0 with respect to the received signal, the probability of error in the resulting system is

(a) $Q\left(\sqrt{\frac{2E}{N_0}}\right)$

(b) $Q\left(\sqrt{\frac{E}{N_0}}\right)$

(c) $Q\left(\sqrt{\frac{E}{2N_0}}\right)$

(d) $Q\left(\sqrt{\frac{E}{4N_0}}\right)$

[GATE 2012: 2 Marks]

Soln. We know that the probability of error in coherent BPSK is given by

$$P_e = Q\left[\sqrt{\frac{2E}{N_0}}\right]$$

Since the local oscillator in coherent receiver is ahead by 45^0 with respect to received signal. It will decrease the signal energy by factor of

$$cos^2 45^0 = \frac{1}{2}$$

$$So, \quad P_e = Q\left[\sqrt{\frac{E}{N_0}}\right]$$

Option (b)

14. At a given probability of error, binary coherent FSK is inferior to binary coherent PSK by.

(a) 6 dB
(b) 3 dB
(c) 2 dB
(d) 0 dB

[GATE 2003: 2 Marks]

Soln. Probability of error for coherent PSK and FSK is given as

For FSK

$$P_e = \frac{1}{2}\ erfc\left(\sqrt{\frac{E_b}{2N_0}}\right)$$

PSK

$$P_e = \frac{1}{2}\ erfc\left(\sqrt{\frac{E_b}{N_0}}\right)$$

From the table of error function table it is found that Binary FSK is 3 dB inferior to binary PSK

Option(b)

15. The input to a matched filter is given by

$$s(t) = \begin{cases} 10\sin(2\pi \times 10^6) & 0 < t < 10^{-4} sec \\ 0 & Otherwise \end{cases}$$

The peak amplitude of the filter output is

(a) 10 volts
(b) 5 volts
(c) 10 millivolts
(d) 5 millivolts

[GATE 1999: 2 Marks]

Soln. In digital modulation schemes the function of receiver is to distinguish between two transmitted signals in presence of noise. Receiver is said to be optimum if it yields minimum probability of error. It is called matched filter when noise at receiver is white. Matched filter can be implemented as integrate and dump correlation receiver.

Maximum amplitude of matched filter output is

$$\frac{A^2T_b}{2} = \frac{10^2}{2} \times 10^{-4} = 5\ mV$$

16. Coherent demodulation of FSK signal can be detected using
(a) correlation receiver
(b) band pass filters and envelope detectors
(c) matched filter
(d) discriminator detection

[GATE 1992: 2 Marks]

Soln. For coherent detection one can use matched filter or correlation receiver, others are not coherent. Matched filter is used when you have only one signal. But FSK has two signals of different frequencies

So, use Correlation receiver

Option (a)

17. In a BPSK signal detector, the local oscillator has a fixed phase error of 20^0.This phase error deteriorates the SNR at the output by a factor of
(a) $\cos 20^0$
(b) $\cos^2 20^0$
(c) $\cos 70^0$
(d) $\cos^2 70^0$

[GATE 1990: 2 Marks]

Soln. In BPSK if detector has fixed phase error, say ϕ, then output power would change by a factor of $\cos^2\phi$

So, option (b)