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Detailed Solutions

ESE-2026 Mains Test Series

E & T Engineering Test No : 15

Full Syllabus Test (Paper-II)

Section A

Q.1 (a) Solution:

Handoff is a procedure for changing the assignment of a mobile unit from one base station to another when the user moves from one cell to another.

Handoff is handled in different ways in different systems and involves a number of other factors. Handoffs are broadly divided in the following ways:

Hard Handoff:

- Hard handoff is a break before make system, i.e., the link to previous base station is broken for establishment of link to another base station.
- The problem with this kind of handoff is that the signal power received from both base stations often fluctuate and so the user is bounded between both base stations switching the link wildly. This phenomeon is known as ping-ponging Hard hand-offs can be further divided as:
  (a) **Intercell Handoff :** In this type of handoff, the source and destination BTS are in different cells. The purpose of the inter-cell handoff is to maintain the call as the subscriber is moving out of the area of the source cell and entering the area of the target cell.
  (b) **Intracell Handoff :** In this, the source destination are in the same cell. Only the channel used for communication is changed. The purpose of intra-cell handoff

is to change a channel, which may be interfered, or fading with a new clearer or less fading channel.

Soft Handoff:

- In soft handoff communication, a connection is made with a new base station before the connection to old base station is cutoff.
- A user is in communication with more than one base station during a handoff.
- It is also called as Make-Before-Break handoff technology.
- Its advantages are that user faces very little interruption and dead zones are practically non-existent.
- It is more reliable to as compared to hard handoff.
- Implementation of soft handoff is more expensive and complex as compared to hard handoff.

Q.1 (b) Solution:

For a QPSK signal with raised-cosine filtering,

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

For the transponder bandwidth of 36 MHz, the bit rate that can be accomodated is,

$$R_b = \frac{2B}{1+\rho}$$

$$= \frac{2\times 36\times 10^6}{1.2} = 60 \text{ Mbps}$$

Hence,

$$[R_b] = 10\log\left(\frac{60\times 10^6}{1s^{-1}}\right)$$

$$= 77.78 \text{ dBbps}$$

For BER = 10^{-5}, it is given that $[E_b/N_0]$ = 9.6 dB

The required C/N_0 ratio is

$$\left[\frac{C}{N_0}\right] = \left[\frac{E_b}{N_0}\right]+[R_b]$$

$$= 77.78 + 9.6$$

$$= 87.38 \text{ dBHz}$$

From the Link budget equation,

$$[\text{EIRP}]_D = \left[\frac{C}{N_0}\right]_D - \left[\frac{G}{T}\right]_D + [\text{Losses}]_D + [k]$$

$$= 87.38 - 32 + 200 - 228.6$$

$$\cong 26.8 \text{ dBW}$$

Q.1 (c) Solution:

$$G(s) = \frac{Ke^{-Ts}}{s(s+1)} \Rightarrow G(j\omega) = \frac{Ke^{-j\omega}}{j\omega(1+j\omega)}$$

$$\angle G(j\omega) = -\omega T - 90° - \tan^{-1}\omega$$

At phase crossover frequency, $\omega = \omega_{pc}$:

$$-\omega_{pc}T - 90° - \tan^{-1}\omega_{pc} = -180°$$

$$\omega_{pc}T = 90° - \tan^{-1}\omega_{pc}$$

$$\omega_{pc}T = \cot^{-1}\omega_{pc}$$

$$\omega_{pc} = \cot\omega_{pc}T$$

Thus, we have $\omega_0 = \omega_{pc}$.

Gain Margin :

$$\text{GM} = |G(j\omega)|_{\omega = \omega_{pc} = \omega_0}$$

$$\text{GM} = \frac{K}{\omega_o\left(\sqrt{1+\omega_o^2}\right)}$$

$$= \frac{K}{\omega_o\sqrt{1+(\cot\omega_o T)^2}}$$

$$= \frac{K}{\omega_o \text{ cosec } \omega_o T}$$

For stability, $\text{GM} < 1$

$$\therefore \quad \frac{K}{\omega_o \text{ cosec } \omega_o T} < 1$$

$$K < \omega_o \text{ cosec } \omega_o T$$

$$K < K_o, \text{ where } K_o = \omega_o \text{ cosec } \omega_o T$$

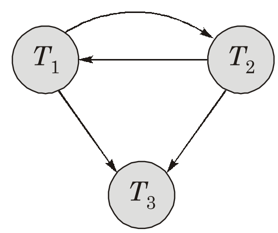
Q.1 (d) Solution:

(i) Precedence Graph for S_1:

To draw the Precedence Graph, create a node T_i in the graph for each participating transaction in the schedule and,

- If a Transaction T_j executes a read_item (X) after Ti executes a write_item (X), draw an edge from T_i to T_j in the graph.
- If a Transaction T_j executes a write_item (X) after T_i executes a read_item (X), draw an edge from T_i to T_j in the graph.
- If a Transaction T_j executes a write_item (X) after T_i executes a write_item (X), draw an edge from T_i to T_j in the graph.

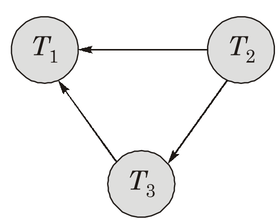
The Schedule S is serializable if there is no cycle in the precedence graph.



There is a cycle between $T_1 \rightarrow T_2$ and $T_2 \rightarrow T_1$.

Because the precedence graph contains a cycle, schedule S_1 is not conflict serializable.

Precedence Graph for S_2:



The graph is a Directed Acyclic Graph (DAG) with edges: $T_2 \rightarrow T_3$ and $T_3 \rightarrow T_1$. Since there are no cycles, S_2 is conflict serializable.

Equivalent Serial Order: $T_2 \rightarrow T_3 \rightarrow T_1$.

(ii) When an instruction misses in L_1, L_2 is checked. The time spent checking L_2 is its hit time, which is 100 cycles. If it hits in L_2, the stall ends there. If it also misses in L_2, it must go to main memory incurring a penalty of 300 cycles.

3 memory references $\rightarrow$ 1 instructions

900 memory references $\rightarrow$? instructions

Number of instructions in 900 memory references = $\frac{900}{3} = 300$

Number of memory stalls/instruction

$$= \left[\frac{\text{Number of miss in } L_1}{\text{Number of instructions}} \times \text{Hit Time of } L_2\right] + \left[\frac{\text{Number of miss in } L_2}{\text{Number of instructions}} \times \text{Miss penalty } L_2\right]$$

$$= \left[\frac{200}{300} \times 100\right] + \left[\frac{80}{300} \times 300\right]$$

$$= \left[\frac{200}{3} + 80\right] \simeq 146.66 \text{ cycles}$$

Q.1 (e) Solution:

We have, $$p_x(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-m)^2/2\sigma^2}$$

Mean, $$E(x) = \int_{-\infty}^{\infty} x\, p_x(x)\, dx$$

$$E(x) = \int_{-\infty}^{\infty} x \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{(x-m)^2}{2\sigma^2}\right) dx$$

It can be written as,

$$E(x) = \int_{-\infty}^{\infty} (x+m) \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{x^2}{2\sigma^2}\right) dx$$

$$E(x) = \underbrace{\int_{-\infty}^{\infty} x \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{x^2}{2\sigma^2}\right) dx}_{I_1} + \int_{-\infty}^{\infty} m \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{x^2}{2\sigma^2}\right) dx$$

Considering I_1,

$$I_1 = \int_{-\infty}^{0} x \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{x^2}{2\sigma^2}\right) dx + \int_{0}^{\infty} x \cdot \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{x^2}{2\sigma^2}\right) dx$$

Swapping integration limits we have,

$$I_1 = -\int_{0}^{-\infty} x \cdot \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{x^2}{2\sigma^2}\right) dx + \int_{0}^{\infty} x \cdot \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{x^2}{2\sigma^2}\right) dx$$

Reversing the limits of first interval, we have,

$$I_1 = \int_0^{\infty}(-x)\cdot\frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{x^2}{2\sigma^2}\right)dx + \int_0^{\infty} x\cdot\frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{x^2}{2\sigma^2}\right)dx$$

$$\Rightarrow \qquad I_1 = 0$$

So, $$E(x) = \int_{-\infty}^{\infty} m\cdot\frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{x^2}{2\sigma^2}\right)dx$$

Considering $\frac{x}{\sigma\sqrt{2}} = u$, we obtain,

$$E(x) = \int_{-\infty}^{\infty} m\cdot\frac{1}{\sqrt{\pi}}e^{-x^2}\,dx = \int_0^{\infty} m\cdot\frac{2}{\sqrt{\pi}}e^{-x^2}\,dx \qquad (\because \text{ It is an even function})$$

Now, $$\frac{2}{\sqrt{\pi}}\int_0^{\infty} e^{-x^2}\,dx = \lim_{t\to\infty}\int_0^{t}\frac{2}{\sqrt{\pi}}e^{-x^2}\,dx = \lim_{t\to\infty}\operatorname{erf}(t) = 1,$$

where erf is error function.

So, Mean: $\boxed{E(x) = m}$

Variance:

$$\text{Var}(x) = \int_{-\infty}^{\infty}(x-m)^2\frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{(x-m)^2}{2\sigma^2}\right)dx$$

Simplifying, $$\text{Var}(x) = \int_{-\infty}^{\infty} x^2\frac{1}{\sigma\sqrt{2\pi}}\exp\left(-\frac{x^2}{2\sigma^2}\right)dx$$

Considering $\frac{x}{\sigma\sqrt{2}} = u$, we obtain

$$= \sigma\sqrt{2}\int_{-\infty}^{\infty}(\sigma\sqrt{2}u)^2\cdot\frac{1}{\sigma\sqrt{2\pi}}\exp(-u^2)\,du = \sigma^2\cdot\frac{4}{\sqrt{\pi}}\int_0^{\infty} x^2 e^{-x^2}\,dx$$

[Replacing u by x]

Now, let $$t = x^2$$

$$\Rightarrow \qquad x = \sqrt{t} \text{ and } 2x\,dx = 2\sqrt{t}\,dx = dt$$

$$\Rightarrow \qquad dx = (2\sqrt{t})^{-1}dt$$

$$\text{Var}(x) = \sigma^2\frac{4}{\sqrt{\pi}}\int_0^{\infty}(\sqrt{t})^2(2\sqrt{t})^{-1}e^{-t}dt = \sigma^2\cdot\frac{4}{\sqrt{\pi}}\cdot\frac{1}{2}\int_0^{\infty} t^{\frac{3}{2}-1}e^{-t}\,dt$$

$$= \sigma^2 \frac{4}{\sqrt{\pi}} \cdot \frac{1}{2} \cdot \Gamma\left(\frac{3}{2}\right)$$

where $\Gamma(\,)$ is a gamma function,

$$\Rightarrow \qquad \text{Var}(x) = \sigma^2 \cdot \frac{4}{\sqrt{\pi}} \cdot \frac{1}{2} \cdot \frac{\sqrt{\pi}}{2} = \sigma^2$$

So, $\qquad \text{Var}(x) = \sigma^2$

Mean Square: $E[x^2] = \text{Var}(x) + \{E(x)\}^2 = \sigma^2 + m^2$

Q.2 (a) Solution:

(i) Gain Margin (GM): The GM is a factor by which the gain of a stable system is allowed to increase before the system reaches instability.

In decibel, GM is given by

$$\text{GM} = 20\log_{10} \frac{1}{|G(j\omega)H(j\omega)|_{\omega = \omega_{pc}}} \text{ dB}$$

where $|G(j\omega)H(j\omega)|$ is calculated at the phase cross-over frequency (ω_{pc}).

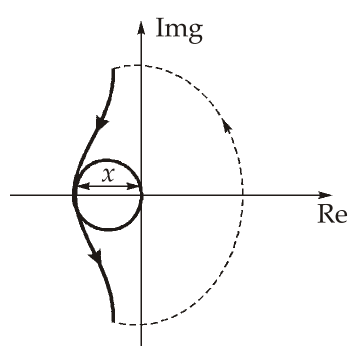
(ii) Phase Margin (PM): The PM of a stable system is the amount of additional phase lag required to bring the system to the point of instability.

The PM is given by, $\qquad \text{PM} = 180° + \angle G(j\omega)H(j\omega)|_{\omega = \omega_{gc}}$

where $\angle G(j\omega)\, H(j\omega)$ is calculated at the gain cross-over frequency (ω_{gc}).

Gain Margin and Phase Margin are used to determine the stability of the system.

GM and PM Using Nyquist Plot: Consider the Nyquist plot of a control system as



Nyquist Plot

To determine the phase crossover frequency, find the point where the Nyquist plot crosses the negative real axis (phase = –180°). Then, the distance of that point from the origin is used to calculate gain margin.

To determine gain crossover frequency, find where the Nyquist plot cuts the unit circle.

Case-I: If $x < 1$, Nyquist plot cuts the negative real axis inside the unit circle.

$$\Rightarrow \qquad GM = 20\log\frac{1}{x} = \text{Positive} \;\text{ and } \omega_{pc} > \omega_{gc}$$

$$\Rightarrow \qquad \angle G(j\omega)H(j\omega)\big|_{\omega=\omega_{gc}} > -180°$$

$$\Rightarrow \qquad PM = 180° + \angle G(j\omega)H(j\omega)\big|_{\omega=\omega_{gc}} = \text{Positive}$$

Therefore, system is stable.

Case-II: If $x = 1$, i.e., Nyquist plot cuts the negative real-axis at the unit circle.

$$\Rightarrow \qquad GM = 20\log\frac{1}{X} = 0\text{ dB} \;\text{ and } \omega_{pc} = \omega_{gc}$$

So, $$\angle G(j\omega)H(j\omega)\big|_{\omega=\omega_{gc}} = -180°$$

Hence, $$PM = 180° + \angle G(j\omega)H(j\omega)\big|_{\omega=\omega_{gc}} = 0°$$

Therefore, system is critically stable.

Case-III: If $x > 1$ i.e. Nyquist plot cuts the negative real-axis outside the unit circle.

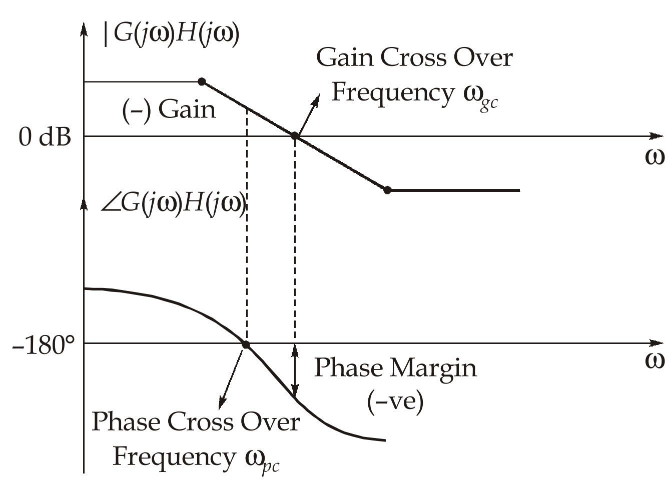
$$\Rightarrow \qquad GM = 20\log\frac{1}{X} = \text{Negative} \;\text{ and } \omega_{pc} < \omega_{gc}$$

$$\Rightarrow \qquad \angle G(j\omega)H(j\omega)\big|_{\omega=\omega_{gc}} < -180°$$

$$\Rightarrow \qquad PM = 180° + \angle G(j\omega)H(j\omega)\big|_{\omega=\omega_{gc}} = \text{Negative}$$

Therefore, system is unstable.

GM and PM using Bode Plot: Consider the Bode plot of a control system as



where, ω_{pc} = Phase cross-over frequency and ω_{gc} = Gain cross-over frequency.
The gain in dB at phase cross-over frequency is the gain margin.

$$GM = -20\log_{10}|G(j\omega)H(j\omega)_{\omega=\omega_{pc}}$$

The phase margin is given by :

$$\text{PM} = 180° + \angle G(j\omega)H(j\omega)\big|_{\omega = \omega_{gc}}$$

For a stable system, both GM and PM are positive.

Q.2 (b) Solution:

(i) The distance from the center of the earth i.e., the oribital radius,

$$r = 1000 + 6378 = 7378 \text{ Km}$$

According to Kepler's third law, orbital period

$$T = \sqrt{\frac{4\pi^2 r^3}{GM}}, \text{ where GM} = 3.986 \times 10^{15} \text{ Km}^3/\text{s}^2$$

$$= \sqrt{\frac{4\pi^2 (7378)^3}{3.986 \times 10^5}} = 6306.94 \text{ seconds}$$

Hence, number of per day (i.e. 24 hours)

$$= \frac{60 \times 60 \times 24}{6306.94} \approx 13 \text{ times}$$

The satellite will pass overhead approximately 13 times per day from a particular location on Earth.

(ii) According to Kepler's third law,

$$T^2 = \frac{4\pi^2 r^3}{3.986 \times 10^5}$$

A sidereal day has approximately 23 hours, 56 minutes, and 4 seconds i.e. 86164 seconds.

So, $$r^3 = \frac{(86164)^2 \times 3.986 \times 10^5}{4\pi^2}$$

$$r = 42164.12 \text{ km}$$

So, the orbital height is

$$r = 42164.12 - 6378$$

$$r = 35786 \text{ km}$$

(iii) Equivalent noise temperature can be calculated as :

$$T = T_o[F - 1]$$

Given: Noise Figure, $4 \text{ dB} = 20 \log_{10} F$

$$F = 10^{4/10}$$

So, $$T = 290\left[10^{\frac{4}{10}} - 1\right] = 438.48 \text{ K}$$

In decibels, $$T = 10 \log_{10}(438.48) = 26.41 \text{ dBk}$$

Now, noise power density

$$N = KT$$

where, K = Boltzmann constant = –228.6 dBW/K/Hz

So, Power density in dB = $K + T$

$$= -228.6 + 26.41$$

$$= -202.19 \text{ dBW/Hz}$$

(iv) The noise figure of the receiver is

$$F_2 = 1 + \frac{T_e}{T_o} = 1 + \frac{900}{290} = 4.1$$

[Assume reference temperature, T_0 = 290 K]

Noise Figure of LNB, $F_1 = 4 \text{ dB} = 10^{0.4}$

Using the Friis formula, the noise figure for the overall system is given by

$$F = F_1 - \frac{F_2 - 1}{G_1}$$

$$= 10^{0.4} + \frac{4.1 - 1}{10^{1.2}} = 2.71$$

Q.2 (c) Solution:

The statement is correct. The view of junction capacitor is shown below:

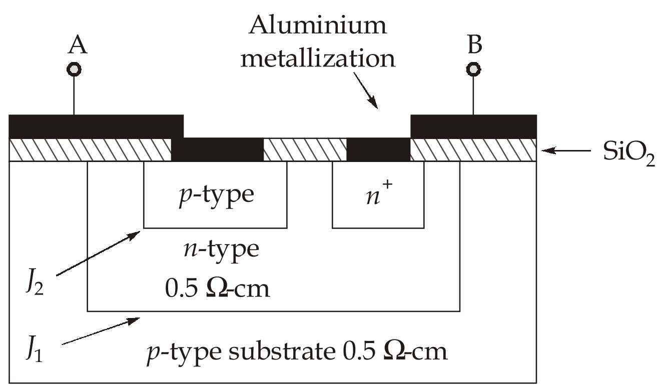


Fig: **Junction monolithic capacitor**

The capacitor is formed by the reversed biased junction J_2 which separates the epitaxial n-layer from upper p-type diffusion area. However, an additional junction J_1 appears between the n-type epitaxial plane and the substrate and a parasitic capacitance C_1 is associated with reverse bias junction. Also, series resistance results due to bulk resistance of n- region. The equivalent circuit is as under:

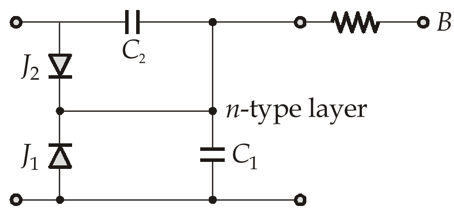


Fig: Equivalent circuit

The desired capacitor C_2 should be as large as possible relative to C_1. The value of C_2 depends upon the junction area and impurities concentration. The series resistance R represents resistance of n-type layer.

It should be noted that the junction capacitor C_2 is polarized and p-n junction J_2 must always be reversed biased.

Q.3 (a) Solution:

(i) Let $u = \dfrac{\sigma}{w\varepsilon}$ = loss tangent

where, σ is conductivity.

Phase constant, $\beta = 15$ rad/m (given)

As we know,
$$\beta = w\sqrt{\frac{\mu\varepsilon}{2}[\sqrt{1+u^2}+1]}$$

$$15 = w\sqrt{\frac{6\times 2\mu_0\varepsilon_0}{2}[\sqrt{1+u^2}+1]}$$

$$15 = \frac{w}{c}\sqrt{6[\sqrt{1+u^2}+1]} \qquad \left(\because \frac{1}{\sqrt{\mu_0\varepsilon_0}} = c\right)$$

$$15 = \frac{2\pi\times 8\times 10^6\sqrt{6}}{3\times 10^8}\sqrt{\sqrt{1+u^2}+1}$$

$$\frac{15}{0.41} = \sqrt{\sqrt{1+u^2}+1}$$

$$36.58 = \sqrt{\sqrt{1+u^2}+1}$$

Now squaring both sides,

$$1338.48 = \sqrt{1+u^2}+1$$

$$\sqrt{1+u^2} = 1337.48$$

$$1 + u^2 = 1788852.75$$

$$u^2 = 1788851.75$$

Loss tangent $u = \boxed{\frac{\sigma}{w\varepsilon} = 1337.47}$

(ii) Assume conductivity of material is σ. Thus,

$$\sigma = w\varepsilon u$$

$$= 2\pi\times 8\times 10^6 \times 2\times\frac{10^{-9}}{36\pi}\times 1337.47 \Rightarrow \boxed{\sigma = 1.188\ \text{S/m}}$$

(iii) The complex permittivity ε_c

$$\varepsilon_c = \varepsilon' - j\varepsilon''$$

$$= \varepsilon - j\frac{\sigma}{w}$$

$$= 2\times\frac{10^{-9}}{36\pi} - j\frac{1.188}{2\pi\times 8\times 10^6}$$

$$\boxed{\varepsilon_c = (1.769\times 10^{-11}) - j(2.36\times 10^{-8})}\ \text{F/m}$$

(iv) Assume the attenuation constant is α. We have,

$$\frac{\alpha}{\beta} = \frac{\sqrt{\sqrt{1+u^2}-1}}{\sqrt{\sqrt{1+u^2}+1}}$$

$$= \frac{\sqrt{1337.47-1}}{\sqrt{1337.47+1}}$$

$$\frac{\alpha}{\beta} = \frac{\sqrt{1336.47}}{\sqrt{1338.47}}$$

$$\frac{\alpha}{\beta} = 0.999$$

$$\alpha = 0.999\beta$$

$$\alpha = 0.999 \times 15$$

$$\boxed{\alpha = 14.98\ \text{Np/m}}$$

(v) The intrinsic impedance is

$$\eta = \sqrt{\frac{\mu}{\varepsilon_c}} = \sqrt{\frac{\mu}{\varepsilon' - j\varepsilon''}} = \sqrt{\frac{\mu}{\varepsilon - j\dfrac{\sigma}{\omega}}} = \frac{\sqrt{\mu/\varepsilon}}{\sqrt{1 - j\dfrac{\sigma}{\omega\varepsilon}}} = |\eta|\angle\theta_\eta$$

where
$$|\eta| = \frac{\sqrt{\dfrac{\mu}{\varepsilon}}}{(1+u^2)^{1/4}}$$

$$= \frac{120\pi\sqrt{\dfrac{6}{2}}}{(1+(1337.47)^2)^{1/4}} = \frac{120\pi\times\sqrt{3}}{(1788827)^{1/4}}$$

$$= \frac{120\pi\times\sqrt{3}}{36.57}$$

$$|\eta| = 17.84$$

We have,
$$\theta_\eta = \frac{1}{2}\tan^{-1}\left(\frac{\sigma}{\omega\varepsilon}\right) = \frac{1}{2}\tan^{-1}(u)$$

$$2\theta_\eta = \tan^{-1}(1337.47)$$

$$\boxed{\theta_\eta = 44.97^\circ}$$

Thus,
$$\eta = 17.84\angle 44.97^\circ\ \Omega$$

Q.3 (b) Solution:

(i) The sliding window protocol are protocols which are used for flow control and error control collectively. These controls are known as data link controls.

Basically there are three sliding window protocols :

1. Stop and Wait ARQ :

- It is half duplex and least efficient of the three.
- In this method, only one packet is sent per round trip time (RTT).
- The sender sends a packet and the receiver receives a packet and sends an acknowledgement frame for the sender to send the next packet.
- If the packet is not received within a time frame, the sender sends the packet again.
- It has low efficiency because the sender must wait for an acknowledgment before transmitting the next packet. It is used for reliable transmission of frames.

2. **Go Back N ARQ :**
   - To improve the efficiency, multiple packets are sent when user is waiting for the acknowledgement.
   - The sender window is a fixed-sized window that defines the number of frames that are transmitted from sender to receiver without waiting for acknowledgement. The integer '*N*' in the Go Back '*N*' is the frame size.
   - The Receiver window in the Go Back N ARQ protocol is always of size 1. This means that the receiver takes at most 1 frame at a single time.
   - Every frame has individual time out counters.
   - If one packet is lost, we retransmit all subsequent packets.
   - The acknowledgements can be individual or cumulative.
3. **Selected Repeat ARQ :**
   - It retransmits only selected packets i.e., those which are only lost.
   - It uses two windows, send and receive.
   - This protocol allows packets to arrive out of order and stores them till all packets have arrived.
   - Receive and send windows are of the same size.
   - If one packet is lost the sender continues transmitting, and the receiver accepts and stores the subsequent packets out of order until the missing packet is received.
   - Each acknowledgement is independent.
   - Piggybacking is used to improve efficiency of bidirection protocols by combining acknowledgment (ACK) information with outgoing data frames.

(ii) PPP : One of the most common protocols for point-to-point access is the point-to-point (PPP) protocol. PPP works at the level of data link layer. PPP does the following tasks :

1. PPP defines the format or frames to be exchanged between devices.
2. PPP defines how two devices negotiate and establish link for data exchange.
3. PPP defines how network layer data are encapsulated in the data link frame.
4. It defines how two devices can authenticate each other.
5. PPP provides multiple network layer services supporting a variety of network layer protocols.
6. PPP provides connection over multiple links.
7. PPP provides network access configuration. (dynamic IP allocation). This is particularly useful when a home user needs a temporary network address to connect to the Internet.

8. PPP does not provide flow control. A sender can send several frames one after another with no concern about overwhelming the receiver.
9. PPP does not have very good error control.
10. PPP does not provide sophisticated addressing mechanism to handle frames in a multipoint configuration.

Q.3 (c) Solution:

(i) The impulse response of the matched filter is given as

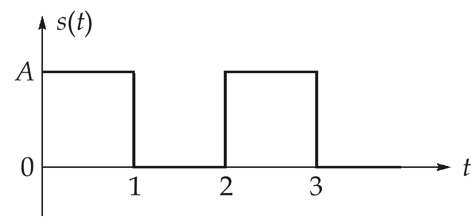
$$h(t) = s(T - t)$$

where T is the total time duration of incoming signal.

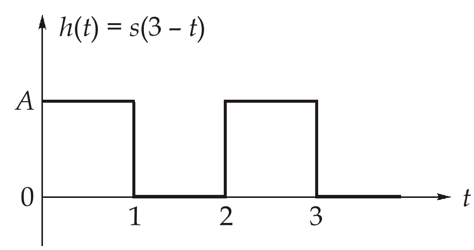
In the question, $T = 3$

Hence, $$h(t) = s(3 - t)$$

As $$s(t) = \begin{cases} A\,; 0 \le t \le 1 \\ A\,; 2 \le t \le 3 \\ 0\,; \text{otherwise} \end{cases}$$



$h(t)$ can be drawn as



(ii) Without considering noise, if the input is $s(t)$, then output $y(t)$ will be

$$(\text{Matched filter})_{o/p} : y_s(t) = s(t) * h(t),$$

where $$h(t) = s(3 - t) = Au(t) - Au(t - 1) + Au(t - 2) - Au(t - 3)$$

Using differentiation property of convolution,

$$\frac{d}{dt} y_s(t) = s(t) * \frac{d}{dt} h(t) \quad \text{...(i)}$$

$$\frac{d}{dt} y_s(t) = s(t) * A[\delta(t) - \delta(t - 1) + \delta(t - 2) - \delta(t - 3)]$$

$$\frac{d}{dt}y_s(t) = A[s(t) - s(t-1) + s(t-2) - s(t-3)]$$

... using the property $x(t) * \delta(t - t_0) = x(t - t_0)$

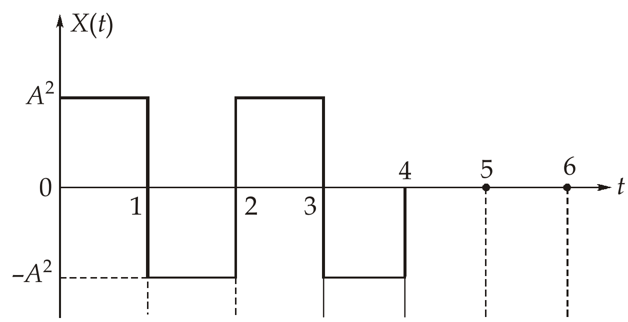
$$\frac{d}{dt}y_s(t) = [X(t) + Z(t)]$$

where, $X(t) = A[s(t) - s(t-1)]$

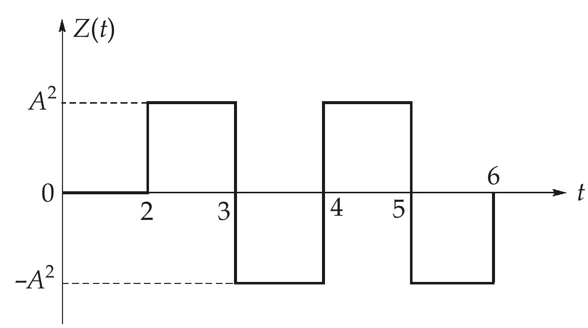
$Z(t) = A[s(t-2) - s(t-3)]$

and $W(t) = X(t) + Z(t)$

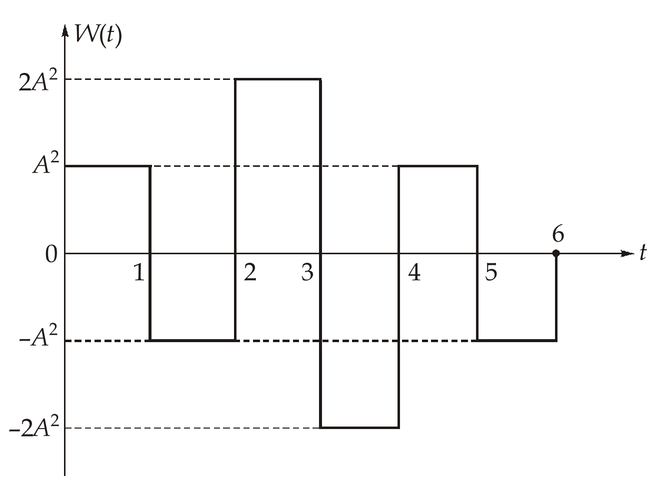
Plot of $X(t)$ can be drawn as



Plot of $Z(t)$ can be drawn as



Plot of $W(t)$ can be drawn as

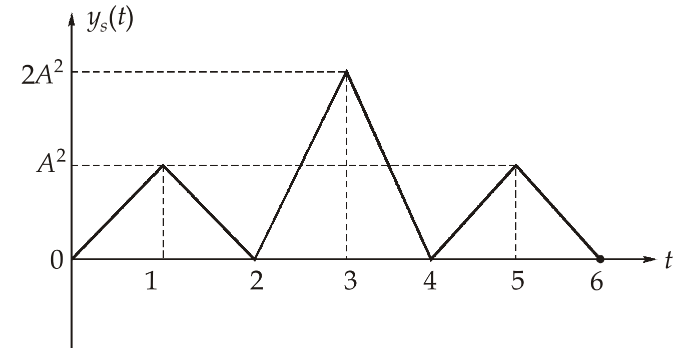


We have, $$\frac{d}{dt}y_s(t) = W(t) \Rightarrow y_s(t) = \int_{-\infty}^{t} W(t)\cdot dt$$

We can write,

$$W(t) = A^2[u(t) - 2u(t-1) + 3u(t-2) - 4u(t-3) + 3u(t-4) - 2u(t-5) + u(t-6)]$$

Thus, $$y_s(t) = A^2[r(t) - 2r(t-1) + 3r(t-2) - 4r(t-3) + 3r(t-4) - 2r(t-5) + r(t-6)]$$



At time instant T, $y_s(t)$ will have maximum value and SNR will be maximum at $T = 3$.

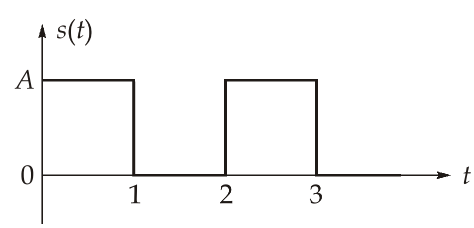
Hence, maximum peak at the output of matched filter,

$$y_s(t)\big|_{T=3} = 2A^2$$

(iii) Variance of Noise sample:

$$\text{Var}[y_{n(T)}] = E[y_{n(T)}^2] = \frac{N_0}{2}\times E_s$$

where E_s is the energy of the incoming signal.



Energy of the incoming signal $(E_s) = A^2 \times 1 + A^2 \times 1$

$$= 2A^2 \text{ Joule}$$

Hence, $$E[y_{n(T)}^2] = \frac{N_0}{2}\times 2A^2$$

$$E[y_{n(T)}^2] = N_0 A^2$$

(iv) BER(P_e) for matched filter is same as BER(P_e) for correlator based receiver.

For binary signalling scheme,

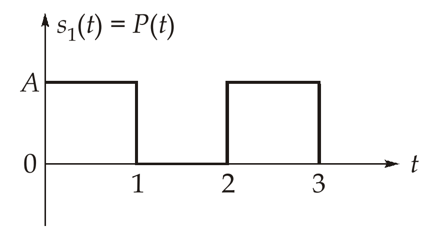
$$P_e = Q\left(\sqrt{\frac{E_d}{2N_0}}\right)$$

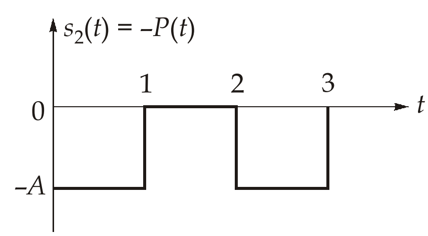
where, E_d = Energy of the difference signal $[s_1(t) - s_2(t)]$

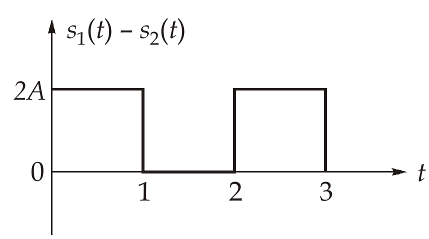
For Antipodal signalling,

$s_1(t) = P(t)$; in transmission of 1

$s_2(t) = -P(t)$; in transmission of 0







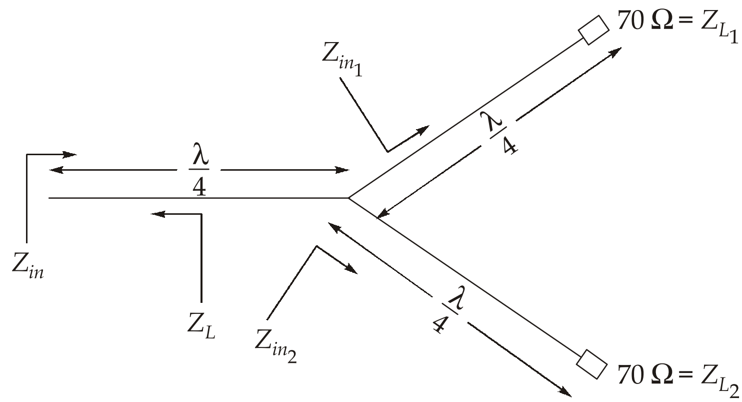
Hence,
$$E_d = (2A)^2 \times 1 + (2A)^2 \times 1$$
$$= 8A^2 \text{ Joule}$$

Thus,
$$P_e = Q\left[\sqrt{\frac{E_d}{2N_0}}\right]$$

$$\text{BER} = P_e = Q\left[\sqrt{\frac{8A^2}{2N_0}}\right] = Q\left[\sqrt{\frac{4A^2}{N_0}}\right]$$

Q.4 (a) Solution:

(i)



Now calculating, Z_{in_1} :

$$l = \frac{\lambda}{4},$$

$$Z_{L_1} = 70\ \Omega$$

$$Z_0 = 50\ \Omega$$

$$\beta l = \frac{2\pi}{\lambda}\times\frac{\lambda}{4} = \frac{\pi}{2}$$

Input impedance is given by

$$Z_{in_1} = Z_0\left[\frac{Z_L + jZ_0\tan\beta l}{Z_0 + jZ_L\tan\beta l}\right]$$

$$= Z_0\left[\frac{Z_{L_1} + jZ_0\tan\beta l}{Z_0 + jZ_{L_1}\tan\beta l}\right]$$

For $\beta l = \frac{\pi}{2}$

$$Z_{in_1} = \frac{Z_0^2}{Z_{L_1}} = \frac{(50)^2}{70} \Rightarrow \boxed{Z_{in_1} = 35.71\ \Omega}$$

For Z_{in_2} :

$$\beta l = \frac{\pi}{2},\ Z_0 = 50\ \Omega,\ Z_{L_2} = 70\ \Omega$$

$$Z_{in_2} = \frac{Z_0^2}{Z_{L_2}} = \frac{(50)^2}{70} \Rightarrow \boxed{Z_{in_2} = 35.71\ \Omega}$$

Now,
$$Z_L = Z_{\text{in}_1} \| Z_{\text{in}_2}$$
$$Z_L = 35.71 \| 35.71$$
$$\boxed{Z_L = 17.85\ \Omega}$$

Input impedance at source end,
$$Z_{in} = Z_0\left[\frac{Z_L + jZ_0 \tan\beta l}{Z_0 + jZ_L \tan\beta l}\right]$$

We have,
$$\beta l = \frac{2\pi}{\lambda}\times\frac{\lambda}{4} = \frac{\pi}{2}$$
$$Z_0 = 50\ \Omega$$
$$Z_L = 17.85\ \Omega$$
$$Z_{in} = \frac{Z_0^2}{Z_L}$$
$$Z_{in} = \frac{(50)^2}{17.85}$$
$$\boxed{Z_{in} = 140.05\ \Omega}$$

(ii)
$$Z_{in} = 140.05\ \Omega$$

Voltage, $V_g = 150$ V

Internal impedance, $Z_g = 90\ \Omega$

Current,
$$I_{in} = \frac{V_g}{Z_g + Z_{in}} = \frac{150}{90 + 140.05}$$
$$\boxed{I_{in} = 0.652\ \text{A}}$$

Average power delivered to antennas is
$$P_{\text{ave}} = \frac{1}{2}|I_{in}|^2 R_{in} \qquad [\because R_{in} = Z_{in}]$$
$$= \frac{1}{2}\times(0.652)^2\times 140.05$$
$$\boxed{P_{ave} = 29.76\ \text{watt}}$$

Power delivered to either antenna is
$$\frac{P_{\text{ave}}}{2} = \boxed{14.88\ \text{watt}}$$

Q.4 (b) Solution:

For the system with state-space model,

$$\dot{x} = Ax + Bu$$

$$y = Cx + Du$$

The response of the system in s-domain is given by

$$X(s) = [sI - A]^{-1} x(0^+) + [sI - A]^{-1} BU(s)$$

$$X(s) = \phi(s)\, x(0^+) + \phi(s)BU(s)$$

where $\phi(s) = [sI - A]^{-1}$ is called the resolvent matrix.

$$X(s) = \phi(s)[x(0) + BU(s)]$$

$$= \phi(s)\left[\begin{bmatrix} 0 \\ 1 \end{bmatrix} + \begin{bmatrix} 1 \\ -1 \end{bmatrix}\frac{1}{s}\right] = \phi(s)\begin{bmatrix} 1/s \\ 1-1/s \end{bmatrix}$$

Given,
$$A = \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix} \Rightarrow [sI - A] = \begin{bmatrix} s & 0 \\ 0 & s \end{bmatrix} - \begin{bmatrix} 0 & 1 \\ -1 & -2 \end{bmatrix}$$

$$[sI - A] = \begin{bmatrix} s & -1 \\ 1 & s+2 \end{bmatrix}$$

$\therefore$
$$\phi(s) = [sI - A]^{-1} = \begin{bmatrix} s & -1 \\ 1 & s+2 \end{bmatrix}^{-1} = \frac{1}{(s+1)^2}\begin{bmatrix} s+2 & 1 \\ -1 & s \end{bmatrix}$$

$\therefore$
$$X(s) = \frac{\begin{bmatrix} s+2 & 1 \\ -1 & s \end{bmatrix}}{(s+1)^2}\begin{bmatrix} \dfrac{1}{s} \\ 1-\dfrac{1}{s} \end{bmatrix}$$

$$= \frac{\begin{bmatrix} 1+\dfrac{2}{s}+1-\dfrac{1}{s} \\ -\dfrac{1}{s}+s-1 \end{bmatrix}}{(s+1)^2} = \frac{\begin{bmatrix} 2+\dfrac{1}{s} \\ -1+s-\dfrac{1}{s} \end{bmatrix}}{(s+1)^2}$$

$$= \begin{bmatrix} \dfrac{2s+1}{s(s+1)^2} \\ \dfrac{s^2-s-1}{s(s+1)^2} \end{bmatrix} = \begin{bmatrix} \dfrac{1}{s} - \dfrac{1}{s+1} + \dfrac{1}{(s+1)^2} \\ \dfrac{-1}{s} + \dfrac{2}{s+1} - \dfrac{1}{(s+1)^2} \end{bmatrix}$$

Taking the inverse Laplace transform, the time response is

$$x(t) = \begin{bmatrix} 1 - e^{-t} + te^{-t} \\ -1 + 2e^{-t} - te^{-t} \end{bmatrix}$$

The output response is given by

$$Y(s) = [0 \quad 1]\begin{bmatrix} X_1(s) \\ X_2(s) \end{bmatrix} = X_2(s)$$

Taking the inverse Laplace transform, the output response is

$$y(t) = x_2(t) = -1 + 2e^{-t} - te^{-t}$$

Q.4 (c) Solution:

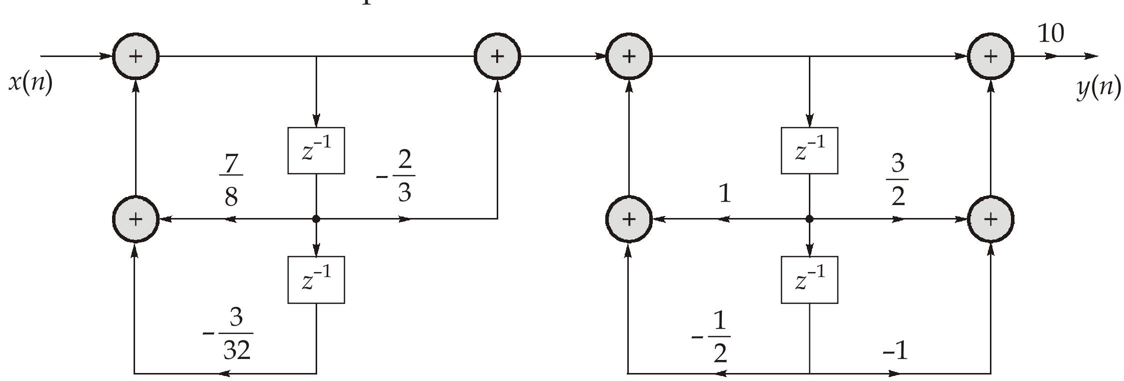
The cascade realizations is easily obtained from this form. One possible pairing of poles and zeros is

$$H_1(z) = \frac{1 - \frac{2}{3}z^{-1}}{1 - \frac{7}{8}z^{-1} + \frac{3}{32}z^{-2}}$$

$$H_2(z) = \frac{1 + \frac{3}{2}z^{-1} - z^{-2}}{1 - z^{-1} + \frac{1}{2}z^{-2}}$$

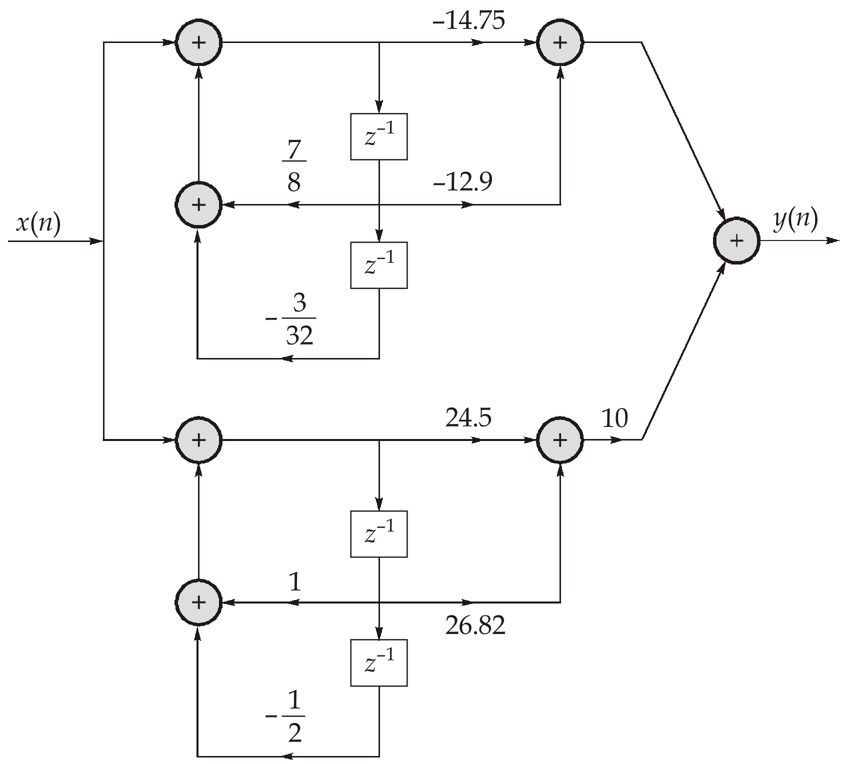
and hence; $H(z) = 10\,H_1(z) \cdot H_2(z)$

The cascade realization is depicted below:



To obtain the parallel realization, $H(z)$ must be expanded in partial fractions. Thus, we have

$$H(z) = \frac{A_1}{1 - \frac{3}{4}z^{-1}} + \frac{A_2}{1 - \frac{1}{8}z^{-1}} + \frac{A_3}{1 - \left(\frac{1}{2} + j\frac{1}{2}\right)z^{-1}} + \frac{A_3^*}{1 - \left(\frac{1}{2} - j\frac{1}{2}\right)z^{-1}}$$



where A_1, A_2, A_3, and A_3^* are to be determined. After solving, we find that

$$A_1 = 2.93, A_2 = -17.68, A_3 = 12.25 - j14.57, \ A_3^* = 12.25 + j14.57$$

Upon recombining pairs of poles, we obtain

$$H(z) = \frac{-14.75 - 12.90z^{-1}}{1 - \frac{7}{8}z^{-1} + \frac{3}{32}z^{-2}} + \frac{24.50 + 26.82z^{-1}}{1 - z^{-1} + \frac{1}{2}z^{-2}}$$

Section B

Q.5 (a) Solution:

(i) $$\frac{d^2y(t)}{dt^2} + \frac{4dy(t)}{dt} + 16y(t) = 10x(t)$$

Taking Laplace Transform on both sides,

$$s^2Y(s) + 4sY(s) + 16Y(s) = 10X(s)$$

$$\Rightarrow \quad \frac{Y(s)}{X(s)} = \frac{10}{s^2 + 4s + 16} = \left(\frac{10}{16}\right)\frac{16}{s^2 + 4s + 16}$$

Comparing denominator with standard characteristic equation of second order system, $s^2 + 2\xi\omega_n s + \omega_n^2 = 0$, we get

$$\omega_n^2 = 16 \Rightarrow \omega_n = 4 \text{ rad/sec}$$

$$2\xi\omega_n = 4 \Rightarrow \xi = 0.5$$

Since $\xi < 1$. Hence, it is an under-damped system. The output response for the step input $Au(t)$ is given as

$$y(t) = AK\left[1 - \frac{e^{-\xi\omega_n t}}{\sqrt{1-\xi^2}}\sin(\omega_d t + \phi)\right]$$

where $\omega_d = \omega_n\sqrt{1-\xi^2} = 4\sqrt{1-0.25} = 3.46 \text{ rad/sec}$

and $\phi = \cos^{-1}(\xi) = \cos^{-1}(0.5) = 60°$

For input, $x(t) = 2u(t)$

$$y(t) = \frac{20}{16}\left[1 - \frac{e^{-4\times 0.5t}}{\sqrt{1-0.25}}\sin(3.46t + 60°)\right]u(t)$$

$$y(t) = \frac{5}{4}[1 - 1.154e^{-2t}\sin(3.46t + 60°)]u(t)$$

(ii) The peak value is obtained at $T = T_p = \frac{\pi}{\omega_d}$ sec

$$\therefore \quad T_p = \frac{3.14}{3.46} = 0.91 \text{ sec}$$

Peak value of the output,

$$y_p = y(t = 0.91) = 1.25\left[1 - 1.154e^{-2\times 0.91}\sin\left(3.46\times 0.91 + \frac{\pi}{3}\right)\right]$$

$$= 1.25[1 - 1.154 \times 0.162 \times -0.87] = 1.453$$

(iii) For 2% tolerance band,

$$t_s = \frac{4}{\xi\omega_n} = \frac{4}{0.5\times 4} = 2 \text{ sec}$$

(iv) Time period of damped oscillation,

$$T = \frac{2\pi}{\omega_d} = \frac{2\times 3.14}{3.46} = 1.815 \text{ sec}$$

Number of cycles completed before the output is settled within 2% of its final value,

$$N = \frac{t_s}{T} = \frac{2}{1.815} = 1.1 \text{ cycles}$$

Q.5 (b) Solution:

START :	LXI H, 1000H	;	Load HL pair with 1000H
	MVI C, 0BH	;	Load Register C with 0BH
LOOP :	IN 16H	;	Load the accumulator with the data from I/O device, whose address is 16H
	MOV M, A	;	Store the content of the accumulator in the address location specified by the HL pair
	INX H	;	Increment the content of the HL register pair by 1
	DCR C	;	Decrement the content of the register C
	JNZ LOOP	;	Jump to the "LOOP" till the content of the register C becomes zero
	HLT	;	Halt the execution

From the above analysis of the program, it is clear that the given program can be used to store the data of 11 bytes [$\because$ 0BH = $(11)_{10}$] given by the I/O device having an address of 16H, in the memory starting from the address location 1000H.

Q.5 (c) Solution:

Given signal :

$$x(t) = \left(\frac{5}{2}\right)\cos(160\times10^3\pi t)+7\cos(170\times10^3\pi t)+\left(\frac{5}{2}\right)\cos(180\times10^3\pi t)$$

$$= 7\cos(170 + 10^3\pi t) + \frac{1}{2}\times 7\times\left(\frac{5}{7}\right)[\cos(160\times10^3\pi t)+\cos(180\times10^3\pi t)]$$

$$= 7\cos(170\times10^3\pi t) + \frac{1}{2}\times 7$$

$$\times\left(\frac{5}{7}\right)\left[2\cos\left(\left(\frac{160+180}{2}\right)\times10^3\pi t\right)\times\cos\left(\left(\frac{180-160}{2}\right)\times10^3\pi t\right)\right]$$

$$= 7\cos(170\times10^3\pi t) + 7\times\left(\frac{5}{7}\right)[\cos(170\times10^3\pi t).\cos(10\times10^3\pi t)]$$

$$= 7\cos(170\times10^3\pi t)\left[1+\frac{5}{7}\cos(10\times10^3\pi t)\right] \quad \text{...(i)}$$

An AM signal with carrier $A_c\cos(\omega_c t)$ and message signal $A_m\cos(\omega_m t)$ is given by

$$X_{AM}(t) = A_c\cos(\omega_c t)[1+m_a\cos(\omega_m t)]$$

On comparing with standard representation of AM signal, eqn. (i) represents an AM signal, with following parameters :

$$c(t) = 7\cos(170\times10^3\pi t)$$

$$m_a = \frac{5}{7}$$

(i) $$P_S = \text{Sideband power} = P_C \times \frac{m_a^2}{2},$$

where P_C is the carrier power

$$\frac{P_S}{P_C} = \frac{m_a^2}{2} = \left(\frac{5}{7}\right)^2 \times \frac{1}{2} = 0.25510$$

(ii) Power efficiency, $$\eta = \frac{P_S}{P_S + P_C} = \frac{P_C\left(\frac{m_a^2}{2}\right)}{P_C\left(1+\frac{m_a^2}{2}\right)} = \frac{m_a^2}{2+m_a^2}$$

$$\eta = 0.20325 = 20.325\%$$

Q.5 (d) Solution:

For Z.I.R [Zero input response], input is taken as zero and response is obtained only because of initial state. Considering $x(t) = 0$, we obtain

$$\ddot{y}(t) + 2y(t) + 3\dot{y}(t) = 0$$

Taking Laplace transform,

$$s^2Y(s) - s \cdot y(0) - \dot{y}(0) + 2Y(s) + 3[sY(s) - y(0)] = 0$$

$$s^2Y(s) - 3s - 4 + 2Y(s) + 3[sY(s) - 3] = 0$$

$$s^2Y(s) - 3s - 4 + 2Y(s) + 3sY(s) - 9 = 0$$

$$Y(s)[s^2 + 2 + 3s] = 3s + 13$$

$$Y(s) = \frac{3s+13}{s^2+3s+2} = \frac{3s+13}{(s+1)(s+2)} = \frac{A}{s+1} + \frac{B}{s+2}$$

We get, $$A = 10, B = -7$$

$\therefore$ $$Y(s) = \frac{10}{s+1} - \frac{7}{s+2}$$

Taking ILT,

$$y_{ZIR}(t) = (10e^{-t} - 7e^{-2t}) \cdot u(t)$$

For zero state response, input is available and the initial conditions are set to zero.

We have;

$$\ddot{y}(t) + 3\dot{y}(t) + 2y(t) = x(t) = 3e^{-4t}$$

Taking Laplace Transform considering initial conditions as zero,

$$s^2Y(s) + 3sY(s) + 2Y(s) = \frac{3}{s+4}$$

$$Y(s)[s^2 + 3s + 2] = \frac{3}{s+4}$$

$$Y(s) = \frac{3}{(s+1)(s+2)(s+4)} = \frac{A}{s+1} + \frac{B}{s+2} + \frac{C}{s+4}$$

We get, $A = 1, B = -3/2, C = 1/2$

Now, $$Y(s) = \frac{1}{s+1} - \frac{3/2}{s+2} + \frac{1/2}{s+4}$$

After taking ILT;

$$y_{ZSR}(t) = \left(e^{-t} - \frac{3}{2}e^{-2t} + \frac{1}{2}e^{-4t}\right) \cdot u(t)$$

Q.5 (e) Solution:

Epitaxy is a term applied to the process of growing a monocrystalline film on a substrate. Epitaxy is termed as homoepitaxy when crystal is grown on a substrate of the same material for eg. silicon grown on silicon substrate. It is called heteroepitaxy when crystal is grown on a foreign substrate, for eg. silicon film grown on sapphire or gallium arsenide is grown on a silicon substrate. The use of epitaxial growth reduces the growth time, wafering cost and eliminate the wastages caused during growth, cutting, polishing etc. The major advantage of epitaxy is uniformity in composition, controlled growth parameter and better understanding of growth itself. Several epitaxial techniques have been used for growth of epilayers of III-V, II-VI compound semiconductor and other materials. The prominent among them are:

- **Liquid phase epitaxy:** It means the growth of thin films from metallic solution on an oriented crystalline substrate. The solvent element can be either a constituent of the growing solid e.g. In or Ga or it can be some other low melting materials like Sn, Bi or Pb, which is incorporated into the solid only as a dopant. The process is best controlled when transport occurs by diffusion i.e. concentration gradient of the solute. Growth rate is typically 0.1 – 1 μm / min.
- **Vapour phase Epitaxy (VPE):** Commonly used for III-V compound semiconductors. In this, growth is carried out by vapourizing the source material for III-V compounds; inorganic or organic materials which react with other materials to form compound semiconductor on substrate. Growth is controlled by the partial pressure of the each of the components of source materials. Growth rate is typically 2 μm / min.

- **Molecular beam epitaxy (MBE):** It is a process of depositing epitaxial thin film from molecular or atomic beams on a heated substrate under ultra-high vacuum. The growth rate is typically 1 μm / hr. The advantage of MBE is that a very precise control of dopant profile is created.

Masking: The photomasking process can be divided into two distinct areas:

(a) Generation of a mask whose image is to be transferred to Si wafer.

(b) The transfer of image from the mask to the surface of the wafer.

For most present day integrated circuits, making is done by using computer controlled drawing boards and other equipment. In either case, copies of the circuit-pattern are photographically reduced until they are ten times the ultimate size. The final mask is made from 10 X plate, using a step and repeat camera which has a reduction factor of 10.

The step and repeat process results in rows and columns of identical image being transferred to a glass plate called a master. The primary mask is used to make contact copies again using photosensitized glass plates. These copies are then used for actual image transfer to a semiconductor wafer.

Another method involves the use of an electron beam exposure system that can directly write the pattern in its final size onto an electron sensitive photoresistor in a hard surface mask.

Etching: It is used for the selective removal of undesired dielectric and metallic layers. Different etching techniques are:

- Wet chemical etching
- Electro chemical etching
- Sputter etching
- Plasma etching
- Reactive ion etching

Wet etching is most widely used technique for selective removal of the regions of semiconductor material, metal, SiO_2 and Si_3N_4. For selective etching, SiO_2 is etched in buffered solution of HF + NH_4F; Si_3N_4 is etched in hot H_3PO_4; while Al is etched in either H_3PO_4, HNO_3 or acetic acid. Wafer is immersed in etching solution at a predetermined temperature.

In electrochemical etching, a voltage is applied between etchant and the material to be etched. Then the etching is performed at controlled rate.

Q.6 (a) Solution:

These protocols are used to handle access to a shared link and belong to a sublayer in the data link layer called the Media Access Layer.

There are certain assumptions made in view of which these protocols are designed :

- There are N independent users.
- A user is blocked until its generated frame is transmitted.
- Only a single channel is available.
- The transmission of two or more frames on the channel creates a collision which destroy data.
- Time can be continuous or slotted i.e. Frame transmission can begin at any instant or time is divided into discrete slots and frame transmission always begin at the start of a slot.
- There could be either carrier sense or no carrier sense. With carrier sense, stations can tell if the channel is in use before trying to use it.

There are three major multiple access protocols :

(1) Pure Aloha :

- Users transmit data randomly.
- Colliding frames are destroyed and this destruction is sensed by the N/W.
- When there is a collision, the user waits a random time before retransmitting.

(2) Slotted Aloha :

- It is very similar to pure aloha.
- But time is divided into discrete frame time slots.
- A user is required to wait till beginning of a slot before transmitting or retransmitting a frame.
- Vulnerable period is halved as compared to pure aloha as transmission is allowed only at the beginning of fixed time slots, reducing the collision interval from $2T$ to T (where T is frame transmission time)..
- It gives maximum throughput of 36.8% as compared to 18.4% in pure aloha.

(3) Carrier Sense Multiple Access (CSMA) Protocols : In this type of protocols, the user can listen to the channel and make out whether channel is empty or not.

1-Persistent CSMA :

- A station ready to transfer the data senses the channel for transmission until it becomes free.
- When it detects an empty channel, it transmits instantly.
- In case of a collision, it waits for a random amount of time before retransmitting.

Non-Persistent CSMA :

- If the channel is free, it transmits immediately. However, if the line is not idle, it waits for a random amount of time and then senses the channel again.

P-Persistent CSMA:

- For P-Persistent CSMA, if the user senses the channel as empty, it transmits with a probability P and differs transmission with a probability 1–P and waits for the next time slot to sense the channel again.

Q.6 (b) Solution:

(i) Let inputs $-A$ and A be represented as s_0 and s_1.

At the output, the received symbols are r_0 and r_1 corresponding to inputs s_0 and s_1.

The probability density function of noise is given as,

$$p(n) = \frac{1}{\sqrt{2}\sigma} e^{-|n|\sqrt{2}/\sigma}$$

$$E[n] = 0$$

$$E[r_0] = E[s_0 + n] = E[-A + n]$$

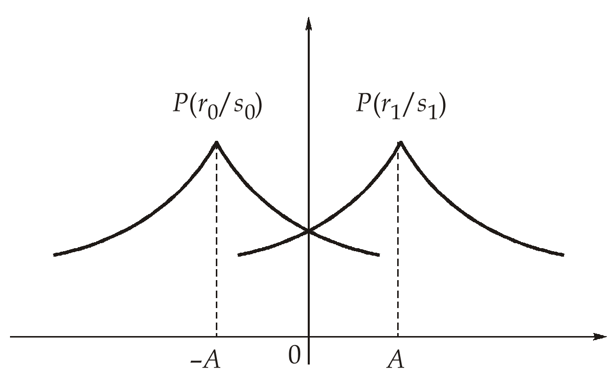
$$= -A$$

$$E[r_1] = E[s_1 + n] = E[A + n]$$

$$= A$$

We can write, $p(r_0/s_0) = \frac{1}{\sqrt{2}\sigma} e^{-|N+A|\sqrt{2}/\sigma}$ and $p(r_1/s_1) = \frac{1}{\sqrt{2}\sigma} e^{-|N-A|\sqrt{2}/\sigma}$

The probability density function of $P(r_0 | s_0)$ and $P(r_1 | s_1)$ can be obtained as below,



For Maximum Likelihood detection, the optimal decision boundary is

$$V_{Th} = \frac{-A + A}{2} = 0 \text{ V}$$

Probability of error, $P_e = P(s_0).P(\text{decide } s_1 | s_0) + P(s_1).P(\text{decide } s_0 | s_1)$

$$= 2 \times P(s_0) \int_0^{\infty} P(r_0 / s_0) \cdot dn$$

.. as $P(s_0)$ and $P(s_1)$ are equiprobable and $P(r_0/s_0)$ and $P(r_1/s_1)$ are symmetrical around V_{Th}.

$$= 2\times\frac{1}{2}\int_0^{\infty}\frac{1}{\sqrt{2}\,\sigma}e^{-|n+A|\sqrt{2}/\sigma}\cdot dn$$

$$= \frac{1}{\sqrt{2}\,\sigma}\int_0^{\infty}e^{-(n+A)\sqrt{2}/\sigma}\cdot dn$$

$$P_e = \frac{1}{\sqrt{2}\,\sigma}e^{-A\sqrt{2}/\sigma}\int_0^{\infty}e^{-n\sqrt{2}/\sigma}\cdot dn$$

$$= \frac{e^{-A\sqrt{2}/\sigma}}{\sqrt{2}\,\sigma}\left(-\frac{\sigma}{\sqrt{2}}\right)\left(e^{-n\sqrt{2}/\sigma}\right)_0^{\infty}$$

$$P_e = \frac{e^{-A\sqrt{2}/\sigma}}{\sqrt{2}\,\sigma}\left(\frac{\sigma}{\sqrt{2}}\right) = \frac{1}{2}e^{-A\sqrt{2}/\sigma}$$

(ii)

$$P_e = \frac{1}{2}e^{-A\sqrt{2}/\sigma}$$

For a Laplacian noise PDF

$$p(n) = \frac{\lambda}{2}e^{-\lambda|n|}$$

Comparing with the given noise pdf, we get

$$\lambda = \frac{\sqrt{2}}{\sigma}$$

Therefore, Noise power, $N = \frac{1}{2\lambda^2} = \sigma^2$

Thus, $\text{SNR} = \frac{A^2}{\sigma^2}$

We can write, $P_e = \frac{1}{2}e^{-\sqrt{2\text{SNR}}}$

$$10^{-6} = \frac{1}{2}e^{-\sqrt{2\text{SNR}}}$$

$$\ln(2\times 10^{-6}) = -\sqrt{2\text{SNR}}$$

$$-13.122 = -\sqrt{2\text{SNR}}$$

$$\text{SNR} = \frac{172.196}{2} = 86.09 = 19.349\text{ dB}$$

Q.6 (c) Solution:

(i) The transfer function for the unity feedback closed-loop system is given as

$$T(s) = \frac{G(s)}{1+G(s)\cdot H(s)}$$

For unity feedback, $H(s) = 1$

Hence,
$$T(s) = \frac{\dfrac{K}{s(sT+2)}}{1+\dfrac{K}{s(sT+2)}} = \frac{K}{s^2T+2s+K}$$

$$T(s) = \frac{K/T}{s^2+\dfrac{2}{T}\cdot s+\dfrac{K}{T}}$$

Comparing with the standard characteristic equation of second-order system $s^2+2\xi\omega_n s+\omega_n^2$, we get

$$\omega_n = \sqrt{\frac{K}{T}} \text{ and } 2\xi\omega_n = \frac{2}{T}$$

$$\therefore \quad \xi = \frac{1}{\omega_n T} = \frac{1}{\sqrt{KT}}$$

For $\xi_1 = 0.3$, let $K = K_1$ and $\xi_2 = 0.9$, let $K = K_2$. Hence

$$\frac{\xi_1}{\xi_2} = \frac{\dfrac{1}{\sqrt{K_1T}}}{\dfrac{1}{\sqrt{K_2T}}}$$

$$\frac{0.3}{0.9} = \sqrt{\frac{K_2}{K_1}}$$

$$K_2 = \left(\frac{1}{9}\right)K_1$$

Hence, to increase damping ratio from 0.3 to 0.9, gain (K) must be multiplied by $\left(\frac{1}{9}\right)$.

From (i) and (ii),

$$\frac{TK_1 - 1}{TK_2 - 1} = \left(\frac{8.82}{2.62}\right)^2 = 11.33$$

(ii) Let for $\xi_1 = 0.9$, $T = T_1$ and for $\xi_2 = 0.3$, $T = T_2$. Hence,

$$\frac{\xi_1}{\xi_2} = \frac{\frac{1}{\sqrt{KT_1}}}{\frac{1}{\sqrt{KT_2}}}$$

$$\frac{0.9}{0.3} = \sqrt{\frac{T_2}{T_1}}$$

$$\Rightarrow \quad T_2 = 9T_1$$

Hence, to decrease the damping ratio from 0.9 to 0.3, the time-constant (T) must be multiplied by 9.

(iii) Percentage overshoot for a second-order system is given as

$$\% M_p = e^{-\pi\xi/\sqrt{1-\xi^2}} \times 100\%$$

when $\% M_p = 70\%$, $K = K_1$, Therefore,

$$\xi = \frac{1}{\sqrt{K_1 T}}$$

$$70 = e^{-\pi/\sqrt{\frac{1}{\xi^2}-1}} \times 100\%$$

$$\Rightarrow \quad 0.7 = e^{-\pi/\sqrt{TK_1 - 1}}$$

$$\Rightarrow \quad \frac{-\pi}{\sqrt{TK_1 - 1}} = \ln(0.7) = -0.356$$

$$\Rightarrow \quad \sqrt{TK_1 - 1} = \frac{3.14}{0.356} = 8.82 \qquad ...(i)$$

When $\% M_p = 30\%$, $K = K_2$, Therefore,

$$\xi = \frac{1}{\sqrt{K_2 T}}$$

$$0.3 = e^{-\pi/\sqrt{TK_2 - 1}}$$

$$\frac{-\pi}{\sqrt{TK_2 - 1}} = \ln(0.3) = -1.2$$

$$\Rightarrow \qquad \sqrt{TK_2 - 1} = \frac{3.14}{1.2} = 2.62 \qquad \text{...(ii)}$$

(iv) For unit ramp input, steady-state error is given as

$$e_{ss} = \frac{1}{K_v}, \text{ where } K_v = \text{Velocity Error Coefficient}$$

$$K_v = \lim_{s \to 0} sG(s) \cdot H(s) = \lim_{s \to 0} s \cdot \frac{K}{s(sT+2)} \qquad (\because H(s) = 1)$$

$$K_v = \frac{K}{2}$$

Hence,
$$e_{ss} = \frac{2}{K} = 0.2 \text{ (given)}$$

$$\Rightarrow \qquad K = 10$$

Q.7 (a) Solution:

(i) For a Hertzian dipole,

$$|H_{\phi s}| = \frac{I_0 \beta dl \sin\theta}{4\pi r}$$

where,
$$dl = \frac{\lambda}{36}, \beta dl = \frac{2\pi}{36} \cdot \frac{\lambda}{36} = \frac{\pi}{18} \text{ rad}$$

Given,
$$|H_{\phi s}| = 6 \times 10^{-6} \text{ A/m} \quad \text{at } r = 3 \text{ km}$$

$$6 \times 10^{-6} = \frac{I_0 \left(\frac{\pi}{18}\right) \sin\left(\frac{\pi}{2}\right)}{4\pi(3 \times 10^3)}$$

$$6 \times 10^{-6} = \frac{I_0}{216 \times 10^3}$$

$$\boxed{I_0 = 1.29 \text{ Amp}}$$

For hertzian dipole,
$$R_{rad} = 80\pi^2 \left(\frac{dl}{\lambda}\right)^2. \text{ Thus,}$$

$$P_{rad} = \frac{1}{2} I_0^2 R_{rad} = 40\pi^2 \left[\frac{dl}{\lambda}\right]^2 I_0^2$$

$$= 40\pi^2 \left[\frac{\lambda/36}{\lambda}\right]^2 (1.29)^2 = \frac{40\pi^2 (1.29)^2}{(36)^2} = 0.506 \text{ watt}$$

$$\boxed{P_{rad} = 506 \text{ m watt}}$$

(ii) For a $\frac{\lambda}{2}$ dipole,

$$|H_{\phi s}| = \frac{I_0 \cos\left(\frac{\pi}{2}\cos\theta\right)}{2\pi r \sin\theta}$$

$$6 \times 10^{-6} = \frac{I_0 \cos\left(\frac{\pi}{2}\cos\frac{\pi}{2}\right)}{2\pi(3\times10^3)\sin\left(\frac{\pi}{2}\right)}$$

$$6 \times 10^{-6} = \frac{I_0 \times 1}{2\pi\times3\times10^3\times1}$$

$$\boxed{I_0 = 0.113 \text{ Amp}}$$

$$P_{rad} = \frac{1}{2}I_0^2 P_{rad}$$

$$= \frac{1}{2}(0.113)^2\times73$$

(∵ For half wave dipole, R_{rad} = 73 Ω)

$$= 0.466 \text{ watt}$$

$$\boxed{P_{rad} = 466 \text{ m watt}}$$

(iii) For a $\frac{\lambda}{4}$ monopole :

I_0 is same as calculated for half wave dipole

$$|H_{\phi s}| = \frac{I_0 \cos\left(\frac{\pi}{2}\cos\theta\right)}{2\pi r \sin\theta}$$

$$6 \times 10^{-6} = \frac{I_0 \cos\left(\frac{\pi}{2}\cos\frac{\pi}{2}\right)}{2\pi\times3\times10^3 \sin\frac{\pi}{2}}$$

$$\boxed{I_0 = 0.113 \text{ Amp}}$$

$$P_{rad} = \frac{1}{2}I_0^2 R_{rad}$$

We have, $R_{rad} = 36.56\ \Omega$ for $\frac{\lambda}{4}$ monopole

Thus, $P_{rad} = \frac{1}{2}(0.113)^2 \times 36.56$

$P_{rad} = 0.233$ watt

$\boxed{P_{rad} = 233 \text{ m watt}}$

(iv) For a loop antenna,

$$|H_{\phi s}| = \frac{\pi I_0}{r}\frac{S}{\lambda^2}\sin\theta$$

For N-turns, $S = N\pi\rho_0^2$, $r = 3 \times 10^3$

Given, $|H_{\phi s}| = 6 \times 10^{-6}$ A/m at $r = 3$ km and $\theta = \frac{\pi}{2}$, $\rho_0 = \frac{\lambda}{30}$, $N = 15$

$$|H_{\phi s}| = \frac{\pi I_0}{r}\left(\frac{N\pi\rho_0^2}{\lambda^2}\right)\sin\left(\frac{\pi}{2}\right)$$

$$= \frac{\pi I_0}{r}N\pi\left(\frac{\rho_0}{\lambda}\right)^2(1)$$

$$= \frac{\pi I_0}{r}N\pi\left(\frac{\lambda}{30\times\lambda}\right)^2$$

$$6 \times 10^{-6} = \frac{\pi I_0}{3\times 10^3}\times 15\pi\times\frac{1}{900}$$

$$I_0 = \frac{6\times 10^{-6}\times 3\times 10^3\times 900}{\pi\times 15\pi}$$

$$\boxed{I_0 = 0.109 \text{ Amp}}$$

For loop antenna, $R_{rad} = \frac{320\pi^4 S^2}{\lambda^4} = \frac{320\pi^4}{\lambda^4}N^2\pi^2\rho_0^4$

$$= 320\pi^6 N^2\left(\frac{\rho_0}{\lambda}\right)^4$$

$$= 320\pi^6\times(15)^2\left(\frac{\lambda}{30\times\lambda}\right)^4$$

$$R_{rad} = 320\pi^6 \times 225 \times \frac{1}{(30)^4}$$

$$R_{rad} = 85.19\ \Omega$$

Thus, $$P_{rad} = \frac{1}{2} I_0^2 R_{rad} = \frac{1}{2}(0.109)^2(85.19)$$

$$P_{rad} = 0.506 \text{ watt}$$

$$\boxed{P_{rad} = 506 \text{ m watt}}$$

Q.7 (b) Solution:

(i) **Cycle Stealing Mode:** In this mode, the DMA controller forces the CPU to suspend its operation for one bus cycle to transfer a single byte/word of data. After the transfer of every byte, the DMA controller releases the bus and then again requests for the system bus. In this way, the DMA controller steals the clock cycle for transferring every byte.

Calculation:

DMA Clock is 2 MHz $\Rightarrow$ Each DMA Clock state is 0.5 μs

Each DMA Cycle has 6 Clock States $\Rightarrow$ Each DMA cycle is of 3 μs

In Cycle Stealing, given that the intermediate CPU Cycle takes 2 μs.

Therefore, every 2 + 3 = 5 μs, 1 byte is transferred by DMA device.

$$\text{Data transfer rate} = \frac{1}{5} \times 10^6 \text{ Bytes/second} = 200 \text{ Kbytes/sec}$$

(ii) Average disk access time = Average seek time + Average rotational latency + Data Transfer time + Controller overhead

Average rotational latency is $\left(\frac{R}{2}\right)$, (R is time for 1 rotation)

$$= 4 \text{ ms} + \frac{0.5 \times 60 \text{ sec}}{20750} + \frac{1 \text{ KB}}{200 \text{ MB}} + 1 \text{ ms}$$

$$= 4 \text{ ms} + 1.44 \text{ ms} + 0.005 \text{ ms} + 1 \text{ ms} = 6.44 \text{ ms}$$

Q.7 (c) Solution:

(i) Given number of message bits,

$$k = 4$$

Number of parity bits, $m = n - k = 4$

Total number of bits in a code word,

$$n = m + k = 8$$

So, given is (n, k), i.e., (8, 4) Linear Block Code.

Generator matrix, $G = [I_k; P^T]$

From the given equations,

Parity matrix, $$P = \begin{bmatrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \end{bmatrix}$$

$$[G] = \begin{bmatrix} \underbrace{\begin{matrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}}_{I_k} & \underbrace{\begin{matrix} 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 \end{matrix}}_{P^T} \end{bmatrix}$$

Parity Check Matrix : $[H] = [P : I_m] = [P : I_4]$

$$[H] = \begin{bmatrix} \underbrace{\begin{matrix} 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \end{matrix}}_{P} & \underbrace{\begin{matrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{matrix}}_{I_m} \end{bmatrix}$$

(ii) $$[H^T] = \begin{bmatrix} 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

The minimum distance of linear block code ($d_{\min}$) is equal to minimum number of rows of H^T, whose sum is equal to zero vector.

For the given $[H^T]$, Sum of 2nd, 3rd, 4th and 6th rows of H^T equals to zero, so $d_{min} = 4$.

LBC can detect upto 't' errors, provided

$$d_{min} \geq t + 1$$
$$4 \geq t + 1$$
$$t \leq 3$$

LBC can correct upto 't' errors, provided

$$d_{min} \geq 2t + 1$$
$$4 \geq 2t + 1$$
$$t \leq 1.5$$

Thus, given LBC can detect upto 3 errors and correct upto '1' error.

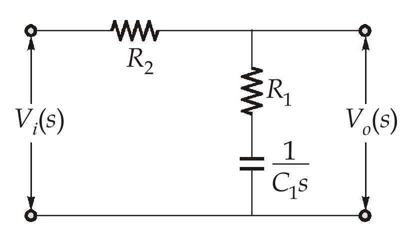
(iii) For the received codeword $r = [10100100]$, the syndrome

$$S = rH^T = [1 \quad 0 \quad 1 \quad 0 \quad 0 \quad 1 \quad 0 \quad 0]\begin{bmatrix} 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \\ 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} = [0 \quad 0 \quad 0 \quad 1]$$

It matches the 8th column of H^T. This indicates an error in 8th bit. Thus, the transmitted codeword is obtained by correcting the error in 8th bit as, [10100101].

Q.8 (a) Solution:

(i) The circuit for phase-lag compensator is drawn below :



$$\frac{V_o(s)}{V_i(s)} = \frac{R_1 + \dfrac{1}{C_1 s}}{R_1 + R_2 + \dfrac{1}{C_1 s}} = \frac{1 + R_1 C_1 s}{1 + (R_1 + R_2) C_1 s}$$

$$\frac{V_o(s)}{V_i(s)} = \frac{1+R_1C_1s}{1+\frac{(R_1+R_2)}{R_1}\cdot R_1C_1s} = \frac{1+\tau s}{1+\beta\tau s}$$

where $\tau = R_1C_1$ and $\beta = \frac{R_1+R_2}{R_1} > 1$

The phase offered by the compensator is

$$\phi = \tan^{-1}\omega\tau - \tan^{-1}\beta\omega\tau$$

For maximum phase lag,

$$\frac{d\phi}{d\omega} = 0$$

$$\Rightarrow \quad \frac{\tau}{1+\omega^2\tau^2} - \frac{\beta\tau}{1+\beta^2\omega^2\tau^2} = 0$$

$$\Rightarrow \quad 1 + \beta^2\omega^2\tau^2 = \beta + \beta\omega^2\tau^2$$

$$\Rightarrow \quad \omega^2\tau^2\beta(\beta - 1) = \beta - 1$$

$$\Rightarrow \quad \omega_m = \frac{1}{\tau\sqrt{\beta}}$$

Hence, the maximum phase lag given by compensator is

$$\phi_m = \tan^{-1}\left[\frac{1}{\sqrt{\beta}}\right] - \tan^{-1}[\sqrt{\beta}]$$

$$\phi_m = \tan^{-1}\left[\frac{\frac{1}{\sqrt{\beta}} - \sqrt{\beta}}{1+1}\right]$$

$$\phi_m = \tan^{-1}\left[\frac{1-\beta}{2\sqrt{\beta}}\right]$$

$$\phi_m = \sin^{-1}\left[\frac{1-\beta}{1+\beta}\right]$$

(ii) Effects and Limitations of Lag Compensator :

- Lag compensator allows high gain at low frequencies, thus it is basically a low pass filter. Hence, it improves the steady-state performance.

- In lag compensation, the gain cross-over frequency is shifted to a lower frequency point. Thus, the bandwidth of the system gets reduced.
- The system becomes more sensitive to the parameter variations.
- Lag compensator approximately acts as proportional plus integral controller and thus, tends to make the system less stable.
- It increases the rise time and settling time.

(iii) Let us assume the transfer function of phase-lag compensator as below :

$$G(s) = \frac{K_c(1+\tau s)}{1+\beta\tau s}; \beta > 1$$

For a maximum phase lag of 30° at ω = 2 rad/sec, we have

$$\phi_m = -30° = \sin^{-1}\left(\frac{1-\beta}{1+\beta}\right) \text{ and } \omega_m = 10 = \frac{1}{\tau\sqrt{\beta}}$$

$$\sin(-30°) = \frac{1-\beta}{1+\beta} = \frac{-1}{2}$$

$$-(1 + \beta) = 2 - 2\beta$$

$$\beta = 3$$

We have, $$\omega_m = \frac{1}{\tau\sqrt{\beta}} = 2$$

⇒ $$\tau = \frac{1}{2\sqrt{\beta}} = 0.289$$

Hence, $$G(s) = \frac{K_c(1+0.289s)}{1+0.867s}$$

$$|G(j\omega)| = \frac{K_c\sqrt{1+0.0835\omega^2}}{\sqrt{1+0.7516\omega^2}}$$

At ω = 2 rad/sec, $|G(j\omega)|_{dB} = 20$

⇒ $20 \log_{10} |G(j\omega)| = 20$

⇒ $|G(j\omega)| = 10$

Hence, $$10 = \frac{K_c\sqrt{1+0.334}}{\sqrt{1+3}}$$

$$K_c = \frac{20}{1.155} = 17.32$$

Hence, the transfer function of the desired lag compensator is

$$G(s) = \frac{17.32(1+0.289s)}{1+0.867s}$$

Q.8 (b) Solution:

(i) It is given that

$$H_x = 3\sin\left(\frac{\pi x}{a}\right)\cos\left(\frac{3\pi y}{b}\right)\sin(\pi\times 10^{11}t-\beta z) \text{ A/m}$$

General equation of H_x is given by

$$H_x = H_{0x}\sin\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)\sin(wt-\beta z) \text{ A/m}$$

Now comparing both equations, we get

$$H_{0x} = 3,\ m = 1,\ n = 3$$

The waveguide is operating at TM_{13} or TE_{13}.

(ii) Cutoff frequency will be same for both modes TM_{13} or TE_{13}. The cut-off frequency for TE_{mn}/TM_{mn} mode is given by

$$f_{c_{mn}} = \frac{u'}{2}\sqrt{\frac{m^2}{a^2}+\frac{n^2}{b^2}}$$

where

$$u' = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{c}{\sqrt{\mu_r\varepsilon_r}} = \frac{c}{\sqrt{9}} = \frac{c}{3}$$

$$u' = \frac{c}{3}$$

For $m = 1$ and $n = 3$,

$$f_c = \frac{c}{2\times 3}\sqrt{\frac{1}{(1.2\times 10^{-2})^2}+\frac{9}{(0.7\times 10^{-2})^2}}$$

$$f_c = 2.18\times 10^{10} = 21.8 \text{ GHz} \qquad (\because c = 3\times 10^8 \text{ m/s})$$

$$\boxed{f_c = 21.8 \text{ GHz}}$$

(iii) Phase constant β will also be same for both modes TM_{13} or TE_{13} given as,

$$\beta = w\sqrt{\mu\varepsilon}\sqrt{1-\left(\frac{f_c}{f}\right)^2} = \frac{w\sqrt{\varepsilon_r}}{c}\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

From the given expression,

$$w = 2\pi f = \pi \times 10^{11}$$

$$f = \frac{10^{11}}{2}\text{Hz} = \frac{100}{2}\text{GHz}$$

$$f = 50\,\text{GHz}$$

Thus,
$$\beta = \frac{\pi\times10^{11}\sqrt{9}}{3\times10^{8}}\sqrt{1-\left(\frac{21.8}{50}\right)^2}$$

$$= 3140 \times 0.899$$

$$\boxed{\beta = 2825.83\ \text{rad/m}}$$

(iv) The propagation constant γ

$$\gamma = j\beta$$

$$\boxed{\gamma = j2825.83\ \text{m}^{-1}}$$

(v) The intrinsic wave impedance for TM_{13} mode will be

$$\eta_{TM_{13}} = \eta'\sqrt{1-\left(\frac{f_c}{f}\right)^2}$$

$$= \frac{377}{\sqrt{\varepsilon_r}}\sqrt{1-\left(\frac{21.8}{50}\right)^2} = \frac{377}{\sqrt{9}}\times0.899$$

$$\eta_{TM_{13}} = 125.67 \times 0.899$$

$$\boxed{\eta_{TM_{13}} = 112.97\ \Omega}$$

The intrinsic wave impedance for TE_{13} mode will be

$$\eta_{TE_{13}} = \frac{\eta'}{\sqrt{1-\left(\frac{f_c}{f}\right)^2}}$$

$$= \frac{377/\sqrt{\varepsilon_r}}{\sqrt{1-\left(\frac{21.8}{50}\right)^2}} = \frac{125.67}{0.899}$$

$$\boxed{\eta_{TE_{13}} = 139.78\ \Omega}$$

Q.8 (c) Solution:

(i) Consider:

$\boldsymbol{P(T_0)}$ **:** Probability of transmitting 0 = 0.45

$\boldsymbol{P(T_1)}$ **:** Probability of transmitting 1 = 0.55

$\boldsymbol{P(R_0)}$ **:** Probability of receiving 0

$\boldsymbol{P(R_1)}$ **:** Probability of receiving 1

1. Probability that a received 0 was transmitted as 0.

We need to find $P(T_0/R_0)$

Using Bayes theorem,

$$P(T_0/R_0) = \frac{P(T_0)\times P(R_0/T_0)}{P(T_0)\times P(R_0/T_0)+P(T_1)\times P(R_0/T_1)}$$

Given, $P(R_1/T_0) = 0.1 \Rightarrow P(R_0/T_0) = 0.9$

Also given, $P(R_0/T_1) = 0.2$

$$P(T_0/R_0) = \frac{0.45\times 0.9}{0.45\times 0.9+0.55\times 0.2} = 0.786$$

2. Probability that a received 1 was transmitted as a 1.

$$P(T_1/R_1) = \frac{P(T_1)\times P(R_1/T_1)}{P(T_1)\,P(R_1/T_1)+P(T_0)\,P(R_1/T_0)}$$

$$P(R_1/T_1) = 1 - P(R_0/T_1) = 1 - 0.2 = 0.8$$

$$P(T_1/R_1) = \frac{0.55\times 0.8}{0.55\times 0.8+0.45\times 0.1} = 0.907$$

(ii) Method 1:

We know that for a VSB modulated signal,

$$P_{\text{VSB}} = \frac{m^2}{4}P_C + K\left(\frac{m^2}{4}P_C\right)$$

K = fraction of other sideband transmitted

m = modulation index

P_c = Carrier power

$$P_{\text{VSB}} = \frac{(0.7)^2}{4}\times 300 + (0.15)\left(\frac{(0.7)^2}{4}\times 300\right)$$

$$P_{\text{VSB}} = 42.2625 \text{ Watts}$$

For a DSB-SC signal,

$$P_{\text{DSB-SC}} = \frac{m^2}{4}P_C + \frac{m^2}{4}P_C$$

$$= \frac{m^2}{2}P_C = \frac{(0.7)^2}{2}\times 300$$

$$= 73.5 \text{ Watts}$$

$$\% \text{ Power saving} = \left(1 - \frac{42.2625}{73.5}\right)\times 100 = 42.5\%$$

Method 2 : $P_c = 300$ kW, $m = 0.7$

Total power of AM, $P_t = P_c\left[1 + \frac{m^2}{2}\right]$

$$= 300\left[1 + \frac{0.49}{2}\right]$$

$$P_t = 373.5 \text{ W}$$

Power of DSB-SC, $P_{\text{DSB}} = P_t - P_c$

$$= 73.5 \text{ W}$$

Power of SSB-SC, $P_{\text{SSB}} = \frac{P_{\text{DSB}}}{2} = 36.75$ W

Power of VSB, $P_{\text{VSB}} = P_{\text{SSB}} + 15\%$ of P_{SSB}

$$= 36.75 + 15\% \text{ of } 36.75$$

$$= 42.2625 \text{ W}$$

Power saved in VSB compared to DSB-SC modulation

$$= 73.5 - 42.2625 = 31.2375 \text{ W}$$

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