still sampled at a rate $1/T_s$, but since the taps are spaced T' seconds apart (the equalizer input signal is sampled at a rate $1/T'$), the equalization action operates on the received signal before its frequency components are aliased. Equalizer simulations over voice-grade telephone lines with $T' = T_s/2$, confirm, that such fractionally-spaced equalizer's performance is superior to the performance of the symbol-spaced equalizer.

2 MARKS

1. What is an intersymbol interference (lSI) in baseband binary PAM systems?

In baseband binary PAM, symbols are transmitted one after another. These symbols are separated by sufficient time durations. The transmitter, channel and receiver acts as a filter to this baseband data. Because of the filtering characteristics, transmitted PAM pulses are spread in time. Let the transmitted waveform be represented as,

$$x(t) = \sum_{k=-\infty}^{\infty} A_k \, g(t - kT_b)$$

Here A_k is the amplitude of k^{th} pulse.

And $g(t)$ is shaping pulse.

The output pulse at $t = iT_b$ can be expressed as,

$$y(t_i) = \mu A_i + \mu \sum_{\substack{k=-\infty \\ k \neq i}}^{\infty} A_k \, p[(i-k)T_b]$$

Here T_b is the bit duration and $'t_i'$ indicates instant of i^{th} pulse. μA_i is the contribution of i^{th} transmitted bit. The second term in above equation occurs due to filtering nature of the transmitter receiver and channel. The second term represents the residual effect (time spread) of all other bits transmitted before and after t_i. This presence of outputs (second term) due to other bits (symbols) interfere with the output of required bit (symbol).This effect is called Intersymbol Interference (ISI).

2. What are eye patterns?

Eye pattern is used to study the effect of ISI in baseband transmission.

i) Width of eye opening defines the interval over which the received wave can be sampled without error from ISI.

ii) The sensitivity of the system to timing error is determined by the rate of closure of the eye as the sampling time is varied.

iii) Height of the eye opening at sampling time is called margin over noise.

3. What is baseband signal receiver?

A baseband signal receiver increases the signal to noise ratio at the instant of sampling. This reduces the probability of error. The baseband signal receiver is also called optimum receiver.

4. What is matched filter?

The matched filter is a baseband signal receiver, which works in presence or white Gaussian noise. The impulse response of the 'matched filter is **matched** to the shape of the input signal.

5. What is the impulse response of matched filter?

Impulse response is given as,

$$h(t) = \frac{2k}{N_0}\{x_1(T-t) - x_2(T-t)\}$$

Here T is the period of sampling $x_1(t)$ and $x_2(t)$ are the two signals used for transmission.

6. What is the value of maximum signal to noise ratio of the matched filter ? When if becomes maximum?

Maximum signal to noise ratio of the matched filter is the ratio of energy of the signal to psd of white noise. i.e,

$$\rho_{max} = \frac{E}{N_0 / 2}$$

This maximum value occurs at the end of bit duration i.e. T_b.

7. On what factor, the error probability of matched filter depends?

Error probability of matched filter is given as,

$$P_e = \frac{1}{2} erfc \sqrt{\frac{E}{N_0}}$$

This equation shows that error probability depends only on energy of the signal. It does not depend upon shape (waveform) of the signal.

8. What is correlator ?

Correlator is the coherent receiver. It correlates the received noisy signal $f(t)$ with the locally generated replica of the known signal $x(t)$. It's output is given as,

$$r(t) = \int_0^T f(t)\, x(t)\, dt$$

Matched filter and correlator are functionally same.

9. How is eye pattern obtained on the CRO?

Eye pattern can be obtained on CRO by applying the signal to one of the input channels and giving an external trigger of $\frac{1}{T_b} Hz$. This makes one sweep of beam equal to 'T_b' seconds.

10. What is the condition for zero Inter Symbol Interference?

Zero ISI can be obtained if the transmitted pulse satisfies the following condition:

$$\text{Time domain :} \quad p[(i-k)T_b] = \begin{cases} 1 & for \quad i = k \\ 0 & for \quad i \neq k \end{cases}$$

$$\text{Frequency domain} \quad = \sum_{n=-\infty}^{\infty} p(f - nf_b) = T_b$$

11. How is the transfer function of matched filter related to the spectrum of the input signal?

It is given as,

$$H(f) = \frac{2k}{N_0} X^*(f)\, e^{-j2\pi fT}$$

Here $X(f)$ is the spectrum of input signal.

12. A TDM signal with bit time of 0.5μs is to be transmitted using a channel with raised cosine roll off factor of 0.5. What is the bandwidth required?

$$T_b = 0.5\ \mu s, \quad \alpha = 0.5$$

$$B_0 = \frac{f_b}{2} = \frac{1}{2T_b} = \frac{1}{2 \times 0.5 \times 10^{-6}} = 1 \times 10^6$$

$$B = B_0(1+\alpha) = 1 \times 10^6 (1 + 0.5) = 1.5 \times 10^6$$

13. From the eye pattern, how is the best time for sampling determined?

It is preferable to sample the instant at which eye is open widest. At this instant, the chances of error are minimum.

14. Why intersymbol interference takes place in a channel? (Refer Q.1)

15. What is the purpose of using an eye pattern?

Eye pattern can be used for :

i) To determine an interval over which the received wave can be sampled without error due to ISI.

ii) To determine the sensitivity of the system to timing error.

iii) The margin over the noise is determined from eye pattern.

16. Why do you need adaptive equalization in a switched telephone network.

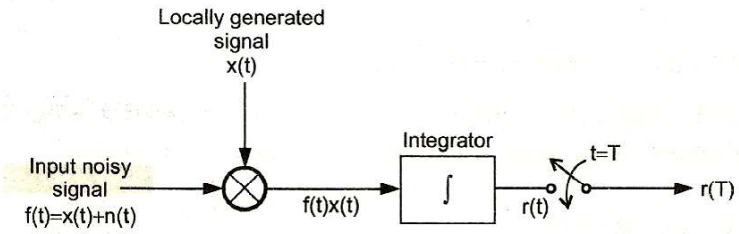
In switched telephone network the distortion depends upon

i) Transmission characteristics of individual links.

ii) Number of links in connection.

Hence fixed pair of transmit and receive filters will not serve the equalization problem. The transmission characteristics keep on changing. Therefore adaptive equalization is used.

17. Draw an illustrative figure to show the operation of a correlation receiver.



18. What is an ideal Nyquist channel?

The ideal Nyquist channel uses sine pulse for transmission. i.e.,

$$p(t) = \frac{\sin(2\pi B_0 t)}{2\pi B_0 t}$$

Such pulses have the spectrum of,

$$p(f) = \begin{cases} \frac{1}{2B_0} & for\ -B_0 < f \le B_0 \\ 0 & elsewhere \end{cases}$$

19. What is meant by intersymbol interference? (Refer Q.1)

20. How does pulse shaping reduce inter symbol interference?

• The shape of the pulse is selected such that at the instant of detection, the interference due to all other symbols is zero.

• The effect of ISI is totally eliminates if signal is sampled at $T_b, 2T_b, 3T_b, \ldots\ldots$ and so on.

21. Bring out the difference between carrier recovery and clock recovery

Sr. No.	Carrier recovery	Clock recovery
1.	Carrier is required for coherent detection at the receiver.	Clock is required to estimate correct bit timing at the receiver.
2.	M^{th} power loop, costas loop are used for carrier recovery.	Closed loop bit synchronizer, early-late synchronizer are used for clock recovery.

22. Why do we need equalization in base band pulse transmission?

When the signal is passed through the channel, distortion is introduced in terms of (i) amplitude and (ii) delay. This distortion creates the problems of ISI. The detection of the signal also becomes difficult. This distortion can be compensated with the help of equalizers. Equalizers are basically filters which correct the channel distortion.

23. State Nyquist criterion for zero ISI. (Refer Q.l0)

24. Give the Nyquist criterion for zero lSI. Plot the impulse response of an ideal Nyquist channel.

Refer answer of Q.10.

Impulse response is given as,

$$p(t) = \frac{\sin(2\pi B_0 t)}{2\pi B_0 t}$$

Fig. shows the plot of above equation.

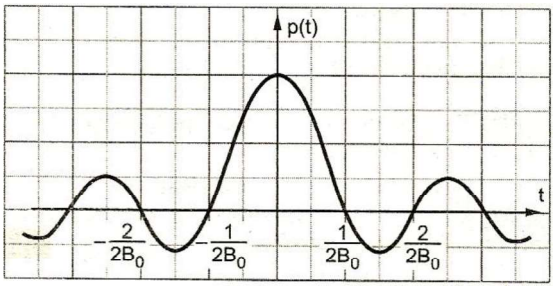


Fig. Impulse response

25. **Draw an eye pattern and represent the ways in which it could be used to evaluate the performance a baseband pulse transmission system. (**Refer Q.2**)**
26. **Why do we require equalization for a communication system ? (**Refer Q.22**)**
27. **What is meant by a matched filter?**

The shape of the impulse response of the matched filter is similar (or matched) to the shape of the input signal $x(t)$. Hence it is called matched filter.

28. **How do we get eye pattern? What do you infer from this? (**Refer Q.9 and Q.2**)**
29. **Define error probability.**

• Error probability is defined as the number of bits or symbols that are detected wrongly in a given number of total bits or symbols.

• For example error probability of 10^{-4} indicates that 1 bit will be detected wrongly in 10,000 bits. Here $\frac{1}{10^{-4}}$ = 10,000.

• Error probability is the important measure to evaluate performance of receivers.

30. **What is the need for a demodulator in case of baseband signaling when the received waveforms are already in pulse like form?**

• When the pulsed waveform is transmitted across the channel, noise interferes the signal. This distorts the pulses. Sometimes the amplitude of noise is so high that it is wrongly detected as a signal pulse.

• The transmission channel exhibits lowpass characteristic. Because of this portion of each pulse is dispersed over infinite time. Thus in the time frame of each pulse, the small signal portion due to all the other pulses is present. This is called inter symbol interference. It also creates errors in detection.

• Hence a detector is required that eliminates interference and detects the pulse correctly.

16 MARKS

1. Derive the expression of probability of error for matched filter (8)
2. Draw the block diagram of adaptive equalization and explain (8)
3. Draw the block diagram of Duo-binary and modified duo-binary system. (16)
4. Why is pre coding used with duo binary signaling scheme? Draw the block diagram of precoder and explain its operation. (8)
5. Draw the block diagram of an adaptive filter and explain the LMS algorithm. (10)
6. Explain how eye pattern is used to study the performance of a data transmission system. (6)
7. (i). with neat sketches, explain the duo binary signaling scheme. (10)