**Name of the Department** : **Electronics And Communication Engineering**

**Subject Code & Name** : **EC8501 / Digital Communication**

**Year & Semester** : **III / V**

## UNIT: I – INFORMATION THEORY

### PART-A

1. **Define entropy and find the entropy of a discrete memory less source with probability s1=1/2, s2=1/4 and s3=1/4.**

Entropy is the measure of the average information content per second. It is given by the expression $H(X) = -\sum_i P(x_i)\log_2 P(x_i)$ bits/sample.

Entropy= $(1/2)\times \log_2(1/2)+(1/4)\times\log_2(1/4)+ (1/4)\times \log_2(1/4)$

2. **State Shannon's Channel capacity theorem.**

The capacity 'C' of an additive Gaussian noise channel is $C = B \log_2 (1 + S/N)$

B= channel bandwidth, S/N=signal to noise ratio.

3. **Explain Shannon-Fano coding.**

An efficient code can be obtained by following a simple procedure, known as Shannon-Fano algorithm. List the source symbols in order of decreasing probability. Partition the set into two sets that are as close to equi-probable as possible, and assign 0 to the upper set and 1 to the lower set. Continue this process, each time partitioning the sets with as nearly equal probabilities as possible until further partitioning is not possible.

4. **Define entropy and its properties.**

Entropy is the measure of the average information content per second. It is given by the expression $H(X) = -\sum_i P(x_i)\log_2 P(x_i)$ bits/sample.

5. **Define mutual information and channel capacity.**

Mutual information I(X, Y) of a channel is defined by I(X,Y) = H(X) - H(X/Y) bits/symbol.

H(X)- entropy of the source, H(X/Y)- conditional entropy of Y.

6. **State the properties of mutual information**.

I(X, Y)=I (Y, X)

$I(X, Y) \geq 0$

I(X,Y)=H(Y)-(Y/X)

I(X,Y)=H(X)+H(Y)-H(X,Y), I(X,Y) isthe mutual information and H(X)- entropy of the source, H(Y)- entropy of the sink, H(X/Y)- conditional entropy of Y.

**7. Give the relation between the different entropies.**

H(X,Y)=H(X)+H(Y/X)=H(Y)+H(X/Y)
H(X)-entropy of the source,
H(X/Y)-conditional entropy,
H(Y)-entropy of destination,
H(X,Y)- Joint entropy of the source and destination.

**8. Define information rate.**

If the time rate at which source X emits symbols is r symbols per second. The information rate R of the source is given by R=r H(X) bits/second, where H(X)- entropy of the source.

**9. What is data compaction?**

For efficient signal transmission the redundant information must be removed from the signal prior to transmission .This information with no loss of information is ordinarily performed on a signal in digital form and is referred to as data compaction or lossless data compression.

**10. State the property of entropy.**

1. Symmetry: $H(P_{k,}, P_{k-1}) = H(P_{k-1,} P_{k,})$
2. Additivity: If the alphabet 'X' has symbols $X = \{S_0. S_1, \ldots, S_n\}$ then partitioning of entropy into different subsets does not affect the value of entropy H (X)
$H(X) = H(S_0, s_1, \ldots, S_m) + H(S_{m+1}, \ldots\ldots, S_n)$
3. Extremal property: $0< H(X) <\log_2 K$ , is the radix of the alphabet X of the source.
4. Continuous Property: the entropy H(X) is continuous in the interval $0 <P_k< 1$.
5. Extension property: $H(X)^n = n H(X)$

**11. What is differential entropy?**

The average amount of information per sample value of x(t) is measured
by $H(X)= f_x(x)\log f_x(x)dx$ bit/sample, where
H(X) –differential entropy of X.

**12. What is the channel capacity of a discrete signal?**

The channel capacity of a discrete signal $C= \max\{I(X,Y)P(x_i)\}$,where I(X,Y)-mutual information.

**13. What is source coding and entropy coding?**

A conversion of the output of a discrete memory less source (DMS) into a sequence of binary symbols is called source coding. The design of a variable length code such that its average code word length approaches the entropy of the DMS is often referred to as entropy coding.

**14. State Shannon Hartley theorem.**

The capacity 'C' of an additive Gaussian noise channel is $C = B \log_2 (1 + S/N)$ ,
where B=channel bandwidth, S/N=signal to noise ratio.

**15. What is the entropy of a binary memory-less source?**

The entropy of a binary memory-less source $H(X)=-p_0 \log_2 p_0-(1-p_0)\log_2(1-p_0)$
$p_0$-probability of symbol '0',$p_1=(1- p_0)$ =probability of transmitting symbol 1'.

**16. How is the efficiency of the coding technique measured?**

Efficiency of the code =H(X) /L, where L= $\sum l_i p_i$ is the average code word length. $l_i$ =length of the code word.

**17. What happens when the number of coding alphabet increases?**

When the number of coding alphabet increases, the efficiency of the coding technique decreases.

**18. What is channel diagram and channel matrix?**

The transition probability diagram of the channel is called the channel diagram and its matrix representation is called the channel matrix.

**19. What is information theory?**

It deals with the mathematical modeling and analysis of a communication system rather than with physical sources and physical channels

**20. What is the channel capacity of a BSC and BEC?**

For BSC the channel capacity is given by $C=1+p\log_2 p + (1-p) \log_2(1-p)$.For BEC the channel capacity C=(1-p).

**21. Define information capacity.**

The information capacity of a communication system represents the number of independent symbols that can be carried through the system in a given unit of time and the most basic symbol is the binary digit (bit).

**22. State the advantages of Lempel-Ziv Coding.**

i) Receiver does not require prior knowledge of the coding table constructed by the transmitter ,
ii) Synchronous transmission.

**23. Calculate the entropy of the source and symbol probabilities 0.6, 0.3, 0.1.**

$H= 0.6 \log_2 1/0.6+0.3 \log_2 1/0.3+0.1 \log_2 1/0.1 = 0.44+0.52+0.33 = 1.29$ bits /symbol.

**24. Define Rate Bandwidth and Bandwidth efficiency.**

It is defined as the ratio of the data rate in bits per second to the effectively utilized channel bandwidth = $R_b/B$ bits/Hz where $R_b$= data rate.

**25. Define Source Coding.**

Source coding is a procedure for mapping a given set of message $[m_1,m_2,\ldots m_N]$ into a new set of encoded messages $[c_1,c_2,\ldots c_N]$ in such a way that the transformation is one to one for each message and there is only one encoded message. This is called source coding.

**26. Why Huffman coding is said to be optimum?**

The Coding is said to be optimum since no other uniquely decodable set of code words, has a smaller average code word length of a given discrete memory less channel.

**27. Define the Bit of information.**

Bit is the basic unit of information. It is defined as the quantity of information required to permit a correct selection of one out of a pair of equiprobable events.

**28. State noise coding theorem.**

In information theory, the noisy-channel coding theorem (sometimes Shannon's theorem or Shannon's limit), establishes that for any given degree of noise contamination of a communication channel, it is possible to communicate discrete data (digital information) nearly error-free up to a computable maximum rate through .

**29. Define mutual information I(x:y) between two discrete random variable X and y.**

Mutual information is a measure of how close the true joint distribution of X and Y is to the independent joint distribution.Mutual information is that of entropy of a random variables.

$$I(X;Y) = \sum\sum P(X,Y)(X,Y)\log(P(X,Y)(X,Y)|Px(X)Py(Y))$$

**30. What is the capacity of the channel having infinite bandwidth?**

channel capacity equation, C = B log(1 + S/N), C-capacity, B-bandwidth of channel, S-signal power, N-noise power, when B -> infinity then channel capacity saturates to 1.44S/N.

## PART-B

**1.**(i)Consider a discrete memory less source with seven possible symbols $X_i$={1,2,3,4,5,6,7} with associated probability $P_r$={0.37,0.33,0.16,0.07,0.04,0.02,0.01}. Construct the Huffman's code and determine the coding efficiency and redundancy**.**

(ii) A discrete memory less source emits 5 symbols whose associated probabilities are as given below. Construct Shannon Fano code and determine the efficiency.

| Symbols: | X0 | X1 | X2 | X3 | X4 |
|---|---|---|---|---|---|
| Probabilities: | 0.4 | 0.19 | 0.16 | 0.15 | 0.1 |

**2.**(i) Derive the channel capacity of a continuous band limited white Gaussian noise channel.
(ii) Discuss about rate distortion theory**.**

**3.** What is the mutual information and channel capacity of the given system

$$P(x_0) = 0.6\ ,\ P(x_1) = 0.4$$

$$P\left(\frac{y}{x}\right) = \begin{bmatrix} 0.8 & 0.2 \\ 0.3 & 0.7 \end{bmatrix}$$

**4.** Encode the source symbols with the set of probabilities {0.4, 0.2, 0.12, 0.08, 0.08, 0.08, 0.04} using Huffman's algorithm. Determine the coding efficiency./ Explain the Huffman coding algorithm with a flow chart and illustrate it using an example.

**5.** The source has five outputs symbols denoted by(M1 M2 M3 M4 M5) with the following set of probabilities {0.41, 0.19, 0.16, 0.15, 0.09}. Encode the source using Shannon fano algorithm and determine the coding efficiency.

**6.** Prove that the entropy of a discrete memory less source is maximized when the symbol are equiprobable.

**7.** Derive the expression for entropy, also state and prove the properties of entropy.

**8.** Derive the capacity of a Gaussian channel.

**9.** Derive the channel capacity of Binary symmetric channel.

**10.** One experiment has four mutually exclusive out comes Ai,i=1,2,3,4 & second experiment has three mutually exclusive outcomes Bj=1,2,3 . The joint probabilities are P(A1,B1)=0.10, P(A1,B2)=0.08, P(A1,B3)=0.13, P(A2,B1)=0.05, P(A2,B2)=0.03, P(A2,B3)=0. 09, P(A3,B1)=0.05, P(A3,B2)=0.12, P(A3,B3)=0.14, P(A4,B1)=0.11, P(A4,B2)=0.04, P(A4,B3)=0.06.
(i) Determine the probabilities P(Ai),i=1,2,3,4 & P(Bj),j=1,2,3
**(ii)** Suppose we have the outcomes of A. Determine the mutual information and the average mutual information.

**11.** Define Mutual information. i)Find the relation between the mutual information and joint entropy of the channel input and channel output.(ii) What are the implications of the information capacity theorem.

**12.** Explain the need for source coding & channel coding? Explain how channel capacity can be improved, Explain SNR in detail**.**

**13.** (i) State and prove mutual information and write the properties of mutual information. (ii) Derive Shannon - Hartley theorem for the channel capacity of a continuous channel having an average power limitation and perturbed by an additive band - limited white Gaussian noise.

**14.** (i) The two binary random variables X and Y are distributed according to the joint PMF given by P( X=0, Y=1) = 1/4; P(X = 1, Y=1)=1/2; P(X=1,Y=1)=1/4; Determine H(X,Y), H(X), H(Y), H(X/Y) and H(Y/X). (ii) Define entropy and plot the entropy of a binary source.

**15.** Prove that the maximum value of the entropy, H(X), of the discrete source X is log2(M), where M is the number of messages emitted by the discrete source**.**

**16.** Define channel capacity and derive the channel capacity of a binary symmetric channel with error probability 'p'. plot and discuss the variation of channel capacity with error probability 'p' **.**

## UNIT: II – WAVEFORM CODING AND REPRESENTATAION

### PART-A

**1. What is the need for coding speech at low bit rates?**

To remove redundancies from the speech signal as far as possible,
To assign the available bits in a perceptually efficient manner.

**2. What are the types of adaptive predictors?**

- Adaptive prediction with forward estimation (APF),
- Adaptive prediction with backward estimation (APB).

**3. Mention the use of Vocoders.**

Vocoders are used to remove redundancies from the speech signal and to constantly adaptto the speech statistics.

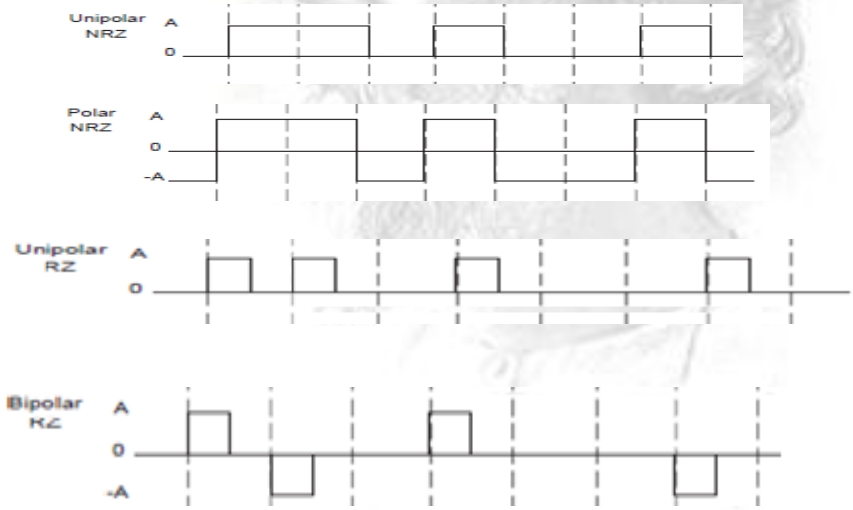
**4. What is the advantage of DM over PCM?**

DM uses one bit to encode one sample. Hence bit rate of delta modulation is lower compared to PCM and also the transmission bandwidth is small.

**5. Define delta modulation.**

Delta modulation is the one bit version of differential pulse code modulation . The present sample value is compared with the previous sample value and this result whether the amplitude is increased or decreased is transmitted.

**6. Draw the Unipolar NRZ, Polar NRZ format, Unipolar RZ & Bipolar RZ for the data sequence 1101001.**




**7. Define APB.**

Adaptive prediction with backward estimation (APB), in which samples of the quantizer output and the prediction error are used to derive estimates of the prediction error are used to derive estimates of the predictor coefficients.

**8. What is Manchester coding and write its advantages?**

It is a multilevel binary code. Binary 1 is represented by +A,-A and Binary 0 is represented by –A,+A. Advantages are i) Null at dc. So, this code is more efficient than other code, ii) Due to alternate +A,-A single error can be easily detected iii) the code is transparent.

**9. Determine (S/N)q of a delta modulation system at a bit rate of 64 kbps and BW of 4 kHz.**

$f_c$ = 4kHz; $f_b$ = 64kbps;

$(S/N)_q = (0.04)\ (f_b/f_c)^3 = 163.84 = 22dB$

**10.Why DM is not suitable for high dynamic range speech?**

DM requires a lesser transmission bandwidth than PCM to achieve the same SNR.Speech signal requires large dynamic range,but to avoid slope overload noise DM has small dynamic range. So DM is not suitable for high dynamic range speech.

**11.Define Adaptive delta modulation.**

In adaptive delta modulation, the step size of the modulator assumes a time varying form. In particular, during a steep segment of the input signal the step size is increased. Conversely when the input signal is varying slowly the step size is decreased.

**12.What is meant by Prediction error?**

The difference between the actual samples of the process at the time of interest and the predictor output is called prediction error.

**13.State the differences between DPCM and DM.**

i) DM uses only one bit information for transmission
ii) Replacement of the prediction filter in DPCM by a single delay element constitutes DM system.

**14.Mention two merits of DPCM.**

Bandwidth requirement of DPCM is less compared to PCM.
Quantization error is reduced because of prediction filter,
and Number of bits used to represent one sample value is
reduced as compared to PCM.

**15.What are the advantages of adaptive delta modulation?**

The advantages of adaptive delta modulation are
1. Slope overload noise is reduced
2. Granular noise is reduced
3. Lesser number of bits is used

**16.Define ADPCM.**

It means adaptive differential pulse code modulation, a combination of adaptive quantization and adaptive prediction. Adaptive quantization refers to a quantizer that operates with a time varying step size. The autocorrelation function and power spectral density of speech signals are time varying functions of the respective variables. Predictors for such input should be time varying. Hence adaptive predictors are used.

**17.Mention the use of adaptive quantizer in adaptive digital wave form coding scheme.**

Adaptive quantizer changes its step size according to the variance of the input signal. Hence quantization error is reduced. ADPCM uses adaptive quantization. The bit rate of such schemes is reduced due to adaptive quantization.

**18. What do you understand from adaptive coding?**

In adaptive coding quantization step size and prediction filter co-efficients are changed as per properties of input signals. Thus quantization error and number of bits used to represent the sample value is reduced. Adaptive coding is used for low bit rates.

**19. Give the properties of line codes.**

The properties are
1. Self-synchronization,
2. Error detection
3. Bandwidth compression
4. Differential encoding
5. Noise immunity
6. Spectral compatibility with channels

**20. Define APF.**

Adaptive prediction with forward estimation (APF), is one in which un quantized samples of the input signal are used to derive estimates of the predictor coefficients.

**21. What is meant by slope-overload distortion in delta modulation system? How can it be avoided?**

This distortion arises because of large dynamic range of the input signal. here is a large error between the staircase approximated signal and the original input signal x(t).This error or noise is known as **slope overload distortion** .

i) The slope overload occurs mainly because of fixed step size in delta modulator.
ii) Step size is more for fast amplitude changes and step size is less for slowly varying amplitude.
iii) The step size is varied according to amplitude variations of input signal.

**22. What are the advantages of delta modulator?**

The advantages are
- High SNR
- Low bandwidth consumption
- Usage of cost effective systems

**23. What is a linear predictor? On what basis are predictor coefficients determined? What is the need of prediction filtering?**

Prediction filtering is done to reduce the error which occurs due to encoding the actual sample directly. Linear predictor is a filter that uses linear combination of finite set of present and past samples of a stationary process to predict a sample of the process in the future. The predictor coefficients are determined in such a way that it minimizes the mean square value of the prediction error.

**24. What is meant by transparency with respect to line codes?**

Transparency is defined as a line code in which the bit pattern does not affect the accuracy of the timing. A transmitted signal would not be transparent if there are a long series of 0's which would cause an error in the timing information. Such that receiver does not go out of synchronization with the any sequence of data symbols. A clock is must for this synchronization.

**25. What is NRZ polar format and RZ polar format?**

Symbol 0 is represented by negative pulse and symbol 1 is represented by a positive pulse. For NRZ format, the pulse will occupy the entire symbol duration.

Symbol 0 is represented by negative pulse and symbol 1 is represented by a positive pulse. For RZ format, the pulse will occupy the half the symbol duration.

**26. Write the expression for output signal to noise ratio of DPCM receiver mentioning both the predictive gain and prediction error to quantization noise ratio.**

$$(SNR)_O = \frac{(\sigma_x^2)}{(\sigma_E^2)}\left(\frac{(\sigma_E^2)}{(\sigma_Q^2)}\right) = G_P * (SNR)_P$$

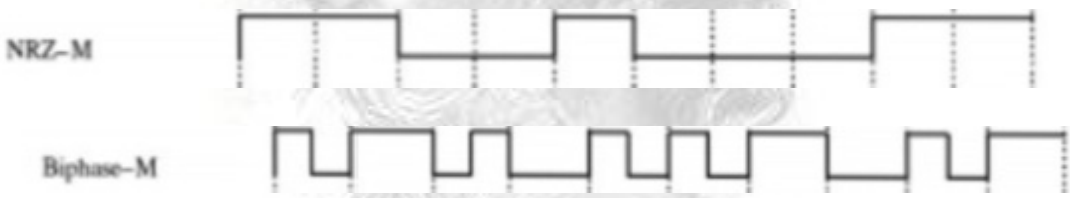
$G_p$ is the predictor Gain and $(SNR)_P$ is the signal to noise ratio of predictor.

**27. A delta modulation system is tested with a 10KHz sinusoidal signal with 1V peak to peak at the input. It is sampled at 10 times the nyquist rate. What is the SQNR?**

The sampling rate is fs = (10*1000*2)10= 0.2 M samples / sec

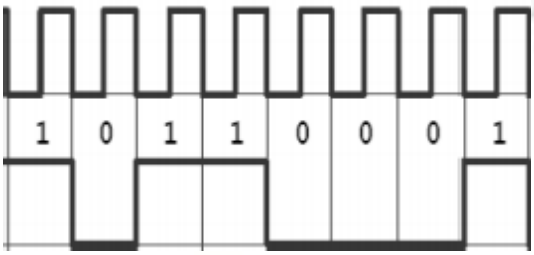
SQNR= 1.76+ 6.02*N

**28. Draw the NRZ-M and Biphase–M baseband encoding forms for the data [1010110010].**

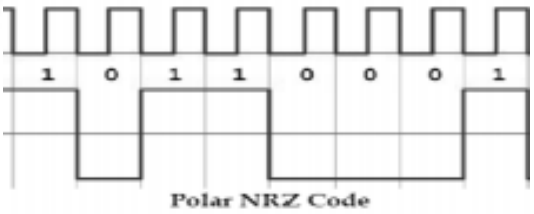



**29. Draw the line encoding waveforms for the binary data 10110001 using (i) unipolar NRZ and (ii) bipolar NRZ.**

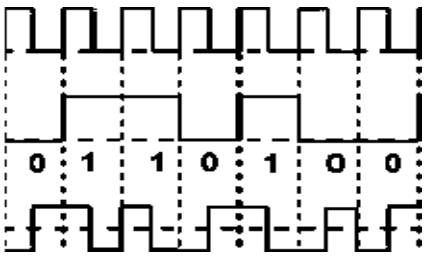
**Unipolar NRZ**




**bipolar NRZ**




**30. For the binary data 0110100, draw Manchester coded signal.**



**PART-B**



**1.** Explain in detail about delta modulation transmitter & receiver. A sinusoidal signal $X(t)= a_0.\cos(2\pi f_0 t)$ is applied to delta modulator that operates at sampling time of Ts and step size $= 2\delta$.

i) Find the expression for the amplitude to avoid slope overload noise.
ii) Compute the maximum permissible value of the output signal power.
iii) Compute the variation of quantization noise in delta modulation.
iv) Find the maximum value of output signal to noise ratio.

**2.** Explain Delta Modulation system in detail. What is slope overload noise and granular noise and how it is overcome in ADM.

**3.** Explain adaptive quantization and prediction in ADPCM with neat block diagram.

**4.** Explain adaptive delta modulation with necessary diagram and compare PCM with DM.

**5.** Consider the linear prediction of a stationary autoregressive process, x(n) generated from the first-order difference equation x(n)=0.9x(n-1)+v(n)is the white noise of zero mean and unit variance. Determine the tap weights of the second order forward prediction error filters.

**6.** i)Derive the expression for the PSD of unipolar NRZ format. ii) Derive an expression for the PSD of Bipolar NRZ format.

**7.** Compare DPCM, ADPCM, DM, and ADM.

**8.** With transmitter and receiver block diagram, explain DPCM in detail.

**9.** Illustrate how the adaptive time domain coders code the speech at low bit rate and compare it with the frequency domain coders.

**10.** i) Draw the block diagram of ADPCM system and explain its function. ii)A DM with a fixed step size of 0.75v, is given a sinusoidal message signal. If the sampling frequency is 30 times the Nyquist rate, determine the maximum permissible amplitude of the message signal if slope overload is to be avoided.

**11.** Derive and plot the power spectra of NRZ unipolar and bipolar signals**.**

**12.** Draw the block diagram of DPCM transmitter and receiver with predictor and explain. What are the advantages of using a predictor in DPCM?

**13.** Derive the expression for the power spectral density of bipolar NRZ data format and list its properties.

## PART-A

**1. How the impulse response of the optimum filter is related to the input signal.**
The impulse response is equal to the input signal displaced to a new origin at t=to and folded about this point so as to run backward. $H_{opt}(t) = K\ x(to-t)$.

**2. Define ISI.**
There are effects of imperfection in the frequency response of the channel ie. Dispersion of the false shape by the channel. The residual effect of all other transmitted bits on the received bit is called as Inter symbol interference.

**3. What is minimum bandwidth required to transmit data at the rate of Rb bits per sec?**
The minimum bandwidth required is $B = R_b/2$ Hz.

**4. What is the function of equalizing filter?**
Equalizing filters are used in the receiver; it cancels any residual ISI present in the received signal.

**5. What is eye pattern?**
When the sequence is transmitted over a baseband binary data transmission system, the output is a continuous time signal. If this signal is out at each interval ($T_b$) and all such pieces are placed over one another, then we obtain eye pattern. It looks like eye. Eye pattern is particularly useful in studying ISI problem.

**6. State Nyquist criterion for zero ISI.**
The spectra of the transmitted pulse should satisfy following equation

$$\sum_{n=-\infty}^{\infty} P(f - nR_b) = T_b ,$$

where P(f) is the spectrum of the transmitted pulse p(t) and $R_b = 1/T_b$ is the rate at which pulses are transmitted.

**7. State any two applications of eye pattern.**
To study the intersymbol interference
To measure the additive noise,timing synchronization, jitter & non –linearity in the channel

**8. How does pulse shaping reduce inter symbol interference.**
Pulse shaping compresses the bandwidth of the data impulse to a smaller bandwidth greater than the Nyquist minimum, so that they would not spread in time. System performance is not degraded.

**9. What is the information that can be obtained from eye pattern regarding the signal quality?**
From the eye pattern-
(i) **WIDTH** defines the time interval over which the received signal can be sampled without error from ISI.

(ii) **SLOPE** determines the sensitivity of the system to timing error.
(iii) **HEIGHT** defines the margin over noise. For zero ISI, the eye is widely opened. For more ISI,the eye will be closed completely.

**10. ISI cannot be avoided. Justify the statement.**
A communication channel is always band limited hence it always disperses or spreads a pulse waveform passing through it .ISI means the spreading of signal pulses and overlapping between consecutive pulses. Equalization techniques are used to combat ISI. So, signal quality is affected by noise as well as by ISI. Even if noise is absent, ISI may be present in a high speed digital communication system.

**11. Mention two properties of matched filter?**
**Property1:** The peak pulse SNR of a matched filter depends only on the ratio of the signal energy to the power spectral density of noise. Max.SNR = 2E/η
**Property: 2** The integral of the squared magnitude spectrum of a pulse signal with respect to frequency is equal to the signal energy, $\int_0^b |S(f)|^2 df = E$

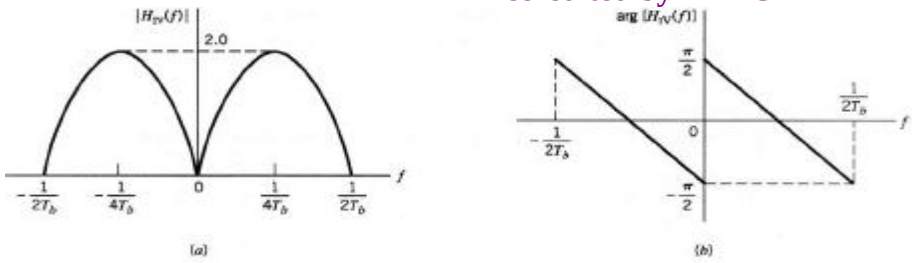
**12. What is matched filter?**
It is a linear filter designed to provide maximum SNR at its output for a given transmitted signal. A matched filter is obtained by correlating a known signal with the unknown signal to detect the presence of the known signal. In communication the matched filter is used to detect the transmitted pulse in the presence of noise
.
**13. State the principle of maximum likelihood detector.**
For equally likely symbols, the detector decides in favour of a particular transmitted symbol whose likelihood function is greater than the other. This strategy is called maximum likelihood detection.
**14. What are the uses of precoder in modified duobinary system?**
The precoder helps in reducing the propagation of error form previous output to the next output as they are correlated.

**15. Define correlative level coding.**
Practical means of achieving the theoretical maximum signalling rate of $2B_o$ bits per sec in a bandwidth of $B_o$ Hz by adding ISI in a controlled manner.

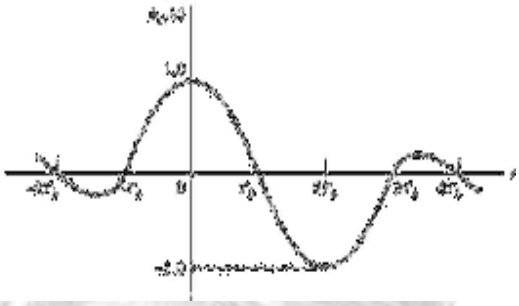
**16. Write the down the decision rule for detecting the original input sequence {bk} form the output binary sequence {ck}of a precoded duo-binary scheme.**
The decision rule for precoded duo-binary is

Ck = { ± 2V , bk is decided in favour of symbol "0"
0V, bk is decided in favour of symbol 1"}

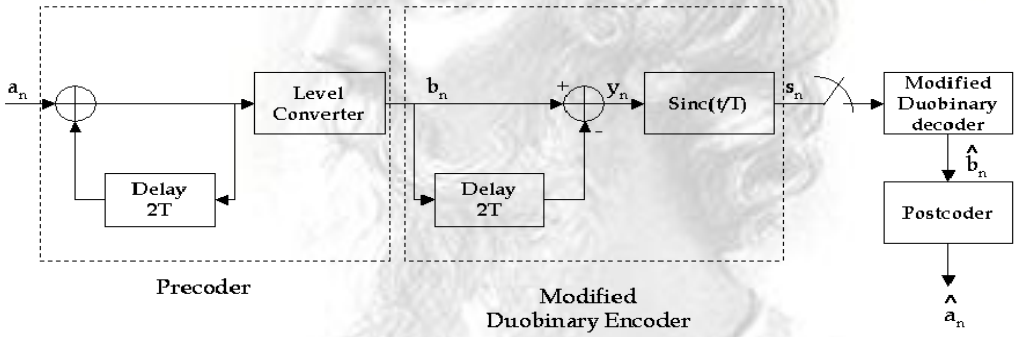
**17. Draw the frequency and phase response of Modified duobinary system.**




**18. Draw the impulse response of Modified Duobinary system.**



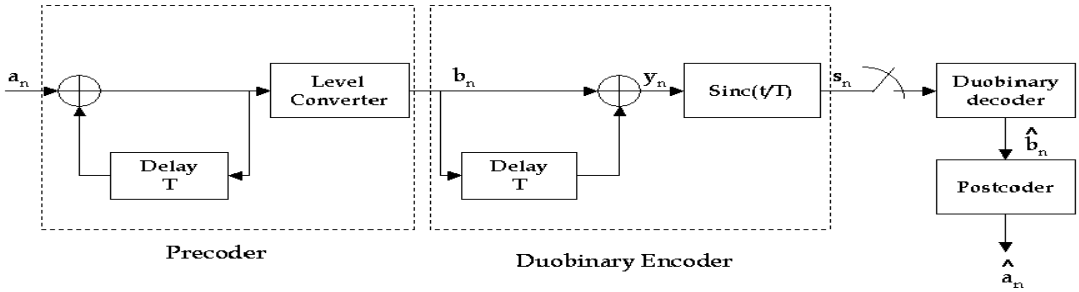
**19. Draw the modified duobinary system.**




**20. What is ISI and what are the causes of ISI.**

ISI is a form of distortion of a signal in which one symbol interferes with subsequent symbols. This is an unwanted phenomenon as the previous symbols have similar effect as noise, thus making the communication less reliable. Spreading of the pulse beyond its allotted time interval causes it to interfere with neighbouring pulses. ISI arises due to imperfections in the overall response of the system.

**21. Draw the block diagram of Duobinary system.**



**22. What are the essential requirements of an equalizer?**

Channel equalization requirement is that the amplitude response of the channel must be flat, it should be same for all frequencies of the channel. If the amplitude response is not flat, it must be equalized using an appropriate device at the receiver, which is called an equalizer.

## PART-B

**1.** State and prove the Nyquist criteria for distortion less baseband transmission.

**2.** (i) The binary data 00 11 01 001 is applied to a duobinary system, Construct the duobinary output and corresponding receiver output.

**(iii)** The binary data 00 10 11 0 is applied to a duobinary system. Construct the duobinary coder output and corresponding receiver output. Assume that there is a pre coder at the input**.**

**3.** Derive an expression for a maximum likelihood detector and prove that the ML detector reduces to minimum distance detector for special case of a white Gaussian noise vector channel.

**4.** Discuss on signal design for ISI elimination.

**5.** Explain modified duo-binary signaling scheme without & with pre coder.

**6.** Obtain an expression for Nyquist criterion for distortion - less baseband transmission for zero symbol interference.

**7.** Describe how eye pattern can be obtained and can be used for observing the characteristics of a communication channel.

**8.** Illustrate the modes of operation of an adaptive equalizer with a neat block diagram.

**9.** Explain the duobinary signaling technique in detail.

**10.** Write short notes on (1) Pulse shaping (2) Correlative coding.

**11.** Describe how eye pattern is helpful to obtain the performance of the system in detail with a neat sketch.

**12.** What is a raised cosine spectrum? Discuss how it helps to avoid ISI**.**

**13.** What is ISI? List the various methods to remove ISI in a communication system. Also state and prove Nyquist first criterion for zero ISI.

**14.** Describe the implementation of the matched filter demodulator with a sample signal s(t) and its matched filter response h(t).

**15.** what is meant by an eye pattern? What are the parameters observed from the eye pattern? Explain with the help of suitable illustration.

**16.** Draw the block diagram of correlator receiver and explain its working.

## UNIT: IV – DIGITAL MODULATION SCHEME

### PART-A

**1. What is Signal Constellation diagram?**

The diagram which defines the collection of M message points in N dimensional Euclidean space is called signal constellation diagram. It helps to find the probability of error.

**2. Define PSK.**

PSK is a modulation technique achieved by keying the phase of the carrier between either of two possible values corresponding to the binary symbols 0,1 with fixed limits set by the channel.

**3. What are the applications of digital modulation technique?**

1.Voice grade modems uses 8 phase DPSK technique,2 Digital Radio uses 16-ary QAM,3.Satellite communication uses BPSK,QPSK technique,4.Voice grade telephone channel uses FSK,5.4 phase DPSK is used as international standard for modems operating at 2400 bits/sec.

**4. What is ASK and mention the drawbacks?**

The symbols 0 and 1 are differentiated by amplitude of the carrier. The drawbacks are

i) Very sensitive to noise,

ii) Amplitude fluctuations occur in the channel,

iii) Not suitable for pass band, wireless communication.

**5. Compare M-ary modulators.**

M-ary FSK requires a considerably increased bandwidth in comparison with M-ary PSK. The probability of error for M-ary FSK decreases as M increases. for M-ary PSK probability of error increases with M.

**6. What is meant by Binary phase shift keying?**

If the transmitted signal is sinusoid of fixed amplitude then it is called as Binary – phase-shift keying. It has one fixed phase when the data is at one level & when the data is at another level the 'phase' is different by 180□

**7. How the BPSK signal is generated?**

The BPSK signal is generated by applying the waveform Cos($u_o$ t) as a carrier to a 'balanced modulator' and applying the base band signal b(t) as the modulating waveform,in this sense BPSK can be thought of as an AM signal.

**8. What is the probability of error of BPSK?**

Eb = Transmitted signal energy, No = Noise PSD, erfc= error function

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

**9. Define FSK.**

PSK is a modulation technique achieved by keying the phase of the carrier between either of two possible values corresponding to the binary symbols 0,1 with fixed limits set by the channel.

**10. Define bandwidth efficiency.**

Bandwidth efficiency is the ratio of data rate to channel bandwidth, measured in units of bits per second per hertz.

**11. List the types of synchronization?**

1. Carrier Synchronization
2. Symbol and bit synchronization
3. Frame synchronization

**12. Why synchronization is needed?**

Signals from various sources are transmitted on single channel by multiplexing. So, synchronization is needed, it is also required for detectors to recover the digital data properly from the modulated signal.

**13. What is the bandwidth efficiency of M-ary FSK?**

The bandwidth efficiency of M - ary PSK is given by $\rho = \frac{\log_2 M}{2}$

**14. What is the bandwidth efficiency of M-ary FSK?**

The bandwidth efficiency of M-ary FSk is given by $\rho = \frac{2\log_2 M}{M}$

**15. What is DPSK?**

Differential phase shift keying uses differential encoding. Phase shift keying is modulated at the transmitter side. Receiver performs detection by comparing the phase of received symbol with that of previous symbol. Non coherent receiver is used.

**16. What is memory less modulation?**

If the symbol to waveform mapping is fixed from one interval to the next, i.e., m $\rightarrow s_m(t)$, then the modulation is memory less. If the mapping from symbol to waveform in the n-th symbol interval depends on previously transmitted symbols (or waveforms) then the modulation is said to have memory.

**17. What is coherent detection/receiver?**

When the receiver exploits the knowledge of the carrier's phase to detect the signal, then the detection is coherent.

**18. What is non-coherent detection/receiver?**

When the receiver does not utilize the phase reference information, then the detection is non-coherent.

**19. A binary shift keying system employs two signal frequencies f1 and f2, the lower frequency is 1200Hz and the signaling rate is 500 baud .Calculate f2.**

$f_2$=1200+500=1700Hz

**20. What is QAM?**

In quadrature amplitude modulation, the information is contained in both amplitude and phase of the transmitted carrier. Signals from two separate information sources modulate the same carrier frequency at the same time. It conserves the bandwidth.

**21. Mention two properties of matched filter?**

**Property1:** The peak pulse SNR of a matched filter depends only on the ratio of the signal energy to the power spectral density of noise. Max. SNR = 2E/η

**Property2:** The integral of the squared magnitude spectrum of a pulse signal with respect to frequency is equal to the signal energy.

**22. Differentiate coherent and non-coherent detection methods.**

In coherent method, carrier is regenerated at the receiver.

In non-coherent method, carrier need not be regenerated at the receiver side.

**23. Mention the advantages of PSK systems.**

i) Generation and Detection of PSK signals require simple circuit ii) Information transmission rate is higher because of reduced bandwidth iii)Carrier power remains constant

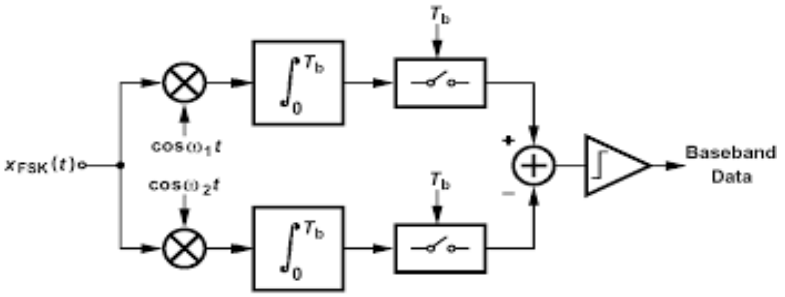
**24. Compare M-ary PSK and M-ary QAM.**

| S No | M-ary PSK | M-ary QAM |
|---|---|---|
| 1. | Carrier experiences phase modulation | Carrier experiences amplitude and phase modulation |
| 2. | Signal constellation is circular | Signal constellation is square |

**25. Define false alarm errors.**

Let hypothesis $H_0$ represents the presence of only noise and hypothesis $H_1$ represents presence of signal in addition to noise. False alarm represents the selection of $H_1$ when $H_0$ is the correct answer.

**26. Draw the block diagram of coherent BFSK receiver.**




**27. Define false dismissal errors.**

Let hypothesis $H_0$ represents the presence of only noise and hypothesis $H_1$ represents presence of signal in addition to noise. False dismissal represents the selection of H0 when $H_1$ is the correct answer.

**28. Distinguish BPSK and QPSK techniques.**

| S No | BPSK | QPSK |
|---|---|---|
| 1. | Two phases are used | Four different phases are used |
| 2. | Lower data rate | Higher data rate |

**29. What is QPSK? Write the expression for the signal set of QPSK.**

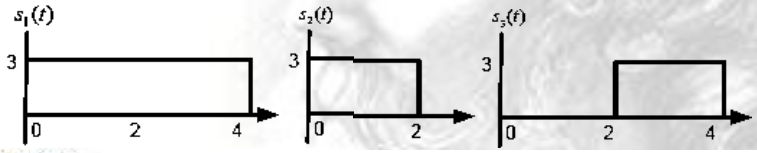
In QPSK, the phase of the carrier wave takes on one of four equally spaced values, namely π/4, 3π/4, 5π/4 and 7π/4.The expression for QPSK is given by

$$s_i(t) = \begin{cases} \sqrt{\frac{2E}{T}} \cos\left[2\pi f_c t + (2i-1)\frac{\pi}{4}\right] & 0 \le t \le T \\ 0 & \text{elsewhere} \end{cases}$$

where I=1,2,3,4 and E be the transmitted signal energy per symbol, T be the symbol duration and $f_c$ be the carrier frequency.

**30.Obtain the orthonormal basis function for the signal.**

Three signals $s_1(t)$, $s_2(t)$ and $s_3(t)$ are as shown in Figure. Apply Gram-Schmidt procedure to obtain and orthonormal basis functions for the signals. Express the signals $s_1(t)$ $s_2(t)$ and $s_3(t)$ in terms of orthonormal basis functions.




Solution:

$$E_1 = \int_0^T s_1^2(t)dt = \int_0^{T/3} 1^2 dt = T/3$$

$$\phi_1(t) = \frac{s_1(t)}{\sqrt{E_1}} = \frac{1}{\sqrt{T/3}} = \sqrt{3/T}$$

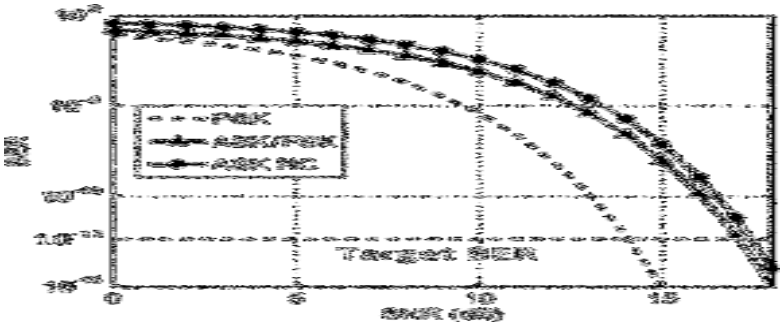
$$E_2 = \int_0^T s_2^2 t dt = \int_0^{2T/3} (1)^2 dt = \frac{2T}{3}$$

$s_{21}$ is

$$s_{21} = \int_0^T s_2(t)\phi_1(t)dt = \int_0^{T/3} 1\sqrt{3/T}\,dt = \sqrt{3/T}$$

$$\phi_2(t) = \frac{s_2(t) - s_{21}\phi_1(t)}{\sqrt{E_2 - s_{21}^2}} = \sqrt{3/T}$$

**31.Draw the BER curve for ASKFSK & BPSK.**



**32.In a BPSK system, the bit rate of a bipolar NRZ data sequence is 1Mbps and carrier frequency of the transmission is 100MHz. Determine the Bandwidth requirement of the communication channel and symbol rate of transmission.**

Fa=fb/2=1/2=0.5 MHz
Bw=99.5-100.5Mhz
=1MHz
Symbol rate is= 1Megabaud

## PART-B

**1.** Describe with diagrams, the generation and detection of coherent binary PSK. Derive the error probability of Binary PSK. Illustrate power spectra of BPSK.

**2.** Describe with diagrams, the generation and detection of coherent binary FSK. Derive the error probability of Binary FSK.

**3.** Describe with diagrams, the generation and detection of coherent binary QPSK. Derive the error probability of Binary QPSK.

**4.** Explain the techniques for carrier synchronization.

**5.** Compare the various coherent and non-coherent digital detection systems.

**6.** Describe with diagrams, the generation and detection of coherent DPSK. Derive the error probability of DPSK.

**7.** Discuss the spectral & representation characteristics of PSK, QAM, and QPSK& FSK.

**8.** Describe with signal space diagram QAM and its differences with respect to QPSK.

**9.** Describe with diagrams, the generation and detection of coherent binary ASK. Derive the error probability of Binary ASK.

**10.** Derive the expression for bit error probability of a non- coherent FSK system.

**11.** Illustrate the transmitter, receiver and generation of non-coherent version of PSK with neat diagram and derive the PSD of BPSK and plot it.

**12.** Explain the principle of working of an early late-bit synchronizer.

**13.**Discuss the generation and demodulation of binary FSK and give their advantages and disadvantages.

**14.**i) Compare conventional QPSK, offset-QPSK $\pi$ / 4 QPSK with respect to their constellation diagrams. ii) What is meant by carrier synchronization? Draw the block diagram of Costas-loop carrier synchronization and explain.

## UNIT : V – ERROR CONTROL CODING



### PART-A

**1. What is Channel Encoding?**
The channel encoder systematically adds digits to the message. These redundant bits carry no information. But used to detect and correct errors in the receiver side.

**2. List the four objectives of a Channel code or error control code.**
1) To have the capability to detect and correct errors.
2) To be able to keep the process of error detection and correction as more practicable.
3) To be able to encode the symbol in a fast and efficient way.
4) To be able to decode the symbol in a fast and efficient way.

**3. What are the types of error control methods?**
1) Error detection and retransmission (ARQ – Automatic Repeat Request Method)
2) Error detection and correction (FEC – Forward Error Correction method)

**4. What is the unique characteristic of convolutional codes which makes it different from linear block codes?(Nov 2019)**
Fixed number of input bits are stored in the fixed length shift register and they are combined with the help of modulo-2- adders.The *code rate* is $r = 1/v$ bit per transmitted symbol.

**5. Explain the term syndrome.**
The syndrome S of the received code word R is defined as $S=RH^T$. If S is not zero then there are one or more errors. If the syndrome is zero then either there are no error or the errors are so many that a transmitted code word has been changed to a different code word.

**6. Write the properties of syndrome in linear block codes.**
1. The syndrome depends only on the error pattern, and not on the transmitted code word.
2. All error pattern that differ at most by a code word have the same syndrome
3. The syndrome S is the sum of those columns of the matrix H corresponding to the error locations.

**7. What are the different methods of describing the structures of convolutional codes?**
(a) State diagram,
(b) Codetree,
(c)Trellis
These methods show the transition between various states.

**8. What is constraint length of convolutional code? What is code rate?**
The number of shifts over which a single message bit can influence the encoder output is called constraint length. Code Rate = L/n(L+M), L – Length of message sequence, n(L+M) – Code word length

**9. Differentiate block code and convolutional code**
In block code the encoder accepts a k-bit message block and generates an n-bit codeword. Thus, code words are produced on a block by block basis.

In Convolutional code the encoder accepts the message bits come in serially rather than in large blocks and generates n- bit code word. The resultant bits are generated using modulo-2 additions.

**10. What is meant by line codes?**

The channel coded data is mapped to a particular pulse waveform before transmission. This waveform is called Line Coding.

**11. Prove that in linear block codes syndrome depends on error pattern not message bits.**

$S = (x + e) H^T = x H^T + e H^T = e H^T$; Thus the syndrome pattern S depends on error pattern and not on message bits

**12. What is meant by cyclic codes?**

A cyclic code has property that a cyclic shift on one code word forms another code word and is important because they are algebraic properties, which allow them to be easily encoded or decoded.

**13. Write the advantages of cyclic codes over block codes.**

1). C**yclic codes** are easy to encode,

2). Cyclic codes possess a well-defined mathematical structure, which has led to the development of very efficient decoding schemes for them.

**14. What is systematic code?**

A code in which the message bits are transmitted in an unaltered form.

**15. What is hamming code?**

Hamming codes are of (n,k) linear block codes that have the parameters Block Length = $2^m - 1$,

Number of message bits $k = 2^m - m - 1$,

Number of parity bits, $n-k = m$ where $m \geq 3$ so called Hamming code

**16. Define the code rate of (n,k) code.**

Code rate = k/n, where k is the length of message bits and n is length of the code word.

**17. Define Hamming weight? Determine the Hamming weight of the code word 0110100.**

Hamming weight is the number of non-zero elements in the code vector. Hamming weight = 3 for 0110100

**18. What are the limitations of Viterbi decoding?**

Viterbi decoding can correct up to 2 errors. A triple error pattern is uncorrectable by the Viterbi algorithm. Constraint length increases, complexity also increases exponentially. Remedy: Sequential decoding procedure is used. In which the error probability decreases easily, Decoding procedure is independent of constraint length.

**19.Find the hamming distance between 101010 and 010101.If the minimum hamming distance of a (n,k) linear block is 3.What is the minimum hamming weight?**

Hamming Distance = 6.

$d_{min}$ (3) ≤ n-k+1.
Hamming weight is no. of ones in the codeword.

**20. Define hamming distance.**
The hamming distance between two codes is equal to the number of elements in which they differ.

**21. State the significance of minimum distance of a block code.**
The minimum distance $d_{min}$ of a linear block code is the smallest hamming distance between any pair of code vectors in the code. Minimum distance is an important parameter of the code. It determines the error correcting capability of the code.

**22. Define code efficiency or code rate.**
Code efficiency or code rate is the ratio of message bits in a block to the transmitted bits for that block by the encoder.

**23. What is Viterbi decoding scheme?**
A **Viterbi decoder** uses the Viterbi algorithm for decoding a bit stream that has been encoded using convolutional code or trellis code.
The Viterbi algorithm is the most resource-consuming, but it does the maximum likelihood decoding. It is most often used for decoding convolutional codes with constraint lengths k≤3. Where in
**Metrics:** It is the discrepancy between the received signal and the decoded signal at particular node. **Survivor path**: This is the path of decoded signal with minimum metric.

**24. Define Constraint length.**
Constraint length is the number of shifts over which a message bit can influence the encoder output.

**25.Define channel coding theorem.**
Let a discrete memory less source with an alphabet S and an entropy H(S), produce symbols. once every Ts seconds Let a discrete memory less every Tc seconds. Then if, H(s)/Ts ,<=C/Tc, there exists a coding scheme for which the source output can be transmitted over the channel and be reconstructed with an arbitrarily small probability of error. The parameter C/Tc is called critical rate.

**26.List the properties of cyclic codes.**
Linearity property: Sum of any two code word is also a code word in the given code. Cyclic property: Any cyclic shift of a code word is also a code word in the given code.

**27.What is a linear code?**
In linear code, the parity bits are generated as a linear combination of message bits.

**28.The generator polynomial G(D) for a(7,4) cyclic code is G(d)=1+D2+D3. Find the code vector for data [1010]**
We know $g(x) = x^3 + x^2 + 1$,Consider a data vector d = 1010
implies $d(x) = x^3 + x$ , So,$x^{n-k}*d(x) = x^6 + x^4$

Perform, $x^{n-k}*d(x) / g(x)$ , Find q(x),p(x)

$C(x) = x^3 d(x)+p(x) = x^3 ( x^3 + x) + 1 = x^6+x^4+1$ and hence C= 1010001

## PART-B

**1.** Design a convolution coder of constraint length 6 and rate efficiency ½. Draw its tree and Trellis diagram.

**2.** Draw the diagram of a ½ rate convolution encoder with constraint length 3. What is the generator polynomial of the encoder? Find the encoded sequence corresponding to the message (10011).

**3.** All zero sequence is transmitted and error has occurred in two locations, Using Viterbi algorithm, find the correct code from the received sequence (01, 00, 01, 00, 00)

**4.** Brief about any one decoding procedure of linear block codes.

**5.** Find generator polynomial for a (7,4) cyclic code and hence find the code word for [1 0 0 0]

**6.** A convolution code is described by $g^1$= [1 0 0]; $g^2$= [1 0 1]; $g^3$= [1 1 1].
(i) Draw the encoder corresponding to this code
(ii) Draw the state transition diagram for this code
(iii) Draw the Trellis diagram
**(iv)** Find the transfer function.

**7.** Consider a linear block code with generator matrix,

$$G = \begin{bmatrix} 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 1 & 0 & 0 & 1 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 & 1 \end{bmatrix}$$

(i) Determine the parity check matrix (3)
(ii) Determine the error detecting and capability of the code (3)
(iii) Draw the encoder and syndrome calculation circuits. (6)
(iv) Calculate the syndrome for the received vector r=[1 1 0 1 0 1 0] (4)
**(v)** Explain Viterbi decoding algorithm for convolutional code. (8)

**8.** i) Describe the cyclic codes with the linear and cyclic property. Also represent the cyclic property of a codeword in polynomial notation (12)
ii) List the different types of errors detected by CRC Code(4)

**9.** i) Describe how the errors are corrected using Hamming code with an example.(12)
ii) The code vector [1110010] is sent, the received vector is[1100010]. Calculate the syndrome.(4)

**10.** The generator polynomial of a (7,4) linear systematic cyclic block code is $1+X+X^3$. Determine the correct if the received word is (i) 1011011 and (ii) 1101111.

**11.** A rate 1/3 convolutional encoder with constraint length of 3 uses the generator sequence $g_1$= (100), $g_2$= (101) and $g_3$= (1,1,1)
(i) Sketch encoder diagram(ii) Draw the state transition diagram(iii) Determine trellis diagram (iv) the input message signal is [1 1 0 10 1 0 0 ]. The received sequence with error is [100 110 111 101 001 101 001 010], using Viterbi algorithm find the transmitted code word sequence.

**12.** For a systematic linear block code, the three parity check digits $P_1$, $P_2$, $P_3$ are given by

$$P_{k,n-k} = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 1 \\ 1 & 1 & 0 \\ 0 & 1 & 1 \end{bmatrix}.$$

i) Construct generator matrix. ii) Construct code words iii) Determine the error correcting capacity. v) Decode received words with an example.

**13.** The generator polynomial (7,4) cyclic code is $G(P)=P^3+P+1$. Find the Codeword for the message X=[1100] in systematic form. Also find out the generator matrix and parity check matrix.

**14.**consider a (6,3) linear block code with generator matrix**(Nov 2019)**

G = 1 1 1 1 0 0
1 1 0 0 1 0
1 0 1 0 0 1

Determine:
i) parity check matrix
ii) All the code words and
iii) Minimum distance of the code
iv) How many errors can be detected and corrected?

**15.**A rate ½ convolutional encoder with constraint length of 3 uses the generator sequences: g1 =(1 1 1) and g2(1 0 1). (i) Draw the encoder and state diagram of the code and (ii) determine the output sequence for the message sequence of 10011.

**16.** Consider a discrete source that emits the symbols{x1, x2, x3, x4, x5, x6, x7} with corresponding probabilities {0.08, 0.2, 0.12, 0.15, 0.03, 0.02, 0.4}. Construct a binary optimal code using Huffman procedure for this source. What is the efficiency of the code?

**17.** The generator polynomial of a (7,4) cyclic code is given g(X) = 1 + X + X^3.
i) Find the generator matrix and parity check matrix of the code in systematic form
ii) Draw the encoder circuit for this code.
iii) Find the code word for the message (1011).

**18.** Consider the (7, 4) linear block code whose generated matrix is given below.

G = 1 1 1 1 0 0
1 1 0 0 1 0
1 0 1 0 0 1

(i) Find all the code vectors.
(ii) Find Parity check matrix (H).
(iii) Find the minimum weight of the code.

**19.** With suitable numerical examples, describe the cyclic codes with the linear and cyclic property and also represent the cyclic property of a code word in polynomial notation.