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# 4th Semester ECE

Internal Test 2 –May 2025

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|---|---|---|---|---|---|---|---|---|---|
| Sub: | Principles of communication systems | | | | | | | Code: | BEC402 |
| Date: | 26/5/2025 | Duration: | 90 mins | Max Marks: | 50 | Sem: | **4** | Branch: | ECE |

Note: Answer any FIVE full questions with neat diagram wherever necessary.

| | | Marks | OBE CO | OBE RBT |
|---|---|---|---|---|
| 1a. | For a random variable, given f(x)=2*exp(-2x) for x>=0. Find the probability that it takes value between 1 and 3. | 3 | CO5 | L3 |
| 1b. | Derive posteriori probability for a binary symmetric channel | 7 | CO5 | L3 |
| 2a | Define autocorrelation and cross correlation. Write the properties of auto correlation. | 5 | CO5 | L2 |
| 2b | Find expectation of random variable Y=cos(X), where, X is a random variable uniformly distributed in the interval (-Π to Π). | 5 | CO5 | L3 |
| 3a | Derive interpolation equation for reconstructing the original signal g(t) from the sequence of sample values. | 7 | CO3 | L2 |
| 3b | Define aliasing effect. How can we combat aliasing effect? | 3 | CO3 | |
| 4a | Describe basic elements of a PCM system with neat diagram. | 6 | CO3 | L2 |
| 4b | Draw unipolar RZ, polar RZ and Manchester line coding for the data stream 1011001. | 4 | CO3 | L3 |

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PTO

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| 5a. | Define Inter Symbol Interference (ISI). Explain the baseband binary data transmission system with suitable diagram and equations. | 7 | CO4 | L2 |
| 5b. | Define eye pattern and write its significance. | 3 | CO4 | L2 |
| 6a. | Derive Nyquist criteria for distortion less transmission. | 5 | CO4 | L3 |
| 6b. | Briefly explain (a) external noise (b) internal noise (c) SNR | 5 | CO4 | L2 |
| 7a. | Explain generation of pulse position modulation with neat block diagram. | 6 | CO3 | L2 |
| 7b. | Explain ergodic process and gaussian process with equation and graphical representation. | 4 | CO5 | L2 |

CI CCI HOD(ECE)

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CI CCI HOD(ECE)

1.(a) $f(x) = 2e^{-2x}$ $\qquad x \geq 0$

between 1 and 3.

$$\int_{-\infty}^{\infty} f(x)\,dx$$

$$= \int_{1}^{3} 2e^{-2x}\,dx$$

$$= 2\int_{1}^{3} e^{-2x}\,dx$$

$$= 2\left[\frac{-1}{2}e^{-2x}\right]_{1}^{3}$$

$$= \left[-1\,e^{-2x}\right]_{1}^{3}$$

$$= -e^{-2(3)} + e^{-2(1)}$$

$$= -e^{-6} + e^{-2}$$

$$= e^{-2} - e^{-6}$$

$$= 0.132$$

The probability that it lies in between 1 and 3 is $\boxed{0.132}$.

1(b). Consider a discrete memoryless transmission channel.

- The channel ~~system~~ is designed to handle discrete mess of 0s and 1s
- The output will be 0 when 1 is transmitted or vice versa.
- But due to noise, when 1 is transmitted 0 recieved.
- Let us consider the probability of transmitted 1 or 0 and recieving them.

$P[A_0] = \cancel{P}$ $\qquad\qquad$ $P[A_1] = \cancel{P}\,1$

$$P[A_0] + P[A_1] = \cancel{P}\,1 \quad \text{—— (1)}$$

$A_0$ is when transmitted bit is 0

$A_1$ is when transmitted bit is 1.

- To analyse noise, let us consider conditional probability.

$$P(B_0/A_1) = P(B_1/A_0) = P \quad \text{—— (2)}$$

where, $B_0$ is when recieved bit is 0

$B_1$ is when recieved bit is 1.

- $\cancel{P(B_0/A_1) + P[A_1] \neq}$

$$P(B_0/A_1) + P(B_1/A_0) = 1$$

from $eq^n$ (2)

$$P(B_0/A_1) + P = 1$$

$$P(B_0/A_1) = 1-P \quad \text{--- (3)}$$

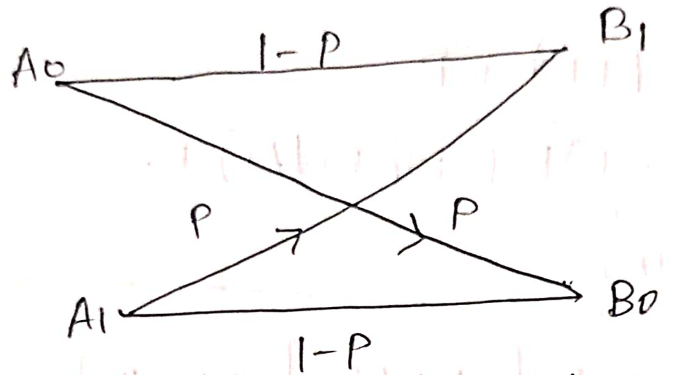
Similarly,

$$P(B_0/A_1) + P(B_1/A_0) = 1$$

from eq$^n$ (2) $P + P(B_1/A_0) = 1$

$$P(B_1/A_0) = 1-P \quad \text{--- (4)}$$

~~When it~~




Binary Symmetric channel.

~~When~~ The probability that the recieved bit is 0.

$$P[B_0] = P[B_0/A_1]\,P[A_1] + P[B_0/A_0]\,P[A_0]$$

$$P[B_0] = (1-P)\,P + P[B_0/A_0]\,P \quad \text{--- (5)}$$

The probability that the recieved bit is 1.

$$P[B_1] = P[B_1/A_0]\,P[A_0] + P[B_1/A_1]\,P[A_1]$$

$$P[B_1] = (1-P)\,P + P[B_1/A_1]\,P$$

Using Baye's Theorem,

$$P(A_1/B_0) = \frac{P[B_0/A_1] + P(A_1)}{\cancel{P[B_1/A_1]P} \; P[B_0]}$$

$$P[A_1/B_0] = \frac{(1-P)+P}{(1-P)P + P[B_1/A_1]P}$$

Similarly,

$$P[A_0/B_1] = \frac{P[B_1/A_0]\ P[A_0]}{P[B_0]}$$

$$= \frac{(1+P)+P}{(1-P)P + B[B_1/A_1)P.}$$

In generalize form,

$$\boxed{P[A/B_i] = \frac{\sum_i P[B_i/A] + P[A]}{P[B_i]}}$$

The above equation is posteriori probability theorem.

2 (a) Autocorelation is the process of finding co-relation with its self.

Cross corelation is the process of finding co-orrelation with another variable.

<u>Properties of auto co-relation</u>:

auto co-relation, = ~~E~~

$$R_x(\tau) = E|x(t+\tau)\, x(t)|. \quad , \text{for all } t. \quad \text{—— (1)}$$

1. The mean of square of variable can be found in auto-corelation, by equating $\tau = 0$.

$$\Rightarrow \cancel{R_X(X\tau)} - R_X(0) = E|X(0+t)\,X(t)|$$

$$R_X(0) = E|X(t)\,X(t)|$$

$$\therefore \quad R_X(0) = E|X^2(t)|$$

2. The auto corelation function is an even function.

$$\Rightarrow \quad R_X(\tau) = R_X(-\tau)$$

Using the above property, we can write the auto corelation function as.

$$R_X(-\tau) = E|X(t)\,X(t-\tau)|$$

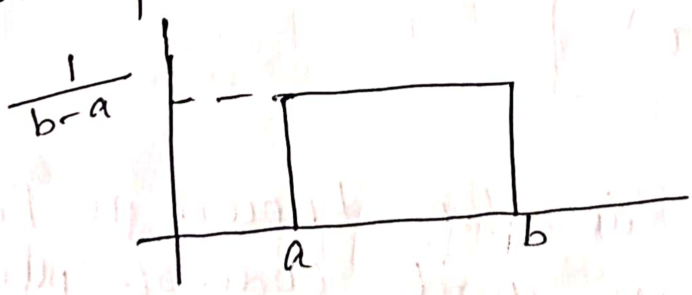
3. The auto corelation value is maximum when it equal to 0.

$$R_X(\tau) \geqslant R_X(0)$$

2(b) $Y = \cos(X)$

$X = [-\pi, \pi]$

for uniform ~~pdf~~ distribution function.




here, $a = -\pi$

$b = \pi$

$$\therefore \quad \frac{1}{b-a} = \frac{1}{\pi - (-\pi)} = \frac{1}{2\pi}$$

$$f(x) = \begin{cases} \frac{1}{2\pi}, & -\pi < x < \pi \\ 0, & \text{elsewhere.} \end{cases}$$

$$\mu_x = E|x| = \int_{-\infty}^{\infty} x f(x)\, dx$$

from the data given,

$$E|x| = \int_{-\pi}^{\pi} \frac{1}{2\pi} \cos(x)\, dx$$

$$= \frac{1}{2\pi} \int_{-\pi}^{\pi} \cos(x)\, dx$$

$$= \frac{1}{2\pi} \left[ \sin x \right]_{-\pi}^{\pi}$$

$$= \frac{1}{2\pi} \left[ \sin(\pi) - \sin(-\pi) \right] \qquad \sin\pi =$$

$$= \frac{1}{2\pi} [0]$$

$$\boxed{E|X| = 0}$$

3 (a) Interpolation formula

- Consider the problem of reconstructing the signal $g(t')$ from the sequence of sample values $[g(n/2W)]$.

$$g(t) = \int_{-\infty}^{\infty} G(f)\exp(j2\pi ft)\, df$$

$$= \int_{-W}^{W} \frac{1}{2W} \sum_{n=-\infty}^{\infty} g\left(\frac{n}{2W}\right) \exp\left(-\frac{j\pi nf}{W}\right) \exp(j2\pi ft)\, df$$

Interchanging the order of summation and integration:

$$g(t) = \sum_{n=-\infty}^{\infty} g\left(\frac{n}{2W}\right) \frac{1}{2W} \int_{-W}^{W} \exp\left[j2\pi f\left(t - \frac{n}{2W}\right)\right] df$$

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$$\int_{a}^{a} e^{jbx}\,dx = \frac{\sin(ab)}{b}$$

$$g(t) = \sum_{n=-\infty}^{\infty} g\left(\frac{n}{2W}\right)\frac{\sin(2\pi Wt - n\pi)}{(2\pi Wt - n\pi)}$$

$$= \sum_{n=-\infty}^{\infty} g\left(\frac{n}{2W}\right)\operatorname{sinc}(2Wt - n), \qquad -\infty < t < \infty$$

Equation provides an interpolation formula for reconstructing the original signal g(t) from the sequence of sample values [ g(n/2W) ] , with the sinc function sinc(2Wt) playing the role of an interpolation function.

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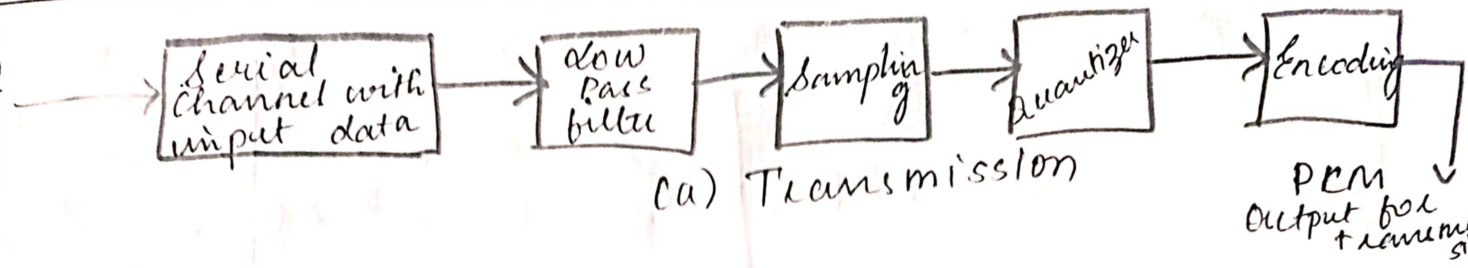
3(b)

- In practice, however, an information- bearing signal is *not* strictly band limited, with the result that some degree of undersampling is encountered.
- Consequently, some *aliasing* is produced by the sampling process.
- Aliasing refers to the phenomenon of a high frequency component in the spectrum of the signal seemingly taking on the identity of a lower frequency in the spectrum of its sampled version
- To combat the effects of aliasing in practice, we may use two corrective measures.

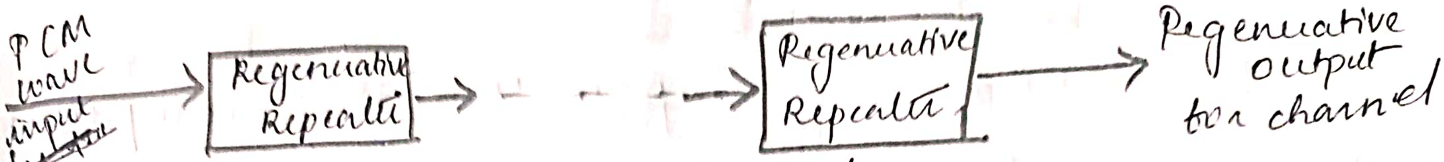
1. Prior to sampling, a low-pass *pre-alias filter* is used to attenuate those high-frequency components of the signal that are not essential to the information being conveyed by the signal.

**2.** The filtered signal is sampled at a rate slightly higher than the Nyquist rate The use of a sampling rate higher than the Nyquist rate also has the beneficial effect of easing the design of the *reconstruction filter* used to recover the original signal from its sampled version.

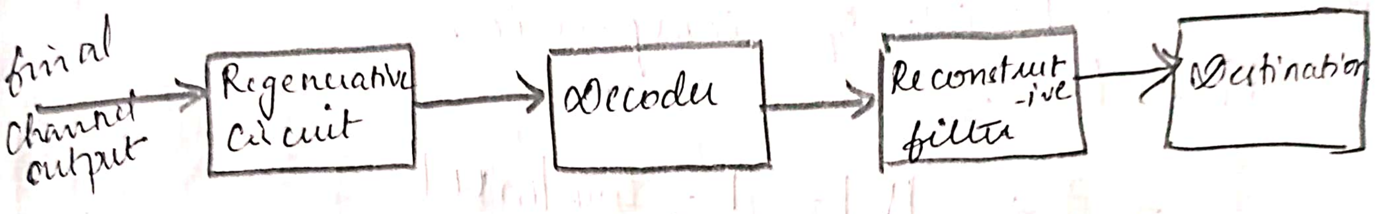
4(a)




(a) Transmission

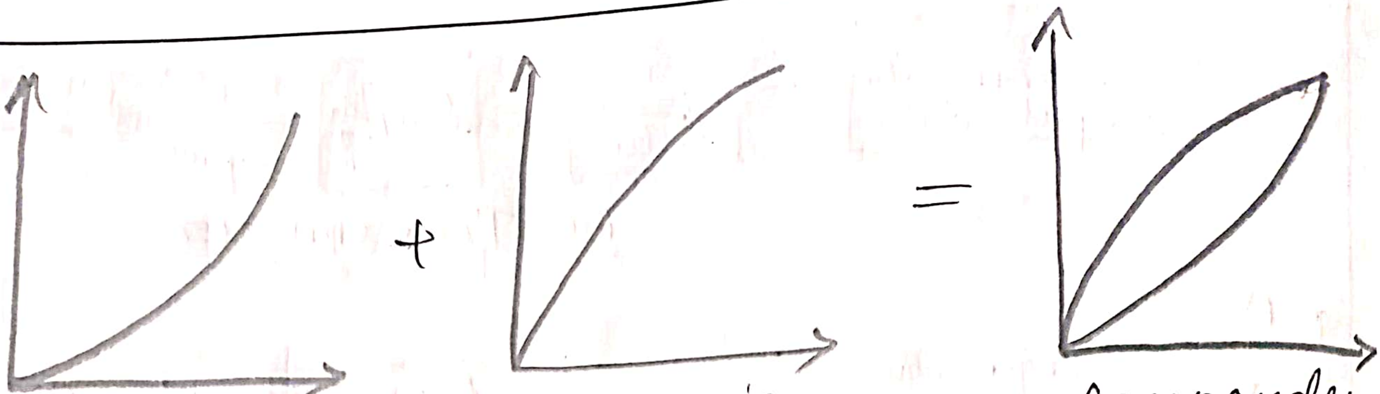



(b) channel




(c) Reciever

- The input signal is bandlimited using Low pass filter.
- Then, it is send for sampling, where sampling frequency is greater than or lesser than maximum frequency.
- The signal is then send for quantizer for ~~~~ quantizing into ~~discrete~~ discrete amplitude.
- The signal is now discreted with time and amplitude.
- The non-uniform quantizing can be made into uniform quantizing with the help of compressor.
- Compressor is used at transmission and expansion is used at reciever.
- ~~a~~ Together, when compression and expansion happens together, then it is compander.

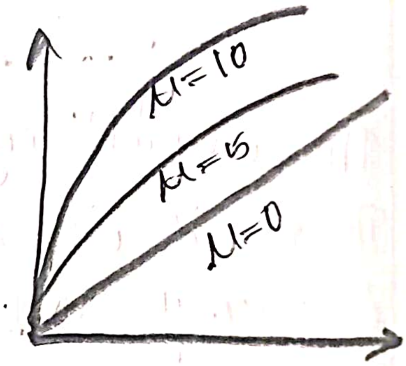


Compression + Expansion = Compander.

There are two rules, which is needed to follow for the process of compression

(i) μ- law,

$$\cancel{F(x)} \quad |V| = \frac{1 - \log|m\mu|}{1 - \log \mu}$$

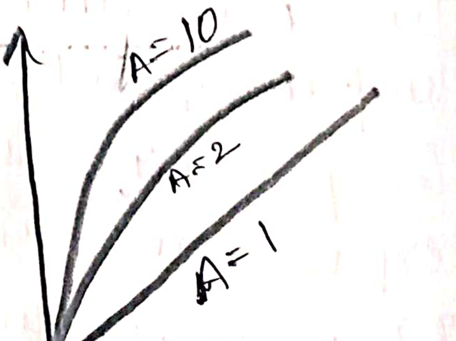



V is normalized output
m is ~~no~~ normalized input
μ is scaling factor.

for μ=0, it is uniform.

(ii) A - law,

$$|V| = \begin{cases} \dfrac{|A\mu|}{1 - \log \mu}, & 0 < \mu < \dfrac{A}{2} \\ \dfrac{1 - \log|\mu A|}{1 - \log \mu}, & \dfrac{A}{2}, \mu, 1 \end{cases}$$



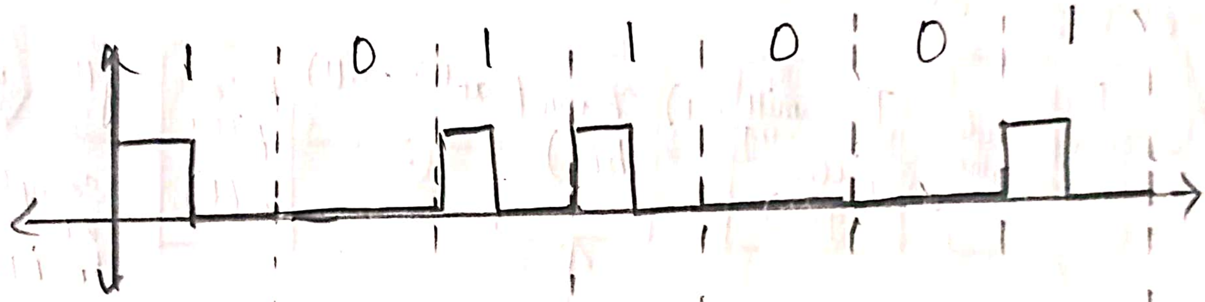

for A=1, it is uniform.

otherwise it is exponential.

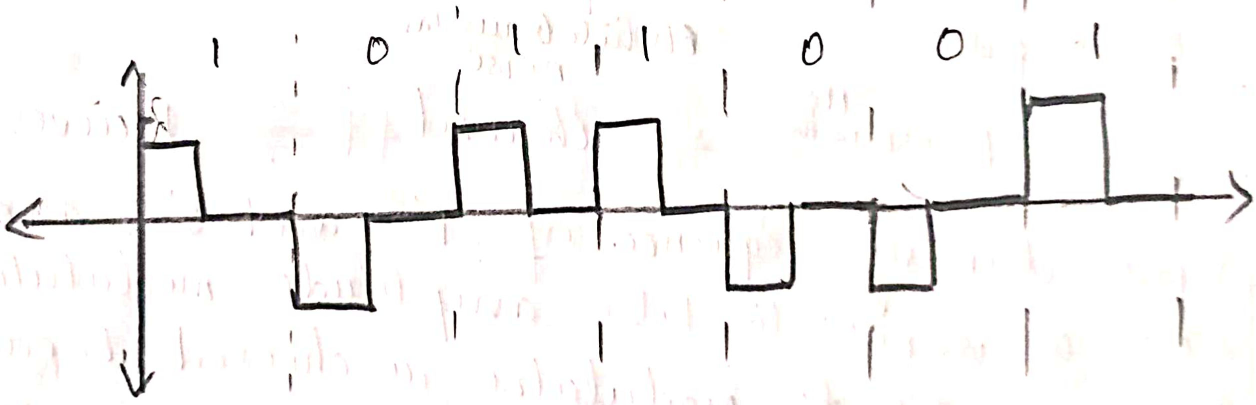
- After quantizing, it needs to encoded for safe transmission.
- Regenerative repeater is used for avoid distorted output and used in need for long transmission.
- Decoder decodes the encoded signal and sends to the destinated source.

4(b). 10 11 001

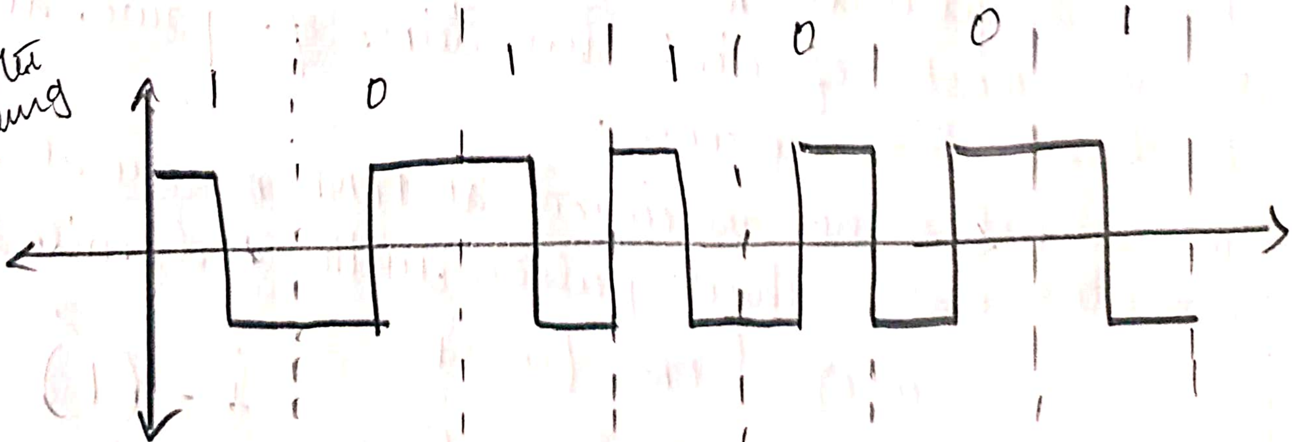
unipolar RZ




polar RZ

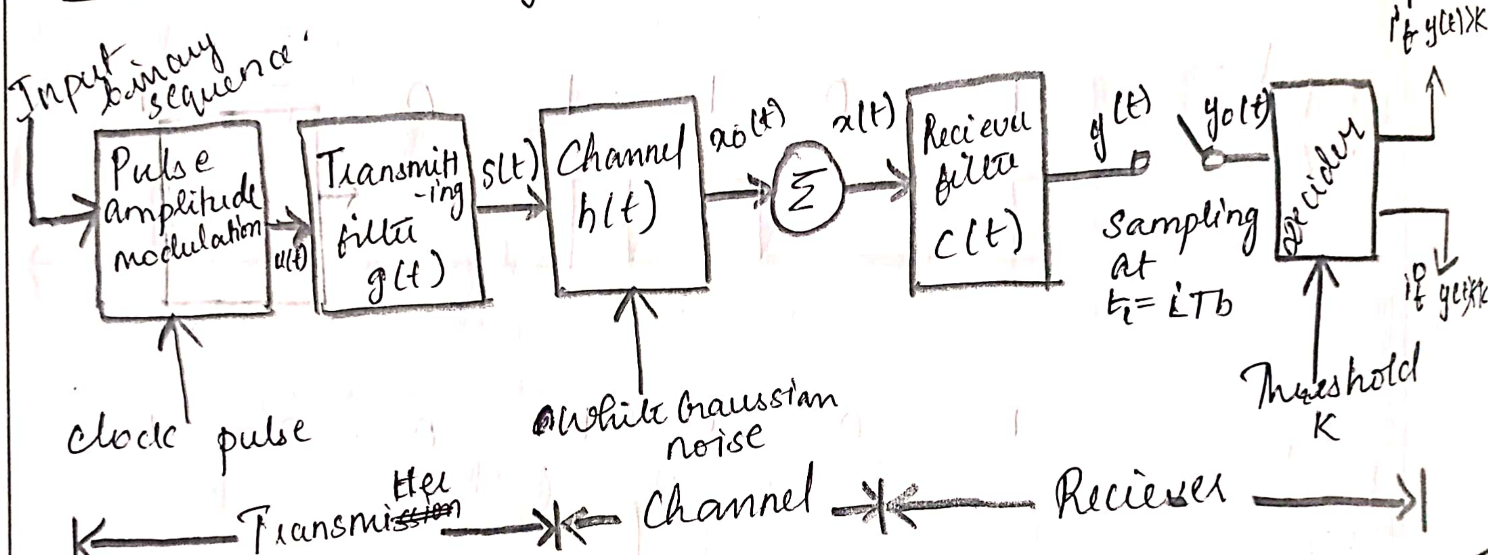



Manchester line coding



5(a) Generally, communication channel is dispersive in nature, whose frequency spectrum ~~[illegible]~~ deviates from low pass filter response. This causes interference of symbol which is called as Inter Symbol Interference (ISI). ISI is one of the factor for creating noise in the channel.

Baseband binary data transmission system:




- Input binary sequence of 1's and 0's are send as input to Pulse amplitude modulator at Tb.
- Pulse amplitude modulator is choosed because it is most efficient in terms of power and baseband transmission.
- The input signal recieved at PAM modulator is converted into short pulses, with a definite amplitude.

$$u(t) = \begin{cases} +A, & \text{for } 1 \\ -A, & \text{for } 0 \end{cases} \quad \text{--- (1)}$$

The short pulse is then fed into transmitter filter with a impulse of $G(t)$, thus the transmitting signal becomes,

$$\therefore S(t) = \sum a_K \, g(t - nT_b) \longrightarrow (2)$$

The signal is then transmitted to channel, with a impulse of $h(t)$.

- At channel, the white gaussian noise is added.
- The additive signal is recieved at reciever filter.
- The reciever filter works synchronisly with transmitting filter.
- The output ~~is set~~ from reciever filter is send to deciding circuit.
- The deciding circuit with a threshold value $\lambda$, decides the output and is transmitted out.
- If $\lambda$ value is much greater than the signal, then it decides the bit to be 1.
- If $\lambda$ value is much lesser than the signal, then it decides the bit to be 0.

$$y(t) = \mu_K \sum a_K \, g(t - nT_b) + n(t) \longrightarrow (3)$$

where $n(t)$ is noise.

$\mu$ is scaling vector.

$$\mu_K(t) = g(t) * h(t) * c(t)$$

in frequency domain.

$$\mu_K(f) = G(f) \times h(f) \times c(f)$$

$$y(t) = \mu_K \sum_{K=-\infty}^{\infty} a_K\, P(t - nT_b) + n(t) \quad \text{— (4)}$$

when the sampling is at $t = t_i$, $t_i = iT_b$.

$$y(t_i) = \mu_K \sum_{K=-\infty}^{\infty} a_k\, P(t_i - nT_b) + n(t_i)$$

$$\boxed{y(t_i) = \mu_K a_K \sum_{\substack{K=-\infty \\ K \neq i}}^{\infty} a_K P(iT_b - nT_b) + n(t_i) \quad \text{— 5}}$$

Eqn (5) represents ISI.

first term represents when there is no effect of ISI.

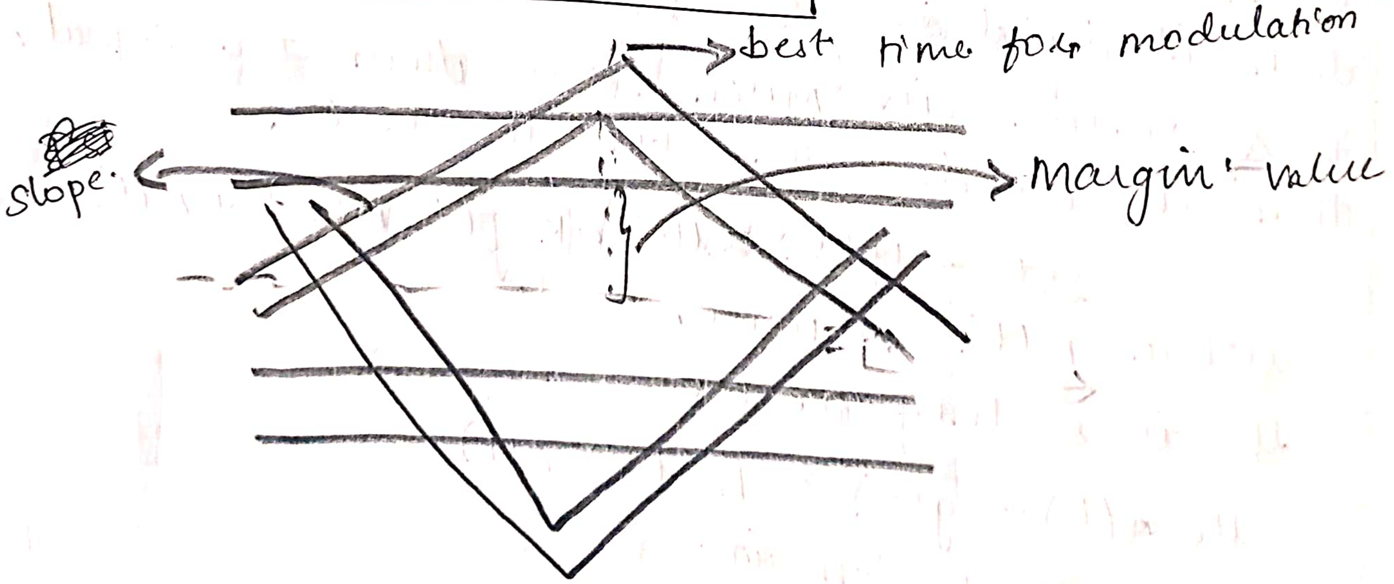
Second term represents ~~whe~~ the ISI

Third term represents noise.

- when there is no ISI,

$$\boxed{y(t) = \mu_K a_K}$$

5(b)




- Eye diagram is a pictorical or graphical representation of study of effect of ISI.

- It is called eye diagram, because it is in the shape of human eye.
- The centre region of eye diagram is called eye opening.
- The width of the eye opening, tells ~~us how the~~ ~~IS~~ us the effects of ISI.
- Eye diagram is important because it tells us the information of the ISI, the noise and when is the best time for transmission.
- If the eye opening is wide enough, then ISI effect is less
- If the eye opening is narrow or less, then ISI effect is more.
- Eye opening and ISI effect is inversely proportional.

6(a) Consider the equation for ISI effect,

$$y(t) = \mu a_i \sum_{\substack{k=-\infty \\ k\neq i}}^{\infty} a_k p(iT_b - nT_b) + n(t) \quad \text{—(1)}$$

To reduce the ISI effect the weighting factor $p(iT_b - nT_b)$ needs to be reduced.

It needs to be equal to $k = i$

$$p(iT_b - nT_b) = \begin{cases} 0, & k = i \\ 1, & k \neq i \end{cases} \quad \text{—(2)}$$

$P(0) = 1$ after normalization.

Eqn (1) can be even represented in frequency domain.

To transmit, we can choose the number of band signals.

$$P(nT_b) = \quad n = 0, \pm 1, \pm 2, \pm 3, \ldots \ldots,$$

Writing the eq$^n$ in frequency domain gives us.

$$P_\delta(f) = R_b \sum_{-\infty}^{\infty} P(f - nR_b) \quad -(2)$$

$R_b$ is baud rate.

$P(nT_b)$ can be written in frequency domain as

$$P_s(f) = \delta \sum_m \Big[ P(t_i - mT_b)\, P(mT_b)\, \exp[-2\pi j f_t] \, dt \quad -(3)$$

Due to normalization,

$$P_\delta(f) = 1 \quad -(4)$$

Comparing eq$^n$ (4) and eq$^n$ (2)

$$\Rightarrow \quad P_\delta(f) = R_b \sum_{-\infty}^{\infty} P(f - nR_b) = 1$$

$$\Rightarrow \quad P_\delta(f) = \sum_{-\infty}^{\infty} P(f - nR_b) = \frac{1}{R_b}$$

$$\boxed{\sum_{-\infty}^{\infty} P(f - nR_b) = \frac{1}{R_b} = T_b} \quad -(5)$$

To transmit the channel without any distortion, i.e to reduce ISI effect it should follow eq$^n$(5) criteria

eq$^n$(5) is <u>Nyquist criteria for distortionless transmission</u>.

6(b). (A) External noise:
External noise is the noise which is not controlled manually. It is the noise outside of the circuit.
(1) Environmental noise; These includes ~~to~~ thunder, lightening, wind, rain
(2) Industrial noise: These includes any disturbances released by industries which include from automobile or etc.
(3) Intraterristial noise: These includes noise from space i.e above the earth for example cosmic rays, light from sun, etc

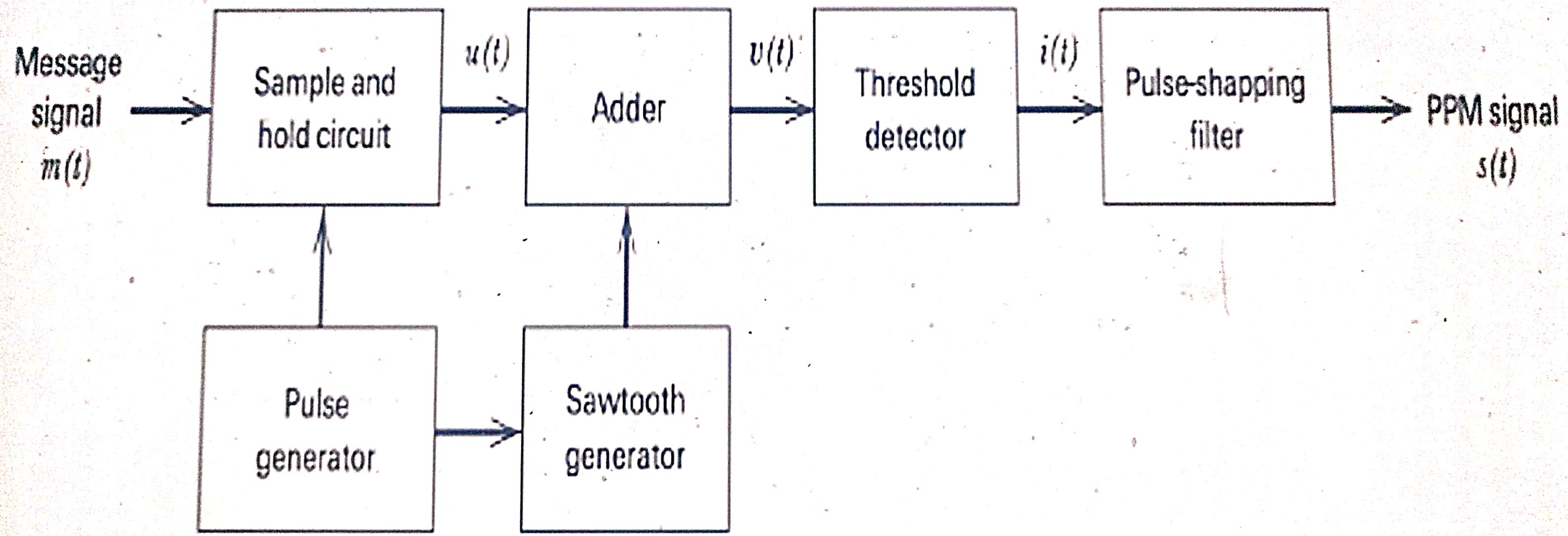
(b) Internal noise:
Internal noise is the noise which produced by the circuit itself due to some elements which include transistors, resistors, capacitors, diode. Due to excessive use can heat the circuitary elements which lead to distortion in output i.e noise.
(1) Transient line noise
(2) flicker noise
(3) Inter modulation distortion.

(C) SNR:
SNR stands for ~~sound~~ signal to noise ratio.

(7)

- In pulse-duration modulation (PDM), the samples of the message signal are used to vary the duration of the individual pulses.
- This form of modulation is also referred to as *pulse-width modulation* or *pulse-length modulation.*
- The modulating signal may vary the time of occurrence of the leading edge, the trailing edge, or both edges of the pulse.
- In PDM, long pulses expend considerable power during the pulse while bearing no additional information.
- If this unused power is subtracted from PDM, so that only time transitions are preserved, we obtain a more efficient type of pulse modulation known as *pulse-position modulation* (PPM).
- In *PPM, the position of a pulse relative to its unmodulated time of occurrence is varied in accordance with the message signal*

# GENERATION OF PPM WAVES



- The message signal $m(t)$ is first converted into a PAM signal by means of a sample-and-hold circuit, generating a staircase waveform $u(t)$.
- Note that the pulse duration $T$ of the sample-and-hold circuit is the same as the sampling duration $Ts$.
- The signal $u(t)$ is added to a sawtooth wave yielding the combined signal $v(t)$
- The combined signal $v(t)$ is applied to a *threshold detector* that produces a very narrow pulse (approximating an impulse) each time $v(t)$ crosses zero in the negative-going direction.
- Finally, the PPM signal $s(t)$ is generated by using this sequence of impulses to excite a filter whose impulse response is defined by the standard pulse $g(t)$.

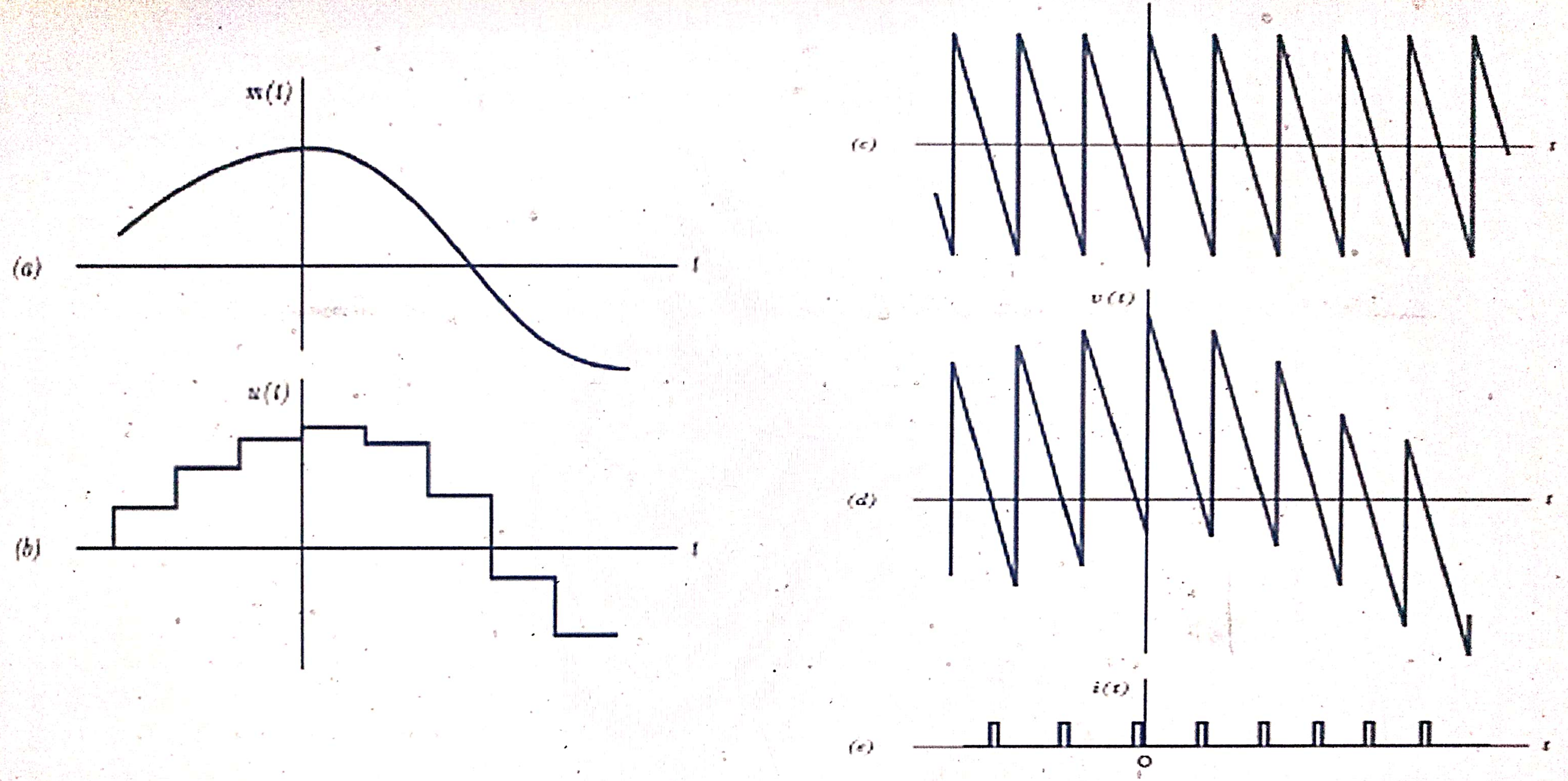



**FIGURE** Generation of PPM signal. (*a*) Message signal. (*b*) Staircase approximation of the message signal. (*c*) Sawtooth wave. (*d*) Composite wave obtained by adding (*b*) and (*c*). (*e*) Sequence of "Impulses" used to generate the PPM signal.

## 7(b) Ergodic Processes

- For many stochastic processes of interest in communications, the time averages and ensemble averages are equal, a property known as *ergodicity.*
- This property implies that whenever an ensemble average is required, we may estimate it by using a time average.
- Example: Imagine recording the daily temperature in a city for 10 years. If the average temperature over a long period is the same as the average temperature computed from many different cities at the same time, then the temperature process is ergodic.

## Gaussian Process

The random variable has a Gaussian distribution if its probability density function has the form

$$f_Y(y) = \frac{1}{\sqrt{2\pi}\sigma_Y} \exp\left[-\frac{(y-\mu_Y)^2}{2\sigma_Y^2}\right]$$

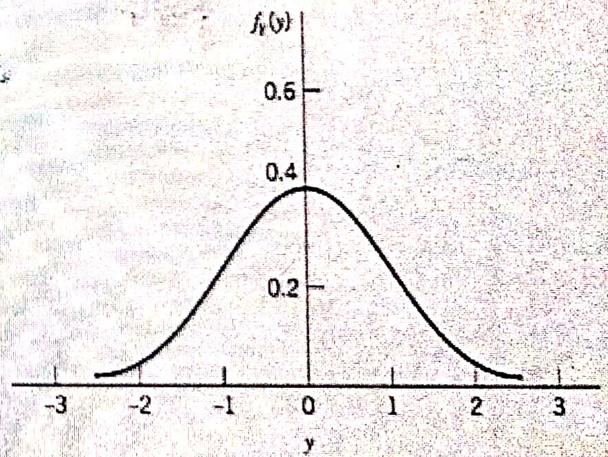



FIGURE . Normalized Gaussian distribution.