Baseband Data Communication Systems

Unit -4

Introduction to Information Theory

- Mathematical modeling and analysis of Communication System.
- Applied Probability theory to study communication system.
- Information: Occurrence of an event.
- Source: Produces event called symbol or letter.
- Source Alphabet: Group or set of symbols.

Introduction to Information Theory

- Information Source:- Produces message signal
- Symbol Rate:- Rate to generate source alphabet or symbol. Symbols/sec
- Entropy:- Average information content per symbol.

$$H(x) = \sum_{i=1}^{m} p(x_i) \log_2\left(\frac{1}{p(x_i)}\right)$$

- Information Rate:- Maximum rate of transmission of errorless data.
- Information rate = Symbol Rate*Entropy

Introduction to Information Theory

- ***<u>Shannon Hartley Channel Capacity Theory:-</u>***
- Channel capacity is defined as the maximum rate at which information may be transmitted without error through the channel is given as
- $C=B \log_2 (1+SNR)$
- Upper limit to transmit data without loss.
- Tradeoff between bandwidth, SNR and Channel capacity.
- Bandwidth compression.

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- ***<u>Shannon Hartley Channel Capacity Theoretical limits:-</u>***
- As the bandwidth of the channel $B \rightarrow \infty$, the channel capacity reaches the upper limit $C \rightarrow \infty$, Noise power $N \rightarrow 0$.
- Noiseless channel is referred as Ideal Channel with zero noise. Channel Capacity $C \rightarrow \infty$.
- Let us take channel consisting of white noise, the channel capacity is given as $C = B \log_2 (1+SNR) = B \log_2 (1+S/N)$.

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PSDF of white Noise can be calculated as

$$P_N = \int_{-B}^{B} S_{WN}(f)\, df$$

$$P_N = \int_{-B}^{B} \frac{N_0}{2}\, df = BN_0$$

putting value of N in eqn (1) we get

$$C = B\log_2\left(1 + S/BN_0\right)$$

$$C = \cancel{B}\,\frac{S}{N_0\cancel{B}}\,\log_2\left(1+\frac{S}{BN_0}\right)^{BN_0/S}$$

Let $\frac{S}{BN_0} = x$ when $B \to \infty$, $x \to 0$

$$C = \frac{S}{N_0}\log_2\left(1+x\right)^{1/x}$$

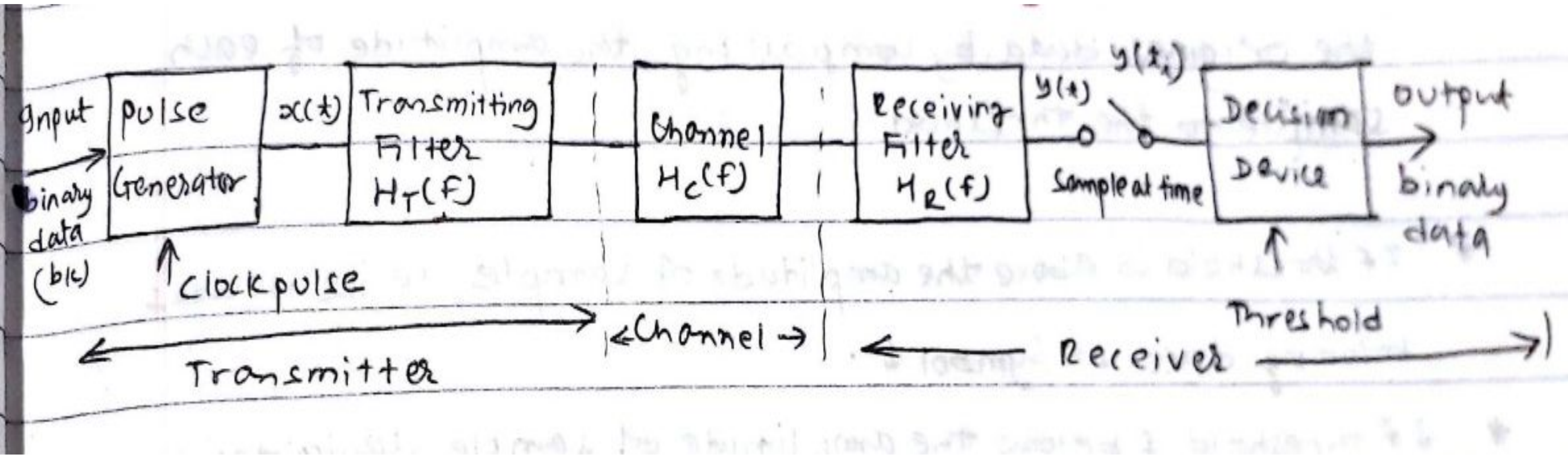
Introduction to Information Theory

- Line code :- The output of the multiplexer of digital signal are coded into electric pulse or waveform.

  1. Unipolar RZ 2. Unipolar NRZ 3. Polar RZ. 4. Polar NRZ 5. Bipolar NRZ or Alternate Mark Inversion(AMI) 6. Split phase Manchester Format. 7. HDB3 code 8. B8ZS Line code.

Introduction to Information Theory

- **Base Band Data Communication System:-**



- Input binary data b_k is feed to the Pulse generator for time duration of T_b seconds in the form of 0,1.
- Output of pulse generator is PAM signal x(t).
- It passes through the transmitting filter.

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- The transmitted signal is passed through the channel.
- At the receiving side received signal is passed through the received filter.
- Sampling Instant are extracted by the receiving filter and fed to the decision device.
- Decision device compares with the threshold.
- Threshold $>$ Amplitude of sample (Symbol 1)
- Threshold $<$ Amplitude of sample (Symbol 0)
- Threshold=Amplitude of sample (Symbol 0/ Symbol 1)

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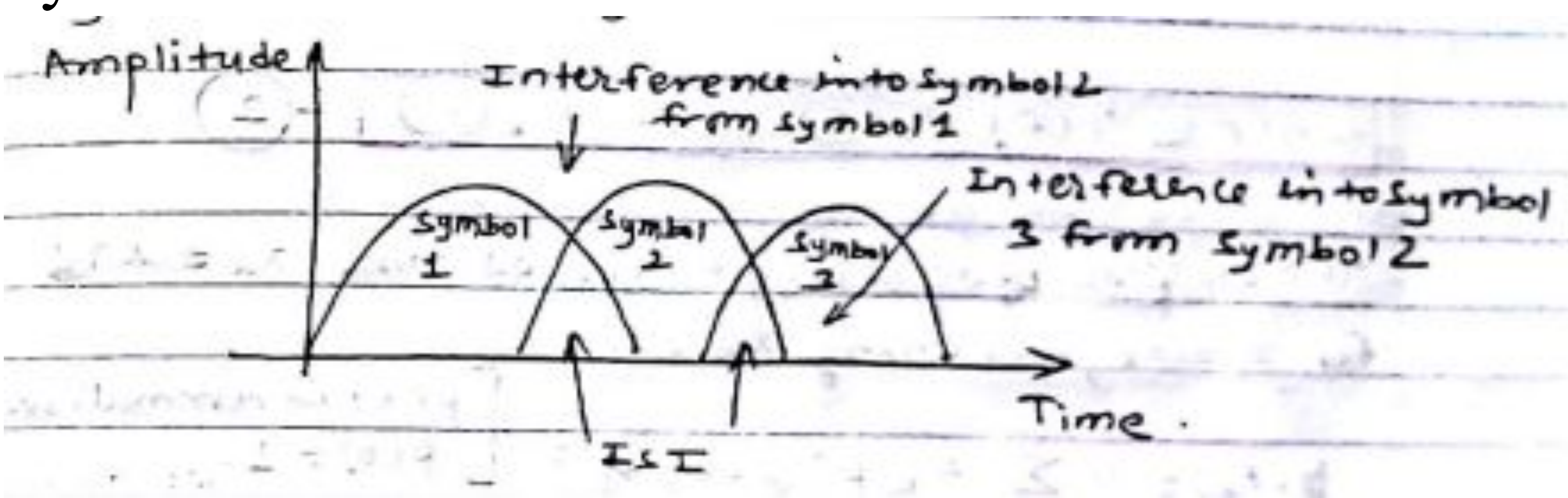
- ***<u>Inter symbol Interference (ISI):-</u>*** It is form of distortion of signal.
- One symbol interferes with subsequent symbol due to dispersion.
- ISI is the major limiting factor in communication system.



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- $y(t_i)=\mu A_i$ is known as Nyquist condition for zero ISI which is then decoded correctly at receiver.
- μ= scaling factor, A_i = Amplitude
- In Frequency domain $\sum_{n=-\infty}^{n=\infty}$ nR_b) = T_b is called Nyquist criterion for distortion less baseband transmission in absence of noise.
- R_b = bit rate = 1/ T_b , T_b = bit duration of T_b second

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- ***<u>Ideal solution to reduce ISI:-</u>*** For the sample frequency function p(f) over range of frequency $+B_o$ to $-B_o$
- For Nyquist bandwidth B_o equal to the minimum transmission bandwidth for zero ISI is given as
- $B_o = R_b/2$
- $p(f) = 1/2\ B_o \ \text{rect}\ (f/2\ B_o\ )$
- Taking IFT
- $P(t) = \text{Sinc}(2\ B_o\ t)$

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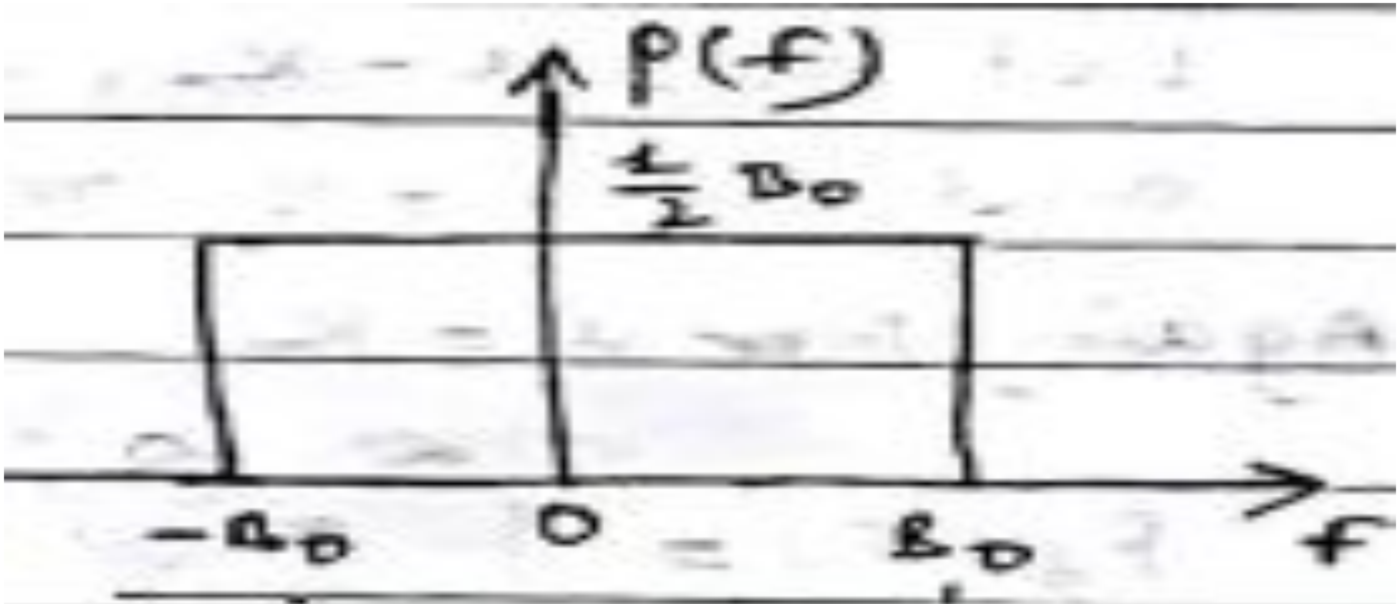

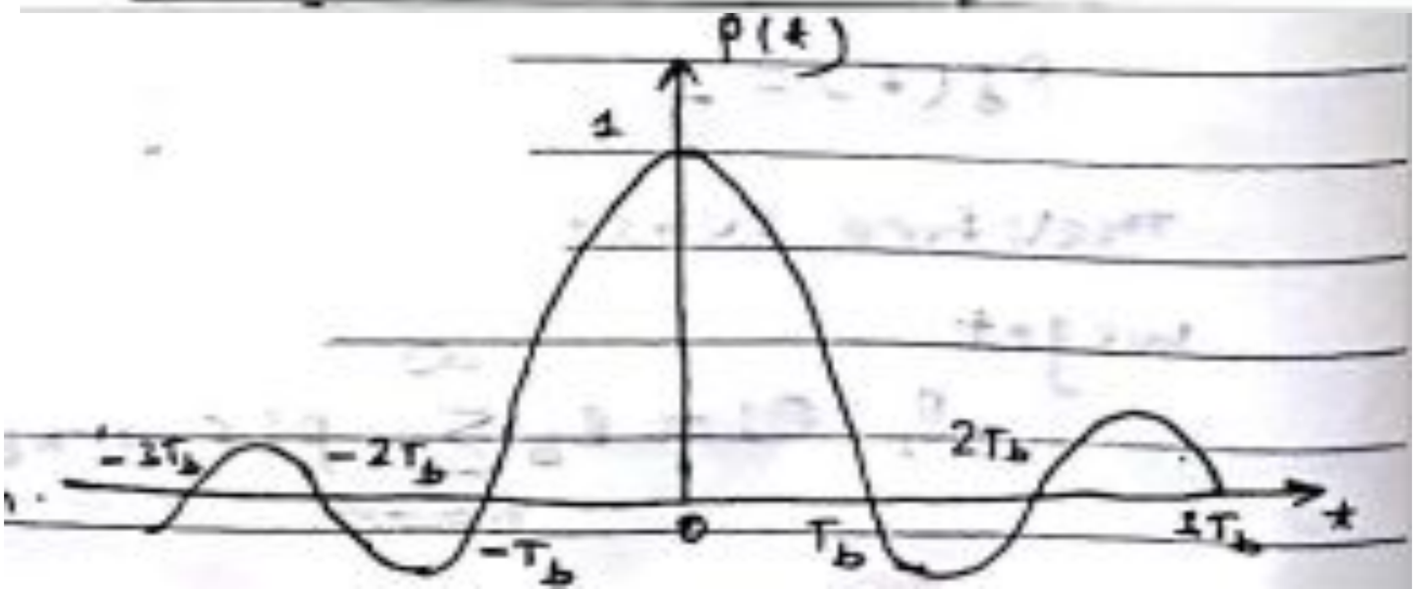

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- ***Raised Cosine Spectrum:-*** Practical difficulties can be overcome by increasing the bandwidth to the adjustable value between B_o to $2\ B_o$.
- Raised cosine function overall frequency response p(f).

$$
p(f) = \begin{cases} \dfrac{1}{2B_0} & 0 \le |f| \le f_1. \\[2ex] \dfrac{1}{4B_0}\ 1-\sin\left(\dfrac{\pi(|f|-B_0)}{2B_0-2f_1}\right) & f_1 \le f \le 2B_0 - f_1 \\[2ex] 0 & |f| \ge 2B_0 - f_1 \end{cases}
$$

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- Frequency f_1 and Nyquist bandwidth related as $\alpha = 1 - f_1 / B_o$, α- Roll factor which defines the abrupt variation for minimum bandwidth.
- Transmission bandwidth required
- $B = 2B_o - f_1$
- $B = 2B_o - B_o + \alpha B_o$
- $B = B_o + \alpha B_o$
- $B = B_o (1 + \alpha)$
- For zero ISI, transmission bandwidth will exceeds ideal solution by αB_o.

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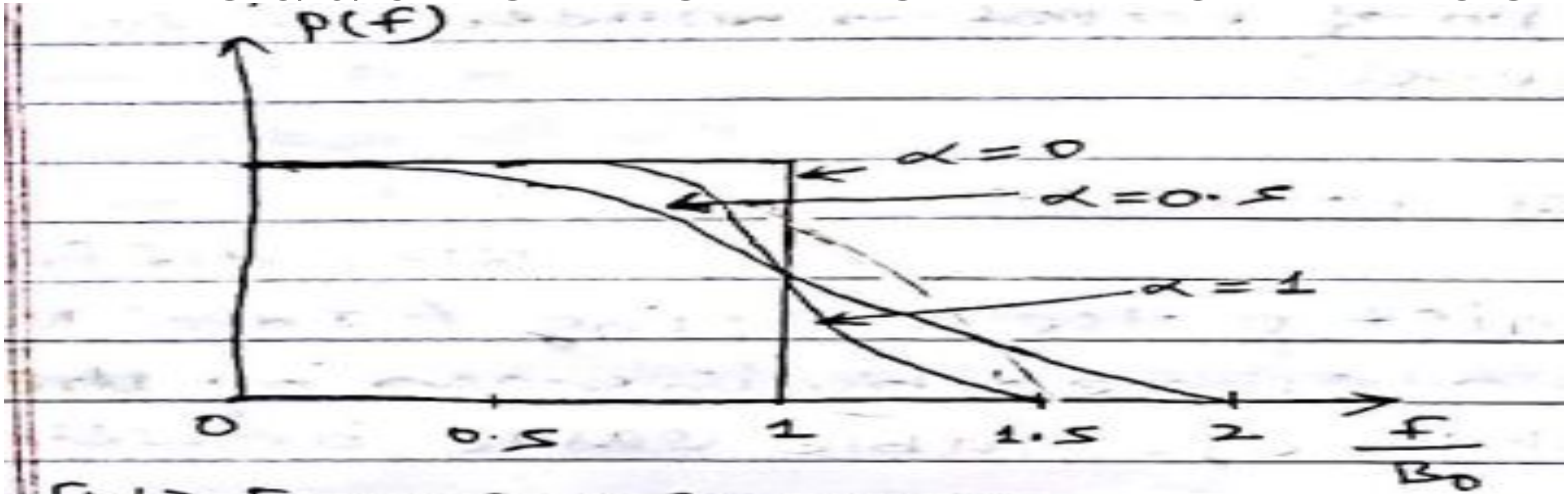

Fig:→ Frequency Response

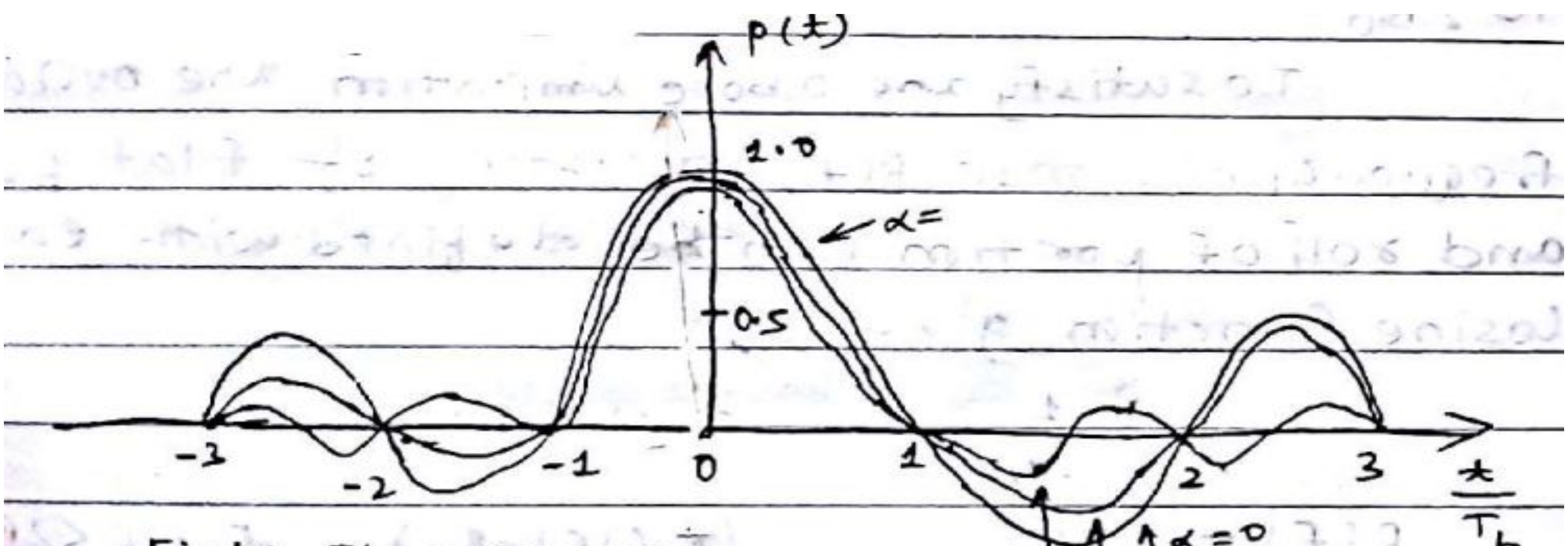

Fig:→ Time Response

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- ***<u>Correlative Coding Technique:-</u>*** Concept of ISI can be used in controlled manner to achieve signaling rate higher than the bandwidth of channel.
- Transmitting signal at rate $2B_o$ symbols/sec in a channel of bandwidth B_o .

1. Duo binary Encoder.
2. Modified Duo binary Encoder.

<u>Duo binary Encoder</u>

- Duo binary Encoder uses duo binary signaling which doubles the transmission capacity.

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- ***Duo binary Encoder***

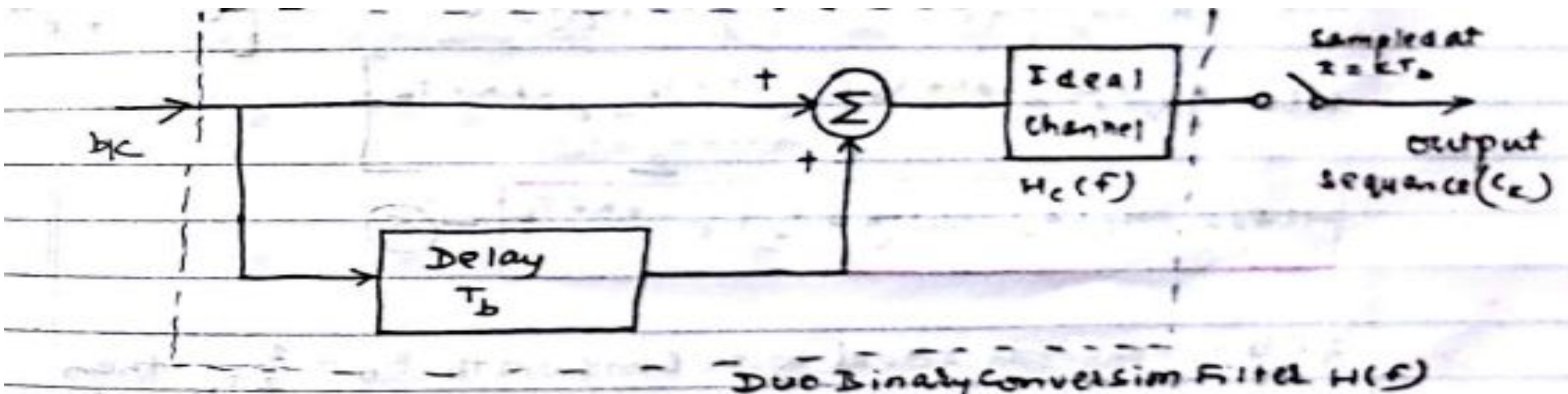

fig:-> Block Diagram of Duo Binary Encoder

At the Receiving side the original message data

$\boxed{\hat{b}_k = c_k - \hat{b}_{k-1}}$ $\hat{b}_{k-1}$ is the estimate at $t = (k-1)T_b$

If error is occurred in previous bit will introduce propagation of error. To overcome this Pre coder is used

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* Precoder :→

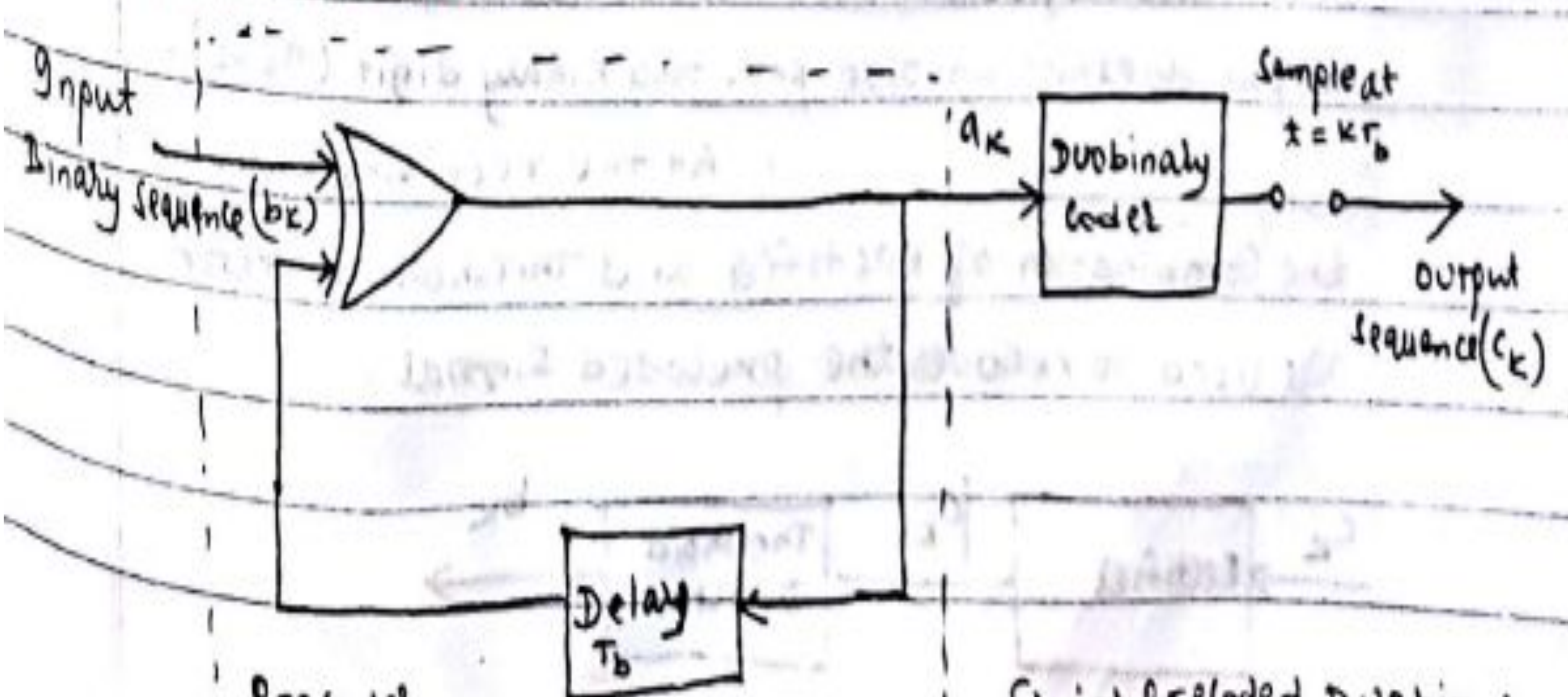

fig :→ Precoded Duobinary Encoders.

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$$\boxed{a_k = b_k \oplus a_{k-1}} \quad \text{--- (1)}$$

Note:→
$\oplus$ Modulo two addition
x-OR operation

Here extra bit is needed in precoded sequence (a_k). Extra bit may be 1 or 0.

The precoded output is then passed to the Duobinary coder there by producing the sequence (c_k) that is related to a_k as

$$\boxed{c_k = a_k \oplus a_{k-1}} \quad \text{--- (2)}$$

b_k	a_{k-1}	c_k
0	0	0
0	1	1
1	0	1
1	1	0

which verifies as

$$\boxed{\begin{array}{ll} c_k = \pm 2V & \text{if } b_k = 0 \\ c_k = 0 & \text{if } b_k = 1 \end{array}} \quad \text{--- (3)}$$

- Symbol 1 represented by +1v and symbol 0 represented by -1v.

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- At the Receiving side Detector consist of Rectifier and Threshold Detector.

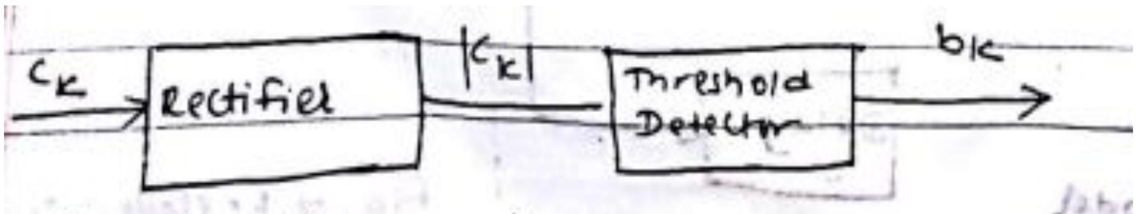

fig:→ Detector

The preloded signal c_k is fed to the Rectifier and the output of rectifier is compared to the threshold voltage of 1V to recover the original binary sequence.

$$\hat{b}_k = \text{symbol } 0 \quad \text{if } |c_k| > 1V$$
$$= \text{symbol } 1 \quad \text{if } |c_k| < 1V$$

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- ***<u>Modified Duo binary Encoder:-</u>***

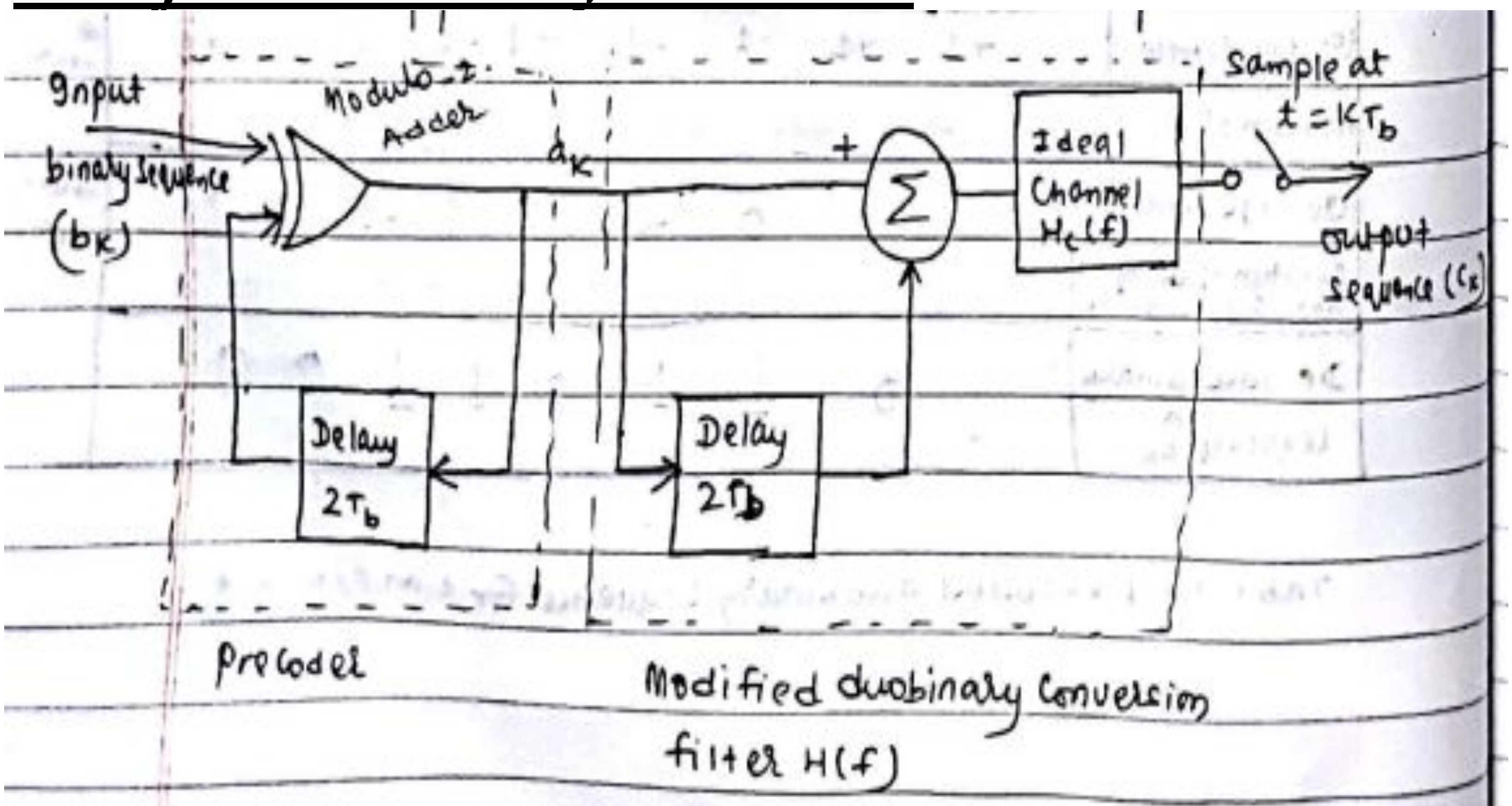

fig:-> Modified Duobinary signalling scheme

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$$\boxed{c_k = a_k - a_{k-2}}$$

$$c_k = 2V \quad \text{for } a_k = a_{k-2} = 1$$
$$= 0 \quad \text{for } a_k \neq a_{k-2}$$
$$= -2V \quad \text{for } a_k = a_{k-2} = 0$$

$$\boxed{a_k = b_k \oplus a_{k-2}}$$

The sequence 'a_k' is the input of the final modified duobinary filter. Here the output c_k is defined as

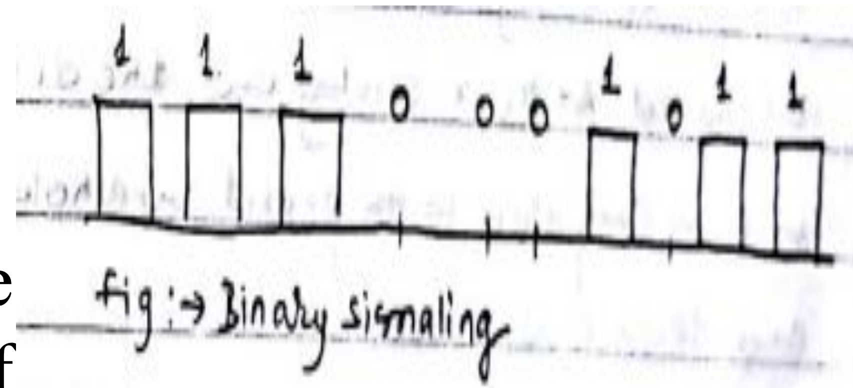
$c_k = 0$	if b_k is represented by symbol 0
$= \pm 2V$	" " " " " Symbol 1

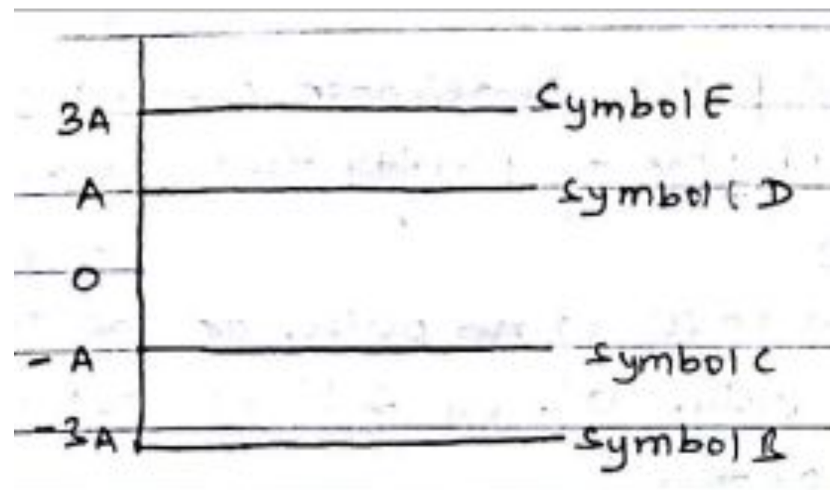
Now, the decoded digit $\hat{b}_k$ at the receiver output are extracted from c_k by

$\hat{b}_k$ = symbol 1	if $\lvert c_k \rvert > 1V$
= symbol 0	if $\lvert c_k \rvert \leq 1V$

Introduction to Information Theory

- ***M-ary signaling, comparison with Binary Signaling***
- Binary signaling of pulse generator output has one of two possible level.
- M-ary signaling has level of $M=2^n$
- Signaling rate of M-ary Signaling $r_s = r_b \log_2 M$.
- $r_b =$ Signaling rate of binary system





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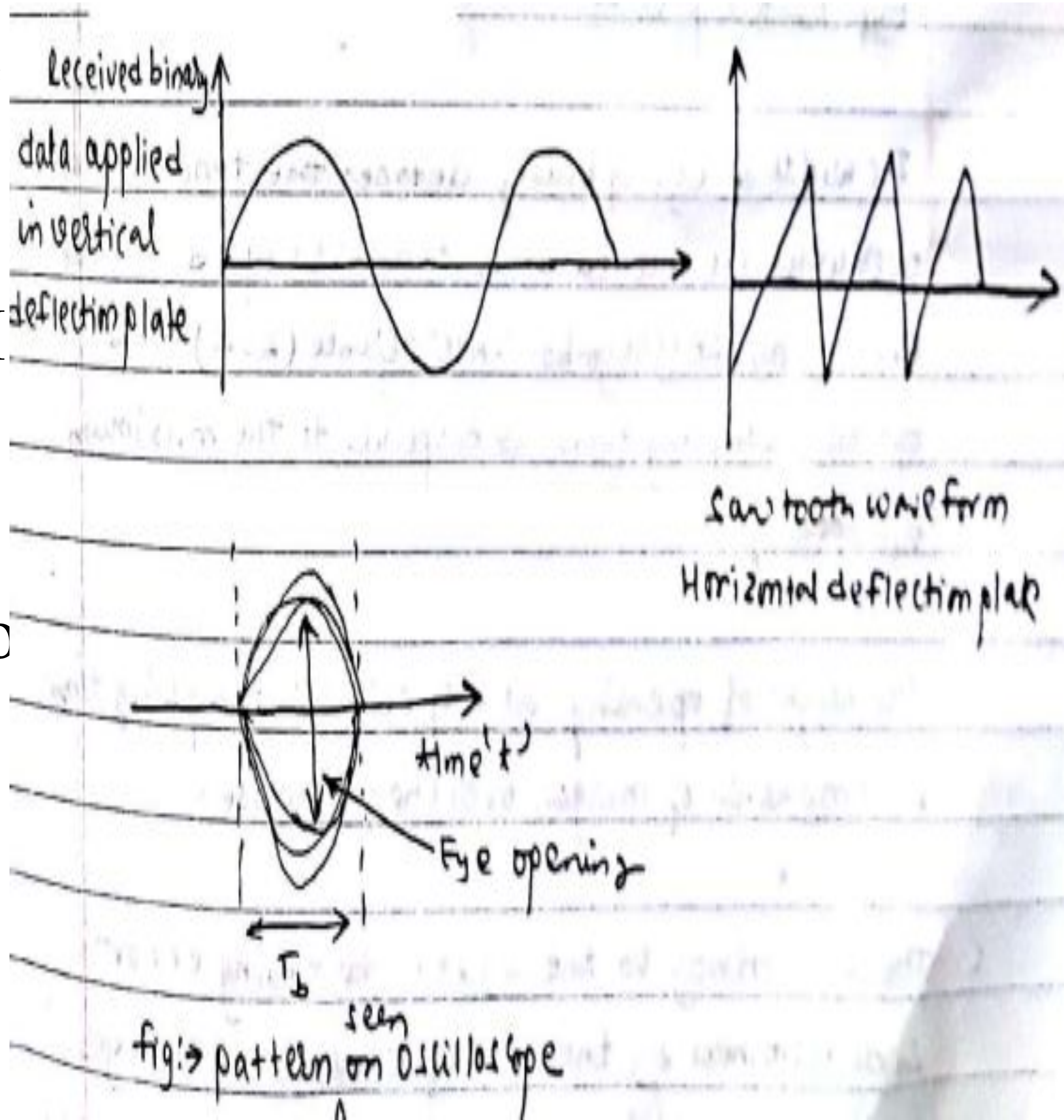
- ***Eye Pattern:-*** Pattern displayed on oscilloscope to study the performance of baseband signal. Practical way to study ISI and its effect on PCM.

- Distorted wave is given to the vertical plate. Saw tooth wave to horizontal deflection plate



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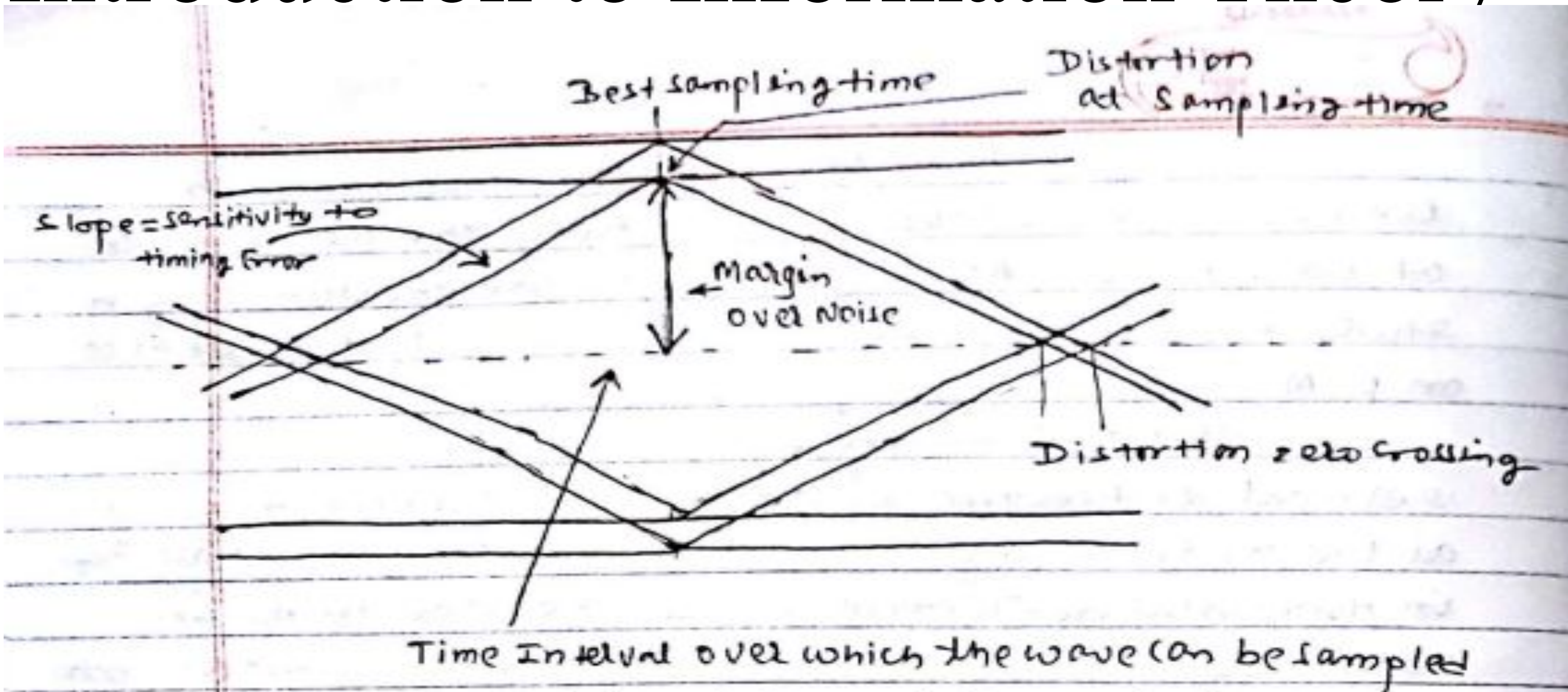

fig:→ Interpretation of Eye pattern.

- Width of eye gives time interval over which the received wave is sampled without error from ISI.
- Best Sampling Time. Sensitivity of the system to timing error.
- Complete close of pattern represents excessive ISI.
- Asymmetric eye pattern resembles nonlinear distortion.
- Measurement of margin over channel noise.

Introduction to Information Theory

End of Chapter

Thank you