Module 4

Baseband system

- Baseband data transmission of binary data - Inter Symbol Interference (ISI), Nyquist criterion for zero ISI, Raised cosine filtering, correlative coding (duo binary and modified duo binary coding), eye pattern – Equalization.

ISI (Intersymbol Interference)

- Digital data is represented by electrical pulse, communication channel is always band limited.
- Such a channel disperses or spreads a pulse carrying digitized samples passing through it. When the channel bandwidth is greater than bandwidth ofpulse, spreading of pulse is very less.
- But when channel bandwidth is close to signal bandwidth, i.e. if we transmit digital data which demands more bandwidth which exceeds channel bandwidth, spreading will occur and cause signal pulses to overlap. This overlapping is called Inter Symbol Interference. In short it is called ISI.
- Similar tointerference caused by other sources, ISI causes degradations of signal if left uncontrolled. This problem of ISI exists strongly in Telephone channels like coaxialcables and optical fibers.

...cont

- Main objective is to study the effect of ISI, when digital data is transmitted through band limited channel and solution to overcome the degradation of waveform by properly shaping pulse.

$$
\begin{aligned}
y(t_i) &= \mu \sum_{k=-\infty}^{\infty} a_k p[(i-k)T_b] + n(t_i) \\
&= \mu a_i + \mu \sum_{\substack{k=-\infty \\ k \neq i}}^{\infty} a_k p[(i-k)T_b] + n(t_i)
\end{aligned}
$$

First term : contribution of the i-th transmitted bit.
Second term : ISI – residual effect of all other transmitted bits.To design transmit and receiver filters to minimize the ISI.When the signal-to-noise ratio is high, as is the case in a telephone system, the operation of the system is largely limited by ISI rather than noise.

- The effect of sequence of pulses transmitted through channel is shown in fig.

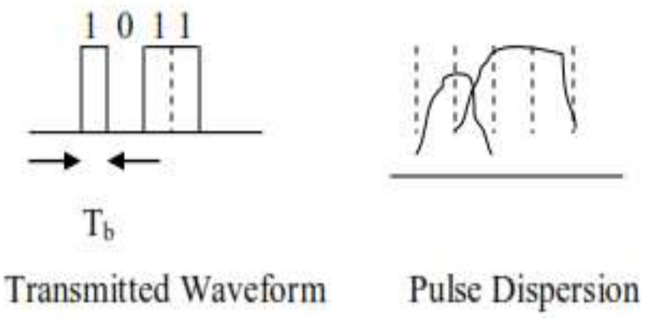

Fig 1: ISI

- The Spreading of pulse is greater than symbol duration, as a result adjacent pulses interfere. i.e. pulses get completely smeared, tail of smeared pulse enter into adjacent symbol intervals making it difficult to decide actual transmitted pulse.

Example1

A certain telephone line bandwidth is 3.5Khz .calculate data rate in bps that can be transmitted if binary signaling with raised cosine pulses and roll off factor $\alpha = 0.25$ is employed.

Solution:

$\alpha = 0.25$ ---- roll off

B = 3.5Khz ---transmission bandwidth

$B = B_o(1+\alpha)$

$$B_0 = \frac{1}{2Tb} = \frac{Rb}{2}$$

Ans: $R_b = 5600$bps

Example2

A source outputs data at the rate of 50,000 bits/sec. The transmitter uses binary PAM with raised cosine pulse in shaping of optimum pulse width. Determine the bandwidth of the transmitted waveform. Given

a. $\alpha = 0$ b. $\alpha = 0.25$ c. $\alpha = 0.5$ d. $\alpha = 0.75$ e. $\alpha = 1$

Solution

$B = B0(1+\alpha)$ B0=Rb/2

a. Bandwidth = 25,000(1 + 0) = 25 kHz

b. Bandwidth = 25,000(1 + 0.25) = 31.25 kHz

c. Bandwidth = 25,000(1 + 0.5) = 37.5 kHz

d. Bandwidth = 25,000(1 + 0.75) = 43.75 kHz

e. Bandwidth = 25,000(1 + 1) = 50 kHz

Correlative coding

- Correlative-level coding (partial response signaling) adding ISI to the transmitted signal in a controlled manner .

- Since ISI introduced into the transmitted signal known, its effect can be interpreted at the receiver .

- A practical method of achieving the theoretical maximum signaling rate of 2W symbol per second in a bandwidth of W Hertz.

Duo Binary Signaling

Duo-doubling of the transmission capacity of a straight binary system.

Consider binary sequence $\{b_k\}$ with uncorrelated samples transmitted at the rate of R_b bps.
Polar format with bit duration T_b sec is applied to duo binary conversion filter.

when this sequence is applied to a duo binary encoder, it is converted into three level output, namely -2, 0 and +2.

To produce this transformation we use the scheme as shown in fig.
The binary sequence $\{b_k\}$ is first passed through a simple filter involving a single delay elements.

For every unit impulse applied to the input of this filter, we get two unit impulses spaced Tb seconds apart at the filter output.

Digit C_k at the output of the duo binary encoder is the sum of the present binary digit b_k and its previous value b_{k-1}.

$$C_k = b_k + b_{k-1}$$

The correlation between the pulse amplitude C_k comes from b_k and previous b_{k-1} digit, can be thought of as introducing ISI in controlled manner.,i.e.,the interference in determining $\{b_k\}$ comes only from the preceding symbol $\{b_{k-1}\}$.

The symbol$\{b_k\}$ takes ± 1 level thus C_k takes one of three possible values-2,0,+2.The duo binary code results in a three level output.In general, for M- ary transmission,we get 2M-1 levels.

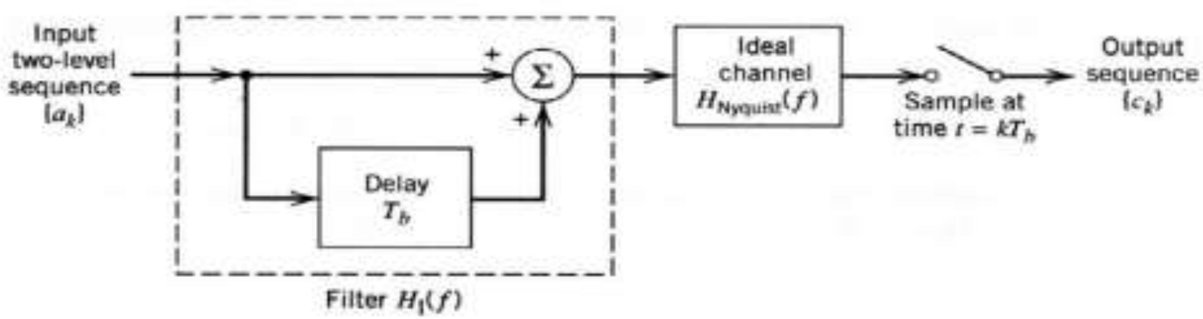

Fig 2: Duo binary Signaling scheme

Transfer function of Duo-binary Filter

The ideal delay element used produce delay of T_b seconds for impulse will have transferFunction exp(-j$2\pi f T_b$)Transfer function of simple filter is 1+exp(-j$2\pi f T_b$),Hence overalltransfer function of this filter connected in cascade with ideal channel $H_c(f)$ is

H(f)=H_c(f)[1+exp(-j$2\pi f T_b$)] ,1 can be written as exp(j$\pi f T_b$) exp(-j$\pi f T_b$) and take exp(-j$\pi f T_b$) common, we get

$$=H_c(f)\,[\exp(j\pi f T_b)+\exp(-j\pi f T_b)]\exp(-j\pi f T_b)$$

$$=2\,H_c(f)\cos(\pi f T_b)\exp(-j\pi f T_b),\ [\frac{e^{j\theta}+e^{-j\theta}}{2}=\cos\theta] \tag{1}$$

For an ideal channel of bandwidth B0=$R_b/2$, we have

$$H_c(f)=\begin{cases}1, & |f|\le R_b/2\\ 0, & otherwise\end{cases} \tag{2}$$

Thus the overall frequency response has the form of a half-cycle cosine function,

$$H(f)=\begin{cases}2\cos(\pi f T_b)\exp(-j\pi f T_b), & |f|\le R_b/2\\ 0, & otherwise\end{cases} \tag{3}$$

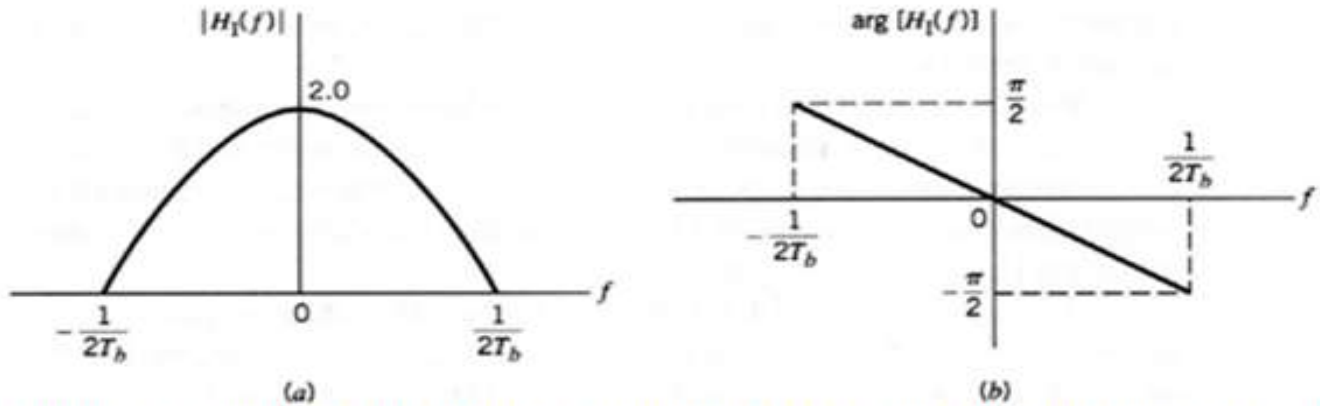

Fig 3: Frequency response of duobinary convertion filters Amplitude and Phase response

Impulse Response

The corresponding value of the impulse response consists of two sinc pulses, time-displaced by T_b seconds,

$$
\begin{aligned}
h(t) &= \frac{\sin(\pi t/T_b)}{\pi t/T_b} + \frac{\sin[\pi(t-T_b)/T_b]}{\pi(t-T_b)/T_b} \\
&= \frac{\sin(\pi t/T_b)}{\pi t/T_b} - \frac{\sin[\pi t/T_b]}{\pi(t-T_b)/T_b} \\
&= \frac{T_b^2 \sin[\pi t/T_b]}{\pi(t-T_b)/T_b}
\end{aligned}
\qquad (4)
$$

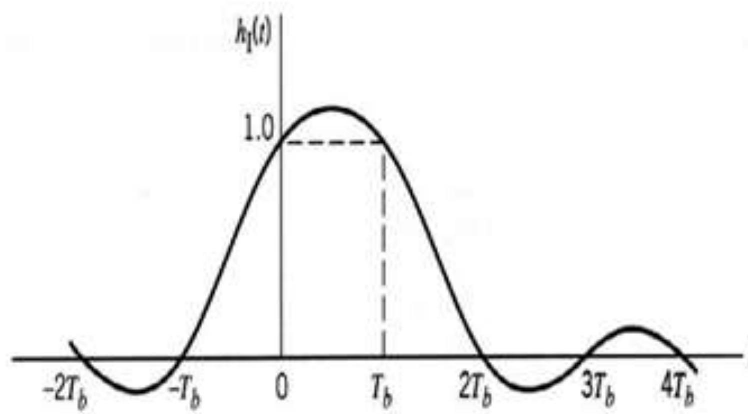

Fig 4: Impulse response of duobinary conversion filter

Decoding

The original data $\{b_k\}$ may be detected from the duobinary-coded sequence $\{c_k\}$ by

$$\hat{b}_k = c_k - \hat{b}_{k-1} \qquad (5)$$

If c_k is received without error and if previous estimate b_{k-1} at time t= (k-1) T_b corresponds to correct decision, then current estimate will be correct. The technique using a stored estimate of the previous symbol is called decision feedback.

Major drawback is error propagation

Differential coding(pre-coding)

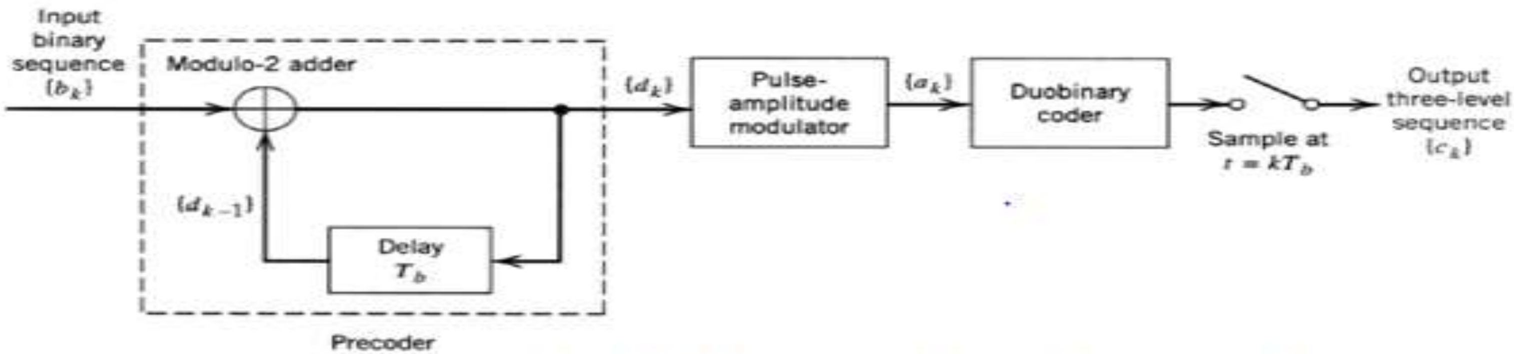

Fig 3: A precodedduobinary scheme

A error propagation can be avoided by using percoding before duobinary coding.Theprecoding operation performed on the input binary sequence $\{b_k\}$ converts it into another binary sequence $\{a_k\}$defined by

$$a_k = b_k + a_{k-1} \qquad \text{modulo-2} \tag{6}$$

Module-2 addition is equivalent to the EXCLUSIVE –OR operation. The resulting precoder output $\{a_k\}$ is next applied to the duobinary coder, thereby producing the sequence $\{c_k\}$ that is related to $\{a_k\}$ as follows:

$$c_k = a_k + a_{k-1} \tag{7}$$

Precoding is nonlinear.

Symbol 0 by -1, Symbol 1 by +1

Therefore from eq (6) and (7) ,

$$c_k = \begin{cases} \pm 2, & if\ b_k\ is\ represented\ by\ symbol\ 0 \\ 0, & if\ b_k\ is\ represented\ by\ symbol\ 1 \end{cases} \tag{8}$$

Decision rule

$$b_k = \begin{cases} symbol\ 0, & if\ |c_k| > 1volt \\ symbol\ 1, & if\ |c_k| < 1volt \end{cases}$$

Modified Duo binary

The modified duobinary technique involves a correlation span of two binary digits.This is achieved by subtracting input binary digits spaced $2T_b$ seconds apart.

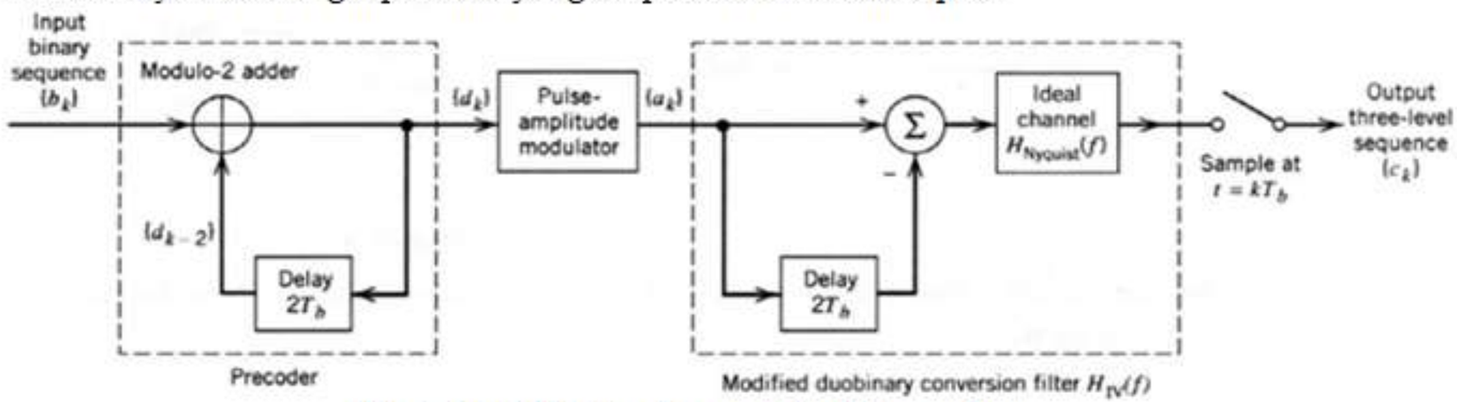

Fig 5: Modified duobinary signalling scheme

The output of the modified duobinary conversion filter is related to the sequence $\{a_k\}$ at its input as follows

$$c_k = a_k - a_{k-2} \qquad (1)$$

Overall transfer function of the tapped-delay line filter connected in cascade with the ideal channel,

$$H(f) = H_c(f)\,[1 - \exp(-j4\pi f T_b)]$$

$$= 2jH_c(f)\sin(2\pi f T_b)\exp(-j2\pi f T_b), \quad \left[\frac{e^{j\theta} + e^{-j\theta}}{2j} = \sin(\theta)\right]$$

Where $H_c(f) = \begin{cases} 1, & |f| \le \frac{R_b}{2} \\ 0, & otherwise \end{cases}$, $H(f) = \begin{cases} 2j\sin(2\pi f T_b)\exp(-j2\pi f T_b), & |f| \le R_b/2 \\ 0, & otherwise \end{cases}$

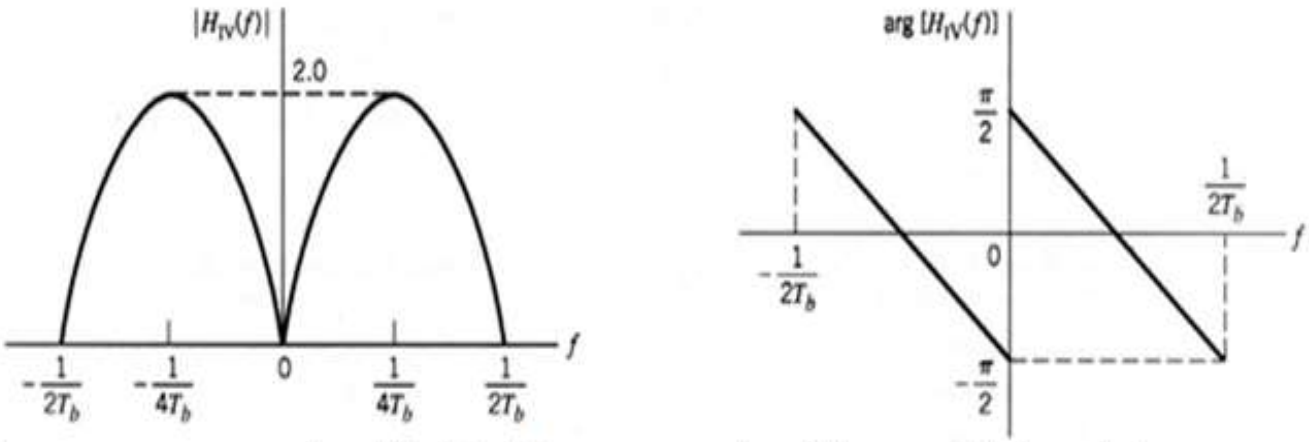

Fig 6: Frequency response of modified duobinary conversion filters amplitude and phase response

<u>Impulse response</u>

The impulse response of the modified duobinary coder consists of two sinc pulses that are time-displaced by $2T_b$ seconds

$$h(t) = \frac{\sin(\pi t/T_b)}{\pi t/T_b} - \frac{\sin(\pi(t-2T_b)/T_b)}{(\pi(t-2T_b)/T_b}$$

$$= \frac{\sin(\pi t/T_b)}{\pi t/T_b} - \frac{\sin(\pi t/T_b)}{(\pi(t-2T_b)/T_b}$$

$$= \frac{T_b^2 \sin(\pi t/T_b)}{(\pi(t-T_b)/T_b}$$

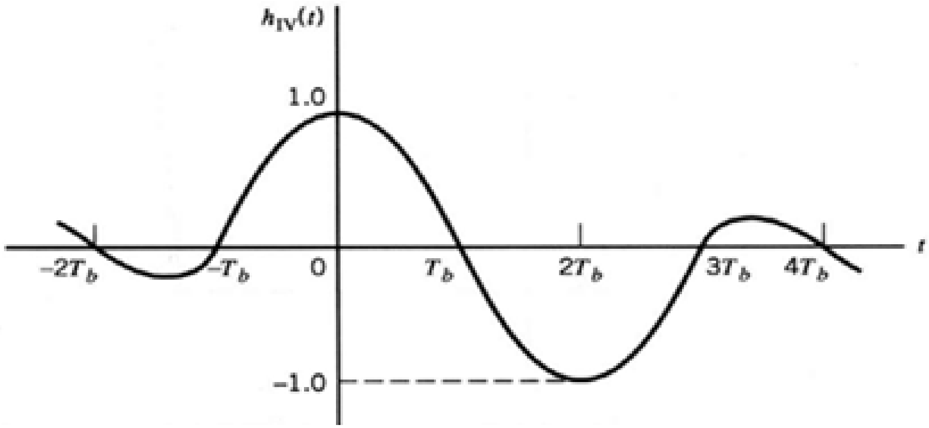

Fig 7: Impulse response of modified duobinary conversion filter

This impulse response shows that it has three distinguishable levels at the sampling instants.

In order to eliminate the possibility of error propagation in the modified duobinary system, precoder is used. Prior to the generation of the modified duobinary signal, a modulo-2 logical addition is used on signals $2T_b$ seconds apart,

$a_k = b_k + a_{k-2}$ modulo-2

The output c_k equals 0, +2 or-2.

$$b_k = \begin{cases} symbol\,0, & if\ |c_k| < 1volt \\ symbol\,1, & if\,|c_k| > 1volt \end{cases}$$

Eye Diagram

- An eye diagram explains the effect of ISI by showing the responses of symbol 0 and 1.
- Eye diagram can be generated by overlaying plots of the received signal for every symbol time period.
- Resultant plot looks like eye. Hence it is called Eye pattern.
- If eye opening is higher, lower the ISI

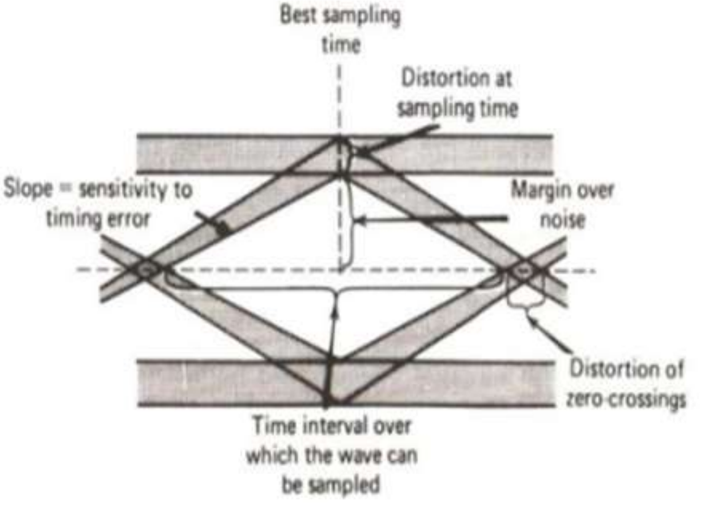

Fig 8:Interpretation of Eye Pattern

- The width of the eye opening defines the time interval over which the received wave can be sampled without error from ISI

- The optimum sampling time corresponds to the maximum eye opening

- The height of the eye opening at a specified sampling time is a measure of the margin over channel noise.

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