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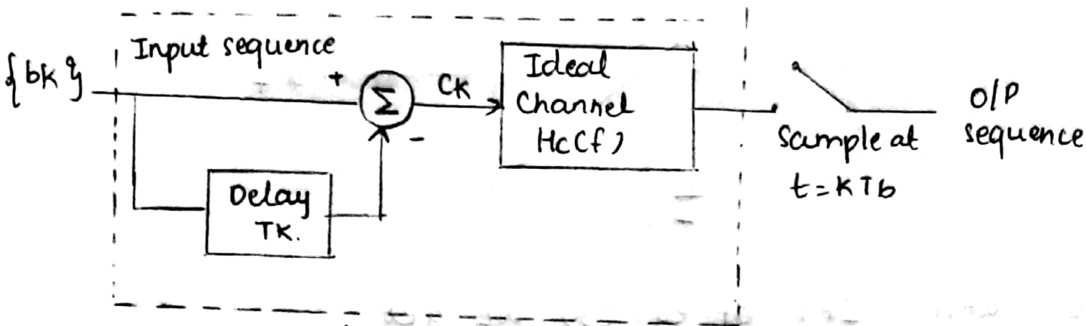
1) Duo- binary signalling :-

Duo- means doubling the transmission capacity.

Consider a binary input sequence $\{b_k\}$ consisting of uncorrelated binary digits each having duration T_b seconds, with symbol 1 represented by a pulse of amplitude +1 volt & symbol 0 by -1V.

When this sequence is applied to a duo-binary encoder, it is converted to a 3-level output namely +2, 0, -2V



Duo binary conversion filter.

The binary sequence $\{b_k\}$ is passed through a simple filter having a single delay element for every unit impulse applied to the i/p of the filter, we get two impulses spaced T_b s apart at the filter o/p.

$$C_k = b_k + b_{k-1} \longrightarrow (1).$$

eq. (1) can be viewed as introducing intersymbol interference into transmitting signal in an artificial manner. However this ISI is under designer's control.

Delay element has T.F $\exp(-j2\pi f T_b)$

$\therefore$ TF of filter $= 1 + e^{-j2\pi f T_b}$.

Overall T.F

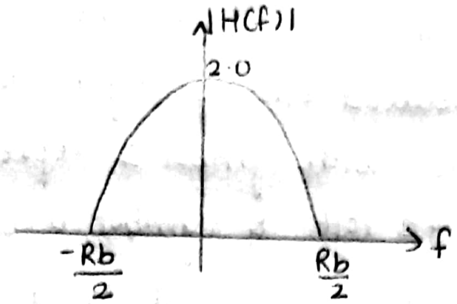
$$H(f) = H_c(f)\left[1 + e^{-j2\pi f T_b}\right].$$

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

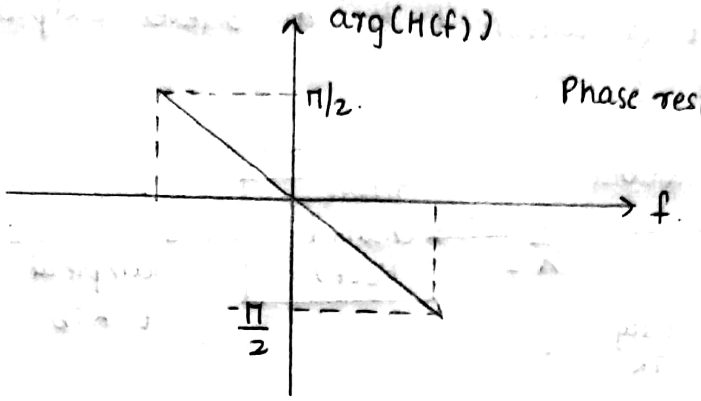
$$H(f) = 2H_c(f)\cos(\pi f T_b)\exp(-j\pi f T_b)$$

For an ideal channel of BW, $B_0 = \frac{R_b}{2}$

$$H_c(f) = \begin{cases} 1 & |f| \le R_b/2 \\ 0 & \text{else} \end{cases} \longrightarrow (3)$$



Amplitude response



Phase response.

By taking IFT of eq. (3) we get

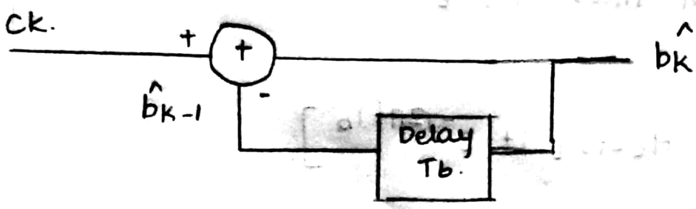
$$h(t) = \frac{T_b^2 \sin(\pi t/T_b)}{\pi t (T_b - t)} \longrightarrow (4).$$

Detection :-

The original data $\{b_k\}$ may be detected from the duo binary-coded sequence $\{c_k\}$ by subtraction of the previous decoded binary digit from the current received digit c_k.

i.e $b_k = c_k - \hat{b}_{k-1} \longrightarrow (5).$

b_k - estimate of original binary digit $\{b_k\}$.



* If the previous estimate is correct then only current estimate will be correct.

* This technique of using a stored estimate of the previous symbol is called decision feed back.

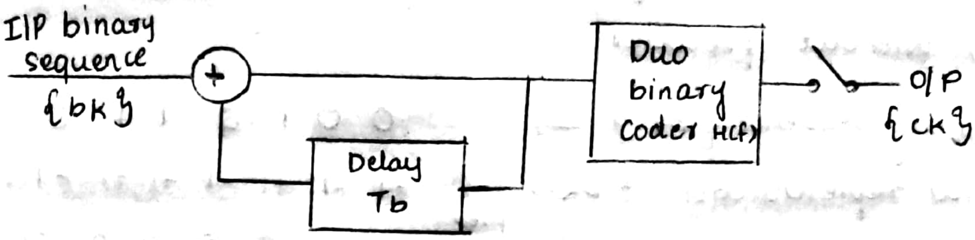
* Main drawback of this detection process is errors tend to propagate.

* To overcome this we use precoding before duo binary coding.

* This precoding operation converts input binary sequence $\{b_k\}$ into another binary sequence $\{a_k\}$ defined by.

$$a_k = b_k \oplus a_{k-1} \longrightarrow (6).$$

moduolo-2. or XOR operation.



Precoder
[non-linear operation]

The pre-coder output $\{a_k\}$ is applied to duo binary coder, there by producing the sequence $\{c_k\}$

$$\text{i.e} \quad c_k = a_k + a_{k-1} \longrightarrow (7).$$

We assume that symbol 1 at the output of precoder is represented by +1 and 0 by -1 then from eq. (6) & (7) we get

$$c_k = \begin{cases} \pm 2\,V & b_k \text{ is symbol } 0 \\ 0\,V & b_k \text{ is symbol } 1 \end{cases}$$

$\{c_k\} \longrightarrow$ Rectifier $\xrightarrow{|c_k|}$ Threshold detector $\longrightarrow \{b_k\}$

Detector consists of a rectifier and threshold detector, o/p of rectifier is compared with a threshold of 1V and original binary sequence $\{b_k\}$ is detected. i.e

$$b_k = \begin{cases} 0 & \text{if } |c_k| > 1V \\ 1 & \text{if } |c_k| < 1V \end{cases}$$

* Main advantage of such a detector is it does not require previous symbol for the recovery of present symbol. Hence error propogation will not occur.

ex:- i/p binary sequence $\{b_k\}$ = 0010110.

1) Without precoder :-

Binary sequence $\{b_k\}$ →		0	0	1	0	1	1	0
Polar representation of b_k →	-1 (prev.)	-1	-1	+1	-1	+1	+1	-1
o/p of duo binary coder $\{c_k\}$ →		-2	-2	0	0	0	2	0
o/p of decoder $\hat{b}_k$ (if no error)	-1 (prev.)	-1	-1	1	-1	+1	1	+1
Corresponding binary sequence		0	0	0	1	0	1	0

Let us assume that error occurs

Received sequence $\{c_k\}$		-2	-2	-2	0	0	2	0
o/p of decoder (with error)	-1 (previous)	-1	-1	-1	1	-1	3	-3
Corresponding binary sequence	x	0	0	0	1	0	1	0

which shows error propogates

With precoder

Binary sequence $\{b_k\}$		0	0	1	0	1	1	0
O/P of precoder $\{a_k\}$	$\boxed{1}$	1	1	0	0	1	0	0
Polar representation of $\{a_k\}$	+1	+1	+1	-1	-1	+1	-1	-1
O/P of duo-binary coder $\{c_k\}$	x	2	2	0	-2	0	0	-2
O/P of decoder (with no error)		0	0	1	$\boxed{0}$	1	1	0

lets assume that error occurs

Received sequence $\{c_k\}$	2	2	0	0	0	0	-2
O/P of detector (with error)	0	0	1	$\boxed{1}$	1	1	0

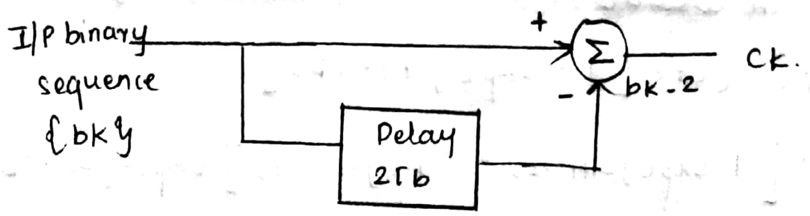
One bit error

∴ It shows error does not propogate.

2) Modified duo-binary technique

This technique involves a correlation span of two binary digits. This is achieved by subtracting input binary digits spaced 2Tb seconds apart as shown in fig.

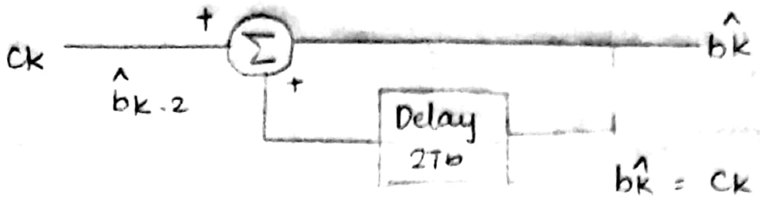
i) Modified duo-binary encoder without precoder



$$O/P \quad C_k = b_k - b_{k-2}.$$

If $b_k = 1V$ for symbol 1 & 0V for 0 we get 3 levels of O/P +2, 0, -2 volts

Decoder:-



$$\hat{b}_k = c_k + \hat{b}_{k-2}$$

If error occurs then this error propogates for other values of b_k.

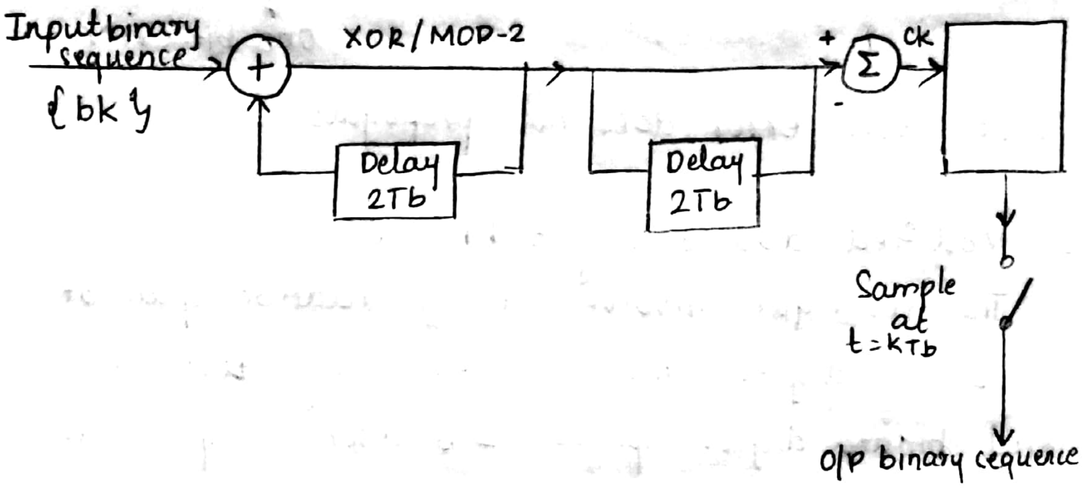
ii) Modified duo-binary encoder with precoder:

o/p of precoder $a_k = b_k \oplus a_{k-2} \rightarrow (1)$.

o/p of modified duo-binary system

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

c_k takes one of 3 values i.e $+2, 0, -2V$ for $a_k = \pm 1V$



Overall T.F of the tapped delay time filter connected in cascade with ideal channel is given by

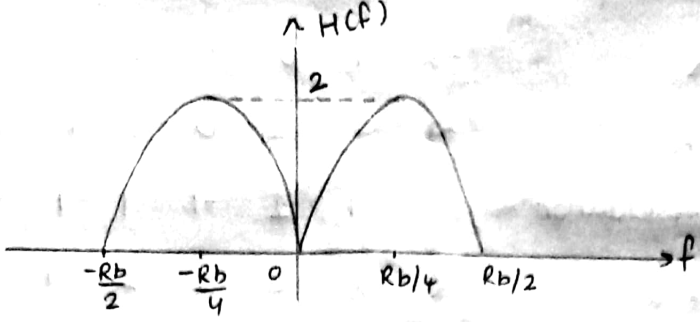
$$H(f) = H_c(f)\left[1 - \exp(-j4\pi f T_b)\right]$$

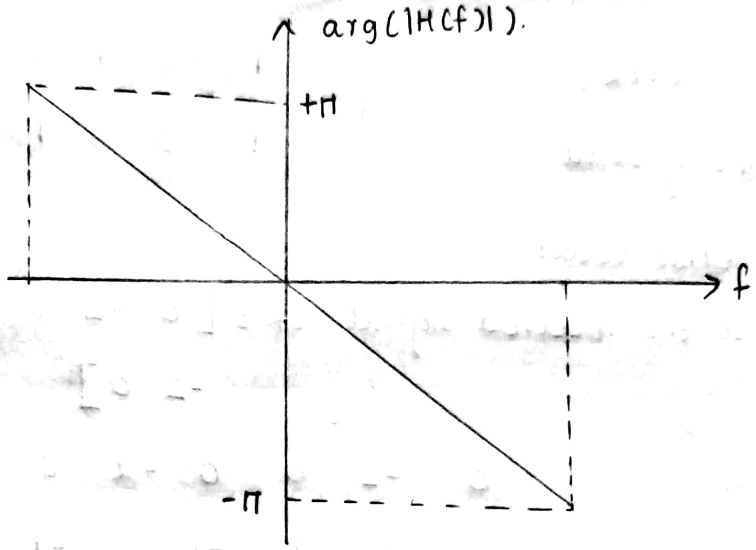
$$= H_c(f)\left[1 \cdot \exp(j2\pi f T_b) - \exp(-j2\pi f T_b)\right]\exp(-j2\pi f T_b)$$

$$\Rightarrow 2j\, H_c(f) \sin(2\pi f T_b) \exp(-j2\pi f T_b). \rightarrow (3)$$

where $$H_c(f) = \begin{cases} 1 & |f| \leq R_b/2 \\ 0 & \text{else} \end{cases} \rightarrow (4)$$

$$H(f) = \begin{cases} 2j \sin(2\pi f T_b) \exp(-j2\pi f T_b), & |f| \le R_b/2 \\ 0 & , \text{else} \end{cases}$$





Taking IFT of eq(5) we get

$$h(t) = \frac{2T_b^2 \sin(\pi t/T_b)}{\pi t (2T_b - t)} \rightarrow (6).$$

Detection:-

$c_k \rightarrow$ Rectifier $\xrightarrow{|c_k|}$ Threshold detector. $\rightarrow b_k$

Incoming bit c_k is rectified & threshold detector compares $|c_k|$ with a threshold of 1V.

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

Example :- bk = { 1 0 1 1 0 1 1 0 1 }

1) Without precoder (with no error)

K	-2 -1 0 1 2 3 4 5
bK	1 0 1 1 0 1 1 0 1
Polar representation	-1 -1 1 -1 1 1 -1 1 1 -1 1
	1 1 1 -1 1 1 -1 1 1 -1 1
bK-2	x x 1 1 1 -1 1 1 -1 1 1
	x x 0 -2 0 2 -2 0 +2 0
$cK = bK - bK-2$	1 -1 1 1 -1 1 1 -1 1
$\hat{bK} = cK + \hat{bK}_{-2}$	1 -1 1 1 -1 1 1 -1 1
binary data	1 0 1 1 0 1 1 0 1

If error occur

Let the received signal $Ck = [0\ -2\ 0\ 0\ -2\ 0\ +2\ -2\ 0]$

CK			0	-2	0	0	-2	0	2	-2	0.
$\hat{bK}$	1	1	1	-1	1	-1	-1	-1	1	-3	1.
binary data			1	0	1	0	0	0	1	0	1.

error propogates

2) With precoder

k	-2 1 0 1
b_k	1 0 1 1 0 1 1 0 1
$a_k = b_k \oplus a_{k-2}$	0 1 1 1 0 0 0 1 1 1 0
Polar representation	1 1 -1 -1 -1 1 1 1 -1
a_{k-2}.	0 1 1 1 0 0 0 1 1 1 0
Polar representation	-1 1 1 1 -1 -1 -1 1 1 1
$c_k = a_k - a_{k-2}$	2 0 -2 -2 0 2 2 0 2
o/p of decoder (if no error).	1 0 1 1 0 1 1 0 1.

If error occurs

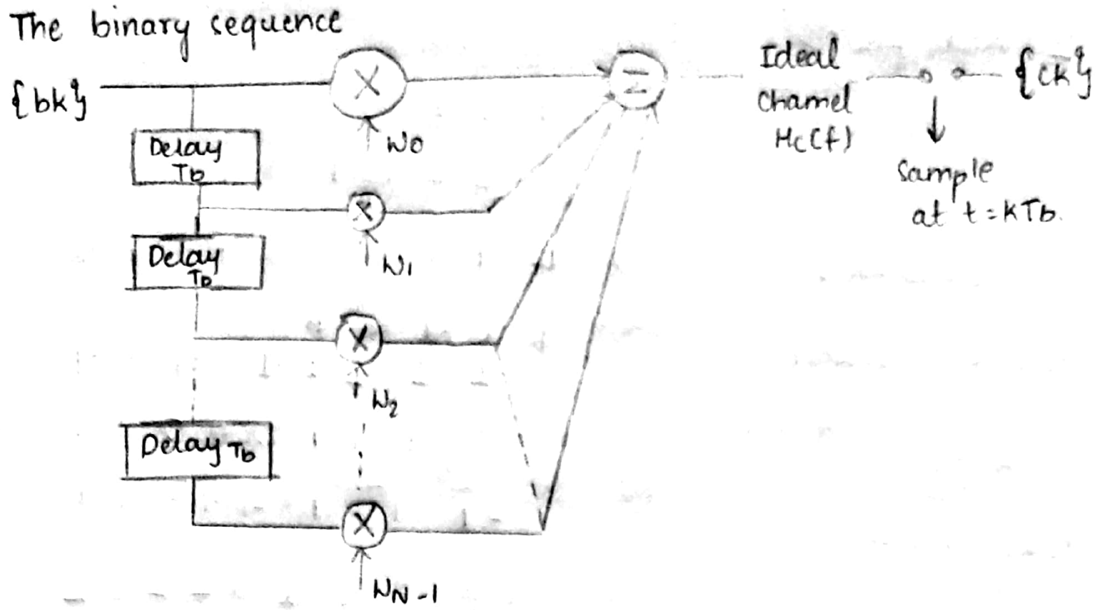
Let c_k =	2 0 0 2 0 2 2 0 -2
o/p of decoder	1 0 $\boxed{0}$ 1 0 1 1 0 1

only one bit error

Error does not propogate

3) Generalised form of correlative coding.

The duo-binary and modified duo-binary techniques have correlation spans of 1 and 2 binary digits. In general we can have any no. of correlation spans.



The generalized coding scheme involves the use of tapped-delay line filter with tap weights.

$w_0, w_1, \ldots w_{n-1}$

Correlative sample c_k is obtained from a super position of N successive i/P samples given by

$$c_k = \sum_{n=0}^{N-1} w_n b_{k-n}.$$

$\therefore$ By choosing various combinations of int values for the w_n, we obtain different forms of correlative coding schemes. ex:- For duo binary coding $w_0 = -1$
$w_1 = +1$

For modified duobinary scheme, $w_0 = +1$ $w_2 = -1$
$w_1 = 0$ $w_n = 0, n \geq 3$.

Eye pattern :- Eye pattern is used to study the effect of ISI in base band transmission. Received wave is applied to the vertical deflection plates of an oscillosope and a saw tooth wave with a tranemission symbol rate, $R = 1/T$ to the horizontal deflection plates. The waveforms in successive symbol intervals are there by translated into one interval on the oscilloscope display as in fig. The resulting display is called an eye system.