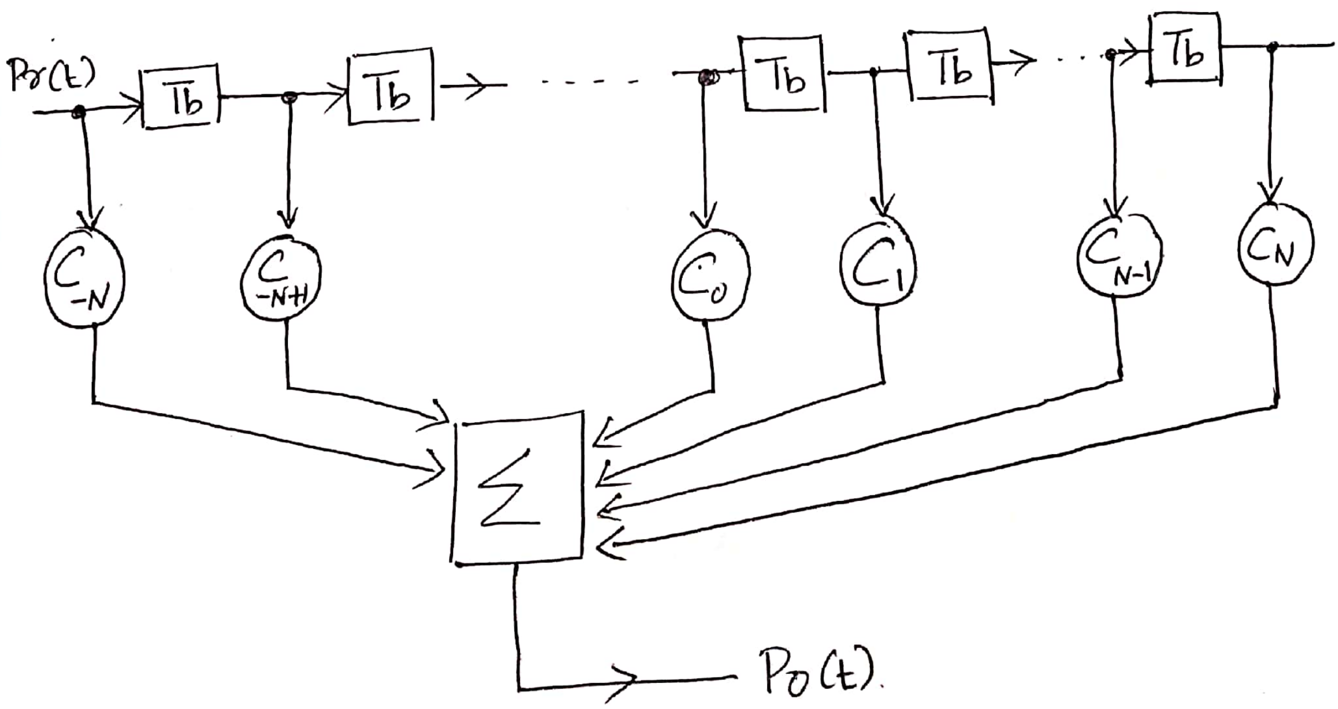
Zero forcing Equalization.

→ When we transmit nyquist criterion pulse for zero ISI through communication channel, then because of channel non-linearities, distortion in the pulse occurs.

→ In other words, pulse which is present at the receiver input is a distorted pulse with non zero values at sampling instants.

→ In order to compensate these distortions at the receiver. In order to get back the nyquist criterion pulse, we use equalizer.

→ One such equalizer is a Zero- forcing Equalizer as shown as,



Fig(1) ⇒ Zero Forcing Equalizer

→ where $P_r(t)$ = input pulse

$P_o(t)$ = output pulse

T_b = Delay Elements

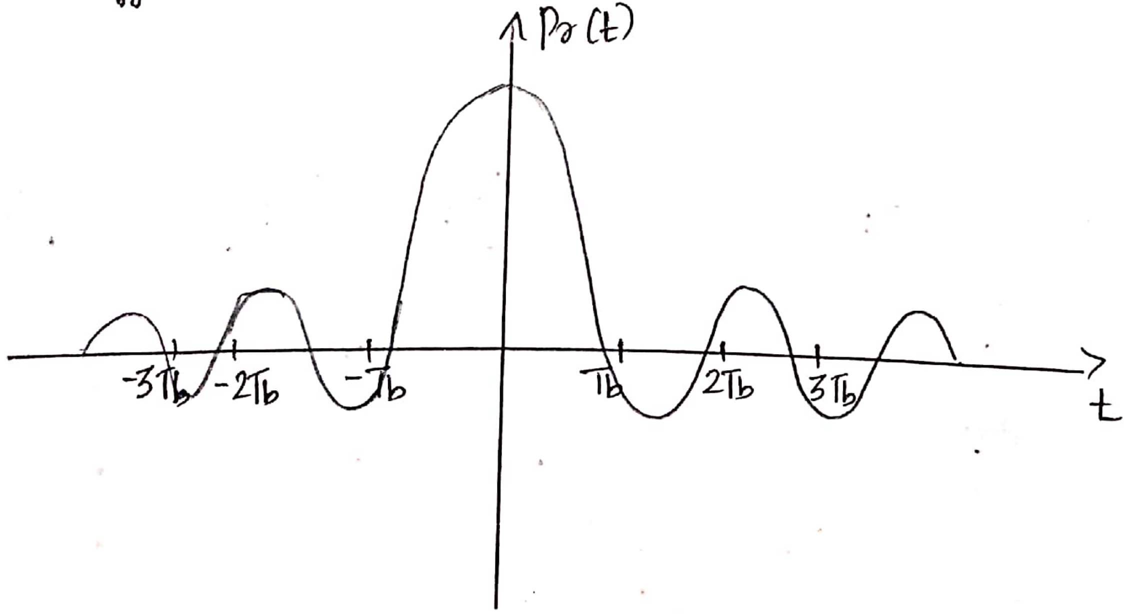
$C_{-N}, C_{-N+1} \cdots C_N$ = Coefficients

→ For zero ISI pulse, we need to select these coefficients in such a way that, the output pulse must satisfy nyquist criteria.

→ The structure shown above is like a tap-delay line filter or FIR filter. It has $-N$ to $+N$ coefficients or taps. ie $2N+1$ taps ⇒ $2N+1$ tap equalizer.

→ Here the number of delay elements are $2N$ while the coefficients are $2N+1$.

→



Fig(2) ⇒ Received Pulse

→ Consider a pulse $P_r(t)$ shown above, we can understand seen that at the sampling instant T_b is not zero, at $2T_b$ is not zero, at $3T_b$ it is not zero & so on... ||rly in negative side also.

→ This implies that, $P_r(t)$ is not a nyquist criterion pulse at the receiver input.

→ So we need to design the equalizer in such a way that, at these sampling instants, the values must be zero. so the effect of ISI can be removed.

→ From the figure (1), the o/p pulse $P_o(t)$ can be written as,

$$P_o(t) = \sum_{n=-N}^{+N} C_n P_r(t - nT_b) \qquad (1)$$

→ At sampling instant, $t = kT_b$, where k is an integer, where $k = 0, \pm 1, \pm 2 \ldots\ldots$

$$P_o(kT_b) = \sum_{n=-N}^{+N} C_n P_r(kT_b - nT_b) \qquad (2)$$

→ If $kT_b = k$ & $nT_b = n$, we can rewrite eqn (2) as,

$$P_o(k) = \sum_{n=-N}^{+N} C_n P_r(k - n) \; ; \; k = 0, \pm 1, \pm 2 \ldots \qquad (3)$$

where n = Tap values $[-N$ to $N]$

k = Sampling instants

→ The aim is to choose the value of coefficient C_n in such a way that the o/p pulse $P_o(k)$ satisfy the nyquist criteria.

→ The nyquist criteria is defined by,

$$\left.\begin{aligned} P_o(k) &= 1 \quad ; k = 0 \\ &= 0 \quad ; k \neq 0 \end{aligned}\right\} \quad \text{——} \quad (4)$$

→ Expanding the eqn. (3) for different values of k from $-N$ to $+N$.,

$$P_o(-N) = C_{-N} P_r(0) + C_{-N+1} P_r(-1) + \cdots\cdots + C_N P_r(-2N)$$

$$P_o(-N+1) = C_{-N} P_r(1) + C_{-N+1} P_r(0) + \cdots\cdots + C_N P_r(-2N+1)$$

(5)

→ The above eqns. (5), can be written in matrix form as,

$$\begin{bmatrix} 0 \\ 0 \\ \vdots \\ 1 \\ \vdots \\ 0 \end{bmatrix} = \begin{bmatrix} P_r(0) & P_r(-1) & \cdots & P_r(-2N) \\ P_r(1) & P_r(0) & \cdots & P_r(-2N+1) \\ \vdots & & & \\ \vdots & & & \\ P_r(2N) & \cdots & \cdots & P_r(0) \end{bmatrix} \begin{bmatrix} C_{-N} \\ C_{-N+1} \\ \vdots \\ C_0 \\ \vdots \\ C_N \end{bmatrix}$$

(6)

→ Eqn (6) shows P_r matrices, Coefficients matrices & P_o matrices.

→ The condition P_o for the given values & P_r, we can easily find out the values of coefficients from C_{-N} to C_N. & then condition of Nyquist criterion will satisfied.

Example

a) Design a three tap zero forcing equalizer if following is given :

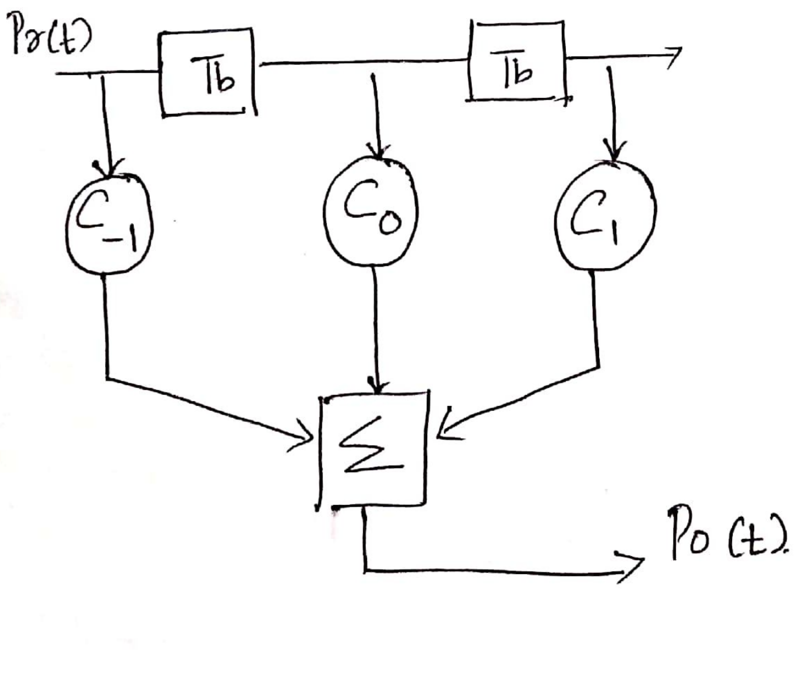
$P_r[0] = 1$ $\qquad$ $P_r[2] = 0.1$

$P_r[-1] = -0.2$ $\qquad$ $P_r[-2] = 0.05$

$P_r[1] = -0.3$

∴ Here $2N+1 = 3$ ⇒ $N = 1$ ⇒ $2N$ ⇒ 2 Delay Elements.

First step : Structure of a 3-tap Equalizer



Step 2 : Put the values or parameters into the matrices of the form,

$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} = \begin{bmatrix} P_r(0) & P_r(-1) & P_r(-2) \\ P_r(1) & P_r(0) & P_r(-1) \\ P_r(2) & P_r(1) & P_r(0) \end{bmatrix} \begin{bmatrix} C_{-1} \\ C_0 \\ C_1 \end{bmatrix}$$

Putting the values,

$$\begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix} = \begin{bmatrix} 1 & -0.2 & 0.05 \\ -0.3 & 1 & -0.2 \\ 0.1 & -0.3 & \cdot 1 \end{bmatrix} \begin{bmatrix} C_{-1} \\ C_0 \\ C_1 \end{bmatrix}$$

→ Solving these equations :

$$0 = 1 \cdot C_{-1} + -0.2 C_0 + 0.05 C_1$$

$$1 = -0.3 C_{-1} + 1 C_0 + -0.2 C_1$$

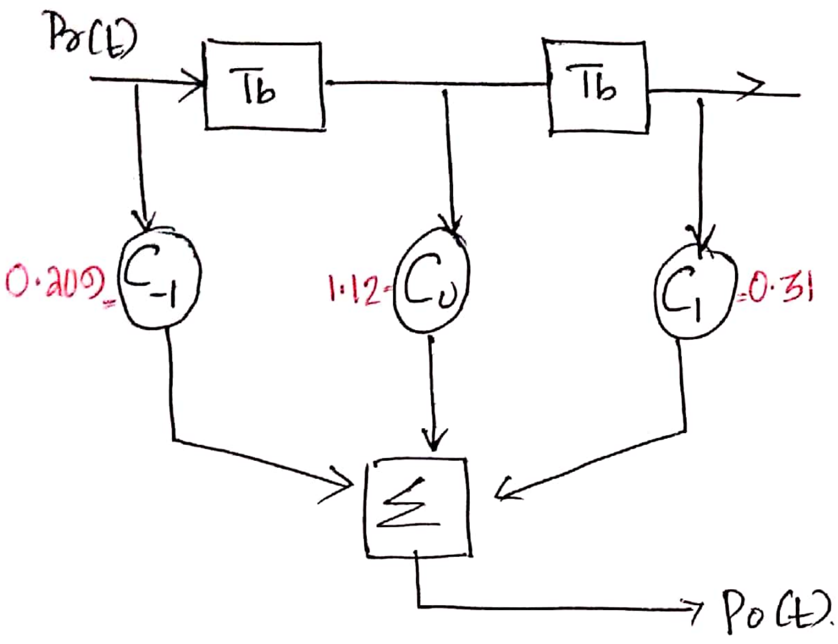
$$0 = 0.1 C_{-1} + -0.3 C_0 + 1 C_1$$

$$\Rightarrow \quad C_{-1} = 0.209$$

$$C_0 = 1.12$$

$$C_1 = 0.31$$

Scanned by CamScanner



→ The name Zero forcing corresponds to bringing down the intersymbol interference (ISI) to zero.

→ Disadvantages of ZF Equalizers

* The zero-forcing equalizer removes all ISI, & is ideal when the channel is noiseless.

* When the channel is noisy, the zero-forcing equalizer will amplify the noise greatly at frequencies f where the channel response $H(j2\pi f)$ has a small magnitude in the attempt to invert the channel completely.