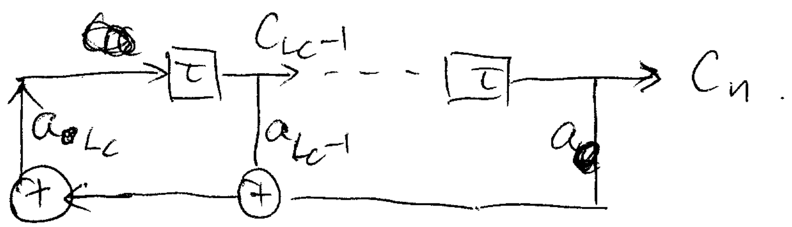
3. CDMA Rake Receiver

3.1. PN code design

- With feedback-shifting register to generate m-sequence with max. length 2^{L_c}.

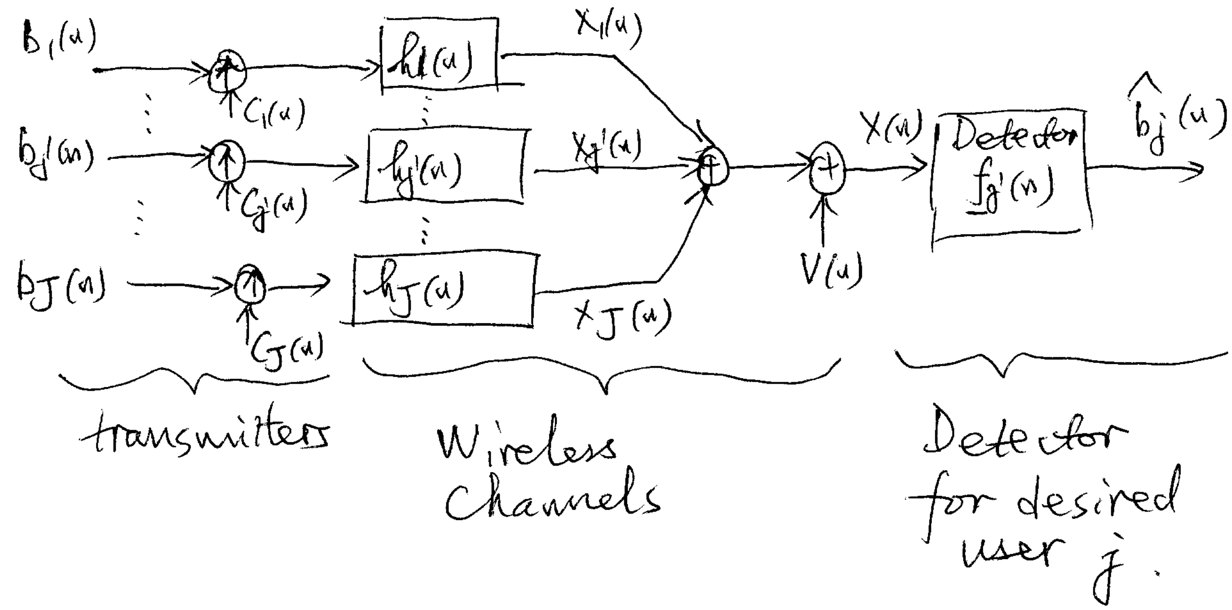


$$C_n = \sum_{i=0}^{L_c} a_i C_{n-i}.$$

- Study sample program longcode.m

3.2. CDMA Rake Receiver

3.2.1. CDMA Signal structure



- Signal from user j: $(1 \le j \le J)$

$$s_j(n) = c_j(n)\, b_j(\lfloor n/p \rfloor),$$ where $\lfloor \frac{n}{p} \rfloor$: the max integer which is less than $\frac{n}{p}$

$$x_j(n) = [h_j(0) \cdots h_j(L)] \begin{bmatrix} s_j(n) \\ \vdots \\ s_j(n-L) \end{bmatrix}$$

- Received Signal.

$$x(n) = \sum_{j=1}^{J} x_j(n) + v(n)$$

3.2.2. Rake Receiver

- From timing of user j, construct sample matrix for $\underline{n = kp + L}$, $k = 0, 1, 2, \ldots$

i) $$\underset{(L+1)\times 1}{\underline{X}(n)} = \begin{bmatrix} x(n) \\ \vdots \\ x(n-L) \end{bmatrix} = \sum_{j=1}^{J} \begin{bmatrix} h_j(0) & \cdots & h_j(L) & & \\ & \ddots & & \ddots & \\ & & h_j(0) & \cdots & h_j(L) \end{bmatrix} \begin{bmatrix} s_j(n) \\ \vdots \\ s_j(n-2L) \end{bmatrix} + \underline{V}(n)$$

$$\left[\underline{X}(n) = \sum_{j=1}^{J} \mathcal{H}_j \, \underline{S}_j(n) + \underline{V}(n) \right]$$

$\underline{X}(n)$: $(L+1)\times 1$, $\mathcal{H}_j$: $(L+1)\times(2L+1)$, $\underline{S}_j(n)$: $(2L+1)\times 1$

ii) $$\underset{(L+1)\times p}{\underline{\underline{X}}(n)} = [\underline{X}(n) \cdots \underline{X}(n+p)] = \sum_{j=1}^{J} \mathcal{H}_j \underline{\underline{S}}_j(n) + \underline{\underline{V}}(n)$$

$\mathcal{H}_j$: $(L+1)\times(2L+1)$, $\underline{\underline{S}}_j(n)$: $(2L+1)\times p$, $\underline{\underline{V}}(n)$: $(L+1)\times p$

iii) $$\underline{\underline{X}}(n) = \mathcal{H}_j \begin{bmatrix} c_j(n) b_j(k+1) & \cdots & c_j(n+p) b_j(k+1) \\ \vdots & & \vdots \\ c_j(n-L) b_j(k) & \cdots & c_j(n-L+p) b_j(k) \\ \vdots & & \vdots \\ c_j(n-2L) b_j(k-1) & \cdots & c_j(n-2L+p) b_j(k) \end{bmatrix} + \sum_{\substack{i=1 \\ i \neq j}}^{J} \mathcal{H}_i \underline{\underline{S}}_i(n) + \underline{\underline{V}}(n)$$

The $(L+1)^{th}$ row contain symbol $b_j(k)$ only

• Detector: $\underline{f}_j(n) = \begin{bmatrix} g_j'(n-L) \\ \vdots \\ g_j'(n-L+p) \end{bmatrix} \frac{1}{P}$

i) $\underline{y}(n) = \underline{X}(n)\, \underline{f}_j'(n) = \begin{bmatrix} h_j'(L) \\ \vdots \\ h_j'(0) \end{bmatrix} b_j'(k)$ + residual ISI MAI

$\underline{y}$: $(L+1)\times 1$, $\underline{X}$: $(L+1)\times p$, $\underline{f}_j$: $p\times 1$

ii) Channel estimation from

$$R_y = E[\underline{y}(n)\, \underline{y}^H(n)] \longrightarrow \begin{bmatrix} h_j'(L) \\ \vdots \\ h_j'(0) \end{bmatrix} [h_j'^*(L) \cdots h_j'^*(0)]$$

estimated channel $\underline{\hat{h}} \rightarrow \begin{bmatrix} h_j'(L) \\ h_j'(0) \end{bmatrix}$

iii) Symbol estimation:

$$\hat{b}_j'(k) = \underline{\hat{h}}^H \underline{y}(n)$$

$$= \underline{\hat{h}}^H \underline{X}(n)\, \underline{f}_j(n)$$

- Sample Program

  i) Construct received samples $x(n)$

  ii) Construct ~~symbol vector~~ sample matrix $\underline{X}(n)$

  Rake Receiver:

  iii) Calculate $\underline{y}(n)$

  iv) Estimate channel $\hat{\underline{h}}$

  v) Estimate symbol $\hat{b}_j(k)$

  vi) Check SER.

- Draw plots of:

  SER ~ SNR

  SER ~ J (# of users)