Multi-User Receiver

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Multi-User Receiver

- A Conventional receiver is designed for a AWGN channel, not a co-channel interference limited environment

- In a multiuser environment,

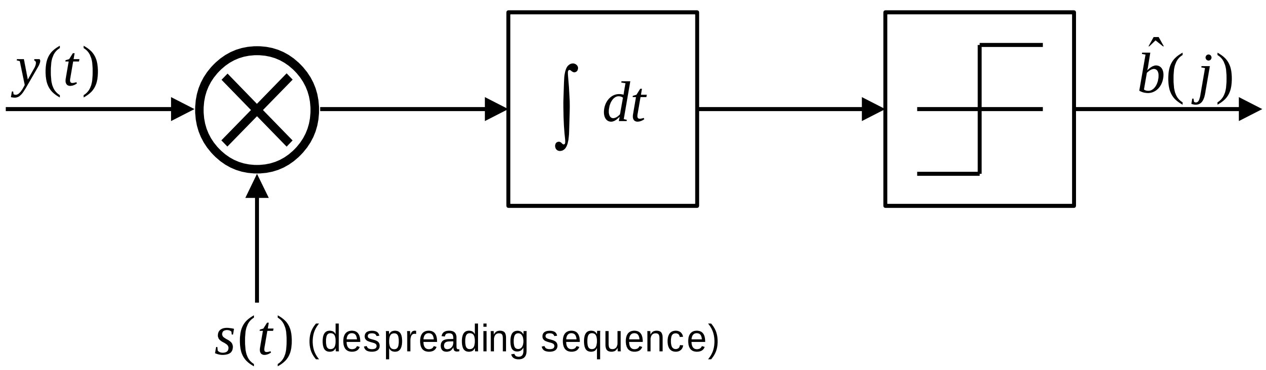
  a conventional receiver is acceptable, if multiuser interference can be modeled as white Gaussian noise

  - Energies of received signals are not dissimilar
  - Cross correlation of signature waveforms is low

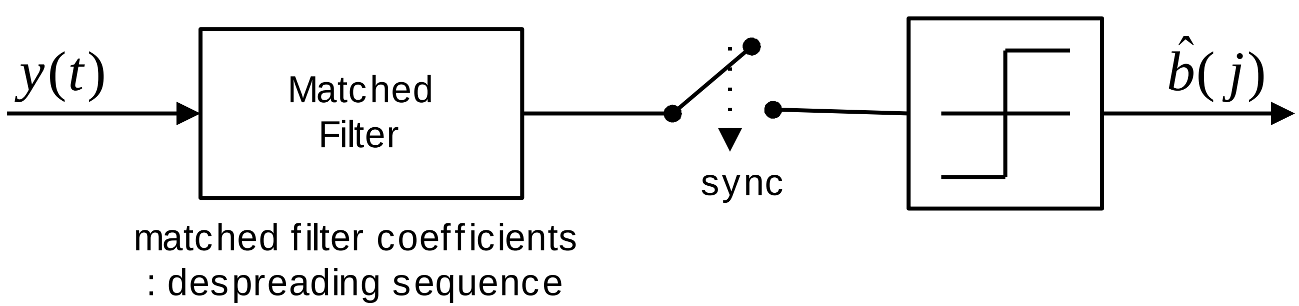
Receiver Types

- Conventional receiver
- Multi-stage detection
- MMSE detection
- Optimum receiver
- Decorrelator

Conventional Single User Receiver



<Correlator type>



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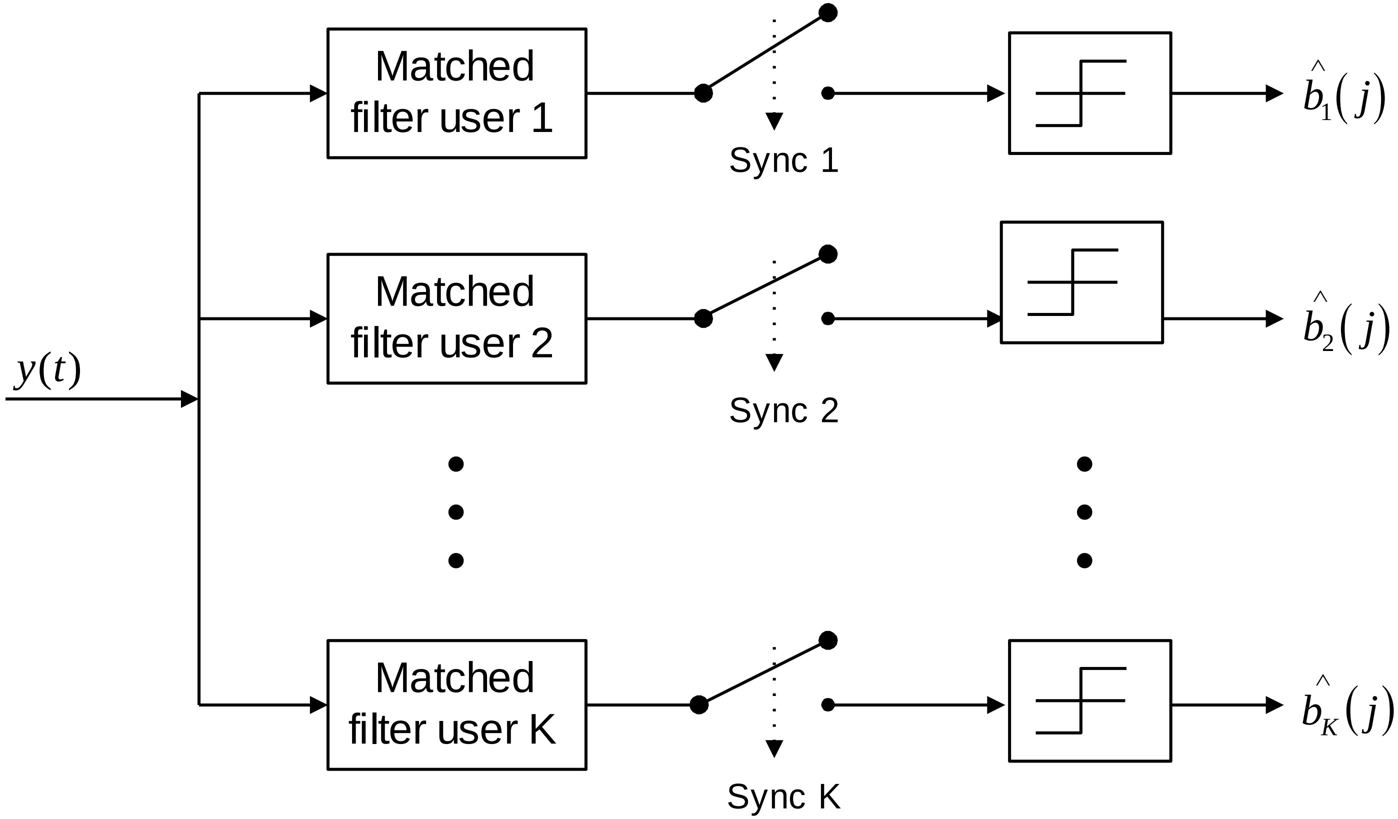
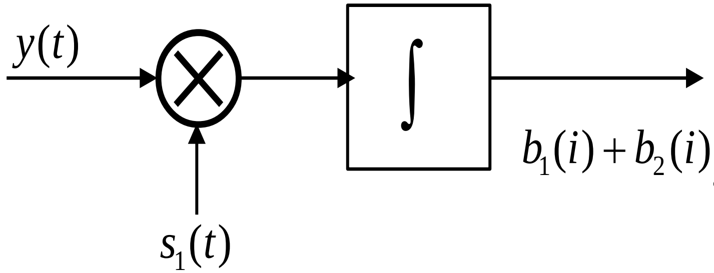
Conventional Multi-User Receiver



Conventional Receiver : Issues
(Two user case)

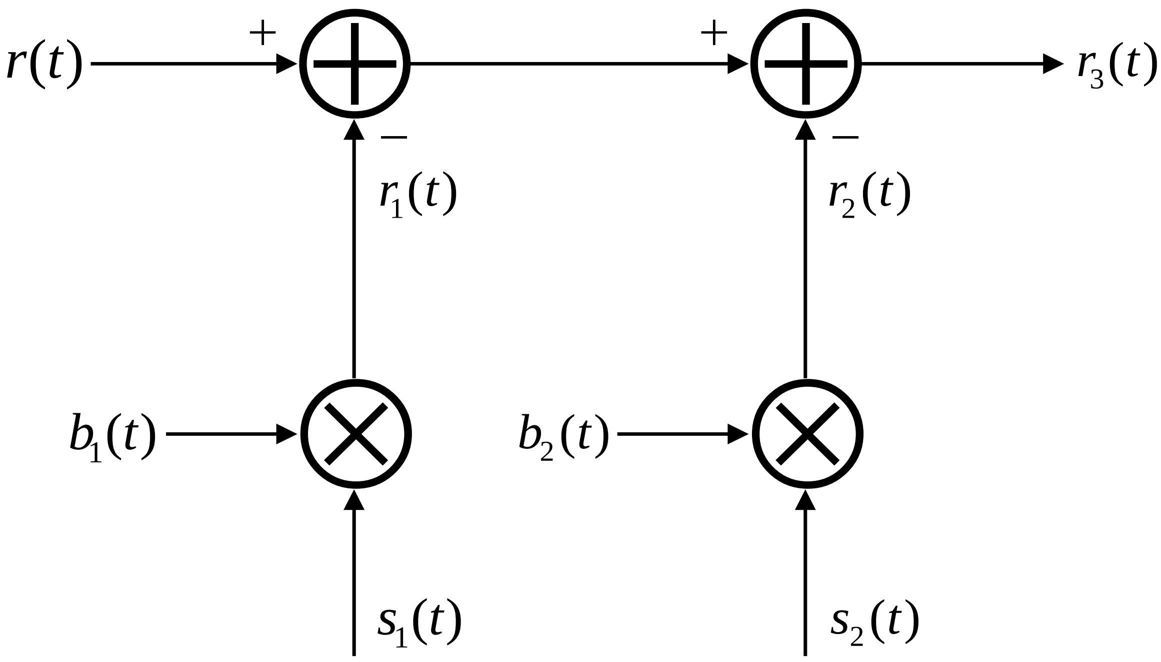
- Asynch. $$y(t) = \sum_{i=-M}^{M} b_1(i) s_1(t - iT - \tau_1) + \sum_{i=-M}^{M} b_2(i) s_2(t - iT - \tau_2) + n(t)$$
- Synch. $$y(t) = \sum_{i=-M}^{M} b_1(i) s_1(t - iT) + \sum_{i=-M}^{M} b_2(i) s_2(t - iT) + n(t)$$



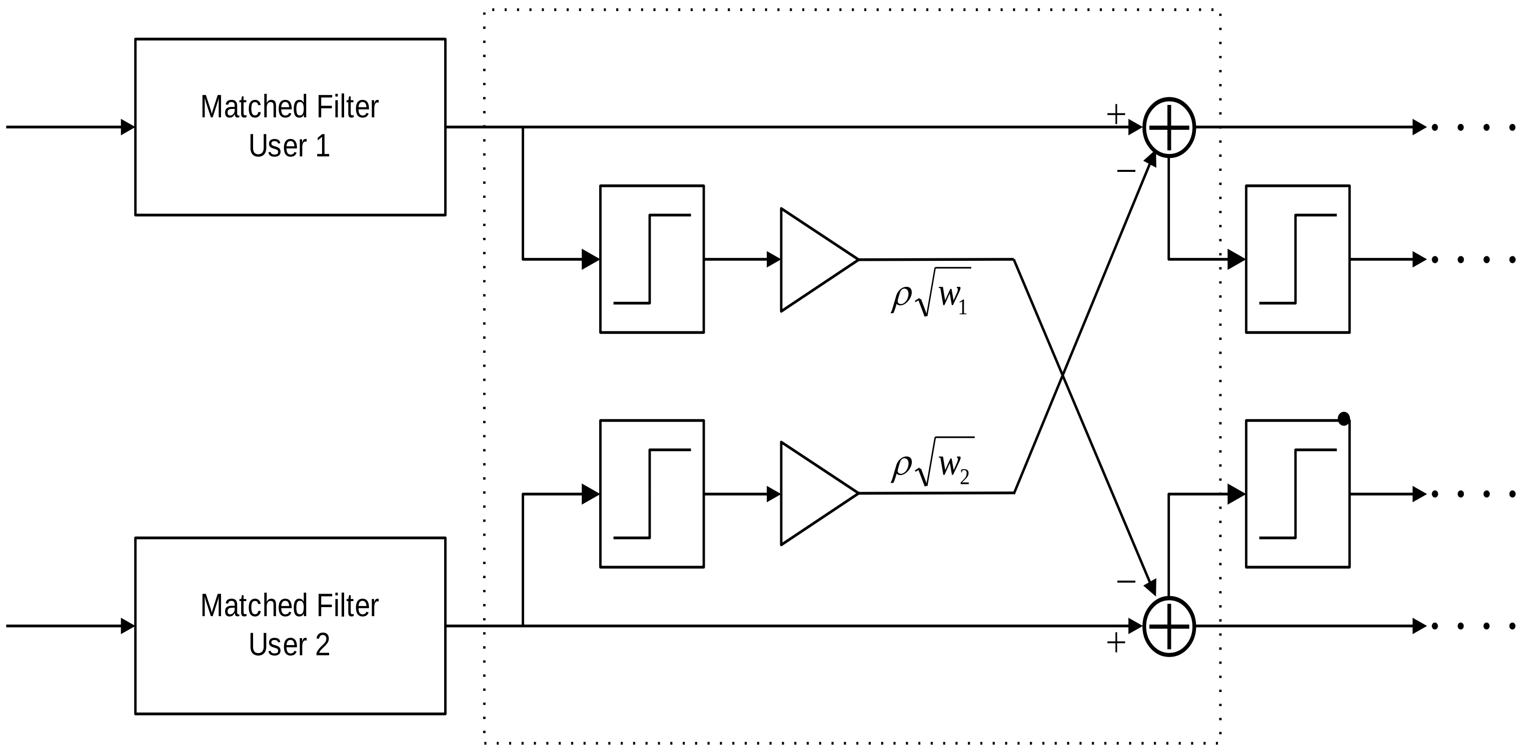
$$b_1(i) + b_2(i) \int s_1(t - iT) s_2(t - iT) dt + \int n(t) s_1(t) dt$$

- Crosscorrelation is not zero
- IS-95 downlink, uplink
- power control
- Walsh sequence

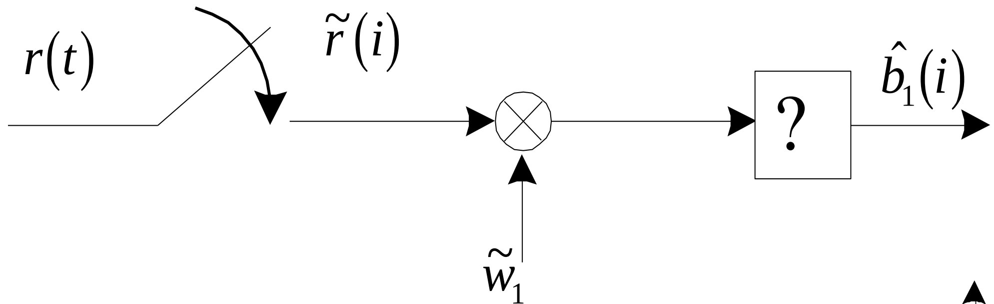
Multi-stage Receiver

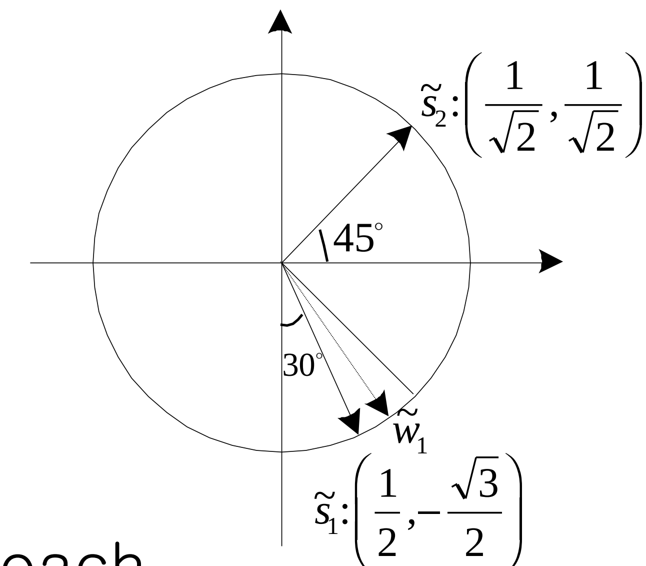


Multi-stage Receiver (Cont'd)



MMSE Receiver





Find $\tilde{w}_1$ minimizing

$$E\left[\left(b_1(i) - \hat{b}_1(i)\right)^2\right] = E\left[\left(b_1(i) - \tilde{r}^T(i)\tilde{w}_1\right)^2\right]$$

No a priori knowledge required

Adaptive signal processing approach

ML receiver

$$\text{Prob}\left(r|d_i\right) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left(-\frac{1}{2\sigma^2}\left(r-d_i\right)^2\right)$$

Choose "d_i" which maximizes $\text{prob}(r|d_i)$

(Ex) 2users

Possible Tx Signals: (3,1), (3,−1), (−3,1), (−3,−3)

Rx Signal	Likely Tx signal
4	(3, 1)
2	(3, −1)
−2	(−3, 1)
−4	(−3,−1)

- Synchronous two-user case

Choose $b_1(i)$ & $b_2(i)$ which minimizes

$$\int_{iT}^{(i+1)T} \left(r(t) - b_1(i)s_1(t) - b_2(i)s_2(t)\right)^2 dt$$

- Asynchronous two-user case

Find $b_1(i)$ & $b_2(i)$ for $i=-M,\ldots M$ which minimizes

$$\int \left(r(t) - \sum_{k=1}^{2} \sum_{i=-M}^{M} b_k(i) s_k(t - iT - \tau_k) \right)^2 dt$$

Decorrelating receiver

- Received signal for a two user case

$$r(t) = \sum_{i=-M}^{M} b_1(i) s_1(t - iT) + \sum_{i=-M}^{M} b_2(i) s_2(t - iT) + n(t)$$

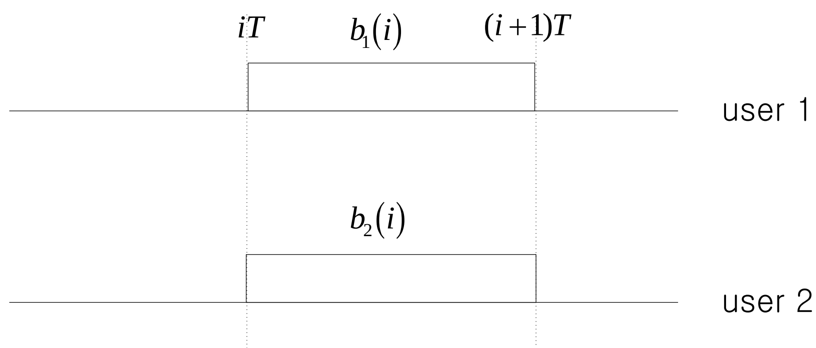
$s_1(t), s_2(t)$: Spreading waveforms, $\int_0^{T_b} s_1^2(t)\,dt = 1$

$b_1(i), b_2(i)$: Symbol sequences

$\left\{-\sqrt{\omega_1}, \sqrt{\omega_1}\right\}, \left\{-\sqrt{\omega_2}, \sqrt{\omega_2}\right\}$, ω_k : received energy per bit

$$y_1(i) = \int_{iT}^{(i+1)T} r(t) s_1(t - iT)\, dt$$

$$= b_1(i) + \int_{iT}^{(i+1)T} \sum b_2(i) s_2(t - iT) s_1(t - iT)\, dt + \text{noise term}$$



$$\rho = \int_0^T s_1(t) s_2(t)\, dt$$

$$y_1(i) = b_1(i) + \rho b_2(i) + \text{noise term}$$

$$y_2(i) = b_2(i) + \rho b_1(i) + \text{noise term}$$

$$\begin{bmatrix} y_1(i) \\ y_2(i) \end{bmatrix} = \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix} \begin{bmatrix} b_1(i) \\ b_2(i) \end{bmatrix} + \begin{bmatrix} n_1(i) \\ n_2(i) \end{bmatrix}$$

$$\tilde{H} \equiv \begin{bmatrix} 1 & \rho \\ \rho & 1 \end{bmatrix}, \quad y(i) \equiv \begin{bmatrix} y_1(i) \\ y_2(i) \end{bmatrix}, \quad \tilde{b}(i) \equiv \begin{bmatrix} b_1(i) \\ b_2(i) \end{bmatrix}, \quad \tilde{n}(i) \equiv \begin{bmatrix} n_1(i) \\ n_2(i) \end{bmatrix}$$

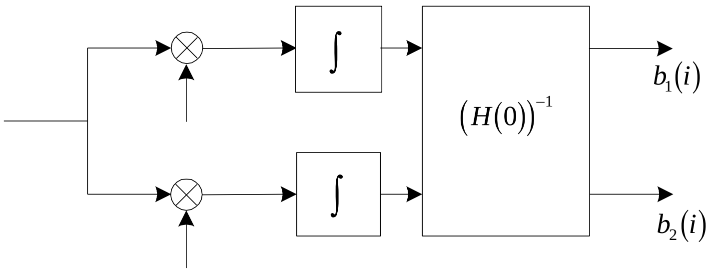
$$\tilde{y}(i) = \tilde{H} \cdot \tilde{b}(i) + \tilde{n}(i)$$

- Synchronous case

$$\tilde{y}(i) = \tilde{H}(0)\cdot\tilde{b}(i) + \tilde{n}(i)$$

Ignoring $\tilde{n}(i)$,

$$\tilde{b}(i) = \left(\tilde{H}(0)\right)^{-1}\tilde{y}(i)$$



$$\left(\tilde{H}(0)\right)^{-1} = \frac{1}{1-\rho_{12}^2}\begin{bmatrix}1 & -\rho_{12}\\ -\rho_{12} & 1\end{bmatrix}$$

$$\tilde{b}(i) = \frac{1}{1-\rho_{12}^2}\begin{bmatrix}1 & -\rho_{12}\\ -\rho_{12} & 1\end{bmatrix}\begin{bmatrix}y_1(i)\\ y_2(i)\end{bmatrix} = \frac{1}{1-\rho_{12}^2}\begin{bmatrix}y_1(i)-\rho_{12}y_2(i)\\ -\rho_{12}y_1(i)+y_2(i)\end{bmatrix}$$

$$\operatorname{sgn}\left(\tilde{b}(i)\right) = \operatorname{sgn}\left(\left(\tilde{H}(0)\right)^{-1}\tilde{y}(i)\right)$$