TSKS04 Digital Communication
Continuation Course

Lecture 8

Linear Equalization

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Another View on Equalization

- Reverse Effects of the Channel
  - Suppress inter-symbol interference
  - Suppress noise

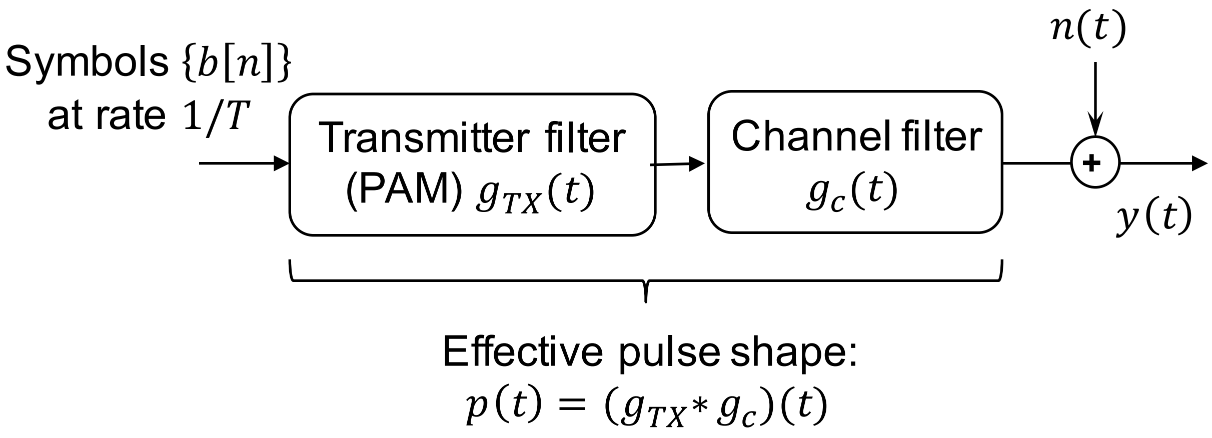
Basically:
Design an inverse filter

- Optimal equalization
  - ML sequence estimation
  - Viterbi algorithm – complexity scales as $(M^L)^2$ per symbol

L = Channel memory

- Suboptimal equalization
  - Sacrifice optimality – gain lower complexity (proportional to L?)
  - Oversampling is useful to improve performance

Discretized Model Using Oversampling



Received analog signal (as before):

$$y(t) = \sum_m b[m]p(t - mT) + n(t)$$

- Use any receive filter $g_{RX}(t)$: $x(t) = (y * g_{RX})(t)$
- Sample period: T/N, for integer $N \geq 1$ (oversampling factor)
- Sample offset: δ

Time-Discrete Model

- Consider L received samples ((L not channel memory)

$$\boldsymbol{x}[n] = \boldsymbol{U} \cdot \boldsymbol{B}[n] + \boldsymbol{w}[n]$$

Received signal vector $L \times 1$

Matrix $L \times K$

Symbol vector $K \times 1$

Noise vector $L \times 1$

Note:

$$\boldsymbol{B}[n] = (b[n-k_1], \dots, b[n], \dots, b[n+k_2])^T$$

$$K = k_1 + k_2 + 1$$

$L =$ Design parameter ($L \geq K$: larger is better for performance)

$\boldsymbol{U}$ contains values from $f[k]$

Linear Equalization

Time-discrete model

$$\boldsymbol{x}[n] = \boldsymbol{U} \cdot \boldsymbol{B}[n] + \boldsymbol{w}[n]$$

Linear equalization

- Take inner product between $\boldsymbol{x}[n]$ and some vector $\boldsymbol{c}$
- Select the $L \times 1$ vector $\boldsymbol{c}$ so that $\boldsymbol{c}^H \boldsymbol{x}[n]$ gives good estimate of $b[n]$

Different Linear Equalization Choices

- Matched filter (MF) equalization
  - Maximize desired signal: $\boldsymbol{c}^H \boldsymbol{u}_0$
  - Fix $\boldsymbol{c}^H \boldsymbol{u}_0 = 1$: $\boldsymbol{c} = \boldsymbol{u}_0 / \|\boldsymbol{u}_0\|^2$

- Zero-forcing (ZF) equalization
  - Force ISI to be zero: $\boldsymbol{c}^H \boldsymbol{U} = (\underbrace{0 \ \dots \ 0}_{k_1} \ 1 \ \underbrace{0 \ \dots \ 0}_{k_2}) = \boldsymbol{e}^T$
  - Achieved by $\boldsymbol{c}_{ZF} = \boldsymbol{U}(\boldsymbol{U}^H \boldsymbol{U})^{-1} \boldsymbol{e}$

Outlook: Equalization of Multi-user Channels

$$\boldsymbol{x}[n] = \boldsymbol{U} \cdot \boldsymbol{B}[n] + \boldsymbol{w}[n]$$

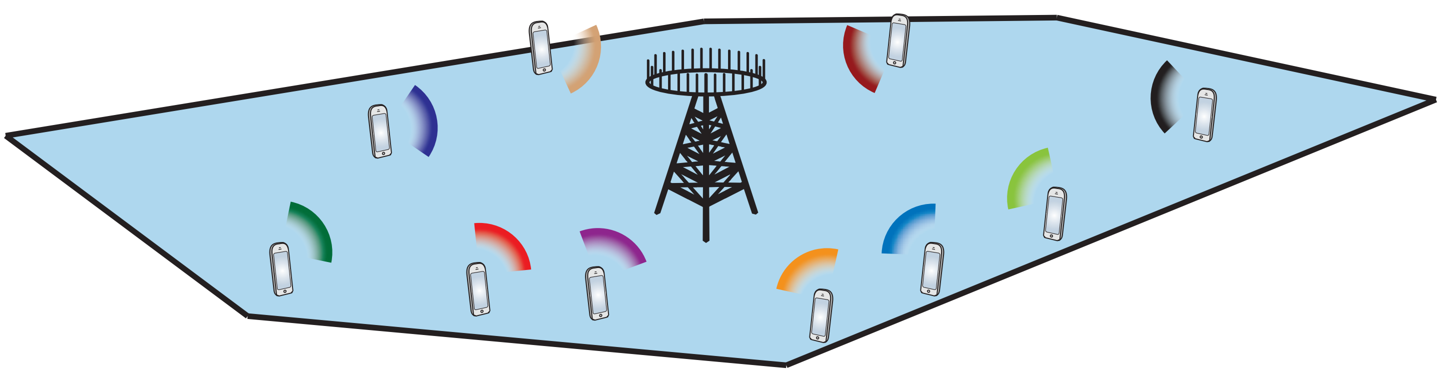
Received signal vector $L \times 1$

Matrix $L \times K$

Symbol vector $K \times 1$

Noise vector $L \times 1$

- Two scenarios, same equations:
  - Single-user channel with ISI: K symbols and L samples
  - Multi-user channel without ISI: K users and L receive antennas



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