06 Feb 2020

- BW scarcity
  1) higher freq
  * mmWave (< 100 GHz)
  * Terahertz (100 GHz < < 10 THz)
    (300 GHz < < 3 THz)

lower freq → coverage advantage

coverage problem → lower frequencies
capacity problem → higher freq.

2) Spectrum sharing
  * DSS: Dynamic spectrum sharing
  * cognitive radio

Static design vs dynamic design

Static design
worst case
- over engineering
- inefficient

long-term statistics

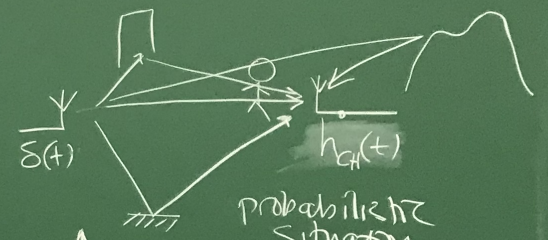
dynamic design
no worst of resources
Penalty: overhead
: complexity
: frequent decision making
ML: important enabler

agility
flexibility

Ex: Wireless Access Network
flying BSs
aerial BSs
drone BSs

* Mismanage if you can

Wireless Channel Impulse Response Characterization

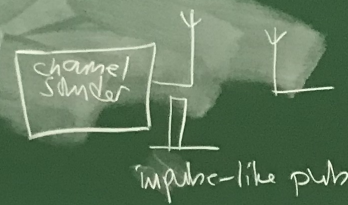


probabilistic situation

$h_{CH}(t)$

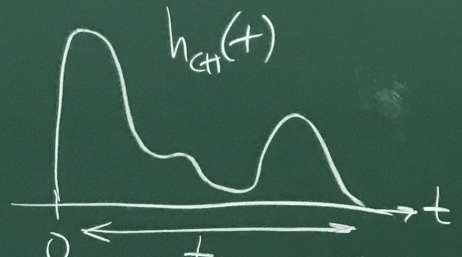
independent of information signal

In practice

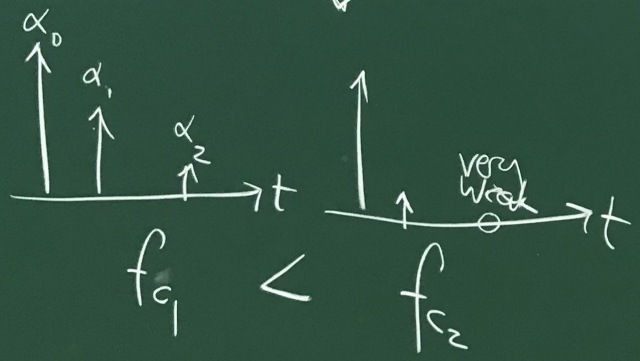


impulse-like pulse

approximation



$\{\alpha\}$ depend on f_c



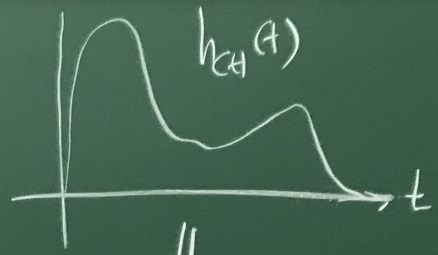
Further simplified ch impulse response for a particular application

transmission rate, T_s

t_d: Delay spread

Tapped-delay line representation

$$\#\text{ of taps} = \left\lfloor \frac{t_d}{T_s} \right\rfloor$$



$$m = \left\lfloor \frac{t_d}{T_s} \right\rfloor$$

$$h_{CH}(t) = \sum_{i=0}^{m} \alpha_i \delta(t - iT_s)$$

α, i depend on f_c

also time-varying but at a longer timescale

Ex: Rapidly changing ch time constant $\sim$ msec

$T_s \ll$ msec

- over several symbols $\rightarrow$ time invariant

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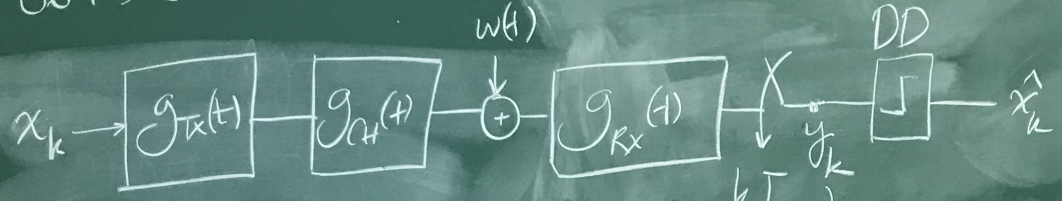
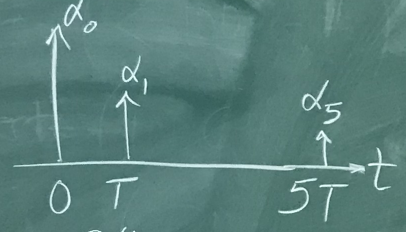


$\sum x_k \delta(t-kT)$

$g_{CH}(t)$



$= \alpha_0 \delta(t) + \alpha_1 \delta(t-T) + \alpha_5 \delta(t-5T)$

decision variable:

desired signal + ISI + noise

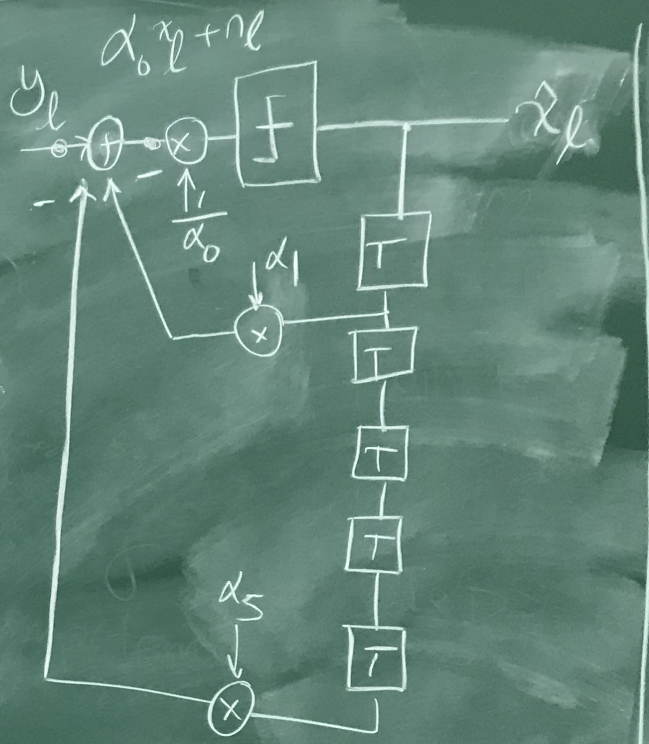
at time $k=l$

$h = g_{Tx} * g_{CH} * g_{Rx}$

$$y_l = \underbrace{\sum_k \alpha_{l-k} x_k}_{\text{desired signal } [x_l] + \text{ISI}} + n_l$$

$$= \underbrace{\alpha_0 x_l}_{\text{desired signal}} + \underbrace{\alpha_1 x_{l-1} + \alpha_5 x_{l-5}}_{\text{ISI}} + \underbrace{n_l}_{\text{noise}}$$

- Assume $\hat{x}_l = x_l$



* amplification does not change SNR, does not change BER

BS ——— * UE (user equipment)

$R = n B \log_2(1+SNR)$

↳ $\min(n_{TX}, n_{RX})$

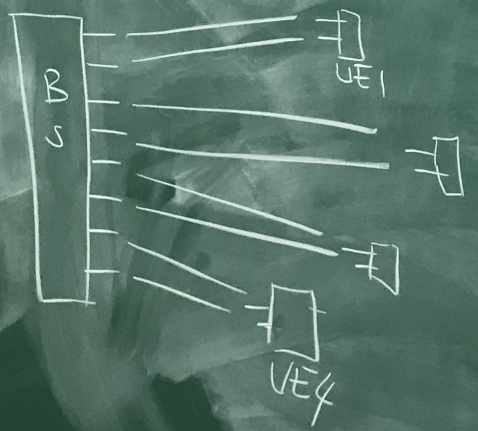
BS

$n_{TX} > n_{RX}$

Multiuser MIMO: MU-MIMO

Multi-stream (multi-layer)

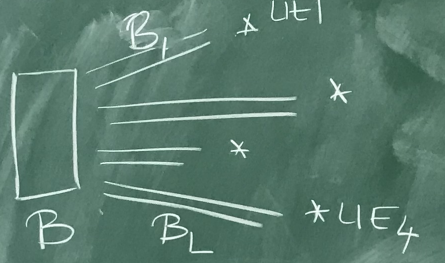
Ex: $n_{TX} = 8$, $n_{RX} = 2$



BS → L UEs

multiple access (competition)

resources have to be shared



$\sum_{i=1}^{L} B_i = B$

* $SE_{max}^{(SISO)} = \log_2(1+SNR) > SE = \frac{r \times \log_2 M}{1+\beta}$

Many modulation rate r RRC pulses with roll off β

$R = \sum_{i=1}^{L} B_i SE_i$

$= \sum_{i=1}^{L} B_i \left(\frac{r_i \log_2 M_i}{1+\beta} \right)$

resource = asset

* RRM

radio resource management

$SE_i = f(SNR_i)$

$SNR_i = \frac{P_{TX,i} \alpha_i^2}{N_0 B_i}$

$h_{CH,i}(t) = \alpha_i \delta(t)$

$\sum P_{TX,i} = P_{TX}$

power assignment