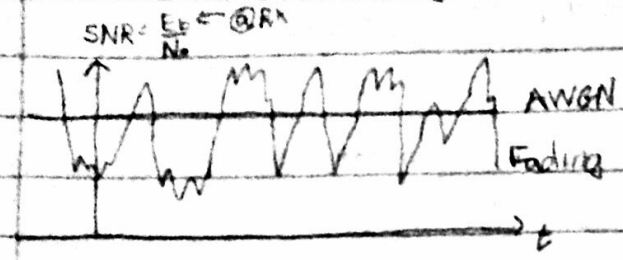
# Lecture 14

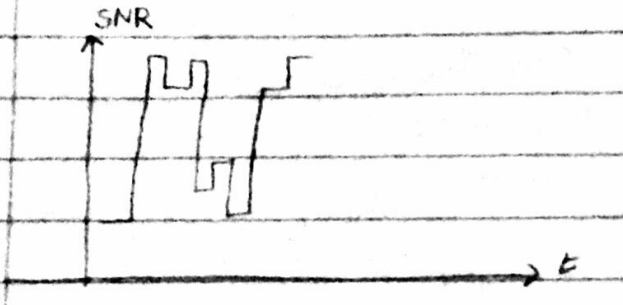
11/24/15

"$h_{AWGN}(t) = \alpha\,\delta(t - t_p)$" + background noise (noise)

↳ constant → ideal channel → AWGN channel

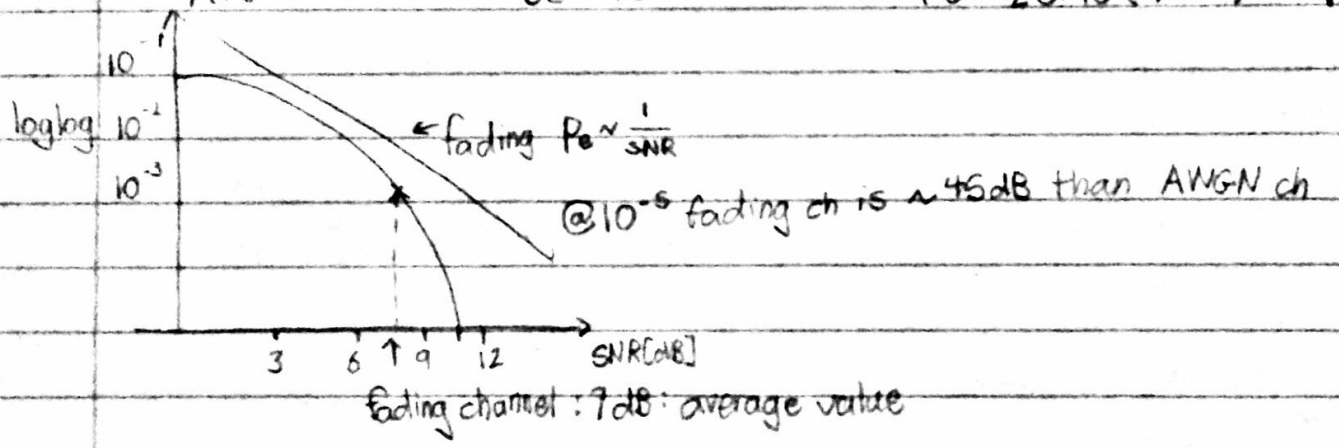
↳ RV → fading channel




AWGN → RX: MF  BER = Pe

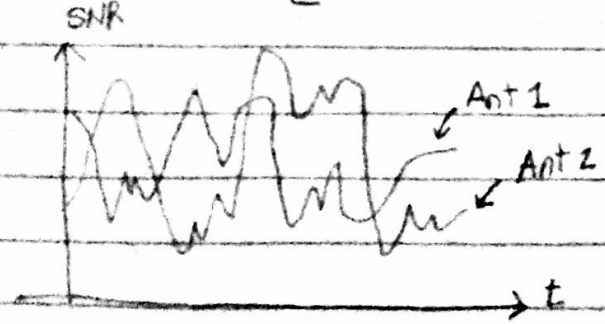
$P_e = \frac{1}{2}\,\mathrm{erfc}(\sqrt{SNR}) \sim \frac{e^{-SNR}}{\sqrt{SNR}} \sim e^{-SNR}$



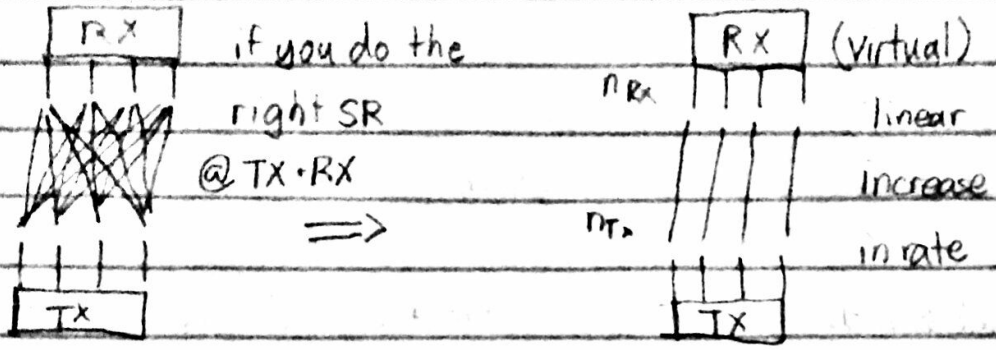

fading ch: performance: terrible

↳ brute-force fix: increase Tx power

What to do? Diversity (usually antenna)

# Multilayer MIMO (~1995)




$\min(n_{Tx}, n_{Rx})$

Array: $16 \times 6$

R: ↑6

physical seperation between antennas: $\sim \lambda = \frac{c}{f_{carrier}}$

→ cellular $\frac{3\times10^8}{1\times10^9} = 0.3m$

→ millimeter in cellular $f_c = 28, 60, 90$ GHz

non ideal ch → distortion → self interference

$h_{CH}(t) \neq \alpha\delta(t - t_p)$ Assume $w(t) = 0$ [no noise]

non-binary

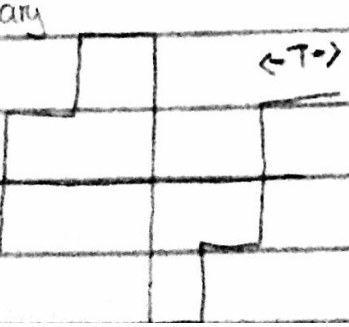
$\sum a_k \delta(t-kT)$ → $h_{Tx}(t)$ → $h_{CH}(t)$ → $h_{Rx}(t)$ → $r(t)$ → $F$ → $\{\hat{a_k}\}$

$r(t) = \sum a_k h(t-kT)$

$h(t) = h_{Tx}(t) * h_{CH}(t) * h_{Rx}(t)$

Special case:
$h_{Tx}(t)$: time-limited [duration T]

4-ary




but, $h(t)$, not time-limited

→ leakage from one symbol to another

→ ISI (Intersymbol Interference)

Under what condition, there is no ISI?

no ISI $\hat{a}_K = a_K$

$$r(t) = \cdots + a_{-2}h(t+2T) + a_{-1}h(t+T) + a_0 h(t) + a_1 h(t-T) + a_2 h(t-2T) + \cdots$$

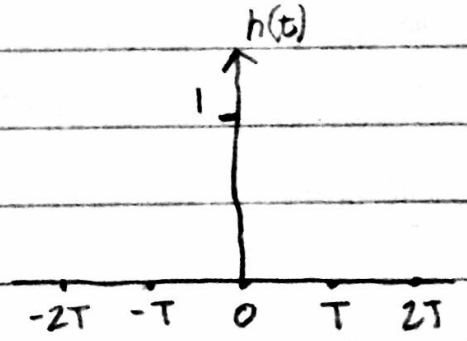
assume $t = 0$ sec

$$r(0) = \cdots + a_2 h(2T) + a_{-1}h(T) + a_0 h(0) + a_1 h(-T) + a_2 h(-2T) + \cdots$$

$\therefore$ I want $r(-T) = a_{-1}$

$r(0) = a_0$

$r(T) = a_1$




when does $r(0) = a_0$ happen?

no ISI $\rightarrow$ $h(t) = \begin{cases} 1, & t = 0 \\ 0, & t = KT \ (K \neq 0) \end{cases}$

$\rightarrow$ infinitely many $h(t)$'s will result in no ISI

$\rightarrow$ which $h(t)$ better? in terms of BW