Lecture 6 EE597

1/26/12

So far:

Physical Layer

- Radio Propagation models & Fading
  - Delay Spread & Coherence BW
  - Coherence Time & Doppler Spread
  - Lognormal, Rayleigh, Nakagami-m, Markov model

- Digital modulation schemes
  BPSK, QPSK, MQAM

- Performance under fading:
  - Outage Probability
  - Av. Prob. of error

Tradeoff between Power / SNR, Error & Rate

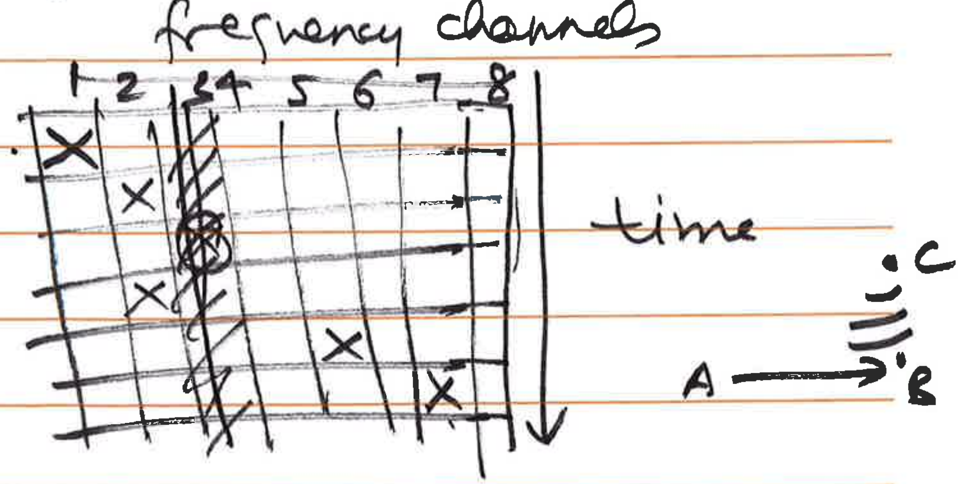
- OFDM – orthogonal frequency Div. Multiplexing

- Coding – Block Codes, Convolutional Codes, (Turbo codes & LDPC)

To do

- CDMA & Spread Spectrum
- MIMO / Diversity techniques.

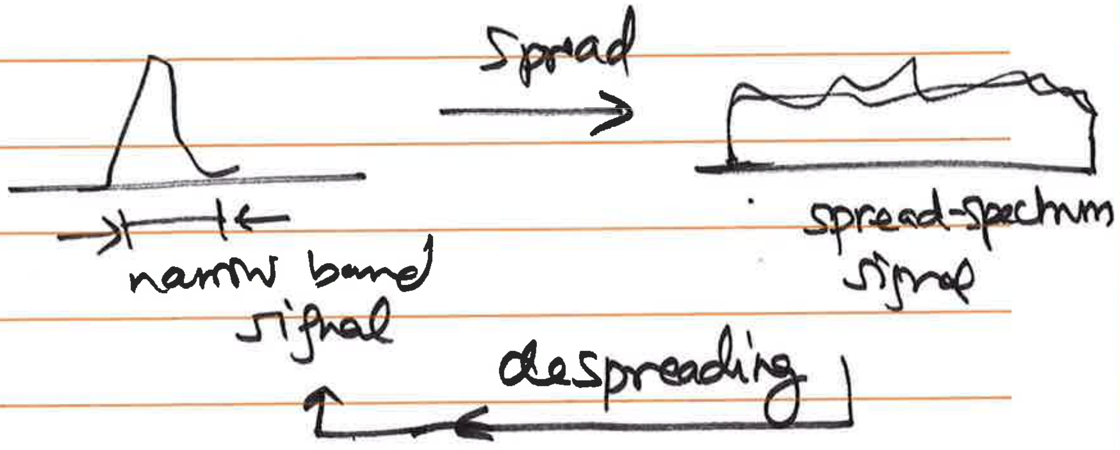
SPREAD SPECTRUM



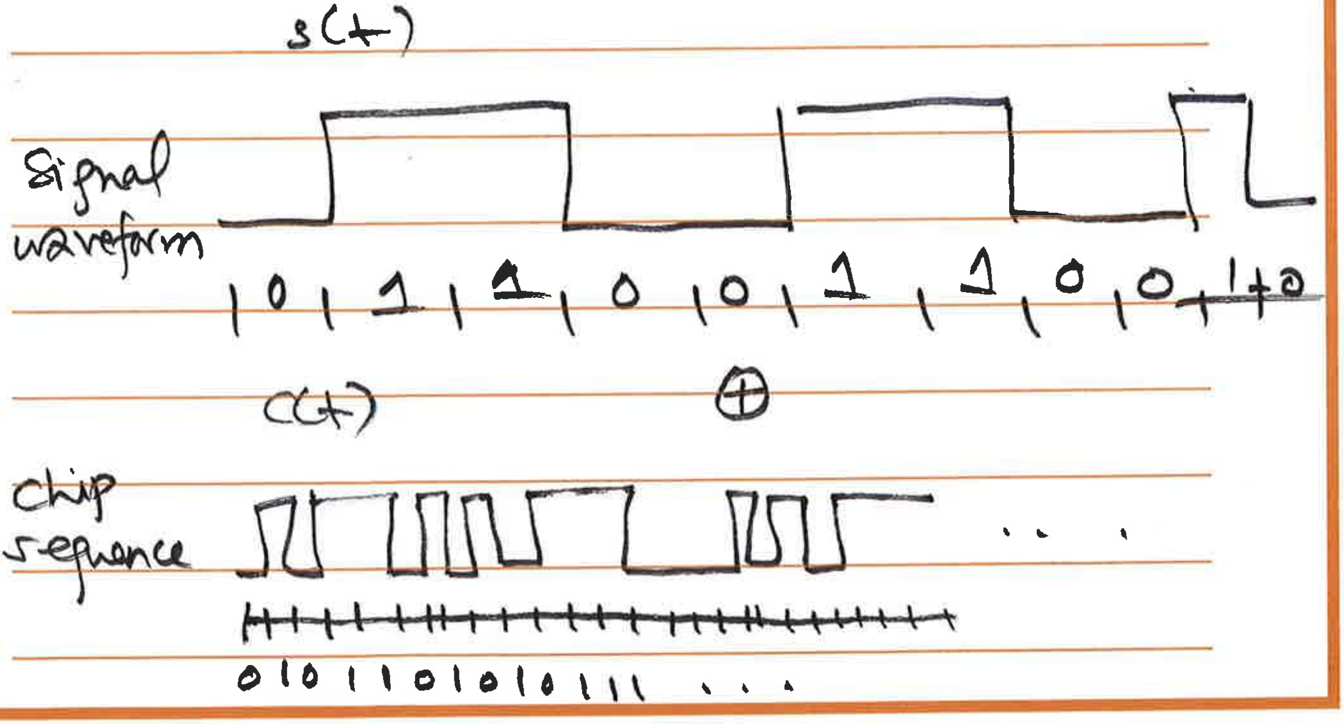
Frequency-hop Spread spectrum (FHSS)

Originall invented ~ WWII for

combatting narrow-band interference



Direct Sequence Spread Spectrum (DS-SS)

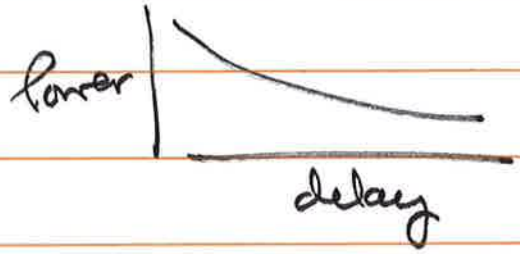


$$\underbrace{\underbrace{s(t) \oplus c(t)}_{\text{Transmitted waveform}} \oplus c(t)}_{\text{despreading operation}} = \underbrace{s(t)}_{\text{recovered signal.}}$$

Spreading Ratio : $\dfrac{\text{chip rate}}{\text{symbol rate}}$

- Using spread spectrum provides robustness to narrow-band interference & fading.

- Spread Spectrum helps mitigate ISI.



$s(t)$

$$\sum_{\tau} a(\tau)\left(s(t-\tau) \oplus c(t-\tau)\right)$$
$$\oplus\ c(t)$$
$$=$$

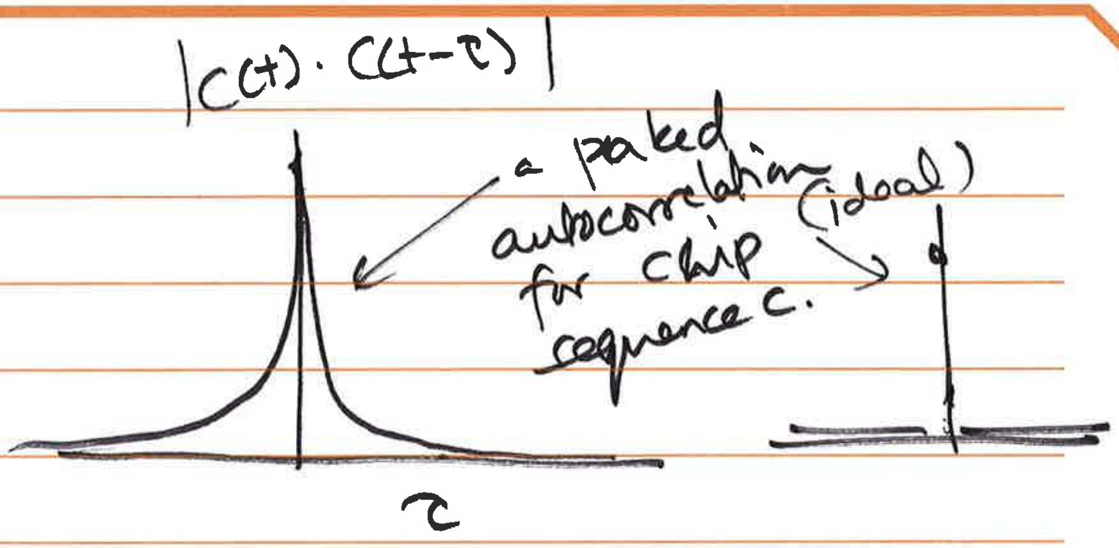
$$\underbrace{\sum_{\tau} a(\tau)\ s(t-\tau) \oplus \underbrace{c(t-\tau) \oplus c(t)}_{}}_{}$$

signal a
chip sequence x

$\underbrace{a\cdot x}_{\text{spreaded sequence}}$.

$a\cdot \underbrace{x\cdot x}_{\downarrow\ 1} = a.$

$$\sum_{\tau} a(\tau)\ s(t-\tau)\cdot \underbrace{c(t-\tau)\cdot c(t)}_{}$$



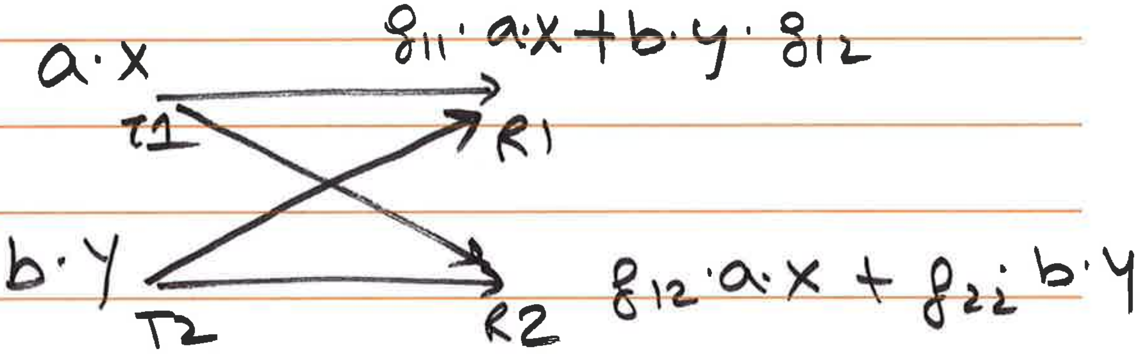
with such a peaked-autocorrelation chip sequence, we would get the output to be

$a(0)\cdot s(t)$ ← in the ideal case

in general, having a well-designed chip sequence mitigates ISI.

CDMA : Code division multiple access

multi-user spread spectrum technique, where each user is given a distinct sequence/code.



At receiver R1, decode as

$$(g_{11}\cdot a\cdot X + b\cdot Y\cdot g_{12})\cdot X$$

$$r = g_{11}\cdot a\cdot X\cdot X + \underbrace{b\cdot Y\cdot g_{12}\cdot X}_{g_{12}\cdot b\cdot X\cdot Y}$$

$X\cdot Y$ are orthogonal iff $X\cdot Y = 0$

if X, Y are orthogonal,

$$r = g_{11}\cdot a\cdot X\cdot X = g_{11}\cdot a$$

i.e., If the codes are orthogonal, the interfering signal can be cancelled (& mitigated).

In general, if the codes have ~~poo~~ low cross-correlation, then the ~~interfence~~ interference can be substantially reduced.

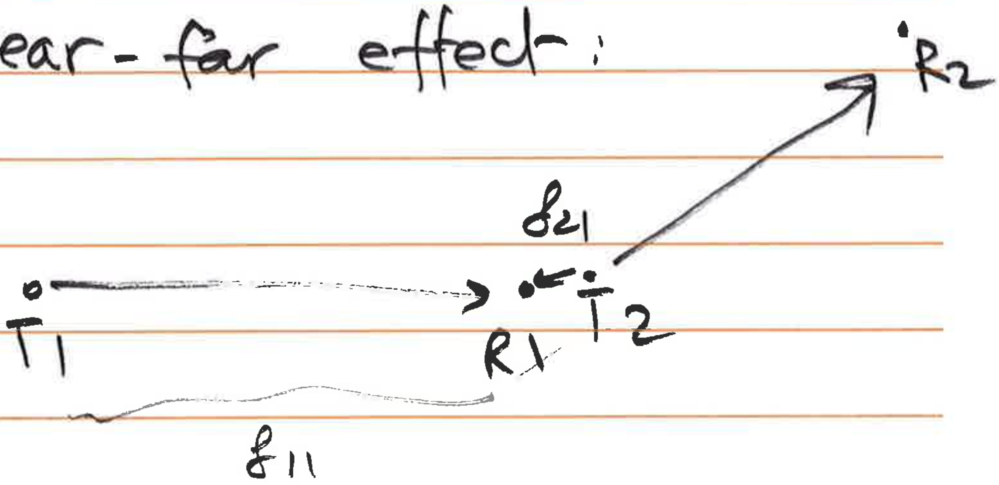
Desiable properties for spreading sequences:

- low cross-correlation w/ other codes → reduce interference
- peaked autocorrelation → mitigate ISI

Random / PseudoRandom noise sequences, m-sequences

Gold codes, Kasami codes, Walsh-Hadamard codes

- near-far effect:



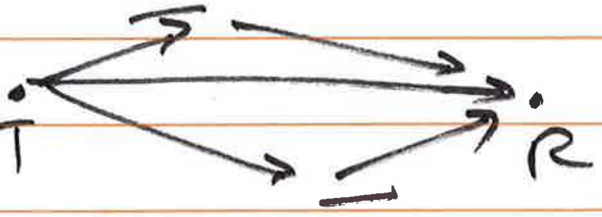
near-interferers can overwhelm far-away signal transmitters.

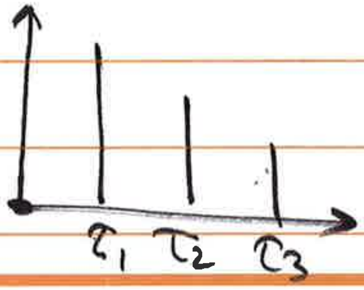
Must be mitigated via power-control.

e.g. of FHSS → Bluetooth
CDMA/DSSS very widely used in cellular
DSSS also used in 802.11 variants

multiuser techniques:
- TDMA
- FDMA (multiuser OFDM)
- CDMA
- CSMA/CA

Diversity Techniques





Rake Receiver

$$r(t) = \sum_i a(\tau_i) \cdot s(t-\tau_i) \cdot c(t \cdot \tau_i)$$

$$r(t) \cdot c(t-\tau_1) = a(\tau_1) s(t-\tau_1) = r_1$$

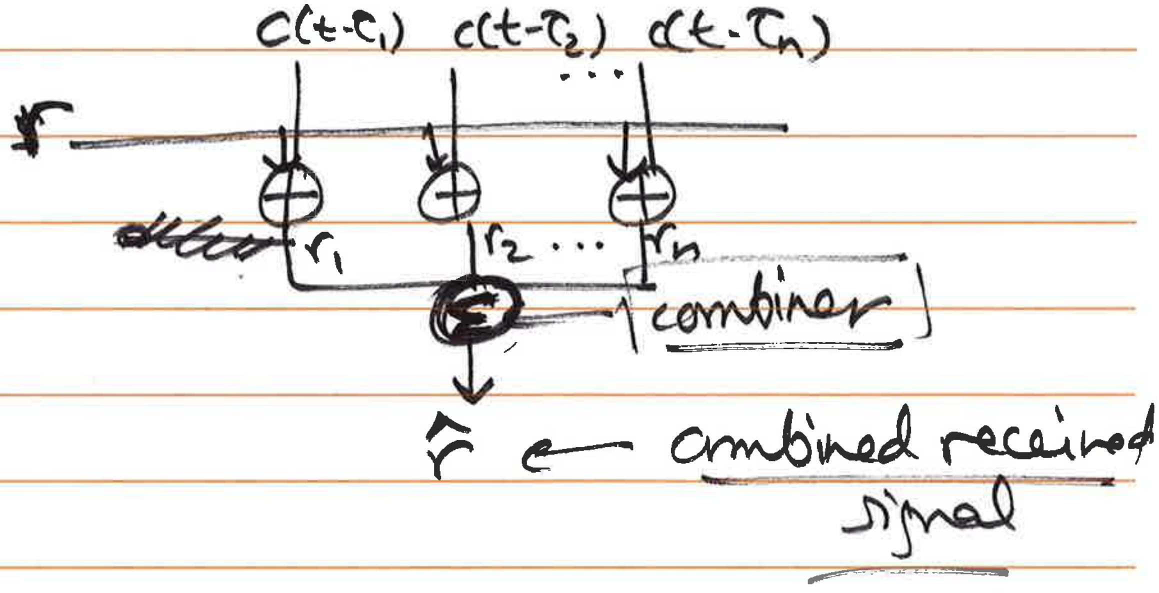
$$r(t) \cdot c(t-\tau_2) = a(\tau_2) s(t-\tau_2) = r_2$$

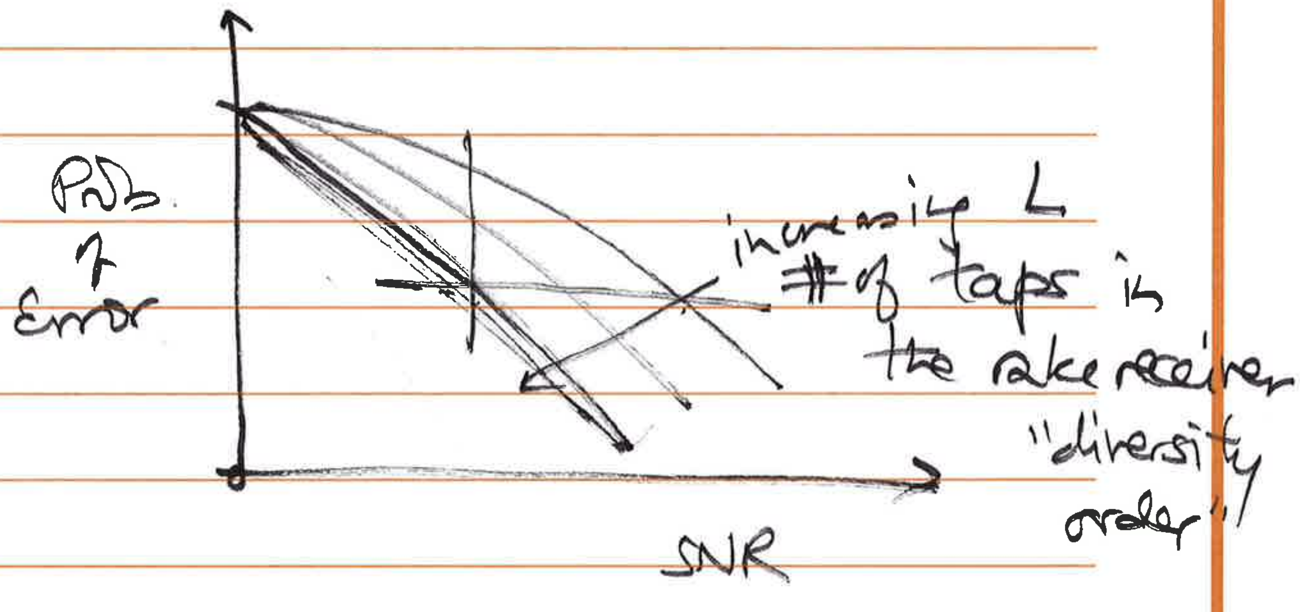
$$\vdots$$

$$r(t) \cdot c(t-\tau_n) = a(\tau_3) s(t-\tau_3) = r_n$$

then, time shift r_i to compensate for relative time difference & combine them.

RAKE RECEIVER





next class : Maximum Ratio Combining

MIMO - multiple input / multiple output communications