Chapter 12 Spread Spectrum Techniques

- Introduction

- Comparison of multiple access/multiplexing techniques

  i) FDMA: frequency division multiple access

  ii) TDMA: time division multiple access

  iii) CDMA: code division multiple access

12.1 Spread spectrum

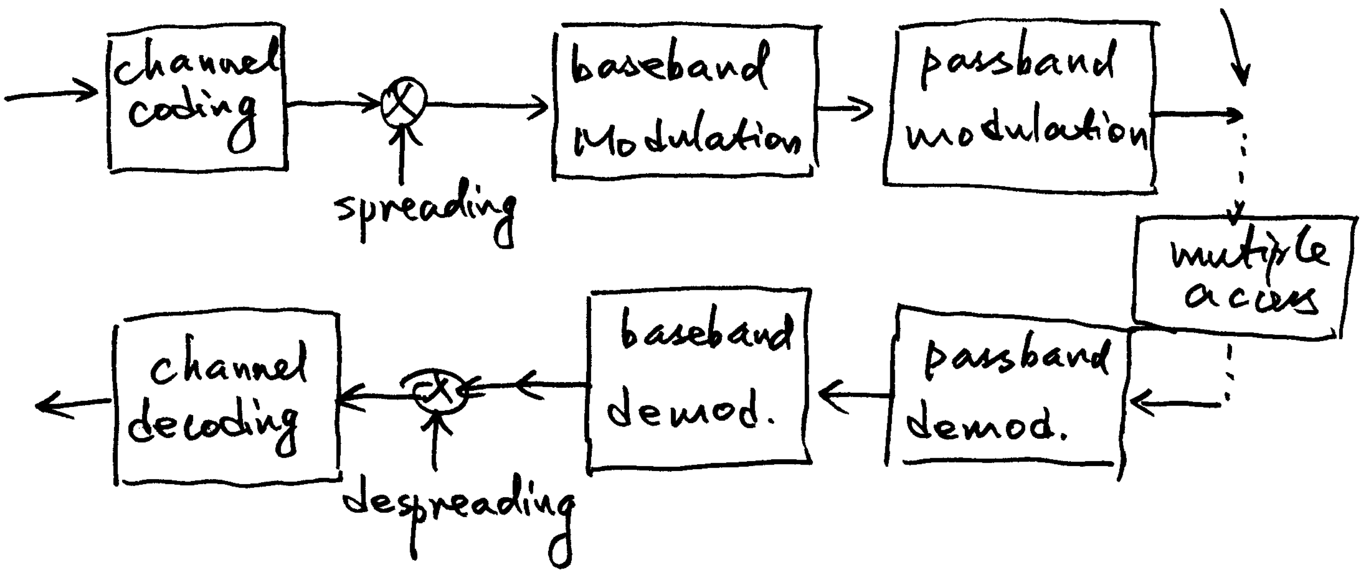
- Implementations:
  - i) DS-CDMA
  - ii) FH-CDMA

- Applications:
  - i) Security in military usage
  - ii) Anti-jamming / noise: military, wireless LAN
  - iii) multiple access: high ~~spe~~ capacity in mobile phone

- What's spread spectrum?

  use a transmission bandwidth which is much greater than the minimum information bandwidth

• <u>System block diagram</u>



12.1.1 Some properties:

- Why SS ~~oo~~has anti-jamming capability?

  i) Jamming: intentional interference, noise

  ii) Jamming usually has fixed energy,
  limited bandwidth (narrowband)

  iii) Narrowband jamming ~~becomes slow~~ has low
  Power density after spreaded

  iv) Narrowband jamming can be filtered out

- SS has high security with low probability of interception:

  i) signal energy are distributed to a wider bandwidth

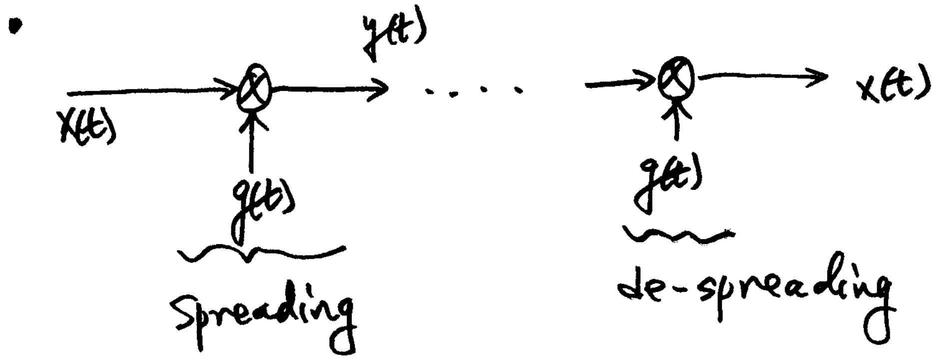
  ii) power density becomes low.

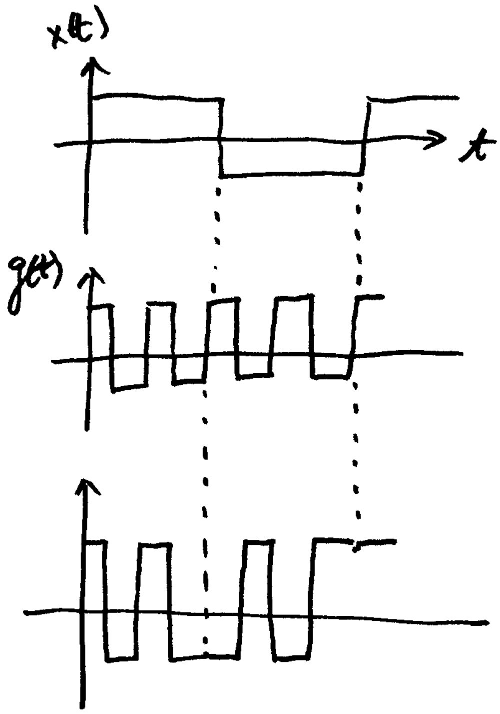
- SS has fine time resolution, for position location

- Good for multiple access:

12.1.3 DS-CDMA model.

- Use a pseudo-noise sequence to spread signal
- PN sequence:
  - i) Appear random ($\delta(t)$-like autocorrelation)
  - ii) deterministic: be able to generate independently at the receiver
-

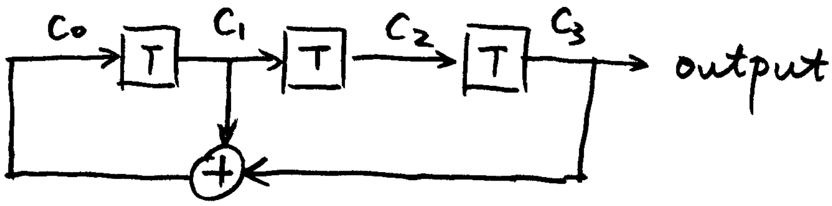




12.2 Pseudo-noise sequences

- A sequence of "1" and "0" with noiselike auto-correlation ~~and zero cross correlation~~
- PN sequences have zero cross correlation
- Generator: linear feedback shift register

e.g.:



	c_0	c_1	c_2	c_3	output (c_3)
at $t=0$,	1	1	0	0	0
$t=1$,	1	1	1	0	0
⋮					
$t=7$,	1	1	0	0	0

∴ output sequence:

0011101 ....

- m-sequence: maximum-length shift register sequence

length: $L = 2^n - 1$,

- shifter register constraint length n

- Sequence period: L

- Auto correlation:

$$R_c(\tau) = \sum_i C_i C_{i+\tau}$$

$$= \begin{cases} L, & \text{if } \tau = 0 \\ -1, & \text{if } 1 \le \tau \le L-1 \end{cases}$$

- example:

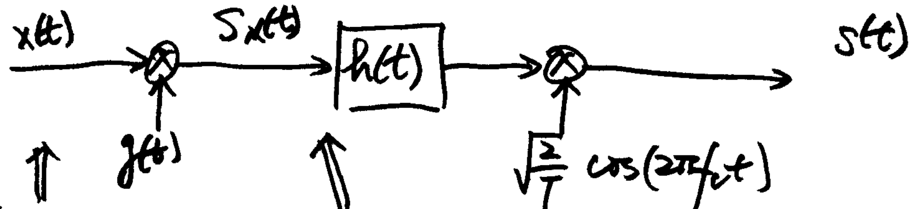
- Cross-correlation:

almost zero: Gold sequence

zero: Walsh code

12.3 DSSS (or DS-CDMA)

- **BPSK modulator**



bit rate: R_b chip rate R_c

bit interval T_b chip interval T_c

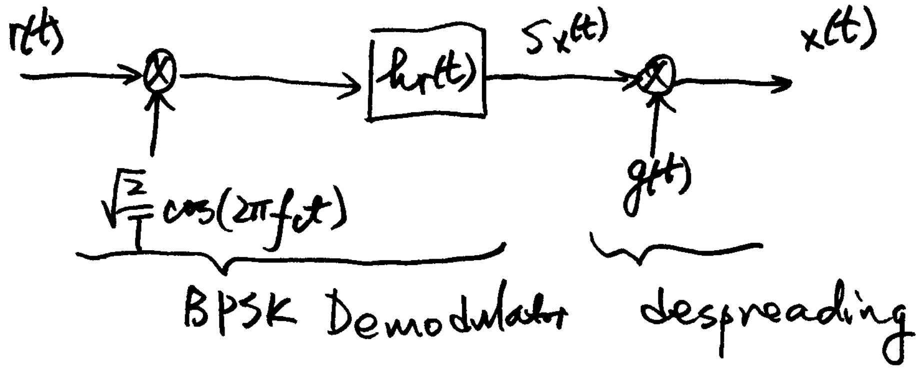
processing gain: $L_c = \frac{R_c}{R_b} = \frac{T_b}{T_c}$

(# of PN chips per bit)
(Anti-jamming capability)
(# of users for multiple access)

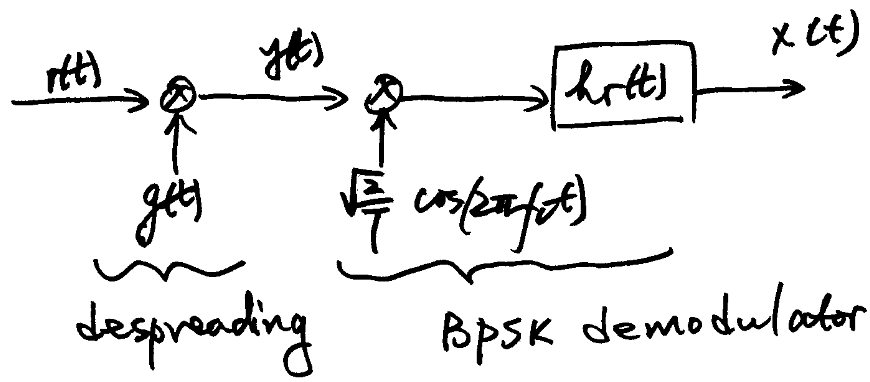
$$s(t) = \sqrt{\frac{2}{T}} \cos(2\pi f_c t)\, x(t)\, g(t)$$

- <u>Demodulator</u> (BPSK)

i)



ii)



- Let $r(t) = s(t) = \sqrt{\frac{2}{T}}\cos(2\pi f_c t)\, x(t)\, g(t)$.

$$y(t) = r(t)\, g(t)$$
$$= \sqrt{\frac{2}{T}}\cos(2\pi f_c t)\, x(t)\, g(t) \cdot g(t)$$
$$= \sqrt{\frac{2}{T}}\cos(2\pi f_c t)\, x(t)$$

- ## Processing gain and anti-jamming

i) Narrowband interference $i(t)$.
Wideband SS signal $s(t)$.
received signal $r(t) = s(t) + i(t)$

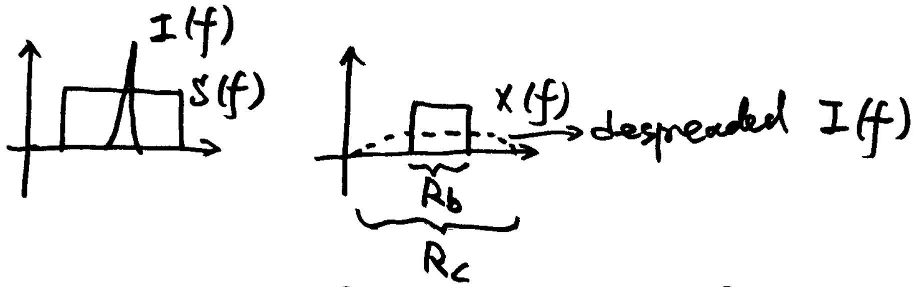
$$= \sqrt{\frac{2}{T}}\, x(t)\, g(t) \cos(2\pi f_c t) + i(t)$$

ii) Despreading:

$$y(t) = r(t) g(t) = \sqrt{\frac{2}{T}}\, x(t) \cos(2\pi f_c t) + i(t) g(t)$$

iii) Demodulation:

$$\left[y(t) \sqrt{\frac{2}{T}} \cos(2\pi f_c t) \right]_{LP} = x(t) + \left[i(t) g(t) \sqrt{\frac{2}{T}} \cos(2\pi f_c t) \right]_{LP}$$



iv) Assume $i(t)$ has fixed power P_J,
then Power density is $J_0 = \frac{P_J}{R_c}$

Jammer power in the signal bandwidth R_b is:

$$N_J = J_0 R_b = P_J \frac{R_b}{R_c} = \frac{P_J}{L}$$

SIR enhancement: $\frac{P_s}{P_J}$ (input) $\longrightarrow$ $\frac{P_s}{P_J} L$ (output)

- Conclusion:

  i) interference power reduced by L times

  ii) SIR increased by L times.

  (L : processing gain)

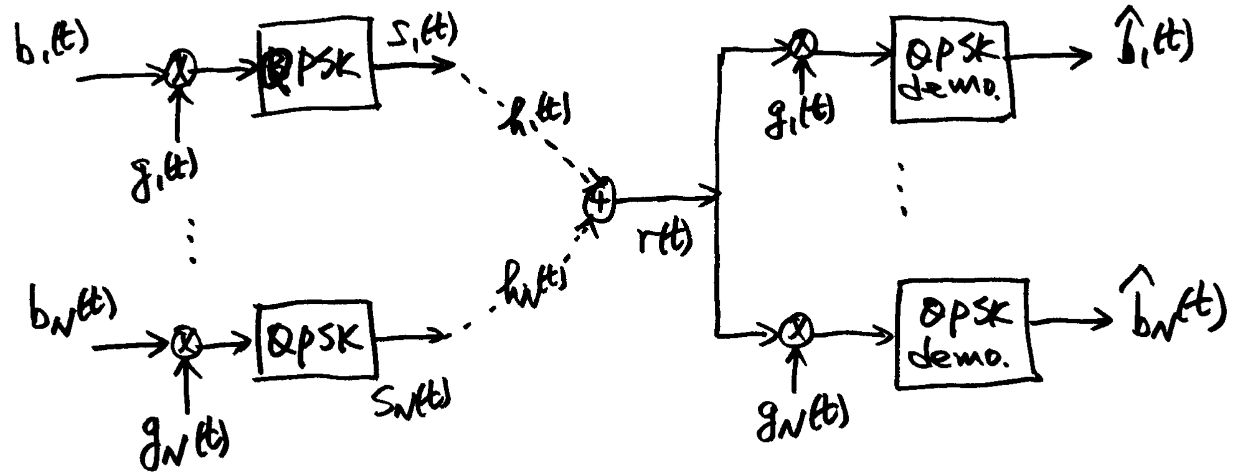
- Example: in wireless LAN IEEE 802.11b,
  11-bit barker sequence is used,
  what is the processing gain?

- Example:

  If the required SIR = 10 dB.
  hower, the received SIR is only −20 dB.
  how much should the processing gain be?

12.7 Commercial applications

- CDMA: N users share the same channel
  each one with a unique spreading code



- IS-95 CDMA Digital Cellular System:

  channel: 1.25 MHz bandwidth

  chiprate: $R_c = 1.2288$ Mc/s

  data rate: $R_b = 9.6$ kbps

  Processing gain: $L = ?$

  Modulator: QPSK

  channel coding: convolutional + Interleaver