SPREAD SPECTRUM TECHNIQUES

Code Division Multiple Access

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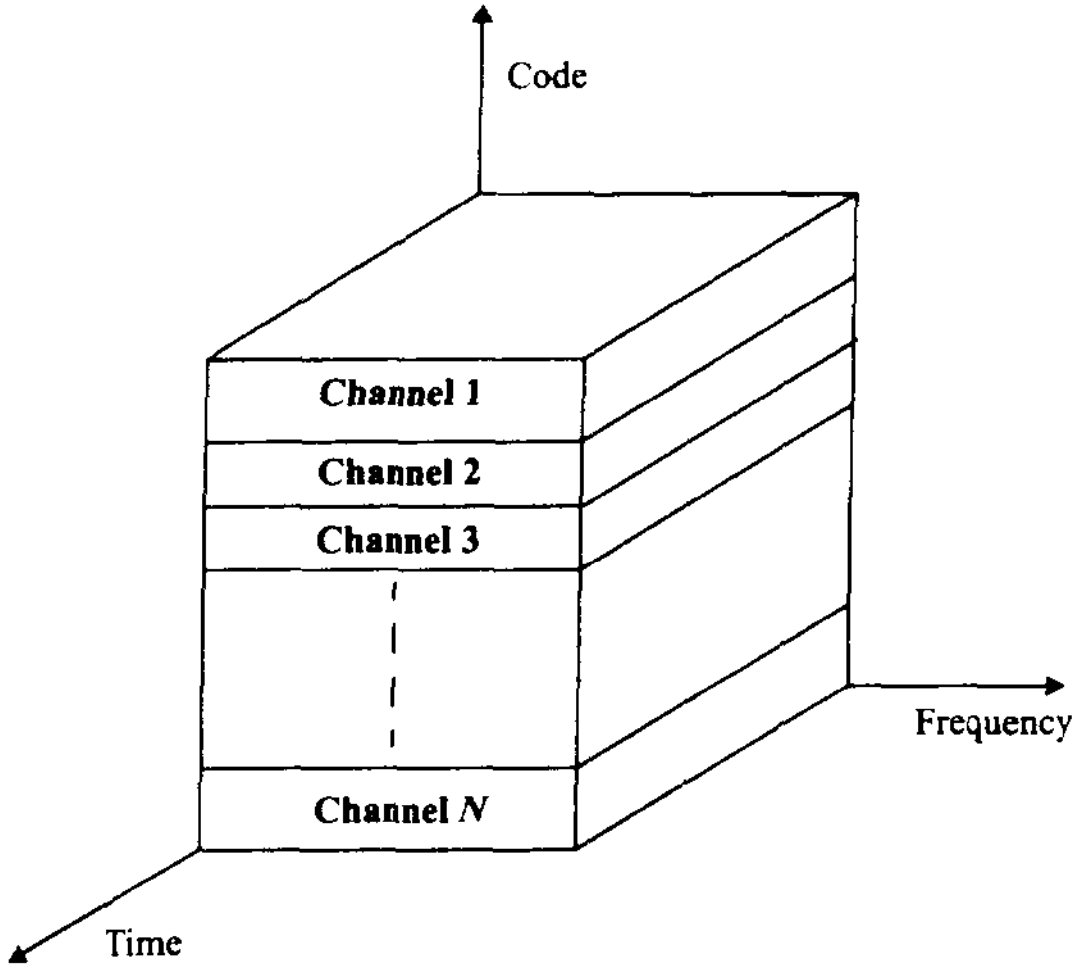
INTRODUCTION

- Mobile telephony, using the concept of cellular architecture, are built based on GSM (Global System for Mobile communication) and IS-95(Intermediate Standard-95).
- CDMA allows a satisfactorily large number of users to communicate simultaneously over a common radio frequency band.

ADVANTAGES

- Cellular CDMA helps to reduce the multi-path fading effects and interference
- supports universal frequency reuse
- more users could be allowed in the system ensuring good quality of signal
- secure communications
- With proper design of pseudo-random sequences, multiple spread spectrum systems can co-exist

CDMA UTILISES SPREAD SPECTRUM MODULATION TECHNIQUES



CDMA in which each channel is assigned a unique PN code which is orthogonal to PN codes used by other users.

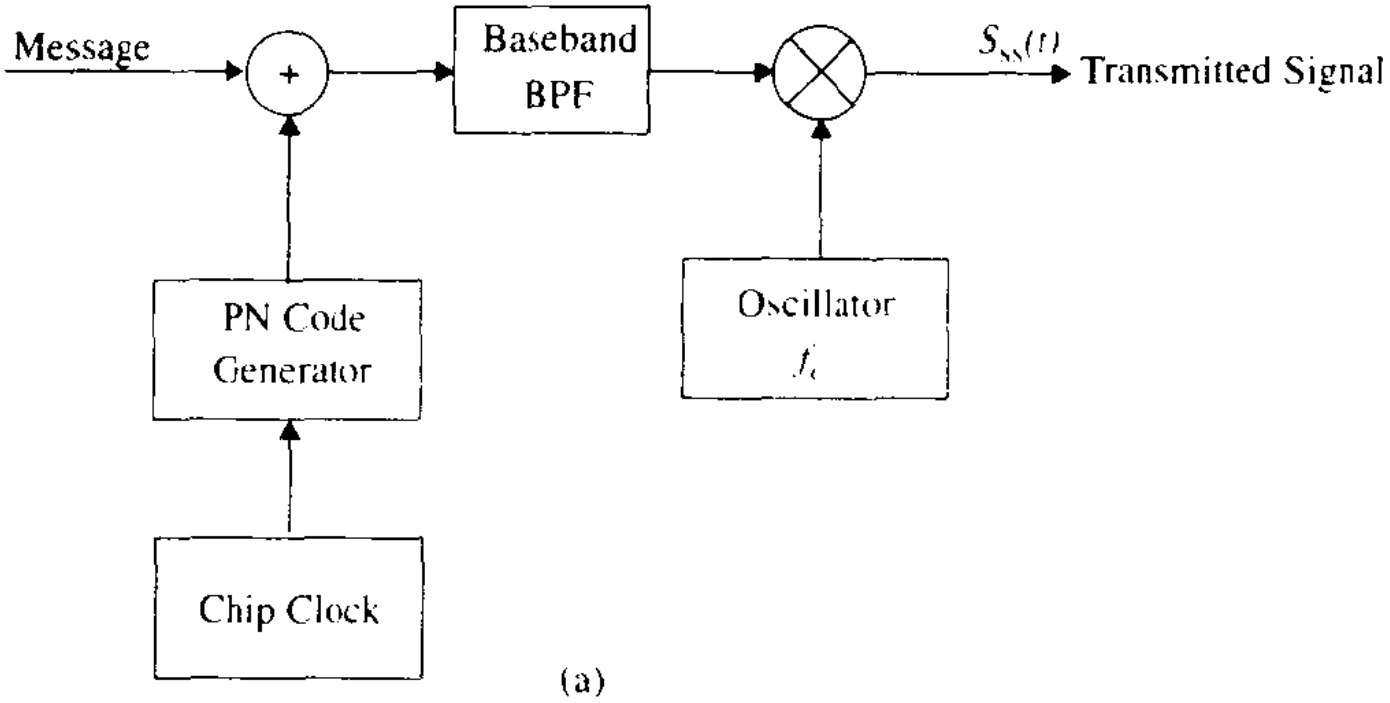
TYPES OF SPREAD SPECTRUM

Based on the kind of spreading modulation, spread spectrum systems are broadly classified as-

- Direct sequence spread spectrum (DS-SS) systems
- Frequency hopping spread spectrum (FH-SS) systems
- Time hopping spread spectrum (TH-SS) systems.
- Hybrid systems

DIRECT SEQUENCE SPREAD SPECTRUM SYSTEM (DSSS)

TRANSMITTER



(a)

A *direct sequence spread spectrum* (DS-SS) system spreads the baseband data by directly multiplying the baseband data pulses with a pseudo-noise sequence that is produced by a pseudo-noise code generator.

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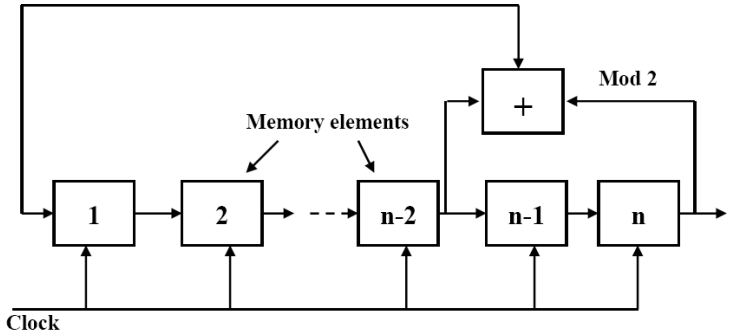
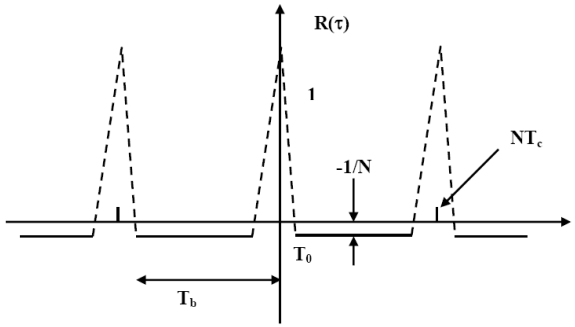
PN SEQUENCE GENERATOR

An L-stage shift register and a few EX-OR gates can be used to generate an m-sequence of length 2L -1.



The number of 1-s in the complete sequence and the number of 0-s will differ by one.



The auto-correlation of an m-sequence is -1 except for relative shifts of (0 ± 1) chips

PROPERTIES OF PN SEQUENCE

Half of the runs of bits in every period of the same sign (i.e. +1 or -1) are of length 1, one fourth of the runs of bits are of length 2, one eighth of the runs of bits are of length 3 and so on.

Example 1001110

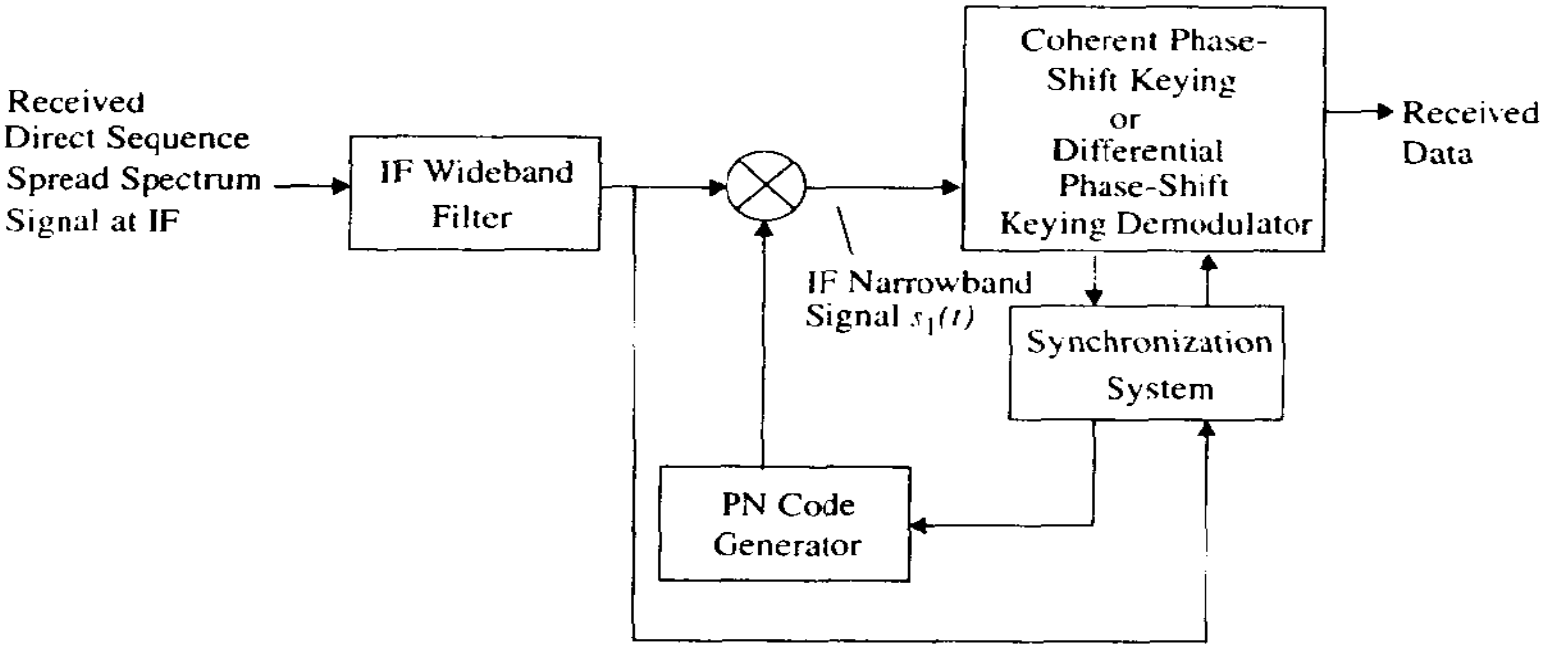
- No Of Runs=4 →1,0,00,111
  - 2 runs have length 1
  - 1 run has length 2

RECEIVER

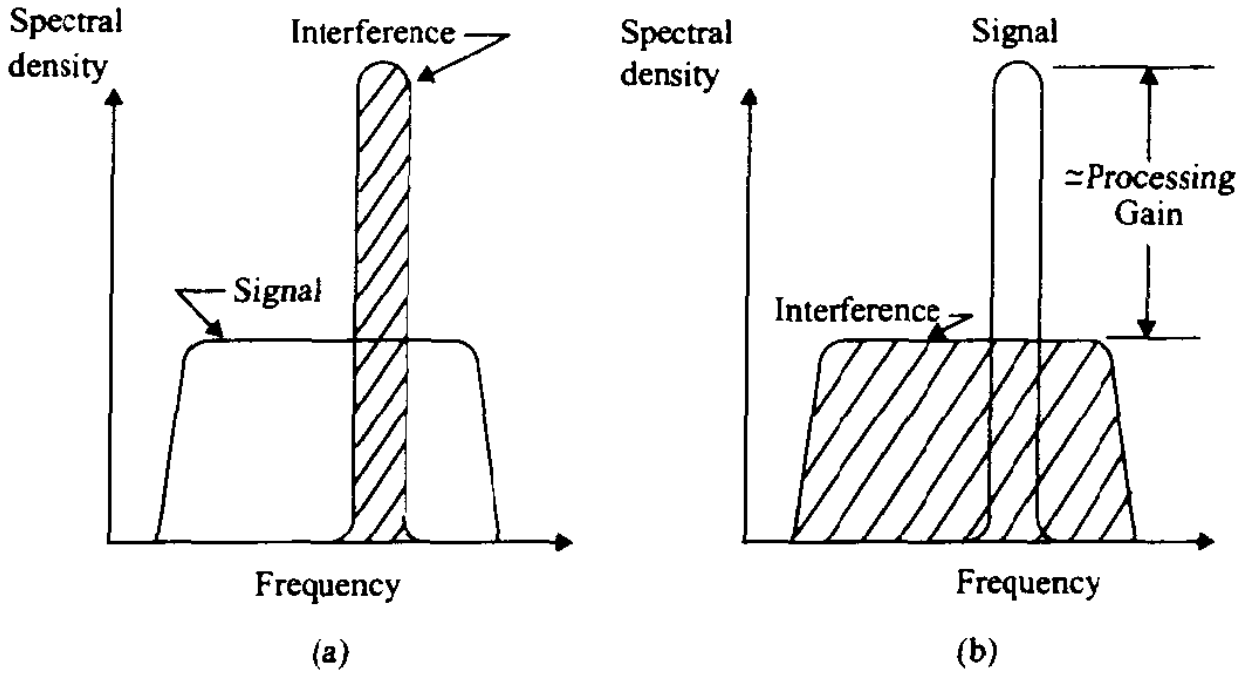
The received spread spectrum signal for a single user can be represented as

$$S_{ss}(t) = \sqrt{\frac{2E_s}{T_s}} m(t)p(t)\cos(2\pi f_c t + \theta)$$

where $m(t)$ is the data sequence, $p(t)$ is the PN spreading sequence, f_c is the carrier frequency, and θ is the carrier phase angle at $t = 0$.



DIRECT SEQUENCE SPREAD SPECTRUM SYSTEM



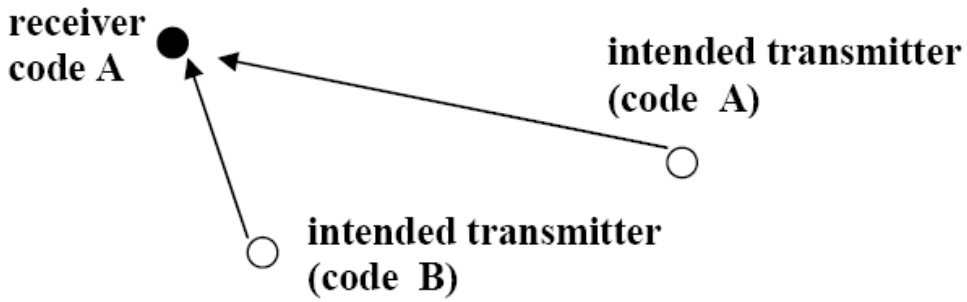
Spectra of desired received signal with interference: (a) wideband filter output and (b) correlator output after despreading.

PERFORMANCE

- Processing gain (PG) of a DSSS system is the ratio of the signal bandwidth to the message bandwidth.

$$PG = \frac{T_s}{T_c} \approx \frac{R_c}{R_s} = \frac{W_{ss}}{2R_s}$$

A major disadvantage of a DSSS system is the 'Near-Far effect'



When an interfering transmitter is close to the receiver than the intended transmitter. The cross-correlation between the received signal from the interfering transmitter and code A can be higher than the correlation between the received signal from the intended transmitter and code A.

Merits

- Simpler to implement
- Low probability of interception
- Can withstand multi-access interference reasonably well

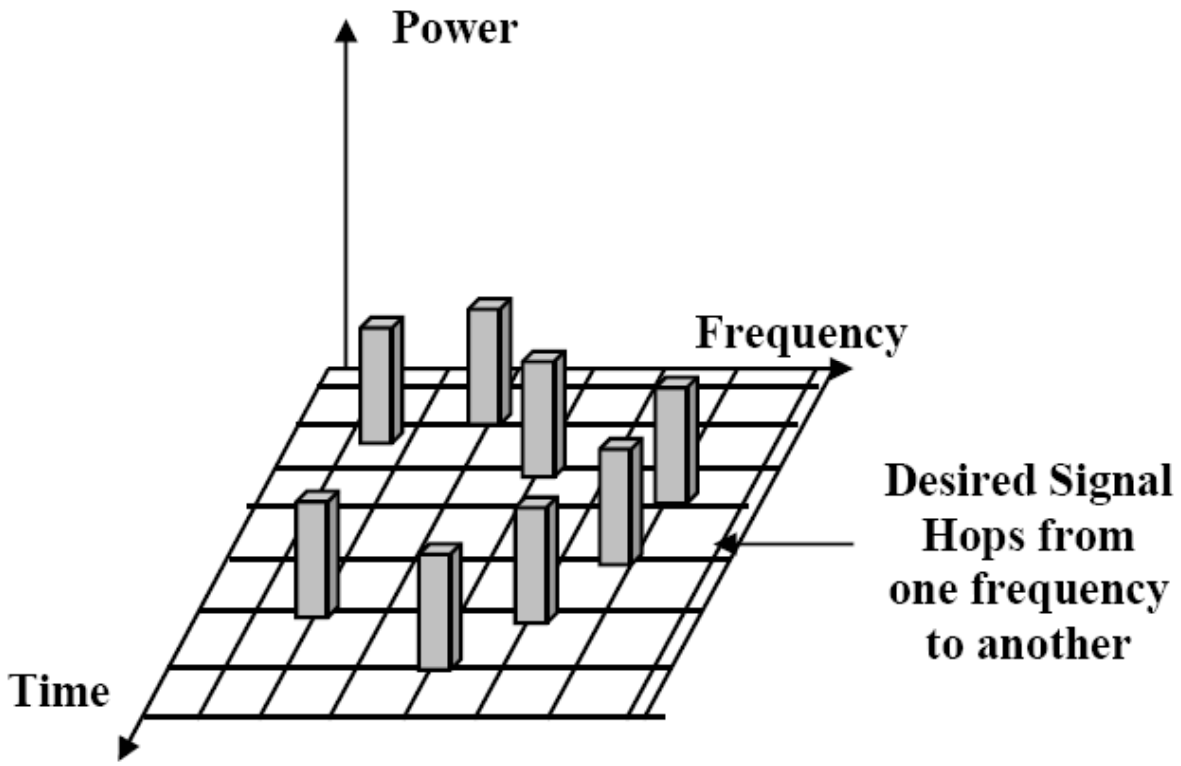
Limitations

- Code acquisition may be difficult
- Susceptible to Near-Far problem
- Affected by jamming

DSSS transmitter can withstand more interference if the length of the PN sequence is increased.

FREQUENCY HOPPING SPREAD SPECTRUM

FREQUENCY HOPPING SPREAD SPECTRUM

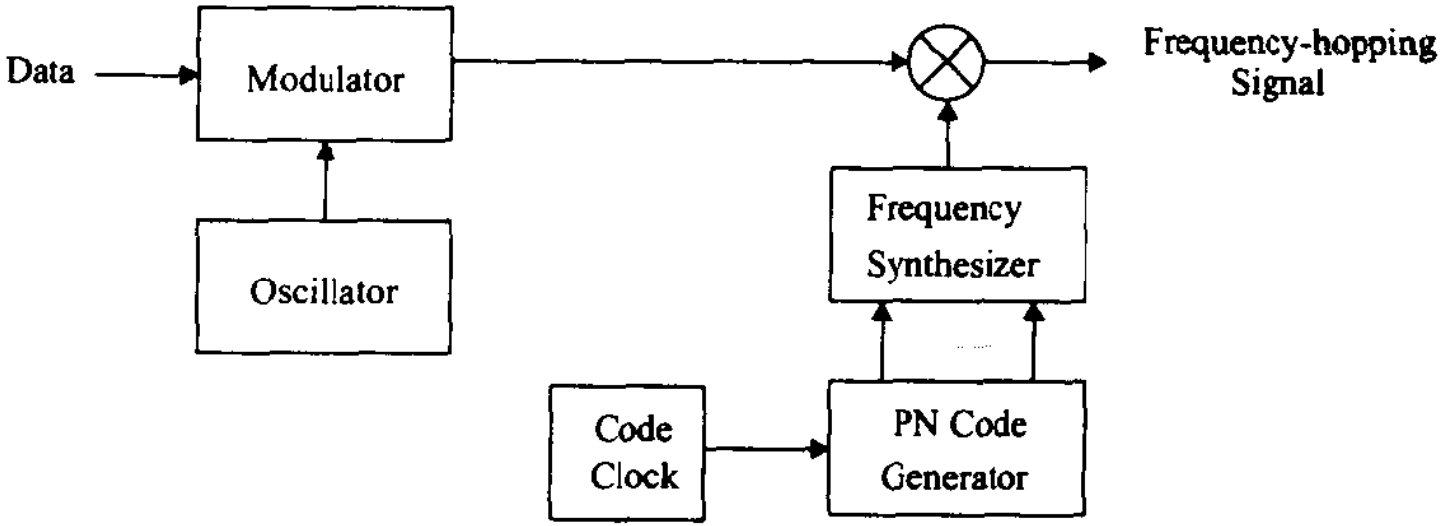


In a frequency hopping (FH) system, the frequency is constant in each time chip; instead it changes from chip to chip.

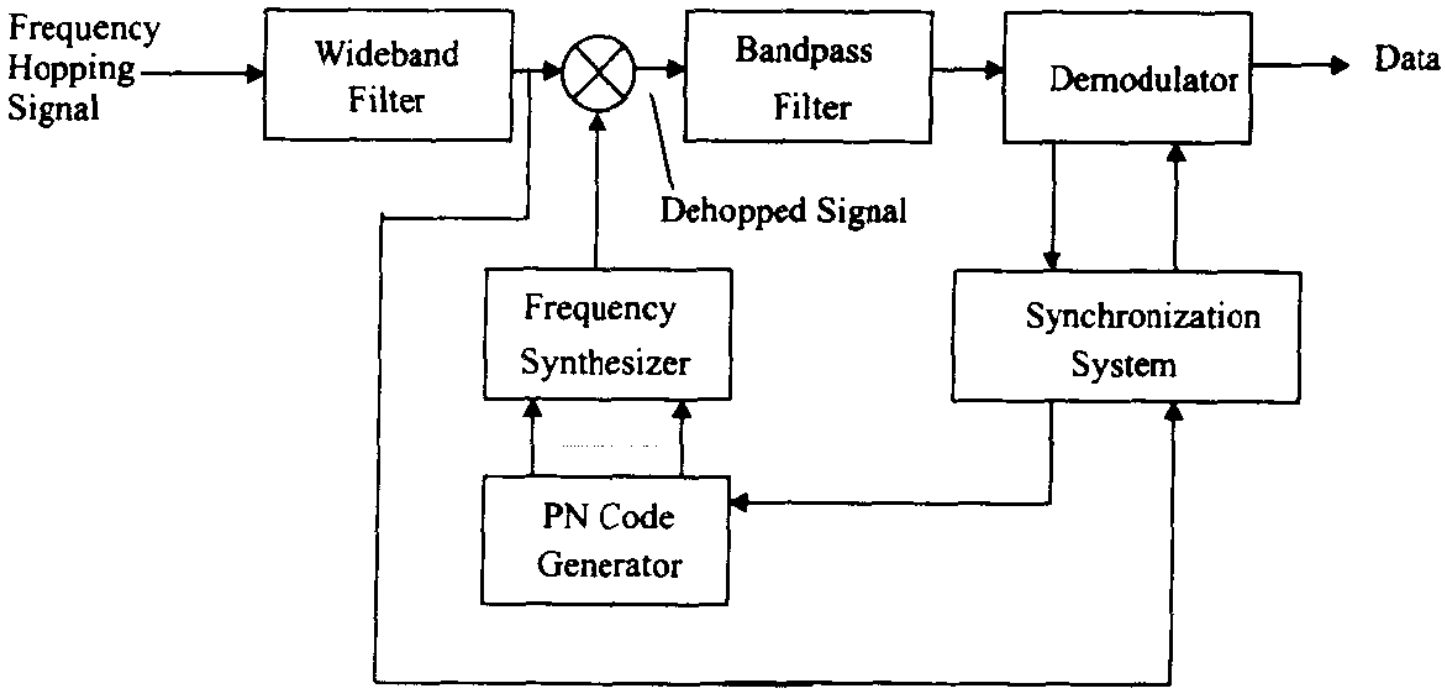
- Frequency hopping systems can be divided into
  - fast-hop
    - Hopping rate is greater than the message bit rate
  - slow-hop
    - Hopping rate is smaller than the message bit rate

Frequency hopping may be classified as fast or slow. *Fast frequency hopping* occurs if there is more than one frequency hop during each transmitted symbol. Thus, fast frequency hopping implies that the hopping rate equals or exceeds the information symbol rate. *Slow frequency hopping* occurs if one or more symbols are transmitted in the time interval between frequency hops.

TRANSMITTER



RECEIVER


Frequency Hopping Signal
Wideband Filter
Bandpass Filter
Demodulator
Data
Dehopped Signal
Frequency Synthesizer
Synchronization System
PN Code Generator

Merits

- Less affected by Near-Far problem
- Better for avoiding jamming
- Less affected by multi-access interference

Limitations

- Needs FEC
- Frequency acquisition may be difficult

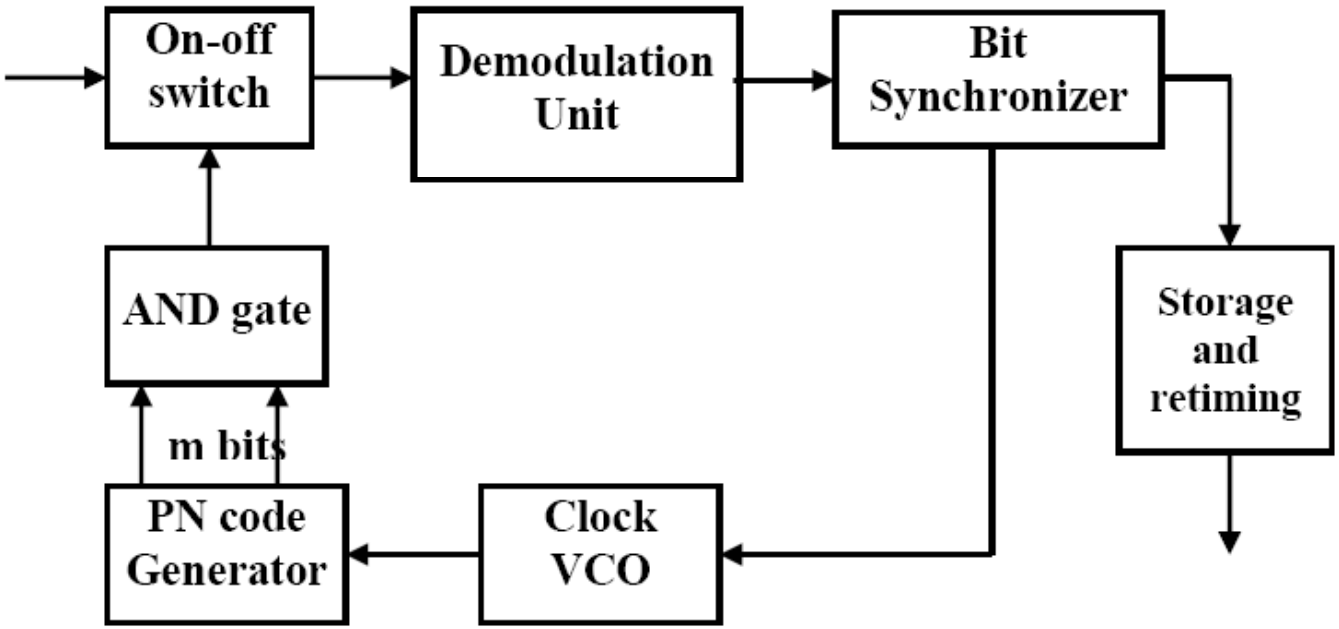
The total hopping bandwidth and the instantaneous bandwidth are denoted by W_{ss} and B, respectively. The processing gain $\approx W_{ss}/B$ for FH systems.

TIME HOPPING

TIME HOPPING

- A time hopping signal is divided into frames, which in turn are subdivided into M time slots. As the message is transmitted only one time slot in the frame is modulated with information (any modulation). This time slot is chosen using PN generator.
- All of the message bits gathered in the previous frame are then transmitted in a burst during the time slot selected by the PN generator.

TIME HOPPING RECEIVER



Merits

- Bandwidth efficient
- Simpler than FH system

Limitations

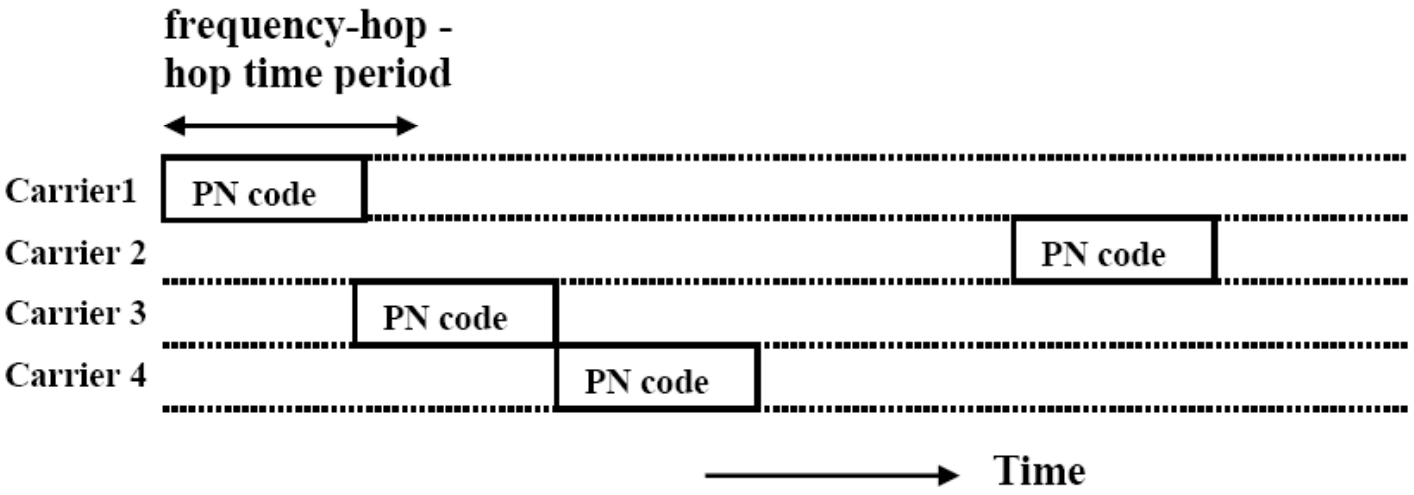
- Elaborate code acquisition is needed.
- Needs FEC*

*FEC→ forward error-correction coding

HYBRID SPREAD SPECTRUM TECHNIQUES

Combination of DS/(F) FH

The DS/FH Spread Spectrum technique is a combination of direct-sequence and frequency hopping schemes. One data bit is divided over several carrier frequencies .



FH-sequence and the PN-codes are coupled

SPREADING CODES

- A random spreading code sequence c(t) of chosen length is used to ‘spread’(multiply) the modulating signal m(t).
- Each bit of the spreading code is called a ‘chip’. Duration of a chip (Tc) is much smaller compared to the duration of an information bit
- Several spreading codes are popular for use in practical spread spectrum systems
  - Maximal Sequence (m-sequence) length codes
  - Gold codes
  - Kasami codes
  - Barker codes

CODE SYNCHRONISATION

- Code synchronization is the process of achieving and maintaining proper alignment between the reference code in a spread spectrum receiver and the spreading sequence that has been used in the transmitter to spread the information bits
- achieved in two stages:
  - code acquisition
    - the process of initially attaining coarse alignment (typically within ± half of the chip duration)
  - code tracking.
    - ensures that fine alignment within a chip duration is maintained

REFERENCE

"Wireless Mobile communications" by Theodore S Rappaport

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