20ITT41 & PRINCIPLES OF COMMUNICATION

Unit - V Spread Spectrum

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Preamble This course explains the concepts of Analog and Digital communication systems that are used for the transmission of information from source to destination. A detailed quantitative framework for analog and digital transmission techniques is addressed.

Unit - I Amplitude Modulation: 9+3

Principles of amplitude modulation – AM envelope - Frequency spectrum and bandwidth - Modulation index and percentage modulation - AM power distribution - AM modulator circuits – Low level AM modulator - AM transmitters – Low level transmitter - AM receivers – Super heterodyne receivers

Unit - II Angle Modulation: 9+3

Angle Modulation – FM and PM waveforms - Phase deviation and modulation index - Frequency deviation - Direct FM and PM demodulators - Frequency spectrum of angle modulated waves - Bandwidth requirement - Narrowband FM and Broadband FM -Average power - FM and PM modulators, Direct FM transmitter - Angle modulation Vs. Amplitude modulation –Indirect FM transmitter.

Unit - III Digital Modulation: 9+3

Sampling - Time Division Multiplexing - Digital T-carrier System – Pulse code modulation – Amplitude shift keying – Frequency and phase shift keying – Modulator and demodulator - bit error rate calculation.

Unit - IV Data Communication: 9+3

Data communication codes: ASCII - BAR codes - Error Control - Error Detection - Redundancy checking - Error Correction -Hamming – Line coding: AMI – NRZ - RZ - Serial interfaces : RS232 - RS485 - Data communication circuits – Data communication modems - Public Switched Telephone Network(PSTN) – ISDN.

Unit - V Spread Spectrum: 9+3

PN sequence code and its properties- Direct sequence spread spectrum system - Processing gain- Frequency hopping spread spectrum.

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TEXT BOOK:

1. Wayne Tomasi, “Electronic Communications Systems: Fundamentals through Advanced”, 5th Edition, Pearson Education,
2008.

REFERENCES:

1. Michael Moher and Simon Haykin, “Communication System”, 5th Edition, Wiley India Pvt. Ltd., New Delhi, 2011.
2. Frenzel and Louis E., “Principles of Electronic Communication Systems”, 3rd Edition, Tata McGraw Hill Publishing Company,
New Delhi, 2008.
3. Anokh Singh, “Principles of Communication Engineering”,S. Chand & Co., New Delhi, 2006.

COURSE OUTCOMES:

On completion of the course, the students will be able to

CO1 illustrâtes amplitude modulation techniques	Applying (K3)
CO2 use the different angle modulation schemes	Applying (K3)
CO3 apply the concepts of digital modulation techniques	Applying (K3)
CO4 detect and correct the errors introduced in the channel using error control coding schemes	Applying (K3)
CO5 illustrate the spread spectrum techniques for modern communication	Applying (K3)

Spread Spectrum

- Spread-spectrum communications technology was first described on
- paper in 1941 Hollywood actress Hedy Lamarr and pianist George Antheil
- described a secure radio link to control torpedos.

Spread-spectrum is apparent in the Shannon and Hartley channel-capacity theorem:

$$C = B \times \log2 (1 + S/N)$$

In this equation,

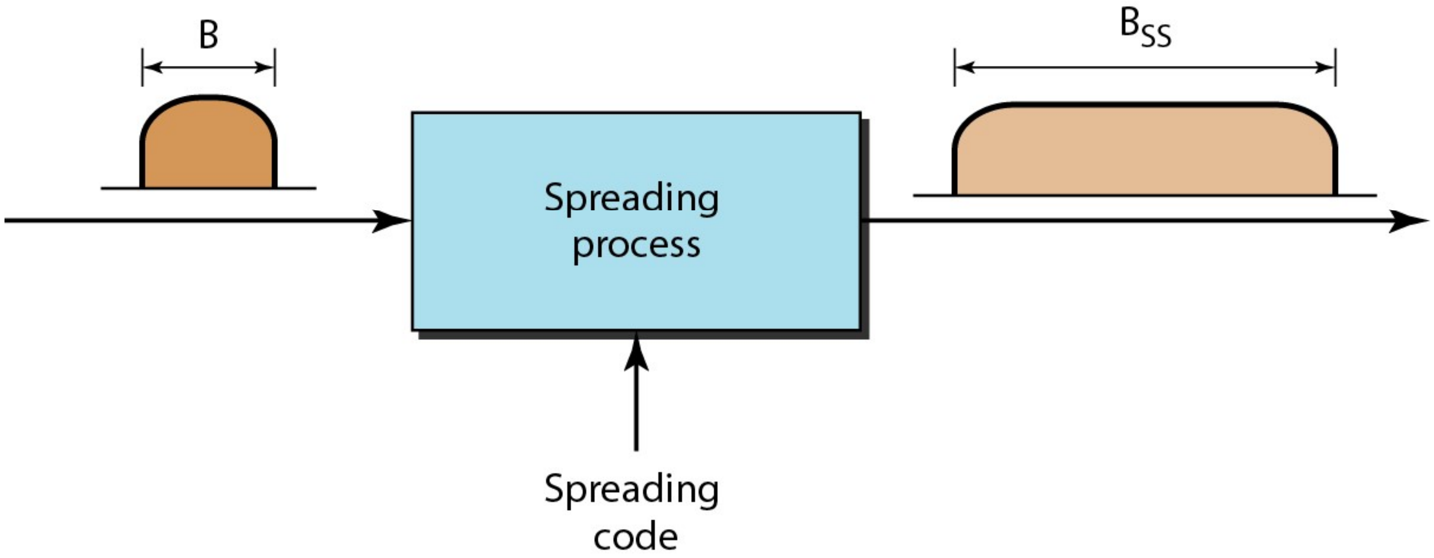
C is the channel capacity in bits per second (bps), which is the maximum data rate for a theoretical bit-error rate (BER).

B = the required channel bandwidth in Hz.

S/N = the signal-to-noise power ratio.

Spread Spectrum

- A signal that occupies a bandwidth of **B**, is spread out to occupy a bandwidth of $\mathbf{B_{ss}}$
- All signals are spread to occupy the same bandwidth $\mathbf{B_{ss}}$
- Signals are spread with different codes so that they can be separated at the receivers.
- Signals can be spread in the frequency domain or in the time domain.

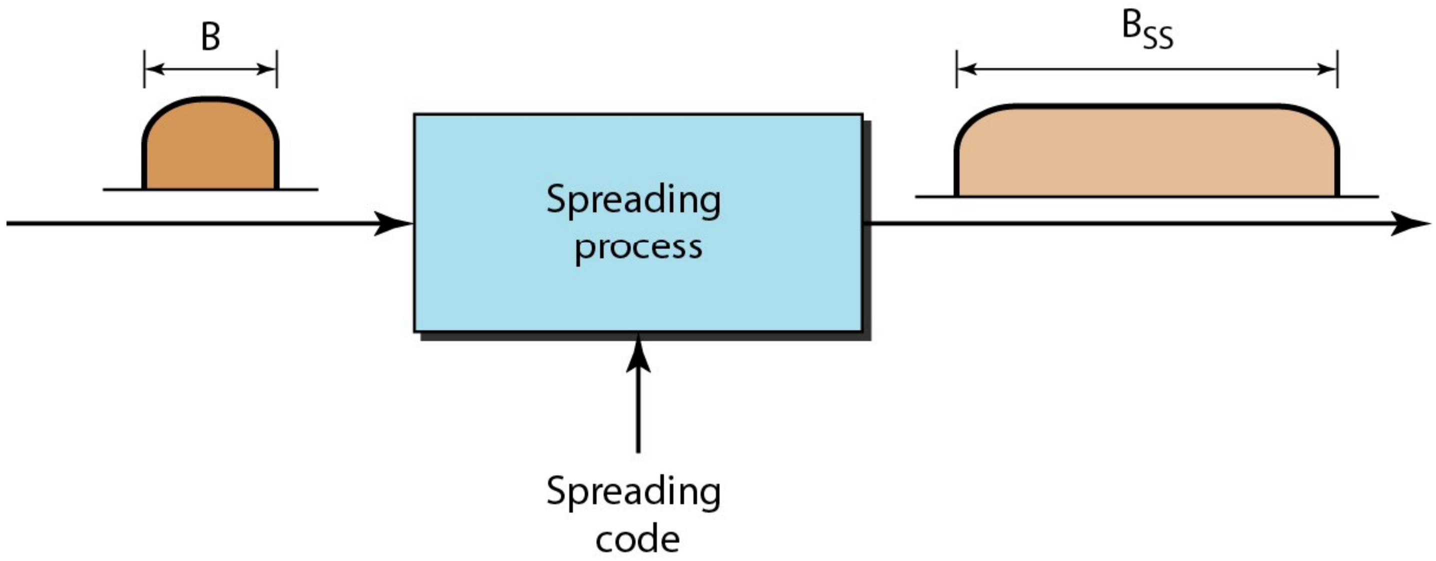


$$\text{Processing Gain } N = \frac{B_{ss}}{R} = 10\log_{1}$$

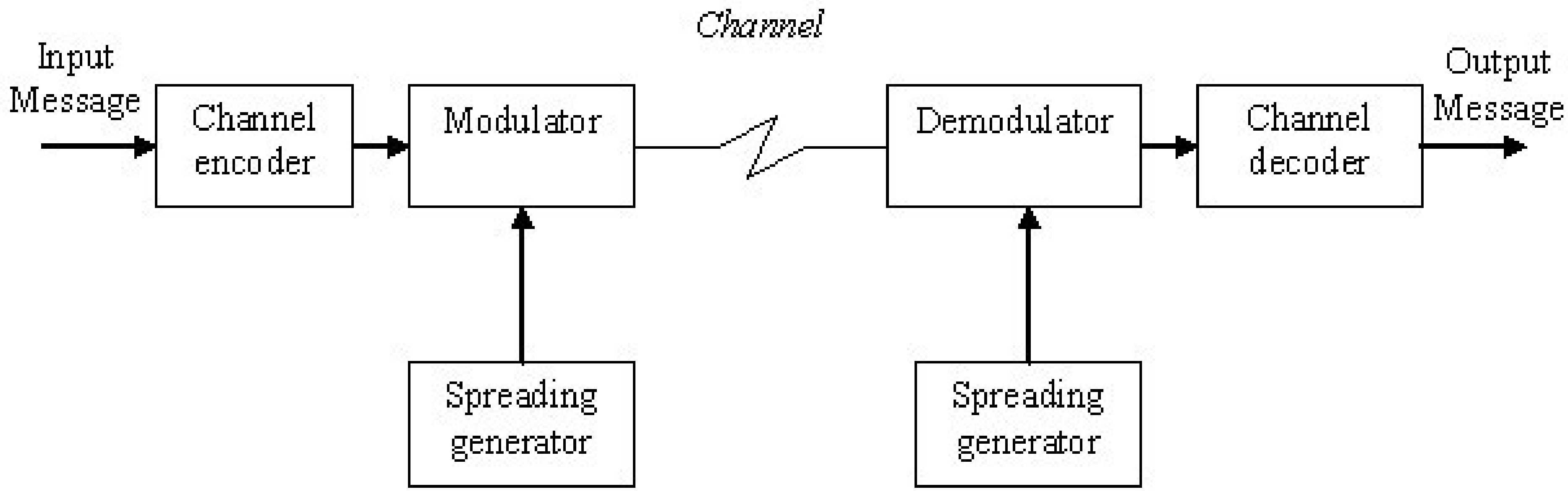
Typical spread-spectrum processing gains run from 10dB to 60dB.

Spread Spectrum

- Definition: Spread spectrum modulation spreads out the modulated signal bandwidth so it is much greater than the message bandwidth.
- It is a modulation techniques in which transmitted BW is larger than information signal BW.
- Bit arte of spreading sequence is much grater than the input data.



Block Diagram of Spread Spectrum



✓Input data is fed into a channel encoder Which Produces analog signal with narrow bandwidth.

✓ Signal is further modulated using sequence of digits. Spreading code or spreading sequence Generated by pseudo noise, or pseudo-random number generator.

✓Effect of modulation is to increase bandwidth of signal to be transmitted.

✓On receiving end, digit sequence is used to demodulate the spread spectrum signal.

✓ Signal is fed into a channel decoder to recover data.

Classifications of Spread Spectrum Systems

There are two major classes of spread spectrum systems. These are:

1. Pure spread spectrum systems
2. Hybrid spread spectrum systems

Under pure spread spectrum systems, the following three spread spectrum systems are obtained:

I. Direct Sequence Spread Spectrum (DSSS)
II. Frequency Hopping Spread Spectrum (FHSS)
III. Time Hopping Spread Spectrum (THSS)

Block Diagram of Spread Spectrum

To qualify as a spread spectrum signal, two criteria should be met:

- ❑ **The transmitted signal bandwidth is much greater than the information bandwidth**
- ❑ **Some function other than the information being transmitted is employed to determine the resultant transmitted bandwidth**

Processing Gain Gp

$$Gp = \frac{\text{Bandwidth of Spread Signal (}}{\text{Bandwidth of digital information}}$$

Benefits of Spread Spectrum

- Interference suppression
- Low power spectral density
- High resolution time of arrival measurements for precise ranging
- Multiple access
- Alleviation of multipath propagation

Pseudo noise (PN) Sequences:

- PN sequences are codes that appear to be random but are not, strictly speaking, random since they are generated using predetermined circuit connections. Nevertheless, they meet a number of randomness criteria.

maximum possible PN sequence length P

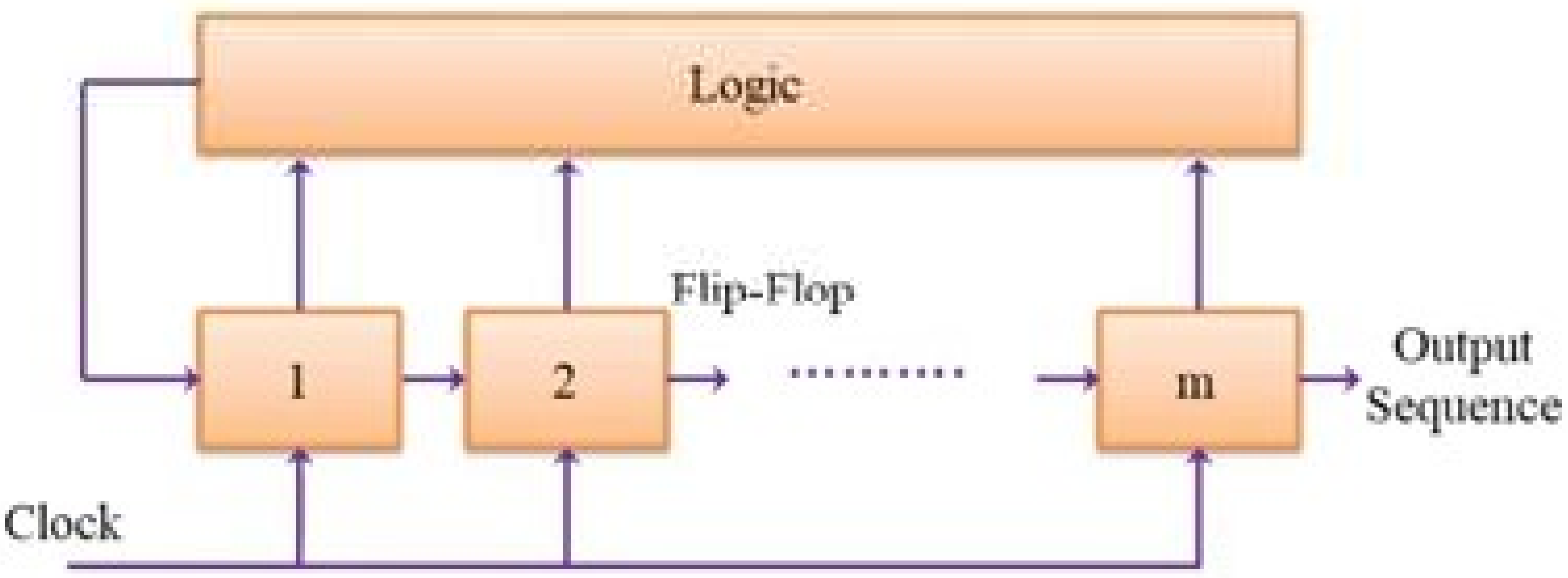
$$p = 2^n - 1$$

Pseudo noise (PN) Sequences:

- Output sequence depends on the number of shift register(m), initial state and feedback logic
- output sequence depends on a number of shift register of (m), initial state and feedback logic
- for m flip flop the number of state is 2^m
- the maximum length of the period of the sequence is $N= 2^m -1$
- In case that feedback lodging consists entirely with modulo-2 adders (XOR gate) only the initial state cannot the all zero state.
- The period of PN sequence produced by linear feedback cannot exceed ($2^m -1$)
- when the period is exactly $2^m -1$ the PN sequence is called a maximum length sequence H M sequence

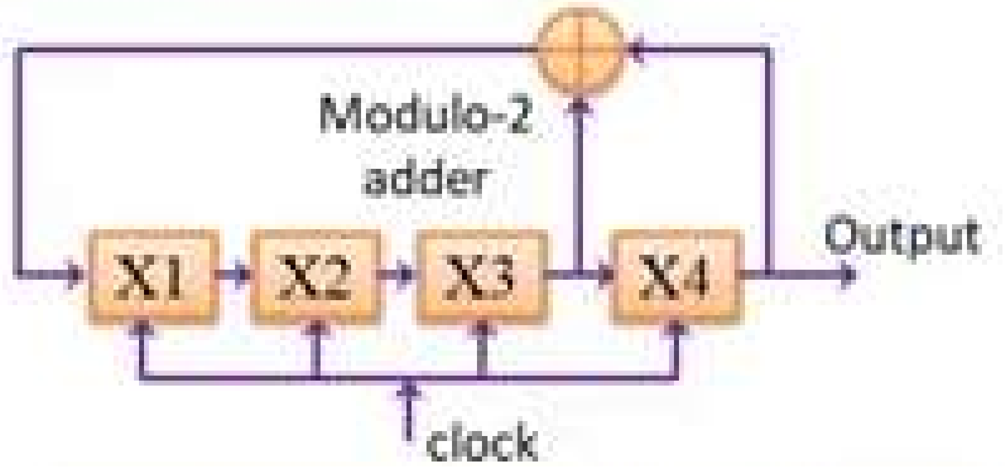
Pseudo noise (PN) Sequences:

- Example of PN sequence generation when m = 4



Pseudo noise (PN) Sequences:

- Example of PN sequence generation when m = 4

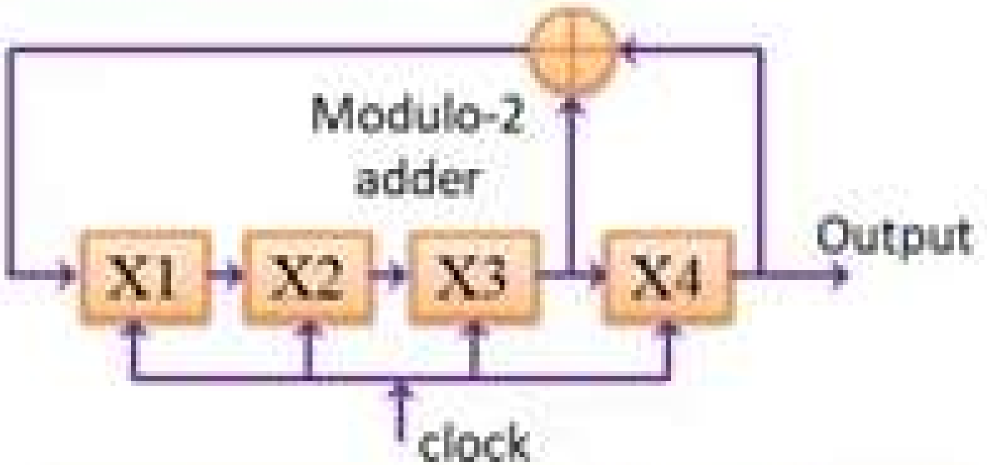


Clock	X1	X2	X3	X4
1	1	0	0	0
2	0	1	0	0
3	0	0	1	0
4	1	0	0	1
5	1	1	0	0
6	0	1	1	0
7	1	0	1	1
8	0	1	0	1

Clock	X1	X2	X3	X4
9	1	0	1	0
10	1	1	0	1
11	1	1	1	0
12	1	1	1	1
13	0	1	1	1
14	0	0	1	1
15	0	0	0	1
16	1	0	0	0

Pseudo noise (PN) Sequences:

- Example of PN sequence generation when m = 4



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14	0	0	1	1
15	0	0	0	1
16	1	0	0	0

Pseudo noise (PN) Sequences:

- since we are taking the output from x 4 in the output of the field and sequence is given as

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**1**	**0**	**1**	**1**	**1**	**1**

Clock	X1	X2	X3	X4
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Pseudo noise (PN) Sequences:

- since we are taking the output from x 4 in the output of the field and sequence is given as

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	**0**	**0**	**1**	**0**	**0**	**1**	**1**	**0**	**1**	**0**	**1**	**1**	**1**	**1**	**0**

To map the sequence in the stream of -1 and + 1 in order to modulate. Hence simple mapping looks like

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
-1	**-1**	**-1**	**+1**	**-1**	**-1**	**+1**	**+1**	**-1**	**+1**	**-1**	**+1**	**+1**	**+1**	**+1**

Properties of PN sequences

- **Balance Property:**

  In the balance property, the number of output binary ones and the number of binary output zeros in a single period differs by at most one.

- **Run Length Property:**

  A run is defined as a continuous sequence of the same type of binary digit. A new run commences with the appearance of a different binary digit. The length of a run is the number of digits contained in a given run. In PN sequences about half of the runs are of length 1, about a quarter of the runs are of length 2, about an eighth of the runs are of length three and so on.

- **Correlation Property:**

  Based on the correlation property if any PN output sequence is compared with any cyclic shift of itself, the number of agreements differs from the number of disagreements by at most one count.

Properties of PN sequences

- Balance Property :
  - Has 2^{n-1} ones and 2^{n-1}-1 zeros
- **Run Length Property** :
  - Sequence contains one run of ones, length n
  - One run of zeros, length n-1
  - One run of ones and one run of zeros, length n-2
  - Two runs of ones and two runs of zeros, length n-3
  - 2^{n-3} runs of ones and 2^{n-3} runs of zeros, length 1
- **Correlation Property**

  The periodic autocorrelation of a ±1 m-sequence is

$$R(\tau) = \begin{cases} 1 & \tau = 0, N, 2N, \ldots \\ -\dfrac{1}{N} & \text{otherwise} \end{cases}$$

Pseudo noise (PN) Sequences:

Balance Property : Number of (+1) = 8 > Number of (-1) = 7

For Large sequence Number of (+1) = Number of (-1)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
-1	-1	-1	+1	-1	-1	+1	+1	-1	+1	-1	+1	+1	+1	+1

Run Property : Run is nothing but the string of continuous values

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
-1	-1	-1	+1	-1	-1	+1	+1	-1	+1	-1	+1	+1	+1	+1

Total number of runs are given by (N+ 1)/2 , (15+1)/2 = 8

In general the runoff length n which can be given as

Run of length of n= $1/2^n$ x total number of runs

Run of Length of '1"= 1/2x 8= 4

Run of Length of '2"= $1/2^2$ x8 = 2

Run of Length of '3"= $1/2^3$ x8 = 1

Pseudo noise (PN) Sequences:

The Auto correlation function of PN sequence is given as

$$R(d) = \frac{1}{N}\sum_{n=0}^{N} c(n)c(n-d)$$

where

N=length of PN sequence

d=shift in the sequence

$c(n)=\pm 1$

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
C(n)	**-1**	**-1**	**-1**	**+1**	**-1**	**-1**	**+1**	**+1**	**-1**	**+1**	**-1**	**+1**	**+1**	**+1**	**+1**
C(n-1)	**+1**	**-1**	**-1**	**-1**	**+1**	**-1**	**-1**	**+1**	**+1**	**-1**	**+1**	**-1**	**+1**	**+1**	**+1**
C(n)* C(n-1)	**-1**	**+1**	**+1**	**-1**	**-1**	**+1**	**-1**	**+1**	**-1**	**-1**	**-1**	**-1**	**+1**	**+1**	**+1**

R(0)= 1

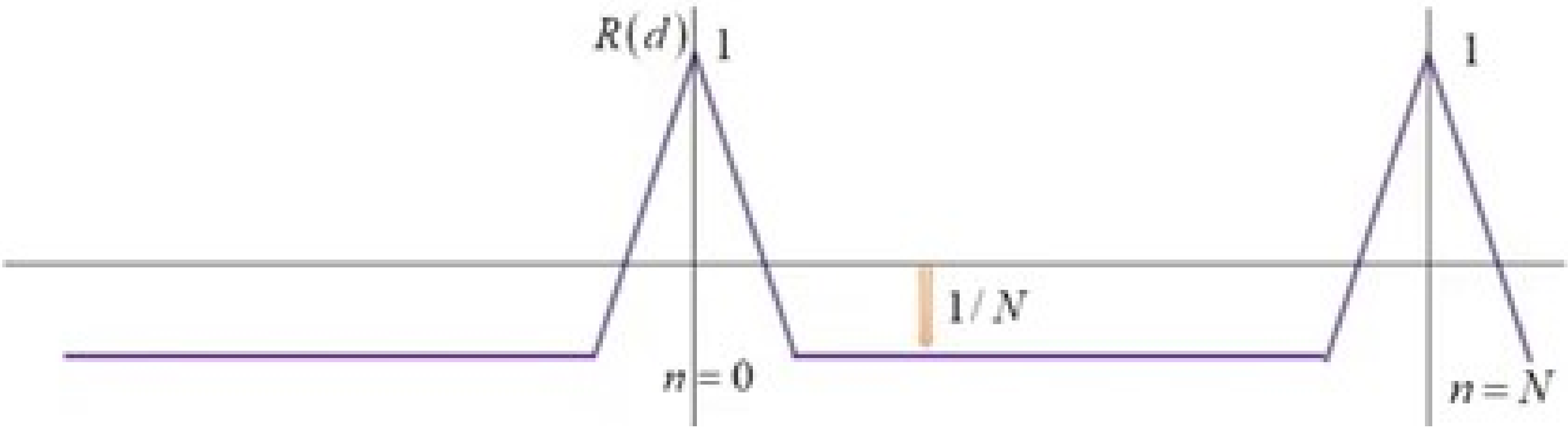
R(1)= 1/15 * (-8 +7)= - 1/15

R(1)=R(2)…..R(15)= -1/15

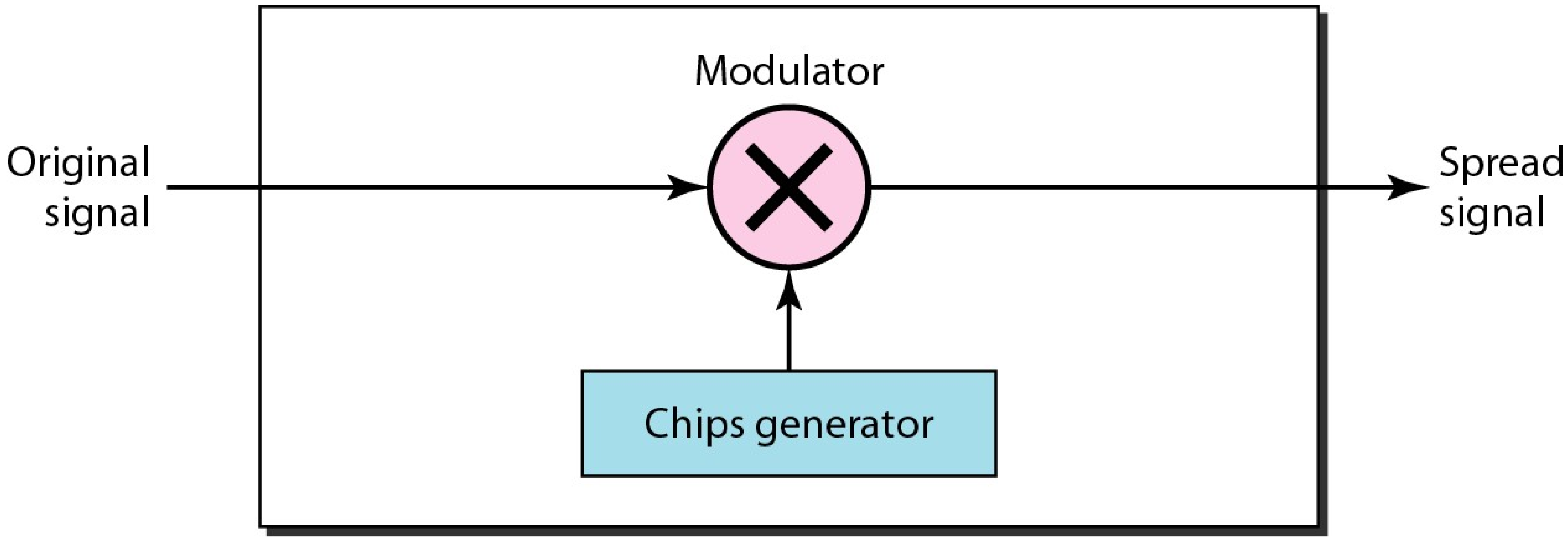
Pseudo noise (PN) Sequences:

In general the Auto correlation function of PN sequence is given as

$$R(d) = \begin{cases} 1 & d = 0 \\ -\dfrac{1}{N}, & d \neq 0 \end{cases}$$



Direct sequence Spread Spectrum

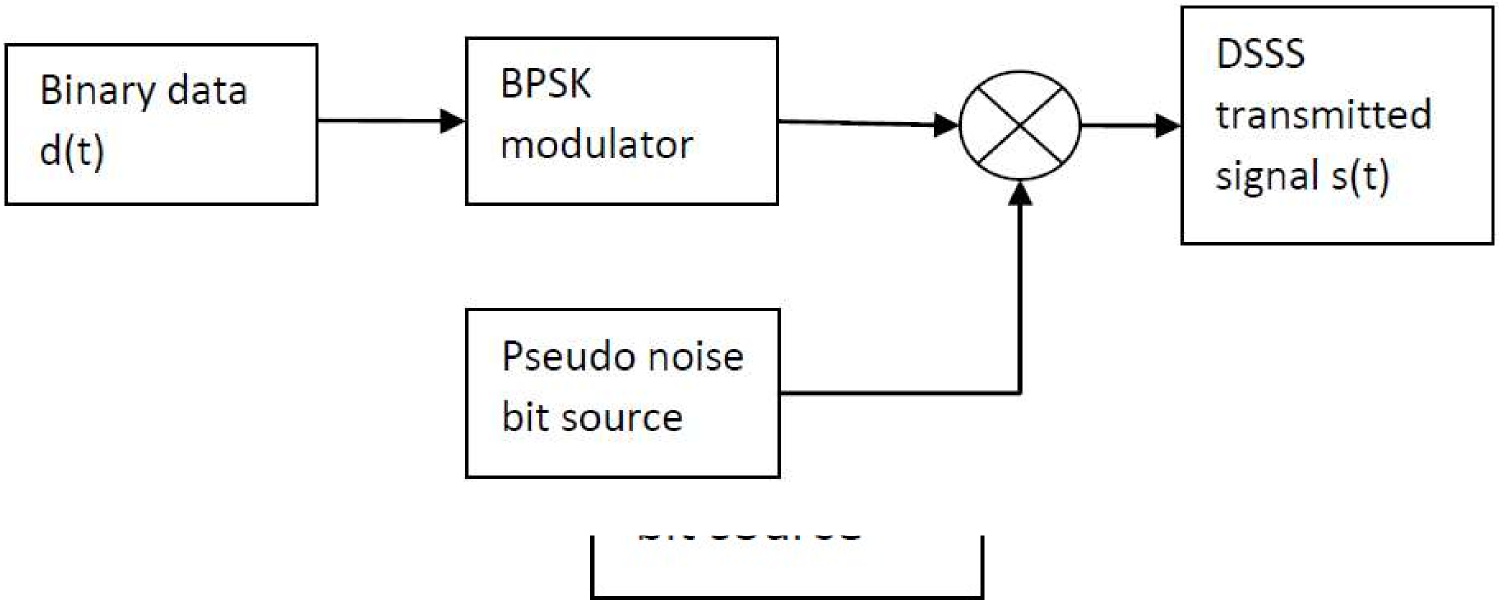


- DSSS which expands BW of input signal
- input signal can be modulated by PSK/QSK/QAM
- It is digital spread spectrum techniques

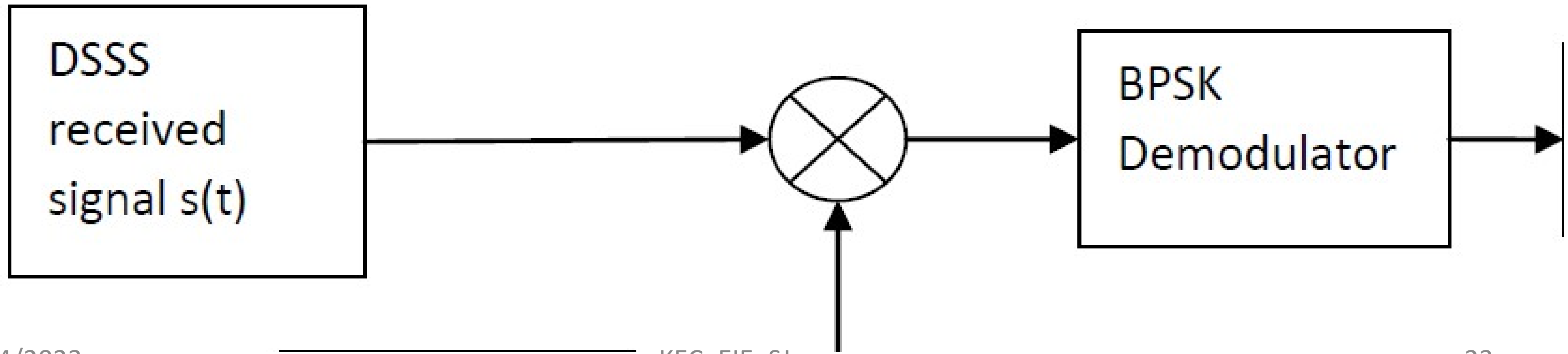
- **Significance of DSSS:**
- Coherent Detection
- Increase bandwidth efficiency
- Reduce bit error

Chip Generator:
It generates Code – Barker code
It has digital o/p{1,-1]

DSSS Using BPSK

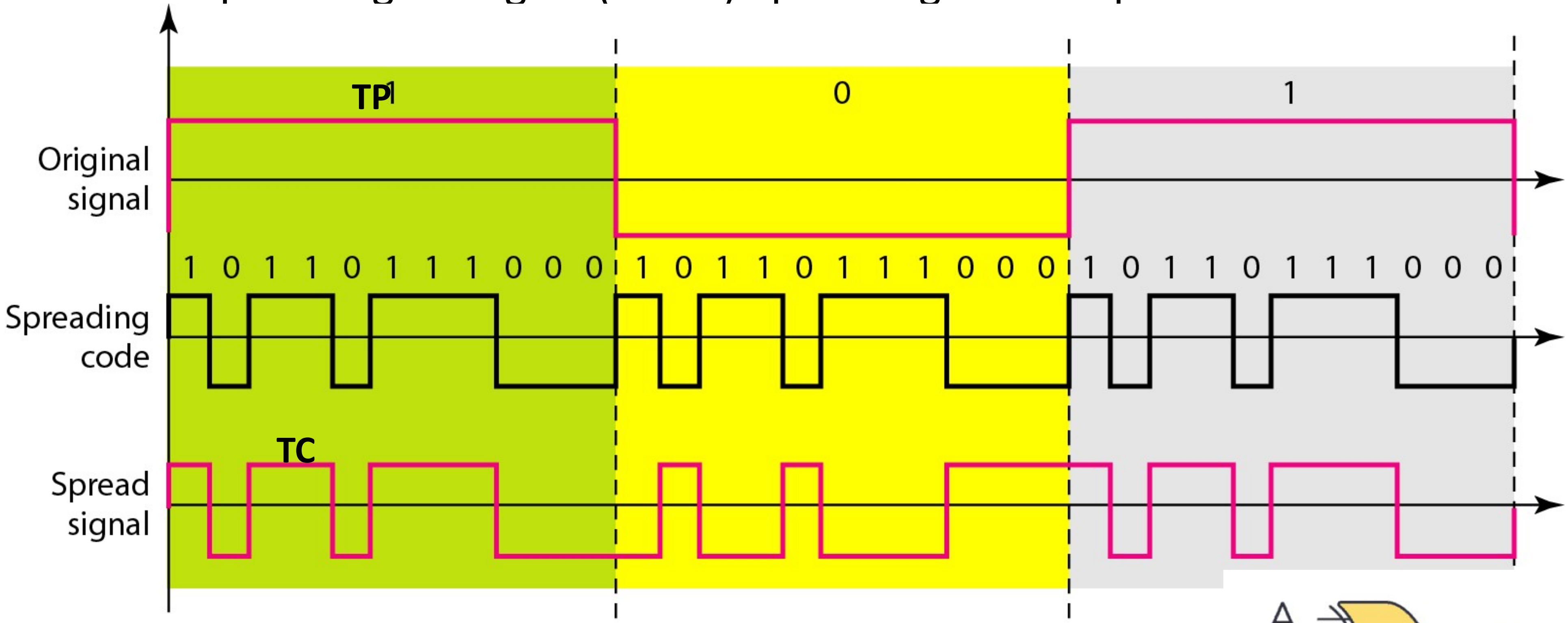


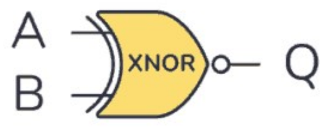
(a)Transmitter



Direct sequence Spread Spectrum

- Example: Original signal (XNOR) Spreading code = Spread code





L= Bit time Tp /Tc

A	B	Q
0	0	1
0	1	0
1	0	0
1	1	1

Direct sequence Spread Spectrum

- Each bit in original signal is represented by multiple bits in the transmitted signal
- Spreading code spreads signal across a wider frequency band
  - Spread is in direct proportion to number of bits used
- One technique combines digital information stream with the spreading code bit stream using exclusive-OR

Advantages:

- Better security
- Immunity against Jamming compared to FHSS

Applications:

- 2G/3G

DSSS Using BPSK

- Multiply BPSK signal,

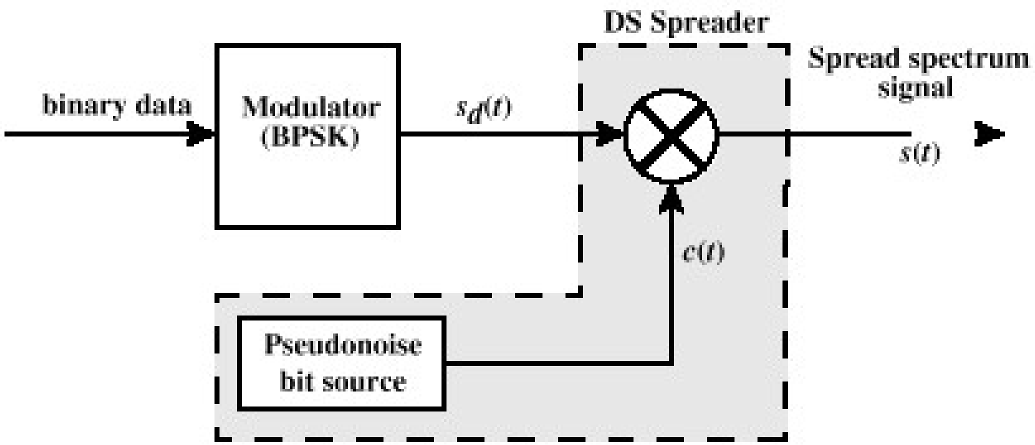
$$s_d(t) = A\, d(t) \cos(2\pi f_c t)$$

  by $c(t)$ [takes values +1, -1] to get

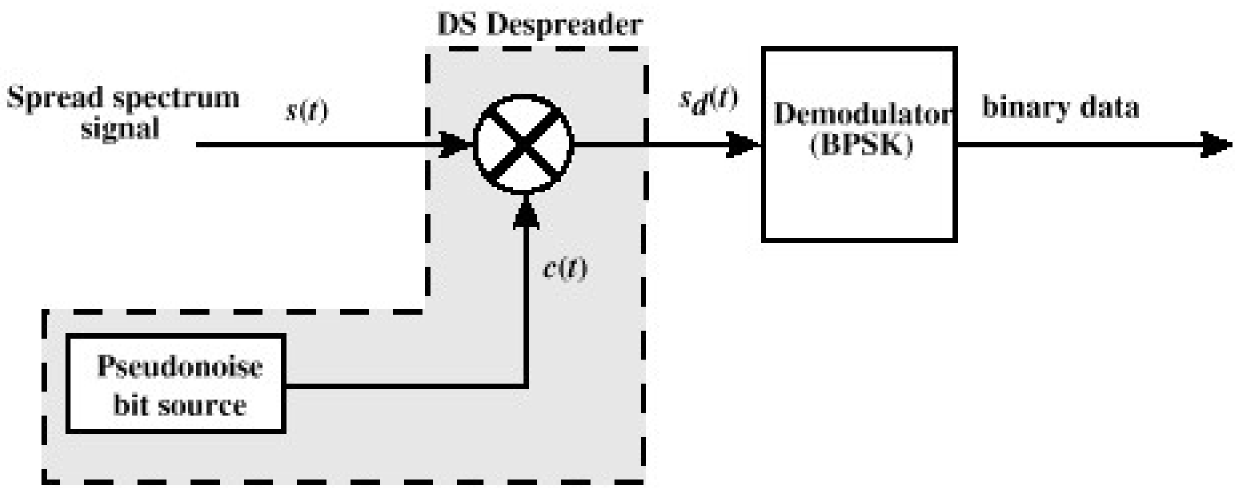
$$s(t) = A\, d(t)c(t) \cos(2\pi f_c t)$$

  - A = amplitude of signal
  - f_c = carrier frequency
  - d(t) = discrete function [+1, -1]
- At receiver, incoming signal multiplied by $c(t)$
  – Since, $c(t)$ x $c(t)$ = 1, incoming signal is recovered

DSSS Using BPSK



(a) Transmitter



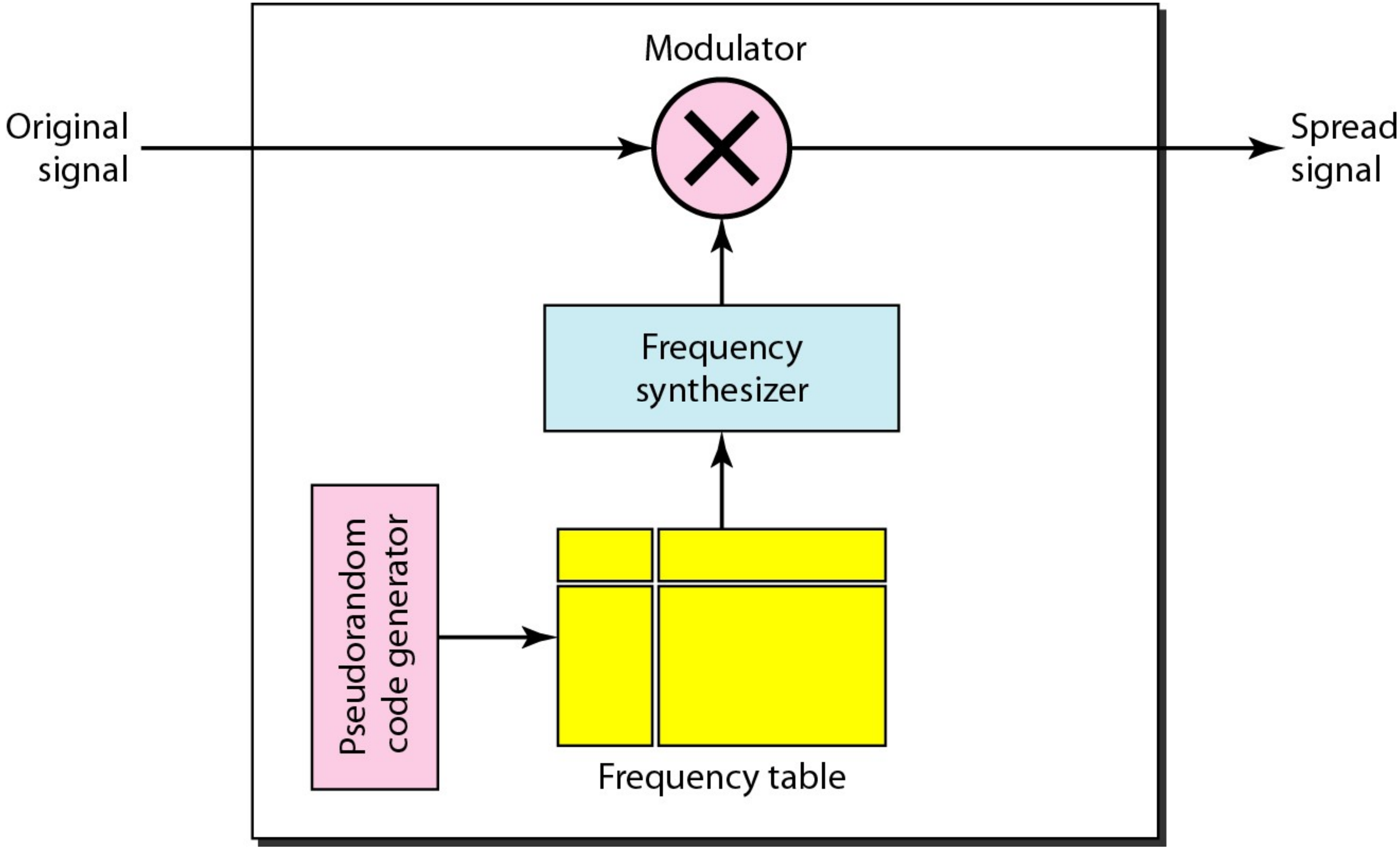
(b) Receiver

Frequency Hoping Spread Spectrum (FHSS)

- Signal is broadcast over seemingly random series of radio frequencies
  - A number of channels allocated for the FH signal
  - Width of each channel corresponds to bandwidth of input signal
- Signal hops from frequency to frequency at fixed intervals
  - Transmitter operates in one channel at a time
  - Bits are transmitted using some encoding scheme
  - At each successive interval, a new carrier frequency is selected

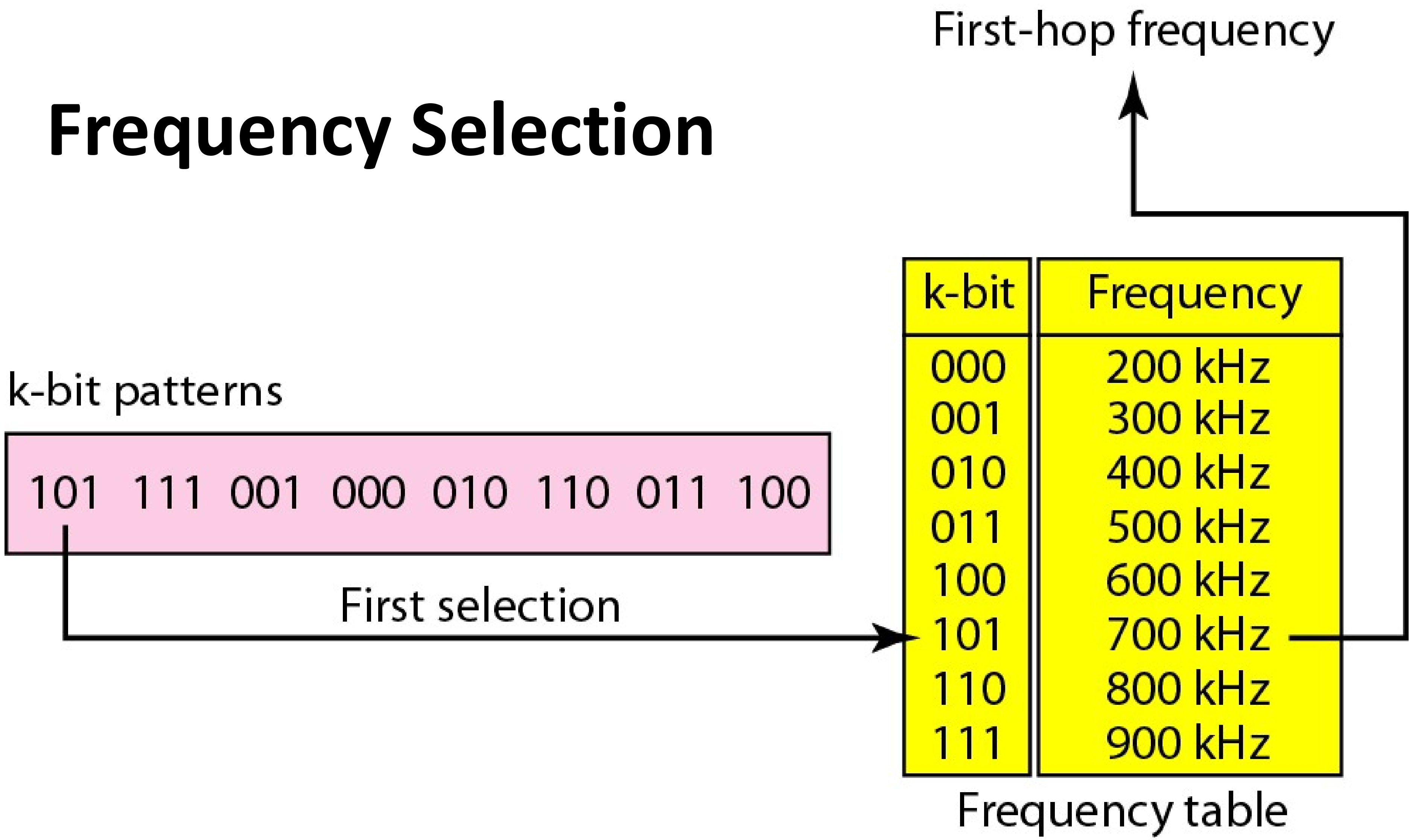
- Channel sequence dictated by spreading code
- Receiver, hopping between frequencies in synchronization with transmitter, picks up message
- **Advantages**
  - Eavesdroppers hear only unintelligible blips
  - Attempts to jam signal on one frequency succeed only at knocking out a few bits

Frequency Hoping Spread Spectrum (FHSS)



Frequency Hoping Spread Spectrum (FHSS)

Frequency Selection



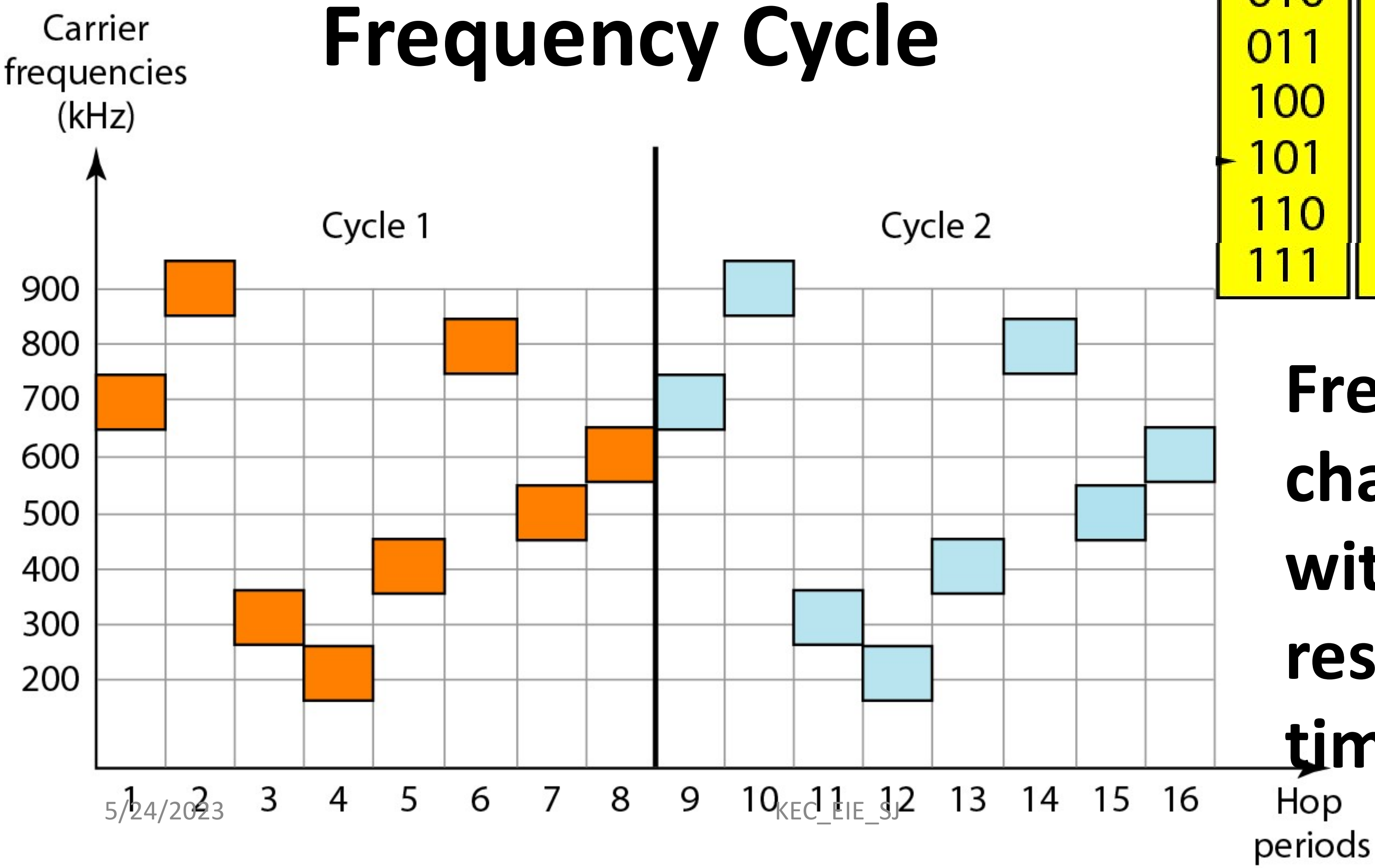
Frequency Hoping Spread Spectrum (FHSS)

k-bit patterns

101	111	001	000	010	110	011	100

k-bit	Frequency
000	200 kHz
001	300 kHz
010	400 kHz
011	500 kHz
100	600 kHz
101	700 kHz
110	800 kHz
111	900 kHz

Frequency Cycle



Frequency changes with respect to time

Frequency Hoping Spread Spectrum (FHSS)

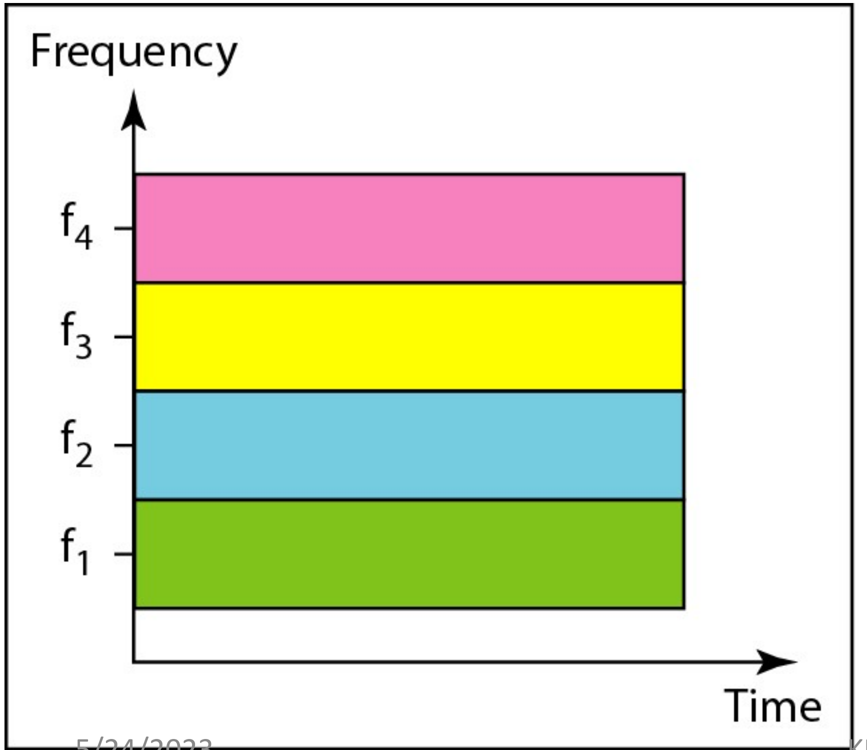
Modulation techniques: QSK, FSK

For coherent signal –FHSSS

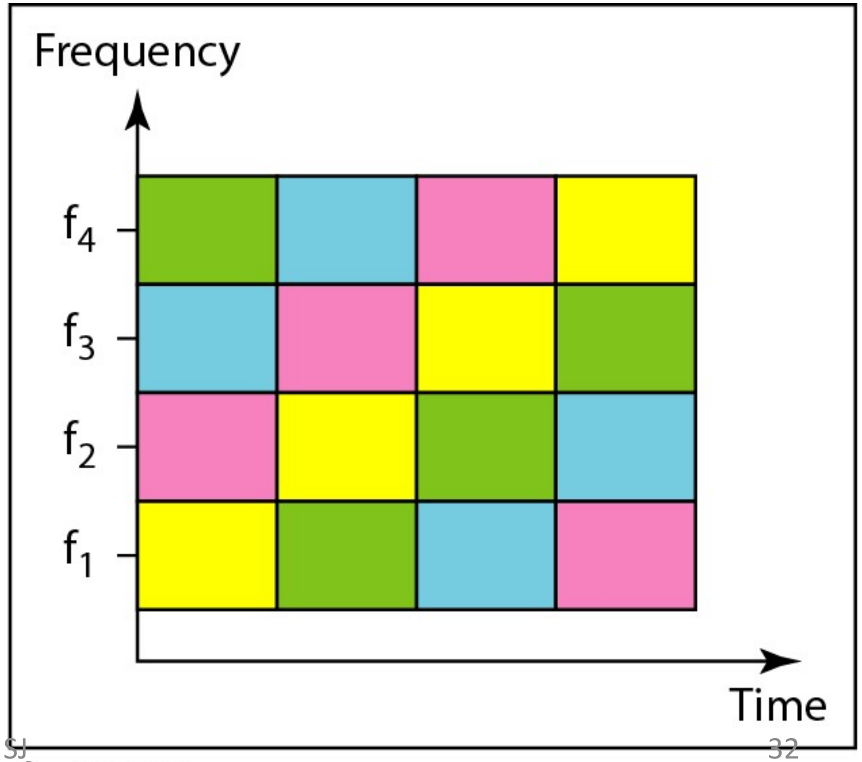
FDM - There is no change in frequency time

FHSS- There is change in frequency time

Bandwidth Sharing



a. FDM



b. FHSS

FHSS Using MFSK

- MFSK signal is translated to a new frequency every T_c seconds by modulating the MFSK signal with the FHSS carrier signal
- For data rate of *R:*
- *Tc- Chip period*
- *Ts – Bit period*
  - duration of a bit: $T = 1/R$ seconds
  - duration of signal element: $T_s = LT$ seconds
- $T_c \geq T_s$ - slow-frequency-hop spread spectrum
- $T_c < T_s$ - fast-frequency-hop spread spectrum

Applications:

- **Bluetooth -1s – 625 times frequency changes**
- **JTRS- Joint Technical Radio system**