Digital Communication 22EC2208

Spread-Spectrum Communications

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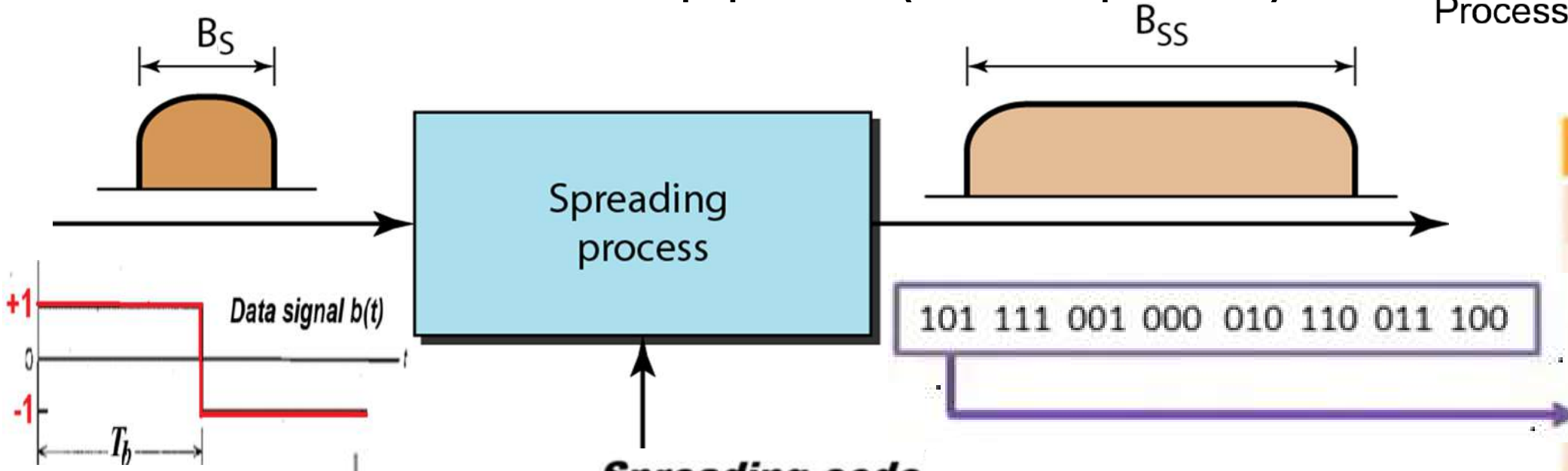
Frequency Hop Spread Spectrum

DSSS BPSK Modulation

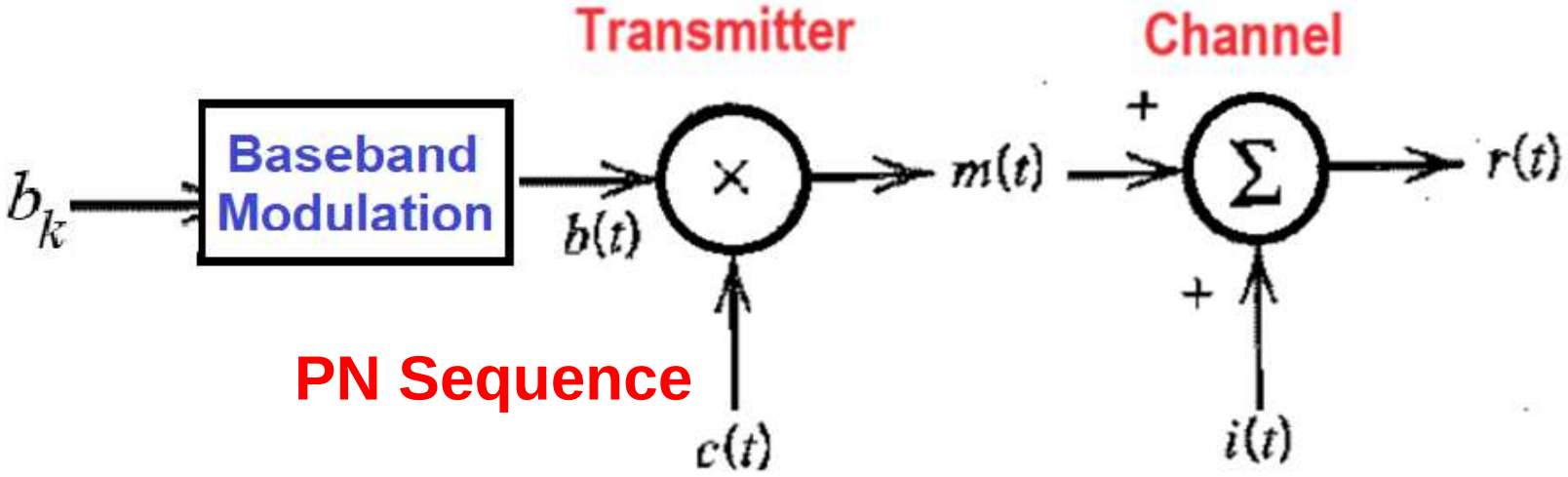
- Use of PN sequence achieves instantaneous spreading of the transmission bandwidth to combat the effects of (Intercepting and jamming) that is determined by the processing gain Gp of the system which is a function of chip period (PN Sequence).

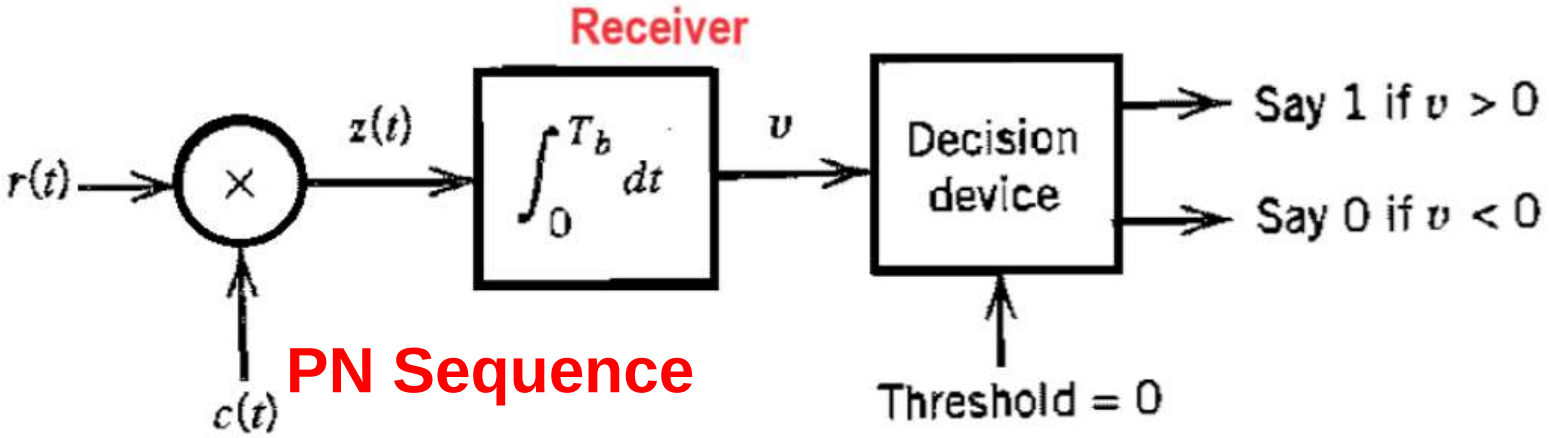
Processing gain $G_p = \frac{B_{ss}}{B_s}$



k-bit	frequency
000	200kHz (f1)
001	300kHz (f2)
010	400kHz(f3)
011	500kHz(f4)
100	600kHz(f5)
101	700kHz(f6)
110	800kHz(f7)
111	900kHz(f8)

Direct Sequence Spread Spectrum





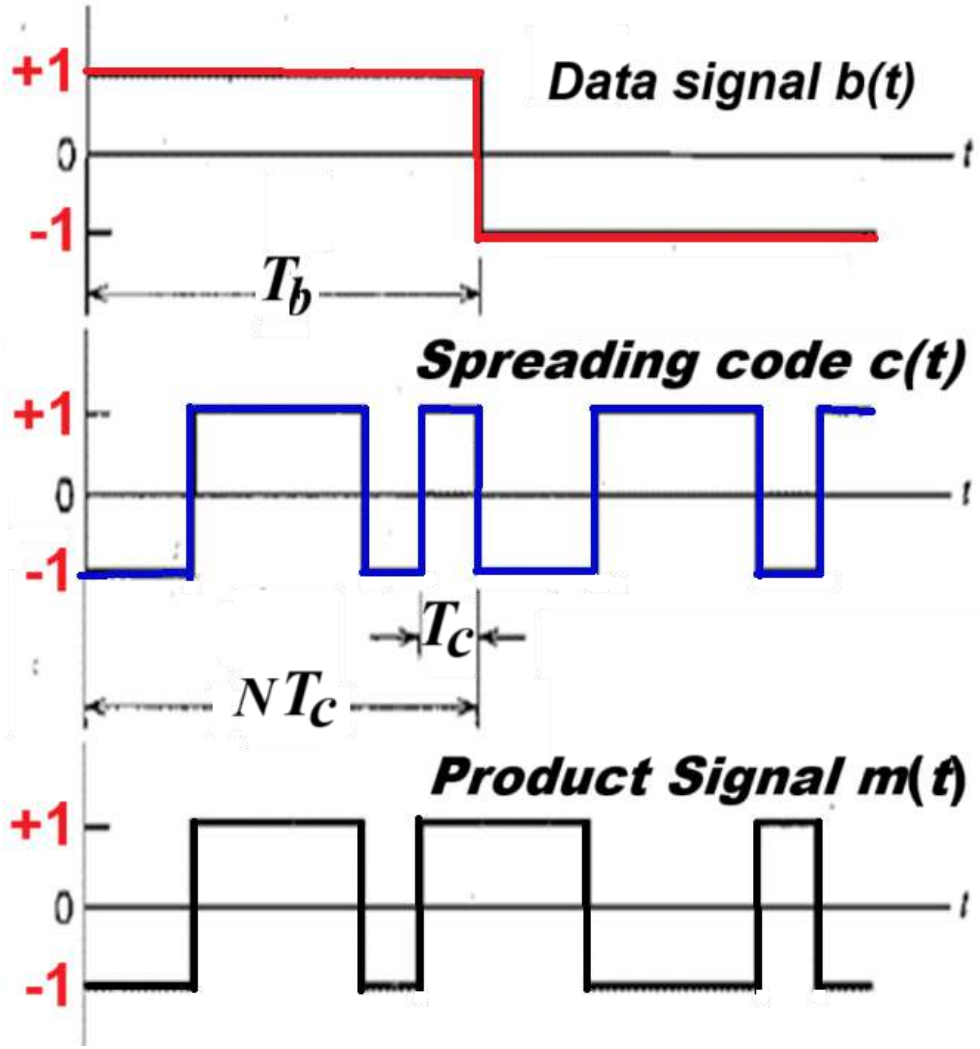
Processing Gain

$$G_p = \frac{B_{ss}}{B_s}$$

Limitations of DSSS

$$G_p = \frac{T_b}{T_c}$$

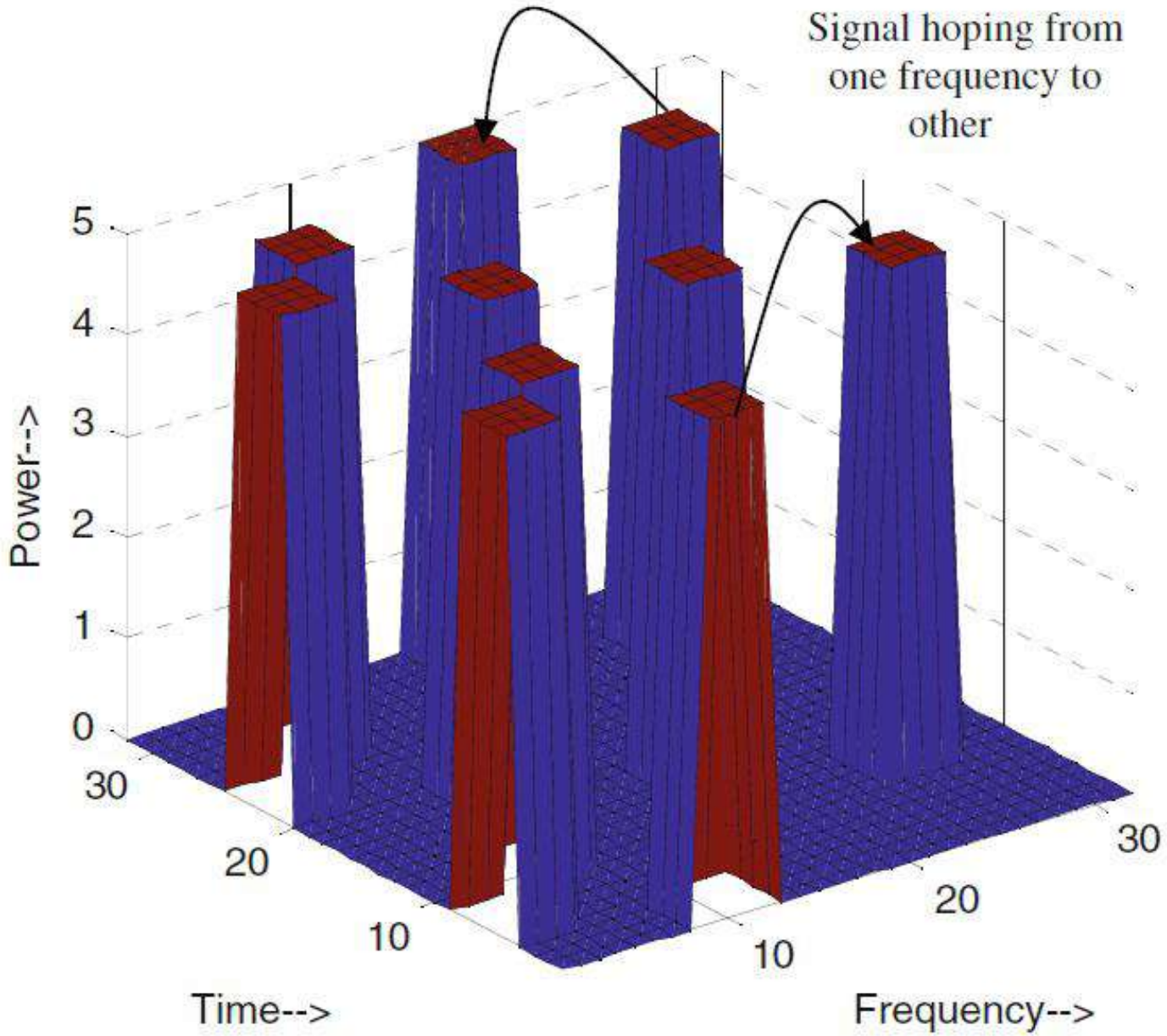
- The Gp can be increased by narrowing chip duration, but limited capabilities of physical device to implement.
- Indeed, the processing gain so attained is not sufficient to achieve large bandwidth.
- To overcome these limitations, frequency hopping spread spectrum is proposed.

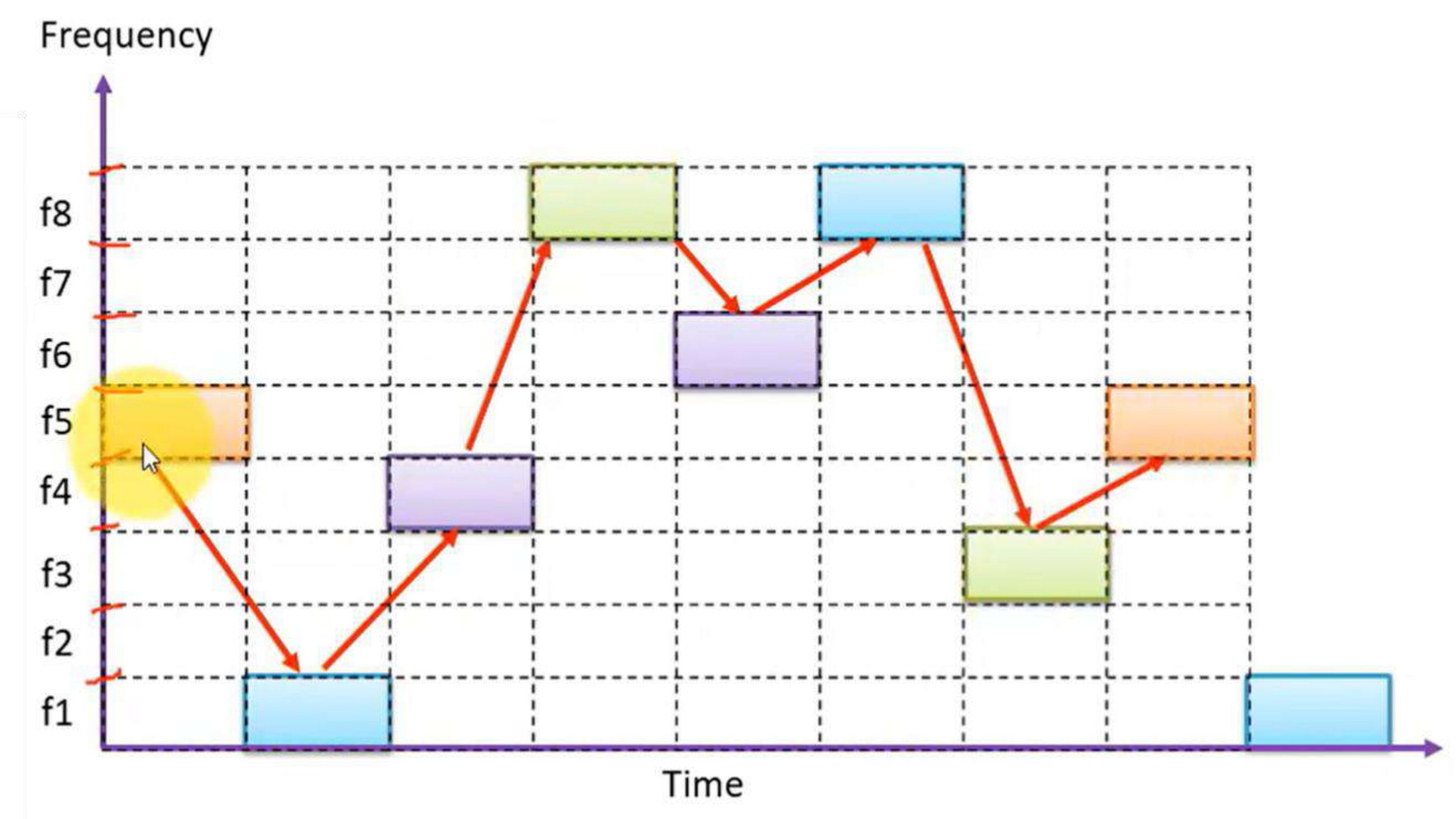


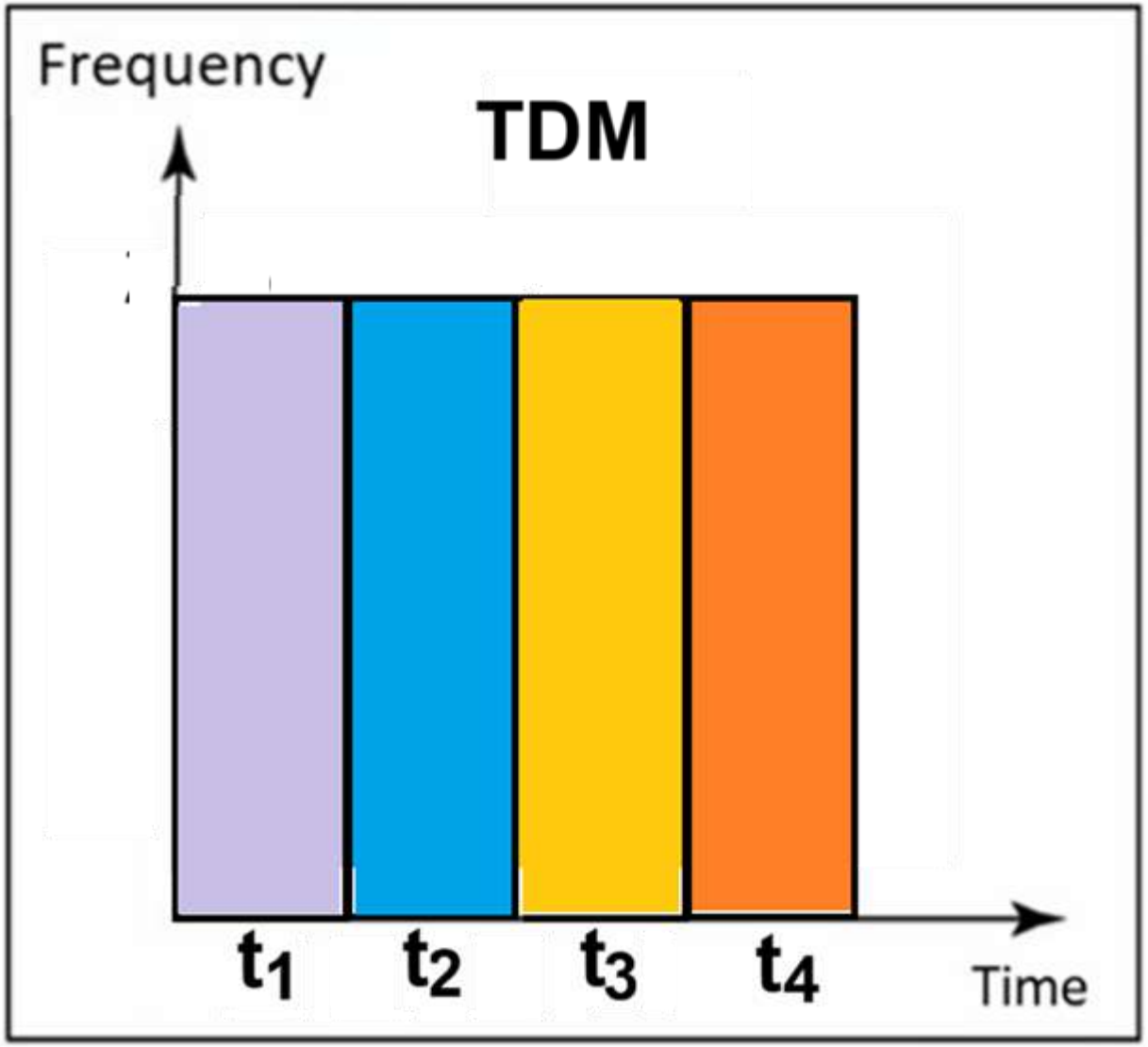
Frequency Hop Spread Spectrum

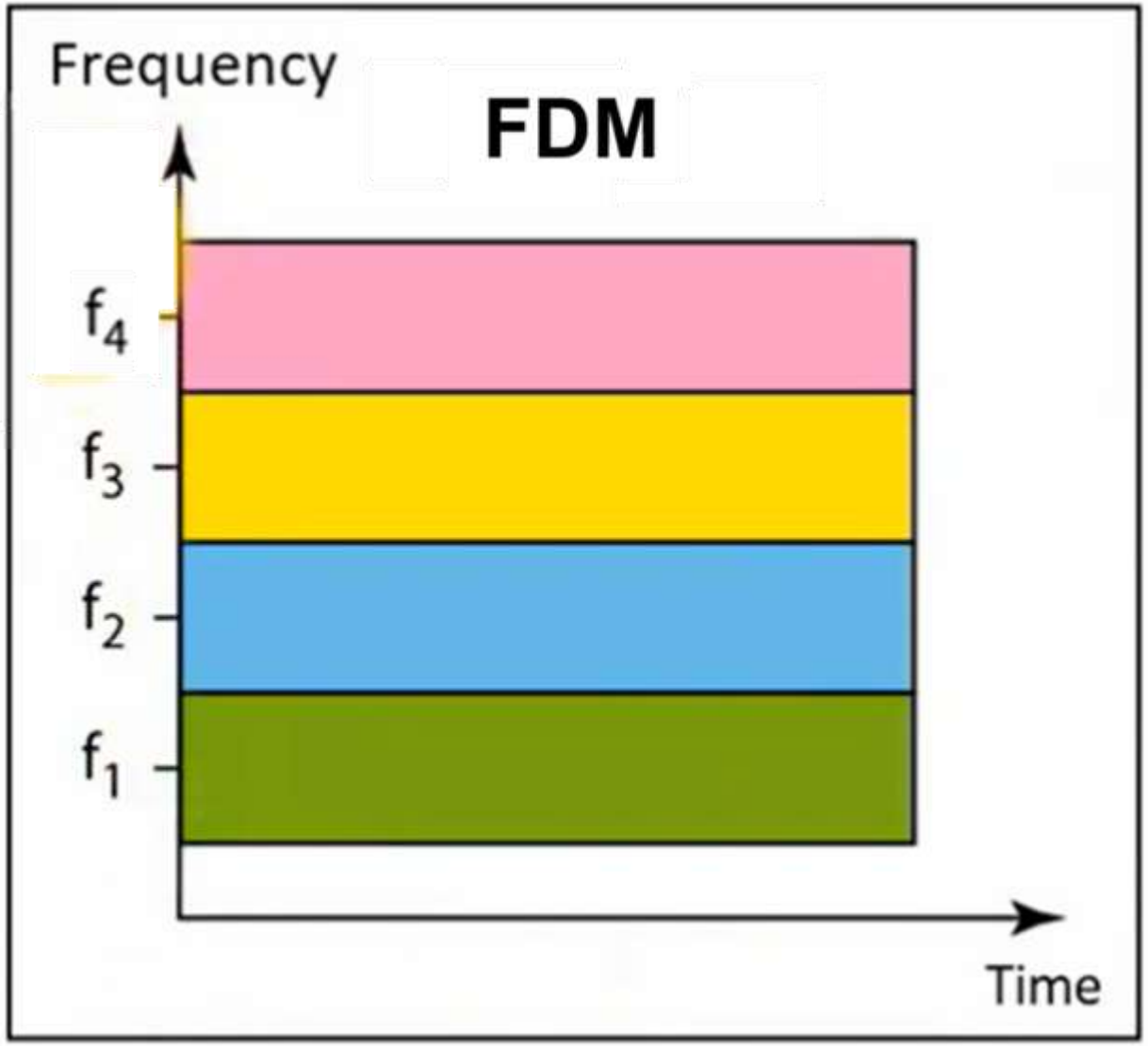
- The type of spread spectrum on which the carrier hops randomly from one frequency to another is referred to as FHSS.
- In FHSS the spectrum of transmitted signal is spread sequentially rather than instantaneously as in DSSS.
- A common modulation format for FH system is that M-ary FSK (MFSK) /BPSK.
- The combination of two techniques is referred to as FH/MFSK.
- Since FH does not cover the entire spread spectrum instantaneously that leads to consider the rate at which the hops occur.
- By this carrier frequency hopping, obviously the bandwidth of the signal increased.
- A disadvantage of Frequency-Hopping over Direct-Sequence is that obtaining a high processing-gain is hard. The faster the 'hopping-rate' is, the higher the processing gain.

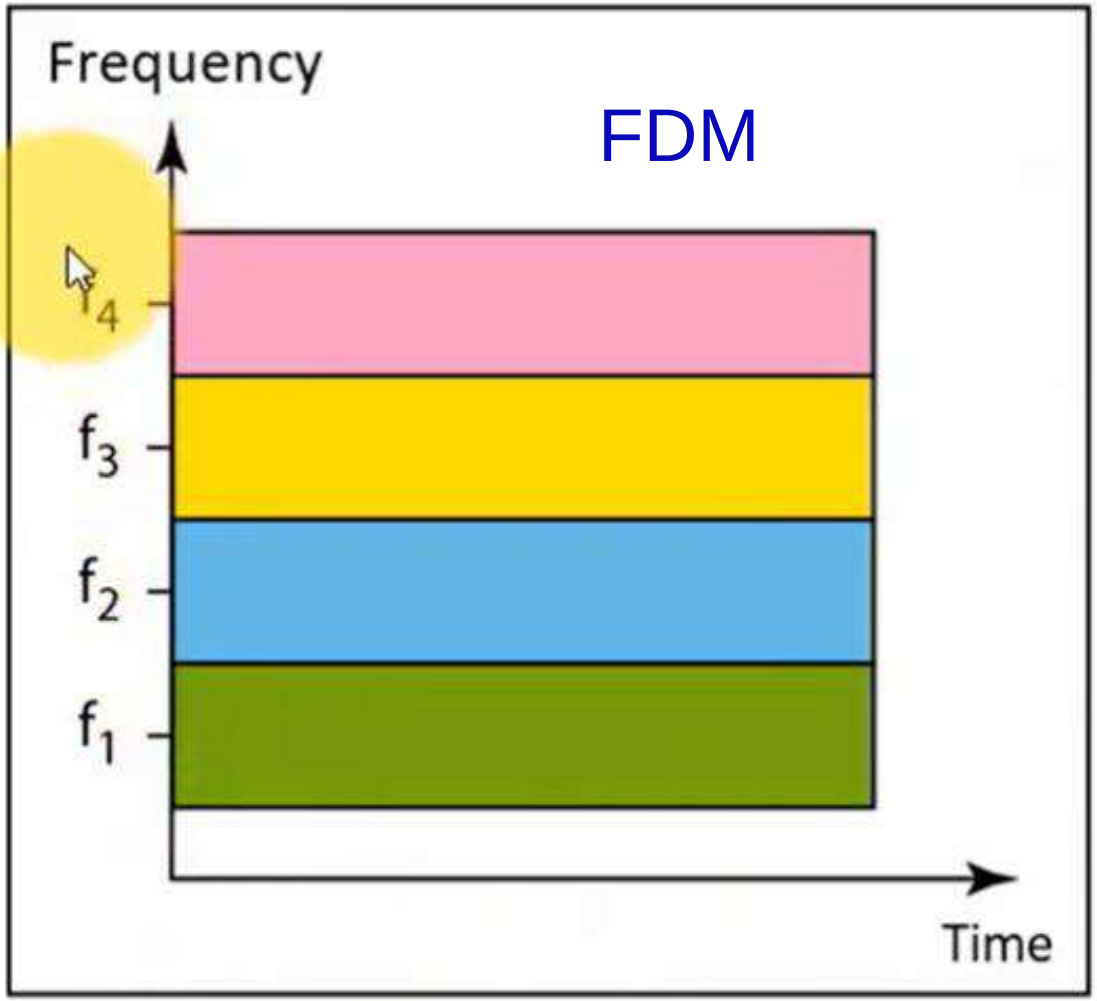
Illustration of the frequency hopping concept

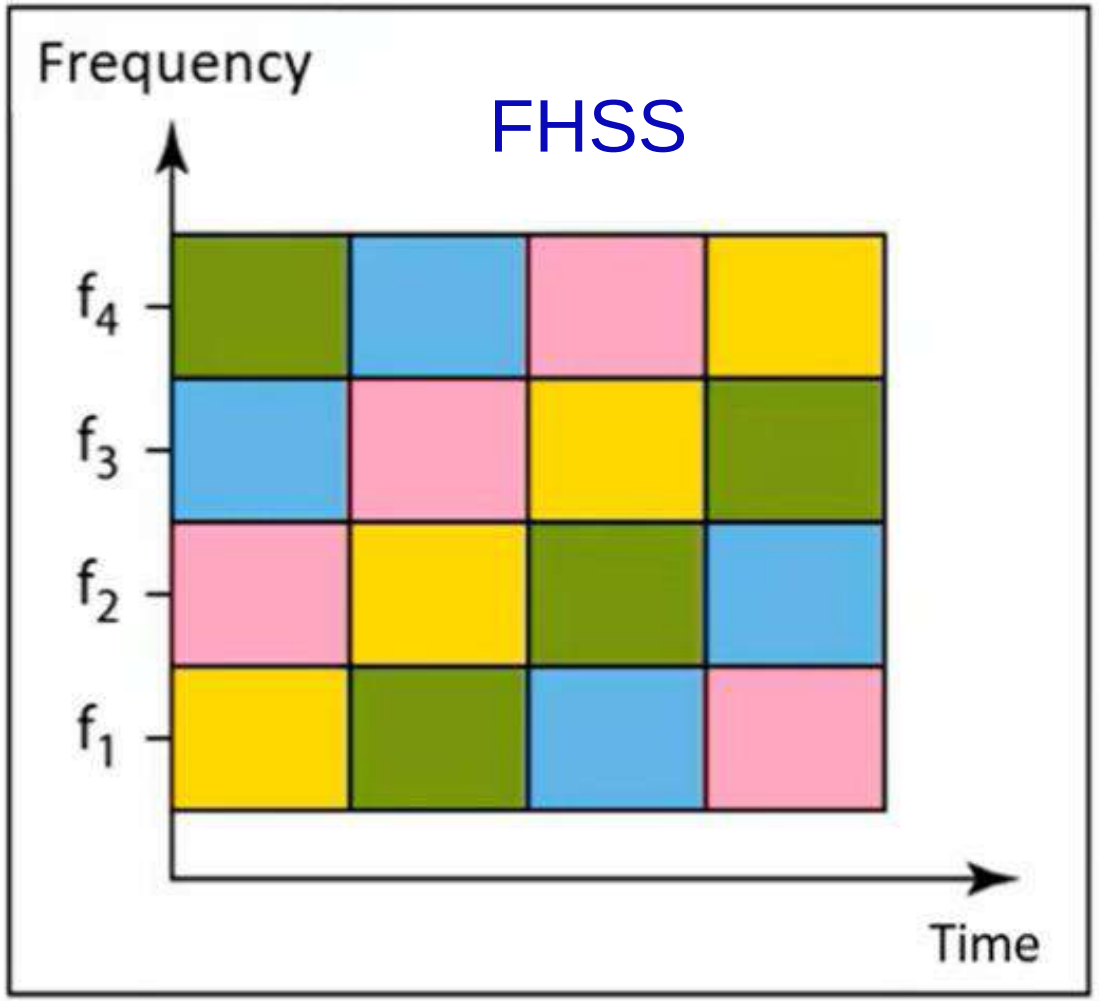


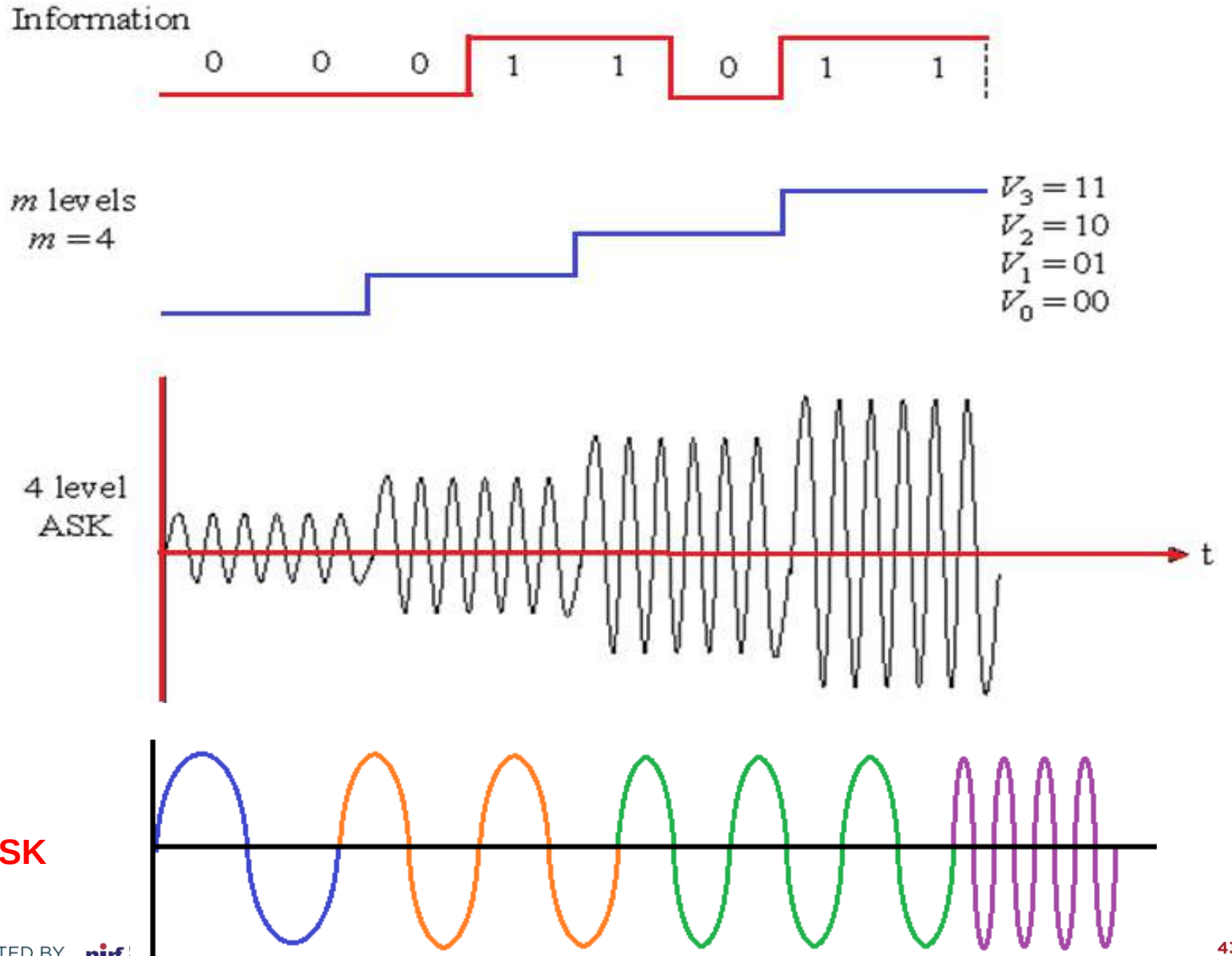

Frequency
f8
f7
f6
f5
f4
f3
f2
f1
Time


Frequency
TDM
t1
t2
t3
t4
Time


Frequency
FDM
f4
f3
f2
f1
Time


Frequency
FDM
f_4
f_3
f_2
f_1
Time

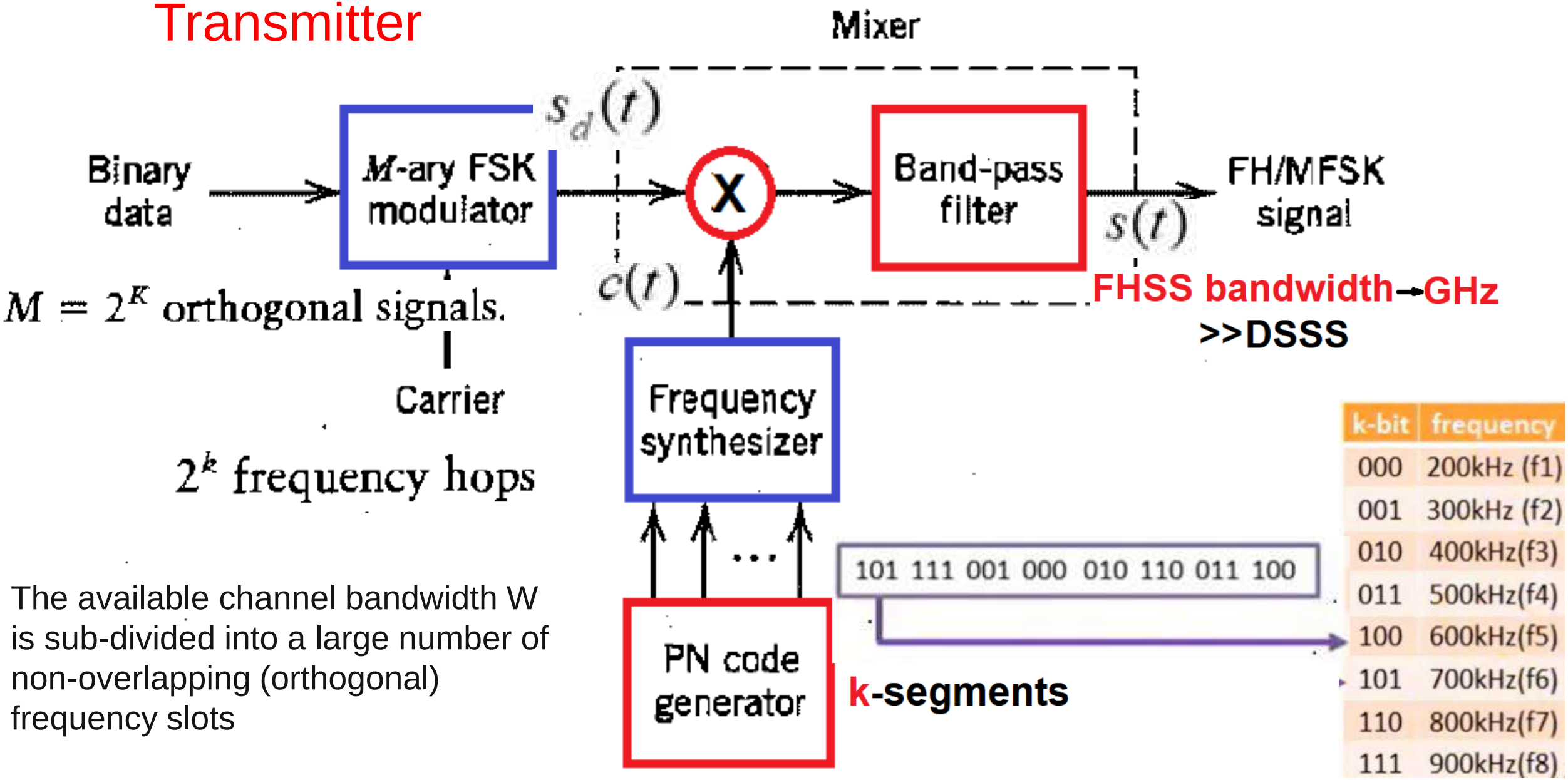

Frequency
FHSS
f_4
f_3
f_2
f_1
Time


Information
0 0 0 1 1 0 1 1
m levels
m = 4
V3 = 11
V2 = 10
V1 = 01
V0 = 00
4 level
ASK
t

4 level FSK

Slow Frequency Hop Spread Spectrum

Transmitter



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111	900kHz(f8)

The available channel bandwidth W is sub-divided into a large number of non-overlapping (orthogonal) frequency slots

FHSS Transmitter

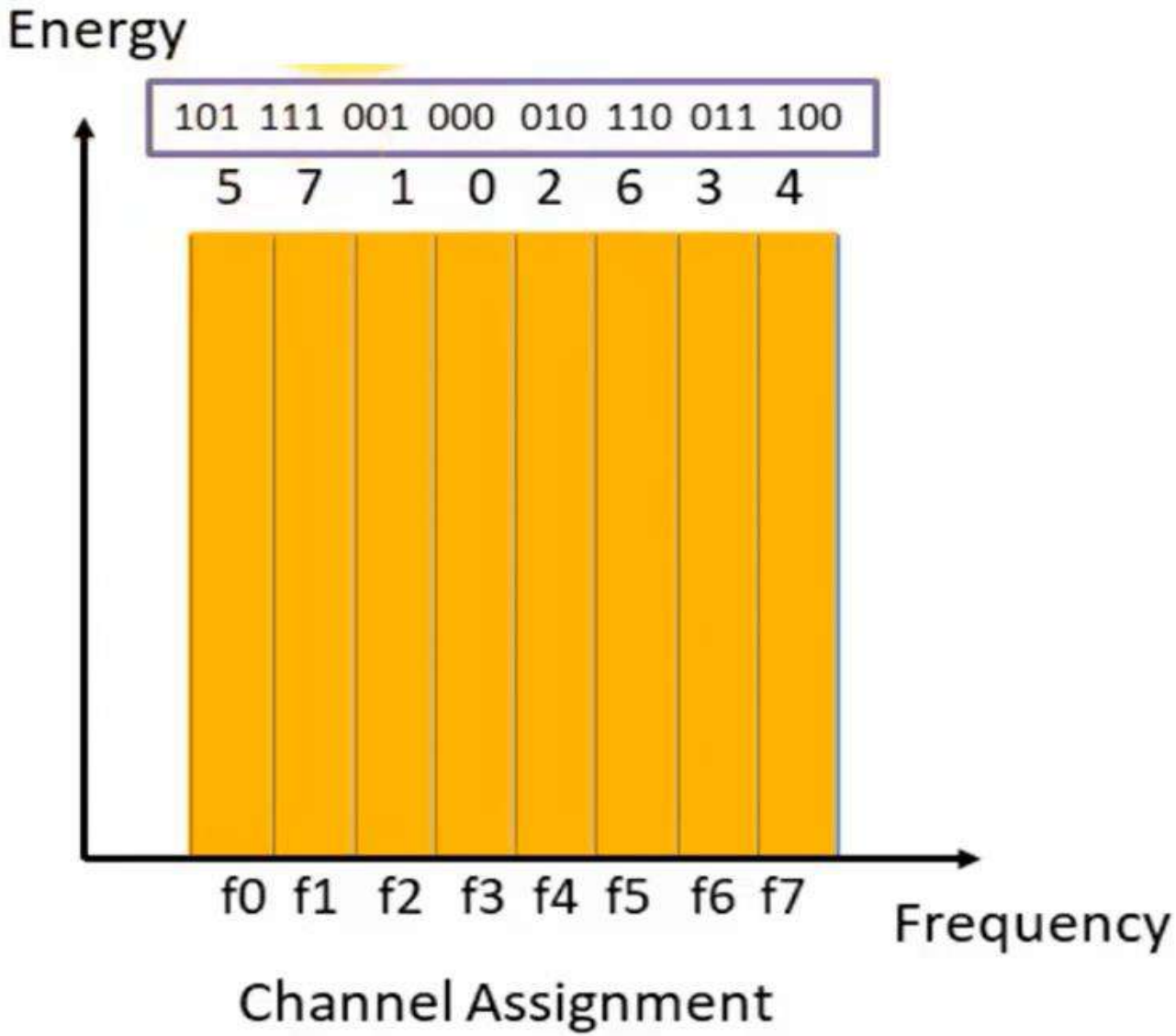
- Binary data are fed into a modulator using frequency shift keying (FSK) or binary phase shift keying (BPSK).
- The resulting signal $s_d(t)$ is centered on some carrier frequency.
- A pseudorandom number serves as an index into a table of frequencies
- Each k bits of the PN source specifies one of the 2^k carrier frequencies. At each successive interval (each k PN bits), a new carrier frequency is selected.

The frequency synthesizer generates a constant frequency tone whose frequency hops among a set of 2^k frequencies, with the hopping pattern determined by k bits from the PN sequence.

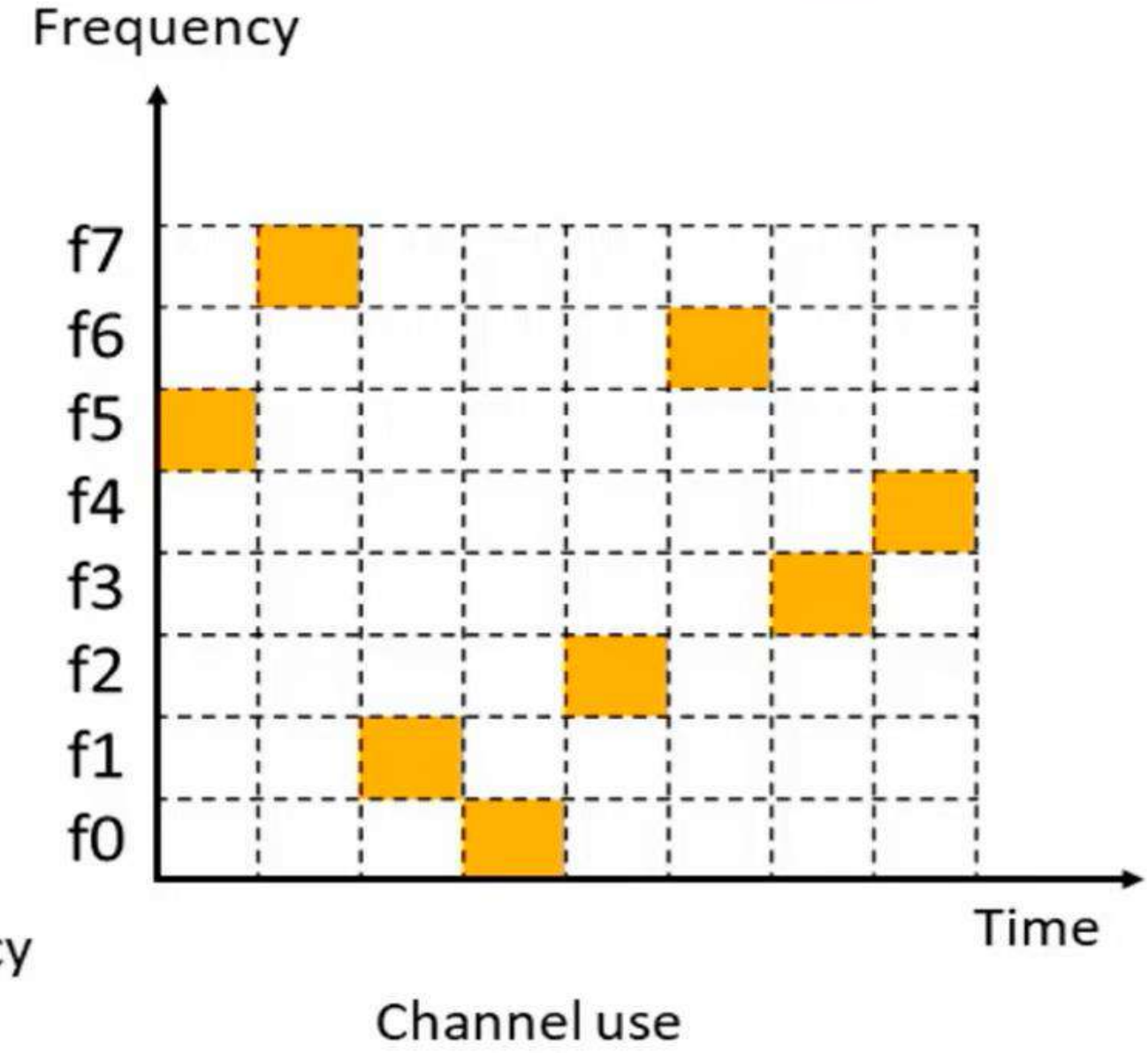
This is known as the spreading or **chipping signal** $c(t)$ for FHSS.

- A bandpass filter is used to block the difference frequency and pass the sum frequency, yielding the final FHSS signal $s(t)$.

Frequency Hopping Example



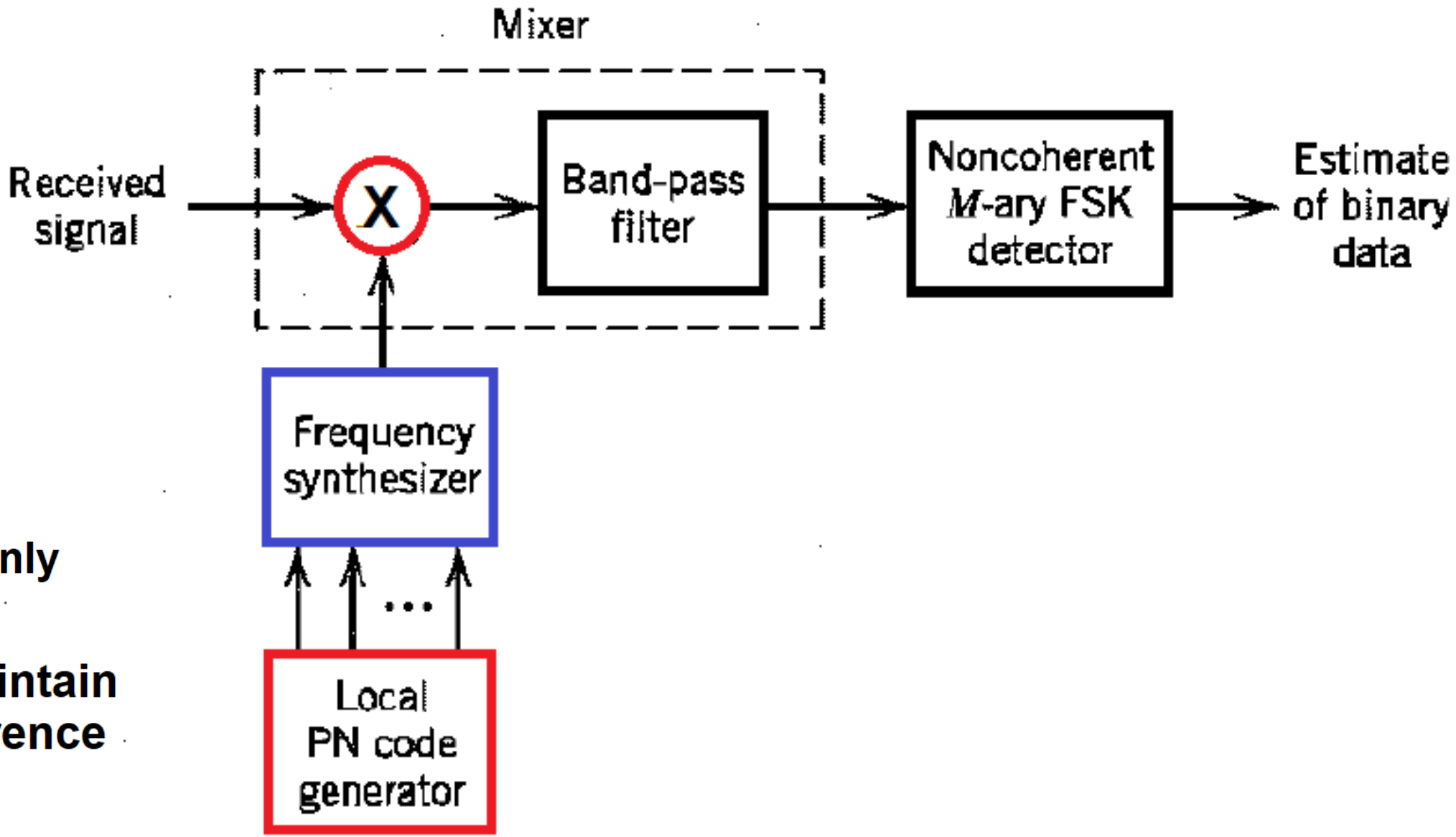
Channel Assignment



Channel use

Slow Frequency Hop Spread Spectrum

Receiver



Coherent Detection only

unable to maintain phase coherence

FHSS Receiver

- The spread spectrum signal is demodulated using the same sequence of PN-derived frequencies and then demodulated to produce the output data.
- At the receiver, a signal of the form $s(t)$ defined on the previous slide, will be received. This is multiplied by a replica of the spreading signal to yield a product signal
- A band-pass filter is used to block the sum frequency and pass the difference frequency, which is then demodulated to recover the binary data.

Applications of FHSS

- WLAN..802.11
- Bluetooth
- Single Channel Ground and Airborne Radio System
- Walkie Talkies

Types of Frequency Hop Spread Spectrum

Two Basic Characteristics: Slow FHSS and Fast FHSS

Let time duration between hops be Tc and data bit duration be denoted by Ts,

- Slow frequency hopping in which symbol / bit rate *Ts* of MFSK signal is an integer multiple of hop rate *Tc* . That is several symbols are transmitted on each frequency hop. That is $Tc \geq Ts$
- Fast frequency hopping in which hop rate *Tc* of MFSK signal is an integer multiple of symbol rate *Ts*. That is the carrier frequency will change or hop several times during the transmission of one symbol. $Tc < Ts$
- Generally fast FHSS gives improved performance in noise (or jamming)

End