Spread Spectrum Techniques

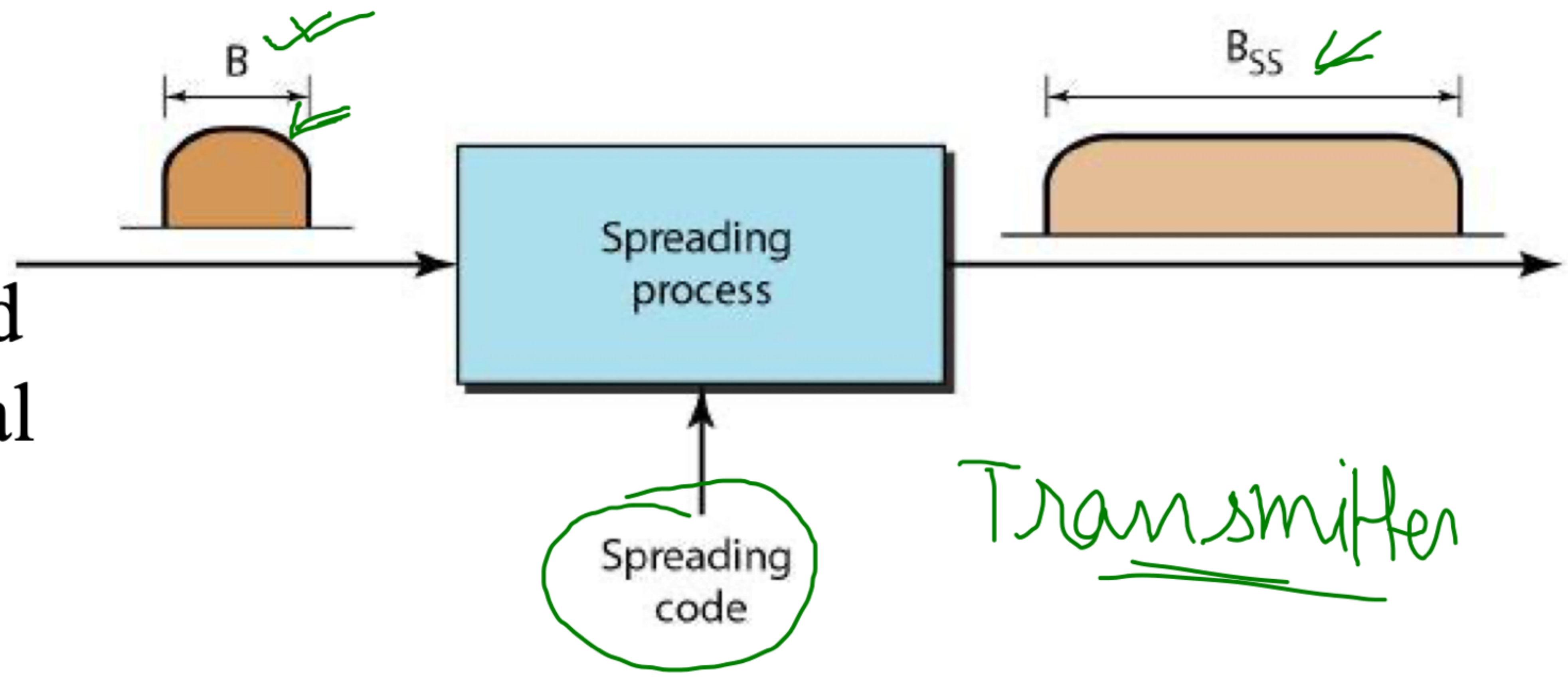
Wireless Communication and Satellite Communication

Spread Spectrum for Communications

- Spread Spectrum System are also called as Wideband Systems.
- Definition: Increasing the bandwidth of the baseband message signal (when compared to original signal) with the help of pseudo random noise.

- Spreading factor or Processing Gain = Spreaded BW/ Bandwidth of the signal

$$= \frac{B_{SS}}{BW}$$



Transmitter

The spreading code is a series of numbers that look random, but are actually a pattern

Spread Spectrum for Communications

- It is a modulation technique in which the transmitted signal Bandwidth is larger than the information Signal Bandwidth.
- In SS, the entire system bandwidth is made available to each user.
- This technique was originally developed for military applications,to provide secure communications by spreading the signal over a large frequency band.

→ Security.

S

Spread Spectrum for Communications

- First: Input is fed into a channel encoder
  - Produces analog signal with narrow bandwidth around some centre frequency=> first modulation
- Second: Signal is further modulated using a sequence of digits
  - Spreading code or spreading sequence (called PN)
  - Generated by pseudo-random number generator
- => Effect of the second modulation is to increase bandwidth of signal to be transmitted
- On the receiving end, the same code is used to demodulate the spread spectrum signal

Block Diagram for Spread Spectrum

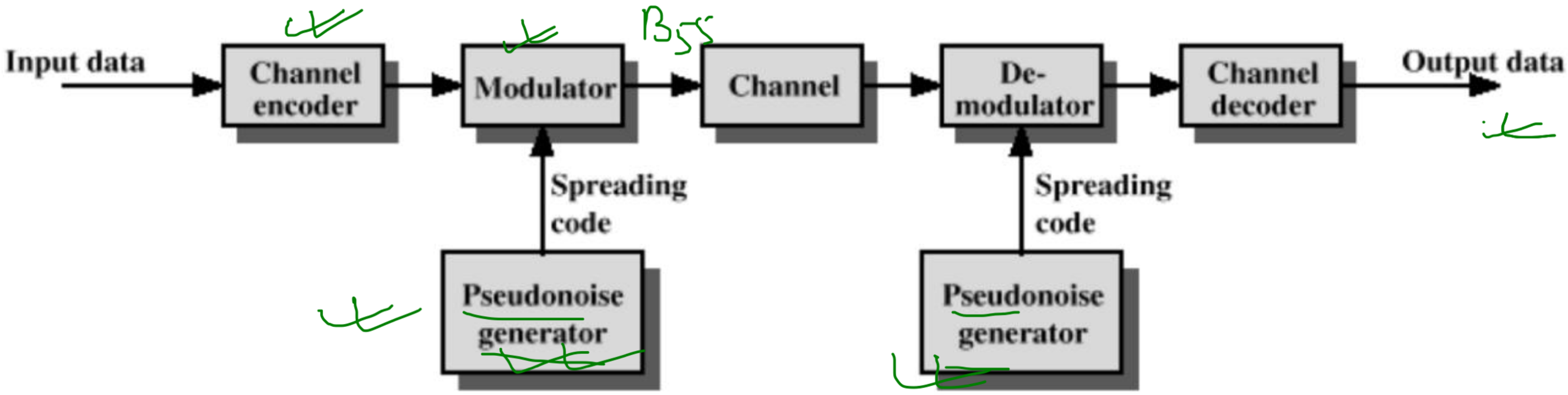


Figure 7.1 General Model of Spread Spectrum Digital Communication System

Spread Spectrum

FHSS

DSSS

What can be gained from apparent waste of spectrum?

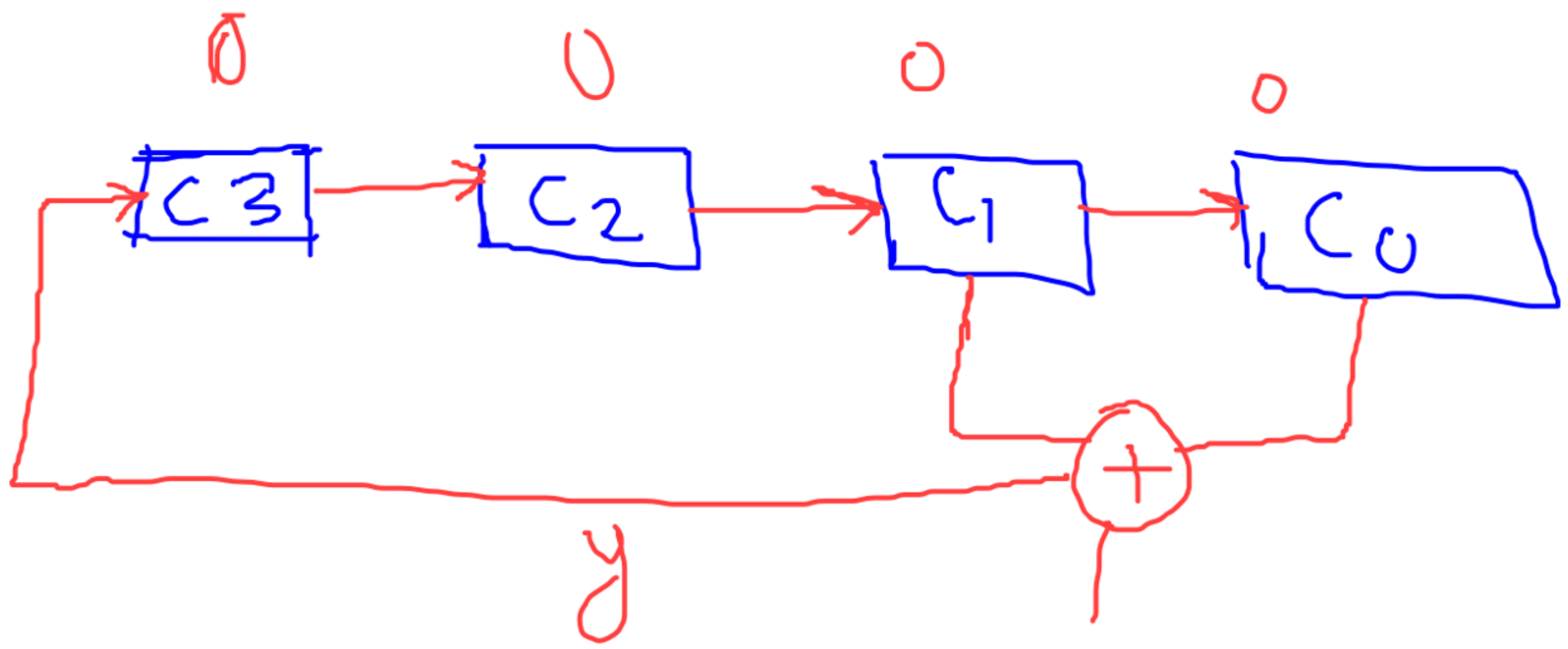
- Security
  - Only a recipient who knows the spreading code can recover the encoded information
- Can be used for hiding and encrypting signals
- Multiple Access is possible.
  - Several users can independently use the same wider bandwidth with very little interference (CDMA

- resistant to interference/ jamming

  ➢ Jamming: deliberate noise to block reception of transmitted signals and to cause a nuisance at the receiving station.

Pseudo-Random Noise; Deterministic / Periodic

→ Linear Feedback Shift Register.



$0 \oplus 0 = 0$

$y = c_1 \oplus c_0$

$n = 4$

$\text{Period} = 2^4 - 1 = 15$

0 0 0 0 → not possible

c_3	c_2	c_1	c_0
1	0	0	0
0	1	0	0
0	1	0	

PN Code: 0001 0011010 1111

Properties of Pseudo Random code

PN Code : 000 1 00 11 0 1 0 1111

(run numbers 1 2 3 4 5 6 7 8 above; run lengths 3 1 2 2 1 1 1 4 below)

(1) Balance Property :

no. of 0's = 7

no. of 1's = 8

$\boxed{\#1's = 1 + \#0's}$

Run of leng 4 = $\frac{1}{2^4} \times 8 = \frac{1}{16} \times 8 = \frac{8}{16} = \frac{1}{2} = 0.5$

Run's of length 1

$= \frac{1}{2^1} \times 8$

$= \boxed{4}$

(II) Run Property :-

Total Run (TR) $= \frac{N+1}{2} = \frac{15+1}{2} = 8$

Run of length n $= \frac{1}{2^n} \times TR$

$2 = \frac{1}{2^2} \times 8 = \boxed{2}$

Direct Sequence Spread Spectrum (DSSS)

- The goal of spread spectrum technique is to prevent eavesdropping and jamming. To achieve this goal, spread spectrum add redudancy and expands the bandwidth of the original signal.
- As per Shannon's theorem, the higher the bandwidth, the more immune the signal transmission is to crosstalk, interference, and noise.
- The DSSS technique helps maintain secure signal transmission with a high signal-to-noise ratio (SNR) at the receiving end.
- And, the DSSS technique helps recover the original data even when a part of the transmitted data is corrupted.

Direct Sequence Spread Spectrum (DSSS)

1011..   PN code

- The original data is mixed with redundant data bits or code, called chips or chipping code.
- A high spreading ratio indicates a wider bandwidth.
  - the ratio of the chips to information is called the spreading ratio.
- Each bit in original signal is represented by multiple bits (n bits) in the transmitted signal using a spreading code.

Chipping

DSSS example

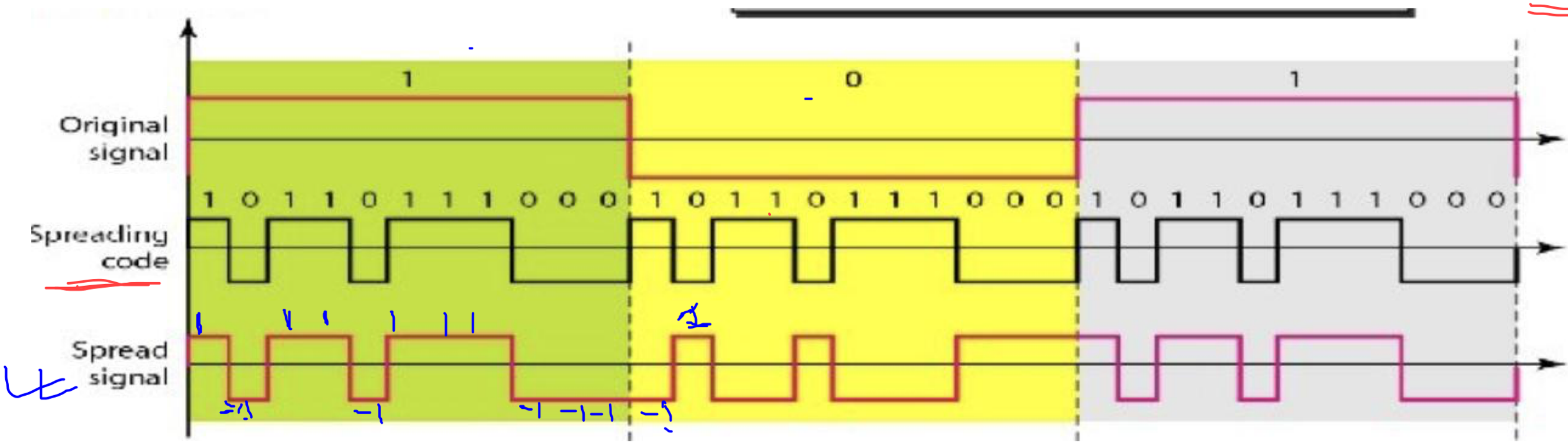
$0 \rightarrow -1$

Original Signal: 101

Spreaded code: 10110111000

1 -1 1 m(t)

1 -1 11 -1 111 -1 -1 -1 → c(t)



m(t)*c(t) = $\underbrace{1\ -1\ 1\ 1\ -1\ 1\ 1\ 1\ -1\ -1\ -1}_{1}$, $\underbrace{-1\ 1\ -1\ -1\ 1\ -1\ -1\ -1\ 1\ 1\ 1}_{0}$, 1 -1 1 1

1

1 1 1 1 1 1 1 1 -1 -1 .

0

DSSS example – 2

0 → 0110
1 → 1001

1 ⊕ 1 - 0

C = A ⊕ B

Input Bit stream A	0				1				0				0				1				0				1				1			
PN sequence B	0	1	1	0	1	0	0	1	0	1	1	0	0	1	1	0	1	0	0	1	0	1	1	0	1	0	0	1	1	0	0	1
Transmitted signal C	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0
Received signal C	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	1	1	0
PN sequence B	0	1	1	0	1	0	0	1	0	1	1	0	0	1	1	0	1	0	0	1	0	1	1	0	1	0	0	1	1	0	0	1
Output Bit stream A	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1	1	1	1	1
	0				1				0				0				1				0				1				1			

DSSS waveforms

Decoded output ⟶ same as Input Bit stream

Frequency Hopping Spread Spectrum (FHSS)

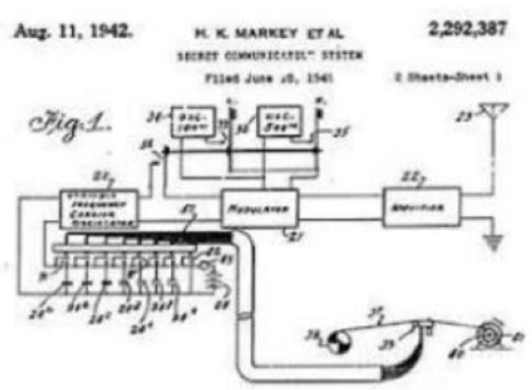
- Invented and patented in 1942 by the actress Hedy Lamarr and pianist George Antheil, which were quite versatile!

Hedy Lamarr and George Antheil. Photo of Hedy Lamarr courtesy of the Academy of Motion Picture Arts & Sciences. Photo of George Antheil courtesy of the Estate of George Antheil.

Frequency Hopping Spread Spectrum (FHSS)

The Mother Of Wireless Technology

Hedy Lamarr was more than a pretty face in Hollywood. Learn how this actress bucked convention and shaped our modern technology through her invention.



INVENTION:
Frequency Hopping
Spread Spectrum

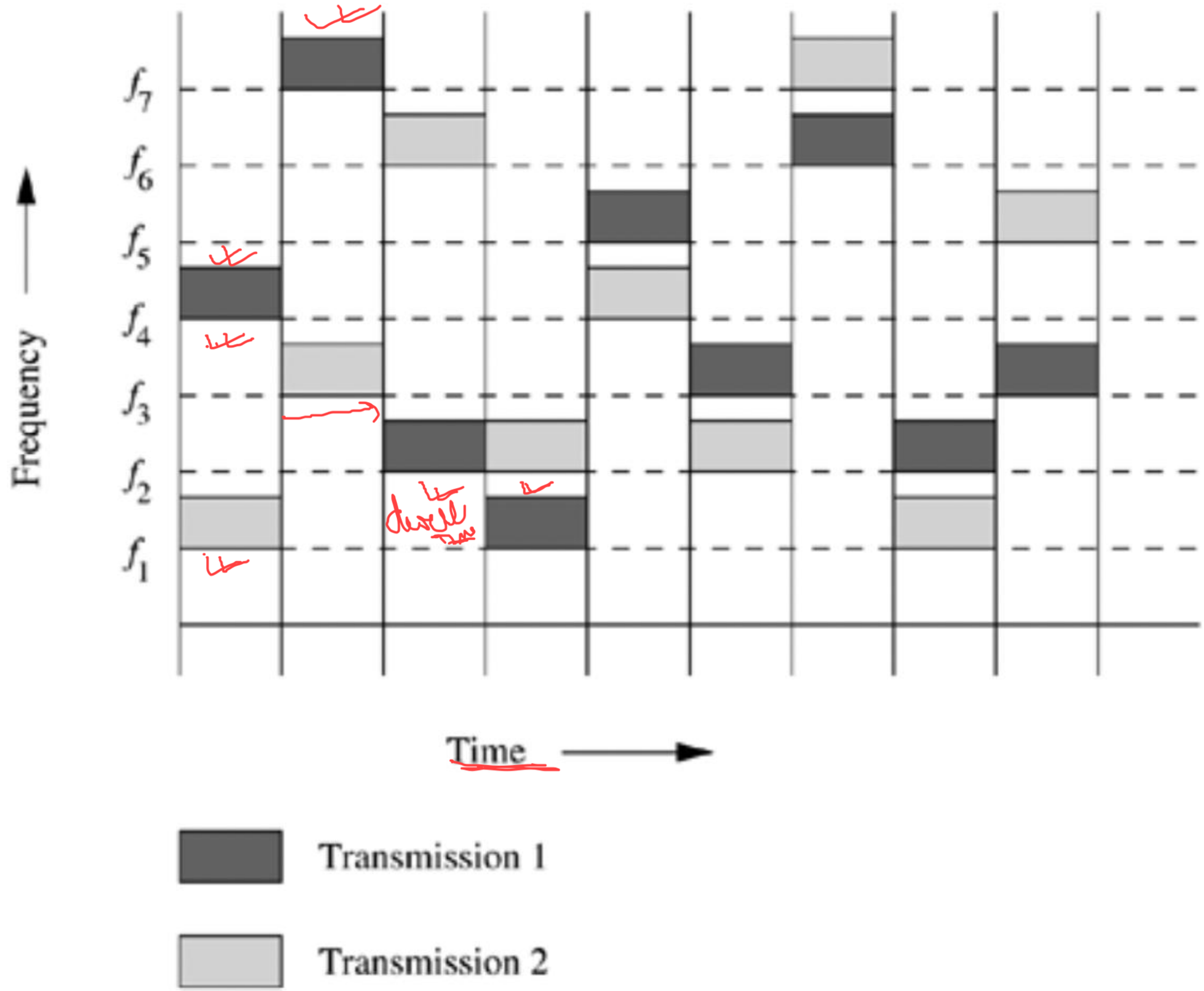
LEGACY:
WiFi, GPS, And Bluetooth

HONORS:
National Inventors Hall
Of Fame Inductee 2014

FHSS

- The principle of FHSS is quite simple: the transmission switches across multiple narrow-band frequencies in a pseudo-random manner.
- The sequence of transmission frequencies is known both at the transmitter and the receiver, but appears random to other nodes in the network.
- The process of switching from one channel to another is termed as Frequency Hopping.
- The frequency is then again de-hoped at the receiver by means of frequency synthesizer controlled by pseudo-random sequence generator.

Illustration of FHSS



Transmission 1:

F_4 F_7 F_2 f_1 f_5
f_3 f_6 f_2 f_3

Transmission 2:

FHSS

- FHSS implements the frequency division multiplexing and time division multiplexing simultaneously.
- It is classified into two types:
  (i) Slow Hopping
  (ii) Fast Hopping

- Few Basic terms to understand Fast and Slow FHSS
  (i) **Hop Time:** Small amount of time during the frequency change in which no transmission takes place.
- (ii) **Dwell Time:** Time spend on a particular channel with a carrier frequency

FHSS

1011100111

Slow FHSS:

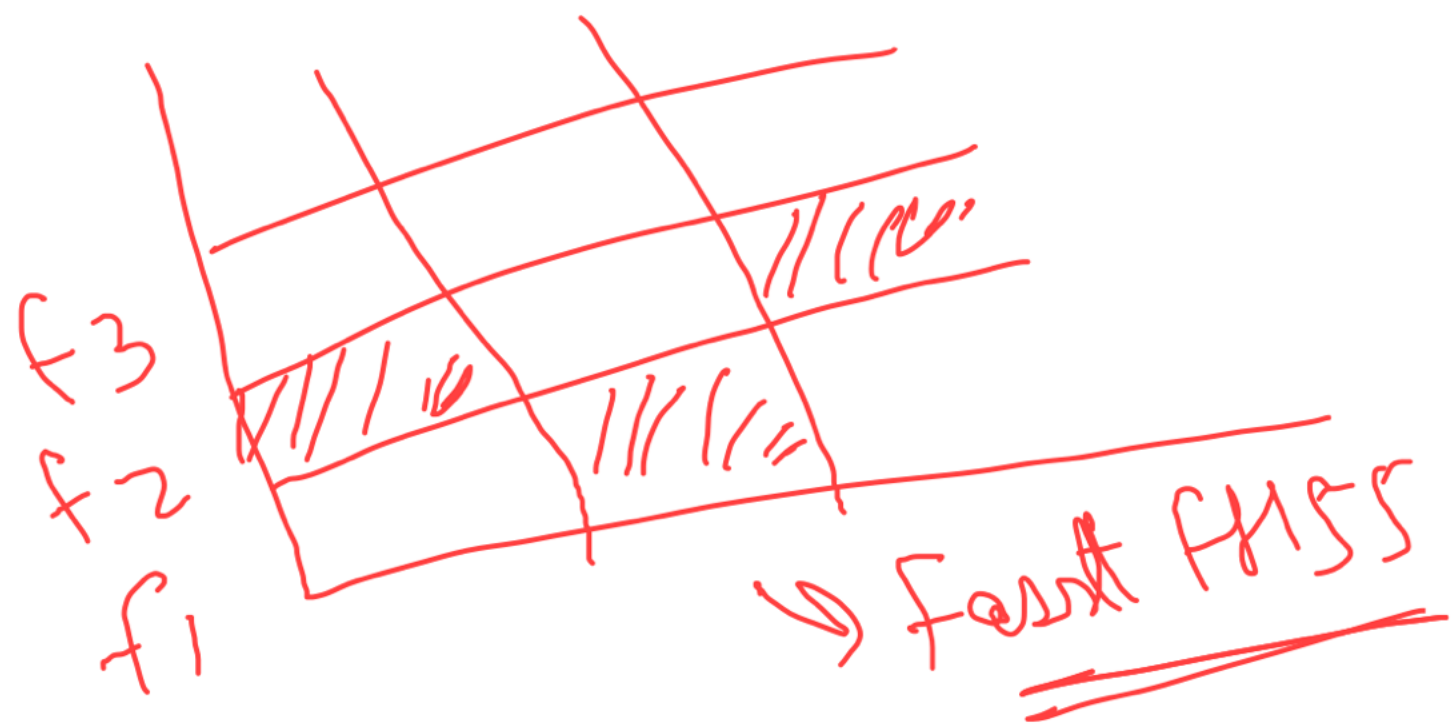
*Multiple bits are transmitted on a specific frequency or same frequency.

* dwell Time > bit duration

Fast FHSS:

* individual bits are split and then transmitted on different frequencies.

* bit duration > dwell time.



FHSS vs DSSS

FHSS	DSSS
FHSS changes the frequency, and the hopping of frequency follows a pattern known to the sender and receiver	DSSS changes the phase, and the carrier frequency remains in a fixed frequency band
Lower signal transmission rate (up to 3Mbps)	Higher signal transmission rate (up to 11 Mbps)
FHSS is a robust spread spectrum technique that is suitable to employ in harsh environments	DSSS is a sensitive spread spectrum technique that is influenced by harsh environmental conditions
FHSS is suitable for single point as well as multipoint communications	DSSS is suitable for point to point communication
The decoding process is simple in FHSS	To decode in DSSS, a particular algorithm is required to make the connection between the transmitter and receiver

FHSS vs DSSS

FHSS	DSSS
FHSS is less reliable	DSSS is more reliable
The analog to digital conversion in FHSS takes less time	The time taken to convert an analog signal to digital is higher
At a lower transmission rate, FHSS is cheaper	The implementation of DSSS at radio frequencies with a high transmission rate is cheaper
FHSS is not dependent on the distance of signal transmission	Distance is an influencing factor in DSSS
At a given transmitting power, FHSS offers higher power spectral density	At a given transmitting power, the wider operating spectrum of DSSS provides lower power spectral density
As the carrier frequency is varied in FHSS, it causes frequency-selective fading, where the error is bursty in nature.	In DSSS, the message bits are both frequency and time spread DSSS. This kind of spreading reduces the influence of interference and fading. The percentage error in DSSS is less than FHSS