Wi-Fi Technology Fundamentals

Module-2

WLAN Physical Layer

Session-2a

Frequency Allocation and Modulation Basics

Recap …..

Module 1: Introduction and History of WiFi

- Evolution of WiFi
  - WiFi Generations, Residential WiFi Applications, Enterprise WiFi Applications, Business Evolution
- WiFi Network Topologies
  - Infrastructure/Mesh/Bridge/Adhoc Modes, Various Backhaul Mechanisms, Various Deployment Use cases
- WLAN Standards and Amendments Alphabet Soup
  - IEEE Standards Bodies, WiFi Alliance, Standards and their extensions
- Basic Functional building blocks of a WiFi AP/Router
  - PHY, Baseband, Lower MAC, Upper MAC, various Interfaces, key functional blocks

How to Stay Connected?

Access Course Webpage

Click here: Wi-Fi Technology Fundamentals Course (candelatech.com)

- ✓ Access course notes, slides, video recordings

Register to Get Updates

Click Here: Registration (zoho.in)

- ✓ Provide basic contact into to get calendar invites, reminders and updates about the material and sessions.

Join Whatsapp Group

Click here: WhatsApp Group Invite

- ✓ Provide basic contact into to get whatsapp messages about calendar invites, reminders and updates about the material and sessions.

Module 2: WLAN Physical Layer

- Frequency Allocation and Modulation Basics
  - ISM and UNII Bands, unlicensed spectrum allocation, channels, Channel BW, Spread spectrum, OFDM
- Modulation/Coding, MIMO Basics
  - Modulation and Coding Rates, Multipath, MIMO, OFDMA, Spectral Efficiency
- MCS Table, PHY Data Rates
  - PHY Data rates, MCS Table, Theoretical Throughput
- PHY Headers and key functions
  - PHY Headers, PCLP and PMD Sub Layers, Key PHY later functions

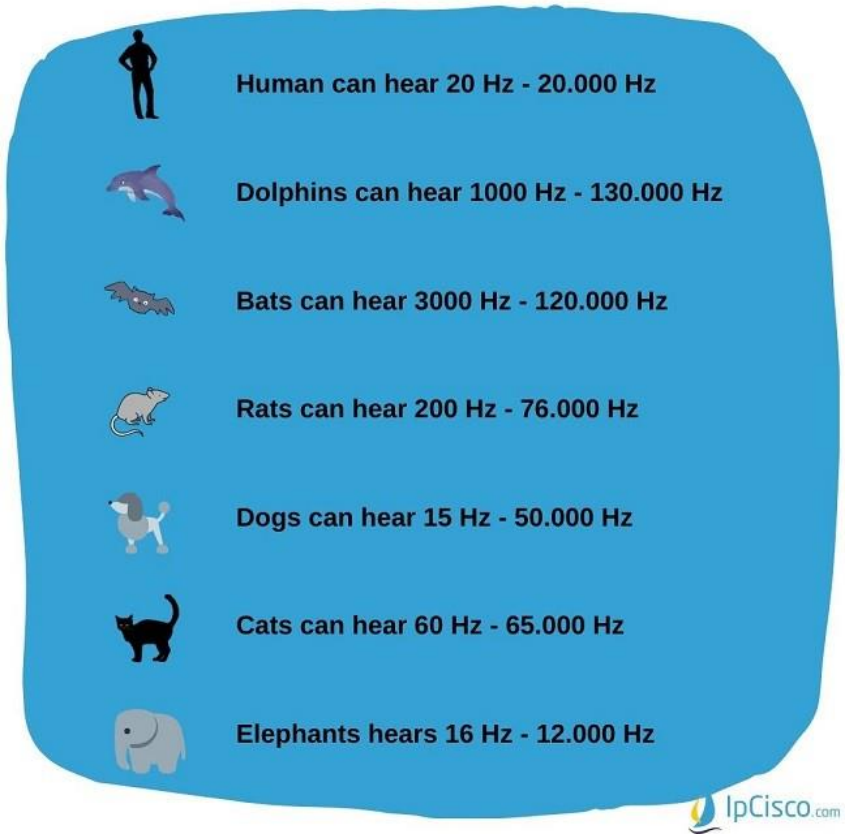
Module-2

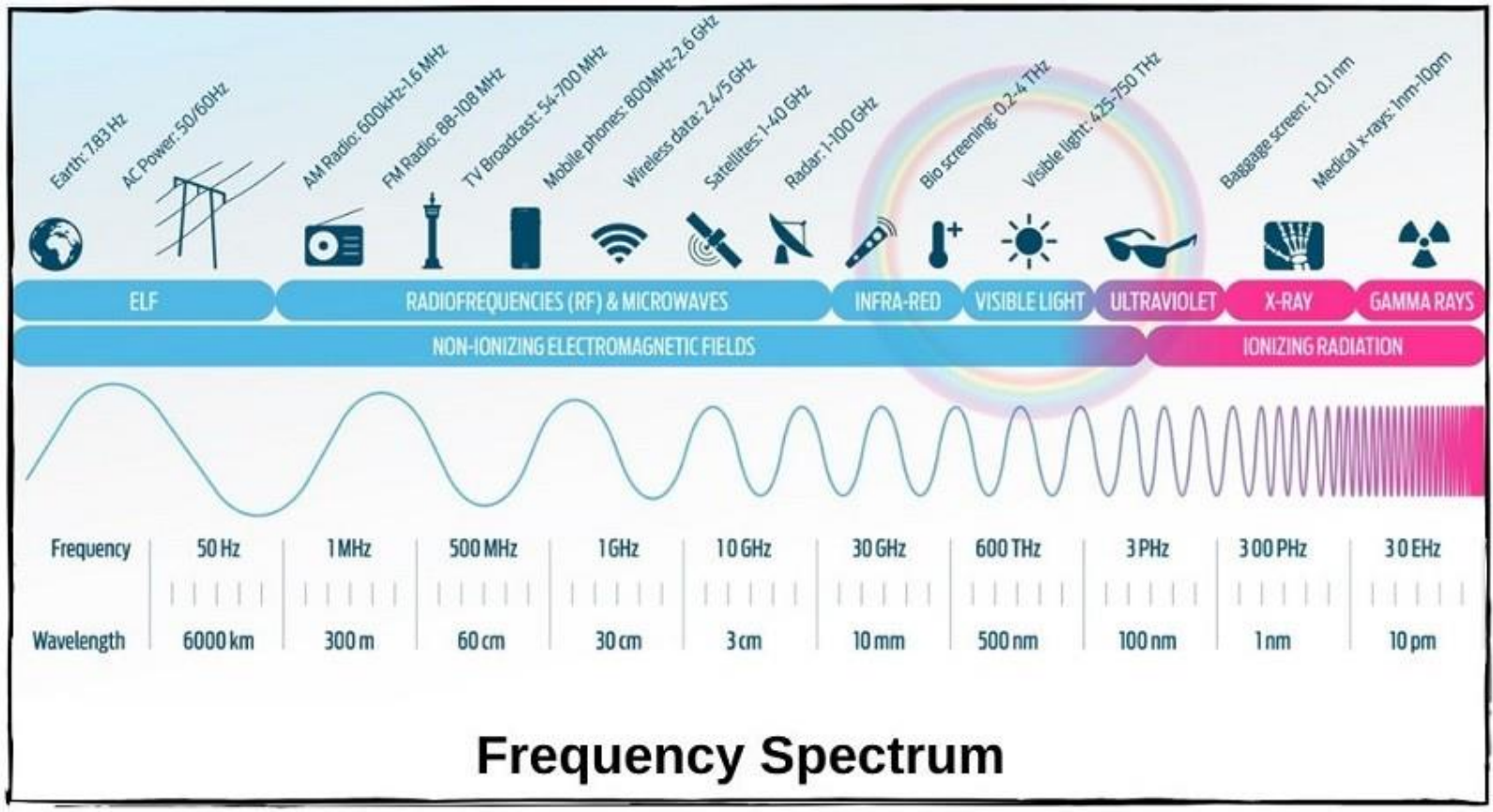
WLAN Physical Layer

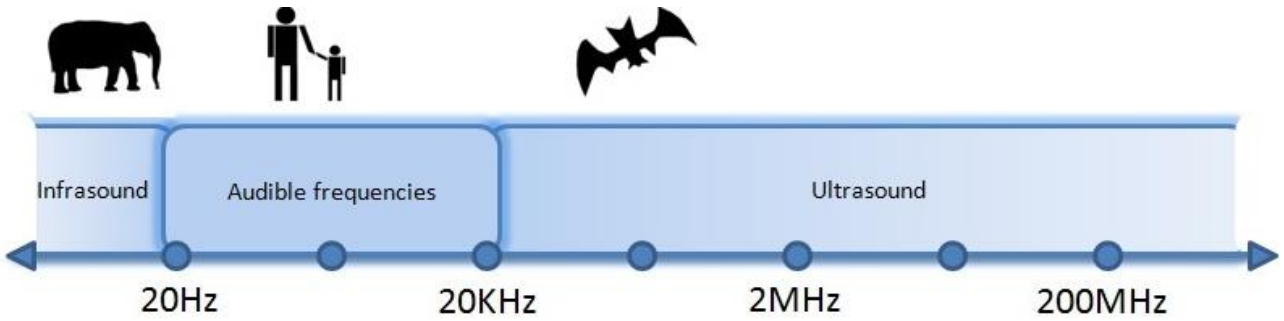
Session-2a

Frequency Allocation and Modulation Basics

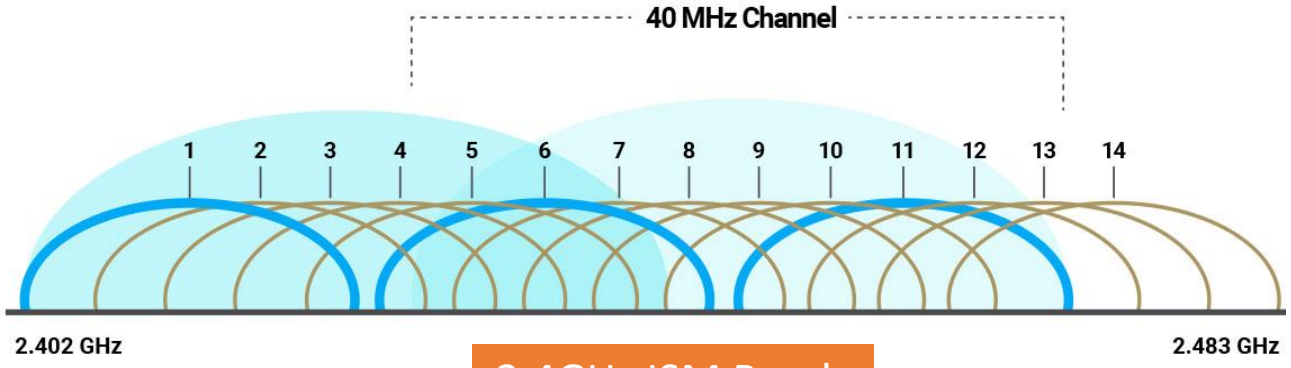
Frequency Spectrum



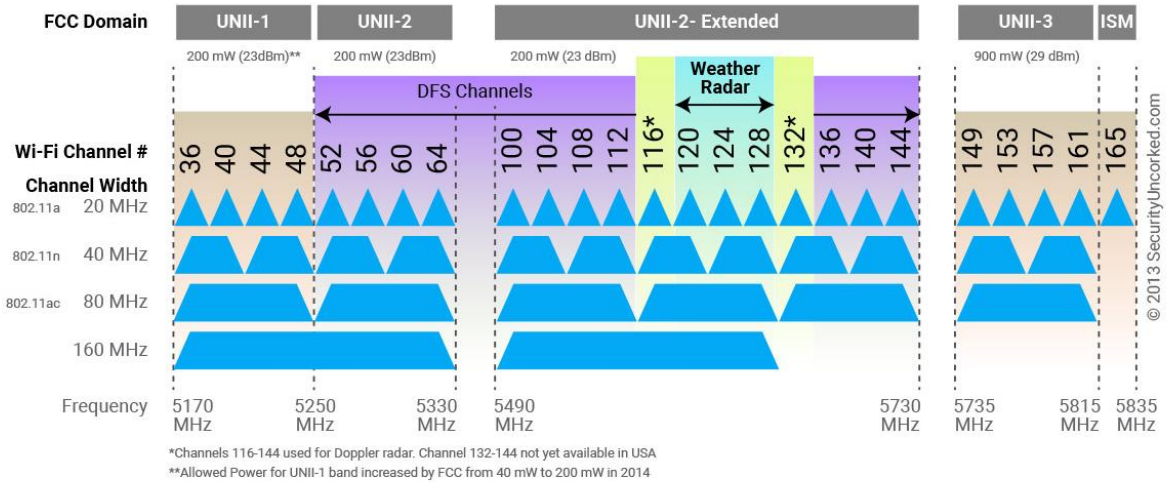




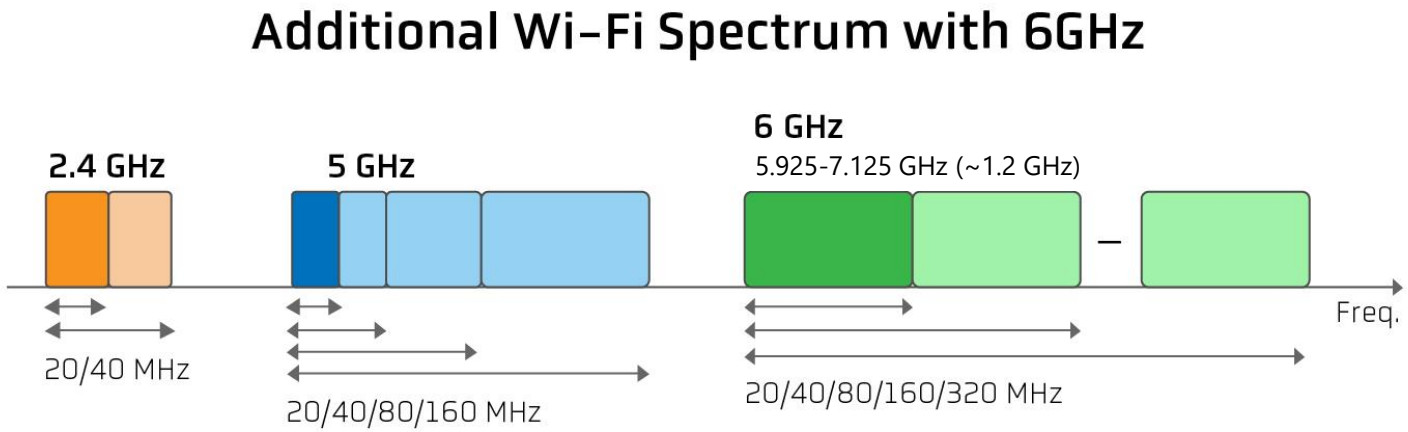
Wi-Fi Unlicensed Frequencies



2.4GHz ISM Bands

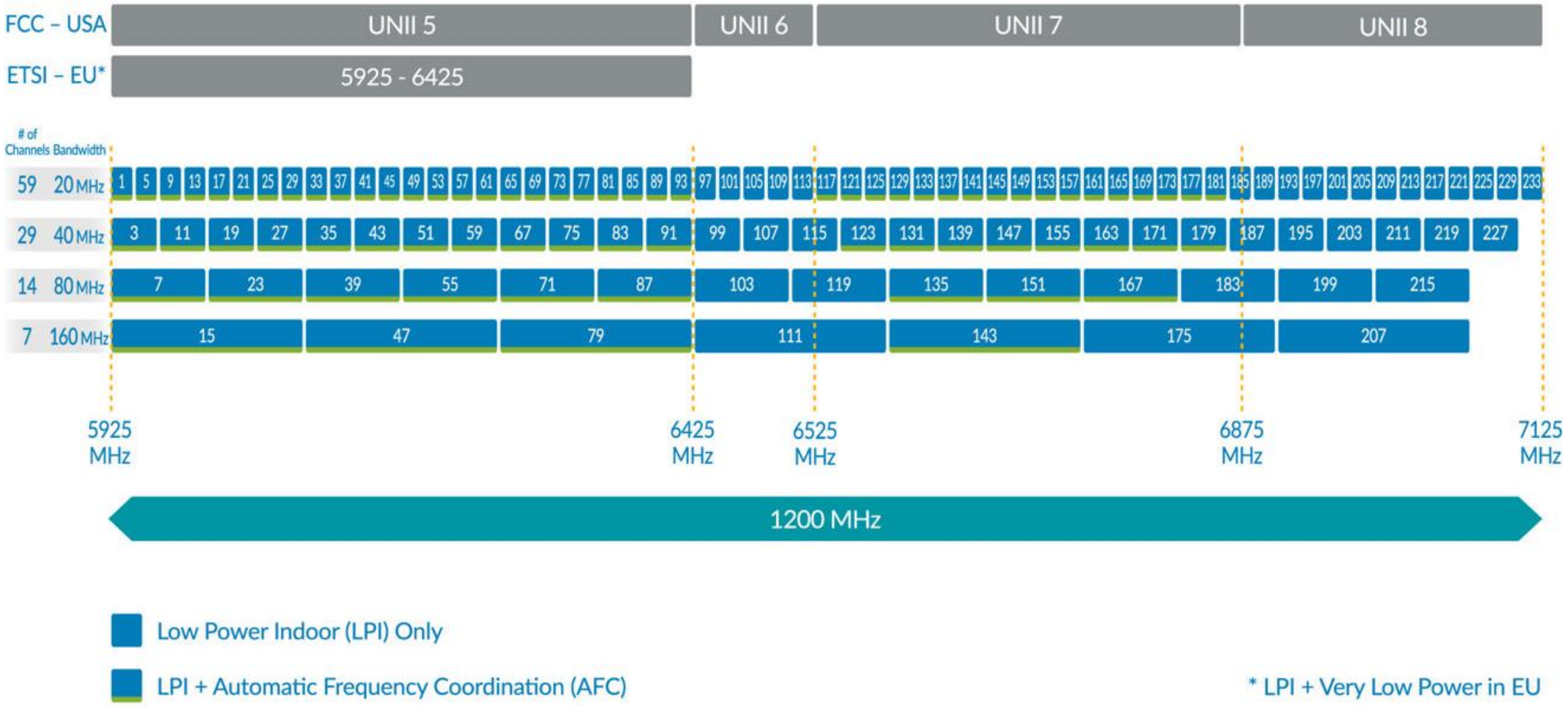


5GHz UNII Bands

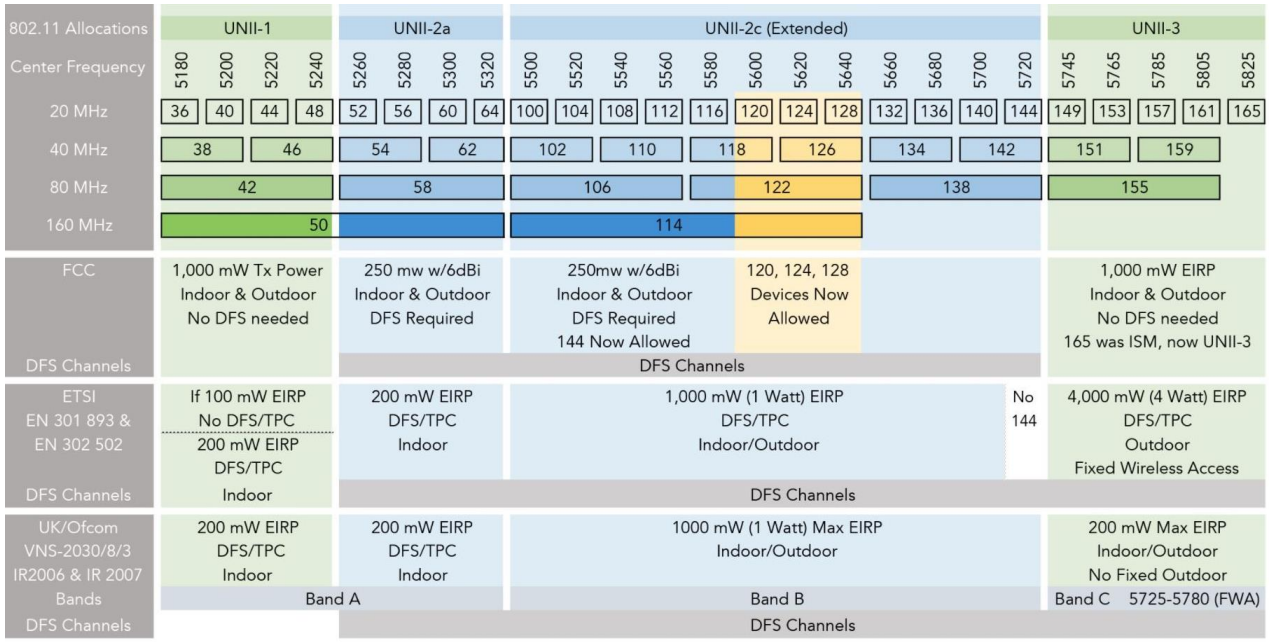


Parameter	2.4GHz	5GHz	6GHz
Available Spectrum	Lowest	Higher	Highest
Range	Highest	Lower	Lowest
Crowded Spectrum	Highest	Lower	Lowest
Data Rates	Lowest	Higher	Highest

6GHz Channel Allocation



UNII Bands Power Restrictions



U-NII #	U-NII 5				U-NII 6		U-NII 7				U-NII 8	
Frequency Band	5925 <----------> 6425 MHz				6425 <---> 6525 MHz		6525 <----------> 6875 MHz				6875 <---> 7125 MHz	
Band Allocation	500 MHz				100 MHz		350 MHz				250 MHz	
e-CFR FCC Rule Part	Part 15.407(a)(4)-(8)				Part 15.407(a)(5), (6), (8)		Part 15.407(a)(4)-(8)				Part 15.407(a)(5), (6), (8)	
Phases	Phase 1 devices		Phase2 devices		Phase 1 devices		Phase 1 devices		Phase2 devices		Phase 1 devices	
Device (New Equipment Class)	Low Power Indoor AP (6ID), Subordinates (6PP), Indoor Clients (6XD), Dual Client (6CD)		Standard Power AP (6SP), Fixed (6FX) & Standard Clients (6FC), Dual Client (6CD)		Low Power Indoor AP (6ID), Subordinates (6PP), Indoor Clients (6XD), Dual Client (6CD)		Low Power Indoor AP (6ID), Subordinates (6PP), Indoor Clients (6XD), Dual Client (6CD)		Standard Power AP (6SP), Fixed (6FX) & Standard Clients (6FC), Dual Client (6CD)		Low Power Indoor AP (6ID), Subordinates (6PP), Indoor Clients (6XD), Dual Client (6CD)	
AP and Associated Clients	Low-Power Indoor AP	Client Connected to Low Power AP	Standard Power AP (AFC Controlled)	Client Connected to Standard Power AP	Low-Power Indoor AP	Client Connected to Low Power AP	Low-Power Indoor AP	Client Connected to Low Power AP	Standard Power AP (AFC Controlled)	Client Connected to Standard Power AP	Low-Power Indoor AP	Client Connected to Low Power AP
Maximum EIRP	30 dBm	24 dBm	36 dBm Additional rule for outdoor operation Max EIRP < 125 mW (21 dBm) at any elevation angle > 30° from horizon	30 dBm	30 dBm	24 dBm	30 dBm	24 dBm	36 dBm Additional rule for outdoor operation Max EIRP < 125 mW (21 dBm) at any elevation angle > 30° from horizon	30 dBm	30 dBm	24 dBm

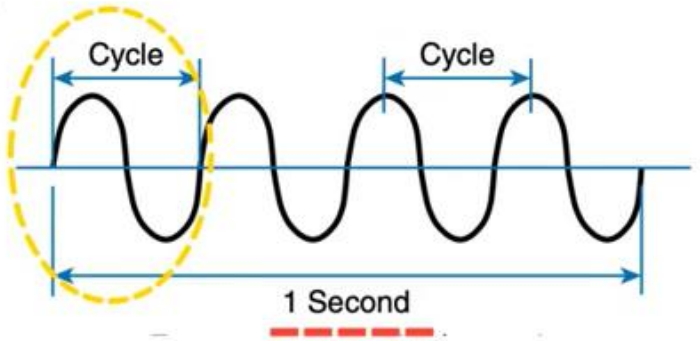
Electromagnetic waves

Frequency = Number of cycles per second

Hz

Standard unit of measurement used for measuring frequency.

1Hz = 1cycle per second



frequency = 4 cycles/second

4 hertz

Unit	Abbreviation	Meaning
Hertz	Hz	Cycles per second
Kilohertz	kHz	1000 Hz
Megahertz	MHz	1,000,000 Hz
Gigahertz	GHz	1,000,000,000 Hz

1 Gigahertz is 1 billion cycles/second

3 kHz to 300 GHz

"Radio frequency (RF)"

TV

AM radio and FM radio

Radar

Wireless LAN com 2.4 and 5 GHz.

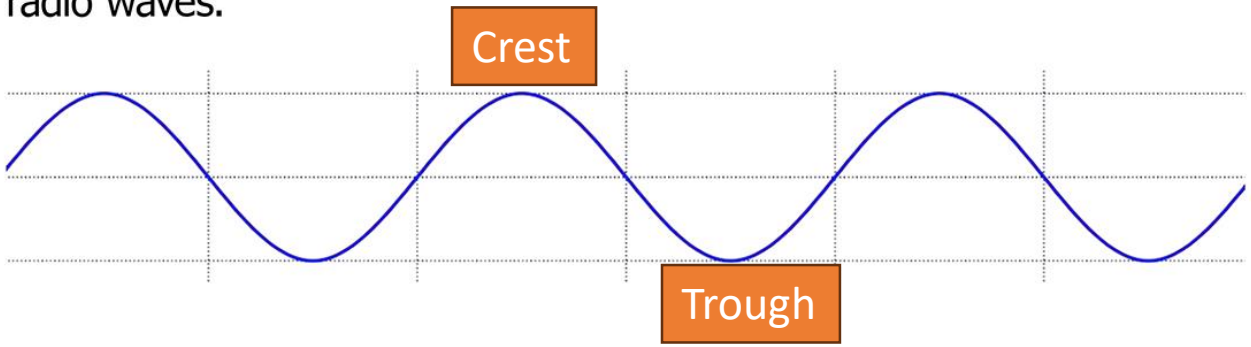
What is a WAVE?

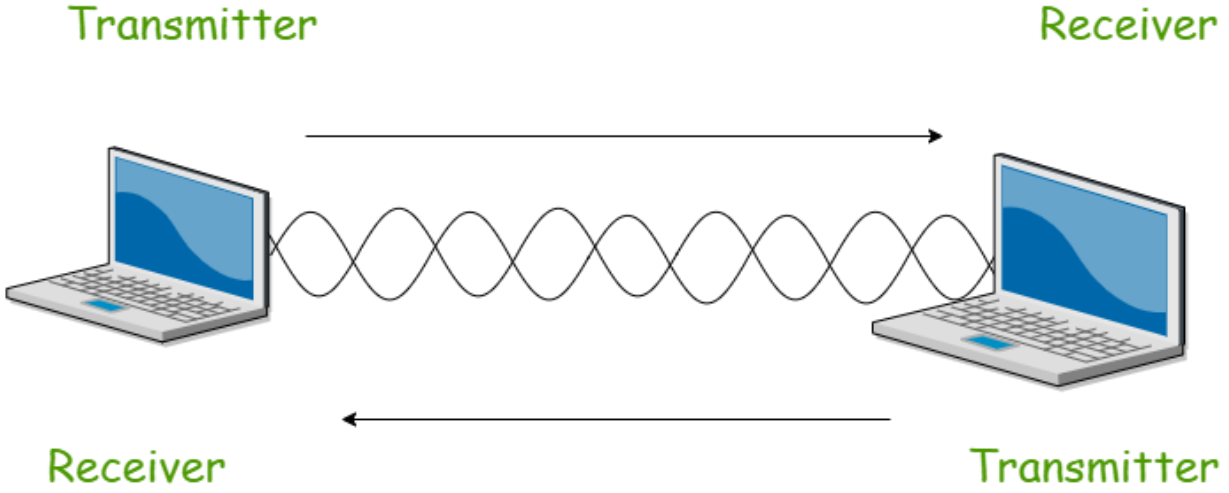
A **wave** is a traveling disturbance that transports energy from one location to another.

The material the energy travels through is the **medium**.

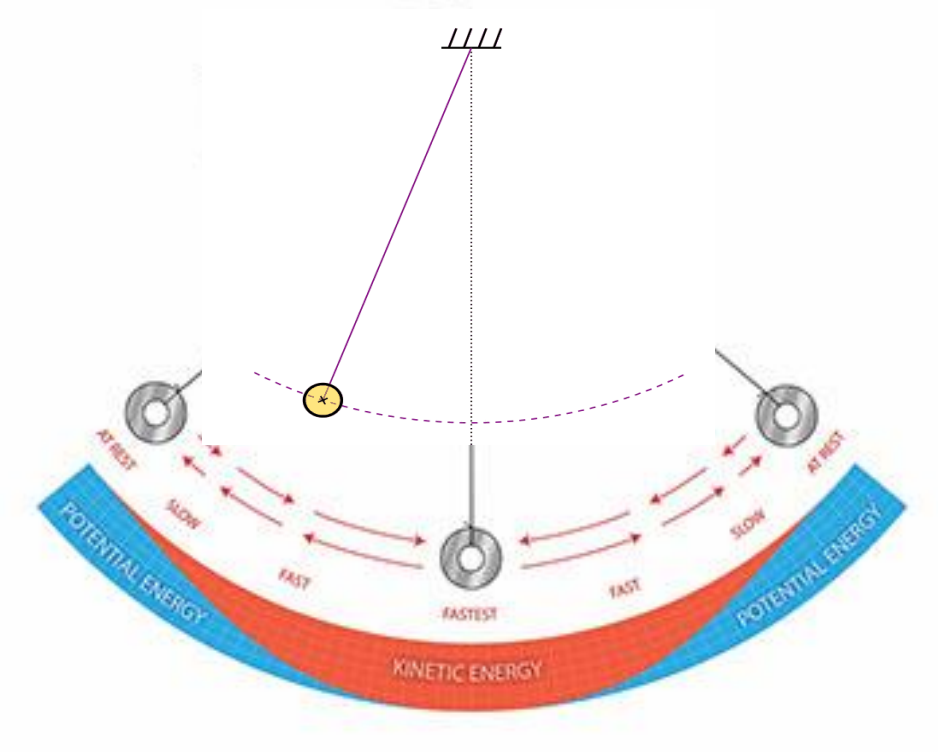
The movement of the energy is called **propagation**.

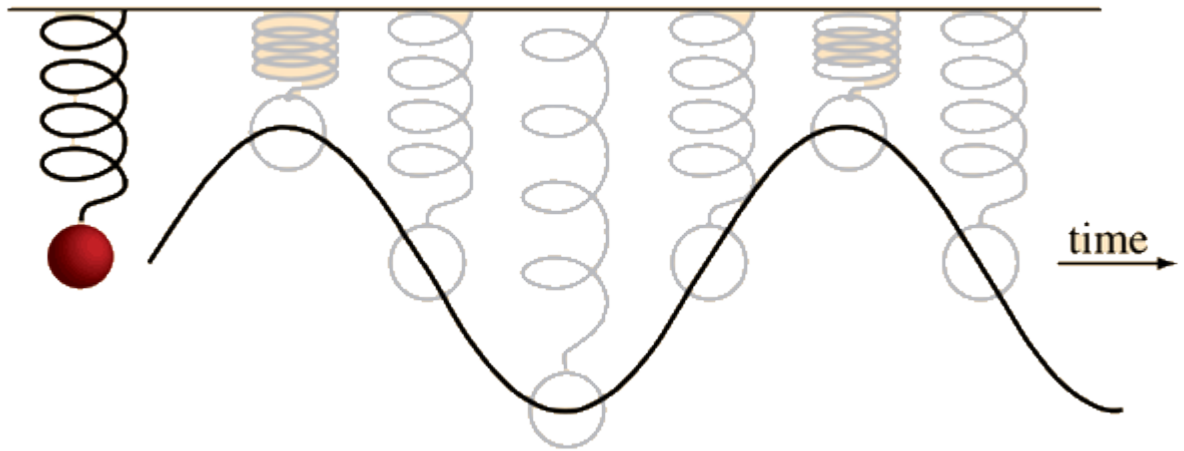
We can find some **examples of waves** inside a microwave or in the radio waves.





Signal/Energy Propagation

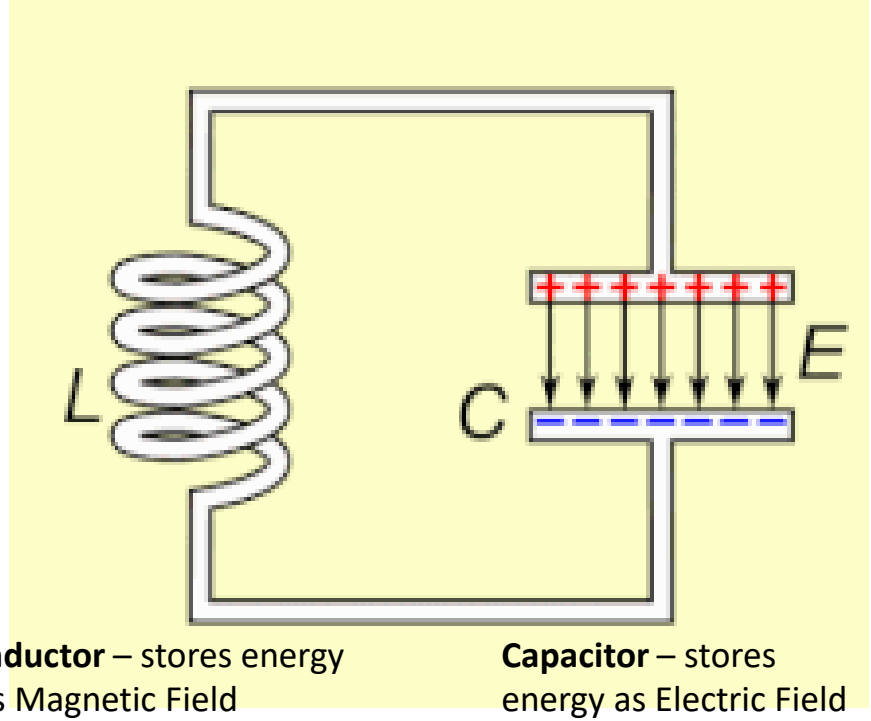




A wave is generated from a periodic shift of energy from potential energy to kinetic energy. The faster this shift happens the higher the frequency of the wave.

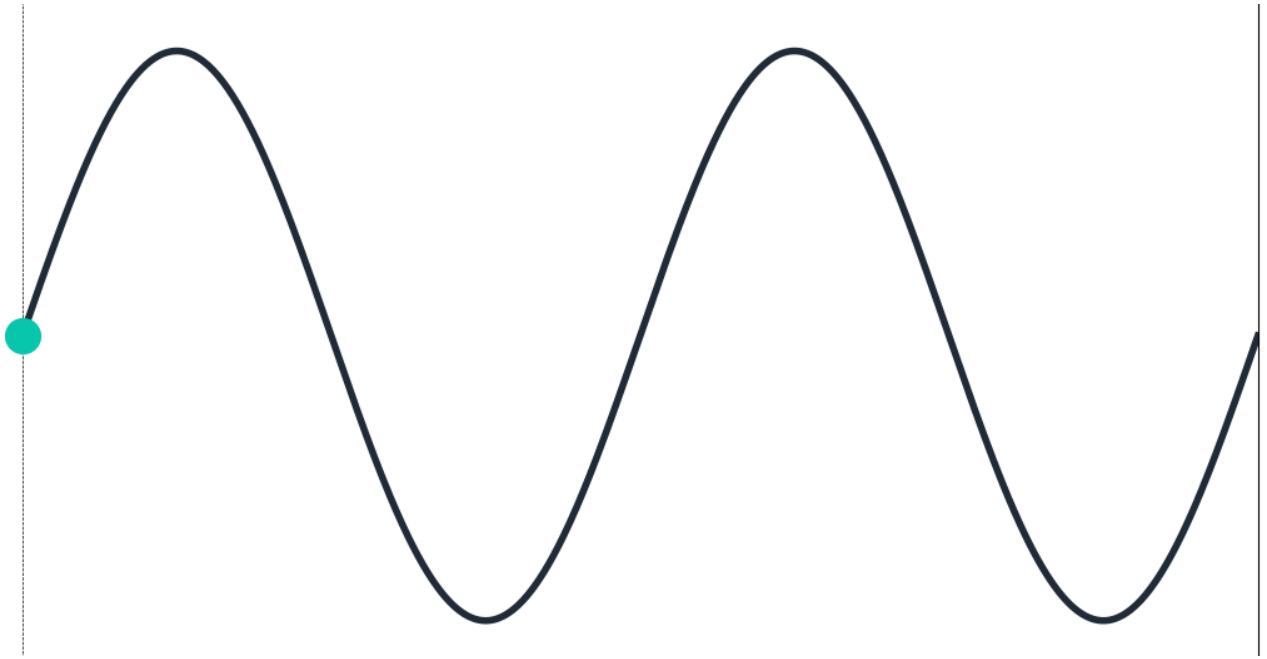
Basics of an Oscillator

An oscillator is a circuit that generates a repetitive waveform, typically a sine wave. There are different types of oscillators, but the most common and basic ones use a resonant circuit, which consists of an inductor and a capacitor. The inductor stores energy in the form of a magnetic field, while the capacitor stores energy in the form of an electric field. These two components are connected in such a way that they exchange energy back and forth, resulting in a waveform that oscillates between the maximum and minimum values. The sine wave is the natural waveform that results from this type of circuit

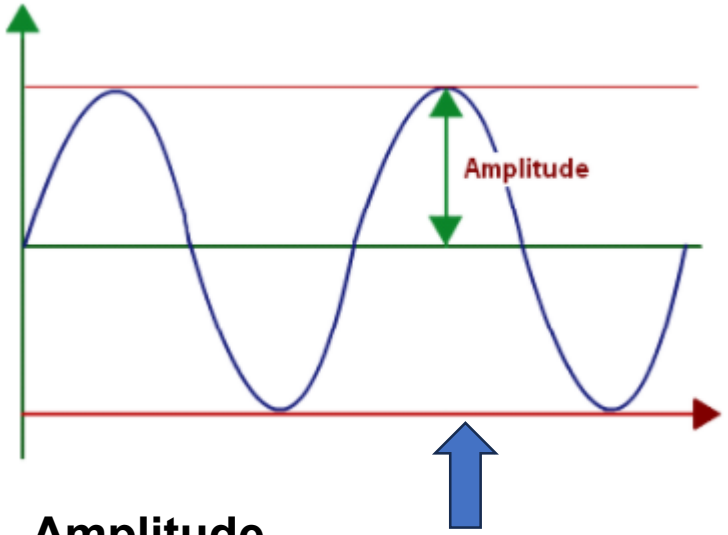


Inductor – stores energy as Magnetic Field

Capacitor – stores energy as Electric Field



Properties of a Periodic Waveform



Amplitude

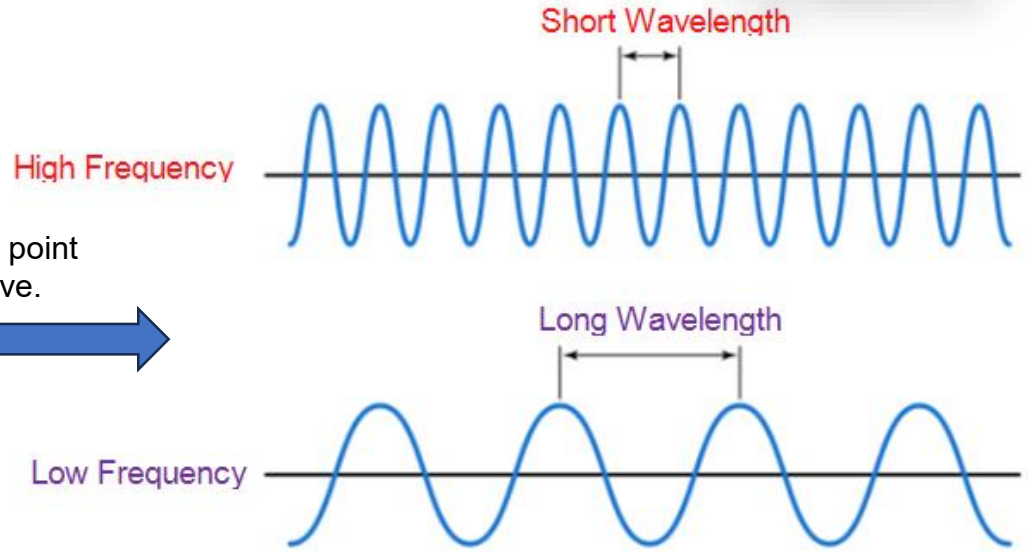
Amplitude is the height of the wave and often related to power.

Wavelength

Wavelength is the physical length from one point of a wave to the same point on the next wave.

Frequency

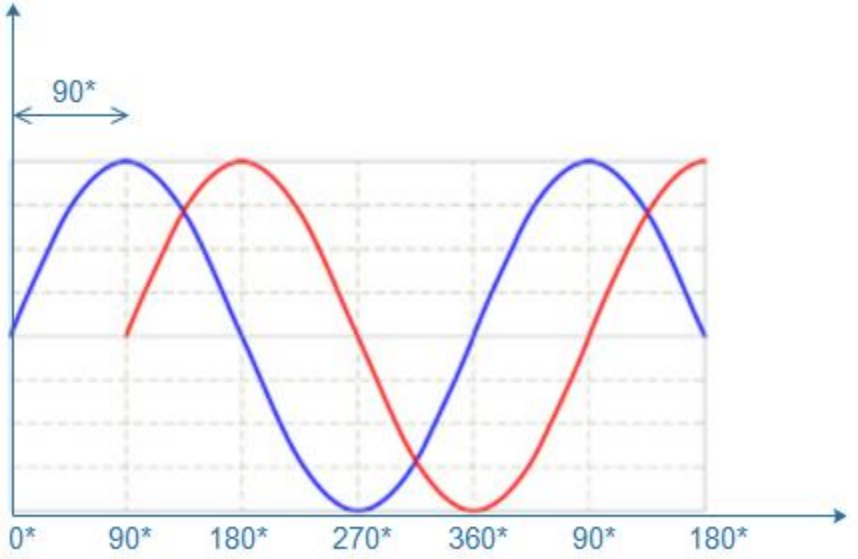
The frequency of a wave is the number of waves that pass by each second, and is measured in Hertz (Hz).



Phase

Phase is not a property of just one RF signal but instead involves the relationship between two or more signals that share the same frequency. The phase involves the relationship between the position of the amplitude crests and troughs of two waveforms.

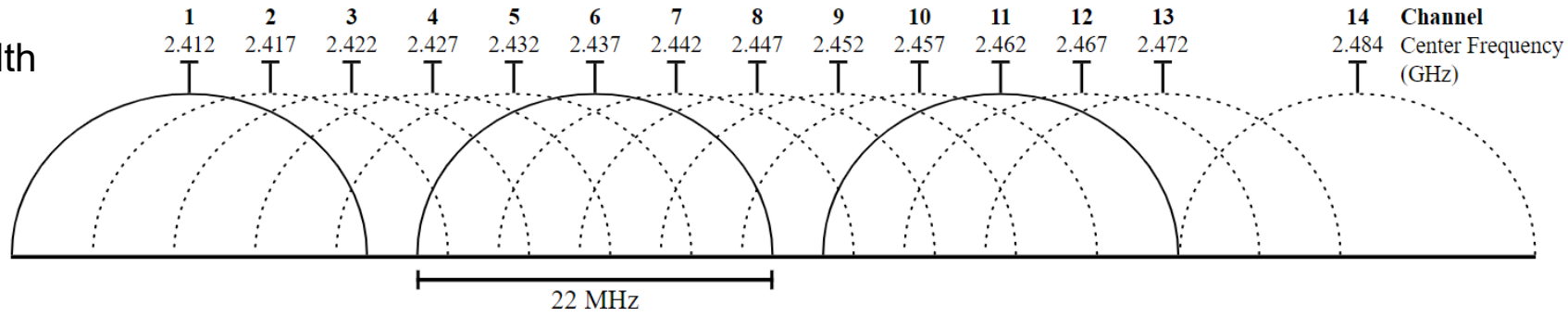
Phase can be measured in distance, time, or degrees. If the peaks of two signals with the same frequency are in exact alignment at the same time, they are said to be in phase. Conversely, if the peaks of two signals with the same frequency are not in exact alignment at the same time, they are said to be out of phase."



Source: https://www.techplayon.com/

What is Channel Bandwidth?

Wi-Fi Channels have 20MHz, 40MHz, 80MHz, 160MHz or 320 MHz of bandwidth



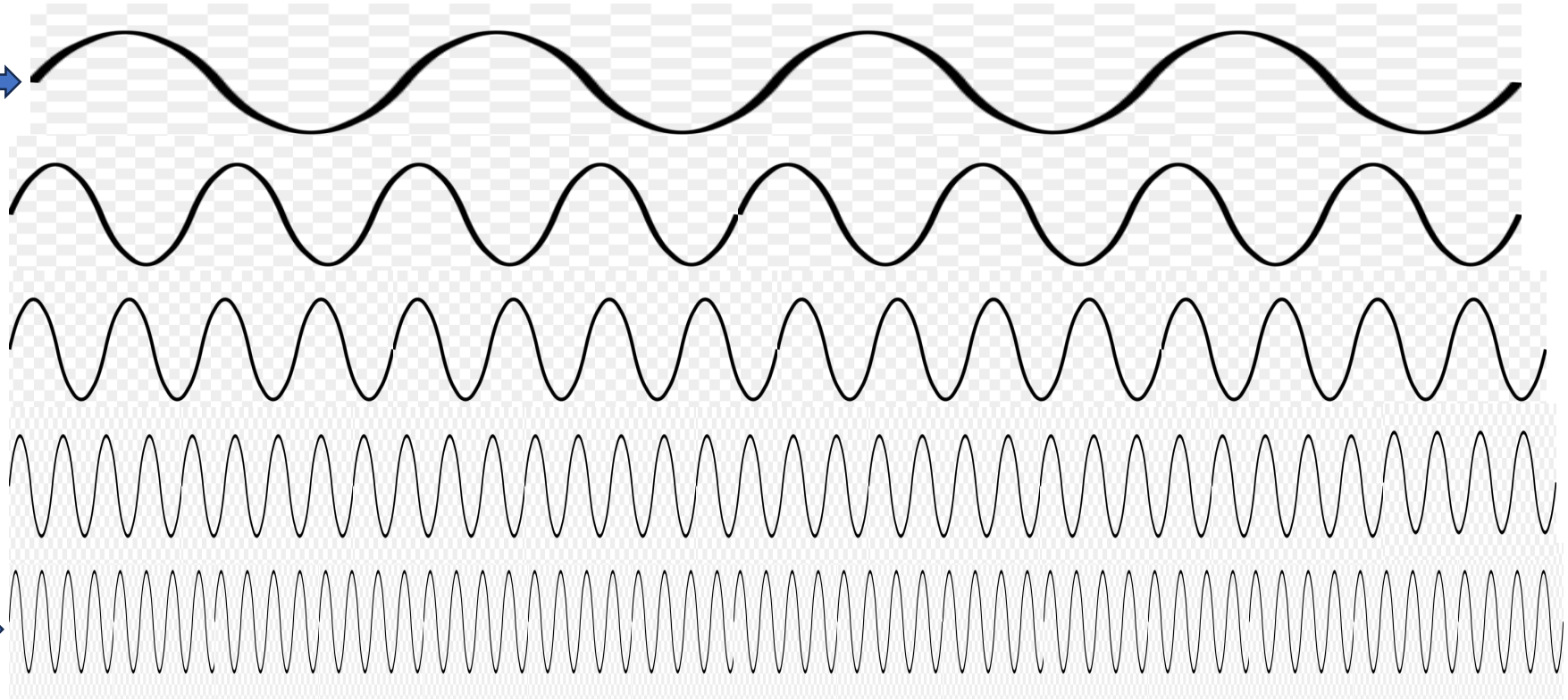
But what is Channel Bandwidth?

Frequency: 2427000000 Cycles/sec or 2.427 GHz

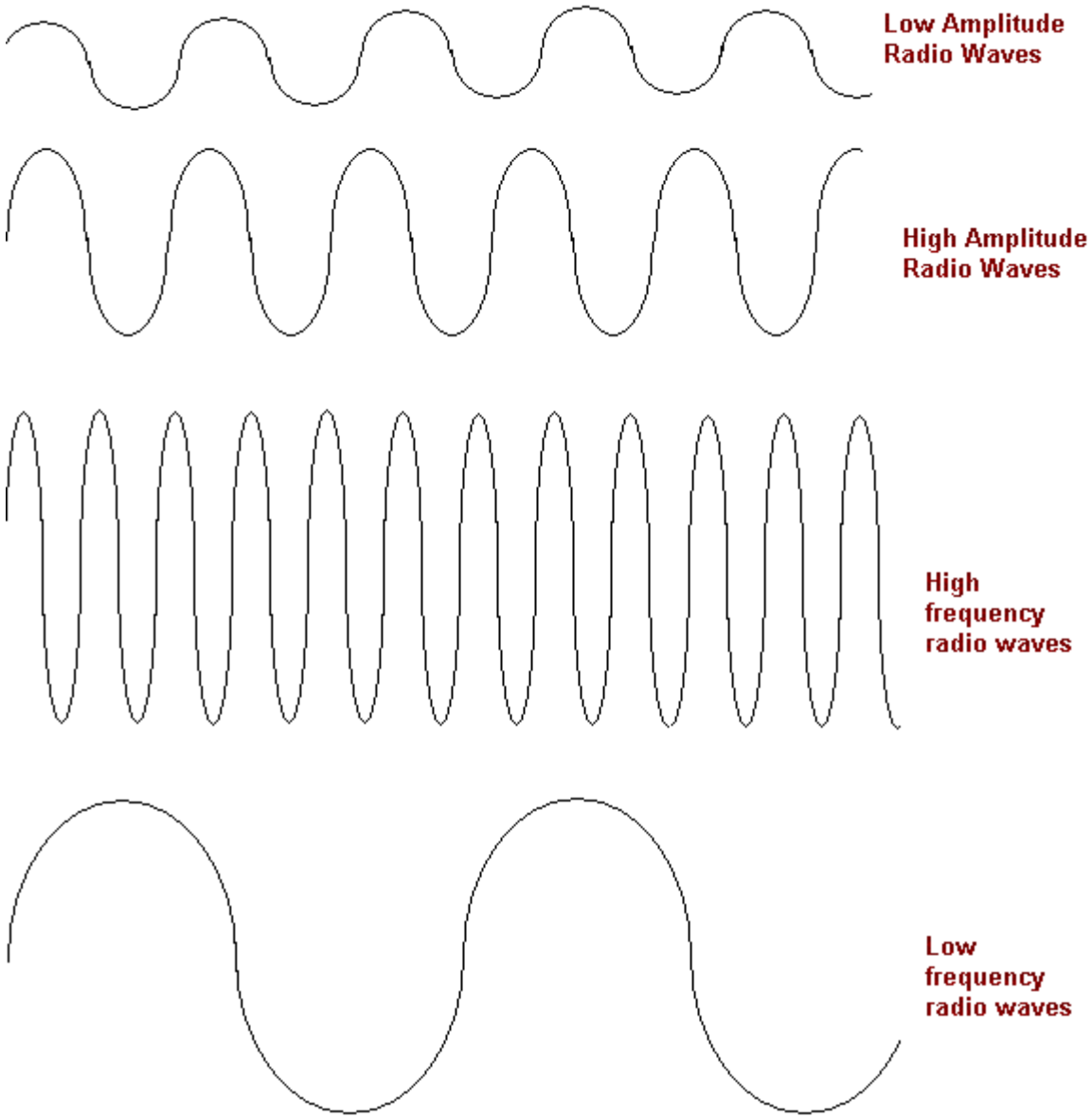
2.447 GHz – 2.427 GHz = 20MHz

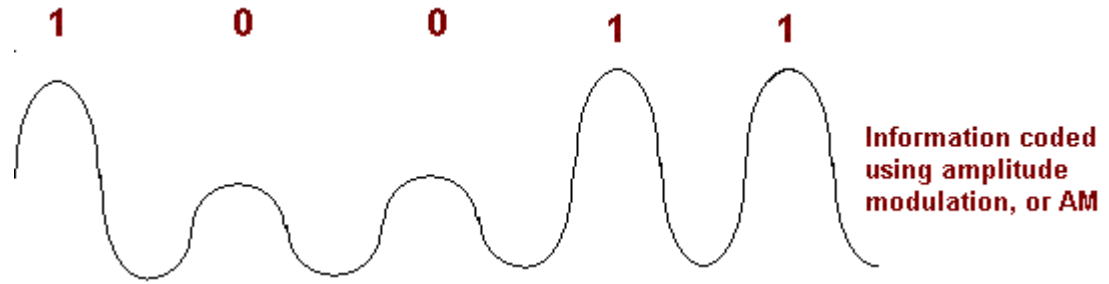
So 20MHz Bandwidth here means that the transmitter can transmit information on all these frequencies between 2.427GHz and 2.447GHz with the center frequency set to 2.437GHz

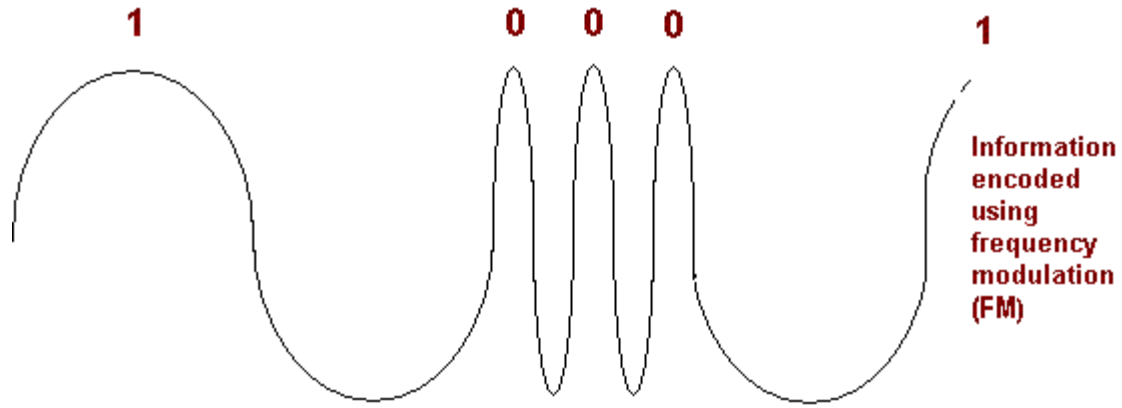
Frequency: 2447000000 Cycles/sec or 2.447 GHz



How Radio Waves Carry Information







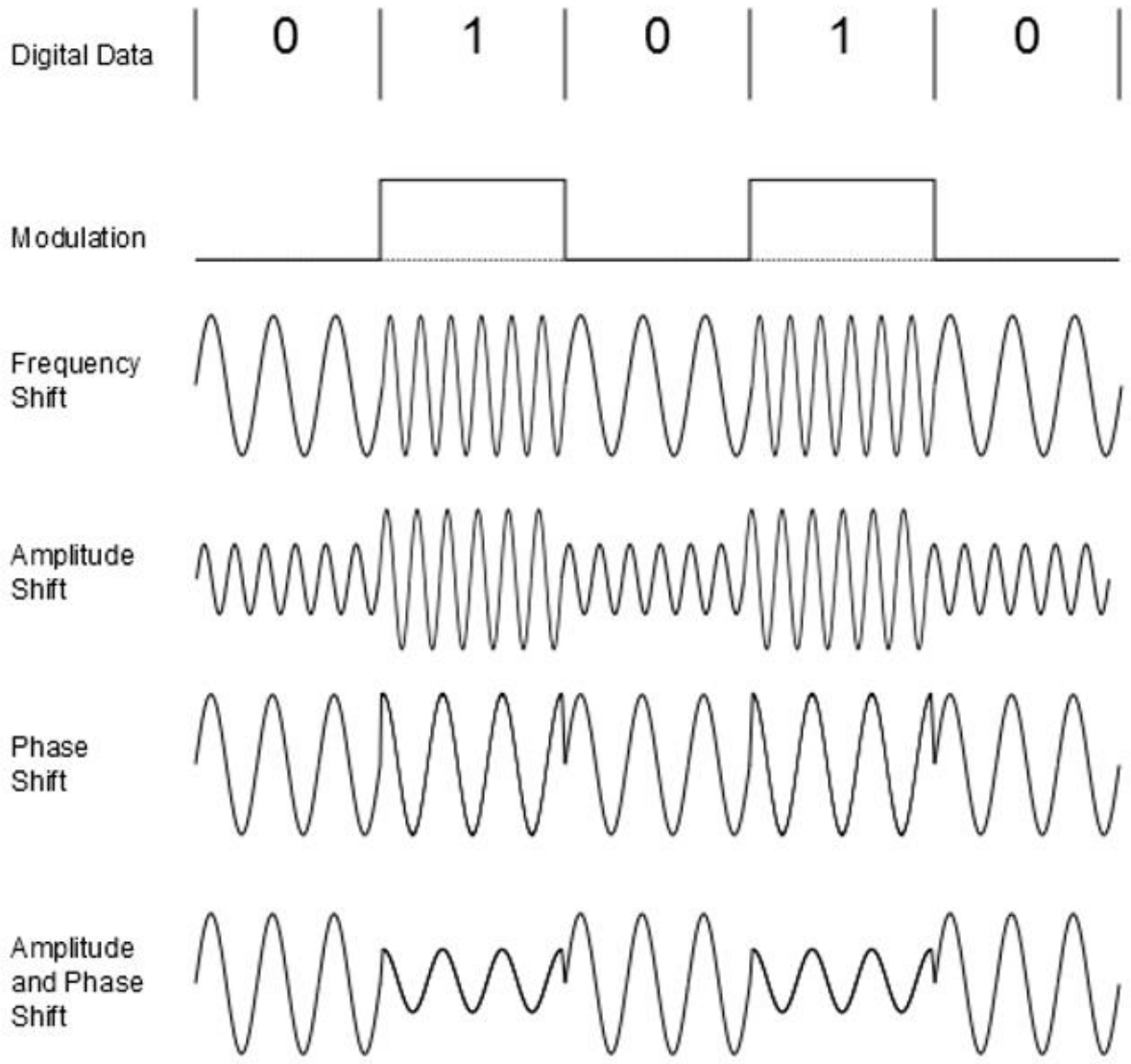
Modulation

Modulation, is the process of varying one or properties of a periodic waveform called a carrier wave in order to carry information.

There are various forms of modulation, each designed to alter a particular characteristic of the carrier wave. The most commonly altered characteristics include amplitude, frequency, phase, pulse sequence, and pulse duration.

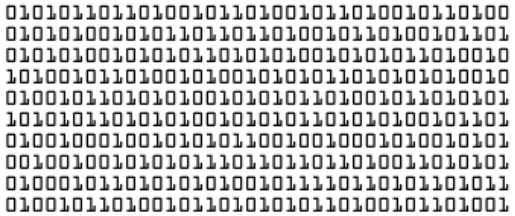
- FSK: Frequency of the carrier signal is varied to represent binary 1 and 0
- ASK: Amplitude of the carrier signal is varied to represent binary 1 and 0
- PSK: Phase of the carrier signal is varied to represent binary 1 and 0
- QAM: Amplitude and Phase of the carrier signal is varied to represent binary 1 and 0

Parameter	FSK	ASK	PSK	QAM
Bandwidth Needed	Higher	Low	Low	Lowest
Noise Immunity	Higher	Low	Higher	Lowest
Complexity	Low	Low	Higher	Highest
Data Rates	Low	Higher	Higher	Highest

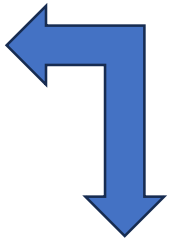


Information Signals and Carrier Signals

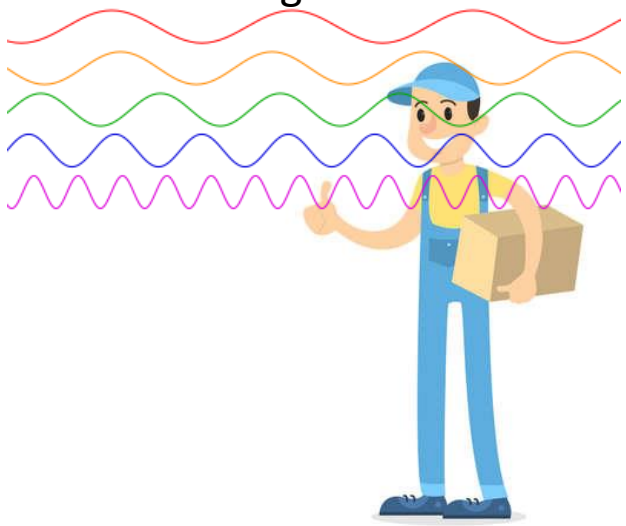
Information

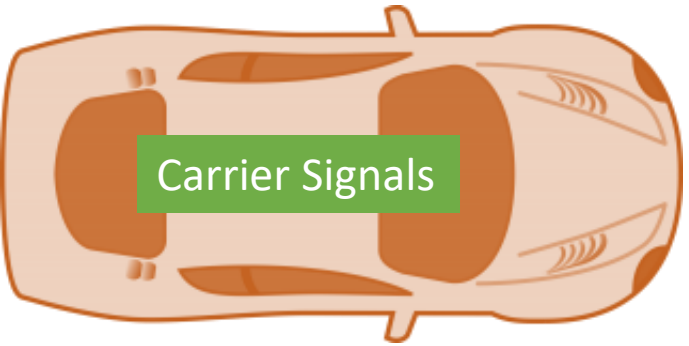


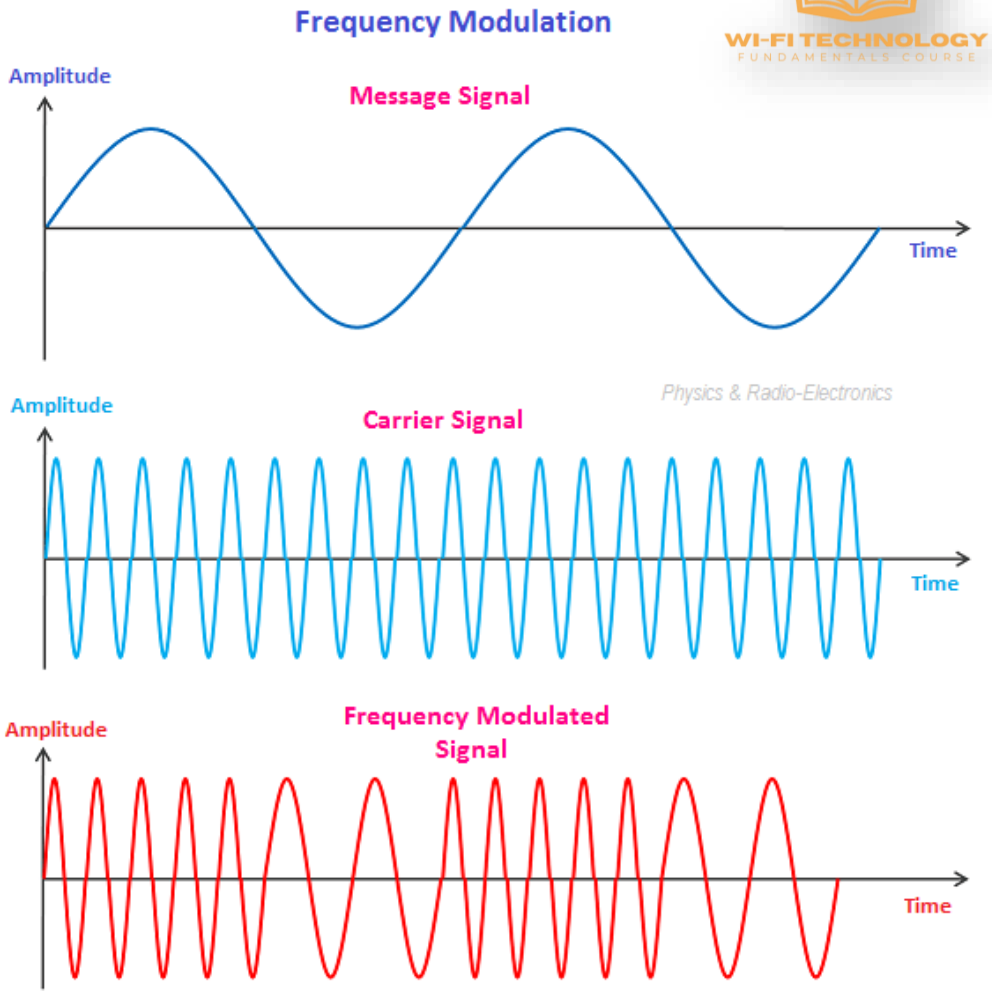
Digital Data



Information Signals

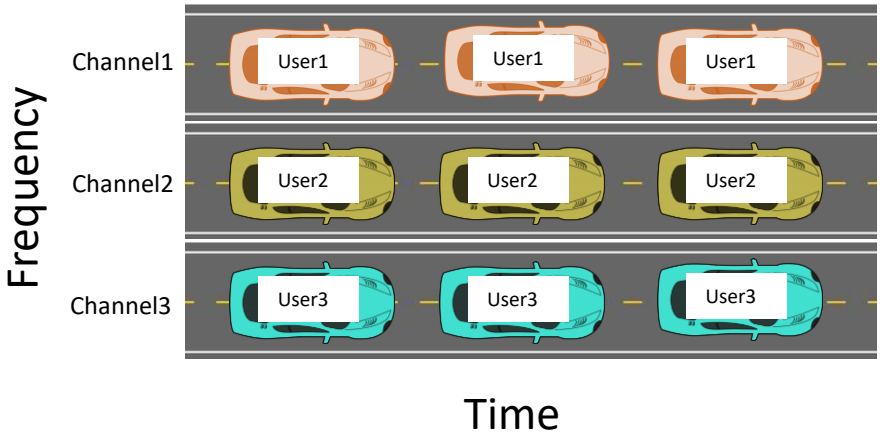




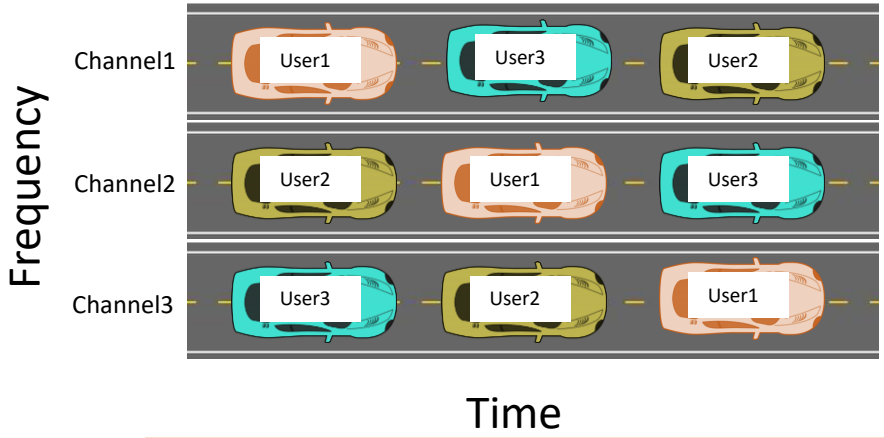


Bandwidth is the frequency range occupied by a modulated carrier signal.

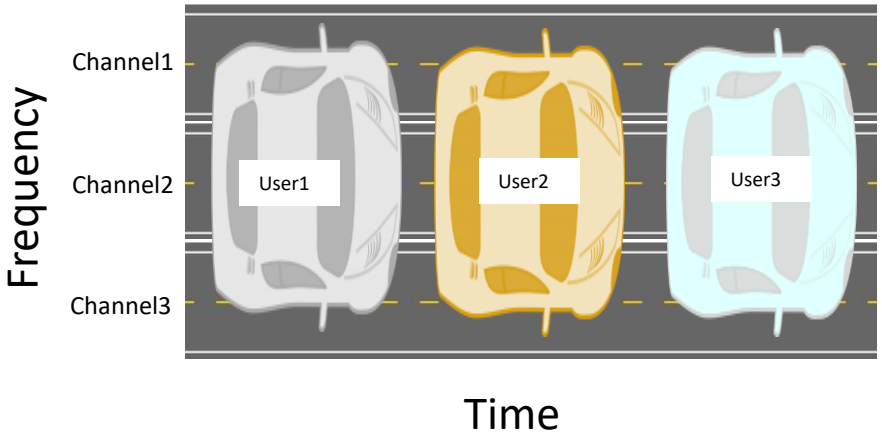
Different Multiple Access Techniques



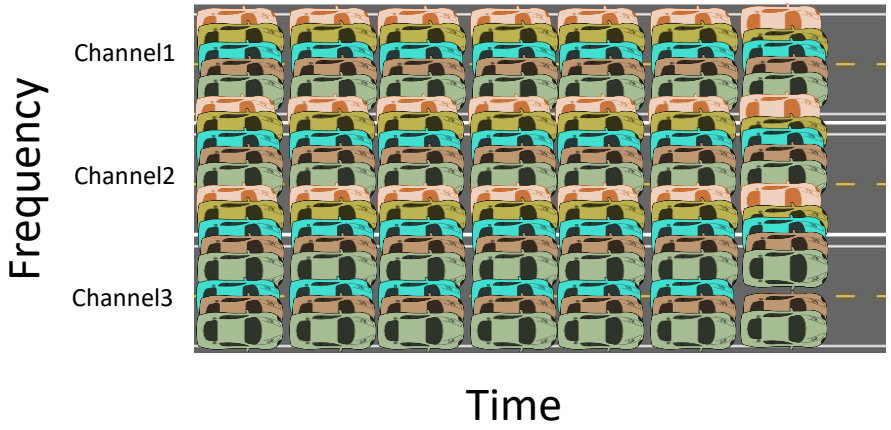
Frequency Division Multiplexing



Frequency Hopping Spread Spectrum



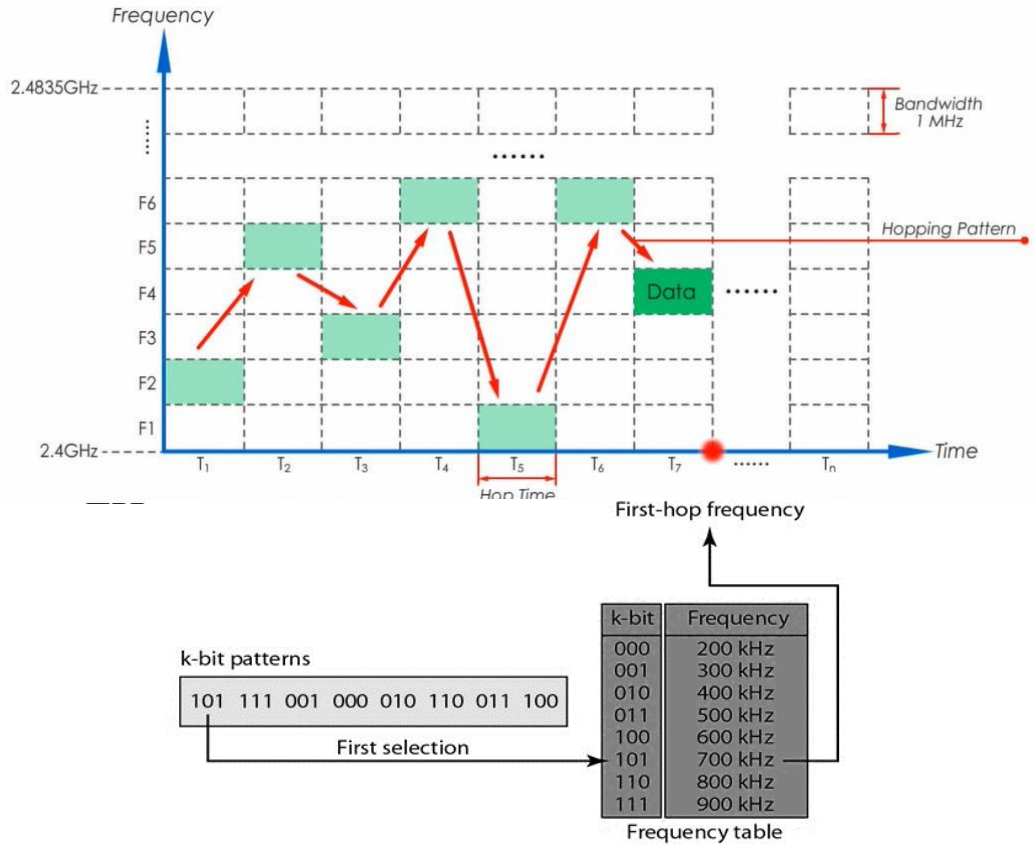
Direct Sequence Spread Spectrum



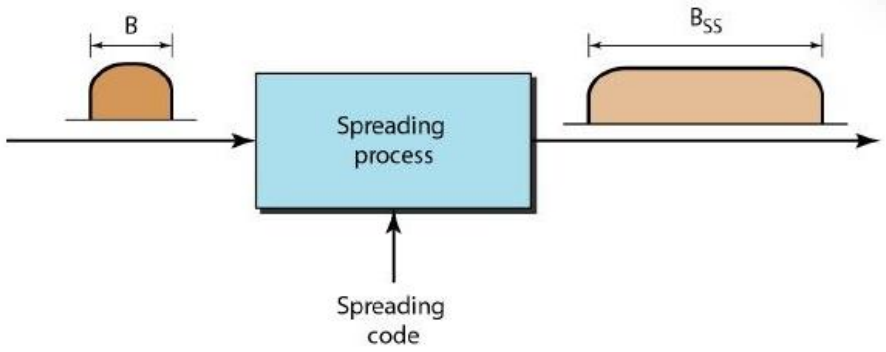
Orthogonal Frequency Division Multiplexing

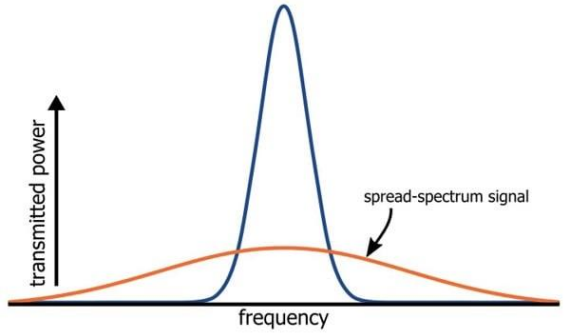
What is Spread Spectrum?

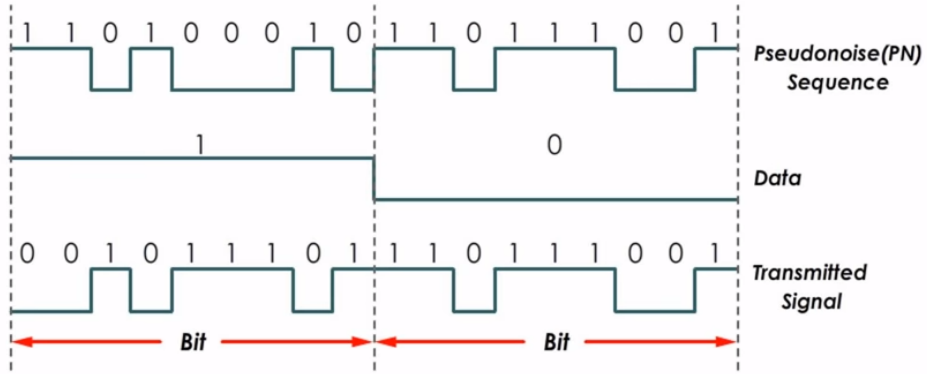
Spread spectrum designates techniques by which a signal generated with a particular bandwidth is deliberately spread in the frequency domain, resulting in a signal with a wider bandwidth. (Source: Wikipedia)



Frequency Hopping Spread Spectrum

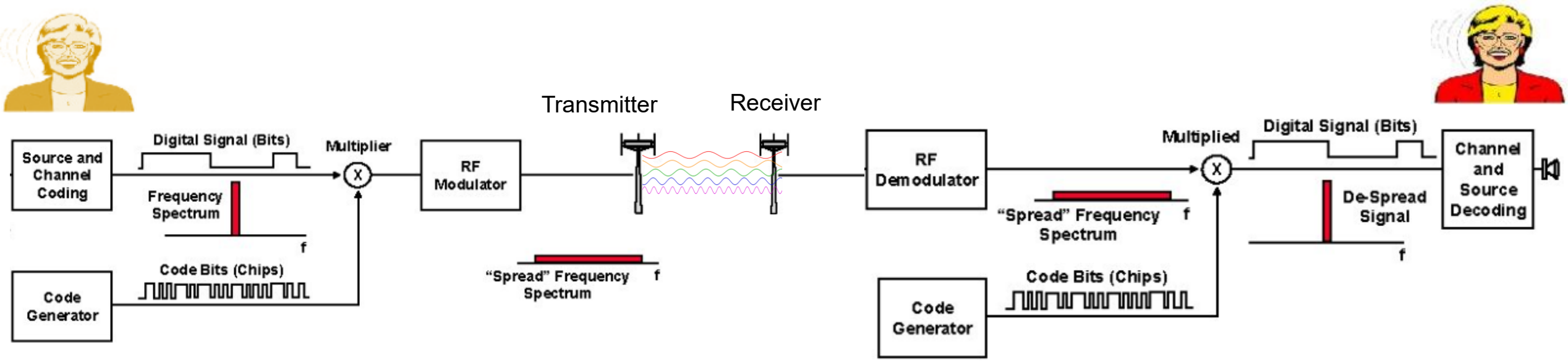






Direct Sequence Spread Spectrum

DSSS Transmit and Receive

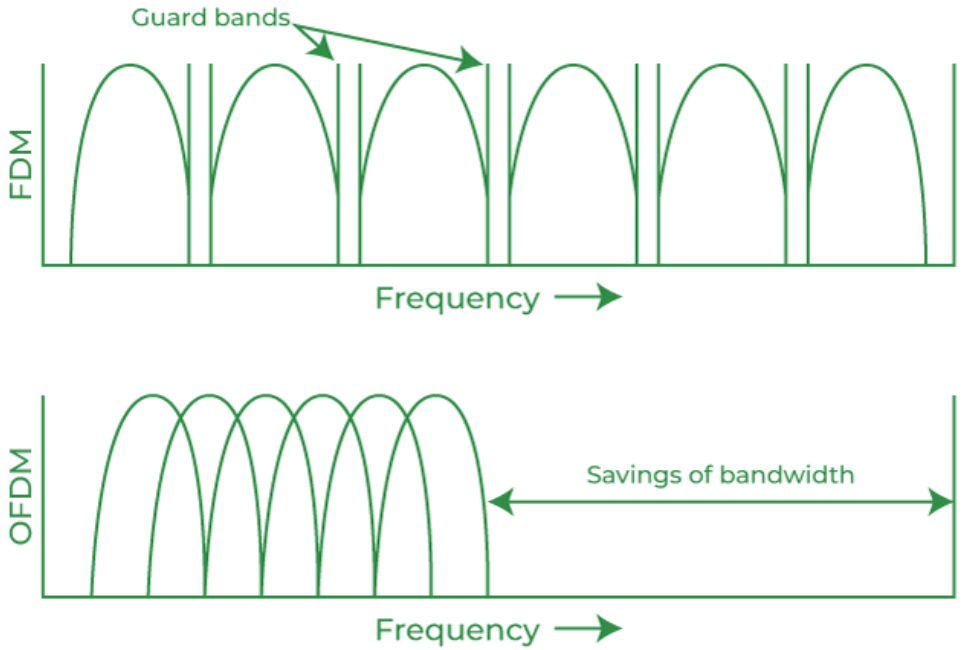


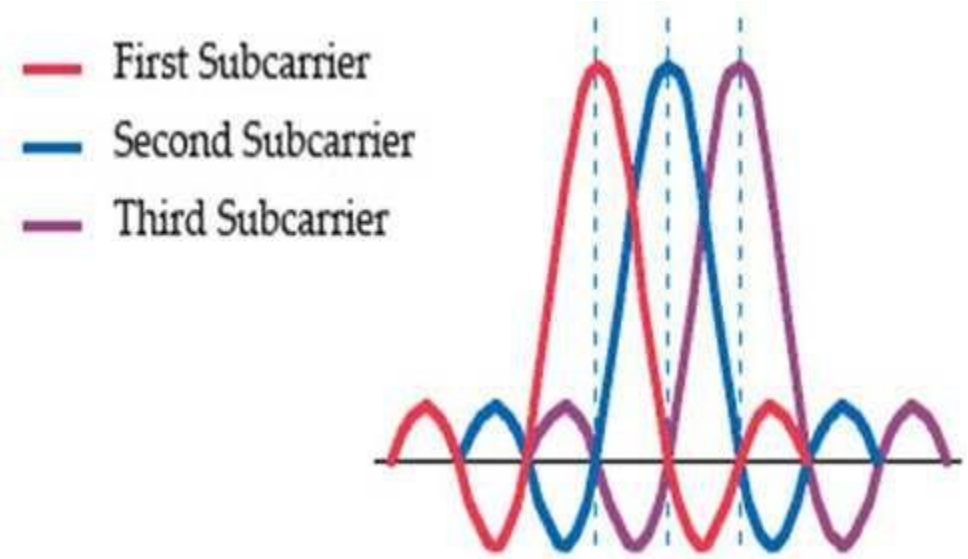
Data Rate	Code Length	Modulation	Symbol Rate	Bits/Symbol
1 Mbps	11 (Barker Sequence)	BPSK	1 MSps	1
2 Mbps	11 (Barker Sequence)	QPSK	1 MSps	2
5.5 Mbps	8 (CCK)	QPSK	1.375 MSps	4
11 Mbps	8 (CCK)	QPSK	1.375 MSps	8

Orthogonal Frequency Division Multiplexing (OFDM)

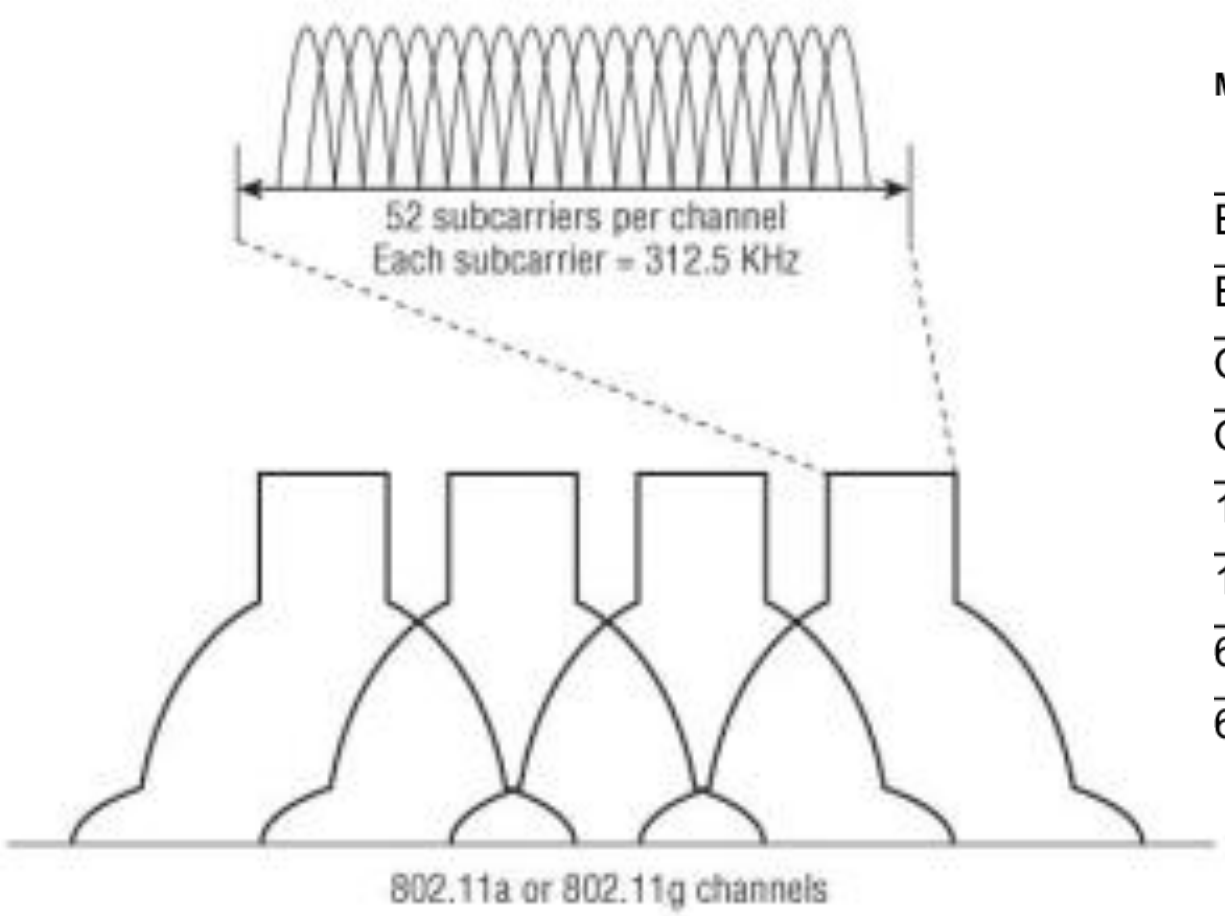
In OFDM, several bits can be sent in parallel, or at the same time, in separate sub stream channels. This enables each sub stream's data rate to be lower than would be required by a single stream of similar bandwidth. This makes the system less susceptible to interference and enables more efficient data bandwidth.

Standard	Modulation Technique
802.11	FSSS, DSSS
802.11b	DSSS, CCK
802.11a	OFDM
802.11g	OFDM
802.11n (WiFi4)	OFDM
802.11ac (WiFi5)	OFDM
802.11ax (WiFi6)	OFDMA





Basic OFDM Data Rates for 802.11a/b



Modulation	Coded bits per sub-carrier	Coded bits per OFDM symbol	Coding rate	Data bits per OFDM symbol	Data rate for 20MHz channel
BPSK	1	48	1/2	24	6 Mbps
BPSK	1	48	3/4	36	9 Mbps
QPSK	2	96	1/2	48	12 Mbps
QPSK	2	96	3/4	72	18 Mbps
16-QAM	4	192	1/2	96	24 Mbps
16-QAM	4	192	3/4	144	36 Mbps
64-QAM	6	288	2/3	192	48 Mbps
64-QAM	6	288	3/4	216	54 Mbps

References

WLAN Frequency Bands
https://ipcisco.com/lesson/wlan-frequency-bands/

Unlicensed Spectrum Charts
https://wlanprofessionals.com/updated-unlicensed-spectrum-charts/

LC Oscillator Basics
https://www.youtube.com/watch?v=2_y_3_3V-so

Introduction to Waves – Definition, Types, Properties
https://www.geeksforgeeks.org/introduction-to-waves-definition-types-properties/

Basics of Modulation
https://en.wikipedia.org/wiki/Modulation

FSSS, DSSS and ODFM Basics
https://www.youtube.com/watch?v=y8tQm-wIoAI

WI-FI TECHNOLOGY
FUNDAMENTALS COURSE


?
QUIZ!
TIME

Quiz 1d Results

Yury Soldatov

Russia

Number of participants - 228