



GAZ  RAB

Wireless Technology Training





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WIREFLESS

LET'S BE THE ANTENNA FOR
OUR PALESTINIAN BROTHERS
TO TRANSFER THEIR VOICE CLEARLY
& FILTER THE INTERNAL
INTERFERENCE
& RESIST THE EXTERNAL NOISE

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Wireless Training

RF Basics

Wi-Fi Fundamentals

New Technology

Site Survey

Wi-Fi Design

Troubleshooting

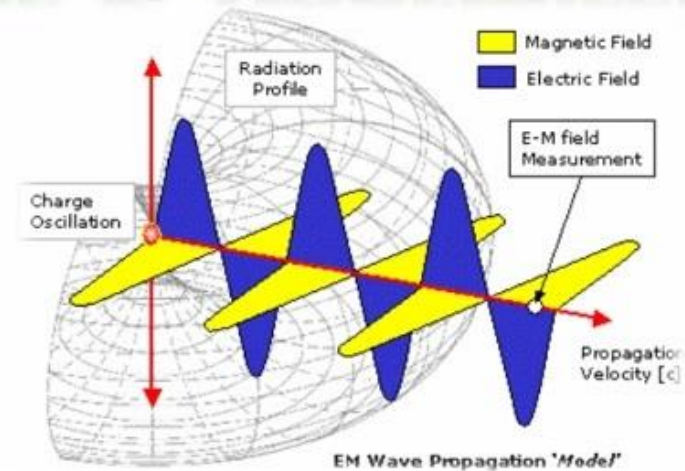


Wireless Training

Part 1-Session 1

RF BASICS

Waves & Transmission



Part 1 : RF Basics

1. What is Radio Transmission
2. RF Bands and Spectrum
3. RF Waves Characteristics
4. RF Measurements Units
5. Signal Indicators RSSI-SNR
6. RF Waves Propagation
7. Channels and bands
8. Interference CCI – ACI

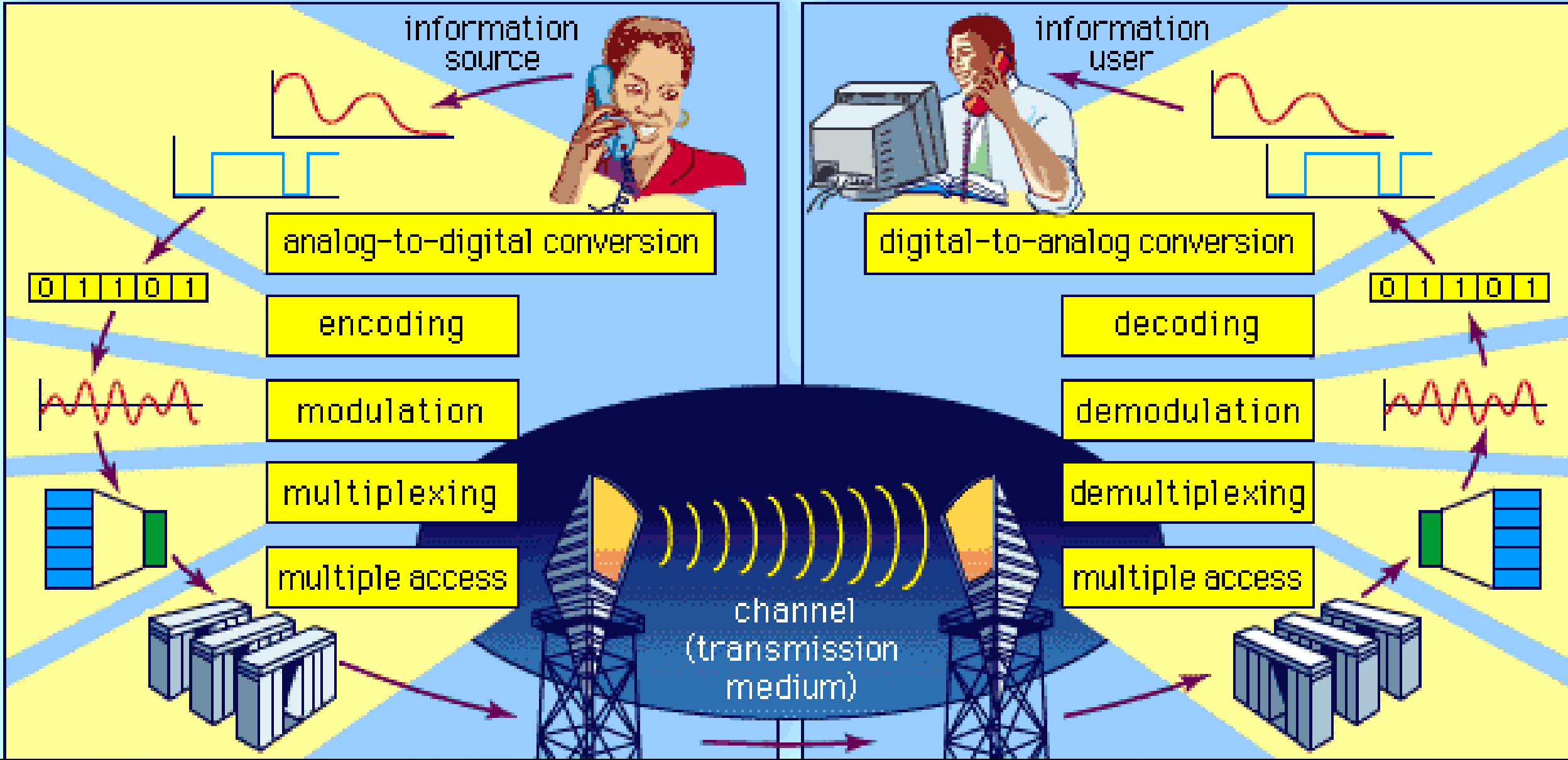


Wireless Transmission

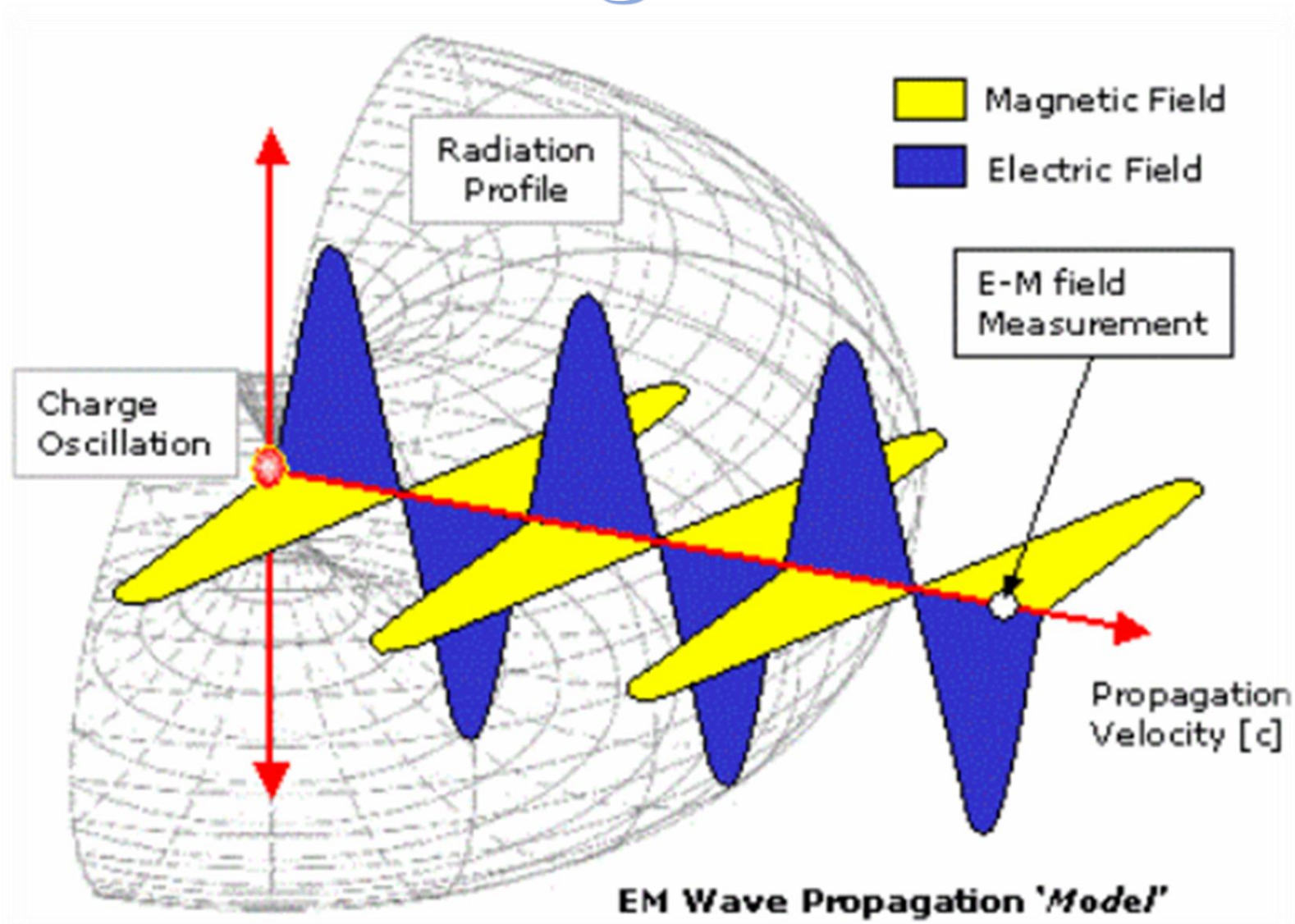


transmitter

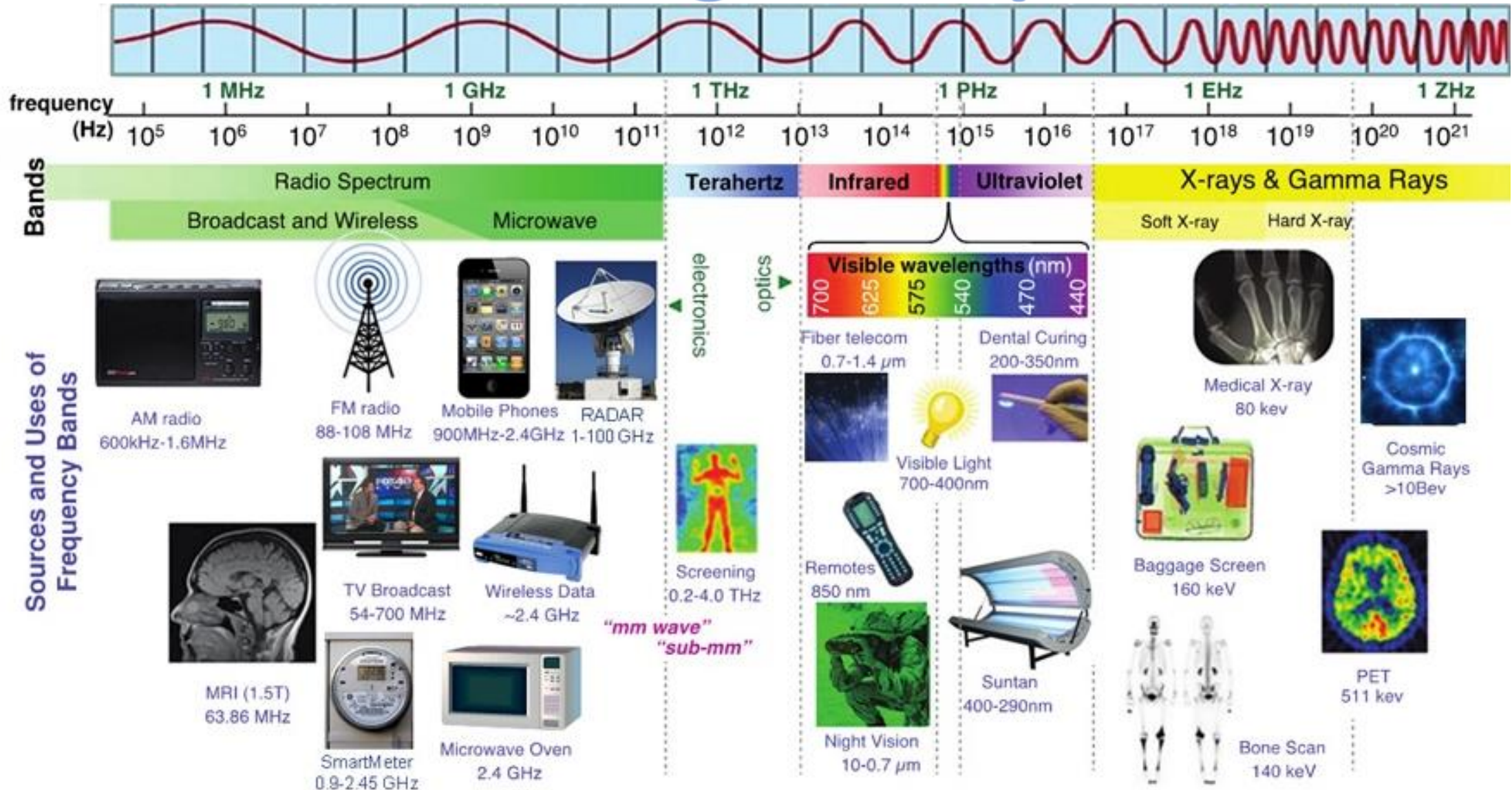
receiver



Electro Magnetic Waves

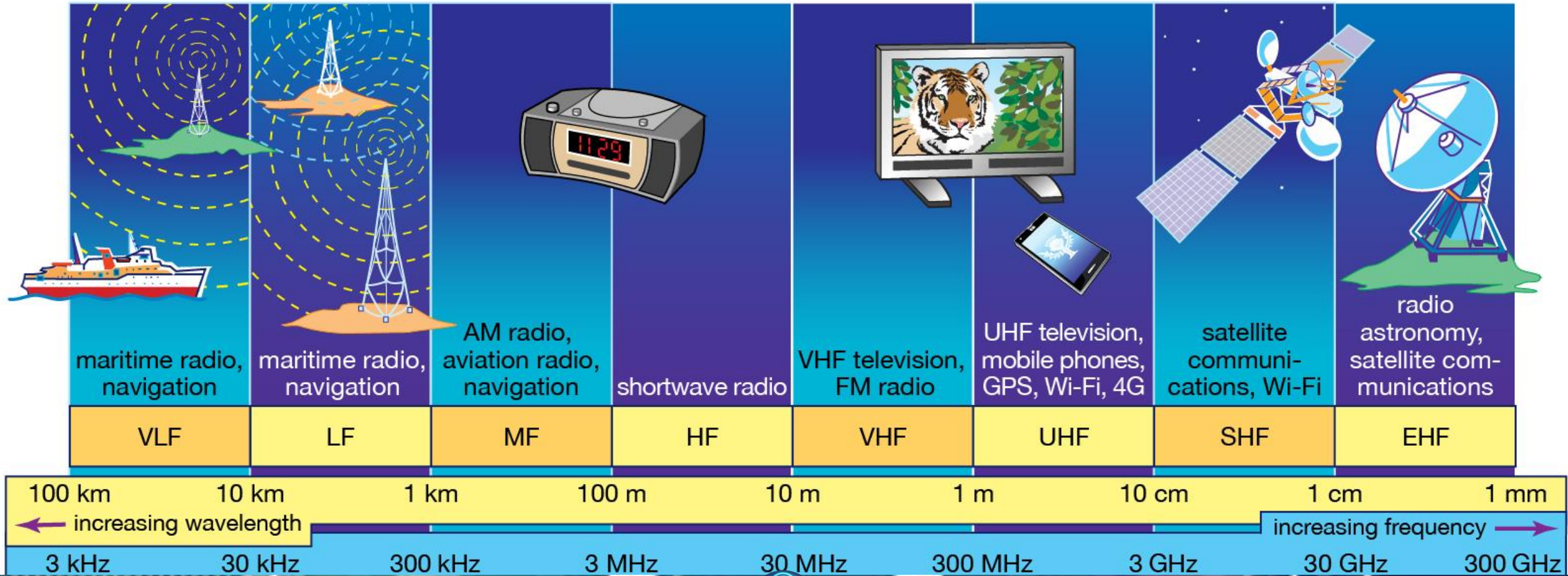


Electro Magnetic Spectrum



EM Spectrum

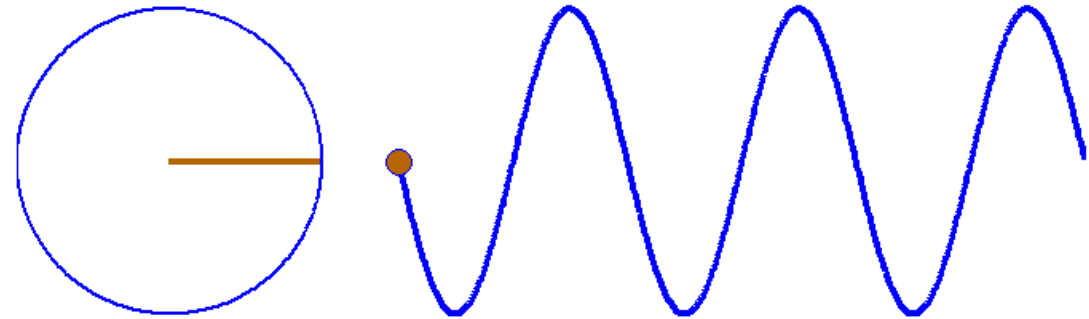
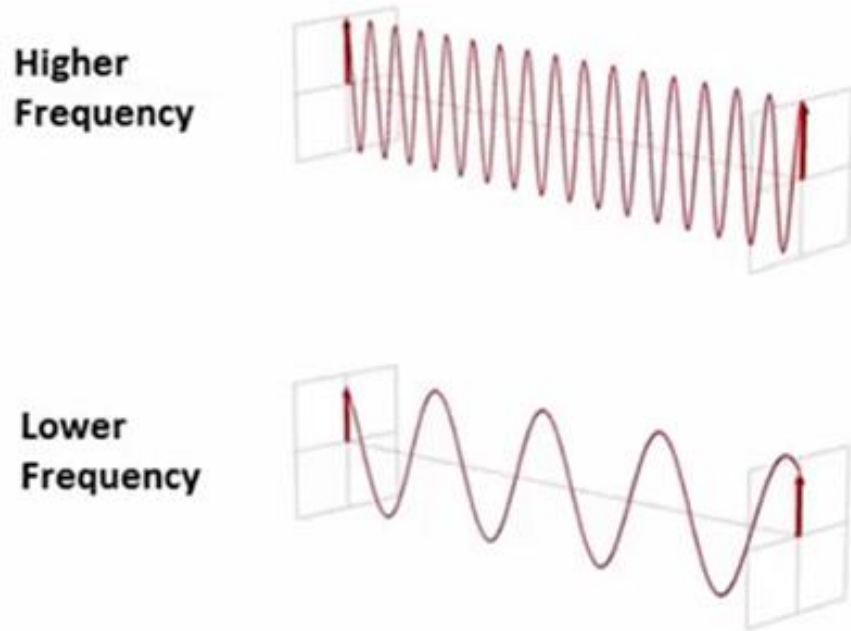
- RF is only one piece of the spectrum, covering AM/FM radios, cell phones, radar, microwave ovens, TVs and of wireless network traffic.



RF Waves

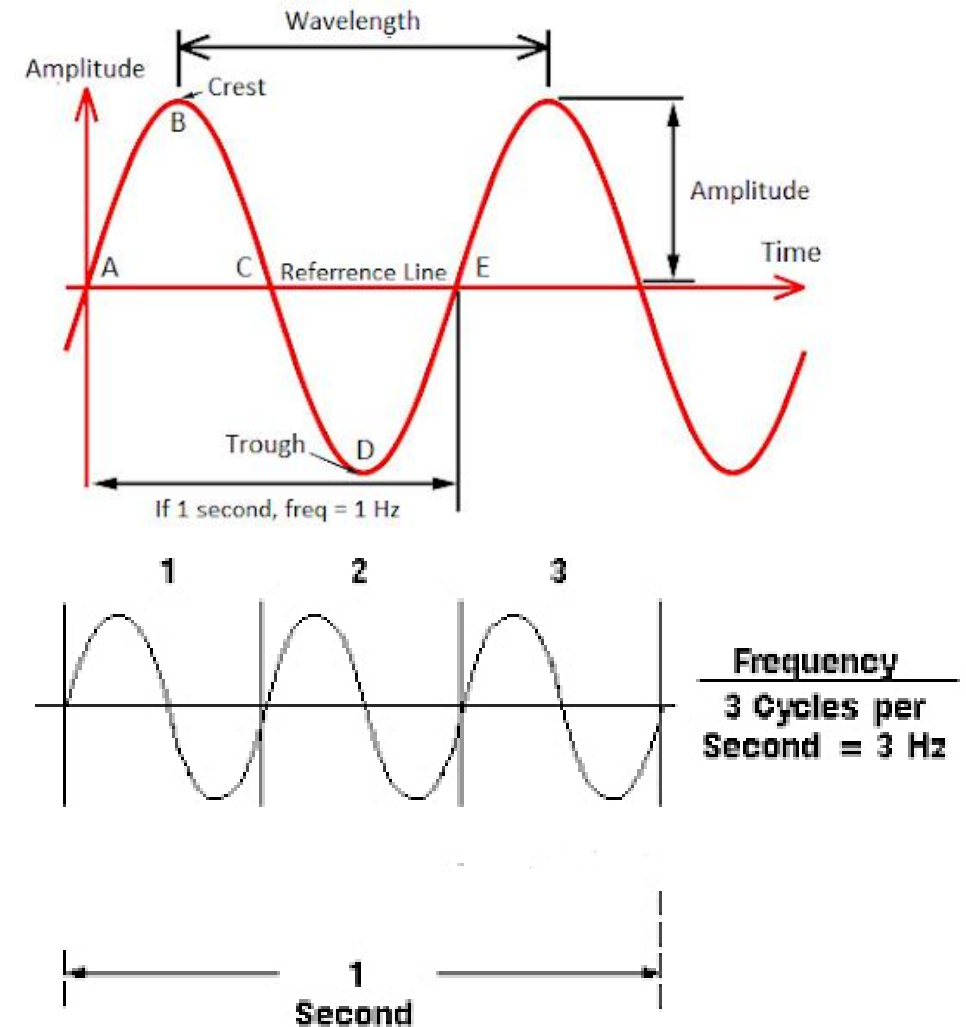
Radio Wave or Radio Frequency

- Type of electromagnetic signal designed to carry information through the air over relatively long distances.
- These signals oscillate at a very high rate , which allows the waves to travel through the air similar to waves on an ocean.
- Radio waves used for carrying music to FM radios and video to televisions and carrying data over a wireless network



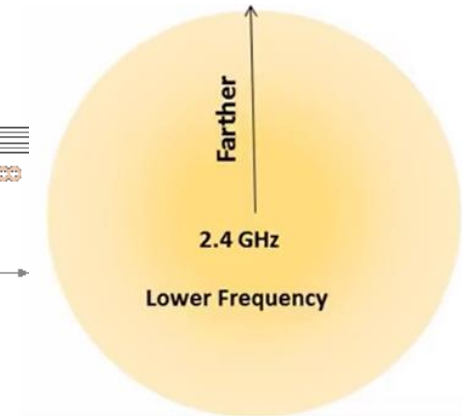
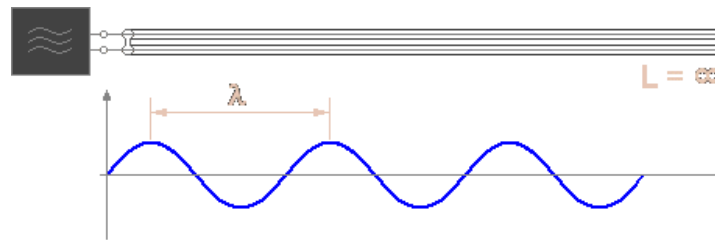
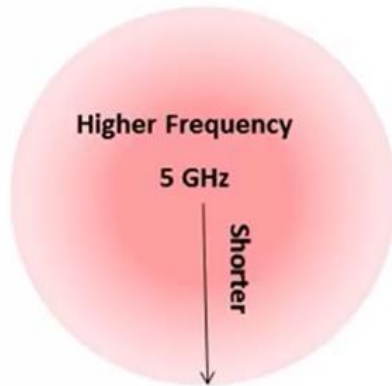
RF Waves Characteristics

- **Frequency : $f = c/\lambda$**
 - The number of times the signal oscillates in one second (Hz)
 - 2.4GHz = 2.4 billion oscillations in one second
- **Amplitude :**
 - The signal's power in volts (2.4GHz frequency has lower amplitude than 5GHz frequency)
- **Wavelength : λ**
 - The measure of one wave to the next wave
 - 2.4Ghz wave = ~4.8 inches, 5Ghz = ~2 inches
 - Antenna length = $\lambda/2$
- **Energy : $E = hc/\lambda$**
 - Required power for transmission
 - More Power Required will have more attenuation and lower distance travelled .



Lower Freq – Longer Wave Length – Less Power -More Distance

RF Waves Characteristics



Lower Freq – Longer Wave Length – Less Power -More Distance



RF Data Transmission

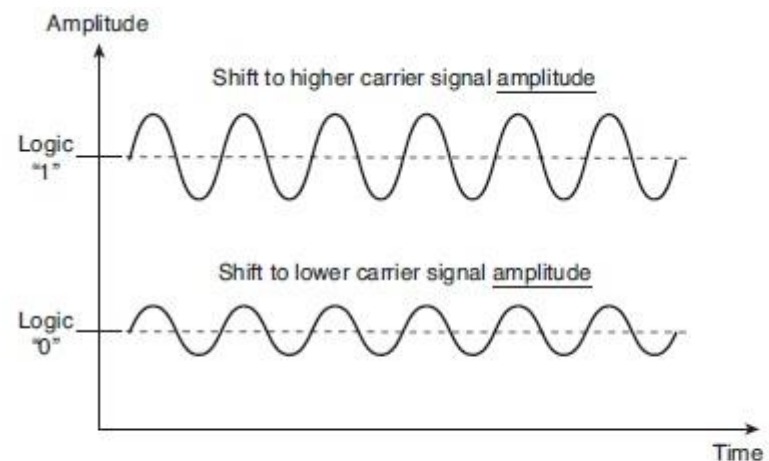
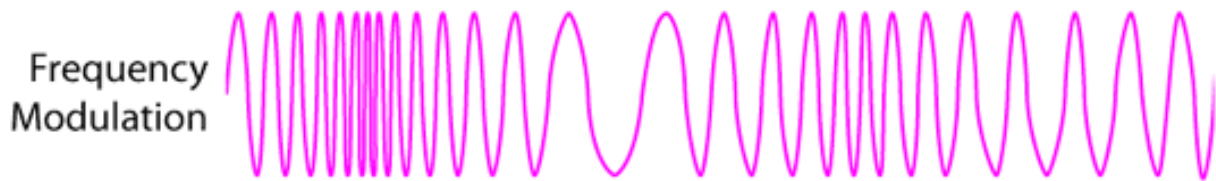
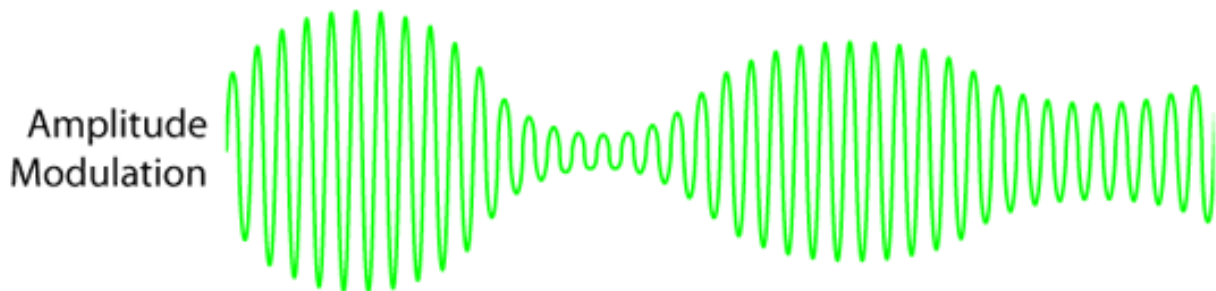
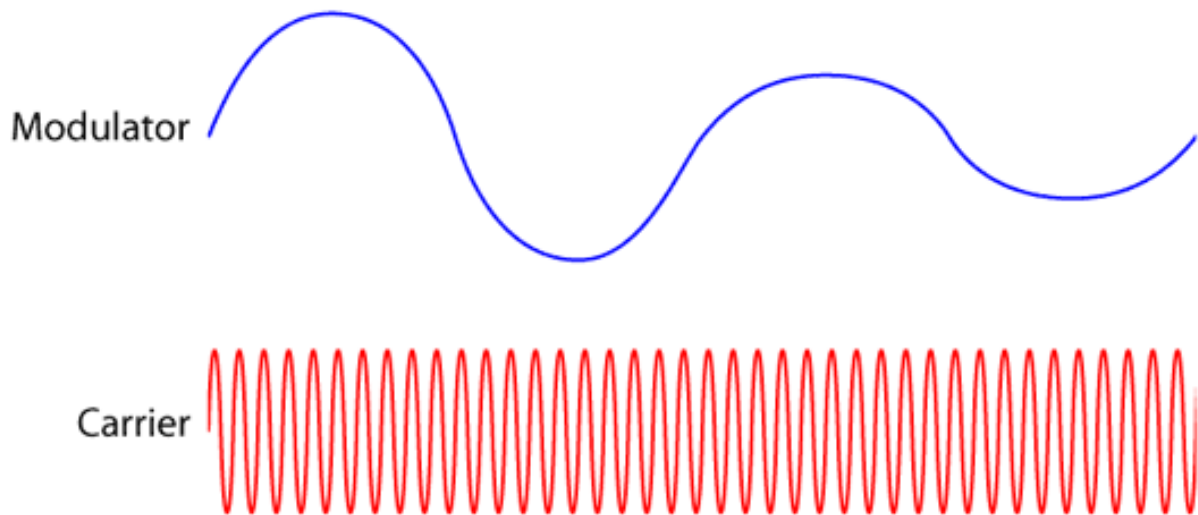


Figure 2-5 Amplitude-Shift Keying Varies the Amplitude of the Signal to Represent Digital Data

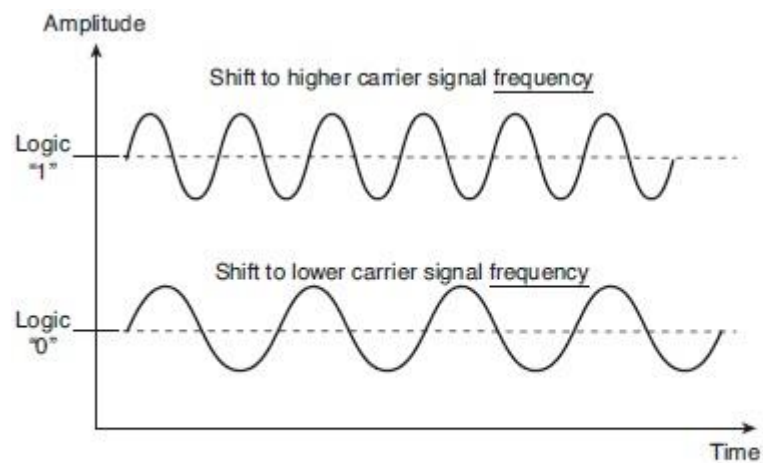
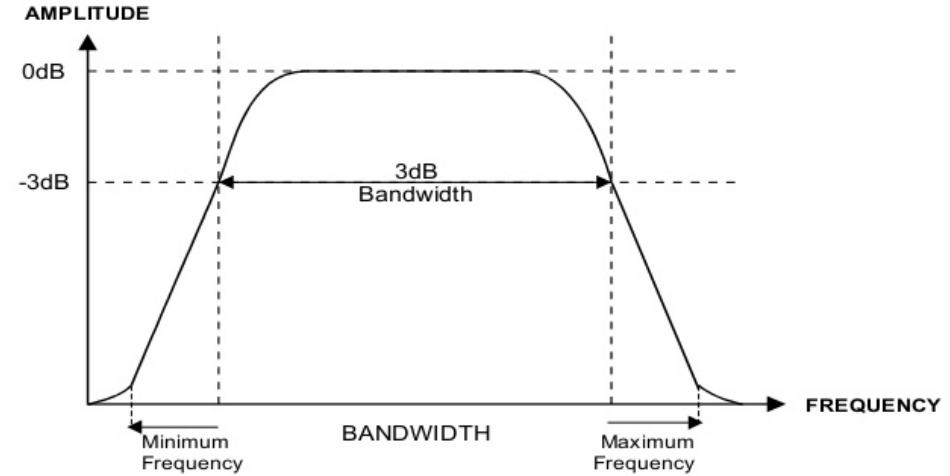
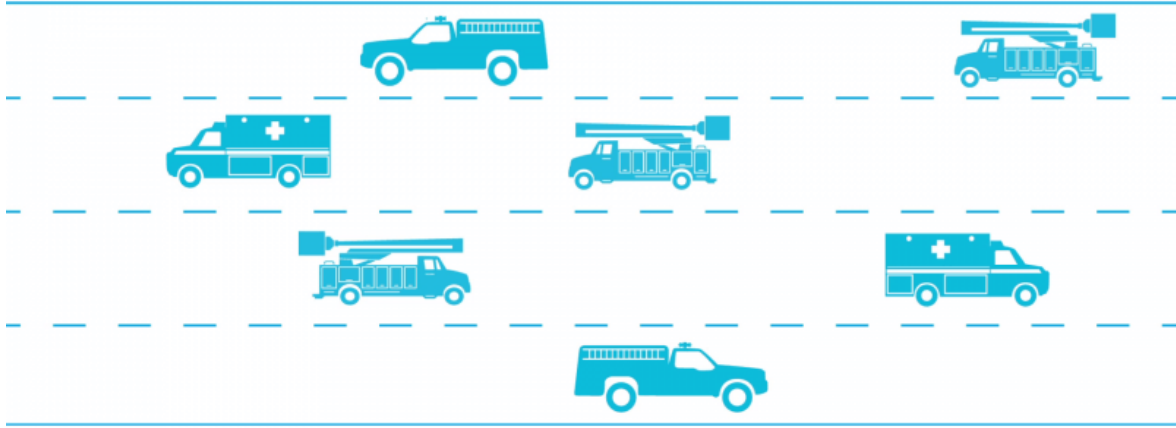


Figure 2-6 Frequency-Shift Keying Makes Use of Changes in Frequency to Represent Digital Data

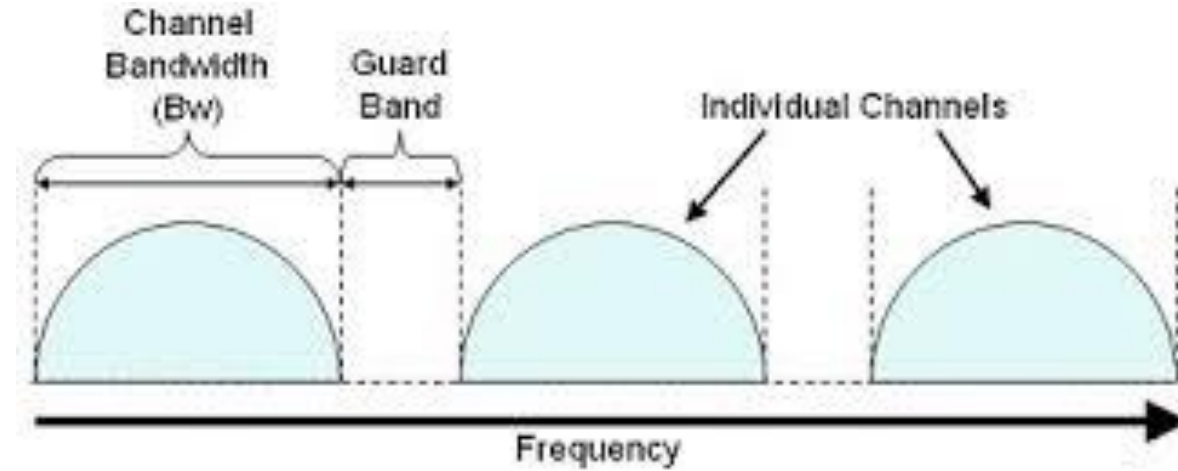
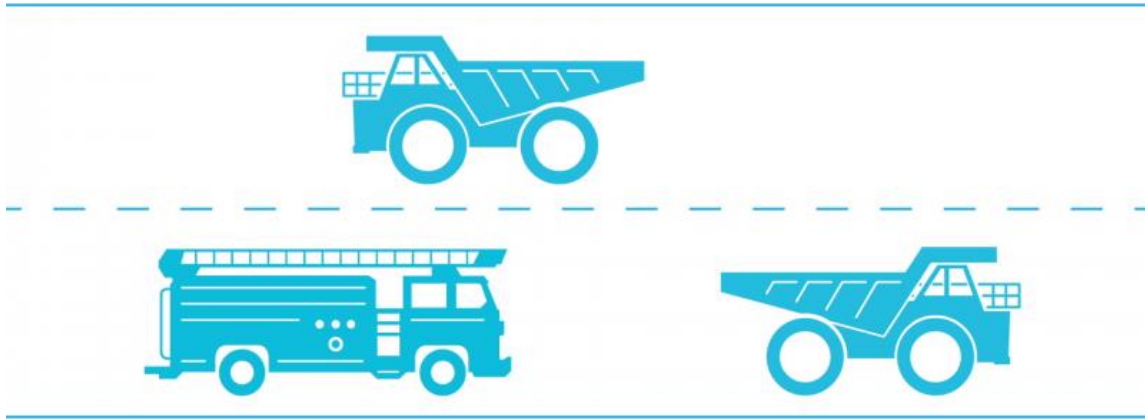


RF Bands and Channel

Narrowband (12.5 kHz)

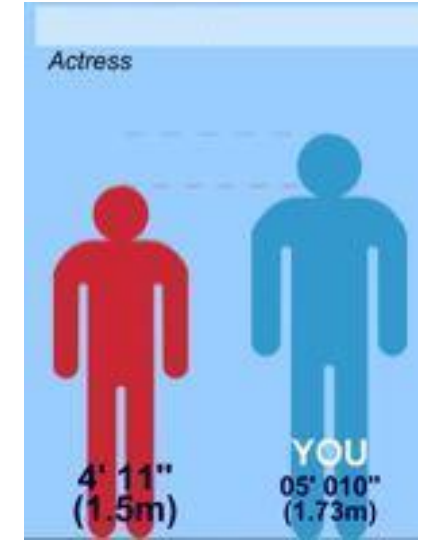


Wideband (25 kHz)



RF Measurements

- Key ideas for wireless are coverage and performance
- To measure power, we can measure absolute or relative power
 - Absolute is compared to a known scale
 - Relative is to another signal
 - Need to Measure the change in power
- Most 802.11 equipment is measured in mill watts
 - Usually 1 to 100 mw



$$100 + 20 - 10 = 90$$



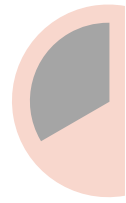
RF Power Units



No units
Power
Related
to
another

$$dB = 10 \log \frac{P_2}{P_1}$$

Received Signal
At Client



Power
Related
to 1 m
watt

$$P(\text{dBm}) = 10 \log \frac{P(\text{mW})}{1 \text{ mW}}$$

Access Point
Output Power



Antenna
Gain
Related to
isotropic
Antenna

Antenna Gain



RF Math Rules

3 dB

Double or
Half actual
power

10
dB

Multiply
absolute
power by 10

6dB

Double
travel
distance

- 3 dB gain = $\text{mW} \times 2$
- 3 dB loss = $\text{mW} \div 2$
- 10 dB gain = $\text{mW} \times 10$
- 10 dB loss = $\text{mW} \div 10$

- 1mW = 0dBm
- 100mW=20dBm
- 200mW=23dBm
- 1000mW=30dBm

Recieved Power

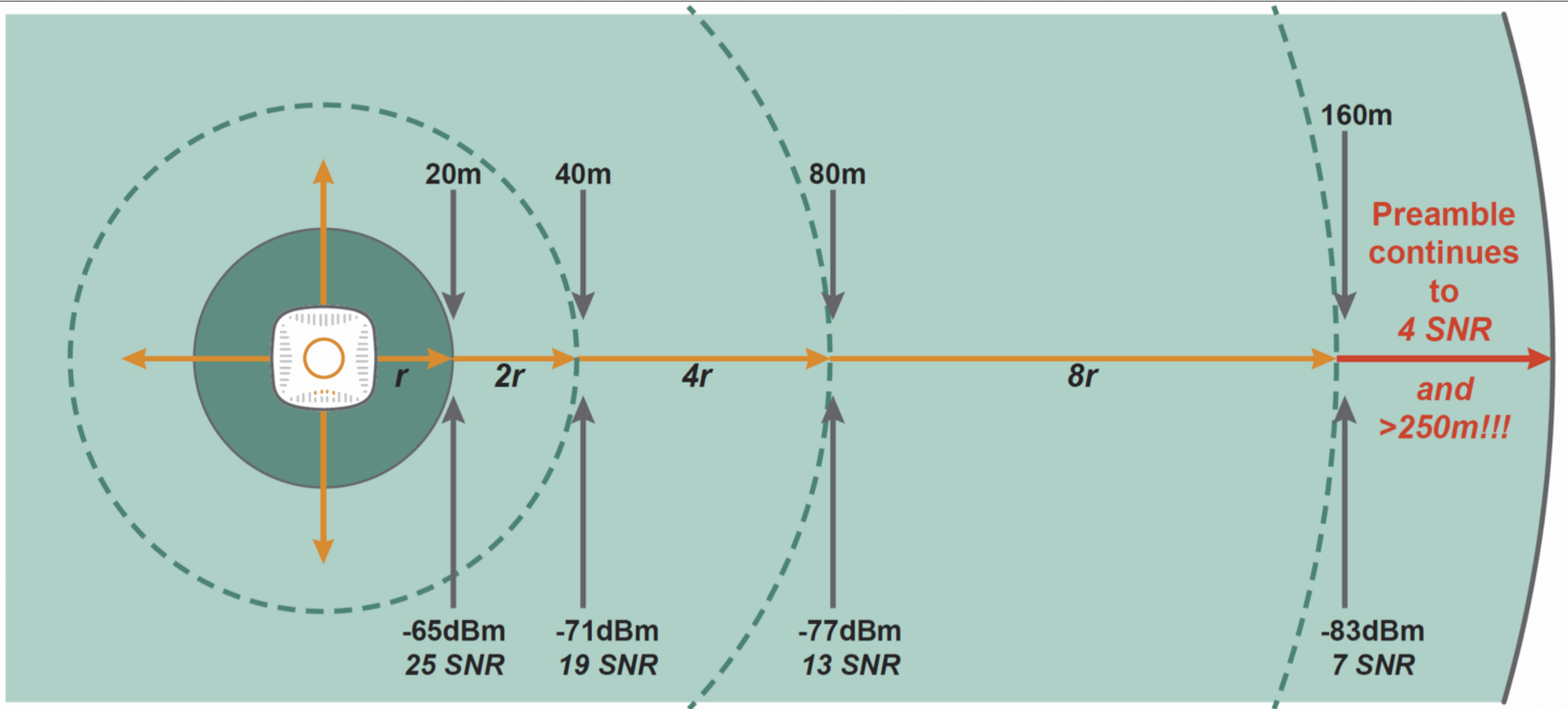
Transmitted Power

$$P_{rx} = \frac{P_{tx}}{4\pi R^2}$$

Distance between Tx and Rx Antenna

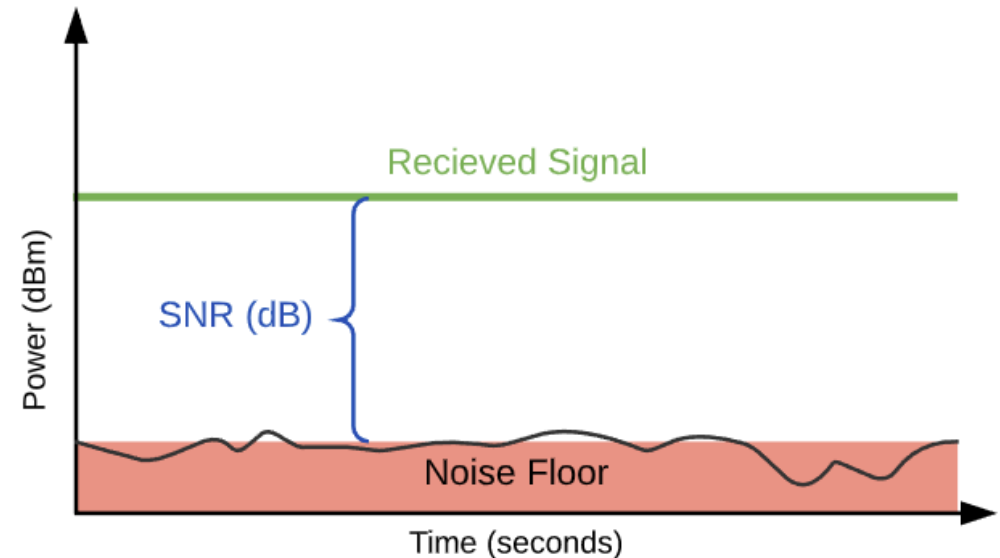
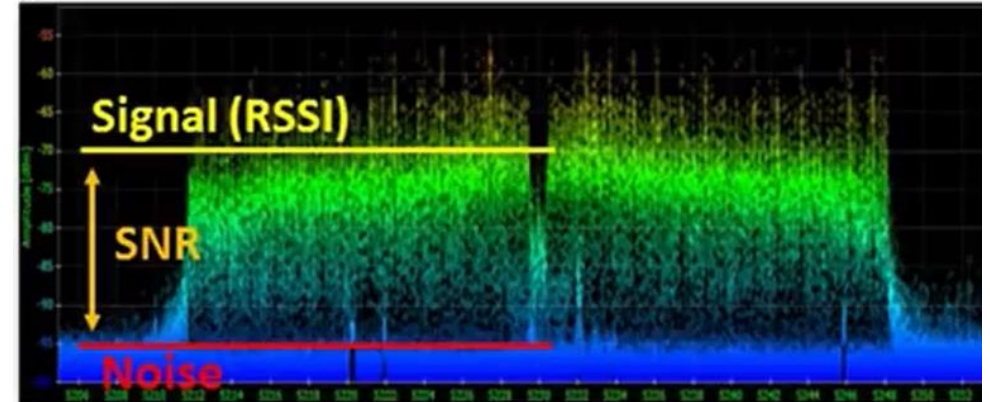


RF Propagation Distance vs Power



RF Signal Indicators

- **RSSI** : measured in milliwatt decibels **dBm**
 - The strength that the device is hearing a AP signal.
 - Accepted Value not less than **-75 dB**
- **Noise Floor** : measured in milliwatt decibels **dBm**
 - Noise is any signal (interference) that is not WiFi traffic
 - Noise Source as cordless phones, microwaves and Radar
 - Accepted value not more than **-85 dB**
- **SNR**: measured in decibels **dB**
 - Ratio between Signal received RSSI and Noise level
 - Measured as a positive value between **0db** and **120db**
 - Accepted value not less than **25 dB**



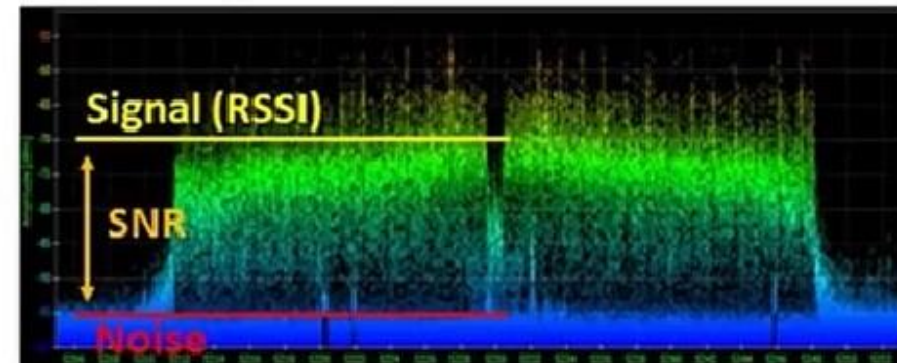
Wireless Training

Part 1-Session 2

RF BASICS

RF Measurements dB

$$dB = 10 \log \frac{P_2}{P_1} \quad P(\text{dBm}) = 10 \log \frac{P(\text{mW})}{1 \text{ mW}}$$



Part 1 : RF Basics

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Channel Width

- **Channel :**
 - Smaller area within frequency bands that are used by Radios network to send and receive data
- **Bandwidth (Width)**
 - Area of Frequency spectrum allocated to certain channel
 - As Channel BW increase more data could be transferred

Wireless: Enable Disable

Wireless Network Name: (Also called SSID)

Mode:

Channel:

Channel Width:

1
2
3
4
5
6
7
8
9

Broadcast

ve

Wireless LAN >> Advanced Setting

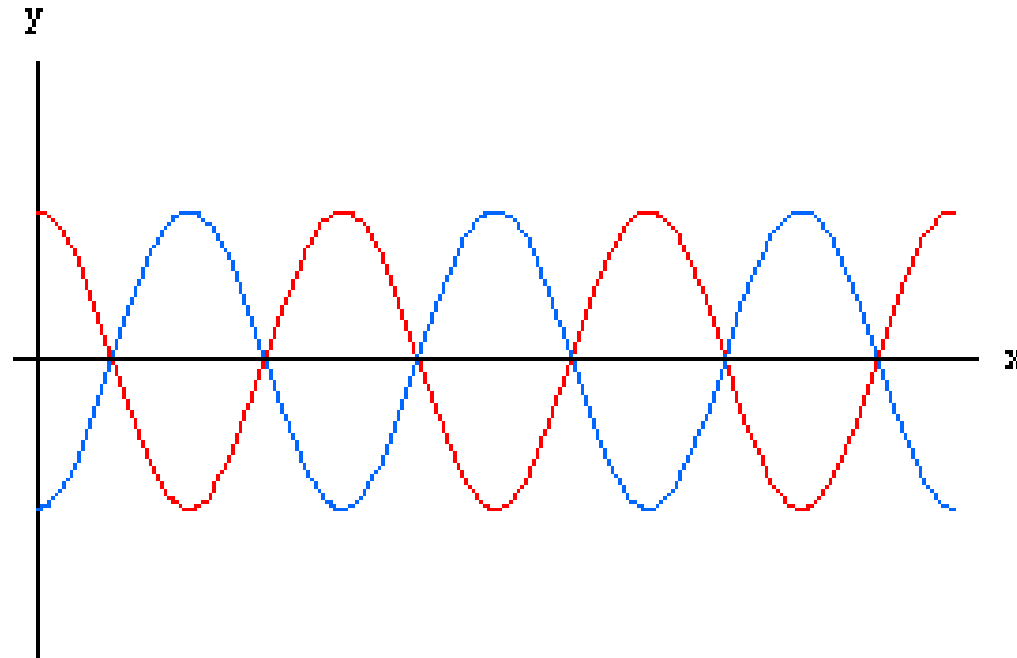
HT Physical Mode

Operation Mode	<input checked="" type="radio"/> Mixed Mode <input type="radio"/> Green Field
Channel Bandwidth	<input checked="" type="radio"/> 20 <input type="radio"/> 20/40
Guard Interval	<input type="radio"/> long <input checked="" type="radio"/> auto
Aggregation MSDU(A-MSDU)	<input type="radio"/> Disable <input checked="" type="radio"/> Enable



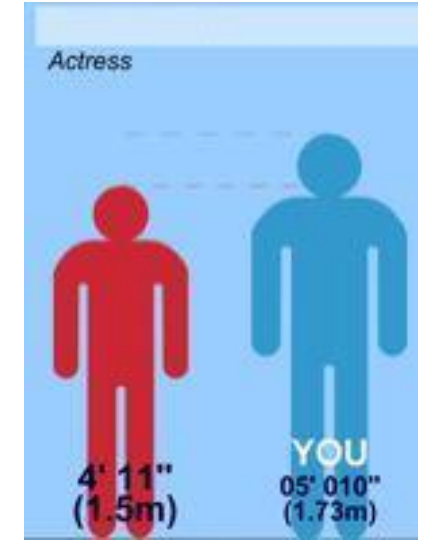
RF Waves Phases

- The offset of a wave from a given point.
- When two waves cross paths, they either cancel each other out or compliment each other
- In Phase wave When multiple signals have same peaks and valleys
- Out of Phase when multiple signals have different peaks and valleys



RF Measurements

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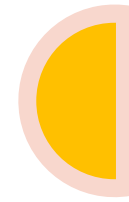
SNR
Signal to Noise Ratio



Power
Related
to 1 m
watt

$$P(\text{dBm}) = 10 \log \frac{P(\text{mW})}{1 \text{ mW}}$$

AP O/P Power
RSSI at Client



Antenna
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Antenna

Antenna Gain



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Received Power

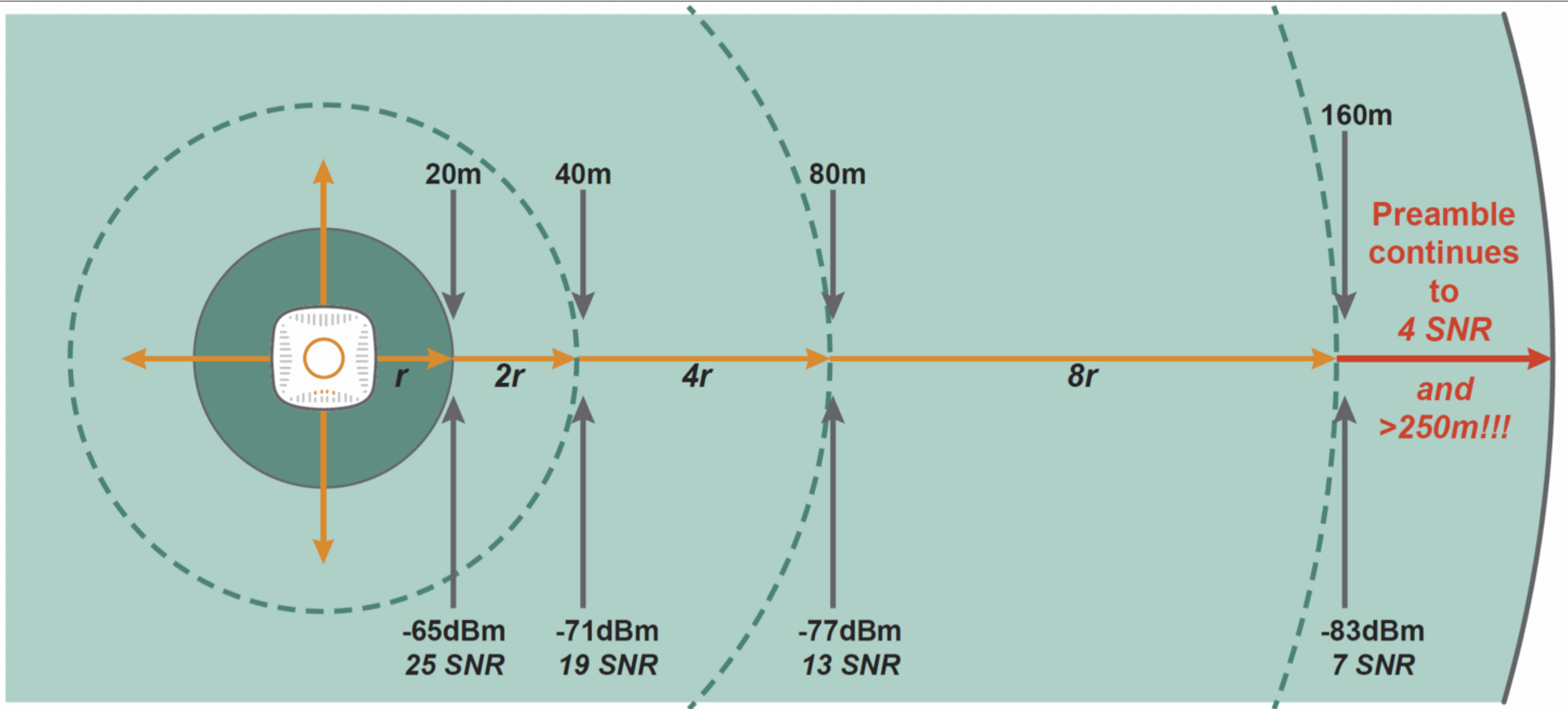
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Distance between Tx and Rx Antenna



RF Propagation Distance vs Power



dBm and mW Relationships

+3 dBm = 2X power

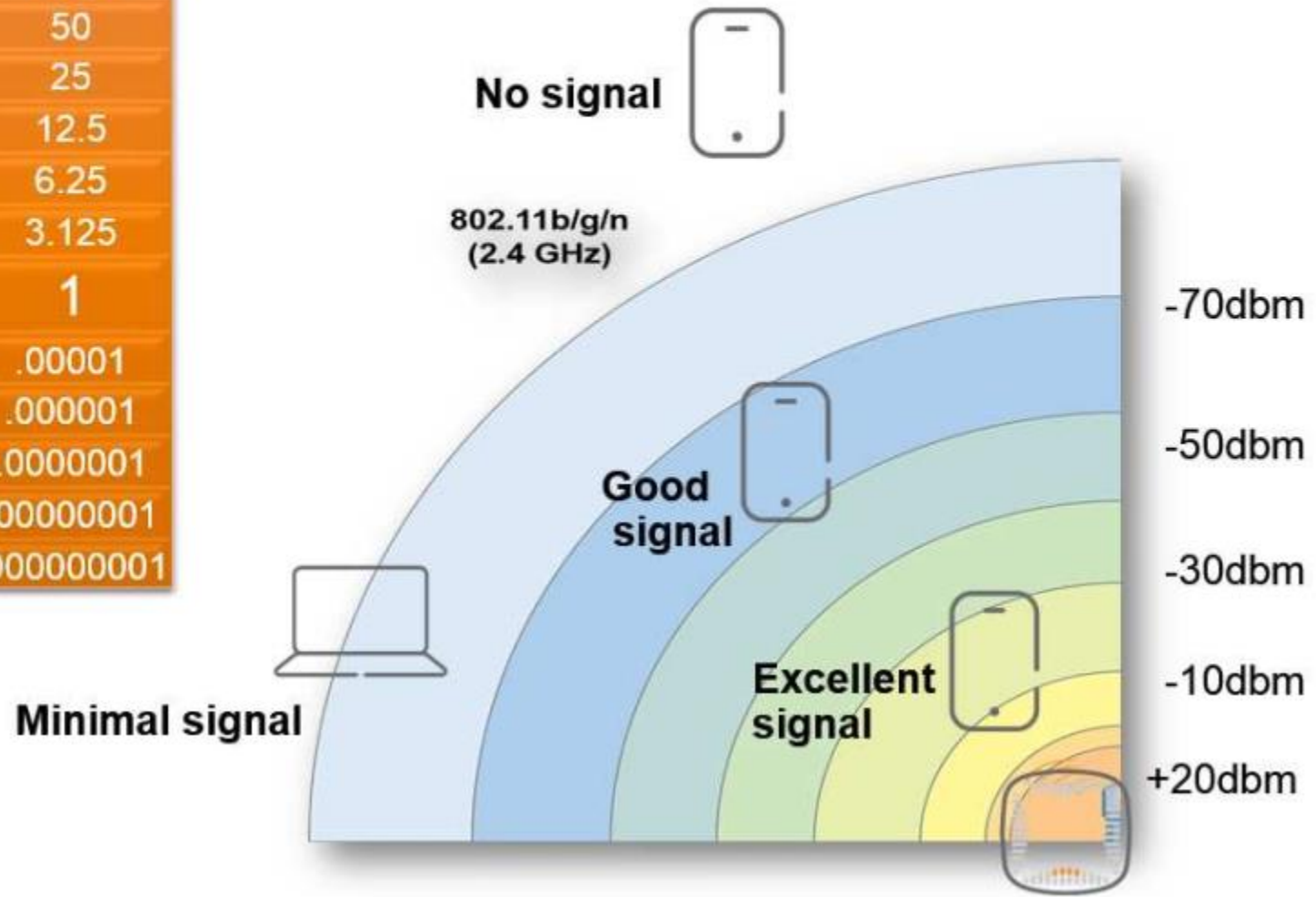
-3 dBm = 1/2 power

0 dBm = 1mW

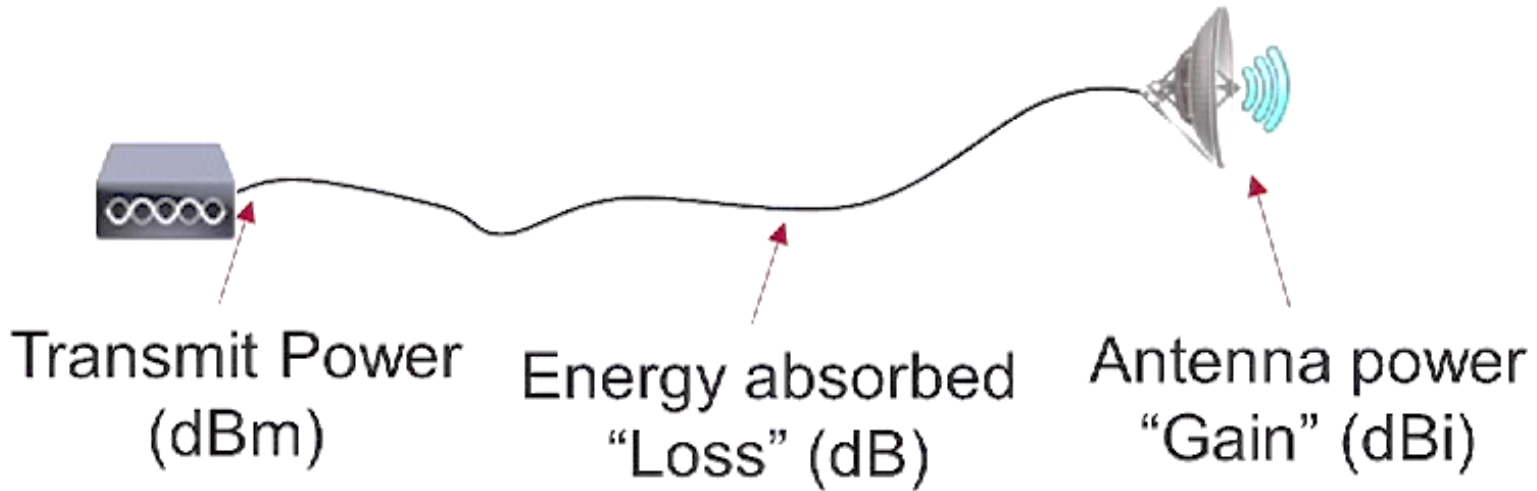
+10 dBm = 10X power

-10 dBm = 1/10th power

dBm	mW
+20	100
+17	50
+14	25
+11	12.5
+8	6.25
+5	3.125
0	1
-50	.00001
-60	.000001
-70	.0000001
-80	.00000001
-90	.000000001



EIRP – Output Power



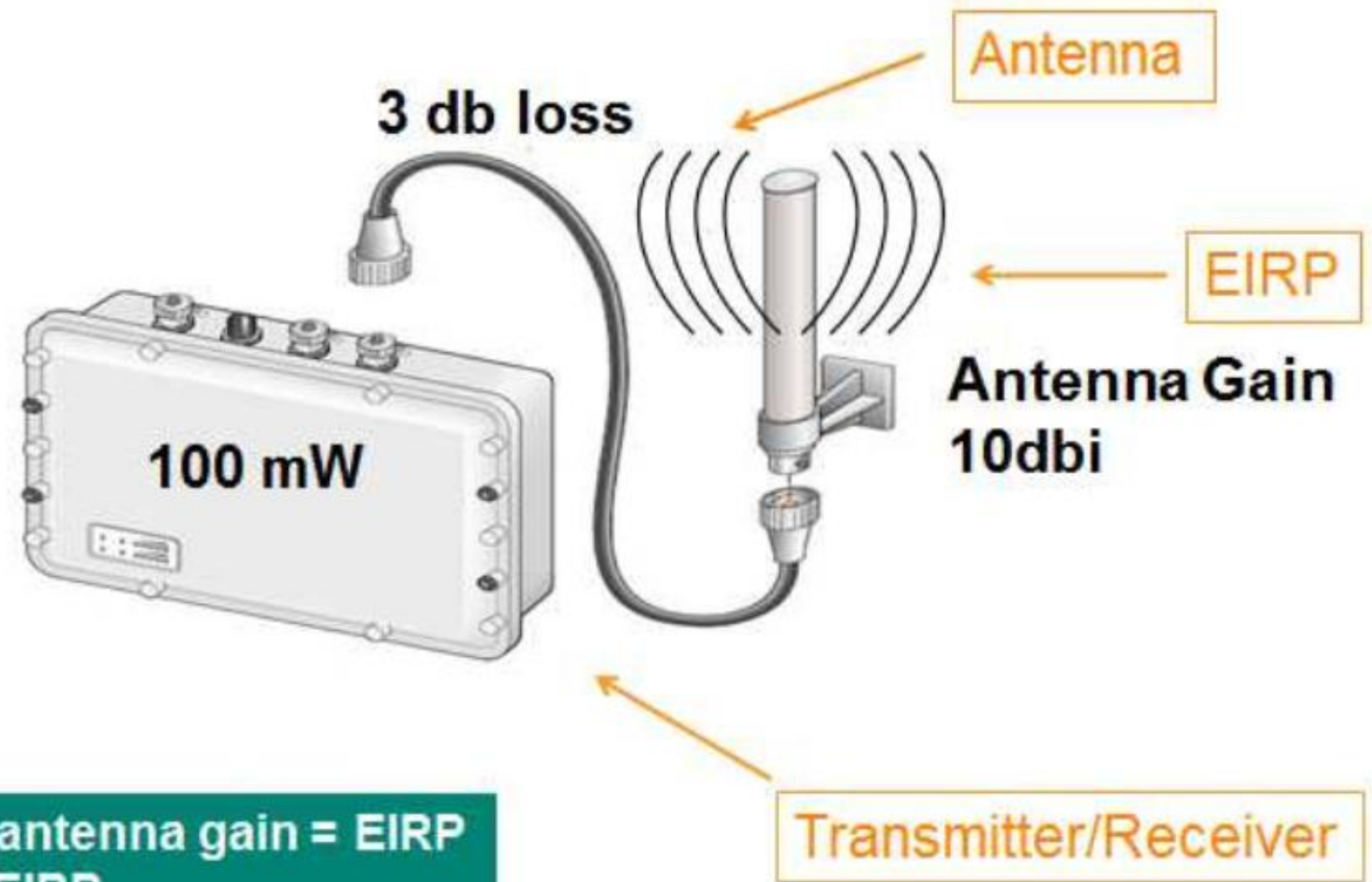
$$20 + 6 - 3 = 17$$

$EIRP \text{ (dBm)} = Tx \text{ Power (dBm)} - \text{cable loss (dB)} + \text{Antenna Gain (dBi)}$

Example: Tx Power = 20 dBm, loss = 3 dB, antenna gain = 6 dBi



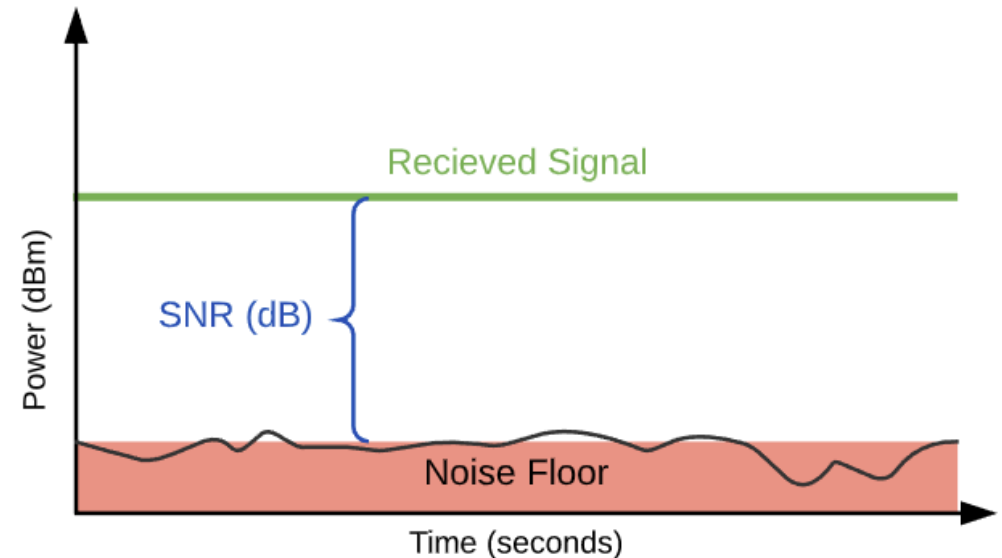
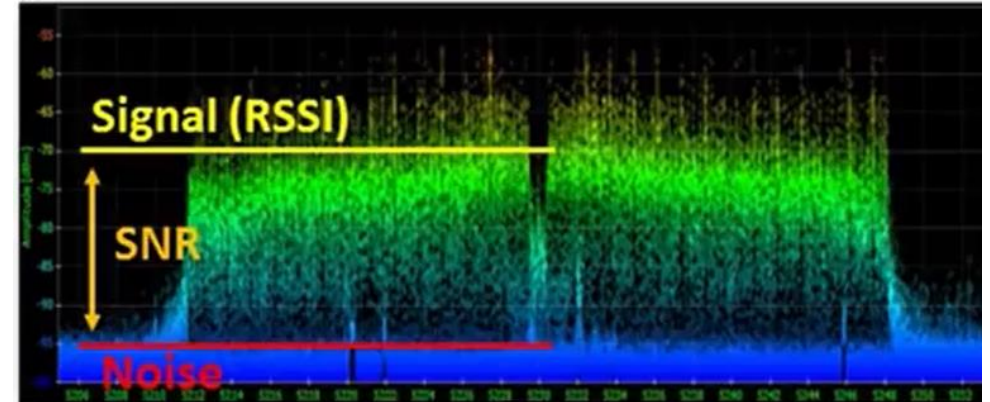
Calculating EIRP



TX Power – cable loss + antenna gain = EIRP
100mW – 3db + 10 dbi = EIRP
20dbm – 3db + 10 dbi = 27dbm

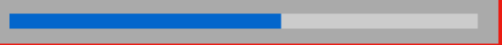
RF Signal Indicators

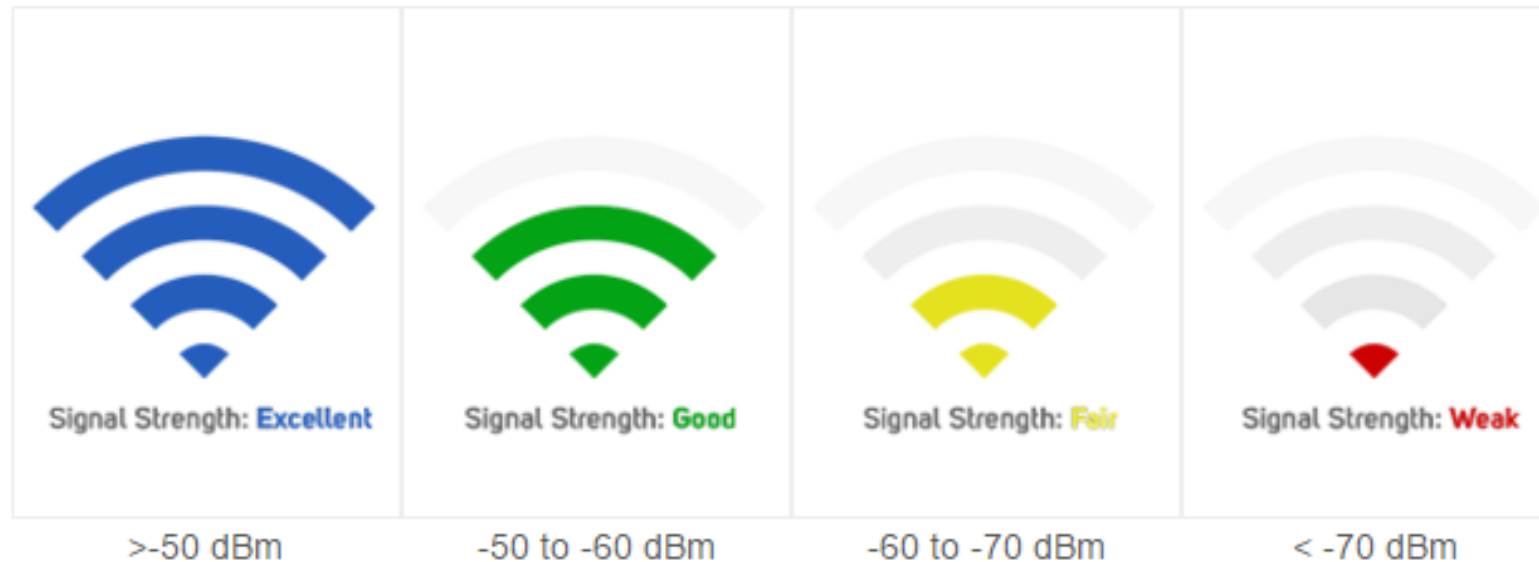
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 - Measured as a positive value between **0db** and **120db**
 - Accepted value not less than **25 dB**



RF Signal Indicators

Your client connection

Client IP	10.92.132.66
Client MAC	3c:15:c2:d6:b0:fa
AP radio	2
Channel	44 (20 MHz wide)
Mode	802.11ac
Max bitrate	173 Mbps
Signal	29 dB 



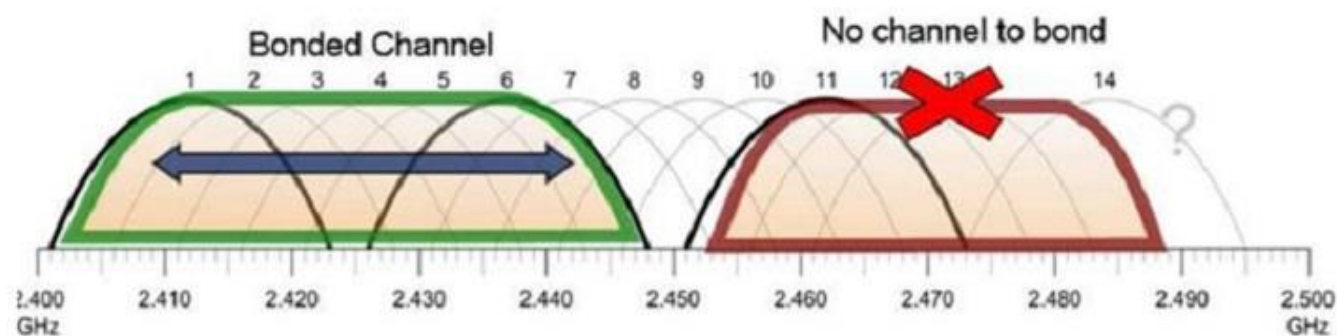
Wireless Training

Part 1-Session 3

RF BASICS

WiFi Bands

Channel Bonding



Part 1 : RF Basics

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Signal Strength

Rule of 3's and 10's

- +3 dB: Double the signal strength
- -3 dB: Half the signal strength
- +10 dB: 10x more signal strength
- -10 dB: 10x less signal strength

Why dBm?

dBm	mW
-60 dBm	.000001 mW
-70 dBm	.0000001 mW
-80 dBm	.00000001 mW
-90 dBm	.000000001 mW

What is "Good" Signal Strength?

-30 dBm	Extremely good- you're likely standing underneath the AP
-65 dBm	Voice applications, mobile devices
-67 dBm	Streaming video
-75 dBm	Web browsing, email, instant messaging
-80 dBm	Generally unreliable
-90 dBm	Approaching or drowning in the noise floor



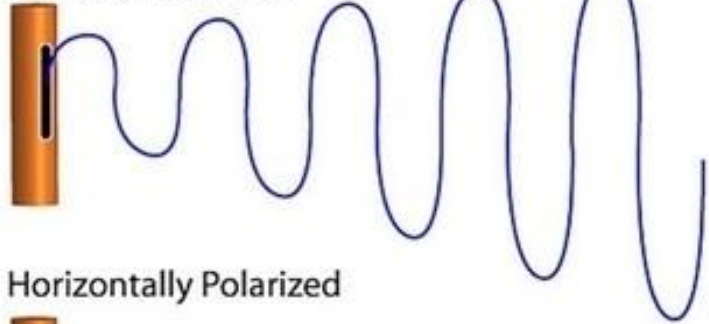
RF Waves Polarization

- **Polarization**

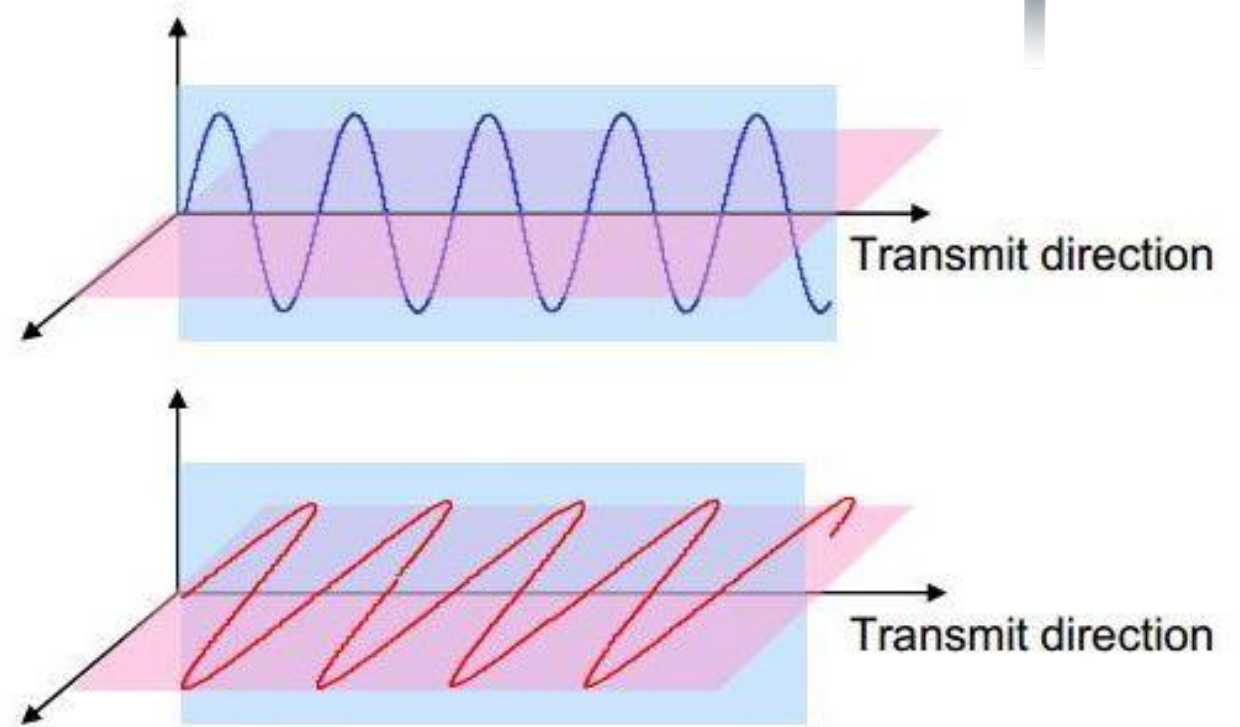
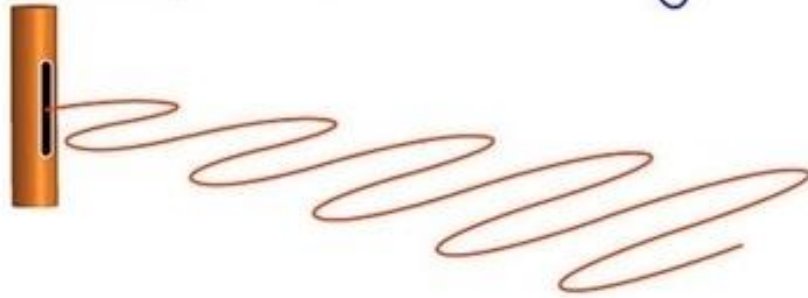
- How an antenna is mounted (Horizontally or Vertically)
- Vertical antennas can hear other vertical antennas
- Dual Polarized Antenna can hear at both directions



Vertically Polarized



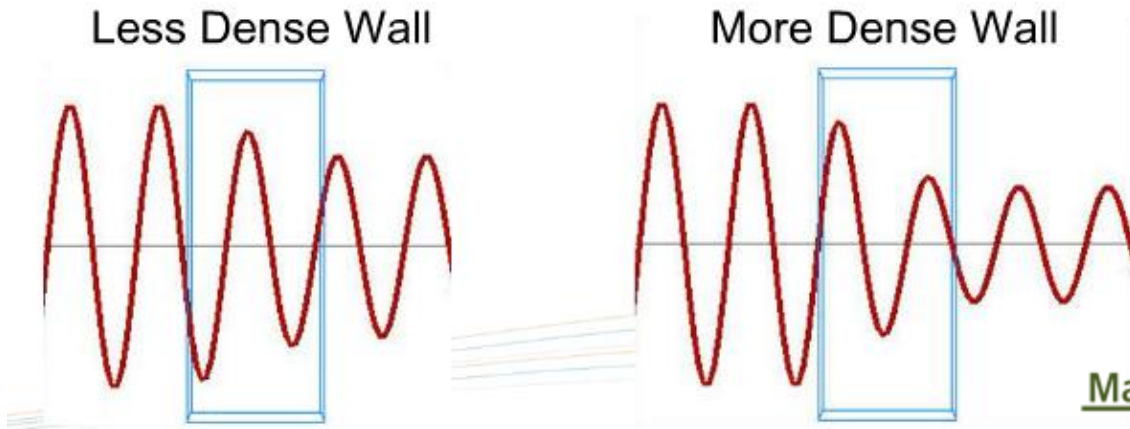
Horizontally Polarized



RF Wave Propagation

- **Absorption**

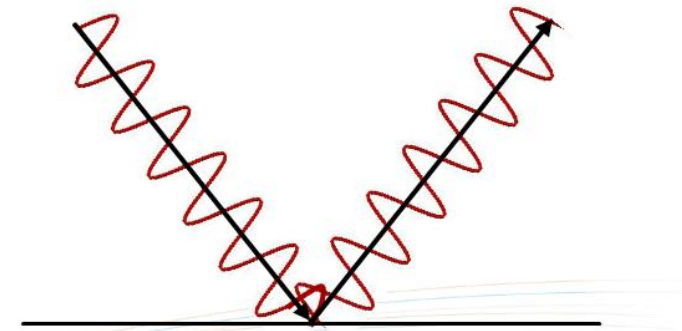
- Signal path through thick walls as bricks and walls



Very Important for Wireless Survey to know how different Obstacles affect Signals

- **Reflection**

- Signal hit metal surface and reflect it's way



Material	Attenuation (dB)	
	2.4 GHz	5.8 GHz
Interior drywall	3-4	3-5
Cubicle wall	2-5	4-9
Wood door (hollow – solid)	3-4	6-7
Brick/concrete wall	6-18	10-30
Glass/window (not tinted)	2-3	6-8
Double-pane coated glass	13	20
Bullet-proof glass	10	20
Steel/fire exit door	13-19	25-32

Wireless Organization

IEEE

(Institute of Electrical and Electronics Engineers)

- Creates standards
 - 802.15.1
 - 802.15.4
 - IEEE 1394
 - 802.3
 - 802.11

Country Regularities

limiting which frequencies WLAN can use and the output power on each of those frequency bands.

IETF : International Standards

FCC : Local Regularity for US

ETSI : Regularity for Europe

NTT : Regularity for Japan

Wi-Fi Alliance

- Composed of major players in the wireless space
 - Apple
 - Comcast
 - Sony
 - Intel
 - Qualcomm
 - T-Mobile
- Provides branding for Wi-Fi
 - "Wi-Fi"
 - WPA/WPA2/WPA3
 - WMM
 - Wi-Fi 6
- Ensures interoperability between vendors



RF ISM Bands

ISM or Industrial, Scientific and Medical bands. These bands have been internationally agreed and unlike most other bands, they can be used without the need for a transmitting license.

2.4 GHz BAND



- Lower Frequency
- Longer Wavelength
- Typically More Range
- More Crowded
- More non-Wi-Fi Interference
- 802.11b/g/n/ax

5 GHz BAND

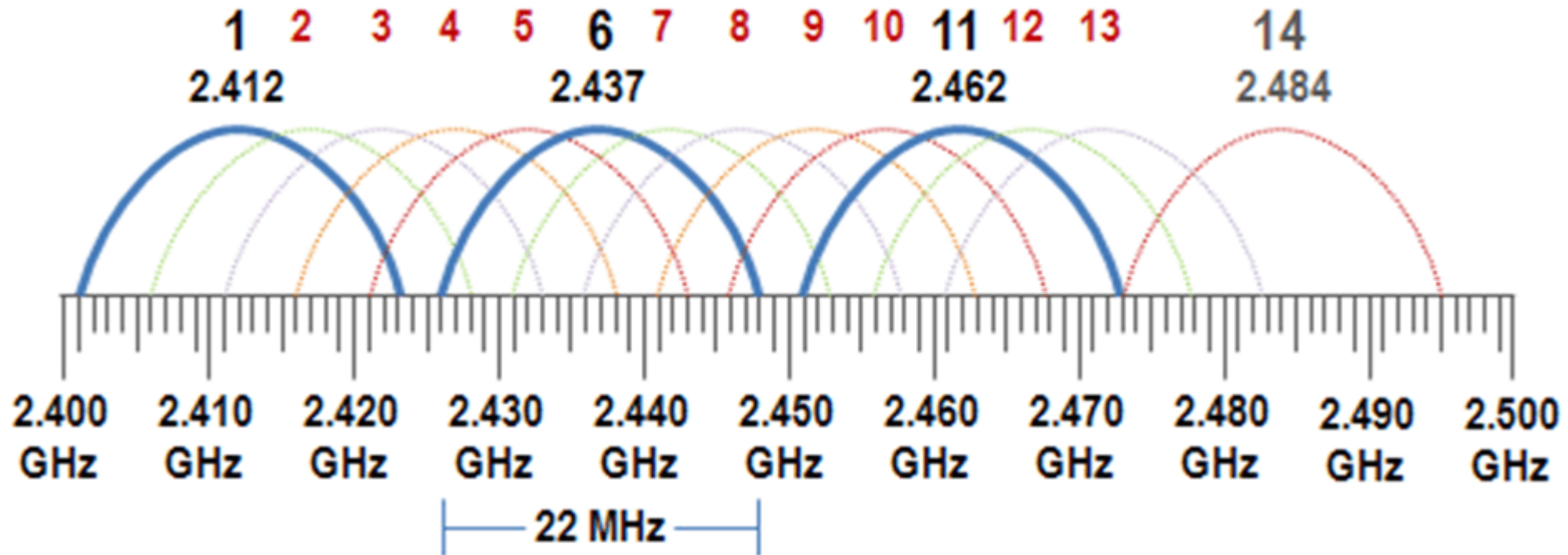


- Higher Frequency
- Shorter Wavelength
- Typically Less Range
- Less Crowded
- Less non-Wi-Fi Interference
- 802.11a/n/ac/ax



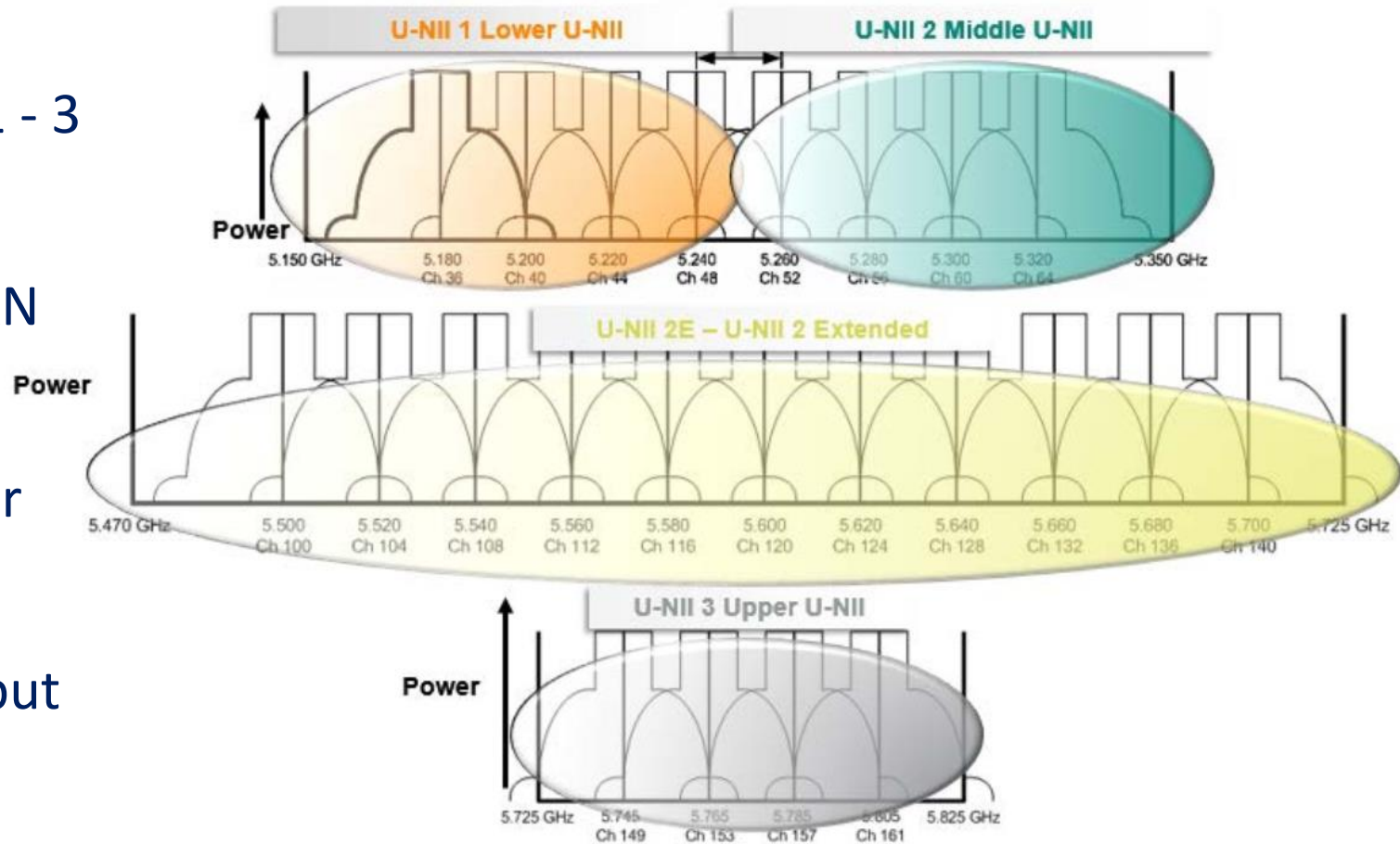
2.4 GHz Band

- Include 11 channels at North American domain, and 13 are allowed in Europe
- Channel width 22 Mhz with Central Frequency every 12 Mhz
- Only provide 3 non overlapping channels
- Crowded with a lot of application as Bluetooth – Dect Phones - Microwave



5 Ghz Band

- Include 45 channels with 21 non overlapping
- Divided into 4 UNI Bands Unlicensed National Information Infrastructure (U-NII) bands, as defined by the FCC.
- First 3 Bands used for WLAN UNI 1 - 3
- UNI 2E was used for Military and Radar at First before apply to WLAN
- UNII-1 & 2 Band used for Indoor
UNII 2E used for Indoor and Outdoor
UNII 3 used For Outdoor
- Less Crowded – less Interference but lower travel distance

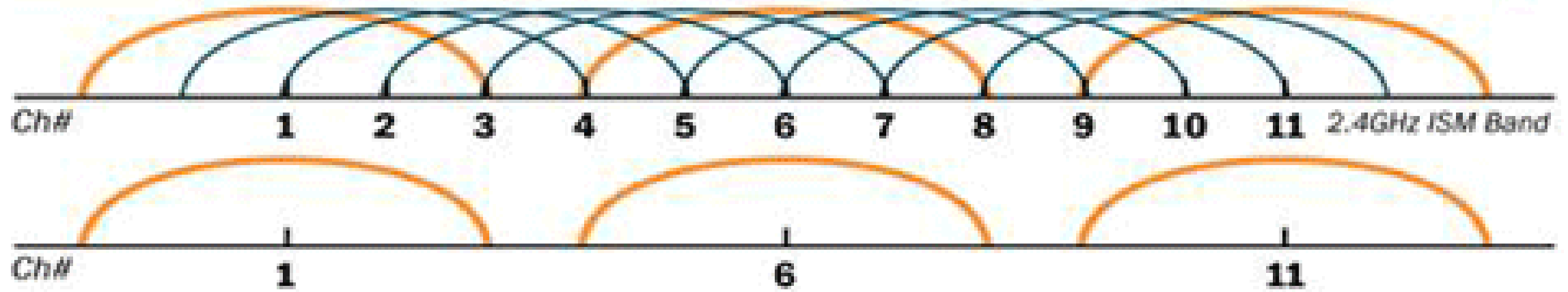


5 GHz Channel Allocations

Frequency (GHz)	5.150				5.250				5.470				5.600 TDWR				5.640				5.725					5.850			
802.11 Allocations	UNII-1				UNII-2a				UNII-2c (Extended)												UNII-3								
Center Frequency	5180	5200	5220	5240	5260	5280	5300	5320	5500	5520	5540	5560	5580	5600	5620	5640	5660	5680	5700	5720	5745	5765	5785	5805	5825				
20 MHz	36	40	44	48	52	56	60	64	100	104	108	112	116	120	124	128	132	136	140	144	149	153	157	161	165				
40 MHz	38		46		54		62		102		110		118		126		134		142		151		159						
80 MHz	42				58				106				122				138				155								
160 MHz	50								114																				
Rules FCC	1,000 mW Tx Power Indoor & Outdoor No DFS needed				250 mw w/6dBi Indoor & Outdoor DFS Required				250mw w/6dBi Indoor & Outdoor DFS Required 144 Now Allowed				120, 124, 128 Devices Now Allowed								1,000 mW EIRP Indoor & Outdoor No DFS needed 165 was ISM, now UNII-3								
DFS Channels																													
Rules ETSI EN 301 893 & EN 302 502	If 100 mW EIRP No DFS/TPC ----- 200 mW EIRP DFS/TPC Indoor				200 mW EIRP DFS/TPC Indoor				1,000 mW (1 Watt) EIRP DFS/TPC Indoor/Outdoor												No 144	4,000 mW (4 Watt) EIRP DFS/TPC Outdoor Fixed Wireless Access							
DFS Channels																													
Rules UK/OFCOM VNS-2030/8/3 Bands DFS Channels	200 mW Max EIRP Indoor Only								1000 mW (1 Watt) Max EIRP Indoor/Outdoor																200 mW Max EIRP Indoor/Outdoor No Fixed Outdoor Band C (5.8GHz)				
Band A								Band B																Band C					
DFS Channels																													

802.11b/g/n

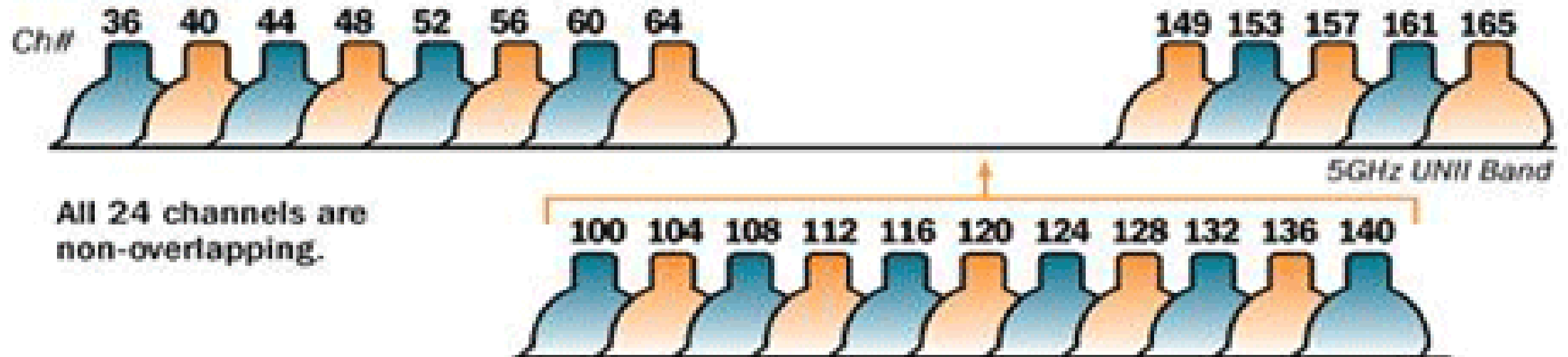
11 channels are available in the U.S. for 802.11b/g/n



Only 3 channels are non-overlapping.

802.11a/n

24 channels are available in the U.S. for 802.11a/n



All 24 channels are non-overlapping.

DFS & TPC

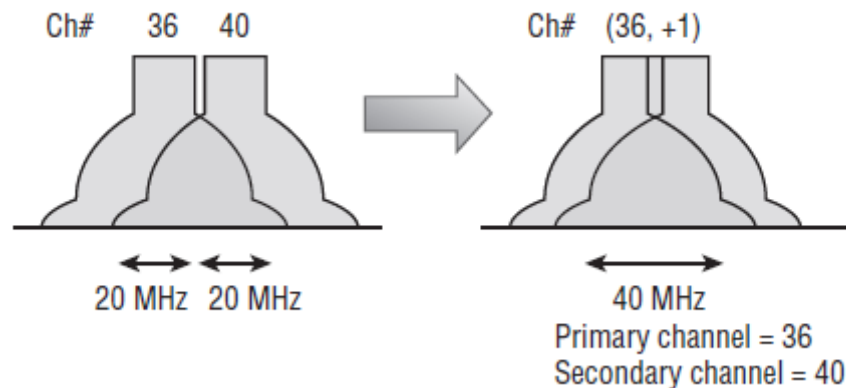
- **Dynamic Frequency Selection (DFS)**
 - UNII-2 and UNII-2E
 - The 5 GHz band had been in use for aviation and weather radars before it was opened for WiFi use
 - If an access point detects a radar signal, it must change its channel, which usually breaks connections to its clients.
 - Radio must detect and avoid radar and satellite systems
Many 5GHz channels are in DFS range
- **Transmit Power Control (TPC)**
 - Dynamically regulates power levels of devices so communication is “just enough”
 - Minimizes interference risk
 - Honor EIRP allowed at country



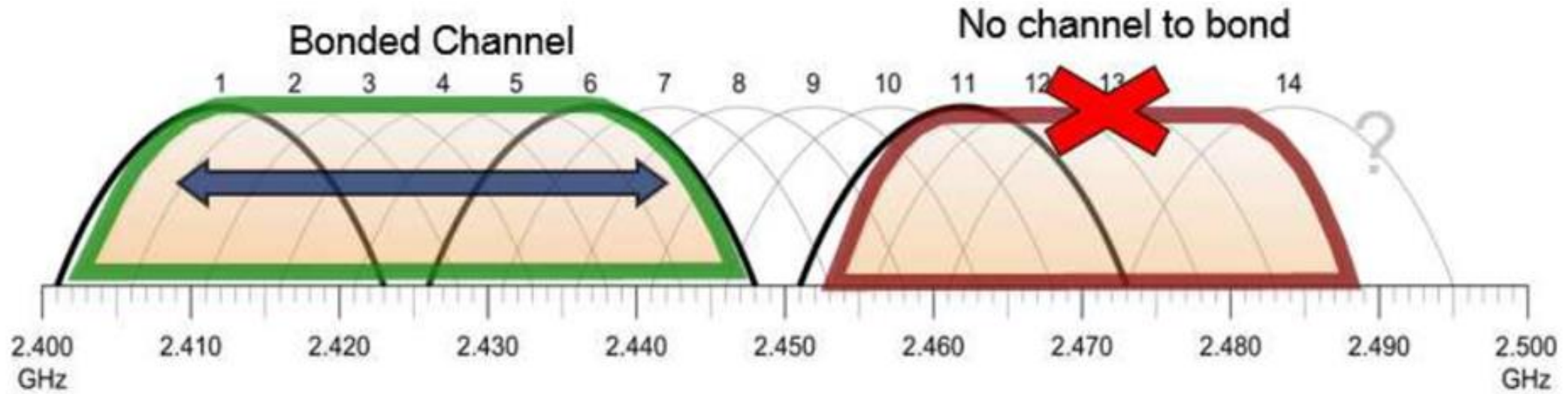
Sample Wi-Fi interference on a radar image

Channel Bonding

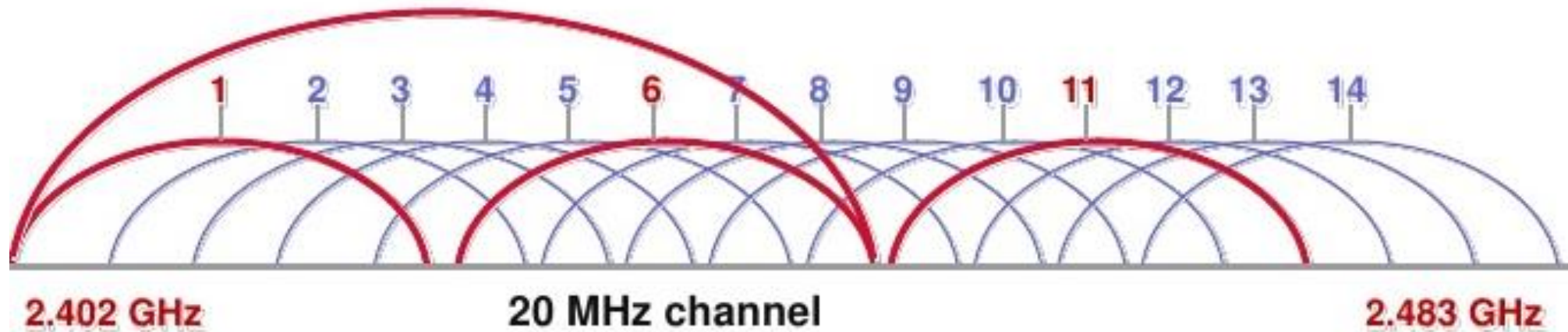
- Combine 2 x 20 MHz into one 40 MHz Channels
- Provide almost double throughput
- Could also combine 4 or 8 channels to get 80 and 160 MHz
- For 2.4 GHz can only use 40 MHz
- For 5 GHz can use 8 channel bonding to 160 MHz
- With more channel bonding – less available channels



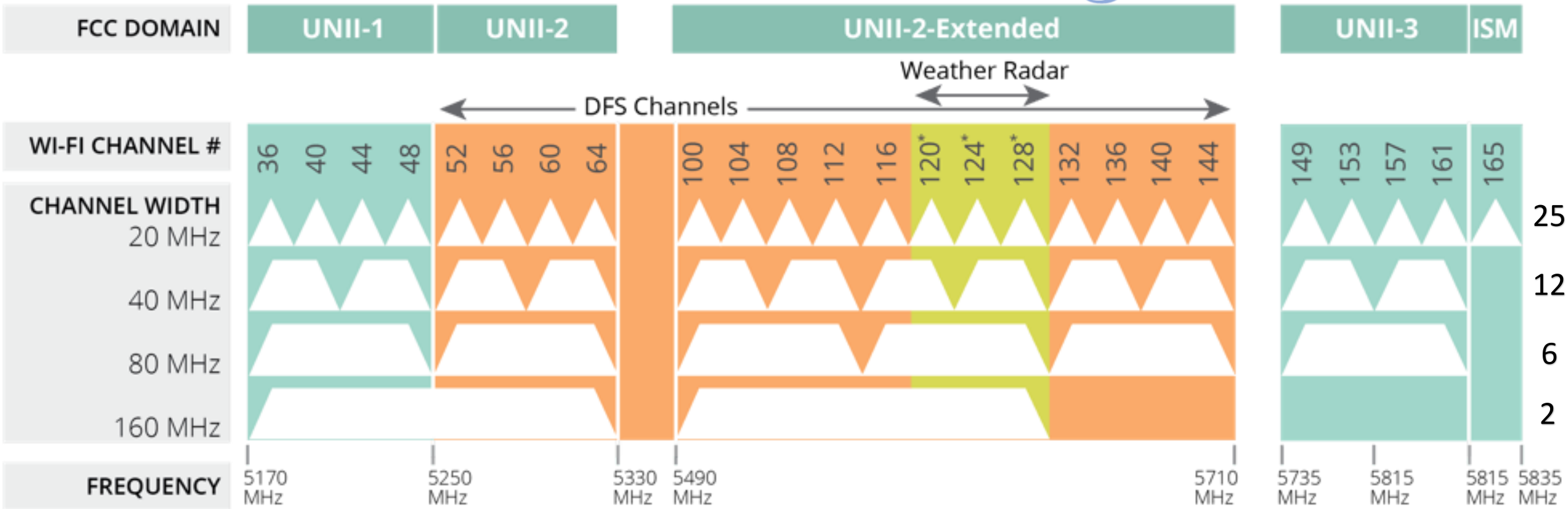
Channel Bonding



40MHz 802.11n channel



Channel Bonding



**Channels 120, 124 and 128 are Doppler Radar channels that may be used in some cases.*

Channels	20 Mhz	40 Mhz	80 Mhz	160 Mhz
DFS	25	12	6	2
No DFS	9	4	2	0



Part 1 : RF Basics

1. What is Radio Transmission
2. RF Bands and Spectrum
3. RF Waves Characteristics
4. RF Measurements Units
5. Signal Indicators RSSI-SNR
6. RF Waves Propagation
7. Channels and bands
8. Interference CCI – ACI



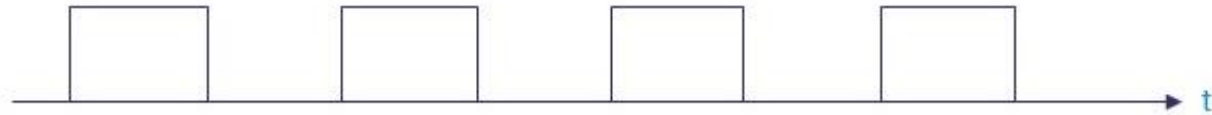
Interference

- Any device transmit signal in same frequency band of WLAN will be interference source and create noise
- Interference is both inevitable and unpredictable. It varies by **device** (microwave, cordless phone), **usage pattern** (time variance), and **location** (local emissions regulations, construction).
- Two elements of interfering devices to be aware of are “duty cycle” and “decibels” (dB).
- **Duty cycle** describes how often an interferer is active, over a given time period.
- **Decibels** provide a scale to measure the strength of the signal
- A lot of BLE with low power and low duty cycle compared to few Microwave Oven with 100 % duty cycle and high power

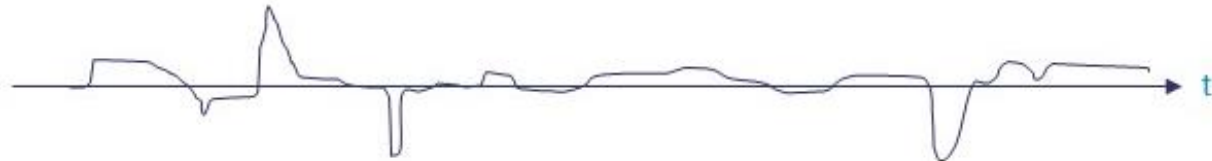
Noise



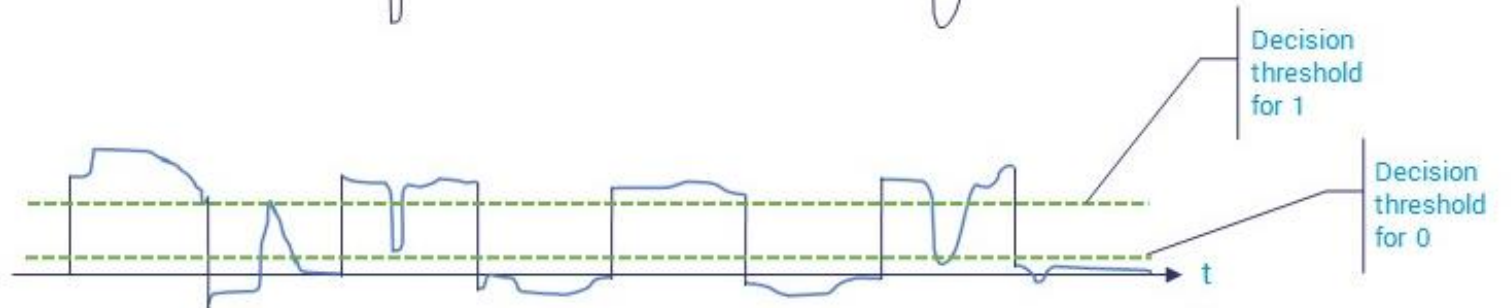
Input signal



Radio Channel (noise)



Output signal



Interference Types

Co-Channel



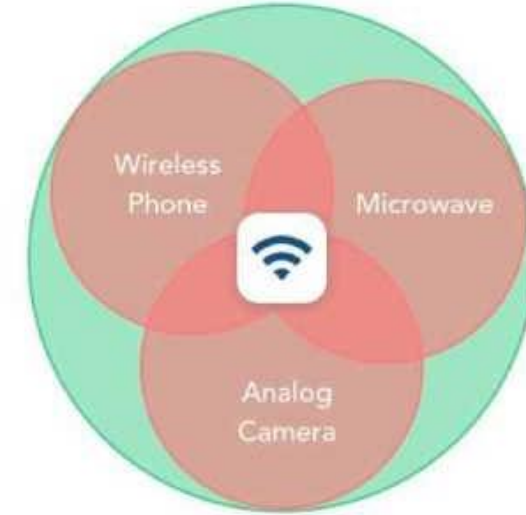
Every client and access point on the same channel competes for time to talk.

Adjacent-Channel



Every client and access point on overlapping channels talk over each other

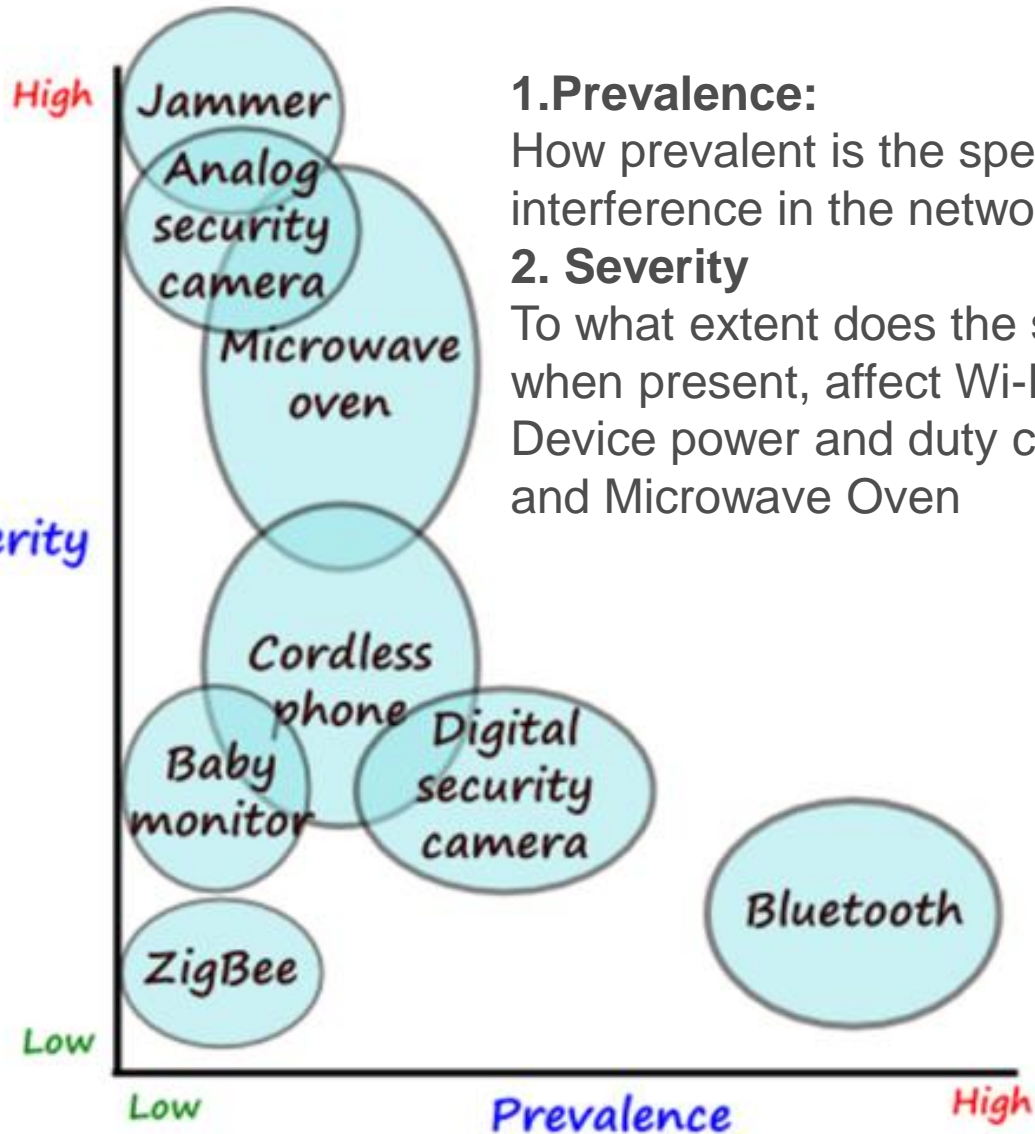
Non-Wi-Fi



Non-802.11 devices compete for medium access

All Wi-Fi connections can be negatively affected by electromagnetic interference, also called **radio-frequency interference**, which happens for three main reasons

Source of Interference

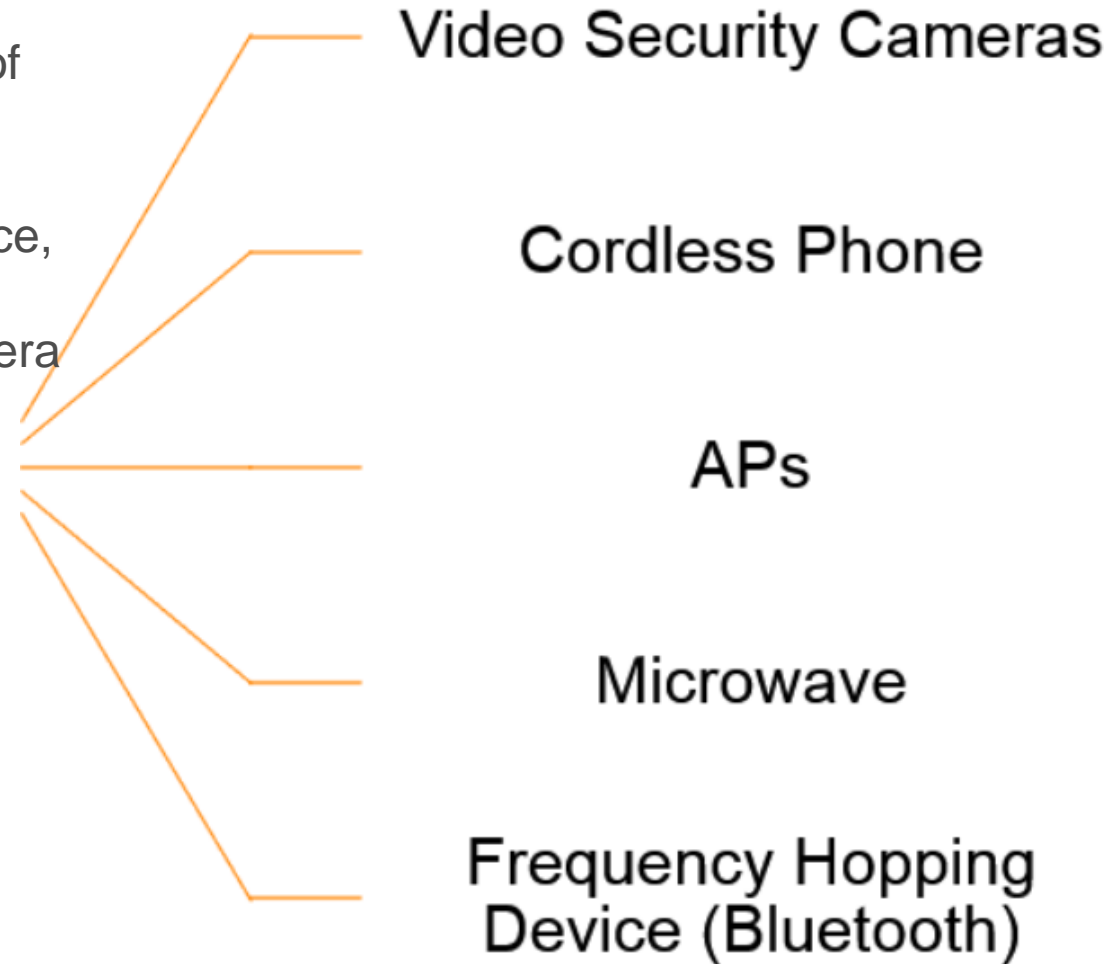


1. Prevalence:

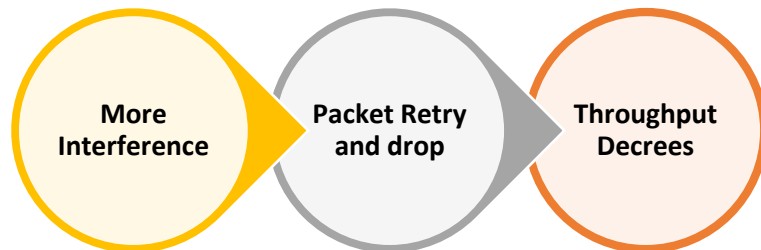
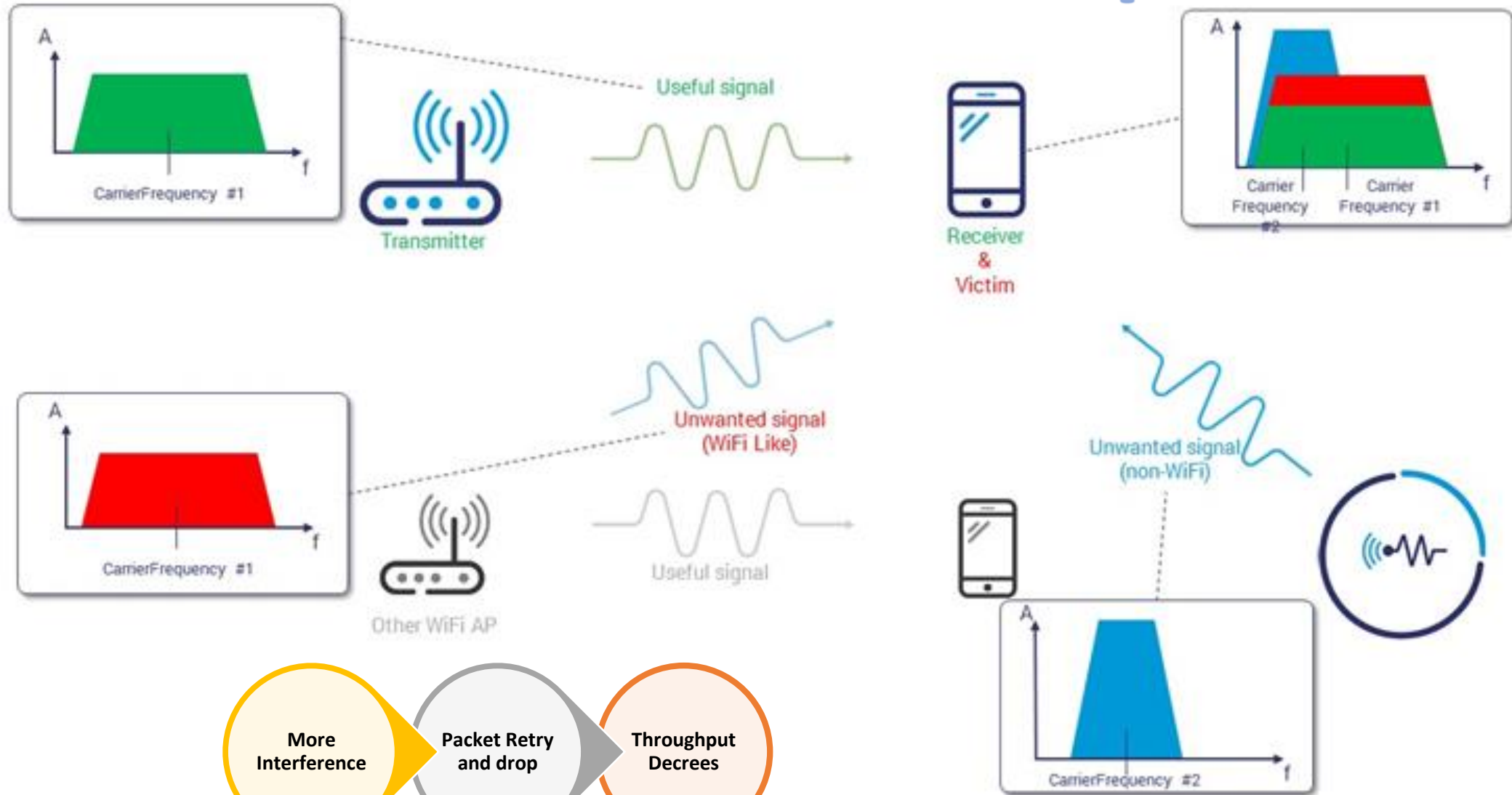
How prevalent is the specific source of interference in the network as BLE

2. Severity

To what extent does the specific source, when present, affect Wi-Fi based on Device power and duty cycle as Camera and Microwave Oven



Interference Example



Interference Effect



- A higher noise floor creates more retransmissions which means lower throughput

RF Interference can cause low throughput and poor performance.

Use a Spectrum Analyzer to find ambient RF environment

- Channels in use
- Noise
- WiFi and non WiFi Interference sources

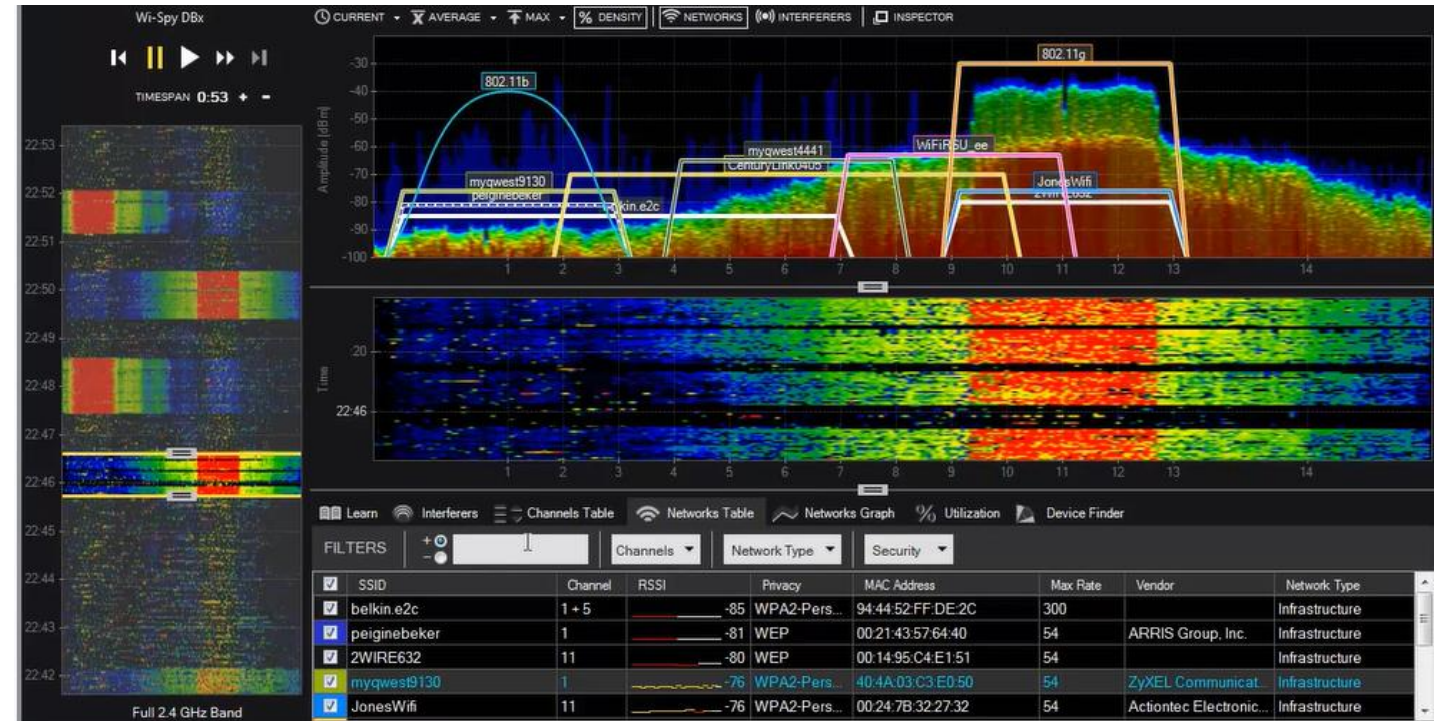
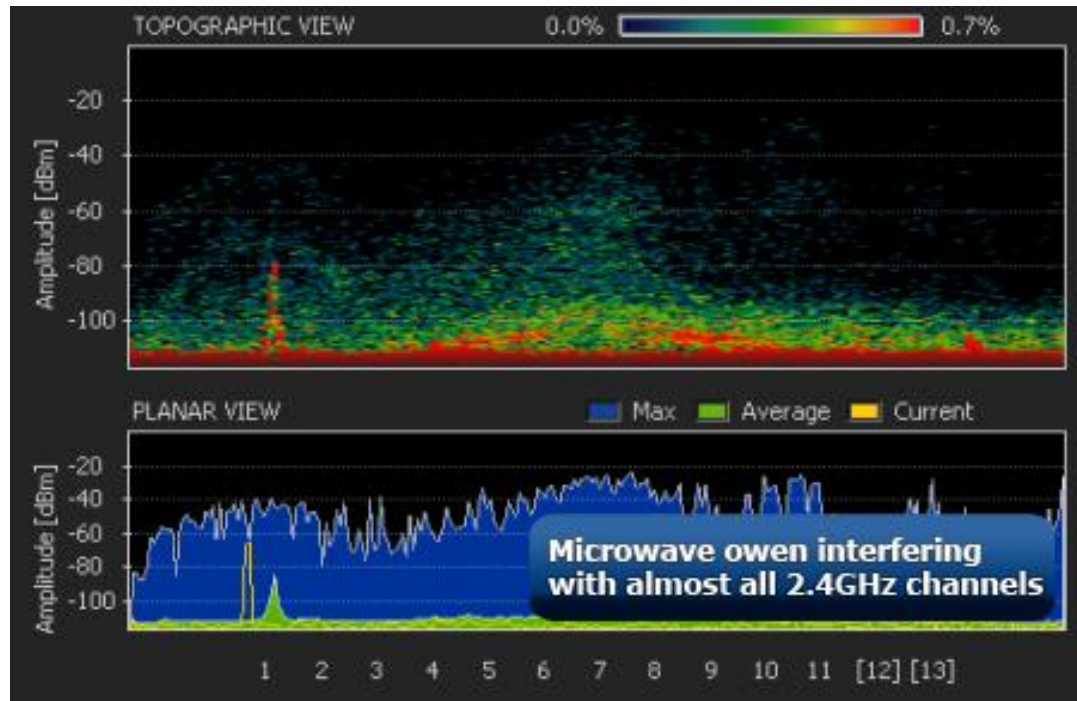
- Determines the best channel for the AP

Automated Channel Management



Channel Availability




- Spectrum analyzer display availability of channels through certain time
- Also can view impact of multiple inference sources including power and duty cycle



Channel Busy

- Due to high noise and Interference sources channel wont be available for connectivity
- A lot of users trying to access AP with shared medium
- Lead to high packet drops and retries
- users are facing slowness, and the ping to the gateway is going high.

Channel Busy (%) (4 of 38): Channel Busy \geq 90% & \leq 100% [Details](#)

AP Name ▲	Band	Channel	Channel Busy	Channel Utilization
ap	2.4 GHz	1	92%	
DEV-X41-INSIDE	2.4 GHz	11	91%	
HR-OFFICE1	2.4 GHz	11	91%	
HR-OFFICE2	2.4 GHz	11	91%	



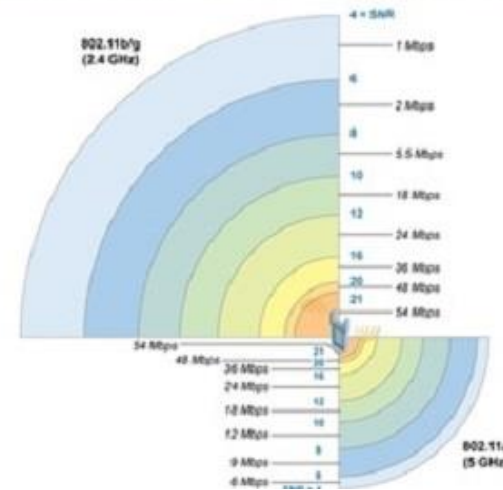
Wireless Training

Part 1 – Session 5

RF BASICS

Wireless Data Rates

Modulation & Coding





Part 1 : RF Basics

1. What is Radio Transmission
2. RF Bands and Spectrum
3. RF Waves Characteristics
4. RF Measurements Units
5. Signal Indicators RSSI-SNR
6. RF Waves Propagation
7. Channels and bands
8. Interference CCI – ACI
9. Wireless Data Rates

RF Wave & Data Transmission

- RF waves are the carriers used to *modulate* data.
- The amplitude or phase is changed to indicate binary bits.
 - ASK – Amplitude Shift Keying
 - PSK – Phase Shift Keying
 - FSK – Frequency Shift Keying

Analog Signal



Digital Signal



Modulation is the process used to manipulate RF waves so that they represent digital data bits.

RF Data Transmission

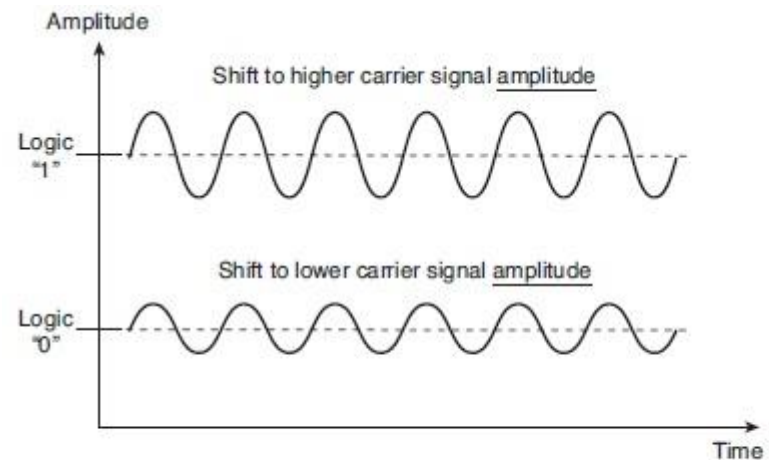
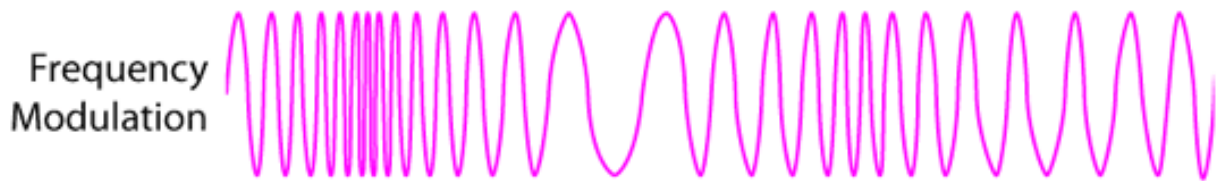
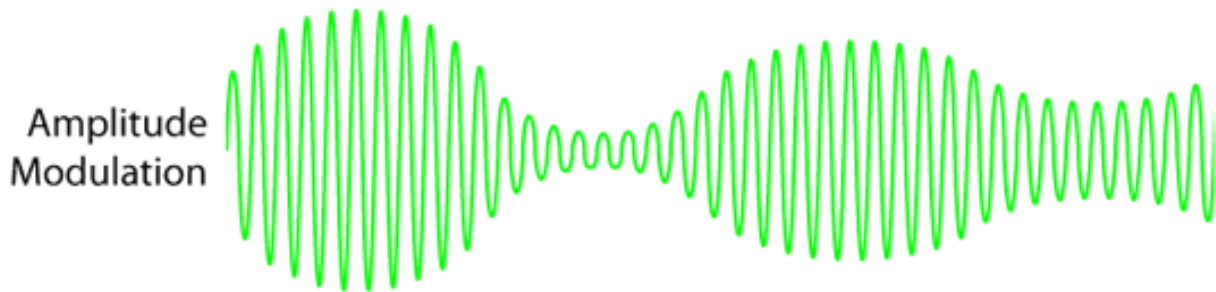
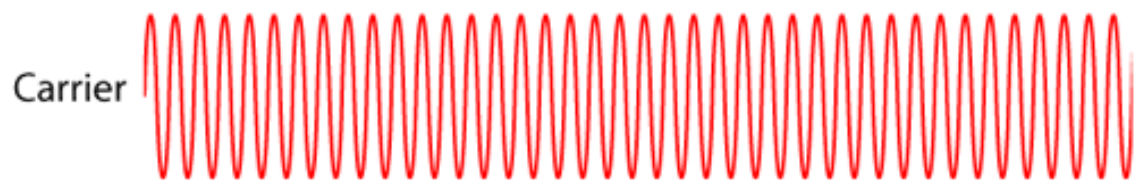
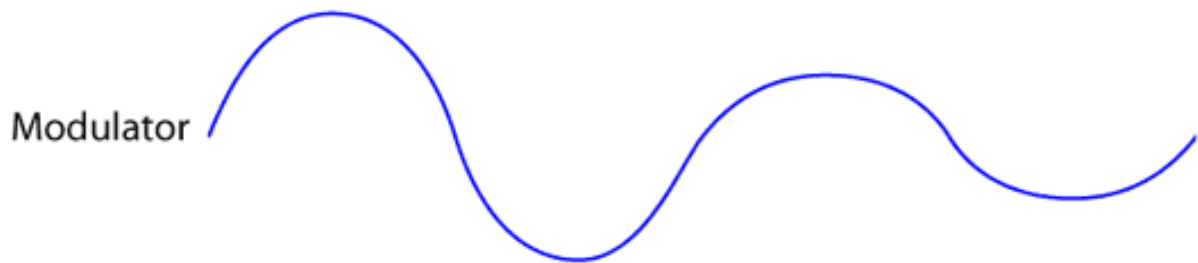


Figure 2-5 Amplitude-Shift Keying Varies the Amplitude of the Signal to Represent Digital Data

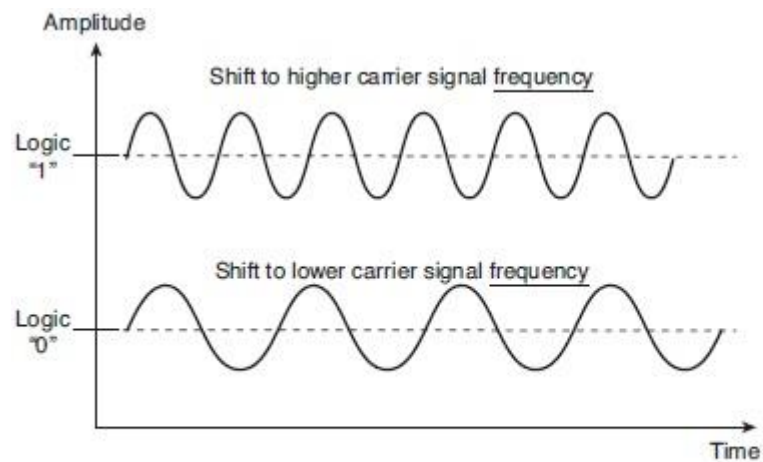
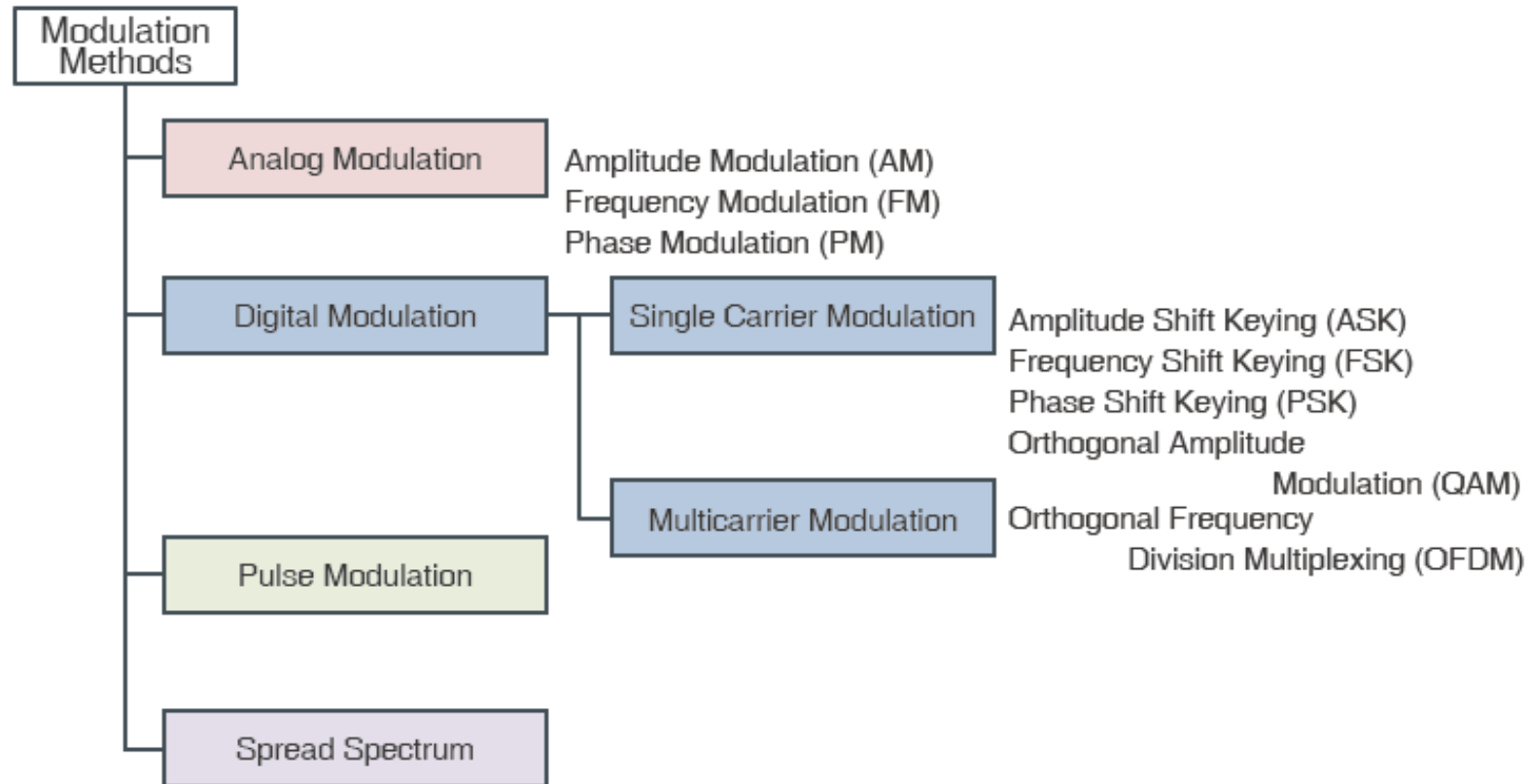


Figure 2-6 Frequency-Shift Keying Makes Use of Changes in Frequency to Represent Digital Data



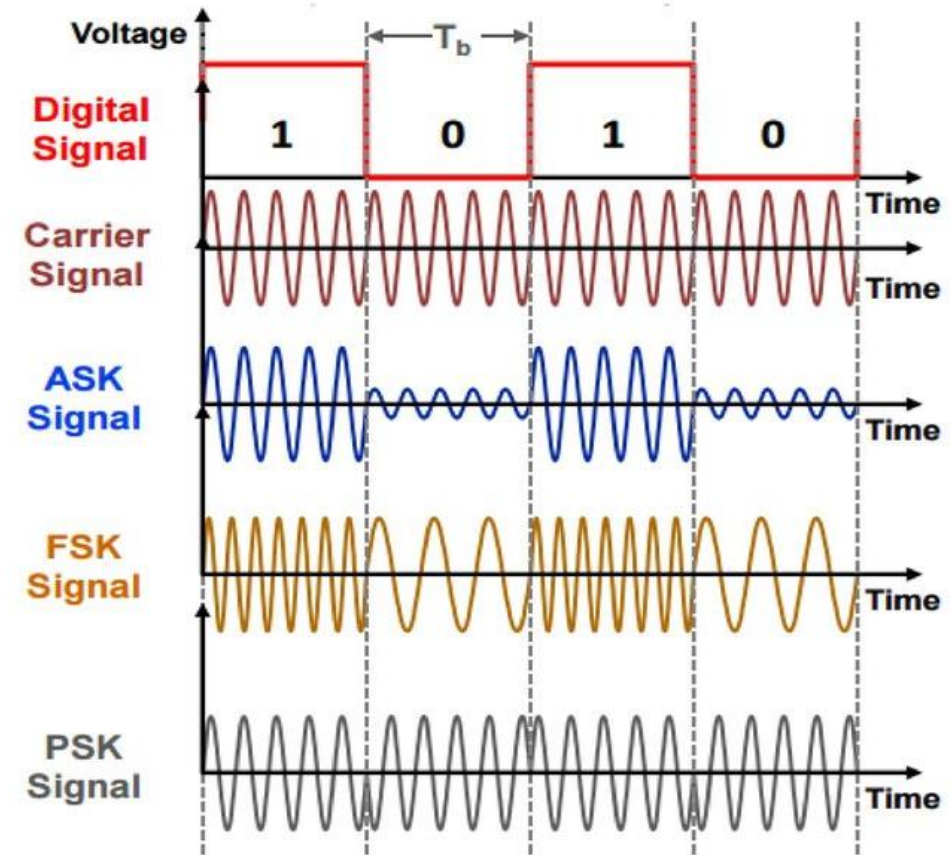
Modulation

- Modulation is the process of **converting data into electrical signals** optimized for transmission.
- Modulation techniques are roughly divided into four types:
 - Analog modulation, Digital modulation, Pulse modulation, and Spread spectrum method.
- **Analog modulation** is typically used for **AM, FM** radio, and short-wave broadcasting.
- **Digital modulation** involves transmission of **binary signals (0 and 1)**.



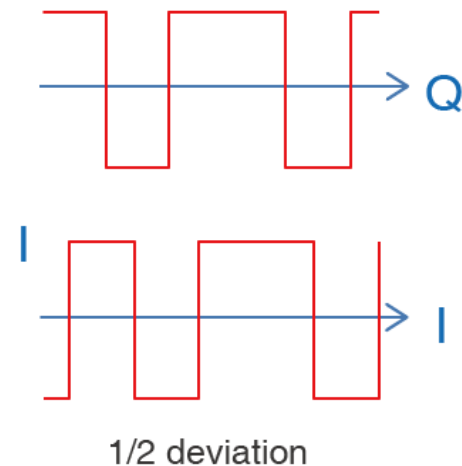
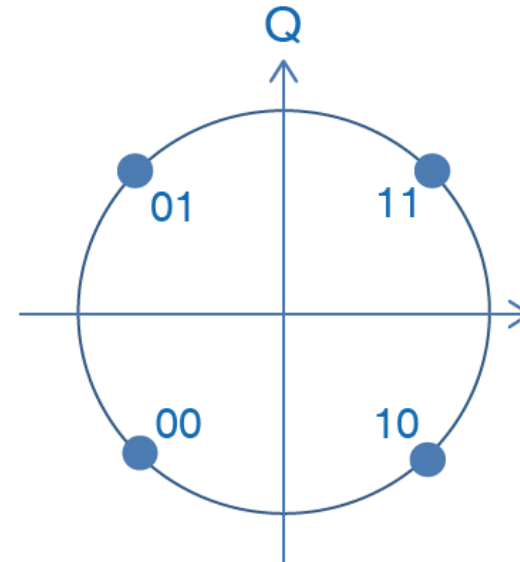
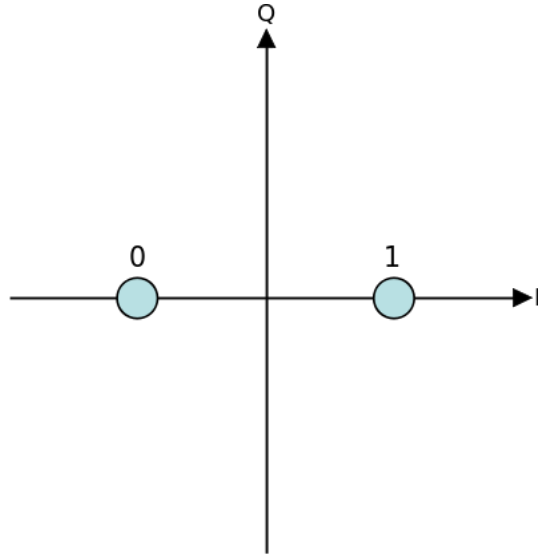
Digital Modulation Types

- **ASK (Amplitude Shift Keying)**
- A digital modulation method that sends transmission data by varying the presence/absence of analog signals.
- **FSK (Frequency Shift Keying)**
- This technique utilizes the difference in the amplitude of analog signals to modulate digital signals by switching between low frequency and high frequency in order to represent 0 and 1.
- **PSK (Phase Shift Keying)**
- This technique utilizes the difference in the phase of analog signals to modulate digital signals by switching between frequency angle (0-90-180-270) in order to represent 0 and 1.

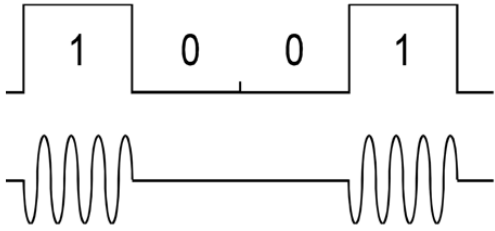
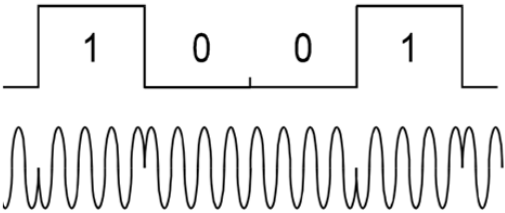
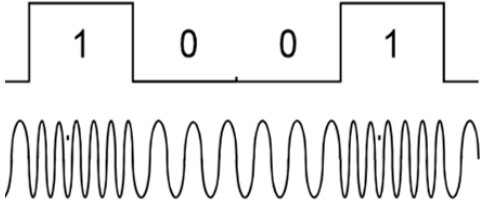


Phase Shift Modulation

- **BPSK (Binary Phase Shift Keying) is**
- A digital modulation scheme that performs data transmission by phase-modulating a reference signal used for lower bit rates with 802.11g clients.
- BPSK paired with half rate encoding, results in a bit-rate of 6Mbps. 9Mbps is achieved with BPSK and 3/4 code rate.
- **O-QPSK (Offset-Quaternary Phase Shift Keying)**
- A digital modulation scheme that performs data transmission by phase-modulating a reference signal.
- The timing of the in-phase component (**I**) and quadrature component (**Q**) are shifted by 1/2 from QPSK, which performs phase modulation in 4 steps

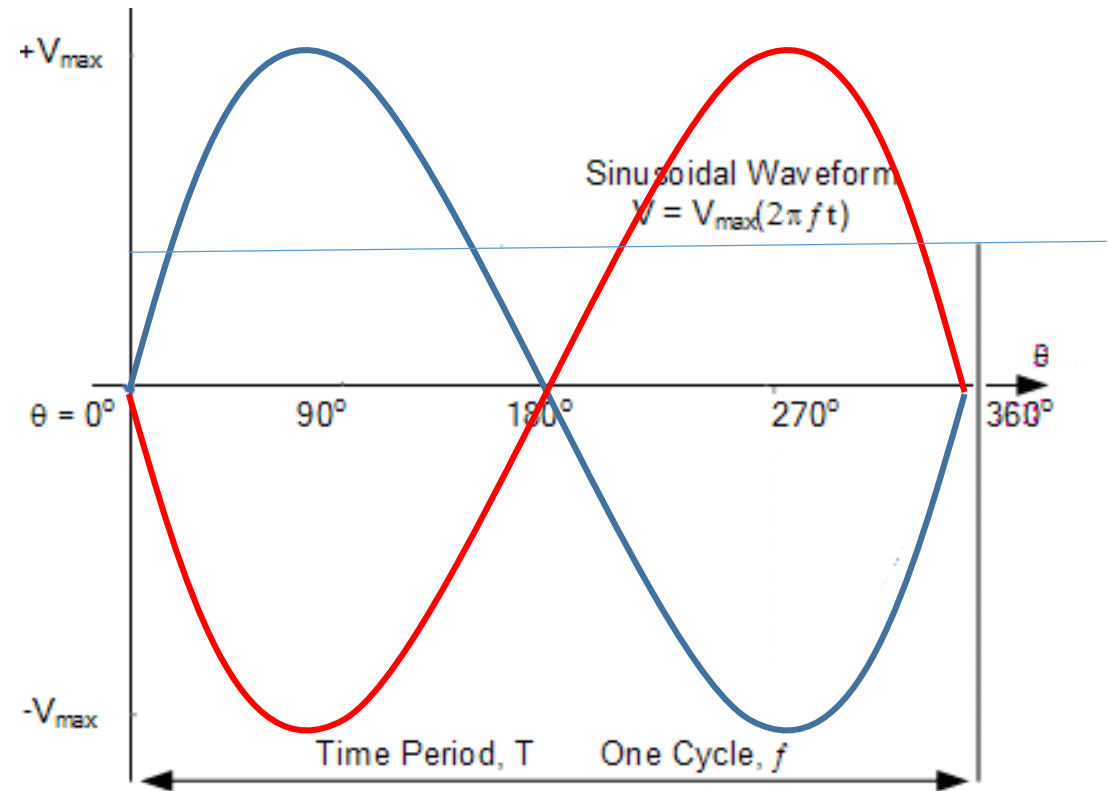
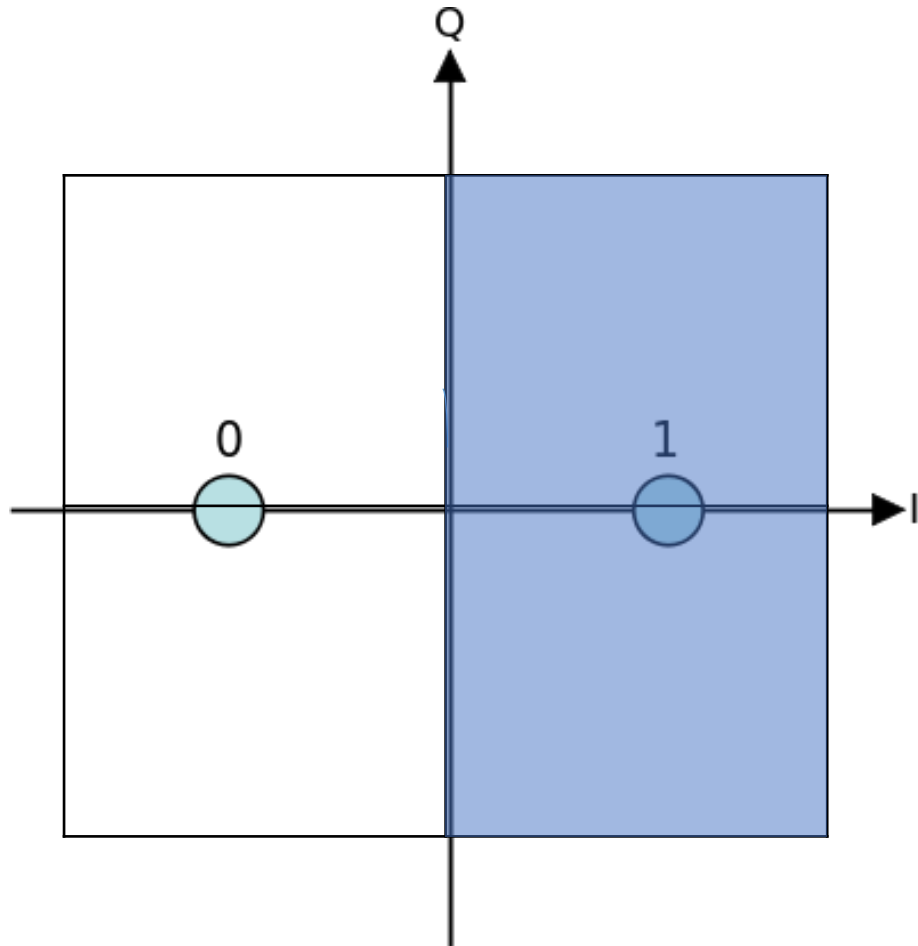


Digital Modulation Types

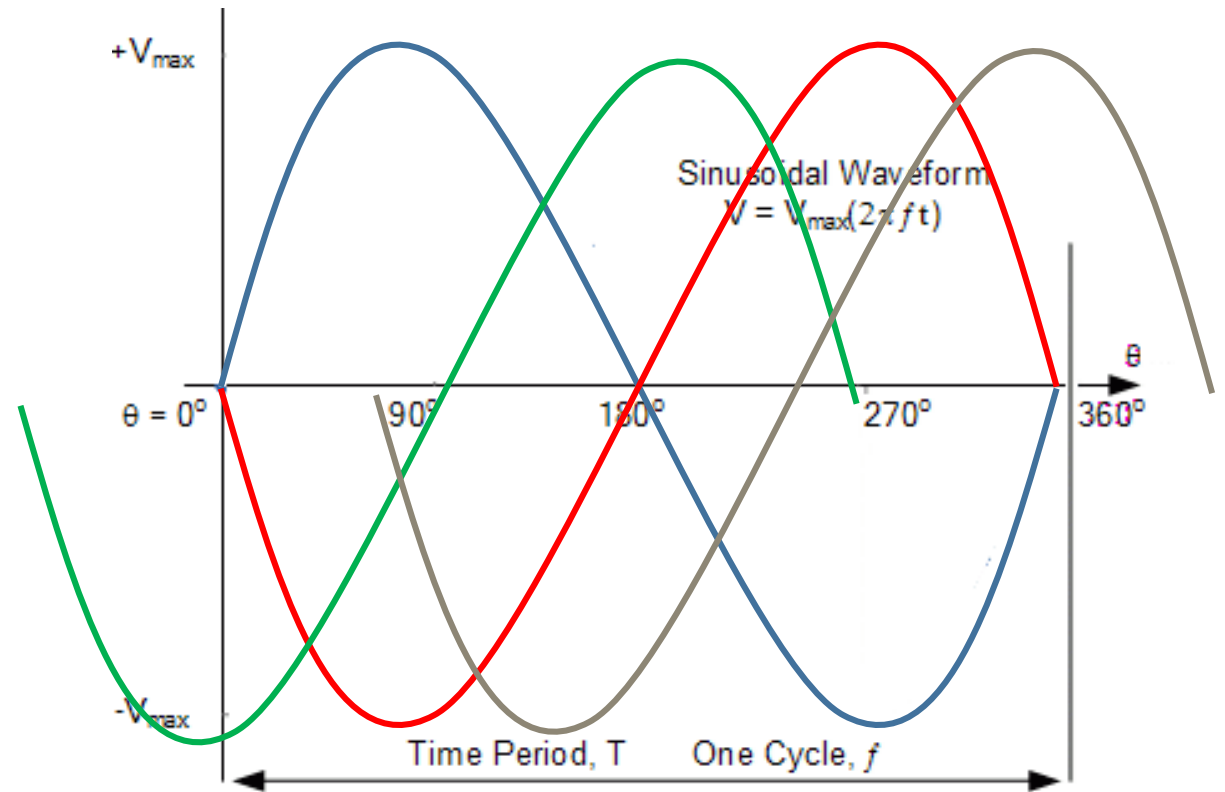
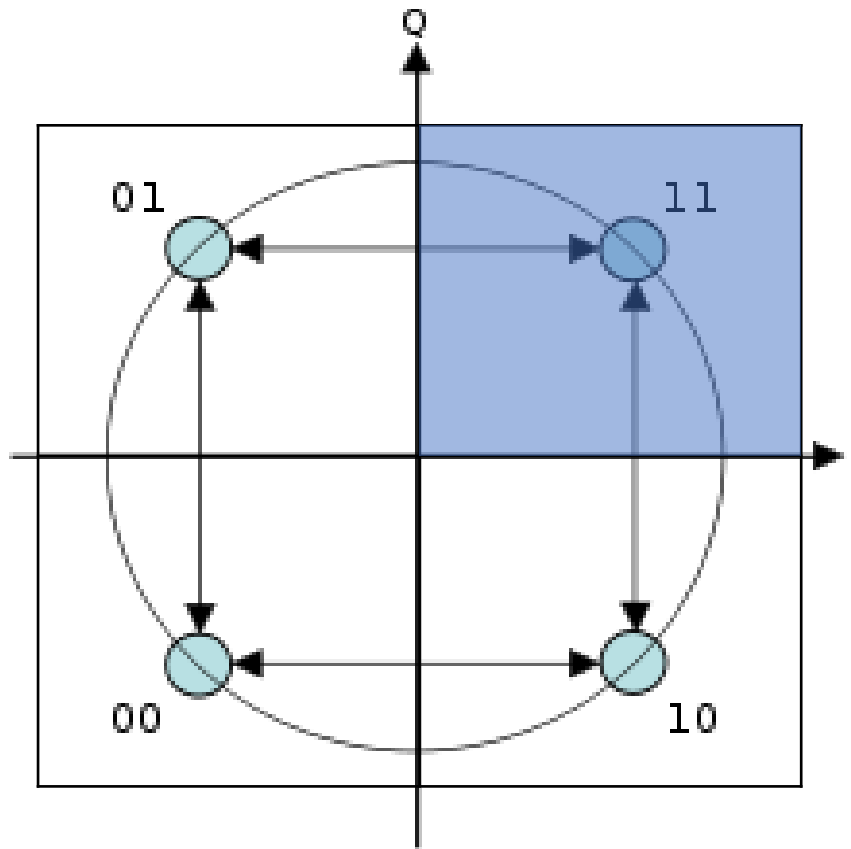
	ASK : Amplitude	PSK : Phase	FSK : Frequency
Baseband → Modulated			
Expression	$A \cdot \sin(2 \pi f t + \theta)$		
	A	θ	f
Feature	Easy to implement Weak to noise/interference	Easy for M-ary bandwidth efficient	Easy to implement For low speed like voice
Example	Quadrature Amplitude Modulation (Amplitude + Phase) BPSK, QPSK, 16QAM, 64QAM, 256QAM, 1024QAM (WLAN)		GMSK = (0.5BT) GBFSK (BT 1M BDR)
		BPSK, QPSK (WLAN)	
		Offset QPSK (Zigbee) pi/4 DQPSK (BT 2M EDR) 8DPSK (BT 3M EDR)	



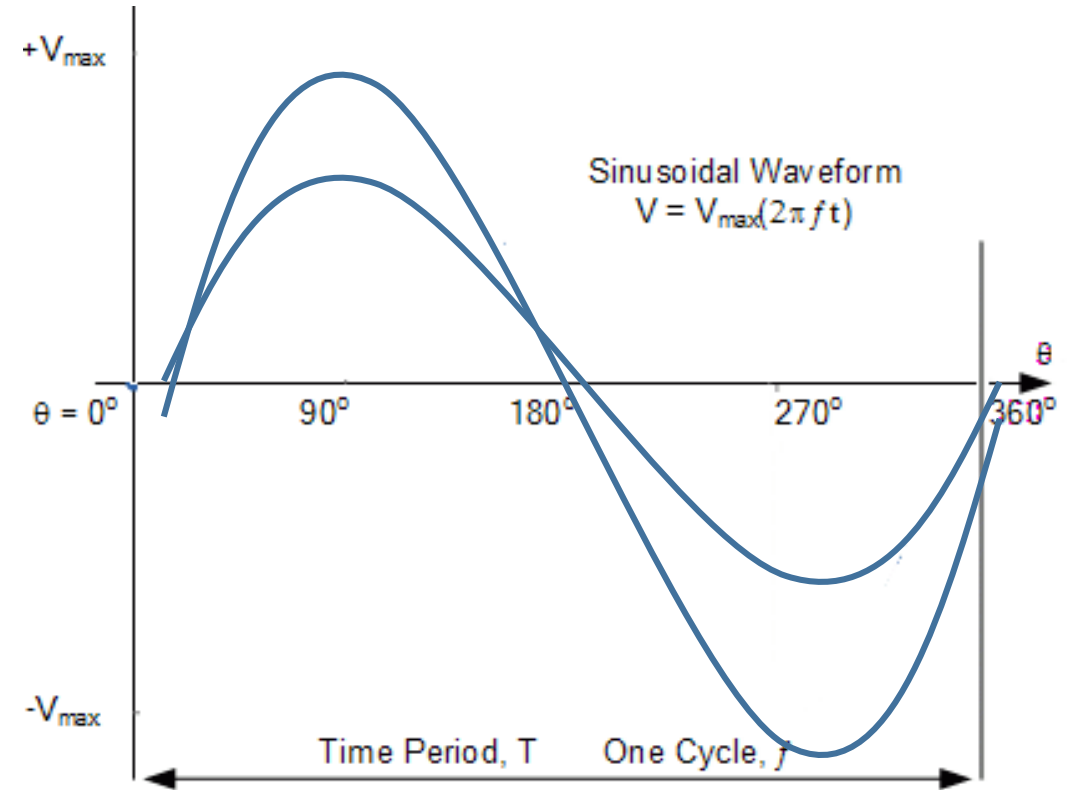
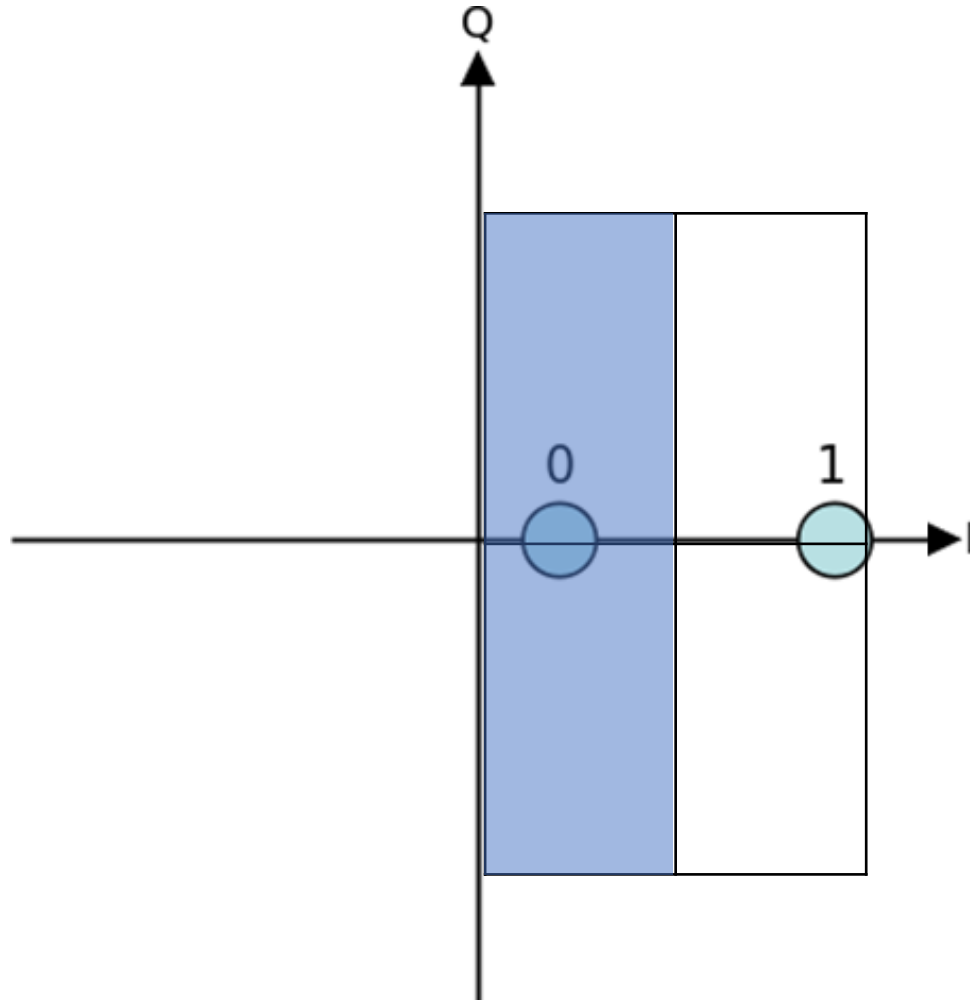
BPSK Modulation



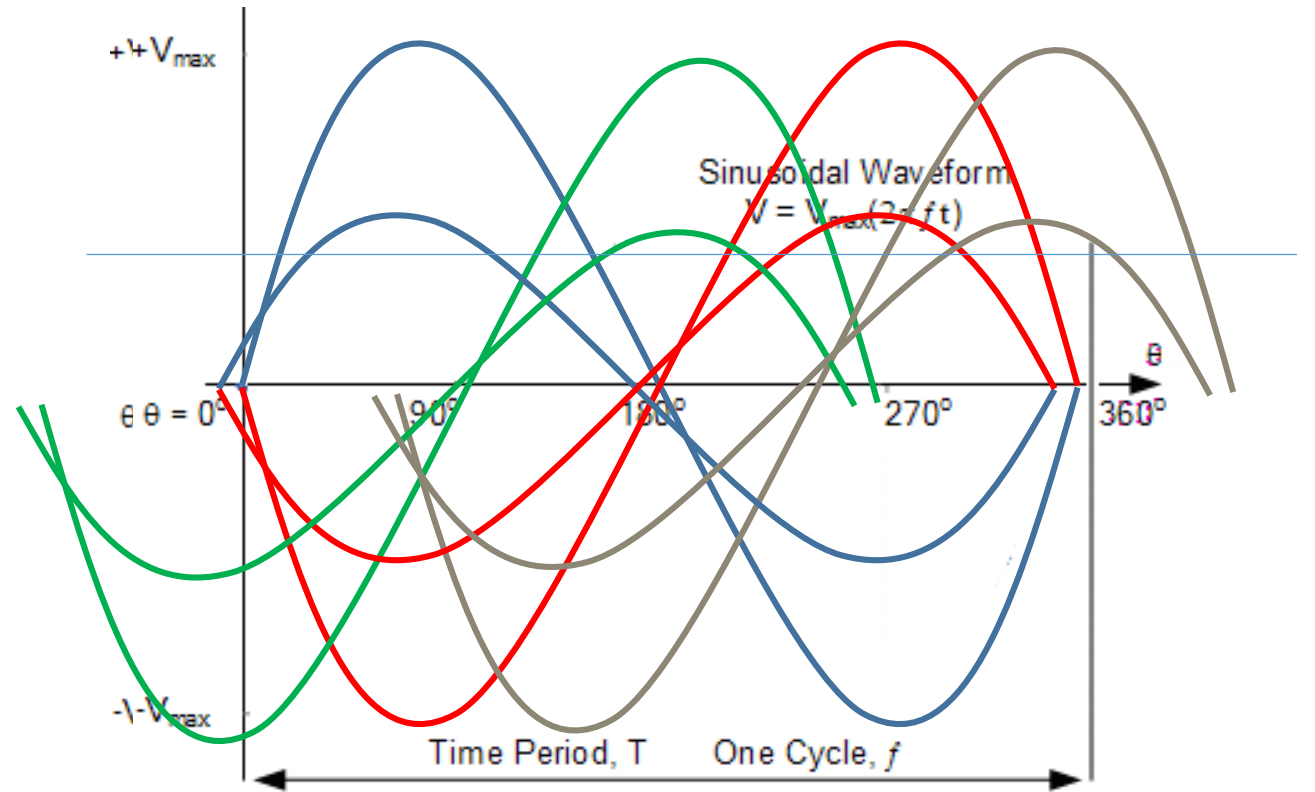
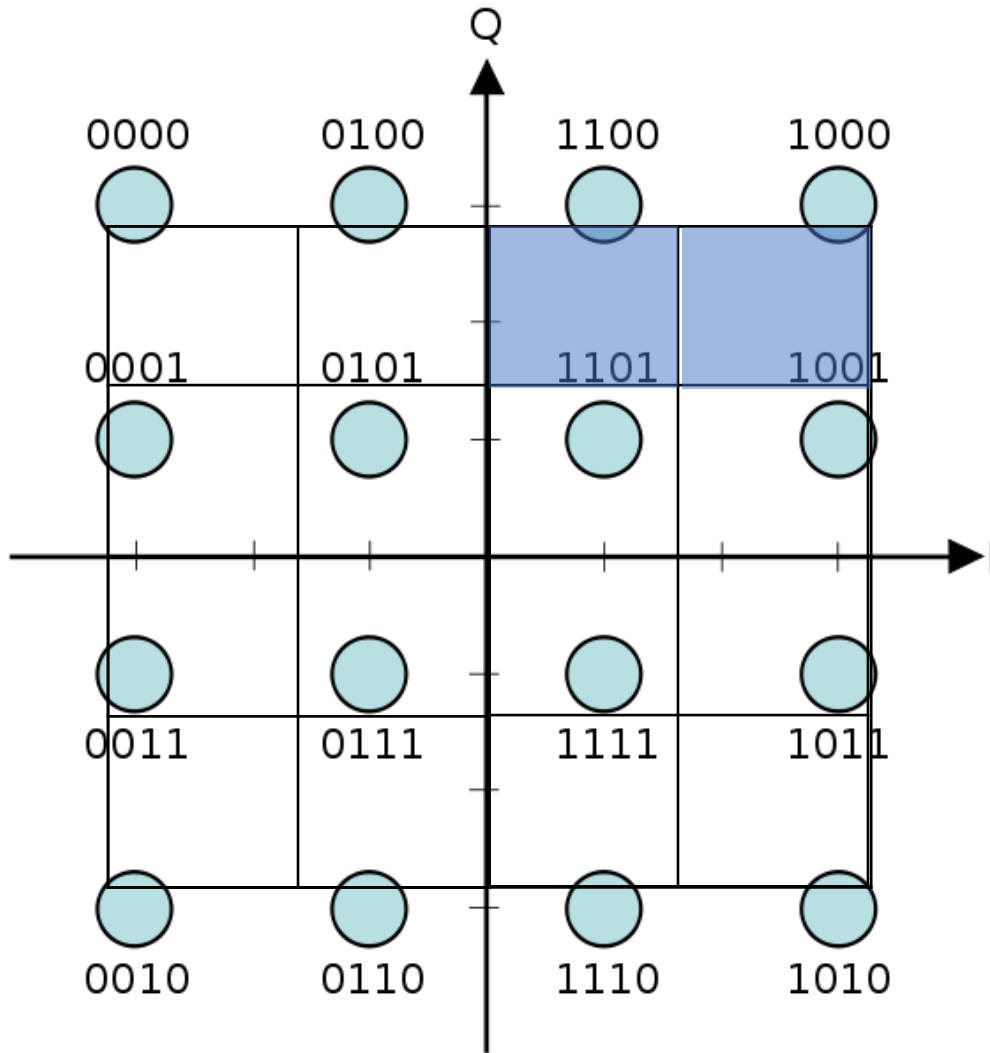
QPSK Modulation



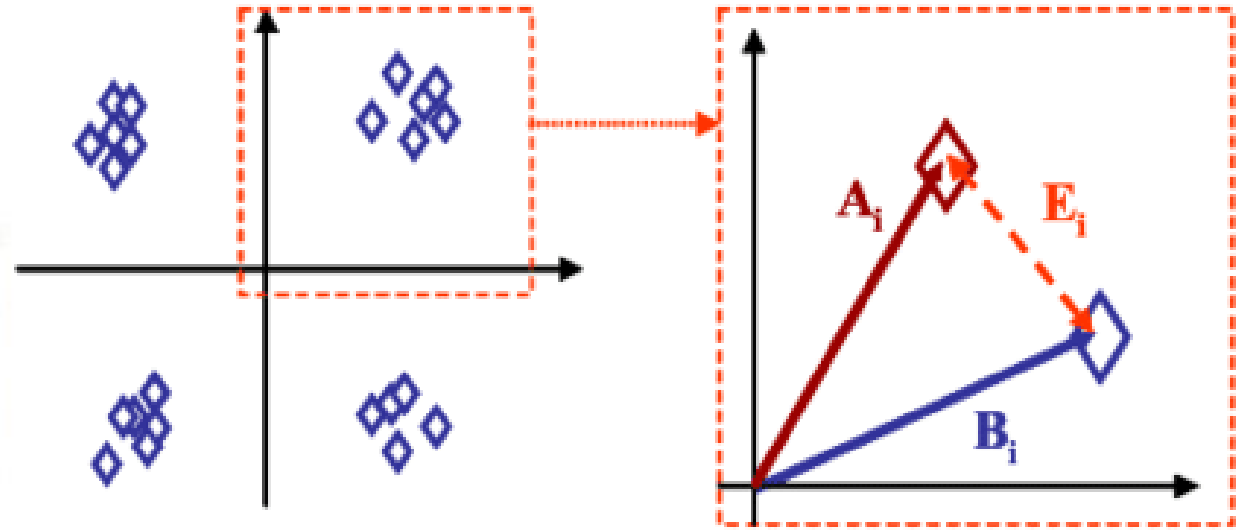
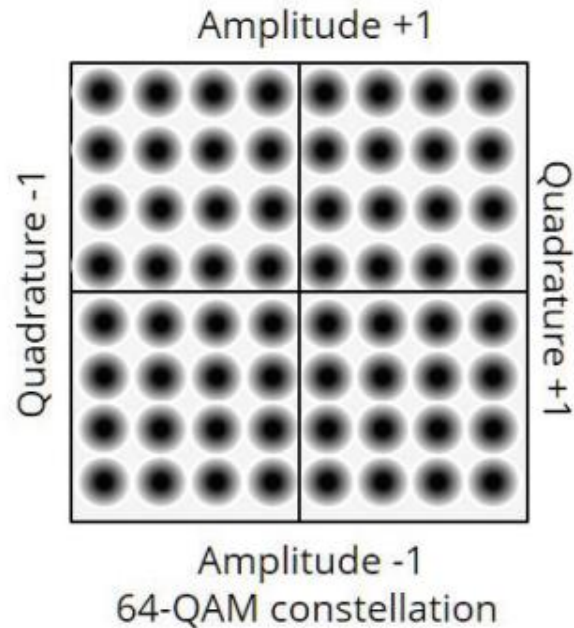
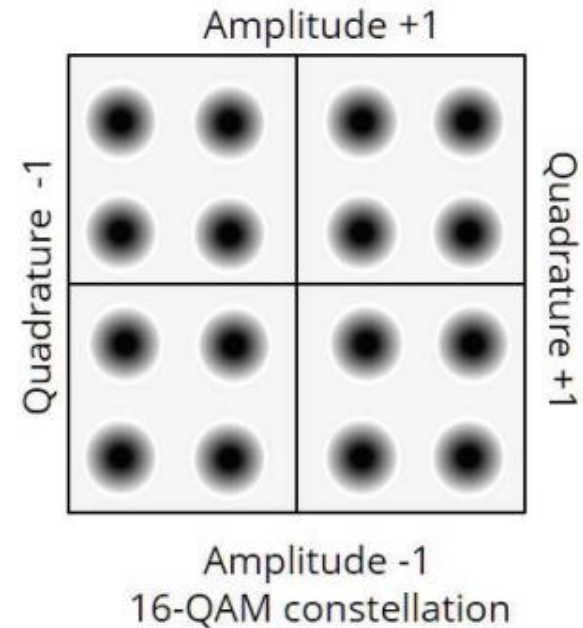
QAM Modulation



16 QAM Modulation



Higher Modulation & EVM



\underline{B}_i : Emitted \underline{A}_i : Ideal \underline{E}_i : Vectorial Error

Wi-Fi Standards

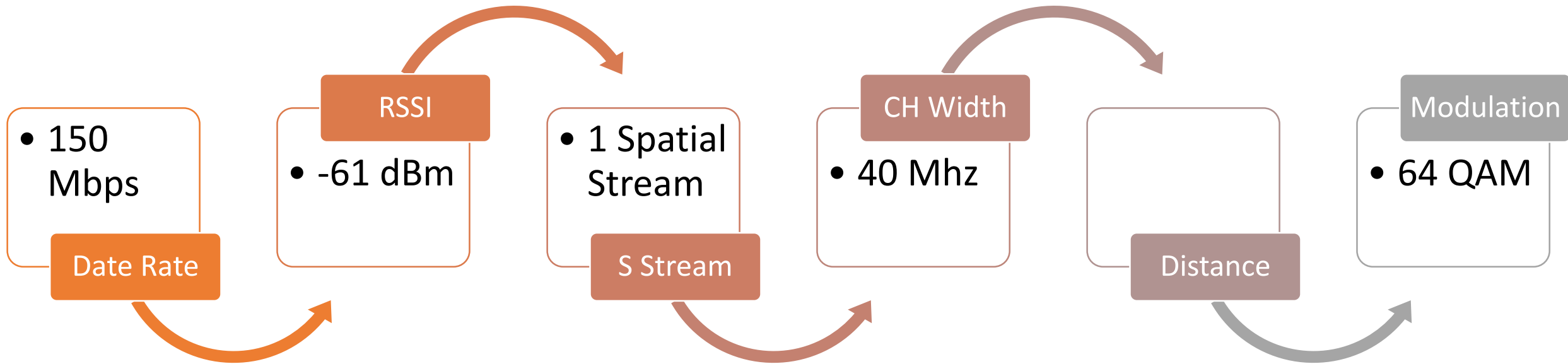
IEEE 802.11 PHY Standards

Release date	Standard	Frequency Band	Bandwidth	Transmission Scheme	Max Modulation	MIMO	Max Data Rate
1997	802.11	2.4 GHz	20 MHz	DSSS, FHSS	QPSK	N/A	2 Mb/s
1999	802.11b	2.4 GHz	20 MHz	DSSS	QPSK	N/A	11 Mb/s
1999	802.11a	5 GHz	20 MHz	OFDM	64QAM	N/A	54 Mb/s
2003	802.11g	2.4 GHz	20 MHz	DSSS, OFDM	64QAM	N/A	54 Mb/s
2009	802.11n	2.4 GHz 5 GHz	20 MHz 40 MHz	OFDM	64QAM	4x4	600 Mb/s
2013	802.11ac	5 GHz	20 MHz 40 MHz 80 MHz 160 MHz	OFDM	256QAM	8x8	6.93 Gb/s
2018	802.11ad	60 GHz	2160 MHz	SC, OFDM	256QAM	Beamforming	6.93 Gb/s



MCS

- **Modulation and Coding Scheme**
- Represent required Signal Strength and expected Data Rate Access Point will use Certain Modulation and Coding methods along with certain values of Channel Width and Spatial Stream
- Distance expresses as free space related to 6 dB rule without barriers



Wireless Half or Full Duplex

MCS index	Spatial streams	Modulation type	Coding rate	Data rate (Mbit/s)			
				20 MHz channel		40 MHz channel	
				800 ns GI	400 ns GI	800 ns GI	400 ns GI
0	1	BPSK	1/2	6.5	7.2	13.5	15
1	1	QPSK	1/2	13	14.4	27	30
2	1	QPSK	3/4	19.5	21.7	40.5	45
3	1	16-QAM	1/2	26	28.9	54	60
4	1	16-QAM	3/4	39	43.3	81	90
5	1	64-QAM	2/3	52	57.8	108	120
6	1	64-QAM	3/4	58.5	65	121.5	135
7	1	64-QAM	3/4	67.5	74.25	145.5	150



1 SS Data Rates VS RSSI

MCS	Modulation	Rate	Minimum Sensitivity [dBm]			
			20 MHz	40 MHz	80 MHz	160 MHz
0	BPSK	1/2	-82	-79	-76	-73
1	QPSK	1/2	-79	-76	-73	-70
2	QPSK	3/4	-77	-74	-71	-68
3	16-QAM	1/2	-74	-71	-68	-65
4	16-QAM	3/4	-70	-67	-64	-61
5	64-QAM	2/3	-66	-63	-60	-57
6	64-QAM	3/4	-65	-62	-59	-56
7	64-QAM	5/6	-64	-61	-58	-55
8	256-QAM	3/4	-59	-56	-53	-50
9	256-QAM	5/6	-57	-54	-51	-48



MCS Data Rate

Theoretical throughput for single spatial stream (in Mbit/s)^{[8][a]}

MCS index ^[b]	Modulation type	Coding rate	20 MHz channels		40 MHz channels		80 MHz channels		160 MHz channels	
			800 ns GI ^[c]	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI	800 ns GI	400 ns GI
0	BPSK	1/2	6.5	7.2	13.5	15	29.3	32.5	58.5	65
1	QPSK	1/2	13	14.4	27	30	58.5	65	117	130
2	QPSK	3/4	19.5	21.7	40.5	45	87.8	97.5	175.5	195
3	16-QAM	1/2	26	28.9	54	60	117	130	234	260
4	16-QAM	3/4	39	43.3	81	90	175.5	195	351	390
5	64-QAM	2/3	52	57.8	108	120	234	260	468	520
6	64-QAM	3/4	58.5	65	121.5	135	263.3	292.5	526.5	585
7	64-QAM	5/6	65	72.2	135	150	292.5	325	585	650
8	256-QAM	3/4	78	86.7	162	180	351	390	702	780
9	256-QAM	5/6	N/A	N/A	180	200	390	433.3	780	866.7

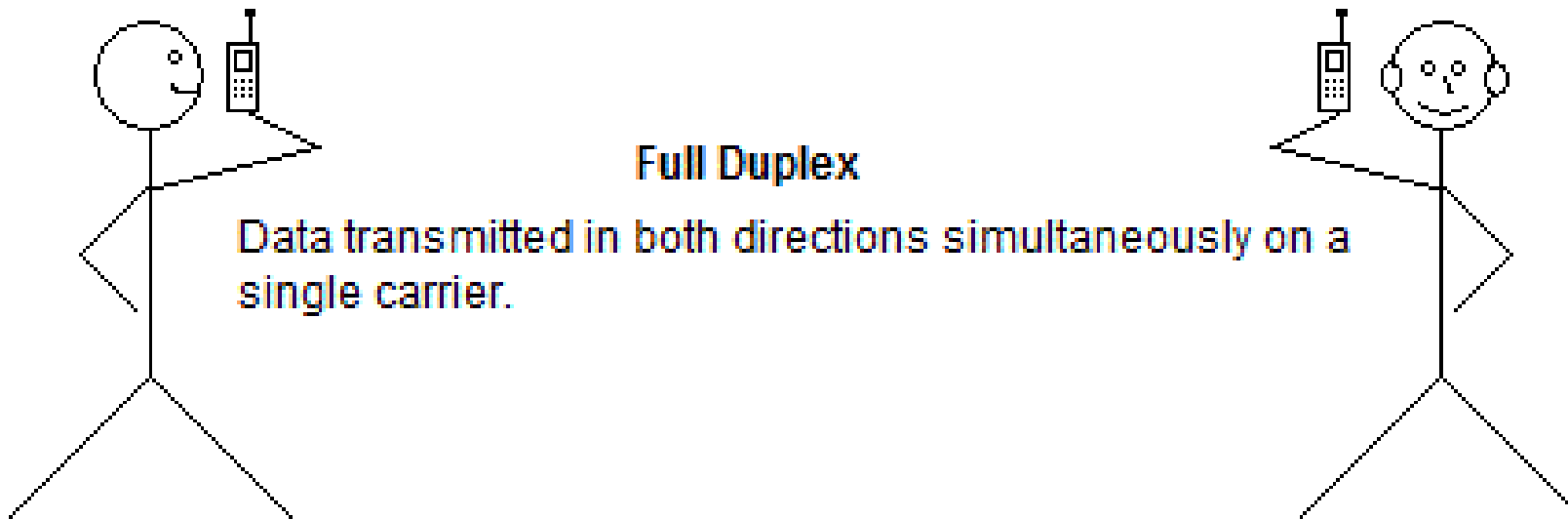
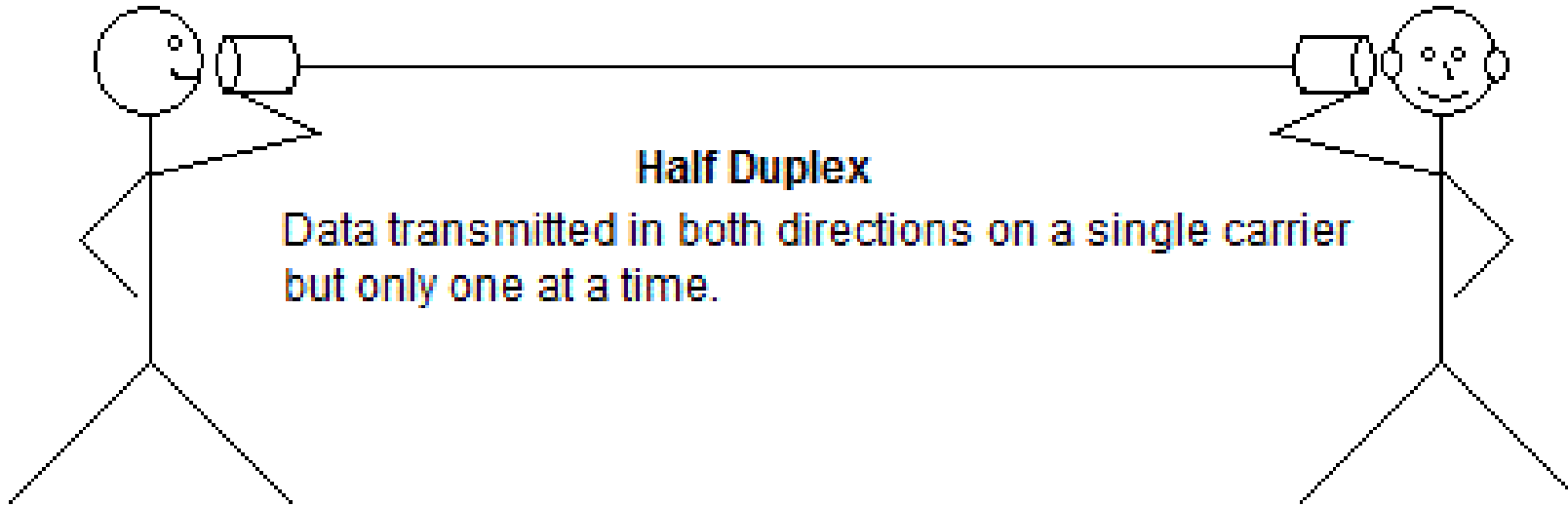


802.11n/HT and 802.11ac/VHT

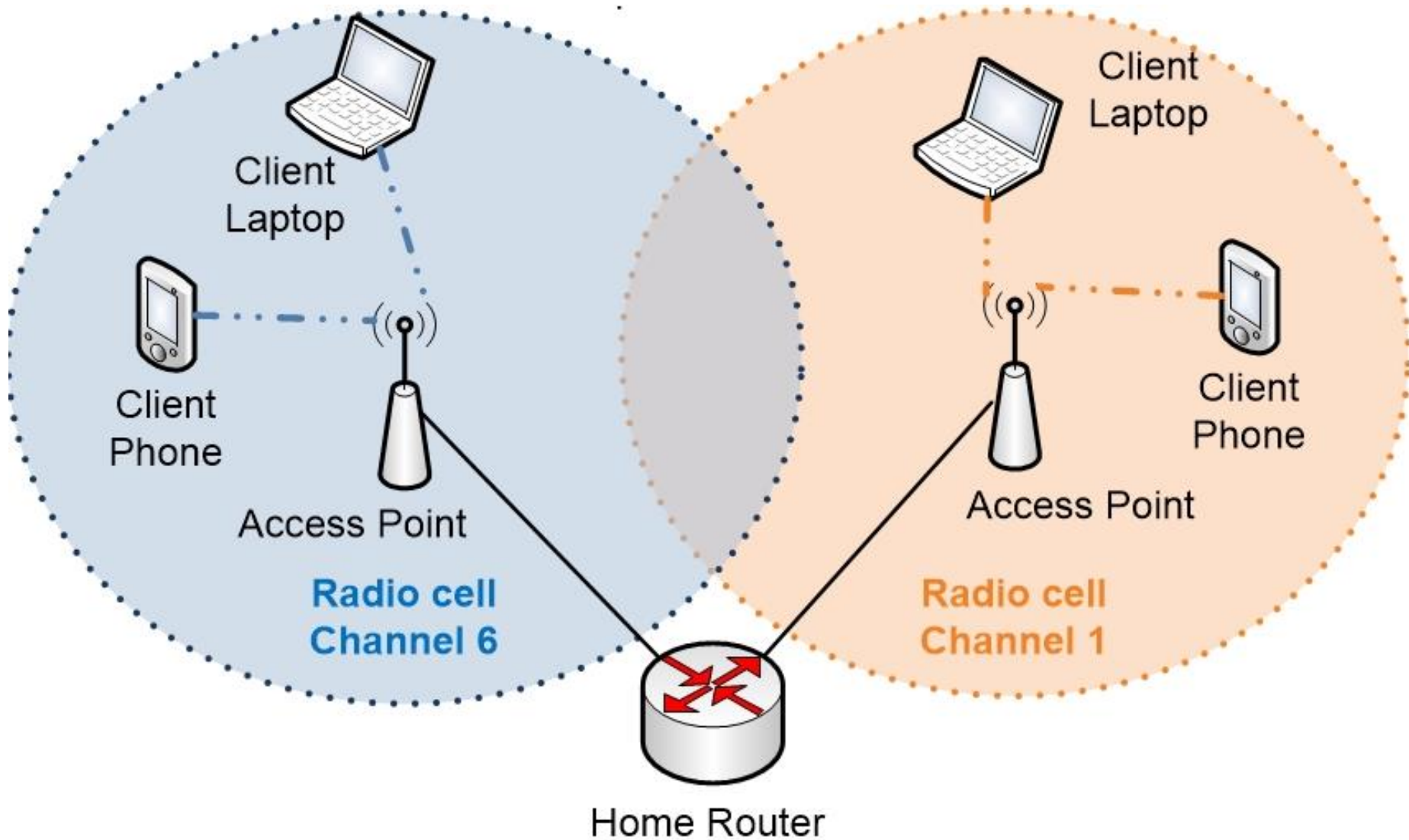
MCS, SNR and RSSI

HT MCS	VHT MCS	Modulation	Coding	20MHz				40MHz				80MHz				160MHz			
				Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI	Data Rate		Min. SNR	RSSI
				800ns	400ns			800ns	400ns			800ns	400ns			800ns	400ns		
1 Spatial Stream																			
0	0	BPSK	1/2	6.5	7.2	2	-82	13.5	15	5	-79	29.3	32.5	8	-76	58.5	65	11	-73
1	1	QPSK	1/2	13	14.4	5	-79	27	30	8	-76	58.5	65	11	-73	117	130	14	-70
2	2	QPSK	3/4	19.5	21.7	9	-77	40.5	45	12	-74	87.8	97.5	15	-71	175.5	195	18	-68
3	3	16-QAM	1/2	26	28.9	11	-74	54	60	14	-71	117	130	17	-68	234	260	20	-65
4	4	16-QAM	3/4	39	43.3	15	-70	81	90	18	-67	175.5	195	21	-64	351	390	24	-61
5	5	64-QAM	2/3	52	57.8	18	-66	108	120	21	-63	234	260	24	-60	468	520	27	-57
6	6	64-QAM	3/4	58.5	65	20	-65	121.5	135	23	-62	263.3	292.5	26	-59	526.5	585	29	-56
7	7	64-QAM	5/6	65	72.2	25	-64	135	150	28	-61	292.5	325	31	-58	585	650	34	-55
	8	256-QAM	3/4	78	86.7	29	-59	162	180	32	-56	351	390	35	-53	702	780	38	-50
	9	256-QAM	5/6			31	-57	180	200	34	-54	390	433.3	37	-51	780	866.7	40	-48
2 Spatial Streams																			
8	0	BPSK	1/2	13	14.4	2	-82	27	30	5	-79	58.5	65	8	-76	117	130	11	-73
9	1	QPSK	1/2	26	28.9	5	-79	54	60	8	-76	117	130	11	-73	234	260	14	-70
10	2	QPSK	3/4	39	43.3	9	-77	81	90	12	-74	175.5	195	15	-71	351	390	18	-68
11	3	16-QAM	1/2	52	57.8	11	-74	108	120	14	-71	234	260	17	-68	468	520	20	-65
12	4	16-QAM	3/4	78	86.7	15	-70	162	180	18	-67	351	390	21	-64	702	780	24	-61
13	5	64-QAM	2/3	104	115.6	18	-66	216	240	21	-63	468	520	24	-60	936	1040	27	-57
14	6	64-QAM	3/4	117	130.3	20	-65	243	270	23	-62	526.5	585	26	-59	1053	1170	29	-56
15	7	64-QAM	5/6	130	144.4	25	-64	270	300	28	-61	585	650	31	-58	1170	1300	34	-55
	8	256-QAM	3/4	156	173.3	29	-59	324	360	32	-56	702	780	35	-53	1404	1560	38	-50
	9	256-QAM	5/6			31	-57	360	400	34	-54	780	866.7	37	-51	1560	1733.3	40	-48
3 Spatial Streams																			
16	0	BPSK	1/2	19.5	21.7	2	-82	40.5	45	5	-79	87.8	97.5	8	-76	175.5	195	11	-73
17	1	QPSK	1/2	39	43.3	5	-79	81	90	8	-76	175.5	195	11	-73	351	390	14	-70

Half Vs Full Duplex

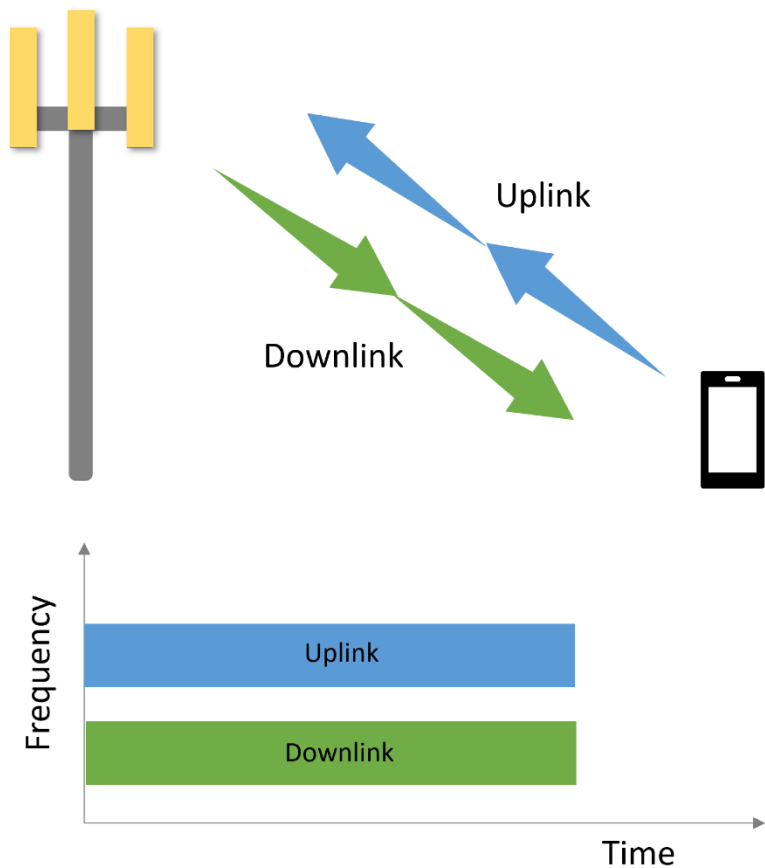


Wireless is Shared Medium

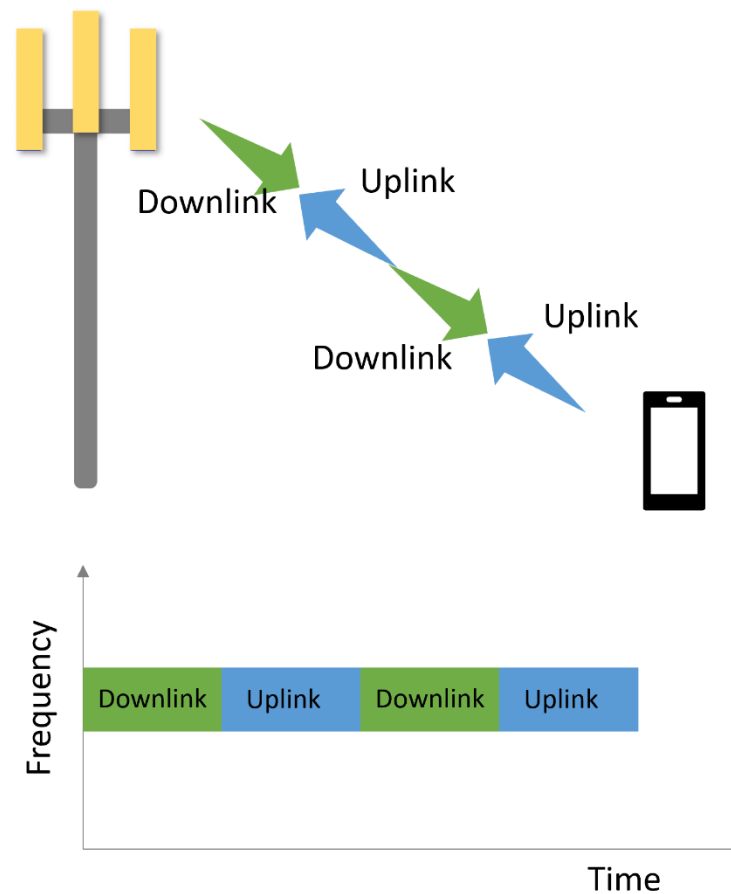


Wireless Half or Full Duplex

FDD



TDD



Wi-Fi is Half Duplex

- **Half-duplex:** A fundamental design of wireless protocol
- **Shared Resource:** The half-duplex wireless channel

Full-duplex:

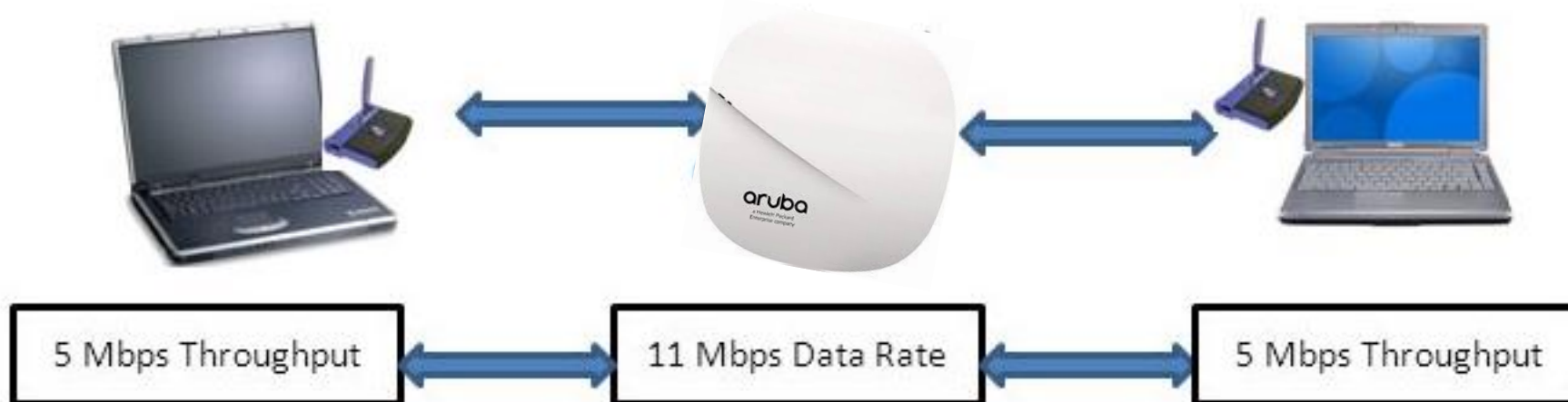


Half-duplex:



Throughput Vs Data Rate

- Data Rate = Total Data Rate through system
- Throughput = Data Payload Rate
- Data Rate = Data Payload Rate + Overhead
- Overhead = Coding + Modulation+ Bandwidth + Hardware + Software + Retransmission(errors)



Advertised AP data rates are only half the equation!

Examples: What 1 AP can support with clients at -67 dBm, 5 GHz, 20 MHz

**Note: 75-80% airtime utilization is maximum, 100% not achievable due to overhead*

3SS Laptops

3 Mbps (ea)

100 Mbps Total



34 Laptops, 77% total airtime utilization



2SS Tablets

3 Mbps (ea)

65 Mbps Total



21 Tablets, 75% total airtime utilization



1SS Smartphones

3 Mbps (ea)

30 Mbps Total



10 Smartphones, 77% total airtime utilization



Client Device Data Rate

	802.11n IEEE Specification		802.11ac Wave 1	802.11ac Wave 2	802.11ac IEEE Specification
Band	2.4GHz & 5GHz	2.4GHz & 5GHz	5GHz	5GHz	5GHz
MIMO	Single User (SU)	Single User (SU)	Single User (SU)	Multi User (MU)	Multi User (MU)
PHY Rate	450 Mbps	600 Mbps	1.3 Gbps	2.34 Gbps - 3.47 Gbps	6.9 Gbps
Channel Width	20MHz or 40MHz	20MHz or 40MHz	20MHz, 40MHz, 80MHz	20MHz, 40MHz, 80MHz, 160MHz	20MHz, 40MHz, 80MHz, 160MHz
Modulation	64QAM	64QAM	256QAM	256QAM	256QAM
Spatial Streams	3	4	3	3-4	8
MAC Throughput	293 Mbps	390 Mbps	845 Mbps	1.52 Gbps - 2.26 Gbps	4.49Gbps

* Assuming a 65% MAC Efficiency with highest MCS



Antenna

- Antenna is electrical device which converts electric power into electromagnetic waves or vice versa.
- Omni directional and directional antennas.

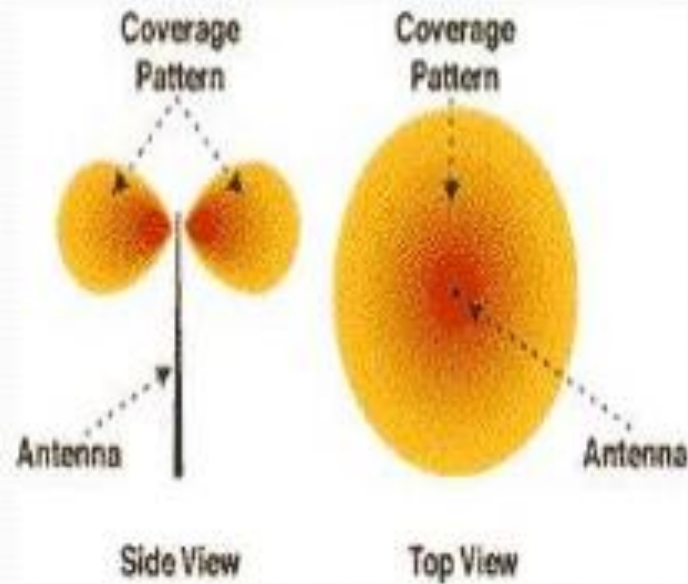
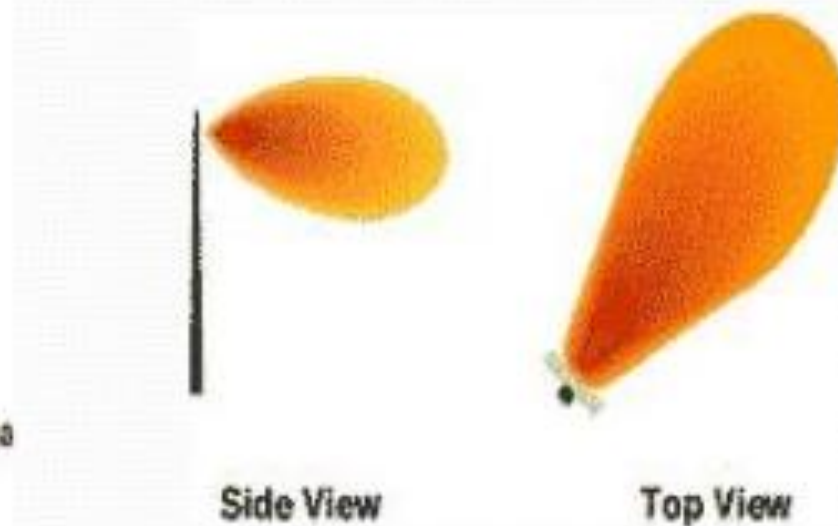


Figure A: Omni directional antenna coverage pattern



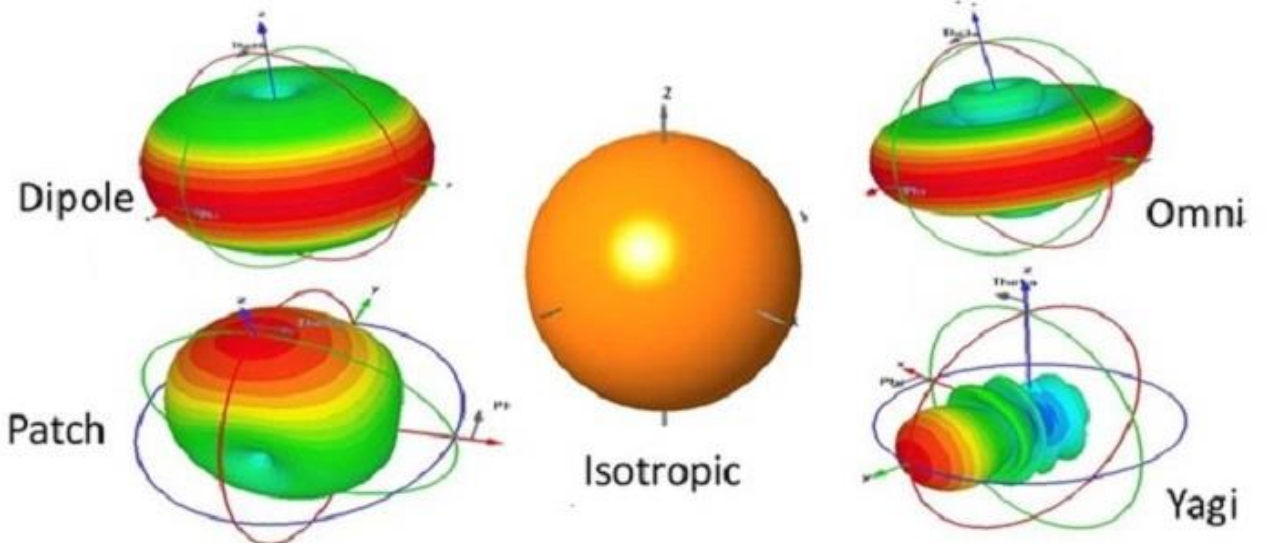
B. Directional antenna coverage pattern

Wireless Training

Part 1 – Session 6

RF BASICS

Antenna Theory

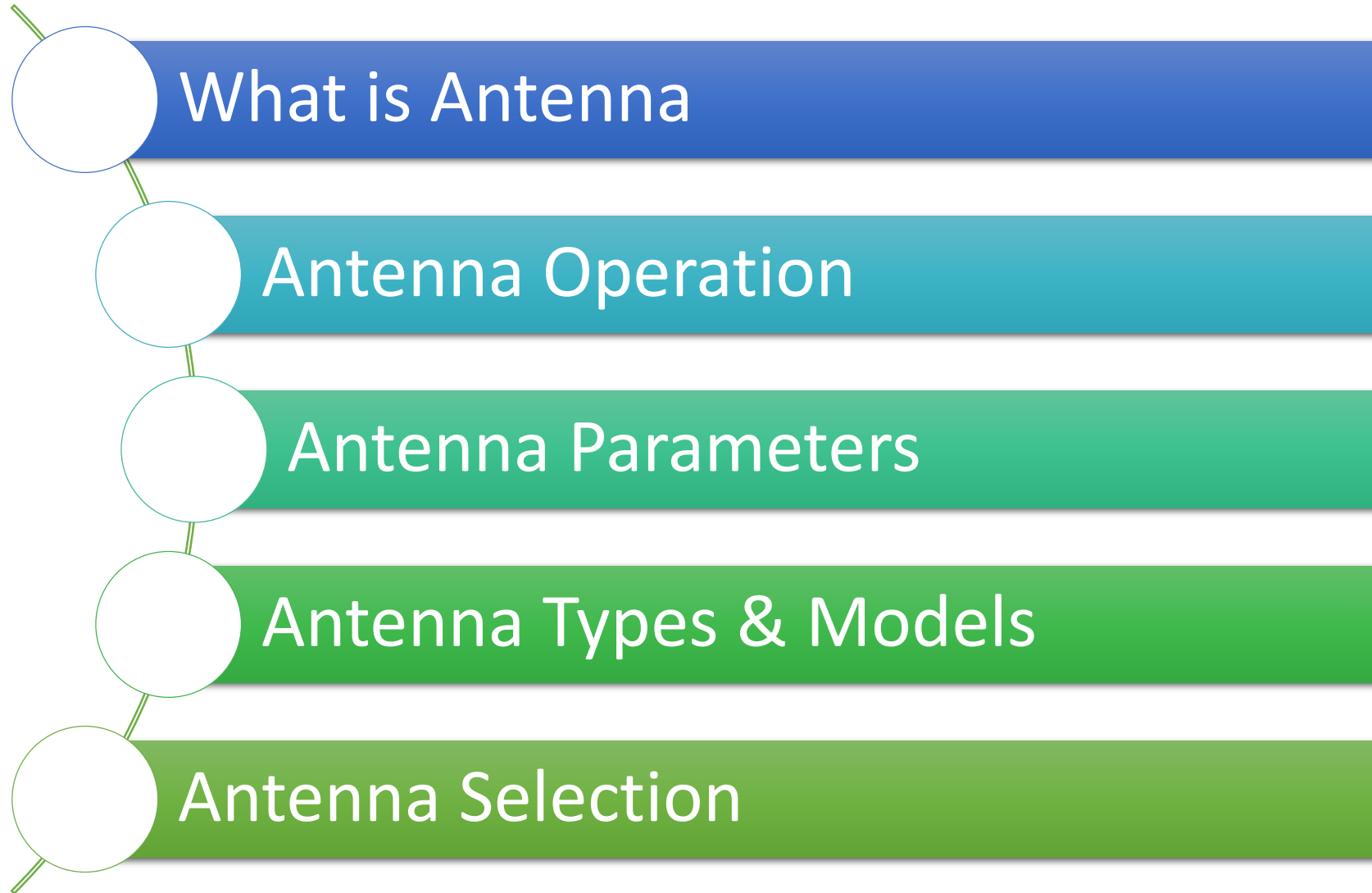




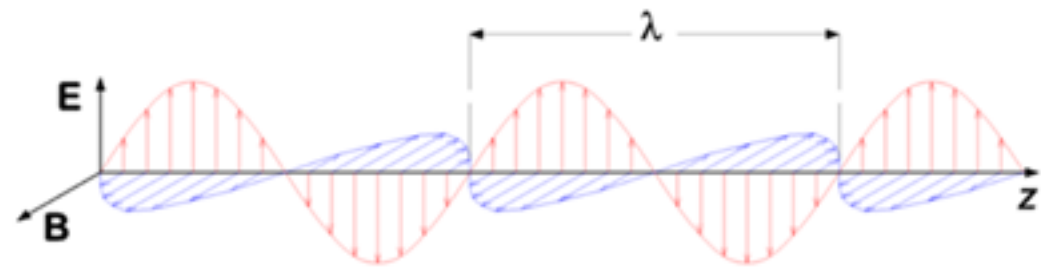
Part 1 : RF Basics

1. What is Radio Transmission
2. RF Bands and Spectrum
3. RF Waves Characteristics
4. RF Measurements Units
5. Signal Indicators RSSI-SNR
6. RF Waves Propagation
7. Channels and bands
8. Interference CCI – ACI
9. Wireless Data Rates
10. Wi-Fi Antenna

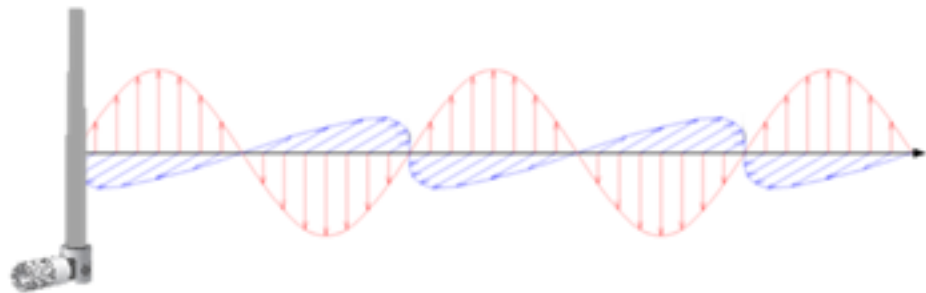
Antenna



Understanding Antennas



Electromagnetic Waves

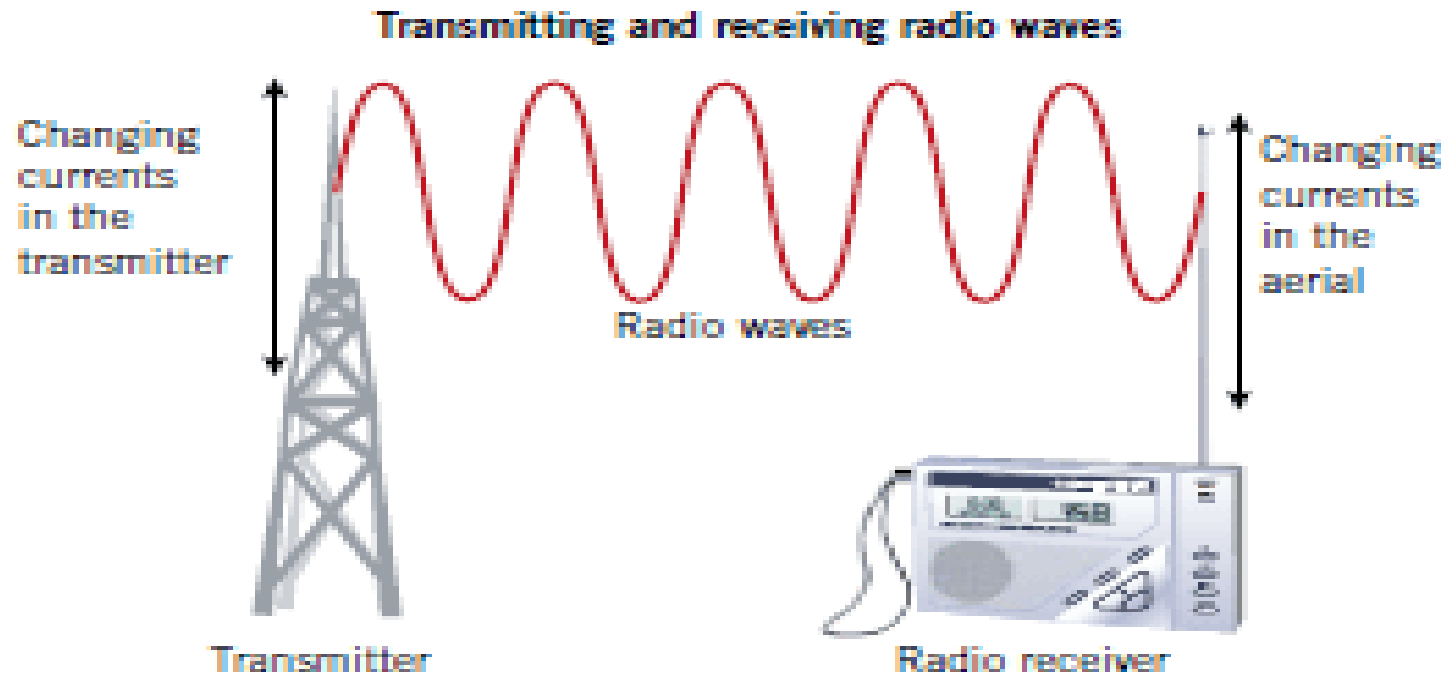


Antennas radiate electromagnetic waves into the air

Antennas both radiate and receive electromagnetic waves. They radiate the waves as the electromagnetic signal escapes from the antenna. They receive waves as the energy is captured by the antenna.

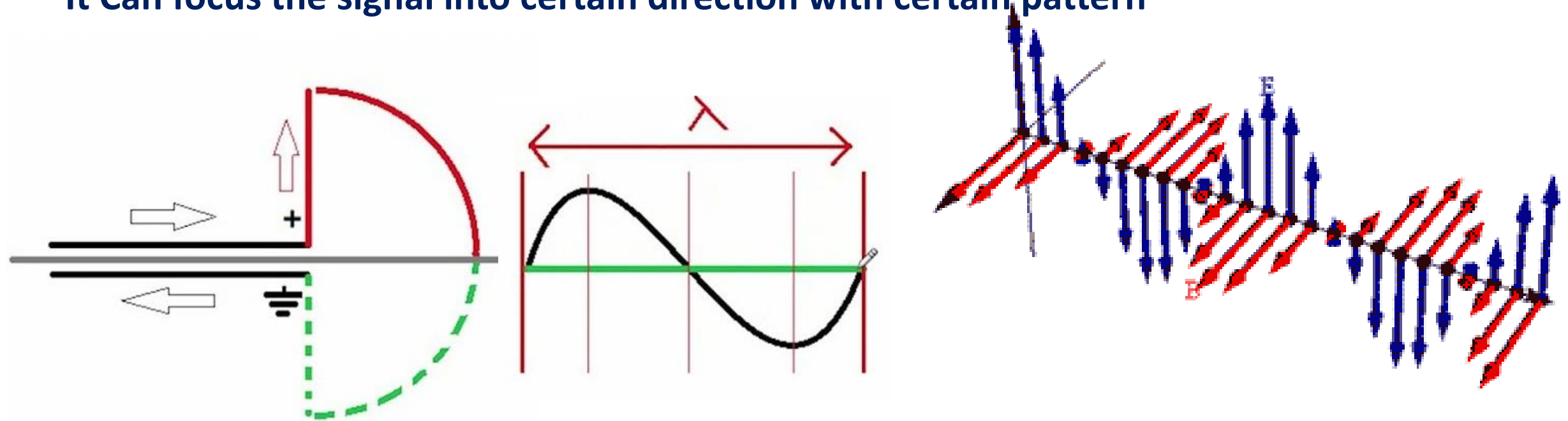
What is Antenna

- Electrical device which Converts electric energy into radio waves, and vice versa.
- It is used with a radio transmitter or radio receiver.
- It Can focus the signal into certain direction with certain pattern

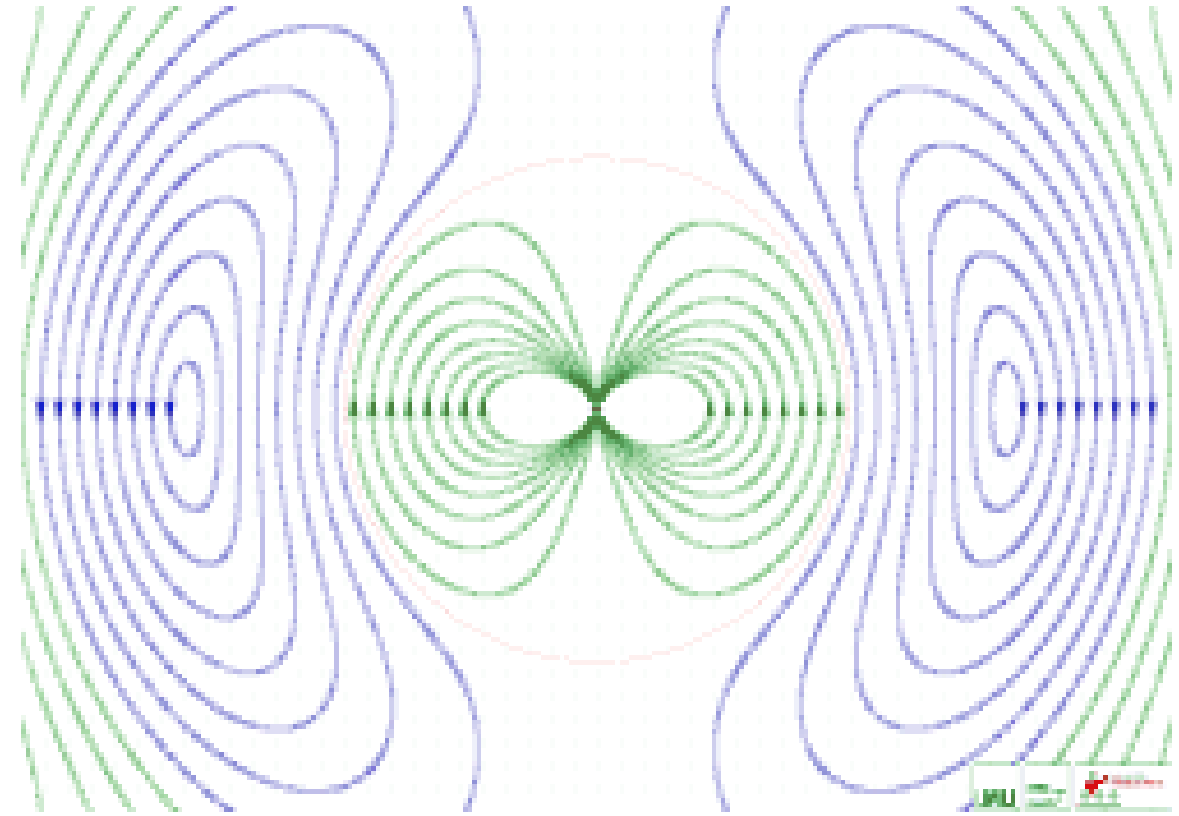
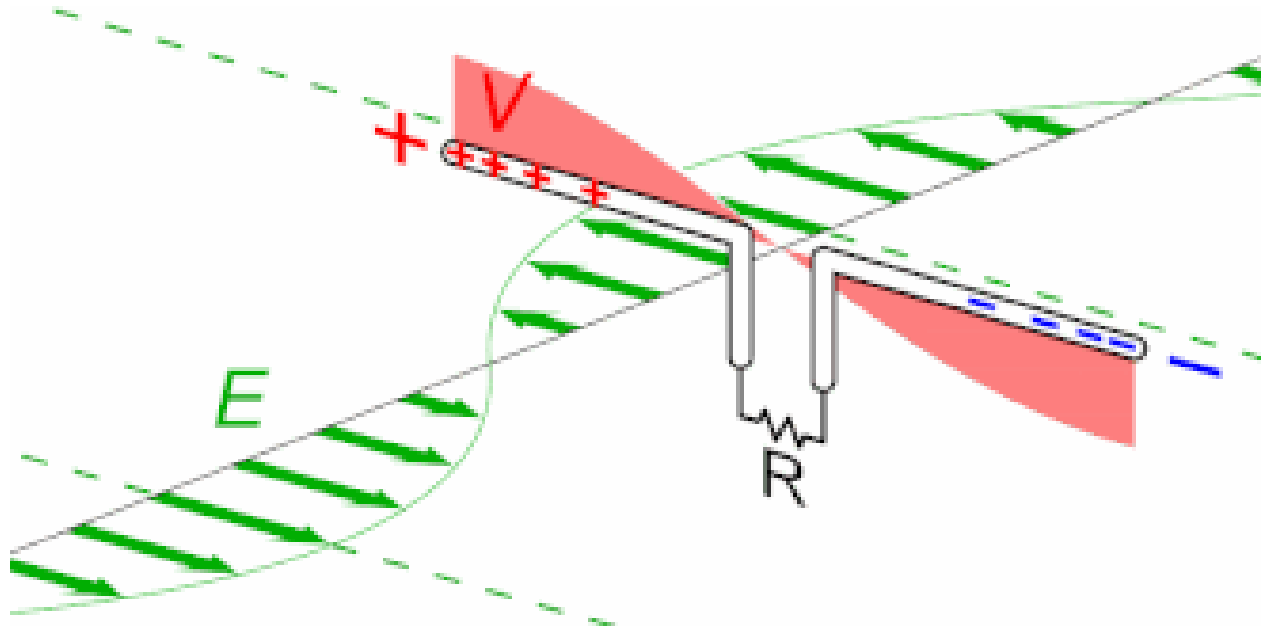


Electric Into Waves

- Electrical device which Convert electric energy into radio waves, and vice versa.
- It is used with a radio transmitter or radio receiver.
- It Can focus the signal into certain direction with certain pattern



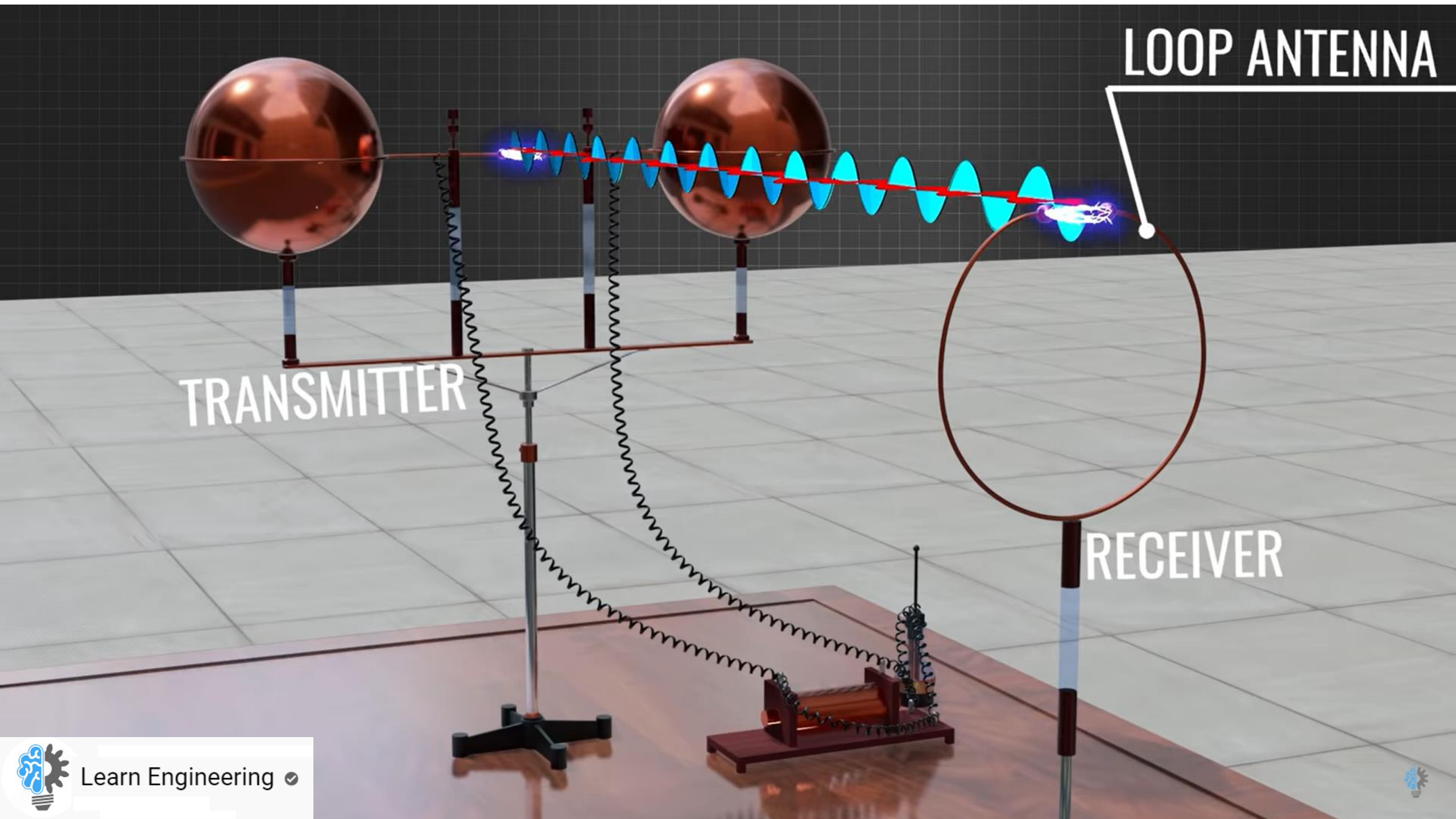
Antenna Operation



LOOP ANTENNA

TRANSMITTER

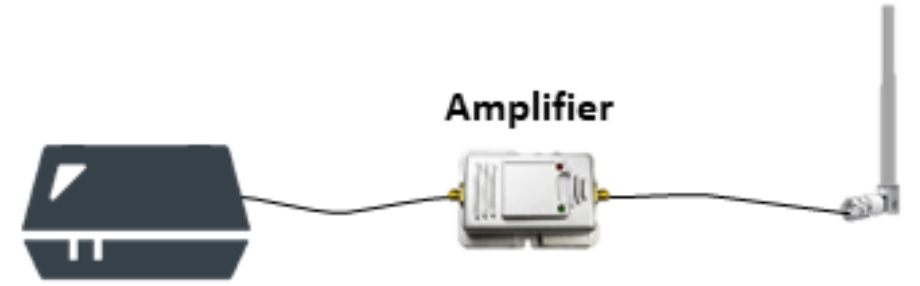
RECEIVER



Active Vs Passive Gain



Passive gain uses no extra amplification and relies fully on the directionality of the antenna for increased RF energy in a desired direction.



Active gain uses an RF amplifier to increase the signal strength. The amplifier is placed in path between the AP and antenna or between the radio and antenna.



Antenna Parameters

RF Lobes

Shape of the radiation patterns

Polarization

Horizontal or vertical orientation

Beam Width

Angles of Wireless Emission

Pattern Charts

Azimuth and Elevation Plane

Gain dBi

Changing the RF coverage pattern (beamwidths)



RF Power Units



No units

dB

Power
Related
to
another

$$dB = 10 \log \frac{P_2}{P_1}$$

SNR

Ratio Between
Noise and Signal



Power
Related
to 1 m
watt

dBm

$$P(\text{dBm}) = 10 \log \frac{P(\text{mW})}{1 \text{ mW}}$$

AP Power O/P
RSSI at Client



Antenna
Gain
Related to
isotropic
Antenna

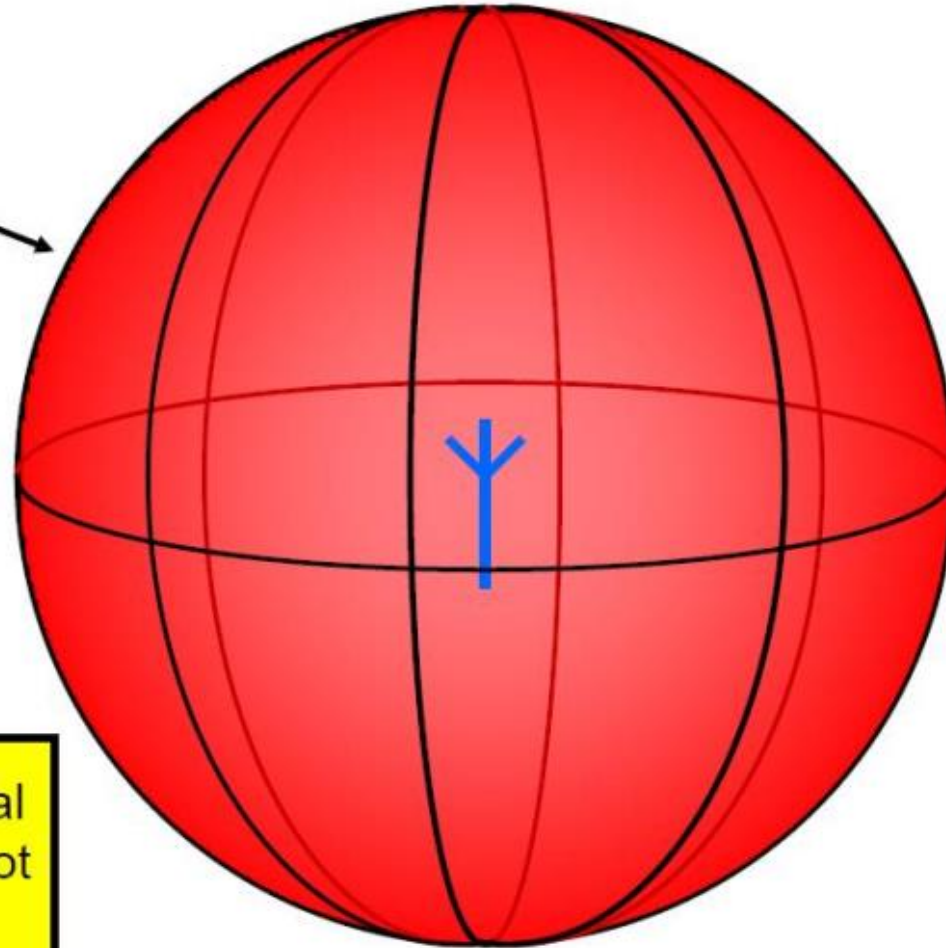
dBi

Antenna Gain



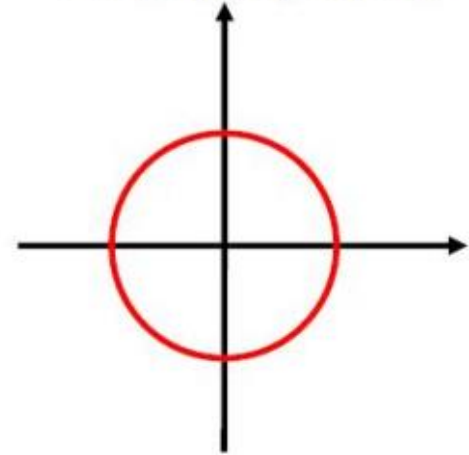
The isotropic antenna radiates equally in all directions

Radiation pattern is spherical

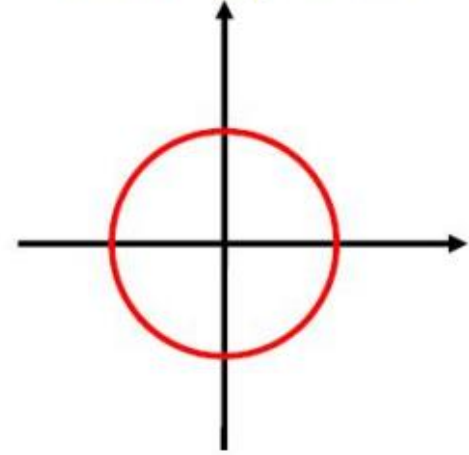


This is a theoretical antenna that cannot be built.

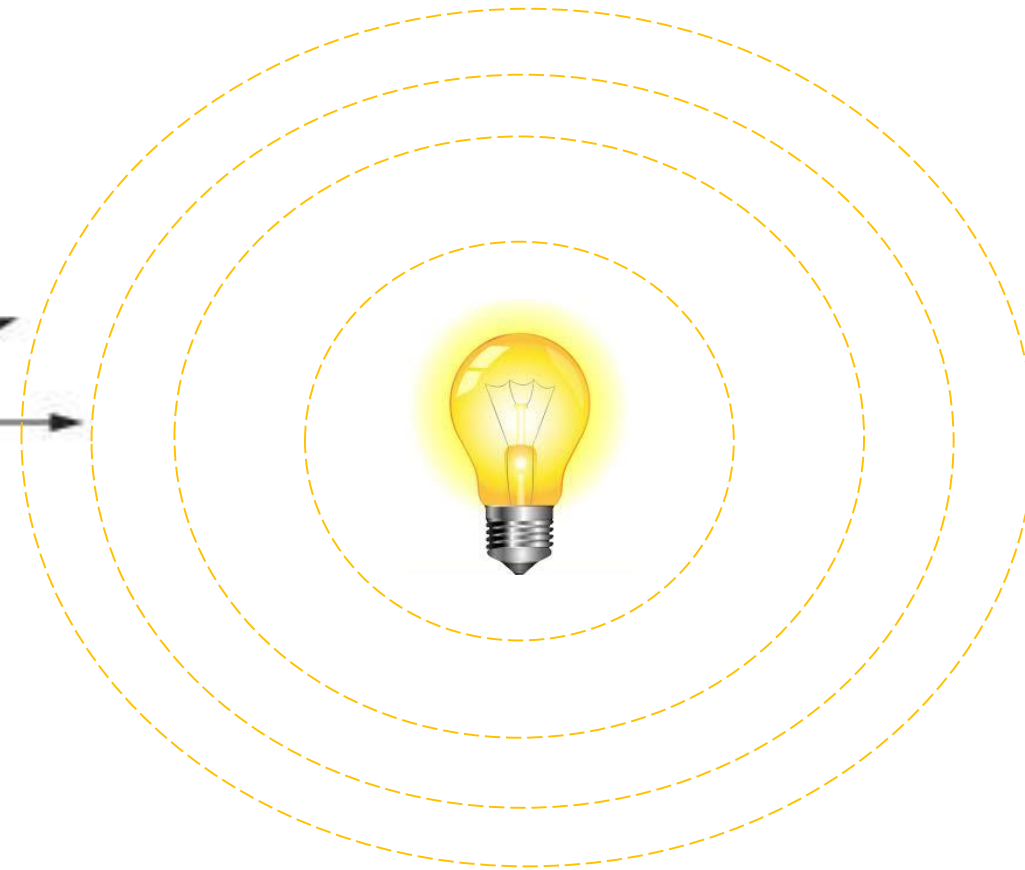
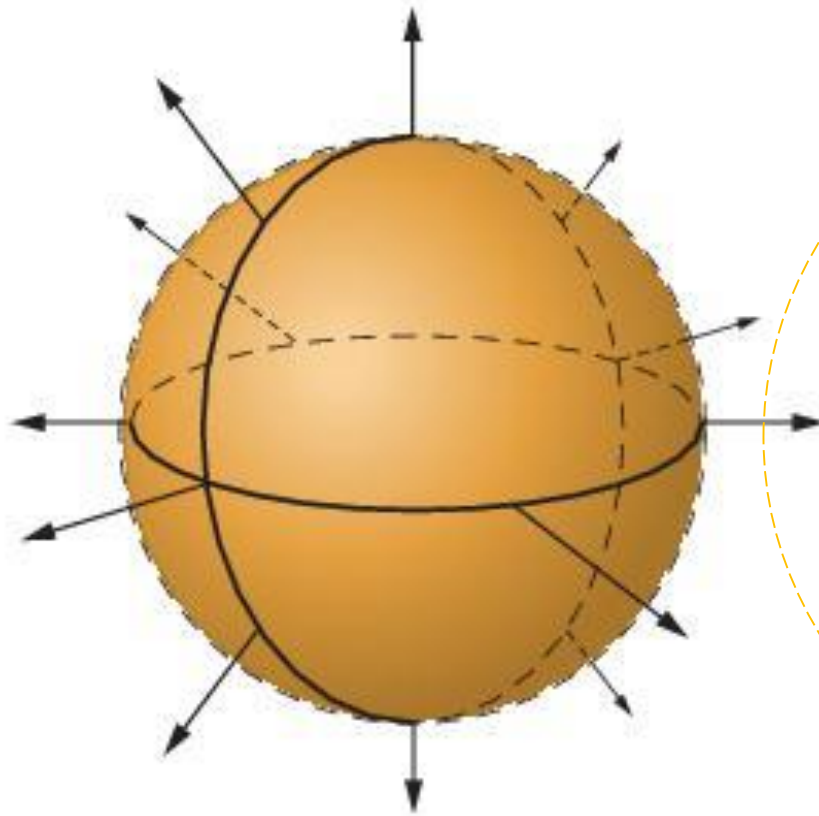
Elevation pattern



Azimuth pattern



Antenna Operation



Total radiated power
equal in all directions

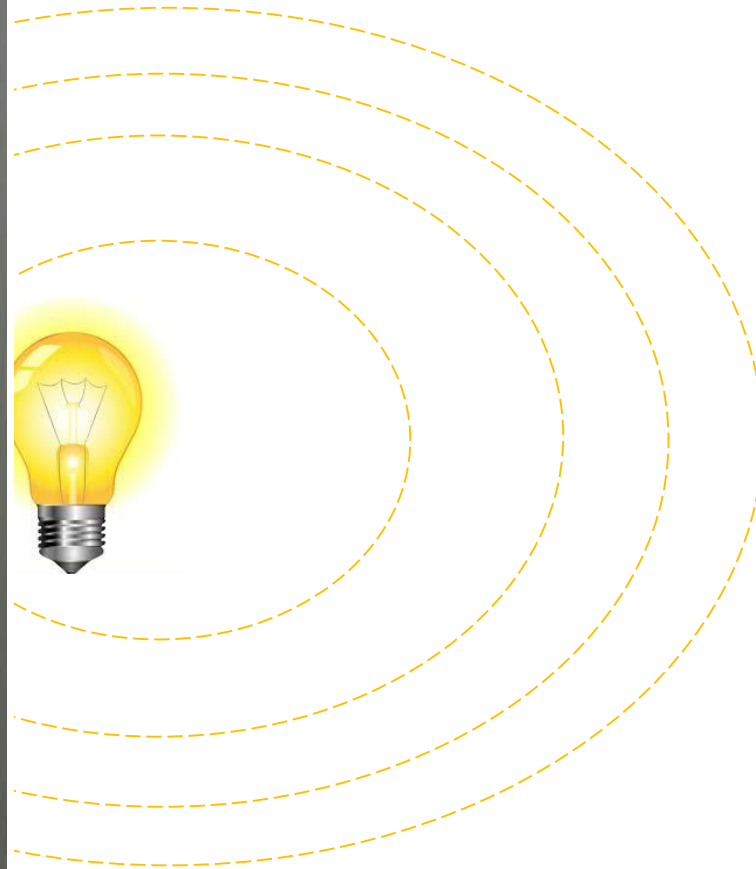
Isotropic Antenna 1 Watt



Antenna Operation

EIRP

Equivalent
Isotropically
Radiated
Power



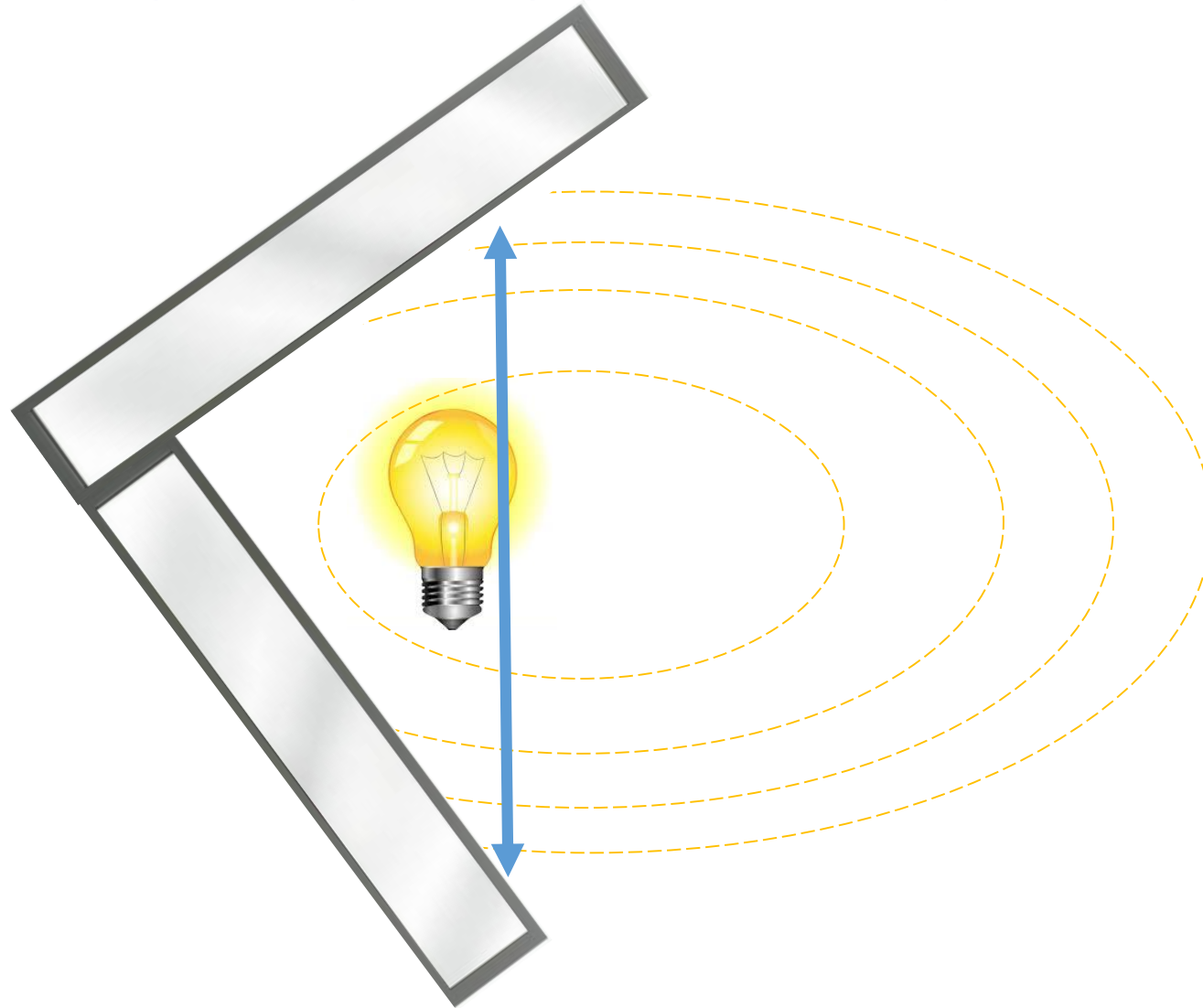
Gain

2 Watt
3dBi

Antenna Beam Width

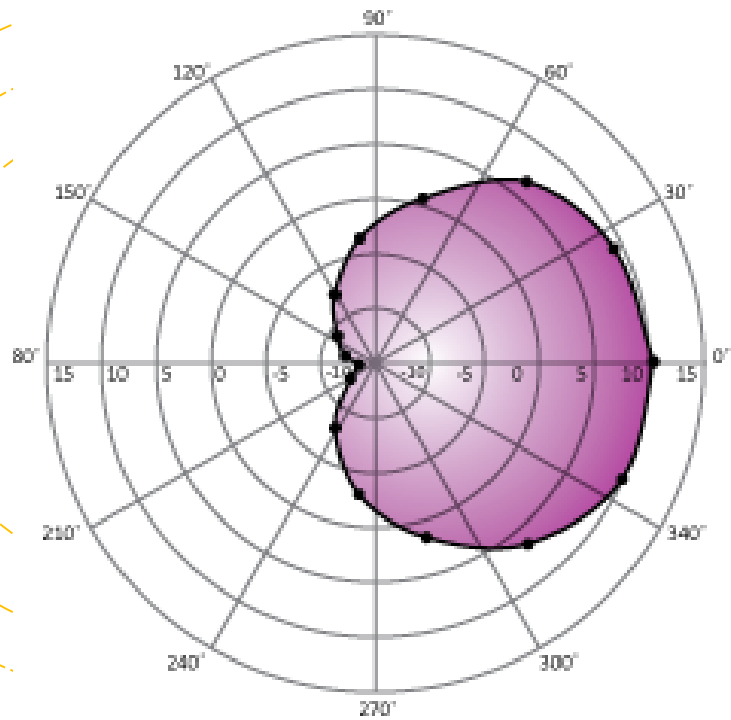
Beam Width

Angle at Which
Gain decreased
by -3dB

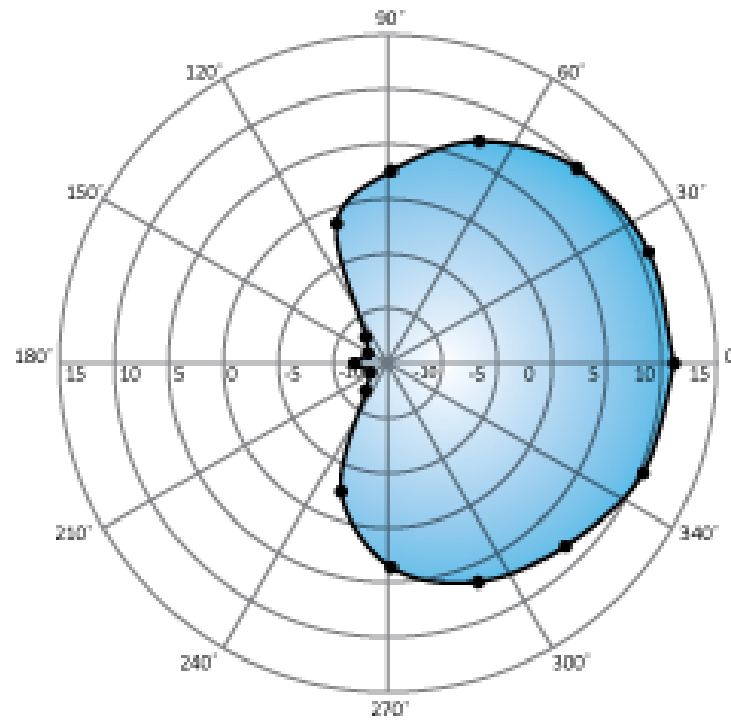


Antenna Operation

Sector

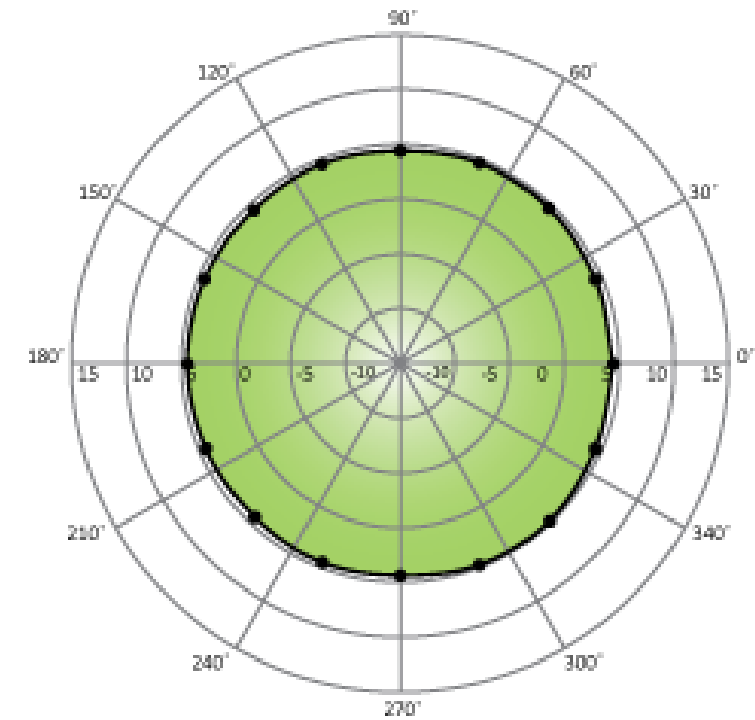


Omni with Reflector



Beam Width -120

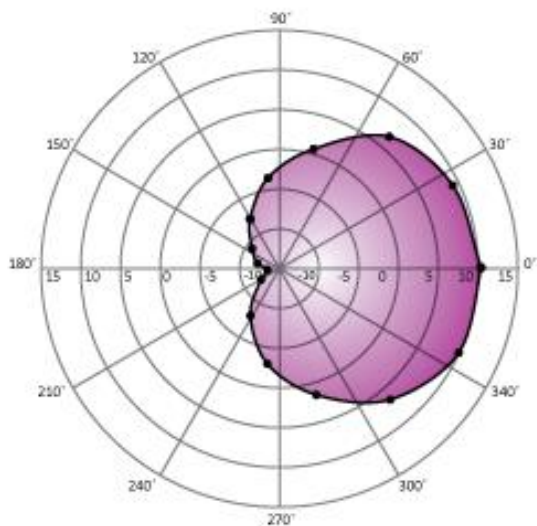
Omni (Full Coverage)



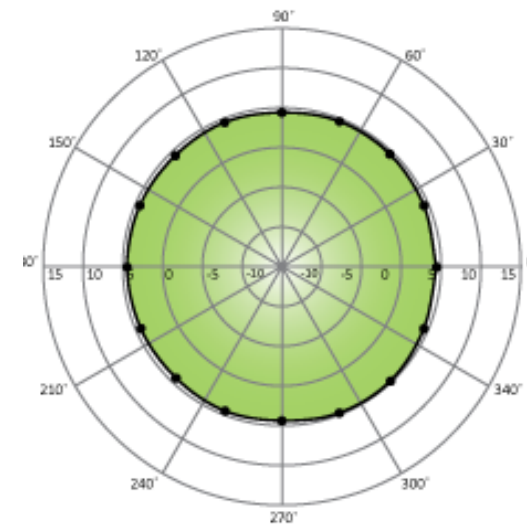
Beam Width -360

Antenna Operation

Sector

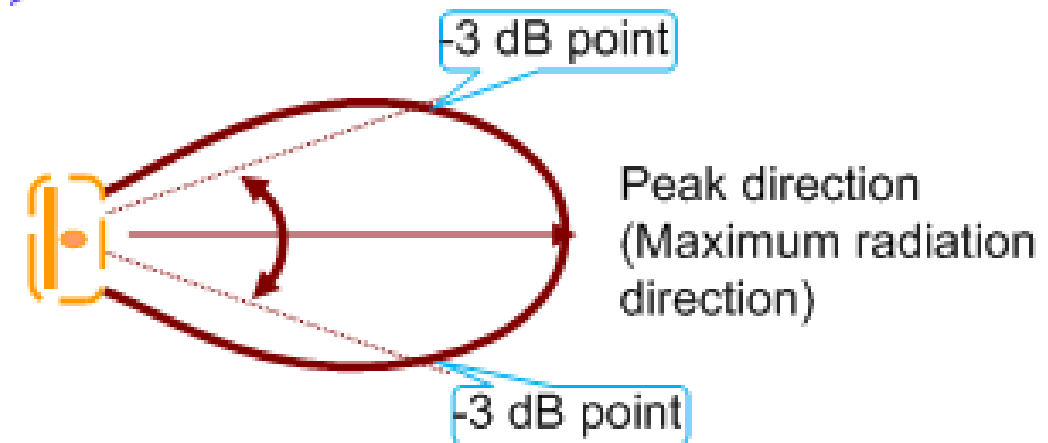
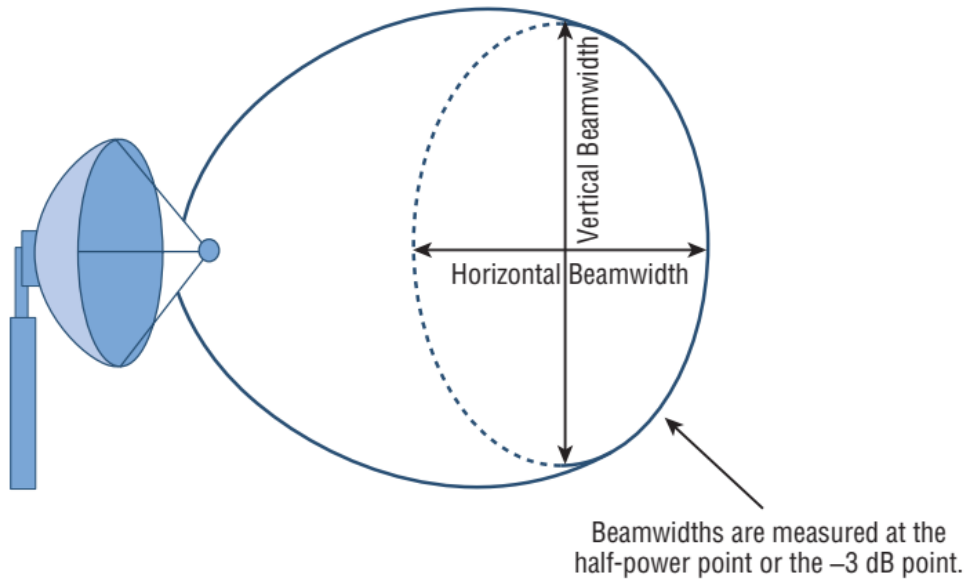


Omni (Full Coverage)



Antenna Beam Width

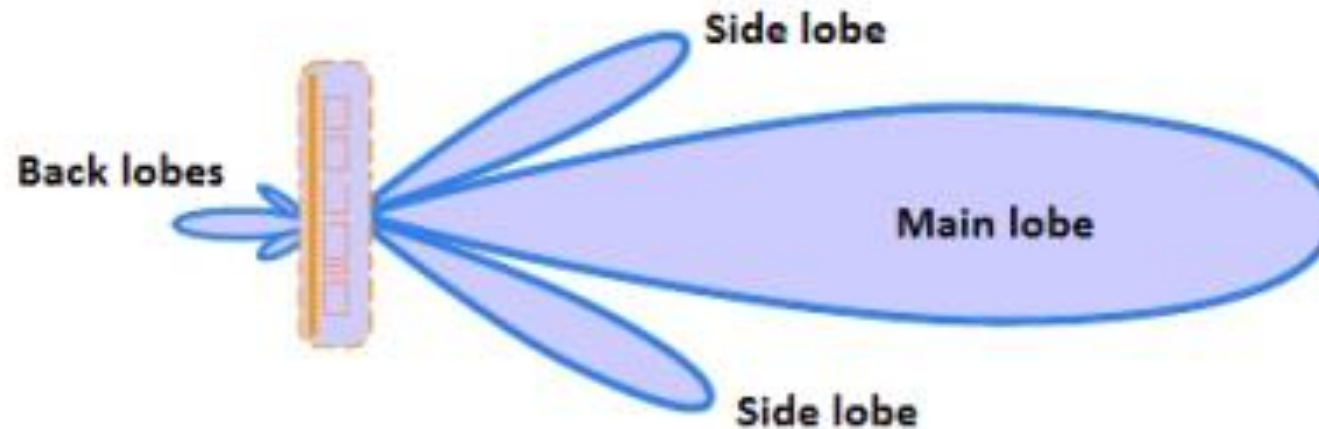
- **Beamwidth** is the angle of measurement of the main **RF lobe** measured at what is called the *half-power point*, or *-3 dB point*.
- This is where the RF power decreases by **50 percent**.
- **Antenna beamwidth** is measured both horizontally and vertically, in **degrees**.
- As Beamwidth change – pattern changes and coverage area changes



Antenna Lobes

- Antenna Send Signal at Main Direction
- Some of Signal Distorted at other Direction
- **Main Lobe** : Direction of Maximum Transmission energy
- **Major Lobe** : additional Lobes to sides or back of main lobe

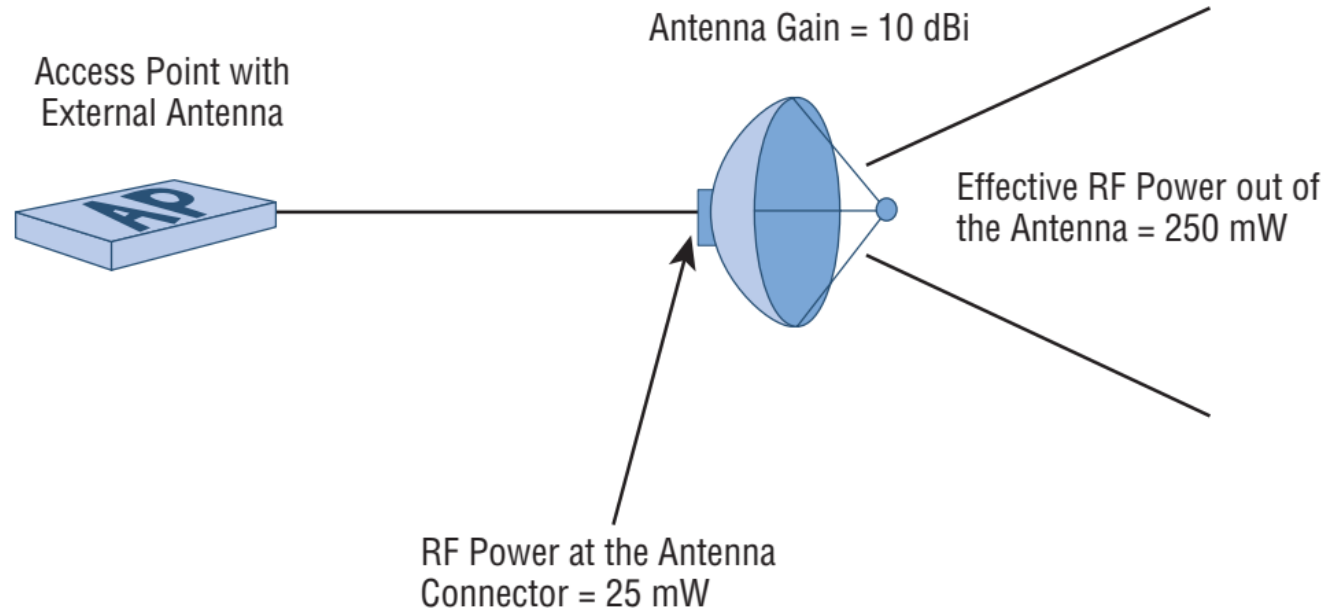
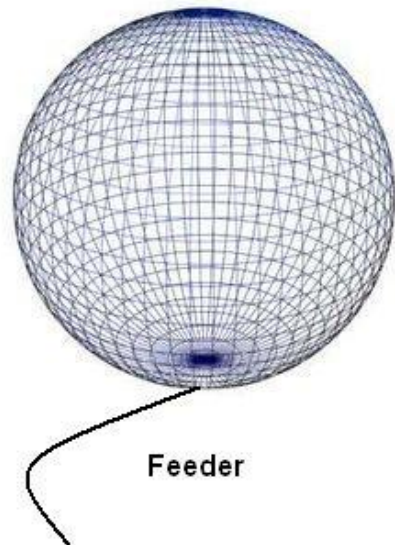
ANTENNA PROPAGATION PATTERN



Antenna Gain

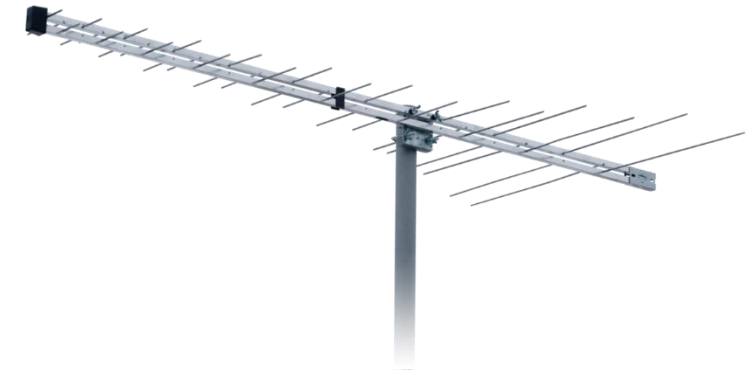
- **Antenna gain** is measured in decibels isotropic (**dB*i***)
- **Gain** is change in intensity as a result of increasing the isotropic energy.
- **Isotropic** energy is defined as energy emitted equally in all directions.
- **Antenna** Considered Passive Gain not active Gain – Just Focus Signal in certain Direction

Radiation pattern from Isotropic antenna

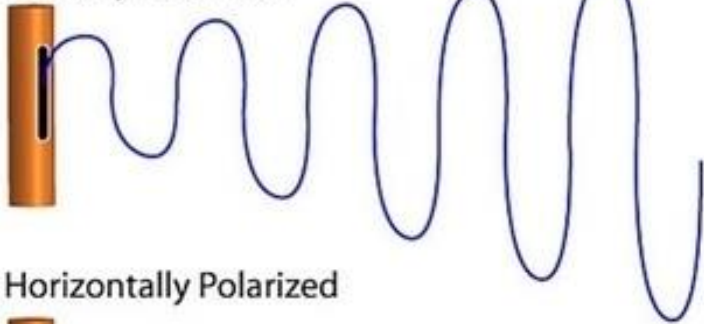


Antenna Polarization

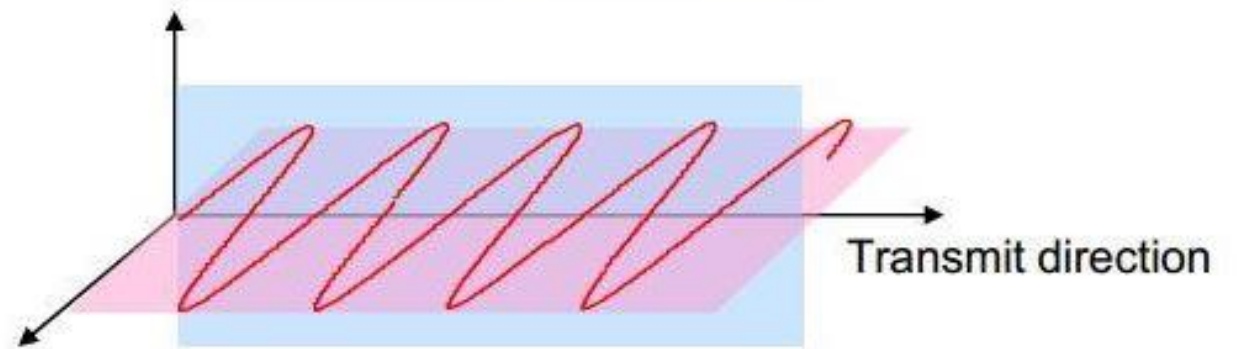
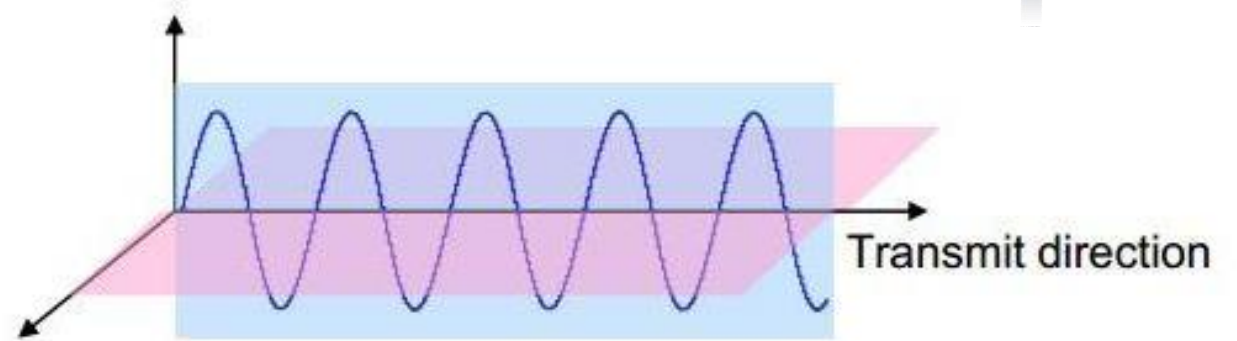
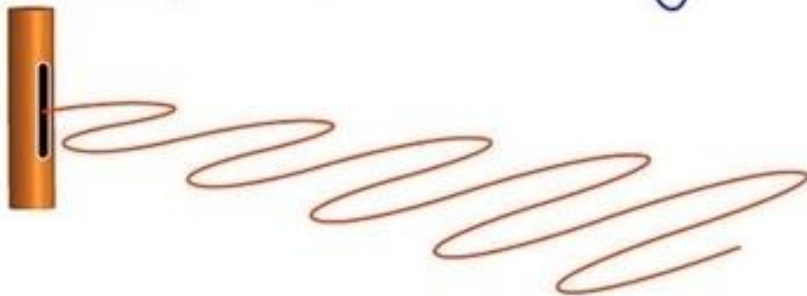
- How an antenna is mounted (Horizontally or Vertically)
- Vertical antennas can hear other vertical antennas
- Dual Polarized Antenna can hear at both directions
- Transmitter and Receiver should have same Polarization



Vertically Polarized

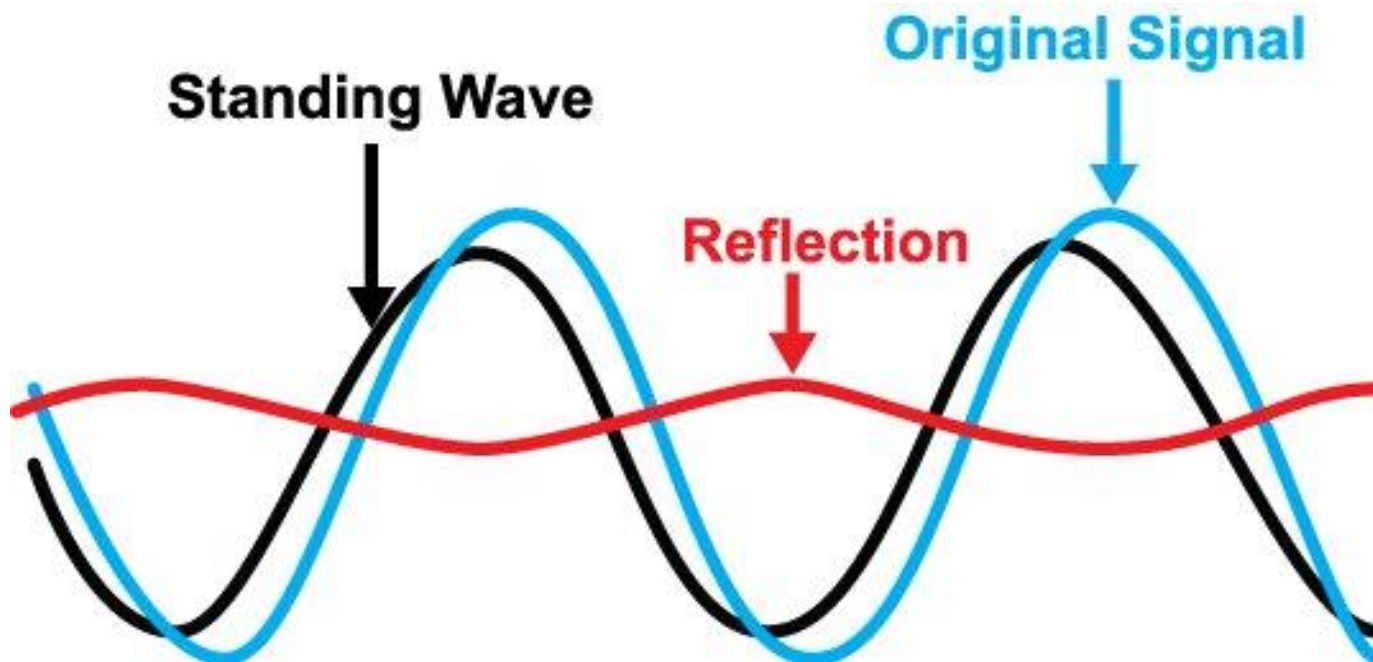


Horizontally Polarized



Antenna Impedance

- **Impedance** is the measurement of alternating current (AC) resistance.
 - Impedance mismatch in a WLAN system almost **50 Ohm** includes antennas, cables and connectors
 - impedances of all components should be matched as closely as possible to optimize performance
- Impedance mismatches can result in what is called *voltage standing wave ratio (VSWR)*



Not all power is transferred from feeder to the load

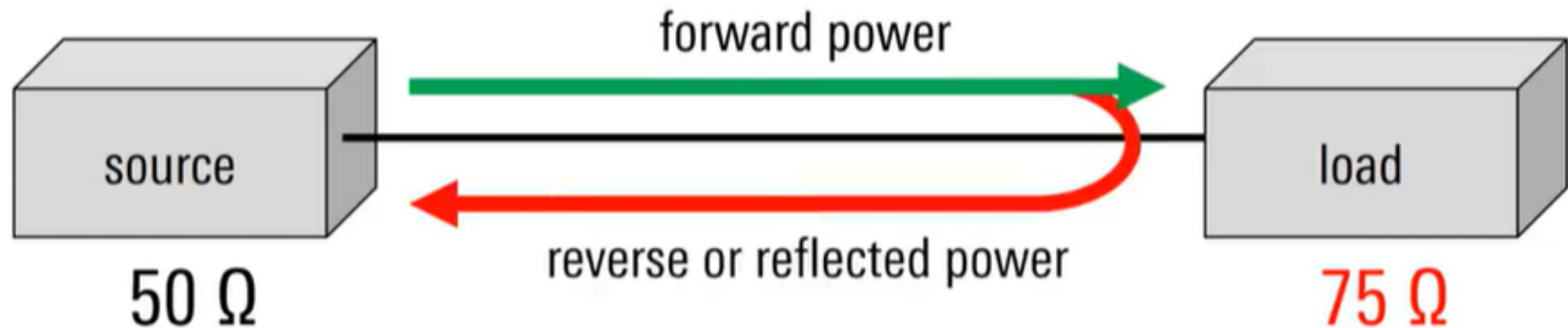
Antenna Impedance VSWR

VSWR is defined as the ratio of the maximum to minimum voltage on a loss-less line.

The resulting ratio is normally expressed as a ratio, e.g. 2:1, 5:1, etc.

A **perfect match** is 1:1 and a complete mismatch, i.e. a short or open circuit is ∞ :1.

Insertion Loss : Losses due To adding Connectors and Cables , usually minor but with bad connecting will resulting in less RF signal and less throughput.



Wireless Training

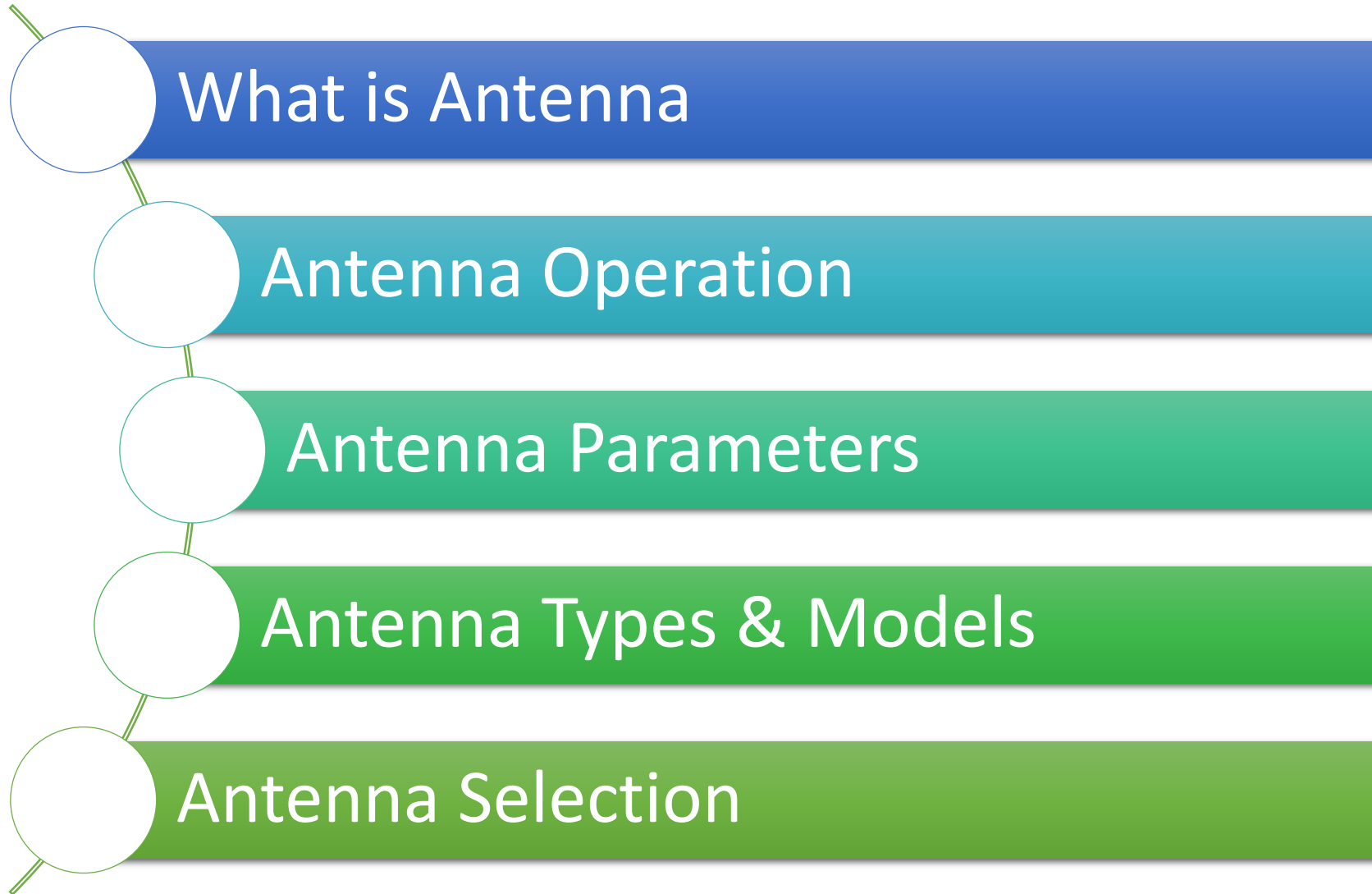
Part 1 – Session 7

RF BASICS

Antenna Types & Design

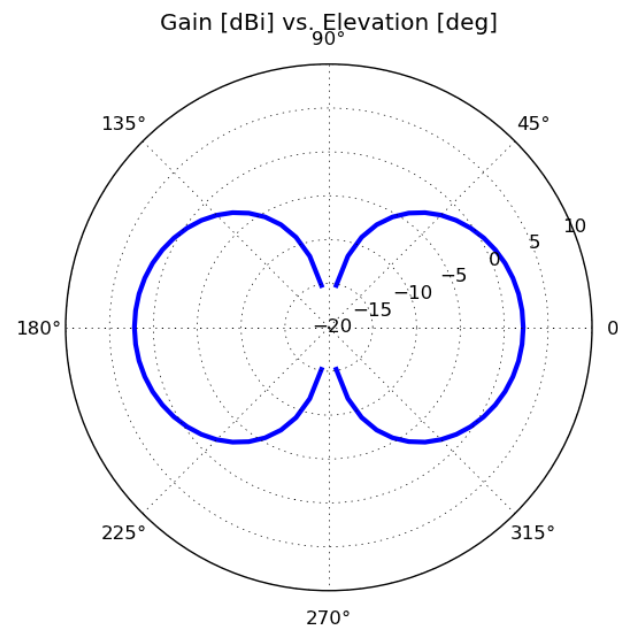
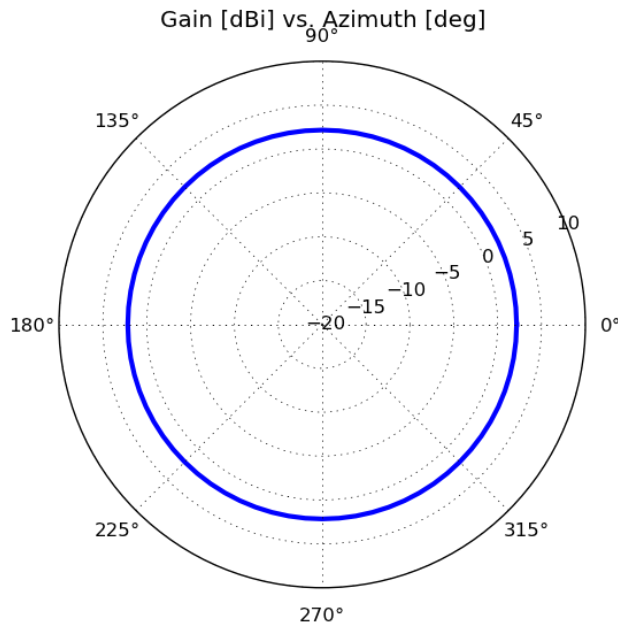


Antenna

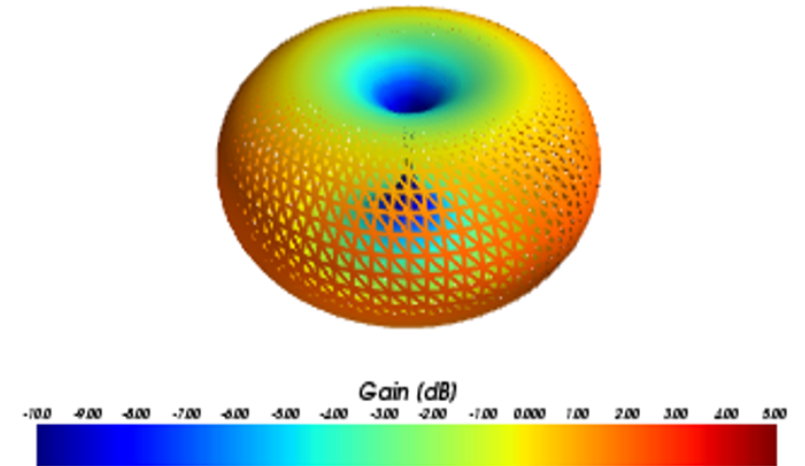


Antenna Charts

- **Antenna charts** show the **angles of RF propagation** from both the azimuth (horizontal or looking down, top view) and the elevation (vertical or side view).
- They give a general idea of the shape of the **RF propagation lobe** based on antenna design.

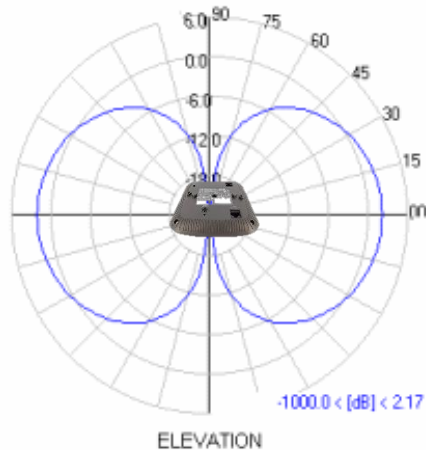
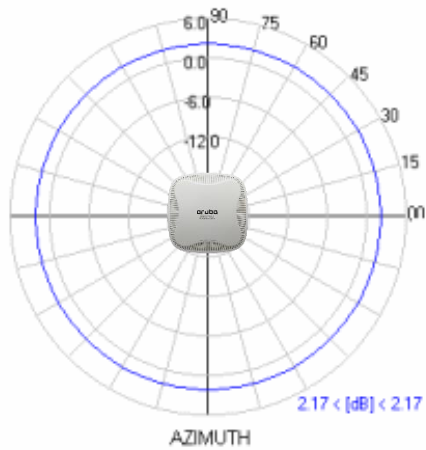
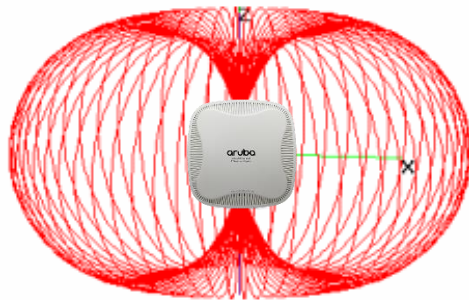


Max Gain (dB): 2.160



Antenna Charts

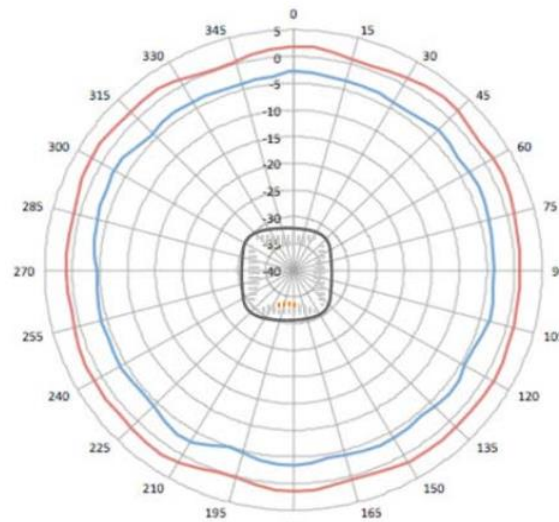
- Antenna charts show the angles of RF propagation from both the azimuth
- Azimuth Horizontal - looking down or top view Elevation - Vertical – Looking side view).
- They give a general idea of the shape of the RF propagation lobe based on antenna design.



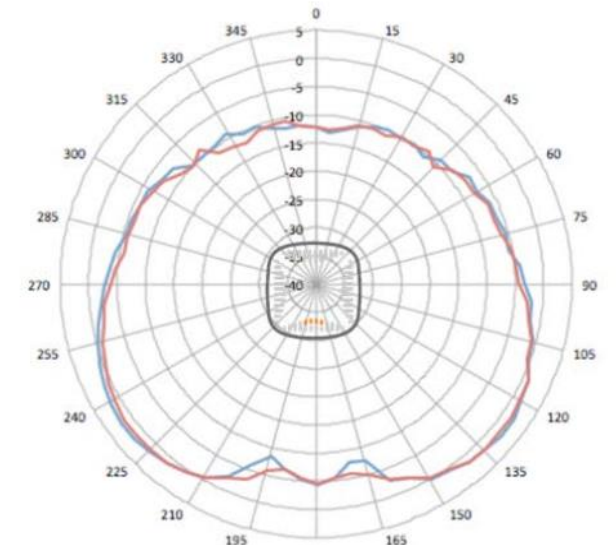
AP-320 ANTENNA PATTERN PLOTS

Horizontal planes (top view, AP facing forward)

Showing azimuth (0 degrees) and 30 degrees downtilt pattern



5.5GHz Wi-Fi (antennas A,B,C,D)



5.5GHz Wi-Fi (antennas A,B,C,D)

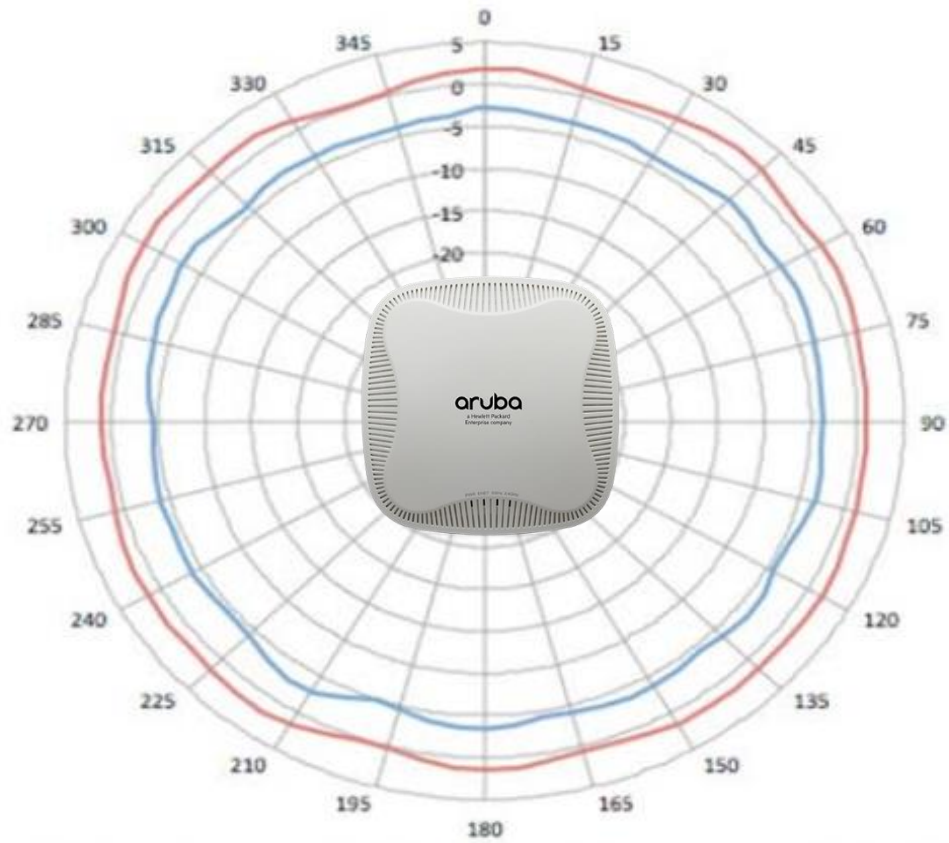


Antenna Charts

AP-320 ANTENNA PATTERN PLOTS

Horizontal planes (top view, AP facing forward)

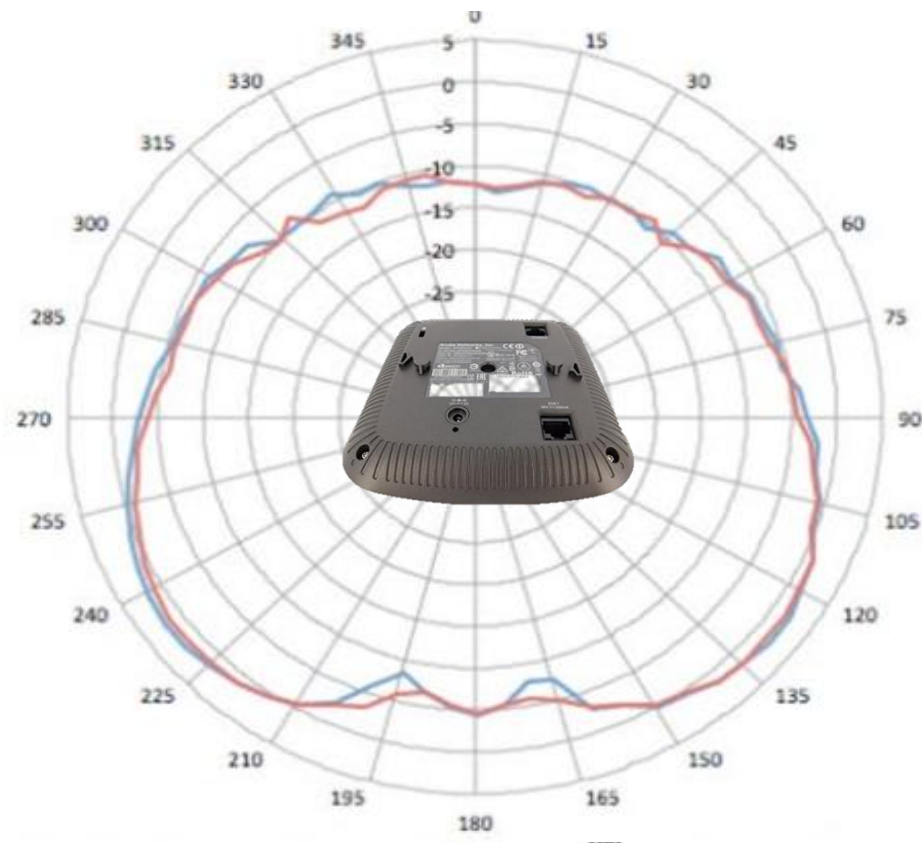
Showing azimuth (0 degrees) and 30 degrees downtilt pattern



— 2.45GHz WiFi Average Azimuth — 2.45GHz WiFi Average Downtilt 30

Elevation planes (side view, AP facing down)

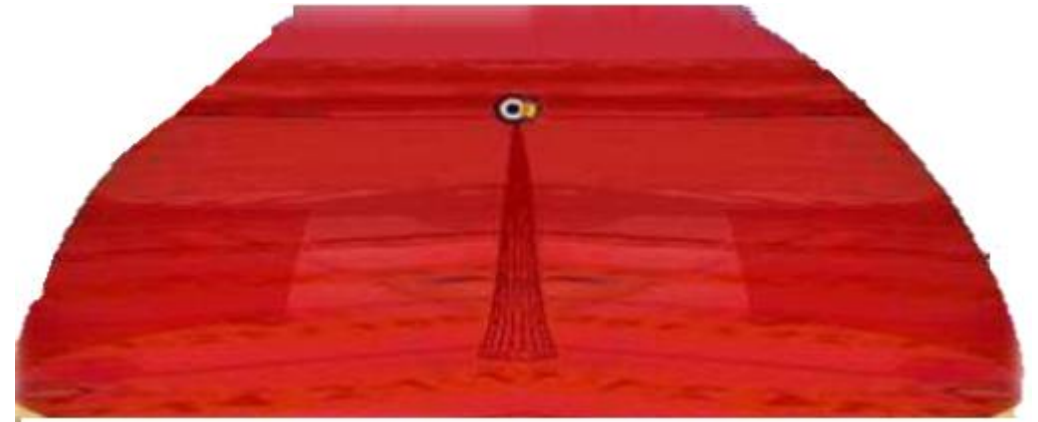
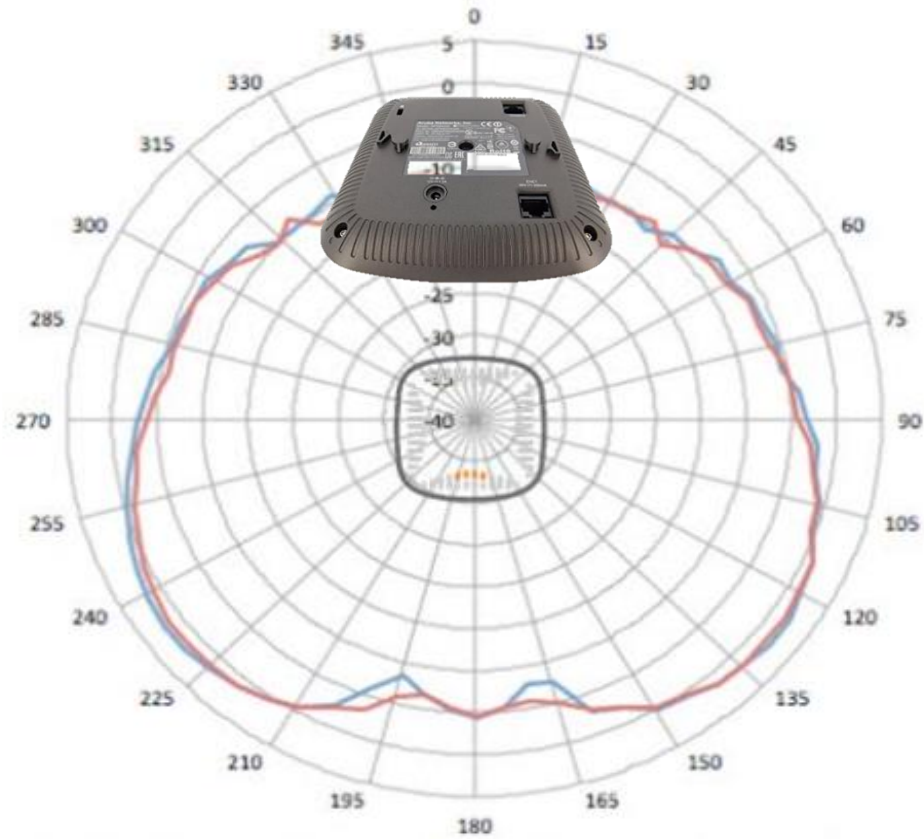
Showing side view with AP rotated 0 and 90 degrees



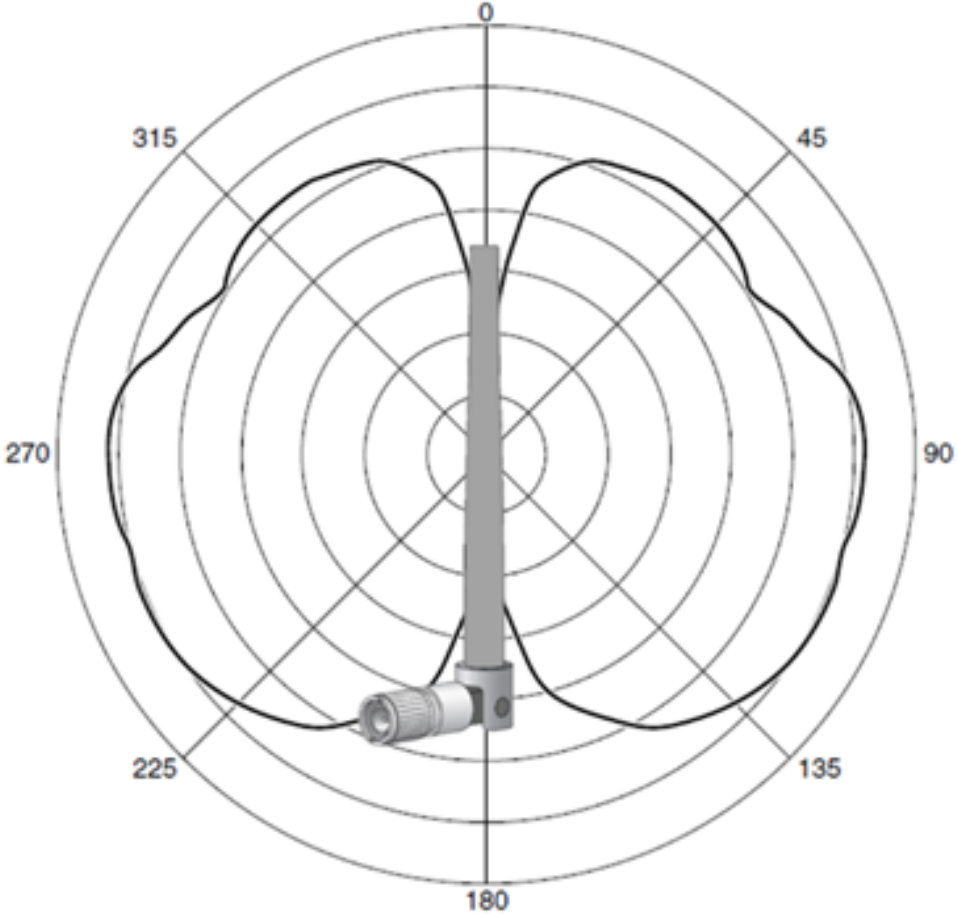
— 5.47GHz Average Azimuth — 5.47GHz Average Downtilt 30



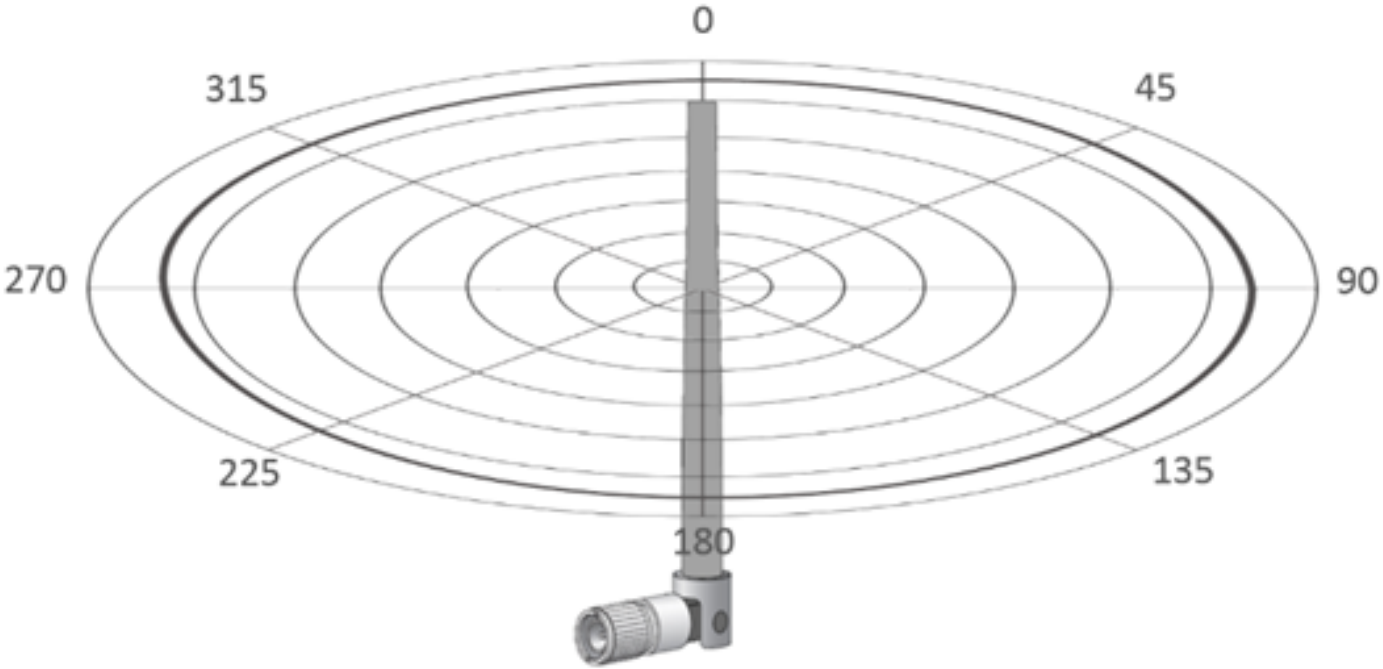
Antenna Charts



Elevation and Azimuth Charts Illustrated



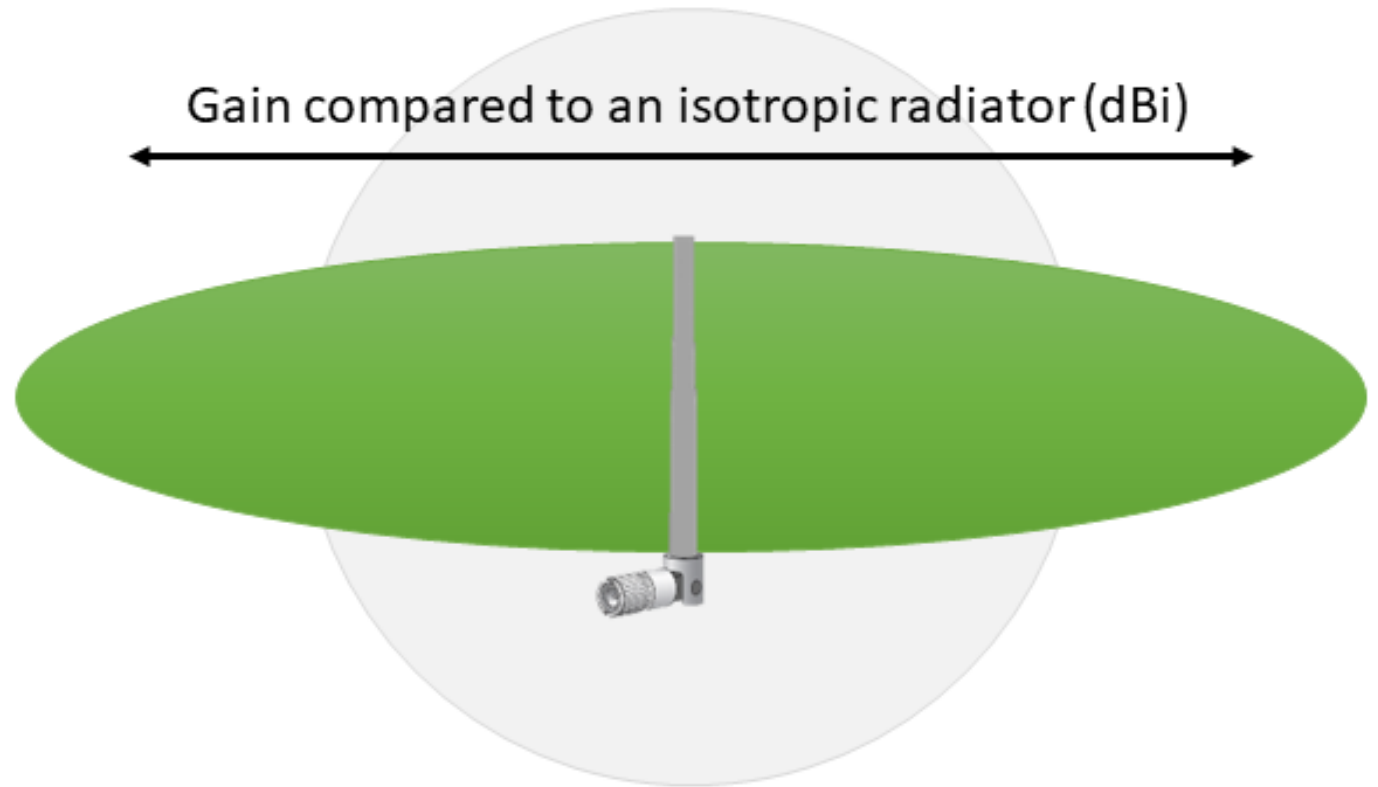
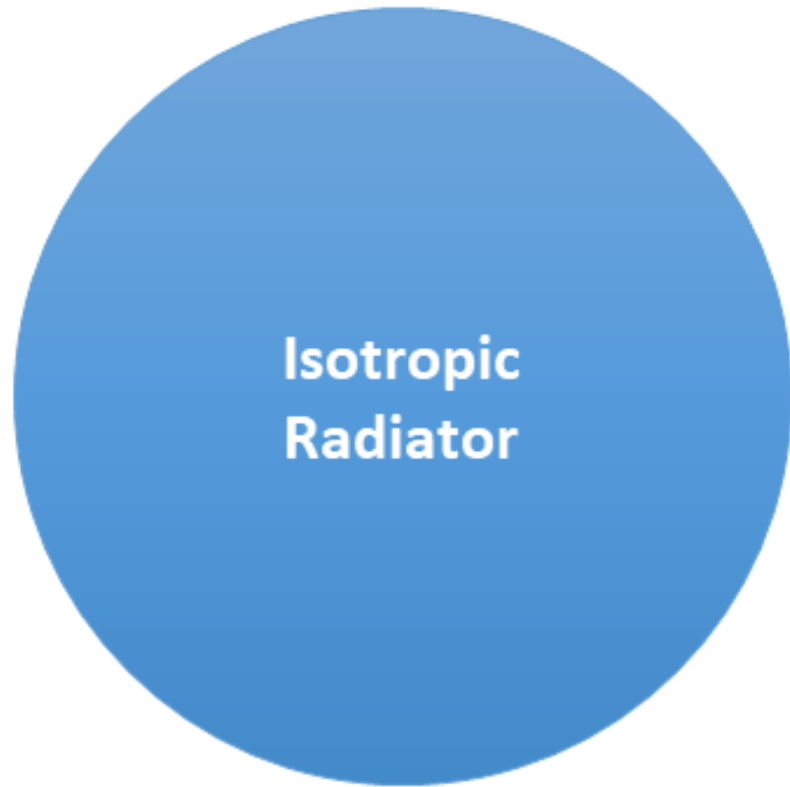
Elevation (Vertical)



Azimuth (Horizontal)

Dipole Antenna Gain

dBi



Antenna Accessories

Short pigtail adapter cable



Cables

Mounting

Connectors

Several common RF connectors used with WLANs



Phoenix Contact 2.4-5.9 GHz surge protection device

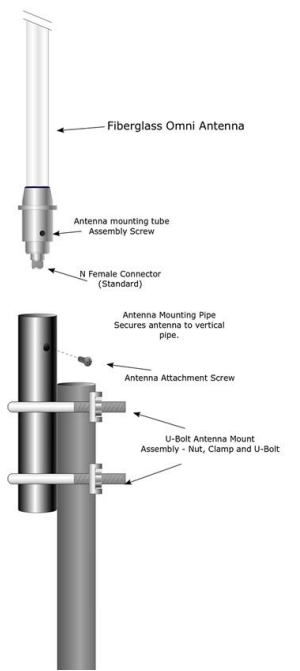


Lighting Arrestor

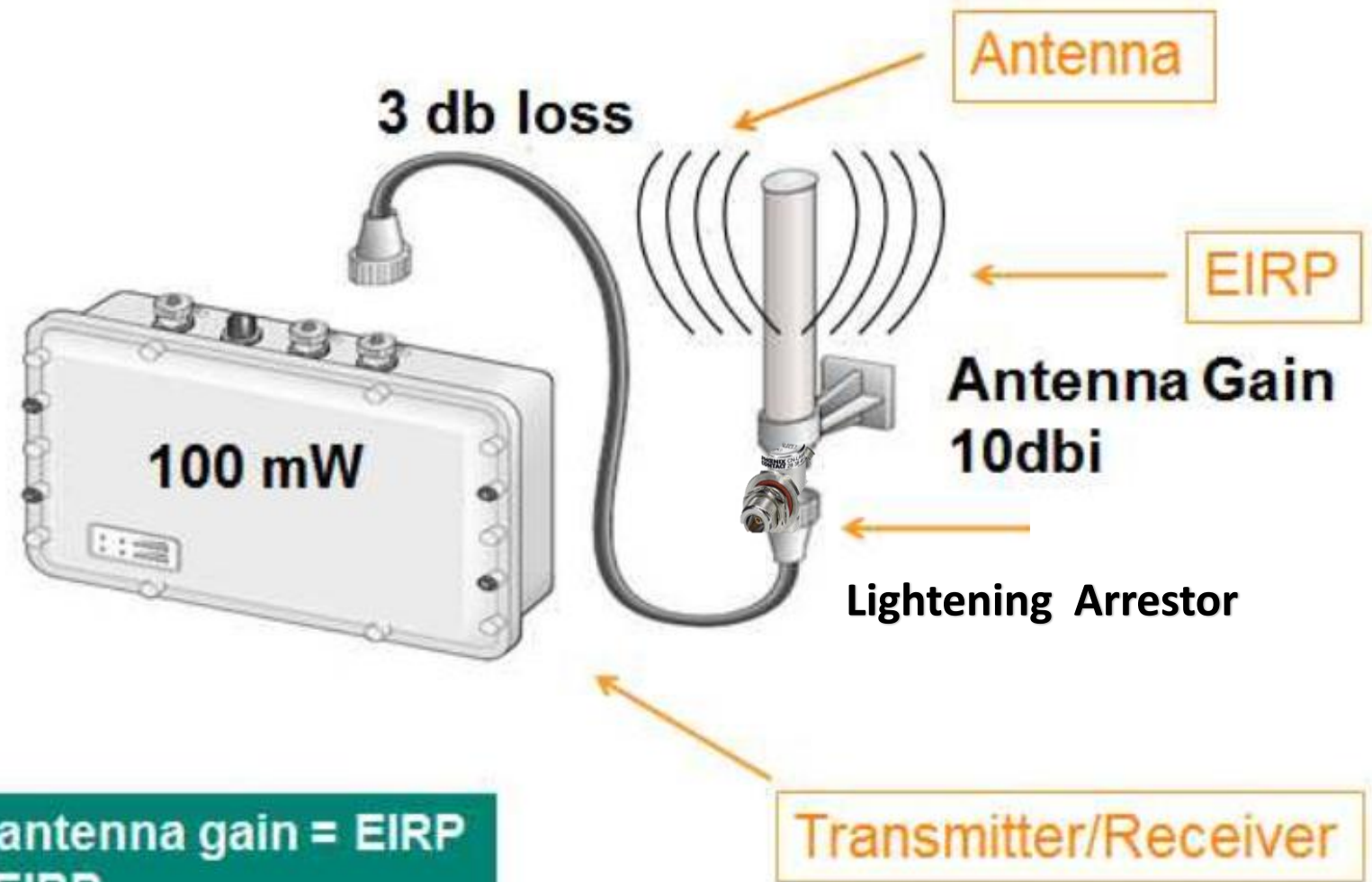
Fiberglass Omni-Directional WiFi Antenna - 12dB - 2.4 GHz Standard WiFi Band



Omni Antenna Mounting Hardware



Calculating EIRP

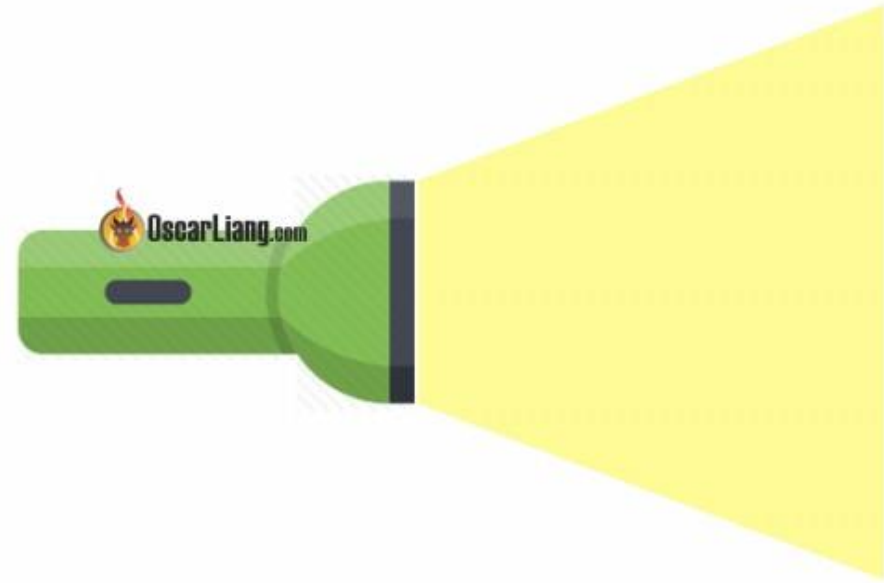


TX Power – cable loss + antenna gain = EIRP
100mW – 3db + 10 dbi = EIRP
20dbm – 3db + 10 dbi = 27dbm

Antenna Types



Omnidirectional



Directional

Antenna Types



Omnidirectional



Patch
Semi-Directional



Dish
Highly Directional

Internal vs. External Antennas

Internal antennas work well for common office space deployments.

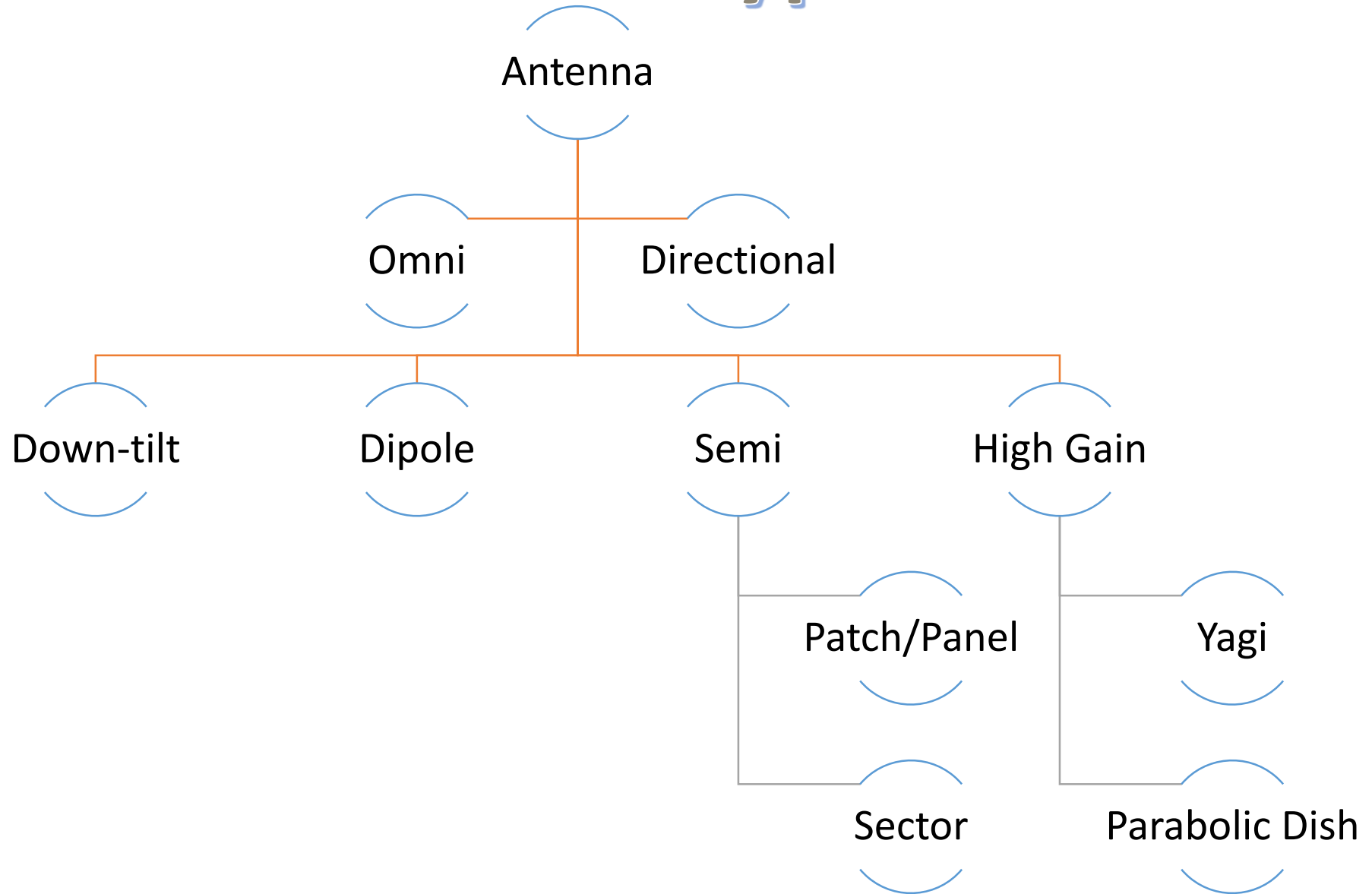


- Most internal AP antennas have a gain of less than 4 dBi.
- For More omnidirectional gain external antennas will usually be required.

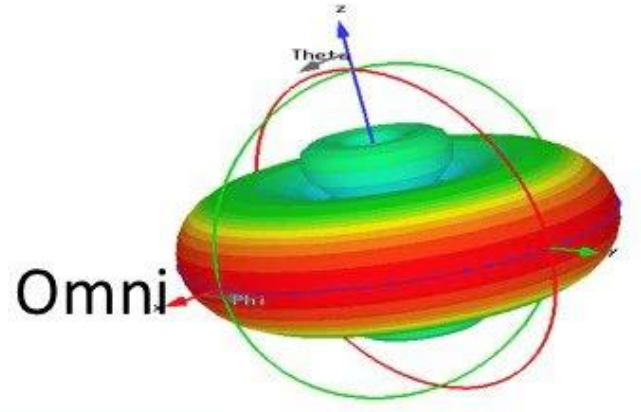
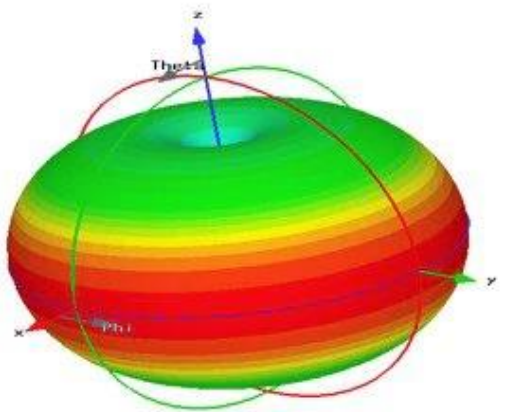
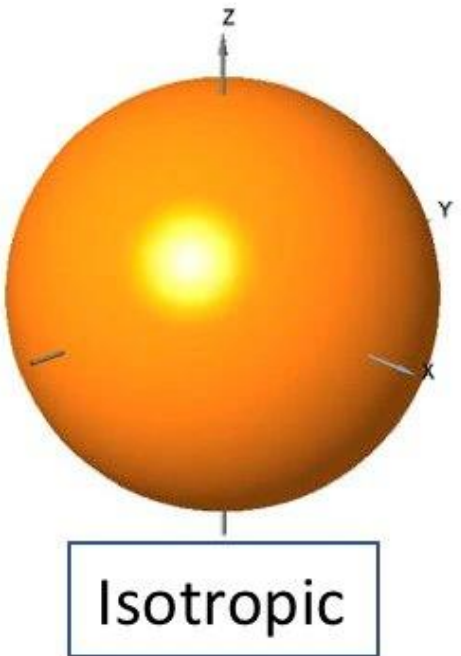


External antennas work well for coverage of large areas or when directionality is needed.

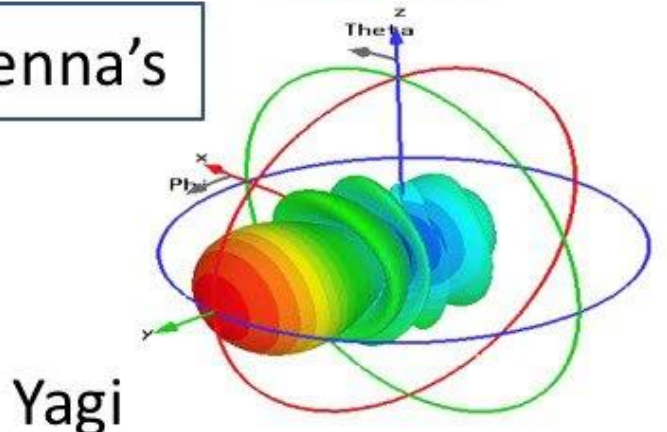
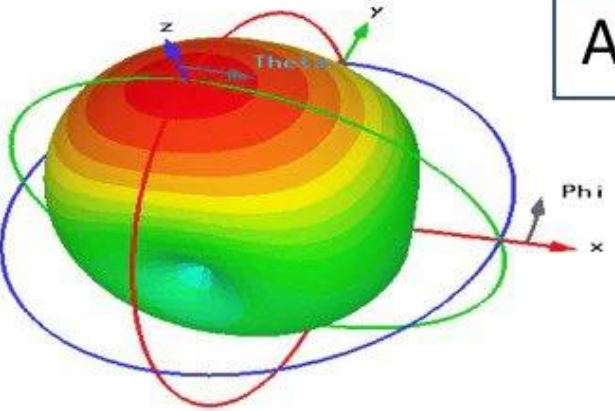
Antenna Types



Antenna Models



Actual Antenna's



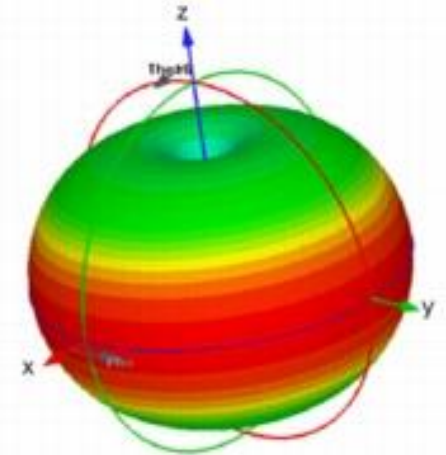
Dipole Antenna



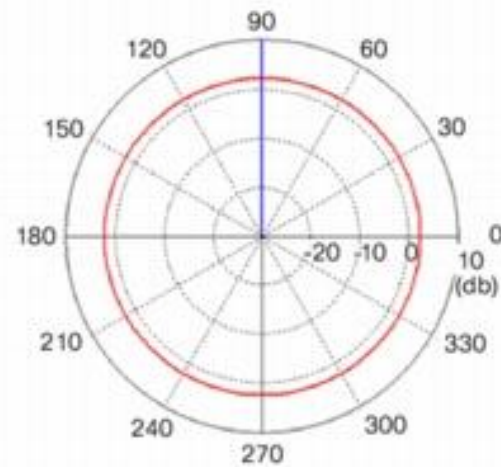
2.4–2.5 GHz and 5.1–5.8 GHz
dual-band rubber duck antenna



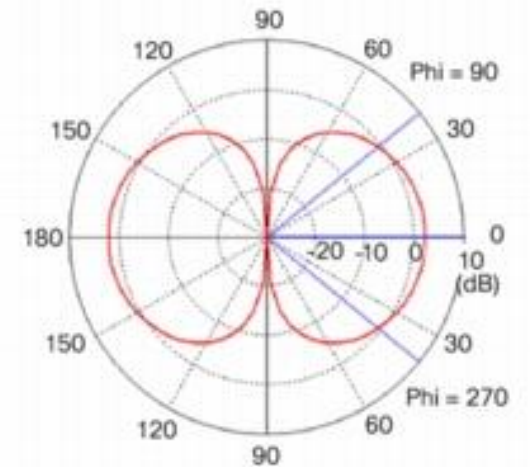
(a) Dipole Antenna Model



(b) Dipole 3D Radiation Pattern

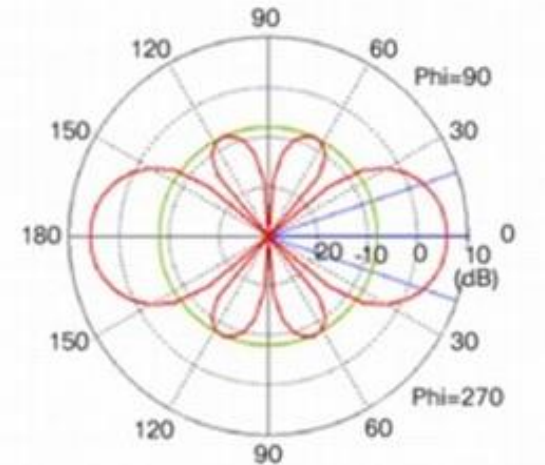
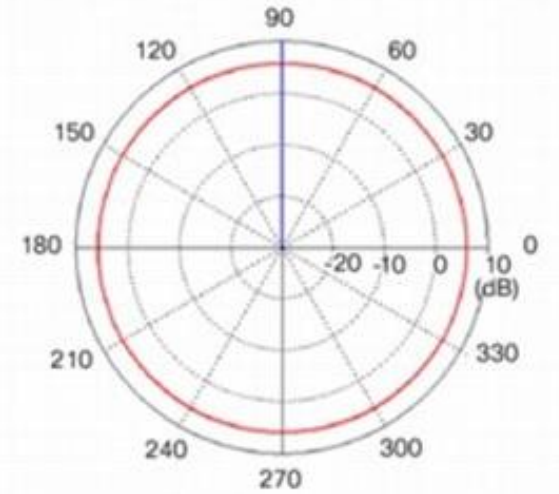
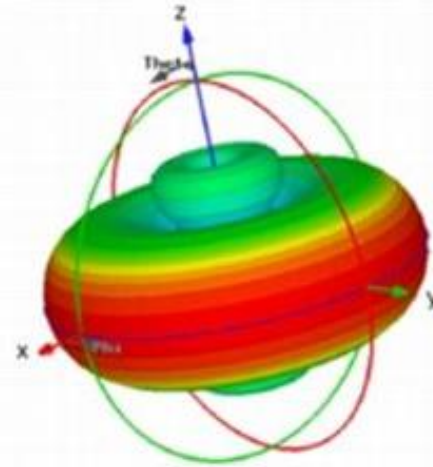
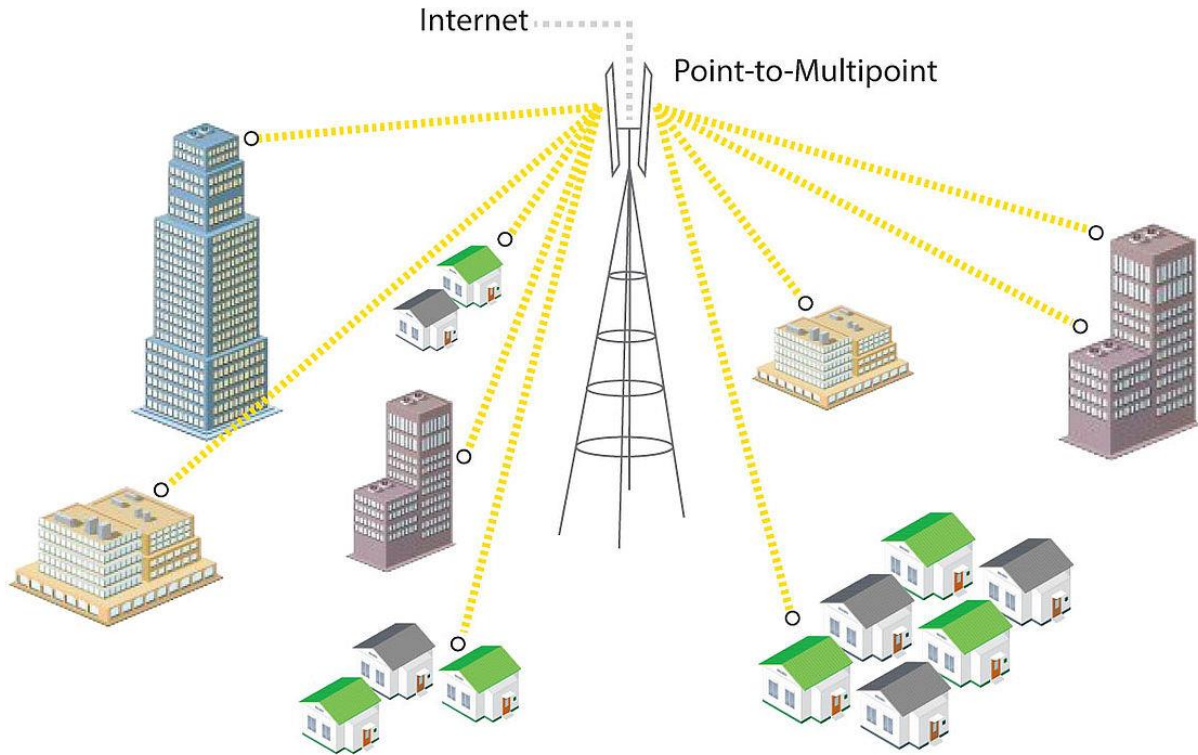


(c) Dipole Azimuth Plane Pattern



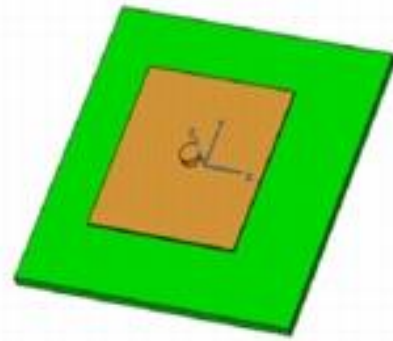
(d) Dipole Elevation Plane Pattern

Omni Antenna

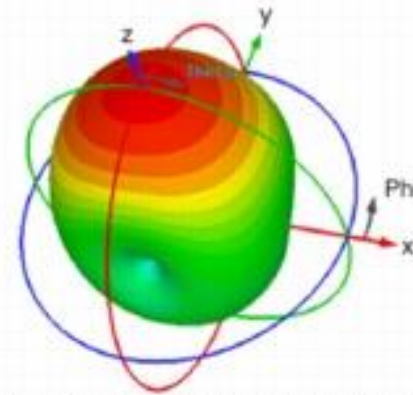


Patch / Panel Antenna

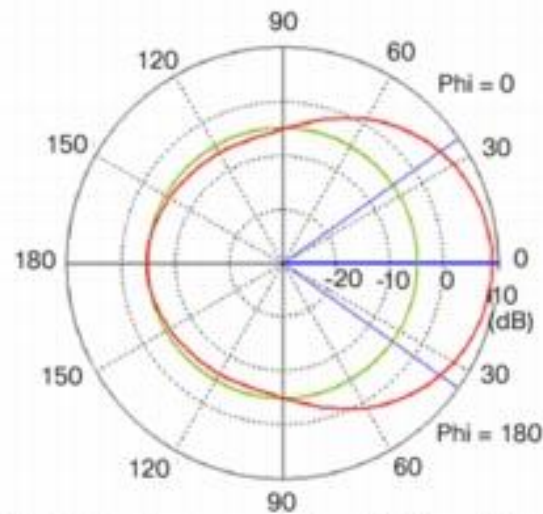
2.4 GHz 11 dBi dual polarization



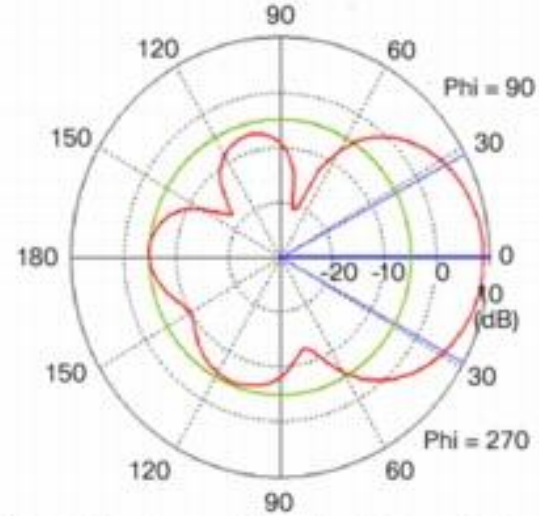
(a) Patch Antenna Model



(b) Patch Antenna 3D Radiation Pattern



(c) Patch Antenna Azimuth Plane Pattern



(d) Patch Antenna Elevation Plane Pattern

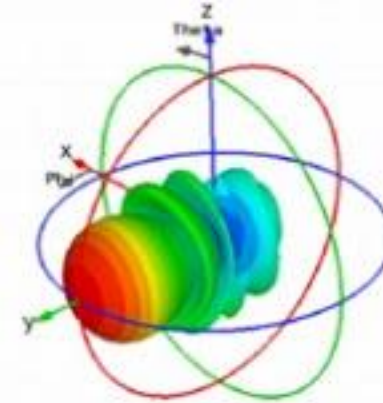


Yagi Antenna

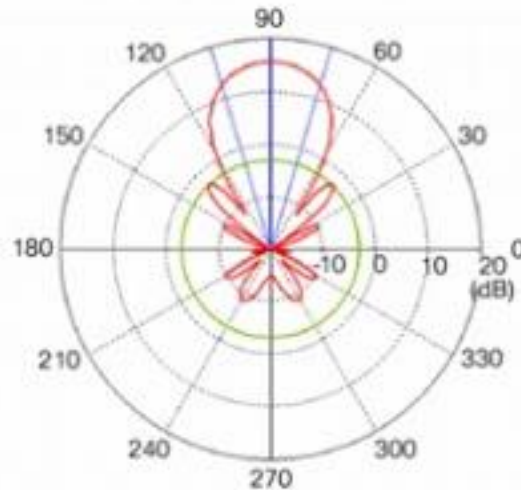
2.4 GHz 15 dBi Yagi WLAN antenna.



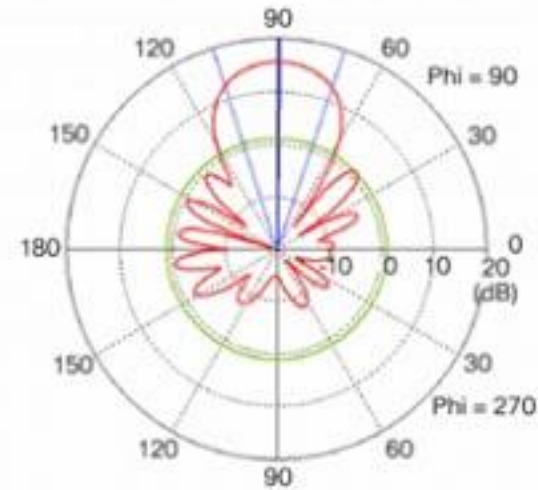
(a) Yagi Antenna Model



(b) Yagi Antenna 3D Radiation Pattern



(c) Yagi Antenna Azimuth Plane Pattern

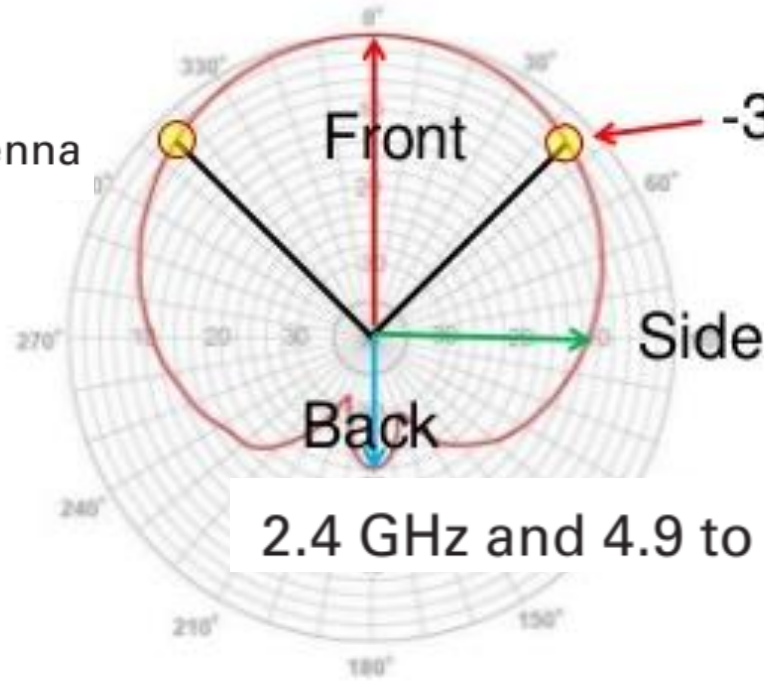


(d) Yagi Antenna Elevation Plane Pattern

Sector Antenna

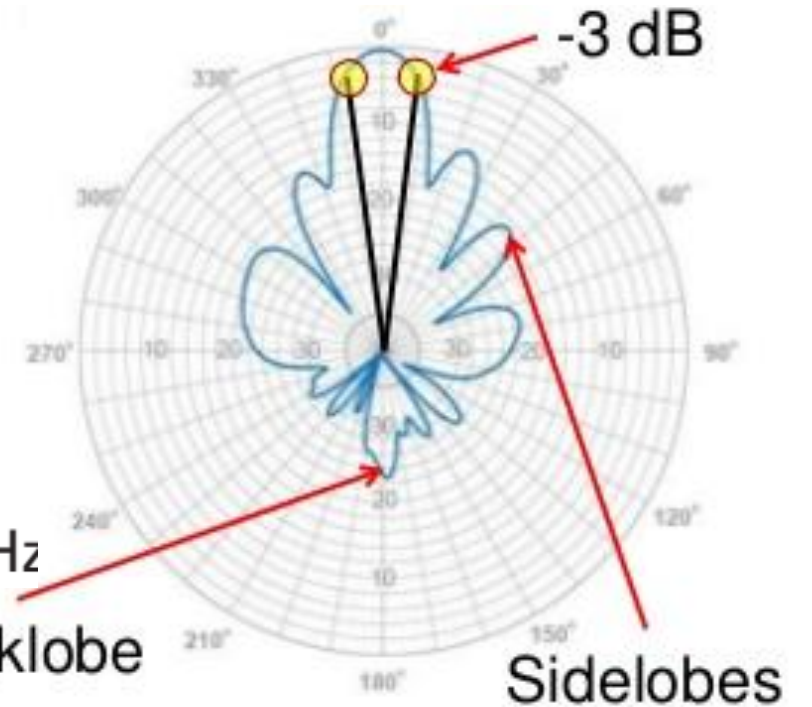
2.4 GHz and 4.9 to 5.8 GHz

dual-band 90° sector panel antenna

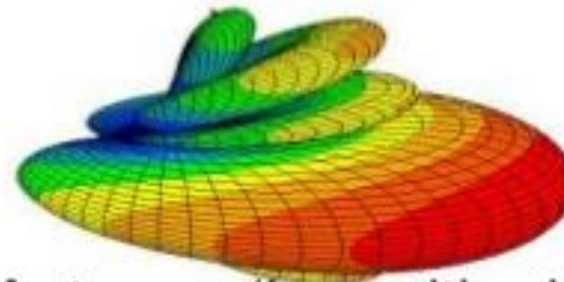


2.4 GHz and 4.9 to 5.8 GHz

Azimuth



Elevation

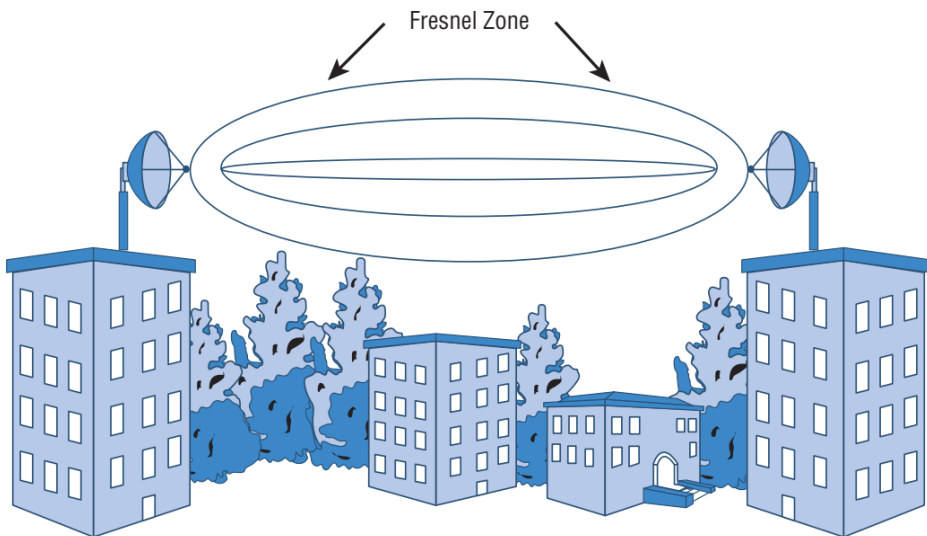
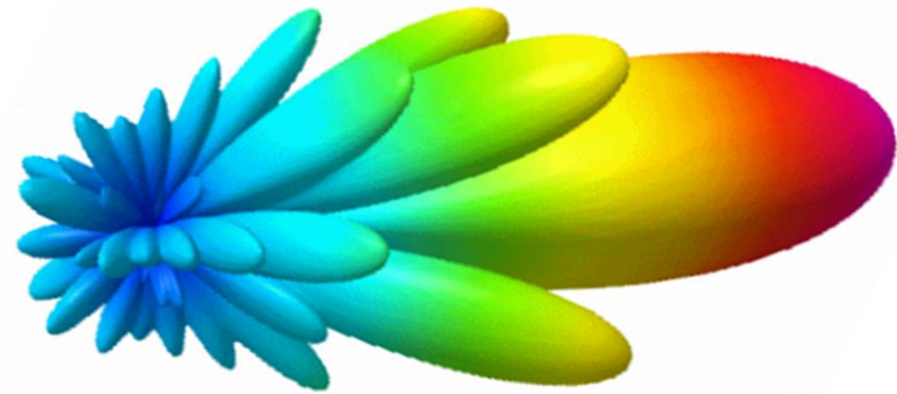


Sector Antenna (Logarithmic View)

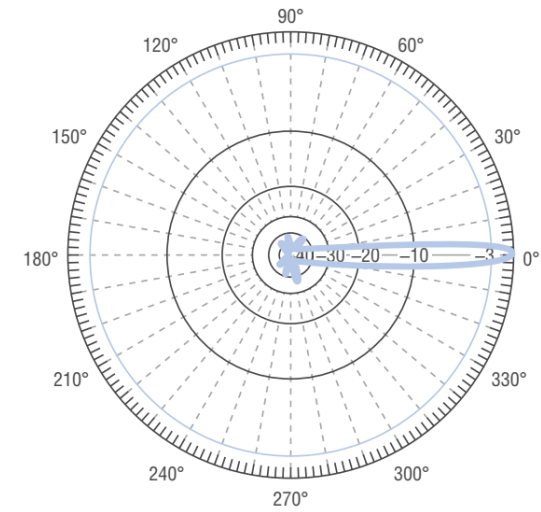
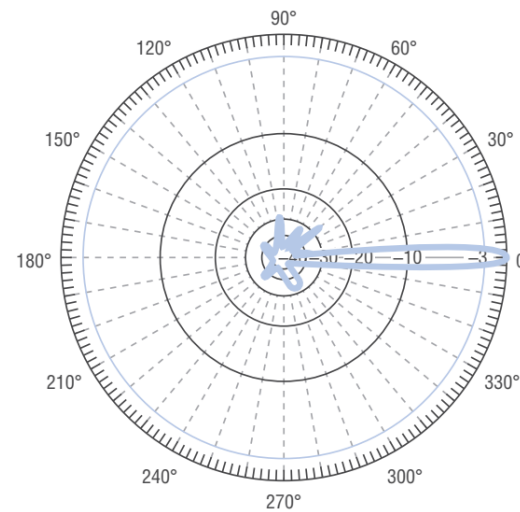


High Gain Directional Antenna

5.8 GHz 29 dBi ISM / U-NII band parabolic dish

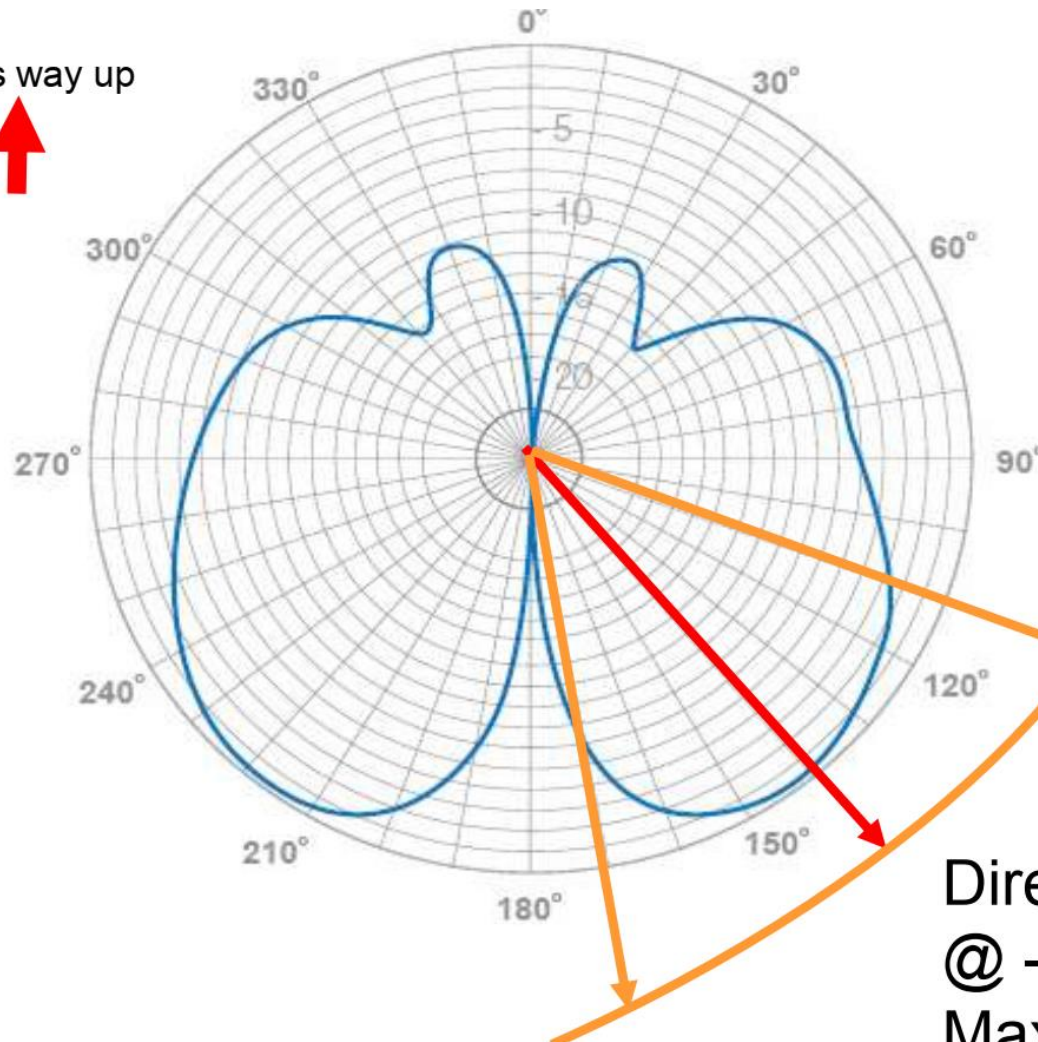


HG5829D



Down Tilt Antenna

This way up



Downtilt

Omnidirectional

+3 dBi Gain at -45°

“downtilt” angle in the E-plane (Vertical Direction)

$3 \text{ dBi} - 3 \text{ dB} = 0 \text{ dBi @ } -20^\circ$

Direction of Maximum Gain

@ -45° to ceiling

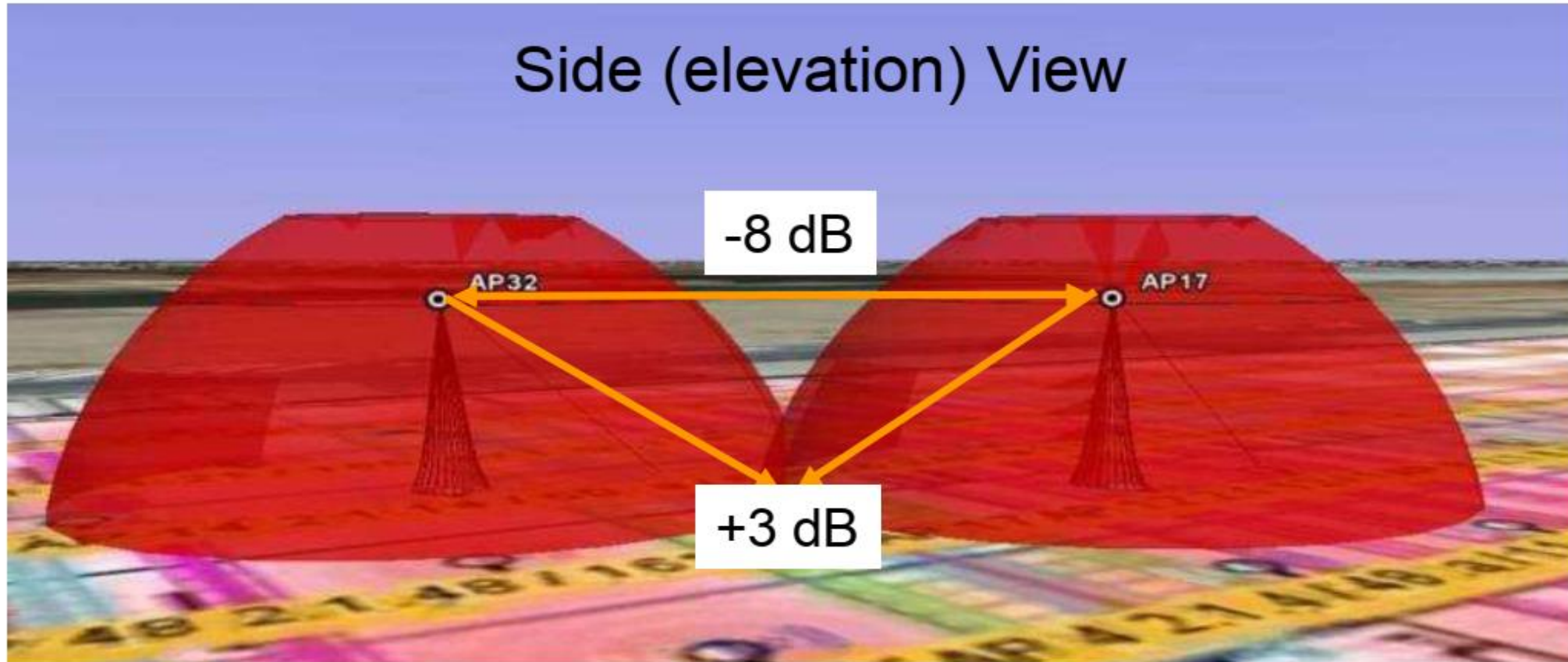
Max Gain = +3 dBi

$3 \text{ dBi} - 5 \text{ dB} = -2 \text{ dBi @ } -80^\circ$

Max Gain is Directed to Clients!



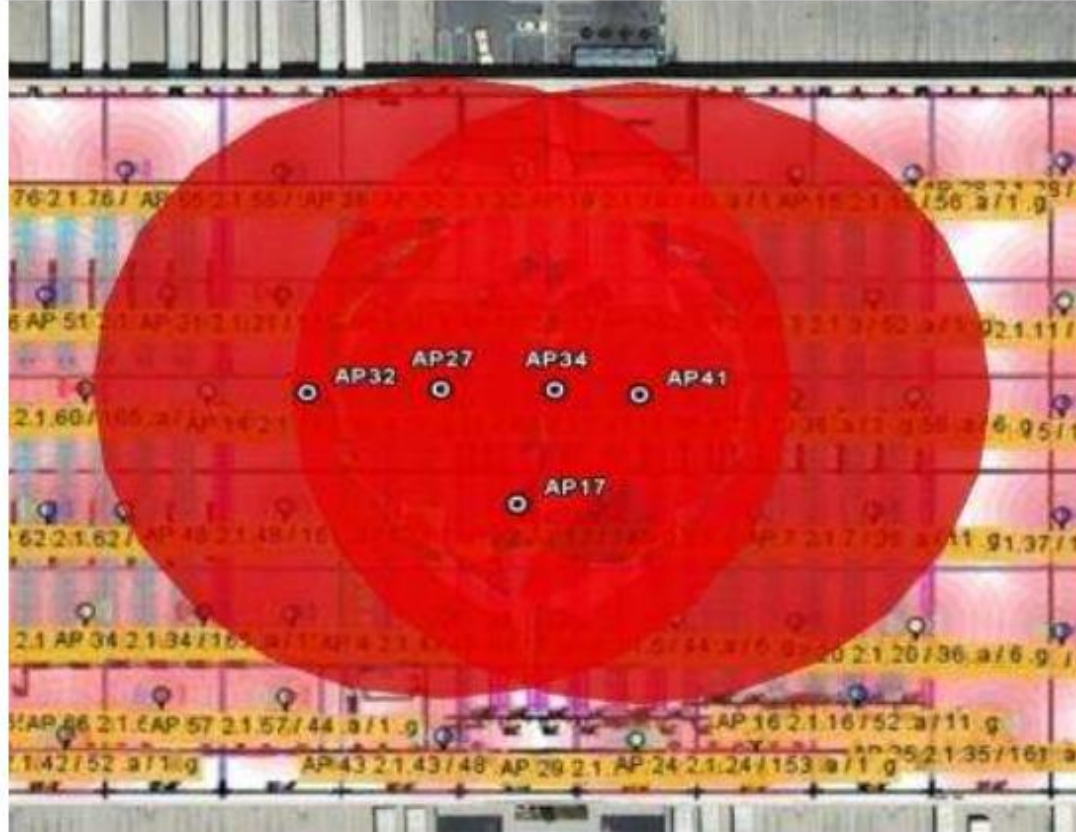
Downtilt Omni – Interference Management



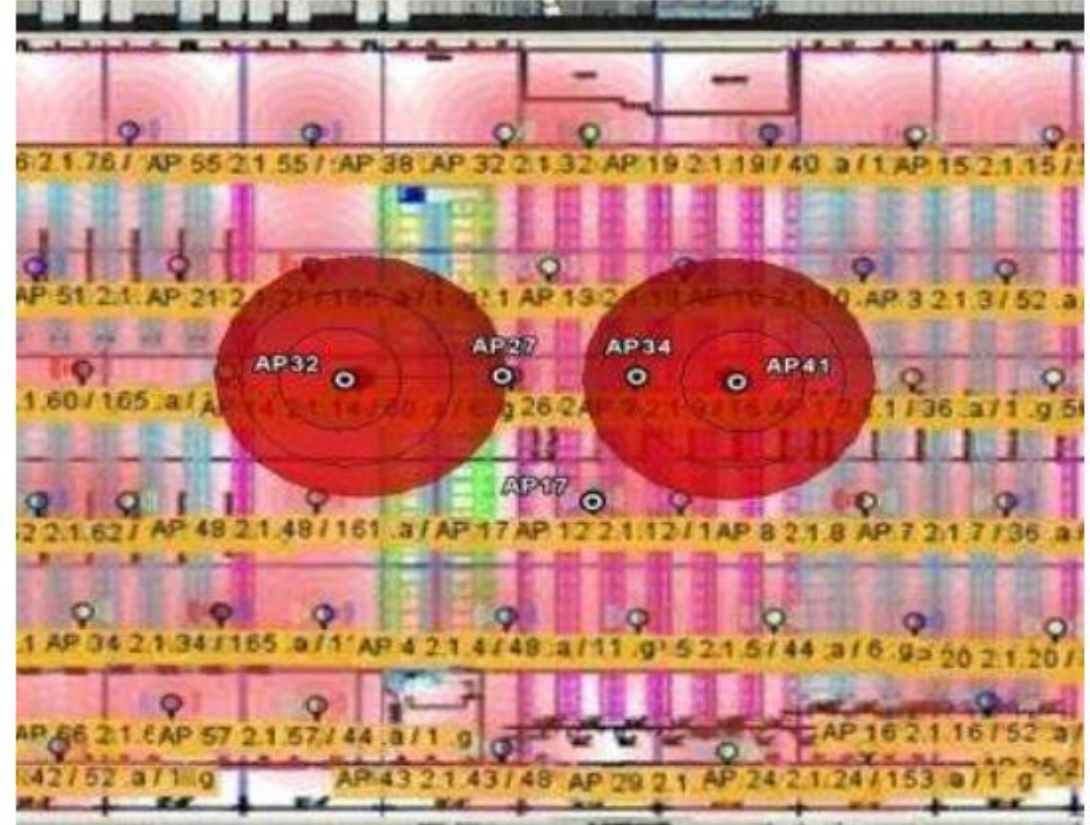
Maximum gain at 45 degrees down

- Reduced AP to AP interference

Antenna Comparison (Plan View)



High Gain Omni (8 dBi)



Downtilt Omni (3 dBi)

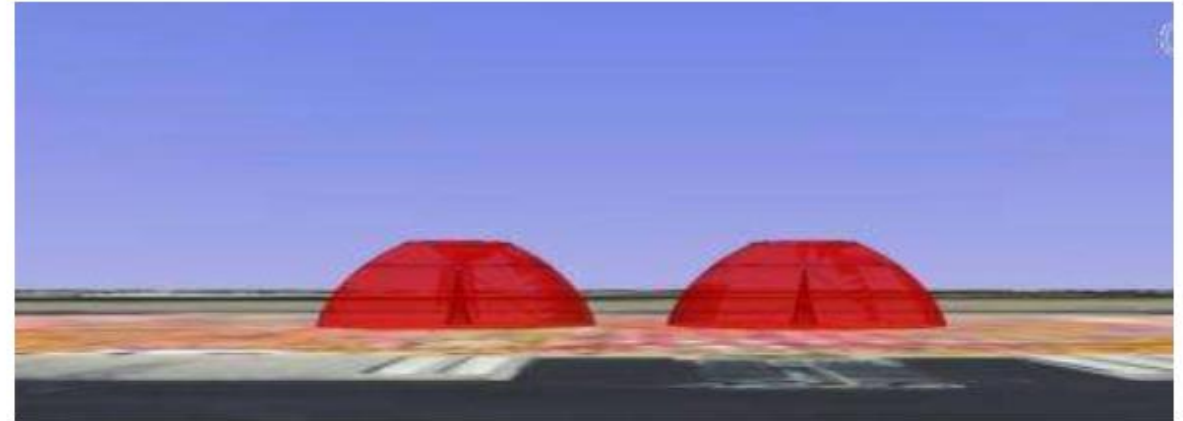
The Horizontal Range of the down tilt antenna is much less than the high gain antenna.

Antenna Comparison (Elevation View)



High Gain Omni

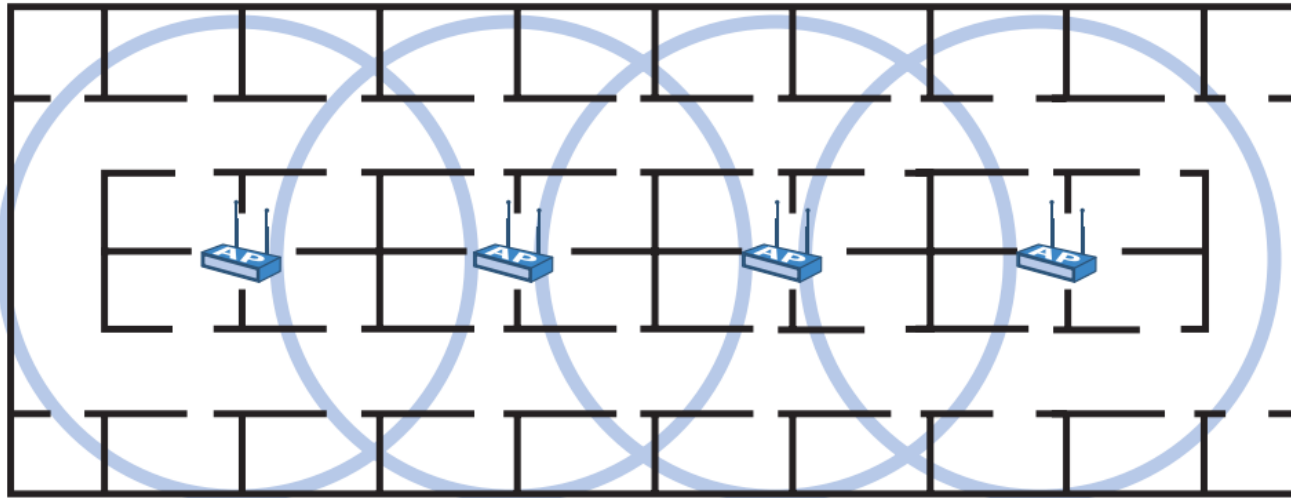
- APs interfere with other APs on the same channel
- But coverage does not reach the clients on the floor.



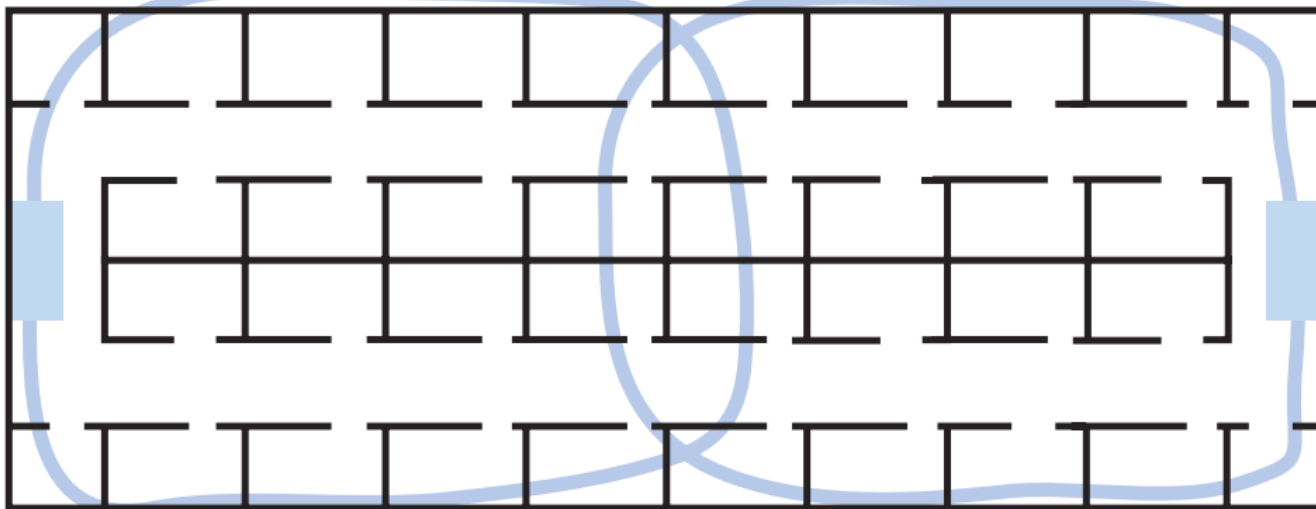
Down tilt Omni

- Coverage does not overlap at the AP height.
- Has omni coverage that reaches the clients on the floor

Directional Patch Antenna



They can be very useful at reducing co-channel interference (CCI) caused by APs that can hear each other in open space



**2 dB Dipole / Omni
Antenna**

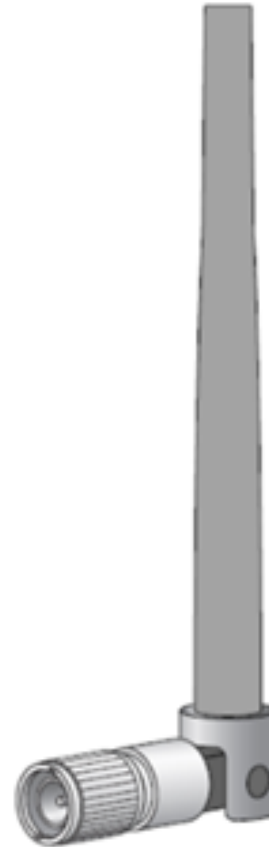


**7 dB Patch/Sector
Antenna**



Antenna Specifications

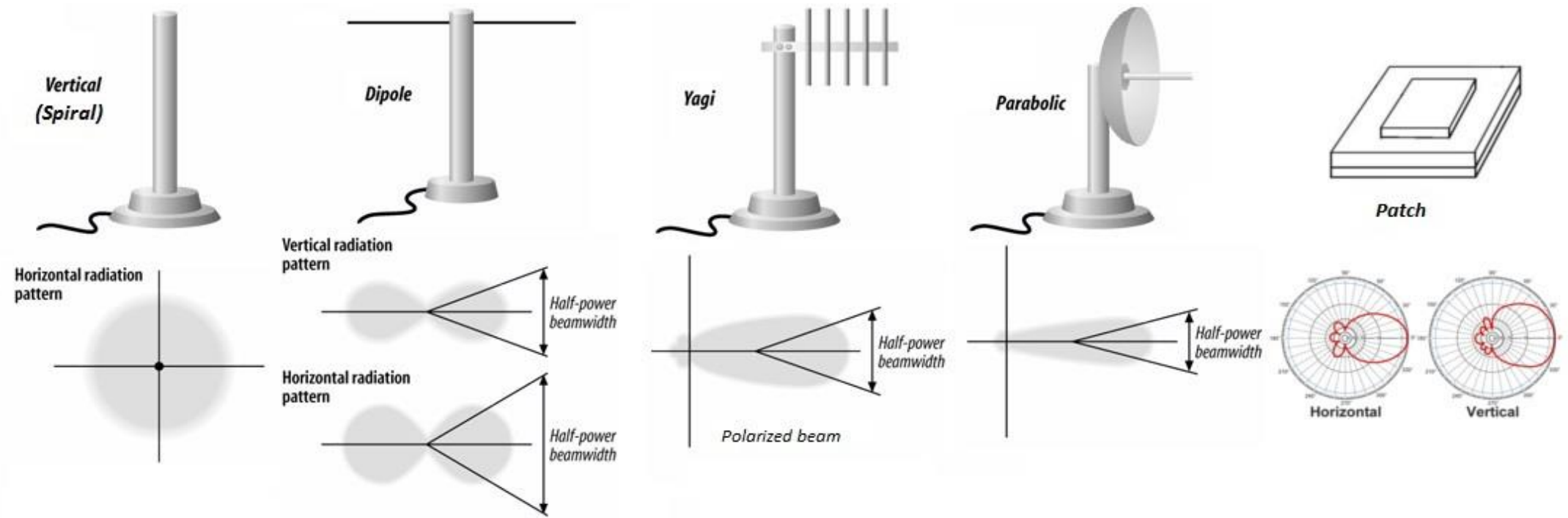
Antenna type	Dipole
Operating frequency range	2402-2495 MHz
Nominal input impedance	50 Ohms
2:1 VSWR bandwidth	2385 - 2515 Mhz
Peak gain	2 dBi
Polarization	Linear, vertical
E-Plane 3-dB beamwidth	70 degrees
H-Plane 3-dB beamwidth	Omnidirectional
Dimensions	5.5 in. (13 cm)
Weight	1 oz.
Connector type	RP-TNC plug
Environment	Indoor
Operating temperature range	32°F to 140°F (0°C to 60°C)



Key Specifications

- Frequency
- Resistance (Ohms)
- Gain
- Connector type
- Beamwidth

Antenna	Type	Gain dBi	Horizontal BW	Vertical BW	Usage
Dipole	Omni	2-6	360	45-90 (75)	Indoor Open Spaces – Center of Area
Down Tilt			180	45-90 (75)	Indoor High Ceiling – Center of Area
Patch/Panel	Semi Directional	7-11	35-60 (60)	30-80 (30)	Indoor -Edges– Hotels – High Density
Sector					Point to Multi Point Outdoor
Yagi	Directional	14-19	25-65 (30)	25-65 (30)	Point to Point Small Distance 1 Km
High Gain					Point to Point Long Distance – 5 Km



Std/High Gain Omni OR Downtilt Omni ?

Std/High Gain Omni

- Highest Gain in direction of Aps
- Increased AP to AP interference
- -12 to -2 dBi Gain towards clients

Low Gain Downtilt

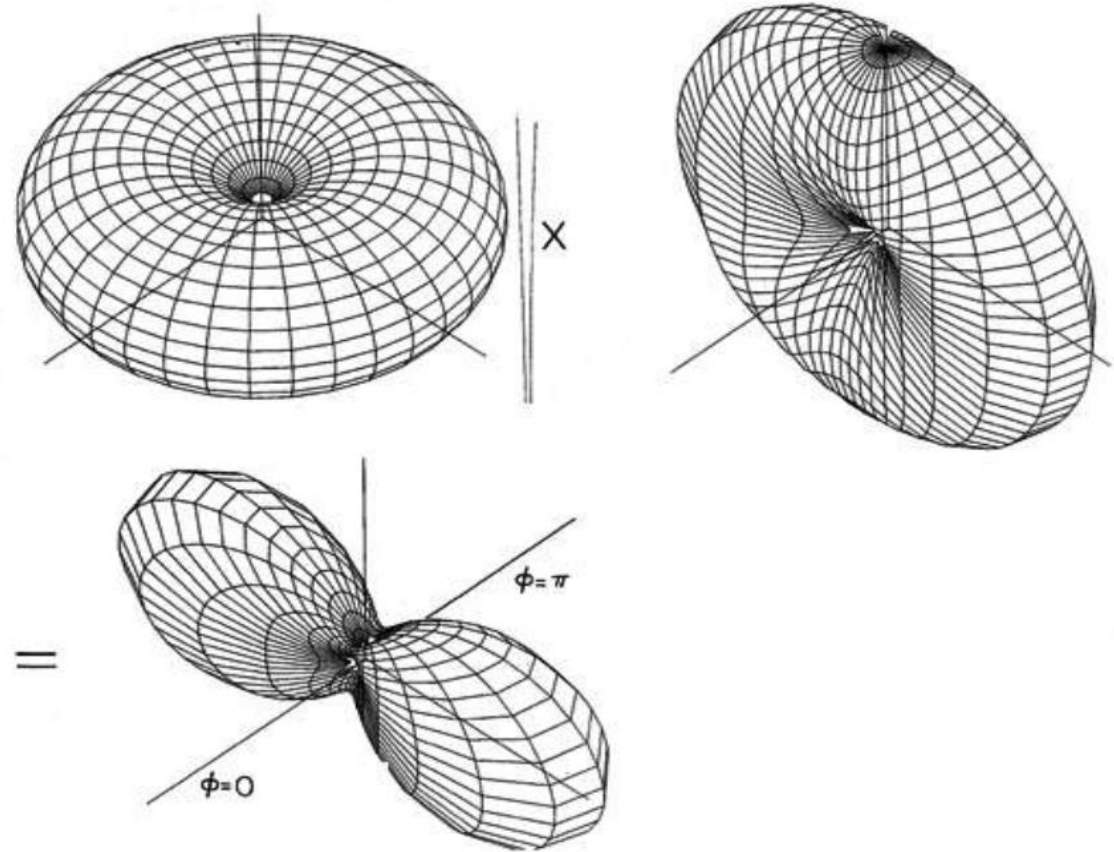
- Maximum gain directed towards clients
- Reduced AP to AP interference
- -2 to +3 dBi Gain towards clients (5 to 10 dBi higher)

Radiation Pattern

- All Antennas radiate in 3 Dimensions.
- Antennas do not create or destroy power, but they can “focus” energy into a tighter region of 3D space. This focusing effect is called “Gain”


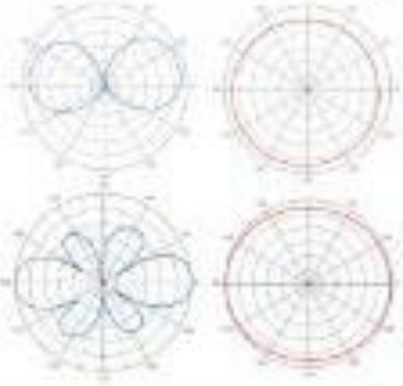

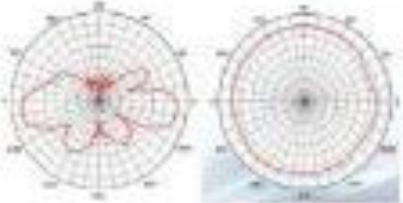

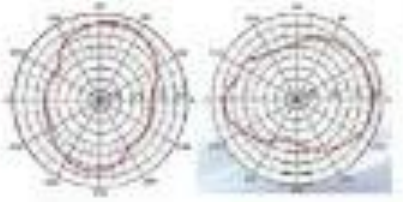
Gain

- Higher the gain, the more tightly focused the coverage in a particular direction
- Higher gain is typically achieved by focusing the vertical direction, which actually reduces energy distributed up/down in order to direct energy farther horizontally
- High gain antennas are typically not appropriate for situations where both horizontal and vertical coverage are needed, as in a warehouse deployment



An antenna that radiates like a sphere in all directions is called the “Isotropic” radiator and is a special case with Gain=1 (or in dB, =0 dBi)

Antenna Types

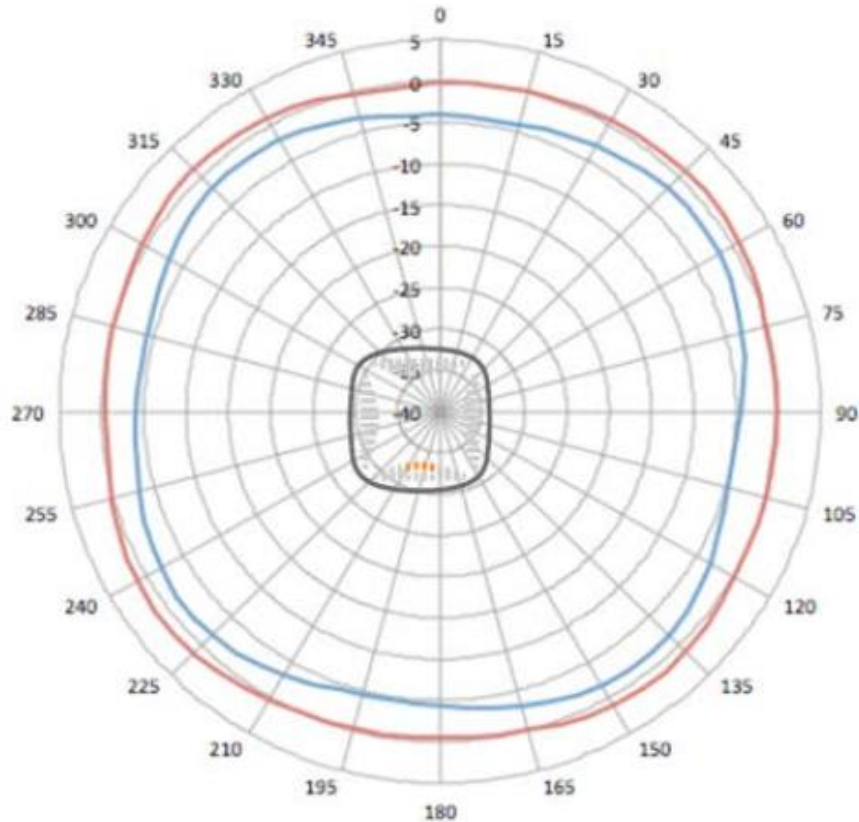
Model	Band	Gain	Polarization & Element Type	Beamwidth	Dimensions	Max Input Power	Operating Temperature	Radiation Pattern (2500MHz unless 5500MHz) Direction of Maximum Gain at 0° Unless Noted
AP-ANT-10 Direct-Mount Omni 	2.4 - 2.5 GHz	3.8 dBi	Vertical, Linear RP-GMA	E-Plane - 50° H-Plane - 360°	1.54" x 0.75" x 5.00" 3.9 x 1.9 x 12.7 cm	2 watts Impedance - 50 Ω VSWR < 2.0:1	-10° F to 131° F -10° C to +50° C	
	4.800 - 5.875 GHz	3.8 dBi		E-Plane - 30° H-Plane - 360°				
AP-ANT-2 Ceiling Mount Omni 	2.4-2.5 GHz	6.2 dBi	Vertical, Linear Linear Array RP-GMA	E-Plane - 18° H-Plane - 360°	10.66" x 1.90" 27.6 x 2.7 cm	32 watts Impedance - 50 Ω VSWR < 2.0:1	-40° F to 158° F -40° C to +70° C	
AP-ANT-3 Bidirectional Patch 	2.4-2.5 GHz	3.0 dBi	Vertical, Linear Linear Patch RP-GMA 3d° signal	E-Plane - 40° H-Plane - 60° Bidirectional	2.72" x 2.52" x 0.79" 6.9 x 6.4 x 2 cm	50 watts Impedance - 50 Ω VSWR < 1.8:1	-40° F to 158° F -40° C to +70° C	

Reading Radiation Patterns Horizontal Plane (azimuth)

AP-320 ANTENNA PATTERN PLOTS

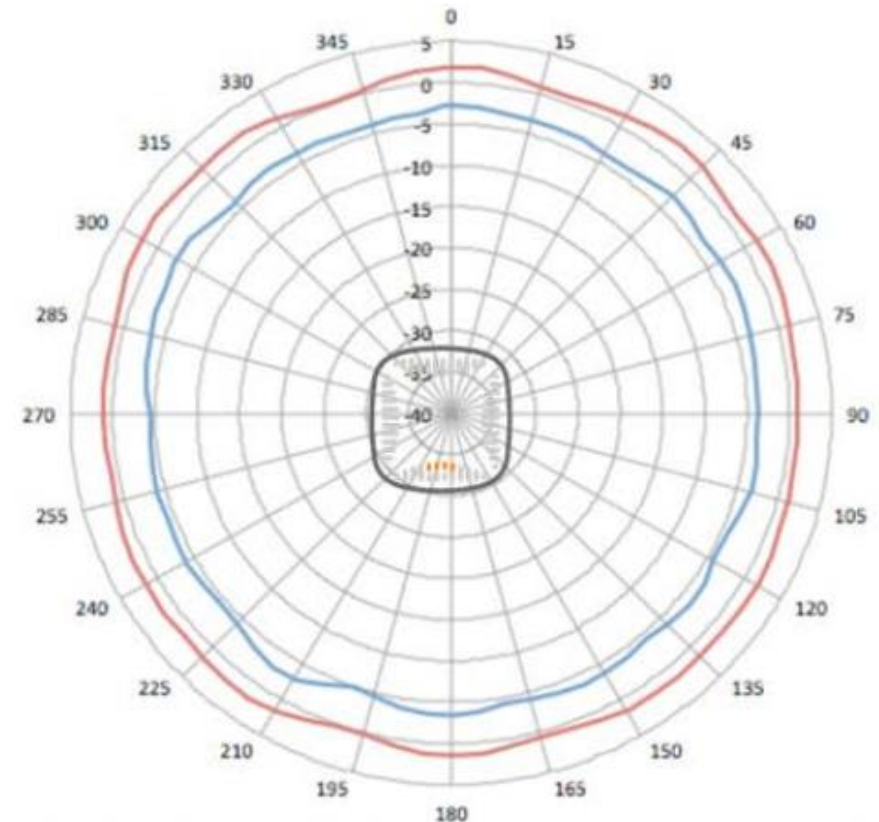
Horizontal planes (top view, AP facing forward)

Showing azimuth (0 degrees) and 30 degrees downtilt pattern



— 2.45GHz WiFi Average Azimuth — 2.45GHz WiFi Average Downtilt 30

2.45GHz Wi-Fi (antennas 1,2,3,4)



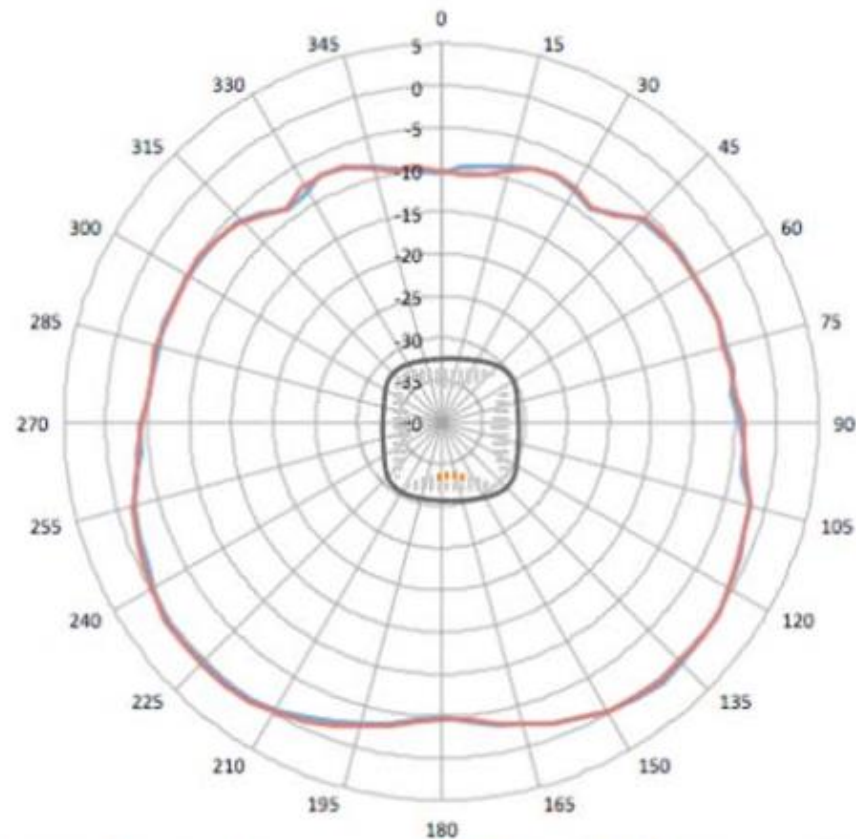
— 5.47GHz Average Azimuth — 5.47GHz Average Downtilt 30

5.5GHz Wi-Fi (antennas A,B,C,D)

Reading Radiation Patterns Vertical Plane (elevation)

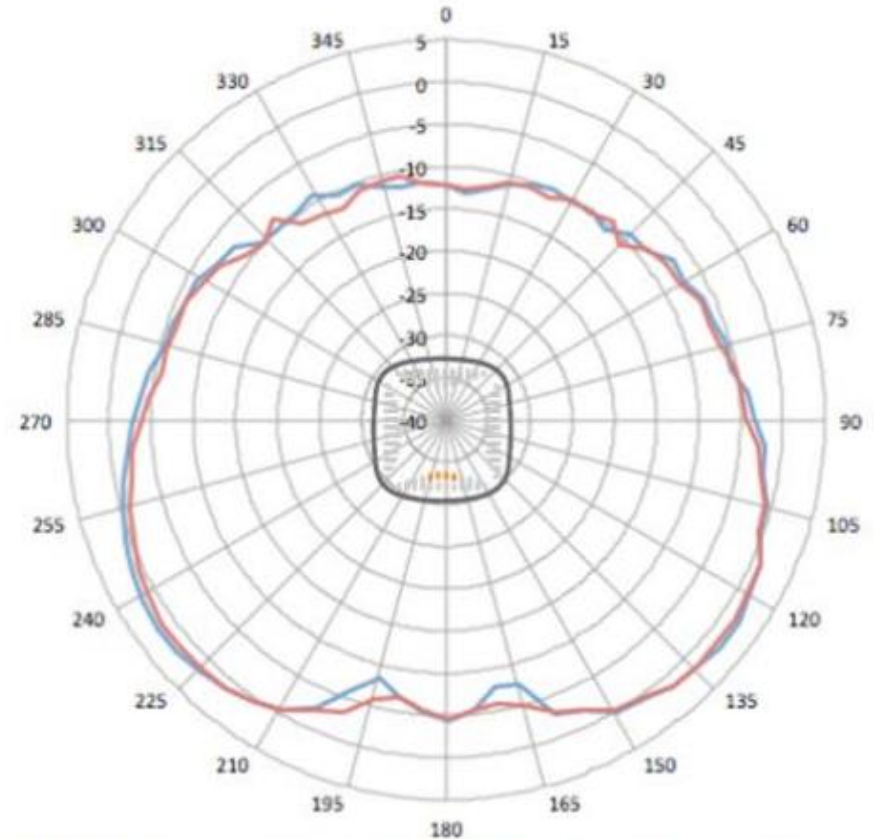
Elevation planes (side view, AP facing down)

Showing side view with AP rotated 0 and 90 degrees



— 2.45GHz WiFi Average Elevation 0 — 2.45GHz WiFi Average Elevation 90

2.45GHz Wi-Fi (antennas 1,2,3,4)



— 5.47GHz Average Elevation 0 — 5.47GHz Average Elevation 90

5.5GHz Wi-Fi (antennas A,B,C,D)

AP Placement and Antenna

- Vertical coverage is especially important in warehouse environments to get coverage in between shelving and stacks and ensure that intended signals reach the clients.
- Low gain, downtilt omnidirectional antennas are ideal for warehouse and high-ceiling store environments because:
 - Low gain limits range to a predictable area around the AP and reduces AP-AP interference
 - Low gain limits users per AP to a controlled area
 - Downtilt omni pattern provides users at ground level a higher signal than APs see from each other
 - Adaptive Radio Management (ARM) functionality is improved for autocalibration of the RF network and realtime visualization.
- The downtilt omni antenna is ideal to work in conjunction with ARM to ease the setup and management of a warehouses and large stores



Summary

- Radio Frequency (RF) waves are used to transmit and receive data on WLANs.
- The RF wavelength is related to the frequency: higher frequencies result in shorter wavelengths and lower frequencies result in longer wavelengths.
- The amplitude of a wave is the power or strength of the wave.
- The phase of a wave is a comparative attribute that relates the wave to another.
- Waves may be in-phase with other waves or some degree out-of-phase.
- Modulation uses phase shifts (PSK) and amplitude shifts (ASK) in WLANs.
- RF waves are reflected off of obstacles that are large in relation to the wavelength and have reflective properties.
- Many materials absorb some of the RF energy as the waves pass through them.
- Absorption results in increased attenuation over that which would occur in free space.
- RF transmission power is often referenced in watts (W) or milliwatts (mW), but received signal strength is typically referenced in dBm.
- 802.11 devices use a modulation and coding scheme (MCS) to achieve the data rate in the link.
- In addition to the modulation and coding, the channel width and number of spatial streams impact the achievable data rate.





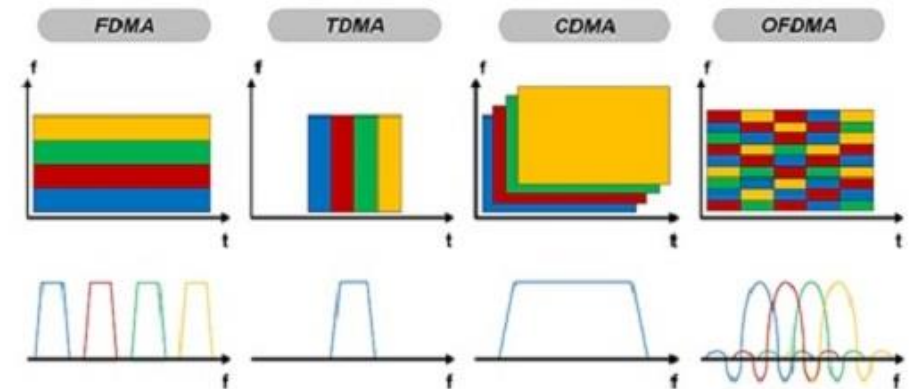
Wireless Training

Part 1 – Session 8

RF BASICS

Multiplexing & Multiple Access

DSSS-TDM-FDM





Part 1 : RF Basics

1. What is Radio Transmission
2. RF Bands and Spectrum
3. RF Waves Characteristics
4. RF Measurements Units
5. Signal Indicators RSSI-SNR
6. RF Waves Propagation
7. Channels and bands
8. Interference CCI – ACI
9. Data Rates & Modulation
- 10. Multiplexing Technology**
11. Antenna Concept & Design

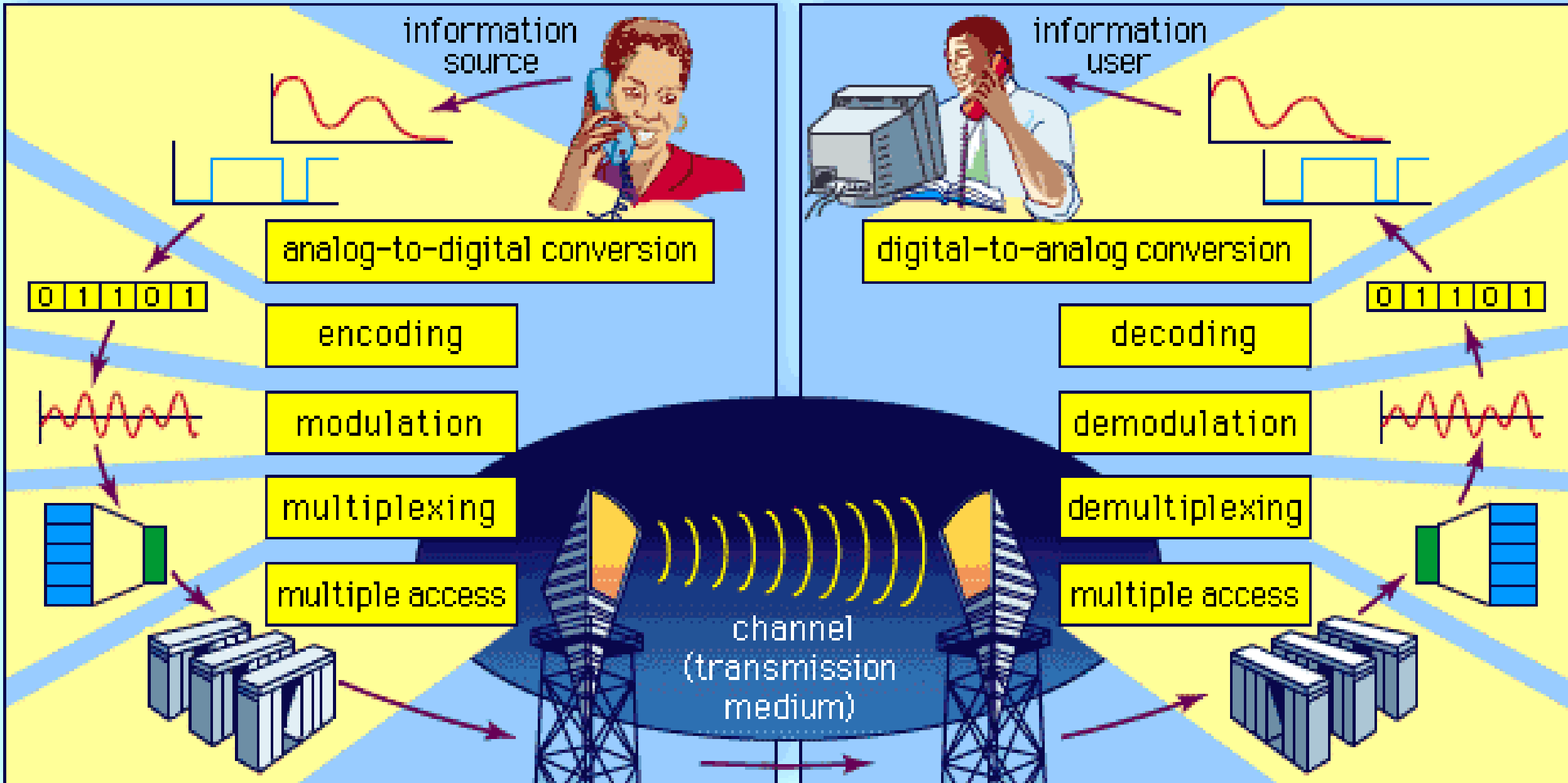
Multiplexing & Multiple Access

1. What is Multiplexing and Multiple Access
2. Multiplexing –TDM-FDM-WDM
3. Multiple Access : TDMA-FDMA-OFDMA
4. Narrow Band Vs Wide Band
5. Spread Spectrum : DSSS – FHSS
6. OFDM Vs FDM Advantages
7. OFDMA Latest WiFi 6



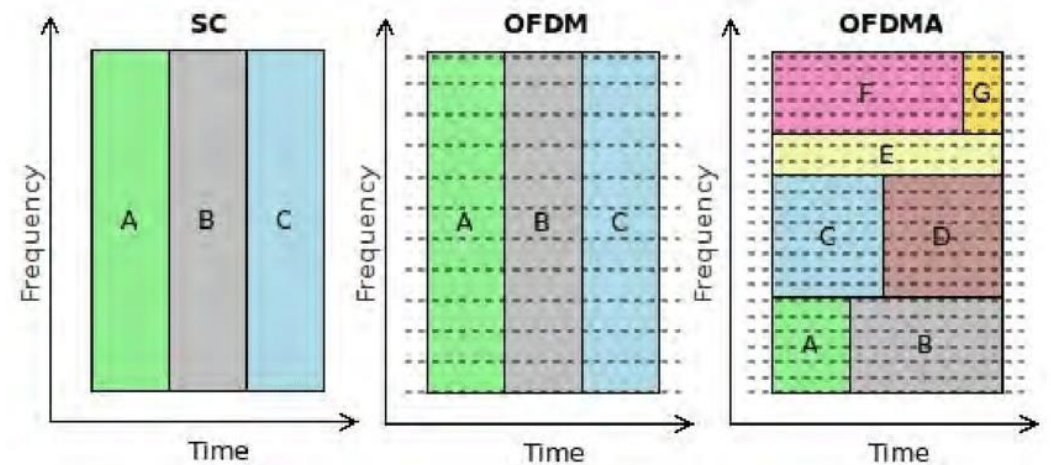
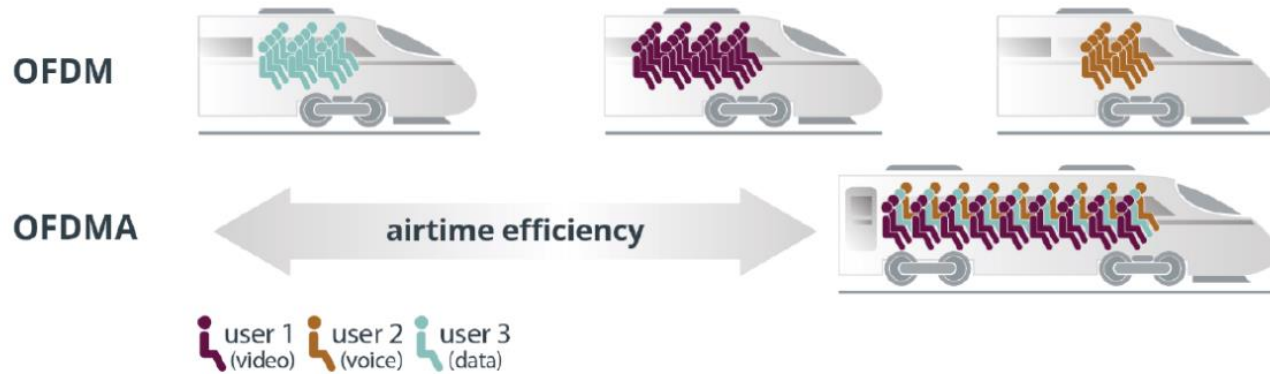
transmitter

receiver



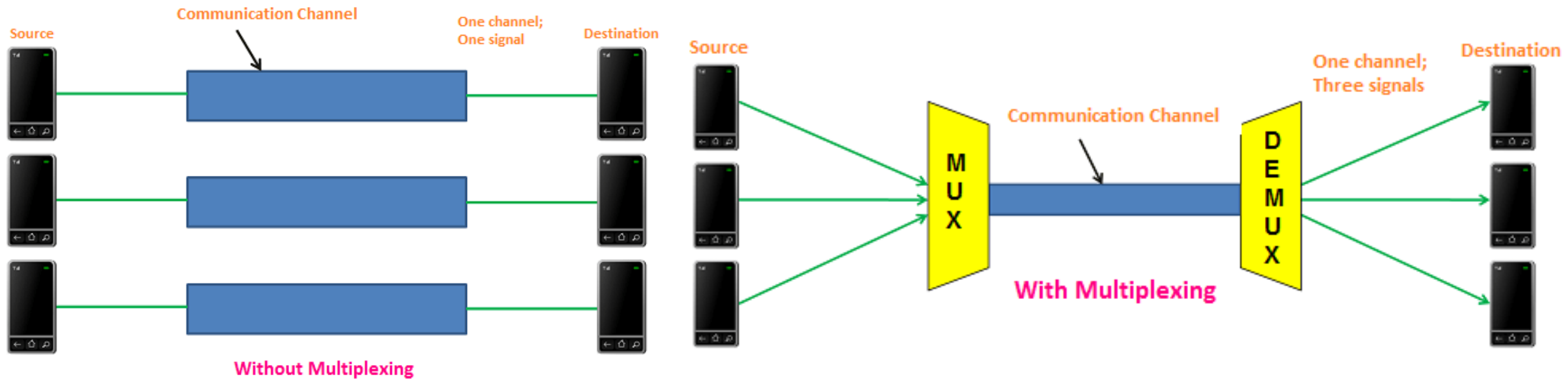
Multiplexing vs Multiple Access

Multiple Access	Multiplexing
It is a technique that permit many users to simultaneously access a given frequency allocation	It is a process to combine multiple signal for transmit it over a single channel or media
Allocate few channels to multiple users at same time	Divide channel to send multiple data stream of one user
Increase Users Capacity	Increase Data Rate Per User
Frequency Division Multiple Access (FDMA) Orthogonal Frequency Division Multiple Access (OFDMA) Time Division Multiple Access (TDMA) Code Division Multiple Access (CDMA Spread Spectrum)	Frequency Division Multiplexing (FDM). Time Division Multiplexing (TDM). Wave Division Multiplexing (WDM)



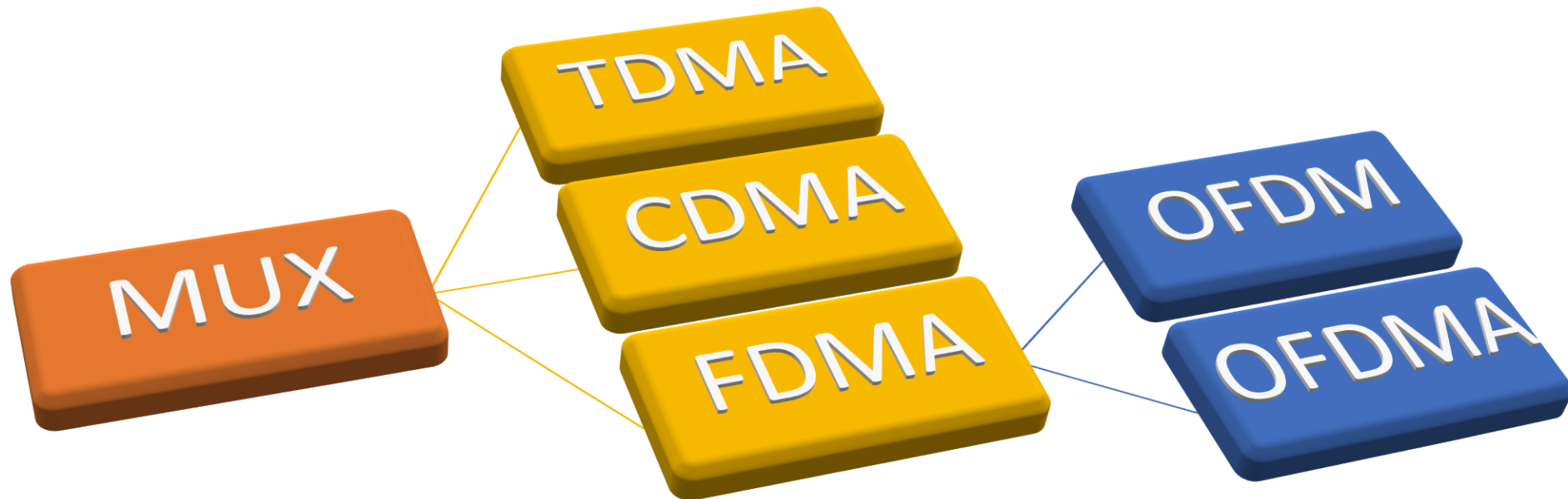
What is Multiplexing

- *Many to One / One to Many*
- *The process of combining various digital signals into one signal over a shared medium*



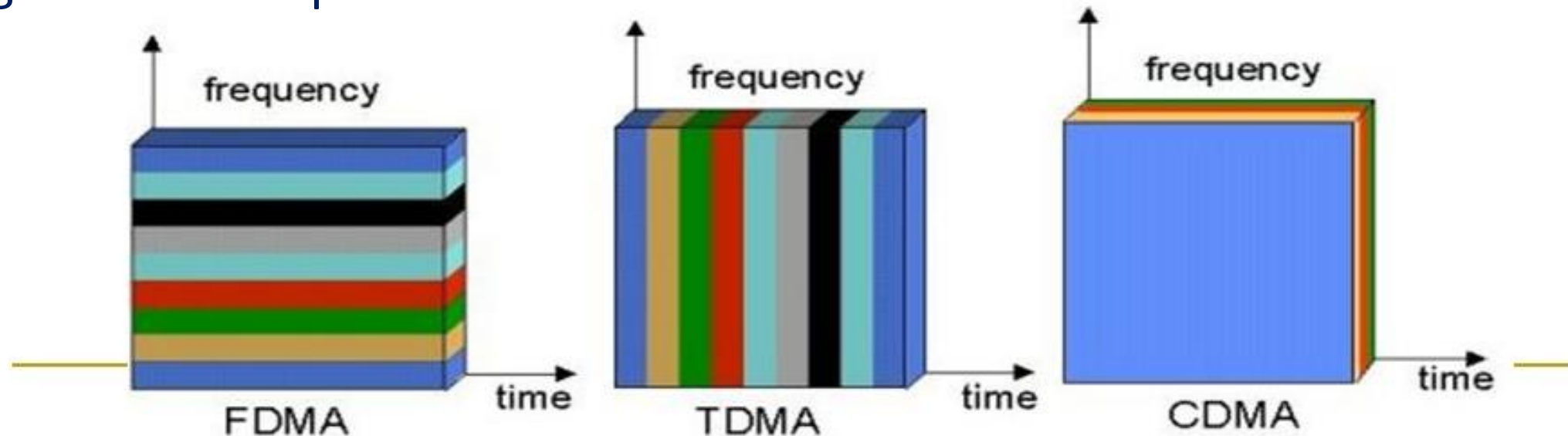
Multiplexing Technologies

- *Multiplexing divided into Analog and Digital based on Signal type need to be shared*
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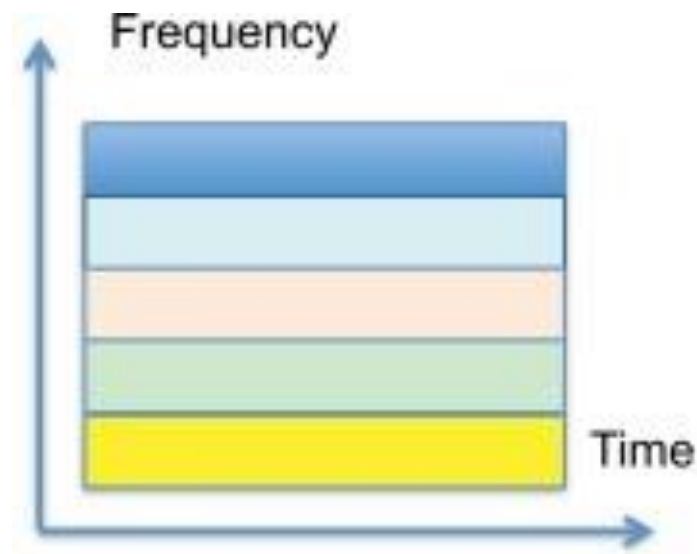
Multiple Access Types

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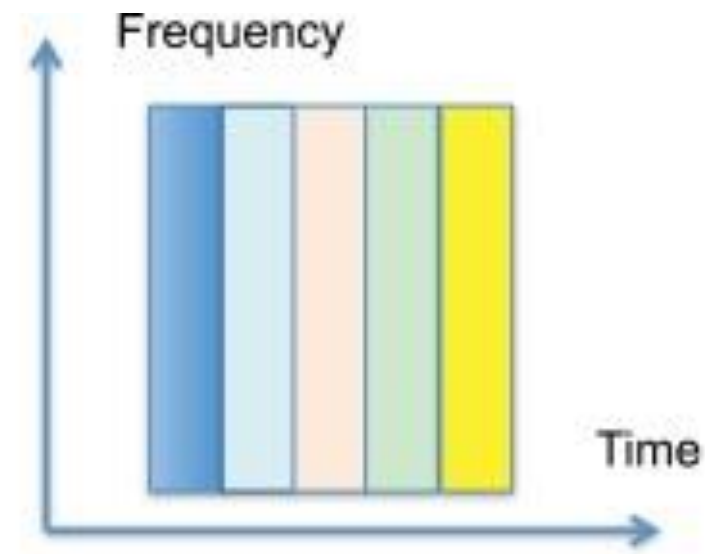


FDMA VS TDMA

- **TDMA** : on Time Division Multiplexing which assign time slot for every client send information at same frequency channel
- **OFDM** is based on the well-known technique of **Frequency Division Multiplexing** (FDM).
- In **FDM** different streams of information are mapped onto separate parallel frequency channels.
- Each FDM channel is separated from the others by a **frequency guard** band to reduce interference between adjacent channels.



FDMA

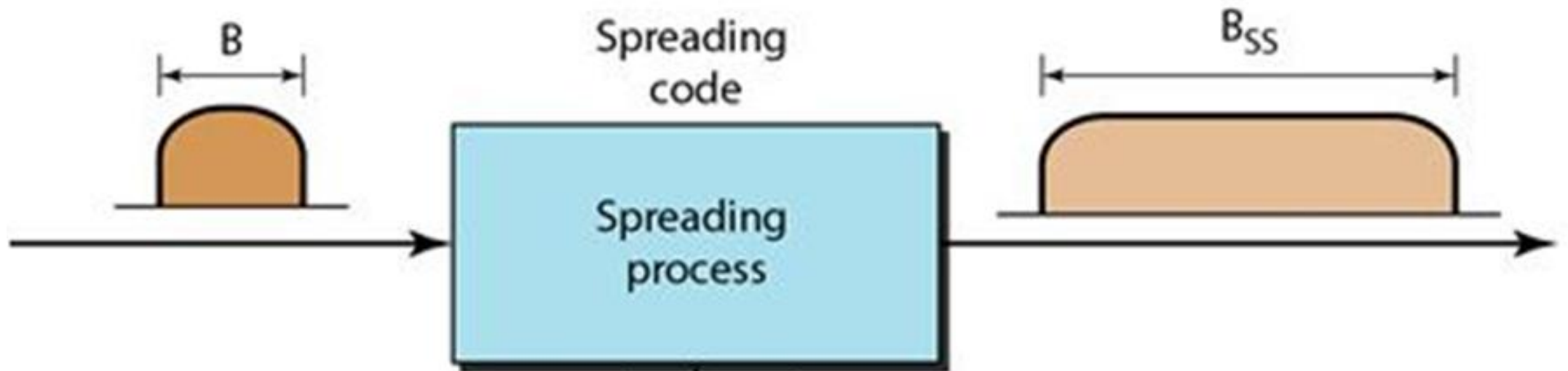


TDMA



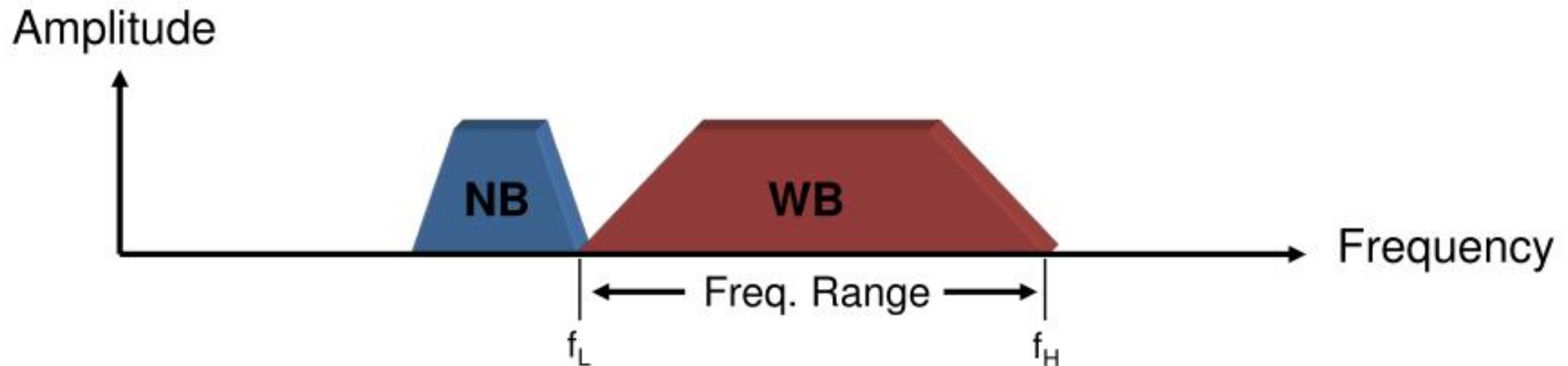
CDMA & Spread Spectrum

- ❑ **Spread spectrum** is a communication technique that **spread data over wider bandwidth**
- ❑ **Spread spectrum** is characterized by **wide bandwidth** and **low power**
- ❑ Signal modulated using sequence of digits & Receiver uses same sequence to demodulate signal
- ❑ **Jamming** and **interference** have **less** effect on **Spread spectrum**
- ❑ **Can hide/encrypt** signal Only receiver who knows spreading code can retrieve signal
- ❑ **Several** users can share same higher bandwidth with little interference

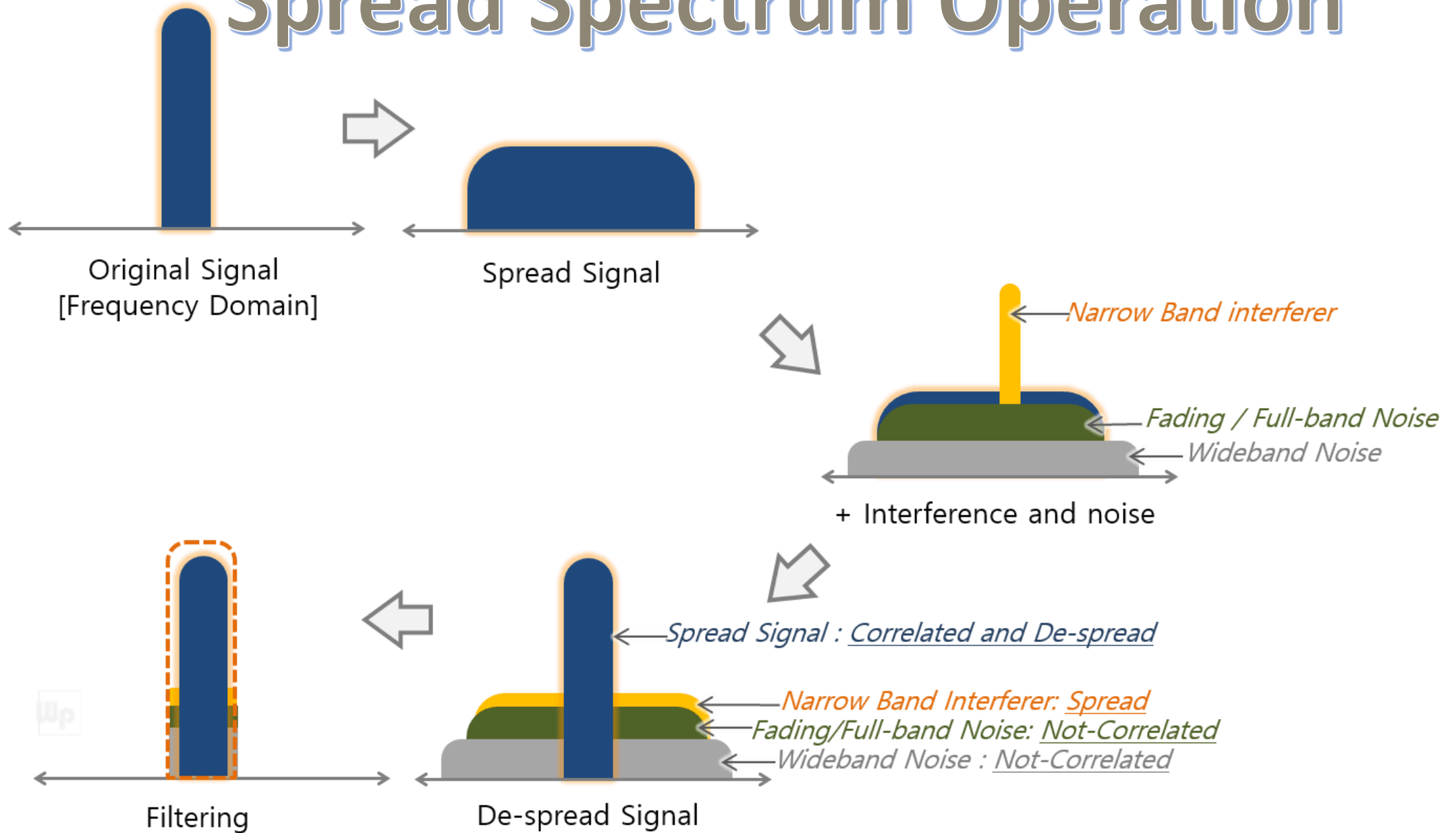


Narrow Band Vs Wide Band

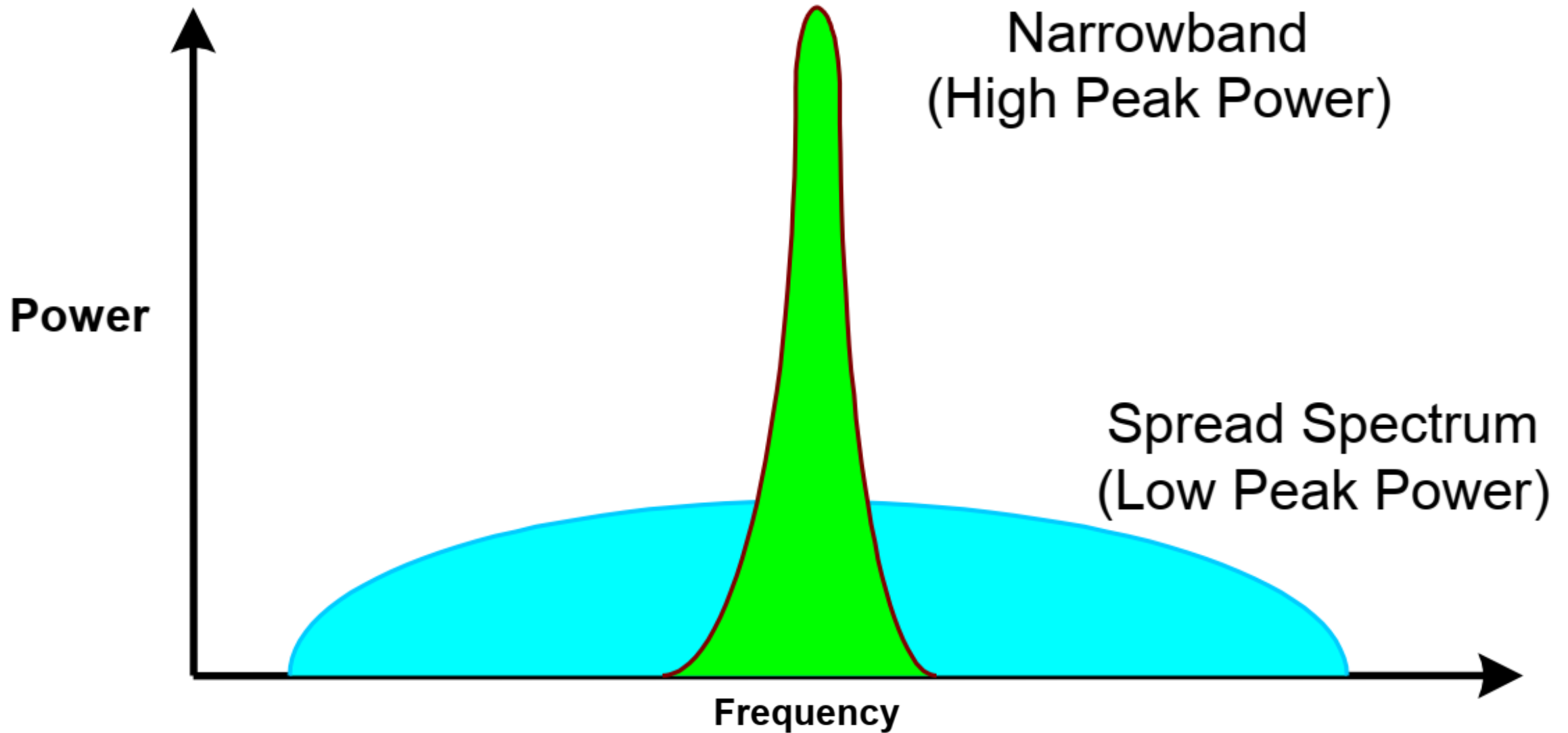
- Narrow and Wide Band – a relative comparison of a group or range of frequencies used in a telecommunications system. Narrow Band would describe a small range of frequencies as compared to a larger Wide Band range.



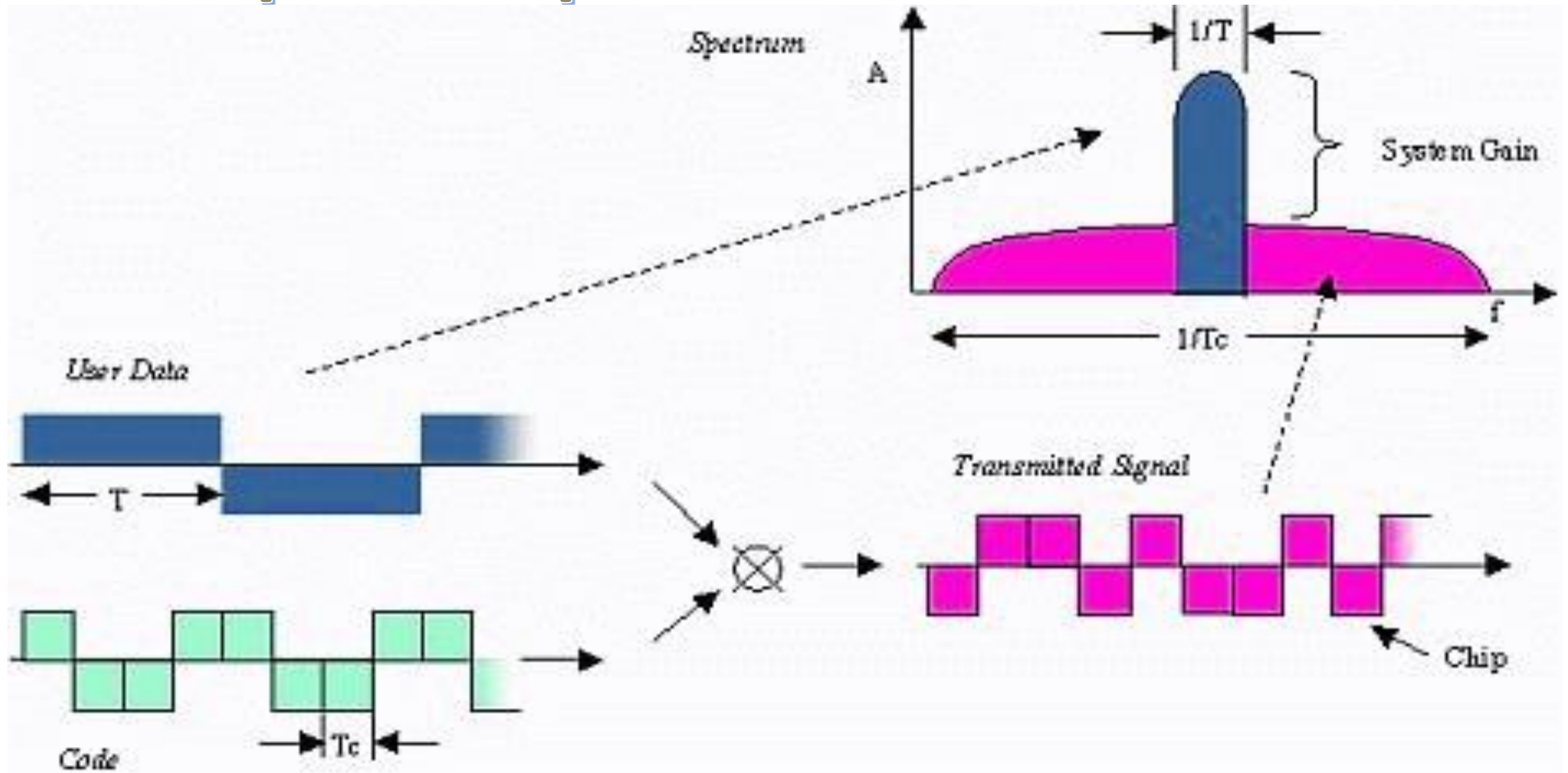
Spread Spectrum Operation



Narrow Band Vs Spread Spectrum



Spread Spectrum Generation



Spread Spectrum Benefits

Narrow Band

- Uses only enough frequency spectrum to carry the signal
- High peak power
- Easily jammed
- Easy to detect

Wide Band

- Bandwidth is much wider than required to send to the signal
- Low peak power
- Hard to detect
- Hard to intercept
- Difficult to jam



WLAN RF Spread Spectrum Techniques

FHSS



- Operates in the 2.4 Ghz
- Rapid frequency switching
- Low data rate 1 Mbps
- Channel width 87 Mhz
- Used for Bluetooth

DSSS



- Operates in the 2.4 GHz
- Data signal is inserted into a higher data rate
- Speed up to 5 Mbps
- Channel Width 22 Mhz
- Use QPSK Modulation

OFDM

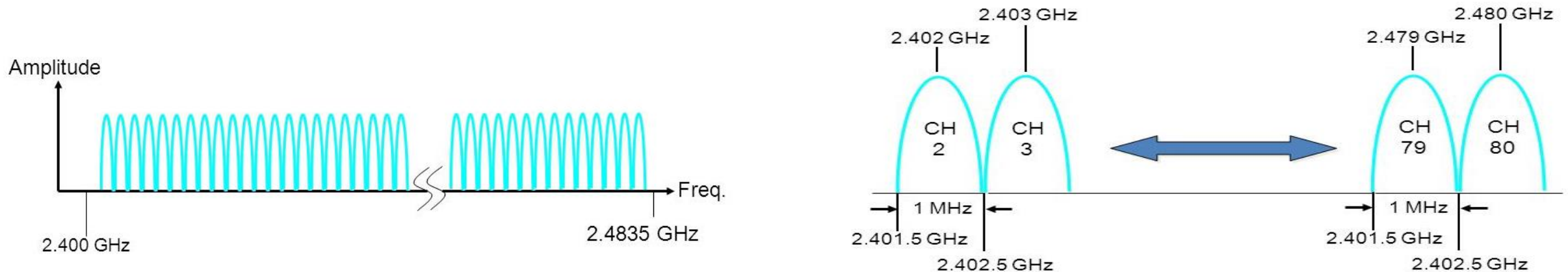


- Operates in both 5 Ghz and 2.4 GHz
- Divide Frequency into Sub Carriers
- Higher Data Rates 54 Mbps
- Channel width 20-40-80 MHz
- Use QAM Modulation

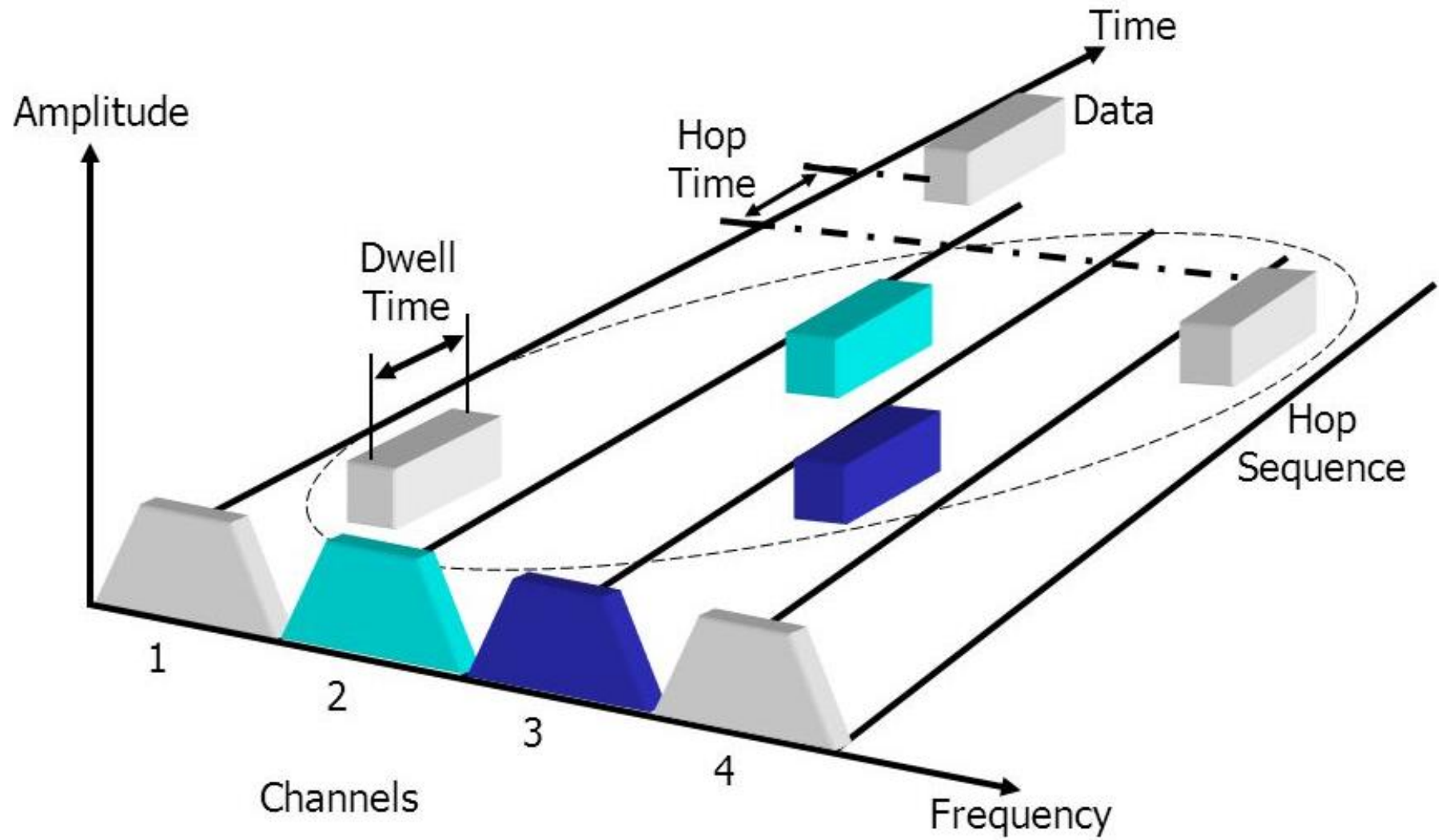


FHSS

- ❑ **FHSS** is frequency hopping spread spectrum
- ❑ Its primary purpose is to avoid **interference** between multiple devices using the **same bandwidth** and in **close proximity** with each other.
- ❑ **Signal broadcast** over **seemingly random** series of frequencies
- ❑ **Bluetooth** radio change transmission frequency **1600 times** per second for each 1 slot packet
- ❑ The data is spread over **83 MHz (total 79 x 1 MHz channel)** in the **2.4 GHz ISM band**
- ❑ Data then transmitted using a hopping pattern (jumping among the channels).
- ❑ Used for **Bluetooth** and **Home RF – Maximum data Rate 1 – 2 Mbps**



FHSS



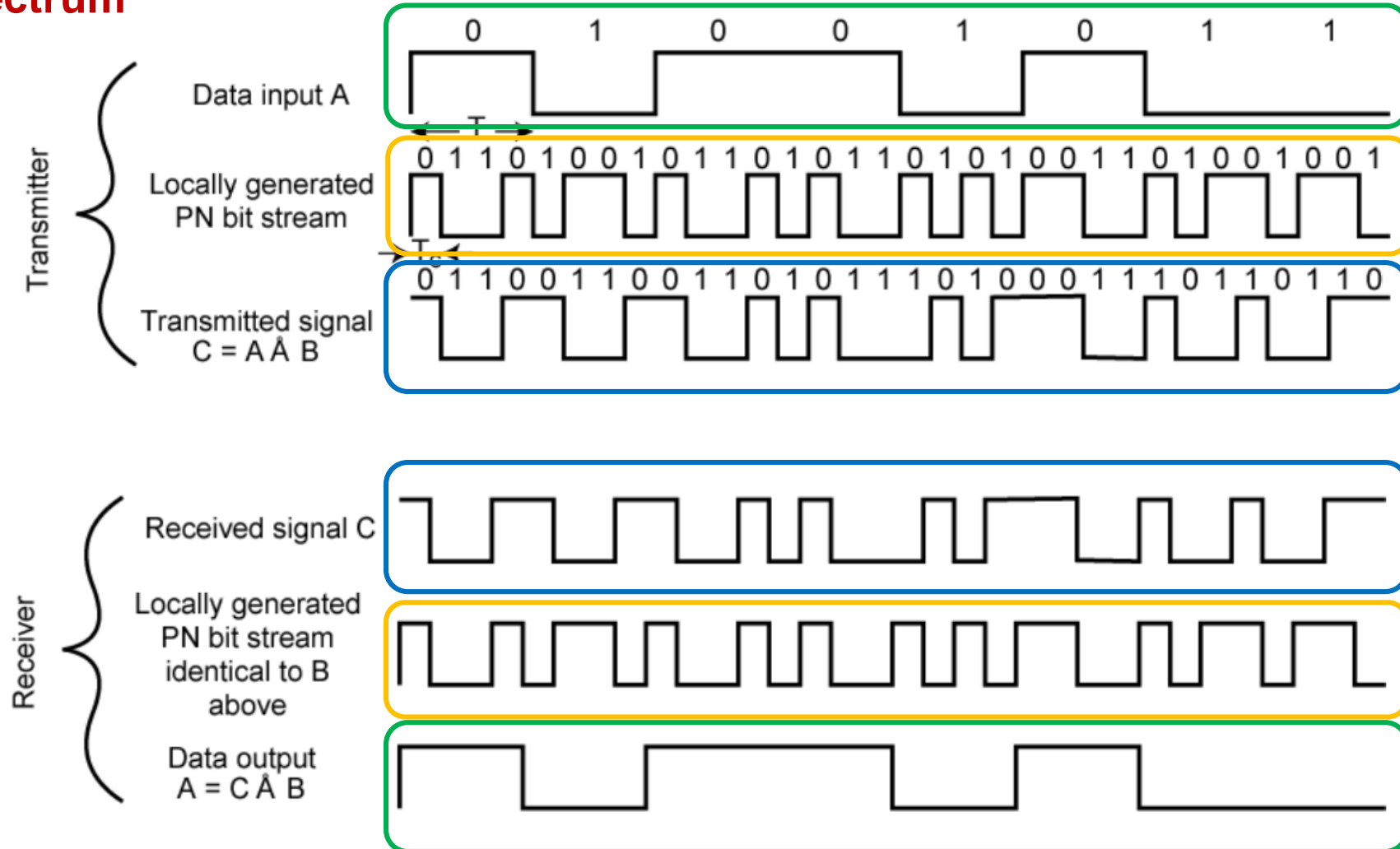
DSSS

❑ Direct Sequence Spread Spectrum

❑ Considered as **CDMA**

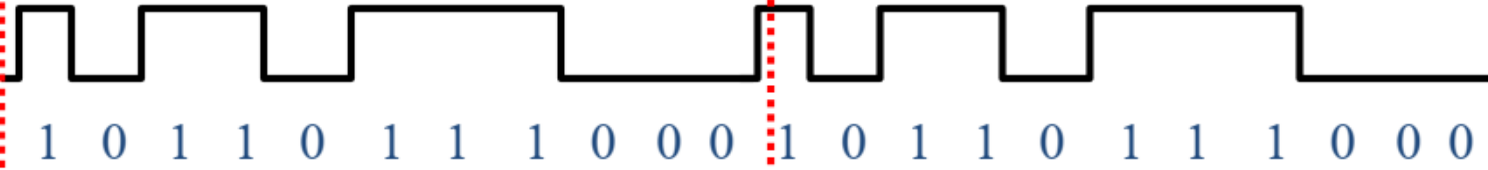
❑ **Each bit** is represented by **multiple bits** in transmitted signal using spreading code

❑ **DSSS** spreads the signal by adding **redundant bits** to the signal prior to transmission which spreads the signal across **22 Mhz**

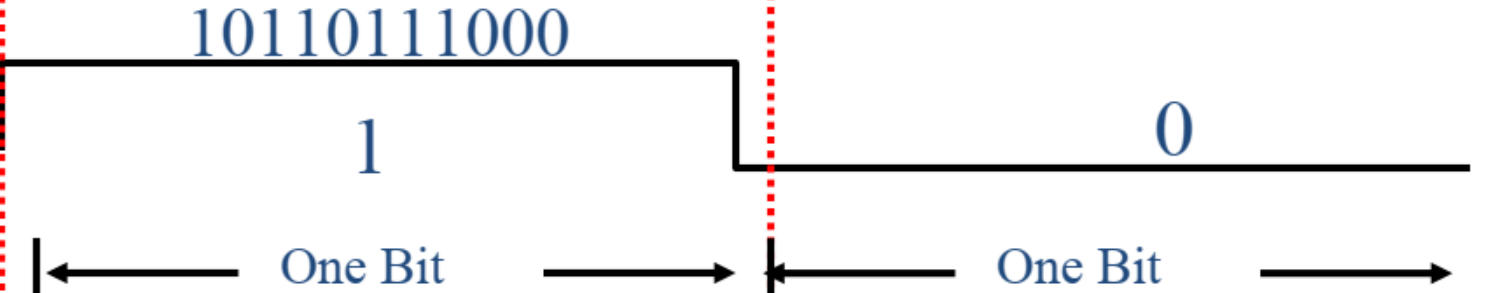


DSSS

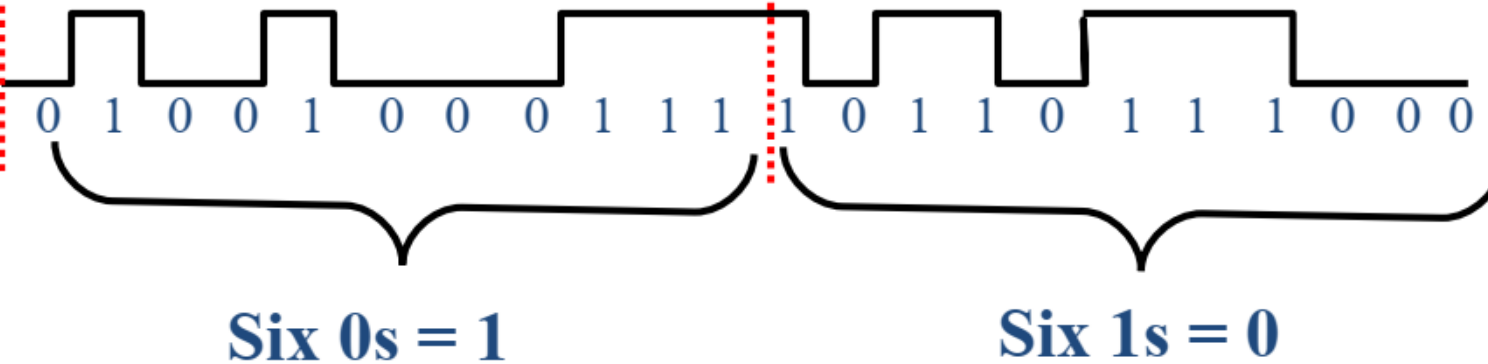
Chipping Code
(Barker Sequence)



Original Data

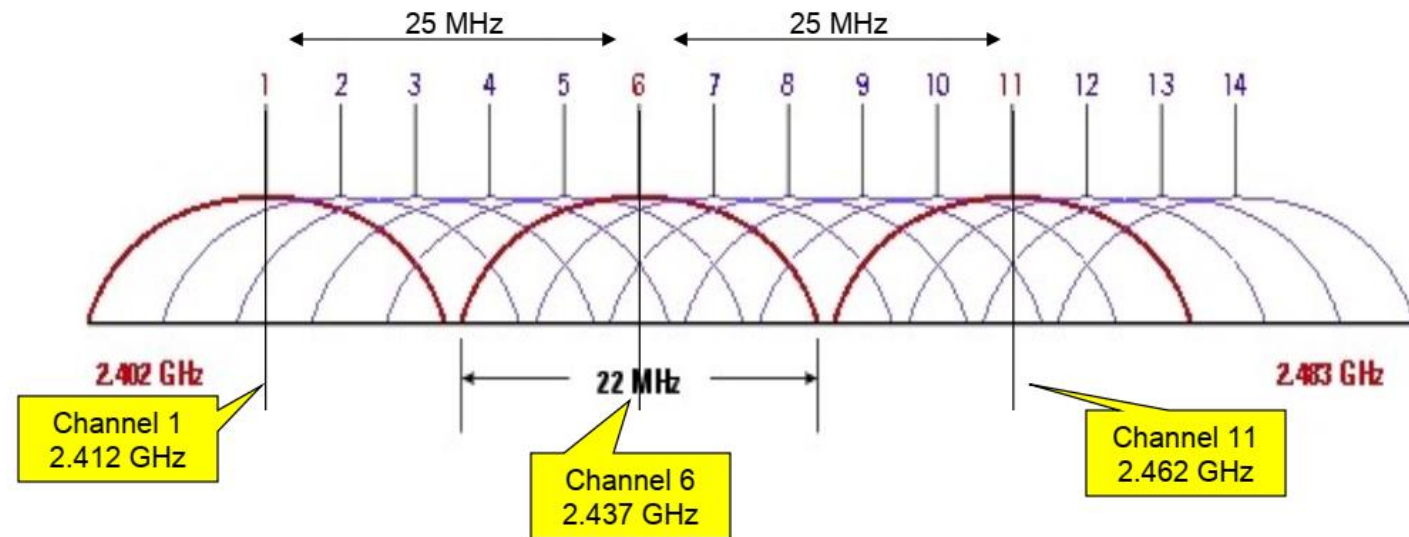
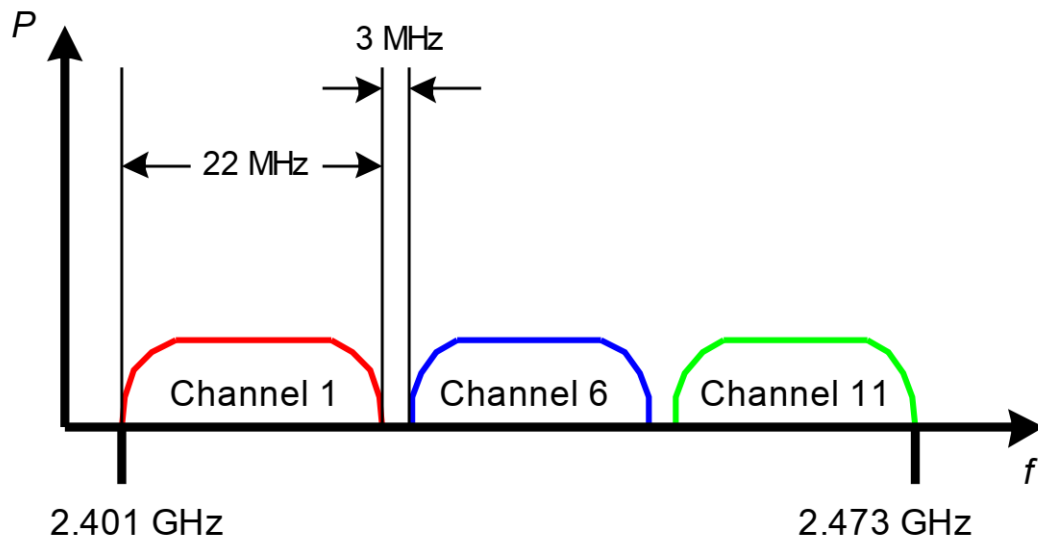


Spread Data

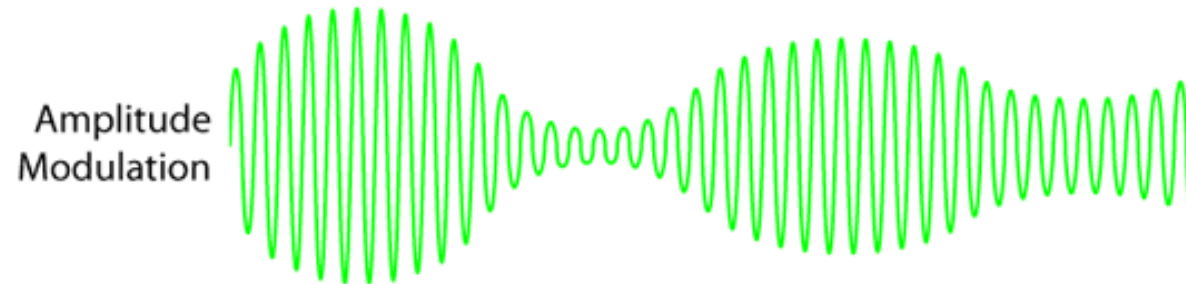
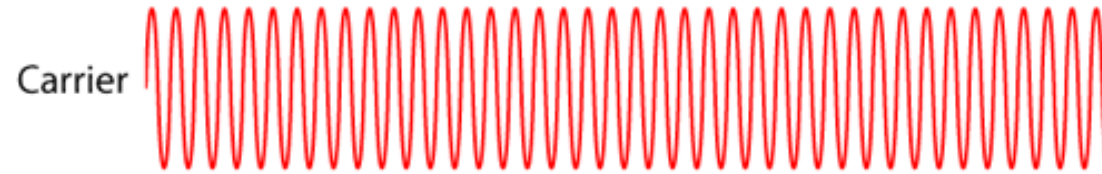
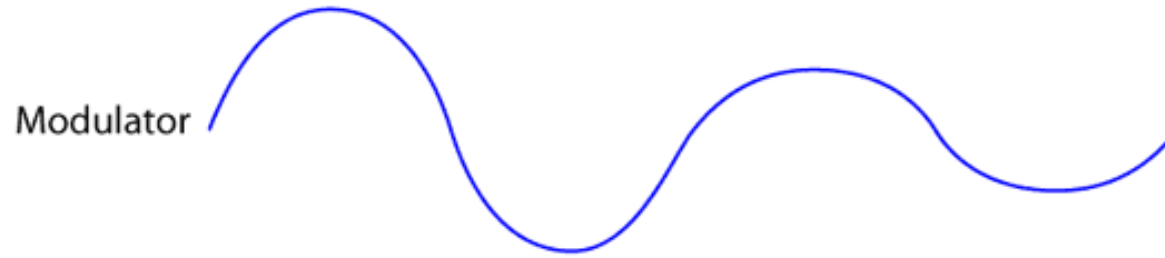


DSSS Frequency Assignment

- The Center **DSSS** frequencies of each channel are only **5 Mhz apart** but each channel is **22 Mhz wide**
- For two bands not to overlap (interfere), there must be five channels **apart**, e.g., Channels 1 and 6, Channels 2 and 7, etc.
- A **maximum of three channels** may be co-located (as shown) without overlap (interference)

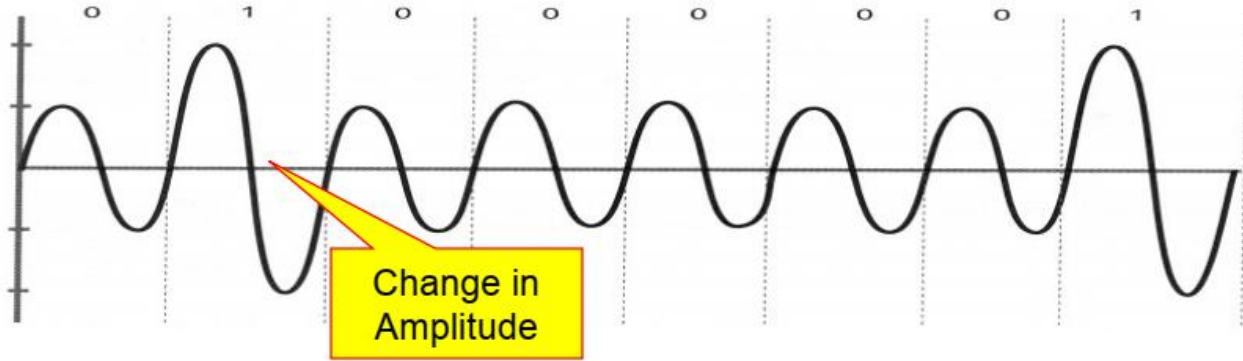


Digital Modulation

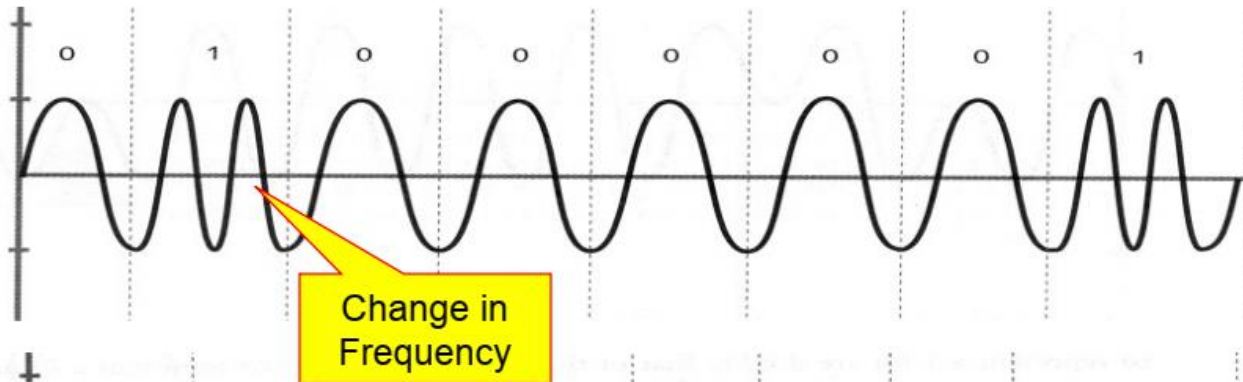


Modulation Methods

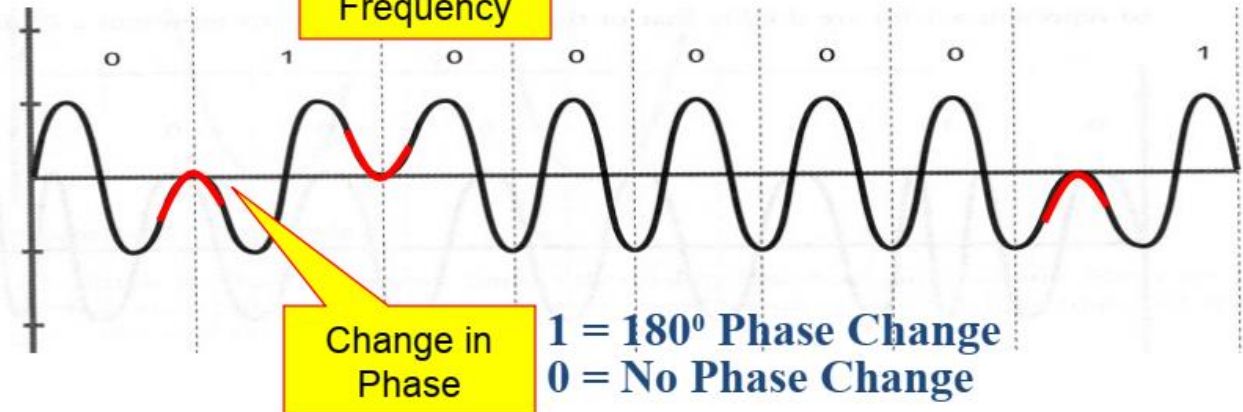
Amplitude Modulation
varies the height of the carrier wave.



Frequency Modulation
varies the number of oscillation (waves) per second



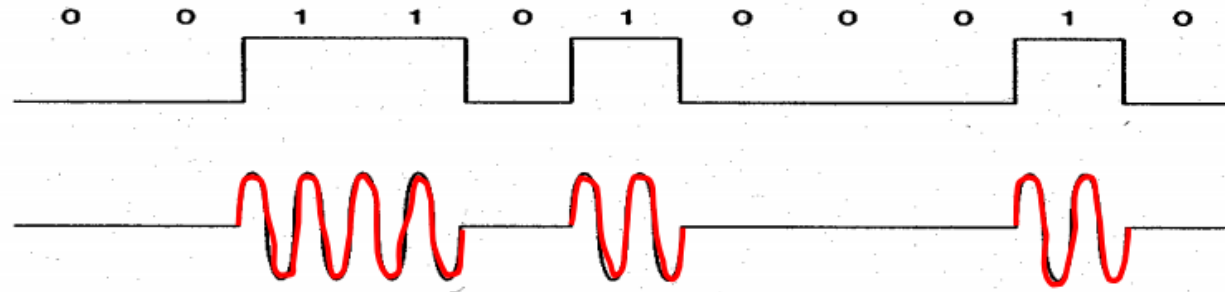
Phase Modulation
changes the starting point of the wave.



Digital Modulation

Amplitude Shift

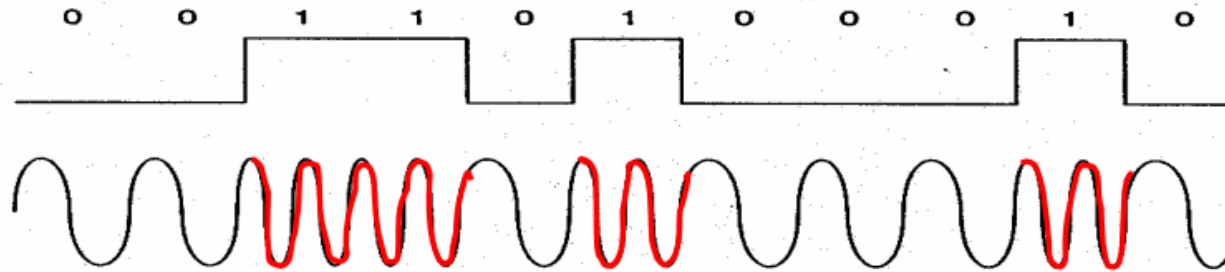
Keying (ASK) changes the amplitude of the carrier wave to represent a 0 or 1.



b. Amplitude Modulation

Frequency Shift

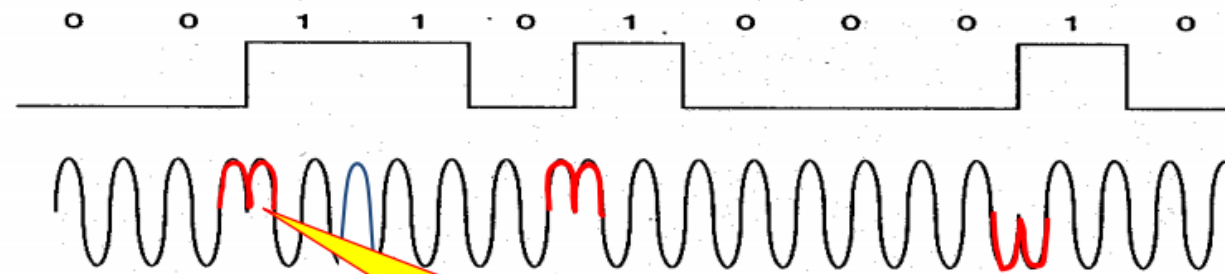
Keying (FSK) changes the frequency of the carrier wave to represent a 0 or 1.



c. Frequency Modulation

Phase Shift Keying (PSK) changes the phase of the carrier wave to represent a 0 or 1.

1 = 180° Phase Change
0 = No Phase Change

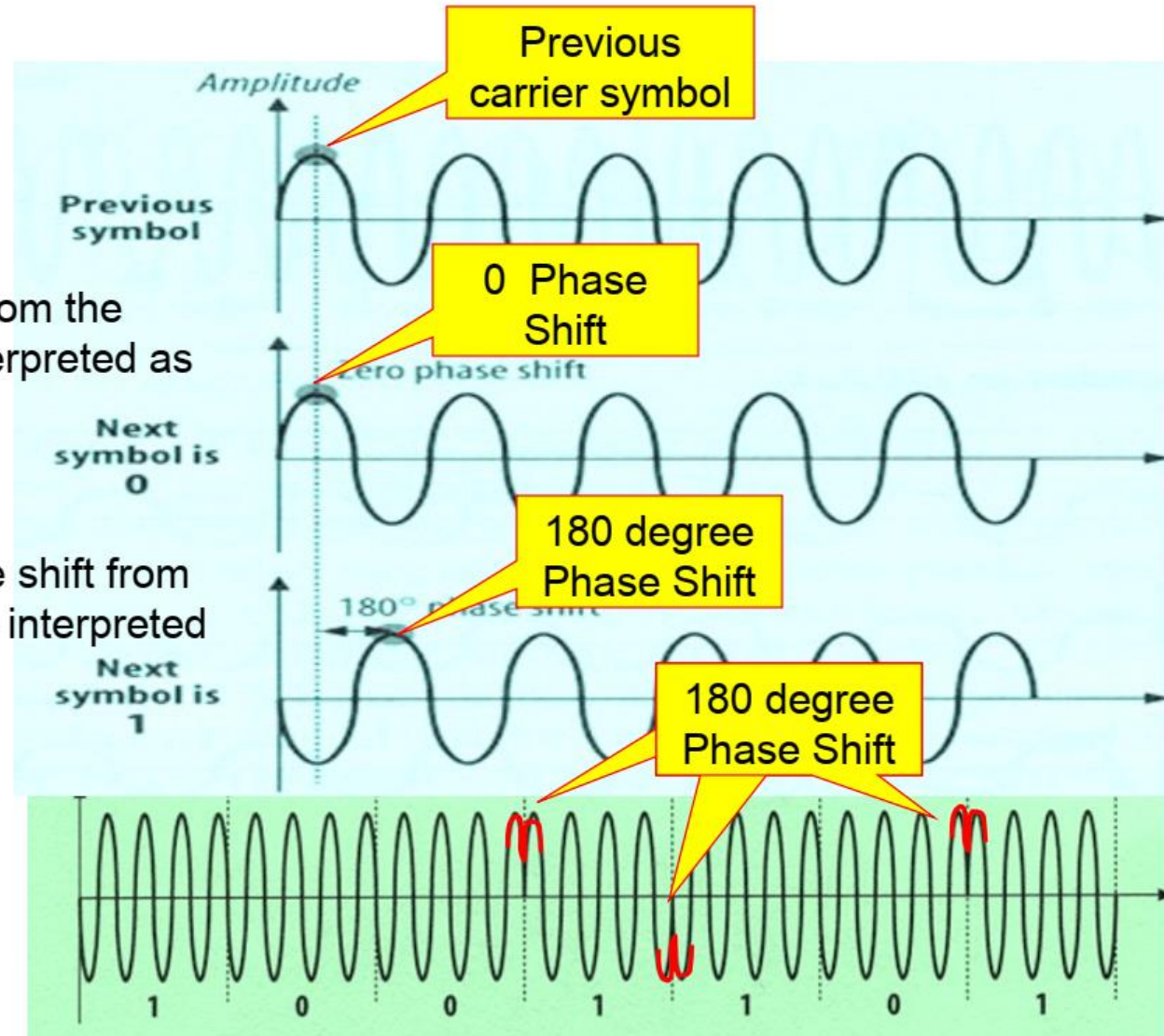


180 degree phase change

DSSS Modulation - QPSK

A Zero phase shift from the previous symbol is interpreted as a 0.

A 180 degree phase shift from the previous symbol is interpreted as a 1.

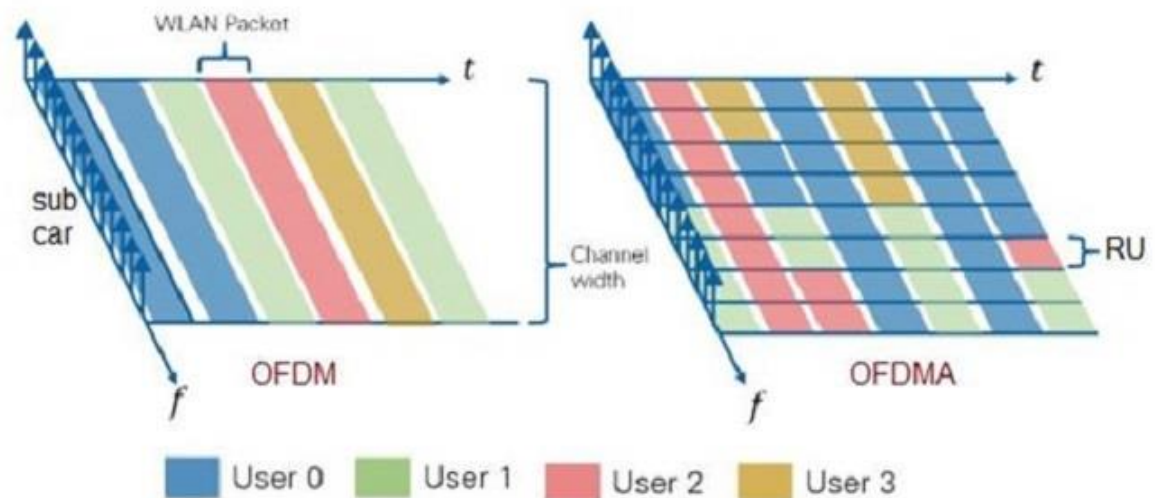


Wireless Training

Part 1 – Session 9

RF BASICS

OFDM & OFDMA



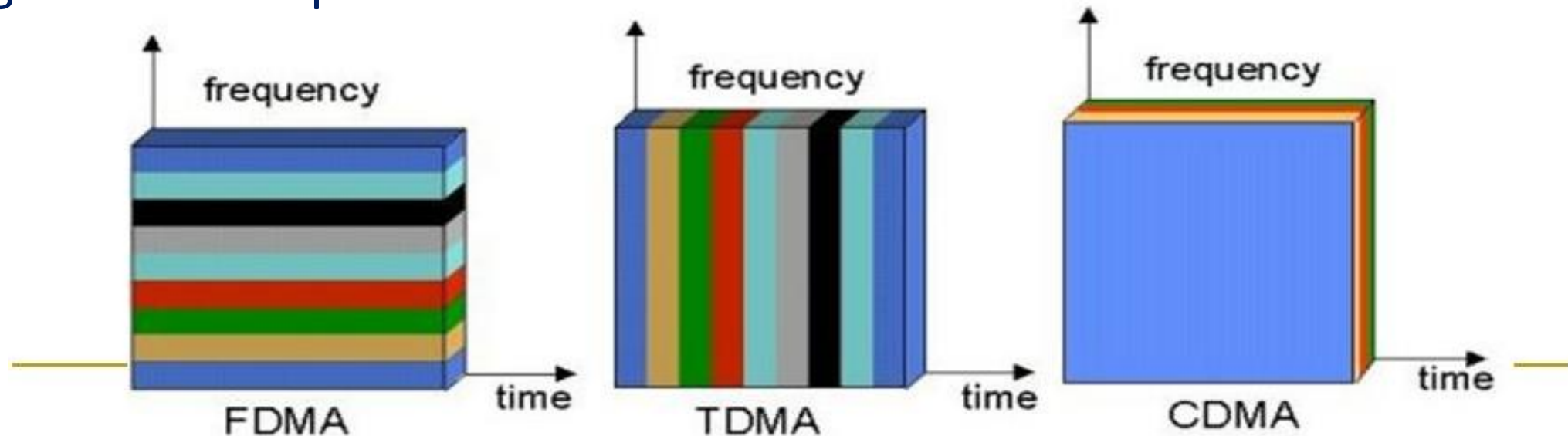
Multiplexing & Multiple Access

1. What is Multiplexing and Multiple Access
2. Multiplexing : TDM-FDM-WDM
3. Multiple Access : TDMA-CDMA-FDMA-OFDMA
4. Narrow Band Vs Wide Band
5. Spread Spectrum : DSSS – FHSS
6. **FDM How it Works**
7. **OFDM Enhancement**
8. **OFDMA Latest Wi-Fi 6**



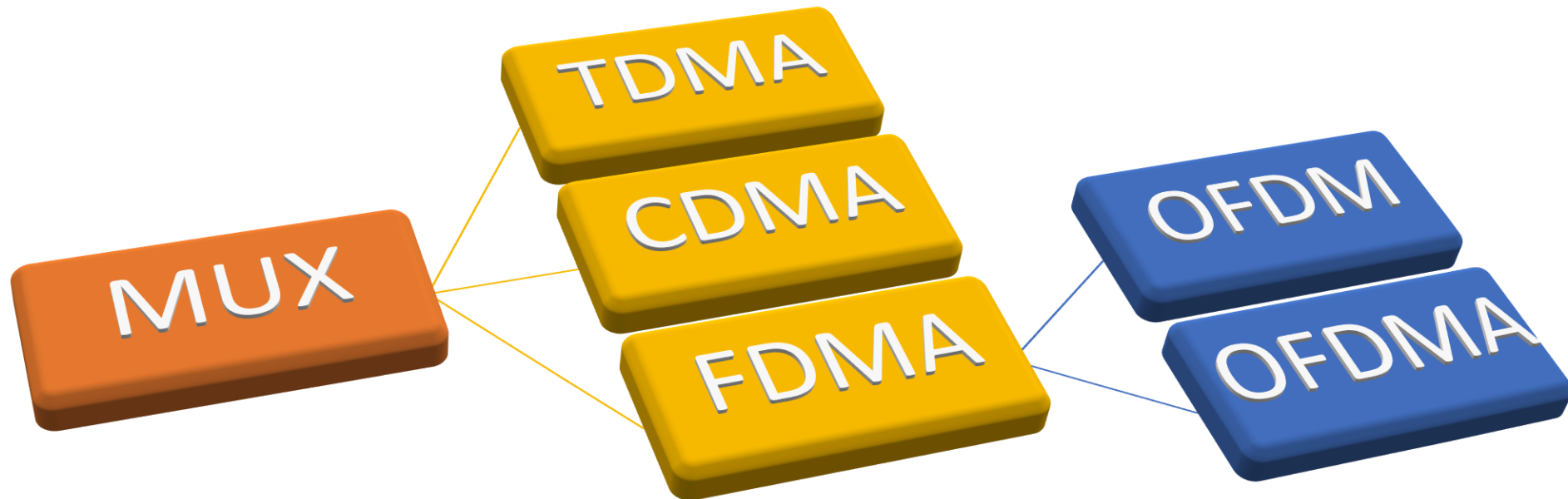
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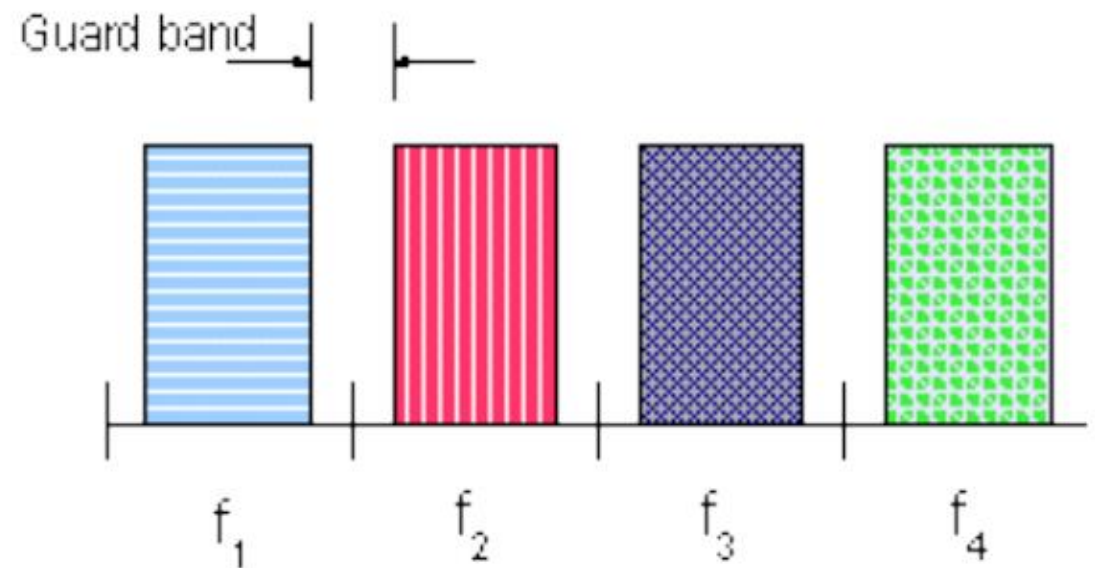
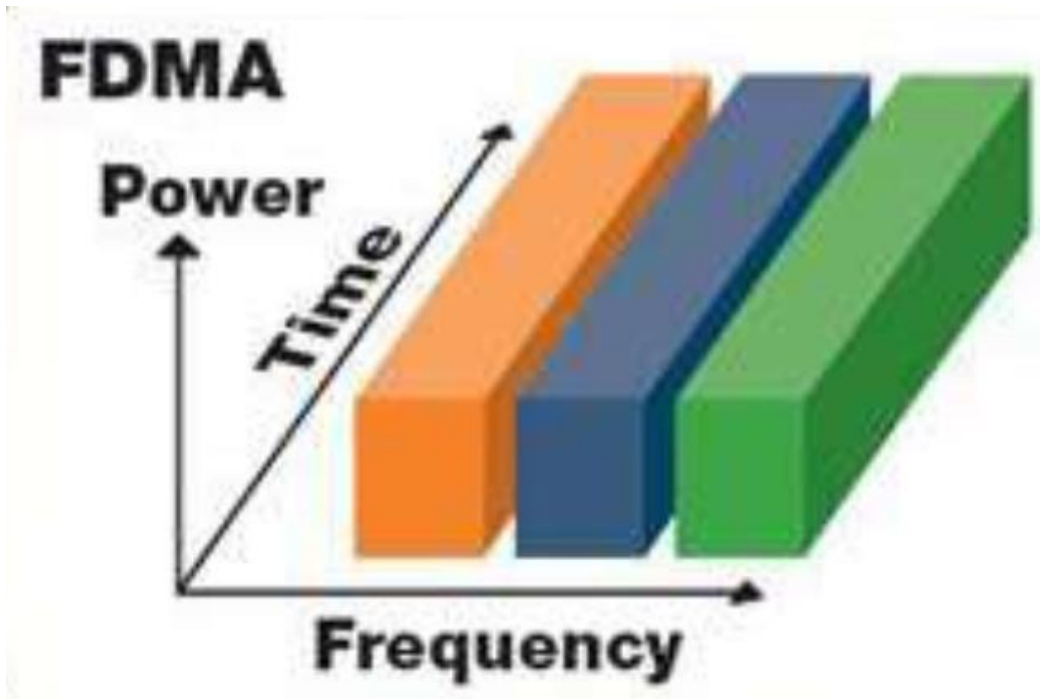
FDM & FDMA

Frequency Division Multiple Access (FDMA)

The **available channel bandwidth** is divided into many **non overlapping frequency bands**, where each band is dynamically assigned to a **specific user** to transmit data.

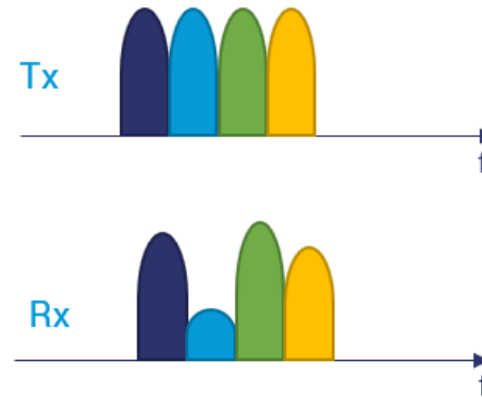
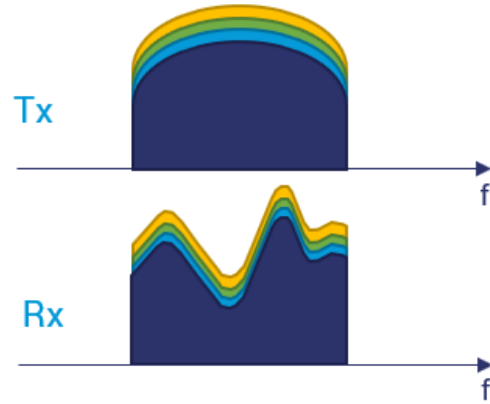
Frequency Division Multiplexing (FDM): Signals from **multiple transmitters** are transmitted simultaneously over **multiple frequencies (Introduce Sub Carriers Idea)**

Each subcarrier is modulated separately by different **data stream** and a **guard band** is placed between subcarriers to avoid signal overlap



OFDM Concept

2 options for transmitting the data



Both carry the same data but a deep fade damages only 1/4 of data

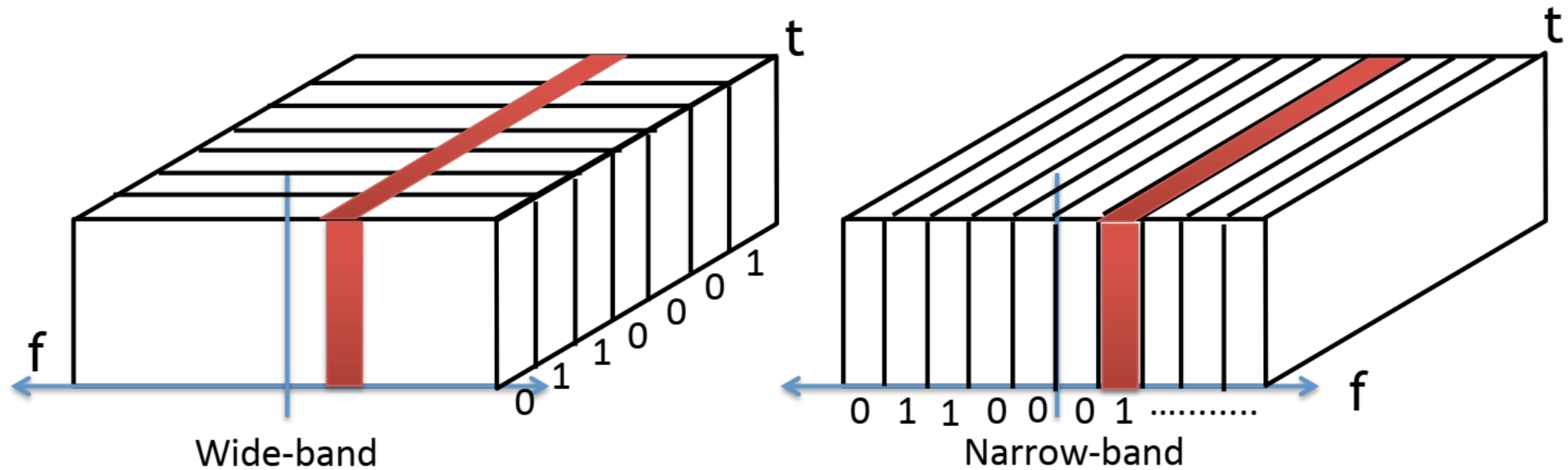
2 options for shipment goods via a truck



Both carry the same goods, but an accident damages only 1/4 of goods

OFDM Advantage

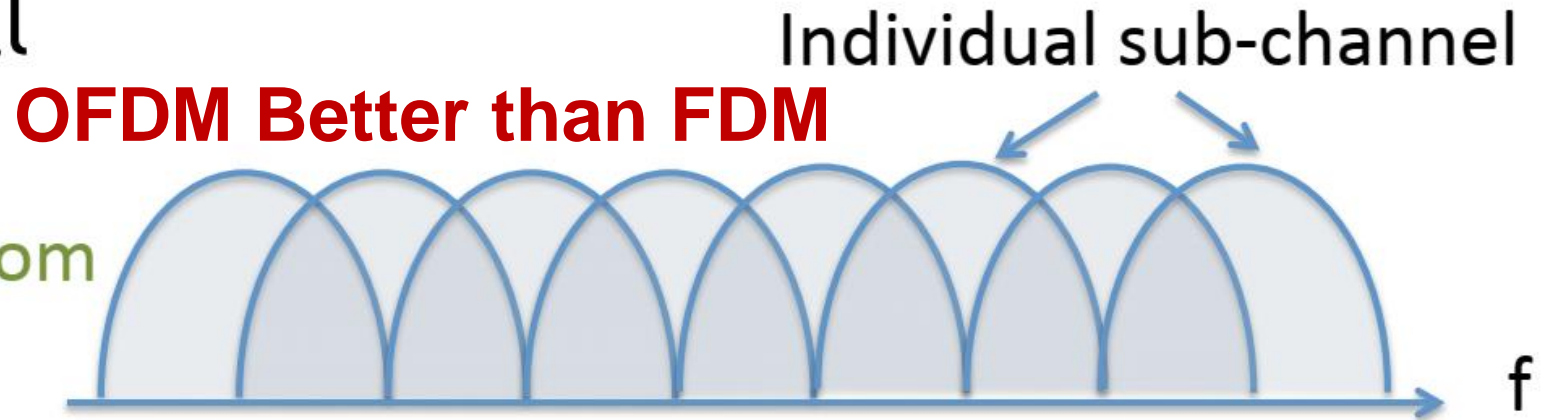
- Multiple sub-channels (sub-carriers) carry samples sent at a lower rate
- Almost same bandwidth with wide-band channel
- Only some of sub-channels are affected by interferers or multi-path effect



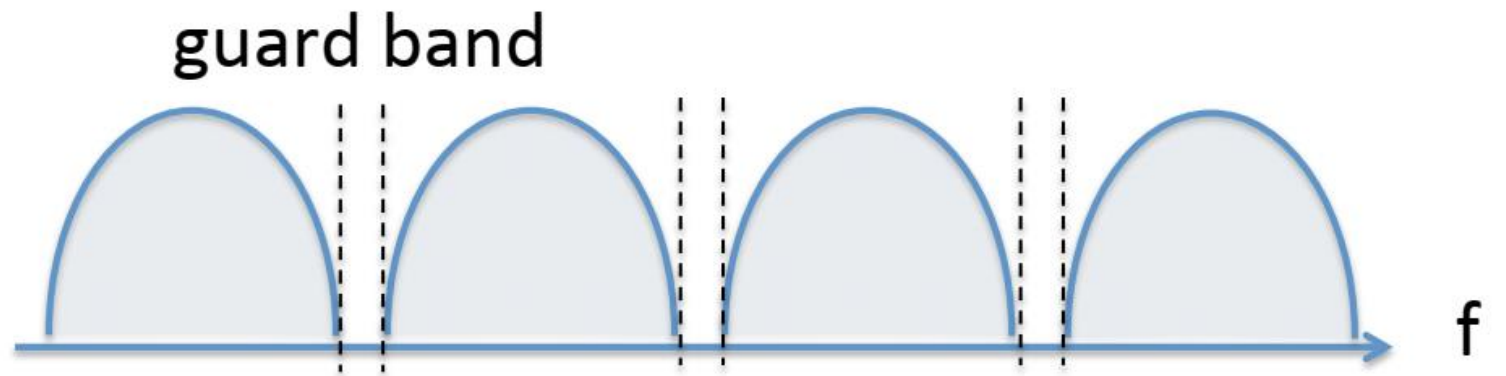
OFDM Orthogonality Benefit

- ▶ Not orthogonal

Leakage interference from adjacent sub-channels



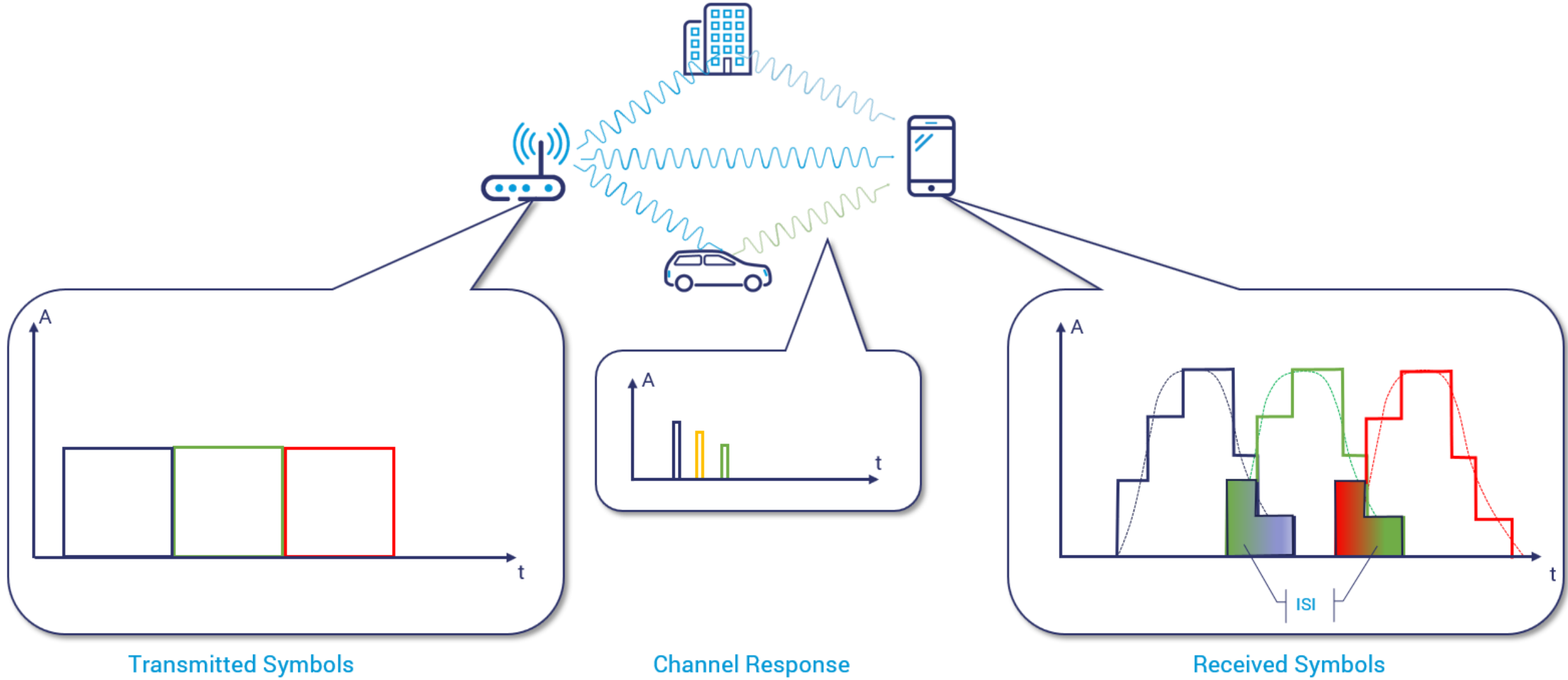
Guard bands protect leakage interference



- Need **guard bands** between adjacent frequency bands → extra overhead and lower throughput



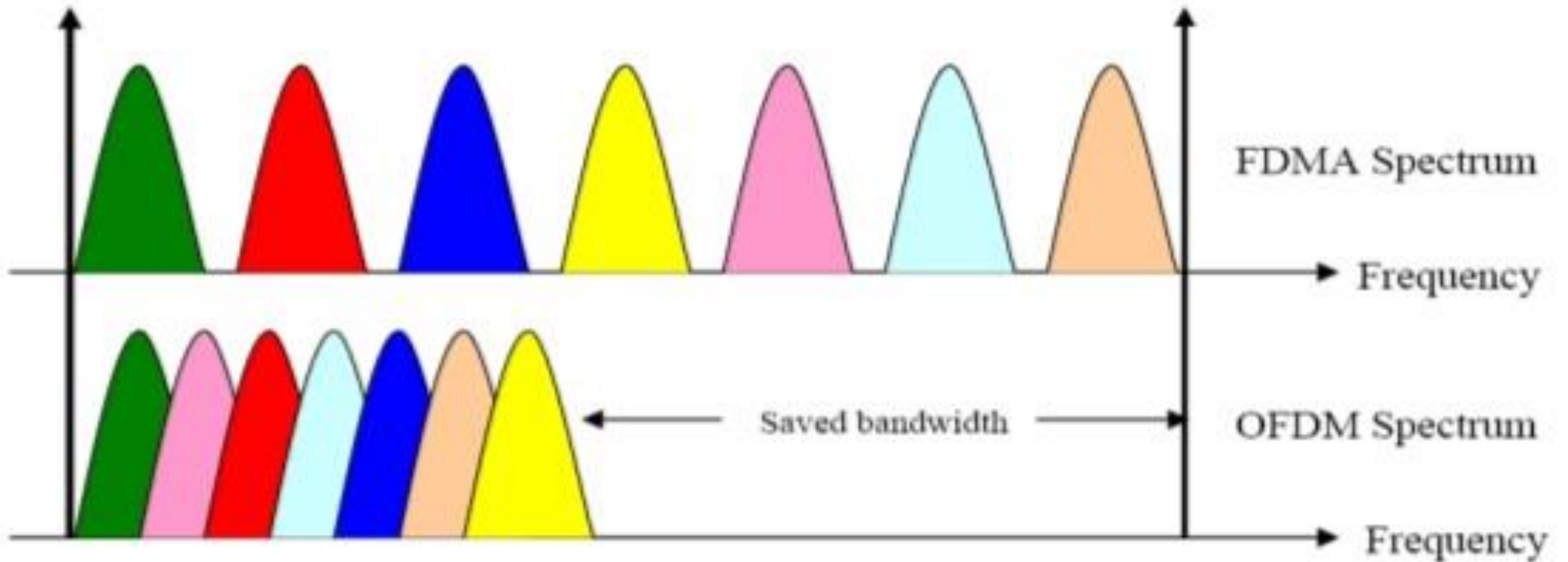
OFDM and Multi-Path



OFDM Advantages

- reduces ISI
- minimizes the effect of multipath fading
- results in bandwidth saving

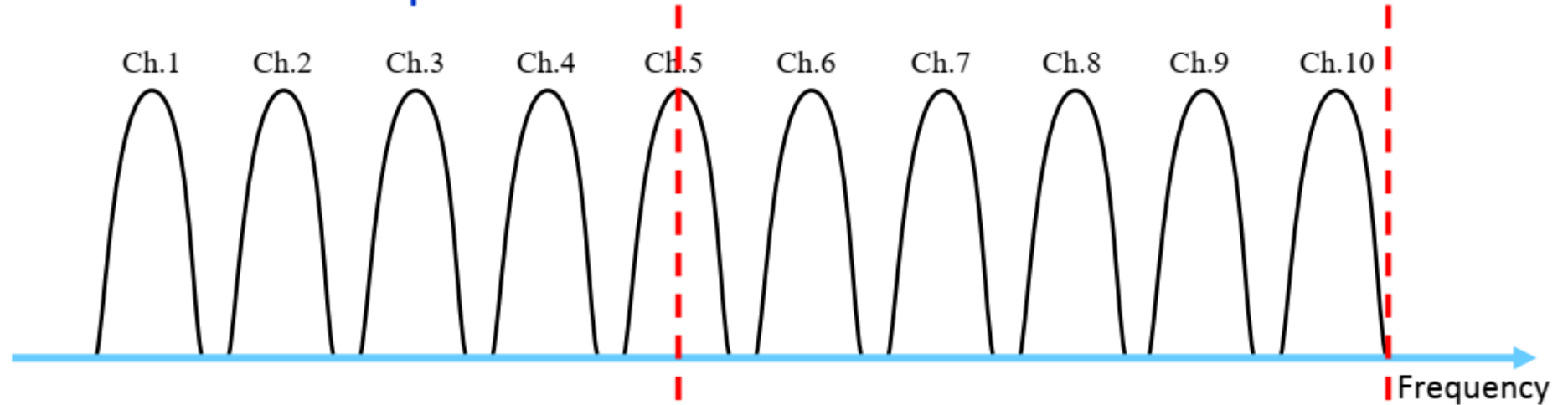
No need for Guard Interval



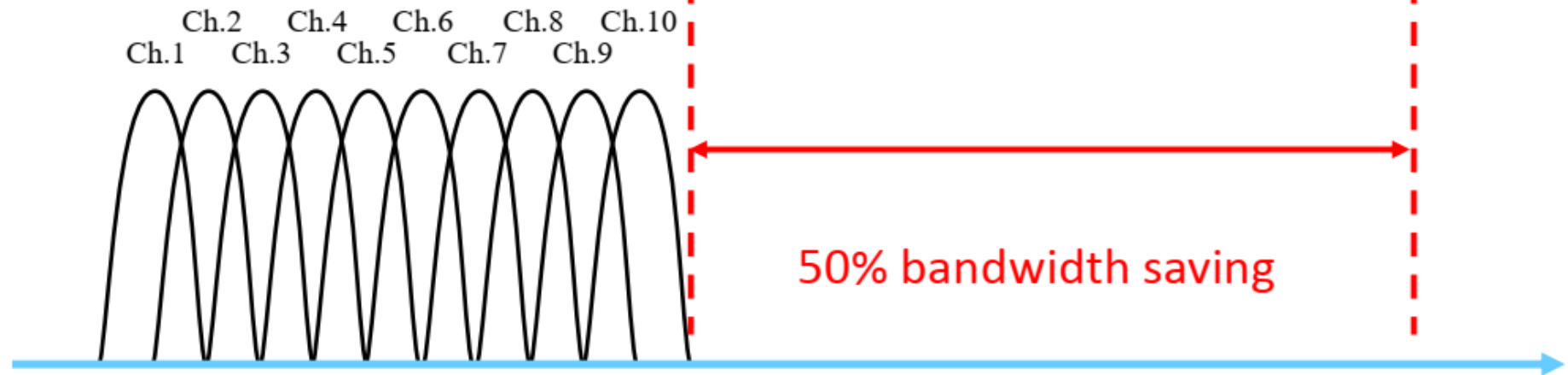
OFDM Vs FDM

Conventional multicarrier techniques

Bandwidth
Utilization



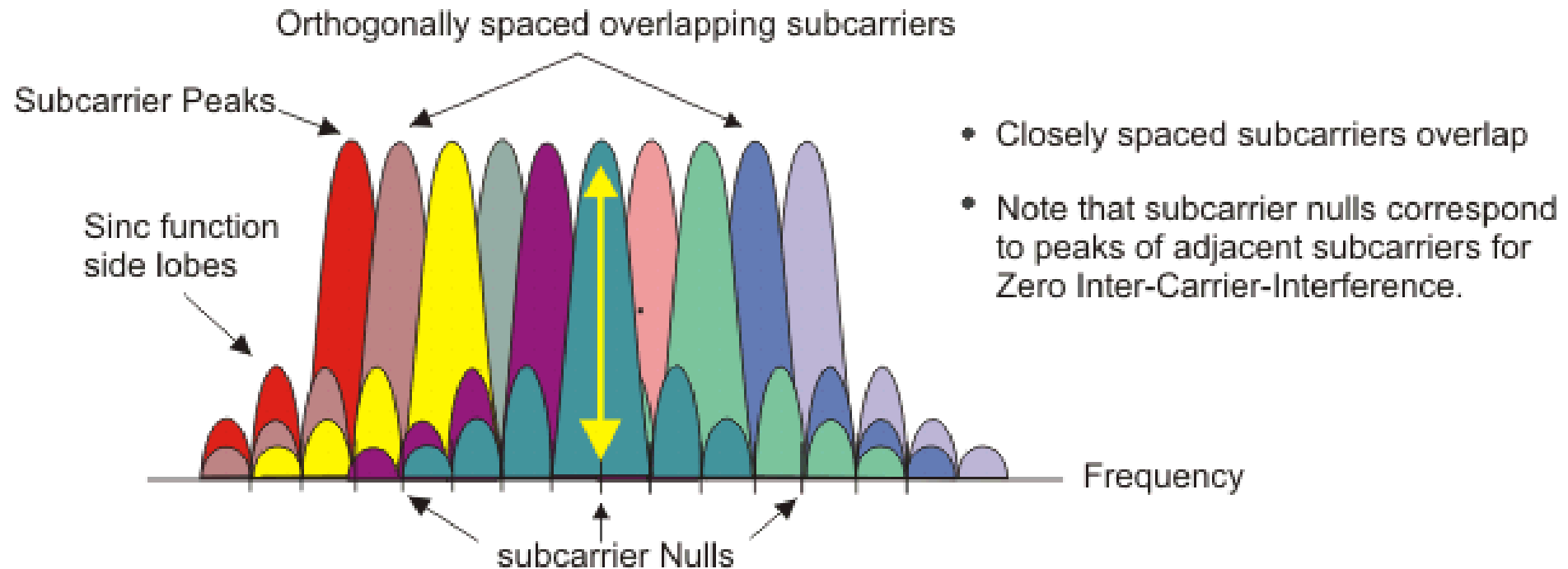
Orthogonal multicarrier techniques



OFDM Vs FDM

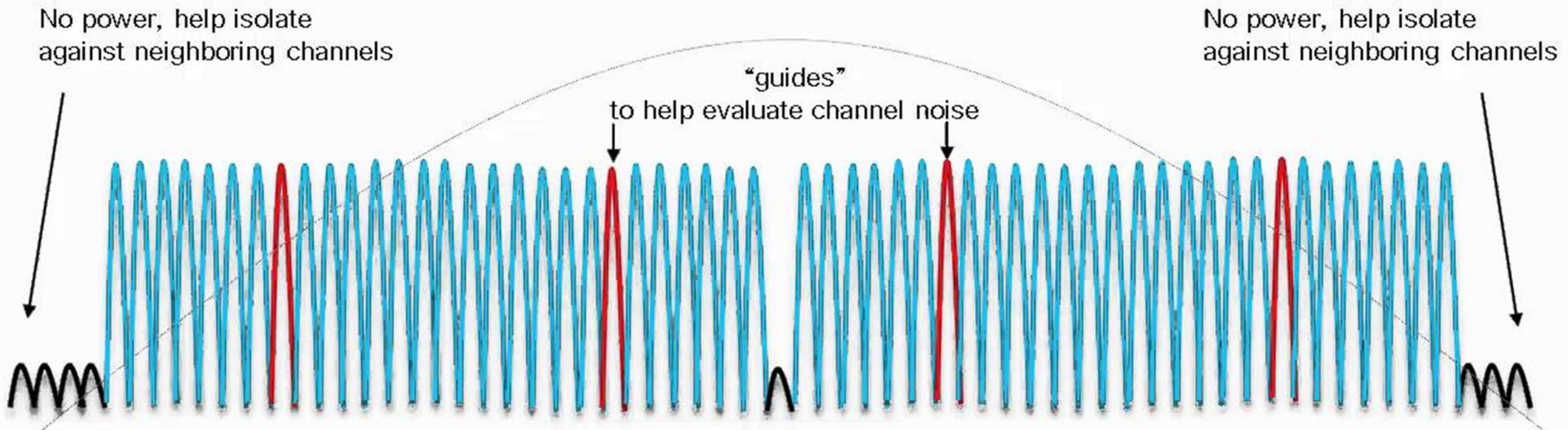
The **OFDM scheme** differs from traditional FDM in the following interrelated ways:

1. **Multiple carriers** (called subcarriers) carry the **information stream**
2. **The subcarriers** are **orthogonal** to each other
3. **A guard interval** is added to each **symbol** to minimize the channel delay spread and **inter-symbol interference**.



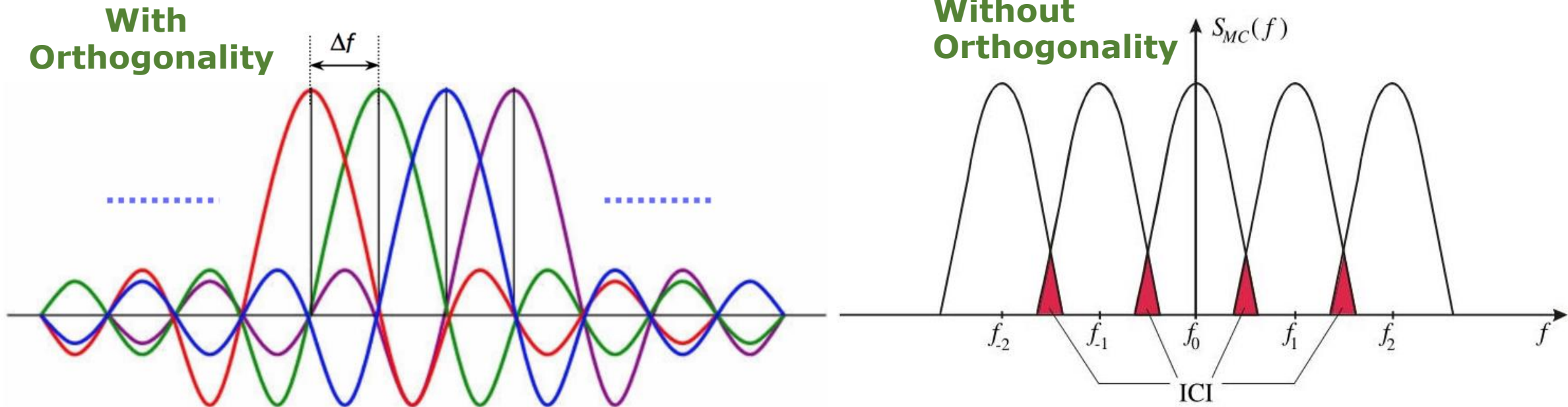
Orthogonal Frequency Division Multiplexing

- Allows **52 channels** to **overlap** without losing their **orthogonality** (individuality).
- **48 sub-channel** are used to **transmit data** and **4 Sub-channel** are used as **Pilot Carriers**.
- The **pilot sub-channels** are used to monitor **path shift** and shifts in sub-channel frequencies (Inter Carrier Interference (ICI))



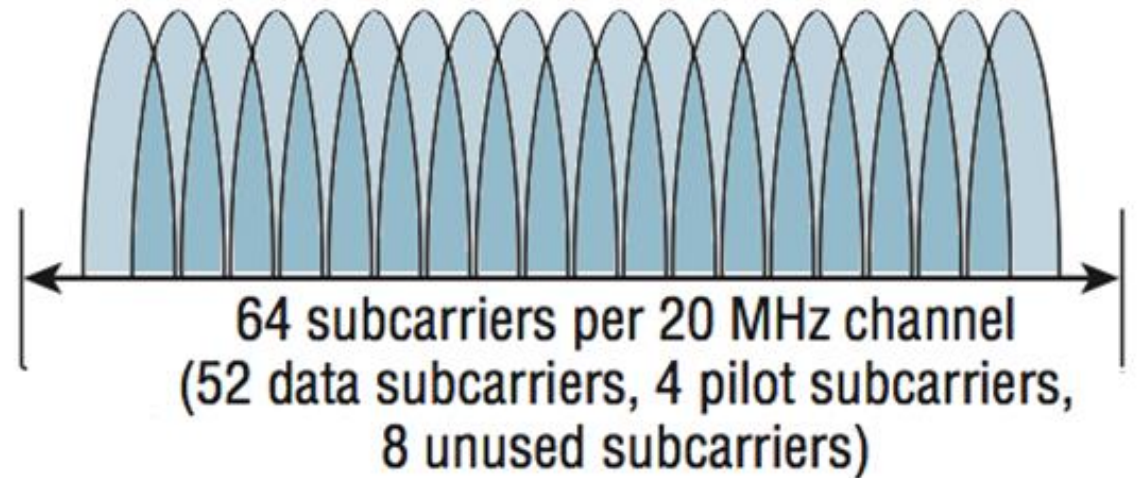
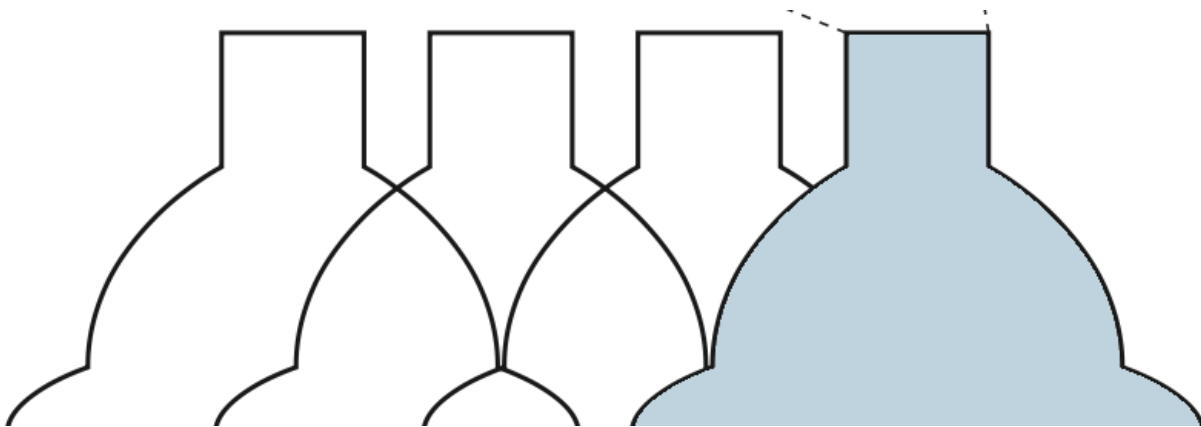
Orthogonal Frequency Division Multiplexing

- **(OFDM)** divides a given channel into many narrower subcarriers.
- **OFDM subcarrier** spacing creates "**nulls**" canceling out **inter-carrier interference (ICI)** without the need for **guard bands** or expensive band pass filters



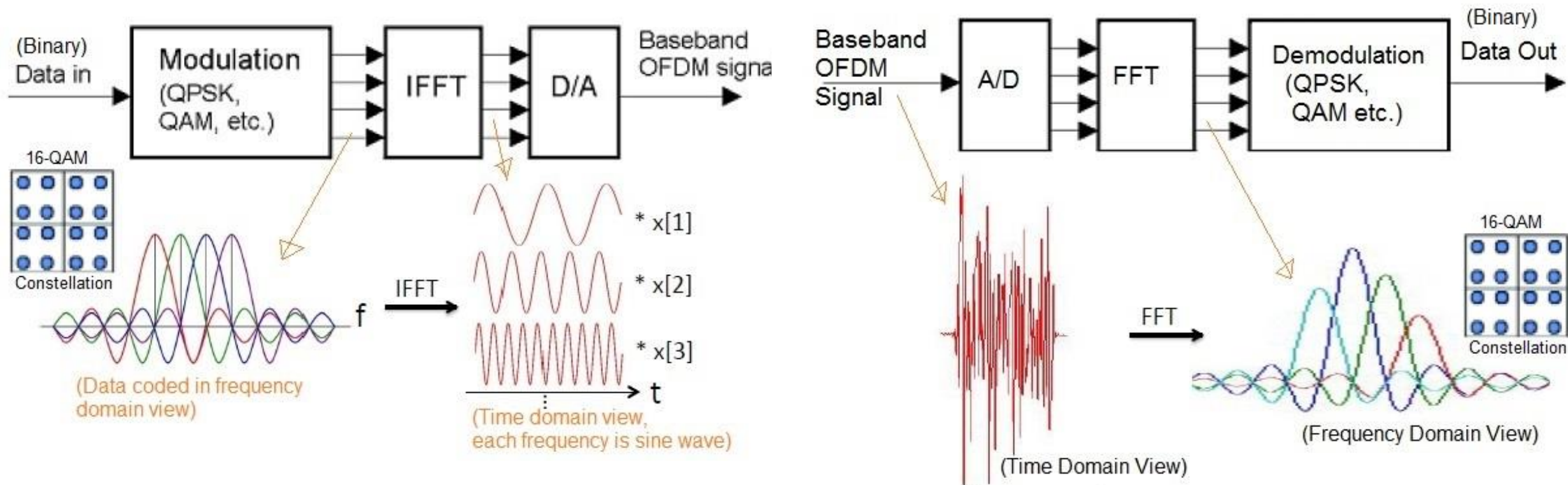
OFDM Sub Carriers

- **Orthogonal Frequency Division Multiplexing (OFDM)** is a digital multi-carrier modulation scheme that use multiple **subcarriers** within the **same single channel**.
- Rather than transmit a **high-rate** stream of data with a **single subcarrier**, OFDM makes use of a large number of **closely spaced orthogonal** subcarriers transmitted in parallel.

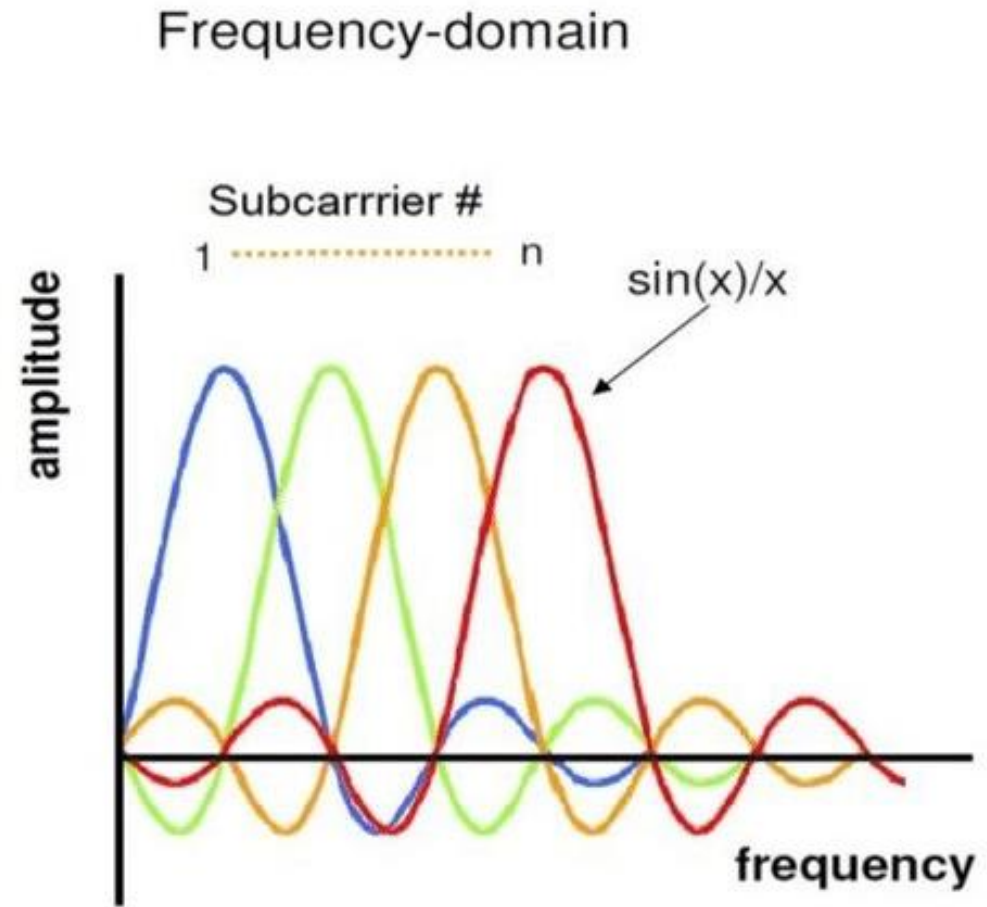
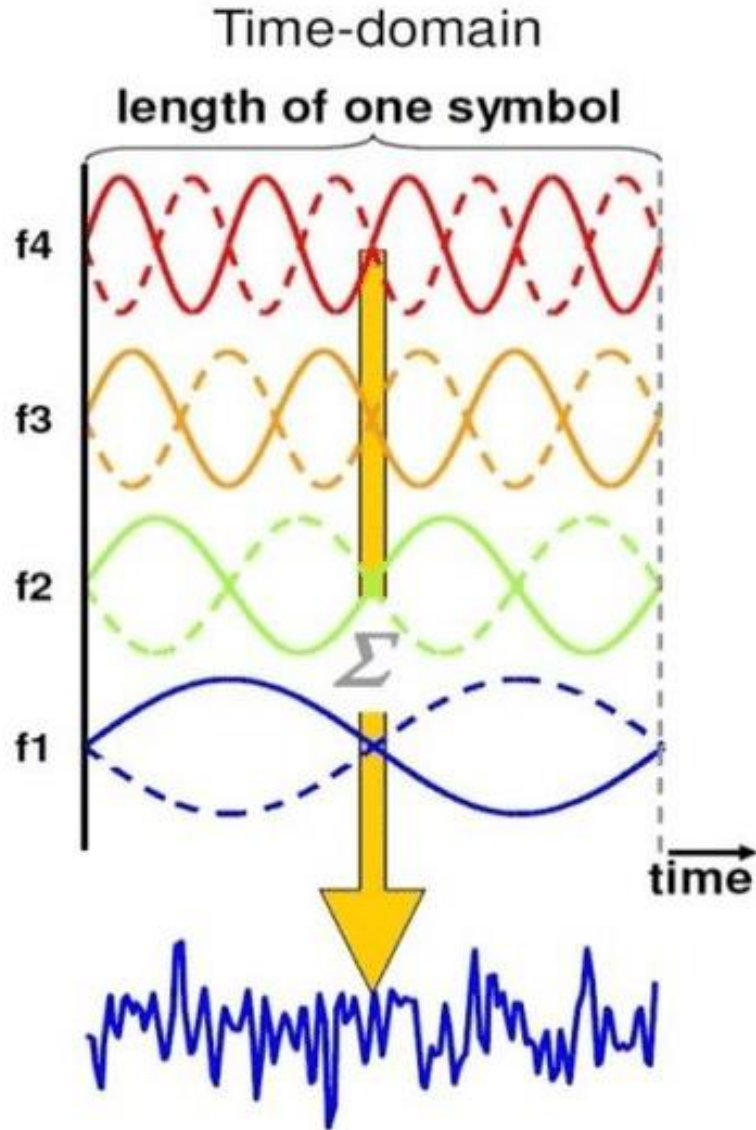


ODFM Operation

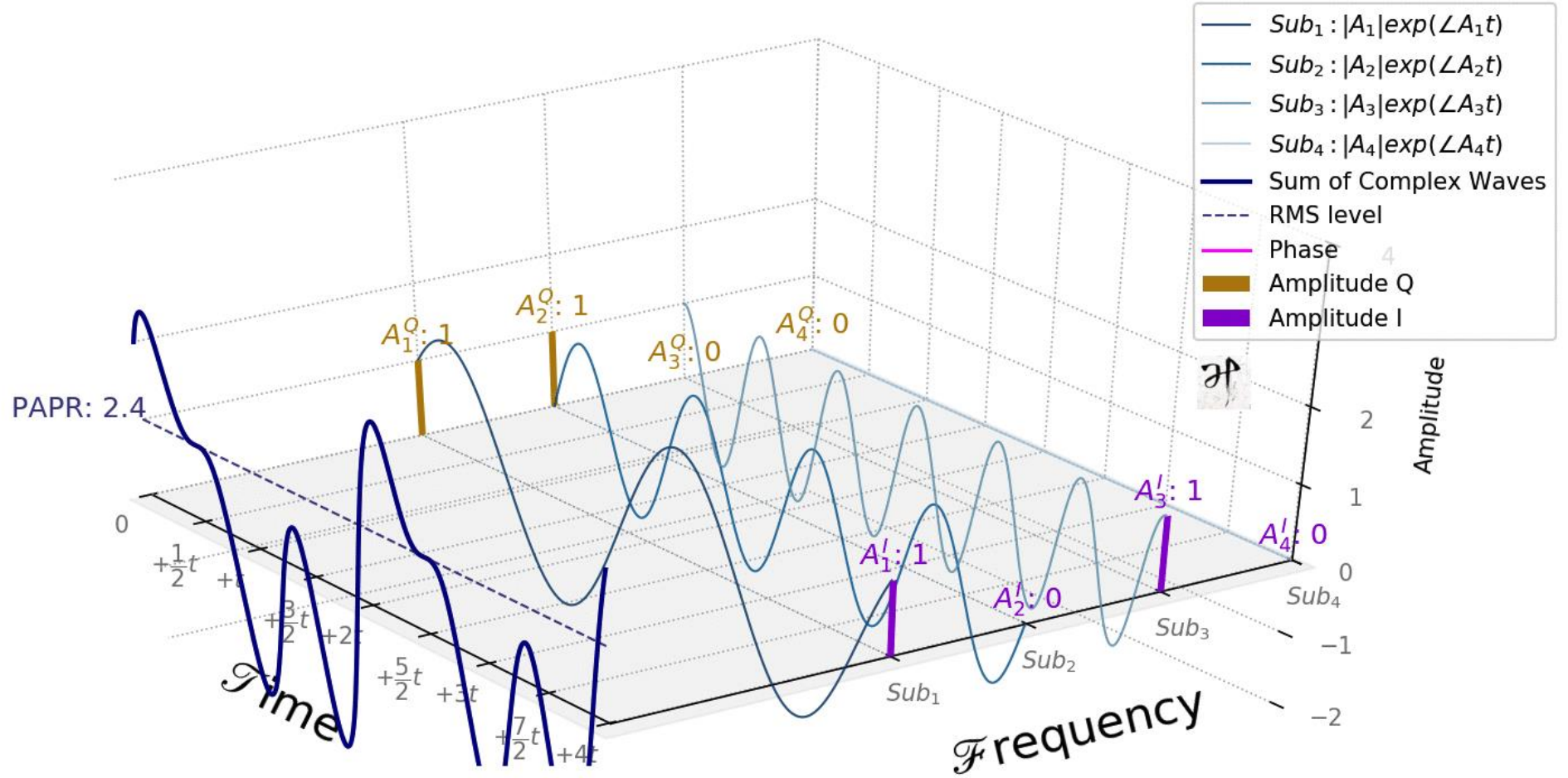
- **Data subcarrier modulation** formats are **BPSK, QPSK, 16QAM, and 64QAM**.
- Each **OFDM subcarrier** carries a single **modulated data symbol**, or "**constellation point**", along with its **magnitude** and **phase** information .
- **Magnitude** and **Phase** will vary for each **subcarrier and OFDM symbol** in transmitted burst.



OFDM Operation



OFDM Operation



OFDM Operation



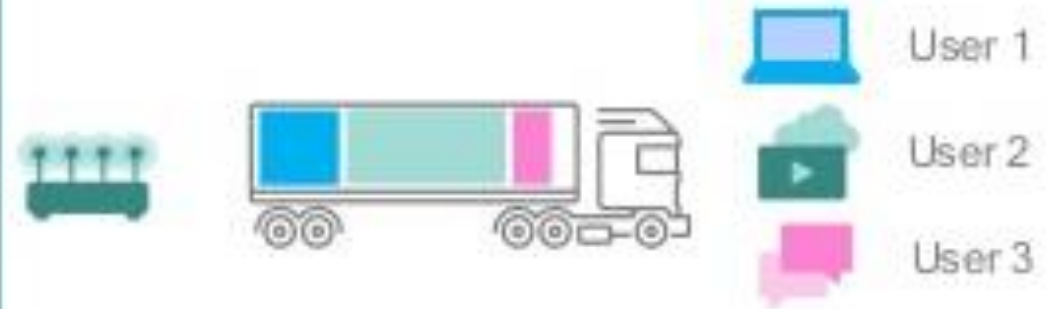
OFDM Vs OFDMA

OFDM



- Fixed overhead independent of payload size
- Uses full channel bandwidth per user

OFDMA

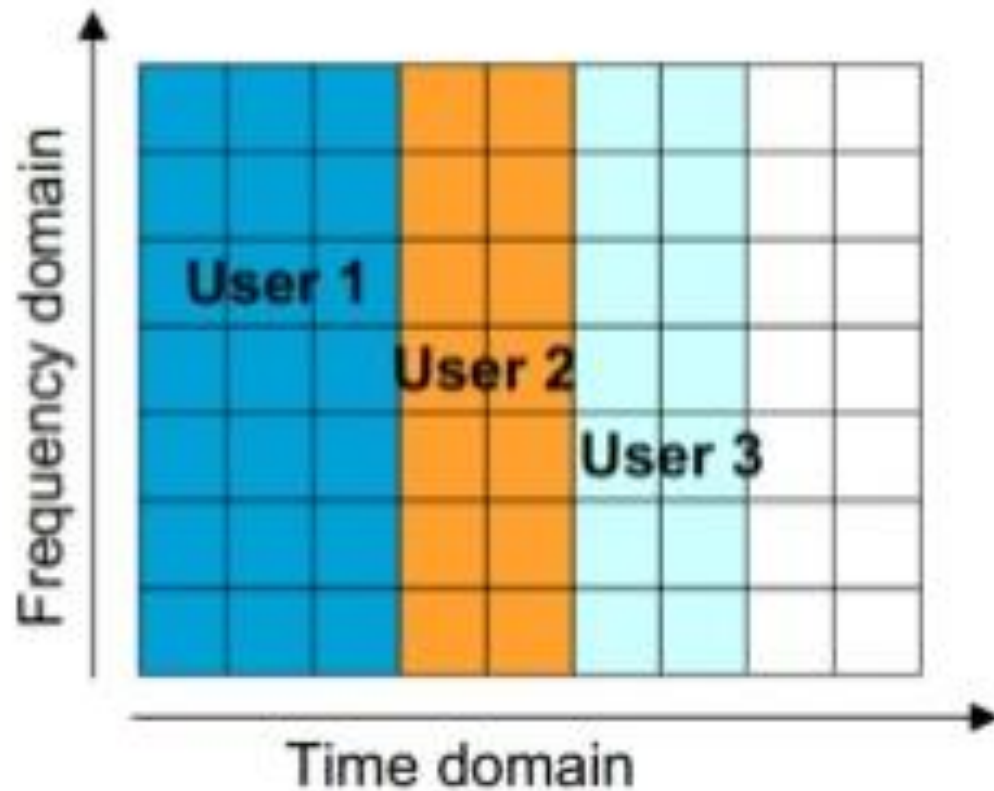


- Overhead amortized among users
- Efficient use of resources
- Scales resources for different types of traffic (e.g. IM vs large download)
- Increases overall efficiency

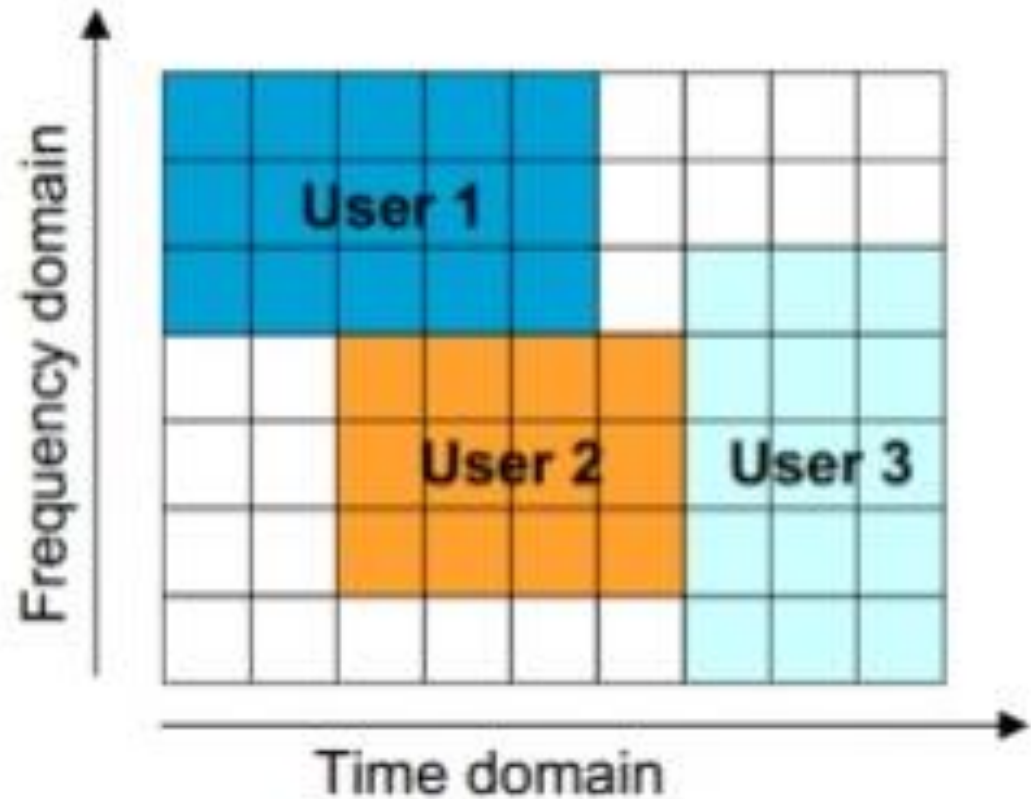
OFDM Vs OFDMA

OFDMA more advanced form of OFDM where subcarriers are allocated to different users over time

I OFDM allocates users in time domain only

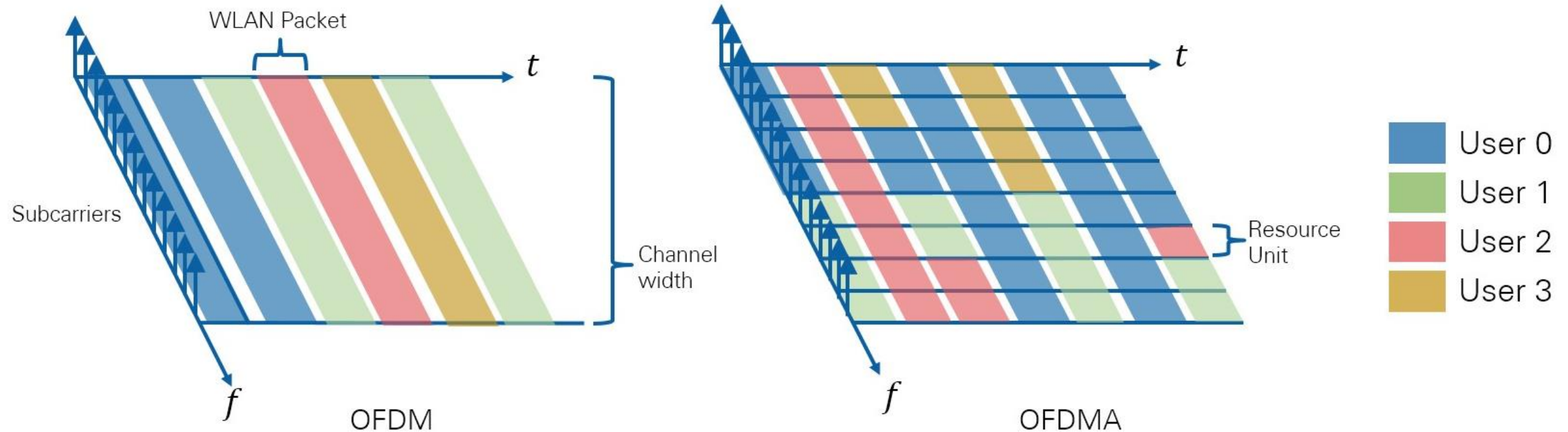


I OFDMA allocates users in time and frequency domain



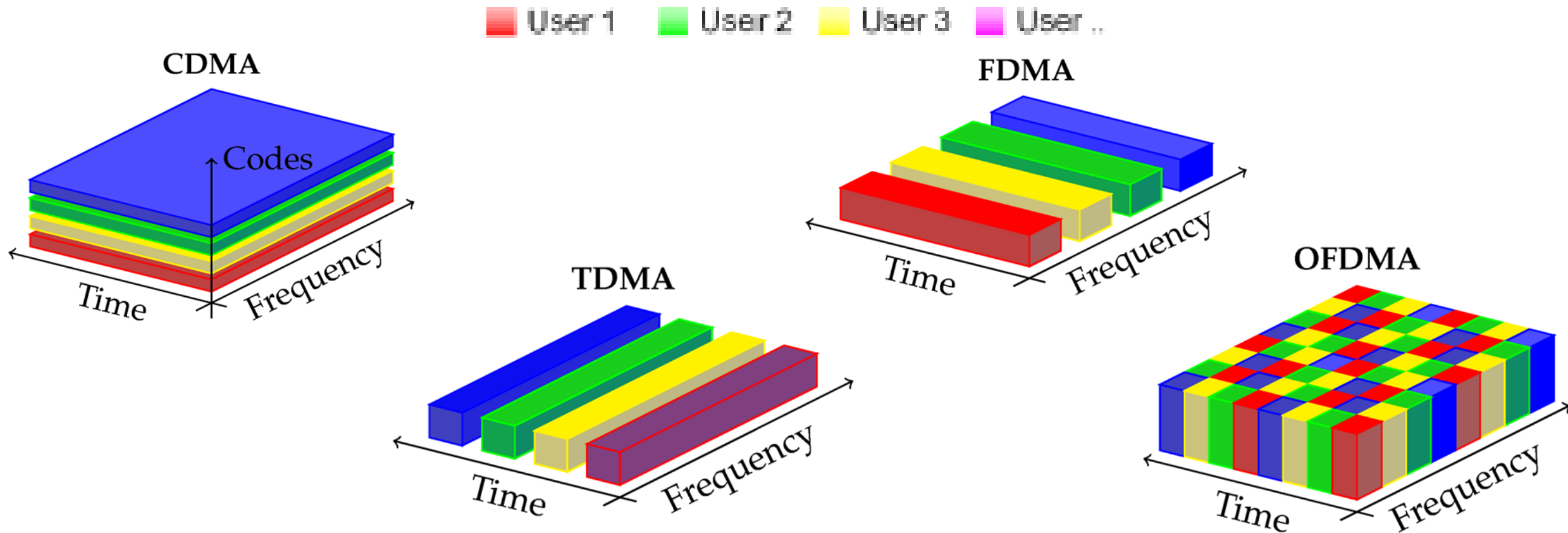
OFDM Vs OFDMA

- **OFDMA** is a **multi-user version** of the **OFDM** digital-modulation technology.
- **OFDMA** subdivides a channel into **smaller frequency** parts named *resource units*
- **Resource Units (RUs)** could be assigned to **different users** at same channel

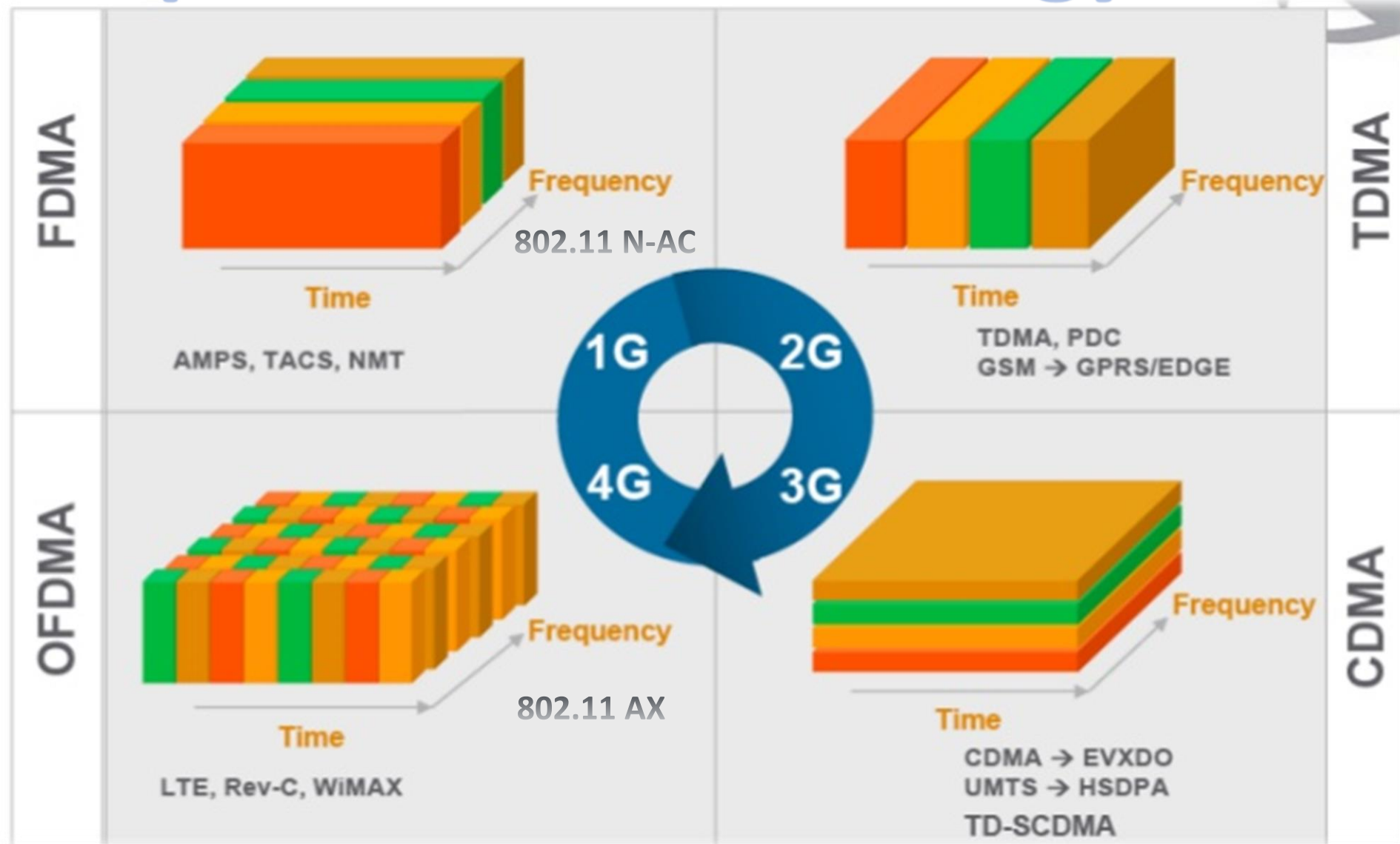


Multiple Access Technology Summary

OFDM is the state-of-the-art and most efficient and robust air interface



Multiple Access Technology Summary





Thanks
For
Watching

GAZ  **RAB**