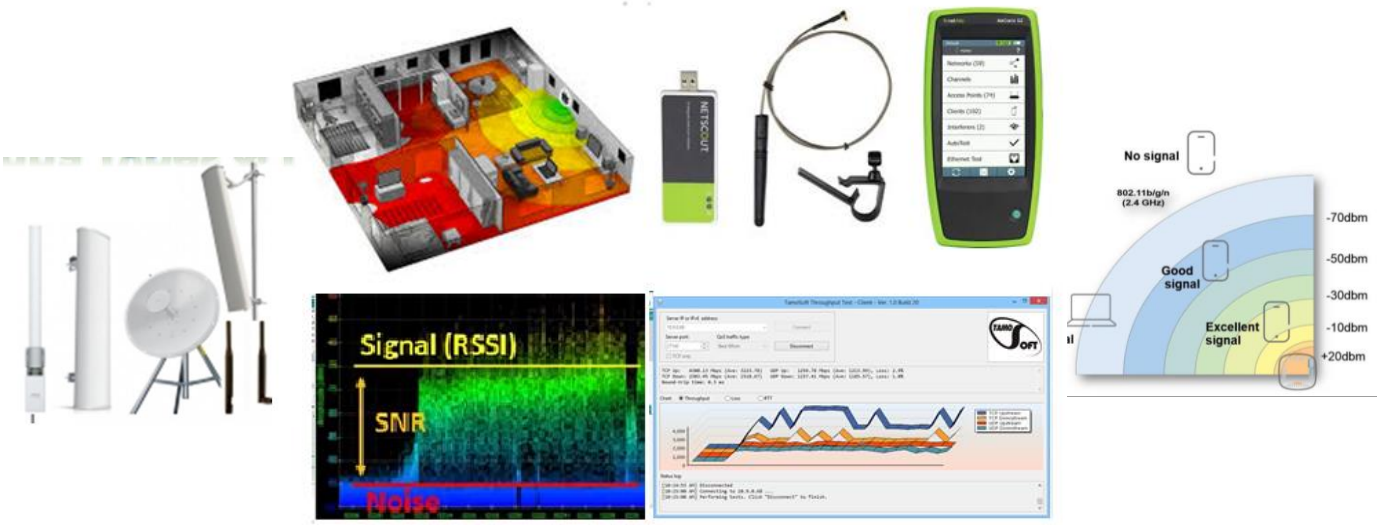
Wireless Technology

WLAN Practical Training



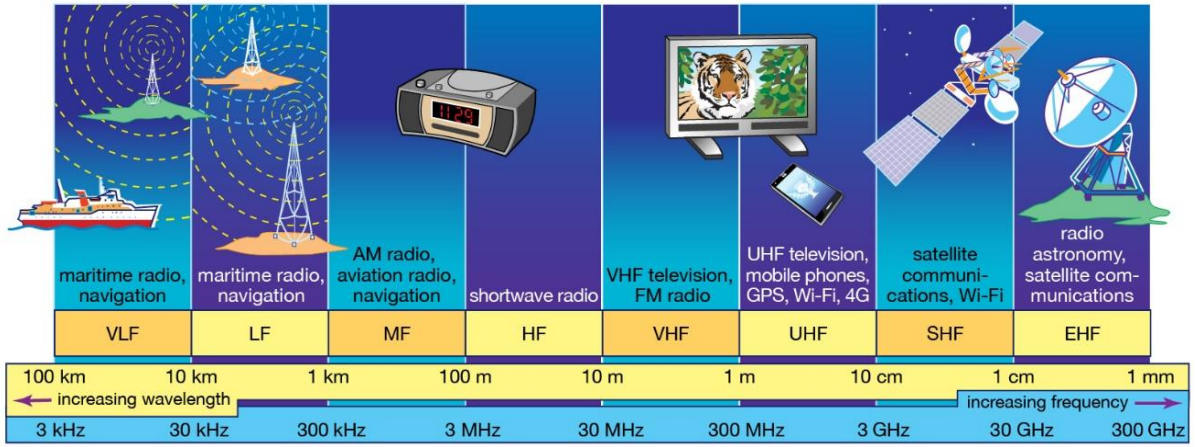
WLAN Practical Training

1. Radio Frequency Basics Revision
2. WLAN Software Types and Usage
3. TOP Vendors for WLAN Software & Tools
4. Analysis Software and Tools
5. Planning and Design Software
6. Assessment Software and Tools
7. Speed and throughput test Software
8. Practical Labs for WLAN Software

WLAN-PRACTICAL LECTURE 1

RF Basics Review

Wi-Fi Channel and Bands



WLAN Practical Training

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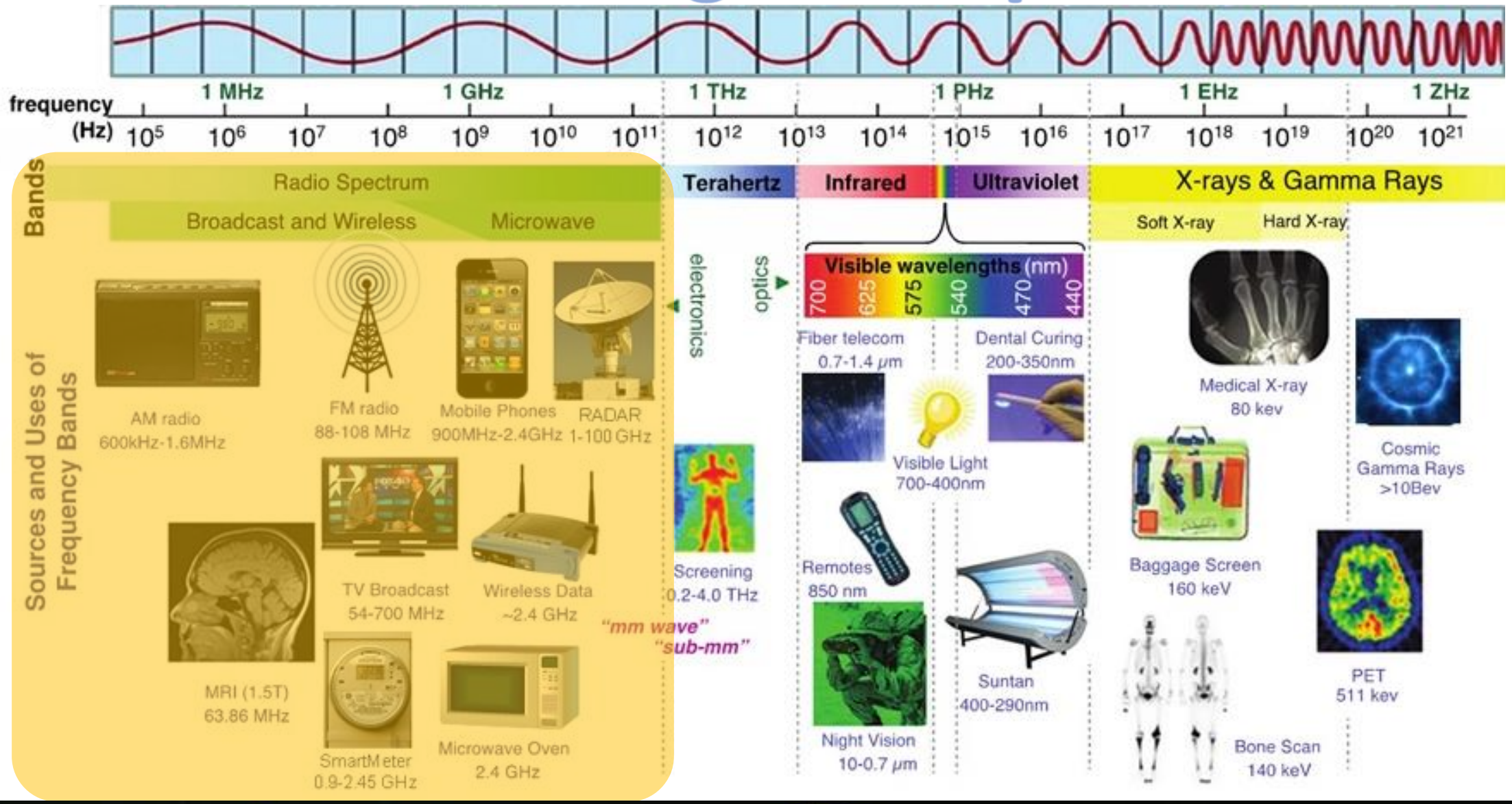
LEC 1 : RF Basics Review

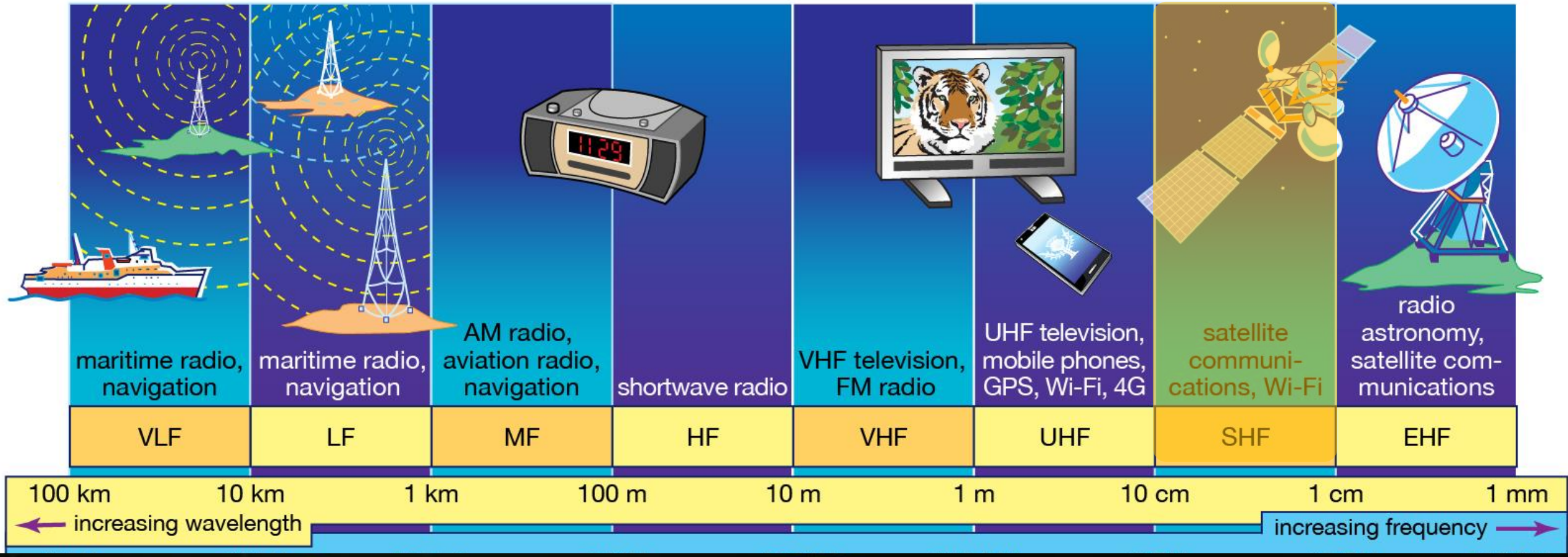
1. Wi-Fi Frequency Bands
2. Channel Width and Channel Bonding
3. Wireless Signal Measurements
4. Wi-Fi Antenna Models
5. Data Rate and Signal Strength Relation
6. WLAN Interference types and Impact

Electro Magnetic Spectrum



Radio Frequency Bands for Wi-Fi

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



802.11 Frequency Bands

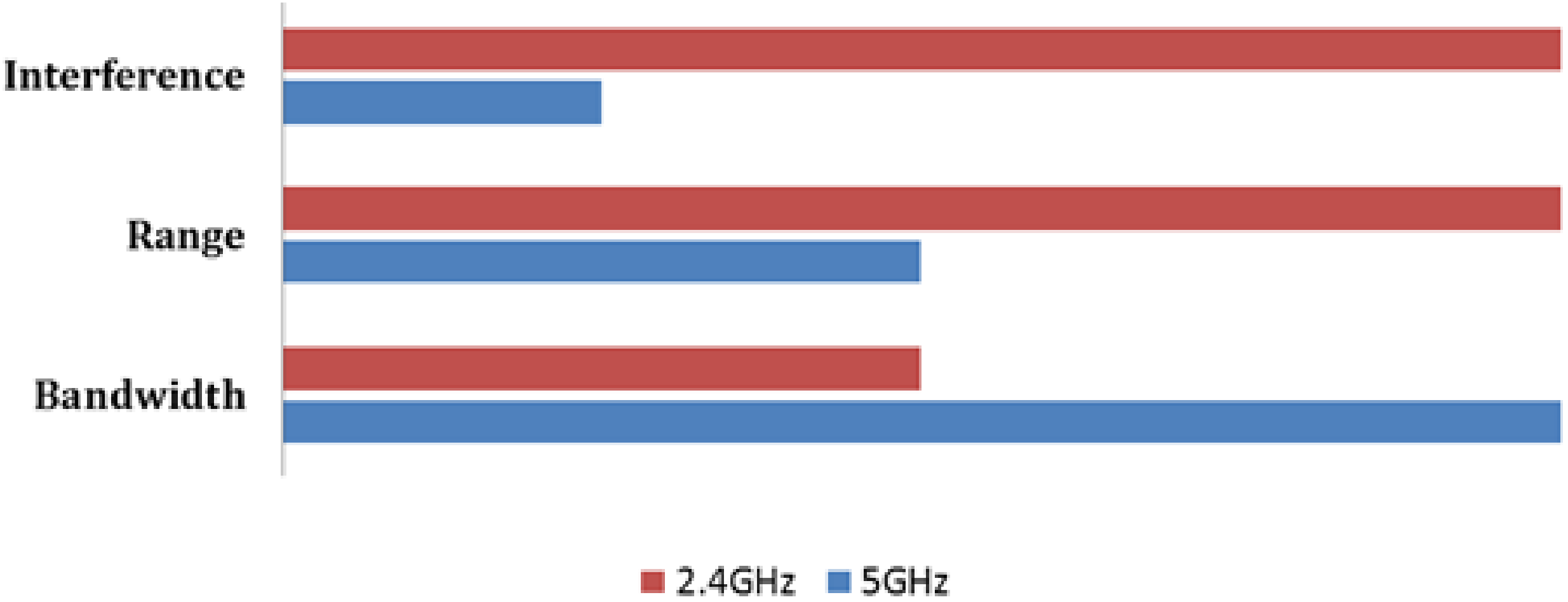
2.4 GHz (802.11b/g/n)

- Greater Range (~300 ft)
- Universal Compatibility
- Congested with Wi-Fi
- Plagued by non-Wi-Fi interference
- 3 non-overlapping channels

5 GHz (802.11a/n/ac)

- Lower Indoor Range (~90 ft)
- Limited Compatibility (a/n/ac)
- 24 non-overlapping channels

2.4 GHz Vs 5 GHz



WiFi Frequency 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.

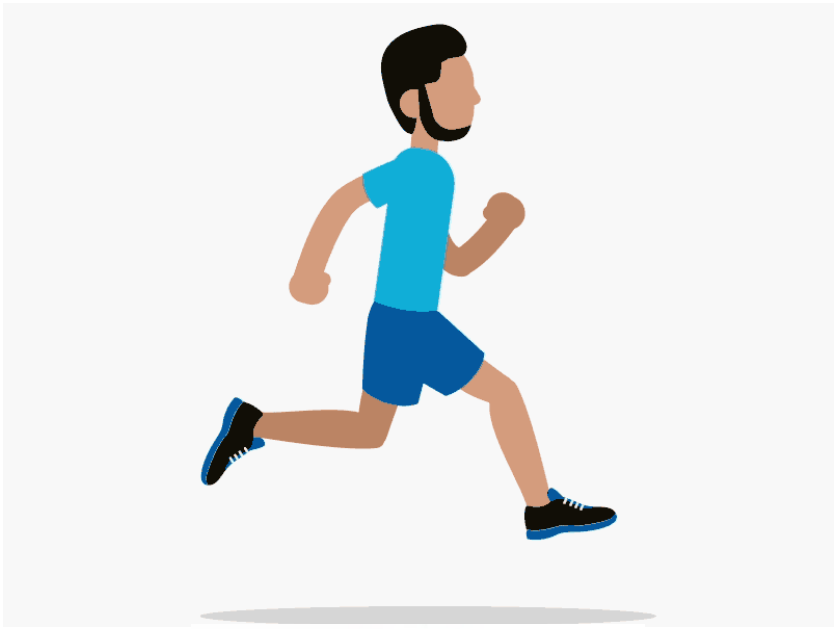
2.4 GHz BAND

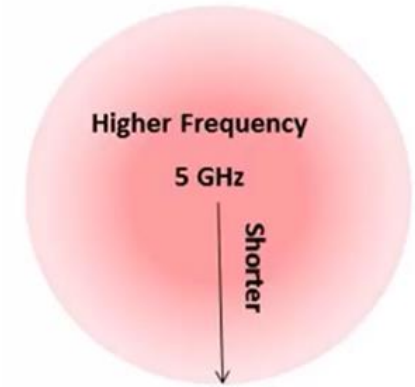
- Lower Frequency
- Longer Wavelength
- Typically More Range
- More Crowded
- More non-Wi-Fi Interference
- 802.11b/g/n/ax

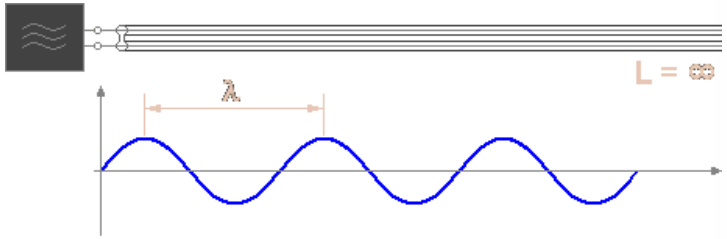
5 GHz BAND

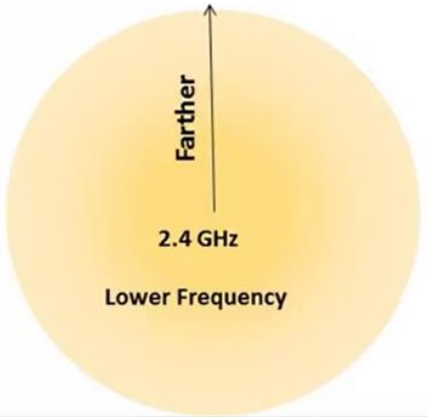
- Higher Frequency
- Shorter Wavelength
- Typically Less Range
- Less Crowded
- Less non-Wi-Fi Interference
- 802.11a/n/ac/ax

RF Waves Characteristics



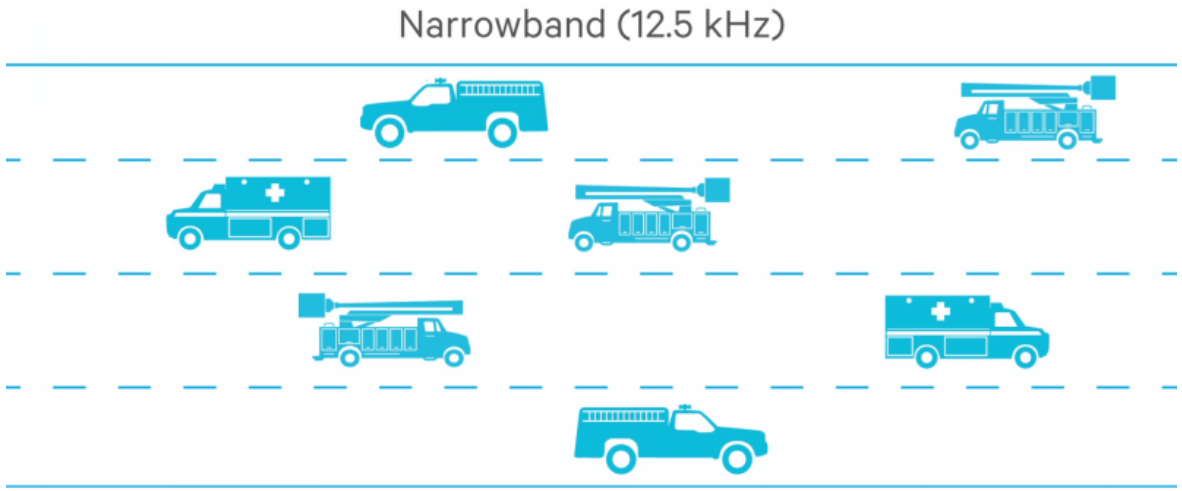


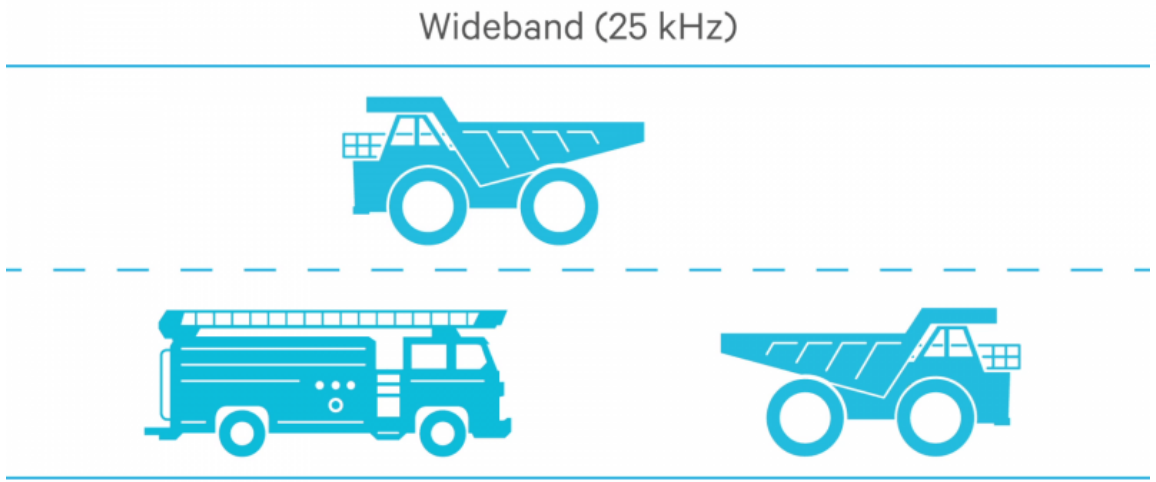


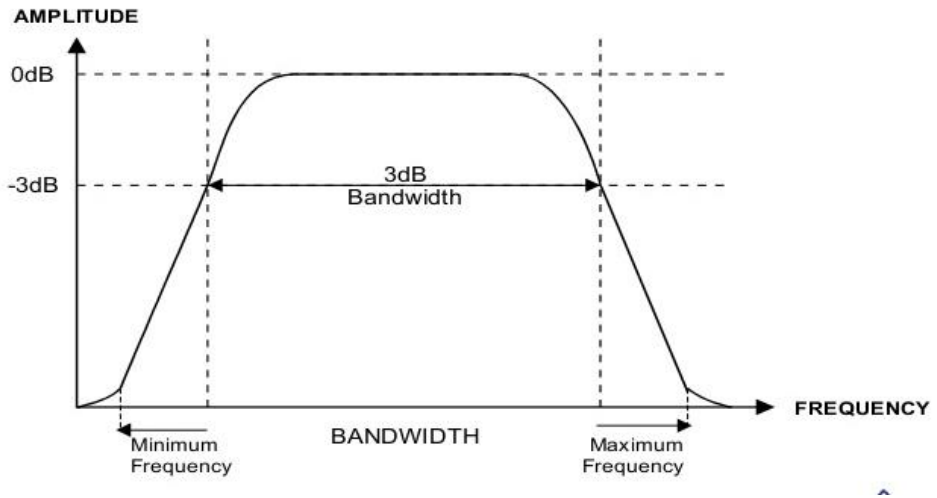


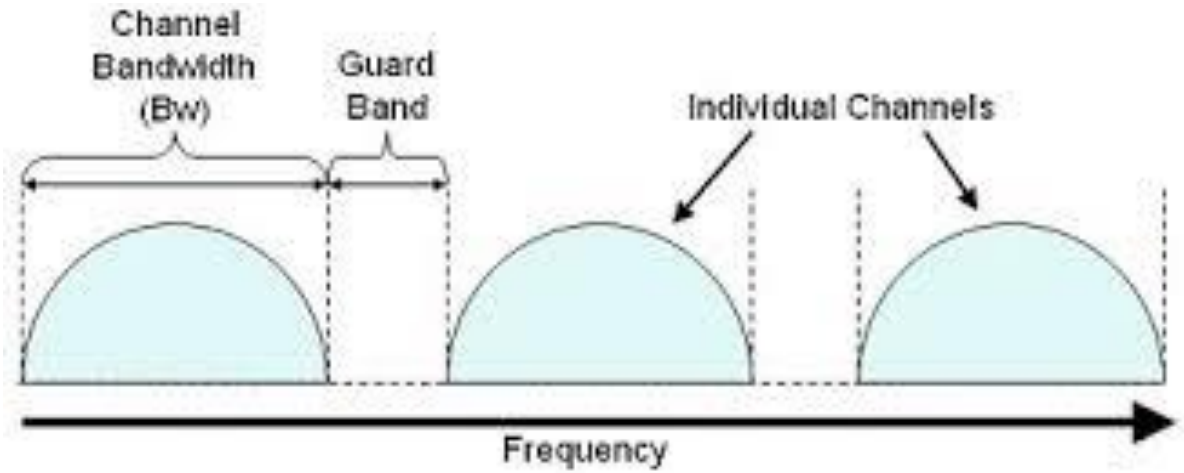
Lower Freq – Longer Wave Length – Less Power -More Distance

RF Bands and Channel Width

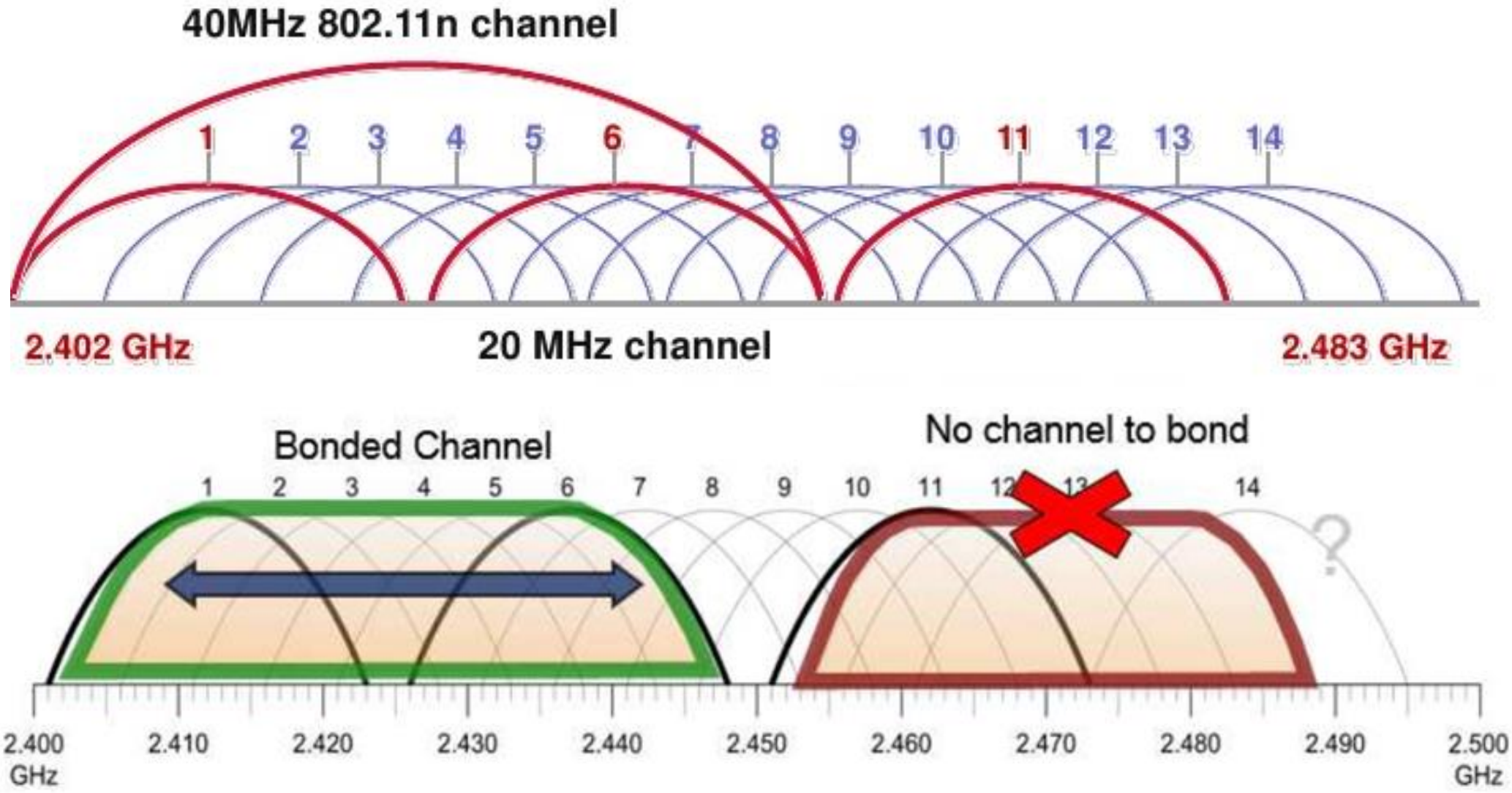




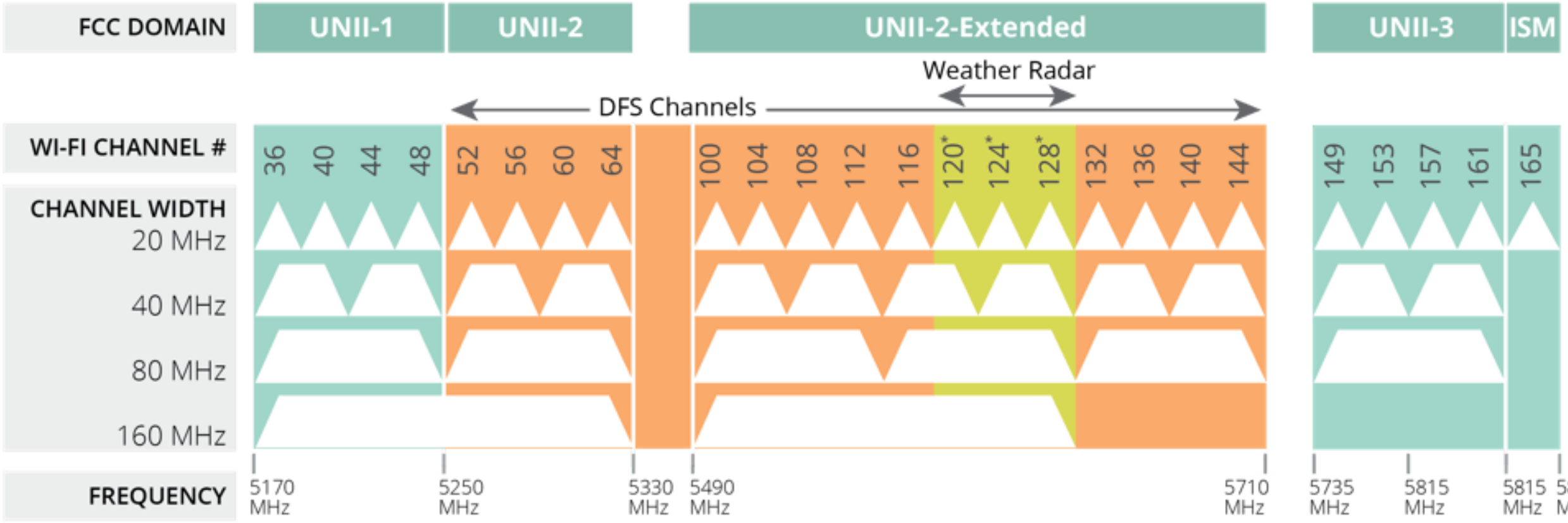




2.4 GHz Channels



5 GHz Channels



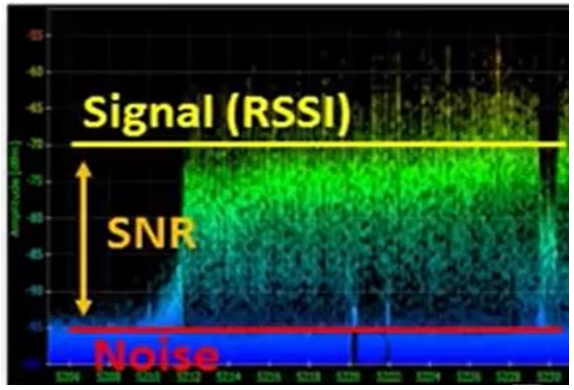
**Channels 120, 124 and 128 are Doppler Radar channels that may be used in some cases.*

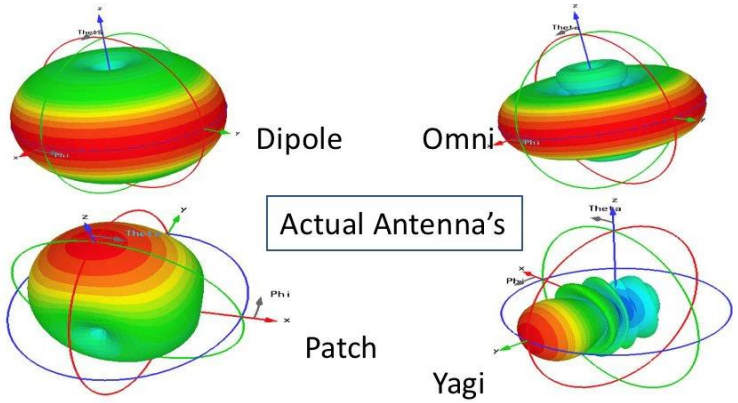
Channels	20 Mhz	40 Mhz	80 Mhz	160 Mhz
DFS	25	12	6	2
No DFS	9	4	2	0

WLAN-PRACTICAL LECTURE 2

RF Basics Review

RF Power Measurements & Antenna Models





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

EIRP

LEC 2 : RF Basics Review

1. Wi-Fi Frequency Bands
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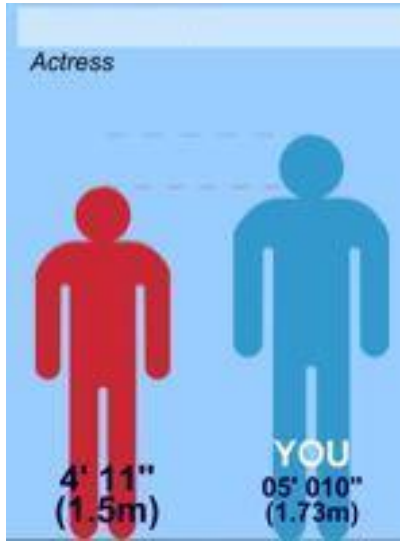
3. **Wireless Signal Measurements**
4. **Wi-Fi Antenna Models**
5. **Data Rate and Signal Strength Relation**
6. **WLAN Interference types and Impact**

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

dB

No units

Power Related to another

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

dBm

Power Related to 1 m watt

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

dBi

Antenna Gain

Related to isotropic Antenna

SNR

Signal to Noise Raito

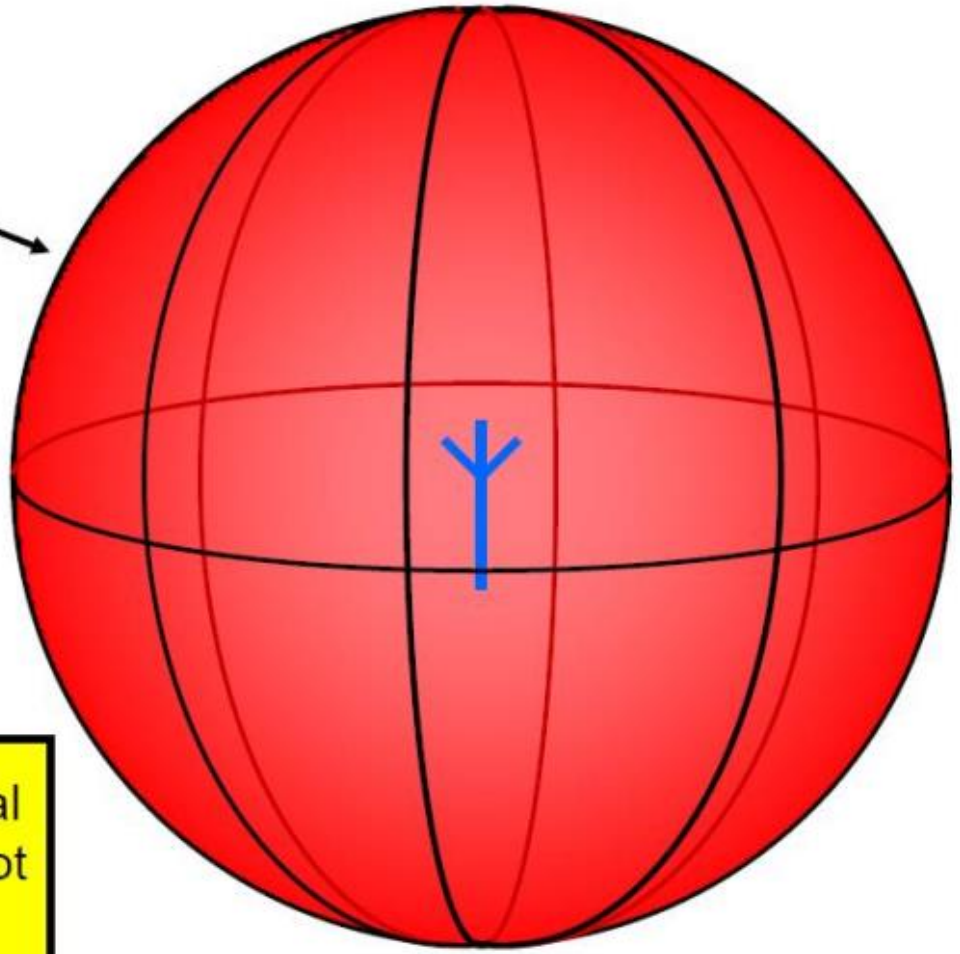
AP O/P Power

RSSI at Client

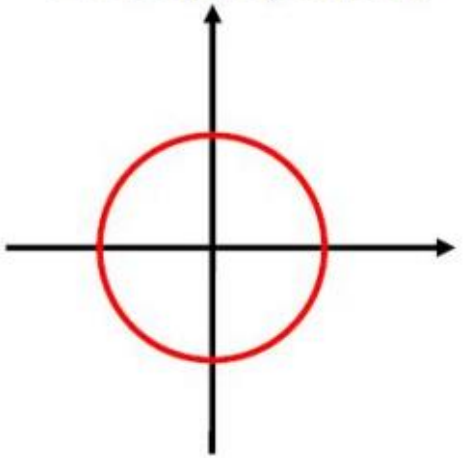
Antenna Gain

The **isotropic antenna** radiates equally in all directions

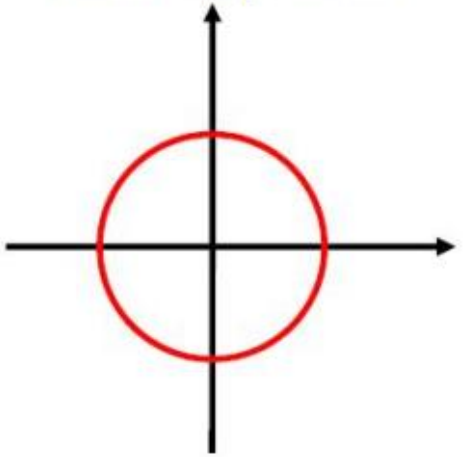
Radiation pattern is spherical



Elevation pattern

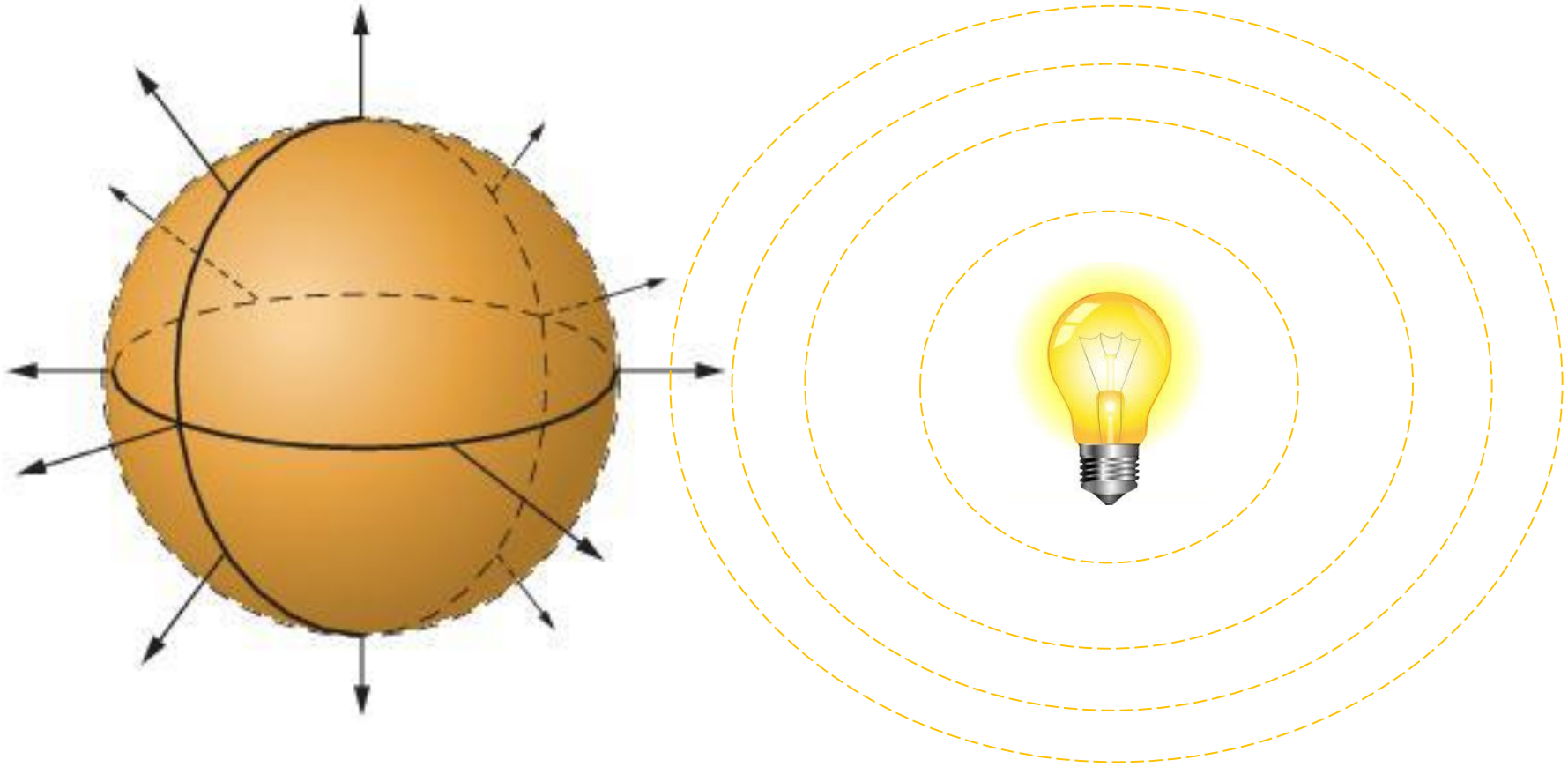


Azimuth pattern



This is a theoretical antenna that cannot be built.

Antenna Operation



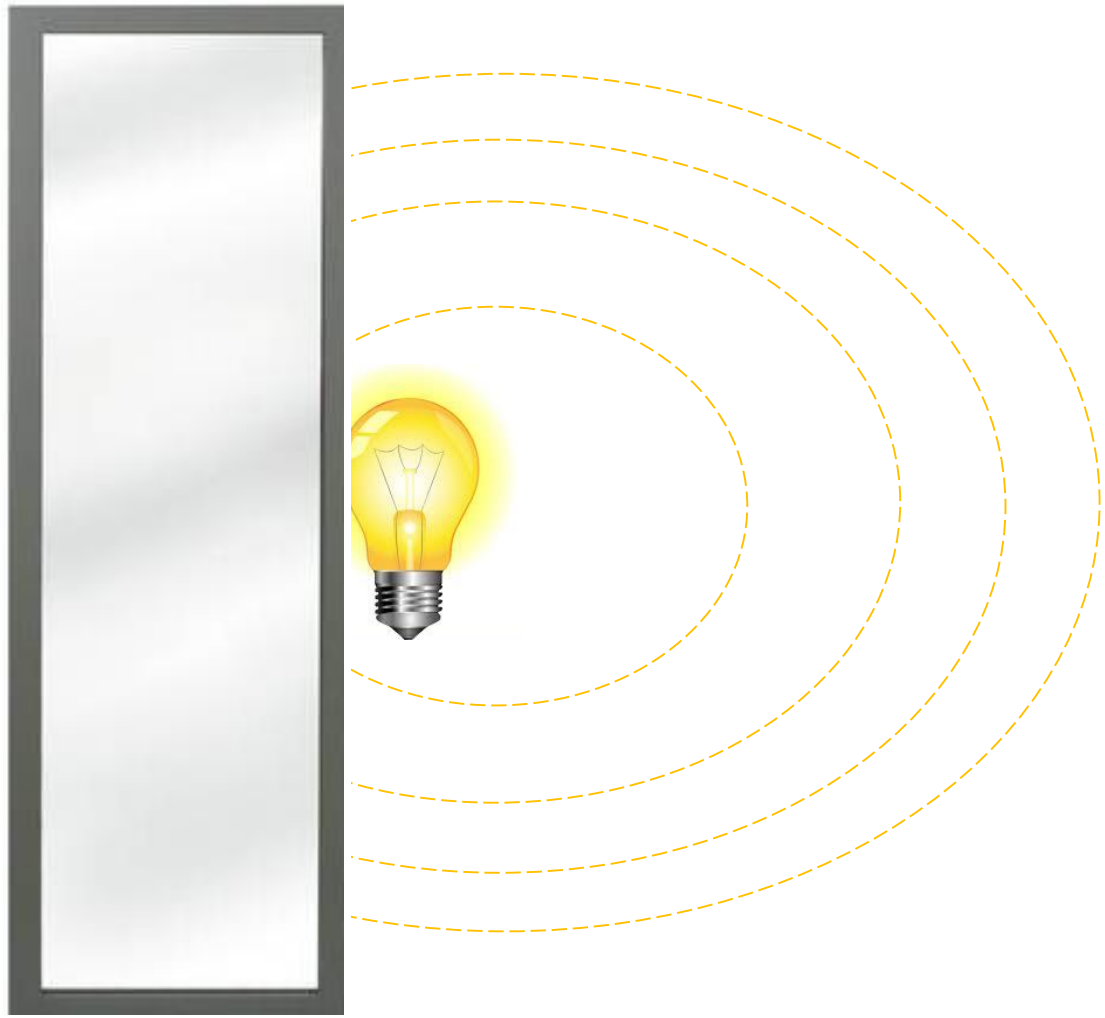
Total radiated power
equal in all directions

Isotropic Antenna 1 Watt

Antenna Operation

EIRP

Equivalent Isotopically Radiated Power



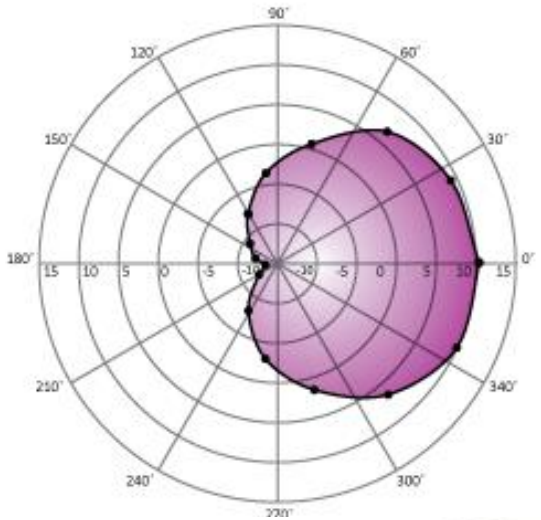
Gain

2 Watt

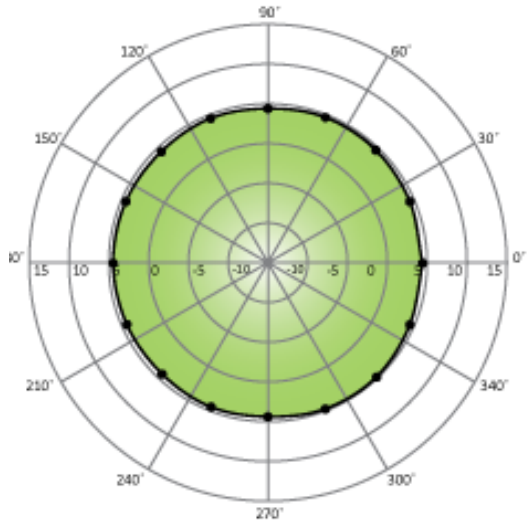
3dBi

Antenna Operation

Sector

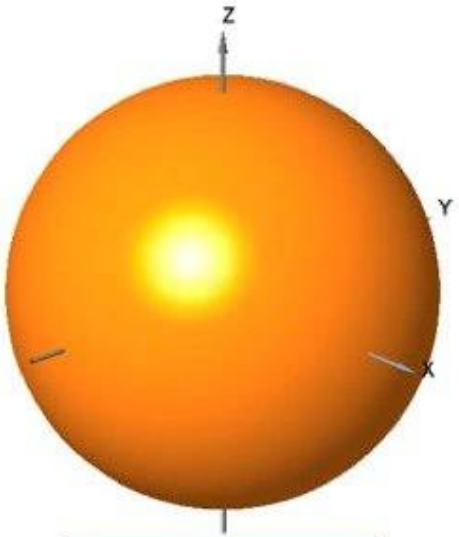


Omni (Full Coverage)

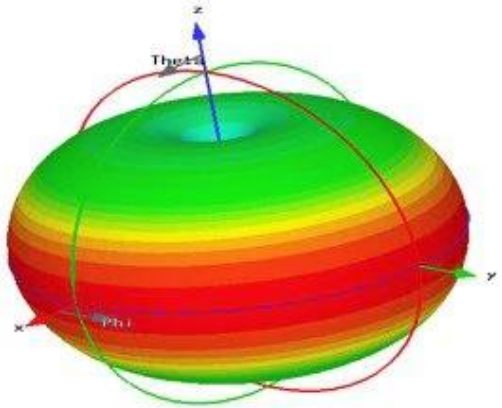


Antenna Models

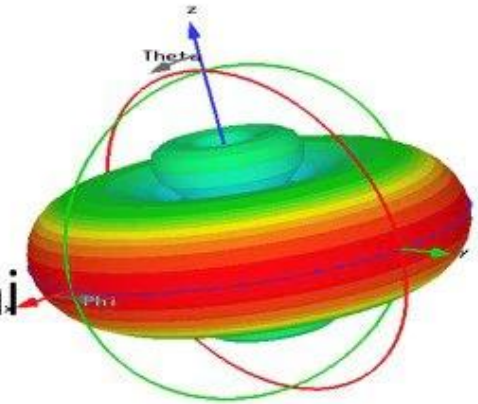
Isotropic → Omni → Dipole → Sector → Down Tilt → Patch → Yagi



Isotropic

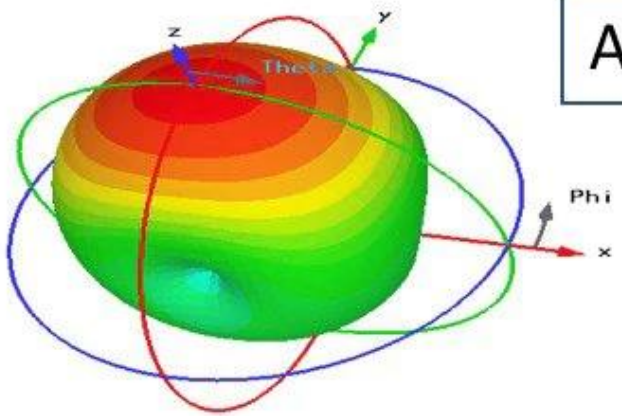


Dipole

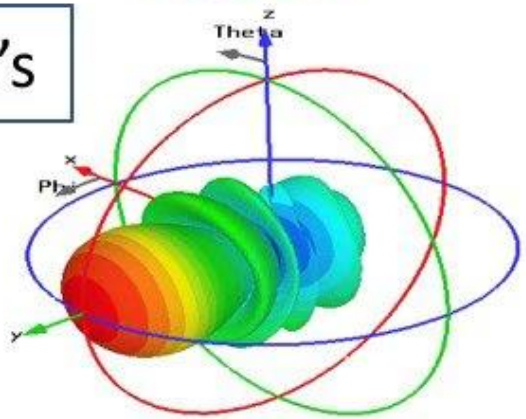


Omni

Actual Antenna's



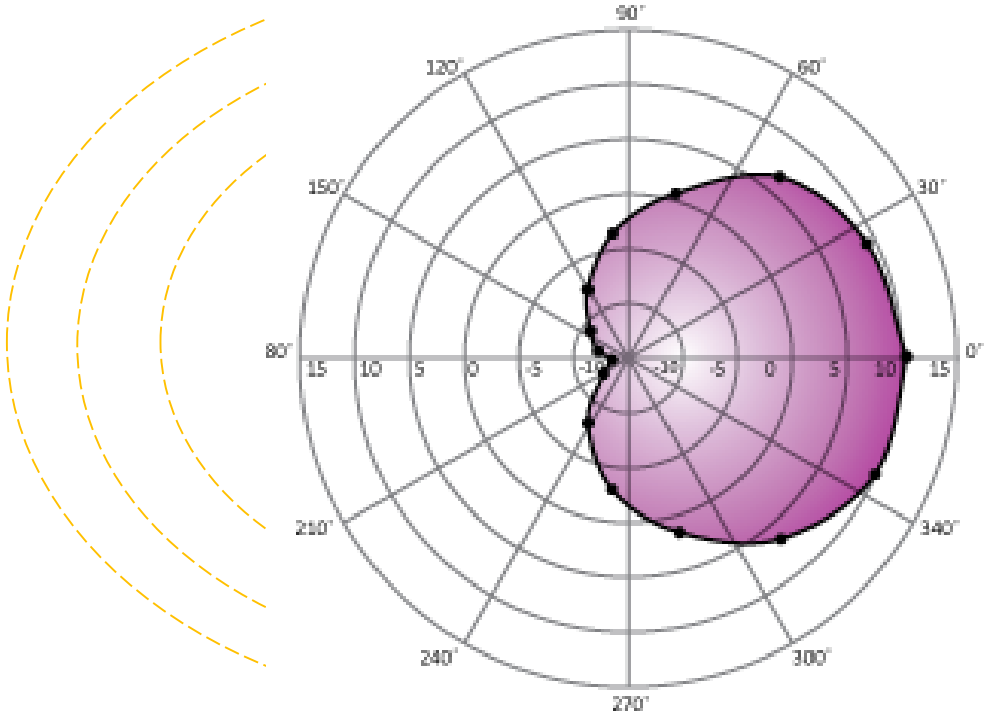
Patch



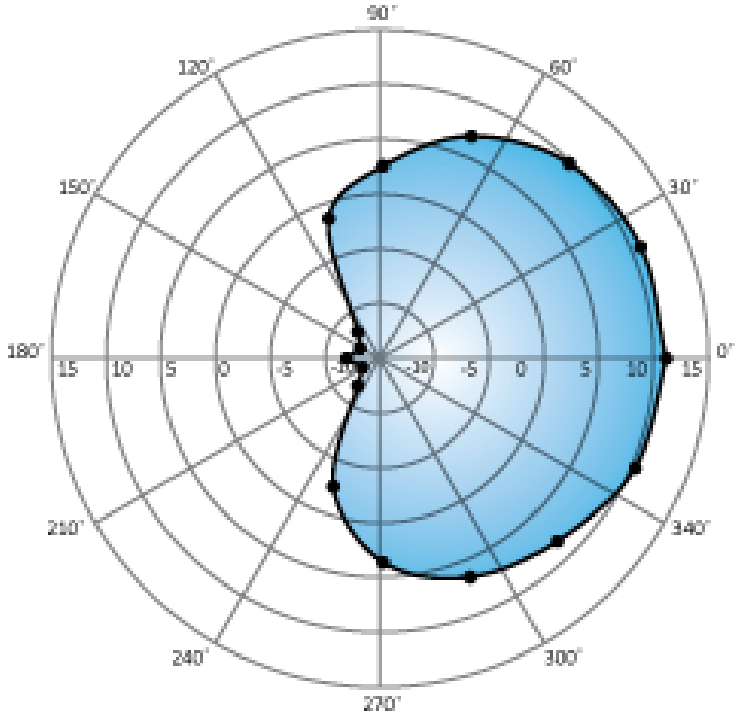
Yagi

Antenna Operation

Sector

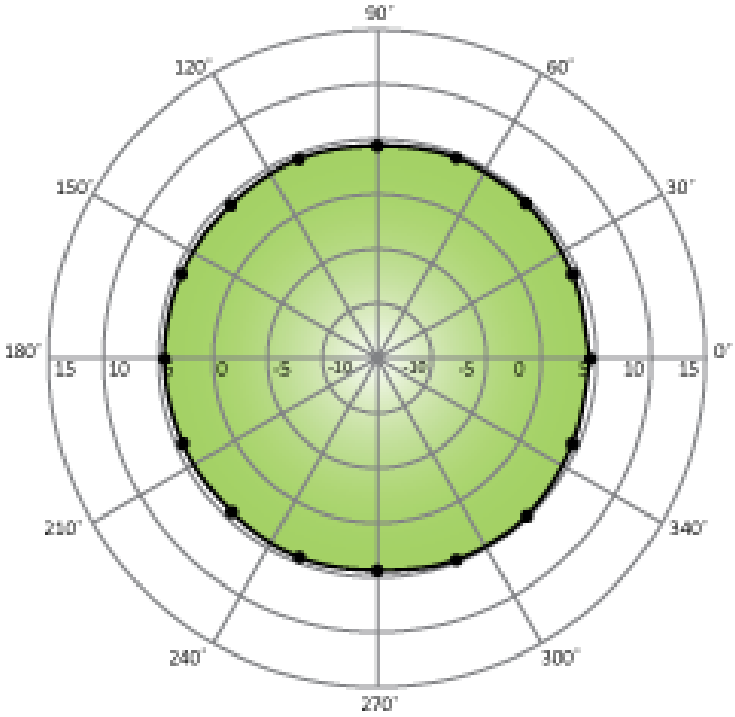


Omni with Reflector



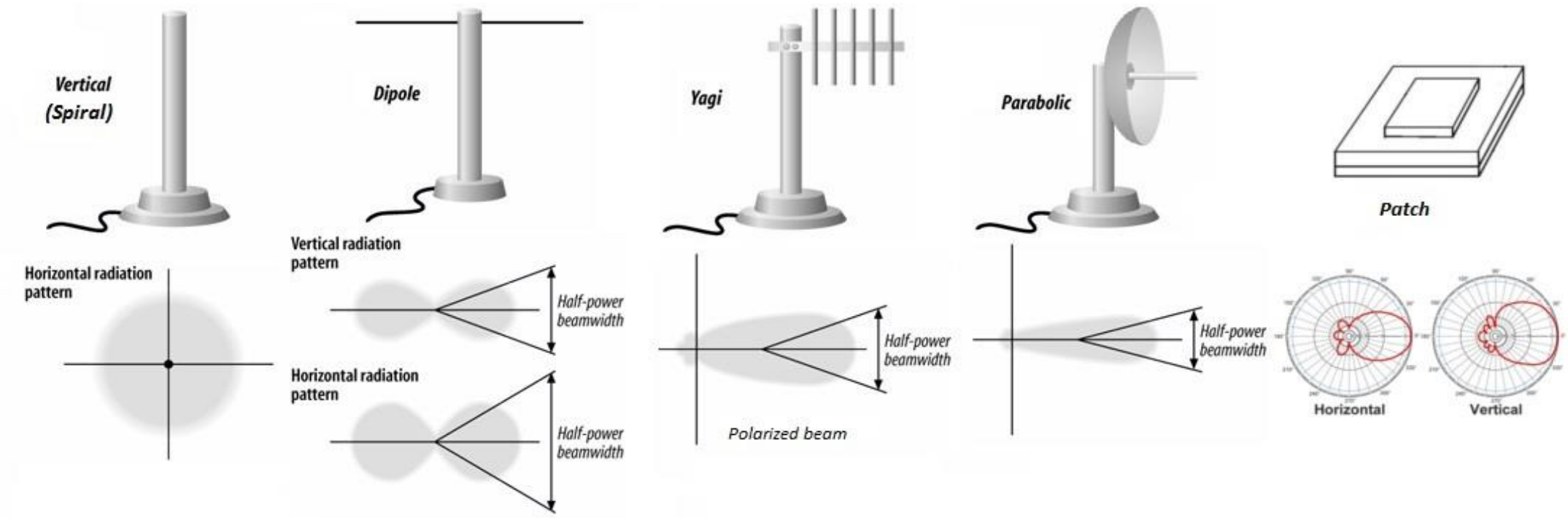
Beam Width -120

Omni (Full Coverage)



Beam Width -360

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		11 -14	90-180 (120)	10-20 (10)	Point to Multi Point Outdoor
Yagi	Directional	14-19	25-65 (30)	25-65 (30)	Point to Point Small Distance 1 Km
High Gain		21-29	3-15 (6)	3-15(6)	Point to Point Long Distance – 5 Km



RF Math Rules

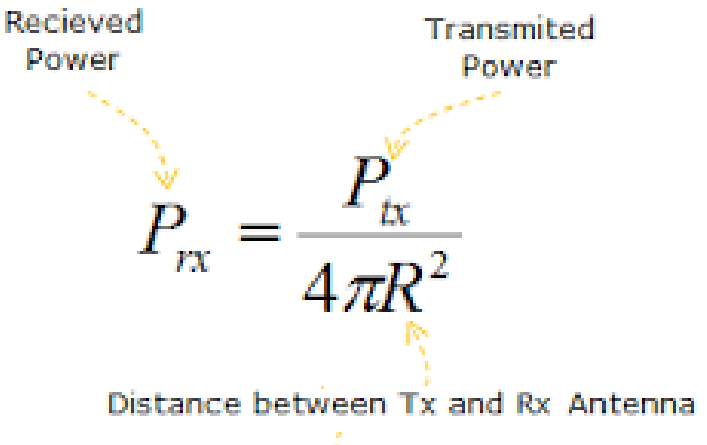
3 dB — **Double or Half actual power**

10 dB — **Multiply absolute power by 10**

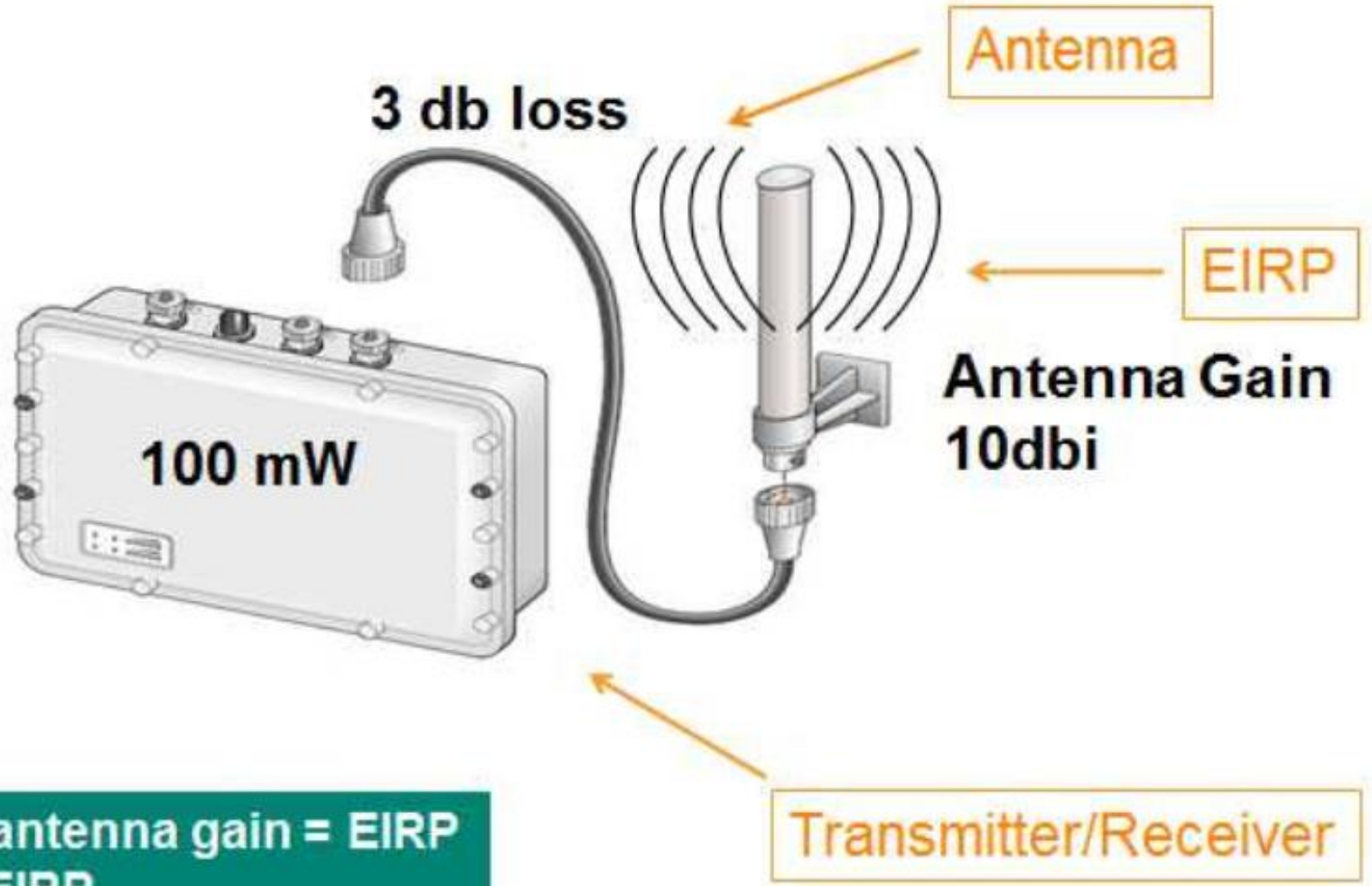
6dB — **Double travel distance**

- 3 dB gain = mW × 2
- 3 dB loss = mW ÷ 2
- 10 dB gain = mW × 10
- 10 dB loss = mW ÷ 10

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



Calculating EIRP



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

dBm and mW Relationships

+3 dBm = 2X power

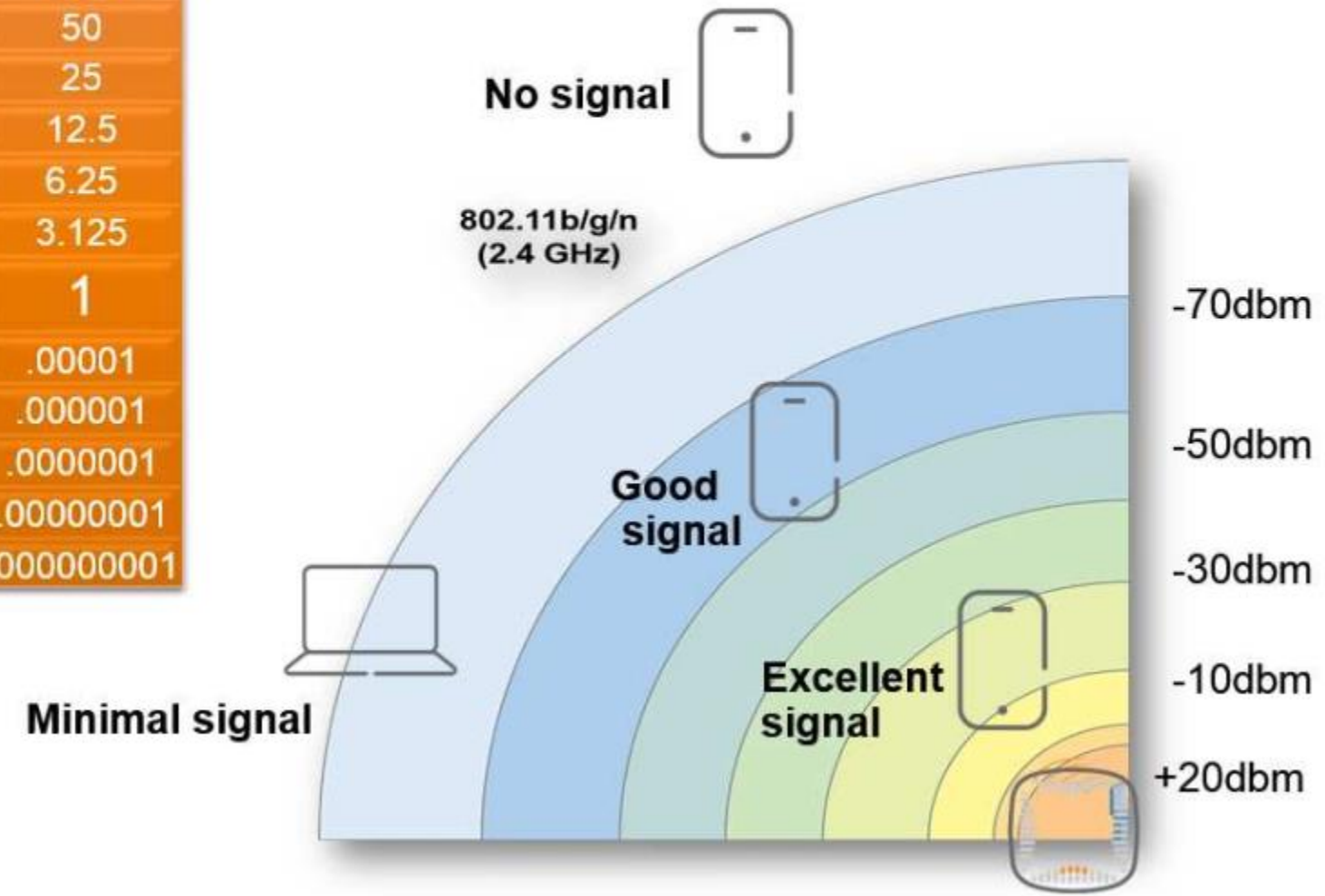
-3 dBm = 1/2 power

0 dBm = 1mW

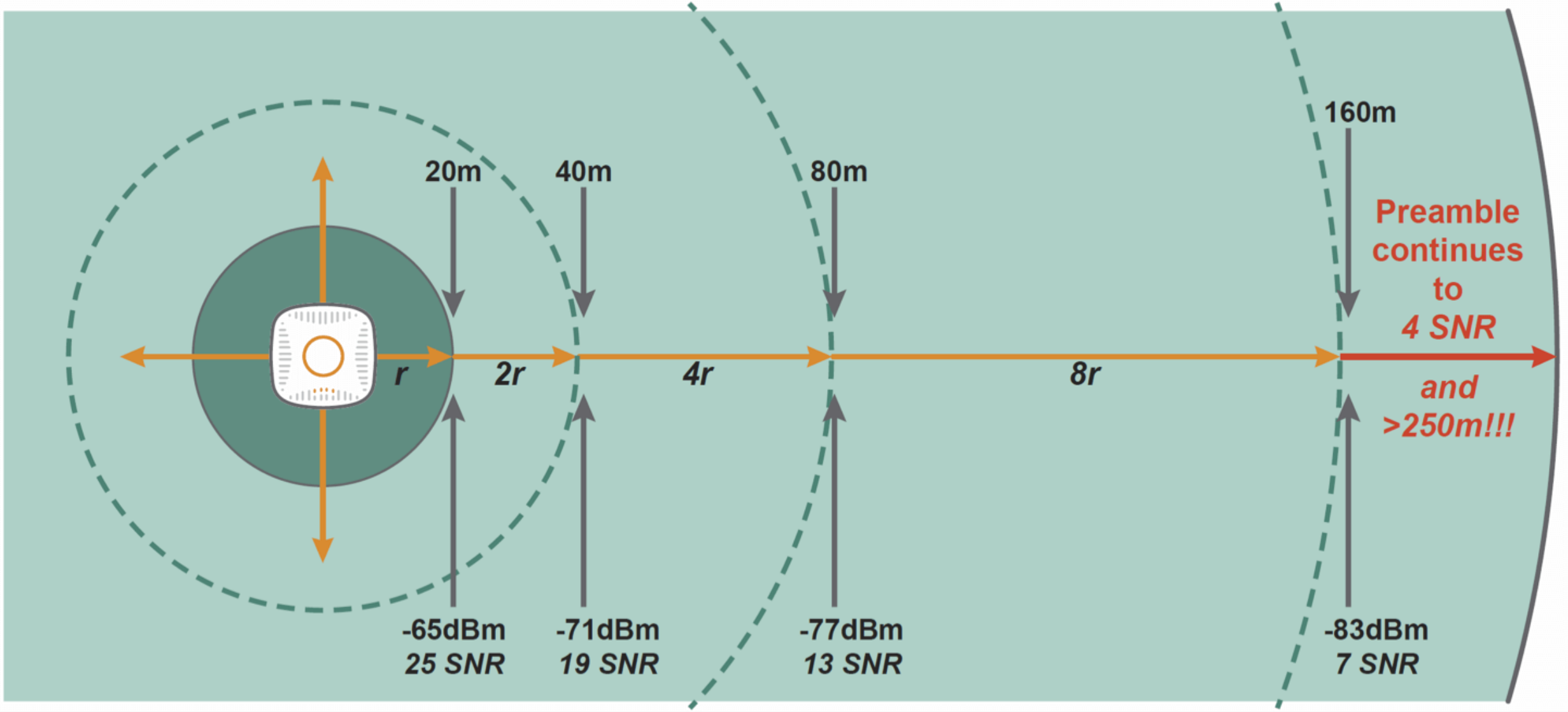
+10 dBm = 10X power

-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

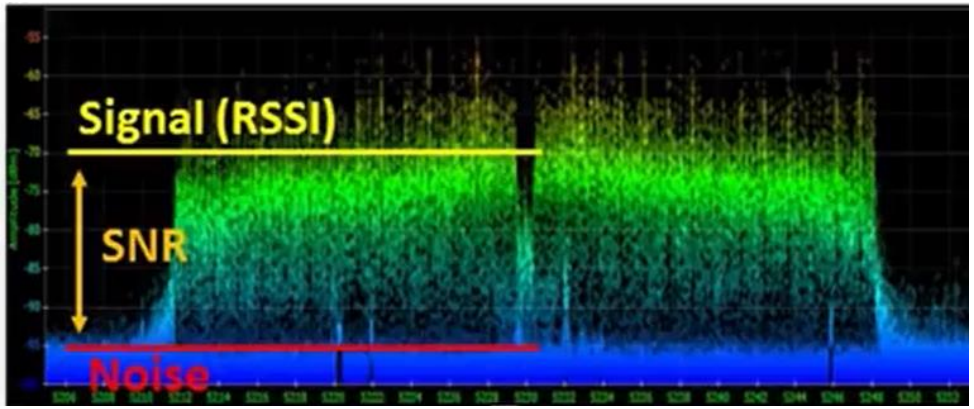


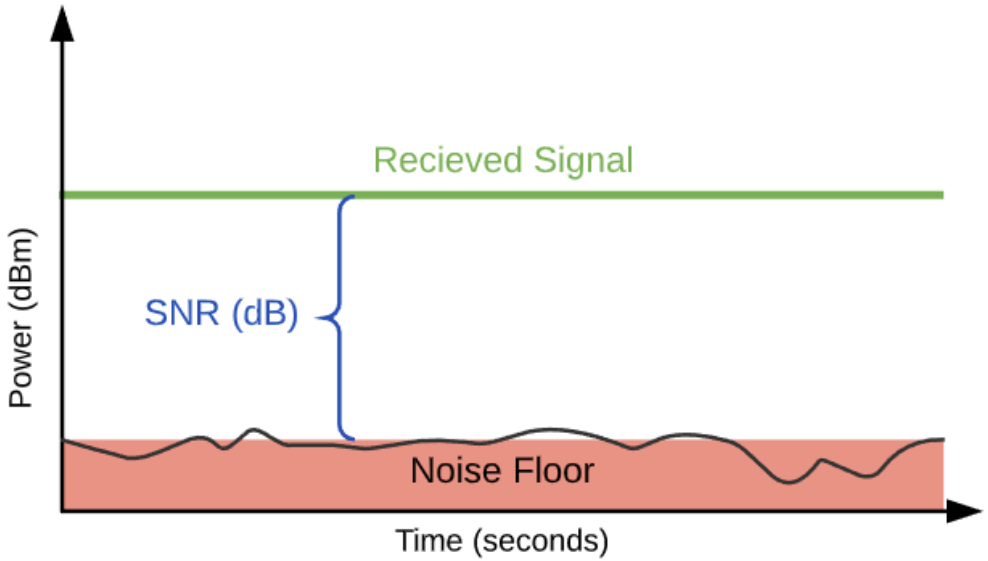
RF Propagation Distance vs Power



RF Signal Indicators

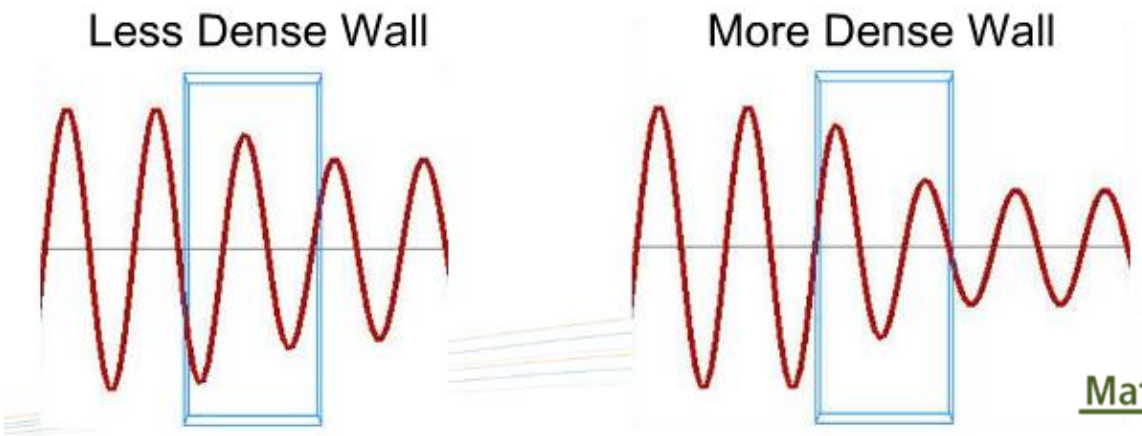
- **RSSI : measured in milliwatt decibels dBm**
  - The strength that the device is hearing a AP signal.
  - Accepted Value not less than **-75 dB**
- **Noise Floor : measured in milliwatt decibels dBm**
  - Noise is any signal (interference) that is not WiFi traffic
  - Nosie Source as cordless phones, 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**



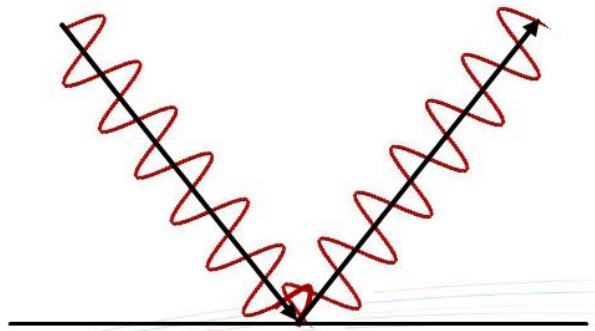


Wireless Signal Propagation

- **Absorption**
  - Signal path through thick walls as bricks and walls



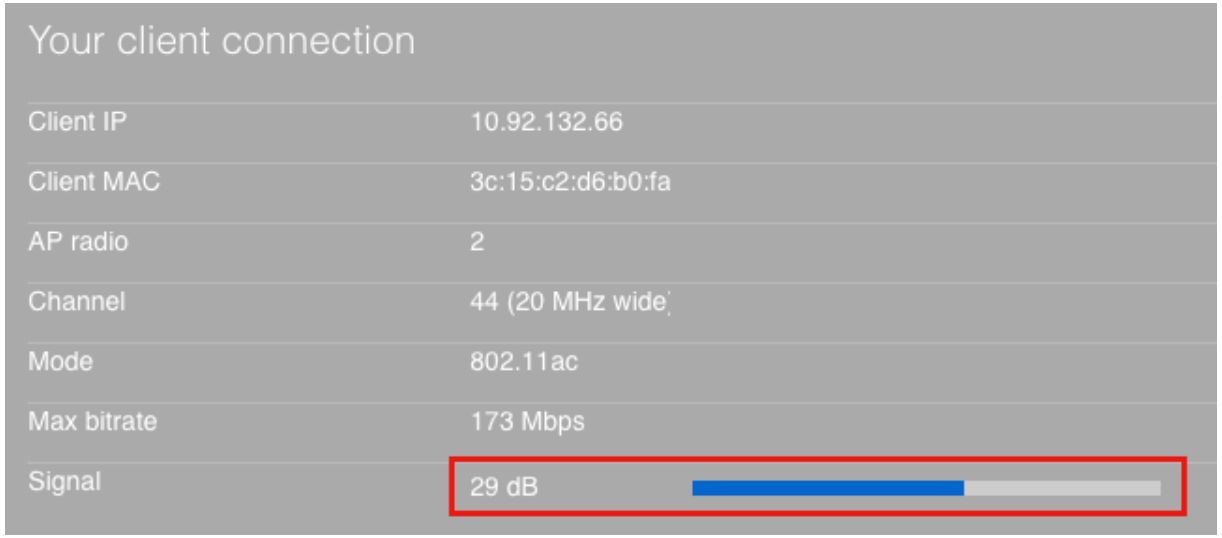
- **Reflection**
  - Signal hit metal surface and reflect it's way



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

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

RF Signal Indicators



Signal Strength in Real Life

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

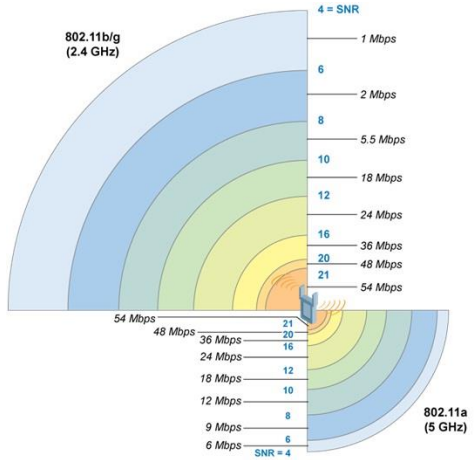
What is "Good" Signal Strength?

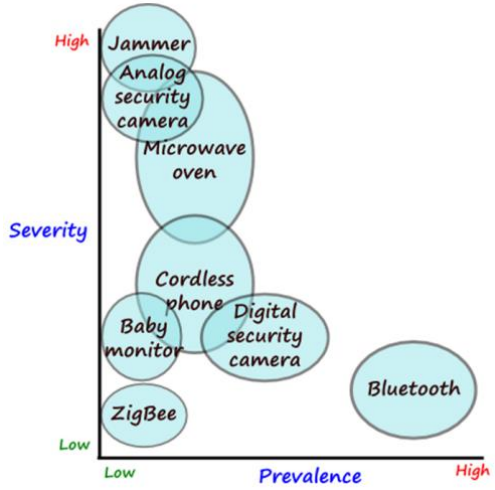
-30 dBm	Extremely good– you're likely standing underneath the AP
-65 dBm	Voice applications, mobile devices
-67 dBm	Streaming video
-75 dBm	Web browsing, email, instant messaging
-80 dBm	Generally unreliable
-90 dBm	Approaching or drowning in the noise floor

WLAN-PRACTICAL LECTURE 3

RF Basics Review

Data Rate - Interference



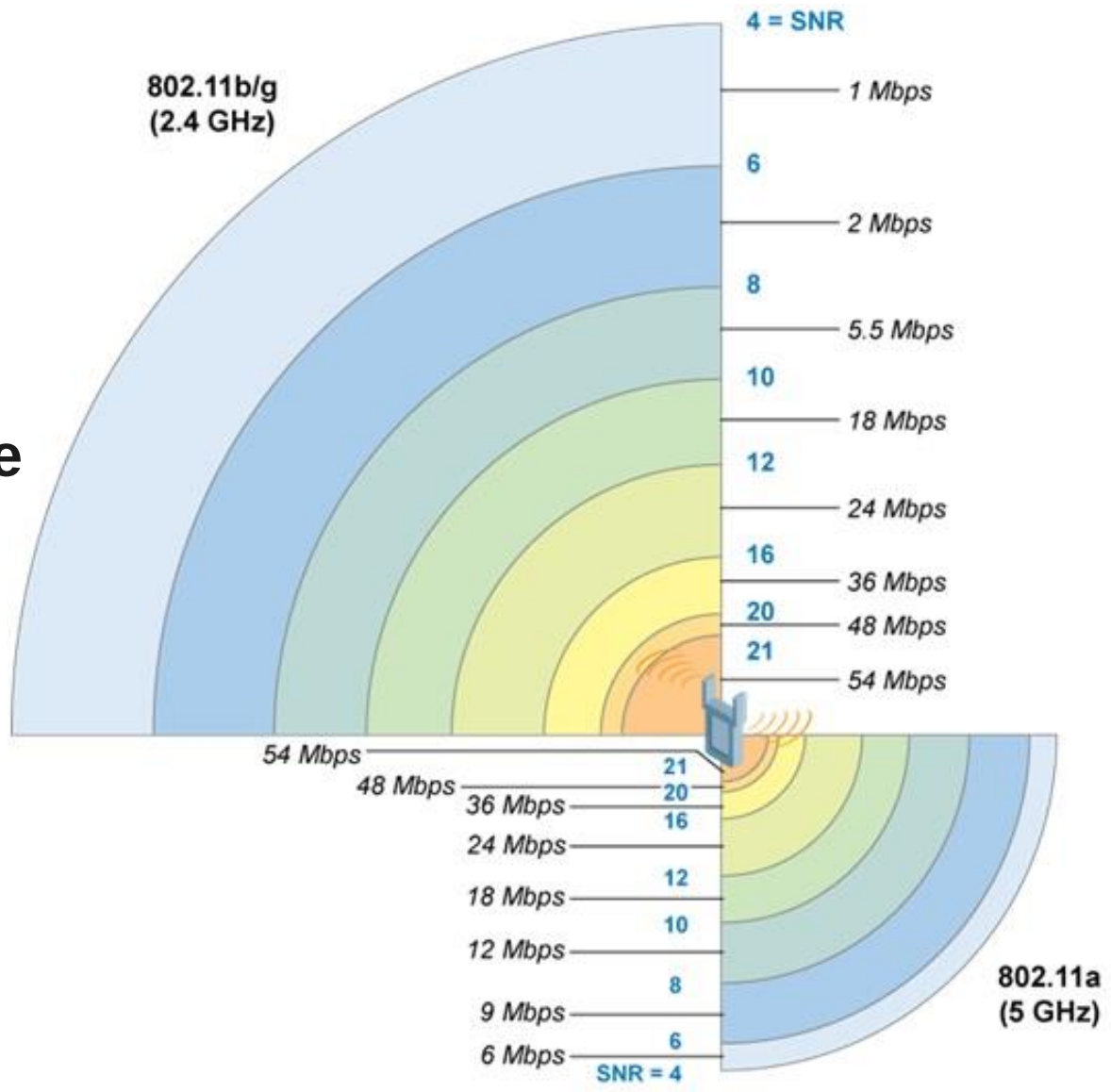


LEC 3 : RF Basics Revision - Continue

1. Wi-Fi Frequency & Bands
2. Channel Width & Channel Bonding
3. Wireless Signal Measurements
4. Wi-Fi Antenna Models
5. **Data Rate and Signal Strength Relation**
6. **WLAN Interference types and Impact**

Wi-Fi Data Rates

- Wireless networks automatically change speeds or “shifts gears” based on a client’s distance
- This reduces communication issues
- As distance increase – ability to encode and recognize packets reduces
- So AP will send lower information at the packet with lower data rate to be able to recognized by receiver



dBm and mW Relationships

+3 dBm = 2X power

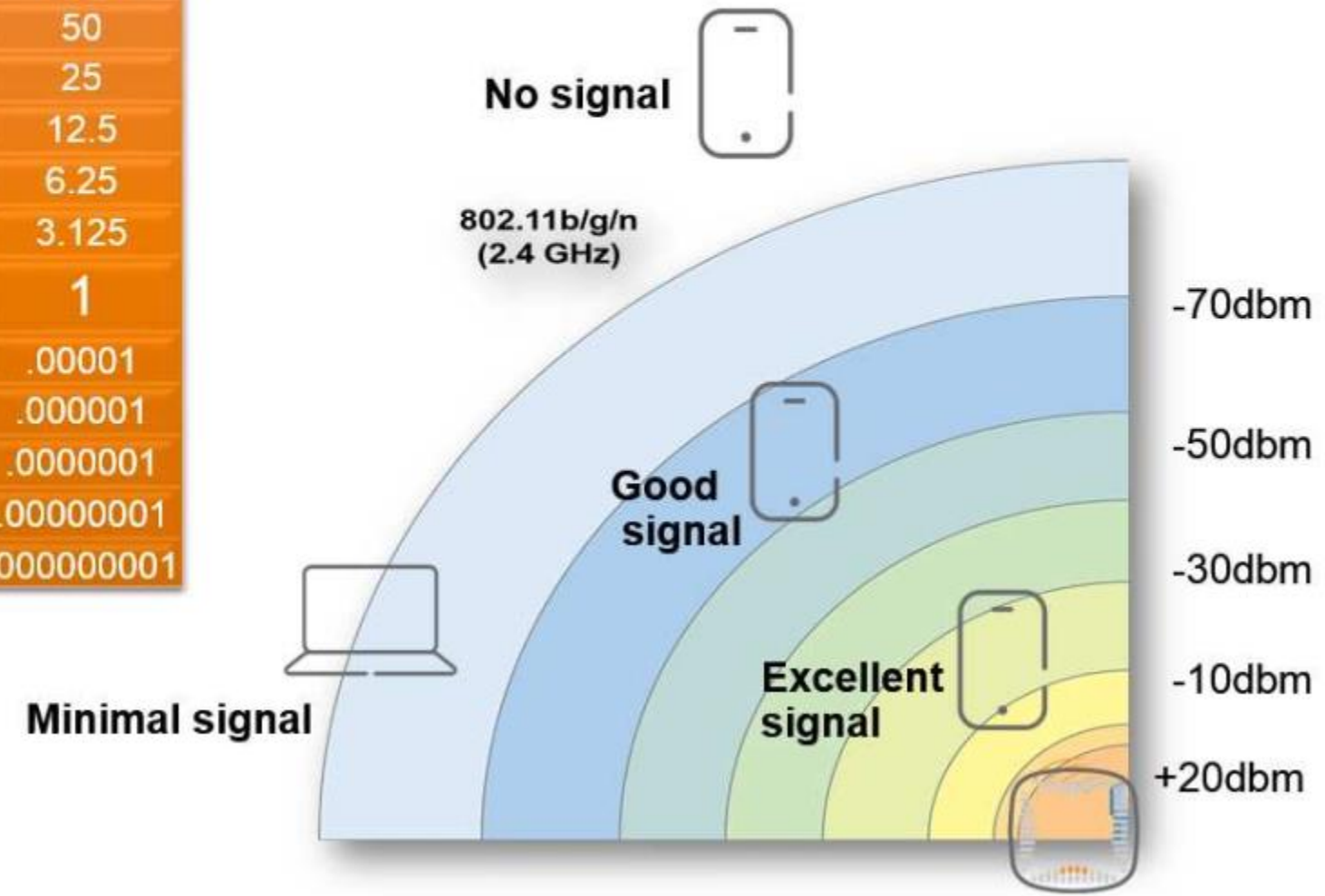
-3 dBm = 1/2 power

0 dBm = 1mW

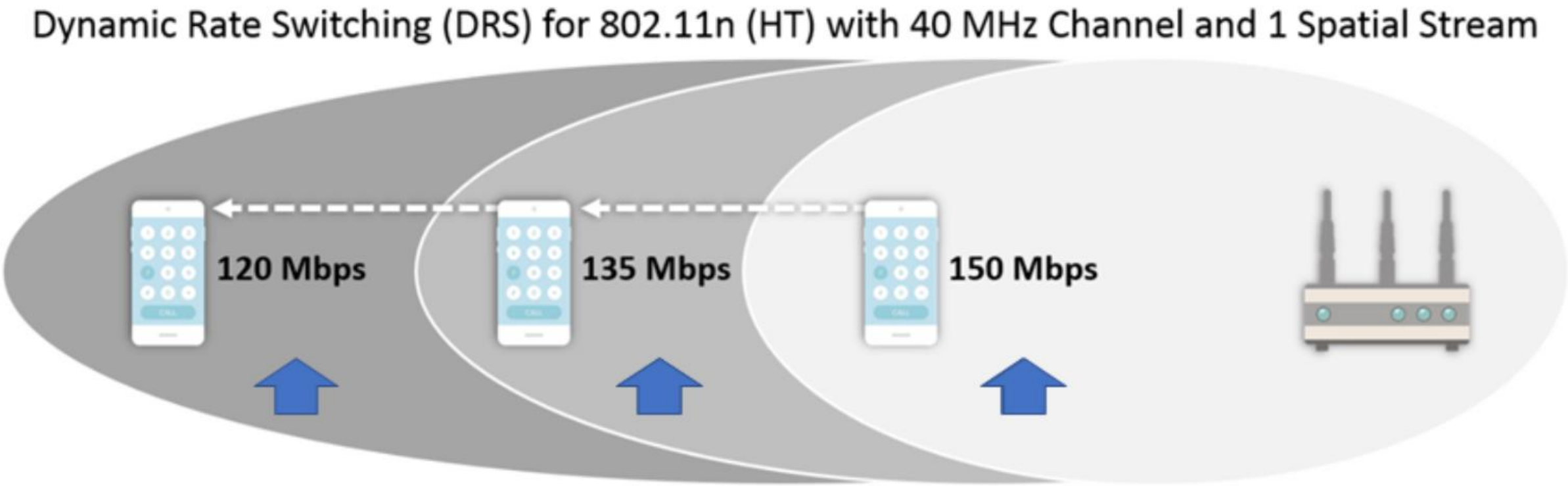
+10 dBm = 10X power

-10 dBm = 1/10th power

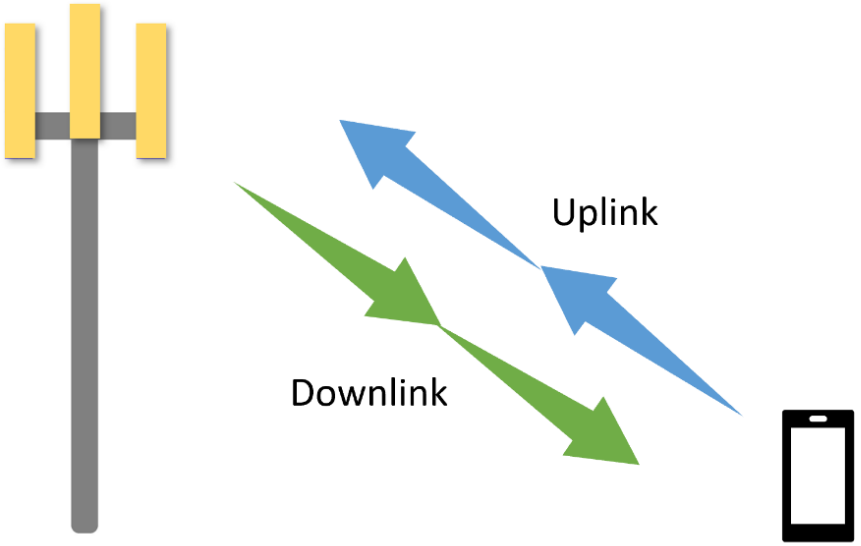
dBm	mW
+20	100
+17	50
+14	25
+11	12.5
+8	6.25
+5	3.125
0	1
-50	.00001
-60	.000001
-70	.0000001
-80	.00000001
-90	.000000001

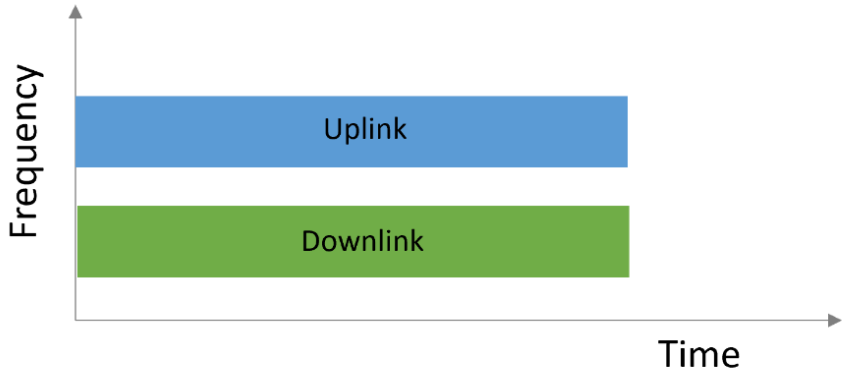


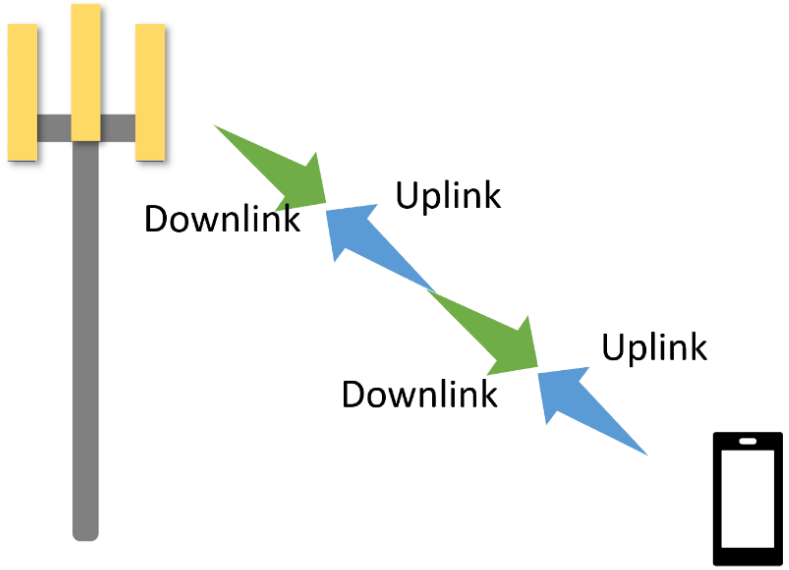
Data Rate and Signal Strength Relation

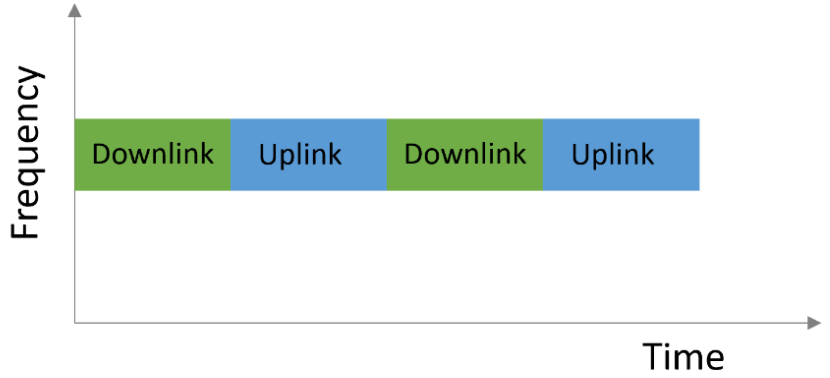


Half Duplex Vs Full Duplex

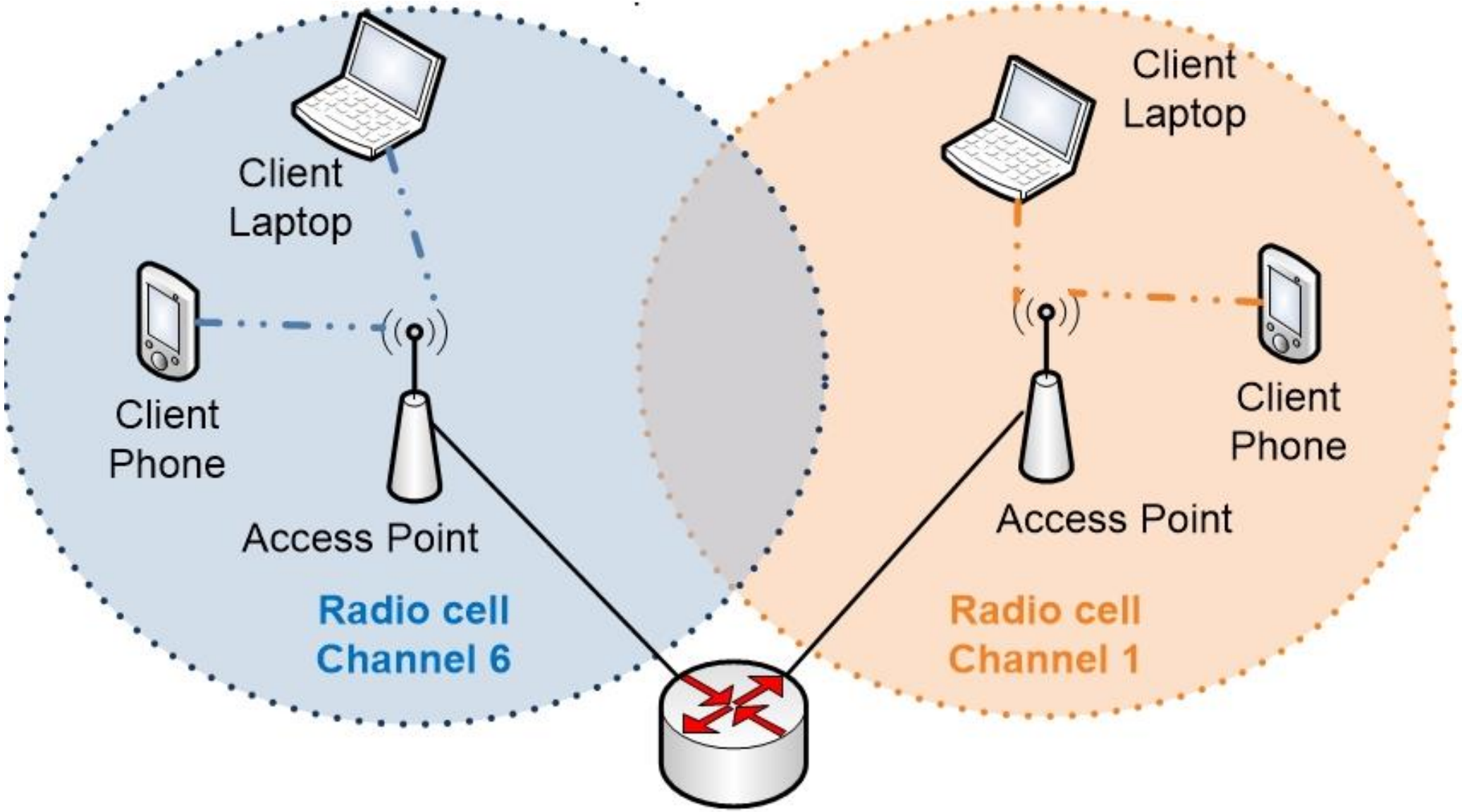








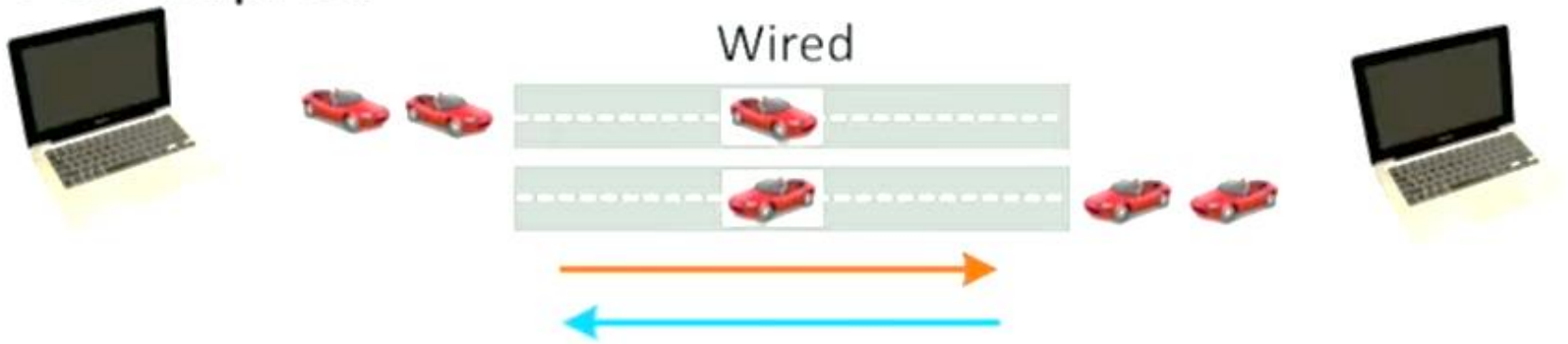
Wireless is Shared Medium



Wi-Fi is Half Duplex

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

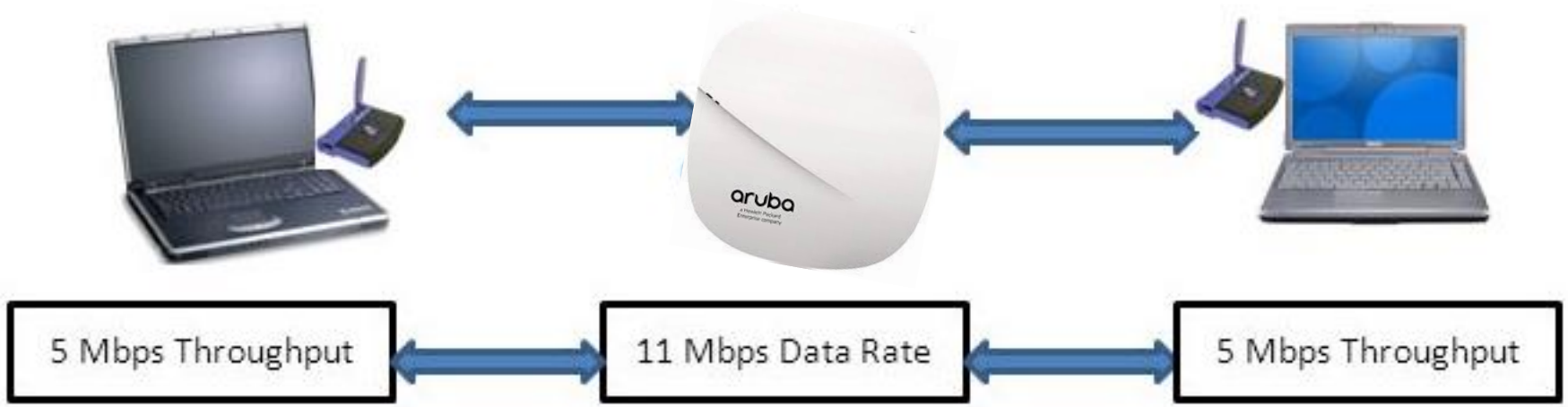
Full-duplex:



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*

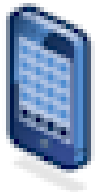
3SS Laptops 3 Mbps (ea) ***100 Mbps Total***

34 Laptops, 77% total airtime utilization

2SS Tablets 3 Mbps (ea) ***65 Mbps Total***

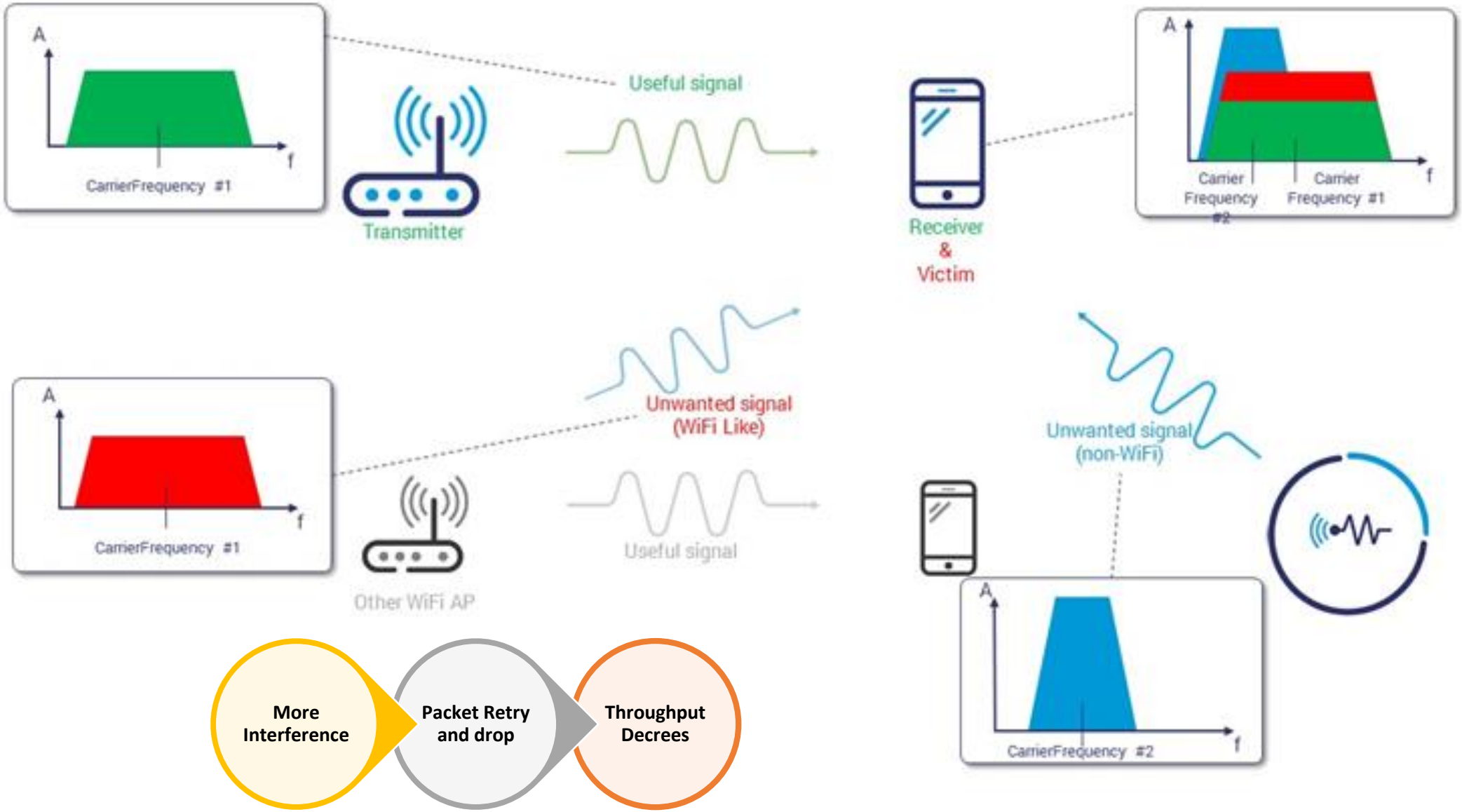
21 Tablets, 75% total airtime utilization

1SS Smartphones 3 Mbps (ea) ***30 Mbps Total***

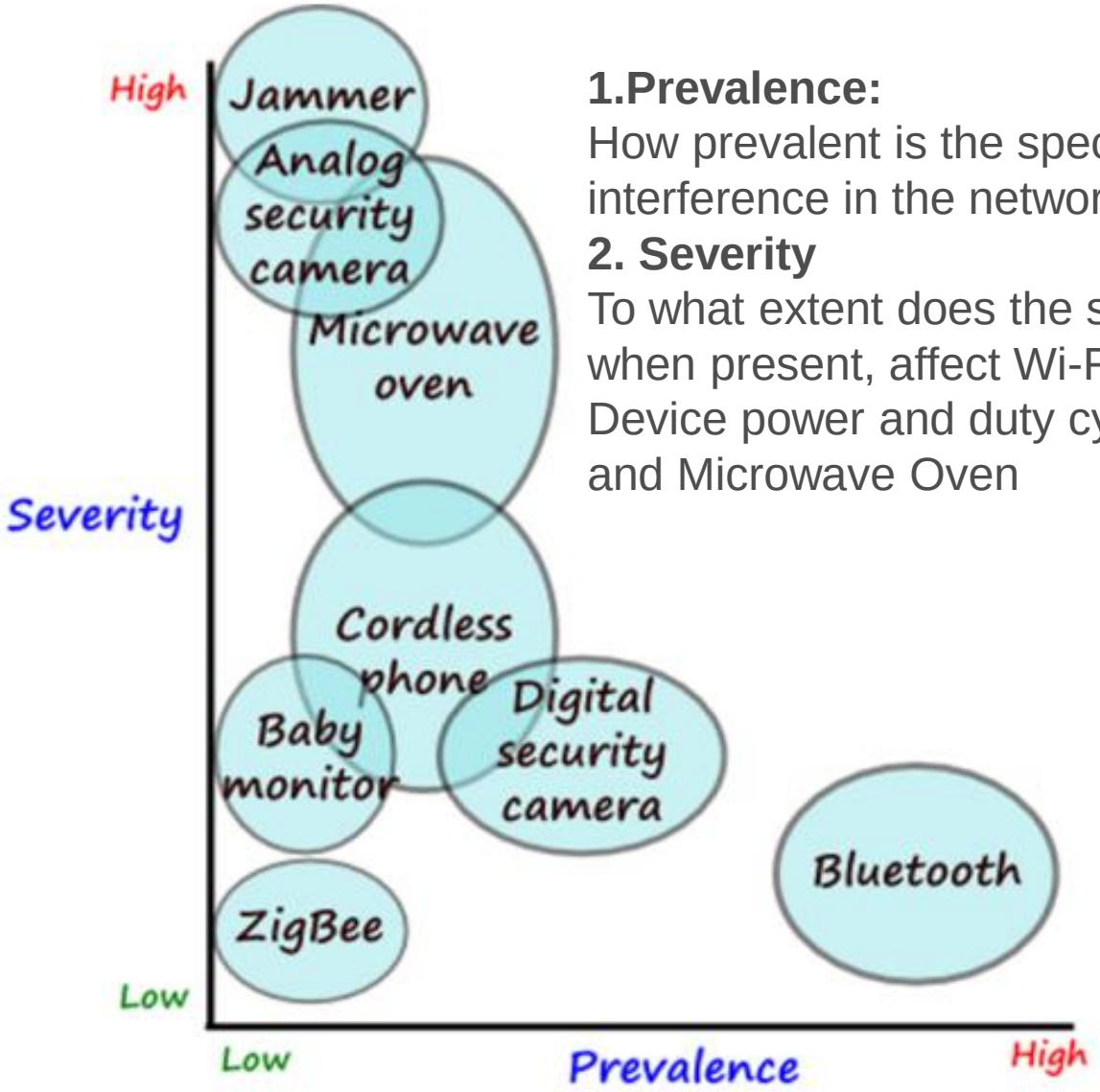


10 Smartphones, 77% total airtime utilization

What is Interference



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

- Video Security Cameras
- Cordless Phone
- APs
- Microwave
- Frequency Hopping Device (Bluetooth)

Interference Types

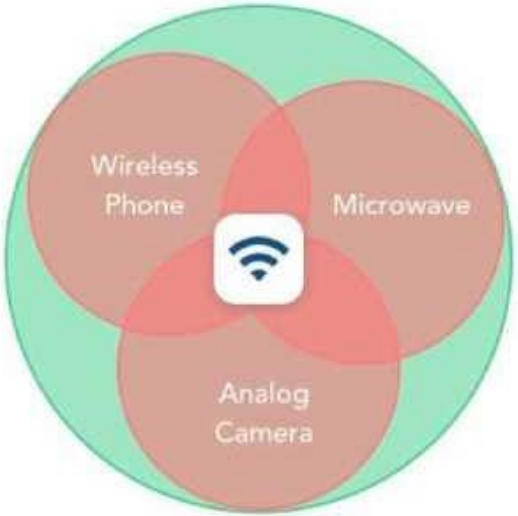
Co-Channel

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

Interference Impact

- 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 Busy

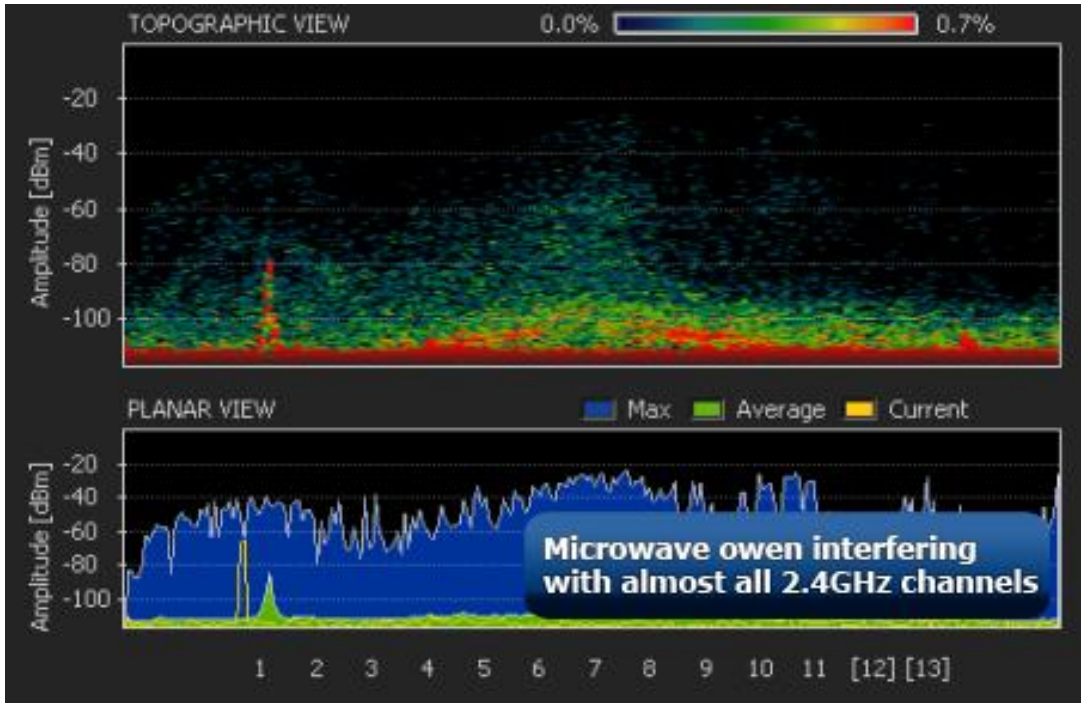
- Due to high noise and Interference sources channel wont be available for connectivity
- A lot of users traying to access AP with shared medium
- Lead to high packet drops and retries
- users are facing slowness, and the ping to the gateway is going high.

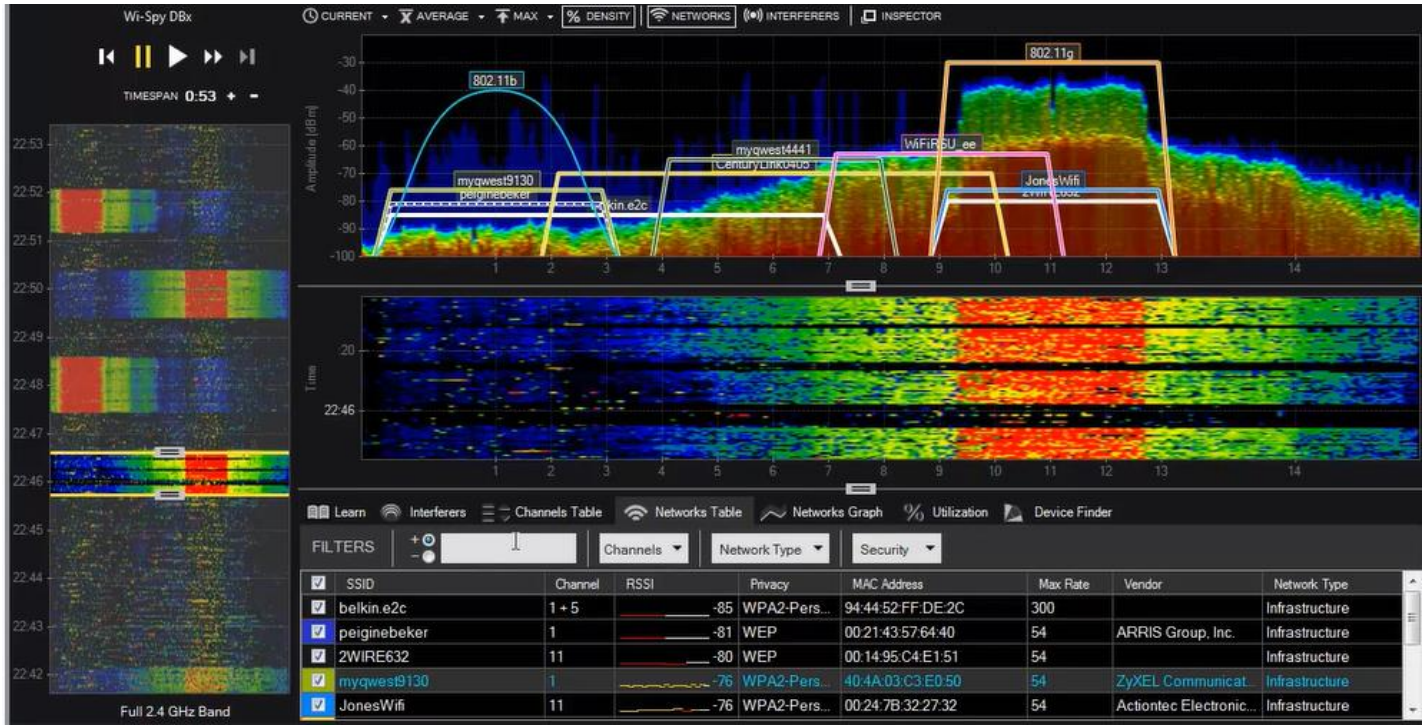
Channel Busy (%) (4 of 38): Channel Busy >= 90% & <= 100%

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%	

Channel Availability

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





WLAN-PRACTICAL LECTURE 4

Wireless Network Life Cycle

LEC 4 : WLAN Software Overview

1. Wireless Network Phases
2. WLAN Software Types and Usage
3. TOP Vendors for WLAN Software and Tools
4. Analysis Software and Tools
5. Planning and Design Software
6. Assessment Software and Tools
7. Speed and throughput test Software

WLAN Project Life Cycle

Pre Production
Testing for Coverage
Roaming and Data Rate
NO Live User Connected

after Production
While Users Connected
Test Coverage & Roaming
and actual Throughput

Define AP Locations &
Count Required
Expected Coverage
Plan & MAP

Physical Survey to Check
Real Location and
Barriers and materials

Check RF Environment
before Installation
Channels and Power
Interference Sources

WLAN Software Tools

Planner

- Design and Planning
- Draw Heat Map
- Predictive Survey

Analyzer

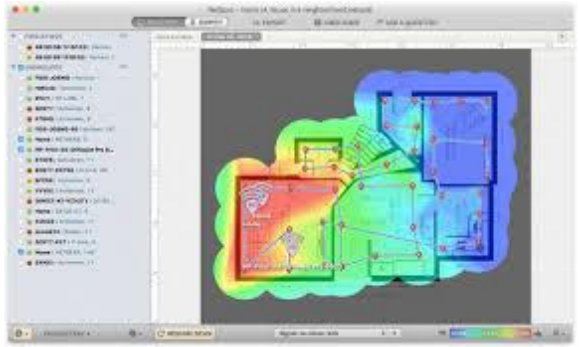
- Analysis for RF Environment
- RSSI-SNR-Noise
- Detect WLAN Issues

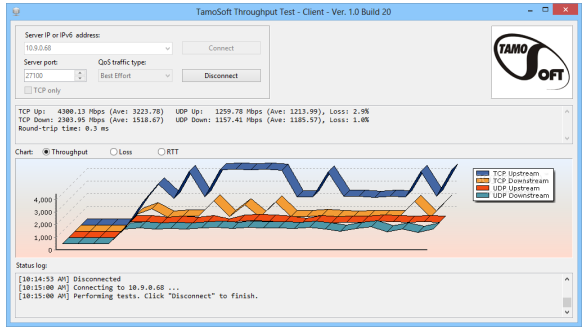
Speed Test

- Measure Actual Throughput
- Measure TCP and UDP Traffic
- Measure Link Quality Jitter and Delay

Assessment

- Measure Actual WLAN Coverage and Data Rate
- Active & Passive Survey
- Hardware Kit Required





Survey

Physical(Manual)

Planning

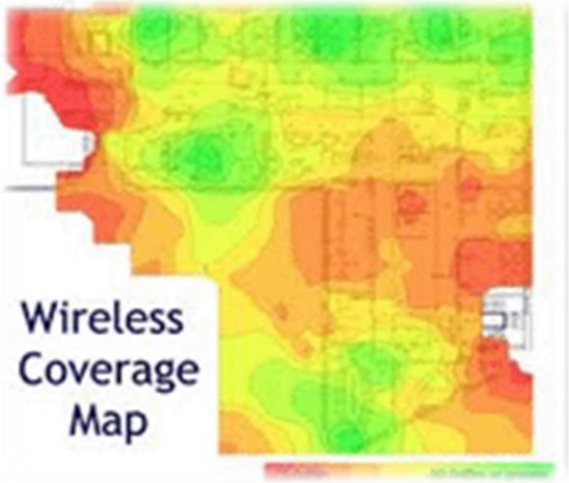
Active

Passive

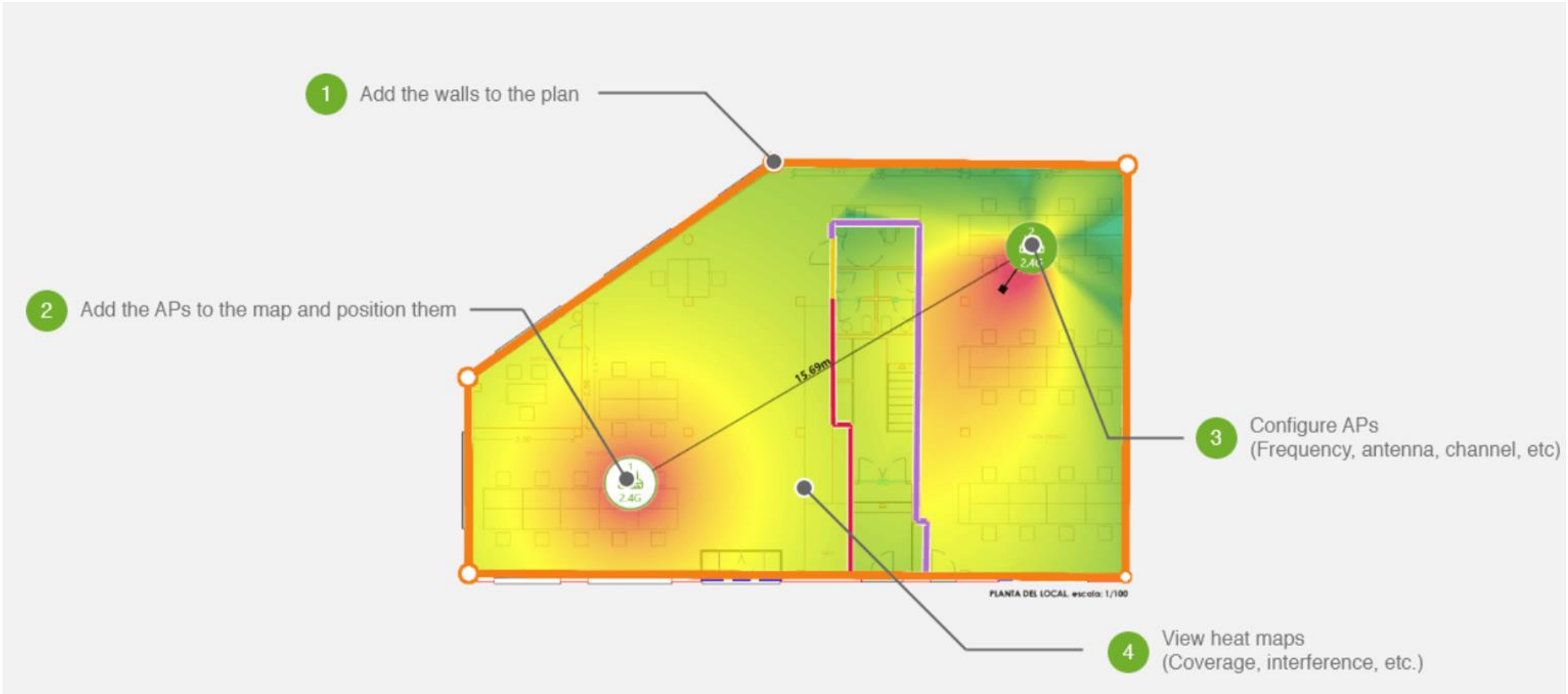
Predictive

Predictive Site Survey

- Simulated coverage and information
  - Software takes information about floor plan, building, etc and plots AP locations and expected coverage
- Can Model:
  - Channel reuse patterns
  - Coverage cell boundaries
  - Access point placement
  - Access point power settings
  - Number of access points
  - Data rates



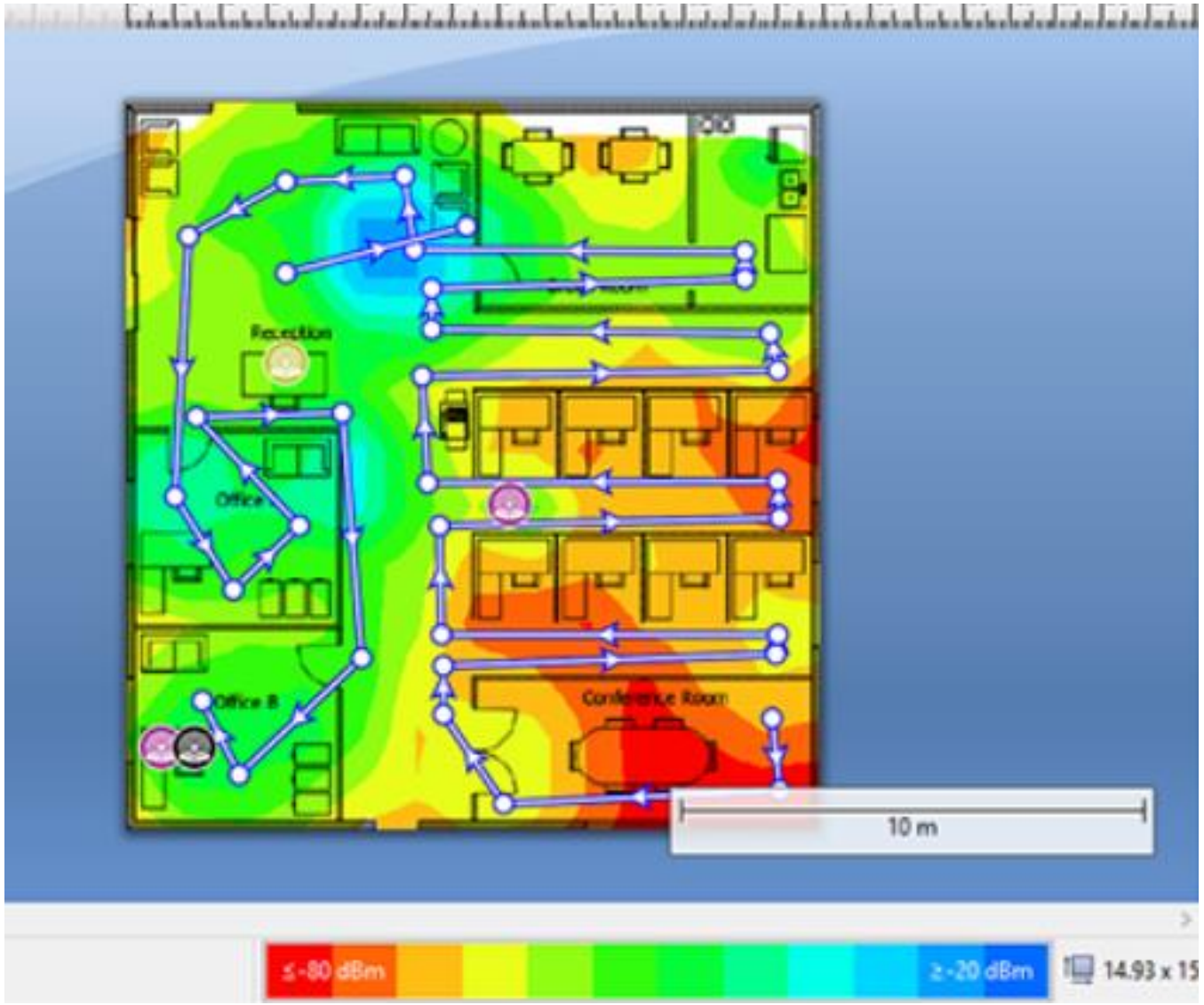
Predictive Site Survey



Physical Site Survey

- **Manual site survey**: requires walking through the area of the WLAN while carrying a wireless client like a laptop or tablet computer
- Can be divided into two categories:
  - *Passive manual site survey*: client device "listens" in order to gather RF measurements such as signal strengths, noise levels, and the signal-to-noise ratio (SNR)
  - *Active manual site survey*: client device sends and receives packets to determine the status of the WLAN

Physical Site Survey

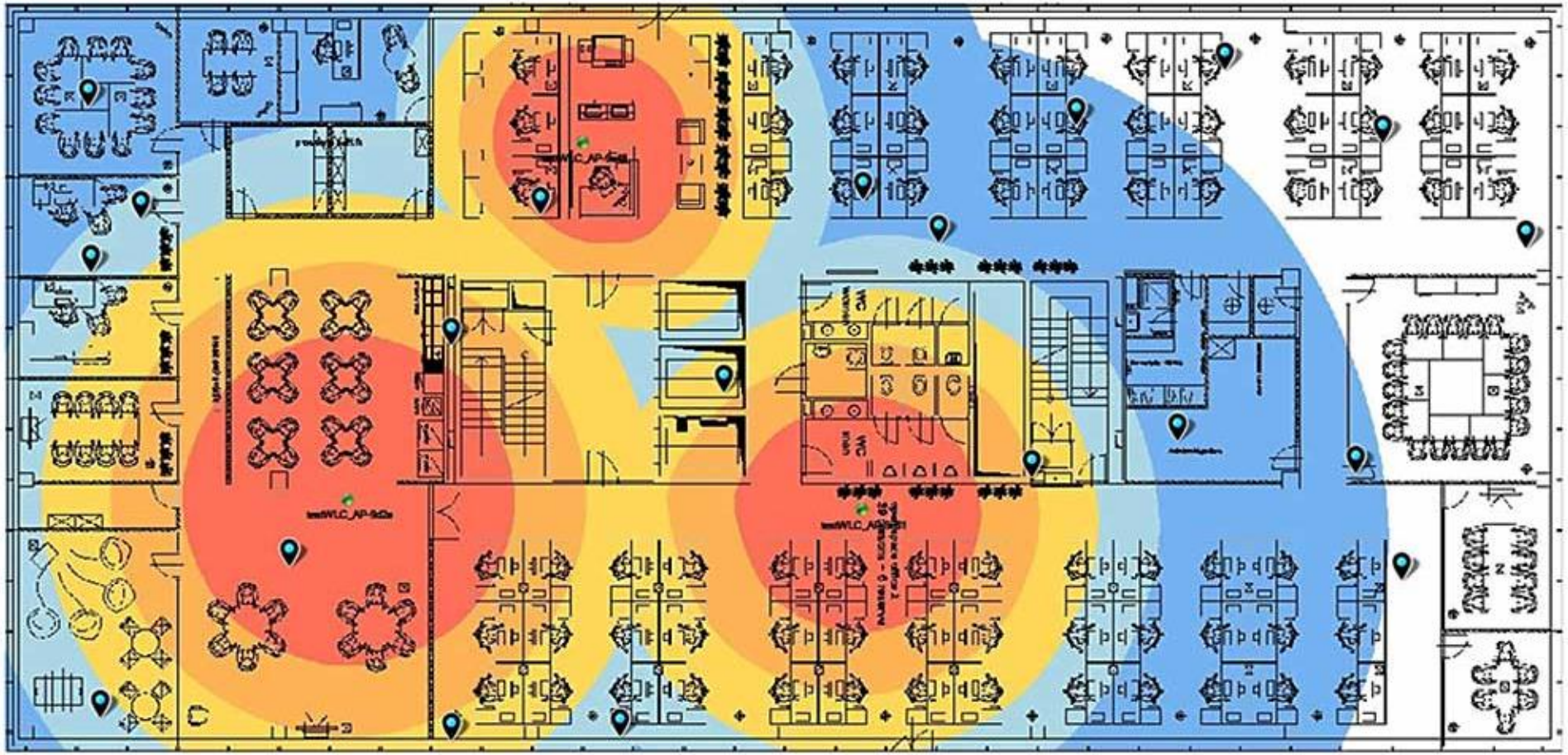


Wireless Site Survey Analysis

	Normal	Monitor	Airpcap
RSSI heatmap	✓	✓	✓
AP coverage	✓	✓	✓
Channel coverage	✓	✓	✓
Data rates	✓	✓	✓
Cell density		✓	✓
Number of APs	✓	✓	✓
Channel overlap	✓	✓	✓
Detailed grid	✓	✓	✓
Signal to noise			✓
Retry rate		✓	✓
Bandwidth *	✓	✓	✓
Latency *	✓	✓	✓
Packet loss *	✓	✓	✓
Roaming *	✓	✓	✓

* Active Wi-Fi site survey functionalities.

WLAN Heat-Map



Wireless Signal Strength:

... -82 dBm -72 dBm -68 dBm -63 dBm -56 dBm -20 dBm

Connected Wireless Clients:

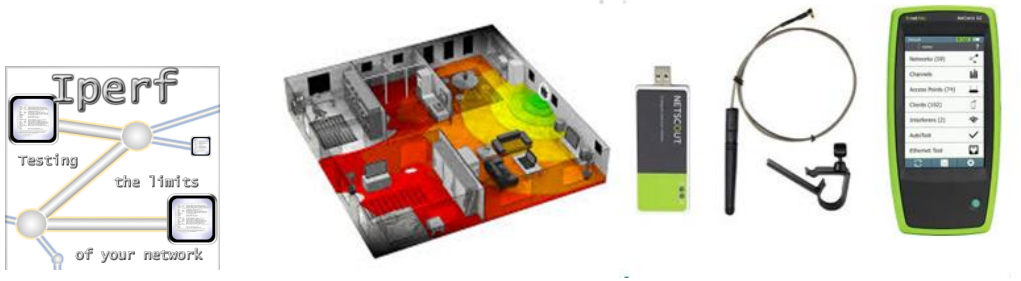
Show connected wireless clients on the map

Displaying: 20 of 20 clients

Last Client Calculation: 4:34 AM (Updated every 5 minutes)

WLAN-PRACTICAL LECTURE 5

WLAN Software Overview



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netAlly

ACRYLIC WiFi

metageek inSSIDer

TAMOSOFT

LEC 5 : WLAN Software Overview

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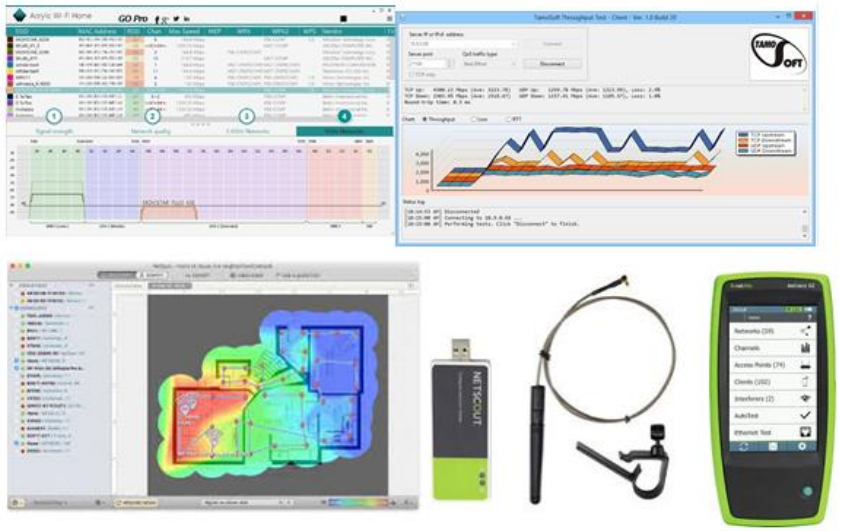
2. Analysis Software and Tools
3. Planning and Design Software
4. Assessment Software and Tools
5. Speed and throughput test Software
6. TOP Vendors for WLAN Software and Tools



WLAN Software Tools

Planner

- Design and Planning
- Draw Heat Map
- Predictive Survey

Analyzer

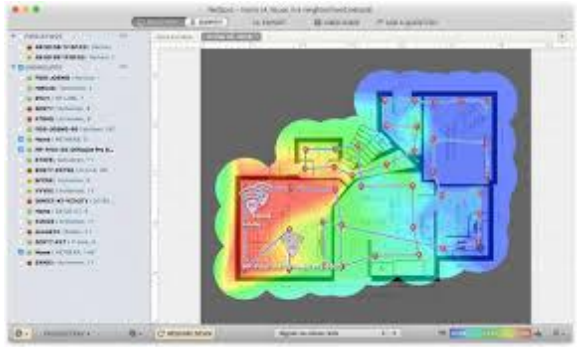
- Analysis for RF Environment
- RSSI-SNR-Noise
- Detect WLAN Issues

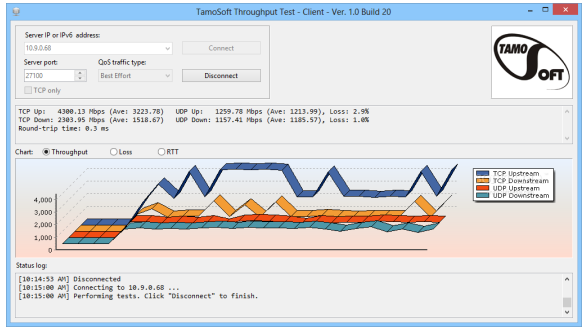
Speed Test

- Measure Actual Throughput
- Measure TCP and UDP Traffic
- Measure Link Quality Jitter and Delay

Assessment

- Measure Actual WLAN Coverage and Data Rate
- Active & Passive Survey
- Hardware Kit Required





Wi-Fi Analyzer

- Detect Wireless AP Power and Channel
- Detect Noise and SNR
- Detect Interference ACI & CCI
- Detect Channel Availability
- Available for PC and Smart Phones

https://www.acrylicwifi.com/en/

https://www.tamos.com/

https://www.metageek.com/products/inssider/

Wi-Fi Planners

- Design Wi-Fi installations from scratch.
- Generates heat maps of signal quality.
- Calculate how many access points are needed.
- Generate Bill of Material
- Each Vendor Has it’s Own Software

https://www.tamos.com/

https://www.acrylicwifi.com/en/

https://www.ekahau.com/

aruba
a Hewlett Packard Enterprise company

VRF Plan

Wi-Fi Planners

- Design Wi-Fi Networks .
- Generates heat maps of signal quality.
- Calculate how many access points are needed.
- Generate Bill of Material
- Each Vendor Has it’s Own Software

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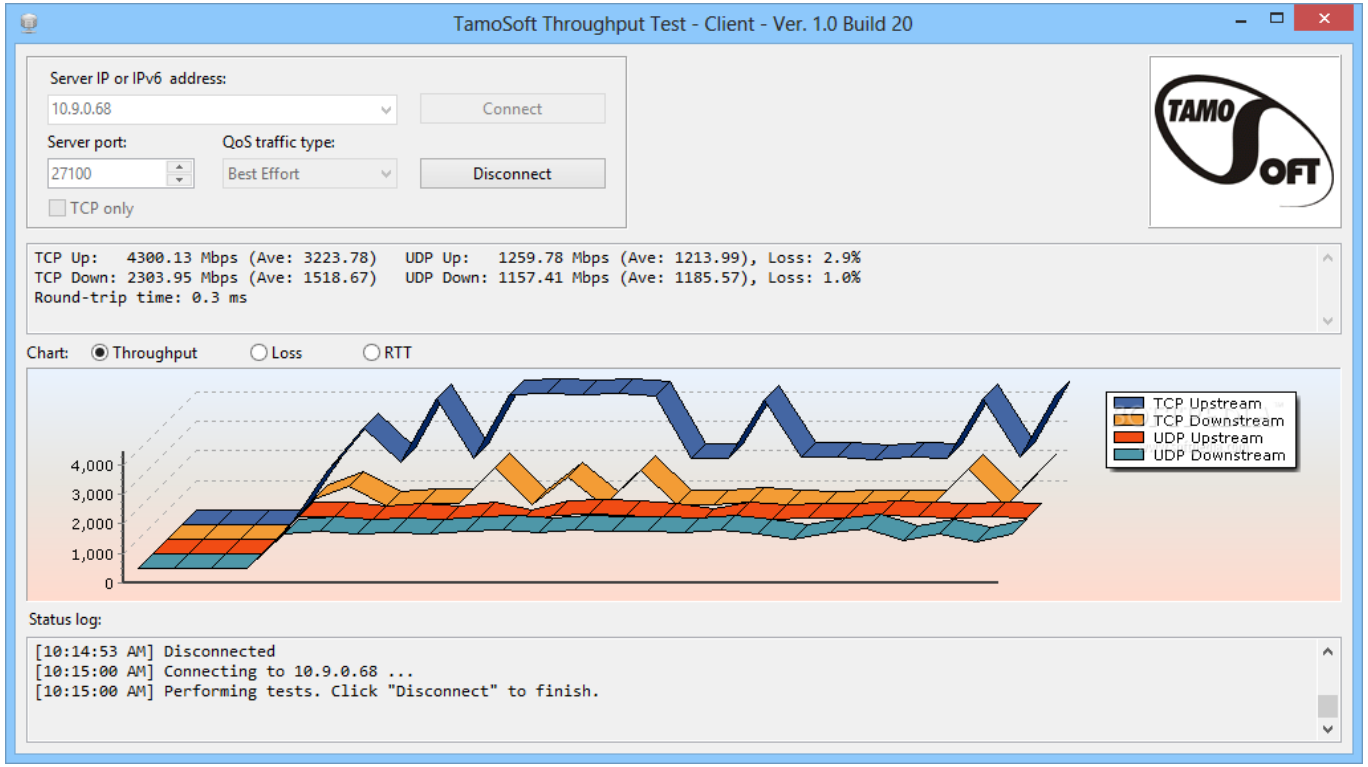
https://www.ekahau.com/

a Hewlett Packard Enterprise company

Speed & Throughput Test

- Measure Actual Throughput
- Measure Link Quality (Jitter – Delay)
- Measure Packet Loss Ratio
- Measure TCP and UDP Traffic
- Used for Mesh & Bridge Links
- Available for PC and Smart Phones



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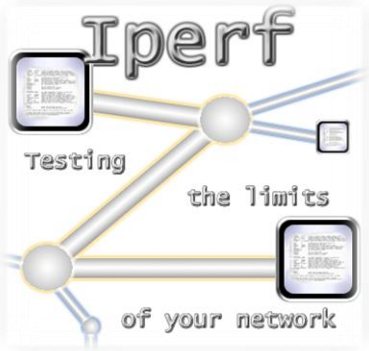

https://www.tamos.com/

WLAN Assessment

- Analyzes an existing Wi-Fi infrastructure
- Work as Spectrum Analyzer
- View Non WiFi Interference as BLE
- Passive Survey and Life Heat-Maps
- Active Survey with Real Data Rate
- Measure Roaming Quality
- Need Hardware and Specific WLAN Card
- Generate Detailed Assessment Reports

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netAlly

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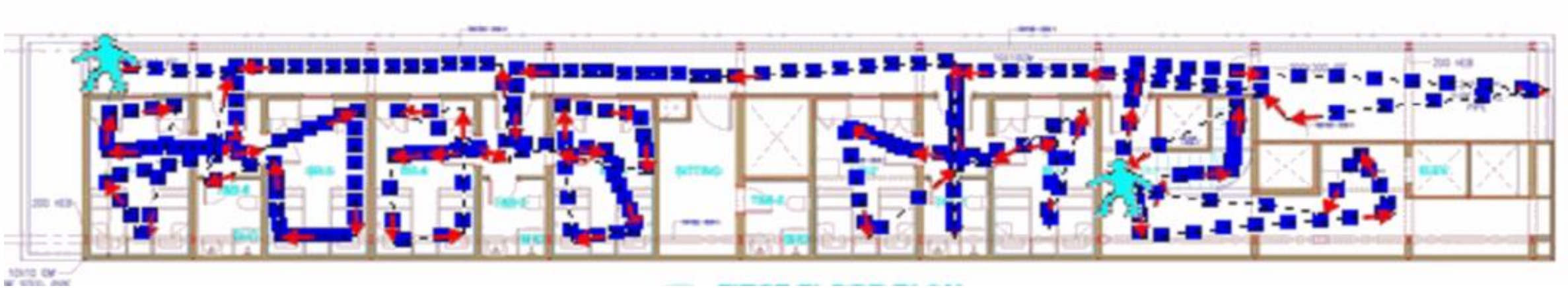

WLAN-PRACTICAL LECTURE 6

WLAN Analyzer

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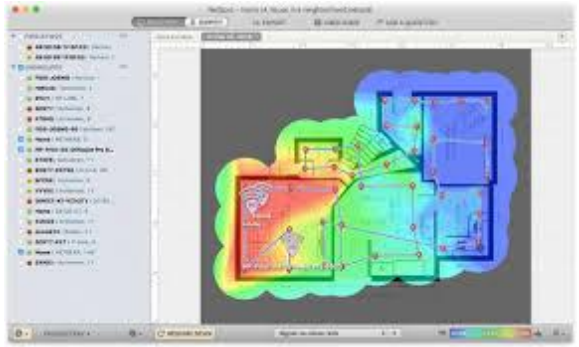

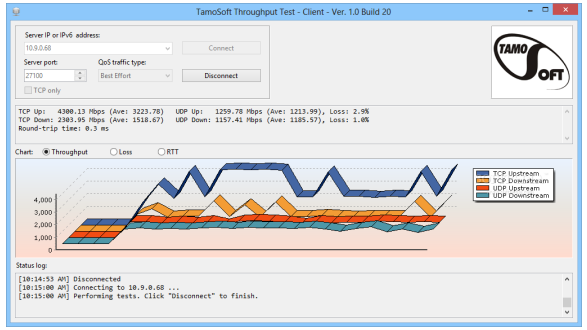

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https://www.metageek.com/products/inssider/

Signal & Noise Levels

RSSI

Received Signal Strength dBm

-45 to -75 dBm

Noise

Unwanted Signal Strength dBm

Less than -85

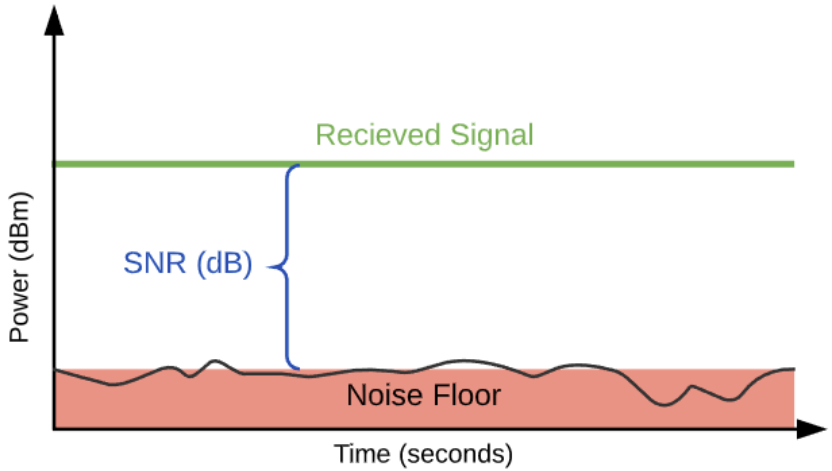
SNR

Ratio between Signal and Noise Level dB

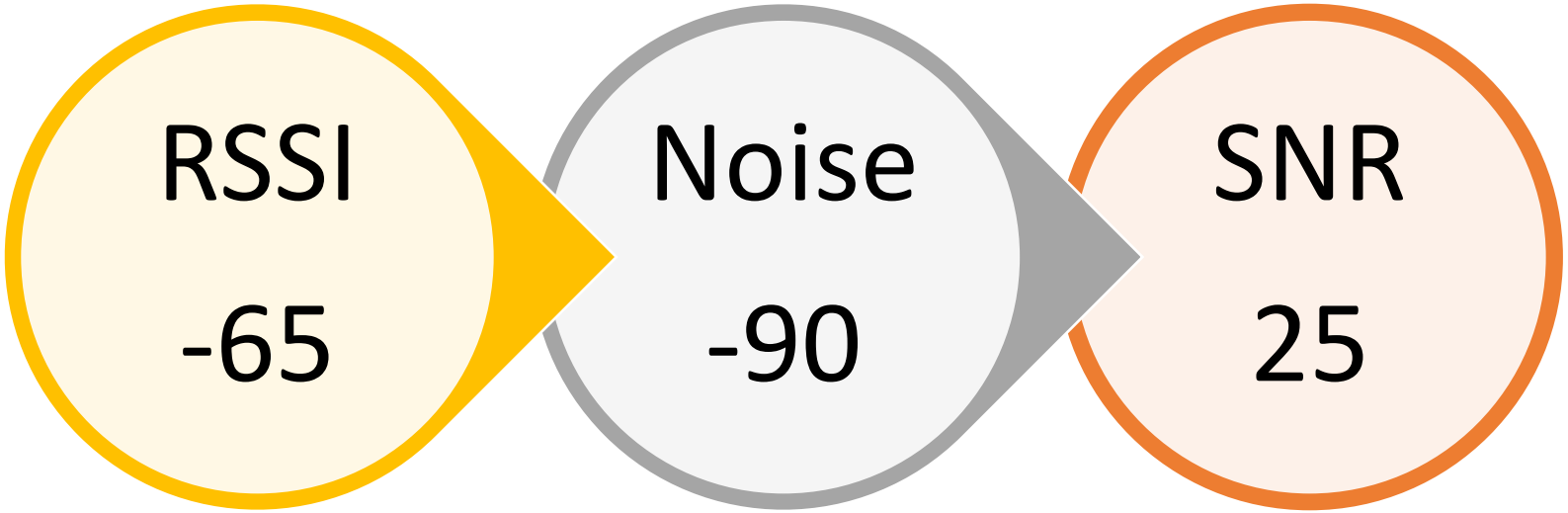
25 dB

RSSI & Noise – minus value -dBm
Minus mean less than 1 m watt
AP power not more than 100 m watt
10 log .5 = -3 dBm

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

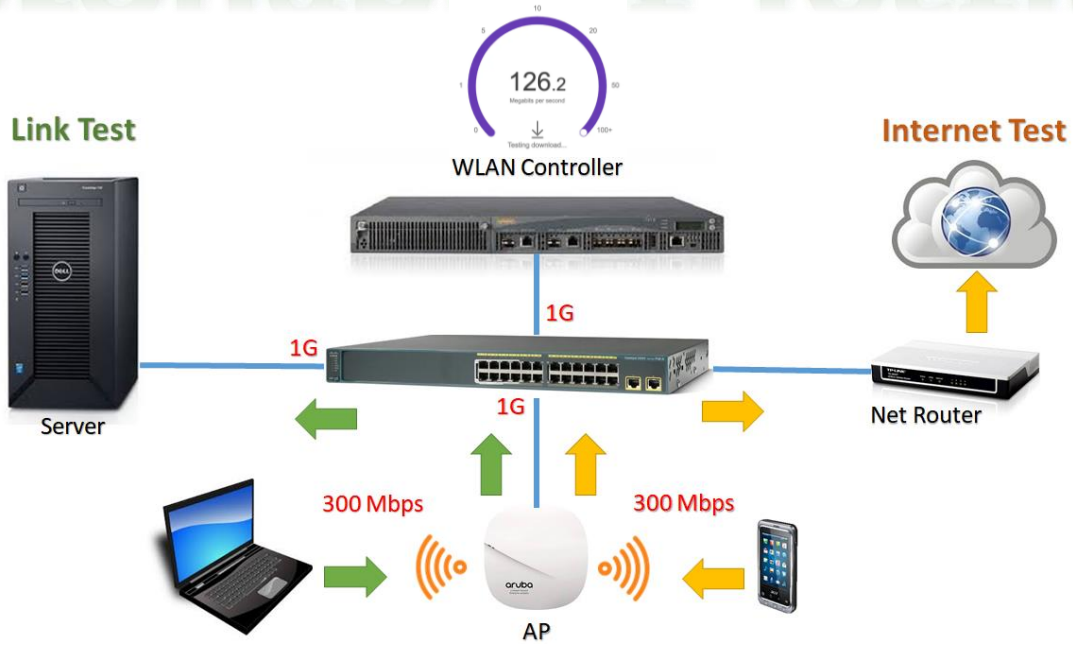


Recommended Values

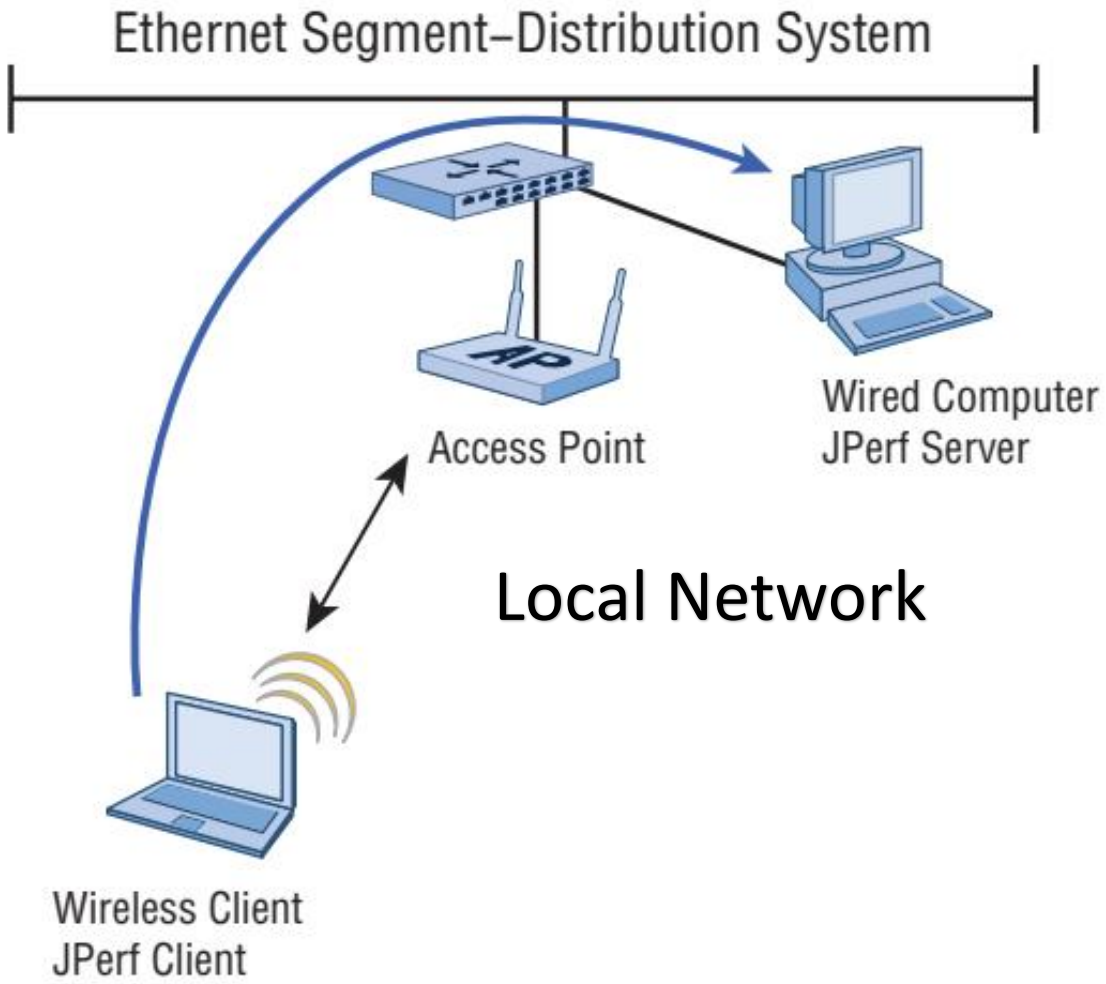


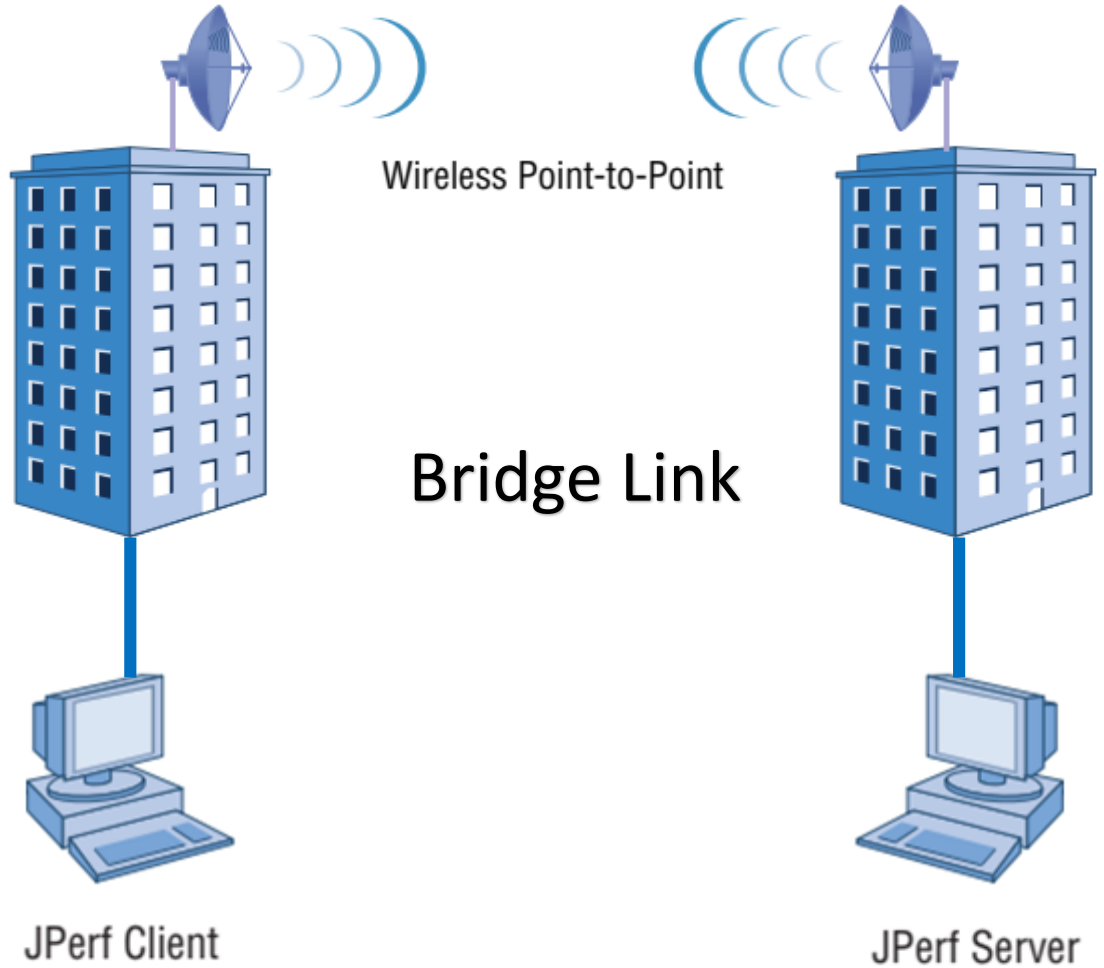
WLAN-PRACTICAL LECTURE 7

WLAN Throughput Testing



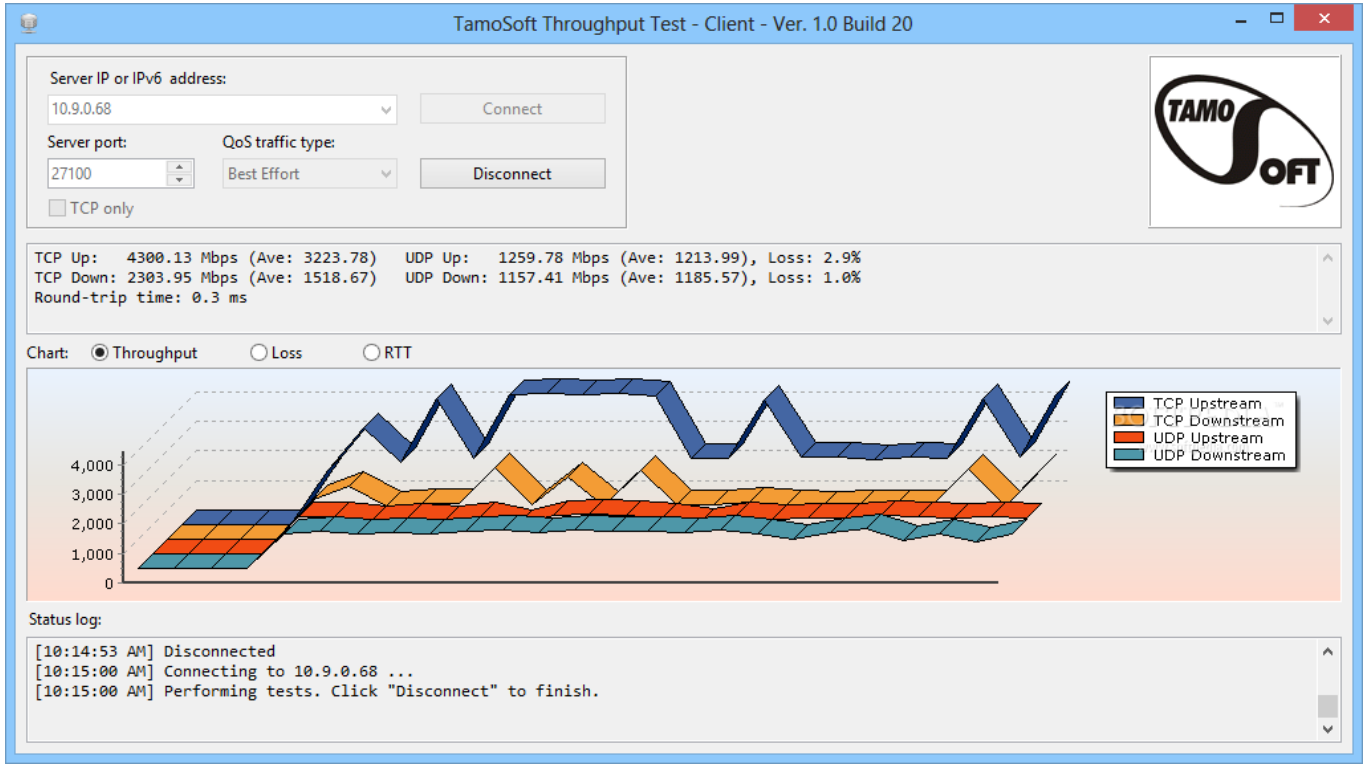
Link Quality and Throughput Testing





Speed & Throughput Test

- Measure Actual Throughput
- Measure Link Quality (Jitter – Delay)
- Measure Packet Loss Ratio
- Measure TCP and UDP Traffic
- Used for Mesh & Bridge Links
- Available for PC and Smart Phones



https://www.tamos.com/

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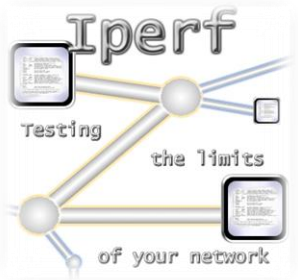
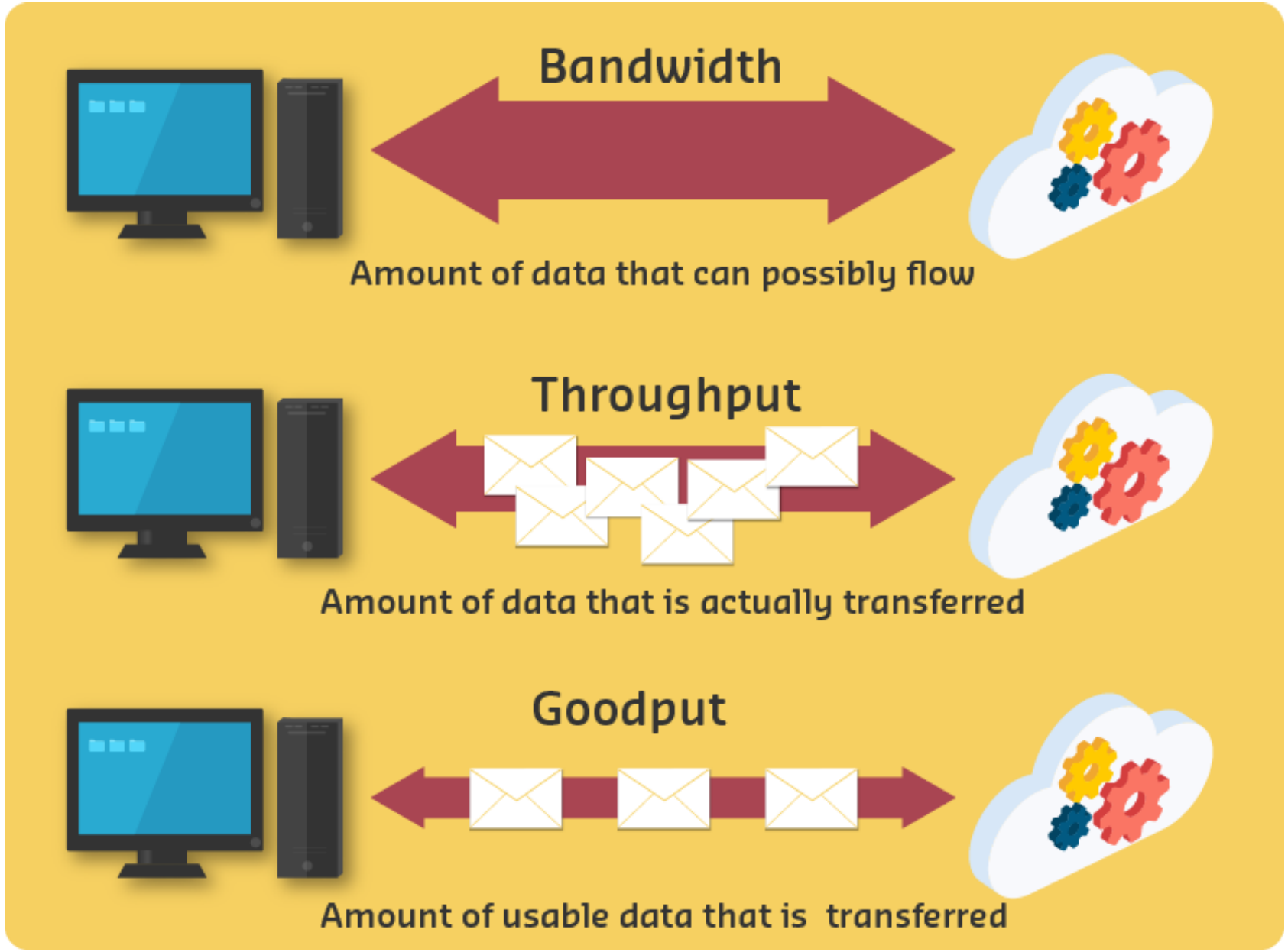


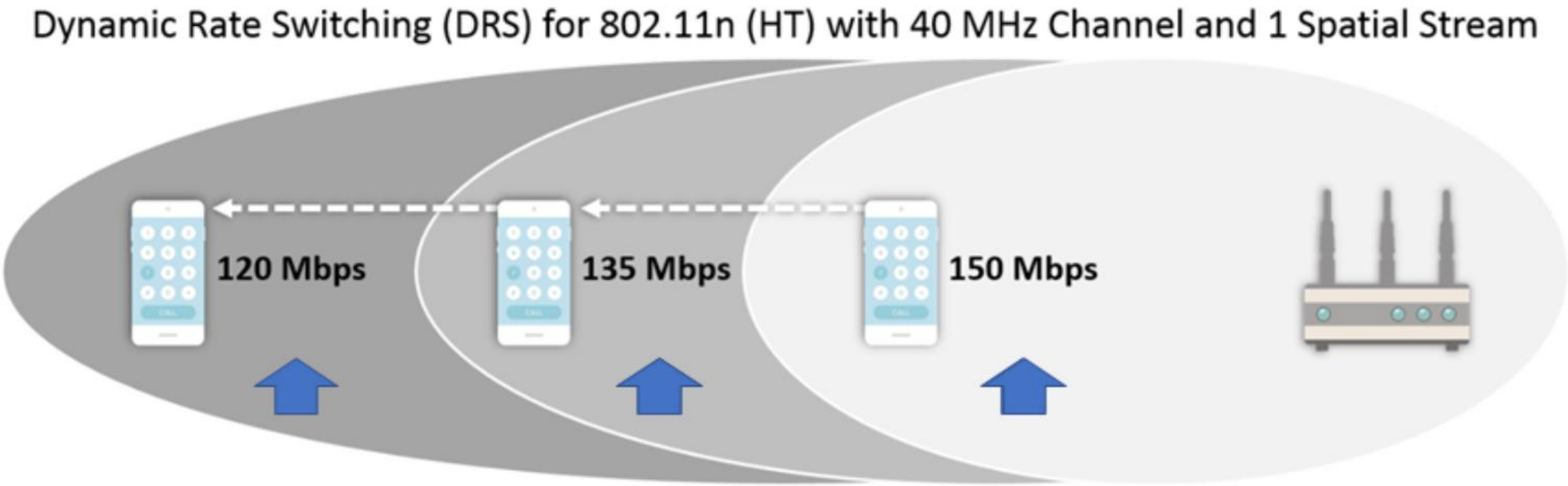
https://iperf.fr/

Speed Vs Throughput

Bandwith	• Bandwidth of the Circuit of RF Channel
Speed	• Current Supported Speed to Client based on SNR
Throughput	• Amount of total transferred data
Goodput	• Amount of Valid transferred Data
Usage	• Amount of download compared to Good put

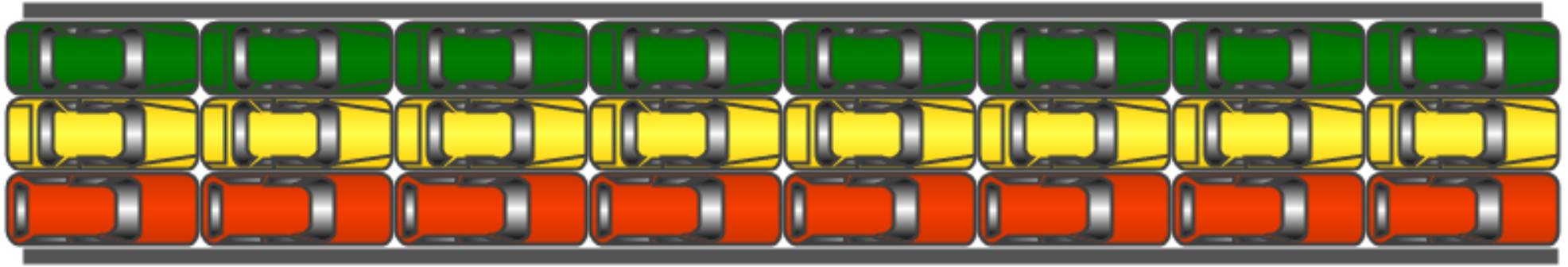

Bandwidth
Amount of data that can possibly flow
Throughput
Amount of data that is actually transferred
Goodput
Amount of usable data that is transferred

Data Rate and Signal Strength Relation



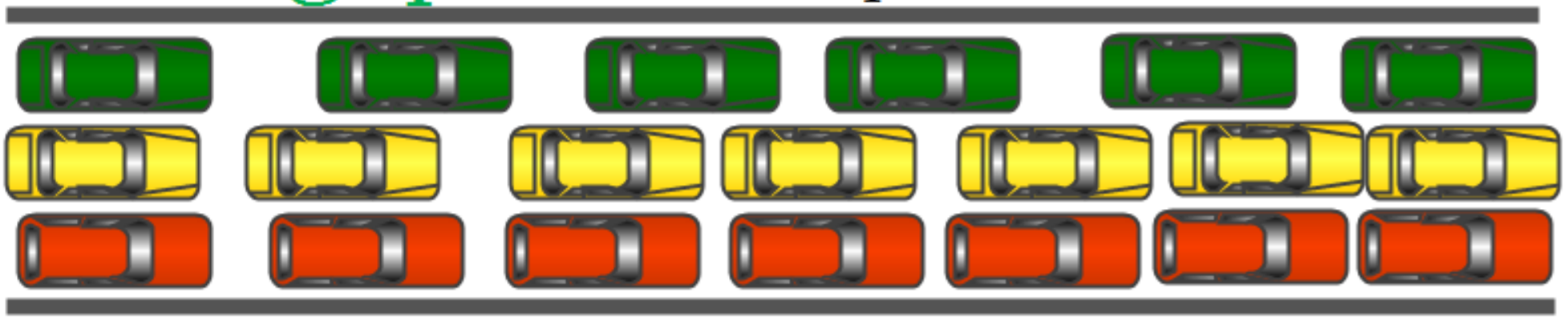
Throughput Vs Bandwidth

Bandwidth 24 Cars per second



Throughput less than BW due to : RF Interference – Delay - Congestion

Throughput 20 Cars per second



+

Testing Scenario

Link Test

Internet Test

Server

WLAN Controller

1G

1G

1G

Net Router

300 Mbps

AP

300 Mbps

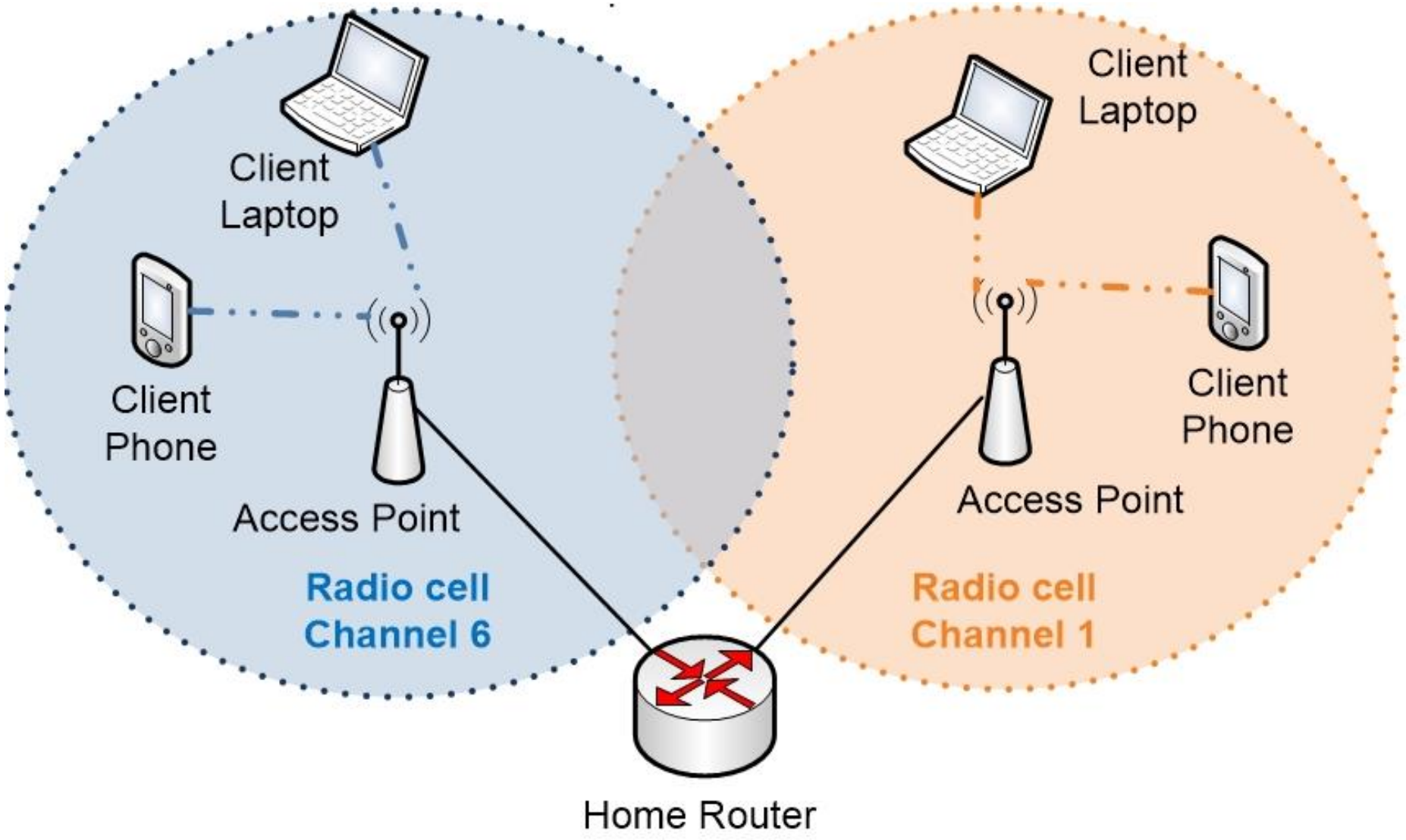
Wi-Fi is Half Duplex

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

Full-duplex:

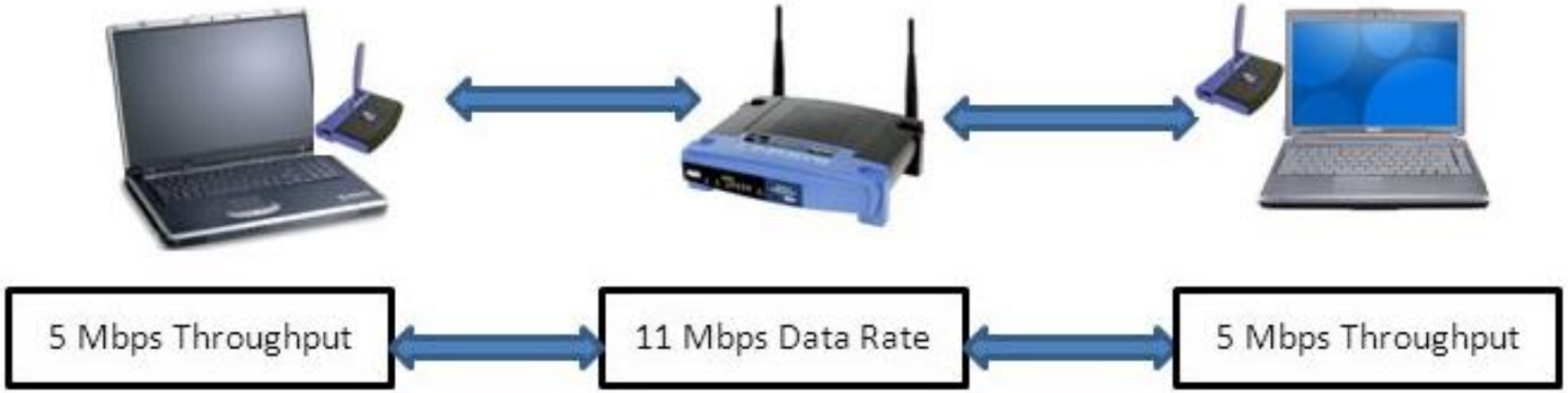
Half-duplex:

Wireless is Shared Medium



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)



Throughput Vs Data Rate

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*

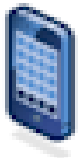
3SS Laptops — 3 Mbps (ea) — ***100 Mbps Total***

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

Throughput Vs Data Rate

Wired	Wireless
• Full-duplex link (no contention)	• Half-duplex link (contention prevalent)
• Single link data rate	• Adaptive link data rate
• Throughput = Link utilization	• Throughput != Link utilization

Iperf - JPerf

Command line option	Description
-s, --server	Run iPerf in server mode. (This will only allow one iperf connection at a time)
-c, --client ***host***	Run iPerf in client mode, connecting to an iPerf server running on ***host***.
-u, --udp	Use UDP rather than TCP. See also the -b option.
-b, --bandwidth ***n[KM]***	Set target bandwidth to n bits/sec (default 1 Mbit/sec for UDP, unlimited for TCP).
-t, --time ***n***	The time in seconds to transmit for. iPerf normally works by repeatedly sending an array of ***len*** bytes for ***time*** seconds. Default is 10 seconds. See also the -l, -k and -n options.
-n, --num ***n[KM]***	The number of buffers to transmit. Normally, iPerf sends for 10 seconds. The -n option overrides this and sends an array of ***len*** bytes ***num*** times,
-k, --blockcount ***n[KM]***	The number of blocks (packets) to transmit. (instead of -t or -n)
-l, --length ***n[KM]***	The length of buffers to read or write. iPerf works by writing an array of ***len*** bytes a number of times. Default is 128 KB for TCP, 8 KB for UDP.
-P, --parallel ***n***	The number of simultaneous connections to make to the server. Default is 1.
-R, --reverse	Run in reverse mode (server sends, client receives).
-w, --window ***n[KM]***	Sets the socket buffer sizes to the specified value. For TCP, this sets the TCP window size. (this gets sent to the server and used on that side too)

Client Device Data Rate

	802.11n	802.11n	802.11ac Wave 1	802.11ac Wave 2	802.11ac
	IEEE Specification				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*

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

Thanks For Watching

GAZ ARAB