AIRHEADS
LAS VEGAS 2012

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RF FUNDAMENTALS

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Aruba Networks
March 2012

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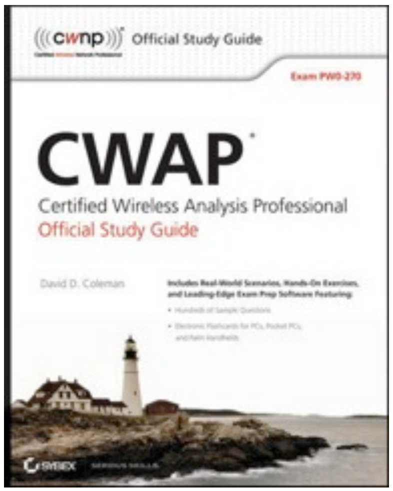
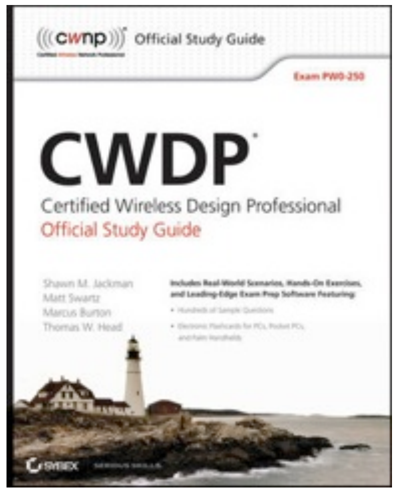
Welcome

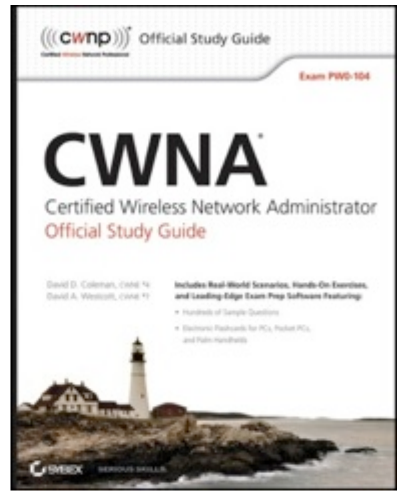
- This is going to go really fast, so hang on
- We're going to cover RF basics
- But we're going skip some of the math
- We will cover 802.11 basics

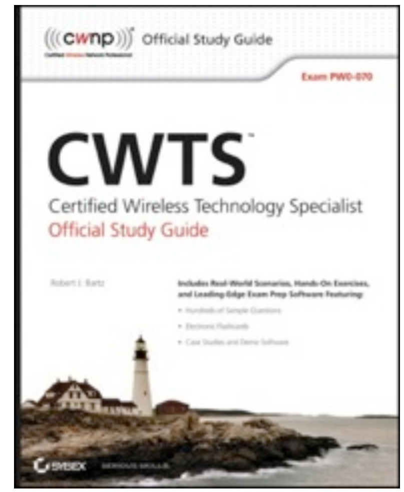
- You can review this material again on our public website – www.arubanetworks.com
- Home > Support > Training > Training Classes > RF Fundamentals

When You Want To Know More









http://www.cwnp.com/

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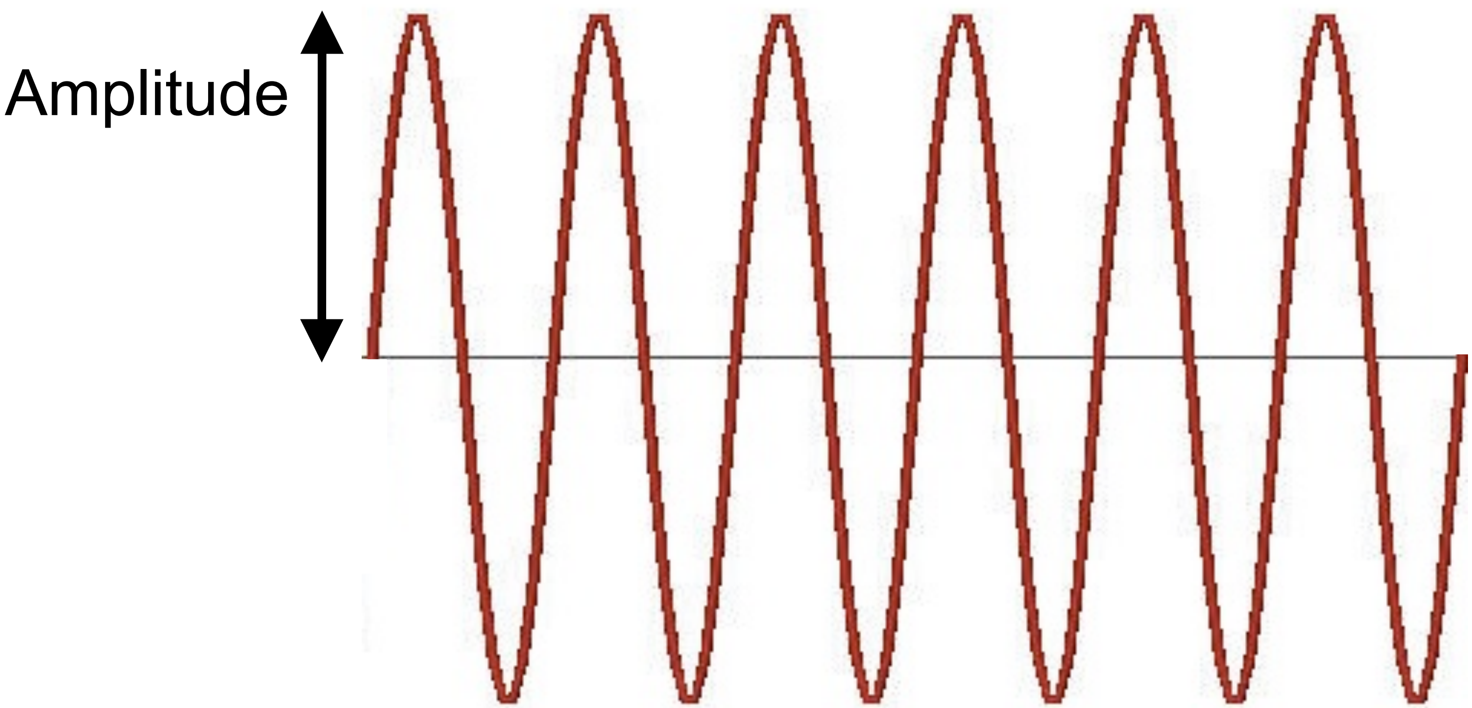
Basics Of Signals

Amplitude

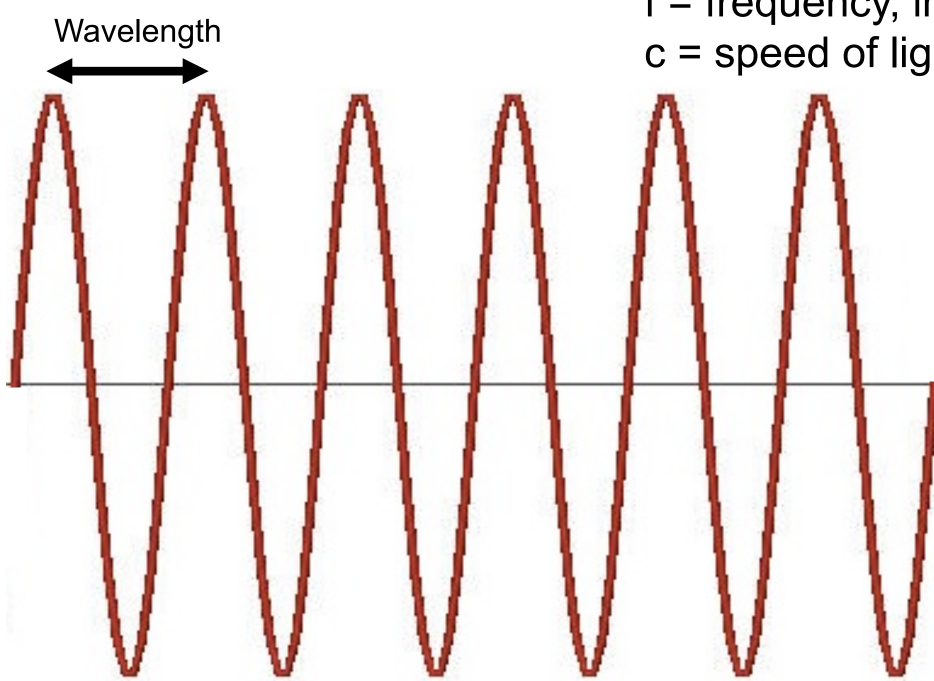
- **The signal's power or strength**



Wavelength

- The distance between repeating components of a wave
- 2.4 GHz wave = about 4.8 inches or about 12 centimeters
- 5.775 GHz wave = about 2 inches or about 5 centimeters
- $\lambda = c / f$

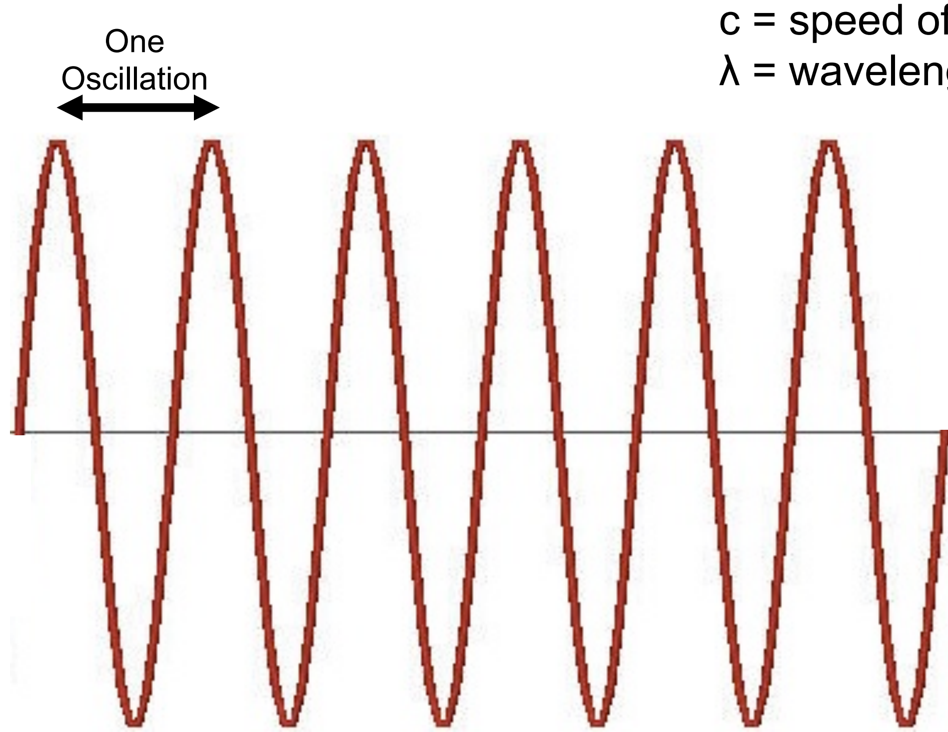
λ = wavelength, measured in meters
f = frequency, in hertz
c = speed of light, 299,792,458 m/s



Frequency

- **The number of times the signal oscillates in one second (Hz)**
- **2.4 GHz = 2.4 billion oscillations in one second**
- **Lower frequencies propagate farther**
- **f = c / λ**

f = frequency, in hertz
c = speed of light, 299,792,458 m/s
λ = wavelength, measured in meters

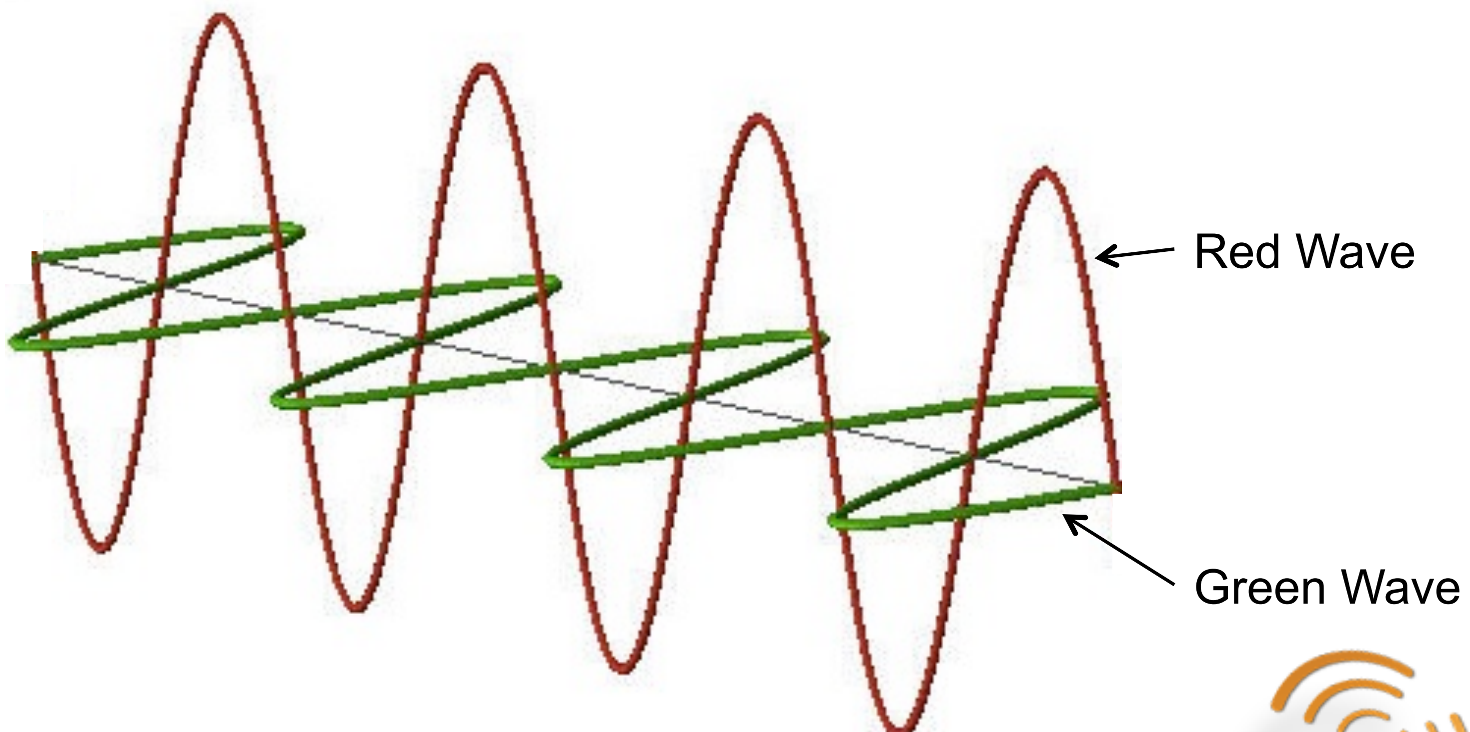


Polarization

The horizontal or vertical orientation of a wave

Red wave has vertical polarization

Green wave has horizontal polarization



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Signal Changes

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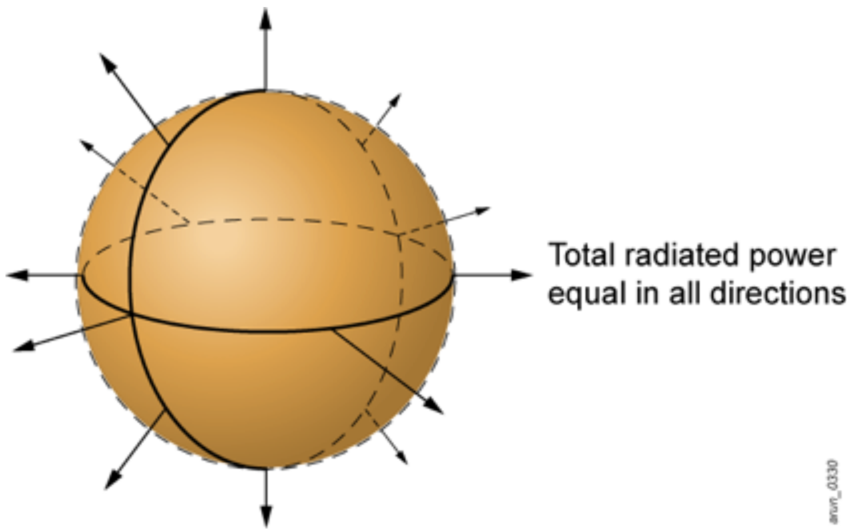
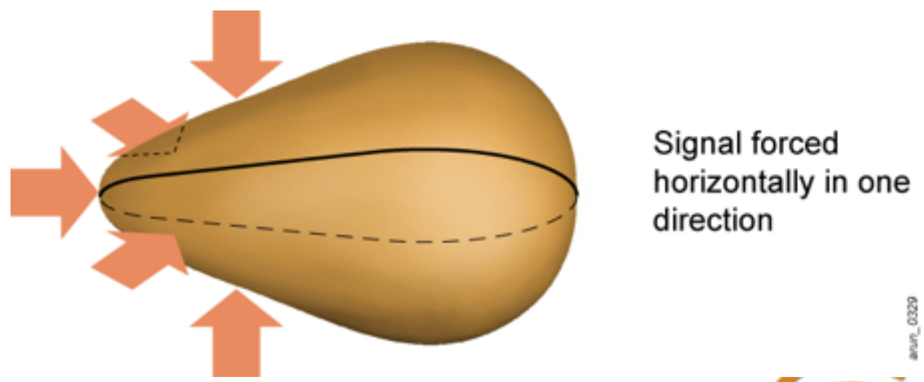
Amplification (Gain)

- **Increase of signal strength or amplitude**
- **Active Gain**
  - Caused by increasing power from the transmitter
- **Passive Gain**
  - Caused by shaping or focusing power (from antenna)





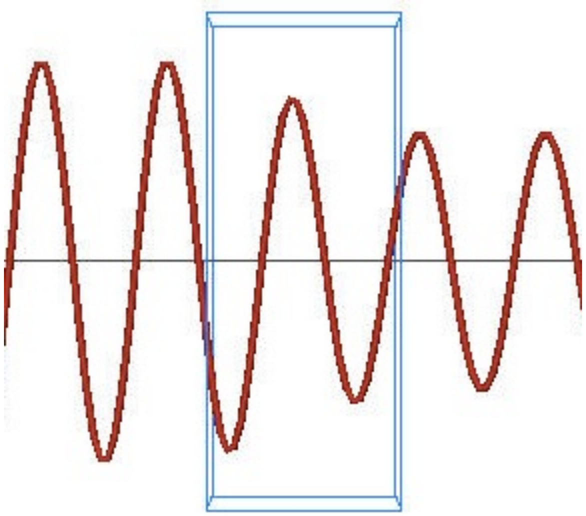
Attenuation (Loss)

- **Decrease of signal strength or amplitude**
- **Occurs when signal passes through an object**
- **Occurs naturally due to the broadening of a wave as it moves further from the source (Free Space Path Loss)**
- **Can be caused intentionally**
  - An engineer installing a hardware attenuator between the transmitter and the antenna, prior to the signal reaching the antenna
- **Can be caused unintentionally**
  - An engineer installing a low quality cable or a long cable between the transmitter and the antenna, prior to the signal reaching the antenna

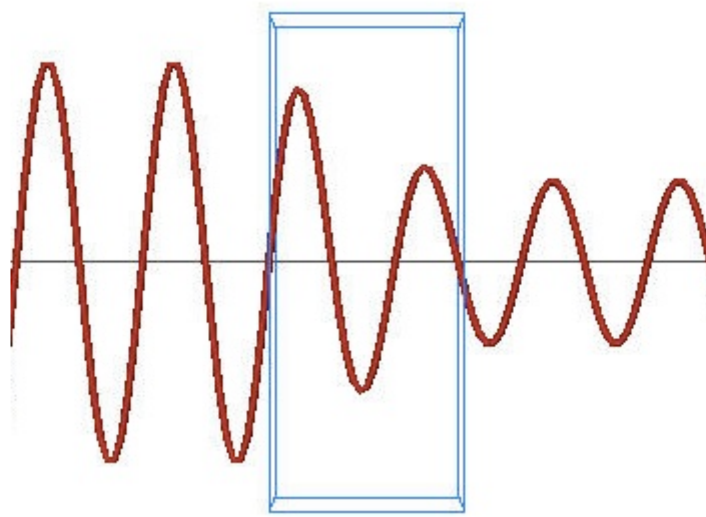
Absorption

- **The weakening of a wave as it moves through an object**
- **Denser materials absorb more signal**
- **As signal travels through buildings or vegetation, part of the signal is absorbed, part is reflected**

Less Dense Wall



More Dense Wall



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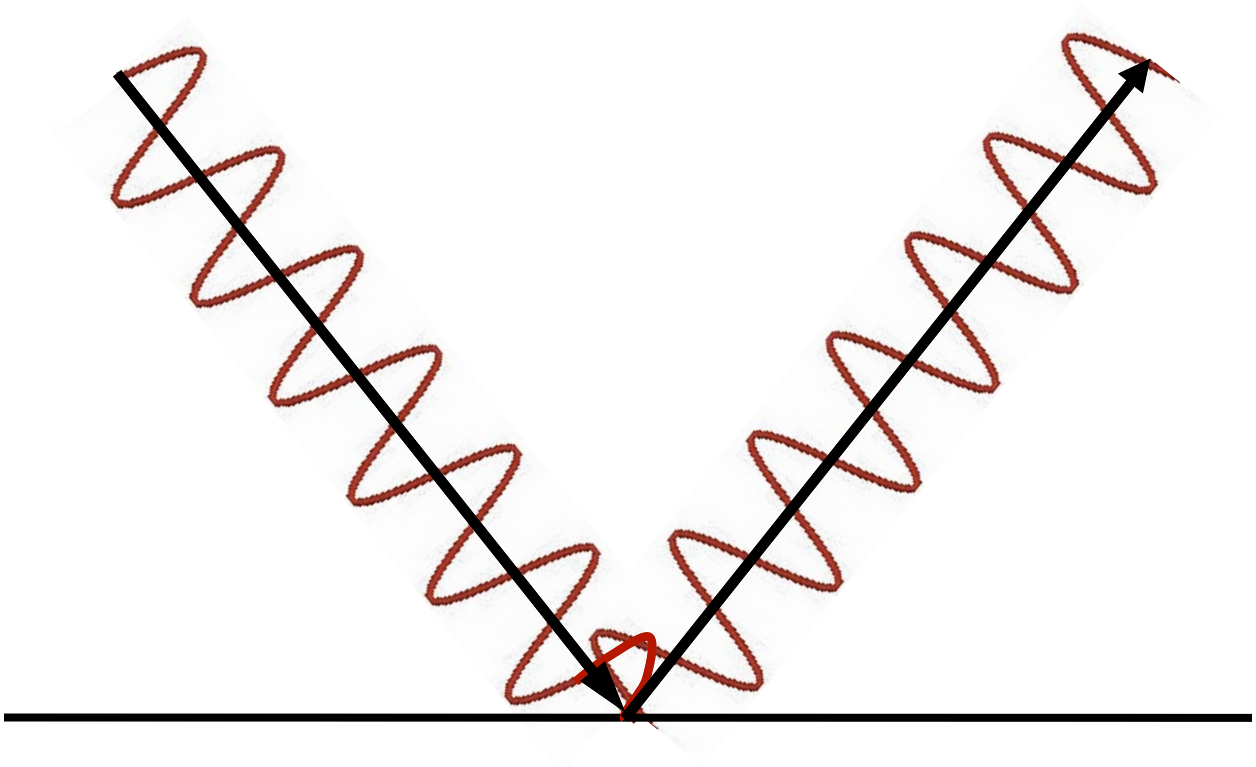
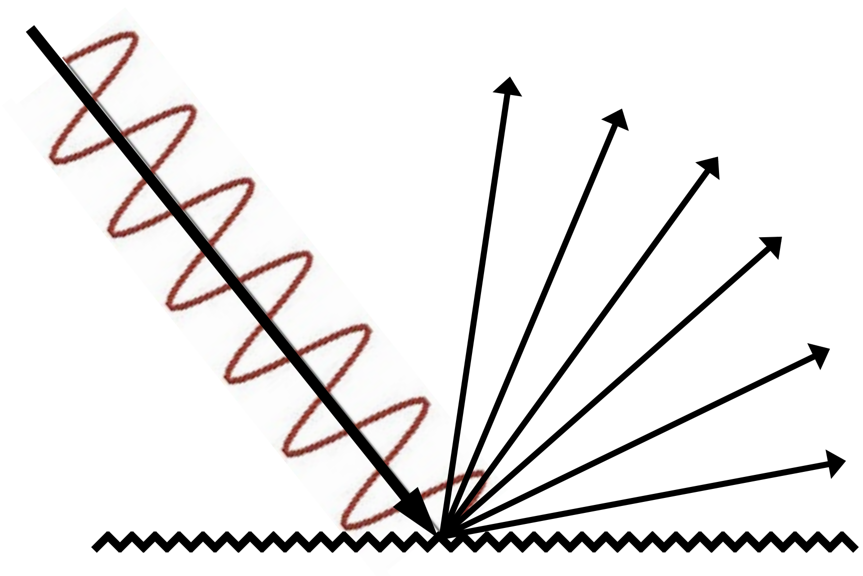
Reflection

- The bouncing of a wave off of a smooth object or surface
- Reflection can even occur off the ground or bodies of water



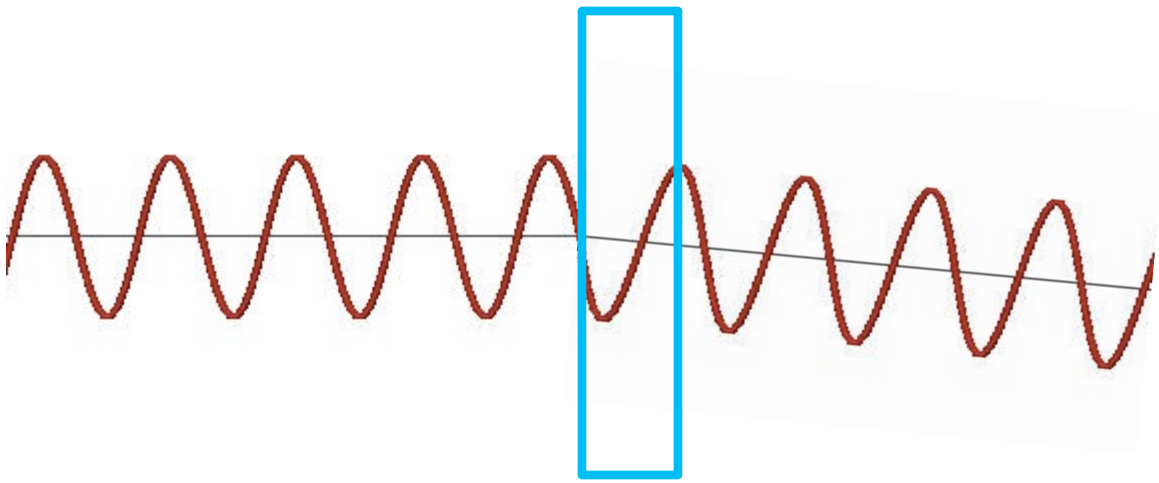
Scattering

- Reflection that occurs when a signal bounces off of a rough or uneven surface.
- RF signal bounces in many directions
- Fencing, foliage, rough terrain can cause scattering



Refraction

- **The bending of a wave as it moves between two mediums with different densities**
- **Three most common causes of refraction**
  - Water vapor
  - Changes in air pressure
  - Changes in air temperature
- **As the wave travels through the objects, it is refracted**



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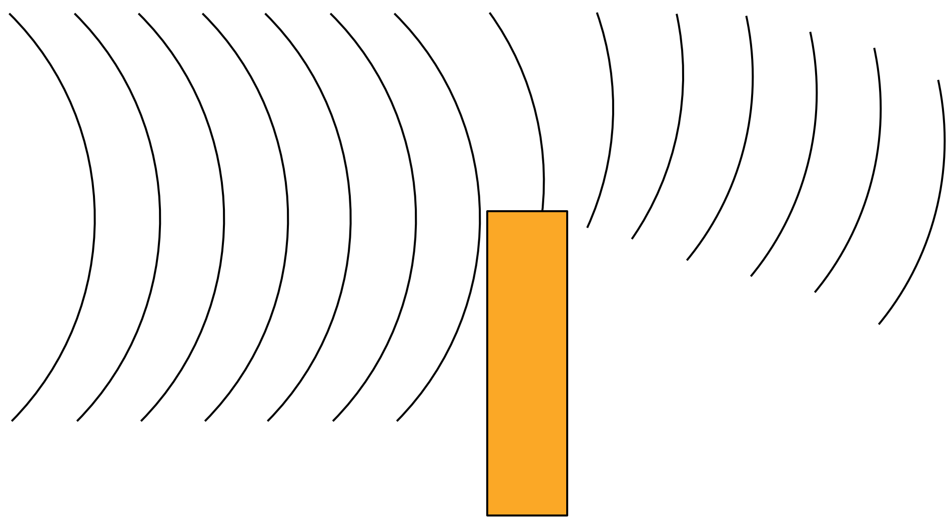
Diffraction

- The bending of a wave around an object as the wave moves past the object
- As a wave of water moves past a rock or pier, the wave will bend around the object
- As the wave encounters the object, it slows down and bends around the object

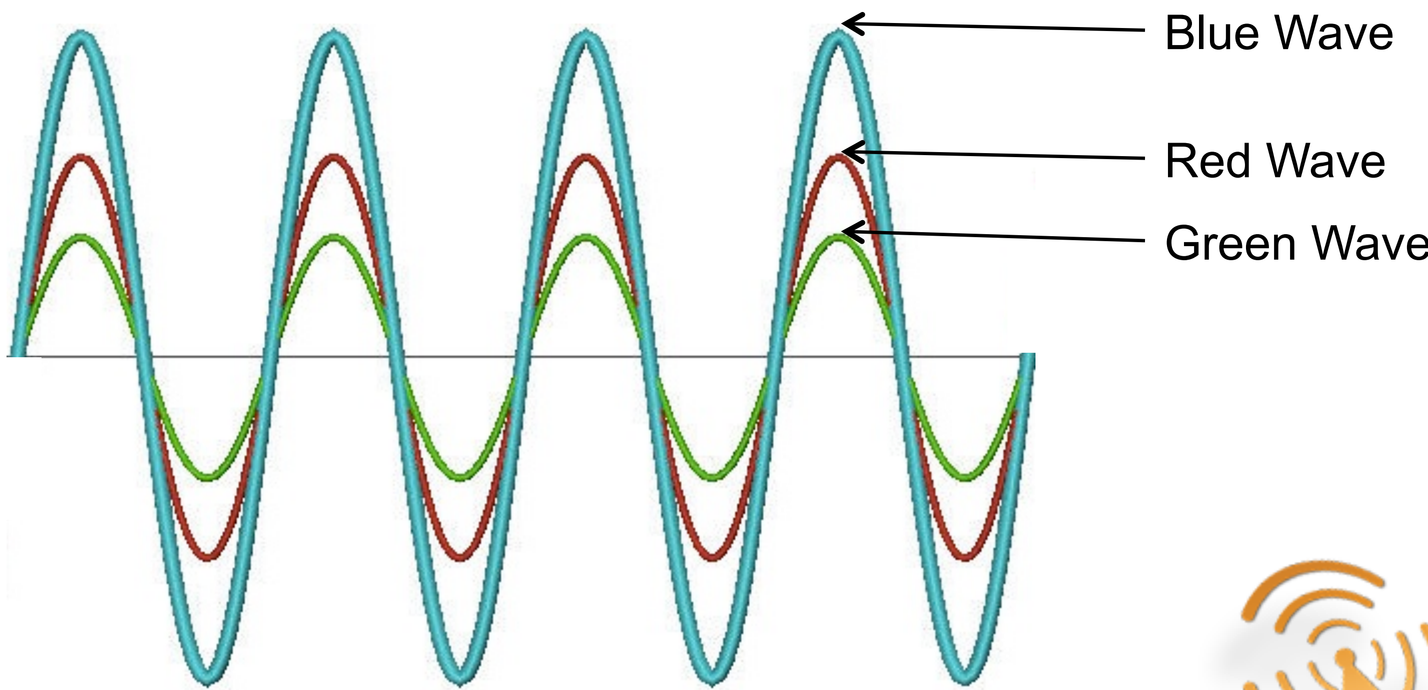


Multipath

- **As RF signals propagate, some will be reflected**
- **Multipath occurs when two or more of these signals arrive at the receiving antenna at the same time**
- **Reflected signals typically arrive after the main signal because they travel further**
- **Time differential = delay spread**
- **Multipath can result in**
  - Downfade
  - Upfade
  - Nulling
  - Corruption

Phase (In Phase)

- **Relationship between waves of the same frequency**
- **In Phase waves are cumulative**
- **Red wave and green wave combine to produce the blue wave**



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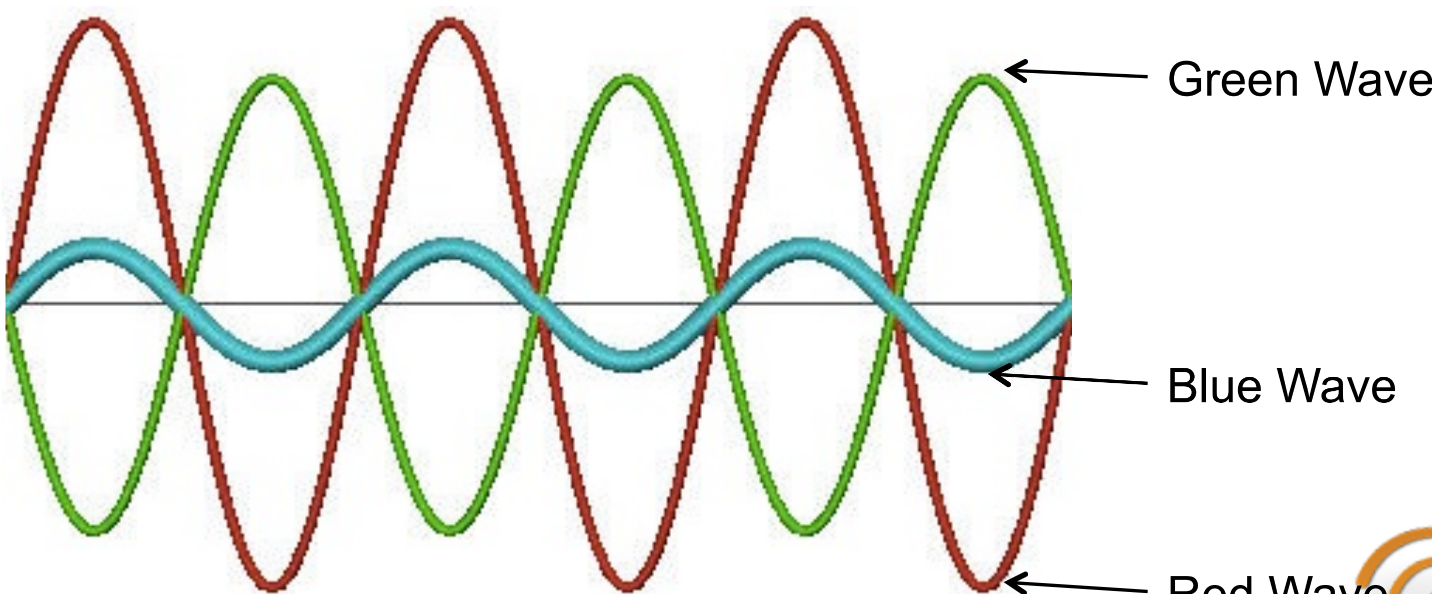
Phase (Out of Phase)

- **Out of Phase waves provide cancellation**
- **Red wave and green wave cancel each other producing the blue wave**



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RF Power

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Why Use dBm Instead of Milliwatts?

- **Due to Free Space Path Loss, signal attenuates quickly**
- **dBm is a logarithmic measure**
- **The amount of power received from a 2.4 GHz, 100mW transmitted signal**

Distance(m)	dBm Signal	mW Signal
1	-20	.0098911
10	-40	.0000989
20	-46	.0000247
100	-60	.0000010
1000 (1km)	-80	.0000000099

- dBm is much easier to work with

dBm and mW Relationships

+3 dBm = double the power

-3 dBm = half the power

+10 dBm = ten times the power

-10 dBm = one tenth the power

dBm	mW
+20	100
+19	80
+16	40
+13	20
+10	10
+9	8
+6	4
+3	2
0	**1**
-3	0.5
-6	0.25
-9	0.125
-10	0.1
-13	0.05

6 dB Rule

- **The 6 dB rule is a useful and functional rule**
- **A 6 dB increase in EIRP will double the distance that the RF signal travels**
- **A 6 dB decrease in EIRP will halve the distance that the RF signal travels**
- **It does not matter what causes the increase or decrease**

Noise & Interference

…. Signals are corrupted so they don’t make sense to the receiver …

- **Noise**
  - **Random** ‘background’ that has got mixed up with your signal. Usually doesn’t vary too much over time.
- **Interference**
  - **Additional** signals are added to the one you want. Can be intermittent or persistent.

Signal to Noise Ratio (SNR)

SNR is not actually a ratio

SNR = Signal (Received Power) – Noise floor

Assume:

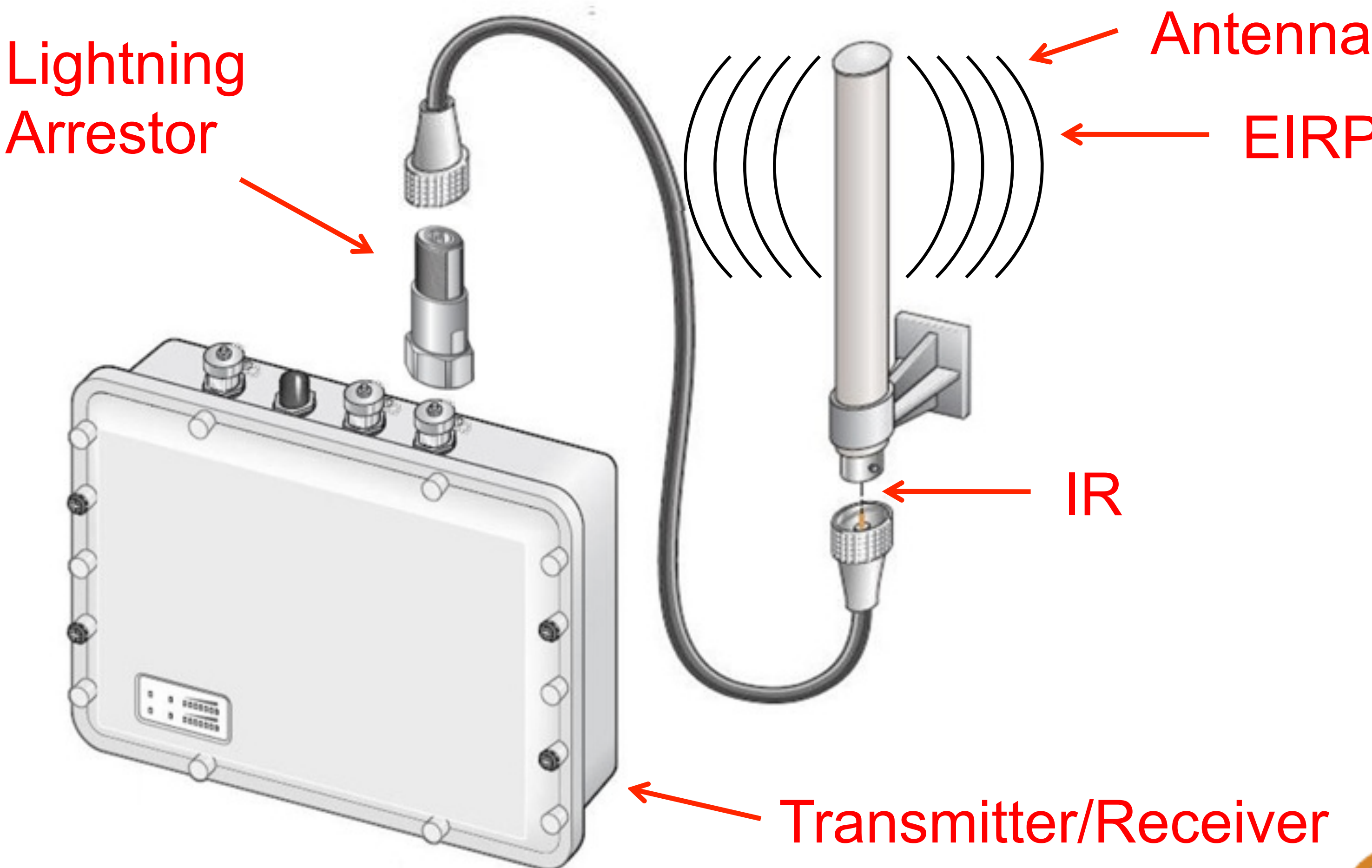
Signal received is -65 dB; Noise floor is -85 dB

SNR = -65 – (-85) = 20

A minimum of 25-30 is essential to decode high 11n data rate

802.11

RF Components



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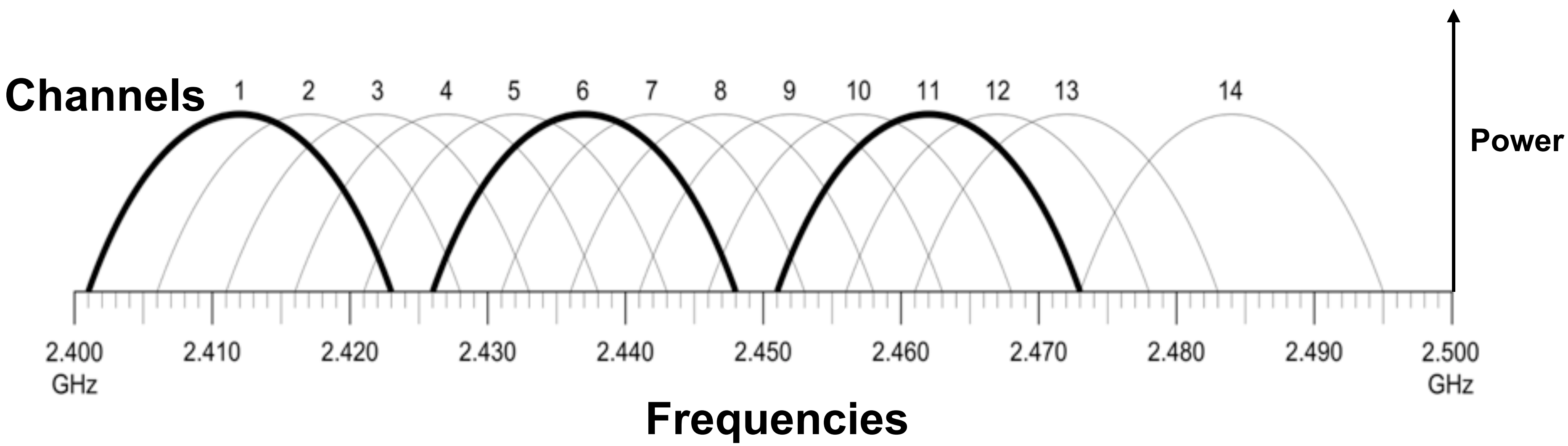
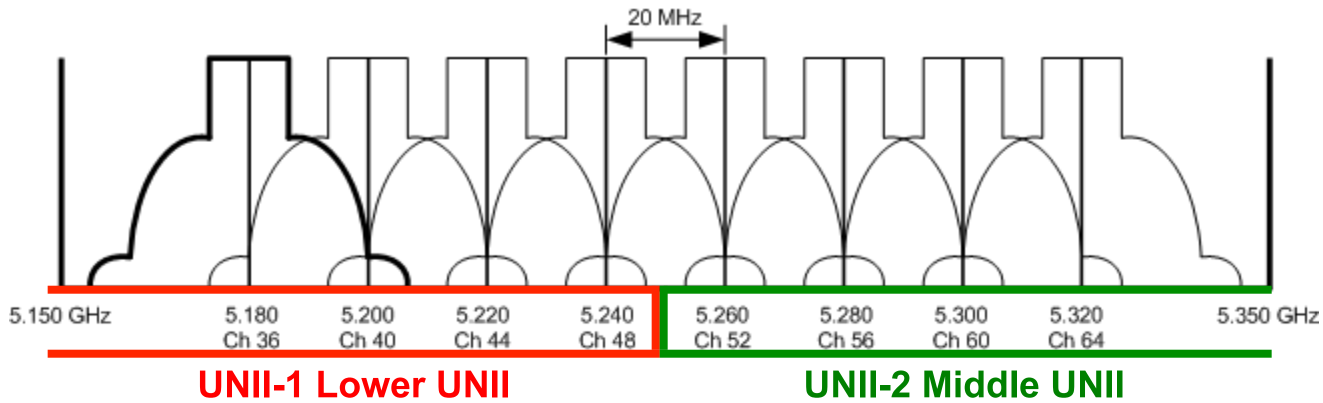
2.4 GHz ISM Band and Channels

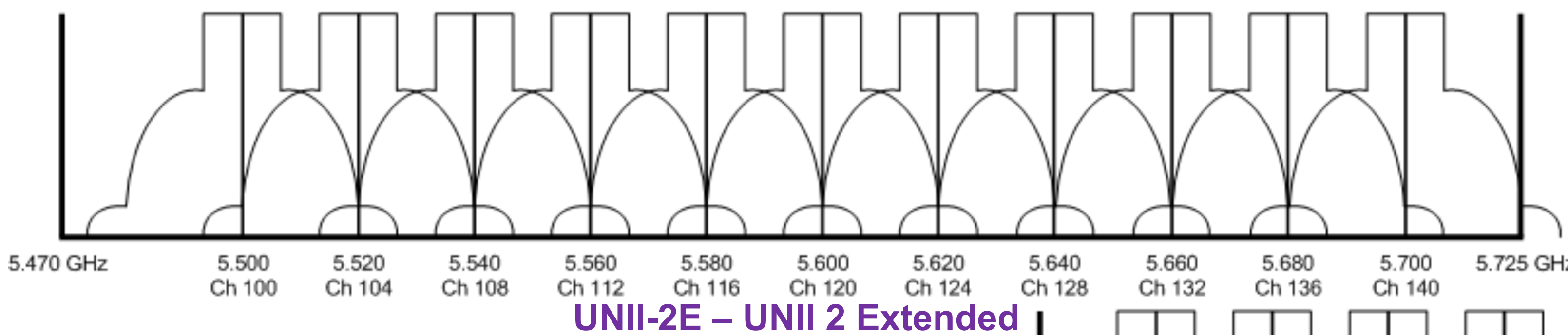
2.4 GHz ISM Band is used by

- **802.11**
- **802.11b**
- **802.11g**
- **802.11n**

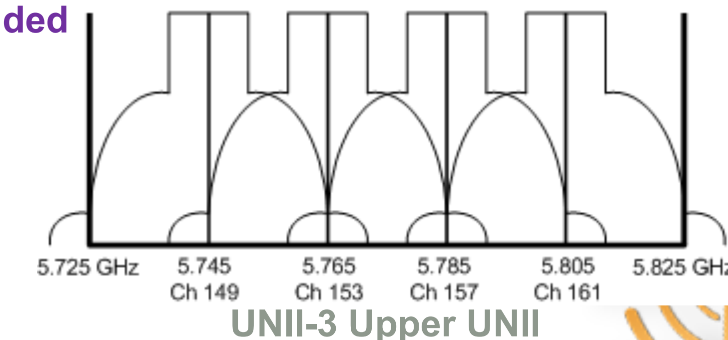


5 GHz UNII Band and Channels





5 GHz UNII Band is used by 802.11a & 802.11n



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802.11h – DFS and TPC

- **Dynamic Frequency Selection (DFS)**
  - UNII-2 and UNII-2E
  - Radio must detect and avoid
    - Radar
    - Satellite systems
- **Transmit Power Control (TPC)**
  - Dynamically regulates power levels of devices
  - Negotiates so that power is just strong enough to communicate
  - Minimizes interference risk

Varying Capacity Channel

Capacity is fixed in typical wired networks

- **10/100/1000/10000 Ethernet**
- **The available capacity is a usually a percentage of the maximum when all clients are of the same type**

Wireless capacity varies based on a variety of factors

- **Distance between the AP and clients**
- **Adjacent and co-channel interference**
  - Number of APs/clients in the network (e.g., contention)
- **Capability and behavior of clients (e.g., rate control)**
- **RF environment and other sources of interference**

Unfair access if there is no airtime management

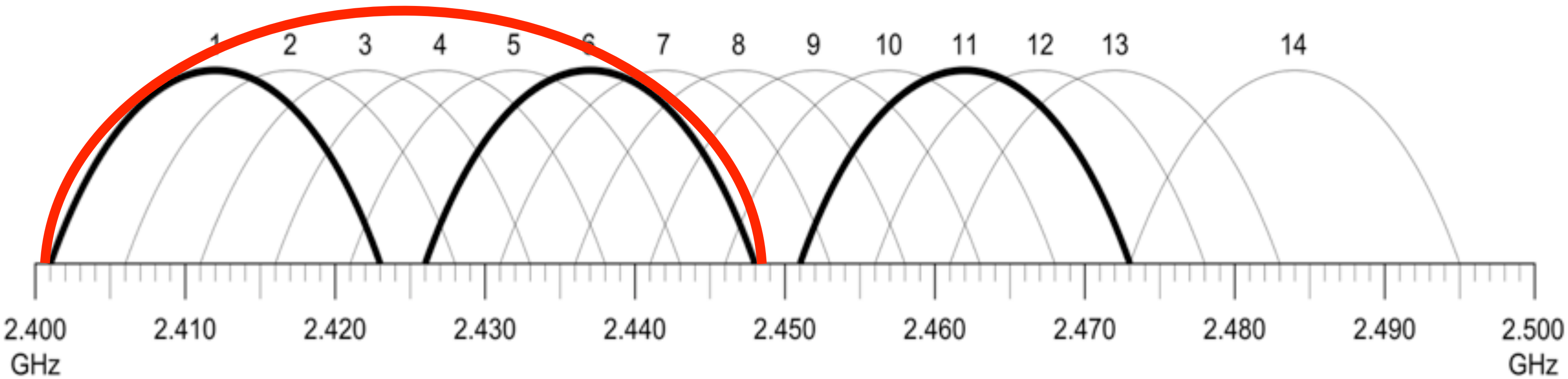
- **Slower clients and faster clients need to be managed**
- **Airtime needs to be fairly allocated**

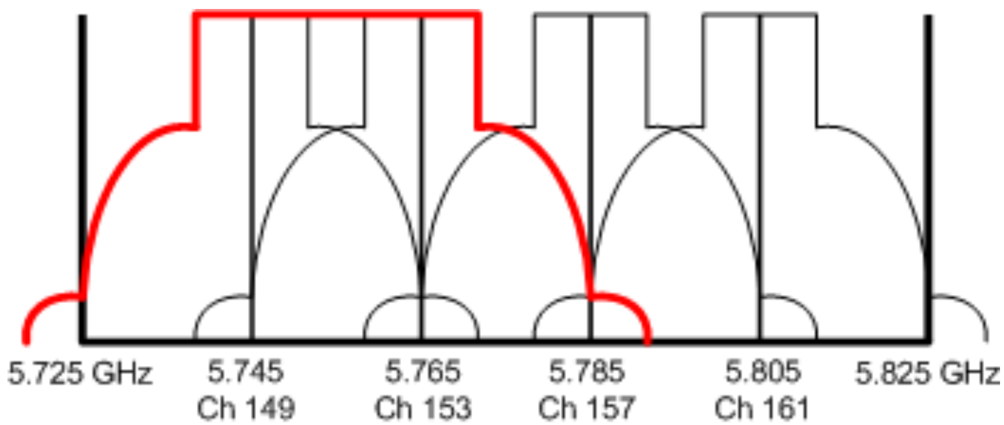
802.11n Enhancements

802.11a/b/g/n Comparison

IEEE Standard	Transmission Speed	Frequency & Band	Comment
802.11 (1997)	1,2 Mbps	2.4 GHz ISM	Original standard. Rarely used anymore. FHSS and DSSS.
802.11b (1999)	1, 2, 5.5, 11 Mbps	2.4 GHz ISM	First standard to gain consumer popularity. Backward compatible with 802.11 DSSS.
802.11a (1999)	6, 9, 12, 18, 24, 36, 48, 54 Mbps	5 GHz UNII	Slowly gained popularity due to less interference in the 5 GHz frequency range. OFDM.
802.11g (2003)	1, 2, 5.5, 6, 9, 11, 12, 18, 24, 36, 48, 54 Mbps	2.4 GHz ISM	Quickly being replaced by 802.11n. Backward compatible with 802.11 DSSS and 802.11b. OFDM.
802.11n (2009)	70+ different rates, from 6.5 to 600 Mbps. 450 Mbps is commonly supported.	2.4 GHz ISM and 5 GHz UNII	The standard for both home and enterprise use. Offers high performance along with backward compatibility.

802.11n Channel Bonding





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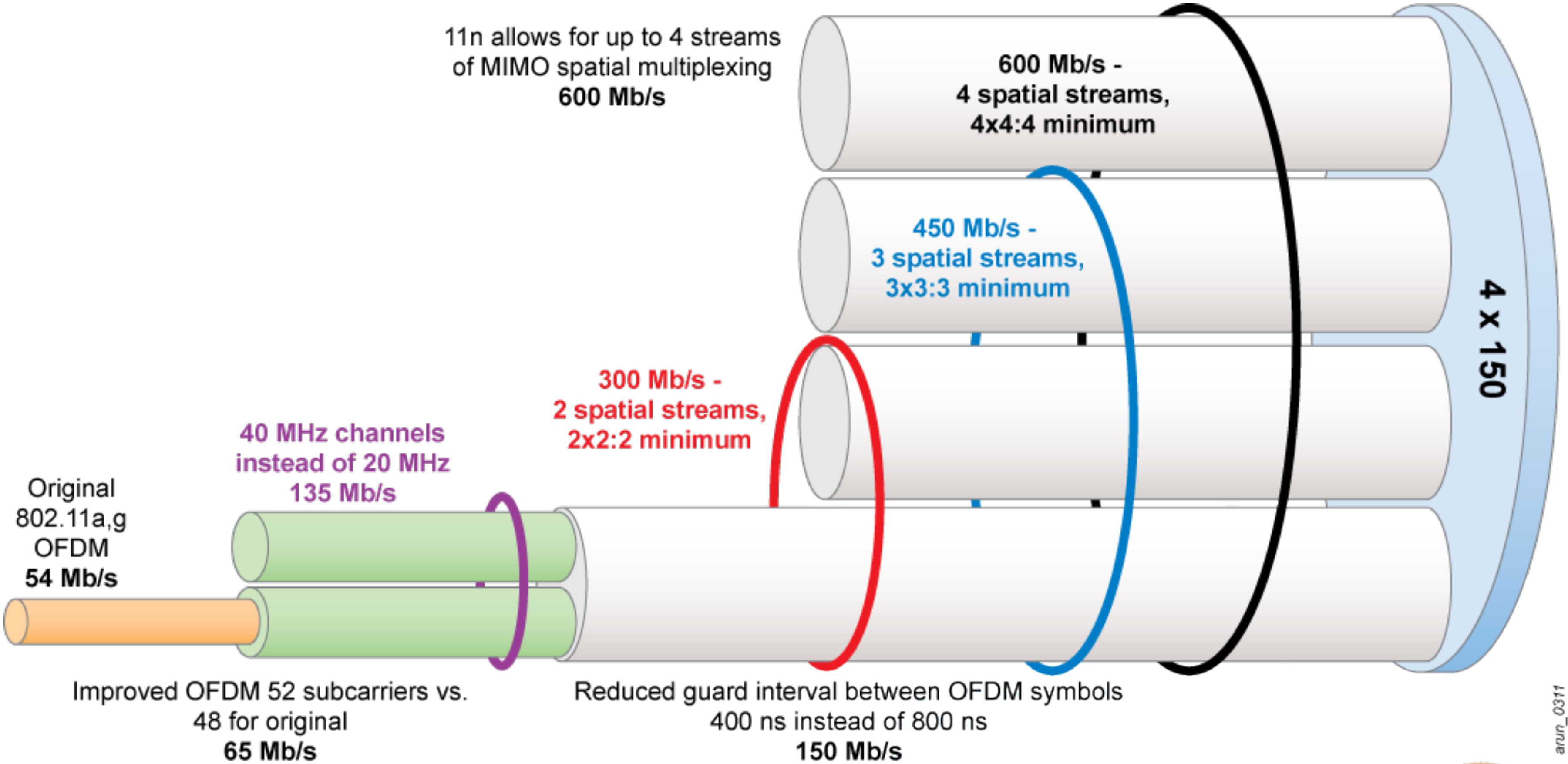
Multiple Input Multiple Output (MIMO)

- **Single Input Single Output**
  - Used by previous 802.11 radio technologies
  - One antenna used for transmitting or receiving at a time
- **Multiple Input Multiple Output**
  - N by M antenna matrix
    - N – Number of Tx antennas
    - M – Number of Rx antennas
    - Maximum is 4 x 4

802.11n Enhancements



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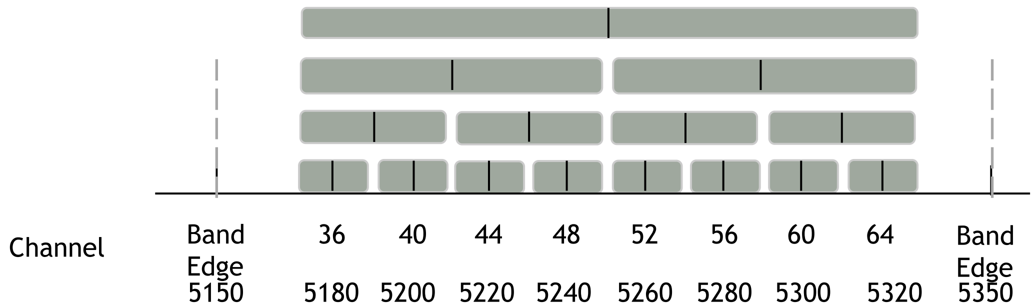
802.11ac Timelines

- Draft 1.3 available, efforts underway to address comments and get to Draft 2.0
- Final Ratification expected in 2013
- Many WLAN silicon vendors are actively developing 802.11ac silicon
- Initial chipsets may start to show up mid-2012, but usable solutions probably in 2013-14
  - Will probably start with no more than 4 spatial streams on APs
  - Smartphones and tablets may not see more than 1-2 spatial streams
- WiFi Alliance test plan work underway (first interoperability events planned in 2012

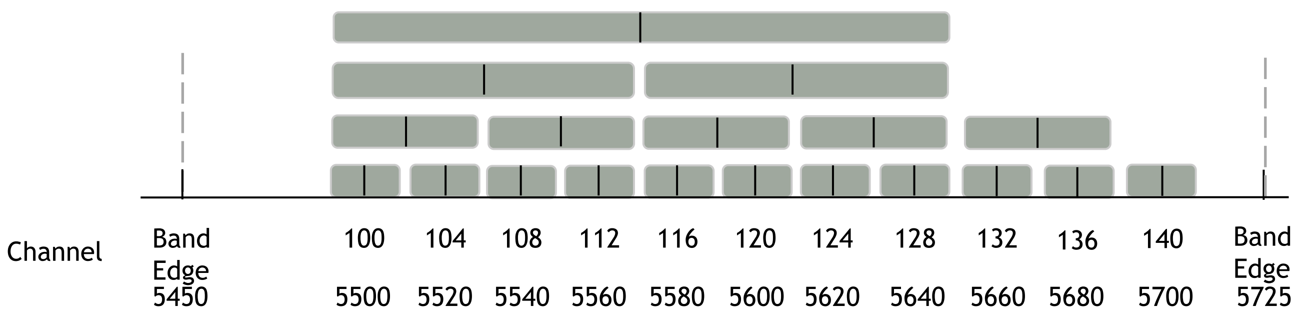
802.11ac Goals

- Multi-station MAC throughput of at least 1 Gbps
- Single link MAC throughput of at least 500 Mbps
- Operation below 6 GHz
- Backward compatibility & coexistence with devices in 5 GHz band
- Exclude operation in 2.4 GHz band
- Wider Channel widths
  - 80 MHz (mandatory support) & 160 MHz channels (optional)
  - 80 MHz is contiguous
  - 160 MHz can be either contiguous or in two non-contiguous 80 MHz slices
- 256-QAM (optional)
  - Provides a 33% increase over 64-QAM
- Downlink Multi-user MIMO
  - One transmitting device, multiple receiving devices
  - Allows for an AP to transmit to multiple stations simultaneously

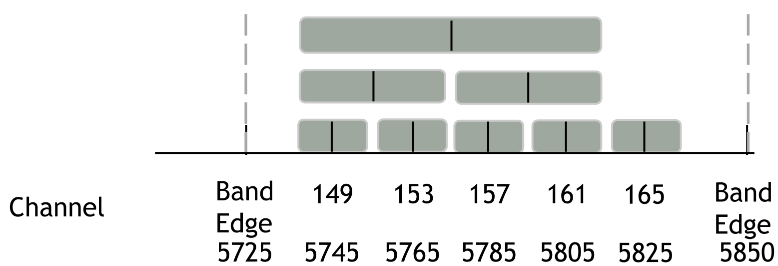
802.11ac Channels in 5 GHz band



US UNII I and UNII II bands
UNII I: 5150-5250 MHz
UNII II: 5250-5350 MHz
8x 20 MHz channels
4x 40 MHz channels
2x 80 MHz channels
1x 160 MHz channel
UNII II requires DFS



US intermediate band (UNII II extended)
5450-5725 MHz
11x 20 MHz channels
5x 40 MHz channels
2x 80 MHz channels
1x 160 MHz channel
Requires DFS



US UNII III / ISM band
5725-5850 MHz
5x 20 MHz channels
2x 40 MHz channels
1x 80 MHz channel

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802.11ac PHY Rates

MCS	Lowest rates Mbps (20MHz channel, 1x SS)		Channel width	Spatial streams	Highest rates Mbps (160MHz channel, 8x SS)	
	Long GI	Short GI			Long GI	Short GI
0	6.5	7.2	x2.1 for 40MHz x4.5 for 80MHz x9.0 for 160MHz	x2 for 2 SS x3 for 3 SS x4 for 4 SS x5 for 5 SS x6 for 6 SS x7 for 7 SS x8 for 8 SS	468.0	520.0
1	13.0	14.4			939.0	1040.0
2	19.5	21.7			1404.0	1560.0
3	26.0	28.9			1872.0	2080.0
4	39.0	43.3			2808.0	3120.0
5	52.0	57.8			3744.0	4160.0
6	58.5	65.0			4212.0	4680.0
7	65.0	72.2			4680.0	5200.0
8	78.0	86.7			5616.0	6240.0
9	(86.7)	(96.3)			6240.0	6933.3

802.11ad

- 60 GHz
- Up to 7 gbps
- In room coverage
- Replace HDMI cables, docking stations, etc

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Questions?