Presented by
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Channel Enablement Manager

INTRO TO RF AND 802.11

AIRHEADS

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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

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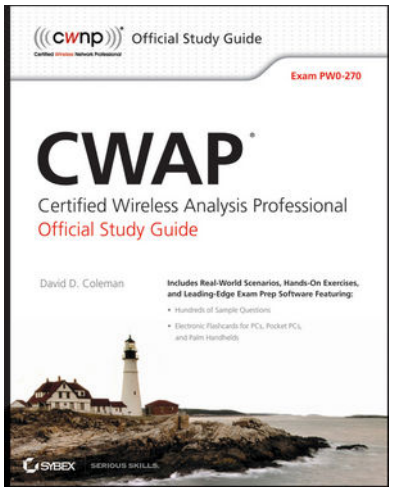
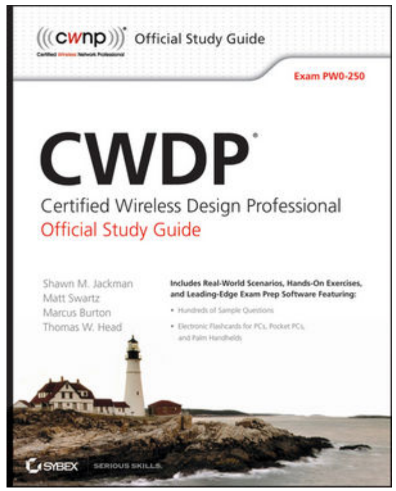
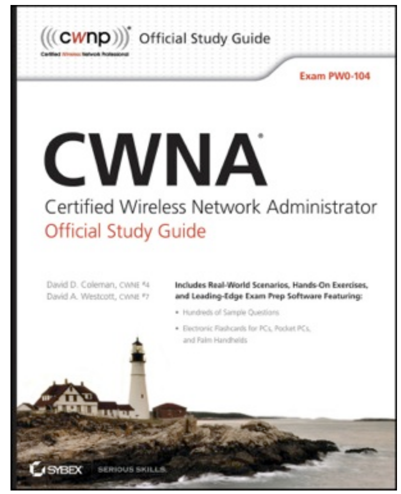
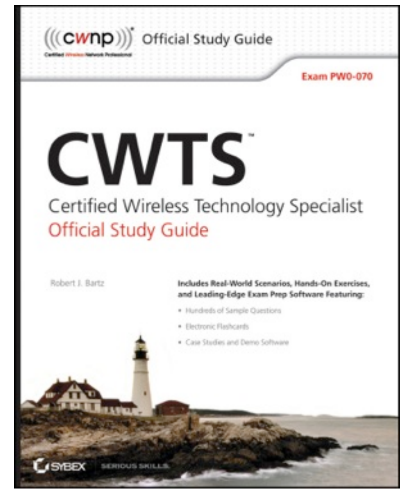
When You Want To Know More









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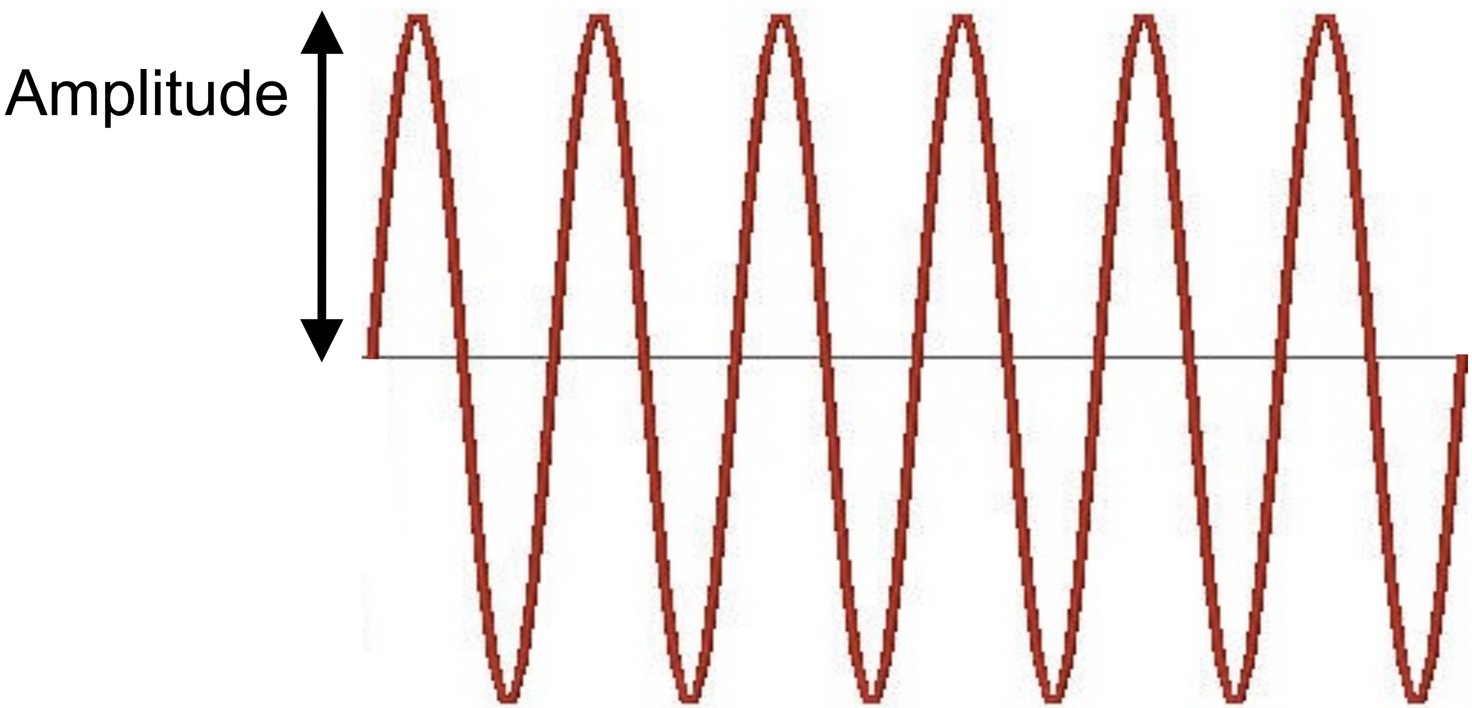
Basics Of Signals

Amplitude

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



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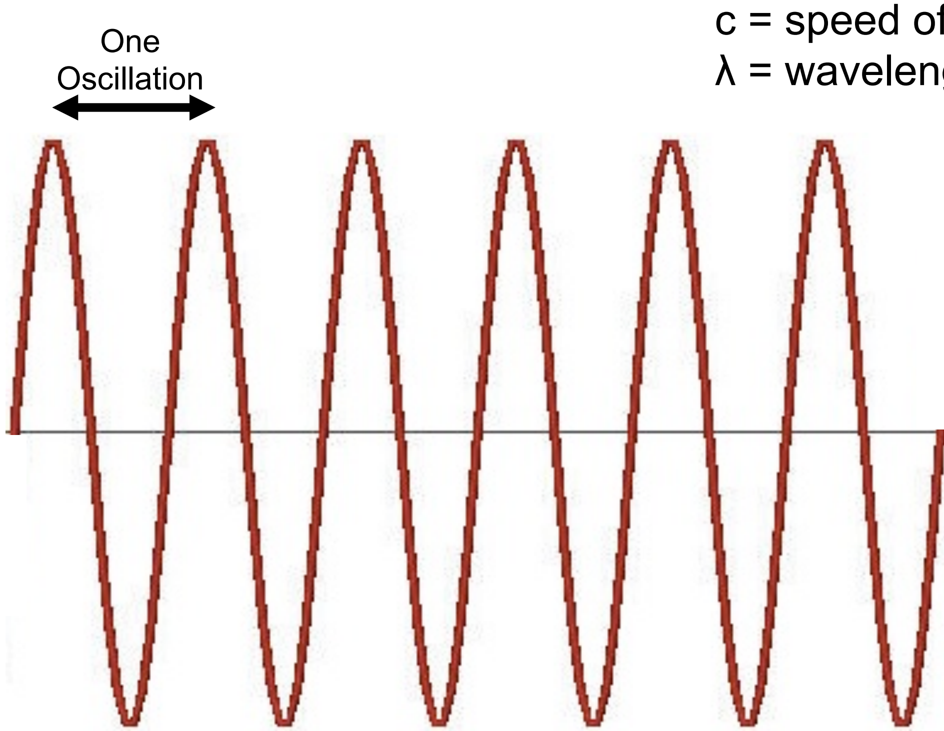
Frequency

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

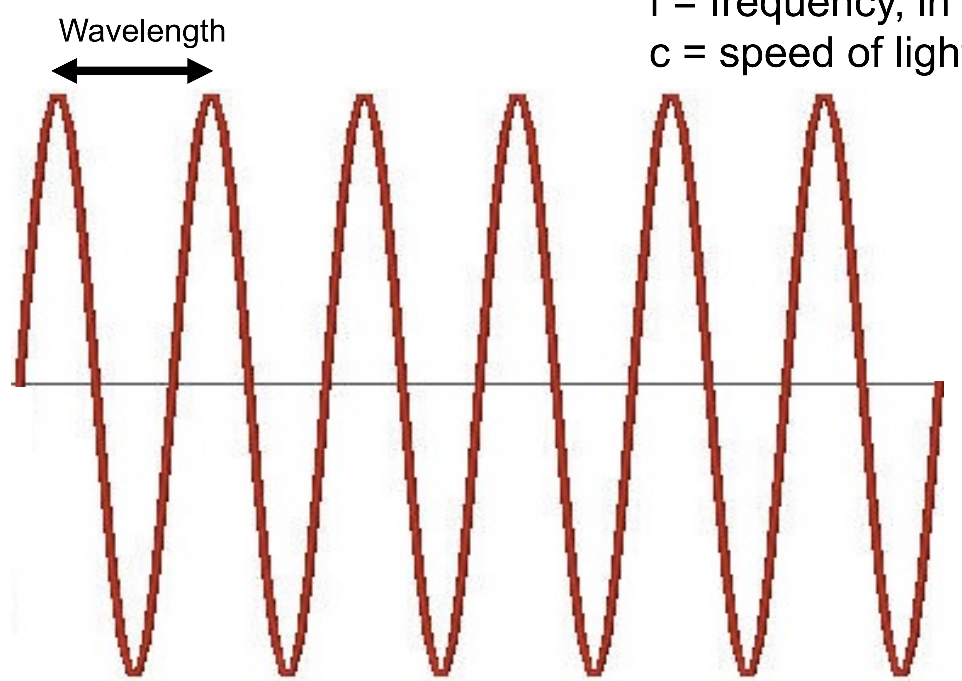
f = frequency, in hertz
c = speed of light, 299,792,458 m/s
λ = wavelength, measured in meters



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



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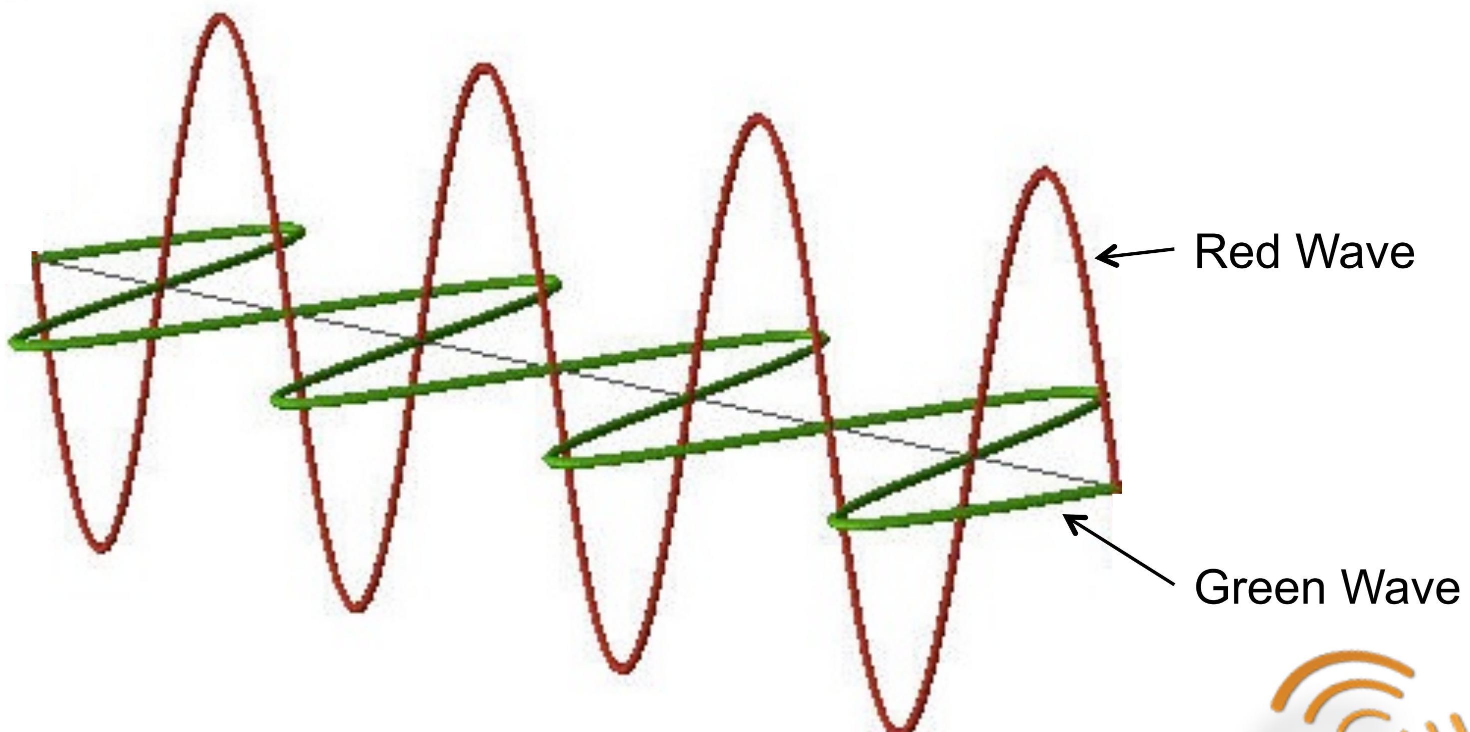
Polarization

The horizontal or vertical orientation of a wave

Red wave has vertical polarization

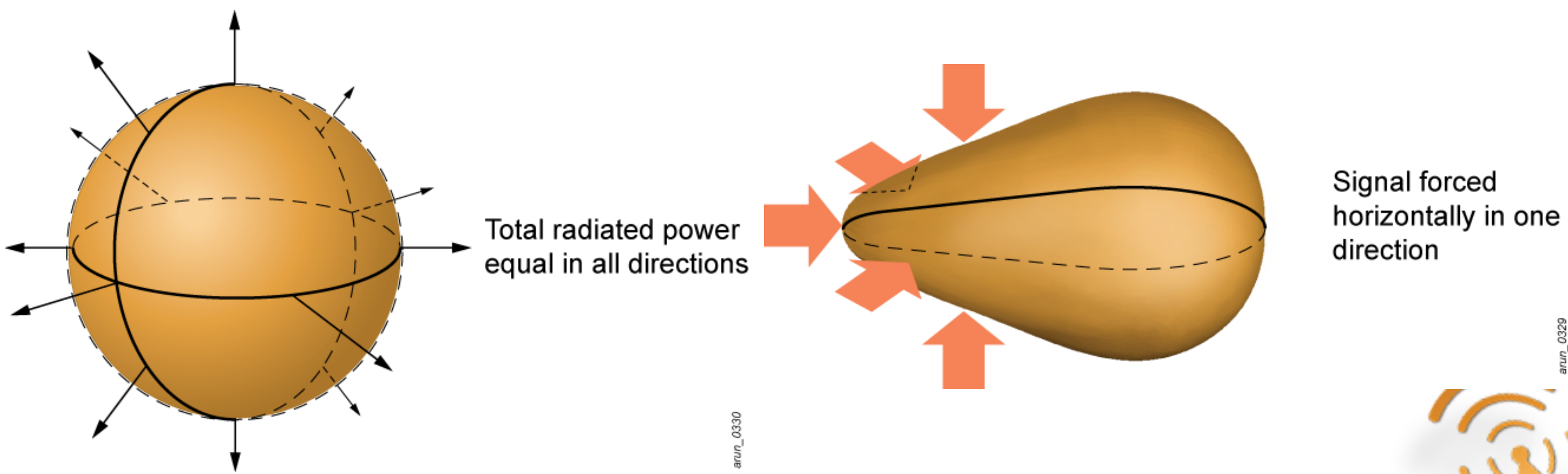
Green wave has horizontal polarization



Signal Changes

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)



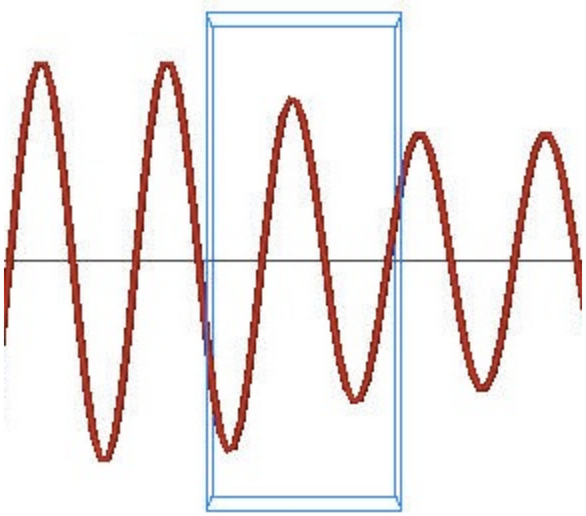
Attenuation (Loss)

- **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

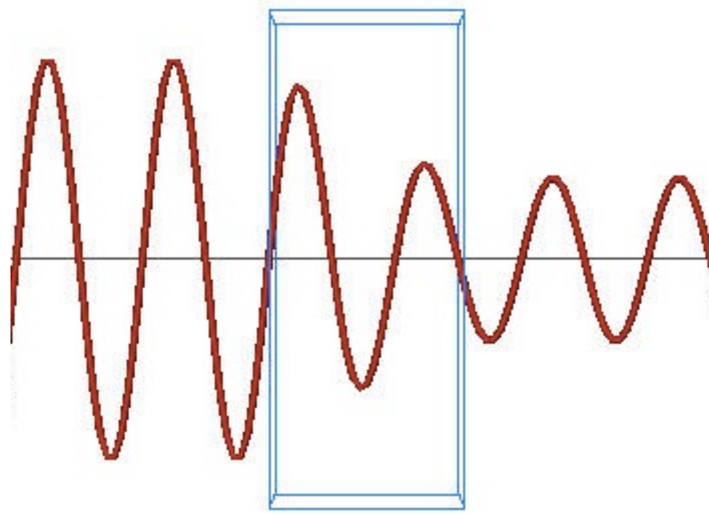
Absorption

- 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

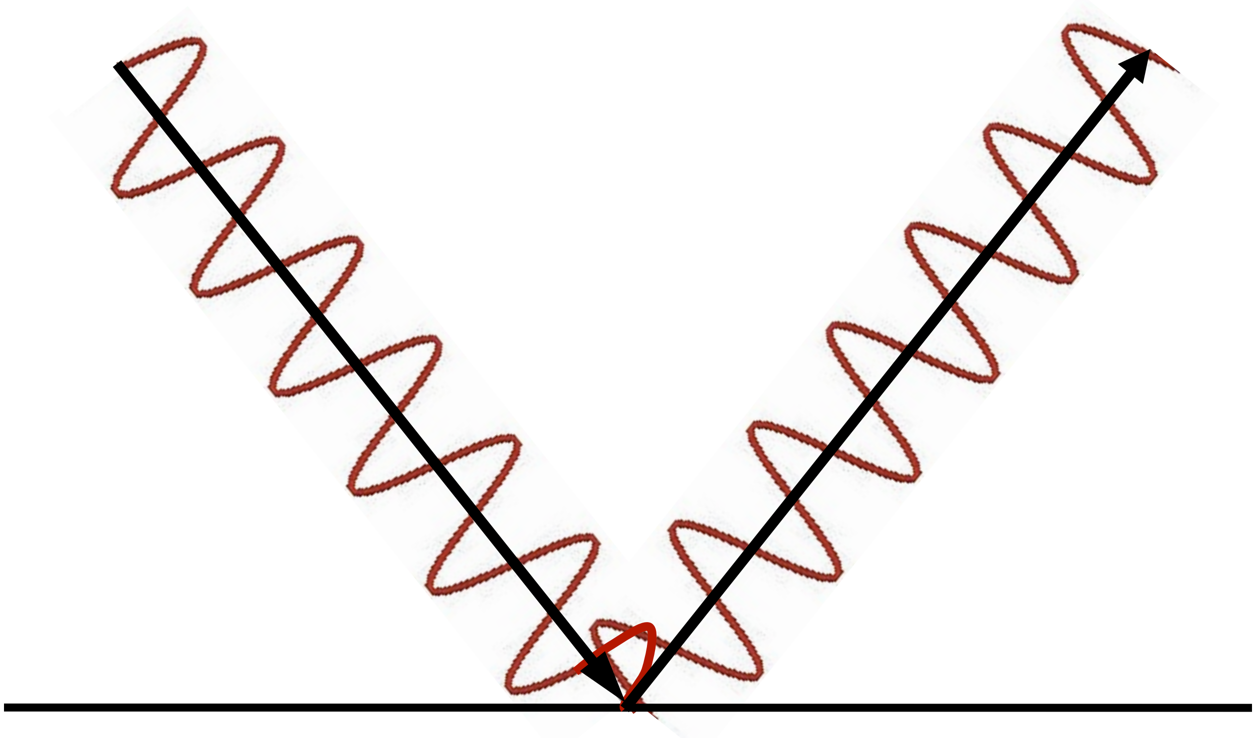


More Dense Wall



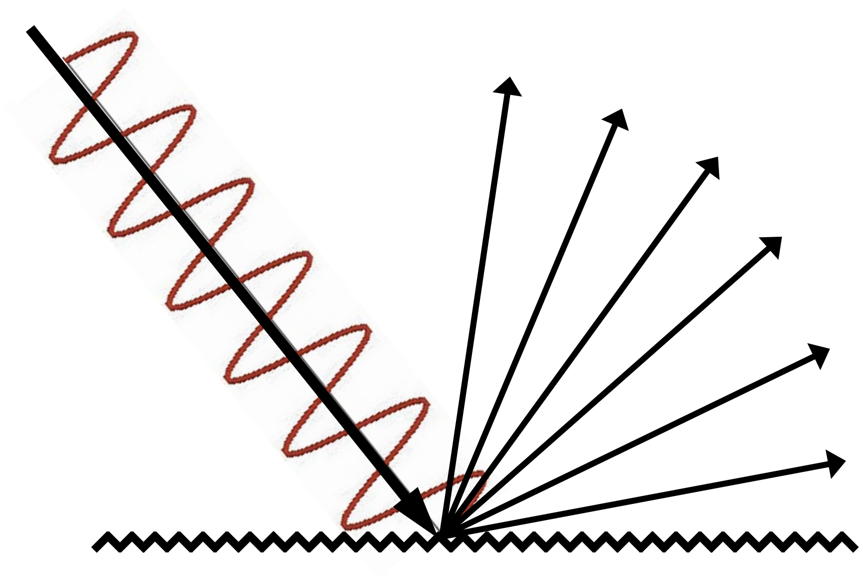
Reflection

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



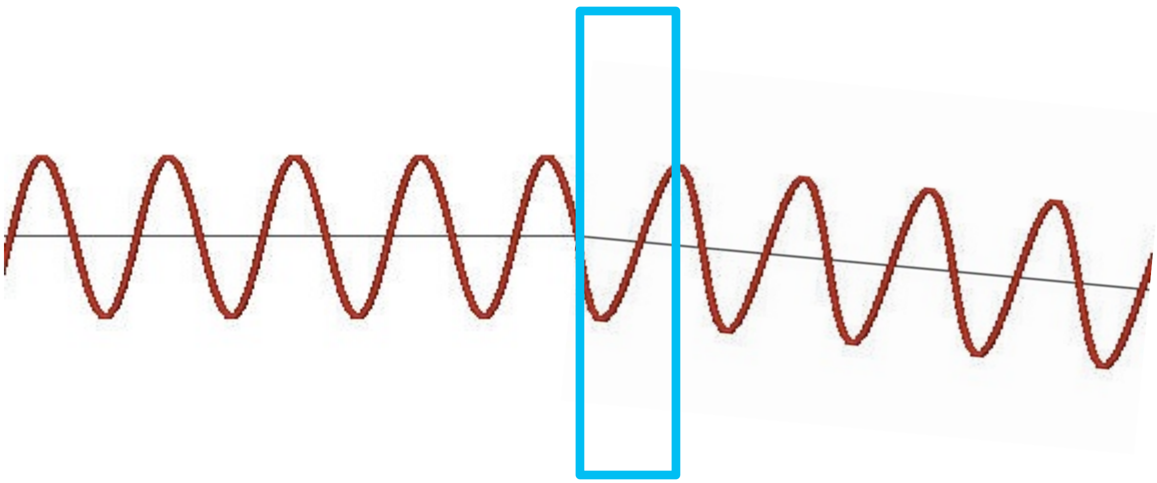
Scattering

- 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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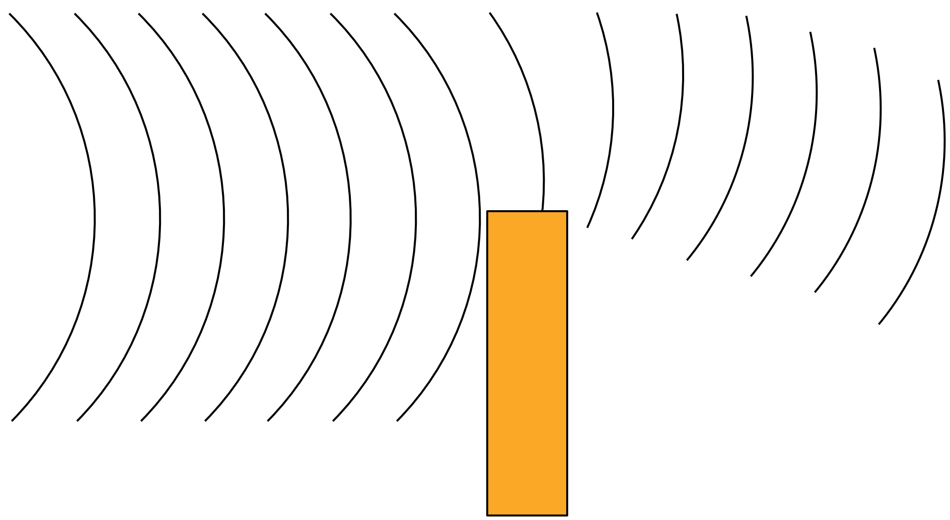
Diffraction

- **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**

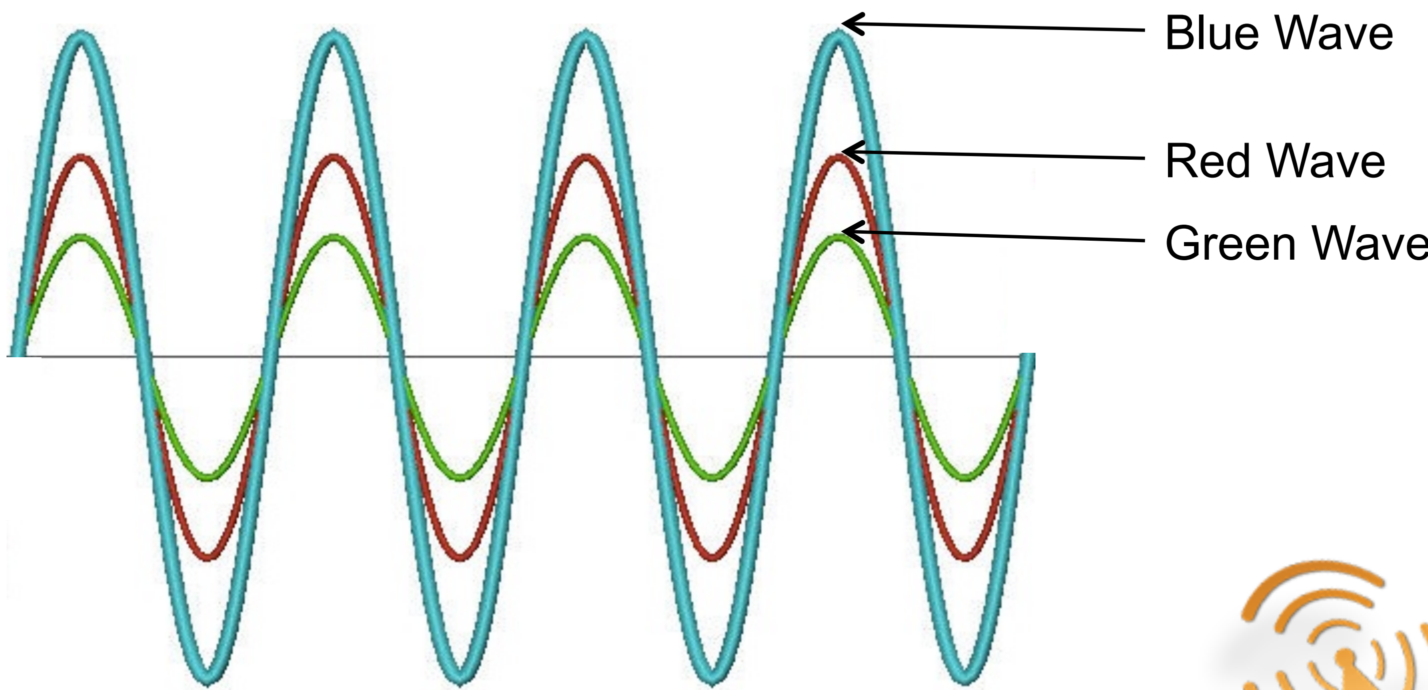


Multipath

- **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

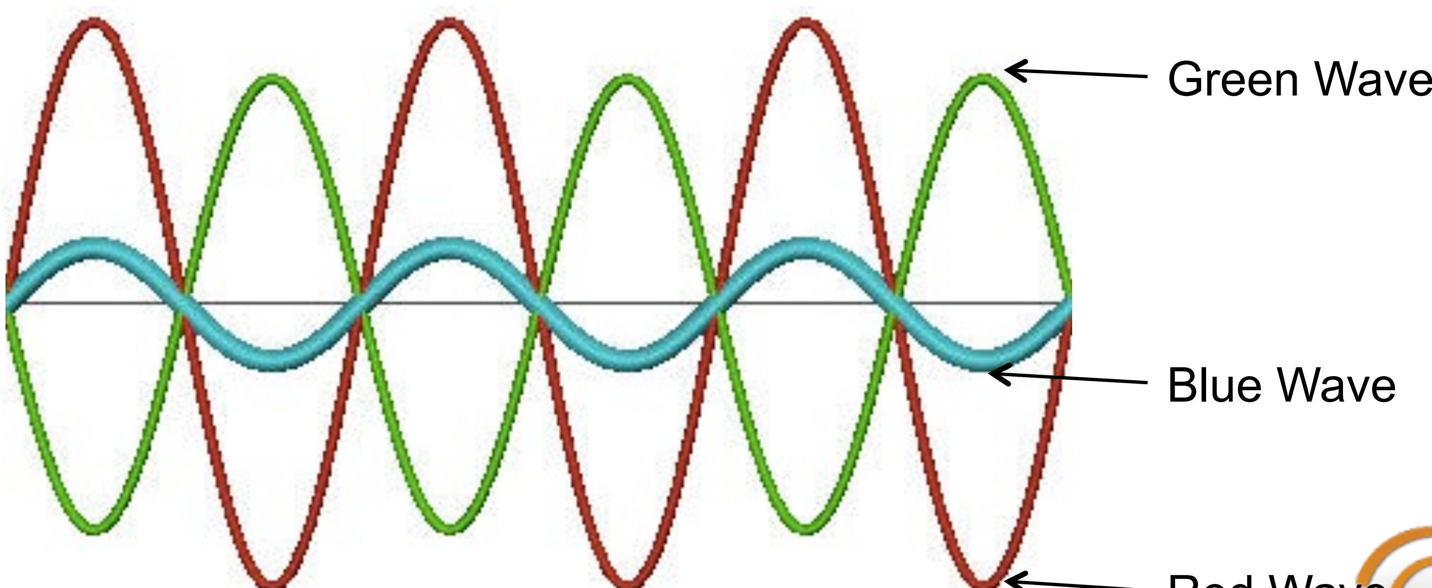
Phase (In Phase)

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



Phase (Out of Phase)

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



RF Power

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Why Use dBm Instead of Milliwatts?

- **Due to Free Space Path Loss, signal attenuates quickly**
- **mW represents the data logarithmically**
- **dBm represents the data linearly**
- **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
-16	0.025
-19	0.0125
-20	0.01

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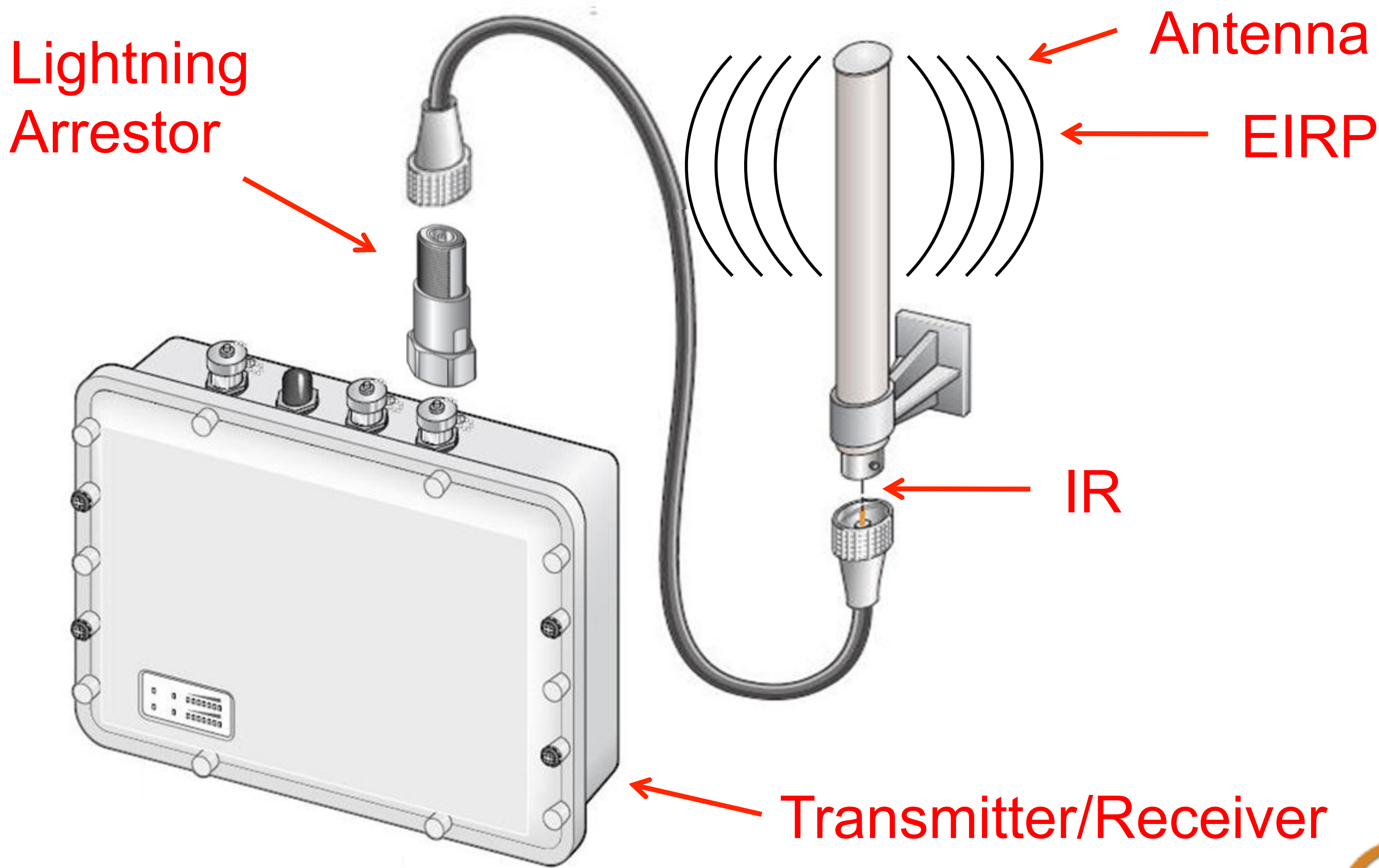
6 dB Rule

- 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 (change in power or change caused by antenna – antennas will be covered in detail later in the course)

802.11

RF Components



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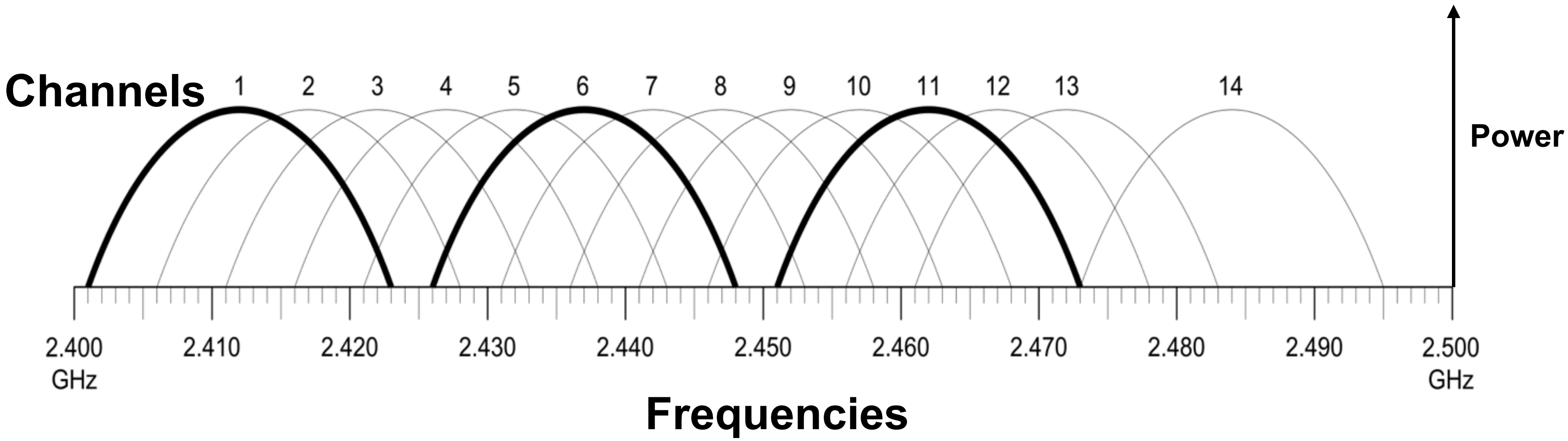
2.4 GHz ISM Band and Channels

2.4 GHz ISM Band is used by

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



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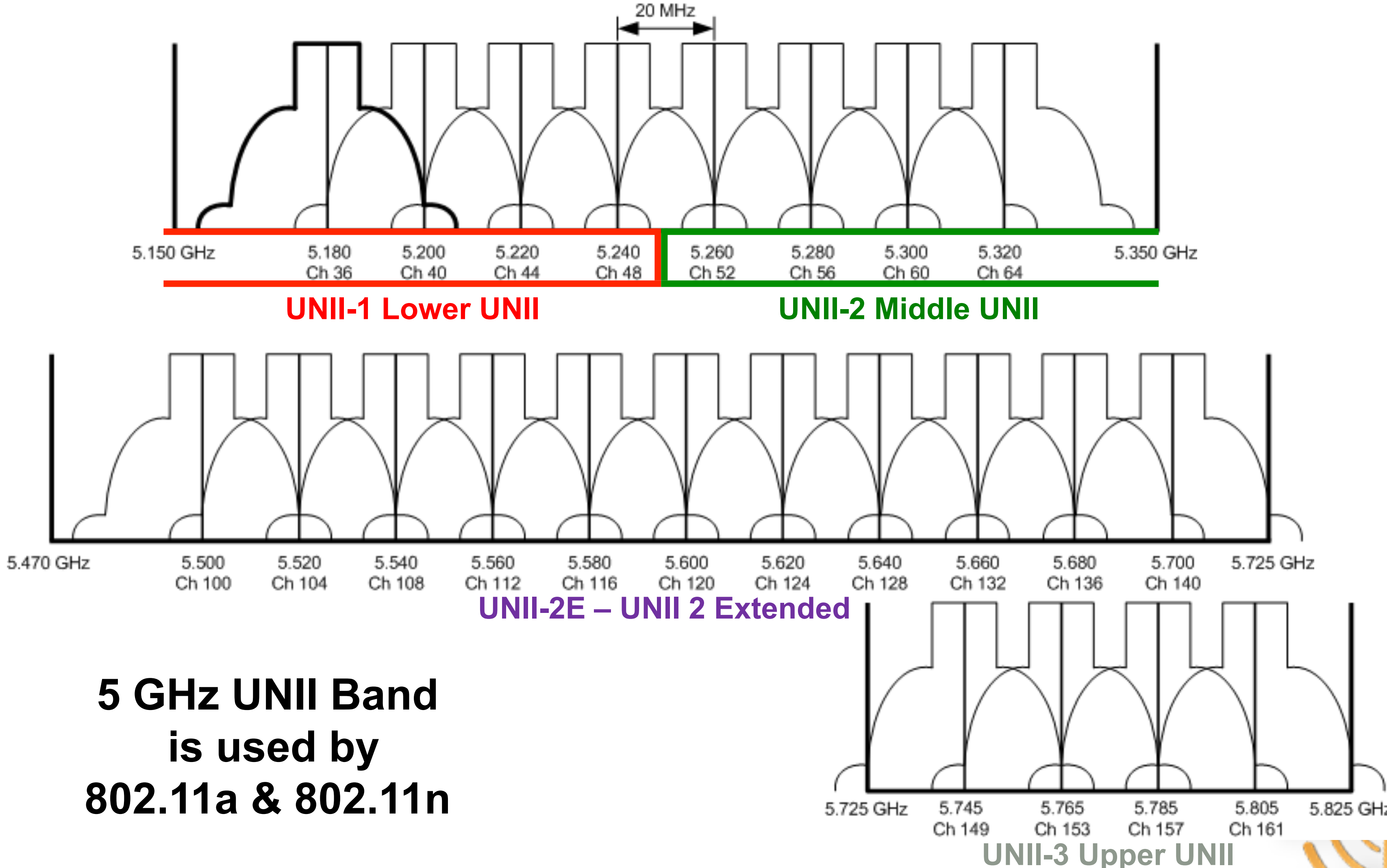
5 GHz UNII Band and Channels



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

802.11n Enhancements

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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	Popular standard, 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. Initially, 300 Mbps is commonly supported.	2.4 GHz ISM and 5 GHz UNII	Quickly becoming the standard for both home and enterprise use. Offers high performance along with backward compatibility.

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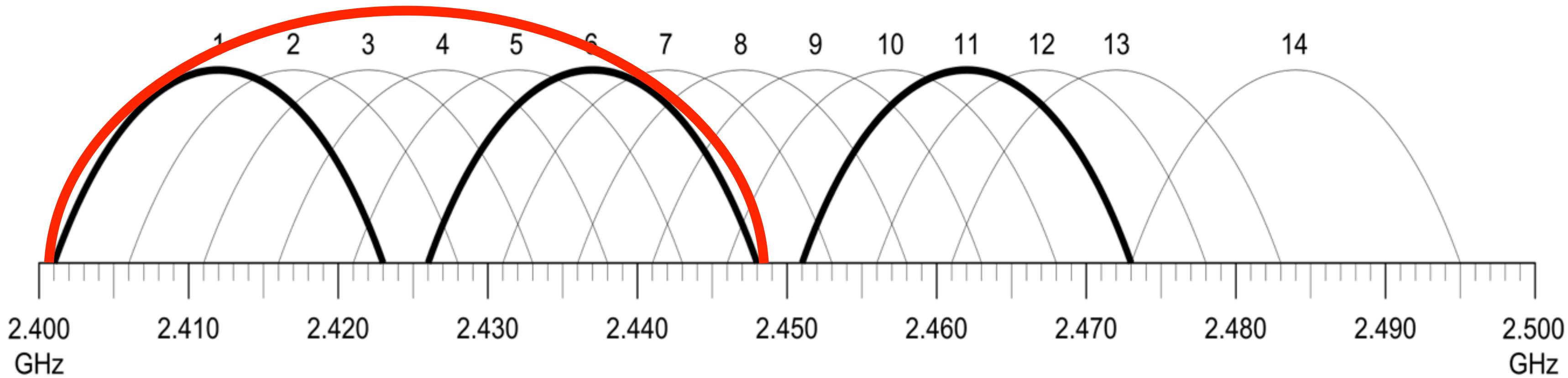
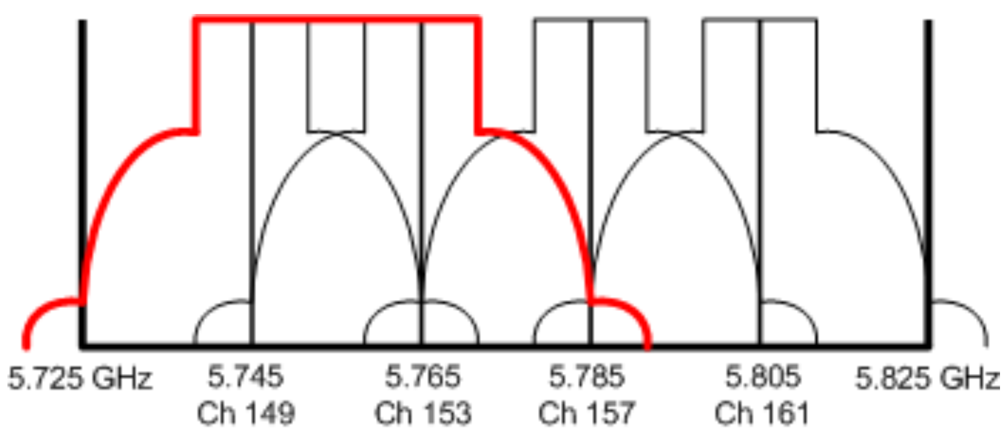
802.11n Channel Bonding





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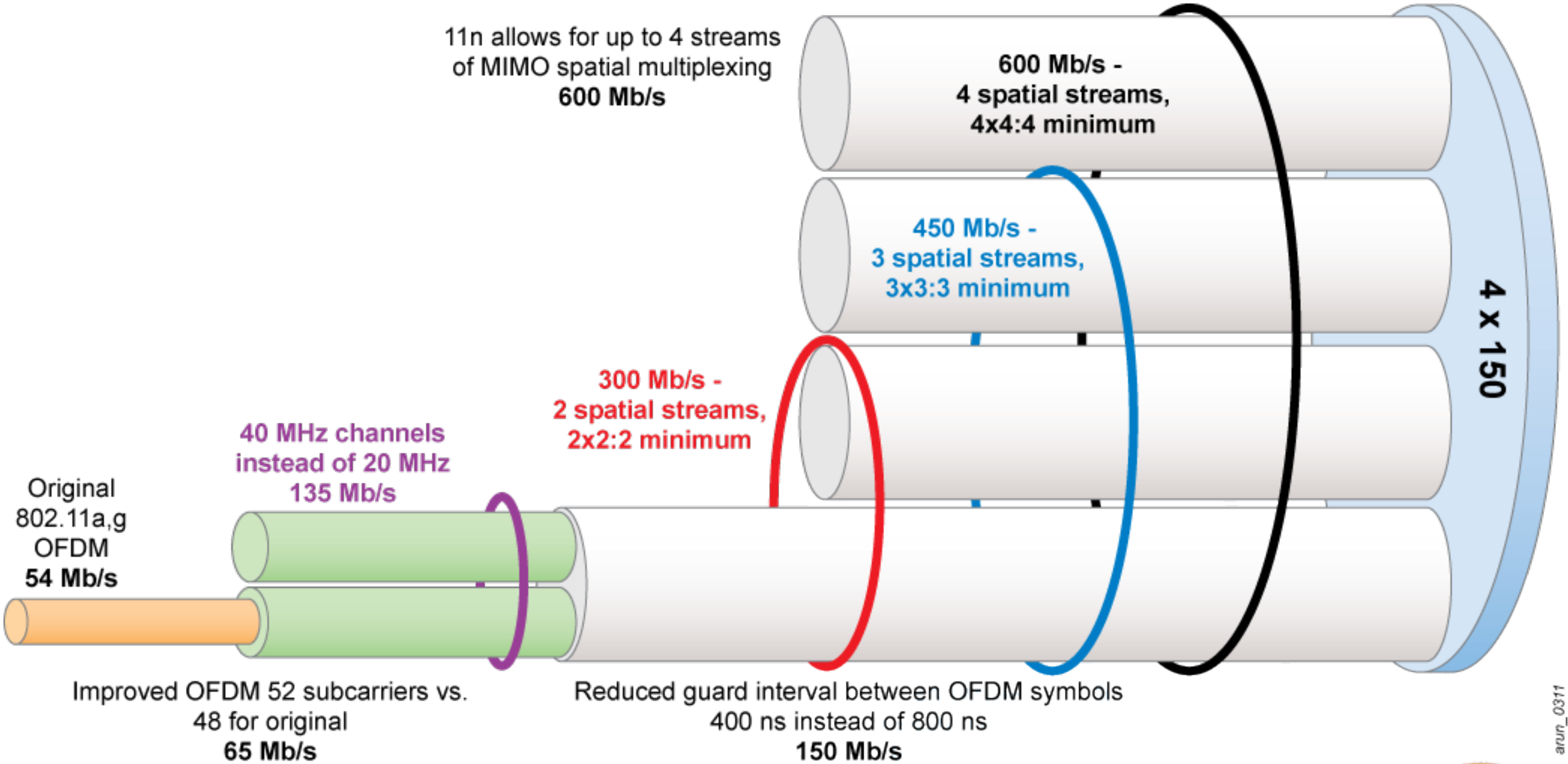
Multiple Input Multiple Output (MIMO)

- **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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