WLAN FUNDAMENTALS

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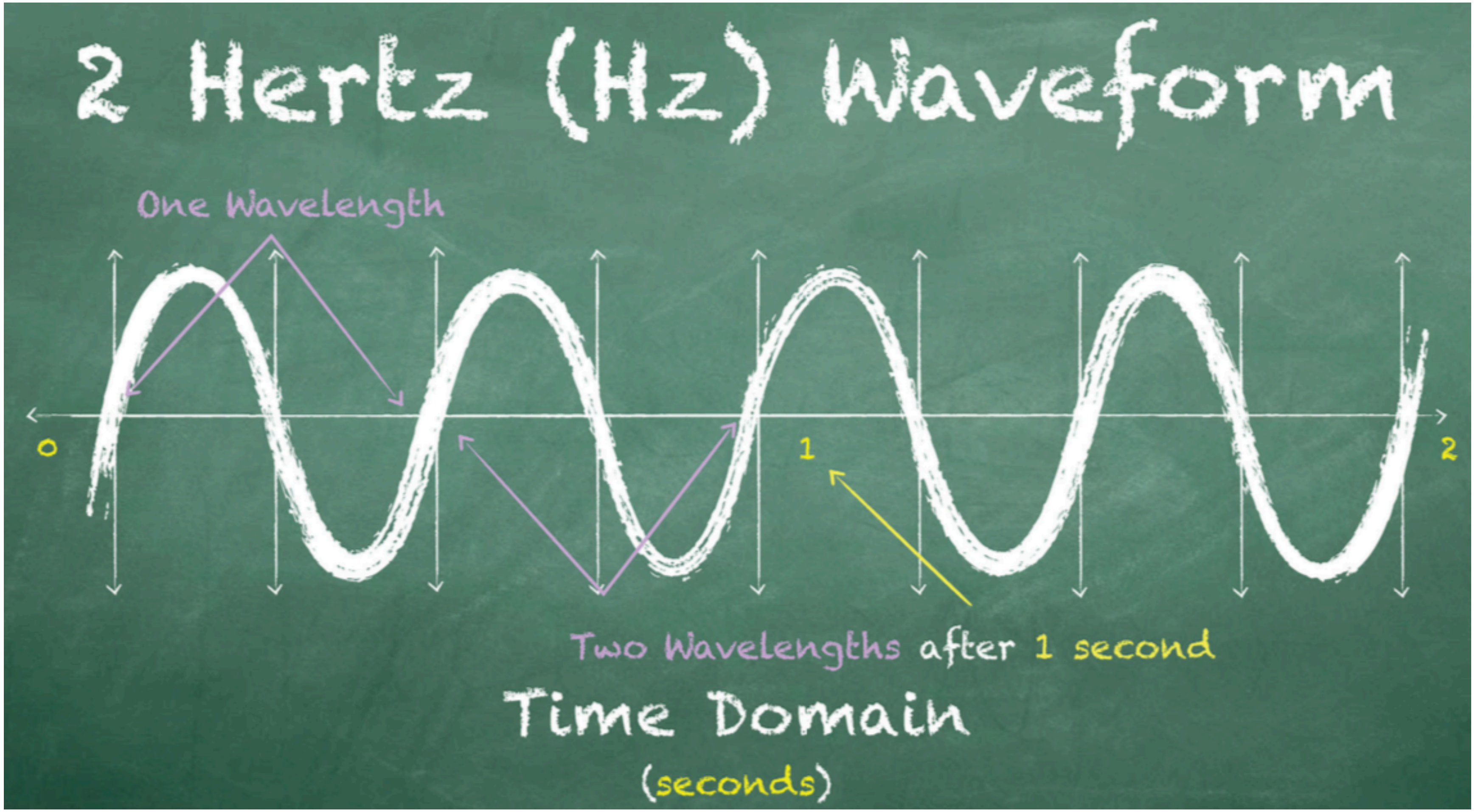
WLAN Fundamentals

- Wireless LANs (WLANs) follow simple laws of physics, which, when adhered, lead to high user performance and scalability.
- The purpose of this section is to introduce basic wireless physics and explain channel assignments so you can begin planning for a WLAN deployment.
- Understanding these concepts allows you to more confidently plan your deployment, or troubleshoot an existing WLAN.

WAVE PROPERTIES

- In order to transmit data from one location to another, stations (wireless APs and client radios) generate energy in the form of electromagnetic waves, which travel at the speed of light.
- These electromagnetic waves operate at different frequencies, which are defined as the number of periodic cycles traversed per second.
- The frequency and wavelength of an electromagnetic wave are inversely proportional and related by the speed of light:

WAVE PROPERTIES



WAVE PROPERTIES

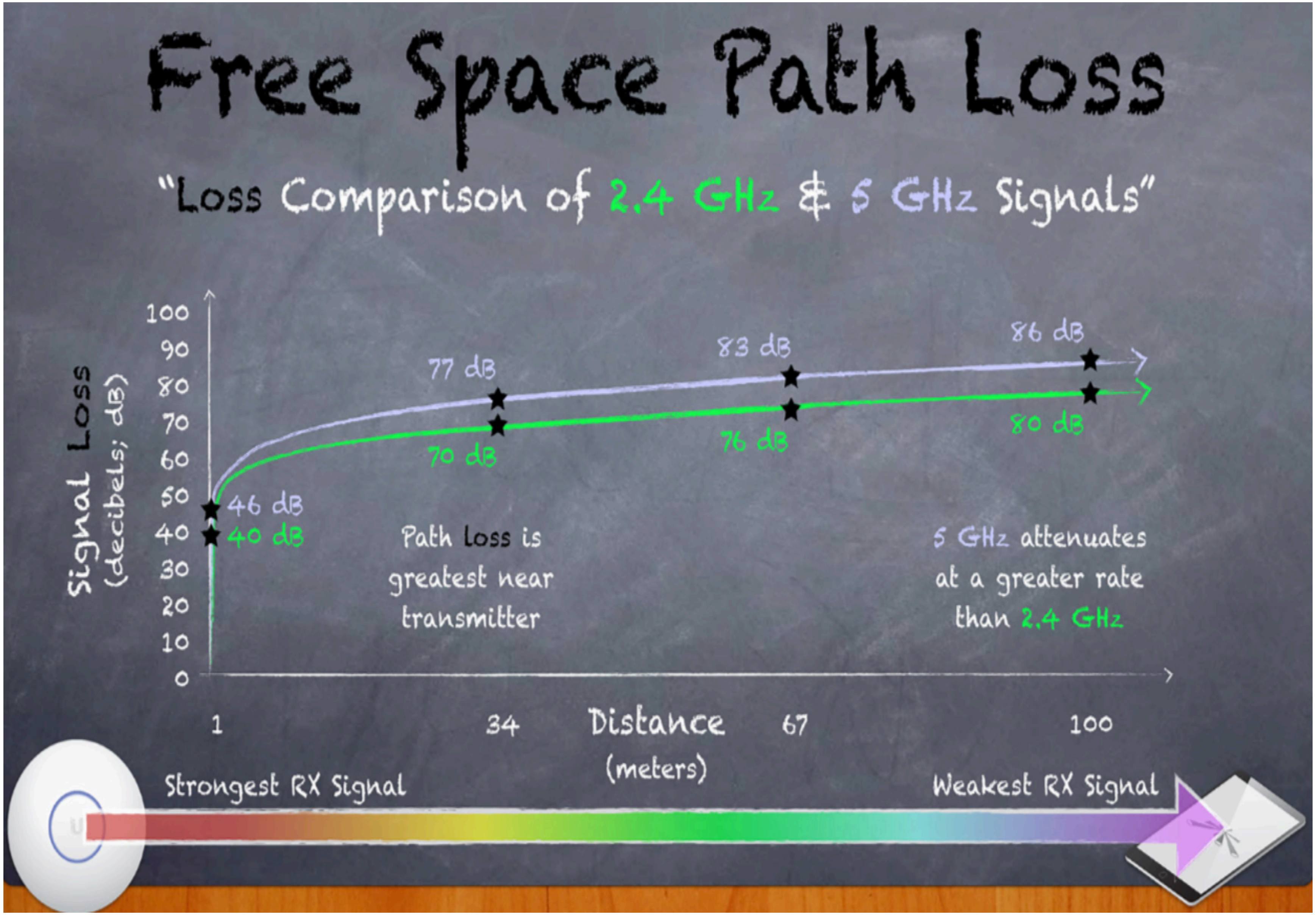
- Frequency is measured in Hertz (Hz), which individually represents one period, wavelength, or wave cycle.
- As a waveform travels from one point to another, it undergoes signal loss due to a phenomenon known as Free Space Path Loss (FSPL).
- However, lower frequencies (ex. 2.4 GHz) have much longer wavelengths and can propagate further than higher frequencies (ex. 5 GHz).

DECIBEL (db)

- To relate the levels of energy associated with wireless receive signals, including attenuation (loss) of a wireless signal, we use decibels (dB).
- Decibels follow a logarithmic relationship where adding & subtracting decibels corresponds to exponential growth or reduction on the linear domain.
- Each time you add 3 dB or 10 dB, the value on the linear domain increases or decreases by a factor of x2 or x10, respectively.

FREE SPACE PATH LOSS

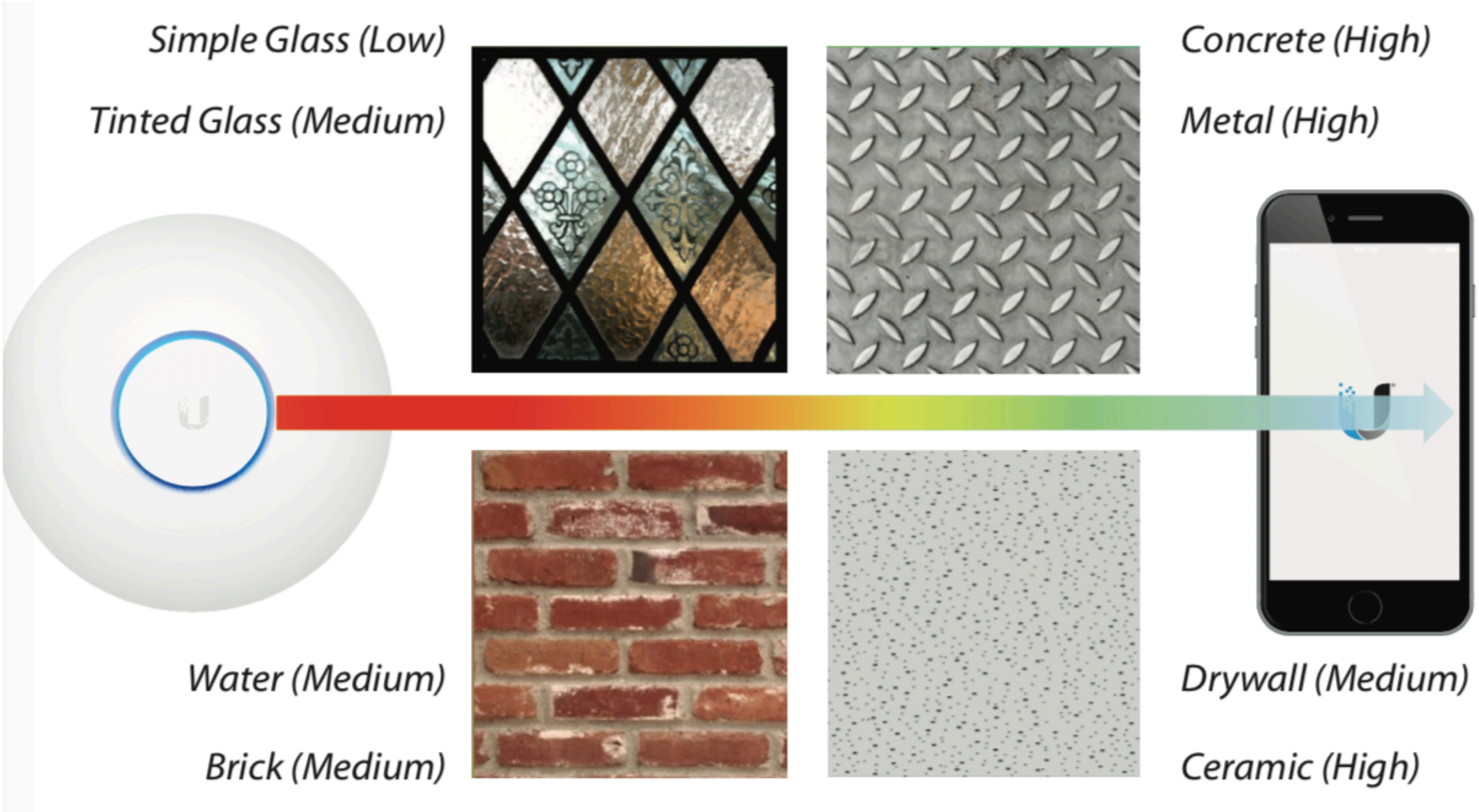
- The relationship between frequency and propagation is best illustrated by the Free Space Path Loss (FSPL) chart for 2.4 and 5 GHz waveforms.
- At a given distance, 5 GHz (the higher frequency) undergoes more attenuation. Therefore, 2.4 GHz WLANs are ideal for coverage scenarios, while 5 GHz are well-suited for density.



Free Space Path Loss
"Loss Comparison of 2.4 GHz & 5 GHz Signals"
Signal Loss (decibels; dB)
100
90
80
70
60
50
40
30
20
10
0
77 dB
83 dB
86 dB
70 dB
76 dB
80 dB
46 dB
40 dB
Path loss is greatest near transmitter
5 GHz attenuates at a greater rate than 2.4 GHz
1
34
Distance (meters)
67
100
Strongest RX Signal
Weakest RX Signal

Propagation

- Different materials can affect the level of attenuation faced by wireless signals. For example, concrete attenuates wireless signals more than wood.
- Certain materials may also cause a wireless signal to propagate, or, ‘behave’ differently. For example, some metal surfaces can cause wireless signals to reflect, leading to less predictability throughout the WLAN environment.
- Other materials, like water (or people) can absorb wireless signals.
- Strategically, the construction of the WLAN environment can help or hinder how you design your wireless network.



Simple Glass (Low)
Tinted Glass (Medium)
Concrete (High)
Metal (High)
Water (Medium)
Brick (Medium)
Drywall (Medium)
Ceramic (High)

Factors Affecting Radio Waves

- Radio Waves are Affected By
  - Absorption
  - Reflection
  - Diffraction
  - Interference

Absorption

- Converts energy into heat
- Decreases power exponentially
  - this is a linear decrease in dB
- Water, Metal, Oxygen
- Stones, Bricks, Concrete
- Wood, Trees

Radio waves: Absorption

- Plasterboard / Drywall Wall: 3-5dB
- Metal Door: 6-10dB
- Window: 3dB
- Concrete Wall: 6-15dB
- Block Wall: 4-6dB

Radio waves: Reflection

- e.g.on Metal
  angle in = angle out

Radio waves: Diffraction

- Diffraction is the apparent bending and spreading of waves when they meet an obstruction. Scales roughly with wavelength.

Radio waves: Interference

- Interference is **misunderstood**
  - Is it really interference?
  - Or are too lazy to find the real problem?
  - Maybe we don't care!

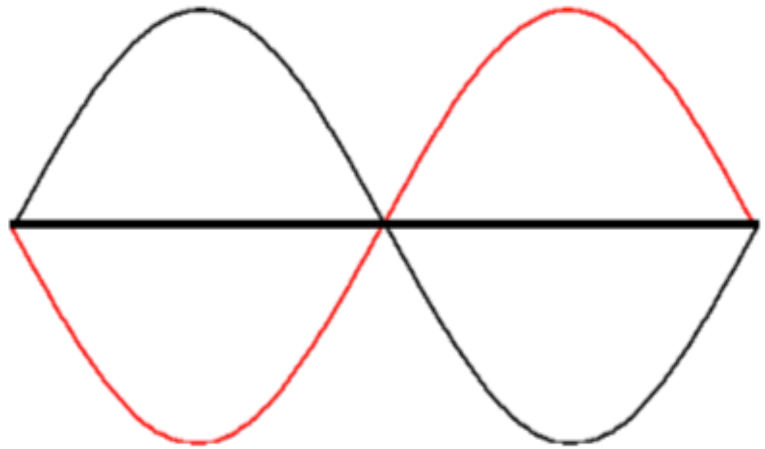
Two Meanings of Interference

- **Physicists View:**
  The behavior of waves
- **Engineer's View:**
  Noise that causes problems
- Both are important for Wireless In different ways!

Interference: Physicist's View

Waves can annihilate each other

$1 + 1 = 0$



...when they have fixed **frequency and phase relation**

Waves can also enhance each other

Interference

TheEngineeringView:

- “any noise that gets in the way” e.g

* High Noise Floor From Busy Spectrum
* Co-Channel Interference
* Adjacent-Channel Interference

  Next frequency, overloading your receiver

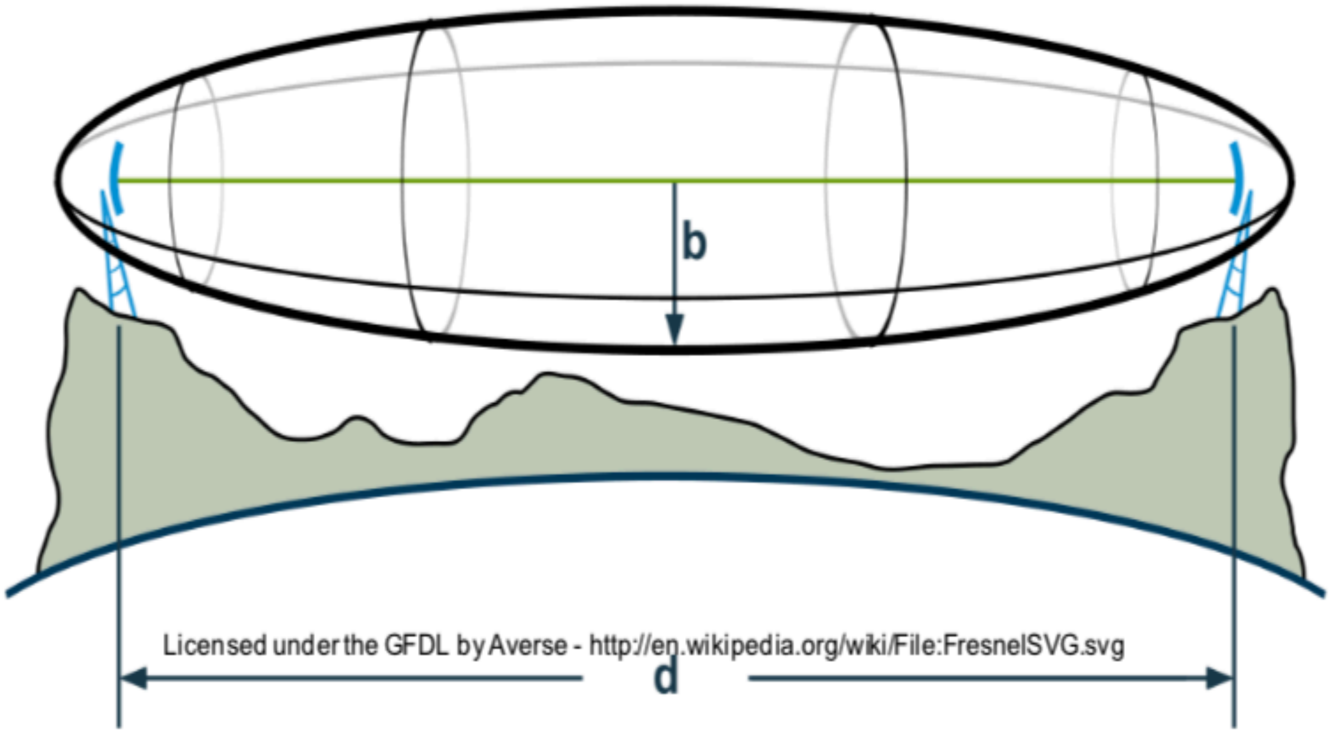
  - Use a better receiver!

  Next frequency, leaking into your channel

  - Time to talk to the interferer

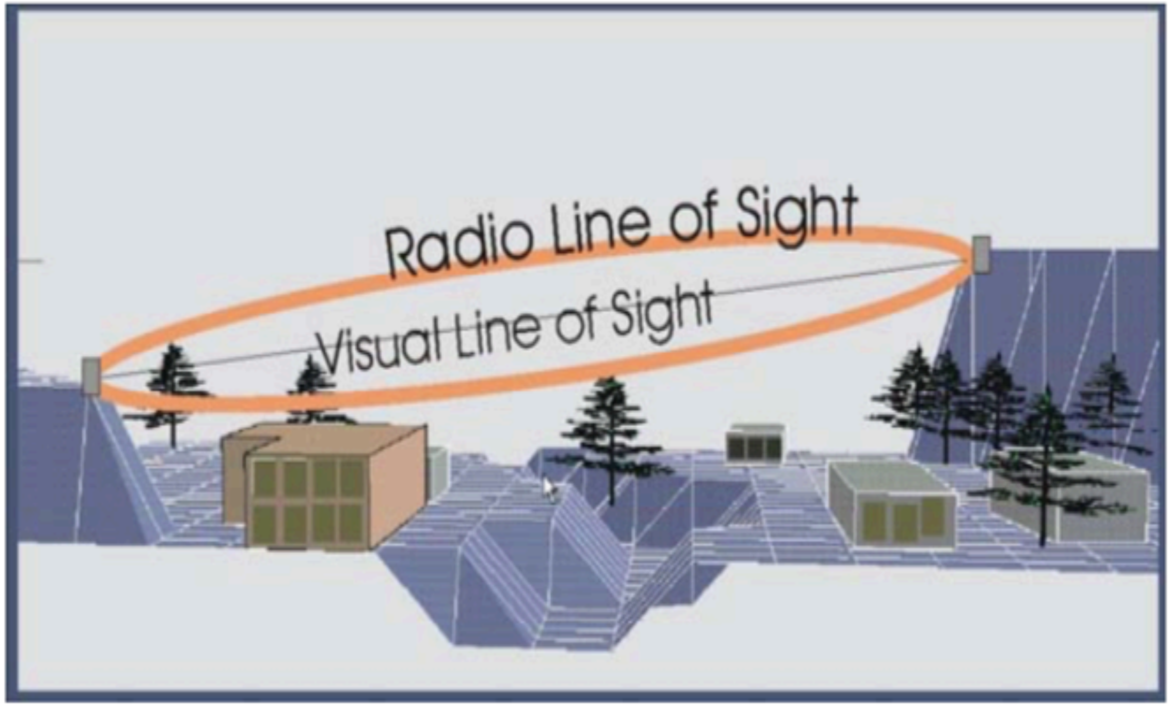
Fresnel zones

Zone where reflections are bad
Reflected waves = (good/bad) interference



Line of sight

Required for Higher Frequencies (> 1GHz)
Less Absorption / Reflection = Better Links

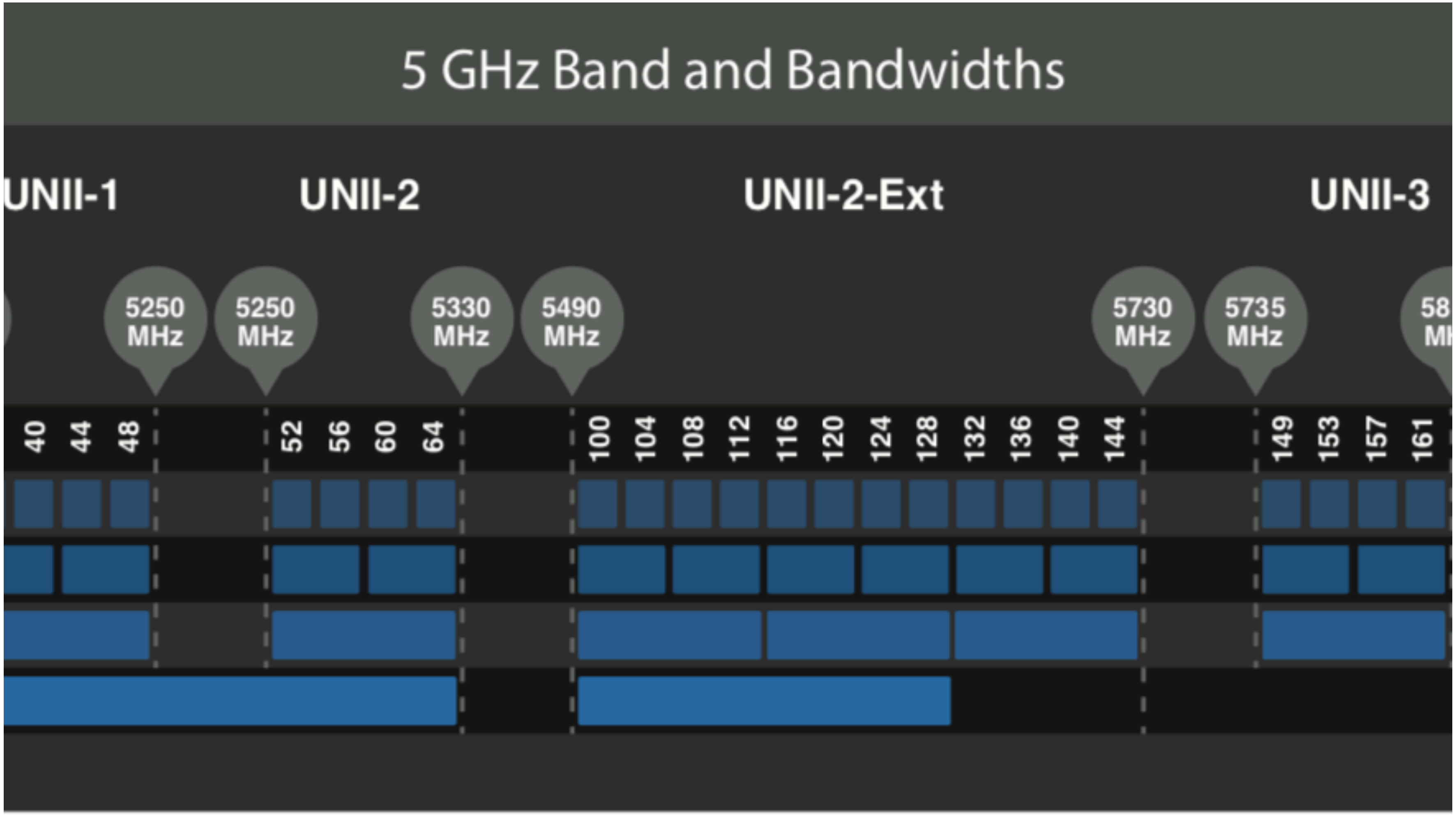


Unlicensed Radio Spectrum

- The 2.4 GHz and 5 GHz bands allow virtually anyone to extend the range of networks with wireless access points.
- In spite of such universal availability, the unlicensed bands face problems from crowded use and inefficient channel assignments; *both of which lead to increased co-channel interference*.
- Faced with these issues, wireless administrators must pay close attention to details in order to plan for the most effective, efficient wireless network possible.


2.4 GHz Spectrum
"'Non-Overlapping' Channels (3x 20 MHz)"
5 MHz Separation
of Channel Edges
Power
Channel 1
Channel 6
Channel 11
2412
2417
2422
2427
2432
2437
2442
2447
2452
2457
2462
Frequency
(MHz)

- In the past, the 2.4 GHz band has been favored over 5 GHz due to its propagation characteristics.
- 2.4 GHz waveforms pass more easily through walls and reach clients at long distances.
- Over time however, the small range of unlicensed spectrum (approximately 83.5 MHz) belonging to the 2.4 GHz band has become overcrowded with competing access points.
- Furthermore, a prevalence of consumer devices (ex. cordless telephones, baby monitors, Bluetooth devices) using the same frequency range as the 2.4 GHz spectrum is considered ‘saturated.’



5 GHz Band and Bandwidths
UNII-1
UNII-2
UNII-2-Ext
UNII-3
5250 MHz
5250 MHz
5330 MHz
5490 MHz
5730 MHz
5735 MHz
40 44 48
52 56 60 64
100 104 108 112 116 120 124 128 132 136 140 144
149 153 157 161

- Compared to the 2.4 GHz spectrum, 5 GHz offers much more flexibility for wireless operators due to greater availability of spectrum and relaxed transmission power requirements.
- Although the 2.4 GHz band only allows for 3 reuse channels without overlap (1, 6 and 11), the 5 GHz band allows for as many as 24, depending on region (36, 40, 149, 153, etc.).
- Given the abundance of available channels and short-range propagation characteristics, high-density WLANs benefit greatly from the 5 GHz band.

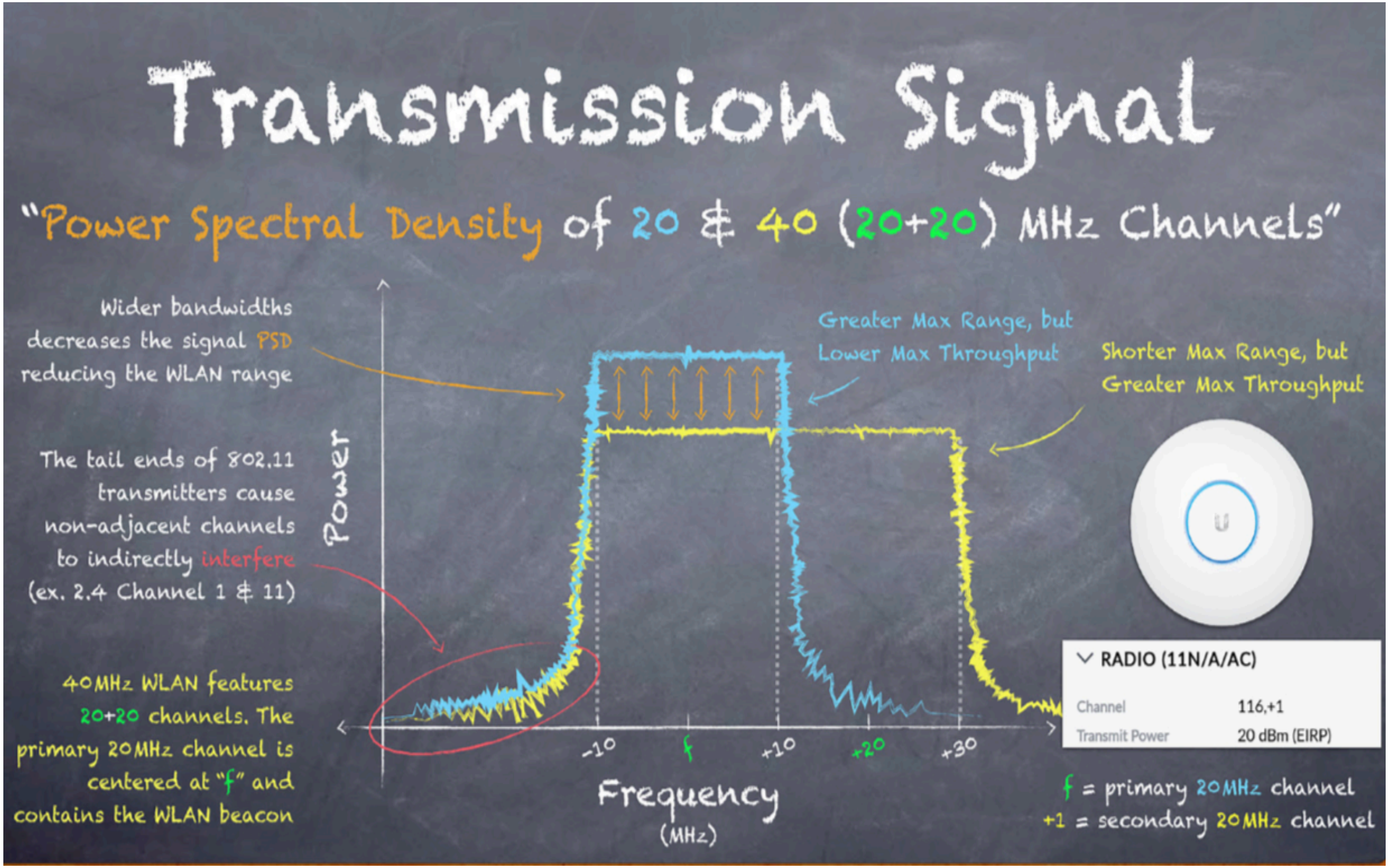
Channel Operation

- Understanding how channels operate is key to avoiding interference and maximizing the performance/scalability of the WLAN.
- In radio communication, a wireless station (like a UniFi Access Point) receives a channel assignment and a specific bandwidth over which it transmits and receives signals to and from nearby stations.
- This channel assignment pertains to the center frequency of the first 20 MHz channel used by the station.

Channel width

- Channel bandwidth refers specifically to the frequency range over which data signals are transmitted.
- However, the actual transmission signal generated by 802.11 radios looks similar to a volcano, where ‘peak’ power levels are spread across the channel bandwidth, and power levels drop off at the edges of the channel bandwidth near the ‘tail ends.’

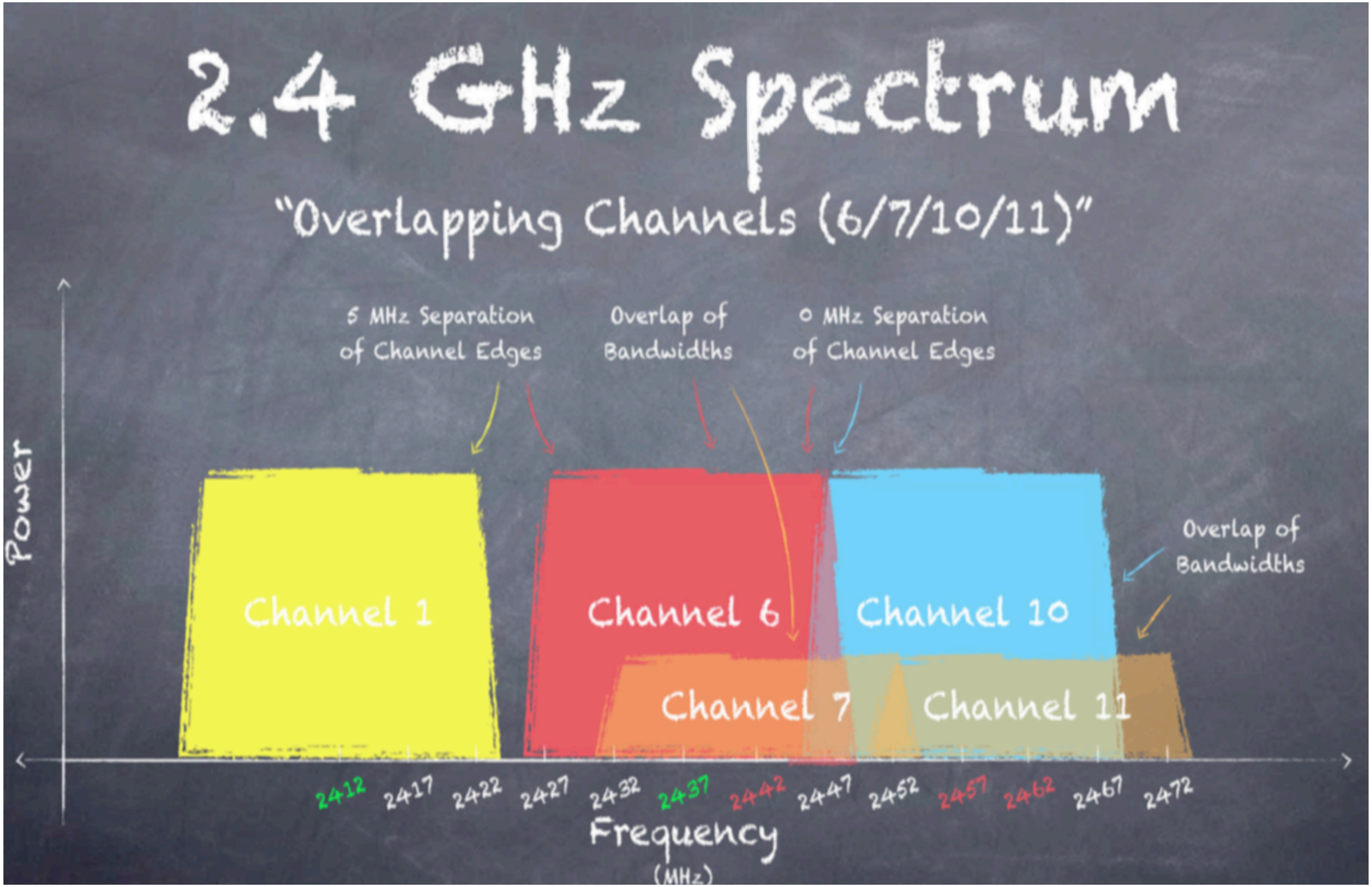
- The following figure demonstrates two APs in competing WLANs. The 20MHz WLAN (blue channel) is centered at frequency “f”, while the 40 MHz WLAN (yellow channel) actually bonds two 20 MHz channels together. Of the two 20MHz channels,
- the primary channel (centered at frequency “f”) contains the WLAN beacon announcements,
- while the secondary channel is optional for compatible, connecting Stations.


Transmission Signal
"Power Spectral Density of 20 & 40 (20+20) MHz Channels"
Wider bandwidths decreases the signal PSD reducing the WLAN range
The tail ends of 802.11 transmitters cause non-adjacent channels to indirectly interfere (ex. 2.4 Channel 1 & 11)
40MHz WLAN features 20+20 channels. The primary 20MHz channel is centered at "f" and contains the WLAN beacon
Power
Greater Max Range, but Lower Max Throughput
Shorter Max Range, but Greater Max Throughput
-10
f
+10
+20
+30
Frequency
(MHz)
RADIO (11N/A/AC)
Channel
116,+1
Transmit Power
20 dBm (EIRP)
f = primary 20MHz channel
+1 = secondary 20MHz channel

- The ‘tail ends’ of adjacent channels can incur noise for nearby wireless networks. For this reason, it is very important to apply a channel planning pattern across the WLAN, to avoid co-channel interference (which reduces speeds and limits the scalability of the network).

- The yellow WLAN depicted in the above diagram represents a ‘bonded’ 40 MHz channel (20+20) according to the 2009-802.11n standard.
- With bonded channels, **802.11n** capable stations can communicate at higher data rates, called “**High Throughput**” (HT) rates.
- By comparison, the **802.11ac** standard supports ‘bonded’ 80MHz channels (20+20+20+20) for “**Very High Throughput**” (VHT) data rates.
- A wireless network whose clients all support the same data rates is called ‘**Greenfield**’. *For example, a greenfield VHT network would only be comprised of 802.11ac stations.*

- Channel availability depends on the world region where the radio will be deployed *e.g for UniFi Controller it is specified under Country Site Settings.*
- In 2.4 GHz deployment scenarios with multiple APs*, use only 20 MHz bandwidths on channels 1, 6 and 11,* since use of other channels (ex. 3, 5, 9) or larger bandwidths (ex. 40 MHz) overlaps with neighbor channels.
- In other words, channels 1,6, and 11 allow for proper channel re-use patterns. Contrast this with a channel plan that uses overlapping channels, as illustrated by the image below.


2.4 GHz Spectrum
"Overlapping Channels (6/7/10/11)"
5 MHz Separation of Channel Edges
Overlap of Bandwidths
0 MHz Separation of Channel Edges
Overlap of Bandwidths
Power
Channel 1
Channel 6
Channel 10
Channel 7
Channel 11
2412
2417
2422
2427
2432
2437
2442
2447
2452
2457
2462
2467
2472
Frequency
(MHz)

- Given its worldwide support of an abundant number of channels, the 5 GHz band allows for more complex 20 MHz channel re-use patterns
- The wider range of available frequencies in the 5 GHz band also permits wider channel assignment including 40 and 80 MHz, for greater WLAN throughput.
- Because wider channel bandwidths require more channel space, be conscious limits the ability of the WLAN administrator to create effective channel re-use patterns across the wireless coverage area.

- **In order to minimize interference**, assign non-adjacent channels to neighboring AP cells.
  - When followed, the WLAN can scale more effectively.
  - When disobeyed, WLANs cannot scale and result in poor performance (higher latency, lower throughput).
- **Before assigning WLAN channels**, *conduct site surveys to analyze noise levels across the spectrum.*
- 2nd Generation 802.11ac UAPs feature RF Scan tools to help WLAN administrators decide the best channel, based on all sources of interference, including competing, in-band WLANs, EMI (electromagnetic interference), etc.

Two important properties WLAN devices

- Transmit Power
- Receiver Sensitivity

Regulatory Bodies & EIRP

- Despite using worldwide unlicensed bands, wireless networks must comply with regulation and norms set by regional governments
- Fortunately, most Wireless device manufacturers teams make sure that the listed channels for your radios legally operate according to the available channels, bandwidths, and power limits in your region.
- E.g for UniFi, as long as the hardware is adopted to a Site whose settings are configured to the correct country, your hardware should operate legally.

EIRP

- **EIRP:** Equivalent Isotropically Radiated Power
- Check the *Properties* settings for your UniFi AP to see its EIRP level (in dBm). To determine its actual Transmit (TX) Power level (**in dBm**), subtract its Antenna Gain (**in dBi**) from its EIRP (**in dBm**).
- *The Transmit Power for the UAP-AC-LITE is 27 dBm, since the EIRP = 30 dBm and its Antenna Gain = 3 dBi.*

dB, dBm, dBw and dBi

- dB: Decibels are a relative measurement unit unlike the absolute measurement of milliwatts
- dBw- Decibel in watt.
- dBm- Decibel in miliwatt.
- dBm: The m in dBm refers simply to the fact that the reference is 1 milliwatt (1 mW) and therefore a dBm measurement is a measurement of absolute power.

dBm

The relationship between the decibels scale and the watt scale can be estimated using the following rules of thumb:

- +3 dB will double the watt value:

  (10 mW + 3dB ≈ 20 mW)

- Likewise, -3 dB will halve the watt value:

  (100 mW - 3dB ≈ 50 mW)

- +10 dB will increase the watt value by ten-fold:

  (10 mW + 10dB ≈ 100 mW)

- Conversely, -10 dB will decrease the watt value to one tenth of that value:

  (300 mW - 10dB ≈ 30 mW)

dBi

- The unit of measurement dBi refers only to the gain of an antenna. The “i” stands for “isotropic”, which means that the change in power is referenced against an isotropic radiator.

RX Sensitivity

- RX Sensitivity is the lowest power level at which the receiver can detect an RF signal and demodulate data.
- Sensitivity is purely a receiver specification and is independent of the transmitter.
- As the signal propagates away from the transmitter, the power density of the signal decreases, making it more difficult for a receiver to detect the signal as the distance increases.
- Improving the sensitivity on the receiver (making it more negative) will allow the radio to detect weaker signals, and can dramatically increase the transmission range.

Questions?

Acknowledgement

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Thank you