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TOMORROW starts here.

Cisco Connect
Split, Croatia

Fundamentals of RF and WLAN building blocks

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Session Abstract

A good wireless network starts with a solid understanding of Radio Frequency coverage.

During this session we will talk about the principles that govern 802.11 protocols, including the new 802.11ac Gigabit WiFi. We will discuss antenna placement, antenna patterns and the importance of performing a site survey. Finally we will have an overview of the latest products available to build a WLAN network and the differences between APs.

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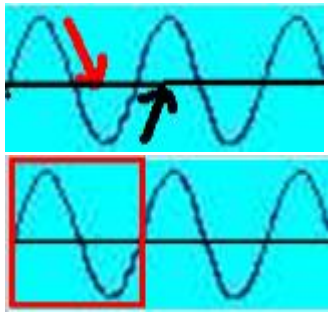
Fundamentals of RF

What is Radio?
How did we end up on these Frequencies?

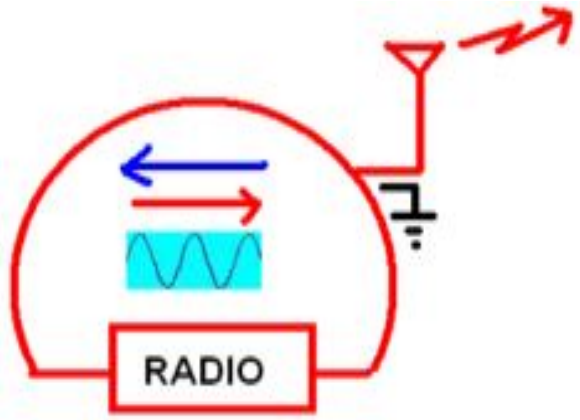
Basic Understanding of Radio…

Battery is **DC**
Direct **C**urrent

Typical home is **AC**
Alternating **C**urrent



AC Frequency 60 Hz or 60
CPS – Cycles Per Second



Waves travel back and forth so fast they actually leave the wire

How fast the AC current goes, is its "frequency"
AC is very low frequency 50-60 Hz (Cycles Per Second)

Radio waves are measured in kHz, MHz and GHz

The lower the frequency, the physically longer the radio wave – Higher frequencies have much shorter waves, and as such, it takes more power to move them greater distances.
This is why 2.4 GHz goes further vs. 5 GHz
(given same amount of RF power).

Popular Radio Frequencies:

AM Radio 520-1610 KHz
Shortwave 3-30 MHz
FM Radio 88 to 108 MHz
Aviation 108-121 MHz
Weather Radio 162.40 MHz
GSM Phones 900 & 1800 MHz
DECT Phones 1900 MHz
Wi-Fi 802.11b/g/n 2.4 GHz
Wi-Fi 802.11a/n 5 GHz

Spark transmitter

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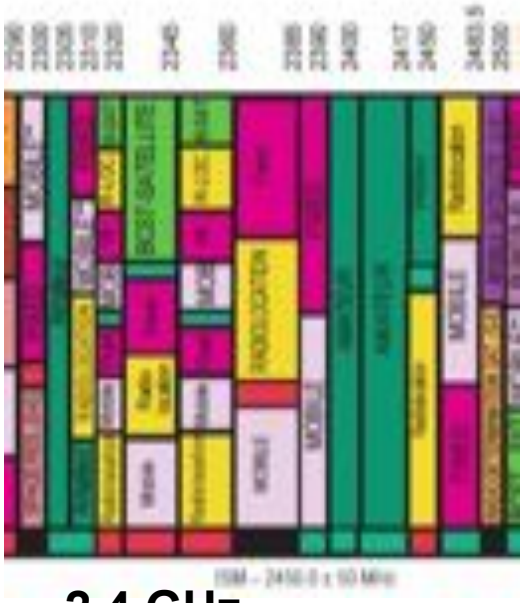
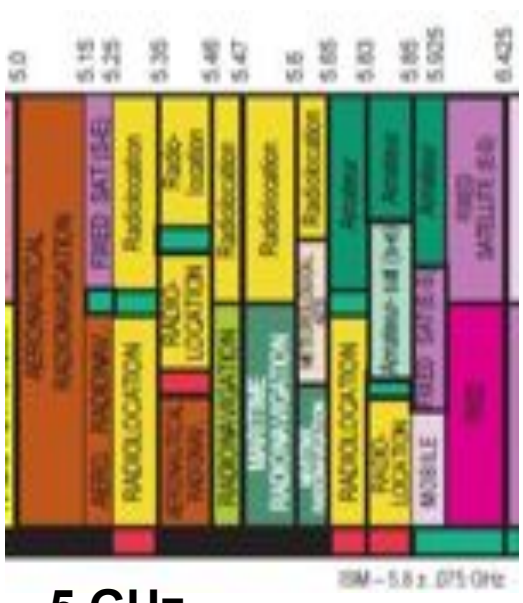
Wi-Fi Radio Spectrum



2.4 GHz



5 GHz

The first frequencies available for Wi-Fi use were in the 2.4 GHz range

As Wi-Fi popularity and usage increased, the regulatory bodies allocated additional spectrum in the 5 GHz band.

The spectrum we use today is also used by Amateur (Ham Radio) and other services such as radio location (radar).

There is more bandwidth in 5 GHz with mechanisms in place to co-exist with licensed services such as (RADAR) RAdio Detection And Ranging using (DFS) Dynamic Frequency Selection (method of automatic channel selection)

Wi-Fi is an "unlicensed" service

It has beginnings in the ISM Industrial Scientific Medical band where it was not desirable or profitable to license such short range devices.

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Wi-Fi Radio Spectrum

Even today, many portable devices in use are limited to 2.4 GHz only, including newer devices, but this is changing as newer 802.11ac (5-GHz) devices emerge

802.11b/g is 2.4 GHz
802.11a is 5 GHz
802.11n (can be either band) 2.4 or 5 GHz
802.11ac is 5GHz

The 2.4 GHz spectrum in the US has 3 non-overlapping channels 1, 6 and 11.

There are plenty of channels in the 5 GHz spectrum and they do not overlap

2.4 GHz and 5 GHz are different portions of the radio band and usually require separate antennas

Most, if not all, 5 GHz devices also have support for 2.4 GHz - however there are still many 2.4 GHz only devices.

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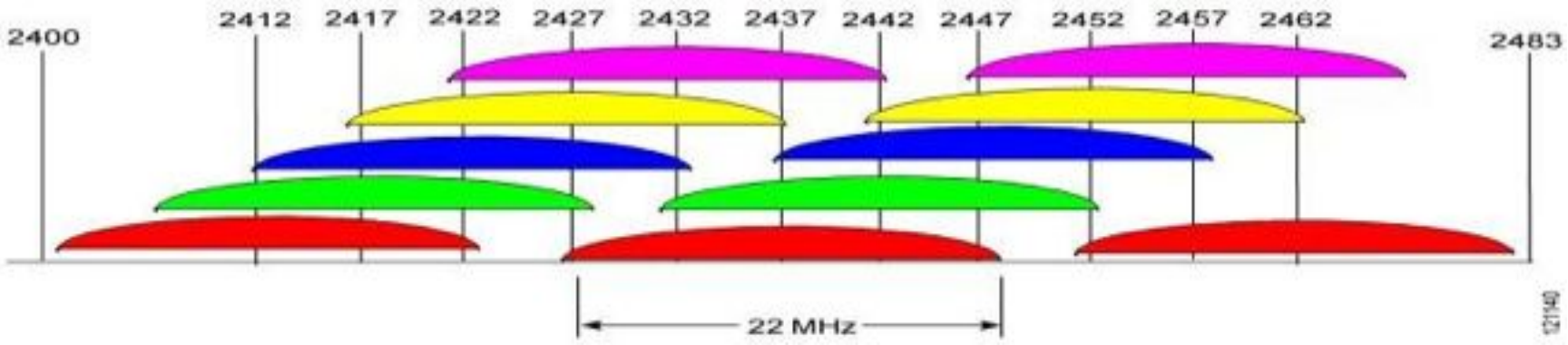
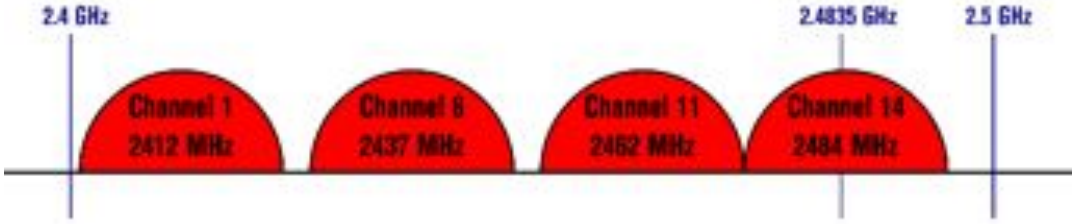
Wi-Fi Radio Spectrum 2.4 GHz

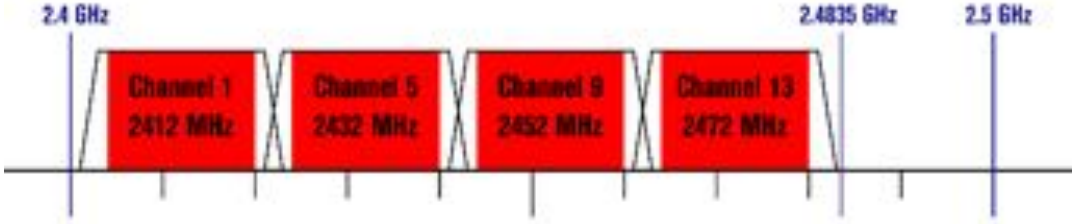


Non-Overlapping Channels for 2.4 GHz WLAN

802.11b (DSSS) channel width 22 MHz



802.11g/n (OFDM) 20 MHz ch. width – 16.25 MHz used by sub-carriers



4 non-overlapping channels? NO

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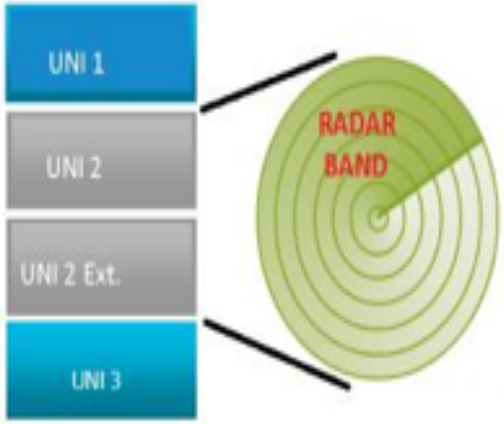
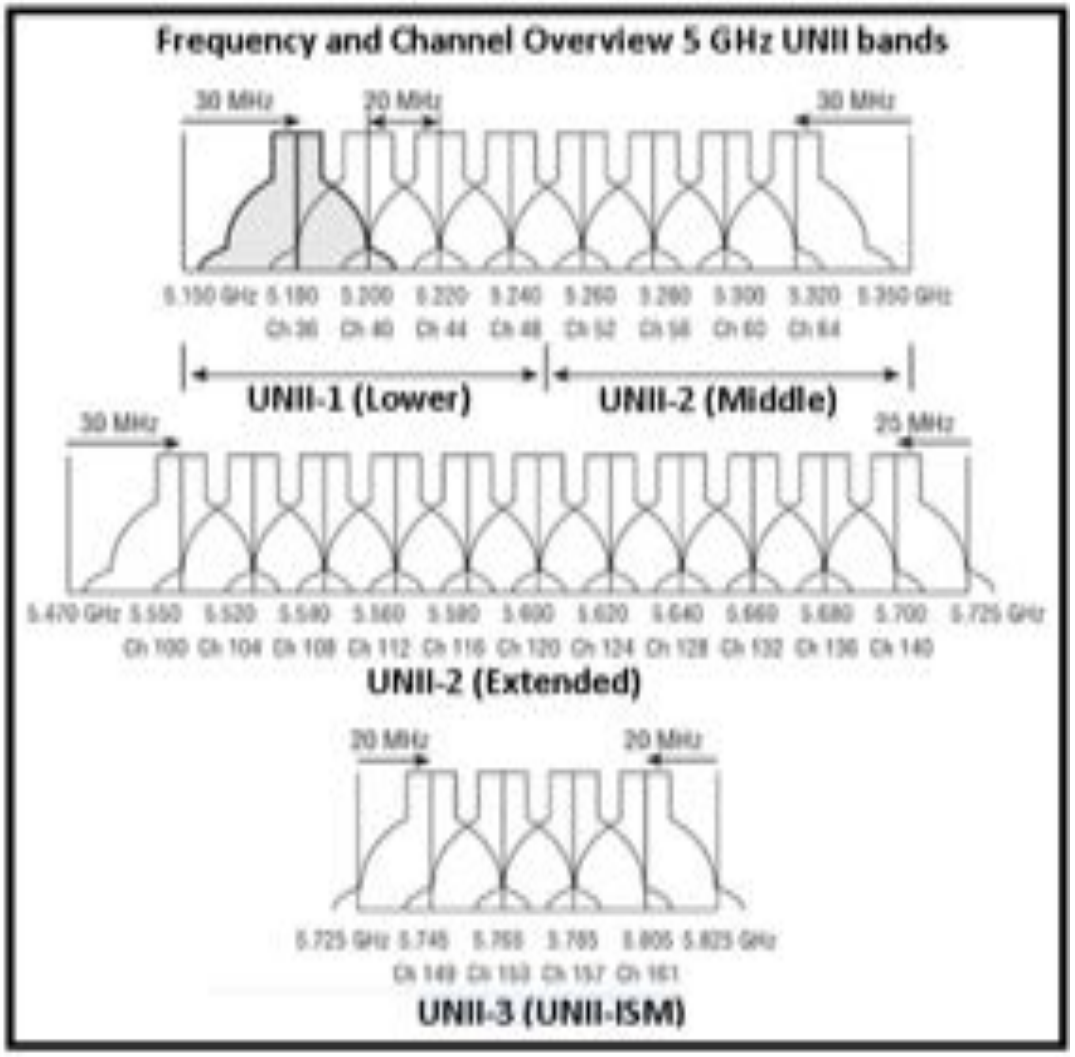
Wi-Fi Radio Spectrum 5 GHz Channels



Note: 5 GHz channels do not have the severe overlap that 2.4 GHz channels have but they use DFS to enable sharing of the band



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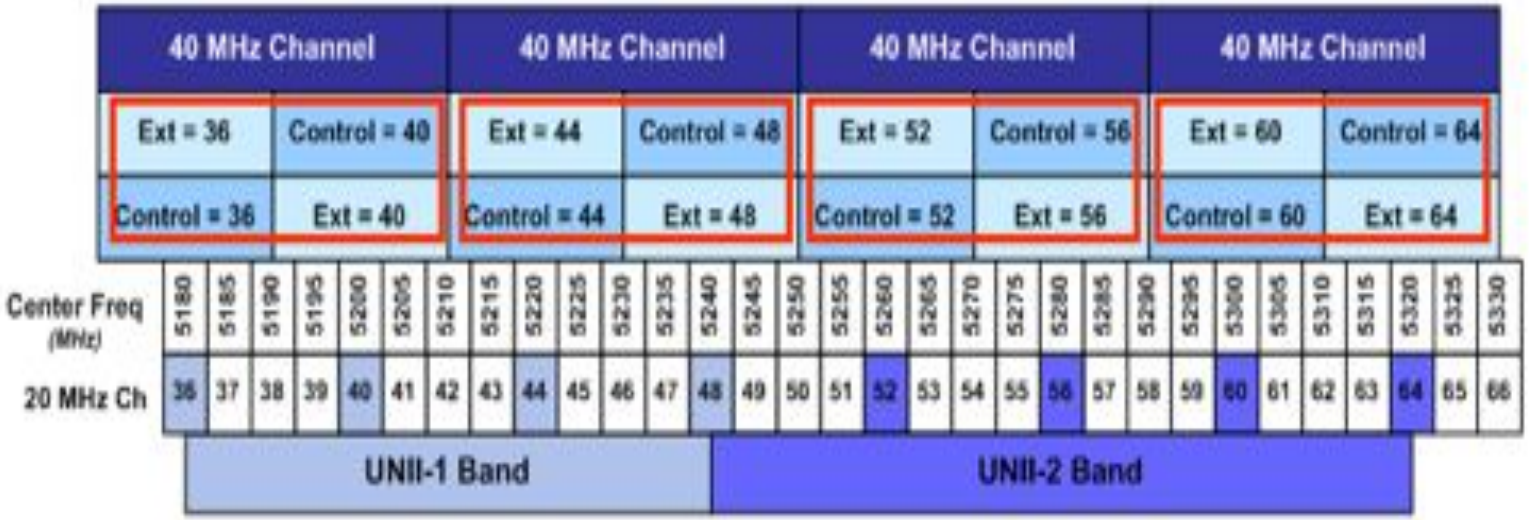
Example: ETSI Lower Band 5-GHz Channel Bonding



In 40-MHz you define the control channel this is the channel that is used for communication by Legacy .11a clients.

The Extension channel is the bonded channel that "HT" High Throughput "802.11n clients use in addition to the control channel for higher throughput as they send data on BOTH channels

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Complex Modulation Schemes

MCS Index	Number of spatial streams	Modulation
0	1	BPSK
1	1	QPSK
2	1	QPSK
3	1	16-QAM
4	1	16-QAM
5	1	64-QAM
6	1	64-QAM
7	1	64-QAM

High-density modulation schemes such as 64-QAM "Quadrature Amplitude Modulation" is used by 802.11n to get additional throughput higher than what is found in 802.11a/b/g. This is one of the advantages of 802.11n

Note: Newer 802.11ac modes can use up to 256-QAM

Radio technology has a lot in common with that old twisted pair phone line that started out at 300 baud and then quickly increased

In order to get faster data rates, (throughput) into the radio signal, complex modulation schemes as QPSK or 64 bit QAM is used.

Generally speaking, the faster the data rate the more powerful the signal needs to be at the receiver end to be properly decoded.

Take-away here is: 802.11n is a method of using special modulation techniques and is *not* specific to a frequency like 2.4 or 5 GHz

802.11n can be used in either band

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Antenna Basics

Antenna Basics

- Antenna - a device which radiates and/or receives radio signals
- Antennas are usually designed to operate at a specific frequency
- Some antennas have more than one radiating element (example Dual Band)
- Antenna Gain is characterized using dBd or dBi
  - Antenna gain can be measured in decibels against a reference antenna called a dipole and the unit of measure is dBd (d for dipole)
  - Antenna gain can be measured in decibels against a computer modeled antenna called an “isotropic” dipole <ideal antenna> and the unit of measure is dBi the “i” is for isotropic dipole which is a computer modeled “perfect” antenna
- WiFi antennas are typically rated in dBi.
  - dBi is a HIGHER value (marketing folks like higher numbers)
  - Conventional radio (Public safety) tend to use a dBd rating.
  - To convert dBd to dBi simply add 2.14 so a 3 dBd = 5.14 dBi

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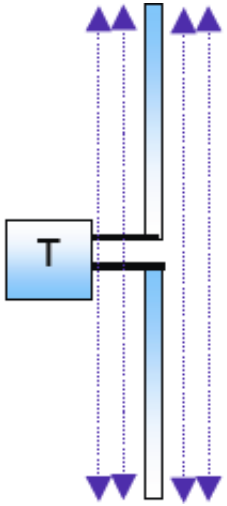
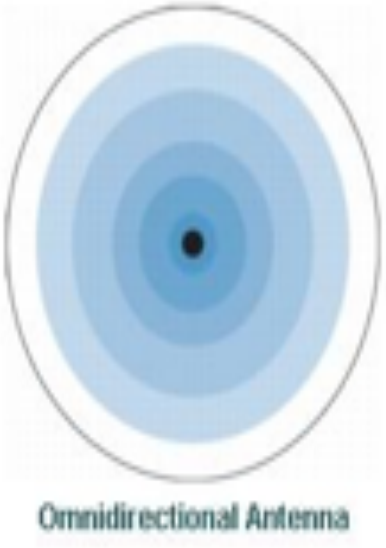
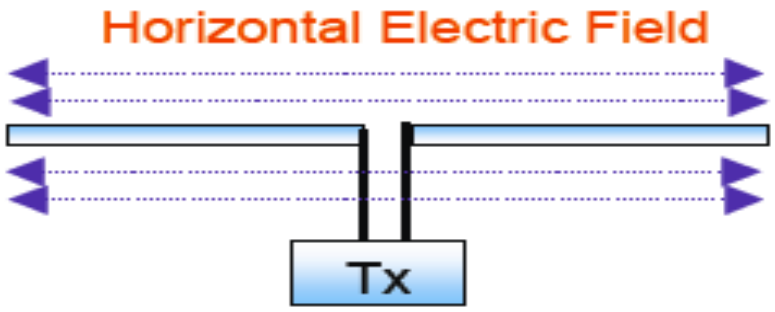
How Does a Omni-Directional Dipole Radiate?

The radio signal leaves the center wire using the ground wire (shield) as a counterpoise to radiate in a 360 degree pattern





Low gain Omni radiates much like a light bulb "360" degrees



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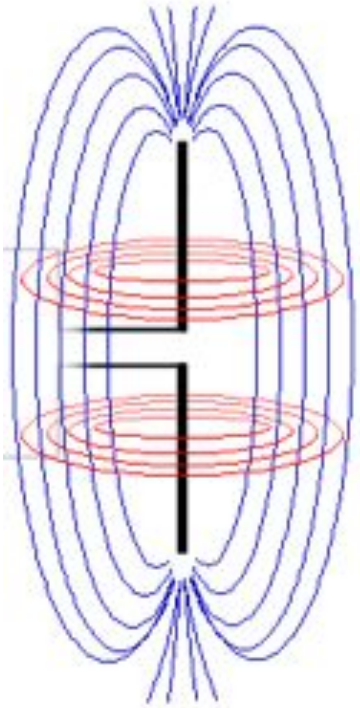
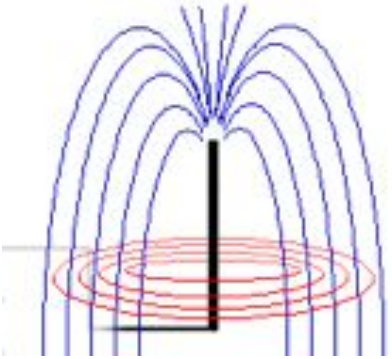
Antenna Theory (Dipole & Monopole)



Monopole



A Monopole requires a ground plane – (conductive surface)

A dipole does not require a ground plane as the bottom half is the ground (counterpoise).

808 Ft Broadcast Monopole WSM 650 AM (erected in 1932)

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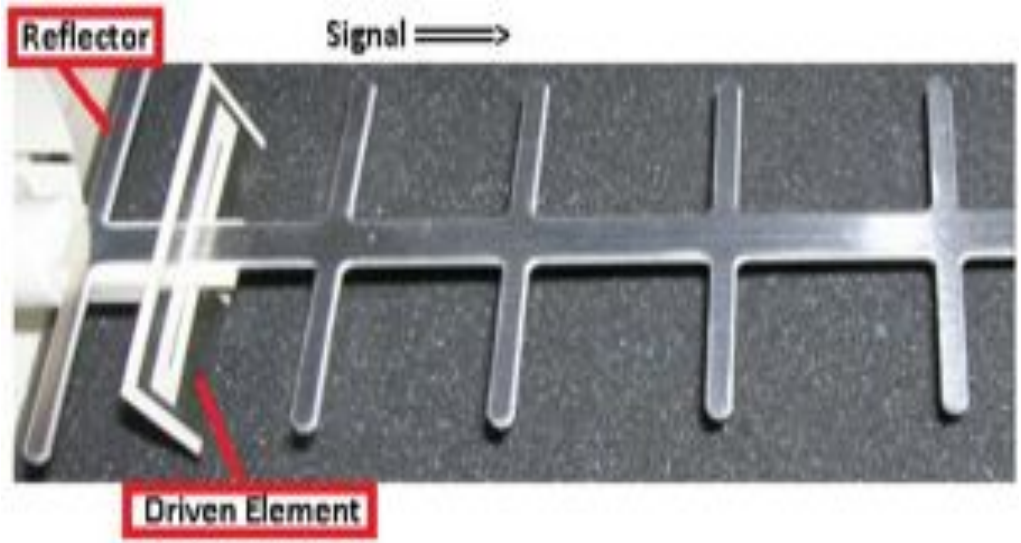
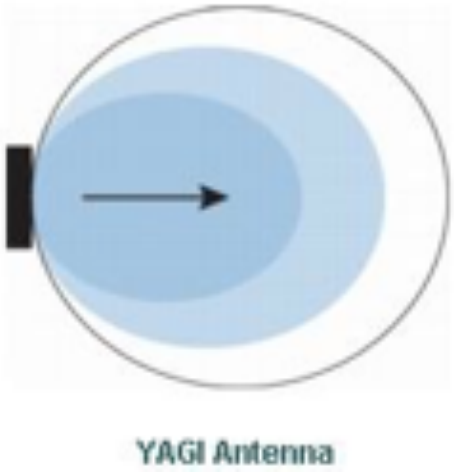
How Does a Directional Antenna Radiate?

Although you don't get additional RF power with a directional antenna, it does concentrate the available energy into a given direction resulting in greater range.

Also a receive benefit - by listening in a given direction, this can limit the reception of unwanted signals (interference) from other directions for better performance





A dipole called the "driven element" is placed in front of other elements. This motivates the signal to go forward in a given direction for gain.

(Inside view of the Cisco AIR-ANT1949 - 13.5 dBi Yagi)

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Antennas Identified by Color

Cisco Antenna Color Coding

Black indicates 2.4 GHz

Blue indicates 5 GHz

Orange indicates 2.4 & 5 GHz (used on AP-1600, 2600, 3600, & 3700)

Cisco antennas & cables are color coded – Black or no markings indicate 2.4 GHz

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Identifying RF Connectors

For Your Reference

RP-TNC Connector
Used on most Cisco Access Points

“RP-SMA” Connector
Used on some Linksys Products

“N” Connector
Used on the 15xx Mesh and outdoor APs

“SMA” Connector
“Pig tail” type cable assemblies

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Most Common 802.11n Antennas

Indoor Access Points (1262 and 3502e) <First Generation AP's>

For Your Reference

These are Single Radiating Element antennas designed for Access Points that have single band 2.4 or 5 GHz connectors (black or blue color)

Product ID	Description	Gain
AIR-ANT2451NV-R=	2.4 GHz 3 dBi/5 GHz 4 dBi 802.11n dual band omni antenna (6)	3 dbi / 4 dBi
AIR-ANT2460NP-R=	2.4 GHz 6 dBi 802.11n directional antenna (3)	6 dBi
AIR-ANT5160NP-R=	5 GHz 6 dBi 802.11n directional antenna (3)	6 dBi
AIR-ANT2422SDW-R=	2.4 GHz 2.2 dBi Short white dipole antenna (1)	2.2 dBi
AIR-ANT5135SDW-R=	5 GHz 3.5 dBi Short white dipole antenna (1)	3.5 dBi
AIR-ANT2450NV-R=	2.4 GHz 5 dBi 802.11n Omni wall mount antenna (3)	4 dBi
AIR-ANT5140NV-R=	5 GHz 4 dBi 802.11n Omni wall mount antenna (3)	4 dBi

Note: do *NOT* use on units with ORANGE label (1600, 2600 & 3600)

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Most Common 802.11n Antennas

Indoor Access Points (1600, 2600, 3600 & 3700) <2nd Generation AP's>

For Your Reference

These are Dual Radiating Element antennas (use with Orange labels)

Product ID	Description	Gain
AIR-ANT2524DB-R AIR-ANT2524DB-R=	2.4 & 5 GHz – Dual Band Dipole Dipole Ant., Black, RP-TNC connector (1)	2 dBi (2.4 GHz) 4 dBi (5 GHz)
AIR-ANT2524DG-R AIR-ANT2524DG-R=	2.4 & 5 GHz – Dual Band Dipole Dipole Ant., Gray, RP-TNC connector (1)	2 dBi (2.4 GHz) 4 dBi (5 GHz)
AIR-ANT2524DW-R AIR-ANT2524DW-R=	2.4 & 5 GHz – Dual Band Dipole Dipole Ant., White, RP-TNC connector (1)	2 dBi (2.4 GHz) 4 dBi (5 GHz)
AIR-ANT2566P4W-R=	2.4 & 5 GHz – Dual Band Directional (Patch) Directional Ant., RP-TNC connectors (4)	6 dBi (2.4 GHz) 6 dBi (5 GHz)
AIR-ANT2524V4C-R=	2.4 & 5 GHz – Dual Band Ceiling Mount Ceiling Mount Omni Ant., RP-TNC connectors (4)	2 dBi (2.4 GHz) 4 dBi (5 GHz)
AIR-ANT2544V4M-R=	2.4 & 5GHz – Dual Band Wall Mount Omni Wall Mount Omni Ant., RP-TNC connectors (4)	4 dBi (2.4 GHz) 4 dBi (5 GHz)

Use on antennas with Orange label *if using (1600) only use 3 antennas (4th unused)

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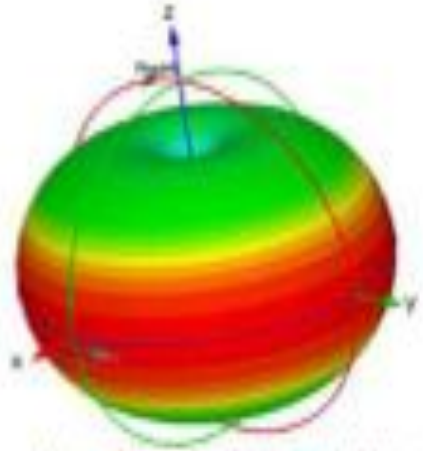
Understanding and Interpreting
Antenna Patterns

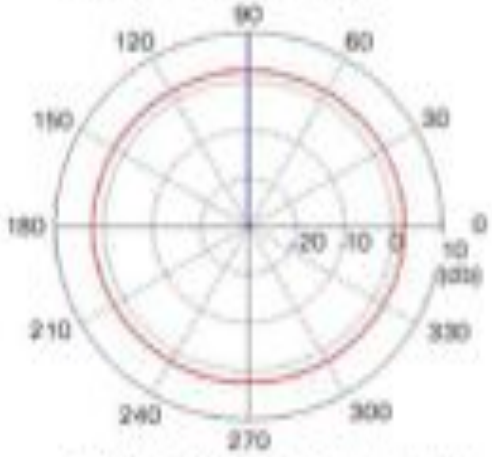
Understanding Antenna Patterns

Dipole (Omni-Directional)

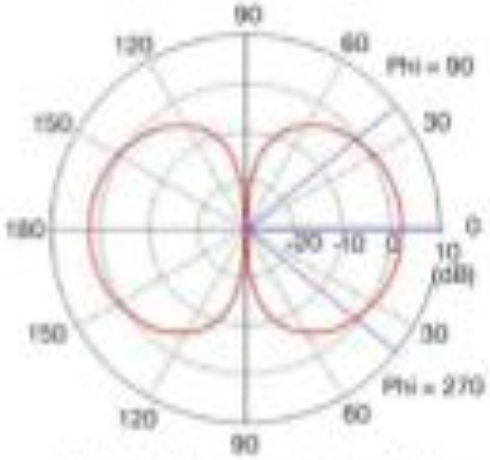
Dipole Antenna Model



Dipole 3D Radiation Pattern



Dipole Azimuth Plane Pattern



Dipole Elevation Plane Pattern

Low gain dipoles radiate everywhere think “light bulb”

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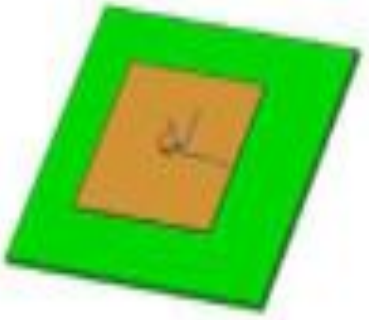
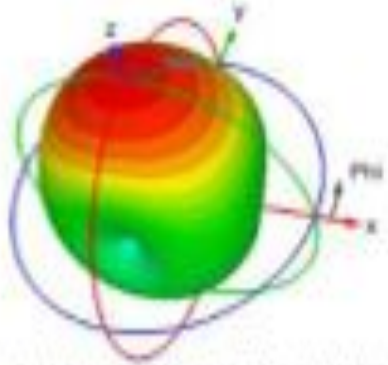
Understanding Antenna Patterns

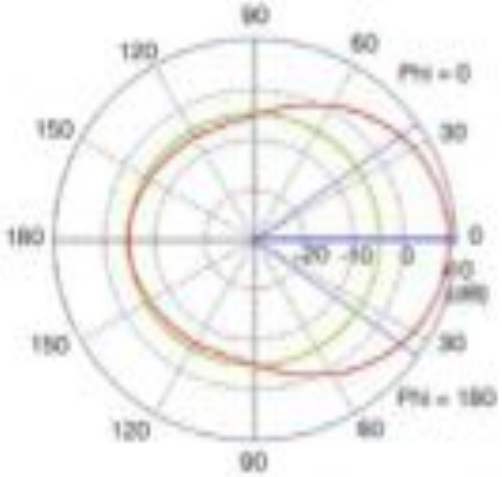
Patch (Directional)



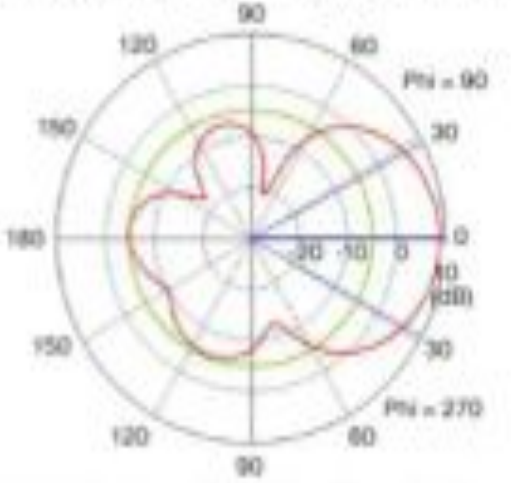
Patch Antenna Model



Patch Antenna 3D Radiation Pattern



Patch Antenna Azimuth Plane Patter



Patch Antenna Elevation Plane Pattern

A low gain Patch Antenna

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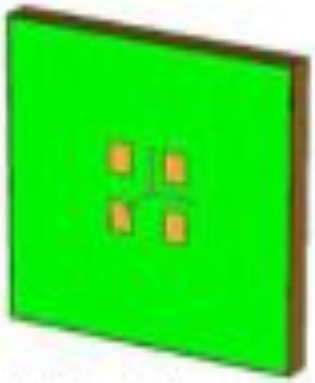
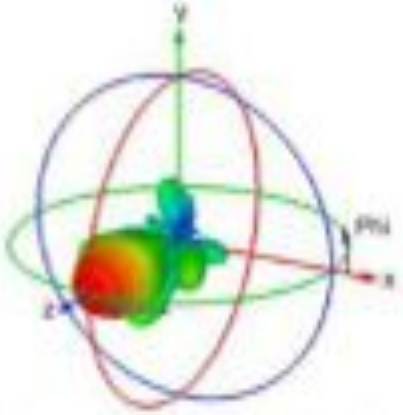
Understanding Antenna Patterns

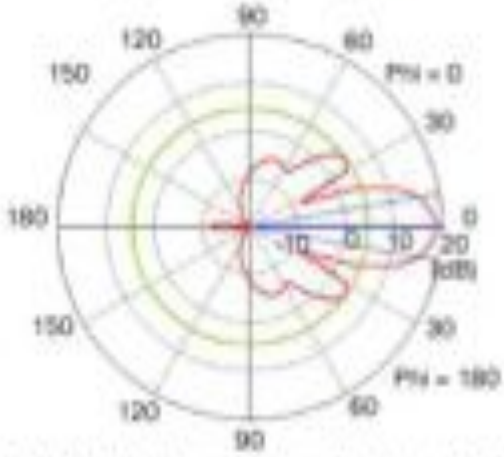
Patch (Higher Gain Directional)



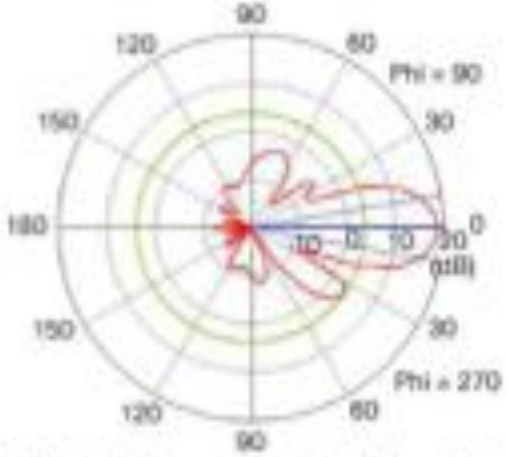
4x4 Patch Array Antenna



4x4 Patch Array 3D Radiation Pattern



4x4 Patch Array Azimuth Plane Pattern



4x4 Patch Array Elevation Plane Pattern

A High Gain Four element Patch Array

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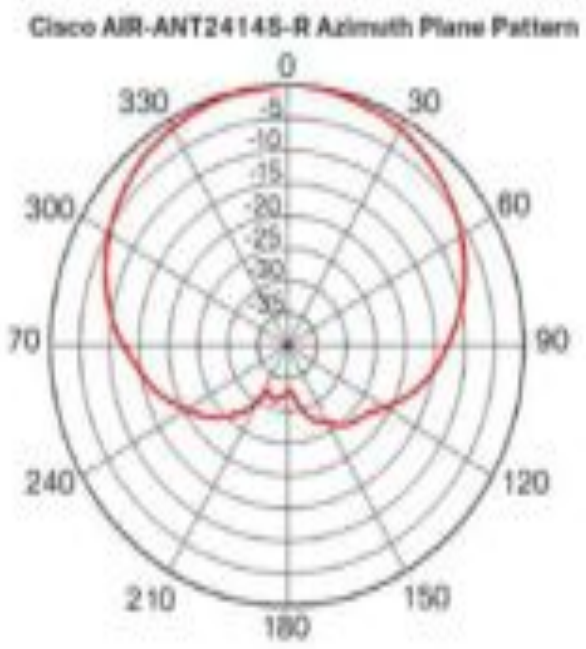
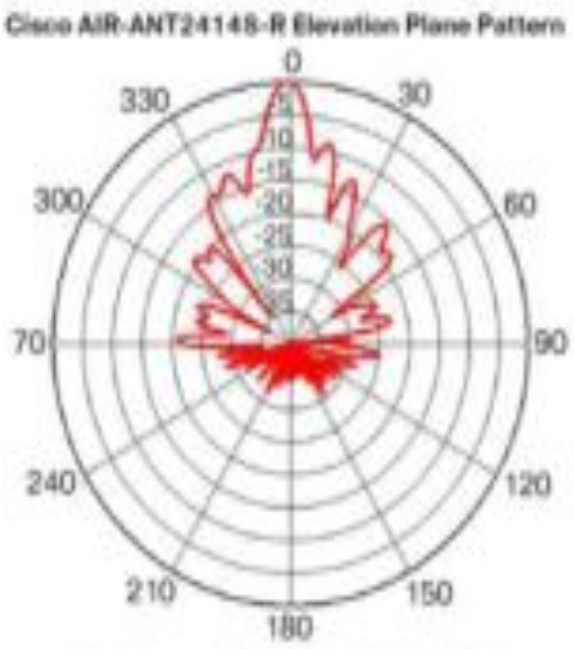
Understanding Antenna Patterns

Sector (Higher Gain Directional)



(b) Cisco AIR-ANT2414S-R Azimuth Plane Pattern



(c) Cisco AIR-ANT2414S-R Elevation Plane Pattern

AIR-ANT2414S-R
14 dBi Sector 2.4 GHz

Elevation plane has nulls due to high gain 14 dBi

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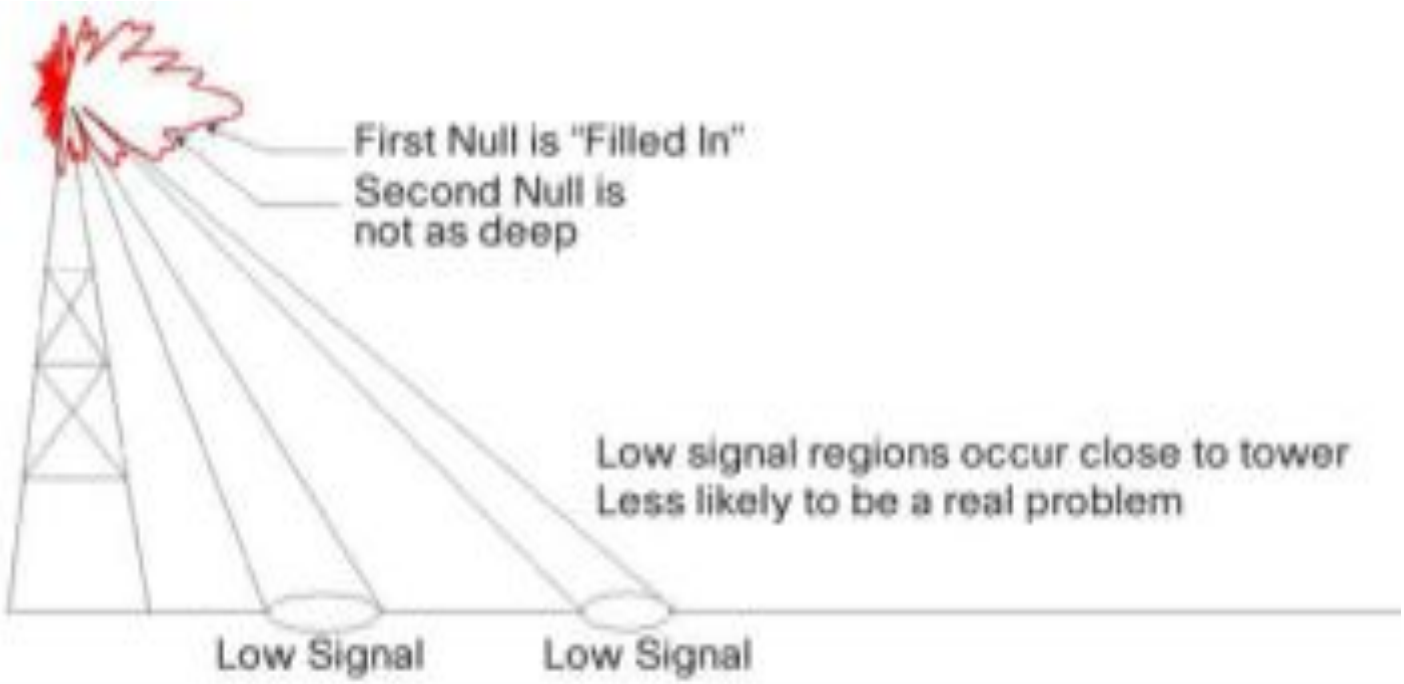
Understanding Antenna Patterns

Sector (Higher Gain Directional)



Elevation plane has nulls due to high gain 14 dBi but this antenna was designed with "Null-Fill" meaning we scaled back the overall antenna gain so as to have less nulls or low signal spots on the ground.

AIR-ANT2414S-R
14 dBi Sector 2.4 GHz

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Understanding Antenna Patterns

Sector (Higher Gain Directional)

Antenna type	90-degree sector
Operating frequency range	2400–2500 MHz
Nominal input impedence	50Ω
2:1 VSWR bandwith	2400–2500 MHz
Gain (including 1.5 m cable)	14 dBi
Polarization	Linear, vertical
Azimuth 3-dB beamwidth	90 degrees
Elevation 3-dB beamwidth	8.5 degrees
Cable length and type	5 ft. (1.5 m) LMR-195 coaxial
Connector type	RP-TNC Male
Environment	Outdoor
Length	35.9 in. (91.2 cm)
Width	6.4 in. (16.3 cm)
Depth	4.03 in. (10.23 cm)
Weight (with hardware kit)	7.5 lb. (3.4 kg)
Operating temperature range	–22°F to 158°F) (–30°C to 70°C
Storage temperature range	–40°F to 185°F (–40°C to 85°C)
Wind rating	100 mph (161 kph)

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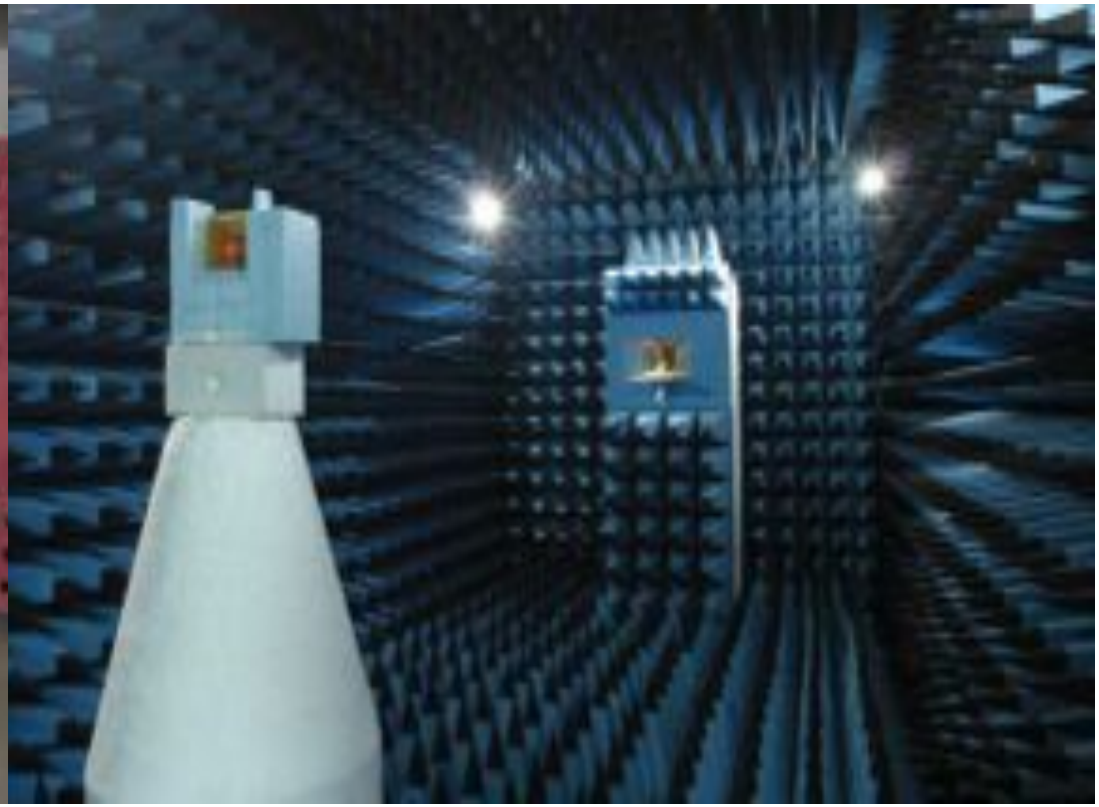
The Richfield Ohio (Aironet) Facility

Qualifying Cisco and 3rd Party Antennas



Satimo software compatible with Stargate-64 System. Basic measurement tool is 8753ES Network Analyzer.

Cisco Anechoic chamber using an 45 cm absorber all the way, around 1-6 GHz

Anechoic means “without echo”

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Understanding 802.11ac

Why is 802.11ac important?

This section will guide you in understanding 802.11ac Wave-1 and Wave-2

802.11ac devices are started to emerge especially mobile devices so there is a customer need for improved performance

Cisco AP-3600 with .11ac module

New .11ac clients starting to emerge

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So let's talk about 802.11ac – Wave1

The Wi-Fi Alliance (WFA) is looking at Wave 1 today with the main features implemented being:

- **Channel Bonding 80 MHz (mandatory)**
- **Faster modulation 256-QAM (optional)**
- **Ability to receive 1,2 & 3 Spatial Streams tested**

  - 2SS is mandatory for non-battery-powered APs

  - Only 1SS is mandatory for battery powered AP's and clients

- **WFA's focus is on 80 MHz, 1-3SS and 256-QAM with WFA compliant products likely sporting a new Wi-Fi Certified logo**

802.11ac is happening in stages Referred to as "Wave-1 and Wave-2

Wi-Fi Alliance logo should look something like this

Wi Fi
Wi-Fi CERTIFIED™ ac

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So let's talk about 802.11ac - How is it like .11n?

802.11ac (Wave-1) introduces 256-QAM

Faster throughput happens when you can use more complex Modulation Coding Schemes (MCS)

MCS	Coding	Modulation	Streams
MCS0	1/2	BPSK	1
MCS1	1/2	QPSK	1
MCS2	3/4	QPSK	1
MCS3	1/2	16-QAM	1
MCS4	3/4	16-QAM	1
MCS5	2/3	64-QAM	1
MCS6	3/4	64-QAM	1
MCS7	5/6	64-QAM	1

802.11n 1-ss MCS up to 64-QAM
64-QAM uses 6 bits per symbol

MCS	Coding	Modulation	Streams
0	1/2	BPSK	1
1	1/2	QPSK	1
2	3/4	QPSK	1
3	1/2	16-QAM	1
4	3/4	16-QAM	1
5	2/3	64-QAM	1
6	3/4	64-QAM	1
7	5/6	64-QAM	1
8	3/4	256-QAM	1
9	5/6	256-QAM	1

802.11ac 1-ss MCS supports 256-QAM
256-QAM uses 8 bits per symbol (up to 4x faster)

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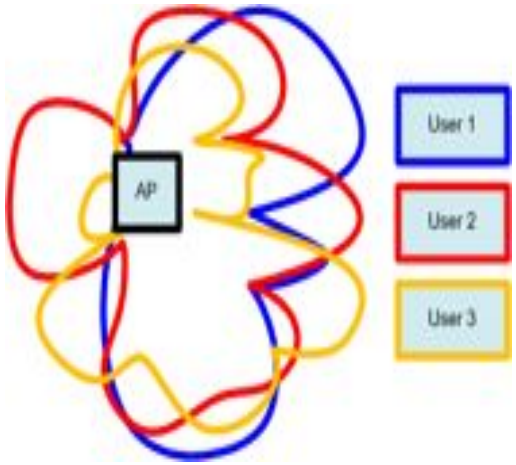
How about Multi-User MIMO (MU-MIMO)

Does it work? Any caveats?

- **802.11ac MU MIMO is like 802.11n MIMO, except instead of one client, there are up to four clients**
  - **AP does pre-coding for all the clients within the Multi-User group simultaneously**
  - **In MU pre-coding, when AP beam-forms space-time streams to one client, it simultaneously null-steers those space-time streams to the rest.**
  - **All users' MPDUs are padded to the same number of OFDM symbols**
- **MU-MIMO is technically risky and challenging:**
  - **Needs precise channel estimation (CSI) to maintain deep nulls**
  - **Precise channel estimation adds overhead**
  - **Rate adaptation is more difficult**
  - **Throughput benefits are sensitive to MU grouping**



WFA Wave 2 certification:
• MU-MIMO

Null-steering:To send data to user 1, the AP forms a strong beam toward user 1, shown as the top-right lobe of the blue curve. At the same time the AP minimizes the energy for user 1 in the direction of user 2 and user 3. This is called "null steering" and is shown as the blue notches. Same logic applies to red and yellow beams.

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So let's talk about 802.11ac - How is it like .11n?

What about channel bonding?

Wave-1 allows up to 80 MHz channel bonding

802.11n can bond up to 40 MHz

802.11ac can bond up to 80 MHz (Wave-1)

***up to 160 MHz (Wave-2)**

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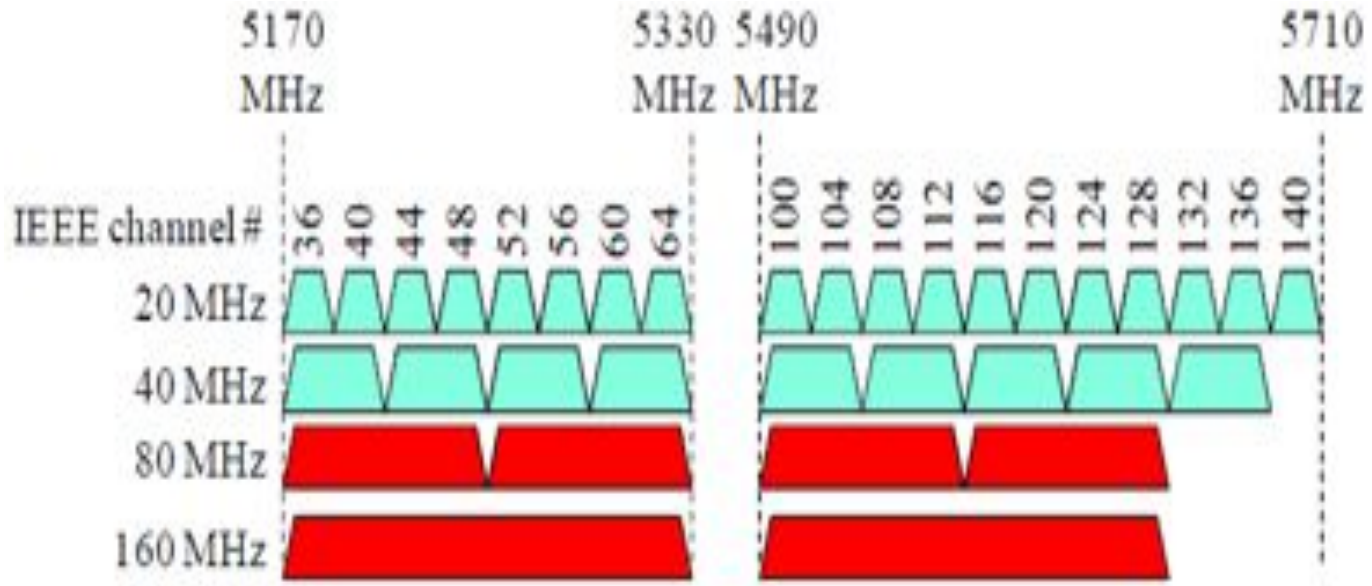
Let's talk about 802.11ac - How is it like .11n?

ETSI and Japan channel allocation plan



80 MHz bonding (Wave-1) 160 MHz (Wave-2)

Note: Efforts are underway globally to expand the number of channels in the 5 GHz band. China probably is progressing a bit quicker then others but everyone sees the need.

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So why is channel bonding so important?

MCS rates @ 1 Spatial Stream in Mbps

MCS	Modulation	Ratio	20 MHz channel	40 MHz channel	80 MHz channel WAVE-1
			400 ns GI	400 ns GI	400 ns GI
0	BPSK	1/2	7.2	15	32.5
1	QPSK	1/2	14.4	30	65
2	QPSK	3/4	21.7	45	97.5
3	16-QAM	1/2	28.9	60	130
4	16-QAM	3/4	43.3	90	195
5	64-QAM	2/3	57.8	120	260
6	64-QAM	3/4	65	135	292.5
7	64-QAM	5/6	72.2	150	325
8	256-QAM	3/4	86.7	180	390
9	256-QAM	5/6	N/A	200	433.3

New Phones such as the HTC One & Samsung S 4 have support for 802.11ac Wave-1

More than 1-SS requires that the client have more radios which draw more power.

The goal is to enable devices to have more throughput with less battery draw

Most mobile devices will use 1-SS

Tablets & laptops can use 2-SS or more

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Just one more EYECHART

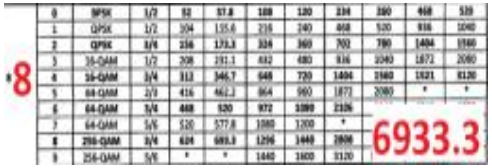
For Your Reference

802.11ac (Wave-2)
Up to 8 spatial streams.

.11ac MCS rates (unlike 802.11n) don't exceed 0-9 -- but rather **it is 0-9** and then you **call out how many Spatial Streams** so a chart like this is quite extensive.

Depicted to the right are only streams 2 & 3 out of the 8 possible spatial streams.

1 stream (80MHz) is 433 Mbps
2 stream (80MHz) is 866 Mbps
3 stream (80MHz) is 1300 Mbps



802.11ac Data Rates — * RATE NOT SUPPORTED — Mb/s

Spatial Streams	MCS Index	Modulation	Coding	20 MHz Guard 800ns	20 MHz Guard 400ns	40 MHz Guard 800ns	40 MHz Guard 400ns	80 MHz Guard 800ns	80 MHz Guard 400ns	160 MHz Guard 800ns	160 MHz Guard 400ns
2	0	BPSK	1/2	13	14.4	27	30	58.5	65	117	130
	1	QPSK	1/2	26	28.9	54	60	117	130	234	260
	2	QPSK	3/4	39	43.3	81	90	175.5	195	351	390
	3	16-QAM	1/2	52	57.8	108	120	234	260	468	520
	4	16-QAM	3/4	78	86.7	162	180	351	390	702	780
	5	64-QAM	2/3	104	115.6	216	240	468	520	936	1040
	6	64-QAM	3/4	117	130	243	270	526.5	585	1053	1170
	7	64-QAM	5/6	130	144.4	270	300	585	650	1170	1300
	8	256-QAM	3/4	156	173.3	324	360	702	780	1404	1560
	9	256-QAM	5/6	*	*	360	400	780	866.7	1560	1733.3
3	0	BPSK	1/2	19.5	21.7	40.5	45	87.8	97.5	175.5	195
	1	QPSK	1/2	39	43.3	81	90	175.5	195	351	390
	2	QPSK	3/4	58.5	65	121.5	135	263.3	292.5	526.5	585
	3	16-QAM	1/2	78	86.7	162	180	351	390	702	780
	4	16-QAM	3/4	117	130	243	270	526.5	585	1053	1170
	5	64-QAM	2/3	156	173.3	324	360	702	780	1404	1560
	6	64-QAM	3/4	175.5	195	364.5	405	*	*	1579.5	1755
	7	64-QAM	5/6	195	216.7	405	450	877.5	975	1755	1950
	8	256-QAM	3/4	234	260	486	540	1053	1170	2106	2340
	9	256-QAM	5/6	260	288.9	540	600	1170	1300	*	*

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Expected 802.11ac Client Throughput (take-away)

1 stream (80MHz) is 433 Mbps
2 stream (80MHz) is 866 Mbps
3 stream (80MHz) is 1300 Mbps

(Now let's drop it to ~70% MAC efficiency)

BW (MHz)	#Spat Strm	MCS (QAM=5/6)	PHY rate (Mbps)	MAC thruput (Mbps)*
80	1	64	290*	210
80	1	64	330	230
80	1	256	430	300
80	2	64	650	460
80	2	256	870	610
80	3	64	980	680
80	3	256	1300	910

802.11ac Performance Table

What's the real expected throughput?*

*** Assumes 70% MAC efficiency**

Smartphones from 210 Mbps*

Tablets from 460 Mbps*

High End Laptops from +680 Mbps*

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Since we are talking about the future (Wave-2)

What are likely to be the minimum requirements?

(Wave-2) Minimum requirements for enterprise will likely include: 256-QAM, 3-SS and 160 MHz

- **For Wave 2, initially it is expected that 160 MHz devices will appear with 1-3SS (typical) with perhaps 4-SS supported with likely data rates of 867-2600 Mbps.**
- **Likely data rates up to 3.5 Gbps PHY and over 2 Gbps MAC (IEEE approval late 2013)?**
- **Will require faster than GigE speeds requiring either 10GbE or perhaps two GbE cables / hybrid**

Future proofing new installations (cabling considerations)

- **A single GbE cable is fine for (Wave-1)**
- **Wave-2 will exceed GbE speeds so for now, it is recommended for new installs requiring Wave-2 that you pull two CAT6a cables until this standard is better defined.**
- **A pair of CAT6a cables allows you to fall back to using 2 GbE ports for some iterations of (Wave-2) if required. If the second cable isn't needed it can be used to bring the console port back.**
- **CAT5e cables may be used or one of each for cost savings but not for 10GbE.**

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Building your network

Choosing the architecture and controller

Cisco Unified Access = Deployment Flexibility

AUTONOMOUS AP

- Limited control plane on AP
- Distributed data plane
- Intended for static installations
- Point-to-point/work group bridge

- Aironet Access Points
- Catalyst switches
- Identity Services Engine
- Prime Infrastructure

CLOUD MANAGED

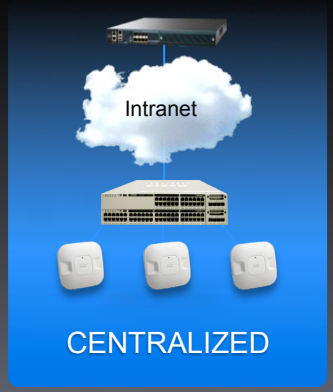
- Centralized control plane
- Distributed data plane
- Common LAN and WLAN OS
- LAN and WLAN feature consistency
- No controller at remote sites
- Optimized for distributed enterprise or branch deployments

- MR Access Points
- MS switches
- MX security
- Dashboard

FLEXCONNECT

- Centralized control plane
- Distributed data plane
- Data center hosted controller
- No controller at remote sites
- Optimized for distributed enterprise or branch deployments

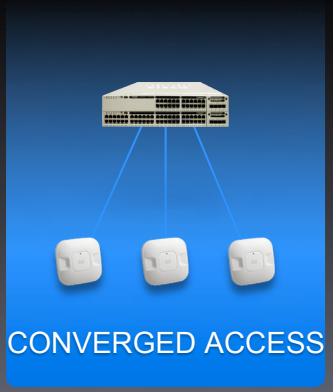
- Aironet Access Points
- FlexConnect capable controllers
- Catalyst switches
- Identity Services Engine
- Mobility Services Engine
- Prime Infrastructure



CENTRALIZED

- Centralized control plane
- Centralized data plane
- Premise-based controller
- Controller at every location
- Optimized for campus deployment

- Aironet Access Points
- Centralized controllers
- Catalyst switches
- Identity Services Engine
- Mobility Services Engine
- Prime Infrastructure



CONVERGED ACCESS

- Centralized control plane
- Distributed data plane
- Common LAN and WLAN OS
- LAN and WLAN feature consistency
- Optimized for high performance
- Optimized for campus and branch

- Aironet Access Points
- Catalyst 3850 Switch
- Identity Services Engine
- Mobility Services Engine
- Prime Infrastructure

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Integrated WLAN Controllers
Cisco Wireless Services Module 2

Key Features

- Supported on
  - Catalyst 6500 Series Switches
- Scalability:
  up to 1000 APs (Single Controller)
- DTLS-Encryption for Control- and Data-Layer
- Up to 20 Gbps backplane connection
- Interoperable with other Service Modules
  (especially 1st Generation WiSMs)

Scalability-Numbers	
Maximum # of APs	1’000
Maximum # of Clients	15’000
Maximum # of FlexConnect-Groups	100
Maximum # of APs per FlexConnect-Group	50
Maximum # of Rogue APs	4’000
Maximum # of Rogue Clients	5’000
Maximum # of RFID-Tags	10’000
Maximum # of APs per RRM-Group	2’000
Maximum # of AP-Groups	500

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Standalone WLAN Controllers
Cisco 2500 Series Wireless Controllers

Key Features

- Scalability: up to 75 APs
- 4x 1GE RJ45 (2x PoE)
- DTLS-Encryption for Control- and Data-Layer
- 1000 Mbps backplane capacity

Scalability-Numbers	
Maximum # of APs	75
Maximum # of Clients	1000
Maximum # of FlexConnect-Groups	20
Maximum # of APs per FlexConnect-Group	25
Maximum # of Rogue APs	2’000
Maximum # of Rogue Clients	2’500
Maximum # of RFID-Tags	500
Maximum # of APs per RRM-Group	500
Maximum # of AP-Groups	50

Some feature are not supported
Examples:
- No Wired-Guest

Please consult documentation!

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Standalone WLAN Controllers
Cisco 5500 Series Wireless Controllers

Key Features

- Scalability: Up to 500 APs
- 8x 1GE SFP (LAG possible)
- DTLS-Encryption for Control- and Data-Layer
- Non-blocking backplane capacity

Scalability-Numbers	
Maximum # of APs	500
Maximum # of Clients	7’000
Maximum # of FlexConnect-Groups	20
Maximum # of APs per FlexConnect-Group	25
Maximum # of Rogue APs	2’000
Maximum # of Rogue Clients	2’500
Maximum # of RFID-Tags	5’000
Maximum # of APs per RRM-Group	1’000
Maximum # of AP-Groups	500

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Standalone WLAN Controllers
Cisco 8500 Series Wireless Controllers

Key Features

- Scalability: Up to 6000 APs
- 2x 10GE SFP
- DTLS-Encryption for Control- and Data-Layer

Scalability-Numbers	
Maximum # of APs	6’000
Maximum # of Clients	64’000
Maximum # of FlexConnect-Groups	2’000
Maximum # of APs per FlexConnect-Group	100
Maximum # of Rogue APs	24’000
Maximum # of Rogue Clients	32’000
Maximum # of RFID-Tags	50’000
Maximum # of APs per RRM-Group	6’000
Maximum # of AP-Groups	6’000

Limited feature support!
Examples:
- No Wired Guest
- No Guest Anchor

Please consult documentation!

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“FlexConnect” WLAN Controllers
Cisco Virtual WLAN Controller

Key Features

- FlexConnect- and Monitor-Mode-Deployments ONLY
- Up to 100 branch locations and 100 APs per branch (H-REAP-Groups)

Scalability-Numbers	
Maximum # of APs	200
Maximum # of Clients	3’000
Maximum # of FlexConnect-Groups	100
Maximum # of APs per FlexConnect-Group	100
Maximum # of Rogue APs	800
Maximum # of Rogue Clients	1’500
Maximum # of RFID-Tags	3’000
Maximum # of APs per RRM-Group	400
Maximum # of AP-Groups	200

Limited feature support!
Examples:
- No Data-Layer DTLS
- No Guest Anchor
- No Mesh-Support

Please consult documentation!

VMWare Requirements
- ESX/ESXi 4.x or 5.x
- Mind. 1 vCPU
- Mind. 2 GB RAM
- Mind. 8 GB Storage
- Mind. 2 VMNICs

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“FlexConnect” WLAN Controllers
Cisco Flex 7500 Series Controllers

Key Features

- Scalability: up to 6000 APs
- FlexConnect- and Monitor-Mode-Deployments ONLY
- 2x10 GE SFP+ Connector (active/standby)
- Up to 1000 branch locations and 50 APs per branch (H-REAP-Groups)
- Up to 1 Gbps centralized Dataplane

Scalability-Numbers	
Maximum # of APs	6’000
Maximum # of Clients	64’000
Maximum # of FlexConnect-Groups	2’000
Maximum # of APs per FlexConnect-Group	100
Maximum # of Rogue APs	24’000
Maximum # of Rogue Clients	32’000
Maximum # of RFID-Tags	50’000
Maximum # of APs per RRM-Group	6’000
Maximum # of AP-Groups	6’000

Limited feature support!

Please consult documentation!

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Converged Access
Cisco 5760 Series Wireless Controller

Key Features

- Scalability: up to 1000 APs
- Hardware based on UADP Asic (Unified Access Data Plane)
- 60 Gbps throughput
- Supports flexible Netflow v9
- Supports dACLs
- MQC-based QoS-Configuration

Scalability-Numbers	
Maximum # of APs	1’000
Maximum # of Clients	12’000

Today this products offers limited feature support!

- Please make yourself familiar with the Converged Access Solution
- Please consult documentation!

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Converged Access
Cisco Catalyst 3650 Series Switches

Key Features

- Scalability: up to 25 APs
- Hardware based on UADP Asic (Unified Access Data Plane)
- 160 Gbps Stacking capacity
- 40 Gbps Uplink capacity
- Supports flexible Netflow v9
- Supports dACLs
- MQC-based QoS-Configuration

Scalability-Numbers	
Maximum # of APs	25
Maximum # of Clients	1’000

Today this products offers limited feature support!

- Please make yourself familiar with the Converged Access Solution
- Please consult documentation!

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Converged Access
Cisco Catalyst 3850 Series Switches

Key Features

- Scalability: up to 50 APs
- Hardware based on UADP Asic (Unified Access Data Plane)
- 480 Gbps Stacking capacity
- 40 Gbps Uplink capacity
- Supports flexible Netflow v9
- Supports dACLs
- MQC-based QoS-Configuration

Scalability-Numbers	
Maximum # of APs	50
Maximum # of Clients	2’000

Today this products offers limited feature support!

- Please make yourself familiar with the Converged Access Solution
- Please consult documentation!

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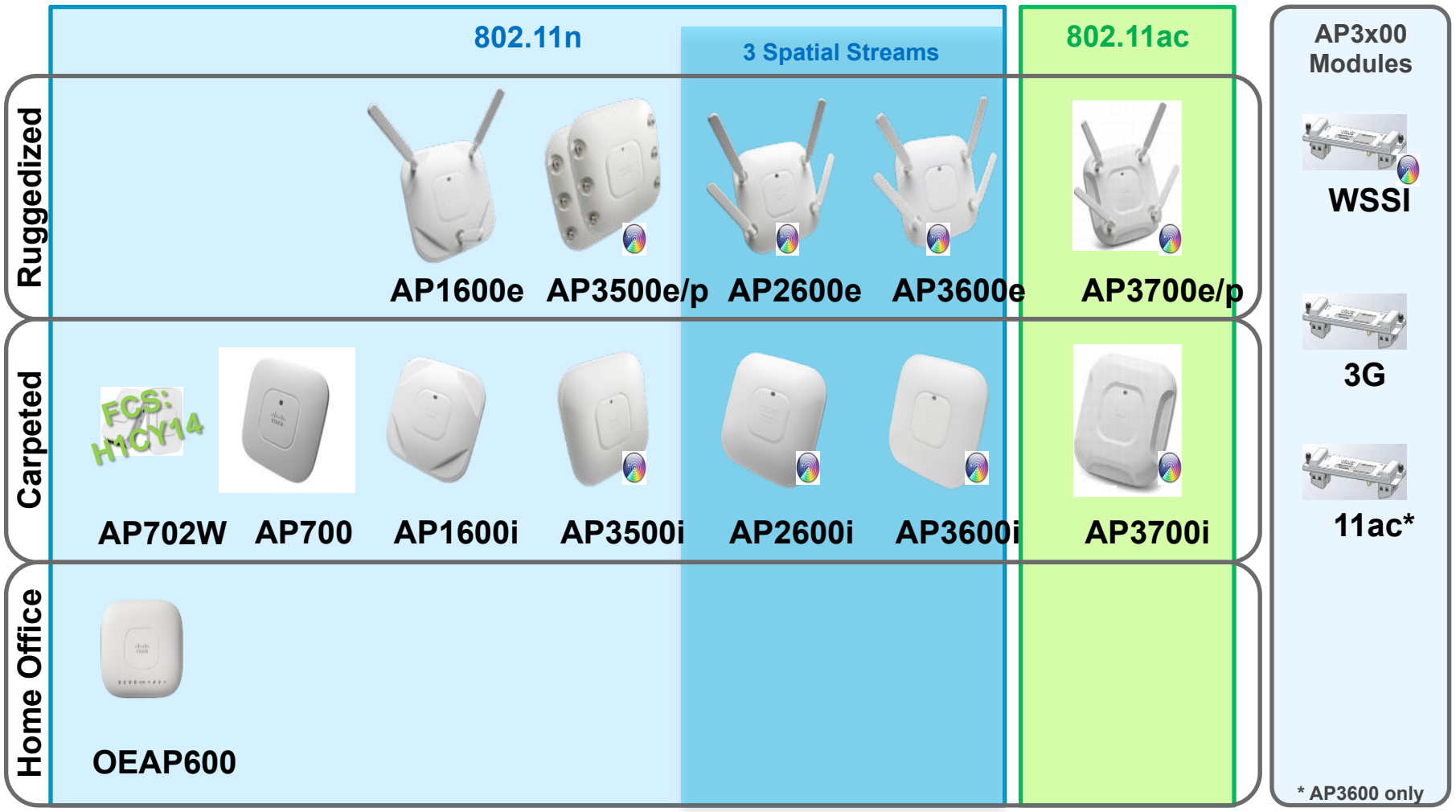
Choosing the right Access Point Model
Integrated or External antennas?

Indoor AP Portfolio



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Integrated Antenna? – External Antenna?

Carpeted areas

Integrated antenna versions are designed for mounting on a ceiling (carpeted areas) where aesthetics is a primary concern

Rugged areas

Use for industrial applications where external or directional antennas are desired and or applications requiring higher temperature ranges or for areas with more challenging RF-environment.

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Cisco Aironet 1600e Series Access Point

Key Features

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- 3 receivers / 3 senders / 2 spatial streams (3x3:2 MIMO)
- Extended range for 300 Mbps per Band
- Dual-Band Antenna-Connectors for both frequencies (max. 6dBi gain)
- Worldclass integrated features using custom-designed silicon:
  → Cisco ClientLink 2.0
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

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Cisco Aironet 2600e Series Access Point

Key Features

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- 4 receivers / 3 senders / 3 spatial streams (3x4:3 MIMO)
- Extended range for 450 Mbps per Band
- Dual-Band Antenna-Connectors for both frequencies (max. 6dBi gain)
- Worldclass integrated features using custom-designed silicon:
  → Cisco CleanAir
  → Cisco ClientLink 2.0
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to todays mission critical Wireless-Networks

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Cisco Aironet 3500e Series Access Point

Key Features

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- Distinguished Antenna-Connectors for each frequency-band (max. 6dBi gain)
- Worldclass Spectrum Intelligence integrated with specific HW:
  → Cisco CleanAir
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to todays mission critical Wireless-Networks

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Cisco Aironet 3500p Series Access Point

Key Features

- Designed with custom configuration settings and narrow-bandwidth, high-gain external antennas to provide very targeted coverage for high-density deployments.
- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- Supports AIR-ANT25137NP-R high-gain “Stadium Antenna”
- Worldclass Spectrum Intelligence integrated with specific HW:
  → Cisco CleanAir
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Please note:

Because of the unique antenna and power settings, FCC regulations require the Cisco Aironet 3500p Access Point to be installed by a certified professional.

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Cisco Aironet 3600e Series Access Point

Key Features

- Modul-Slot for additional radios
- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- 4 receivers / 4 senders / 3 spatial streams (4x4:3 MIMO)
- Large range for 450 Mbps per Band
- Dual-Band Antenna-Connectors for both frequencies (max. 6dBi gain)
- Worldclass integrated features using custom-designed silicon:
  → Cisco CleanAir
  → Cisco ClientLink 2.0
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to todays mission critical Wireless-Networks

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Cisco Aironet 3700e Series Access Point

Key Features

- Modul-Slot for additional radios
- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n/ac
- 4 receivers / 4 senders / 3 spatial streams (4x4:3 MIMO)
- Large range for 1.3 Gbps
- Dual-Band Antenna-Connectors for both frequencies (max. 6dBi gain)
- Worldclass integrated features using custom-designed silicon:
  → Cisco CleanAir
  → Cisco ClientLink 3.0
- Controller-based and Autonomous(later)
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to todays mission critical Wireless-Networks

Works with 802.3af, but will fall back to 3x3:3 MIMO.
802.3at, EPoE or UPoE recommended!

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Cisco Aironet 3700p Series Access Point

Key Features

- Modul-Slot for additional radios
- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n/ac
- 4 receivers / 4 senders / 3 spatial streams (4x4:3 MIMO)
- Large range for 1.3 Gbps
- Supports special high-gain Stadium-Antenna
- Worldclass integrated features using custom-designed silicon:
  → Cisco CleanAir
  → Cisco ClientLink 3.0
- Controller-based and Autonomous(later)
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Please note:

Because of the unique antenna and power settings, FCC regulations require the Cisco Aironet 3700p Access Point to be installed by a certified professional.

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Cisco Aironet 700W Series Access Point

Disclaimer:
Information about future developments is subject to change

Key Features

- Wall-Mount AP
- Integrated Switch

- More details will be added closer to FCS

Please note:

AP700W will become available only in H1CY14

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Cisco Aironet 700 Series Access Point

Key Features

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a
- 2 receivers / 2 senders / 2 spatial streams (3x3:2 MIMO)
- Simultaneous dual band, dual radio
- Available for controller-based (lightweight) setups.
  Autonomous support in future
- Small formfactor and design

Please note:

AP700 is smaller than other Cisco APs and therefore it uses its own, smaller mounting brackets

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Cisco Aironet 1600i Series Access Point

Key Features

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- 3 receivers / 3 senders / 2 spatial streams (3x3:2 MIMO)
- Extended range for 300 Mbps per Band
- Integrated Dual-Band Antenna-Connectors
- Worldclass integrated features using custom-designed silicon:
  → Cisco ClientLink 2.0
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

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Cisco Aironet 2600i Series Access Point

Key Features

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- 4 receivers / 3 senders / 3 spatial streams (3x4:3 MIMO)
- Extended range for 450 Mbps per Band
- Integrated Dual-Band Antenna-Connectors
- Worldclass integrated features using custom-designed silicon:
  → Cisco CleanAir
  → Cisco ClientLink 2.0
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to todays mission critical Wireless-Networks

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Cisco Aironet 3500i Series Access Point

Key Features

- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- Dedicated and integrated antennas for each frequency-band
- Worldclass Spectrum Intelligence integrated with specific HW:
  → Cisco CleanAir
- Controller-based and Autonomous
- Same nice formfactor and design as AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to todays mission critical Wireless-Networks

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Cisco Aironet 3600i Series Access Point

Key Features

- Modul-Slot for additional radios
- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n
- 4 receivers / 4 senders / 3 spatial streams (4x4:3 MIMO)
- Large range for 450 Mbps per Band
- Integrated Dual-Band Antenna
- Worldclass integrated features using custom-designed silicon:
  → Cisco CleanAir
  → Cisco ClientLink 2.0
- Controller-based and Autonomous
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to todays mission critical Wireless-Networks

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Cisco Aironet 3700i Series Access Point

Key Features

- Modul-Slot for additional radios
- 2.4 GHz, IEEE 802.11b/g/n
- 5 GHz, IEEE 802.11a/n/ac
- 4 receivers / 4 senders / 3 spatial streams (4x4:3 MIMO)
- Large range for 1.3 Gbps
- Integrated Dual-Band Antenna
- Worldclass integrated features using custom-designed silicon:
  → Cisco CleanAir
  → Cisco ClientLink 3.0
- Controller-based and Autonomous(later)
- Nice formfactor and design adapted from AP1140 → same mounting-brackets

Cisco CleanAir enables the network to make intelligent decisions on the appearance of Non-WiFi-Interferers depending on their impact – providing higher network availability to todays mission critical Wireless-Networks

Works with 802.3af, but will fall back to 3x3:3 MIMO.
802.3at, EPoE or UPoE recommended!

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Wireless Security & Spectrum Intelligence Module (WSSI)

Key Features

- Allows the AP to concurrently serve clients and scan all channels – always on
- Offloads CleanAir Monitoring & WIDS/ WIPS Security capabilities to the Monitor Module
- Independent integrated antennas 0x4 (0 Tx antenna's x 4 Rx Antenna's)
- No configuration required!
  Module automatically scans all channels on 2.4 and 5 GHz bands
- Module powered from AP
  AP-Power requires ~20W
  - Enhanced PoE
  - IEEE 802.3at
  - Power-Injector
  - Local Power-Supply
- Requires AP to be mounted with either:
  - Universal Mounting Brackets (Bracket-2; included)
  - Ceiling Mounting Brackets (Bracket-3)

This module eliminates the need for an extra cable pull and additional infrastructure costs, if full aWIPS scanning or CleanAir Spectrum Analyses is required!

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IEEE 802.11ac Wave 1 Module

Key Features

- 5 GHz, IEEE 802.11ac (Wave 1)
- 3 receivers / 3 senders / 3 spatial streams (3x3:3 MIMO)
- 1.3 Gbps throughput
- Together with Host-AP the module supports b/g/n on 2.4 GHz and a/ac/n on 5 GHz
- Supports “Explicit Beamforming” as per the 802.11ac standard
- Module powered from AP
  AP-Power requires ~20W
  - Enhanced PoE
  - IEEE 802.3at
  - Power-Injector
  - Local Power-Supply
- Requires AP to be mounted with either:
  - Universal Mounting Brackets (Bracket-2; included)
  - Ceiling Mounting Brackets (Bracket-3)

This field-upgradable IEEE 802.11ac module add-on to the AP3600 allows today investment protection for this emerging Wireless-Standard!

This module is not supported in the AP3700!

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Cisco Universal Small Cell 5310

Key Features

The Cisco USC 5310 is field-upgradeable and contains a dedicated third-generation (3G) small cell base station that can efficiently deliver mobile services indoors while offloading traffic from the outdoor macro network.

This approach:

- improves the mobile user experience
- reduces costs by eliminating the need for dedicated macro base station sites
- reducing the need to acquire new small cell real
- decreasing the backhaul infrastructure required to support small cell deployments.

Please note:

This module works in the licensed band, so you have to work with the local SP that owns the right to operate equipment in that frequency range!

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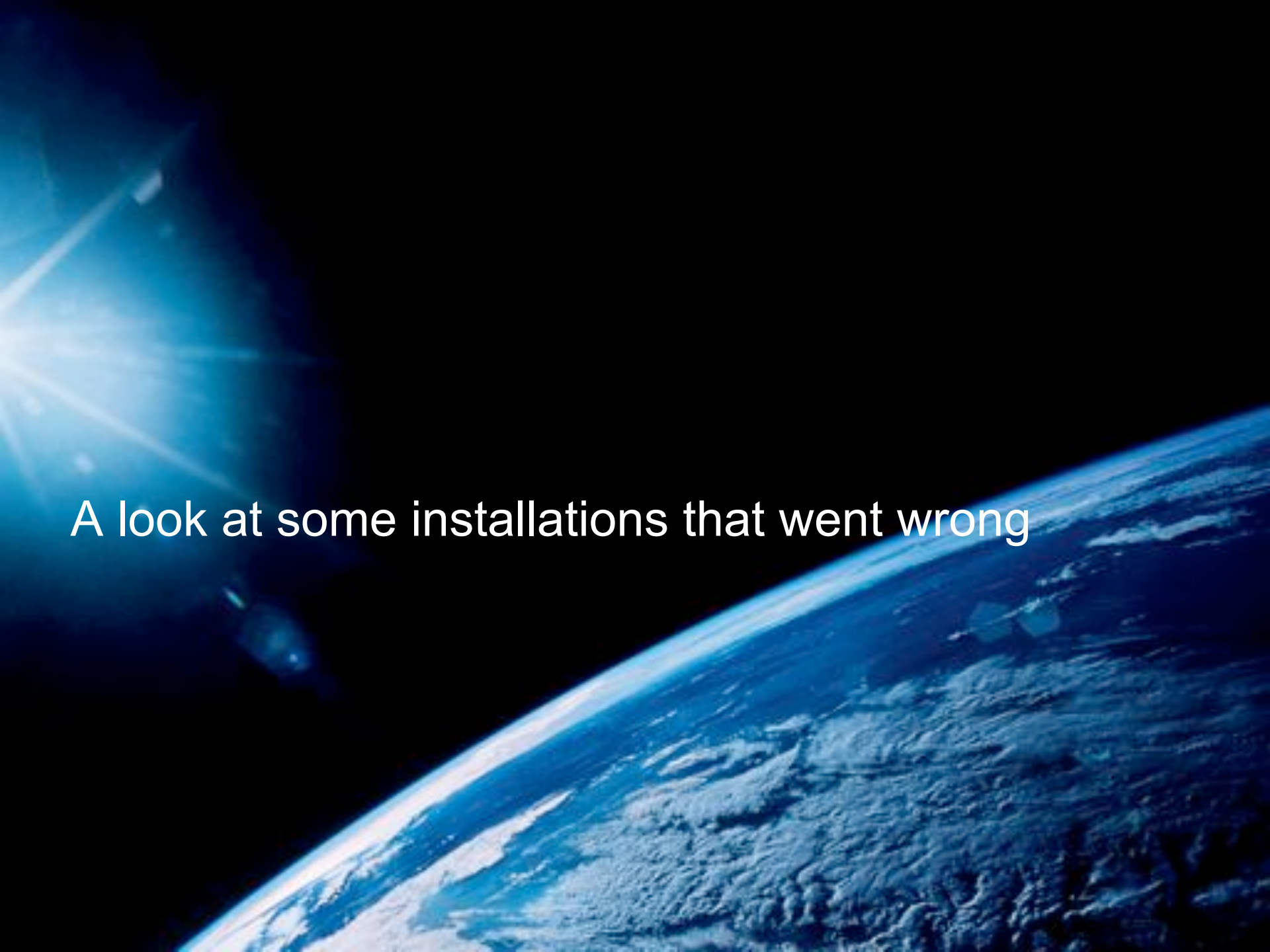
A look at some installations that went wrong

Installations that Went Wrong

NEVER EVER MIX ANTENNA TYPES

same RF cell

watch polarity

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Above ceiling installs that went wrong

Yes it Happens and When it Does it is Expensive to Fix and No One is Happy

Tip: Access Points like light sources should be in the clear and near the users

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Above Ceiling Installs that Went Wrong

Huh?? You Mean it Gets Worse?

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Other Installations that Went Wrong

Ceiling mount AP mounted on the wall up against metal pipe (poor coverage)

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Installations that Went Wrong

Patch antenna shooting across a metal fence
Multipath distortion causing severe retries

Mount the box horizontal and extend the antennas down and not right up against the metal enclosure

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Installations that Went Wrong

Sure is a comfy nest –

Glad this model runs pretty warm

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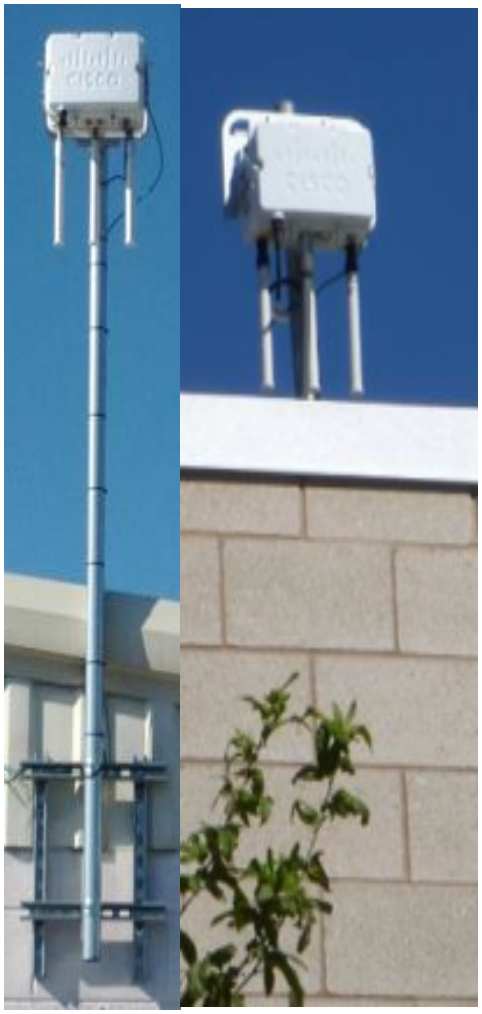
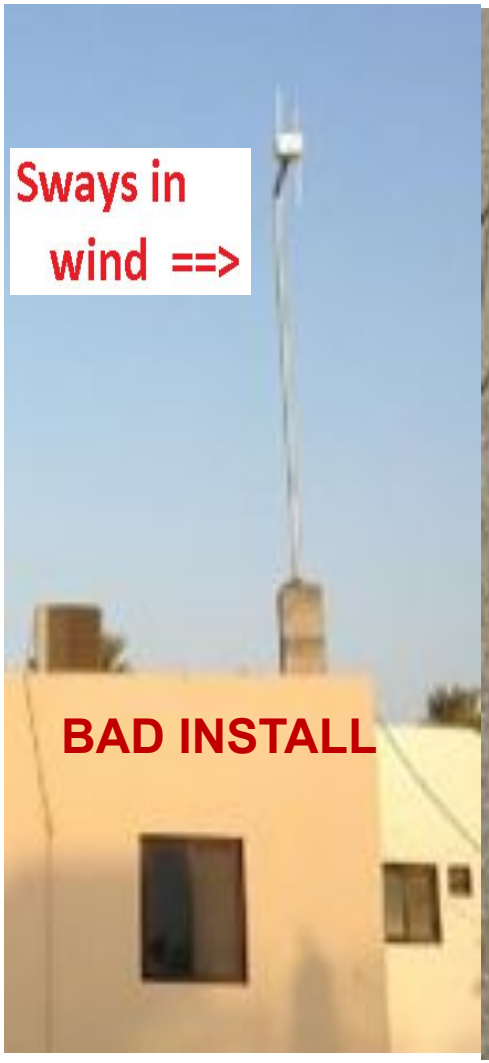
Installations that Went Wrong - Mesh



GOOD INSTALL



BAD INSTALL

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Installations that Went Wrong - Mesh

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Installations that Went Wrong - Mesh

Building aesthetics matters – Antennas obstructed

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Reference slides

Basic 802.11 RF Terminology

Common RF Terms

For Your Reference

- **Attenuation – a loss in force or intensity – As radio waves travel in media such as coaxial cable attenuation occurs.**
- **BER – Bit Error Rate - the fraction of bits transmitted that are received incorrectly.**
- **Channel Bonding – act of combining more than one channel for additional bandwidth**
- **dBd – abbreviation for the gain of an antenna system relative to a dipole**
- **dBi – abbreviation for the gain of an antenna system relative to an isotropic antenna**
- **dBm – decibels milliwatt -- abbreviation for the power ratio in decibels (dB) of the measured power referenced to one milliwatt of transmitted RF power.**
- **Multipath – refers to a reflected signal that combines with a true signal resulting in a weaker or some cases a stronger signal.**
- **mW – milliwatt a unit of power equal to one thousandth of a watt (usually converted to dBm)**
- **Noise Floor – The measure of the signal created from the sum of all the noise sources and unwanted signals appearing at the receiver. This can be adjacent signals, weak signals in the background that don't go away, electrical noise from electromechanical devices etc.**
- **Receiver Sensitivity – The minimum received power needed to successfully decode a radio signal with an acceptable BER. This is usually expressed in a negative number depending on the data rate. For example the AP-1140 Access Point requires an RF strength of at least negative -91 dBm at 1 MB and an even higher strength higher RF power -79 dBm to decode 54 MB**
- **Receiver Noise Figure – The internal noise present in the receiver with no antenna present (thermal noise).**
- **SNR – Signal to Noise Ratio – The ratio of the transmitted power from the AP to the ambient (noise floor) energy present.**

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Installation and Deployment Considerations

Site Survey Prepares for 802.11n

- Recommended to optimize 11n deployment
- Survey reveals effects of building characteristics on the wireless spectrum
- Measure RF variations due to human activity and time of day
- Survey with client types that you plan to implement (11n, 11abg, VoIP, location tags)
- Spectrum intelligence to detect interference

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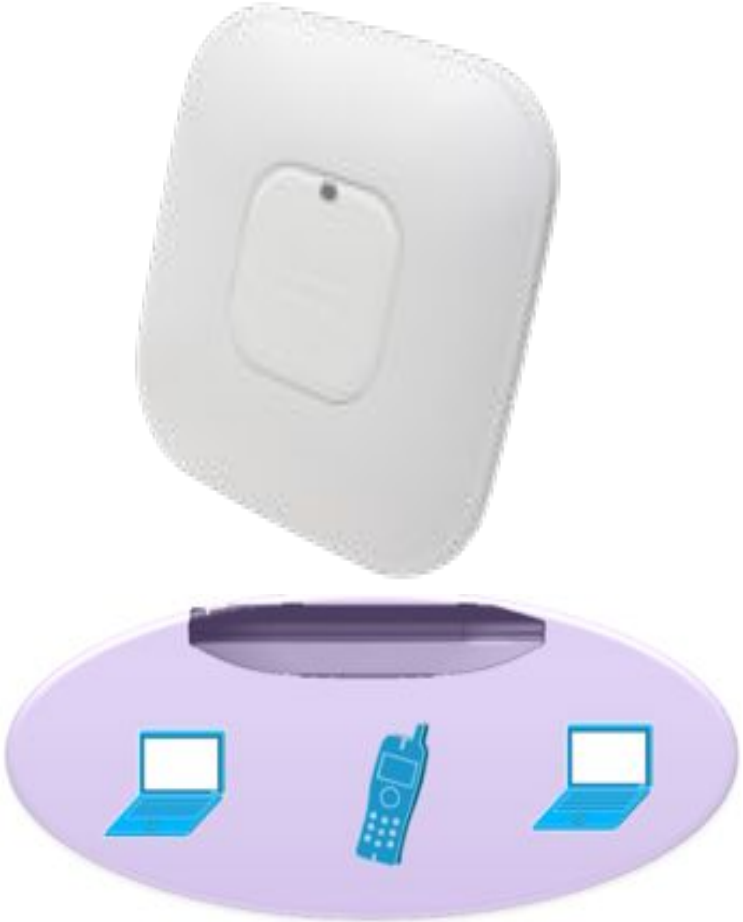
Wall Mounting Access Point with Internal Antennas



Coverage is always more uniform when installed on the ceiling tile or grid area

Note: Wall mounting may create unwanted coverage areas on the floor above or below - This is not desirable for voice as it may cause excessive roams and is directional as metal is behind the antennas (backside).

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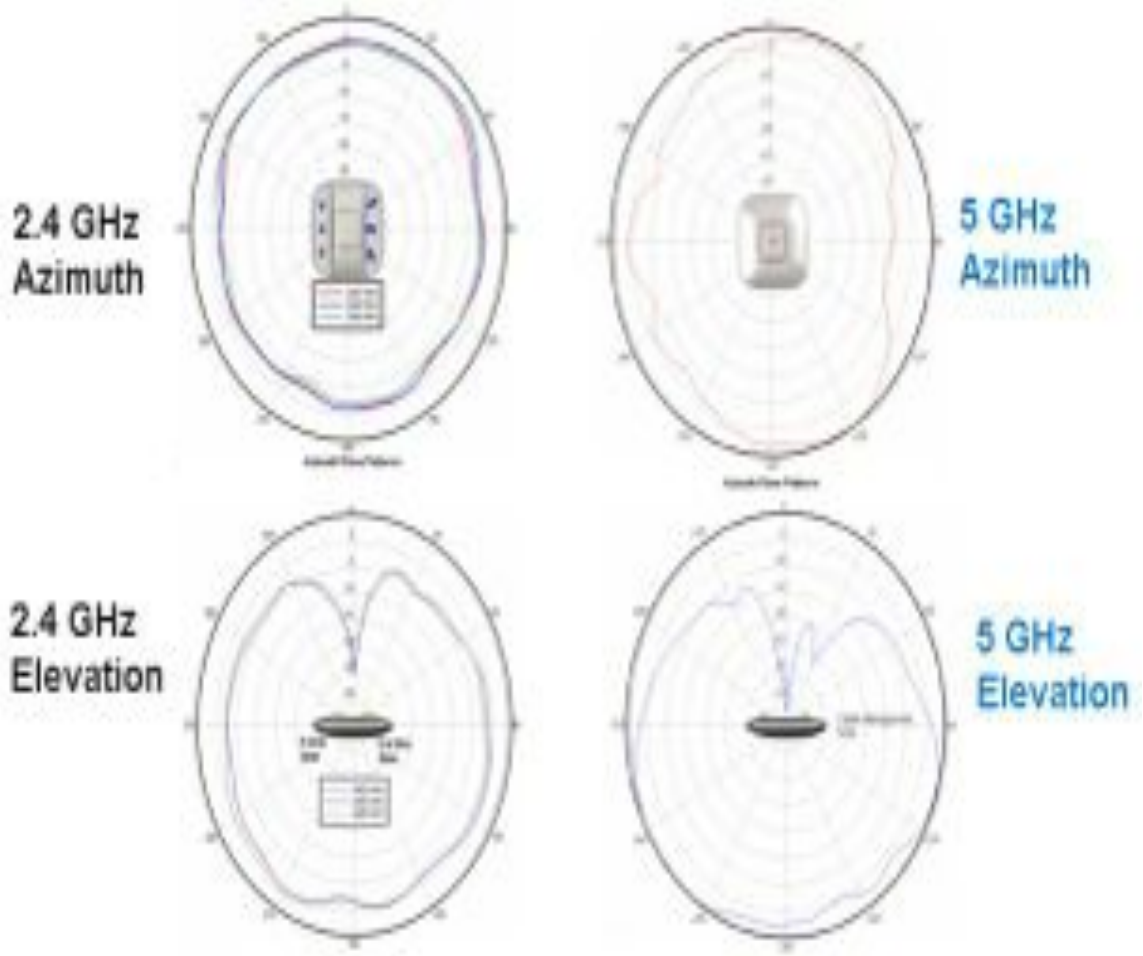
Antenna Patterns – Internal Access Points

Azimuth and Elevation Patterns for 2.4 GHz & 5 GHz



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Access Points 3600 with Module installed

Designed Primarily for Ceiling (carpeted) installations

AP-3600 antenna system with module installed

This shows how the module antennas are extended into the radiation ground plane for best performance

Module antennas (top) extend next to the four dual band integrated antennas

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Wall mounting AP-1260, 3500e & 3600e

Orientation of the Dipoles if Wall Mounting

Note: The ceiling is usually higher and a better location for RF.

If using advanced features like location or voice try to locate the AP on the ceiling, or when mounting the AP on a wall orient the dipoles in this configuration.

Because dipoles on a wall can easily get orientated wrong as people touch and move them. Better still might be to use a Patch antenna or use the Oberon wall bracket. Be aware walls can add directional properties to the signal as they can have wiring, metal 2x4 construction and the wall attenuates the signal behind the AP limiting a nice 360 degree coverage.

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What About Mounting Options?

Different Mounting Options for Ceiling APs

Cisco has options to mount to most ceiling rails and directly into the tile for a more elegant look

Locking enclosures and different color plastic "skins" available from third party sources such as

www.oberonwireless.com

www.terrawave.com

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AP Placement Above False Ceiling Tiles Areas

- **When placing the Access Point above the ceiling tiles (Plenum area) Cisco recommends using rugged Access Points with antennas mounted below the Plenum area whenever possible**
- **Cisco antenna have cables that are plenum rated so the antenna can be placed below the Plenum with cable extending into the plenum**
- **If there is a hard requirement to mount carpeted or rugged Access Points using dipoles above the ceiling – This can be done however uniform RF coverage becomes more challenging, especially if there are metal obstructions in the ceiling**
- **Tip: Try to use rugged Access Points and locate the antennas below the ceiling whenever possible**

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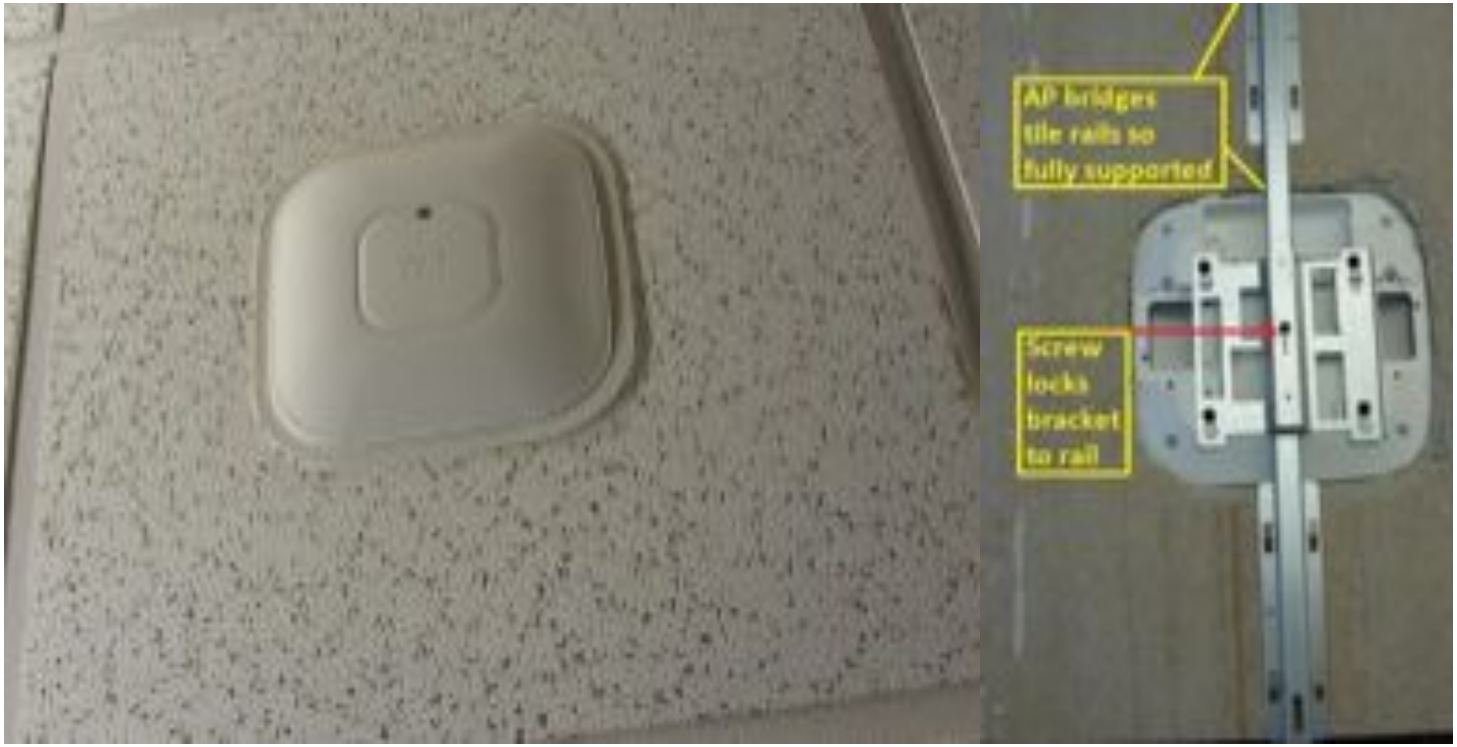
Integrated Ceiling Mount – Public Areas



AIR-AP-BRACKET-3

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Antenna Placement Considerations

- AP antennas need placements that are away from reflective surfaces for best performance
- Avoid metal support beams, lighting and other obstructions.
- When possible or practical to do so, always mount the Access Point (or remote antennas) as close to the actual users as you reasonably can
- Avoid the temptation to hide the Access Point in crawl spaces or areas that compromise the ability to radiate well
- Think of the Access Point as you would a light or sound source, would you really put a light there or a speaker there?

Never mount antennas near metal objects as it causes increased multipath and directionality

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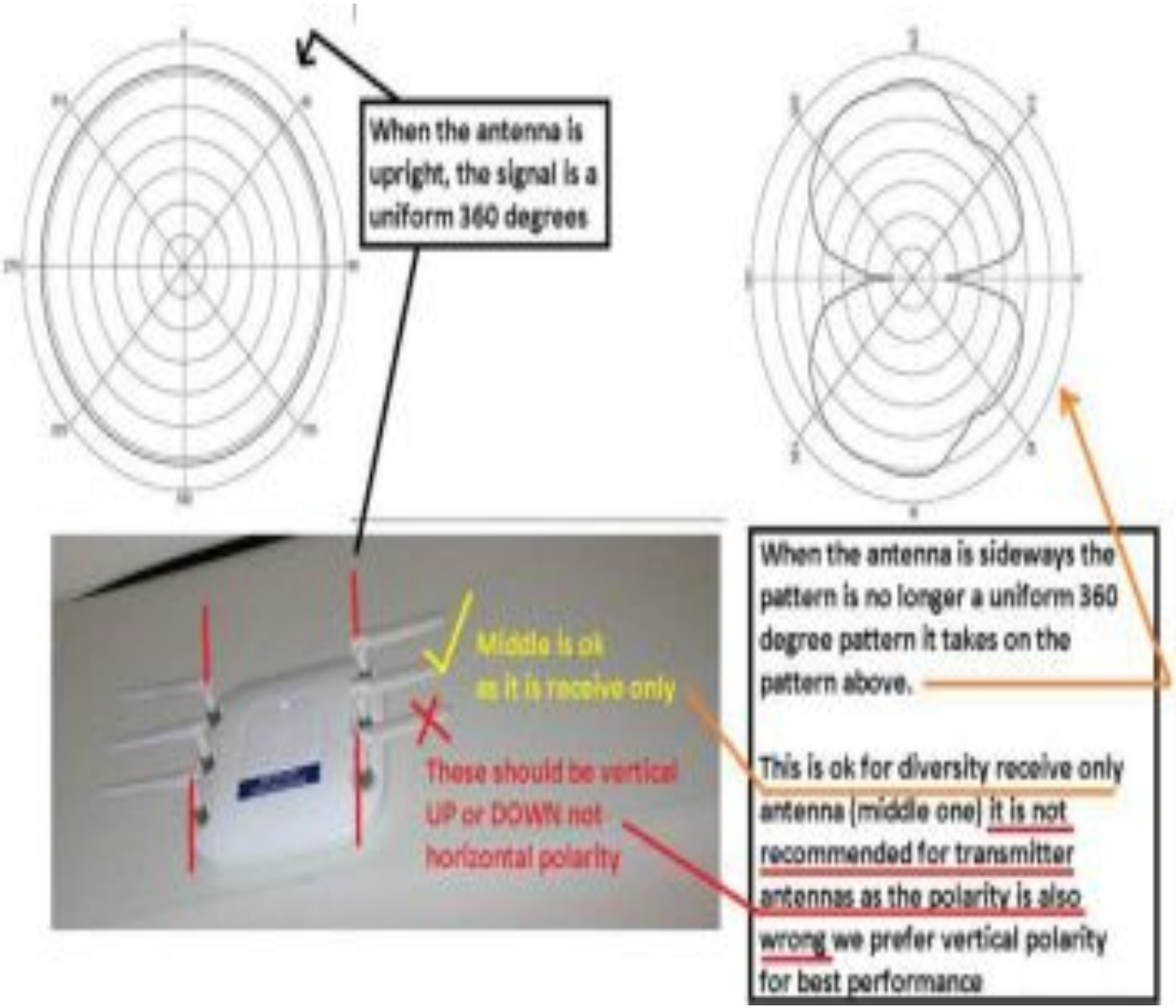
Wall Mounting AP-1260e, 3500e & 3600e

Orientation of the Dipoles if Wall Mounting



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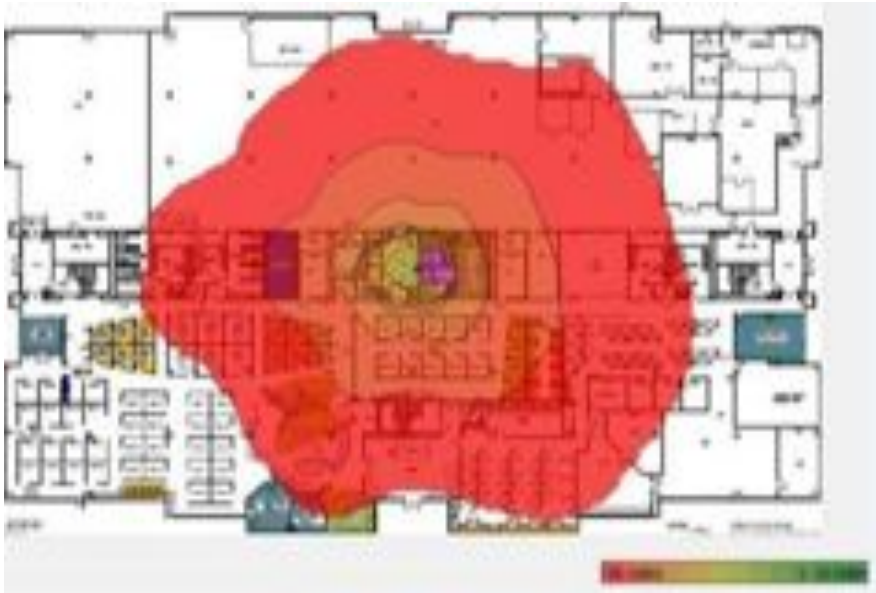
Wall Mounting AP-1260e, 3500e & 3600e

Orientation of the Dipoles if Wall Mounting



vertical polarity

horizontal polarity

Note: Cisco recommends transmitting antennas use vertical polarity

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Example: Warehouse Design

As Stock Levels Change so Does Coverage

You can suspend an AP from the ceiling or use patch or Yagi on walls

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Example: Warehouse Design

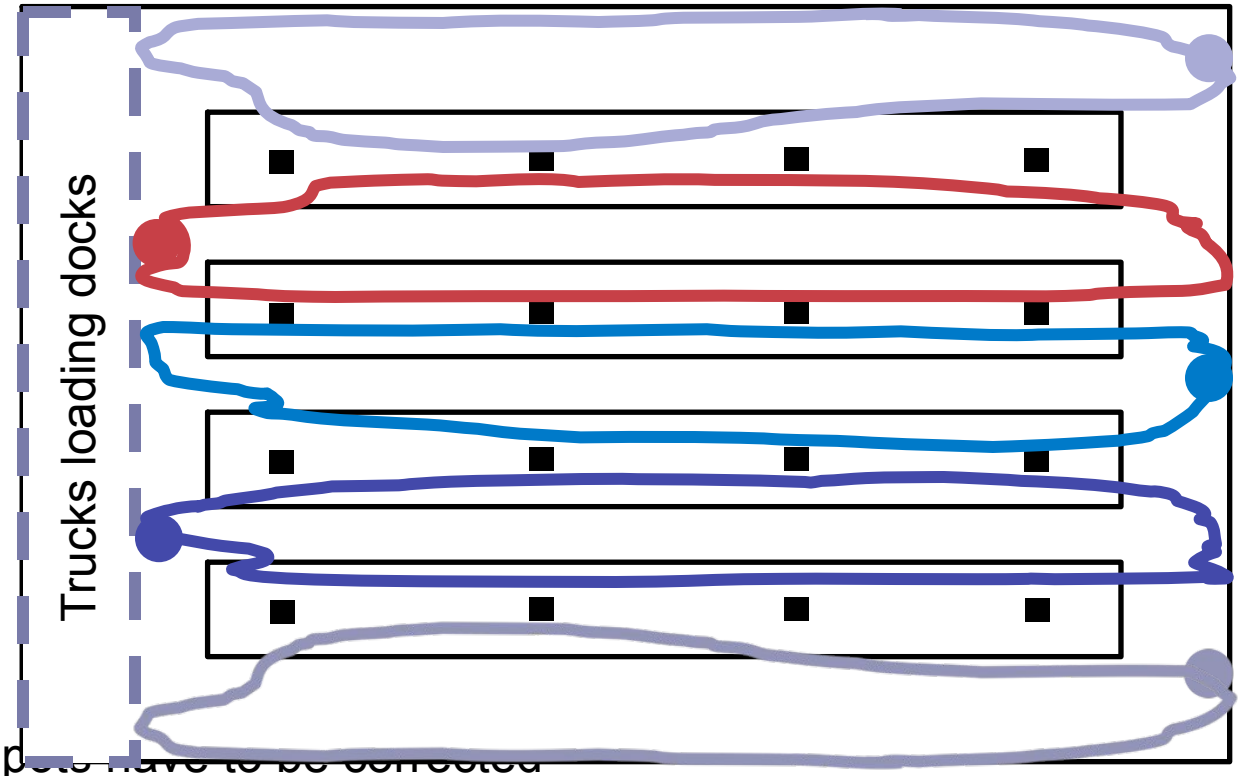
As Stock Levels Change so Does Coverage

Maximum Tx power

Patch or Yagi antennas

Easy power

Easy Ethernet drop



Null sp[illegible]

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Example: Warehouse Design

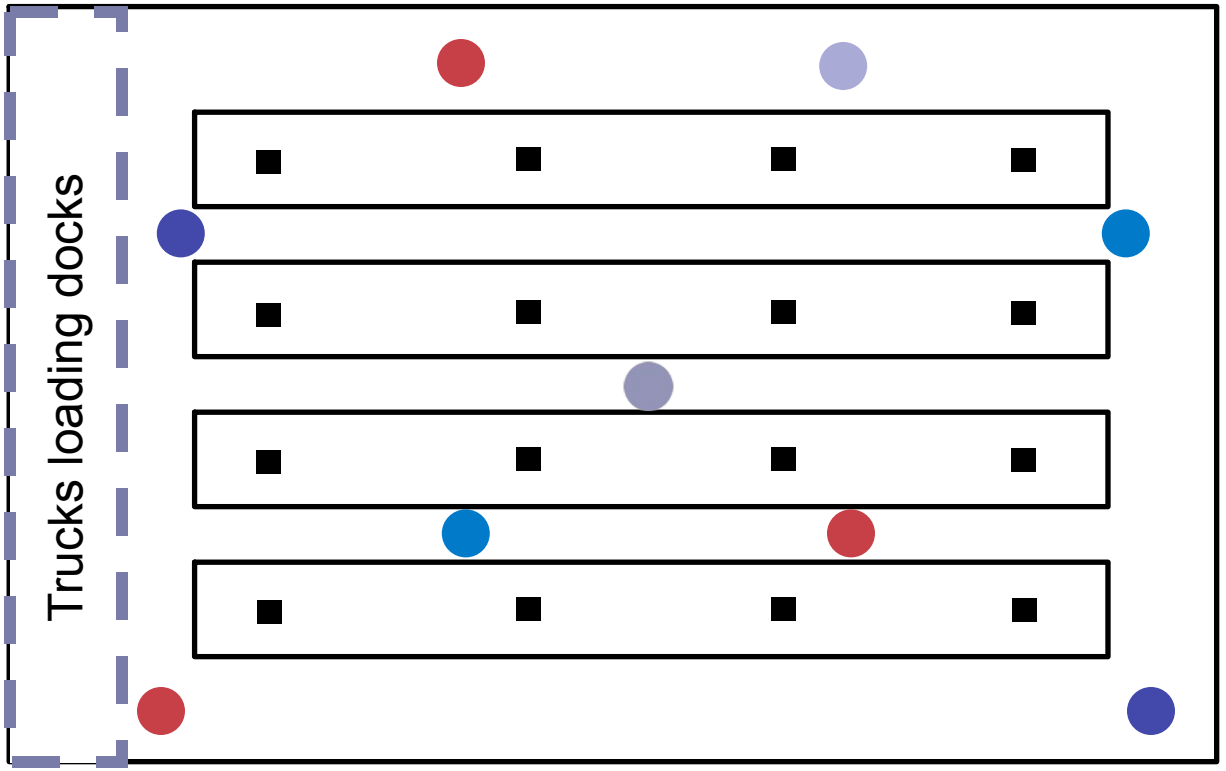
As Stock Levels Change so Does Coverage

Reduced Tx power (RRM)

Omni directional antennas

More APs (+ power drops)

AP wire distance to nearest switch



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