

Cisco Aironet Antennas

Overview

Executive Overview

This antenna reference guide is intended to provide information to assist in understanding the issues and concerns of antennas used with a Cisco Aironet® Wireless LAN system, or Wireless Bridge system. It details deployment and design, limitations, and capabilities, and basic theories of antennas. This document also contains information on the Cisco antennas and accessories as well as installation scenarios, regulatory information, and technical specifications and diagrams of the available antennas.

Overview of Antennas

Each Cisco Aironet radio product is designed to perform in a variety of environments. Implementing the antenna system can greatly improve coverage and performance. To optimize the overall performance of a Cisco wireless LAN, it is important to understand how to maximize radio coverage with the appropriate antenna selection and placement. An antenna system comprises numerous components, including the antenna, mounting hardware, connectors, antenna cabling, and in some cases, a lightning arrester. For additional consultation, please contact your authorized Cisco Aironet partner. Cisco Partners can provide onsite engineering assistance for complex requirements.





Radio Technologies

In the mid 1980s, the FCC modified Part 15 of the radio spectrum regulation, which governs unlicensed devices. The modification-authorized wireless network products to operate in the Industrial, Scientific, and Medical (ISM) bands using spread spectrum modulation. This type of modulation had formerly been classified and permitted only in military products. The ISM frequencies are in three different bands, located at 900 MHz, 2.4 GHz, and 5 GHz. This document covers only the 2.4GHz band.

The ISM bands typically allow users to operate wireless products without requiring specific licenses, but this will vary in some countries. In the U.S., there is no requirement for FCC licenses. The products themselves must meet certain requirements to be certified for sale, such as operation under 1 watt transmitter output power (in the U.S.) and maximum antenna gain or EIRP ratings.

Radio Frequency Fundamentals

Radio Frequency (RF) engineering is a very complex field of study and far too involved to explain in detail here.

2.4GHz Spectrum

The Cisco Aironet 350 Series uses RF spectrum in the 2.4 GHz unlicensed ISM band. In the U.S., three bands are defined as unlicensed and known as the ISM bands (Industrial, Scientific, and Medical). The ISM bands are as follows:

- 900 MHz (902-928MHz)
- 2.4 GHz (2.4 - 2.4835 GHz)—IEEE 802.11b
- 5 GHz (5.15-5.35 and 5.725-5.825 GHz)—IEEE 802.11a, HIPERLAN/1 and HIPERLAN/2. This band is also known as the UNII band.

Each range has different characteristics. The lower frequencies exhibit better range, but with limited bandwidth and hence lower data rates. The higher frequencies have less range and subject to greater attenuation from solid objects.

Direct Sequence Spread Spectrum

The Direct Sequence (DS) Spread Spectrum approach involves encoding redundant information into the RF signal. Every data bit is expanded to a string of chips called a chipping sequence or Barker sequence. The chipping rate as mandated by the U.S. FCC is 10 chips at the 1 and 2 Mbps rates and 8 chips at the 11 Mbps rate. So, at 11 Mbps, 8 bits are transmitted for every one bit of data. The chipping sequence is transmitted in parallel across the spread spectrum frequency channel.

Frequency Hopping Spread Spectrum

Frequency Hopping (FH) Spread Spectrum uses a radio that moves or hops from one frequency to another at predetermined times and channels. The regulations require that the maximum time spent on any one channel is 400mS. For the 1- and 2-Mb FH systems, the hopping pattern must include 75 different channels, and must use every channel before reusing any one. For the Wide Band Frequency Hopping (WBFH) systems, that permit up to 10-Mb data rates, the rules require use of at least 15 channels, and they cannot overlap. With only 83MHz of spectrum, it limits the systems to 15 channels, thereby causing scalability issues.

In every case, for the same transmitter power and antennas, a DS system will have greater range, scalability and throughput than an FH system. For this reason Cisco has chosen to support only DS systems in the Spread Spectrum products.



Antenna Properties and Ratings

An antenna gives the wireless system three fundamental properties—gain, direction, and polarization. Gain is a measure of increase in power. Direction is the shape of the transmission pattern. The good analogy for an antenna is the reflector in a flashlight. The reflector concentrates and intensifies the light beam in a particular direction similar to what a parabolic dish antenna would do to a RF source in a radio system.

Antennas are rated in comparison to *isotropic* or *dipole* antennas. An isotropic antenna is a theoretical antenna with a uniform three-dimensional radiation pattern (similar to a light bulb with no reflector). dBi is used to compare the power level of a given antenna to the theoretical isotropic antenna. The FCC in the U.S. uses dBi in its calculations. An isotropic antenna is said to have a power rating of 0 dB, for example, zero gain/loss when compared to itself.

Unlike isotropic antennas, dipole antennas are real antennas (dipole antennas are standard on Aironet Access Points, Base Stations and Workgroup Bridges). Dipole antennas have a different radiation pattern compared to isotropic antennas. The dipole radiation pattern is 360 degrees in the horizontal plane and 75 degrees in the vertical plane (assuming the dipole antenna is standing vertically) and resembles a donut in shape. Because the beam is “slightly” concentrated, dipole antennas have a gain over isotropic antennas of 2.14 dB in the horizontal plane. Dipole antennas are said to have a gain of 2.14 dBi (in comparison to an isotropic antenna).

Some antennas are rated in comparison to dipole antennas. This is denoted by the suffix dBd. Hence, dipole antennas have a gain of 0 dBd (= 2.14 dBi).

Note that the majority of documentation refers to dipole antennas as having a gain of 2.2 dBi. The actual figure is 2.14 dBi, but is often rounded up.

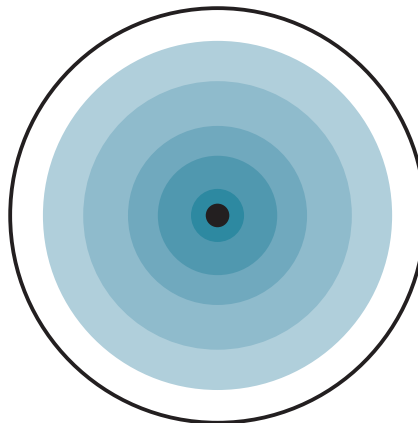
Type of Antennas

Cisco offers several different styles of antennas for use in the 2.4GHz ranges. Every antenna offered for sale has been FCC approved. Each type of antenna will offer different coverage capabilities. As the gain of an antenna increases, there is some tradeoff to its coverage area. Usually gain antennas offer longer coverage distances, but only in a certain direction. The radiation patterns below will help to show the coverage areas of the styles of antennas that Cisco offers, omni-directional, yagis and patch antennas.

Omni-Directional Antennas

An omni-directional antenna is designed to provide a 360 degree radiation pattern. This type of antenna is used when coverage in all directions from the antenna is required. The standard 2.14 dBi “Rubber Duck” is one style of an omni-directional antenna.

Figure 1 Omni-Directional Antenna





Directional Antennas

Directional antennas come in many different styles and shapes. An antenna does not offer any added power to the signal, and instead simply redirects the energy it received from the transmitter. By redirecting this energy, it has the effect of providing more energy in one direction, and less energy in all other directions. As the gain of a directional antenna increases, the angle of radiation usually decreases, providing a greater coverage distance, but with a reduced coverage angle. Directional antennas include yagis, patch antennas, and parabolic dishes. Parabolic dishes have a very narrow RF energy path and the installer must be accurate in aiming these at each other.

Figure 2 Directional Patch Antenna

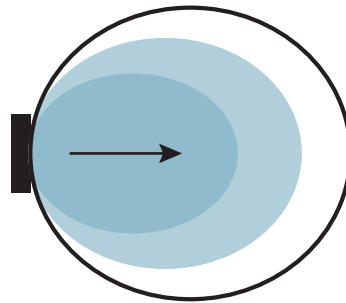
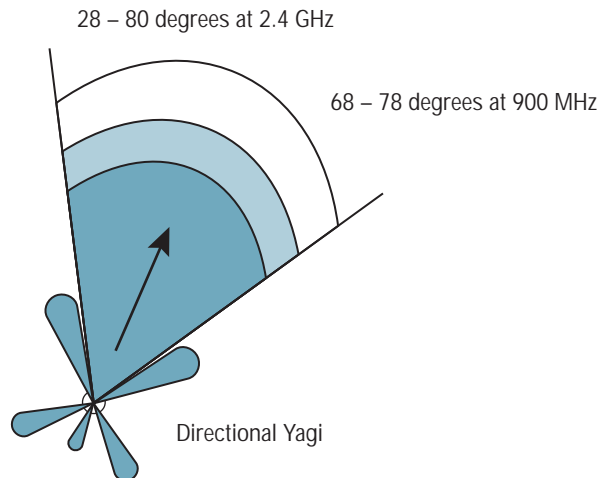


Figure 3 YAGI Antenna



Diversity Antenna Systems

Diversity antenna systems are used to overcome a phenomenon known as multipath distortion of multipath fading. It uses two identical antennas, located a small distance apart, to provide coverage to the same physical area.



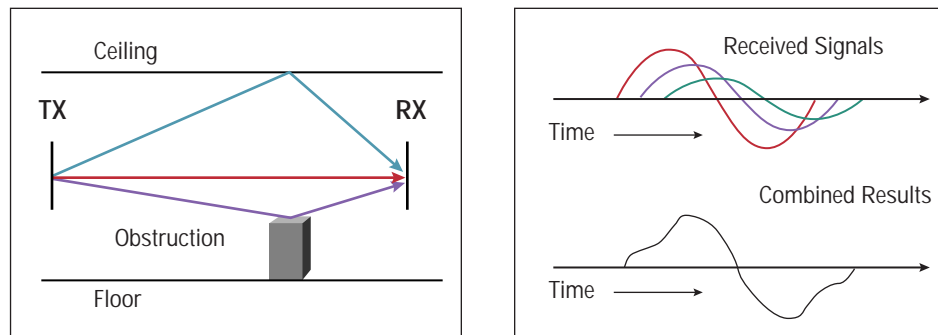
Multipath Distortion

Multipath interference occurs when an RF signal has more than one path between a receiver and a transmitter. This occurs in sites that have a large amount of metallic or other RF reflective surfaces.

Just as light and sound bounce off of objects, so does RF. This means there can be more than one path that RF takes when going from a TX to and RX antenna. These multiple signals combine in the RX antenna and receiver to cause distortion of the signal.

Multipath interference can cause the RF energy of an antenna to be very high, but the data would be unrecoverable. Changing the type of antenna, and location of the antenna can eliminate multipath interference.

Figure 4 Multipath Distortion



You can relate this to a common occurrence in your car. As you pull up to a stop, you may notice static on the radio. But as you move forward a few inches or feet, the station starts to come in more clearly. By rolling forward, you move the antenna slightly, out of the point where the multiple signals converge.

A diversity antenna system can be compared to a switch that selects one antenna or another, never both at the same time. The radio in receive mode will continually switch between antennas listening for a valid radio packet. After the beginning sync of a valid packet is heard, the radio will evaluate the sync signal of the packet, on one antenna, then switch to the other antenna and evaluate. Then the radio will select the best antenna, and use *only* that antenna for the remaining portion of that packet.

On transmit, the radio will select the same antenna it used the last time it communicated to that given radio. If a packet fails, it will switch to the other antenna and retry the packet.

One caution with diversity, it is *not* designed for using two antennas, covering two *different* coverage cells. The problem in using it this way, is that if antenna #1 is communicating to device #1, while device #2 (which is in the antenna #2 cell) tries to communicate, antenna #2 is not connected (due to the position of the switch), and the communication fails. Diversity antennas should cover the same area, from only a slightly different location.

With the introduction of the latest DS physical layer chips, and the use of diversity antenna systems, DS systems have equaled or surpassed FH in areas of how Multipath interference is handled. While the introduction of WBFH does increase the bandwidth of the FH systems, it drastically effects the ability to handle multipath issues, further reducing its range compared to present DS systems in high RF reflective sites.



Wireless LAN Design

Before the physical environment is examined, it is critical to identify the mobility of the application, the means for coverage and system redundancy. An application such as point-to-point which connects two or more stationary users may be best served by a directional antenna, while mobile users will generally require a number of omni-directional micro cells. These individual micro cells can be linked together seamlessly via the wired LAN infrastructure or by using the wireless repeater functionality built into every Cisco Aironet Access Point. All Cisco Aironet Wireless LAN products are designed to support complex multicell environments transparently through the Cisco patented MicroCellular Architecture.

The Physical Environment

Once mobility issues are resolved, the physical environment must be examined. While the area of coverage is the most important determining factor for antenna selection, it is not the sole decision criteria. Building construction, ceiling height, and internal obstructions, available mounting locations and customers aesthetic desires must be considered. Cement and steel construction have different radio propagation characteristics. Internal obstructions such as product inventory and racking in warehousing environments are factors. In outdoor environments, many objects can affect antenna patterns, such as trees, vehicles, buildings, and trains, to name just a few.

The Network Connections

The access points use a 10/100 Mb Ethernet connection. Typically the access point is in the same location as the antenna. While it may seem that the best place to put the access point is in a wiring closet with the other networks components such as switches, hubs and routers, this is not the case. Placement of the antenna in an area that provides the best coverage (determined by a site survey) is required. Therefore many people new to wireless LANs want to locate the access points in the wiring closet and connect the antenna via RF coax. Antenna cable introduces losses in the antenna system on both the transmitter and the receiver. As the length of cable increases, so does the amount of loss introduced. To operate at optimum efficiency, cable runs should be kept as short as possible. (See the section on cabling later in this document).

Building Construction

The density of the materials used in a building's construction determines the number of walls the RF signal can pass through and still maintain adequate coverage. Here are just a few examples. Actual effect on the RF must be tested at the site, and therefore a site survey is suggested.

Paper and vinyl walls have very little affect on signal penetration. Solid walls and floors and pre-cast concrete walls can limit signal penetration to one or two walls without degrading coverage. This may vary widely based any steel reinforcing within the concrete. Concrete and concrete block walls may limit signal penetration to three or four walls. Wood or drywall typically allows for adequate penetration of five or six walls. A thick metal wall causes signals to reflect off, resulting in poor penetration. Steel reinforced concrete flooring will restrict coverage between floors to perhaps one or two floors.

Recommendations for some common installation environments are outlined below:

- *Warehousing/Manufacturing*—In most cases, these installations require a large coverage area. Experience has shown that an omni-directional antenna mounted at about 20 to 25 feet, typically provides the best overall coverage. Of course this will also depend upon the height of the racking, material on the rack and ability to locate the antenna at this height. Mounting the antenna higher will sometimes actually reduce coverage as the angle of radiation from the antenna is more outward than down. The antenna should be placed in the center of the desired coverage cell and in an open area for best performance. In cases where the radio unit will be located against a wall, a directional antenna such as a patch or yagi can be used for better penetration of the area. The coverage angle of the antenna will affect the coverage area.



- *Small Office/Small Retail*—The standard dipole may provide adequate coverage in these areas depending upon the location of the radio device. However, in a back corner office a patch antenna may provide better coverage. It can be mounted to the wall above most obstructions for best performance. Coverage of this type antenna depends upon the surrounding environment.
- *Enterprise/ Large Retail*—In most cases, these installations require a large coverage area. Experience has shown that omni-directional antennas mounted just below the ceiling girders or just below the drop ceiling typically provide the best coverage (this will vary with stocking, type of material and building construction). The antenna should be placed in the center of the desired coverage cell and in an open area for best performance. In cases where the radio unit will be located in a corner, or off to one end of the building a directional antenna such as a patch or yagi can be used for better penetration of the area. Also for areas that are long and narrow, such as long rows of racking, a directional antenna, used at one end may provide better coverage. The radiation angle of the antennas will also affect the coverage area.
- *Point-to-Point*—When connecting two points together (such as an Ethernet bridge), the distance, obstructions, and antenna location must be considered. If the antennas can be mounted indoors and the distance is very short (several hundred feet), the standard dipole or mast mount 5.2 dBi omni-directional may be used. An alternative is to use two patch antennas. For very long distances (1/2 mi. or more) directional high gain antennas must be used. These antennas should be installed as high as possible, and above obstructions such as trees, buildings, and so on; and if the directional antennas are used, they must be aligned so that their main radiated power lobes are directed at each other. With a line-of-site configuration, distances of up to 25 miles at 2.4GHz can be reached using parabolic dish antennas, if a clear line-of-site is maintained. With the use of directional antennas, you are subject to fewer interference possibilities, and less likely to cause interference to anyone else.
- *Point-to-Multipoint Bridge*—In this case (in which a single point is communicating to several remote points) the use of an omni-directional antenna at the main communication point must be considered. The remote sites can use a directional antenna that is directed at the main point antenna.

Cabling

As stated above, cabling introduces losses into the system, negating some of the gain an antenna introduces, and reducing range of the RF coverage.

Interconnect Cable

Attached to all antennas (except the standard dipoles), this cable provides a 50 Ohm impedance to the radio and antenna, with a flexible connection between the two items. It has a high loss factor and should not be used except for very short connections (usually less than 10 feet). Typical length on all antennas is 36" (or 12" on some outdoor antennas).

Low Loss/Ultra Low Loss Cable

This cable provides a much lower loss factor than the interconnect cable, and it is used when the antenna must be placed at any distance from the radio device. While it is a low loss cable, it should still be kept to a minimum length. This cable is the only cable type supplied by Cisco for mounting the antenna away from the radio unit. It is offered in four different lengths with one RTNC plug and one RTNC jack connector attached. This allows for connection to the radio unit and to the interconnect cable supplied on the antennas.

Connectors

Connectors used on equipment manufactured after June 1994 must be unique, nonstandard connectors (per FCC and DOC regulations). Therefore, Cisco Aironet products use a connector known as Reverse-TNC (RTNC) connectors. While they are similar to the normal TNC connectors, they cannot be mated to the standard connectors. To ensure compatibility with Cisco Aironet products, use antennas and cabling from Cisco.



Mounting Hardware

Each antenna requires some type of mounting. The standard dipole antenna simply connects to the RTNC connector on the back of the unit. The 5.2 dBi mast mount omni and the yagi antennas are designed to mount to a mast up to 1.5 inches, and each comes with mounting hardware for attachment. The 13.5 dBi yagi has an articulating mount option listed in the back of this document. For most indoor applications, a .75" or 1" electrical conduit provides a suitable mounting. For outdoor application, a heavy galvanized or aluminum wall mast should be used that will withstand the wind loading rating of the selected antenna. Patch antennas are designed to mount flat against a wall or ceiling. Ceiling mount antennas are equipped with a drop ceiling cross member attachment. The 21 dBi Parabolic Dish mounts to a 1.625" to a 2.375" mast. Fine threaded turnbuckles allow accurate aiming of the antenna.

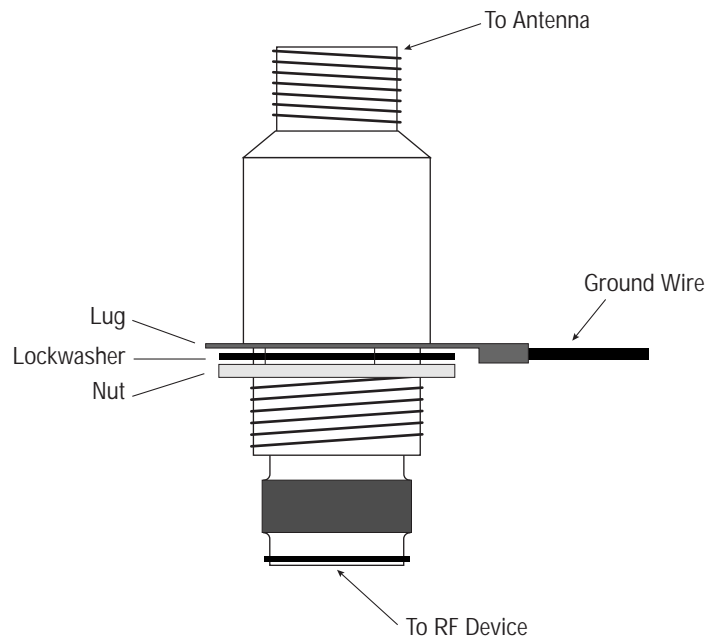
Lightning Arrestors

When using outdoor antenna installations, it is always possible that an antenna will suffer damage from potential charges developing on the antenna and cable, or surges induced from nearby lightning strikes. The Aironet Lightning Arrestor is designed to protect radio equipment from static electricity and lightning induced surges that travel on coaxial transmission lines. It protects equipment from surges up to 5,000 Amperes. This will not prevent damage in the event of a direct lightning hit.

Theory of Operation

The Cisco Aironet Lightning Arrestor prevents energy surges from reaching the RF equipment by the shunting effect of the device. Surges are limited to less than 50 volts, in about .0000001 seconds (100 nano seconds). A typical lightning surge is about .000002 (2 micro seconds).

Figure 5 Cisco Aironet Lightning Arrestor





The accepted IEEE transient (surge) suppression is .000008 seconds (8 micro seconds). The Lightning Arrestor is a 50 ohm transmission line with a gas discharge tube positioned between the center conductor and ground. This gas discharge tube changes from an open circuit to a short circuit almost instantaneously in the presence of voltage and energy surges, providing a path to ground for the energy surge.

Installation

This Arrestor is designed to be installed between your outdoor antenna cable and the Aironet Wireless Device. Installation should be indoors, or inside a protected area. A good ground must be attached to the Arrestor. This can be accomplished by use of a ground lug attached to the Arrestor, and a heavy wire (#6 solid copper) connecting the lug to a good earth ground. See Figure 5.

Understanding RF Power Values

Radio Frequency signals are subject to various losses and gains as they pass from transmitter through cable to antenna, through air (or solid obstruction), to receiving antenna, cable and receiving radio. With the exception of solid obstructions, most of these figures and factors are known and can be used in the design process to determine whether an RF system such as a WLAN will work.

Decibels

The Decibel (dB) scale is a logarithmic scale used to denote the ratio of one power value to another—for example:

- $dB = 10 \log_{10} (\text{Power A}/\text{Power B})$

An increase of 3 dB indicates a doubling (2x) of power. An increase of 6 dB indicates a quadrupling (4x) of power. Conversely, a decrease of 3 dB is a halving (1/2) of power, and a decrease of 6 dB is a quarter (1/4) the power. Some examples are shown below in Table 1.

Table 1 Decibel Values and Corresponding Factors

Increase	Factor	Decrease	Factor
0 dB	1 x (same)	0 dB	1 x (same)
1 dB	1.25 x	-1 dB	0.8 x
3 dB	2 x	-3 dB	0.5 x
6 dB	4 x	-6 dB	0.25 x
10 dB	10 x	-10 dB	0.10 x
12 dB	16 x	-12 dB	0.06 x
20 dB	100 x	-20 dB	0.01 x
30 dB	1000 x	-30 dB	0.001 x
40 dB	10,000 x	-40 dB	0.0001 x



Power Ratings

WLAN equipment is usually specified in decibels compared to known values.

Transmit Power and Receive Sensitivity are specified in “dBm,” where “m” means 1 milliWatt (mW). So, 0 dBm is equal to 1 mW; 3 dBm is equal to 2 mW; 6 dBm is equal to 4 mW, and so on. For example, a Cisco Aironet 350 Series Access Point at 100 mW transmit power is equal to 20 dBm. dBw is occasionally used for the same purpose, but as a comparison against 1 Watt (1000 mW).

Common mW values to dBm values are shown below in Table 2.

Table 2 Common mW Values to dBm Values

dBm	mW	dBm	mW
0 dBm	1 mW ¹	0 dBm	1 mW
1 dBm	1.25 mW	-1 dBm	0.8 mW
3 dBm	2 mW ¹	-3 dBm	0.5 mW
6 dBm	4 mW	-6 dBm	0.25 mW
7 dBm	5 mW ¹	-7 dBm	0.20 mW
10 dBm	10 mW	-10 dBm	0.10 mW
12 dBm	16 mW	-12 dBm	0.06 mW
13 dBm	20 mW ¹	-13 dBm	0.05 mW
15 dBm	32 mW	-15 dBm	0.03 mW
17 dBm	50 mW ¹	-17 dBm	0.02 mW
20 dBm	100 mW ¹	-20 dBm	0.01 mW
30 dBm	1000 mW (1 W)	-30 dBm	0.001 mW
40 dBm	10,000 mW (10 W)	-40 dBm	0.0001 mW

1. The 1, 2, 5, 20, 50, and 100 mW transmit power settings for the Cisco Aironet 350 Series radios correspond to 0, 3, 7, 13, 17, and 20 dBm.

Outdoor Range

The range of a wireless link is dependent upon the maximum allowable path loss. For outdoor links this is a straightforward calculation as long as there is clear line of sight between the two antennas with sufficient clearance for the Fresnel zone.

For line of sight, you should be able to visibly see the remote locations antenna from the main site. (Longer distance may require the use of binoculars). There should be no obstructions between the antennas themselves. This includes trees, buildings, hills, and so on.

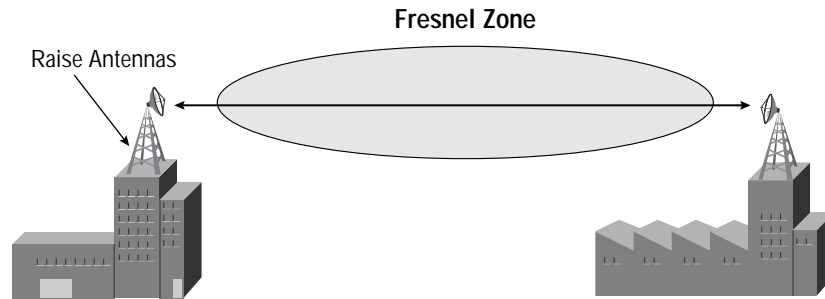
As the distance extends beyond 6 miles, the curve of the earth (commonly called earth bulge) affects installation, requiring antennas to be placed at higher elevations.



Fresnel Zone

Fresnel zone is an elliptical area immediately surrounding the visual path. It varies depending on the length of the signal path and the frequency of the signal. The Fresnel zone can be calculated, and it must be taken into account when designing a wireless link.

Figure 6 Fresnel Zone



Based on both line of sight and Fresnel zone requirements, the following table provides a guideline on height requirements for antennas as various distances. This refers to height above any obstacles located in the middle of the RF path.

Table 3

Wireless Link Distance (miles)	Approx. Value "F" (60% Fresnel Zone) ft. at 2.4 GHz	Approx. Value "C" (Earth Curvature)	Value "H" (mounting Ht.) ft. with no obstructions
1	10	3	13
5	30	5	35
10	44	13	57
15	55	28	83
20	65	50	115
25	72	78	150

Cisco.com provides an Outdoor Bridge Range Calculation Utility that calculates the Fresnel zone and maximum range based upon cable types and lengths; transmitter and receiver models; and antennas. The utility can be found at:

<http://www.cisco.com/go/aironet/calculation>.

Note that as path loss increases and distance decreases with frequency, these distances are only applicable to the 2.4 GHz band. A 10dB fade margin is included for dependable communications in all weather conditions. The distances given are only theoretical and should only be used to determine the feasibility of a particular design.

Outdoors, every increase of 6 dB will double the distance. Every decrease of 6 dB will halve the distance. Shorter cable runs and higher gain antennas can make a significant difference to the range.



Regulations

North America

- **Connectors**—In 1985, the FCC enacted standards for the commercial use of spread spectrum technology in the ISM frequency bands. Spread spectrum is currently allowed in the 900, 2400, and 5200 MHz bands. In 1989, the FCC drafted an amendment governing spread spectrum systems in the unlicensed ISM band. This amendment is commonly referred to as the “new” or “’94” rules because it impacts all spread spectrum products manufactured after June 23, 1994. Products manufactured before June 23 are not affected by the amendment. Congress enacted this amendment into law in 1990. The FCC 1994 rules are intended to discourage use of amplifiers, high-gain antennas or other means of significantly increasing RF radiation. The rules are further intended to discourage “home brew” systems which are installed by inexperienced users and which-either accidentally or intentionally-do not comply with FCC regulations for use in the ISM band. Both the original rules and the amendments sought to enable multiple RF networks to “coexist” with minimum impact on one another by exploiting properties of spread spectrum technology. Fundamentally, the FCC 1994 rules intend to limit RF communications in the ISM band to a well defined region, while ensuring multiple systems can operate with minimum impact on one another. These two needs are addressed by limiting the type and gain of antennas used with a given system, and by requiring a greater degree of RF energy “spreading.”
- **Antenna Gain and Power Output**—FCC regulations specify maximum power output and antenna gain. At 2.4GHz the maximum transmitter power is 1watt, or 30dBm. Using this maximum power, the maximum antenna gain is 6dBi. However, the regulations also define the maximum values in regards to the following two different system scenarios.

In Point-to-Multipoint systems, the FCC has limited the maximum EIRP (effective isotropic radiated power) to 36dBm. $EIRP = TX\ power + antenna\ gain$. For every dB that the transmitter power is reduced, the antenna may be increased by 1dB. (29dBm TX, +7dB antenna = 36dBm EIRP, 28dBm TX, +8dB antenna = 36dBm EIRP).

The Cisco Aironet Bridge transmitter power is 20dBm, which is 10dBm lower than maximum. This then allows the use of antennas up to 10dB over the initial 6dBi limit, or 16dBi.

In Point-to-Point systems for 2.4GHz systems, using directional antennas, the rules have changed. Because a high gain antenna has a narrow beamwidth, and therefore the likelihood is high that it will cause interference to other area users. Under the rule change, for every dB the transmitter is reduced below 30dBm, the antenna may be increased from the initial 6dBi, by 3dB. (29dB Transmitter means 9dBi antenna, 28dB transmitter means 12dBi antenna). Because we are operating at 20dBm, which is 10dB below the 30dBm level, we can increase the out antenna by 30dB. However Cisco has never tested, and therefore is not certified with any antenna larger than 21dBi.

The main issue concerns what components comprise a point-to-point and multipoint system.

In Figure 7, Point A communicates to a single point, B, and Point B communicates to a single point A. Therefore it is simple to see that both locations see this as a point to point installation.

In Figure 8, Point A communicates to more than one, or multiple points. Therefore Point A is operating in a multipoint configuration, and the largest antenna permitted is 16dBi. Point B or Point C can each communicate to only one point, (Point A). Therefore Point B and Point C actually operate in a single point or point-to-point operation, and a larger antenna may be used.

Figure 7 Point-to-Point Wireless Bridge Solution

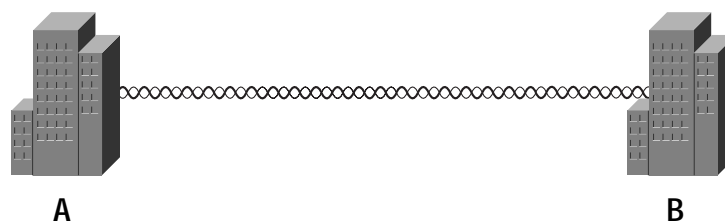
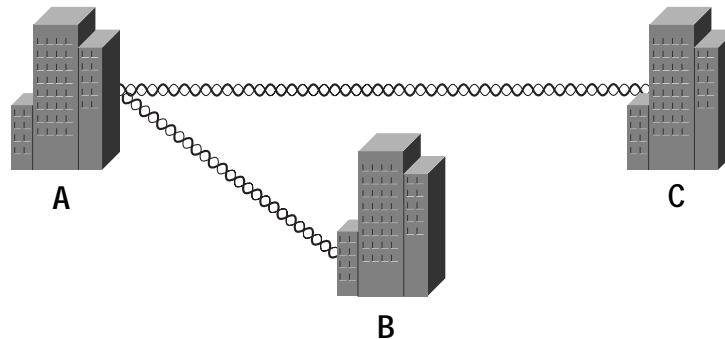




Figure 8 Point-to-Multipoint Wireless Bridge Solution



- **Amplifiers**—The FCC rules Section 15.204-Part C states “External radio frequency power amplifiers shall not be marketed as separate products...” Part D states “Only the antenna with which an intentional radiator (transmitter) is originally authorized may be used with the intentional radiator.” This means that unless the amplifier manufacturer submits the amplifier for testing *with* the radio and antenna, it cannot be sold in the US. If it has been certified, then it must be marketed and sold as a complete system including transmitter, antenna, and coax. It also must be installed exactly this way.

If using a system that includes an amplifier, remember that the above rules concerning power are still in effect. If the amplifier is 1/2 watt (27dBm) this means in a multipoint system the maximum antenna gain is only 9dBi, and in a point-to-point system, it is only 15dBi.

ETSI

The European Telecommunication Standardization Institute has developed standards that have been adopted by many European countries as well as many others. Under the ETSI regulations, the power output and EIRP regulations are much different than in the US.

- **Antenna Gain and Power Output**—The ETSI regulations specify maximum EIRP as 20dBm. Since this includes antenna gain, this limits the antennas that can be used with a transmitter. To use a larger antenna, the transmitter power must be reduced, so that the overall gain of the transmitter, plus the antenna gain less any losses in coax is equal to or less than +20dBm. This drastically reduces the overall distance an outdoor link can operate.
- **Amplifiers**—Since the ETSI regulation has such a low EIRP the use of amplifiers are typically not permitted in any ETSI system.

Frequencies and Channels Sets

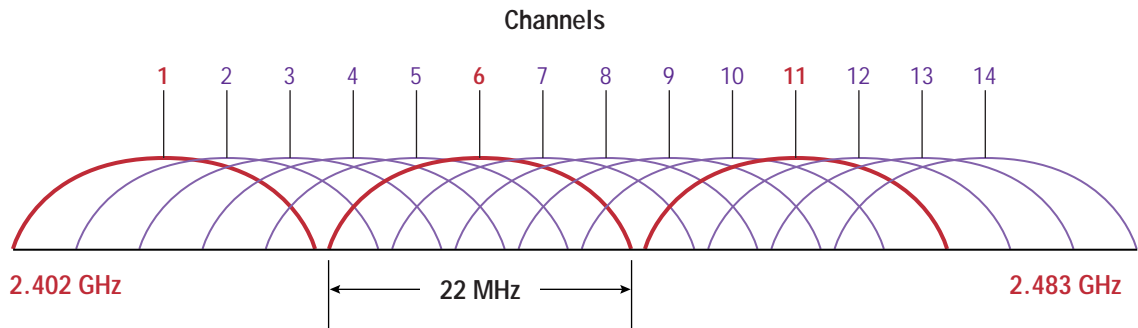
IEEE 802.11b Direct Sequence Channels

Fourteen channels are defined in the IEEE 802.11b Direct Sequence (DS) channel set. Each DS channel as transmitted is 22 MHz wide, however the channel center separation is only 5 MHz. This leads to channel overlap such that signals from neighboring channels can interfere with each other. In a 14-channel DS system (11 usable in the US), only three non-overlapping (and hence, non-interfering) channels, 25 MHz apart are possible (for example, Channels 1, 6, and 11).

This channel spacing governs the use and allocation of channels in a multi-access points environment such as an office or campus. Access points are usually deployed in “cellular” fashion within an enterprise where adjacent access points are allocated non-overlapping channels. Alternatively, access points can be collocated using Channels 1, 6, and 11 to deliver 33 Mbps bandwidth to a single area (but only 11 Mbps to a single client). The channel allocation scheme is illustrated in Figure 9.



Figure 9 IEEE 802.11b DSSS Channel Allocations



Below is a chart that exhibits the channels permitted in the corresponding approval areas.

Table 4 DSSS PHY Frequency Channel Plan

Channel	Frequency (MHz)	Regulatory Domain			
		Americas (-A)	EMEA (-E)	Israel (-I)	Japan (-J)
1	2412	X	X	-	X
2	2417	X	X	-	X
3	2422	X	X	X	X
4	2427	X	X	X	X
5	2432	X	X	X	X
6	2437	X	X	X	X
7	2442	X	X	X	X
8	2447	X	X	X	X
9	2452	X	X	X	X
10	2457	X	X	-	X
11	2462	X	X	-	X
12	2467	-	X	-	X
13	2472	-	X	-	X
14	2484	-	-	-	X



Cisco Antennas

Cisco Part Number	Antenna Type	Description	Gain
AIR-ANT3351	Diversity Omni	POS diversity dipoles for use with LMC radio cards with two MMCX connectors—This antenna contains two standard 2.2 dBi “rubber duck” and 36" of cable with two MMCX connectors. It has a platform with a adhesive backing to raise the antennas above obstructions.	2.2dBi
AIR-ANT5959	Diversity Omni	Ceiling mount diversity Indoor antenna with RP-TNC—This antenna was designed for WLAN applications for frequencies of 2400 to 2500 MHz. The antenna is omni directional and has a nominal gain of 2.2 dBi. Its low profile allows it to remain unnoticed in the ceiling. It comes with a clip that permits it to be mounted to a drop ceiling cross member.	2.0
AIR-ANT2012	Diversity Patch	Wall mount indoor/outdoor antenna with two RP-TNC—Similar to the above patch, but providing diversity antennas in the same package for areas where multipath problems exist.	6dBi
AIR-ANT3213	Diversity Omni	Pillar mount diversity, indoor antenna with two RP-TNC—Cosmetic antenna ideal for retail or hospital environment. Includes 36" of white RG58 cable with a separation of Siamese co-ax of 10". Has a tan cloth covering, in a 12 x 5 rectangle. Included are two mounting brackets that will keep the antenna 6 inches off of the wall.	5.2dBi
AIR-ANT1728	Omni	Ceiling mount indoor antenna with RP-TNC connector—This antenna was designed for WLAN applications for frequencies of 2400 MHz to 2500 MHz. The antenna is omni directional and has a nominal gain of 5.2 dBi. It comes with a clip that allows it to be mounted to a drop ceiling cross member.	5.2dBi
AIR-ANT4941	Omni-directional	Single dipole antenna with an RP-TNC connector. The antenna provides indoor omni-directional coverage and is for use in the 2400-2500 MHz frequency band. It has a 90' articulation radius. It is for use with all radios that utilize an RP-TNC antenna connector.	2.2 dBi
AIR-ANT3549	Patch	Wall mount indoor/outdoor antenna with RP-TNC—Special type of antenna unique to data transmission is the patch antenna. This works well and fits aesthetically into most work environments. Mechanically they are small rectangles about 1/2 inch thick. They are designed to mount flat to a wall and seem to disappear into the wall in most environments. The radiation pattern is in the shape of a hemisphere. A typical application would be for coverage of an area where the transmitter is located on the side of the coverage area. Good for both indoor and outdoor use.	8.5dBi
AIR-ANT1729	Directional	Wall mount, indoor/outdoor directional patch antenna. Designed for use with any radio that features an RP-TNC antenna connector. For use in the 2400-2500 MHz frequency band. The pigtail cable is 30" long.	6.0 dBi
AIR-ANT2506	Omni	Mast mount indoor/outdoor antenna with RP-TNC—This antenna was designed for WLAN applications for frequencies of 2400 MHz to 2500 MHz. The antenna is omni directional and has a nominal gain of 5.2 dBi. It is designed to be mounted on a round mast.	5.2dBi
AIR-ANT4121	Omni	Mast mount outdoor high gain antenna with RP-TNC—This antenna was designed for WLAN applications for frequencies of 2400 MHz to 2500 MHz. The antenna is omni directional and has a nominal gain of 12 dBi. This design uses an elevated center-feed to produce an elevation pattern with very little “squint” or beam-tilt. It is designed to be mounted on a round mast.	12dBi



Cisco Part Number	Antenna Type	Description	Gain
AIR-ANT1949	Yagi	High gain outdoor directional antenna with RP-TNC—This WLAN antenna is a completely enclosed 16 element yagi. It is designed to be used as a bridge antenna between two networks or for point-to-point communications. It has a nominal VSWR of 1.5:1 and is less than 2:1 over the entire frequency band. The gain is 13.5 dBi and the half-power beamwidth is 30 degrees. This antenna is normally mounted on a mast and is vertically polarized.	13.5dBi
AIR-ANT3338	Dish	Very high gain outdoor antenna with RP-TNC—This WLAN antenna is a parabolic dish designed to be used as a bridge antenna between two networks or for point-to-point communications. It consists of an aluminum parabolic reflector and feed antenna. The antenna features a rugged mount. It also offers 20 degree fine adjustment for both horizontal and vertical planes. The antenna is provided with hardware for mast mounting.	21dBi

Cisco Cables

Table 5 Cisco Cables

Cisco Part Number	Type of Cable	Description	Loss (2.4GHz)
AIR-CAB020LL-R	Interconnect	20 ft. low-loss cable with RP-TNC connectors	1.3 dB
AIR-CAB050LL-R	Interconnect	50 ft. low-loss cable with RP-TNC connectors	3.4 dB
AIR-CAB100ULL-R	Interconnect	100 ft. ultra-low-loss cable with RP-TNC connectors	4.4 dB
AIR-CAB150ULL-R	Interconnect	150 ft. ultra-low-loss cable with RP-TNC connectors	6.6 dB
AIR-420-002537-060	Bulkhead	60" RG58 type cable with RP-TNC connectors	2dB

Table 6 Accessories

Cisco Part Number	Name	Description
AIR-ACC2662	Yagi Articulating Mount	This mount permits the yagi antenna to be mounted to a flat surface or a mast, and then be adjusted in both horizontal and vertical angles.
AIR-ACC3354	Lightning Arrestor	Provides lightning and related energy surges at the antenna from reaching the radio circuitry. A ground ring is included.

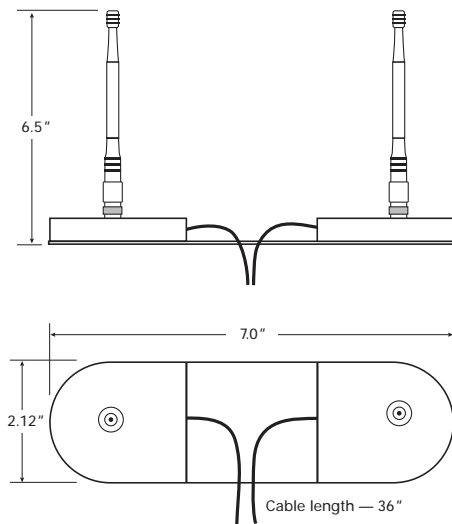


2.2dBi POS Diversity Dipole
for use with LMC cards

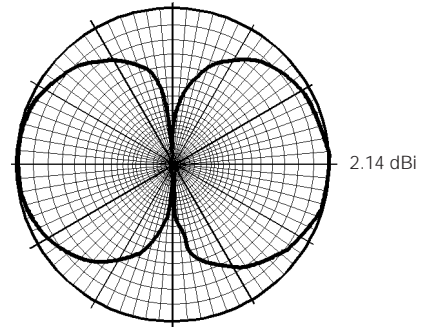
AIR-ANT3351



Dimensions and Mounting Specifications



Vertical Radiation



Frequency Range	2.4-2.483GHz
VSWR	Less than 2:1
Gain	2.14 dBi
Polarization	Linear
Azimuth 3dB BW	Omni directional
Elevations 3dB BW	80 degrees
Antenna Connector	MMCX (2)
Dimensions (H x W x D)	6.5 x 7.0 x 2.12 in.

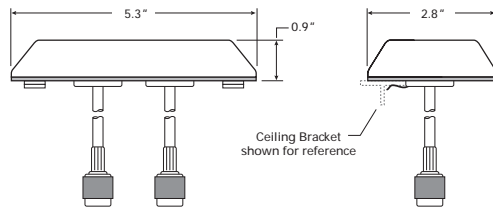


2.0dBi Diversity Ceiling Mount Patch

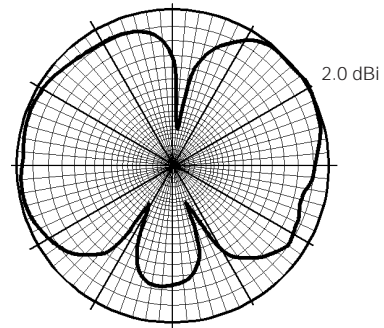
AIR-ANT5959



Dimensions and Mounting Specifications



Vertical Radiation



Frequency Range	2.4-2.5GHz
VSWR	1.7:1
Power	5 watts
Gain	2dBi
Polarization	Vertical linear
Azimuth 3dB BW	Omni directional
Elevations 3dB BW	80 degrees
Antenna Connector	RP-TNC
Dimensions (H x W x D)	5.3 x 2.8 x 0.9 in.
Mounting	Drop ceiling cross member mount

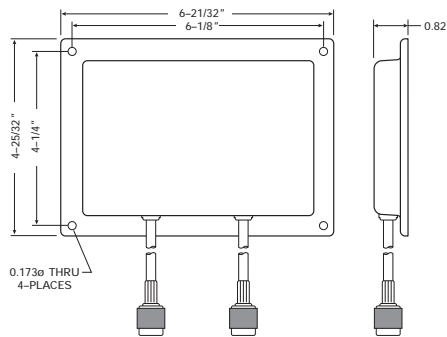


6dBi Diversity Patch

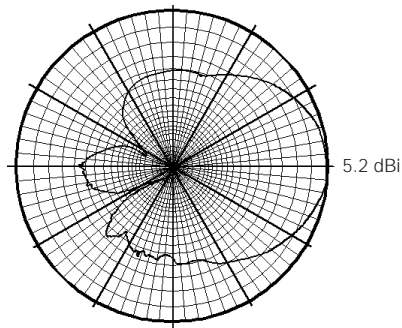
AIR-ANT2012



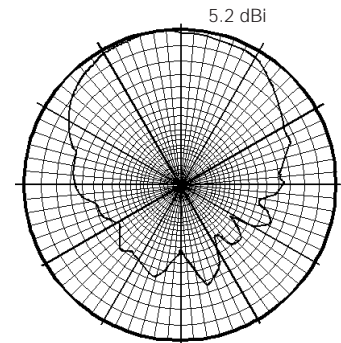
Dimensions and Mounting Specifications



Vertical Radiation



Horizontal Radiation



Frequency Range	2.4-2.5GHz
VSWR	1.7:1 Nominal
Gain	6dBi
Polarization	Vertical
Azimuth 3dB BW	80 degrees
Elevations Plan (3dB BW)	55 degrees
Antenna Connector	RP-TNC
Dimensions (H x W x D)	6.65 x 4.78 x .82 in.
Mounting	Wall mount

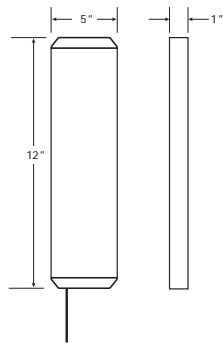


5.2dBi Pillar Mount Diversity Omni

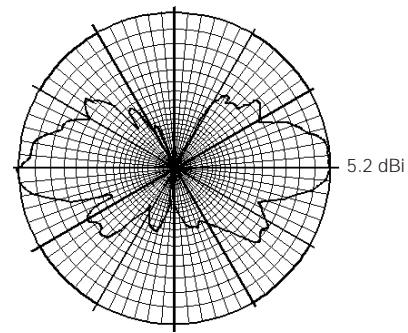
AIR-ANT3213



Dimensions and Mounting Specifications



Vertical Radiation Pattern



Frequency Range	2.4-2.83GHz
VSWR	2:1 Nominal
Gain	5.2dBi
Polarization	Vertical
Azimuth 3dB BW	Omni directional—360 degree
Elevation 3dB BW	25 degrees
Antenna Connector	RP-TNC
Dimensions (H x W x D)	12 x 5 x 1 in.

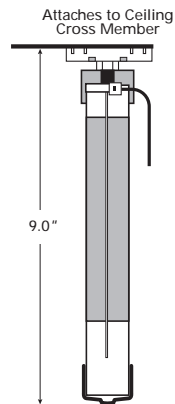


5.2dBi Ceiling Mount Omni

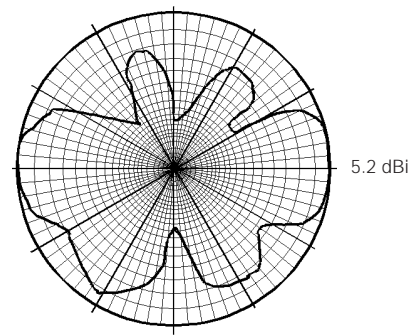
AIR-ANT1728



Dimensions and Mounting Specifications



Vertical Radiation Pattern



Frequency Range	2.4-2.83GHz
VSWR	Less than 2:1, 1.5:1 Nominal
Gain	5.2dBi
Polarization	Vertical
Azimuth 3dB BW	Omni directional 360 degrees
Elevations Plan (3dB BW)	50 degrees
Antenna Connector	RP-TNC
Dimensions (H x W)	9 x 1.25 in.
Mounting	Drop ceiling cross member—indoor only

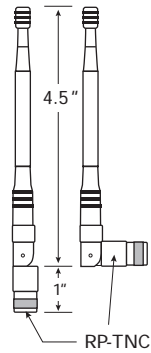


2dBi Standard Dipole

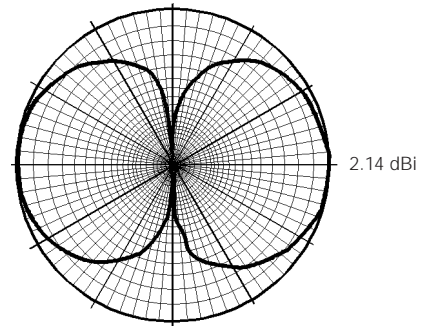
AIR-ANT4941



Dimensions and Mounting Specifications



Vertical Radiation



Frequency Range	2.4-2.484GHz
VSWR	Less than 2:1
Power	5 watts
Gain	2 dBi
Polarization	Linear
Azimuth 3dB BW	Omni directional
Elevations 3dB BW	70 degrees
Antenna Connector	RP-TNC
Dimensions (H x W x D)	See Drawing
Mounting	Wall mount

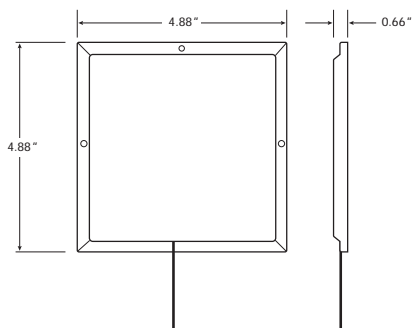


8.5 dBi Patch

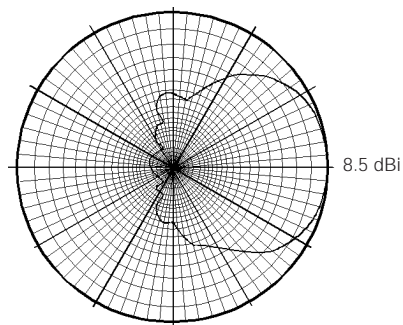
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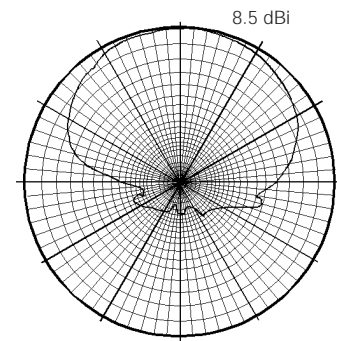
Dimensions and Mounting Specifications



Vertical Radiation



Horizontal Radiation



Frequency Range	2.4-2.5GHz
VSWR	2:1 Max, 1.5:1 Nominal
Gain	8.5dBi
Polarization	Vertical
Azimuth 3dB BW	60 degrees
Elevations 3dB BW	55 degrees
Antenna Connector	RP-TNC
Dimensions (H x W x D)	4.88 x 4.88 x .6 in.
Mounting	Wall mount

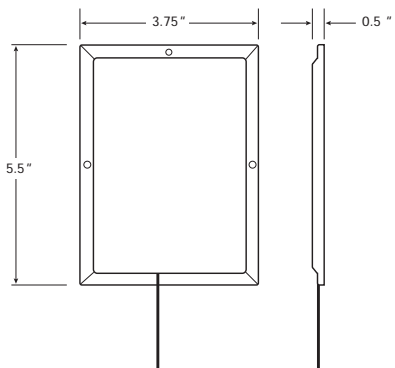


6dBi Patch

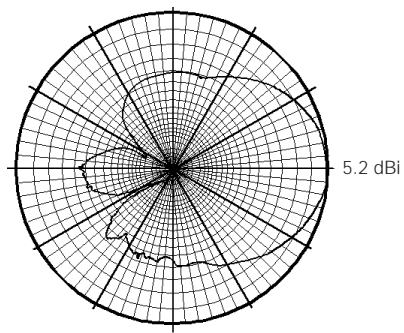
AIR-ANT1729



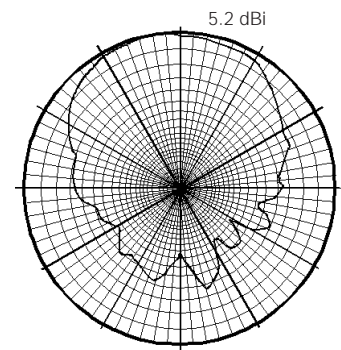
Dimensions and Mounting Specifications



Vertical Radiation



Horizontal Radiation



Frequency Range	2.4-2.5GHz
VSWR	Less than 2:1
Gain	6dBi
Polarization	Linear
Azimuth 3dB BW	65 degrees
Elevations Plan (3dB BW)	70 degrees
Antenna Connector	RP-TNC
Dimensions (H x W x D)	See Drawing
Mounting	Wall mount

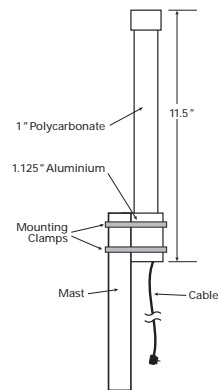


5.2dBi Mast Mount Omni

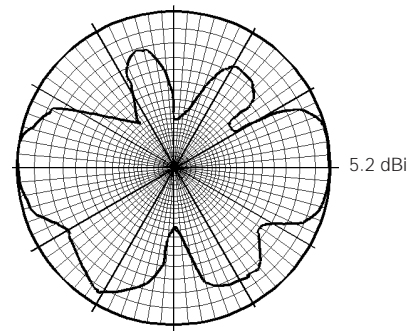
AIR-ANT2506



Dimensions and Mounting Specifications



Vertical Radiation Pattern



Frequency Range	2.4-2.83GHz
VSWR	Less than 2:1, 1.5:1 Nominal
Gain	5.2dBi
Polarization	Vertical
Azimuth 3dB BW	Omnidirectional 360 degrees
Elevations Plan (3dB BW)	50 degrees
Antenna Connector	RP-TNC
Dimensions (H x W)	11.5 x 1.125 in.
Mounting	Mast mount—indoor/outdoor

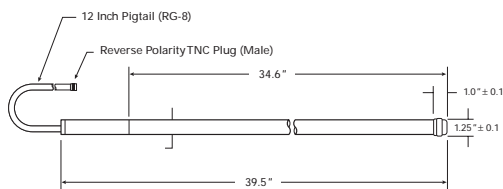


12dBi Omni

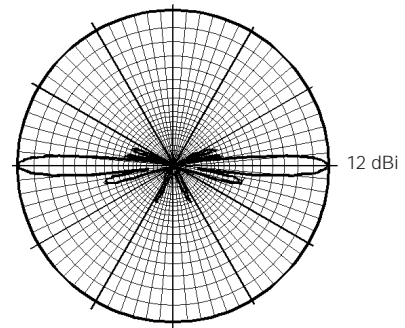
AIR-ANT4121



Dimensions and Mounting Specifications



Vertical Radiation Pattern



Frequency Range	2.4-2.83GHz
VSWR	2:1 Nominal
Gain	12dBi
Polarization	Vertical
Azimuth 3dB BW	Omni directional—360 degree
Elevation (3dB BW)	7 degrees
Antenna Connector	RP-TNC
Dimensions (H x W)	40 x 1.25 in.
Wind Rating	100MPH

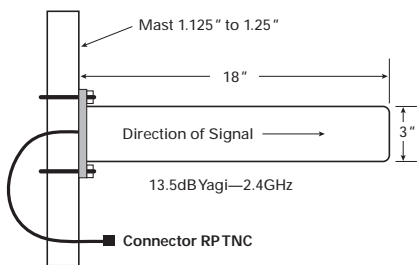


13.5dBi Yagi

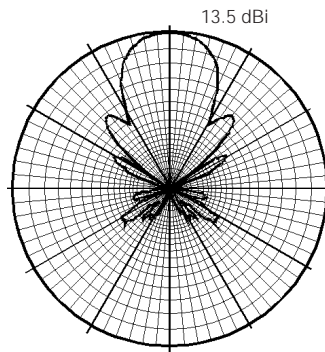
AIR-ANT1949



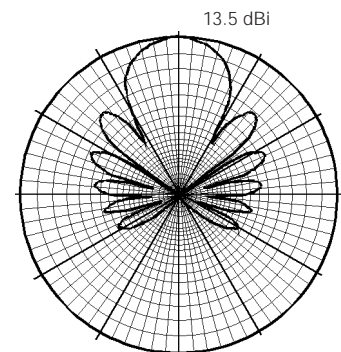
Dimensions and Mounting Specifications



Horizontal Radiation Pattern



Vertical Radiation Pattern



Frequency Range	2.4-2.83GHz
VSWR	Less than 2:1, 1.5:1 Nominal
Gain	13.5
Front to Back Ratio	Greater than 30dB
Polarization	Vertical
Azimuth 3dB BW	30 degrees
Elevations 3dB BW	25 degrees
Antenna Connector	RP-TNC
Dimensions (H x W)	18 x 3 in.
Wind Rating	110MPH

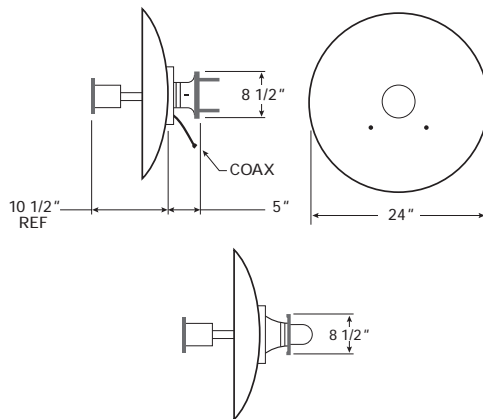


21dBi Parabolic Dish

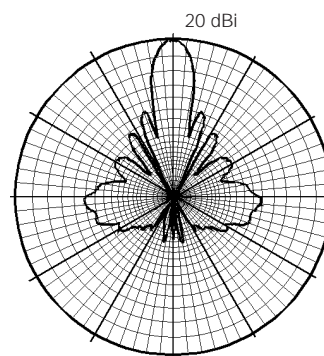
AIR-ANT3338



Dimensions and Mounting Specifications



Radiation Pattern



Frequency Range	2.4-2.83GHz
VSWR	Less than 1.8:1, 15:1 Nominal
Power	5 watts
Gain	21dBi
Front to Back Ratio	Greater than 25dB
Maximum Side Lobe	-17dB
Polarization	Vertical
Azimuth 3dB BW	12.4 degrees
Elevation 3dB BW	12.4 degrees
Antenna Connector	RP-TNC
Dimensions (H x W)	24 x 15.5 in.
Wind Rating	110MPH



Corporate Headquarters
Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134-1706
USA
www.cisco.com
Tel: 408 526-4000
800 553-NETS (6387)
Fax: 408 526-4100

European Headquarters
Cisco Systems International BV
Haarlerbergpark
Haarlerbergweg 13-19
1101 CH Amsterdam
The Netherlands
www-europe.cisco.com
Tel: 31 0 20 357 1000
Fax: 31 0 20 357 1100

Americas Headquarters
Cisco Systems, Inc.
170 West Tasman Drive
San Jose, CA 95134-1706
USA
www.cisco.com
Tel: 408 526-7660
Fax: 408 527-0883

Asia Pacific Headquarters
Cisco Systems, Inc.
Capital Tower
168 Robinson Road
#22-01 to #29-01
Singapore 068912
www.cisco.com
Tel: +65 6317 7777
Fax: +65 6317 7799

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