

2 Antenna Fundamentals

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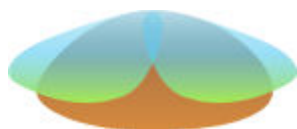
2.1 Antenna Types

Antennas are used to transmit or receive radio waves and play an important role in a WLAN. The following describes how antennas are classified based on different criteria.

Antenna Classification by Horizontal Radiation Pattern

Antennas can be classified into the following types based on the horizontal radiation pattern:

- Omnidirectional antenna



- The goal of an omnidirectional antenna is to radiate energy equally in all directions in a plane (azimuth plane), with a directional pattern in any orthogonal plane.
- The radiation pattern of an omnidirectional antenna is similar to that of an incandescent lamp, which radiates visible light in all directions in a plane.

- Directional antenna



- A directional antenna radiates its energy more effectively in one (or some) direction than others. Typically, these antennas have one main lobe and several minor lobes.
- The radiation pattern of a directional antenna is similar to that of a flashlight, which radiates visible light towards a specified direction. With the same radio energy, a directional antenna provides a longer coverage distance than an omnidirectional antenna in a particular direction.

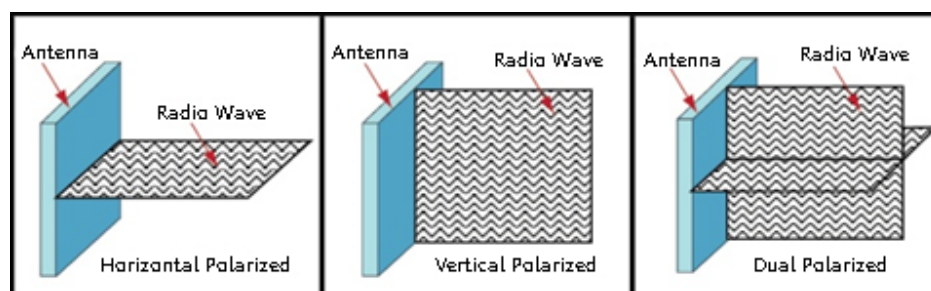
- Smart antenna



- A smart antenna supports multiple directional radiation patterns and one omnidirectional radiation mode on a horizontal plane.
- A smart antenna receives signals from transmitters in omnidirectional mode. Based on the received signals, the smart antenna algorithm can determine the location of a transmitter and control the CPU to send control signals to the transmitter in the directional radiation pattern with the direction of the maximum radiation.

Antenna Classification by Polarization Mode

By polarization mode, antennas are classified to single-polarized antennas and dual-polarized antennas. Single polarization and dual polarization are essentially linear polarization, allowing antennas to be horizontally or vertically polarized.



- Single-polarized antenna: supports only one polarization mode. Such an antenna can only receive or transmit signals in either the horizontal or vertical plane at a time. Therefore, more installation space and maintenance workload are required.
- Dual-polarized antenna: supports the horizontal and vertical polarization modes. Such an antenna can both receive and transmit signals.

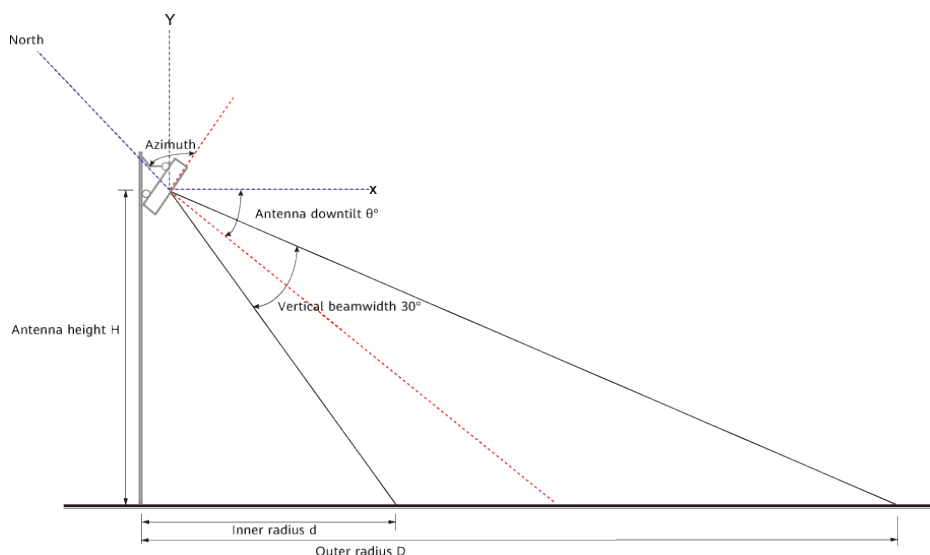
2.2 Antenna Angle

Antenna angles include the azimuth and downtilt angles, which are formed between an antenna and the north and horizontal directions, respectively.

There are two antenna types by directionality: omnidirectional and directional antennas. An omnidirectional antenna receives or transmits signals in all horizontal directions. Therefore, angles of antennas usually refer to azimuth and downtilt angles of directional antennas, as shown in [Figure 2-1](#).

A small antenna angle provides a high antenna gain. However, the key to selecting an antenna gain is to meet signal coverage requirements. The signal coverage range of an antenna can be controlled by adjusting the antenna azimuth and downtilt angles.

Figure 2-1 Antenna angles



Related Concepts

- Azimuth angle: defined by a horizontal angle measured clockwise from north.
- Downtilt antenna: formed between an antenna and the horizontal plane.
- Lobe angle: angle between the points in the main lobe that are down from the maximum gain by 3 dB. For details, see [2.5 Beamwidth](#).
- Antenna gain: ratio of the power density in a given direction to the power density of a reference antenna (using an ideal radiation source) in the same direction. For details, see [2.3 Antenna Gain](#).

2.3 Antenna Gain

Definition

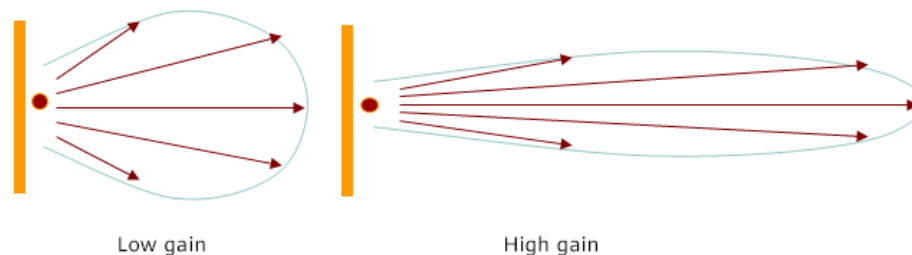
Antenna gain is the ratio of the power density in a given direction to the power density of a reference antenna (using an ideal radiation source) in the same direction. It is expressed in dBd or dBi.

Physically, a gain is the ratio of the signal output of a system to the signal input of the same system. If the transmit antenna is an ideal unidirectional source, the input power should be 100 W. If the transmit antenna is a directional antenna with a gain of 13 dB (20 times), only 5 W (100/20) of input power is required. That is, an antenna's gain is the amplifier of input power of the unidirectional ideal radiation source.

Antenna gain can be used to measure the capability of an antenna to receive and send signals in a specified direction, which is one of the most important parameters to consider when selecting an antenna. The antenna gain is related to the antenna radiation pattern. If the main lobe is narrow, the side lobe is small and the gain is high. [Figure 2-2](#) shows the relationship between the main lobe width and antenna gain.

Under the same condition, a higher antenna gain indicates a longer transmission distance. In practice, select a proper antenna gain to ensure that beamwidth matches the target coverage area. If the coverage area is small, select a low-gain antenna with a wide vertical lobe.

Figure 2-2 Relationship between the main lobe width and antenna gain



Related Concepts

- dBd: unit for measuring the balanced dipole's gain.
- dBi: unit for measuring the radiation source antenna's gain, with equal signal radiation in all directions. The relationship between dBi and dBd is as follows: $\text{dBi} = \text{dBd} + 2.15$.
- Lobe angle: defined as the angle between the points in the main lobe that are down from the maximum gain by 3 dB. For details, see [2.5 Beamwidth](#).
- Ideal radiation source: ideal isotropic antenna, that is, a simple point-shaped radiation source that provides the same radiation performance in all directions.

Formula

$G = 10 \lg(P_2/P_1)$ Antenna gain = $10 \lg(\text{Power density of an antenna} / \text{Power density of a reference antenna})$

2.4 Receiver Sensitivity

Receiver sensitivity refers to the minimum signal received power on an antenna port for receivers to accurately decode a given signal. Receiver sensitivity can be degraded by inter-system interference, affecting the quality of received signals. Therefore, receiver sensitivity is usually used as a criterion to protect the interfered system.

Receiver sensitivity is similar to hearing of human beings. In the daily environment, people with good hearing can capture voice more flexibly. Similarly, higher receiver sensitivity enables a receiver with higher capability to capture weak signals. If the signal strength is lower than receiver sensitivity, the receiver will not receive data.

Factor

- Thermal noise power within the bandwidth range
- Noise factor (NF)
- Minimum signal-to-noise ratio (SNR) required for decoding signals

Formula

$$S = 10 \lg(kTB) + NF + SNR$$

- S: receiver sensitivity, in dBm. A smaller value indicates better performance of the receiver. A larger value indicates lower performance of the receiver.
- k: Boltzmann constant, in J/K.
- T: absolute temperature, in K. As the temperature increases, receiver sensitivity becomes larger, degrading receiver performance. Therefore, lower the ambient temperature as much as possible.
- B: signal bandwidth, in Hz. Higher signal bandwidth represents a larger NF, higher receiver sensitivity, and therefore lower receiver performance.
- kTB: thermal noise power within the bandwidth range, in Watts.
- NF: noise factor, in dB.
- SNR: signal-to-noise ratio required for decoding signals, in dB. A small value of the minimum SNR can enhance receiver performance. The minimum SNR is related to the STA moving speed, wireless environment, and required communication quality. Minimum SNR requirements are different for wireless standards and services of the same wireless standard.

Receiver sensitivity of a common 802.11g product is -85 dBm. Wireless products on the market have -105 dBm receiver sensitivity. Professional receivers provide up to -120 dBm receiver sensitivity. Receiver sensitivity doubles every time the transmit power increases by 3 dB. In most cases, the receiver sensitivity value marked on Wi-Fi devices, such as -83 dBm, is a measurement of receiver sensitivity at a rate of 11 Mbit/s and a bit error rate (BER) of $10E-5$ (99.999%).

STAs have lower receiver sensitivity than APs. Therefore, the outdoor coverage distance is restricted by the STA uplink. If an AP transmits signals at full power, users may find strong signal strength on STAs but Internet access experience is poor. To prevent such an issue, reduce the transmit power of the AP to slightly higher than the receiver sensitivity of the STAs, so that the uplink and downlink of the STAs have a similar modulation and coding scheme (MCS) level after the link power budget is completed.

2.5 Beamwidth

Beamwidth is the angular separation between the points in the main lobe that are down from the maximum gain by 3 dB. The angle is called the lobe angle. An antenna has horizontal beamwidth and vertical beamwidth, forming a horizontal lobe angle and a vertical lobe angle, respectively. Beamwidth is a key counter for directional antennas.

Figure 2-3 shows the radiation pattern of a directional antenna. The signal strength gradually increases from the blue area to the red area. **Figure 2-4** shows the horizontal and vertical patterns, and beamwidth.

Figure 2-3 Antenna radiation pattern

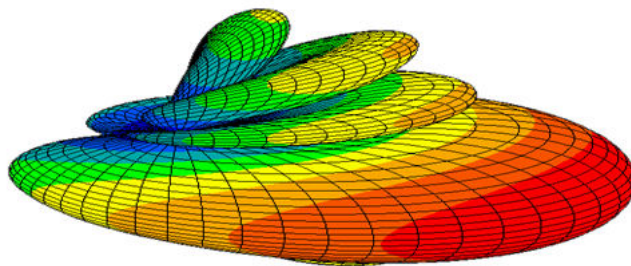
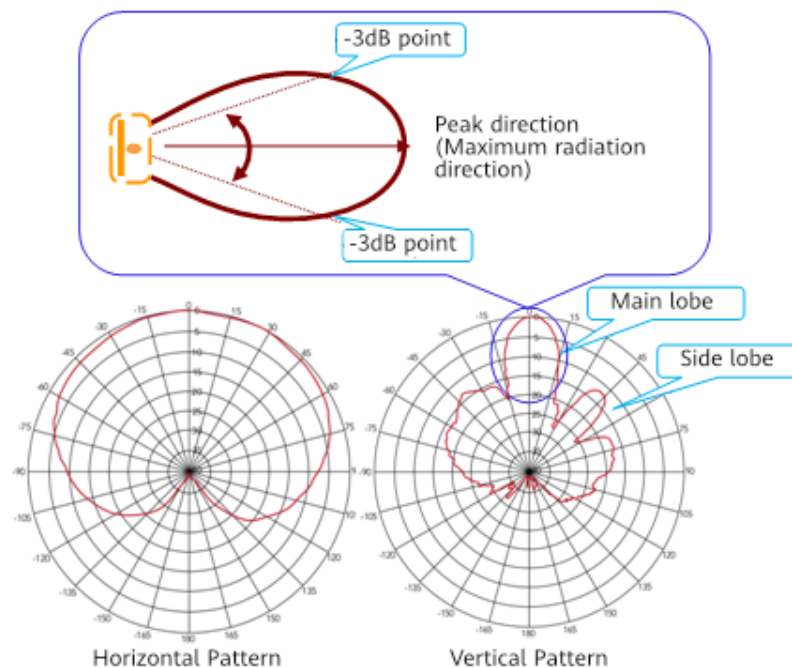


Figure 2-4 Beamwidth



When the beamwidth is narrow, the radiation distance is long and the anti-interference capability is strong.

- When deploying antennas, note that side lobes interfere with peripheral residential areas. In most cases, main lobe radiation needs to be enhanced, and side lobe radiation needs to be suppressed. However, in the areas near the antennas, side lobes are needed to enlarge the coverage distance.
- H-plane half-power beamwidth determines the beamwidth of an antenna in the horizontal plane. When beamwidth is wide, good signal coverage is available at the sector boundary. However, when the downtilt angle becomes larger, beam distortion is more likely to occur, leading to overshoot coverage. On the contrary, when beamwidth is narrow, signal coverage is poor at the sector boundary. Increasing the downtilt angle can resolve this issue to a certain degree, which can prevent overshoot coverage. Base stations in the downtown are deployed at short intervals and have antennas with large downtilt angles installed. In this case, antennas with small H-plane half-power beamwidth are recommended. In the suburbs, antennas with large H-plane half-power beamwidth are recommended.
- V-plane half-power beamwidth determines the beamwidth of an antenna in the vertical plane. When beamwidth is narrow, signals that deviate from the main beam attenuate fast. In this case, it is easier to control the coverage by adjusting the downtilt angle, therefore improving coverage quality for cells.

Related Concepts

- Main lobe: Antennas have various radiation patterns. Some of them look like petals. The one with the strongest radiation "sticks out". It is the main lobe.
- Side lobe: lobes other than the main lobe on a radiation pattern.

- 10 dB beamwidth: angle between the points in the main lobe that are down from the maximum gain by 10 dB (power density reduced to one tenth).