Antenna Tutorial

AeroComm is engaged in the research, development and manufacture of high-performance, low-cost, 2.4GHz radios. A significant portion of AeroComm customers are Original Equipment Manufacturers ("OEMs") that integrate these radios into their products. Each OEM has unique antenna requirements to meet packaging and performance criteria. AeroComm has worked with a number of these OEMs to identify off-the-shelf antenna solutions or has developed proprietary antenna designs to meet specific needs.

An antenna is a crucial element in the successful design of any radio system. This paper explores antenna characteristics and different types of antennas that OEMs should consider when selecting an antenna.

Antenna Characteristics

An antenna is a device that is made to efficiently radiate and receive radiated electromagnetic waves. There are several important antenna characteristics that should be considered when choosing an antenna for your application as follows:

- Antenna radiation patterns
- Power Gain
- Directivity
- Polarization

Antenna Radiation Patterns

An antenna radiation pattern is a 3-D plot of its radiation far from the source. Antenna radiation patterns usually take two forms, the elevation pattern and the azimuth pattern. The elevation pattern is a graph of the energy radiated from the antenna looking at it from the side as can be seen in Figure 1a. The azimuth pattern is a graph of the energy radiated from the antenna as if you were looking at it from directly above the antenna as illustrated in Figure 1b. When you combine the two graphs you have a 3-D representation of how energy is radiated from the antenna (Figure 1c.).

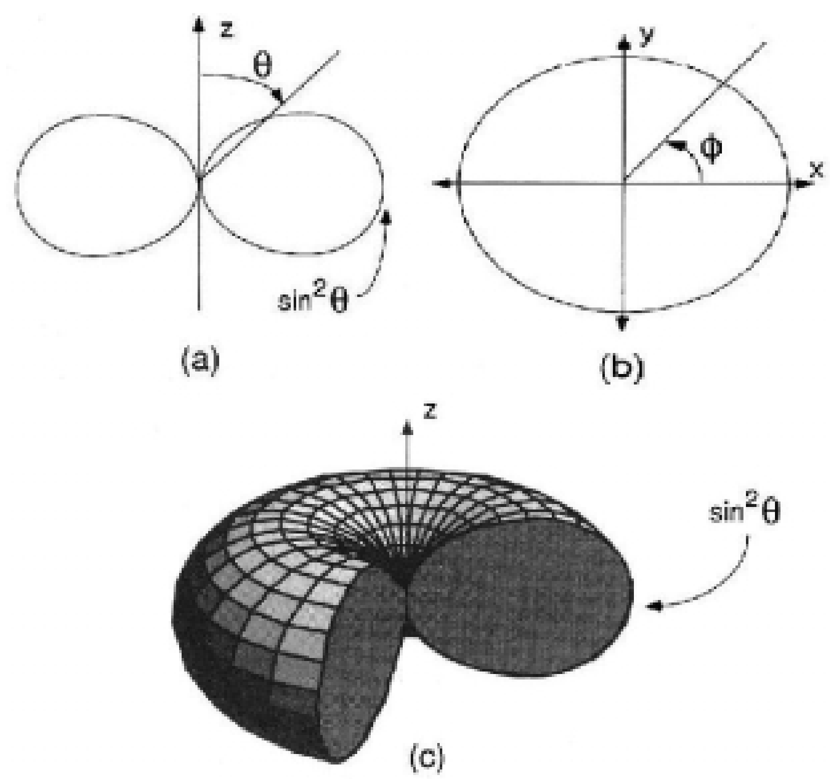


Figure 1. a) Generic Dipole Elevation Pattern b) Generic Dipole Azimuth Pattern c) 3-D Radiation Pattern.

N.J. Kolias et. al., "Antennas" Copyright 2000 CRC Press L.L.C. http://www.engnetbase.com.

Power Gain

The power gain of an antenna is a ratio of the power input to the antenna to the power output from the antenna. This gain is most often referred to with the units of dBi, which is logarithmic gain relative to an isotropic antenna. An isotropic antenna has a perfect spherical radiation pattern and a linear gain of one.

Directivity

The directive gain of an antenna is a measure of the concentration of the radiated power in a particular direction. It may be regarded as the ability of the antenna to direct radiated power in a given direction. It is usually a ratio of radiation intensity in a given direction to the average radiation intensity.

Polarization

Polarization is the orientation of electromagnetic waves far from the source. There are several types of polarization that apply to antennas. They are Linear, which comprises, Vertical, Horizontal and Oblique, and circular, which comprises, Circular Right Hand (RHCP); Circular Left Hand (LHCP), Elliptical Right Hand and Elliptical Left Hand. Polarization is most important if you are trying to get the maximum performance from the antennas. For best performance you will need to match up the polarization of the transmitting antenna and the receiving antenna.

Note: Clockwise rotation of the Electromagnetic wave is *right-hand polarization*; counterclockwise rotation is *left-hand polarization*.

Antennas Types

There are many different types of antennas. Antennas most relevant to designs at 2.4GHz that are further detailed are as follows:

- Dipole Antennas
- Multiple Element Dipole Antennas
- Yagi Antennas
- Flat Panel antennas
- Parabolic Dish antennas
- Slotted Antennas
- Microstrip Antennas

Dipole Antenna

All dipole antennas have a generalized radiation pattern. First, the elevation pattern shows that a dipole antenna is best used to transmit and receive from the broadside of the antenna. It is sensitive to any movement away from a perfectly vertical position. You can move about 45 degrees from perfect verticality before the performance of the antenna degrades by more than half. Other dipole antennas may have different amounts of vertical variation before there is noticeable performance degradation.

A sample elevation pattern can be seen above in Figure 1a. From the azimuth pattern, you find that the antennas work equally well in a full 360 degrees around the antenna. This is illustrated above in Figure 1b. This graph shows that the dipole antenna is not a directive antenna. Its power is equally split through 360 degrees around the antenna. Physically, dipole antennas are cylindrical in nature, and may be tapered or shaped on the outside to conform to some size specification. The antennas are usually fed through an input coming up to the bottom of the antenna but can be fed into the center of the antenna as well.

Multiple Element Dipole Antennas

Multiple element dipole antennas have some of the same general characteristics as the dipole. We see a similar elevation radiation pattern, as well as a similar azimuth pattern. The biggest differences will be the directionality of the antenna in the elevation pattern, and the increased gain that is a result of using multiple elements.

By using multiple elements to construct the antenna, the antenna can be configured with different amounts of gain. This allows for multiple antenna designs with similar physical characteristics. As can be seen from the elevation pattern in Figure 2, multiple element dipole antennas are very directive in the vertical plane. Since the dipole antenna radiates equally well in all directions on the horizontal plane it is able to work equally well in any horizontal configuration.

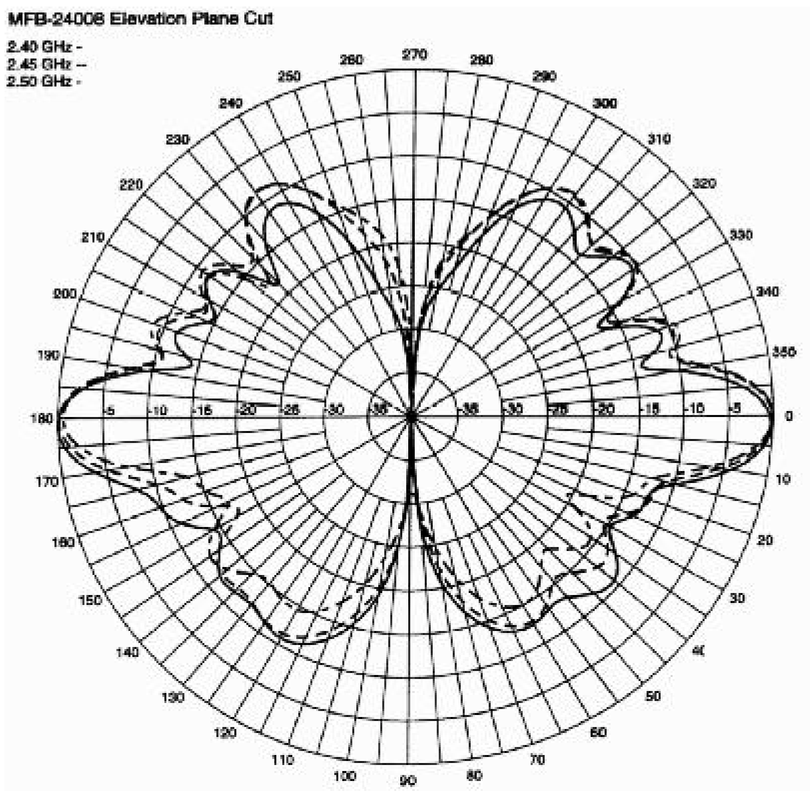


Figure 2. Multiple Element Dipole Elevation Pattern
Source: Maxrad, Inc.

Yagi Antennas

Yagi antennas consist of an array of independent antenna elements, with only one of the elements driven to transmit electromagnetic waves. The number of elements (specifically, the number of director elements) determines the gain and directivity. Yagi antennas are not as directional as parabolic dish antennas, but more directional than flat panel antennas.

Figure 3. Yagi Antenna Construction, Yagi-Uda Antenna
(Source: Sasaki Printing and Publishing Company, 1954)

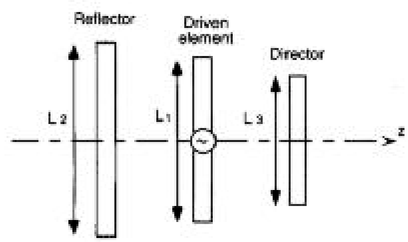
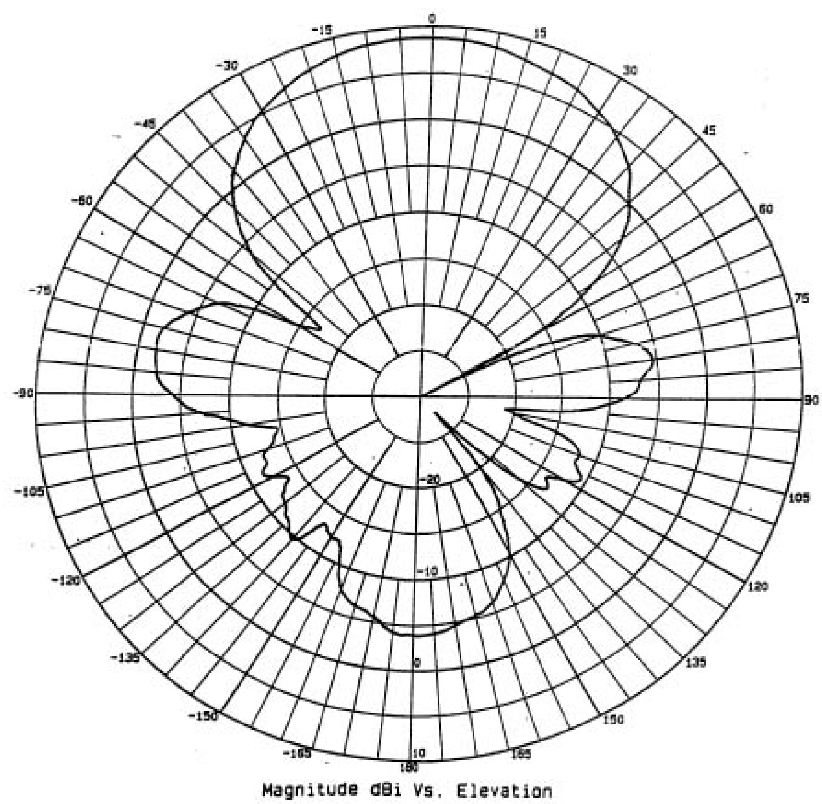


Figure 4. Yagi Antenna Elevation Radiation Pattern
(Source: Maxrad, Inc.)



Flat Panel Antennas

Flat panel antennas are just that, configured in a patch type format and physically in the shape of a square or rectangle. Flat panel antennas are quite directional as they have most of their power radiated in one direction in both the vertical and horizontal planes. In the elevation pattern below, Figure 4, and in the azimuth pattern, Figure 5, the directivity of the plat panel antenna can be seen. Flat panel antennas can be made to have varying amounts of gain based on the construction. This can provide excellent directivity and considerable gain.

Figure 4. High Gain Flat Panel Elevation Pattern
(Source: Maxrad, Inc.)

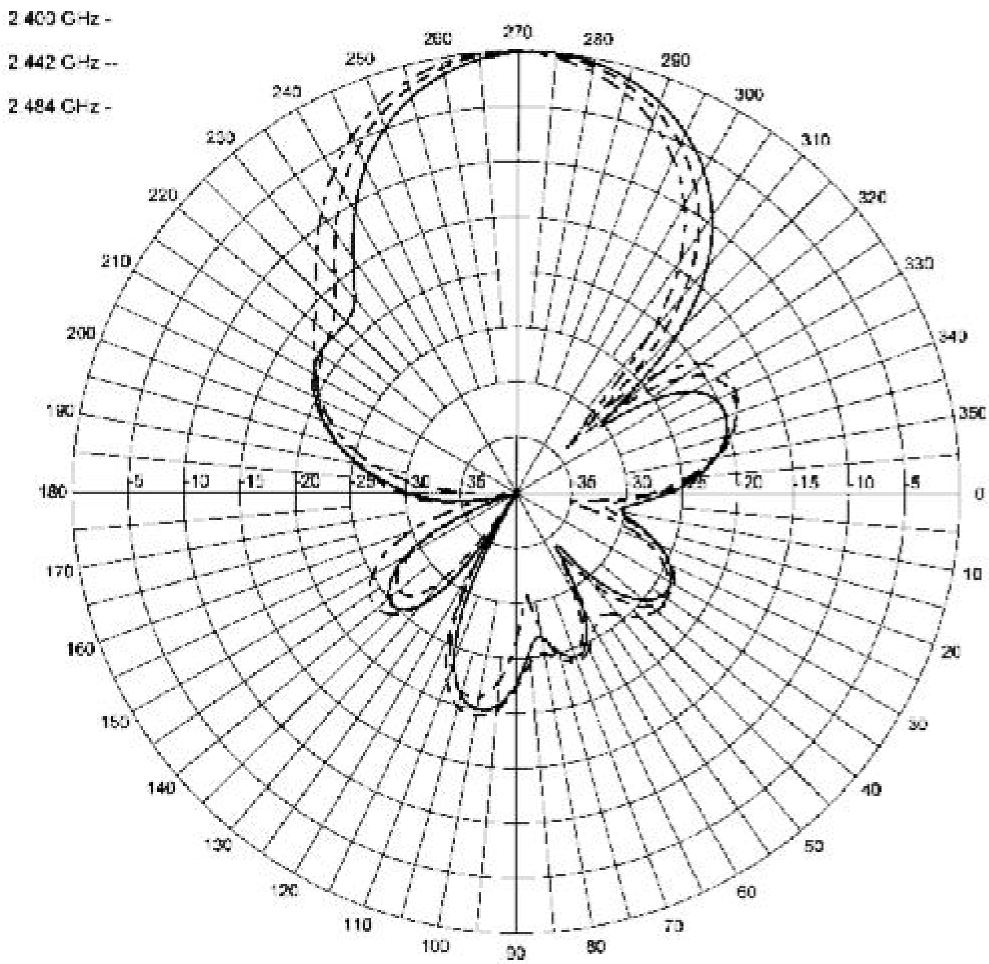
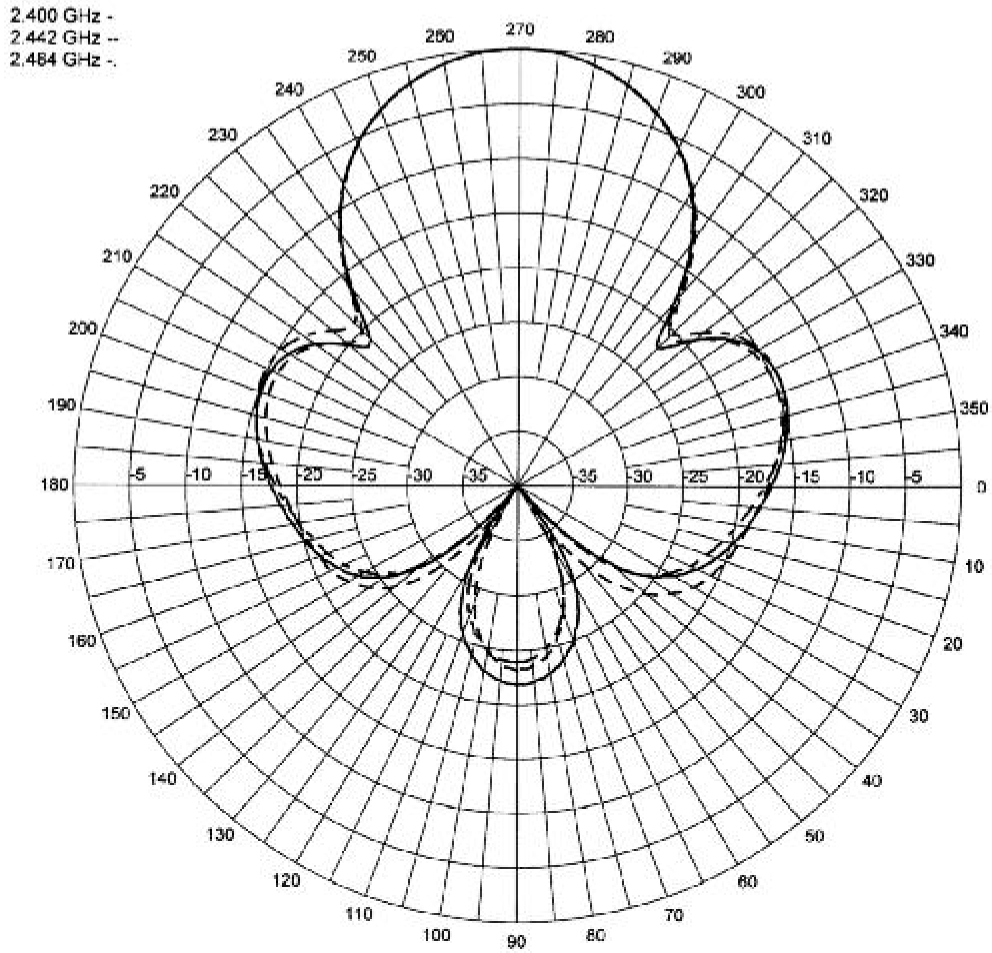


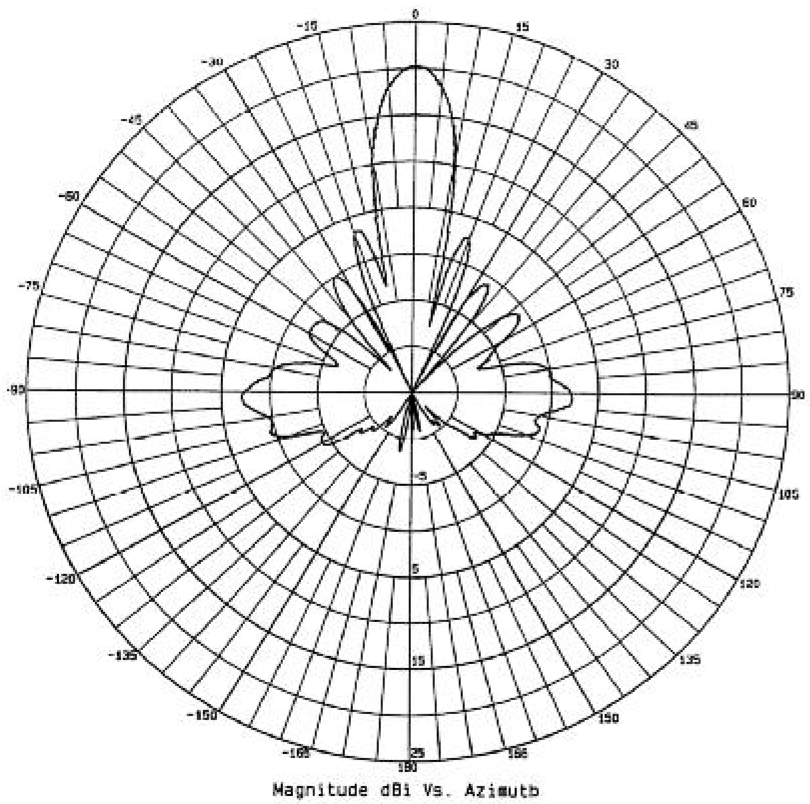
Figure 5. High Gain Flat Panel Azimuth Pattern
(Source: Maxrad, Inc.)



Parabolic dish antennas

Parabolic dish antennas use physical features as well as multiple element antennas to achieve extremely high gain and sharp directivity. These antennas use a reflective dish in the shape of a parabola to focus all received electromagnetic waves on the antenna to a single point. The parabolic dish also works to catch all the radiated energy from the antenna and focus it in a narrow beam when transmitting. As can be seen in Figure 5, the parabolic dish antenna is very directional. By harnessing all of the antenna's power and sending it in the same direction, this type of antenna is capable of providing high gain.

Figure 6. Elevation Pattern of a Parabolic Dish Antenna
(Source: Maxrad, Inc.)



Slotted Antennas

The slotted antenna exhibits radiation characteristics that are very similar to those of the dipole. The elevation and azimuth patterns are similar to those of the dipole, but its physical construction consists only of a narrow slot cut into ground plane. As with microstrip antennas mentioned below, slotted antennas provide little antenna gain, and do not exhibit high directionality, as evidenced by their radiation plots and their similarity to the dipoles. Their most attractive feature is the ease with which they can be constructed and integrated into an existing design, and their low cost. These factors most often offset their mediocre performance characteristics.

Microstrip Antennas

Microstrip antennas can be made to emulate many of the different styles of antennas explained above. Microstrip antennas offer several tradeoffs that need to be considered. Because they are manufactured with PCB traces on actual PCB boards, they can be very small and lightweight. This comes at the cost of not being able to handle as much output power as other antennas, and they are made for very specific frequency ranges. In many cases, limiting the frequencies that can be received is actually beneficial to the performance of a radio. Due to this characteristic, microstrip antennas are not well suited for wideband communications systems.

Conclusion

From this very basic introduction to antennas, we can come away with a better understanding of how to choose the right antenna for an application. For example, dipole antennas, while not providing a large amount of gain offer the best flexibility as far as orientation of the antenna. The flat panel antenna offers greater directionality and would be suited for a fixed installation. The parabolic dish antenna with its high gain and sharp directionality would be best suited to providing a point to point link over a long distance, with permanently installed antennas. Finally, the slotted antenna and the microstrip antenna are well suited for moderate performance applications that need to integrate the antenna and radio into OEM applications.

In addition, it is possible to use different types of antennas in the same system. For example, you could mount a flat panel antenna on a wall near an access point. Whenever a piece of equipment with a dipole antenna passed near the access point, the system could immediately update the statistics on the equipment.

To aid in choosing the correct antenna for your application, Table 1, below, is provided as a means of easy comparison between the different types of antennas.

Table 1. Antenna Comparison

	Radiation Patterns	Power Gain	Directivity	Polarization
Dipole	Broadside	Low	Low	Linear
Multi Element Dipole	Broadside	Low/Medium	Low	Linear
Flat Panel Antenna	Broadside	Medium	Medium/High	Linear/Circular
Parabolic Dish antenna	Broadside	High	High	Linear/Circular
Yagi Antenna	Endfire	Medium/High	Medium/High	Linear
Slotted Antenna	Broadside	Low/Medium	Low/Medium	Linear
Microstrip Antenna	Endfire	Medium	Medium	Linear

About the Author

Jeremy Smith, a BSEE graduate from Kansas State University, has been designing, testing and implementing antennas since joining AeroComm in 1995. Jeremy can be reached at:

AeroComm, Inc.
13256 W. 98th St.
Lenexa, KS 66215
(913)492-2163
jsmith@aerocomm.com

Bibliography

MAXRAD, Inc. 4350 Chandler Drive Hanover Park, IL 60103-6763
Sales:(800) 323-9122 Ph: (630)372-6800 Fax: (630)372-8077

N.J. Kolias et. al., "Antennas" Copyright 2000 CRC Press L.L.C. http://www.engnetbase.com.

S. Uda and Y. Mushiake, Yagi-Uda Antenna, Sendai Japan: Sasaki Printing and Publishing Company