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DESIGN BRIEF

Selecting Antennas for Low-Power Wireless Applications

By Audun Andersen
Field Application Engineer, Low-Power Wireless

Introduction

The antenna is a key component in an RF system and can have a major impact on performance. High performance, small size, and low cost are common requirements for many RF applications. To meet these requirements, it is important to implement a proper antenna and to characterize its performance. This article describes typical antenna types and covers important parameters to consider when choosing an antenna.

Antenna Types

Antenna size, cost, and performance are the most important factors to consider when choosing an antenna. The three most common antenna types for short-range devices are PCB antennas, chip antennas, and whip antennas. Their pros and cons are shown in Table 1.

Antenna Parameters

Some of the most important things to consider when choosing an antenna are: the radiation pattern, antenna efficiency, and antenna bandwidth.

Radiation Pattern and Gain

Figure 1 shows how the radiation pattern from a PCB antenna varies in different directions in the plane of the PCB. Several parameters are important to know when interpreting such a plot. Some of these parameters are stated in Figure 1.

In addition to the plot information, it is important to relate the radiation pattern to the positioning of the antenna. Radiation pattern is typically measured in three orthogonal planes, XY, XZ and YZ. It is possible to perform full 3D pattern measurements, but it is usually not done because it is time consuming and requires expensive equipment.

Table 1. Pros and Cons for Antenna Types

Types	Pros	Cons
PCB Antenna	• Low cost • Good performance is possible • Small size is possible at high frequencies	• Difficult to design small and efficient antennas • Potentially large size at low frequencies
Chip Antenna	• Small size	• Medium performance • Medium cost
Whip Antenna	• Good performance	• High cost • Difficult to fit in many applications

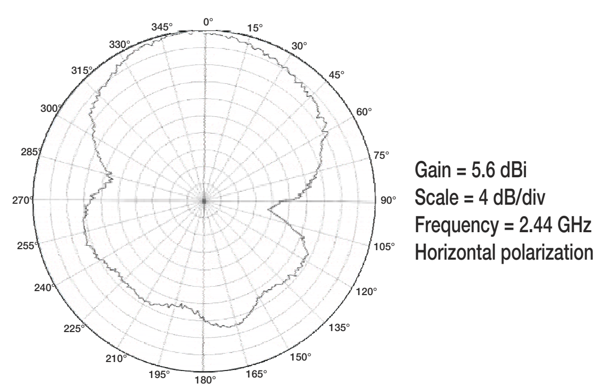

Figure 1. Radiation pattern.

The gain, or reference level, usually refers to an isotropic radiating antenna, which is an ideal antenna with uniform radiation in all directions. When an isotropic antenna is used as a reference, the gain is given in dBi or specified as the effective isotropic radiated power (EIRP). The outer circle in Figure 1 corresponds to 5.6 dBi and the 4-dB/div label means that for each progressively smaller circle, the emission level is reduced by 4 dB. Compared to an isotropic antenna, the PCB antenna will have a 5.6-dB higher level of radiation in the 0° direction.

As shown by Equation 1, antenna gain, G, is defined as the ratio of maximum-to-average radiation intensity multiplied by the efficiency of the antenna.

$$G = e \times D = \frac{P_{rad}}{P_{in}} \times D = \frac{P_{rad}}{P_{in}} \times \frac{U_{max}}{U_{avg}}, \qquad (1)$$

where U_{max} is the maximum radiation intensity, U_{avg} is the average intensity, and the ratio of these two values is known as directivity, D. Ohmic losses in the antenna element and reflections at the antenna feed point determine the efficiency, e, which is simply the radiated power, P_{rad}, divided by the input power, P_{in}. High gain does not automatically mean that the antenna has good performance. Typically, mobile systems require an omnidirectional radiation pattern so the performance will be about the same for any antenna orientation.

To accurately measure an antenna radiation pattern, it is important to measure only the direct wave from the device under test and avoid reflecting waves that could affect the result. To minimize picking up reflected energy, measurements are often performed in an anechoic chamber or at an antenna range. Another requirement is that the measured signal must be a plane wave in the far field of the antenna. The far field distance, R_f, is determined by the wavelength, λ, and the largest antenna dimension, DIM, as shown by Equation 2. Since the size of anechoic chambers is limited, it is common to test large, low-frequency antennas in outdoor ranges.

$$R_f = \frac{2 \times DIM^2}{\lambda} \qquad (2)$$

Bandwidth and Impedance Matching

A common method to determine antenna bandwidth is to measure the radiated power while stepping a carrier across the frequency band of interest. Figure 2 shows the first method which is measurement of radiated power from a 2.4-GHz antenna that has approximately 2-dB variation in output power across the 2.4-GHz frequency band and has maximum radiation near the center of this band. This measurement was done by stepping a continuous-wave signal from 2.3 GHz to 2.8 GHz. Such measurements should be performed in an anechoic chamber to obtain a correct absolute level. However, this measurement can be very useful even if an anechoic chamber is not available.

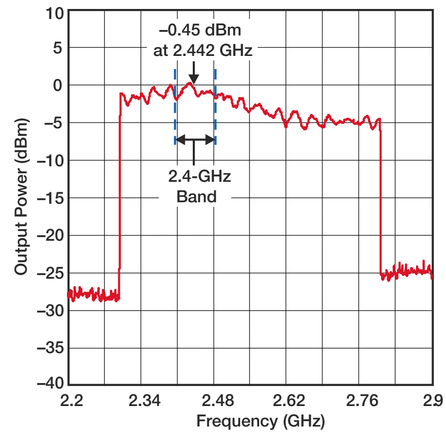

Figure 2. Bandwidth of a 2.4-GHz antenna.

A second method to determine bandwidth is measuring the reflection at the antenna feed point with a network analyzer. See Reference 1 for details.

Size, Cost and Performance

The ideal antenna is infinitely small, has zero cost and has excellent performance. In real life, however, a compromise between parameters is necessary. For example, decreasing the operating frequency by a factor of two can double the RF range. Thus, one of the reasons to operate at a lower frequency is often to achieve longer range. The down side is that most antennas need to be larger at lower frequencies to achieve good performance. In some cases where the board space is limited, a small, efficient high-frequency antenna may provide equal or greater range performance than a small, inefficient low-frequency antenna. A chip antenna is a good alternative when seeking a small antenna solution. This is particulary true with frequencies below 1 GHz because the chip antenna will allow a much smaller solution than the traditional PCB antenna. The main drawbacks with chip antennas are the increased cost and typically narrow-band performance.

Antenna Reference Designs

Texas Instruments offers a wide range of RF products designed to operate in license-free frequency bands. See Reference 2 for more information.

References

Please see Reference 1 for the complete version of this article, which includes more information about choosing antenna types, antenna polarization, and another method to characterize antenna bandwidth.

1. View the complete article at http://www-s.ti.com/sc/techlit/slyt296
2. www.ti.com/lpw