Taken for granted

Often abused and neglected, portable radio antennas are indispensable

By Jay M. Jacobsmeyer, P.E.

Land mobile radio antennas come in two basic types: the base station or repeater site antenna and the user radio antenna. This article focuses on user radio antennas, with an emphasis on the portable radio antenna.

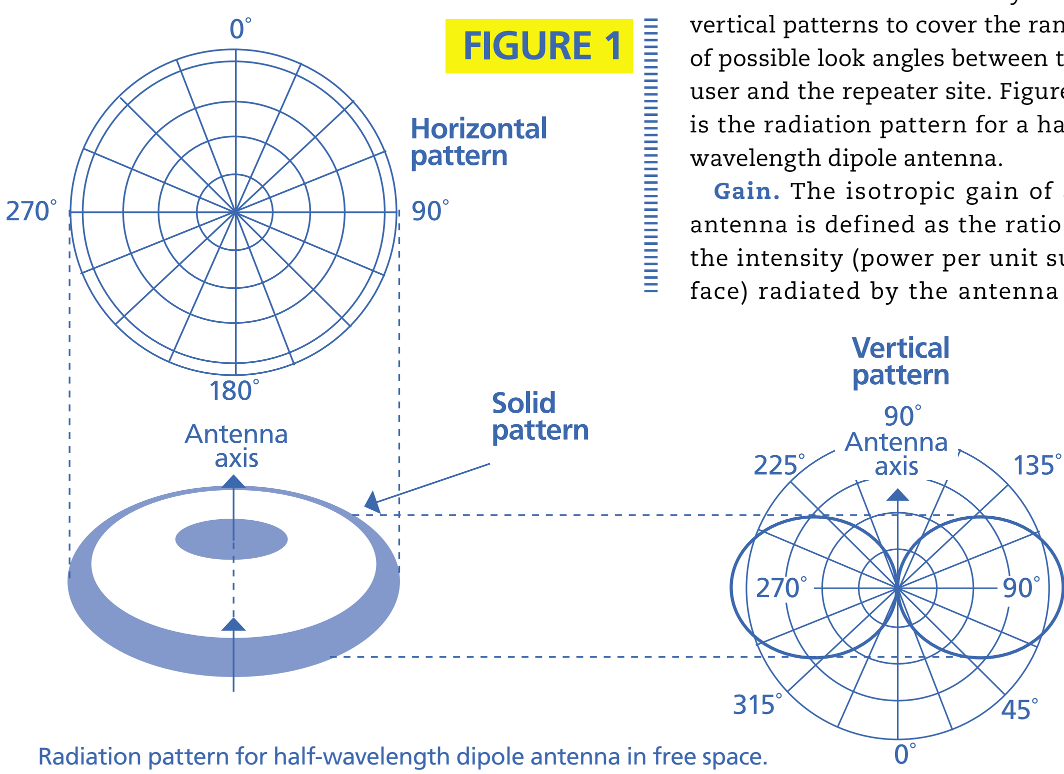
The land mobile radio antenna is a transducer that converts voltage and current on a coaxial cable to an electromagnetic wave traveling in free space. The principle of antenna reciprocity ensures that the antenna has the identical pattern whether it is used to transmit or receive. This property is helpful because most mobile radio antennas are duplexed, meaning that a single antenna is used for both purposes.

Antenna performance is characterized by several parameters. The antenna parameters of greatest interest to us are the radiation pattern, gain, impedance, efficiency, polarization and bandwidth. Let's briefly look at each.

Radiation pattern. The radiation pattern is a three-dimensional description of the angular dependence of radiation from (or to) the antenna. Because three-dimensional patterns are difficult to view on two-dimensional surfaces, it is common to describe the radiation pattern in two parts: the azimuth pattern and the vertical pattern. Note that an omnidirectional antenna radiates energy equally in all directions in the azimuth plane, but it can be quite directional in the vertical plane. In other words, omnidirectional does not mean isotropic. Desirable patterns for portable radio antennas are omnidirectional with relatively wide vertical patterns to cover the range of possible look angles between the user and the repeater site. Figure 1 is the radiation pattern for a half-wavelength dipole antenna.

Gain. The isotropic gain of an antenna is defined as the ratio of the intensity (power per unit surface) radiated by the antenna in

FIGURE 1



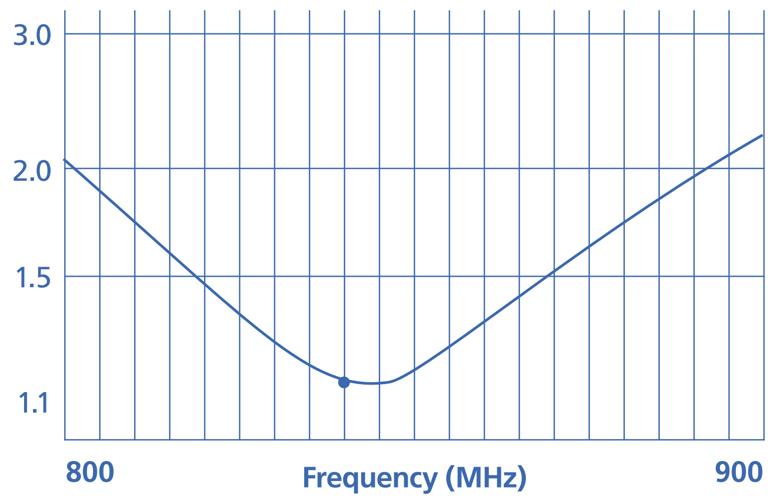
Radiation pattern for half-wavelength dipole antenna in free space.

a given direction divided by the intensity radiated at the same distance by a hypothetical isotropic antenna. Isotropic gain is usually specified in terms of decibels relative to isotropic, or dBi. In mobile radio, it is common to specify gain relative to a half-wavelength dipole, which is dBd. Because a dipole has a gain of 1.64 or 2.15 dBi, the gain of an antenna in dBi is always 2.15 dB greater than the gain in dBd.

Impedance. In general, an antenna has an impedance of $Z = R + jX$, where R is the real part and X is the imaginary part (i.e., capacitance or inductance). Only the real part of the impedance contributes to radiation, so ideally we want an antenna with $X = 0$. Mobile and portable radios are generally designed for a 50-ohm impedance, so it is desirable that the antenna be as close to 50 ohms as possible. The transmitter usually drives the allowed impedance match because a poor match results in high reflected power that can cause a multitude of problems for the final amplifier. Metal objects in the near field of the antenna will change its impedance. Reported problems with the radio sometimes can be traced to a user hanging keys or other foreign objects from the antenna.

Efficiency. The real part of the antenna impedance, R, is the sum of two parts, the radiation resistance and the ohmic resistance. Ohmic resistance does nothing for radiation, so it is important to keep it small in an absolute sense but also small as a fraction of the radiation resistance. Antenna efficiency is defined as the ratio of radiation resistance to total resistance. Most mobile radio antennas above 800 MHz have efficiencies greater than 90%, but electrically small antennas used at VHF have low radiation resistance and therefore poor efficiency. The effective gain of an antenna is directly proportional to its efficiency.

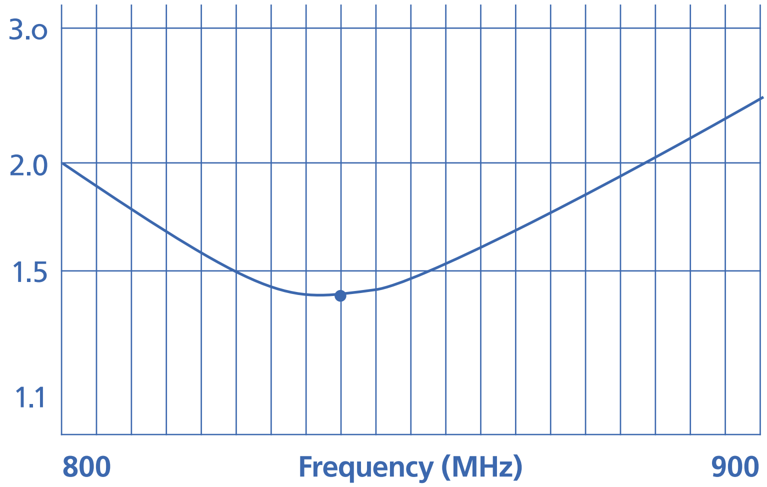
FIGURE 2 VSWR versus frequency for quarter-wavelength monopole over finite ground.
(*L*=3.25 inches, Z = 43.5 + j0.17 ohms at 840 MHz)



Polarization. The polarization of an antenna is defined as the orientation of the antenna's electric field relative to the surface of the earth. The most common polarizations are vertical, horizontal and circular. Ideally, the transmitting and receiving antennas employ the same polarization. Most mobile radio antennas installed on vehicles employ vertical polarization, but the polarization of portable radio antennas depends on the angle in which the user is holding the radio. To comply with FCC rules, land mobile repeater sites use vertical polarization. In contrast, many cellular radio base stations use dual 45° slant polarization for antenna diversity. It is important to note that a polarization mismatch on a mobile radio channel is not cause for concern because diffraction and reflection in the path (which is usually not line-of-sight) cause random rotations of the polarization anyway.

Antenna bandwidth. The antenna bandwidth usually is defined as the bandwidth over which the antenna's voltage standing wave ratio (VSWR) is lower than some maximum allowed level, say 2:1. Antenna bandwidth has become an important parameter in recent years because radios are asked to operate over much wider

FIGURE 3 VSWR versus frequency for half-wavelength dipole in free space.
(*L*= 6.5 inches, Z = 70.4 – j4.9 ohms at 840 MHz)



bands (e.g., 746–869 MHz) as new spectrum becomes available. In the cellular radio industry, it is necessary for some phones to operate at 720, 850, 1700, 1900 and 2100 MHz. A single antenna cannot perform well in all of these bands simultaneously, but designers have invented multiband antennas that resonate in multiple discrete bands, creating the effect of multiple antennas in one device.

Now that we've laid the groundwork, let's look at some common land mobile radio antenna types.

Quarter-wavelength monopole. The monopole antenna resonates at one-quarter wavelength and has an impedance of approximately 50 ohms when positioned over a very small ground plane. It is commonly used in the UHF band (380–512 MHz) and less often in the 800 MHz band. The radiation pattern is the familiar omnidirectional donut. Figure 2 is a plot of VSWR versus frequency for a 3.25-inch-tall monopole manufactured from 0.08-inch-diameter wire over a ground plane with a diameter of 1.6 inches. Note that the wire diameter and the ground plane combine to create a resonance at 30% of a wavelength rather than 25%.

Helical monopole. In the low VHF band (30–54 MHz) — and even the high VHF band (150–174 MHz) — a quarter-wavelength antenna is too long (17 inches to 8 feet) to be practical on portable radios. One could arbitrarily cut the monopole down, but short monopoles have low radiation resistance and are therefore inefficient. One solution is to use a helical antenna. A helix with a diameter that is small relative to a wavelength has an omnidirectional pattern like a quarter-wavelength monopole, but with a higher radiation resistance, making it more efficient. One side effect of the helix is a narrower bandwidth than the quarter-wavelength monopole.

Half-wavelength center-fed dipole. Unike the monopole, a half-wavelength center-fed dipole does not require a ground plane. It is a popular antenna for frequencies above 800 MHz where its length is practical for portable devices. Figure 3 is a plot of VSWR versus frequency for a 6.5-inch-long dipole manufactured from 0.08-inch-diameter wire in free space. The antenna resonates at a length of 0.46 wavelength. An ideal dipole made from infinitely thin wire resonates at roughly 0.49 wavelength.

Patch antenna. A patch or microstrip antenna consists of a dielectric sandwiched between two parallel metal plates. Patch antennas are popular at frequencies above 1 GHz; the GPS receiver in cell phones is a common application. The wavelength in a dielectric is smaller than in free space because the velocity of propagation is lower, and this property is used to make small, efficient antennas. Patch antennas are generally not omnidirectional. A hemispherical pattern is typical. ■

Jay Jacobsmeyer is president of Pericle Communications Co., a consulting engineering firm in Colorado Springs, Colo. He holds BS and MS degrees in electrical engineering from Virginia Tech and Cornell University, respectively, and has more than 25 years of experience as a radio frequency engineer.