# Designing Antennas For Cellular Telephones

*Whether designing or specifying antennas for use in cellular-telephone handsets, certain electrical and mechanical parameters must be considered.*

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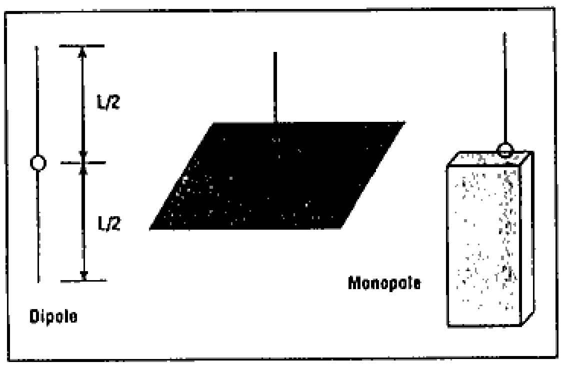
**ANTENNAS for handheld cellular telephones must meet stringent electrical and mechanical requirements. The type of housing, for example, often dictates the type of antenna design. By understanding the key design rules and important antenna-design parameters, the task of creating or specifying antennas for handheld cellular telephones can be greatly simplified.**

A cellular telephone's antenna supports transmitter and receiver functions, launching energy within the transmit band while intercepting signals within the receive band. From a system point of view, every 1 dB of antenna performance variation will result in overall system-performance variations of 2 dB. Since the antenna handles RF signals, the physical dimension or length of the antenna is dictated by the wavelength of the RF signal. Usually, the optimum length for efficiency is the quarter-wavelength of the center frequency for the band of interest. This type of antenna is called a monopole design (Fig. 1) and is relative easy to implement as a whip antenna on a cellular telephone. As a result, this type of antenna is fairly ubiquitous on today's handsets.

A quarter-wavelength antenna for the cellular frequency band (824 to 894 MHz) has a length of approximately 3.5 in (8.89 cm). Since it is approximately three-quarters of a wavelength at personal-communications-services (PCS) frequencies (1850 to 1990 MHz), this basic design can act as a dual-band antenna with slight modifications to its geometry. The 3.5-in. (8.89-cm) length, however, is too long for some users. As a result, a "stub" antenna (which is also known as helical antenna) was developed. This configuration is nothing more than the 3.5-in. (8.89-cm) length wound in a




1. Monopole antennas, which usually operate over the quarter wavelength of a frequency of interest, are simple to implement and commonly used in cellular-telephone handsets. A dipole is commonly two half-wavelength monopole antennas that are electrically connected.

helical-coil shape (Fig. 2) thereby shortening the physical length of the antenna to approximately 1 in. (2.54 cm). This design can also handle dual-band applications with slight modifications to its geometry. As a result, current cellular-telephone designs incorporate both geometries. The whip is extended through the telephone housing when in use and when it is retracted, the stub section is activated.

The whip- and stub-antenna designs do not require a coaxial connection or a physical ground connection. However, they do require a spatial ground return for proper operation. In this case, the ground return may be the cellular-telephone housing if it is metal plated, and/or metal shielding within the housing, and/or the printed-wiring-board (PWB) ground pattern of the telephone's electronic circuitry. The use of a ground return, however, causes RF ground currents to circulate either on the plated housing or the metal shielding or the PWB ground plane. As a result, it is important to note rule number one for cellular-telephone antennas—the plated housing or shielding on the PWB becomes part of the antenna.

## HOUSING EFFECTS

A cellular telephone's housing configuration can affect various antenna parameters, including the gain pattern and the voltage standing-wave ratio (VSWR). This leads to rule number 2 for cellular-telephone antennas—an antenna engineer should be involved when a cellular telephone's housing is initially being specified or designed.

**THE ANTENNA-DESIGN TEAM MUST HAVE A HOUSING AND PWB BEFORE DESIGNING AN ANTENNA FOR A PARTICULAR CELLULAR TELEPHONE.**

When the housing is finally chosen and the internal PWB is designed, it then becomes necessary to contact an antenna-design team (an internal design team or an external vendor) to develop prototype antennas for that particular telephone design. Since the housing is part of the antenna, and the PWB must have the necessary electrical components to match the antenna's impedance to the telephone's front-end circuitry, it is important that the antenna-design team gets involved with designing the housing and PWB together. They must be able to consider the interactions among these different telephone components. A prototype antenna design cannot start until the housing, the PWB, and the shielding details are known. This leads to rule number 3 for cellular-telephone antennas—the antenna-design team must have a housing and PWB before designing an antenna for a particular cellular telephone. The housing (including the shielding) does not have to be a final design, but should be fairly close to the final design.

A cellular-handset antenna's mechanical requirements, aside from size, include the ability to pass a series of environmental stress tests, such as drop tests and thermal cycling tests. An antenna's mechanical stability should be tested at the prototype stage, when some of the components inside the housing, such as the keypad, battery, and internal circuitry, may not have been finalized. For drop testing, it may be necessary to simulate the final weight of the telephone by placing dummy weight inside the housing. In this way, the telephone with antenna attached will achieve the proper force when striking the floor.

## FUTURE TRENDS

Modern whip or stub antennas are external, mounted on the outside of the telephone housing. There have been considerable efforts to design antennas that would be within the housing. Although external antennas still dominate handheld terminal applications, internal antenna concepts are drawing more and more attention from cellular-handset designers. There are mainly two reasons for the interest in internal antennas. One is that industrial-design studies have shown that to some users, external antennas may appear to be obtrusive or not aesthetically pleasing to the eye. The other, probably more important, regards the EM interactions between the handset antenna, the telephone housing, and the user. Since there is limited space inside the housing, design approaches for internal antennas tend to be planar in nature. Such designs are essentially printed types (Fig. 3), consisting of either a radiating patch or a meander-line radiator.

Although there is a great deal of interest in the patch antenna, narrow bandwidth and large size limit its use for handheld applications. The bandwidths of cellular (824-to-894-MHz) and PCS (1850-to-1990-MHz) systems are 8.15 and 7.3 percent, respectively. The traditional patch antenna has a bandwidth of less than 4 percent. The size of a patch antenna is proportional to the wavelength of its operating frequency—as the frequency of operation decreases, the size of the patch increases. This makes it even more difficult to use a patch antenna for dual-band operation. Nonetheless, patch antennas or modifications of this type are still considered to be the one of the most-promising candidates for internal handset applications. New configurations and new materials are being developed to improve the performance of patch antennas to those levels required for cellular-handset applications.

**WITH ANY NEW ANTENNA DESIGN, IT IS IMPORTANT TO ASK CERTAIN QUESTIONS TO DETERMINE IF THAT TECHNOLOGY CAN MEET THE REQUIREMENTS OF CELLULAR-PHONE HANDSETS.**

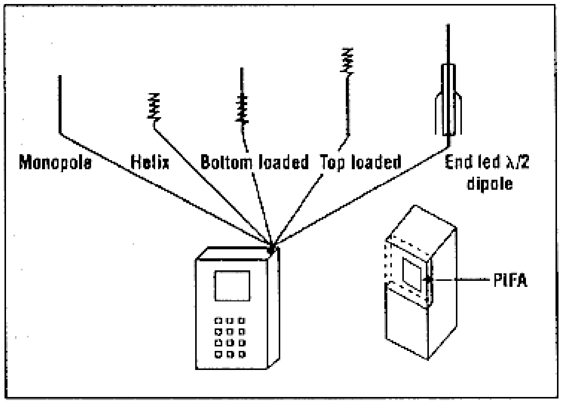
A meander-line antenna consists of printed traces on a circuit board. These traces can be in many different patterns, such as zig-zag, spiral, random, or broadside coupled traces in multiple layers of dielectric material. The performance of this type of antenna can be degraded by close proximity to metal structures such as shields or PWB ground planes. Any antenna mounted inside a cellular-telephone housing means that the housing itself cannot be metallic plated, at least near the aperture of the antenna, so any shielding would have to take place over the RF circuitry on the PWB.

These printed antennas, in general, do not perform as well as external antennas in terms of uniform gain and omnidirectional radiation patterns. This may not be too much of a problem since the standard whip antenna's pattern is distorted when the telephone is held to the ear because the user affects the antenna pattern. In fact, the directional radiation pattern is one printed-antenna property that antenna designers want to use to isolate the loading effects of the user. However, any antenna must be carefully designed in order to obtain the widest possible coverage angle with the minimum human loading effects.

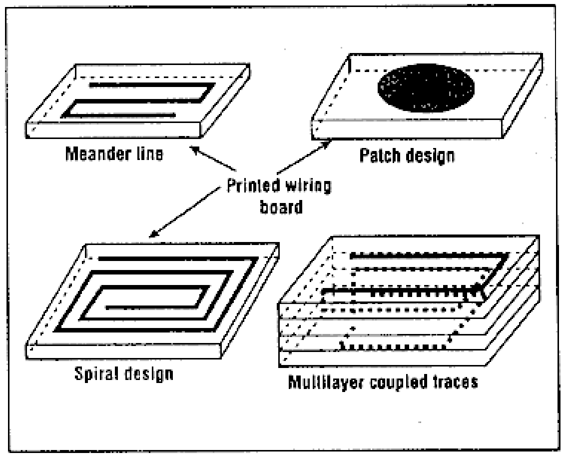
With any new antenna design it is important to ask certain questions to determine if that technology can meet the requirements of cellular-phone handsets. These questions for new antenna designs are as follows:

1. What is the operating frequency band and bandwidth of the antenna? In the US, two frequency bands are allocated to cellular-telephone service—the 824-to-894-MHz band for cellular users and the 1850-to-1990-MHz range for PCS users. A single-band antenna works in one range or the other, while a dual-band antenna operates over both ranges. All antennas have an operating frequency bandwidth characteristic. Typically, high-gain antennas have narrow bandwidths while low-gain antennas have wide bandwidths. This bandwidth parameter is sometimes not specified by vendors on new designs for handheld applications. This bandwidth parameter is important, however, for the cellular and PCS bands since the antenna must serve receive and transmit functions. Sometimes the bandwidth specification is given as a percent bandwidth—the operating bandwidth divided by the center frequency multiplied by 100. For cellular and PCS applications, the percent bandwidth is approximately 8 percent.

2. What is the gain referred to an isotropic antenna? An isotropic antenna (Fig. 4) is a theoretical antenna with an ideal spherical pattern and a point source at the center. This theoretical antenna is considered as a standard reference of comparison for other antennas. If an antenna has a gain of 2 dB compared to an isotropic antenna, its gain is then given as 2 dBi. Since practical antennas do not exhibit perfect spherical patterns, it is important to find out where the




**2. A variety of different external-antenna designs are used in cellular handsets, including monopole, helix, and dipole antennas, as well as designs that combine monopole and helix structures. Recently, interest has grown in printed antennas for internal mounting.**




**3. Antennas designed for internal mounting in a cellular-handset design are essentially printed types consisting of either a radiating patch or a meander-line radiator.**

gain has been measured in its pattern shape. Because the pattern is three dimensional, two angles are given to locate where the gain is specified. Sometimes the average gain is specified, which is an integrated value over the entire radiation pattern. If the pattern has deep nulls, average gain data may be misleading since the peaks and nulls are not indicated.

3. What is the three-dimensional shape of the antenna's radiation pattern? The shape of an antenna's radiation pattern is important because it shows what direction the antenna performs best or where nulls (the areas of minimum performance) occur.

4. What is the VSWR across the operating frequency band(s)? This parameter determines the electrical impedance match across the total band of operation. It is important to know this parameter since the performance of a cellular telephone's transmit (power) amplifier depends upon how well its output circuitry is impedance matched to the antenna for maximum power transfer.

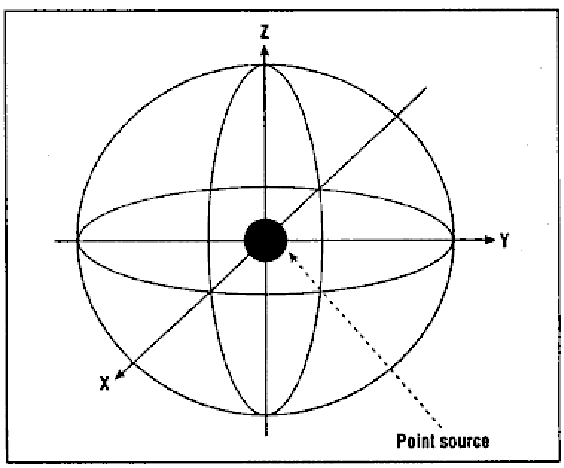
5. What is the physical structure of the antenna? The physical details of an antenna are important in order to understand whether it can be implemented inside the housing or near the PWB. In some cases, new designs for planar or printed antennas espouse certain electrical characteristics without mentioning size or how the device must be mounted. In addition, it is important to find out if the antenna can be mounted near any metal or ground points without any effects on its performance.

6. What is the manufacturability of the antenna? This is an important requirement since a particular antenna design must be supported by automated assembly equipment for high-speed, high-volume production.

7. What is the cost of the antenna? This is one of the most important questions since its answer determines in part how the antenna impacts the profitability of a cellular-handset design.

8. What are the mechanical properties of the antenna in terms of a particular cellular handset's specifications? This question must be answered early in the design of the antenna, since it may be related to the housing design. The internal-antenna-design team or external-vendor supplier must perform drop tests as soon as possible. It is not necessary for the internal-design team or vendor to have an electrical working model, but they should choose the right plastic and wire for the antenna to survive the drop test and other environmental specifications such as operational temperature changes.

These questions are important in searching for new antenna designs. They help specifiers sort through the many claims of antenna vendors for performance and reliability. In general, if an antenna manufacturer cannot supply hard data for such parameters as gain, VSWR, or bandwidth, that antenna design will not suit cellular or PCS applications. ••




**4. Used as a reference, an isotropic antenna is a theoretical configuration with an ideal spherical pattern and a point source at the center.**