Software and Materials Support Antenna Design and Manufacturing

Antennas are an essential part of all systems that use radiated electromagnetic waves—communications, radar, sensing, and measurement. Antenna design and construction techniques have paralleled recent growth in all of these application areas. This report is a brief overview of the major advances in antenna engineering over the past several years. It is intended to provide background for electronics professionals who do not specialize in antennas, but who would benefit from some additional general knowledge.

Software for Simulation and Analysis

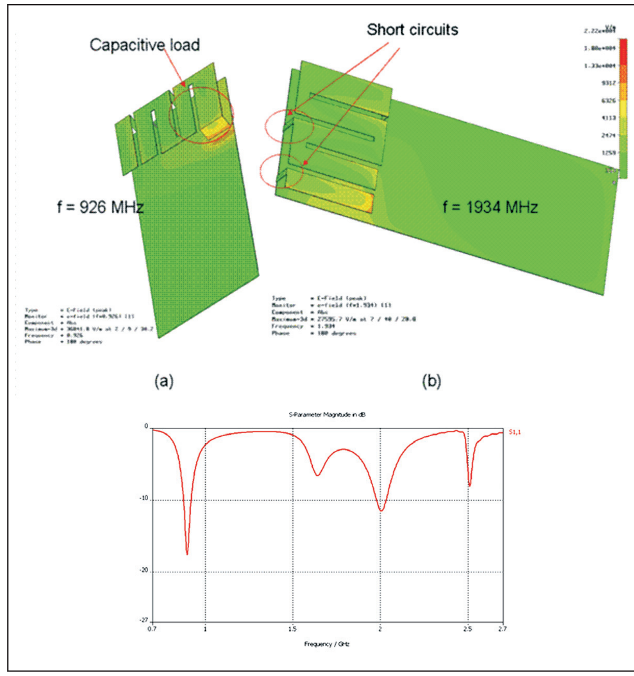
The single biggest advance in antenna engineering is the availability of multiple software tools that solve Maxwell's equations using various numerical methods. The first of these (from the 1980s) were Method of Moments programs such as the Numerical Electromagnetics Code (NEC), which has been regularly updated and is still an important part of antenna design. NEC uses segmented lines, determining current and phase of each segment, then integrating the entire structure. Near-field, far-field radiation, as well as response to an applied plane wave can all be accurately calculated.

Similar methods are used in other software that applies the segmentation of the structure in different ways: planar structures, including layers (e.g., for patch antennas), and three-dimensional tools for solid materials, conformal structures and other antenna configurations that cannot be analyzed as planar structures.

More recently, over the past ten years, finite difference time domain (FDTD) techniques have been refined, providing analysis that offers different insight into electromagnetic behavior. Time domain-based simulation allows the antenna designer to examine the flow of current in the antenna conductors, as well as the radiation characteristics. This insight is most important in traveling wave structures like transmission lines and waveguide that are part of an antenna's feed system.

These antenna tools are closely related to (in some cases identical to) electromagnetic tools for circuit design and analysis. Where there are differences, they are usually in the setup of physical parameters for simulation, and in the choice of data output for analysis.

Like all software tools, their accuracy is mathematical, not measured. They rely on precise characterization of the antenna structure and its environment. For example, a wireless base station antenna system should be analyzed along with neighboring antennas and the supporting tower structure. This is especially important for new smart antenna systems which must maintain predictable directive performance.



This dual-band patch antenna is an example of a structure developed for a specific application, using electromagnetic simulation and analysis software. *(Image courtesy CST)*

Many times, the surrounding environment is unpredictable or too complex to characterize completely. Examples include antennas close to earth, buildings and vegetation. The dielectric properties of the surrounding objects may not be known, or may be variable in the case of moving objects such as vehicles or aircraft. In cases like these, system design requires that idealized antenna models be supplemented with measurements, or with measurement-based statistical models.

Conductive and Dielectric Materials

The rapid growth in wireless systems has created new demands for size, performance, cost and manufacturability of antennas. To make smaller antennas, high dielectric constant ceramics may be used to slow the wave and reduce the physical size of a wavelength. Patch antennas on ceramic are common for GPS receiving antennas.

Large-scale manufacturing requires materials that are inexpensive and easy to fabricate, while providing the necessary performance. A good example is the evolution of base station antennas from stamped aluminum sheets assembled into a fiberglass radome, to photo-etched copper patterns on large sheets of printed circuit board laminate with proper dielectric constant for the feed system, enclosed in a much lower profile radome.

Handset antennas represent a variety of designs and materials. Some use conventional whip or loaded whip antennas, while others use structures integrated into the device housing. Patch antennas, conventional or on various alternative substrates, may be used, along with folded, loop, strip or other configurations that are adapted to fit the physical constraints of a particular device.

Other low cost applications may use antennas that are printed onto the same p.c. board as the circuitry, or on a flexible substrate that is glued to the inside of a non-conductive enclosure. High performance antennas may also be integrated into the host structure—there is a large amount of effort into the design and manufacture of antennas that conform to the fuselage of aircraft, or that are embedded within composite materials used in aircraft and many vehicles.

The automotive industry has adopted some of these techniques to incorporate the growing number of antennas in cars and trucks. In addition to aesthetic concerns, these antennas are exposed to harsh environments: temperature, moisture, solar UV and vibration. A recent analysis of a high-end auto revealed at least 12 antennas: entertainment (AM/FM/TV), satellite (GPS and satellite radio), multiple wireless communications antennas, Bluetooth, keyless entry, security, radar (front and rear), tire pressure monitor, etc.

A wireless handset may also include multiple functions such as multiband operation, GPS, Bluetooth, WiFi and TV broadcast. These functions will require either multiple antennas, or multiband antennas with supporting multiplexing circuitry. Achieving desired performance levels makes this type of design a major challenge.

What's Next? Integration?

Integration at the "box" level will likely evolve into closer integration of antennas with circuitry. We already have active antennas, with preamp or power amplifier located adjacent to the antenna, so it is a relatively small step to continue that integration to higher complexity. Examining the performance—both radiated and within the circuitry—will require even better software tools, used by engineers who understand the workings of both the circuit and antenna.

The spread of wireless technology appears to be nearly boundless. Those new applications will need to be supported by the appropriate new antenna techniques and technologies.

From July 2007 *High Frequency Electronics*