E911 GPS Mandate Challenges Accepted Antenna Designs

By Andrew Beutmueller

In June of 1996, the Federal Communications Commission (FCC) proposed the Enhanced 911 (E911) Mandate # 94-102. During phase I of the FCC order, carriers were required to provide 911 operators with the caller's telephone number as well as the base station location. Clearly this was not precise enough for mortal emergencies. Phase II required that coordinates for locating the caller had to be provided within 125 meters in 67% of 911 calls. The FCC established a four-year rollout schedule for Phase II, beginning October 1, 2001 and to be completed by December 31, 2005. The question is how can carriers best comply with the mandate, perhaps making it an opportunity rather than a liability? Carriers should take a look at improving antenna performance on the handset before they spend too much on other measures that may turn out to be superfluous. New antenna technology offers not only improved reception but enables location-based services including fleet management, location-based marketing, billing, navigation, emergency assistance and a host of other billable services. How will this be accomplished?

Much attention has been paid to improving GPS receiver sensitivity for mobile phone use. However, when practically applied to the phone, the receiver improvements alone are not enough to ensure a reliable location service. "What is required to support GPS reception is antenna technology that maintains high performance in a small volume while the phone is being used," according to Dr. Oliver Leisten, CTO of Sarantel Ltd. Because GPS is a line-of-sight service, a network-assisted form called "A-GPS" has been deployed to provide coverage in difficult environments, like urban canyons and inside buildings. A-GPS gives the GPS receiver in the mobile phone a 10-15dB advantage over standalone GPS, supposedly overcoming many of the disadvantages of not being able to directly view the GPS satellites.

Two important antenna issues come into play when integrating GPS into mobile phones:

1. near-field interaction with the user holding the phone; and
2. polarization of the antenna. All conventional antennas have a reservoir of energy called the near-field that is stored in the air surrounding the antenna. When the user's hand or head intersect with that reservoir, the characteristics of the antenna change. The resonant frequency shifts, the reception pattern changes, and energy that would otherwise be available to the receiver is absorbed by the head and hand of the user.

The reason for this is that energy tends to flow to the highest dielectric medium. Air is a relatively low dielectric; the human body is a higher dielectric. When the near-field intersects with the user, energy is literally sucked out of the air surrounding the antenna and reception is diminished.

The second issue regards polarization of the radio signal. GPS signals are circularly

polarized, meaning the wave is transmitted in a spinning helix orientation. Voice signals are typically linearly polarized. That is to say, a pull-up antenna must receive a signal that is oscillating up and down &#151 if the signal and the antenna line up just right, reception is normal; in the case of GPS, which is transmitted via "a spinning wave" the pull-up antenna will only receive a signal where its line of reception intersects the circle of the GPS signal. On the other hand, a circularly polarized antenna would intersect with the entire spinning wave, sending the maximum amount of signal to the receiver.

What's the Answer?

The average mobile phone antenna does not fully support A-GPS or standalone GPS thus undermining the advantages and safety standards intended by the location service. Furthermore, integrating a GPS receiver in a mobile telephone is a technically difficult task. The mobile telephone must be able to receive relatively weak satellite signals with enough clarity to perform all or part of a fix (in the case of network-assisted GPS) over interference from higher power voice band signals. The GPS antenna is a critical element of the location system. It must have a broad view to track satellites that at any given moment may be high overhead or down near the horizon. It must be small enough to fit in the mobile phone, including all of its ancillary parts like ground plane, additional filters, etc. It must work when pointed in any of the directions a user holds a mobile phone &#151 dialing, talking, or clipped to the user's belt.
The ideal solution is to reduce the size of the near-field so that it does not interact with a higher-dielectric medium.

The Antenna

Solving the problem associated with near field interaction has been accomplished using a combination of advanced materials and antenna structure to constrain the near field to a space small enough so that it never interacts with the user. As a result, the antenna performs as well in free space as it does next to the user's head. Preventing this interaction provides a significant advantage in terms of signal power offered to the receiver, gaining back all the energy lost by conventional antennas and improving the reliability of the receiver. "Sarantel uses a core of high-dielectric ceramic, which increases the antenna's ability to store energy compared to other energy blocking/ absorbing bodies in its proximity. Ceramic also allows the antenna to be reduced in size," explained Brad Hurte, President of Sarantel Inc., the US arm of the UK antenna manufacturer. "The use of high-dielectric ceramic at the core of the antenna also confines the near-field to a volume not much larger than the antenna itself. Proximity de-tuning effects simply do not occur with these antennas because the user never gets the opportunity to interact with the near-field."

New miniature ceramic "PowerHelix", source Sarantel

Secondly, wireline network engineers understand that paired wires conduct noise through magnetic induction. By twisting the wires, they were able to moderate induced noise. However, this creates magnetic pole reversals along the cable that cancel each other out. In the same way, a mobile antenna should be designed as a twisted loop. As the loops wind around the cylindrical ceramic core, they create a magnetic reversal at the middle of the antenna. This causes the magnetic field of the antenna to be very tightly confined, also restricting the size of the near field.
Thirdly, antennas with an integral balun can be balanced without a ground plane. Ground planes consume precious handset real estate and cannot be shared by different antennas because they conduct noise, which is subsequently channeled by the antenna into the receiver.
Finally, the dielectrically-loaded antenna has a frequency response wide enough to cover the bandwidth required for the application, but narrow enough for filter-like response. For certain applications, designers can replace the cheap conventional antenna and its ground plane plus an expensive filter network with just a new dielectrically-loaded antenna ceramic antenna, which is considerably smaller.

GPS Reception Test Results

Linear polarized antennas, like the antennas used to transmit and receive voice band signals, perform remarkably poorly when required to pick up circularly polarized GPS signals, see Fig. 1.

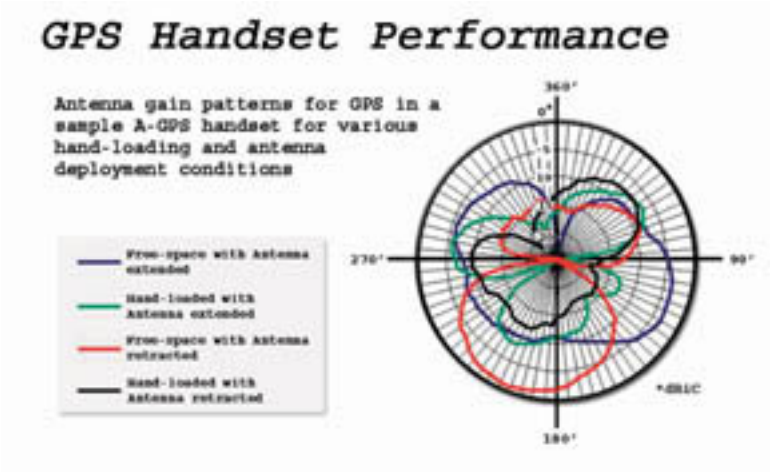

Fig. 1. Standard handset antenna results, source Sarante

When a circular polarized antenna is mounted on the same phone, a 10-15dB improvement in gain is realized, offsetting the loss from the linear polarized antenna, improving the ability of the GPS subsystem in the phone to get a reliable position fix in difficult environments. It has been asserted that CP is not possible when the antenna is placed near human tissues, like the user's hand or head. But if you examine the test results in Fig. 2, you will see that a dielectrically loaded quadrifilar helix antenna demonstrates strong CP characteristics whether the antenna is located near the user's body or not.

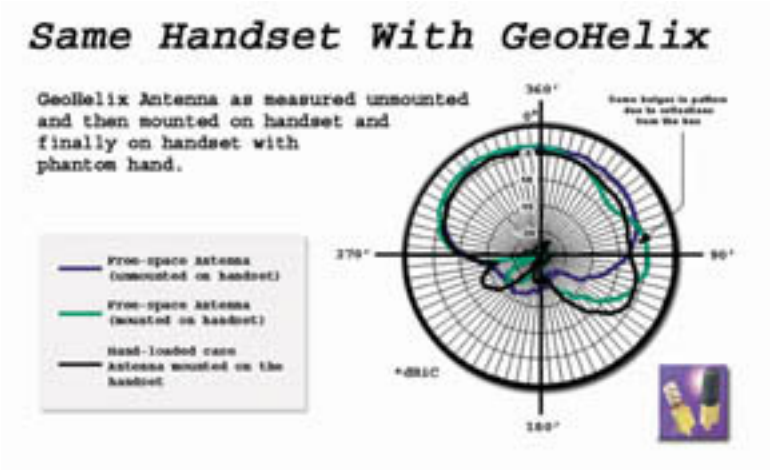

Fig 2. Measurements of GeoHelix antenna on same commercial handset, source Sarantel

"The reason for this improved performance is restriction of the antenna's near-field to a space only a few millimeters larger than the antenna, diminishing near-field interaction with the user that degrades antenna performance," said Hurte. "It has also been claimed that CP is unnecessary for a service that will require indoor reception due to loss of polarization of source signals from scattering. On the

contrary, any CP retained by the source signal in any environment should and will naturally be favored by a receiver coupled with a good CP antenna," Hurte explained.
Tests of a commercially available handheld receiver have shown that performance improves measurably (a 4dB improvement in signal-to-noise ratio) when antennas of nominal difference in zenith gain (0.5dB) but measurably different CP (7dB in front/back ratio) are employed as in fig. 2.

Opportunities

What it all boils down to is Quality of Service; customers want strong signal reception above all other quality of service issues. And when it comes to the personal security implications of E911, the survey numbers are even higher. In a recent story by Antone Gonsalves in TechWeb News, a mobile phone customer survey indicated that reception was the number one quality of service issue, and was a strong determinant of customer loyalty. So when reception becomes a matter of life as in GPS location fixing, customers will obviously look for carriers to provide the strongest antenna technology available. The carrier in turn will enjoy increased customer loyalty as well as value-added services and applications that superior antenna performance engenders. GPS will ultimately provide the accuracy required for location-based services beyond E-911 including new fleet management, location-based marketing, billing, navigation, emergency assistance and a host of other billable services; and advancements in mobile handset antenna technology will play a key role.

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