Antenna design for portable tracking devices by Professor Simon Kingsley, Antenova

Figure 1: An 80x50x6.9mm tracker device with GPS RF antenna module (at the bottom of the picture).

Specialist tracking devices, that you can interrogate by cellular radio to find out where the host platforms are, have been around for some time.

Adapting these vehicle trackers to make them consumer devices for tracking children, workers, old people, pets, luggage and other personal property requires adaptations to the antennae and radio antenna modules to create very small tracking devices and other mobile GPS units.

Some trackers are equipped to provide an alert if the device is tampered with, or if the host device is removed or even if it goes out of a programmed area (known as geo fencing). Trackers can also be equipped with a panic or call button if the device is being worn by a lone worker; Figure 1 shows a credit card size tracking device suitable for lone worker and executive security applications.

In principle a tracker is a simple device having a GPS receiver, so that it knows where it is, and a cellular radio terminal so that it can transmit this information when commanded to do so. However, in practice there are some challenging problems involved in designing the necessary radio system.

Portable tracking devices come in all shapes, they can be watches, credit card format, USB sticks, even dog collars, but unfortunately they are mainly one size, i.e. small. Small form factors create problems with shrinking the GPS and cellular radio components to the limited space available, preventing them from interfering with each other and getting the antennae to transmit or receive signals efficiently.

GPS signals are circularly polarised and, in the past, ceramic patch antennae have mainly been used to receive them. Patch antennae work well in devices with a fixed horizontal orientation because they have a relatively narrow beam looking upwards at the sky. They are efficient if they are large enough and are mounted on a suitably large ground plane. However, in a mobile device such as a tracker, the orientation may vary, so patch antennae are much less suitable. There is a need for an antenna with a more omni-directional pattern so the orientation of the tracker is less important. Unfortunately the more omni-directional an antenna pattern is, the lower the antenna gain and, as a result, the satellite signals are received with a slightly weaker signal strength, resulting in lower location accuracy. This, however, is a necessary requirement and is somewhat compensated by the fact that the tracker can receive signals from a greater number of satellites; this in turn can help to recover the location accuracy. Antenova has been working on a number of antennae and radio antenna modules that are specially adapted for very small tracking devices and other mobile GPS units.

The GPS system

The GPS system is based on a constellation of satellites, currently numbering around 30. Each satellite continually transmits continuous radio signals containing navigation messages, and a GPS receiver calculates its position by careful timing of these signals. One of the most important parameters is the carrier/noise ratio (C/N0), which the receiver computes and reports for each satellite. The carrier is the wanted signal from the satellite and the noise is the unwanted background signals. Background thermal noise is always present, but there may be noise from the tracker itself and any other electrical devices that are nearby. With a good C/N0 (low noise, a good view of the sky and plenty of satellites visible) a stationary GPS tracker can locate itself with a median error of about 2.5m. When the noise level rises this rapidly gets worse, so it is important to maximise C/N0.

Navigation systems for cars or hand-held devices used for hiking are relatively large structures and do not generally include a cellular radio. In a small tracking device the GPS receiver and the cellular radio are squeezed into a very small space.

Engineers will need to bear in mind that noise from the GSM system, the host processor and even the LCD (where fitted) may interfere with the reception of GPS signals. Another feature to bear in mind is that coupling between the GSM antenna and the GPS antenna reduces the efficiency of both radio systems. Other problems are that GSM transmissions may swamp the GPS front-end LNA creating harmonics and other problems and that wideband noise from the GSM PA may de-sensitise the GPS receiver. Additionally, the close proximity of other components, such as batteries, may affect the performance of both radio systems. Finally, the space available for the GPS antenna may not be suitable for the best signal reception. With tracking devices the orientation of the device in use is unknown and so an antenna pattern that is as omni-directional as possible is required. There will always be one location for the antenna that is best for omni-coverage but this position may not be available because of the ID of the device and the layout of all the other components. This is less of a problem on larger platforms.

Coupling GSM and GPS

The solution to these issues lies in careful system design and a good understanding of antennae. Coupling between the GSM and GPS radios and antennae, for example, may be minimised by mounting them on opposite sides of a PCB. A blocking filter before the GPS LNA, and a second one after it, can prevent the GSM transmissions affecting the GPS system.

Combining the radio and antenna is particularly useful for the GPS system where the radio and antenna are roughly the same size and can be manufactured as a single radio-antenna unit; optimising the design is then a matter of good design practice and know-how. It is also important to have good measurement facilities for both passive and active testing. Testing is usually carried out in an anechoic chamber equipped to emulate the signals coming from GPS satellites and from cellular base stations.

The 3G network

Although the 3G network may be used for trackers, GSM is usually preferred because of its more universal coverage. The DCS and PCS bands are not usually a significant problem for the tracker designer, but the two low frequency bands at 850 and 900MHz are a major problem. If you ask the question: "Can an antenna be made indefinitely smaller?" the answer is there is a physical limit preventing this. This limit, sometimes called the Chu-Harrington limit, is related to the smallest volume that will enclose the antenna, expressed in wavelengths. If a small antenna working at long wavelengths falls below this limit then either bandwidth or efficiency will be lost. The ideal length of a mobile phone for low-band GSM performance is around 120mm, but reasonable performance can be achieved down to about 80mm. Unfortunately, many tracking devices are as little as 40mm in their largest dimension so the antenna design is a significant challenge.

Every antenna must have two halves, the antenna itself is one part and the PCB forms the other. The only exception to this is when the antenna itself has two halves, such as with a di-pole antenna. With a typical tracker antenna arrangement the antenna must be very small as many other components must fit inside the tracker box. In effect the PCB is the main radiating component and its lack of length becomes critical.

One solution to this problem is to extend the PCB groundplane outside the box as part of any external features such as the strap on a watch-based tracker, or the collar on a pet tracker. Even a loop on the end of the tracker for attaching a cord can make a useful difference to the antenna performance. If no external features are available, it is worth considering using a balanced di-pole-like structure, having two antenna arms, because it may be possible to get them a long way apart by attaching them to the inside of the box at opposite ends.

The eternal triangle

The designer of portable tracking devices is trapped in a space with three types of boundaries. One is the laws of physics that limit how effective a small antenna can be. There is not much that can be done about this except to make use of good engineering practice and experience. Another boundary is cost, because trackers must often be inexpensive devices. Engineering for cost reduction is an established and effective art but it does not increase the designer's options. The third restriction is formed by the technology available. For example, if better components were available, could the tracker design and performance be improved? Let's look at this.

Shape changers

A typical complete GSM module that might be used in a tracker measures roughly 30x30x5mm3 and the battery is often a similar size. These two components take up the majority of space available as the processor and GPS systems are generally smaller. Suppose now that the whole of the GSM radio could be shrunk to a single chip or a much smaller module. Suddenly a lot of space is freed up in the tracker, but how best to use it? It would not help to make the box smaller, but perhaps the box could be made longer and thinner, especially if a suitable battery could be chosen. The tracker now becomes a thick strip that might be hidden in the frame of a painting or concealed in the lining of a luxury designer bag, just to give two possible examples.

Now imagine that it is possible to introduce flexible printed circuit technology together with a curved battery. The strip tracker can be turned into the watch strap, instead of being part of the watch, or become part of a dog collar or a belt. The long format of the device would mean the GSM radio would work well and the device would be easier to hide. At present the size and rigid shape of the SIM card and holder would prevent this type of design being realised, so a new SIM card format would be needed. These considerations show that improved components can help the designer and that this is the boundary to aim for.

Low cost tracking devices are growing in popularity and will find an ever-increasing role in protecting people and property. To ensure that the radios and antennae are located in the best possible positions for efficient radiation and minimum coupling, both GPS and GSM radios and antennae must be designed in from the start of the tracker development. Greater integration is needed between radios and antennae to create compact modules that are easy to build into prototypes.

For example, Antenova's GPS RadioNova RF antenna module contains both the antenna and all the RF and signal-processing circuits. It requires only the addition of some processor power on the motherboard and application software. The module provides an RF subsystem to add GPS and location functionality to a portable tracking device, for both RF and satellite acquisition performance.

By Professor Simon Kingsley, Antenova. This article was originally published in EPN magazine, 25/06/2010

For more information, or details on the full range of Antenova's products available from Anglia please call +44 (0)1945 474747 or email info@anglia.com

Alternatively, click on this link to go to the main Antenova section where you can view other news articles and product data.

back to product news

This news article was originally published in September 2010.

www.anglia.com
info@anglia.com

Tel : +44 (0)1945 47 47 47
Fax : +44 (0)1945 47 48 49

20/9/10