BALANCED ANTENNAS FOR GPS AND GALILEO RECEIVERS

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Abstract

A new type of antenna has been developed for receiving GPS and Galileo signals. The antenna is an efficient balanced dipole structure fed from an integral transmission line balun. The antenna is small, linearly polarised and designed for integration in handsets, laptop computers and other small data devices such as USB dongles. Field tests have shown that the performance of the antenna is generally similar to that of larger and more expensive circularly polarised ceramic patch antennas and helical structures.

Introduction

The GPS and Galileo position determination systems operate by measuring the signals propagated from super-accurate synchronised clocks carried on a constellation of satellites in orbits with a height of 23,000km. To obtain a full 3-D fix it is necessary to receive signals from four different satellites; the maximum accuracy will be obtained when three of these are widely spread in azimuth (optimally at 120°) and the fourth is within 30° or so of the zenith. The initial position estimate can be improved by receiving signals from additional satellites – this allows multiple estimates of position to be made, allowing a better estimate of the actual position. The satellite signals use direct-sequence spread spectrum and each satellite has a unique spreading code. Although the signal levels (and signal-to-noise ratios) of each signal are very low (below -140dBm), the de-spread signals are used to report the time and position at which each was transmitted from its satellite. Knowledge of the relative positions of the satellites them allows initial coordinates of the receiver to be determined. Data relating to position and timing is transmitted in frames at 50b/s. A frame is transmitted in 30s and a complete cycle of 24 frames takes 12.5 minutes.

When a receiver is switched on it correlates the known spreading codes with the signals from each satellite and acquires the ephemeris data from the signals. Multiple correlators are used to speed up the time needed to match the available codes with each signal. The time taken by this process for a receiver in a given location depends on the signal/noise ratio of the incoming signals and is known as the Time to First Fix (TTFF). (Different typical TTFFs apply depending on when the receiver was last used and whether it was used in a similar or far distant location.) The usual time for a 'cold start' in which the receiver has stored the almanac data is about 45 seconds. A 'warm start' takes less time because the receiver already contains valid ephemeris data.

The signals radiated by the satellites have right-hand circular polarization (RHCP). An ideal receiving antenna *for use in an unobstructed outdoor environment* therefore requires a wide, generally upward-looking beam and receives RHCP.

Antenna choices

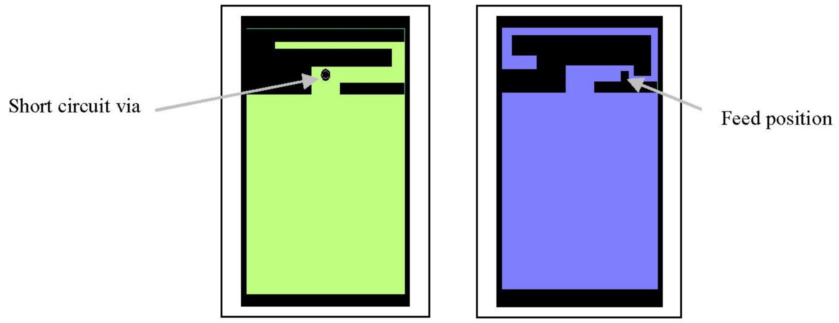
The most suitable antenna for a fixed receiver provides RHCP with a beam extending down to about 15° elevation over a range of 360° azimuth with some gain reduction overhead.. However the situation for hand-held devices is not so clear. Installed in a mobile phone handset, an antenna mounted on the front of the system PCB will look upwards when the handset is held horizontally, but when in use for a phone call its view of the sky will be severely obstructed by the user's head. An antenna on the rear will see only part of the sky without obstruction.

The polarisation of the signal from the satellite is RHCP and a signal reflected from the ground is LHCP. While this gives good rejection of a ground-reflected signal in a clear environment, in a city street or indoors there may be no direct signals from many satellites and the reflected signals may have almost any polarisation. This implies that in the conditions that give rise to the lowest signal levels the polarisation is poorly defined and the advantage of an RHCP has been lost. In these scenarios the beamwidth and look-direction of the receiving antenna are much more important than its polarisation.

Antenna choices for circular polarisation include crossed dipoles, Lindenblad arrays, quadrifilar helices, and CP patches. Of these the Lindenblad is too large for hand-held devices, the patch is too directional and the Quad-helix in a suitable compressed form is too costly and does not conform well to the shape of modern slim-line handsets. Pathak et al (2003) demonstrated that the performance of a wide-beam linearly polarised antenna can out perform an RHCP antenna in a cluttered multipath environment. A simple dipole or inverted-F antenna can provide very wide pattern beamwidths and is simple to integrate into a handset. A balanced antenna such as a dipole is also less susceptible to detuning caused by application-dependent factors such as different PCB sizes. However, the main problem with a dipole at 1575 MHz is that it is 95 mm long, too large to be incorporated easily into a handset. Another problem is that many mobile radio systems use unbalanced RF inputs and interfacing with a balanced antenna introduces additional cost and insertion loss.

A compact design

A more compact dipole antenna can be constructed by making both radiating arms coplanar, one on each side of a PCB substrate, see figure 1. This arrangement can be quite efficient provided the substrate material is sufficiently low loss at 1575 MHz. PTFE-glass laminates have been found to work well. To keep the design compact, the radiating arms of the dipole have been meandered, as Fig 1 shows. Although the radiating arms of the dipole may lie over one another, it has been found that displacing the arms with respect to each other so that they do not follow exactly the same path in their respective planes can provides improved radiation efficiency and bandwidth. Likewise, although the radiating arms may be of the same length, it has been found that arms having different lengths lead to improved bandwidth.



(a) (b)

Figure 1. (a) front side and (b) reverse side of the new antenna structure showing the meandered arms displaced somewhat with respect to each other and having slightly different lengths.

The two conducting arms are connected together by a short-circuit conductor whose function is to limit excitation to the region of the feedline and antenna, so the arrangements in the remainder of the circuit of the device to which the antenna is attached do not affect the balance of the antenna circuit. The arrangement is derived from a Pawsey Stub balun; it is electrically balanced and is excited by a voltage applied across the balanced transmission line. This can be seen in the cross-section shown in figure 2. Most types of feed structures – coaxial, microstrip of CPW line – may be used in conjunction with this arrangement

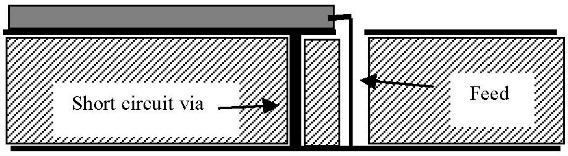


Figure 2. Cross-section of the antenna feed.

This new design has been given the marketing name of GPS RADIONOVA® and is protected by a UK and international patent applications [3]. The antenna can be mounted vertically (it is only 7 mm high) or coplanar with The PCB in a handset or USB dongle. An example of co-planar mounting is shown in figure 3 where the antenna and an accompanying evaluation board are shown for handset and dongle applications.

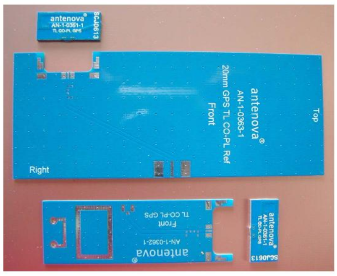


Figure 3. Co-planar mounting of the antenna and on evaluation boards

Performance

Like any antenna, the radiation pattern varies depending on the size of the nearby PCB of the application device. However, the pattern is essentially dipolar and can give good coverage of the sky, especially at low elevation angles. An Ansoft HFSS simulation of the radiation pattern for a vertical mounted antenna is shown in figure 4.

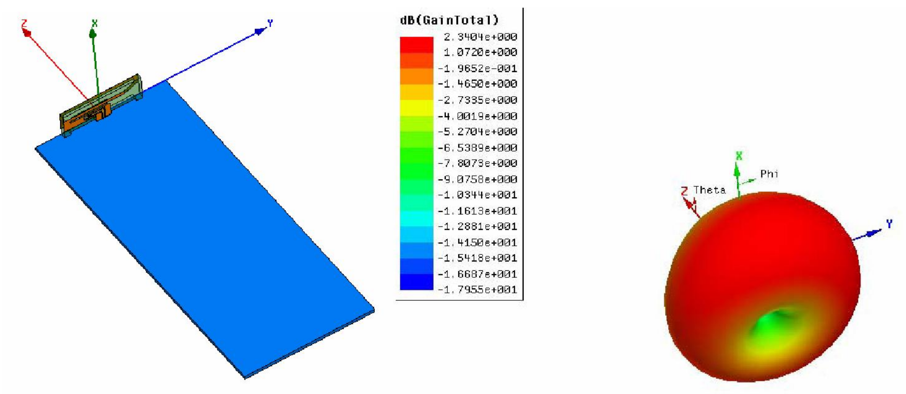


Figure 4: Simulated 3D radiation pattern

Being balanced, the resonant frequency of the antenna has little susceptibility to the size of the main PCB or its location on the PCB. The efficiency is about 70% if the antenna is located at the edge of a PCB, such as at the top edge of a handset, but lower if it is placed towards the centre.

The antenna has been field-tested on a GPS USB dongle and compared with a similar dongle using a 18x18mm ceramic patch antenna. Care was taken in positioning the dongle and the cable in the same way for both sets of measurements. The results are shown in table 1 and it can be seen that although the carrier to noise ratio (C/N) is around 1dB lower than for the RHCP patch, the new antenna enables more satellites to be detected and reduces the time to first fix.

	TTFF	No satellites	Max C/N	Average C/N
Ceramic patch	36 sec	5	41 dB	39 dB
Antenova design	33 sec	8	40 dB	37 dB

Table 1. Comparison of a RHCP ceramic patch antenna and linear Antenova antenna under the same conditions.

Discussion

A novel GPS antenna design has been developed that compares favourably with conventional patch and helix antennas but has a lower manufacturing cost and is smaller and lighter. In the complex multipath environment often encountered by handset users the linear polarisation of the antenna is not found to be a disadvantage. Any slight gain disadvantage is off-set by the better coverage of the sky. Although balanced, the antenna contains an integral transmission line balun and can be connected to conventional 50-ohm unbalanced RFIC inputs.

Because the antenna is stable in frequency it can be used with a fixed matching circuit and be permanently connected to a GPS RF integrated circuit. Such a complete module comprising the antenna and receiver will be available shortly in a format measuring 35 x 7 x 1.6 mm (l x h x w). The module contains the antenna and all the RF and signal-processing circuits and requires only the addition of some processor power on the motherboard and appropriate application software, thus forming a complete RF solution when adding location systems to mobile phone handsets.

Acknowledgements

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[3] “Balanced Antenna Devices”, UK patent application GB 0518996.4