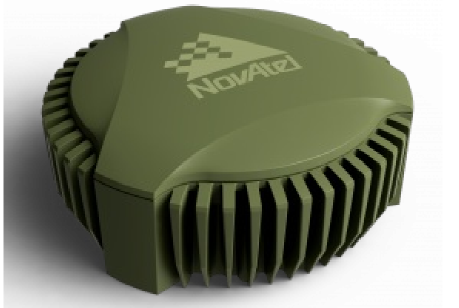
PAST, PRESENT AND FUTURE OF POSITIONING

GNSS receivers â€“ evolution or revolution?









Satellite surveying… are there any industry professionals out there not using it on (almost) a daily basis? Over the last 30 years, GNSS has become the main positioning instrument for most applications, writes Huibert-Jan Lekkerkerk. Of course, there are still some exceptions where correct relative positioning is needed and dedicated optical systems such as a total station or level instrument are used, but even these are often set up over control points determined using GNSS techniques. This article investigates the developments in GNSS over the last decade and attempts to predict the future.

Around a decade ago, a review of GNSS systems would have entailed two types of systems. The most prevalent was the high-end RTK unit costing over €20,000, and the second type was the handheld GIS data collector. The main difference between them was their accuracy – centimetre versus (deci)metre level – and their antenna. The high-end systems all had a large antenna with an integrated receiver and separate controller that you had to mount on your survey pole, whereas the GIS types had a (small) patch antenna, receiver and controller integrated into a single unit. The only other type of system one could have were the machine control units for the construction industry; these were based on the same technology as the high-end RTK units.

Applications

All the above instruments are still used today. The high-end RTK system still looks the same but has come down in price. And, where the standard setup in the past would be two units connected by UHF radio, most brands now offer that just as a choice. The main connectivity comes from mobile data networks with corrections sent over the internet. Rather than supplying a similar unit as a base station, most manufacturers now offer what they call a network receiver capable of transmitting (and receiving) network corrections (Figure 1).

Figure 1: Networked continuously operating reference station (CORS) (Satlab).

Another major development in GNSS receivers over the last few years is the integration of an ‘electronic’ bubble in the pole (Figure 2). Whereas in the past the pole had to be kept exactly upright for a correct position (and height) measurement, the modern receiver now has an integrated roll and pitch sensor like those in a smartphone. Using the readings from the sensor (and the antenna height), the position of the antenna is corrected towards the ground point up to an angle of 30 degrees. Based on this additional information it is possible to hold the pole at an angle and still obtain the correct position and height information. This not only makes accurate measurements easier; it also allows the surveyor to measure otherwise inaccessible points by positioning the pole at an angle.

Taking the use of freely available satellite-based augmentation system (SBAS) corrections and post-processing of earlier GIS data collectors a step further, this type of receiver is nowadays capable of receiving RTK corrections as standard, thus allowing the collection of GIS data to centimetre level rather than metre level. Also, GIS receivers increasingly no longer have an integrated controller but rely on any Bluetooth connected device such as an Android smartphone instead (Figure 3).

Figure 2: Tilt-enabled high-end land survey RTK receiver (ComNavTech).

In addition to the receivers mentioned above, there are a multitude of small black-box RTK receivers designed specifically for use on unmanned aerial vehicles (UAVs or ‘drones’) or for machine control (Figure 4). Often these have a large integrated memory allowing them to (also) store raw data for post-processing, giving even more accurate positions.

GNSS constellations

About ten years ago, GNSS life was simple for the end user: it was pretty much GPS or nothing. Glonass, the Russian GPS equivalent (and the first to reach operational capability in the early 1990s), had deteriorated due to the economic crisis at the end of the 1990s. Glonass was revived a few years later, getting back to full operation about five years ago.

At the same time, although we all used GPS, another system was becoming ‘the talk of the town’: Europe’s Galileo. Set up as a public-private partnership in the early 21st century, it was reshaped into a government-only (but still civilian) system. Although Galileo is not expected to reach full operational capability until sometime in 2020, the reception of Galileo signals already benefits positioning quality.

Last but not least, seemingly out of nowhere, has come BeiDou, the Chinese GNSS. It was initially set up as a regional system, but the Chinese were quick to start launching satellites. With 23 satellites in orbit (of which a considerable number are indeed regional), there is now full capability over central Asia and initial capability in the rest of the world. In other words, for those using their receivers in central Asia it is worthwhile to ensure that their system also has BeiDou reception.

Figure 3: Bluetooth receiver for mobile device connection â€“ Note: Apple devices not to scale (SxBlue GPS).

System developments

But it is not just the number of satellite systems that have increased from 1.5 GNSS to over four GNSS in the last ten years; developments within the systems have also taken place. On 24 December 2018, almost five years after the original plan, the first GPS-III satellite capable of new (and more accurate) positioning signals was launched. In 2020, the first launch of Glonass satellites with a full range of so-called CDMA signals is expected to bring the system onto the same signal basis as the other GNSS.

Whereas ten years ago a receiver with 80 channels would be considered technologically advanced, a modern receiver needs over 500 channels in order to optimally support all the signals from the four current GNSSs (Figure 5). After all, a single signal from a single frequency on a single satellite in a single GNSS accounts for a single channel in a GNSS receiver, and each GNSS has between 25 and 30 satellites in space, each broadcasting two to three signals on around three frequencies.

Correction signals and accuracy

Merely receiving signals from the four GNSSs does not give the professional user the required accuracy. Standard positioning from any of the four GNSSs alone (or combined) is at the metre level. However, for any modern job sub-metre accuracy is a common requirement. To achieve this higher accuracy, correction signals are needed. The most usual types of correction signals are the free-to-air SBAS such as the American WAAS or the European EGNOS. These signals, which are broadcast in many parts of the world from the various SBAS systems, can be received by all GNSS receivers, whether they are professional ones or inside a smartphone. SBAS corrections make it possible to achieve an accuracy of around one metre.

For those needing better accuracy, the standard correction signal to go to is real-time kinematic (RTK dGNSS or RTK). As a standard, all professional RTK receivers can run RTK GPS whilst most of them also support RTK Glonass corrections. No receivers currently offer more than joint GPS and Glonass RTK solutions, but manufacturers are looking into the addition of Beidou besides GPS and Glonass in the RTK solution. But even with ‘just’ two GNSS constellations being used in the RTK solution, the current accuracy is less than 1cm + 1ppm (68%) horizontal and 1.5cm + 1ppm (68%) vertical for most RTK-capable receivers. And with the modern network-type RTK, the 15km range limit of the early days with a single base RTK, has been replaced by the requirement to be within the virtual network and have internet connectivity.

The use of precise point positioning (PPP) is new to the land survey industry but has been common in the offshore surveying community for many years. With this technology, accuracies horizontal and vertical of sub-decimetre to the decimetre level are achievable at considerable distances from the base stations. Rather than SBAS and RTK (where the base stations are used for computing differential corrections), in PPP the base stations are used to find accurate corrections to the raw satellite position information. The roving receiver uses this information to compute an improved position, giving a first ‘convergence’ time of around 20 minutes. As the PPP correction signals are proprietary, not all receivers can use PPP correction signals (Figure 5). All PPP solution providers provide GPS corrections and some also work with a combination of the other available GNSSs.

Figure 4: Miniaturized RTK receiver for UAV use (Tersus-GNSS).

Anti-jamming and anti-spoofing

Whereas a decade ago GNSS was a mainly a professional tool, apart from perhaps being an expensive consumer accessory for in-vehicle navigation, it is now integrated into many applications – principally as a positioning system but also as an accurate basis for timing. With ‘autonomous’ being the buzzword in the navigation industry, the reliance on both accurate and reliable positioning is increasing by the day. Where reliable positioning is needed, the challenge is not only to tackle weak satellite or correction reception, but also to avoid interference. After all, in view of the rising number of autonomous cars, drones and even ships, a GNSS outage anywhere could quickly lead to all sorts of potentially serious issues. It is relatively easy to ‘jam’ GNSS signals (causing loss of signal) because the signals are weak. This is not always intentional. A few years ago, a legal argument was fought out in the USA between LightSquared and the American GPS community over LightSquared’s proposed transmission network due to its interference risk. This illustrates the concern about GPS jamming. In the end LightSquared went bankrupt (and was recently refloated as Ligado with a GPS-friendly solution). Even more potentially dangerous is what is known as ‘spoofing’, in which the original signal is intentionally replaced by a stronger incorrect signal. Tests have shown that if this is done subtly, many receivers and applications will start to follow the incorrect signals, which could ultimately cause ships or aircraft to collide or military troops to be directed off course. To counteract these effects, industry-leading manufacturers such as NovAtel are not only researching anti-jamming and anti-spoofing solutions but are also introducing new antennas that are more resistant to jamming (Figure 7).

Figure 5: Modern receiver capable of receiving 572 channels (Geo-Fennel).

Into the future

Technology has clearly progressed over the past ten years. The main change has been from just one fully operational GNSS (i.e. GPS) towards four (almost) fully operational systems today. But other improvements have also been made. As a result, we will see receivers with more channels appearing in the market. For the next decade no radical changes are foreseen. The greatest change will be that of Glonass moving from the current FDMA signal structure to a CDMA structure interoperable with the other GNSSs.

On the technical side, receivers have changed too and – even more importantly – accuracy has been improved across the board, with RTK becoming the standard. Over the next decade we will see new systems bridging the gap between RTK and PPP allowing sub-decimetre-level positioning anywhere in the world and reducing initialization times from the current 20 minutes to a couple of minutes for the first start and to mere seconds after a loss of signal. One of the other changes that is hoped for is the introduction of the Galileo Commercial Service, not only as a free-of-charge PPP alternative but, perhaps more importantly, as a standard to facilitate interoperability of the current PPP solution providers’ PPP signals with any GNSS receiver. Lastly, we will see anti-jamming and anti-spoofing solutions becoming more available, with price levels coming down to the current levels of ‘standard’ equipment.

Figure 6: Mobile receiver capable of PPP positioning using Atlas corrections (Hemisphere GNSS).

Figure 7: Anti-jamming GPS L1 and L2 antenna (NovAtel).