Tracking New Signals from Space— GPS Modernization and Trimble R-Track Technology

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The US DoD (Department of Defense) is modernizing GPS (Global Positioning System) with new civilian satellite signals, thus presenting a challenge to companies who develop surveying products utilizing GPS technology. While GPS Modernization will support older receivers, new receiver technology is required to enable users to receive the added support and benefits intended by GPS Modernization. In this white paper, we outline this challenge, introduce the R-Track technology developed by Trimble to support GPS Modernization, and demonstrate how R-Track technology is leading the industry in bringing the benefits of GPS Modernization to surveyors.

Introduction

GPS was developed in 1973 by the U.S. DoD to provide positioning, timing, and navigation signals to the U.S. military and civilians worldwide. Since then GPS technology has enormously impacted surveyors and how they carry out their everyday tasks. In particular, since the introduction of RTK (real-time kinematic) surveying by Trimble in the 1990s, surveyors have experienced a huge leap forward in accuracy, efficiency, and productivity. Additionally, today's cable-free, all-on-the-pole systems from Trimble are smaller, lighter, more productive, and significantly easier to use than ever before.

These advances in GPS surveying have all occurred through development in GPS surveying equipment. Apart from the turning on and off of Selective Availability (SA), GPS signals themselves have remained the same since the launch of the first satellite in 1978. (See Figure 1.) However, this situation is about to change: In 1998 the U.S. DoD announced a plan for GPS Modernization, which is scheduled to commence within twelve months and to continue over the next decade.[1]

Figure 1. GPS Block-IIR Satellite Today

[1] This white paper focuses on GPS modernization only. However, over the next decade significant additional satellite navigation changes are scheduled to take place; most notably the introduction of the European satellite system, Galileo. Trimble is actively involved in Galileo through ongoing research contracts.

New GPS Satellites Are on the Horizon

The schedule for GPS Modernization slates the launch of new satellites that will transmit not only new military signals, but also two new signals for civilian users. By adding these signals to its satellite constellation, the DoD is making a strong statement to civilian users—they are recognizing the strength and importance of the civilian user community, of which surveyors form a significant part.

While the new signals open exciting possibilities for better satellite tracking and GPS data, most current GPS receivers will not support GPS Modernization. They will remain effective, but they will not enable surveyors to benefit from the new stronger signals.

GPS Signals and Receiver Technology Today

Today's GPS satellites transmit two carrier frequencies—L1 and L2—both of which contain pseudo-random codes that provide positioning, timing, and navigation information. These pseudo-random codes enable GPS receivers to track several satellite signals at the same time, so that precise positioning can be calculated anywhere on earth. The difference between the two carriers is shown in Table 1.

Table 1. GPS Carriers Today

Carrier	Frequency	Code
L1	1575.42 MHz	C/A and P/Y
L2	1227.6 MHz	P/Y

As shown in Table 1, the L1 carrier contains the C/A (Coarse/Acquisition) code, which is commercially available. The L2 carrier contains only the P/Y code, an encrypted code reserved for military use.

Initially, commercial GPS receivers could only receive the civilian L1 carrier, and to achieve survey-accuracy positioning, surveyors had to postprocess their GPS data. However, within a decade the scientific and surveying communities had developed innovative ways to use the L1 carrier to also acquire use of the L2 carrier. These communities developed dual-frequency GPS receivers that measured the arrival time of the L1 and L2 carriers, and corrected for the errors that accumulate over distance.

Dual-frequency receivers were originally only used for long-distance postprocessed measurements, but now they are used for real-time measurements also. It is therefore no surprise that of all civilian users, surveyors use the L2 carrier more than any other group to achieve centimeter-level accuracy for RTK work.

Although today's indirect method of acquiring the use of the L2 carrier works satisfactorily, L2 measurements are not received with the same strength as L1 measurements.

The First New Civilian Signal: L2C

As part of GPS Modernization, the U.S. DoD is adding a commercial code, called the "civil signal" or "CS", to today's L2 carrier. The resulting civilian L2C signal will enable receivers to access two clean signals for the error correction required for advanced RTK surveying.

L2C will include a more sophisticated code that modern receivers can use to recover a more powerful L2 measurement than is available to civilian users with today's satellites. L2C will become available when the first "modernized" Block IIR-M satellite is launched. (At the time of writing, this launch is scheduled to take place within the next twelve months.)

It is generally expected that L2C will become the most popular GPS signal used in the future.

Also Planned: The L5 Carrier

The second step in GPS Modernization will comprise an entirely new carrier broadcast at 1176.45 MHz. This carrier, to be called L5, will provide a higher power level than other carriers, and will use a larger bandwidth, enabling longer codes. As a result, acquiring and tracking weak signals will be much easier.

The L5 carrier will be introduced on a new generation of satellites called Block IIF, which is under development. The introduction of L5 will commence, and be completed, later than that of L2C.

A full comparison of the modernized carriers is shown in Table 2.

Table 2. Modernized GPS Carriers

Carrier	Frequency	Code
L1	1575.42 MHz	C/A and P/Y
L2	1227.6 MHz	L2C and P/Y
L5	1176.45 MHz	L5 Civil

Trimble's Response to GPS Modernization: Trimble R-Track

In response to the U.S. DoD's announcement, the research and development team at Trimble immediately began working on receiver technology to support the new civilian signals. As a result, in late 2003 Trimble released three new future-ready dual-frequency GPS receivers containing **Trimble R-Track**, a technology that will support the L2C signal as soon as the modernized satellites begin being launched and transmission commences.

How Trimble R-Track Works

Trimble R-Track technology is based on a new-generation integrated circuit inside the GPS receiver, which accommodates the new L2C signal structure. This new circuit enables:

- L1 and L2 carrier phase measurements with low noise and less than 1 mm precision
- Increased signal-to-noise ratios for L2C satellites
- Maximum multipath error reduction
- Superior low-elevation tracking

While offering this new L2C capability, Trimble R-Track still optimally supports legacy satellites.

Tried and Tested…On the Ground

Trimble R-Track technology was used to verify the interoperability of the new Block IIR-M GPS satellite payload with current and modernized survey equipment. The Trimble R7 GPS system was the only L2C-ready survey equipment available to test the new satellite signal by the Joint Program Office (JPO), which manages the Navstar GPS system. Trimble R7, which can take advantage of today's GPS satellites as well as future L2C signals, successfully showed that the Block IIR-M satellite's data can be acquired, tracked, and logged.

Tests were run with Trimble R7 at ITT Industries in New Jersey, where the Block IIR-M satellites are being tested before launch. JPO used a commercial simulator to imitate the GPS constellation and generate current signals. The simulated constellation was then coupled with the output from a IIR-M satellite; this made it possible to track and use the current signals together with a Block IIR-M satellite and produce a solution.

Initial development of Trimble R-Track had been carried out with the aid of a GPS simulator with L2C capability. However, there had still been concern that the actual Block IIR-M satellite might behave differently once in space. The testing opportunity in New Jersey therefore enabled Trimble to ensure the quality of R-Track technology.

Trimble R-Track: Surveying Solution for L2C

As mentioned earlier, while the L2C signal will open exciting possibilities for better satellite tracking and surveying data, most of today's dual-frequency GPS receivers do not contain the sophisticated technology required to track the new signal—Trimble R-Track receivers are the first solution for surveyors wishing to benefit from L2C.

Even before a complete constellation of L2C-transmitting satellites is available, a surveyor using a Trimble R-Track receiver will be able to recover more powerful L2 measurements for enhanced productivity —the first L2C satellite launched will strengthen the solution even while it is the only satellite in the constellation transmitting L2C. This is because the L2C signal is an enhancement of the current dual-frequency solution, and GPS Modernization is backward compatible with legacy user equipment.

Conclusion

The coming L2C signals that are part of GPS Modernization will present surveyors with opportunities for more robust satellite tracking and all the inherent benefits that this will provide. They also demonstrate a commitment by the U.S. DoD to support the many civilian GPS users worldwide, of whom surveyors represent a significant percentage. However, while the new L2C civilian signals will soon be available, most GPS receiver technology today is not capable of accommodating the new signals. Trimble R-Track technology, which has already been tried and tested on an actual modernized satellite, can enable surveyors to utilize those benefits to increase their accuracy, efficiency, productivity, and competitiveness.

Since most surveyors use their surveying equipment for several years, those purchasing a GPS receiver today—whether for field surveying or infrastructure—should take GPS Modernization into consideration. By purchasing a receiver that is ready to receive L2C without hardware upgrades, they will protect their investment for many years to come and ensure maximum accuracy and productivity through their equipment's lifetime.

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