Technical Note:
GNSS Enhances Timing Applications

Typically, applications for timing use GPS as a precise, traceable, high availability, and free source of synchronization. But GPS is not the only satellite in the sky. More and more Global Navigation Satellite Systems (GNSS) are being developed and deployed. This white paper describes the trend to multi-GNSS using the example of the Russian GLONASS system as a complement to GPS. Dual mode GNSS receivers are now state-of-the art in timing systems and are commonly available in products offered by Orolia. They improve signal availability and overall resilience. Some parts of the world prefer dual mode receivers to reduce reliance on the US military-controlled system with some countries requiring them in laws and industry standards.
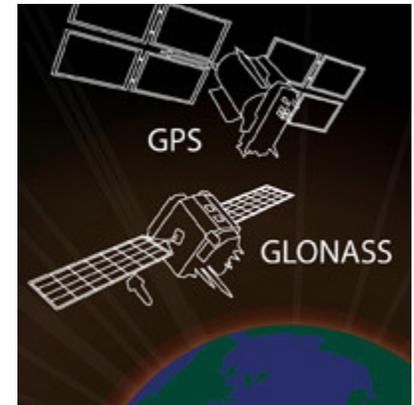
Introducing GLONASS

Though GPS has entered the vernacular to mean satellite positioning, when we are talking about satellite navigation systems generally, the accepted term is GNSS – Global Navigation Satellite Systems. The main systems are GLONASS from Russia, Galileo from the European Union, and BeiDou from China. Newer systems include Japan's Q2SS and India's IRNSS/NAVIC The primary motivation for these systems was geopolitical independence, but now the user community realizes the value of interoperability of these systems all over the world.

The Russian GLONASS and European Galileo system became fully operational within the past few years, where as other systems are still in their early phases of deployment. A relic of the cold war, the original GLONASS system was contemporary with the original GPS system, but fell into disrepair after the collapse of the Soviet Union. In the 2000s, the entire system was revitalized with new satellites and is operating well. Since it operates in the same bands as GPS (L1 and L2), though at a slightly higher frequency, dual mode receivers that operate on both systems are practical and growing in popularity and availability.

A common myth about GLONASS is that it only offers coverage for Russia. Not true. It is a worldwide system with 24 satellites orbiting the globe in Medium Earth Orbit (MEO) with about 12 hour periods, similar to GPS. Coverage is slightly optimized for the higher latitudes, but more than a sufficient number of satellites are visible at any point on earth with a full view of the sky. The overall system accuracy is slightly less than GPS, but if you use both GPS and GLONASS together the resulting performance is improved, especially in noisy environments.

Wanted: More Satellites

Applications for global navigation satellite systems work better with more satellites. The benefits for timing applications include:

1. **Mobile Apps:** If the timing device is embedded into a mobile application, more satellites will enable better tracking characteristics and reduced effects of signal obscuration due to dynamic conditions.

2. **Better Acquisition:** Faster start-up in marginal locations such as urban canyons.

3. **GPS Backup:** In the case of loss of GPS, a second satellite system offers signal diversity, in the case of intentional or unintentional jamming or spoofing.

Problems can occur when satellite availability is limited. Various schemes are sometimes employed to overcome limited satellite availability such as direct input of position, assisted-GPS techniques, and single-satellite mode for stationary applications. But consider the requirement of tracking four satellites as is required as part of the "survey" to determine the position fix used in timing calculations in an "urban canyon" scenario (or similar limited availability conditions). As shown in the figure below, height of the buildings in a city masks the satellites at available horizon to reduce the available satellites below the minimum.
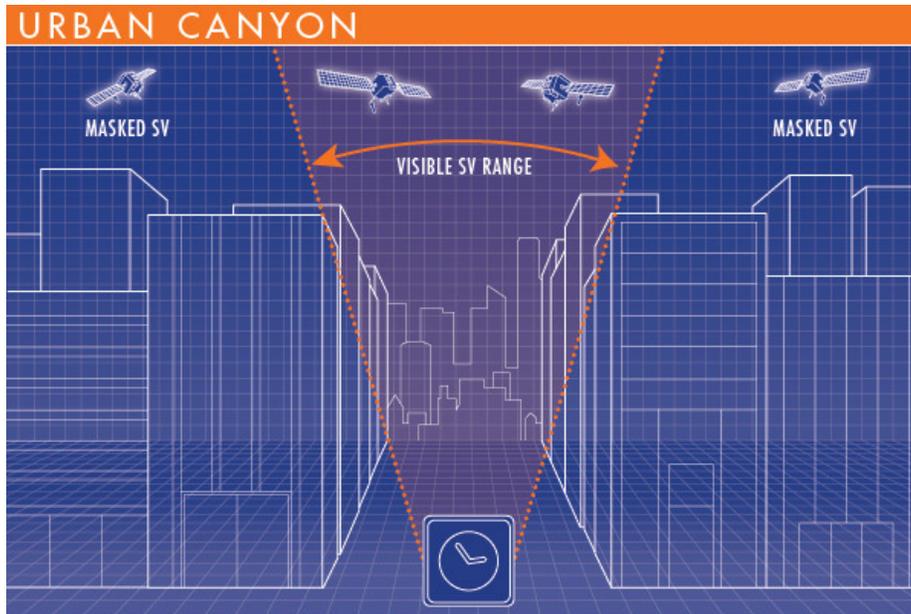

Figure 1: Testing NTP Request Threshold with a Single Host

With a dual mode GPS+GLONASS receiver, there are twice as many satellites available, making it more likely to acquire four satellites and maintain sync even when in a highly masked condition. The graph in Figure 2 shows this quantitatively. The elevation mask angle is measured up from the horizon, so a zero value is a full view of the sky.
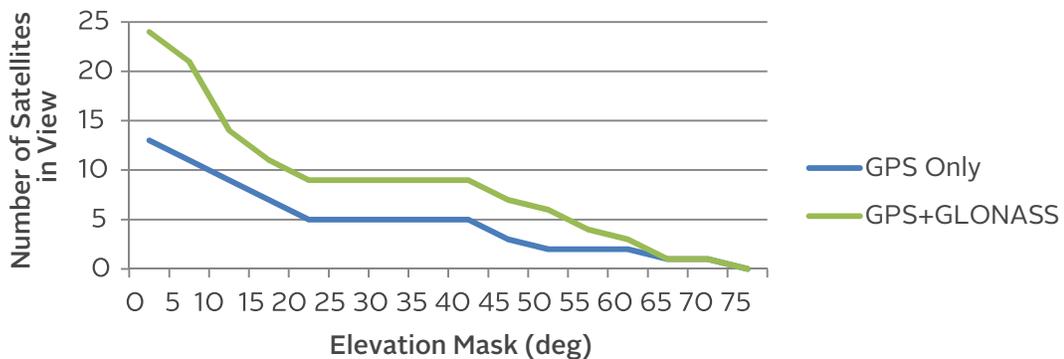

Figure 2: More satellites overcomes a higher degree of masking

With GPS only, the number of satellites in view falls below four above 40 degrees, but with both systems available, this doesn't occur until above 55 degrees. Moreover, in the 20 to 40 degree range, the availability of nine satellites instead of five reduces the GDOP in those situations, as the receiver can choose the best four of the nine.

Coverage improvements occur even when masking is not an issue. With an open view of the sky, having more satellites (20 or more with no masking) in an over-defined solution can maintain better tracking in the presence of noise or interference. Satellites that are experiencing multipath will be marginalized or eliminated because their noticeably higher range error will make them an outlier. Those satellites with no multipath errors converge to a single point quickly, so with 20 or more satellites in view, the receiver can afford to throw away the outliers.

Better, more accurate tracking means the time to acquire weaker signals is shorter, raising the effective sensitivity of the receiver. The signal from the satellite is very weak, below the noise floor. Spread spectrum techniques are used to integrate the signal from the noise. To do this, the receiver's signal processor must search for the signal in both time and frequency. Initially, the time and frequency of the incoming signal is only known approximately. Since the satellites are moving relative to the earth, as well as the receiver moving across the surface of the earth, there is a Doppler shift in frequency. To find these weak signals, the receiver must search a number of frequency ranges or "bin", both above and below the nominal carrier frequency as the Doppler shift can be positive or negative. The better the receiver knows its own position and movement, the better it can predict the Doppler shift from each satellite, and therefore the less frequency range error over which it must search. With less search range, it will find the weak signals faster, and track them that much longer.

There is frequency diversity between GPS and GLONASS that provides another complement. As shown in Figure 3, all the GPS satellites operate on the same frequency at 1574 MHz with a different spreading code for each (CDMA or Code Division Multiple Access, similar to how our mobile phones operate). The GLONASS system operates in an FDMA fashion – Frequency Division Multiple Access, with each satellite transmitting at a slightly different frequency in the range of 1598 to 1606 MHz. Frequency separation offers two distinct advantages: multipath performance and interference rejection. For multipath, the wavelength matters. A bounced signal path reinforces or diminishes the direct path if it is an integral number of wavelengths different. Changing frequency changes the wavelength, so operating on different frequencies will change multipath behavior. One frequency is not necessarily better than the other, but whatever multipath conditions you have at frequency A (good or bad), the conditions on frequency B will be different (bad or good). So diversity can help.
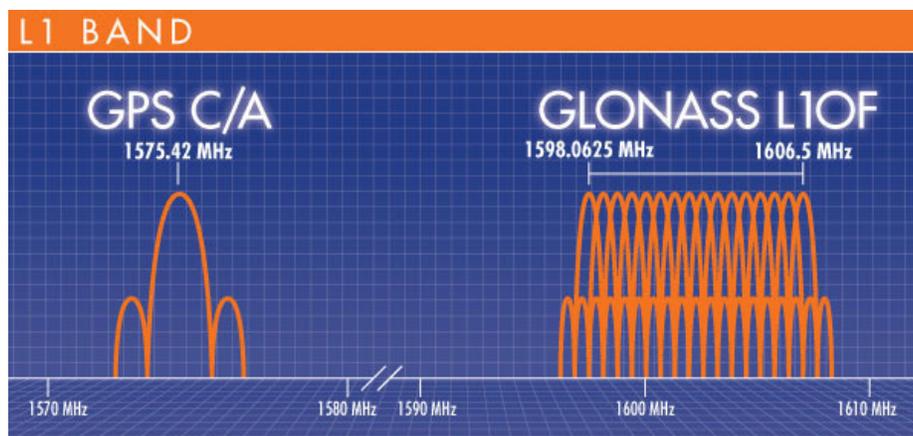

Figure 3: Frequency diversity with GPS+GLONASS

The other factor is interference. Granted, there is not a large frequency separation between GPS and GLONASS – only about 25 to 30 MHz (which makes it easy to build a receiver that can receive both) – but that separation can sometimes be enough to offer a small amount of interference rejection from a narrowband source. Often, interference in the GPS band is from a narrowband, unintended source, such as the third harmonic of a high-powered TV transmitter near 525 MHz. A slight change in frequency can do much to avoid these problems.

Conclusion

Having more satellites to track improves overall robustness and availability of timing applications. With so many satellites to choose from, a problem with any one satellite or constellation for any reason – noise, interference, masking, or failure – allows one to drop that faulty satellite or constellation and continue operation with the functioning ones.

Beyond the technical advantages, there are business reasons to adopt multi-GNSS receivers. Restrictions may apply if deploying a timing system in Russia and some Eastern Europe countries, if they are not GLONASS-capable. Moreover, there are several countries that disallow systems solely dependent on the GPS system.

Multi-GNSS Timing Systems from Orolia

The world leader in resilient positioning, navigational timing devices, Orolia offers dual-mode GNSS timing systems. The SecureSync® modular synchronization system is one of several products that offer GPS+GLONASS receivers and compatible antenna systems to improve performance of the timing application.