GLONASS Overview

The OEMV-1G-based, OEMV-2-based, and OEMV-3-based products are GLONASS-enabled with full code and Real Time Kinematic (RTK) positioning, as well as the ability to record raw GPS and GLONASS measurements. We discuss these capabilities further in this overview[1].

RTK performs significantly better when tracking both GPS and GLONASS satellites, than when tracking GPS satellites only. Adding GLONASS to GPS improves all aspects of satellite navigation and RTK operation (availability, reliability, stability, time of RTK initialization, and so on).

The use of GLONASS in addition to GPS provides very significant advantages:

- increased satellite signal observations
- markedly increased spatial distribution of visible satellites
- reduced Horizontal and Vertical Dilution of Precision (DOP) factors
- decreased occupation times means faster RTK results

In order to determine a position in GPS-only mode the receiver must track a minimum of four satellites, representing the four unknowns of 3-D position and time. In combined GPS/GLONASS mode, the receiver must track five satellites, representing the same four previous unknowns and at least one GLONASS satellite to determine the GPS/GLONASS time offset.

With the availability of combined GPS/GLONASS receivers, users have access to a potential 48+ satellite-combined system. With 48+ satellites, performance in urban canyons and other locations with restricted visibility, such as forested areas improves, as more satellites are visible in the non-blocked portions of the sky. A larger satellite constellation also improves real-time carrier phase differential positioning performance.

Russia has committed itself to bringing the system up to the required minimum of 18 active satellites by the end of 2007, and signed an agreement with India that provides for the launches of GLONASS satellites on Indian launch vehicles. At the time of publication, April 2007, there are 12 operational GLONASS satellites and one newly launched GLONASS satellite at its commissioning phase. The Russian Government have set 2009 as the full deployment date of the 24-satellite constellation and ensured financial support to meet that date. [2]

The OEMV-1G, OEMV-2 and OEMV-3 receivers acquire and track GPS and GLONASS signals. Combined GPS and GLONASS measurements allow both real-time and post-processing GNSS applications. OEMV-based output is compatible with GrafNav post-processing software from NovAtel's Waypoint Products Group. Visit http://www.novatel.com/products/waypoint_pps.htm for details.

---

1 This GLONASS Overview section was originated, and reviewed, with contributions from Professor Richard B. Langley, Geodetic Research Laboratory, Department of Geodesy and Geomatics Engineering, University of New Brunswick, Fredericton, N.B., Canada E3B 5A3; http://www.unb.ca/GGE/

2 Refer to the Russian Space Agency's website at http://www.glonass-ianc.rsa.ru

GLONASS System Design

As with GPS, the GLONASS system uses a satellite constellation to provide, ideally, a GLONASS receiver with six to twelve satellites at most times. A minimum of four satellites in view allows a GLONASS receiver to compute its position in three dimensions, as well as become synchronized to the system time.

The GLONASS system design consists of three parts:

- The Control segment
- The Space segment
- The User segment

All these parts operate together to provide accurate three-dimensional positioning, timing and velocity data to users worldwide.

The Control Segment

The Control Segment consists of the system control center and a network of command tracking stations across Russia. The GLONASS control segment, similar to GPS, must monitor the status of satellites, determine the ephemerides and satellite clock offsets with respect to GLONASS time and UTC (Coordinated Universal Time), and twice a day upload the navigation data to the satellites.

The Space Segment

The Space Segment is the portion of the GLONASS system that is located in space, that is, the GLONASS satellites that provide GLONASS ranging information. When complete, this segment will consist of 24 satellites in three orbital planes, with eight satellites per plane. *Figure 1* on *Page 3* shows a combined GPS and GLONASS satellite system.

The User Segment

The User Segment consists of equipment (such as a NovAtel OEMV family receiver) that tracks and receives the satellite signals. This equipment must be capable of simultaneously processing the signals from a minimum of four satellites to obtain accurate position, velocity and timing measurements. Like GPS, GLONASS is a dual military/civilian-use system. The system’s potential civil applications are many and mirror those of GPS.

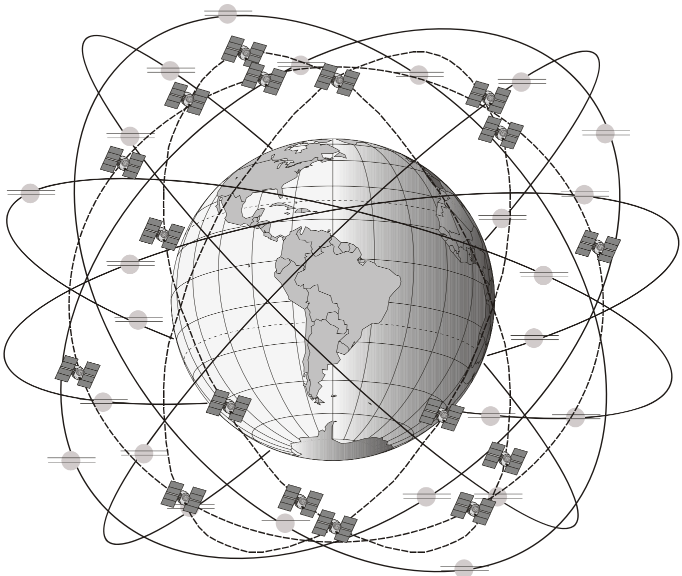

Figure 1 View of GPS and GLONASS Satellite Orbit Arrangement

Following are points about the GLONASS space segment:

- The geometry repeats about once every 8 days. The orbit period of each satellite is approximately 8/17 of a sidereal day such that, after eight sidereal days, the GLONASS satellites have completed exactly 17 orbital revolutions. A sidereal day is the rotation period of the Earth relative to the equinox and is equal to one calendar day (the mean solar day) minus approximately four minutes.
- Because each orbital plane contains eight equally spaced satellites, one of the satellites will be at the same spot in the sky at the same sidereal time each day.
- The satellites are placed into nominally circular orbits with target inclinations of 64.8 degrees and an orbital height of about 19,140 km, which is about 1,050 km lower than GPS satellites.
- Some of the GLONASS transmissions initially caused interference to radio astronomers and mobile communication service providers. The Russians consequently agreed to reduce the number of frequencies used by the satellites and to gradually change the L1 frequencies in the future to 1598.0625 – 1605.375 MHz. Eventually the system will only use 12 primary frequency channels (plus two additional channels for testing purposes).
- The GLONASS satellite signal identifies the satellite and provides:
  - position, velocity and acceleration vectors at a reference epoch to compute satellite locations
  - synchronization bits, data age and satellite health
  - offset of GLONASS time from UTC (SU) (formerly Soviet Union and now Russia)
  - almanacs of all other GLONASS satellites

GPS and GLONASS Satellite Identification

The GLONASS satellites each transmit on slightly different L1 and L2 frequencies, with P- code on both L1 and L2, and with C/A code, at present, only on L1. GLONASS-M satellites reportedly[3] transmit the C/A code on L2.

Every GPS satellite transmits the L1 frequency centered at 1575.42 MHz. The GPS satellites are identifiable by their Pseudorandom Noise code number (PRN) with a NovAtel receiver.

Unlike GPS, all GLONASS satellites transmit the same code at different frequencies. They derive signal timing and frequencies from one of three on-board cesium atomic clocks operating at 5 MHz:

For example,

L1 = 1602 MHz + (n x 0.5625) MHz

where

n = the frequency channel number (n = 0, 1, 2 and so on)

It means that satellites transmit signals on their own frequency, separated by multiples of 0.5625 MHz or 562.5 kHz, from the frequency of other satellites; see *Figure 2* below.

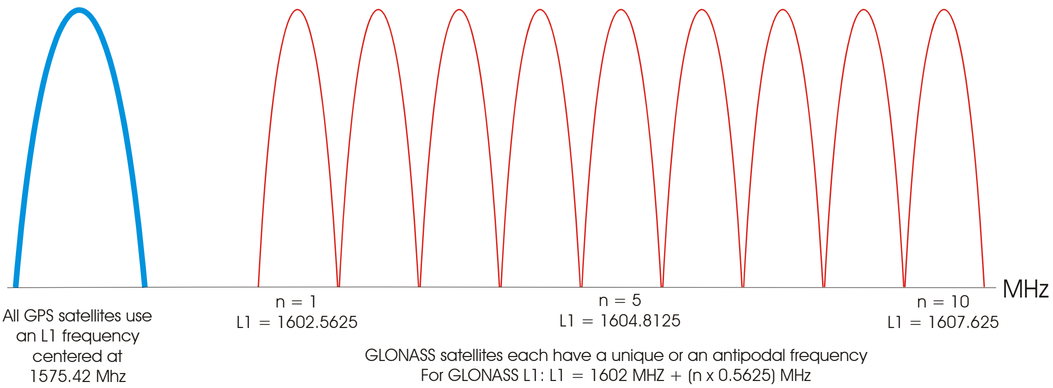

Figure 2 GPS and GLONASS L1 Frequencies

The signals are right-hand circularly polarized, like GPS signals, and have comparable signal strength.

GLONASS accomplishes system operation (24 satellites and only 12 channels) by having antipodal satellites transmit on the same frequency. Antipodal satellites are in the same orbit plane separated by 180 degrees in argument of latitude. This is possible because the paired satellites will never appear at

---

3 Refer to the GLONASS Interface Control Document (ICD), Version 5.0, Moscow, 2002 for more details; http://www.glonass-ianc.rsa.ru

the same time in view of an operational receiver that is on the earth's surface, see *Figure 3* below. At the time of publication, April 2007, four pairs of operational satellites share frequencies.

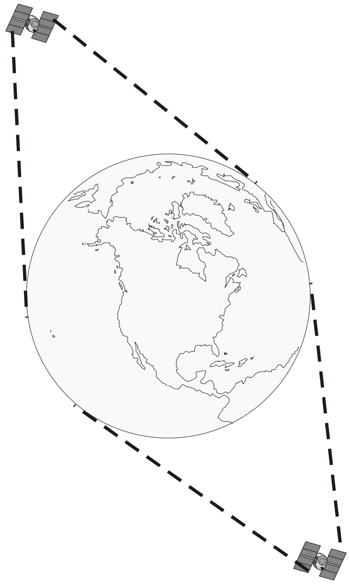

Figure 3 GLONASS Antipodal Satellites

A comparison of GPS with GLONASS satellites, signals, and messages is in *Table 1* on *Page 7*.

Time

As stated earlier, both GPS and GLONASS satellites broadcast their time within their satellite messages. NovAtel's OEMV family of receivers are able to receive and record both time references as well as report the offset information between GPS and GLONASS time. Although similar, GPS and GLONASS have several differences in the way they record and report time. Please see the following sections for information on GPS and GLONASS time, as well as on how NovAtel's OEMV receivers are GPS week rollover compliant.

GPS Time vs. Local Receiver Time

All logs output by the receiver report GPS Time expressed in GPS weeks and seconds into the week. The time reported is not corrected for local receiver clock error. To derive the closest GPS Time, you must subtract the clock offset shown in the TIME log from GPS Time reported. Refer also to the *OEMV Family Firmware Reference Manual*, available in PDF format from our website at http://www.novatel.com/support/docupdates.htm.

GPS Time is based on an atomic time scale. Coordinated Universal Time as maintained by the U.S. Naval Observatory (UTC (USNO) reported in NMEA logs) is also based on an atomic time scale, with an offset of an integer number of seconds with respect to GPS Time. GPS Time is designated as being coincident with UTC (USNO) at the start date of January 6, 1980 (00 hours). GPS Time does not count leap seconds, and therefore an offset exists between UTC (USNO) and GPS Time (at this date in April 2007: 14 seconds). The GPS week consists of 604800 seconds, where 000000 seconds is at Saturday/ Sunday midnight GPS Time. Each week at this time, the week number increments by one, and the seconds into the week resets to 0.

GLONASS Time vs. Local Receiver Time

GLONASS time is based on an atomic time scale similar to GPS. This time scale is UTC as maintained by Russia (UTC (SU)).

Unlike GPS, the GLONASS time scale is not continuous and must be adjusted for periodic leap seconds. Leap seconds are applied to all UTC time references as specified by the International Earth Rotation and Reference System Service (IERS). Leap seconds are used to keep UTC close to mean solar time. Mean solar time, based on the spin of the Earth on its axis, is not uniform and its rate is gradually changing due to tidal friction and other factors such as motions of the Earth's fluid core.

GLONASS time is maintained within 1 ms, and typically better than 1 microsecond (μs), of UTC (SU) by the control segment with the remaining portion of the offset broadcast in the navigation message. As well, Moscow offsets GLONASS time from UTC (SU) by plus three hours. The GLOCLOCK log, refer to the *OEMV Family Firmware Reference Manual*, contains the offset information between GPS and GLONASS time.

Datum

A datum is a set of parameters (translations, rotations, and scale) used to establish the position of a reference ellipsoid with respect to points on the Earth’s crust. If not set, the receiver’s factory default value is the World Geodetic System 1984 (WGS84).

GLONASS information is referenced to the Parametri Zemli 1990 (PZ-90, or in English translation, Parameters of the Earth 1990, PE-90) geodetic datum, and GLONASS coordinates are reconciled in the receiver through a position filter and output to WGS84.

See also the DATUM command in the *OEMV Family Firmware Reference Manual*, available in PDF format from our website at http://www.novatel.com/support/docupdates.htm.

Table 1 Comparison of GLONASS and GPS Characteristics

Parameter	Detail		GLONASS	GPS
Satellites	Number of satellites		21 + 3 spares [a]	21 + 3 spares [a]
	Number of orbital planes		3	6
	Orbital plane inclination (degrees)		64.8	55
	Orbital radius (kilometers)		25 510	26 560
Signals	Fundamental clock frequency (MHz)		5.0	10.23
	Signal separation technique [b]		FDMA	CDMA
	Carrier frequencies (MHz)	L1	1598.0625 - 1609.3125 [c]	1575.42
		L2	1242.9375 - 1251.6875	1227.6
	Code clock rate (MHz)	C/A	0.511	1.023
		P	5.11	10.23
	Code length (chips)	C/A	511	1 023
		P	5.11×10^6	6.187104×10^{12}
C/A-code Navigation Message	Superframe duration (minutes)		2.5	12.5
	Superframe capacity (bits)		7 500	37 500
	Superframe reserve capacity (bits)		~620	~2 750
	Word duration (seconds)		2.0	0.6
	Word capacity (bits)		100	30
	Number of words within a frame		15	50
	Technique for specifying satellite ephemeris		Geocentric Cartesian coordinates and their derivatives	Keplarian orbital elements and perturbation factors
	Time reference [d]		UTC (SU)	UTC (USNO)
	Position reference (geodetic datum) [e]		PZ-90	WGS84

---

a At the time of publication, April 2007, there are 29 operational GPS satellites and 12 operational GLONASS satellites in orbit.

b Full GLONASS system operation will consist of 24 satellites and only 12 channels. Such a system of simultaneous multiple transmissions is known as frequency division multiple access (FDMA) and distinguishes GLONASS from GPS, which is a code division multiple access (CDMA) system. See also the *GPS and GLONASS Satellite Identification* section of this overview starting on *Page 4*.

c Refer to the GLONASS Interface Control Document (ICD), Version 5.0, Moscow, 2002 for more details. You can find GLONASS contact information on their website at http://www.glonass-ianc.rsa.ru.

d GLONASS and GPS use different time systems. GLONASS time is referenced to UTC (SU), the Russian National Etalon time scale, whereas, GPS Time is referenced to UTC as maintained by the U.S. Naval Observatory UTC (USNO). The GLONASS control segment periodically applies a time step to bring the system's time within several hundred nanoseconds of UTC.

e GLONASS ephemerides are referenced to the Parametry Zemli 1990 (PZ-90, or in English translation, Parameters of the Earth 1990, PE-90) reference frame. The realization of the PZ-90 frame through adopted reference station coordinates has resulted in offsets in origin and orientation as well as a difference in scale with respect to WGS84 used by GPS. Relationships between PZ-90 and WGS84 have now been established.