

NAVIGATION SATELLITES

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GLONASS—The Russian GPS

In this issue of *Satellite Times* we will look at an alternative satellite navigation system, the Russian Ministry of Defense version of GPS—GLONASS. GLONASS is an acronym derived from Global Navigation Satellite System. Like GPS, it provides users the ability to determine three dimensional position, velocity, and accurate time referencing.

Also similar to GPS, the GLONASS system is comprised of 24 satellites and a ground monitoring network which provides telemetry to the satellites for status and control purposes. Each satellite is in a 19,100 kilometer (11,937 mile) orbit with an inclination of 64.8 degrees. The orbital period is slightly shorter than GPS, at 11.25 hours. The antennas on each satellite have a wide beamwidth in excess of 30 degrees. This means the navigation service is also available to users at altitudes of 2000 kilometers (1,250 miles), ideal for navigating to space stations and other space vehicles.

In 1988, the then-Soviet Union offered the world free, unrestricted use of the GLONASS system even though it consisted of less than 10 satellites. The GLONASS system operates two services just as GPS system does. These are known as the standard position service (SPS) allocated for civilian use, and the high precision service (HP) available exclusively to military users.

In the GLONASS system, a receiver determines its position by processing the inbound signal from each satellite and quantifying the time of arrival (TOA) just as GPS

does. The difference is that while GPS uses the same frequency with a different pseudorandom code used for each satellite, GLONASS uses the same code for each satellite, but a different frequency (in most cases). Some GLONASS system satellites actually share the same frequency, but their signals are sent only when in the appropriate orbital position. The principle of using the same code with different frequencies is known as frequency division multiple access (FDMA). The codes used are pseudorandom noise (PRN) in nature, but with different chip rates to those in GPS. Table 1 shows these values.

As can be seen, the course acquisition (C/A) code has the same 1 millisecond cycle time as GPS. The GLONASS satellites carry three on-board cesium clocks, providing a timing standard similar to that offered by GPS. The clocks, also subject to offset and bias from system time, induce errors in the ranging measurements as GPS would. The frequencies used in the GLONASS system depend on the individual satellite in question since they typically have their own L-band frequency. The L1 frequency is calculated according to the following formula.

$$f\text{MHz} = 1602 + (n \times 0.5625 \text{ MHz})$$

(Where n is the channel or satellite number)

The L2 frequency for each satellite is calculated using a similar formulae :

$$f\text{MHz} = 1246 + (n \times 0.4375 \text{ MHz})$$

As an example, channel 3 in the GLONASS system is 1603.6875 MHz for L1 and 1247.3125 MHz for the L2 frequency.

To say each satellite has its own frequency is not exactly correct. The same frequencies can be reused by satellites placed in an antipodal orbital slot (i.e., provided they are on opposite side of the earth), thus not causing interference which would degrade the accuracy.

The civilian service specification quotes an accuracy within 100 meters (110 yards) and a

TABLE 1: Current GLONASS Constellation Information

All GLONASS spacecraft are part of the general Cosmos series of satellites. The Cosmos numbers (nnnn) invoked by USSPACECOM have often differed from the numbers (NNNN) associated in Russia; when different, the USSPACECOM Cosmos numbers are shown in parentheses. The corresponding GLONASS numbers are Russian numbers. The operating frequencies in MHz are computed from the channel number K. Frequencies (MHz) are L1 = 1602.0 + 0.5625K and L2 = 1246.0 + 0.4375K.

Cosmos NNNN (nnnn)	ID (Catalog #)	Channel number	Inc (deg)	GLONASS number
COSMOS 2111	90-110C (21008)	23	65.1	GLONASS 249
COSMOS 2178	92-005B (21854)	2	65.1	GLONASS 769
COSMOS 2179	92-005C (21855)	23	65.1	GLONASS 771
COSMOS 2204 (2205)	92-047B (22057)	24	64.8	GLONASS 758
COSMOS 2206 (2204)	92-047A (22056)	1	64.8	GLONASS 774
COSMOS 2235 (2336)	93-010C (22514)	21	65.1	GLONASS 759
COSMOS 2236 (2235)	93-010B (22513)	5	65.1	GLONASS 757
COSMOS 2275 (2277)	94-021C (23045)	10	64.7	GLONASS 758
COSMOS 2276 (2275)	94-021A (23043)	24	64.7	GLONASS 780
COSMOS 2277 (2276)	94-021B (23044)	3	64.7	GLONASS 761
COSMOS 2287	94-050A (23203)	22	64.8	GLONASS 767
COSMOS 2288 (2289)	94-050C (23205)	9	64.8	GLONASS 770
COSMOS 2289 (2288)	94-050B (23204)	22	64.8	GLONASS 775
COSMOS 2294 (2296)	94-076C (23398)	12	65.0	GLONASS 762
COSMOS 2295 (2294)	94-076A (23396)	21	65.0	GLONASS 763
COSMOS 2296 (2295)	94-076B (23397)	13	65.0	GLONASS 764
COSMOS 2307	95-009A (23511)	1	64.7	GLONASS 765
COSMOS 2308	95-009B (23512)	10	64.7	GLONASS 766
COSMOS 2309	95-009C (23513)	3	64.7	GLONASS 777
COSMOS 2316	95-037A (23620)	4	64.9	GLONASS 780
COSMOS 2317	95-037B (23621)	9	64.8	GLONASS 781
COSMOS 2318	95-037C (23622)	4	64.8	GLONASS 785
COSMOS 2323	95-068C (23736)	6	64.8	GLONASS 776
COSMOS 2324	95-068B (23735)	11	64.8	GLONASS 778 (Spare)
COSMOS 2325	95-068A (23734)	6	64.8	GLONASS 782

The GLONASS NNN series orbits in three distinct planes that are 120 degrees apart. Each plane has eight "slots." Following are the members of the planes/slots.

Plane 1	Plane 2	Plane 3
slot-1 771	slot-9 776/778	slot-17 760
slot-2 757	slot-10 781	slot-18 758
slot-3 763	slot-11 785	slot-19 777
slot-4 762	slot-12 767	slot-20 765
slot-5 249	slot-13 782	slot-21 756
slot-6 764	slot-14 770	slot-22 766
slot-7 759	slot-15 780	slot-23 761
slot-8 769	slot-16 775	slot-24 774

For more information on the GLONASS system contact: Coordination Scientific Information Center (CSIC) Russian Space Forces.
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velocity accuracy of 0.15 meters per second (m/s) (6 inches per second). It appears that so far that the Russians have not introduced selective availability; measurements performed reveal an accuracy in the order of 26 meters (28.4 yards) with velocity measurements down to 0.04 m/s. (1.6 inches per second). The performance of GLONASS exceeds GPS in one aspect—it provides a better visibility to satellites in Northern latitudes greater than 50 degrees.

Differential GLONASS

Currently, no differential GLONASS service exists on the scale that GPS users can enjoy. Discussions are underway regarding a variety of solutions to this, including equipping the Russian military space force's command and control sites with differential equipment. Since these sites have already been precisely surveyed, most of the ground work has been completed. A second proposal utilizes the existing maritime radio beacons to transmit the differential corrections, offering a solution on par with the

U.S. Coast Guard DGPS system. Additionally, the Russians are planning to apply GLONASS techniques at airports for use in all categories of landing and approach. This system is comparable to the Federal Aviation Administration's plans for using local area differential GPS (LADGPS) systems.

GLONASS and GPS together would provide a formidable satellite navigation system with one system augmenting the other. GPS equipment manufacturers are now marketing dual system receivers, taking advantage of GLONASS and *Glasnost*. One problem that had to be overcome in designing the dual system receivers was standards. The Rus-

Global navigation satellite system GLONASS that provides precise, three-dimensional position, velocity, and time, for national military and civil users and international civil users community was formally put into operation in September 23, 1993 by the Order of the President of Russian Federation.

System Performance:

- Accuracy (95.7 % probability)
 - horizontal..... 50.70 m
 - altitude..... 70 m
 - velocity..... 15 m/s
 - time vs. UTC(CS)..... 1 m/s
- Time required to make a first detection..... 1-3 min and then..... with 1-10 seconds interval (depending on navigation equipment)
- Coverage..... global
- Number of users..... unlimited
- Determination of location in real time depending on meteorological conditions, year season and time of the day environment.

GLONASS is launched by "Proton" launch vehicle and booster "D".

Technical specifications:

- 24 satellites GLONASS
- 3 orbital planes
- Orbital altitude..... 19100 km
- Inclination..... 64.8 deg

GLONASS satellite

sian system uses its own coordinate and time referencing system—a system not widely used outside Russia. However, by applying on-board firmware that converts between the two standards, the problem was solved and dual system integrity is now available.

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TABLE 2: Current Keplerian Element Sets for the GLONASS constellation

Glonass 49 (249)		Glonass 67 (770)	
1 21008U 90110A	96274.96121677 .00000007 00000-0 00000+0 0 2864	1 28205U 94050C	96275.44106891 .00000004 00000-0 00000+0 0 3471
2 21008 65.2362 81.1499 0008835	270.1078 89.8098 2.13099558 45249	2 28205 64.7587 200.5658 0002058	284.0619 75.9358 2.13102896 16663
Glonass 54 (769)		Glonass 68 (763)	
1 21854U 92005B	96277.91743529 .00000032 00000-0 00000+0 0 3478	1 23398U 94076A	96275.28490538 .00000009 00000-0 00000+0 0 3256
2 21854 65.1883 80.8748 0015649	23.0851 337.0087 2.13104619 36428	2 23398 65.1294 80.6813 0029909	188.0338 171.8336 2.13102382 14500
Glonass 55 (771)		Glonass 69 (764)	
1 21855U 92005C	96278.10889737 .00000015 00000-0 00000+0 0 3359	1 23397U 94076B	96277.80746025 .00000031 00000-0 00000+0 0 3091
2 21855 65.1853 80.7411 0007655	192.1487 167.8498 2.13102005 36373	2 23397 65.1181 80.6031 0011025	321.8567 38.0856 2.13101822 14552
Glonass 58 (774)		Glonass 70 (762)	
1 22056U 92047A	96275.06798326 -.00000049 00000-0 00000+0 0 2656	1 23398U 94076C	96275.34486519 .00000009 00000-0 00000+0 0 3307
2 22056 64.7251 319.8592 0006131	263.2964 96.6981 2.13103165 32446	2 23398 65.1076 80.6628 0001595	269.9908 90.0071 2.13101703 14511
Glonass 57 (758)		Glonass 71 (765)	
1 22057U 92047B	96275.83396556 -.00000049 00000-0 00000+0 0 2325	1 23511U 95009A	96278.24174577 -.00000050 00000-0 00000+0 0 2406
2 22057 64.7327 319.8620 0008122	307.3704 52.6183 2.13102551 32430	2 23511 64.6238 320.4361 0008232	221.4772 138.5238 2.13103592 12258
Glonass 60 (757)		Glonass 72 (766)	
1 22513U 93010B	96276.16413745 .00000016 00000-0 00000+0 0 9768	1 23512U 95009B	96277.30010203 -.00000048 00000-0 00000+0 0 2517
2 22513 65.1945 80.6096 0007646	183.3498 176.6618 2.13102623 28165	2 23512 64.6138 320.4030 0006566	301.8673 58.1308 2.13101528 12275
Glonass 61 (759)		Glonass 73 (777)	
1 22514U 93010C	96276.45815286 .00000018 00000-0 00000+0 0 9714	1 23513U 95009C	96277.12247695 -.00000047 00000-0 00000+0 0 2639
2 22514 65.2136 80.5993 0011283	181.2192 178.7955 2.13101879 28172	2 23513 64.6223 320.4243 0015053	205.1938 154.7942 2.13102875 12272
Glonass 62 (760)		Glonass 74 (780)	
1 23043U 94021A	96277.00460577 -.00000047 00000-0 00000+0 0 4073	1 23620U 95037A	96275.49849180 .00000003 00000-0 00000+0 0 1870
2 23043 64.6088 320.1368 0007455	201.3490 158.6818 2.13102791 19305	2 23620 64.8156 200.4138 0018575	170.1963 188.8620 2.13102826 9273
Glonass 63 (761)		Glonass 75 (781)	
1 23044U 94021B	96276.41779664 -.00000049 00000-0 00000+0 0 3776	1 23621U 95037B	96276.14531928 -.00000002 00000-0 00000+0 0 1971
2 23044 64.6082 320.1560 0031881	205.6685 154.2358 2.13102858 19288	2 23621 64.8263 200.4000 0018265	181.2354 178.7807 2.13102034 9280
Glonass 64 (758)		Glonass 76 (785)	
1 23045U 94021C	96276.12613648 -.00000050 00000-0 00000+0 0 3844	1 23622U 95037C	96277.61122407 -.00000016 00000-0 00000+0 0 2005
2 23045 64.5915 320.1675 0010129	28.7209 331.3988 2.13101851 19288	2 23622 64.8199 200.3502 0036677	166.3317 193.7904 2.13102409 9310
Glonass 65 (767)		Glonass 79 (782)	
1 23203U 94050A	96276.26347110 -.00000003 00000-0 00000+0 0 3450	1 23734U 95068A	96275.38280590 .00000004 00000-0 00000+0 0 1705
2 23203 64.7630 200.5242 0006672	151.7215 208.3370 2.13101997 16683	2 23734 64.8255 200.3358 0018398	321.7452 38.1532 2.13102005 6232
Glonass 66 (775)		Glonass 78 (778)	
1 23204U 94050B	96276.02778652 -.00000001 00000-0 00000+0 0 3610	1 23735U 95068B	96277.93015137 -.00000019 00000-0 00000+0 0 1654
2 23204 64.7445 200.5651 0015003	344.5011 15.4750 2.13102166 16673	2 23735 64.8160 200.2404 0007429	217.0035 142.9882 2.13102349 6285
		Glonass 77 (776)	
		1 23736U 95068C 96276.08652814 -.00000001 00000-0 00000+0 0 1457	
		2 23736 64.8086 200.3228 0007868 203.2237 156.7638 2.13102089 6246	