
OmniSTAR HP⁺ worldwide DGPS service for decimetre GIS mapping

Authors: Ir. Hans Visser, Ing Tony ten Wolde, Ir. EJ Hammega, Drs Nicole Leclercq

Email: h.visser@omnistar.nl

Revision: 1.42, dated 01 June 2006

BIOGRAPHY

Hans Visser has been working as a technical manager at OmniSTAR BV in the Netherlands since 1999. He has studied Geodesy at the University of Delft from 1980-1988. As of 1984 he has been working on the subject of GPS.

ABSTRACT

OmniSTAR provides High Performance (HP⁺) differential corrections for GPS via satellite channels. These differential corrections are based on data from our worldwide network of reference stations combined with precise orbit and clock information for every satellite in the NAVSTAR GPS satellite constellation.

OmniSTAR broadcasts these corrections as a subscription service over a number of geostationary satellites. This service, referred to as OmniSTAR HP⁺, allows a user anywhere in the world to work with true decimetre level absolute accuracy.

In this article, the application of OmniSTAR HP⁺ in the field of Mapping and GIS will be discussed. Concepts such as 'Kick-starting' (i.e. starting the HP⁺ process from a known location) and 'Static Convergence' will be explained.



1. Introduction

OmniSTAR BV is located in the Netherlands and is part of the Fugro group of companies. Together with sister companies in Houston (USA), Perth (Australia), Cape Town (South Africa), Dubai (UAE) and Singapore, OmniSTAR sells GPS differential correction signals for on-land and aerial use. OmniSTAR differential corrections are broadcasted by a number of geo-stationary satellites (see table 1 below).

Depending on the type of service used, OmniSTAR differential corrections allow for sub-metre (VBS) or decimetre level accuracy (HP⁺) around the world. This document will discuss the OmniSTAR HP⁺ service and its usage in the GIS field of application.

OmniSTAR broadcasts over six high power geo-stationary satellites, located at 36,000 km above the equator. Frequencies are in the range of 1525-1559 MHz (GPS L1=1575.42 MHz, GPS L2=1227.60 MHz). In order to receive the OmniSTAR HP⁺ broadcast, a special combined L1/L2/L-band antenna is required.

Nr.	Satellite name	Area of Coverage	Frequency (Hz)	Data rate	Centre Longitude	East Border	West Border	South Border	North Border
1	EA-SAT	Europe, Russia, Middle Africa	1 535 152 500	1200 bps	25° East	56° W	106° E	80° S	80° N
2	AF-SAT	Africa, Middle East	1 535 180 000	1200 bps	25° East	56° W	106° E	80° S	80° N
3	AP-SAT	Asia, India, Australia, New Zealand	1 535 137 500	1200 bps	109° East	28° E	168° W	80° S	80° N
4	AM-SAT	North and South America	1 535 137 500	1200 bps	98° West	179° W	17° W	80° S	80° N
5	OPTUS	Australia and New Zealand	1 558 510 000	1200 bps	145° East	95° E	173° E	66° S	7° N
6	MSV-W	USA-West	1 536 782 000	1200 bps	120° West	25° N	67° N	80° S	80° N
	MSV-C	USA-Central	1 534 741 000	1200 bps	94° West	25° N	67° N	80° S	80° N
	MSV-E	USA-East	1 530 359 000	1200 bps	80° West	25° N	67° N	80° S	80° N
7	OC-SAT	Pacific Ocean, Australia, New Zealand	1 535 185 000	1200 bps	143.5° East	62° E	136° W	80° S	80° N

Table 1: OmniSTAR Geo-stationary L-band satellites

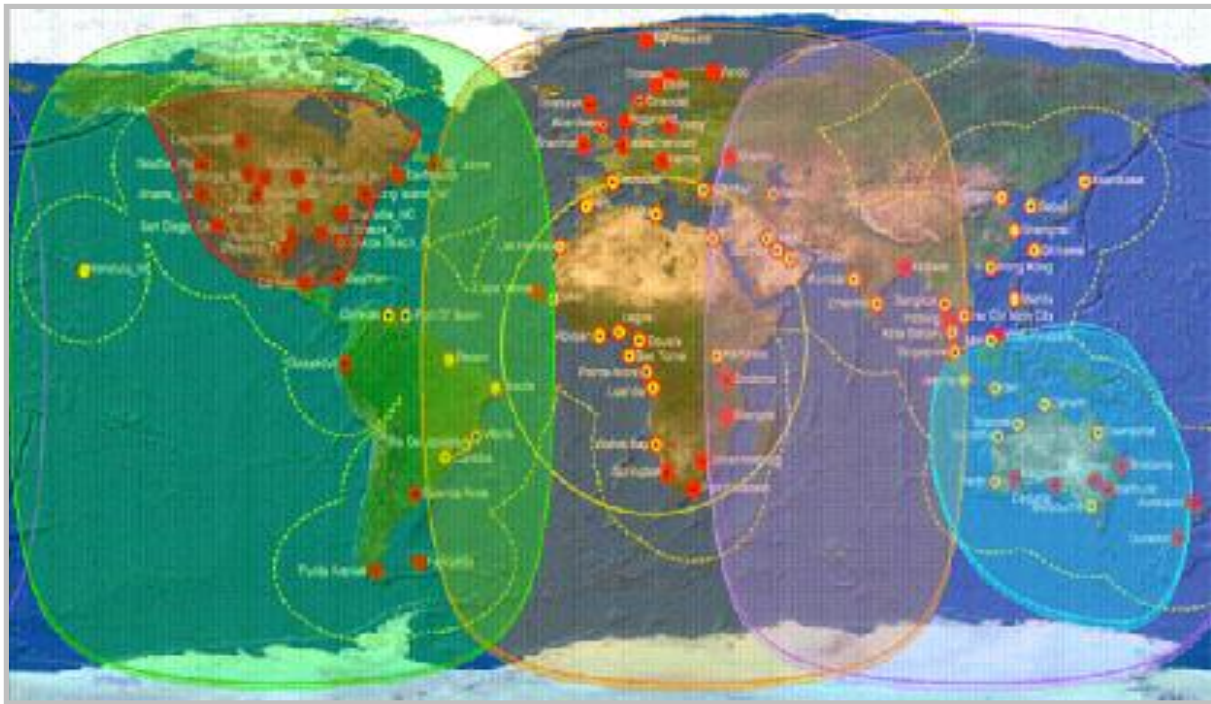


Figure 1: OmniSTAR worldwide satellite coverage and reference stations

2. OmniSTAR HP⁺ (High Performance)

OmniSTAR HP⁺ is a dual frequency DGPS service and can therefore only be used on dual frequency hardware. Our OmniSTAR HP⁺ broadcast consists of very different data streams:

OmniSTAR HP (without the +): Networked reference station technology

The OmniSTAR HP broadcast consists of phase and code measurements from all reference stations in a satellite footprint. Due to the fact that dual frequency reference stations are used in our network, the information is already free of any errors due to signal delays in the ionosphere. After receiving the phase and code measurements from our satellite, these measurements are applied to the raw GPS information gathered by the GPS receiver. In this process, the number of wavelengths to each satellite is estimated, using estimated values for position, receiver clock and tropospheric conditions.

OmniSTAR HP uses measurements of the nearest surrounding reference stations. Up to a distance of 1000 km there are enough common satellites to guarantee good position accuracy. Beyond 1000 km the position solution slowly degrades.

OmniSTAR XP: Precise orbits and clocks

In addition to OmniSTAR HP, we also broadcast OmniSTAR XP. OmniSTAR XP is based on precise orbits and clocks. We send precise satellite orbits every minute and precise clock information every ten seconds. Provided the position of the satellites is known within 20-30 cm and the satellite clock error is known within a nanosecond (30 cm), it is possible to estimate positions up to the decimetre level without the use of any reference stations. This technique is also called “Precise Point Positioning” (PPP).

OmniSTAR HP⁺ combines these two technologies into a very robust positioning solution:

- a) Far away from reference stations the solution relies on precise orbits and clocks.
- b) Close to reference stations the solution is improved using a network solution.
- c) Rare outages of individual reference stations will not influence the solution.

2.1. Position convergence speed

After a receiver has been switched on, the position solution converges from the meter level in the first minute to the cm level in 24 hours. As soon as the sum of the standard deviations is smaller than 30 cm, a flag is raised and the solution is considered converged. The NMEA GGA quality indicator will indicate code 5, which stands for RTK float ambiguity fixing or code 4, which stands for RTK accuracy level.

$$\sqrt{\sigma_{Lat}^2 + \sigma_{Lon}^2 + \sigma_{Height}^2} \leq 30cm$$

Formula 1: OmniSTAR HP⁺ convergence criteria

The convergence speed depends on

- a) the number of GPS satellites tracked,
- b) the constellation change of these satellites over time, and
- c) the distance to reference stations.

The convergence process can be visualised as trying to fit the relative measured change of distance to the satellite with the actual orbit. In order to successfully fit measured and actual orbit, the orbit needs curvature. It takes time before the orbit is curved.

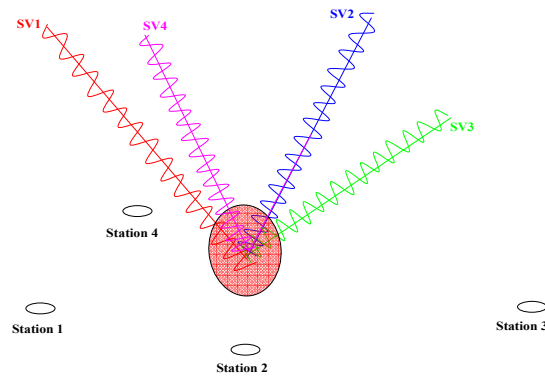


Figure 3: The OmniSTAR HP⁺ after 1 minute convergence process

Pseudo range and phase measurements give a meter position

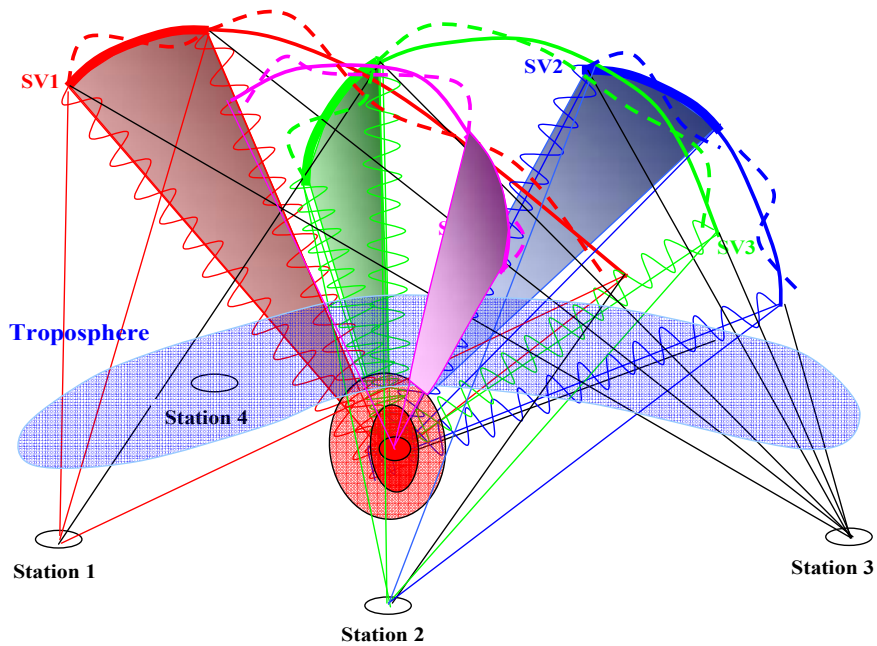


Figure 4: The OmniSTAR HP⁺ convergence process after 10-20 minutes

2.2. Kick-starting (Seeding)



When the receiver starts at a point with known coordinates, this position can be injected directly in to the HP⁺ algorithm. This is called Kick-starting or Seeding (the start position is the “Seed” of the computation process). With Kick-Starting the solution will converge within a minute after switching on the receiver.

2.3. Static convergence

If the receiver is stationary, the HP algorithm will take advantage of this, resulting in average convergence times of 10 minutes with a maximum of 20 minutes.

2.4. Dynamic convergence

When the receiver is moving in relatively open areas, like on tractors or aircraft it takes an average of 25 minutes and maximum 55 minutes to converge. Tests, measuring convergence times, performed in the Netherlands gave the following results (see table 2 below).

HP Convergence time in minutes		SEP*=30 cm
Kick-starting	Average	00' 36"
	Minimum	00' 30"
	Maximum	02' 12"
Static convergence	Average	09' 31"
	Minimum	06' 01"
	Maximum	17' 03"
Dynamic convergence	Average	23' 46"
	Minimum	10' 43"
	Maximum	54' 36"

*SEP=Spherical Error Probability

Table 2: HP⁺ Kick-starting and Static and Dynamic convergence times

These results will vary for other locations in the world, based on the satellite geometry and the number of satellites used in the position calculation. However the results will be in the same order of magnitude.

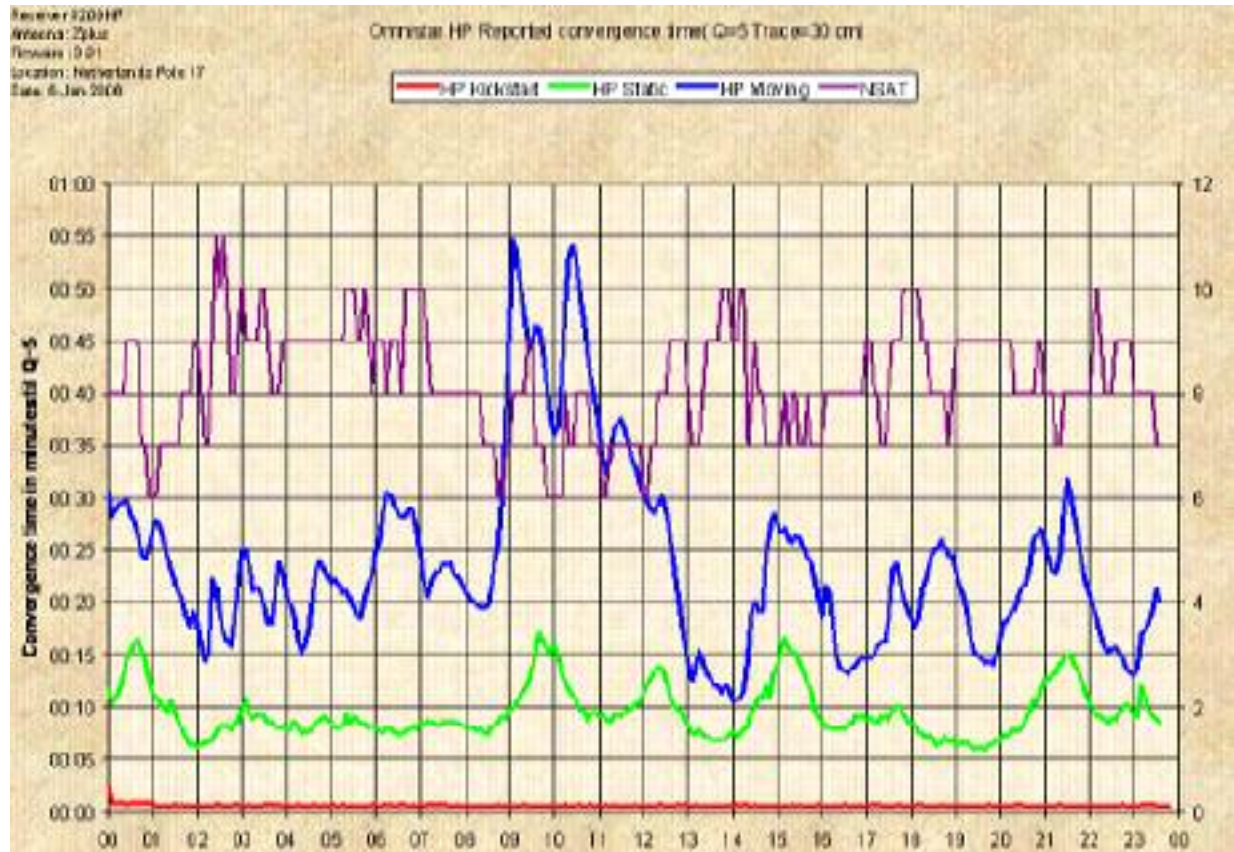


Figure 5: HP+ convergence time until Spherical Error Position (SEP) <30 cm for Kick-start, Static convergence and Dynamic convergence

2.5. Convergence as a function of the number of satellites

We have looked at the number of satellites available at the moment of convergence as possible indicator for convergence time.

Convergence time	HP Static			HP Dynamic		
	Average	Min	Max	Average	Min	Max
6	12' 08"	10' 12"	17' 04"	32' 53"	25' 37"	48' 20"
7	12' 15"	07' 34"	19' 58"	28' 44"	12' 34"	54' 10"
8	10' 56"	06' 56"	18' 15"	23' 27"	11' 59"	54' 36"
9	09' 36"	06' 38"	17' 29"	20' 29"	10' 45"	46' 25"
10	09' 15"	07' 32"	10' 48"	19' 05"	10' 43"	28' 59"
11	-	-	-	20' 07"	18' 51"	21' 23"

Table 3: Convergence time in minutes versus the number of satellites

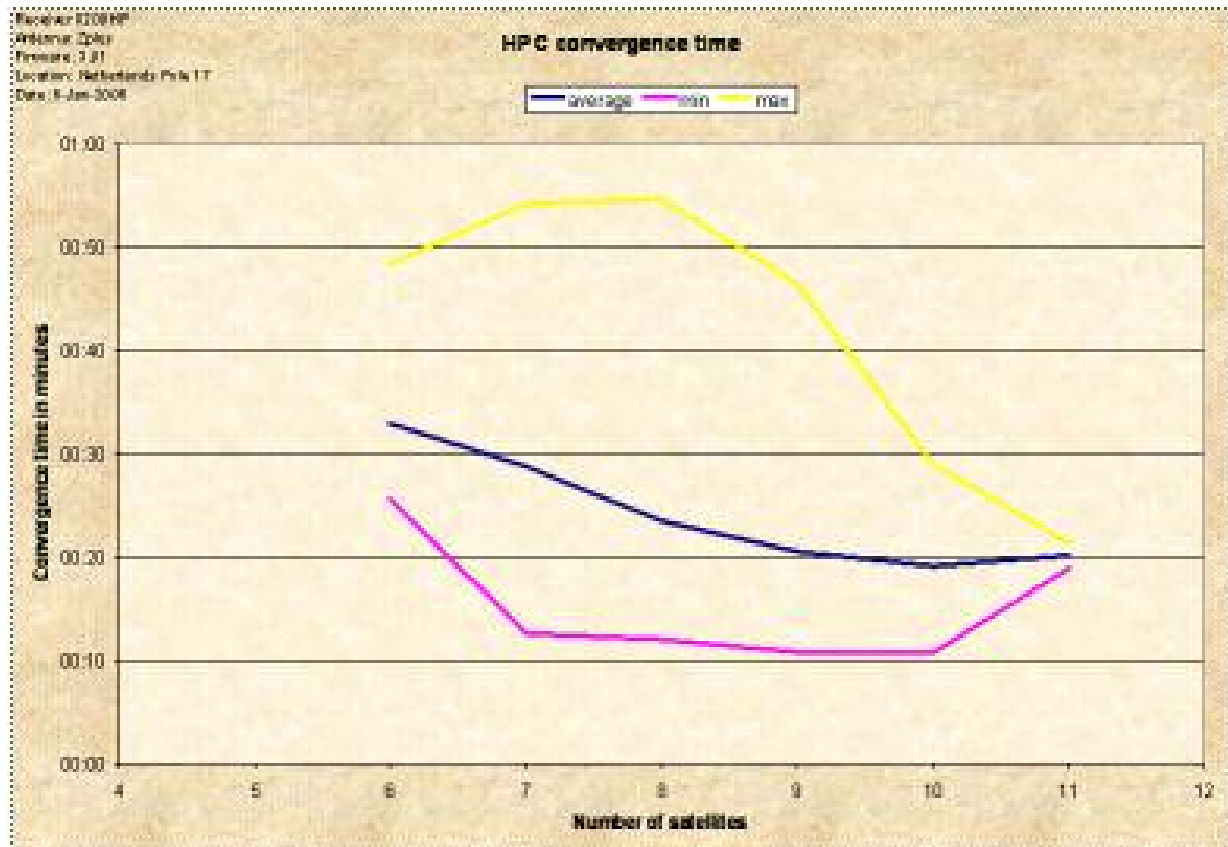


Figure 6: HP⁺ convergence speed as a function of the number of satellites

These values can be used to create a rule of thumb for the amount of time it will take before the solution is converged.

2.6. GPS Satellite blockage

The HP⁺ solution can be restored after the line of sight to a number of GPS satellites was blocked by buildings or trees, as long as there is a minimum of five common satellites available before and after the interruption.

In case less than 5 satellites are available, because the GPS receiver goes in to a tunnel or under heavy tree canopy, HP⁺ can quickly regain the same level accuracy, provided the blockage does not take longer than 3 minutes. This is also known as re-initialisation.

The success rate of re-initialisation depends on

- a) the time without GPS measurements,



-
- b) the phase and code multipath before and after the interruption, and
 - c) the number of satellites available before and after the gap.

2.7. OmniSTAR L-band satellite interruptions

Sometimes the line of sight to the geo-stationary satellite broadcasting the OmniSTAR corrections can be blocked by buildings or trees. If this happens, the HP solution remains valid for a maximum of 5 minutes. Once, after such a blockage, a new correction message is received, the solution will instantly be of the same quality again as before the outage.

2.8. OmniSTAR HP⁺ compatible GPS devices

OmniSTAR algorithms have been implemented in GPS hardware by the GPS manufacturers listed below (see table 4).



Manufacturers	Models	Main Markets	Firmware version	Release date	VBS/HP ¹
Hemisphere (CSI/Satloc/Outback)	DGPSMAX	Marine/GIS	4.8	Dec 2005	VBS2
	SLX1,2,3	Ag/Avionics			
	Outback	Ag			
	Cornerpost	AG/GIS			
Leica	GS50/GS20 +RTS	GIS	1.37	Jan. 2005	Nearest Station
Novatel	Propak LB Propak LB Span	OEM Vehicle	2.312	Nov. 2005	VBS2/HP
Omnistar	3000 and 3100LR series	GIS	3.00.22	Sept. 2004	VBS
	3200LR12	Vehicle/GIS/Ag	3.0	Sept. 2005	VBS2
	3500LR	L-band Demodulator	02.06.05	June. 2005	VBS2
	3510LR	L-band Demodulator	02.06.05	June. 2005	VBS2
	7114LR12	Ag/GIS	3.0	Sept. 2005	VBS2
	8300HP	GIS/Vehicle	2.310	Nov. 2005	VBS2/HP
	8400HP	GIS/Vehicle	1.0p2b2	June 2005	VBS/HP
Raven	Invicta 310	GIS/Vehicle/Marine	?	2005	VBS2
	RPR 410	Ag	?	2006	HP/VBS2
Sokkia	GSR2650 LB	GIS	2.310	Nov. 2005	VBS2/HP
	Axis3	GIS	4.8	Dec 2005	VBS2
Thales	MKIV	Ag/GIS	1.37	Jan. 2005	Nearest Station
Topcon	MAP-RT	GIS	3.0a7	Feb-2006	VBS
	MAP-HP	GIS/Construction	1.0p2b2	June 2005	VBS/HP
Trimble	AgGPS 110	Ag/GIS	3.0	Oct. 2005	VBS2
	AgGPS 114	Ag/GIS	3.0	Sept. 2005	VBS2
	AgGPS 132		3.0	Sept. 2005	VBS2
	AgGPS 252	Ag Autosteer	3.21	Mar 2006	VBS2/HP
	AgGPS 332	Ag			
	DSM 332	Marine			
	SPS-550	Marine/Construction			
	SPS-750	Construction			
	SPS-850	Construction			
	Pathfinder power	GIS	1.70	March 2005	VBS
	PRO-XRS	GIS	1.70	Jan. 2003	VBS

Table 4: Overview of Omnistar capable receivers and firmware releases

2.9. OmniSTAR HP⁺ compatible PDA GIS Software

All OmniSTAR capable receivers support the NMEA output format. However, to start the HP⁺ process by Kick-starting (Seeding) or in Static mode, a command has to be sent to the receiver. The following PDA software packages support HP⁺ Kick-starting (Seeding).

	Name	Manufacturer
1.	PocketGIS	Pocket, Positioning Resources
2.	Arcpad 6.01	ESRI (using a plug-in)
3.	Solo Software	TDSWay
4.	Imap	Sokkia
5.	Topsurv	Topcon
6.	FieldGenius	MicroSurvey
7.	Omnilogger	OmniSTAR South Africa (Psion)
8.	Viewall	OmniSTAR Europe

3. Working procedure for GIS Point measurements

When using OmniSTAR HP⁺ in GIS applications, one has to be aware that HP⁺ works best in relatively open terrain with not too many possible obstructions.

3.1. Transformations to local coordinate systems

OmniSTAR measurements are in the ITRF-2000 coordinate system, which is identical to WGS'84 realisation 2000. Omnistar reference station coordinates are updated whenever they differ more than 1 cm from the ITRF-2000 coordinate system. The ITRF coordinate system is stable, however the continents move and drift several centimetres per year, e.g. in Europe the drift is 2-3 cm/year in the North-North East direction. With a 14 parameter transformation, (i.e. Soler 7-parameter dx, dy, dz, rx, ry, rz, scale and the dx/dt, dy/dt, dz, dt, drx/dt, dry/dt, drz/dt, ds/dt) one can transform these coordinates to the local coordinate system e.g. ETRS89. Hereafter, datum transformations to the country datum and local projections may also be required, depending on the end users requirements.

3.2. Relative method

As the accuracy of OmniSTAR HP⁺ is in the decimetre range, it is fairly easy to determine the offset in x, y, z to the local coordinate system by measuring a minimum of 2, but preferably 4 points relative to known points in the local coordinate system. To be on the safe side, a minimum of one-hour static convergence should be applied, after which the determined shifts can be applied to the measurements.

3.3. GIS point positioning

After the conversion to the local coordinate system has been determined, one can start measuring points. It is wise to regularly store so called Kick-start or Seed points to be able to quickly recover from interruption of satellite reception due to signal blockage by trees or buildings.

When measurements are taken using the relative model it is good survey practice to verify the measured points by ending at a known point (see figure 6 below).

From the indicated starting points one can start walking and map all required points. If the HP solution becomes invalid due to blockage as indicated above, one can easily return to a seed position to resume measuring from there. The collection of a seed point only takes a few seconds and may save considerable time in the overall process. One should always verify measurements by finishing a session at a pre-surveyed point. The difference between the first and the last measurement should be less than 20 cm.

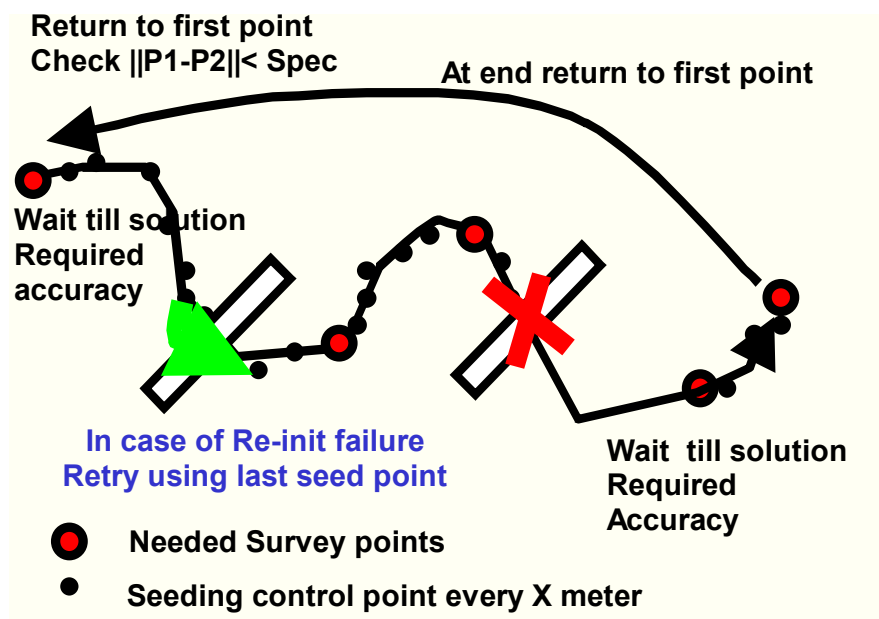


Figure 6: HP+ procedure to work with Kick-start points

4. Conclusions

- With OmniSTAR HP⁺ the customer does not need owned reference stations.
- OmniSTAR HP⁺ can be used worldwide.
- OmniSTAR reference stations increase accuracy and solution robustness.
- Kick-starting allows for immediate decimetre production.
- Static convergence takes on average 10 minutes (20 minutes max).
- Dynamic convergence takes on average 25 minutes (50 minutes max).
- Convergence time is depended on the number visible satellites.
- The converged OmniSTAR HP⁺ solution has a 4-5 cm standard deviation.
- The majority of GPS manufacturers support OmniSTAR HP⁺ in their hardware.
- OmniSTAR HP⁺ can be used for GIS measurements in relatively open terrain to get fast decimetre level accuracy.
- OmniSTAR HP⁺ cannot do miracles. Standard surveying practice such as verifying results on-site by building in checks is still required.

5. References

- | | | |
|----|--|---|
| 1. | Wide Area Carrier Phase Positioning Comparison of the Two Alternate Methods ENC-GNSS, May 2004, Rotterdam, The Netherlands | Dariusz Lapucha and Richard Barker
Fugro Chance Incorporated, USA
Henk Zwaan, Fugro Intersite B.V.
The Netherlands |
| 2. | A note on frame transformations with applications to geodetic datums | Tomás Soler et al
NGS, NOS, NOAA, N/NGS22, #8825 |
| 3. | The ITRF2000 | Claude Boucher et al
IERS ITRS Centre |