Guidelines to Static and Rapid Static GPS Surveying

Controller V 3.30 and higher

SKI V 2.1 and higher

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Leica

Contents

1. Introduction

Surveying with GPS has become popular due to the advantages of accuracy, speed, versatility and economy. The techniques employed are completely different however, from those of classical surveying.

Provided that certain basic rules are followed GPS surveying is relatively straightforward and will produce good results. From a practical point of view it is probably more important to understand the basic rules for planning, observing and computing GPS surveys rather than to have a detailed theoretical knowledge of the Global Positioning System.

This guide outlines how to carry out Static and Rapid Static GPS surveys and emphasizes those points to which particular care has to be paid.

Although this guide has been written specifically for Leica GPS - System 300, much of the information is of a general nature and applicable to all GPS surveying. Further information may be found in the various guidelines contained in the SKI documentation and in the SKI and Technical Reference Help systems.

2. Overall planning for a GPS survey

2.1. Baseline length

A GPS receiver measures the incoming phase of the satellite signals to millimeter precision. However, as the satellite signals propagate through space to earth they pass through and are affected by the atmosphere. The atmosphere consists of the ionosphere and the troposphere. Disturbances in the atmosphere cause a degradation in the accuracy of observations.

GPS surveying is a differential method. A baseline is observed and computed between two receivers. When the two receivers observe the same set of satellites simultaneously, most of the atmospheric effects cancel out. The shorter the baseline the truer this will be, as the more likely it is that the atmosphere through which the signals pass to the two receivers will be identical.

Rapid Static surveys feature short observation times. It is particularly important for Rapid Static that ionospheric disturbances are more or less identical for both sites.

Thus, for all GPS surveying, and for Rapid Static in particular, it is sound practice to minimize baseline lengths

2.2. Temporary reference stations for Rapid Static surveys

As observation time and accuracy are mainly a function of baseline length, it is highly recommended that baseline lengths should be kept to a minimum.

Depending on the area and number of points to be surveyed by GPS, you should consider establishing one or more temporary reference stations.

Baselines radiating from a temporary reference station can be several kilometers in length. Remember, however, that it is advantageous to minimize baseline lengths. The table in section 4 provides a guide to baseline lengths and observation times.

In terms of productivity and accuracy, it is much more advantageous to measure short baselines (e.g. 5km) from several temporary reference stations rather than trying to measure long baselines (e.g. 15 km) from one central point.

2.3. Check the newly surveyed points

In all types of survey work it is sound practice to cross check using independent measurements. In classical survey you check for inaccurate or wrong control points, wrong instrument orientation, incorrect instrument and target heights, etc. You close traverses and level loops, you fix points twice, you measure check distances! Depending on the job and accuracy needed it is well worthwhile applying the same principles to GPS surveying.

One should be particularly careful with Rapid Static with short observation times. If the observation time is too short, or the satellite geometry (GDOP) is poor, or the ionospheric disturbances are very severe, it can happen that the post-processing software will resolve ambiguities but the results may exceed the quoted specifications.

Depending on the accuracy required, the user should be prepared to check newly surveyed points. This is particularly important if observation times have been cut to a minimum and recommendations regarding GDOP ignored.

For a completely independent check:

- Occupy a point a second time in a different window. This ensures that the set-up, the satellite constellation, and the atmospheric conditions are different.

- Close a traverse loop with a baseline from the last point to the starting point.

- Measure independent baselines between points in networks

A partial check can be obtained by using two reference stations instead of one. You will then have two fixes for each point but each will be based on the same roving-receiver observations and set up.

2.4. Night versus day observations. Measuring long lines

Generally speaking, the longer the baseline the longer one has to observe.

The ionosphere is activated by solar radiation. Thus ionospheric disturbance is much more severe by day than by night. As a result, the baseline range for night observations with Rapid Static can be roughly double that of day observations. Or, put another way, observation times for a baseline can often be halved at night.

At the present time ionospheric activity is decreasing in an 11-year cycle.

The table in section 4 provides a guide to baseline lengths and observation times under the current very unfavourable ionospheric conditions.

For baselines up to about 20 km, one will usually attempt to resolve the ambiguities using the Rapid Static algorithm in SKI post-processing software.

For baselines over 20 km, it is usually not advisable to resolve ambiguities. In this case a different post-processing algorithm is used in SKI. This algorithm eliminates ionospheric influences to a large degree but destroys the integer nature of the ambiguities.

2.5. Observation schedule - best times to observe

When you inspect the satellite summary and GDOP plots, you will usually see several good windows (see 3.2) distributed through a 24 hour period. You should try to work with Rapid Static during good windows, and plan your schedule carefully.

It is impossible to plan GPS observations to the minute. Rather than trying to squeeze the maximum number of points into a window by cutting observation times to the bare minimum, it is usually better to measure one point less and to observe for a few minutes longer. Particularly for high-accuracy work, it pays to be conservative and not to risk poor results.

2.6. Consider the transformation to local coordinates

System 300 provides accurate relative positions of points that are observed in a GPS network and linked in post-processing. The coordinates are based on the WGS 84 datum.

For most projects it will be necessary to transform the WGS 84 coordinates obtained from GPS survey into local grid coordinates, i.e. into grid coordinates on the local projection based on the local ellipsoid.

In order to be able to compute this transformation, known points with local coordinates have to be included in the GPS network. These common points, with WGS 84 and local coordinates, are used to determine the transformation parameters and to check the consistency of the local system.

The common points should be spread evenly throughout the project area. For a correct computation of all transformation parameters (shifts, rotations, scale), at least three - but preferably four or more - points have to be used.

Read the Guidelines to Datum/Map in the SKI Documentation for details on transformation using Datum/ Map.

Overall Planning

✓ Plan the campaign carefully

✓ Consider the job, number of points, accuracy needed

✓ Consider connection to existing control

✓ Consider the transformation to local coordinates

✓ Consider the best ways to observe and compute

✓ For high accuracy, keep baselines as short as possible

✓ Use temporary reference stations

✓ Consider the need for independent checks:
Occupying points twice in different windows
Closing traverse loops
Measuring independent baselines between points

✓ Consider using two reference stations

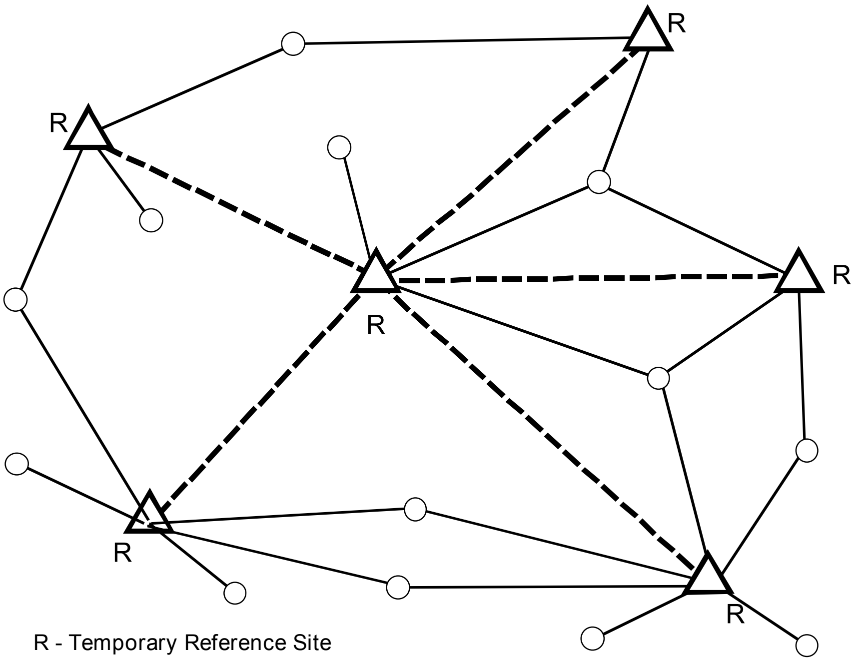
✓ Use good windows

✓ Consider observing long lines at night

✓ For high-accuracy work, try not to squeeze the maximum number of points into a window

Temporary Reference Stations

In terms of productivity and accuracy, it is usually preferable to measure short baselines from several temporary reference stations rather than trying to measure long baselines from just one central point.



Example:
Establish 6 temporary reference stations using Static or Rapid Static.

- Check network of temporary reference stations using double fixes or independent baselines.
- Fix new points from temporary reference stations using Rapid-Static radial baselines.
- Consider the need to check critical points.

3. Mission planning

3.1. GDOP - Geometric Dilution of Precision

The GDOP value helps you to judge the geometry of the satellite constellation. A low GDOP indicates good geometry. A high GDOP tells you that the satellite constellation is poor. The better (lower) the GDOP the more likely it is that you will achieve good results.

Poor satellite geometry can be compared with the "danger circle" in a classical resection. If the geometry is poor, the solution in post-processing will be weak.

For Rapid Static you should observe when the GDOP is less than or equal to 8. A GDOP of 5 or lower is ideal.

3.2. Selecting good windows for successful GPS surveying

For successful, high-accuracy GPS surveying it is advisable to take the observations in good windows. Provided that you know the latitude and longitude to about 1°, the satellite summary, GDOP, elevation, and sky-plot panels in the Survey Design component of SKI will help you to select good windows in which to observe.

You should take particular care when selecting windows for Rapid Static observations.

A suitable observation window for Rapid Static must have four or more satellites, with GDOP < or = 8, above a cut-off angle of 15° at both the reference and roving receiver.

GDOP plots often show steep flanks at each side of a good window. These flanks of rapidly changing GDOP are usually due to rising or setting satellites. Avoid these flanks. Avoid taking Rapid Static observations when the GDOP is changing quickly.

Poor windows should only be used to bridge between two or more good windows when observing for long periods of time, e.g. at reference stations and for long lines.

If there are obstructions near a point, use the sky plot to find out if the signals from a satellite could be blocked. This could cause the GDOP to deteriorate. Check the GDOP by clicking the satellite "off" in the Survey Design component. A careful reconnaissance of such sites is well worthwhile.

Selecting Good Windows

Window for Rapid Static:

✓4 or more satellites above 15° cut-off angle.

✓GDOP < or = 8.

Whenever possible:

✓5 or more satellites.

✓GDOP < or = 5.

✓Satellites above 20°.

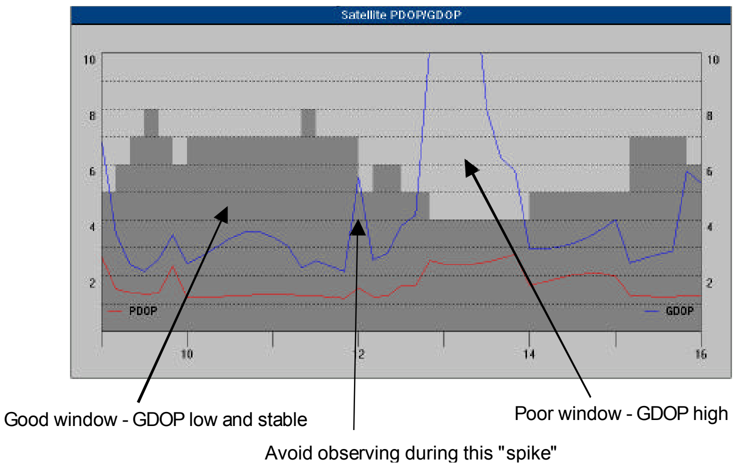
Always:

✓Avoid flanks of rapidly changing GDOP at side of good windows.

✓Use sky plot to check for obstructions.

✓Recompute GDOP if a satellite is obstructed.

✓Be wary if 2 out of 4 or 5 satellites are low (<20°).



4. Observation times and baseline lengths

The observation time required for an accurate result in post-processing depends on several factors: baseline length, number of satellites, satellite geometry (GDOP), ionosphere.

As you will only take Rapid Static observations when there are four or more satellites with GDOP ≤ 8, the required observation time is mainly a function of the baseline length and ionospheric disturbance.

Ionospheric disturbance varies with time and position on the earth's surface. As ionospheric disturbance is much lower at night, night-observation times for Rapid Static can often be halved, or the baseline range doubled. Thus it can be advantageous to measure baselines from about 20km to 30 km at night.

Unless one is extremely restrictive, it is impossible to quote observation times that can be fully guaranteed. The following table provides a guide. It is based on tests in mid-latitudes under the current levels of ionospheric disturbance with a dual frequency Sensor.

Obs. Method	No. sats. GDOP≤ 8	Baseline Length	Approximate observation time	
			By day	By night
Rapid Static	4 or more	Up to 5 km	5 to 10 mins	5 mins
	4 or more	5 to 10 km	10 to 20 mins	5 to 10 mins
	5 or more	10 to 15 km	Over 20 mins	5 to 20 mins
Static	4 or more	15 to 30 km	1 to 2 hours	1 hour
	4 or more	Over 30 km	2 to 3 hours	2 hours

Ionospheric activity is currently decreasing from a high level in an 11-year cycle. As the activity decreases it can be expected that observation times can be reduced or baseline lengths increased. Ionospheric activity is also a function of position on the earth's surface. The influence is usually less in mid latitudes than in polar and equatorial regions.

Note that signals from low-elevation satellites are more affected by atmospheric disturbance than those from high satellites. For Rapid Static observations, it can be worth increasing the observation times if two out of four or five satellites are low (say < 20°).

Times and Baseline Lengths

Observation time depends upon:

- Baseline length
- Number of satellites
- Satellite geometry (GDOP)
- Ionosphere

  Ionospheric disturbance varies with time, day/night, month, year, position on earth's surface.

The table provides an approximate guide to baseline lengths and observation times for mid latitudes under the current levels of ionospheric activity when using a dual frequency Sensor.

No. of Sats	*Approximate*	*Approximate observation time*	
GDOP≤8	*Baseline length*	*By Day*	*By Night*
Rapid Static			
4 or more	*Up to 5 km*	*5 to 10 mins*	*5 mins*
4 or more	*5 to 10 km*	*10 to 20 mins*	*5 to 10 mins*
5 or more	*10 to 15 km*	*20mins or more*	*5 to 20 mins*
Static			
4 or more	*15 to 30 km*	*1 to 2 hours*	*1 hour*
4 or more	*Over 30 km*	*2 to 3 hours*	*2 hours*

5. Field observations

5.1. Reference site

GPS surveying is a differential technique with baselines being "observed" and computed from the reference to the rover. As many baselines will often be measured from the same reference station, the choice and reliability of reference stations are of particular importance.

Sites for reference stations should be chosen for their suitability for GPS observations. A good site should have the following characteristics:

✓ No obstructions above the 15° cut-off angle.

✓ No reflecting surfaces that could cause multipath.

✓ Safe, away from traffic and passers-by. Possible to leave the receiver unattended.

✓ No powerful transmitters (radio, TV antennas, etc.) in the vicinity.

The results for all roving points will depend on the performance of the reference receiver! Thus the reference receiver must operate reliably:

✓ Power supply must be ensured. Use a fully-charged battery. Consider connecting two batteries. Consider a car battery. When possible, consider a transformer connected to the mains.

✓ Check that there is ample capacity left in the memory device for storing all observations. Consider using a PC with SPCS software.

✓ Double-check the antenna height and offset.

✓ Make sure that the mission parameters (observation type, recording rate etc.) are correctly set and match those of the roving receiver.

Note that the reference receiver does not have to be set up on a known point. It is far better to establish temporary reference stations at sites that fulfill the requirements listed above than to set up the reference receiver on known points that are not suitable for GPS observations.

For computing the transformation from WGS 84 to the local system, known points with local coordinates have to be included in the GPS network. These points do not have to be used as reference stations. They can be measured with the roving receiver.

5.1.1. Need for one known point in WGS 84

The computation of a baseline in data processing requires that the coordinates of one point (reference) are held fixed. The coordinates of the other point (rover) are computed relative to the "fixed" point.

In order to avoid that the results are influenced by systematic errors, the coordinates for the "fixed" point have to be known to within about 20 meters in the WGS 84 coordinate system. Whenever possible, the WGS 84 coordinates for the "fixed" point should be known to within about 10 meters otherwise scale errors of about 1 to 2 ppm will be introduced.

This means that for any precise GPS survey the absolute coordinates of one site in the network have to be known in WGS 84 to about 10 meters. WGS 84 coordinates for one site will often be available or can be easily derived as explained in section 7.

If WGS 84 coordinates for one site are not known or cannot be derived, the Single Point Position computation in SKI can be used. Remember, however, that Selective Availability (SA) is usually switched on. The only way to overcome SA is to observe for sufficient time for the effects of SA to be averaged out in the Single Point Position computation.

The reference receiver will usually observe for several hours as the rover moves from point to point. In such a case, the Single Point Position for the reference receiver computed in SKI should be relatively free from the effects of SA.

If a Single Point Position is computed from only a few minutes of observations, the effects of Selective Availability will not be averaged out. The result could be wrong by 100m or more due to SA.

When computing the Single Point Position for the starting point of a network, always compute for a site for which you have several hours of observations. The resulting WGS 84 coordinates should then be correct to within about 10 meters.

The minimum observation for the computation of a reliable Single Point Position is probably about 2 to 3 hours with four or more satellites and good GDOP. The longer the observation time, the better the Single Point Position will be.

5.2. Observing new points with the roving receiver

The operator of the roving receiver should also pay attention to certain points. This is particularly important for Rapid Static surveys with short measuring times.

✓ Make sure that the mission parameters (observation type, recording rate etc.) are correctly set and match those of the reference receiver.

✓ Check the antenna height and offset.

✓ Watch the GDOP when observing for only a short time at a point.

✓ For 5 to 10mm + 1 ppm accuracy with Rapid Static, only take measurements with GDOP < or = 8.

✓ GDOP plots often show steep flanks with a rapidly changing GDOP. Avoid these flanks in Rpid stsic observations. It is better to stop logging data than to observe when the GDOP is changing quickly. In such circumstances wait for a reasonable GDOP and then measure again.

5.2.1. Use the Stop and Go Indicator as a guide

The Stop and Go Indicator in the Controller provides the roving-receiver operator with an approximate guide to measuring times for Rapid Static observations with four or more satellites and GDOP less than or equal to 8. It estimates when sufficient observations should have been taken for successful post-processing (ambiguity resolution) to be possible.

At the present time estimates are calculated for two baseline ranges, 0 to 5 km and 5 to 10 km. The estimates are based approximately on the current situation for GPS observations in mid latitudes and assume that the reference and roving receiver are tracking the same satellites.

As the Stop and Go Indicator can only monitor the roving receiver it can only provide an estimate for the required measuring time. It should be used only as a guide.

5.3. Fill out a field sheet

As with all survey work, it is well worthwhile filling out a field sheet for each site when taking GPS observations. Field sheets facilitate checking and editing at the data-processing stage.

Reference Stations

✓No obstructions above 15° cut-off angle.

✓No reflecting surfaces (multipath).

✓Safe, can leave equipment unattended.

✓No transmitters in vicinity.

✓Reliable power supply.

✓Ample memory capacity.

✓Correct mission parameters (observation type, recording rate).

✓Check antenna height and offset.

✓Does not have to be a known point

✓

✓It is better to establish temporary reference stations at good sites rather than at unsuitable known points.

* * *

For precise GPS surveying, WGS 84 coordinates for one point have to be known to about 10 meters.

Roving Receiver

✓ 15° cut-off angle.

✓ Obstructions should not block signals.

✓ No reflecting surfaces (multipath).

✓ No transmitters in vicinity.

✓ Fully-charged battery.

✓ Sufficient memory capacity.

✓ Correct mission parameters (observation type, data-recording rate).

✓ Check antenna height and offset.

✓ Observe in good windows.

✓ Watch the GDOP ≤ 8.

✓ Use Stop and Go Indicator as a guide.

✓ Fill out a field sheet.

Practical Hints

✓Tribrachs: check the bubble and optical plummet.

✓Level and center the tribrach and tripod correctly.

✓Check the height reading and antenna offset.

✓An error in height affects the entire solution!

✓Use a radio to maintain contact between reference and rover.

✓Consider orienting the Sensors for the most precise work.

Field Sheet

Point No.:	Date:	
Sensor Serial No.:	Operator:	
Controller Serial No.:		
Memory card No.:		
Type of set up:		
Height reading:		
Antenna offset:		
Time started tracking:		
Time stopped tracking:		
Number of epochs:		
Number of satellites:		
GDOP:		
Navigation position: Lat.	Long.	Height
Notes:		

6. Importing the data to SKI

6.1. Checking and editing during data transfer

Data can be transferred to SKI via a card reader, from the Controller, or from a disk with backed-up raw data. During data transfer, the operator has the opportunity to check and edit certain data. It is particularly advisable to check the following:

✓ Point identification: Check spelling, upper and lower case letters, spaces etc.

✓ Make sure that points that have been observed twice have the same point identification. Make sure that different points in the same project have different point identifications.

✓ Height reading and antenna offset: Compare with field sheets.

✓ Initial coordinates: As explained in 5.1.1, for precise survey the coordinates of one site in a network should be known in WGS 84 to about 10 meters. It is preferable to input these values during Import rather than after computation using the View and Edit.

Note that some of the above site-related parameters can be changed in View and Edit. However, the affected baselines have then to be recomputed.

6.2. Backing up raw data and projects

After reading in a data set always make a back-up on either a diskette or on the hard disk. You can then erase and reuse the memory card but you still have the raw data. When backing up data from several memory cards, it is advisable to create a directory for each card.

After importing all the data related to the project it is often worthwhile making a backup of the whole directory where the project is located before starting to process the data. You can do this using standard DOS commands. If for some reason the project data base should become corrupted you have only to delete all files in the original directory and restore the backup files. This is quicker than importing all the raw data again.

SKI databases may be corrupted by:

- Switching off the computer before exiting SKI.
- Deleting individual files from the project directory.
- Deleting whole projects under DOS and not through the SKI Project Manager.

7. Deriving initial WGS 84 coordinates for one point

As explained in 5.1.1, the computation of a baseline requires that the coordinates of one point are held fixed. The coordinates of the other point are computed relative to the "fixed" point.

For any precise GPS survey the absolute coordinates of ONE site in the network have to be known in WGS 84 to about 10 meters. WGS 84 coordinates for one site will often be available or can be easily derived.

Using the Datum/Map component of SKI it is easy to transform the grid coordinates of a known point to geodetic or Cartesian coordinates on the local ellipsoid. If the approximate shifts between the local datum and WGS 84 are known, WGS 84 coordinates to well within the required accuracy can be obtained. The local Survey Department or University will usually be able to provide approximate transformation parameters.

As explained in 5.1, the reference receiver does not have to be on a known point. If the reference receiver was on a new (unknown) point and a known point was observed with the roving receiver, simply compute the first baseline from the known point (rover) to the unknown point (reference) in order to obtain and store the required initial WGS 84 coordinates for the reference receiver.

If good initial WGS 84 coordinates for the reference site are not known or cannot be derived as explained in the last two paragraphs, the Single Point Position computation in SKI can be used. When using the Single Point Position computation always compute for a site for which there are several hours of observations. The effects of Selective Availability should then average out and the resulting WGS 84 coordinates should be correct to within the required 10 meters. See section 5.1.1 for further details.

Always keep in mind that poor initial coordinates for the reference receiver will affect the baseline computation and can lead to results outside the quoted specifications.

8. Data-processing parameters

In the vast majority of cases, the default settings for data-processing may be accepted and may never be altered by the operator. On some rare occasions the operator may need to modify one or more of the data processing parameters. The most common ones are described below.

8.1. Cut-off angle

It is common practice in GPS surveying to set a 15° cut-off angle in the receiver. 15° is also the system default value in data processing. Avoid cut-off angles less than 15° if precise results are to be obtained.

Although you can increase the cut-off angle you should be cautious when doing so. If the cut-off angle for data processing is set higher than in the receiver some observations will not be used for the baseline computation and you may "lose" a satellite. It could happen that only three satellites would be used in the computation instead of four. You cannot expect a reliable answer with only three satellites.

It can sometimes be advantageous, however, to increase the cut-off angle to about 20° in case of a disturbed ionosphere and provided that sufficient satellites above 20° with good GDOP have been observed (use the Survey Design component in SKI to check the GDOP).

You may sometimes find that a baseline result is outside specifications even though five satellites have been observed. If one of the satellites never rises above about 20° the observations to this satellite may be badly affected by the ionosphere. Raising the cut-off angle and computing with only four high-elevation satellites can sometimes produce a better result.

8.2. Tropospheric model

It will not make much difference to the end result as to whether you select the Hopfield or Saastamoinen model, but you should never work with "no troposphere". You cannot expect to achieve good results if no tropospheric model is used.

8.3. Ionospheric model

This parameter is only used for baselines up to the limitation value (see 8.7.), that is for baselines for which SKI will try to resolve ambiguities.

The Standard model is based on an empirical ionospheric behaviour and is a function of the hour angle of the sun. When the Standard model is chosen corrections are applied to all phase observations. The corrections depend on the hour angle of the sun at the time of measurement and the elevation of the satellites.

A computed model may be used instead of the standard model. This is computed using differences in the L1 and L2 signal as received on the ground at the Sensor. The advantage of using this model is that it is calculated according to conditions prevalent at the time and position of measurement. At least 45 minutes of data is required for a computed model to be used.

An incorrect ionospheric model or no model will introduce a scale factor in the computed baselines. The computed baselines will usually be too short if "no model" is applied.

If the option "no model" is used no corrections are applied. Results of baselines observed during day can then be too short by up to 4 to 5 ppm.

For long lines above the limitation value (see 8.7), the ionospheric effects are eliminated by evaluating a linear combination of L1 and L2 measurements, the so-called L3 observable. Ambiguity resolution is not attempted.

8.4. Ephemeris

SKI uses the broadcast ephemeris recorded in the receiver. This is standard practice throughout the world for all routine GPS surveying. For standard GPS survey work there is little to be gained by using a precise ephemeris.

8.5. Data used for processing

For precise GPS surveying, one will normally accept the system default setting of "code and phase".

"Code only" can be used for the rapid calculation of baselines when high accuracy is not required, for instance in exploration or offshore work. If only code observations are evaluated the accuracy cannot be better than about 0.3m in position when data from an SR399/E or SR9400 is used.

For the precise measurement of baselines it should make little difference whether one processes "code and phase" measurements together or "phase only". The results should be more or less identical.

For long lines above about 100 km, code observations can assist a high-accuracy solution provided that the ephemerides are sufficiently good.
If code measurements are corrupted for some reason, one can process baselines using "phase only".

For processing kinematic data, "code and phase" have to be used for precise results. Code only can be used if high accuracy is not required.

8.6. Phase Frequency and Code Frequency

The SR 299 and SR399 are dual-frequency receivers. Short observation times with Rapid Static are only possible with dual-frequency observations. Long lines can only be processed successfully using L1 and L2 data.

SKI will automatically select to process whatever data is available. Thus there is little point in processing with anything but Automatic. Take full advantage of the System 300 dual-frequency hardware and software. Always use "Automatic".

8.7. Limitation

With this parameter you can determine how SKI should compute baselines. The system default value is 20 km.

For baselines up to the limitation value, L1 and L2 measurements are introduced as individual observations into the least-squares adjustment. Resolution of the L1 and L2 integer ambiguities using the Fast Ambiguity Resolution Approach (FARA) is always attempted.

For baselines above the limitation value, a so-called L3 solution is performed. The L3 observable is a linear combination of the L1 and L2 measurements. The advantage of the L3 solution is that it eliminates the influence of the ionosphere. However, it also destroys the integer nature of the ambiguities, therefore no ambiguity resolution can be carried out. This is not important, however, as successful ambiguity resolution over long distances is in any case hardly feasible.

8.8 A priori rms

The à priori rms is used to minimize the possibility of unreliable baseline results.

During the computation of a baseline, the least-squares adjustment computes the root mean square (rms) of a single-difference phase observation (i.e. the rms of unit weight). This value is compared with the à priori rms.

The rms of a single-difference phase observation is largely dependent on the baseline length, observation time, and ionospheric disturbance. Ionospheric disturbance is less at night.

The following table provides a very approximate guide to the rms of a single difference that a user could expect:

	Day		Night	
Distance	Observation Time		Observation Time	
	≤ 10 min	> 10 min	≤ 10 min	> 10 min
Up to 5 km	< 10 mm	< 10 mm	< 10 mm	< 10 mm
5 to 10 km	< 15 mm	< 25 mm	< 10 mm	< 15 mm
10 to 20 km	< 15 mm	< 40 mm	< 10 mm	< 15 mm

If the rms of a single-difference observation exceeds the à priori rms, the baseline solution with fixed ambiguities will be rejected and only the float solution will be presented (ambiguities not resolved).

The system default value for à priori rms is 10mm.

For Rapid Static observations with up to 10 minutes of measurement time, one should be cautious about increasing the à priori rms because an unreasonably high rms value could lead to a weak solution being accepted.

For longer observation times - let us say about 30 minutes or more - the à priori rms can be set higher without undue risk.

Note that the à priori rms applies only to base lines up to the limitation value (see 8.7). For base lines over the limitation value ambiguity resolution is not attempted.

9. Baseline selection. Strategy for computation.

Before starting data processing one should consider carefully how best to compute the network. Points to be considered include:

- Obtaining good initial WGS 84 coordinates for one point.
- Connections to existing control.
- Computing the coordinates of temporary reference stations.
- Rapid static measurements from temporary reference stations.
- Long lines.
- Short lines.

If more than one temporary-reference station has been used, this "network" of temporary-reference stations should be computed first. This may also involve the connection to existing control points. Select and compute line by line, inspect the results, and store the coordinates of temporary reference stations if the baseline computations are in order.

It is highly advisable to check the coordinates for each temporary-reference station using double fixes or other means, as all radial roving points depend on temporary-reference stations.

Once the "network" of temporary-reference stations has been computed, all remaining baselines - i.e. the radial baselines from the temporary-reference stations to roving-receiver points - can be computed.

If baselines of greatly differing lengths have to be computed, it can be worthwhile making two or more baseline selections and computation runs. In this way you can select and compute batches of baselines which fall into the same category of expected à priorims (see 8.9).

Try to avoid mixing baselines of totally different lengths in the same computation run. And avoid mixing short-observation Rapid-Static baselines with long-observation Static baselines.

Data Import and Computation

Check and edit during data transfer:

✔ Point identification
✔ Height reading and antenna offset
✔ WGS 84 coordinates of initial point

✔ Back up raw data and project

Consider the following carefully:

- How best to compute the network
- The need for good WGS 84 coordinates for one point
- Connection to existing control
- The need to transform to local coordinates
- Computation of network of temporary reference stations
- Computation of new points from temporary reference stations
- Long lines
- Short lines
- Data-processing parameters

10. Interpreting the baseline results

When interpreting the results, one has to distinguish between baselines up to the limitation value and baselines above this value (see 8.7).

For baselines up to the limitation value, ambiguity resolution using the Fast Ambiguity Resolution Approach (FARA) is always attempted.

For baselines above the limitation value, a so-called L3 solution (linear combination of L1 and L2 measurements) is performed. This eliminates the ionospheric effects but destroys the integer nature of the ambiguities. Thus ambiguity resolution is not carried out.

10.1. Baselines up to the limitation value

10.1.1. Ambiguities resolved (A=Y)

For baselines up to 20 km (system default for limitation), ambiguity resolution should always be successful if good results are to be achieved.

For baselines up to the limitation value, FARA searches for all possible combinations of ambiguities and evaluates the rms of a single-difference observation for each set of ambiguities. It then compares the two solutions with the lowest rms values. If there is a significant difference between the two rms values, the ambiguity set yielding the lowest rms value is considered as the correct one. This decision is based on statistical methods.

The reader will realize, of course, that a least-squares adjustment can only provide the "most probable" values. These will usually be the "true values".

However, one should also be aware that very severe ionospheric disturbances can cause systematic biases in the phase observations. In this case, although the results of the least-squares adjustment will be statistically correct, they could be biased away from the true values.

The statistical methods implemented in FARA are based on very restrictive criteria in order to try to ensure the highest probability of a reliable result. When the ambiguities are resolved, you know that the FARA algorithm has found a "most probable" solution with an rms value that is significantly lower than for any other possible ambiguity set.

If the guidelines for baseline lengths, observation windows, number of satellites, GDOP, and observation times are followed (combined perhaps with your own experience), the results of baselines for which the ambiguities are resolved should be within the system specifications.

Nevertheless, as explained above, it is simply impossible to eliminate completely the possibility of the occasional biased result.

10.1.2. Ambiguities not resolved (A=N)

As already explained, ambiguity resolution should always be successful for baselines up to 20 km if good results are to be obtained.

If insufficient observations were taken or the satellite constellation was poor, the FARA algorithm will not be able to resolve the ambiguities. If the ambiguities are not resolved it is most unlikely that the system specifications will be achieved.

If the ambiguities are not resolved in Rapid Static (short observation times) it is difficult to give an indication of accuracy. However, as a rough guide, one could multiply the sigma values for each estimated coordinate by 10 in order to obtain an approximate estimate of the accuracy of the baseline computation.

Note that for baselines up to 20 km it should normally be possible to resolve the ambiguities provided that sufficient observations have been taken (see section 4 for a guide to baseline lengths and observation times). If the ambiguities are not resolved check the rms values in the logfile (see section 11).

10.2. Baselines above the limitation value

For baselines above the limitation value (system default = 20 km), SKI eliminates the ionospheric effects but does not attempt to resolve ambiguities.

Thus the result will always show "ambiguities not resolved" (A=N).

Note that there is usually no benefit in trying to resolve ambiguities for lines over 20km.

11. Inspecting the logfile and comparing results

11.1. Baselines up to the limitation value

For baselines up to the limitation value, ambiguity resolution using the Fast Ambiguity Resolution Approach (FARA) is always attempted.

When you look at the logfile, you will find a summary of FARA at the end of each baseline output. You should check the following:

- Number of satellites: there should always be at least four.
- The rms float: this is the rms value before fixing ambiguities.
- The rms fix: this is the rms value after fixing ambiguities. The rms fix will usually be slightly higher than the rms float.
- The à priori rms: this is the value set in the data-processing parameter table.

As explained in 8.9, if the rms float exceeds the à priori rms, the baseline solution with fixed ambiguities will be rejected and only the float solution will be presented (ambiguities not resolved). Thus if ambiguities are resolved the rms float and rms fix have to be lower than the à priori rms.

The table in 8.9 provides an approximate guide to the rms values (float and fix) that can be expected.

If the à priori rms is lower than the rms float or rms fix one can consider increasing the à priori rms value. However, as explained in 8.9, one should exercise a certain amount of caution when doing this for Rapid Static observations with up to 10 minutes of measurement time. The reason is that this could allow unreasonably high rms float and fix values and could therefore lead to a weak solution being accepted.

For longer observation times - let us say about 30 minutes or more - the à priori rms can usually be set higher without undue risk.

Widening the à priori rms value for successful baseline computation requires a certain amount of experience and judgement.

If baselines of greatly differing lengths have to be computed, it is advisable to make two or more computation runs. In this way you can select and compute batches of baselines which fall into the same category of expected à priori rms (see 8.9).

11.2. Baselines above the limitation value

For baselines above the limitation value (system default = 20 km), SKI eliminates the ionospheric effects but does not attempt to resolve ambiguities.

When inspecting the logfile check the following:

- The number of satellites observed.
- The rms of weight unit

The rms of unit weight should be less than about 20 mm for lines of about 20 km to 50 km. For lines over 50 km the rms of unit weight will usually be higher due to the minor inaccuracies in the broadcast ephemeris.

11.3. Compare the logfile against the field sheets

If the results are not as good as you would expect, it can be well worthwhile comparing the information in the logfile with that in the field sheets. Check if the number of satellites used in the baseline computation is the same as that noted in the field sheets. Remember to check the reference station as well as the rover. If the number of the satellites is not the same, the GDOP values could be higher than you expected. Check the actual GDOP for the satellites used in the computation using the Survey Design Component of SKI.

11.4. Compare the results for double fixes

If a point was observed twice in different windows or two reference receivers were operating simultaneously, you should compare the resulting coordinates.

12. Storing the results

After inspecting the summary of results and the logfile, store the results that meet your accuracy requirements.

The coordinates are meaned (weighted mean) if more than one solution for a point is stored. For instance if you store the coordinates for point A from one baseline solution and then you compute and store the coordinates for point A again from another baseline solution, the stored coordinates will be updated to the weighted mean values from the two solutions. The weighted mean is taken provided the coordinates agree in both height and position to within the averaging limit set in the Project component of SKI (default = 0.075m).

It follows that you should exercise a certain amount of care when storing points that have been fixed in more than one baseline computation. Compare the results before storing.

Interpreting and Storing the Results

- For lines up to 20 km, ambiguity resolution should be successful if high-accuracy results are to be obtained.

- For long lines over 20 km, the L3 solution without ambiguity resolution will normally be used.

- Baselines up to the limitation value (default = 20 km):
  - Rapid Static using FARA.
  - Ambiguity resolution always attempted.
  - Ambiguities resolved (A=Y):
    - FARA has found most probable solution.
    - Results should normally meet specifications.
  - Ambiguities not resolved (A=N):
    - Float solution presented.
    - Result outside specifications, inspect logfile.
    - Consider increasing à priori rms and recomputing.

- Baselines above the limitation value (default = 20 km):
  - Static, FARA not used.
  - L3 solution, ambiguity resolution not attempted.
  - Results should meet specifications provided sufficient observations taken.
  - Long lines need long observation times.

- Inspect double fixes, independent baselines etc.

- Store results that meet accuracy requirements.

- Coordinates meaned if more than one result stored.

13. Adjustment, Transformation and output of results

After the observations have been computed, you may wish to adjust the results if multiple observations to points exist. This provides the best estimates for the position of the points. See Guidelines to Adjustment in the SKI documentation for further details.

The results of the baseline computations are coordinates in the WGS 84 system. Using the Datum/Map component of SKI, these coordinates can be transformed into coordinates in any local datum or grid system.

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