Combining TPS and GPS
SmartStation and SmartPole
High performance GNSS systems

- when it has to be **right**

Leica
Geosystems

Contents

1. TPS total stations and GPS RTK support each other perfectly

A conventional total station needs local control points over which it can be set up, from which it can traverse, and to which it can measure to resect its position.

A GPS RTK receiver can determine its position within a few seconds to centimeter-level accuracy using data from a GPS reference station that may be 50km or more away.

A GPS RTK rover is fast and efficient to use but needs an open view of the sky in order to receive the satellite signals. RTK is best in wide, open areas.

A total station can measure and stakeout where RTK cannot be used: to building corners, to points under trees and bushes, in city canyons etc.

SmartStation and SmartPole combine TPS surveying with cm-accuracy RTK to give you the full advantages of both systems.

SmartStation and SmartPole are different tools and are used in different ways.

This book describes how to survey and stake out using SmartStation and SmartPole. It also explains RTK in a simple way that will be understood by equipment operators that have never used GPS before.

SmartStation

1.1 GNSS

The SmartAntenna, used for both SmartStation and SmartPole, is a GNSS receiver.

GNSS stands for Global Navigation Satellite System. GNSS satellites include the US GPS satellites, Russian GLONASS satellites, and also satellites from several space-based augmentation systems such as EGNOS and WAAS.

GPS is the main system. For simplicity, much of this book refers only to GPS.

SmartPole

2. SmartAntenna, SmartStation, SmartPole

2.1 SmartAntenna

SmartAntenna is a small, light, compact, dual-frequency, GNSS satellite receiver. SmartAntenna is used for both SmartStation and SmartPole. There are two versions of SmartAntenna: one for GPS only, one for GPS and GLONASS.

2.2 SmartStation

SmartStation comprises a TPS1200 total station with a SmartAntenna. The receiver is controlled entirely from the total station. TPS and GPS are perfectly integrated.

With SmartStation there is no need to search for and set up over control points, run traverses, or resect the position.

With SmartStation you simply:
• Set up wherever it is convenient.
• Determine the position coordinates in a few seconds to centimeter accuracy with RTK.
• And then survey and stake out with the total station.

SmartStation is more versatile than a standard total station and measures to points and objects that can never be occupied with an RTK receiver.

Surveying with SmartStation

2
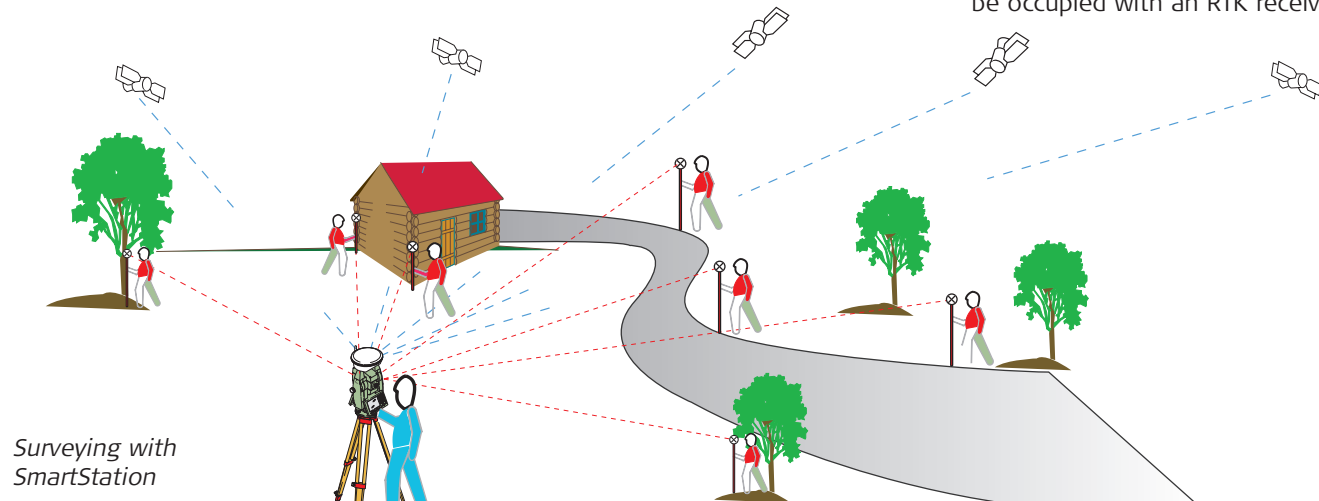
2.3 SmartPole

SmartPole comprises a new, hardlock, lightweight, telescopic pole with a precise 360° EDM reflector, RX1250T Controller and Smart Antenna. The RX1250T controls the SmartAntenna via Bluetooth[R] and the remote TPS1200 total station via a radio link.

SmartPole combines all the advantages and flexibility of an RTK rover with the remote control of a total station.

With SmartPole, simply establish control points wherever you want with RTK and measure to them simultaneously with the total station to resect its position.

Survey and stake out with RTK and/or the remote total station. Use whichever is best, depending on the area and the points to be measured to.

Surveying with SmartPole
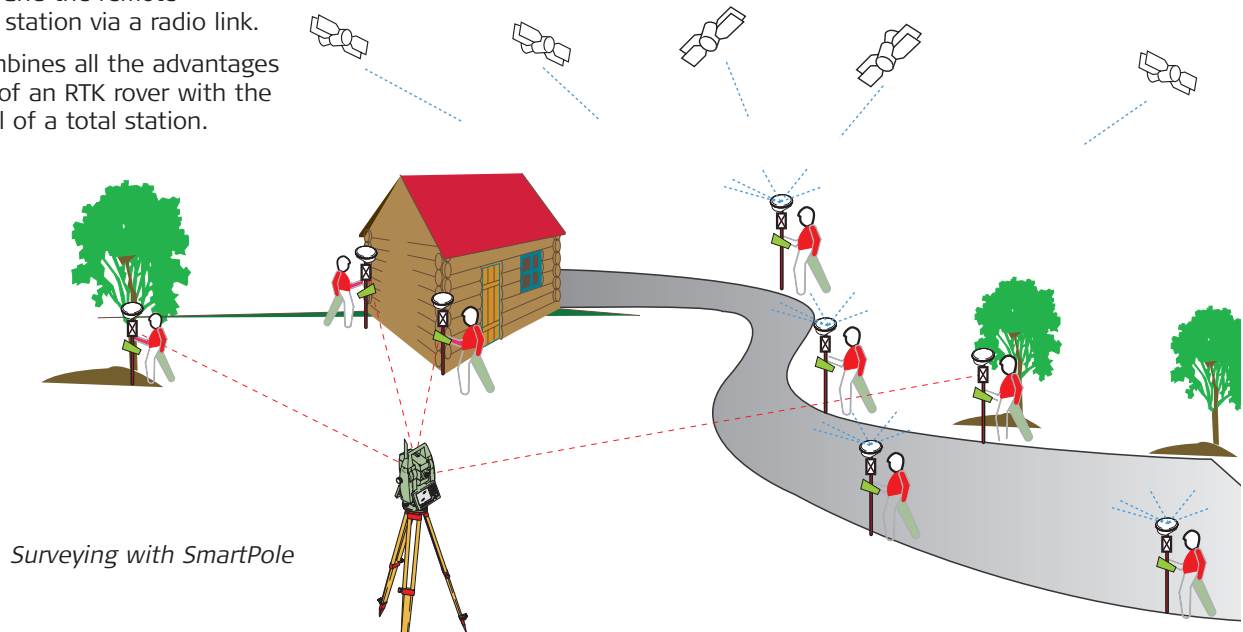
2.4 SmartStation versus SmartPole

Although both SmartStation and SmartPole combine RTK with total station surveying, the techniques are different.

With **SmartStation** the entire survey is carried out by and controlled from the total station. SmartStation is ideal for manually operated total stations.

With **SmartPole** the entire survey is carried out by and controlled from the pole. As the total station is remote controlled, only one operator is required. Measurements can be angle and distance from the total station and/or RTK.

SmartPole is ideal for robotic total stations and provides total flexibility.

Whichever system you use, you save time, speed up work, reduce costs and increase profits.

2.5 Modular hardware

The SmartAntenna can be used in various ways:

(i) On a TPS1200 total station for SmartStation.
(ii) On a pole with 360° reflector and RX1250(T) Controller for SmartPole.
(iii) On a pole with any RX1250 type Controller for an independent RTK rover.

Combine and use equipment, as you prefer, according to the work you have to do.

(i)   (ii)   (iii)
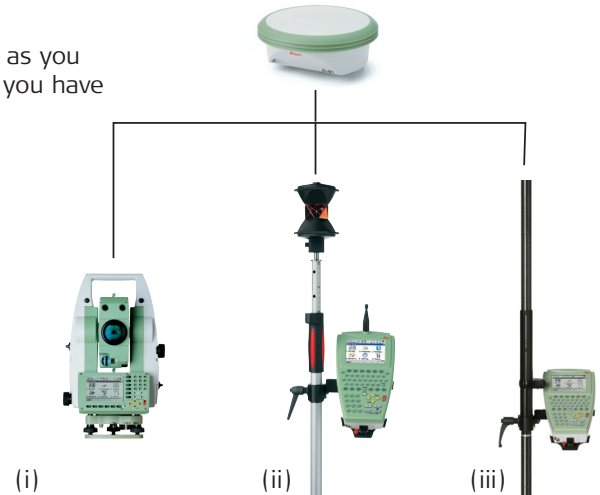
3. A short note on RTK

To determine position using RTK, SmartStation and SmartPole combine the satellite data taken by SmartAntenna with the satellite data taken by a reference receiver that is set up on a known point.

The reference data are transmitted to SmartStation and/or SmartPole by radio, phone or the Internet.

The reference will often be a public reference station that transmits data for use by all GPS rover units in the surrounding area. However, it could also be a private reference receiver that is set up on a known point specifically to support SmartStation or SmartPole.

RTK stands for Real Time Kinematic and is extremely reliable. Using RTK, SmartStation and SmartPole determine position within a few seconds to centimeter-level accuracy.

SmartPole   *Reference*   *SmartStation*
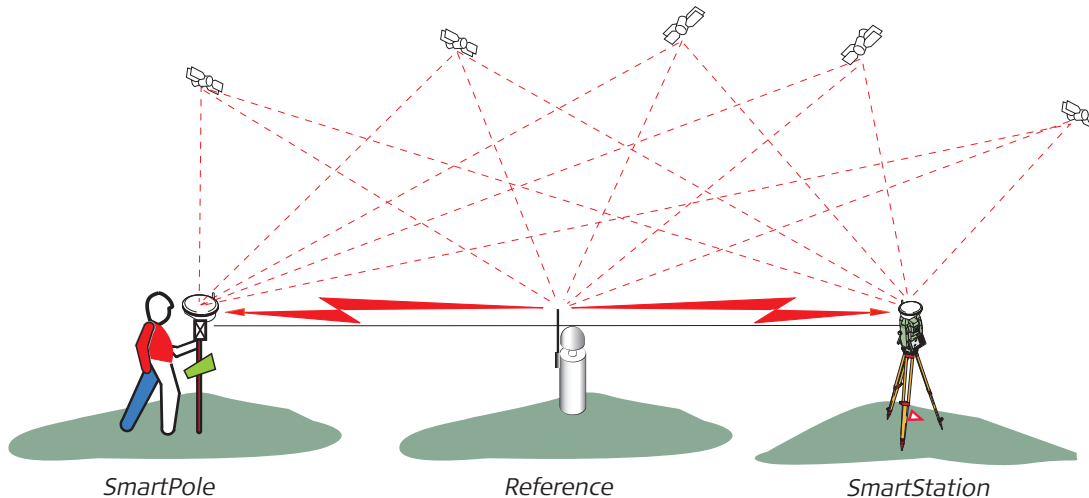
4. SmartStation and how it is used

With SmartStation, the SmartAntenna is on the TPS 1200 total station. The SmartStation operator has total control over the equipment and measurements. SmartStation is ideal for manually operated total stations.

As the position of SmartStation is determined by RTK, control points are not needed. Simply set up SmartStation wherever it is convenient. Various orientation methods are available.

With SmartStation on a tripod, the SmartAntenna setup is much more stable than that of a standard RTK rover on a handheld pole. Stability assists the RTK computation and improves the range.

Using RTK, SmartStation will usually determine its position within a few seconds to centimeter-level accuracy at 50km or more from a reference station.

The following examples illustrate how SmartStation is used and the advantages that it provides.
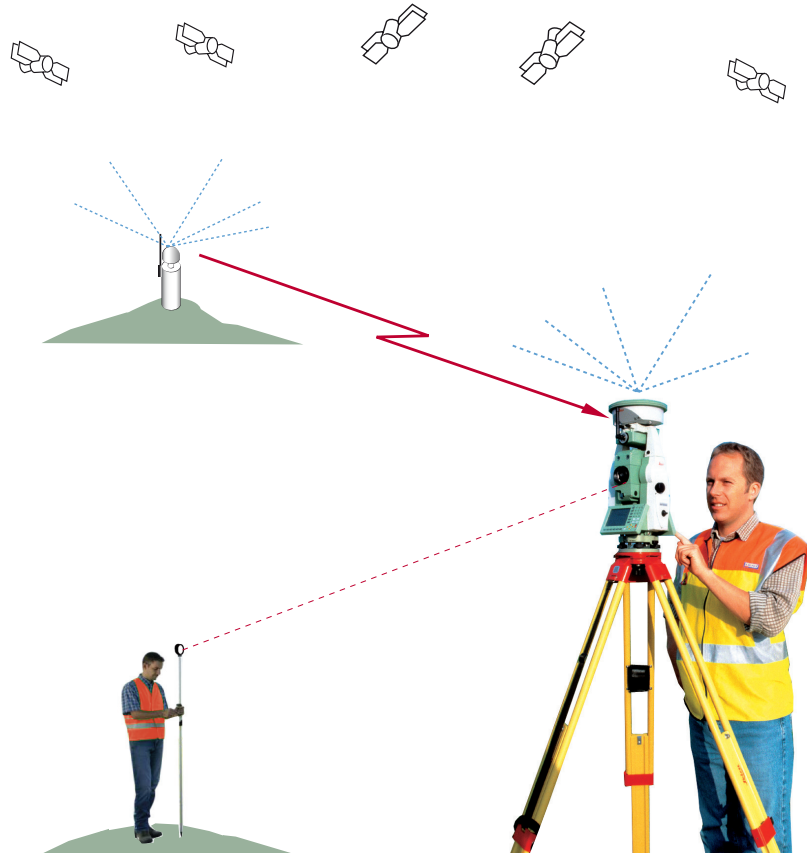
4.1 Topographic survey

The task
A topographic survey is needed. Due to trees, vegetation and the nature of the work, a total station is more suitable than a standard RTK rover for surveying the detail.

There are no control points in the area on which a total station survey can be based. However, there is a reference station about 40km away that transmits data for use by RTK rovers.

The conventional way
Fix a series of control points throughout the area using standard GPS equipment. Transfer the coordinates into the total station. Occupy the control points with the total station, orient to other control points, and survey the detail.

Points have to be occupied twice, once with GPS and once with the total station. Two sets of equipment are needed. Two crews may be needed.

The SmartStation way
Set up SmartStation wherever it is convenient and where there is a reasonably open view of the sky.

At the first point P1, determine the position with RTK. Orient to a second point P2 that will be used but is not yet fixed. Survey the detail from P1.

Set up at P2 and determine the position with RTK.

As the bearing P1-P2 is now known, SmartStation will automatically re-compute the coordinates of all of the detail points surveyed from P1.

Orient to P1 and survey the detail from P2.

Continue in this way.

The advantages
• No traversing.
• Control established where required by RTK.
• Points occupied only once.
• Only SmartStation is needed.
• Only one crew is needed.
• Re-computation made automatically in SmartStation.
• Consistent high accuracy.
• The survey takes less time.
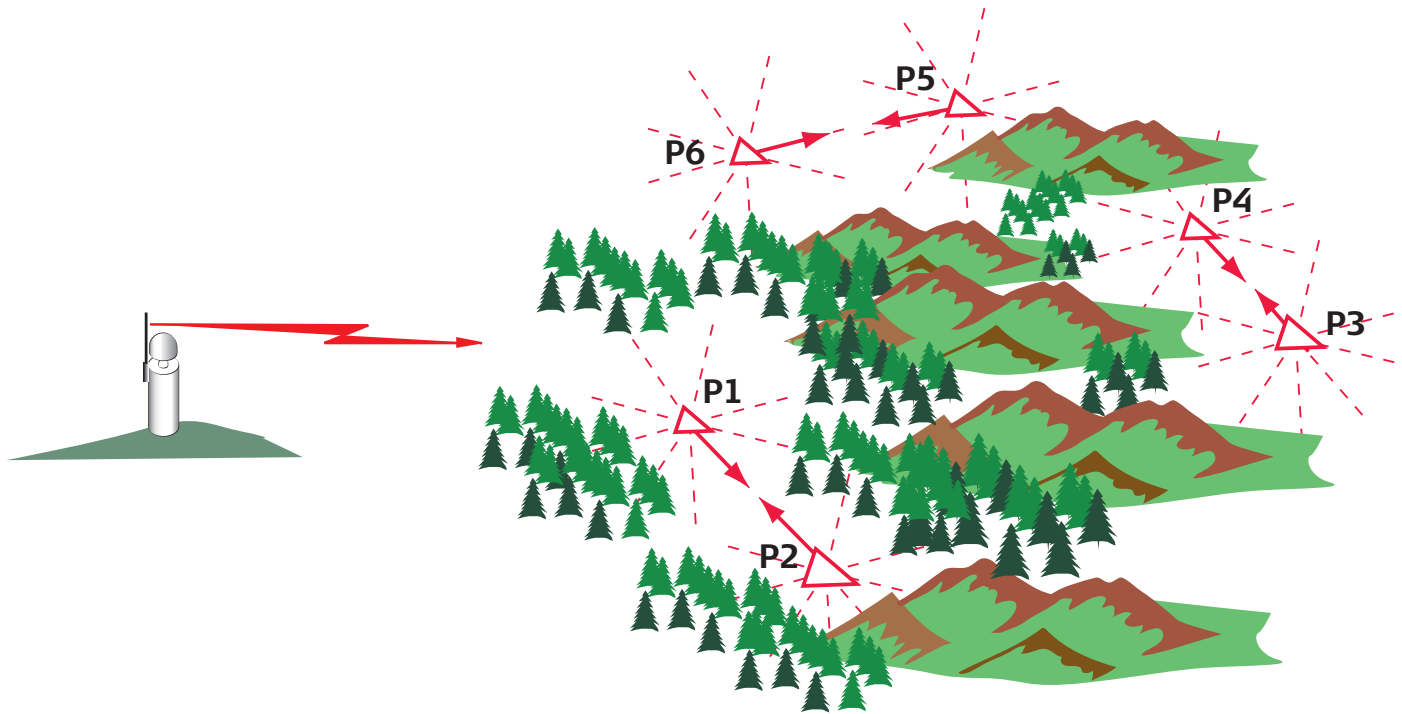
4.2 Surveying utilities in an urban environment

Mapping public utilities
The positions of all manholes, covers, hydrants, distribution boxes etc. for water, gas and electricity have to be determined. High buildings and trees along the roads make it difficult to use RTK rovers. As many objects are close to buildings or under trees, they can be measured to with total stations but cannot be occupied by GPS rovers. The city operates a GPS reference station.

Using a total station
Control points exist but traffic, parked vehicles and other obstructions make it very difficult to set up over them and to orient between them. If a standard total station is used, a lot of traversing in a very difficult environment is necessary. Both careful planning and improvisation are needed. The work is awkward and slow.

Using SmartStation
Set up SmartStation where RTK fixes are possible, such as at road intersections, open spaces and even on the tops of buildings. Use pairs or clusters of SmartStation setups (e.g. P1-P2, P2-P3, and P4-P5) as explained in the previous example. Measure angles and distances to the objects that have to be surveyed.

If the correct circle orientation is only available after the measurements have been taken, SmartStation will re-compute all the coordinates automatically.

The advantages
• Control points not needed.
• No awkward traversing.
• Positions determined by RTK.
• Re-computation in SmartStation.
• Consistent high accuracy.
• Fast, flexible, convenient.
• Much easier, saves time.

P5

P3

P2

P4

P1
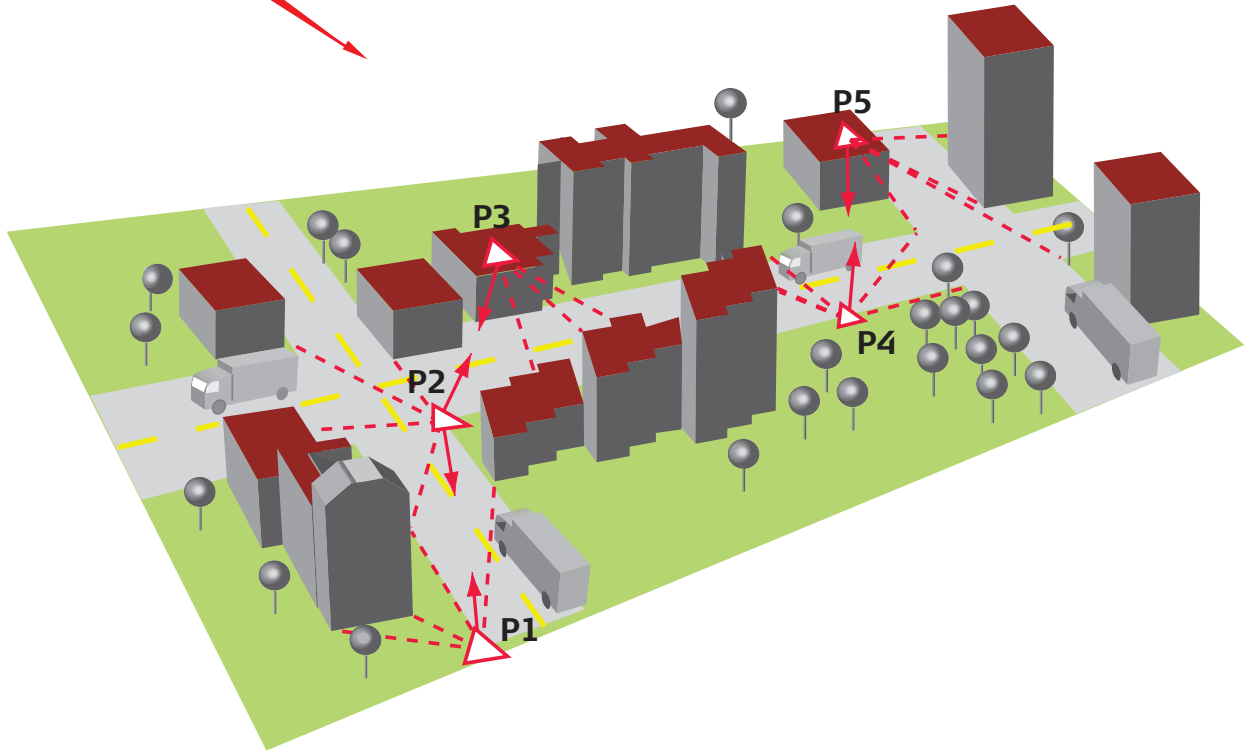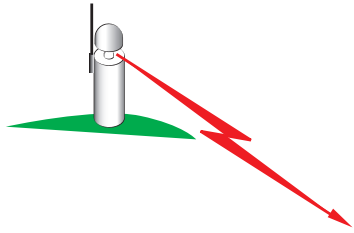
4.3 Stakeout on a large construction site

Stakeout job
A large number of markers have to be placed and many components positioned. Control points exist but often get damaged or are covered by equipment, material, vehicles etc.

There is a GPS reference station transmitting data to RTK rovers but, due to obstructions and the type of construction, most points cannot be set out with RTK.

Conventional stakeout
Stakeout with a total station is possible but difficult and time consuming. Traversing is needed to get around obstructions. Temporary points, which can be used for stakeout, have to be established. The work plan has to be revised constantly. Equipment and material have to be moved, which slows both the survey and construction work.

SmartStation stakeout
Control points are not required. Simply set up SmartStation wherever it's convenient and let RTK determine the position.

Set up at P1 and fix the position with RTK. Set up at P2, fix the position with RTK and orient to P1. Now stakeout from P2.

Work in this way establishing pairs or groups of points from which to stake out. As the positions are determined by RTK, the pairs or groups do not have to be connected by total station measurements.

The advantages
• Set up where it's convenient.
• No control points needed.
• No traversing needed.
• Positions by RTK.
• Fewer obstructions.
• Less downtime
• Faster stakeout.
• Faster construction.
• High accuracy.
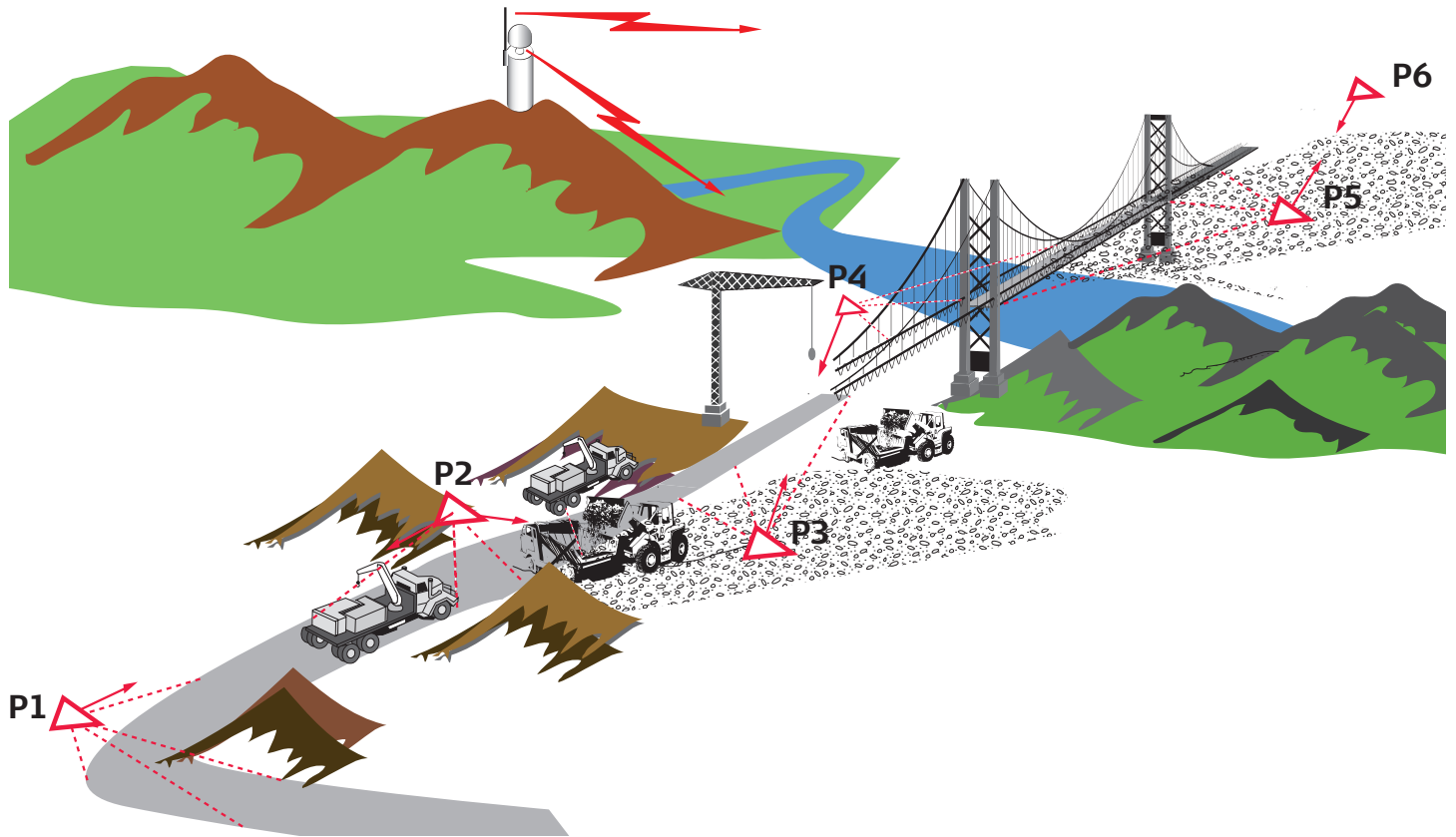
5. SmartStation: three methods of orientation

RTK determines the coordinates and height of the point over which SmartStation is set up. The horizontal circle has to be set by orienting to another point (or points). The point (or points) used should be sufficiently far away to provide a good orientation. There are three ways in which the orientation can be carried out.

5.1 Orienting to a known point (Known BS Point)

Set up SmartStation at a point P1. Determine the position of P1 with RTK. Point accurately to a second point P2, the coordinates of which are known and are stored in SmartStation. SmartStation computes the bearing P1›P2 and sets the horizontal circle reading correctly. You can now measure angles and distances, survey and stakeout, with SmartStation.

P2 can be a standard control point, the coordinates of which have been stored in SmartStation. P2 can also be a point that has been occupied by SmartStation and the coordinates of which have been determined by RTK

With this method, the position coordinates (E, N) and the height (H) are determined by RTK.

Grid North

Hz = 0

Known BS Point

P2
Known point

P1
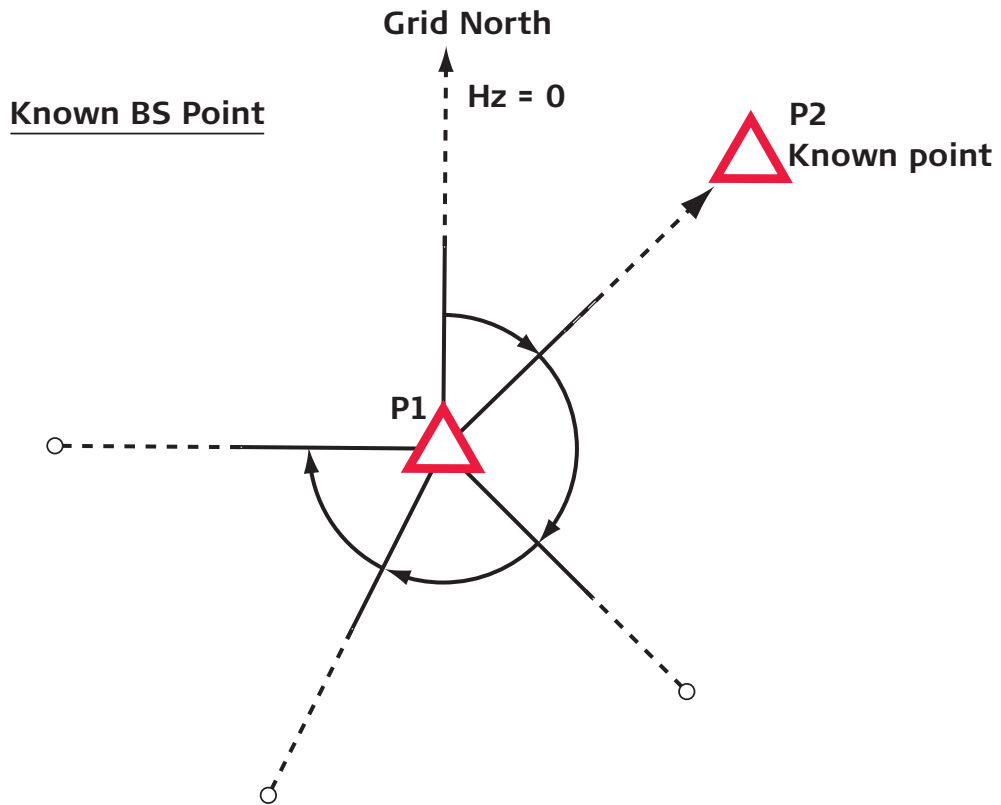
5.2 Orienting to a point the coordinates of which are not yet known (Set Azimuth)

In this method, the orientation is to a point whose coordinates will be determined later.

Set up SmartStation at a point P1 and determine the position with RTK. Point accurately to a second point P2, the coordinates of which have not yet been determined.

You can now measure angles and distances and survey from P1. Note, however, that as the bearing P1 ›P2 is not yet known, the horizontal circle readings (bearings) and, therefore, the coordinates of the surveyed points will not be the final ones. After all the points and detail have been surveyed from P1, move to P2.

Set up SmartStation at P2 and determine the coordinates with RTK. SmartStation does the following fully automatically:
• Computes the bearings P1 ›P2 and P2 ›P1.

• Applies the correct bearing P1 ›P2 to all of the measurements taken at P1 and recomputes the coordinates automatically.
Orient to P1. SmartStation sets the horizontal circle reading correctly. You can now measure angles and distances and survey from P2.

Note that P2 does not have to be occupied immediately after P1. The coordinates of P2 can be determined (or input) at any time, whenever convenient. As soon as the coordinates of P2 are determined (or input), SmartStation will re-compute the coordinates of all points surveyed from P1.

The advantage of the method is that there is no need to determine control points before starting surveying. Simply go to the site, setup SmartStation wherever it's convenient and start work.

Determine the control points where you can see the detail to be surveyed as you go along.

When using this method, the position coordinates (E, N) and the height (H) are determined by RTK.

Note that this method cannot be used for stakeout. For stakeout, either of the other two methods (5.1 or 5.3) has to be used. For stakeout you must first orient to a known point (or points).

Set Azimuth

Grid North

Initial
Hz = 0

Final
Hz = 0

P2
Coordinates
determined
later

Difference

P1

Initial

Final
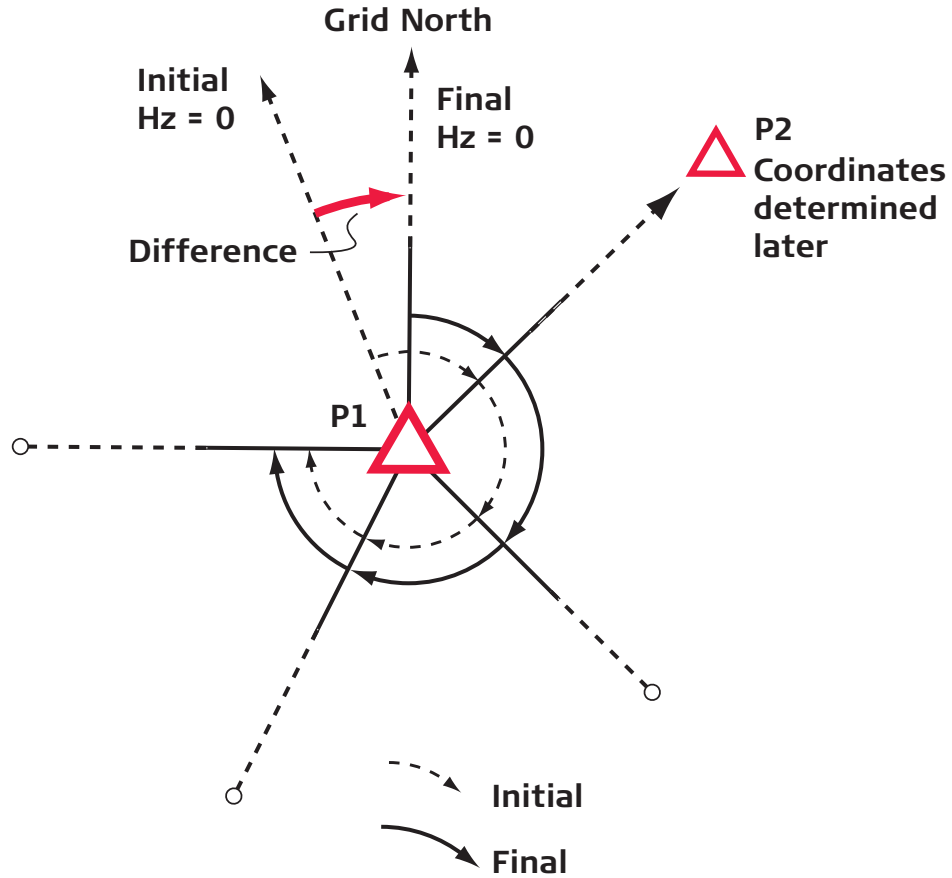
5.3 Orienting to one or more known points and transferring the height from one or more of these points (Ori & Ht Transfr)

This method is similar to 5.1, except that it provides the following options:
• The orientation can be made to one or more points (maximum 10 points).
• The height can be derived from one or more of the control points (height transfer from control points).
• Or the height that is determined by RTK can be accepted.

Set up SmartStation at P1 and determine the position with RTK. You can now point to one or more (up to 10) control points. The control points can have:
• Position coordinates (E, N) and height (H).
• Position coordinates (E, N) only.
• Height (H) only.

If a control point has only a height (e.g. a benchmark), the distance has to be measured.

After pressing the CALC (calculation) key, SmartStation does the following:
• Sets the horizontal circle based on the orientation to all of the points
• Computes the height of P1 from the height of the control points.

With this method, the position coordinates (E, N) are determined by RTK. You can accept the height (H) computed from the control points or the height (H) determined by RTK. This method of orientation has many options and provides total flexibility.

You can now measure angles and distances, survey and stakeout, with SmartStation

When heights have to be based on a particular height datum for the area, e.g. for irrigation, drainage, water, construction and engineering surveys, it can be advantageous to accept the height computed from the control points.

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Ori & Ht Transfr

E, N, H

E, N

H
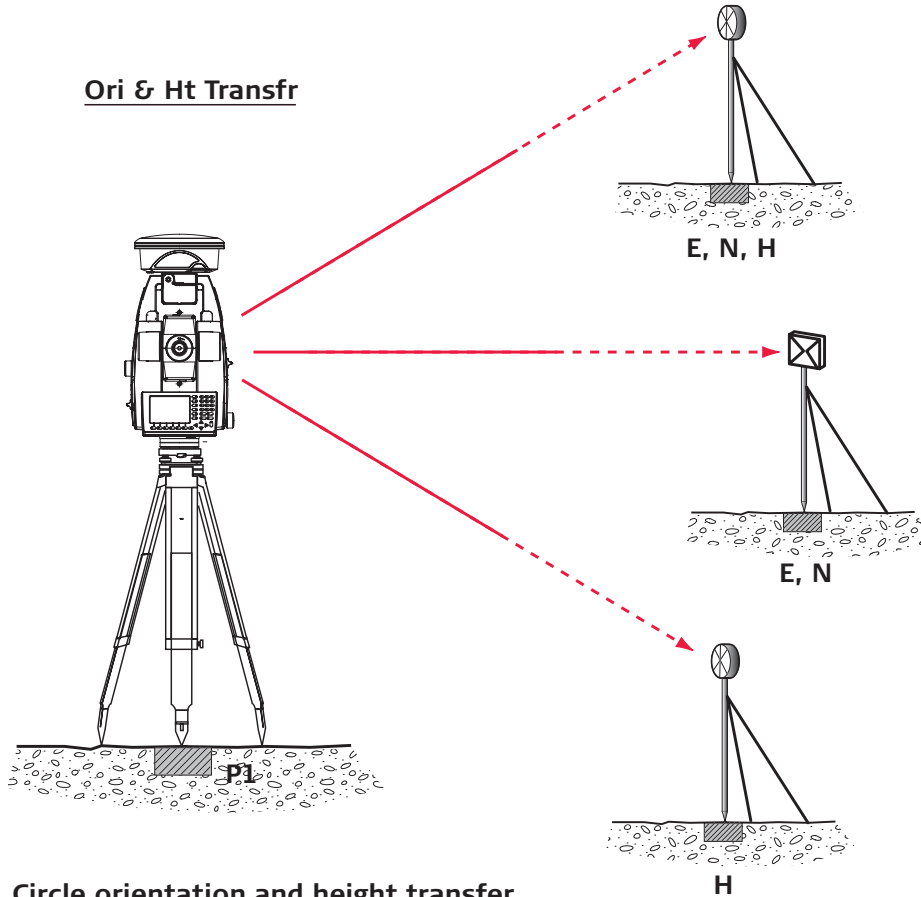
Circle orientation and height transfer

P1

6. SmartStation: post processing instead of RTK

The vast majority of users will always use SmartStation with RTK.

If, however, in remote areas, there are no reference stations within suitable range transmitting RTK data, it is possible to use post processing to compute the position of SmartStation.

Carry out the survey work as outlined in section 4. However, instead of using RTK, record the satellite data collected by SmartStation/SmartAntenna.

Use Leica Geo Office software to download data via the Internet from any distant reference stations that are available.

Afterwards, use Leica Geo Office to determine the coordinates of SmartStation by post processing the baselines from the reference stations.

Leica Geo Office will now re-compute the coordinates of all detail and topo points surveyed with SmartStation.

In order to be sure that you can compute the coordinates of Smart Station to centimeter-level accuracy - i.e. resolve the ambiguities in post processing - always measure for a sufficient length of time.

It is advisable to mark the points over which SmartStation is set up. You will then be able to re-occupy and collect more satellite data should this be necessary.

Most SmartStation users will never need to use post processing.
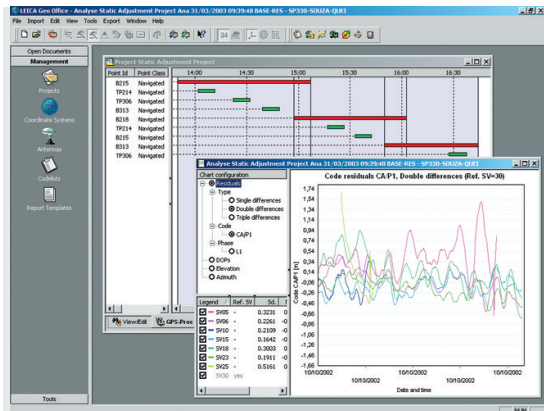
7. SmartPole and how it is used

Although both SmartStation and SmartPole combine RTK with total station surveying, the techniques are quite different.

With SmartPole, the entire survey or stake out process is carried out by and controlled by the surveyor at the pole. He or she can switch between RTK and total station measurements as required and use whichever is the most suitable. The total station is remote controlled.

SmartPole consists of a hardlock, light-weight, telescopic pole, a precise 360° EDM reflector, a Smart Antenna, and an RX1250T / RX1250Tc Controller. The RX1250T communicates with the SmartAntenna via Bluetooth[R] and the remote TPS1200 total station via a radio link.

SmartPole is the complete one-man survey system, combining all-on-the-pole RTK with robotic total station measurements. All GPS, RTK and total station software, as well as all survey and stakeout application software reside in the RX1250T / RX1250Tc.

With SmartPole, conventional control points are not required. Simply set up the total station wherever it is convenient and begin surveying immediately with SmartPole. Take RTK or total station measurements. Switch from one to the other, depending on which is most convenient for the points and detail to be surveyed.

At any time during the survey, set up SmartPole where both RTK and total station measurements are possible. With the pole held steady, determine the coordinates with RTK and also measure angles and distance to the reflector with the total station. Such a point, with both RTK and total station measurements, is called a "SmartPole Control Point".

As soon as two or more "SmartPole Control Points" are available, the resection routine computes the coordinates of the total station and orients the circle. The coordinates of all other points surveyed up until this time are re-computed automatically.

SmartPole does everything and has everything you need.

The examples 7.2 and 7.3 illustrate how SmartPole is used and the advantages that it provides.

◯ *RTK fix*

⊠ *Total station measurement*

◯
⊠ *"SmartPole Control Point"*
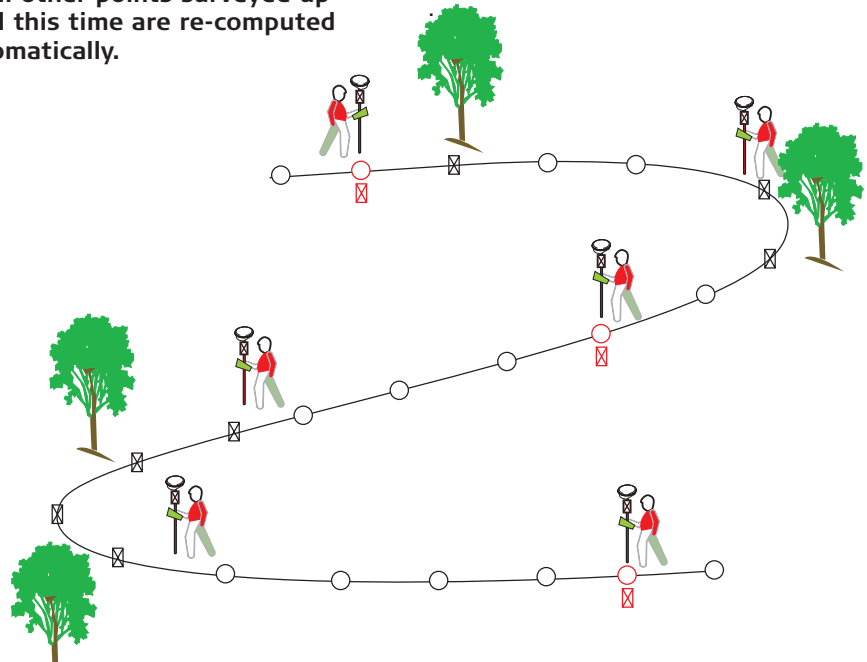
7.1 SmartPole: position, orientation and height

The coordinates and orientation of the total station are determined by measuring angles and distances to at least two "SmartPole Control Points". Keep the pole vertical and steady when taking RTK and total station measurements.

Adding more "SmartPole Control Points" will improve the coordinates and orientation of the total station. The "SmartPole Control Points" should be evenly distributed and at a reasonable distance from the total station.

The position coordinates (E, N) of the total station are based on RTK, i.e. on the RTK coordinates of SmartPole.

Similarly, the height (H) of the total station is also based on RTK.

Note, however, that the resection computation gives you the option of determining the height (H) of the total station from an independent height control point (e.g. a benchmark). This can be advantageous when heights have to be based on a specific height datum.

7.2 Property and detail survey

The task
Property boundaries and all detail have to be surveyed. It is convenient to use a total station to measure to building corners, as well as to boundary marks and detail near hedges and trees. Where the area is relatively open, it is easier and faster to survey with RTK. There are no control points close by, but RTK data can be received from a GPS reference station.

Using a conventional total station
Bring in control by running a traverse from distant control points. Traverse around the area. Coordinate the boundary marks and detail from the traverse stations. Traversing is awkward and time consuming. Many temporary points have to be established.

Using a conventional RTK rover
Detail and boundary marks can be surveyed directly with RTK when the area is open. But RTK measurements can be difficult or even impossible at building corners and at points close to hedges and trees. Hidden point

methods using offset measurements can be used, but are often cumbersome and inaccurate. The other solution is to establish temporary control points with RTK and then to survey from them with a total station.

Using SmartPole
Set up the robotic total station from where detail and boundary marks are visible. Start surveying with SmartPole.

Use RTK when there is good satellite reception and the pole can be placed on the markers or at the detail points. Trigger total station measurements to points at which RTK cannot be used. Take RTK fixes when the total station cannot be seen.

Whenever it is convenient, determine a "SmartPole Control Point" with RTK and total station measurements. Once two or more such "SmartPole Control Points" are available, the on-board resection routine computes the coordinates of the total station, orients the horizontal circle, and re-computes

the coordinates of all surveyed points.

Additional "SmartPole Control Points" can be included and the re-computation updated at any time.

Survey in this way. Switch from RTK to total station measurements according to the points to be surveyed. Re-position the total station whenever necessary.

The advantages
• One-man surveying
• TPS and GPS perfectly combined
• Switch easily from one to the other
• Use whichever is the most suitable
• Re-computation made automatically
• Saves time and manpower
• Provides uniform high accuracy
• Conventional control points not required.
• No traversing.

Total station

RTK fix

Total station measurement

"SmartPole Control Point"
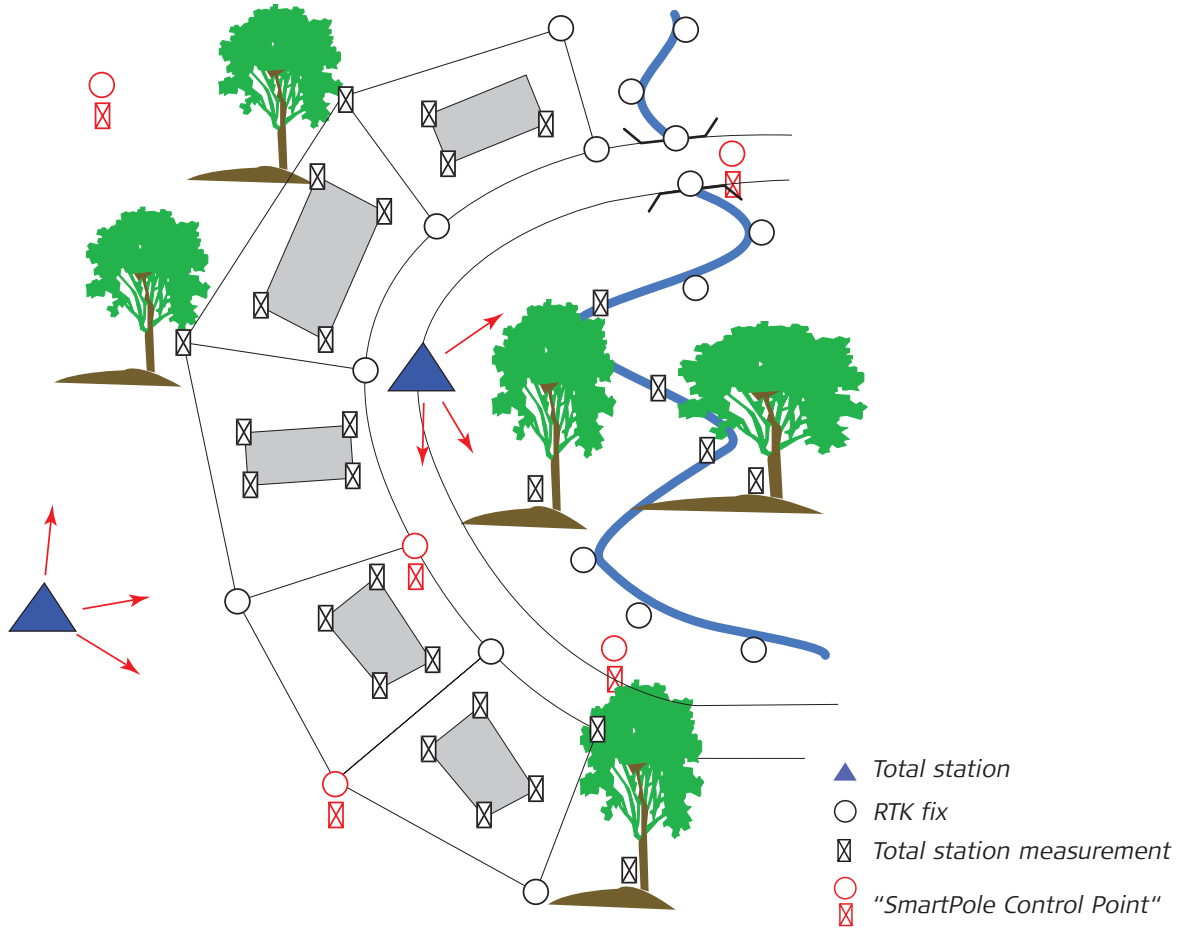
7.3 Staking out

Staking out with SmartPole is similar to surveying with SmartPole in that you can switch between total station and RTK measurements. Note, however, that the coordinates and orientation of the robotic total station have first to be determined.

Staking out for a new road junction
A major road junction has to be modified. The roads have to be widened, the alignments improved, and new slip roads built. There are high buildings close to some roads and the large trees in the area are under protection and cannot be cut. Once work begins, the site will be cluttered with equipment, machines, vehicles, material dumps etc. RTK data can be received from a reference station.

The usual way
The standard approach would be to traverse with a total station to bring in control and to establish temporary control points from which to set out throughout the area. Due to the ever changing obstructions and the

complexity of the site, many setups would be needed. The stakeout strategy would have to be revised frequently.

With SmartPole
Set up the robotic total station where sections of the site are visible and points can be staked out. Determine the coordinates and orientation of the total station by fixing at least two "SmartPole Control Points" with RTK and taking measurements to them with the total station.

Now start the stakeout work. Use total station measurements to stakeout points where RTK cannot be used. Stakeout with RTK where there is good satellite reception and where the total station cannot be seen.

Whenever necessary, move the robotic total station to a new position and, again, determine the coordinates and orientation by taking measurements to at least two "SmartPole Control Points".

The advantages
• Very flexible
• Switch easily from TPS to GPS
• Use whichever is most suitable
• Fewer setups needed
• One-man operation
• All control by RTK
• Uniform high accuracy
• Less downtime due to obstructions
• Speeds up stakeout work

▲ Total station
○ RTK fix
⊠ Total station measurement
○ "SmartPole
⊠ Control Point"
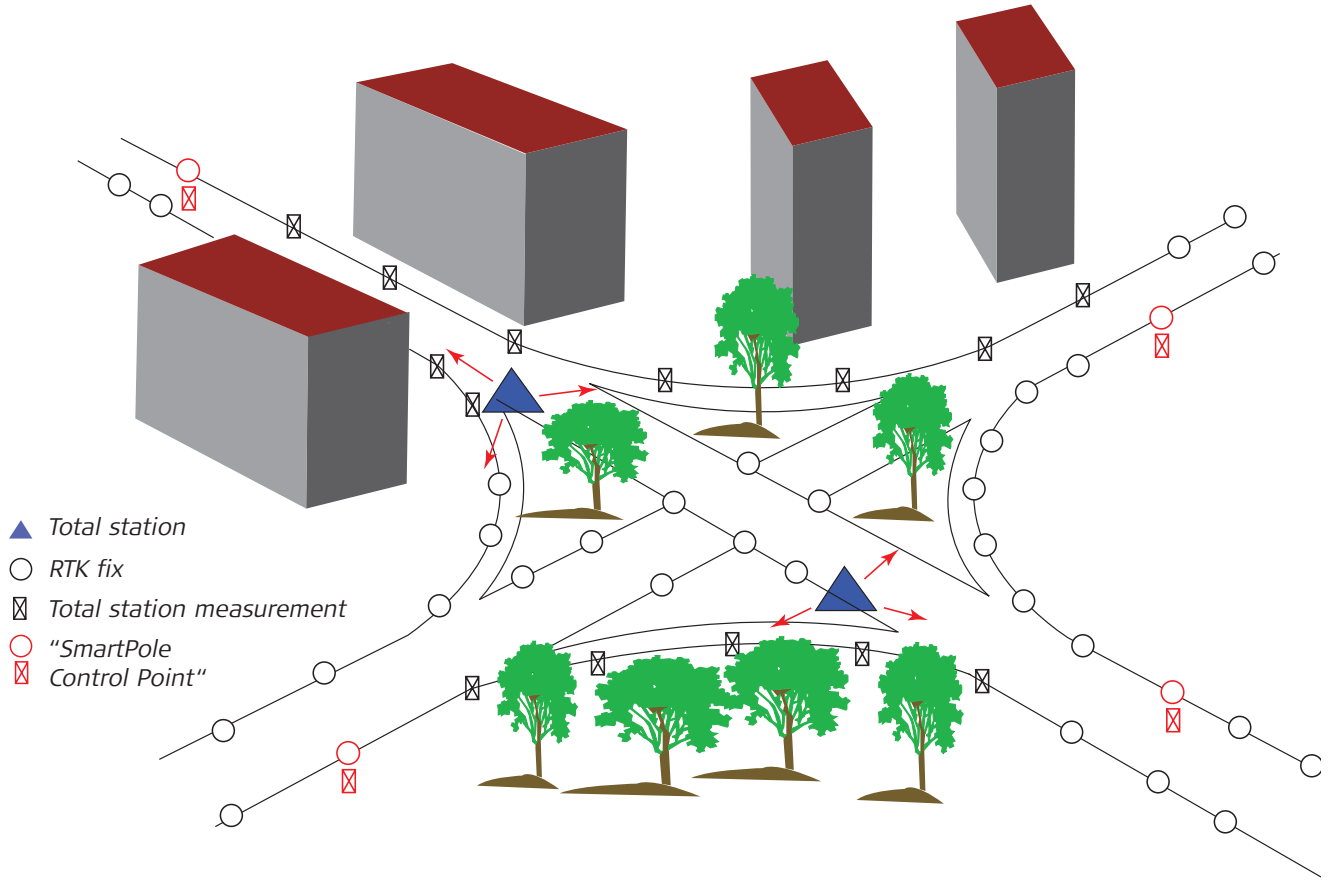
8. GNSS Positioning

GNSS stands for Global Navigation Satellite System.

Each GNSS satellite transmits on two frequencies. The signals are carrier (sine) waves on which codes are modulated.

GNSS satellites include the US GPS satellites, Russian GLONASS satellites, and also satellites from several space-based augmentation systems such as EGNOS and WAAS.

8.1 Navigation position

When a GNSS receiver of any type receives signals from 4 or more satellites, it will calculate and display its position. This is the navigation position. Uncertainties in the satellite orbits, disturbances to the signals as they pass through the ionosphere and troposphere, and other errors limit the accuracy of the navigation position to about 5m.
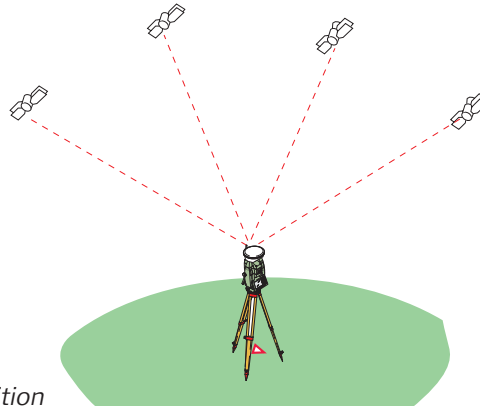
8.2 Differential GPS

The errors can be reduced and the position accuracy improved if measurements on the satellite signals are taken simultaneously at two stations and differenced (subtracted from each other). One of the receivers is set up at a known point and is termed the reference; the other receiver is set up at an unknown point and is termed the rover. The position of the rover is obtained relative to the position of the reference.

If only code measurements are used, the position accuracy will usually be about 30cm to 1m. This is termed DGPS or differential code.

If phase and code measurements are used, the position accuracy will usually be about 1cm to 5cm. This is termed differential phase.


Navigation position

8.3 RTK, differential phase

Dual frequency receivers are used for surveying. The two frequencies help to minimize error influences related to disturbances in the ionosphere.

Dual frequency receivers take phase measurements on both frequencies in addition to code measurements. The reference receiver transmits its phase and code measurements to the rover. The rover uses the phase and code measurements from the reference together with its own phase and code measurements and computes its position relative to the position of the reference receiver. With dual frequency phase and code measurements from at least 5 satellites, an RTK rover will compute its RTK (differential phase) position to an accuracy of about 1cm to 5cm.

RTK differential phase

Rover

Reference

Rover
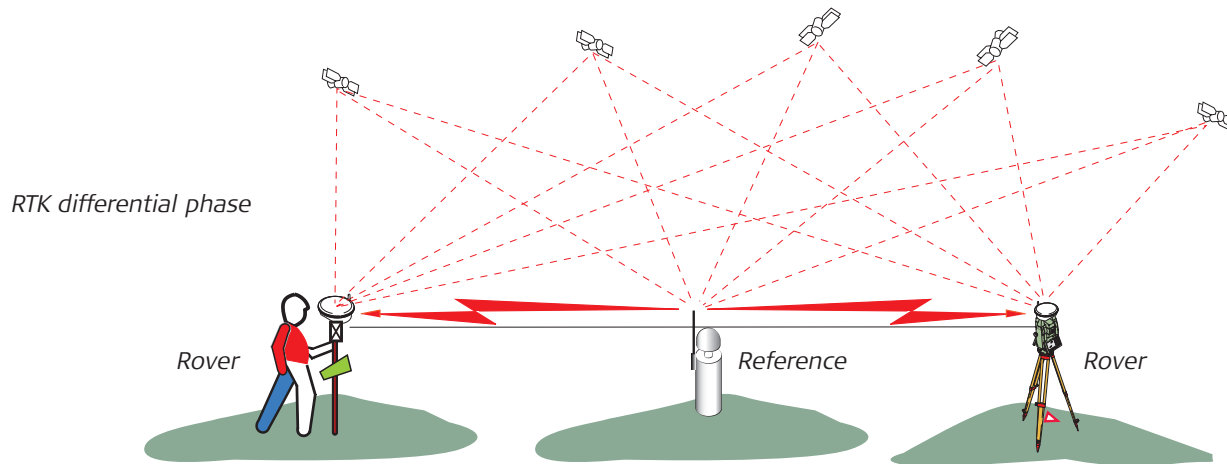
8.4 SmartCheck for total RTK reliability

SmartCheck is the Leica Geosystems RTK technique used for SmartStation and SmartPole.

SmartCheck computes at least two independent RTK fixes before the position coordinates are first available. The coordinates are then updated continuously as long as SmartStation/SmartPole receives the required phase and code data from SmartAntenna and the reference.

SmartCheck continuously computes independent position fixes in order to ensure that the coordinates are correct. This continuous process ensures the highest possible RTK reliability, 99.99% for RTK fixes at up to 30km to 50km from a reference station.

SmartCheck needs only a few seconds to compute an RTK position. The horizontal accuracy is 10mm + 1ppm. The vertical accuracy is 20mm + 1ppm.

8.5 The range of RTK

The maximum range at which an RTK rover can calculate centimeter-level accuracy positions depends on error influences related to the ionosphere, troposphere and satellite orbits. Depending on the prevailing atmospheric conditions, the range limit for RTK can vary from about 30km to 50km or more.

SmartCheck　　　*Reliability 99.99%*

Accuracy 10mm + 1ppm　　*Range about 30km to 50km*

RTK is extremely reliable and is unlikely to fail. In spite of this, the user should be aware that:

• If obstructions block some of the satellite signals, or if the distance to the reference is too long for the prevailing conditions, an RTK rover may only be able to compute a DGPS (code) position and not an RTK (phase) position.

• If the reference receiver stops working, or if the communication link between the reference and rover fails, the rover will not receive data from the reference and will only compute a navigation position.

SmartStation and SmartPole have accuracy status icons and a coordinate quality indicator. These show the type of position and the accuracy achieved.
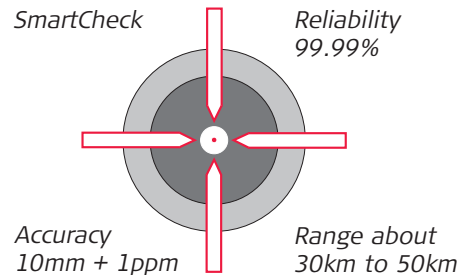
9. Before using SmartStation and/or SmartPole

SmartStation/SmartPole will probably have been configured for you so that you can start using RTK immediately.

This may have been done by your Leica representative or by your own technical support personnel.

If the equipment has not been configured for RTK, the following have to be considered:

• Reference stations,
• Communication link
• Coordinate system
• Configuration set

9.1 Reference stations

Reference stations can transmit data in various ways and in various formats. SmartStation/SmartPole has to be configured to receive the data in the transmitted format.

Depending on how the data are transmitted, it may or may not be necessary to enter the following: identification number of reference station, type of receiver at reference station, type of antenna at reference station.

GNSS reference station, Florence, Italy

9.2 Communication link

Data can be transmitted from the reference to SmartStation/SmartPole by radio, phone or Internet.

SmartStation/SmartPole has to be equipped with the appropriate communication device and configured for it. Various parameters have to be set.

9.3 Coordinate system

GPS coordinates are in the WGS84 system. This is a three dimensional Cartesian coordinate system. WGS84 coordinates are given as X, Y, Z Cartesian coordinates, or latitude, longitude and height (above the WGS84 ellipsoid).

Conventional surveying is carried out in grid coordinates: Eastings, Northings and Height (above a datum).
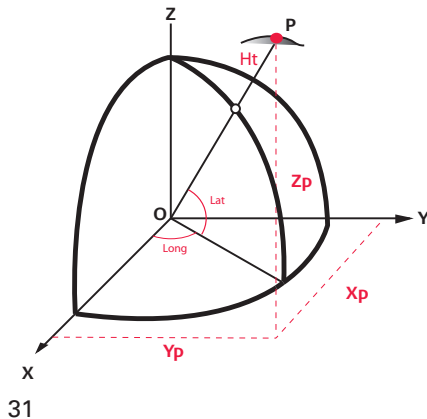
SmartStation and SmartPole use RTK to determine position. For conventional surveying, the RTK WGS84 coordinates have to be converted to the required grid coordinates.

Your technical support personnel, or possibly your Leica representative, will usually have entered a so-called coordinate system into SmartStation/ SmartPole for the area, region or even country in which you are working. The equipment uses the coordinate system to transform RTK WGS84 coordinates instantly into the required N, E, H grid coordinates.

If the required coordinate system has not been entered, you will have to determine and enter it. If you move to a new area that has a different system of grid coordinates, you will have to determine and enter a new coordinate system for that area.

See the System 1200 Technical Reference Manuals.
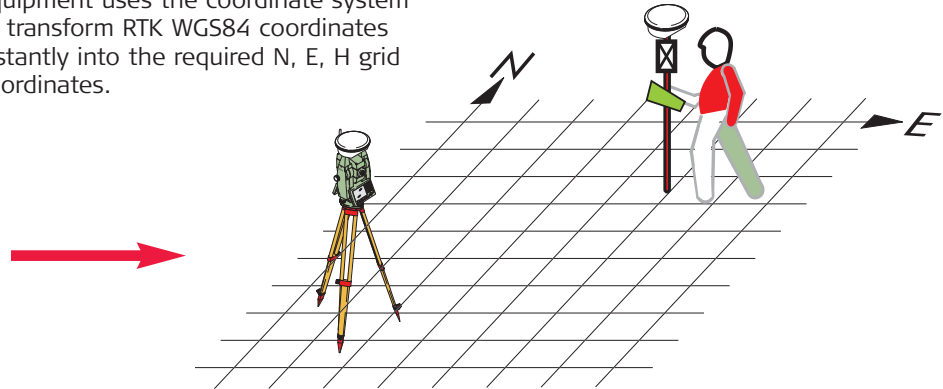
9.4 Configuration set

Different people, all over the world, use SmartStation and SmartPole in different ways and for different applications. To satisfy these requirements, SmartStation and SmartPole have many functions, options, routines and programs.

SmartStation and SmartPole can be set to work in exactly the way that the individual user wants them to work.

Your technical support personnel, or your Leica representative, will normally have defined a so-called configuration set that includes the correct settings for the reference stations (9.1) and the communication link (9.2) that you use.

The configuration set makes the equipment work and display in exactly the way that you want it to do.

If your needs change, or you have new applications, or you move to another area with different reference stations, you may have to modify the configuration set or define a new configuration set.

See the System 1200 Technical Reference Manuals.

10. What the operator needs to know about RTK

10.1 Number of satellites

Due to its ease-of-use, versatility, cm-level accuracy and high reliability, RTK has become a standard survey tool.

Provided that you set up SmartStation or SmartPole where there is a reasonably clear view of the sky and reliable communication with the reference station, determining the coordinates with RTK will usually be a matter of a few seconds only.

Although RTK is very easy to use, the SmartStation or SmartPole operator (as any other RTK rover operator) should have a basic understanding of the technique.

In order for SmartStation or SmartPole to compute its position using RTK:
• The equipment has to track at least 5 satellites.
• The reference has to track at least the same 5 satellites.
• The reference has to transmit the data to SmartStation and/or SmartPole.

The status icons in the display show the number of satellites above the cut-off angle and the number of satellites being tracked. The cut-off angle is usually set to 10° in the configuration set. With the present constellation of more than 30 GNSS satellites, there will almost always be at least 5 satellites available provided that you set up the equipment where there is a reasonably clear view of the sky. In most cases there will be more than 5 satellites.
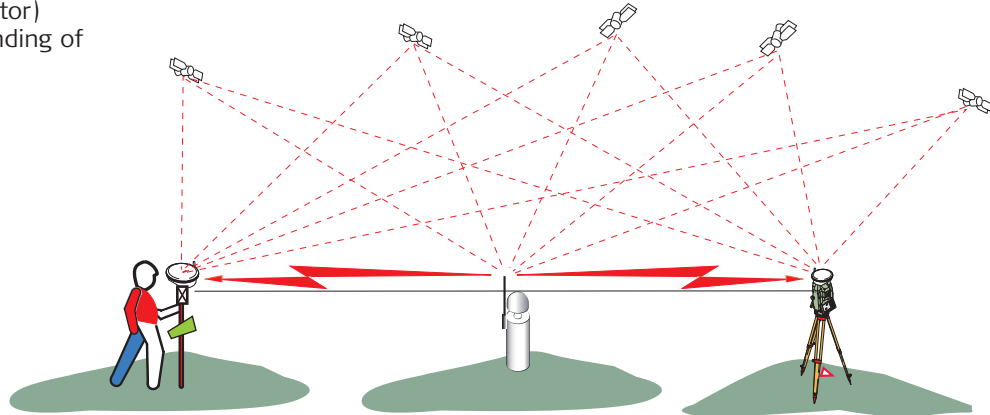
10.2 Obstructions

Buildings, large trees with heavy foliage and other obstructions can block the signals from one or more satellites. Although the signals can pass through trees with light foliage, the strength of the signals will be reduced.

Whenever possible, set up SmartStation or SmartPole in clear areas or where there are few obstructions.

When surveying in or around wooded or developed areas, it is usually impossible to avoid obstructions completely.

With experience you will soon be able to judge where you can set up the equipment and acquire sufficient satellites.
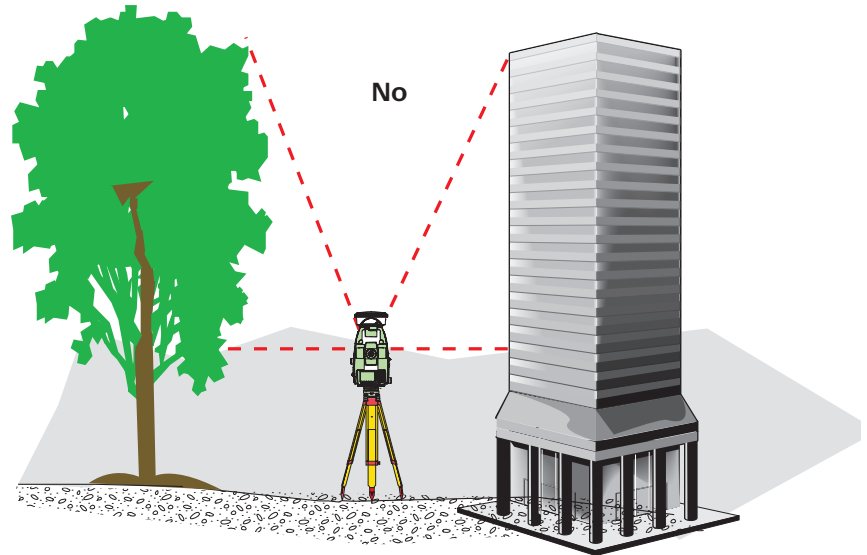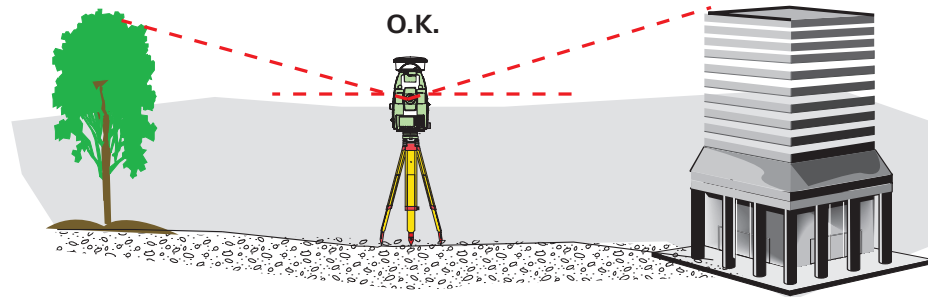
10.3 Multipath

The satellite signals reflect off buildings and similar objects.

If SmartStation or SmartPole is set up close to a tall building or next to a truck or other vehicle, the SmartAntenna may receive both direct and reflected signals. This is termed multipath.

As the SmartAntenna and the processing algorithms are designed to suppress the influence of reflected signals as much as possible, multipath will usually have little influence.

Note, however, that if a building or object has a very smooth reflective surface, multipath may be severe. In such a case, the equipment (as any other RTK rover) may take somewhat longer than usual to compute an RTK position fix.
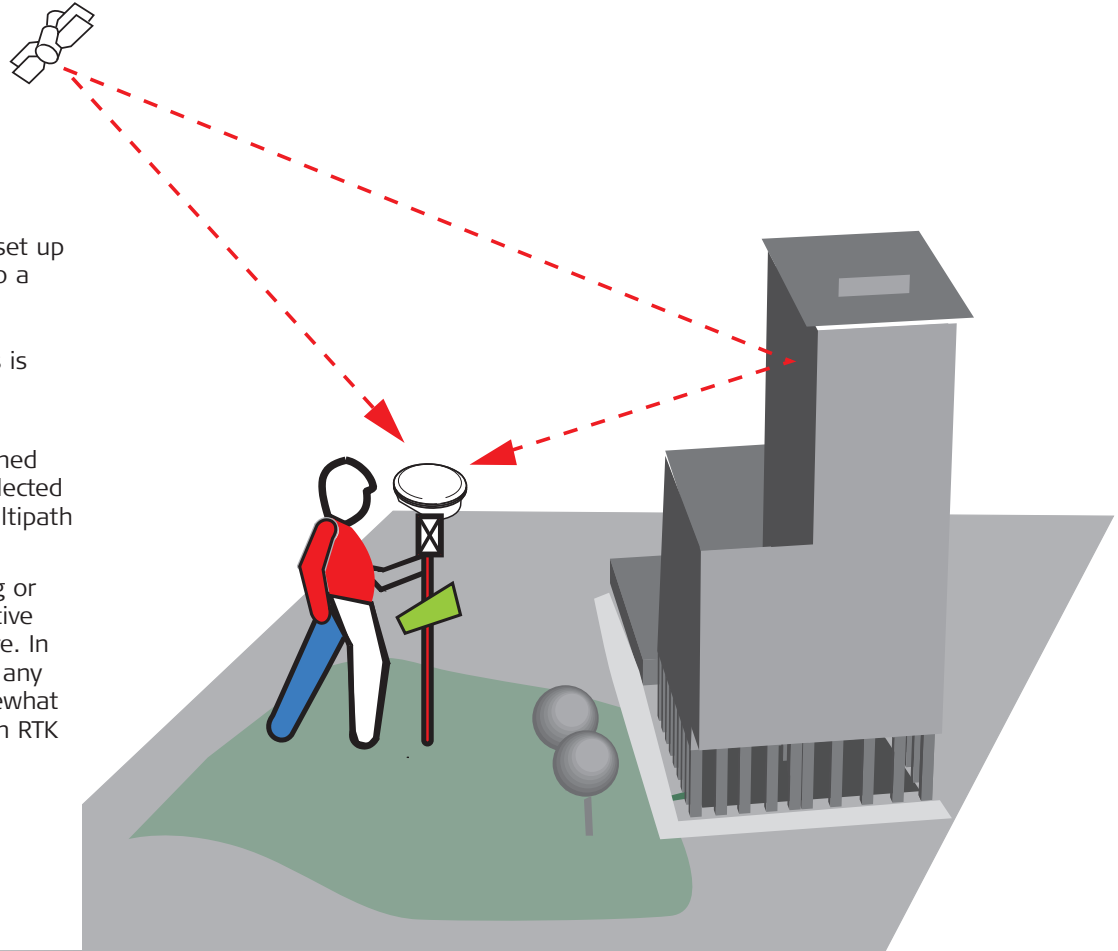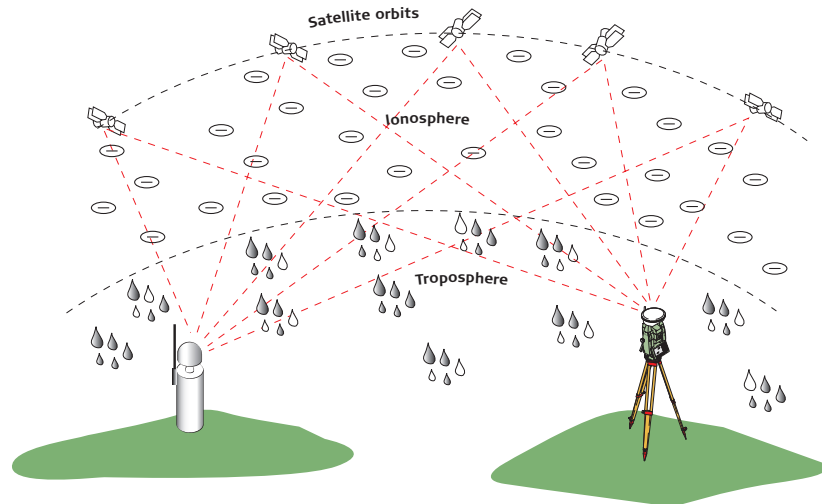
10.4 Range and accuracy of RTK

Various error influences, particularly those relating to ionospheric delays, tropospheric delays and satellite orbits, affect the satellite signals.
If the rover is close to the reference, the errors will be similar at both the rover and reference and will be largely eliminated by the differential RTK technique. The greater the distance between rover and reference, the more the errors will differ and the more diffi-cult it becomes to eliminate them. It follows that, as the distance increases, a range will be reached at which RTK can no longer determine the position to centimeter-level accuracy.

As the troposphere and ionosphere vary considerably from place to place, with the time of day, time of year, and from year to year, it is impossible to specify an exact maximum range. RTK range will often be somewhat longer during the cool of the night than during the heat of the day. RTK range also tends to be longer in mid latitudes than at low and high latitudes.

The RTK range for a moving RTK rover is usually quoted as about 30km in mid latitudes in favorable conditions. The RTK accuracy is usually given as 10mm + 1ppm. A handheld SmartPole is usually used in a moving mode.

As SmartStation is static (on a tripod), movements do not affect the data. SmartStation's RTK algorithms are optimized for static mode and will compute position fixes at about 50km from a reference station in mid latitudes in favorable conditions. The RTK accuracy of 10mm + 1ppm is maintained, even at maximum range.

10.5 Standard reference stations and networks of reference stations

10.5.1 Standard reference stations

A standard GPS reference station transmits data directly to SmartStation, SmartPole and other GPS rovers. The RTK range and accuracy quoted in 10.4 are for standard reference stations.

Standard reference station
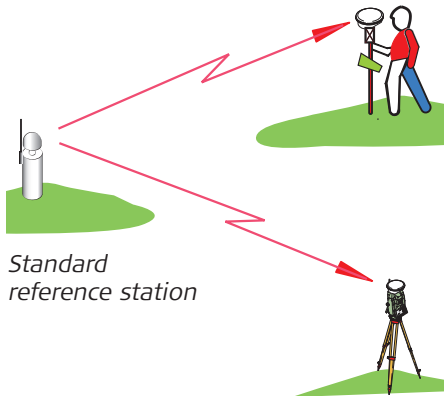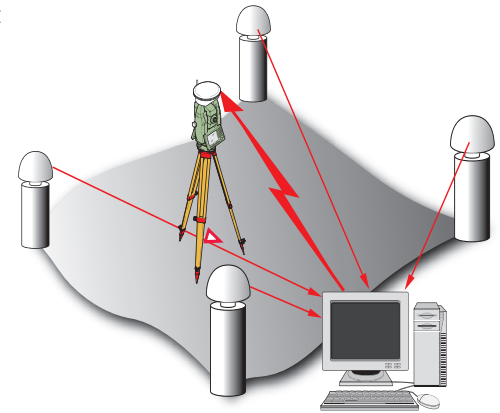
10.5.2 Networks of reference stations

If RTK could be carried out in a perfect environment, there would be no ppm accuracy component and no restriction to range. Unfortunately, however, the environment is not perfect and it also changes continuously. Various influences lead to distance-dependent errors and restrict the range at which a rover can compute an RTK position fix.

By combining reference stations into a network and continuously analyzing the data, it is possible to model the distance-dependent errors and compute corrections.

Measurement data and correction parameters, or corrected reference station measurement data, can be transmitted to the rovers. The rovers can then compute RTK position fixes at longer ranges and with higher accuracy.

10.5.3 SmartStation and SmartPole

SmartStation and SmartPole accept data from standard reference stations and from networks of reference stations. The appropriate settings have to be made in the configuration set.

Network of reference stations

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10.6 Communication between the reference and SmartStation/SmartPole

Reference stations, or control centers of networks, transmit data to RTK rovers. Radios, phones or the Internet can be used.

In order to receive the data, SmartStation and SmartPole have to be equipped with the appropriate communication device. Various settings have to be made in the configuration set.

10.6.1 Radio modems

The advantages:
• No running costs (charges).
• Any number of RTK rovers can obtain the data.
The disadvantages:
• The range at which a rover, or SmartStation or SmartPole, can operate is usually less than if phones are used.
• Obstructions, particularly at longer ranges, can cause loss of reception.
• Interference on adjacent frequencies may also lead to poor reception.

10.6.2 Phone modems

The advantages:
• Reliable connection.
• No interference.
• Little loss of reception due to obstructions.
• Few restrictions to the range at which reliable communication is possible.
The disadvantages:
• Rovers, i.e. SmartStation and SmartPole, incur call charges.

10.6.3 The Internet

The Internet is being used more and more for transmitting data from reference stations to RTK rovers.
The advantages:
• Charges should be less than with mobile phones.
• Few restrictions to range at which communication is possible.
The disadvantages:
• The reliability of connections may not always be as high as with phones.

10.7 Type of position and coordinate quality indicator

RTK is extremely reliable. Provided that SmartStation/SmartPole is configured correctly, is receiving data from the reference, and is set up in a reasonably open area, RTK is unlikely to fail. Position icons and the coordinate quality indicator show the type of position.

**RTK position
CQ quality indicator -
about 0.01m to 0.05m**

If there are 5 or more satellites, and if the distance to the reference is not too great for the prevailing atmospheric conditions, SmartStation/SmartPole will compute an RTK position. **This will be the usual case.**

The two ticks indicate that SmartCheck is computing independent position fixes to ensure that the RTK position is correct (see 8.4).

**DGPS Differential code position
CQ quality indicator -
about 0.3m to 2m**

If only 4 satellites are used, or if the distance to the reference is too great for the prevailing atmospheric conditions, SmartStation/SmartPole will compute a differential code position.

**Navigation position
CQ quality indicator -
about 3m to 20m**

If there is no communication between the reference and SmartStation/SmartPole, the communication arrow in the display will not move/blink. As no data is received from the reference, the equipment can only compute a navigation position.

A maximum value for the CQ quality control can be specified in the configuration set. If the value is exceeded, a warning appears when you try to STORE the computed coordinates.

If you set a maximum value of 0.05m for CQ, you can be sure that only centimeter level RTK position fixes will be accepted and stored.

11. SmartStation and SmartPole - new ways to survey

SmartStation and SmartPole are revolutionary tools that combine Leica GPS1200 RTK surveying with Leica TPS1200 total station surveying.

SmartStation and SmartPole are quite different and are used in different ways.

SmartStation uses RTK to determine the position of the total station directly. All survey and stakeout work is then carried out by the TPS1200 total station.

SmartPole is a GPS1200 RTK rover that also fully controls a remote TPS1200 total station. SmartPole can switch from RTK measurements to total station measurements depending on the area and the points to be measured. With SmartPole, one man controls the entire survey and stakeout process.

As RTK provides the control for SmartStation and SmartPole surveys, conventional control points and traversing are not needed.

With SmartStation or SmartPole, you can go straight to the site and start working immediately.

Both SmartStation and SmartPole are incredibly versatile:

• Survey and stakeout are faster.

• Fewer total station setups are needed.

• They can be used for any type of job.

• They save time and manpower.

• They increase productivity and profits.

• And RTK ensures uniform high accuracy throughout the entire work area.

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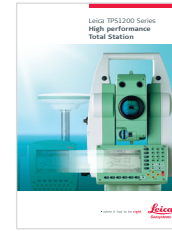
Leica SmartPole
Product brochure

Leica SmartWorx
Product brochure

Leica SmartStation
Product brochure

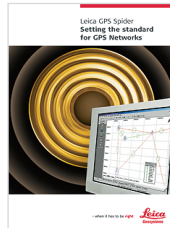**Leica GPS1200**
Product brochure

Leica TPS1200
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Leica System1200 Software
Product brochure

Leica GRX1200
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- when it has to be **right**

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