Part 6: Base Station Installation

Practical Satellite Navigation

Probably the most important step in the installation of a GPS system is mounting the GPS antenna. One should distinguish between mounting the base and the rover. The actual antenna installation has two main aspects: the mounting of the antenna on the survey platform (survey rod, tripod or object) and the position of the survey platform relative to the world. This article focuses on the installation of an RTK base station with a radio telemetry link.

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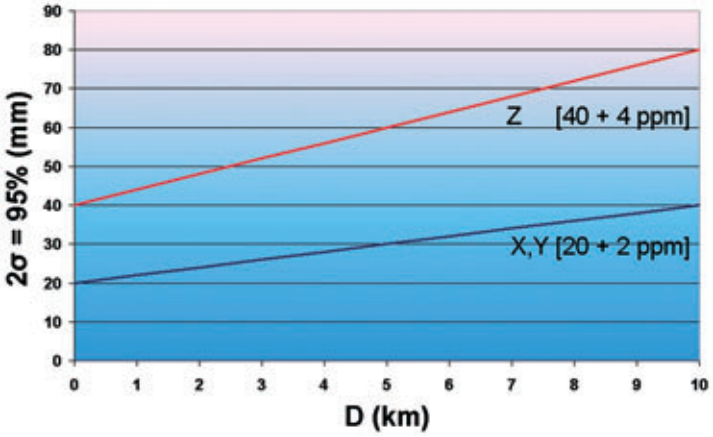


Precision (2sigma = 95%) of an RTK system in relation to the working distance.

Base Station

A complete dGPS system consists of at least one base station and one or more rovers. In the previous articles it was shown that with most code phase dGPS systems the user does not need to install his own base station while operating in the 'civilized' world or when willing to pay for correction signals.
With carrier phase dGPS the situation is different. There are some third party base stations, but these are usually not available for other users or have a limited range. Privately owned commercial RTK networks do exist in some countries but are mainly used for relatively small projects or as a back-up. For larger projects or when working in third world countries, a project-specific base station is usually installed by the survey contractor.

Installation Procedure

First it is necessary to determine whether the installation is to be permanent (days to months) or temporary (hours to days). Temporary installations are generally used for survey work prior to the design phase while permanent stations are used during the execution of construction works. In the latter case the user group usually consists not only of the survey team but of the construction equipment as well.
The following steps can be distinguished during the installation of a base station:

1 Reconnaissance;
2 Selection of a location;
3 Trials;
4 Permanent installation;
5 Determining antenna position;
6 Checking of the system.

It is of utmost importance that every step of the installation is documented. Not only can the documentation be used to convince the client of the quality of the survey, it can also serve as documentation for future projects in the same area. When executing a temporary installation, steps 1, 2 and 5 will usually be shortened considerably or skipped altogether.

Reconnaissance

This step involves searching for all objects (such as a building, or a mast) that can be used for installation based upon the construction and geographical position in relation to the project area. The following aspects need to be addressed:

- Type of object, accessibility and location relative to other objects in the immediate surrounding;
- Permissions needed for installation, operation and maintenance;
- Objects in the neighbourhood that are liable to radio interference to either the GPS or the differential signal.

Reconnaissance usually starts with the determination of potential locations based on a detailed (topographic) map. Next is the check of the most probable locations in the field. Too often the local situation differs greatly from that derived from the map.

Selection

One of the main criteria for selection is possibly the absence of objects like buildings and trees that shield the horizon from the proposed antenna location or those objects liable to create multi-path problems. The closer we can place the station to the project area, the better the precision will be since this is a function of the distance between base and rover.
Furthermore, when working over short distances (up to 2 kilometres) it is usually possible to use low power, and licence free radio signals. The higher we can place the antenna, the further the differential signal will probably reach. The single exception to this rule is when working at short distances from the base station. In this case the differential signal may 'overshoot' the survey area as a result of the beam angle of the antenna.

Stability

When installing a permanent station the stability of the object is important as well. When mounted on top of a high building or radio mast, it should be realised that these objects can sway over some centimetres or decimetres in heavy winds thus rendering the station unusable under these wind conditions. Movement of the underground can also pose a problem, especially if there is going to be (or have recently been) major construction works in the direct neighbourhood of the station. The author of this article has observed height

This temporary station is located too close to the tree line to achieve optimum results. (source: www.nmri.go.jp)

Permanent station. Potential problems with this set-up: multi-path and shifting. The first was remedied by a ground plane, the second by regular resurveys.

changes of some centimetres over a period of weeks on certain – larger - projects.

Accessibility

Finally the accessibility of the object for survey personnel and the power supply are important when selecting objects for permanent installation. When a base station goes down this may have serious implications for the entire project. The sooner it can be reached and restarted, the lower the downtime of equipment and the lower the amount of money lost. Last but not least there is the need for (building) permits to be considered when installing permanent stations.

Trials

When installing a permanent station it is often advisable to test the station before spending money on other steps. Especially with multiple users, the additional cost of a trial is generally much lower than the costs resulting from downtime of the base station. The following aspects should be monitored during a trial:

- Radio coverage of the project area;
- Prevention of multi-path.

These aspects are important for temporary stations as well but will in general be solved on a more pragmatic basis by for example moving the station or temporarily stopping the survey.

Coverage Test

Coverage tests are performed to ascertain coverage of the differential signals throughout the project area. The simplest method is going round the survey area with a handheld radio scanner. The main disadvantage of this method is that only the existence of the differential signal can be determined. A better alternative is to use a rover to log the signal strength (if possible) as well as the quality of the position determination. This should be done on various (representative) locations around the project area.

Multi-path Test

The goal of this test is to detect multi-path at the potential location of the base station. Since the GPS constellation revolves around the earth in 11 hours and 58 minutes this will also be true for multi-path errors. For a good detection of multi-path a continuous measurement of at least 2x24 hours is needed. After the data has been collected it should be examined carefully for positional errors that repeat roughly every 12 hours.

Determining Antenna Position

When the proposed location meets all previous requirements, the time has come to install the antenna permanently and determine its position. For temporary installations the antenna is usually installed directly over a geodetic control point. This way the horizontal coordinates are nearly identical to those of the control point. However we still need to determine the height of the phase centre of the antenna in relation to the control point. The latter can be done using a measuring tape or yardstick. It should be noted that the distance determined is usually the slant range between the rim of the antenna and the control point and not the vertical height. Some manufacturers can provide a survey rod, which, together with the antenna, has a length of exactly 1 or 2 meters. This greatly reduces the chance of errors in the determination of the antenna height and allows for easy correction if errors are made.

Permanent Stations

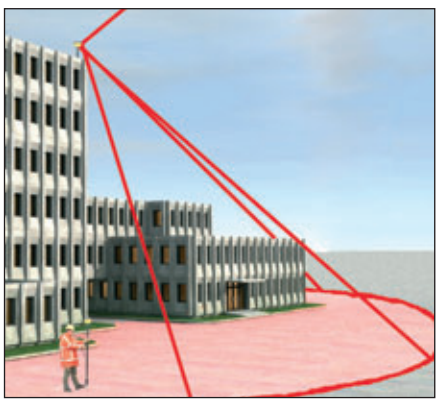
The determination of the antenna position is more difficult with permanent stations since these will rarely be installed directly over a control point. In this case the position of the phase centre of the antenna needs to be determined using other methods. The following methods are commonly used:

- Position determination using another (RTK) GPS network;
- Land survey using static GPS measurements;
- Land survey using a total station and level instrument.

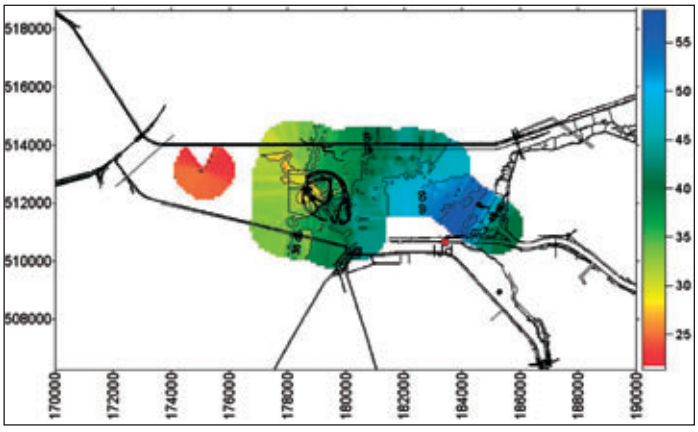
As a rule the best results are achieved using conventional land survey techniques. However, GPS based techniques have the advantage that the exact phase centre of the antenna can be determined and that no transformation to WGS84 coordinates is needed. One should realise however that when using GPS as a survey a fairly long large amount of time is needed (preferably > 12 hours) to achieve an accuracy similar to using conventional land survey techniques. When measuring for short periods of time (minutes to half an hour) it must be realized that the accuracy of the height determination is usually less than 2 to 5 centimetres. In combination with the precision of the RTK system itself this will result in height accuracies at the rover that will usually be worse than 5 to 10 centimetres.

Checking of the System

With the system up and running the base station needs to be checked for correct operation before engaging the survey. This checking can be done in various ways. The most extensive



High antenna mountings may result in deteriorated reception of differential signals. (source: www.cornucopia3d.com [adapted])



Coverage tests executed during the sanitation of Lake Ketelmeer (base station IJsseldijk – red point). Values in decibel; below 30 dB no signals are received.

check is the installation of a monitor station that continuously monitors the difference between the derived RTK position and the true position of the station. This is however an expensive solution which can only be used on construction sites where the accuracy needs to be high and/or must be proven to the client. A monitor station has to be installed with the same specifications as the base station.
For most projects however it is sufficient to perform a quick check. Usually this involves installing a rover over a control point. Then the position of the antenna is registered over a certain amount of time (usually 15 to 30 minutes). Based on the results of this check, the actual precision and reliability of the system can be determined and verified against the requirements of the job. The disadvantage of this method is that only a snapshot of the real situation is derived. It is therefore advisable to perform a similar, but shorter, check on a regular basis, for example at the start and end of a survey day.

Conclusion

Installing a (permanent) base station is a job that requires quite some knowledge and experience and is not to be thought of lightly. Using an already established station from a third party seems much easier, but one should always question the quality of this other station. In some countries like the Netherlands an independent certification service is available that will certify a GPS station installation, but this is more an exception than a rule. When no certification is available it is advisable to perform independent checks before using a third party reference station. Remember that checking is in general less expensive than downtime during construction!

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Difference between the (theoretical) phase centre and the housing of a Thales NAP2 antenna. (source: www.thales-navigation.com [adapted])