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Proposed standard for permanent GNSS reference stations in the Nordic countries

Subproject A0 of the project 'Nordic Real-time Positioning Service'

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Introduction

During the period 1990-2003 permanent reference stations for GPS have become more and more important sites in the global geodetic infrastructure. It started with the CIGNET network, which was initiated by the US Nation Geodetic Survey in the late 1980's. In 1992 the International GPS Service for Geodynamics (IGS) was formed. IGS organized a global network of permanent GPS stations delivering data for various purposes. As indicated by the name, the main object for scientific analysis was geodynamics. In order to develop GPS for this purpose a number of obstacles had to be addressed: orbital errors, atmospheric and tropospheric refraction, antenna phase center errors, global reference frames etc. Along with the scientific results from the IGS, the permanent stations forming the basis have been improved and standards developed. Today we have the IGS network with 357 stations (16 March 2003). Outside IGS there are many stations in regional or national arrays with similar high accuracy goals. In the aviation, land and marine navigation fields permanent reference stations have also become more and more important. A new application area for permanent reference stations is in climate/atmosphere monitoring, another new application area is timing applications for GPS. However these applications are considered to be outside the scope of this project (see external oscillators).

In the next few years we foresee a growth in the number of permanent reference stations for GPS and in the number of people using them. Especially interesting are the permanent RTK/DGPS reference stations that presumably will be used both for geodetic surveying and high-precision navigation applications. These stations will be reference stations producing RTK/DGPS corrections either in 'single-station mode' or by means of an RTK/DGPS networking program. In the latter case several reference stations are connected to a control center where the network corrections are computed. In both cases the corrections are then transmitted to the users by a radio link. The common types of links are dedicated radio links, satellite links, GSM or FM sub-carriers.

Many permanent reference stations will probably see an escalation of the demands on accuracy, availability and stability. A future RTK reference station that have been in operation for a couple of years may have started as a simple test station with a few users and only weak demands on the quality and accuracy of the operation. After a couple of years the same station may be supplying data to many more users, then the issues of accuracy, stability and availability of the station will become critical. This sub-project aims to introduce a standard for GPS reference stations in the Nordic countries, especially with regard to the project Nordic Real-time Positioning Service.

Classes of reference stations

This project has used geodetic accuracy to divide the set of permanent reference stations for GPS into three classes:

> Class A: very high-precision stations, IGS, EUREF stations, stations defining the national datums, stations with more than 12 months position time-serie verifying the stability of the station..
>
> Class B1 and B2: high-precision stations, e.g. RTK reference stations, local reference stations (see below).
>
> Class C: navigation reference stations

Since the JPL Dorne-Margolin design currently is the only type of antenna that is manufactured by all major GPS receiver manufacturers and has well-defined relations with most antenna types. We propose two sub-classes of RTK reference stations: B1 with Dorne-Margolin antenna and B2 with another type of antenna.

A possible scheme would be that all stations start as C stations. After the stability of the station has been verified by a time series of position estimates of length (X - to be decided), the station is promoted to a class B station and so on.

Documentation

The IGS site log is today the only widely used standard for documenting permanent GNSS reference stations (see ftp://igscb.jpl.nasa.gov/pub/station/general/sitelog_instr .txt). This standard seems to be adaptable to other types of permanent reference stations than the IGS stations.
The project therefore proposes that all permanent reference stations of class A and B1 in the Nordic area shall have IGS site logs and that these logs shall be updated regularly.

Monument environment:

Monuments and its nearby physical environment should be controlled and preserved from critical physical changes in space and time i.e. with what in Danish is called 'tinglysning'.

Monument and its environment should be monitored and controlled. Changes in the environment should be evaluated and reported to users.

The monument environment also includes radio interference/noise e.g. cellular base stations. The agencies responsible for the permanent reference station should co-operate with the government agencies responsible for protecting the radio-frequencies used for satellite navigation e.g. www.pts.se.

The horizon as seen from the antenna must be free from obstructions above 10 degrees (preferably 5 degrees). A free horizon is more important for a RTK reference station than for a very high-precision station.

If the conditions of permanent station deteriorate very much caused by factors of the physical environment or other circumstances, an alternative monument should be established and the positional information transferred via an overlapping period of at least a year (to monitor seasonal changes).

Multipath effects should be taken into account and controlled e.g. by avoiding reflecting objects (water, flat surfaces especially metal surfaces) and controlling the vegetation round the antenna..

Monument:

The monument should be stable in space and time. Deformation monitoring via local control networks or tilt measurements are especially important because deformations can otherwise be absorbed in the position time-series.

Regional footprint surveys in the vicinity of 30-50 km. More dense permanent networks (50 km-100 km) can be considered a footprint survey by itself.

Monuments should be kept as low as possible. However with regard of the North European landscape with trees everywhere and the North European inclination to avoid fences, pillars and low masts seems to be a good compromise.

The monument shape should be made with respect to symmetry and multipath (as little metal as possible under the antenna). The antenna platform should preferably be a small circular disc with a radius of 6-7 cm (see www.soest.hawaii.edu/cgps_tg).

Geology: documentation of long-term stability

Stability should be verified/documented by a time-series.

Ground water level should be monitored.

Antennas

Classes A and B1: Dorne-Margolin antenna elements (different manufacturers use different versions) and JPL designed choke-rings. The antenna part number should already be included in the IGS pcv-files (phase center variations).

Radomes

Radomes are recommended in a Nordic climate and should be restricted to the types recommended by IGS.

Antenna cables

The GPS receiver and antenna can be separated by long distances. Distances of 150-200 m can be covered with low-noise coaxial cables. Using signal amplifiers instead of low noise antenna cables is not recommended for high accuracy stations. Length and type of the antenna cable, amplifiers, signal splitters, lightning protection devices etc. shall be documented.

Receivers

Minimally dual frequencies and 12 channel L1/L2 geodetic receivers listed in the IGS receiver-antenna table. Receivers with extended capabilities like more than 12 satellites tracking, GLONASS, GPS modernisation signals (L2 and L5) and Galileo are an advantage.

The receiver must have at least 3 serial ports or built-in Ethernet (TCP/IP) and should be able to provide all data types from all ports simultaneously.

Squaring or cross-correlation L2 tracking receivers should be avoided (Trimble 4000Ssi, older TurboRogue models).

In Nordic climate it is necessary to have temperature control of the receiver environment.

Redundant receivers are important for the availability and continuity of the system. Redundant receivers are especially important for real-time class A and B1 stations.

External frequency oscillator

Co-located hydrogen masers and atomic clock's can be used as an external frequency source to the receiver. If the station is going to be used in GPS timing applications, the receiver must use the external frequency directly, not through an intermediate phase-locked loop (PLL). For GPS high-accuracy timing applications it is important that the antenna, antenna-cable and receiver are temperature-controlled.

Meteorology

Meteorological equipment at a permanent reference station is an option especially if the station is used for climate/atmospheric monitoring.

Temperature (+/- 1 degree ° C accuracy)
Barometric Pressure (+/- 0.1 mbar accuracy)
Relative humidity (+/- 1 % accuracy).
Sensors at same height (+/- 0.1 m) as reference antenna.
(from http://www.ngs.noaa.gov/CORS/).

Power and lightening protection

The permanent reference station must be supplied with UPS or at least with a power conditioner. Permanent reference stations with the intention to be used by super-conducting gravimeters must have an efficient electrical grounding system.

The permanent reference station must be supplied with a lightening protection scheme where all incoming electrical cables (power, telecommunications and antenna cables) are connected to a common ground point and are protected by lightening protection devices (see www.askskyddskonsult.se).

Lightening protection of the reference station building is optional.

Data

1 second updated GPS raw data should be standard for GPS reference stations. Optionally 0.5, 2 or 5 seconds update rates can be used.
Data files should normally be available as 1 hour or 24 hour data files. Optionally 15 minutes data files can be used, as in the LEO (low earth orbiter) project (see igscb.jpl.nasa.gov).

Data availability

Up-time +99.5% (on yearly basis) on stations with local storage on stations
Up-time +98% (on yearly basis) on stations with real-time communication to a control center.

Station security and data security

At a permanent reference station for GPS there should be limited access to antenna, receiver and communications equipment.

A permanent reference station should have a local point-of-contact and an alarm system.

Local storage of satellite raw data can provide a backup when the communication lines to the station are broken.

Real-time data on redundant communication tracks can improve the availability of raw data.

Links and information

igscb.jpl.nasa.gov	International GPS service Central Bureau
www.epncb.oma.be	EUREF Permanent Network Central Bureau
www.ngs.noaa.gov/CORS	National Geodetic Survey - Continously Operating Reference Stations
www.scign.org	Southern California Integrated GPS Network
sopac.ucsd.edu	Scripps Orbit and Permanent Array Center
www.unavco.ucar.edu	Unavco
www.soest.hawaii.edu/cgps_tg	CGS@TG working group
www.leicaatl.com	Leica Advantage Support Services
www.statkart.no/satref	SATREF
www.swepos.com	SWEPOS
www.fgi.fi/osastot/geodesia/projektit/finnref/index_eng.html	FinnRef
www.kms.dk	Kort & Matrikelstyrelsen
www.gpsnet.dk	GPSnet
www.askskyddskonsult.se	Lightening Protect