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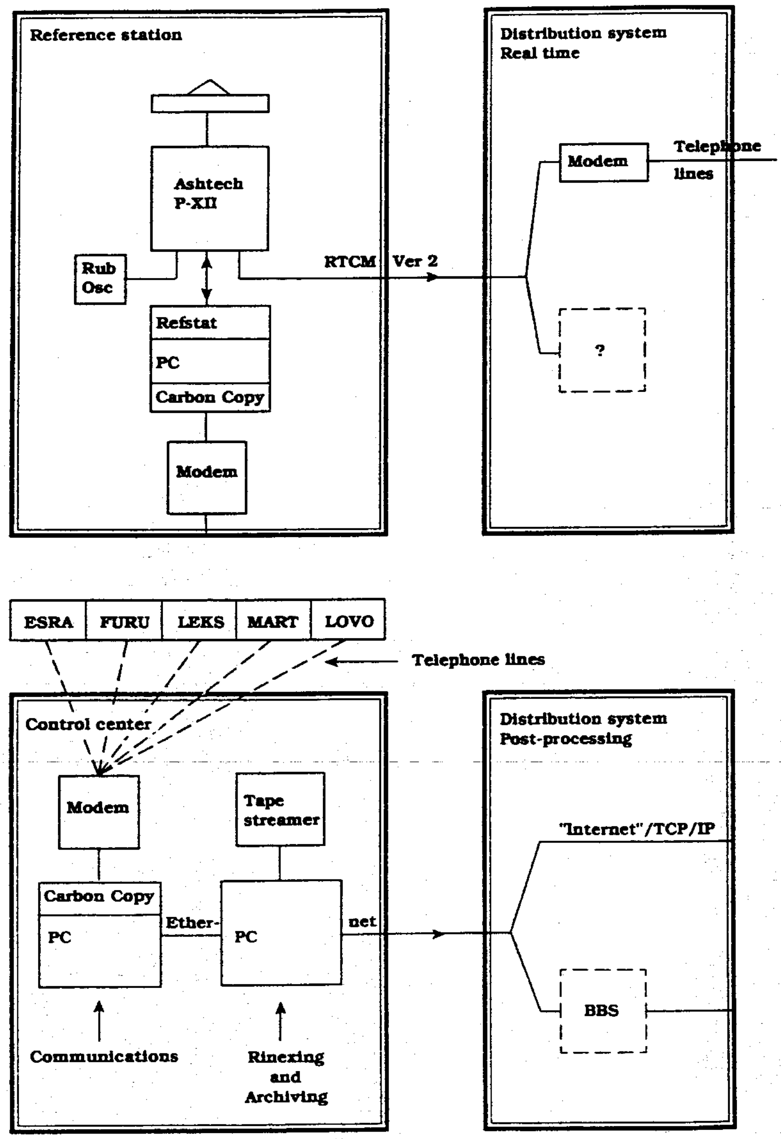
PREF - a test of a Swedish network of reference stations for positioning.

Gunnar Hedling and Bo Jonsson



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by Gunnar Hedling and Bo Jonsson

Huvudinnehåll

In "Geodesy 90", a report on the future role of geodesy in Sweden - prepared by the National Land Survey of Sweden - a sketch of a system of reference stations for GPS is made. These would have the purpose of:

- acting as high-precision control points for Swedish users - monitoring the integrity of the GPS-system
- providing differential messages for broadcasting to real time users
- acting as fiducial stations in very high-precision networks.

Six reference stations are today in operation on a test basis in order to evaluate the benefits of a national network of such stations.
In this paper the configuration of the reference station equipment and practical experiences from the operation of the stations are shown.

Application experiments using data from these stations have also been carried out. Practical results and experiences from these test are presented in this paper.

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Contents

PREF - a test of a Swedish network of reference stations for positioning.

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Key words: DGPS, GPS, reference stations

Abstract

In "Geodesy 90", a report on the future role of geodesy in Sweden - prepared by the National Land Survey of Sweden - a sketch of a system of reference stations for GPS is made. These would have the purpose of:

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Abbrevations

NLS: National Land Survey of Sweden
OSO: Onsala Space Observatory
PREF: NLS experiment with permanent reference stations for GPS
RINEX: Receiver Independent Exchange format
SWEREF, SWEPOS, SWENAV: Swedish networks of reference points for GPS

1. INTRODUCTION

The plans for a system of reference sites and permanent reference stations in Sweden presented in the report "Geodesy 90", did take big steps in it's realization during 1992, however these plans have also evolved in a somewhat different direction from what was first planned, see Hedling and Jonsson (1991).

During the autumn 1991, NLS started the projekt PREF, which is an experiment with permanent reference stations for GPS. The goals of PREF is to get experiences of the operation of permanent reference stations and to study the usefulness of reference stations data in different GPS applications: navigation, low accuracy and high accuracy positioning.

At the same time Onsala Space Observatory and the Smithsonian Astrophysical Observatory proposed a network of Swedish stations for monitoring vertical and horizontal crustal movements associated with the postglacial rebound in Fennoscandia.

The concepts in "Geodesy 90" and the proposal for monitoring crustal movements have been realized in the following three networks.

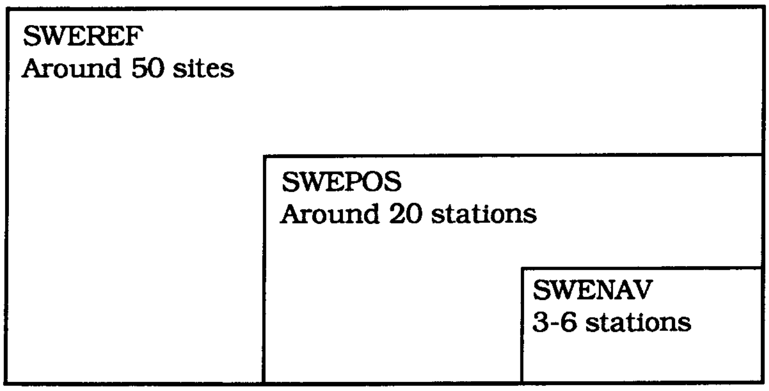

Figure 1. Relations between the SWEREF, SWEPOS and SWENAV Networks.

SWEREF consists of about 50 reference points. These will be used for connection of GPS measurements to the national triangulation and levelling networks. The distances between the SWEREF points are about 50 km. These points shall be easily accessible and may temporarily be used as GPS reference stations.

SWEPOS is a subset of SWEREF and consists of 20 points permanently equipped with GPS-receivers. The stations are monumented with concrete pillars on bedrock and are surrounded by a miniature network which is used for observing movements of the pillars. They can therefore be used both for monitoring crustal movements and for more prosaic production work, see figure 2.

SWENAV consists of 3 - 6 SWEPOS-stations and has the purpose to generate differential corrections for the whole of Sweden.

Today (January 1993) the locations for all of the SWEPOS-stations have been reconnaitred and fourteen stations are already monumented with concrete pillars. GPS-receivers are installed on six stations, see Table 1 and figure 6. In collaboration with Onsala Space Observatory additional GPS-receivers will be installed in the SWEPOS-network during 1993.

Figure 2. The reference station Furuögrund

2. PREF

The PREF project started on July 1 1991 and runs to June 30 1994. The objects of the PREF project are to:

-Acquire equipment for NLS funded GPS reference stations.

-Develop routines and computer programs necessary for running a reference stations network.

-Participate in the establishment of reference stations financed by interested parties.

-Run the established reference stations.

-Study different applications where the reference station data can be useful.

-Investigate the possibilities for establishing a network of reference stations for real time positioning with decimeter accuracy.

Six stations have already been established during the project, see table 1 and figure 6. Onsala was of course established long before the PREF project. Mårtsbo, Lovö and Leksand have been financed by NLS, Furuögrund and Esrange by interested parties.

Table 1. Reference stations in January 1993

Station	Code	Receiver	Established
Mårtsbo	MART	Ashtech P-XII	December 1991
Lovö	LOVO	Ashtech P-XII	March 1992
Furuögrund	FURU	Ashtech P-XII	June 1992
Esrange	ESRA	Ashtech P-XII	June 1992
Leksand	LEKS	Ashtech P-XII	October 1992
Onsala	ONSA	Rogue SNR-800	November 1987

The configuration of the equipment on the reference stations is described in figure 3.

A part from Onsala and Esrange all of the stations are unmanned and are steered through remote control from the control center at NLS. The Esrange Station is of course manned but is still steered from NLS. The Onsala station is controlled by OSO, the data though is available both from OSO and NLS.

A diagram of the control center at NLS and the data flow is shown in Figure 3.

2.1 Daily routines

During most of 1992, routines for the stations and the data flow was developed.

A PC-program, Refstat, that controls the GPS receiver and stores the raw data at the reference station has been developed at NLS.

The observations is normally made with 15 s interval and a 10 degree elevation mask. The daily observations is divided into four sessions with six hours each. The amount of Ashtech raw data is almost 4 Mbytes a day. During photogrammetric tests 1 s observations is taken.

The daily schedule starts automatically at midnight when the raw data that has been collected during the day is transfered from the reference stations to the control center at NLS using the file transfer module of Carbon Copy Plus, se figure 3. These transfers are made from one station at the time and takes about 40 minutes per station and day. In the morning the data is checked manually and can after that be automatically translated into RINEX and forwarded to a TCP/ IP-node.

Daily status information of the PREF-stations is available through NLS's computerized bulletin board service, LMV-BBS. In the near future we also hope to have GPS observation data in RINEX format from the PREF stations available on the BBS.

2.2 Precision measurements

Each SWEPOS site is monumented with one or two three meter high concrete pillars on bedrock. The pillars have stainless steel plates on the top. The GPS

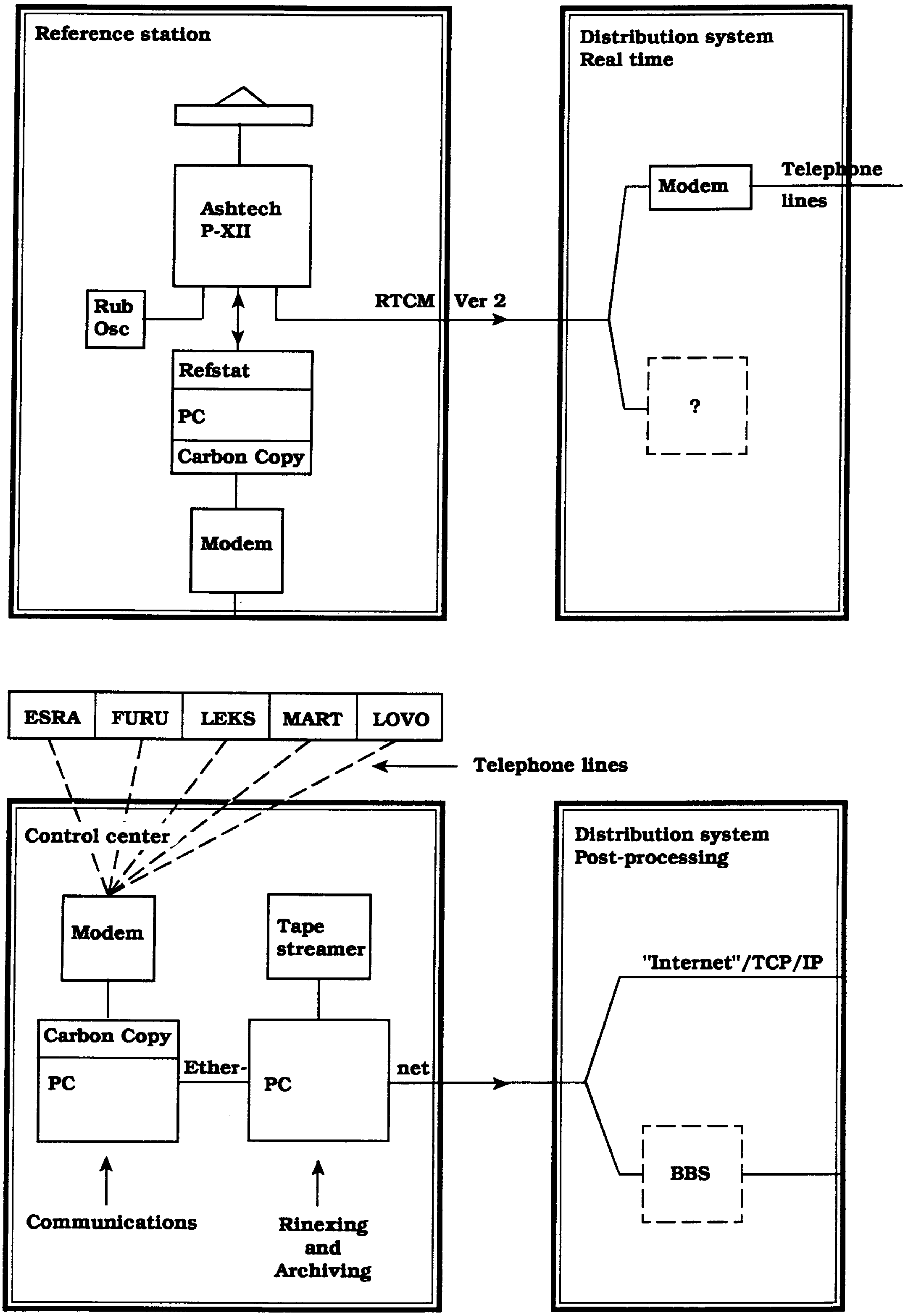

Figure 3: Diagram of a PREF station and the Control Center at NLS

antenna is fixed to the steel plate with a 3-inch conical bolt. Surrounding the pillars, at a distance of 10 m or so, is a small precision network marked with steel bolts in bedrock. These bolts may be sighted directely by a theodolite which is mounted on the steel plate instead of a GPS antenna. Before each campaign or at regular intervals a theodolite is used to measure the horizontal and vertical angles to the marks and through resection the position of the pillar can be calculated. By comparing the position of the pillar at different epochs the movement of the pillar with respect to the bedrock can be estimated.

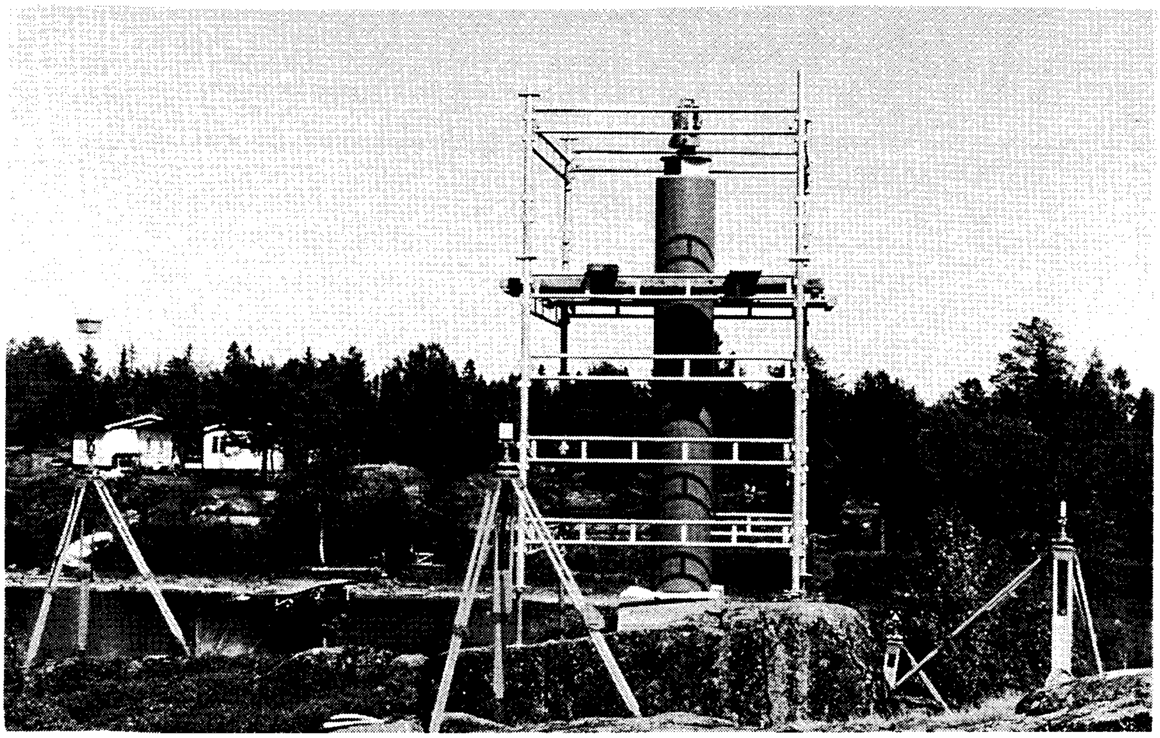

Figure 4. Measurements of the miniature network at the SWEPOS site in Umeå

3. APPLICATIONS

Studies of crustal dynamics is an application to which the data from the GPS reference stations can be used. PREF observations was used for geodynamical applications during the IGS campaign, see bellow.

In most applications a remote (or mobile) GPS receiver is used. To obtain the advantages of relative GPS the observations of the remote receiver have to be corrected by data from a reference stations. This exchange of data can be done after field work in a post processing program or it can be done in the field in a real time system. Curiously the post processing technique has been very difficult to implement for the simple C/A-code-based receivers that have become very common. This seems to be because of incompatibilities of the data formats between different receiver manufacturers. Combinations of GPS data for this kind of receiver is most easily done in real time by using the RTCM SC-104 ver. 2 dataformat. This format works well with most GPS-receivers.

NLS has therefore connected ordinary modems to the differential corrections output ports on the Ashtech receivers. These modems with correction data can be called up via ordinary telephone lines or by cellular telephones and thus form a simple distributionssystem for the corrections. So far several GPS users in Sweden, who have wanted to test DGPS, have used this system. At NLS cellular telephones have been used both in tests of DGPS for cadastral surveying and photogrammetry.

The more expensive surveying instruments based on carrier-phase observations; Leica, Ashtech and Trimble 4000, usually have more regular data formats and always support the RINEX-format (Gurtner et al., 1989). Combining this kind of instrument with reference station data in a post-processing system is not a big problem today.

3.1 IGS

The International GPS Service Test Campaign took place, June 21 - September 22, later it was prolonged to October 31 1992. During IGS, compressed RINEX-data from the PREF-stations, Mårtsbo, Lovö, Furuögrund and Esrange, which were fiducial stations in the campaign, was forwarded by NLS via Internet to OSO where the data was available via anonymous FTP during the whole campaign. Onsala who was a core station during the IGS campaign also acted as a regional data and analysis center for the Swedish stations during the campaign.

During a short period of IGS, October 6-9, Onsala, Lovö and Mårtsbo were equipped with both Rogue and Ashtech P-code receivers. The purpose of this short instrument test was to compare Ashtech P-code receivers with the TurboRogue receiver. These measurements also gave an excellent check of the measurements of the same baselines during the Epoch 92 period, July 27 - August 9. Preliminary results for the baseline Mårtsbo-Onsala (470 km) are given in figure 5 (Johansson et al., 1992). In figure 5 it can be seen that the two epochs agree very well even if the Epoch 92 measurements were made with mixed receivers Rogue/Ashtech whereas the October measurements so far only have been computed as Ashtech/Ashtech and Rogue/Rogue.

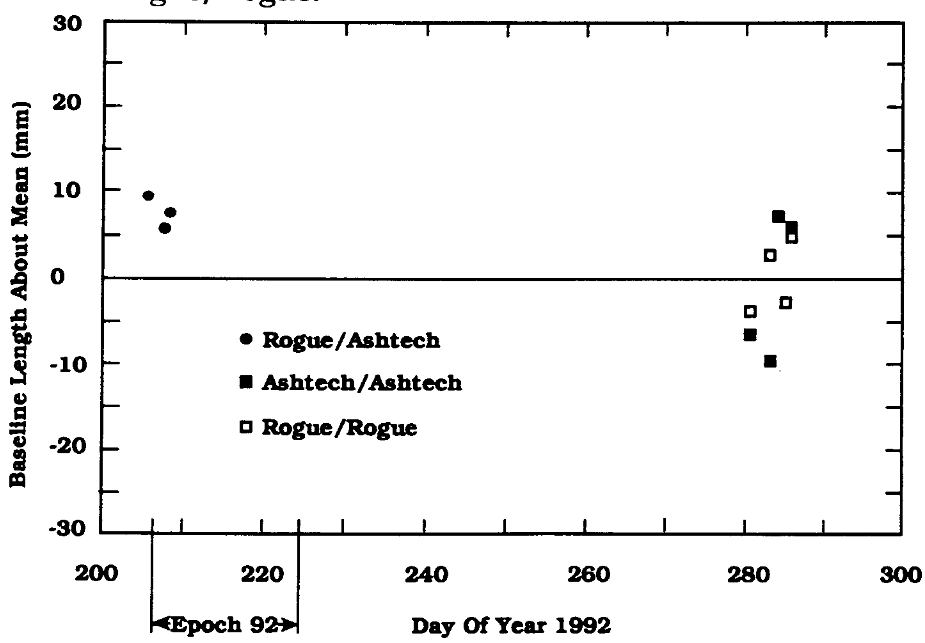

Figure 5. Daily Estimates of the baseline lenght from Onsala to Mårtsbo (from Johansson et al., 1992)

3.2 Other campaigns

Other campaigns which have used the PREF stations are SWET-92 17/8-26/8, 1992 and EUREF-BAL 28/8-4/9, 1992.

The purpose of SWET-92 was to measure a west-east GPS height profile from Bergen in Western Norway to the eastern part of Finland, with an interstation distance of about 50 km. The results will be used to check the Scandinavian geoid model NKG 89 (Forsberg,(1990)).

EUREF-BAL is an extension of EUREF-89 to the Baltic countries.

3.3 Cadastral surveying

A very important application for the reference stations is in cadastral surveying. In the less densely populated parts of Sweden, which by the way is the main part, the connection of cadastral surveys to the national control network is often accomplished through approximate connections in ortophoto maps or land-use maps. This makes these measurements inappropriate to use in the geographical databases that are under construction at NLS and elsewhere today. GPS measurements to reference stations is thought to be the most cost-effective way to connect these cadastral surveys to the national control network in areas with no control network.

At NLS a sub-project to PREF is studying applications of GPS for cadastral surveying.

3.4 Positioning

The purpose of the SWEPOS Network is to provide reference stations data continously for as many applications as possible, both carrier phase observations and pseudorange corrections, in real time and for post-processsing.

During autumn 1992 some experiments using data from reference stations have been carried out by GPS-users:

- The Swedish University of Agricultural Sciences have been working with test spots in forest. To position the test spots they have used post-processing of carrier smoothed pseudoranges.

- SKANSKA/Swedish Building Trade Research Foundation: Post-processing of carrier phase observations for positioning of drill-holes for geotechnical investigations.

4. OTHER DGPS NETWORKS IN SWEDEN

The National Maritime Administration established their first DGPS station on Almagrundet in March 1991, the distribution of the correction data is via radiobeacon. Since then DGPS stations have been established on Kullen and on Hoburg (Gotland). The stations are sending corrections through radiobeacons, according to the specifications developed by IALA (International Association of

Lighthouse Authorities). A network of seven stations is planned to be operational in 1996.

The board of Civil Aviation is doing experiments with a GPS reference station at Gothenburg-Landvetter International Airport, see Nilsson (1992).

5. THE FUTURE

An important question about the last object of the PREF project remains, namely to investigate the possibilities for establishing a network of reference stations for positioning with decimeter accuracy. Can this be done in real time or do we have to rely on a post processing system? We are therefore very interested in the proposed revisions to the RTCM SC-104 standard (see Gloeckler et al.,1992) which maybe can make a standardized real time system with decimeter accuracy possible.

That this task is achievable with a proprietary solution has been proved to us by Ashtech's VPDGPS program (Qin et al., 1992). This program has been used together with data taken at a photogrammetric test at NLS in August last year. The results are very promising.

In collaboration with OSO the SWEPOS Network will be equipped with additional GPS-receivers during 1993.

6. CONCLUDING REMARKS

Experiments show that it is possible to obtain a positioning accuracy on the decimeter level with the SWEPOS distribution of reference stations for GPS. One limitation is the local connection to the existing triangulation network.

The distribution of pseudorange corrections and in the near future carrier phase data is a major bottle-neck today. We have not yet found an existing distribution system at a reasonable cost, that can satisfy our requirements.

The practical experiences gained in the operation of the present network of six reference stations will be very valuable for the design of a twenty stations network.

Additional reference stations will be established during 1993 in collaboration with Onsala Space Observatory. Our goal is to have the SWEPOS network operational for carrier phase postprocessing applications during 1996 and for real time carrier phase applications at the latest in 1999. We expect a decision in January 1994 about the financing of an operational SWEPOS network.

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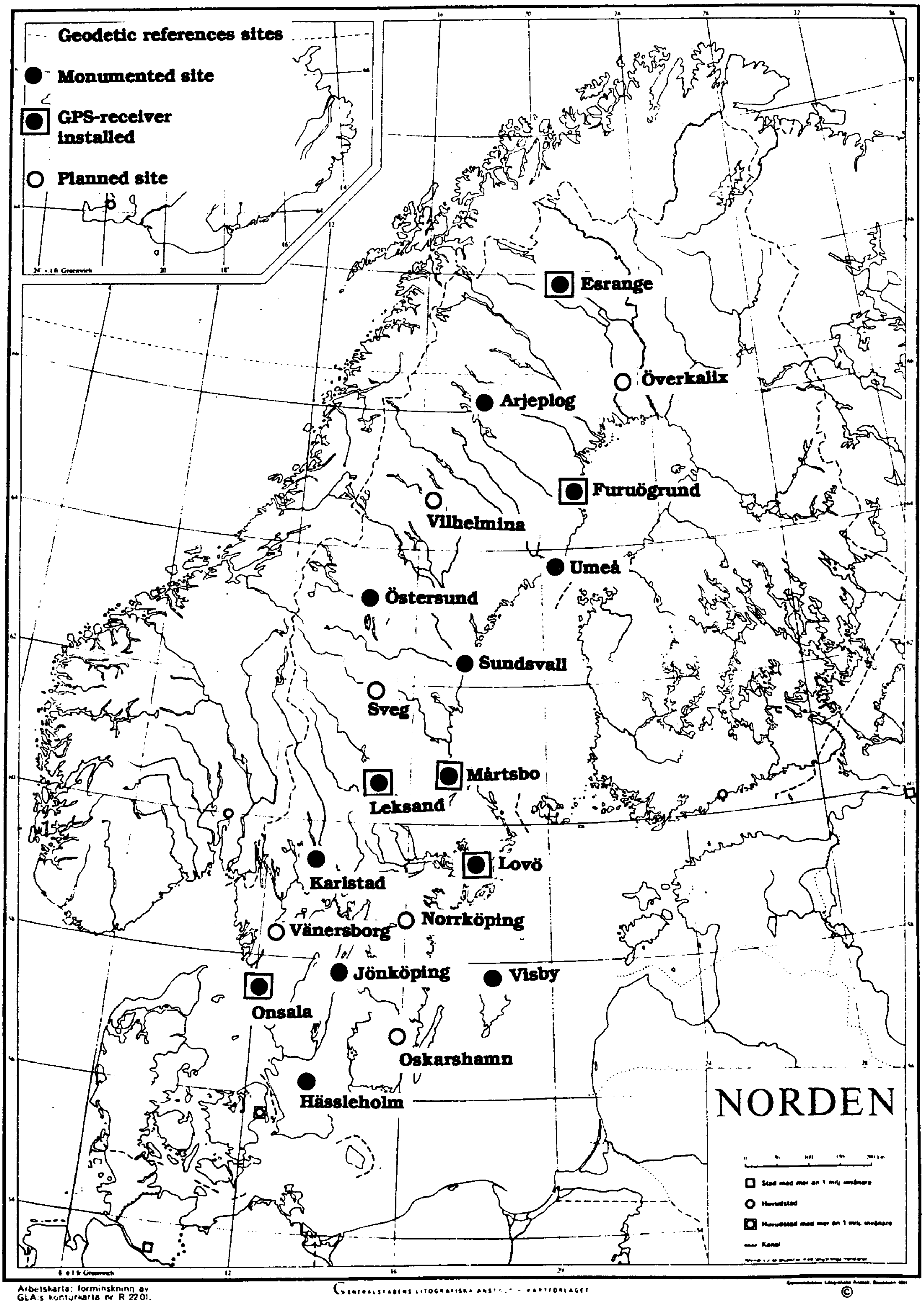

Figure 6. SWEPOS - a Swedish network of reference sites for GPS (Jan 1993)