National Report of Finland

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1 National realizations of the ETRS89 and the EVRS

The Finnish Geodetic Institute (FGI) and National Land Survey of Finland (NLS) are responsible for creating and maintaining national reference frames in Finland. EUREF-FIN is the national realization of the ETRS89. The first order network (E1), including 12 FinnRef® stations and 100 other benchmarks, was measured 1996–97. It defines the EUREF-FIN reference frame.

The national realization of the ERVS, N2000, was realized in Nordic and European cooperation in the framework of the Baltic Levelling Ring (BLR2000). The work with the BLR2000 was coordinated by the Nordic Geodetic Commission (NKG) and supported by the IAG Reference Frame Sub-Commission for Europe (EUREF) and the countries around the Baltic. The datum of the N2000 derives from the NAP (Normaal Amsterdams Peil) through the adjustment of the BLR2000. As in the BLR2000, the land uplift model NKG2005LU was used to reduce all the observations to the epoch 2000.0. The N2000 complies with the definitions (2007) of the European Vertical Reference System (EVRS). The NKG2005LU and the epoch 2000.0 were subsequently adopted by EUREF for the North European part of the most recent pan-European realization of the EVRS, the EVRF2007. Consequently, the differences between the N2000 and the EVRF2007 are small, less than one centimetre.

In Finland, there is no binding legislation on geodetic systems: in principle, government institutions and municipalities are free to choose the reference frame that they deem to be the most suitable for their use. This has led to a situation where e.g. municipalities have either stayed at one of the old national reference frames or created their own local reference frame that is loosely connected to one of the nationwide reference frames.

In order to harmonize the frames used, the FGI with the NLS have prepared a set of recommendations for public administration that promote the use of the EUREF-FIN and the N2000. Now also the INSPIRE directive of the European Commission requires local authorities to make their geospatial data available in these systems.

EUREF-FIN was introduced a decade ago. Several governmental authorities have already changed to EUREF-FIN, and as an example national topographic maps have been printed in ETRS-TM35FIN (UTM projection of EUREF-FIN) for a couple of years now. NLS took EUREF-FIN into use in 2010. However, within local authorities the change has been slower: only recently cities and municipalities started to change over to EUREF-FIN but this is now progressing. The main driving forces seem to be the INSPIRE directive, the increasing data exchange and also the fact that the old reference frames do not fulfil the present requirements anymore.

The N2000 height system was introduced in 2007. The densification of the levelling network and re-levellings of some old levelling lines were continued. Adjustments of the 2nd order levelling lines into the new height system have been finished but adjustments of 3rd order levelling lines are still on-going. The adoption of N2000 is in progress. Government institutions started to apply the N2000 in their work in 2008. However, only a few municipalities have changed their system so far but it seems that several more will do it already in the near future. One of the incentives is that the post-glacial rebound (PGR) complicates the relation of old municipal height systems to the national system. If the epoch difference is large enough, this relation cannot always be described by an offset: even tilt parameters may be needed. The first step in the implementation of the N2000 was to produce an accurate transformation from the N60 height system to the N2000, covering the country in detail including areas where the heights were derived from lower-order levelling lines. This transformation was realized 2008–2009 by the NLS. It is based on a triangulation network formed by a selection of first and second order levelling benchmarks. Such a triangle-wise transformation is capable of correcting local distortions caused by e.g. incomplete accounting for the PGR in earlier lower-order levelling.

2 Permanent reference station network, FinnRef

The Finnish permanent GPS network FinnRef® consists of 13 stations. The network is maintained by the FGI and it is the basis of the national ETRS89 realization. It is also the link to the international reference frames through one IGS station (Metsähovi) and four EPN stations (Metsähovi, Vaasa, Joensuu, Sodankylä). All data from FinnRef® stations is transferred via broadband Internet connections (ADSL) hourly or in real time. Four FinnRef® EPN stations provide real time data stream to EUREF-IP service.

The stations are also monitored independently from GNSS with precision tacheometry and precise levelling. The stability of the antenna platforms is controlled by tacheometer measurements that are repeated every 2–3 years. Recently we have also started to use precise levelling for controlling the height of the GPS antenna with respect to reference benchmarks. In 2010 control measurements were made at four stations.

Time series of FinnRef® network have essential role in geodynamical studies, e.g. for determination of Glacial Isostatic Adjustment (GIA). Since changes in instrumentation, especially change of antennas or radomes have been shown to cause jumps in time series, FinnRef® stations have been kept unchanged since the beginning.

Unfortunately, the GPS antenna of METS (AOAD/M_B), that had been kept untouched since 1992, was broken down during the summer 2010. The antenna on top of the 20 m high steel grid mast is stabilized with a special invar wire construction which eliminates the thermal expansion of the mast (Fig. 1). The broken antenna was replaced with an individually calibrated AOAD/M_T antenna that was directed to true North. To ensure the exact relocation of the new antenna to the stabilization system we measured the tie between antenna and the ground markers with tacheometer before and after the change.

In order to get more precise height difference between the antenna ARP and the ground markers we applied the space intersection technique with a pair of TC2003 tacheometers, prisms and a calibrated carbon fibre measurement rod (Fig. 2). From the measurements, the standard deviation of the height differences between the target points on the bottom of the GPS antenna and the ground markers was 0.4 mm. The measurements were repeated after the antenna change, and the height difference between the old and the new ARP were calculated. The aim of the measurements was to verify that the invar stabilization system remains unchanged during the antenna change. Our results were consistent with the height difference determined from physical antenna elements and thus confirm that the stabilization system was successfully preserved during the antenna change.

The antenna change causes a jump to time series if type calibration values of the new antenna model are used. However, this offset can be greatly reduced by using the individual calibration values of the antenna that are available in the latest EPN antenna file in Antex format.

Fig. 1. The antenna on top of the 20 m high steel grid mast is stabilized with a special invar wire construction which eliminates the thermal expansion of the mast**.** Photo: Hannu Koivula

Fig. 2. Local tie measurements of METS GPS station with space intersection technique. Photo: Hannu Koivula

3 Metsähovi fundamental station

The Metsähovi Geodetic Observatory was founded in 1978 and it has through the years become an essential part of the activities of the FGI. The instrumentation covers the satellite laser ranging (SLR), geodetic VLBI, GPS and GLONASS receivers, DORIS beacon, superconducting gravimeter and seismometer. In addition the national gravity reference station and the fundamental benchmark of N2000 height system are located in Metsähovi. Due to its versatile set of instruments, it can be called a Fundamental Station in the global geodetic network.

As a co-operation project with the Metsähovi Radio Research Station of the Aalto University (formerly Helsinki University of Technology), geodetic VLBI observations started in 2005 were continued in 2011. Metsähovi participated in seven geo-VLBI campaigns (IVS and EUROPE). These campaigns are carried out for terrestrial reference frame definition. The observation data have been transferred to the Bonn correlation centre. The IVS Data Centres, located in Germany, France and USA store the correlated data.

Recently, the FGI has started to analyze the geodetic VLBI observation sessions by using the VieVS software developed at Vienna University of Technology. The comparative analysis of the EUROPE and IVS-T2 geodetic VLBI sessions of 2002–2009 was performed. In this analysis the interest was to understand the influence of network configuration on the estimated parameters and, also, how much the results of these two campaigns are consistent.

The old Metsähovi Satellite Laser Ranging (SLR) system was discontinued in 2006. A decision was made to purchase a modern kilohertz laser and a contract was signed with the High Q Laser Production GmbH of Austria. The laser ordered is a diode-pumped Nd:VAN solid state laser with a pulse rate up to 2 kHz and the pulse energy > 0.5 mJ. The laser is of the same type that e.g. the Graz and Herstmonceux stations are currently using.

At the same time, a major renovation of the 1 m Cassegrain-Mangin telescope was needed. It includes the replacement of the drive and control system as well as separation of outgoing and incoming signals. A new encoder has been installed to the azimuth ring. The new optical solution for separating outgoing and incoming beam has been developed together with the University of Latvia in Riga and installing of the new system will start in the near future.

Parallel to that, work on new 2 kHz operational software is ongoing. It is tailored to our new equipment and is currently capable of dealing with 2 kHz observations frequency. Improvement in the filtering of residuals, automation in the range gate setting, time bias estimation and management as well as smart session planning is implemented. Laser control as well as telescope communication and steering are under development.

The Metsähovi GPS station (METS) continued as a part of the Finnish permanent GPS network FinnRef®. Data were submitted to the computations of the European Permanent GNSS Network (EPN) as well as to the IGS and JPL networks. Also, data from Javad/Legacy GPS/ GLONASS receiver (METZ) were submitted to the GLONASS data centre of the IAG.

4 Local tie between VLBI and GPS at Metsähovi

The local ties between the co-located instruments in Metsähovi have been measured with tacheometers in 1997 and 2004. However, the radome over the radio telescope blocks the visibility to the telescope and makes the precise definition of the geometric centre of radio telescope challenging.

The work on improved local ties, especially for VLBI, was started in 2007. Altogether seven new concrete pillars with a steel antenna platform were built outside the VLBI radome and around the GPS mast. The concrete pillars, fixed tripods and some additional ground points inside the radome form the frame for VLBI local tie measurements. This network was levelled and measured with tacheometer and GPS, and adjusted as a combined network.

The local tie between the IGS station METS and the reference point of the radio telescope antenna was performed with terrestrial and GPS measurements. The reference point of a VLBI antenna is defined as the point to which VLBI observations refer. It is the intersection of the primary axis (azimuth axis) of the telescope with the shortest vector between the primary axis and the secondary axis (the elevation axis). Because there are no physical markers, we have applied an indirect method to determine the reference point.

The first method was to measure positions of targets fixed on the solid structure of the radio telescope with the space intersection technique when the telescope is turned into different positions. This was done using two TC2003 tacheometers. In the second method we carried out static GPS observations with two Ashtech Dorne Margolin type GPS antennas attached to the opposite edges of the radio telescope dish. A total of 110 two-hour sessions in pre-planned VLBI antenna positions were used to determine the VLBI reference point with respect to the GPS station METS.

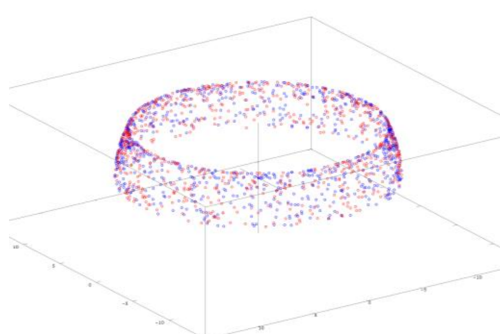

Fig. 3. Geometry of the GPS observations (derived from GPS antennas attached to VLBI telescope).

The methods consume a lot of telescope time. We were able to get nine days for the GPS measurement. Tacheometry observations were taken at times when weather prevented radio astronomical observations. To overcome the schedule problems, we decided to test kinematic GPS during a geo-VLBI campaign. The first tests were carried out in November 2008. The method along with a new mathematical model developed in 2009 turned out to be promising. The reference point, axis offset and the orientation of the radio telescope antenna were computed. The computation model is suitable for sparse and scattered data as well, not only for data taken in pre-planned circular motion of the antenna.

Comparisons show that the precision achieved with the kinematic GPS method was better than with the static GPS. This is due to the fact that the static GPS measurements, even over the nine day observation period, give considerably less points than a kinematic GPS solution during a 24-hour geo-VLBI session. The quality of the coordinates of one position of the antenna from static observations was slightly better but not enough to compensate for fewer points. An additional advantage of the kinematic method is that the normal use of the telescope is not interrupted and the tie can be measured simultaneously during a VLBI session.

Our tests show that it is possible to achieve a millimetre level accuracy in local-tie vector determination with the kinematic GPS method. We have used the kinematic GPS method during 14 geo-VLBI campaigns in 2008–2010 and continue using it during the geo-VLBI campaigns.

5 Renovation of the First Order Gravity Net (FOGN)

With the First Order Gravity Net (FOGN) of Finland, the FGI provides users with precise reference values for practical relative gravimetry. The FOGN consists of 50 stations in easily accessible outdoor locations, mostly in permanent monumental buildings like churches, and covers all Finland. The FOGN was first measured in 1962-63 and checked in 1988. The published system of reference gravity values has been maintained stable since 1971. It has epoch 1963.0 and the tidal system is mean-tide from the original IGSN71 reference. Thus the results of gravity surveys undertaken by various agencies over the years are all in this epoch and tidal system. They can be consistently transformed to any epoch and to the zero tidal system for, say, geoid computations.

The renovation of the FOGN started in 2009. The old sites are retained and a few additional sites measured to fill gaps especially in Lapland. The outdoor absolute gravimeter A10-020 of IGiK (Institute of Geodesy and Cartography, Warsaw, Poland) was used, operated by M. Sekowski of IGiK.

The work with the A10-020 was performed 2009–2010 (Figs. 5–6). Altogether 51 field stations at 47 sites were occupied, all in two independent setups in opposite azimuths. From the difference of the setups the repeatability of their mean is better than 4 μGal. Maximally two stations could be observed in one day. As a control, 9 Finnish absolute gravity stations were occupied with the A10-020 altogether 25 times. From preliminary computations, the offset of the A10-020 relative to the FG5-221 absolute gravimeter of the FGI was negligible and the rms difference was 3 μGal. The length and frequency standards of the A10-020 were calibrated before and after the surveys at MIKES (Finnish Centre for Metrology and Accreditation).

The work at a station is not complete with just the A10 measurement done. A separate support expedition measures the vertical gradient of gravity, performs relative-gravity ties when the FOGN and A10 stations are not identical, does levelling to a bench mark, determines coordinates using RTK-GPS and tacheometer, and documents the station in photos and sketches. Around one day per absolute station is needed for these supporting measurements, slightly more or slightly less depending on the amount of relative gravimetry needed and on the levelling distance to the nearest bench mark. The supporting measurements were completed in 2011.

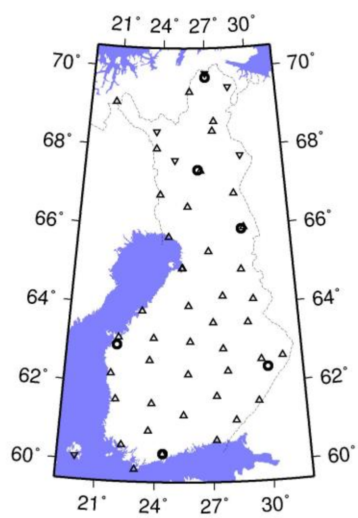

Fig. 4. Sites occupied with the A10-020 in 2009–2010. Triangles pointing up show old FOGN sites, triangles pointing down show new FOGN sites, and open circles show laboratory-type sites for comparison with FG5-221 measurements.

Fig. 5. The A10-020 at the station Turku Vartiovuori. Note the transportable benches and weights to mount the tent on stairs. Photo: Jaakko Mäkinen

Most FOGN stations are on massive stairs. The stairs cause a markedly non-constant vertical gradient of gravity. The users that visit the FOGN sites have relative gravimeters with different sensor heights and mount them on tripods of their own choice. Therefore the gradient measurements are performed using three levels, and the final gravity value will be published as a (non-linear) function $g = g(z)$ of elevation z above station.

The gravity values of the 35000 stations in the National Gravity Net of the FGI will be recomputed with reference to the new FOGN values.

6 National Standards Laboratory

The Finnish Geodetic Institute is a National Standards Laboratory for two quantities, acceleration of free fall and length. The metrological research and measurements include measurements at the Nummela Standard Baseline, maintenance and development of the Väisälä interference comparator and the associated quartz gauge system, levelling rod and levelling system calibration, the national gravity network, absolute and relative gravity measurements, and continuous recording of temporal gravity variations with a superconducting gravimeter. The calibration services include instruments and systems used in height determination, geodetic baselines and electronic distance measurement (EDM) instruments.

6.1 Acceleration of free fall

The FGI is the National Standards Laboratory for the acceleration of free fall. The FGI maintains the national measurement standard (the FG5-221 absolute gravimeter), the national gravity reference station at the Metsähovi Geodetic Observatory, the Masala–Vihti calibration line for relative gravimeters, and the First Order Gravity Net (FOGN).

Absolute gravity (AG) measurements have been regularly performed at Metsähovi with the FG5-221. The variation in gravity at Metsähovi is also monitored with the superconducting gravimeter GWR T020. In 2010 AG measurements were repeated at 6 field stations in Finland, as a part of the Nordic Absolute Gravity Project.

Final results of two international comparisons of absolute gravimeters where the FG5-221 participated were published in 2010. A bilateral comparison of the FG5-221 with the FG5-233 of Lantmäteriet (Gävle, Sweden) was made in Metsähovi in March 2011.

6.2 Length

The FGI published in 2010 the results of two remarkable measurement projects for geodetic baselines. The results of the interference measurements at the 864-m Nummela Standard Baseline in 2005 and 2007 were reported in detail in the publication series of the FGI. This world-class measurement standard has again been utilized in several recent national and international measurement projects for scale transfers to other geodetic baselines and test fields. As a delivery of the joint research project “Absolute long distance measurement in air” of the European Metrology Research Programme (EMRP) the results of the calibration of the 1 080-m geodetic baseline of the BEV in Innsbruck, Austria, were published in 2010.

Also within the aforementioned project of the EMRP, the FGI offered testing facilities for the new instrument prototypes at field conditions at the Nummela Standard Baseline. The tested new absolute distance measurement (ADM) methods are based on synthetic multi-wavelength interferometry, supplemented by improved determination of refraction. The expert groups from PTB, Germany, CNAM, France, and MIKES, Finland, visited Nummela in autumn 2010.

Instruments and systems used in height determination are calibrated and researched using a horizontal and an automated vertical laser rod comparator, and as system calibration of digital levelling. In addition to domestic calibrations, levels and rods were calibrated for China, Estonia, Iceland, Latvia, Lithuania and Sweden. The calibrations in 2010 included 35 invar rods and 24 digital levels. Co-operation with the Chinese Academy of Surveying and Mapping (CASM) was started. Planning and construction work for the modernized comparator is in progress.

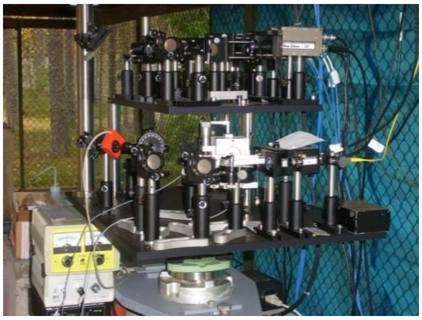

Fig. 6. A part of the new ADM equipment of the PTB on the zero pillar of the Nummela Standard Baseline. Photo: Jorma Jokela

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