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Local Ties Between the Space Geodetic Techniques at the Onsala Space Observatory

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Abstract

We describe the local tie measurements between the collocated space geodetic techniques at the Onsala Space Observatory. Several classical geodetic measurement campaigns have been performed since the beginning of the 70s. Later also short baseline VLBI measurements and GPS campaigns have been performed. So far all realizations of local tie measurements had to use some information from construction drawings of the 20 m telescope. Thus, the local tie between the IVS reference point, i.e. the intersection of the azimuth and elevation axes of the 20 m radio telescope, and the IGS reference point, i.e. the phase center of the GPS antenna, has an uncertainty at a level of several millimeters. Footprint GPS-campaigns indicate that the observatory site is more stable than the uncertainty of these measurements which is 1–3 mm. Currently a small network of new observation pillars is installed to allow a new classical geodetic determination of the local tie between the IGS and the IVS reference points. We expect this new realisation of the tie to reach sub-millimeter uncertainties.

1. Introduction

The Onsala Space Observatory (OSO) is a network station for the International VLBI service for Geodesy and Astrometry (IVS) as well as a global station for the International GPS Service (IGS). IVS and IGS are the major contributors to the International Terrestrial Reference Frame (ITRF) [1]. In order to maintain the ITRF with high accuracy, the knowledge of the local ties at sites with collocated space geodetic techniques is required. This includes an accurate determination of the tie between the reference points and the monitoring of its temporal stability.

2. History of Local-tie Efforts at Onsala

The first space geodetic instrument used at the Onsala Space Observatory was the 25 m radio telescope errected in 1964 [2]. Already in 1968 Onsala participated in the first Mark-I geodetic VLBI experiment [3]. A classical geodetic measurement campaign was performed in 1973 to connect the reference point of the 25 m telescope to the triangulation reference point of the Swedish national geodetic system situated on the observatory estate [4]. In 1976 the 20 m radio telescope was constructed. Its reference point was connected by classical geodetic observations to the triangulation reference point in 1978. Since 1979 the 20 m telescope has been used for geodetic VLBI observations. In order to connect the reference points of the 25 m telescope and the 20 m telescope, a classical campaign was performed in 1981, and the earlier measurements of 1973 and 1978 were re-adjusted at the same instance [5]. Short baseline X-band VLBI experiments between the two telescopes were performed in 1980 and 1981 [6]. Precise levelling between the different geodetic markers at the observatory was performed in 1986 [7].

The Global Positioning System (GPS) was introduced at the observatory in 1987 and a few geodetic markers were established in the bedrock surrounding the GPS site. In connection to that, classical geodetic measurements and several GPS campaigns were performed around 1990 to connect the new GPS monument with the existing VLBI reference points [8], [9]. Some distances in the 20 m telescope were taken from construction drawings, since its reference point is not accessible as a real physical marker.

A short baseline VLBI campaign was performed when the mobile telescope MV-2 was at Onsala in 1992 [10]. In 1993 the coordinate differences of the geodetic markers at Onsala were transformed to WGS84 [11]. In order to monitor the vertical height changes of the 20 m telescope, an invar-rod based measurement system was installed in the telescope tower in 1996 [12], see Figure 1.

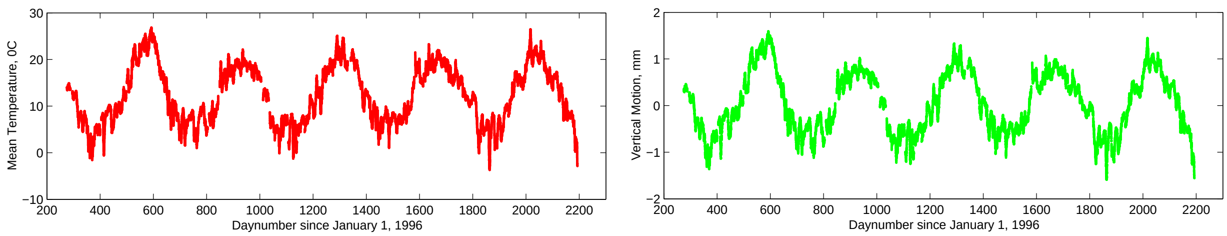

Figure 1. Left: Mean temperature of 16 temperature sensors in the concrete telescope tower. Right: Relative vertical height of the telescope tower as measured by the invar rod.

3. A GPS-VLBI Tie Using GPS-antennas on the 20 m Telescope

In the summer of 1999, a Dorne Margolin GPS antenna was installed permanently on top of the VLBI telescope behind the sub-reflector close to its Apex position [13]. Sporadically, an additional GPS antenna has been mounted close to the vertex position of the main reflector. The idea is to monitor the local tie between the IVS and the IGS reference monuments on regular intervals. During breaks in the ordinary observing schedule the telescope is oriented to its zenith position and GPS observations are performed. Analysis of the GPS data using the Bernese GPS-software yields daily solutions for the position of the APEX and VTEX antennas with respect to the IGS station. Figure 2 shows the residuals of the daily solutions compared to a combined solution. The deviation in north component of the APEX antenna between the 1999/2000 and the 2001/2002 experiments is not yet fully understood. However, the usage of different telescope pointing models over time is one possibility.

4. Local and Regional Footprint Campaigns

A local and regional GPS footprint campaign was performed in 2001 [14]. Geodetic markers at the observatory (inner-network of size $\sim$ 1 km) and its surrounding region (outer-network of size $\sim$ 30 km) were equipped with choke-ring antennas and Turbo Rogue or Ashtech-Z12 receivers for several weeks. The GPS-data were analysed together with data from the IGS permanent station at Onsala and three SWEPOS sites surrounding the observatory using the Bernese software Version 4.2 [15]. For nearly all stations the repeatabilities are at the level of 1–2 mm for the

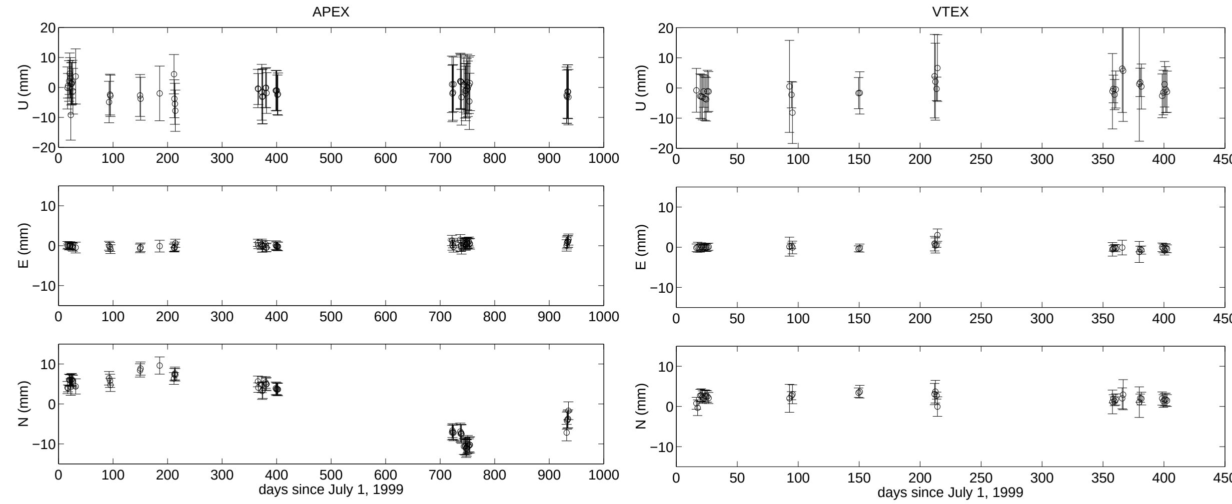

Figure 2. Left: Time series between July 1999 and February 2002 for the up, east and north components of the GPS antenna APEX ontop of the 20 m telescope. Right: Time series between July 1999 and mid 2000 for the up, east and north components of the GPS antenna VTEX ontop of the 20 m telescope.

horizontal components and 2–3 mm for the vertical component. Two stations with less data due to failing equipment and severe interference from a relay station for cellular telephony, respectively, performed worse. The estmated coordinates were compared to earlier GPS results from 1990 [9]. We performed a seven parameter Helmert transformation using both coordinate sets as random variables [16] and determined the transformation parameters. Given the observed repeatabilities during the campaign, none of the markers has been significantly displaced between 1990 and 2001.

5. A New Classical Geodetic Tie

A new classical geodetic tie between the GPS and the VLBI reference points of the 20 m telescope will be performed in 2002. For this purpose five new observation pillars will be installed on the concrete foundation of the radome. Survey targets will be mounted on both sides of the telescope cabin close to the elevation axis. These survey targets will be observed from the new observation pillars with two theodolites simultaneously, thus allowing accurate determination of their position. The procedure will be similar to the one described in [17]. The 20 m telescope is going to be positioned at several different elevation and azimuth directions, so that the positions of the survey targets describe circles around the telescope's azimuth and elevation axes. Thus, the telescope's geodetic reference point, which should be the intersection of the azimuth and elevation axes, can be determined. The new observation pillars will be connected by angular and distance measurements to the geodetic markers in the bedrock around the IGS permanent station and the IGS reference point itself. We expect to derive the local tie between the IGS and IVS reference points by this method with a sub-millimetre uncertaincy.

Figure 3 shows a topview of the telescope inside the radome and the new survey pillars and supporting points (left picture), and a crossview of the observation of survey targets on the telescope cabine (right picture).

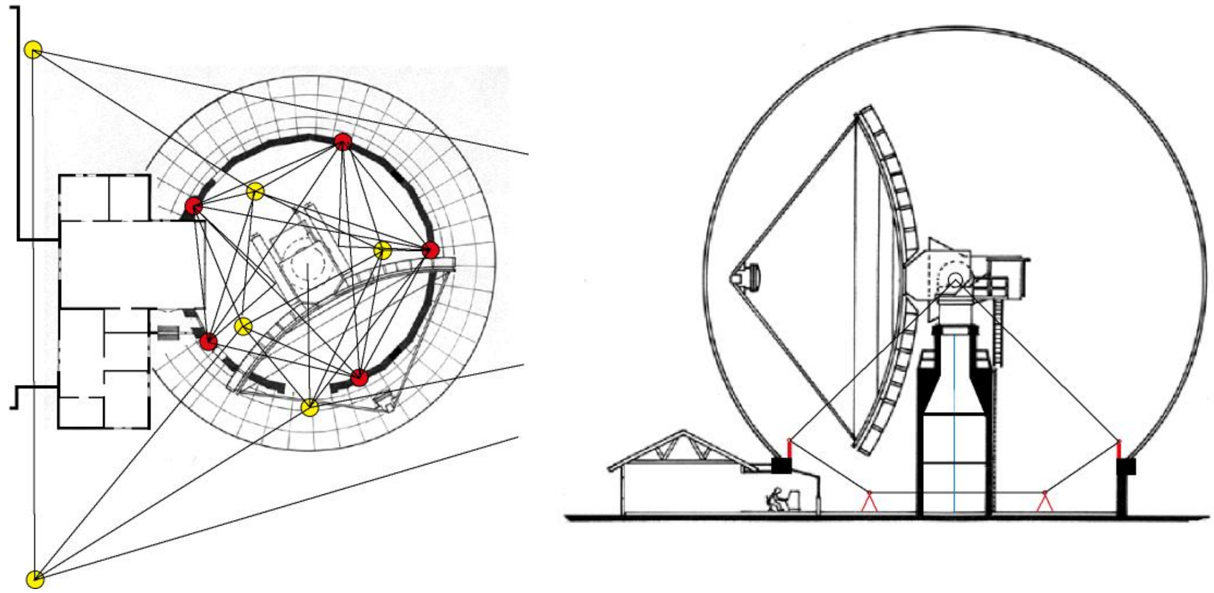

Figure 3. Left: Topview of the local network for the tie to be performed in 2002. Five observation pillars on the radome foundation and are going to be tied by classical geodetic observations and additional temporary supporting markers to the IGS reference marker. Right: Crossview through the radome showing the geometry of observation pillars and the survey targets mounted on the telescope cabin close to the elevation axis of the telescope.

6. Conclusions and Outlook

Several efforts concerning the local ties at the Onsala Space Observatory have been performed through the years. However, since some distances have been taken from construction drawings, the local tie between the IVS and the IGS reference points currently has an uncertainty of a few millimetres. Since the tie is of interest for the maintenance of the ITRF, the efforts will continue to monitor the vertical height changes of the telescope foundation using the invar rod measurement system and to carry out repeated GPS campaigns involving GPS antennas on the VLBI telescope. The new determination of the tie by classical geodetic techniques to be performed in 2002 has the potential to reach an uncertainty at the sub-millimetre level.

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