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A New GPS–VLBI Tie at the Onsala Space Observatory

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Abstract

Onsala is a collocated reference site for IVS as well as IGS. In order to establish a new type of tie between the two reference frames, we have installed two Dorne Margolin GPS choke ring antennas on the 20 m VLBI telescope that is situated inside a radome. One of the antennas is permanently mounted on the subreflector support structure, the other one is intermittently attached close to the vertex of the parabola with a rigid support. Since mid 1999, repeated measurements have been performed pointing the VLBI telescope to the zenith position. In addition we made experiments with a moving 20 m dish, but without success. To obtain accurate positions of the two antennas, we found that measurements inside the radome are feasible without further multipath suppression than that already provided by the choke rings and that a data set consisting of 24 hour uninterrupted measurements was necessary.

1. Introduction

The Onsala Space Observatory (OSO) is a joint IVS (International VLBI Service for Geodesy and Astrometry) and IGS (International GPS Service) component. With increasingly improved accuracy within and interaction between the VLBI and the GPS techniques, the demand for accurate ties at common reference points has increased. Since the 20 m VLBI antenna at Onsala is operating inside a radome and the reference point is immaterially suspended in free air inside a stainless steel cabin, optical measurement of the reference point is quite complicated to achieve.

Our main objective has been to improve the local connection between VLBI and GPS, inspired by Combrinck and Merry [1], and Matsuzaka *et al.* [2]. We try to develop a method for frequent measurements of the tie to check monument stability. A second order objective is the ability to perform GPS measurements inside the radome, an environment anticipated to have serious multipath problems caused by the aluminium frame for radome support and the 20 m dish. Currently, we use an invar rod to measure height deformation of the concrete foundation. We hope to be able to detect that signal with the GPS and possibly also the thermal deformation of the subreflector support structure. The general idea has been to mount GPS antennas on the 20 m antenna and do measurements while pointing to the zenith. As an extracurricular activity, we have tried to measure during VLBI experiments in order to monitor the reference point simultaneously with the different techniques.

At OSO, previous ties between the the two techniques have been made in two ways, the first being a combination of classic surveying techniques and construction drawings; the second a combination of mobile VLBI and classic surveying. The disagreement between the ties is on the centimetre level and partly poorly documented. A new accurate tie would certainly contribute to connect the IVS and IGS reference frames. The present work involves a combination based on GPS data, classic measurements and technical drawings; something we hope to be able to reduce to a combination of GPS data and classic measurements in the future.

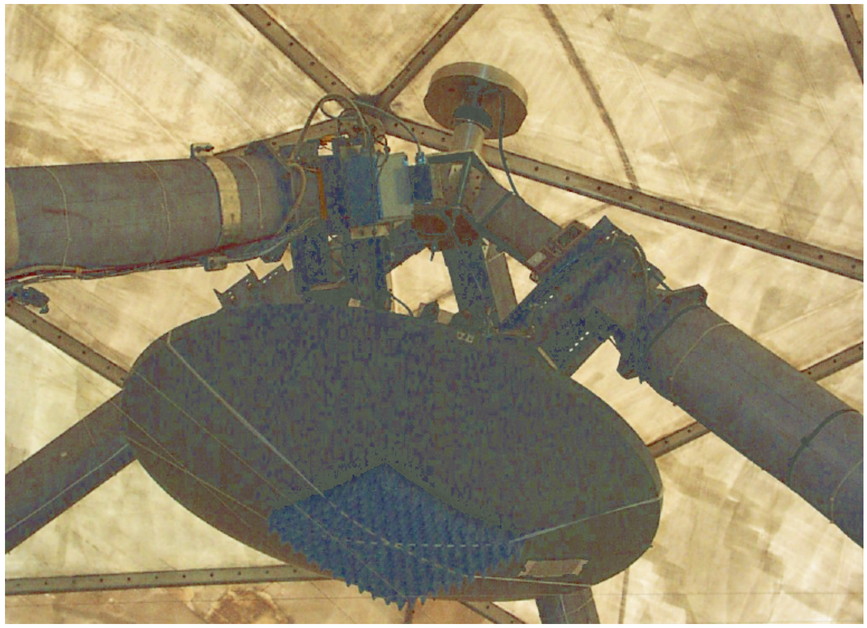

Figure 1. APEX antenna on top of the subreflector support structure.

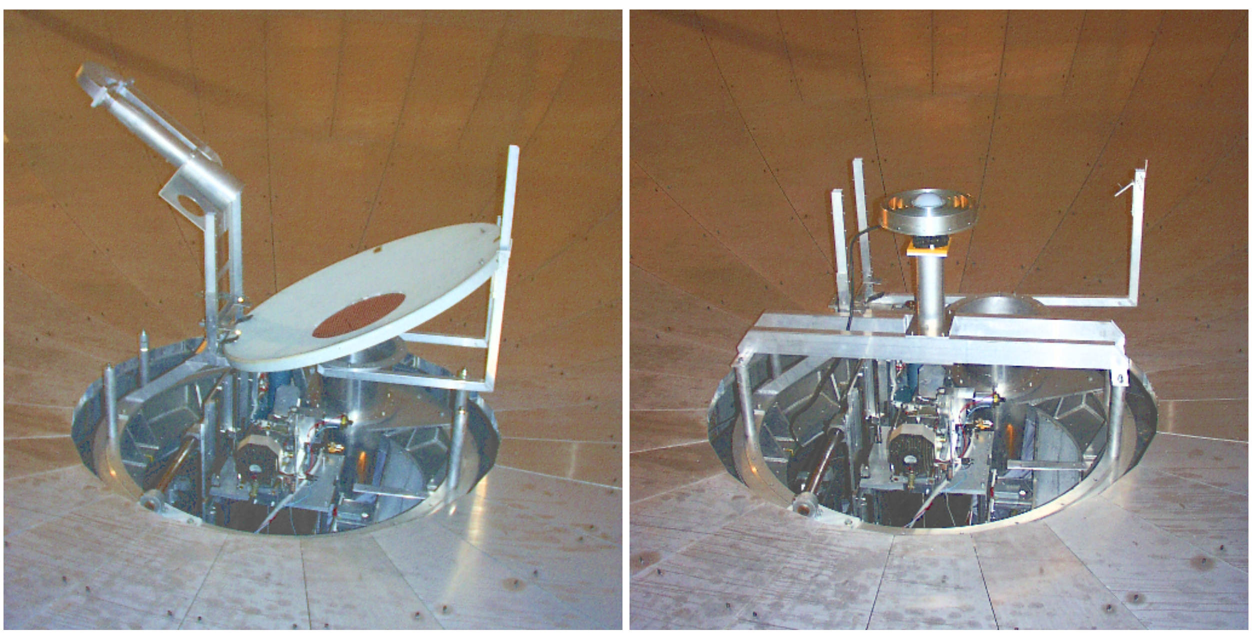

Figure 2. a) Normal S/X set-up with dichroic surface and S-band waveguide. b) VTEX antenna mounted, S-band waveguide removed.

2. Set-up

In order to pursue both objectives, GPS measurement of the IVS reference point as well as thermal deformation of the antenna, we have mounted two Dorne Margolin choke ring antennas on the structure. One is permanently mounted on top of the subreflector support structure, henceforth referred to as APEX (Fig. 1), and one is intermittently mounted close to the vertex of the parabola, hence VTEX (Fig. 2). APEX is permanently connected and should in principle be able to measure at all times. When OSO is measuring S/X-band, a dichroic reflector surface is mounted in front of the X-band horn. The dichroic surface reflects S-band signals into a waveguide that redirects the signals into the S-band horn. When VTEX is used, the normal VLBI configuration's dichroic surface and S-band waveguide have to be removed in order to get rid of objects that affect the electromagnetic environment. On the 20 m antenna at OSO, this procedure seemed to be the best compromise between proximity to the actual vertex and rapid mounting with submillimetre repeatability. Measurements may now commence within an hour from antenna hand-over. The actual antenna in VTEX is electrically insulated from the remaining structure in order to maintain the antenna's a priori characteristics and refrain from disturbing interaction of the 20 m dish. For acquisition and recording, we use Turbo-Rogue receivers and sample once every 30 seconds. Experiments have been made with as well as without absorbing material on the subreflector in order to evaluate the possible impact on multipath effects (Fig. 3).

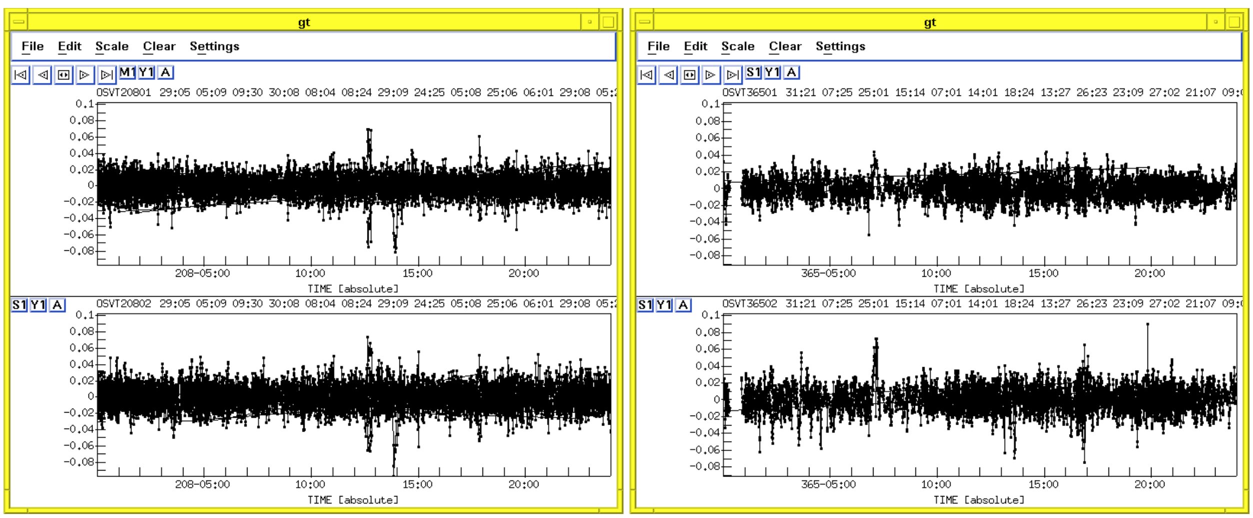

Figure 3. a) Residuals with absorbing material. b) Residuals without absorbing material. Absorbing material on subreflector has no significant impact on multipath suppression.

3. Data Acquisition

Data have mainly been acquired during maintenance periods and with benevolent permission from fair-weather astronomers (the 1999 Onsala autumn has favoured our measurements). That meant that most experiments were recorded from Friday afternoon to Monday morning. Excluding preliminary tests, we have performed five successful experiments commencing with a full week in July, the rest being "weekend experiments". We have also tried to measure at APEX during VLBI experiments, but in the most favourable cases the receiver lost track of satellites, started "open sky search"-mode and obtained preposterous results (worst cases meant losing track of satellites completely).

4. Data Analysis

We processed the recorded data of APEX and VTEX together with data from the IGS permanent station at Onsala as a three station network. For preparation, we used the Bernese 4.1 software [3] in “manual-automatic” mode. We used the graphic option to manually reduce the influence of obvious outliers in the residuals when satellites were getting close to the horizon. From the VTEX antenna, the rim of the 20 m dish is at 12 degrees elevation, and the used software elevation cut-off is 15 degrees. Solutions were obtained from 24 hour periods, midnight to midnight whenever possible. During processing, we assumed the IGS reference antenna to be the most stable in the set-up and determined the position of the other two antennas relative to that. When we analysed the data, we realized that days with less than 24 hours of observations, i.e. the Fridays and Mondays of our weekend experiments, showed outlying results and larger formal errors as compared to days with 24 hours of observations, although they appeared to be reasonable at first inspection. In other words, we do have a multipath problem, but the longer the observation period, the better the results. Apparently, the averaging reduces the impact from multipath. Therefore, we use the 24 hour period as a criterion for position fidelity (Fig. 4).

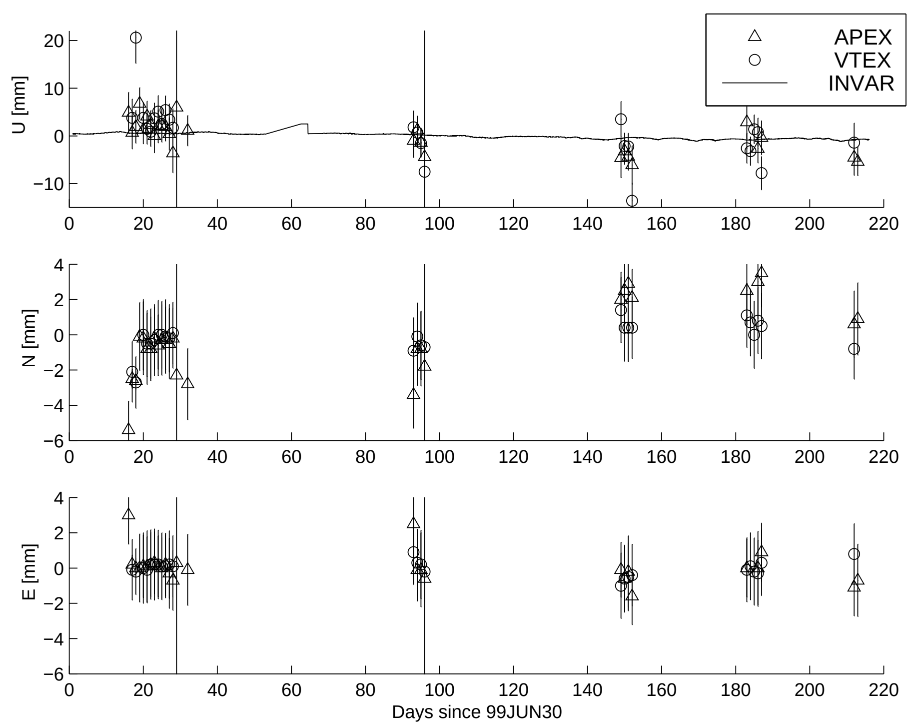

Figure 4. Up, North and East residuals from mean positions. Days 29 and 96 have less than 12 hours of data and larger formal errors. Invar measurement for comparison of vertical components.

5. Results

Although the radome is causing serious multipath, RMS errors of the APEX and VTEX positions are of the same order as measurements made outside. As a fiducial solution we have run an automatic check with the GIPSY/OASIS software [4] for the "favourable" measurement days. The automatic GIPSY solutions that model data differently than the Bernese software accommodate the Bernese values within their error limits.

Since our GPS results are still somewhat preliminary and too many distances on the telescope remain to be measured with high accuracy, we prefer not to communicate the results yet, but consider this to be a status report and show only the residuals. Formal errors for North and East components are of equal order, whereas the Up-component, as expected, has larger formal errors. The errorbars shown in Fig. 4 are Bernese repeatability output. For the Up component (first row) we also show the relative height measurement of the telescope obtained by the invar rod device installed inside the concrete foundation. For more details on the invar measurement system see for example Haas *et al.* [5]. Experience from GPS experiments with stable monuments for determination of crustal movement in Scandinavia (Bergstrand et al., in preparation), suggest an up-scaling of formal errors from GPS analysis software packages by a factor of three.

6. Conclusion and Outlook

We have tried to establish a new tie between the IGS and IVS reference frames at the co-located site Onsala by mounting GPS antennas on the 20 m VLBI antenna. We found that the quality of GPS measurements inside the radome is comparable to the quality of measurements in a less multipath prone environment (even without absorbing material on subreflector), given that measurements are made over at least a 24 hour period. The GPS antennas need therefore to be positioned with an accuracy of 1 millimetre in order to get a good tie. Since the results are more accurate than anticipated, we are currently exploring the possibility to monitor the GPS antenna positions and align them with the azimuth axis of the 20 m antenna more accurately. We anticipate that a receiver with a quicker update (e.g. Ashtech ZXII) will be able to track satellites even when the 20 m antenna is moving. If we can utilise such receivers, we will try to determine the reference point of the VLBI telescope as the centre of a hemisphere created by the positions of the roving GPS antennas.

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