Status of the Wettzell Radio Telescope Triple and the O'Higgins VLBI System at Antarctica

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Abstract This contribution portrays the latest developments regarding the Wettzell and O'Higgins radio telescope systems devoted to geodetic VLBI. The technically revised 20-m RTW is currently the backbone of all VLBI operations at Wettzell. It will be superseded by the smaller 13.2-m VGOS-compliant TWIN radio telescopes. The first of this pair, TTW1, is currently prepared for operations and features a tri-band feed horn. A broadband feed horn is foreseen for integration into the second telescope, TTW2. It is planned to support further geodetic VLBI activities and special missions with the 20-m RTW in the future. In addition, the VLBI telescope at O'Higgins, Antarctica, is currently being revised for improved remote operation, which is a key to enhancing operational performance at this remote location.

Keywords TWIN, RTW, GARS O'Higgins

1 Overview

The Geodetic Observatory Wettzell is on its way to operate three radio telescopes completely devoted to geodetic services in the near future (see Figure 1): the 20-m Radio Telescope Wettzell (RTW) with its long time series of observations and the new 13.2-m TWIN radio Telescope Wettzell pair (TTW1 and TTW2), which fulfills the VGOS specifications [1].

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TTW1 was officially inaugurated in May 2013 after completion of the mechanical construction. At that time, it was equipped with a preliminary S-/X-band receiver for the demonstration of first-light capabilities. This telescope will be operated using a tri-band feed horn for S-, X-, and Ka-band in dual-polarization mode during a certain transition phase. In contrast, the second telescope, TTW2, is planned to feature a wideband feed horn ("Elevenfeed").

The existing 20-m RTW was revised in order to continue operations. It will be able to close the gap between the classic IVS sessions and the future VGOS network. In addition, some important technical improvements such as L-band tracking capabilities for special experiments were implemented. A demonstration was successfully carried out in January 2013 and in January 2014.

Finally, a 9-m antenna at O'Higgins, Antarctica is operated for geodetic VLBI by BKG for geodesy in partnership with the German DLR (remote sensing). It is currently enhanced with respect to dewar and receiver components. Efforts are carried out to enable an extension of the remote operation capabilities for a more effective use of this site in the future. First promising remote control tests were already performed in the year 2009 [4].

2 TWIN Telescope Status

2.1 Technical Characteristics

The TWIN telescopes were developed according to VGOS (VLBI2010) specifications (see [1]) and feature a ring focal design with a ratio of f/D = 0.29. This

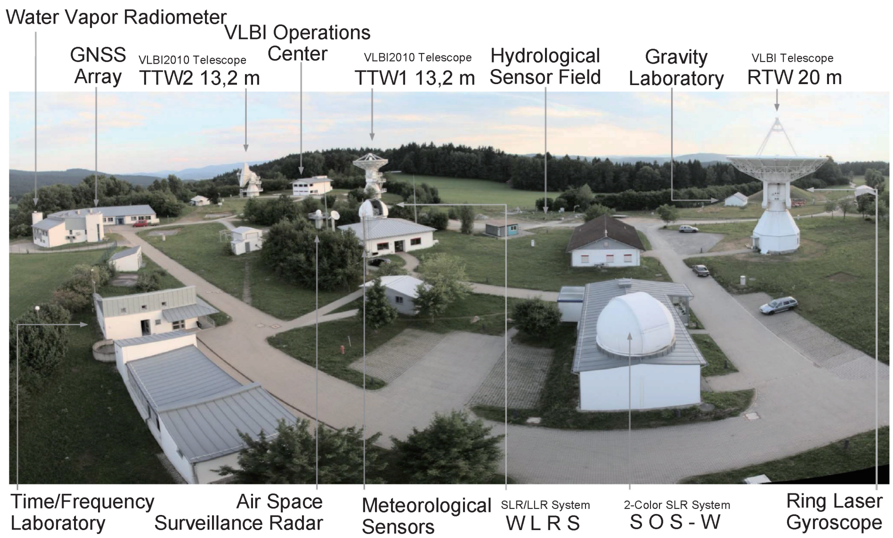

Fig. 1 Geodetic Observatory Wettzell, a fundamental station of geodesy featuring three VLBI radio telescopes.

choice is linked to the broadband design of the telescope. The surface finish of the main reflector is specified to be better than 0.3 mm RMS, where real control measurements reveal a finish even significantly below this threshold. An ALMA mounting was adopted for reasons of performance and quality. The slew rates are up to 12 degrees per second in azimuth and 6 degrees per second in elevation with a drive range from −90.0 to +450.0 degrees horizontally and 0 to 115 degrees vertically.

The overall antenna design of the TWIN telescopes is "balanced" in the sense that the antenna cannot pitch downwards in a powerless situation. Encoders with a discretization of 27 bits are in use yielding a resolution of 1 arc-second. The sub-reflector is adjustable by a hexapod, which is necessary and related to the stringent requirements for the surface finish that necessitates a mechanism for path length compensation especially for higher frequencies up to the Ka-band.

2.2 Milestones – History and Progress

The TWIN project officially started in 2009. The first antenna dish was mounted one year later in 2010, and finalization work was carried out until March 2012. The tri-band S-/X-/Ka-band feed horn was installed in the TTW1 in December of the same year, and the first test was carried out in March 2013, followed by the official inaugural act in April 2013. First light functionality was achieved in July with positive correlation results during several IVS Intensive sessions. The current plan foresees continuous test observations starting at the end of June 2014. Regarding the second TWIN telescope, TTW2, the critical design review for the broadband feed horn ("Elevenfeed", see Figure 2) is expected around mid-2014 with a possible integration until the end of that year.

2.3 Tri-band Feedhorn Efficiency Test, Receiver Design and Phase-calibration

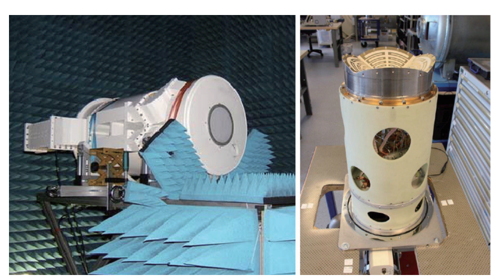

Fig. 2 S-/X-/Ka-band feedhorn by Mirad, Switzerland (left), Elevenfeed with cryogenic system by Omnisys, Sweden (right).

Fig. 3 A first assembly of the microwave wave part of the S-/X-/Ka-band receiver, as it will be used in the future (IF part and synthesizer are not shown in this picture).

S- and X-band efficiency measurements for the tri-band feed horn manufactured by Mirad, Switzerland, agree with the expected values at a very satisfactory level (see Figure 2). S-band efficiency is between more than 0.65 and partially slightly higher than 0.70 throughout the frequency band between 2.2 and 2.7 GHz. X-band efficiency is usually around 0.8 in the frequency band between 7.0 and 8.5 GHz and drops down to slightly better than 0.7 for 8.75 until 9.50 GHz. Measured SEFD (System-Equivalent Flux Density) is between 1400 and 1600 Jy for S-band and 700 to 840 Jy in X-band. The Ka-band calibration is still pending and will be performed with a suitable calibration source.

Note that the broadband feed horn for TTW2 ranging from 2 to 14 GHz has not been integrated yet. The critical design review is expected around mid-2014 so that its implementation into the system will likely not be performed before the end of 2014.

The receiver design and development is accomplished by the local Wettzell team of specialists. A preliminary receiver was set up for the time of the inauguration ceremony serving also to achieve first light functionality. It is now superseded by the final tri-band receiver as shown in Figure 3.

Similarly, a phase-calibration unit (see Figure 4) was developed, which can be used both for S-/X-band in TTW1 as well as for the broadband feed foreseen in TTW2. The output power level shows a linear to constant shape up to around 12 GHz and appears to be very suitable for phase calibration [6].

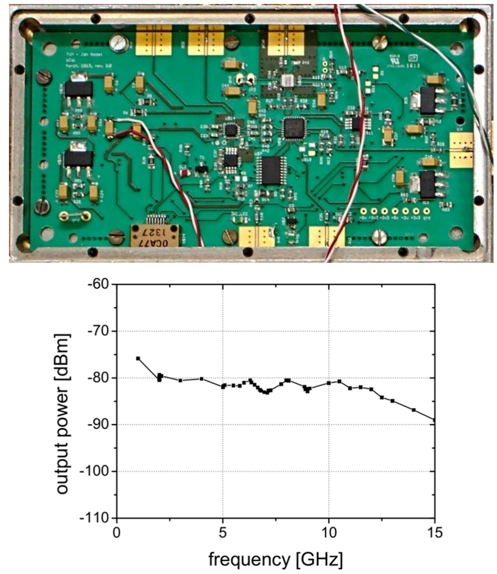

Fig. 4 Phase-calibration unit (top) and output power level versus frequency.

3 RTW - Technical Upgrades

The 20-m aperture RTW VLBI telescope has served the geodetic community reliably for 30 years now. Maintenance and repair efforts have been moderate so far. In order to preserve RTW for a sufficiently long period of time, a number of technical and mechanical enhancements were carried out in 2013. In particular, the obsolete servo motors and gears were replaced by a new digitally controlled servo system. The main and subreflector received a new coating. Moreover, the antenna control unit (ACU) was updated. It is now compatible with the TWIN ACU and supports “Green mode” and is capable of continuous satellite tracking, using Two-Line Elements (TLE). This is important for GNSS VLBI tracking experiments, for instance. Finally, the new ACU is Ethernet-controlled for a better integration into the in-house automation concepts.

3.1 Participation in Special Experiments

A number of special experiments were conducted with RTW between 2013 and 2014. In particular, it is worth mentioning that the receiving system is now able to track GNSS satellite signals in L-band, although this capability is currently limited to the L1 frequency, which is the lowest possible frequency transmitted over the existing S-band feed and waveguides. Successful correlation results from experiments between Onsala and Wettzell were demonstrated [5].

Moreover, RTW was also employed in support of EVN (European VLBI Network) with respect to observations of the Venus Express orbiter and PRIDE (Planetary Radio Interferometry and Doppler Experiment), testing a possible contribution to the upcoming ESA deep space missions. The first goal of these observations was to develop and test the scheduling, data capture, transfer, processing, and analysis pipeline. The high dynamic range of the detections allowed the extraction of the phase of the spacecraft signal carrier line. Apart from other important results, the measured phase fluctuations of the carrier line at different time scales can be used to determine the influence of the solar wind plasma density fluctuations on the accuracy of the astrometric VLBI observations [2].

3.2 Future of the RTW Telescope

Although the two TWIN telescopes will take over much of the routine observing load of RTW as soon as VGOS-related operations are started, it is planned to keep RTW as an active part of the IVS, based on the recommendations expressed for the future VGOS observing network (see [1], page 22). This concept "foresees the contribution of larger antennas [...] mostly for the densification and maintenance of CRF." The minimum VGOS network should "have at least 8 larger ($\geq$20 m) antennas (4 per hemisphere)." Currently it is guaranteed, that RTW operations are continued for the next five years. A corresponding concept for future operations is planned to be presented to the funds-giving agency within that period.

4 Geodetic VLBI at O'Higgins Station (Antarctica)

The GARS (German Antarctic Receiving Station) O'Higgins radio telescope (see Figure 5) is jointly operated by the German DLR (80%, mainly as a remote sensing—receiving station for the TerraSAR-X

Fig. 5 The 9-m radio telescope at O'Higgins.

mission) and BKG (20%, geodetic VLBI). The site has been under the administration of the Chilean army with a corresponding station since 1948. The German receiving station has existed since 1993. Up to now, the VLBI campaigns have been conducted once or twice a year. In the future, the remote operations and remote control capabilities are planned to be significantly enhanced in order to increase the efficiency of the VLBI observations.

The O'Higgins site features a compact and stable antenna. The aerodynamic form of the VLBI telescope is resistant to wind speeds up to 300 km/h. It has a tilted elevation axis and can realize high slew rates of up to 11 degrees per second in azimuth and 6 degrees per second in elevation, which are almost VGOS-compliant. The diameter of the main reflector is 9 m. The VLBI receiver operates at frequencies in S-band (2.1–2.3 GHz) as well in X-band (8.1–8.9 GHz).

4.1 Contributions to IVS and Special Sessions

Due to the lack of VLBI sites in the southern hemisphere, as well as close to the South Pole, the O'Higgins site is of significant importance for geodesy (see Figure 6). Typically, the O'Higgins VLBI telescope contributes to the following IVS sessions:

- T2 (Terrestrial Reference Frame) experiments with radio telescopes distributed globally; participation of O'Higgins as one of the very few radio telescopes in the southern hemisphere improves VLBI solutions.

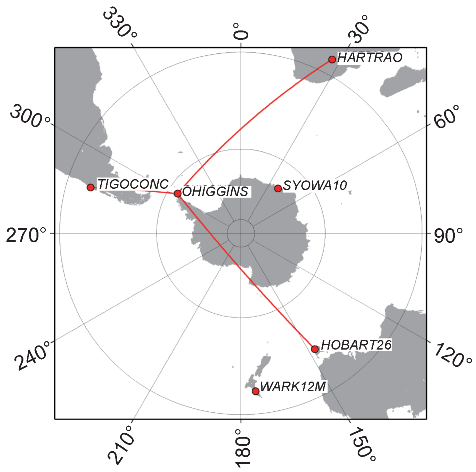

Fig. 6 Antarctica – VLBI stations around the South Pole.

- OHIG (Southern Terrestrial Reference Frame) experiments optimized to cover the Southern Terrestrial Reference Frame (TRF) with intent to supply precise measurements of the region around the south pole.

Moreover, a number of special experiments were supported by the O'Higgins VLBI telescope, in particular:

- IYA09 (International Year of Astronomy 2009)
- VIEPR01 (TU Vienna)
- TANAMI

The improved imaging capabilities of radio sources due to the increased resolution by integration of the O'Higgins telescope are revealed in [3].

4.2 *Technical Upgrades and Remote Operation*

A number of technical improvements of the VLBI system have been carried out so far. A new cryogenic dewar was manufactured by the team of the Centro Astronómico de Yebes, Spain, featuring new high performance LNAs and an extended stability of the cryo-temperature. Moreover, a newer hydrogen maser (EFOS-50) was brought to the site. Finally, the remote control of the VLBI system is getting extended using the e-RemoteCtrl software [4]. The Mark IV BBC is replaced by a digital baseband converter (DBBC/ADS3000). The ultimate goal of these measures is to reach an extended VLBI observation period in the future with help of better remote operation capabilities.

5 Conclusions

The Geodetic Observatory Wettzell will support the VGOS goals and is on the way to realize the design for GGOS core sites. The observatory will strongly continue the support of geodetic VLBI with the Wettzell Radio Telescope Triple and the O'Higgins VLBI System in Antarctica in the future.

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