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Twin Telescope Wettzell — a VLBI2010 Radio Telescope Project

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Abstract. With its Twin Telescope Wettzell (TTW) project BKG is realizing a radiotelescope system based on the specifications of the IVS VLBI2010 vision. It consists of a pair of identical fast moving radio telescopes of the 13.2 m class with innovative ring focus optics which are optimized for observations with a wide spectrum receiver up to at least 12 GHz (covering S/X band). The two radio telescopes will allow non-stop 24 h/d observations. The two antennas will also be used in an array mode for higher sensitivity. The project is scheduled to be carried out at the Geodetic Observatory Wettzell during 2008-2011.

1. Motivation

In the early 80s at the beginning of geodetic VLBI observations, a number of radio telescopes originally designed for astronomical or satellite tracking purposes, had been transformed into geodetic instruments. The Wettzell 20-m radio telescope was the first specifically designed for geodetic VLBI observations. It started operations in 1983. This instrument has been so far the most productive geodetic VLBI instrument worldwide. After more than 25 years of daily operations it is time to consider to meet future objectives and requirements with a modern replacement.

With the inception of the IVS in 1999 an official international organization for geodetic VLBI served as a platform to discuss common issues on the international level focusing on the improvement of the indispensible VLBI service. The IVS Working Group 2 "Product Specification and Observing Program" identified a number of IVS products which require a continuous 24 hours/7 days

VLBI operation [1]. The most important VLBI parameters are the Earth orientation parameters, station coordinates and some physical parameters related to the atmosphere.

For the realization of the updated product catalogue the "IVS VLBI2010 Vision" was developed by the Working Group 3 [2]. The task of this group was to analyze 1) the existing approach to geodetic VLBI observations with respect to newer technical components (wide band frontends, high speed sampler, digital backends), 2) the increasing problem of radio frequency interference at observing sites due to commercial exploitation of the S-band and X-band and 3) the need for more frequent observations to increase the global accuracy to 1 mm in the position and to 1 mm/y in the velocity level.

The VLBI2010 Vision concluded in a raw specification for the next generation VLBI instrument. The future instrument should:

- guarantee that the error in position and velocity of the reference point are less than 1 mm and 1 mm/y respectively. This must be achieved by the construction of the radio telescope.
- allow continuous observations of Earth orientation. Due to telescope maintenance cycles this is only possible with more than one radio telescope per site.
- observe much more sources per time unit. This requires a reduction of antenna idle and slewing time which calls for faster moving antennas.
- be less susceptible to external radio frequency interference. This implies the observation of a wider spectrum in a much larger range from 2 – 18 GHz.

On the basis of these requirements the Wettzell VLBI group specified a new radio telescope project: The Twin Telescope Wettzell (TTW).

2. Twin Telescope Wettzell

The Twin Telescope Wettzell is a rigorous approach to comply with the demands of the VLBI2010 vision. It consists of two identical radio telescopes. The technical specification was written in Wettzell during 2006–2007 [3]. The bidding procedure followed afterwards and resulted in contracting the German company Vertex Antennentechnik GmbH as the main contractor. The project started in January 2008 and will finish by the end of 2011.

2.1. Technical Features

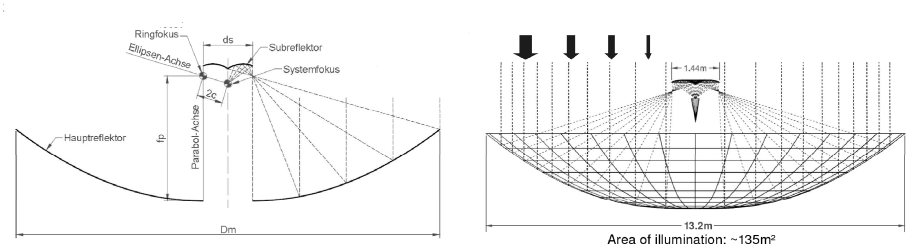
The challenges in the construction of radio telescopes for geodetic VLBI are 1) high stability of directivity and path length in the antenna optics to maintain phase coherence, 2) very low system noise temperature also at higher frequencies – contradicting with 3) a wide band feed system.

Based on these challenges the Vertex company proposed a rarely built ring focus design. Its radial symmetric concept combines the low noise advantage of a dual-offset antenna with good mechanical stability, antenna control and weight of a common Cassegrain or Gregory design.

2.1.1. Ring Focus Optics

The ringfocus design is also known under the term axially-displaced ellipse reflector [4]. The radial symmetric reflector is achieved by a rotating parabel whose vertex is offset by a given radius vertical to the rotational axis. Hence the primary focus and the vertex itself transform into a focal ring instead of a point. In order to focus the ring beam of the primary reflector to a secondary focal point a rotating ellipse defines the shape of the subreflector. The parameters of the rotating ellipse must be chosen to ensure that the primary focus ring defines the first focal point of the ellipse and that the second focal point is located on the optical axis [5].

If the subreflector radius is not larger than the radius of the shifted vertex, there exists no obstruction by the subreflector in the main reflector. Only the support legs cause a small loss (Fig. 1).



Geometric design elements. Illumination and path geometry.

Figure 1. Optics in an Axially-Displaced Ellipse Reflector (Ring Focus)

There are several advantages of the TTW ring focus design: 1) rays from the main reflector rim illuminate the pointed vertex of the subreflector and 2) rays from the main reflector central area illuminate the subreflector rim; 3) minimum reflection of energy towards the feed horn; 4) feed horn can be positioned close to the subreflector as it is needed for a cooled wide band feed.

The TTW radial symmetric main reflector will have a diameter of 13.2 m with an area of illumination of about 135 m^2. As Vertex is delivering 25 12-m radio telescopes to the Atacama Large Millimeter Array (ALMA) the TTW is benefitting from this thoroughly tested, slightly modified ALMA elevation over azimuth mount for the main reflector. The TTW reflector itself will be accurate for up to 40 GHz observations — although initially the observed band shall be in the $2 - 18$ GHz spectrum.

In order to keep path lengths constant and adjust the focus the subreflector is mounted on a hexapod positioner. This positioner provides 3 axial translations with a repeatability of 5 μm and a tilt of 5”.

2.1.2. Feed System

According to the VLBI2010 vision the feed system has to accommodate a wide spectral range from $2 - 18$ GHz. The ideal wide band feed demonstrates a constant beam characteristic over the entire spectrum. It must further comply with the condition to have a fixed phase center for the spectrum range. Otherwise there will be no coincidence of the phase center with the focal point leading to a significant decrease of the aperture efficiency. Unfortunately currently known wide band feeds exhibit a fairly small gain in the range of $6-14$ dB and therefore will request permanent cooling. The cooling aspect is important for the definition of the lowest observable frequency which corresponds to the longest wavelength and which ultimately defines the outer dimensions of the feed: the smaller, the better.

Currently there are no satisfactory feeds available. They have to be developed and tested. A promising design is the so called Eleven Feed from Per-Simon Kildal [6]. Alternative designs with combinations of different feed architectures are under investigation. A final decision for the TTW feed system is anticipated by the end of 2008.

In any case, the ring focus design allows the mount of the feed to be close to the subreflector which will then serve as a sun heat shield.

2.1.3. Kinematic Parameters

The TTW radio telescopes will be fast moving. The kinematic parameters had been set to 12 deg/s and 6 deg/s for azimuth and elevation velocity respectively and to 3 deg/s^2 acceleration for both axes. These high velocities shall enable source observation and slewing to the next source in 30 s intervals.

A 27 bit encoder with 0.0003 deg resolution will provide the pointing accuracy.

2.2. VLBI2010 Operation

A 24h/7d operation will either require more staff at the stations or the introduction of a centralized network control which may travel with the daylight zones. This concept requires a corresponding operation control room, which contains e.g. one monitor per network station for remote controlled operation. The TTW operation control room will be designed with sufficient space to allow remote controlled network operation.

Remote control software has been developed in Wettzell and tested with O'Higgins. A PC-Field System remote control interface was also developed at the TIGO observatory and might serve for a future PC-Field System upgrade.

For the IVS Operation Centers the development of the scheduling modes for TTW is still an outstanding issue. If the two radiotelescopes operate simultaneously, they can either be used in the array mode to increase the sensitivity — or observe simultaneously in different directions. Both modes may even temporarily include the existing 20 m radio telescope in Wettzell as a third contributor to a VLBI2010 observing session.

3. Outlook

The major milestones of the TTW project are the following:

- end of 2008: Design review,
- end of 2009: Fundaments, operations building finished,
- in 2010: beginning of TTW assembly at Wettzell,
- end of 2011: final acceptance and start of operation.

4. Conclusion

The TTW-Project is the first rigorous approach to realize a suitable observing instrument according to the VLBI2010 vision of the IVS. It will guide the IVS to an improved service promising more accurate products. It is hoped that the transition time from current IVS operation to future 24h/7d operation can be made together with partners elsewhere in the world by sharing our upgrade experience.

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