Geodetic Observatory Wettzell – 20-m Radio Telescope and Twin Radio Telescopes

Alexander Neidhardt [1], Christian Plötz [2], Gerhard Kronschnabl [2], Torben Schüler [2]

Abstract The Geodetic Observatory at Wettzell, Germany mainly contributed very successfully to the IVS observing program and to some observations of the EVN in the years 2017 and 2018. Technical changes, developments, improvements, and upgrades had been made to increase the reliability of the entire VLBI observing system. While the 20-m Radio Telescope Wettzell (RTW, Wz) and the 13.2-m Twin radio Telescope Wettzell North (TTW1, Wn) are in regular S/X sessions, the 13.2-m Twin radio Telescope Wettzell South (TTW2, Ws) is equipped with a VGOS receiving system and participates in all test and regular international and European VGOS sessions.

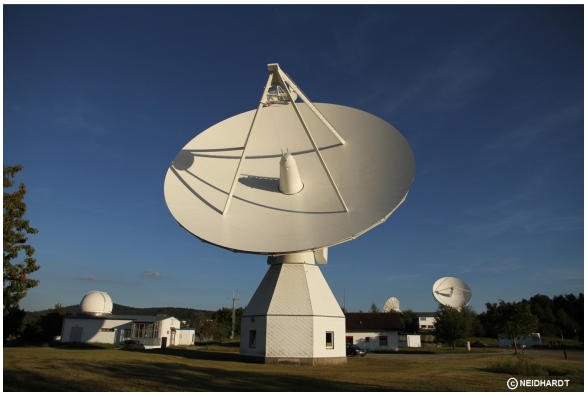

Fig. 1 The Geodetic Observatory Wettzell with the two 13.2-m TWIN radio telescope antennas in the background on the right and the 20-m Radio Telescope Wettzell in the center.

1 General Information

The Geodetic Observatory Wettzell (GOW; see Figure 1) is jointly operated by the Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie, BKG) and the Research Facility Satellite Geodesy (Forschungseinrichtung Satellitengeodäsie, FESG) of the Technical University of Munich (TUM). The 20-m Radio Telescope at Wettzell (RTW) has been an essential component of the IVS since the year 1983. Meanwhile, the 13.2-m Twin radio Telescope Wettzell North (TTW1, Wn) also produces S/X-data as a regular station with up to three-fourths of the load of RTW in 2018. Doing observations with the second 13.2-m Twin radio Telescope Wettzell South (TTW2, Ws), which is the first complete VGOS antenna at Wettzell, the observatory is prepared for future requirements in the IVS.

In addition to VLBI, an ILRS laser ranging system, several IGS GNSS permanent stations, a large laser gyroscope G (ring laser) and corresponding local techniques, e.g., time and frequency, meteorology and super conducting gravity meters, are also operated. Wettzell also runs a DORIS beacon as a complete geodetic core site. Activities to monitor atmospheric parameters use a continuously growing amount of equipment, including a Nubiscope and weather balloons. Another project with external contractors has been established to improve the timing system with compensated fiber-optic transfers and a frequency comb. The developments also must meet the requirements for future operation strategies, so projects to increase automation and remote control are on-going.

1. Forschungseinrichtung Satellitengeodäsie (FESG), Technische Universität München
2. Bundesamt für Kartographie und Geodäsie (BKG)

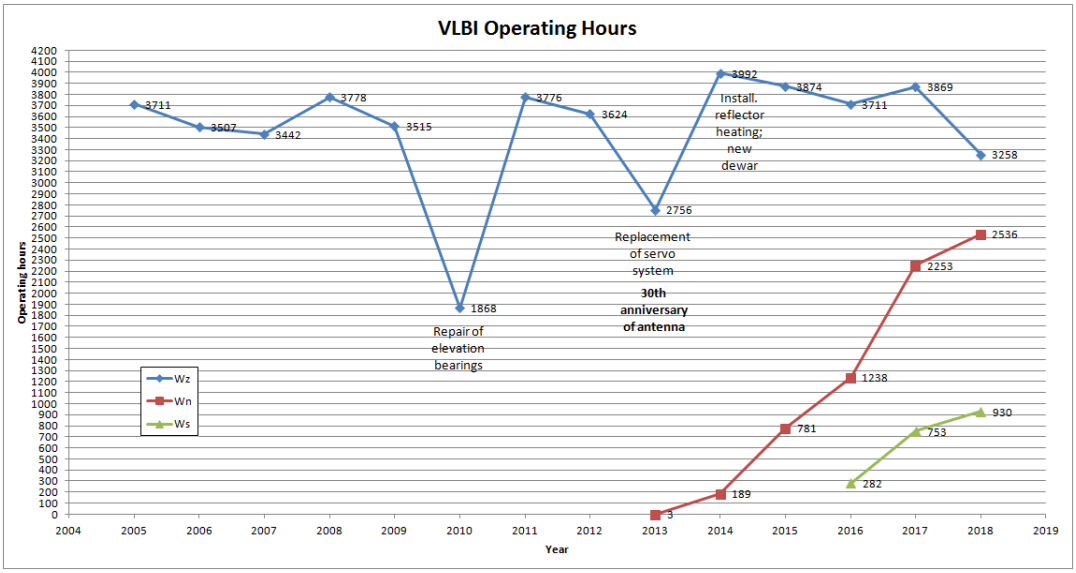

Fig. 2 Annual hours of operation of the Wettzell antennas since 2005.

The GOW is also responsible for the AGGO system in La Plata, Argentina (which is the former station TIGO in Concepción, Chile), and the German Antarctic Research Station (GARS) O'Higgins on the Antarctic Peninsula (see separate reports).

2 Staff

Table 1 Staff members of RTW.

Name	Affiliation	Function	Mainly working for
Torben Schüler	BKG	head of the GOW	GOW
Alexander Neidhardt	FESG	head of the microwave group, VLBI chief	RTW, TTW
Erhard Bauernfeind	FESG	mechanical engineer (until Dec. 2018)	RTW
Ewald Bielmeier	FESG	technician	RTW, TTW
Martin Brandl	FESG	mechatronic engineer	RTW, TTW
Gerhard Kronschnabl	BKG	electronic engineer (chief engineer TTW)	TTW, RTW
Christian Plötz	BKG	electronic engineer (chief engineer RTW)	RTW, TTW, O'Higgins
Raimund Schatz	FESG	software engineer	RTW
Walter Schwarz	BKG	electronic engineer	RTW, WVR
Armin Böer	BKG	electronic engineer	Infrastruct., RTW
Apurva Phogat	BKG	MSc	correlation
Nadine Schörghuber	FESG/ BKG	student (until Sept. 2017)	Operator VLBI

The staff of the GOW consists of over 30 members in total (plus student operators) on permanent and fixed-term contracts to do research, operations, maintenance, and repairs, or to improve and develop all GOW systems. The staff operating VLBI are summarized in Table 1.

3 20-m Radio Telescope Wettzell (RTW, Wz)

The 20-m RTW (see Figure 3) has been supporting geodetic VLBI activities of the IVS and partly other partners, such as the EVN, for over 35 years now. Operational hours in the reporting period are plotted in Figure 2 (also see Table 2). The telescope is still in a very good and stable state. The main priority was the participation in all daily one-hour Intensive sessions (INT/K) to determine UT1–UTC. Increasing the know-how, sessions can now also be scheduled, correlated, and analyzed by the Wettzell observatory's staff. Therefore, several of Wettzell's own local and global sessions were operated, including a 10-day local CONT campaign testing the stability of all Wettzell antennas at the end of 2018. Using the Field System extension for remote control, weekend Intensives were partly done remotely. The antenna supported all main IVS 24-hour sessions and is still one of the IVS' main

components. Up to 94% of the operations were IVS schedules in 2017, and up to 86% in 2018. About maximum 1% of the observation load was for EVN in 2018. Local sessions increased in 2018 to over 13% of the operations. In 2017, IVS again scheduled a CONT campaign (CONT17) where a continuous operation over 15 days was supported.

Table 2 Annual participation of RTW allocated to services.

Network	Number of observations	Hours of operation	Percent of operation
2017			
IVS	510	3627	93.75 %
Local	30	198	5.12 %
Others	2	44	1.14 %
2018			
IVS	470	2797	85.85 %
EVN	3	28	0.86 %
Local	52	433	13.29 %

All VLBI data from the 20-m RTW is transferred with e-VLBI techniques to Bonn, Tsukuba, Haystack, Washington, and Socorro, using TSUNAMI or now only Jive5ab anymore on the 1 Gbit/sec connection of the Wettzell observatory. Meanwhile, the Bonn and Washington correlators fetch sessions from Flexbuff systems at the Wettzell observatory. Most of the sessions are recorded on Mark5B+ systems and later on transferred to the local Flexbuff servers. But also direct recording is possible. Mainly the weekend Intensives are directly recorded as VDIF streams on the Flexbuff systems. Additionally, 24-hour sessions were recorded with this technique to evaluate the stability in parallel to the classic recording. About 5% of all sessions at the 20-m RTW were directly recorded on Flexbuff in 2018 (0.36% in 2017).

The 20-m antenna, together with the northern twin telescope Wn, also supported the final Wettzell high-speed VLBI session (WHISP) sessions in 2017, planned by colleagues of the Bonn University. WHISP sessions schedule a large number of observations to validate turbulence models in a local application. During WHISP, common clock tests were made where all telescopes were connected to maser EFOS-60. These tests were quite interesting for finding issues in technical solutions for stable frequency transfers over hundreds of meters using classic techniques. The problems found should be obsolete after using a new optical time distribution system with active phase compensation.

Fig. 3 20-m Radio Telescope Wettzell during sunset.

Monthly maintenance days were scheduled to give enough time to maintain the systems. Additionally, service periods were necessary to finalize the cleaning and coating of the antenna tower, the back structure, and the cabins by an external contractor. Using a replacement dewar, built by IVS Centro de Desarrollos Tecnológicos de Yebes, Spain enabled short maintenance times for the cryo-systems, because the complete dewar hardware can be replaced and the repair can be done in the workshop while keeping the antenna operative. The NASA Field System is now on version 9.11.19. All DBBC2s use now firmware DDC v106 and are connected or integrate a FILA10G to stream data over 10 Gbit/s networks.

A main change was switching from the Mark4 rack to digital DBBC recording. All sessions are now recorded using DBBC2 and a Mark5B (partly Flexbuff in addition). On October 1, 2017, the conformity declaration to follow the EC Machinery Directive was signed, so that now all VLBI antennas ensure legal certainty in the sense of European right. Open issues are an oil leakage in two elevation gears, the upgrade of the IF or maybe RF distribution, and an improvement of control structure.

4 13.2-m Twin Telescope Wettzell North (TTW1, Wn)

The Twin Telescope Wettzell (Figure 4) project is Wettzell's realization of complete VGOS conformity. The northern antenna Wn is still equipped with an

S/X/Ka receiving system to support the standard S/X sessions of the IVS and of local performance tests and research questions. The northern antenna was the first available antenna supporting fast slewing modes in the IVS and uses now a DBBC2 (firmware DDC v105_1) in combination with a Mark5B+. It is used in sessions like the 20-m antenna. Its performance in operating hours can be found in Figure 2 (also Table 3). It mainly participates in IVS sessions where it also supported a separate network in the CONT17 campaign. The EVN uses about 1% of the time. Locally scheduled and analyzed sessions increased to about 18%. Missing partners for Ka sessions reduce the possibilities to demonstrate geodetic Ka observing. All recorded data is transferred with e-VLBI techniques.

Table 3 Annual participation of TTW1 allocated to services.

Network	Number of observations	Hours of operation	Percent of operation
2017			
IVS	129	1956	86.82 %
Local	39	207	9.19 %
Survey	5	46	2.04 %
Others	2	44	1.95 %
2018			
IVS	160	2017	79.53 %
EVN	3	29	1.14 %
Local	58	448	17.67 %
Survey	4	42	1.66 %

Fig. 4 The Wettzell Twin Telescope with its two 13.2-m antennas (Wn in the front) and the control building.

The Wn antenna is quite stable and reliable. It is controlled with NASA Field System version 9.11.19. Minor changes were made. It is now additionally equipped with a cable calibration system built by IVS Centro de Desarrollos Tecnológicos de Yebes, Spain.

5 13.2-m Twin Telescope Wettzell South (TTW2, Ws)

The southern antenna Ws of the twin telescopes is Wettzell's first VGOS-compliant antenna using a broadband feed (Elevenfeed). It uses a tunable up-down converter, two DBBC2s, and a Mark 6 to record four bands in both polarizations. Meanwhile, Ws is a regular part of the IVS VGOS network doing bi-weekly observations. Its performance in operating hours can be found in Figure 2 (also see Table 4). In 2017, the main part of the work was to find issues and to stabilize the system. After some tests it was able to be integrated into the Wettzell telescope array, so that all three telescopes can be used and correlated for local sessions. Data of the VGOS sessions is shipped to Haystack for correlation because of the huge data amount of about 16 or 32 Terabytes per day. Local sessions are correlated at Wettzell, and their observation takes about a quarter of the operation time.

Table 4 Annual participation of TTW2 allocated to services.

Network	Number of observations	Hours of operation	Percent of operation
2017			
IVS	21	476	63.21%
Local	15	194	25.76%
Survey	8	83	11.02%
2018			
IVS	25	590	63.44%
Local	12	263	28.28%
Survey	4	41	4.41%
Others	9	36	3.87%

The Wettzell staff does continuous upgrades, implementations, and tests of the backend system. The DBBC2 got new firmware, PFB v106. A DBBC3 was installed and will be tested. Ws now uses the same cable calibration system as Wn installed in 2018. Ws uses the NASA Field System version 9.12.7 VGOS branch.

6 Other VLBI-relevant Activities

To improve the e-VLBI capacities, three Flexbuff systems with 21 TB, 72 TB, and 102 TB were installed. The main systems behind are extendable DELL PowerVault MD3460 Storage Arrays connected to a DELL PowerEdge R730 server. All systems are accessible with Jive5ab, while the use of Tsunami will fade out.

To connect all Flexbuff, Mark 6, and FILA10G systems and to support a flexible, selectable recording, a new 10 Gbit/sec network was installed using fiber links between the telescopes and suitable network switches. The network supports a direct recording of VDIF streams from different FILA10G sources.

A cluster with ten nodes (including one head node), each with four cores, was installed for correlating local sessions at Wettzell using the software correlator DiFX and hardware from the previous Bonn correlator. The installation was supported by Bonn colleagues. Also, all necessary software for scheduling (Sked, VieVS), fringe fitting (fourfit etc.), and analysis (VieVS, nuSolve) was installed, so that staff at Wettzell can now do the whole processing chain from scheduling to analysis. The local software LEVIKA is used for planning observation times and for analyzing local sessions. To exchange the latest news about correlation with a software correlator, the 12th DiFX Users and Developers Meeting was held at Wettzell from September 3 to 7, 2018.

For a better overview of antenna parameters and for emergency detections, a monitoring system was installed as a central data archive using ZABBIX software. Data from the NASA Field System and the recording systems, but also from the antenna control unit, UPS systems, and meteorological sensors, are collected and evaluated to generate triggers showing alerts according to different severity levels. The TUM at Wettzell also joined the project "Joining up Users for Maximizing the Profile, the Innovation and Necessary Globalization of JIVE" (Jumping JIVE) to implement a monitoring infrastructure for the whole EVN network coordinated by Joint Institute for VLBI ERIC, Dwingeloo, The Netherlands. Jumping JIVE is funded by the Horizon 2020 program of the European Union. Part of the local Wettzell development and installation was a Web-based remote monitoring Web page for the NASA Field System (see Figure 5) which can be used to retrieve about 110 parameters. Additionally, data collectors and Web screens were implemented for Mark 6 systems and different other hardware. The guard of the Wettzell observatory got a monitoring tablet showing current problems and alarms as a central monitoring point.

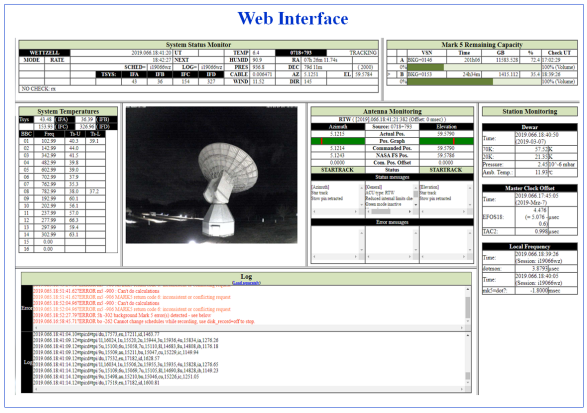

Fig. 5 Web interface of the NASA Field System for the 20-m radio telescope Wettzell.

The permanent survey of the reference point of the twin antennas was continued, using total stations on different pillars and 20 to 30 reflectors in the back structure of the antenna. With about four sessions per year, a continuous monitoring of the reference point over the year is possible.

7 Future Plans

Dedicated plans for the next reporting period are:

- Establishing automated observations
- Studying future use of the 20-m radio telescope
- Implementing VGOS compatibility for TTW1 using a QRFH feed
- Continuous improvements with the VGOS broadband system at TTW2
- Installing a DBBC3 and further Flexbuff systems
- Establishing monitoring of atmospheric parameters
- Increasing the correlation capabilities