Effelsberg Radio Observatory Report

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Abstract The 100-m radio telescope of the Max-Planck-Institut für Radioastronomie (MPIfR) is one of the largest fully steerable, single-dish radio telescopes in the world and a unique high-frequency radio telescope in Europe. The telescope can be used to observe radio emissions from celestial objects in a wavelength range from 90 cm (300 MHz) down to 3.5 mm (90 GHz).

1 General Information

The Effelsberg radio telescope was inaugurated in 1971 and was (for almost 30 years) the largest fully steerable, single-dish radio telescope in the world. It is situated in a protected valley near Bad Münstereifel (about 40 km southwest of Bonn) and operated by the Max-Planck-Institut für Radioastronomie (MPIfR) on behalf of the Max-Planck-Society (MPG). To this day, it is the largest radio telescope in Europe, and it is mostly used for astronomical observations.

This extremely versatile and flexible instrument can be used to observe radio emissions from celestial objects in a wavelength range from about 1 m (corresponding to a frequency of 300 MHz) down to 3.5 mm (90 GHz). The combination of the high surface accuracy of the reflector (the mean deviation from the ideal parabolic form is ∼0.5 mm rms) and the construction principle of 'homologous distortion' (i.e., the reflector in any tilted position has a parabolic shape with a well-defined, but shifted, focal point) enables very sensitive observations to be made at high frequencies (i.e., $\nu > 10$ GHz).

The wide variety of observations with the 100-m radio telescope is made possible by the good angular resolution, the high sensitivity, and a large number of receivers which are located either in the primary or in the secondary focus. Together with a number of distinct backends dedicated to different observing modes, this provides excellent observing conditions for spectroscopic observations (atomic and molecular transitions in a wide frequency range), high time-resolution (pulsar observations), mapping of extended areas of the sky, and participation in a number of interferometric networks (IVS, mm-VLBI, EVN, and Global VLBI etc.).

Table 1 Telescope properties.

Name	Effelsberg
Coordinates	6:53:01.0 E, +50:31:29.4 N
Mount	azimuthal
Telescope type	Gregorian (receivers in primary and secondary focus)
Diameter of main reflector	100 m
Focal length of prime focus	30 m
Focal length of secondary focus	387.7 m
Surface accuracy	0.55 mm rms
Slew rates	Azi: 25 deg/min, Elv: 16 deg/min
Receivers for geodetic observations	3.6 cm/13 cm secondary-focus (coaxial)
T_{sys} (3.6 cm/13 cm)	25 K, 200 K
Sensitivity (3.6 cm/13 cm)	1.4 K/Jy, 0.5 K/Jy
HPBW (3.6 cm/13 cm)	81 arcsec, 350 arcsec
Tracking accuracy	∼ 2 arcsec

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Effelsberg Network Station

IVS 2023+2024 Biennial Report

Fig. 1 Aerial view of the Effelsberg radio observatory in winter 2023/2024. The image shows the observatory along with the entrance road. (photo N. Tacken, MPIfR).

2 Staff

The staff at Effelsberg consists of about 40 people, including telescope operators, technical personnel for receivers, electronics, and mechanics, scientists, and administrative personnel. Involved in IVS activities are, besides the telescope operators, **Dr. Alexander Kraus** as station manager and scheduler for the 100-m Effelsberg telescope and **Dr. Uwe Bach** as support scientist and VLBI friend. Two of the telescope operators, **Marcus Keseberg** and **Peter Vogt**, are also involved in the preparation of schedules and disk management and shipping.

3 Activities during the Past Years

Effelsberg has participated regularly in the EUROPE IVS sessions since 1991. In 2023 and 2024, the experiments T2P158, T2164, and T2P166 were observed. All observations were successful, but in T2P164 the S-band receiver turned out to be broken. T2P171 in December 2024 could not be observed because of an upgrade of the main axis control system that was not finished at that time. About 30% of the observing time of the Effelsberg antenna is used for VLBI observations. Most of them are astronomical observations for the European VLBI Network (EVN), High Sensitivity Array (HSA), Global MM VLBI Array (GMVA), or other global networks, but also geodetic VLBI observations within the IVS are performed.

In 2023 a company was commissioned to upgrade the main axis control system of the 100-m antenna at the Effelsberg observatory. The hardware replacement began in June 2024, at which point scientific observations had to be suspended. In a first step, about a dozen hardware racks had to be removed from the antenna base containers and were replaced by new ones (see Figure 2). In the context of this project, also the angular encoders and safety switches were renewed, as well as the control panel in the telescope's control room. Additionally, we took the opportunity to modernize various parts of the astronomical software.

Due to unforeseen problems, the project was delayed by quite some time, which also affected the participation of the Effelsberg antenna in T2P171 and the EVN Session III in 2024. It seems, however, that the upgrade was a success, improving the telescope's operation substantially. Not only is the technical handling of the system much easier and more comfortable, we are already observing noticeable improvements in both tracking and scanning accuracy. A few software details still need refinement; these are expected to be resolved in the near future.

4 Current Status

Effelsberg uses the DBBC2, Fila10G, and a Mark 6 recorder for all EVN, global, and geodetic VLBI observations. The Mark 6 recorders provide 390 TB of storage capacity and most of the recorded data is e-transferred to the correlators in Bonn and JIVE. One slot is currently kept for modules that can be shipped.

In addition to the DBBC2, there are two NRAO RDBEs connected to one of the Mark 6 recorders that are used for observations with the VLBA and HSA. The data to Socorro is now being sent using e-transfer as well. Both VLBI backends and their recorders are controlled by the Field System (current release FS 10.2.0). The observatory is connected via a 10 GE optical fiber to the e-VLBI network and can do real time e-VLBI observations (performed about monthly within the EVN) and e-transfers.

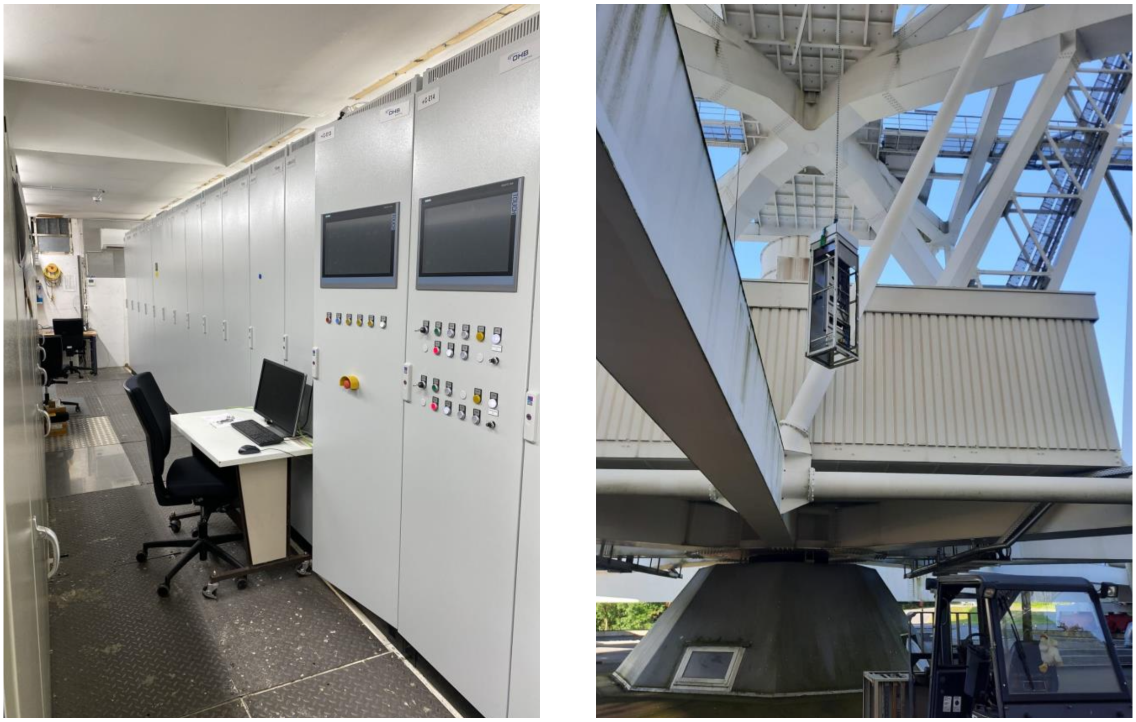

Fig. 2 Installation of the new racks in the telescope (photos by H. Homburg).

5 Future Plans

The DBBC3 is currently being commissioned for regular use for all Effelsberg VLBI observations. In principle it is fully compatible with both existing systems, the DBBC2 and the RDBEs, and can therefore replace both. However, before this is finalized, tests within the EVN and GMVA, and together with the VLBA, have to be performed to ensure that the correlation and calibration of data is as good as before. Also the operators have to be trained to work with the new backend.

In parallel the direct digitalization of the RF signals from the receivers in Effelsberg is progressing. The same digitizers that are used for Meerkat digitize up to 3 GHz at the receiver, and the full band at 10 to 12 bits is streamed over 100-Gbps Ethernet using the SPEAD protocol to the software backend. A software backend on a GPU cluster is being developed that currently supports single-dish continuum and spectroscopy observations in full Stokes and pulsar observations. A first implementation of a tunable digital down conversion algorithm that writes out channelized VLBI VDIF data at data rates of up to 2 Gbps is being developed as well. After the verification with local zero-baseline tests, tests with real VLBI observations are planned. There are currently three receivers that provide the digitized signals, the 21 cm (1.29 to 1.51 GHz), a prime focus wide-band receiver at 1.3 to 6 GHz, and a secondary focus receiver from 4 to 9.3 GHz (7.5 cm to 3.2 cm) that cover some of our typical VLBI frequency bands. Once the system is established, it is planned to digitize more and more of the Effelsberg receivers over the next years.