Effelsberg Radio Observatory 2021–2022 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 is 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 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

Max-Planck-Institut für Radioastronomie, Bonn, Germany

Effelsberg Network Station

IVS 2021+2022 Biennial Report

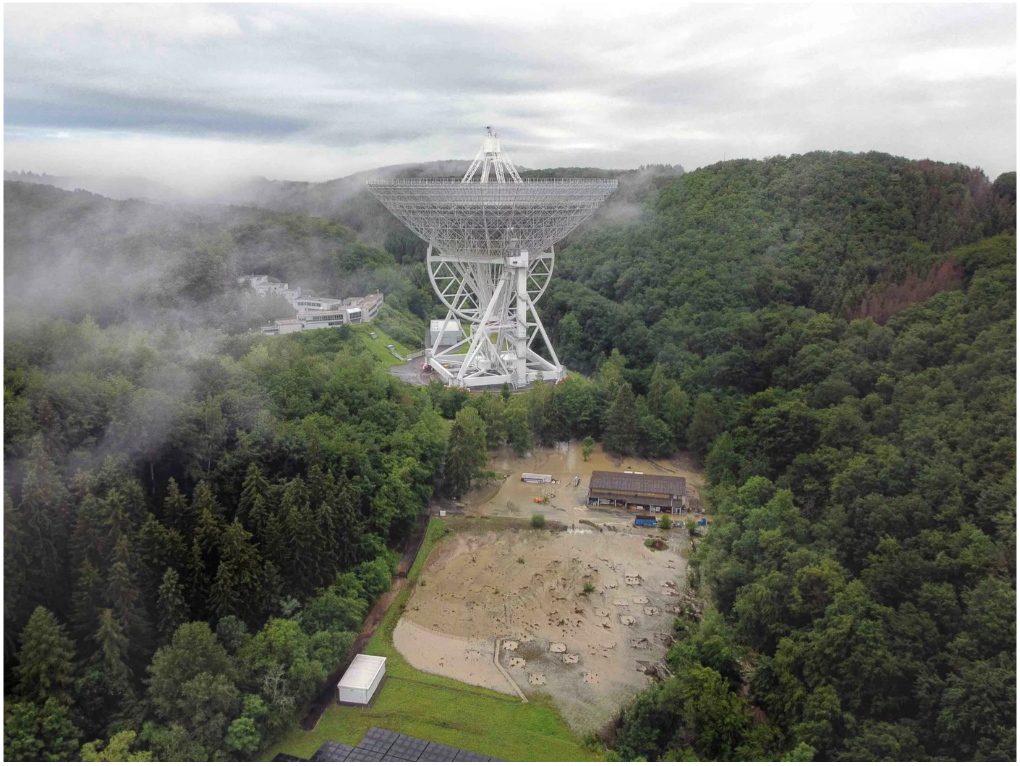

Fig. 1 Aerial view of the Effelsberg radio observatory on the morning of July 15, 2021. The image shows in the foreground the completely flooded “low-band” part of the Effelsberg station of the European LOFAR telescope network. In the background is the 100-m radio telescope and to the left the observatory building with the control room (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 2021 and 2022, the experiments T2P144, T2148, T2P151, and T2P157 were observed. All observations were successful. Only T2P157 was partly affected by snow fall, and a few scans were lost. 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.

Despite the restrictions caused by the worldwide pandemic that also caused shutdowns in Germany in 2021, the operation of the observatory was not interrupted. A reduced staff ensured the operation, and observations were conducted remotely. Since 2022, there have been no general shutdowns, and the restrictions have only applied to individual measures, such as quarantine in the event of infection.

In summer 2021 an extreme weather situation with heavy rainfalls on July 13 and 14, 2021 caused serious flooding in the Ahr valley and neighboring regions of the Eifel, with partly devastating destruction. To a

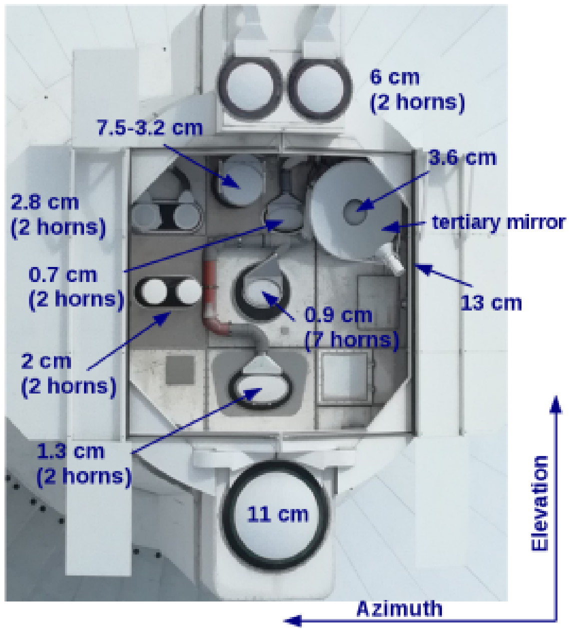

Fig. 2 Picture of the secondary focus cabin with several astronomical receivers. Secondary focus receivers are permanently mounted on their positions and can be used "quasi-parallel", i.e., one can easily change by software from one receiver to another in a timescale of about 40 seconds. The geodetic SX system with the 3.6-cm horn and the tertiary mirror for the 13-cm horn is visible on the top right side of the cabin.

relatively small extent—compared to the neighboring valleys—the observatory was also affected. Due to its location in a valley, with the Effelsberger Bach and the Rötzelbach (normally tiny creeks), there was also massive flooding here. Part of the ground was overflowed, including the access road and the storage building south of the telescope. A container with technical equipment was washed away, and some low-band antennas of the LOFAR field were destroyed (see also the photo in Figure 1). Fortunately, no one was harmed during this event. But the institute was without electricity, water, and telephone for a few days. Thanks to the energetic efforts of many colleagues from Effelsberg and Bonn, the situation was soon eased. Astronomical observations with the 100-m telescope was restarted after just five days.

4 Current Status

Effelsberg uses the DBBC2, Fila10G, and a Mark6 recorder for all EVN, global, and geodetic VLBI observations. The Mark6 recorders provide 390 TB of storage capacity, and most of the recorded data are 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 Mark6 recorders that are used for observations with the VLBA and HSA. Mark6 modules to Socorro are still being shipped. Both VLBI backends and their recorders are controlled by the Field System (current release FS-10.1.0). 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.

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. But before this is finalized, tests within the EVN, GMVA, and together with the VLBA have to be performed to ensure that the correlation and calibration of data is as good as before. The operators have to also 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, see Figure 2)—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.

A larger project to upgrade the main axis control systems and encoders in azimuth and elevation has started. The contract with a company that specializes in radio telescopes has been signed, and the detailed design study has started. The actual change of the hardware requires an observational stop of several weeks and is currently foreseen for summer 2024. We will try to minimize the downtimes during the regular EVN sessions and the planned e-VLBI dates.