Effelsberg Radio Observatory 2019–2020 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 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 $\sim$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 (e.g., IVS, mm-VLBI, EVN, and Global VLBI).

Table 1 Telescope properties.

Name	Effelsberg
Coordinates	$6^\circ 53' 01.0''$ E, $+50^\circ 31' 29.4''$ 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	0.55mm 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	$\sim$ 2 arcsec

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Fig. 1 Aerial image of the Effelsberg radio observatory. Shown are the 100-m Effelsberg antenna and the institute's building (left of the antenna).

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, beside 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 2019 and 2020, the T2132, T2135, T2138, T2142, and T2P144 experiments were observed. 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 late 2019 Effelsberg started commissioning the new DBBC3 backend. In preparation of higher recording rates (up to 32 Gbps), wideband C-band observations at 4 Gbps were observed with the new DBBC3 backends at Yebes, Onsala, and Effelsberg. Yebes and Onsala used their VGOS antennas and Effelsberg used the linear polarization broadband C-band receiver. The fringe test was successful, but further tests got delayed due to required firmware developments and upgrades of the DBBC3 hardware.

Despite the restrictions caused by the worldwide Covid-19 pandemic in 2020, the Effelsberg observatory did not have to close completely. Due to suitable

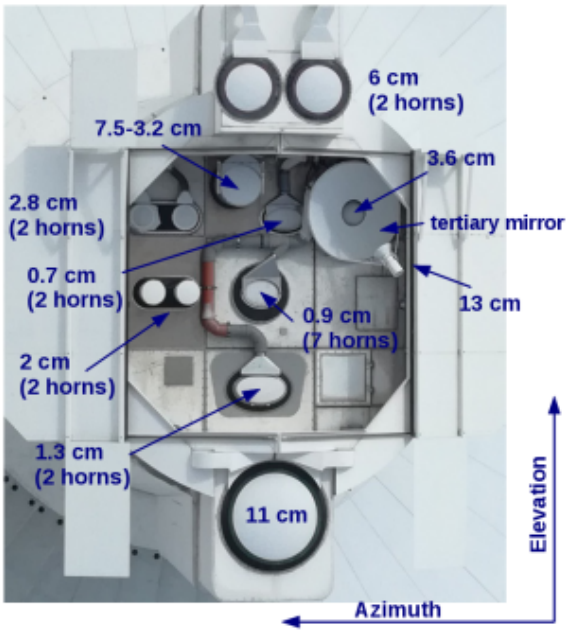

Fig. 2 Picture of the secondary focus cabin with several astronomical receivers, e.g., the new Ku-band with two horns, the geodetic S/X system with the 3.6-cm horn, and the tertiary mirror for the 13-cm horn.

safety measures, operations of the 100-m telescope were not interrupted.

In 2019, a new Ku-band receiver covering 12 to 18 GHz was installed in the secondary focus, providing an IF bandwidth of up to 4 GHz. Although not an IVS/EVN band, the receiver is regularly used for observations together with the VLBA.

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. The modules in one of the recorders are mounted as Raids, and each module of eight disks forms a tpye 5 Raid. One disk can fail without data loss. 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. Mark 6 modules for Socorro are still being shipped. Both VLBI backends and their recorders are controlled by the Field System (current release FS-9.13.2). 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 for Effelsberg is in the lab in Bonn and is being upgraded for the use with the BRAND receiver. It will be equipped with more and new boards and optical Ethernet inputs for the BRAND signals. The same hardware can be used for other receivers as well. The installation is delayed because the labs were closed for some time because of the pandemic restrictions.

Plans for a direct digitalization of the RF signals from the receivers in Effelsberg are becoming more concrete. The same digitizers that are used for Meerkat digitize up to 3 GHz at the receiver and the full band at 12 or 14 bit is streamed over 40 Gbps Ethernet using the Speed protocol to the software backend. The digital lab is developing a software backend on a GPU cluster. It currently supports single dish continuum and spectroscopy observations in full Stokes and pulsar observations. A basic support for VLBI VDIF is implemented and a first zero baseline test to the DBBC2 yielded fringes.

To use the down conversion capabilities of the DBBC3, it is planned to send the digitized band from the GPU cluster directly into the DBBC3 for further processing. This should provide the best compatibility with the current VLBI operation.