Effelsberg Radio Observatory 2015–2016 Biennial Report

Uwe Bach, Alex Kraus

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 ∼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., ν >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 etc.).

Max-Planck-Institut für Radioastronomie, Bonn, Germany

Effelsberg Network Station

IVS 2015+2016 Biennial Report

Table 1 Effelsberg 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

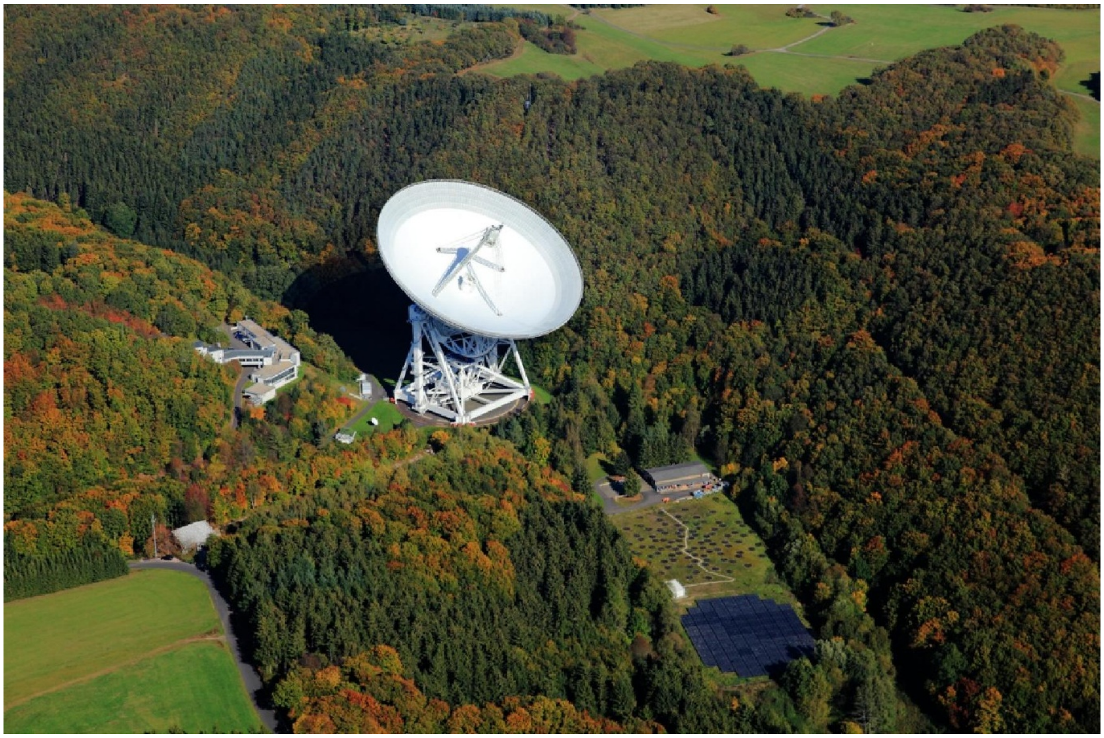

Fig. 1 Aerial image of the Effelsberg radio observatory. Shown are the 100-m Effelsberg antenna and the institute's building (left of the antenna). Effelsberg hosts also a station of the European Low Frequency Array (LOFAR), seen in the lower part of the picture.

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. **Thomas Georgi**, who was involved in schedule and disk management and shipping for several years, retired in January 2017. His duties will be taken over by two of the telescope operators, **Markus Keseberg** and **Peter Vogt**.

3 Activities during the Past Years

Effelsberg has participated regularly in the EUROPE IVS sessions since 1991. In 2015 and 2016, the experiments EUR135, EUR138, EUR142, and EUR144 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. Since 2011, the Russian Astro Space Center has been operating a 10-m space radio antenna on board the satellite SPEKTR-R (RadioAstron) to perform VLBI observations. Effelsberg is highly involved in the ground based support of this mission, and 296 of a total of 428 VLBI observations in 2015 and 208 of 368 observations in 2016 were connected to RadioAstron observations.

Two Mark 6 recorders have been installed for data acquisition of the DBBC2. The two recorders are equipped with large 32 TB or 64 TB diskpacks that stay in Effelsberg, providing a total local storage capacity of 256 TB. All recorded data is e-transferred via the e-VLBI network to the correlators in Bonn, at the ASC in Moscow, and at JIVE. For storage of

Effelsberg EVN data at JIVE, the MPIfR provided a 120 TB raid system for JIVE as well.

The K-band receiver (18 to 26 GHz) that was installed in the secondary focus in 2014 (see Figure 2) has been commissioned and is in regular use for VLBI observations of the EVN, HSA, and RadioAstron.

In 2015 a new broadband receiver for C- and X-band, covering a frequency range of 4 GHz to 9.3 GHz (7.5 cm to 3.2 cm), was installed in the secondary focus cabin (top left in Figure 2). Primarily, the receiver has been built for high sensitivity continuum observations and spectroscopy of molecule transitions, such as Formaldehyde and Methanol. With its two linear polarizations it is not naturally the first choice for VLBI observations, as most stations in VLBI record left and right-circular polarization (LCP and RCP) signals.

In December 2016, the regular real time e-VLBI observations were scheduled at 6.65 GHz, but the standard VLBI 6-GHz prime focus receiver box at Effelsberg was not available due to maintenance. To support the observations it was decided to use the new C+ receiver. The correlation and calibration of the recorded data was successful, and Effelsberg showed good and stable fringes from the start of the experiment. Further tests to convert the linear to circular polarization using a newly developed algorithm (Marti-Vidal et al. 2016, A&A, 587, p. 143) are in progress. Depending on the results, the new receiver might be an option for C-band observations in general.

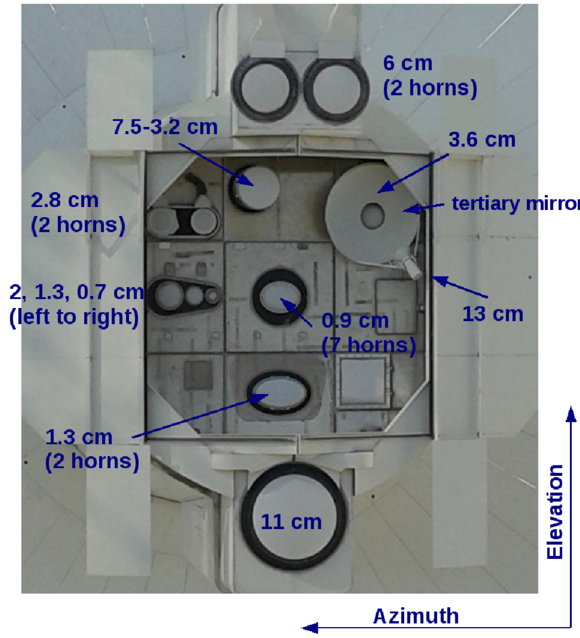

Fig. 2 Picture of the secondary focus cabin with several astronomical receivers, e.g. the new K-band with two horns, the new C/X-band, and the geodetic S/X system with the 3.6-cm horn and the tertiary mirror for the 13-cm horn.

4 Current Status

Effelsberg uses the DBBC2, Fila10G, and a Mark 6 recorder for all EVN, global, RadioAstron, and geodetic VLBI observations. Most of the recorded data is e-transferred to the correlators in Bonn, at the ASC in Moscow, and at JIVE. In addition there are two NRAO RDBEs and a Mark 5C recorder that are used for observations with the VLBA, HSA, and GMVA. Mark 5 diskpacks to Socorro are still being shipped. Both VLBI backends and their recorders are controlled by the Field System (current release FS-9.11.8). 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

Upgrades for several receiving systems are planned for 2017. The construction of a new Q-band receiver (38 to 50 GHz) was delayed because of unexpected problems in the RF chain but is planned to be installed in summer 2017. In parallel the installation of a Ku-band receiver (12 to 18 GHz) is planned as well. The new receivers will provide wideband IF signals of 2.5 GHz and 4 GHz bandwidth which can be used with the next generation of digital VLBI backends and recorders (e.g., DBBC3 and Mark 6) to record data at recording rates of up to 32 Gbps. The installation of a DBBC3 is planned for summer 2017.