“Quasar” VLBI Network Stations 2017—2018 Biennial Report

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Abstract The current status as well as activities in 2017 and 2018 of the “Quasar” VLBI Network Stations are considered.

1 General Information

The “Quasar” VLBI Network is a unique Russian astronomical instrument created at the Institute of Applied Astronomy of the Russian Academy of Sciences (IAA RAS). The main purpose of the “Quasar” Network is to improve the celestial and terrestrial reference frames and other data products essential for understanding the Earth’s environments. The network consists of three stations, including Svetloe in the Leningrad Region, Badary in Eastern Siberia, and Zelenchukskaya in the Northern Caucasus, and the Data Processing Center in St. Petersburg. Svetloe Observatory was the first to be put into operation in 1999, then Zelenchukskaya in 2002, and finally Badary in 2005. The baselines of the radio interferometer vary from 2,000 to 4,400 km. Each station is equipped with at least three co-located instruments of different techniques: VLBI, SLR, combined GNSS receivers, and the DORIS system [1]. All observatories are linked by optical fiber lines and are equipped with identical hydrogen Time Standards, Water Vapor Radiometers, and meteorological stations which are used for all types of observations.

Institute of Applied Astronomy of RAS

“Quasar” VLBI Network Stations

IVS 2017+2018 Biennial Report

The main instrument in each of the three observatories is a 32-m radio telescope (RT-32), which provides a completely automatic process of observing the radio sources and satellites in a radiometric or a radio interferometric mode. The main technical characteristics of the antennas are presented in Table 1. Each RT-32 radio telescope is equipped with highly sensitive receivers, providing signal amplification in the Ka (22.02–22.52 GHz), X (8.18–9.08 GHz), C (4.6–5.5 GHz), S (2.15–2.5 GHz), and L (1.38–1.72 GHz) frequency bands in both circular polarizations. A cooled low-noise amplifier is used at all frequency bands in order to achieve a less than 50 K noise temperature for the radio telescope and radiometer system. We use an R1002M data acquisition system with 16 converters developed in the IAA RAS [2] and the Mark 5B recording systems. Observational data are transmitted to the ARC correlator [3] in the Data Processing Center in the IAA RAS, which is capable of processing the data in Mark 5 format received simultaneously from three stations at an average rate up to 1,024 Mbps.

In 2015 two multi-band fast rotating antennas with a mirror diameter of about 13.2-m (RT-13) were installed at the Zelenchukskaya and Badary stations [4]. The inaugural ceremony of the third RT-13 radio telescope at the Svetloe observatory was held on September 19, 2018 (Figure 1). Table 2 presents some specifications of the RT-13 Antenna System, which meet all requirements of the VGOS program. Each RT-13 radio telescope is equipped with a specially designed receiver system. The main feature of this system is the cryogenic receiver unit that includes a cooled tri-band feed and low-noise amplifier. Such a design makes it possible to achieve high sensitivity to receive weak noise signals of the cosmic origin.

The feed design allows us to receive signals in three frequency bands: S (2.2–2.6 GHz), X (7.0–9.5 GHz), and Ka (28–34 GHz) in both circular polarizations simultaneously [5]. Wideband intermediate frequency (1.024—1.536 GHz) signals from the receiver outputs are digitized by the Broadband Acquisition System (BRAS). The BRAS digitizes the input signals, performs signal processing, and packs the output data into ten Gigabit Ethernet VDIF frames [6].

Since 2016 the IAA RAS has been conducting regular observations with RT-13 radio telescopes. During the observations the dataflow generated by BRAS (up to 16 Gbps) is routed via optical fiber line to a data transfer and recording system (DTRS). DTRS then transfers the data to the Russian Academy of Sciences FX (RASFX) correlator in the Data Processing Center in St. Petersburg. The registration and transmission procedures take place simultaneously. The RASFX correlator based on a hybrid-blade HPC cluster was designed in IAA RAS in 2014 and is now used to process wideband signals of RT-13 radio telescopes [7].

Table 1 Specifications of the RT-32.

Mount	alt-azimuth
Configuration	cassegrain
Subreflector scheme	asymmetrical
Main mirror diameter	32 *m*
Subreflector diameter	4 *m*
Focal length	11.4 *m*
Azimuth speed	1.0 $^\circ/sec$
Elevation speed	0.5 $^\circ/sec$
Limits by Az	$\pm 265^\circ$
Limits by El	$0^\circ - 85^\circ$
Axis offset	0.9 ± 1.0 *mm*
Tracking accuracy	± 10 *arcsec*
Surface accuracy (RMS)	0.5 *mm*
Frequency range	$1.4 - 22$ *GHz*
Polarization	LCP + RCP

2 Current Status and Activities

During 2017–2018 the RT-32 and RT-13 radio telescopes of the “Quasar” VLBI Network participated in both the IVS and domestic VLBI observations. Activities of the observatory are presented in Table 3 and Table 4. E-VLBI mode is used for the domestic sessions data transfer. Since 2015, the RT-13 radio telescope has participated in the following geodetic sessions:

- One-hour geodetic sessions in S/X bands for UT determination (R);
- Sessions performed simultaneously with RI sessions at RT-32 antennas with the same schedule (RI-RT13);
- 24-hour geodetic sessions in S/X bands for improving the position of the RT-13 antennas (24-h);
- 30-minute geodetic sessions in S/X/Ka bands for UT determination (S/X/Ka-TEST).

Fig. 1 The RT-13 antenna at the Svetloe observatory.

Table 2 Specifications of the RT-13.

Mount	alt-azimuth
Configuration	cassegrain
Subreflector scheme	ringfocus
Main mirror diameter	13.2 *m*
Subreflector diameter	1.48 *m*
Focal length	3.7 *m*
Azimuth speed	1.0 $^\circ/sec$
Elevation speed	0.5 $^\circ/sec$
Limits by Az	$\pm 245^\circ$
Limits by El	$6^\circ - 109^\circ$
Axis offset	-0.3 ± 0.5 *mm*
Operation	$24h/7d$
Tracking accuracy	± 15 *arcsec*
Surface accuracy (RMS)	$0.3 - 0.1$ *mm*
Frequency range	$2 - 40$ *GHz*
The surface efficiency	> 0.7
Polarization	LCP + RCP

Table 3 VLBI observations with the RT-32 radio telescopes.

	Sv		Zc		Bd	
Sessions	2017	2018	2017	2018	2017	2018
IVS-R4	23	19	17	16	24	21
IVS-R1			2		2	
IVS-T2	5	3	5	7	6	6
EUROPE	1	1	2	1	1	4
EURR & D		4		4		
IVS-CONT17			15		15	
AUA	3		2		1	
AOV		1		1		1
IVS-Intensive	18	18				
RuE	40	40	40	40	40	40
RI	32	35	340	340	358	349

Table 4 VLBI observations with the RT-13 radio telescopes.

	Sw		Zv		Bv	
Sessions	2017	2018	2017	2018	2017	2018
R			1298	1401	1298	1401
RI-RT13			331	355	331	355
24-h		1	8	3	8	3
S/X/Ka-TEST			256	236	256	236

3 Staff

The list of the staff members of the "Quasar" VLBI network stations in 2017+2018 is given below.

3.1 Svetloe

- Prof. Ismail Rahimov — observatory chief;
- Vladimir Tarasov — chief engineer;
- Tatiana Andreeva — engineer;
- Alexander Isaenko — engineer.

3.2 Zelenchukskaya

- Andrei Dyakov — observatory chief;
- Dmitry Dzuba — FS, pointing system control;
- Anatoly Mishurinsky — front end and receiver support.

3.3 Badary

- Valery Olifirov — observatory chief;
- Alex Maklakov — chief engineer, FS, pointing system control;
- Roman Kuptsov — engineer.

4 Future Plans

In the next two years all stations of the "Quasar" VLBI network will continue to participate in IVS and domestic VLBI observations, upgrade the existing equipment, and replace obsolete equipment.

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