

“Quasar” VLBI Network Stations Report

Dmitry Ivanov, Alexander Ipatov, Dmitry Marshalov, Sergey Kurdubov, Gennady Ilin

Abstract This report provides a comprehensive overview of the status and principal activities of the “Quasar” VLBI Network Stations during 2023–2024. The report covers technical upgrades, new scientific services, and the participation of the network in both international and national VLBI programs.

1 General Information

The “Quasar” VLBI Network constitutes a unique astronomical infrastructure of the Russian Federation operated by the Institute of Applied Astronomy of the Russian Academy of Sciences (IAA RAS) [1]. It includes three operational observatories—Svetloe, Badary, and Zelenchukskaya—equipped with RT-32 and RT-13 radio telescopes. Each site also hosts a GNSS receiver, a satellite laser ranging (SLR) system, a water vapor radiometer (WVR), and a meteorological station. The fundamental technical parameters of the RT-32 and RT-13 antennas remain consistent with those reported in earlier biennial reports [2].

The network is undergoing expansion with the construction of a fourth observatory near Ussuriysk in the Russian Far East. A new VGOS RT-13 telescope, fully compliant with the specifications of the existing RT-13 facilities, is currently being assembled. In the subsequent phase, the site will also host a Sazhen-TM satellite laser ranging system, a second RT-13 antenna, and auxiliary geodetic instruments. This co-location of

IAA RAS

IAA Network Stations (“Quasar” VLBI Network Stations)

IVS 2023+2024 Biennial Report

VLBI, SLR, and GNSS technologies will ensure compliance with international standards in space geodesy and significantly enhance geodetic accuracy. During 2023–2024, significant efforts were directed toward modernizing observatory infrastructure and strengthening operational reliability.



Fig. 1 Svetloe Observatory.

2 Staff

The personnel structure at the “Quasar” VLBI observatories has remained unchanged since the 2019–2020 reporting period [3].

3 Current Status and Activities

During 2023–2024, the RT-32 and RT-13 telescopes of the “Quasar” VLBI Network actively participated in both IVS observing sessions and national VLBI pro-

grams. Tables 1 and 2 summarize the activities at each site.

Table 1 VLBI observations with the RT-32 radio telescopes.

Sessions	Sv		Zc		Bd	
	2023	2024	2023	2024	2023	2024
IVS-R1	13	7	12	9	13	9
IVS-R4	15	13	22	29	22	30
IVS-T2/IVS-T2P	1	1	1	1	1	1
CRF	–	–	–	–	–	–
IVS-Intensive	11	10	–	–	–	–
RI	159	31	299	355	324	353

Table 2 VLBI observations with the RT-13 radio telescopes.

Sessions	Sw		Zv		Bv	
	2023	2024	2023	2024	2023	2024
R	2030	2011	2015	2015	2022	2013
24-hour	10	10	10	10	10	10
S/X/Ka	2023	2024	2023	2024	2023	2024

At Svetloe Observatory, essential infrastructure upgrades were performed, including reinforcement of the RT-32 foundation and replacement of five azimuth track segments. These efforts ensured operational stability and long-term reliability.

3.1 The Ussuriysk Station

The establishment of the co-location station at the Ussuriysk Observatory of the IAA RAS is currently in progress. The equipment for both the initial and subsequent phases has been defined. In the first phase, the primary instrument will be a fully steerable VGOS radio telescope with a main reflector diameter of 13.2 meters, closely matching the specifications of the RT-13 radio telescopes already operating in the “Quasar” VLBI Network. Complementary instruments will include a multi-system GLONASS/GPS/Galileo/BeiDou receiver, a water vapor radiometer, and a meteorological complex.

In the second phase, the facility is planned to host an additional RT-13 telescope, a Sazhen-TM satellite

laser ranging system, and auxiliary geodetic instrumentation. This co-location of VLBI, SLR, GNSS, and WVR technologies will enable high-precision geodetic measurements and ensure compliance with international standards for space geodesy.

The existing infrastructure of the Ussuriysk Observatory is being modernized to support the integration of these instruments. Design work has been completed, and manufacturing of major components for the RT-13 antenna is underway, including the reflector support structure, surface panels, load-bearing elements, the moving cabin, and the antenna foundation. Development of the receiving and recording systems for the new telescope is also in progress. The assembly, installation, and commissioning of the first-phase instruments are scheduled for the 2027–2028 period.

3.2 The Pulsar Ephemeris Service

The IAA RAS has established a dedicated monitoring service for the Crab pulsar (B0531+21), based on systematic observations of its radio giant pulses with the RT-13 radio telescopes of the “Quasar” VLBI Network [4]. Since mid-2023, the service has conducted regular observations in the S and X bands using advanced data registration systems and dedicated processing software. Major methodological improvements include optimized algorithms for dispersion measure estimation and precise determination of pulse arrival times, ensuring high accuracy and reliability.

Over a period of 1.5 years, the service has produced weekly ephemerides of outstanding precision; measured arrival times deviate from the Jodrell Bank reference values by approximately 100 microseconds RMS, while pulsar periods agree within about 2.5 picoseconds [5]. These results clearly demonstrate the advantage of giant-pulse timing compared with traditional average-profile methods, which are more strongly affected by scattering.

At present, the Crab pulsar ephemeris service delivers high-quality data that are valuable for pulsar timing research, instrumental calibration, synchronization of geographically distributed observatories, and prospective applications in deep-space navigation.

3.3 Laser Ranging System

In 2024, the laser ranging system at the Badary Observatory was upgraded through the installation of a new laser emitter with improved pulse characteristics. The reduction of the laser pulse width to 30 ps, combined with an upgraded time measurement system, has more than doubled the accuracy of normal point measurements. This modernization represents the second upgrade of a laser ranging system within the “Quasar” VLBI Network over the past five years, significantly enhancing the contribution of the network to high-precision space geodesy.

3.4 Multifunctional Digital Backend

In line with the development plans [6], the “Quasar” VLBI Network radio telescopes have been fully equipped with the Multifunctional Digital Backend (MDBE). In 2023, the original 8-channel MDBE systems were installed on the RT-13 radio telescopes at the Zelenchukskaya and Badary observatories, replacing the previously used BRAS units. As a result, all RT-13 observations within the “Quasar” VLBI Network are now carried out using identical MDBE systems.

At the same time, modified 4-channel MDBEs with integrated intermediate-frequency distribution modules were deployed on the RT-32 telescopes. These systems operate in parallel with the standard P1002M signal conversion equipment, thereby maintaining compatibility while providing expanded functionality.

The release of new MDBE firmware for both VLBI and single-antenna observing modes has significantly increased system flexibility (see the IAA Technology Development Center Report for 2023–2024). This upgrade has enabled reliable radiometric observations and calibration procedures under elevated RFI conditions in the L and S bands, through the use of spectral-selective operating modes.

4 Future Plans

In the short term, priority will be given to accelerating the establishment of the co-location station at Usuriysk. Over the next biennium, all observatories of the “Quasar” VLBI Network will continue their active participation in both IVS sessions and national VLBI programs. Sustained technical support will be provided to ensure the reliability of existing facilities, while modernization efforts will focus on upgrading and gradually replacing obsolete equipment. These initiatives will further enhance the long-term performance, resilience, and scientific output of the network.

References

1. N. Shuygina, D. Ivanov, A. Ipatov et al., ‘Russian VLBI network “Quasar”: Current status and outlook’, in: *Geodesy and Geodynamics* 10 (2019), DOI: 10.1016/j.geog.2018.09.00, pp. 150–156.
2. D. Ivanov, A. Ipatov, D. Marshalov, G. Ilin, ‘“Quasar” VLBI Network Stations Report’, in: *International VLBI Service for Geodesy and Astrometry 2019+2020 Biennial Report*, edited by D. Behrend, K. L. Armstrong, and K. D. Bayer, NASA/TP-20210021389, pp. 100–104, 2021.
3. D. Marshalov, E. Nosov, G. Ilin, E. Khvostov, V. Bykov, A. Isaenko, V. Stempkovskiy, A. Shishikin, ‘IAA Technology Development Center Report for 2019 – 2020’, in: *International VLBI Service for Geodesy and Astrometry 2019+2020 Biennial Report*, edited by D. Behrend, K. L. Armstrong, and K. D. Bayer, NASA/TP-20210021389, pp. 279–282, 2021.
4. S. Kurdubov, D. Marshalov, ‘Probing the New Generation Geodetic Radio Telescopes for FRB Observations’, *JAL*, 11, 2250015. doi:10.1142/S2251171722500155, 2022.
5. I. Bezrukov, I. Gayazov, A. Dyakov, D. Ivanov, A. Ipatov, S. Kurdyubov, D. Marshalov, et al., ‘Observations of giant pulses from B0531+21 at the Institute of Applied Astronomy’, *maeu.conf*, 74. doi:10.26119/VAK2024.008, 2024.
6. D. Marshalov, E. Khvostov, M. Zotov et al., ‘IAA Technology Development Center Report for 2021–2022’, in: *International VLBI Service for Geodesy and Astrometry 2021+2022 Biennial Report*, edited by K. L. Armstrong, D. Behrend, and K. D. Bayer, NASA/TP-20230014975, pp. 279–282, 2023.