IAA Technology Development Center Report for 2019–2020

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Abstract The main activities of the IAA Center for Technological Development in 2019–2020 were focused on the work on upgrading equipment for the 32-m radio telescopes and creating equipment for the 13-m VGOS-compatible antennas. The presented report provides a brief overview of these activities.

1 The Electric Drive Pointing System of the 32-m Radio Telescopes

The automated pointing system is an integral part of the antenna system of the RT-32 radio telescope. The automated control system is a hardware and software complex for controlling the antenna drives. In the process of modernization, the control computers were updated, and the coordinate measuring system of the main mirror and subreflector was improved. A new subsystem for collecting data on the electric drive (DCS) was added.

1.1 Improving the Characteristics of the Coordinate Measurement Subsystem

Coordinate conversion units (CCUs) for four main mirror angle encoders (two main and two backup) and four counter reflector angle encoders were replaced. The CCUs of the subreflector were moved to the overmirror cabin from the electric drive room, significantly reducing the length of the analog lines. The CCUs of the main mirror encoders remained in their places, next to the encoders. RS-485 and Ethernet interfaces are used to transfer data to the control system. The bit width of the new coordinate conversion units has been increased from 20 to 24 for the main mirror and from 14 to 16 for the subreflector (Figure 1). The data refresh rate is 125 Hz.

1.2 New Subsystem for Collecting Data on the Antenna System Electric Drive

The data collection system provides the RT-32 motion control system with additional data on the components of the electric drive. The DCS is designed as an independent device, consisting of a standard 19-inch rack with controllers located in it and separate data collection units—a block of current sensors and a block of tachogenerators. The system measures in real time the electrical parameters of the RT-32 antenna movement and provides processing and storage of the data of the electric drive, thermal stabilization of the angular coordinate pickup encoders, and the RT-32 antenna electric drive rooms (Figure 2). The DCS is built on the basis of two programmable logic controllers: Aries PLC110-60K.M and Aries SPK110.

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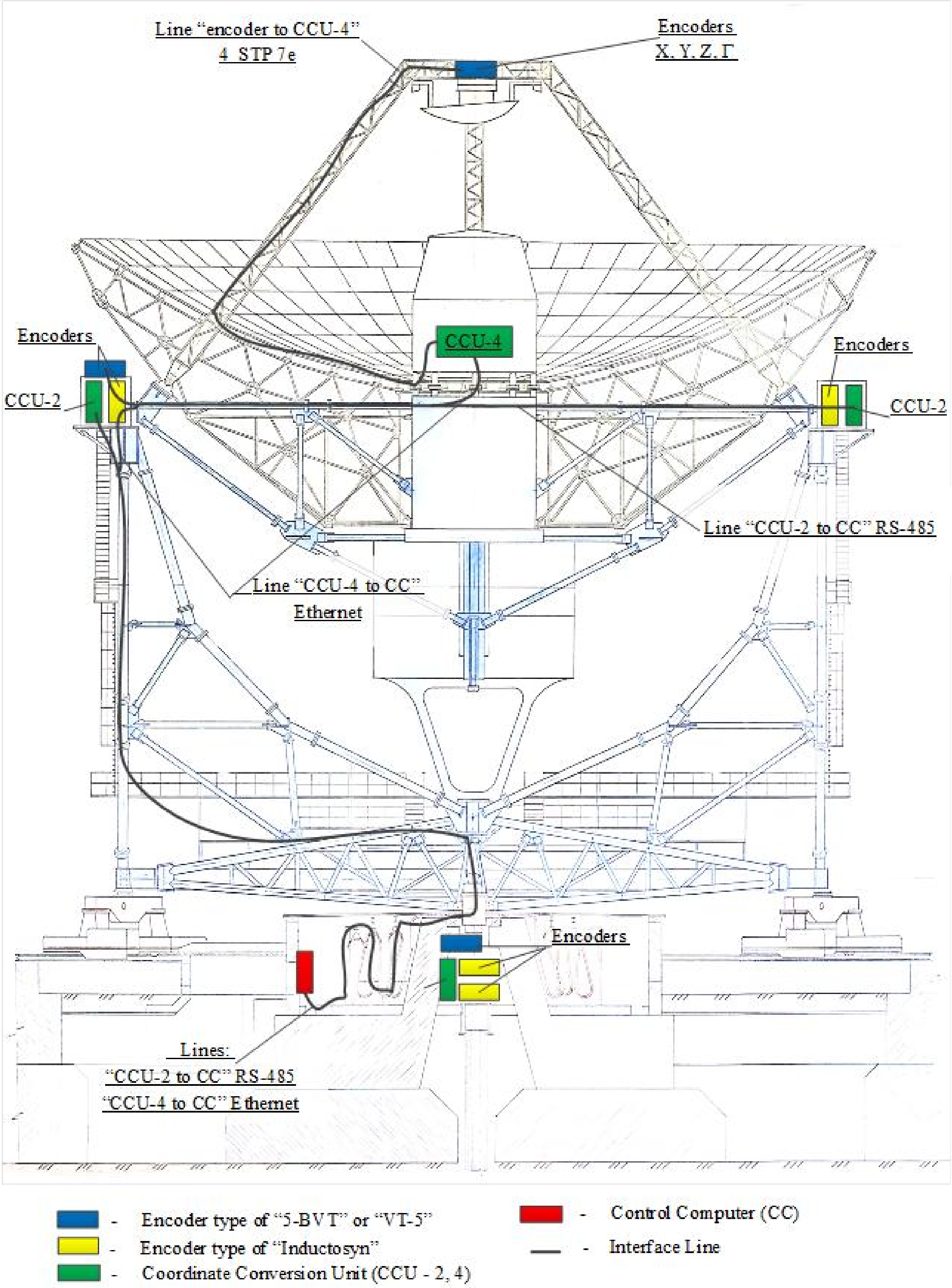

Fig. 1 New CCU blocks and their location on the antenna.

Fig. 2 General view of the DCS rack.

1.3 The Electric Drive Control Computer and Software

An industrial computer with up-to-date components that supports modern operating systems and has sufficient performance to implement the assigned tasks in the software part is used as a hardware basis. The new control software implements all previously developed control algorithms, provides for work with new measuring equipment, and also implements additional functions. The modernized software provides new opportunities, the demand for which arose during the long-term operation of RT-32 radio telescopes:

- optimization of the movement of the antenna in the high speed mode to reduce the loads on the mechanical structures,
- smooth passage of speed limit zones,
- automatic selection of the control voltage for the beginning of the movement of the antenna at a given coordinate, and
- correction of the parameters of the tracking algorithm for tracking sources, depending on the current values of the azimuth and elevation coordinates of the antenna.

The modernization of the automated control system of the RT-32 radio telescope made it possible to improve the operational and technical characteristics, which contributes to a more efficient use of the radio telescope for radio astronomy observations, as well as when servicing the radio telescope and ensuring its readiness for operation.

2 Ultra-Wide Band Receivers Upgrade

The Ultra-Wide Band (UWB) receiving system for the RT-13 radio telescopes of the “Quasar” VLBI network was designed at the IAA RAS [1]. The UWB receiver system operates on dual linear orthogonal polarizations in the 3–16 GHz band. In 2019–2020, the equipment was built and tested. The radio telescopes at the Badary and Svetloe stations were equipped with UWB receivers, and test observations were made. In order to widen the bandwidth of the initial UWB receiver design (from 1024–2048 MHz to 48–2048 MHz), the following parts of the receiver’s Frequency Conversion Unit were replaced: the first Intermediate (IF) bandpass waveguide filter, the second IF filter, and the output amplifier. The Svetloe station’s RT-13 radio telescope has undergone the upgrade mentioned. Badary and Zelenchukskaya are scheduled for 2021–2022.

3 Multifunctional Digital Backend (MDBE)

The MDBE is intended for equipping all radio telescopes of the “Quasar” VLBI network with unified, both legacy- and VGOS-compatible digital backends [1]. The system consists of up to 12 DSP units, connected by backplane with the Synchronization and Control Unit. Each DSP unit digitizes the input IF signal using the 4096 MHz sampling frequency, performs necessary digital processing in an FPGA, and outputs the data through a 40 Gbps or 10 Gbps fiber optical link. Table 1 presents basic parameters of the MDBE.

Table 1 Basic parameters of the MDBE.

Number of IF inputs (DSP units)	up to 12
Input frequency range	0.5–2048 MHz
Sampling frequency	4096 MHz
Synchronization	5/10/100 MHz 1 PPS (two inputs) 1 PPS monitor
Outputs per DSP unit	1x10 Gbps (SFP+) 1x40 Gbps (QSFP)
Output format	VDIF in raw Ethernet frames VDIF in UDP packets
Calibration features	PCAL extractor and analyzer Inner delay variation control Noise calibration
Control interface	10/100/1000 Ethernet (Fiber or copper)
Basic VLBI modes	Wideband channels: 2048, 1024, or 512 MHz DDCs mode: 0.5, 2, 4, 8, 16, or 32 MHz
Size	19” 3U case + 1U fan unit

Like the previous backend, the BRAS [2], the MDBE can be located in the focal cabin of the antenna, near to the receivers. As there is no direct access to the system for the staff while an observation is in progress, the MDBE provides full remote control of the system. The control features include measuring voltages, currents, fan speeds, and temperatures at key points of the system. Each DSP unit logs signal power, statistics of two-bit output data, the extracted PCAL signal (in the time domain), estimation of its group delay, and phases and amplitudes of the tones. The MDBE has an embedded calibration system that allows control of the phase/delay stability of the clock synthesizer, ADCs, and clock distributors.

Since September 2020, the MDBE has operated at the Svetloe observatory for the domestic observation program. Figure 3 presents the view of the MDBE installed in the focal cabin of the RT-13 radio telescope. Most of the time the MDBE is used in the 512 MHz bandwidth mode, although it was also tested in the 32 MHz mode (VGOS mode) in joint observations with the Onsala twins. In 2021, the next two MDBEs will be produced. The team is also working on improving the firmware and adding new features. The detailed description of the MDBE can be found in the paper “Multifunctional Digital Backend for Quasar VLBI Network”, which is expected to be published in the Journal of Instrumentation in 2021 (it has been accepted for publication, but the DOI has not been issued yet).

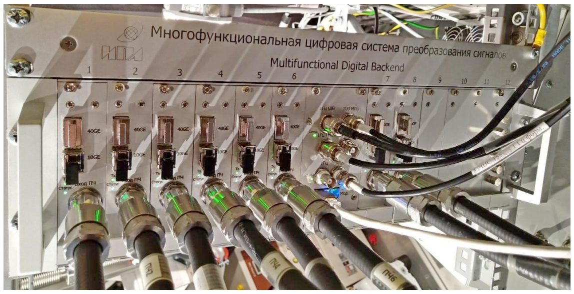

Fig. 3 The MDBE installed in the focal cabin of the RT-13 radio telescope at the Svetloe observatory.

References

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2. E. Nosov, D. Marshalov, A. Melnikov. “Operating Experience with the Broadband Acquisition System on the RT-13 Radio Telescopes”. *IVS 2016 General Meeting Proceedings*. Edited by D. Behrend, K. D. Baver, and K. L. Armstrong. NASA/CP-2016-219016. pp. 53–57, 2016.