IAA Technology Development Center Report 2014

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Abstract This report discusses the aspects of the IAA RAS Technology Development Center in 2014.

1 Tri-band Receiving System for the Interferometer

The interferometer receiving system [1] is applied at the IAA RAS stations “Zelenchukskaya” and “Badary”. It operates in S-band (2.2-2.6 GHz), X-band (7.0-9.5 GHz) and Ka-band (28-34 GHz) with a multiband feed. The design of the feed gives the possibility for cooling and operating with dual circular polarization simultaneously. All receiver units are placed in the focal container (Figure 1) which is mounted at the secondary focus of the antenna. The container is specially designed for the 13.2-m dish and provides rigid airtight housing. The design of the focal container makes cool air circulation available inside.

The multiband feed and low noise amplifiers are placed in a special cryostated container (cryostat) (Figure 2) and are cooled by a cryogenic system of closed cycle to a temperature at the level of hydrogen. All the equipment of the cryostat for both polarizations of all three bands is tightly placed in the space between the feed and coldhead flange. The S- and X-band signal lines are coaxial, and Ka-band is fully waveguide. The equipment is screened with the metal heat shield. The infrared filter is placed between the feed and the vacuum window. It is made of 0.1 mm teflon film. Cooling with the use of a Sumitomo closed cycle refrigerator takes seven hours. The measured feed physical temperature is about 26 K, and the temperature of the amplifiers is about 20 K.

Fig. 1 Tri-band receiver focal container (without housing).

The external vacuum window is closed with radio transparent covering, which consists of two parts. The external sealing surface is made of Mylar film 0.05 mm thick. The film is supported by the inner layer of solid foam polyester with 17 mm thick. The covering is blown with warm air through a special nozzle to protect from atmospheric precipitation.

It is then focused with antenna electromagnetic waves that get to the feed inside the cooled unit through

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Fig. 2 Cryostat assembly: equipment, container with vacuum window, thermal screen.

the radio-transparent cover. They are separated to three bands and two circular polarizations, mixed with the noise and phase calibration signals, and amplified with cooled LNAs. Almost all of the equipment located inside the cryostat is cooled to a temperature near 20 K, significantly reducing noise temperature of the "radio telescope-radiometer" system.

Amplified signals are directed to the intermediate frequency converter units. These units provide sub channel splitting and frequency conversion to the IF band of the digital acquisition system. Sub channels to record are selected by the commutator unit. The calibration unit contains an adjustable noise source for each band. External picoseconds pulses for the phase calibration are used, and the calibration unit has a special input for them.

For measuring the noise temperature of the cooled unit, special broadband-matched loads were applied. These wide-aperture loads are enclosed in a Dewar and can be filled with liquid nitrogen, providing "cold" reference points ("hot" points can be achieved with an empty Dewar). There are loads for lab tests (Figure 3) and loads for telescope measurements (Figure 4).

The first results of the total noise temperature measurements for the stand-alone receiving system and the complete radio telescope are the following. X-band has the best results — 15 K for the receiver, 25 for the radio telescope. Ka-band with improved LNAs has the noise temperature 50 K and 75 K accordingly; this is 40% lower than the results with the first samples of LNAs. The measurements of noise temperature in the S-band are obstructed by the RFI even in a far location. The approximate result is 20 K and 35 K. The difference between left and right circular polarization channels is insignificant.

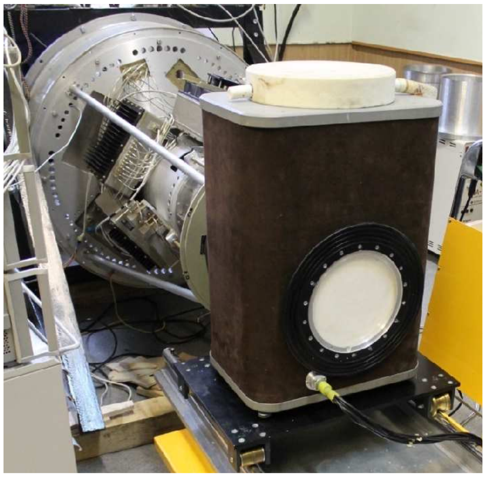

Fig. 3 Laboratory receiver calibration with load.

Fig. 4 Telescope receiver calibration with load.

2 Putting BRAS into Operation

The eight-channel digital Broadband Acquisition System (BRAS) was developed and manufactured by IAA RAS [2, 3]. Key features of BRAS are summarized in Table 1.

On September 4, 2014 the first test observations (Ru-TEST 108) with BRAS were carried out on radio telescopes RT-32 at the "Badary" and "'Zelenchukskaya" observatories. BRAS was connected to the X-band receiver outputs at both stations. Mark 5C was

Table 1 Key features of BRAS.

Number of channels	8
IF inputs	1024 - 1536 MHz
Channel bandwidth	512 MHz
ADC	8 bits, F_s=1024 MHz
Output samples width	2/8 bits
Total data rate	16/64 Gbps
Data frames format	VDIF
VDIF payload size	1000, 1024, 1280, 1600, 2000, , 8000, 8192 bytes
Output interface	10G Ethernet, X2 transceiver, fiber/copper
Output headers modes	Pure Ethernet frame, Ethernet+IP, Ethernet+IP+UDP
Control interface	10/100 Ethernet
Sync signals	5/10/100 MHz, 1 PPSx2
Automatic gain control	For each channel, 31 dB
Analysis features	Signal power, 2-bit data statistics, PCAL extraction, Both 8 and 2-bit signal capture (1024 samples), Spectrum analysis of captured signal and extracted PCAL (implemented in software), 1 PPS int.-ext. delay monitoring
Telemetry	Power circuit current, temperature of PCBs and ADC
Power consumption	75 W
Size	19” case 483x314x242 mm (WxHxD)

used as the recording system. The recording was carried out in a single 512 MHz frequency band located from 8592.00 to 9104.00 MHz. All scans were transferred through the network to St. Petersburg and processed in the IAA correlator [4]. In this session, the 24 sources from the RFC 2012c catalog with a flux density from 0.6 Jy to 7.6 Jy were observed. Good fringes were received for each of the observed sources. The fringe quality is good enough for high-precision group delay measurement (see Figure 5).

The first BRAS sample was mounted on the 13-m radio telescope (RT-13) at the “Badary” observatory (see Figure 6). We are going to put BRAS into operation at the RT-13 “Badary” and “Zelenchukskaya” observatories in 2015.

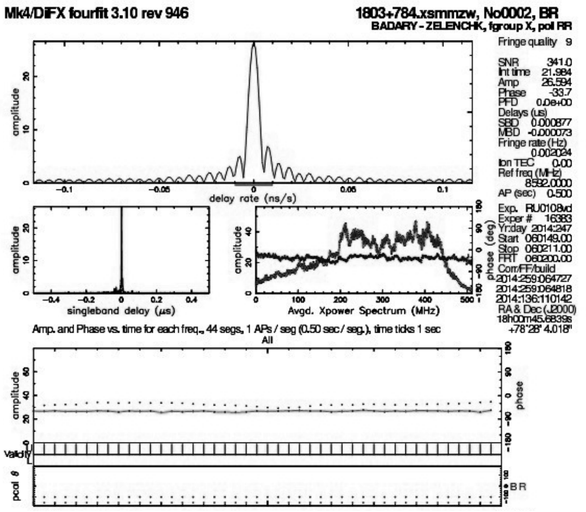

Fig. 5 Fringe plot for scan of 1803+784 source, X-band, BRAS, and Mark 5C.

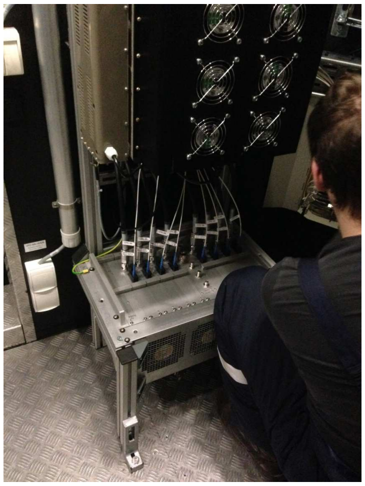

Fig. 6 The BRAS on the RT-13 radio telescope at the Badary observatory.

3 Multipurpose Digital Backend (MDBE)

The development of BRAS gave the required experience to design a more complex and advanced backend - Multipurpose Digital Backend (MDBE). MDBE is intended to upgrade the backends of “Quasar” network antennas and allow it to operate both in conventional downconverter mode for compatibility with existing data acquisition systems and in broadband channel mode. The MDBE has two 4-channels ADC with 1024 MHz sampling frequency giving overall eight channels with 512 MHz bandwidth (Figure 7). By using ADC interleaving mode, the MDBE can combine adjacent channels and operate in 4-channel mode with 1024 MHz bandwidth per channel. The powerful FPGA with an embedded dual-core ARM processor used in the MDBE can perform quite complex digital signal processing. Along with remote firmware reloading supported by MDBE, it allows utilization of the device for many radio astronomical tasks besides conventional VLBI applications. For example, the spectrometer and radiometric backend modes are planned to be implemented. That is, the MDBE can combine all required backends in one device which can greatly simplify signal chain structure (Figure 8). The MDBE will be located in the focal cabin of the antenna which allows elimination of long coaxial cables and auxiliary equipment used for signal transmission from antenna to control room and replacement with fiber optics. Digital signals transmitted through fibers are insensitive to EMI, frequency response distortions, group delay variations, and so on. Using it can improve the quality of VLBA data.

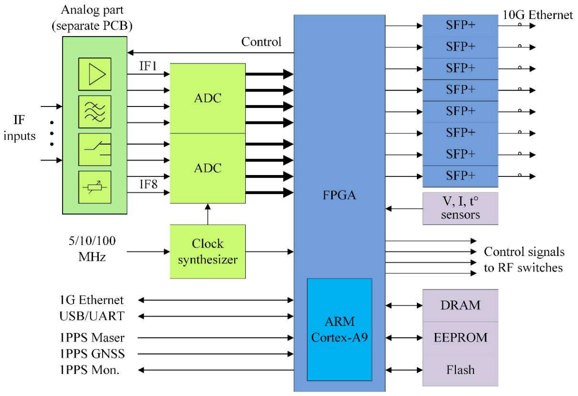

Fig. 7 Multipurpose Digital Backend structure.

The data recording system based on the COTS components will be used to buffer the data [5]. It is also possible to copy data from the data recording system to Mark 5B in the case that the e-VLBI mode is unavailable. MDBE is designed to be functionally compatible with existing VLBI equipment to support operations in international observations.

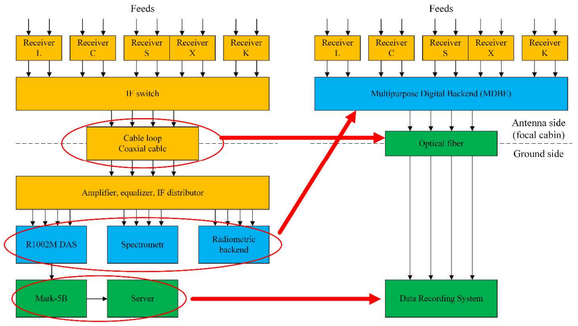

Fig. 8 Planned upgrade of signal chain for RT-32 antennas.

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