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Continuum spectrum receiving complexes on the RATAN-600 radio telescope

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Abstract. The results of many years of work on the creation and modernization of the continuum spectrum receiving complexes on the RATAN-600 radio telescope are presented. These complexes are located in the cabins of four secondary mirrors of the radio telescope, three of which can simultaneously conduct observations for three independent programs using separate sectors of the radio telescope primary mirror. To date, a total of 23 radiometers (35 frequency channels) operate on the radio telescope around the clock and all year round. The receiving complexes operate according to technical and scientific programs such as observation of individual objects or round-the-clock sky surveys. The main attention is payed to increasing the sensitivity and long-term stability of the radiometers. With a large number of receivers, the operational characteristics are also important (ease of maintenance, mean time to failure, dimensions, power consumption). One of the tasks being solved is the problem of noise protection in the operating frequency ranges as well as active noise reduction in the decimeter wavelength ranges. The groundwork and prospects in this direction are presented. The immediate plans for the commissioning of new radiometers are also introduced.

Keywords: instrumentation: detectors

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1 Introduction

The RATAN-600 radio telescope currently operates as three antenna systems: the Northern Sector, the Southern Sector (or the Southern Sector with a flat mirror) and the Western Sector. Each antenna system is equipped with its own set of receiving equipment.

RATAN-600 is a transit instrument. The observations are carried out in the mode of radio source passage at a certain azimuth. The primary horns of the radiometers are located on the focal line of the secondary mirrors, making up a "multicolor" receiving system with a range of recorded frequencies up to five octaves (1–32 GHz).

2 Complexes of continuum radiometers

The currently existing continuum radiometer complexes are presented in Table 1. They are located at four secondary mirrors ("feed cabins" 1, 2, 3, and 5) of the radio telescope.

The continuum radiometers of the centimeter waves on RATAN-600 are modular radiometers (one radiometer is one microwave module). We described this design earlier in Berlin et al. (2012); Tsybulev et al. (2018, 2022a,b). All modular uncooled radiometers are made based on modern circuit technologies using low-noise transistors, precise low-noise voltage regulators, and modern microwave components. Therefore, they show the lowest possible noise even in the absence of cooling. For example, our C band radiometer demonstrates a root mean square of noise in the low-frequency band 0–1 Hz, equal to 0.25 millikelvin. Also it demonstrates the lowest $1/f$ noise (see Tsybulev et al. 2018). While the former says about the high sensitivity of the radiometer on short timescales, the latter means preserving this sensitivity over sufficiently long time intervals and the long-term stability of the radiometer.

The modular architecture of the radiometers also means that it has a minimum number of microwave connections. It also improves the long-term stability and performance of the receivers. We also work on reducing the energy consumption of the radiometers. This is not so much to save energy as, mainly, to reduce the receiver self-heating. This approach reduces the thermal component of $1/f$ noise.

Also, the modular design means the small size of radio astronomy receivers. RATAN-600 does not have a focal point, like paraboloids, but a focal line to accommodate the input horns of the receivers. This makes it possible to place a sufficiently large number of radiometers on the focal line for quasi-simultaneous observation of radio emission in a wide frequency band. The small size of the radiometric modules helps successfully implement this task. For example, secondary mirror number 1 con-

Table 1. The RATAN-600 continuum radiometers. The last four rows correspond to one (out of four) multichannel radiometer.

Center frequency, GHz	Bandwidth, MHz	Flux density sensitivity, mJy	HPBWx, arcsec
Feed cabin No. 1			
30	5000	100	9
22.25	2500	50	11
14.4	2000	25	13
11.2	1000	15	15.5
8.2	1000	10	22
4.7	600	5	45
2.25	80	40	80
1.25	60	200	110
Feed cabin No. 2			
30	5000	200	11
22.25	2500	95	16.5
14.4	2000	50	18
11.2	1000	30	23
8.2	1000	20	30
4.7	600	10	53
Feed cabin No. 3			
30	5000	200	11
8.2	1000	20	30
4.7	600	10	53
Feed cabin No. 5			
14.4	2000	50	11
2.25	80	40	80
4.475	150	10	35
4.625	150	10	35
4.775	150	10	35
4.925	150	10	35

tains eight radiometers, which allow observations in fairly wide bands (5–15%) in the range from 1 to 32 GHz (five octaves).

We have paid great attention to the stabilization of supply voltages, stabilization of the currents in solid-state noise generators, galvanic isolation of power and control circuits, etc.

The data acquisition system for all the continuum radiometers is presented in Tsybulev (2011). Its architecture and software are unified for all the radiometers. The system is easily scalable: when new radiometers are added, new modules of the data logging system are added as well. Also, the system can operate in both low-speed ($\sim$64–512 Hz) and high-speed (up to 16 kHz) modes.

3 Decimeter-wave radiometers

Observations in the decimeter ranges—1245 MHz (bandwidth $B = 50$ MHz) and 2250 MHz ($B = 80$ MHz)—are complicated by severe interference conditions. We currently work on upgrading the decimeter radiometers to enable active rejection of the interference. Two dual-band horn antennas have been designed and manufactured for us for this task. Both antennas have two identical ranges: 1450 MHz ($B = 100$ MHz) and 2250 MHz ($B = 100$ MHz). The appearance of horn antennas is shown in Fig 1.

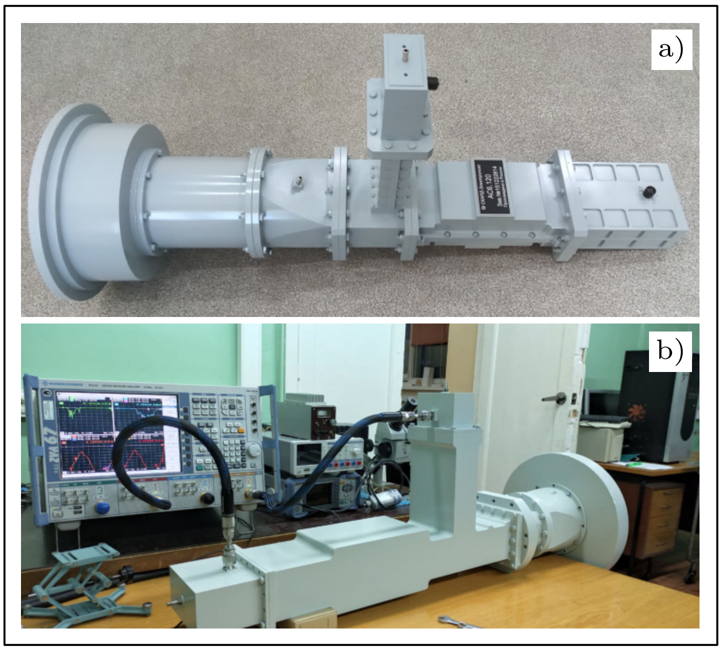

Fig. 1. Dual-band (13 and 25 cm) decimeter-wave antennas: (a) development of SKARD-Electronics, Kursk; (b) development of the Special Design Bureau of the Institute of Radioengineering and Electronics of the Russian Academy of Science.

For the possibility of active interference rejection, we develop a two-band digital receiver-spectrum analyzer designed to be used as a digital backend of the radiometer. The spectroanalyzer is designed to operate in three modes. The first is time–frequency interference suppression. This mode has a low spectral resolution of 128 channels in the 100 MHz band and low temporal resolution (100 milliseconds). In this mode, complete or partial removal of channels with interference is assumed. The remaining clear channels will be combined to receive a broadband signal. The second mode of operation is the mode of observing fast radio bursts (FRBs). This mode will also have a high spectral resolution (32 channels in the 100 MHz band) and high temporal resolution (10 microseconds). In this case, short (<1 second) pulses will be analyzed for the presence of FRB signals. The third mode of spectroanalyzer operation is the high spectral resolution mode for observing spectral lines. The temporal resolution in this mode, as in the first one, is 100 milliseconds. The use of new antennas and spectrum analyzers at the outputs of the decimeter receivers will effectively solve all these tasks.

4 Summary

In this paper, we presented the result of many years of efforts in creation of multifrequency radiometric complexes on the RATAN-600 radio telescope. The latest results obtained with the help of our receiving systems are presented in Vlasyuk et al. (2023); Trushkin et al. (2023); Sotnikova et al. (2023); Veledina et al. (2024); Trushkin et al. (2024); Krishna Mohana et al. (2024).

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