PROCEEDINGS OF SCIENCE

Continuum radiometers of the RATAN-600 radio telescope: current state and directions of development

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The composition and technical characteristics of the RATAN-600 continuum radiometer sets are described. The main direction of the efforts in the past few years was the development of the receivers based on the radiometric modules. We equip all the RATAN-600 radiometer sets with these radiometers. The main characteristics of the radio-modules developed by the "Micran" company are presented. Also we discuss some other ways of development of the RATAN-600 radiometric facilities.

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1. Introduction

RATAN-600 radio telescope today operates as three independent radio telescopes with linear aperture of about 250 m (geometrical area $\sim$ 1900 m^2). This is possible due to the separate use of three sectors of the total ring aperture: North, South and Western. The observations are carried out at four receiving sets placed on the secondary mirrors of the radio telescope.

One of our main tasks is to equip these receiving sets with the modern wide-band high-sensitive radiometers at centimeter and decimeter wavelengths (1 – 30 GHz) and one of the new direction of our efforts is to develop so called "modular" radiometers. Here "modular" means the radiometer which is mainly constructed as one small-sized module (except for some external circuitry).

Another important task is the observations at decimeter wavelengths which are highly saturated by radio frequency interference (RFI).

Both of the tasks will be detailed in the next sections.

2. Radiometric modules

The first example of the "modular" architecture at RATAN-600 was the radiometer MARS-3 [1], developed as a non-cooled miniature radiometric module to operate at 30 GHz central frequency with 5000 MHz bandwidth. This module consists of full gain High Frequency (HF) stages (60 dB), a band-pass filter, square-law detector and a low-frequency preamplifier.

It should be noted here that RATAN-600 in "sector" mode of operation has such layout when the radiometer's inputs are placed at the focal line rather than the focal point, as in the case of a parabolic antenna. The development of the modular radiometers MARS-3 allows to construct one-dimensional "focal matrix" which can be placed at the focal line of the radio telescope. Such device with 16 radiometers was developed in early 2000's and was used in the "Cosmological Gene" project led by Yu.N. Parijskij.

The development of the modular radiometers was continued and in 2015–2017 yrs. a new C-band radiometric module was developed together with "Micran" company, Tomsk (central frequency f_0=4.7 GHz, bandwidth B=600 MHz) [2]. New module consists only of the HF part of the radiometer without a square-law detector or low-frequency amplifier. These components in the new concept should be external with respect to the module. In contrast to the MARS-3 radiometer, which has $\sim$ 2.3 *dB* Noise Figure (NF), new non-cooled radiometric module has NF=0.3 dB! Radiometers based on these modules were installed at all RATAN-600 receiving sets.

Today 3 of 4 radiometer sets consist of the radiometer sets presented in Table 1. The remaining radiometer set at the secondary mirror №3 contains only one continuum radiometer at 4.7 GHz central frequency (like radiometer at the secondary mirror №2, see Table 1).

The next iteration in the radiometric modules development was made recently, in 2021-2022. As a result, 3 radiometric modules were developed (also with "Micran" company): modules at central frequencies 22.25, 14.4 and 8.2 GHz (see table 2 for their characteristics). Table 2 accumulates all of our modular radiometric developments. The radiometers based on new modules will be installed at all of the receiving sets with planned frequency coverage, shown in Fig. 1. New recently developed modules are shown in Fig. 2–4.

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Table 1: RATAN-600 continuum radiometers.

Center Frequency GHz	Bandwidth MHz	Flux density sensitivity, mJy	HPBWx arcsec
Secondary mirror №1			
22.25	2500	50	11.0
11.2	1400	15	15.5
8.2	1000	10	22
4.7	600	5	80
2.25	80	40	80
1.25	60	200	110
Secondary mirror №2			
22.25	2500	95	16.5
11.2	1400	30	23
4.7	600	10	53
2.25	80	80	121
Secondary mirror №5			
4.475	150	10	35
4.625	150	10	35
4.775	150	10	35
4.925	150	10	35

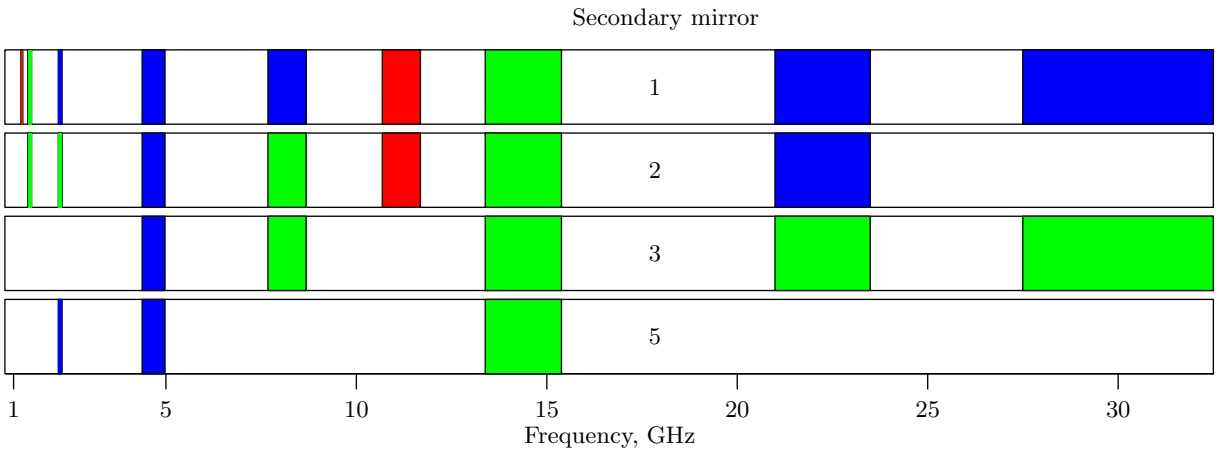

Figure 1: Frequency ranges of RATAN-600 continuum radiometers. Planned frequency coverage. Red regions – radiometers will be removed. Green - new radiometers will be installed. Blue - working radiometers.

3. Decimeter two-band horn antenna

A two-band horn antenna was developed for the decimeter wavelength observations, Fig. 5. The development was made by Special Design Bureau of Institute of Radio-engineering and Electronics

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Table 2: Radiometric modules.

Center Frequency GHz	Bandwidth MHz	Noise Figure dB
30	5000	2.5
22.25	2500	1.3
14.4	2000	1.0
8.2	1000	0.7
4.7	80	0.3

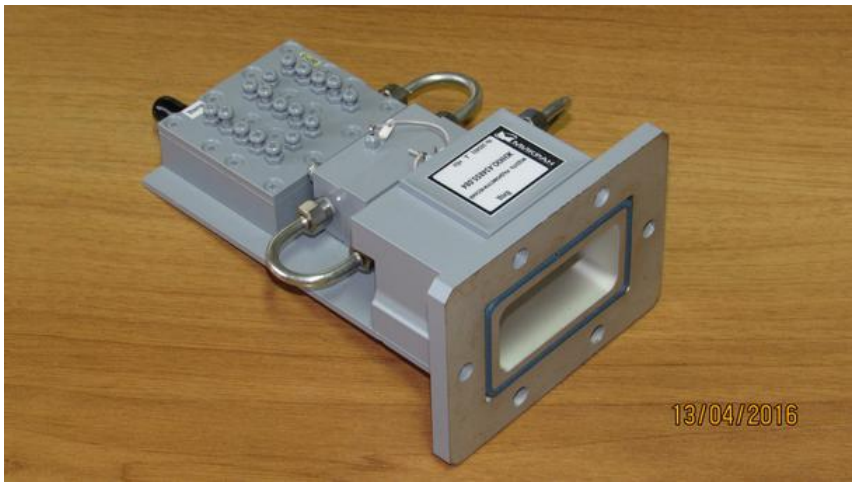

Figure 2: Radiometric module $F_0 = 4.7\ GHz,\ B = 600\ MHz$.

Figure 3: Radiometric module $F_0 = 22.25\ GHz,\ B = 2500\ MHz$.

of Russian Academy of Sciences (FSUE SDB IRE RAS). Antenna receives linear polarization in each of two bands: 1400–1500 MHz and 2200–2300 MHz and has a waveguide construction. One of the advantages of the construction is the absence of signals at frequencies below 1.15 GHz at the antenna outputs due to critical frequency in waveguide. This eliminates strong GSM signals which

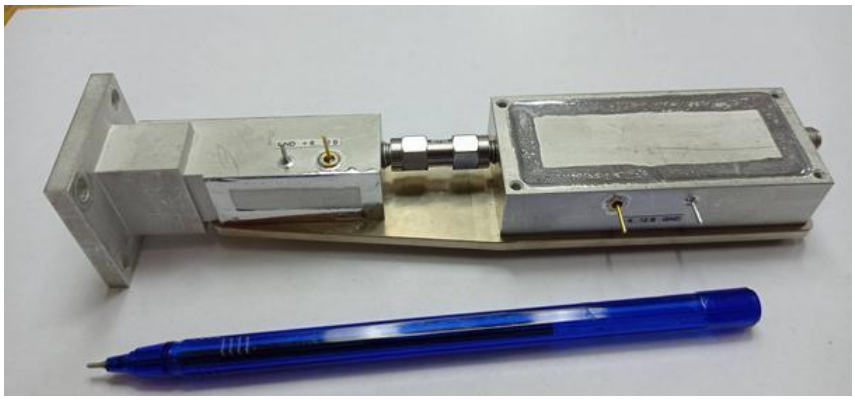

Figure 4: Radiometric module $F_0 = 14.4\ GHz,\ B = 2000\ MHz$.

overload the radiometer. Another strong GSM region and 3G region are also out of the band of the horn.

We are planning the development of the digital receiver as the radiometer back-end for each frequency channel of the horn in the future.

4. Acknowledgments

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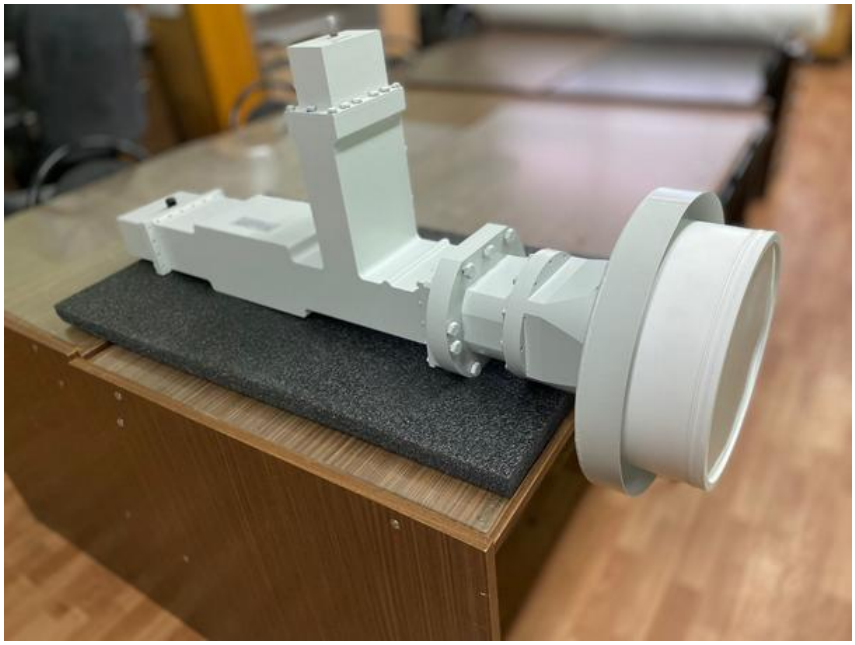

Figure 5: Two-band horn antenna 1400–1500 MHz and 2200–2300 MHz.

References

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