Continuum Radiometers for RATAN-600: Current State and Direction of Development

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Abstract. The current state of the continuum radiometers for the RATAN-600 radio telescope is presented together with the brief description of the corresponding observational methods. Also the main directions for current and future development are shown.

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1 Introduction

RATAN-600 is the world largest radio telescope, which now operates using three independent parts of antenna (sectors) in two- or thee-mirror configurations: Northern, Southern and Western antenna sectors in two-mirror mode (in pairs with the secondary reflector) and Southern sector plus Flat mirror and secondary reflector in 3-mirror mode. Observations are carried out in a transit mode, when the radio source passes through fixed (with respect to the sky) beam pattern due to Earth rotation. All of four working secondary reflectors equipped with the sets of radiometers including the low noise continuum radiometers. "Continuum" means that the working bandwidth of the radiometers covers the relatively wide spectral band, usually $\sim 4 - 15\%$ of the central frequency.

2 Observational Methods

Now there are three observational methods at the RATAN-600 radio telescope that use continuum radiometers. The first one is the measurement of the flux spectral density of the cosmic objects radiation at 1.25 - 23.5 GHz frequency range. The corresponding radiometric set located on the secondary reflector N^o1

with the radiometers is shown in the Table 1. Usually this radiometric facility operates at Northern sector of the radio telescope.

The second observational method is the measurement of the flux spectral density of the cosmic objects radiation at 2.25 - 23.5 GHz frequency range. The corresponding radiometric set (see Table 2) is located on the secondary reflector \mathbb{N}^2 and operates either with the Southern sector of the radio telescope or in the 3-mirror scheme which includes the Southern sector and the Flat mirror.

The third method operates in the secondary mirror N_{25} in pair with the Western sector and contains four multi-channel radiometers. The parameters of one of these radiometers are shown in the Table 3.

Table 1. The main parameters of the continuum radiometers of the secondary reflector $\mathbb{N}^{\underline{0}}1$. Here f_0 – center frequency and B – bandwidth of the radiometer and ΔS_{ν} – it's sensitivity at a flux density, HPBWx – half power beam width at x direction.

f_0	В	ΔS_{ν}	HPBWx
GHz	MHz	mJy	arcsec
22.3	2500	50	11
11.2	1400	15	15.5
8.2	1000	10	22
4.7	600	5	35
2.25	80	40	80
1.25	60	200	110

Table 2. The main parameters of the continuum radiometers of the secondary reflector \mathbb{N}^{2}

f_0	B	ΔS_{ν}	HPBWx
GHz	MHz	mJy	arcsec
22.3	2500	95	16.5
11.2	1400	30	23
4.7	600	10	53
2.25	80	80	121

All the continuum radiometers are direct detection receivers built on the *total* power radiometer (Kraus et al. 1986) scheme. It should be mentioned that the

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f_0	В	ΔS_{ν}	HPBWx
GHz	MHz	mJy	arcsec
4.475	150	10	35
4.625	150	10	35
4.775	150	10	35
4.925	150	10	35

Table 3. The main parameters of the continuum radiometers of the secondary reflector $N^{\circ}5$. One of four identical multichannel radiometers is shown in the table.

previous main radiometric scheme used in the RATAN-600 continuum radiometers was the *modulation radiometer* developed by Dicke & Beringer (1946). It was proposed in order to reject the strong 1/f noise, intrinsic to the *total power radiometer*. Also, many of the previous continuum radiometers at centimeter band were cryogenically cooled to maintain the low-noise operation.

However, the modern microwave electronic devices (especially Low Noise Amplifiers (LNA) and diode detectors) exhibit the very low 1/f noise (Tsybulev et al. 2014) together with the very low white noise level or system temperature. This lets us to use an uncooled LNA in the total power radiometer scheme. Such LNA was developed for us by "MICRAN" company in Tomsk (Russia).

The *data acquisition system* for all continuum radiometers is based on the new measurement ER-DAS system (Embedded Radiometric Data Acquisition System). It is a "building block" for the development of distributed systems and multi-channel signal acquisition. The details of the measuring system construction are described in Tsybulev (2011).

3 Directions of Development

Modular Radiometer. This direction became available due to miniaturization of the microwave circuitry and uncooled mode of operation. The main approach is the one radiometer – one module. Example of this approach is presented in Tsybulev et al. (2018). The C-band modular radiometer was developed for RATAN-600 by "MICRAN" company and exhibits the lowest system temperature and the lowest 1/f noise. The new modular radiometer at the central frequency 22.3 GHz is developed recently by "MICRAN" company for RATAN-600 and will be put into operation soon.

Focal Matrices. The modular radiometer lets to construct the radiometric linear matrix, which joins the required number of radiometers into one multi-beam

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device. This approach applied at the radiometric system of the secondary mirror \mathbb{N}_5 and lets to expand a field of view of the radio telescope since RATAN-600 has a *focal line* rather than a *focal point* in parabolic antenna.

Fast Data Acquisition. The main mode of operation of the RATAN-600 radio telescope is a *transit mode* in which a radio source passes through a fixed (on the sky) beam pattern. This requires relatively slow data acquisition ~ 10 samples per second per radiometric channel. However the modern requirement for the observations of the fast transient events assumes a relatively fast data capture. Now 16000 samples per second registration speed is implemented for all the continuum radiometers. The future plans assume 1 microsecond resolution in a time domain.

Spectrometer Back-End for decimeter (DM) radiometers. The main goals for this development are the radio frequency interference (RFI) mitigation and the fast transient cosmic events detection. There are three main DM ranges which require such a back-end: 13, 25 and 50 cm. Currently this project is in a stage of discussion of the technical and observational requirements.

Improving the Sensitivity and the Long-Term Stability of the Radiometers. There are many factors that worsen the long-term stability of the radiometer itself. The main of them is the physical temperature variations, that result in the variations of the microwave amplifiers gain, detector characteristic, calibration diode power, system temperature. The considering and removing such the factors is our main task in the current and future development.

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