



## Radio frequency interference at the RATAN-600 radio telescope site

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**Abstract.** The analysis of the radio frequency interference (RFI) shows an exponential increase of the artificial RFI level near the radio telescope RATAN-600 over the years. The current RFI situation is presented.

**Keywords:** radio frequency interference; frequency management; RFI mitigation

## 1. Introduction

The need for constant monitoring of the radio frequency interference (RFI) situation at radio telescopes is dictated by a sharp increase in the number of radio frequency bands the use of which is limited or unavailable for radio astronomy observations. The radio telescope RATAN-600 performs astronomical observations in a wide range of wavelengths from 1 GHz to 30 GHz. The bandwidths of the RATAN-600 receivers and their protective zones are shown in Fig. 1.

The RFI situation is currently particularly complex in the decimeter wavelength range from 1 to 3 GHz. This is due to the rapid development of communication systems, television, radio broadcasting, and household microwave equipment. Classical methods of RFI mitigation such as frequency tuning to interference-free areas are becoming unavailable due to the absence of such intervals in the decimeter wavelength range for frequency bands that are 10–15% wide (Kratov et al. 2010). Out-of-band radiation, variable both in amplitude and frequency, makes effective long-term filtering of the signal impossible, and moving to RFI-free zones does not provide the expected long-term effect since the RFI situation in the decimeter wavelength range changes dynamically, which requires constant RFI monitoring (Tsybulev et al. 2007).

## 2. RFI measurement methods at RATAN-600

### 2.1. Method 1 — RFI measurement using the radio telescope antenna

The main method of RFI measurement at RATAN-600 is the standard operation mode as in usual radio astronomical observations with the total microwave gain of the radiometer. However, this method requires suspension of observations on the radiometer which is being measured, so its use is limited in time. To use the method without interruptions, a small modification of the standard radio telescope radiometers is necessary. A typical solution to complement a radiometer is shown in Fig. 2. The modification of the radiometer allows conducting the RFI investigation during observations. This method has a number of obvious advantages:

- measurement of the exact spectrum of the RFI that is intercepted by the radio telescope antenna during observations;
- detection of even the smallest variation in RFI power, which is achieved by using the large radio telescope antenna and full amplification of standard radiometers;
- a side effect of this method is the ability to quickly test the amplification paths of radiometers using the interference measurement system connected to the output of the microwave radiometer blocks.

### 2.2. Method 2 — RFI measurement with a portable antenna

The primary receiver is a broadband antenna HL040 manufactured by Rohde & Schwarz, designed for the range of 400 MHz – 3.2 GHz, and a spectrum analyzer Rohde & Schwarz FSU46 for the range of 20 Hz – 46 GHz. The spectrum analyzer is connected to the HL040 antenna using a 5-m-long semirigid copper coaxial cable. Additionally, a block of two broadband low-noise amplifiers with an operating range of 200 MHz – 3 GHz with a gain of 34 dB is installed at the output of HL040. We call this solution a “Mobile highly sensitive complex for measuring RFI in the decimeter and meter wavelength range”.

Based on the results of testing the measuring complex, it was established that the complex is also capable of measuring RFI within 80 to 400 MHz outside the standard range with an efficiency of approximately 20 percent lower than the manufacturer’s specifications.

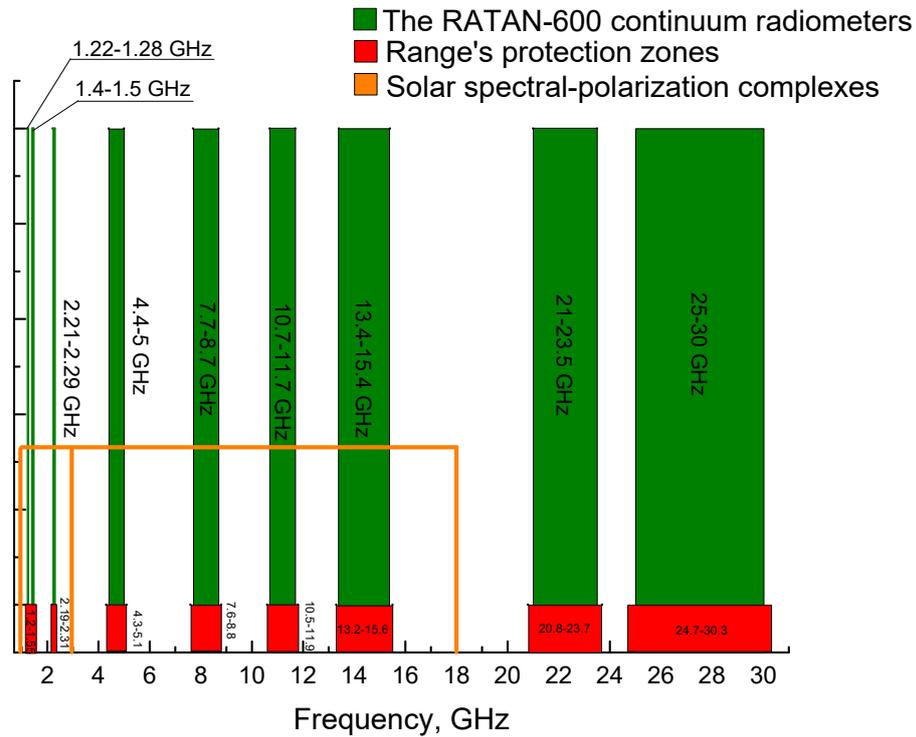


Figure 1. Operating bandwidths of the RATAN-600 receivers.

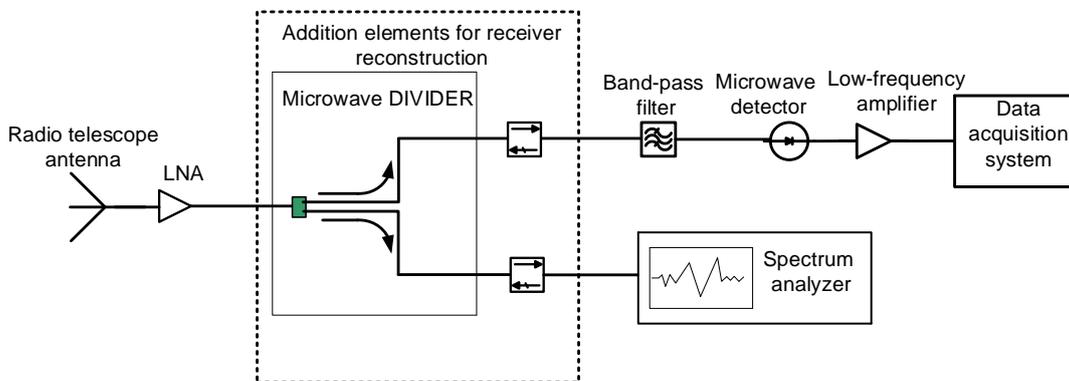
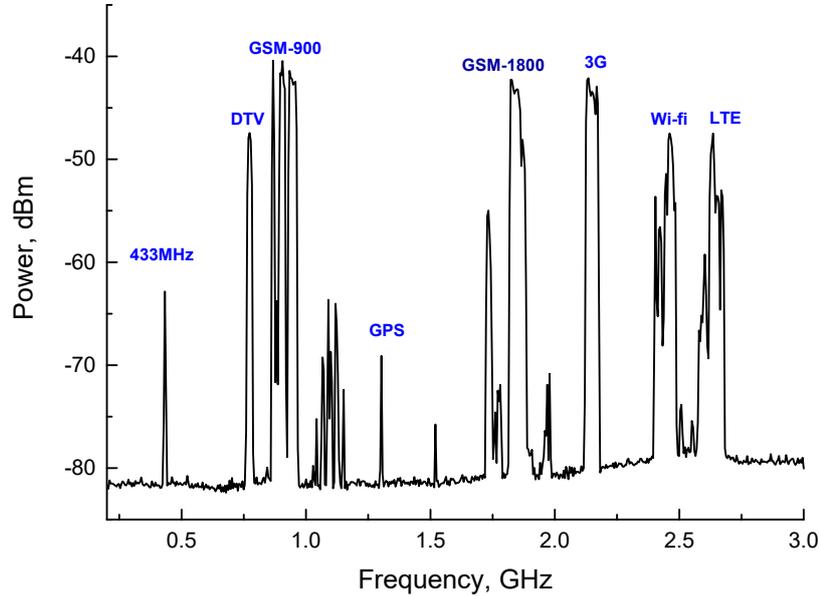


Figure 2. Block diagram of RATAN-600 receiver modification.

### 3. Results of RFI measurements

The main strong sources of RFI in the decimeter wavelength range are the GSM communication networks working in the bands of 850–980 MHz, 1700–1900 MHz, 2100–2170 MHz (3G), and 2570–2680 MHz (LTE). Among the strong RFI, we can also highlight Wi-Fi in the range of 2400–2480 MHz and frequencies around 400 MHz: these are usually radios, automatic doors, gates, etc. This type of interference does not act constantly both in the frequency range and in time. We can



**Figure 3.** Known sources of RFI in the decimeter wavelength range.

also point out a high RFI level from digital television (DVB-T2) in the range of 750–800 MHz and from global positioning systems at several frequencies in the range of 1100–1600 MHz.

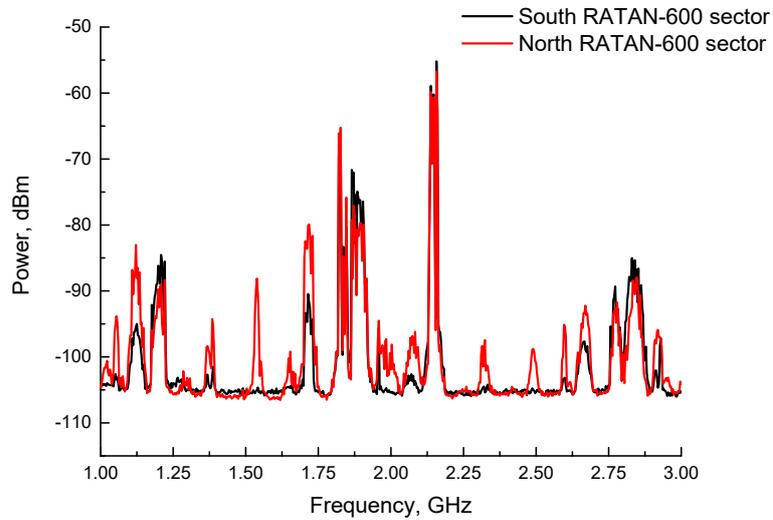
Harmonics or out-of-band radiation of strong RFI signals are the only other types of weaker interference. In Fig. 3 the interference environment is shown, considering the known sources of RFI.

Due to its design, RATAN-600 simultaneously conducts several observing programs using different sectors of the primary mirror and different secondary mirrors. Usually, three observing programs are carried out simultaneously. Since they use different primary mirror sectors, the RFI situation differs for each of the program because the beam patterns of the sectors and secondary mirrors are oriented differently with respect to the RFI sources. Figure 4 demonstrates this difference in RFI for two sectors of the RATAN-600 antenna in the decimeter wavelength range. The measurements were carried out using method 1 described above.

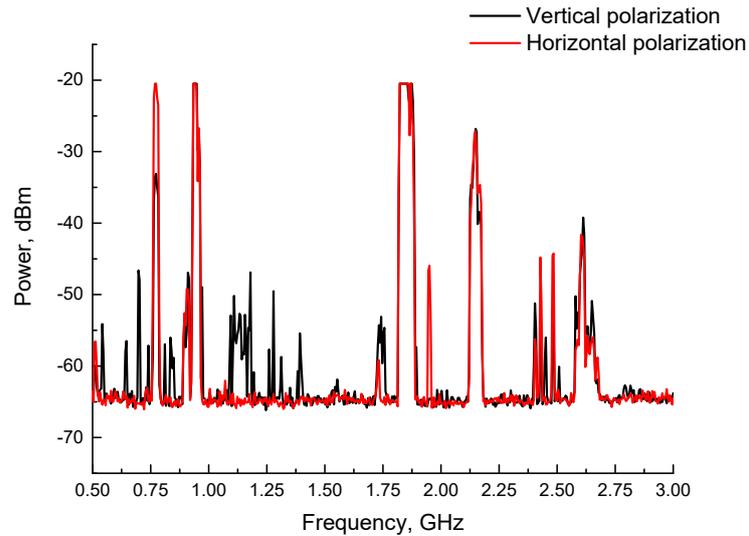
We should note that the above-described features of RATAN-600 can be both an advantage and a disadvantage of the radio telescope, depending on the observing program. It should also be taken into account that part of the RFI signals are polarized. Figure 5 shows the difference in the RFI situation depending on polarization.

At the same time, the RFI situation in the decimeter wavelength range at RATAN-600 is not that bad as it could have been if the telescope were located elsewhere. Let us compare the RFI at RATAN-600 with the RFI near the 6-m optical telescope (BTA) located not far from RATAN-600. In a simple case (the mathematical model of the absolute sphere), the difference between the radio horizons at the RATAN-600 altitude (we take it as the zero altitude) and at the BTA height of +800 meters is approximately 116 km, i.e. the radio horizon for the RFI reception at the BTA location is approximately 116 km further compared to the RATAN-600 site.

The above-described result of calculating the radio horizon does not take into account refraction and diffraction, the properties of the medium and underlying surface, and other phenomena. In reality, most often the effect of “bending” the wave downward occurs (although sometimes it happens the other way around), which allows “looking beyond the horizon”; and to take this effect



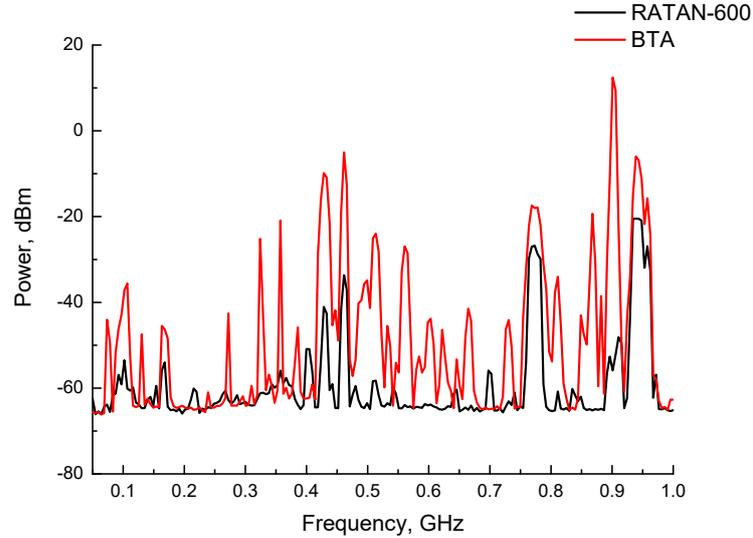
**Figure 4.** Comparison of RFI in the decimeter wavelength range for different RATAN-600 sectors.



**Figure 5.** RFI dependence on polarization.

into account, an empirical coefficient of  $4/3$  is usually used, which increases the radio horizon by 33%, although this is also a simplification to a very large extent and does not take into account the dependence on wavelength, the state of the atmosphere at a particular moment in time, etc. Based on the above, we accept the difference between the “ideal” radio horizons at the RATAN-600 and BTA locations as 154 km.

In the case of comparing the terrain of the BTA and RATAN-600 locations, this difference is even worse, since RATAN-600 is located in the valley of the Bolshoy Zelenchuk River. This means that RATAN-600 is shielded on two sides by the natural landscape of the valley (the height of the slopes above the RATAN-600 altitude is on average about 80 meters), on the third side it is protected by



**Figure 6.** A comparison of RFI at the RATAN-600 and BTA locations, 50 MHz–1 GHz.

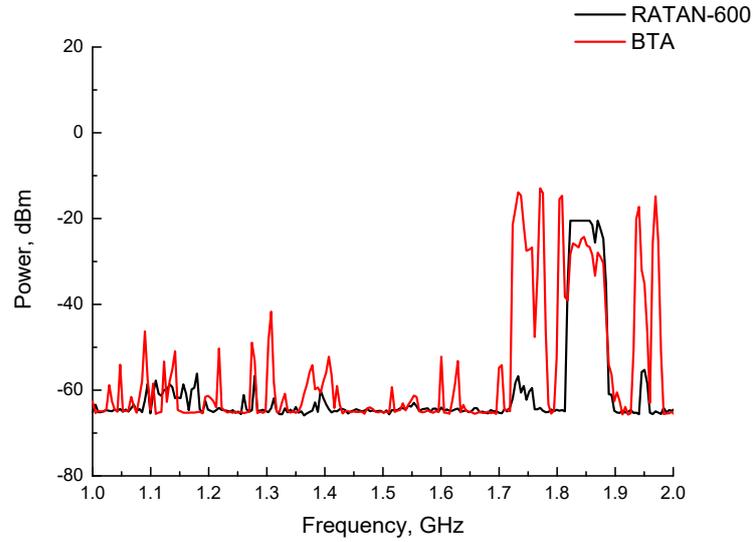
Mount Dzhissa (about 300 m above RATAN-600), and from the side of Georgia/Abkhazia there is the Greater Caucasus Range. Thus, in the neighborhood of RATAN-600, RFI comes mainly from the settlements closest to the telescope (Zelenchukskaya, Dausuz, Ermolovka): government and civilian services and home appliances.

At the BTA location, RFI are detectable from settlements at least 154 km farther. These are cities such as Cherkessk, Dzheguta, and Karachayevsk, and at least more than 80 smaller settlements. It is likely that at the BTA site we also detect RFI from Mineralnye Vody, Stavropol, Kislovodsk, Pyatigorsk, and other cities, which are formally farther than the calculated distance of 154 km, but this value does not take into account the terrain and the location of RATAN-600 under the “natural screen” protection provided by the valley of the Zelenchuk River and by the mountains in the directions toward these relatively large cities. Figures 6, 7, and 8 show a comparison of RFI at the RATAN-600 and BTA locations.

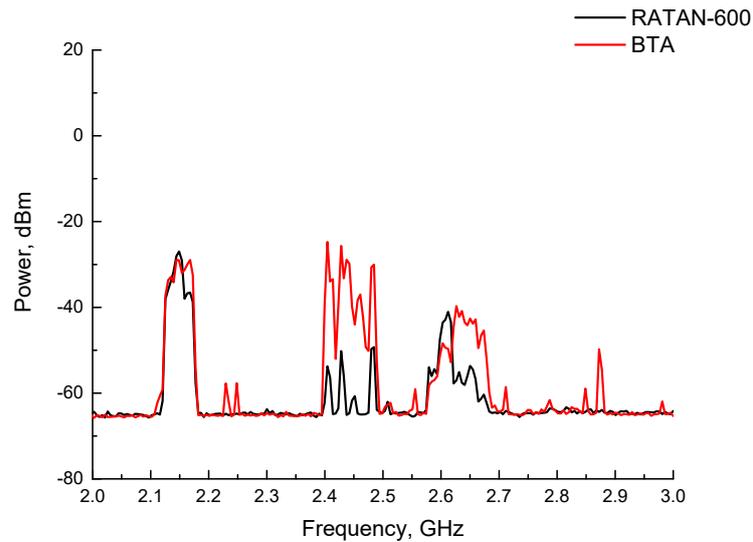
#### 4. Summary

The electromagnetic environment in all wavelength ranges used by RATAN-600 has been deteriorating for the last 30 years and will continue to deteriorate. One possible solution in the decimeter wavelength range is shielding RATAN-600 from the main source of RFI – Zelenchukskaya. Satellite Internet systems and other services are being independently developed in the EU, China, Russia, Brazil, and India, and despite the fact that their frequency grids are most likely going to be close to Starlink, they still will be shifted for each new system relative to its predecessors, which may affect the frequencies currently used by observational radio astronomy.

The recently approved 5G range (4.4–4.99 GHz) in Russia will make it impossible to observe with one of our radiometers at the 4.4–5 GHz bandwidth. The RFI situation in the band from 300 MHz to 6.2 GHz is going to worsen due to the upcoming data transmission technologies in this frequency range. It may be assumed that in the coming years the RFI in the range from 3 GHz to 6 GHz will become similar to the situation in the decimeter wavelength range at present.



**Figure 7.** A comparison of RFI at the RATAN-600 and BTA locations, 1–2 GHz.



**Figure 8.** A comparison of RFI at the RATAN-600 and BTA locations, 2–3 GHz.

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