The results of atmospheric parameters measurements in the millimeter wavelength range on the radio astronomy observatory “Suffa Plateau”

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ABSTRACT
The results of measurements of atmospheric absorption and the amount of precipitated water on the Suffa Plateau for the period from January, 2015 to November, 2020, are presented. The measurements of atmospheric parameters in the 2 and 3 mm range of the radio waves spectrum were carried out using the MIAP-2 radiometer. The results of more than six years of measurements have show that on the Suffa Plateau, atmospheric parameters in the above range remain fairly stable. The median value of the atmospheric absorption and the amount of precipitated water over the entire observation period were 0.14 and 0.12 Nep and 5.91 and 9.83 mm, respectively, for the ranges of 2 and 3 mm.

1. INTRODUCTION
Recently, thanks to the rapid development of microwave technology, the creation of adaptive large-aperture radio telescopes and the possibility of combining them into a system of ground-based and ground-space interferometers with very long baselines, has gained considerable interest. In fact, this represents a real possibility to fully realize the advantage of the millimetre range in solving fundamental problems of cosmology, as well as in solving a number of applied problems at a completely new level.

At the same time, such a rapid technological breakthrough in the development of microwave technology inevitably required the solution of new problems in a detailed study of the parameters of the medium for the propagation of mm-wave radio waves.

Significant factors, in addition to insignificant attenuation in space plasma due to scattering and absorption, affecting the propagation of mm waves from the source of radiation to terrestrial observation are distortions introduced by the terrestrial atmosphere.

In addition, the Earth’s atmosphere absorbs electromagnetic radiation of most wavelengths. However, there are frequency bands (radio windows) in which the atmosphere is substantially transparent. Such a radio window in the mm region of the spectrum is a region from 1 to 15 mm, in which several absorption lines of oxygen and water vapor are located.

A large number of papers and monographs have been devoted to theoretical studies of molecular absorption of mm waves. In these papers, it is emphasized that, in theoretical absorption calculations, special attention should be paid to the feasibility of the physical approximations used and to the adequacy of the description of the corresponding processes. From this point of view, interesting results were obtained in [1], where it was possible to achieve agreement between the theory of molecular absorption in water vapor in transparency windows and experimental data by taking into account the duration of molecular collisions in the framework of the memory function method.
The study of the atmospheric absorption at the Radio Astronomy Observatory "Suffa Plateau" (Uzbekistan) has been carried out from 2015 to 2020 in atmospheric transparency windows of 2 and 3 mm using the MIAP-2 measuring complex. A detailed description of the radiometer, its functional diagram, basic principles of measurements and calculations, estimates of permissible errors are given in [16].

2. CHARACTERISTICS OF THE MEASURING COMPLEX

The MIAP-2 measuring complex is a radiometric system that includes two radiometers for frequencies of 84-99 GHz ($\lambda_{\text{mm}} = 3 \text{ mm}$) and 132-148 GHz ($\lambda_{\text{mm}} = 2 \text{ mm}$), a turntable and a control, acquisition and processing system based on a personal computer.

The receiver in the range (84-99) GHz is made according to the direct amplification scheme with detection at the fundamental frequency. The modulator at the input of the receiver is made on the basis of chains of series-parallel connected diodes with a Schottky barrier (SBB) installed in the waveguide of the main section. The modulator control and synchronous data acquisition are carried out using a PC via the USB-4716 module. The modulation frequency is about 36 Hz. The noise temperature of the receiver is 1300 K.

The solid-state receiver of the radiometer in the range (132-148) GHz is made according to the super heterodyne circuit and includes a local oscillator based on the Gunn diode, a balanced mixer on the DBSH and an IF in the range (4-8) GHz. The modulator is similar to the one described above, it is also controlled and data is collected via the USB-4716 module. The modulation frequency is also about 36 Hz. The noise temperature of the receiver is 6300 K.

The turntable consists of a support frame for mounting the radiometer module, a swivel mirror, and a mirror drive system based on a stepper motor. The weather protection housing is made of stainless steel and has a radio-transparent PTFE window. The limits of change of the angle of observation are 0º-90º. The drive is controlled according to a given program via the USB-4716 module.

The control, data collection and processing system ensure fully automatic operation of the complex in the mode of cyclic observations at a given time.

Both radiometers are equipped with lens antennas with a conical feed. The lenses are made of Teflon and are limited on one side by a hyperbolic surface and flat on the other. Each of the boundary surfaces has an enlightenment, which is made in the form of periodic circular concentric grooves ("corrugations"), providing a reflection coefficient in the entire operating range of each of the radiometers no more than 0.5 %. The irradiators are in the form of circular cones with a break. The antenna beam width at half power level in both bands is about 2.5º.

Atmospheric absorption measurements of radio waves in the millimetres range carried out by the method of vertical cuts were described in [17]. The method is based on measuring the intrinsic thermal radiation of the atmosphere, while comparing the brightness temperature increments of two parts of the atmosphere at different zenith angles relative to the known temperature of a certain reference region.

In spite of all its advantages, this method is limited by the choice of one or another model of the structure of the atmosphere. In oceanic and atmospheric water mixtures must be monitored regularly and precisely [15].
particular, it is assumed that the Earth's atmosphere is isothermal in horizontal coordinates, which can lead to errors associated with drifting temperature in homogeneities of the surface layers of the atmosphere.

The measurement principle is illustrated in Figure 2. The left side shows a typical temperature distribution in the troposphere with respect to height (the so-called temperature profile). In the middle - a typical distribution of humidity in height. These profiles are subject to significant seasonal and daily changes, in fact, from them it is possible to calculate the amount of precipitated water and extrapolate it to absorption. On the right are the zenith angles (that is, the number of atmospheres) by which the radiometer approximates the brightness temperature profile [16].

Before starting, the device is set to a strictly horizontal position according to the hydraulic level. The measurement cycle begins with the rotation of the mirror along the photo sensor exactly in the "zenith" direction. Next, the mirror is moved using a stepper motor (the "step" value is 0.72 degrees) to a certain position according to the hydraulic level. The measurement cycle consists by which the radiometer approximates the brightness temperature profile.

At the end of the observation session, we obtain a chronology of measurements at 2 and 5 angles indicate both the normal operation of the device and the absence of interference in the form of clouds or ground objects (at the "lowest" angle) in the direction of observation, as well as "calm state of the atmosphere.

3. OBSERVATIONAL STATISTICS

The significant array of measurements of atmospheric absorption in the mm spectral range has been accumulated on the Suffa plateau for the period from January 2015 to November 2020.

As an example, the full time series of atmospheric absorption obtained on the Suffa plateau for the above period are shown in the 2 mm radio wave band is shown in Figure 3. Some gaps of data in observations is due to technical reasons. As can be seen from the figure, the value of atmospheric absorption over the entire observation period remains stable. A similar trend is also observed in the values of atmospheric absorption and the amount of atmospheric deposited water in the 2 and 3 mm ranges. It should be noted that equipment malfunctions appeared

![Figure 2](image-url)

**Figure 2.** The principle of measurement by the method of vertical cuts. The left side shows a typical temperature distribution in the troposphere with respect to height (the so-called temperature profile). In the middle - a typical distribution of humidity in height. These profiles are subject to significant seasonal and daily changes, in fact, from them it is possible to calculate the amount of precipitated water and extrapolate it to absorption. On the right are the zenith angles (that is, the number of atmospheres) by which the radiometer approximates the brightness temperature profile [16].

![Figure 3](image-url)

**Figure 3.** The atmospheric absorption time series obtained from January 2015 to November 2020 on the Suffa plateau during the entire period in the 2 mm range.
The amount of deposited water on the Suffa plateau, calculated for the 2 and 3 mm radio wave bands of 2 and 3 mm, from January 2015 to November 2020. The amount of precipitated water in January is about 4.84 mm for the 2 mm range, 10.0 mm for the 3 mm range, and in July 7.40 and 13.38 mm for the 2 and 3 mm ranges, respectively. The temporal dynamics of precipitated water in January and July are characteristic of extreme climate conditions. The average value of deposited water in January is about 4.84 mm for the 2 mm range, 10.0 mm for the 3 mm range, and in July 7.40 and 13.38 mm for the 2 and 3 mm ranges, respectively. The diurnal variations of the deposited water in the summer period are more significant than in winter. On some nights in December and January, the amount of precipitated water drops to a minimum of about 2 mm, in summer it rises to 12 mm.

4. CONCLUSIONS

Based on this study, it can be concluded that over a six-year period of time, the atmospheric parameters on the Suffa plateau remain fairly stable. The values of atmospheric absorption and deposited water presented here correspond to the values of the entire thickness of the atmosphere at the zenith. Measurements of atmospheric parameters on the Suffa Plateau showed that the value of atmospheric absorption at the zenith at a wavelength of 3 mm, sometimes for several is was within 0.06–0.08 Nep, and at a wavelength of 2 mm - within 0.08–0.10 Nep. At shorter time intervals, for several hours, the absorption of the 3 mm wave sometimes drops to 0.06–0.08 Nep, and at a wavelength of 2 mm to 0.05–0.06 Nep. Such cases occur in the winter. The amount of precipitated water for several days is in the range of 1.6-2.0 mm.

They can be reduced to parameters at any angle, as well as extrapolated to any height, taking into account the standard atmosphere model.

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