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SURA heating facility: 40 years of active ionospheric experiments, studying the atmosphere and near-Earth space.

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Abstract

The paper is dedicated to the 40th anniversary of the SURA heating facility. The history of construction, technical characteristics, research fields and the results of the last modernization are presented.

1 Introduction

Systematic studies of the interaction of high-power HF radio emission with the ionosphere began in the early 1970s at special facilities in the USA in Platteville (Boulder, Colorado), in Arecibo (Puerto Rico), as well as in the USSR (Zimenki, Nizhni Novogorod region). Very soon it became clear that the construction of more powerful facilities was required. In 1980 and 1981 facilities EISCAT/heating and SURA had been constructed in Auroral and middle latitudes (56.13° N and 46.10° E), respectively. In 2021 the SURA turns 40.

2 The SURA origin

The SURA was constructed in the remote laboratory Vasil'sursk of the Radiophysical Research Institute (now the department of Lobachevsky University of Nizhni Novgorod), situated at 7 km from the confluence of the Sura and Volga rivers.

The scientific management of the SURA project was carried out by German G. Getmantsev, and Vitaly I. Morozov supervised the construction directly. At the same time, Yury V. Tokarev was the head of the facility, and then the head of the Vasilsursk remote laboratory. The unique antenna system of the heating facility had been developed by Ivan F. Belov. Donat M. Kozitsyn implemented the antenna design. The construction was completed in the 80th year. The commissioning certificate was signed in February 1981.

3 Technical Characteristics

The SURA facility [1] consists of a three-section antenna and three broadcasting PKV-250 transmitters with a rated power of 250 kW. Each transmitter operates on its own antenna section. The total size of the antenna field is 300x300 m. The antenna consists of a 12×12 phased array of broad band dipoles. The transmitters can operate in-phase and independently. Beam scanning is possible in the plane of the magnetic meridian in the range of local zenith angles $\pm 40^{\circ}$. Working frequency range: 4.5-9.3 MHz. The project effective radiated power was 150-280 MW depending of the carrier frequency. The SURA facility can be used not only for transmission, but also for reception of radio waves of both circular polarizations.

The diagnostic equipment at SURA facility consists of a high-gain wideband antenna array [2] (4×4 crossed dipoles), a multi-channel HF and LF receiving stations, GNSS receivers, vertical and chirp sounders, bistatic optical equipment. For diagnostics of the HF-induced ionospheric disturbance, the remote receiving sites (near Nizhni Novgorod, Kazan, Moscow and Rostov-on-Don), as well satellites are used.

4 Research fields

Investigations at the SURA facility are carried out in the next directions.

1. Artificial ionospheric turbulence in the F-region of the ionosphere [3, 5, 6, 7, 8, 9]: HF quasi-electrostatic disturbances (plasma waves), LF disturbances, including plasma density irregularities with scales from tens of cm up to tens of kilometers, electron acceleration, stimulated electromagnetic emission, artificial airglow and additional ionization.
2. Generation of ULF/VLF radio emission of the ionosphere by modulated HF pumping [10, 11].
3. Diagnostics of the parameters of the lower ionosphere using scattering on artificial periodic irregularities [12, 13].
4. Investigations of artificial ionospheric irregularities by radio transillumination with signals from satellites [14].

Figure 1. Antenna field of the SURA heating facility in January 2021.

5. Precipitation of energetic electrons from the Earth's radiation belt [15].
6. A control of HF radio propagation in the ionosphere [16].
7. Research of multifractal properties of artificial ionospheric turbulence [17].
8. Radar studies of the magnetosphere [18].
9. Radio sounding of the Moon at decameter wavelengths [19, 20].
10. Radio astronomy observations [21].

On the base of physical models of the processes occurring in the ionosphere heated volume and interrelation of the characteristic times of these processes, at the SURA facility, special diagnostic complicated pumping schemes have been developed, which made it possible to study effectively the HF-induced disturbances of the ionosphere and parameters of the background atmosphere and ionosphere.

5 International Cooperation

In the 1990s - 2000s, a large series of experiments at the SURA facility was carried out in cooperation with scientists from the USA [22, 23], Sweden [24, 25], Germany [26, 27] and Great Britain [28]. In particular, long-term studies of near-Earth space environment by receiving of the SURA signals on board the WIND spacecraft have been conducted [29, 30]. This technique has been used to calibrate the Cassini sp/c HF receiver during the Earth flyby in August 1999 [31]. In 2005-2010 the international program SURA-DEMETER for the analysis of precipitation of energetic electrons was carried out using the equipment of the DEMETER satellite [15]. Now similar experiments continue with multisatellite SWARM mission [32]. Since the 90s, the diagnostic methods and complicated pumping schemes developed at the SURA have also been implemented at the other facilities: HAARP (Alaska, USA) [33], EISCAT/heating [34] and Arecibo (Puerto-Rico, USA) [35].

6 Scientific Team

The great contribution to the studies of the HF modifications of the ionosphere had been made by V. V. Belikovich, E. A. Benediktov, L. M. Erukhimov, N. A. Mityakov, V. O. Rapoport, V. V. Vas'kov, V. Yu. Trakhtengercz, V. A. Alimov, P. P. Belyev, Yu. A. Ignat'ev, A. V. Rakhlin, now deceased. Now active investigations are carried out by groups of N. V. Bakhmet'eva, V. L. Frolov, S. M. Grach, D. S. Kotik, E. N. Sergeev, V. P. Uryadov, F. I. Vy'bornov. Note that the person provided the SURA facility start in 1980 and its further reliable operation during all 40 years is George P. Komrakov.

7 Modernization

For 40 years of operation, many technical parameters of the SURA facility have been lost. As a result of repairs carried out within the framework of a grant from the Ministry of Science and Higher Education in 2020, technical

characteristics of the SURA facility restored: the structural elements of the phased antenna array were restored, the pumping scheme control system is improved, the high-voltage power circuit of the transmitters was completely replaced. Improvement and additional equipment of diagnostic and transmitting equipment (vertical CADI ionosonde, chirp ionosonde, low-noise generators) have been carried out. In addition, the infrastructure of the Vasil'sursk remote laboratory was modernized and repaired.

In 2021 we plan to perform a new experimental series at the modernized SURA facility.

8 Conclusion

The SURA facility is a unique multipurpose diagnostic complex for remote sensing of the lower, middle, upper atmosphere and near-Earth objects open for wide international collaboration.

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