Results of radar observations by the Irkutsk Incoherent Scatter Radar in 2018 – 2021

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The Irkutsk Incoherent Scatter Radar (IISR) is a powerful diagnostic tool for experimental research in the field of upper atmosphere physics. In terms of the set of measured parameters (altitude profiles of the electron density, electron and ion temperatures, plasma drift velocity at altitudes from 200 to 1000 km), the radar has no equal among other ground-based geophysical instruments deployed in Russia. At present, a new hardware and software complex makes it possible to use IISR in experimental research of the ionosphere with incoherent scatter technique and in observations of spacecraft and space debris (SD). For these purposes, IISR is used as an independent device and together with other ISTP SB RAS optical instruments.

The problem of controlling SD, especially small ones, has been existing for more than a decade, and now the number of registered SD fragments is several tens of thousands. World practice has shown the prospects of using HP radars as KM measuring instruments and confirmed the relevance of data obtained with their help.
Due to its high sensitivity, IISR observes numerous space objects (SOs). A significant part of these objects is small (~10 cm), information about such objects is extremely important. To ensure high accuracy in determining the spacecraft coordinate and non-coordinate characteristics, we take account of the influence of the propagation medium on the characteristics of radar signals.

The development of the IISR diagnostic capabilities and the expansion of the range of tasks to be solved became possible due to the complete modernization of the entire complex of control, receiving, recording devices and signal processing facilities (2018 - 2021). The IISR hardware and software complex makes it possible to generate various complex broadband signals that allow us to achieve a higher level of measurement of ionospheric plasma parameters, as well as coordinate and non-coordinate information of low-orbit space objects (SOs). The main specific feature of IISR is the antenna that transmits and receives one (linear) polarization of electromagnetic field waves. Like for other similar radar stations, the actual task of IISR is to determine radar cross section (RCS) of spacecraft, taking into account the rotation of the polarization plane vector in ionospheric plasma (Faraday and Cotton-Mouton effects). The created hardware and software complex allows us to diagnose the ionosphere simultaneously with SO observation. This, in turn, allows us not only to refine the coordinate information, but also to determine the phase of polarization effects of the radar signal for a correct determination of the spacecraft RCS.

The hardware and software complex includes a software module, which is the IISR mathematical model, which allows us to take into account all the features of the IISR antenna system, the transmitting and receiving process of a radar signal, etc.

Depending on the tasks to be solved, the IISR hardware and software complex allows us to quickly select different signal forms, algorithms for scanning and signal processing. Using the chirp signal, we managed to achieve high accuracy of measuring the SO coordinate information due to a large number of calculations. For example, for each receiving channel, it is necessary to make a correlation analysis with approximately 20,000 variants of the received chirp signal models. The program implementing such consistent processing in real time is executed by GPU.

The development of the IISR diagnostic capabilities also increases the potential capabilities of the ISTP SB RAS radio-optical complex consisting of interacting optical telescopes. Coordinated measurements on the radio-optical complex made it possible to expand the set of measured characteristics of the observed SOs. Due to this, we managed to improve both the accuracy of determining coordinate and non-coordinate characteristics, as well as the reliability of the SO identification and the control of a spacecraft's technical characteristics.

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