Abstract

This dissertation presents scintillation observations of the brightest radio sources (Cassiopeia A, Cygnus A) and observations of pulsars performed using the LOFAR radio telescope. These observations were utilized to investigate ionospheric irregularities at mid-latitudes. The data collected by the radio telescope were compared with GNSS measurements.

The objective of this dissertation was to develop a methodology for complementary examination of ionospheric irregularities at mid-latitudes, based on LOFAR radio telescope observations and GNSS measurements. An additional aim was to create a methodology for analyzing the influence of the ionosphere on pulsar observations conducted with the LOFAR radio telescope.

In the study, a new methodology for calculating the S_4 index based on scintillation observations was established. The designed algorithm was implemented in a pipeline for calculating Cassiopeia A IDOLS observations. Radio source observations were used to determine the scales, velocities, and phenomena responsible for the development of ionospheric irregularities.

A significant part of the study discusses the impact of the ionosphere on pulsar observations. The analysis distinguishes between the contributions of the interstellar medium and the ionosphere to pulsar observations. An observational experiment was designed and performed in collaboration with the LOFAR Łazy station.

The aim of the study was to confirm the hypothesis: "The LOFAR radio telescope enables joint and complementary ionospheric studies in conjunction with GNSS measurements and provides unique insights into instabilities in plasma structures and their physics."A subsidiary hypothesis was also formulated: "The ionosphere has a significant impact on pulsar observations, visible as signal scintillation."

To prove these hypotheses, the following tasks were undertaken: (1) development of

a methodology for S_4 index calculation for broadband LOFAR observations, including radio interference detection and detrending,(2) comparison of GNSS measurements with the S_4 index, (3) determination of line-of-sight relative velocities of irregularities based on the secondary spectrum.

Pulsar observations were used to address the following tasks: (1) calculation of signal-to-noise spectrum, (2) visualization of scintillation in S/N spectra, resulting from signal propagation through the interstellar medium, (3) simultaneous observations of pulsars using the PL611 and PL612 LOFAR stations.

The analysis confirmed that LOFAR radio telescope and GNSS measurements are mutually supportive techniques. Using both instruments allows for a comprehensive description of the ionospheric state. Scintillation observation results revealed irregularities at the auroral oval boundary and ionospheric structures potentially generated by Perkins instability at mid-latitudes.

It was demonstrated how the interstellar medium affects pulsar signal propagation, evidenced by scintillation in dynamic spectra and arcs in secondary spectra. Dynamic, broadband enhancements and decreases in the signal-to-noise ratio were observed in pulsar dynamic spectra, potentially caused by ionospheric effects. Simultaneous observations using two LOFAR stations showed, in one case, time-correlated structures, while in the other, the results were ambiguous.

Keywords: ionospheric irregularities, LOFAR, pulsars, GNSS, S_4 index