A NEW APPROACH TO HF SOUNDING AND VISUALIZATION OF WAVELIKE IONOSPHERIC DISTURBANCES

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Providing the diagnosis of traveling ionospheric disturbances (TIDs) and identifying their sources is a problem of importance both for increasing our understanding of the upper atmosphere physics and for the practice of environmental monitoring and development of the 'space weather' concept. The reason is that the TIDs, or quasiperiodic electron density disturbances in the ionosphere, derive from the propagation of atmospheric gravity waves (AGWs) that play an outstanding part in the energy exchange between various regions of the upper atmosphere. Besides, the AGW/TIDs may serve as indicators of the primary driving processes which can be either natural or technically stimulated events (earthquakes, particle precipitations in auroral areas, powerful hurricanes, typhoons, solar terminator passages, etc. on the one hand and industrial accidents, ionosphere modification experiments, powerful blasts, chemical releases, etc. on the other).

As of mid-1980s, the Institute of Radio Astronomy of the National Academy of Sciences of Ukraine (RINAN) has been promoting an original approach to TID diagnostics [1] based on the use of the emissions from the great many HF broadcasting radios existing (over 6000 throughout the world) in the capacity of the sounding signals. The input data for the analysis are trajectory parameter variations of the HF signals (specifically, variations in the angles of arrival and Doppler frequency shifts) at point-to-point propagation paths. The inverse problem of wave diffraction has been analyzed for the model where a TID is represented as a perfectly reflecting corrugated surface moving through the atmosphere at characteristic ionospheric altitudes. A set of equations has been derived in the ray optical approximation to relate the parameters of ionospherically reflected signals with characteristics of the effective corrugated reflector. The linear theory involves a TID diagnostics procedure, including algorithms to recover the disturbance parameters within the dynamic and statistical formulations of the problem for a variety of model frequency-and-angular spectra of the ionospheric wave disturbances.

The financial support of STCU, the Science and Technology Center in Ukraine, within the Project Agreement No827 has enabled developing and constructing at RINAN a compact-size data acquisition/data processing complex implementing the Doppler interferometry principle (i.e. phase difference-based direction finding combined with Doppler frequency filtering). The sounding signals are received at three spaced points, the Doppler filtering is applied to separate partial signal components in the spectral domain, after which the phase-difference direction finding is applicable to each of the components. The antenna system of the complex involves small-size broadband dipole antennas placed at the vertices of an equilateral triangle of side length ~ 60 m. The signals are registered in a three-channel coherent receiver clocked by a stabilized reference oscillator and equipped with a compensation system to correct the inter-channel phase errors. The receiver provides for long term measurements of the angles of arrival and Doppler frequency shifts in the sounding signals to accuracies within 0.5 deg and 0.02 Hz, respectively. The package of applied software that has been developed permits recovering the TID parameters and visualizing the wavelike disturbances. The format adopted for the data output allows following the dynamics of the disturbances in (quasi)-real time and mapping their spatial distribution similar as is done for atmospheric air masses in meteorology.

The equipment was used in four measuring campaigns aimed at TID diagnostics over different seasons of the year. The total volume of the data collected corresponds to more than 800 hr of continuous, round-the-clock observations at several sounding frequencies and a variety of propagation paths. The primary data have been processed to recover the disturbance parameters and represent the wavelike disturbances visually. The TID parameters have been analyzed statistically for different seasons and times of the day, and compared with geomagnetic conditions variations during the measurements. It has been found, in particular, that under quiet geomagnetic conditions the most probable source of wavelike disturbances in the ionosphere is the moving solar terminator. Magnetically disturbed days may be characterized by the appearance of TIDs at high geographic latitudes.

The paper will be presented as a 10-minute CD-video.

Reference:

[1] V. S. Beley, V. G. Galushko, and Y. M. Yampolski. “Traveling ionospheric disturbance diagnostics using HF signal trajectory parameter variations,” *Radio Science*, vol. 30, No. 6, pp. 1739-1752, 1995.