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The Radiophysical Observatory for Remote Sounding of the Ionosphere

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Abstract

A short discription of facilities and experiments carried out at Radiophysical Observatory of Kharkov State University is given.

1. Introduction

The Space Radiophysics Department of the Kharkov State University deals with the design and upgrading of the technical means (both stationary and mobile) of a complex radiophysical investigation of near-to-Earth space and its diagnostics; radio wave propagation characteristics are being investigated as well. The aim of this paper is to outline the capabilities of the Radiophysical Obervatory where experiments are conducted.

2. Remote sounding of the lower ionosphere

Stationary and mobile facilities were made to investigate the complicated structure and dynamics of the lower ionosphere by means of partial reflection, spaced antenna, cross-modulation, and resonance scattering methods. The basic parameters of the stationary complex that is situatied at the Radiophysical Obervatory 40 km away from Kharkov and of the mobile complex that is installed in a trailer are listed in Table 1. Both the complexes are eqipped with standard ionospheric stations. Each complex utilizes a computer to control the experiment, format the data, and provide some real-time data reduction.

The transmitting antenna array of the stationary complex comprises 16 linearly polarized elements. The single array element is a rhombus antenna. A linear polarization is generated. The incident wave is split into two circularly polarized waves in the ionosphere. The receiving antenna consists of the two crossed double rhombi. The receiving antenna polarization switch enables a separation of the ordinary and extraordinary modes of about 22 dB. The two modes are received in the 10 ms interval. The signal plus noise and the noise are determined separately, and the signal power found by subtraction. The echoes returned from any of 250 selected altitudes in the ionosphere are analyzed either in real time or after digital storage. A few data reduction methods are possible.

The space antenna technique is used to measure wind velocities in the ionosphere. In this technique, the same stationary complex employs the receiving antenna of two crossed double rhombi as a transmitting antenna and the transmitting array of 16 elements, divided into four subarrays, as receiving antennas.

Table 1. Lower ionosphere stationary and mobile complex design specifications

	Stationary	Mobile
Operational frequency band (in 0.01 Hz steps)	1.5-15 MHz	1-10 MHz
Transmitting antenna	16 elements	4 elements
polarization	linear	linear
aperture		
f=1.5-4.5 MHz	300 x 300 m	150 x 150 m
f=4.5-15 MHz	60 x 60 m	
gain (f=1.5-4.5 MHz)	100-200	25-50
Receiving antenna	2 crossed double rhombi	4 delta antennas
polarization	circular	circular
polarization switch 22 dB	22 dB	
Transmitter N1		
peak power	100 kW	
average power	100 kW	
pulse length	any value	
pulse repetition	0-100 Hz	
Transmitter N2		
peak power	300 kW	300 kW
pulse length	10-300 μs	10-300 μs
pulse repetition	1-100 Hz	1-100 HZ
Receiver		
dynamic range	86 dB	86 dB
IF bandwidth	60 kHz	60 kHz
Ionospheric station	standard	standard

Considerable upgrading of the complexes is being carried out in order to widen their capabilities. Thus, the usage of a computer to control experiments allows one to change equipment parameters from one pulse to another, providing the possibility of widening the dynamic range of recorded signals, to obtain practically simultaneous data at many frequencies and to realize new methods of conducting experiments. Thus, for instance, methods and computer programs were worked out which provide simultaneous measurements of height profiles of the electron density, N(z), the drift velocity of an ionospheric plasma v(z), and the collision frequency of electrons with the neutral molecules, $\nu(z)$, by means of the partial reflection, spaced antenna, and vertical sounding techniques.

The availability of the mobile complex allows one to obtain ionospheric parameters with separation in latitude and longitude. From the partical reflection measurements performed in the vicinity of Kharkov and Volgograd (simultaneously with rocket measurements in situ and using radio beacons) in middle latitudes and in the vicinity of Murmansk in high latitudinal variations of N(z) and $\nu(z)$ in the D region were investigated. It has been shown that the diurnal $\nu(z)$-changes in the D region are not large (smaller than 50 %); the seasonal changes are $\sim$ 150-200%, and the latitudinal ones are $\sim$ 150-170 %, [1].

Investigations on the effects of some natural disturbing factors (strong thunderstorms, terminator, qowerful earthquakes, solar flares, and magnetic storms) in the middle-latitude ionspeheric region were conducted [2,4]; parameters of the generated or enhanced disturbances were studied in these cases.

3. Doppler Sounding

Stationary and mobile decameter Doppler radars were worked out to investigate the ionospheric plasma dynamics during disturbances (both natural and artificial). The basic parameters of these facilities are listed in Table 2.

Table 2. Stationary and mobile Doppler decameter radar design specifications

	Stationary	Mobile
Operational frequency band (in 0.01 Hz steps)	1.5-15 MHz	3-30 MHz
Antenna		
transmitting	delta antenna	delta antenna
receiving	delta antenna	delta antenna
Transmitter		
peak power	1 kW	1 kW
pulse length	500 μs	500μs
pulse repetition	100-200 Hz	100-200 Hz
Receiver		
dynamic range	80 dB	80 dB
IF bandwidth	10 kHz; 20 kHz	10 kHz; 20 kHz
system bandwidth	10 Hz	10 Hz
Master oscillator	rubidium vapoor	crystal, 10^{-9} stability

The stationary complex comprises two units of the facilities listed in Table 2. The signal is passed through the 20 kHz or 10 kHz IF filter widths of which correspond to a 7.5 km or 15 km height resolution for the altitude range of 90-450 km. This feature favorably distinguishes these radars from systems employing the continous sounding radio waves. The digitized output is spectrum analyzed using the fast Fourier transform algorithm. The instrument error of the measurements of frequency deviations does not exceed $\pm 2.10^{-2}$ Hz for the maximum Doppler frequency shift of ± 5.0 Hz. In this case, the error in the Doppler velocities of the ionospheric layers is about ± 1.0 m/s. The high spectral intensity of a useful signal (in the absence of concentrated noise interference in an analyzed band of ~ 10 Hz) causes high sensitivity of the Doppler ionosonde, allowing to record signals reflected from the ionospheric formations having a small effective reflection cross-section. The frequency resolution provides the possibility of studying wavelike distrubances in the ionosphere with a minimum relative change in the electron density of 0.1%. The availability of the stationary complex and the mobile complex allows one to information on the irregular structure of the ionosphere with a spatial separation of 10-10.000 km.

The above-described decameter Doppler radars mwere used to investigate travelling ionospheric disturbances generated by a terminator, a shadowed region under a total solar eclipse, powerful acoustic waves, etc. The most interesting results were obtained when sounding artificial ionospheric formations were caused by releases of plasma-creating and plasma- extinguishing reagents at the E-region altitudes [4,5].

4. Multipurpose program-equipment complex

The multipurpose program-equipment complex was designed and created to investigate the variations of characteristics of radio signals over 0.003-30 MHz and to study change-rate phenomena in the ionospheric plasma. All receiver oscillators are controlled by a frequency-synthesizer system (depending on the operation mode, with a sensitivity of 0.2-8 μ V for the VLF and HF bands, respectively; an input dynamic range not smaller than 80 dB); a radio transmitter operating over 0.4-30 MHz (average power 1.5 kW); and an IBM compatible computer.

The complex operates in the modes of a vertical (active) and oblique Doppler sounding and with panoramic monitoring of an electromagnetic situation; choice of the observation mode is defined by a problem solved in a particular experiment. Signal sources for oblique Doppler sounding are: broadcasting radio stations, navigation and time-keeping services.

The software allows one to carry out effective filtering of digital signals in real time with their following decimation. The further data processing realizes the different types of detection (linear, square-law, peak), histogram construction, algorithms of obtainin the spectral and statistical characteristics of received signals an their presentation in digital or plot form. A satisfactory accuracy of hyothesis testing and parameter determination of radio signals is, in some cases, achieved when data is processed in real time at the same time, the results of calculations are shown by a plotter.

At the present time, the complex is being equipped with an antenna array for the estimation of the angles of arrival of HF radio waves.

Among other equipment available at the Radiophysical Observatiory, there are nineteen systems for the reception of signals of different navigation systems (TRANSIT, CICADA, NAVSTAR, GLONASS, etc.) and rocketborne beacons, a three-axes magnetometer, and now under construction, a multipurpose UHF radar for investigation of the atmosphere and ionosphere using scattered signals. The parameters of this radar are expected to be as follows: $f \approx 1.6$ GHz; peak power of about 3.4 MW; a fully steerable parabolic dish antenna, 15 m in diameter with a gain of 5.10^4; and system noise temperature of 60 K.

5. Experimental Results

The described facilities allow one to investigate the fine structure of ionospheric response to sources of distrubances of different nature. Figure 1 reflects an example of the experimental results. It shows the typical results obtained by means of the partial reflection technique at a distance of about 10.000 km from the Shuttle launch complex. The lower pannel contains temporal variations of the smoothed over 30 s intervals ordinary and extraordinary components of the intensity of partially reflected signals $< A^2_{0,x} >$. The upper panel shows temporal variations smoothed over the same intervals ordinary and extraordinary components of the intensity of the noise. The time $t = 0$ corresponds to the ignition. The distinguishing features include a substantial rise in the magnitude of the ordinary component of the noise and a subsequent 'negative ' value of the signal.

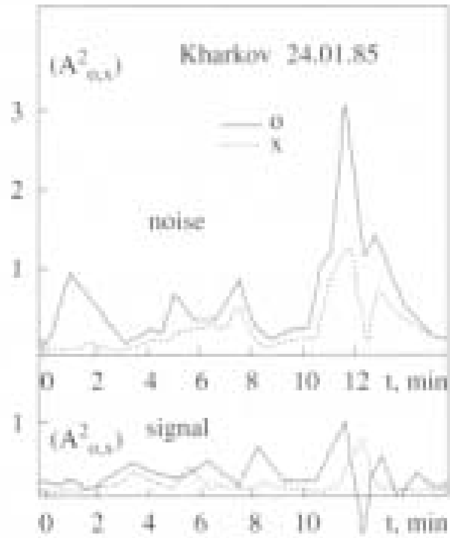

Figure 1. Variation with time of relative power

Thus of the Kharkov State University experimental base, the Radiophysical Observatory allows on to attain operational and detailed information on the atmosphere-ionosphere-magnetosphere system and the radio wave propagation conditions on different wave bands.

6. Discussion

The described Radiophysical Observatory allows one to conduct complex investigations on the morphological features of change- rate processes in near-to-Earth space which are related with the effects of such powerful local sources as earthquakes, strong thunderstorms terminators, solar flares, magnetic storms, the launch and flight of space vehicles, reentry into the Earth's atmosphere, explosions, release of chemical reagents, powerful radio frequency radiation, etc.

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