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KHARKIV INCOHERENT SCATTER FACILITY

The structure, parameters and operating modes of the incoherent scatter radar of the Institute of Ionosphere, Kharkiv are presented. Some results of the ionosphere research obtained by this facility are shown.

Keywords: incoherent scatter radar, ionosonde, ionospheric observatory, ionospheric parameters, incoherent scatter method.

Introduction. Incoherent scattering (IS) is the most informative technique of radio-physical exploration of near-Earth space. It allows measuring a wide set of ionospheric parameters at the same time and in a large range of heights. IS radars are used for this technique realization. These radars are complex technical systems, which include powerful transmitters, large size antennas, high sensitivity receivers and high-performance computer data processing systems. Currently there are 11 active IS radars in the world. One of them is the IS radar of Institute of Ionosphere of National Academy of Sciences of Ukraine and Ministry of Education and Science of Ukraine.

Purpose of the article is to present the current state of the IS equipment in the Ionosphere observatory of Institute of Ionosphere, to show radar potential and to introduce techniques for the parameters of the ionosphere measurement and ionospheric data processing.

Facility. Ionospheric Observatory of the Institute of Ionosphere is located in 50 km to the south-east from Kharkiv city (49.676º N, 36.292º E; InvDip=45.74º). This location is best one to carry out studies of the longitude and latitude effects in the ionosphere together with radars in Millstone Hill (43° N, 71° W), Irkutsk (52° N, 104° E) and Tromsø (78° N, 19° E).

The Ionospheric Observatory facilities include the VHF IS radar equipped with the zenith parabolic Cassegrain antenna of 100 m diameter; the VHF IS radar equipped with the fully steerable parabolic antenna of 25 m diameter; ionosonde “Bazis” [1].

Radar with 100-m antenna was put into operation in the 1970s [1–3] and being modernized right along.

Radar allows to measure with high accuracy (usually error is 1–10 %) and acceptable altitude resolution (10–100 km) the following ionospheric parameters: electron density N_e, electron T_e and ion T_i temperatures, a vertical component of the plasma drift velocity V_z, and ion composition [1, 4]. The investigated altitude range is 100–1500 km.

At the present time, the main parameters of IS radar are as follows: the frequency is about 158 MHz, the effective aperture of the 100-m antenna is about 3700 m^2, the two way half-power antenna beam width is close to 1.3°, the peak pulse power of the transmitter is up to 3.6 MW and the average power is 100 kW, pulse repetition frequency is 24.4 Hz, and the polarization is circular or linear. The noise temperature of the receiver is 120 K and the receiver bandwidth is 11–19 kHz. The effective noise temperature of system is 470–980 K.

Block diagram of IS radar is shown on Fig. 1.

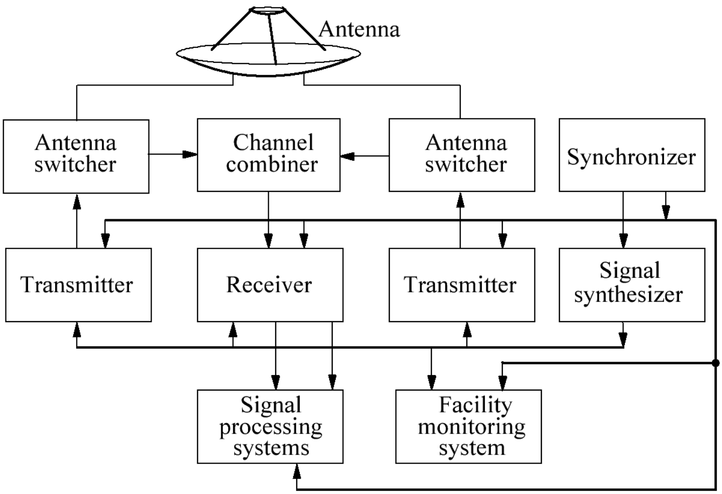


Fig. 1 – Block diagram of IS radar of Institute of Ionosphere

Antenna (Fig. 2) allows to transmit and receive circular and linear polarized signals due to the presence of two orthogonal dipoles [5]. The antenna pattern was measured using the reflections of the sounding signal from spacecrafts. The antenna pattern is shown in Fig. 3 [6].

Feeder circuit is based on dual-channel scheme. It is built on 1330×660 mm rectangular waveguide section and partially on 160/70 mm rigid coaxial lines.

Feeder length in each of the channels is more than 200 m. It consists of coaxial and waveguide sections, high power waveguide-coaxial transitions, waveguide expansion compensators (thermal expansion compensators), ball switches, coaxial and waveguide directional couplers. Isolation between radio receiving and transmitting devices is provided in each of the two channels of the waveguide feeder line by using balanced antenna waveguide switches performed on gas-filled surge arrester.

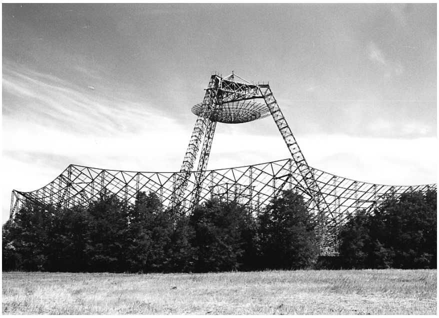


Fig. 2 – The 100-m-diameter parabolic antenna

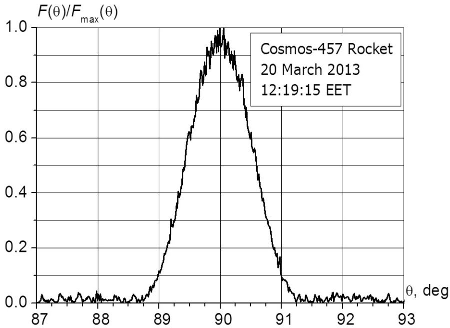


Fig. 3 – Cross-section of the 100-m antenna pattern in the plane of φ = 203°, measured by reflections from Cosmos-457 Rocket

Transmitter consists of two channels of high-power amplifiers operating with an external excitation by common signal synthesizer [7]. Peak pulse power of each channel is up to 1.5 MW. Usually it is about 1 MW. Transmitted pulse duration is defined by measurement mode. The total pulse length does not exceed 800 μs. Pulse repetition frequency is 24.4 Hz.

To transmit signals with linear or circular polarization, the desired phase difference between the signals of two channels (either 0 or 90 degrees, respectively) is set. Block diagram of the transmitter is shown in Fig. 4. Each channel consists of a preamplifier, power amplifier, system of the formation of the pulse anode voltages (modulator and high voltage rectifier), and the power supply and cooling equipment.

Driving signal with power of about 130 mW comes from the synthesizer to inputs of the preamplifiers. These preamplifiers are made as multistage scheme with metal-ceramic electron tubes. Output three-stage power amplifiers are made with powerful triodes cooled distilled water. Modulator is a pulse voltage source for these stages. It consists of a multisection LC charge integrator with full discharge of energy via the pulse transformer. All elements of the modulator are matched so as to minimize the transmitter noise level in the interpulse periods. It is possible to operate using four transmitter channels with the pairwise summation of their signals via coaxial combiner bridges. In this case, a total peak power reaches up to 3.5 MW.

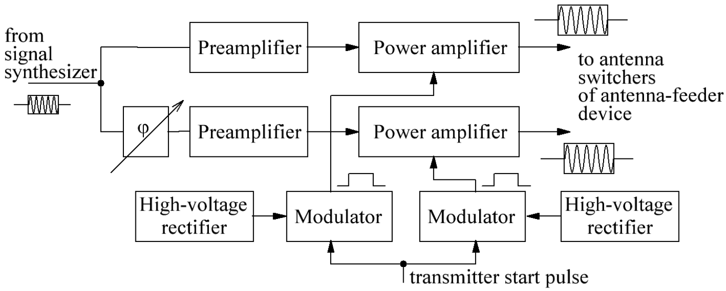


Fig. 4 – Block diagram of the IS radar transmitter

Radio receiver of IS radar is a multi-channel receiver with a triple frequency transformation [8]. The spectrum of the received signal is sequentially translated from the carrier frequency (158 MHz) to a low frequency region where correlation processing is carried out. The receiving equipment is located near the outputs of antenna-feeder system in order to minimize signal power losses at the receiver input and reduce interference.

Block diagram of receiver for the reception of two signals spaced apart in frequency is shown in Fig. 5.

A system of the received signal polarization choice (consisting of a phase shifter and coaxial combiner of the signals from two feeder line channels), a circulator for a better match of input resistance to the feeder line impedance (75 ohm), blank switch device (to close the receiver during pulsing), and a low noise transistor amplifier VHF1 are at the receiver input. Receiver blanking is provided using two high-speed electronic switches of radio-frequency path (with p-i-n diodes) to avoid overload of the receiver and analog-to-digital converters (ADC) of processing devices. The amplifier VHF1 provides sufficient for VHF radio receiver sensitivity: the receiver noise factor is equal to 1.4. A number of pairs of quadrature signals in outputs of receiver are formed (for correlation processing) by synchronous detection and low-pass filtering. The receiver bandwidth depends on the low-pass filters. Usually the 7th-order Cauer filters with the bandwidth of ΔF=9.5 kHz and ΔF=5.5 kHz, as well as the third-order Gauss filters with ΔF=6.0 kHz are used. Unevenness of the flat part of amplitude-frequency characteristic of these filters does not exceed 0.18 dB.

The receiver heterodyne signals are formed from signals of synthesizer to ensure coherence of IS radar systems. Due to this we are able to detect small (relative to width of the IS signal spectrum) Doppler frequency shifts, which are used for determining the radial velocity of the ionospheric plasma.

A first heterodyne signal with the frequency f_{g1} is formed from the synthesizer signal with frequency ($f_{g1}/8$) using frequency multiplier. Since the carrier frequency of the sounding signal is formed by the synthesizer according to the expression $f_0=((f_{g1}/8)-2f_\beta)\cdot 8$, the first intermediate frequency (IF) is $f_{if1}=f_{g1}-f_0=16f_\beta$. Thus, it is known accurate to a Doppler shift of the IS signal spectrum due to the plasma motion. Second heterodyne signal is formed according to the expression: $f_{g2}=16f_\beta+f_{sg}$. Third (synchronous) heterodyne signal is formed by quartz crystal filtering of the synthesizer signal with the frequency f_{sg}. Therefore the second intermediate frequency f_{if2} coincides with the frequency f_{sg} of the synchronous heterodyne (up to Doppler shift). As a result of the synchronous detection, the signal is translated to the zero frequency with Doppler shift. Thus, the coherent radar system operation is achieved and the possibility of the ionospheric plasma drift velocity measurement is provided.

Signal synthesizer system is designed to form the signals required for operation of the transmitter, receiver and facility monitoring system. In particular, the driving signal for transmitter and heterodyne signals for receiver are formed. All signals are synthesized from the highly stable reference oscillator signal with frequency of 5 MHz.

Synchronization system is intended to ensure synchronous operating of the equipment. It produces a signal of start of transmitting, a strobe pulse for synchronizer to form driving signal for transmitter, a blank pulse to close the receiver input during transmitting, and other control signals for radar systems.

Several independently working signal processing systems are used in the Kharkiv IS radar. All systems work in one local area network.

Two dual-channel correlators based on the TMS320 family signal processors operate since 1996 [9]. Each correlator runs the own program and allows to obtain unique data. For example, one of them is intended to calculate autocorrelation functions (ACFs) for the electron density, ion composition, ion and electron temperatures estimation. At the same time another correlator calculates quadrature ACFs for the plasma velocity estimation.

Four-channel programmable correlator consists of four 10-bit precise high-speed successive approximation ADC and the general-purpose personal computer (PC) [10]. It was put into operation in 2003. In contrast to correlators based on the TMS320 family signal processors, the four-channel programmable correlator allows to obtain a full set of the IS signal ACFs for all ionospheric plasma parameters estimation.

Since 2012, a new data processing system based on E20-10 ADC module operates in structure of the IS facility. It provides continuous acquisition of 16-bit data with processing rate up to 10 MHz and their transfer to PC using USB 2.0 interface. The software developed for system maintenance is an application for Microsoft Windows operating system. It sets up E20-10 appropriate mode, records signal data for every radar scan (1464 scans are response to 1 min session of measurement), calculates IS signal ACFs, and visualizes obtained data. High-speed interface and a high-performance PC allowed significantly increase sampling rate (currently up to 6 times) [11].

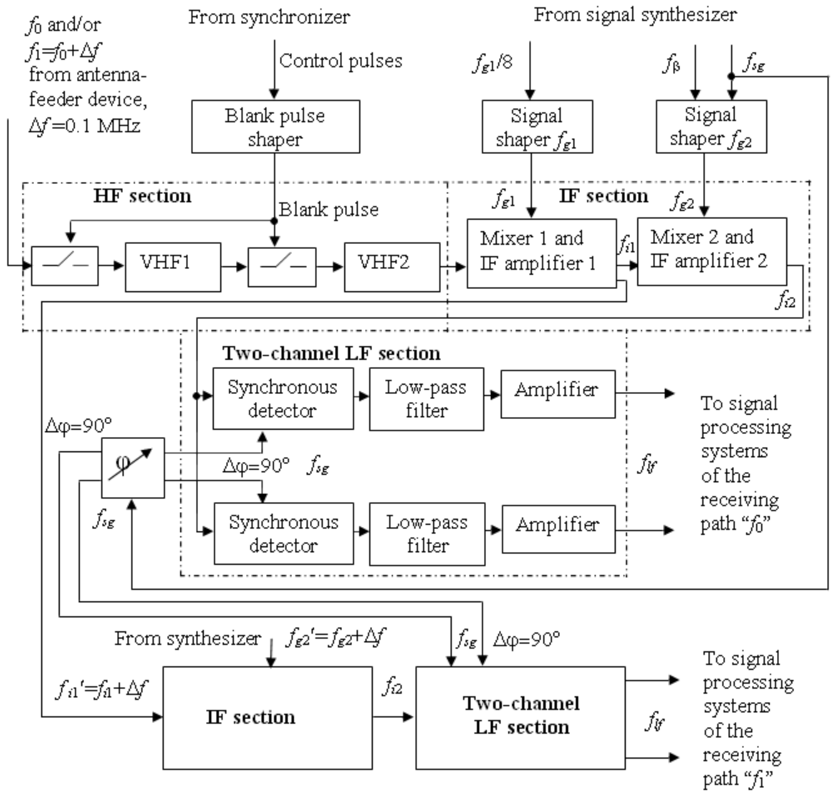


Fig. 5 – Block diagram of the IS radar receiver

Fig. 6 – The fully steerable 25-m-diameter antenna

Facility monitoring system is designed to test the radar operation. It produces a harmonic or random signal with characteristics similar to the IS signal. These signals are transmitted by the control antenna with orthogonal vibrators and received via 100-m antenna and feeder circuit to the receiver input.

Radar with a steerable 25-m antenna (Fig. 6) was put into operation in 1980s and has a similar structure of transmitter, receiver and feeder system [1, 3]. The effective aperture of the 25-m antenna is about 290 m^2, the two ways half-power antenna beam width is close to 5.1°. Radar is used to study the dynamics and wave disturbances of the ionosphere.

From time to time we work simultaneously using two radars (with zenith and steerable antennas). Because of this, it is possible to study the spatial structure of the ionosphere over Ukraine, to measure the full vector of the ionospheric plasma motion velocity, and to research in detail wave effects in the ionosphere.

Ionosonde "Bazis" allows to provide vertical, oblique and transionospheric pulse sounding of the ionosphere [12, 13]. Ionosonde is used independently to determine the basic parameters of the ionosphere (electron density, critical frequency, etc.) and in conjunction with the IS radar for binding measured value of the electron density at the maximum of ionization and normalized altitudinal profile of N_e. The ionosonde of Institute of Ionosphere can work in the international network of ionospheric stations, in particular, to observe the latitude and longitude effects in co-operation with the ionosonde in Pruhonice (Czech Republic, 50.0° N, 14.6° E), Dourbes (Belgium, 50.1° N., 4.6° E), Moscow (Russia, 55.5° N, 37.3° E) [14–16].

Main technical characteristics of the ionosonde “Bazis” are: peak pulse power of transmitter is not less than 15 kW, operating frequency range in vertical sounding mode is 1–20 MHz, frequency sweeping law is linearly increasing one with a discrete step in the range of 1 to 100 kHz, a number of operating frequencies are 400, pulse repetition frequency is 100 Hz, pulse duration is 100 ms. Antennas are rhombic ones with vertical radiation. Receiving and transmitting antennas are identical and located orthogonally.

The main elements of the “Bazis” are transmitter, receiver, control unit and recording device with PC.

Operating modes. Kharkiv IS radar can operate in the following modes (Fig. 7) [2, 17]:

– Sounding with a pulse of about 800 μs length to measure the parameters of the upper ionosphere and the ionosphere at the altitudes near the peak of the ionospheric F layer with altitude resolution of about 120 km (polarization is circular to avoid Faraday fading of the IS signals).

– Sounding with a cyclic sequence of double pulses (65 or 135 μs length) with a variable delay between pulses from one period of sounding to another. Every delay is equal to the respective lag of measured correlation function. Polarization is circular. This mode is used for measurement of the ionospheric parameters at altitudes of 100–550 km with altitude resolution of about 10 or 20 km respectively. Space between the double pulses is filled by the signal with an offset carrier frequency (f_1=f_0+0.1 MHz) to ensure stable operation of the transmitter and to reduce error of the ionospheric plasma drift velocity measurement, as well as because of the transmitter specifics [18]. This mode was actively used during the peak of solar cycle 23 [19].

– Sounding with a signal of 135 μs length with linear polarization to determine the electron density using the Faraday effect [20].

Since 2006, the main mode of the IS radar operation is radio sounding of the ionosphere using composite two-frequency radio pulse, where the first element has a pulse length of about 650 μs (the carrier frequency f_0 = 158 MHz) and the second element has the pulse length of about 135 μs (the frequency f_1 = (158 + 0.1) MHz) [3, 21]. As a result of receiving and processing of the first signal element scattered by the ionosphere, the electron density, the electron and ion temperatures, the vertical component of the plasma velocity, and the ion composition are measured for the altitudes near the peak of the ionospheric F layer and in the upper ionosphere. The height resolution for the first pulse element is about 120 km. Return signal from the second pulse element allows to determine the altitude profile of the IS signal power at the altitudes of 100 to 550 km with the height resolution of 20 km to correct the altitude electron density profile. Polarization of both pulse elements is circular.

The 135 μs pulse element is transmitted and received with linear polarization by two orthogonal antenna vibrators in case of need to determine the electron density using the Faraday effect.

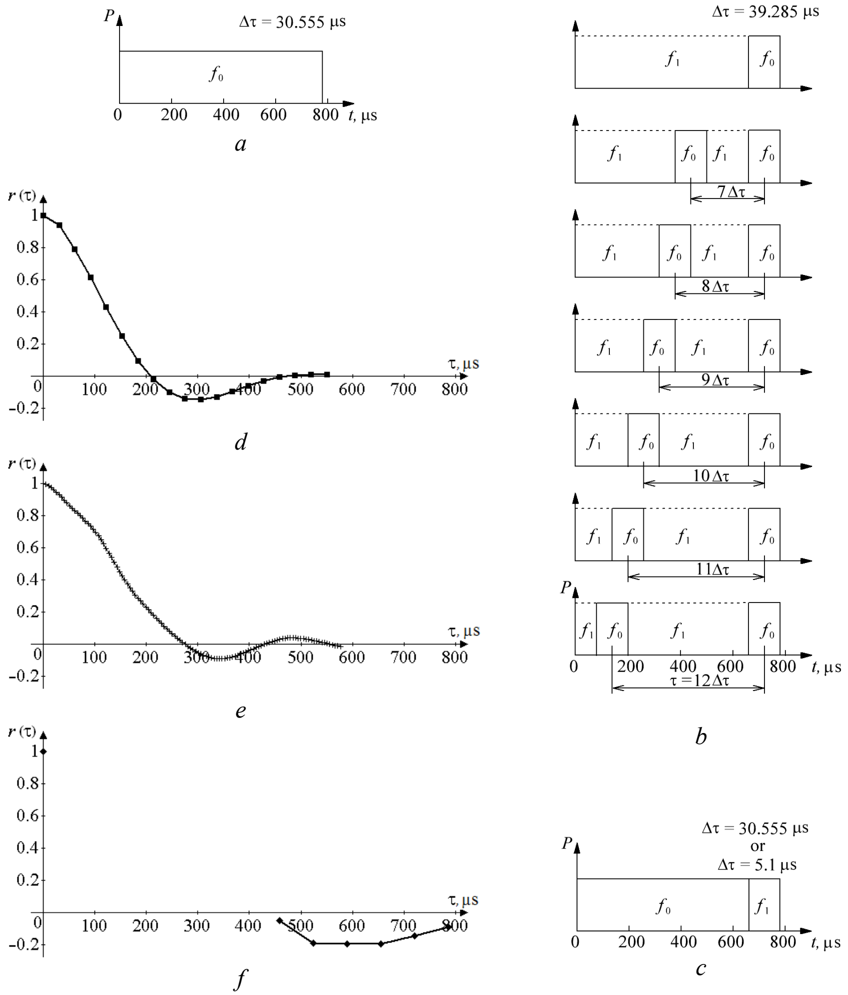


Fig. 7 – Diagrams of sounding signal for three main modes of Kharkiv IS radar: *a* – one-pulse mode, *b* – double-pulses mode, *c* – dual frequency sounding with long and short radio pulses. IS signal ACFs: *d* – lag step Δτ equals 30.555 μs, *e* – 5.1 μs, and *f* – 39.285 μs.

Processing techniques. Parameters of the ionospheric plasma for a number of discrete heights are determined as follows [4, 22]. For each signal delay, which is corresponding to height of the center of the scattering volume, ACFs of mixture of signal and noise are estimated using a variety of realizations. IS signal ACFs are calculated for several discrete delays as the difference between the measured mixture of signal and noise ACFs and noise ACFs averaged using a number of measurements at the end of scan where IS signal is negligible. Temperatures T_i and T_e are obtained using IS signal ACFs. Altitude N_e profile normalized to the peak of electron density is calculated using the obtained temperatures and the signal-to-noise ratio. Absolute values of N_e are determined by binding its normalized profile to the maximum value measured by the ionosonde. The ionospheric plasma velocity is determined using the measured IS signal ACFs quadrature components.

IS radar data processing software was developed in the Institute of Ionosphere. UPRISE (Unified Processing of the Results of Incoherent Scatter Experiments) package based on optimal techniques of IS radar data analysis includes programs for viewing the initial data, interference filtering, time integration, altitudinal data correction and ionospheric plasma parameters estimation [23].

Software development at the Institute is aimed to use of advanced networking technologies and databases [24, 25]. Thus, for example, a developed data processing system works on a remote server and uses the database of the radiophysical experiments. Its main task is to give information in text and graphics form about the data presented in the database. Information about size and quality of data is provided using a web interface to the system.

Some results of the ionosphere research. The research activity of the Institute of Ionosphere includes a broad spectrum of research topics devoted to the mid-latitude ionosphere. The observation of seasonal and diurnal variations in the electron density, ion and electron temperatures, plasma drift velocity, and hydrogen ions fraction during the winter and summer solstices, the vernal and autumnal equinoxes in the altitude range 200–1000 km is carried out [26]. The model of the mid-latitude ionosphere CERIM IION (Central Europe Regional Ionospheric Model) was developed using the Kharkiv IS radar data obtained over a period of more than two cycles of solar activity (from 1986 to 2011) [27]. Large variety of studies addressed different types of ionospheric perturbations, the ionospheric plasma dynamics in general [28, 29], and the wave disturbances in the ionosphere caused by the solar terminator [30], by the launches of rockets [31], and by the effect of high power HF radio transmission on the ionospheric plasma [32, 33]. The Institute also continues to study the response of the ionosphere to geomagnetic storms [34–36] and solar eclipses [29, 37, 38]. A model of ion composition of the topside ionosphere over Kharkiv is currently under development [39, 40].

As an example, the altitude-time variations of ionospheric parameters in the quiet conditions (Fig. 8) and during magnetic storm (Fig. 9) are presented.

The scientific results are regularly presented at topical conferences, symposia and seminars also at many international forums. The Institute of Ionosphere coordinates its activity with foreign scientific institutions that are actively involved in ionospheric studies.

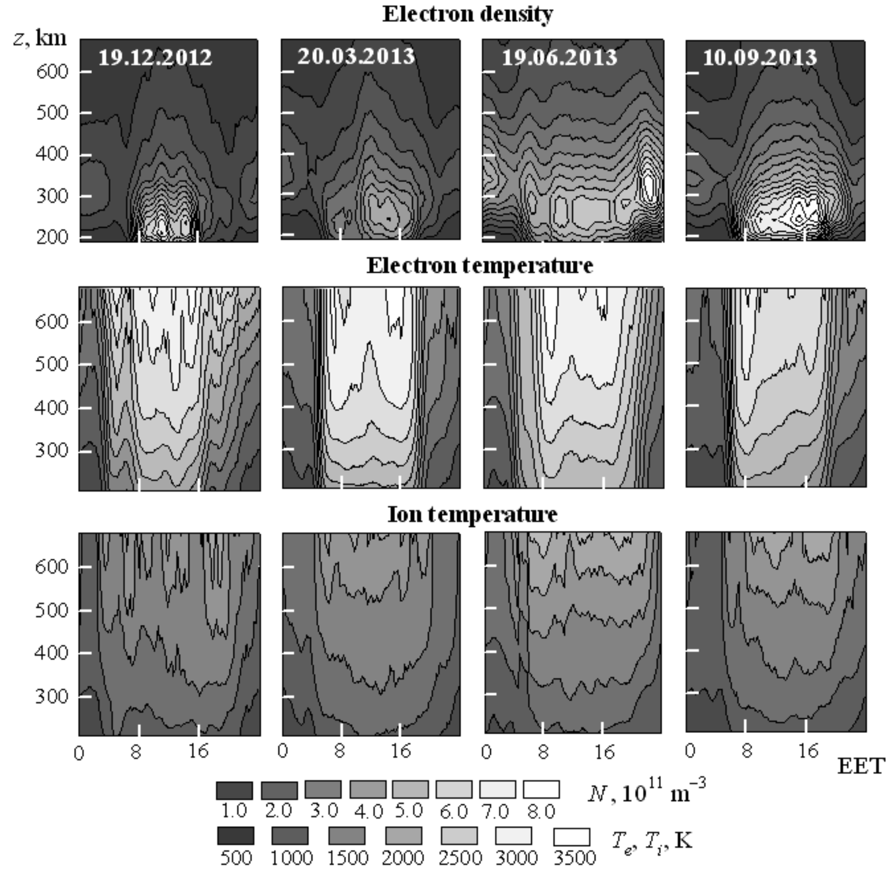
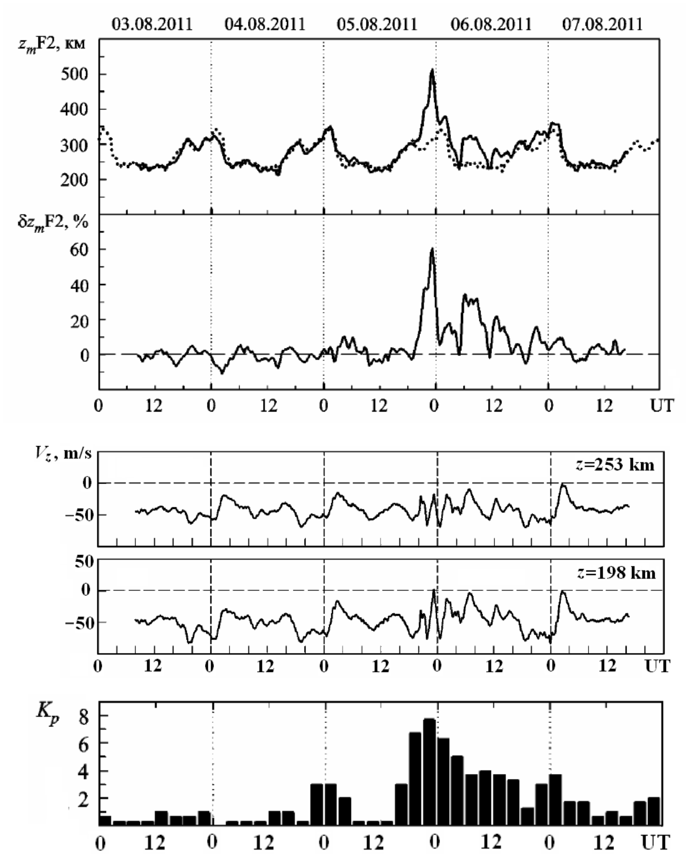


Fig. 8 – Altitude and temporal variations of electron density (top panel), electron (middle panel) and ion (bottom panel) temperatures for typical geophysical periods according to the Kharkiv incoherent scatter radar data



a

b

c

Fig. 9 – Temporal variations in z_mF2 height (upper panel) on 3–7 August 2011 (solid line) and its relative deviation δz_mF2 (lower panel) (*a*), the variations in the vertical component of the ionospheric plasma drift velocity V_z at altitudes 198 and 253 km (*b*), obtained by the IS Kharkiv radar, and distribution of geomagnetic index K_p (from http://www.swpc.noaa.gov/). The dashed line shows the temporal variations in z_mF2 obtained by averaging data of 3, 4 and 7 August 2011 when conditions were magnetically quiet

Conclusions.

– Kharkiv incoherent scatter facility is a powerful tool for study of the ionosphere. It is the only one in the middle latitudes of the Central European region and it is used to study the longitude and latitude effects in the ionosphere together with the similar foreign facilities.

– Due to significant modernization of the IS facility, the development of measurement techniques of ionospheric parameters, algorithms, and software for processing of ionospheric data, we obtain reliable information about the state of the ionosphere over Ukraine at a high level.

– The Institute of Ionosphere database of ionosphere parameters (http://database.iion.org.ua/) is developed.

– Experimental researches of the ionospheric parameters variations in a wide range of altitudes (100–1000 km) over Ukraine (Central Europe) during over 3 solar activity periods were carried out with Kharkiv IS radar.

– Experimental and theoretical studies of the effects in geospace during a number of geomagnetic storms of various intensity (from weak to very strong) and solar eclipses were carried out.

– Study of the aperiodic and quasi-periodic disturbances in the ionosphere during rocket launches and the ionosphere modification by high power HF radio transmission far from the antenna beam pattern of the heater (at the distance of about 1000 km) are carried out using the IS facility of the Institute of Ionosphere.

References: **1.** *Taran V.I.* Ionosphere research by incoherent scatter radars in Kharkiv / *V.I. Taran* // Bulletin of the Kharkiv State Polytechnic University. – 1999. – № 31.– P. 3-9 (in Russian). **2.** *Golovin V.I.* Observations of the ionosphere using the incoherent scatter method / *V.I. Golovin, E.V. Rogozhkin, V.I. Taran, S.V. Chernyaev* // Bulletin of the Kharkiv Polytechnic Institute “The study of ionosphere by the incoherent scatter method”. – 1979. – № 155, Issue 1. – P. 12-22 (in Russian). **3.** *Emelyanov L.Ya.* History of the development of IS radars and founding of the Institute of Ionosphere in Ukraine / *L.Ya. Emelyanov, T.G. Zhivolup* // History of Geo- and Space Sciences. – 2013. – № 4. – P. 7-17, doi:10.5194/hgss-4-7-2013. **4.** *Pulyaev V.A.* Determination of the ionospheric parameters using the incoherent scattering technique: Monograph / *V.A. Pulyaev, D.A. Dzyubanov, I.F. Domnin*. – Kharkiv: NTU “KhPI”, 2011. – 240 p. (in Russian). **5.** *Gukasov Yu.G.* Measurement of NDA-100 antenna patterns by currents on the mirror surface / *Yu.G. Gukasov, V.N. Ivchenko* // Bulletin of the Kharkiv Polytechnic Institute “The study of ionosphere by the incoherent scatter method”. – 1979. – № 155, Issue 1.– P. 29-33 (in Russian). **6.** *Chepurnyy Ya.M.* Measurement of NDA-100 antenna pattern using the reflections from the man-made space objects / *Ya.M. Chepurnyy, L.Ya. Emelyanov, D.A. Iskra* // Bulletin of National Technical University “Kharkiv Polytechnic Institute”: Special Issue “Radiophysics and ionosphere”. – 2013. – № 28 (1001). – P. 14-18 (in Russian). **7.** *Smaglo N.A.* Radio transmitting device the meter band radar / *N.A. Smaglo, A.D. Koval, V.K. Bogovskiy* // Bulletin of the Kharkiv State Polytechnic University. – 1999. – № 31. – P. 113-116 (in Russian). **8.** *Emelyanov L.Ya.* Radio receiver system of the incoherent scatter radar / *L.Ya. Emelyanov* // Bulletin of the Kharkiv State Polytechnic University. – 1999. – № 31. – P. 108-112. (in Russian). **9.** *Lysenko V.N.* Features of correlation processing incoherent scatter signal by sounding the ionosphere in the VHF band with the radio pulses of 800 μs duration / *V.N. Lysenko* // Bulletin of the Kharkiv State Polytechnic University. – 1999. – № 31. – P. 90-95 (in Russian). **10.** *Lysenko V.N.* Programmable correlator to measure the ionospheric parameters using the incoherent scatter method / *V.N. Lysenko, A.F. Kononenko, Yu.V. Chernyak* // Bulletin of National Technical University “Kharkiv Polytechnic Institute”, Special Issue “Radiophysics and ionosphere”. – 2004. – № 23.– P. 49-62 (in Russian). **11.** *Iskra D.A.* Improving the accuracy of determining the autocorrelation functions of incoherently scattered signal / *D.A. Iskra* // Bulletin of National Technical University “Kharkiv Polytechnic Institute”: Special Issue “Radiophysics and ionosphere”. – 2013. – № 33 (1066). – P. 34-37 (in Russian). **12.** *Emelyanov L.Ya.* Ionosonde “Bazis” of the Institute of Ionosphere as a tool for monitoring the state of the ionosphere / *L.Ya. Emelyanov, A.A. Kononenko* // Radiotekhnika: All-Ukr. Sci. Interdep. Mag. – 2011. – № 167. – P.

30-33 (in Russian). **13.** *Emelyanov L.* Analysis of variations of the critical frequency f_oF2 of the ionosphere over Kharkiv during two solar cycles / *L. Emelyanov*, *A. Kononenko* // International School-Conference "Remote radio sounding of the ionosphere" (ION-2013) September, 30 – October, 4, 2013. – Maly Mayak (Big Alushta), Crimea, Ukraine. – Book of Abstracts. – 2013. – P 48. **14.** Pruhonice / Digisonde-4D / Czech Republic. – http://147.231.47.3 **15.** Dourbes / Digisonde DPS-4/ Belgium – http://digisonde.oma.be **16.** Moscow / Digisonde DPS-4 / Russia – http://dps.izmiran.ru/ **17.** *Rogozhkin E.V.* Sounding signals to study the ionosphere by the incoherent scattering: Monograph / *E.V. Rogozhkin*, *V.A. Pulyaev*, *V.N. Lysenko*. – Kharkiv: NTU "KhPI", 2008. – 256 p. (in Russian) **18.** *Emelyanov L.Ya.* Issues of reducing the effect of the sounding signal to the accuracy of the determination of the ionospheric plasma drift velocity / *L.Ya. Emelyanov, I.B. Sklyarov*, *S.V. Chernyaev* // Bulletin of National Technical University "Kharkiv Polytechnic Institute", Special Issue "Radiophysics and ionosphere". – 2002. – Vol. 5, № 9. – P. 25-28 (in Russian). **19.** *Siusiuk M.M.* Features of investigation of the middle ionosphere by incoherent scatter technique / *M.M. Siusiuk* // Bulletin of National Technical University "Kharkiv Polytechnic Institute": Special Issue "Radiophysics and ionosphere". – 2013. – № 33 (1066). – P. 62-65 (in Russian). **20.** Patent 71162. Ukraine, G01S 13/95. A method of measuring the parameters of the ionosphere and magnetosphere / *L.Ya. Emelyanov*, *T.A. Skvortsov*, *I.B. Sklyarov*, *A.V. Fesun*.; patented 14.11.2011; published 10.07.2012, Bulletin N 13 (in Ukrainian). **21.** *Lysenko V.N.* Dual-frequency measuring channel for determining the parameters of the ionosphere by the incoherent scattering / *V.N. Lysenko*, *Yu.V. Chernyak* // Radiophysics and electronics. – 2004. – Vol. 10, № 2.– P. 217-223 (in Russian). **22.** *Emel'yanov L.Ya.* Incoherent Scatter Measurement of the Electron Density Altitude Profiles / *L.Ya. Emel'yanov* // Geomagnetism and Aeronomy. – 2002. – Vol. 42, № 1. – P. 109-113. **23.** *Bogomaz O.V.* Unified Processing of the Results of Incoherent Scatter Experiments (UPRISE), a new generation program package for incoherent scatter radar data processing / *O.V. Bogomaz*, *D.V. Kotov* // Bulletin of National Technical University "Kharkiv Polytechnic Institute": Special Issue "Radiophysics and ionosphere". – 2013. – № 28 (1001). – P. 29-37 (in Russian). **24.** *Miroshnikov A.E.* Kharkiv Institute ionosphere incoherent scatter radar (Ukraine) express data processing on a remote server and visualization of results / *A.E. Miroshnikov*, *O.V. Bogomaz* // 16th International EISCAT symposium, 12–16 August 2013, Lancaster, United Kingdom. – Lancaster, 2013. – http://eiscat2013.lancs.ac.uk/wp-content/uploads/2013/08/3_Miroshnikov_Miroshnikov_Abstract.pdf **25.** *Bogomaz O.V.* Express incoherent scatter radar data processing on a remote server / *O.V. Bogomaz, A.E. Miroshnikov* // Bulletin of National Technical University "Kharkiv Polytechnic Institute": Special Issue "Radiophysics and ionosphere". – 2013. – № 28 (1001). – P. 63-68 (in Russian). **26.** *Chernogor L.* Study of ionospheric processes over Ukraine / *L. Chernogor*, *I. Domnin*, *L. Emelyanov*, *D. Kotov*, *M. Lyashenko* // Space Research in Ukraine / By Ed. O. Fedorov. – 2012. – P. 47-67 (in Russian). **27.** *Lyashenko M.* Development of Central Europe Regional Ionospheric Model (CERIM IION) based on Kharkiv incoherent scatter data / *M. Lyashenko*, *I. Domnin*, *L. Chernogor* // Workshop on Assessment and Validation of Space Weather Models (Alcala de Henares, Spain, 16–17 March, 2011). – 2011. – P. 23–24. **28.** *Yemelyanov L.Ya.* The Peculiarities of Mid–Latitude Ionosphere Plasma Drift Velocity Determination / *L.Ya. Yemelyanov, D.A. Dzyubanov* // Telecommunications and Radio Engineering. – 2007. – Vol. 66, № 14. – P. 1313-1327. **29.** *Domnin I.F.* Dynamics of the ionospheric plasma above Kharkiv during the January 4, 2011 solar eclipse / *I.F. Domnin*, *L.Ya. Emelyanov*, *L.F. Chernogor* // Radio Physics and Radio Astronomy. – 2012. – Vol. 3, № 4. – P. 311-324. **30.** *Burmaka V.P.* Wave Disturbances in the Ionosphere during a Lasting Solar Activity Minimum / *V.P. Burmaka*, *L.F. Chernogor* // Geomagnetism and Aeronomy. – 2012. – Vol. 52, № 2. – P. 183-196. **31.** *Burmaka V.P.* Complex Diagnostics of Disturbances in the Ionospheric Plasma Parameters Far from the Trajectories of Launched Rockets / *V.P. Burmaka*, *L.F. Chernogor* // Geomagnetism and Aeronomy. – 2009. – Vol. 49, № 5.– P. 637-652. **32.** *Burmaka V.P.* Variations in the parameters of scattered signals and the ionosphere connected with plasma modification by high-power radio waves / *V.P. Burmaka*, *I.F. Domnin*, *V.P. Uryadov*, *L.F. Chernogor* // Radiophysics and Quantum Electronics. – 2009. – Vol. 52, № 11. – P. 774-795. **33.** *Domnin I.F.* Results of Radiophysical Study of Wave Disturbances in the Ionospheric Plasma During Its Heating by High-Power HF Radio Transmission of "Sura" Facility /

I.F. Domnin, *S.V. Panasenko*, *V.P. Uryadov*, *L.F. Chernogor* // Radiophysics and Quantum Electronics. – 2012. – Vol. 55, N 4. – P. 253-265. **34.** *Grigorenko Ye.I.* Analysis and classification of ionospheric storms at the midlatitudes of Europe / *Ye.I. Grigorenko*, *V.N. Lysenko*, *V.I. Taran*, *L.F. Chernogor* // Kosmichna nauka i technologiya. – 2007. – Vol. 13, № 5. – P. 58-96 (in Russian). **35.** *Chernogor L.* Ionospheric storm effects above Kharkiv during the August 5–6, 2011 / *L. Chernogor*, *I. Domnin*, *L. Emelyanov*, *S. Kharytonova*, *M. Lyashenko* // EGU General Assembly 2012, Vienna, Austria, 22–27 April 2012. – Geophysical Research Abstract. – EGU2012-630-1. – 2012. – P. 14. **36.** *Domnin I.F.* Dynamic processes in the ionosphere during a very moderate magnetic storm on 20–21 January 2010 / *I.F. Domnin*, *L.Ya. Emelyanov*, *S.A. Pasura*, *S.V. Kharitonova*, *L.F. Chernogor* // Kosmichna nauka i technologiya. – 2011. – Vol. 17, № 4. – P. 26-40 (in Russian). **37.** *Emelyanov L.Ya.* Effects in geospace plasma during the partial solar eclipse on August 1, 2008 over Kharkiv. 1. The results of observations / *L.Ya. Emelyanov*, *M.V. Lyashenko*, *L.F. Chernogor* // Kosmichna nauka i technologiya. – 2009. – Vol. 15, № 3. – 70-81 (in Russian). **38.** *Chernogor L.F.* Effects in the geospace during partial solar eclipses over Kharkiv / *L.F. Chernogor*, *Ye.I. Grigorenko*, *M.V. Lyashenko* // International Journal of Remote Sensing. – 2011. – №. 32. – P. 3219-3229. **39.** *Kotov D.V.* Spatial and temporal variation in the hydrogen ions fraction under various space weather conditions / *D.V. Kotov*, *L.F. Chernogor* // Proceedings of XII Conference of Young Scientists “Interaction of fields and radiation with substance” (Irkutsk, Russia, September, 19–24, 2011). – Irkutsk. – 2011. – P. 202-204 (in Russian). **40.** *Kotov D.* The upper transition height over the Kharkiv incoherent scatter radar before, during and after the extreme minimum of the solar activity: Observational results and comparison with the IRI-2012 model / *D. Kotov*, *V. Truhlik*, *P. Richards*, *J. Huba*, *L. Chernogor*, *O. Bogomaz*, *I. Domnin* // EGU General Assembly 2014, Vienna, Austria, 27 April–2 May 2014. – Geophysical Research Abstract. – EGU2014-5652. – 2014.

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Kharkiv incoherent scatter facility / I. F. Domnin, Ya. M. Chepurnyy, L. Ya. Emelyanov, S. V. Chernyaev, A. F. Kononenko, D. V. Kotov, O. V. Bogomaz, D. A. Iskra // Bulletin of NTU “KhPI”. Series: Radiophysics and ionosphere. – Kharkiv: NTU “KhPI”, 2014. – No. 47 (1089). – P. 28-42. Ref.: 40 titles.

Наведено структуру, параметри і режими роботи радара некогерентного розсіяння Інституту іоносфери (м. Харків). Показано деякі результати спостережень іоносфери за допомогою цього обладнання.

Ключові слова: радар некогерентного розсіяння, іонозонд, іоносферна обсерваторія, параметри іоносфери, метод некогерентного розсіяння радіохвиль.

Представлены структура, параметры и режимы работы радара некогерентного рассеяния Института ионосферы (г. Харьков). Показаны некоторые результаты наблюдений ионосферы с помощью этого оборудования.

Ключевые слова: радар некогерентного рассеяния, ионозонд, ионосферная обсерватория, параметры ионосферы, метод некогерентного рассеяния радиоволн