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A LIBRARY OF ROUTINES FOR INCOHERENT SCATTER RADAR DATA PROCESSING

The structure of the developed dynamic link library of routines for incoherent scatter radar data processing and incoherently scattered signals simulation and the examples of its application are described.

Keywords: incoherent scatter, data processing, simulation, numerical computing routines.

Introduction. Incoherent scatter radar data processing is produced by the complicated program packages GUISDAP and UPRISE for example [1, 2].

GUISDAP (Grand Unified Incoherent Scatter Design and Analysis Package) is used on EISCAT radars and needs a MATLAB environment in the Linux or Windows operating system (OS). The MATLAB application is built around the own high-level language and provides a lot of numerical computing routines for data processing. These features make GUISDAP sources more clear to understand and simpler to improve.

UPRISE (Unified Processing of the Results of Incoherent Scatter Experiments) package is used for processing of the data obtained by means of Kharkiv incoherent scatter radar (ISR). The package includes programs for viewing the initial data, interference filtering, time integration, altitudinal correction and estimating of ionospheric plasma parameters. It is written using FreeBASIC, runs in Windows OS and doesn't need any third-party software. The most used routines for UPRISE were exported to the dynamic link library (DLL) *albom.dll* written in C programming language.

Purpose of the article is to present the developed dynamic link library of routines for incoherent scatter radar data processing.

Library structure. *Albom.dll* consists of more than 100 functions that can be divided into several groups.

The first group is represented by functions for manipulating the initial data. The library can handle files produced by all Kharkiv ISR data processing systems operating since 1996. There are functions for loading and saving files of data processing system based on TMS320 signal processors [3], multichannel programmed correlator [4] and the data acquisition system based on E20-10 analog-to-digital conversion module [5]. There are functions for file testing and metadata reading and writing.

Functions for calculating altitude of the scattered volume are also present in this group. An altitude h can be calculated using $h = H_0 + \Delta h \cdot i$ formula, where Δh –

an altitude step (4.583 or 9.81 km), i – a current altitude position, H_0 – an altitude for the first position. Constants H_0 for every ISR data processing system were verified using the reflections from the International Space Station (fig. 1).
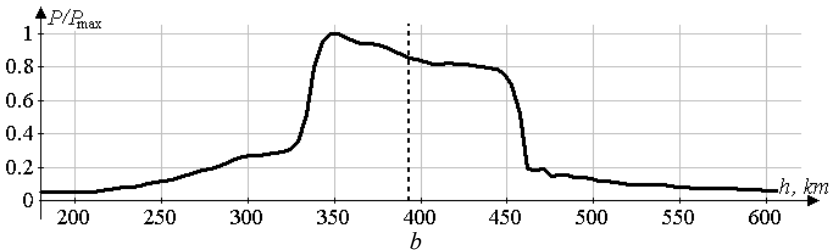

a

b
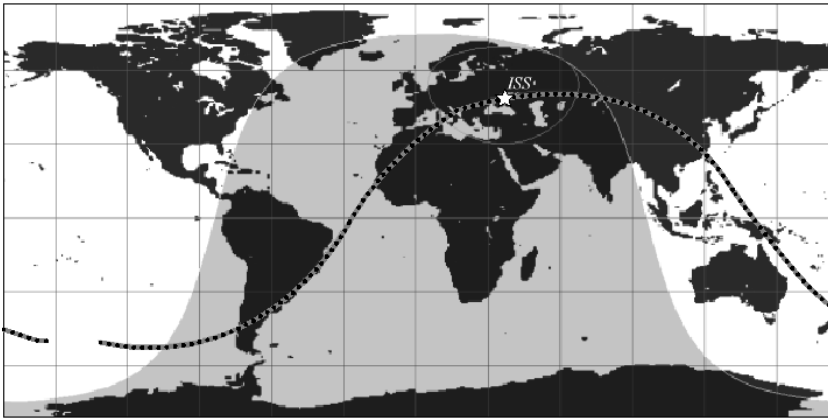
Fig. 1 – International Space Station (ISS) location on August 11, 1999 at 2:41 EEST (*a*) and recieved by the Kharkiv radar reflected power profile
showing distance to the ISS is equal 393 km (*b*)

The group also includes functions for working with files in the specified directory in the disk file system. For example it is possible to make a list of files in a directory and get its length using only one function. There is a need to perform this task often because the number of initial files always varies.

The second group of functions contained in the *albom.dll* gathers ones for output data manipulating. This data can be binary or text files with IS signal autocorrelation functions (ACFs) or estimated ionospheric plasma parameters (such as ion and electron temperatures, ion composition, velocity etc.). It is possible to work with buffer in memory as with a file and after writing to it file is flushed to disk.

The third group provides time and date functions. The one of the main of them converts date to UNIX timestamp. It is used for sorting the initial data. Inverse conversion is also available. Another function returns the next day value. It checks if the date is valid, takes into account number of days in the month and determines whether the year is leap. For example if the input date is February 29, 2012, the function will return March 1, 2012.

The fourth group contains functions for calculating IS signals' spectra and ACFs. Wavelength is taken to be 1.9 m. Such other parameters as sampling interval, ion composition, ion and electron temperatures and electron density are definable. As ACF calculating is time-consuming operation, it is not desirable to carry out it in the real time while the inverse problem is solving for example. So routines for building of ACF libraries and working with them are also present in the DLL.

Lastly a lot of routines for data processing are implemented in the fifth group of functions.

Statistical routines are presented by functions for distribution law, arithmetic mean, standard deviation and variance of a list of numbers calculating.

A set of functions is intended for arrays manipulation (maximum and minimum values searching, trends building, normalization of series, convolution between two series, element-wise addition, subtraction, multiplication and division).

ISR data can be interpolated and approximated using a number of functions (linear and spline interpolation, polynomial approximation).

The discrete Fourier transform, fast Fourier transform and their inverses are implemented in the library and are widely used in the UPRISE package.

Two functions in the library generate random real numbers with uniform and normal distributions. The initial value can be set by lower 32 bits of the Time Stamp Counter (TSC) when x86 architecture processor is used. RDTSC (Read TSC) instruction returns the number of cycles since processor's reset and is available starting from Pentium.

Other applications of the albom.dll. The library using is quite wide in programs developed in the Institute of ionosphere.

First of all it is programs for the initial data export to analyze them using third-party software. These programs have a simple user interface (fig. 2). One click is needed to choose directory with files and one more to choose directory to export data to text files.

Secondly, programs using *albom.dll* are designed for incoherently scattered signals simulation. The developed software for signal simulation allows to obtain statistical errors of ionospheric plasma parameters estimation [6] and to test ISR data acquisition systems [7].

Data stored in the DLL. Besides the code of routines, the *albom.dll* contains data related to the Kharkiv ISR characteristics such as frequency response, impulse response and ACF of impulse response for analog low-pass filters that are used in the radar receiver (fig. 3). Appropriate functions easily fill arrays and there is no

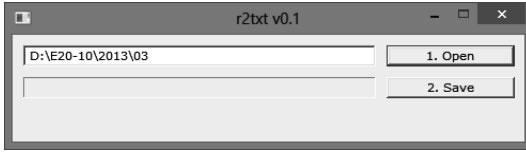need to store data in many files and to load them from disk.

Fig. 2 – Graphical user interface of the program for the initial data exporting
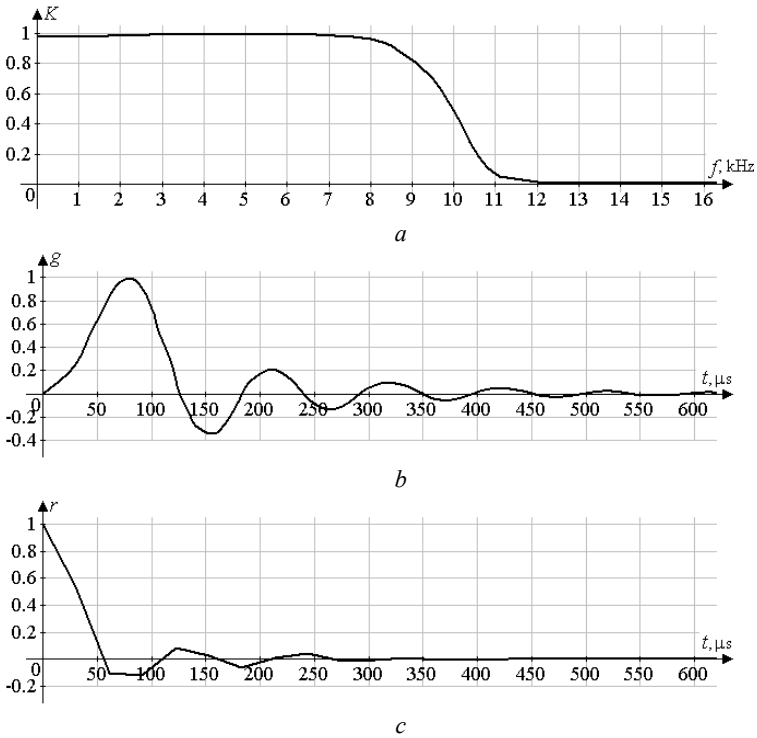that uses *albom.dll*

a

b

c

Fig. 3 – Frequency response (*a*), impulse response (*b*) and
ACF of impulse response (*c*) for 9.5 kHz low-pass filter
used in Kharkiv incoherent scatter radar receiver

Conclusions. The *albom.dll* library contains a lot of routines that
significantly simplify the process of development of programs for ISR data

processing and incoherently scattered signals simulation. It can be used with almost all modern programming language (C/C++, Delphi, Python, FreeBASIC etc.).

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В статье описана структура разработанной динамической библиотеки процедур для обработки данных радара некогерентного рассеяния и имитации некогерентно рассеянных сигналов, а также приведены примеры её применения.
Ключевые слова: некогерентное рассеяние, обработка данных, моделирование, численные вычислительные процедуры.

У статті описано структуру розробленої динамічної бібліотеки процедур для обробки даних радара некогерентного розсіяння та імітації некогерентно розсіяних сигналів, а також приведено приклади її використання.
Ключові слова: некогерентне розсіяння, обробка даних, моделювання, чисельні обчислювальні процедури.

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VARIATIONS OF THE ELECTRIC FIELD ZONAL COMPONENT, THE VERTICAL COMPONENT OF THE PLASMA DRIFT AND NEUTRAL WIND VELOCITIES IN IONOSPHERE OVER KHARKOV (UKRAINE) DURING AUGUST 5 – 6, 2011 AND NOVEMBER 13 – 15, 2012 MAGNETIC STORMS

The modeling results of the zonal electric field and the vertical component of the plasma transfer velocity due to electromagnetic drift during August 5–6, 2011 and November 13 – 15, 2012 magnetic storms were presented. Confirmed that has a penetration of electric fields from magnetospheric origin in the mid-latitude ionosphere during strong geomagnetic disturbances. For the considered disturbed periods the neutral wind parameters were calculated using Kharkov incoherent scatter radar data.

Keywords: ionosphere, geospace storm, zonal electric field, plasma drift.

Introduction. It is well known that in quiet conditions the contribution of magnetospheric sources in electric fields and currents in the middle and low latitudes is fairly small. As the presented in [1 – 4], the results of experimental studies and theoretical calculations, the magnitude of the electric field in the mid-latitude ionosphere without geomagnetic disturbances does not exceed several mV/m. At altitudes of the ionospheric F2-peak the plasma drift caused by these fields is small compared to the transport processes of charged particles due to ambipolar diffusion and neutral winds. During strong geomagnetic disturbances has penetration of electric fields at the altitudes of the mid-latitude ionosphere and, consequently, increasing the plasma velocity in crossed electric and magnetic fields. It should be noted that the transfer of the plasma due to the electromagnetic drift during geomagnetic storms have a significant impact on the altitudinal distribution of the parameters of the mid-latitude ionosphere.

The aim of this work is to calculate the parameters of the zonal electric field in the ionosphere over Kharkov (Ukraine), as well as modeling the transport velocity variations due to the electromagnetic plasma drift and neutral wind during August 5 – 6, 2011 and November 13 – 15, 2012 magnetic storms.

The observation means. For modeling of the neutral wind parameter variations were used the Kharkov incoherent scatter radar (ISR) (geographic coordinates: 49,6º N, 36,3º E; geomagnetic coordinates: 45,7º, 117,8º) data. At present time the Kharkov ISR is the only reliable and most informative data source of the geospace plasma state at the mid-latitudes of Central Europe.

Radar allows measuring with high accuracy (usually error is 1 – 10%) and acceptable altitude resolution (10 – 100 km) the following ionospheric parameters: