

Interpre: a Windows software for semiautomatic scaling of ionospheric parameters from ionograms[☆]

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Abstract

By analysing an ionogram several important parameters like foF2 and MUF(3000)F2 can be found, that have a significant role in the studies concerning ionospheric physics and related phenomena. Furthermore, the observation of ionospheric plasma and the forecasting of physical phenomena connected to the Sun-Magnetosphere-Ionosphere-Thermosphere system holds a remarkable scientific interest with respect to space weather, because of the influence that these phenomena have on satellite and terrestrial communications. From this point of view, the development of models whose input are real-time ionospheric parameters has become fundamental.

This paper will introduce a Visual Basic program for semi-automatic scaling of ionospheric parameters from ionograms. This software allows to increase the speed of the scaling phase performed by the operator trying also to improve the output in terms of reliability.

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1. Introduction

Ionospheric observations are performed by a high-frequency radar known as ionosonde. The ionosonde sends short pulses of radio energy vertically into the ionosphere. These pulses are reflected back towards the ground and the ionosonde records the time delay between transmission and reception of pulses. By varying the carrier frequency of pulses from 1 to 20 MHz, the time delay at different frequencies is recorded. This record is referred to as an ionogram and is usually presented in the form of a graph, where normally in place of time delay the virtual height is plotted according to the following equation:

$$\Delta t = \frac{2}{c} h', \quad (1)$$

[☆] Code on server at <http://www.iamg.org/CGEditor/index.htm>

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where Δt is the time delay, h' is the virtual height and c is the free space speed of electromagnetic waves.

From the analysis of one ionogram several important parameters can be found (Fig. 1) that have a significant role in the studies concerning ionospheric physics and related phenomena.

With the advent of new technologies, softwares have been developed for real-time ionospheric monitoring in order to perform an automatic scaling of the obtained trace (Reinisch and Huang, 1983; Fox and Blundell, 1989; Igi et al., 1992). PC facilities have also been developed for semiautomatic scaling of ionograms and/or manual validation of data (Pulinets, 1995; Zuccheretti, 1998).

An advanced digital ionosonde, that is able to separate the wave components using a cross antenna system, is produced by the Lowell University of Massachusetts (Reinisch and Huang, 1983). In 2001, a new ionosonde was developed at the Istituto Nazionale di Geofisica e Vulcanologia (INGV). The INGV ionosonde does not separate the ordinary and extraordinary traces by the

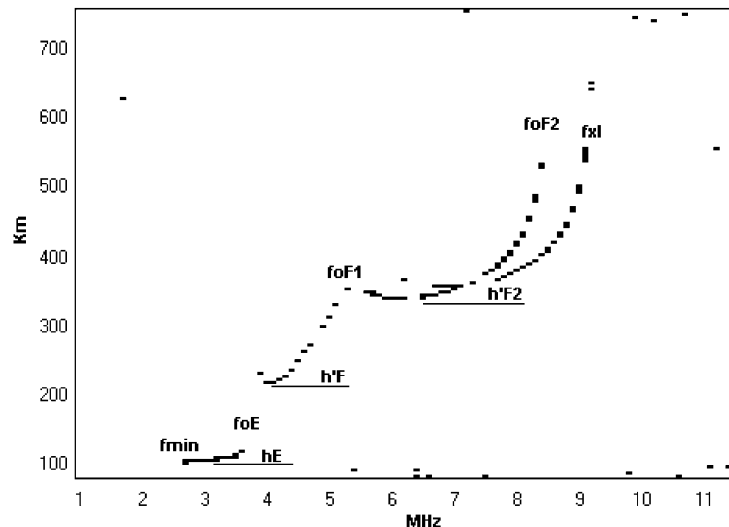


Fig. 1. Example of ionogram with some of its main characteristics.

hardware of the system, but it is equipped with an automatic scaling software of foF2 and MUF(3000)F2 that separates the components using image recognition techniques (Scotto and Pezzopane, 2002). In addition “Interpre”, a software capable of semiautomatic scaling of ionograms has been designed and developed to increase the speed and the precision of the scaling of all ionospheric parameters.

In the following paragraphs, we will describe how “Interpre” operates, the format of the ionogram files that can be scaled with this software and the format of the output files containing the results of the scaling.

2. Installation, ionogram files and output files

The program is written in Visual Basic 6.0 (Cornell, 1998); it runs under W9X, W2000, NT 4.0 and XP. Minimum system requirements: 133 MHz processor, at least 32 Mb of RAM, SVGA graphics of 1024×768 pixels. In a directory chosen by the operator the following files and directories must be present: the file “*interpre.exe*” that is the real interpretation program, the file “*setting.txt*” that keeps tracks of the parameters of the on-going interpretation, and the directory “*ionograms*” inside which all files corresponding to the ionograms under study must be kept.

2.1. Content of file *setting.txt*

The file “*setting.txt*” is an ASCII file and it is made of 5 records. The first, the second and the third record hold, respectively, the date, the hour and the minutes of the last interpreted ionogram; the fourth record contains

the chosen difference in minutes that has to pass between two consecutive ionograms and the fifth record memorises the number of the line, of the output file, where the program writes the values obtained from the interpretation of the ionogram.

2.2. Ionogram file format

All ionogram files have extension .RDF; they are binary files. The name of the ionogram file is *yyggglm l mm.rdf*, where *yy* are the last two digits of the year, *ggg* are the three digits for the giulian day, *l* is the letter that identifies the hour (see Table 1) and *mm* (that can only take following values: 00, 05, 10, 15, 20, 25, 30, 35, 40, 45, 50 and 55) represents the minutes (ex. *02151b00.rdf*, where *02* are the last two digits of the year 2002, *151* is the giulian day, *b* corresponds to the hour 01 and 00 are the minutes). Every file has a header of 197 bytes, where the bytes between 1 and 6 represent the initial frequency of the sounding (that cannot be smaller than 1 MHz), the bytes between 8 and 13 represent the final frequency of the sounding (that cannot be bigger than 20 MHz) and the bytes between 15 and 19 represent the frequency step (whose size can be 0.050, 0.100, 0.200 or 0.500 MHz), while the remaining bytes are parameters concerning the receiver settings, the signal processing algorithm and geophysical constants depending on the specific installation site. Next to the header these files are structured in a certain number (depending on the monitoring frequency band width) of records of 150 bytes, each record representing the sounding in height in correspondence of a determined value of the frequency; the value of the first byte represents the energy reflected back towards the ground from a height of 90 km, the

Table 1
Correspondence between letters and hours

Letter	Hour
A	00
B	01
C	02
D	03
E	04
F	05
G	06
H	07
I	08
J	09
K	10
L	11
M	12
N	13
O	14
P	15
Q	16
R	17
S	18
T	19
U	20
V	21
W	22
X	23

byte 150 represents the energy reflected back towards the ground from a height of 760.5 km, therefore the passage between two successive bytes of the record is equal to a movement in height of 4.5 km.

2.3. Output file format

The output files are ASCII files whose name is *ddmmyyDD.txt*, where *dd* stays for the day, *mm* stays for the month, *yy* are the last two digits of the year and *DD* is the chosen difference in minutes between the ionograms under study (ex. *31010260.txt* is the output file of January the 31st, 2002 with a difference of 60 min between the ionograms under study). They are positioned in the directory “*ionograms*” while the interpretation of the ionograms goes on.

The standard record of the output file is made of 248 bytes. The first 5 bytes identify the hour of the ionogram, byte number 6 is a blank byte, thereafter the record structure is 16(8A, “=”,3I,2A, “blank”), where 8A identifies the name of the ionospheric parameter, 3I the corresponding numeric value obtained from the interpretation, 2A the corresponding qualifying and descriptive letters (Wakai et al., 1987) if brought in during the interpretation phase; the last two bytes of the record are those of carriage and return.

The number of records of these files depends on the chosen difference in minutes in the initial graphic

interface (Fig. 2) of the program; choosing 60, the number of records will be 24; choosing 30, the number of records will be 48; choosing 15, the number of records will be 96; choosing 5, the number of records will be 192.

3. Start up and operating system of INTERPRE

To start up the software you have to double-click the icon “*interpre.exe*”; on doing this the graphic interface of Fig. 2 appears, where you can select the date of the day you want to scale the ionograms and the difference in minutes between the ionograms that can be of 5, 15, 30 or 60 min; if you select 60 the program will look for the ionogram files whose names start with 00 instead of *mm*; if you select 30 the program will look for the ionogram files whose names start with 00 or 30 instead of *mm*; if you select 15 the program will look for the ionogram files whose names start with 00, 15, 30 or 45 instead of *mm*; if you select 5 the program will look for the ionogram files whose names start with 00, 05, 10, 15, 20, 25, 30, 35, 40, 45, 50 or 55 instead of *mm*.

Once these parameters are set, clicking on IONOGRAMS INTERPRETATION you will be introduced to the graphic interface that will be used for the real interpretation of the ionograms (Fig. 3). Now you will be able to notice that when the cursor is inside the ionogram it becomes a green cross and in the upper part of the graphic interface you can see the frequency and the height of the corresponding point of the ionogram.

To scale an ionospheric characteristic you need to click on the corresponding tag; upon this operation the tag becomes green and, this way it is possible to write on the fields qualifying letter (q.l.) and descriptive letter (d.l.). As for the value field, it is necessary to move the cursor inside the ionogram and click the point which is more suitable for the characteristic you need to scale. This procedure is executed for the ionospheric characteristics *fmin*, *h'E*, *foE*, *foEs*, *h'Es*, *fbEs*, *h'F*, *foF1*, *h'F2*, *foF2*, and *fxl*.

For the ionospheric characteristics MUF(3000)F1 and MUF(3000)F2, clicking on the corresponding tag it appears on the ionogram a transmission curve (initially corresponding to a MUF of 15 MHz), the slope of which you have to modify until you find the tangential point with the ordinary trace in the region F1 and in the region F2, respectively; by varying the slope of the transmission curve the value of the MUF is automatically modified in the value field.

Plotting the transmission curve the following equation is used (Davies, 1990):

$$f_o = kf_v \frac{1}{\cos \left[\arctg \left(\frac{\sin \varphi/2}{1 + h_o/a - \cos \varphi/2} \right) \right]}, \quad (2)$$

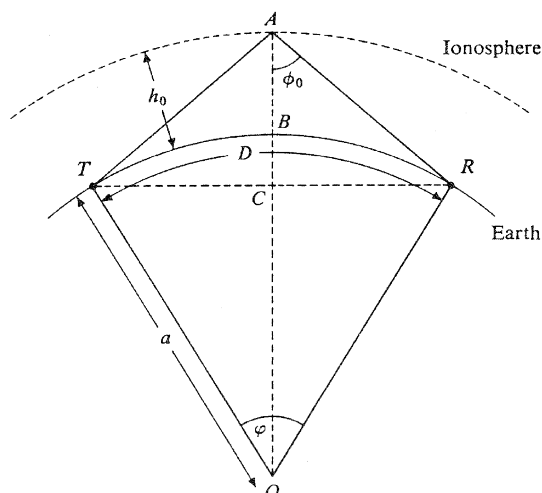


Fig. 4. Geometry of reflection from a thin curved ionosphere.

where f_o is the frequency of the wave reflected obliquely, f_v is the equivalent vertical frequency corresponding to f_o , k is the correction factor (that besides the terrestrial curvature also considers the ionospheric curvature) that varies from 1.000 and 1.200 and in the calculation of the MUF(3000) is considered equal to 1.114, h_o is the height of the reflecting layer and φ is the angle at the center of the earth subtended by the path (see Fig. 4).

Regarding the characteristics M(3000) of the layer F1 and F2, it is not possible to click on the corresponding tags since these characteristics in terms of value, qualifying and descriptive letters, are automatically calculated once you have values, qualifying and descriptive letters for the critical frequency and MUF of the corresponding layer. In the value field of the main graphic interface, values are stored following the URSI (International Union of Radio Science) standard (Piggott and Rawer, 1972). For the characteristic Es-types click on the corresponding tag and then write the sporadic E-type in the value field considering that it will not be possible to input from the keyboard the number zero and the letters which are different from A, C, D, F, H, K, L, P, Q, and R. As for the qualifying and descriptive letters of all characteristics, the corresponding fields will not accept from the keyboard letters that are not valid; in case you try for example to enter an U as a descriptive letter the message “This is not a descriptive letter” will be displayed.

Once the interpretation of all characteristics is done you can move on to the next or previous ionogram by clicking on the corresponding buttons. In the passage between ionograms, if the property “Interpretation Control” is set to YES, the ionogram you are leaving will be subjected to the control rules, otherwise the control on the interpretation will not be performed.

If moving from an ionogram to another the next ionogram should be unavailable, then the space where normally the ionogram is visualised is totally black; in this case the menu “no ionogram” is activated and, when clicking, in correspondence to the ionospheric characteristics fmin, foF2, MUF(3000)F2, M(3000)F2, h'F and fxl, the descriptive letter C is automatically displayed.

Using previous and next buttons the passage from ionograms of the same day is possible; when you need to scale ionograms belonging to different days you have to go back to the graphic interface of Fig. 2 and insert the requested date.

4. Control rules

Passing between ionograms when the property “Interpretation Control” is set to YES, the ionogram you are leaving will be subjected to the control rules and you will be prevented from leaving the ionogram in the following cases:

- if there are ionospheric parameters which have only the qualifying letter (that is to say that the value field and the descriptive letter field are empty),
- if, for the ionospheric parameters fmin, h'F, foF2, MUF(3000)F2 and fxl, the value field and the descriptive letter field are empty,
- if the ionospheric parameter foE has the value field or the descriptive letter field (or both) not empty, while the ionospheric parameter h'E has both the value field and the descriptive letter field empty,
- if the ionospheric parameter h'E has the value field or the descriptive letter field (or both) not empty, while the ionospheric parameter foE has both the value field and the descriptive letter field empty.

5. Checks during the interpretation phase

Normally, the limits of some characteristics are highlighted; if during the interpretation phase the scaled values exceed these limits a message like “Impossible value for this characteristic. Continue?” will appear, if you answer YES the value will be written in the value field, on the contrary no action will be performed. The limits for the characteristics are the following:

- h'E: must be between 80 and 150 km,
- foE: must be higher than fmin,
- h'Es: must be between 70 and 195 km and in addition it cannot be h'Es < (h'E-10),
- h'F: must be between 180 and 400 km; if h'Es has been read then it cannot be h'F < h'Es,
- h'F2: if h'F has been read it must be between 200 and 600 km.

In addition, a warning message will be displayed and a storage of the data will not be allowed for the following cases:

- in the interpretation of foE or foF1, if you click inside the ionogram on points corresponding to values in frequency that are greater than or equal to 10.0 MHz (displayed message: “Impossible value for this characteristic”),
- in the interpretation of foF2 or MUF(3000)F2, if you go to the case where foF2 is greater than MUF(3000)F2 (displayed message: “foF2 cannot be greater than MUF(3000)F2”),
- in the interpretation of foF1 or MUF(3000)F1, if you go to the case where foF1 is greater than MUF(3000)F1 (displayed message: “foF1 cannot be greater than MUF(3000)F1”),
- in the interpretation of foF2 or MUF(3000)F2, if you go to the case where MUF(3000)F2 is 10 times greater than foF2 (displayed message: “MUF(3000)F2 cannot be 10 times greater than foF2”),
- in the interpretation of foF1 or MUF(3000)F1, if you go to the case where MUF(3000)F1 is 10 times greater than foF1 (displayed message: “MUF(3000)F1 cannot be 10 times greater than foF1”).

6. Available commands from the keyboard

- ESC: from the graphic interface of Fig. 3 returns to the graphic interface of Fig. 2.
- F1: this command is used to delete the value, the qualifying and descriptive letters of the selected characteristic.

When interpreting MUF(3000)F1 and MUF(3000)F2 the following commands are available in the keyboard:

- DOWN ARROW: increases by 0.1 MHz the value of MUF(3000) referred to the displayed transmission curve,
- UP ARROW: decreases by 0.1 MHz the value of MUF(3000) referred to the displayed transmission curve,
- CTRL + DOWN ARROW: increases by 2.0 MHz the value of MUF(3000) referred to the displayed transmission curve,
- CTRL + UP ARROW: decreases by 2.0 MHz the value of MUF(3000) referred to the displayed transmission curve.

7. Conclusions

The scaling of ionospheric parameters starting from ionograms is still a fundamental necessity, because of its

importance in different studies, like those related to the space weather or the terrestrial and satellite communication. This work presents a user-friendly software that makes scaling of ionograms semiautomatic, trying to increase the reliability of the ionospheric parameters in output.

On request the author can write additional code lines to read other types of ionogram files or to change the format of the output file.

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