A SOFTWARE FOR AUTOMATIC SCALING OF FoF2 AND MUF(3000)F2 FROM IONOGRAMS

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ABSTRACT

A software for automatic scaling of critical frequency f_0F2 and *MUF(3000)F2* is presented. The program is designed to scale the ionograms without using information on polarization and can be applied to both single antenna systems and crossed antenna systems. A data set of 619 ionograms recorded at the ionospheric observatory of Rome has been used to test the performance of the software. The test has been performed comparing the values obtained automatically with the ones obtained by the standard manual method.

INTRODUCTION

Ionospheric observations are performed by a high frequency radar know as an ionosonde. The ionosonde sends short pulses of radio energy vertically into the ionosphere. These pulses are refracted back towards the ground and the ionosonde records the time delay between transmission and reception of the pulses. By varying the frequency of the pulses from 1 to 20 MHz, a record is obtained of the time delay at different frequencies. This record is referred to as an ionogram and is usually presented in form of a graph.

The National Institute of Geophysics and Vulcanology is developing an ionosonde to be used for standard ionospheric soundings. This instrument is designed for minimally attended, remotely controlled operation. This system must also be able to provide scaled data within few minutes the ionogram being produced. In the last years efforts have been made to achieve real time scaling of ionograms which led to many softwares [1] [3] [4]. Among these, widely used is the ARTIST system [2], developed at University of Lowell, Center for Atmospheric Research (UMLCAR).

In this work it is presented a software for automatic scaling of f_0F2 and *MUF(3000)F2* and a test of its performance.

THE SOFTWARE

The software developed at the INGV for automatic scaling of ionograms is based on technique of image recognition and it is able to work without using information on polarization. Hence, it can be applied to both single antenna system and crossed antenna system.

A maximum contrast technique has been applied using a family of functions having the typical shape of the ionograms. In this way an analytical function of this family is selected and it is considered as representative of the *F2* layer trace. The vertical asymptote of the selected analytical function corresponds to the critical frequency f_0F2. The *MUF(3000)F2* is calculated finding numerically the transmission curve tangent to the selected function.

TEST: SOFTWARE COMPARED WITH MANUAL METHOD

The test has been performed using 619 ionograms recorded by the digisonde DPS 42 manufactured by the UMLCAR. To allow for a possible seasonal variation in the performance of our software the comparisons has been performed using data from Winter, Summer and equinoctial months.

In these ionograms the quality of the images has been reduced, the information about polarization has been not considered and a low level of radio noise has been artificially added. All these ionograms have been scaled both automatically by the INGV software and manually by the same person.

In order to study the robustness of the algorithm a second test has been performed using the same set of ionograms in which a high level of noise has been artificially added.

The Fig. 1 reports three samples of ionograms used for the first test, with a low level of radio noise.

The Fig. 2 reports three samples of ionograms used for the second test, with a high level of radio noise.

In addition the Fig. 3 reports three samples of ionograms among the few ones recorded by the prototype of the Pulse Compression Ionosonde developed at the INGV during its first running tests.
The results of the comparison between the values scaled automatically and manually are reported in the form of histograms for the characteristic f_0F2 in the Fig. 4 and for the characteristic *MUF(3000)F2* in the Fig. 5, for the first test with a low level of radio noise.
The Fig. 6 and Fig. 7 show the analogous histograms, for the same two characteristics, corresponding to the second test with a high level of radio noise artificially introduced.
In this work an accurate value is considered to lie within ±0.05 MHz of the true value for f_0F2 and ±0.5 MHz for *MUF(3000)F2*. An acceptable value is considered to lie within ±0.5 MHz for f_0F2 and ±0.9 MHz for *MUF(3000)F2*. The percentage of accurate and acceptable values obtained in the test are reported in Table1 (for a low level of radio noise) and in Table 2 (for a high level of radio noise).

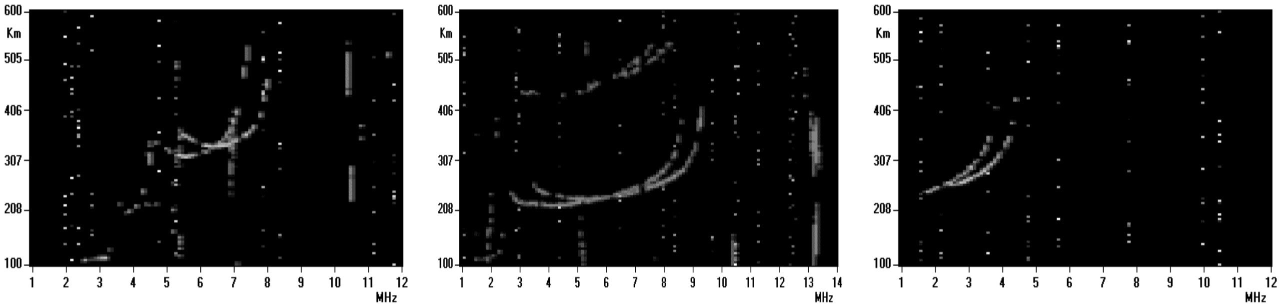

Fig. 1. Samples of ionograms with a low level of radio noise used in the first test.

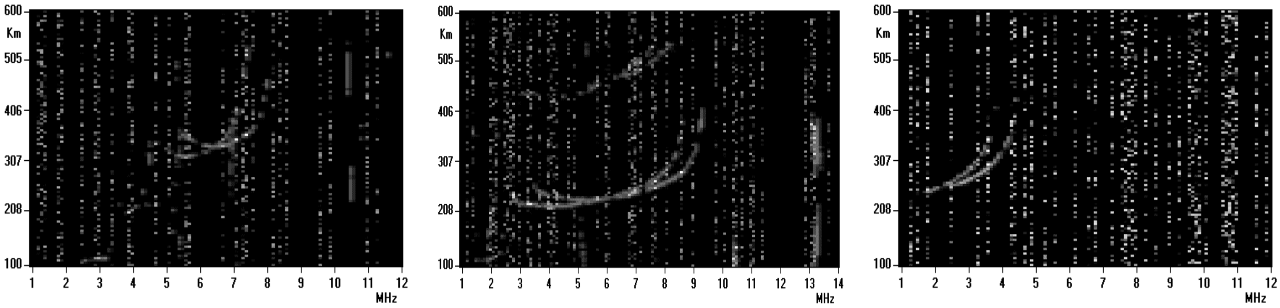

Fig. 2. Samples of ionograms with a high level of radio noise used to test the robustness of the software.

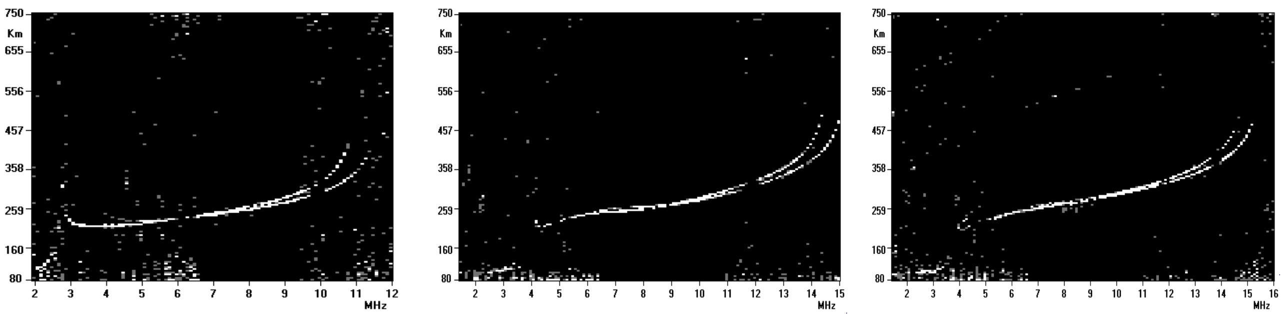

Fig. 3. Samples of ionograms among the few ones recorded by the prototype of the Pulse Compression Ionosonde developed at the INGV

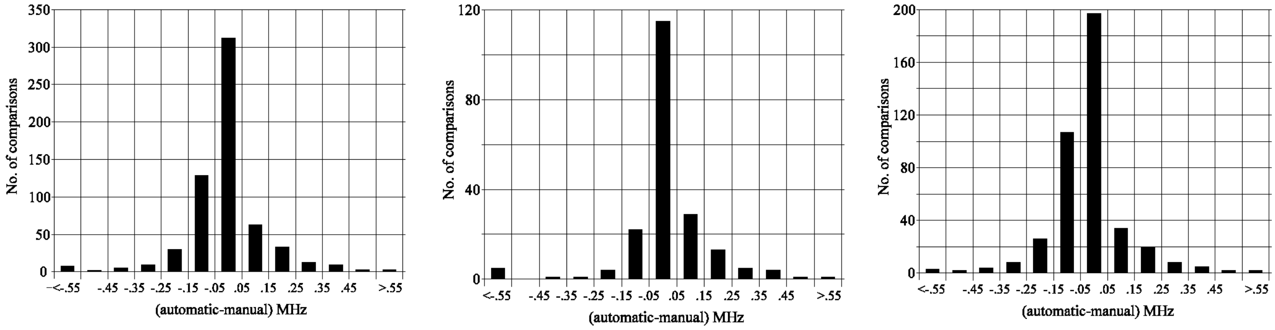

Fig 4. Differences between the values of f_0F2 scaled by the INGV software and by the standard manual method considering ionograms with a low level of radio noise. From the left to right the histograms show the result obtained for all the ionograms, daytime ionograms, nighttime ionograms respectively.

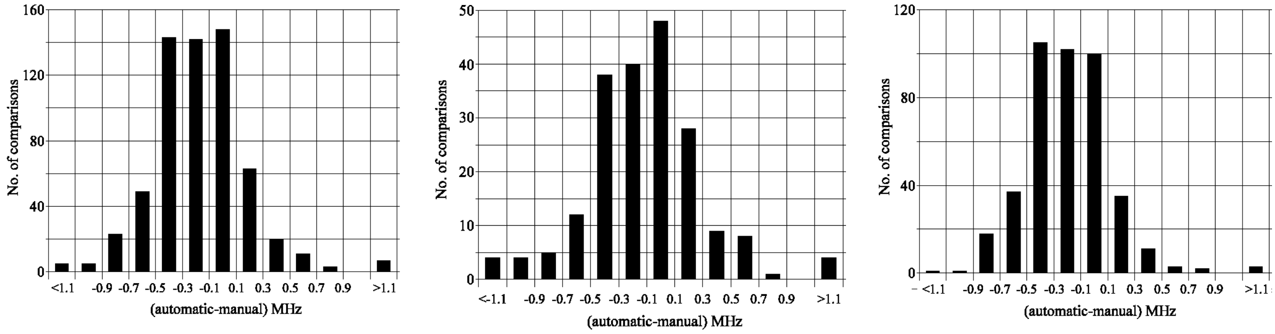

Fig 5. Differences between the values of *MUF(3000)F2* scaled by the INGV software and by the standard manual method considering ionograms with a low level of radio noise. From the left to right the histograms show the result obtained for all the ionograms, daytime ionograms, nighttime ionograms respectively.

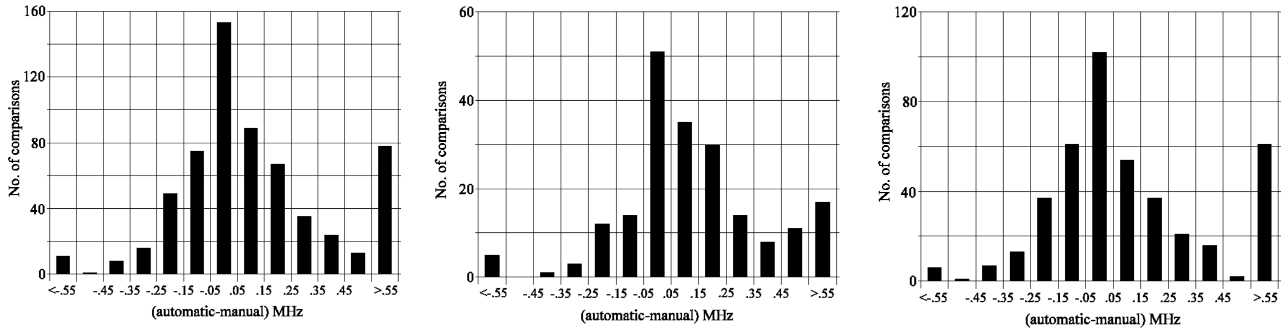

Fig 6. Differences between the values of f_0F2 scaled by the INGV software and by the standard manual method considering ionograms with a high level of radio noise. From the left to right the histograms show the result obtained for all the ionograms, daytime ionograms, nighttime ionograms respectively.

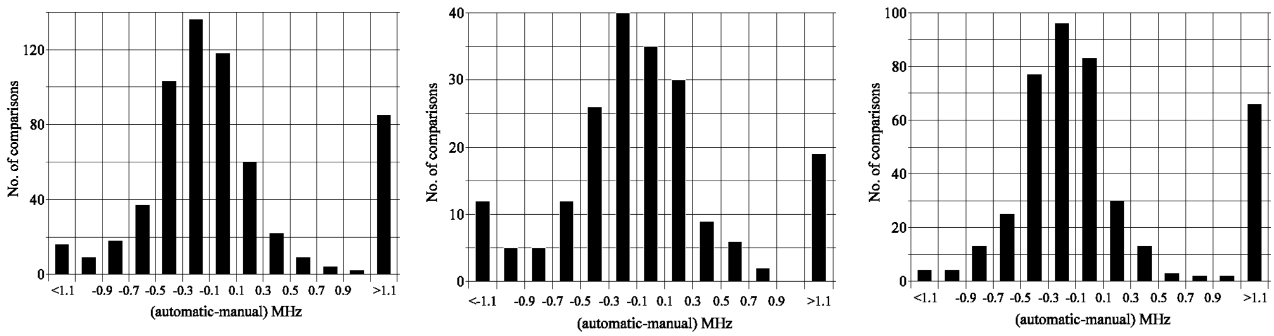

Fig 7. Differences between the values of *MUF(3000)F2* scaled by the INGV software and by the standard manual method considering ionograms with a high level of radio noise. From the left to right the histograms show the result obtained for all the ionograms, daytime ionograms, nighttime ionograms respectively.

Table 1. Percentage of acceptable and accurate values for the test carried out with a low level of radio noise.

	***f_0F2* (Nighttime and Daytime)**	***f_0F2* (Nighttime)**	***f_0F2* (Daytime)**	***MUF(3000)F2* (Nighttime and Daytime)**	***MUF(3000)F2* (Nighttime)**	***MUF(3000)F2* (Daytime)**
% Acceptable	97%	97%	98%	97%	94%	98%
% Accurate	50%	57%	47%	83%	81%	84%
No. Ionograms Considered	619	418	201	619	418	201

Table 2. Percentage of acceptable and accurate values for the test carried out with a high level of radio noise.

	***f_0F2* (Nighttime and Daytime)**	***f_0F2* (Nighttime)**	***f_0F2* (Daytime)**	***MUF(3000)F2* (Nighttime and Daytime)**	***MUF(3000)F2* (Nighttime)**	***MUF(3000)F2* (Daytime)**
% Acceptable	83%	83%	84%	70%	71%	70%
% Accurate	24%	24%	25%	82%	82%	82%
No. Ionograms Considered	619	418	201	619	418	201

CONCLUSIONS

The comparison between the INGV software for automatic scaling of ionograms used in this work and a well experienced manual scaler have revealed that INGV software provides acceptable values of f_0F2 and *MUF(3000)F2* for 98% of the cases, although it has been applied to ionograms of medium quality (first test), as the ones shown in Fig. 1. If the INGV software is applied to bad quality ionograms, as the ones shown in Fig. 2 (second test), the results are acceptable for 83% , demonstrating a sufficient robustness of the algorithm.

REFERENCES

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