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COMPARATIVE PRELIMINARY IONOSPHERIC FORECASTING IN ROMANIA WITH DATA FROM THE EUROPEAN IONOSONDE SERVICE VERSUS DATA EXTRACTED FROM THE INTERNATIONAL REFERENCE IONOSPHERE MODEL

Simona MICLAUS*, Paul BECHET*,
Mircea STANIC*, Cora IFTODE**

***"Nicolae Balcescu" Land Forces Academy, Sibiu, Romania,**
****Politehnica University of Timisoara, Timisoara, Romania**
simo.miclaus@gmail.com, pbechet@gmail.com,
stanicmircea@yahoo.com, cora.iftode@gmail.com

Abstract: *Radiocommunications in the HF band depend on the ionospheric parameters of radiowaves reflexion, though the quality of a radio link depends on: the time of day; season; solar cycle; geographical position. Taking into account the ionosphere characteristics over Romania, a forecasting is made over four cities in our country in order to provide the values of the critical frequency foF2 of the F2 ionospheric layer over a 24 hours cycle. A comparative analysis of this parameter is applied by using the International Reference Ionosphere model and interpolated experimental data collected from the European Ionosonde Service. Results show that the f0F2 values are slightly underestimated in all four locations in the model versus measurements, sustaining the necessity of own measurements in order to prepare quality data links in Romania if HF band is to be used for emergency data communications.*

Keywords: ionosonde, IRI model, HF communication, critical frequency

1. Introduction

In high frequency (HF) communications spatio-temporal variations of ionospheric channel, external noise level (ambient and artificial) and bandwidth limitations of the communication channel, are among the most critical and problematic issues taken into account when considering the design and operational management of communications in this spectral range. Against this background, knowledge of the behaviour of the ionosphere is of fundamental importance, because of the way it influences the selection of optimal transmission frequency. This means that a HF transceiver must have a high level of adaptability to cope with external constraints. Basically, it is necessary to develop an adequate management of frequencies but also the waveform used in HF, which takes into account the geographic location and ionospheric particularities of that area every time.

Due to the nature of the ionosphere, it is particularly sensitive to solar activity, geomagnetic field variations and the density and content of the atmosphere at different altitudes and latitudes. So can sometimes disturbed ionosphere [1]. Relevant spatial variations occur in middle latitudes in the equatorial and polar regions and temporal variations occur diurnal, seasonal and with the solar cycle of 11 years.

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Therefore, to make predictions about the characteristics of a radio signal received from the ionosphere - such as amplitude, polarization, relative phase, propagation duration and dispersive scattering, it is necessary to know how the electron density variations (Ne) influences the propagation of radio signals between transmitter and receiver. A system is needed to monitor the ionosphere. The most important ionospheric monitoring technique utilizes a network of ionosondes providing ionospheric parameters for a number of heights and frequencies in the form of ionograms [2].

Usable frequency range to achieve HF radio link depends on: 1. time of day; 2. season; 3. solar cycle; 4. geographical position.

The upper limit of usable frequencies mainly depend on the factors afore mentioned, while the lower limit depends on the geometry of the circuit parameters and ionospheric absorption. To maintain radio communication it is necessary to have reliable estimates of the state of the ionosphere at a given time and a given location. Predictions of the ionosphere are made for years in different parts of the world, but in Romania there is still no similar database.

F2 ionospheric layer plays the most important role in HF radio communications, therefore ionospheric predictions are based largely on models of the F2 layer.

One of ionospheric prediction programs developed in Italy is the Servizio Nazionale Ionosferico from INGV and uses a single station for data collection - ionospheric observatory in Rome [3].

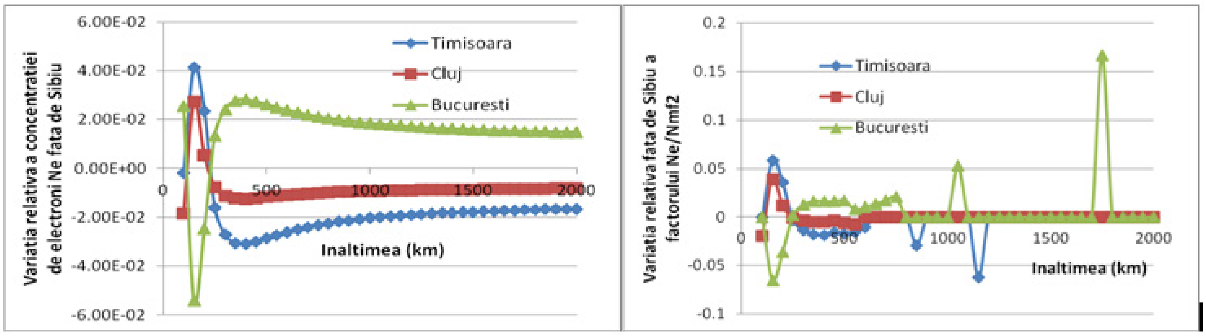
Using monthly median values measured by the vertical sounding at over 100 ionospheric stations maps are made of the anticipated monthly values of foF2 frequency and of M(3000)F2 parameter [4, 5]. These maps are extended across the globe through the development of spherical harmonic functions of FoF2 and M (3000), which depends on three variables: latitude, longitude and time [1]. These maps allow then developing predictions point to point, available everywhere in the world, though with different accuracy, which applies only to the European space.

Various ionospheric prediction models were produced in the last twenty years [6]-[10] and they can be categorized in 5 classes. The most common used model is International Reference ionosphere - IRI [11] – and it provides inter alia average monthly electronic density, temperature and composition of the ionosphere over altitude in the range of altitudes 50-2000km.

2. Use of the International Reference Ionosphere model - IRI 2012, to characterize the ionosphere over Romania

By using IRI 2012 model [11] ionospheric data were extracted for the date of November 21, 2014 for the following geographic locations in Romania: Sibiu, Timisoara, Cluj Napoca and Bucharest. For these locations, we determined: a. the relative variations of electron concentration Ne in the ionosphere; b. the relative variations of the ratio between the concentration of electrons and maximum charge density in the F2 layer, NmF2. To compute the relative values we referred to (divisor) the absolute values of the quantities for Sibiu. The graphs are depicted in Fig. 1 and they show that relative variations are maximal at heights between 50-150 km. The maximum variations are positive for Cluj and Timisoara but negative for Bucharest. The minimum amplitude variation appears above Cluj and highest above Bucharest. For heights larger than 250 km, the relative variations change the sign but the absolute value for Cluj remains minimal. From Fig. 1b can one can estimate the distribution on the height of the relative variations of electronic concentration ratio; it is observable that the most extensive and frequent skips appear for Bucharest and the most negligible for Cluj. We expect therefore that the HF waveforms emitted from Sibiu to Cluj and to Timisoara to be unsuitable for radio link between Sibiu and Bucharest.

In Fig. 2 by the use of IRI prediction model, electronic density distribution curves versus altitude were represented above Sibiu city, to observe differences due to seasons and arising during a day. It is found that variations in the course of 24 hours are significantly higher than those at the same time of day, but in different season. Therefore, robust waveforms can be constructed mainly considering the time of day.



(a) *(b)*

Figure 1: Differences in electronic concentration in the ionosphere over 3 cities in Romania: Timisoara, Cluj, Bucharest, relative to Sibiu city

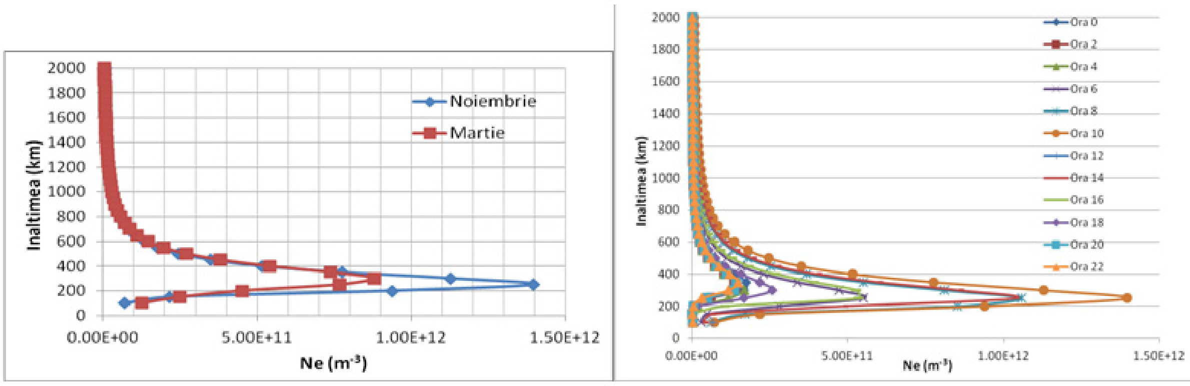


Figure 2: Distribution of electronic density versus altitude in the ionosphere above Sibiu: a. Spring (March) and comparatively autumn (November), at 10 a.m.; b) in November, at intervals of every 2 hours for a period of one day (24 hours)

3. Variation of critical frequency f0F2 over Romania area from data extracted from the European Ionosonde Service versus data from the ionospheric IRI 2012 model

European Ionosonde Service (EIS) of the SSA Space Network Weather Service [12] collects real-time data and process information obtained from the 10 ionosonde placed over Europe. Near-real-time portal SSA-SWE allows later retrieval and use of data for monitoring achievement of the fundamental ionospheric parameters variation in any part of Europe, depending on geographic location, date and time of day. Based on data extracted from this portal we have been represented the variations during a day of winter (November 28th 2014) and a summer day (28 June 2014) of the critical frequency foF2 over the four cities in Romania (Fig.3). The measured values were then compared against the estimated values of IRI 2012 model for the same days and hours in case of Sibiu city. The differences between measurements and model can be observed in Fig. 4.

The variations of the critical frequency above the 4 cities follow the same trend, with very small differences between them. The coefficient of variation of critical frequency is much higher during winter than during summer. The f0F2 variation during winter time covers the range from 3.8MHz - 12MHz while during summer it covers the range 8.3MHz - 5.3MHz.

From Fig. 4 one extracts the conclusion that IRI model can introduce large errors of prediction of the critical frequency, which in certain times of day (eg. winter day) can reach absolute values of 2MHz. This observation indicates that it is necessary to evaluate the deviations of IRI predictions on a longer term, in order to extract clearer conclusions.

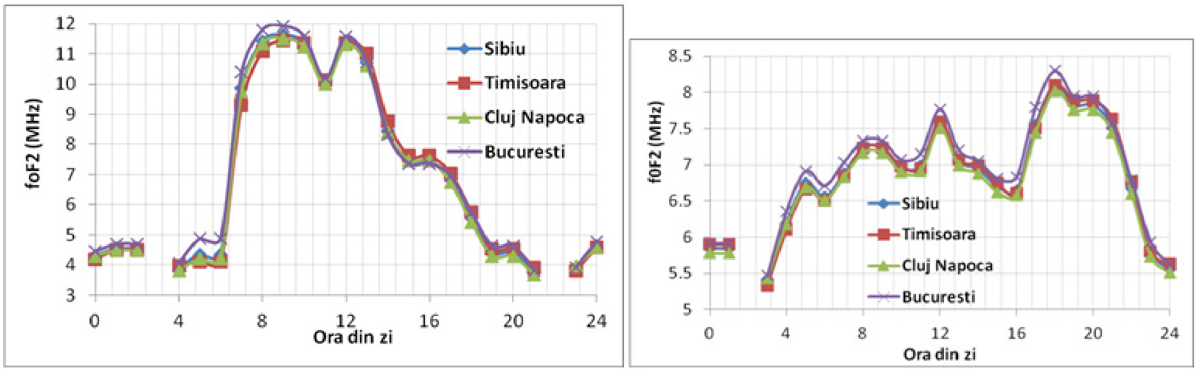


Figure 3: f0F2 critical frequency variation, as measured by the European System of Ionosonde, along 24h, in the days of November 28, 2014 (left) and June 28, 2014 (right) over the Romanian cities

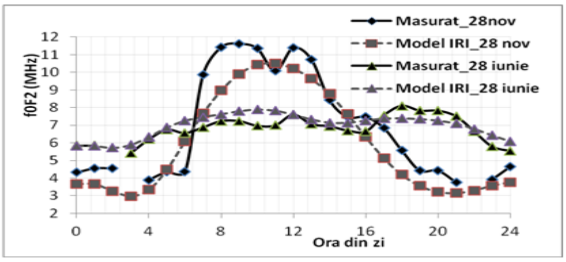


Figure 4: f0F2 critical frequency variation in time, with data measured by the European System of Ionosonde versus data extracted from IRI model 2012, above Sibiu city, on 28 November 2014 and 28 June 2014 respectively

4. Observations extracted from ionospheric monitoring for a period of 22 days: comparison between results obtained from data provided by the European Ionosonde Service and the IRI 2012 ionospheric model

A statistical study was made in order to follow the evolution of critical frequency f0F2 within 22 days, between 15 November and 6 December 2014, in 4 cities: Sibiu, Timisoara, Cluj and Bucharest. The experimental data were extracted from interpolations based on data provided by EIS program tool [12] under European Ionosonde Service. The initial data were extracted with a period of 1h over the 22 days degment. On the other hand, modeled data were extracted from the IRI 2012 model [11], with the same periodicity.

In Fig. 5 f0F2 verus time of the day is presented in the 4 urban locations during the monitoring period for experimental data. The average and standard deviations were represented. One observes that the critical frequency hourly repeatability distribution, for a period of 22 days, is very good, so it is not necessary to monitor longer period in the same season. There are no significant differences between the 4 locations, so one city in Romania assures reliable forecasting for entire national territory.

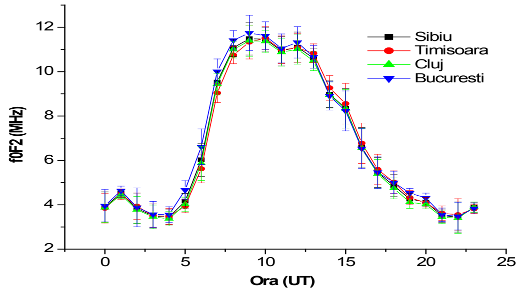


Figure 5: F0F2 critical frequency variation and the standard deviations, during a cycle of 24 hours, over 22 days period - corresponding to the Romanian cities

In Fig. 6 a comparison between the predicted data from ionosondes and IRI 2012 model is shown for the f0F2 average value evolution within 24 hours over Sibiu city. The averaging period was of 22 consecutive days.

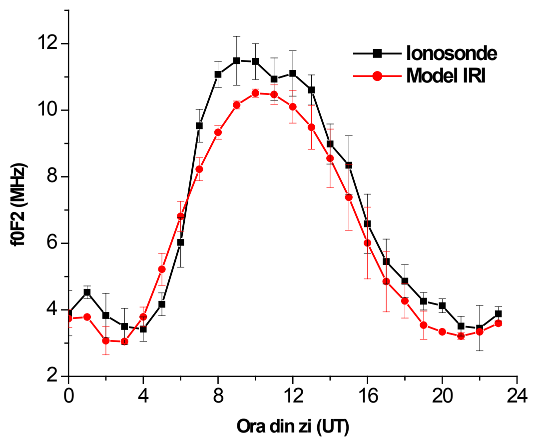


Figure 6: f0F2 average±standard deviation evolution in a cycle of 24 hours, over a 22 day period, over Sibiu: comparison between measured and model data

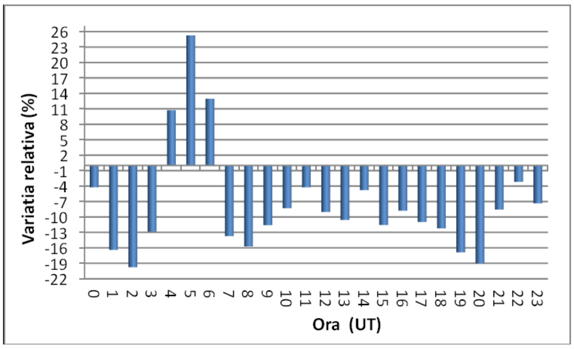


Figure 7: Variation of the mean f0F2 values of IRI forecast relative to ionosonde measured values during a cycle of 24 hours over Sibiu

In Fig. 7 the relative variations of IRI forecasts against measurements from ionosondes (interpolated data) are depicted in case of Sibiu city. One observed an underestimation of f0F2 values in 87.5% of the time during one day. Limit values of deviations due to IRI forecast relative to interpolated data from measurements are -20% and +25%. The IRI model is closer to the measured values between 9-17 hours.A similar approach as for Sibiu was applied to Bucharest and also to Athens (Greece) were one of the ionosondes is placed. Very similar results were obtained as for Sibiu.

5. Conclusions

Based on the results obtained at this stage, it is found that the reference ionospheric model - IRI 2012, capable of very long-term forecasts (approximately 3 years) has only an acceptable degree of accuracy. A higher degree of accuracy in ionospheric forecasting over Romania is obtained from data calculated by interpolation from measurements provided by the European System of Ionosonde. In that database, however, one may find frequent technical gaps, starting from a time period of several hours - when no data are provided, up to falling of the customer server (as we encountered – for example at EIS service, between December 11 to 15, 2014). European Ionosonde Service provides a "long-term" forecatsing, but only for a period of max. 3 months, and this may become operationally insufficient sometimes. Gaps or blocking of the server was also encountered for the forecasting capability. From such perspective, it becomes desirable to identify own forecasting possibilities based on specific and more reliable modelling, in particular for Romania.

Forecasting of ionospheric conditions up to 24 hours ahead for the management of radio services becomes particularly useful to national defence industry - with its wide variety of applications, including HF radiocommunication. The possibility to apply reliable countermeasures in time will contribute to the decrease of the hazard degree due to space weather events.

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