A STUDY ON THE BEHAVIOUR OF THE CRITICAL FREQUENCY OF F2 LAYER FOR LOW GEOMAGNETIC LATITUDES AND HIGH SOLAR ACTIVITY

José L. Bendito, José M. Albornoz and Alexander Carrasco

Observatorio Ionosférico
Mérida, Venezuela

Abstract

We present a statistical analysis of the time series corresponding to hourly critical frequencies of the F2 layer (foF2) by using parametric and non-parametric methods. Based on these studies, we conclude that the critical frequency exhibits a non-random behavior, and show variations with a fundamental period of 24 hours, which can be explained in terms of the solar activity during the day/nigth cycle. Shorter period variation which help to explain the behavior of foF2 are also observed. The frequencies corresponding to these periods, have been determined by spectral analysis of the time series which have been reconstructed with great accuracy by using the corresponding model. The data presented in this work has been gathered at the ionosferic station in Mérida , Venezuela, during the period 1991-1992.

1 Introduction

The ionosphere, being the plasma that surrounds the Earth, plays an important role in the propagation of electromagnetic waves around the planet. Due to its electrical properties, the ionosphere can reflect radio waves and make possible long distance communications.

Ionospheric science started with measurements of the physical properties of the ionosphere. The high spatial and temporal variability that was observed in the measured parameters led to the necessity of systematically describing the ionosphere, that is, its variations with height, place above the Earth and time.

Much of the investigations carried upon the ionosphere arise from studies based in the analysis of data obtained by means of vertical sounding from the surface of theearth using radio waves. These waves are reflected in the ionosphere and return to their starting point, bringing information about the state of the ionized regions above.

In this work we present a method of describing the behaviour of the critical frequency, foF2, based on the results obtained from the spectral analysis of the data gathered in the ionosphere Station in Mérida (Lat 8.6°, Long 71.1°) during 1991 - 1992.

2 Statistical Treatment

The statistical treatment of our time series was carried upon as follow:

2.1 Randomness Test

This test consists in determining if a time series is random or if it shows a certain patter in response to a stimulation. This non-parametric method is based on calculating the number of runs above and below the median of the series, and comparing this number with the expected runs for a normally distributed sample. By using this procedure it was found that for the whole time series, since 1991 up to 1992, hour by hour, the behaviour of foF2 shows a well defined, non-random pattern.

To back-up this affirmation from another viewpoint, we represented graphically all the time series that form our database, and so it was observed that the variation pattern shows the same shape consistently, with minimums and maximums at approximately the same time, that seems to show that it is the response of the ionosphere to solar activity as a consequence of Earth's rotation.
Then, there is no doubt that the critical frequency foF2 responds to a stimulus that makes it vary in a continuous manner along the day, showing a maximum in that time lapse.
In such a complex system as the ionosphere, it is likely that some other stimulating agents exist with periods that differ from 24 hours, superposing its effect and producing the observed behaviour of foF2. In this line of thought, we performed a spectral analysis of all our time series, which is explained in the following paragraph.

3 Spectral analysis

Spectral analysis, sometimes called "spectrum analysis", is the name given to methods of estimating the espectral density function, or spectrum, of a given time series.

In this work spectral analysis is a exploratory diagnostic tool. To determine the existence of harmonics in foF2, the series were analysed using the discret Fourier transform. This method allows the analysis of a time serie of any length. The results of the spectral analysis are shown in the periodograms of Fig. 1, where the existence of three peaks at frequencies of 1/24, 1/12, and 1/8 cicles per hour can be appreciated:

$$\begin{aligned} \omega_o &= 2\pi/24 \\ \omega_1 &= 2\pi/12 = 2\omega_o \\ \omega_2 &= 2\pi/8 \;= 3\omega_o \end{aligned} \tag{1}$$

where ω_o is the fundamental harmonic. This result is valid for all months with high solar activity during the period 1991-1992

4 Model for foF2

Taking into account the results obtained from spectral analysis, a model of foF2 has been constructed, based on a Fourier series of the form

$$foF2(t) = a_o + \sum_{t=1}^{N}(a_n cos\omega_n t + b_n sin\omega_n t) \tag{2}$$

Using the relations

$$\begin{aligned} a_n &= M_n sin\varphi_n, \quad b_n = M_n cos\varphi_n \\ M_n &= (a_n^2 + b_n^2)^{1/2}, \quad tan\varphi_n = a_n/b_n \end{aligned}$$

equation (1) can be written as:

$$foF2(t) = M_o + \sum_{t=1}^{N}(M_n sin(\omega_o nt + \varphi_n)) \tag{3}$$

where M_o represents the average value of $foF2$ for the chosen intervals. The modules M_n and the phases φ_n have been obtained performing a least squares fit between the observations and the trigonometric functions corresponding to those harmonics found in the spectral analysis. Fig. 2 presents the observational values versus those calculated using equation (2). The corresponding values of the correlation coefficient between model and observations are show in Table 1.

5 Discussion

1. The detected harmonics in the time series for $foF2$ have been also reported by Canziani et al (1987) for other latitudes. These workers suggest that data corresponding to the maximum electron concentration in the F2 layer can be used to study tidal effects in the atmosphere.

2. The incorporation of these harmonics in eq (2) allow a satisfactory explanation of the daily changes in the critical frequency, as shown in Fig. 2.

3. When this model is used for days with high geomagnetical activity, the correlation coefficient between model and observations is around 0.71, lower than the 0.93 coefficient found for days with $Ap < 7$. This suggests that the geomagnetic field introduces a noise effect in $foF2$, thus showing rapid variations which can be seen in Fig. 3.

6 Conclusions

This study of the ionospherical variable critical frequency of F2 layer lead us to the following conclusions:

a) The spectral analysis, applied to the time series for foF2, has shown the existence of periodical components of 24, 12 and 8 hours, respectively. This result allows us to affirm that the critical frequency shows a regular behaviour in time, that is far from being aleatory.
b) The presence of three harmonics in foF2 is independent of month, year, etc. Proof of this are the spectrums shown in Fig. 1.
c) It has been possible, using the results of the spectral analysis, to elaborate a model of the hourly values of foF2, in terms of a Fourier series which has all the detected harmonics. This model permits a satisfactory explanation of the hourly variations in the observed critical frequency.
d) The application of this model to days with high and low geomagnetic activity reveals that the Earth's magnetic field introduces a noise effect of

great proportions, which makes the critical frequency differ from its normal behaviour patterns.

7 Reference

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