Ionosondes - A Study on the Use of Electromagnetic Wave Propagation as a Technique to Observe the Ionized Layer of the Earth's Atmosphere

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The terrestrial atmosphere can be understood as an immense laboratory that hosts various physical phenomena. One of the main effects of the interaction of solar radiation in the upper atmosphere is the ionization of its gaseous constituents. This ionization, which starts at around 60 km and extends to the limits of the atmosphere, forms the ionosphere. This ionized layer develops an important role in the propagation of radio waves. This work presents a brief theory on the propagation of electromagnetic waves in the ionosphere. In this purpose, the ionosonde is shown - a device that makes use of radio techniques for ionospheric sounding. Are shown examples of ionograms and is explained its interpretation to obtain ionospheric parameters.

I. INTRODUCTION

The terrestrial ionosphere is a layer that starts about 60 km and extends to about 1000 km high above the planet's surface. This layer is generated due the interaction between the solar radiations and the atmospheric constituents. Among the various methods used to explore the ionospheric regions, the method that deserves great prominence, being practically a method used worldwide, is the method of the pulses, introduced by Breit and Tuve [1]. In this method, pulses of radio signal are transmitted upward and, depending on the plasma frequency, these signals are reflected from the ionospheric layers. (see Figure 1). The equipment used to transmit pulses of radio signal is named ionossonda. The operating principle of ionossonda is based on the timing measurement between the transmitted and the received wave signals. The time between transmission and reception of RF pulse provides information on the ionospheric layer height for a given frequency.

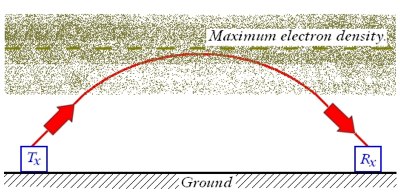

Figure 1: Tilting the path of a wave in an ionized medium.

II. METHODOLOGY

When an electromagnetic wave passes through a region with an electron density Ne, the electrons will be immersed in an electric field and will vibrate under the action of the electric force of the wave. This electronic motion produces two kinds of electronic current: convection current and a displacement current. Then, the total current is given by the sum of the convection current and displacement current. Is important to note that the amount of electrons reduces the value of the dielectric constant of the medium and change the phase velocity of the wave. Thus, electromagnetic waves transmitted vertically upward from surface of the planet will suffer reflection in the ionized regions of the upper atmosphere. The condition of total reflection for the case that the radio waves are sent vertically upward is given by the following equation:

$$\frac{4\pi.N_e.e^2}{\omega^2.m} = 1 \tag{1}$$

Where m is the mass of the electron, e is the charge of the electron and ω is the signal frequency.

III. CANADIAN ADVANCED DIGITAL IONOSONDE (CADI)

The ionosonde used by the research group of UNIVAP is the type CADI (Canadian Advanced Digital Ionosonde) and is located in São José dos Campos (23,21° S, 45,86° O).

This equipment is formed by the transmitter, receiver, computer (to control the data acquisition and the all equipment), and the transmitter and receiver antenna (booth delta antennas). The transmitter produces 600W of peak power of the transmitted pulse in a range between 1 and 20 MHz, and 40 pulses are emitted per second [2]. The research altitude is located between 100 and 1000 km.

IV. OUTCOMES: IONOGRAMS

When the pulses of high frequency are broadcast by an ionossonda they are reflected by the ionosphere and return to the receiver. The time necessary for the occurrence of this feature is stored in the form of traits called ionograms.

The ionograms generated by ionosondes are analyzed and interpreted to obtain the ionospheric parameters, such as the

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plasma frequency of the ionospheric layers, reflection or critical frequencies of the layers E, F1 and F2, i.e. f_0E, f_0F1, f_0F2,their minimum virtual heights of reflection h'E, h'F and h'F2, and the vertical profile of electron density from the bottom of the ionosphere up to the peak of maximum density

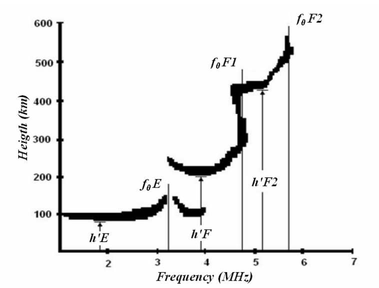

Figure 2: Empirical Illustration of the idealized ionogram.

The experimental determination of the maximum electron density, which corresponds to the maximum critical frequency of reflection, is produced by the gradual increase in operating frequency of the pulses until that frequency of the echo disappears [3]. The mathematical representation of the maximum electron density is given by:

$$N_{max} = 1.24 \times 10^4 \omega^2 \tag{2}$$

Where ω is the signal frequency. An ionogram is presented in the Figure 3. In this figure is possible to see some of the points that correspond to the same parameters showed in Figure 2.

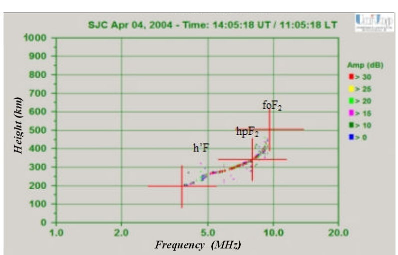

Figure 3: Ionogram showing the virtual height of the layer (h'F), maximum or critical frequency (f_oF2) and the height in the F layer (h$_p$F2). Adapted from [2].

However, depending on the direction of polarization of the transmitted wave, the echoes can be presented in two ways that correspond to the common components (linear polarization) and extraordinary (nonlinear polarization) in the ionogram. This is a result of the magnetic field (see Figure 4), which causes the ionosphere to be bi-refractive [4].

With the ionosonde is also possible to identify plasma irregularities. In this case, the ionogram becomes diffuse, as seen in Figure 5.

Applying this method is possible to infer the behavior of the ionosphere and to study, for example, the propagation of gravity waves and its features.

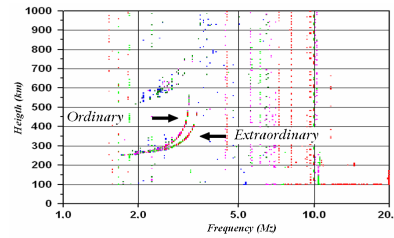

Figure 4: Ionogram with the ordinary and extraordinary traces. Adapted from [4].

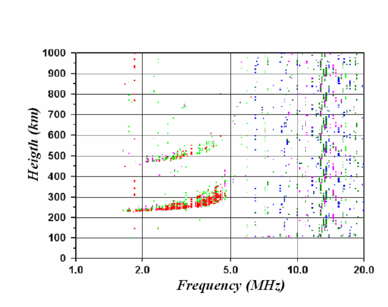

Figure 5: Ionogram with the presence of scattering-type frequency. Adapted from [4].

V. ACKNOWLEDGEMENTS

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