STUDY OF D, E AND F REGIONS OF IONOSPHERE

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Abstract

The D-region of the ionosphere is remotely probed by ground-based radar. The method used is referred to as the partial reflection-drift experiment. The partial-reflection experiment is used to determine the horizontal-drift velocity of ionized irregularities in the ionosphere. If a point radio source is used, the stratified irregularities produce a diffraction pattern over the ground. By sensing this diffraction pattern with a minimum of three antennas the horizontal-drift velocity can be computed. To determine the horizontal-drift velocity of the ionosphere it is necessary to illuminate the ionosphere with a single radio-wave point source. When this is done a diffraction pattern is formed from the ionosphere irregularities in the D-region. The E and F region of ionosphere is studied using the ionospheric data from archives of ionospheric station. The ionospheric datas were used for training neural networks (NNs) to predict the parameters required to produce the final profile. The NNs have been trained to predict the individual ionospheric characteristics and coefficients that were required to describe the profile.

1. Objective

The basic objective is to study the D, E and F-regions of the ionosphere.

i. To study the D-region the radio waves are directed at vertical incidents, it is therefore necessary to have system of spaced antennas to track the motion of irregularities. With three spaced antennas to sample the amplitude of the diffraction pattern observed on the ground, spatial properties and the movement of the pattern can be detected. A micro controller (peripheral interface controller) is used for switching of antennas and data acquisition.

ii. A computer is used to simulate fading records that might have been observed in a spaced antenna drift experiment. The model of computer analysis permit scattering centre to be located at random position, then moved stepwise across the sky to simulate drift; random changes are also studied. The output format matches that of the actual experimental equipment, and the simulated records are used to validate standard correlation analysis correctly detects the mean direction and speed of the “diffraction pattern” produced in this way, and estimates a random velocity fluctuations magnitude directly related to random changes in the model. The statistically rigorous formulation of correlation analysis to estimate reasonable error limits for the wanted parameters.

iii. To study the E and F-region from the data received from the archives of Kodaikanal ionospheric station.

2. Methodology

i. The evaluation of ionospheric drift by the spaced receiver method. After each measurement of 3 min the auto-and cross-correlation functions are automatically calculated from recorded values of the signs of the departures of the signals from their mean values (the signs of [u(t) - u(t)]) this quantity is called the ‘polarity’ of the recorded signal. It is shown that the results agree well with those calculated by the method of ‘similar fades’.

ii. The statistical method of analysis for a quick measurement of ionospheric wind parameters for isotropic patterns is possible. It is found that Putter’s method of analysis, extended by Banerji in presence of random velocities, gives different orders of magnitude of true and random velocities and of the direction of the wind velocities with different groups of time delays. Results indicate that the statistical method of analysis for finding the direction of wind flow, are expected to give values of V, Vv and θ, the wind parameters for an isotropic pattern, approximating to those of the correlation method without undertaking a lengthy computation process.

iii. Correlation analysis of the fading of radio waves, for the purpose of determining ionospheric drifts, has usually required certain manual and graphical calculations. It is shown how the complete analysis can be carried out numerically by a computer. The definition of the characteristic velocity V_c for anisometric patterns is discussed. It is shown that for certain simple models of the movements in the ionosphere V_c can be identified with the speed of hypothetical wave-like systems of irregulations.

iv. Two different aspects of ionospheric drifts are discussed. The effect of the receiver triangle size on the drift parameters derived from full correlation analysis is investigated, when partial reflections from altitudes near 90 km. are used. It is found that, for frequencies near 2 MHz, the scale of the diffraction pattern on the ground is of the order of 100 m, and that the drift parameters show little dependence on triangle size for aerial separations greater than 100m.

In addition, a number of drift records obtained using both partial and total reflections have been analyzed by a dispersion method in order to look for any systematic variation of the drift velocity with fading frequency. It is shown that dispersion is present in only a minority of records, but that it occurs more frequently for the partial reflection example than for records to totally reflected waves from the E-region. Some possible interpretations of this result are discussed.

v. A Computer is used to simulate fading records that might have been observed in a spaced antenna drift experiment. The model for computer analysis permits scattering centers to be located at random positions, then moved stepwise across the sky to simulate a drift; random changes are also studied. The output format matches that of actual experimental equipment, and the simulated records are used to validate standard correlation analysis programs. Correlation analysis correctly detects the mean direction and speed of the 'diffraction' pattern produced in this way, and estimates a random velocity fluctuation magnitude directly related to the random changes in the model. The statistically rigorous formulation of correlation analysis by FEDOR (1967) is shown to estimate reasonable error limits for the wanted parameters.

vi. The Neural Networks are trained from the ionospheric datas received from the ionospheric station to predict the the parameters to produce the final profile of the E and F layer.

3. Study of D Region

The closely spaced receiver method employs radio waves from a single ground based transmitter. These waves, after reflection in the ionosphere, lead to a finely structured amplitude pattern at ground level as a consequence of ionospheric irregularities. The pattern is monitored by three or more closely spaced receivers, each of which exhibits fading in response to changes in the ionization distribution. The fading records from the different receivers are then compared with one another in some fashion, with the objective of identifying some overall motion of the pattern across the ground, and thence of deducing a general 'drift' motion of the ionospheric irregularities.

IF Radio waves from a single source, after reflection from the ionosphere, are received at a number of points on the ground spaced so that the fading in amplitude is reasonably well correlated over the array, any steady drift of the irregularities in the reflecting layer can be detected and measured. Of the available methods of analyzing fading records for this purpose, the ''method of similar fades'' (MITRA, 1949; KRAUDTKRAMER, 1950) has been most used, but it is generally agreed that the method of BRIGGS et al. (1950) and PHILLIPS and SPENCER (1955), known as ''correlation analysis'', gives the most accurate estimate of the velocity drift, in addition to a reasonably complete statistical picture of the fading pattern.

The horizontal drift of irregularities in the ionosphere has been studied for many years using the variation in amplitude of echoes recorded at a minimum of three closely spaced receiver sites (MITRA, 1949; KRAUTKRAMEr, 1950). Most observations make use of waves totally reflected from the E-and F-regions, but the method has recently been extended to heights below 100 km. by the use of weak partial reflections from the D-region (FRASER, 1965, 1968), as proposed by AWE (1961). The use of these partial reflections, which extend from 60 to 100 km. Under favorable conditions, has the advantage that height profiles of drift velocity can bee obtained, the echoes returned from various range intervals being selected by a 'gate'.

4. Analysis

The points about correlation analysis which have been made are;

1. Peak values of cross-correlation, rather than instantaneous values, should be used to determine *Vc*', making use of equation (1).
2. The mean of the three auto-correlation functions can be used as an improved estimate of the true function.
3. The complete analysis can be done by a computer, using the methods given in the Appendices as numerical equivalents of graphical calculations.
4. *Vc* can be defined for anisometric patterns in a simple way which makes no extra assumptions about the statistical behaviour of the pattern.
5. If Vc is so defined, it can be shown that, with a rather special model of the random movements of the irregularities, Vc can be identified with the speed of movement of wavelike components making up the fading pattern.

The computer analysis described in this section is intended to simulate fading records similar to those observed in actual experiments, and uses geometry representative of an actual experimental setup. The output from the simulation program is stored on tape for input to the correloid analysis program (FEDOR, 1967). The complete set of simulated records produced and analyzed in this study is thus available for trials employing other methods of analysis. They may also be plotted by digital devices (as are the actual kinesonde recordings) for inspection. An example of one of the simulated fading records for four antennas is given in Fig.7. The magnetic tape and plotting format for the fading record generation program is chosen to match the experimental kinesonde recordings: logarithmic intervals with increments of 0.4 db, i.e. 50 $\log_{10}$ (signal strength), scaled to operate in the range 0 to 200.

Most of the experimental data involves fading patterns observed at four spaced receivers, and the simulation program allows the input of location data for four or more receivers. The depth of fading can be controlled by a parameter specifying the relative strength of the reflected and scattered waves; (the two-dimensional problem studied in the previous section was restricted to either weak scatter or, at the other extreme, no reflected wave at all, in order to minimize time sharing run times). Other input parameters specify the wave frequency, reflection height, length of records required, sampling rate (associated with the drift velocity through an arbitrary time element) and the number and spatial extent of the scattering centers. Random fluctuations and polar diagrams associated with the transmitter, the receivers and the scattering centers themselves can also be involved through mechanisms described later in this section. Other experimental effects (gradually increasing drift velocity, for example, or several transmitting centers operating together in phase) are more conveniently introduced through minor program modifications.

5. Study of E and F Region

The bottomside ionosphere is that region of the upper atmosphere lying between about 80 km and 350 km. This region of the ionosphere is divided into layers, referred to as E, F1 and F2. The division of the bottomside ionosphere into layers and the physical processes that give rise to these layers are described in detail in McNamara [1991] and Davies [1990].

The E layer is that region of the ionosphere from 85 km to about 150 km. Below the E layer is the D layer. The ionosonde is not able to take measurements from the D layer and, therefore, the lowest region for which Kodaikanal, India data exists is the E layer.

An example of the E layer of a model electron density profile for Kodaikanal, India midday Indian Standard Time (SAST). This profile is shown as a height versus frequency profile, where the x-axis variable is frequency in MHz instead of electron density. Electron density is proportional to the frequency squared, as shown in equation (1-1), therefore, frequency will be used throughout this thesis, reserving the option to convert to electron density in the final model if required. In figure 4-1 the ionospheric characteristics that are important for defining the start and end points of the profile are indicated.

Several neural networks (NNs) have been designed to predict the parameters needed to describe the electron density profile in the E layer.

The F layer of the bottomside ionosphere falls in the region from about 150 km to 350 km and is divided into two sections, the F1 and F2 layers. Details on the physical processes that give rise to the distinction between F1 and F2 can be found in McNamara [1991]. For the purposes of HF propagation the most important layer in the ionosphere is the F2 layer, since this layer is always present and measurable. There are specific conditions under which an F1 layer is not present at all. In particular, the F1 layer is never present at night. For the development of a model for the F layer, three points on the electron density profile need to be identified. Firstly, there is the peak of the F layer corresponding to the point of maximum electron density in the ionosphere, which is described by the ionospheric characteristics, foF2 and hmF2. Secondly, the starting point of the F layer is identified by the characteristics fsF and hsF, which are determined by the E layer model. The third point is identified by the ionospheric characteristics foF1 and hmF1, which define the peak of the F1 layer. An example of the F layer profile for the daytime ionosphere over Kodaikanal,India, showing both an F1 and F2 layer, is illustrated in figure 5-1, in which the important points, as mentioned above, are shown.

6. Results

The Tirunelveli, India (8.67N, 77.82E; 30 m alt) 1.98 MHz MF radar has been in continuous operation since December 1992. On day 359 of 2001 at 89 km altitude, the apex magnetic coordinates were (6.8, 149.8) degrees. The magnetic inclination and declination angles were 1.4 deg and -2.6 deg. The magnetic local time at 0 Universal Time (UT) is about 0554 MLT. The solar local time (SLT) is UT plus 5 hours and 11 minutes (77.82/15.=5.188).

The original data files are hourly averages of the zonal and meridional velocity in Indian Standard Time (IST), which is 5 hours and 30 minutes later than UT. Samples are taken every 2 min, so a possible 30 samples can be had between IST 0:00:00 and IST 0:59:00, which is labelled as hour 1:00:00 IST. These times have been converted to the mid-point solar local time (or 0:11 SLT or 0.188 SLT for this example).

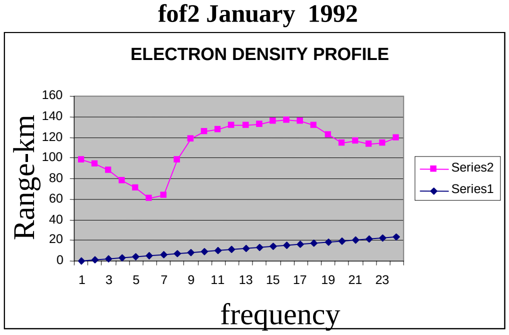
The MF radar system is identical to the one operating at Christmas island (2E,158W) and designed by Robert Vincent (robert.vincent@adelaide.edu.au) of the University of Adelaide in Australia (Vincent, 1991). The operating frequency is 1.98 MHz, with a peak transmitter power of 25 kW. The radar operates as a spaced-antenna system (Vincent, 1986), relying on coherent echo signals from middle atmosphere ionization. The inter-pulse period is 12.5 millisec during the day and 25 millisec during the night. There are 32 coherent integrations during the day and 16 at night, using 256 samples in the full correlation analysis (FCA) of Briggs [1984] with built-in rejection criteria. [ie, want about 2 min or 102.4 sec integration during day and night, or 12.5x10-3sec * 32 integ * 256 samples = 102.4 sec and 25x10-3sec * 16 integ * 256 samples = 102.4 sec.]

The height coverage is 68-98 km during the day and 70-98 km during the night. The pulse width is 30 microsec, giving a height resolution of 4.5 km assuming a simple rectangular wave pulse [range of heights illuminated by the wave pulse = velocity of light * pulse-width / 2 = 3x10**8 m/s * 30x10-6s / 2 = 4.5 km]. However, neutral velocities are given every 2 km between 80 and 98 km since the ionization is less below 80 km.

Various upgrades to the system are planned, possibly as soon as 2003. The analog to digital (A/D) signals are presently in 8-bits, which should be upgraded to 12-bits to avoid signal saturation problems. The system may also be upgraded to monitor electron densities, and also improve the antenna systems.

Starting in 2002, the data are also contributed to the joint TIMED-CEDAR program of the National Aeronautics and Space Administration (NASA) and the National Science Foundation (NSF). The original hourly velocities are converted to harmonic analyses in UT over sliding 4-day intervals. The Mesosphere-Lower Thermosphere Radars (MLTR) organized for the TIMED-CEDAR program provide horizontal and sometimes 'vertical' neutral winds to the processing center at the University of Colorado. Summary plots from several types of MLTRs in the TIMED-CEDAR program and references for the instruments, analyses using the radars, and comparisons with other satellite or ground-based instruments can be found at: /instr/mltr.html The harmonic analyses are also available at that site, or from the University of Colorado at:
http://sisko.colorado.edu/TIMED/data/MLTR/

fof2 January 1992



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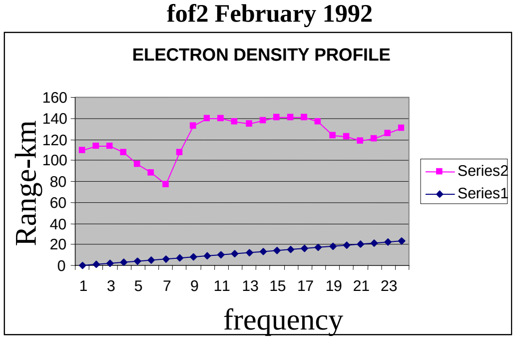

Ionospheric and Magnetic Studies at the Kodaikanal Observatory :

A NBS C3 analogue ionosonde was installed at the Observatory in 1955, for vertical soundings of the ionosphere. Quarterly soundings were made round the clock. In 1993, a digital ionosonde model IPS 42/DBD43 was commissioned enabling five minute or better sounding rates. A HF Doppler radar was built indigenously and made operational. A lacour magnetometer and a Watson magnetometer have been made available at the observatory since the beginning of the century. The lab is thus equipped for studying the ionospheric and geomagnetic effects of solar activity. The ionograms, geomagnetic data and F-region vertical drift observations are being obtained regularly. The data collected by the lab so far is the longest series of its kind in the country. Further the geographic location of Kodaikanal has made possible the interesting observations of equitorial electrojet. The presence of solar observational facilities on campus has been an added advantage to the laboratory. Besides the above regular observations, the ionospheric lab has been participating successfully in a large number of national and international campaign observational programmes. The lab sends monthly summaries of data obtained,to the national data centers.

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Biography

The author P.Senguttuvan Completed his graduation in ECE at GCT, Coimbatore in the year 1984 and his post graduation in communication system at Guindy Engineering College, Anna university in the year 1987. He has total 22 years of teaching experience. Presently working as Dean / CSE and Vice Principal at V.M.K.V.Engg.College, Salem