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Comparative Analysis of different Characteristic Parameters and its Association with ionospheric Propagation

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ABSTRACT

Ionosphere is an ionized region of the upper atmosphere produced by solar radiation and high energy particles from the Sun. The ionosphere is divided into different layers e.g. D, E, F1 based on the electron density in that region, which is strongly dependent on the condition of the geomagnetic field. In other words, geomagnetic storms are formed when the flow of solar charged particles from the Sun reaches the Earth. This results in the decrease of electron density in the F region and hence effecting radio communication severely e.g. the maximum usable frequency is reduced. Characteristics like frequency, maximum usable frequency, electron density and signal strength of radio wave propagation through the atmosphere especially ionosphere were analyzed using Proplab simulations. This research covers the comparative analysis of those characteristics when an electromagnetic ray or combination of different rays is propagating from the transmitter to the receiver in various conditions, time and frequency.

Keywords: *Propagation, ionosphere, frequency, electron density*

1. INTRODUCTION

Recent development in radio communication have developed high interest in research in the region of Ionosphere, which is a region above the Earth's surface from a height of 50 kilometers up to 1000 km, consisting of different layers named as D, E, F1 etc. [1]. The radio waves propagating in this region are affected by radiations from the Sun as well solar particles of high energy which depends on different ionospheric parameters like geomagnetic location, seasons, time, solar activity and disturbances [2]. The propagation through ionosphere, in other words, is proportionally dependent on the electron density in the ionospheric region which vary in different seasons of the year [3]. This results in unwanted reduction in the signal strength which depends specifically on two propagation parameters given by (i) path length between transmitter and receiver and (ii) frequency of operation of the transmitter, along with other parameters like elevation angle and Maximum Usable Frequency (MUF). The detailed discussion on such characteristic parameters and their effects on radio wave propagation at UHF and VHF frequencies is given in [4] and [5] on a spatial as well as temporal basis.

Numerous studies on arora region focusing on the high latitude have been conducted [6-11]. In this research we are focusing on the propagation of radio waves passing through the region over Uppsala (Sweden) – Leicester (UK). The exact location of the communication path considered at Leicester is 52.6369° N, 1.1398° W and at Uppsala is 59.8586° N, 17.6389° E of the geomagnetic coordinate and the coordinated universal time (UTC) is taken at night and day. The other parameters used in the analysis include distance between transmitter and receiver as 1413.25 km, frequency of operation as 10 MHz (fixed unless stated otherwise), Air distance as 1622 km.

To improve the understanding associated with the ionogram which are responsible for different propagation effects at radio frequencies, elevation angle, plasma frequencies and hourly MUF are analyzed in this work. Large number of patches and arcs consisting of enhanced electron densities are responsible for affecting the signal, both in magnitude and direction, in propagation from the great circle path. These patches and arcs are classified and shown in different ionogram in [12] giving rise to different propagation conditions. Numerous studies have been undertaken on the association of total electron contents and its association with the propagation conditions [13-15].

2. RESULTS

A. *Effect of Channing the elevation angle and frequency*

In this research the elevation angle is increased in steps at a fixed frequency as shown in Fig 1. In this section a particular elevation angle is investigated at which the signal hits the receiver completely or as close as possible to it. The simulation is repeated for different ranges and step sizes. The observations are made for rays that are penetrating the E and F regions of the ionosphere. It is noted that rays emanating at an elevation angles of 20°, 24°, 28° and 32° penetrate the E layer and rays at 36° and 40° penetrate the F layer. Fig 2 makes it clear that when the elevation angle is kept at 18° and the frequency is swept between different values and step sizes, the rays at frequencies of 10 MHz to 30 MHz penetrate the E layer and those at frequencies of 16, 18, 20, 22, 24, 26, 28 and 30 MHz penetrate the F layer.

The results shown in Fig 3 traces the rays at fixed frequency of 10 MHz and an elevation angle of 18° when the rays are launched between Uppsala and Leicester where the time of the day is sweeping from 0 UT to 2300 UT at a step size of 2 hours. As shown in the figure, the rays travelling farther are the ones which can be seen above the height of 300 km having colour light to dark green. They represent night time communication as expected.

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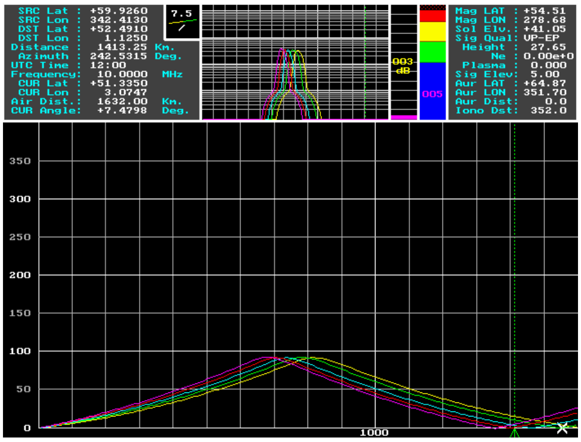

Fig 1 Elevation angle variation at one frequency

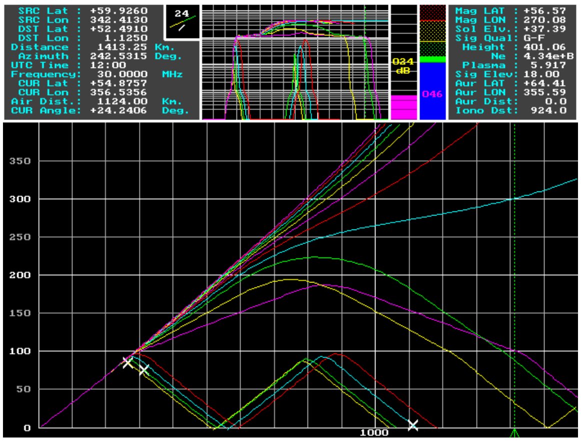

Fig 2 Frequency variations at one elevation angle

B. Plasma frequncy and hourly MUF

The plot for the plasma frequencies and hourly MUF along the path of investigation between transmitter and receiver is shown in Fig 4 and Fig 5 respectively. The plasma frequency is the critical frequency (one beyond which ray penetrates the layer) of a section of ionosphere and is associated directly with the electron density of the ionosphere. In other words, at a specific electron density of a layer, a signal of plasma frequency would be reflected from that layer.

MUF is required in cases where long distance communication is desired where it becomes necessary to find a frequency at which signals penetrate the E layer but not the F layer. In other words, the E layer propagation (where signal reflection occurs from E layer) is used for short range communication and the F layer propagation is used for the long rang communication. The graph of hourly MUF is calculated for E and F layers (along with the average and optimum plots) on hourly basis. The time for Sun rise for the transmitter at Leicester is taken as 6 to 10 GMT and that for Sun set is taken as 3 to 7 GMT (equivalent time for UT is calculated by subtracting 5 in general).

At Sun rise, the MUF for both E and F layers is increasing and vice versa for the Sun set as shown in Fig 5. It is also observed that during day time (from 6 UT to 15 UT) the width of the usable frequencies reduces and the probability of the signal to penetrate the F layer and lost in the space as compared to night time. Also the increase in critical frequency during Sun rise is faster than the decrease during Sun set time.

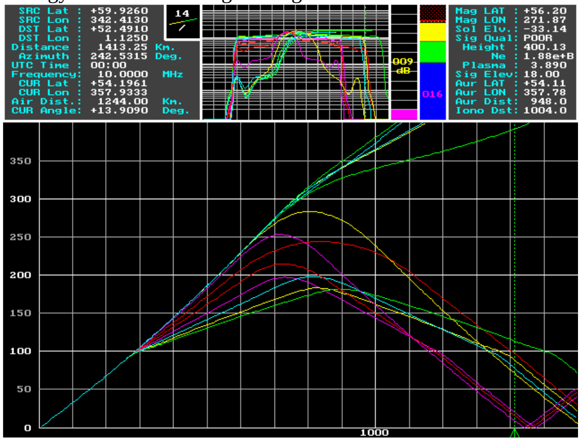

Fig 3 Effect of different time of day from 0 to 2300 UT

In other words, the increase in electron density of the layer during Sun rise is faster than the decrease in electron density during Sun set time.

C. Ionogram

An oblique ionogram gives information regarding optimum working frequencies, maximum and minimum usable frequencies, signal strength and its multipath effects. In this part of the research an ionogram is constructed to get a picture of the electron density of each layer and different signal characteristics are obtained as a result of variations in it, which are then compared with the communication path from Uppsala to Leicester.

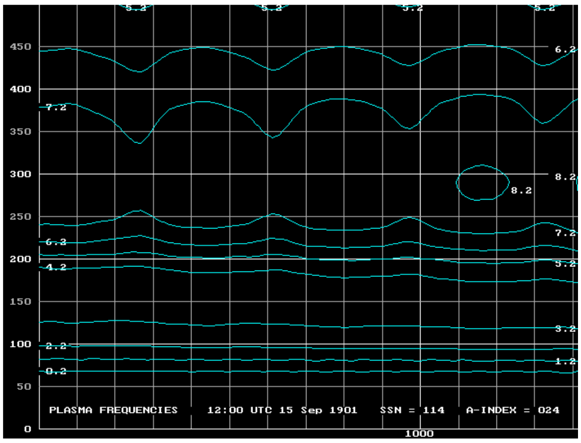

Fig 4 Plasma frequencies

The ionogram is constructed by sweeping different frequencies at the transmitter and the content of the electron density of the ionosphere is assessed based on the reflected signal at the receiver. We checked if the frequency is low, which would signify that the relatively low contents of electrons would reflect the signal and hence give the lower layer's contents. The Uppsala to Leicester communication path was equipped with special transceiver devices like Ionsondes to get the ionogram which was simulated in Problab. The ionogram shown in Fig 6 is the final one obtained from the simulation for day time of noon to compare it with the measured one on the communication path Uppsala-Leicester. The upper portion of this figure is the signal strength information and the lower part is the E and F layer contents.

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It is observed in Fig 6 that from 9 to 13 MHz a correlation exists of the simulated work with the measured electron density of the selected communication path in [9] for the F layer whereas from 13 MHz to 16.5 MHz the electron density is similar to that of the E layer.

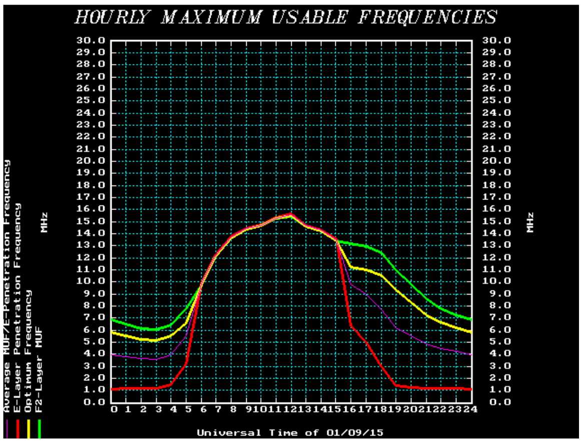

Fig 5 Hourly MUF

3. ANALYSIS

The effect of Changing the elevation angle and frequencies was analyzed and according to the results in section II-A, the effect of the three important layers (D, E and F) of the ionosphere varies with different time of the day and night. It was observed that layer D is present only during day time. E and F are present all the time but E is very weak at night time and F is very strong at day time.

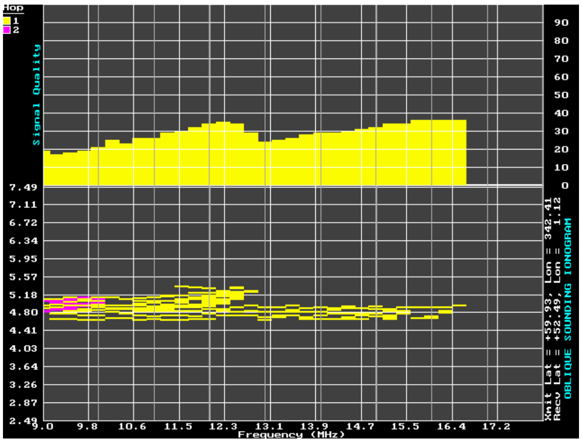

Fig 6 Ionogram

From section II-B it was analysed that at Sun rise, the MUF for both E and F layers is increasing and vice versa for the Sun set. The width of the usable frequencies reduces and the probability of the signal to penetrate the F layer and further lost in the space at night time was more. Furthermore, the increase in critical frequency during Sun rise is faster than the decrease during Sun set time.

By the results produced through the ionogram it was observed that at lower frequencies a correlation was found of the simulated work with the measured electron density of the selected communication path whereas at higher frequencies the electron density is similar to that of the E layer.

4. CONCLUSION

In this research the ionogram which are responsible for different propagation effects at radio frequencies, elevation angle, plasma frequencies and hourly MUF are analyzed. We can conclude that the effect of the three layers of the ionosphere varies throughout the 24-hour period, with the MUF for both E and F layers increasing at Sun rise and decreasing at Sun set. The width of the usable frequencies reduces and the probability of the signal to penetrate the F layer increases, with the possibility to get lost in space. Critical frequencies tend to increase faster during Sun rise as compared to Sun set. The electron density was found to correlate more at lower frequencies as compared to higher frequencies which was similar to the E layer electron density contents.

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