CHAPTER - I

INTRODUCTION

The Kolhapur city is situated at low latitude. The study of ionosphere absorption of cosmic radio noise is very important in this region, because at the low latitude region not much observations on the measurement of ionospheric absorption measurements using cosmic radio noise at 30MHz.

The Indian Institute Geomagnetism (I IG) Mumbai, has installed riometer to study the cosmic radio noise absorption in the ionosphere. Using this opportunity the Department of Physics, Shivaji University, Kolhapur started ionospheric absorption measurements using cosmic radio noise at 30 MHz.

I I G has also supplied with riometer the standard antenna. It consists of two half wave dipoles separated horizontally by $\sim\lambda / 2$ distance to give an effective half-power beam width of $\sim 60^0$ in both E and H planes. To test, the antenna was connected to riometer through balun & observations were made using chart recorder. It was observed that the quality of riometer records was not satisfactory. It could be due to the manmade interference. To get a good quality record it was decided to design and construct a high gain, narrow beamwidth antenna for riometer. In this M.Phil dissertation work, main emphasis is given to study, the design and construction of high gain, narrow beam-width antenna.

Before going to design and construction of antenna, it is necessary to describe briefly about the ionosphere, riometer and cosmic radio noise.

1.1 IONOSPHERE :

Historically man first began to use radio waves for the exploration of ionosphere and advanced his knowledge of upper atmosphere sufficiently upto some altitude. He also used the radio waves emitted by natural processes like that impulsively radiated from lighting flashes near the earth known as whistlers (low freq. e.m.waves). For direct measurement of atmospheric properties like densities, temperature compositions etc. more advanced techniques like rockets or artificial earth satellite are in use. Basically satellites and rockets help more, for collection of ionograms of outer regions of ionosphere, magnetosphere and beyond.

Sun`s radiation causes ionization of the earth's atmosphere. The ionized region of the atmosphere is called the ionosphere. The electron concentration is at its peak at a height of 300 kms. Determination of height distribution and in particular the distribution at heights below the peak electron concentration is possible by ground-based technique.

The electron concentration below the peak has been extensively studied for many years with the help of ground based ionosondes. The ionograms displays panoramically the weakely marked peaks in the height distribution of electron content. Those that occur near heights of 120, 200 ad 300 kms are said to belong to the E-layer, F_1–layer and the F_2- layer respectively. Always at night the F_1 peak is absent. The single layer above the E-layer is then called the F-layer. There is also a layer called D-layer below the E-layer during daytime. Its peak is at 90 km. From an ionogram it is easy to determine the frequency of radio wave that just penetrates the layer at vertical incidence, from which the electron concentration at peak may be determined.

The behaviour of F_2 region is very complicated and it depends on geomagnetic latitude. The ionic composition of the ionosphere is the result of ionic production due to photo ionization of major atmospheric constituents N_2, O_2 and O. Even though the behaviour of the ionosphere is truly determined by ionic reactions, the ionosphere is often characterized in terms of its electron densities.

The electron density increases with the height (as shown in Fig.1.1) from about 10^3 cm^{-3} in the D-region to about 10^5 cm^{-3} in the E-region and to about 10^6 cm^{-3} in the F-peak. The vertical distribution of the electron density in and above the F_2 peak is governed by diffusive equilibrium and not by chemical equilibrium. Thus, at high altitude, the diffusion processes between the charged particles determine the ionospheric behaviour.

1.2 IONOSPHERIC ABSORPTION :

The ionosphere contains free electrons and ions which are set in motion by the passage of an electromagnetic wave. The ions being more massive, their movements can be neglected in comparison to those of electrons. If each electron is assumed to be entirely free, so that its movement under the influence of the wave is uninterrupted, then it will execute regular periodic oscillations so long as the wave is passing. The system is powerless i.e. on the whole, no energy is absorbed from the wave. The oscillating electrons however scatter some of the incident radiation and the scattered wavelets add up with the incident radiation causing a change of phase of the transmitted

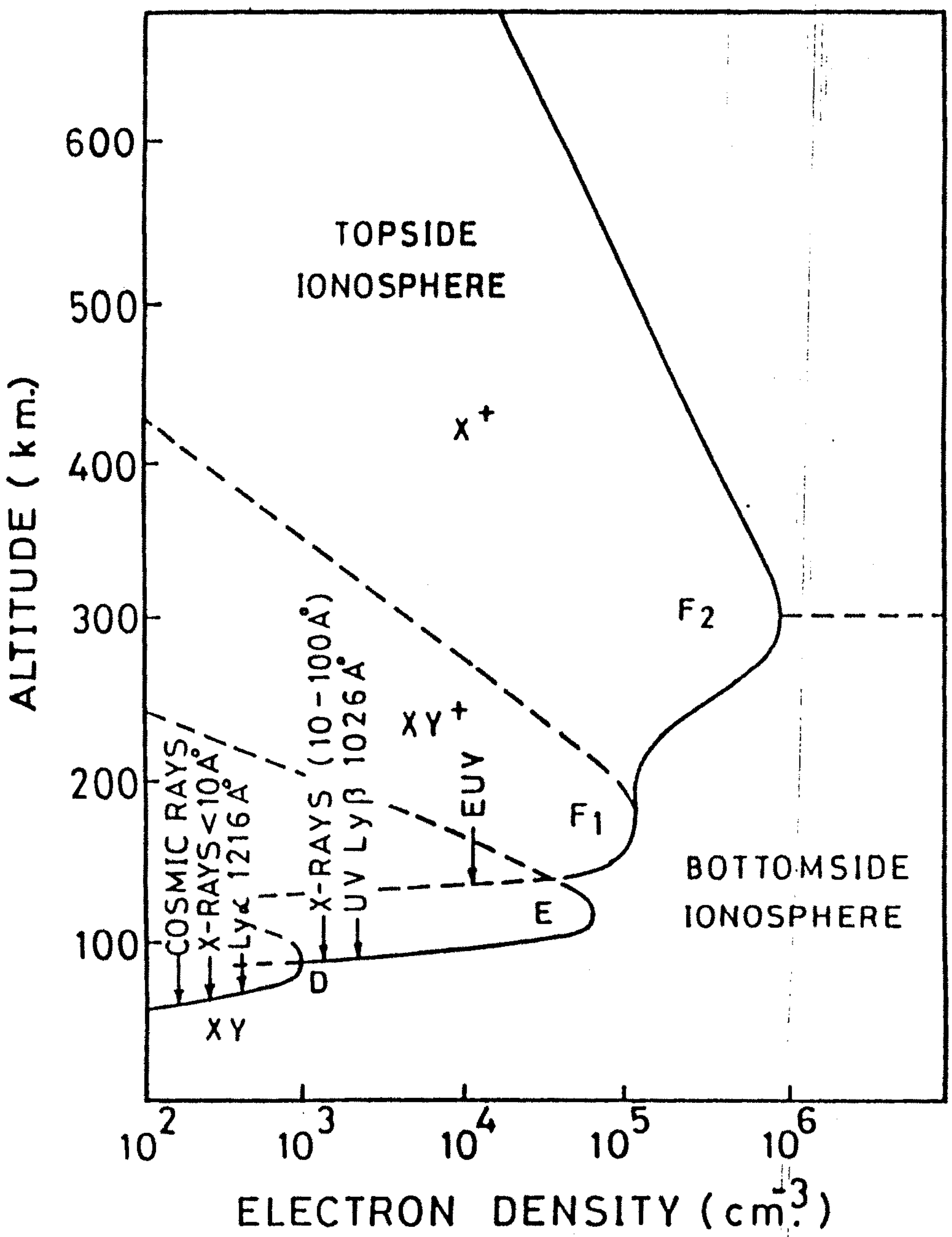

Fig. 1·1 – Electron density distribution in the D, E and F regions of the daytime ionosphere and ionizing radiations responsible for the formation of these ionospheric layers.

wave and hence a retardation. The intensity of the incident waves undergoes some attenuation due to scattering. On the whole no net work is done on the electron, as the electron re-radiates what it receives. If, however, the electrons are not entirely free, they collide with the molecules and ions, which are present in the ionosphere and in doing so, they change the ordered energy of oscillatory motion, which they acquire from the electromagnetic wave, into the kinetic energy of random movement. The energy is then lost from the point of view of wave and the latter therefore becomes attenuated. The overall, attenuation per unit length of the path will depend upon $N\upsilon$ and ω here N is the electron concentration, υ is the collision frequency of the electron and ω is, the angular frequency of the wave. If ω is very much larger than υ, then attenuation decreases as the frequency increases. N and υ are functions of height and the absorption per unit length of path at any height depends directly on the product $N\upsilon$.

Absorption Coefficient 'K':

Magneto-ionic theory shows that, provided the direction of phase propagation is not perpendicular to the magnetic field, the absorption coefficient, 'K' is given by the expression,

$$K = \frac{2\Pi e^2}{mc} \cdot \frac{1}{\mu} \cdot \frac{N\upsilon}{\upsilon^2 + (\omega \pm \omega_L)^2} \qquad \text{\{1.1\}}$$

Where c is the velocity of electromagnetic waves in vacuum, e and m are the charge and mass of the electron, ω is the angular frequency of the wave, ω_L is the angular gyro-frequency corresponding to the longitudinal component of the earth's magnetic field.

The positive sign refers to ordinary wave and negative sign to extraordinary wave.

1.2a DEVIATIVE ABSORPTION :

If ω is large compared with ω_L the influence of the earth's magnetic field may be neglected and the absorption coefficient may be written as

$$K = \frac{2\Pi e^2}{mc} \cdot \frac{1}{\mu} \cdot \frac{N\upsilon}{\upsilon^2 + \omega^2} \qquad \text{\{1.2\}}$$

Further, if $\upsilon^2 << \omega^2$, then eqn {1.2} becomes,

$$K = \frac{2\Pi e^2}{mc} \cdot \frac{1}{\mu} \cdot \frac{N\upsilon}{\omega^2} \qquad \text{\{1.3\}}$$

where, $$\mu^2 = 1 - \frac{4\Pi N e^2}{m\omega^2} \qquad \text{\{1.4\}}$$

Combining eqns. {1.3} & {1.4} , we get,

$$K = \frac{\upsilon}{2c}\left(\frac{1}{\mu} - \mu\right) \qquad \text{------------} \quad \{1.5\}$$

Equation {1.5} shows that the absorption index K and the total absorption $\int Kds$ will depend critically on the value of the refractive index μ. Since the bending or deviation of a group of waves is also governed by the value of the refractive index, this type of absorption is termed as deviative absorption.

1.2b NON-DEVIATIVE ABSORPTION :

When $\mu \approx 1$, then eqn {1.1} takes the form,

$$K = \frac{2\Pi e^2}{mc} \cdot \frac{N\upsilon}{\upsilon^2 + (\omega \pm \omega_L)^2} \qquad \text{------------} \quad \{1.6\}$$

If $\upsilon^2 << (\omega \pm \omega_L)^2$, then the total non-deviative absorption may be written as

$$\left(\int Kds\right)_{\mu=1} = \frac{2\Pi e^2}{mc} \cdot \frac{1}{(\omega \pm \omega_L)^2} \int N\upsilon ds \qquad \text{------------} \quad \{1.7\}$$

The above expressions apply only to the so-called "quasi-longitudinal" propagation of waves of angular frequency much greater than the collision frequency of electrons.

1.3 METHODS OF MEASURING IONOSPHERIC ABSORPTION :

There are different techniques for studying ionospheric absorption. Here, we shall restrict our discussion only to extraterrestrial radio waves and ionospheric absorption.

The normal method of investigating ionosphere absorption is to measure the strength of manmade signals reflected from the ionosphere. Such a method, in essence, measures the total attenuation undergone by radio signals in their path from the transmitter to the receiver and includes contributions due to divergence of beam, partial reflections, polarization effects, collision losses, losses due to scattering and deviative absorption. The use of extraterrestrial radio waves for the study of the changing transparency of the ionosphere has certain important and useful features. These are the constancy of the source & the relative simplicity of the equipment since no transmitters are required, and the fact that radio waves from the galaxy traverse the whole ionosphere instead of only the region below the level of reflection or scattering. Moreover, if frequencies well above the critical frequency are used, the absorption can be measured even when it is very much increased during SID`s associated with solar flares and polar blackouts. The use of frequencies well above the gyromagnetic and critical frequencies has the advantage that uncertainties arising from polarization effects and deviative absorption are much reduced. But the exact level at which the absorption taken place cannot be determined.

The cosmic noise method of measuring ionosphere absorption was, first used in 1953 by Mitra & Shain[4].s They compared the signal strength of extra-terrestrial radio waves actually received on a fixed receiving system under different ionospheric conditions with the signal strength received on the same system at the same sidereal time under conditions of negligible absorption.

Little and Leinbach[2] devised an instrument called riometer which is sensitive & self balancing noise measuring equipment. The riometer incorporates sweep frequency and minimum signal detector circuits in conjunction with the receiver. The riometer registers the minimum noise level as a 6 KHz exploring band are swept across at the rate of 2.5 KHz through 100 KHz search band.

1.4 ADVANTAGES OF THE RIOMETER :

The riometer has three important advantages over a simple total power type receiver

(1)It provides linear input/ output characteristics.

(2) The equipment is capable of operating with high accuracy in the presence of narrow band R.F interference and

(3)The equipment possesses good long term stability since receiver acts as a null detector rather than as an amplifier.

RIOMETER :

The Riometer technique for examining electron density enhancement in the ionosphere is based on the absorption of cosmic radio noise and the broadband RF energy radiated by stellar sources in the galaxy. Riometer measurements are usually made at frequencies in the range of 20 to 50 MHz; the absorption of radio energy at these frequencies is sensitive to changes in electron density in the ionospheric D,E and F regions. Auroral absorption is caused by the precipitation of energetic (>10 Kev) electrons from the magnetosphere, which increases the ionosphere electron density between about 70 and 120 km altitudes. Riometers are usually operated with broad beam antennas, with beam width of the order of 60 degrees. These integrate absorption activity over a large portion of the ionosphere, so small scale details of the actual physical distribution of electron density enhancements are lost. Narrow beam antennas, with beam widths of 10 to 20 degrees, are sensitive to smaller scale features of ionization; but are generally limited in the ionosphere area, which can be examined at one time. The data from several Riometers operated at different frequencies, but examining the same sky with broad beam antennas, show effects which have been interpreted as being due to small scale spatial structure in the electron precipitation region which does not completely fill the antenna beam.

Recent trend in riometry is toward the use of antennas providing several narrow beams, which examine different parts of the sky. Some of these systems have been constructed to provide several fixed beams, and others scan the ionosphere in a linear path with one or more steerable beams.

To calculate the ionosphere attenuation, a narrow single beam antenna is designed and constructed. This directional antenna scans the same strip of sky once in a sidereal day owing to the diurnal rotation of the earth about its axis and the amount of cosmic noise picked up by the antenna depends firstly upon sidereal time and secondly, upon the transparency of the ionosphere, which is a function of local time. It is necessary to know the amount of the incident cosmic noise power, which is assumed to remain constant, outside the earth's atmosphere. This can be known with fair accuracy if one has a reliable cosmic noise data for a period of one year. This directional antenna must receive cosmic noise through the "hole" in the ionosphere and this is made possible using a narrow beamwidth of antenna.

So in Shivaji University, behind the Physics Department, we have constructed an antenna with beam widths (11.46^0 E-W; 14.32^0 N-S) to study the cosmic radio noise absorption in the ionosphere.

1.5 WORKING OF THE RIOMETER :

The sky is filled with stars and galaxies that emit radio noise. Some stars are noiser than others. The Rio meter listens at 30 MHz to the noise coming to earth from the sky by using the directional antenna pointed upwards. It rejects noise coming in from sources on the ground and responds mostly to signals coming from outside the ionosphere.

This noise varies from one hour to the next as the earth rotates and is a constant repeatable function of local sidereal time. Therefore it is possible to develop a "quite day" curve, which represents the greatest noise that would be heard for any given hour of the day using cosmic noise recordings for one year.

Then the Riometer is put into operation monitoring the actual noise heard. If that noise is the same as the quite day curve, we know the ionosphere is not affecting it as it passes to us from space. If the monitored noise is less than the quite day curve, we know the ionosphere has absorbed some of the noise signal. In this way we can tell if the ionosphere is being affected by a disturbance, from energetic particle emissions from the sun for example.

1.6 COSMIC RADIO NOISE :

Cosmic radio noise was discovered in 1932 by Karl G. Jansky of the Bell Telephone Laboratories in the course of observations of the direction of arrival of atmospherics. These observations at 20 MHz showed that in addition to atmospherics, there was a steady source of radio waves in the direction of the Milky way with a pronounced maximum near the center of the galaxy. Jansky`s work was followed up by Grote Rebar who carried out galactic surveys at 160 and 480 MHz. In 1946-47, Hey, Parsons and Phillips and Bolton and Stanley discovered the existence of discrete sources of radio noise. Cosmic radio waves are composed of different distinct types of radiation; a hydrogen line emission restricted to a narrow frequency range near 1420 MHz, and emission of a broad spectrum extending over practically the whole of the radio frequency range and arising both from temperature radiation and from synchrotron radiation. The continuous radiation from the Milky way is similar to random noise and is unpolarised. The radiation from the discrete sources show marked fluctuations both in intensity and direction. These fluctuations are analogous to the twinkling of stars and have been shown to be caused by irregularities in the ionosphere. Radio observations are now extensively employed to study both galaxies and discrete sources.

Radio waves have an advantage over light in such studies, because they are not absorbed by dust- cloud of interstellar space.

Applications Of Cosmic Radio Noise For Ionosphere Studies :

Since cosmic radio waves have to pass through the atmosphere before they reach the earth, they are subject to deviation and absorption in the atmosphere. The atmosphere may be considered to be partially transparent from about 20 MHz to 3000 MHz. At the lower frequencies the ionosphere can modify the intensity by absorption, scattering, emission and by producing divergence or convergence of beams. From the point of view of astronomical studies, these effects are an inconvinient as they complicate the interpretation of observations. But from the standpoint of geophysics they provide a means for studying the terrestrial ionosphere.