3.1. Introduction

The high frequency (HF) band has been employed for broadcasting of standard frequency and time signals for a countrywide coverage. The signal parameters received at a distance exhibit a diurnal, seasonal and solar cycle variations. Besides these, certain transient variations of the field strength often occur during ionospheric disturbances caused by the wave and particle radiations from the sun or from nuclear explosions. Under normal conditions, the D and E regions absorb the energy of the sky wave of high frequency signals which are reflected back to earth by the E-region. The absorption coefficient for HF signal in the E-region is about a hundred times as great as it is in the F-region. For a standard time and frequency transmission using high frequencies, the most important factors which must be taken into considerations are: firstly, the frequency used must be lower than the maximum usable frequency (MUF) for the propagation path and for a given ionization density of the reflecting layer; secondly, the absorption of waves in the D and E region must not be too heavy. The signal strength produced by ordinary transmitters and ordinary antennas should be sufficient for reliable receptions. The first condition is a critical one because, otherwise, radio waves will not be reflected from the E-layer altogether, despite any increase in transmitter power. The second condition is not so critical, because the use of a lower frequency may be compensated by an increase in transmitter power; indeed it is possible to maintain radio traffic on a relatively low frequency transmission in HF band
by the use of high power transmitter. Since the electron density of the F-layer goes down in the night time, the usable frequency must be brought down for reflection from F-region. The electron density in the E-layer at night time is considerably reduced and D-region disappear altogether, because of which the night time attenuation will be insignificant even for the lower frequencies of HF band. Maps are now available based on practical measurements from ionospheric sounding stations which show the characteristics of F-region throughout the world for a given sunspot activity, at different times and seasons with a fairly adequate degree of accuracy. The maps show the highest frequency which the ionospheric layer is capable of reflecting at vertical incidence. The approximate frequency can be calculated for use over any given path by using the simple trigonometrical relationship between the highest reflected frequency at vertical incidence and the highest reflected frequency at oblique incidence.

Now-a-days the propagation path of the signal between two points, including a number of hops, the total attenuation and the resultant signal strength can be calculated by using computer programme.

Because of the irregularities in the ionosphere and the ascending and descending motions of air masses in the upper atmosphere, the electron density of the ionosphere fluctuates. As a result, the reflection height of the radiowaves also fluctuates. The most commonly observable phenomena of the variation of the field strength of the radiowaves reflected from the ionosphere is termed fading. The observed characteristic of an ionospherically propagated radiowave can, in fact, be explained by the movement of the ionosphere causing interference fading, rotation of the axes
of the polarization ellipses, time variations in ionospheric absorption, focussing and skipping of the signal due to MUF failure.

The period of a fading cycle may vary from a fraction of a second to a few seconds in interference and polarization fading. Absorption fading may have a period of an hour or longer, whereas, the focussing effect may have a duration of the order of 15 or 30 minutes. If the frequency of the signal is near the maximum frequency and the critical frequency is changing with time, then the signals can fade in or fade out. The period of it is highly irregular and may occur at dawn or dusk.

Fading is faster on high frequencies than on low frequencies because a given movement in the ionosphere produces a greater phase shift on the shorter wavelengths. A beam of radiowaves incident on the ionosphere is not reflected from a point but from an extended region. Small irregularities in electron density near the level of reflection give rise to individual reflected wavelets and the received signal is the vector sum of the individual signals at the receiving antenna. Movements of ionospheric irregularities give rise to variations in the relative phase of the individual wavelets. The received high frequency signal may consist of high and low range rays, each having extra-ordinary and ordinary components; each such set may be combined with other sets corresponding to rays having a different number of hops.

The results of an analysis of the HF standard frequency broadcast signal strength and fading rate (number of fades per hour) data for the period from November, 1979 to October, 1980 with emphasis on the diurnal and
seasonal variations are presented in this chapter. The studies on the regular diurnal, seasonal variation of the median, upper and lower decile points of the field strength and for the fading rate have also been examined.

3.2. Observations

The high frequency standard time transmission ATA at 15 MHz from National Physical Laboratory (NPL), New Delhi (28°33'N; 77°18'E) at a great circle distance of about 1294 km has been recorded at Calcutta (22°34'N; 88°24'E) and at Kavalur (12°35'N; 78°50'E). Figure 3.1 shows the location of the observational sites.

3.2.1. Typical records

A typical record of the signal strength of the ATA signal is shown in Fig. 3.2. The decrease in signal strength after the transmission is on, is mainly due to the fact that the D and E layers start building up, causing the signal strength to drop down considerably. After that the level of signal strength gradually increases to a maximum towards the evening hours. This increase should be attributed to the increase in ionization of the E-region which predominantly controls the signal strength.

Figure 3.3 depicts an example of the random fading of ATA 15 MHz from NPL, New Delhi as recorded at Calcutta with chart speed 1" per hour. The time constant of the recorder is 4.7 secs. The variety of the waveshapes of the fading are shown in Fig. 3.4a and 3.4b obtained at a faster chart
Fig. 3.1 Location of the observational sites.
FIG. 3.2 Typical record of the signal strength of ATA transmission.
Fig. 3.4. Typical record of trading obtained at a faster speed of 12 per hour.
speed of 12" per hour. It seems that fading rate increases from noon till evening.

3.2.2. Diurnal and seasonal variations

A statistical analysis of the daily records was made to investigate the diurnal variations as well as the variations of seasonal patterns of the field strength and for the fading rate (number of fades per hour). The results of the diurnal variation of the hourly averages together with respective upper and lower decile points of the field strength and the fading rate of the HF standard signal at 15 MHz are presented respectively in Fig. 3.5 and Fig. 3.6. It is seen from these figures that the field strength as well as the fading rate had a tendency to decrease gradually from morning to noon after which it increases steadily towards evening. Such a behaviour is observed in almost all the months of the year. The mid-day decrease is more sharp in the summer months than in the winter months and the minimum occurs earlier than that in the winter. The mid-day minimum appears to be more pronounced in the lower than in the upper decile point. The diurnal average of the field strength is more in winter than in summer. A similarity of the nature of variations of the fading rate with the field strength is apparent from Fig. 3.6. The rate of increase of field strength towards the evening is more pronounced in summer than in winter, the field strength attains a maximum around 1700 hours IST.

The seasonal variation of the mid-day values of the field strength of HF standard signal ATA at 15 MHz and the fading rate of the same signal are shown in Fig. 3.7 and 3.8 respectively. The winter maximum is more
Fig. 3.5 Diurnal variation of median, upper and lower decile values of the field strength of HF standard signal on 15 MHz in different months observed at Calcutta.
Fig 3.6 Diurnal variation of median, upper and lower decile values of the fading rate of HF standard signal on 15 MHz in different months observed at Calcutta.
Fig. 3-7 Mid-day values of seasonal variation of median, upper and lower decile values of the field strength of HF standard signal observed at Calcutta
Fig. 3.8 (a) Average mid day values of seasonal variation of the fading rate (b) the ratio of the fading rate to signal strength of HF standard signal observed at Calcutta.
pronounced than in summer. Such double maxima have also been observed at Calcutta (Sen et al., 1980) and at Ahmedabad (Kotadia et al., 1980). From Fig. 3.6 it appears that the average mid-day fading rate is more in winter than in summer. It seems that when the field strength increases, the fading rate also increases. In fact, the ratio of the fading rate to the signal strength tends to be constant exhibiting very little seasonal variation as shown in Fig. 3.8. The seasonal variation of signal strength of A2A received at Kavalur (12°35 'N; 78°50 'E) at 10 and 15 MHz for the year 1979-80 measured everyday at 1600 hours (IST) (Dixit et al., 1981) is shown in Fig. 3.9. The figure exhibits a similar trend of the seasonal variation as that observed at Calcutta with, however, a difference that the summer maximum is less pronounced in the Kavalur data.

Figure 3.10 shows the total number of days in a given month for 1979-80 when good A2A signals were received at Kavalur and at Calcutta. We used SINPO code (Mathur, 1977) for signal labelled as poor, fair, good and excellent. The data excludes sundays and holidays when there is no A2A transmission after 1400 hours IST.

3.3. Discussion

The absorption of the radiowaves, in general, is due to the D, E, F₁ and F₂ layers of the ionosphere. The absorption by F₁ and F₂ is deviative in nature and that by D and E is non-deviative. Usually the D and E region absorptions dominate in the day time. The observed increase in signal strength towards the evening may have a relation to the decrease
Fig. 3.9 The seasonal variation of median, upper and lower decile values of the field strength of HF standard signal at Kavalur.
Fig. 3-10 Total number of days when good ATA signal received from Kavalur and Calcutta against month.
in the D and E layer absorption occurring at such times (Davies, 1965; Dolukhanov, 1971). The usual trend of the signal strength variation with a single maximum occurring in winter is expected from the solar zenith angle dependence of the effective ionizing flux affecting the ionization of the D and E region. The appearance of the secondary peak in summer as observed in Fig. 3.7 suggests the influence of the hydrated ion clusters which is now known to affect the electron density in the D-region (Sechrist (Jr.), 1970; Reid, 1970; Mitra, 1974; Thomas, 1976). Such constituents include O, O$_3$, H$_2$O and CO$_2$. The H$_2$O molecules in the form of water vapour are dissociated at a height above 70 km and a large part of atomic hydrogen produced escapes from the atmosphere and there is continuous transport of water vapour through the stratosphere and mesosphere (Mitra, 1970a). The water vapour causes hydration of ions in the D-region. In fact, below about 82 km the water cluster ion [H$^+$(H$_2$O)$_n$] dominate during day and night. The major components of cluster ion are H$_2$O$^+$, H$_2$O. Due to the very large dissociative recombination coefficient (10$^{-5}$ cm$^{-3}$ sec$^{-1}$), the hydrated ions lead to a net loss of electrons (Sechrist (Jr.), 1970; Reid, 1970). This is strikingly demonstrated by a sharp ledge of electron density around 82 km height during day, but only at 86 km at night above which the cluster ions suddenly disappear (Mitra, 1970a; Thomas, 1976, 1976a). The concentration of the cluster ions is more in the summer month, July, than in the winter month, January (Thomas, 1976a). Such a seasonal trend is likely to be more prominent in tropical regions where the water vapour content is significantly higher. The supply of water vapour from surface level to the ionospheric or
stratospheric height would be abundant in tropical region during the summer months. Fedynsky and Ushkov (1979) have found that the water vapour content between heights 30 and 80 km is maximum in July - August and minimum in February - March. The water vapour content at lower atmospheric levels and water vapour density near surface are, in fact, highly correlated (Sen et al., 1980). It has been found from the recent work of Aro (1976) that the correlation is more than 0.95 and the water vapour content as well as the water vapour density is maximum in summer and minimum in winter. The loss of electrons from the absorption level of the HF standard signals due to the dominance of the hydrated ions in the summer months may explain the second maximum of signal strength in summer. The less pronounced summer maximum observed at Kavalur compared to that at Calcutta may have a relation to a difference in the water vapour content and hence, the hydrated ion concentration in the two regions involved.

Fading on the HF standard signals clearly shows itself as random variations the signal strength between maxima and minima. The main cause of fading is the interfering components of two or more sky waves that have followed different paths from the same transmitter which occurs randomly due to several causes. Fluctuations in the state of the ionosphere can produce significant variations in the reflection height at any time. Owing to these irregularities of the ionosphere, the incident waves experience mostly diffuse instead of specular reflections. For this, the rays emerging from the ionosphere appears as a bundle of elementary rays.
The angular spread of such a bundle of rays may be from one to five degrees. As a result, a multitude of elementary rays belonging to different bundles may strike the same point on the earth's surface. Since each ray continually changes in phase owing to fluctuation in the reflecting layer, the result is random variations in the signal strength. The negligible seasonal variation (shown in Fig. 3.8b) of the ratio of the fading rate to the signal strength is interesting. The result suggests that ionospheric absorption and fading rate are directly related.

3.4. Conclusion

The diurnal and seasonal variations of the field strength and the fading rate of HF standard signal have been critically examined. The signal level, in general, starts decreasing from the morning hours to a minimum around noon after which the level gradually increases towards the evening. The average level of the signal throughout the period of 0900 to 1900 hours is higher in winter than in summer, presumably due to the lower D and E region ionizations and higher E-region ionization. The ionization of these regions depend on the solar zenith angle, while the anomalous additional maximum in signal strength in summer is due to the diffusion of hydrated cluster of positive ions from the stratospheric heights to E-region heights. Such a trend is prominent in tropical regions because both the water vapour content and the surface water vapour density are significantly higher in summer than in the winter in those regions.