CHAPTER V

LONG TERM VARIATIONS IN THE IONOSPHERIC REFLECTION PROCESSES
FOR 164 KC/S RADIO-WAVES

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5.1 Introduction

The earliest investigations on the effect of solar activity on the propagation of long and very long radio waves were made by Austin (1922, 1924) and Pickard (1922, 1927) in the early half of the present century. Over a period of twenty years (1911 - 1930), Austin carried out a series of field strength measurements over trans-atlantic paths, with frequencies ranging from 13 to 60 Kc/s and showed that a direct correlation existed between sunspot number and daylight field-strength. From a similar study over a much wider range of frequencies, Pickard concluded that sunspots near the solar meridian were followed by disturbances of terrestrial magnetism, lowered night reception and higher day reception. Night static at 1330 Kc/s was found to be inversely related to the day signal strength at the same frequency and finally, day static at 15-25 Kc/s was also in general inversely correlated with sunspots.

In recent years, extensive studies on the long term variations of the field strength of long and very long radio waves have been made by *Lauter et al (1961) in Germany and by Egeland and Reidler (1964) at Kiruna in Sweden.

*Also see Lauter (1966).
Lauter's investigations on a frequency of 245 Kc/s propagated over a distance of 180 km, corresponding to an equivalent vertical incidence frequency of 164 Kc/s showed that the waves were more strongly reflected at sunspot minimum than at sunspot maximum, the magnitude of the effect depending partly on the sunspot number and partly on the season. His studies also revealed that for waves at 245 Kc/s the difference in attenuation between the sunspot maximum and sunspot minimum periods was a function of solar zenith angle. There was a maximum difference in attenuation of 15 db at $\chi = 70^\circ$, where $\chi$ is the solar zenith angle. Monthly mean values of the logarithm of the reflection coefficient at a constant zenith angle were closely correlated with sunspot number, but the linear regression held only upto $R = 150^\circ$, for higher sunspot number there was little change.

Egeland and Riedler studied the field strength changes on the 16 Kc/s transmission from Rugby at Kiruna in Sweden and concluded that the height of the D-region was lowest during years of high solar activity and highest during quiet years. The 16 Kc/s signal strength was a maximum in 1960 about two years after the sunspot curve reached its maximum, and conditions deteriorated substantially in 1962 and 1963.

5.2 Field strength measurements on 164 Kc/s at Ahmedabad

The present discussion concerns the long term changes observed in the field strength of 164 Kc/s radio-waves received at Ahmedabad (23°N, 12°36'E) from Tashkent (42°N, 69°E) over a great circle distance of 2150 km, during
the period March 1960 - July 1964. The recording was discontinued for a period of eight months (August 1964 - March 1965) when the receiver used for the recordings was modified for use in a Radio-Polarimeter which was being constructed to study the polarisation changes in the downcoming 164 Kc/s radio-waves. A new receiver of the Tuned Radio frequency type was designed and put into commission in April 1965 and the recording has been continuing without a break ever since. The calibration of the recording system was carried out with a standard Signal Generator, type G.R.805-C and was found to remain steady over long periods. Fig.5.1(A and B) shows two typical day time records each in October-April and in May-September respectively.

5.3 Diurnal changes in the day-time field strength

The diurnal variation of day-time signal strength for the period January to December 1961 is shown in Fig.5.2 (A and B) the values used being the monthly means of the hourly values of the signal strength. As mentioned by Alurkar (1965) in an earlier report, the year could be divided into two seasons, depending on the nature of the signal strength changes, (a) June to October corresponding to local summer and autumn (b) November to May corresponding to winter and spring.

During the summer months the field strength varies regularly with the position of the sun (see Fig.5.1 A) attaining a maximum round about noon. Assuming the dependance
Fig. 5.1 A. Two examples of field strength records obtained at Ahmedabad on a typical summer day.
Fig. 5.1 B. Two examples of field-strength records obtained at Ahmedabad on a typical winter day.
Fig. 5.2 A. Diurnal variation of field strength during summer months (May to October).
Fig. 5.2 B. Diurnal variation of field strength during non-summer months (November to April).
of the mean field strength "F" on the cosine of the solar zenith angle to be approximately of the form

\[ F \propto \cos \lambda \]

a plot of \( F \) versus \( \cos \lambda \) on logarithmic paper yields a straight line whose slope "n" has a different value in each month.

During non-summer months the field-strength exhibits oscillatory features in the late morning and early afternoon hours, in the form of two prominent maxima, the position of these maxima on the diurnal curve being controlled by the sun. The overall field strength in winter is higher than in summer.

5.4 Night-time field strength changes

Fig. 5.3 shows a typical record obtained at night; it shows a series of rapid fluctuations superposed on a steady increase in field strength towards mid-night; the level at mid-night being two to three times higher than the level in the early hours of the night. The night time field strength is on an average twenty to thirty times the corresponding day-time field strength.

5.5 Diurnal variation in the field-strength from 1960-65

The diurnal changes in field-strength for the period 1960-65 are shown in Figures 5.4 and 5.5, where the monthly mean field-strengths for January, April, July and September are shown for each year. The change in noon field-strength
Fig. 5.3. Typical record illustrating the night time field strength changes observed at Ahmedabad (Scale - 0.1 mA = 50 μV).
Fig. 5.4. Daytime variation of 164 Kc/s field-strength at Ahmedabad (July 1960-65; September 1960-65).
Fig. 5.5. Daytime variation of 164 Kc/s signal strength at Ahmedabad (January 1961-66, April 1960-64).
between July 1960 and July 1964 was about 10 decibels, with an almost similar value for September. The most interesting feature in the diagrams is the steady increase in field strength from 1960 or 1961 to 1964, the nature of the diurnal variation remaining the same.

Fig. 5.5 shows the field strength curves for two non-summer months, January and April. The same decrease in field strength with decreasing solar activity is also evident here.

5.6 Annual change in the day-time absorption at Ahmedabad

The seasonal and yearly variations of the observed signal strength from March 1960 to January 1966 are shown in Fig. 5.6. The changes are shown in terms of the absorption loss in decibels (db). The method of calculation was as follows:

In the A-3 method of calculating absorption at low frequencies, the ratio of sky to ground wave is used to estimate the reflection coefficient. The absorption can then be determined using a simple relation. Since the great circle distance between Tashkent and Ahmedabad is large, the ground-wave signal would be very small, rendering the use of this method impracticable.

An alternative approach to the problem was by making use of the night-time signal strength, since there is an insignificant amount of absorption below the E-region at night. A careful examination of the night-time signal strengths
Fig. 5.6. Variation of monthly noon absorption of 164 Kc/s radio-waves 1960-65 vs Sunspot number.
between 1960 and 1964 brought out two features clearly: a) the field strength in any month reaches a maximum at about mid-night. b) The field-strength increased with decreasing solar activity, reaching its maximum value in 1963-64. The mean mid-night field strength for 1963-64 was taken to be a measure of the unabsorbed sky-wave field strength. The ratio $E_n/E_m$ where $E_n$ is the mean noon day-time signal strength is then used to calculate the absorption loss using the relation:

$$L(\text{db}) = -20 \log \frac{E_n}{E_m}$$

The noon absorption loss determined in this way is shown in Fig.5. In the same figure is shown the absorption loss corrected for the variation of the noon zenith angle with season. For this purpose, the relation

$$L_\chi = L_\chi_0 \cos^n \chi$$

where $\chi$ is the solar zenith distance at noon, was used. The value of the index $n$ was found by measuring the slope of the straight line obtained by plotting the absorption loss in decibels against the zenith angle on logarithmic paper. The mean value came out to be $n = 0.6$.

It is evident from Fig.5 that the 164 Kc/s signal strength between Tashkent and Ahmedabad is roughly correlated with sunspot activity, but there is no detailed correlation.

5.8 Solar X-ray emissions and their effect on signal strengths of reflected long radio waves

The immediate effect of solar flares on the reflection
of long radio waves is well known. It has been established that the effect is due to the ionization of the lower part of the D-layer by solar X-rays in the kev range. Three examples of the effect are shown in Fig. 5.7 where the changes in signal strengths of Tashkent 164 kHz waves received at Ahmedabad are shown against the times of reception of solar X-rays in Oso I and Ariel Satellites on 21st April and 1st and 3rd May 1962.

In the preceding chapter it was pointed out that an examination of the field strength records between 1960-65 revealed groups of two to six days of high day time intensity which were sometimes preceded by a solar flare.

Early in 1966, on comparing the day-to-day signal strengths of 164 kHz received at Ahmedabad with the X-ray fluxes (0-8 $\mu$ and 8-20 $\mu$) from N.R.L. satellites recorded at the satellite telemetry station at Ahmedabad, the interesting fact was noticed that on a number of occasions when the 0-8 $\mu$ solar X-ray flux increased in intensity the signal strength fell down and vice versa. This effect, unlike the well known solar flare effect persisted for a number of days at a time.

Figs. 5.8 and 5.9 show a comparison of the field strengths at Ahmedabad and solar X-ray fluxes in the two bands 0-8 $\mu$ and 8-20 $\mu$ in March, April and July, August 1966. The field strengths relate to the noon hours 11 to 13 hrs local time and the X-ray fluxes are the average values during the day according to the data published from World Data Centre A. The high field strengths on 2-12 March and the corresponding
Fig. 5.7. Solar flare effect - Signal strengths of Tashkent 164 Kc/s radio waves received at Ahmedabad and times of solar X-rays telemetered from OSO and ARIEL satellites.
Fig. 5.8 A. Solar X-ray flux, 0-8 R and 8-20 R and Tashkent 164 Kc/s field strength at Ahmedabad - March 1966.
Fig. 5.8 B. Solar X-ray flux, 0-8 Å and 8-20 Å and Tashkent 164 Kc/s field strength at Ahmedabad - April 1966.
Fig. 5.9. Solar X-ray flux, 0-8 Å and 8-20 Å and Tashkent 164 Kc/s field strength at Ahmedabad - July 1966.
Fig. 5.9 B. Solar X-ray flux, 0-8% and 8-20% and Tashkent 164 Kc/s field strength at Ahmedabad - August 1966.
low X-ray fluxes are very striking; similarly, the low field strength from 14-22 March and the corresponding high X-ray fluxes. There are similar changes in other months also. In July (Fig.5.9) the low field strengths from the 23rd to the 29th were associated with comparatively high X-ray fluxes in the 0-8 Å band. In the period 7 to 12 July there were high fluxes in both the bands, but the signal strengths were not markedly low. This and a few other similar occurrences suggest that while the 0-8 Å band causes a decrease in signal strength, the 8-16 Å band has perhaps an opposite influence. The resultant effect will therefore depend on the relative strengths of the radiation in the two bands.

The persistence of low values of L.F. signal strengths for many days during a period of enhancement of non-flare solar X-rays and their absence at night suggests that the ionization produced by these X-rays exists in the form of negative ions and that electrons are liberated from the negative ions during day-time by photo-dissociation. Various molecular ions have been suggested as being responsible for this; \( \text{NO}_2^+ \), \( \text{O}_3^- \) and recently \( \text{CO}_3^- \). More Laboratory and mass spectrometry work are required to elucidate this.

It may be mentioned that as may be expected, the enhancement of solar X-rays in the 0-8 Å band is associated in a general way with an increased emission from the sun of \( \text{10.7 Cm radio-waves} \). Examples are given in Figs.5.8 and 5.9 (Dotted lines).
## REFERENCES

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