VHF scintillations over anomaly crest region

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The VHF scintillation observations over Nagpur, situated close to the anomaly crest region, using the 244 MHz beacon from FLEETSAT (73°E) are described for the period May 1989-January 1992. The maximum mean hourly occurrences of scintillations for this epoch of high solar activity are found to be about 35% during equinoxes, 15% during winter and 10% during summer. The scintillations occur in small patches of duration ranging up to 140 min with a median value of about 20 min.

1 Introduction

Radio wave scintillation technique using satellite beacons has been used extensively to study the plasma density fluctuations associated with the phenomenon of spread-F. Aarons has reviewed the scintillation observations globally. The equatorial belt of scintillations extends up to ± 20° latitude during high sunspot years. In the Indian longitude region, first detailed studies of scintillations were made at Thumba and Ootacamund during the ATS-6 phase II (August 1975-July 1976). Away from the magnetic equator, detailed studies have been made from observations at Calcutta near the anomaly crest region and at Delhi, situated beyond the anomaly crest. However, detailed morphological features were not available on the occurrence pattern of scintillation in the Indian longitude region until recently. Regular observations at Trivandrum and Bombay started nearly a decade ago and provide a long series of data both at the magnetic equator and near the anomaly crest region. Scintillation observations at Nagpur were first made in February 1980 for few days in association with observations at Delhi, Hyderabad and Bangalore, using ETS-2 satellite. Later, regular observations were made during April 1980-January 1981. Under the All India Coordinated Programme on Ionospheric and Thermospheric Studies (AICPPTS), a chain of VHF scintillation receivers was set up in India, covering a region from dip equator to 40° dip. As a part of this programme regular observations were started at Nagpur (geogr. lat., 21.1°N; long., 79.1°E) since May 1989, using the 244 MHz beacon onboard FLEETSAT (73°E). The sub-ionospheric point at 400 km for the satellite-to-Nagpur ray path lies at a dip angle of 26.6°. The basic features of the scintillations for the period May 1989-January 1992 are reported here.

2 Experimental details and data

The recording system used at Nagpur is one of those set up by IIG, Bombay, at various stations. The data were recorded on paper charts with a speed of 1 cm/min. Scintillations above 1 dB level have been marked and, based on these data, quarter hourly occurrences have been prepared along with the start and end times of each patch of scintillations. An example of scintillations recorded during the night of 4-5 Mar. 1991 is shown in Fig. 1. The scintillations during this night started developing at around 1945 hrs IST with a slow fading of small amplitude fluctuations of about 1 dB (peak-to-peak). Strong scintillations of about 10 dB (peak-to-peak) developed at around 2013 hrs IST. The first patch lasted till 2045 hrs IST. Between 2052 and 2236 hrs IST another patch appeared. The scintillations did not disappear but are weak between 2236 and 2242 hrs IST. Another patch of strong scintillations is seen from 2242 to 0042 hrs IST. Thus, scintillations were seen during this night (1945-0242 hrs IST) in five different patches. The scintillations before midnight seem to have faster fading as compared to the latter part of the night.
3 Results

The nature of the scintillations occurring over Nagpur can be seen in the daily time history of the scintillations plotted in Fig. 2 for three months, namely, November, October and August 1990, representing the three seasons. It is evident that scintillations occur on more days during October-1990 as compared to the other two months. In addition to it, the scintillations occur for a longer duration of night extending up to 0200-0500 hrs IST during October 1990, whereas during November patches of scintillations are seen basically before midnight. Also during October 1990, one finds longer patch duration than that for the other two months. The histograms of percentage occurrence of the patch duration are shown in Fig. 3 based on entire period of observations. The patch duration is generally ranging up to 140 min. On 80% of time, patch duration is
less than an hour and only on 7% of times it exceeds 100 min.

The seasonal dependence of the occurrence of scintillations is studied from the maximum hourly percentage occurrence of scintillations during this period of observations. The month-to-month variation of the maximum hourly percentage occurrence of scintillations is shown in Fig. 4. The monthly values of the sunspot number \( R_z \) are also plotted in Fig. 4. The sunspot number decreases from 159 to 124 during this period. Equinoctial maxima are very clear from the plot of the maximum hourly value of the monthly mean percentage occurrence of scintillations. Another prominent feature to note is that the peak during September-October (65%) is much higher than the peak during March-April (30-40%). The mean seasonal variations of the occurrence of scintillations during this period for pre-midnight (2000-2200 hrs IST), midnight (2300-0100 hrs IST), post-midnight (0200-0400 hrs IST) and for the whole night (2000-0400 hrs IST) are shown in Fig. 5. The variations for the pre-midnight and midnight show clear equinoctial maxima with March-April peak of about 20-25% and September-October peak of about 45%. There is no clear seasonal variation during the post-midnight hours. However, equinoctial values are little higher than other seasons.

The nocturnal variations of the occurrence of scintillations for the period May 1989-January 1992, a high solar activity epoch with mean sunspot number of 131, have been studied from the quarter hourly values of the percentage occurrence. The annual mean nocturnal variations of this period along with the seasonal mean variations are shown in Fig. 6. The scintillations usually start at around 1900 hr IST and last till 0400 hrs IST in the morning. The maximum occurrence frequency during winter is 14% with a peak at around 2100-2200 hrs IST. During equinoctial months maximum occurrence frequency is 36% with broad peak at around 2200-2300 hrs IST.
The occurrence is least during summer with a maximum value of 10%. There are two peaks in the nocturnal variation during summer, one occurring at around 2200 hrs and another at around 0100 hrs IST.

4 Discussion

The equinoctial maxima of occurrence of scintillations at Nagpur during high sunspot period are consistent with the results at similar latitudes. In the equatorial region in India this pattern has been noted for low sunspot period, whereas at stations close to the anomaly crest region, equinoctial maxima are seen during high sunspot period, but a winter maximum during low sunspot period. The maximum hourly occurrences of 35% during equinoxes, 15% during winter and 10% during summer for this period of observations at Nagpur are also consistent with the values reported for Rajkot\(^{11}\) and Ahmedabad\(^{12}\). Beyond the anomaly crest, observations at Varanasi\(^{13}\) show comparatively lower occurrences of 20% during equinoxes and 10-15% for other seasons. At Bombay, situated south of Nagpur, the maximum occurrences during 1989 are about 50% in winter and equinoxes and about 40% during summer which is higher than the values at Nagpur. The shift in peak towards midnight during summer is also reported for other stations in the anomaly crest region or beyond. Mathew \textit{et al.}\(^{14}\) have reported month-to-month variations in the occurrence of scintillations at Rajkot for the period 1987-1989. The values for September-October are higher than those for March-April for the years 1988 and 1989. However, at an equatorial station Karur\(^{15}\), there is no significant difference in the occurrence of scintillations during March-April and September-October for the epoch 1987-1989. Pathan \textit{et al.}\(^{15}\) have studied the scintillation occurrence over Bombay and Trivandrum for the period July 1985-June 1990. The month-to-month variations of the mean nighttime occurrence over Bombay show clear equinoctial maxima for the high sunspot years 1988 and 1989. For both the years, the September-October peak of about 40% is higher than the March-April peak of about 25%. At Trivandrum, the peaks during September-October and March-April are equal for the year 1988 (50%), but during the year 1989, the September-October peak (60%) is higher than the March-April peak (40%). Another difference in the seasonal variation at Trivandrum has been that, while for the year 1988 with a medium sunspot number of 98, equinoctial maxima are seen, for the year 1989 with sunspot number 154, summer peak is seen. This trend is repeated for the year 1990 which is also a high sunspot year with a sunspot number 149. This aspect of the seasonal variation needs further investigations. Data collected at the chain of stations during AICPITS could be examined for this.

The nature of scintillations observed over Nagpur is different from that over equatorial region. The scintillation occurs in short patches of duration with a median value of 20 min. This is lower than the median values recorded at equatorial stations. The scintillations at equatorial region are, generally, continuous and may show weakening for a short duration in between patches of strong scintillations, whereas the scintillations near anomaly crest region show gaps of no scintillations between different patches. The patch duration has been studied at different stations of AICPITS chain for the campaign\(^{10}\) conducted during March-April 1991. For the stations in the equatorial zone, the patch duration ranged up to 5 h,
while for stations in the anomaly crest region it ranged up to 3 h. As, the patch duration represents the E–W extent of the patch which can be easily estimated if the velocity is known. Koparkar and Rastogi\(^6\) have studied the eastward velocity of the patches from simultaneous SIRIO and FLEETSAT observations at Bombay and reported velocities in the range of 100-150 m s\(^{-1}\). Assuming a velocity of 100 m s\(^{-1}\), the E–W extent of scintillation patches at Nagpur ranges up to 840 km with a median value of 120 km.

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**References**