Study of scintillations observed at Delhi during high solar activity period*

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Diurnal and seasonal variations in the occurrence of both daytime and nighttime scintillations observed at Delhi during high solar activity period of 1979-80 are described. The occurrence of daytime scintillations is maximum in summer and minimum in winter months. They peak around midday and show negative correlation with solar activity. The nighttime scintillations are of two types, viz. class I (with fading rate more than 6 per min) and class II (with fading rate less than 6 per min). Class I type scintillations show maximum occurrence in equinox and class II in summer. The nighttime class I type scintillations show positive correlation with solar activity, while class II type show negative correlation.

1 Introduction

The fluctuations that ionospheric irregularities impose on signals passing through the ionosphere are usually called scintillations by analogy with the intensity fluctuations of luminous stars when viewed through a turbulent atmosphere.

A study of low latitude scintillations is of great importance as these are associated with plasma irregularities present in those regions which are found to produce scintillations even at SHF frequencies. Ionospheric scintillations have been observed and studied in low latitudes using HF and VHF beacons from orbiting, and VHF and UHF beacons from geostationary satellites. Krishna Moorthy et al., on the basis of a thorough study of association of scintillations with spread-F, showed that class I scintillations (with fading rate more than 6 per min) are associated invariably with range spread-F and class II (with fading rate less than 6 per min) with frequency spread-F. The occurrence of spread-F at Delhi was totally absent during the period under investigation. But scintillation occurrence at Delhi has been found to closely follow the spread-F occurrence at Kodaikanal (10.2°N, 77.4°E, dip lat. 1.75°N). Also, Somayajulu et al. showed that during high solar activity, nighttime scintillations at Delhi are controlled by irregularities at the equator. Therefore, it is reasonable to assume that same kind of criterion as that for equatorial stations can be applied for the classification of nighttime scintillations observed at Delhi. Thus, Delhi nighttime scintillations have been classified into class I and II depending on their fading rates. Daytime scintillations are having fading rate generally less than 6 fades per min and thus seem to resemble with class II type of nighttime scintillations.

2 Data and method of analysis

Amplitude and Faraday rotation of the 136 MHz transmissions of ETS-II geostationary satellite located at 130°E longitude were recorded using a VHF polarimeter. The amplitude data from November 1979 to October 1980 have been utilized for the study of scintillations. There were no data for the months of March and September 1980. The occurrence of scintillations was noted each day on hourly basis and percentage occurrence calculated for each month. Only those scintillations which had a depth of 1 dB (power) or more have been included for the purpose of present analysis.

Nighttime scintillations are classified into two types, namely, class I and class II depending upon their fading rates and association with bottomside spread-F. Krishna Moorthy et al., on the basis of a thorough study of association of scintillations with spread-F, showed that class I scintillations (with fading rate more than 6 per min) are associated invariably with range spread-F and class II (with fading rate less than 6 per min) with frequency spread-F. The occurrence of spread-F at Delhi was totally absent during the period under investigation. But scintillation occurrence at Delhi has been found to closely follow the spread-F occurrence at Kodaikanal (10.2°N, 77.4°E, dip lat. 1.75°N). Also, Somayajulu et al. showed that during high solar activity, nighttime scintillations at Delhi are controlled by irregularities at the equator. Therefore, it is reasonable to assume that same kind of criterion as that for equatorial stations can be applied for the classification of nighttime scintillations observed at Delhi. Thus, Delhi nighttime scintillations have been classified into class I and II depending on their fading rates. Daytime scintillations are having fading rate generally less than 6 fades per min and thus seem to resemble with class II type of nighttime scintillations.

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3 Results and discussion

3.1 Daytime scintillations

From the observations recorded at Delhi, it has been found that daytime scintillations have their maximum occurrence around noon and may occur continuously the whole day or appear intermittently with long durations. On a few occasions scintillations occur in the form of small patches. A typical daytime scintillation record showing patches of duration ranging from 5 min to 15 min observed on 8 June 1980 is shown in Fig. 1. A perusal of simultaneous records of amplitude and Faraday rotation shows that no travelling ionospheric disturbances (TIDs) are present during the patchy daytime scintillations. The same conclusion can be drawn from the observations reported by Rama Rao et al.\textsuperscript{7}. As Faraday rotation is the sum total of contributions to rotation of the plane of polarization of the wave from different heights, and contribution to Faraday rotation is significant only above 150 km, E-region irregularities will not be visible on Faraday rotation records. Further, if patchy types of scintillations are caused by TIDs then they will have regular periodicity. From the example shown in Fig. 1, no such periodicity is visible. Thus it may be concluded that the scintillation patches observed are not caused by TIDs.

The daytime scintillations are observed to have fades less than 6 per min during high solar activity period. Somayajulu et al.\textsuperscript{11} reported the same fading rate for scintillations at Delhi in low solar activity period. Based on diffraction theory, daytime scintillations associated with E-region irregularities should have a higher fading rate than those associated with F-region irregularities (by a factor of 2). Thus they concluded that there is substantial contribution to the occurrence of daytime scintillations from F-region irregularities also.

Figure 2(a) shows the percentage occurrence of daytime scintillations in the form of monthly histograms on hourly basis. It is found that maximum occurrence takes place in summer in the months of May and June 1980, being about 25%. The occurrence in winter and equinoctial months is about 10%. Somayajulu et al.\textsuperscript{11}, using low solar activity data from Delhi, found the percentage occurrence of daytime scintillations for summer to be about 30% and for winter and equinox about 20%. Thus the occurrence of daytime scintillations decreases with
increased solar activity. Tyagi\textsuperscript{10}, using orbiting satellites data, also found that scintillation activity is maximum during low solar activity period. Rama Rao \textit{et al.}\textsuperscript{7} have not observed any daytime scintillation at Waltair (17.7° N, 83.3°E, dip lat. 9.6° N) during high solar activity period of 1979-80. Using 1984-87 data for low solar activity period, they have observed that at Waltair daytime scintillations are present from 0600 to 1800 hrs LT almost in all the seasons and that the percentage occurrence is maximum during summer months (∼ 20%) and minimum during winter and equinoctial months (∼ 10%).

The occurrence of daytime scintillations has been found to show good correlation with $f_{o}Es$ which also decreases with increase in solar activity. This confirms the earlier results reported by DasGupta and Kersley\textsuperscript{12}, Tyagi\textsuperscript{10}, Sahu and Manohar Rao\textsuperscript{16} and Rastogi and Mullen\textsuperscript{13}.

### 3.2 Nighttime scintillations

At Delhi nighttime scintillations occur from sunset onwards and build up till around midnight and then start decaying. Sometimes scintillations continue throughout the night. On a number of occasions they occur in patches. The scintillations observed during pre-midnight are of class I as well as of class II types, whereas during post-midnight often class II type of scintillations are observed.

The monthly percentage occurrence of nighttime scintillations is presented in Fig. 2(b). On the same figure, the occurrence of class I type of scintillations is shown by shaded histograms; the difference from the total occurrence will provide the information for class II type of scintillations. From the figure it is obvious that overall occurrence of scintillations is maximum during the summer months of May and June 1980, being about 50%, followed by equinoctial and winter months being about 15% and 10% respectively. Similar results were reported by Rama Rao \textit{et al.}\textsuperscript{7} for low as well as high solar activity period where the nighttime scintillation activity was severe during summer and weak during equinox and winter. The class I type of scintillations at Delhi during high solar activity period show maximum occurrence in equinox and winter (16%), while class II type scintillations show maximum in summer (30%).

From the analysis of low solar activity data (1975-76), Somayajulu \textit{et al.}\textsuperscript{11} found that nighttime scintillations are mostly of class II type, the class I type occurring only rarely. The class II scintillations show percentage occurrence to be maximum in summer (60%) followed by equinox and winter (25%). From the comparison of these results with the present work, it may be inferred that the percentage occurrence of class I type of scintillations increases with increase of solar activity and they peak in equinox, while the percentage occurrence of class II type of scintillations decreases with increase of solar activity and they peak in summer. Krishna Moorthy \textit{et al.}\textsuperscript{8}, using the low solar activity data from Trivandrum (8.54° N, 76.87° E, dip lat. 0.30° S), showed that occurrence of class II type of scintillations is maximum in March and June 1976 whereas that of class I is maximum in December 1975 and February 1976. Somayajulu in his review paper\textsuperscript{17} has inferred that there are two types of nighttime scintillation mechanisms operating simultaneously based on seasonal characteristics: one, the so-called equatorial type, confined to a narrow latitude belt of ± 10° and seems to be associated with equatorial range-type of spread - F, and another to low latitude belt, extending to ± 25° -30° with maximum occurrence during local summer months associated with frequency spread - F.
With a view to comparing the occurrence of daytime scintillations with those of nighttime in different seasons during high solar activity period, we have presented the percentage occurrence in all the three seasons in the form of histograms (Fig. 3). From the figure it is clear that peak percentage occurrence of nighttime scintillations in all the seasons is almost double than those of daytime scintillations. We may notice here that peak during nighttime occurs around 2200-2300 hrs IST during high solar activity, whereas during low solar activity, Somayajulu et al. found the evidence of pre-midnight and post-midnight peaks at Delhi.

4 Conclusions

From the present study it is concluded that at Delhi occurrence of daytime scintillations is maximum in summer and minimum in winter during low as well as high solar activity periods. The percentage occurrence decreases with increase of solar activity. The observed fading rate is less than 6 fades per min which may be attributed to the substantial contribution from the F-region.

Nighttime scintillations observed are mostly of class II type during low solar activity, and both class I and class II types during high solar activity period at Delhi. Seasonal dependence is similar to that of daytime scintillations for class II type, i.e. maximum in summer and minimum in winter. Class I type scintillations show maximum in equinox and minimum in summer months. Class I type scintillation occurrence increases with increase of solar activity while class II type occurrence decreases.

References