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A morphological study of VHF scintillations at Agra

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A morphological study of scintillations in the VHF signals at 244.16 MHz from satellite, FLEETSAT, has been made at Agra (geogr. lat., 27.2°N; geogr. long., 78°E) and reported in this paper. It is shown that the scintillations occurred at Agra mostly during nighttime, predominantly in pre-midnight hours, with peak-to-peak amplitude variation of less than 15 dB. The occurrence is highly increased during equinoxes and considerably reduced during summer. The activity is found to vary substantially during magnetically disturbed periods in the post- and pre-midnight hours of winter and summer. The daytime scintillations are slow and weak and occur rarely. The scintillation index for nighttime scintillation fluctuates between 20 and 45% from pre- to post-midnight hours in winter and equinoxes and falls smoothly below 10% in summer. Most of the present results are found to be similar to those at Varanasi (another station outside the anomaly zone), but differ markedly with those at other stations near and inside the zone.

1 Introduction

Ionospheric irregularities like spread-F affect the radio and satellite communications on the ground severely. These irregularities are found to occur predominantly in the equatorial region with $\pm$ 20° latitude during nighttime[1]. Since the occurrence characteristics of such irregularities indicate high degree of variability with latitude, longitude, magnetic activity and solar geophysical conditions, numerous attempts have been made with different techniques to study the generation mechanism, scale sizes, movement and other characteristics of these irregularities[2]. The techniques include rocket-borne and satellite-based measurements, satellite radio beacon studies of the scintillations, coherent and incoherent back scatter radar, and other ground-based equipments like ionosonde and airglow measurements[3].

Since India provides unique location of covering latitudes right from magnetic equator to well beyond the anomaly crest region, extensive efforts have been made to study the phenomena of spread-F and associated irregularities. Recently, a chain of stations were established to study the morphological features of the irregularities under All India Coordinated Programme of Ionosphere-Thermosphere Studies (AICPITS)[3]. Besides, several attempts have been made at individual levels to study these irregularities both experimentally and theoretically. For example, Methew and Iyer[4] and Rama Rao *et al.*[5] have studied the Faraday polarization fluctuations along with the amplitude scintillations of VHF signals at stations outside and inside the anomaly zone, respectively; Methew *et al.*[6] have studied amplitude scintillations at a station near the anomaly crest region; Vijay Kumar *et al.*[7] and Mohan and Reddy[8] have studied the generation mechanism of irregularities from VHF scintillation data at Delhi; Koparkar *et al.*[9] have studied the drift of the irregularity patches from the data at Trivandrum and Tiruchendur; Singh *et al.*[10] have studied the morphology of scintillation activity at Varanasi, and Vyas and Chandra[11] have studied the VHF scintillations and Spread-F at a station inside the anomaly crest region. In this paper, we report the morphological features of VHF scintillation activity observed at Agra which is another station beyond the anomaly crest region and compare the present results with those obtained at stations outside and inside the anomaly crest region.

2 Observation and analysis of data

Amplitude scintillations in VHF signals from FLEETSAT at 244.16 MHz have been recorded at Agra since 12 Jan. 1991 under AICPITS using simple analog system designed and built at Indian Institute of Geomagnetism (IIG), Bombay. The scintillations are recorded over charts which are calibrated (2.5 dB/cm). From these charts detailed information like the occurrence number, starting and end times of scintillations, peak-to-peak fluctuations, etc. are noted. In this study only those scintillations are

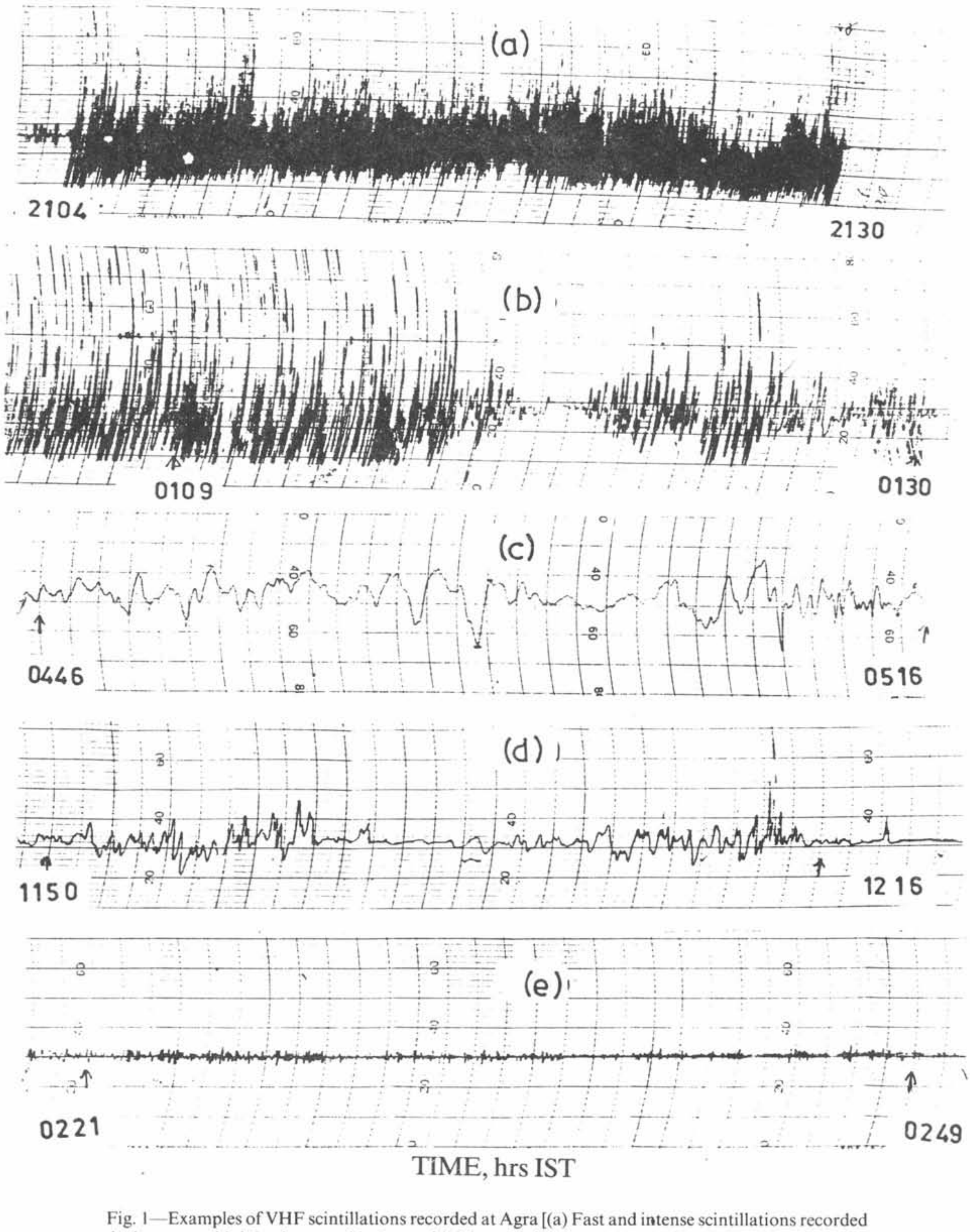

Fig. 1—Examples of VHF scintillations recorded at Agra [(a) Fast and intense scintillations recorded during pre-midnight hours, (b) Post-midnight scintillations, (c) Early morning hours slow scintillations, (d) Slow and weak daytime scintillations, and (e) Periodic scintillations]

considered whose peak-to-peak amplitudes were $\geqslant$ 1dB. Further, since round-the-clock data are available for the period January-December, 1991, only this period is considered for the present study.

3 Results and discussion

3.1 General features

In an earlier paper Singh *et al.*[12] have reported some preliminary results of VHF scintillation observations at Agra. The prolonged observations and analysis of the data indicate that scintillations occur at Agra in patches of small duration, usually less than 30 min, mainly during nighttime and rarely during daytime. In general, nighttime scintillations are fast and intense with peak-to-peak amplitude varying between 8 and 10 dB. However, on some occasions, amplitude variation goes higher than 15 dB. Weak and slow type scintillations occur mostly during early morning and daytime hours. In Fig. 1, are shown some typical examples of scintillations recorded at Agra. The scintillations shown in Fig. 1(e) are a peculiar example of periodic type of scintillations recorded at Agra during morning hours. This type of scintillation was also recorded at Rajkot[6] in daytime hours of summer months during low sunspot years. The scintillation activity at Agra, in majority of cases, is found to build up gradually, though abruptly starting scintillations are also very common. Further, the scintillations observed at Agra are mostly saturated types similar to those observed at Varanasi[10]. It appears that this feature of scintillations is a characteristic of the outside anomaly belt region.

Since the sources and occurrence characteristics of night and daytime scintillations are different, they are discussed separately.

3.2 Nighttime scintillations

3.2.1 *Daily occurrence pattern*—The daily occurrence of nighttime scintillations during all the months of 1991 is shown in Fig. 2. The months are grouped into three categories corresponding to December and June solistices (D and J months) and equinoxes (E months). Figure 2 shows that the scintillation activity is very low in J months and very high in E months and some of the D months. Further, the activity is randomly distributed throughout the nights of January and February, but a clear shift to pre-midnight hours may be seen during E months.

The per cent occurrence of scintillation at Agra during each month and during pre- and post-midnight hours of each month are shown in Fig. 3. It may be seen that the activity peaks during January and October and majority of scintillation activity

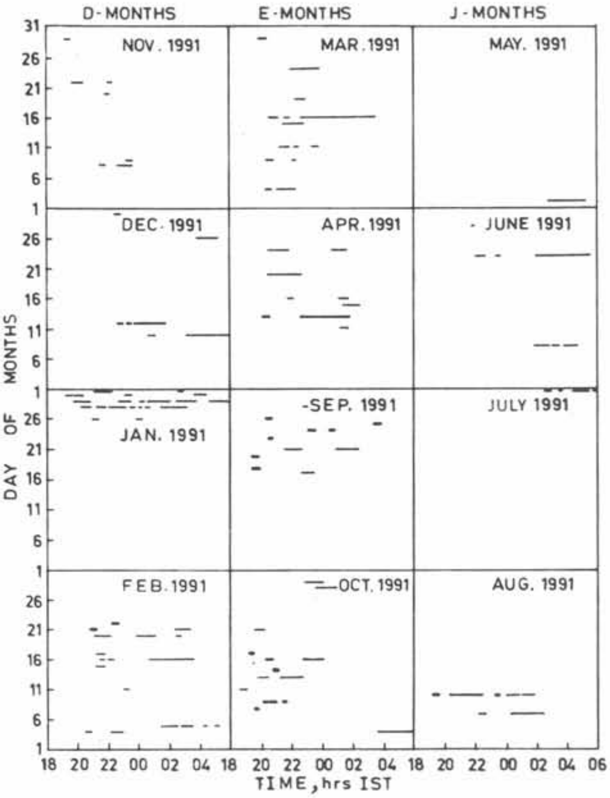

Fig. 2—Daily occurrence of nighttime scintillation at Agra

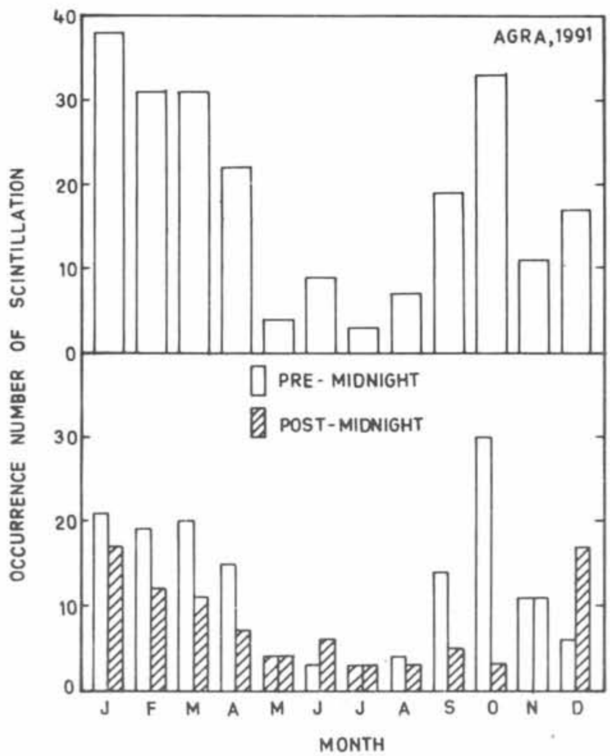

Fig. 3—Occurrence number of pre- and post-midnight scintillations in different months

occur during pre-midnight hours. This occurrence pattern is similar to that obtained at Varanasi except with some minor differences. For example, no scintillation activity has been observed at Varanasi during November[10], whereas we have recorded scintillations on four occasions. It has been mentioned earlier that fast and intense scintillations are observed mostly during pre-midnight hours. This result is very similar to those obtained at other stations, particularly, at Trivandrum and Rajkot[6] and could be attributed to the association with range type of spread-F (Ref. 13). The slow and weak scintillations which are observed mostly in the early morning and day hours are believed to be associated with frequency type of spread-F (Ref. 13). The ionospheric irregularities responsible for these two phenomena are believed to be arising from class I and class II diffracting plasma irregularities[14].

3.2.2 *Seasonal variation*—The seasonal variation in the scintillation activity at Agra is shown in Fig 4. The peak activity occurs in the pre-midnight hours during equinox and winter but shifts to post-midnight hours during summer. Singh *et al.*[10] have reported a similar result from their observations at Varanasi except that they found the peak activity around midnight hours in summer season. The annual variation shows a peak around 2200 hrs IST as shown in the top panel of Fig. 4.

3.2.3 *Variation with magnetic activity*—To examine the effect of magnetic activity on scintillation occurrence at Agra, the quiet and disturbed time data have been separated according to *Solar Geophysical Data Bulletin* in a manner similar to that adopted by Singh *et al.*[10]. Further, the data have been grouped for summer, winter, and equinox months. The quiet and disturbed time variations with local time are shown by Q and D curves in the three panels of Fig. 5 which is self explanatory. Some notable points are:

(i) In summer, the activity during disturbed period is delayed as compared to that during quiet period.

(ii) In equinox, the disturbed time activity is suppressed in pre-midnight hours, but remains almost similar to that during quiettime for rest of the local time.

(iii) In winter months, the activity during disturbed period is considerably enhanced in pre-midnight hours and disappears for rest of the local time. These results differ with those at Varanasi in the sense that at Varanasi, the scintillation activities during disturbed conditions are highly enhanced in midnight hours in summer and in pre-midnight hours in winter, but considerably reduced in equinoxes.

Rastogi *et al.*[13] have shown that during high sunspot years scintillation occurrence in any season is suppressed due to magnetic disturbance, while it is not affected during low sunspot years at the magnetic equator (Trivandrum) in the Indian zone. The scintillation activity at Rajkot during the increasing solar activity period (1987-1989) shows a considerable suppression of scintillation in equinox and winter by magnetic disturbance and the trend is reversed in summer when the scintillations are generally rare and weak.

3.2.4 *Scintillation index*—Scintillation index is an important parameter which characterizes the degree

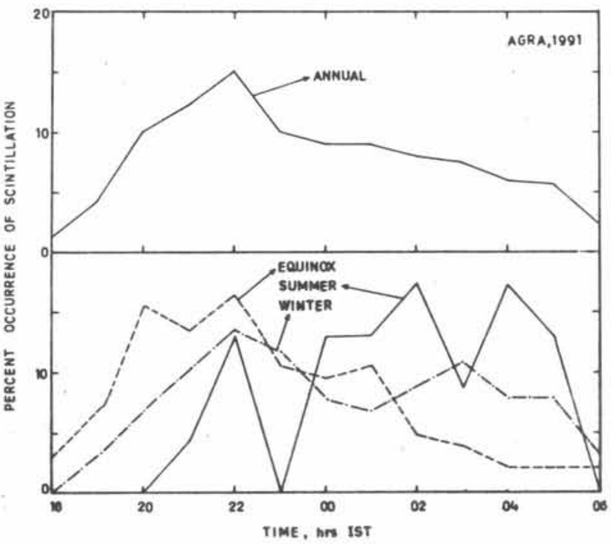

Fig. 4—Seasonal variation of scintillations at Agra

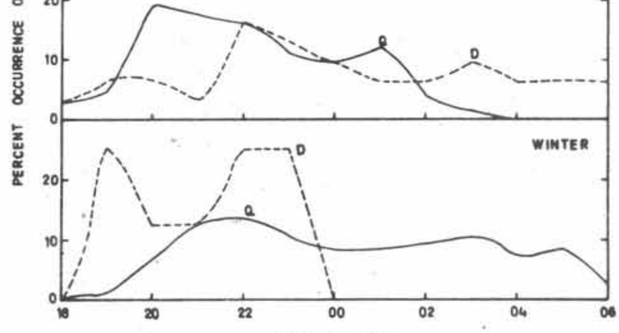

Fig. 5—Effect of magnetic activity on scintillation activity at Agra

to which a signal is fluctuating. Many information about the characteristics of the irregularities causing scintillations are derived from the study of the variation of the scintillation index. There are a number of ways to determined the scintillation index depending on the data. The S_4 index is the most meaningful index in scintillation studies, but it requires the data to be collected through digital recording. Since we are using analog method here in which scintillations are recorded on charts, we follow a simple technique to determine the index. We employ the formula[15].

$$SI = \frac{P_{max} - P_{min}}{P_{max} + P_{min}}$$

where, P_{max} is the power amplitude of the third peak down the maximum excursion and P_{min} the power amptitude of the third level up from the minimum excursion. This is scaled every 15-min interval throughout the period of the scintillations.

The mean scintillation indices for January and February in D months, March and April in E months, and August in J months are plotted against local

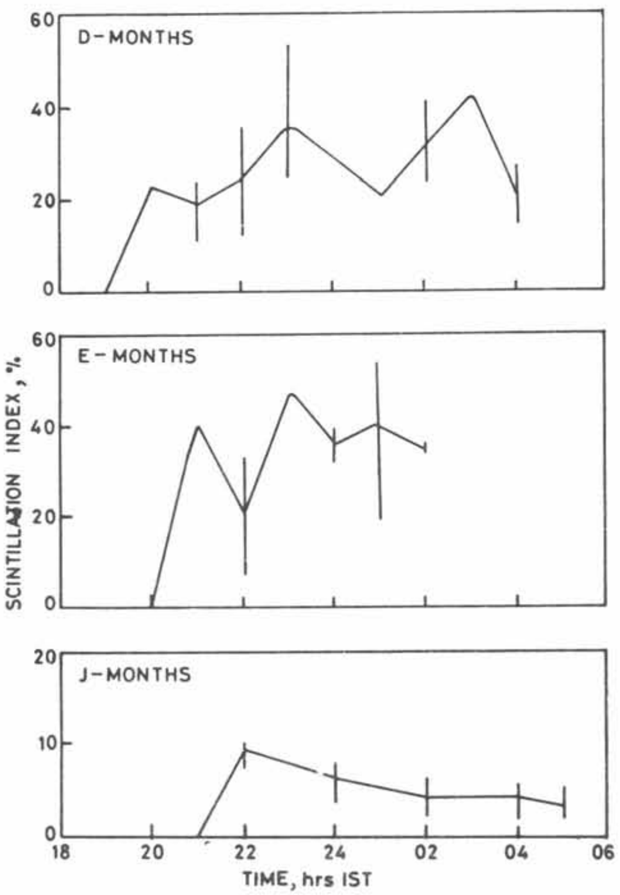

Fig. 6—Variation of scintillation index at Agra

nighttime and shown in Fig. 6. Other months could not be included in the analysis on account of either unsatisfactory patches or nonavailability of the scintillation data. The vertical bars indicate the deviation of the index at the corresponding time. From Fig. 6, it may be seen that in D and E months, the scintillation index varies between 20 and 45% during the time interval of 1900-0400 hrs IST. Beyond 0400 hrs IST there is no significant data for statistical analysis in the above months except in January when the index rose to 71% at 0500 hrs and fell to 68% at 0600 hrs (not shown). The variation of the index in both the D and E months is similar. The fluctuating nature of the index and the range indicate that at Agra, scintillations are caused by irregularity patches of varying scale sizes.

The scintillation index in J months is small (less than 10%) throughout the night and unlike D and E months, the index falls smoothly with time. This may be due to rare occurrence of slow but strong scintillations in the post-midnight hours.

3.3 Generation mechanism

It is an established fact that the VHF scintillations in satellite signals are caused by ionospheric irregularities which are generated near the equatorial region. One of the necessary conditions for generating the F-region irregularities in nighttime ionosphere is that the F-layer should be lifted to the region where the effects of recombination become unimportant in relation to the nonlinear evolution of Rayleigh-Taylor instability (RTI) mechanism which is triggered in the post-sunset hours at the magnetic equator under the influence of some or the other geophysical phenomena[16]. The RTI grows in strength under certain favourable conditions resulting in vertically rising plasma structures, referred to as plasma bubbles and plumes often observed over the magnetic equator. These are plasma depletions. The maximum height attained by these depletions over the equator is of the order of 900-1200 km and it is a measure of the growth of the convective instability set forth from the equator. This convective instability fills the entire flux tubes with scintillation producing irregularities.

The association between the spread-F and the scintillation has been examined by many researchers[17] who have suggested that strong and fast scintillations of VHF signals, mainly in pre-midnight hours, are closely associated with the range type of spread-F and weak and slow scintillations are due to the frequency type of spread-F. Since equatorial spread-F irregularities extend down the field line, higher the altitude of plasma depletion, wider is the

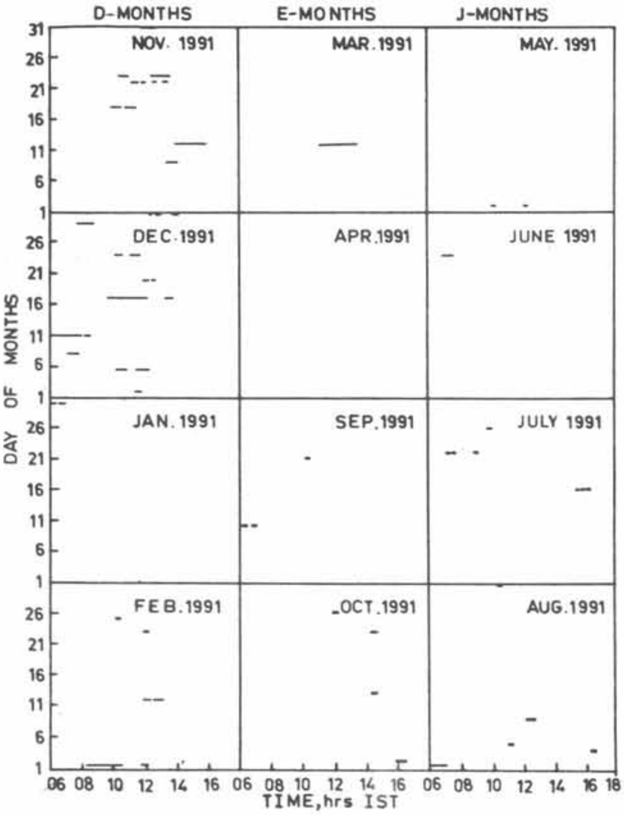

Fig. 7—Daily occurrence of daytime scintillations at Agra

latitudinal extent of the irregularities. However, there are still a number of points not fully understood. These include the day-to-day variability of the occurrence of spread-F, the characteristics of plasma density fluctuations in different scale sizes, and the mechanism of generation. The work presented in this paper along with other recent efforts made in this area is thus believed to be of some help to understand these points.

3.4 Daytime scintillations

Several workers[18-20] have reported a fair degree of correlation between the daytime scintillations and occurrence of sporadic-E. The occurrence of daytime scintillations at low latitude stations in Indian Zone has not been investigated in greater detail. Even during current wake of investigations under AICPITS, adequate attention has not been paid to daytime observations and analysis of the data. The individual efforts like those at Rajkot[6] have shown that blanketting type of Es with critical frequency greater than 4 MHz are responsible for daytime scintillations. This result was in good agreement with the suggestion of DasGupta and Kerseley[19] on the simultaneous occurrence of Es-layers and scintillations.

The occurrence of daytime scintillations at Agra is very rare in all the months except November and December. This is clearly seen in Fig. 7 where daily occurrence of scintillations has been shown against local daytime. It is worthwhile to note here that during the above two months the nighttime activity was very low (see Fig. 2). Further, the daytime scintillations in the above two months are concentrated mostly during midday hours and before. Rama Rao *et al.*[21] have found a peak in daytime scintillation during midday hours at Waltair, whereas no such peak was observed at Rajkot. It appears that during high solar activity period the peak activity in daytime scintillations occurs at noon at equatorial stations, whereas during decreasing phase of the solar activity it shifts to stations outside the anomaly belt.

4 Summary and conclusion

The results of the present scintillation studies at Agra during the period January-December 1991 may be summarized as follows:

(i) The scintillation activity at Agra (a station outside the anomaly belt) is a nighttime phenomena. The daytime activity is very rare except November and December when the nighttime activity is low.

(ii) The scintillation activity shows fast and intense scintillations during pre-midnight hours, slow and strong scintillations during post-midnight hours, and slow and weak scintillations during daytime hours.

(iii) Scintillations occurred mostly during equinoxes and winter and rarely during summer.

(iv) The activity during magnetically disturbed periods is increased in pre-midnight hours of winter, remains unaffected in summar and reduced in equinoxes, whereas it is completely eliminated in post-midnight hours of winter, slightly increased in equinoxes and considerably enhanced in summer.

(v) The scintillation index fluctuates between 20 and 45% in winter and equinoxes and is less than 10% in summer.

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