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Studies on Ionospheric Scintillations Recorded at Nagpur*

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Ionospheric scintillations of 136 MHz plane polarized signals from the geostationary satellite ETS-II were observed at Nagpur, a low latitude station, during the period 1980-81. The onset time of scintillation was found to be predominantly around 1930 hrs LT. This has been explained in terms of sunset at the mean field height of the ionosphere. The diurnal and seasonal variation of scintillation activity has been analyzed. The preliminary results show that there is an apparent correlation between scintillation activity and the total electron content (TEC) of the ionosphere. The correlation with solar activity was found to be positive and significant in summer but not as significant in winter. The correlation with magnetic activity was observed to be negative during summer and positive in winter.

1 Introduction

When plane polarized waves of very high frequency are transmitted through the ionosphere from outside the earth they undergo amplitude and phase changes which are called scintillations. The occurrence of scintillations depends upon the time of the year, geographic location, frequency of radio wave, solar activity, magnetic storms and a host of other factors. The study of scintillations is important not only for a better understanding of the physics of the ionized region but also on account of its importance in earth-satellite communication and navigation systems.

Ionospheric scintillations have been studied for the last three decades employing radio stars as a source of radio waves and now radio beacons, on board the orbiting or geostationary satellite. Global morphology of scintillations has been reviewed by many workers[1-6]. The first work on scintillations in the Indian zone was reported by Bhargava[7] using radio stars and a good correlation between spread-F and scintillation was noted. The recordings of amplitudes of radio beacon signals from the geostationary satellite ATS-6 provided a unique opportunity to study equatorial ionospheric scintillations in some detail[8-11].

In this paper are presented some preliminary results of the observations of scintillations of 136 MHz plane polarized signals received at Nagpur, a low latitude station (21.1°N; 79.1°E; dip lat. 11.2°N), from the geostationary satellite ETS-II (130°E) having subionospheric points of 19.3°N and 85.1°E at the mean field height of about 420 km. The onset time of scintillation has been explained in terms of sunset at the mean field height of the ionosphere. The diurnal and seasonal variation of scintillation activity has been analyzed and an attempt has been made to find correlation with other parameters such as TEC, solar activity and magnetic activity.

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2 Observations and Analysis

Amplitude scintillations were recorded during the period Apr. 1980 to Jan. 1981 except for the month of September when the satellite was inoperative. Simultaneous recording of Faraday rotation of the plane polarized signals enabled computation of total electron content (TEC) of the ionosphere. Scintillation onset time and its duration were plotted for the entire period of observation as shown in Fig. 1. The total duration of scintillation was about 468 hr spread over 106 days out of 224 days of recording of the satellite signals. Light to heavy scintillations occurred during the period of observation, but very heavy scintillations were observed on two occasions in May and on six occasions in August, each event lasting for a duration ranging between 45 min and $3\frac{1}{2}$ hr. A histogram [Fig. 2] showing the number of events of onset of scintillation versus local time indicates that maximum number of events occurred between 1900 and 2000 hrs and that the occurrence of daytime scintillations was negligibly small at this latitude.

2.1 Onset Time of Scintillation

The onset time of scintillation was predominantly found to be around 1930 hrs LT. It was noticed that on about 57 occasions the scintillation commenced at about 1930 hrs. Using the geometry of Fig. 3 (not drawn to scale) the difference between the ground sunset time and sunset time at the altitude of 420 km was calculated which was found to be about 56 min.

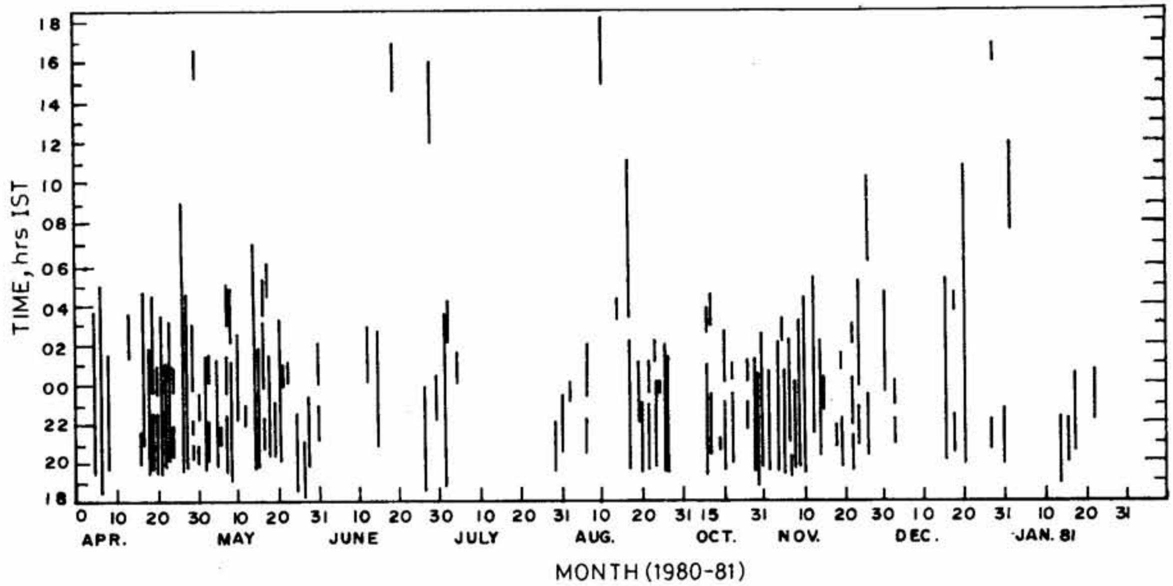

Fig. 1—Scintillation occurrences recorded at Nagpur

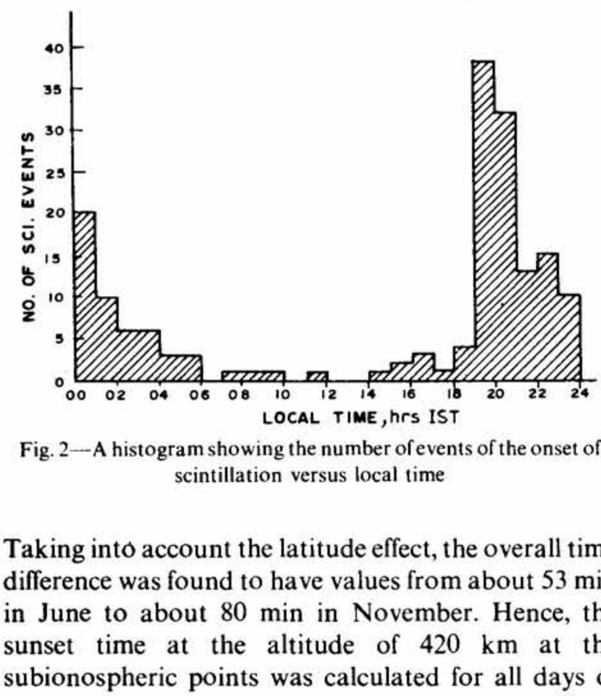

Fig. 2—A histogram showing the number of events of the onset of scintillation versus local time

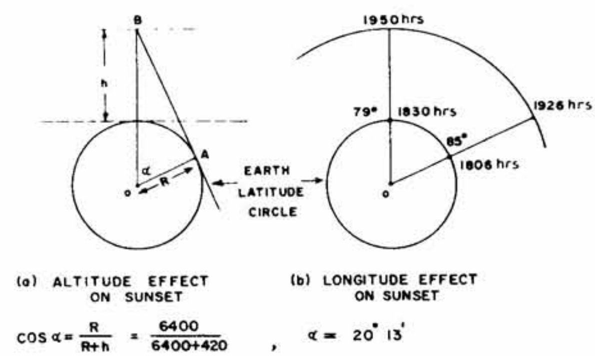

Fig. 3—(a) Altitude effect on sunset [h is the mean field height of the ionosphere, and R is the radius of the earth.]; and (b) longitude effect on sunset [Typical timings of sunset at Nagpur (79°E) and at subionospheric longitude (85°E) are used.]

Taking into account the latitude effect, the overall time difference was found to have values from about 53 min in June to about 80 min in November. Hence, the sunset time at the altitude of 420 km at the subionospheric points was calculated for all days of scintillation occurrences. It was found to be in good agreement with the observations.

2.2 Scintillation Activity and Its Seasonal Variation

During the period of observation the rate of scintillation fades was too high to isolate each event independently for evaluation of the scintillation index. Therefore, a new parameter of monthly scintillation activity was defined as follows.

$$\text{Scintillation activity (S A)} = (n/N) . S_T \qquad \dots (1)$$

where n is the number of days on which scintillation occurred, N is the number of days of signal recording in a month and S_T is total duration (in hours) of scintillation in a month.

From the observations as recorded in Table 1, scintillation activity for each month has been calculated and its variation over the entire period of observation has been plotted as shown in Fig. 4(a). It is seen that the scintillation activity was maximum in April-May, minimum in June and medium in October-November. The least activity was observed in solstices, especially around the summer solstice. That the scintillation activity could be moderate during equinoctial months may be inferred, since data for these months were not available.

2.3 Connection between TEC and Scintillation Activity

The scintillation onset is often associated with rapid changes in the Faraday rotation angle[12]. With a view to study the connection between scintillation activity and TEC, the monthly median TEC_{max} values were

Table 1—Observations of Scintillations and Scintillation Activity

Month	No. of days of signal recording	No. of days of scintillation occurrences	Total duration of scintillation (hrs)	Scintillation activity
	N	n	S_T	$(n/N)S_T$
1980				
Apr.	26	17	106	68.9
May	31	23	95	70.1
June	30	6	23	4.6
July	14	5	18	6.5
Aug.	26	13	47	23.5
Sep.	Data not available			
Oct.	17	10	46	27.1
Nov.	30	17	82	46.7
Dec.	26	8	31	9.6
1981				
Jan.	24	7	20	5.8
Count 9	224	106	468	...

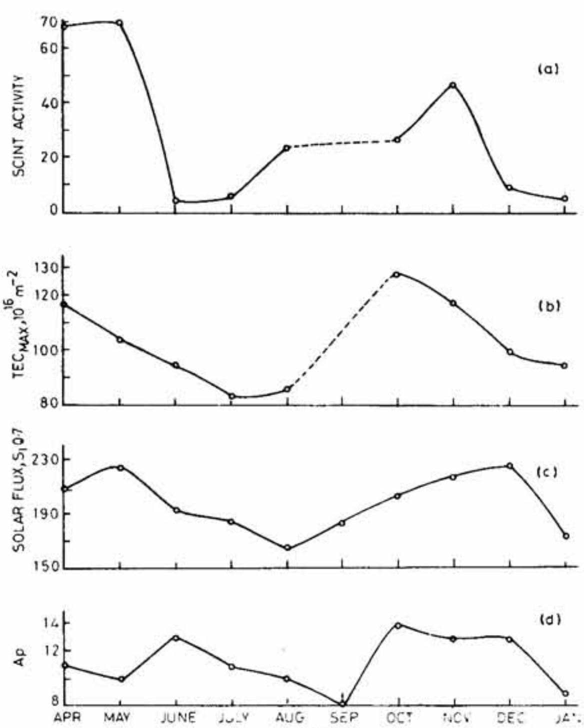

Fig. 4—Seasonal variations: (a) Scintillation activity; (b)TEC$_{max}$; (c) Solar flux $S_{10.7}$; and (d) Magnetic index A_p

plotted as shown in Fig. 4(b). It was observed that when TEC was around its annual average value in April-May, scintillation activity was maximum. As TEC decreased below the average value, scintillation activity also decreased and reached a minimum in June-July. In October-November both again reached a maximum. The striking similarity between the two curves led to the calculation of the correlation coefficient, which showed a positive and significant correlation of scintillation activity with TEC.

2.4 Correlation with Solar and Magnetic Activities

The monthly values of $S_{10.7}$ solar flux obtained from the solar-geophysical data were plotted as shown in Fig. 4(c) to study the correlation. Both the curves showing variation of scintillation and solar activity have a similar characteristic doublehumped shape. The distortion in scintillation activity curve may be due to unusually high solar activity during the period. Calculations further indicate that correlation of scintillation activity with solar activity was positive and significant in summer, but not as significant in winter.

To find correlation with magnetic activity, monthly mean values of the planetary magnetic index A_p were plotted as shown in Fig. 4(d). From the nature of the curve the correlation was not obvious. The seasonal correlation coefficients, however, revealed that summer scintillation activity had a negative but significant correlation with magnetic activity, whereas correlation of winter scintillation activity was positive but not as significant.

3 Discussion

The onset time of scintillation is around 1930 hrs LT and corresponds to the solar flux cut-off at altitudes of 420-500 km at the subionospheric point. The difference between the averaged onset time and the calculated time is partly generated due to delays in drift and diffusion at these heights. It can be noted that scintillation activity is quite widespread during equinoctial months and not so widespread during solstices. This shows that ionization imbalance may perhaps be generated in the equatorial anomaly region (around dip 24°N) due to solar cut-off leading to diffusion and drift to compensate for the effect.

The connection between irregularities and TEC in transionospheric propagation has already been reported[13]. These irregularities give rise to scintillation during the diurnal decay of TEC. The present study confirms that scintillation onset is always connected with steep decrease in the post-sunset TEC and that there is a clear depletion in TEC between 1900 and 2000 hrs. Further it was observed that whenever scintillation was absent the post-sunset TEC value was higher than the corresponding monthly median value.

The scatter plots between scintillation activity and other parameters such as TEC, solar activity and magnetic activity are as shown in Fig. 5. It is seen that there is a high degree of correlation of scintillation activity with TEC and it is almost completely

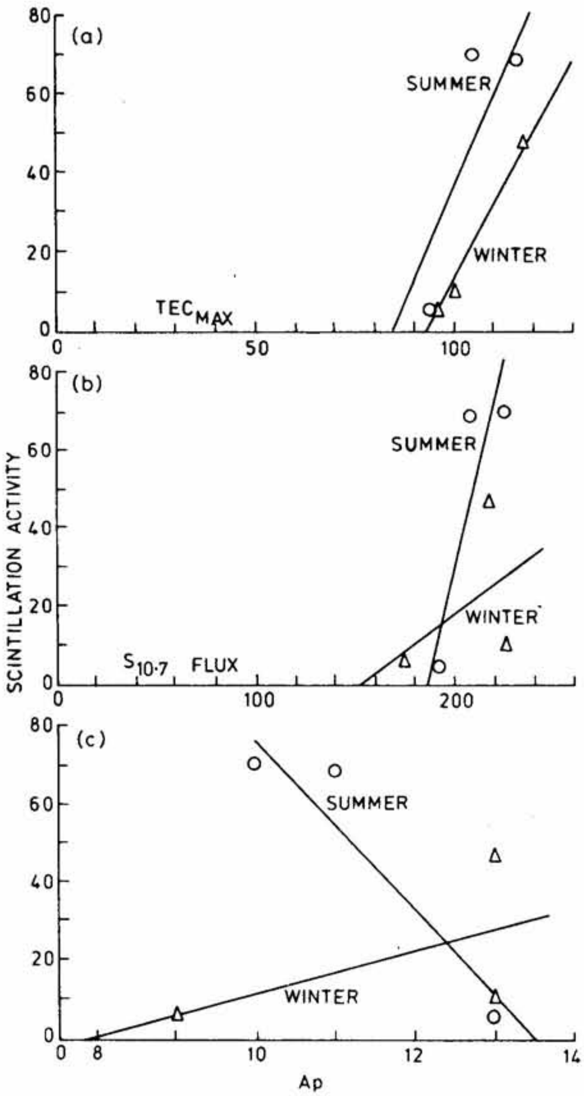

Fig. 5—Scatter plots between: (a) scintillation activity and TEC_{max}, (b) scintillation activity and solar flux; and (c) scintillation activity and A_p

controlled by the TEC in winter (November-January); but it is controlled to the extent of about 60% in summer (April-June). Obviously there are other factors which control the summer scintillation activity. Possibly solar activity is a major controlling factor of summer scintillation activity which also appears to be influenced by magnetic activity, although there is a negative correlation.

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