Characteristics of Sporadic-E Irregularities using Daytime Scintillations at Low Latitude Station Varanasi

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Abstract

The VHF amplitude scintillations recorded during the daytime period from January 1991 to December 1993 in the declining phase of a solar cycle and April 1998 to December 1999 in the ascending phase of the next solar cycle at low latitude station Varanasi (geomag. Lat. = 14^0 55′ N, long. = 154^0 E, Dip angle = 37.3^0, Sub-ionospheric dip = 34^0) have been analyzed to study the characteristics of ionospheric irregularities during the active solar and magnetic periods. It is shown that daytime scintillation occurrence is linked with high critical frequency of the sporadic-E irregularities. The auto-correlation functions, power spectral densities, half de-correlation times are computed to study the temporal features of sporadic-E irregularities. Derived spectral index ranges between –2 and –9. The characteristics length is estimated which varies from 100 m to 2000 m. These results are in close agreement with other reported works.

1. Introduction

It is generally accepted that daytime scintillations are linked to E-region irregularities [1, 2]. After simultaneous observation of vertical soundings and the Faraday fading of the beacons from a low orbiting satellite, Rastogi and Iyer [2] showed the existence of cloud of intense sporadic-E in the path of radio waves, which produces scintillation even during the daytime at low latitudes. Recently, Hajkowicz and Minakoshi [3] have made a comprehensive evaluation of VHF ionospheric scintillation morphology in East Asia (Kokobunji, Japan) and concluded that daytime scintillations are due to occurrence of sporadic-E. During daytime the electrojet region generates plasma density irregularities, which may be associated with the observed daytime scintillations. Aarons and Whitney [1] showed that the mid-day summer scintillation has a high probability of occurrence when $f_oE_s > 5$ MHz. Although a high value of f_oE_s may sometimes be associated with scintillation, the precise characteristics of sporadic-E layer which causes scintillation, are yet to be identified. In this paper, daytime VHF amplitude scintillations recorded during the last decade of twentieth century at the low latitude station Varanasi are analyzed to examine the association of daytime scintillation with occurrence of sporadic-E irregularities during the active solar and magnetic periods.

2. Experimental Observations and Data Analysis

The amplitude scintillations of 250 MHz signals transmitted from geostationary satellite FLEETSAT situated at 73^0 E longitudes were monitored continuously at Varanasi using a fixed frequency VHF receiver and strip chart recorder. In addition to the normal chart recorder, data were recorded digitally, at the sampling rate of 10 Hz on a few nights. The scintillation at Varanasi predominantly observed in the pre-midnight periods in small patches with duration < 30 minutes [4, 5]. In this paper, data recorded during daytime for the period Jan. 1991 to Dec. 1993 in the declining phase of solar cycle and Apr. 1998 to Dec. 1999 in the ascending phase of the next solar cycle have been analyzed. The percentage occurrence of scintillation, scintillation index (S_4), auto-correlation function and power spectra have been computed. Each one-minute (60 sec) digital data have been analyzed to compute auto-correlation function and scintillation index S_4. Total 100 samples of auto-correlation functions have been plotted and we have computed half de-correlation time, τ for each sample of auto-correlation plots. For computation of power spectra we have analyzed each six-minute digital data. Total 30 samples of digital data have been analyzed for estimating power spectra. These parameters yield information about temporal features of ionospheric irregularities.

In this study, we have used ionogram data recorded at the nearest available station; Ahmedabad (geog. Lat. = 23^0 N; long. = 72.4^0 E, Dip angle = 33.8^0, Sub-ionospheric dip = 30.7^0), for the critical frequencies of sporadic-E irregularities and examined the association of daytime scintillation with it.

3. Results and discussions

3.1 General features

The diurnal variation of occurrence of daytime scintillation for different seasons is shown in Fig. 1. The maximum occurrence of daytime scintillations is observed around 1545 hrs IST during all seasons. The fade rate is generally observed slow for the daytime scintillations. At Varanasi daytime scintillations occur in small patches and average patch duration is usually < 20 minutes. Assuming that the irregularities causing the daytime scintillation are drifting across the line of propagation of the signal, the above results indicate the patchy nature with small horizontal scale of the irregularity clouds. Hajkowicz and Dearden [6] have studies the characteristics of radio waves scintillations over a solar cycle (1973-1985) using the 150 MHz transmission from polar orbiting satellite at Brisbane and found a pronounced increase in daytime scintillations in southern winter throughout the solar cycle.

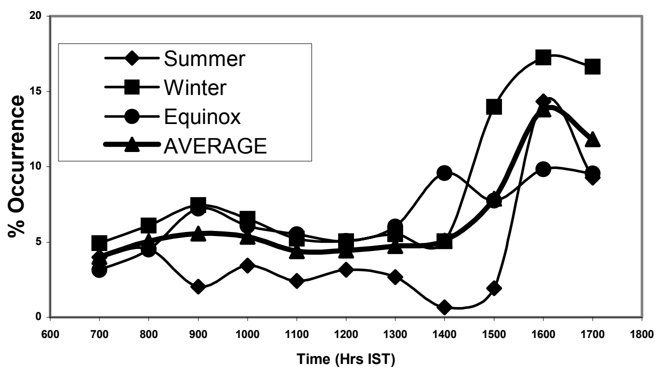

Fig. 1. The diurnal variation of percentage occurrence of daytime scintillation for different seasons.

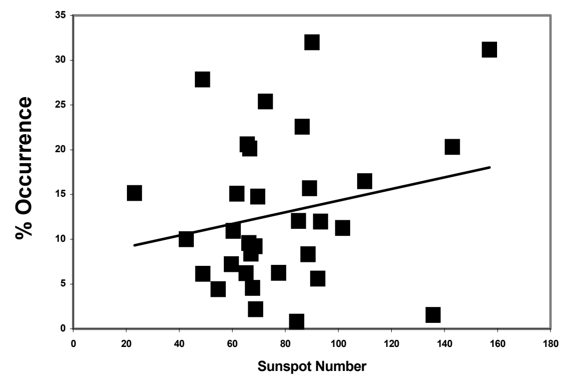

Fig. 2. The variation of daytime scintillation occurrence rate with the mean sunspot number (R_z).

3.2 Effect of Solar Activity

Since the solar activity is measured by the number of sunspots, the variation of daytime scintillation occurrence rate with the mean sunspot number (R_z) is shown in Fig. 2. The daytime scintillation occurrence rate shows scattered points increasing with R_z. Briggs [7] at Cambridge (52.2^0 N) reported positive correlation between scintillation index and solar flux.

4. Association of Daytime Scintillation with Sporadic-E Irregularities

Ionograms of sporadic-E recorded at Ahmedabad were examined to study its association with daytime scintillations observed at Varanasi. Sporadic-E is characterized by diurnal and seasonal variations of the f_oE_s values. The variations of the median f_oE_s values for years 1991 and 1998 are presented as contour plots in Fig. 3a,b. In general, occurrence of daytime scintillation at Varanasi is associated with sporadic-E of high f_oE_s values. It was found that more than 60% of the daytime scintillation occurrences with duration of more than 15 minutes were associated with $f_oE_s \geq 5$ MHz while the association with $f_oE_s \geq 4$ MHz was 75%. To examine more close association we have studied an individual point-to-point correspondence between sporadic-E data and daytime scintillation. One typical example of simultaneous occurrence of daytime scintillation and corresponding associated sporadic-E irregularities are shown in Fig. 4a,b on 19 Dec. 1998.

It must be noted here that an individual point-to-point correspondence between sporadic-E data and daytime scintillation cannot be expected more due to large separation between the ionosonde location at Ahmedabad and scintillation observation at Varanasi. It has been found that a high sporadic-E critical frequency, probably $f_oE_s \geq 4$ MHz is a necessary condition for scintillation but in addition, a diffuse or even stratified vertical nature of sporadic-E layer as indicated by range spread on ionograms is important in the production of scintillation [8, 9].

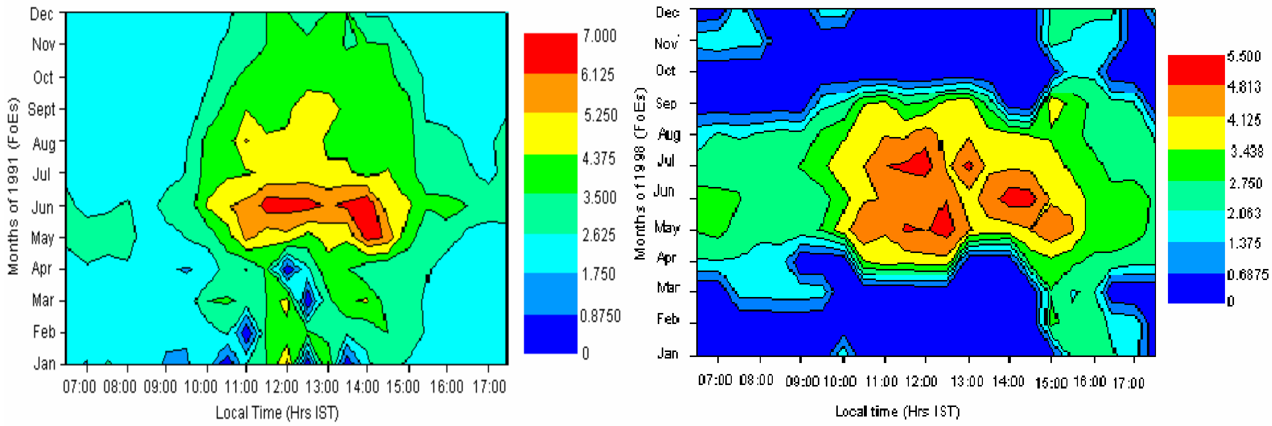

Fig. 3. The contour plots for the variation of the median critical frequency of the sporadic-E layer (f_oE_s) for years (a) 1991 and (b) 1998.

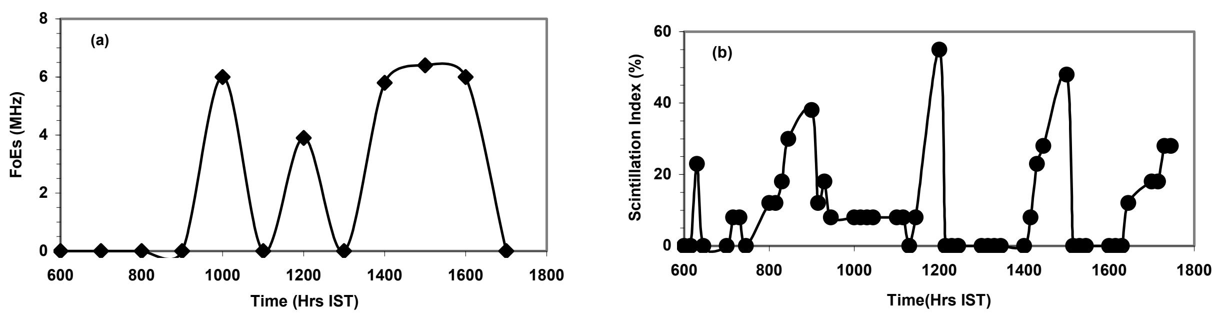

Fig. 4. A typical example of simultaneous occurrence of daytime scintillation and corresponding associated sporadic-E irregularities on 19 December 1998 (a) f_oE_s with time (b) scintillation index with time.

5. Spectral analysis of sporadic-E irregularities

The analysis of digital data gives scintillation index S_4, auto-correlation function and power spectra, which contain information about relative power of irregularities in different temporal scales. Twenty five samples have been analyzed for estimating power spectra. One typical example of the power spectra computed from the daytime data recorded on 17 Apr. 1998 at 0933-0939 Hrs IST is shown in Fig. 5a. The important features of interest are the slop of the high frequency portion of the scintillation spectra under consideration of weak scatter. The slope of the corresponding spectra in the frequency range 0.1 Hz $\leq$ f $\leq$ 0.5 Hz is –6.25. We have computed spectral slopes of all 25 samples and found that the spectral index ranges between –2 and –9 with a mean value of –4. The size of the irregularities is determined from its definition according to which the size of the irregularities is equal to the distance at which the auto-correlation function falls to 0.5 [10]. One typical example of auto-correlation function derived from daytime scintillation data recorded on 17 Apr. 1998 at 0933-0936 Hrs IST is shown in Fig. 5b. According to Fig. 5b the half de-correlation time, τ for three different cases are τ_1 = 5 sec, τ_2 = 4.1 sec and τ_3 = 3.2 sec. Considering the average drift velocities of irregularities observed over Varanasi as 100 m/sec [11] we have estimated the characteristic length of sporadic-E irregularities. The computed characteristic length of 100 samples varies between 100 m and 2000 m. Basu et al. [12] have shown that irregularities for daytime scintillations cover the scale size range at least few meters to 1 km.

6. Summary

It has been observed that transionospheric signals are subjected to daytime scintillations particularly in the late afternoon hours may be due to E-region irregularities. It has been found that a high sporadic-E critical frequency, probably $f_oE_s \geq 4$ MHz, is a necessary condition for daytime scintillation. The diurnal variation of occurrence of scintillations at Varanasi shows two peaks at 0900 Hrs IST and 1545 Hrs IST respectively, which are roughly the most

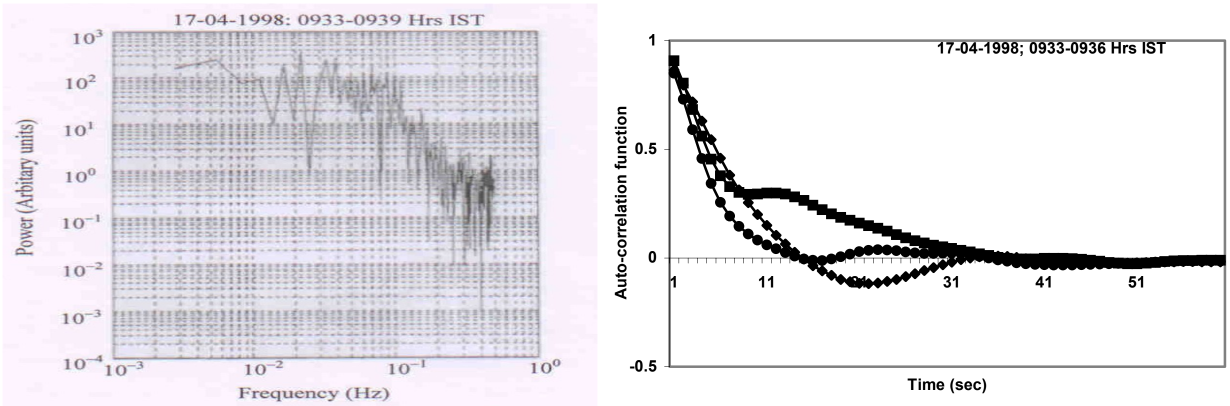

Fig. 5. One typical example of power spectra computed from daytime scintillation data and corresponding auto-correlation function observed at Varanasi on 17 April 1998 at 0933-0939 Hrs IST.

probable times for the occurrence of blanketing type of E_s layer at low latitudes. The increase in solar activity normally increases the occurrence of scintillation. The auto-correlation and power spectral analysis of daytime scintillation data at Varanasi shows that the spectral index of overhead sporadic-E irregularity generally ranges between –2 and –9 with mean value of –4. The estimated characteristics lengths varies between 100 m – 2000 m. It is clearly seen that the sporadic-E irregularity parameters computed by us are in good agreement with those reported for low latitudes.

7. Acknowledgements

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