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Daytime equatorial VHF radiowave scintillations and sporadic-E layer

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Daytime VHF radiowave scintillations at Trivandrum are compared with the E-region irregularities at Kodaikanal. It is shown that daytime scintillations at Trivandrum are basically of two categories. One type of scintillations is associated with the *q* type of sporadic-E occurrence during normal electrojet condition and is weak with peak-to-peak fluctuations of 1-2 dB. The other type of scintillations is associated with blanketing type of sporadic-E occurrence during counter electrojet condition with magnitude greater than 5 dB.

1. Introduction

The earlier studies of radiowave scintillations had shown that it is basically a nighttime phenomenon associated with spread-F condition[1-4]. At high latitudes, some scintillations were observed during the daytime hours[5-12]. Using spaced receivers, McClure[13] estimated the height of irregularities responsible for the daytime scintillations to be in the E-region. Daytime scintillations were later reported at low latitude station Ahmedabad[14,15]. Scintillation depth was found to increase with increase in *f*Es, reaching a saturation value for *f*Es > 16 MHz. Daytime scintillations at Athens[16] were found to be associated more with sporadic-E layer showing height spreading than with sporadic-E with high critical frequency. Das Gupta and Kersley[12] suggested that sporadic-E layer critical frequency (*f*Es > 4 MHz) is a necessary condition for scintillations, but a diffuse or a stratified vertical nature of sporadic-E layer is important for the production of scintillations.

Regarding the equatorial region, Mullen and Hawkins[17] reported daytime VHF scintillations at Huancayo with scintillation index of 20% in the months May-August of the minimum sunspot years. The scintillations of ATS-6 radio beacon at Ootacamund showed largest occurrence[18] for about 60% of cases at around 2000 hrs LT and secondary maxima for about 25% cases at around 0900 and 1400 hrs LT. The daytime scintillations at Ootacamund were suggested to be due to non-*q* type of Es layer. Later, Rastogi *et al.*[19] showed that VHF scintillations at Ootacamund are associated with non-*q* type of Es configuration on the ionograms. Basu *et al.*[20] found that scintillations at Huancayo were generated when Es-q echoes appeared on ionograms and when the 50 MHz radar detected type II electrojet irregularities. They did mention the level of daytime scintillations to be of the order of 1-2 dB at 140 MHz and around 5 dB at 41 MHz which were very low in comparison to the nighttime scintillations. Rastogi and Mullen[21] described two cases of intense daytime VHF scintillations at Huancayo exceeding the amplitude of 10 dB and showed that these events were associated with intense blanketing type of equatorial E layer. The results at American sector (Huancayo) and Indian sector (Ootacamund) have generated apparent discrepancies in the behaviours of sporadic-E and scintillations at low latitudes. Murthy *et al.*[22] have felt it puzzling that the scintillations at Huancayo, on an average, are of 1-2 dB amplitudes and at Ootacamund, on an average, are of 5-6 dB amplitudes as reported by Rastogi[23]. In view of these differences in the American and Indian data, we have examined the scintillations on 244 MHz radio beacon from FLEETSAT (73°E) at Trivandrum (lat., 8.5°N; long., 77°E; dip 0.3°N) with the ionograms at Kodaikanal (lat., 10.2°N; long., 77.5°E; dip. 2.4°N). These are the first results of VHF radiowave scintillations from the station close to the magnetic equator in India.

2 Experimental results

As viewed from Trivandrum, FLEETSAT is at an elevation of 80° and azimuth of 217° east of north. It may be noted that ionospheric region explored by vertical sounding at Kodaikanal was slightly at north of that which was explored by trans-ionospheric radio signal received at Trivandrum.

In Fig. 1 are shown the examples of 244 MHz radiowave amplitude records at Trivandrum and ionograms at Kodaikanal for the forenoon, midday and afternoon hours on 9 May 1986. The magnetogram of horizontal component H at Trivandrum for the day is also shown in Fig. 1. The day was magnetically quiet, ΣK_p being 12. The magnetogram indicates a period of normal electrojet between 0600 and 1530 hrs. Referring to the ionogram at 0715 hrs it is seen that F1 and F2 layers had developed by then, the retardation due to underlying E layer ionization has appeared in F layer trace but no Es reflections were recorded by then. The corresponding satellite beacon amplitude records showed very steady signal level without any scintillations.

The ionogram at 1100 hrs showed very strong Es-q reflections and F2 layer had been lifted upwards making F1-F2 transition very clear. These results of strong equatorial electrojet on equatorial ionosphere were expected. The corresponding satellite beacon amplitude record showed rapid fluctuations with amplitude slightly less than 2 dB.

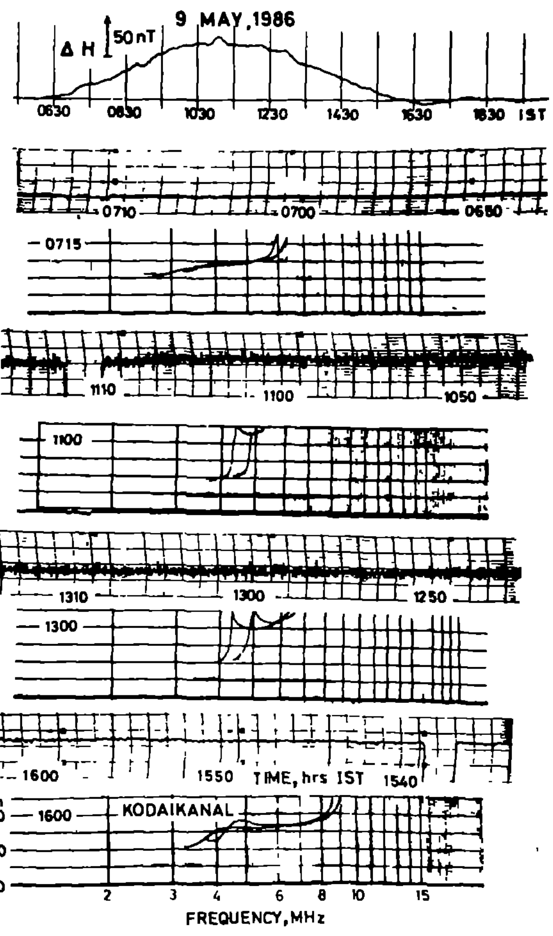

Fig. 1 — Records of radiowave scintillations and magnetogram at Trivandrum and vertical sounding ionograms at Kodaikanal for 9 May 1986

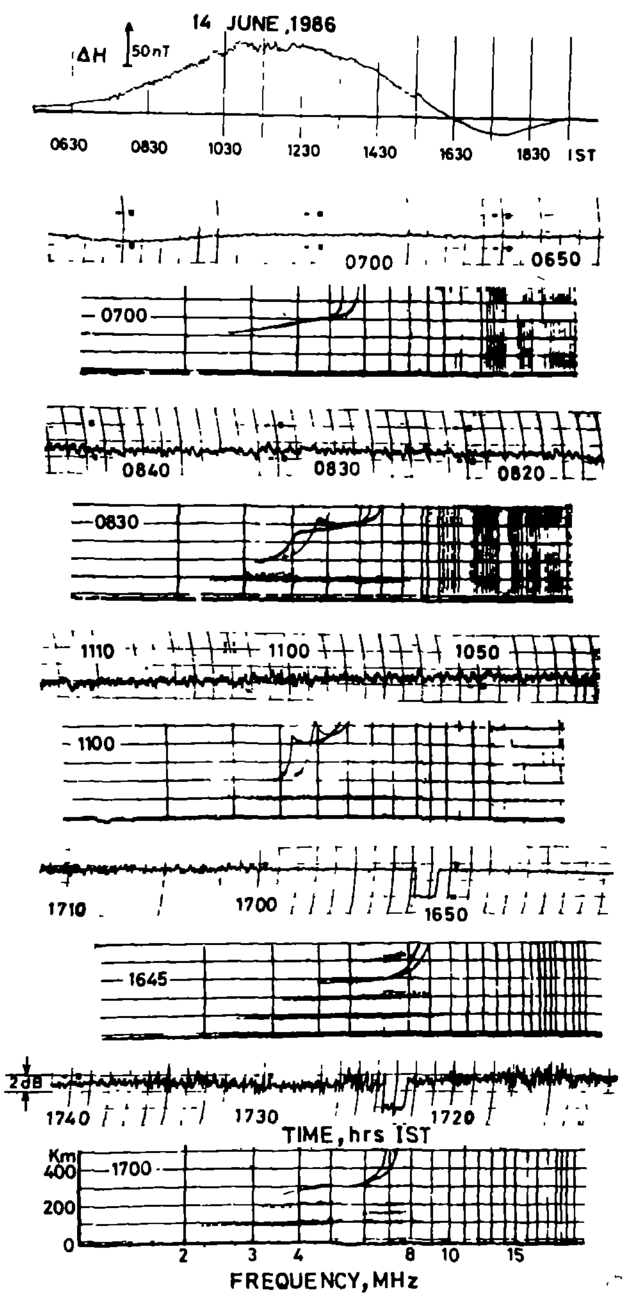

Fig. 2 — Amplitude scintillation records and magnetogram at Trivandrum and vertical sounding ionograms at Kodaikanal for 14 June 1986

The ionogram records at 1300 hrs also showed strong Es-q with associated satellite beacon scintillations of less than 2 dB.

The ionogram at 1600 hrs showed absence of Es-q and small traces of E2 (or Es-s) were visible. The height of F2 layer had also decreased as compared to the same around noon hours. The records of beacon signal amplitude showed practically no scintillations. It is to be noted that the VHF scintillations due to Es-q are almost regular without any impulsive or spiky nature.

In Fig. 2 are shown examples of Kodaikanal ionograms and Trivandrum scintillations on 14 June 1986. The *H* magnetogram at Trivandrum is also shown in Fig. 2. The day was magnetically quiet showing the development of electrojet after sunrise hours reaching a peak at 1100 hrs. There was a period of counter electrojet after 1500 hrs.

The ionogram at 0700 hrs showed absence of any type of sporadic-E layer, and the satellite beacon amplitude records showed absence of scintillations. At 0830 hrs, strong Es-q layer was observed and the F1 and F2 layer had bifurcated. Height of Es layer is indicated below 100 km due to zero error in the height scale. Similarly at 1100 hrs strong Es-q layer was observed with large uplifting of the F2 layer. Continuous uniform scintillations (about 2 dB amplitude) were observed throughout this period. The ionograms at 1645 hrs and 1700 hrs indicate multiple type of Es layer. This corresponds to the counter electrojet period and, hence, these Es-b reflections are to be considered as the actual accumulation of ionizations in the E-region. It is to be noted that the scintillations due to the blanketing Es are impulsive in nature as compared to the uniform scintillations due to Es-q.

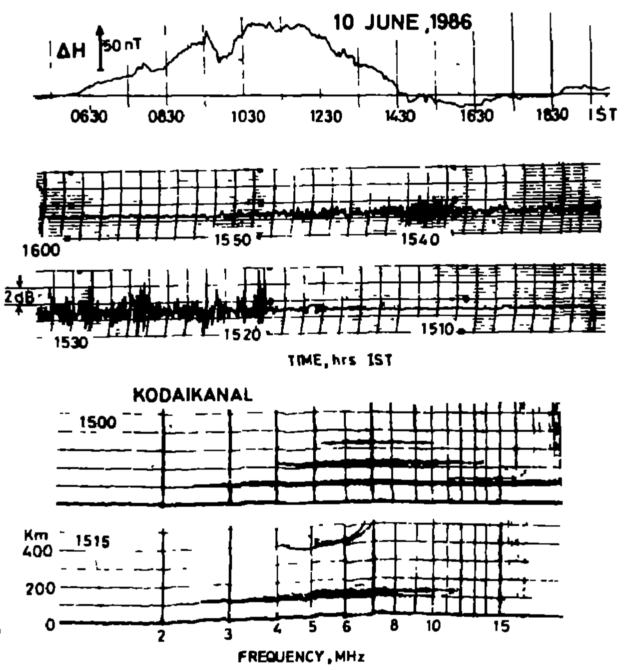

Fig. 3 — Amplitude scintillation records and magnetogram at Trivandrum and vertical sounding ionograms at Kodaikanal for 10 June 1986

In Fig. 3 are shown the examples of blanketing Es and the resulting scintillations on 10 June 1986. It is seen that the ionogram at 1515 hrs indicates three multiples of Es completely blanketing the F reflections. The amplitude records showed steady signal up to 1515 hrs LT after which sudden onset of scintillations were noted with amplitudes of about 5 dB. The fadings were impulsive and were bunched rather than being uniform in nature.

3 Discussion

The recordings of VHF scintillations at the magnetic equator, Trivandrum, have revealed distinctively two types of daytime fadings, namely, (i) normal uniform fading due to Es-q layer with amplitude of less than 2 dB associated with normal electrojet periods and (ii) occasional impulsive strong fadings due to Es-b layer with amplitudes $\geqslant 5$ dB and associated with counter electrojet events.

It may be remarked that there was no complete time coincidence in the occurrence of Es at Kodaikanal and scintillations at Trivandrum. This may be due to the fact that the volumes of ionosphere sampled by two experiments were not the same. Around the equatorial regions the Es phenomena are very sensitive to the latitude and the ionization patches may not be too extensive in dimensions. Further, the movement of these patches would also produce time delays between the phenomena at even slightly different locations. It is expected that the ionograms at Kodaikanal and satellite beacon data at Karur would provide precise data for such studies in future.

Reddy and Rao[24] showed from simultaneous observations of midlatitude sporadic-E by rocket and ionosondes that the blanketing frequency (f_bEs) gives the maximum electron concentration in the Es layer with an average error of about 10%. At equatorial latitude also the signature of blanketing sporadic-E layer (as seen by ionosonde) was associated with a sharp layer of intense ionization ($N_m \approx 10^{12}$ el./m^3) during the rocket experiment Equion[25]. Extensive studies of plasma instabilities in the equatorial ionosphere by rocket borne probes[26] have shown that the plasma irregularities in the scale sizes of 1-5 m are detected as sporadic-E layer by ionosonde and are associated with equatorial electrojet. The amplitude of these irregularities in the height range 80-95 km is about 0.2% of the background ionization, and the amplitude increases rapidly with height reaching a value of 1-2% in the 100-120 km region. Thus the weak Es-q irregularities are of only 1-2% of the background ionization density while the Es-b irregularities are associated with ionization more than one order of magnitude larger than background ionization. The Es-q irregularities do not produce second multiple echoes on the ionograms while Es-b irregularities may generate sometimes more than six or seven multiple reflections. The scintillations of radiowaves traversing sporadic-E layer are correspondingly much stronger in case of Es-b than in case of Es-q irregularities.

This clarifies the apparent discrepancy of the observations of almost regular weak daytime scintillations at Huancayo and only frequent but strong daytime scintillations at Ootacamund. The scintillations at Huancayo are associated with Es-q and at Ootacamund with Es-b type of irregularities.

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