Ionosphere scintillations associated with features of equatorial ionosphere

by

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ABSTRACT. – *Amplitude scintillations of radio beacons aboard ATS-6 satellite on 40 MHz. 140 MHz and 360 MHz recorded during the ATS-6 phase II at an equatorial station Ootacamund (dip 4°N) and the ionograms at a nearby station Kodaikanal (dip 3 5°N) are examined for the scintillation activity. Only sporadic E events, other than Es-q, Es-c or normal E are found to be associated with intense daytime scientillations. Scintillations are also observed during night Es conditions The range spread is associated with strong scintillations on all frequencies while frequency spread causes weaker scintillations and that too mainly on 40 MHz.*

RESUME – *On a étudié l'amplitude des scintillations des balises radio à bord du satellite ATS-6 aux fréquences de 40 MHz, 140 MHz, et 360 MHz, enregistrées pendant la phase II d'ATS-6 à une station équatoriale Ootacamund (valeur dipolaire 4°N) et les ionogrammes à une station voisine Kodaikanal (valeur dipolaire 3°5 N) On a trouvé que seuls les évènements E sporadiques autres que les Es-q, Es-c et le E normal sont associés aux scintillations diurnes intenses Des scintillations sont également observées pendant des conditions de Es nocturnes L'élargissement en amplitude est associé aux scintillations fortes sur toutes les fréquences, tandis que l'élargissement en fréquence provoque des scintillations plus faibles, et cela, surtout, à une fréquence de 40 MHz*

Introduction

Ionospheric scintillations have been studied in the last three decades employing radio stars as a source of radio waves in the earlier days and now radio beacons on board the orbiting or geostationary satellites Global morphology of the scintillations have been reviewed by different authors (Aarons and Whitney 1971, Hartman 1973; Crane 1977) The night time scintillations have been found to be associated with the occurrence of spread-*F* on ionograms and as in case of spread-*F*, there is a belt of strong scintillations in the equatorial region Occasionally there are daytime scintillations also which are associated with the *E*-region irregularities In the equatorial region there have been comparatively fewer studies of scintillations and much of the work has come from the observations made at Legon in Africa (Koster 1972) and at Huancayo in South America (Mullen 1973) Work on equatorial scintillations has been reviewed recently by Aarons (1977) and Basu and Kelley (1977) The first work on scintillations in the Indian zone was reported by Bhargava (1964) using radio stars and a good correlation between spread-*F* and scintillations was noted Chandra and Rastogi (1974) from a limited number of observations at Thumba from orbiting satellites correlated night time scintillations with spread-*F* and also estimated the width of the equatorial scintillation belt.

The recordings of the amplitudes of radio beacon signals on 40 MHz, 140 MHz and 360 MHz on board ATS-6 satellite at Ootacamund (dip 4°N) in India during the period October 1975 – August 1976 when the satellite was positioned at 34°E provided an unique opportunity to study the equatorial ionospheric scintillations in some detail (Rastogi *et al* 1977a) A preliminary examination of the scintillation records with the ionograms at a nearby station Kodaikanal (dip 3 5°N) during the brief period of October 20 – November 10, 1975 showed that the occurrence of scintillations was not limited to night time only, but there were daytime events quite often Intense scintillations were in fact recorded at a time when l or h type of sporadic *E* were present No scintillations were noted at times of equatorial type *Es* (*Es-q*) or during the absence of any sporadic *E* (Rastogi *et al* 1977b)

The scintillation data have been examined further over the complete period of October 1975 – August 1976 and the ionograms obtained at Kodaikanal have been examined critically at times of scintillations Different features of the equatorial *E*-region and

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F-region have been looked into and their association with the presence or absence of scintillations are discussed in this paper. The *E*-region features examined here are (i) equatorial type of *Es* (*Es-q*), (ii) normal *E*-layer, (iii) cusp type of *Es*, (iv) non *Es-q* type layer associated with *M* reflections, (v) blanketing type of *Es* and (vi) night *Es*. The *F*-region features studied are the range and frequency types of spread-*F*. The occurrence of these *Es* features are compared with the scintillation indices computed for each quarter hourly periods for the three frequencies 40, 140 and 360 MHz according to the method suggested by Whitney *et al.* (1969).

Equatorial type of Es

The *q* type of *Es* (*Es -q*) is the most regularly observed event during daytime hours in the equatorial region. The probability of *q* type of *Es* in the Indian zone near noon is about 98 % during low sunsport years and nearly hundred per cent during high sunspot years. However, scintillations during daytime are not that common. Figure 1 shows an example of ionograms on 24 October, 1975 showing development of *q* type of *Es* and corresponding amplitude scintillation records. At 07 hr there is no *Es* and amplitude fluctuations are not present (at 40 MHz there are small fluctuations). From 08 hr to 16 hr *Es-q* is present The amplitudes on 140 MHz and 360 MHz are again free from any fluctuations. However, there are some fluctuations on 40 MHz. At 17 hr again there is no *Es* and no amplitude fluctuations. Thus normal *E* layer is not causing any scintillations and even *q* type of *Es* does only weakly affect amplitudes on 40 MHz. It must be noted here that scintillation index around 20 % is nearly always present on 40 MHz amplitude records.

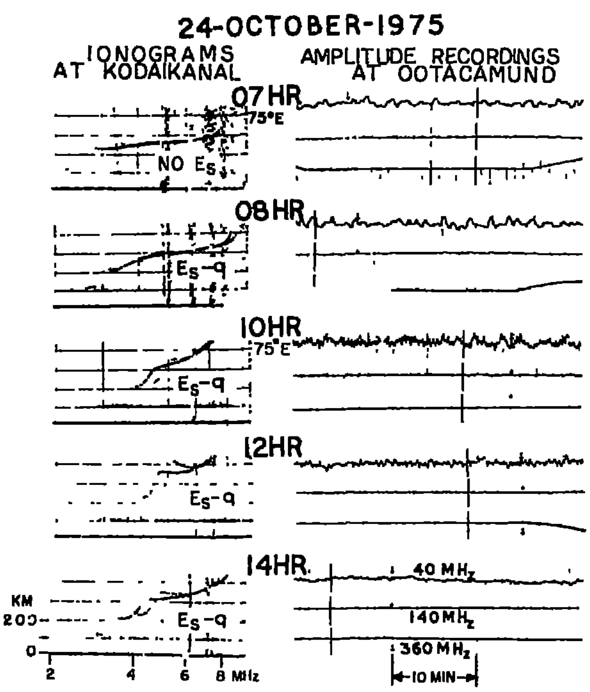

Fig. 1

Examples of ionograms showing no *Es* and the equatorial type of *Es* (*Es-q*) at Kodaikanal alongwith simultaneous amplitude scintillation records at 40, 140 and 360 MHz recorded at Ootacamund.

Cusp type of *Es*

The cusp type of *Es* is generally not very common in the equatorial region. Ionograms showing cusp type of *Es* on 18th June 1976 are shown in Figure 2(a) where from 0800 hr LT to 0900 hr LT cusp type of *Es* was noted. The scintillation index plot on this day is shown in Figure 2(b). Since generally there were no amplitude fluctuations on frequencies of 140 MHz and 360 MHz during the day time the scintillation index on 40 MHz is only shown in figure. Thus, there is no enhancement

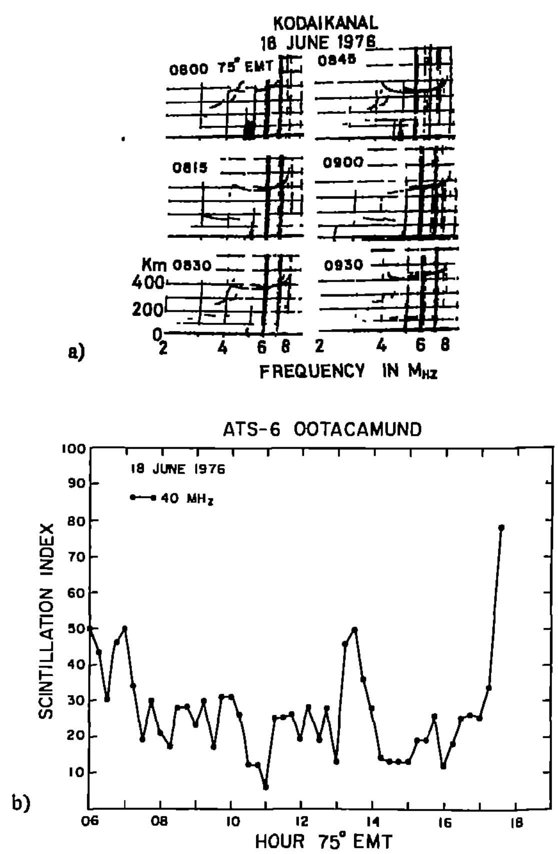

Fig 2

Examples of ionograms at Kodaikanal showing cusp type of *Es* on 18th June 1976 (*a*). The daily variation of scintillation index at 40 MHz on same day (*b*).

of the scintillation index coincident with the formation of the cusp type of *Es*.

Blanketing type of *Es*

Several instances of the blanketing *Es* associated with scintillation activity have been noticed during this period. Two such examples of blanketing *Es* events on 27th and 28th April 1976 are shown in Figure 3a and 3b. On 27th April strong blanketing *Es* is seen at 1515 hr and 1530 hr LT along with *M* reflection. At 1500 hr blanketing *Es* is present but of not intense form. Looking into the variations of scintillation indices on this day (Fig. 4a), there is strong enhancement of the scintillation indices at all the three frequencies from 1300 hr LT to 1500 hr LT. The peak scintillation indices are noted between 1430 and 1445 hr LT. Thus the peak scintillation activity is seen about 30-45 minutes earlier then the peak blanketing *Es* seen over Kodaikanal. The exemple on 28th April also shows strong blanketing *Es* at 1445 and 1500 hr LT. The corresponding scintillation indices shown in Figure 4b clearly demonstrate strong enhancement of scintillations at 40 MHz and

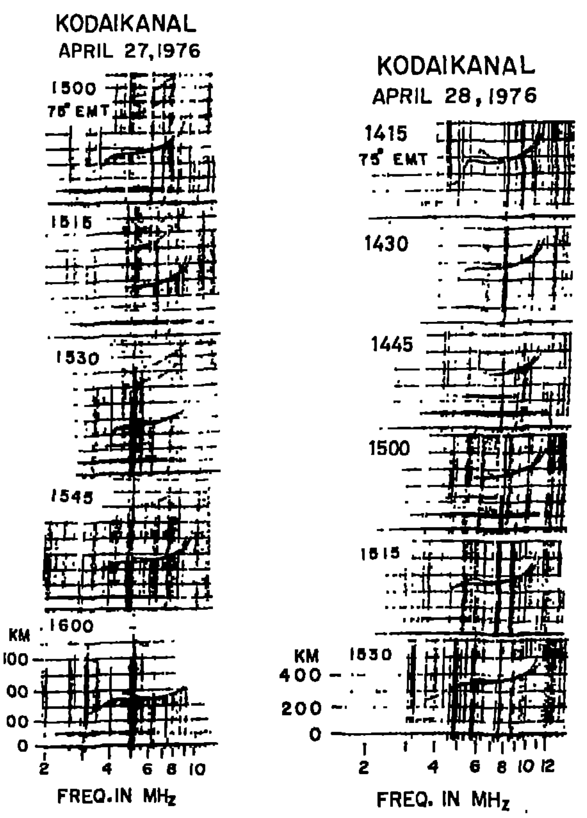

Fig. 3

Examples of ionograms at Kodaikanal showing blanketing type of *Es* on 27 April 1976 (*a*) and on 28 April 1976 (*b*).

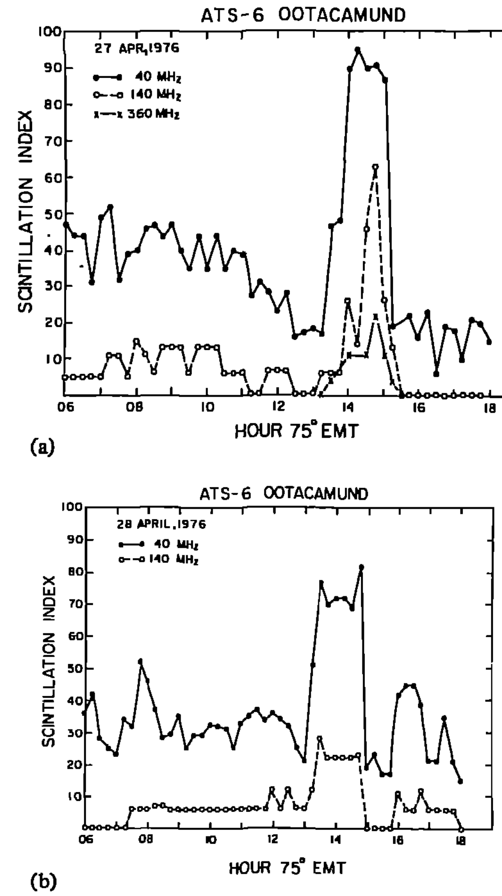

Fig. 4

Daily variations of scintillation indices on 40, 140 and 360 MHz on 27 April 1976 (*a*) and on 28 April 1976 (*b*)

140 MHz from 1300 hr to 1500 hr LT. Again the peak scintillation indices are centred around 1400 hr LT. Thus once again a time difference of about 45 minutes is noted between the peak scintillation activity and strongest blanketing *Es* event. Since there is a longitude difference of about 250 km between Ootacamund and Kodaikanal and about 100 km latitude separation the possible explanations for this time delay would be slow eastward drift of the blanketing *Es* patch, or southward drift of the blanketing *Es* patch, or a combination of both. From earlier observations (Chandra and Rastogi 1975) at Thumba/Kodaikanal, it has been shown that blanketing *Es* events occur usually following counter-electrojet events and show a significant southward drift. Thus the time delay observed is consistent with the earlier observations of the movements of ionisation patches associated with blanketing *Es*.

A comprehensive picture of *Es* and its association with scintillation is shown in Figure 5 where scintillation indices at 40 MHz, 140 MHz and 360 MHz are plotted for daytime hours on 28thOctober 1975, 5th November

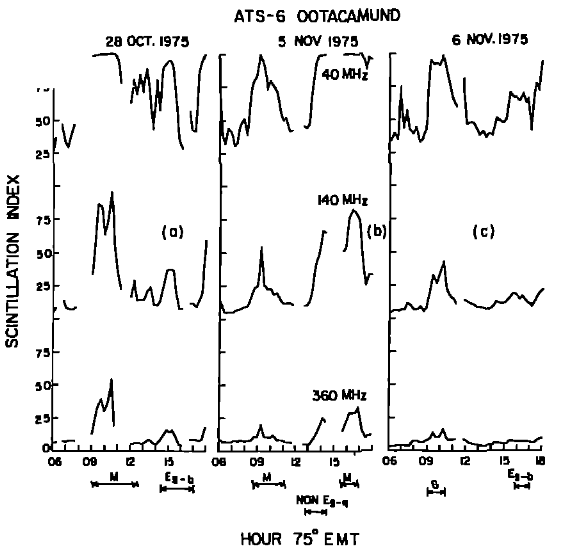

Fig. 5

Daily variations of scintillation indices on 40, 140 and 360 MHz for the days 28 October 1975, 5 November 1975 and 6 November 1975. Various features in the *E*-region as seen from the ionograms at Kodaikanal are also marked.

1975 and 6th November 1975 alongwith the *E*-region features noted on ionograms on these days, marked at the base of these figures. On 28th November clear enhancements are seen on all the frequencies around 10 hr LT and 15 hr LT. Non *Es-q* type *Es* with *M* reflection was noticed from 09 hr to 12.30 hr LT, and blanketing type of *Es* was noticed from 14.15 hr to 1700 hr LT. On 5th November 1975 there was a *Es* layer with *M* reflection from 0830 hr LT to 1 100 hr LT and a non Es-*q* type of sporadic *E* from 12.30 hr LT to 14.15 hr LT. Correspondingly there are enhancements in the scintillation indices. On 6th November, 1975 enhanced scintillations are observed around 10 hr LT and around 1600 hr LT. Coincident with these enhancements were seen a *G* layer (disturbance near the peak of *F* region) and a blanketing *Es* in the ionograms.

Night Es

A few cases of scintillations associated with the occurrence of night *Es* (at times when no spread-*F* was seen) have been encountered during the year of data examination. Another example of the night *Es* and its association with scintillation is shown in Figure 6. On the night of 4-5 November 1975 night *Es* was noticed from 22 hr LT to 00 hr LT and the scintillations enchanced during this period.

Spread-*F*

Spread-*F* studies from ionograms have been reported for Thumba by Chandra and Rastogi (1972). Broadly

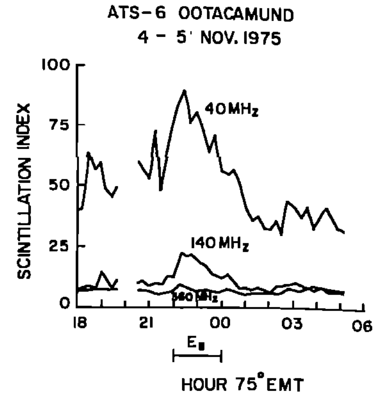

Fig. 6

Nocturnal variations of the scintillation indices on 40, 140 and 360 MHz for the night 4-5 November 1975 showing enhancement during the night *Es* event.

three types of spread-*F* configurations are noted. First the range spread where spreading is seen at lower frequencies only, with clear trace near penetration frequency. Second, the intense or complete spread when spreading extends along the complete trace and neither range nor the penetration frequency can be measured. Third the frequency spread when the trace is clear at lower frequencies and spreading is seen near the penetration frequency. Range spread occurs in the post-sun set period and is the initial development stage. Intense spread-*F* is encountered for most part of night at Thumba and frequency spread is usually seen in the presunrise period.

Case of the development of spread-*F* and associated amplitude scintillations on three typical nights are shown in Figure 7. Scintillation indices have been computed quarter hourly and the nocturnal variations plotted. The durations of the range spread (*R*), complete spread (*R, F*) and frequency spread (*F*) are marked along the time axis. On the night of 20-21 October 1975, range spread was noted from 1845 hr LT to 2000 hr LT, complete spread from 2000 hr LT to 0300 hr LT and frequency spread from 0300 hr LT to 0530 hr LT. Intense scintillations are noted right from the development stage of range spread. During the complete spread scintillation indices of 100 % are seen at all the three frequencies. Scintillations were mild at the time of only frequency spread. Nearly similar results are seen on other two nights of 25-26 October 1975 and 27-28 October 1975.

The statistical results of an analysis of the occurrence of scintillations during the entire period of October 1975 – August 1976 are summarised in Figure 8 where the contours of the percentage occurrence of scintillations at 140 MHz are drawn in a grid of local time versus months. Low values are noticed around 0600 hr in the morning and around 19-19 hr in the evening which are also the times of the electric field reversals (Chandra

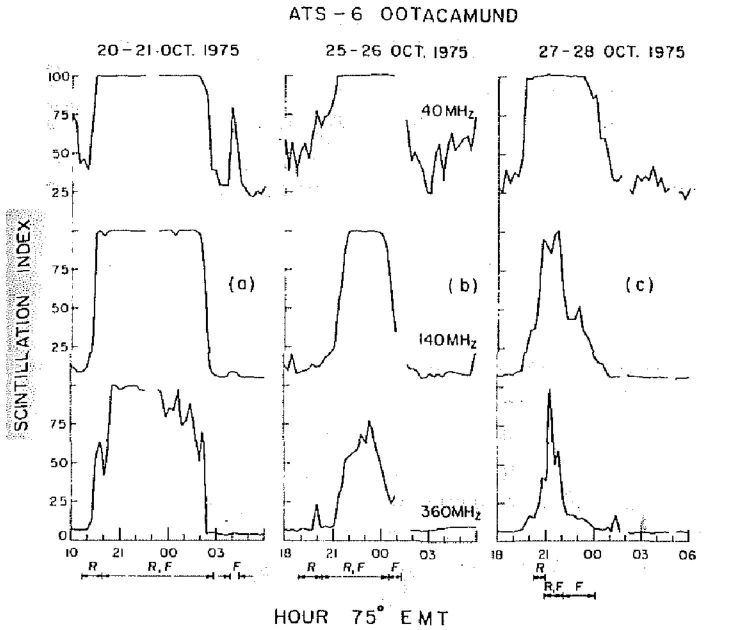

Fig. 7

Scintillation indices at 40, 140 and 360 MHz deduced from the amplitude records at Ootacamund on a few nights during the month of October 1975. The types of spread-*F* viz. Range (*R*), complete (*R*, *F*) and Frequency (*F*) are marked along the time axis.

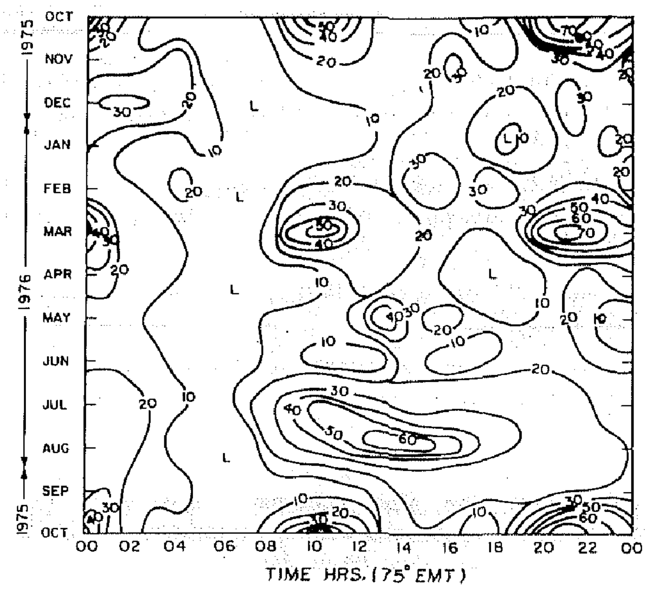

Fig. 8

Contours of percentage occurrence of scintillations at 140 MHz at Ootacamund plotted in a grid of local time versus months.

and Rastogi 1970). Clear equinoctial maxima are noted around 21-22 hr which are associated with the premidnight peaks of the spread-*F* occurrence (Chandra and Rastogi 1972). Equinoctial maxima around 10 hr LT and a broad summer maximum around 14 hr LT are associated with the daytime features. No maximum is noticed in the presunrise hours of summer months associated with the maximum in frequency type of spread-*F* (Chandra and Rastogi 1972).

The dependence of scintillation on geomagnetic activity have been studied next. Data are divided into four groups viz. forenoon (06-11), afternoon (12-17), premidnight (18-23) and post-midnight (00-05) hours. Groupings have been further made according to the 3 hourly Kp values appropriate to the four hour groups. Variation in the mean percentage occurrence of scintillation with *Kp* index is shown in Figure 9 for the three seasons winter, equinoxes and summer separately. Error bars in mean have been plotted to signify the reliability of the results. No consistent pattern is noted for the daytime events. However, for the premidnight spread-*F* condition, a decrease is evident during winter and equinoxes while an increase is probably inferred during summer. For the post-midnight hours an increase with increasing *Kp* is the likely result even though the variations of the order of the error bars make it difficult to conclude it with much confidence. The trends are however similar to the magnetic activity effects on the occurrence of spread-*F* at Kodaikanal recently reported (Chandra and Vyas 1978).

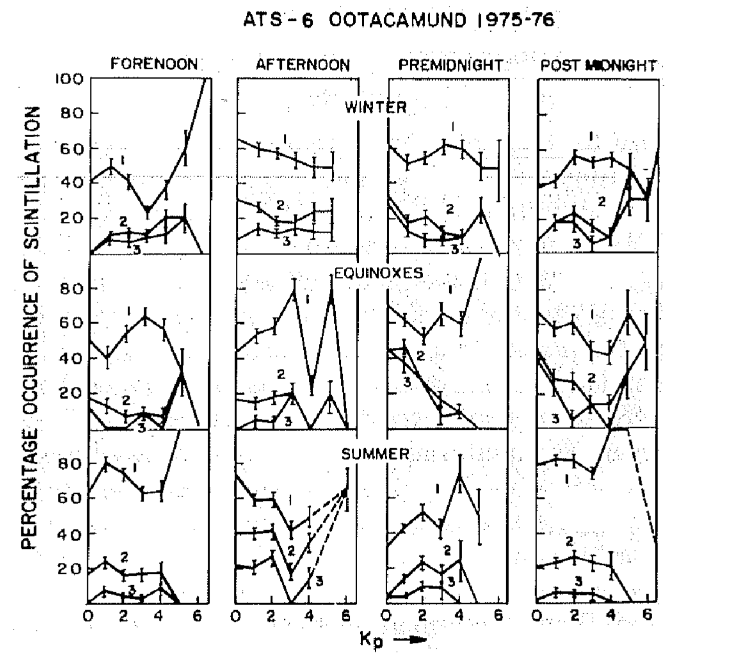

Fig. 9

Variations of the percentage occurrence of scintillations at 40 MHz, 140 MHz and 360 MHz with the three hourly *Kp* values.

Discussion

Association of the daytime scintillations with *E* region irregularities have been shown earlier at high latitude (Bolten *et al.* 1953 ; Dueno 1956 ; Chivers and Greenhow 1959 ; Munro 1966 ; Aarons and Whitney 1968). Koster and Wright (1963) observed unusually regular type of scintillation during daytime at Accra which was associated with equatorial electrojet disturbances. At the low latitudes, the effect of blanketing *Es* on scintillations has been shown by Rastogi and

Iyer at Ahmedabad and a positive correlation is shown between the scintillation index and f_oE_s (Rastogi and Iyer 1976 , Iyer and Rastogi 1978)

Raghava Reddy *et al* (1977) have reported scintillations on 40 MHz at Thumba to be present on nearly 70 % of the daytime hours and suggested this to be [illegible] Basu *et al* (1977) noted that [illegible] on 40 MHz and 140 MHz at Huancayo occurred simultaneously with the backscatter echoes on 50 MHz from the *E*-region over Jicamarca and suggested the VHF scintillations over the equator to be associated with *Es-q*.

One thing which is of considerable interest here is that strong scintillations during daytime occur in the equatorial zone whenever blanketing type of *Es* is present. The occurrences of blanketing *Es* in the Asian sector during the afternoon hours of summer months is particularly very high during low sunspot years and this is to be taken care in the future systems design for radio communications in *vhf* range. Daytime scintillations are not included in the existing scintillations models and therefore new models must be constructed including these daytime effects.

Very few authors have attempted a one to one correlation study of the range and frequency types of spread-*F* with scintillations Huang (1970) found a very high correlation between range type of spread-*F* and scintillations deduced from geostationary satellite and a very weak correlation between scintillations and frequency type of spread-*F* at a low latitude station Taipei (25°N) Similar results have been obtained recently at Brisbane (27 5°S) using orbiting satellite (Hajkowiz 1977, 1978) However, at equatorial latitudes such studies have been reported for the first time A comparison of the radar backscatter observations at Jicamarca and ionosonde observations at Huancayo shows strong backscatter signals to be present only at times of range spread (Rastogi and Woodman, 1978). Basu *et al* (1978) have compared radar backscatter observations at Jicamarca and simultaneous *vhf* scintillations at 137 MHz and 254 MHz and report intense scintillations when irregularities are found to penetrate into the topside and a thick irregularity layer is present When radar observes only bottoms [illegible] scintillations are weak to moderate [illegible] was reached by Morse *et al* (1977) for the scintillation and radar study during the EQUION rocket flight on 28 March 1974

In view of the recent developments it seems that in the initial stages of spread-F irregularities are generated at the base of *F* layer only which give rise to typical range spread-*F* configurations in the ionograms With the development of irregularity structure extending upto topside one obtains spreading in the ionograms right through the trace and intense scintillations are encountered. When irregularities are confined to a narrow region near N_{max} level again scintillations are weak and these are associated with frequency spread. The classification of range or frequency type of spread is based only on the ionogram configuration and depends on the location of irregularities

Acknowledgements

The *ATS*-6 Radio Beacon recording program at Ootacamund was a joint undertaking of the PRL, Ahmedabad, India and NOAA, Boulder, U S.A. The project was supported by DOS, Govt of India and by NASA, U S A Grateful thanks are due to Dr. K Davies for the loan of equipments and to Prof G Swarup for the facilities provided at Ootacamund Thanks are also due to Miss Chhaya Shah for computational assistance.

Manuscrit reçu le 29-08-78
sous sa forme définitive le 14-02-79

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