Scintillations of VHF radio beacons from two satellites

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Abstract. Analysis of scintillations of VHF beacons from two very closely spaced geostationary satellites shows that the drift of irregularities is generally westward at the initial stages and changes to eastward during the later part of the night when the irregularities are fully developed or decaying.

Keywords. VHF radio beacons; scintillations; geostationary satellites; irregularities.

1. Introduction

Although night time equatorial radio wave scintillations have been known to be associated with spread *F* irregularities, recent studies on the types of ionograms which cause scintillations have provided a new method of studying the generation and dynamics of the *F* region irregularities. Using the scintillation data of radio beacons from a number of satellites recorded at Huancayo and Ancon, Aarons *et al* (1980) studied the movement of the ionisation patches and concluded that the patches have minimum east-west dimensions of 100 km. The patches initially have a westward expansion following the solar terminator and later drift eastward with velocities ranging from 100 to 200 m/sec.

Knecht (1960) using the data from the chain of ionosondes in Peru studied the movement of spread *F* patches and found the east-west velocity to be westward during the early hours of the night changing to eastward at later periods. Backscatter of HF waves studied by Clemesha (1964) showed velocity of the patches to be mostly towards the east but very occasionally towards the west.

During November–December 1974 scintillations were recorded at Huancayo (12°S, 75°3′W) on 137 MHz signals from ATS-3, 140 MHz signals from ATS-6 and 254 MHz signals from LES-6. All these satellites were geostationary and the transmission paths from these satellites are shown in figure 1, indicating the cross-over location at different heights in the ionosphere. The satellite ATS-3 was situated at 70°W longitude at an elevation of 72° and azimuth of 6°E of north from Huancayo, and the 350 km cross-over point was about 95 km from Huancayo. The satellite ATS-6 situated at 94°W was at an elevation of 64° and azimuth of 58°W of north from Huancayo, the 350 km point being 180 km from Huancayo. As the north-south extension of spread *F* irregularities is of the order of 2000 km or greater (Aarons 1980) the simultaneous recordings of ATS-6 and ATS-3 signals at Huancayo corresponded to east-west displacement of the ionospheric cross-over points by about 150 km only, which corresponds roughly to the dimension of a single patch in E-W direction. This provided one of the best sets of two very closely spaced satellite beacons on the same frequency band. The 350 km cross-over point of LES-6 on the Huancayo path was about 350 km from Huancayo, the azimuth of the path

Figure 1. Map showing the transmission path of satellite beacons received at Huancayo.

being 75° East of north. Rastogi (1983) has shown that the onset of spread F is a rather explosive phenomenon and the scintillations on different frequencies start almost at the same time. The present paper discusses the starting of scintillations of radio beacons from these separated satellites simultaneously recorded at Huancayo.

2. Observations and Discussions

Figure 2 shows the monthly average nocturnal variations of the scintillations of three beacons ATS-3 (137 MHz), ATS-6 (140 MHz) and LES-6 (254 MHz) received at Huancayo for December 1974. The parameters shown are mean scintillation index (s_i in %) and the percent of time the scintillation index exceeded the level 80%. The mean s_i of 137 MHz radio beacon from either ATS-3 or ATS-6 showed a sharp increase since 1900 hr LT with a major maximum around 2200–2300 hr LT and a secondary maximum after-midnight hours 0200–0400 hr LT. The s_i of the more eastward transmission path of LES-6 (254 MHz) to Huancayo showed a sharp increase after 1900 hr LT but maxima of comparatively lesser magnitude were observed at 2000, 2400 and 0300 hr LT. The mean s_i as well as the percentage times of scintillation exceeding 80% showed lower values on LES-6 (254 MHz) signals or compared to ATS-6 (140 MHz) or ATS-3 (137 MHz) signals. This is consistent with the inverse relationship between scintillations and frequency (Rastogi 1982). However a peak in the scintillations of LES-6 signals around midnight is not seen in ATS-3 or ATS-6 signals.

The significant point to be noticed is that in the initial stage of the night, scintillations started first on LES-6 signals, then on ATS-3 and next on ATS-6 signals specifying clearly a westward advancement of the F region irregularity boundary following the sunset terminator. The median time of evening reversal of the vertical drift at Jicamarca during the low sunspot years (1971–75) was 1850 hr LT (Woodman *et al* 1977). There were quite a few observations of field reversing before 1800 hr LT most probably due to the occurrence of counter electrojet events. The sunset at 100 km during these months was at about 1900 hr LT. When the scintillation activity is expressed as the percent of time s_i

Figure 2. Monthly mean nocturnal variations of the SI (in %) and the fraction of time SI exceeds the level of 80% on 137 MHz from ATS-3, from ATS-6 on 140 MHz and from LES-6 on 254 MHz received at Huancayo.

> 80%, the temporal variations seemed clearer. The premidnight peak was very distinct for ATS-3 and ATS-6 signals between 2200–2300 hr LT. The LES-6 signals also show a distinct peak at 2000–2100 hr LT. The comparatively early peak may be due to the path from LES-6 being east of the receiving station, the sunset terminator occurs earlier than on other transmission paths.

Thus, with proper selection of satellite transmission with a small distance between the satellites, one can very easily study the development of the *F* region irregularities.

Figure 3 shows the nocturnal variations of the scintillation indices of 137 MHz beacon from ATS-3 and 140 MHz beacon from ATS-6 both received at Huancayo on individual nights. One can see the remarkable similarities between the two curves on any one of the nights. This indicates that the character of the irregularity patch had not changed between its movement between the two ionospheric cross-over points. The starting of the scintillations were not same on different nights. The time varied from around 1800 hr LT on 3 December 1974 to 1900 hr LT on 9 December 1974 and beyond midnight on 17–18 December 1974. The onset time may have considerable day-to-day variability possibly related to different reversal times of the horizontal field particularly under solar minimum conditions. However, in each case irrespective of the LT of the onset of *F* region irregularities, the scintillations started earlier on ATS-3 beacon than on ATS-6 beacon.

To further examine the starting of scintillations on individual days, in figure 4 are shown the nocturnal variations of scintillations on ATS-3 and ATS-6 beacons on each of the days from 21 November to 10 December 1974. It is seen that except on 9 and 10 December 1974, scintillations started earlier on ATS-3 signals than on signals from the westward situated satellite ATS-6.

Figure 3. Nocturnal variations of the SI of ATS-3 (137 MHz) and ATS-6 (140 MHz) beacons received at Huancayo on individual nights.

This confirms that at initial stages of development of the spread F irregularities the drifts are westward.

Figure 5 shows the nocturnal variations of the SI of ATS-3 (137 MHz) and ATS-6 (140 MHz) radio beacons on some of the days with large fluctuations of magnitude of the index. It is seen that the temporal variations of the SI of the two or the large dropouts in the intensity of scintillation were observed on both the transmission paths. The signatures of the fluctuations in scintillation index did not seem to have systematic time delay and as such it was difficult to estimate any drift velocity from these time delays. These data were obtained on visual inspection of the scintillation records and they represented average over a period of 15 min. As such it cannot be ascertained if the same patches were observed at the ionospheric cross-over points of the two transmission paths. These patches may have changed considerably between the two locations.

The present analysis is based on the SI data averaged over consecutive 15 min intervals. A better estimate of the time shift between the onset of scintillation at two locations separated by 150 km does require SI data computed for shorter intervals because the movement of the solar terminator across these locations itself is of the order of 4–5 min only.

Another method for evaluating the drift of scintillation irregularities is by recording the amplitude fluctuations at receiving sites displaced by some 100 m and computing the time shift for optimum cross correlation coefficients between the scintillation records at the two places. AFGL had conducted spaced receiver experiment in PERU

Figure 4. Nocturnal variations of the SI of ATS-3 (137 MHz) and ATS-6 (140 MHz) beacons received at Huancayo on each day from 21 November to 10 December 1974.

during October 1976 (Whitney *et al* 1977). Two antennae spaced on a 366 m east-west base line were used to record the scintillations of 249.6 MHz signals from satellite LES-9 at Ancon, Peru. On 20 October 1976, the maximum cross correlation coefficient was 0.88 with a delay of 2.39 sec yielding the drift velocity of 153 m/sec.

Figure 6 reproduces some of the parameters of the fluctuations of 249.6 MHz beacon received at Ancon on 18 October 1976 after Whitney *et al* (1977). It is seen that the magnitude of the peak-to-peak fluctuations of the signal exceeded 20 dB and the S4 index was close to 1 suggesting that the period under consideration had severe

Figure 5. Some examples of the nocturnal variations of ATS-3 and ATS-6 beacons showing large fluctuations in the magnitude of scintillations.

(after Whitney et al (1977) AFGL Tech. Rep. TR-77-0282 p 37)

Figure 6. Temporal variations of the spaced antenna drift velocity, S_4 , scintillation amplitude (dB) and fading rate of 249.6 MHz beacon received at Ancon on 18 October 1976.

scintillations. The fading rate of the signal in the initial stages was between 30–40 fades per min and later decreased to slower but still large fade of about 20/min. It is consistent with general findings that in the initial phase of the scintillation activity the fadings are very fast and at later stages of fully developed scintillation the fadings become slow while the peak-to-peak fluctuations may remain the same. It is interesting to find that during the initial stages when fadings are fast, the drift speed was westward; only after about 2100 hr did the drift change to the eastward direction.

3. Conclusions

- (i) At the initial stage of development of the equatorial spread *F* irregularities drift is generally westward probably as the consequence of the westward movement of the sunset terminator.
- (ii) At later stage generally by the time the irregularities are fully developed, the drifts are eastward.
- (iii) The east-west extension of the irregularity patch is at least of the order of 100 km as the patches are seen simultaneously at two locations in the ionosphere with this order of separation. With the availability of the satellite radio beacons in VHF range in Indian longitude it would be very useful if simultaneous recordings of scintillations at varying distances are made in India to critically examine the drift and the life time of the associated irregularities.

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