VHF SCINTILLATIONS AS A DIAGNOSTIC TOOL FOR THE STUDY OF IONOSPHERIC IRREGULARITIES

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Abstract. In this paper we present the results of observations of the scintillations of radio beacon on 250.351 MHz from geostationary satellite FLEETSAT (73° E) recorded at Bombay on April 9-10, 1992 during night hours. The scintillation index, $S_4$, is used to describe the strength of the scintillations. The variation of scintillation index with local time shows a maxima of 0.589 at 02:55 IST. This scintillation activity is linked with the spread $F$-irregularities. A brief description of the scintillation theories like phase screen theory and theory for weak scintillations -- Rytov solution is given. These theories provide an integral measure of the fluctuations in terms of phase and amplitude fluctuations imposed on VHF signals while traversing through the ionosphere. Power spectrum analysis for the log-amplitude and phase departure and cross spectrum between them have also been carried out. Using spectral index $p = 1$, we have shown that the scale sizes for the ionospheric irregularities are greater than 1 km.

1. Introduction

The word "Scintillation" refers to the amplitude and phase changes of HF, VHF or UHF signals transmitted by sources like radio stars or artificial geostationary satellites. The scintillation studies involving transionospheric propagation is of considerable interest in understanding the physical processes controlling high latitude ionospheric plasma density like generation mechanism and transport of ionospheric irregularities, soft particle precipitations with energies $\sim 100$ eV, penetration of magnetospheric electric fields and auroral current systems (Kelley et al., 1982; Anderson et al., 1987; Kersley et al., 1988). First measurement of scintillations was performed by Hey et al., in 1946 from the radio source Cygnus. Ryle and Hewish (1950) have predicted the origin of scintillations to be due to the presence of ionospheric irregularities at $E$ and $F$ regions of the ionosphere. With the aid of first man-made satellite Sputnik-1 launched in 1957 by Russian Scientists and other satellites like explorer 22 and 27, BE-B, BE-C, S-66, AE-C, AE-E, NNSS etc. it became possible to measure scintillations of transionospheric signals in order to understand the basic physics and dynamics of the ionospheric irregularities (Kent, 1959; Yeh and Swenson, 1959; Aarons et al., 1963; Basu and Dasgupta, 1969; Koster, 1972; Chandra and Rastogi, 1974; Chatterjee et al., 1974; Rastogi and Iyer, 1976; Iyer and Rastogi, 1978; Basu et al., 1980, 1983; Valladares et al., 1983; Kersley et al., 1988). After the introduction of geostationary satellites, continuous observations were possible for recording scintillations at low latitudes. In India, the first work on scintillations was reported by Subbo and Somayajulu (1949) and later on by Bhargava (1964) using radio stars and a
good correlation between spread $F$ and scintillations was noted. The scintillation recording was started in India during the period August 1975–July 1976 when ATS-6 satellite was positioned at 34° E (Rastogi et al., 1977, 1978; Chandra et al., 1979; Krishna Moorthy et al., 1979).

The scintillations arise for the most part from irregularities in the $F$-layer and is associated mostly with the nighttime phenomena whereas very rarely in the $E$-layer particularly sporadic $E$ and auroral $E$ and is associated with the day time scintillations. The correlation between nighttime scintillations and spread $F$ was reported by many workers (Ryle and Hewish, 1950; Wright et al., 1956; Bhargava, 1964; McClure, 1964; Frihagen, 1968; Bandopadhyoy and Aarons, 1970; Paul et al., 1970; Koster, 1972; Weber et al., 1978; Basu et al., 1980). Rastogi et al. (1990) have compared the scintillation results obtained during nighttime in the Indian zone with the corresponding data obtained from the American Sector. Also Rastogi (1980) compares in a similar manner the results taken during daytime in the Indian zone and American sector and found slow and weak fluctuations of about 1–2 dB in the American longitudes whereas 4–5 dB in the Indian zone and that these were associated with eastward electrojet currents. Many other workers (Lockwood and Petrie, 1963; McClure, 1964; Bramley and Browning, 1978; Rastogi et al., 1991) have proposed daytime scintillations caused mainly by $E$-region irregularities.

The $E$-region (100–120 Km) and $F$-region (200–1000 Km) of the ionosphere contain irregularities with scale sizes of the order of several hundred meters to a few kilometers, extending from the plasmapause through the trough to the polar cap (Ossakow, 1981; Tsunoda, 1981; Kersley et al., 1988, 1989). Several mechanisms have been proposed for the formation of irregularities of sub-kilometric size in the high latitude $F$-region which are responsible for the phase and amplitude scintillations (Kersley, 1989). The morphology of the medium scale irregularities is now well documented (Shimikazi, 1959; Singleton, 1960, 1968; Tao, 1965; Rodger and Aarons, 1988). The existence of ionospheric irregularities over a wide spectral range is well summarized by Booker (1979) as reproduced in Figure 1.

As the incoming signal traverses the ionosphere containing free electrons, a phase change occurs in relation to free space propagation along the same path. If, in addition, the ionosphere contains irregularities of plasma density, phase fluctuations build up across the wavefront. As the wave traverses away from the ionosphere, phase mixing occurs and fluctuations in amplitude develop. This concept can be used to study the observed phase and amplitude scintillations (Fejer and Kelley, 1980). The source of the wave appears to scintillate if it has very small angular size and that the bandwidth of the receiver is sufficiently narrow, otherwise its apparent angular size is broadened by the scattering phenomena. Booker (1956) and Ratcliffe (1956) were the first to put the theoretical aspects of ionospheric scintillations in terms of thin phase screen theory. The global morphology of ionospheric scintillations have been discussed by Aarons (1982) in