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Radio Star Scintillations in Equatorial Region

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ABSTRACT

The technique of obtaining information on ionospheric irregularities by observing scintillation of signal from discrete sources of radio noise is described. Work on scintillation carried out at a few equatorial stations in Ghana and Nigeria is briefly reviewed. Observations of radio star scintillation made at Kodaikanal, situated close to the magnetic equator, are described and the main features of rate of scintillation are broadly outlined.

INTRODUCTION

STUDIES of the phenomenon known as spread F, frequently observed in night-time vertical incidence ionograms, have made valuable contribution to our knowledge of irregularities in the F-region of the ionosphere. The nature of these irregularities has been studied by fading analysis of echoes also. The data obtained by these techniques, although valuable, are often of limited usefulness because the observations do not provide information on the ionospheric F-region above the level of maximum electron density. The technique of observing radio star scintillation is, therefore, admirably suited for understanding the nature of the irregularities irrespective of the height at which these are located. It is well known that the ionosphere contains clouds of ionization with electron densities different from those in the surrounding region and moving at speeds up to several hundred metres per second. The resulting irregularities impose phase variations on waves from the radio stars in their passage through the ionosphere. With different components of the wave combining at the ground, the received signal undergoes irregular fluctuations in amplitude as well as in the direction of its arrival. This phenomenon is particularly marked when the signal being observed is in the metre wavelength region. Radio star scintillation was observed as early as in 1946 by Hey, Parsons and Phillips[2] in the course of a survey of galactic radiation at a frequency of 64 Mc/s. The discovery of radio stars, sources of radio noise of small angular dimensions, followed with the discovery by Bolton and Stanley[1] of an intense source in the Cygnus region. That the fluctuations in the received signal resulted from its passage through irregularities in the terrestrial ionosphere was, however, established some years later by Smith, Little and Lovell[5]. As a result of the work on scintillation carried out at Cambridge and Manchester in England, in Australia and elsewhere considerable information has been added in the last decade to the knowledge of F-region irregularities. It is now known that the irregularities are located in the region of 200-400 km. and are elongated in the direction of the lines of force of the earth's magnetic field. While in the auroral region the irregularities are believed to be due to impact of particles responsible for aurorae, their origin in the middle and low latitudes has not been established with certainty. Scintillation is generally confined to night hours and is closely correlated with the ionospheric condition known as spread F.

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TABLE 1

Source	I.A.U. No.	Right Ascension hr. min.		Declination 0		Flux (W.m.^{2} cps^{-1} × 10^{-25})
Cassiopeia A	23N5A	23	21	58	32	1700
Cygnus	19N4A	19	58	40	36	1250
Taurus A	05N2A	05	31	21	59	190
Virgo A	12N1A	12	28	12	40	125

The perturbations imposed upon radio waves in their passage through the ionosphere consist of fluctuations in amplitude, known as ' amplitude scintillation ' and fluctuations in position called ' phase scintillation '. For carrying out analysis of scintillation records it is convenient to assign an amplitude index and a rate index over a given time interval. The amplitude index is defined as the ratio of mean deviation in intensity to the mean intensity. The rate index is proportional to the average number of peaks per minute. The amplitude of fluctuations is often noticed to exceed the amplitude of undisturbed trace; under disturbed conditions, the apparent position of a radio star has been known to shift by as much as half a degree.

The flux from radio stars in Cassiopeia and Cygnus being very large, these two sources are generally used for observing scintillation. The sources Taurus A and Virgo A, the flux from which is smaller by a factor of about 10, are also utilized for scintillation observations. The positions and flux densities at 100 Mc/s. from these four sources are given in Table 1.

EQUATORIAL OBSERVATIONS

In the equatorial region, scintillation observations have been made at Accra in Ghana, at Ibadan in Nigeria and at Kodaikanal in South India. The results of investigations carried out at the African equatorial stations have been reviewed by Koster and Wright[4]. The temporal, seasonal, solar cycle and geomagnetic activity variations of scintillation have been discussed in this review. Scintillation activity has been compared with related ionospheric phenomena such as spread F, flutter fading and doppler shift. From scintillation data obtained with spaced receivers additional information on ionospheric irregularities has been presented. The extent of irregularities, their height and velocity have also been estimated. Scintillation has been found to occur only during night and is generally very strong with its peak at about 2200 hrs. local time. Near solar cycle minimum, little correlation is observed between scintillation and magnetic activity; during high solar activity, when scintillation is also very strong, a high negative correlation has been found with magnetic activity. Scintillation has also been observed to be closely correlated with spread F. Kent[3], who conducted scintillation observations utilizing satellite signals, obtained similar results on scintillation correlation with spread F and geomagnetic activity. Seasonal effects in the African equatorial region are very marked with scintillation index being highest during autumnal equinox with a smaller peak at vernal equinox.

The irregularities responsible for radio star scintillation are known to be field-aligned and are horizontal in the equatorial regions. Large longitudinal anomalies exist in these regions. The strength of the earth's magnetic field is maximum in the

Far East and minimum in the American equatorial region. In the behaviour of several ionospheric characteristics such as equatorial type sporadic E, blanketing sporadic E and spread F, significant differences exist between the Far Eastern and American equatorial regions. In view of these anomalies adequate geographic coverage is necessary for a proper understanding of the phenomenon of equatorial scintillation.

KODAIKANAL SCINTILLATION OBSERVATIONS

By virtue of its proximity to the magnetic equator, Kodaikanal, where a solar observatory has been functioning for about 65 years, is ideally placed for geomagnetic, ionospheric and radio star scintillation observations. The magnetic observatory has been functioning continuously at this station since 1948. A vertical incidence sounding equipment (CRPL type C-3) was installed at this station in 1952. Since 1960 radio star scintillation observations have been made for three to five months every year. A radio interferometer, designed for registering solar radio emission during day time, has been utilized for recording noise from Cassiopeia A and Cygnus A. The antenna part of this interferometer, which is of low resolution, consists of twin-stacked Yagis with an east-west spacing of about 6 wavelengths. The receiver, locally designed, includes a low-noise converter followed by a high gain wide band intermediate-frequency amplifier, a second detector and a direct coupled amplifier. For scintillation observations, the driving clock work of the recording milliammeter is disconnected and the chart is driven by a small synchronous motor for a paper speed of about 18 in. per hour. With this speed, fluctuations with rates up to 8 per minute — the largest ever recorded at this station — are clearly resolved. Observations are made for about four hours each night with the antennas directed at the declination of the radio star under observation. From the records it was found that the amplitude of the scintillation was fairly constant over a 15 min. period centred at the peaks of the five central lobes of the interferometer pattern. Records of 15 min. duration from each of the five lobes were, therefore, used for reduction of data. Typical records of observed signal from Cygnus A with strong and moderate scintillation and with low scintillation rate are shown in Fig. 1. The results summarized in this paper are based on scintillation rate data obtained from observations of Cygnus A from 1960 to 1963. The rate of scintillation is related to the velocity of the irregularities and is a good measure of the drift speed. Processing of records for amplitude indices is now in progress and the results will be published elsewhere in due course.

At the latitude of the observing station at Kodaikanal, Cygnus is above the horizon for just over 13 hrs. However, to limit the observations to five central lobes of the interferometer pattern the registration of flux from Cygnus was restricted to about 4 hrs. centred around transit. It is worth mentioning here that the ionospheric region observed by its scintillation activity is at a distance from the observing station which depends upon the latitude of the place, declination of the source and the hour angle. For instance, when the hour angle of Cygnus is 0200 or 2200 hrs. the points of intersection of the line of sight with ionosphere at 300 km. are both at a distance of 387 km. along the line of sight. This distance reduces to 345 km. at transit. The corresponding points at ground, vertically below the points of intersection, are at distances of 239 and 167 km. respectively. The minimum distance between the part of the ionosphere at 300 km. height which is observed by vertical sounding and the region observed by

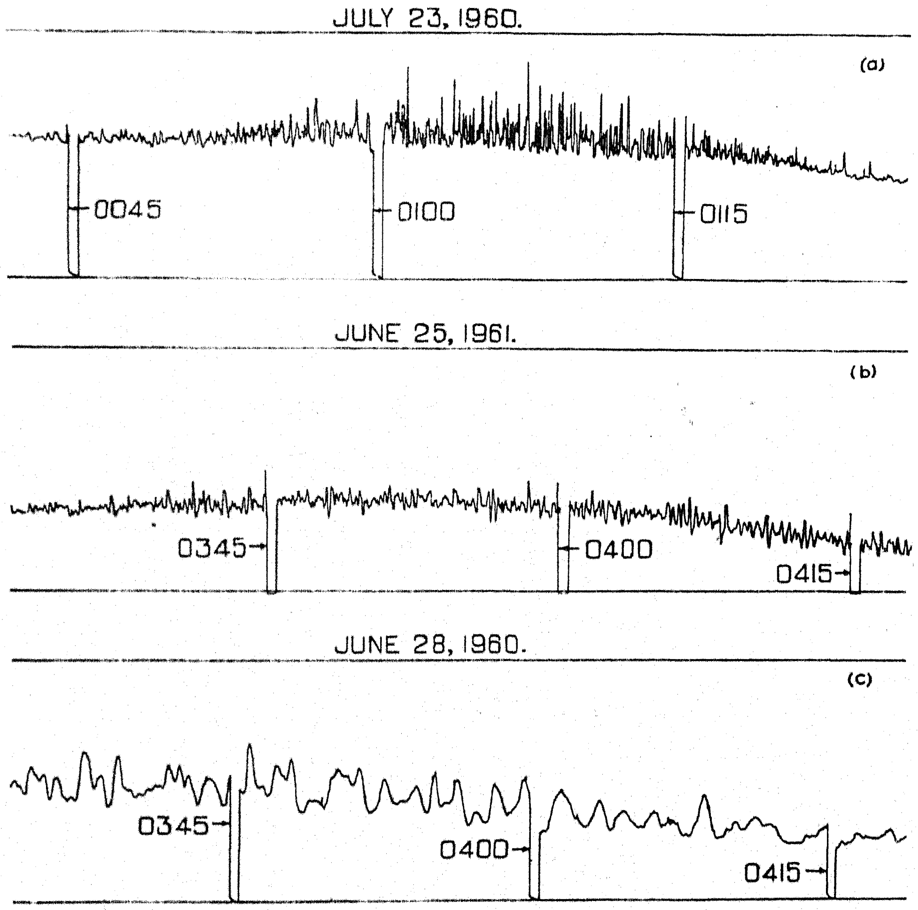

Fig. 1 — Typical scintillation records at Kodaikanal [(a) strong scintillation, (b) moderate scintillation, and (c) scintillation of low rate but large amplitude]

scintillation of signal from Cygnus A is 167 km. In view of this an attempt at correlation between scintillation and characteristics observed by vertical sounding is of limited value. In the present report the correlation between scintillation rate and spread F has, therefore, been attempted only using data around transit when the zenith angle is smallest.

SCINTILLATION RATE AT KODAIKANAL

Scintillation observations from Cygnus during night were possible only during summer months and the results, which are summarized below, are representative of the summer conditions only.

(i) Scintillation rates depend on many factors such as zenith angle of the source, time of observation, spread F index and magnetic activity. The largest rates observed at this station were about 8-9 per min. Lowest rates of scintillation were of the order of 0·5 per min.

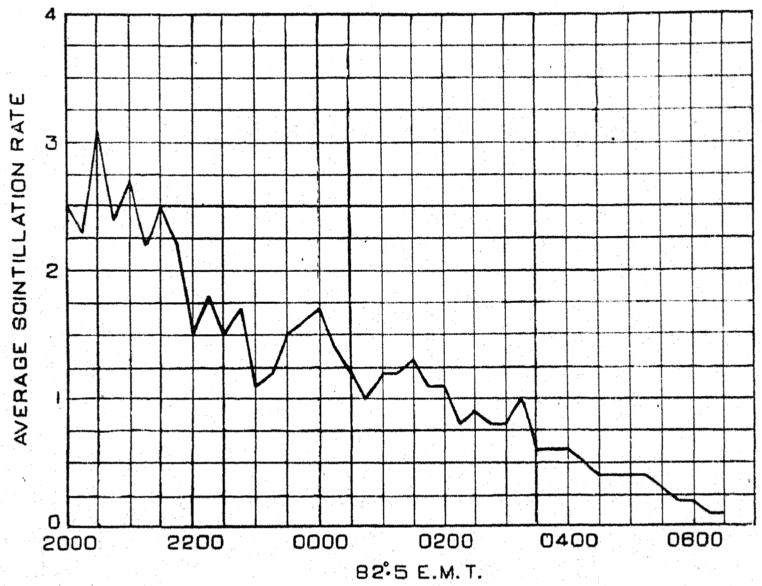

Fig. 2 — Variation of scintillation rate with time

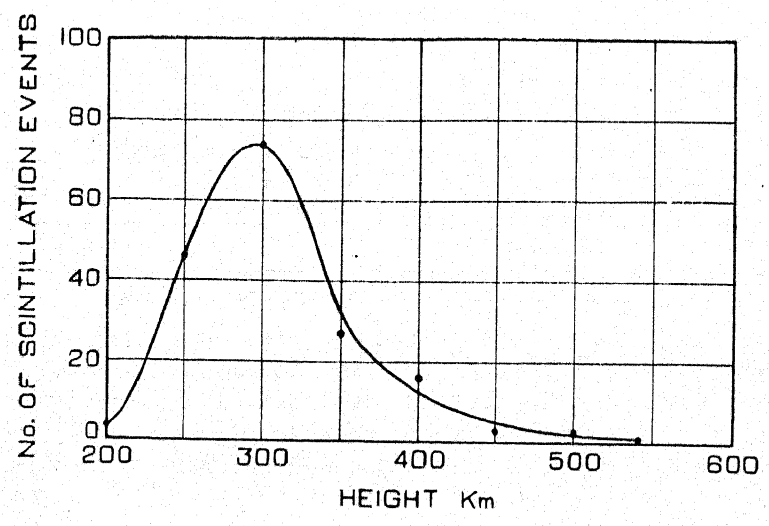

Fig. 3 — Variation of scintillation occurrence with F-layer virtual height

(ii) Scintillation rates were highest between 2000 and 2200 hrs. I.S.T. The rate progressively decreased to a very low value in the early morning. The diurnal variation of scintillation rate, shown in Fig. 2, has been computed from all available observations during the 4-year period.

(iii) Scintillation rate followed decrease of solar activity from 1960 to 1962. While solar activity decreased further in 1963 scintillation rates remained practically unaltered.

(iv) The frequency of scintillation occurrence was highest when the minimum virtual height of the F-layer was about 290 km. This is shown in Fig. 3. Scintillation decreased rapidly when the height of F-layer was in excess of 300 km.

(v) Average scintillation rate increased with spread F index. The spread F index obtained from inspection of ionograms (on a scale of 0-3) was computed for every interval for which scintillation rate was available. The rate of increase in scintillation rate was highest for spread F index greater than one. This is shown in Fig. 4. A significant difference between diurnal variations of scintillation rate and spread F has, however, been noticed. Maximum rate of scintillation has been observed to occur several hours before the maximum spread F.

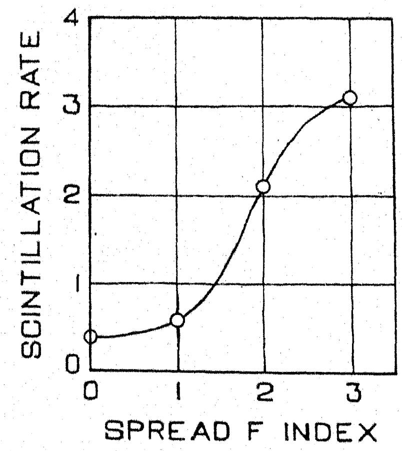

Fig. 4 — Variation of scintillation rate with spread F index

(vi) The fluctuation index at a location generally increases with increase in the zenith angle of the source because the length of the path through the ionosphere is proportional to the secant of the zenith angle of the source. Observations at Cambridge have indicated a steep rise in the fluctuation index when the zenith angle exceeded 40°. At Kodaikanal the zenith angle of the source in Cygnus is 30°22′ at transit and two hour prior to or after transit it is 40°17′. The change in zenith angle during the observing time of 4 hrs. is, therefore, small and is not adequate to determine the change in scintillation rate with zenith angle. However, the available data analysed for zenith angle variation, indicate a small increase in the rate as the zenith angle changes from 30°22′ to 40°17′.

Day-time scintillation has not been observed at Kodaikanal with any degree of reliability. In a recent review Koster and Wright[4] have stated that day-time scintillation does occur in equatorial regions. They have illustrated an unusually regular type of day-time scintillation and have stated that it is closely related to disturbances of equatorial electrojet. At Kodaikanal, excursions similar to the one illustrated by these authors have been observed in the output of the 100 Mc/s. radiometer during the afternoon hours and have generally been found to occur simultaneously with the disappearance of equatorial sporadic E. On careful examination, the oscillations in the trace have been traced to periodic fading of signal from a broadcast station radiating close to the I.F. of the radiometer. Small random fluctuations do appear on radiometer records on some occasions. It is, however, not possible to associate these with irregularities in the ionosphere with any degree of certainty.

REFERENCES

1. Bolton, J. G. & Stanley, G. J., *Nature, Lond.*, **161** (1948), 312.
2. Hey, J. S., Parsons, S. J. & Phillips, J. W., *Nature, Lond.*, **158** (1946), 234.
3. Kent, G. S., *J. atmos. terr. Phys.*, **22** (1961), 255.
4. Koster, J. R. & Wright, R. W., *Radio Astronomical and Satellite Studies of the Atmoshere*, edited by Jules Aarons (North-Holland Publishing Company, Amsterdam), 1963, 114.
5. Smith, F. G., Little, C. G. & Lovell, A. C. B., *Nature, Lond.*, **165** (1950), 422.