551.510.535

Observations of spread echoes from the *F* layer over Kodaikanal—A preliminary study

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(Received 19 February 1957)

ABSTRACT. Occurrence of spread *F* echoes at Kodaikanal for a period of about one year has been analysed and diurnal and seasonal characteristics have been found to exist in the frequency of occurrence of these echoes. It has been found that the phenomenon occurs only during night-time with largest frequency between 1900 and 0400 hrs local time. While the seasonal variation is characterised by equinoctial maxima as in the case of geomagnetic activity, the day-to-day variations in scattering indicate a negative correlation with the degree of magnetic activity. Thus, scattering persists for largest percentage of time during comparatively quiet periods and is often altogether absent on magnetically stormy nights. The phenomenon is discussed in relation to ionospheric irregularities and radio-star scintillation.

1. Introduction

Studies of spread *F* have been made by several workers who have discussed the diurnal, seasonal and sunspot cycle characteristics of these echoes, their variation with latitude, with geomagnetic activity and their relationship with ionospheric irregularities and radio-star scintillation. Booker and Wells (1938), who analysed the diffuse night-time echoes at Huancayo, interpreted them as due to Rayleigh scattering caused by spatial irregularities in electron density distribution. Osborne (1951) indicated large changes in layers' apparent height after sunset, preceding the onset of scattering at Singapore. Wells (1954) found that at Huancayo, scatter is maximum when the sun is overhead but he failed to find any close relationship to solar activity. Reber (1954) discussed the diurnal and seasonal variation of spread *F* over Hawaii, Washington and six other stations. Maxwell (1954) obtained a value of 300 for Reynold's number for the upper *F* region from available data on mean free path and kinematic viscosity and suggested that spread *F* may be due to diffracting screens caused by non-laminar flow as a result of turbulence at night-time. In a recent paper considerable correlation between spread *F* and radio-star scintillation has been found by Wright, Koster and Skinner (1956). They find that the diurnal and seasonal characteristics of spread *F* over Ibadan show considerable relationship with geomagnetic disturbance.

Over Kodaikanal (geomagnetic latitude 0·6°N) intense scatter has been observed during most nights since September 1955 when night-time *h'f* observations commenced. A preliminary study of diurnal and seasonal characteristics of the scatter and its relationship with the degree of geomagnetic activity has been made in this paper. For a few months for which Singapore data are available, day-to-day scatter at the two stations has been compared. The data for Kodaikanal have been derived from *h'f* records made at half-hour intervals and those for Singapore have been taken from *Ionospheric Characteristics* published by Radio Research Station, Slough.

2. Type of Scatter

Dieminger (1950) has classified the scattering observed by him into four main types *E*, 1*F*, 2*F* and *G*. The scatter at Kodaikanal is predominantly of the type 1*F* of Dieminger classification, but *G* scatter has also been observed on some occasions when echoes of a diffused nature have been received at frequencies greater than the

F layer critical frequency. The onset of scatter is rather abrupt after sunset and is often preceded by forked traces near critical frequencies and splitting of the layer into two distinct layers indicating horizontal gradient in electron density. On a few occasions, spread echoes are restricted to the lower frequency or the higher frequency ends of the $h'f$ traces, but on most nights these are observed over a wide range of frequencies when the layer structure is completely diffuse with no trace of group retardation. A few Kodaikanal ionograms illustrating scatter of different types are reproduced in Fig. 1.

3. Diurnal and Seasonal Characteristics

The scattering appears to be closely related to F layer height changes at Kodaikanal. Commencing at about 1700 hrs the virtual height increases rapidly for about two and a half hours when it reaches a maximum. The average increase in virtual height for equinoctial months was found to vary from 60 km in September 1955 to 170 km in March 1956. Scattering appears to closely follow these changes in height and attains a maximum about half an hour after the maximum in height. The variation of scattering and $h'F2$ is shown in Fig. 2. It would be seen that the virtual height returns to normal by about midnight but scattering persists until early hours of the morning. This pattern of the diurnal variation in scatter is practically same throughout the year.

For seasonal variation of scatter, the total number of hours, during which scatter was present, was obtained for every month using hour-hourly $h'f$ record. This variation, shown in Fig. 3, indicates that there are predominant maxima during the equinoctial months. It appears to be a characteristic of individual station and is different for different low latitude stations. The variation at Kodaikanal is practically identical to that at Singapore, but differs from that at Huancayo and Ibadan where maximum scatter occurs in local summer. At four temperate latitude stations in Japan maximum scatter has been reported to occur during the solstices. Kasuya, Katano and Taguchi (1955) have also shown that for these four stations an inverse correlation exists between scatter and monthly mean noon $F2$ layer critical frequency. This correlation again appears to be characteristic of these stations; at Kodaikanal, maximum scatter occurs during equinoxes while the F layer critical frequency has somewhat different seasonal characteristics as shown in Fig. 3.

While many features of scatter at Kodaikanal differ from those at Huancayo and Ibadan, there is some evidence of similarity of these features with those at Singapore—including changes in the heights of the layer preceding onset of scatter and diurnal and seasonal variation. Although the percentage of time scatter present appears appreciably higher for Kodaikanal than at Singapore for corresponding period, there is, for certain months, great similarity in day-to-day occurrence of scatter. The daily percentage of scatter at these two stations for part of September 1955 is shown in Fig. 4.

4. Geomagnetic Disturbances and Scatter

From published work it appears that scatter and geomagnetic activity show different relationship at different stations. Thus while Booker and Wells (1938) found that at Huancayo no obvious correlation with geomagnetic activity existed, Kasuya, Katano and Taguchi (1955) who compared the magnetograms of Kakioka Magnetic Observatory with spread F for the corresponding period at four Japanese stations, found that one particular type of spread F was observed at the time of the main phase of the magnetic storm. Wright, Koster and Skinner (1956) who have investigated the phenomenon at Ibadan find that for winter months there is markedly decreased scatter with increased geomagnetic activity, in summer there is slight increase in scatter with increase in Kp and during equinoxes there is no significant difference.

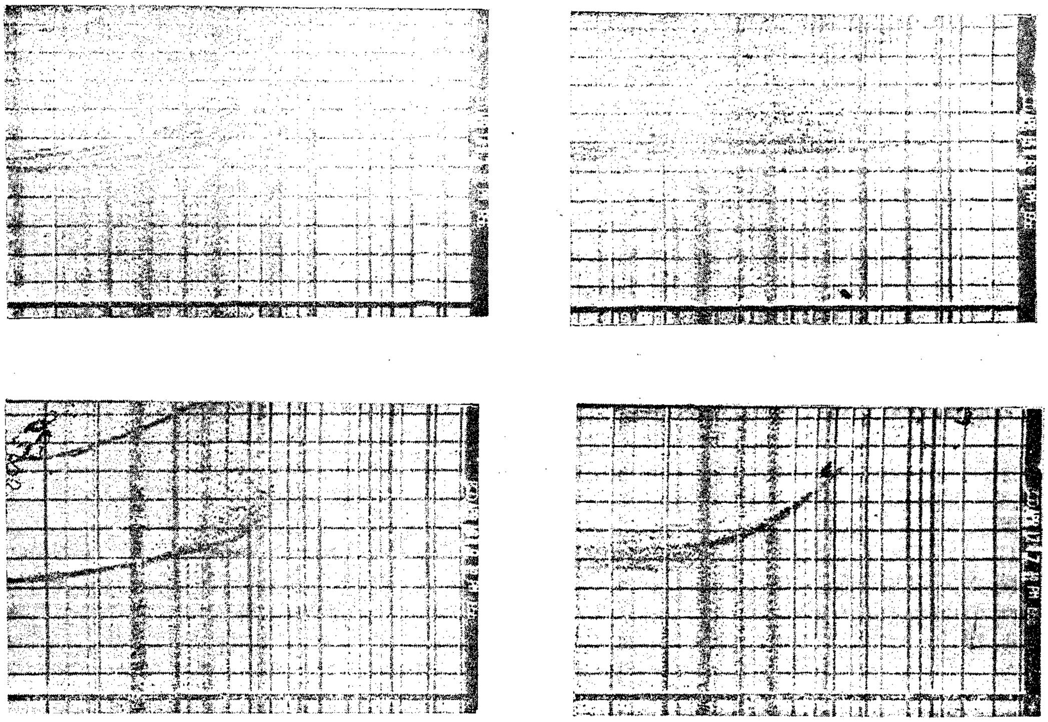
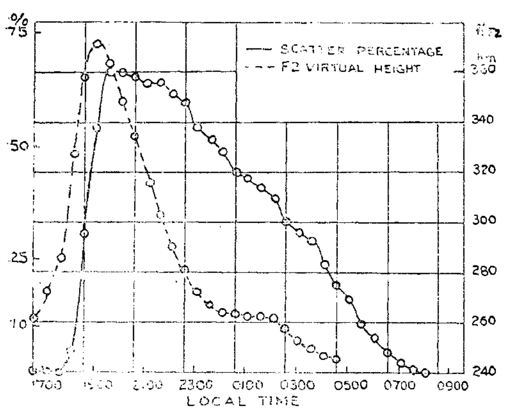


Fig. 1. Ionograms illustrating scatter of different types



2. Diurnal variation of scatter and $h'F2$

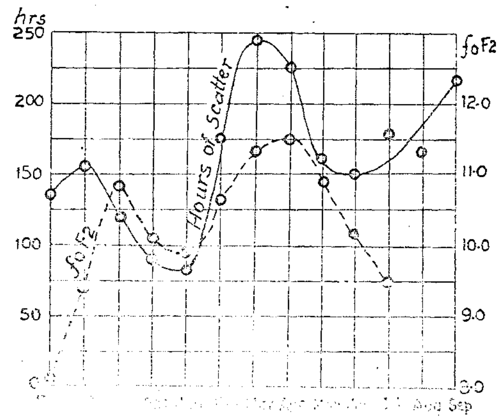


Fig 3. Seasonal variation of scatter and of $foF2$

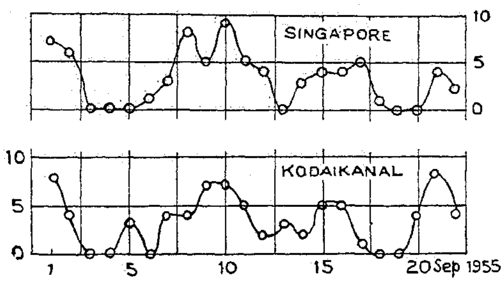


Fig. 1 Day-to-day variation of scatter at Singapore and Kodaikanal

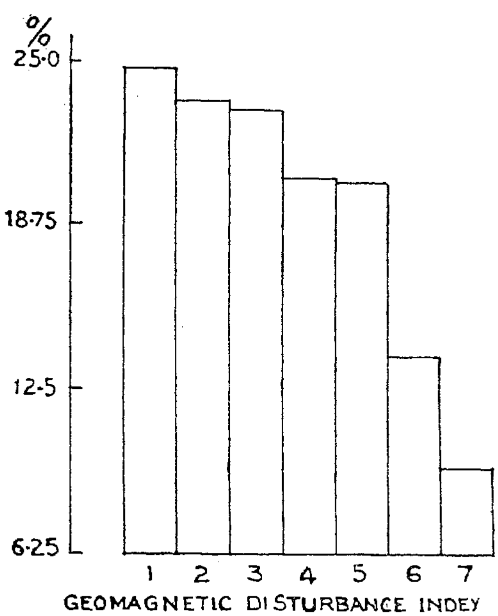


Fig. 6. Percentage of scatter and geomagnetic disturbance index

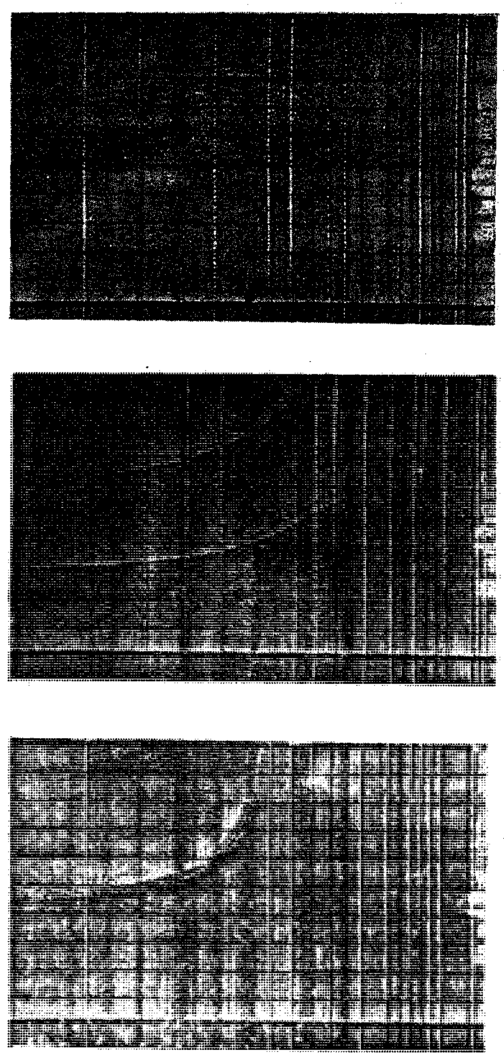
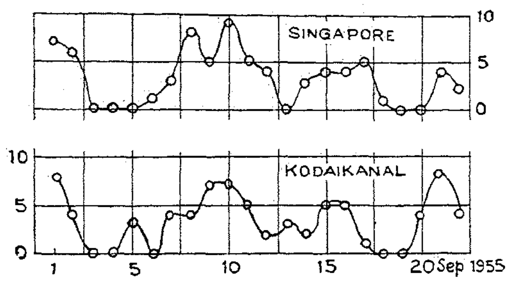


Fig. 5. Kodaikanal ionograms on the nights of 24, 25 and 26 February 1956



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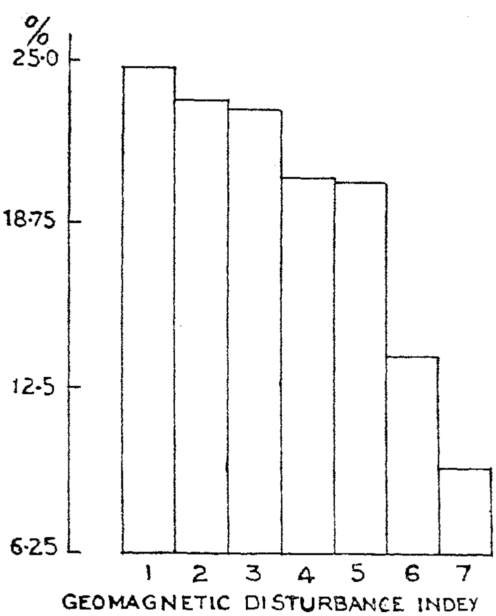
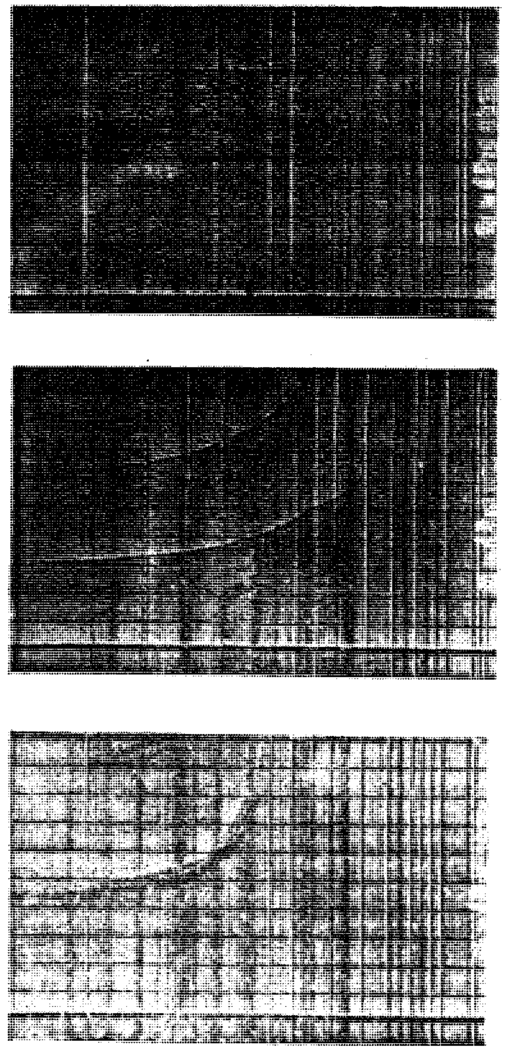


Fig. 6. Percentage of scatter and geomagnetic disturbance index



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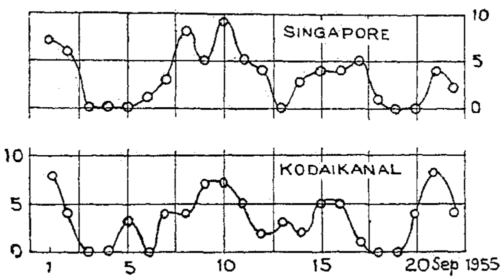
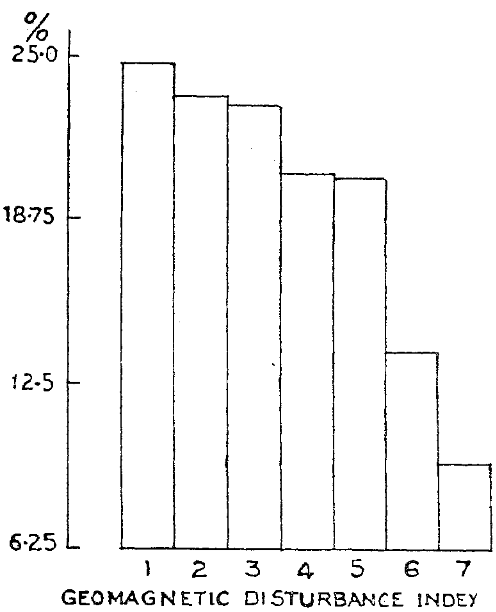


Fig. 4 Day-to-day variation of scatter at Singapore and Kodaikanal



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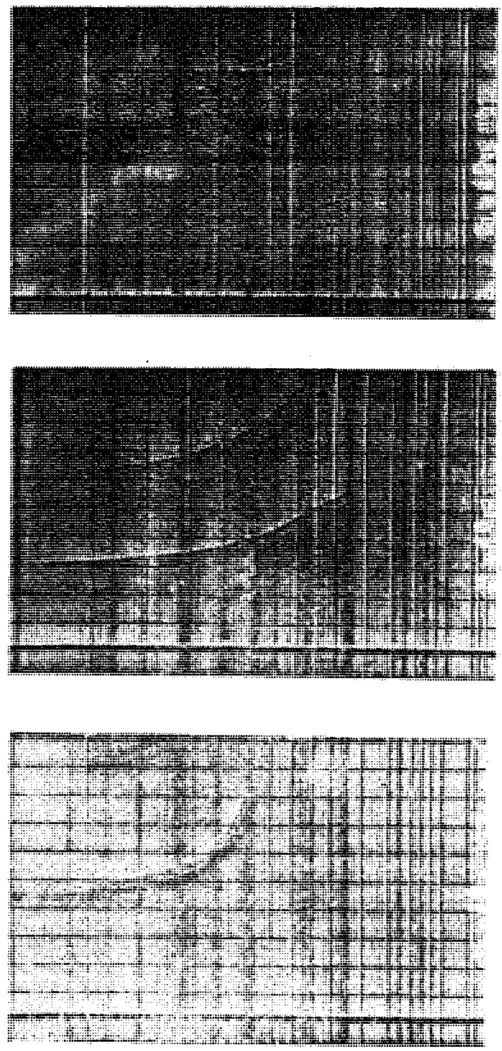

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At Kodaikanal, the effect of geomagnetic activity on scatter came at once into notice when it was found that when a severe magnetic storm commenced on a particular day, the succeeding night was completely free of scatter. For example, during February 1956, spread *F* existed on all nights except on the 25th on which date a severe magnetic storm began, the International Magnetic Character-figure for the day being 2·0. Similar absence of scatter during the main phase of a storm has been noticed on many occasions. Fig. 5 shows Kodaikanal 2030 hr ionograms on 25 February and the preceding and succeeding nights.

In order to find if a definite relationship existed between scatter and the degree of geomagnetic activity, 233 days, for which International Magnetic Character-figures were available, were classed into seven groups designated from 1 to 7, group 1 corresponding to C-figures between 0·0 and 0·2, group 2 for C-figures between 0·3 and 0·5 etc. The percentages of time scatter observed on days in each group were averaged. These averages are shown in Fig. 6. It will be seen that upto C-figures of about 0·8 there is progressive but slight decrease in scatter with increase in geomagnetic activity. With C-figures greater than 0·8, there is a more rapid decrease in scatter and for highly disturbed days, scatter is negligible. While, to some extent, this result is in agreement with that at Ibadan, there is no agreement with the third low latitude station of Huancayo. Further, there is apparently a reversal of the relationship between the low latitude stations of Kodaikanal and Ibadan and the temperate latitude stations in Japan.

Different hypotheses have been put forward to explain the absence of scatter during day-time or its occurrence only during nights. According to Maxwell (1954) it is so because of reduced turbulence due to large temperature gradient, lower drift velocities or increased kinematic viscosity during day-time. The other explanation of this behaviour attributes scatter to interception of extra-terrestrial matter, moving in the gravitational field of the sun, by earth on the dark side of the atmosphere. It is worth mentioning here that the shape of diurnal variation of scatter at Kodaikanal has been found to be nearly similar during different months of the year and as Ryle and Hewish (1950) state, it would indicate that the relative motion of solar system and interstellar matter is small compared with the earth's orbital velocity. Another interesting observational fact is that, almost throughout the year, maximum scatter occurs not at local midnight, as one would expect, but about three hours earlier.

As stated earlier, the scatter occurrence is inhibited by increased geomagnetic activity at least at some of the low latitude stations. During past few years, there is definite evidence to show that spread *F* and radio-star scintillation are both caused by ionospheric irregularities. The observations of Ryle and Hewish (1950) indicated definite diurnal variation in radio-star scintillation with a maximum at about 0100 hour. Little and Maxwell (1951) and Wright, Koster and Skinner (1956) have found a high correlation between radio-star fading and spread *F*. Wells (1954) observed that while there was no seasonal variation in radio-star fading at Huancayo, the diurnal characteristics of the two phenomena were in good agreement. If, therefore, the two phenomena originate from a common mechanism, considerable agreement should exist in their diurnal and seasonal variation and relation with geomagnetic activity. For no single station such an agreement appears to exist. Observations of geomagnetic disturbances, of the ionosphere at vertical incidence, ionospheric irregularities and drifts and of fading of radio-star source near zenith, all at the same station, are likely to result in a better understanding of the phenomena.

5. Scatter and Radio Propagation

F scatter appears to have considerable importance from the point of view of radio propagation. During intense scatter at Kodaikanal no estimate of critical frequencies and *MUF* factors is possible. Received field strengths also appear to be considerably affected by scatter. The recordings of field intensity of station WWVH have been made at 15,000 Kc/sec at Kodaikanal since November 1955. The signal from this station, located in Hawaii, is normally weak until about 1400 hr local time but increases rapidly after that time and continues to be strong until after midnight. On many days the signal strength undergoes severe fading at about 1800 hr and continues to be weak for fraction of an hour to several hours. It is very likely that these changes in the signal strength of WWVH are associated with scatter in the *F* region at one or the other reflection points along the great circle path.

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J36DGOB—3—330—8-0-58—GIPS