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Occurrence of M & N Echoes at the Equatorial Station, Kodaikanal

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In quarter-hourly ionograms of Kodaikanal, close to the magnetic dip equator, for the period January-December 1968, M and N echoes occur in association with the Es configuration characteristic of the equatorial zone. Also one notices either an isolated M echo or a combination of M and N echoes but rarely an isolated N echo. The M and N echoes together occur mostly with blanketing Es and is basically a post-noon event whereas the M echo occurs usually with equatorial Es and is a pre-noon event with a characteristic seasonal variation.

1. Introduction

IT IS WELL KNOWN that the occurrence of sporadic E is a regular daytime feature of the equatorial ionosphere and usually manifests itself in the two configurations, equatorial sporadic E and equatorial slant sporadic E. The blanketing poradic E, characteristic of temperate latitudes, whose origin is ascribed to the vertical convergence of ionization due to vertical shears of horizontal neutral winds in the E region, is not expected to occur at and close to the dip equator due to the ineffectiveness of the ion convergence mechanism at these latitudes.[1,2] However, observational evidence exists to indicate that blanketing sporadic E does occur at and around the dip equator and alternative mechanisms have been proposed to account for this feature[3,4].

Owing to the partial transparency of the sporadic E layers, ray paths for multiples are sometimes complicated giving rise to reflections which are termed M and N echoes. The virtual heights of the M and N traces (h' M and h' N) are, assuming the Es layer thickness to be negligible, given as

$$h' \mathrm{M} = 2\,h' \mathrm{F} - h' \mathrm{E_s}$$

$$h' \mathrm{N} = h' \mathrm{F} + h' \mathrm{E_s}$$

It has been reported earlier that M echoes occur in the temperate zone for about 80-90 percent of all E_s occurrences and that they never occur with the two configurations of sporadic E at equatorial latitudes, i. e. equatorial sporadic E and equatorial slant sporadic E[5]. Bhargava and Saha[6] were the first to observe that M and N echoes did occur at equatorial latitudes. Very little work has been done either on the morphological characteristics of the M and N echo occurrence or the relevant theoretical aspects. In fact, Ratcliffe[7] suggested that attention should be paid to the observation and theory of M echoes in his final remarks of 1957 AGARD conference of sporadic E ionization. We present here the resul of a study on the occurrence of M and N traces o ionograms at the equtorial station, Kodaikanal (lat 10° 14′; long, 77° 28′ E; magnetic dip., + 3·5°) an its association with the various sporadic configurations.

2. Observations and Results

The quarter-hourly ionograms taken at Kodai kanal with a C-3 ionosonde during January-Decem ber 1968, a period of high solar activity, have bee examined to work out the morphological character stics of the occurrence of M and N echoes and it association with the different types of sporadic l layers. The ionogram data showed the occurrence o 187 events of M and N echoes, the total duration o an event ranging from 30 min to 9 hr. Very fain traces of M and N type have been left out and onl clearcut cases where M and N traces are sufficientl intense compared to the fundamental traces hav been taken into account. Out of the 187 event observed, 99 events were characterized by the pre sence of an M echo alone on the ionogram whereas the rest 88 were characterized by the presence o both M and N traces and in some cases even by their multiples. The M echo occurs frequently during January, February and March while the M and N echoes together occur frequently during the months of local summer : May, June, July and August, as can be seen from Fig. 1. It is to be clarified here that the poor quality of ionogram data for the months of June and July did not permit us to evaluate the exact number of the occurrence of M and N echoes during these months and this is responsible for the low frequency of occurrence of M and N echoes during June and July as shown in Fig. 1. The number of occurrences of M and N echoes was considerably longer in June and July of the preceeding

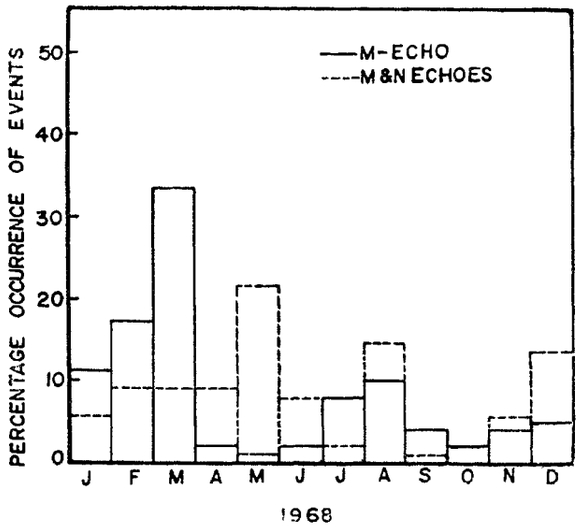

Fig. 1—Histogram of the monthly occurrence of M and M and N echoes on ionograms at Kodaikanal

and succeeding years, i. e. 1967 and 1969. In Fig. 2 is shown the local time variation of the percentage occurrence of M and N echoes during the D (January, February, November and December), E (March, April, September and October) and J (May, June, July and August) months, to infer the diurnal and seasonal behaviour. Two points may be noticed from Fig. 2. Firstly, the occurrence of M echo is mostly a pre-noon event with a maximum around 1000 hrs LT while the occurrence of M and N echoes is invariably a post-noon event with a maximum between 1500 and 1600 hrs LT. Secondly, there is a seasonal variation in the occurrence of M echo in that the pre-noon maximum observed during the D and E months is shifted to post-noon period during the J months. It is to be recalled here that the occurrence of blanketing sporadic E at Kodaikanal is maximum during local summer[3] and that close to the dip equator blanketing sporadic E layers occur during daytime after 1500 hrs local time in more than 90 per cent of the cases[4]. These features clearly indicate the close association between the simultaneous occurrence of M and N echoes on ionograms

Table 1—Statistical Details of the Association of M and N Echoes with Various Types of Sporadic E Layers at Kodaikanal

Type of event	Total number of events	Number of events associated with Equatorial sporadic E	Equatorial slant sporadic E	Blanketing sporadic E
M echo	99	93	2	4
Simultaneous M and N echoes	88	6	2	80

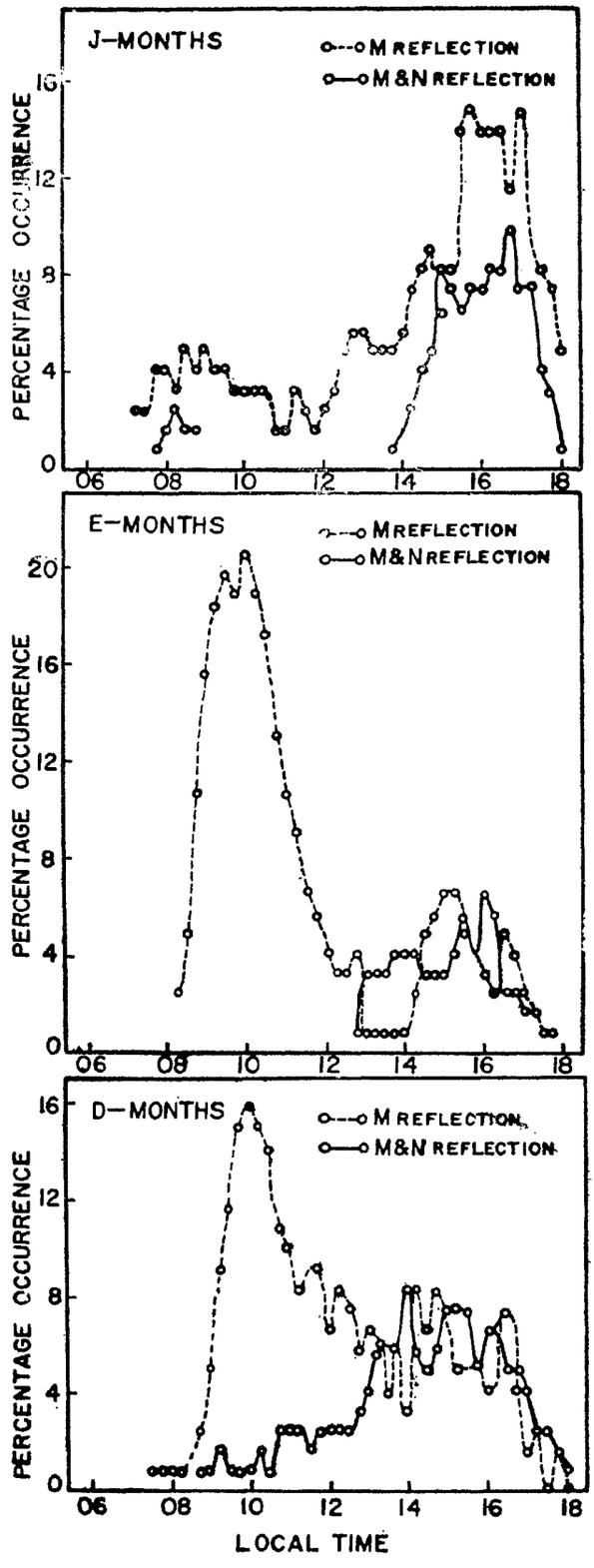

Fig. 2—Diurnal variation of occurrence of M and simultaneous M and N traces on ionograms during D, E and J months

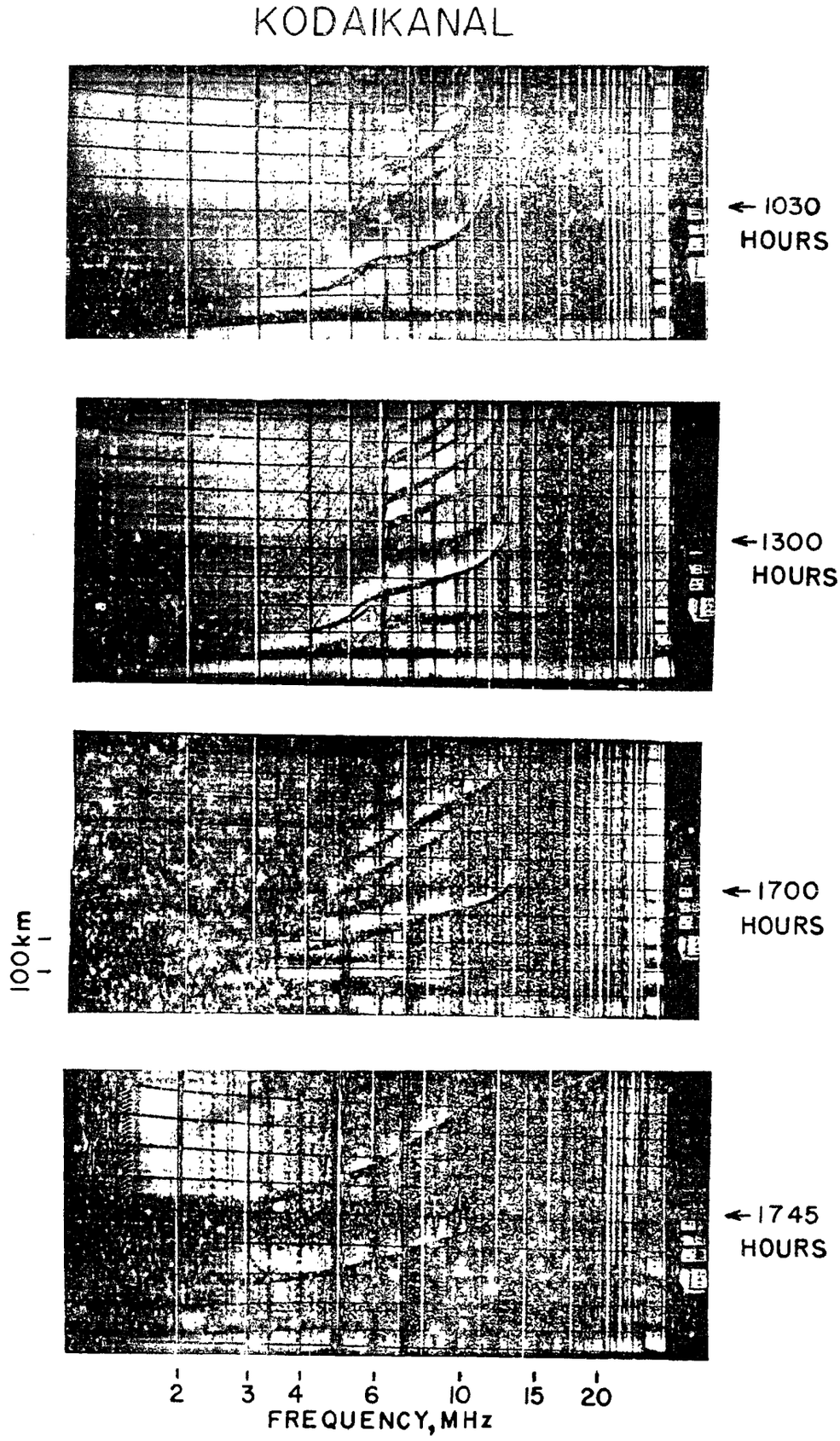

Fig. 3—A typical sequence of ionograms showing the occurrence of the M and N event on February 15, 1968

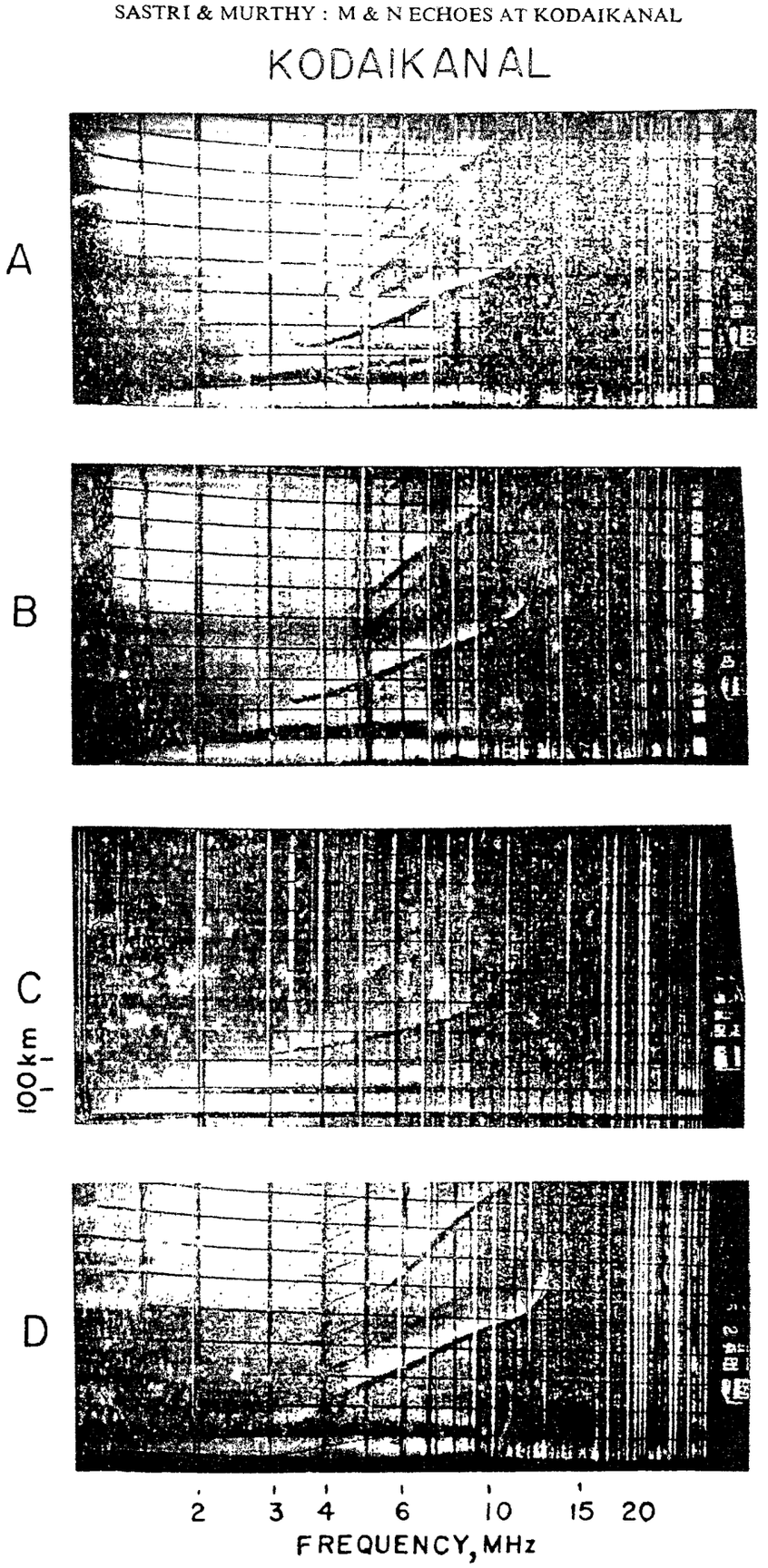

Fig. 4—Miscellaneous aspects of the occurrence of M and N traces with various Es configurations (A, M and N with slant and blanketing Es; B, M and N with equatorial Es; C, M with blanketing Es; D, N with equatorial Es)

and blanketing sporadic E which is further supported by the results presented below. Table 1 presents the statistical aspects of the association between the occurrence of M echo and of simultaneous M and N echoes and the three types of Es configurations near the dip equator. It may be seen that the combined presence of M and N echoes on ionograms occurs with blanketing sporadic E in about 90% of the cases whereas the M echo alone occurs with equatorial sporadic E in about 94 percent of the cases.

The occurrence of the M and N traces together on the ionograms at Kodaikanal usually follows the following sequence, a typical example of which is shown in Fig. 3. At 1030 hrs only an M echo is seen in association with equatorial sporadic E. The sporadic E configuration then changes and develops into a blanketing layer characterized by multiple reflections and the M and N echoes appear (1300 hrs). Near the end of the event the sporadic E configuration reverts back to that of equatorial type and only M echo is seen (1745 hours). In Fig. 4 are presented some ionograms that illustrate the various aspects of the occurrence of M and N echoes with different types of sporadic E layers. The ionogram shows the occurrence of M and N echoes with both blanketing and slant sporadic E configurations (A); which is a rare event, and with equatorial sporadic E (B); the occurrence of M echo with blanketing sporadic E (C), and the occurrence of N echo with equatorial sporadic E (D), which again is a rare event.

3. Conclusions

M and N echoes do occur on ionograms close to the magnetic dip equator in association with the E_s configurations that are characteristics of the equatorial zone. Their occurrence is characterized by the presence of either an M echo or a combination of M and N echoes and rarely as an N echo. The M and N echoes together occur mostly with blanketing type sporadic E layers and is basically a post-noon event whereas the M echo occurs with equatorial sporadic E and is a pre-noon event with a characteristic seasonal variation.

It is still a matter of speculation as to how an upgoing or down-coming radio wave could suffer simultaneous reflection at different levels in the ionosphere giving rise to the M and N traces on the ionograms in addition to the fundamental traces. It is known that sporadic E layers are semi-transparent and give rise to partial reflections over the frequency range between the blanketing frequency fbEs and top (penetration) frequency ftEs and is understood to be due either to reflection from sharp electron density gradients or to scattering from small scale weak irregularities in Es[8]. A study of the propagation of radio waves through regions of thin layers with sharp electron density gradients might help to understand the physical processes that are responsible for the occurrence of M and N traces on ionograms.

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