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Ionospheric propagation of Atmospherics

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ABSTRACT. With the equipment described in an earlier communication numerous waveforms of atmospherics in the frequency region 50 c/s to 300 kc/s have been reported at this station during the period April 1957 to December 1958. A large number of these show a multi-hop propagation and the results of measurements of these waveforms are analysed and presented in this paper.

It is found that the height of the reflecting layer varied from about 55 km to about 120 km but most frequently it lies between 80 and 90 km. The frequency distribution curve of height is skew and has a tendency to show Gaussian distribution around two values, *viz.*, 60 and 90 km.

Similarly the distance of the source of atmospherics varied from about 200 to 2000 km. The frequency distribution curve in this case shows principal peaks at about 750 and 1750 km with subsidiary peaks on either side of these. This trend is also shown by the individual monthly histograms for distances. Further, when separate histograms were drawn for distances which were associated with a height of 60 km and those that were associated with a height of 90 km it was found that the two principal peaks at 750 and 1700 km were prominently shown by the 90-km group alone and only the first peak was shown by the 60-km group, thus indicating a preponderant role of the upper layer.

This statistical distribution of distances has been interpreted qualitatively with the help of Holingworth interference pattern of field strength.

When heights of the reflecting layers are plotted against the corresponding source distances, it is seen that the height increases rapidly at first and then gradually reaches a limiting value around 95 km. However, other evidence shows that there exist two reflecting layers, one at about 60 km and the other at about 90 km.

The reflection coefficient of the ionosphere varied from 0·4 to 0·9 or more. Occasionally even smaller values upto 0·25 were also observed. The reflection coefficient is higher in winter than in summer.

1. Introduction

Experimental investigations on different aspects of atmospherics in the low and very low frequency regions are being carried out at Poona station (Lat. 18° 31′ N and Long. 73° 52′ E) since 1954. The study of waveforms of atmospherics is one of these aspects and a preliminary account of this has already been published earlier (Chiplonkar *et al.* 1958). In this paper we further present and discuss the results of analysis of the data obtained during the period April 1957 to December 1958.

2. Experimental and method of observation

Fig. 1 shows the experimental set-up used to record the waveforms of atmospherics at the station. Atmospherics received on a T-type of aperiodic aerial with an effective height of about 60 ft, were amplified by a wide band push-pull amplifier (see the circuit diagram in Fig. 2). The response of the amplifier is flat over the range 50 cycles/sec to 300 kc/sec as shown in Fig. 3. The output of the amplifier was given to the vertical deflecting plates of a C.R.O. (DuMont 304 with a short persistence blue screen). The waveforms were recorded photographically on a moving drum camera with an aperture of $f/1{\cdot}5$. The drum was driven by a synchronous motor and the speed of the rotation of the drum was checked to be constant by a stroboscope; and thus a time resolution of about 50μ sec per millimetre was obtained. Special circuits for automatically controlling the brilliancy of the C.R.O. beam and maintaining it at a high value for a definite period (1/50th of a second) were incorporated. In order to prevent overlapping of successive traces of atmospherics coming in quick succession, an automatic arrangement was devised to move the drum axially by about 1 cm after each atmospheric was recorded.

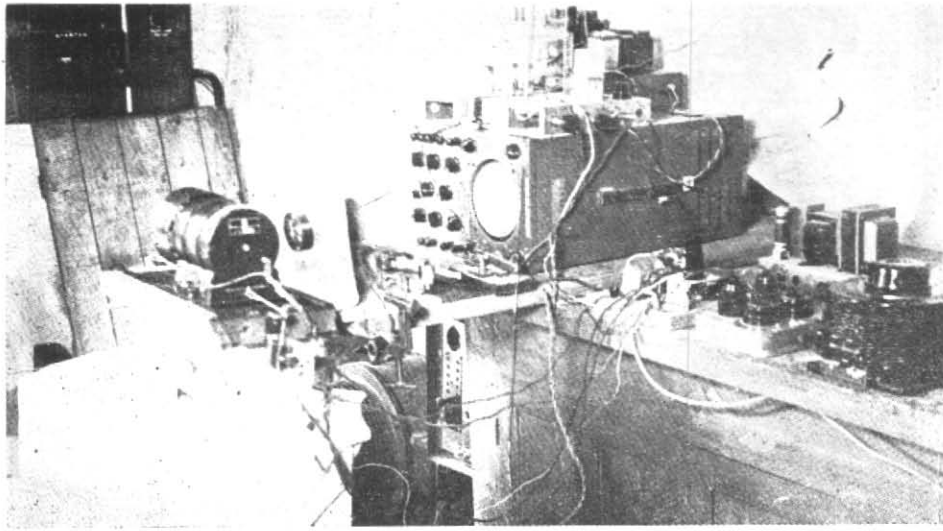


Fig. 1. A general view of the experimental arrangement used for recording the waveforms of atmospherics

The C.R.O. is seen in the centre ; above it are the main amplifier and triggering units; the synchronous motor with the rotating drum is on the extreme left ; the camera lens is in between these two ; the electromagnetic clutch is in the foreground near the drum

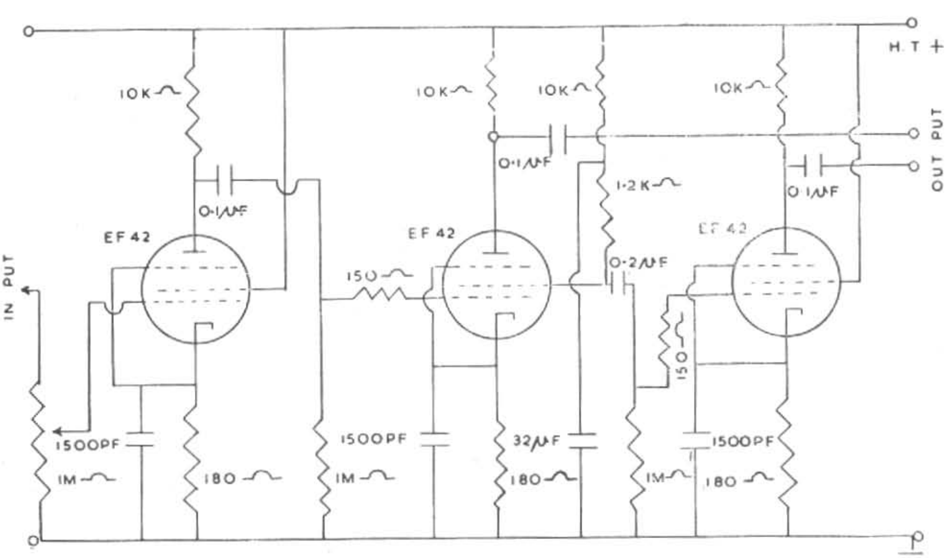


Fig. 2. Circuit diagram of the main amplifier

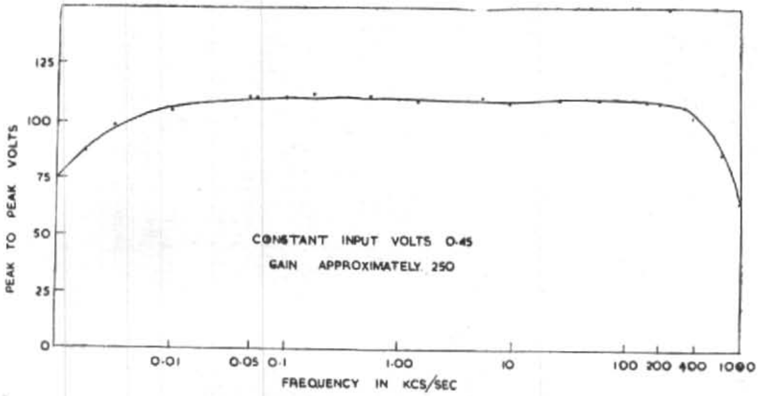


Fig. 3. The response curve of the main amplifier

Both these arrangements were actuated by the atmospherics themselves. The amplifier unit was checked from time to time for constancy of gain, linearity, etc.

Waveforms were recorded every day usually between 2000 and 2100 IST but some times when the local noise disturbed, these records were repeated after an hour or so.

3. Results

As is the practice at the station we have classified the different kinds of observed waveforms into four types (Chiplonkar *et al.* 1958, Chiplonkar and Hattiangadi 1945). Generally the first two types (and occasionally the third type also) show the phenomenon of multiple reflection of the atmospherics pulses between the earth and the ionosphere and only these two types are considered here. They form only 10 to 15 per cent of the total number of recorded atmospherics. The amplitudes of the ground pulse and the successive sky pulses, the time intervals between them and the duration of the first half cycle were directly read from the photographic records with the help of a small travelling magnifier. They are tabulated in separate tables.

From this tabulated information and following the method of Caton and Pierce (1952) the heights of reflecting layer and the distances of the sources of the atmospherics were deduced. Similarly reflection coefficient defined by the following relation was calculated for each waveform (Laby *et al.* 1940).

$$\text{Reflection coefficient } R = \left[\frac{S(n+p)}{Sn} \right]^{\frac{1}{P}}$$

where $S(n+p)$ and Sn are the observed amplitudes of $(n+p)^{\text{th}}$ and n^{th} sky pulses.

4. Analysis of the data and discussion

Table 1 shows the monthly distribution of the positive and the negative pulses. Except in the month of June, the negative pulses are on the whole about three to four times as numerous as the positive ones. In the month of June the ratio is about 2 : 1.

Fig. 4 is a histogram of height of the reflecting layer. It shows that the mode or the most frequent height group is 80—90 km. We may refer here to the heights found by a few other workers using this same method of multi-reflected atmospherics. Laby and coworkers (1940) have given the height as 70 to 86 km for night period in Australia. Schonland and others (1940) have given a height of about 88 km for night period in South Africa which remains practically constant throughout the night. Chiplonkar and Hattiangadi

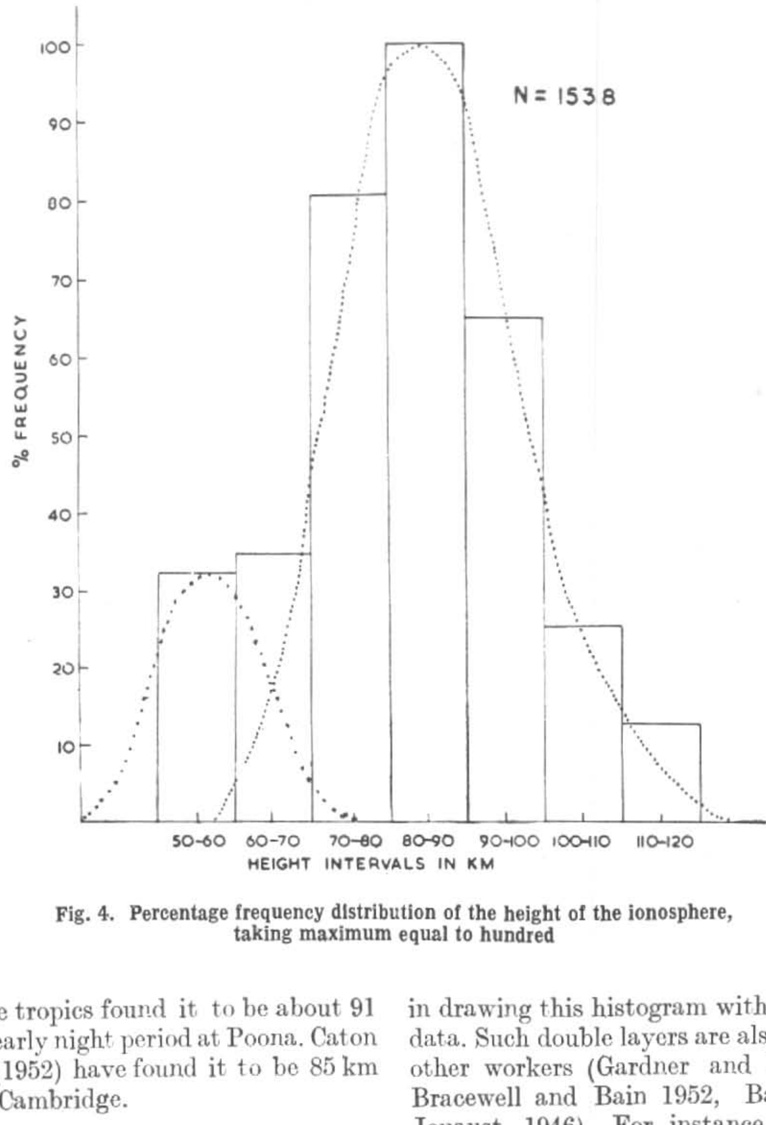


Fig. 4. Percentage frequency distribution of the height of the ionosphere, taking maximum equal to hundred

(1945) in the tropics found it to be about 91 km for the early night period at Poona. Caton and Pierce (1952) have found it to be 85 km at night at Cambridge.

A more careful examination of the curve in Fig. 4 shows that the distribution is not symmetrical about this group ; it falls rapidly on the side of higher values and gradually on the other side. It is possible that this assymmetry may be due to a double structure of the lower ionospheric layer with one layer at 85 km and the other at 58 km as indicated by the dotted curves in this figure. It should be pointed out that 10 km is the smallest interval of height that could be used in drawing this histogram with the available data. Such double layers are also reported by other workers (Gardner and Powsey 1953, Bracewell and Bain 1952, Bain 1953 and Jouaust 1946). For instance Gardner and Powsey (1953) have found from vertical pulse sounding experiments that there is a layer at 70 km which continues to reflect for one hour after sunset and two other layers at 90 km and 100 km which continue to reflect for at least four to five hours after this.

Similarly Fig. 5 is a histogram of the distance of the source of an atmospheric for the total period. It should be noted that the

TABLE 1

Monthly percentages of positive and negative pulses observed at Poona

Month	Pulses Positive (per cent)	Negative (per cent)
Mar	17	83
Apr	16	84
May	21	79
Jun	34	66
Jul	18	82
Aug	18	82
Sep	23	77
Oct	22	78
Nov	22	78
Dec	19	81

group interval used in this histogram is sufficiently large, *viz.*, 100 km to wipe out minor variations but it brings out the structure clearly. At shorter distances, *i.e.*, <200 km, the number is small mainly because of the fact that good records could not be obtained when storm centres were very near. This diagram shows that the frequency distribution is not uniform nor Gaussian but there appear to exist some preferred distances such as 500,750, 1050, 1450 and 1750 km approximately from which relatively larger number of atmospherics seem to come than from those in between. Similar trend is also present in a few of the monthly histograms shown in Fig. 6. It is felt, therefore, that it is not merely the actual distances of the storm centres which give the particular shape to the histogram, but that there appear to be some preferred distances, the atmospherics from which are less attenuated and, therefore, received in greater number.

Histograms (Fig. 6) of the distance of the sources of atmospherics drawn for each month separately show no definite trend, except that there is a slight increase in the number in summer than in winter. One would have normally expected that there

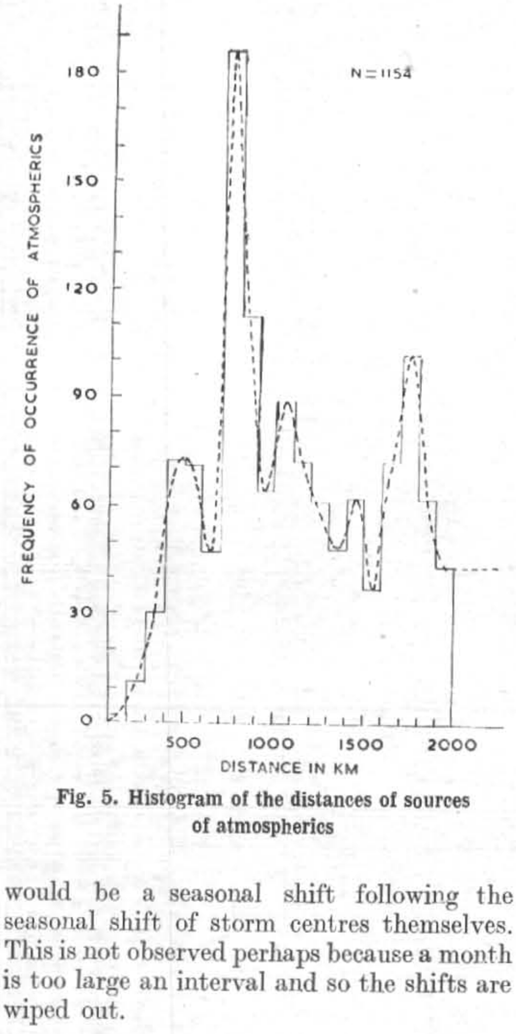


Fig. 5. Histogram of the distances of sources of atmospherics

would be a seasonal shift following the seasonal shift of storm centres themselves. This is not observed perhaps because a month is too large an interval and so the shifts are wiped out.

Scatter diagram of amplitude of the first sky pulse against the corresponding distance is plotted in Fig. 7. A dotted line is drawn to mark the approximate boundary of the density of points on this plot. It also shows that there are three broad peaks at 750, 1450 and 1750 km with minima at about 500, 1250 and 1600 km. This again means that there may be preferred distances, the atmospherics from which are probably less attenuated and/or more frequent, relative to the neighbouring distances which show minima. The dashed curve enveloping the three peaks represents the way in which amplitude of the

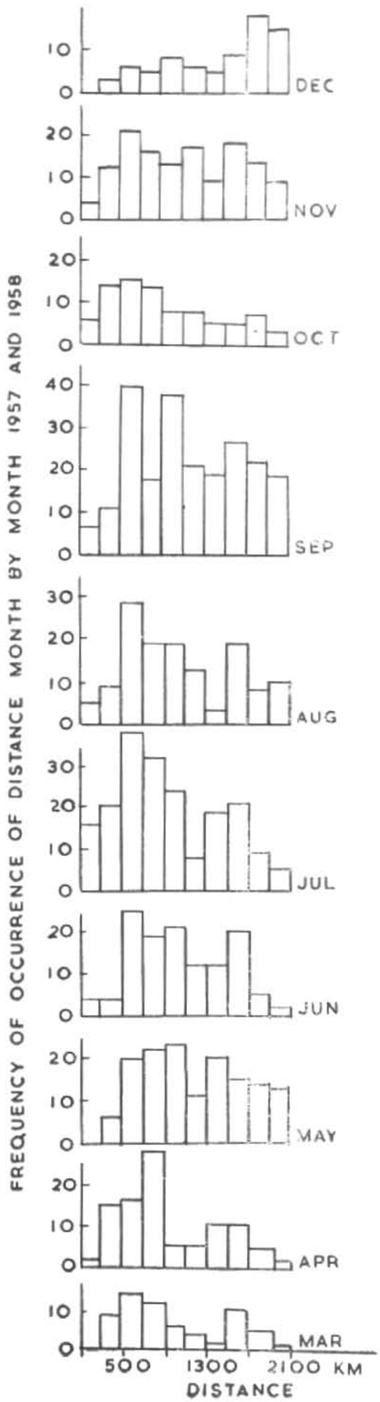


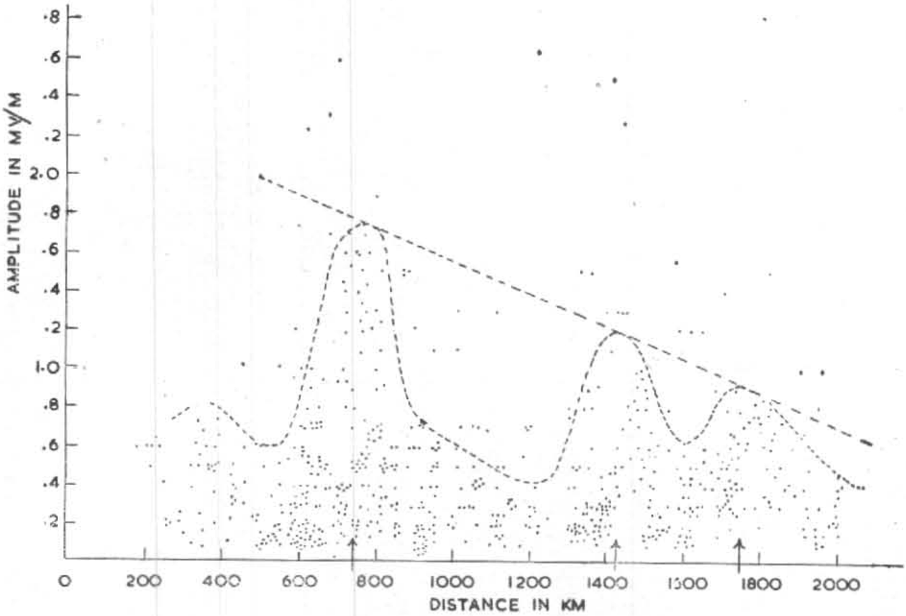
Fig. 6

first sky pulse decreases with distance of the source.

The scatter diagram of height of layer against distance of the source (Fig. 8) shows on the whole some definite trend as indicated by the dashed curve in this figure. However, a more careful scrutiny of the distribution of points on this diagram shows that for distances less than about 1100 km the lowest height from which the reflections of atmospherics could be obtained is seen to be about 60 km but for distances greater than about 1500 km it is 80 km and intermediate distances show a transitional rise. This is indicated by the lower dotted boundary in the diagram. On the other hand, the maximum height from which the reflection could be obtained, is seen to increase very rapidly at first and then reach a steady value as the distance is increased from zero to about 1300 km, after which it shows a sudden step-like rise. This is indicated by the upper dotted boundary.

Attention may be drawn here to the study by Weekes (1950) of Hollingworth (1926) interference pattern with the Rugby transmitter signals on 16 kc/s. He has found some change in the pattern at about 500 km which he could explain as due to a change of height of the reflecting layer at this distance. The reflecting layer for shorter distances is at a lower height and for the longer distances it is at a greater height.

It was thought, therefore, that the preferred distances observed in Figs. 5-7 may also be due partly to the 'interference' phenomenon reported by Hollingworth and Weekes. The pattern in Fig. 5 may probably be partly due to the superposition of two patterns: (*i*) due to reflections from a lower layer and (*ii*) that due to reflections from an upper layer. Two separate histograms of distances were, therefore, drawn for two different height groups corresponding to the height intervals around the peaks indicated by dotted curves in Fig. 4 : (*a*) 55 to 65 km and (*b*) 85 to 95 km (Fig. 9). The two histograms show quite different patterns. For the lower reflection height, Fig. 9 (A), there are three peaks



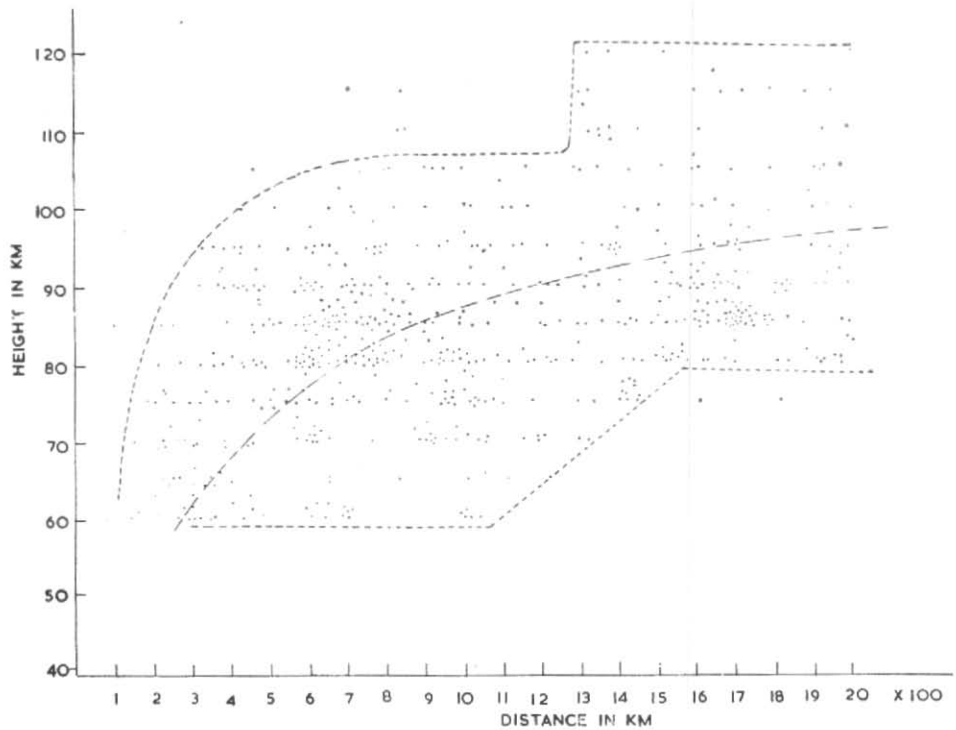
SCATTER DIAGRAM OF AMPLITUDE—DISTANCE

Fig. 7

at 300—400, 600—700 km and a small peak at 1000—1100 km intervals, with minima in between at 400—500 km and 800—1000 km intervals. For the upper reflection height also, Fig. 9 (B), there are three peaks at 600—700 km, 1300—1400 km and 1600—1700 km intervals with minima in between at 1200—1300 km and 1400—1500 km intervals. But here the central peak is not so significant. A comparison of our pattern in Fig. 9 (A) with those reported by Weekes shows some broad similarities such as a maximum at about 300 km and a minimum at about 500—600 km. The pattern for the upper layer (Fig. 9 B) is, however, different from that of Weekes. Of course, the conditions under which Weekes' observations were made are also different from those of ours.

The assumption that these patterns are at least partly due to something like a Hollingworth interference pattern appears to be quite logical especially in Fig. 7. In the case of Weekes' observation the transmitter was fixed and field strength at different distances was measured, whereas in our case the observation post is fixed and the lightning flashes are at different distances. For the sources at distances corresponding to maximum intensity of the Hollingworth pattern, the reception of atmospherics would be better. Naturally, the number of atmospherics received from such distances would also be larger. Assuming, on the average, sources of equal strength distributed uniformly around the receiver, the patterns of Fig. 7 would very nearly correspond to Weekes' pattern. In the patterns of Figs. 5 and 6, the decreasing field strength with distance may be compensated for by the increase in the number of sources with distance; since the field strength varies inversely as the distance while number varies as the square of the distance.

When a scatter diagram of reflection coefficient against that height of the layer was drawn it indicated that there is a difference in the reflection coefficient for heights below 80 km and for those above 80 km. The



SCATTER DIAGRAM HEIGHT—DISTANCE

Fig. 8

lowest reflection coefficient observed for the latter is lower than that for the former. This again points to the existence of two different reflecting layers.

The daily values of reflection coefficient when plotted against the corresponding day it was found that on the whole the reflection coefficient is higher in winter than in summer. This is also indicated by the shift of modal group in the histograms of reflection coefficient drawn for each month separately (Fig. 10). Similar results are reported by Bracewell (1950).

Scatter diagrams of height of layer against duration of the first half cycle (as a rough measure of periodic time or the wave length) were drawn separately for each of the four distance groups : 0—400 km, 400—800 km, 800—1200 km and above 1200 km. It was thought that as the duration (or the wave-length) increases the atmospherics would show lesser penetration into the reflecting layer and therefore, a lesser height. But no such definite trend is observable.

5. Concluding remarks

In concluding this account, attention may be drawn to the following significant points that have emerged from this investigation—

(*i*) There are probably two layers at about 60 and 90 km from which most of the atmospherics in the low frequency region are reflected. This is supported by the frequency distribution of height of the layer, distribution of the amplitude of the first sky pulse with height, and the variation of height of reflection with the distance of the source.

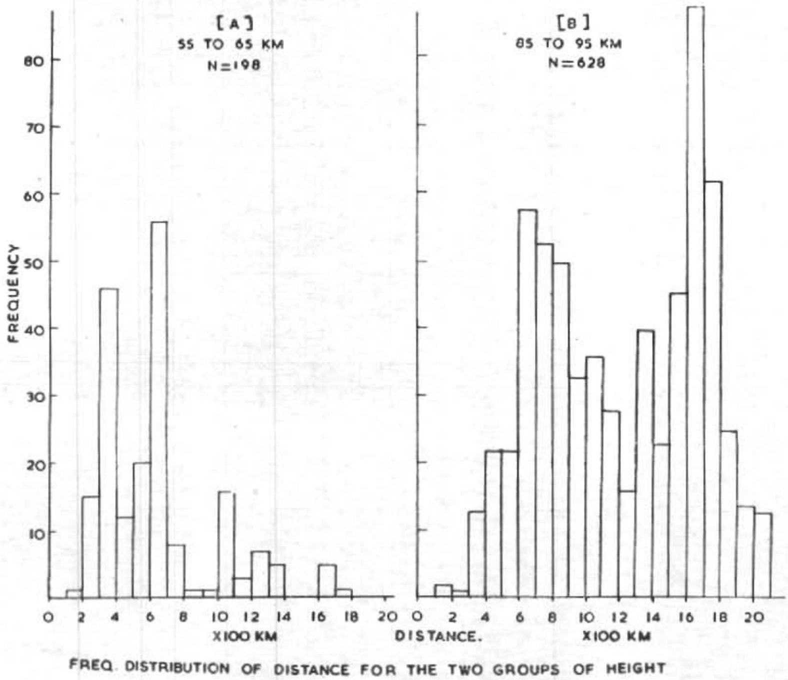


Fig. 9

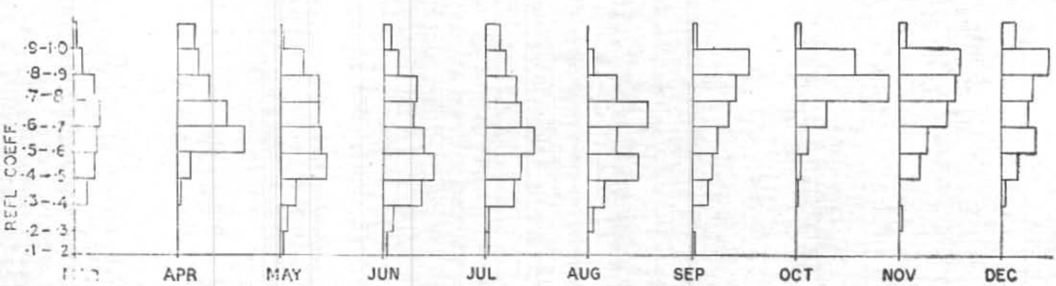


Fig. 10. Frequency distribution of reflection coefficient month by month 1957 to 1959

(*ii*) The reflection coefficient of ionosphere is greater in winter than in summer.

(*iii*) Statistically speaking there exists a kind of an interference pattern both in the distribution of the distance of sources of atmospherics and field strengths which show that there are certain preferred distances from which greater numbers as also larger field strengths of atmospherics are received. All of these preferred distances are not identical in the two cases. Approximate distances such as 700, 1050, 1400, 1700 km are common to both and therefore have greater significance relative to those which are not common. The non-preferred distances indicated by the minima in the pattern have also their place in this scheme.

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