# STUDIES IN FADING OF MEDIUM-WAVE RADIO SIGNALS

By B. A. P. TANTRY and S. R. KHASTGIR.

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**ABSTRACT.** In the present investigation, intensity variations of the down-coming waves of medium radio frequencies from Delhi, Dacca, Lahore and Vijayawada Broadcasting stations as received at Banaras were studied in the evening and early night hours, there being no ground waves from these distant stations at the receiving point. Medium-wave signals from Lucknow, Patna and Allahabad Radio Stations were also received at Banaras and their intensity variations investigated.

The observations were made with a straight receiver having a suitable galvanometer in the balanced anode circuit of the detector valve. In most cases visual observations of the galvanometer deflections due to the varying intensities of the signals were made. In a few cases only the galvanometer deflections were recorded photographically on a rotating drum system.

The following types of fading patterns were observed:

(*i*) Periodic or *quasi*-periodic fading of slow and quick periods.

(*ii*) Random fading.

Regarding the observed periodic or *quasi*-periodic fading, there were two distinct orders of periodicity. The 'slow' periodicity has been attributed to the interference of the ordinary and extraordinary components of the wave in the ionosphere as described by Appleton and Beynon (1947). The comparatively 'quick' periodicity, which was also frequently observed, has been considered as due to the vertical movement of the ionospheric layer which usually takes place in the early morning or in the evening or early night hours. The Döppler-beat interpretation of this type of periodic fading is outlined and the expressions for the periodicity given.

The vertical velocity of the ionospheric layer, as computed from the Döppler-beat consideration of the so-called 'quick' periodicity, was found to be of the order of 3.5 metres/sec. during the evening or early night hours.

With regard to random fading observed with signals from distant stations, the analysis showed that the actual distribution curve did not agree with the Rayleigh's formula for random scattering. Rayleigh's formula is applicable to one downcoming wave only. With longer distances the existence of a number of waves following slightly different paths in the ionosphere may partly explain the discrepancy between the observed results and those computed from Rayleigh's formula. For more distant stations, more than one peak in the observed intensity distribution curve were observed. This must be due to the simultaneous single and double reflections from the E-layer.

## INTRODUCTION

It is generally known that with medium-wave radio signals from distant stations, the intensity-variation is of a random nature. With short-wave signals, however, periodic or quasi-periodic types of intensity variation are often observed, besides the random type of fading. The object of the present investigation was to find whether any periodic variation prevailed in the reception of medium-wave signals from distant stations and to obtain a detailed knowledge regarding the nature and origin of such periodic fading, if and when it was observed. The object was also to analyse the random type of intensity variation observed with medium-wave signals. Signals from some of the broadcasting stations of medium wavelengths in India and Pakistan were therefore received at Banaras in the evening hours after sunset. The names, wavelengths, powers of these stations and their distances from Banaras are tabulated below.

TABLE I

| No. | Broadcasting station. | Power in kw | Wavelength in metres. | Distance from Banaras in km. |
|---|---|---|---|---|
| 1 | Delhi | 10.0 | 338.6 | 680 |
| 2 | Dacca | 5.0 | 257.1 | 775 |
| 3 | Vijayawada | 1.0 | 357.1 | 1050 |
| 4 | Lahore | 5.0 | 276.0 | 1145 |
| 5 | Allahabad | 1.0 | 389.6 | 120 |
| 6 | Patna | 5.0 | 265.3 | 224 |
| 7 | Lucknow | 5.0 | 293.5 | 268 |

In the case of the first four stations, the ground waves do not usually reach Banaras even in the night time. For the last three stations, ground waves are present along with the sky waves at the receiving station.

The usual modulated waves, when the programme was on, were studied. Measurements were made on a specially constructed straight receiver with a mirror galvanometer in the anode circuit of the detector valve, the steady anode current of which was balanced out. The galvanometer deflections $\delta$ were noted at regular intervals of 10 seconds continuously for a long interval of time. An attempt was also made to record photographically the galvanometer deflections for varying intensities of the signals on a rotating drum-system.

In the present paper, the fading of signals, as indicated by the galvanometer deflections noted at intervals of 10 seconds, has only been considered. The observed periodic patterns have been classified and the origin of the fading pattern has been fully discussed.

## EXPERIMENTAL ARRANGEMENTS

### (a) *Receiver with galvanometer at the detector output* :

The circuit diagram of the receiving set used in the investigation is shown in figure 1. An outdoor aerial was used with the receiving set. For

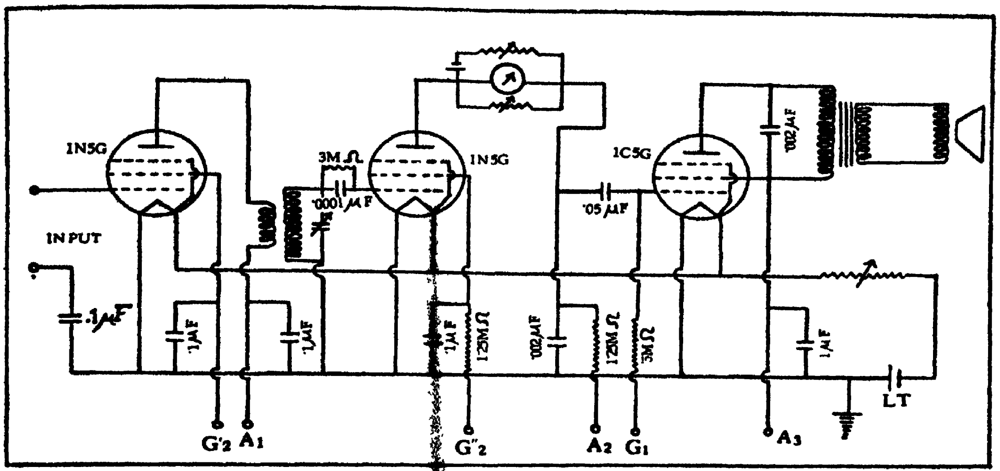

FIG. 1

absolute determinations of the field-strength, a loop aerial was also at times employed. The first valve (1N5-G) of the receiver was an H.F amplifier followed by a transformer-coupled detector valve (1N5-G). A suitable current-sensitive mirror galvanometer was inserted in the anode circuit of the detector valve. The galvanometer was shunted by some suitable resistance and there was the conventional arrangement for balancing the no-signal anode current by sending a current from a storage cell through a variable resistance to the galvanometer in the opposite direction. The detector valve was followed by an R-C coupled L.F. amplifier (1C5-G). The loudspeaker, which was connected through an output L.F. transformer to the anode circuit of the L.F. amplifying valve, was used for the aural response of the signal and was found extremely useful for tuning purposes.

### (b) *Calibration of the receiver and calculation of the field-strength in some cases.*

The receiver was calibrated in the usual way and the calibration graphs were drawn showing galvanometer deflections for different input voltages for the various frequencies corresponding to the broadcasting stations which were received for the study of signal variations. It is to be noted that for each frequency, the curve is almost linear, except for very small and large input voltages.

The relevant characteristic curve was used to find the induced voltages due to different signal intensities in any set of experiments. For the purpose of determining the field-strength a tuned loop aerial was worked with the receiver and the field-strength was calculated with the help of the standard formula.

## EXPERIMENTAL RESULTS

With signals of medium wavelengths from distant broadcasting stations (Delhi, Dacca, Lahore and Vijayawada) from where ground-waves could not reach the receiving station, the fading patterns observed in the early night hours were of the following types :

(i) *Periodic or quasi-periodic fading.*
   - (*a*) With a slow period.
   - (*b*) With a comparatively quick period.
   - (*c*) With a combination of slow and quick periods.

(*ii*) *Random fading.*

With signals from Lucknow and Patna, which are not too distant to transmit ground waves to a certain extent during the night hours, the above types of fading were also observed. With signals from Allahabad, which is only at a distance of 120 km. from Banaras, random fading was most frequently observed. Only in a few cases there was evidence of a quasi-periodic variation of somewhat rapid period.

(*i*) *Periodic or quasi-periodic fading* :

It is to be noted that there were two distinct orders of periodicities in the fading patterns: one a very slow periodic variation, the periodicity ranging from about 3 to 8 minutes (the quasi-frequency range being 0.12-0.31 cycles per minute) and the other, a comparatively quick variation, the periodicity of which ranged from about 25 to 110 seconds (the quasi-frequency ranging from about .55-2.5 cycles/minute). Both types of periodic fading were observed with the signals from the distant stations, *viz*, Delhi, Dacca, Vijayawada, Lahore and Lucknow. With the signals from Patna and Allahabad which are near Banaras, only the quick periodic type was observed.

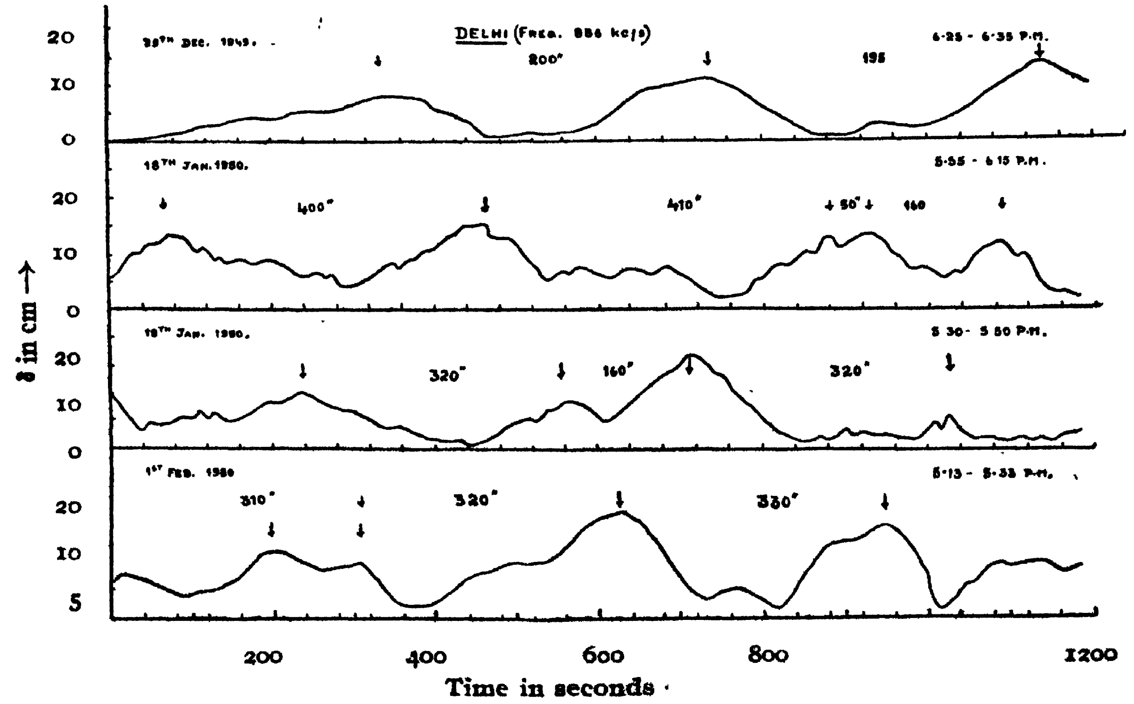

FIG. 2

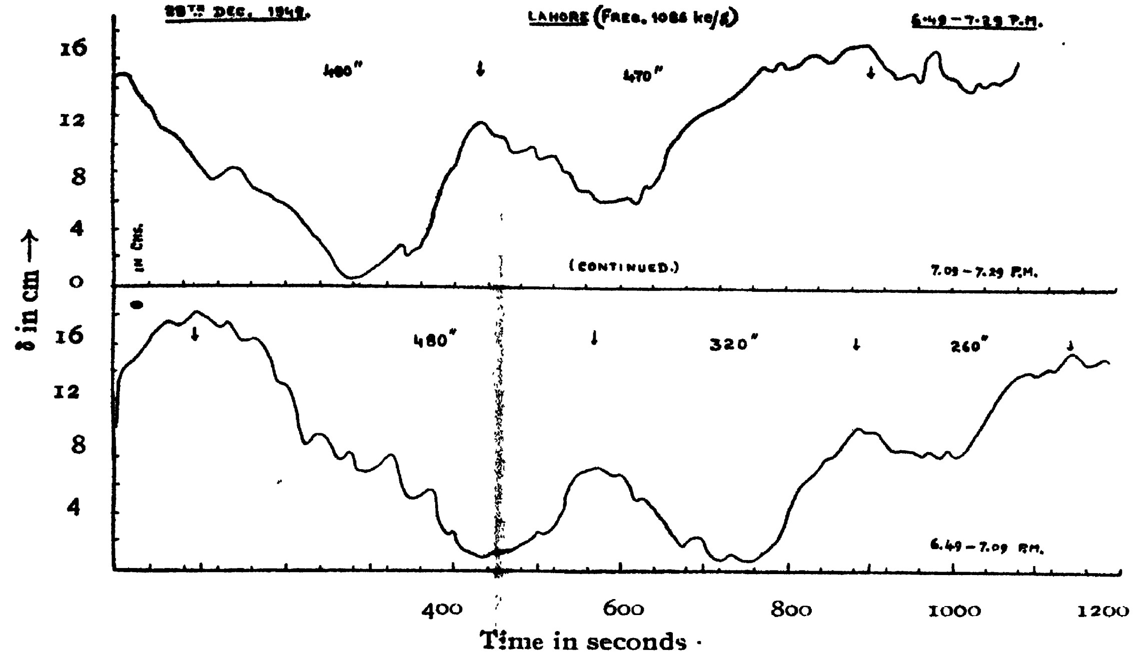
28TH DEC. 1949.
LAHORE (FREQ. 1086 kc/s)
6·49 – 7·29 P.M.
480"
470"
(CONTINUED.)
7.09 – 7.29 P.M.
480"
320"
260"
6.49 – 7.09 P.M.
δ in cm →
IN CMS.
16
12
8
4
0
16
12
8
4
400
600
800
1000
1200
Time in seconds

FIG. 3

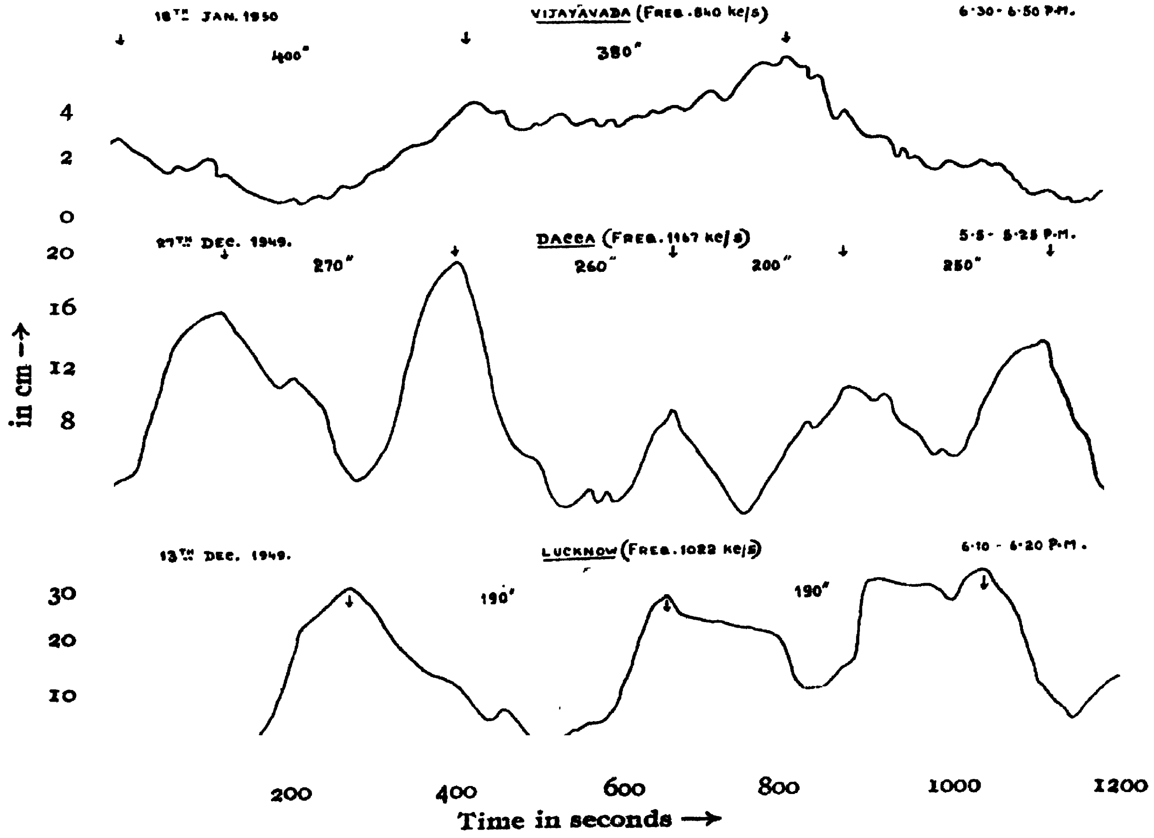
18TH JAN. 1950
VIJAYAVADA (FREQ. 840 kc/s)
6·30 - 6·50 P.M.
400"
380"
27TH DEC. 1949.
DACCA (FREQ. 1167 kc/s)
5·5 - 5·25 P.M.
270"
260"
200"
250"
13TH DEC. 1949.
LUCKNOW (FREQ. 1022 kc/s)
6·10 - 6·20 P.M.
190"
190"
in cm →
4
2
0
20
16
12
8
30
20
10
200
400
600
800
1000
1200
Time in seconds →

FIG. 4

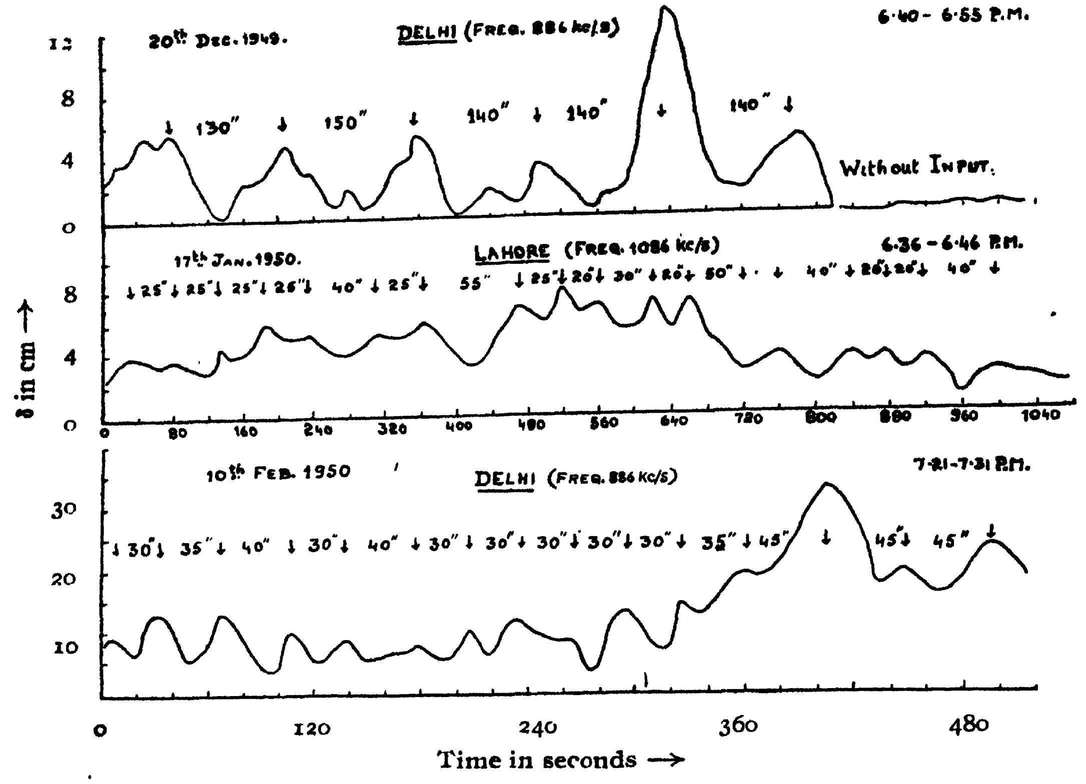
20th Dec. 1949.
DELHI (Freq. 886 kc/s)
6·40 - 6·55 P.M.
130″
150″
140″
140″
140″
Without Input.
17th Jan. 1950.
LAHORE (Freq. 1086 kc/s)
6·36 - 6·46 P.M.
10th Feb. 1950
DELHI (Freq. 886 kc/s)
7·21 - 7·31 P.M.
δ in cm →
0
4
8
12
10
20
30
0
80
160
240
320
400
480
560
640
720
800
880
960
1040
120
240
360
480
Time in seconds →

FIG. 5

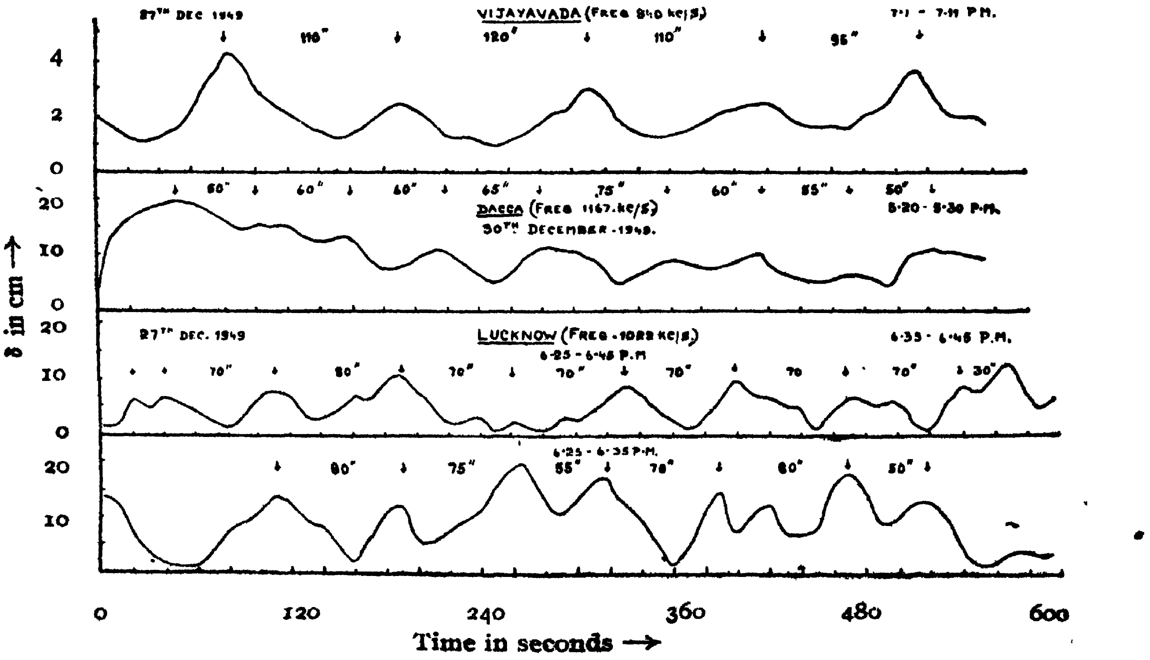
27th Dec 1949
VIJAYAVADA (Freq. 840 kc/s)
7·1 - 7·11 P.M.
110″
120″
110″
95″
DACCA (Freq. 1167 kc/s)
30th December - 1949.
8·20 - 8·30 P.M.
27th Dec. 1949
LUCKNOW (Freq. 1022 kc/s)
6·35 - 6·45 P.M.
6·25 - 6·45 P.M.
6·25 - 6·35 P.M.
δ in cm →
0
2
4
10
20
0
120
240
360
480
600
Time in seconds →

FIG. 6

Representative slow and quick periodic patterns, observed with the signals from the distant stations, are shown in figures 2-6. Figure 7 illustrates some observations showing the slow periodic type with quicker periodicity superposed on the slow one. The quick periodic patterns observed with Patna and Allahabad signals are shown in figure 8.

Actual field-strength variations, as determined from the calibration curves and the field-strength formula for two typical sets of observations, are illustrated in figure 9.

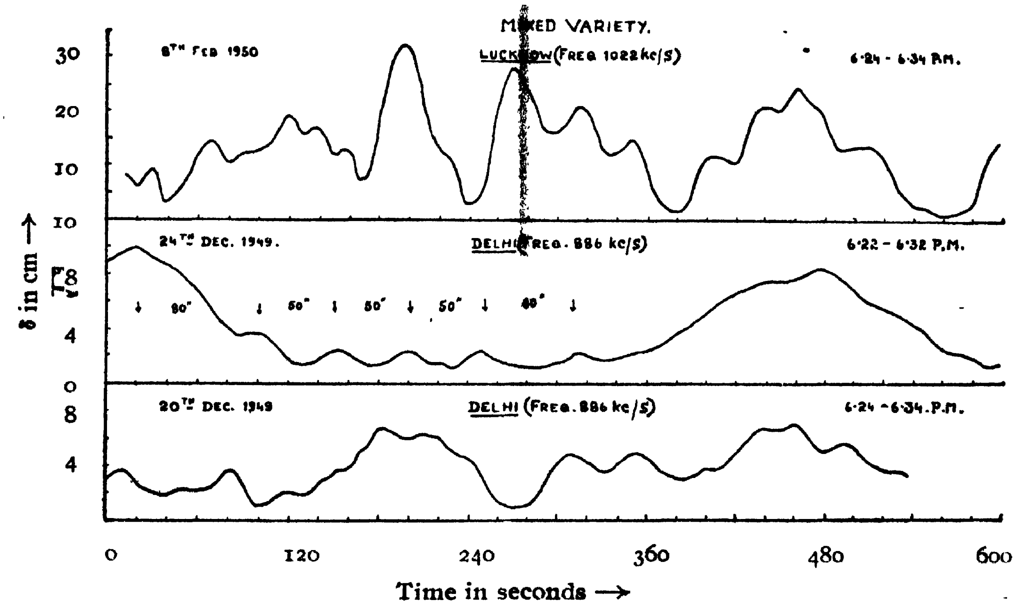

FIG. 7

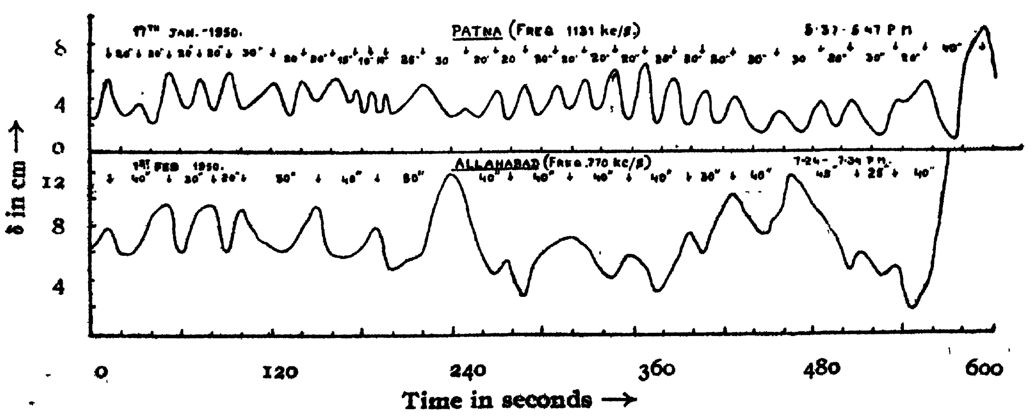

FIG. 8

The quasi-frequency and other details of the observed periodic patterns are given in Table II.

TABLE II

| Date | Time P.M. I.S.T. | Periodicity in secs. | | Frequency in cycs./minute. | | Remarks. |
|---|---|---|---|---|---|---|
| | | Slow | Quick | Slow | Quick | |
| Delhi | | | | | | |
| 20-12-49 | 6.40—6 55 | | 140 | | ·43 | |
| 24-12.49 | 6.25—6.30 | | 50-60 | | 1.10 | |
| 29-12-49 | 6.25—6.35 | 200-195 | | ·30 | | λ=338.6 metres. Banaras-Delhi distance =680 km. |
| 1- 2-50 | 5·13—5·33 | 320 | | .19 | | |
| 18- 1-50 | 5·30—5·50 | 320 | | .19 | | |
| 18- 1-50 | 5·55—6.15 | 400-410 | | .15 | | |
| 10- 2-50 | 7·21—7·30 | | 30-45 | | 1·58 | |
| 10- 2-50 | 7·33—7·43 | | 107 | | ·56 | |
| Dacca | | | | | | |
| 27-12-49 | 3·5 —5·25 | 260 | | ·23 | | λ=257·1 metres Banaras-Dacca distance =775 km. |
| 30-12-49 | 5·20—5·30 | | 50-75 | | ·97 | |
| Vijayawada | | | | | | |
| 27-12-49 | 7·1 —7·11 | | 109 | | ·55 | λ=357·1 metres. Banaras-Vijayawada distance =1050 km. |
| 18- 1-50 | 6.30—6.50 | 380-400 | | ·15 | | |
| Lahore | | | | | | |
| 28-12-49 | 6.49—7.29 | 260.480 | | .23-.12 | | |
| 17- 1-50 | 6.38—6.46 | | 25-65 | | 1·5 | λ=276 metres. Banaras-Lahore distance =1145 km. |
| Lucknow | | | | | | |
| 13-12-49 | 6.10—6.20 | 190 | | ·32 | | |
| 24-12-49 | 7.00—7.5 | | 55-70 | | .96 | λ=293.5 metres Banaras-Lucknow distance =268 km. |
| 25-12-49 | 7·20—7·25 | | 40-70 | | 1.09 | |
| 27-12-49 | 6.25—6.35 | | 50-80 | | ·93 | |
| 27-12-49 | 6.35—6.45 | | 70 | | .86 | |
| Patna | | | | | | |
| 29-12-49 | 5·20—5·30 | | 55-60 | | 1.04 | |
| 29-12-49 | 5·30—5·40 | | 60 | | 1.00 | λ=265.3 metres. Banaras-Patna distance =224 km. |
| 29-12-49 | 5·40—5·50 | | 50-70 | | 1.00 | |
| 29-12-49 | 5·50—6.00 | | 40-50 | | 1·33 | |
| 17- 1-50 | 5·37—5·47 | | 20-30 | | 2·39 | |
| 10- 2-50 | 6.38—6.48 | | 40-80 | | 1.00 | |
| 10- 2.50 | 6.51—7.01 | | 50-60 | | 1.09 | |
| Allahabad | | | | | | |
| 1 -2 ·50 | 7·24—7·32 | | 40 | | 1·5 | λ=389.6 metres. Banaras-Allahabad distance =120 km. |

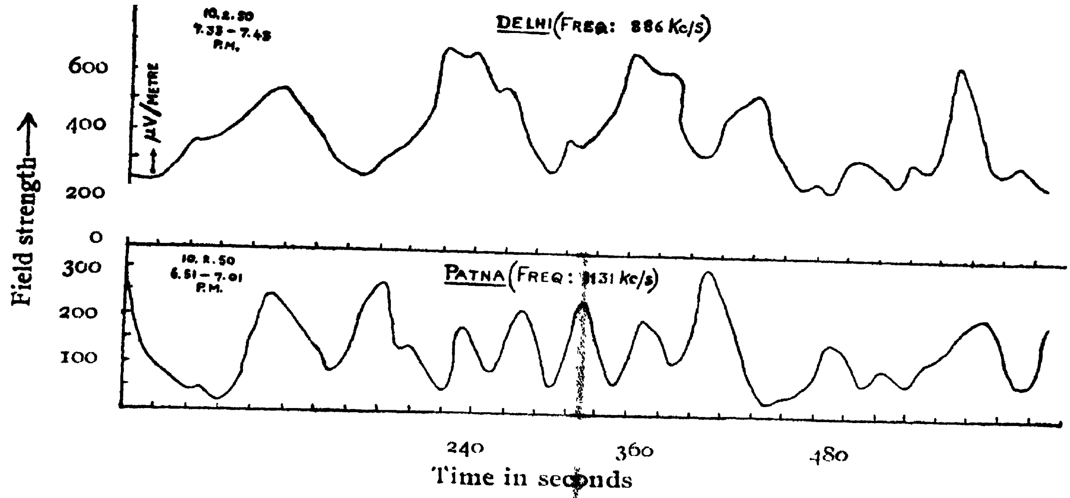

FIG. 9

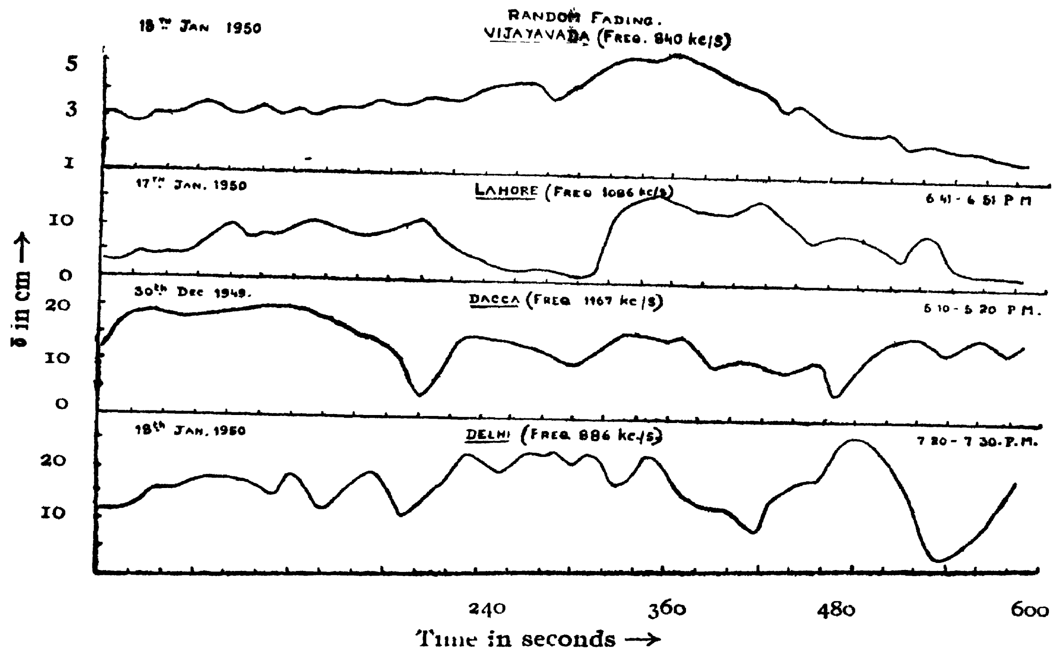

FIG. 10

### (ii) *Random fading of medium-wave signals*

The random fading curves for some of the distant stations from which the ground waves cannot reach the receiving point are shown in the figure 10.

## ORIGIN OF PERIODIC FADING

With regard to the periodic or quasi-periodic type of fading observed usually with short waves, it is now known that there are two distinct conditions under which the periodic type of fading can be observed. Appleton and Beynon (1947) have shown that the interference of ordinary and extraordinary components of the wave caused by magneto-ionic splitting gives rise to a periodic fading at a time, usually during the evening or early morning hours when there is a continuous decrease or increase of electron density of the ionospheric layer. The slow periodic fading is usually associated with the interference between the lower-trajectory ordinary and extraordinary waves. The rapid periodicity arises only when the upper trajectory ordinary wave (which is often termed the Pedersen ray) is received along with the lower trajectory ordinary and extraordinary waves. For this interference of magneto-ionic components, the electron density of the ionosphere should be just enough for a single reflection between the transmitting and receiving stations. This means that the frequency of the transmitter should be in the neighbourhood of the maximum usuable frequency (M.U.F.) for the particular reflecting layer and over the particular transmission distance. Under such condition, we may say that the Appleton-Beynon type of periodic fading is expected. The possibility of a periodic fading of a different origin under relatively high ionospheric ionisation, when the Appleton-Beynon type of periodic fading is too slow to be discernible in the fading records, was reported by Banerjee and Mukherjee (1949) and by Banerjee and Singh (1949) and later by Khastgir and Das (1950). Under conditions of high electron density, periodic patterns were observed and the periodicity was attributed by Banerjee and his colleagues to the interference between the two waves singly and doubly reflected from the same ionospheric layer or between the singly reflected waves from the two different layers, when one or both possessed a vertical movement producing a continuous change in the path-difference of the two interfering waves and yielding thereby intensity maxima and minima with a periodicity depending on the vertical velocity of the ionospheric layer or layers. Such periodic type of fading was usually observed in the evening or early night hours when the ionospheric layer tended to move upwards.

An equivalent representation of the same phenomenon was put forward by Khastgir (1949) and this view-point was outlined as follows:
With a vertical movement of the ionospheric layers in the evening (or early morning), when the ionospheric ionization is sufficient for the simultaneous single and double reflections from the same layer, it is evident that they will suffer different amounts of Dôppler change of frequency as they proceed towards the receiving point from distinctly different directions. Thus there will be a difference in the frequencies of the singly and doubly reflected waves from the same moving layer. A similar difference in frequency is also expected in the case of simultaneous single reflections from the E and F-layers when both have vertical movement. In either case the two interfering waves of slightly different frequencies would give a resultant beat-note with a progressively increasing amplitude followed by a corresponding decrease in amplitude in a periodic manner. When the beat-note is received by the receiver, the output after rectification in the detector stage would constitute the envelope of such resultant beat-note with one side wiped out. This would be similar in

appearance to a slow rhythmic fading, the periodicity of which would correspond to the difference in the frequencies of the down-coming waves as determined by the Doppler effect formula. It has been shown by Khastgir and Das (1950) that the Doppler-beat interpretation of the observed periodic fading is essentially the same as the path-retardation theory of Banerjee and his colleagues.

With regard to the periodic fading of magneto-ionic origin, it is extremely difficult to calculate the periodicity. In the case of periodic fading due to vertical movement of the ionosphere, when there are simultaneous single and double reflections from the same moving layer or when there are simultaneous single reflections from both the moving layers, it has been found possible to obtain expressions for the periodicity from Doppler effect considerations.

Considering the case when the singly and doubly reflected waves from the same layer proceed towards the receiving point, the quasi-frequency of the fading pattern is given by

$$n=\frac{2v}{\lambda}(2\cos\theta_2-\cos\theta_1) \qquad \ldots \quad (1)$$

where $\theta_1$ and $\theta_2$ are the angles of incidence for the singly and doubly reflected waves from the same layer moving with a velocity, $v$ in the vertical direction and $\lambda$, the wavelength of the up-going waves. In the case of singly reflected waves from the two layers moving with the same vertical velocity $v$ the quasi-frequency of periodic fading is given by

$$n=\frac{2v}{\lambda}(\cos\phi_1-\cos\theta_1) \qquad \ldots \quad (2)$$

where $\theta_1$ and $\phi_1$ are the angles of incidence at the E- and F-layers respectively for simultaneous single reflections.

## OBSERVED PERIODIC FADING WITH MEDIUM WAVE SIGNALS

### (a). *Periodic fading of magneto-ionic origin*

In the present investigation the wavelengths of the medium waves ranged from 257.1 to 357.1 metres and the distance ot the transmitting stations from Banaras ranged from 120 to 1145 km. In most cases, there was reflection only from the E-layer. The M. U. F. value for the E-layer for the average transmission distance would be in the neighbourhood of 3-4 Mc/s in the evening and early night hours. The frequencies of the signals were therefore very much less than the M. U. F. value. It is therefore expected that the interference between the ordinary and extra-ordinary components would give rise to an extremely slow periodic pattern, if that is at all discernible. The slow periodic patterns (.12 to .31 cycles/minute) observed in the investigation have been attributed to this cause.

### (b) *Periodic fading due to vertical movement of the ionospheric layer or layers*

The relatively quick periodic fading (.55 to 2.5 cycles/min) has been considered to be due to the vertical movement of the ionospheric layers during the evening hours. With medium waves it is possible to have both single and double reflections from the E-layer. In rare cases we may expect single reflection from the F-layer, when the E-layer is 'patchy' enough to allow penetration of the medium waves through it. The angles of incidence $\theta_1$ and $\theta_2$ for the singly and doubly reflected waves from the same E-layer and also the angle $\phi_1$ for the singly reflected wave from the F-layer are determined by taking the E-layer to be at a height of 90 km. and the $F_2$ region at a height of 360 km. above the earth's surface.

Taking the values of $\theta_1$, $\theta_2$ and $\phi_1$ for different transmission distances between the transmitting station and the receiving station the factors, $(2 \cos \theta_2 - \cos \theta_1)$ and $(\cos \phi_1 - \cos \theta_1)$, in the formulæ (1) and (2) are calculated and shown in the Table III.

TABLF III

| To Banaras | $(2 \cos \theta_2 - \cos \theta_1)$ | $(\cos \phi_1 - \cos \theta_1)$ |
|---|---|---|
| Delhi | .68 | 47 |
| Dacca | .62 | .46 |
| Vijayawada | .48 | .40 |
| Lahore | .45 | .38 |
| Lucknow | 1.048 | .38 |
| Patna | 1.060 | .33 |
| Allahabad | 1.066 | .155 |

Using formulæ (1) and (2) with the relevant multiplying factors given in Table III, the vertical velocity of the ionospheric layer can be calculated from the observed frequency of the periodic fading patterns. The observed quick periodicity ranging from about 25 seconds to about 110 second (the corresponding quasi-frequency being.55 to 2.5 cycles/minute) is considered as due to the vertical movement of the ionosphere when the singly and the doubly reflected waves from the E-layer (or when the singly reflected waves from both E-and F-layers) interfere.

The calculated values of the vertical velocity for the various observed quick periodicities are given in Table IV.

The vertical velocity computed from the observed quick periodicities according to the formula (1) ranges from 1.8 to 7.7 metres per second, the mean value being 3.6 metres per second. As this agrees fairly with the

TABLE IV

| Date | Time P. M. I S.T. | Transmitting station | Observed quick fading in cycles/min. (mean value) | Ionospheric vertical velocity | |
|---|---|---|---|---|---|
| | | | | From (1) m/sec. | From (2) m/sec |
| 20-12-49 | 6.40-6.55 | Delhi | .43 | 1.79 | 2.58 |
| 24-12-49 | 6.25-6.30 | Delhi | 1.09 | 4.52 | 8.02 |
| 10- 2-50 | 7.21-7.30 | Delhi | 1.58 | 6.50 | 9.47 |
| 10-2 -50 | 7.33-7.43 | Delhi | .56 | 2.33 | 3.37 |
| 30-12-49 | 5.20-5.30 | Dacca | .97 | 3.34 | 4.51 |
| 27-12-49 | 7.01 7.11 | Vijayawada | .55 | 3 41 | 4.10 |
| 17- 1-50 | 6.38-6 46 | Lahore | 1.50 | 7.66 | 9.08 |
| 24-12-49 | 7.00-7.5 | Lucknow | .96 | 2.26 | 6.22 |
| 25-12-49 | 7.20-7.25 | Lucknow | 1.09 | 2.00 | 7.07 |
| 27-12-49 | 6.25-6.35 | Lucknow | .93 | 2.16 | 5.94 |
| 27-12-49 | 6.35-6.45 | Lucknow | .86 | 2.01 | 5.52 |
| 29-12-49 | 5.20-5.30 | Patna | 1.04 | 2.17 | 6.97 |
| 29-12-49 | 5.30-5.40 | Patna | 1.00 | 2.09 | 6.70 |
| 29-12-49 | 5.40-5.50 | Patna | 1.09 | 2 28 | 7.31 |
| 29-12-49 | 5.50-6.00 | Patna | 1.30 | 2.81 | 8.93 |
| 17- 1-50 | 5.37-5.47 | Patna | 2.39 | 4.98 | 16.00 |
| 10- 2-50 | 6.38-6.41 | Patna | 1.00 | 2.09 | 6.7 |
| 10- 2.50 | 6.51-7.01 | Patna | 1.09 | 2.28 | 7.31 |
| 1- 2-50 | 7.24-7.34 | Allahabad | 1.50 | 4.60 | |

approximate estimate from the ionospheric data, we are inclined to the view that the quick periodic fading was more often due to the interference of the singly and doubly reflected waves from the E-layer.

## RANDOM FADING OBSERVATIONS WITH DOWN-COMING WAVES ONLY AND COMPARISON WITH RAYLEIGH'S FORMULA FOR RANDOM SCATTERING

Random fading, which was frequently observed with downcoming waves of medium wavelengths, was explained by Ratcliffe and Pawsey (1933) as due to the random scattering of the waves from a large number of diffracting centres in the ionosphere. Late Lord Rayleigh deduced an expression for the probability of occurrence of any resultant amplitude on the assumption of a large number of components of random phases. The probability is given by

$$P' = \qquad e^{-r^2/R^2} r \tag{8}$$

where $R^2$ = sum of the squares of the components and $P'dr$, the probability of a resultant amplitude between $r$ and $(r+dr)$.

The actual distribution curves showing the number of observations for different amplitudes of the downcoming wave were drawn for the several random fading patterns obtained with medium wave signals from the various transmitting stations. The procedure was as follows : Taking amplitudes of the downcoming wave at regular short intervals of time (10 seconds), the whole range of observed amplitudes for a continuous set of observations was divided into a number of equal parts ($dr$) and the number of times the observed amplitude lies between $r$ and $(r+dr)$ was counted. A distribution curve was thus drawn showing the number of amplitudes lying between $r$ and $(r+dr)$ against the mean value of $r$ and $r+dr$.

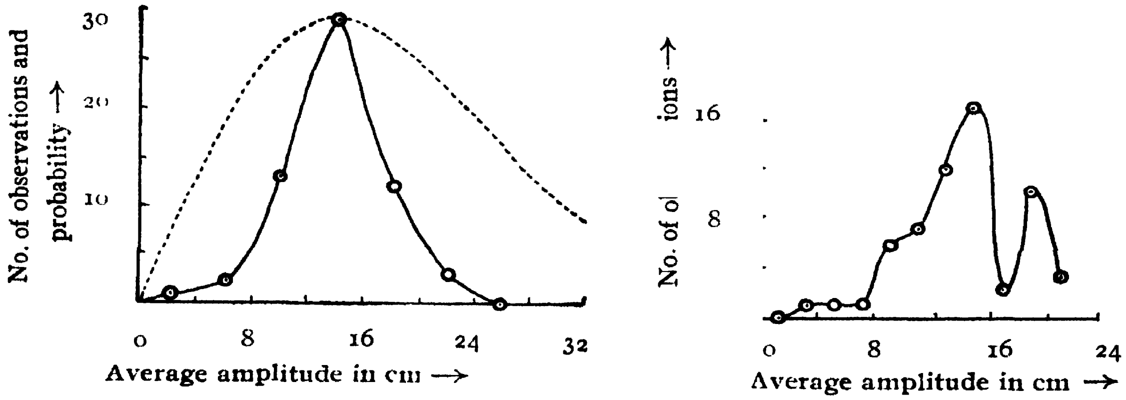

FIG. 11 *a* (Dacca)

— — — Rayleigh

—o—o—o—Experiment

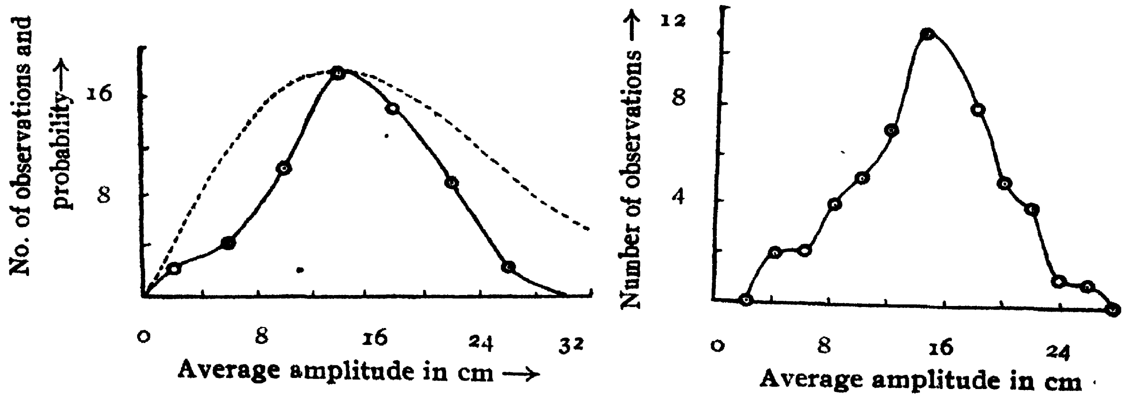

FIG. 11 *b* (Delhi)

— — — — Rayleigh

· Experiment

The Rayleigh distribution curves were drawn in the manner already described by Khastgir and Ray (1940) and Khastgir and Das (1950). Each of the theoretical distribution curves is shown along with the actual distribution curve in the figures 11 and 12

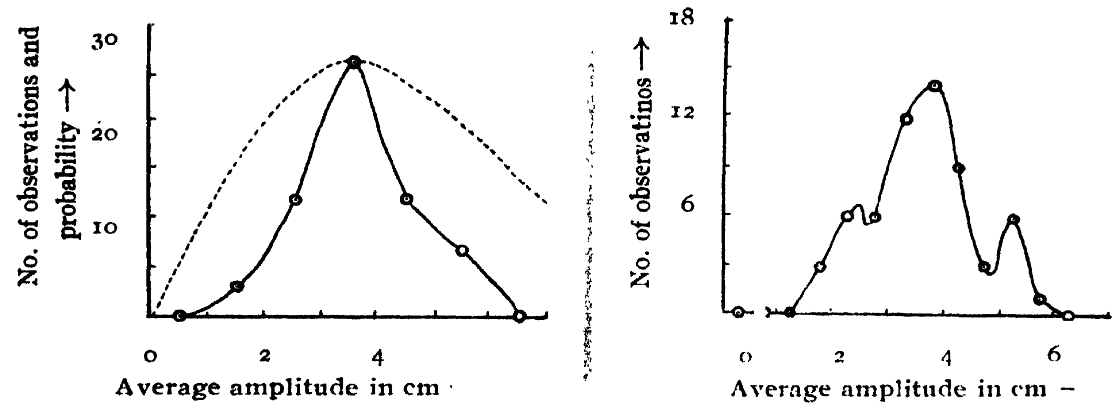

FIG. 12 *a* (Vijayawada)
— — — — Rayleigh
—o—o— Experiment

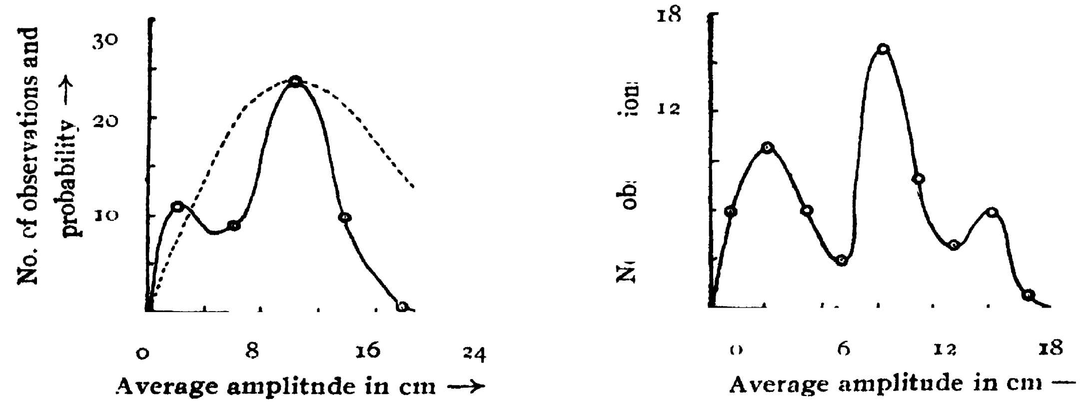

FIG. 12 *b* (Lahore)
— — — — Rayleigh
—o—o— Experiment

It will be observed that there is no agreement between the observed distribution of intensity and the theoretical distribution according to Rayleigh's formula. In the case of Delhi, Dacca, and Lahore signals, when the intensity values are divided into four centimetres groups, there appeared one pronounced peak for Delhi and Dacca and two for Lahore. When the dispersion was doubled, there appeared one peak for Delhi, two for Dacca and three for Lahore signals. For Vijayawada signals, there appeared one pronounced peak when the intensity was taken to lie within 1 cm and three peaks when the dispersion was doubled.

For distant stations like Lahore (1145 km) and Vijayawada (1050 km) it was likely to have singly and doubly reflected waves from the E-layer.

The double peaks could be interpreted as due to the simultaneous single and double ionospheric reflections. For Delhi, the nearest of the four stations we observed only one peak for both the dispersions.

It is to be noted that Rayleigh's formula for random scattering is valid for only one downcoming wave. Even for a single reflection, if the distance between the transmitting and receiving station is large, we may have a number of waves following slightly different paths in the ionosphere. The existence of a number of waves following slightly different paths will partly explain the cause of the discrepancy between the observation and Rayleigh's formula.

WIRELESS LABORATORY
PHYSICS DEPT.
BANARAS HINDU UNIVERSITY.

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