APPLICATION OF THE THEORY OF RANDOM SCATTERING ON THE INTENSITY VARIATIONS OF THE DOWN-COMING WIRELESS WAVES OVER LONG TRANSMISSION PATHS

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(Received for publication, May 20, 1941)

ABSTRACT. Pawsey's theory of random scattering to explain the variation of the amplitude of down-coming radio waves was applied in the case of transmission over moderately great distances in the medium wave band Results indicate that while random scattering is a predominant factor in determining the strength of the down-coming waves, the observational data cannot be fully accounted for by this theory alone. It is suggested that for long transmission paths the presence of other factors must also be taken into consideration.

INTRODUCTION

Pawsey[1] has shown that a single reflected ray from ionosphere does not consist of a single ray but is built up of elementary contributions from a series of diffracting centres distributed more or less at random in the ionosphere. Working with a wavelength in the medium band (200 m. to 500 m.), he found that the variation of the amplitude of the down-coming wave is consistent with the probability formula given by Lord Rayleigh. The result of his experiments, was obtained with a transmission path of 56 Kms. (London Regional Transmitter —Sydney Sussex College Receiving Station); it was thought desirable to test whether the theory of random scattering as given by Pawsey is applicable even when the transmission path is made considerably great. The present communication gives an account of the study of variation of intensity of down-coming waves in the medium band (wavelengths 370.4 m. and 257.1 m.) from two Indian Broadcasting stations, *viz.*, Calcutta and Dacca, at distances as great as 480 and 610 Kms.* All the data for measurements were obtained in our case from automatic photographic records of received signals taken between the hours 6 P.M. and 10-30 P.M. over a period of about two years.

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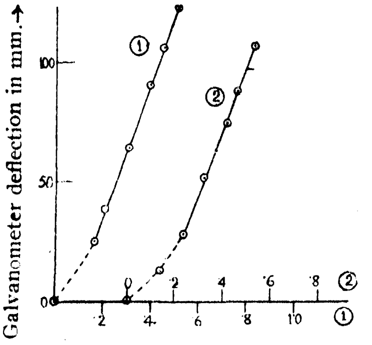
* Recently a paper has been published by Khastgir and Ray (*Indian Journal of Physics*, **14**, 283, 1940), but here also the distance was not more than 245 Kms Moreover, the data were secured from visual observation of galvanometer deflections

AUTOMATIC RECORDING

The automatic recording was made as follows :—A bromide paper was fixed on a drum rotated by a clockwork, the whole system being put inside a light-tight box. On one side of the box there was a fine horizontal slit which could be opened or closed. The vertical image of the straight filament of a lamp formed by reflection from the galvanometer mirror was allowed to fall on the slit. The deflection of the spot of light at any instant was thus automatically recorded. The vertical lines in the photographic records of Fig. 4 were obtained by means of another clockwork making contacts of an electric circuit containing a 4-volt lamp every 4 minutes.

RECEIVING SYSTEM

The receiver was a battery set of the superheterodyne type consisting of two stages of H. F. amplification preceding an octode frequency-changer with a separate oscillator and one stage of I. F. amplification followed by a second detector which was a double-diode-triode giving a linear detection. The relation between the input voltage and the deflection in the galvanometer is shown in Fig. 1. It will be observed that it is practically linear within the working range except for field strengths below 70 $\mu v/m$. We had also used a square-law detector in some of our measurements. The circuit diagrams of both types of detection are shown in Figs. 2 and 3.

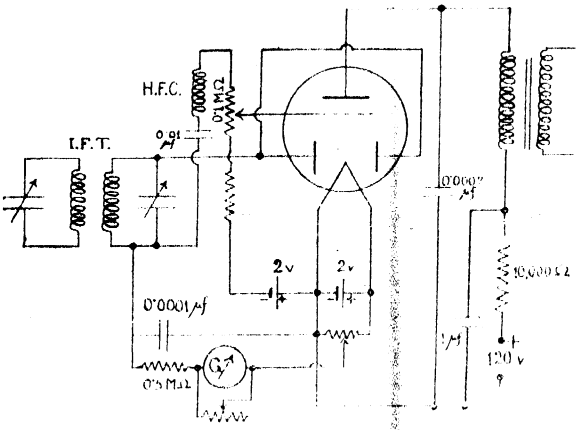


Calibrating H. F. current in the coil of 2 turns.

(1) Diode bias ... 0 volt.

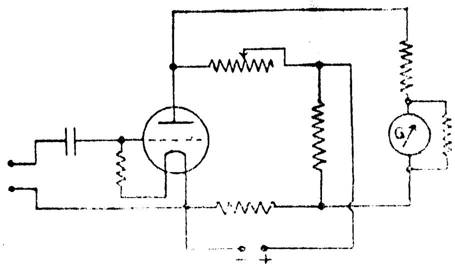
(2) Diode bias ... 0.5 volt.

FIG. 1



Linear Detector

FIG. 2



Square-law Detector.

FIG. 3

The calibration of the receiving set (photographically) and calculation of the field strengths.—The calibration of the receiving set was done by the method adopted by the Standardization Committee of Radio Engineers (Hund's High Frequency Measurements, page 346). A small coil of 2 turns was placed along the axis of the loop aerial. The deflections d_1, d_2, d_3 [Fig. 4(*b*)] in the output galvanometer (G) corresponding to known H. F. currents in milliamps. of the same frequency as that of the signal in suitable steps were photographed. This was done both in the beginning and at the end of each observation with the loop set in the minimum position. The line joining the spots in the beginning and end of each observation for a particular H. F. current thus gave the strength level when reduced to micro-volts per metre. A graph was plotted with galvanometer deflection against calibrated field strength, from which the desired field strength corresponding to any deflection could be easily evaluated.

It will be observed from photographic records that the zero setting remained almost undisturbed throughout the period of observation which was 2 hours generally and about 30 minutes in some cases. In some of the records of the spots, changes of deflection could be noticed in the beginning but this invariably settled down to constant values. The variations noticed were due to the movement of the spot while setting the loop from maximum to minimum position or due to fluctuation of H. F. current while adjusting to a particular value [Fig. 4(*b*)]. The beam of light giving the spot when switched off while bringing the loop to minimum position or adjusting the H. F. current and switched on again after a minute or so, the variations disappear. The level line in each case was drawn along horizontal portion of the path traced by the spot.

The frequency of the calibrating H. F. currents was set by adjusting the local oscillator to exact no beat condition with the help of a very slow motion vernier dial of ratio 1 : 80 operated by a long earthed handle outside the shielded cover of the oscillator. The strength of the H. F. current (I mA) passing through the inducing coil of N turns and radius r was measured by Cambridge Vacuum Junction of 5 mA range which had been previously calibrated by comparison with Moullin's Multi-range Thermal Milliammeter. The voltage E induced in the loop at a perpendicular distance d from the coil was then calculated from the formula*

$$E = k \frac{18840\ I\ r^2 N}{(d^2 + r^2)^{3/2}} \mu v/m.$$

The deflections due to the calibrating fields in the case of the diode detector were found to be linear except for very low field strengths. All our observations excepting a few in the beginning were, therefore, taken with the diode detector. This facilitated evaluation with greater accuracy of results than was possible with the square-law detector.

GROUND WAVE SUPPRESSION

For reliable results due consideration must be paid to the ground wave effect as well as the antenna effect. In our experiments the magnitude of the ground wave was found to be negligible relative to that of the sky wave. This is quite in accordance with the experimental results given by Sommerfield and Eckersley. The distances of the two broadcasting stations Calcutta ($\lambda = 370{\cdot}4$ m.) and Dacca ($\lambda = 257.1$ m.) are 480 Km. and 610 Km. respectively. Corresponding to these distances and wavelengths the strength of the ground wave field intensities given are $40 \mu v/m$ for good ground and $1.4\ \mu v/m$ for poor ground assuming power output in the transmitter to be 2 kilowatts for Calcutta ; for Dacca these are zero for distances over 500 Km. for good ground and also zero for distances over 350 Km. for poor ground. These values are obtained from unmodified Sommerfield curves and if diffraction corrections are applied according to Eckersley,[2]

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* As d was not very large in comparison with the dimensions of the loop, the correction factor k was introduced in the actual calculation.

these become still less. The length of the horizontal slit in front of the bromide paper was 130 mms. only and so the output galvanometer G had to be adjusted in our case for 130 mm. deflection for the maximum field intensity in any setting. This maximum field intensity recorded was of the order of 300 $\mu v/m$ for Dacca and 600 $\mu v/m$ for Calcutta. Thus even assuming the ground wave intensity for good conducting grounds, the deflection that will be recorded will not be more than 1 mm. for Calcutta, while for Dacca it would be still less. In Pawsey's experiments the ground wave component was as much as 20 times stronger than the sky wave component* and hence the ground wave suppression was absolutely necessary in his case. From the above considerations it will be seen that at the transmission distances with which we worked, the ground wave component being practically negligible compared to the sky wave component no special arrangement was necessary for its suppression.

In order to minimise the antenna effect as much as possible, the dimensions of the loop were made purposely small. The loop was nearly 86 cm. square and had 6 to 8 turns of wire. The effective height was about 100 cms. The following procedure was adopted to test the magnitudes of both the ground wave effect and the antenna effect relative to the maximum sky wave component :—During daytime the zero position of the galvanometer was noted with all the high tensions of the set switched on except that of the oscillator valve. The reading in the galvanometer (G) gave the actual zero of the graph, *i.e.*, the real zero signal strength level [B in Fig. 4(*a*)]. The H. T. of the oscillator valve was then switched on with the loop set both in the maximum and minimum positions. It was seen that there was absolutely no change recorded in the zero reading B in Fig. 4(*a*) for the whole period of observation which was not less than half an hour indicating that both the ground and antenna effects were practically negligible. The readings for different strength levels were then taken in steps in the way explained before (under the heading 'Calibration of the Set'). Without disturbing the adjustments made during the daytime, the above procedure was repeated during the night-time reception period 6.00 to 10.30 P.M., but now with the loop in the minimum position only. The records showed again the absence of any appreciable change either in the zero level or in those for the different strength levels both in the beginning as well as at the end of the period of observation (Fig. 4). Thus it will be seen that in our arrangements the antenna effect was negligible even during the night time.

Some typical records giving the variation of galvanometer deflection with time are shown in Plate XIV.

The ordinate r representing the galvanometer deflection was divided into a large number of small parts each representing equal change of field intensity by

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* In Khastgir and Ray's work the ground wave component was 3 to 4 times stronger than the sky wave component.

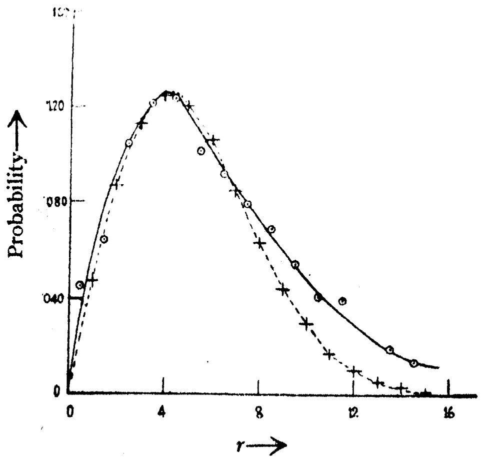
utilising the calibration graph plotted with field intensity against galvanometer deflection. The abscissa representing time was also divided into half-minute intervals. The number of a particular amplitude between r and $r+dr$ that occurred during the period was counted, the amplitude within the range occurring for half a minute being counted as one. From this the fraction of the total time during which the amplitude lay between r and $r+dr$ was determined. As mentioned before, all our records were taken for periods varying from half an hour to two hours.* Distribution curves were then drawn with values of fractions so obtained against average amplitudes of r and $r+dr$. From these curves the value of the most probable amplitude r_m was obtained; this value of r_m was used in drawing the theoretical probability curves in accordance with Rayleigh's expression

$$P' = \frac{2r}{R^2} e^{-\frac{r^2}{R^2}}$$

(where R^2 ... the sum of the squares of the components

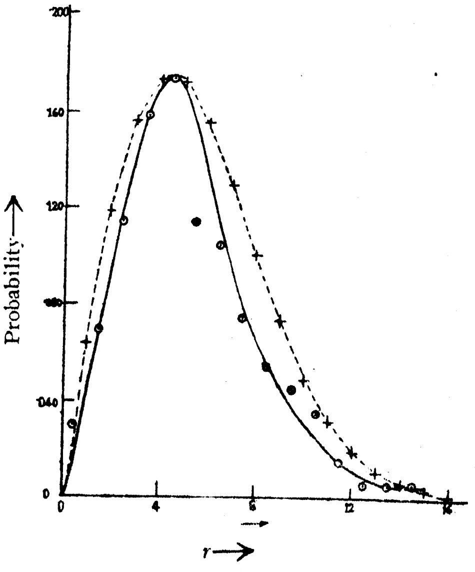
$P'dr$ ... the probability of a resultant amplitude between r and $r+dr$)

for the probability of occurrence of any resultant amplitude on the assumption of a large number of components of random phases. The maximum value of P' corresponds to $R^2 = 2r_m^2$ where r_m is the most probable value of r in the experi-



for (a) Calcutta
2-12-37

FIG. 5(a)



for (b) Dacca
16-1-40

FIG. 5(b)

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* The chief considerations being practical convenience and sufficient number of readings, we made the total period of observation half an hour and more.

PLATE XIV.

Fig. 4(a)—Calcutta, 18. 1. 39.

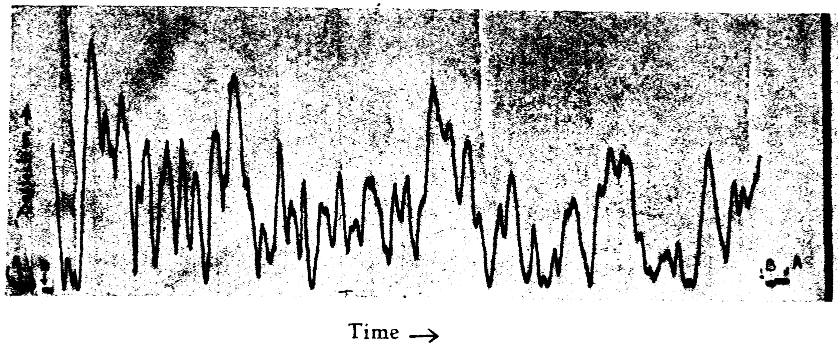


Fig. 4(b)—Dacca, 12. 2. 40.

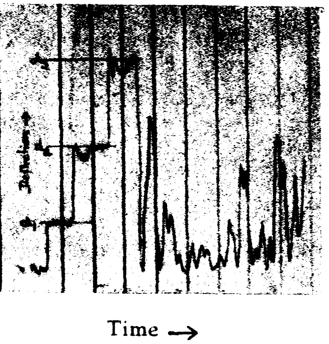
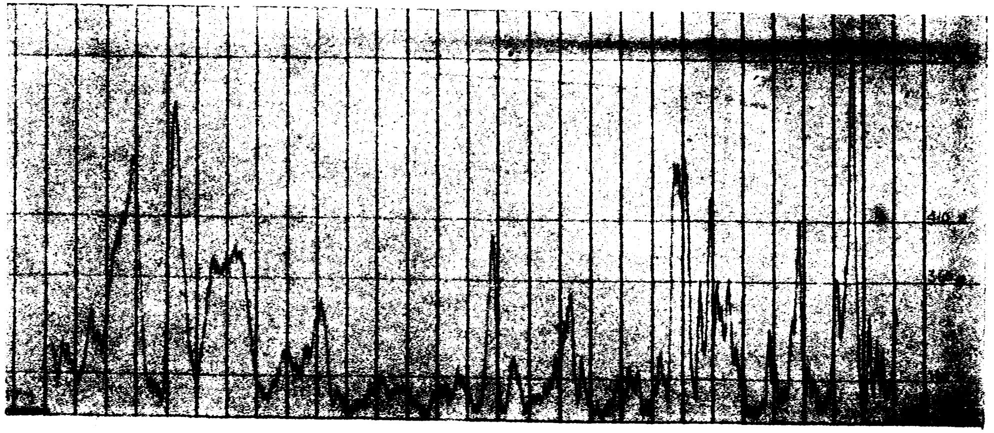
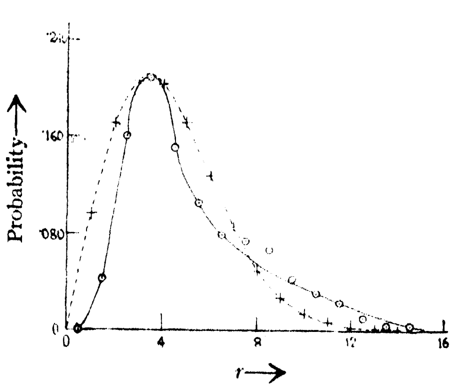


Fig. 4(c)—Calcutta, 7. 12. 37.



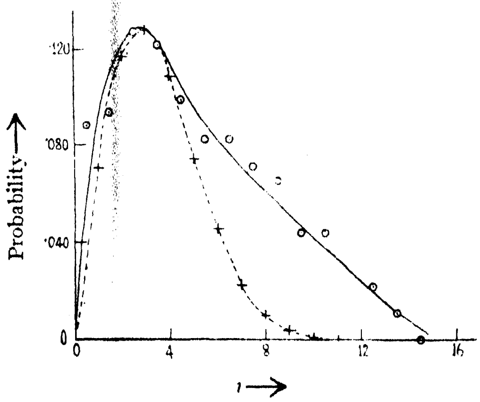
7-49 P.M.

mental distribution curves. The scales in the figures have been adjusted to give the best fit. Figs. 5 and 6 give the typical results in which the experimental curves are shown as full-line curves and the theoretical ones as dotted. It will be seen from the experimental results that the agreement between the theoretical and experimental curves are not as good as in cases of experiments* with smaller transmission distances. We have, therefore, shown the results in two broad representative types, *viz.*, those with fair agreement (Fig. 5) and those showing great divergence (Fig. 6). It may, therefore, be concluded on the basis of our observations that for long transmission paths the intensity of the down-coming waves is not determined only by irregular scattering at the ionosphere but also by



for (*a*) Calcutta
7-12-37

FIG. 6(*a*)



for (*b*) Dacca
12-2-40

FIG. 6(*b*)

the existence of other factors; the effect of the latter sometimes becomes quite appreciable as may be found in the 2nd type of curves (Fig. 6). Observations are being continued to study fully the nature of these factors.

In conclusion, the authors take this opportunity to thank Principal K. Prosad, I.E.S., who has taken much interest in our work. One of us (S. K. D.) is grateful to the Government of Bihar for the grant of a research scholarship which has enabled him to take part in this work.

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* Experiments by Pawsey[1] and by Khastgir and Ray.[3]

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[1] Pawsey, *Proc. Camb. Phil. Soc.*, **31**, 125 (1935).

[2] Eckersley, *Proc. I.R.E.*, **20**, 1555 (1932).

[3] Khastgir and Ray, *Indian Jour. of Phys.*, **14**, 283 (1940)