41

Radio-field-strength Survey of the Town of Dacca

BY

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1. *Introduction.*

Due to the importance of the radio-field-strength measurements in different directions round the transmitter, many experiments have been made in various cities from time to time. In India there has been only one radio-field-strength survey, namely, that round the Calcutta Broadcasting station at Cossipur carried out by H. Rakshit[1] under the direction of Prof. S. K. Mitra. It was, therefore, contemplated to undertake a similar survey in the town of Dacca. The object of the investigation was to obtain, as exactly as possible, the nature of the field-strength distribution locally round the transmitter of the Dacca University. Determination of the exact law of direct-ray transmission from an ideal dipole oscillator was not, however, the object of this work. With the transmitting aerial as it is, a systematic study was therefore made over the entire municipal area of the town of Dacca. The method and the results of the study are presented in this paper.

1 'Phil. Mag.,' Vol. II, p. 174 (1931).

2. *Theory of the Method of Field-strength Measurement.*

Before describing the method of procedure, the theory of the method for measuring the field-strength with a loop aerial connected to a receiving apparatus is given.

When the electromagnetic waves from a transmitter fall upon a loop aerial, there must be a certain amount of voltage V developed across its ends due to the field strength E of the locality. This voltage can be expressed as :

$$V = \frac{2\pi ANE}{R\lambda}\sqrt{R^2+4\pi^2f^2L} \quad \text{volts}$$

Where N = Number of turns of wire in the loop
A = Area of each turn in sq. cms.
R = Total radio-frequency-loss-resistance of the loop in ohms.
λ = Wave-length of incoming waves in cm.
f = Frequency of the waves in cycles per second.
L = Inductance of the loop in henry.

From this on simplification we can get

$$E = V\frac{7 \cdot 6R}{ANf^2L} 10^{13} \text{mv/ metre}$$

The values of A and N are known. The Inductance L and radio-frequency resistance R can be measured without difficulty. The field-strength E can thus be calculated after V has been determined experimentally.

3. *The Transmitter.*

Continuous unmodulated waves of 181·5 metres length were sent out from the one-valve Hartley Transmitter

(Figure 1). With an input voltage between 800 to 900 volts and plate current between 80 and 90 m.a. the output aerial

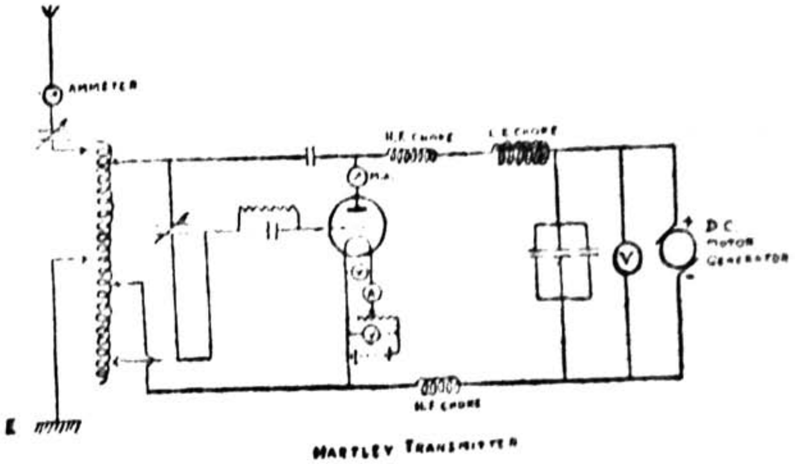


Fig. 1

current was kept steadily constant at ·3 amperes. The wave-length measured by a standard wavemeter, was checked from time to time by means of a Heterodyne arrangement. The transmitter was on the ground-floor and the transmitting aerial was an outdoor one of about 150 ft. horizontal length supported on two long masts. The lead was taken in an inclined way from the middle of the horizontal part.

4. *The Receiving Apparatus.*

The loop aerial used, was a "box"-type square loop of 5 turns of No. 18 bare copper wire, each side 126 cm. long, which could be rotated about a vertical axis. The angle of rotation could be read on a horizontal scale.

The distributed capacity of the loop was found by the well-known resonance method. The self-capacity and the inductance of the loop were found to be 40 $\mu\mu$ F and 93·4 μ H respectively.

The "Antenna" effect, which is a great disadvantage with the frame-aerials, was very effectively removed by employing a new and very simple type of shielded transformer.[3]

The receiver consisted of a screen-grid valve followed by a leaky grid detector, with ordinary reaction between the two reaction coils. The reaction could be varied by changing the position of the coils, but they were always placed beyond the point where self-oscillations could start. To check the tendency of self-oscillation, one terminal of the grid coil was joined to the sliding contact of a potentiometer, connected across the terminals of the filament battery. This, however, caused a slight diminution in the sensitiveness of the receiver; nevertheless, a distinct advantage was at times felt, as it checked the starting of self-oscillations.

A sensitive unipivot 'Max Kohl' portable Galvanometer with proper shunt was placed in the anode circuit. The diminution in the anode current was measured when the receiver was tuned to the incoming waves. By means of a two-way switch, the galvanometer could be replaced by a telephone, and the hum of the high voltage generator could be heard.

For comparatively large field strengths, the galvanometer was shunted by means of a resistance. For feeble signals the shunt was removed and the no-signal anode current was balanced by sending a current through the galvanometer in the opposite direction. The instrument was thus able to record small changes of anode current due to weaker signals.

To prevent the signal from directly exciting the receiver, the receiver box was shielded on all sides by earthed tin linings. The high tension and low tension batteries were also placed in a well-shielded box.

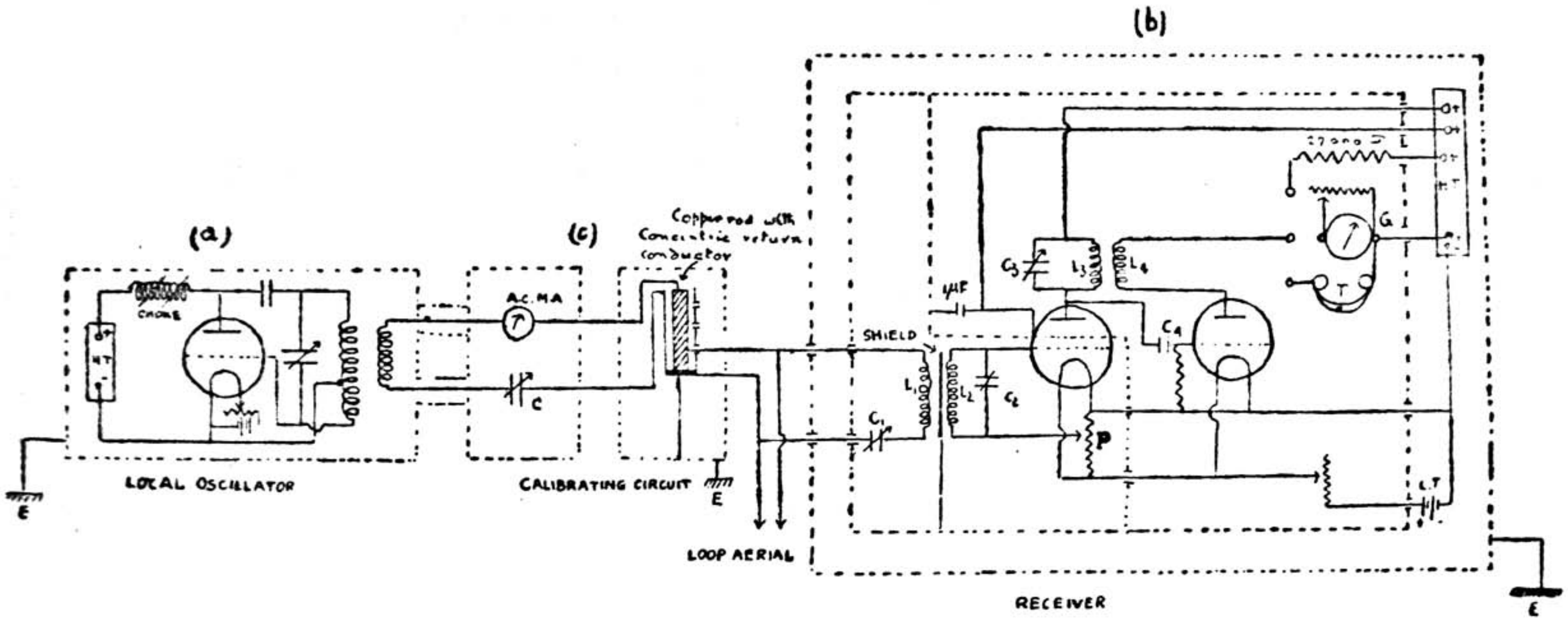
[3] S. R. Khastgir and D. N. Chowdhuri, 'Ind. Jour. Phys.,' Vol. 8, p. 189 (1933).

5. *Calibration of the Apparatus.*

The resonance voltage across the terminals of the loop aerial induced by the incoming signals at any point was known in terms of the change in the galvanometer deflection. To obtain small known voltages of the same order as the voltage developed in the field, the method followed was that of Hull and Williams [3] in their investigations on the measurement of " e " from the Shot effect. The inductive drop in a small section of a long straight copper rod surrounded by a concentric return conductor was utilised. A small Hartley oscillator (Fig. 2) enclosed in a shielded box was arranged to induce a suitable current of the required frequency into a suitable coil which formed a closed circuit with a variable condenser, a thermal-galvanometer and a copper rod (·56 cm. in diameter) surrounded by a concentric brass cylinder (internal diameter 3·11 cm.). The closed circuit was tuned by means of the variable condenser.

One end of the cylinder was kept open, while the other end was closed by a brass disc sweating into the cylinder, and this end was earthed. At a distance of 2·5 cm. from the inner surface of the end disc, a copper wire was soldered to the copper rod and led out of the cylinder through a small hole. Other similar wires were soldered at distances of 3 cm. from each other and led out through similar holes. The end point and a tapping point gave the small voltage. The inductive drop L for one cm. distance of the rod is given by $L = 2 \log_e \frac{R}{r}$ (electromagnetic units) where r and R are the outer radius of the rod and the inner radius of the cylinder respectively. The potential drop therefore equals, L. w. I. l where w and I are the angular frequency and the amount of

[3] 'Phys. Rev.,' Vol. 25, p. 147 (1925).



(a)
CHOKE
H.T.
LOCAL OSCILLATOR
E
(c)
A.C. MA
C
Copper rod with Concentric return conductor
CALIBRATING CIRCUIT
E
LOOP AERIAL
(b)
SHIELD
1µF
C_1
L_1
L_2
C_2
C_3
L_3
L_4
C_4
P
G
T
L
H.T.
L.T.
RECEIVER
E

FIG. 2.

current in the circuit and l the distance between the tapping points. Expressing in microhenries,

$$L = \cdot 0046 \log_{10} \frac{R}{r} \mu \text{ H per cm.}$$

Thus a known potential difference could be applied to the input terminals of the screened receiver. To draw the calibration curve for some definite position of the reaction coils (for which one set of field-strength measurements was taken), a set of different known voltage differences were obtained by changing the current in the circuit. A curve showing changes in the deflections of the galvanometer in the receiver for different voltages was thus obtained.

The thermal galvanometer had a lower limit for the current it could measure and for still weaker fields it was necessary to use condenser shunts. A capacity of the order of ·0001 μ F was joined in series with the Hull cylinder. This small capacity and the Hull cylinder was placed in parallel with a comparatively larger capacity (of the order of ·001 μ F). (Fig. 3.) The condenser circuits were carefully

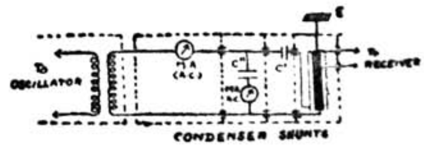


Fig. 3.

shielded from each other. The current distribution in branched circuits were carefully measured for large currents and the fraction of the main current (measured by the thermal galvanometer) which passed through the cylinder could thus be known. The calibration curves for still weaker fields were thus obtained.

During calibration, when the effect of a very small difference of potential was to be measured, it was essential to ensure that no spurious effects were obtained due to (*a*) stray magnetic field either from the local oscillator, or from elsewhere and (*b*) feed-in due to stray capacities.

Each part of the calibrating arrangement was therefore carefully shielded from each other and the receiver with oscillator and all their accessories were placed in separate metal boxes. Careful tests were made and it was definitely ascertained that no such spurious effects were present. With the calibrated set, the high-frequency resistance of the loop circuit was measured by means of the variable reactance method. The value obtained was 44·6 ohms for $\lambda = 181{\cdot}5$ metres. The value of this resistance was determined for different positions of the reaction coils in the receiver for which calibration curves had been previously drawn, and was found to be the same.

6. *Typical Survey.*

A hackney carriage with all the measuring equipment was stopped at the place of observation, previously chosen from an authorised map of the town. The site chosen was, as far as possible, away from trees, large buildings, walls, telegraph posts, etc., for these were found to affect the radio fields considerably. The loop aerial was placed in the ground about 3 ft. away from the carriage and a long copper rod pierced into the ground, served as the earthed end. The receiver was tuned, hearing the hum in the phones. The galvanometer was then connected and by rotating the loop, the position for the maximum signal was noted on the circular scale with a Mariner's compass and the galvanometer change recorded. The absence of any "Antenna" or direct effect was tested by rotating the loop through 90°.

The reaction between the two anode coils was kept at a definite value, so as to obtain the maximum signal strength, but safely away from the point where self-oscillations could occur. Calibration was made for the particular setting of the reaction coils.

Two typical records of the field-work are given in the following Table:—

TABLE I.

	Site 1 (Shunted Galv.)	Site 2 (Balanced Galv.)
A Screen-Grid Plate-Voltage ...	150 V	150 V
„ Voltage ...	80 V	80 V
Detector Plate- „ ...	40 V	40 V
Filament- „ ...	4 V	4 V
„ Current ...	·52 Amp.	50 Amp.
Potentiometer Reading ...	0	0
Reaction Position ...	4	8
Galv. Sensitiveness ...	Shunted 70 div ≡ 1·2 m.A.	Balanced by 140 volts 1 div ≡ 1 micro amp.
B Locality ...	Kayettooly Lane	River Bank (Farashganj temple)
Distance ...	½ mile	2 miles
Location from Map ...	277°	296°
„ „ Loop position	278°	294°
Galv. Readings Loop off ...	66·0	48·0
„ „ „ on ...	49·8	36·0
Deflection ...	16·2	12·0
Time for observation ...	3-55 P. M.	11-30 A.M.
C From Calibration Curve Input Voltage ...	844μv	13·4 μv
Field Strength ...	141 μv/metre	2·44 μv/metre

All observations were made during the three months of March, April and May, 1933.

7. *Some Precautions.*

1. The calibration was made immediately after or before the field-work was carried out and very often repeated to ascertain the constancy of the amplification of the receiving set.

2. Before going out, field-strength was measured at a fixed point each time to ascertain that the receiving apparatus and the transmitter were in the required condition.

3. The transmitter aerial current was kept constant and when the field-survey was being done, a record was kept of the transmitter input voltage and current, etc., every five minutes. Time for any fluctuation was carefully noted. The times at which field-strength observations were made, were also noted and these two time readings were compared after each days work.

4. The anode and filament voltages and currents for the receiver valves were kept constant for each set of calibration.

8. *Contour Map.*

In order to make fairly close observations in all directions, an authorised map of the town was taken and concentric circles were drawn in it round the transmitter at ten different distances, *viz.*, $\frac{1}{8}$ mile, $\frac{1}{4}$ mile, $\frac{3}{8}$ mile, $\frac{1}{2}$ mile, 1 mile, $1\frac{1}{2}$ miles, 2 miles, $2\frac{1}{2}$ miles and 3 miles. Some eight to twelve points were chosen on each circle. The location of each point was carefully determined by means of a protractor with respect to an arbitratory fixed north. The field-strengths were measured at these points and several curves were drawn plotting field-strengths against different angular directions for a particular distance. The curves were not regular and indicated the effect of local conditions on the field-strengths and also the directional properties of the transmitting aerial to a certain

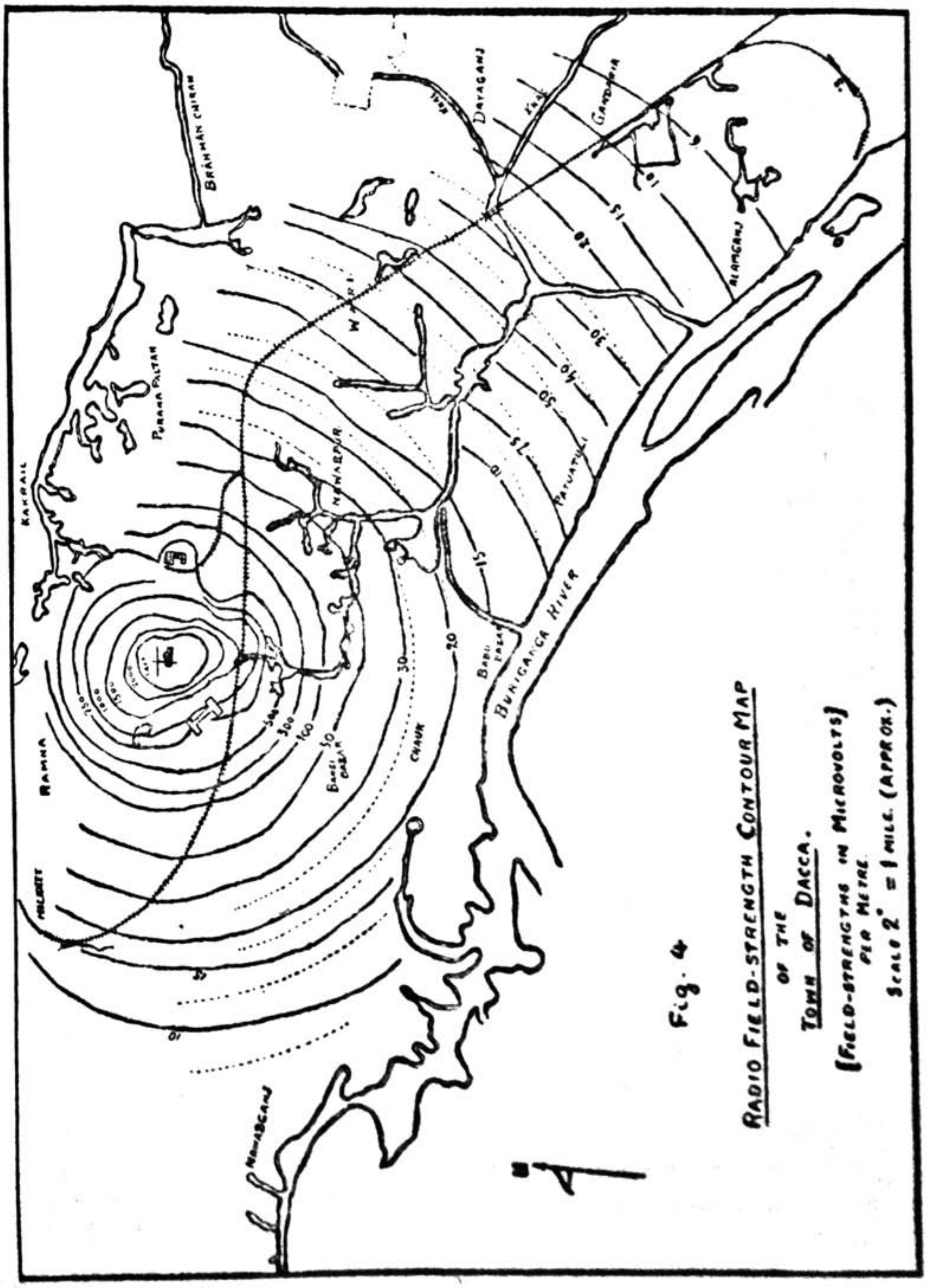


Fig. 4

RADIO FIELD-STRENGTH CONTOUR MAP OF THE TOWN OF DACCA.
(FIELD-STRENGTHS IN MICROVOLTS PER METRE.)
SCALE 2" = 1 MILE (APPROX.)

extent. From these curves, values of field-strengths in 18 different directions were obtained for different distances and for each direction a curve was drawn showing field-strengths against actual distances from the transmitter. From each of these curves for each direction, it was easy to obtain distances which would correspond to definite values of field-strengths. The contour map thus drawn, is shown in Figure 4.

9. *Discussion of Results.*

1. The radio-field-strength map shows that equal-field-strength lines roughly assume circular shapes, with a few exceptions. Very near the transmitter there is a distinct elongation in the North and South directions, showing better transmission in these directions. This must be due to the peculiarity of the transmitting aerial. The lead-in wire of the aerial is taken out in an inclined fashion and the projected part with its plane in the North-South direction, acts as an independent L-aerial. The flattening of the contour lines near the transmitter towards the East can be attributed to the roof of our Laboratory. At a distance of $\frac{3}{4}$ miles, the contour lines almost assume circular shapes.

2. The contour line of 500 μv shows the influence of the local electric power house.

3. The dotted lines show the amount of bulging of the contour lines near the river Buriganga. This is what is expected, because of the increased conductivity of the soil in these directions. The soil near the riverside has, generally, a larger value of conductivity.

4. The most striking result, however, is the abnormally large value of attenuation (Figure 5). The attenuation is uniformly high in all directions round the transmitter. The mean values of field-strengths are shown in Table 2.

FIG. 5.

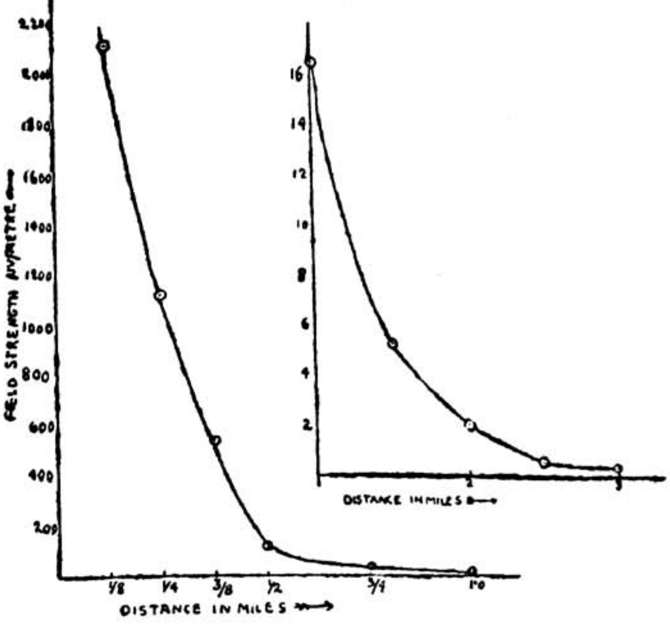


TABLE 2.

Distances from Transmitter.	Field-strengths.
⅛ mile.	2117·2 microvolt/metre.
¼ ,,	1123·3 ,,
⅜ ,,	539·4 ,,
½ ,,	115·4 ,,
¾ ,,	31·7 ,,
1 ,,	16·51 ,,
1½ miles.	5·28 ,,
2 ,,	2·01 ,,
2½ ,,	·58 ,,
3 ,,	·34 ,,

10. *Cause of the High Attenuation.*

An attempt was made to explain the high attenuation from the soil conditions of the locality and the soil properties were studied. Theoretical expressions for the attenuation has been given by Zenneck [4] and Sommerfeld [5] for a dipole oscillator. Rolf [6] has calculated from Sommerfeld's theory the values of the attenuation factor for different distances and for different values of the electric constants of the soil. Exact calculations were impossible as the aerial employed was a multipole inclined aerial. Besides, the observed attenuation was far too high to be explained on any theory of ground-absorption.

It appears, however, certain that the observed high value of attenuation is due to the transmitting aerial system. The leading wire from the horizontal part is very much inclined to the vertical and the total length from the one end of the aerial to the earth point is about 60 metres; that is one-third of the radiated wave-length. The voltage antinode must be at one end of the horizontal part of the aerial and a node somewhere down on the leading wire. Electrical oscillations have been evidently taking place between one part of the aerial to another in a slanting direction and the propagation of waves concentrated in an upward direction. The ground ray would thus appear to be very highly attenuated.

In conclusion we express our sincere thanks to Prof. S. N. Bose for his kind interest and advice throughout the investigation.

Physics Laboratory,
Dacca University,
February, 1934.

[4] Zenneck, 'Ann. d. Physik.,' Vol. 23, p. 846 (1907).
[5] Sommerfeld, 'Ann. d. Physik.,' Vol. 28, p. 665 (1909).
[6] Rolf, 'Proc. I. R. E.,' March, 1930.