CHAPTER IV

ATMOSPHERIC NOISE INTERFERENCE TO BROADCASTING IN THE 3 Mc/s BAND AT POONA

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ABSTRACT

Systematic measurements of atmospheric radio noise at 2.9 Mc/s. were taken at Poona (18.31 N, 73.55 E), during the hours, 18 to 23 I.S.T. for the whole year, 1953, by a method previously described by one of the authors. The details of the experimental work and the analysis of the results are given in the paper. Noise data as required for broadcast services have been calculated. These new data have been compared with the estimates of noise as deduced from circular No. 462 of the U.S. National Bureau of Standards and with the experimental results as reported in the Radio Research Special Report No. 26, London. Noise levels have been estimated from lightning discharge data on the basis of the known distribution of thunderstorm activity over the globe and compared with measured values.

INTRODUCTION

A possible way of assessing atmospheric noise interference to broadcasting has already been reported (AIYA, 1954a). The object of the present paper is to describe the first experiments carried out and discuss the results obtained. Measurements at 2.9 Mc/s. were taken at Poona for the whole year, 1953, during
during the hours, 18 to 23 I.S.T. In the first section, the experimental work is described in detail and utilised to deduce the noise data as required for broadcast services. The second section is devoted to a comparison between the new and the existing noise data. In the last section, an attempt is made to estimate noise levels from lightning discharge data and compare them with the results obtained by experiments described in the paper.

2. EXPERIMENTAL WORK

(a) Design of the experiments: - In order to interpret the results theoretically, it is necessary to know as many factors as possible with reasonable accuracy. Ground constants being not known sufficiently well, it was decided to avoid ground ray reception as far as possible. For ionospheric propagation, calculations become less indeterminate during night when absorption is negligible and reflection is only possible through the F$_2$ layer.

On examining the charts giving the distribution of thunderstorm activity over the globe (BROOKS), it is found that there are sources of thunderstorms both
both to the East and the West of Poona. The western sources could be eliminated and night conditions could be realised for all eastern sources as far as Java and Sumatra by choosing for the hours of observation, the period, 18 to 23 hrs. I.S.T. (Indian Standard Time is 5 hrs. 30 min. ahead of G.M.T.). Even during this period, the first hour of observation would be under daylight conditions for months near the Summer Solstice. The period, 18 to 23 hrs. I.S.T. is of importance to Indian broadcasting and is a period of high noise level.

Except for extremely local thunderstorms, ground ray has to be completely eliminated. The frequency must be such that reliable propagation should be possible all the year round during the hours stated for regions to the East of Poona upto distances of 4500 Kms. Further, it should be possible to see without ambiguity for the sources involved whether the transmission is by a single or double hop path via the F₂ layer. Noise is reported to be higher, the lower the frequency. Taking all these factors into account, it was found that the 3 Mc/s band was suitable. The 90 metre band broadcast transmissions in India add interest to investigations in the 3 Mc/s band. In this band, interference could be avoided and observations taken continuously by working at 2.9 Mc/s.
Atmospheric noise, therefore, was measured at 2.9 Mc/s. during the hours, 18 to 23 I.S.T., continuously at Poona. Periodically, investigations have been carried out for 24 hours to study the diurnal variation of noise. An examination of these results indicates that the assessment made for the period, 18 to 23 hrs., can be taken as valid for the period of day, 18 to 24 hrs. I.S.T.

(b) Equipment and its installation :- Measurements were carried out using the equipment designed for investigations in the 2.5 to 20 Mc/s. band and its details are as follows :-

A vertical aerial, 8' 3" high is mounted at a height of 8' from the terrace, of a laboratory, which is 50' from ground. All the constants of the aerial are determined at site. Its effective height is 1.22 metres. The aerial terminates into a cathode follower mounted at the bottom of the aerial. The output of the cathode follower is taken through a feeder to a receiver mounted in the room below. Necessary precautions are taken for balancing, shielding, etc. so that the stray pick-up is 40 db. below that of the aerial. The receiver used is a Hammerland SP-400-SX. The R.F. stages are carefully aligned and the I.F. stages
Fig. 1. Receiver frequency response characteristic.
Fig. 2. Circuit diagram of output unit.
stages are aligned using an alignment oscilloscope. The bandwidth characteristics of the receiver are shown in Figure 1.

The second channel selectivity of the receiver is 80 db. down. The receiver is used with AVC off and its R.F. volume control is replaced by fixed resistances and a switch to provide ranges for the noise meter. Power is supplied to the receiver through a constant voltage transformer. The receiver gain is checked twice a week. The A.F. output of the receiver is fed to the output unit built specially for these experiments and shown in Figure 2.

The value of the choke in the output unit is 25 henries. Since it has to record impulses, some overload protection is necessary and, for this purpose, it must have some form of logarithmic response. Further, the value of the choke must be such that it has no effect on the time constants of the circuit. The procedure adopted for the design of the output unit is as given by HUNT (1933). An additional feature introduced into the design of the output unit was to provide a linear response from 100 to 5000 c/s. This represents the range of frequencies of interest in the reproduction of broadcast programmes and the A.F. out-
output resulting from noise within this range had, therefore, to be provided with a high fidelity reproduction. The charging and discharging time constants of the meter are 10 and 500 milliseconds respectively.

The noise meter thus set up is calibrated by using signals from a standard signal generator modulated 30 per cent by a 400 c/s. note. The signals from the signal generator previously tested and checked are fed through the equivalent impedance of the aerial to the cathode follower at the point at which the aerial is connected. At any frequency at which the calibration is carried out, the strength of the signal from the signal generator is gradually varied and the noise meter read. The results obtained are reduced to correspond to an aerial of one metre effective height. The calibration is checked at one point in each range twice a month. The equipment thus set up can be used in the range, 0.5 to 500 µV/m. A higher range has also been provided.

The procedure for the recording and analysis of observations is as previously reported. (AIYA, 1954a).

(c) Experimental Results :- In a previous communication (AIYA, 1954a), atmospheric noise has been classified into three types :- (i) type A noise giving
giving the impression of continuous noise, (b) type B noise coming as distinct impulses and (c) type C noise, a special form of type B noise arising from local thunderstorms. This classification is followed in reporting the results. When only type A noise is present, or when the number of impulses due to type B or type C noise is less than five per minute, only type A noise values are computed. When the number of impulses due to type B or type C noise is between five and ten per minute, values of both type A and type B or type C noise are computed and stated. When the number of impulses due to type B or type C noise exceeds ten per minute, only type B or type C noise values are calculated and type A noise observations are ignored.

Systematic observations were taken during the period, 18 to 23 hrs. I.S.T. for the whole year, 1953, at 2.9 Mc/s. As stated in section 2 (a), these results can be taken as valid for the period, 18 to 24 hours, I.S.T. To assist theoretical understanding, if two forms of type B noise are received, their values are computed separately as also the weighted value for the month. Similarly, during the period, May to July, values are also computed for the hours, 19 to 23, as 18 to 19 hours fall under daylight conditions. Table I summarises the results.
<table>
<thead>
<tr>
<th>Month</th>
<th>Type of noise</th>
<th>H.D. value in µV/m</th>
<th>Med. value in µV/m</th>
<th>% days</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>A</td>
<td>0.1</td>
<td>0.8</td>
<td>90</td>
<td>5 impulses/min.</td>
</tr>
<tr>
<td>February</td>
<td>A</td>
<td>1.2</td>
<td>3.6</td>
<td>100</td>
<td>Weighted value</td>
</tr>
<tr>
<td>March</td>
<td>B</td>
<td>4.6</td>
<td>6.0</td>
<td>100</td>
<td>One day only</td>
</tr>
<tr>
<td>April</td>
<td>C</td>
<td>10.1</td>
<td>7.2</td>
<td>33</td>
<td>18-23 hours.</td>
</tr>
<tr>
<td>May</td>
<td>B</td>
<td>15.0</td>
<td>12.1</td>
<td>25</td>
<td>19-23 hours.</td>
</tr>
<tr>
<td></td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>------</td>
</tr>
<tr>
<td>June</td>
<td>10.3</td>
<td>15.5</td>
<td>60</td>
<td>18-23 hours.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>10.6</td>
<td>15.7</td>
<td>60</td>
<td>19-23 hours.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17.8</td>
<td>28.0</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>July</td>
<td>10.4</td>
<td>15.4</td>
<td>72</td>
<td>18 to 23 hours.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11.0</td>
<td>15.6</td>
<td>72</td>
<td>19-23 hours.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>17.8</td>
<td>25.8</td>
<td>28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>August</td>
<td>5.0</td>
<td>7.3</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>10.4</td>
<td>14.8</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.8</td>
<td>11.2</td>
<td>85</td>
<td>Weighted value</td>
<td></td>
</tr>
<tr>
<td></td>
<td>16.3</td>
<td>20.0</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>September</td>
<td>5.6</td>
<td>8.1</td>
<td>32</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11.0</td>
<td>15.0</td>
<td>54</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8.7</td>
<td>12.0</td>
<td>86</td>
<td>Weighted value</td>
<td></td>
</tr>
<tr>
<td></td>
<td>14.8</td>
<td>19.8</td>
<td>14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>October</td>
<td>6.2</td>
<td>9.6</td>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>9.9</td>
<td>13.6</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>7.4</td>
<td>10.9</td>
<td>75</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14.3</td>
<td>20.4</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>November</td>
<td>1.0</td>
<td>1.2</td>
<td>90</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.1</td>
<td>1.4</td>
<td>90</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NOTE: During November-January, there can be type B or type C noise for about 10 per cent of the days and values can go up to 30 μV/m. Data is not adequate for analysis.
(d) Noise data for broadcast services: - The experimental results given in Table I are of direct scientific interest and can be useful for a theoretical understanding of the problem. Further, it is known that the approach and recession of thunderstorm activity varies from year to year. Therefore, the percentage days given in Table I can only be considered useful for giving an idea of the number of days in a month when a particular type of noise is predominant. However, if a longer period than a month, viz. a quarter, is considered, it is very probable that the percentage days when a particular noise predominates will remain the same from year to year. Therefore, for service purposes, the data of Table I can be utilised to calculate noise values for satisfactory service during 50, 75 and 90 per cent of the time in the four quarters of the year and the complete year. The results are given in Table II. Calculated values have been rounded off to the nearest higher whole numbers. The letter in bracket below the value indicates the type of noise.

An examination of Tables I and II shows clearly that the median and higher decile values of any one type of noise do not necessarily represent the noise values for satisfactory service for 50 and 90 per cent of the time. Such a coincidence can, however, occur
Table II

NOISE VALUES IN $\mu$V/m FOR 50, 75 AND 90 PER CENT
OF THE TIME SATISFACTORY BROADCAST SERVICE

Place: POONA (18.31N, 73.55 E) Time: 18-24 hrs.
I.S.T.
3 Mc/s. BAND

<table>
<thead>
<tr>
<th>Season</th>
<th>II 50%</th>
<th>III 75%</th>
<th>IV 90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec - Feb.</td>
<td>1 (A)</td>
<td>2 (A)</td>
<td>6 (B)</td>
</tr>
<tr>
<td>Mar - May</td>
<td>13 (B)</td>
<td>42 (C)</td>
<td>85 (C)</td>
</tr>
<tr>
<td>Jun - Aug.</td>
<td>14 (B)</td>
<td>18 (C)</td>
<td>25 (C)</td>
</tr>
<tr>
<td>Sept - Nov.</td>
<td>8 (B)</td>
<td>12 (B)</td>
<td>15 (C)</td>
</tr>
<tr>
<td>Whole year</td>
<td>11 (B)</td>
<td>15 (B)</td>
<td>20 (C)</td>
</tr>
</tbody>
</table>

NOTE 1: The letter in bracket below value indicates the type of noise.

NOTE 2: The value in column IV for Dec-Feb. is an estimate based on scanty data and actual values for March and October.
occur at high latitudes where only type A noise may be observed for a whole season.

(e) **Accuracy of the results** :- In discussing this question, the first problem is instrumental accuracy. This is as good as one can expect it to be and is estimated to be correct to within 5 per cent for measurements exceeding 2 $\mu$V/m. For values of the order of 1 $\mu$V/m and lower, the accuracy may be as poor as 20 per cent. Measurements of such low values are beset with several difficulties. Other noises including man made noise and interference enter into the picture. Occasions arise when it becomes extremely difficult to say that only atmospheric noise is being measured. Over the whole spectrum, there is always a small background due to radiations from stations at their authorised frequencies or their harmonics. This is generally so bad that no useful purpose may be served by measuring atmospheric noise of values of the order of 1 $\mu$V/m. Fortunately, in the 3 Mc/s band, this interference has not been so bad as to prevent measurement.

The statistically computed values are expected to hold from year to year but for possible variations of ionospheric absorption etc. and the year to year variations of thunderstorm activity. The latter becomes
becomes important for type C noise and this assumes significance during March-May. Observations have been taken for some months during 1952 and 1954. A comparison of the results for the corresponding months shows agreement within 3 db. or better. Most satisfactory agreement is obtained for type B noise. All these facts appear to support the conclusion that the averaged seasonal values for service purposes should be considered satisfactory from year to year and do not need a factor of safety beyond 3 db.

(f) Conversion data:— In the results presented, the ten highest impulses recorded during a minute are averaged to give the noise value. It is not outside the limits of probability that some may consider 5, 15 or 20 impulses per minute to have an annoyance value. To make the results useful in such cases, 36 hourly sets of observations selected at random from type B noise data were analysed. In each case, the average value of the ten highest impulses per minute, the five highest impulses per minute, the fifteen highest impulses per minute and the twenty highest impulses per minute were calculated. These values were converted into ratios in terms of the value calculated for the ten highest impulses per minute. The results are shown in Table III.
They represent the arithmetically averaged ratios for all the hours.

Table III
DATA FOR CONVERTING 10 IMPULSES/MIN. TYPE B NOISE VALUE TO 5, 15, OR 20 IMPULSES/MIN. VALUE

<table>
<thead>
<tr>
<th>Ratio to value of 10 per min. (db. above value of 10 per min.)</th>
<th>Average of 5 highest peaks/min.</th>
<th>Average of 15 highest peaks/min.</th>
<th>Average of 20 highest peaks/min.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.14±0.03</td>
<td>0.912±0.013</td>
<td>0.843±0.020</td>
<td></td>
</tr>
<tr>
<td>1.15</td>
<td>-0.85</td>
<td>-1.45</td>
<td></td>
</tr>
</tbody>
</table>

From the limits of error, it is seen that the ratio is about the same for all the hours selected for averaging. Such tables are not necessary for type A noise. The type C noise data is not large enough to attempt any such generalisation.

The bandwidth characteristics of the receiver has already been described. This can be used to convert the results to other bandwidths approximately.
The results in this paper are given in terms of signals modulated 30 per cent by a 400 c/s. note. The equipment was also calibrated using signals modulated 15 per cent and 50 per cent with the same note. By multiplying the results in this paper by 2.5 and 0.58 respectively values corresponding to 15 and 50 per cent modulation calibrations can be obtained, but they will be approximate to 5 per cent.

(g) Some stray phenomena:— It is now necessary to mention some stray phenomena noticed during the measurements. During the period, March-October, there can be a day or two when thunderstorm activity occurs over the point of observation. In such cases, continuous noise exceeding 100 µV/m and lasting for periods ranging from half to one minute may be observed for an hour. This may be followed by impulsive noise having values of the order of 800 µV/m and lasting about an hour. The number of such high value impulses is of the order of ten per minute. In addition, there can be three or four days when the average value for the hour exceeds 100 µV/m for several hours and can have values of the order of 250 µV/m for an hour or so. Before the break of the monsoon (April, May), precipitation static of value 100 µV/m can be observed for a minute or so, occasion-
occasionally, when it starts raining or the intensity of rainfall increases.

3. COMPARISON BETWEEN THE NEW AND EXISTING NOISE DATA

In a previous communication (AIYA, 1954a), it has been pointed out that the following information is necessary for making a fair comparison of the results of different workers: -

(a) details of the aerial,
(b) bandwidth characteristics of the receiver,
(c) detailed particulars of the receiver and the measuring system.
(d) method of calibration,
(e) criteria of the number of impulses per minute, and if possible, suitable data for converting the results to other criteria,
(f) the details of the way the observations have been recorded and assessed, and
(g) standards of satisfactory signals in relation to the noise level as measured.

When details on the several points mentioned above are not available, comparisons become difficult and will
will not be made in this paper.

(a) **Available data** :- Estimates of noise level can be deduced from the data provided by the Central Radio Propagation Laboratory (CRPL) in Circular No. 462 of the United States National Bureau of Standards on Ionospheric Radio Propagation (NATIONAL BUREAU OF STANDARDS, 1949). These estimates will be compared with the data given in Table II.

Atmospheric noise has been measured at the places given below which are in or around India :-

1. Calcutta..... (CHAKRAVARTI, GHOSH & GHOSH)
2. Dacca......... (KHASTGIR & ALI:KHASTGIR & RAO)
3. Lahore....... (ALL INDIA RADIO)

For (1), (2) and (3), the details necessary for making a fair comparison are not available. Therefore, the data of Table II will be compared with the results of the Radio Research Board, London, only.

(b) **Comparison with the estimates of CRPL, Washington** :- In the circular No. 462 referred to above, the world is divided into atmospheric radio noise zones. Areas of the world in which thunderstorms are most fre-
frequent are indicated as zones 4 and 5. The areas most remote from the principal thunderstorm areas and in which little atmospheric radio noise may be expected are indicated as zone 1. The other zones are intermediate in radio noise expectations. Thus, the world is divided into five noise zones. Four noise maps are drawn to correspond to four different seasons of the year and each map indicates the noise zone to which any place in the world belongs during the season. The five noise zones correspond to five noise grades. Corresponding to each noise grade, the required field intensity for telephony with 100 per cent modulation for satisfactory service in the presence of atmospheric radio noise is given in the form of graphs for six different times of the day. The required field intensity is given in r.m.s. values and is believed to represent a signal to 'average noise' ratio of 15 db. The graphs give the field intensity and the 'average noise' can be deduced from the field intensity by assuming the former to be 15 db. lower than the latter. 'Satisfactory Service' in these calculations is expected to assure radio telephone communication for 90 per cent of the time and is expected to provide 90 per cent intelligibility of 100 per cent modulated radio telephone service.
'Average noise values' can be deduced from the circular for 16, 20 and 24 hours L.M.T. Having regard to the measurement reported in this paper, it is adequate to abstract the necessary information for 20 hours, L.M.T. This has been done for Poona, Delhi, Calcutta and Colombo and is reproduced in Table IV. (page 100) Noise values have been rounded off to the nearest whole numbers. The noise grades have been estimated from the maps in intervals of half a unit. The values of noise given are 'average noise values' as described in the circular quoted and are for a receiving set bandwidth of '3 Kc. each side of the carrier frequency'.

In examining the extent to which noise grade maps can be satisfactory, the following questions arise:

(a) Whether one noise grade can satisfactorily represent noise levels at a place at all frequencies having regard to the varying propagation characteristics at different frequencies and the known thunderstorm distribution over the globe.

(b) Whether it is at all possible to give noise levels for 90 per cent of the time satisfactory service by such noise grade maps.

These questions will not be discussed here as it
### Table IV

**ESTIMATED NOISE GRADE AND NOISE VALUE**

**IN µV/m AT 20 HRS. L.M.T. FOR 3 Mc/s**

(From Circular No. 462 of the National Bureau of Standards, Washington)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade</td>
<td>Value</td>
<td>Grade</td>
<td>Value</td>
</tr>
<tr>
<td>Poona</td>
<td>2.5</td>
<td>8</td>
<td>3.5</td>
<td>16</td>
</tr>
<tr>
<td>Delhi</td>
<td>2.5</td>
<td>8</td>
<td>3.0</td>
<td>11</td>
</tr>
<tr>
<td>Calcutta</td>
<td>2.5</td>
<td>8</td>
<td>3.5</td>
<td>16</td>
</tr>
<tr>
<td>Colombo</td>
<td>3.0</td>
<td>11</td>
<td>3.5</td>
<td>16</td>
</tr>
</tbody>
</table>
it is proposed to examine them along with the signi-
ificance of the noise grade and a possible way of revi-
sion of the noise grade as assigned at present to dif-
f erent places, in a future paper.

A careful examination of the description and graphs
given in circular No. 462 of the National Bureau of
Standards leads to the following inferences :-

(a) The calculations on which the CRPL estimates
of noise at 3 Mc/s as given in Table IV are
based, appear to be restricted to consider-
ing the noise received by sky wave propaga-
tion only, at the places listed in the Table.
Type C noise which arises from local thunder-
storms appears to have been ignored.

(b) The calculations appear to have been carried
out without any criterion for the minimum
number of impulses per minute. In this
paper, if the number of impulses received is
less than 5 per minute, type B noise obser-
vations are ignored. Type B noise values
only are computed when the number of impulses
per minute exceeds ten. There appears to
be no such criteria for the CRPL estimates.

The net effect of (a) is to make the estimate
estimate lower than the actual value during periods of significant local thunderstorm activity. This is actually the case for Poona during March-May, June-August and September-November. The net effect of (b) is to make the estimate higher than the actual value when a few stray impulses are being received. This is the case for Poona during the season, December-February. The above conclusions follow by a comparison of the values in Table IV with those in Table II.

The values given in Table IV can be deduced from the experimental results as given in Table I by adopting the assumptions (a) and (b) as stated above. Adoption of such assumptions is certainly not a justifiable step but it is useful for a rational understanding of the estimates in Table IV. If Table I is examined carefully after ignoring type C noise, it will be noticed that there is one type B noise having a median value between 10 and 11 μV/m and a higher decile value between 14 and 16 μV/m. This noise can be assigned to one set of sources. It will be shown later in Section 4 (e) that this arises from sources spread over an area lying between 400 and 1000 Kms. from Poona and having a mean distance of 700 Kms. In round figures, the median value of noise due to this source can be taken as 11 μV/m and the higher decile value as 16 μV/m.
This follows by an examination of the results in Table I. This noise is predominant during March-May and June-August. Therefore, for 90 per cent of the time satisfactory service, the higher decile value has to be adopted and this value, 16 \( \mu \text{V/m} \) agrees with the value given in Table IV for March-May and June-August. During September-November, this noise is very much less frequent. Therefore, for this season, the median value of this noise, viz. 11 \( \mu \text{V/m} \) has to be adopted for 90 per cent of the time satisfactory service and this is the value given in Table IV.

An examination of Table I shows that there is a second type B noise which is observed quite prominently during March, August and September. It has a median value between 5 and 6 \( \mu \text{V/m} \) and a higher decile value between 7 and 8 \( \mu \text{V/m} \). This noise can be assigned to a second set of sources. It will be shown later in Section 4 (e) that this noise arises from sources for which a mean distance of 2000 Kms. from Poona can be assigned. Noise from this source has been noticed in the measurements during the period, December-February, but the number of impulses per minute was very small for most of the time. The scanty data indicated that the number of impulses per minute for this noise did not exceed ten per minute for more than 10 per cent of the
the time. Therefore, its median value rounded off is given in Table II for 90 per cent of the time satisfactory service as 6 $\mu$V/m. But, if the number of impulses per minute criterion is ignored, the higher decile value of this noise viz. 8 $\mu$V/m, will have to be taken as the value for 90 per cent of the time satisfactory service. This corresponds to the value given in Table IV for the period, December-February.

The above discussion appears to indicate that only two possible sources have been taken into account for arriving at an estimate of noise level as given by the CRPL data. It is obvious that these estimates cannot be considered entirely satisfactory.

(c) Comparison with measurements of RRB, London:- On behalf of the Radio Research Board, London, measurements of atmospheric noise at high frequencies (2 to 20 Mc/s.) have been in progress at a number of stations spread all over the world. The results of such measurements during the years, 1945-1951, have been published as Special Report No. 26 (RADIO RESEARCH BOARD, 1953). The method used has been described by Thomas (THOMAS, 1950). It measures the minimum required field intensity for 95 per cent intelligibility of C.W. signals sent at 10 words per minute in the presence of atmospheric noise.
It is a subjective method and the values recorded by observers are their estimates of the signal strength required. Subjective tests have revealed that the maximum range of error of this method is from +4 to -7 db. above the correct value. The method is not likely to give rise to an error beyond ± 5 db. The likely error can be regarded to be within ± 3 db. The signal generator used with the equipment has a course calibration in steps of about 3 db. The measurements are carried out with a receiver bandwidth of 10 Kc/s.

Each station at which measurements are taken, produces one measurement of noise level each hour on each of the five frequencies 2.5, 5.0, 10, 15 and 20 Mc/s. These results are utilised for determining the monthly median, higher and lower decile values for each hour. The number of observations from which the results are computed is not very large. This is partly compensated by observations being available for a number of years. Mean diurnal curves for the whole period of observation for each season of the year have been given in an appendix to the special report, No. 26 and they can be used for the abstraction of data.

The Radio Research Board results give the minimum required field intensities for satisfactory reception
reception in the presence of noise. To compare these results with the results reported in this paper, it becomes necessary to make a statement about standards but this should be considered tentative. For steady signals, it appears that a signal of r.m.s. value equal to half type A noise, one fourth type B noise and one fifth type C noise can give 90 per cent intelligibility of C.W. signals sent at about 10 words per minute. The values of noise to be used are those as given actually in the paper. The bandwidth of the receiver is as stated in section 2(b).

The special report No. 26 of the Radio Research Board gives the result of measurements at 2.5 Mc/s. for Delhi, Calcutta and Colombo. For purposes of comparison, it is adequate to abstract the data for 20 hrs. L.M.T. On the basis of Table IV, Poona is in the same noise grade as the other places in the Table viz. Delhi, Calcutta and Colombo during September-November. During the other seasons, two out of the other three places have the same noise grade as Poona. Therefore, assuming that places having the same noise grade have the same noise level, a comparison can be made.

Table V (page 107) gives the data abstracted from the special report No. 26 of the Radio Research Board. The median and higher decile values as used in this Table
Table V

MINIMUM SIGNAL R.M.S. VALUES IN µV/m AT 2.5 Mc/s.
FOR SATISFACTORY RECEPTION OF C.W. SIGNALS IN
THE PRESENCE OF ATMOSPHERIC NOISE AT 20 HRS. L.M.T.

(Radio Research Board - Special Report No. 26)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Delhi</td>
<td>-</td>
<td>-</td>
<td>2.0</td>
<td>7.1</td>
</tr>
<tr>
<td>Calcutta</td>
<td>-</td>
<td>2.0</td>
<td>2.5</td>
<td>10.0</td>
</tr>
<tr>
<td>Colombo</td>
<td>1.6</td>
<td>3.2</td>
<td>2.8</td>
<td>6.3</td>
</tr>
</tbody>
</table>
Table are the terms used in the Report and they really correspond to '50 and 90 per cent of the time satisfactory service' values in Table II. Using the tentative standards as stated earlier and the data from Table II, the minimum r.m.s. signal values for satisfactory reception of C.W. signals in the presence of atmospheric noise on the basis of the results reported in this paper for Poona have been calculated and are shown in Table VI (page 109). While comparing the results in Table VI with those in Table V for the same noise grade, it is useful to take account of the differences in the two sets of measurement and they are listed in Table VII (page 109). It may further be added that, if noise due to local thunderstorms is taken into account, the assignment of the noise grades as in Table IV is not satisfactory on the basis of the distribution of thunderstorm days on the land mass of India (AIYA, 1954b).

A comparison of the results as given in Tables V and VI appears to indicate generally that the Radio Research Board measurements give lower values of noise than what is to be expected on the basis of the Poona experiments. The two sets of results can, however, be reconciled by making an allowance of 6 db. for errors. Since the statement about standards is tentative, no useful purpose can be served by a detailed discussion at this stage.
Table VI
MINIMUM SIGNAL R.M.S. VALUES IN µV/m AT 2.9 Mc/s
FOR SATISFACTORY RECEPTION OF C.W. SIGNALS IN
THE PRESENCE OF ATMOSPHERIC NOISE DURING 18-24 HRS.I.S.T.
(Calculated from Table II of this paper)

<table>
<thead>
<tr>
<th>Place</th>
<th>Dec - Feb. 50%</th>
<th>Dec - Feb. 90%</th>
<th>Mar - May 50%</th>
<th>Mar - May 90%</th>
<th>June - Aug. 50%</th>
<th>June - Aug. 90%</th>
<th>Sept - Nov. 50%</th>
<th>Sept - Nov. 90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poona</td>
<td>0.5</td>
<td>1.5</td>
<td>3.3</td>
<td>17.0</td>
<td>3.5</td>
<td>5.0</td>
<td>2.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Table VII
DIFFERENCES OF EXPERIMENTAL DETAILS FOR MEASUREMENTS
REPORTED IN TABLE V AND IN TABLE VI

<table>
<thead>
<tr>
<th>Table number</th>
<th>Frequency in Mc/s.</th>
<th>Receiver bandwidth in Kc/s.</th>
<th>Time of day</th>
<th>Percentage intelligibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>V</td>
<td>2.5</td>
<td>10</td>
<td>20 L. M. T.</td>
<td>95</td>
</tr>
<tr>
<td>VI</td>
<td>2.9</td>
<td>6 at 6 db. down</td>
<td>18-24 I.S.T.</td>
<td>90</td>
</tr>
</tbody>
</table>
4. ESTIMATIONS OF NOISE FROM LIGHTNING DISCHARGE DATA

The source of all atmospheric radio noise appears to be the natural electrical discharges associated with thunderstorms. Extensive investigations have revealed 'no evidence that is incompatible with the provisional hypothesis that every atmospheric received on a set of high sensitivity within the commercial range is radiated by a lightning flash'. (RADIO RESEARCH BOARD, 1947). Therefore, estimation of noise from lightning discharge data and its comparison with measured values is of importance to our understanding of the problem of atmospheric radio noise.

Useful data on the distribution of thunderstorm activity over the globe have been published. Valuable information on lightning discharges and their associated fields and on the nature of atmospherics which are responsible for the noise is available in the classical papers of APPLETON, CHAPMAN, WATSON WATT, SCHONLAND and their collaborators and of BERGER, LUTKIN, McEACHRON, NORINDER and others. The data can be utilised to determine the position, form and power of a radiator that can be considered as equivalent to the natural phenomenon at any given frequency during a specified period of day.
day in a month or a season. The field strength at any point due to such an equivalent radiator can then be calculated on the basis of the known laws of propagation. It is thus possible to estimate atmospheric radio noise levels from lightning discharge data.

Attempts have been made to estimate the frequency distribution of energy radiated by a lightning flash and to calculate the noise levels by OLENDORF, JAEGAR, and THOMAS & BURGESS (OLENDORF: JAEGAR : RADIO RESEARCH BOARD, 1947). The most recent of such attempts is that of THOMAS & BURGESS. Their calculations are based on the data for the return stroke and the lightning discharge thus becomes equivalent to a long linear aerial. They assume a value for the rate of occurrence of the impulses. In carrying out field strength calculations from the working equations, they assume that radiation at all angles to the assumed vertical discharge channel is the same as that computed for the normal. The return stroke is of no real importance in the case of tropical thunderstorms which are responsible for the noise as measured and reported in this paper. A critical summary of the present position of noise estimations from lightning discharge data is given elsewhere by one of us (AIYA, 1955) and it has been shown therein that a fresh approach to the problem is necessary.
(b) Approach to the problem:— When the intensity of the electric field at some point in the cloud exceeds the disruptive strength of the dielectric, a discharge occurs and this leads to the initiation of a lightning flash. Theoretically, such a flash can occur (a) within the cloud, (b) from a cloud to the upper atmosphere and (c) from a cloud to the earth. At higher latitudes, specially in temperate regions, the third type is common, and hence, the return stroke from the earth to the cloud becomes important. Owing to the greater height of the tropopause, thunderstorms occur at a higher altitude in the tropics. Consequently, the most common type of a flash is the one that occurs within the cloud. Therefore, an analysis of the lightning discharge data as they apply to typical tropical thunderstorms becomes necessary.

A lightning discharge radiates an impulse. The field strength measured depends, therefore, on the several processes involved in the technique of measurement. Further, the results reported in this paper are based on the collection and assessment of data on a certain statistical basis. These facts have to be taken into account in evolving the equivalent radiator from lightning discharge data.
The whole problem has been examined in detail by one of us and reported elsewhere. (AIYA, 1955). It has been shown that a step in a stepped leader stroke is responsible for the radiation that appears as radio noise. Lightning discharge data have been utilised to deduce an idealised statistically valid representation of a typical lightning flash as it occurs in a tropical thunderstorm. An expression is deduced for the average electric field due to a stroke in a flash. This is used to evaluate the power at the source that should correspond to the noise field strength as measured by the noise meter used for the experiments reported in this paper. It has also been shown that the radiator is equivalent to a short vertical dipole in free space. All the deductions are expected to be valid in the frequency range, 1-20 Mc/s. The power radiated by this equivalent dipole is given in the formula:–

\[ \text{Power in watts} = W = \frac{45}{f^2} \quad (1) \]

where 'f' is the frequency in Mc/s.

Equation (1) is based on an idealised statistically valid representation of a lightning flash. It is, therefore, strictly not applicable to an individual thunderstorm. In a paper under preparation by AIYA,
AIYA, PHADKE, KHOT and SANE on 'Tropical Thunderstorms as Noise Radiators', the growth and decay of the activity of tropical thunderstorms are discussed and the peak activity defined. It is shown therein that this peak activity lasts 4 to 6 hours and that, in the majority of cases, the maximum is reached after local sunset. Equation (1) gives the mean power during the period of peak activity. Since the hours of observation for the measurements reported in the paper are 18 - 23, I.S.T. it is found that the power given by equation (1) can be used for the calculation of statistically assessed results.

Having fixed the form and power of the equivalent radiator, it is now necessary to fix its position. Suppose that, during a certain period, say a month, the thunderstorm activity is spread over a certain area. Then, the mean centre of this area is located and it is supposed that the equivalent radiator is at this mean centre.

(b) Propagation calculations :- Impulses radiated by lightning flashes travel via the ground, via. the troposphere or as an optical ray in exactly the same manner as other radio waves. A Fourier analysis of an impulse shows that it consists of a large number of com-
components of different amplitudes and frequencies. Any receiver tuned to a frequency, \( f \), picks up all frequencies lying within the receiver bandwidth at the frequency, \( f \). This is exactly what happens with the noise meter and, when it is tuned to a frequency, \( f \), it picks up all the Fourier components of the impulse radiated by a lightning flash which are within 3 Kc. each side of the carrier frequency, \( f \), to which the receiver of the noise meter is tuned. For these Fourier components lying within a bandwidth of 6 Kc. at a frequency, \( f \), it will be assumed that the propagation characteristics are the same as for the frequency, \( f \). This type of assumption is usual in considering the propagation of modulated waves as in radio telephony or broadcasting.

Change of propagation characteristics with frequency, however, become perceptible for changes of frequency much larger than what are implied by the 'bandwidth of a receiver'. This can be expressed in general terms by saying that, as the carrier frequency, \( f \), varies, the propagation characteristics vary. This paper is concerned with only one value of frequency, \( f \), viz., 2.9 Mc/s.

Detailed numerical calculations in this paper are restricted to only one type of propagation viz. iono-
ionospheric propagation. During the period of observation, 18 - 23 hrs. I.S.T., reliable and continuous propagation from the sources involved to Poona is via the F<sub>2</sub> layer. In the results reported in the paper, the average of the ten highest impulses out of the large number received every minute is taken as a measure of the noise. Hence, in almost all cases, values measured correspond to maximum values. Fading can, therefore, be neglected. For these pulses of short duration, focussing can also be neglected. There may be absorption but this will be small during the period of observation.

It has been shown in Section 4 (a) that the noise source is equivalent to a short vertical dipole in free space. Since the height of the clouds above ground level is not very high, it can be assumed that this dipole is practically at ground level for long distance calculations. The unabsorbed field intensity, \( E_T \), in \( \mu \text{V/m} \) due to this dipole is given by

\[
E_T = \frac{212 \sqrt{P} \sin^2 \theta}{d} \quad \ldots (2)
\]

where

\( \theta \) = angle the direction of radiation makes with the vertical dipole.
d = distance of the source from the point of reception in \(10^6\) metres.

\[ P = \text{power of the source at the frequency}, \ f, \text{ in kilowatts.} \]

The power, \( P \), can be obtained from equation (1) for any particular frequency. Equation (2) gives the field intensity for a single hop transmission. Assuming a suitable loss factor for ground reflections, the field intensity for a double hop transmission can be calculated.

If there is absorption, following the CRPL method (NATIONAL BUREAU OF STANDARDS, 1949), the following relations can be written:

Absorption index = \( \alpha \) = JQKS = \( \log \left( \frac{E_t}{E_E} \right) \) ... (3)

\[ \log \left( \frac{E_t}{E_E} \right) = AS \] ... (4)

The significance of the different symbols in the equations and the source from which numerical values have been obtained for the calculations in this paper are given below:

(i) \( J \) is called the seasonal variation factor. Values for different months are given in circular No. 462 of the National Bureau of Standards quoted earlier.
(ii) Q is the solar cycle variation factor. It can be calculated for each month on the procedure described in circular 462 quoted and using the CRPL predictions.

(iii) K is the absorption factor. This is a quantity to be deduced from experimental results if necessary.

(iv) \( E_T \) is the unabsorbed field intensity. It is the field intensity for \( K = 0 \), i.e. \( A = 0 \).

(v) \( E_E \) is the observed field intensity for different values of \( K \) i.e. for different values of \( A \).

(vi) \( A = JQK \). - This can be calculated from the values of \( J \), \( Q \) and \( K \).

(vi) \( S \) is a function of the frequency and the distance travelled in the absorbing medium.

The only other quantity required for calculations is the loss factor for ground reflection and this is required for double hop calculations. From circular 462 quoted above, this will be taken as 0.63. The height of the \( F_2 \) layer will be assumed to be 320 Kms., the value given in the circular mentioned.

'S' values are not directly given in the circular
circular mentioned. They can, however, be calculated from the data in the circular mentioned as follows.

Figures 7.11 to 7.30 in circular 462 give the field intensity for different values of $A$ including the value, $A = 0$. Each figure gives the field intensity for a particular distance at different frequencies for different values of $A$ for 1 kW effective radiated power. Therefore, from each figure, the value of $S$ can be calculated by using equation (4). Thus $S$ values can be obtained for single hop transmissions for different distances like 400, 800 etc. in Kms. Then, a graph is plotted 'S value - distance'. From this graph, the required values of $S$ can be read off for the distances for which they are necessary.

It will thus be seen that the numerical data required for the different constants in propagation calculations are chosen entirely from circular No. 462 of the U.S. National Bureau of Standards.

The CRPL method of calculations for the $F_2$ layer ionospheric propagation has been chosen for the calculations in this paper because of its simplicity. The method has been used for propagation calculations in connection with some field strength and absorption measurements in the laboratory and is found to give
to give consistent and satisfactory results.

(c) **Probable sources of noise:** For defining the position of the equivalent radiator, the probable sources of atmospheric radio noise have to be indicated and their position defined by a mean distance from Poona. The distribution of thunderstorm days over the globe is available in the form of charts (BROOKS). The latest available information on the distribution of thunderstorm days on land masses has been published in the form of Tables (WORLD METEOROLOGICAL ORGANISATION). The latest available information on the distribution of thunderstorm days on the land mass of India has been analysed (AIYA, 1954b). It is, therefore, possible to indicate the regions from which noise arises during different months and estimate the mean distance of such sources from Poona. The details of the possible sources of atmospheric noise at 2.9 Mc/s. at Poona during the period of day, 18 - 23 hrs. I.S.T. are as follows.

(i) Regions lying in or about Malaya, Java, etc.: These are equatorial regions lying within about 5 degrees of the equator. There is intense thunderstorm activity all the year round. At any given time, several thunderstorms may be in progress. Noise from these sources is made up of a very large number of impulses
impulses and will give the impression of type A noise. The mean distance of these sources from Poona is 4000 Kms. The noise radiation probably reaches Poona by a double hop transmission. The received noise field strength will be low and will become important in the absence of other nearer sources. They thus appear to be responsible for type A noise received during November, December, January and February.

(ii) Bay of Bengal: There is, throughout the year, some activity in the Bay of Bengal. Very reliable and detailed data are not yet available. The World Meteorological Organisation is at present busy converting the available data on lightning seen to thunder heard, by a statistical process. The available data indicate that the activity extends over a wide area. At a mean distance of about 2000 Kms. from Poona, there is always some activity but it is not such as to give rise to more than ten impulses per minute all the year round. However, the activity becomes pronounced from February onwards and continues in this manner till about November. This is particularly so in regions nearer the land mass of India. These sources lie between 5 and 20 degree North. They give rise to impulsive noise i.e. type B noise and the magnitude of the noise will be greater than that due to sources listed
listed in (i). Between February and November, noise
due to these sources will predominate during periods
of a month when the activity on the land mass of
India is weak i.e. during February, early November, and
some days of March, August and September. During October,
noise due to activity on the land mass of India round
Bengal being more probable, the effect of these sources
may not be felt in Poona.

(iii) Land mass of India :- From March to October,
there is enough activity on the land mass of India to
give rise to noise at Poona. There can be local thunder­
storms giving rise to type C noise. During March-May,
the cloud heights are very high and noise due to extre­
mely local thunderstorms may be received as an optical
ray. If the E layer persists for sometime after sun­
set, some reflection from the E layer may be possible.
Similarly, there is the possibility of reflection from
the sporadic E layer. In all such cases, type C
noise has been noticed, but these are all exceptions.
Ordinarily, type C noise, which is due to ground ray
propagation and arises from local thunderstorms
occurring within about 40 Kms. from Poona, is what is
to be expected at 2.9 Mc/s. and what is actually
observed. In this common case, there is no abrupt or
every sudden change of noise value from hour to hour.
Changes of noise value from before sunset to after sunset are also gradual and show the general trend that corresponds only to the growth and decay of the activity of a thunderstorm.

The equivalent of a tropical thunderstorm as a noise radiator is a short vertical dipole in free space. Therefore, for $F_2$ layer propagation, the sky wave intensity due to sources between 400 and 1000 Kms. from Poona will be greater than the sky wave intensity due to sources within 400 Kms. from Poona. Hence, the major sources of atmospheric noise in Poona during March-October are sources lying between 400 and 1000 Kms. from Poona. All of them are between 8 and 28 degrees North. They give rise to type B noise and can be assumed to be at a mean distance of 700 Kms. from Poona.

During October, sources in and around Bengal at a mean distance of 1500 Kms. from Poona may predominate when nearer sources are weak or inactive. The south Indian sources continue in activity during November and even December and are probably responsible for impulsive noise received occasionally during these months. The mean distance of these sources is about 1300 Kms.

(d) **Estimation of power radiated by noise sources:**

As explained in Section 4 (a), the noise source is equi-
equivalent to a short vertical dipole. The median value of the power radiated by this equivalent radiator which corresponds to the noise field strength as measured by the noise meter used for measurements reported in this paper during the period of peak activity of the source is given by equation (1). This gives a power of 5.35 watts at 2.9 Mc/s. This value of power will be used to estimate noise levels.

It is seen from Section 4(c) that there are various sources responsible for noise in Poona. All of them are in the tropics but some are on land masses and some over the sea. Equation (1) is based on the idealised statistically valid representation of a lightning flash. Before using the power given by the equation, it is necessary to examine how far this statistically idealised representation is a true picture of lightning flashes associated with thunderstorms occurring over land and sea during the period of observation, 18-23 hrs. I.S.T. There is no simple and direct way of doing this. It is, however, possible to draw some inference on this point indirectly. It is possible to estimate the power radiated from the statistically assessed noise field strengths for the same type of noise arising in the same month from two different sources, by assuming that the power radiated by both the
the sources is the same. If this estimate is of the same order as that given by equation (1), it would be reasonable to assume that the power given by equation (1) is valid for the different sources. An attempt will, therefore, be made to estimate the power on the lines indicated from the results given in Table I.

Suppose there are two sources of noise in the same month. One may be called source 1, and the other source 2. Assume, for argument purposes, that there is a small absorption in the ionosphere for the F\textsubscript{2} layer propagation under night conditions and that it is the same for both sources. Then, using equation (2) and (3), the following can be written:

\[
\frac{212 \cdot \sqrt{F} \cdot \sin^2 \theta_1}{\log \frac{d_1 E_1}{d_2 E_2}} = \frac{\alpha_1}{\log \frac{JQKS_1}{S_1}} = \frac{\alpha_2}{\log \frac{JQKS_2}{S_2}} = \delta. \tag{5}
\]

and therefore

\[
\log \sqrt{F} = \frac{1}{1-\delta} \left\{ \log \frac{d_1 E_1}{212 \cdot \sin^2 \theta_1} - \delta \log \frac{d_2 E_2}{212 \cdot \sin^2 \theta_2} \right\} \tag{6}
\]

In equation (5) and (6), the letters have the same significance as in equations (2) and (3). The subscripts 1 and 2, stand respectively for the correspond-
corresponding values of the two sources. \( E_1 \) and \( E_2 \) stand for the respective median values of noise field strengths of the two sources as given in Table I. \( 'P' \) can be calculated from equation (6).

An examination of Table I shows that, during March, August and September, type B noise is received from two sources. From the discussion in Section 4(c), it is clear that one is probably due to a source on the land mass at a mean distance of 700 Kms. and that the other is probably due to a source at a mean distance of 2000 Kms. from Poona. The latter source is over the sea. The relevant data and the calculated value of power from equation (6) are given in Table VIII.

The accuracy of the estimated power in the last column of Table VIII depends on the accuracy of all the seven quantities listed in the Table and particularly on the value of \( \delta \). Since all the quantities except the values of \( E_1 \) and \( E_2 \) are the same for all the three months, the differences in the calculated values of power are due to the differences in the values of \( E_1 \) and \( E_2 \). It is possible that the actual mean distance of the sources may be differing slightly from month to month from the mean distance assumed. Further, the values of \( \theta \) depend on the assumed height of the \( F_2 \) layer. It is not impossible that this height
Table VIII

ESTIMATES OF SOURCE POWER FROM TWO SETS OF TYPE B NOISE DATA

<table>
<thead>
<tr>
<th>Month</th>
<th>$\delta$</th>
<th>$E_1$</th>
<th>$d_1$</th>
<th>$\theta_1$</th>
<th>$E_2$</th>
<th>$d_2$</th>
<th>$\theta_2$</th>
<th>Power in watts</th>
</tr>
</thead>
<tbody>
<tr>
<td>March</td>
<td>$\frac{2.1}{3.1}$</td>
<td>10.8</td>
<td>0.7</td>
<td>50</td>
<td>5.4</td>
<td>2</td>
<td>77</td>
<td>6.1</td>
</tr>
<tr>
<td>August</td>
<td>$\frac{2.1}{3.1}$</td>
<td>10.4</td>
<td>0.7</td>
<td>50</td>
<td>5.0</td>
<td>2</td>
<td>77</td>
<td>7.5</td>
</tr>
<tr>
<td>September</td>
<td>$\frac{2.1}{3.1}$</td>
<td>11.0</td>
<td>0.7</td>
<td>50</td>
<td>5.6</td>
<td>2</td>
<td>77</td>
<td>5.7</td>
</tr>
</tbody>
</table>

Mean value of Source Power = 6.4 watts.
may differ slightly from month to month from the assumed mean height of 320 Kms. The mean value of the estimated power is 6.4 watts and this is within one db. of the power estimated from lightning discharge data viz. 5.35 watts. In the light of the discussion, this agreement should be considered satisfactory. It will, therefore, be reasonable to assume the power as deduced from lightning discharge data viz., 5.35 watts as the power of the equivalent radiator for all noise estimations.

(e) Estimation of noise levels :- The noise level at Poona at 2.9 Mc/s. can be estimated from lightning discharge data on the basis of the discussion in this section. A lightning flash is equivalent to a short vertical dipole carrying a power of 5.35 watts. This equivalent radiator is considered to be located at a distance from Poona equal to the mean distance of the particular set of sources involved. The noise received by the sky wave has been calculated in the manner explained in sub-section 4(b) and the results are shown in Table IX. The values of noise field strength given in the Table are median values.

Noise received by sky wave propagation at Poona at 2.9 Mc/s appears to arise from three principal
<table>
<thead>
<tr>
<th>No.</th>
<th>Source</th>
<th>Mean dist. of noise in Kms.</th>
<th>Type of noise</th>
<th>Value in μV/m</th>
<th>Mode of Trans.</th>
<th>Months when expected.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Land mass of India</td>
<td>700</td>
<td>B</td>
<td>13.0</td>
<td>One hop</td>
<td>Very frequently between March and October.</td>
</tr>
<tr>
<td>2</td>
<td>&quot;</td>
<td>1300</td>
<td>B</td>
<td>10.2</td>
<td>&quot;</td>
<td>Sometimes during November-December.</td>
</tr>
<tr>
<td>3</td>
<td>&quot;</td>
<td>1500</td>
<td>B</td>
<td>9.2</td>
<td>&quot;</td>
<td>Occasionally during October.</td>
</tr>
<tr>
<td>4</td>
<td>Bay of Bengal</td>
<td>2000</td>
<td>B</td>
<td>7.3</td>
<td>&quot;</td>
<td>Throughout the year whenever stronger sources are not active. Ten impulses per min. not always probable during November-February.</td>
</tr>
<tr>
<td>5</td>
<td>Malaya, Java, etc.</td>
<td>4000</td>
<td>A</td>
<td>2.3</td>
<td>Two hop</td>
<td>All the year round but presence felt when all other sources are absent, i.e. November-February.</td>
</tr>
</tbody>
</table>
principal sources viz. 1, 4, and 5. Sources 1 and 4 are responsible for type B noise and source 5 for type A noise.

Type C noise arises from local thunderstorms and is received mainly as a ground ray. Assuming that, $\sigma = 10^{-13}$ e.m.u. and $\Sigma = 4$ for regions round Poona, if ground ray calculations are carried out by following the procedure given by BREMMER (1949), it is found that the field strength varies from 13 to 290 $\mu$V/m as the distance of the source decreases from 40 to 10 Kms. from Poona. Values of special interest are those which can be compared with the 90 per cent of the time satisfactory service data in Table II. A possible way of estimating these is given below.

A thunderstorm day is defined as a local calendar day on which thunder is heard. This requirement limits the area covered to a circle of radius 20 Kms. Suppose, during a season, a place is in an area having 'n' local thunderstorm days. Then, the radius, R, of the circle in which ten local thunderstorms occur is given by

$$\frac{10}{n} = \frac{nR^2}{n \cdot (20)^2} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots
corresponding values of the two sources. $E_1$ and $E_2$ stand for the respective median values of noise field strength of the two sources as given in Table I. $P$ can be calculated from equation (6).

An examination of Table I shows that, during March, August and September, type B noise is received from two sources. From the discussion in Section 4(c), it is clear that one is probably due to a source on the land mass at a mean distance of 700 Kms. and that the other is probably due to a source at a mean distance of 2000 Kms. from Poona. The latter source is over the sea. The relevant data and the calculated value of power from equation (6) are given in Table VIII.

The accuracy of the estimated power in the last column of Table VIII depends on the accuracy of all the seven quantities listed in the Table and particularly on the value of $\delta$. Since all the quantities except the values of $E_1$ and $E_2$ are the same for all the three months, the differences in the calculated values of power are due to the differences in the values of $E_1$ and $E_2$. It is possible that the actual mean distance of the sources may be differing slightly from month to month from the mean distance assumed. Further, the values of $\theta$ depend on the assumed height of the $F_2$ layer. It is not impossible that this height may
Hence, 'R' can be calculated, if 'n' is known. This, R, therefore, is the maximum distance from the place at which any one of the ten local thunderstorms can occur. Hence, the minimum noise field strength due to local thunderstorms during a season when the number of local thunderstorms is taken as ten, is the field due to a local thunderstorm occurring at a distance, R, from the place. Let this field strength be called 'Ec'.

In a season, there are 90 to 92 days. Therefore, if there are 10 local thunderstorm days in a season, the noise value for 90 per cent of the time satisfactory service is that due to local thunderstorms. Hence, 'Ec' gives the noise value for 90 per cent of the time satisfactory service when Ec is greater than noise received by sky wave. The values of 'n' for Poona have been published (AIYA, 1954b). These values have to be corrected if the local thunderstorms do not show their peak activity after sunset. Experimental observations for the last three years have shown that this correction is necessary for the season, September-November, when only 30 per cent of the local thunderstorms show peak activity after sunset. Table X gives the results.
Table X

MINIMUM VALUES OF LOCAL STORM NOISE AT POONA AT 2.9 Mc/s. FOR 10 PER CENT OF THE TIME IN A SEASON FOR THE HOURS 18 - 23 I.S.T.

<table>
<thead>
<tr>
<th>Season</th>
<th>'n' No. of thunderstorm days</th>
<th>Corrected 'n'</th>
<th>'R' Radius of circle in which 10 thunderstorms occur in Kms.</th>
<th>'E_c' Noise value in µV/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>March-May</td>
<td>8</td>
<td>8</td>
<td>22.5</td>
<td>51</td>
</tr>
<tr>
<td>June-Aug.</td>
<td>4</td>
<td>4</td>
<td>31.6</td>
<td>25</td>
</tr>
<tr>
<td>Sept-Nov</td>
<td>9</td>
<td>3</td>
<td>36.5</td>
<td>16</td>
</tr>
<tr>
<td>Dec-Feb.</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Type C noise estimations cannot be carried out for a month as the number of local thunderstorms are too few and calculations will have no significance. Even for a season, calculations of Table X are for 10 local thunderstorms only. If these occur in a circle of radius, R, it is assumed that the field strength due to the source being at this extreme distance of the area is the noise value. The value of power used for the calculations is the statistical median value of 5.35 watts. Taking into consideration all these facts, it appears that the calculated
calculated values may be lower than actual values by factors upto 6 db. These questions will be discussed in detail in a future communication referred to already in section 3 (b) in discussing noise grade, etc.

(f) **Comparison of estimated and measured values:**

For noise received by sky wave propagation, there are three principal sources. The estimates of noise for these sources and the corresponding measured values during different months from Table I are given in Table XI.

It will be observed from the Table that the measured values of Type B noise are within 3 db. of the estimated values. Having regard to the wide range of data required, this agreement appears to be very satisfactory. For type A noise, the measured values are lower than the estimated values by 6 db. Even after allowing for possible inaccuracies of calculation or data and experimental inaccuracies, this difference between measured and estimated values appears to be rather large. This fact and the general trend of all type B noise measured values being consistently lower than the estimates indicate that (a) either there is some quantity in the data for
Table XI

MEASURED AND ESTIMATED SKY WAVE NOISE AT POONA AT 2.9 Mc/s. DURING 18.23 HRS. I.S.T.

<table>
<thead>
<tr>
<th>Probable source</th>
<th>Type of noise</th>
<th>Mean distance of source in Kms.</th>
<th>Estimated Noise from lightning discharge data in uv/m.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land mass of India</td>
<td>B</td>
<td>700</td>
<td>13.0</td>
</tr>
<tr>
<td>Bay of Bengal</td>
<td>B</td>
<td>2000</td>
<td>7.3</td>
</tr>
<tr>
<td>Regions near Malaya Java</td>
<td>A</td>
<td>4000</td>
<td>2.3</td>
</tr>
</tbody>
</table>

"_" indicates "Not observed"

"X" indicates "Observed occasionally"
Table XI

MEASURED AND ESTIMATED SKY WAVE NOISE AT POONA AT 2.9 Mc/s. DURING 18.23 HRS. I.S.T.

<table>
<thead>
<tr>
<th></th>
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<td></td>
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</tr>
<tr>
<td>-</td>
<td>-</td>
<td>10.8</td>
<td>10.0</td>
<td>11.0</td>
<td>10.6</td>
<td>11.0</td>
<td>10.4</td>
<td>11.0</td>
<td>9.9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>X</td>
<td>X</td>
<td>5.4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5.0</td>
<td>5.6</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>0.7</td>
<td>0.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1.0</td>
<td>1.1</td>
</tr>
</tbody>
</table>

"_" indicates "Not observed"

"X" indicates "Observed occasionally"
for estimates which is perhaps high or (b) that there is probably a very small absorption in the ionosphere even for $F_2$ layer propagation under night conditions. The increase of the difference between measured and estimated values with increase of distance of the source appears to indicate that some small absorption may possibly be one of the factors contributing to the difference between measured and estimated values. Calculations carried out on the procedure described in Section 4(b) show that the difference between measured and estimated values of noise can be explained by assuming an absorption factor of value between 0.03 and 0.05 for the period 18-23 hours I.S.T. for a month. No conclusions about the possibility of absorption in the ionosphere of this order can possibly be drawn from noise measurements. However, the discussion indicates that measurements of ionospheric absorption under night conditions would be of interest to workers in the field of noise interference.

A comparison of the results in Table I with those in the last column of Table II shows satisfactory agreement for type C noise.

Actual noise estimations as required for a detailed comparison with the results as given in Table II have to be based on a generalised analysis of the dis-
distribution of thunderstorm activity over the globe for noise estimation purposes, the definition of noise grade, etc. and these questions will be discussed as mentioned earlier in a future communication.

5. CONCLUSION

There appears to be reasonable agreement between measured and estimated values of noise at 2.9 Mc/s. at Poona for the period of day, 18-23 hrs. I.S.T. It seems that an objective method of measuring noise evolved out of subjective considerations when used for the collection and assessment of noise data on a statistical basis, can prove useful for noise measurements. The results reported in this paper are for one service viz. broadcasting. From the comparison of the results reported in this paper with the measurements of the Radio Research Board, London, it appears that the data as collected for this paper may prove useful for another service viz. low speed C.W. telegraphy.

The probability of some ionospheric absorption at night i.e. after sunset has recently been reported. (APPLETON & PIGGOTT). It has been indicated in the section on comparison of measured and estimated values
values of noise that some data on night absorption in
the ionosphere can prove helpful in understanding the
differences between estimated measured values.

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