EFFECT OF RECEIVER BANDWIDTH ON ATMOSPHERIC RADIO NOISE BURSTS

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ABSTRACT

The paper gives a report of the investigations carried out by the author on the effect of receiver bandwidth on the audible radio noise burst parameters viz., *the quasi-peak value, the duration of the noise burst and the time interval between successive noise bursts. Within the limits of accuracy of measurement,* viz., *±50 msec, there is no effect of receiver bandwidth either on the duration of the noise burst or the time interval between successive noise bursts. The quasi peak value varies as the square root of the bandwidth from 300* Hz *to 6* kHz, *and this shows that the audible noise arising from a noise burst has to be treated as a form of continuous noise and that it is not impulsive. At high frequencies, the square root bandwidth law breaks down. For both amplitude and time parameters, the distribution which is log-normal does not change with bandwidth, and the standard deviation is unaffected by changes of bandwidth.*

1. INTRODUCTION

Extensive investigations of Aiya and collaborators[1-10] have shown that at tropical latitudes, atmospheric radio noise arising in the form of distinct and well separated bursts is the principal source of interference to the reception of radio signals at frequencies below 15 *MHz*. Each noise burst arises from one complete lightning flash. An atmospheric radio noise burst represents the radiation received from one complete lightning flash at the frequency to which a receiver is tuned and within the receiver bandwidth[4]. The parameters of such noise bursts investigated are (i) the quasipeak amplitude as measured by Aiya noise meter[1], (ii) the duration of a noise burst and (ii) the time interval between successive noise bursts, all measurements being made at the detected output. The duration of noise bursts arising from lightning flashes are taken into account to evaluate the occupation time of the noise bursts. This has led to the concept of the

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noise burst level which gives the average amplitude of the ten hightest noise bursts received in a minute. These bursts are known to occupy about ten per cent of the observation time. The amplitude parameters, *viz.*, the quasi-peak value of a noise burst represents the annoyance as felt by an average human ear. It will thus be seen that the parameters of noise burst investigated are those which are of relevance for assessing their interfering effect to one class of service *viz.*, voice communications.

By and large these investigations have been made with a receiver bandwidth of 6 *kHz* referred to between 6 *dB* points. Now not all the systems operate with the same bandwidth *viz.*, 6 *kHz*. and thus noise burst data has to be furnished at all bandwidths of interest. However, it may be possible to convert the noise data with this bandwidth to data with other bandwidths if the nature of the noice burst is known. The audible noise burst arising out of a noise burst has to be treated as continuous or impulsive. Thus if the noise burst is regarded as impulsive the amplitude should be expected to vary directly as the bandwidth, otherwise as the square-root of the bandwidth. The investigations reported in this paper furnish the answer to this unsolved problem *i.e.*, the results obtained decide whether the audible noise burst is to be treated as impulsive or continuous.

This paper is thus restricted in scope to extending the investigations of Aiya and collaborators. Hence the techniques of measurements adopted are essentially the same as those adopted by the previous investigators, except for some differences which are dictated by the very nature of the problem, and the justifications given by them hold for the current investigations also. The techniques of measurement are briefly described in the next section.

The effect of receiver bandwidth on the amplitude and time parameters can be deduced theoretically, at least, approximately. A preliminary check was made of the effect of bandwidth on the noise burst amplitude. This showed departures from theoretical expectations. Hence, it was decided to obtain data experimentally on all the three parameters.

The subject matter of the paper is treated in the following order Firstly, the technique of measurements has been described briefly. This is followed by a presentation of the results. The last section gives possible conclusions that have emerged out of these investigations.

2. TECHNIQUES OF MEASUREMENTS

The investigations of Aiya and collaborators on atmospheric radio noise interference have been related to voice communications systems only *i.e.* to systems in which the ultimate judge of the interfering effect is the human ear. Thus all the measurements are related to listening and are made on the detected output of the receiver. The Aiya noise meter which was developed with this consideration measures the annoyance felt by an average human ear due to the atmospheric radio noise both in the continuous and burst forms. This is an objective noise meter based on extensive subjective considerations[1,2] This method has been used for measurement of noise levels in the frequency range 30 *kHz* to 16 *MHz* over several years.

The Aiya noise meter essentially consists of a short vertical antenna, a communications receiver with its automatic gain control switched off and a metering unit that simulates an average human ear. Thus the charging and discharging time constants of the metering unit are arranged to be 10 and 500 milliseconds respectively. The indicating instrument is a 0-300 μA meter with a 170 millisecond time constant. The noise meter is calibrated in terms of a continuous signal at the receiver frequency and modulated to 30 per cent depth by a 400 *Hz* sinusoid using a standard signal generator.

The pointer of the meter kicks when a noise burst is received. The highest 10 μA mark crossed by the pointer is recorded and this in terms of the calibration becomes a measure of the noise burst amplitude. This is the quasipeak amplitude of a noise burst.

On the basis of his extensive subjective test, Aiya developed a criterion according to which noise bursts cause annoyance to listening only when the burst rate is at least ten per minute or that the bursts occupy about at least ten per cent of the observation time[4]. That these two criteria are just the same is seen from the fact that the mean duration of a noise burst is about 500-600 milliseconds[4]. Thus the arithmetical average of the ten highest noise burst amplitudes received in a minute has been taken as the annoyance value or the noise burst level. The noise burst level has generally been found to be 3 *dB* higher than the mean value of all the amplitudes received in the five minute period[4,10].

The method specifies manual recording of the burst amplitudes. In order to make sure that the noise bursts are not contaminated with man-made signals or other interfering signals, all the measurements are made with continuous aural monitoring.

Aiya and Lakshminarayan[4] have also investigated the time characteristics of noise bursts, examining the noise bursts in their entirety. The time parameters have been measured using an audio magnetic tape recorder.

The time parameters have also been measured by recording the detected output due to noise bursts on a level recorder with the recording paper running at a known speed. This recording is also done with continuous aural monitoring. An accuracy of better than $\pm$ 50 milliseconds is not expected from either of the methods.

It is to be added that the average value of the time interval between successive bursts can be obtained from a knowledge of the burst rate *i.e.*, the number of bursts received in a unit time.

3. RESULTS

Properly designed experiments were carried out to investigate the effect of bandwidth on the parameters of noise burst. Measurements were made using the Aiya noise meter with adjustable bandwidth and a level recorder. For the purposes of investigations, extensive data had to be collected and analysed. Proper randomization of the data becomes necessary as the data are subjected to statistical analysis. Thus the time at which measurements were made were spread over all parts of the day and over all seasons of the year.

In what follows are described the results of investigations on the effect of receiver bandwidth on the amplitude and time characteristics of the noise bursts.

3.1. AMPLITUDE CHARACTERISTICS

3.11. AMPLITUDE PROBABILITY DISTRIBUTIONS

The effect of bandwidth on the amplitude probability distributions was investigated. The investigations were carried out over a wide range of bandwidth *viz.*, 300 *Hz* to 16 *kHz*. This was done by recording all the burst amplitudes over successive five minute periods with different receiver bandwidths. The data collected were utilized to draw the amplitude probability distributions. These distributions were generally found to be log-normal. The records invariably showed that the bandwidth had no effect on the nature of the distribution, it only changed the mean value. Some typical distributions are shown in Fig. 1. The figure reveals that the standard deviation of the distribution does not vary with the bandwidth.

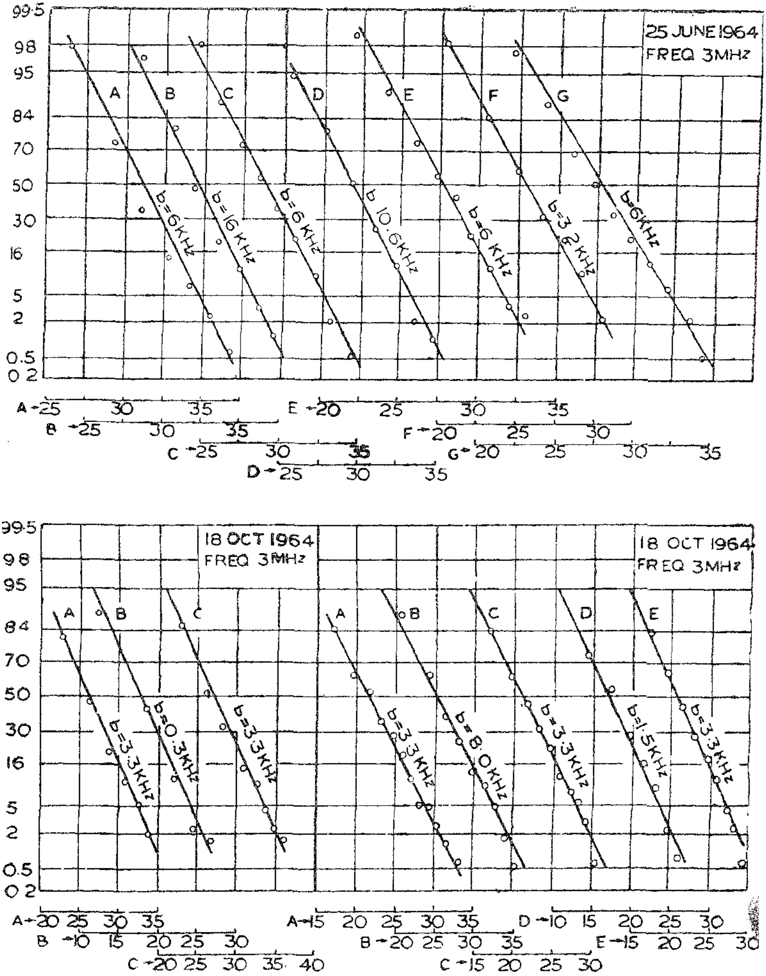
When an observed distribution is found to differ from a log-normal one, as shown in Fig. 2, the distributions with all the bandwidths are found to show the same trend.

Measurements were made at seven spot frequencies in the range 100 *kHz* to 9 *MHz*. The results obtained at all the frequencies were identical.

3.12. NOISE BURST LEVEL

Extensive measurements were made to investigate the effect of bandwidth on the noise burst level. The frequency range covered was 0.1 *MHz* to 9 *MHz*, with bandwidth ranging from 300 *Hz* to as high as 16*kHz*, in the higher frequency ranges. The results obtained from such investigations are being furnished and discussed in what follows. The results presented are based on the recording of about a million burst amplitudes.

Fig. 3 has been drawn using the average values of the ratios of the noise burst levels with selected bandwidths to those with reference bandwidths *viz.*,



BURST AMPLITUDE IN DECIBELS ABOVE 1 $\mu v/m$

FIG. 1

Amplitude probability distributions for noise bursts at different receiver bandwidths.

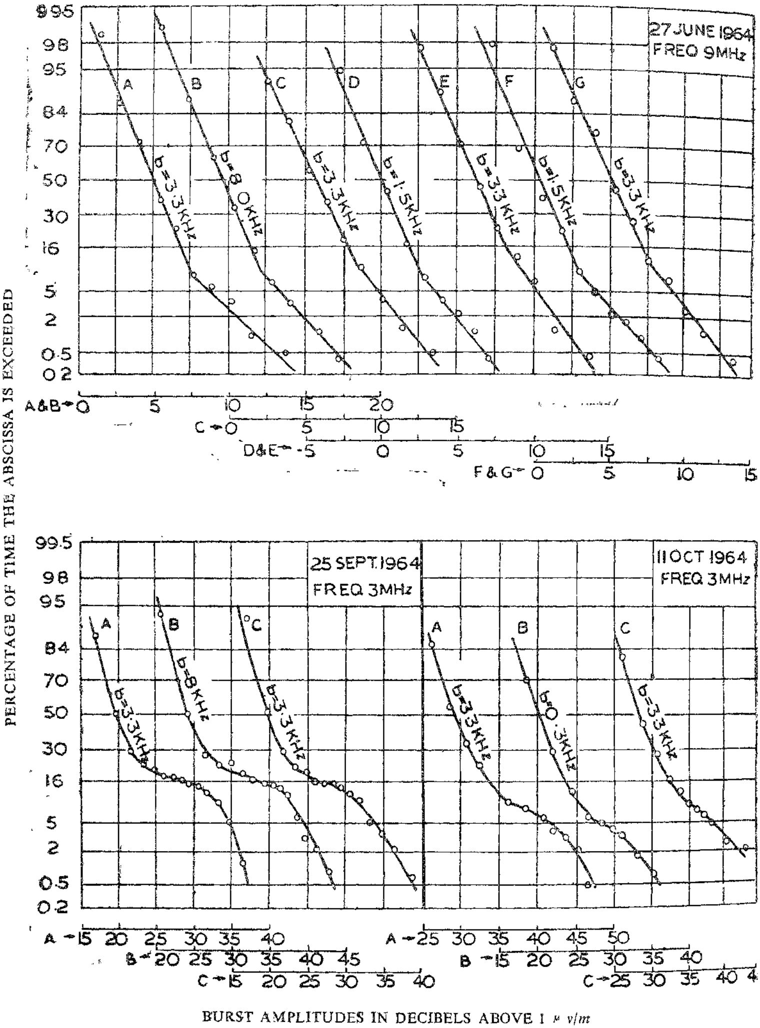


FIG. 2

Some special cases of amplitude probability distributions for noise bursts at different receiver bandwidths.

6 *kHz*. This figure gives the variation of the noise burst level with bandwidths at different frequencies of measurements. The straight lines drawn in the figure correspond to the square-root-bandwidth law. This has been drawn to facilitate the comparison of the observed results with the square-root-bandwidth law.

An examination of Fig. 3 reveals that the noise burst level varies as the square-root of the bandwidth over a range 300 *Hz* to 6 *kHz*. This is true for all frequencies between 100 *kHz* to 9 *MHz*. The square-root-bandwidth law appears to breakdown at frequencies above 3 *MHz* and for bandwiths above 6 *kHz*.

An important outcome of the result is that for the measurement of the noise burst level, any bandwidth between 300 *Hz* and 6 *kHz* can be employed and the data obtained can be converted to any other bandwidth in this range by using the square-root-bandwidth law. It is preferable to use smaller bandwidths for measurements on noise bursts as it is easier to get an interference-free channel with a smaller bandwidth.

3.2 Time Characteristics

Aiya and Lakshminarayan have investigated the time characteristics of noise bursts examining the noise bursts in their entirety[4]. The probability distributions of burst durations and the time interval between successive bursts have been shown to be log-normal. Aiya has also measured the duration of noise bursts as heard through a speaker[1]. These investigations also have been carried out at a preselected bandwidth. The time characteristics are not expected to show a significant variation with bandwidth in the range $300Hz - 16kHz$, within the attainable accuracy. Since the investigations on the amplitude characteristics revealed some interesting results, the investigations on the time characteristics were also taken up.

Burst duration and time interval measurements were made on records taken with a level recorder for different receiver bandwidths. The probability distributions of the burst durations and the time intervals were invariably found to be log-normal. For both the duration and interval, the mean values and standard deviations were found to be unaffected by bandwidth changes. This agrees well with theoretical expectations. Some typical distributions are shown in Figs. 4 and 5.

The mean value of the time interval between successive bursts can also be obtained from a knowledge of the burst rate. The burst rate is found to be unaffected by bandwidth changes.

Thus it may be concluded that the time characteristics do not vary with bandwidth in the bandwidth range 300 *Hz* – 16 *kHz*, within the limits of accuracies, as is to be expected.

4. CONCLUSION

As mentioned previously, the primary object of the investigations was to furnish data for converting the noise burst level as furnished by Aiya and collaborators for a receiver bandwidth of 6 *kHz* to other bandwidths of interest. It is seen that the quasi-peak amplitude varies as the square root of the bandwidth and not directly as the bandwidth as is sometimes visualised. Further, the square-root-bandwidth law breaks down after a bandwidth of 6 *kHz*.

The burst duration and the time interval between successive bursts are, as expected, unaffected by the bandwidth changes. This is true within the limits of accuracy of the measurements. This result shows that even with bandwidth changes ten bursts occupy about ten per cent of the observation time and hence the noise burst level is a proper measure of annoyance to listening at all bandwidths.

The log normal distribution law for any of the parameters of noise burst remains unaffected by bandwidth changes. All these are experimental results obtained by properly designed experiments over the frequency range 100 *kHz* -9 *MHz*.

Another conclusion of importance that has emerged out of these investigations is that the measurements can be made with a smaller bandwidth as it is relatively easy to get an interference free channel with smaller bandwidth and then convert the obtained data to corresponding bandwidth.

The utility of the results is restricted to the interfering effect of noise bursts to those classes of communications in which the ultimate judge is the human ear. Extension of the utility of the results to other classes of service is outside the scope of the paper.

5. ACKNOWLEDGEMENTS

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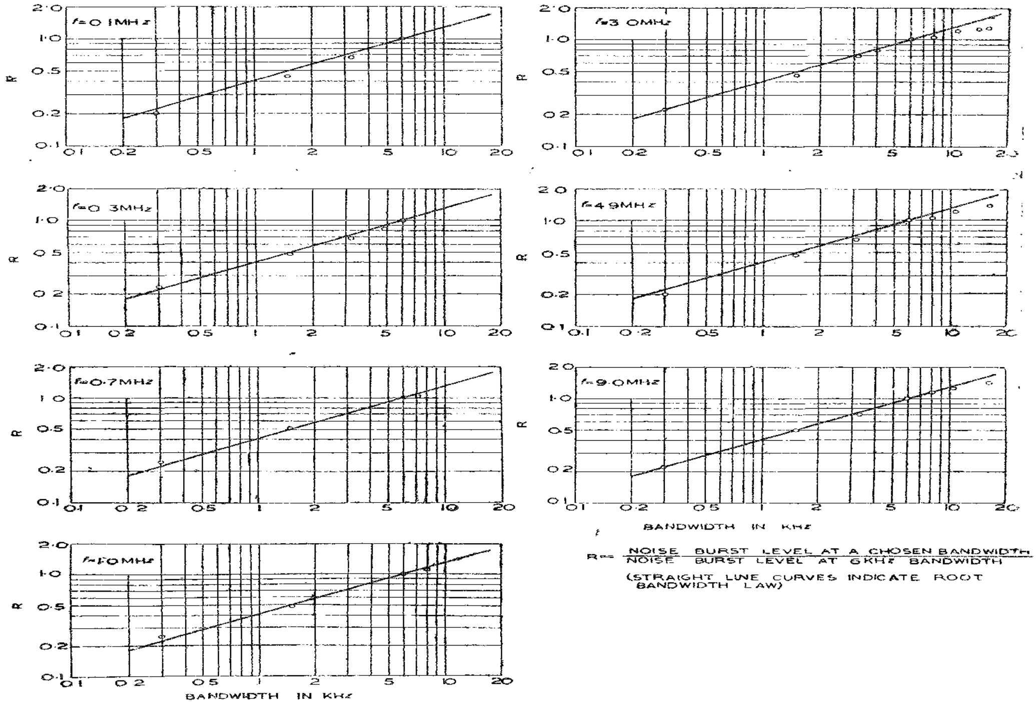

FIG. 3

Variation of noise burst level with bandwidth at different frequencies.

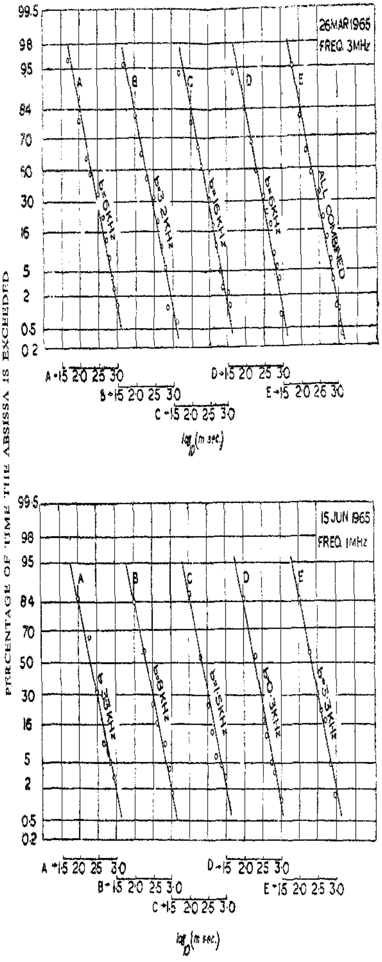

Fig. 4

Probability distributions of burst durations with different receiver bandwidths.

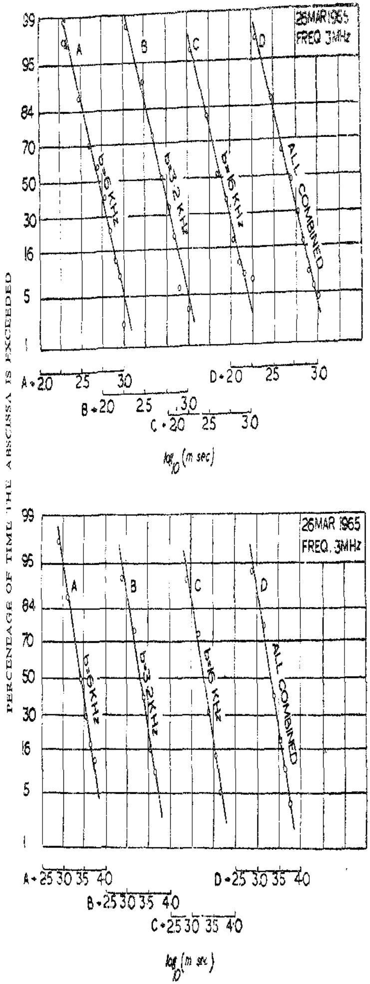

Fig. 5

Probability distributions of time interval between successive bursts with different receiver bandwidths.

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