Short Papers

Correlation Between Atmospheric Radio Noise-Burst Amplitudes with Different Bandwidths

SURESH N. GUPTA

Abstract—**Correlation between atmospheric radio noise-burst amplitudes measured by the Aiya noise meter with different bandwidths was examined during periods of local thunderstorm activity. The investigations were carried over a frequency range of 100 kHz to 9 MHz and over a 6-dB bandwidth range of 300 Hz to 16 kHz. The correlation observed in all cases was so high that the standard error of estimate was nearly equal to the accuracy of measurement itself. This suggests that the phenomenon is deterministic rather than statistical. The practical utility of the result is discussed.**

Introduction

At tropical latitudes, the atmospheric radio noise appearing in the form of bursts is the principal source of interference to radio communications systems operating below 15 MHz. A noise burst arises from radiations received from one complete lightning flash. A suitable amplitude parameter of a noise burst for assessing the interfering effect of this form of noise is the quasi-peak value as discussed by Aiya [1], [2]. This value gives the integrated effect of a noise burst, and thus a noise burst gets treated in its entirety. The investigations of Aiya and collaborators [1]–[5] have been confined to a single bandwidth of the noise meter, generally 6 kHz measured between 6-dB points. Since different systems may operate with different bandwidths, noise data have to be furnished for all bandwidths of interest. It has been shown theoretically [6] that the peak value of fluctuation type of noise varies as the square root of the bandwidth, while that of unit impulses varies directly as the bandwidth. These results have been experimentally verified by Jansky [7] and Landon [8] using atmospheric noise, thermal noise, and laboratory generated pulses. Thus, if a noise burst can be treated as purely continuous or purely impulsive, the variation of its peak value with bandwidth can be determined. Since the structure of a noise burst shows statistical variations [9], [10] (see Fig. 1), and since the parameter under examination is the quasi-peak value, it was considered more appropriate to determine the effect of bandwidth on a noise burst experimentally.

Other investigations [11]–[15] on the effect of bandwidth on noise are restricted to average and rms values, dynamic range, and amplitude probability distribution.

Measurement Technique and Collection of Data

Investigations were carried out at Bangalore (12°58′ N, 77°35′ E) using Aiya's method [1]. This method stipulates manual recording of burst amplitudes with continuous aural monitoring. Each burst produces a kick on the pointer of the indicating meter (0–300 μA). The meter readings are taken in steps of 10 μA. This means that if a burst gives 93 μA on the meter, it is taken as 90 μA, and if it gives 96 μA it is taken as 100 μA. This limits the measurement accuracy to about ± 10 percent, i.e., about ± 1 dB. The internal noise does not affect the accuracy as it is too small to be significant.

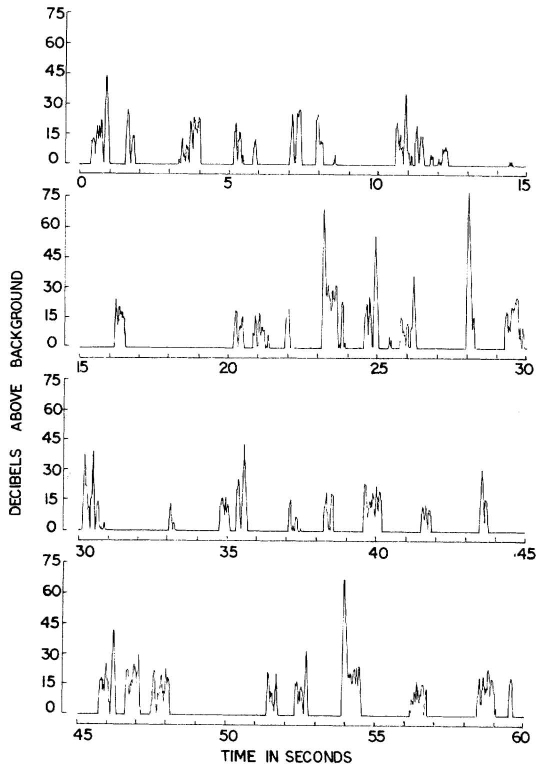

Fig. 1. Noise bursts as recorded on level recorder.

Two noise meters of adjustable bandwidths were used. Measurements on an individual noise burst were made simultaneously on both meters, and the measured values were compared. As a preliminary check of the noise meters, some observations were made with nearly equal bandwidth settings (the bandwidths were 3.2 kHz and 3.3 kHz) on the two meters. As expected, the amplitudes measured on the two meters were almost identical. One set of such observations is shown in Fig. 2. In this diagram, the spread about the straight line is of the order of measurement accuracy.

The time period during which measurements could be made had to be chosen very carefully. Since the individual burst amplitudes were to be compared, the measurements had to be made over periods when it was possible to draw one-to-one correspondence between the values recorded on the two meters. Because of the manual nature of recording, it was possible to draw the correspondence when the burst rate was low. Under conditions of normal activity, the bursts occur at a rate of about 20 per min [2], which is rather high. Periods of low burst rate exist when there is a local storm. Thus almost all the observations for the present investigations were made during periods of local

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The author is with the Department of Electrical Engineering, Indian Institute of Technology, Delhi 29, India.

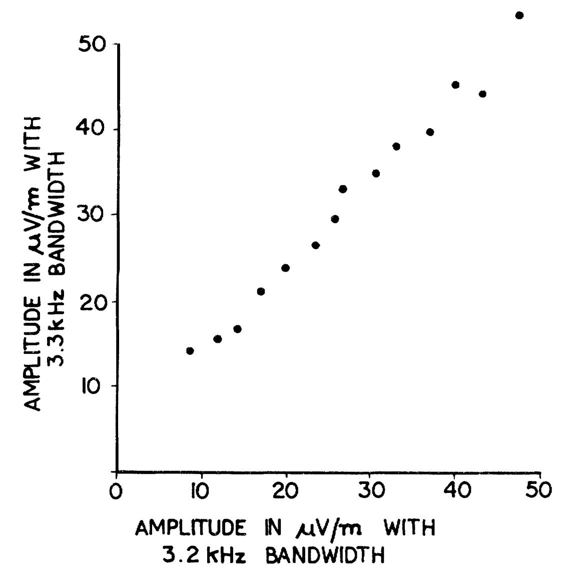

Fig. 2. Scatter diagram of noise-burst amplitudes with 3.2-kHz and 3.3-kHz bandwidths.

activity. Another advantage of choosing such periods is that during these periods the amplitudes are very high and the effect of other interfering signals, if any, is negligibly small.

Measurements were made at a number of spot frequencies in the range of 100 kHz to 9 MHz by selecting different pairs of bandwidths, each bandwidth lying in the 300 Hz to 16 kHz range. Measurements made with a single pair of bandwidths for about half an hour constituted one sample for the purpose of analysis. Samples of varying sizes were obtained depending upon the burst rate and the time interval over which measurements were made. Samples containing as many as 1000 bursts could be obtained at times, while some others did not contain more than 10 bursts. All these samples were individually analyzed or inspected to determine the possible correlation.

Analysis of Data

The correlation between burst amplitudes with different bandwidths was determined by means of correlation and regression analysis. A typical scatter diagram, drawn with burst amplitudes at 3 MHz, is shown in Fig. 3. In this figure, quasi-peak values measured with a 6.0-kHz bandwidth are represented by the random variable y, while those with a 3.0-kHz bandwidth are represented by the random variable x. The number of observations for each pair of x and y values is also indicated in the figure. The average value of y for the given x is shown as a small circle. These circles appear to lie on a straight line, which is the regression line of y on x. The equation of the regression line when y is subjected to error can be written as

$$\bar{y}(x) = \bar{y} + b(x - \bar{x})$$
$$= (\bar{y} - b\bar{x}) + bx \qquad (1)$$

where $\bar{y}(x)$ is the mean estimate of y for a given x, b is the slope of the regression line, and $\bar{y} - b\bar{x}$ is the line intercept on the y axis. Since in almost all the samples that were analyzed the intercept $\bar{y} - b\bar{x}$ was found to be very small as compared to the y value, (1) could be written as

$$\bar{y}(x) = bx \qquad (2)$$

without introducing an appreciable error. The equation now implies that the ratio of the burst amplitude equals the slope of the regression line.

The standard error of estimate S_{yx} is also calculated. The correlation coefficient r is determined from the standard error of estimate and the standard deviation S_y of y values. The goodness of fit of the regression line is indicated by the magnitude of the correlation coefficient.

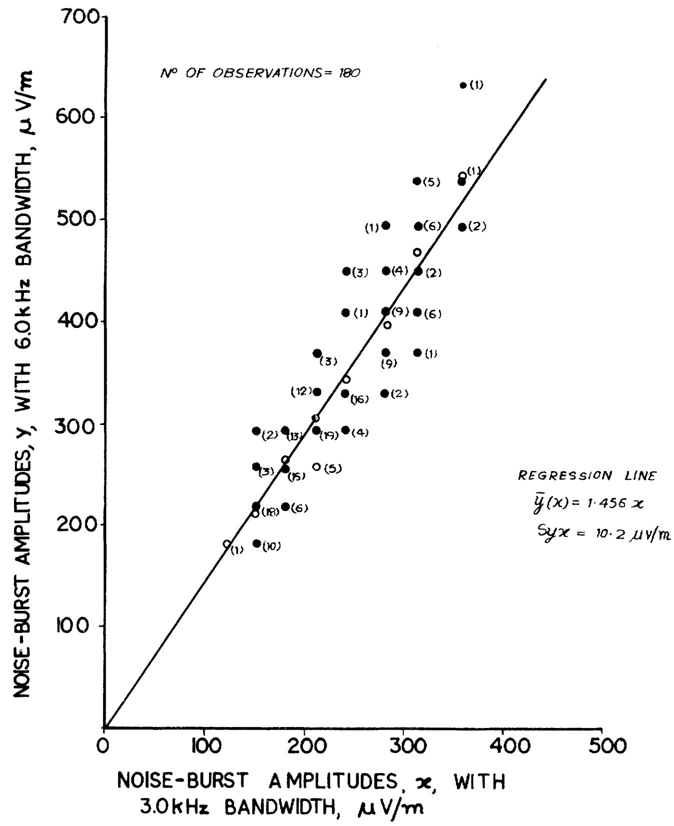

Fig. 3. Scatter diagram of noise-burst amplitudes with 3.0-kHz and 6.0-kHz bandwidths at 3.0 MHz. Numbers in parentheses indicate number of observations for each pair of amplitudes. Straight line is regression line.

TABLE I

Bandwidth Pair (kHz)	Number of Observations	Slope of Regression Line
3.2/0.3	47	0.32
3.2/1.5	22	0.64
3.3/3.2	13	1.06
6.0/3.0	331	1.45
8.0/3.2	191	1.60
10.6/3.0	27	1.70
13.8/3.0	42	1.81
16.0/3.0	15	1.85

Results

The equation of the regression line (of Fig. 3) is

$$\bar{y}(x) = 392.5 + 1.456(x - 269.6)$$
$$= 1.456x.$$

This means that for a given x, the mean estimate of y is 1.456 times x. Other details of the analysis follow:

mean values	$\bar{x}$: 269.6 μV/m
	$\bar{y}$: 392.5 μV/m
standard deviations	S_x: 110 μV/m
	S_y: 161 μV/m
slope of regression line	b: 1.456
standard error of estimate	S_{yx}: 10.2 μV/m
correlation coefficient	r: greater than 0.99.

Similar analysis was carried out for a large number of samples. As a result of the analysis, the standard error of estimate was invariably found to be less than 1 dB and the correlation coefficient always greater than 0.98. A high value of the correlation coefficient coupled with a small value of the standard error of estimate suggests that a pair of values is related deterministically rather than statistically. Therefore, the most important quantity in the analysis is the slope of the regression line. Results obtained at 3 MHz for various bandwidth pairs are given in Table I. Similar results were obtained at other frequencies in the range of 100 kHz to 9 MHz. Table I shows that the quasi-peak value varies as the square root of the bandwidth over the 0.3–10 kHz range.

Discussion

From the foregoing description it is obvious that given the quasi-peak value of a noise burst with a certain bandwidth, the quasi-peak value with another bandwidth (both bandwidths lying in the 300 Hz to 16 kHz range) can be estimated with an accuracy of ± 1 dB, which is the accuracy of the measurement itself. The amplitudes obtained with two different bandwidths are linearly related to each other. Thus any statistical amplitude parameter, such as the mean value (the average of all burst amplitudes received in a given time interval) or the noise level (the average of the 50 highest burst amplitudes received in a 5 min interval, see [2] for details) is expected to vary with bandwidth in the same manner as the individual burst amplitudes. Furthermore, the amplitude probability distributions with different bandwidths have to be identical except for a change in the mean value.

The effect of bandwidth on these statistical parameters has also been studied by making measurements with different bandwidths over successive 5-min periods [16] and similar results have been obtained. However, these studies do not throw any light on the variation of individual burst amplitudes, and furthermore, the effect on amplitude probability distribution cannot be derived from these studies.

The quasi-peak value of a burst is found to vary as the square root of the bandwidth. This suggests that a noise burst could be treated as a form of continuous noise. This conclusion is supported by the fact that a noise burst has a quasi-continuous structure [10], [11] and as such, can be considered as continuous over its duration. The essential features of a noise burst are depicted in Fig. 1, which is a record of noise bursts made with a level recorder having a writing speed of 1000 mm/s.

The square-root bandwidth law appears to break down at a bandwidth of 10 kHz. This is probably because 10 kHz is the crossover bandwidth and the receiver response to noise burst changes at this bandwidth [17].

A definite relationship between burst amplitudes, measured with different bandwidths, has a great practical significance as far as the measurement of noise is concerned. For noise measurement, a suitable bandwidth is to be chosen. A large bandwidth may be desirable, but a wide-band interference-free channel may not always be available. On the other hand, if a smaller bandwidth is used, the theory cannot tell us what the noise would have been with a higher bandwidth [18]. The results of the present investigation solve these practical and theoretical difficulties in that the measurements can be carried out with a smaller bandwidth, and the data collected can then be converted to larger bandwidths of interest.

Conclusion

Quasi-peak values of a noise burst measured with different bandwidths are related deterministically and are found to follow a square-root bandwidth law. From this information the quasi-peak value, the mean value, the noise burst level, and the amplitude probability distribution of noise can be converted from a given bandwidth to another. The conversion does not introduce any inaccuracy.

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