Proceedings of ISAP'04, Sendai, JAPAN

POS-B-9

MEASUREMENTS OF THE IMPULSIVITY OF ATMOSPHERIC NOISE AT LOW AND VERY LOW FREQUENCY IN THE MID-ATLANTIC AREA

Sophie FIEVE, Philippe PORTALA
DGA/CTSN
83800 TOULON ARMEES, FRANCE
sophie.fieve@dga.defense.gouv.fr
philippe.portala@dga.defense.gouv.fr

Louis BERTEL
Université de Rennes 1
IETR Campus Beaulieu 35042 RENNES CEDEX, FRANCE
louis.bertel@univ-rennes1.fr

1. Introduction

The atmospheric noise is one of the main electromagnetic disturbances from the ELF up to the HF range. It originates mainly from the lightning discharges of the thunderstorms and propagates through the ionospheric media.

The Vd, or voltage deviation, is a measure of the rms to average ratio of the noise envelope voltage [1] [2]. It indicates the departure of the noise from a thermal-type distribution, and thus the impulsivity of the noise. The study of this important parameter of atmospheric noise provides information on both the structure of the noise and its origin.

The purpose of this paper is to present an accurate description of the levels and variations of the impulsivity in the Mid-Atlantic at low and very low frequency, and to deduce various influences on noise generation. The final goal is an improvement of noise prediction in the area.

2. Measurement

The CTSN runs a worldwide network of VLF/LF recording stations. For this study, limited to the mid-atlantic area, the measurements at three stations, Martinique, Guyane, and Dakar, were processed. The average and rms fields were recorded in a 200 Hz bandwidth at several frequencies in the VLF and LF range. The Vd parameter was then calculated as the ratio of the rms to average noise envelope voltage.

Data were acquired over 7 years from 1997 to 2003. The low dispersion between the years allowed us to group several years of data and work specifically on daily and monthly trends.

To process the data, the different periods of the day were defined as following :

DAY, one hour after sunrise ↔ one hour before sunset ; NIGHT, one hour after sunset ↔ one hour before sunrise ; TRANSITION, rest of the time.

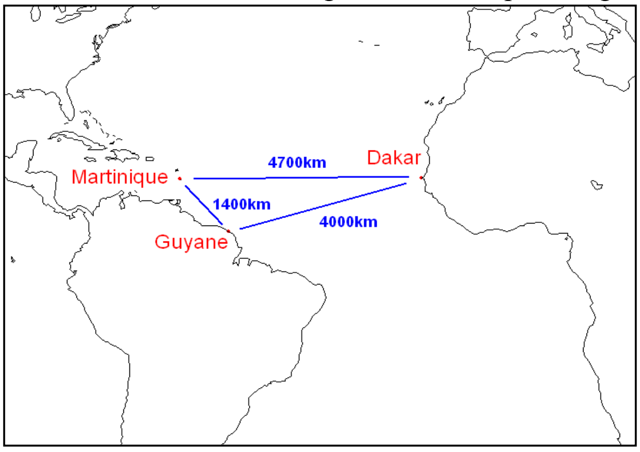

Figure 1: location of measurement sites →

Table 1 : Measure of the Vd levels, median, lower and upper decile, over the year 2001 (Dakar & Guyane) and 2003 (Martinique), at one VLF and one LF frequency.

	Dakar		Martinique		Guyane	
Frequency	17 kHz	50 kHz	17 kHz	57 kHz	17 kHz	64 kHz
Median	7.3 dB	7.5 dB	8.6 dB	7.7 dB	7.3 dB	5.6 dB
Lower decile	5.6 dB	4.7 dB	6.7 dB	5.4 dB	5.1 dB	3.7 dB
Upper decile	9.9 dB	11.9 dB	10.5 dB	10.0dB	9.2 dB	9.5 dB

ISBN: 4-88552-207-2 C3055©IEICE

3. Results

The characteristics of the diurnal variations of the Vd parameter may be described as a combination of the characteristics of the ionospheric propagation and of the noise sources : the lightning discharges. For the first parameter, its consequences on noise are now, if not completely modelised, well apprehended, and explain partly the dependence of the noise with frequency or with day periods [5]. For the second parameter, noise sources, the Vd measurement depends, in addition to the number of the sources, mainly on their distance to the measurement location and on the frequency and bandwidth of the receiver.

The background atmospheric noise is the result of the propagation of multiple distant discharges. Its distribution is close to a normal one, due to the addition of a high number of components and their attenuation in the ionospheric wave-guide ; this phenomena induces a low Vd. At the contrary local thunderstorms bring few high pulses, high compared to the background noise, and result in a higher Vd without much effect on the average noise (Cf. figure 2 and 3, presence of a close thunderstorm). The characteristics of the Vd help then to differentiate both types of noise, local and background noises, that contribute to the global atmospheric noise.

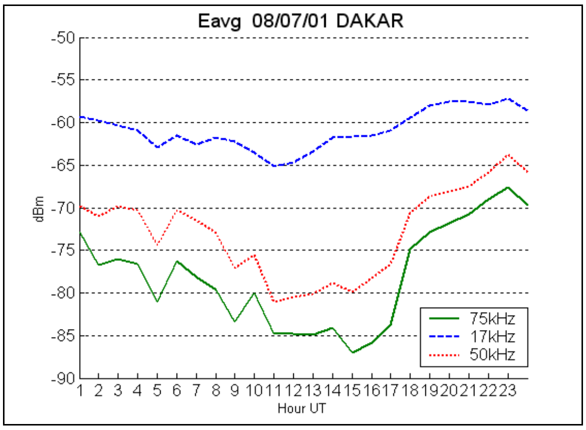

Figure 2: Measure of the E_{avg} at different frequencies, 08/07/01 Dakar.

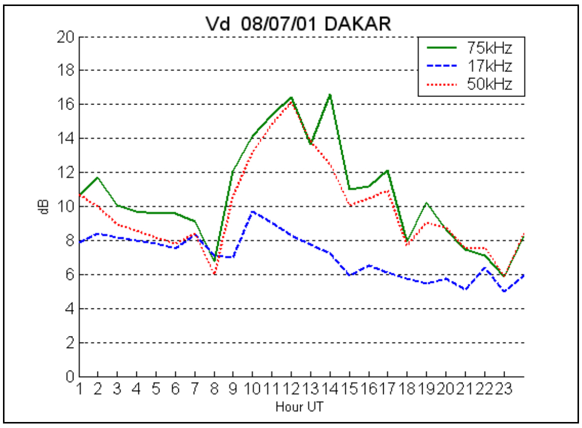

Figure 3 : Measure of the Vd at different frequencies, 08/07/01 Dakar.

The limit between the so-called 'local' noise and 'background' noise depends mainly on the propagation conditions, influenced by several parameters. Among them the frequency, the period of the day, the period of the year and the solar cycle are the most significant.

Different propagation conditions can change the characteristics of the Vd. During reduced propagation conditions (higher frequency, daytime propagation) the size of the area of influence over a measurement site decreases. By such the background noise also decreases and the influence of local storms increases. This has been observed through a higher dispersion of the Vd and the appearance of marked day and seasonal patterns at LF compared to VLF and at day time compared to night time.

3.1 diurnal variations

The figure 4 shows an example of the differences that appear between measurements at 17.4 kHz (VLF) and at 70 kHz (LF) at Dakar.

The higher dispersion at daytime at 70 kHz should be particularly noticed (Cf. also figure 5 and 6). A peak is also observed between 7:00 and 11:00 (UT). At morning hours (in July at Dakar, sunrise is around 6:50 UT) the background noise is indeed lower and the local thunderstorms are more visible and give a high Vd. Thunderstorms being however seldom at this time of the day, the increase of Vd appears only in the upper decile.

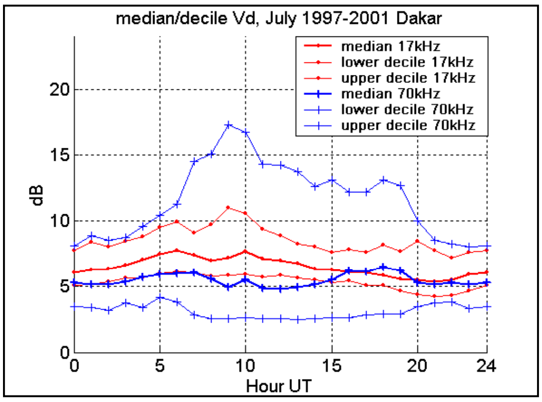

Figure 4: median and deciles of Vd, 17 kHz and 75 kHz, July 1997 – 2001, Dakar.

Those phenomena can be also observed in Martinique and Guyane. Even if the patterns differ, as the thunderstorm areas of influence in Guyane and Martinique differ from those around Dakar [3], the physical explanation is identical. In particular the higher dispersion at LF frequency is observed at all sites (cf. tab. 1).

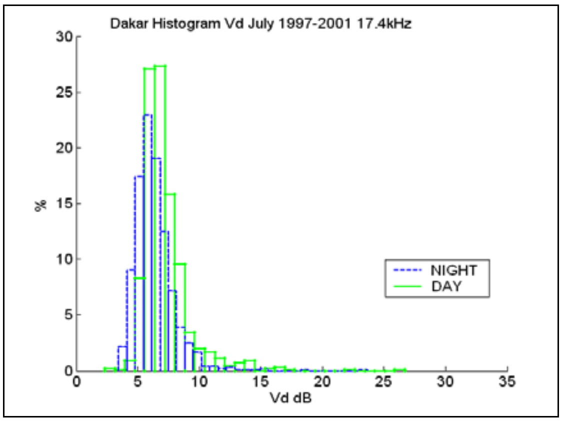

Figure 5 : Histogram Vd July, Dakar 17.4kHz.

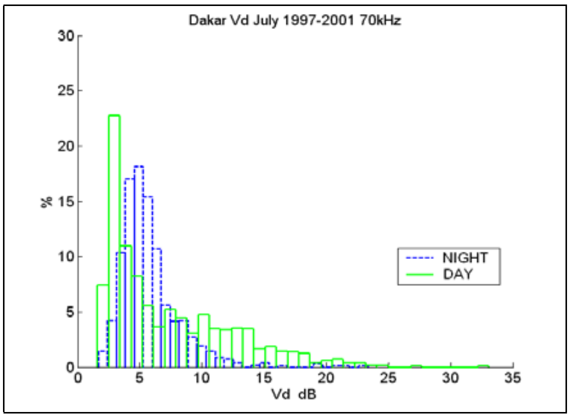

Figure 6 : Histogram Vd July, Dakar 70kHz.

3.2 Monthly variations

The monthly analysis gives access to the sources origin and to their seasonal activity.

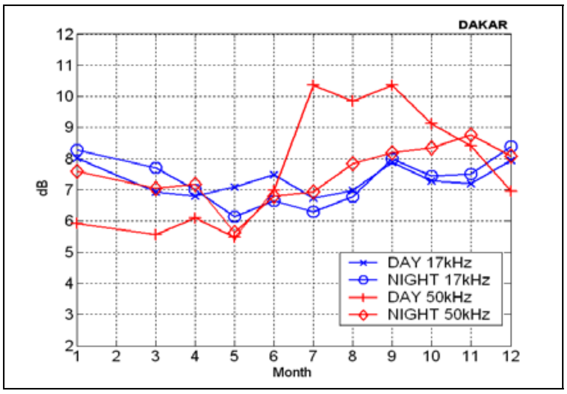

Figure 7: DAKAR, Vd median at 17kHz and 50kHz, night and day time, 1997-2001.

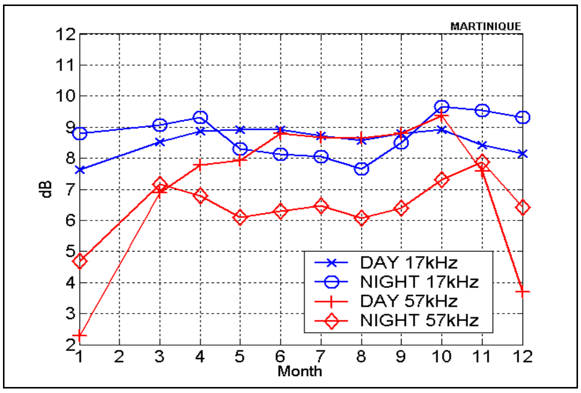

Figure 8: MARTINIQUE, Vd median at 17kHz and 57kHz, night and day time, 1997-2003.

The Vd measurements in Dakar (fig. 7) show that the monthly variations have no particular impact at 17.4 kHz (max. 2 dB) during both night and daytime. However at 50 kHz, and especially at daytime, appears a seasonal pattern, the impulsivity is particularly higher from July to October (+ 5 dB between May and July).

The measurements in Martinique (fig. 8) are only slightly different : the level at LF and daytime is higher from June to October but particularly lower from December to October. Those patterns correspond to the local thunderstorm activity [3] [4] [5].

The seasonal pattern on the Vd measurements is less visible at lower frequencies and at night. A lower frequency and night conditions extend the area of influencing thunderstorms, which then reaches regions that are active all year long. This is particularly observed in equatorial areas, around which the measurement sites are located. On the contrary higher frequency and daytime propagation conditions decrease the influence area and let appear a seasonal pattern that corresponds to local seasonal activity.

4. Comparison with the ITU model

The values from the ITU model were obtained from a worldwide measurement campaign realised between 1957-1966 [1] [2]. Our measurements were conducted in a similar way (in particular with the same 200 Hz bandwidth) and so could be compared to the model.

The model gives values of Vd for the different period of the year and different frequency, but without geographical basis, whereas it appears, based on the measurements and given its dependency on the thunderstorm distribution, that the Vd differs from one site to another.

The comparison with our median measurements indicates that the values of the ITU model are always higher. Moreover the model for the diurnal variations does not fit accurately the observations. This is partly due to the 4-hour sampling of the model that cannot represent precisely the sharp variations due to the propagation [6] [7].

Sites \ Seasons	Winter		Spring		Summer		Fall		Year	
DAKAR	17 kHz	50 kHz	17 kHz	50 kHz	17 kHz	50 kHz	17 kHz	50 kHz	17 kHz	50 kHz
Night	1.4	1.6	2.5	2.9	3.2	2.0	2.6	1.6	2.4	2.0
Transition	3.5	3.7	3.4	5.2	3.6	2.5	3.8	2.2	3.6	3.4
Day	4.1	4.7	4.6	6.0	3.9	2.3	4.9	3.0	4.4	4.0
MARTINIQUE	17 kHz	57 kHz	17 kHz	57 kHz	17 kHz	57 kHz	17 kHz	57 kHz	17 kHz	57 kHz
Night	0.8	3.9	0.5	2.8	1.4	2.5	0.9	2.7	0.9	3.0
Transition	2.5	6.0	1.9	3.8	3.1	3.3	2.7	3.4	2.6	4.2
Day	4.1	8.2	2.8	4.2	2.7	3.1	3.8	3.9	3.3	4.8
GUYANE	17 kHz	64 kHz	17 kHz	64 kHz	17 kHz	64 kHz	17 kHz	64 kHz	17 kHz	64 kHz
Night	3.0	3.9	2.0	4.0	2.9	3.1	2.2	4.0	2.6	3.7
Transition	4.9	5.6	3.4	4.6	3.8	3.8	3.8	4.9	4.0	4.7
Day	6.7	6.5	4.8	5.9	3.4	4.4	5.5	6.5	5.1	5.8

Table 2 : Comparison of the ITU predictions with the measurement of the mid-atlantic sites of the network at **LF and VLF** (median values of the Vd measurements) $\Delta Vd = Vd_{UIT} - Vd_{network}$ [dB]

5. Conclusion

This work gives a better understanding of the structure of atmospheric noise and shows how it is possible, by using the impulsivity parameter, to separate the different influences on noise characteristics in the Mid-Atlantic area. Clear differences between the influence areas at VLF and LF frequency range can be observed. Those results will be used to define coherence areas in the modeling of atmospheric noise.

The comparison with the ITU model showed in particular a lack of a geographical dependence in the predictions of the Vd.

6. References

[1] International Telecommunication Union, “Radio Noise”, Recommendation P372-7, Geneva, 2001.

[2] A. D. SPAULDING, J. S. WASHBURN, ‘Atmospheric Radio Noise Worldwide Levels and Other Characteristics’, NTIA report 85-173, US Department of commerce, April 1985.

[3] S. J. GOODMAN, H. J. CHRISTIAN, ‘Global Observations of Lightning’, Atlas of satellite observations related to global changes, p191-219, Gurney Edition, Cambridge University Press, New York. 1993.

[4] M. KOTAKI, C. KATOH, ‘The global distribution of thunderstorm activity observed by the ISS-b’, Journal of Atmospheric and Terrestrial Physics, vol.45, N°12, p833-847, 1983.

[5] E. L. MAXWELL, D. L. STONE, R. D. CROGHAN, D. BALL, A. D. Watt, “Development of an atmospheric noise model”, office of naval research, Washington DC, 1972.

[6] S. FIEVE, P. PORTALA, L. BERTEL, “Study of some characteristics of atmospheric radio noise at 17.4kHz over a tropical area”, PIERS 2003 proceedings, USA.

[7] P. PORTALA, “A Comparison of the CCIR noise model in VLF and acquisitions of the CTSN network”, PIERS 2001 proceedings, Osaka, Japan.