Results of measurements of the atmospheric radio noise at 27 kc/s at fixed measuring stations in northern, central and south-eastern Europe

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ABSTRACT

The paper presents measurements of the atmospheric radio noise (ARN) at 27 kc/s made between 1963 and 1966 at four unified European stations: Uppsala (60° N), Kühlungsborn (54° N) Prague-Panská Ves (50.5° N) and Sofia (43° N). The results concern the daily and annual variations and the latitude dependence of the mean integrated field strength. The diurnal maximum-level variations at Uppsala and Kühlungsborn are shown by an amplitude probability-distribution function. Finally, the results are compared with the predictions of the ARN level made by the C.C.I.R.

Introduction

The Observatory for Ionospheric Research (OIR) at Kühlungsborn initiated in the period before and during the IQSY an European network of stations for the continuous measurement of the integrated ARN field strength at 27 kc/s. The network includes the following stations: Uppsala, Sweden (17.6° E, 59.9° N) (the Research Institute of Electricity; head Prof. S. Lundquist), Kühlungsborn, GDR (11.8° E, 54.1° N) (OIR; head Prof. E. A. Lauter), Prague-Panská Ves, Czechoslovakia (14.6° E, 50.5° N) (the CSAV Geophysical Institute; head Dr. P. Triska), and Sofia, Bulgaria (23.4° E, 42.7° N) (the Geophysical Institute of the Bulgarian Academy of Sciences; head Dr. G. Nestorov).

The measuring installations are periodically checked by the unified calibration method (Glöde *et al.*, 1965). Long-wire horizontal receiving antennae are used, and the effective height is determined in the particular case by comparison with the measurements made with a loop antenna. All values of the electric field strength are related to a 3 dB receiver bandwidth of 500 c/s. For comparative purposes we use the measurements of the Belgian station Uccle (4.4° E, 50.8° N) (Observatoire Royal de Belgique. *Bulletin d'Observations*. Activité Solaire. 3. Observations des Atmosphériques lointains sur 27 kHz, 1964–1966). The insignificant differences may be explained by the inequalities of the receivers.

The daily trend of the VLF ARN

The characteristic trend of the daily variations of the integrated mean value of the ARN at a frequency in the very low frequency (VLF) range may be described at all the measuring stations as a combination of the earth-ionosphere wave-guide propagation characteristics and the daily variation of the source intensity—the thunderstorm activity. The resulting form of this combination is in general defined by the distance and direction of the noise sources with respect to the site of the recording station.

Figs. 1 and 2 show the daily variations of the integrated mean value (E_{av} in dB above 1 μV/m; av = average) of the ARN field strength at 27 kc/s for summer and winter, measured by the European network of fixed stations and a mobile station at Svalbard (12° E, 79° N). The time scale represents the local mean time (LMT) at the respective station. A significant

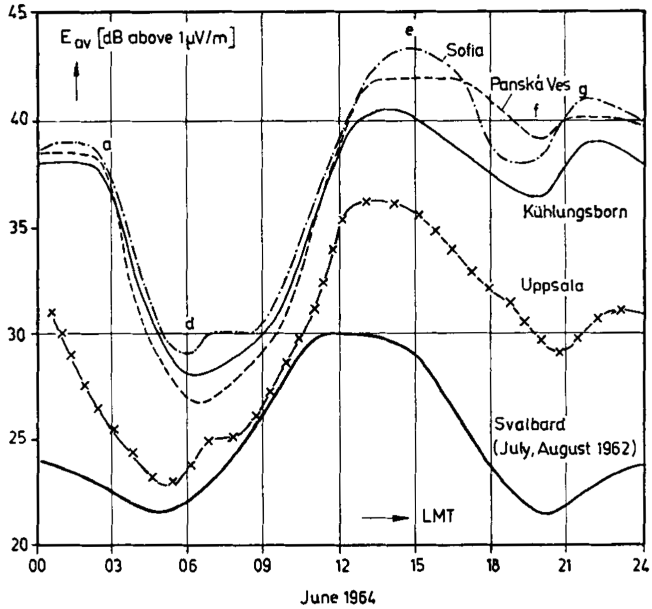

Fig. 1. Monthly means of the diurnal trends of the integrated atmospheric noise level on 27 kc/s in summer, measured at the stations of the European network and at Svalbard (12° E, 79° N).

feature is the symmetry of the Arctic record in respect of the noon time. This can be explained by the absence of the local noise sources and the fact that the daily trend of the VLF ARN record is determined by the earth-ionosphere wave guide propagation characteristics—*D*-layer propagation in the daylight, and dawn conditions during the polar summer "night" time (Glöde *et al.*, 1964). The continent of Europe differs from the polar regions in that the nearby noise

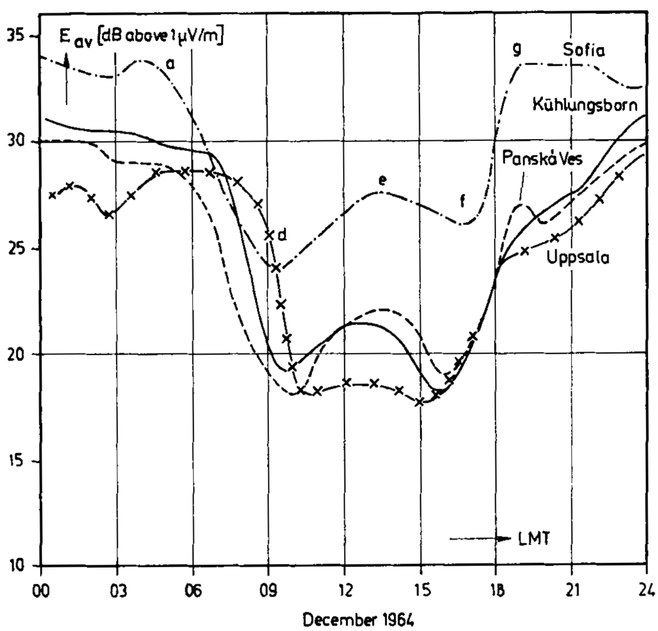

Fig. 2. Monthly means of the diurnal trends of the integrated atmospheric noise level on 27 kc/s in winter, measured at the stations of the European network.

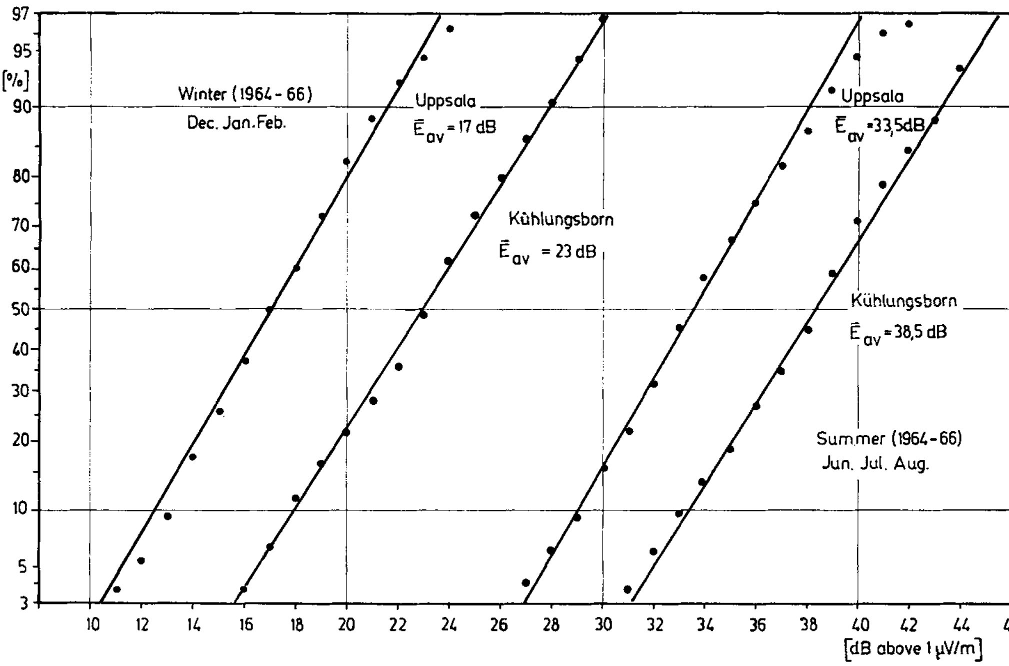

Fig. 3. Probability distributions of the maximum afternoon intensity of atmospheric noise on 27 kc/s in winter and summer at the Uppsala and Kühlungsborn station.

sources (not exceeding a distance of 1000 km) are the most important factors in the determination of the ARN level in the summer months. This entails a strong increase of the daylight maximum (point *e*) and its desplacement towards the afternoon. The daily trend of the ARN for Uppsala, for example is partly defined by the relative proximity of strong East-European noise sources (WMO, 1956) and partly by the high attenuation on the propagation path, due to the dawn conditions predominating in the northern summer nights.This characteristic situation increases the strong daytime maximum of the ARN level. The minimum of daily thunderstorm activity and the poor propagation properties of the transmission guide (transition from the *E*- to the *D*-layer propagation conditions) are directly reflected in the low value of the ARN morning minimum (point *d*). The favourable night-time connection through the *E*-layer to distant noise source areas over the Atlantic to equatorial America is interrupted at the time of sunrise (point *a*). The sunset is also characterized by a minimum (point *f*), the shape of which results from the superposition of the daytime maximum and the onset of the "dawn" conditions in the evening. The variations in the occurrence of the morning and evening minima (points *d* and *f*) are in agreement with the changes in the daylight part of the day at various geographical latitudes. The night maximum (point *g*) is reached before midnight. This confirms the statement that the decreasing European noise sources influence the ARN level in the first half of the night much more strongly than the sources in equatorial America in the second half of the night. The African noise sources have at that time a minimum activity (WMO, 1956). At the northern stations the effect of the *E*-region propagation is in the winter easily recognized (Fig. 2). The next feature characteristic of the northern stations is the symmetry of the daily noise trend in respect of noon (like the summer measurements at Svalbard). This is due to the relatively great distance from the effective noise sources, lying in the daylight time over the Mediterranean, and to the low sunheights which do not allow a perfect formation of the *D*-layer. The result is a low daylight maximum and a predominant night maximum. In comparison with the other stations of the network the Sofia station has the strongest daylight maximum (point *e*), which is obviously due to its geographical position.

The interdiurnal variations of the ARN level at 27 kc/s

The day-to-day variations of the absolute value of the daylight maximum are shown in Fig. 3. The graphs show the amplitude probability-distribution functions for the summer and winter months at Uppsala and Kühlungsborn. Differences of 15.5 dB and 16.5 dB are observed between the median values for summer and winter at Kühlungsborn and Uppsala respectively.

It is surprising that no significant difference between the summer and winter curves can be observed from the graphs in Fig. 3. However, considering the probability limit between 3 % and 97 % is at the southern station (Kühlungsborn), the amplitude dynamic 1.5 dB higher than at the northern station (Uppsala). At the latter station a perceptible deviation from the normal probability distribution at the highest noise levels (nearby thunderstorms) can also be observed.

The annual variation and the latitude dependence of the ARN level

The annual variations of the night values (20.00–24.00 LMT) of the ARN at 27 kc/s show at all stations of our network an explicit asymmetrical character. The afternoon values (12.00–16.00 LMT) of the ARN are strongly dependent on the ecliptics, which is a consequence of the *D*-layer propagation conditions. For comparison we investigate the measurements of the Belgian station Uccle. It should be pointed out that the afternoon level of the ARN exhibited a higher maximum value at the coast stations Kühlungsborn and Uccle in the months January to March than at the Panska' Ves station, which has the same geographical latitude as Uccle. In summer the circumstances at these stations are just the opposite. Such behaviour of the noise level may be explained by the influence of the Atlantic noise sources or by a greater probability of winter thunderstorms in the coast regions.

We observed some small differences between the noise levels measured at Uccle and those measured in our network. These differences may be explained by the different properties of the recording systems. The Uccle station uses a receiving system with an amplitude dynamic of 28 dB, which is 32 dB below the dynamic range of our apparatus. As regards the annual variation of the mean value of the daylight maximum (12.00–16.00 LMT), the lowest level change (13 dB) is at the Sofia station and the highest (20 dB) at the Uppsala station. This is obviously due to the relatively short distance to the main European noise-source regions for the Sofia station, and the absence of nearby sources and worse *D*-layer propagation conditions at the Uppsala station in winter time. The annual variation of the mean night values (20.00–24.00 LMT) is only 9 dB at the Sofia station and 11 dB at the Uppsala station.

Moving from latitude 42.75° N to latitude 60.0° N, a decrease of the ARN afternoon level of 12 dB in winter and of 7 dB in summer was measured. For the night hours of the day the dependence of the ARN level on the geographical latitude is much more blurred. As regards the ARN level in the night time in winter and summer, the mean difference for the Sofia and Uppsala stations was found to be 8 dB. This same difference may be explained by the low night-time noise level at the Uppsala station, due to the strong absorption of the VLF in the region of the polar summer, where in the "night" time dawn conditions exist. Whereas the latitude dependence of the ARN night level in summer results in a decrease of 3 dB, moving from 42.75° N to 54.0° N, a level change of 5 dB is representative of the latitude change from 54.0° N to 60.0° N.

The annual distribution of the ARN field strength at the northern and southern station of the network (Fig. 4) confirms the expectation raised by the diagrams of the daily variations (Figs. 1 and 2). There are differences in the absolute values of the ARN field strength at the maximum and minimum points on the daily trend.

The seasonal variation of the ARN

The ARN level decrease with increasing latitude during all seasons of the year. In conformity with the annual characteristic of the thunderstorm activity in Europe and improved VLF propagation conditions due to the smaller zenith angle of the sun the highest noise level is observed at all stations in the summer months. The highest fluctuations of the median level—

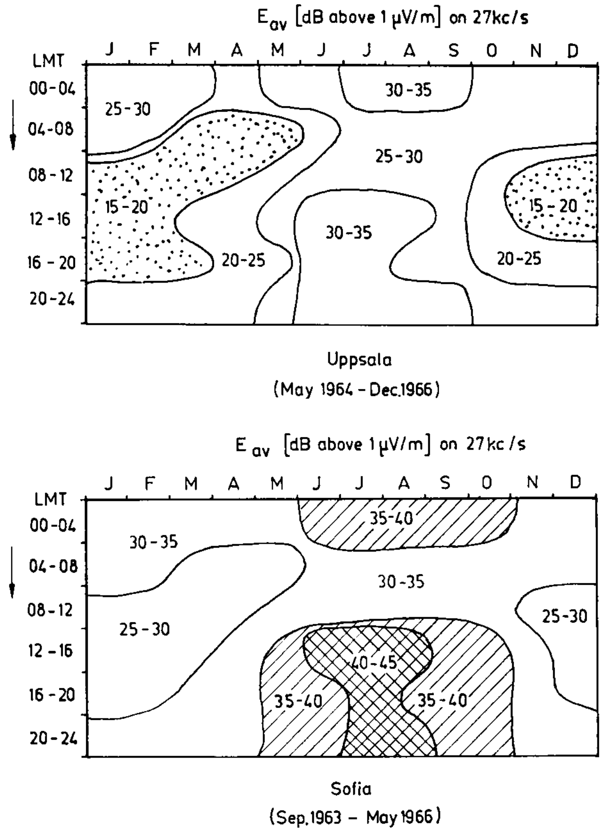

Fig. 4. The annual distribution of the integrated atmospheric noise level on 27 kc/s at Uppsala and Sofia.

from 6 dB to 18 dB—occur during the spring and autumn. An exception is the Panská Ves station, where the highest fluctuations take place in summer.

Comparison of the described results with the predictions made by the C.C.I.R.

For purposes of telecommunication technique and comparison, the most suitable description of the ARN level is given by the effective antenna noise factor Fa. This factor is defined by the C.C.I.R. as the ratio of the available to the thermal noise power, relating to a short vertical antenna at a temperature of 288°K above a good conducting ground plane, expressed in dB.

This parameter is related to the rms noise field strength along the antenna by the equation.

$$Fa = E_n + 65.5 - 20 \log_{10} f_{\mathrm{Mc/s}}, \qquad (1)$$

where E_n is the rms noise field strength for a 3 dB bandwidth of 1 kc/s in dB above 1 μV/m, Fa is the effective antenna noise factor in dB and f is the frequency in Mc/s.

The value of the field strength for any bandwidth b in c/s, other than 1 kc/s, can be obtained by adding the following expression to E_n:

$$10 \log_{10} b - 30.$$

Between E_n and E_{av} (the average value of the noise envelope in dB above 1 μV/m at a bandwidth of $b = 500$ c/s) there exists the relation

$$E_n = E_{\mathrm{av}} + V_{dw} + 3\ \mathrm{dB} - 3\ \mathrm{dB}.^1 \qquad (2)$$

[1] $+3$ dB: $30 - 10 \log_{10} 500 = +3$ dB (correction for $b = 1$ kc/s). -3 dB: the rms value of the noise voltage is 3 dB lower than the rms value of the envelope of the noise voltage.

Table 1. *Comparison of the C.C.I.R. predictions (Report No. 322) with the measurements of the European network (median values of the antenna noise factors F_a for 27 kc/s in decibels)*

The negative sign means that the C.C.I.R. prediction is less than the values measured by the European network, $\Delta F_a = F_{\text{CCIR}} - F_{\text{Network}}$ [dB]

	Mar., Apr., May	Jun., Jul., Aug.	Sep., Oct., Nov.	Dec., Jan., Feb.
Station: Uppsala. LMT				
00–04	137 − 135 = 2	141 − 140 = 1	137 − 140 = −3	136 − 136 = 0
04–08	128 − 129 = −1	135 − 139 = −4	135 − 140 = −5	134 − 137 = −3
08–12	128 − 132 = −4	138 − 143 = −5	130 − 134 = −4	127 − 130 = −3
12–16	132 − 137 = −5	145 − 144 = 1	131 − 135 = −4	127 − 129 = −2
16–20	135 − 132 = 3	138 − 139 = −1	136 − 135 = 1	131 − 131 = 0
20–24	137 − 135 = 2	144 − 140 = 4	137 − 140 = −3	134 − 135 = −1
Station: Kühlungsborn. LMT				
00–04	138 − 141 = −3	143 − 146.5 = −3.5	138 − 144 = −6	137 − 140 = −3
04–08	131 − 135 = −4	137 − 142 = −5	137 − 145 = −8	135 − 141 = −6
08–12	128 − 133 = −5	138 − 144.5 = −6.5	131 − 139 = −8	127 − 133 = −6
12–16	135 − 140 = −5	149 − 149 = 0	132 − 140 = −8	122 − 135 = −13
16–20	137 − 135 = 2	143 − 146 = −3	137 − 138 = −1	132 − 133 = −1
20–24	140 − 138 = 2	147 − 146.5 = 0.5	140 − 142 = −2	136 − 137 = −1
Station: Panská Ves. LMT				
00–04	138 − 137 = 1	144 − 145 = −1	141 − 143 = −2	137 − 137 = 0
04–08	132 − 132 = 0	139 − 139 = 0	137 − 140 = −3	135 − 137 = −2
08–12	129 − 132 = −3	138 − 144 = −6	131 − 137 = −6	127 − 132 = −5
12–16	136 − 141 = −5	150 − 149 = 1	132 − 140 = −8	122 − 133 = −11
16–20	138 − 136 = 2	146 − 144 = 2	138 − 139 = −1	132 − 133 = −1
20–24	140 − 138 = 2	147 − 146 = 1	140 − 142 = −2	137 − 137 = 0
Station: Sofia. LMT				
00–04	139 − 142.5 = −3.5	145 − 149 = −4	142 − 148 = −6	138 − 142 = −4
04–08	133 − 140.5 = −7.5	142 − 145 = −3	138 − 146.5 = −8.5	136 − 142 = −6
08–12	130 − 140 = −10	138 − 146.5 = −8.5	131 − 144 = −13	127 − 141 = −14
12–16	138 − 146 = −8	151 − 151 = 0	133 − 150 = −17	122 − 142 = −20
16–20	139 − 143 = −4	147 − 149 = −2	140 − 147 = −7	132 − 140 = −8
20–24	140 − 144 = −4	147 − 150 = −3	141 − 149 = −8	137 − 143 = −6

V_{dw} is the ratio between the rms value of the noise voltage envelope and the average value of the noise envelope for $b = 500$ c/s.

The value of V_{dw} is a function of the site, time of day and season. The values have been obtained from CCIR Report No. 322 with the aid of linear interpolation.

For F_a and E_{av} we get the following expression:

$$F_a = E_{\text{av}} + V_{dw} + 65.5 - 20 \log_{10} f_{\text{Mc/s}}. \quad (3)$$

Table 1 gives the values of the equation $\Delta F_a = F_{\text{CCIR}} - F_{\text{Network}}$ (dB), where F_{CCIR} represents the values of the antenna noise factor, according to CCIR Report No. 322, and F_{Network} is the corresponding factor, according to equation 3. The negative sign before ΔF_a means that the measuring results of the CCIR network predict lower levels than have been obtained by our stations. Fig. 5 shows the mean value of ΔF_a for our four stations. According to the CCIR measurements, the noon values (12.00–16.00 LMT) of the noise level at Uppsala in the winter time should be higher than in Sofia, which is in contradiction to our results. The fact that the CCIR measurements were made during a period of high sunspot activity was not taken into account. The investigations made by Lauter (1966) have shown that the light daytime noise level reaches values 1 to 2 dB higher during the sunspot maximum in comparison with the night-time level. The values of F_{Network} are based on the measurements made during the period of low sunspot activity (1964–1966). These two facts increase the difference between the measured values and those predicted by the CCIR. Owing to the small number of CCIR measuring stations, the predictions for Europe are of low accu-

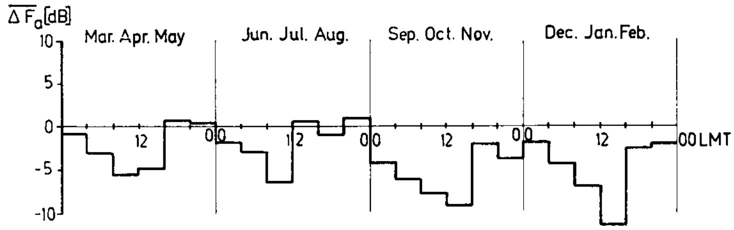

Fig. 5. Comparison of the C.C.I.R. predictions (Report No. 322) with the measurements of the European network (median values of the antenna noise factors F_a for 27 kc/s in decibels). $\overline{\Delta F_a} = F_{\mathrm{CCIR}} - F_{\mathrm{Network}}$ [dB]. Averages for all the stations of the European network.

racy and the differences shown in Table 1 are quite reasonable.

Similar results have also been obtained by other authors (Clarke, 1962; Ibukun, 1965).

The monthly median values and the appearance of the characteristic points (Lauter & Ehmert, 1956) of the diurnal trend of the atmospheric noise level at 27 kc/s will be published in the *Geophysikalische Messreihen* (Monthly Bull. of the OIR, Kühlungsborn) and in the *Ionospheric Data of the Pruhonice and Panská Ves Observatories* (Monthly Bull., Geophys. Inst. Acad. Sci., Prague).

REFERENCES

C.C.I.R. Report No. 322, 1963. World distribution and characteristics of atmospheric radio noise. International Telecommunications Union. Geneva, 1964.

Clarke, C. Atmospheric radio-noise studies based on amplitude-probability measurements at Slough, England, during the IGY. Proc. *IEE 109* B (1962), 393–404.

Glöde, P., Lauter, E. A. & Schäning, B. Sommerliche Tagesgänge des atmosphärischen Störpegels auf Längstwellen in verschiedenen Breiten. *Gerl. Beitr. z. Geophysik 73*, H. 3 (1964), 137–153.

Glöde, P., Meyenburg, D. & Schäning, B. Messung statistischer Parameter des atmosphärischen Funkstörpegels im Längstwellenbereich. *Zs. f. Met. 18*, H. 1/2 (1966), 1–12.

Ibukun, O. On the predictions of atmospheric radio-noise levels in the tropics. *J. Atm. Terr. Phys. 27* (1965), 1059–1080.

Lauter, E. A. Geophysical aspects of low-frequency atmospheric noise measurements. *Zs. f. Met. 18* (1966), 201–211.

Lauter, E. A. & Ehmert, A. Atmospheric noise recording. II. World Symposium on Atmospherics. Zürich, 1956. Recommendation 2, WMO 40 (57-CAe).

WMO. World distribution of thunderstorm days. Pt. 2. Tables of marine data and world maps. WMO, No. 21. Organis. Météorol. Mond., Geneva, 1956.

РЕЗУЛЬТАТЫ ИЗМЕРЕНИЙ АТМОСФЕРНЫХ РАДИОШУМОВ НА ЧАСТОТЕ 27 КГЦ НА ФИКСИРОВАННЫХ СТАНЦИЯХ В СЕВЕРНОЙ, ЦЕНТРАЛЬНОЙ И ЮГО-ВОСТОЧНОЙ ЕВРОПЕ

В статье представлены результаты измерений атмосферных радиошумов (АРШ) на частоте 27 кгц, произведенных в 1963–66 гг. на четырех связанных европейских станциях: Уппсала (60° с. ш.), Кюлунгсборн (54° с. ш.), Прага–Панска Вес (50,5° с. ш.) и София (43° с. ш.). Получены суточные и годичные вариации и зависимость от широты для средней проинтегрированной напряженности поля. Для суточных вариаций максимума уровня в Уппсале и Кюлунгсборне построены функции распределения вероятностей. В заключение, результаты измерений сравниваются с предсказаниями уровня АРШ, сделанными C.C.I.R.