Results of ship-borne atmospheric radio noise measurements at 27 kHz on the North Atlantic during winter

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ABSTRACT

Ship-borne and land-station measurements of atmospheric radio noise (ARN) at 27 kHz in latitudes between 60° N and 23° N during winter 1968/69 and 1970/71 are presented. The results concern the diurnal variations, the latitude dependence and the longitudinal distribution of the mean integrated field strength. The diurnal variations are explained by reference to the prevailing meteorological and ionospheric conditions. Finally, the results are compared with the predictions of the ARN level made by the C.C.I.R.

1. Introduction

As a contribution to the world-wide synopsis, atmospheric radio noise (ARN) measurements at 27 kHz have been made on a network of four European recording stations: Uppsala 60° N, Kühlungsborn 54° N. Prague-Panská Ves 50.5° N and Sofia 43° N, (C.C.I.R. Report, 1963), and in addition on board a cargo ship during passages across the Atlantic from Europe to Central America and back in the winter of 1968/69 and 1970/71. The integrated ARN field strength was measured continuously and the measured values are related to a 3 dB-receiver bandwidth of 500 Hz. Table 1 summarizes the dates and the positions of the ship at the beginning and at the end of the ARN measuring program during four crossings of the North Atlantic and two stays at Havana.

The results of the ship-borne ARN-measurements are compared with simultaneous land-station ARN-measurements, carried out at Uppsala 59.9° N, 17.6° E and Kühlungsborn 54.1° N, 11.8° E.

2. The diurnal variations of the VLF ARN at different latitudes

The pronounced diurnal variation of the VLF ARN intensity may be described at all measuring stations as the combined effect of the daily variation of the ARN-generating thunderstorm activity, the prevailing propagation conditions and the energy spectra of the lightning discharges. The nature of this combination mainly changes by differences in any or all of these factors.

Fig. 1 shows the diurnal variations of the integrated mean value of the ARN field strength[1] at 27 kHz for winter, measured at Uppsala and Kühlungsborn, and on a mobile station at Havana (Cuba), these three sets of measurements being regarded as representative for the conditions at subpolar, temperate and subtropical geographical locations. The plots are the mean values obtained during the measurements in February 1969 and in January 1971. The vertical lines mark the range between the upper and the lower quartile, during a four hour interval, and indicate the day-to-day scatter of of the ARN level. The time scale is given in the Local Mean Time (LMT) at the respective station. At all three stations the mean ARN field strength was somewhat higher during February 1969 than January 1971. This may suggest that the main noise sources for these three stations are the same during winter.

Consider at first the incidence of thunderstorm activity. From investigations by Fri-

[1] E_{av}: the average value of electric field in dB above 1 μV/m.

Table 1

Start	Position: geogr. coord.	
Dec. 26, 1968	54°28′ N	11°32′ E
Feb. 21, 1969	25°47′ N	76°48′ W
Dec. 11, 1970	54°25′ N	11°50′ E
Feb. 1, 1971	23°59′ N	80°53′ W

Stay at Havana (23°08′N, 82°20′ W)
Feb. 4, 1969–Feb. 20, 1969
Dec. 30, 1970–Jan. 31, 1971

End	Position: geogr. coord.	
Jan. 19, 1969	20°09′ N	94°48′ W
Feb. 28, 1969	41°09′ N	30°09′ W
Dec. 29, 1970	23°18′ N	82°08′ W
Feb. 15, 1971	54°15′ N	12°03′ E

sius & Heydt (1971) we know the average direction distributions of thunderstorm activity for the period from February 3–February 24, 1969, observed simultaneously on board the research vessel "Meteor" on the North Atlantic and at the recording station at Berlin. For the periods from December 30, 1970–February 8, 1971, and from December 19, 1970–February 1, 1971, respectively we may use the observations made at the stations at Berlin 52.6° N, 13.1° E

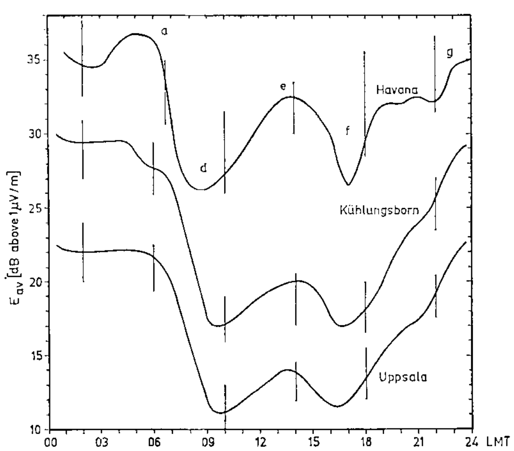

Fig. 1. Monthly means of the diurnal trends of the integrated atmospheric noise level on 27 kHz in winter, measured on board a ship at Havana (Cuba) and at the stations at Kühlungsborn and Uppsala. The vertical lines in the figure indicates the range of maximum deviations of the measured noise levels from the mean value.

and at Waldorf near Washington 38.6° N, 77° W (Frisius & Heydt, 1971). As a result of these observations, sources of considerable atmospheric activity for the region between Europe and America were indicated at the coastal area south of the gulf of Panama, in the area of the Amazon, in the northern part of South America, in an area in front of the Californian peninsula, in the area of the islands of Hawaii, in some areas of the Atlantic and in the area of the Mediterranean Sea.

On the account of the relatively small distance between Havana and the main ARN-sources in South America and in California we observed at this station the highest ARN field strength, whereas at Uppsala, the field strength (Fig. 1) was low. Comparing the diurnal variations we find at all stations an almost symmetrical variation of the ARN field strength with a daytime maximum (point *e*), which does not exceed the high values during the night (point *g*) and depends on the geographical position. This symmetry in respect to the noon time can be explained by the absence of nearby noise sources which do not exceed a distance of 1 000 km during the daytime and by the fact that the daily variation of the VLF ARN records is mainly determined by the Earth-ionosphere waveguide propagation characteristics: D-region propagation during daytime. The distance between the nearest main source of the ARN in the coastal area south of the gulf of Panama and the station at Havana is more than 1 700 km while it is more than 1 500 km between the source in the Mediterranean area and the station at Kühlungsborn. In these cases the ionospheric conditions predominate in influencing the diurnal variation of the ARN field strength. The daytime D-region propagation suffers always a higher attenuation than the E-layer propagation during the night-time when a connection to distant sources up to 10 000 km is possible.

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 is interrupted at the time of sunrise (point *a*). The sunset (point *f*) is again an effect of propagation conditions.

Observations of noise sources by Heydt (1971) show a maximum of activity for the South America ARN-sources at the hours shortly before and after sunset, whereas the activity of the areas on the Atlantic has a flat maximum at the hours before sunrise.

The observations made by Heydt (1971) can even be confirmed by the measured values of the ARN which are plotted in Figs. 1 and 2. The first increase of the field strength at Havana after the sunset (point *f*) corresponds to the increased thunderstorm activity in the gulf of Panama and south of the Californian peninsula. The second increase of field strength at Havana at about 22.00 LMT corresponds to the increased thunderstorm activity in the area of the Hawaiian islands, where the local time is just about sunset. In the hours before sunrise the ARN field strength at Havana is influenced also by the noise sources from the North Atlantic and from the gulf of Mexico. It is remarkable that the storm activity one hour before the sunset in the area of the Amazon river 50° W has not been observed on the ARN field strength records at Havana 82° W. This can only be explained by the high wave attenuation during the daytime on the 3 500 km long propagation path between the ARN source and the measuring station. At that time the main part of the propagation path to Kühlungsborn and to Uppsala is under the night-time propagation conditions, and the high ARN-level at those two stations at about 22.10 LMT is caused by the storm activity in the nothern part of South America.

Fig. 2 shows the diurnal variation of the integrated mean value of the ARN field strength at 27 kHz on the North Atlantic during winter. The plots are the mean of measurements during the four passages documented in Table 1. The ARN field strength increases with decreasing distance between the receiving station and the main noise sources. As it is to be expected from the daily variation of the thunderstorm activity on the North Atlantic we observed at all latitudes a low daytime maximum of the ARN field strength and a predominant night maximum. The diurnal variation of field strength at the latitudes 54°–50° N is similar to that of Kühlungsborn and at the latitudes 30°–24° N the diurnal variation of the ARN level is similar to that of Havana.

The vertical lines in Figs. 1 and 2, which

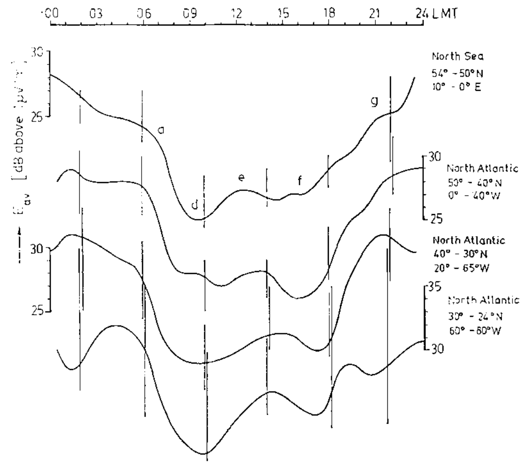

Fig. 2. The diurnal trends of the integrated atmospheric noise level on 27 kHz in winter between Europe and Central America.

show the day-to-day scatter of the ARN level indicate the increase of sporadical thunderstorm activity in subtropical latitudes in the region around the observation site. For this reason the smallest scattering in the ARN level was observed at the temperate and at the higher latitudes.

3 The longitudinal distribution of the VLF ARN

Fig. 3 shows the longitudinal distribution of the integrated mean value of ARN field strength at 27 kHz on the North Atlantic during winter (Table 1). The time scale represents Greenwich Mean Time (GMT). It should be remembered that the measurements between longitudes 0° W and 45° W mainly refer to the latitudes between 50° N and 35° N, and the measurements between the longitudes 45° W and 82° W refer to the latitudes between 40° N and 25° N. According to the diurnal variations of the ARN field strength (Figs. 1 and 2) the highest levels were observed during the night. Two pronounced cluster centers of the ARN field strength have been found to exist during the night-time at the longitudes 60° W and 32° W—in the area of the Azores.

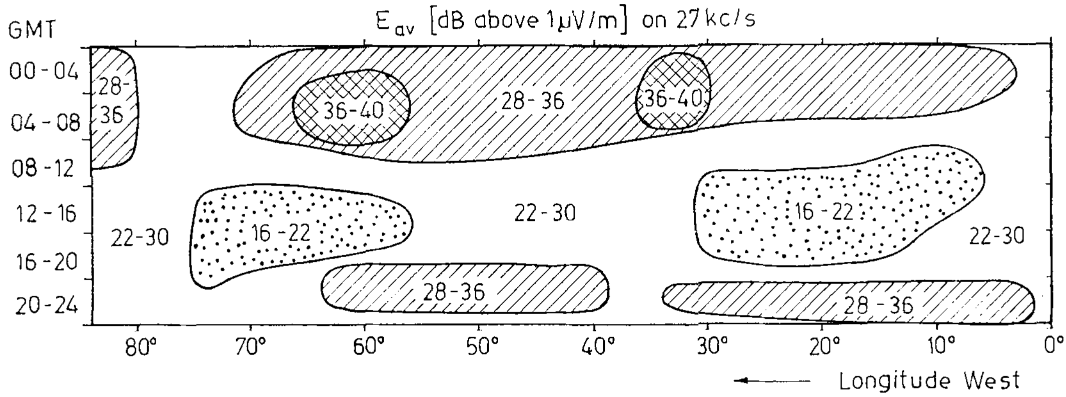

Fig. 3. The longitudinal distribution of the integrated atmospheric noise level on 27 kHz in winter on the North Atlantic.

4. Comparison of the ship-borne ARN-measurements with the predictions made by the C.C.I.R.

For the purpose of prediction of the ARN-level and for the purpose of comparison of different measurements, it is most suitable to express the ARN level by the effective antenna noise factor F_a. This factor is defined by the C.C.I.R. (1964) 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 decibel.

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

$$F_a = E_n + 65.5 - 20 \log_{10} f \qquad (1)$$

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

The value of the field strength for any bandwidth in Hz, other than 1 kHz, can be obtained by adding the following expression to E_n:

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

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

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

[1] +3 dB: 30–10 $\log_{10} 500 = +3$ dB – correction for b = 1 kHz. –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 2. *Comparison of the C.C.I.R. predictions (Schäning & Scuka, 1969) with ship-borne measurements*

Median values of the antenna noise factor F_a for 27 kHz in decibels. The negative sign means that the C.C.I.R. prediction is less than the ship-borne measurements, $F_a = F_{\text{CCIR}} - F_{\text{ship}}$ [dB].

Dec., Jan., Feb.		
North Sea		North Atlantic
54°–50° N, 10° E–0°		50°–40° N, 0°–40° W
LMT		
00–04	137–136.5 = 0.5	137–138.5 = –1.5
04–08	134–135.5 = –1.5	134–139 = –5
08–12	127–130 = –3	127–133 = –6
12–16	122–131 = –9	125–133.5 = –8.5
16–20	131–132 = –1	132–132.5 = –0.5
20–24	135–135.5 = –0.5	135–139 = –4
North Atlantic		North Atlantic
40°–30° N, 20°–65° W		30°–24° N, 60°–80° W
LMT		
00–04	138–140 = –2	139–140 = –1
04–08	135–139 = –4	136–141.5 = –5.5
08–12	130–134.5 = –4.5	128–136.5 = –8.5
12–16	127–135 = –8	127–138 = –11
16–20	133–134.5 = –1.5	134–138 = –4
20–24	136–140.5 = –4.5	137–139.5 = –2.5
Jan., Feb.		
Station: Havana (23°08′ N, 82°20′ W)		
LMT		
00–04	139–145 = –6	
04–08	136–145 = –9	
08–12	128–141 = –13	
12–16	129–144.5 = –15.5	
16–20	134–142 = –8	
20–24	137–144 = –7	

V_{dw} is the ratio between the rms value of the noise voltage envelope and the average value of the noise envelope for $b = 500$ Hz. The value V_{dw} is a function of the site, time of day and season. The values have been obtained from Schäning & Scuka (1969) with the aid of linear interpolation.

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

$$F_a = E_{av} + V_{dw} + 65.5 - 20 \log_{10} f, \quad (3)$$

where f is in MHz.

Table 2 gives the values of the equation $\Delta F_a = F_{CCIR} - F_{ship}$[dB], where F_{CCIR} represents the values of the antenna noise factor, according to C.C.I.R. (1964) and F_{ship} is the corresponding factor, according to equation (3). The measurements confirm the results published earlier by Schäning & Scuka (1969). They show that the interpolated values of the ARNlevel which is obtained from the predictions of the C.C.I.R. (1964) for the North Sea and the North Atlantic for the time interval 12–16 LMT lies 8.5 to 15.5 dB below the actual noise level. The smallest differences were measured during the night-time. Owing to the limited number of the C.C.I.R. measuring stations, the predictions for the North Atlantic are of low accuracy and the differences shown in Table 2 are quite reasonable.

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РЕЗУЛЬТАТЫ ИЗМЕРЕНИЙ АТМОСФЕРНЫХ РАДИОШУМОВ НА 27 *кгц*. С КОРАБЛЯ В СЕВЕРНОЙ АТЛАНТИКЕ В ТЕЧЕНИЕ ЗИМЫ

Представлены результаты измерений атмосферных радиошумов (АРН) на 27 *кгц* с корабля и наземных станций в интервале широт между 60° и 23° с. ш. в течение зим 1968–69 и 1970–71 гг. Результаты описывают суточные вариации, зависимость от широты и распределение по долготе средней проинтегрированной интенсивности поля. Суточные вариации объясняются ссылкой на превалирующие метеорологические и ионосферные условия. Наконец, результаты сравниваются с предсказаниями уровня АРН, сделанными МККР (Международным консультативным комитетом по радио).