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On the Radio Noise Level at Low and Very Low Frequencies in Polar Regions

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Measurements of the noise called hiss at low and very low frequencies in polar regions show that hiss can exceed the atmospheric noise caused by thunderstorms and so determine the minimum field strength of a detectable radio signal.

Existing predictions of radio noise levels do not take account of hiss as an interfering noise, probably because of the relatively small number of noise measurements carried out in polar regions. Predictions should therefore be used with caution for the low and very low frequencies in polar regions.

1. Introduction

The smallest detectable radio signal which can be received is limited by the radio noise level at the receiving antenna. The noise sources which normally contribute to this noise level are thunderstorms, man-made noise, precipitation static during sandstorms or blizzards, and cosmic radio noise at frequencies above the maximum plasma frequency of the ionosphere [Hermann, 1964].

In polar regions the noise level is smaller than at lower latitudes, because of the great distances to the thunderstorm centers in Africa, South and Central America, and the East Indies.

Graphs are published from time to time showing the expected noise level in the frequency range 10 kc/s to Mc/s everywhere on the earth as a function of the hour and season. The latest available atmospheric radio noise data were published by C.C.I.R. [1964]. The noise predictions are based upon observations from a number of stations, but only a few of these were situated in polar regions, so the uncertainty of the predictions must be considered the largest here.

The purpose of this paper is to show that in polar regions, hiss sometimes exceeds the types of noise mentioned above and so determines the minimum fields strength which can be received. While the predictions show a decreasing noise effect from the equator polewards, the hiss measurements show that the intensity and frequency of occurrence of hiss increase towards higher latitudes.

The importance of hiss as a disturbing noise regarding radio communication is greatest during geomagnetically disturbed periods. On these occasions, strong absorption in the short-wave range prevents communication, which then will be carried through at low frequencies, at the same time as the hiss activity is maximum [Jørgensen, 1964].

2. Comparison of Hiss Measurements and Predictions of Radio Noise

The predictions of atmospheric radio noise are given by the parameter Fa [Crichlow et al., 1955], which is defined as the ratio of the available noise power from a short, vertical, earthed, loss-free antenna relative to the thermal noise power KTB which would be available from the antenna if it were at a specified temperature, T.

The available noise power from hiss of field strength E ($\mathrm{Vm}^{-1}(\mathrm{c/s})^{-1/2}$) from a short vertical antenna is

$$p = E^2 h_e^2 / 4r \tag{1}$$

where h_e is the effective height of the antenna (here equal to one half of the real antenna height h), r, the radiation resistance, is

$$r = 40\pi^2 (h/\lambda)^2, \tag{2}$$

and λ is the received wavelength.

From (1) and (2) is found

$$p = E^2 \lambda^2 / 640\pi^2.$$

The hiss level expressed at Fa is then

$$Fa(\text{hiss}) = 10 \log (E^2 \lambda^2 / KT\ 640\pi^2). \tag{3}$$

3. Measurements of Hiss at Hobart, Tasmania

From mid-September to mid-November 1959, Dowden recorded hiss at the frequencies 9 and 230 kc/s [Dowden, 1960]. The recordings took place at Hobart, Tasmania, situated at 52° geomagnetic latitude, about 1000 km outside the auroral zone. Hiss was observed on three occasions only, and at one of these the maximum field strengths at 9 and 230 kc/s were $0.8\cdot10^{-6}\mathrm{Vm}^{-1}(\mathrm{c/s})^{-1/2}$ and $16\cdot10^{-9}\mathrm{Vm}^{-1}(\mathrm{c/s})^{-1/2}$ respectively. In table 1 these field strengths are converted to corresponding spectral densities p given by

$$p=E^2/120 \qquad (\mathrm{Wm}^{-2}(\mathrm{c/s})^{-1})$$

and also expressed in terms of Fa(hiss) by eq (3). For comparison the predicted atmospheric noise given by C.C.I.R. [1964] is also shown.

The atmospheric noise predictions are not given below 10 kc/s, but since the curves between 10 and 100 kc/s have a smooth frequency variation, the predictions can be extrapolated with good accuracy down to 9 kc/s to find a measure for the expected atmospheric noise to compare with the hiss at 9 kc/s.

Table 1 shows that the expected atmospheric radio noise at 9 kc/s exceeds the hiss by 17.5 dB while the hiss at 230 kc/s is 2.4 dB over the expected atmospheric noise.

TABLE 1. *Comparison of maximum hiss spectral density and predicted atmospheric radio noise at Hobart between 03 and 04 UT on November 6, 1959.*

Recorded hiss					
Frequency	Field strength	Spectral density	Fa (hiss)	Predicted atm. noise Fa	Fa (hiss) $-Fa$
kc/s	($Vm^{-1}(c/s)^{-1/2}$)	($Wm^{-2}(c/s)^{-1}$)	(*dB*)	(*dB*)	(*dB*)
9	$0.8\cdot10^{-6}$	$1.7\cdot10^{-15}$	134.5	152	-17.5
230	$16\cdot10^{-9}$	$0.68\cdot10^{-18}$	72.4	70	2.4

4. Measurements of Hiss in Greenland

At Narssarssuaq, located in the zone of maximum zenithal auroral frequency (71.2°N; 36.7°E geomag.), and at Godhavn, which is about 1000 km inside the auroral zone (79.9°N; 32.6°E geomag.), VLF noise has been recorded through several years. Both wideband recordings of the frequency range 0.5 to 20 kc/s during one or two minutes per hour and continuous selective recordings at 8 kc/s have been carried out.

Comparing our data from Greenland to the hiss recordings by Dowden [1960] and to recordings carried out by Ellis [1959], we have found that the hiss bursts in auroral regions are more numerous and of a greater spectral density than those at lower latitudes. While Dowden during 2 months recorded a total of three bursts with maximum spectral density $1.7\cdot10^{-15}$ $\mathrm{Wm}^{-2}(\mathrm{c/s})^{-1}$ at 9 kc/s, we at Narssarssuaq in February 1964 measured 49 bursts with spectral densities of $1.7\cdot10^{-15}$ $\mathrm{Wm}^{-2}(\mathrm{c/s})^{-1}$ and above. The duration of the hiss bursts varies from between fractions of a minute to a few hours. At Narssarssuaq in February 1964 the hiss exceeded $10^{-15}\mathrm{Wm}^{-2}(\mathrm{c/s})^{-1}$ during 8 hours in total, or 1.2 percent, of the time and exceeded $5\cdot10^{-15}\mathrm{Wm}^{-2}(\mathrm{c/s})^{-1}$ in about one-half hour, or only 0.07 percent of the time. Both at Godhavn and at Narssarssuaq the maximum spectral densities at 8 kc/s are found to be about $10^{-14}\mathrm{Wm}^{-2}(\mathrm{c/s})^{-1}$.

Unfortunately because of limitations set by the equipment, we do not have records of hiss above 20 kc/s, but hiss is often recorded in a smooth spectrum from a few to 20 kc/s, and there is no reason to think that the hiss does not exist at higher frequencies.

Under the assumption that hiss in Greenland occurs at 230 kc/s, as is the case at Hobart, and also that the frequency dependence is the same as in the recording from Hobart, we will compare hiss recorded at Godhavn with the predicted atmospheric radio noise level. For Hobart we have compared the maximum hiss spectral density which was $1.7\cdot10^{-15}\mathrm{Wm}^{-2}(\mathrm{c/s})^{-1}$ with the predicted atmospheric noise level at the same time of the day in November. Since November is a spring month in Australia, we must make our comparisons in a spring month at Godhavn.

At 2150 UT on April 19, 1964 a hiss burst of maximum spectral density $6\cdot10^{-15}\mathrm{Wm}^{-2}(\mathrm{c/s})^{-1}$ at 8 kc/s was recorded. A sonagram of this hiss burst is shown in figure 1b, where it is seen that the hiss exceeds the atmospheric noise. On the other hand in the recording at 2050 UT shown in figure 1a, the atmospheric noise is exceeding the hiss, which was at this time measured to about $10^{-16}\mathrm{Wm}^{-2}(\mathrm{c/s})^{-1}$. On both sonagrams it will be seen that the noise is less at 14 to 16 kc/s than at lower frequencies. This is caused by the frequency response of the equipment.

If we assume it is permissible to extrapolate the atmospheric noise predictions down to 8 kc/s and also that the hiss varies with frequency in the same way as the hiss at Hobart, we will find the comparison of hiss and atmospheric noise as shown in table 2.

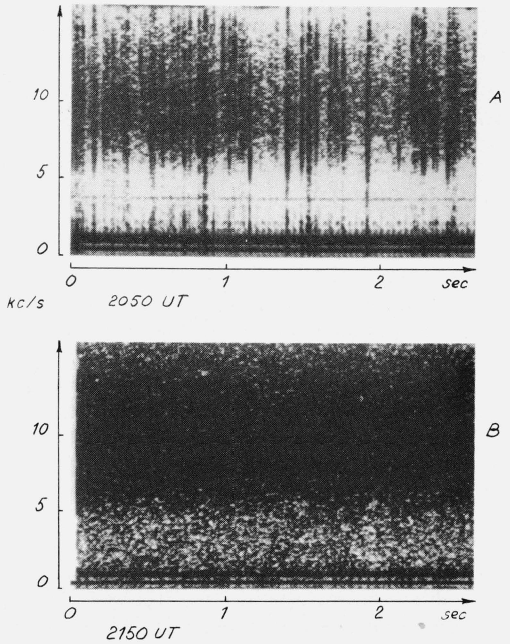

FIGURE 1. *Sonagrams of VLF noise recorded at Godhavn, Greenland, April 19, 1964.*

At 2050 UT the atmospheric noise is predominant, while at 2150 UT the hiss exceeds the atmospheric noise.

TABLE 2. *Comparison of maximum hiss spectral density and predicted atmospheric radio noise at Godhavn between 21 and 22 UT on April 19, 1964.*

Recorded hiss				Predicted atm. noise Fa	Fa (hiss) $-Fa$
Frequency	Field strength	Spectral density	Fa (hiss)		
kc/s	$(Vm^{-1}(c/s)^{-1/2})$	$(Wm^{-2}(c/s)^{-1})$	*dB*	*dB*	*dB*
8	$1.5 \cdot 10^{-6}$	$6 \cdot 10^{-15}$	141.3	152	−10.7
230			77	67	10

At 8 kc/s the atmospheric noise exceeds the hiss by 10.7 dB. This result does not fit well with figure 1b, where the hiss is seen to be the strongest, but probably the atmospheric noise during the disturbed ionospheric conditions is somewhat attenuated. At 230 kc/s the hiss exceeds the atmospheric noise by 10 dB.

5. Conclusion

By comparison of hiss recorded at Hobart, Tasmania, and at Godhavn, Greenland, with predictions of atmospheric radio noise given by C.C.I.R. [1964], it is shown that the intensity of hiss can exceed the expected atmospheric radio noise level at low frequencies, and also that the disturbing effect of hiss is greater in auroral regions than at lower latitudes.

Preliminary investigations show that possible interference of radio communications caused by hiss will not occur very often and that the duration of the interference will be of the order of minutes.

However, more measurements, especially around a few hundred cycles per second, have to be carried out before a clear picture of the interfering effect of hiss on radiocommunication is obtained.

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6. References

Crichlow, W. G., D. F. Smith, R. N. Morton, and W. R. Corliss (1955), Worldwide radio noise levels expected in the frequency band 10 kilocycles to 100 megacycles, NBS Circ. 557.

Dowden, R. L. (1960), Geomagnetic noise at 230 kc/s, Nature **187,** No. 4738, 677–678.

Ellis, G. R. A. (1959), Low frequency electromagnetic radiation associated with magnetic disturbances, Planetary Space Sci. **1,** 253–258.

Hermann, J. R. (1964), Radio noise problems in arctic regions, AGARDograph No. 78, 127–146.

International Radio Consultative Committee C.C.I.R. (1964), World Distribution and Characteristics of Atmospheric Radio Noise, Geneva International Telecommunication Union (Its Report 322). This report constitutes a comprehensive revision of Report 65.

Jørgensen, T. S. (1964), Some observations of VLF-hiss and correlated phenomena, J. Atmospheric Terrest. Phys. **26,** 626–628.

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