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STUDY OF LATITUDINAL, DIURNAL AND SEASONAL VARIATION OF IONOSPHERIC ABSORPTION ACCORDING TO OBSERVATIONS OF THE RIOMETER NETWORK IN FINLAND

by

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Abstract

Riometer data from five Finnish riometer stations in the years 1972–73 have been analyzed and these results have been compared with results from Norway, the U.S.S.R., Alaska and Canada. Maximum absorption occurs at corr. geom. lat. 67° – 64° N. The diurnal variation of absorption at different latitudes has been analyzed. Absorption has two maxima and one minimum at latitudes 62° – 77° N, one nightmaximum at latitudes >77° N and one daymaximum at latitudes <62° N. Occurring and lasting time of maxima and minimum depends on the longitude. An exception to those results is results from Alaska, where diurnal variation has only one clear daymaximum at all latitudes.

1. *Introduction*

The cosmic noise power has been recorded continuously at several Finnish stations with riometers [14] operating at 27.6 MHz. The riometers measuring ionospheric absorption of radio waves have been operating in Kevo since 1968, in Ivalo since 1972, in Sodankylä since 1964, in Oulu since 1967 and in Nurmijärvi since 1967. In this article riometer data from the years 1972–73 have been analyzed. The geographic coordinates of the stations are given in table 1 and their locations are shown in figure 1.

The riometers are connected to vertically directed three-element Yagi antennae with half-power beamwidths of approximately 60° in the E-plane and 120° in the

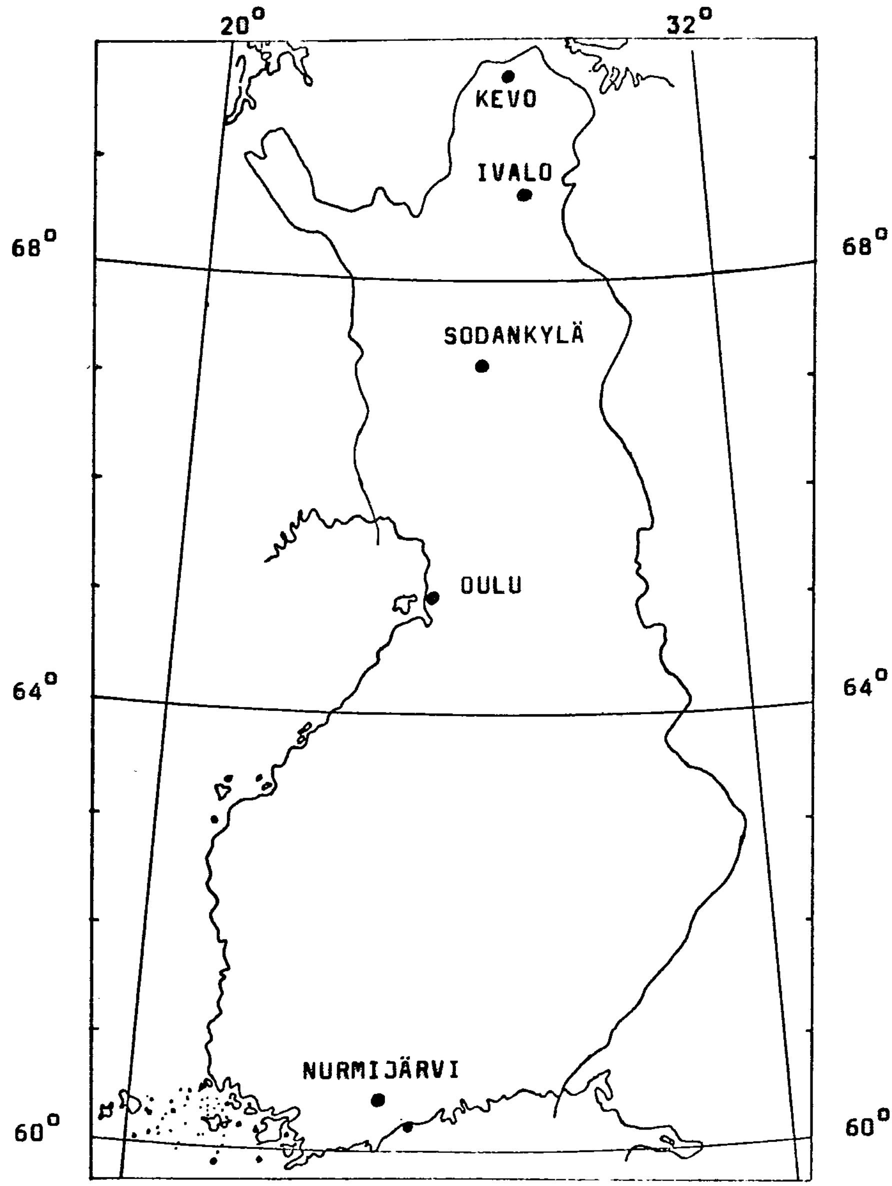

Figure 1. The location of Finnish riometer stations (Kevo, Ivalo, Sodankylä, Oulu, Nurmijärvi).

Table 1. The geographic coordinates of the riometer stations in Finland.

Kevo	69°45′ N	27°01′ E
Ivalo	68°36′ N	27°26′ E
Sodankylä	67°25′ N	26°24′ E
Oulu	65°06′ N	25°29′ E
Nurmijärvi	60°31′ N	24°39′ E

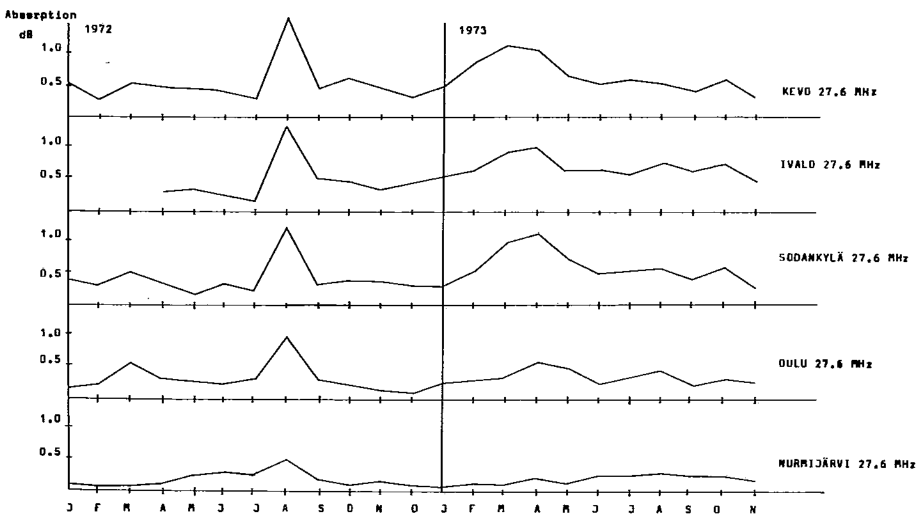

Figure 2. Medians of monthly absorption for the stations Kevo, Ivalo, Sodankylä, Oulu and Nurmijärvi in the years 1972–1973.

H-plane. The absorption has been computed for the first minute of each hour from the formula

$$A = 10\log_{10}\frac{P_0}{P}$$

where P is the received cosmic noise power and P_0 the cosmic noise under quiet conditions at the same sidereal time. The quiet day level has been determined separately for every month from a sidereal time-cosmic noise plot. In figure 2 the medians of the monthly absorption are shown in the years 1972–1973 for every station. In August 1972 there was very strong PCA event which was seen in every station.

2. *Latitudinal variation of ionospheric absorption*

The latitudinal variation of ionospheric absorption of radio waves has been studied by several scientists: in Norway by HOLT [11], in Alaska by BASLER [1] and HOOK [12], in Canada by HARZ [9] and in the U.S.S.R. by DRIATSKIY [3–6]. BERKEY [2] has compared those results and concluded that there is a great similarity between the results. The location of the riometer stations is shown in figure 3.

BASLER studied riometer data from five Alaskan stations between 56° N and 70° N geom. lat. in the years 1957–63. He calculated the absorption for the first minute of every quarter of an hour.

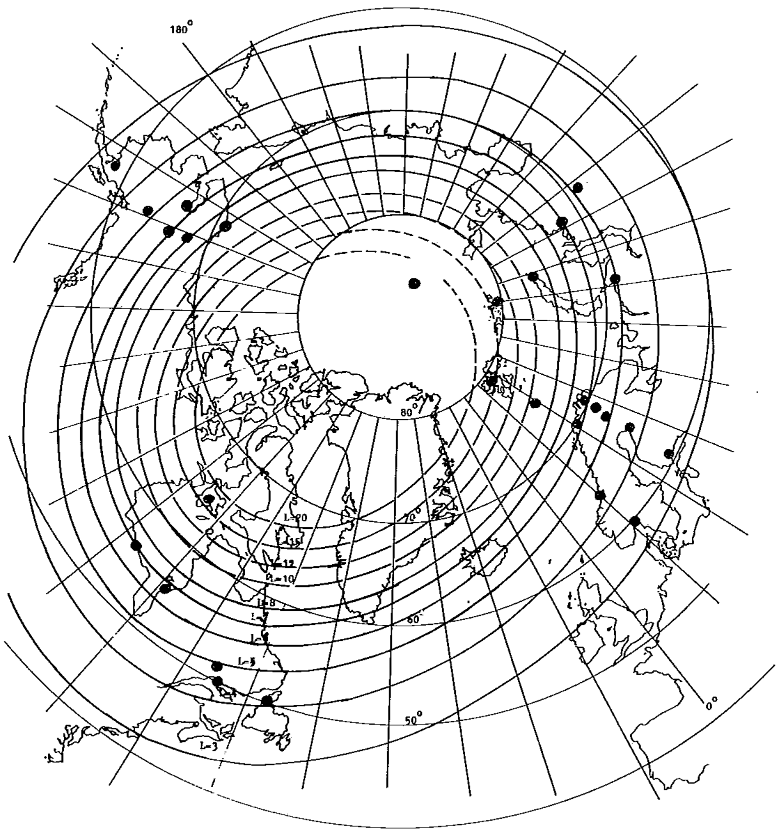

Figure 3. Location of riometer stations named in the article in Norway, in Finland, in U.S.S.R., in Alaska and in Canada.

HOLT examined riometer data from five Norwegian stations between 57° N and 75° N in the years 1958–59. He calculated the fraction of the total observation time that the absorption fell within the intervals 0.5 – 1.0, 1.0 – 2.0 and > 2 dB.

Riometer data from six Canadian stations located between 58° N and 84° N were analyzed by HARZ in the years 1959–61. He calculated the occurrence

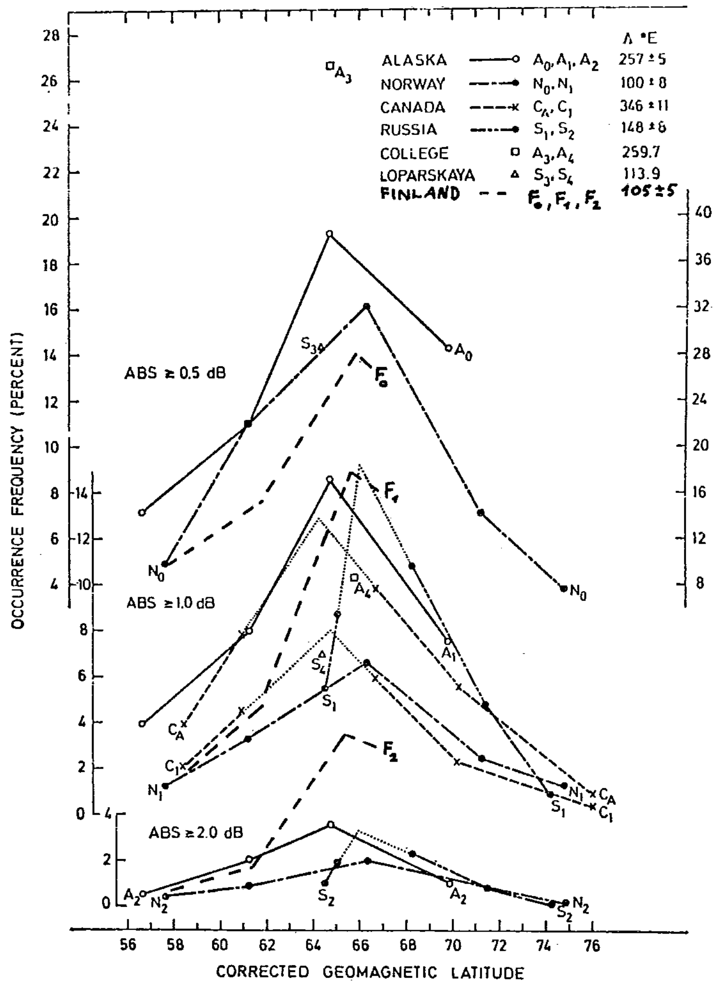

Figure 4. Latitudinal profiles of riometer absorption at several longitudes expressed in percentage occurrence as a function of corrected geomagn. latitude. Note that the occurrence of curves A_0 and F_0 are to be determined from the righthand axis. [2]

frequency of absorption ⩾ 1.0 dB and also determined the ratio of the number of 1/2-hr periods during which the absorption was ⩾ 1.0 dB for at least 2 min to the total number of 1/2-hr periods.

DRIATSKIY studied the riometer data from six riometer stations in the U.S.S.R., located between 64° N and 84° N, in the years 1963–64. He calculated the absorption for the first minute of each hour.

Also HARGREAVES and COWLEY [7] and HOOK [12] have studied the variation of absorption at different latitudes in Norway, Canada and the U.S.S.R.

The Finnish riometer stations are located between 57° N and 67° N corr. geom. latitude. The absorption has been calculated in the same way as the absorption in riometer data of the U.S.S.R. The results from the Finnish riometers have been added in figure 4 taken from the article by Berkey. In figure 4 latitudinal profiles of riometer absorption have been shown expressed in percentage occurrence as a function of corrected geomagnetic latitudes. The results have been collected in table 2.

Table 2. Latitudes of maximum riometer absorption.

	geom. lat.	geom. long.	obs. years	>0.5 dB value of max.	>0.5 dB lat. abs.	>1.0 dB value of max.	>1.0 dB lat. abs.	>2.0 dB value of max.	>2.0 dB lat. abs.
Norway	57–75°N	100 ∓ 8	1958–59	16 %	67°N	7 %	67°N	2 %	67°N
Finland	57–67°N	105 ∓ 5	1972–73	27 %	66°N	15 %	66°N	7 %	66°N
U.S.S.R.	64–84°N	148 ∓ 8	1963–64			15 %	66°N	3 %	66°N
Alaska	56–70°N	257 ∓ 5	1957–63	36 %	65°N	15 %	65°N	5 %	65°N
Canada	58–84°N	346 ∓ 11	1959–61			13 %	64°N		
						8 %	64°N		

It seems that the place of maximum absorption is moving regularly with geomagnetic longitude, the maximum absorption being located at the latitude 67° N in Norway and 64° N in Canada. The occurrence frequencies of different absorption values are not similar, probably because of different methods of handling riometer data. Small differences are caused by the fact that in some countries very strong PCA events are excluded so that the calculated absorption values are mainly auroral absorption values and moreover the results are from different years. But one can say that at the latitudes 63° – 68° N the absorption events > 0.5 dB are usually occurring 20 – 40 %, the absorption events > 1.0 dB about 10 – 20 % and the absorption events > 2.0 dB 10 % of the total observation time. At the latitudes 56°–63° N and 68°–75° N the occurrence frequencies are almost the same:

occurrence frequency of absorption events > 0.5 dB 10–20 %, absorption events >1.0 dB 5–10 % and absorption events > 2.0 dB 1–5 %. At the latitudes <56° N and >75° N there are very few absorption events.

3. *Diurnal variation of absorption at different latitudes*

The diurnal variation of riometer absorption in Norway in the years 1958–59 has been studied by HOLT [1]. He had found that at Longyearbyen (78° N, 16° E geographic coord.) an absorption maximum occurred in the evening during the winter and equinoxes, at Björnöyä (74° N, 19° E) no diurnal variation was noted, at Skibotn (69° N, 21° E) a maximum absorption was found in all seasons about 0600 LT and a secondary maximum occured during the evening, at Trondheim no clear diurnal variation was observed and at Kjeller (60° N, 11° E) a maximum was noted near noon during the winter and equinoxes.

HULTQVIST [13] has reported absorption results from Kiruna (67° N, 20° E geographic coord.) in Sweden. According to his studies the absorption has two maxima, one maximum at about 6–7 LT and a secondary maximum late in the evening.

At the riometer stations in the U.S.S.R. (between geom. lat. 64° N and 80° N) the main absorption maximum is, according to DRIATSKIY [4], in the forenoon hours local geomagnetic time (10 – 11 h) which is manifest at all zonal stations. This maximum weakens gradually toward the north and finally disappears at the North Pole 10 (78° N – 81° N). It reaches its maximum values on Dixon Island (68° N). A secondary maximum is observed near midnight (00 – 01 h). It appears at all latitudes and is shifted to late evening hours towards the north. A noteworthy feature of the diurnal absorption pattern is the fact that a well-defined minimum is observed in the evening hours at all latitudes. It moves somewhat depending on the season and the latitude but is observed at about 19 h, on the average, over the year.

BASLER [1] and HOOK [12] have examined the diurnal variation of absorption in Alaska. According to the results by Basler of absorption at College (65° N, 212° E geographic coord.) during the winter and the equinoxes, there is a pronounced daily variation with a rather broad minimum between 1900 and 2200 local time. During the summer there is a striking absence of any daily variation. HOOK examined the diurnal variation of absorption at different stations between 62° N and 72° N in Alaska in the years of sunspot maximum and minimum, 1958 and 1964, respectively. During the winter and equinoctial periods a minimum of absorption is observed between 2 and 4 hours before local midnight and a broad

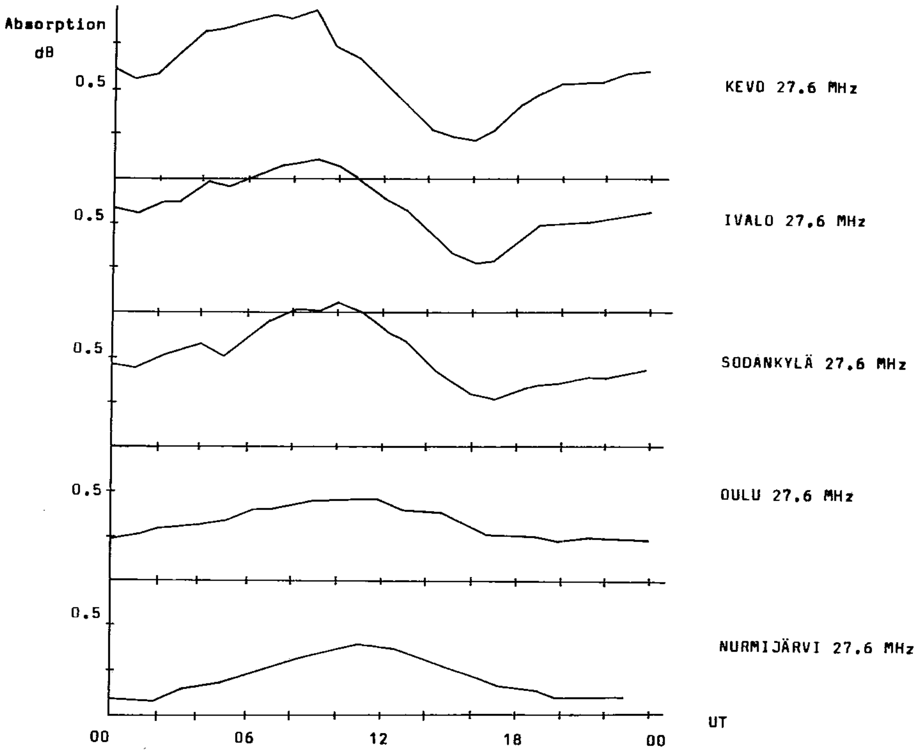

Figure 5. Diurnal variation of absorption in different stations throughout the year for the first minute of each hour in the years 1972–1973.

maximum is usually seen centered 2 hours before local noon. During the summer the daily variation in absorption is generally not significant.

HARZ [10] examined the diurnal variation of absorption in Canada (58° N – 84° N geom. coord.). In each case there is a dominant maximum at about 0800 hours geomagnetic time, a secondary maximum just before midnight and a pronounced minimum at about 1900 hours.

Absorption values of the Finnish riometer stations have been analyzed using the UT time scale. Diurnal variation of absorption at different stations, figure 5, have first been analyzed using absorption values in dB for the first minute of each hour. Throughout the year the absorption has maxima in Kevo at 07–09 UT and 22–00 UT, in Ivalo at 8–10 UT and 22–00 UT, in Sodankylä at 9–11 UT and 22–00 UT, in Oulu at 10–12 UT and in Nurmijärvi at 10–13 UT. The diurnal variation of absorption in Kevo, Ivalo and Sodankylä differs from that of Oulu and Nurmijärvi. In Oulu and Nurmijärvi there is only a maximum by day and no maximum by night. A clear minimum is observed in Kevo at 15–16 UT, in Ivalo at 16–17 UT and in Sodankylä at 17 UT. In Oulu and Nurmijärvi there is very little absorption in the evening and by night. The absorption has been calculated also in different seasons, figures 6–9. The diurnal variations of absorption at different stations are approximately similar in all seasons: two maxima in Kevo, Ivalo and Sodankylä and one maximum in Oulu and Nurmijärvi. Some differences can be seen: the strongest absorption occurs at equinoxes. In winter the absorption is slightly stronger than in summer in Kevo, Ivalo and Sodankylä, but in Oulu and Nurmijärvi the absorption is stronger in summer. The absorption values for the first minute of each hour have also been analyzed by calculating how great a percentage of the absorption events throughout the year is between 0.5–1.0 dB, 1–2 dB and > 2 dB, figures 10–12. The absorption values of 0.5–1.0 dB have almost the same kind of diurnal variation as the total absorption values. In Kevo, Ivalo and Sodankylä there are two maxima and one clear minimum, but in Kevo the night and day maxima are almost merging. Oulu and Nurmijärvi have only one maximum by day. The diurnal variation of absorption values of 1–2 dB and > 2 dB has two maxima and one minimum in Kevo, Ivalo and Sodankylä, but in Oulu there is no clear diurnal variation, and these absorption values are not seen in Nurmijärvi.

4. *Discussion*

According to the latitudinal profiles of the diurnal variation in riometer absorption from the results in Norway, Finland, the U.S.S.R. and Canada, given before, one can say that the diurnal variations are very much similar in all those results: The diurnal variation has two maxima and one clear minimum between geomagnetic latitudes ~ 77° N and ~62° N. The greatest value of the daytime maximum is at the latitude 67° N in Norway, 66° N in Finland, 67° N in the U.S.S.R. and 66° N in Canada. At those latitudes the maximum occurs at 8 GT (local geomagnetic time) in Norway, 11 GT in Finland, 11 GT in the U.S.S.R. and 8 GT in Canada. The day maximum decreases when one goes north or south. According to the results in the U.S.S.R. the day maximum is no more seen at the latitude >77° N. The day maximum is seen later in the day when one goes south. The maximum in the night is seen at 00–02 GT according to all results and its greatest value appears at the same latitudes as the greatest value of the day maximum. No night maximum exists at the latitudes <65° N in Norway, <62° N in Finland, <60° N in the U.S.S.R. and <65° N in Canada. A clear minimum in

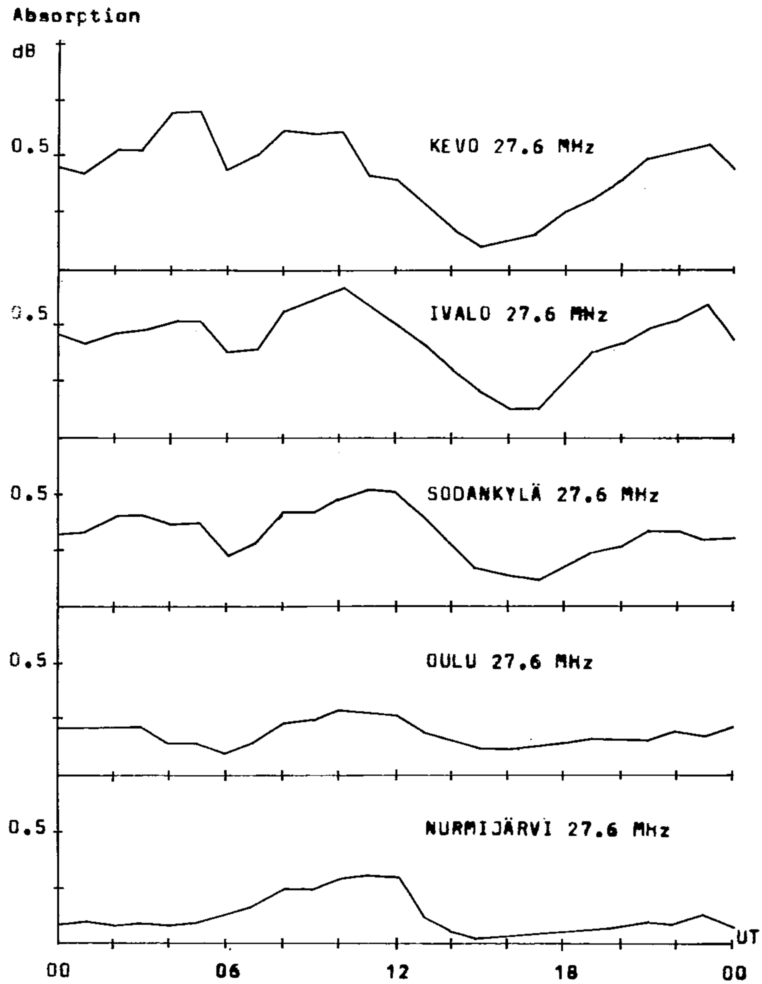

Figure 6. Diurnal variation of absorption in the winter (Nov.-Jan.) in the years 1972–1973.

absorption can be seen at 18–19 GT in Norway, 20 GT in Finland, 19–20 GT in Canada. Using the results of the U.S.S.R. and Finland one can schematically represent the latitudinal variation of diurnal variation of riometer absorption at those longitudes in the manner shown in figure 13.

The diurnal variation of riometer absorption is also changing with longitude as RAPOPORT [17] and DRIATSKIY [6] have shown. In this study the longitudinal variation has not been examined. But by comparing the results of this study with

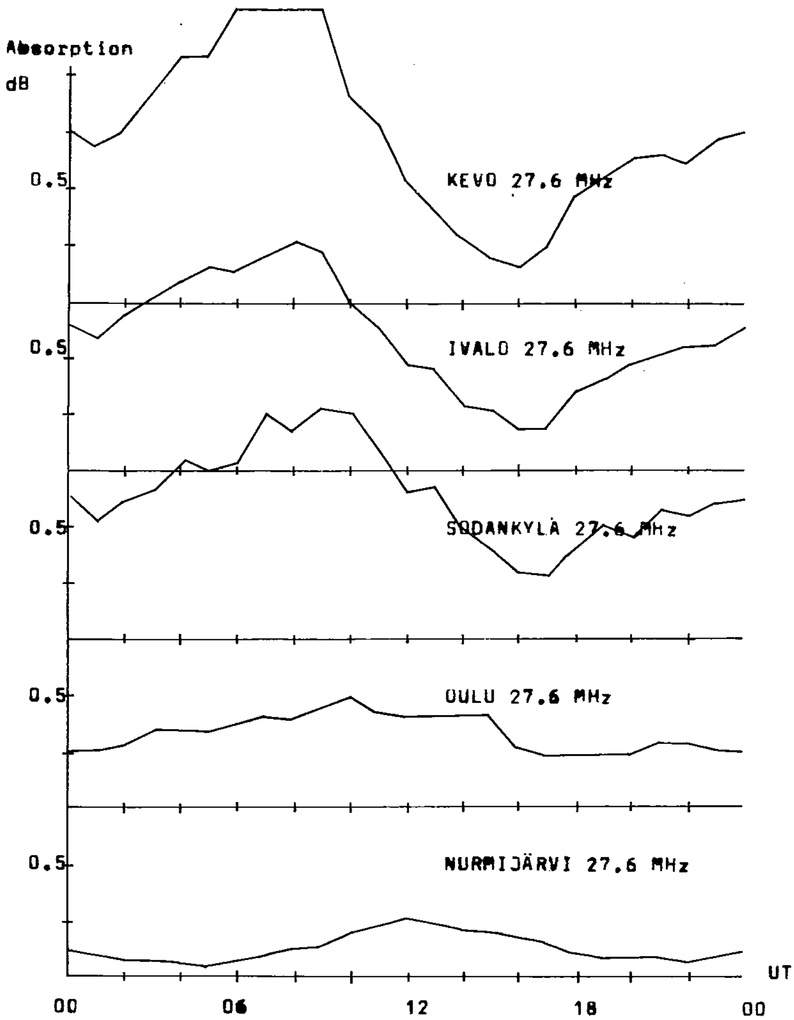

Figure 7. Diurnal variation of absorption in the spring (Febr.-April) in the years 1972–1973.

those of Rapoport and Driatskiy it can be stated that the diurnal variation of absorption differs at different longitudes in time of occurrence and duration of the maxima and the minimum. The diurnal variation of riometer absorption at different latitudes shown in figure 13 is seen at 100–150° E geomagnetic longitude. The absorption results of the diurnal variation in Alaska are different from these results. In Alaskan sector there exists only one maximum in the daytime at

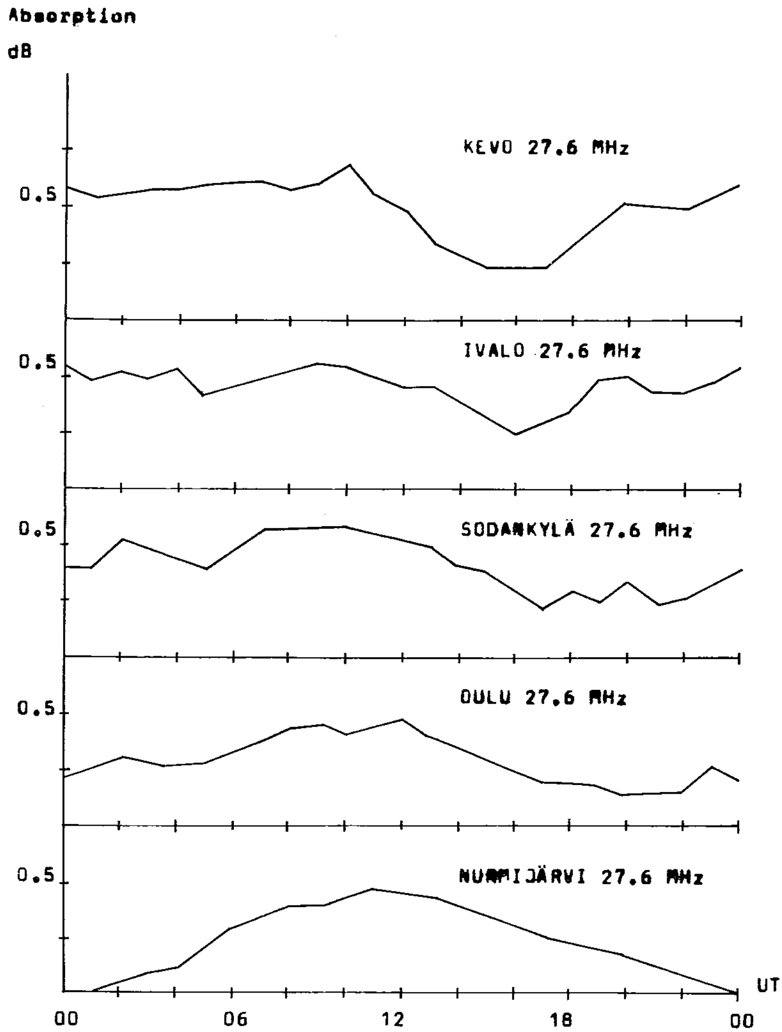

Figure 8. Diurnal variation of absorption in the summer (May-July) in the years 1972–1973.

all latitudes. This also proves that the riometer absorption is greatly dependent on longitude.

In the absorption values of Finnish riometer data all kinds of absorption events are lumped together. In some results of other countries PCA events are excluded though they have only a small influence on the mean diurnal variation of absorption. It seems that at geomagnetic latitudes $> 62^\circ$ N the absorption is mainly

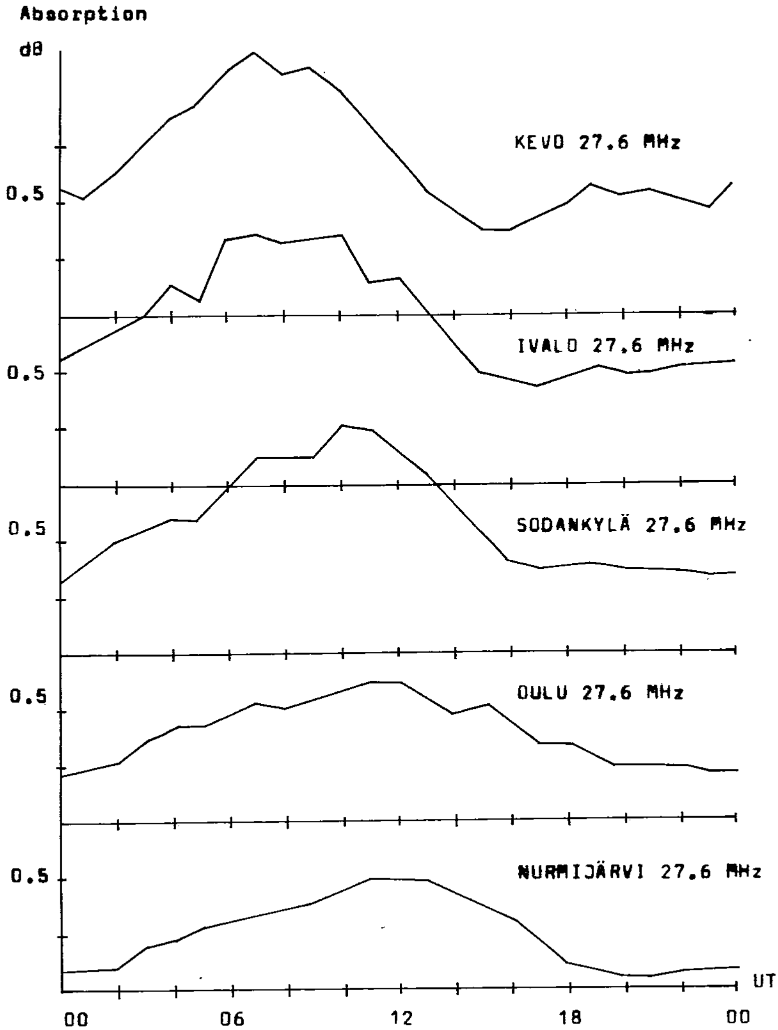

Figure 9. Diurnal variation of absorption in the autumn (August-Oct.) in the years 1972–1973.

caused by particles which are precipitating near midnight sector from the tail of the magnetosphere [3, 12, 16]. The precipitation may occur anywhere between early evening and late morning, but the maximum occurrence is near midnight. The maximum precipitation occurs according to these results at geomagnetic latitudes 65° N – 67° N. Some results show that the latitude where precipitation occurs depends also on magnetic activity: when the level of magnetic activity

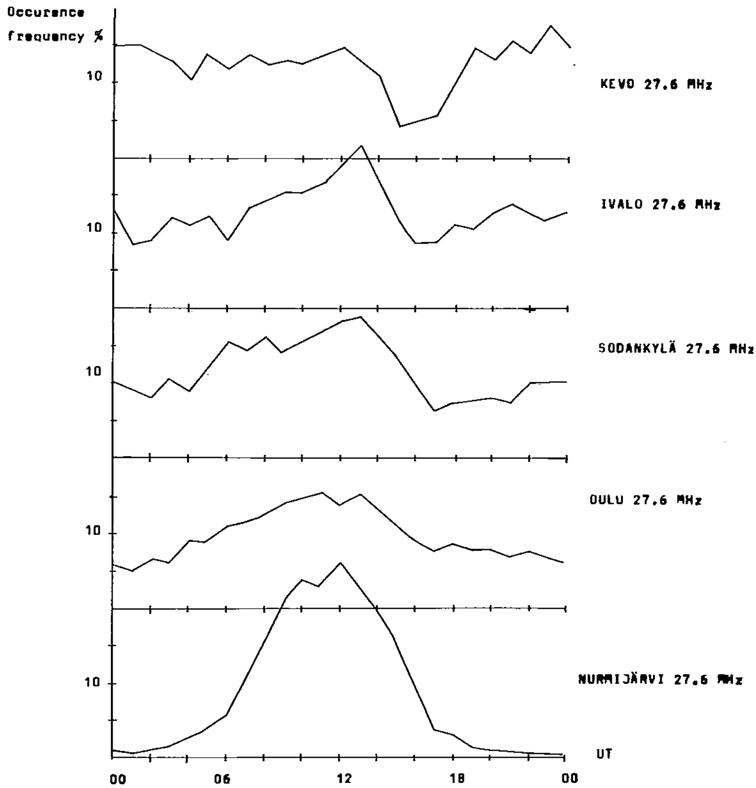

Figure 10. Diurnal variation of absorption events between 0.5 dB–1.0 dB in the years 1972–1973.

increases, the latitude of onset moves towards the equator. The night maximum which is seen at geom. lat. $> 62^\circ$ N is caused by electrons whose energies are 40–300 keV and sometimes even 1 MeV. These electrons are drifting east at a nearly constant L-shell and causing a day maximum of absorption. These electrons are different from those which cause the visible aurora and those energies are 1–10 keV. At the latitudes $> 77^\circ$ N no day maximum is seen any more, because the electrons are no more drifting to the dayside. Solar radiation is ionizing the D-region and causes the riometer absorption by day. At the latitudes $< 62^\circ$ N the riometer absorption is mainly caused by ionization of the D-region by solar

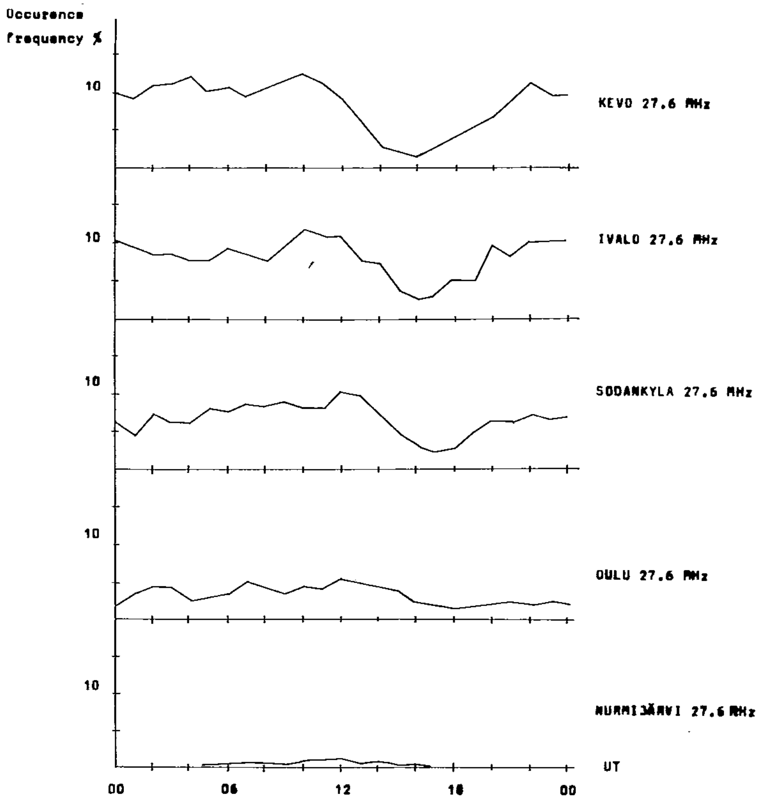

Figure 11. Diurnal variation of absorption events between 1.0 dB–2.0 dB in the years 1972–1973.

radiation. The absorption at geom. lat. ~ 58° N (Nurmijärvi) is usually < 0.5 dB. Also the seasonal variation of absorption in Nurmijärvi and in Oulu indicates that the main part of absorption there is caused by solar radiation: the greatest absorption is observed in the summer and very little absorption in the winter. The absorption depends on the solar zenith angle in Nurmijärvi and Oulu. The absorption caused by solar radiation has some influence on the diurnal variation of absorption also at geom. lat. > 62° N: in the summer the diurnal variation is not

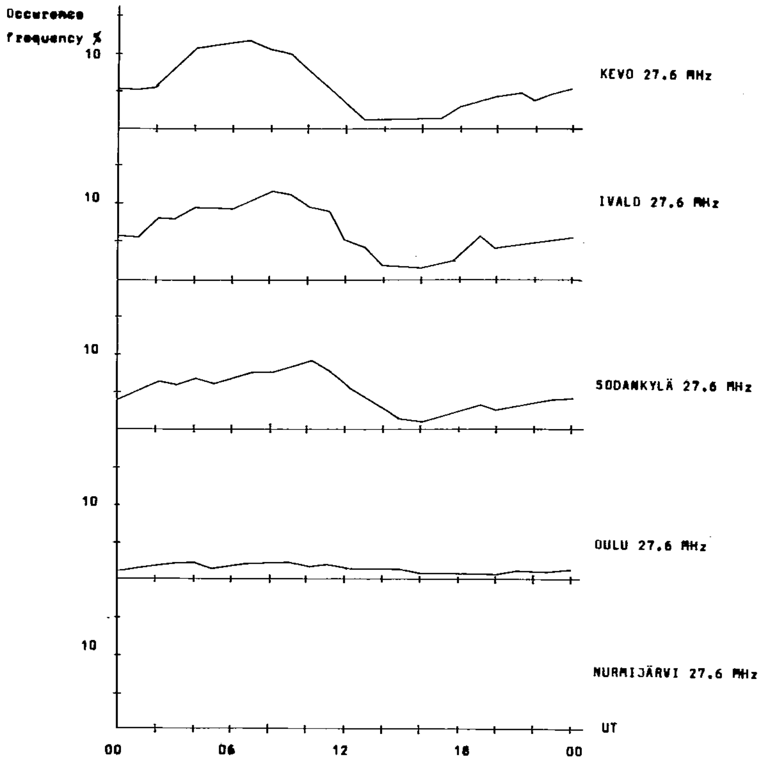

Figure 12. Diurnal variation of absorption events $\geqslant 2$ dB in the years 1972–1973.

as clear as in the winter and during the equinozes and this can depend on absorption caused by solar radiation. The riometer absorption caused by solar radiation decreases when latitude increases. The absorption caused by solar radiation perhaps makes the day maximum occur a little later in the day when one goes towards the equator. Differences in the occurence time of the day-maximum between Finnish riometer stations Kevo and Ivalo is about one hour in the winter and equinoxes, but in the summer the day maxima are almost coinciding.

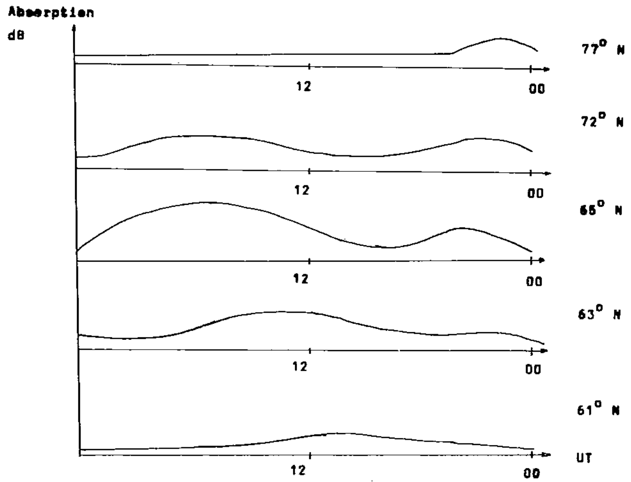

Figure 13. The diurnal variation of absorption at the longitudes 100–150°E and at different geomagnetic latitudes schematically.

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