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Auroral-Zone Absorption Effects on an HF Arctic Propagation Path

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Simultaneous measurements of cosmic noise absorption and signal strength on the 18 Mc/s Thule, Greenland-College, Alaska propagation path were made during aurorally disturbed periods. An intense and an average strength auroral-zone absorption (AZA) event were studied in detail and compared with signal attenuation and absorption for a quiet day. This analysis revealed that there is no significant peak-to-peak correlation between signal attenuation and cosmic-noise absorption for the typical AZA event. A statistical analysis gave the following correlations:

Auroral-zone absorption versus 18 Mc/s signal attenuation, $R=0.21$.
Quiet-day absorption versus 18 Mc/s signal attenuation, $R=0.11$.

Observations from a vertical ionosonde located near the midpoint of the Thule-College path (Resolute Bay, Canada) indicated that insufficient ionization exists to allow a great-circle propagated mode on a typical quiet day.

1. Introduction

It is the purpose of this paper to relate simultaneous measurements of cosmic noise absorption at 27.6 Mc/s and attenuation of an 18 Mc/s trans-auroral zone signal during periods of aurorally associated absorption. The Thule-College path was selected for study because the signal passes through the auroral zone only once. Figure 1 shows the Thule-College path and the auroral zone after Vestine [1944] along with other HF propagation paths investigated by the Geophysical Institute.

Strong auroral-zone absorption (AZA) events have a profound effect on the attenuation of HF signals. Gartlein and Sprague [1962] found that when a radio propagation path passed within 2° latitude of the southern edge of an aurora, the signal deteriorated; when the aurora "touched" the path, HF transmission was impossible. The authors used magnetic K-indices to indicate auroral presence and the CRPL radio propagation "quality figure" as a measure of the signal attenuation.

Another investigation by Hill [1963] utilized an idealized network of HF circuits covering polar and middle latitudes to evaluate HF communication during ionospheric storms. Observed values of foE_s, $foF2$ and f_{min} from vertical ionosondes, and reception of WWV 10 and 20 Mc/s transmissions were used to determine optimum operating frequencies. It was concluded that communication between polar and midlatitude stations should have been possible most of the time with proper frequency and link switching, even during PCA and AZA events. Hill's conclusions were based on data from a network of vertical incidence sounders, and were verified by recording quality figures for WWV transmissions.

The following analysis is based on reception of 18 Mc/s pulse signals from the Thule, Greenland, IGY fixed-frequency backscatter sounder operating with a power output of 4.0 kw peak [Peterson, Egan, and Pratt, 1959]. The Thule-College great-circle distance is 2900 km. Figure 2 shows the normal great circle one- and two-hop F-layer modes (assuming a 300 km height of reflection) along with the location of the normal auroral absorption region as reported by Basler [1963]. The vertical radiation pattern of the 3-element Yagi antenna ($h=0.6\lambda$) used for receiving the Thule transmissions is indicated by the letters on the degree circle. P denotes the angle of maximum radiation and $P/2$ the half-power points of the main lobe. The vertical radiation angle for a one-hop mode is 5°, for a two-hop mode is 18.5°. and for a three-hop mode is 30°. The one-hop mode is quite improbable because of the null in the vertical radiation pattern and the most probable F-layer modes are two- and three-hop modes or a combination of E- and F-layer modes. Only the one- and two-hop modes are shown in figure 2 for the sake of clarity.

Absorption data for this path were obtained with a riometer operating on 27.6 Mc/s using a 3-element Yagi antenna $\lambda/2$ above ground with the main antenna lobe directed along the Thule-College great-circle propagation path.

2. Strong AZA Event

Simultaneous cosmic-noise absorption measured at oblique incidence along the signal transmission

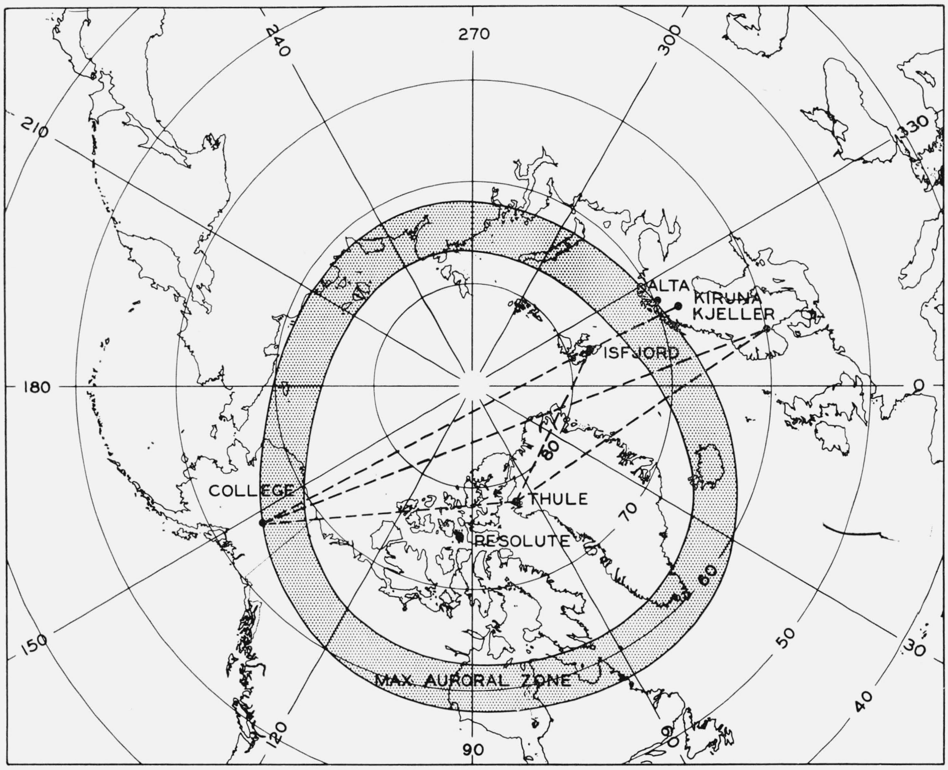

FIGURE 1. *Map showing great-circle propagation paths and the normal visual auroral zone (after Vestine).*

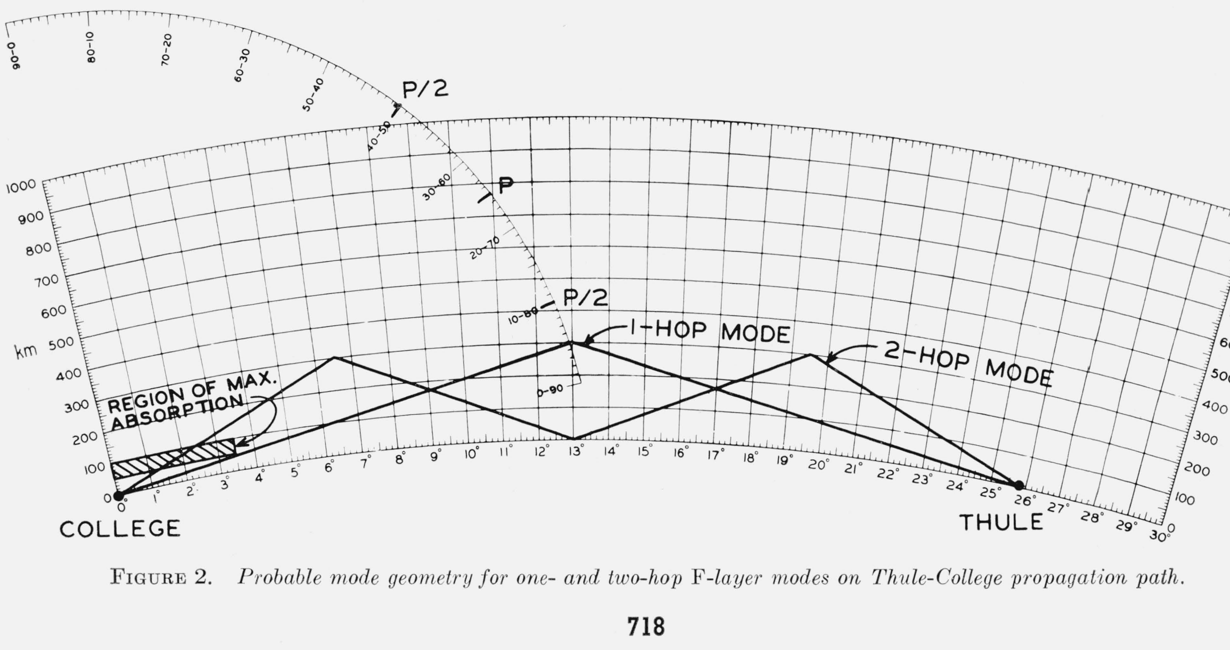

FIGURE 2. *Probable mode geometry for one- and two-hop* F-*layer modes on Thule-College propagation path.*

path and signal attenuation data were available for the Thule-College 18 Mc/s propagation path during an extremely strong auroral zone absorption event on 11 September 1961 shown in figure 3. Continuous data were available except during the periods 0330–0630, 0645–0730, and 0830–1100 UT, when strong interference made identification of the Thule pulse signal doubtful. A complete blackout of the 18 Mc/s signal occurred between 1140–2400 and lasted until the absorption level returned to approximately 1.5 db at 0730 12 September. This was the strongest auroral absorption event recorded during this investigation and should not be regarded as a typical event. It was the only auroral absorption event studied which produced an appreciable 18 Mc/s blackout on the Thule-College path. Note that there is no strong peak-to-peak correlation between oblique absorption and 18 Mc/s signal attenuation.

2.1. Typical Auroral Event

A typical auroral-zone absorption event is shown in figure 4 with a maximum absorption amplitude of 3.8 db.

Examination of these curves does not indicate peak-to-peak correlation between the oblique absorption and the 18 Mc/s signal attenuation.

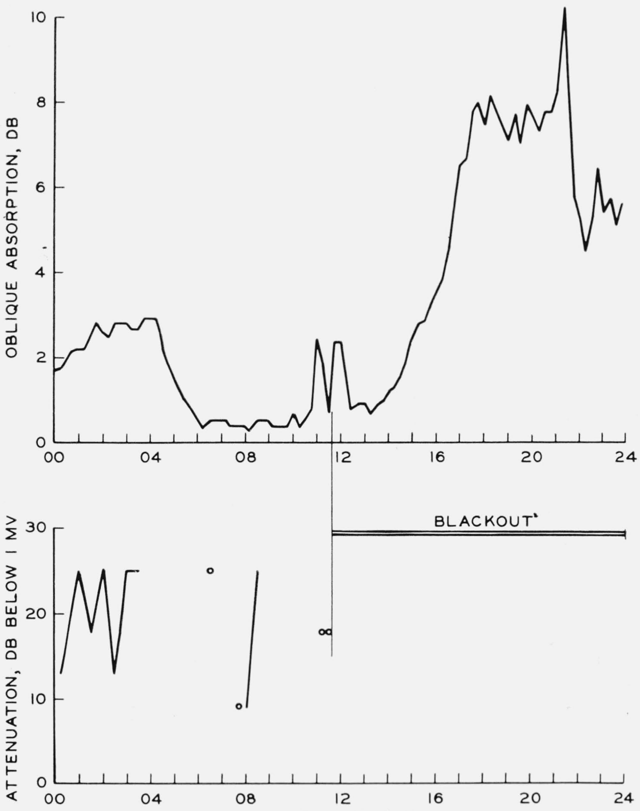

FIGURE 3. *Effects of strong auroral-zone absorption (AZA) event on 18 Mc/s Thule-College circuit.*

3. Absorption Versus Attentuation for a Quiet Day

It is instructive to compare a plot of absorption versus attenuation on the 18 Mc/s Thule-College path for the cases of undisturbed ionospheric conditions with aurorally disturbed conditions. Planetary *K*-indices, College *K*-indices, and vertical ionosonde data from College and Resolute Bay were utilized to select a typical quiet day (8 June 1962). The plot of oblique attenuation versus Thule-College 18 Mc/s signal attenuation (fig. 5) shows that there is no consistent peak-to-peak correlation.

The heavy bar below the Thule signal strength curve denotes periods when the MUF (3000)*F*2 value obtained from Resolute Bay ionosonde data was less than the Thule operating frequency (18 Mc/s). This illustrates that propagation conditions deduced by vertical ionosonde data are not necessarily valid for many polar HF propagation paths.

Correlation coefficients between instantaneous values of cosmic noise absorption and 18 Mc/s signal strength recorded every 15 min were computed for both disturbed and quiet-day conditions and are presented in table 1.

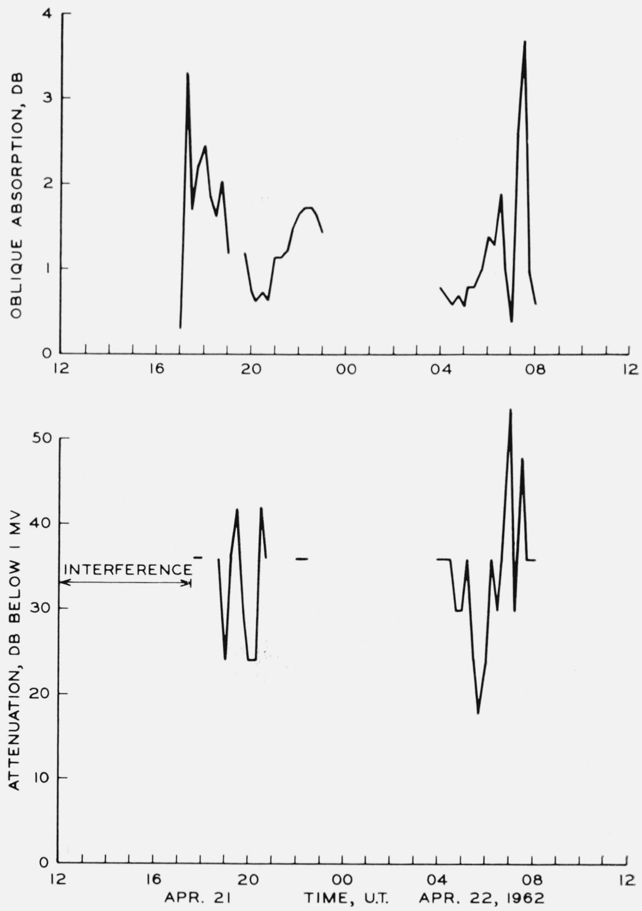

FIGURE 4. *Typical auroral-zone absorption (AZA) event effects on 18 Mc/s Thule-College circuit.*

Breaks in the curves indicate periods when data were not available because of equipmental malfunctions.

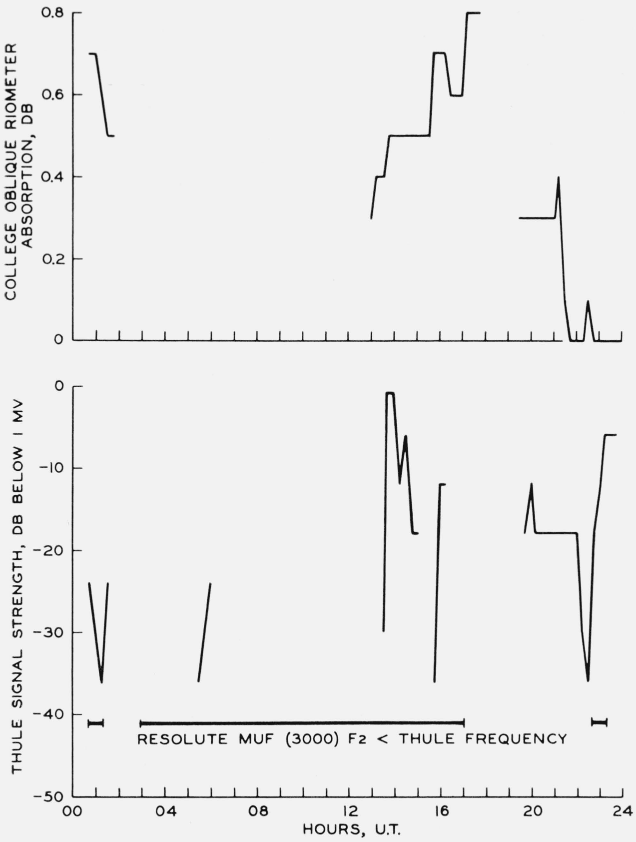

FIGURE 5. *Oblique absorption at College versus Thule 18 Mc/s signal attenuation for a quiet day (8 June 1962).*

The breaks in the curve denote periods when riometer or pulse reception data were not available.

TABLE 1

Absorption type	Correlation coefficient	No. of data pairs
Quiet day	R=0.11	156
Auroral zone	R= .21	116

4. Discussion

These results indicate that there is no significant correlation between 18 Mc/s signal attenuation and aurorally associated absorption measured with the 27.6 Mc/s oblique riometer on the Thule-College propagation path. An exception to this rule was the unusually strong auroral event of 11 September 1961, when oblique absorption values exceeding 10 db at 27.6 Mc/s were observed. It was also observed that the Resolute Bay ionosonde located near the midpoint of one-hop of a two-hop mode usually indicated that the MUF (3000)$F2<18$ Mc/s.

From the preceding results we can tentatively conclude that during aurorally associated absorption events, Thule-College 18 Mc/s propagation is not a conventional two-hop great-circle mode.

We must then consider what other modes might be feasible for the conditions observed. A normal one-hop mode is possible for this distance but is highly improbable since the vertical radiation patterns of the Yagi antennas are extremely insensitive below 10°. (The vertical angle required for a one-hop mode is 5°.) Tilted-layer modes are sometimes observed in the polar regions with the layer tilted upward toward the north. This mode is quite improbable for the Thule-College path, however, since layer tilts are only observed for a few hours per day; and the geometry is not favorable for a low angle ray passing under the auroral absorbing region at the College end of the circuit. A high angle Pedersen ray could exist for this path but it would pass through the absorbing region and thus should be correlated with auroral absorption. Another possibility is a laterally deviated mode (nongreat circle) which would bypass the region where the riometer measures the absorption. Two items of evidence supporting this mode are the lack of correlation between absorption and signal attenuation, and the observations from the Resolute Bay ionosonde indicating that insufficient ionization exists to allow a great-circle propagated mode. Additional evidence for the existence of such a mode was presented by Owren [1963] for the 18 Mc/s transpolar propagation path between College and Kiruna, Sweden.

Very strong evidence of multipath propagation associated with the auroral zone was presented by Egan and Peterson [1960]. The 12 and 18 Mc/s pulse signals from Thule and College monitored at Stanford revealed very strong multipath effects with time delays up to 12 msec between the direct mode and the "sidescatter" modes.

Analysis of a synchronized step-frequency circuit between Öya, Norway, and College, Alaska by Hunsucker [1964] gave further evidence that the actual frequencies propagated over a transauroral zone HF propagation path are generally much higher than the MUF's predicted from vertical ionosonde data.

5. Conclusions

Analysis of simultaneous 27.6 Mc/s cosmic-noise absorption and 18 Mc/s signal attenuation data on the Thule-College circuit has revealed that there is no significant peak-to-peak correlation between signal attenuation and absorption. An extremely strong event (10 db on the oblique riometer, produced a short blackout of the 18 Mc/s signal, but the typical AZA event usually causes only moderate signal deterioration on this circuit. A statistical analysis gave the following correlations:

Auroral-zone absorption versus 18 Mc/s signal attenuation, R=0.21.

Quiet-day absorption versus 18 Mc/s signal attenuation, R=0.11.

One possible explanation of the poor correlation between 18 Mc/s signal attenuation and 27.6 Mc/s absorption is that the Thule-College 18 Mc/s signal is propagated over a nongreat-circle path such as that reported by Ortner and Owren [1961]. Thus, the College oblique riometer and the Thule vertical riometer would not, in fact, observe the absorption which the 18 Mc/s signal encountered.

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