JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN Vol. 17, SUPPLEMENT A-I, 1962
INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part I

I-2-9. Polar Cap Absorption Events Identified from H.F. Vertical Ionosonde Data*

Doris H. JELLY

Defence Research Telecommunications Establishment, Ottawa, Canada

The phenomenon now known as polar cap radio wave absorption (PCA) has been identified in several ways—from riometer data, VHF scatter circuits and HF blackout data. In the present study, the deviations of minimum frequencies recorded by ionosondes from their monthly medians (Δf_{min}) are found to be a very sensitive means of detecting the polar cap absorption events. All those events which have been listed from riometer records are easily identified from plots of Δf_{min} for both Arctic and Antarctic ionosonde stations. Additional very weak absorption events are seen which have all the characteristics of the larger PCA events. The morphology of one of these weak events is described in detail.

Abnormal absorption of radio waves in the polar cap is one of the absorption phenomena currently under investigation at the Defence Research Telecommunications Establishment, Ottawa. This type of absorption now known as polar cap absorption (PCA) has been studied in considerable detail using several different methods: VHF scatter circuit data (Bailey), riometer data (Little and Leinbach; Reid and Leinbach), vertical incidence minimum frequency and blackout data (Hakura and Goh; Hill; Collins, Jelly and Matthews). From these various studies, the characteristics of the absorption events are now well known and several lists of the events have been drawn up using the different methods of identifying them. These lists show good agreement where the absorption is intense but tend to differ when the absorption level is low.

In the present work, f_{min} (the minimum frequency recorded by vertical incidence ionosondes) is examined in detail as a means of detecting low intensity absorption. Since data used in the analysis were from both the Arctic and the Antarctic, conclusions could be drawn about the coincidence of PCA in both polar regions. To support the use of minimum frequencies in analyzing PCA, Churchill data were compared with the corresponding riometer data and the two measurements will be shown to correlate very well. f_{min} was then used as a sensitive means of detecting low level PCA and an event will be described which was not detected by other methods. It can also be used to establish more accurately the starting times of events and their durations. It should be noted that this study was primarily concerned with the occurrence of PCA. Other types of absorption (auroral and S.I.D.) were excluded as much as possible.

The data used in this study were the f_{min}s recorded at hourly intervals by regular H.F. ionosondes. Because of the quantity of data available the IGY period was chosen and many of the data used were obtained from the IGY World Data Center at Boulder, Colorado. To emphasize the solar variation of the abnormal absorption, the regular diurnal absorption was eliminated from the f_{min} data by subtracting the monthly medians from each hourly value. The residuals, or Δf_{min}, were used in all the plots. First, all the events listed for the IGY were plotted for both Arctic and Antarctic. Several stations were used to insure that the effects being studied were not local in nature but were widespread over the polar caps. Hourly polar plots were constructed for two of the events.

Samples of these plots shown in the first two figures demonstrate the general configuration of PCA using the event of the 10th of April, 1958, as an example. This event is very suitable for illustrating the features of PCA because it was not contaminated by the magnetic storm and auroral absorption which usually are associated with events of

* This paper was read by C. O. Hines.

this nature.

Fig. 1, the polar plot for 1400 hrs, UT, April 10, shows the spatial extent of the absorption at that time. The maps are centred on the geographic poles. Geomagnetic poles are marked in white. In the Arctic, all stations within the darkest region reported blackout, i.e. complete absorption of H.F. radio waves. A narrow ring of positive Δf_{min} corresponding to absorption of less intensity extends down to about 65° geomagnetic

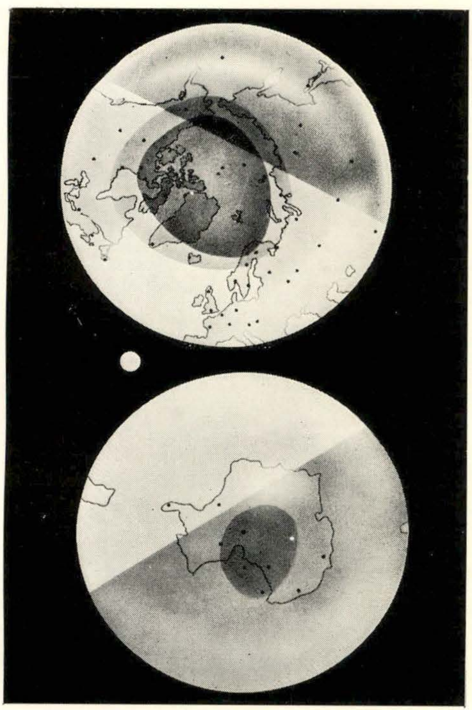

Fig. 1. Spatial extent of PCA of 10th April, 1958 at 1400 hours, U.T.

latitude. In the Antarctic, where there were fewer stations, the patterns are not as well defined. There was no blackout at this time but high Δf_{min} covered the polar cap. The position of the sun and ground sunrise-sunset lines are indicated. The north pole is seen to be sunlit and the south pole was in darkness. This difference in solar illumination no doubt explains the more intense absorption in the Arctic. When the hourly plots are studied in sequence, the absorption patterns are seen to rotate with the sun, the areas expanding and contracting with the increase and decay of the particle influx.

Fig. 2 shows the temporal variations of Δf_{min} for the same event. Stations used are Resolute Bay (74.7°N, 94.9°W), Churchill (58.8°N, 94.2°W), Winnipeg (49.9°N, 97.4°W), Godley Head (43.6°S, 172.8°E), Cape Hallett (72.3°S, 170.3°E) and Byrd (80.0°S, 120.0°W). Flat portions of the curve represent blackout.

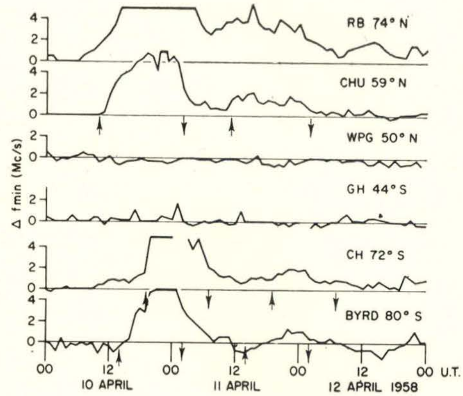

Fig. 2. PCA of 10th April, 1958. Stations—Resolute Bay, Churchill, Winnipeg, Godley Head, Cape Hallett, Byrd.

The plot is in Universal Time. Times of sunrise and sunset at an arbitrary altitude of 50 km are marked by arrows for three of the high latitude stations; at Resolute Bay the sun did not set at the 50 km level. The local time difference between the Arctic and the Antarctic stations can be seen in the shift of the solar variations. Of interest also are the apparent differences in the starting times of the event. At Resolute Bay, the first weak absorption appears at 0700 UT while at Churchill it does not start till 1000 UT, approximately the time of local sunrise at the 50 km level. From the hourly polar plots, the first definite increases in Δf_{min} appeared near the north geomagnetic pole at 0800 UT spreading southward on the sunlit hemisphere till 1100. First increases in the Antarctic appeared at 1000 hrs. A starting time of 1130 hrs. was quoted by Reid and Leinbach from riometer measurements at College and the flare which they associated with the event occurred at 1010 UT. From the time of onset seen using Δf_{min}, the particle-producing flare which caused the absorption must have occurred prior to 0800 hrs. Thus, we see that the wide distribution of the ionosonde stations makes it possible to determine the starting time of events more accurately than is possible with any one station and hence in some cases the flares associated may be more accurately established.

It is difficult to determine if small variations in the minimum frequencies reflected by the ionosphere represent real absorption changes. For this April, 1958 event, the Δf_{min}s from Churchill were compared with the absorption in decibels measured at 30 Mc/s by the riometer at the same station.

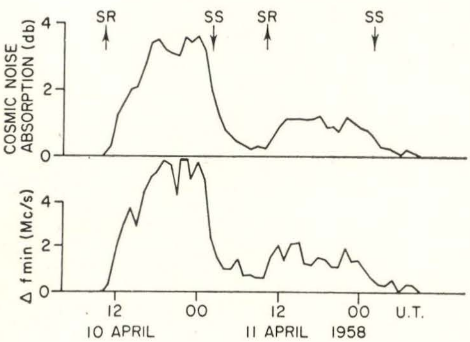

Fig. 3. Comparison of Δf_{min} and absorption at 30 Mc/s in decibels for PCA of 10th April, 1958.

From the curves plotted in Fig. 3, the correlation is seen to be very good (about .9) confirming that Δf_{min}s do represent real variations in absorption. When decibels are plotted against Δf_{min}, 1 Mc/s difference from the monthly median is found to be equivalent to about .6 decibels absorption on the 30 Mc/s riometer. Thus, Δf_{min} at Churchill can actually be used instead of absorption in decibels at 30 Mc/s to fill in gaps in riometer data. This factor applies only to the Churchill data since ionosonde equipment parameters vary from station to station.

Δf_{min}s were plotted in this way for all events listed during the IGY using several Arctic and Antarctic stations. The general pattern of each of these events was seen to be similar to the event of April 10. Even the smallest events were similar to this example and could be recognized by the same Δf_{min} pattern. Although absorption occurred in both polar regions for all the events, starting times, intensity and duration of the PCA were dependent on solar illumination, i.e. if the north pole were sunlit and the south pole in darkness, the absorption was observed earlier in the north, was more intense there and lasted longer. Thus we see the importance of considering both polar regions when establishing UT starting times.

For a quick approximation of the PCA pattern during the IGY period, noon Δf_{min}s were plotted for four polar stations—two Arctic and two Antarctic. The stations selected were at latitudes high enough to avoid contamination by auroral absorption. Fig. 4 is abstracted from a portion of the plot, the first six months of IGY. Blocks represent $\Delta f_{min} \geq 1$ Mc/s. Arrows indicate PCA identified by other methods. All these events appear unmistakably using this very simple method of detecting them. From this figure there appear long periods of absorption associated with overlapping events, e.g. June-July, 1957, abnormal absorption continued for 17 days. In addition to the absorption marked by arrows, there are similar periods where absorption appeared simultaneously at 2 or more stations, e.g. Aug. 10 and Nov. 5. If the Δf_{min}s during these periods followed the pattern of the other events, they might reasonably be considered to be PCA also.

By plotting Δf_{min}s of Nov. 5 (Fig. 5 and 6) in the same manner as the April, 1958 event, the absorption is seen to follow a similar pattern. Fig. 5 shows the spatial distribution of Δf_{min} at 1000 hours on 5 Nov. 1957. The Antarctic is now sunlit and the absorption there is correspondingly intense. The northern polar cap is seen to be covered by weak absorption, typical of night-

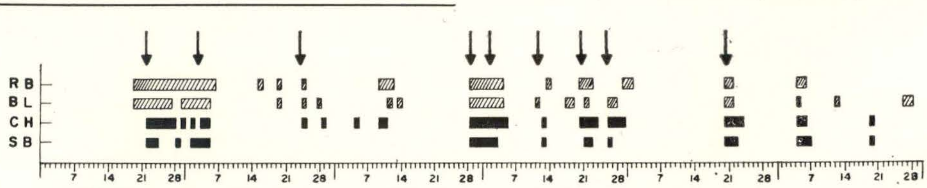

Fig. 4. Days when noon $\Delta f_{min} \geq 1.0$ Mc/s at Resolute Bay, Baker Lake, Cape Hallett and Scott Base.

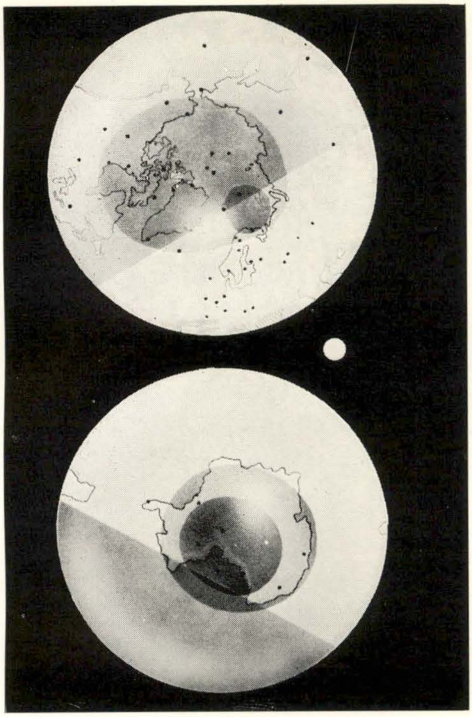

Fig. 5. Spatial extent of 5th Nov., 1957 at 1000 hours, UT.

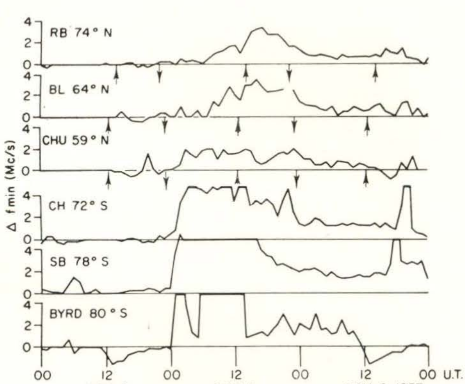

Fig. 6. PCA of 5th Nov., 1957. Stations—Resolute Bay, Baker Lake, Churchill, Cape Hallett, Scott Base, Byrd.

time conditions.

In Fig. 6, the temporal distribution of the same event is shown. Two of the stations used in Fig. 2 are replaced by Baker Lake (64.3°N, 96.0°W) and Scott Base (77.8°S, 166.8°E). For the Antarctic stations, there was no sunset at 50 km. altitude and the data do not show any diurnal variations. At the northern stations, there was some absorption before sunrise with increases at sunrise. The local noon decrease at Churchill can be explained by the increase in returned signal strengths due to the change from F layer reflections to E layer reflections. When the Churchill riometer records were examined carefully, about 1 db absorption was found present during the day.

The morphology of this event is seen to be simliar to the first event described if allowances are made for the change in the position of the earth relative to the sun. According to Obayashi and Hakura, the magnetic storm of 6 Nov. 1957 was not preceded by polar cap blackout but these f_{min} plots indicate there was PCA for about 40 hours before the SC at 1821 hrs. Using the plot of noon Δf_{min}s as a guide, several events of this nature were found to occur during the IGY period. From the plot, 80 days of abnormal absorption occurred at Resolute Bay. This means that during the IGY, about 1 day in 7 was affected by PCA, a much higher proportion than has hitherto been suggested.

In conclusion, we see that these ionosonde minimum frequency data have advantages over riometer data for selecting weak PCA events. Making use of the sensitivity of the data, and the wide geographic distribution of the stations, the PCA events have been shown to occur at the same time in the Arctic and the Antarctic. These data are also useful for determining onset times of PCA and durations of the events.

References

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Discussion

Nagata, T.: Is your result that f_{min} increase (or black-out) is much more intense in sunlit polar cap compared with that in dark polar cap a general behaviour even in magnetically quiet periods or a special characteristic only in magnetically disturbed period?

Hines, C. O.: It is quite a general behaviour, although I could not say whether or not it might be subject to some variation from quiet to disturbed conditions. The behaviour is certainly less clear during disturbed conditions—it is, then, more clear during quiet conditions in contrast to the behaviour that might be implied in the question.

Pigott, W. R.: The variation of f_{min} with absorption, as measured on frequencies near 300 Mc/s is dependent on the variation of sensitivity and noise level with frequency. Thus, experimentally, as the measured absorption increases, f_{min} at first remains constant and then increases linearly with frequency at most stations. The agreement between f_{min} and absorption measured on high frequencies should therefore be expected to be linear. The knee in the curve accounts for many apparent differences between stations when the absorption is small.

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I-2-10. Observations of Unusual Low Frequency Propagation Made During Polar Cap Disturbance (PCD) Events*

J. S. BELROSE and D. B. ROSS**

Defence Research Telecommunications Establishment, Ottawa, Canada

The Radio Physics Laboratory has undertaken a series of experiments for the purpose of studying the lower ionosphere at high latitudes by the propagation of long radio waves, in particular the effects caused by polar cap disturbance (PCD) events. Phase and amplitude recordings made during the series of intense solar eruptions of 10, 12, 15 and 20 November and 5 December, 1960, together with amplitude recordings made during previous PCD events, have established the following facts. When the PCD is weak, i.e. a weak event affecting propagation at high latitudes, or a strong event affecting propagation near the low latitude extent of the disturbance, the diurnal variation of field strength is opposite to that normally observed, and the diurnal variation of phase is less than normal. When the effect is intense the diurnal variations of both phase and amplitude disappear almost entirely. The phase measurements, in addition, suggest that the apparent reflection heights are 10–12 km less than a normal day, and the long waves are probably reflected from heights of about 50–55 km. The remarkable feature of a lack of any diurnal variation during an intense PCD suggests that the lower edge of the ionization produced is independent of normal ionospheric processes, such as attachment of free electrons to form negative ions during the night, and must be determined mainly by the characteristics of the bombarding particles, such as the steepness of the energy spectrum, and nocturnal ionization processes, such as collisional removal of electrons from negative ions.

The Transmission Paths

The experimental observations with which we are concerned are field strength, and in one case phase recordings of CW transmissions at frequencies about 80 kc/s propagated to distances about 2000 km. The various transmission paths monitored are shown in

* This paper was read by I. Paghis.