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DIURNAL MEASUREMENTS WITH PROTOTYPE CMOS OMEGA RECEIVERS

The Ohio University Prototype CMOS Omega Sensor Processor is capable of receiving all eight Omega channels on 10.2 KHz. Diurnal recordings of selected station pairs made during the period October-November 1976, demonstrate the receiver performance and illustrate limitations for navigation using diurnal corrections.

by

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INTRODUCTION

The Ohio University CMOS Omega Sensor Processors fabricated under NASA LRC Contract NAS1-14124, provide an analog LOP output for monitoring the receiver performance. Daily (24 hour) recordings of selected station pairs using a slow speed RUSTRAK chart recorder (1/4" hour) provide a means of checking the receiver operation as well as a ground station monitor for determining propagation effects on the Omega signals. The CMOS MAPLL sensor has an output bandwidth of 0.1 Hz.[1] This bandwidth was chosen originally such that the receiver would be able to track signals at 250 knot general aviation velocities with a relatively simple first-order tracking loop. This choice of output bandwidth is not optimum for ground station monitoring or for very low velocity users; however, reception of signals from all Omega stations at 10.2 KHz has been possible even in a noisy ground monitoring location.

GROUND MONITOR NOISE ENVIRONMENT

In nearly all cases, superior performance has been obtained in using the Ohio University CMOS receiver for airborne measurements when compared to ground station monitoring. The basic reason for this is that many urban ground monitoring locations are contaminated with locally generated 10.2 KHz signals which are harmonics of 60 Hz AC power line radiation. Airborne Omega receivers are usually not contaminated with this type of noise. The 170th harmonic of 60 Hz is exactly 10.2 KHz. The noise has relatively wide bandwidth appearing as if it were an intermittent carrier signal cycling through the 10.200 KHz center frequency at a several cycle-per-second rate. A receiver with an output tracking bandwidth of 0.1 Hz will tend to ignore this noise. However, very weak Omega signals will be obscured in ground system monitors, which might not otherwise be the case if 60 Hz harmonic radiation were not present. One way around this problem is, of course, to select ground station sites that are relatively free of local 60 Hz power line noise. Another way is to provide the receiver with a much narrower output tracking loop bandwidth of 0.02 Hz or so, which is common in marine type of Omega sensors. The later approach is not easily possible with the present CMOS receiver processor.

The preprocessing RF bandwidth of the Ohio University receiver was chosen as 4 Hz after airborne tests indicated this might provide somewhat better quality signals compared to a 30 Hz RF front-end bandwidth system.[2] Of interest here is the long term performance of this particular receiver system as a ground station monitor without any modification. A series of diurnal monitoring tests on all eight Omega channels at 10.2 KHz have been conducted with the following results.

C-D

Figure 1 is an example of the strong signal pair C-D (Hawaii minus North Dakota). Each recording has a vertical scale (ordinate) range of 0 to 100 centicycles (one cycle) and a time scale range (abscissa) of 24 hours at a 1/4"/hour chart speed. The diurnal change is quite predictable on a day-to-day basis with seasonal variations in the overall shape. The C-D pair is a baseline-extension situation for Ohio and the resulting lane is rather wide at about 27 miles making it less interesting for navigation purposes. However, the diurnal changes are consistent and could be used to provide corrected local navigation data in the absence of a better LOP pair geometry.

The 50% (50 CEC) point on some of the following recordings has a slight gap because of a 5% error in the MSB resistor used in the D/A converter driving the RUSTRAK recorder; however, the actual digital output signal produced by the CMOS MAPLL sensor processor is correct. The width of the trace here is a measure of the ground station S/N ratio on all of these recordings. The rising and falling change in the slope occur at times corresponding to sunrise-sunset transition for the observer and for both stations of the pair. Further illustration of the sunset-sunrise phenomena will be presented in a discussion of the B-C diurnal recordings.

The total excursion of the trace over a 24-hour period is a direct measure of the extent of the diurnal correction required. In general, a usable signal for navigation purposes will have a 24 hour change of one lane (a cycle) or less if it is predictable based on the published propagation correction tables for the stations used. A further criterion for a usable navigation signal based on observing these diurnal combinations is that the LOP should return to about the same relative position 24 hours later when measured at a fixed ground location.

D-F

Figure 2 is an illustration of the North-South pair combination of a strong station D, North Dakota minus a much weaker station F, Argentina. The power of the Argentina station had been increased to the full 10 kw radiated a few days prior to this observation. The total diurnal change over a 24 hour period is less than one lane and is quite stable during daylight hours. The D-F combination for Ohio gives an 8 mile lane making it a reasonable pair for North-South navigation purposes. The signal is somewhat obscured at nighttime in these ground station observations but would be better in airborne systems. The often quoted ± 2 nautical mile uncertainty in nighttime corrected observations can be seen in the more erratic excursions after 2000 hours compared to the more consistent daytime observations around local noon or 1200 hours.

Figure 3 is a set of recordings of the same D-F combination made about one month earlier when the Argentina station was radiating at a reduced power level of 5 to 7 kw. Assuming the noise levels are approximately the same for Figure 2 and Figure 3, then it appears that there is slight improvement in the signal quality of Figure 2 with the full 10 kw radiated from the Argentina station.

D-G

The upper part of Figure 4 is the combination D, North Dakota - G, Trinidad which provides a very stable navigation pair for both daytime and nighttime observations. Unfortunately this North-South combination will only be temporarily useful since the Trinidad station is due for shutdown by 1978 to make room for the G channel move to a South Pacific location. The total diurnal change here is about 75% of a lane or 75 CEC in this example over a 24 hour period. It is worth noting here that Trinidad is only operating with 1 kw radiated power for these observations.

D-H

The lower part of Figure 4 is an example of D, North Dakota - H, Japan where the H signal is at a very long range. The total diurnal change is 80 CEC or so, making it a usable navigation combination, except for the fact that the signal is obscured during daylight hours for ground observers in Ohio. This pair combination or others using the H, Japan channel might be considered in some airborne situations for Omega users in North America.

A-D

Figure 5 illustrates the East-West pair of A at Norway minus D, North Dakota. The A station signal is severely attenuated by propagation over the Greenland icecap for USA observers West of Pennsylvania. Even so, the signal during early morning hours when the Norway station is in daylight, appears to be usable. While the total diurnal change is difficult to estimate because of the daytime noise at the Ohio observing station, the excursion appears to be less than a full lane and not contaminated with multiple mode affects (the diurnal change returns to the same point 24 hours later).

A-C

A similar pair is A at Norway minus C, Hawaii as shown in Figure 6. The signal levels here appear to be somewhat better than Figure 5, possibly because Figure 6 was made during a period of much colder weather when the overall atmospheric noise level was less.

D-E

One of the most interesting types of propagation phenomena associated with Omega is that of antipodal reception where the signal from the transmitter appears as if it is arriving from some antipodal point halfway around the earth from the normal transmitter location. A case of this is reception of the E channel from LaReunion Island near Madagascar. The signals are much stronger in Ohio than would normally be expected based on a one-way propagation mode. Figure 7 illustrates the effect for the D-E pair.

Here the diurnal effect appears to be quite reproducible or returns to the same relative position 24 hours later. However, the total excursion is some 180 CEC or greater than a lane which is not predictable based on the use of present published ionosphere correction tables. The problem here is that it is not possible to assume a single dominant propagation path for prediction purposes. Yet, the total change for this local observing situation looks so reproducible that it suggests there might be some empirical ways of using signals like this for navigation purposes. While the rate of change over the apparent usable observation time from 2400 to 1200 hours each day are high, they appear consistent. Perhaps some alternate models for local area users might be devised where antipodal reception of an Omega station is a dominating factor.

B-C

Another phenomena associated with Omega is that of multi-mode propagation where there is a distinct difference in day-night relative propagation velocity caused by the earth magnetic field. The effect is very pronounced for propagation paths in an East to West direction when one of the stations is located near the magnetic equator. A case in point is illustrated in Figure 8, where B, Liberia - C, Hawaii are measured over a four day period. The records all appear to be similar and reproducible at a single observing site such as Ohio. However, there is a major effect shown here of cycle skipping on a daily basis. That is, the propagation appears to be going through a normal diurnal change during daylight hours at the observer but skips one complete cycle each nighttime observation and does not return to the same point 24 hours later.

A more idealized sketch of this modal interference is shown in Figure 8 where the cycle lost during each 24 hour observing period is illustrated, along with the approximate times of sunrise and sunset at the points in question. This phenomena is not predictable based on the present ionosphere correction tables. The effect has been of much concern among Omega users in the North Atlantic and East-Coast North America areas.[3] Thus Liberia which is intended to be a replacement for Trinidad, turns out to be not usable for many observers in the North American region about 50% of the time. Although the signal levels are satisfactory, the phase velocity uncertainities or unpredictability (based on present models) create a problem for many observers trying to use the B station signal.

B-D

The same multi-modal propagation effect is also noted for the pair combination B, Liberia - D, North Dakota as illustrated in Figure 10. It has been suggested that the cycle skipping phenomena for some observers here is rather like a parametric amplifier where an Omega transmitter is pumping the ionosphere to oscillate at a one cycle/day rate due the magnetic field rotation.

CONCLUSIONS

Diurnal signals from all eight Omega channels have been monitored at 10.2 KHz for selected station pairs. All eight Omega stations have been received at least 50% of the time over a 24 hour period during the month of October 1976. The data presented confirm the expected performance of the Ohio University CMOS Omega Sensor Processor in being able to dig signals out of a noisy monitoring environment. The diurnal data present many problems to the user in choice of station pairs for navigation when using diurnal correction tables. Of particular interest are possibilities for use of antipodal reception phenomena and a need for some ways of correcting for multi-modal propagation affects.

ACKNOWLEDGMENTS

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[2] L. Wright, "Flight Test of 4 Hz and 30 Hz Omega Receiver Front-End", Technical Memorandum (NASA) 21, Avionics Engineering Center, Ohio University, Athens, Ohio, February 1976.

[3] Phillip J. Klass, "Omega Navaid Improvement Pushed", Aviation Week and Space Technology, Vol. 105, No. 16, pp. 73-81, October 18, 1976.

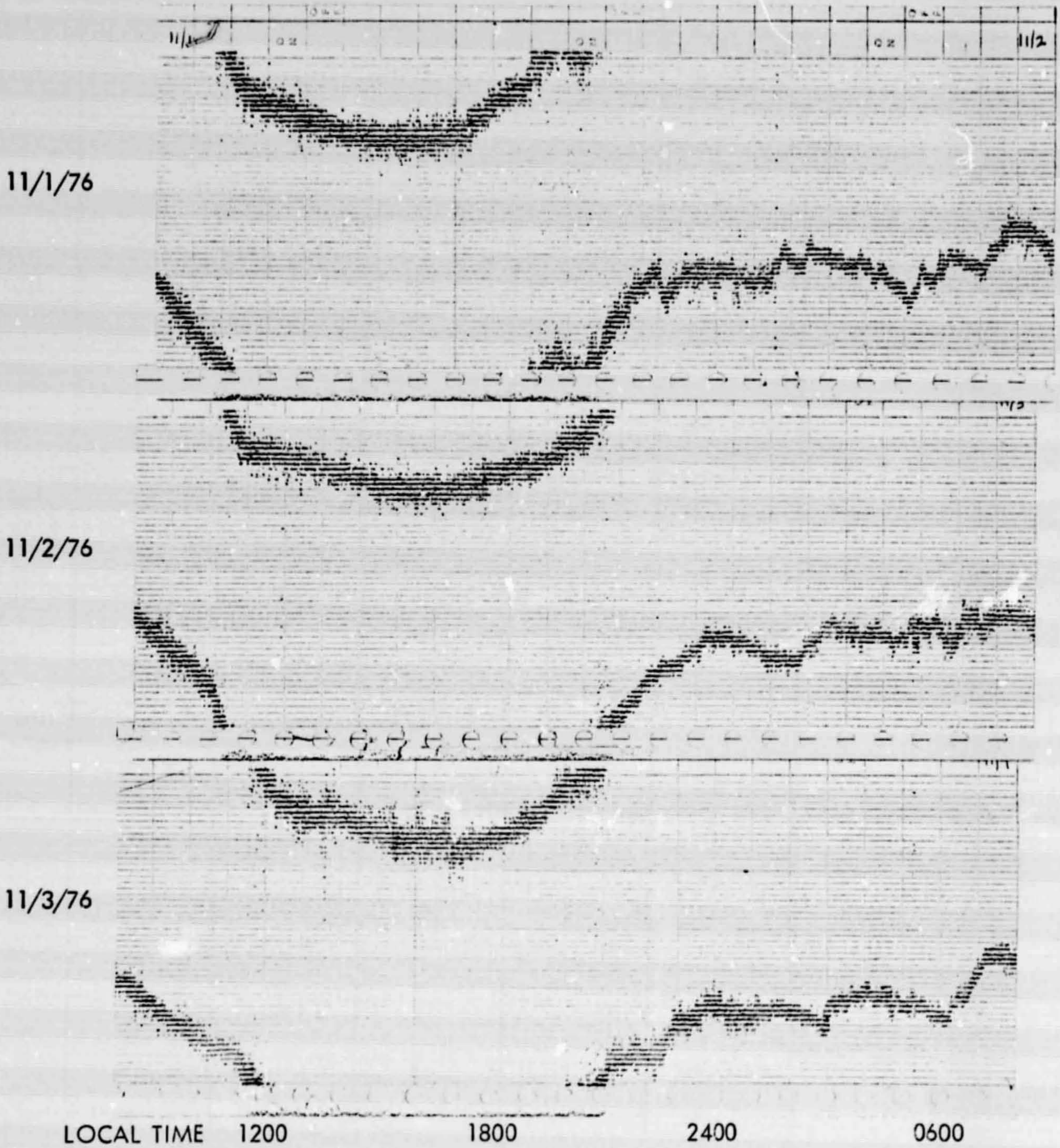

Figure 1. C–D Diurnal Recordings (1/4"/hr).
(Strong Signal Pair)

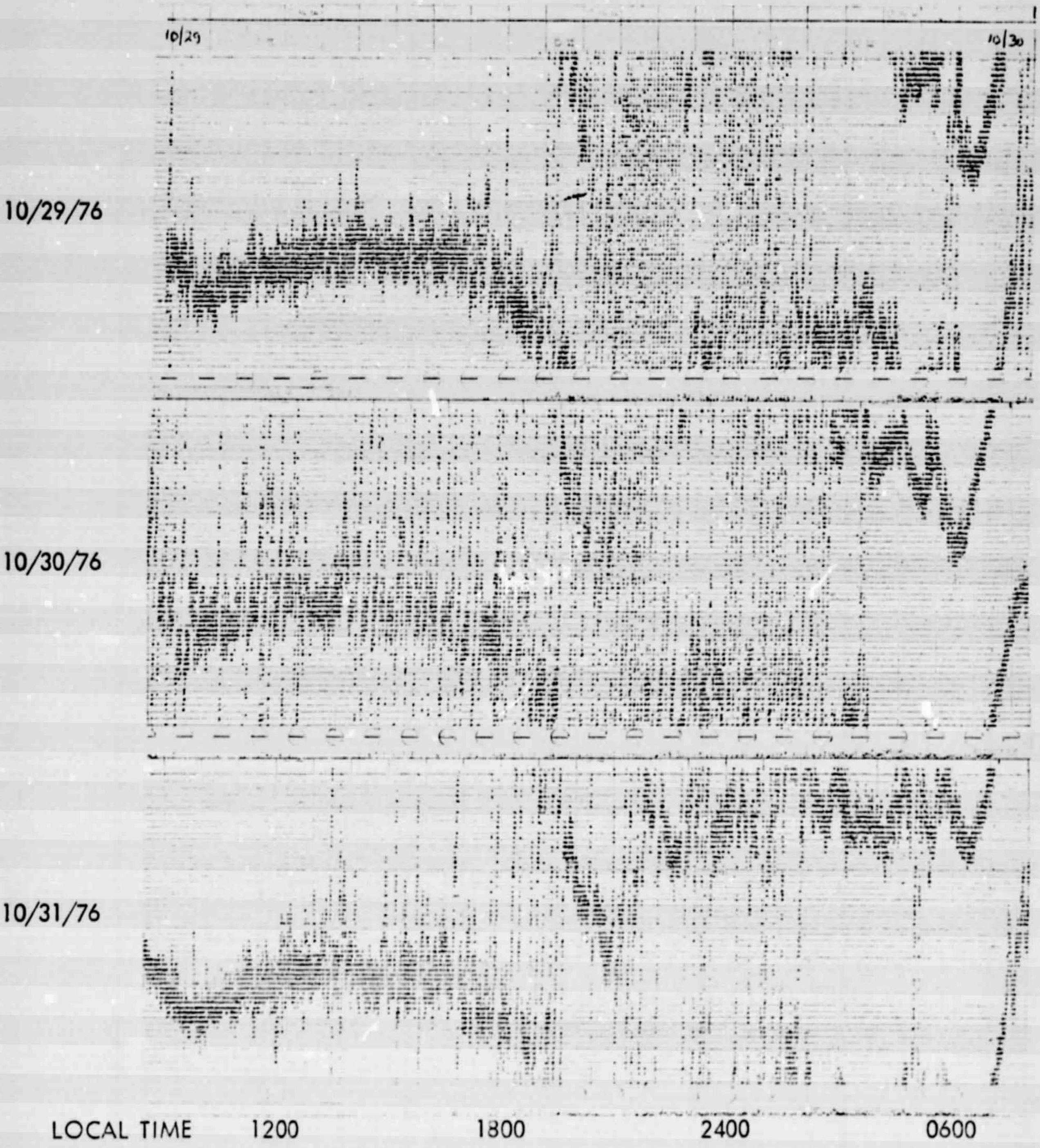

Figure 2. D-F Diurnal Recordings (1/4"/hr).
(North-South Signal Pair)

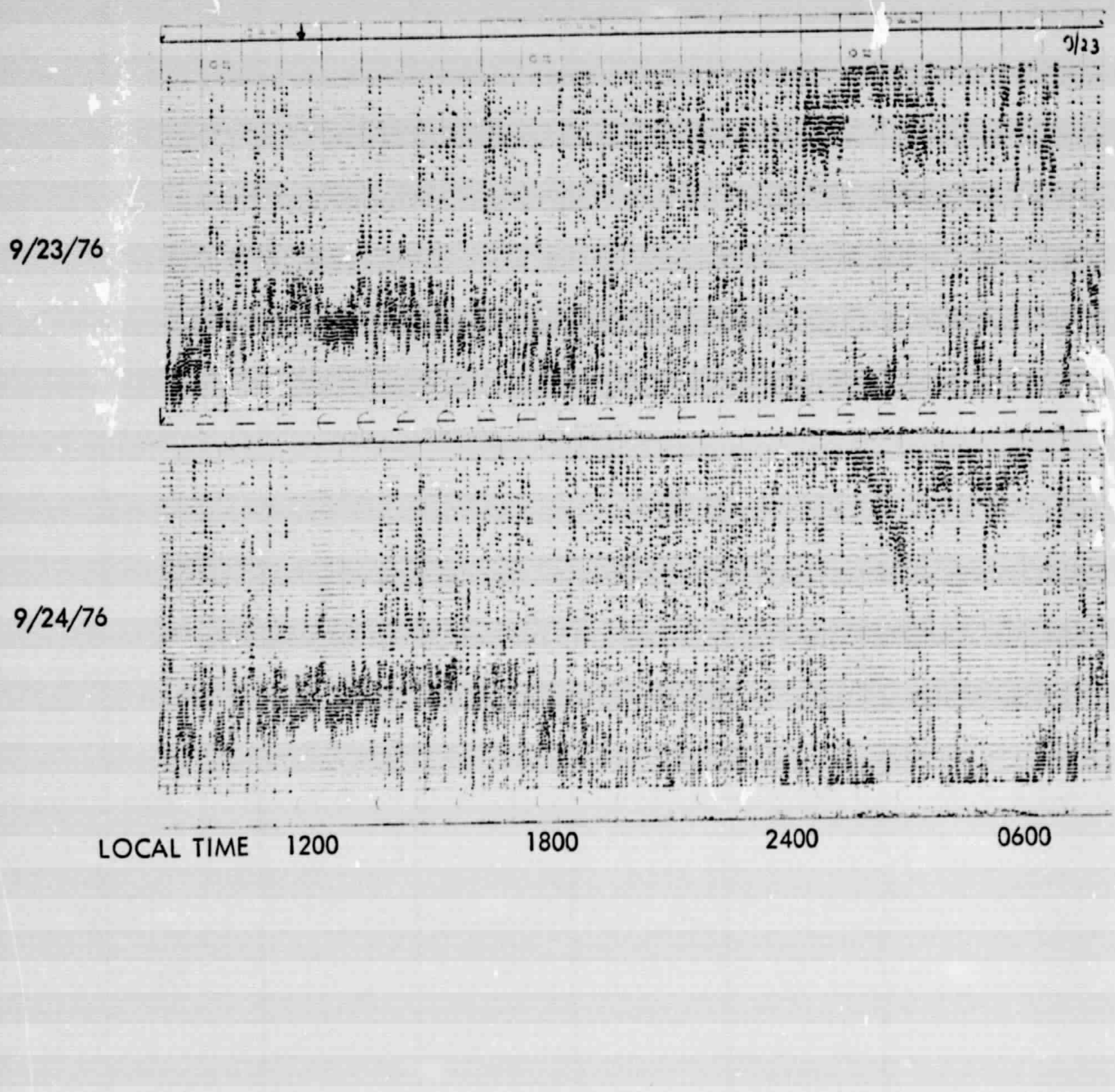

Figure 3. D-F Diurnal Recordings (1/4"/hr).
(F, Argentina operating at reduced power, 7 kw)

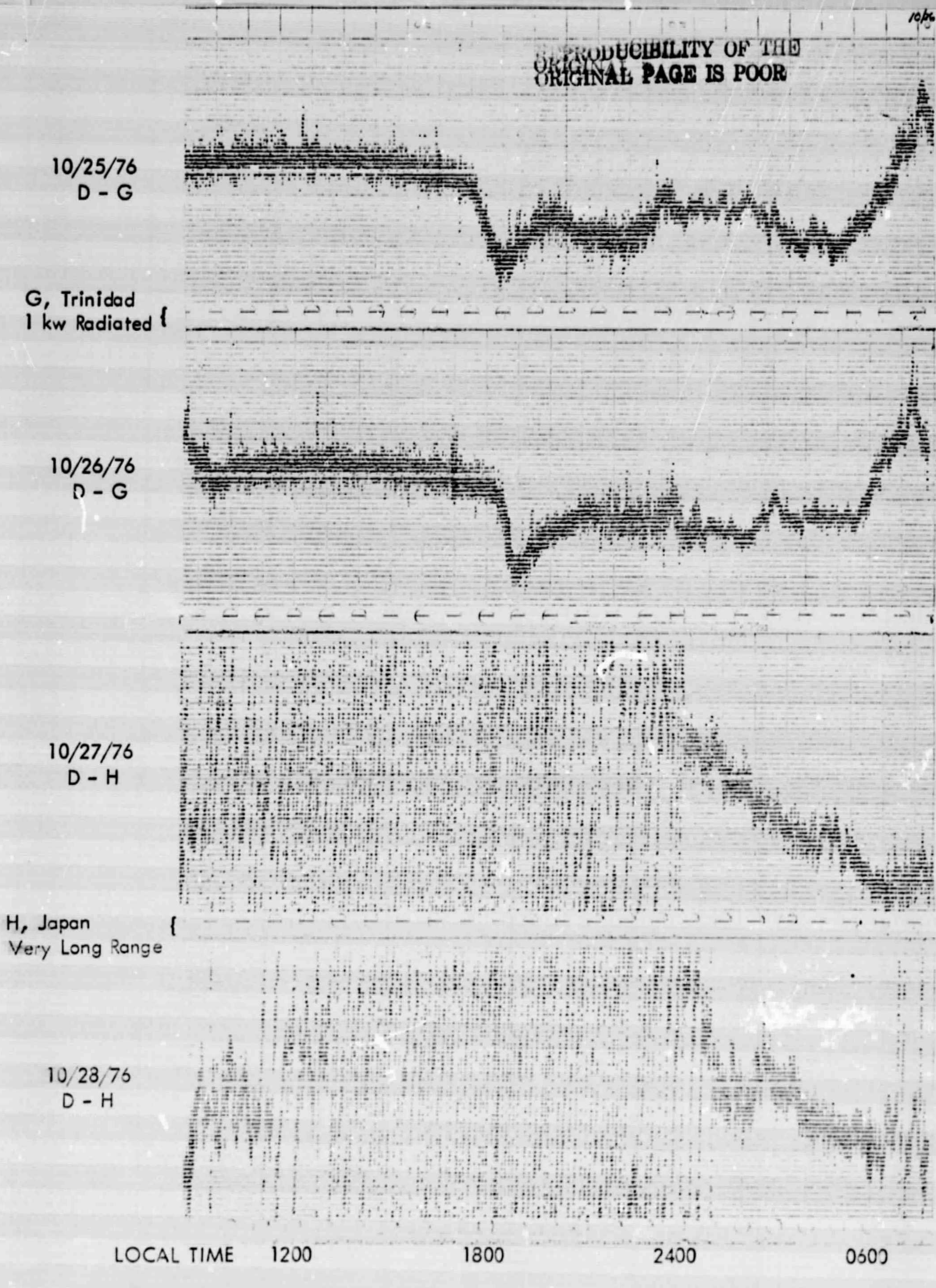

Figure 4. Diurnal Recordings (1/4"/hr).

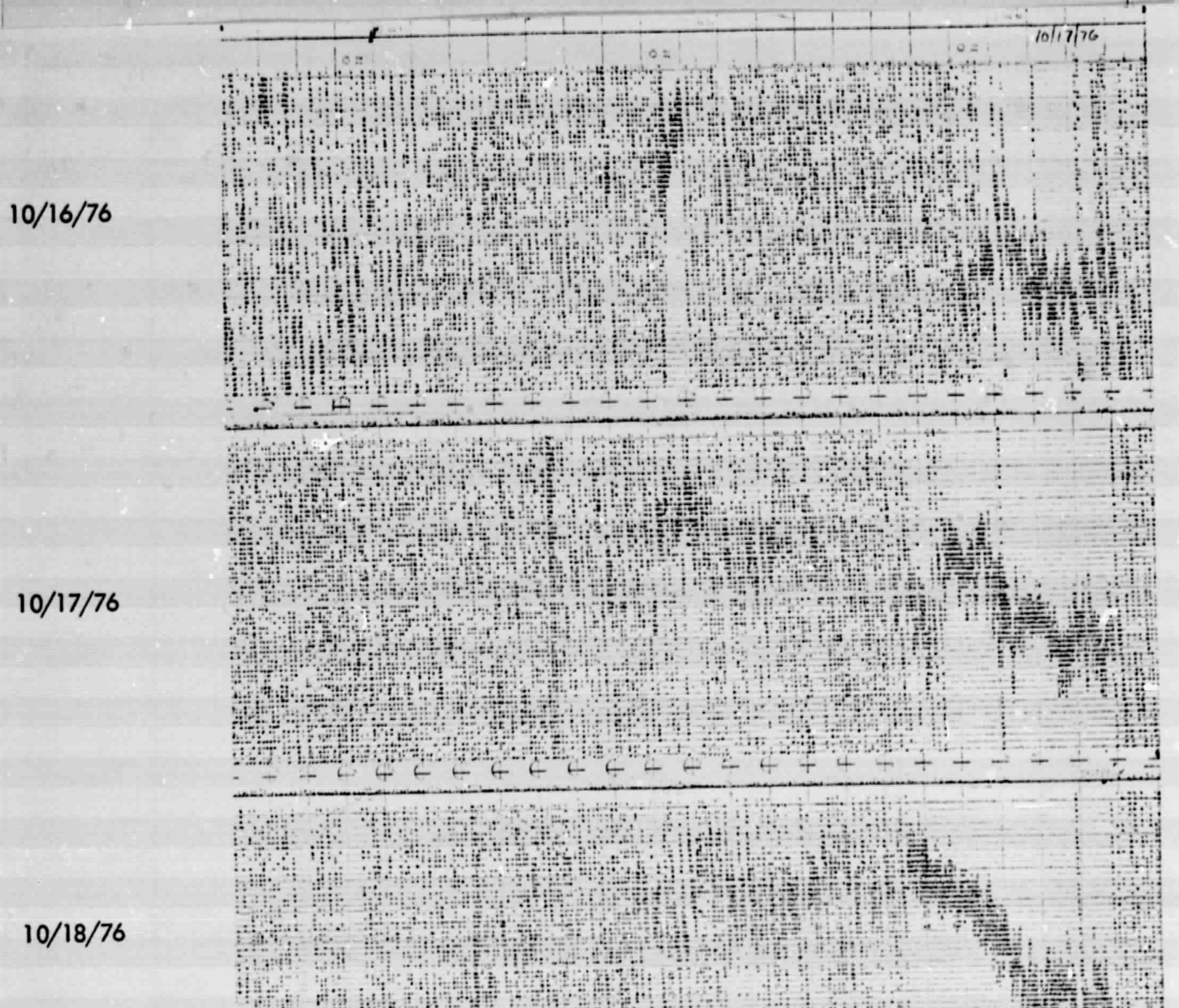

Figure 5. A-D Diurnal Recordings (1/4"/hr).
(Norway, A Shadowed by Greenland Icecap)

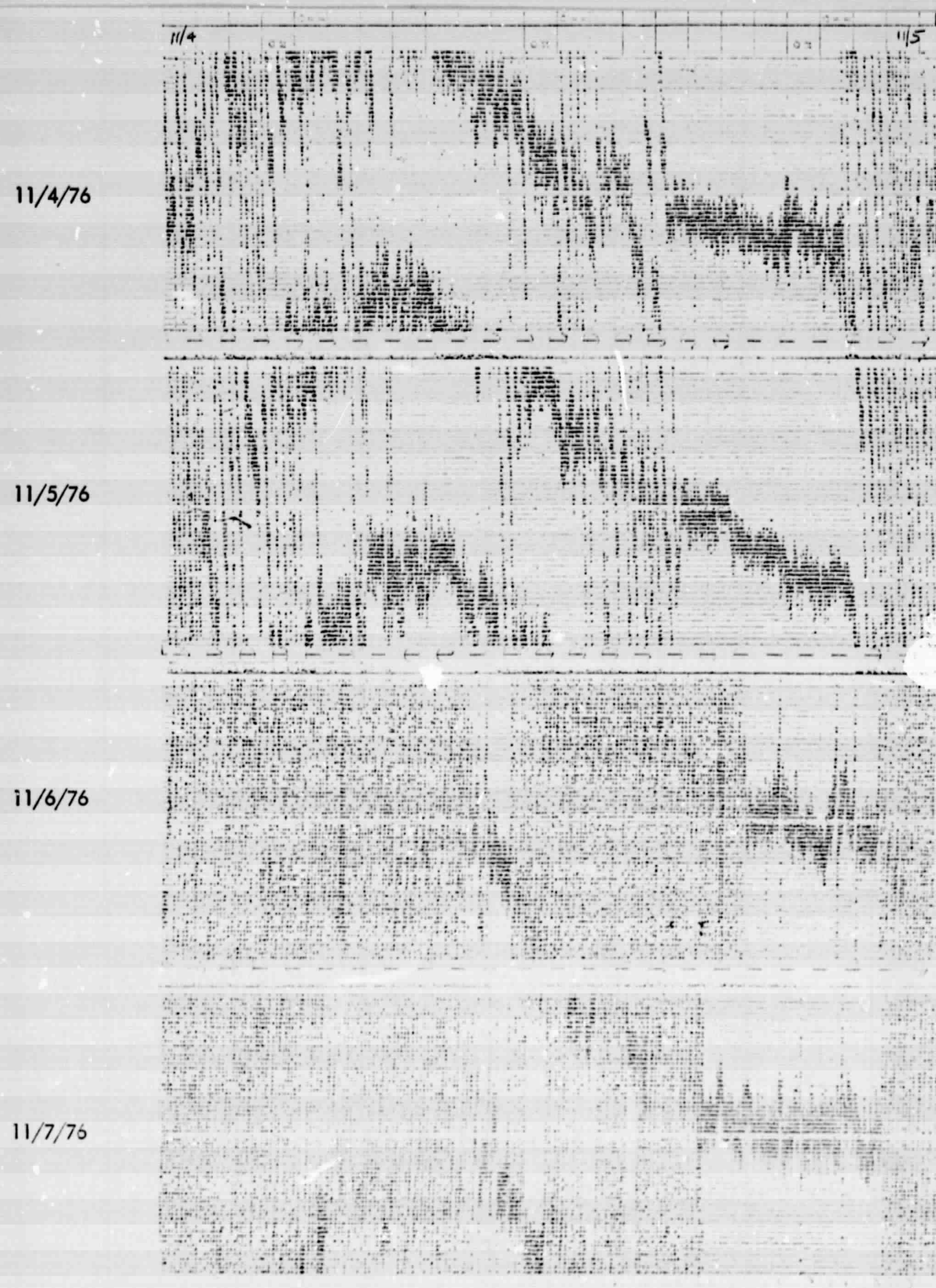

Figure 6. A-C Diurnal Recordings (1/4"/hr).
(Norway, A Shadowed by Greenland Icecap)

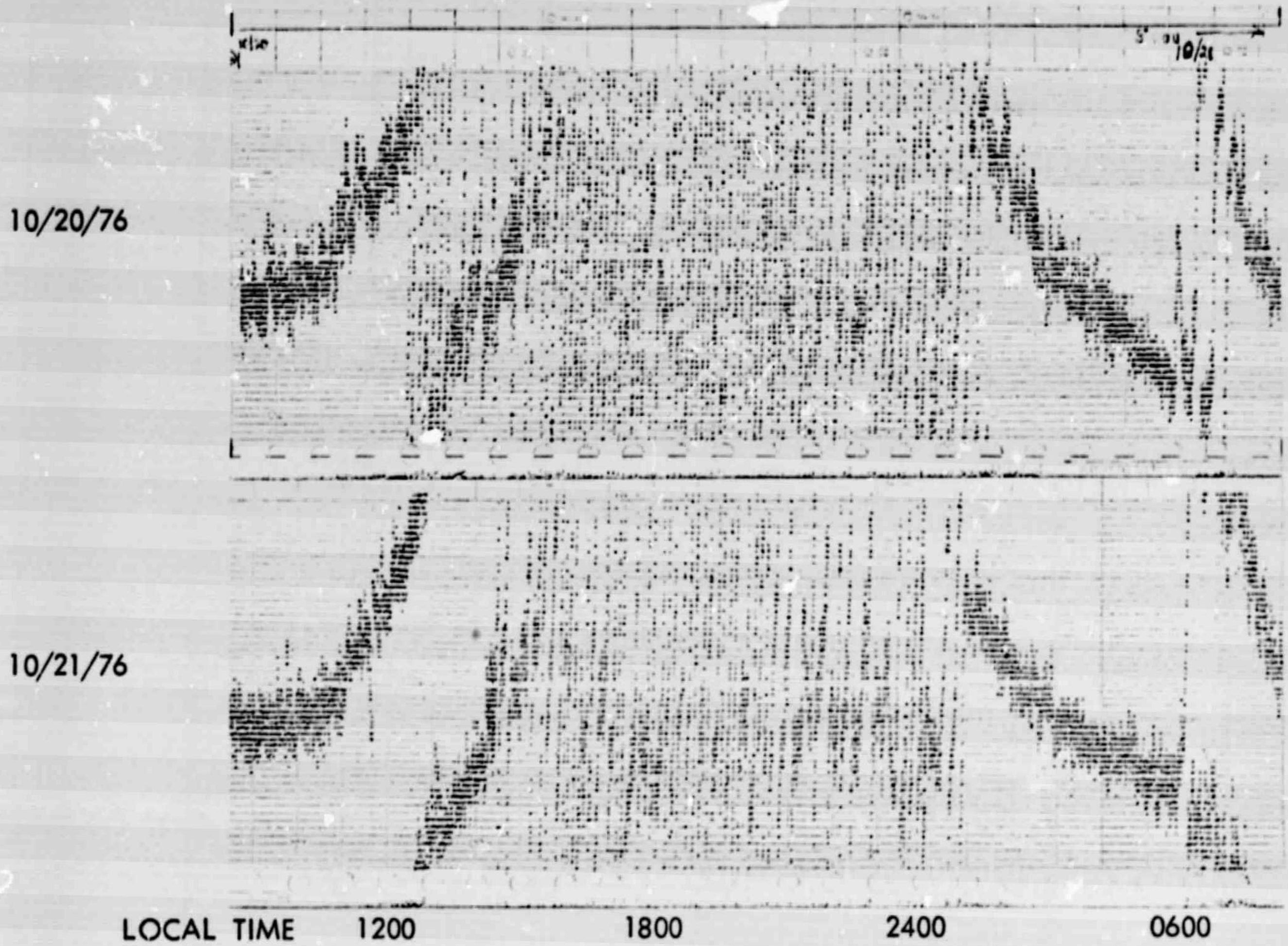

Figure 7. D-E Diurnal Recordings (1/4"/hr).
(Antipodal Reception of E).

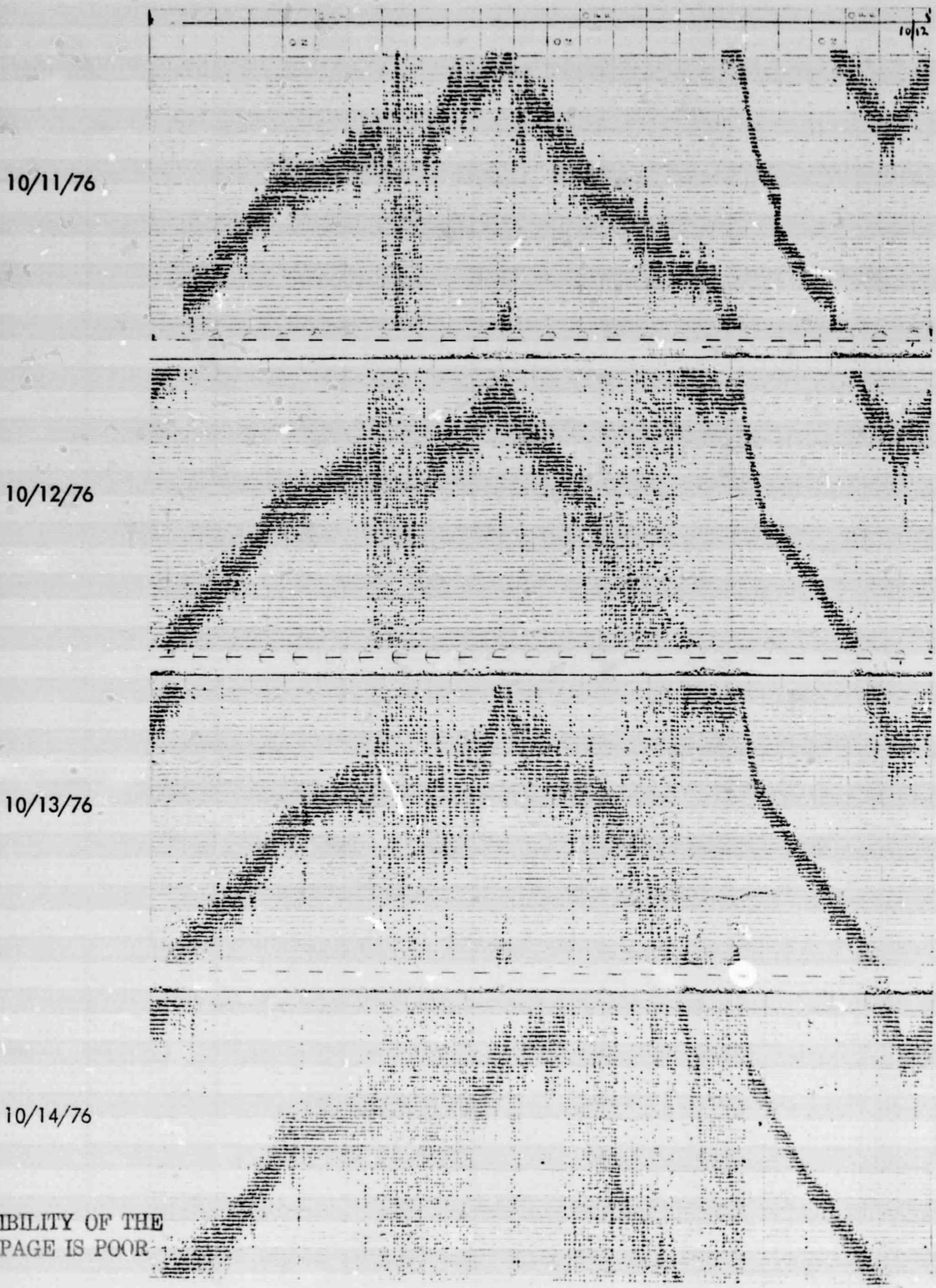

Figure 8. B-C Diurnal Recordings (1/4"/hr).
(Modal Interference on Liberia, B at Night)

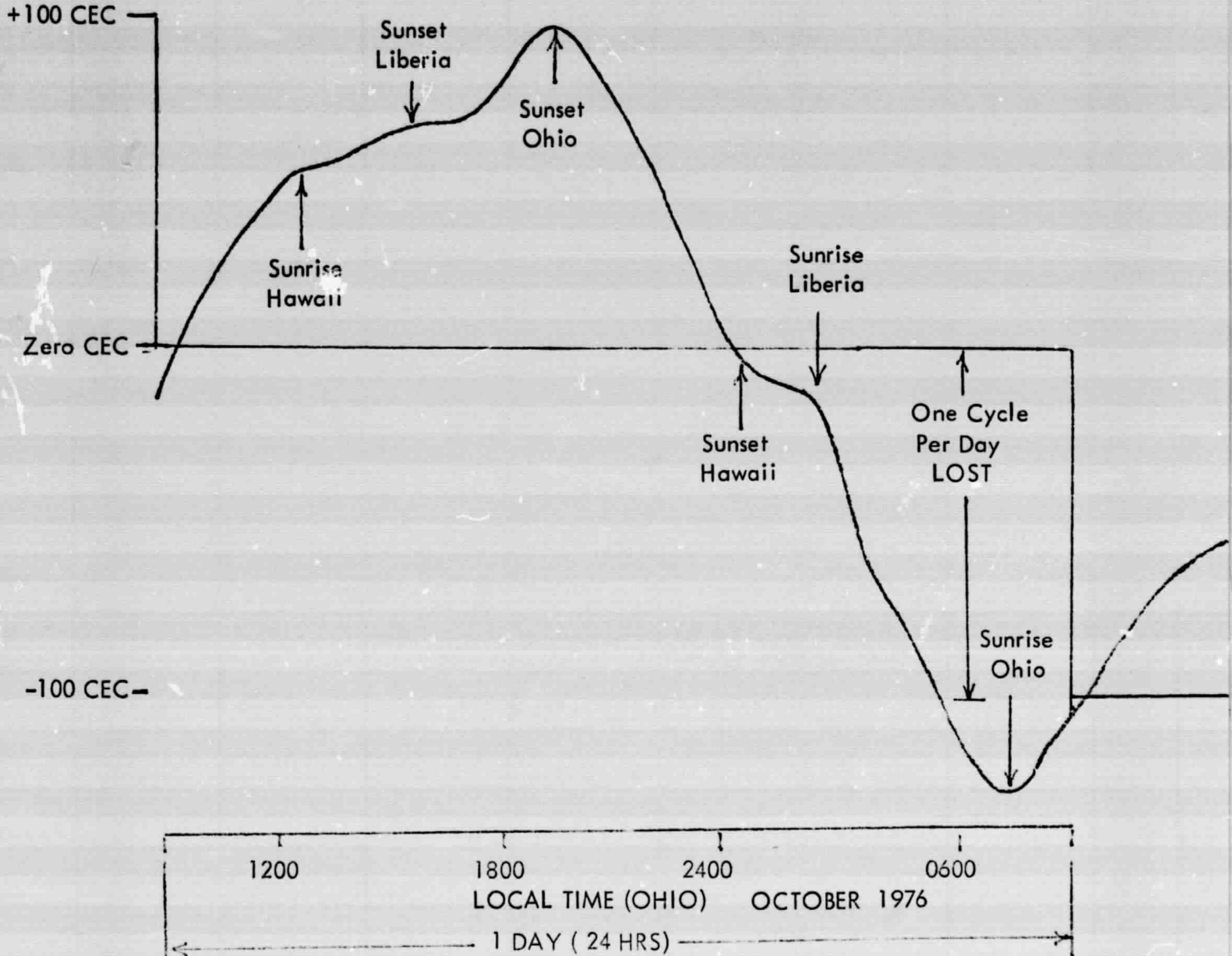

Figure 9. Modal Interference on B-C Diurnal Recording.

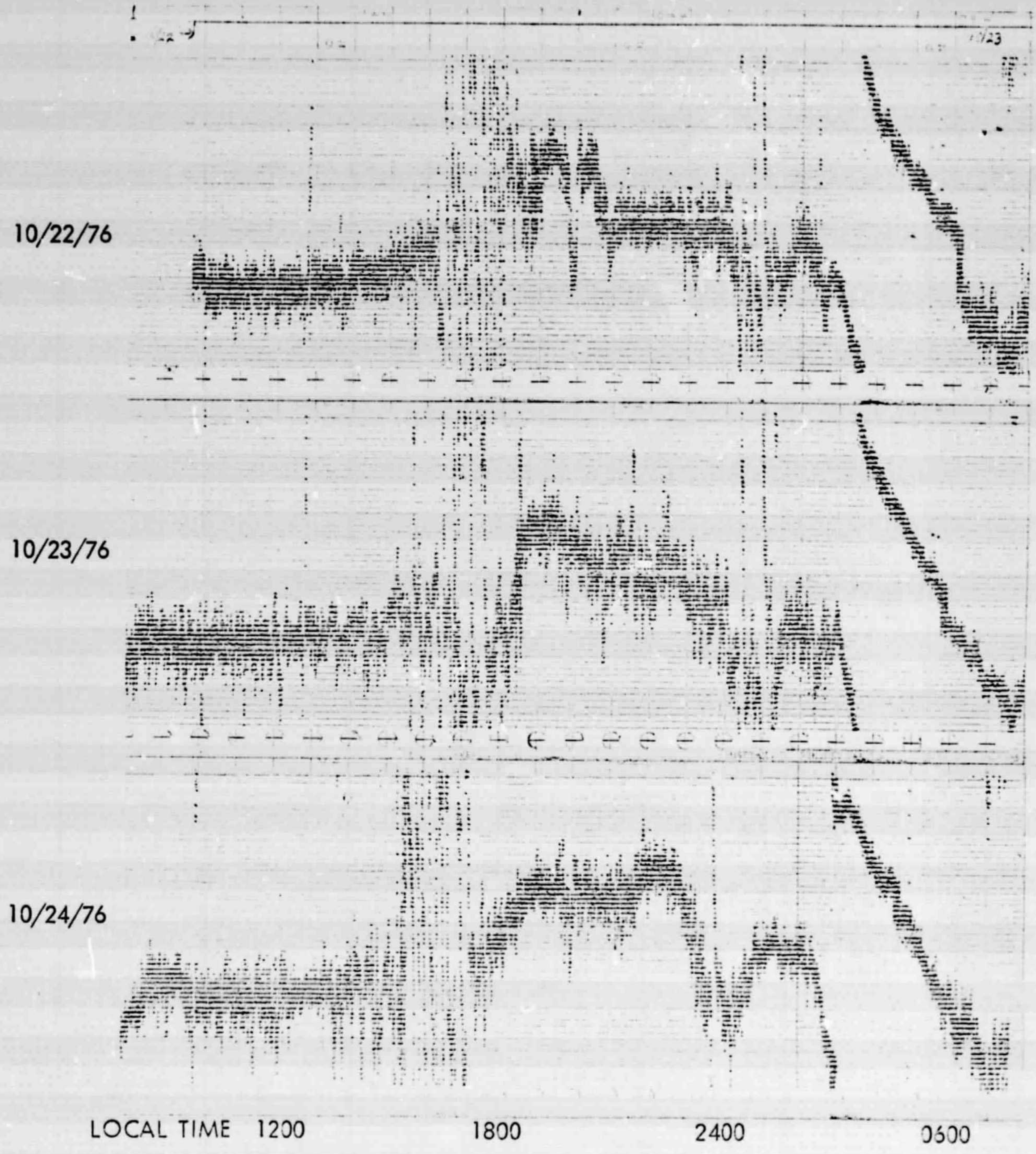

Figure 10. B-D Diurnal Recordings (1/4"/hr).
(Modal Interference on Liberia, B at Night)