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PRELIMINARY REPORT OF S-BAND PROPAGATION DISTURBANCE DURING ALSEP MISSION SUPPORT (NOVEMBER 19, 1969 — JUNE 30, 1970)

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JUNE 1971

GSFC

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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ABSTRACT

Severe fluctuations of the ALSEP S-band downlink telemetry signal have resulted in unexpected data dropouts. Due to the important implications, it was decided to gather and analyze the available data for the period November 19, 1969 - June 30, 1970. In all, some 41 station support periods with fluctuation reports have been tentatively attributed to an unspecified phenomena. The occurrences have been highly localized to the Ascension Island (ACN) and the Canary Islands (CYI) stations, even though other stations of the MSFN Network have had equivalent exposure. The signal fluctuations at these stations have been as large as 20 and 25 db. A comparison of the fluctuations with solar events has failed to show any correlation. Further analysis resulted in a working hypothesis as to a pattern of occurrence. This pattern indicates that the disturbance occurs primarily during the local hours of 2000 to 2400, on days clustered about the phase of the full moon, in months centered at the equinox. This pattern strongly suggests a connection between the fluctuations and some phenomena occurring in the lower magnetosphere or ionosphere. A review of the most likely known phenomena fails to provide an explanation of the cause of the fluctuations.

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1. INTRODUCTION

On November 19, 1969, the ALSEP-1 (Apollo Lunar Surface Experiment Package) was placed on the surface of the moon. The package contains an S-band receiver (2119 MHz) and transmitter (2278.5 MHz) compatible with the Manned Space Flight Network (MSFN) tracking stations. The MSFN stations have been receiving and recording the downlink signal on an around-the-clock basis since November 19. Table 1 identifies and gives the locations of the MSFN stations.

The station support of the ALSEP package appeared to be nominal until February 1970 when the Ascension Island station (ACN) reported severe fluctuations of the downlink signal causing dropouts of telemetry data. These reports were surprising since the effects of ionospheric scintillation is generally considered to be negligible at these frequencies and no equipment problem could be found to explain the observations. The situation was further confused when it developed that at times several other MSFN stations reported simultaneous reports of fluctuations, while at other times other stations could not verify simultaneous observations. The reports continued for a period of 11 days and then ceased. The problem was tentatively attributed to some propagation phenomena caused by unusual solar activity.

In March, several stations again were effected by the signal fluctuations over a period of 15 days. Recordings were made of signal fluctuations as large as 20 and 25 db at times. The effects overall were severe, causing numerous dropouts of telemetry data. Due to the important implications, it was decided to gather and analyze the available data.

Table 1. MSFN STATIONS

Symbol	Station	Latitude	Longitude
ACN	Ascension Island	-07° 57'	-14° 20'
BDA	Bermuda Islands	32° 21'	-64° 39'
CRO	Carnarvon, Australia	-24° 54'	113° 43'
CYI	Canary Islands	27° 46'	-15° 38'
GDS	Goldstone, California	35° 21'	-116° 52'
GWM	Guam	13° 19'	144° 44'
GYM	Guaymas, Mexico	27° 58'	-110° 43'
HAW	Hawaii	22° 07'	-159° 40'
HSK	Honeysuckle Creek, Australia	-35° 35'	148° 59'
MAD	Madrid, Spain	40° 27'	-4° 10'
MIL	Cape Kennedy, Florida	28° 30'	-80° 42'
TEX	Corpus Christi, Texas	27° 39'	-97° 23'

2. DATA SOURCES

2.1 STATION REPORTS

All the data for this report has been obtained from standard operational sources. The initial reports were made by voice contact between the stations and the duty network controller.[1] In addition, a postpass summary report message (PSRM) is required to be transmitted by teletype after each station support period. These reports include the times of weak signal strength and any resultant signal loss. The station personnel are requested to make comments on any abnormalities, such as signal strength fluctuations, and give approximate values of the deviations. All of the data prior to March 1970, has come from these sources.

2.2 RECORDED DATA

Every station makes a strip chart recording of certain key analog and event signals from the S-band equipment during the complete ALSEP support period. The receiver AGC, calibrated in terms of the received signal strength, is one of the recorded signals. This results in a continuous record of the received signal level during the complete support period. These recordings are used by the stations to supply the information concerning signal strength that is required for the PSRM's. The ALSEP downlink signal is received by the standard MSFN S-band receivers. Its narrow AGC bandwidth (0.16 Hz.) is used to make the strip chart recordings. The scale factor used makes it normally possible to observe 1 or 2 dB fluctuations in the signal level. Only a portion of the strip chart recordings starting with March 1970 are still available for detailed study.

2.3 EXTENTS AND LIMITS OF THE DATA SAMPLE

The fact that the data being gathered is based on the signal emitted from the ALSEP package leads to some unusual considerations. It is a steady signal. There is no problem with a varying aspect angle. The transmitter power level has been continuously monitored and is known to be steady. The ALSEP operational plan calls for continuous station support. This yields data on a continuous basis. Any phenomena which would affect the total earth environment would be detected by the then operating station.

The primary limitation is that the data is time limited to the moon view period at any specific geographic location. This means that there can be no data at any specific location over a 24 hour period. Nor can the hour of the observation be chosen freely. The approximate moon view periods for any geographic location are shown in Table 2 for a lunar month.

TABLE 2

Approximate Moon View Periods

Moon Phase	Approximate Rise	Approximate Set
New	Sunrise	Sunset
First Quarter	Noon	Midnight
Full	Sunset	Sunrise
Last Quarter	Midnight	Noon

If the phenomena to be observed is a function of local time, it can only be observed during certain phases of the moon.

Further data limitations have resulted from the requirements and policies of scheduling station support periods. There is no requirement for more than one station to support at any given time. Therefore, there is only data from a single station at any given time. Stations are usually scheduled in blocks of days, and then released for other activities for blocks of days. The length and frequencies of the periods of support depend on the number of stations having overlapping view periods and varies widely from station to station.

3. REPORTS OF FLUCTUATIONS

3.1 TIMES AND LOCATIONS OF FLUCTUATIONS

During the time span covered by this report, there have been 41 reported unexplained occurrences. One station with a record of one or more periods of observations during a given support period is considered here as a "single occurrence." Therefore one occurrence may represent anywhere from several minutes to several hours of observed activity. "Unexplained" means that no equipment problem or physical phenomena was found to account for the observation. Table 3 gives a breakdown by station and month of the number of support periods and the number of reported occurrences.

A pattern begins to appear in Table 3, approximately 88% of the reports are from ACN and CYI. Also, the number of reports peaked in February and March. To further clarify the data, the complete time line for support periods at ACN and CYI are shown in Figures 1 through 6*. The time lines were plotted from noon to noon to best show the nocturnal occurrence of the phenomena. The full impact of the peak periods of February and March stand out. The February observations at ACN were spread over 11 days and lasted for as long as 4 to 5 hours on some days. CYI was only scheduled one time during this period - that was on the night of February 19 when they verified that the signal was fluctuating. The March observations at the two stations were spread over 14 days and lasted over 5 to 6 hour periods on some days.

The hours of occurrence are of interest. All of the reports fall within the period 1900 to 0320 hours, local time.

A further review of the ACN time line shows a smaller period of observations in January. These reports covered a 6 day period with brief observations up to an hour in length. The time frame of the observations is consistent with the February - March observations. There was a report of possible fluctuations on December 24, within the same time frame, but no further details are known. Finally, there was an ACN report on the morning of May 28. This is not consistent with other observations either with respect to the time frame or the fact that it was a single occurrence.

The CYI time line shows several scattered events in addition to the February-March reports; December 13, April 16, May 21, and May 22. Again, all are consistent with the general time frame of observations.

The GWM time line is shown in Figures 7 through 9. GWM has three recorded observations. The recordings show fluctuations on the nights of March 19 and 20. These are on the same days and in the same local time frame as the observations at ACN and CYI. The third report was on April 10, again consistent with the previous local time frames.

* Some of the limits of the data sample are in evidence. ACN, CYI, and MAD are at approximately the same longitude. One of these stations must support daily to provide continuous ALSEP coverage. MAD was not brought into operation until April. Prior to that it was necessary to schedule ACN or CYI for support each day. Also, the dependence of the view period on the phase of the moon can be seen.

TABLE 3

SUMMARY OF SUPPORT PERIODS AND FLUCTUATION REPORTS.

		ACN	BDA	CRO	CYI	GDS	GWM	GYM	HAW	HSK	MAD	MIL	TEX	TOTAL
Nov. 1969	Support Periods	4	3	5	5	0	7	8	0	1	1	0	6	41
	Fluct. Reports													
Dec. 1969	Support Periods	17	0	16	14	0	18	11	7	0	0	0	14	97
	Fluct. Reports	1			1									2
Jan. 1970	Support Periods	15	14	15	17	0	15	13	15	0	0	0	7	112
	Fluct. Reports	5												5
Feb. 1970	Support Periods	14	9	12	14	2	16	8	13	0	0	0	8	96
	Fluct. Reports	10			1				1					12
March 1970	Support Periods	17	10	16	13	0	13	12	9	0	0	0	8	101
	Fluct. Reports	7			7		2							16
April 1970	Support Periods	8	5	10	15	5	11	9	4	10	6	5	14	103
	Fluct. Reports				1		1							2
May 1970	Support Periods	10	8	11	10	9	9	10	11	10	10	5	8	111
	Fluct. Reports	1			2				1					4
June 1970	Support Periods	16	7	8	5	8	16	13	12	5	9	0	6	106
	Fluct. Reports													
Total Support Periods		101	56	93	93	24	105	84	71	26	26	10	71	767
Total Fluct. Reports		24	–	–	12	–	3	–	2	–	–	–	–	41

The total includes 7 unidentified periods as follows: Nov.(1), Jan. (1), Mar. (3), Apr (1), June (1)

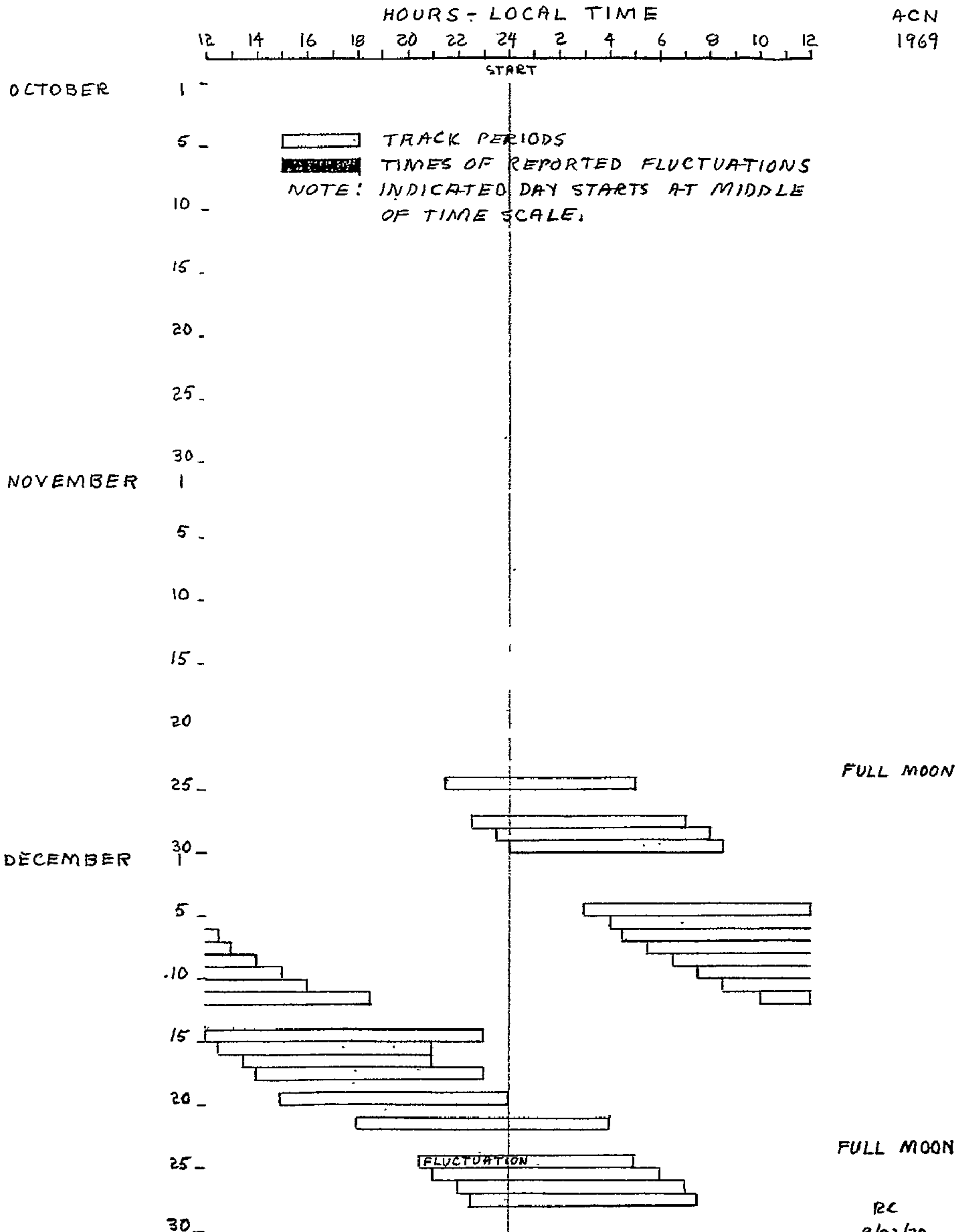

Figure 1.--ACN Support Periods and Reports of Fluctuations, Nov.-Dec., 1969.

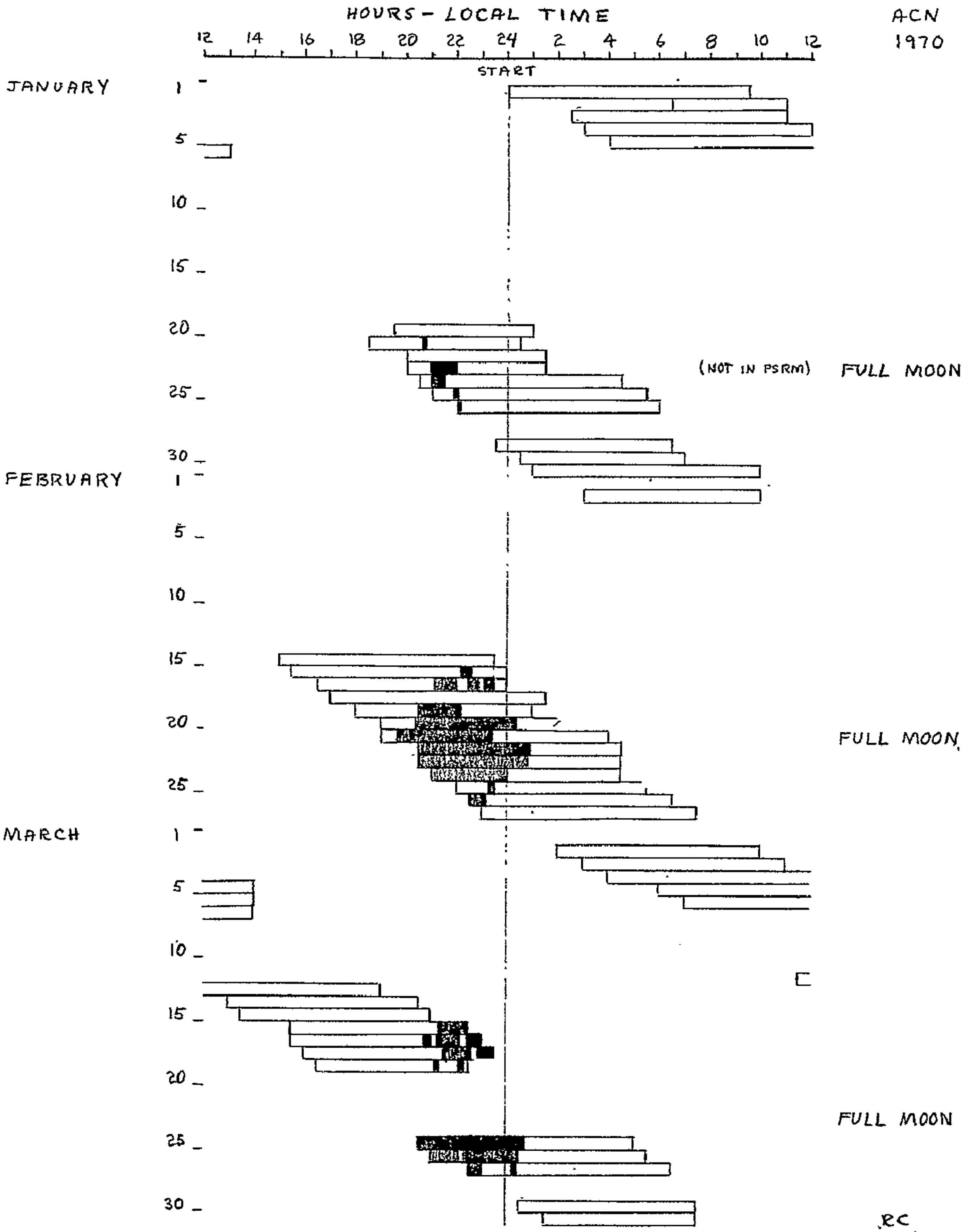

Figure 2 - ACN Support Periods and Reports of Fluctuations, Jan. - March, 1970.

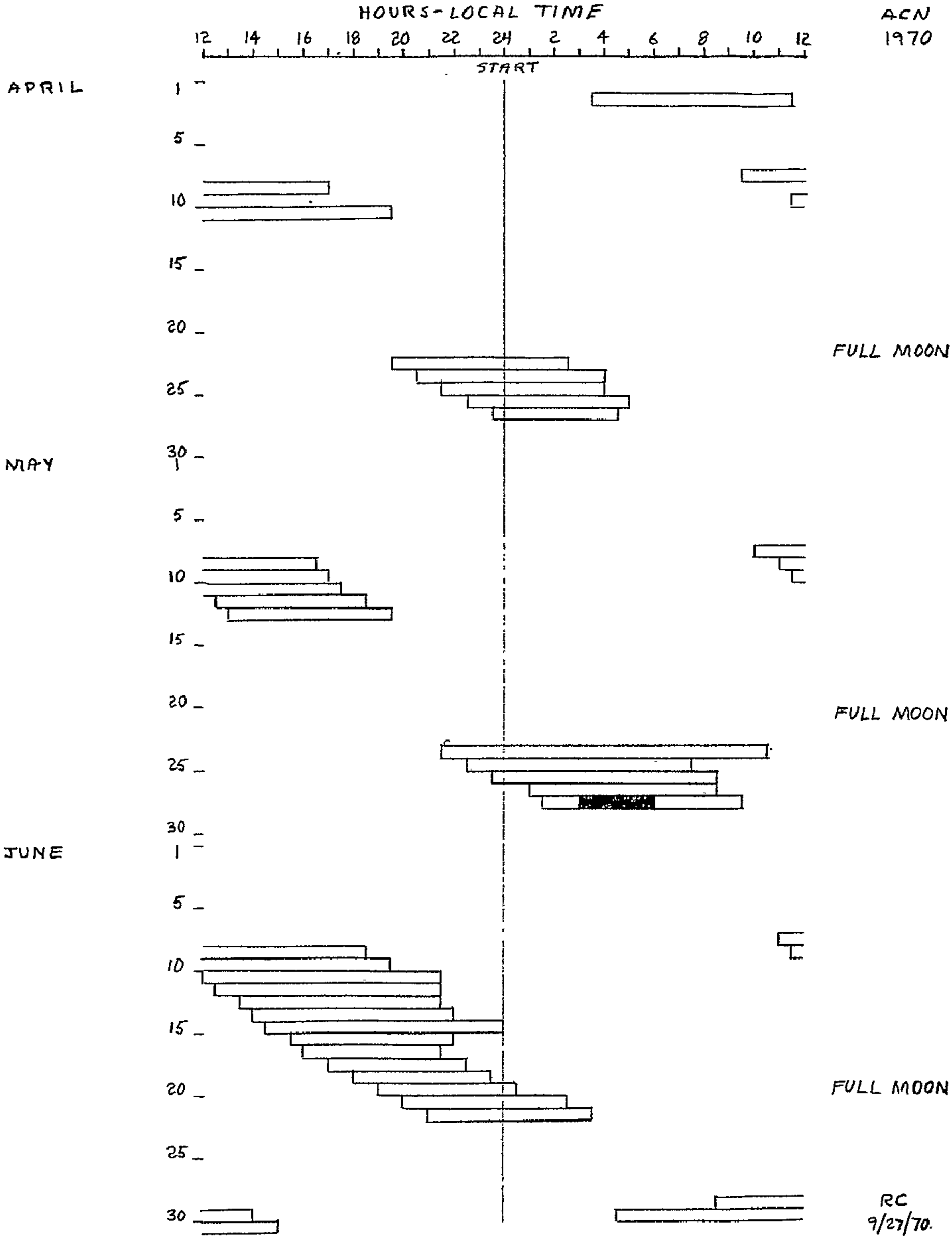

Figure 3 - ACN Support Periods and Reports of Fluctuations, April - June 1970.

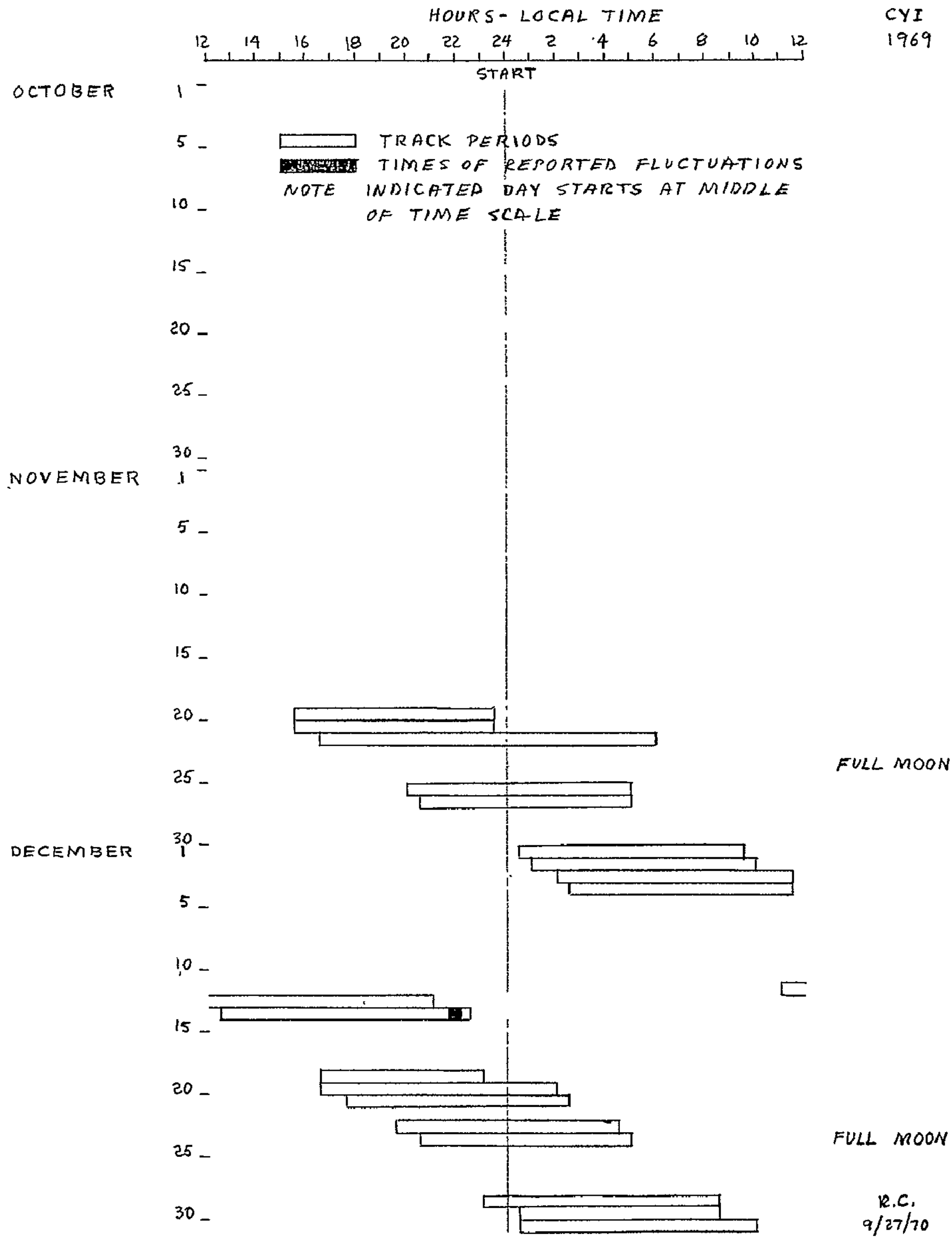

Figure 4 - CYI Support Periods and Reports of Fluctuations, Nov. - Dec. 1969.

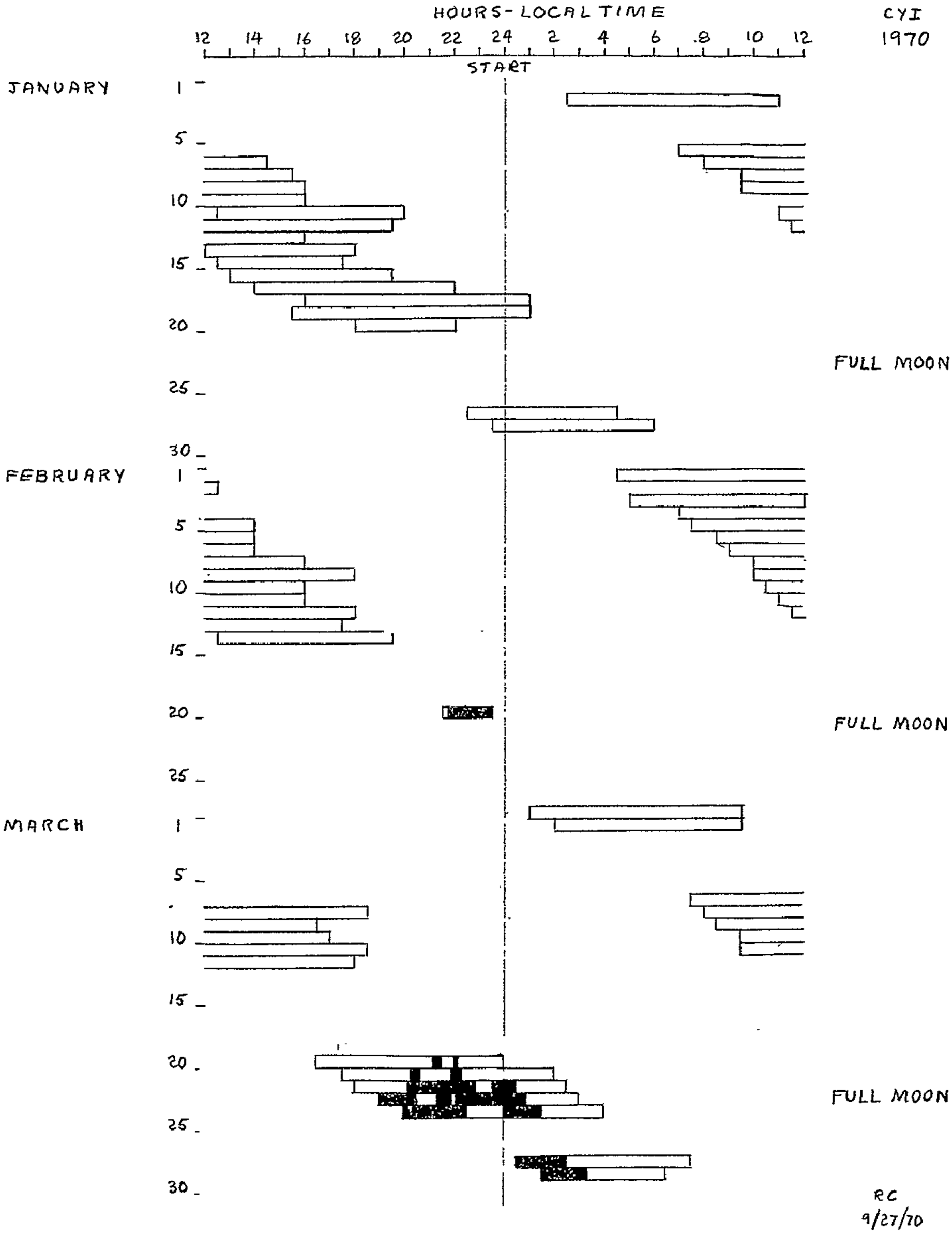

Figure 5 - CYI Support Periods and Reports of Fluctuations, Jan.-March, 1970

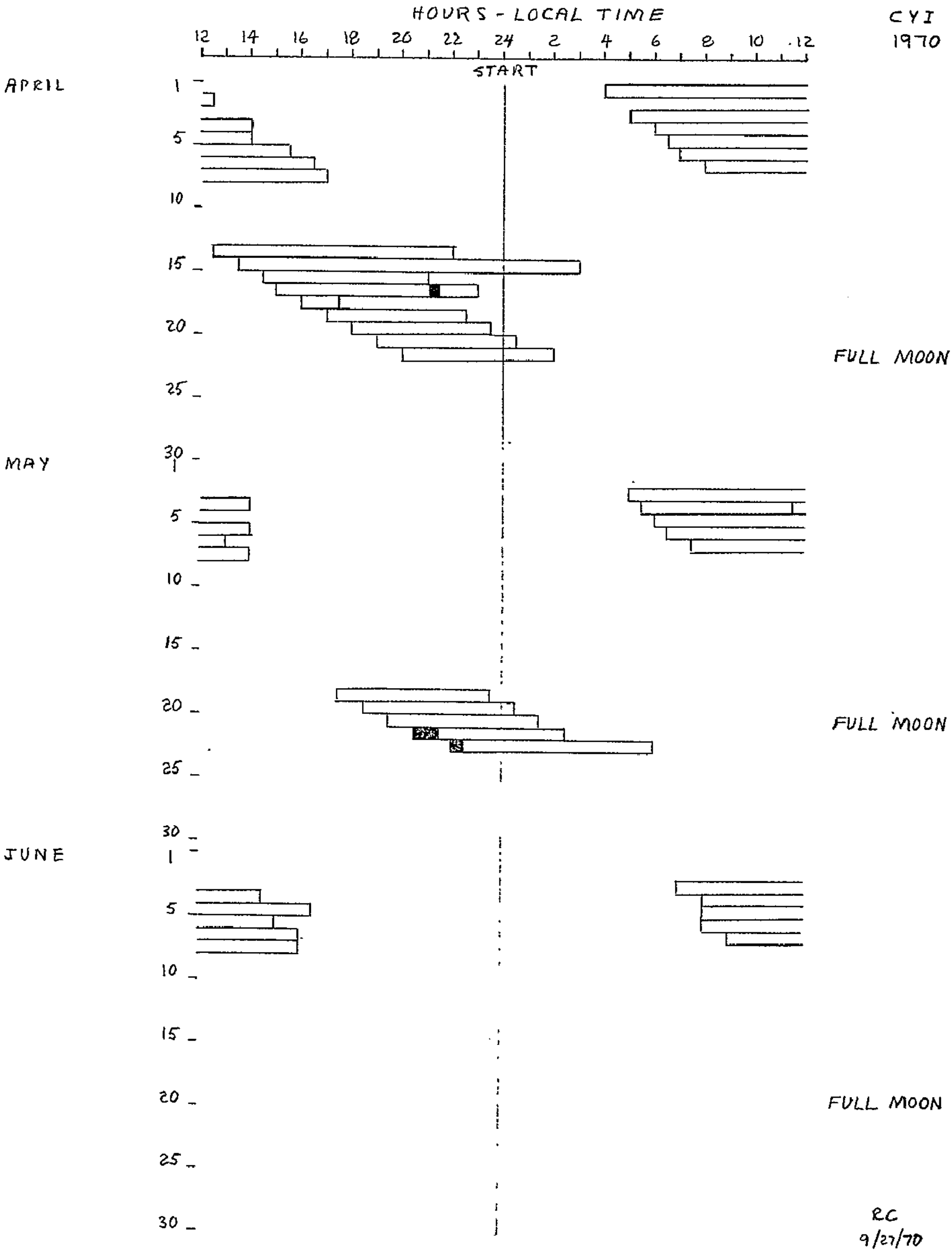

Figure 6 - CYI Support Periods and Reports of Fluctuations, April-June, 1970

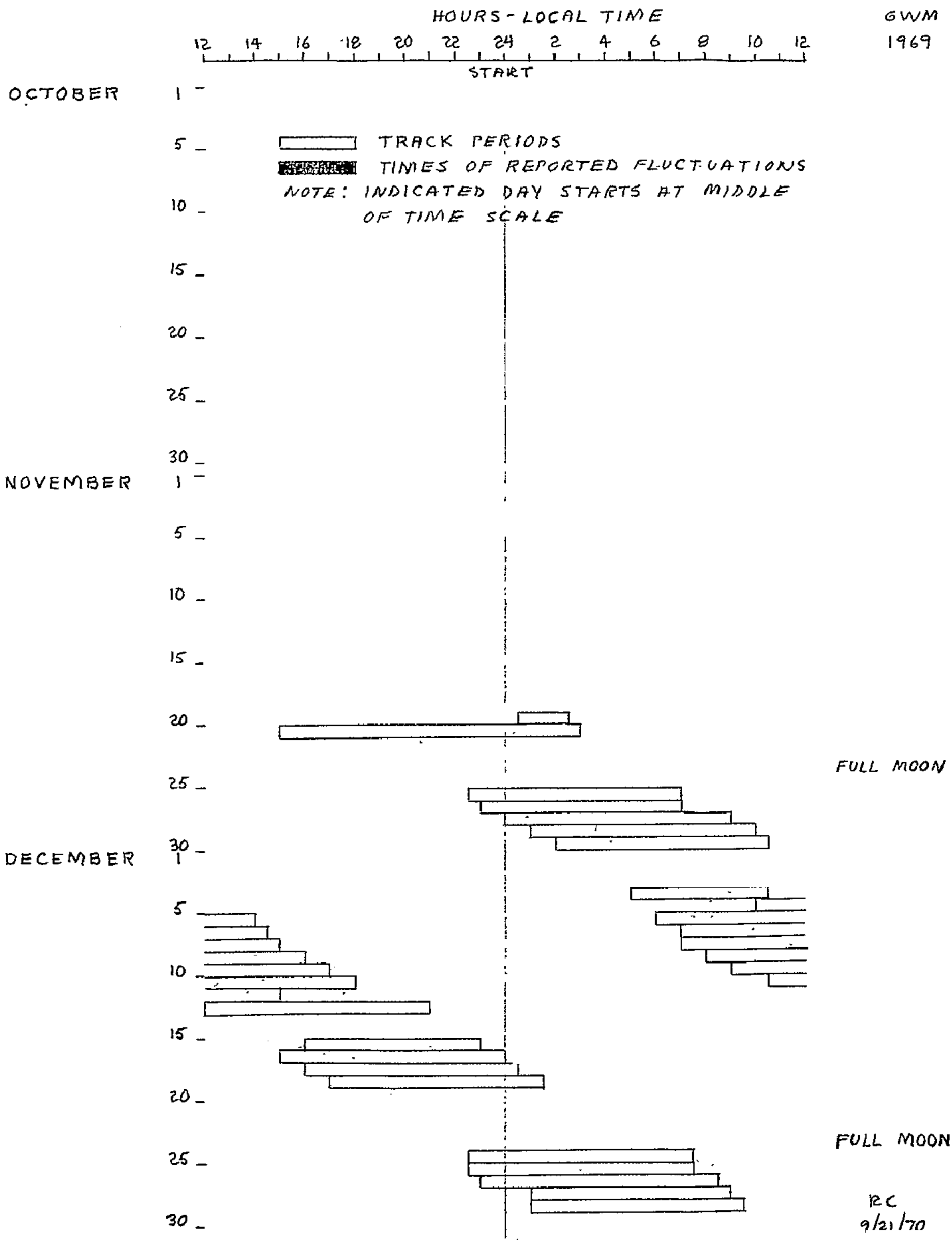

Figure 7 - GWM Support Periods and Reports of Fluctuations, Nov. - Dec., 1969

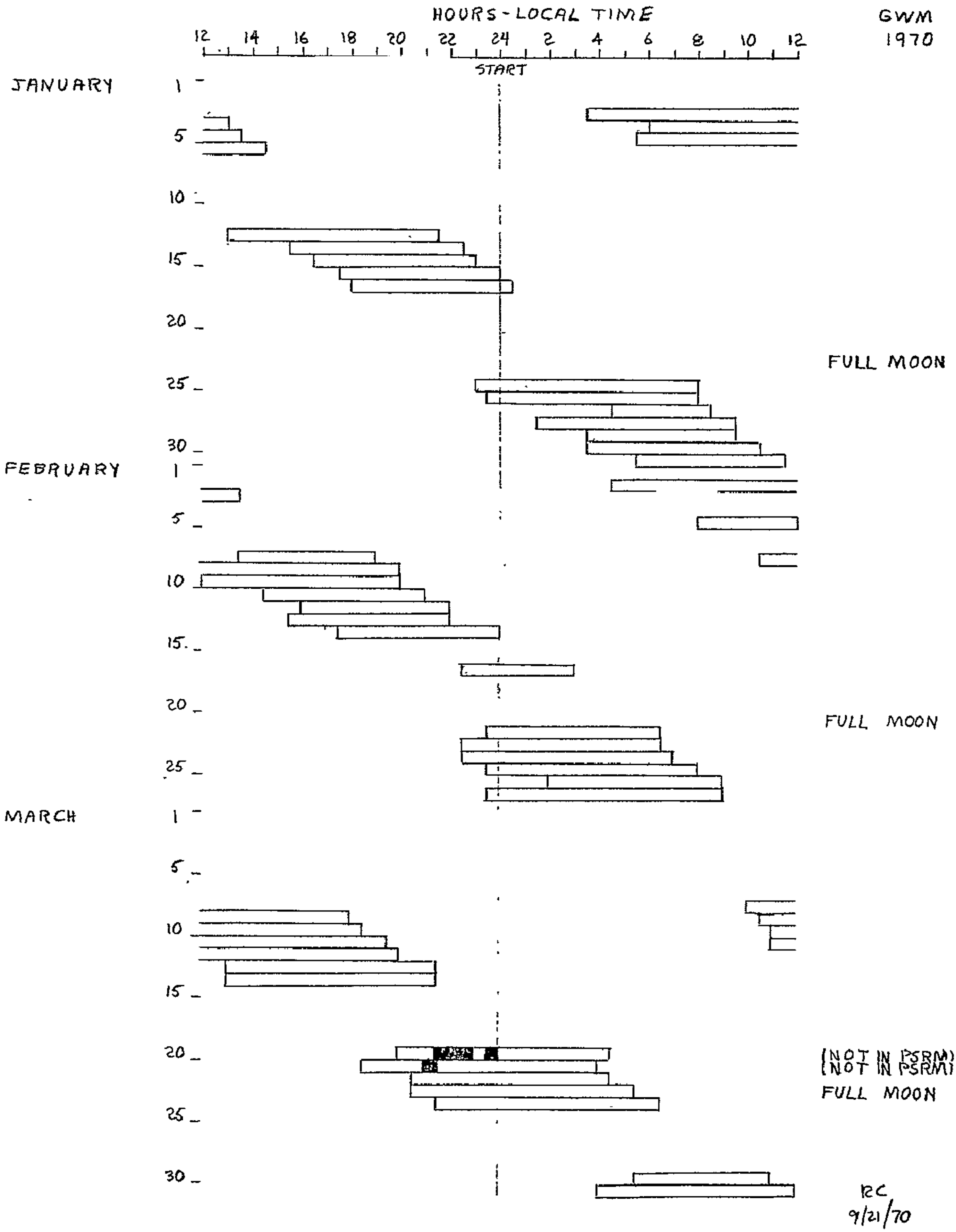

Figure 8 - GWM Support Periods and Reports of Fluctuations, Jan.-March, 1970

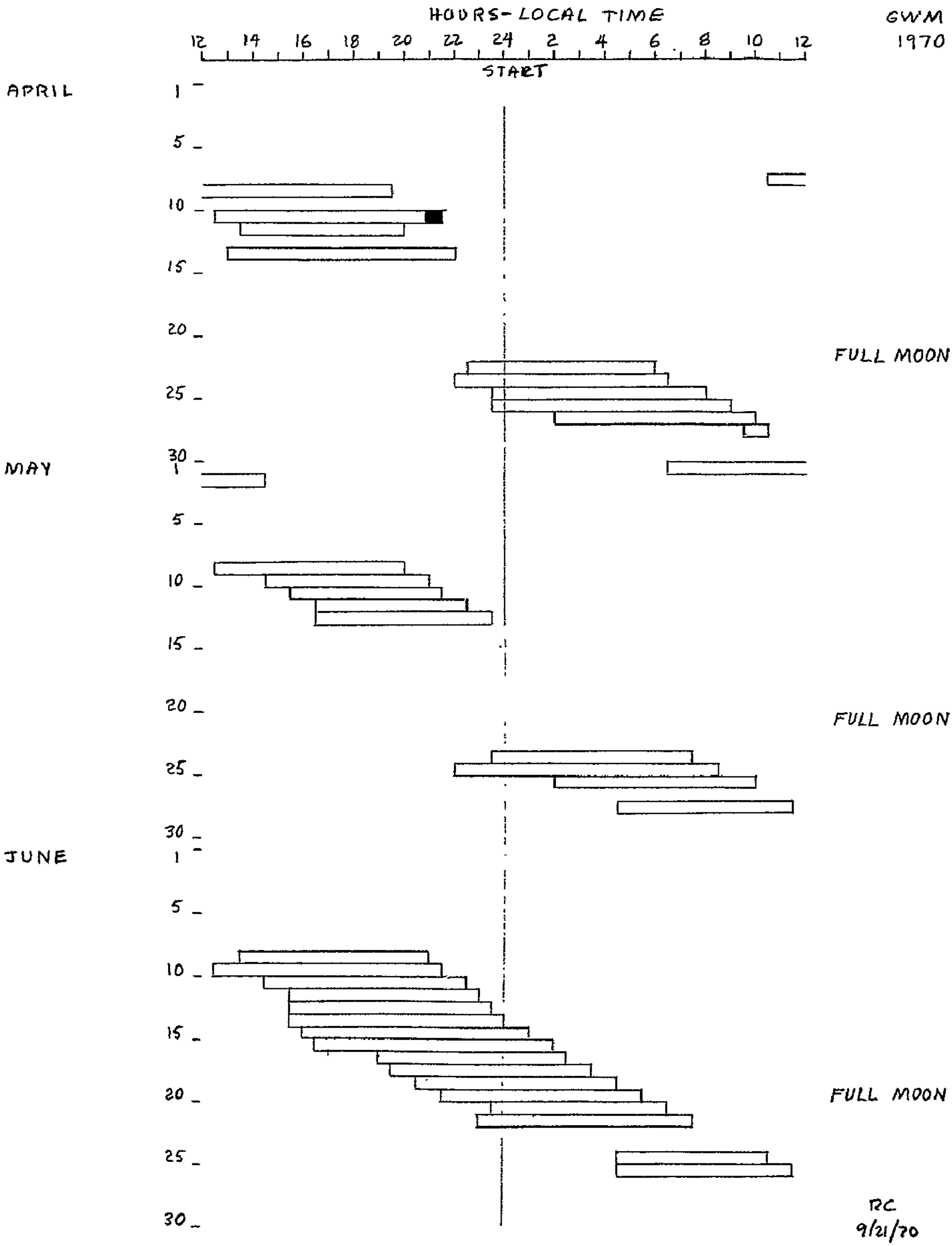

Figure 9 - GWM Support Periods and Reports of Fluctuations, April-June, 1970

The only other station with any reported occurrences is HAW, with only two reports; - February 19 and May 22-23. The local times of occurrence were 2344 to 2400 on February 19, and 0020 to 0100 on the morning of May 23, - again consistant with the general time frame of other observations. It is noted that February 19 was the date with reports at both ACN and CYI also, and May 22 was one of the dates of a report at CYI.

3.2 MAGNITUDES OF FLUCTUATIONS

Unfortunately, there is no program available at this time to perform a statistical analysis on the magnitudes of the signal disturbances. All of the data is based upon visual observations from analogue recording of the signal levels. To make the best use of the available recordings, the data has been broken, where possible, into segments containing similar levels of maximum signal deviations. By comparing the periods of maximum deviations, it may be possible to gain insight as to the nature of the responsible phenomena.

3.2.1 NOVEMBER, DECEMBER AND JANUARY REPORTS

There were no reports in November, 1969. The reports for December 1969 and January, 1970 are summarized in Table 4. There were two isolated reports in December.

Table 4

Magnitudes of December 1969 and January 1970 Fluctuation Reports

Date	Station	Start (L.T.)	Stop (L.T.)	Length (Minutes)	Max. Fluct.
Dec. 13	CYI	2138	2212	34	4 dB
Dec. 24	ACN	N. R.	N.R.	N.R.	~6 dB
Jan. 20	ACN	2041	2049	8	5 dB
Jan. 22	ACN	2101	2200	59	3 dB
Jan. 23	ACN	2055	>2133	> 38	13 dB
Jan. 24	ACN	2150	2210	20	N.R.
Jan. 25	ACN	2152	2205	13	N.R.

N. R. - Not reported
L.T. - Local time

The January period disturbances peaked at 13 dB on the 23rd.

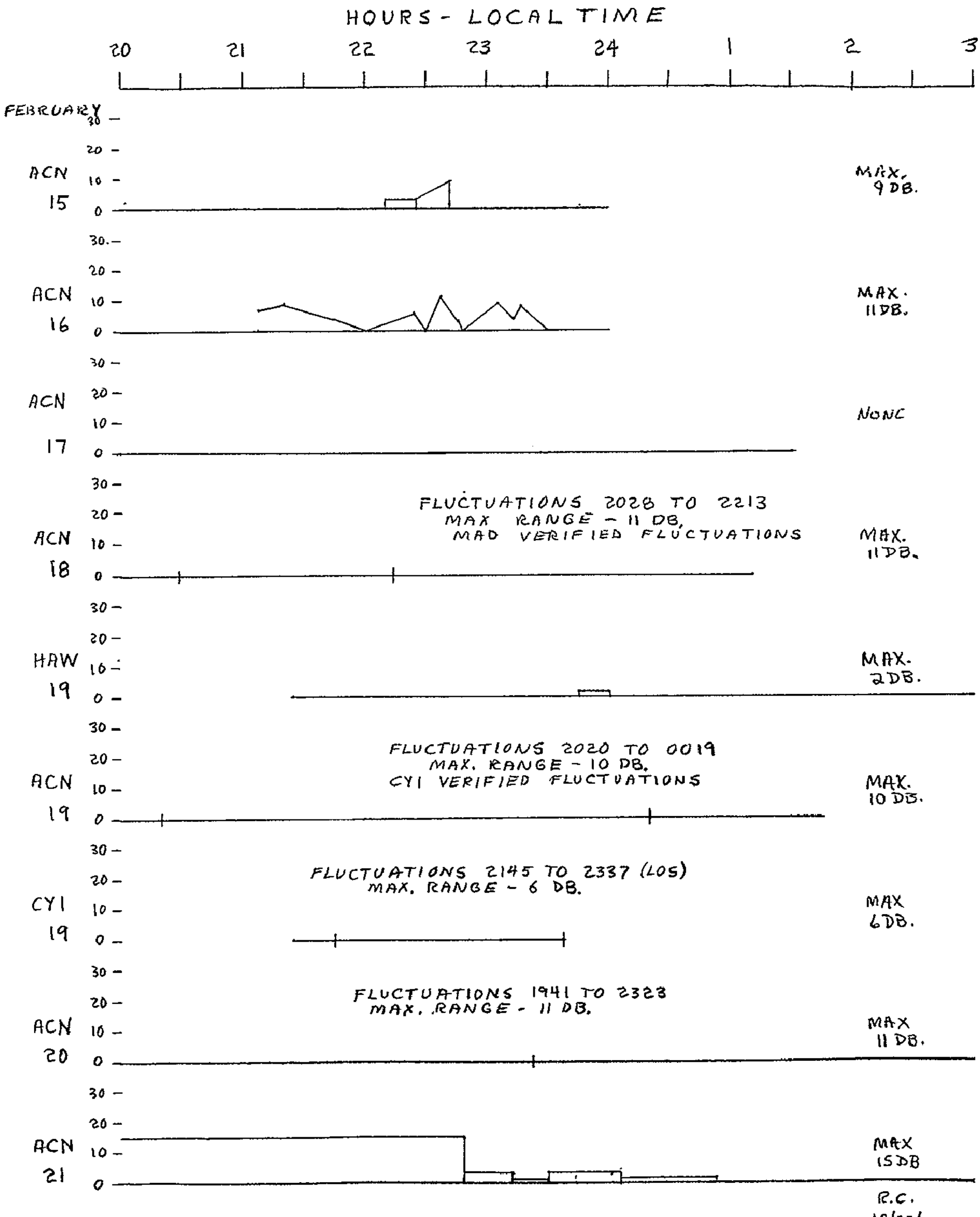

Figure 10. Maximum Reported Signal Fluctuations (DB.). Source: PSRM's

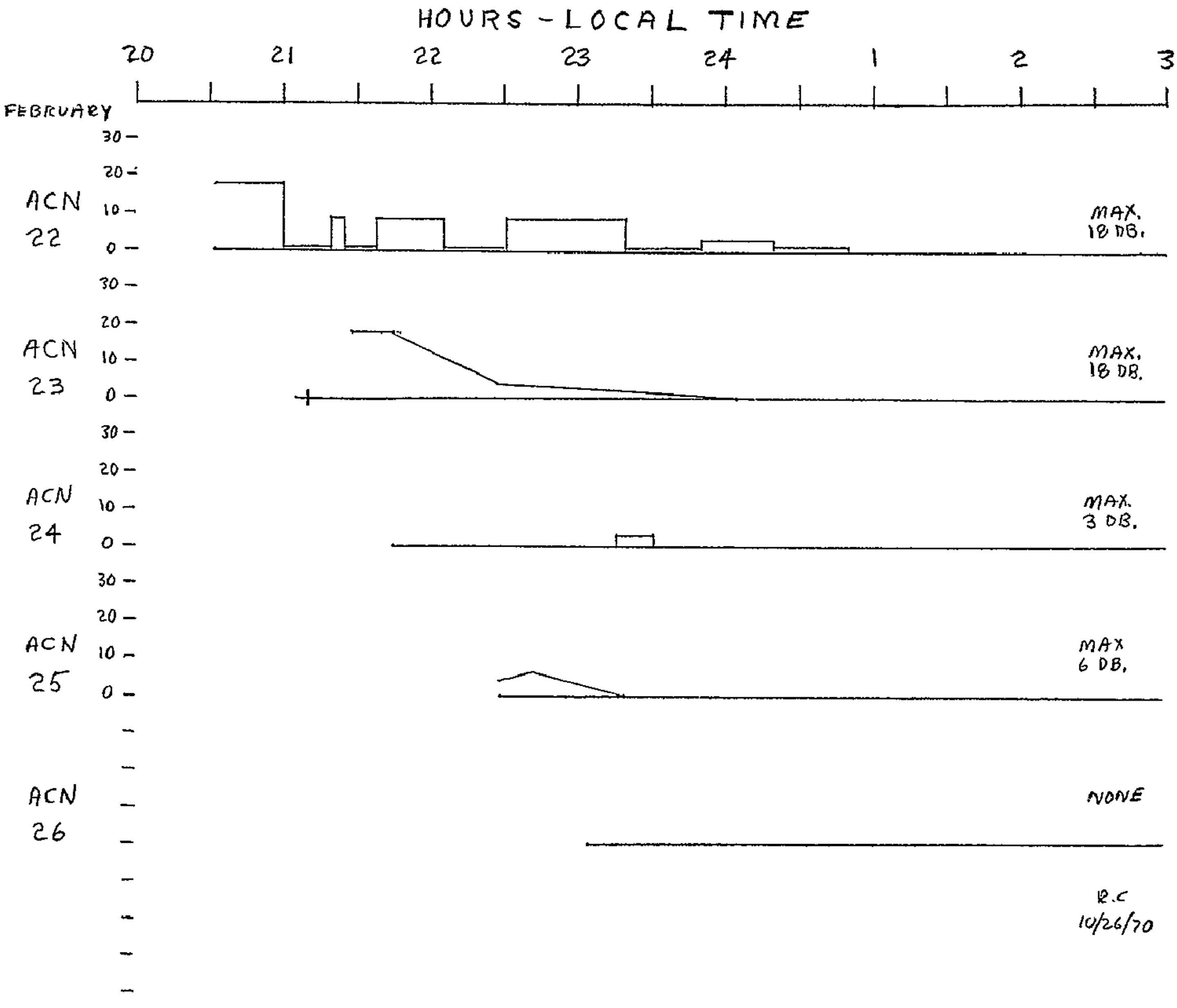

Figure 11. Maximum Reported Signal Fluctuations (DB.). Source: PSRM's

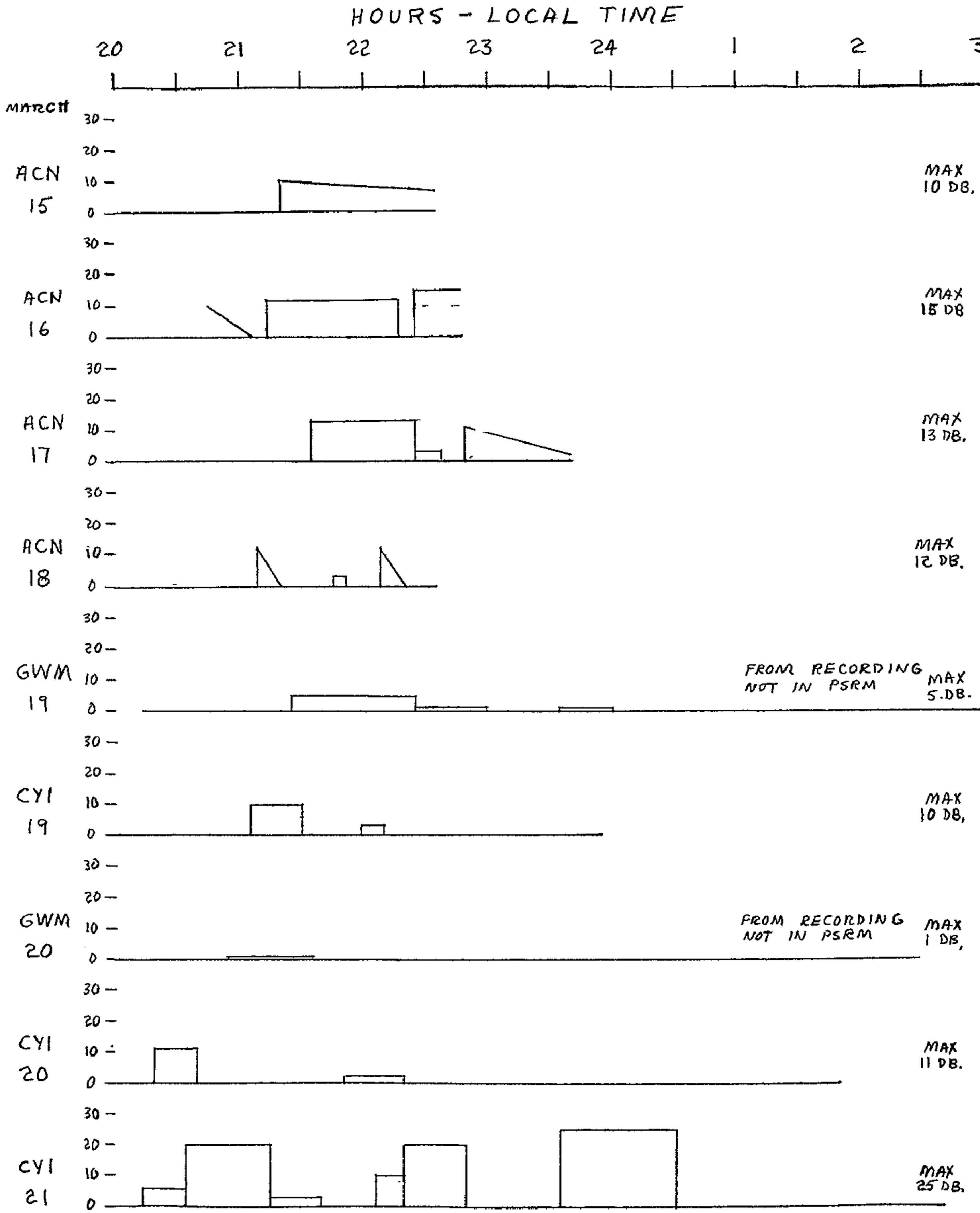

Figure 12. Maximum Reported Signal Fluctuations (DB.)
Source: PSRM's and Chart Recordings

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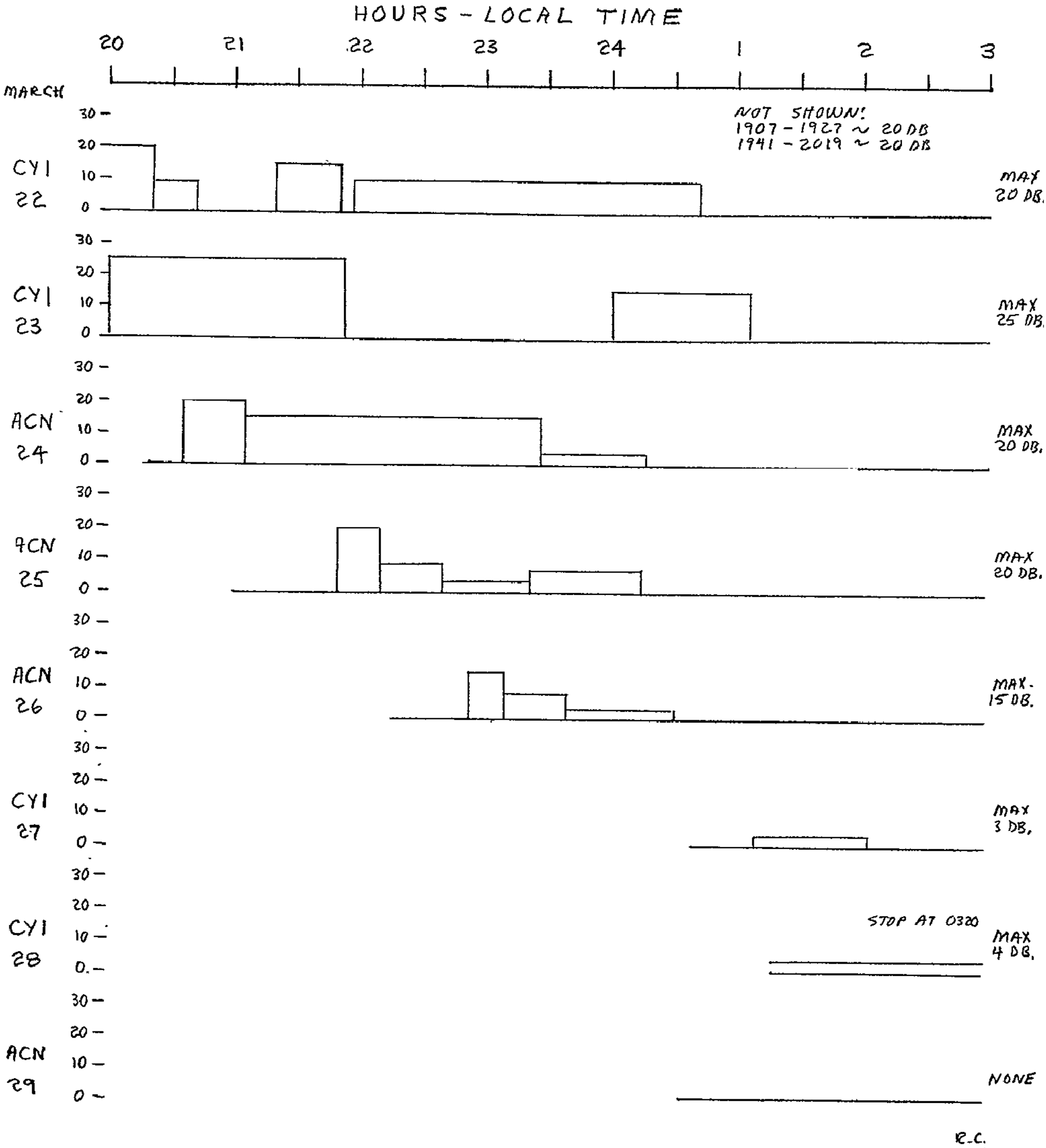


Figure 13. Maximum Reported Signal Fluctuations (DB.)
Source: PSRM's and Chart Recordings

3.2.2 FEBRUARY REPORTS

The reports for February are shown in Figures 10 and 11. In February, ACN was providing continuous support during the period of reported observations. Thus it is clear that, for ACN at least, the disturbances peaked at 18 db on the 22nd and 23rd. CYI reported a peak 6 db disturbance on the 19th, during the brief period they were called up to verify the ACN reports. No simultaneous reading was recorded to compare the magnitude of the disturbance at the two stations. The only data along this line is the one simultaneous reading reported back to the Network Controller which showed ACN observing 8 db when CYI was observing 4 db variations. This was the only time CYI supported during the period of reported observations. HAW reported a brief period of 2 db peak variations on the 19th.

3.2.3 MARCH REPORTS

The reports for March are shown in Figures 12 and 13. ACN and CYI were both providing support. The peak reports for the month were 25 db at CYI on the 21st and 23rd. The only station besides ACN and CYI reporting any observation during this period was GWM, with peak disturbances on the order of 5 db. The reports for March are more detailed than those for February, since the March recordings are still available for analysis. One interesting fact was determined from reviewing these recordings in detail. That is the fact that there are periods of no signal disturbance interspersed with the signal fluctuations, even on the days of highest reported disturbances.

Samples of the AGC recordings for three disturbed support periods in March are shown in Appendix A. These samples are taken from the recordings of CYI on the 21st (Figures A-1 through A-3), CYI on the 23rd (Figures A-4 through A-7), and ACN on the 24th (Figures A-10 through A-12). These samples were chosen to represent typical periods of observation, and not necessarily the worst case in each support period.

The samples from March 21 are taken over an approximately 3 hour period. By referring to Figure 12, it can be seen that the times of the samples place them in the three different periods of activity on that night. There were long periods of no signal disturbance between each of the samples. The first sample (Figure A-1) is taken from a peak period of signal fluctuation. During these times the signal fades are at least to the receiver threshhold, -159 dbm. The recording also shows signal enhancement of at least 5 db over the nominal level of -140 dbm. These fluctuations cause numerous dropouts of the PCM decom (top of figure) and can cause the receiver to lose lock (shown here once after the 2039 mark). The other two samples (Figures A-2 and A-3) are taken from less active periods, but the fluctuations still resulted in dropouts of the PCM decom.

Four samples are shown for CYI on the night of March 23. The first three are from the most active period of the month, with the second (Figure A-5) being the most severe of all samples shown here. Here there are many dropouts of the PCM decom and the receiver is seen to lose lock several times. The fourth sample was taken after local midnight during a separate period of activity.

The final three samples (Figures A-10 through A-12) are shown for ACN on the night of March 24. These were not taken from the most active period on that night, but are rather typical of the less severe fluctuations. These fluctuations did not cause any dropouts of the PCM decoms.

3.2.4 APRIL, MAY AND JUNE REPORTS

The reports for April and May 1970 are summarized in Table 5. There were no reports in June, 1970. There were only two reports in April and they were not grouped. The maximum report was 20 db at GWM on the 10th. The May reports are grouped in the May 21-22 period, with a peak disturbance of 7 db at CYI on the 21st. There was one additional isolated report of 4 db variations at ACN on May 28.

Table 5

Magnitudes of April and May 1970 Fluctuation Reports

Date	Station	Start (L.T.)	Stop (L.T.)	Length (Minutes)	Max. Fluct.
April 10	GWM	2047	2137	50	20 db (at LOS)
April 16	CYI	2104	2130	26	7 db
May 21	CYI	2042	2130	48	7 db (from AOS)
May 22	HAW	0020	0110	50	3 db (8 db in wide BW)
May 22	CYI	2149	2230	41	5 db (from AOS)
May 28	ACN	0317	0544	87	4 db

L.T. = local time

4. COMPARISON WITH SOLAR EVENTS

Initially, these observations had been attributed to some undesignated solar phenomena. In fact, a lot of known ionospheric disturbances are related to magnetic storms, which in turn are related to solar flare activity. The primary delayed effect can occur as long as 40 hours after the flare when charged particles arrive at the earth. These particles charge the radiation belt, and cause magnetic storms, which in turn causes ionospheric storms and auroral phenomena. A review was made of the direct observation of solar flare activity and the indirect observations of several associated geophysical phenomena during the period covered by this study to determine if there could be any connection between these phenomena and the signal fluctuations.

A solar flare is a sudden brightening of the solar surface, normally viewed in the spectral line $H\alpha$ of atomic hydrogen. During an active period, the spectral intensity rises to a maximum in a few minutes, and then decays for periods extending from one-half to several hours. Flares of importance 2 and above usually result in observable terrestrial disturbances.

A review was made of all solar flares of importance 2 or greater for the period November 1969 through June 1970. [2]The periods of considerable activity that stand out are:

1. November 18-24 (12 flares)
2. February 11-13 (6 flares)
3. March 1-3 (8 flares)
4. March 24-26 (5 flares)
5. April 5-8 (6 flares)
6. June 10-16 (30 flares)

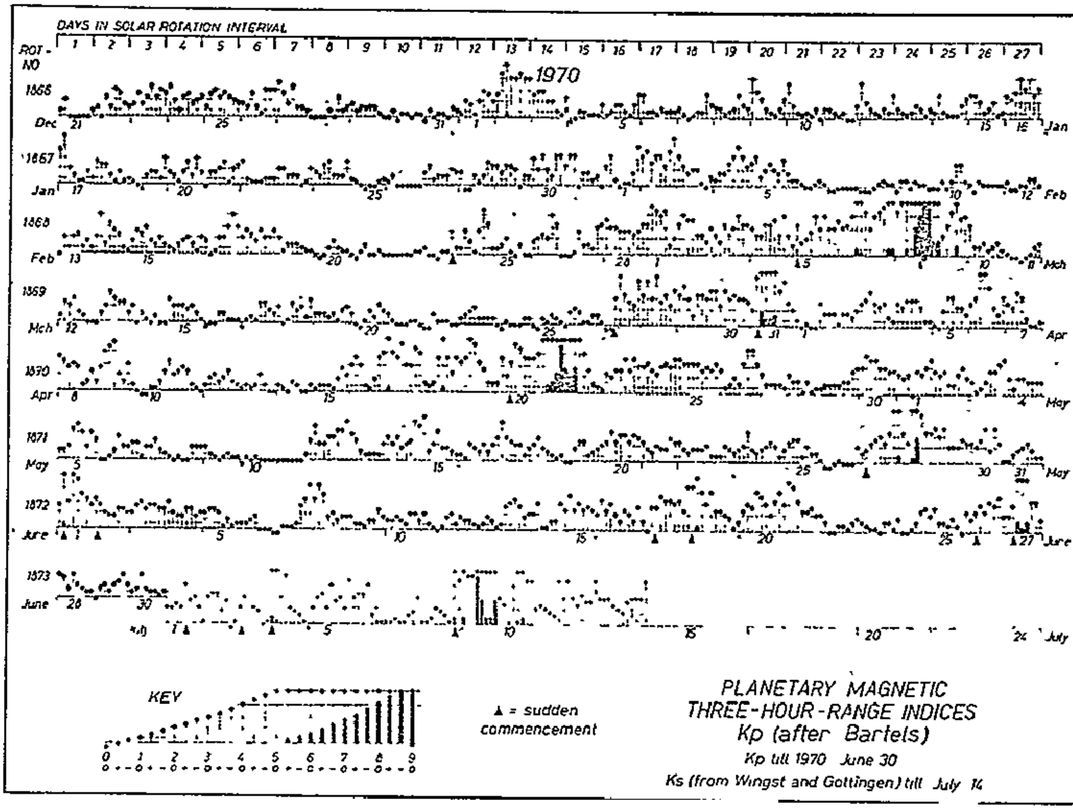
There are no reports of ALSEP signal fluctautions during the two extreme periods of solar flares, 1 and 6 above. In fact, there are no reports of fluctuations during any of the above periods of activity except the March 24-26 period, which is the least active of the six periods shown.

A review was made of the index of solar radio emissions based on the observations at 2800 MHz made at the Algonquin Radio Observatory near Ottawa. This index is a good guide to any nominal solar emission that could interfere with S-band propagation.

Appendix B contains plots of the observations of 2800 MHz solar emission for the period November 1969 through June 1970. [2]It can be seen that the observed flux varies by a factor of two to one over the 27-day (solar rotation) cycle. Peak readings were obtained on November 23, February 12, April 10, May 15 and June 15. None of these dates correspond to the periods of fluctuation reports.

The Kp and Ap magnetic indices are shown in Figure 14[3] for the period of this report. The two peak periods of extremely disturbed magnetic field are March 8-9 and April 21-22. There are no reports of fluctuations on these days. CYI was supporting on both days. On the night of April 21, CYI was supporting for the hours 1945Z through 0200Z, the time during which the majority of observations have been made. The Kp index during the February and March periods of fluctuation reports is at a minimum of activity, and if anything, shows a negative correlation with the observation of fluctuations.

GEOMAGNETIC ACTIVITY INDICES



DAILY AVERAGE INDICES Ap

	1969						1970					
DAY	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE
1	17	3	3	20	3	5	8	9	22	6	11	28
2	6	5	2	31	11	4	30	20	16	6	9	9
3	3	14	4	18	16	4	9	7	15	11	10	11
4	3	13	4	10	6	7	3	12	16	10	6	8
5	2	7	18	6	6	18	6	10	12	9	12	6
6	4	5	20	16	3	19	5	4	25	23	6	3
7	6	8	13	6	12	5	5	2	42	10	6	9
8	5	9	19	3	14	5	6	2	149	12	4	13
9	7	11	10	9	40	12	10	3	47	18	4	5
10	7	6	8	21	37	8	6	5	7	3	2	6
11	6	4	8	10	11	11	4	3	3	8	3	4
12	12	21	4	9	7	5	8	3	6	6	15	5
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14	13	6	11	3	2	4	6	11	3	3	13	8
15	5	4	19	3	2	5	7	8	7	5	10	13
16	10	4	7	5	2	11	17	5	3	14	6	9
17	4	6	12	6	3	4	11	10	5	29	10	13
18	3	7	19	7	4	3	6	9	6	18	5	27
19	2	13	9	10	7	4	5	4	5	21	6	8
20	3	7	8	5	4	3	7	3	4	21	13	18
21	4	6	5	8	2	3	6	2	3	90	8	17
22	7	5	3	7	10	7	5	2	2	41	6	4
23	5	11	7	4	5	11	5	4	5	14	7	4
24	4	6	6	14	6	9	7	11	2	16	6	6
25	4	4	10	7	6	9	2	4	3	17	7	6
26	20	15	4	4	11	10	2	10	5	13	2	13
27	45	21	6	8	22	9	6	8	16	10	15	35
28	4	6	47	6	9	4	5	14	21	5	45	7
29	2	4	71	4	14	4	6		17	7	13	6
30	13	4	90	1	18	2	12		16	18	11	5
31	6	5		5		3	8		51		6	
MEAN	8	8	15	9	10	7	7	7	17	16	9	10

Figure 14. Geomagnetic Activity Indices

A review was also made of the listings of reports of SID events in "Solar-Geophysical Data" reports for the period of interest. No correlation was found between the SID events and the fluctuation reports.

In summary, no correlation has been found between solar events and the reported disturbances to the S-band signal.

5. ANALYSIS OF OCCURRENCES

Since the observations cannot be attributed specifically to solar events, other phenomena must be investigated if an explanation is to be found. This requires further analysis and development of the data.

5.1 PATTERN OF OCCURENCES

The overriding pattern of occurrence was previously mentioned, i.e., the fact that some 88 per cent of the reports were from ACN and CYI. However, the Network-wide experiences should be reviewed if an explanation is to be attempted. Combining the results of the studies of both the times and magnitudes of occurrences shows that the peak of activity was in a definite time period in March. This is true from either the standpoint of extent of time, up to 5 or 6 hours per day and 14 continuous days, and magnitude, maximum 25 db variations. The February reports also fit a definite time period and were nearly as severe, up to 4 or 5 hours per day and 11 continuous days, and maximum 18 db variations. Several other periods are also indicated. There is a period in January covering six days with a maximum 13 db variation, and there is a two day period in May with maximum 7db variation. These periods account for 36 of the 41 reports being in some definite pattern of active periods, i.e., more than just isolated reports. In addition to falling into periods of continuous days, these reports all fall within a daily local time frame of 1900 to 0300 hours. Actually, in the majority of reports, the time frame is narrower, 2000 to 2400 hours local time. In fact, even the five remaining isolated reports fit into the same pattern of local time of occurrence.

There is another factor in the above pattern which initially is not so obvious. That is a correlation of the phases of the moon with the reported observations. The times of the full moon have been included in the time lines in Figures 1 through 9. In fact, the four periods of activity outlined above are clustered about the times of the full moon in their respective months.

Finally, a case can be made at this time for an overriding longer term pattern. The peak of the reported disturbances was in March, with February a close second. There were comparatively minor reports for the two proceding months (December and January) and the two following months (April and May). And the whole period of the data for this study was begun by a partial month with no reports (November) and completed with a month of no reports (June). This results in a somewhat symmetrical monthly pattern centered during the February - March period. It was noted above that the peak of activity was in March and also that the peak reports for March were on the 21st and 23rd. March 21 was the date of the vernal equinox. The phenomena would appear to peak near the equinox and disappear near the solstice.

In summary, based on the data in hand, the pattern appears to be comprised as follows: a geographically limited nocturnal phenomena dependent upon a monthly (or lunar) cycle, and peaking at the equinox. While realizing the extent and nature of the data (the wide range of observation sources and the lack of quantitive data), this at least provides a working hypothesis which can be developed further. The dependent on the equinox will have to await further data. The other patterns are further substantiated in the following sections.

One final puzzling factor about the observations is that, while they do generally occur during the same hours of local time, no further correlation (or pattern) of the data has yet been found on a day to day basis. The recording of CYI on March 23rd is a good example. This was a day of peak 25 db disturbances, but with a two hour period of no observations. There is nothing comparible in the previous or following day's recordings. This is also demonstrated by looking at several of the AGC samples in Appendix A. Comparing the same time period on two succeeding nights at CYI and ACN (Figures A-5 and A-10) fails to show any manner in which the two are comparible.

As mentioned previously, Figure A-5 represents the most severe of all samples shown here, while Figure A-10 is typical of relatively minor disturbance.

5.2 NOCTURNAL PATTERN

All of the occurrences were reported during night-time hours, generally between 2000 and 2400 hours local time. Due to the nature of the moon view periods, each hour of the day has had approximately the same allocation of support assignments. This has varied from station to station depending on the result of station scheduling, but is true network wide. A summary of the approximate number of times ACN and CYI were supporting at various hours around the clock is shown in Table 6.

Table 6

Tabulation of support assignments during specific hours at ACN and CYI

		0600	1200	1800	2400
ACN	Nov. - Dec. 1969	10	9	7	10
	Jan. - March 1970	18	6	12	24
	April - June, 1970	7	9	14	12
	Total	35	24	.23	46
CYI	Nov. - Dec. 1969	8	1	8	8
	Jan. - March 1970	8	23	17	9
	April - June, 1970	7	15	7	7
	Total	23	39	32	24
	Total for ACN & CYI	58	63	55	70

It can be seen that the two stations which did have the majority of reports, had quite sufficient exposure at other hours of the day to make observations if there were anv to be made.

5.3 GEOGRAPHICAL PATTERN

It is quite obvious which stations have made observations. However, it would be presumptious to assume that the phenomena does not occur at the locations of all of the balance of the stations. For example, several stations were not scheduled for support activities until after the peak of the disturbances reported in February - March. To establish the overall geographical pattern it was necessary to examine the support periods for all stations to verify that each had sufficient operation during the time of the reports to establish its status in the pattern. Such a station by station analysis has been made.

Table 7 summarizes the sufficiency of the data available from all stations and gives the resulting judgment as to whether or not the phenomena occurs, where data is judged sufficient.

Table 7

Data Sufficiency and Resultant Effects

Station	Not Sufficient	Partially Sufficient	Sufficient	Judgment
ACN			X	full effect
BDA		X		no known effect - reduced effect could be undetected
CRO			X	no effect
CYI			X	full effect
GDS		X		no known effect
GWM			X	minor effects
GYM			X	no effect
HAW		X		minor effects - additional effects could be undetected
HSK	X			
MAD	X			
MIL	X			
TEX			X	no effect

To carry these results further, it can be summarized that only ACN and CYI are known to have observed the full phenomena. At the other extreme, CRO, GDS, GYM and TEX show no observations. This leads to the conclusion that the phenomena is localized, although the exact local can not be firmly established from the available data. Indications are that it is centered around the ACN - CYI region. However, the extent of the region is confused by the fact that MAD is unknown, with a strong suspicion that it is involved, and BDA and MIL remain completely unknown factors. This simple approach to a localized geographical pattern is further confused by the reports of minor observations at GWM and HAW. These reports might suggest some connection between the phenomena and the geographic latitude. A quick check of the station locations (Table 1) shows that both GYM and TEX which show no disturbances are at the same latitude as CYI. Therefore the geographic latitude does not appear to be a factor.

5.4 LUNAR CYCLE PATTERN

It is important to extablish that the monthly pattern of reports is genuine and not just a result of coincidence arising from the limitation of data gathering being restricted to the moon view periods. Table 6 showed that ACN and CYI had a fairly uniform exposure of hours of the day for support activities. Because of the nature of the moon view periods (see Table 2) this also shows that the stations had a fairly uniform exposure to various phases of the moon during support periods. This can also be seen by referring to the time lines of figures 1 through 6. This fact also applies network wide, since the network supported on a continuous basis.

Since the February active period was continuously covered by ACN, a review of these reports gives insight into the pattern at a single station. The effect appears to start with a brief occurrence of minor disturbance. On the succeeding nights the length of the occurrence is increased in both directions, and the magnitude increases until a peak is reached 6 or 7 nights later. Due to the limit of the view period, it is not possible to determine if the effect trails off in the same manner.

The coverage of the March active period was shared by ACN and CYI. It was previously noted that the peak reports for this period were at CYI on the 21st and 23rd. Since ACN was not supporting during this critical 5 day period, it is not possible to determine if the disturbance would have peaked at ACN on the same dates. Also it is not possible to tell if the magnitude would have been larger at ACN than at CYI. A further review of the reports points out the problem. ACN had peak reports of 10 to 15 db on the 15th, 16th, 17th and 18th. ACN also had reports of 20 db peaks on the 24th and 25th. It is assumed that the causing phenomena is continuous and that had ACN been supporting during these interim 5 days, they would have recorded observations of peak deviations of at least 15 db. But it is also possible that the readings may have reached a peak of greater than the 20 db of the 24th. On the 19th and 20th CYI supported, but only recorded peaks of 10 and 11 db, respectively. On these two days, CYI was supporting during the critical hours of 2100 to 2300 when the peaks had been noted at ACN the previous four nights. Comparing the respective values of peak disturbance and the extent of time over which the observations were made, can lead to the following possible alternatives:

1. The phenomena occurs simultaneously at both stations, but affects ACN more than CYI.

2. The phenomena does not occur simultaneously, but rather occurs later at CYI than at ACN.

Unfortunately, there is insufficient data available to resolve this question. At the end of this active period, on the 26th, 27th and 28th, the stations were not supporting during the hours of previous peak observations. Here again these limitations of the moon view period on the data prevents us from accurately establishing the extent of the phenomena.

6. DISCUSSION

The theory of amplitude scintillation due to the ionosphere is well developed, and it has been generally accepted that amplitude fluctuation varies inversely proportional to the square of the frequency. Under normal conditions the influence of the ionosphere on various scintillation effects has been considered to be negligible at frequencies of the order of 500 MHz and above.[4] The highly selective pattern of the reported S-band disturbances makes it unlikely that the cause is any such nominal effects.

The fact that the occurrences have appeared around the time of the full moon suggests a possible connection with the passage of the moon through the magnetic tail. If this were the case, then it would be expected that all operating stations would have observed the phenomena during the periods of peak observations from the anomalous stations. Because continuous around the clock station support was maintained, either two or three other stations had opportunities to make observations each day in the February and March periods when ACN and CYI were making observations. BDA, CRO, GDS, GWM, GYM, HAW and TEX all had opportunities on some of these days. Due to the nature of the view period, all of the stations had the opportunity during approximately the same local hours as ACN and CYI. With the exception of the few previously reported cases, the stations did not make any such observations. Therefore, the observations cannot be attributed to any magnetic tail properties.

Consideration was also given to the possibility that the phenomena could be related to geomagnetically trapped particles[5]. The radiation belts are maintained by charged particles becoming trapped along the field lines of the earth's magnetic field. If the mirror point of these trapped particles is at a low enough altitude, the particles will eventually be removed from the trapped population via ionization energy loss. This process may cause disturbance to the ionosphere or the atmosphere, depending on the altitude of the mirror point. This is known to effect low frequency propagation paths, at least.

Because of the nature of the motion of trapped particles, it would be a complex problem to predict which station locations might be effected. The problem is made more complex by not knowing at which mirror point altitude the disturbance may be occurring, since any relationship between the particle diffusion process and a mechanism that would disturb S-band propagation is not apparent. However, at this time there is a possibility of a correlation between the pattern of trapped particle motion and the irregular geographic pattern of the S-band observations. To carry this idea one step further, the approximate values of magnetic intensity over the MSFN stations are shown in Table 8. The interesting point here is that ACN stands out with the smallest value of magnetic intensity, followed in order by GWM, HAW, and CYI. The trapped particles travel down the field lines until the magnetic intensity increases enough to cause them to reverse direction (at the mirror point). If trapped particles are involved, they would penetrate to lower altitudes at ACN than at any other MSFN station.

Table 8[6]

Approximate Magnetic Intensities over MSFN Stations (300 KM Altitude)

Station	Magnetic Intensity (Gauss)	Station	Magnetic Intensity (Gauss)
ACN	.243	GYM	.41
BDA	.44	HAW	.317
CRO	.47	HSK	.51
CYI	.335	MAD	.380
GDS	.44	MIL	.44
GWM	.315	TEX	.43

This reflects the fact that ACN is the MSFN station situated closest to the "South Atlantic Anomaly." The anomaly acts as a sink in the trapped particle diffusion process and it is where radiation belt particles have their greates chance to interact with the earth's atmosphere. It is an interesting fact that three STADAN stations where VHF propagation disturbances have been reported[7] are also situated closer to the anomaly than other STADAN stations. This is shown by their approximate magnetic intensites (300 KM altitude): Quito, 0.28; Lima, 0.248; Santiago, 0.24, which are close to the ACN level. This would still leave the balance of the pattern of the occurrences to explain: time of day, lunar cycle and dependence on the equinox. The dependence on the equinox is especially puzzling since the seasonal variation of the magnetic intensity at the altitudes of interest is negligible. Any such reasonal correspondence would then probably be with the particle source mechanism.

Several previous studies [7,8] on data gathered by the STADAN tracking stations show the same general pattern of propagation disturbance as is shown here with the ALSEP data. While the STADAN data represents signals in the VHF frequency range vs. the ALSEP S-band data, it does indicate a phenomena which may be scaled to fit our case. The data records for the STADAN tracking stations at Quito, Lima and Santiago over a full year show a diurnal maximum of disturbance close to local midnight and a seasonal maxima during and immediately following the equinoxes. Other STADAN stations located away from the geomagnetic equator failed to show any such pattern. This is in good agreement with the results presented here as far as the time of day and the seasonal nature of the occurrences. What is not in agreement is the dependence of the ALSEP data on the lunar cycle. The STADAN data does not show any tendency to be grouped with the lunar cycle. In fact, this is the most puzzling aspect of all of the ALSEP data. It may still be the result of the peculiar nature of the geometry of the situation, but it is not readily apparent.

The STADAN data is based upon the percentage of time of the loss of data. Therefore no details are given as to the nature (time history) or magnitude of the disturbance to compare with the recorded continuous time histories of the ALSEP data. But it does seem likely that the same or similiar phenomena must be causing both effects.

The proximity of the affected STADAN stations with the geomagnetic equator has been developed further in one of the studies[7]. In the study, the three South American stations with geomagnetic latitude of up to 30° were effected, with the magnitude of the disturbance varying inversely with the distance from the magnetic equator.

Table 9[9]

Approximate Geomagnetic Latitudes of MSFN Stations (300 KM Altitude)

Station	Geomagnetic Latitude	Station	Geomagnetic Latitude
ACN	19°S	GYM	38°N
BDA	45°N	HAW	24°N
CRO	36°S	HSK	46°S
CYI	28°N	MAD	41°N
GDS	44°N	MIL	43°N
GWM	5°N	TEX	41°N

Table 9 shows the approximate geomagnetic latitudes of the MSFN stations. ACN, CYI, GWM and HAW are all within 30° of the geomagnetic equator, while all of the balance of the stations (with nor reports) are greater than 30° from the equator. Based on the STADAN experiences, it would be expected that the decreasing order of disturbances would be: GWM, ACN, HAW, CYI. This is not supported by the ALSEP data since GWM, which is the station closest to the magnetic equator (5°), has only minor possible disturbances instead of showing the peak of the disturbances as was the pattern with the STADAN stations. Also, this would place HAW in the order to be more effected than CYI, which is not supported by the data. The alternative to this conclusion would be that there is also a longitudinal factor to the pattern. There is insufficient data to resolve that factor at this time.

7. CONCLUSIONS AND RECOMMENDATIONS

The data reported here from the operation of the MSFN station establishes the existence of propagation disturbances in at least part of the magnetic equatorial region at frequencies much higher than any previously reported. The similarities between the experiences of the MSFN stations and the STADAN stations indicate that the same phenomena has been affecting the operations of both networks, and could be expected to affect other RF receiving stations located in the appropriate regions.

The ALSEP package has continued to operate since the data for this report was gathered. As a result there is now further data available for analysis, to be used to further establish the patterns of occurrence developed here. The PSRM's report that there were further observations of signal fluctuations in September and October 1970 which are in agreement with the pattern of the previous reports. In fact, the pattern of occurrence outlined here was used to predict the September and October observations and to permit scheduling several days of simultaneous chart recordings of signal level at several of the key stations.

Reviewing the above possible causes has not produced an explanation which can account for the reported observations. Yet the relationship of the occurrences with the equinox, the lunar cycle, and the limited geographical locations, strongly suggests a connection between the observations and some phenomena dependent on the lower magnetosphere or the ionosphere. Reports of further observations from both the MSFN and the STADAN stations continue, as well as from other satellite ground stations. A most recent propagation test program at the Quito STADAN station has demonstrated scintillation of a 1550 MHz (L-band) signal,[10] thus giving independent evidence of a phenomena affecting these higher frequencies.

There obviously is a very real phenomena at work here which follows the pattern outlined. It will have to be taken into account for future planning and should be studied further. However, more data is needed to identify the phenomena and to determine how extensive its effects will be on the frequency spectrum.

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APPENDIX A

Samples of AGC Recordings

Figure	Station	Date	Local Time
A-1	CYI	March 21	2035 - 2040
A-2	CYI	March 21	2211 - 2216
A-3	CYI	March 21	2345 - 2350
A-4	CYI	March 23	2040 - 2045
A-5	CYI	March 23	2130 - 2135
A-6	CYI	March 23	2141 - 2146
A-7	CYI	March 24	0025 - 0030
A-8	GYM	March 23	2040 - 2045
A-9	GYM	March 23	2130 - 2135
A-10	ACN	March 24	2130 - 2135
A-11	ACN	March 24	2200 - 2205
A-12	ACN	March 24	2230 - 2235

APPENDIX B

Daily Solar Flux at 2800 MHz

October, 1969 through June, 1970

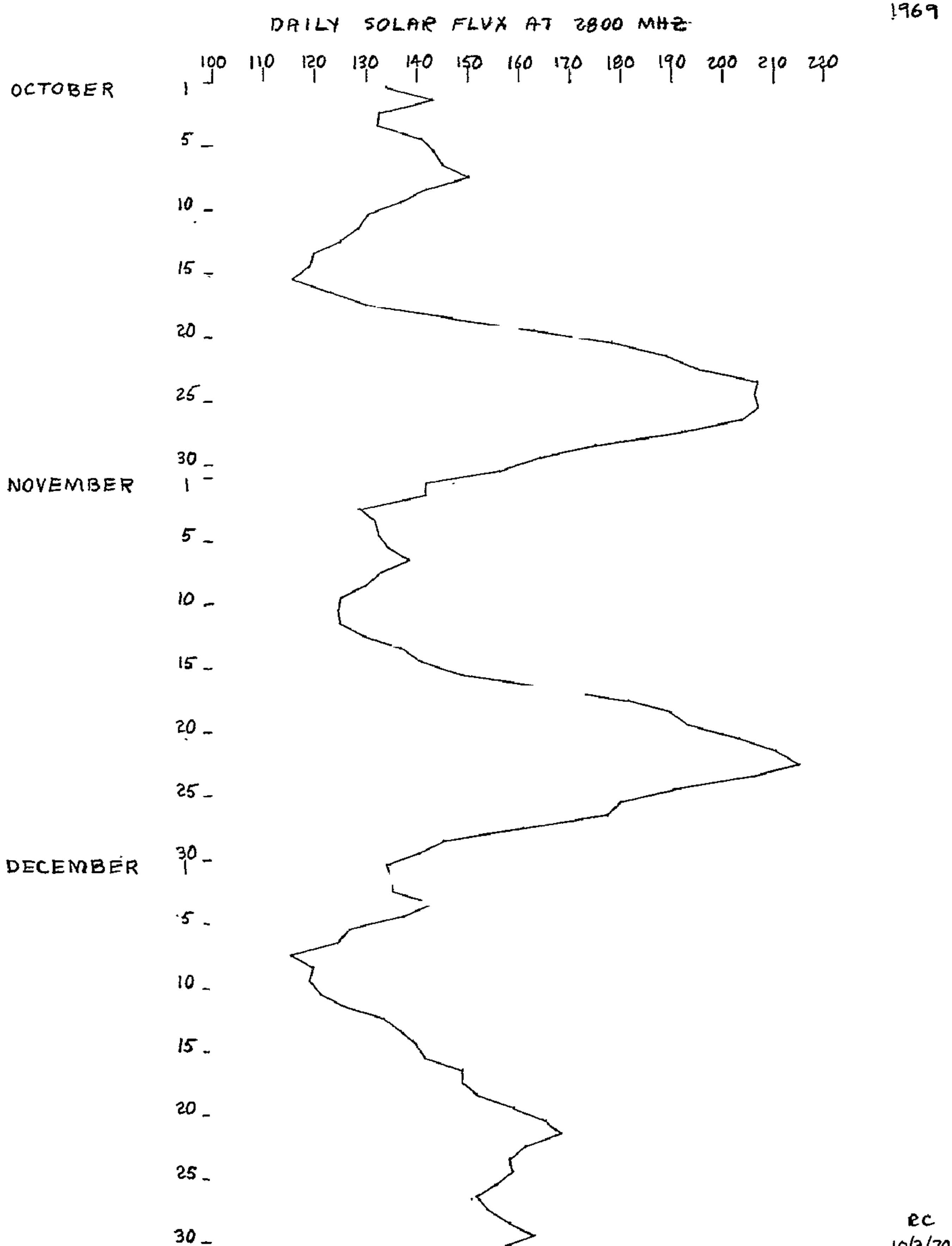

Figure B-1. Daily Solar Flux at 2800 MHz, Oct. - Dec. , 1969

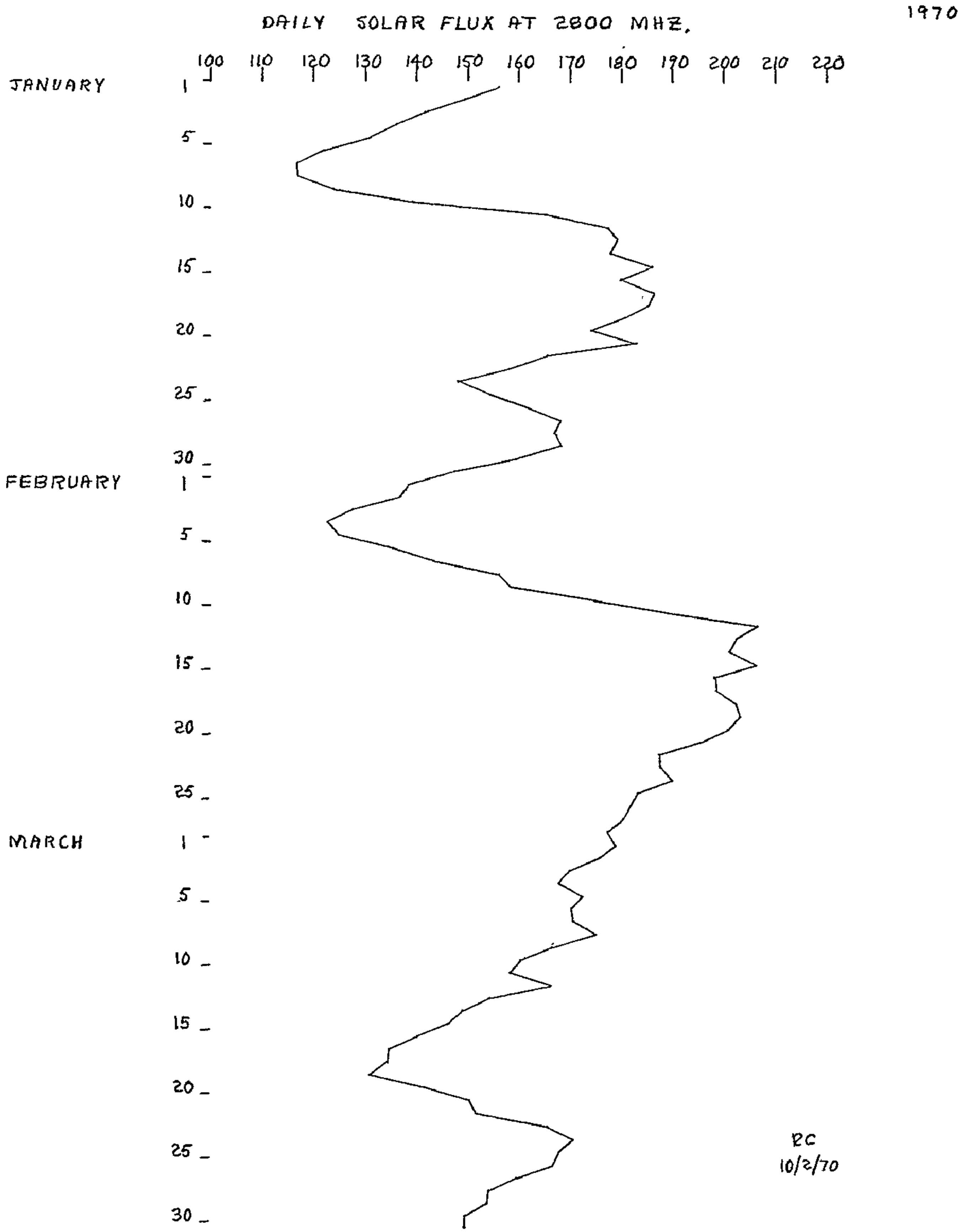

Figure B-2. Daily Solar Flux at 2800 MHz, Jan. - Mar., 1970

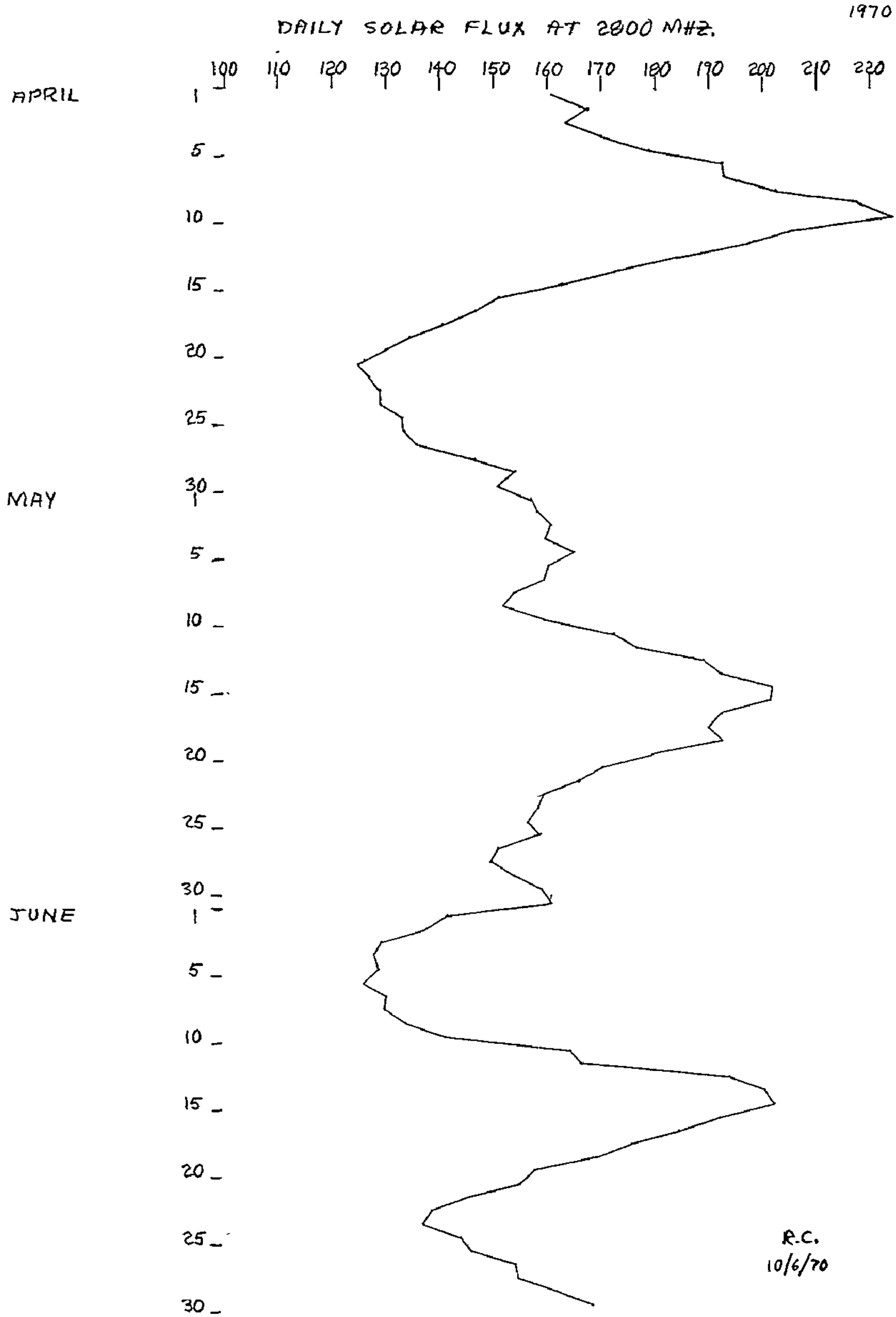

Figure B-3. Daily Solar Flux at 2800 MHz, Apr. - June 1970