Final Technical Report

for a

STUDY OF LOW FREQUENCY HYDROMAGNETIC WAVES USING ATS-1 DATA

(NGR-19-011-007

by

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Project Director Warren David Cummings
W. D. Cummings

August 20, 1976

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FORWARD

Several things have been achieved through this grant:

(1) Three papers have been written. Two have been published in the Journal of Geophysical Research and the third was presented at a meeting of the American Geophysical Union.

(2) A catalog of low-frequency oscillations has been created. This catalog spans a continuous time interval of twelve months, from September, 1967 through August, 1968.

(3) Several undergraduate students have benefited from working on the project. The three most outstanding students were Freddie Mason, Calvin Countee, and Donald Lyons. Mr. Mason is now working in a technical capacity for Libby-Owens-Ford. Mr. Countee is a graduate student in the Physics Department at Louisiana State University. Mr. Lyons will enter the graduate program in Physics at Stanford University this fall.

SOME CHARACTERISTICS OF LOW FREQUENCY OSCILLATIONS OBSERVED AT ATS-1

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Low frequency oscillations of the magnetic field at ATS-1 have been analyzed for the 25 month data interval, Dec., 1966 through 1968. Irregular oscillations and those associated with magnetic storms were excluded from the analysis. Of the 222 events identified, 170 were found to be oscillating predominantly transverse to the background magnetic field. The oscillations were observed to occur most frequently in the early afternoon hours. They also seemed to occur more frequently during Dec., Jan., and Feb. than at any other time of the year. During a given event the frequency was fairly constant. The frequency of individual events varied between 1.5×10^{-3} Hz $< f < 20 \times 10^{-3}$ Hz with a broad peak near $f = 10 \times 10^{-3}$ Hz. The event duration varied between a minimum of 10 min. and a maximum of 14 hrs and 26 min. During a given event the amplitude varied. The average maximum event amplitude was $\delta B = 3\ \gamma$.

Low frequency oscillations of the magnetic field at ATS-1 have been analyzed for the two year period, Dec., 1966 through 1968. During 17 of the 25 months of the data interval the magnetometer was operating more than 90 percent of the time. In only two months did the observation time fall below 90 percent: April, 1967 (40%) and Sept., 1968 (no data). A previous report (Cummings, et. al., 1969) was based on data from only one month (Jan., 1967).

A variety of periodic variations in the magnetic field are observed at ATS-1. Non-transverse oscillations are frequently observed during magnetic storms (Barfield and Coleman, 1970), and magnetic substorms (McPherron and Coleman, 1970). These rather irregular oscillations are not included in this report. However, compressional oscillations that are very occasionally observed during magnetically quiet conditions are included. The oscillations referred to here as transverse were selected under the criterion that the amplitude of the oscillation transverse to the spin axis of the spacecraft was at least three times as large as the amplitude of the oscillation parallel to the spin axis of the spacecraft. Under quiet, or non-storm, magnetic conditions the spin axis of the spacecraft is with 15° of the earth's magnetic field. The selection criterion eliminates oscillations for which the component of the magnetic field transverse to the earth's field is less than twice the parallel component.

As with the previous report, fifteen second averages of the data were used. The details of the ATS-1 magnetometer experiment are given in Cummings and Coleman, (1968). The period range under investigation is $50 < T < 600$ sec, or a frequency range of $1.5 \times 10^{-3} < f < 20 \times 10^{-3}$ Hz. This period range falls within the Pc4 (45-150 sec) and Pc5 (150-600 sec.) micropulsation ranges (Jacobs et. al., 1964). Approximately 85% of the time that oscillations were occurring at ATS-1, the oscillation period was in the Pc4 range.

A total of 222 separate events were recorded during the two year interval. Of these, 170 events could be classified as transverse. During a given event the period remains fairly constant, but the period of the oscillations varies from event to event. The average frequency was determined by averaging several measurements made over different intervals of the event. For each measurement the period was determined by counting the number of crests or troughs in a given time span. An average frequency was then computed by averaging the inverted periods. Whenever possible, time spans of at least 10 minutes in length were chosen.

The longest duration recorded for an individual event was 14 hrs and 26 min., and the shortest duration was only 10 min. The average duration was 2 hrs and 23 min.

Figure 1 shows the annual variation of the rate of occurrence of oscillations. The occurrence rate was determined by summing the event durations for a given month and then dividing by the total number of hours for which data was available for that month. This quotient was then multiplied by 100 to give a percentage figure. The rate of occurrence varies from a high of 11.0% in January, 1968 to a low of 0.2% in July, 1968. In this figure the complete histogram gives the rate of occurrence for all oscillations, while the shaded histogram gives the rate of occurrence of transverse oscillations only.

During both years of the data sample, the rate of occurrence tended to be maximum during December, January, and February. The annual variation is apparent not only in the rate of occurrence, but also in the number of hours of observed oscillations, and in the number of events.

A non-seasonal annual variation in the period of both Pc4 and Pc5 has been reported by Saito (1969). No such annual variation in the period of oscillations observed at ATS-1 was evident from the data.

Local Time Distribution

Figure 2 summarizes the distribution of the hours of observed low frequency oscillations as a function of local time. The ordinates in Figure 4 represent for each hour of local time the number of hours in which oscillations were observed to occur. The complete histogram gives the distribution for all oscillations, while the shaded histogram gives the distribution for transverse oscillations only. Both show well-defined peaks between 1200 and 1500 L.T. The broad minimum in occurrence frequency extends from dusk through midnight to a few hours past dawn.

Saito (1969) reports a broad day-time maximum in the diurnal variation of Pc4 amplitude, which is consistent with the diurnal variation in occurrence frequency reported here. However, Saito and others also report a double maxima in the diurnal variation of Pc5; one in the early morning and one in the evening, with the morning maximum superior to the evening (Saito, 1964 and references contained therein). The diurnal variation of oscillations in the Pc5 range observed at ATS-1 is similar to that shown in Figure 3. It consists of a single broad maximum centered near noon.

Frequency Distribution

Figure 3 shows the distribution of the hours of observed low frequency oscillations as a function of average frequency. The ordinate of the histogram gives the number of hours of observed oscillations for each frequency interval. The complete histogram gives the distribution of all low frequency oscillations, whereas the shaded part gives the distribution of those oscillations that can be classified as transverse. The distribution shows a broad peak centered around $f = 10 \times 10^{-3}$ Hz, which corresponds to an oscillation with a period of $T \approx 100$ seconds.

Samson et. al. (1971) have recently published a study of the latitude dependence of geomagnetic micropulsations. Their Figure 10 shows that oscillations in the range $1.5 \times 10^{-3} < f < 20 \times 10^{-3}$ Hz are observed between the geomagnetic latitudes of 59° and 77°N, with the average frequency decreasing with increasing latitude. At 67° geomagnetic north, which is the latitude at which field lines passing through ATS-1 intercept the earth's surface, the average frequency is $\approx 10 \times 10^{-3}$ Hz. The ATS-1 data are therefore quite consistent with these ground observations.

Amplitudes

During a given event the amplitude of the transverse oscillations usually varied gradually. In a typical event the amplitude would increase to a maximum during several oscillations, and then decrease in about the same time interval. It was therefore not possible to assign a single amplitude to a given event. It was, however, possible to measure the maximum amplitude for each event. The average maximum amplitude was 2.8 γ.

Summary and Conclusions

The low frequency oscillations at ATS-1 are predominantly transverse. They tend to occur most frequently in the early afternoon hours. They also seem to occur more frequently during December, January, and February than during other months. The frequency distribution of the oscillations has a broad peak centered near $f = 10 \times 10^{-3}$ Hz and extending from $f = 5 \times 10^{-3}$ Hz to $f = 15 \times 10^{-3}$ Hz. During a given event, the frequency of the oscillation is fairly constant. The average duration of an event is 2 hours and 26 minutes, and the average maximum amplitude is 2.8 γ.

The local time and frequency distributions of transverse oscillations are essentially the same as the distributions for all oscillations, whether transverse or not. Furthermore, neither the local time nor the frequency distributions suggest an obvious physical distinction between oscillations in the Pc4 and Pc5 ranges.

ACKNOWLEDGEMENTS

We would like to thank Dr. Andre Konradi and Mr. Joe Snyder of the NASA Manned Spacecraft Center for their support of this project.

The research at Grambling College was supported by the National Aeronautics and Space Administration under contract NAS 9-10213 and grant NGR 19-011-007. The research at UCLA was supported by the National Aeronautics and Space Administration under grant NGR-05-007-004.

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Saito, Takao, Geomagnetic pulsations, Space Science Reviews, 10, 319, 1969.

Samson, J. C., J. A. Jacobs, and G. Rostoker, Latitude-dependent characteristics of long-period geomagnetic micropulsations, J. Geophys. Res., 76, 3675, 1971.

FIGURE CAPTIONS

Figure 1 The complete histogram gives, for each month of the data interval, the rate of occurrence of low-frequency oscillations at ATS-1. The shaded part of the histogram gives the rate of occurrence of oscillations that are classified as transverse in this paper.

Figure 2 The complete histogram gives, for each hour of local time, the number of hours of observed low-frequency oscillations at ATS-1. The shaded part of the histogram gives the number of hours of oscillations that are classified as transverse in this paper.

Figure 3 The complete histogram gives for each 10^{-3} Hz frequency interval, the number of hours of observed low-frequency oscillations at ATS-1. The shaded part of the histogram gives the number of hours of oscillations that are classified as transverse in this paper.

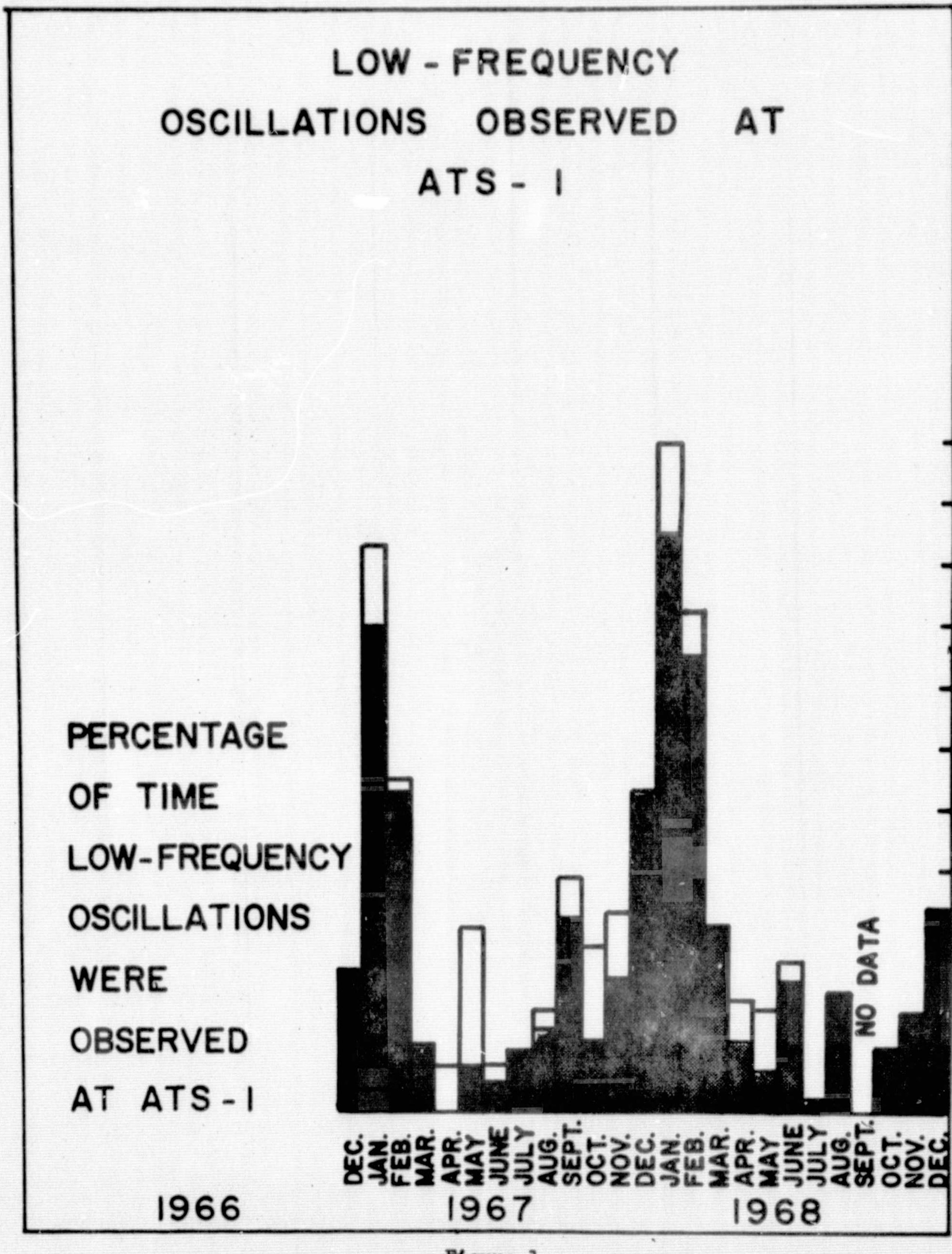
LOW - FREQUENCY
OSCILLATIONS OBSERVED AT
ATS - 1
PERCENTAGE
OF TIME
LOW-FREQUENCY
OSCILLATIONS
WERE
OBSERVED
AT ATS - 1
11
10
9
8
7
6
(%)
5
4
3
2
1
0
NO DATA
DEC.
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
JAN.
FEB.
MAR.
APR.
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
1966
1967
1968

Figure 1

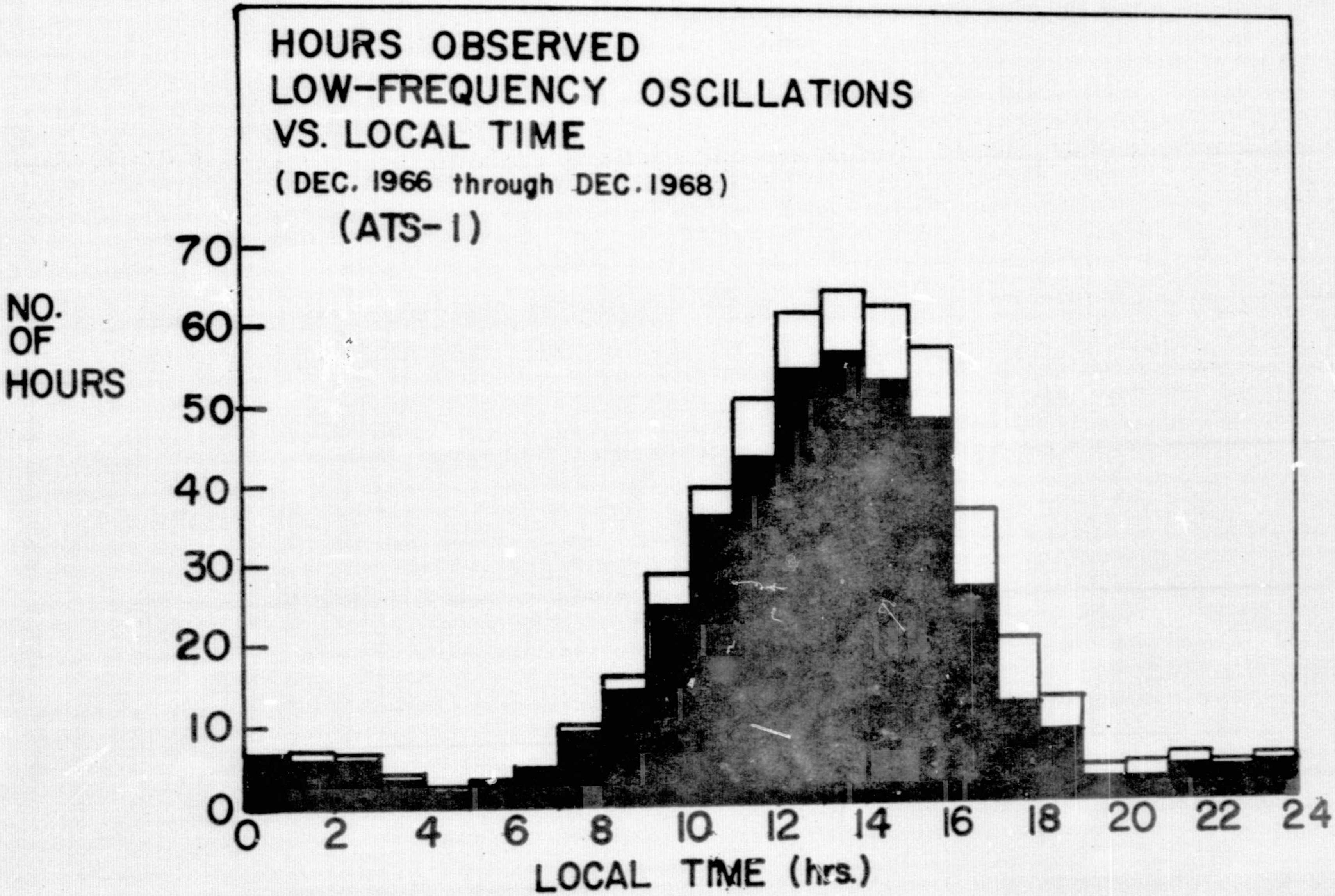
HOURS OBSERVED
LOW-FREQUENCY OSCILLATIONS
VS. LOCAL TIME
(DEC. 1966 through DEC. 1968)
(ATS-1)
NO.
OF
HOURS
70
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
22
24
LOCAL TIME (hrs.)

Figure 2

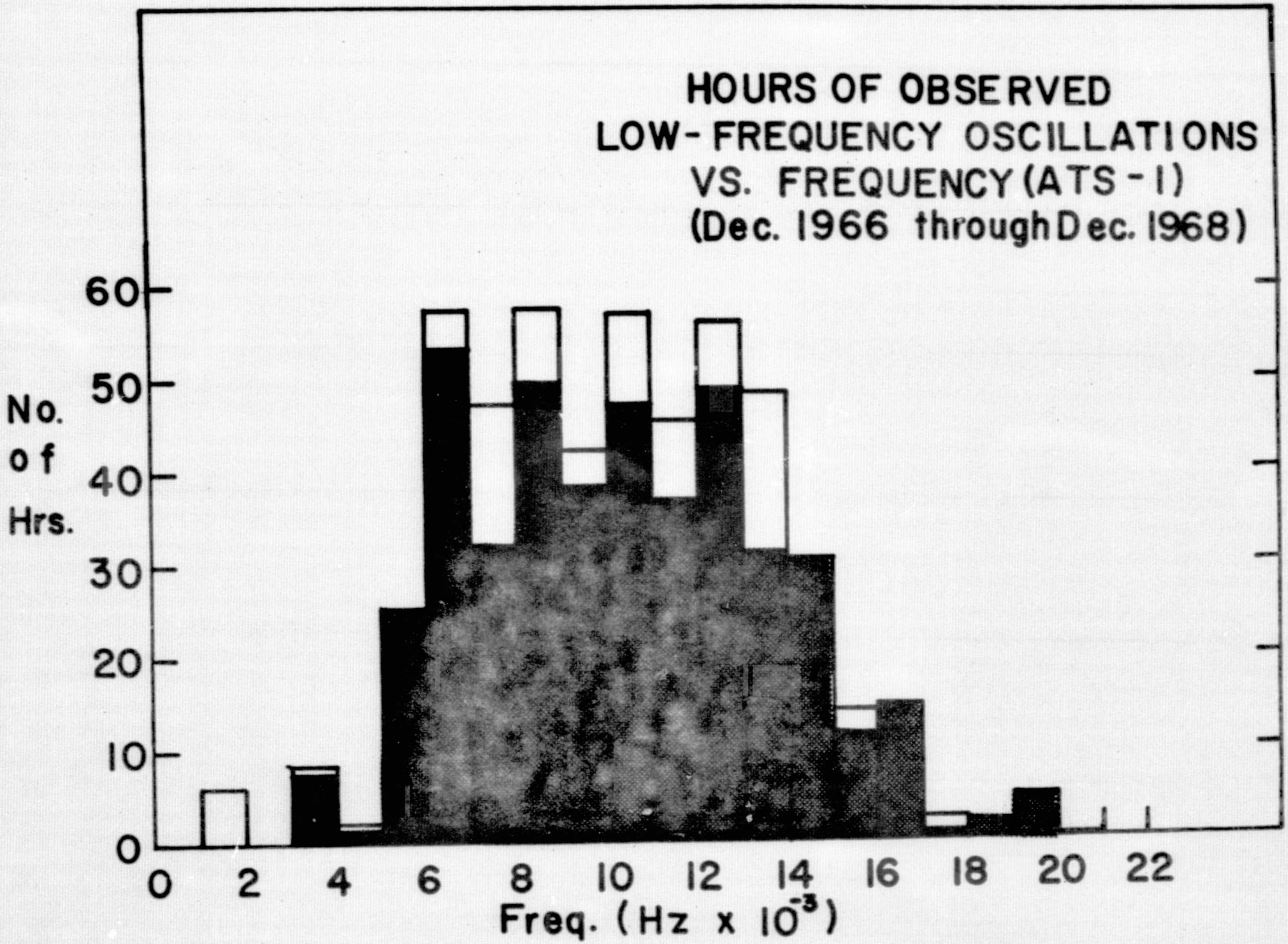
HOURS OF OBSERVED
LOW-FREQUENCY OSCILLATIONS
VS. FREQUENCY (ATS-1)
(Dec. 1966 through Dec. 1968)
No. of Hrs.
0
10
20
30
40
50
60
0
2
4
6
8
10
12
14
16
18
20
22
Freq. (Hz x 10^-3)

Figure 3

Spectral and Polarization Analysis of Micropulsations Observed at ATS-1

by

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May, 1972

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Abstract

Spectral and Polarization Analysis of Micropulsations Observed at ATS-1. This paper reports the results of an analysis of low-frequency oscillations in the earth's magnetic field as observed at the synchronous orbit by the UCLA magnetometer experiment on board ATS-1. Oscillations in the range $2 \times 10^{-3} < f < 20 \times 10^{-3}$ Hz for the one year period Dec. 1966 through Dec. 1967 were studied. The analysis combines a detailed, computer processed, spectral analysis of selected events with a less detailed manual analysis of all events in the two year time interval. The computer analysis revealed that a given event is often characterized by a dominant, narrow, spectral peak whose associated oscillations are almost entirely limited to a plane, together with several minor peaks. Dynamic spectral analyses reveal that the minor spectral peaks appear as short isolated bursts. The sense of rotation of the perturbation vector tends to change from right-handed elliptical at the beginning of a burst to left-handed elliptical at the end. The major axis of the polarization ellipse is inclined by typically 30° east of radial.

In this paper we report on some characteristics of the magnetic oscillations in the Pc4 range that occur at the geosynchronous satellite ATS-1. The events chosen were those in 1966 and 1967 that had durations greater than six (6) hours. The principal conclusions at this point in the analysis are:

(1) The oscillations appear to occur in bursts of approximately one hour duration.

(2) There appears to be a trend in the sense of rotation of the perturbation vector during a burst. The sense of rotation changes from right-handed elliptical at the beginning of the burst to left-handed elliptical at the end.

(3) The azimuth of the major axis of the polarization ellipse is inclined by typically 30° east of radial.

Slide 1. The first slide shows the result of an eigen-analysis of the real part of the spectral matrix for a typical quiet time event. The procedure of the analysis is equivalent to creating the variance ellipsoid of the perturbation at a given frequency interval and determining the length and orientation of its eigenvectors. The important point of the slide is the sharp peak in the power density at about 5 milli-hertz (or a period of about 200 seconds) with a rms power of 1 γ.

The bottom portion of the slide indicates that the average polarization was 80% and almost completely linear. However, as we shall show later, the ellipticity varies systematically throughout each of the bursts making up an event. The variation is such that the sense of rotation is right handed as often as it is left handed. This accounts for the average polarization being linear.

Slide 2. The next slide shows the dynamic power spectrum for oscillations in the plane transverse to the dipole axis. There were three bursts centered at 1811, 1931, and 2248 U.T. The first two bursts are of 171 second period and the third burst is of 213 second period. The time derivative of the signal is plotted above the dynamic power spectrum. The contour map is a dynamic spectrum of the derivative of the transverse signal.

Slide 3. The next slide shows the log of the power, the ellipticity, and the azimuth of the major axis of the polarization ellipse for the component of the signal at the frequency of peak power. The significant point of the slide is that at at each point when the signal power was maximum the ellipticity changed from positive, or right handed, to negative or left handed.

We have found no such systematic variation of the orientation of the major axis of the polarization ellipse in the events analysed to date.

Slide 4. The next slide shows in more detail the change in the sense of rotation of the perturbation vector at peak power. We have plotted the transverse components of the magnetic field during a typical short duration burst. On the same time scale we indicated the polarization ellipses as determined from an eigen value analysis of the transverse data. The ellipticities before and after the peak power point are typically .3. The sense of rotation is right handed before the point of peak power and left handed afterwards.

The major axis of the polarization ellipse is inclined to the radial by 30-40° throughout the burst.

Slide 5. To date we have yet to find a significant dependence of the orientation of the major axis of the polarization ellipse on any of the usual magnetic indices. However, we have found that the major axis of the polarization ellipse is generally inclined east of radial. This slide shows the results of several determinations of the azimuth of the polarization ellipse for each of the long duration events of 1966 and 1967. The most frequently measured azimuth angles are in the range 20-40°.

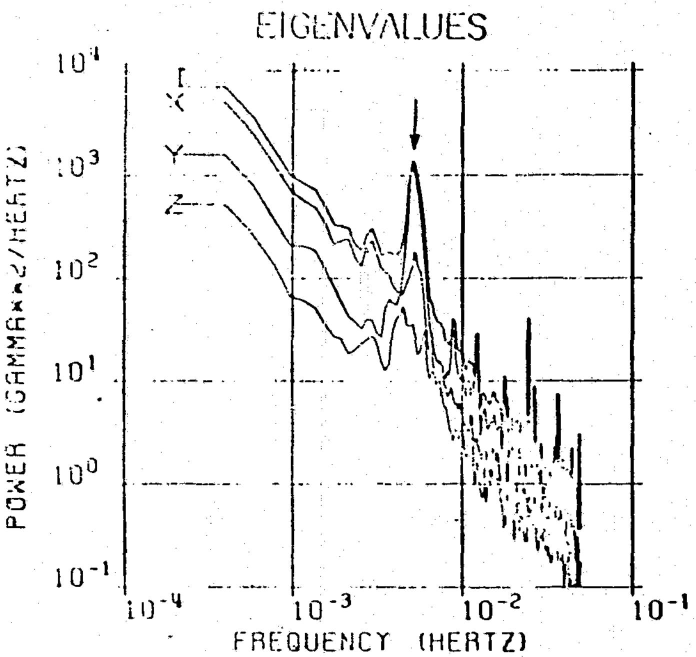
In summary we have found that the Pc4 events observed at ATS-1 occur in bursts of typically 1 hour duration. The sense of rotation of the perturbation vector usually changes from right handed to left handed at the peak power point. And finally the major axis of the polarization ellipse is usually inclined by about 30° east of radial.

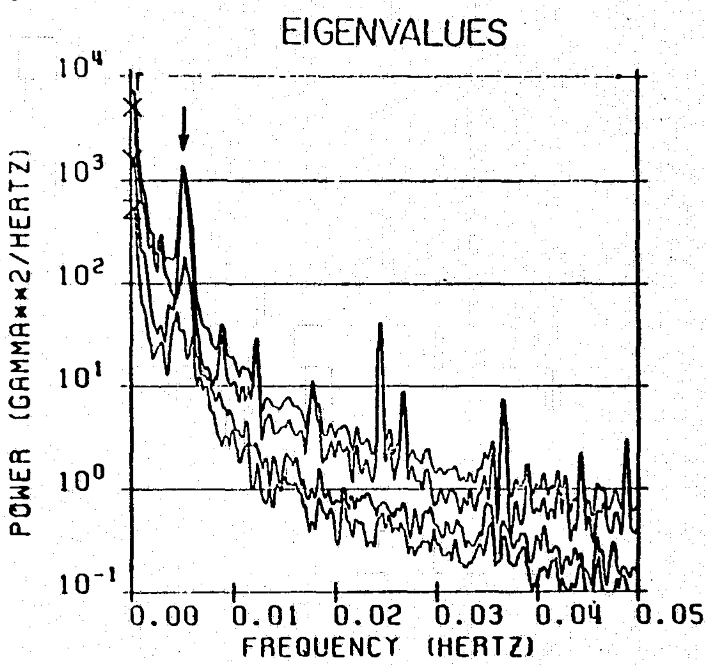
Acknowledgements

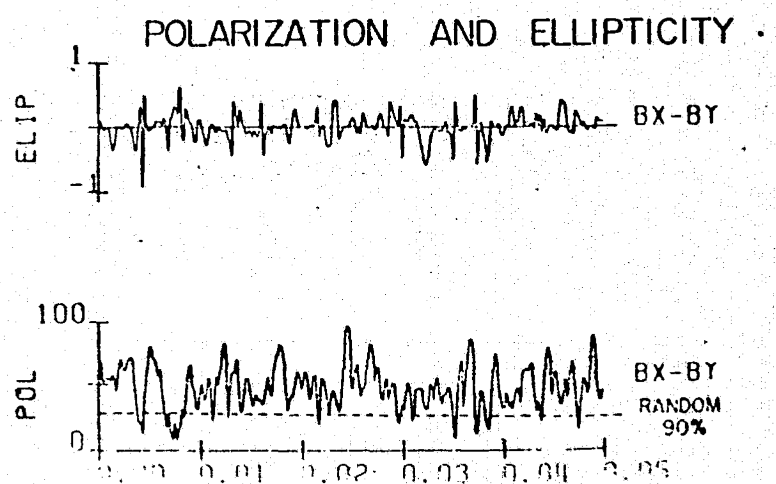
The work done at Grambling College was supported by The National Aeronautics and Space Administration grant NGR-19-011-007. The work done at UCLA was supported by The National Aeronautics and Space Administration grant NGL-05-007-004.

Pc4-5 MICROPULSATIONS
UCLA Fluxgate Magnetometer
ATS-1

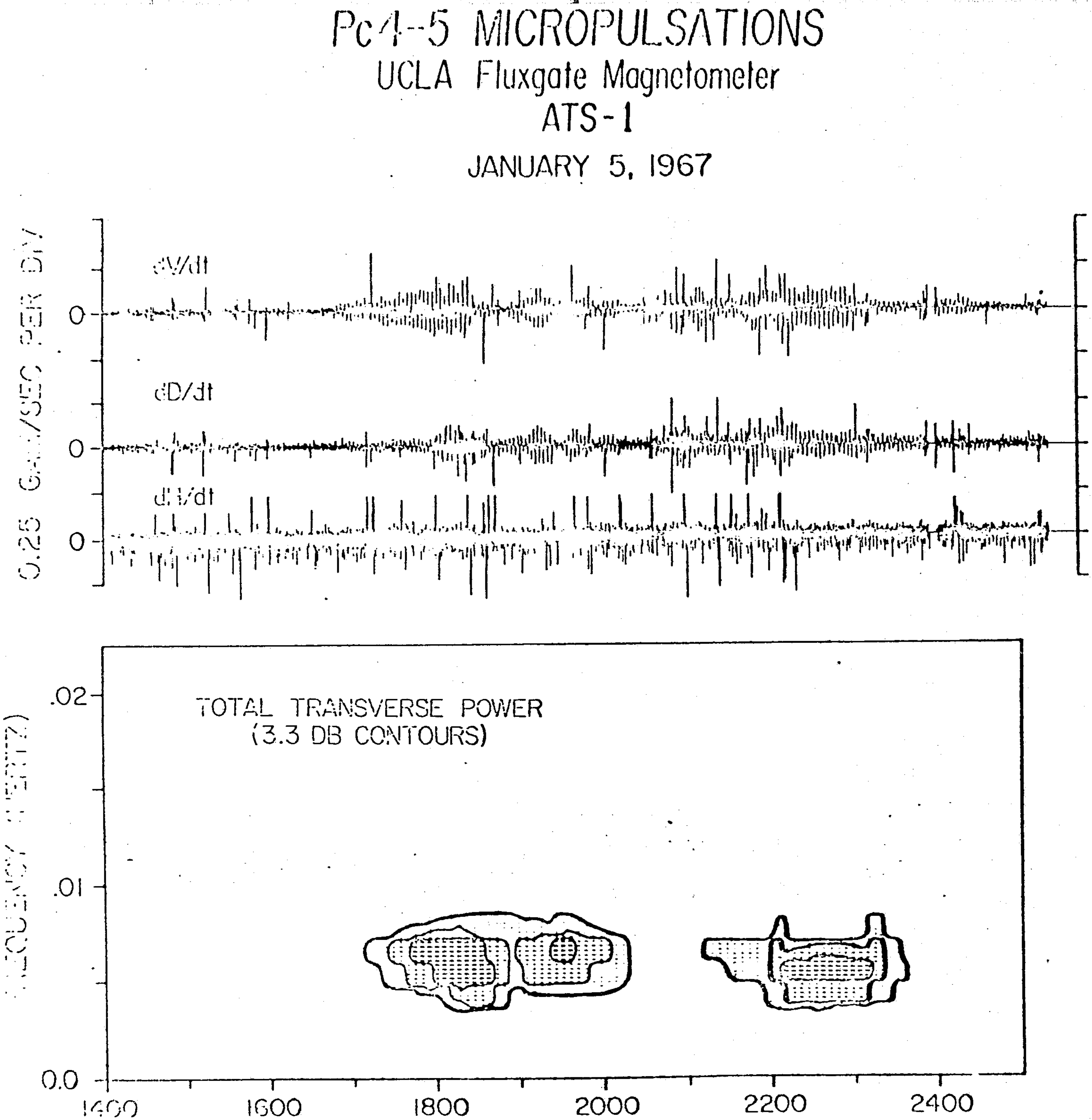
1400 0122, 5-6 JAN. 1967





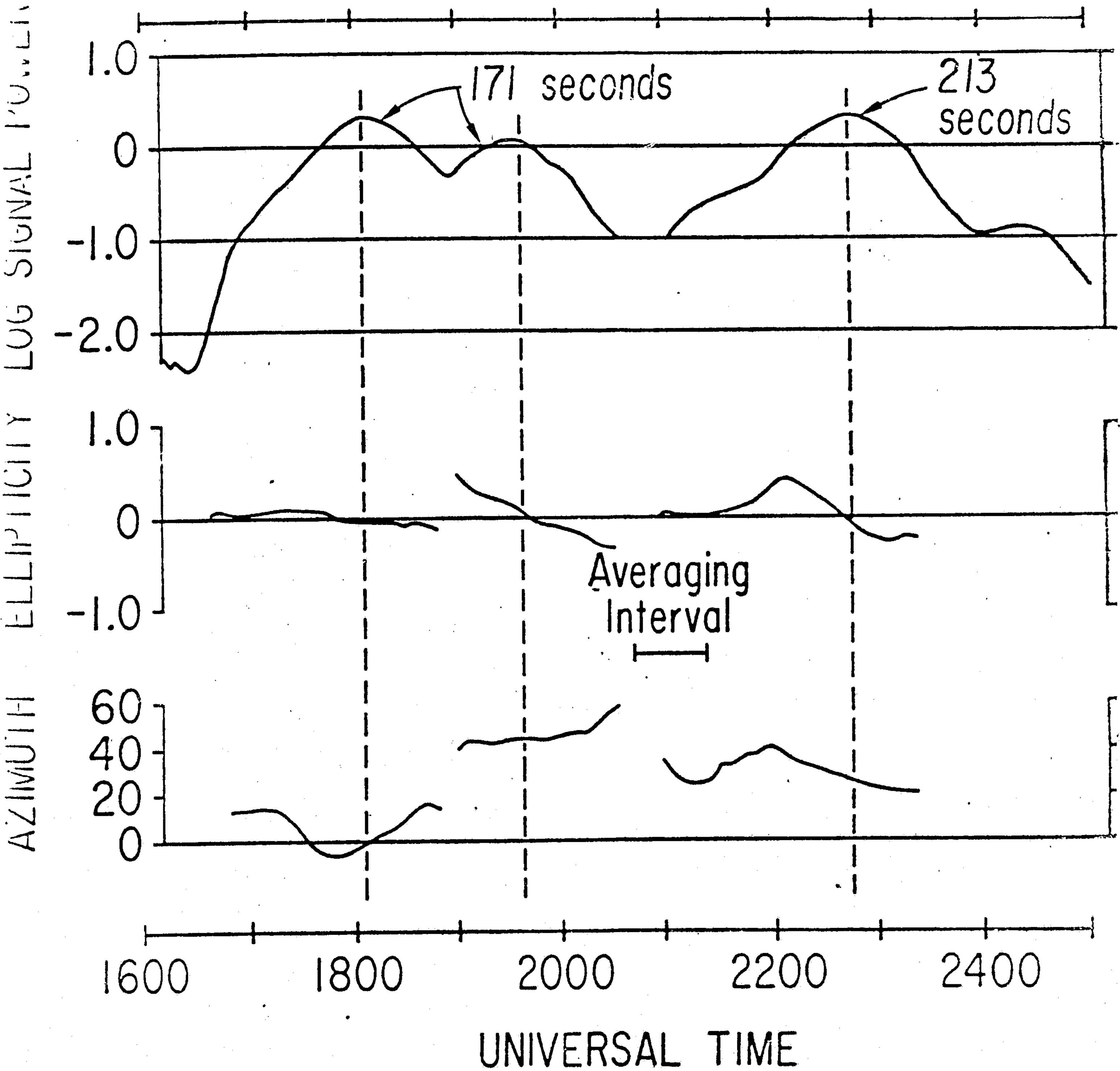


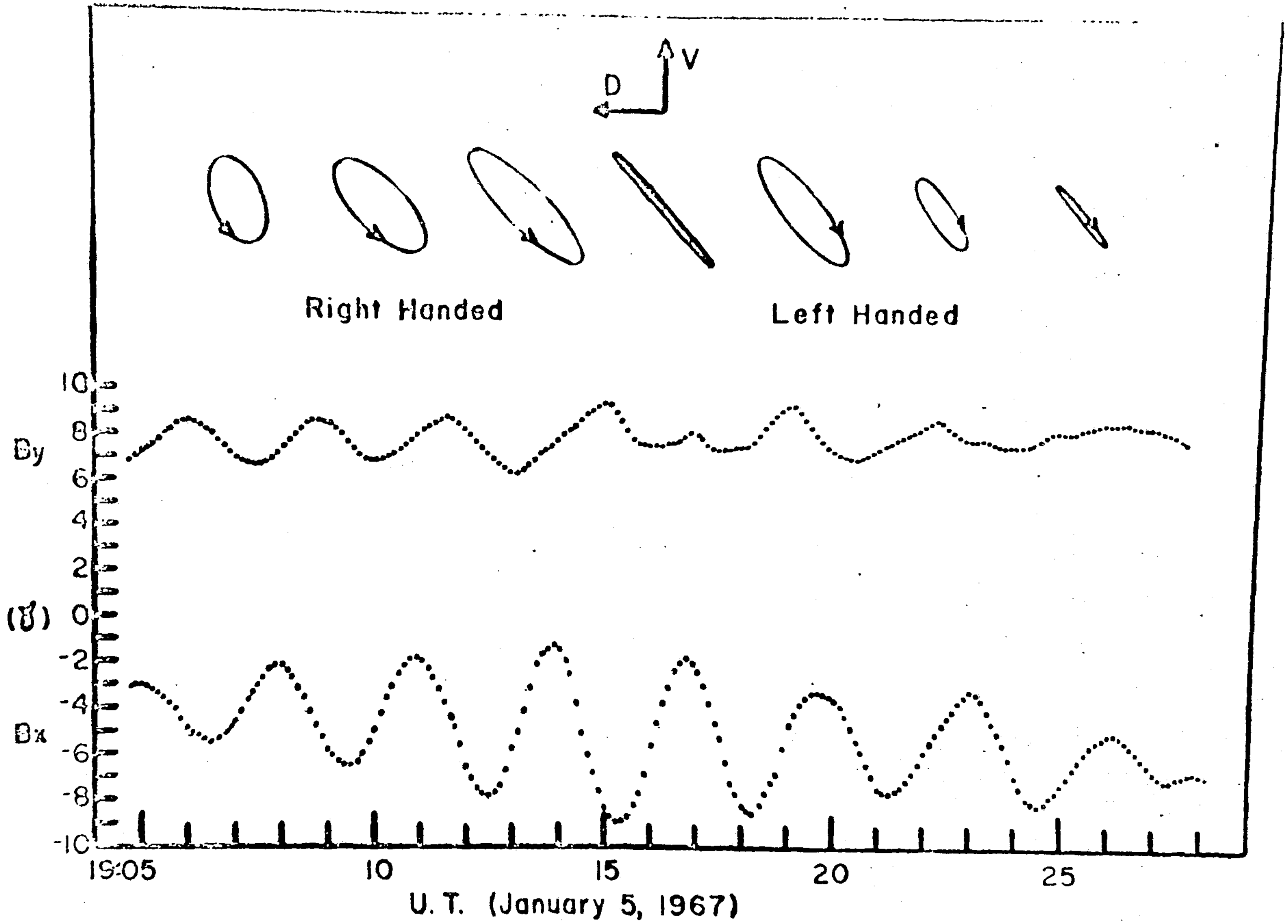
[illegible] PARAMETERS
[illegible] = 10.0 SEC
[illegible] FREEDOM = 26
[illegible] OF POINTS = 4096
[illegible] $\times 10^{-3}$ HZ
[illegible] = 0.20×10^{-3} HZ



Pc4-5 MICROPULSATIONS
UCLA Fluxgate Magnetometer
ATS-1
JANUARY 5, 1967
dV/dt
dD/dt
dH/dt
0
0
0
TOTAL TRANSVERSE POWER
(3.3 DB CONTOURS)
.02
.01
0.0
1600
1800
2000
2200
2400

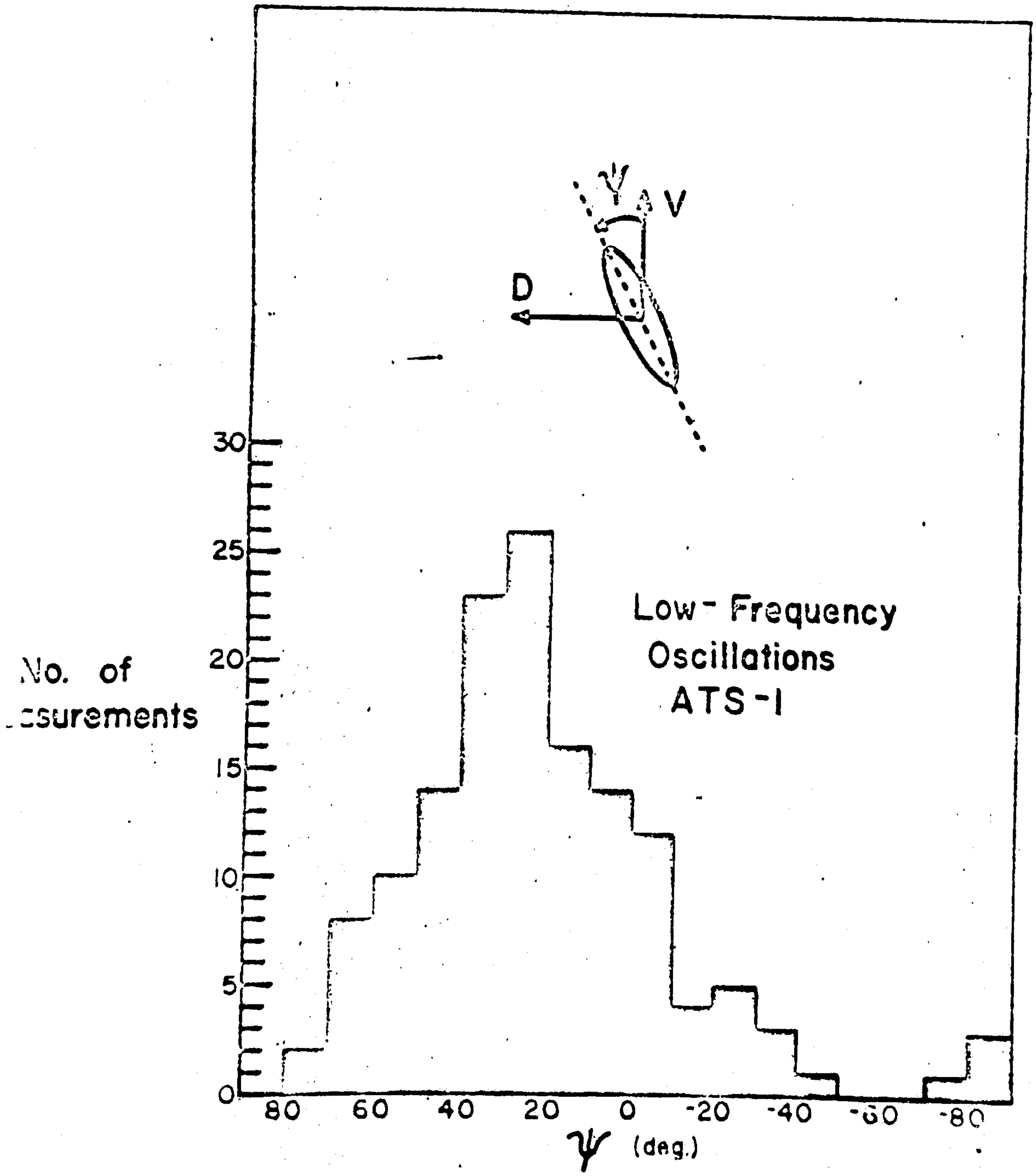
Pc 4-5 MICROPULSATIONS
UCLA FLUXGATE MAGNETOMETER
ATS-1
JANUARY 5, 1967





V
D
Right Handed
Left Handed
10
8
By
6
4
2
(γ) 0
-2
-4
Bx
-6
-8
-10
19:05
10
15
20
25
U. T. (January 5, 1967)

Slide 4



ψ
V
D
30
25
20
15
10
5
0
No. of
csurements
Low- Frequency
Oscillations
ATS-I
80
60
40
20
0
-20
-40
-60
-80
ψ (deg.)

Slide 5

The Dominant Mode of Standing Alfvén Waves at the Synchronous Orbit

W. D. Cummings, Calvin Countee, Donald Lyons, and William Wiley III

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Low-frequency oscillations of the earth's magnetic field recorded by the University of California at Los Angeles magnetometer on board ATS 1 have been examined for the 6-month interval January–June 1968. Using evidence from Ogo 5 and ATS 5 as well as the data from ATS 1, we argue that the dominant mode at ATS 1 must be the fundamental rather than the second harmonic of a standing Alfvén wave. We also conclude that these transverse oscillations are more accurately associated with magnetically disturbed days than with quiet days. Both of these results represent changes of tentative conclusions based on our initial analysis. From 14 instances when oscillations of distinctly different periods occurred during the same time interval at ATS 1 we also conclude that higher harmonics can exist. The period ratio in seven of the 14 cases corresponds to the simultaneous occurrence of the second harmonic with the fundamental, and four other cases could be identified as the simultaneous occurrence of the fourth harmonic with the fundamental.

Lanzerotti and Fukunishi [1974] have recently given a review of experimental and theoretical work related to the modes of magnetospheric Alfvén waves. The goal of their review was to raise the question of whether the dominant mode was odd or even. They conclude from their own conjugate data that near $L = 4$ the dominant mode is odd.

Lanzerotti and Fukunishi correctly pointed out that in our initial paper [*Cummings et al.*, 1969] we assumed that the oscillations observed at ATS 1 were even mode. This assumption was made primarily because ATS 1 is located on the magnetic equator, and at least in our idealized model this position represents a node for standing Alfvén waves of odd mode. It should also be noted that our initial analysis was based on only 25 events during January 1968 and that we only studied oscillations in the period range 50–300 s. The latter limitation of the period range resulted from the fact that we analyzed 15-s averages of the data. Therefore our ability to observe oscillations diminished with decreasing period and was certainly marginal near a period of 50 s. This limitation turned out to be critical, since it is now apparent from the present analysis that a dominant period at the synchronous orbit is in the range 40–90 s.

In a second analysis [*Cummings et al.*, 1972] we analyzed 222 events over a 25-month data interval. However, 15-s averages of the data were also used in this study, so the limitation at low periods still existed.

The present analysis is based on 273 events that were recorded in the 6-month interval January–June 1968. The minimum period recorded was 20.7 s, and the maximum period was 410.8 s. An artificial oscillation at a period of 5.12 s, the interval of one data sequence, sometimes contaminated the data. Therefore a practical lower limit to the periods that we could observe is approximately 20 s, even though we used 0.32-s averages of the data in the analysis.

ATS 1 was located at 150°W longitude, which is approximately the intersection of the geomagnetic and geographic equatorial planes. The magnetometer experiment on board ATS 1 has been described by *Cummings et al.* [1969] and *Cummings and Coleman* [1968]. It should be mentioned that the plasma detector scheduled for ATS 1 failed prior to launch and the remaining particle detectors did not provide a complete spectrum of the ambient charged particle population. It has therefore been impossible to determine the ambient total ion number density from ATS 1 particle data. In this study we have made use of Ogo 5 data and published ATS 5 data to help fill this unfortunate gap in the ATS 1 data.

General Results

Of the 273 events that occurred during the 6-month interval, 25 were recognized as being similar to those described by *Barfield et al.* [1972]. That is, they were compressional, were usually related to storms or substorms, and occurred in the dusk sector. We have excluded these events from this analysis.

The distribution of periods for the remaining 248 events is shown as a histogram in Figure 1. The most striking feature of the histogram is the peak in the range 40–90 s. The most frequently occurring period is in the range 60–70 s. We cannot rule out an additional peak at periods below 20 s. Oscillations with periods in this range are often unobservable in the ATS 1 data, as was explained above.

The distribution of the 248 events in local time is shown in Figure 2. In the histogram of Figure 2 the ordinate represents the number of hours in which oscillations occurred in a given local time interval. The peak of the local time distribution is 1–3 hours past noon, but the distribution is asymmetric, favoring the morning hours.

The distribution is broadly similar to that observed at 6.25 R_E with the Dodge experiment [*Dwarkin et al.*, 1971] in that both distributions show that the great majority of oscillations occur in the day sector. The local time distribution in our second analysis [*Cummings et al.*, 1972, Figure 2] was similar in shape to the present distribution, the peak also being shifted slightly toward the afternoon sector.

In our first analysis [*Cummings et al.*, 1969] we reported that the oscillations were observed predominantly on geomagnetically quiet days. It is certainly true that many of the longer-period oscillations are found to occur during the quiet recovery phase of magnetic storms. However, it is clear from the present analysis that one should not associate the more typical oscillations observed at the synchronous orbit with prolonged periods when the magnetosphere is quiet. On the contrary, these oscillations seem to be more closely related to magnetic storms or periods of magnetic activity.

To illustrate the above point, we used the hourly values of equatorial *Dst* [*Sugiura and Poros*, 1971] for January–June 1968 to identify the hours when the *Dst* value was at a local minimum. We required the local minimum to be greater in absolute value than 35 γ, and 50 such instances were found.

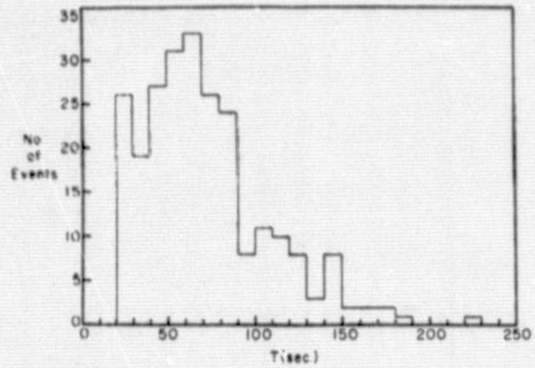

Fig. 1. Histogram showing the number of events recorded at ATS 1 with periods occurring in each 10-s interval from 20 to 250 s. As was explained in the text, oscillations with periods below about 20 s are often obscured by an artificial oscillation and are therefore not included in this study. The data interval for Figures 1, 2, and 3 is January–June 1968, and compressional storm-related oscillations are excluded.

Next, we compared this set of times t_{min} with the onset times t_{onset} for the oscillations observed at ATS 1. In particular, for a given t_{onset} we looked for the nearest t_{min} and measured ($t_{min} - t_{onset}$). Figure 3 illustrates the result of the study with a histogram showing the number of events versus the time difference ($t_{min} - t_{onset}$). Half of all the events observed at ATS 1 occurred within 1 day of one of these local minima.

Dominant Mode

The most frequently observed period at ATS 1 is in the range 40–90 s, and the average period is $T_{ave} = 77.4$ s. If an oscillation with this average period corresponds to the second harmonic of a standing Alfvén wave, then according to Table 2 of *Cummings et al.* [1969] the average equatorial number density will be in the range $5.6 \leq n_0 \leq 15.3$ cm^{-3}, depending upon how the plasma is distributed along the ATS 1 field line. In the model of *Cummings et al.* [1969] the background magnetic field was assumed to be that of a dipole, and the proton number density was assumed to vary as

$$n = n_0(r_0/r)^m \qquad m = 0, 1, 2, 3, 4, 5, \text{ or } 6$$

where r_0 is the geocentric distance to the equatorial crossing point of the ATS 1 field line and n_0 is the proton number density at r_0.

Since we know that the oscillations are associated with periods of magnetic disturbance, when ATS 1 is most likely in the trough region on the day side of the magnetosphere, these number densities are unacceptably high. Measurements of the particle density by detectors aboard ATS 5 [*DeForest and McIlwain*, 1971] indicate that the maximum expected density at synchronous orbit on the day side is $n_0 \approx 2.2$ cm^{-3}, the typical density being $n_0 \approx 1$ cm^{-3}.

If, on the other hand, an oscillation with the average period $T_{ave} = 77.4$ s is interpreted as the fundamental mode of a standing Alfvén wave, the average equatorial number density will be in the range $1.4 \leq n_0 \leq 2.2$ cm^{-3}. These densities are much more easily reconciled with the direct measurements made by ATS 5.

We have already noted that the oscillations observed at ATS 1 seem to occur preferentially during disturbed times. *DeForest and McIlwain* [1971] also point out that intrusions of hot plasma at the synchronous orbit occur during magnetic substorms. The plasma that supports the oscillations must be composed primarily of the substorm-injected plasma rather than the cold plasma, whose source is the ionosphere. Using Ogo 5 cold plasma data kindly supplied by C. R. Chappell, we have tried to compare a few individual cases when Ogo 5 was near ATS 1 and oscillations were recorded at ATS 1. In each case we found that the cold plasma density was below that required to explain the oscillations in terms of the fundamental mode of a standing Alfvén wave.

The case of April 17, 1968, is typical of cases that we studied. Ogo 5 was inbound on its seventeenth orbit and crossed $L = 6.6$ at approximately 1640 UT near 0900 LT. ATS 1 passed through 0900 LT a little more than 2 hours later, and oscillations with an average period of 55.7 s were recorded. The density of cold plasma measured by Ogo 5 was approximately $n = 0.4$ cm^{-3}. If the oscillations observed at ATS 1 are to be interpreted as the fundamental mode of a standing Alfvén wave, then the total equatorial proton number density will have to be $n_0 \approx 1$ cm^{-3}.

In the theoretical models of *Southwood* [1974] and *Chen and Hasegawa* [1974], surface waves excited by the solar wind at the magnetopause couple to the shear Alfvén waves of the resonant local field lines inside the magnetosphere. The wave amplitude is greatly enhanced at the resonance region, but it is theoretically possible to observe wave events of diminished amplitude away from the resonance field lines. It should be noted here that when the model of *Cummings et al.* [1969] is used in this paper, it is assumed that the oscillations observed at ATS 1 are resonance oscillations of local field lines near $L = 6.6$.

Higher Harmonics

Of the 248 events under investigation, 28 either overlapped another event or almost did so. That is, there were 14 cases when oscillations of different periods were occurring during the same time interval. These events are listed in Table 1, which shows the beginning time and ending time for each event, the average period, and the ratio of the larger period to the smaller period.

There are several interesting features in Table 1. First, note that most of the overlapping events occurred near noon, 2200 UT. (Recall that ATS 1 is located at approximately 150°W longitude. Thus the local time is 10 hours less than the universal time.) The exceptions are sets 3, 11, 12, and 14. Second, note that the period ratios cluster around two values, $R_1 \approx 2.2$ and $R_2 \approx 4.5$. The exceptions are sets 8, 12, and 14. Third, note that for all the sets that have ratios clustering around R_1 the larger period is in the range 40–90 s, which we identify as the dominant mode from the histogram in Figure 1.

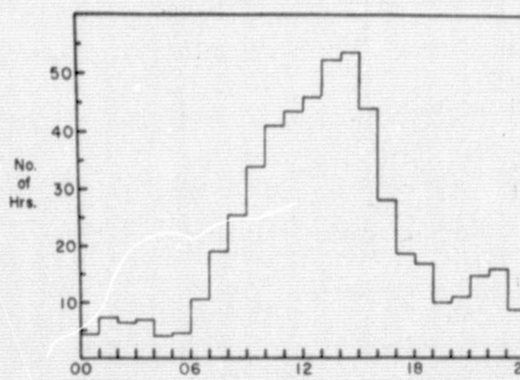

Fig. 2. Histogram showing the number of hours in which oscillations were recorded at ATS 1 for each hour of local time.

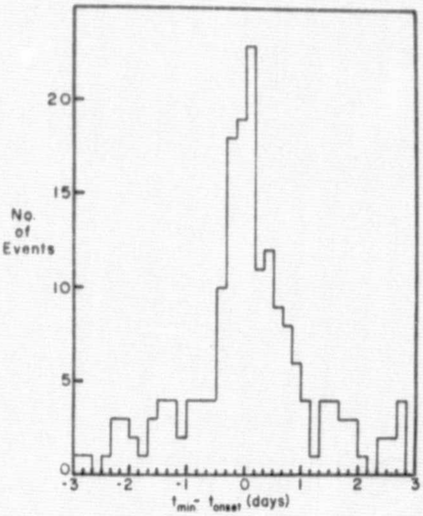

Fig. 3. Histogram constructed as follows: The onset time t_{onset} for each event was recorded and compared with the time of the nearest minimum in *Dst*, t_{min}. The amplitude of the excursion in *Dst* at the minimum point was required to be at least 35 γ. The histogram shows the number of events recorded at ATS 1 for each 4-hour interval of ($t_{min} - t_{onset}$). A negative value of ($t_{min} - t_{onset}$) means that the onset of the event was prior to the nearest minimum in *Dst*.

The above observations suggest that these overlapping events represent cases when the fundamental and a higher harmonic of the Alfvén standing waves were occurring simultaneously. It is possible to check this hypothesis by using the simple model of Alfvén standing waves that we presented in our initial analysis [*Cummings et al.*, 1969]. Theoretical ratios of the period of the fundamental and of higher harmonics can be computed by using Table 1 of that paper. These ratios, computed for the toroidal mode, are only weakly dependent on the distribution of plasma along the field lines. The theoretical ratio of the period of the fundamental to the period of the second harmonic, T_1/T_2, has a range of 2.0–2.6. This range corresponds to a variation in the density index from $m = 6$ ($T_1/T_2 = 2.0$) to $m = 0$ ($T_1/T_2 = 2.6$). Six of the seven overlapping sets that cluster around R_1 fall within the above range. The seventh set (set 5) has a period ratio of 1.9, which falls only slightly below the theoretical limit.

The theoretical ratio of the period of the fundamental to the period of the third harmonic, T_1/T_3, has a range of 3.0–4.3. None of the 14 sets of overlapping events have period ratios that fall within this range.

The theoretical ratio of the period of the fundamental to the period of the fourth harmonic, T_1/T_4, has a range of 4.0–5.9. All four of the overlapping sets that cluster around R_2 fall within this range.

Two sets that do not have period ratios falling within any of the above ranges are sets 12 and 14. Both of these sets occurred in the dusk sector, where the description of the field as being dipolar is probably less valid than it is in the noon sector.

Eleven of the 14 cases when oscillations at two different frequencies were occurring simultaneously at ATS 1 can be interpreted by our simple model as either the fundamental and the second harmonic (seven cases) or the fundamental and the fourth harmonic (four cases). As was noted above, for all seven cases that we interpret as the simultaneous occurrence of the fundamental and the second harmonic, the larger period is in the range 40–90 s. This is the dominant range of periods observed at ATS 1; more than half of all events recorded have periods in this range. We thus have added evidence that the dominant mode observed at ATS 1 is the fundamental mode of a standing Alfvén wave.

TABLE 1. Overlapping Events at ATS 1

Set	Beginning		Ending		Average Period, s	Ratio of Periods
	Date	Hours, UT	Date	Hours, UT		
1	Jan. 2	1906	Jan. 2	2256	354.3 ± 81.3	4.4
	Jan. 1	1820	Jan. 2	2343	80.5 ± 12.5	
2	Jan. 18	2309	Jan. 19	0105	63.9 ± 5.4	2.3
	Jan. 19	0059	Jan. 19	0112	28.1 ± 1.9	
3	Jan. 20	0628	Jan. 20	1002	88.4 ± 9.3	2.0
	Jan. 20	0815	Jan. 20	0823	44.8 ± 7.1	
4	Jan. 21	1742	Jan. 22	0024	52.6 ± 5.9	2.2
	Jan. 21	1812	Jan. 22	0019	24.4 ± 2.9	
5	Jan. 22	1522	Jan. 22	1806	46.2 ± 7.4	1.9
	Jan. 22	1609	Jan. 23	0105	24.4 ± 2.2	
6	Jan. 23	2159	Jan. 24	0112	160.6 ± 19.3	5.1
	Jan. 23	1708	Jan. 24	0154	31.4 ± 6.5	
7	March 1	2110	March 2	0010	285.2 ± 45.2	4.6
	March 1	2022	March 1	2124	61.8 ± 3.3	
8	March 29	1952	March 29	2255	410.8 ± 19.3	7.7
	March 29	1820	March 29	2220	53.4 ± 6.3	
9	May 12	2238	May 12	2310	55.5 ± 7.3	2.1
	May 12	1959	May 13	0015	26.4 ± 4.8	
10	May 13	2026	May 14	0110	76.8 ± 9.1	2.5
	May 13	1914	May 13	2239	30.2 ± 4.8	
11*	May 16	0059	May 16	0120	59.7 ± 8.7	2.2
	May 16	0016	May 16	0053	26.6 ± 0.6	
12	June 9	0325	June 9	0459	130.5 ± 23.8	1.6
	June 9	0411	June 9	0433	79.8 ± 6.2	
13†	June 11	1710	June 11	2022	290.0 ± 5.9	4.5
	June 11	2042	June 11	2323	64.0 ± 13.5	
14	June 17	0006	June 17	0228	101.3 ± 6.0	1.2
	June 17	0026	June 17	0135	82.6 ± 2.3	

*These two events fail to overlap by 6 min.
†These two events fail to overlap by 20 min.

We also note here from the histogram of Figure 1 that much of the peak in the period range 20–30 s is attributable to the occurrence of the second harmonic. In five of the seven cases of the simultaneous occurrence of the fundamental and the second harmonic the period of the higher harmonic was in this range.

[illegible]

During the interval January–June 1968 the oscillations observed at ATS 1 most frequently occurred with periods in the range 40–90 s. The great majority of the events recorded at ATS 1 occurred on the day side of the synchronous orbit. The onset of the oscillations seems to be associated with a disturbed magnetosphere rather than with a quiet one, as was previously supposed. The current best estimates of the total proton number density on the day side of the synchronous orbit are consistent with the interpretation of the dominant mode of oscillations observed at ATS 1 as the fundamental mode of a standing Alfvén wave. From the few cases when oscillations of distinctly different periods occurred simultaneously we conclude that the second and fourth harmonics can also occur.

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Catalog of Low-Frequency Oscillations
of the
Earth's Magnetic Field as Observed at ATS-1

September, 1967 - August, 1968

Explanation of the Catalog

In this catalog an event is defined as an oscillation of the magnetic field with a duration of at least ten minutes, and a frequency that remains roughly constant. Events are distinguished on the basis of the frequency of the oscillation, e.g., when a high frequency oscillation is superimposed upon a lower frequency oscillation, two events are identified.

The oscillation of an event usually occur in bursts that are typically one hour in duration. In a burst, the amplitude of the oscillation begins at a low level, grows to a maximum, and then decreases to a low level again. Because the oscillation begins with a low amplitude, it is often difficult to exactly specify the beginning time of the event.

The beginning time is given in Universal Time. ATS-1 is stationed in the geographic equatorial plane at a geocentric distance of 6.6 R_E and at 150^oW longitude. One can easily arrive at the Local Time for the beginning time of the event by substracting 10 hours from the Universal Time (or by adding 14 hours if the hour of the beginning time (U.T.) is less than 10).

Gaps of as much as an hour may occur between bursts in a given event. However, we defined the duration of an event as the time interval between the beginning of the first burst and the end of the last burst.

We have used microfilm copies of the data of 0.32 second averages to measure the time interval between successive peaks. We tried to make at least ten such measurements during an event to determine the average period. In a few cases, we were unable to make ten measurements, but in all cases we made at least five. The error figure associated with the average period is the standard deviation of the individual measurements of the period. This error figure is more a measure of the real variability of the time interval between successive peaks than it is of uncertainty in determining that time interval.

The average frequency was determined by inverting each individual measurement of the time interval between successive peaks and then averaging these individual measurements of the frequency. The error figure associated with the average frequency is the standard deviation of the individual measurements of the frequency.

Low Frequency Oscillations in the Earth's Magnetic Field
Observed at ATS-1

September, 1967

Event No.	Beginning Day	Time Hour	(U.T.) Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (milli-Hz)
01	Sept. 01	11	10	78	89.1 ± 10.3	10.9 ± 1.4
02	01	18	14	275	28.0 ± 6.5	37.4 ± 7.8
03	08	19	45	30	27.4 ± 4.6	37.4 ± 6.3
04	13	21	00	110	65.3 ± 6.1	15.4 ± 1.4
05	14	18	41	76	23.1 ± 2.5	43.8 ± 4.5
06	17	15	54	103	33.0 ± 3.1	30.5 ± 2.9
07	18	17	57	161	29.2 ± 2.9	34.5 ± 3.3
08	20	00	55	65	62.0 ± 8.7	16.4 ± 2.5
09	22	19	00	298	58.6 ± 2.5	17.1 ± 0.8
10	22	19	04	286	55.8 ± 5.2	18.1 ± 1.7
11	25	00	09	132	120.9 ± 2.0	8.3 ± 0.1
12	25	19	08	430	127.9 ± 16.4	8.0 ± 1.2
13	26	21	32	356	144.0 ± 16.3	7.0 ± 0.8
14	28	12	35	72	80.3 ± 10.0	12.6 ± 1.6

Low Frequency Oscillations in the Earth's Magnetic Field Observed at ATS-1

October, 1967

Event No.	Beginning Day	Time Hour	(U.T.) Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (milli-Hz)
DATA GAP 10/02/hr 8 through 10/02/hr 10						
01[a]	Oct. 02	20	14	26	335.3 ± 29.3	3.0 ± 0.3
02	04	11	28	499	31.3 ± 1.5	32.0 ± 1.5
03	04	22	07	36	82.3 ± 2.3	12.2 ± 0.3
04	06	00	09	26	79.5 ± 3.3	12.6 ± 0.5
05	08	15	22	30	276.3 ± 9.1	3.6 ± 0.12
06	08	18	14	137	32.7 ± 7.5	32.1 ± 7.4
07	09	10	27	41	85.9 ± 13.2	4.9 ± 1.6
08	09	11	11	498	38.4 ± 9.8	27.4 ± 5.9
09	09	21	15	60	129.3 ± 12.9	7.8 ± 0.7
10	10	01	53	101	194.7 ± 64.7	5.5 ± 1.4
11	10	08	17	132	67.4 ± 9.4	15.1 ± 1.9
12	10	15	59	321	34.0 ± 7.4	30.7 ± 6.2
13	11	01	09	150	62.5 ± 6.9	16.2 ± 2.25
DATA GAP 10/11/hr 11 through 10/11/hr 16						
14	12	00	17	41	51.2 ± 6.3	19.8 ± 2.6
DATA GAP 10/13/hr 8 through 10/13/hr 11						
DATA GAP 10/13hr 23 through 10/14/hr 01						
15	15	00	31	40	77.3 ± 7.7	13.1 ± 1.4
16	15	09	12	38	89.8 ± 3.4	11.1 ± 0.4
17	15	18	10	570	149.9 ± 97.8	7.9 ± 2.4

Event No.	Beginning Day	Time Hour	(U.T.) Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (milli-Hz)
18[a]	15	19	07	509	29.2 ± 5.9	35.6 ± 7.0
19[a]	16	13	53	814	38.8 ± 9.4	27.1 ± 5.9
---------- DATA GAP 10/17/hr 11 through 10/17/hr 16 ----------						
20	17	17	18	208	21.4 ± 2.0	47.0 ± 4.2
---------- DATA GAP 10/20/hr 11 through 10/20/hr 16 ----------						
21[a]	20	17	06	180	31.7 ± 5.5	32.3 ± 5.2
22					29.7 ± 5.14	34.6 ± 5.3
23	20	21	02	293	183.8 ± 8.4	5.4 ± 0.3
24	21	14	57	340	41.5 ± 6.5	24.6 ± 3.8
25[a]					40.1 ± 5.1	25.3 ± 3.2
26	22	20	00	30	144.1 ± 8.7	7.0 ± 0.4
27	31	21	21	92	104.3 ± 4.5	9.6 ± 0.4

[a]Measurements made on B_z only.

Low Frequency Oscillations in the Earth's Magnetic Field

Observed at ATS-1

November, 1967

Event No.	Beginning Day	Time Hour	(U.T.) Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (milli-Hz)
01	Nov. 01	18	05	39	35.0 ± 5.4	29.2 ± 4.9
02	01	22	52	68	124.9 ± 4.2	8.0 ± 0.3
03[a]	02	09	09	11	50.0 ± 5.9	20.2 ± 2.4
04	02	21	20	399	148.4 ± 9.12	6.8 ± 0.42
---------------------- DATA GAP				11/03/18 to 11/07/21 -------------------------		
05	07	22	05	110	182.5 ± 8.25	5.5 ± 0.25
06[a]	07	22	42	62	20.8 ± 4.0	49.5 ± 8.6
07[a]	08	01	27	29	48.3 ± 3.2	20.8 ± 1.4
08	09	00	17	248	142.0 ± 19.8	7.2 ± 1.0
09	11	14	52	176	24.6 ± 3.5	41.4 ± 5.3
10	11	17	15	104	164.9 ± 6.7	6.1 ± 0.3
11	11	20	20	10	24.0 ± 4.7	43.0 ± 8.6
---------------------- DATA GAP				11/12/00 to 11/14/00 -------------------------		
12	14	02	21	29	131.8 ± 35.2	7.9 ± 1.7
13	15	23	31	19	69.1 ± 8.7	14.7 ± 1.8
14	16	18	35	120	39.5 ± 1.4	25.4 ± 0.9
15	17	17	40	390	87.6 ± 6.5	11.5 ± 0.9
16	17	23	03	106	37.9 ± 6.2	27.1 ± 4.5
17	18	23	13	46	213.8 ± 11.7	4.7 ± 0.3
18	20	23	34	48	193.4 ± 5.3	5.2 ± 0.1
19	21	18	30	45	38.6 ± 0.7	25.9 ± 0.4
20	21	19	34	18	229.8 ± 27.2	4.4 ± 0.6
21	22	01	06	149	129.1 ± 11.0	7.8 ± 0.6

Event No.	Beginning Day	Time Hour	(U.T.) Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (milli-Hz)
22	22	19	30	346	82.4 ± 6.0	12.2 ± 0.9
23	23	20	17	19	26.8 ± 1.3	37.4 ± 1.8
24	24	01	26	30	95.3 ± 12.6	10.7 ± 1.5
25	29	00	02	127	147.0 ± 22.6	6.9 ± 1.0
26[a]	29	00	02	20	92.4 ± 7.2	10.9 ± 0.9
27	29	08	14	23	61.1 ± 9.7	16.7 ± 2.5
28	29	11	03	42	82.8 ± 7.9	12.2 ± 1.2
29	29	21	25	135	68.6 ± 8.1	14.8 ± 2.0
30	30	03	35	388	67.9 ± 7.1	14.9 ± 1.6
31	30	17	19	10	27.3 ± 2.2	36.8 ± 2.9

[a]Measurements made on B_z only.

Low Frequency Oscillations in the Earth's Magnetic Field
Observed at ATS-1

December, 1967

Event No.	Beginning Day	Time Hour	(U.T.) Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (milli-Hz)
01	Dec. 01	00	01	147	92.3 ± 3.3	10.9 ± 0.4
02	01	12	19	31	76.2 ± 13.3	13.5 ± 2.4
03	01	18	01	56	39.8 ± 10.9	26.8 ± 7.0
04	02	00	20	70	186.7 ± 17.3	5.4 ± 0.5
05	02	03	45	34	47.7 ± 4.8	21.2 ± 2.2
06	02	12	11	18	75.6 ± 9.1	13.4 ± 1.7
07	02	19	31	59	53.0 ± 5.4	19.0 ± 2.1
08	02	22	58	232	77.4 ± 9.9	13.1 ± 1.7
09	03	04	02	17	39.7 ± 0.9	25.2 ± 0.6
10	04	03	58	23	77.9 ± 8.7	13.0 ± 1.4
11	04	20	25	370	60.9 ± 7.6	16.7 ± 2.2
12	07	16	28	801	23.9 ± 4.3	43.4 ± 8.6
13	08	04	39	184	44.9 ± 9.7	23.1 ± 4.7
14	08	15	01	159	41.0 ± 6.1	25.0 ± 4.4
15	08	16	10	90	20.9 ± 1.7	48.2 ± 3.8
16	08	19	55	106	23.4 ± 5.9	45.6 ± 12.0
17	10	00	33	189	32.9 ± 5.5	31.1 ± 5.0
18	10	17	24	147	26.1 ± 4.0	39.1 ± 5.6
19	12	19	48	106	51.8 ± 5.8	19.6 ± 2.3
20	13	19	40	112	49.4 ± 10.4	21.0 ± 3.9

Event No.	Beginning Day	Time Hour	(U.T.) Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (milli-Hz)
21	Dec. 15	11	25	123	64.3 ± 7.5	15.8 ± 2.2
22	16	03	00	40	175.1 ± 17.4	5.8 ± 0.7
23	16	10	51	128	141.8 ± 18.0	7.2 ± 0.8
24	16	21	30	128	52.9 ± 7.2	19.2 ± 2.4
25	17	03	11	26	45.7 ± 3.0	22.0 ± 1.4
26	17	20	17	248	66.4 ± 6.3	15.2 ± 1.3
27	18	02	01	54	68.2 ± 3.8	14.7 ± 0.8
28	18	09	17	162	96.1 ± 11.4	10.6 ± 1.3
29	19	16	22	243	27.6 ± 6.1	37.7 ± 7.2
30	21	11	27	335	68.7 ± 10.0	14.8 ± 2.0
31	21	19	33	305	74.6 ± 7.8	13.6 ± 1.5
32	23	07	44	25	56.3 ± 8.8	18.1 ± 2.7
33	24	16	00	360	110.8 ± 15.3	9.2 ± 1.2
34	25	15	48	18	42.7 ± 2.4	23.5 ± 1.3
35	25	17	40	420	153.0 ± 5.9	6.5 ± 0.3
36	31	02	37	29	34.6 ± 5.8	29.6 ± 4.8

Low Frequency Oscillations in the Earth's Magnetic Field

Observed at ATS-1

January, 1968

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (milli-Hz)
01	Jan 01	00	57	126	100.0 ± 12.0	10.1 ± 1.3
02	01	20	00	113	59.5 ± 9.8	17.2 ± 2.8
03	02	00	30	136	72.6 ± 5.2	13.8 ± 1.1
04	02	03	34	60	56.8 ± 9.3	18.1 ± 3.1
05[a]	02	04	45	99	44.0 ± 5.1	23.0 ± 2.7
06	02	12	19	86	66.2 ± 8.1	15.3 ± 1.7
07	02	15	49	51	83.3 ± 6.5	12.1 ± 1.0
08	02	18	20	323	80.5 ± 12.5	12.7 ± 2.0
09	02	19	06	230	354.3 ± 81.3	2.9 ± 0.6
10	03	02	35	70	97.2 ± 11.9	10.4 ± 1.4
11	03	19	20	335	65.8 ± 7.0	15.4 ± 1.7
12	04	02	09	139	88.3 ± 8.2	11.4 ± 1.1
13	04	09	19	44	117.8 ± 8.4	8.5 ± 0.6
14	04	19	52	38	77.5 ± 7.6	13.0 ± 1.3
15	04	21	45	292	133.0 ± 16.2	7.6 ± 0.9
16	05	07	30	25	46.7 ± 3.2	21.5 ± 1.3
17	05	10	52	17	78.9 ± 3.9	12.7 ± 0.6
18	06	02	19	99	83.6 ± 20.4	12.6 ± 3.0
19	06	07	30	85	104.0 ± 11.2	9.7 ± 1.1
20	06	16	29	206	28.8 ± 3.0	35.2 ± 4.1
21	06	21	22	12	68.3 ± 12.4	15.0 ± 2.5

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min)	Average Period T (Sec)	Average Frequency f (milli-Hz)
22	06	22	57	62	32.2 ± 2.1	31.2 ± 1.9
23	07	01	40	39	32.0 ± 3.7	31.6 ± 3.9
24	07	18	28	167	27.1 ± 1.6	37.5 ± 2.2
25	08	18	48	250	56.9 ± 6.3	17.8 ± 2.3
26	09	20	54	136	158.4 ± 15.2	6.4 ± 0.7
27	10	20	40	10	31.9 ± 2.6	31.5 ± 2.7
28	10	23	36	14	32.1 ± 3.8	31.5 ± 3.8
29	12	22	52	53	37.9 ± 4.5	26.7 ± 3.4
30[a]	13	05	42	15	55.4 ± 11.2	18.6 ± 3.7
31	13	17	47	119	29.3 ± 3.1	34.2 ± 2.5
32	14	23	02	93	69.5 ± 10.2	14.7 ± 2.7
33	15	01	30	37	121.8 ± 17.3	8.4 ± 1.2
34	15	08	31	37	49.4 ± 2.4	20.3 ± 1.0
35	16	00	35	151	142.8 ± 13.4	7.1 ± 0.6
36	16	20	50	61	20.7 ± 3.8	49.8 ± 8.6
37	16	22	36	383	75.9 ± 13.4	13.6 ± 2.9
38	17	12	27	68	67.0 ± 4.8	15.0 ± 1.1
39	17	14	56	242	28.6 ± 6.0	36.3 ± 6.9
40	17	20	15	289	24.0 ± 6.0	44.1 ± 10.3
41	18	02	50	90	112.3 ± 18.3	9.1 ± 1.4
42	18	05	25	87	49.1 ± 6.6	20.7 ± 2.7
43	18	23	09	116	63.9 ± 5.4	15.8 ± 1.3
44	19	00	59	13	28.1 ± 1.9	35.8 ± 2.3
45	19	11	05	90	46.8 ± 1.8	21.4 ± 0.8
46	19	16	16	564	25.8 ± 2.9	39.2 ± 3.9

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min.)	Average Period T (Sec)	Average Frequency f (milli-Hz)
47	20	06	28	214	88.4 ± 9.3	11.4 ± 1.3
48	20	08	15	18	44.8 ± 7.1	22.9 ± 4.5
49	20	16	28	228	26.1 ± 2.4	38.7 ± 3.7
50	21	00	06	76	27.0 ± 3.9	38.0 ± 7.0
51	21	04	15	171	58.5 ± 14.3	18.3 ± 5.4
52	21	17	42	402	52.6 ± 5.9	19.3 ± 2.4
53	21	18	12	367	24.4 ± 2.9	41.6 ± 5.4
54	22	16	09	536	24.4 ± 2.2	41.3 ± 3.8
55	22	15	22	164	46.2 ± 7.4	22.2 ± 3.6
56	23	17	08	526	31.4 ± 6.5	33.1 ± 6.3
57	23	21	59	193	160.6 ± 19.3	6.3 ± 0.8
58[a]	27	03	55	175	195.4 ± 63.3	5.6 ± 1.8
59	27	08	10	72	41.5 ± 8.2	25.0 ± 5.5
60[a]	28	02	02	28	41.9 ± 10.9	25.4 ± 7.2
61	28	20	42	17	69.4 ± 5.4	14.5 ± 1.2
62[a]	29	00	38	24	66.4 ± 16.0	15.8 ± 3.4
63	29	02	40	124	117.0 ± 81.0	12.6 ± 7.8
64	29	23	45	185	82.5 ± 17.0	12.6 ± 2.5
65	30	04	46	14	174.3 ± 2.2	5.7 ± 0.1
66	30	11	02	82	80.7 ± 6.6	12.5 ± 1.1
67	30	20	02	378	69.8 ± 15.8	15.0 ± 3.1

[a]Measurements made on B_z only.

High resolution data not available from January 21, Hr. 00 to January 27, Hr. 03.

Low Frequency Oscillations in the Earth's Magnetic Field

Observed at ATS-1

February, 1968

Event No.	Beginning Time (U.T.) Day		Hour	Min.	Duration (Min.)	Average Period T(Sec.)	Average Frequency f(milli-Hz)
01	Feb.	01	19	18	62	68.8 ± 3.1	14.6 ± 0.7
02		04	18	33	343	71.5 ± 10.1	14.3 ± 2.3
03		06	00	04	78	107.3 ± 4.6	9.3 ± 0.4
04		07	17	30	602	98.0 ± 4.2	10.2 ± 0.4
05		10	01	16	24	119.8 ± 25.1	8.6 ± 1.7
06		11	20	19	93	80.4 ± 10.3	12.6 ± 1.6
07		13	05	21	235	55.8 ± 5.2	18.0 ± 1.6
08		13	12	19	791	75.0 ± 11.8	13.8 ± 2.9
09		14	17	32	548	91.8 ± 13.8	11.2 ± 1.9
10		15	06	39	66	89.8 ± 15.5	11.7 ± 3.1
11		15	19	39	312	44.2 ± 8.8	23.4 ± 4.2
12		17	04	26	62	129.4 ± 23.0	7.9 ± 1.3
13		17	07	58	46	44.0 ± 2.8	22.8 ± 1.4
14		17	10	48	272	78.5 ± 14.0	13.1 ± 2.4
15		17	22	06	158	126.8 ± 21.9	8.1 ± 1.6
16		18	06	48	219	81.3 ± 12.9	12.7 ± 2.7
17		19	00	30	53	64.5 ± 4.6	15.6 ± 1.1
18		19	06	20	123	54.4 ± 8.2	18.8 ± 3.1
19		19	20	53	247	52.3 ± 4.6	19.2 ± 1.6

Event No.	Beginning Time(U.T.) Day		Hour	Min.	Duration (Min.)	Average Period T(Sec.)	Average Frequency f(milli-Hz)
20	Feb.	20	10	50	25	95.2 ± 6.4	10.5 ± 0.7
21		20	17	40	150	35.9 ± 5.1	28.3 ± 3.9
22[a]		20	22	25	145	25.0 ± 4.7	41.0 ± 6.1
23		22	01	37	71	59.3 ± 11.2	17.4 ± 3.4
24		23	17	06	211	77.1 ± 9.0	13.2 ± 2.0
25		23	21	30	160	105.4 ± 1.8	9.5 ± 0.2
26		25	19	22	82	147.4 ± 7.2	6.8 ± 0.4
27		26	17	34	780	134.8 ± 14.8	7.5 ± 0.9
28		28	01	45	495	117.8 ± 18.2	8.7 ± 1.3
29		28	10	40	50	110.8 ± 18.5	9.3 ± 1.6
30		28	20	08	25	142.3 ± 5.6	7.0 ± 0.3
31		28	22	44	211	233.4 ± 41.3	4.4 ± 0.8

[a] measurements made on B_z only.

Low Frequency Oscillations in the Earth's Magnetic Field

Observed at ATS-1

March, 1968

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min.)	Average Period T(Sec.)	Average Frequency f(milli-Hz)
1	Feb 29	20	57	290	78.9 ± 7.6	12.8 ± 1.2
2	Mar 01	20	22	62	61.8 ± 3.3	16.2 ± 0.8
3	01	21	10	180	285.2 ± 45.2	3.6 ± 0.5
4	02	00	54	141	45.6 ± 5.6	22.2 ± 2.8
5	02	21	50	260	56.6 ± 4.2	17.8 ± 1.3
6	03	03	07	63	80.9 ± 20.6	13.0 ± 3.3
7[a]	03	07	33	101	54.9 ± 10.2	18.8 ± 3.2
8	03	23	32	98	66.0 ± 7.0	15.3 ± 1.6
9	04	01	33	51	111.9 ± 19.4	9.2 ± 1.5
10	04	06	58	19	45.7 ± 3.5	22.0 ± 1.9
11	04	13	47	53	62.0 ± 7.9	16.4 ± 2.2
12	04	23	04	26	50.9 ± 8.2	20.1 ± 3.2
13	05	00	02	104	88.7 ± 22.8	12.0 ± 3.1
14	05	03	58	74	37.1 ± 5.0	27.6 ± 4.6
15[a]	05	06	02	13	57.1 ± 4.6	17.6 ± 1.4
16	05	07	51	11	53.2 ± 6.3	19.0 ± 2.0
17	05	19	30	375	64.6 ± 11.4	15.9 ± 2.5
18	06	20	00	116	48.4 ± 9.4	21.3 ± 3.9
19	07	22	37	203	88.3 ± 8.1	11.4 ± 1.1
20	08	03	55	37	147.3 ± 14.3	6.8 ± 0.6

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min.)	Average Period T(Sec.)	Average Frequency f(milli-Hz)
21	08	18	55	205	96.1 ± 11.9	10.6 ± 1.4
22	09	01	10	120	105.7 ± 15.8	9.7 ± 1.4
23	10	00	20	145	164.5 ± 12.7	6.1 ± 0.5
24	10	04	58	52	81.8 ± 10.3	12.4 ± 1.5
25	10	06	52	120	52.0 ± 3.0	19.3 ± 1.0
26	10	13	35	17	89.6 ± 11.3	11.3 ± 1.4
27	11	03	22	15	72.2 ± 8.8	14.0 ± 1.6
28	15	17	37	175	25.7 ± 2.5	39.3 ± 3.5
29	16	01	28	35	144.3 ± 10.3	7.0 ± 0.5
30[a]	16	03	40	65	68.2 ± 8.2	14.8 ± 1.8
31	16	09	10	17	42.7 ± 6.4	21.6 ± 3.4
32	16	20	6	32	26.7 ± 2.6	37.8 ± 4.0
33	17	00	9	51	35.3 ± 3.6	28.7 ± 3.4
34	22	19	40	17	57.4 ± 4.5	17.5 ± 1.4
35	24	00	55	30	141.1 ± 26.9	7.3 ± 1.2
36[a]	24	04	57	93	103.2 ± 13.7	9.8 ± 1.5
37	25	03	47	25	38.2 ± 3.4	26.3 ± 2.4
38	25	22	35	75	54.4 ± 6.5	18.6 ± 2.3
39	27	11	30	40	60.6 ± 4.1	16.5 ± 1.1
40	27	23	10	95	67.5 ± 4.9	14.9 ± 1.1
41	29	00	25	106	126.6 ± 7.9	7.9 ± 0.5
42	29	18	20	240	53.4 ± 6.3	19.0 ± 2.3
43	29	19	52	123	410.8 ± 19.3	2.4 ± 0.3
44[a]	30	01	19	11	87.0 ± 12.2	11.7 ± 1.5

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min.)	Average Period T(Sec.)	Average Frequency f(milli-Hz)
45	30	07	55	227	61.4 ± 7.9	16.5 ± 1.9
46	30	20	48	17	69.9 ± 10.2	14.6 ± 2.0
47[b]	30	23	30	80	312.7 ± 36.6	3.2 ± 0.4
48	31	01	45	40	83.9 ± 12.1	12.1 ± 1.7
49	31	15	58	27	25.2 ± 1.6	39.8 ± 2.5

[a]Measurements made on B_z only.

[b]Beginning time and duration are uncertain because a gap in the data preceded the event.

The following gaps in the ATS-1 data are noted:

(1) From March 11, Hr. 08, Min. 0 to March 15, Hr. 13, Min. 0

(2) From March 18, Hr. 08, Min. 0 to March 22, Hr. 13, Min. 0

(3) From March 25, Hr. 15, Min. 12 to March 25, Hr. 15, Min. 33

(4) From March 30, Hr. 22, Min. 0 to March 30, Hr. 23, Min 29

Low Frequency Oscillations in the Earth's Magnetic Field

Observed at ATS-1

April, 1968

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min.)	Average Period T(Sec.)	Average Frequency f(milli-Hz)
01	Apr. 01	21	48	15	50.7 ± 8.5	20.3 ± 3.6
02	02	00	59	147	105.4 ± 13.1	9.6 ± 1.2
03	03	18	54	78	55.3 ± 5.0	18.2 ± 1.7
04	04	04	15	46	80.3 ± 6.7	12.5 ± 1.1
05	05	00	06	103	129.3 ± 11.7	7.8 ± 0.7
06	06	03	02	100	95.9 ± 28.5	11.3 ± 3.4
07	06	15	12	278	31.9 ± 6.3	32.6 ± 6.7
08	06	22	22	98	78.5 ± 3.6	12.8 ± 0.6
09	09	20	19	401	141.3 ± 17.1	7.2 ± 0.9
10	10	21	17	173	79.5 ± 6.7	12.7 ± 1.1
11	11	01	56	126	105.3 ± 9.9	9.6 ± 1.0
12[a]	11	16	02	13	125.4 ± 8.3	8.0 ± 0.5
13	13	06	55	125	54.5 ± 6.1	18.6 ± 2.2
14	13	21	56	34	45.5 ± 7.2	22.5 ± 3.6
15	13	23	30	128	61.0 ± 13.2	17.2 ± 4.2
16	14	05	56	34	38.7 ± 4.8	26.2 ± 3.7
17	15	01	10	310	59.5 ± 6.7	17.0 ± 1.9
18	15	19	39	102	27.1 ± 3.5	37.5 ± 5.0
19	17	00	22	48	29.4 ± 8.4	36.1 ± 8.7

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min.)	Average Period T(Sec.)	Average Frequency f(Milli-Hz)
20	17	02	02	108	81.0 ± 5.4	12.4 ± 0.9
21	17	18	12	98	55.7 ± 3.8	18.0 ± 1.4
22	23	00	46	29	96.5 ± 14.7	10.6 ± 1.5
23	23	04	07	18	149.0 ± 7.8	6.7 ± 0.4
24	24	08	02	57	49.7 ± 5.5	20.3 ± 2.4
25	25	18	10	48	77.2 ± 2.5	13.0 ± 0.4
26[a]	26	03	12	53	212.7 ± 30.4	4.8 ± 0.7
27[a]	26	10	54	18	69.2 ± 4.9	14.5 ± 1.1
28	27	19	34	56	22.7 ± 2.1	44.5 ± 4.4
29	28	00	54	120	47.9 ± 7.6	21.4 ± 3.4
30	29	12	21	11	102.4 ± 4.7	9.8 ± 0.5
31	30	02	08	21	54.7 ± 3.4	18.3 ± 1.2
32	30	20	22	83	54.7 ± 9.3	18.7 ± 2.8

[a] Measurements made on B_z only.

Low Frequency Oscillations in the Earth's Magnetic Field

Observed at ATS-1

May, 1968

Event No.	Beginning Day	Time Hour	(U.T.) Min.	Duration (Min.)	Average Period T. (Sec.)	Average Frequency F (Milli-Hz)
01	May 01	22	09	199	85.8 ± 19.4	12.3 ± 3.1
02	02	04	09	75	48.0 ± 17.1	23.2 ± 7.6
03[a]	02	04	45	65	198.8 ± 41.4	5.2 ± 1.2
04	02	23	32	577	50.4 ± 10.8	20.8 ± 5.1
05	04	00	38	32	28.8 ± 3.1	35.1 ± 4.2
06	06	21	511	46	34.0 ± 4.7	29.9 ± 3.8
07	07	01	06	144	81.4 ± 5.8	12.3 ± 0.9
08	09	08	12	16	48.7 ± 3.6	20.6 ± 1.6
09	09	14	20	12	72.0 ± 7.9	14.0 ± 1.6
10	09	19	33	387	71.7 ± 13.2	14.5 ± 3.2
11[a]	10	04	10	50	158.0 ± 19.8	6.4 ± 0.8
12	10	23	47	23	60.4 ± 6.0	16.7 ± 1.8
13[a]	11	02	22	32	133.2 ± 33.5	7.9 ± 1.7
14[a]	11	06	26	20	225.2 ± 30.2	4.5 ± .7
15	11	10	27	188	109.5 ± 17.3	9.4 ± 1.8
16	11	16	05	334	32.2 ± 9.9	33.8 ± 9.9
17[a]	12	00	39	31	126.0 ± 21.9	8.1 ± 1.4
18[a]	12	03	20	23	126.7 ± 11.6	7.9 ± 0.7
19	12	15	32	156	28.7 ± 6.3	36.3 ± 7.4

Event No.	Beginning Day	Time Hour	(U.T.) Min.	Duration (Min.)	Average Period T. (Sec.)	Average Frequency P. (Milli-Hz)
20	12	19	59	256	26.4 ± 4.8	39.3 ± 8.4
21	12	22	38	32	55.5 ± 7.3	18.3 ± 2.5
22	13	08	45	15	52.1 ± 8.4	19.6 ± 3.2
23	13	16	02	94	27.5 ± 3.6	37.0 ± 5.1
24	13	19	14	205	30.2 ± 4.8	33.7 ± 4.4
25	13	20	26	282	76.8 ± 9.1	13.2 ± 1.5
26	14	21	33	13	54.0 ± 1.8	18.5 ± 0.6
27	16	00	16	37	26.6 ± .6	37.7 ± .9
28	16	00	59	21	59.7 ± 8.7	17.0 ± 2.4
29	16	04	07	10	60.6 ± 6.2	16.7 ± 1.8
30	16	23	08	157	73.6 ± 7.8	13.7 ± 1.5
31	17	08	05	124	28.5 ± 5.1	36.6 ± 6.9
32	17	21	50	103	64.9 ± 6.8	15.6 ± 1.7
33	18	01	20	55	123.4 ±16.9	8.3 ± 1.3
34	20	13	01	28	78.7 ± 2.2	12.7 ± 0.4
35	21	00	39	31	40.4 ± 8.3	25.6 ± 5.3
36[a]	21	02	20	30	130.9 ±24.7	7.9 ± 2.0
37	21	03	53	201	73.1 ±10.4	14.0 ± 2.3
38	21	10	52	12	47.0 ± 4.1	21.4 ± 1.8
39	22	23	35	35	47.3 ± 3.8	21.3 ± 1.8
40[a]	24	02	49	18	157.2 ±13.5	6.4 ± 0.6
41	26	22	10	213	152.3 ± 4.8	6.6 ± 0.2
42	29	00	00	32	112.7 ± 7.4	8.9 ± 0.6
43	29	06	39	62	47.5 ± 4.1	21.2 ± 1.8
44	29	22	48	35	67.7 ± 4.0	14.8 ± 0.9

Event No.	Beginning Day	Time Hour	(U.T.) Min.	Duration (Min.)	Average Period T. (Sec.)	Average Frequency P. (Milli-Hz)
45[a]	30	03	09	33	132.0 ± 23.9	7.8 ± 1.6
46	30	06	00	96	60.7 ± 9.8	16.9 ± 2.8
47	30	22	54	22	65.6 ± 1.9	15.3 ± 0.4

[a]Measurements made on B_z only.

Low Frequency Oscillations in the Earth's Magnetic Field

Observed at ATS-1

June, 1968

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (Milli-Hz)
01	Jun 01	02	00	55	71.0 ± 6.6	14.2 ± 1.4
02	01	19	21	45	30.2 ± 3.5	33.5 ± 4.1
03	01	23	44	35	62.5 ± 10.3	16.4 ± 2.5
04[a]	03	02	21	94	209.4 ± 55.5	5.0 ± 1.1
05	03	07	16	34	49.1 ± 6.5	20.7 ± 2.7
06	03	09	31	12	48.1 ± 6.8	21.2 ± 3.2
07	03	21	19	73	32.2 ± 3.5	31.4 ± 3.7
08	04	00	12	12	67.3 ± 12.5	15.3 ± 2.8
09	07	17	08	91	27.1 ± 6.1	38.5 ± 8.9
10	07	23	26	93	115.3 ± 8.1	8.7 ± 0.6
11	08	02	50	58	75.2 ± 2.0	13.6 ± 2.3
12	08	06	33	126	50.4 ± 10.3	20.6 ± 4.4
13	09	03	25	94	130.5 ± 23.8	7.9 ± 1.5
14	09	04	11	22	79.8 ± 6.2	12.6 ± 1.0
15	09	07	01	324	65.6 ± 4.5	15.3 ± 1.2
16	09	21	19	97	33.9 ± 7.2	30.7 ± 6.7
17	09	23	20	27	73.7 ± 7.8	13.7 ± 1.6
18[a]	10	03	45	40	170.7 ± 29.7	6.0 ± 1.4
19	10	09	53	10	47.5 ± 4.5	21.3 ± 2.2
20	10	17	59	100	71.6 ± 11.4	14.4 ± 3.1
21	11	13	07	62	103.7 ± 18.5	9.9 ± 1.7

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (Milli-Hz)
22	Jun 11	17	10	192	290.0 ± 5.9	35.8 ± 6.9
23	11	20	42	161	64.0 ± 13.5	16.3 ± 3.5
24[a]	12	02	08	22	183.6 ± 16.2	5.5 ± 0.5
25	12	09	24	23	54.2 ± 8.1	18.8 ± 2.8
26	13	16	50	17	60.7 ± 16.9	17.6 ± 4.5
27	13	20	02	67	70.5 ± 11.5	14.6 ± 2.7
28	14	17	44	38	82.6 ± 8.4	12.2 ± 1.3
29	14	20	36	344	68.6 ± 8.0	14.8 ± 2.0
30	15	23	28	148	63.3 ± 9.5	16.1 ± 2.4
31	16	09	48	12	79.7 ± 13.1	12.9 ± 2.4
32	17	00	06	142	101.3 ± 6.0	9.9 ± 0.6
33	17	00	26	69	82.6 ± 2.3	12.1 ± 0.3
34[a]	17	01	42	24	157.1 ± 19.5	6.5 ± 1.0
35	17	19	08	340	36.2 ± 6.3	28.5 ± 5.4
36	19	07	12	16	44.8 ± 3.9	22.5 ± 2.0
37	22	01	24	26	118.3 ± 11.6	8.5 ± 0.9
38	22	21	54	21	48.3 ± 4.9	20.8 ± 2.0
39	22	23	00	195	66.4 ± 6.7	15.2 ± 1.7
40	24	17	13	42	87.9 ± 10.7	11.6 ± 1.9
41[a]	26	11	17	14	181.2 ± 10.0	5.5 ± 0.3
42	26	12	18	152	87.1 ± 12.5	11.7 ± 1.8
43	28	00	30	38	360.0 ± 40.7	2.8 ± 0.3
44	28	02	05	16	176.0 ± 32.5	5.9 ± 1.1
45	28	03	19	143	57.5 ± 7.0	17.7 ± 2.3
46	29	16	36	47	129.2 ± 10.0	7.8 ± 0.6
47	29	23	46	26	99.5 ± 7.4	10.1 ± 0.8

[a]Measurements made on B_z only.

Low Frequency Oscillations in the Earth's Magnetic Field

Observed at ATS-1

July, 1968

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (Milli-Hz)
01	July 01	00	08	34	64.8 ± 9.5	15.7 ± 2.3
02[a]	01	03	31	11	134.4 ± 17.8	7.6 ± 1.1
03	01	05	51	41	36.5 ± 6.0	28.1 ± 4.6
04[a]	02	01	50	26	96.6 ± 18.1	10.6 ± 2.0
05[a]	02	08	15	132	49.9 ± 12.3	21.3 ± 5.05
06	04	00	20	61	39.3 ± 5.6	29.7 ± 4.4
07	04	05	19	11	77.6 ± 15.9	13.4 ± 3.1
08[a]	04	06	58	27	53.8 ± 8.2	18.9 ± 3.1
09	04	09	40	25	47.1 ± 10.4	22.5 ± 6.6
10	04	12	11	23	69.0 ± 7.4	14.7 ± 1.8
11	04	19	43	30	28.1 ± 5.3	36.5 ± 5.9
12	04	21	53	18	30.8 ± 7.3	33.6 ± 5.5
13	04	22	50	77	32.0 ± 6.4	32.2 ± 5.4
14	06	10	24	47	48.8 ± 3.4	20.6 ± 1.4
15	10	03	37	125	61.0 ± 11.61	16.9 ± 3.2
16	10	12	38	70	48.1 ± 9.7	21.6 ± 4.5
17	10	15	10	13	44.5 ± 9.7	22.7 ± 2.3
18	18	15	03	12	39.3 ± 5.3	25.8 ± 3.9
19	19	04	07	33	78.8 ± 12.0	13.0 ± 1.9
20	20	00	50	110	116.7 ± 19.7	8.8 ± 1.5

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (Milli-Hz)
21	July 20	16	01	84	38.0 ± 6.22	26.9 ± 4.7
22	20	18	18	57	42.5 ± 7.5	24.2 ± 4.5
23	10	18	21	73	33.9 ± 5.5	30.5 ± 5.5
24	10	21	35	286	38.2 ± 7.9	22.2 ± 5.8
25	11	03	55	83	51.5 ± 8.9	20.0 ± 3.7
26[b]					241.5 ± 9.0	4.1 ± .16
27	11	06	57	62	42.2 ± 8.7	24.5 ± 4.5
28	12	02	28	49	66.5 ± 13.6	15.7 ± 3.9
29	13	20	16	121	83.2 ± 14.3	12.3 ± 2.2
30	14	00	33	266	44.9 ± 9.0	23.0 ± 4.1
31	14	16	34	50	623.2 ± 244.4	1.8 ± .7
32	14	21	25	83	50.8 ± 4.3	19.8 ± 1.9
33	20	21	40	208	43.4 ± 6.5	23.6 ± 3.6
34[a]	25	12	07	45	55.7 ± 8.1	18.3 ± 2.6
35[a]	26	03	27	107	84.4 ± 13.9	12.2 ± 2.3
36	26	09	28	86	74.5 ± 11.7	12.8 ± 1.9
37	26	17	09	143	23.8 ± 2.2	42.3 ± 3.7
38	26	20	46	305	47.7 ± 9.1	21.7 ± 4.0
39	27	04	59	82	43.5 ± 7.7	23.5 ± 3.9
40	28	00	18	54	28.0 ± 4.6	36.3 ± 4.7
41	28	03	42	35	43.0 ± 6.6	23.7 ± 3.6
42[b]					76.5 ± 9.5	13.6 ± 1.7
43	30	00	08	113	81.3 ± 10.1	12.5 ± 1.6

[a]Measurements made on B_z only.

[b]1st Harmonic of previous event.

Low Frequency Oscillations in the Earth's Magnetic Field

Observed at ATS-1

August, 1968

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (Milli-Hz)
01[a]	Aug 03	05	01	76	44.3 ± 5.1	22.8 ± 2.8
02	03	08	15	43	47.8 ± 8.5	21.6 ± 4.4
03	03	22	29	278	48.8 ± 8.5	21.1 ± 4.1
04[b]					82.9 ± 12.8	12.3 ± 1.7
05	05	04	33	18	52.3 ± 9.2	19.5 ± 3.0
06	06	01	17	34	68.6 ± 13.7	15.0 ± 2.5
07	06	03	08	147	42. ± 7.8	24.3 ± 4.7
08	06	23	24	19	32.6 ± 5.9	31.7 ± 6.7
09	07	01	34	64	92.5 ± 11.7	10.9 ± 1.2
10	07	05	11	13	50.7 ± 10.2	20.4 ± 4.4
11[a]	09	02	25	25	56.0 ± 8.7	18.2 ± 2.9
12	09	23	39	15	121.2 ± 16.7	8.4 ± 1.1
13	14	02	23	18	100.0 ± 17.6	10.3 ± 1.8
14[a]	14	06	04	26	43.8 ± 6.8	23.3 ± 3.5
15	14	08	17	133	39.8 ± 4.9	25.5 ± 3.3
16	15	01	26	114	105.2 ± 14.5	9.7 ± 1.3
17	15	06	40	181	47.6 ± 6.6	21.4 ± 3.2
18	15	21	22	12	28.7 ± .8	34.8 ± .9
19	16	00	41	20	50.6 ± 10.2	20.4 ± 4.0
20	16	16	38	21	24.3 ± 3.2	41.7 ± 4.9

↑ misprint

Event No.	Beginning Time (U.T.) Day	Hour	Min.	Duration (Min.)	Average Period T (Sec.)	Average Frequency f (Milli-Hz)
21	Aug 16	19	05	12	~~22~~27.5 ± 3.1	36.6 ± 3.7
22	16	23	17	13	33.1 ± 6.2	31.2 ± 6.5
23[a]	17	22	43	21	34.5 ± 4.2	29.3 ± 3.4
24	18	00	17	120	29.8 ± 4.8	34.3 ± 5.5
25[b]					61.0 ± 7.2	16.6 ± 1.8
26	18	09	02	33	55.8 ± 6.6	18.2 ± 2.3
27	19	09	36	175	52.1 ± 8.4	19.7 ± 3.4
28[b]					89.0 ± 6.9	11.3 ± .9
29	19	18	55	15	84.7 ± 19.9	12.4 ± 2.9
30	19	23	29	33	40.1 ± 5.8	25.5 ± 3.8
31	22	22	03	116	37.2 ± 8.3	29.9 ± 5.1
32	23	06	33	37	39.1 ± 4.1	25.9 ± 3.0

[a]Measurements made on B_z only.

[b]1st Harmonic of previous event.