DIURNAL VARIATIONS IN THE POWER SPECTRUM AND POLARIZATION OF TELLURIC CURRENTS AT CONJUGATE POINTS, $L = 2 \cdot 6$

By K. B. Mather,* E. J. Gauss,* and G. R. Cresswell*

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Summary

The power spectrum of telluric currents, at the sub-auroral latitude where $L = 2 \cdot 6$, shows a pronounced diurnal variation. The variation is contributed mainly by a strong peak at about 40 s, which shows a large cyclic fluctuation in amplitude and also a tendency to shift in frequency. The amplitude is larger and the period somewhat shorter during the day-time. The 40-s peak is also subject to appreciable random fluctuation in period. The spectrum shows shorter periods (7–14 s), and longer periods (several hundred seconds) in addition to the 40-s peak. There is a general shift to slightly longer periods at the time of auroral onset. The spectra are compared with those obtained at other latitudes. A period of about 40 s appears to have a wide distribution in latitude. It can be followed from mid latitudes to latitudes in the auroral zone and polewards of the auroral zone. The significant variation with geomagnetic latitude seems to be the relative amount of power associated with any one period rather than in the period itself. The observations are not readily reconciled with theoretical estimates of magnetospheric oscillations in the transverse and compressional modes.

A diurnal variation occurs also in the polarization of the electric vector. Directions of rotation are opposite at conjugate points for the 40-s period. A reversal of the direction of polarization seems to occur roughly along the line perpendicular to the Sun-Earth direction.

Introduction

The conjugacy of telluric currents was reported in an earlier paper (Mather and Wescott 1962) based on an analysis of data obtained at Cold Bay in the Aleutian Islands and Oamaru in New Zealand. The geographic coordinates of the stations were 55°16′ N., 162°52′ W. and 44°59½′ S., 170°58′ E. respectively, corresponding to a geomagnetic latitude of approximately 53° and an L-value (McIlwain's parameter) of $2 \cdot 6$. Amplitude-time records were generally similar at the two stations, while differing from those at other (non-conjugate) points, in much the same way that magnetic, auroral disturbances and various ionospheric phenomena have been shown to follow the same pattern at points linked by a common field line. (See, for instance, the papers presented in the *Proceedings of the International Conference on the Ionosphere*, London, July 1962.) The satisfactory proof that telluric currents show conjugate behaviour is important not only to the general study of conjugacy, but also in establishing beyond reasonable doubt that electric currents in the Earth can be interpreted, if care is exercised in choice of sites, in terms of ionospheric or magnetospheric perturbations without undue distortion due to the local geology or man-made sources of electrical interference.

* Geophysical Institute, University of Alaska, College, Alaska.

In the previous paper, brief reference was made to the spectral composition of the telluric currents and to their polarizations. The present paper deals with this aspect in more detail, as part of the continuing study of the Oamaru–Cold Bay conjugate pair. In particular we are concerned with (i) the dominant periods of oscillation present at this magnetic latitude, (ii) the systematics of the direction of rotation of the E-vector in northern and southern hemispheres, and (iii) diurnal effects in the spectrum and in the polarization.

The determination of the power spectrum is part of a broader program which involves a comparison of dominant frequencies over a wide range of geomagnetic latitudes up to about 78°, and is not directly related to questions of conjugacy so much as to the origin of periodic phenomena in and near the auroral zone. However, as pointed out in the first paragraph, the fact that conjugate data are available allows us to interpret the spectrum without the suspicion that local interference is contributing to the telluric currents.

The comparison of polarizations at the conjugates is an important source of information concerning the field linkage between the hemispheres and the mode of excitation of hydromagnetic oscillations in the exosphere (Sugiura 1961; Wilson and Sugiura 1961).

Diurnal variations in both the power spectrum and the polarizations have been sought, in the hope that they may shed light on the nature of the solar-terrestrial relationship. The most likely source of the almost continuous micropulsation activity is the fluctuating pressure of the stream of solar particles on the magnetospheric boundary. Consequently one might expect the characteristic frequencies at a pair of stations to follow a 24-hr cycle related to the cyclic distortion of that segment of the magnetosphere as it rotates in the solar corpuscular stream. The day-night (and seasonal) condition of the ionosphere probably also plays a part in modifying the spectrum of hydromagnetic waves whose electromagnetic component is detected at the Earth's surface.

In a previous report dealing with the Shepherd Bay–Scott Base pair* (Wescott and Mather 1963), some evidence was presented for a diurnal variation in the degree of correlation between magnetic disturbances recorded at very high geomagnetic latitudes ($\approx 78°$), polewards of the auroral zone, and a tentative interpretation of this was suggested in terms of a gross distortion of the Earth's outer field. Although the same effect is not expected to persist at the sub-auroral latitudes of Cold Bay and Oamaru, it is of some interest to find out whether any related effects occur, e.g. spectral changes and polarizations. However, in view of the difference in the type and magnitude of disturbances being correlated at sub-auroral latitudes, different instrumentation had to be employed.

The Askania Variographs used at the auroral zone and polar cap stations have sufficient sensitivity ($\approx 25\ \gamma$/mm) for most of the activity. At Cold Bay and Oamaru, where the activity is an order of magnitude smaller, the same instruments are too insensitive to record any but major disturbances.

* Geographic coordinates: Shepherd Bay 68°48′ N., 93°24′ W. on the Boothia Peninsula in northern Canada; Scott Base 77°51′ S., 166°45′ E. in Antarctica, $L \approx 25$.

Equivalent Sensitivity of Telluric Current System

Telluric current equipment is considerably cheaper than magnetometers of comparable sensitivity, and, provided one is chiefly interested in qualitative or semiquantitative information (e.g. onsets of disturbances, sense of the polarization ellipse, spectral analysis, etc.) rather than absolute magnitudes of the field, the uncertainties due to local environment do not generally matter. Nevertheless, for comparison with other magnetic stations it is useful to know the approximate equivalence between the electric field (mV/km) recorded with telluric current equipment and the magnetic field (γ) at the same site. In the case of Oamaru, this was determined for long-period, large-amplitude disturbances by comparing with Askania magnetograms obtained at the same site. For typical events of $\sim$ 20–30 min period the relationship is 1 mV/km $\simeq 1 \cdot 5\ \gamma$. (Full-scale deflection on the telluric current recorders was 34 mV/km.) However, for short-period oscillations ($T \gtrsim 1$ min) the equivalent sensitivity is 1 mV/km $\sim 0 \cdot 2\ \gamma$.

These relationships are very rough but they serve to indicate that the subsequent discussion of telluric current spectra and polarizations relates to the range of field activity generally classed as *micropulsation*. Typical telluric current variations at Oamaru of period somewhat less than 1 min range from about 2–20 mV/km throughout a day (excluding the night-time auroral disturbance, which may be much greater). This range corresponds to $\sim 0 \cdot 4$ to $4\ \gamma$.

Conjugacy versus Large-scale Coherence

It is important to appreciate what type of activity is being considered here, because any considerations of conjugacy at these sub-auroral latitudes must distinguish between the low amplitude, high frequency, essentially continuous micropulsation activity and the larger amplitude, longer period disturbances which accompany auroral activity nearer the poles.

Many forms of micropulsation activity are known to be coherent over a wide area of latitude and longitude, and cannot therefore be treated as a conjugate phenomenon in a restricted sense, i.e. similar and simultaneous magnetic variations within field-linked localized areas of the northern and southern hemispheres.

On the other hand auroral zone phenomena do tend to exhibit conjugacy in a quite restricted sense (Wescott 1961, 1962; DeWitt 1962; Hook 1962). More recently, Wescott (unpublished data) has plotted "correlation contours" delineating zones of equal correlation coefficient based on a computer analysis of magnetograms from a network of 11 stations in Alaska and the U.S.S.R. and Macquarie Island in the South Pacific. For typical bay-type events the zone of good correlation ($> 0 \cdot 8$) is restricted to an elliptical area, typically $\sim$ 1000 km along the major axis (approximately parallel to the geomagnetic latitude) and 400 km along the minor axis.

In a previous paper dealing with conjugacy of telluric currents, we concentrated attention on the auroral disturbances recorded at Cold Bay and Oamaru (Mather and Wescott 1962). The present paper deals with the background micropulsation activity.

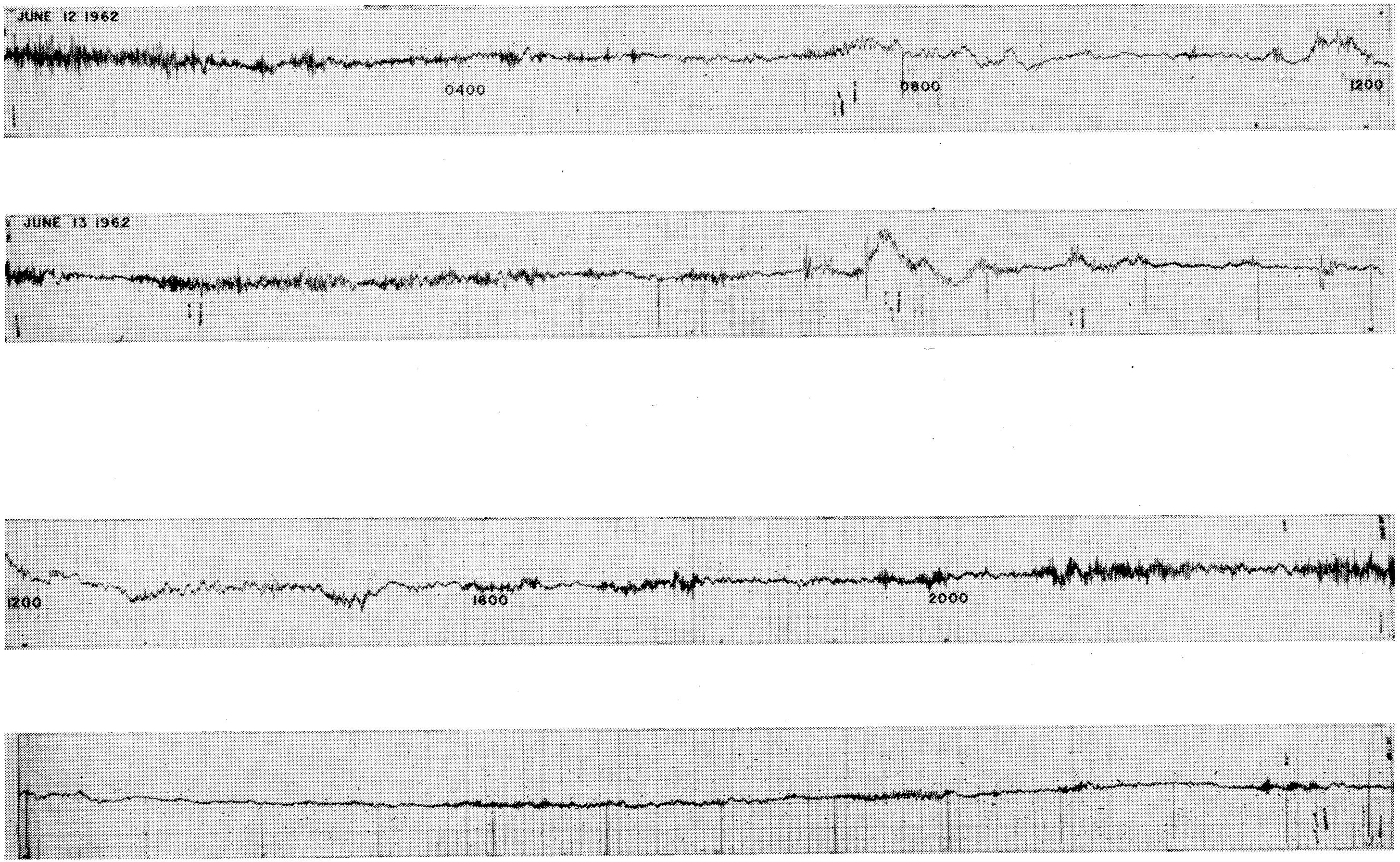

Fig. 1.—North-south telluric current records from Oamaru, New Zealand, June 12–13, 1962. Times shown in U.T. (Local noon is about 0000 U.T.)

Diurnal Variation of Amplitude

Even a casual inspection of the slow-run (6 in/hr) charts from Oamaru and Cold Bay shows an obvious 24-hr cycle in the spectral composition. (In view of the greater sensitivity at Oamaru, as discussed by Mather and Wescott (1962), the following remarks are based on data from there.) Figure 1 shows two successive days of Oamaru record. Disregarding the long periods ($\sim$ several minutes) including large amplitude auroral disturbances, the short-period "fuzz" on the records has a maximum amplitude at about local midday and a minimum at about local midnight. The general characteristics of this high frequency component identify it with the 30-s magnetic activity noted by Stewart (1861), Eschenhagen (1897), Birkeland (1901), and studied in some detail by Terada (1917) at Tokyo.

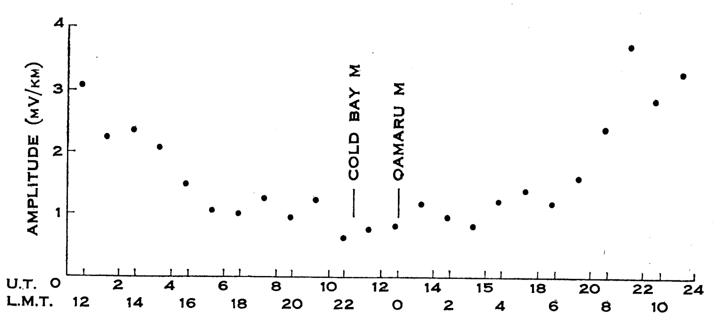

Fig. 2.—Diurnal variations of amplitude of high frequency "fuzz" on Oamaru north-south telluric current record. Average of data during period June 11–17, 1962. Local midnight is shown for Oamaru and Cold Bay.

To exhibit the diurnal occurrence quantitatively, the amplitude of short-period fluctuations at Oamaru was sampled every 10 minutes for seven days (June 11–17, 1962), and the amplitudes averaged for each hour of the day. Figure 2 shows the result for the north-south component. The minimum amplitude occurs about an hour before local midnight at Oamaru (170°58′ E. meridian), but the distribution is fairly flat between 1800 and 0400 Local Time (L.T.). North-south and east-west fluctuations show the same diurnal behaviour, which is therefore a genuine cyclic effect in the power associated with the fuzz frequencies of telluric currents, rather than a diurnal rotation of the preferred direction of the electric vector. This is confirmed by the more detailed study of polarization dealt with later.

The *average* behaviour represented by Figure 2 must not be allowed to conceal the essentially random character of individual micropulsation bursts occurring during a 24-hr period. It merely expresses the fact that bursts are more frequent on the day side, leading often to almost continuous activity, but less frequent on the night side.

One other comment can be made on the basis of inspection of the slow-run records. The activity at noon is noticeably higher in frequency than that around midnight. Whereas the amplitude quoted for the fuzz at noon refers to a period of $\sim 0{\cdot}5$ min, that accompanying the auroral disturbances near midnight appears to be somewhat longer. Thus, Figure 2 is a composite of at least two frequencies, and the "valley" around midnight would probably be closer to zero amplitude if attention were confined to the 0·5-min oscillation alone.

The Power Spectrum

To obtain more quantitative information on the spectral composition, a number of fast-run records were made at $\frac{5}{6}$ in/min during the occupation of Oamaru and Cold Bay. Power spectra were obtained from samples of the north-south records at intervals throughout a 24-hr period (April 11–12, 1962), the amplitude scalings being derived from the semi-automatic Bensen Lehner "Oscar" and attached card punch. The scaling increment was 0·05 in ($\equiv 3\cdot6$ s). The samples scaled generally represented 18-min runs, but in some instances they were 36-min and in one case a 72-min sample of continuous scaling was taken in order to derive the longer periods present.

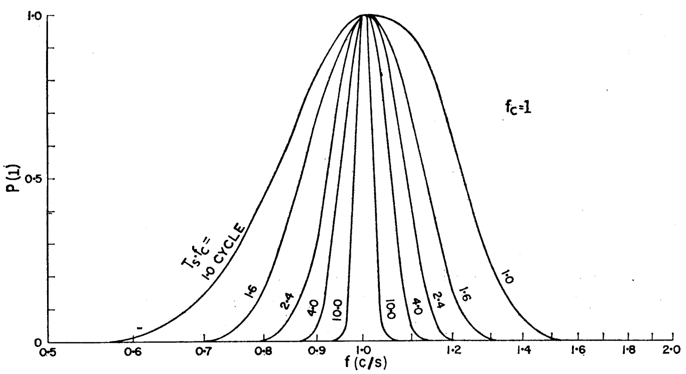

Fig. 3.—Properties of $P(f_c)$ showing the influence of the bandwidth parameter.

Power spectral densities were computed on an IBM-1620, using a program developed by one of the authors (Gauss 1963, 1964), as follows.

An array of filters and power detectors can provide an estimation of power spectral density. The array may be electronic and process electrical data or, as used here, it may be in the form of a computer program and process data on punched cards. If $P(f_c)$ is the power output from a filter of centre frequency f_c, and its bandwidth is controlled by the parameter T_s, for data y_j which have been sampled every Δt the power output may be found by

$$P(f_c) = \frac{\Delta t}{(T_s/\Delta t)}\left[\left(\sum_{j=1}^{T_s/\Delta t} y_j \cos 2\pi f_c t\right)^2 + \left(\sum_{j=1}^{T_s/\Delta t} y_j \sin 2\pi f_c t\right)^2\right].$$

This assumes that $T_s/\Delta t$ is an integer. In general it is not, and a practical computing formula must use the nearest integer. When the record is long compared with T_s, power outputs are computed for sequential segments of the record and then averaged.

The properties of $P(f_c)$ and the influence of the bandwidth parameter T_s are illustrated by Figure 3. For the graph, the filter centre frequency f_c is set equal to one.

For each T_s, values of $P(1)$ were computed for each of several sets of data. The data were formed by sampling $y(t) = \sin 2\pi ft$ every Δt where $\Delta t \leqslant 1$. Each set corresponded to a different frequency covering the range from 0·5 to 2·0. The curves so obtained are analogous to the response curves of electrical filters.

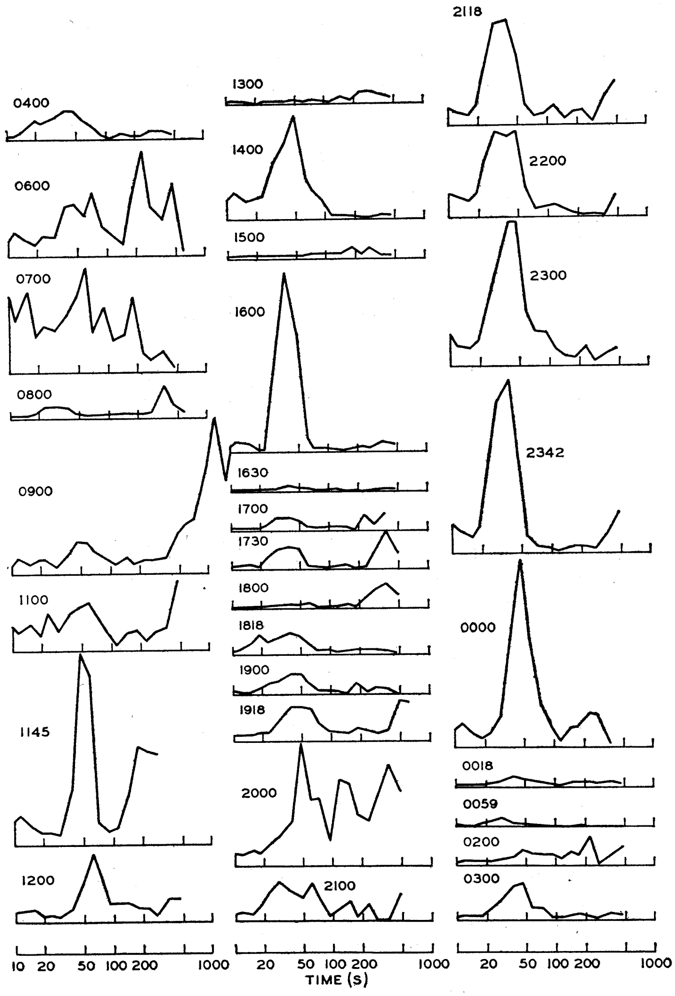

Fig. 4.—Power spectra from Oamaru, taken at intervals during a 24-hr period, April 11–12, 1962. The ordinate scales for the 0900 and 1600 spectra are contracted by the factor 1/2·5 compared with the other spectra.

For the determination of spectra an array of filters is needed. The bandwidth of the filters, expressed in percentage of centre frequency, is constant. A bandwidth of 7% either side of centre was used. This corresponds to $T_s f_c$ equal to 4 cycles. The centre frequency of each filter was separated from those of its neighbours so that the response curves overlap. This causes the centre frequencies to be spaced by equal ratios.

Diurnal Variations in the Spectrum

The set of spectra shown in Figure 4 was produced with the program described above, the ordinates being the power coefficient $P(f_c)$. Intervals sampled during the 24-hr period were selected without regard to any particular system; in some instances they happen to cover moderately disturbed periods and in others fairly quiet periods. The most conspicuous feature is the peak at 30–70 s (centred on about 40 s), which is evidently the oscillation noted from visual inspection of slow-run records. There is also a minor peak, not well defined by the present data but probably about 7–14 s, and a spread of energy at a period of several hundred seconds.

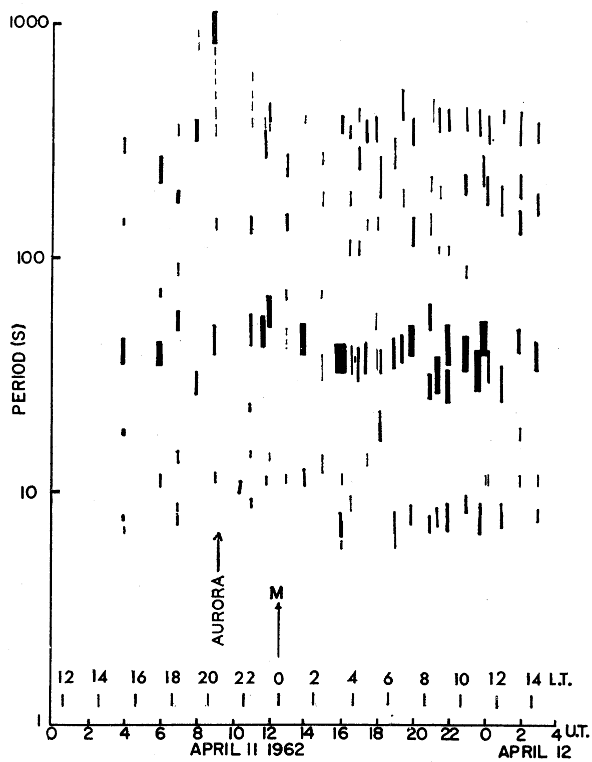

Fig. 5.—Peaks in power spectra of Oamaru data, plotted as a function of time during the 24-hr period April 11–12, 1962.

The peaks obtained in this analysis are plotted on a 24-hr time base in Figure 5. From Figures 4 and 5 the following points can be listed.

(1) In general, peaks of highly changeable intensity are superposed on a continuous background. The background may, of course, comprise minor peaks (possibly overtones* which are unresolved by the present technique), or it may be genuinely continuous.

* See reference in later section to Wilson (1963).

(2) When the section of analogue chart analysed happens to include one of the frequent bursts of micropulsations, the peak appears strongly developed on the spectrogram, e.g. 1200, 1600 U.T. However, even when the record is fairly quiet, it may consist of quasi-sinusoidal oscillations showing a pronounced peak in the power spectrum, e.g. 0800 U.T. Less often, the power is more uniformly distributed through the spectrum, and the analogue record is correspondingly irregular, but even in such cases the 40-s peak nearly always appears when the record is analysed, e.g. 1100, 2000 U.T. This is a persistent oscillation, rarely missing entirely from the Oamaru and Cold Bay records.

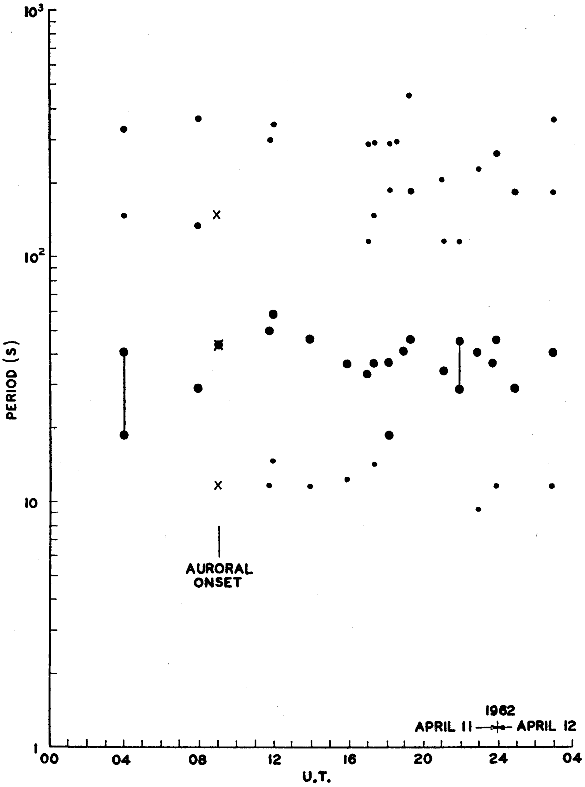

Fig. 6.—Peaks in power spectra of Oamaru data, April 11–12, 1962, using only the regular and quasi-regular sections of the analogue chart.

(3) As seen in Figure 5, appreciable variability can occur, both randomly and systematically, in the exact period of the "40-s" peak. The systematic effect is shown better by Figure 6, which resembles Figure 5 except that it is restricted to quasi-regular oscillations, i.e. those showing essentially a monochromatic spectrum. The average period tends to be longer during the night.

(4) The sharp onset of auroral activity to the north at 0909 U.T. (determined from telluric current records at College) was accompanied by a burst of oscillations of longer-than-average period at Cold Bay and Oamaru. This was repeated several

times, on each occasion accompanying a resurgence of the activity at College, during the next few hours. College records were fairly quiet by 1500 U.T., by which time the Oamaru spectra were again showing shorter period oscillations.

(5) From about 1700 to 0500 U.T. (early morning to evening local times), periods around 30 s and shorter occur. These contribute to the fuzz of Figure 2. However, Figures 2 and 5 should not be compared in detail because the former is based on averages while the latter is intended to display the behaviour during a single day. There is always a random factor present also, so that at any one time, day or night, this peak might be found between about 25 and 60 s. The chief point is that, on the average, longer periods tend to occur at night, especially during the presence of aurora, whereas during the day the trend is towards shorter periods.

(6) Peaks in the power spectrum of Oamaru data rarely occur between 70 and 120 s, and are also uncommon between 15 and 25 s. In a few cases, a peak occurred quite strongly near 20 s, so there is evidently a mode of oscillation which can be excited in this part of the spectrum under the right conditions, e.g. at 0400, 0900, and 1900 U.T., Figure 4. (See also Duffus, Shand, and Wright 1960.)

(7) For $T < 15$ s, there appears to be a relatively weak component which cannot be properly resolved on the present records. Some of the data suggest that this component also exhibits a diurnal variation, occurring more frequently on the day side of the Earth.

(8) For $T > 120$ s, there is a broad band of frequencies which at times is associated with a large proportion of the total power. These are, of course, conspicuous on all slow-run magnetograms and telluric current records as slow, quasi-regular or irregular variations, including the very long "bay" disturbances which accompany the aurora.

Relatively little comparative information on spectra in this frequency range has been published, as distinct from the considerable amount of work being done on synoptic observations of micropulsation occurrence.

Horton and Hoffman's (1962) analysis of the telluric currents at the mid latitude station Tbilisi in the U.S.S.R. dealt with only the longer periods, 2·4–60 min. They were also more concerned with the average spectrum over many hours or days, whereas the present study was designed to observe short-term fluctuations in the spectrum. Horton and Hoffman obtained a very complex spectrum for the north-south component, with marked minima (day and night) at about 550, 220, and 160 s. Their east-west component gave a fairly smooth spectrum, in contrast to the Oamaru–Cold Bay results for which the two components were essentially identical (apart from the phase change due to vector rotation—see later). There is no apparent resemblance between the spectra from Tbilisi and Oamaru in the region of overlap.

Power spectrum analysis using the Blackman and Tukey (1959) technique has been applied to Canadian magnetic observations (Duffus, Shand, and Wright 1960) for magnetic latitudes very similar to those of Oamaru–Cold Bay. These show a peak at 30–40 s and also at 70–90 s and ~ 20 s. The 70–90 s case is rather surprising as this is one of the quietest sections of our spectra; on the other hand it is not unlikely that considerable variations occur according to the state of the magnetosphere in the solar corpuscular stream. The Canadian spectra were obtained several years earlier, nearer the peak of the solar cycle. A micropulsation period of about 80 s, is one of the periods observed in small bps events (bays with pulsations and a sudden commencement), e.g. Ward (1963). In the four cases quoted, Ward observed pulsations of period 80, 42, 120, and 30–48 s. Data from Fredericksburg are also comparable ($L = 2 \cdot 4$), and periods ranging from 35 to 60 s are commonly observed.

The idea that a resonant mode of oscillation can be excited in the magnetic field was suggested many years ago; indeed it is difficult to escape this conclusion in view of the strong evidence for "line spectra", such as presented in Figure 4. The concept has ceased to be merely academic since the observation of hydromagnetic waves *in situ* by means of satellites (Coleman *et al.* 1960; Sonett *et al.* 1960; Judge and Coleman 1962; Heppner *et al.* 1963.)

For purposes of calculations, the model commonly adopted is that of a standing wave on a field line, where the wave velocity is taken as that of the transverse (Alfvén) mode, $V(s) = H(s)\{\mu/\rho(s)\}^{\frac{1}{2}}$. (In general, three modes of oscillation should accompany a hydromagnetic disturbance; see MacDonald (1961).) H is the magnetic field intensity and ρ the mass density at line element ds; μ is the permeability. A good deal of uncertainty remains in the absolute value of V, chiefly due to uncertainties in ρ. Consequently, the period of the standing wave, $T = \int_0^L 2\mathrm{d}s/V(s)$, where L is the length of the field line, is also rather subject to the conditions adopted. Nevertheless, this model necessarily leads to a fundamental period which is extremely latitude sensitive at high magnetic latitudes. This appears to be in conflict with Ellis's observations (1960) at a chain of stations in Australia, having geomagnetic latitudes of 28°, 42°, and 51°S. Ellis did not detect any increase in the micropulsation *period* with latitude, although the *amplitude* did increase monotonically with latitude for all periods between 10 and 100 s, suggesting that the oscillations orginate at high latitudes. Many other observations confirm that the 40 s oscillation is not restricted to a particular latitude, but this does not exclude the possibility that it may originate on field lines linking particular geomagnetic latitudes, whence it propagates to other latitudes. It is, of course, very difficult to reconcile the widespread occurrence of a "favoured" frequency with the set of mode frequencies (latitude dependent) calculated by MacDonald (1961).

That the problem is complex is adequately demonstrated by the changing spectrum registered in the course of a single day (Fig. 4). Seasonal and solar-cycle effects may also occur, due to changes in H and ρ. Moreover, the variation in V along a field line is conducive to the excitation of many overtones, and it is not evident which, if any, of the observed periods should be regarded as the fundamental. Many more observations will be needed to separate these effects and to define the problem clearly—preferably spectral analyses of magnetograms obtained with identical instrumentation over a wide range of latitudes, both ground-based and satellite-borne.

Wilson (1963) endeavoured to analyse the power spectra of a number of sudden commencements observed at College ($L = 5 \cdot 4$) and Sitka ($L = 4 \cdot 0$), in terms of a set of harmonic sequences. None of his results can be compared directly with ours ($L = 2 \cdot 6$) but it is interesting to note the general trend of the spectrum at higher geomagnetic latitudes. Sitka showed a peak in the power spectrum at 35–40 s, but the power was relatively greater at the longer periods (100–500 s). There is a tendency in some of the spectra for harmonic relationships to appear, e.g. 45 and 90 s, 35 and 70 s, etc. (plus longer periods in each case). For College, Wilson suggests the following four harmonic sequences:

A	B	C	D
(1) 340 or 220 s	(1) 140 s	(1) 270 s	(1) 180 s
(2) 110	(2) 70	(3) 90	(3) 60
(4) 55	(4) 35	(6) 45	(6) 30

A, B usually can occur together, in any one sudden commencement, and likewise C, D. The larger number of periods allows, of course, considerable flexibility in fitting any given set of data. Reference should be made to Wilson's paper for details of the analysis.*

In view of the observed widths of peaks on spectrograms obtained so far, this would seem to imply that any one peak in the Oamaru spectra, the 40-s peak say, is in reality a mixture of many overtones varying in their relative proportions according to the excitation conditions; in other words, an observed spectrum represents the superposition of many modes, and the exact position of the peak power depends merely on the relative strengths of the constituent modes. This is not unreasonable, considering the complexity of the medium and random fluctuations in the solar pressure. However, it is difficult to see what experimental checks can be applied, in the absence of a theoretical estimate of the relative strengths of the numerous modes of oscillation to be expected for any given boundary conditions.

Applied to the Oamaru spectra, the question becomes: What are the conditions prescribing that the spectrum becomes a remarkably sharp single peak (1600 U.T., Fig. 4), two sharp peaks (0800, 1145, 1730 U.T.), or a semi-continuous "mess" (0600, 0700, 1100 U.T.)?

One approach that might be helpful is to follow the fortunes of particular peaks polewards of the auroral zone where the outer exposed field lines link to the Earth. Spectra are now being run for a number of higher latitude stations, and some preliminary data are available for Pt. Barrow ($L = 7 \cdot 5$) and Shepherd Bay ($L \sim 25$). Comparing Oamaru with these, it is evident that no major change occurs in the *band* of frequencies encountered, in the sense that from $L = 2 \cdot 6$ to 25, a large amount of power can appear in almost any part of the 10–500 s range, and probably at longer periods also. (The spectrum for 0900 U.T., Fig. 4, covered a longer time interval, 72 min, hence the longer periods are more reliable. This shows a peak at about 1000 s.) However, the significant point is that *relatively* much more power appears at the longer periods, 100–500 s, at the higher latitudes. For instance, the 40-s peak at Oamaru–Cold Bay does not have comparable relative strength at higher latitudes, although it certainly appears on some of the spectrograms—much less

* Satellite observations in the distant geomagnetic field confirm the existence of a wide spectrum of frequencies. Judge and Coleman (1962) discussing Explorer 6 data, noted an apparent harmonic relationship: 200 s (attributed to the transverse mode) and 100 s (compressional) in the vicinity of a field line linking to geomagnetic latitude $67 \cdot 5°$.

strongly at Sitka and College, weakly at Barrow, and very feebly at Shepherd Bay. This will be discussed further in a later paper.

One other result of immediate interest, as it bears on the earlier discussion of diurnal variations at Oamaru–Cold Bay, is that the shorter periods, $T \sim 10$–100 s, continue to occur more strongly on the day than on the night side at higher latitudes.

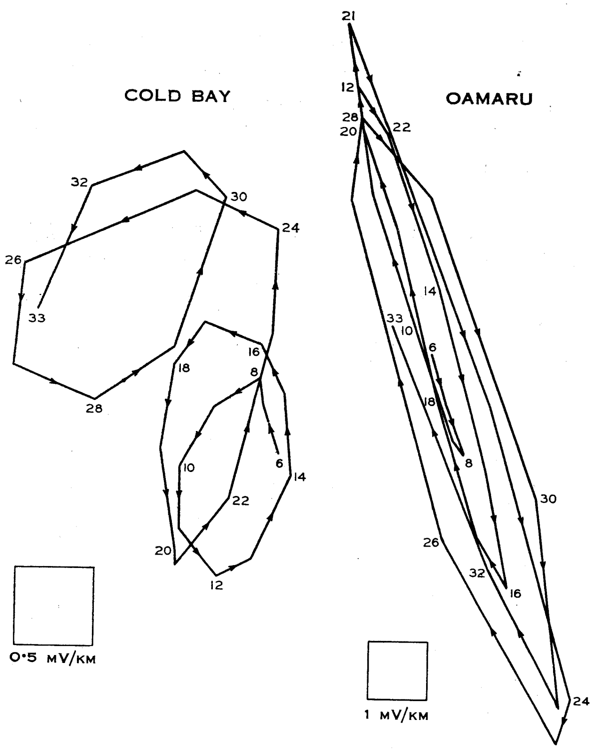

Fig. 7.—Vectorgrams from Cold Bay and Oamaru, telluric current records.

Diurnal Variations of Polarization

The orientation of the E-vector was determined from the fast-run north-south and east-west telluric current records at both Oamaru and Cold Bay, for certain days between April 11 and July 9, 1962. A detailed study was made of the same 24-hr interval, April 11–12, for which spectral analyses were carried out (preceding section). Because of the greater sensitivity at the Oamaru station and the tendency for suppression of the higher frequencies at Cold Bay (Mather and Wescott 1962), the vectorgrams were generally superior at Oamaru but in very few cases is there any actual doubt concerning their interpretation at either station. About 50 vectorgrams were plotted.

Figure 7 shows a pair of typical vectorgrams. The most noteworthy points are:

(1) The disturbance vector rotates oppositely at the conjugate points; in this example it is clockwise at Oamaru and counterclockwise at Cold Bay.

(2) The cyclic period is 40 s; the remarks on polarization therefore refer to the dominant peak in the spectrograms (Fig. 4) unless stated otherwise.

(3) Major changes in direction on the Oamaru vectorgram, namely, at the apex points 8, 12, 16, 21, 25, 28, and 31, are generally accompanied by similar major changes in direction at Cold Bay, namely, points 8, 12, 17, 21, 24–25, 27–28, and 30–31, to within the 6-s scaling interval.

Examination of many vectorgrams showed that the direction of rotation did not remain the same at either station. The result of a systematic hour-by-hour analysis of the April 11–12 interval, for which fast-run records were available, appears in Figure 8. This is a 24-hr "clockface" marked in Universal Time and also showing local midday and midnight for each station.

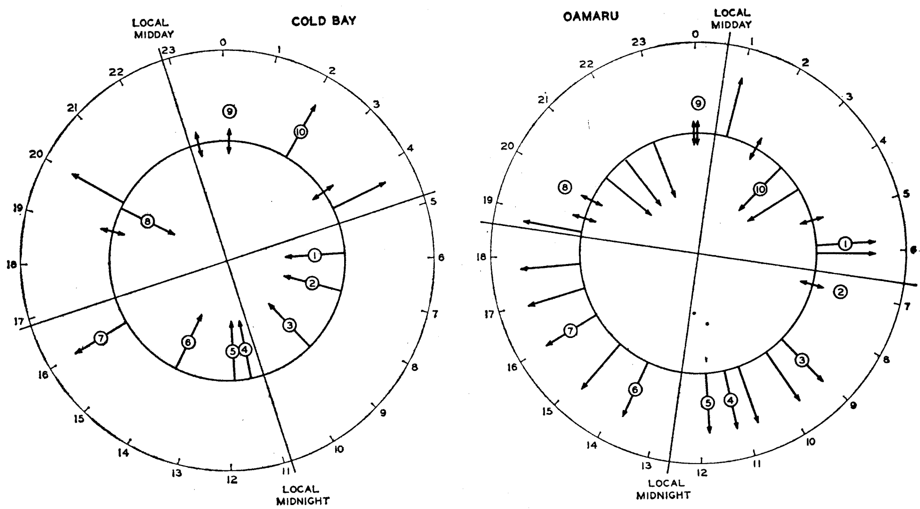

Fig. 8.—Summary of polarization data for Cold Bay and Oamaru for the 24-hr period, April 11–12, 1962.

Radial arrows drawn from the reference circle denote the direction of rotation at various times throughout the day. Long arrows directed outwards denote clockwise rotation. Long arrows directed inwards denote counterclockwise rotation. Short bi-directional arrows imply that both directions were present, with neither preferred, or that the disturbance vector showed linear polarization. (Vectorgrams from Oamaru, of predominant period $\sim 4 \cdot 0$ s, occasionally had shorter period loops superposed. The direction of rotation of these was not necessarily the same as that of the main loop. They were not a regular feature of Oamaru and were absent entirely from Cold Bay records. This higher frequency component is referred to in the preceding section, but the systematics of its polarization is not dealt with in the present paper.)

The numbered arrows (1–10 in Fig. 8) refer to the same events at the two stations, i.e. to simultaneous conjugate disturbances. Number 6 (1341 U.T.) is illustrated in Figure 7. Only 4 out of the 10 pairs of matched vectorgrams manifested undeniable point-to-point correspondence on oppositely rotating loops, i.e. the disturbance vector maintained the same phase relationship between the two hemispheres. It will be noted that all are evening–night-time events. In addition, number 3 (night-time) showed a weak tendency for conjugacy (opposite rotations but not exactly point-to-point). Number 7 (night-time) showed the *same* directions of rotation, number 10 (day-time) showed opposite directions, while the remainder (2, 8, and 9) were indefinite.

The conclusions drawn from Figure 8 are that (i) the polarization behaviour is more orderly on the night side, (ii) at night the polarization is generally clockwise at Oamaru and counterclockwise at Cold Bay, and (iii) during the day the preferred pattern of polarization seems to be counterclockwise at Oamaru and clockwise at

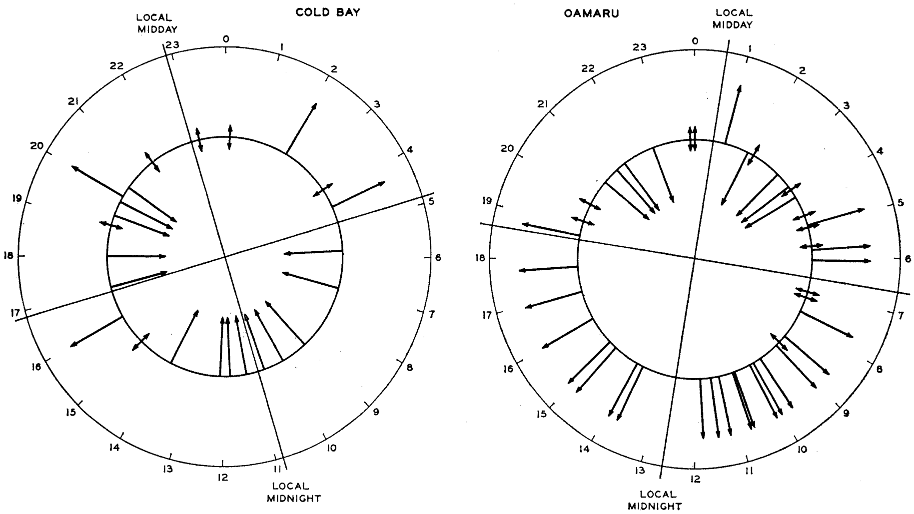

Fig. 9.—Summary of all polarization data for Cold Bay and Oamaru.

Cold Bay, but the behaviour is irregular. The latter is not unexpected in view of the fact that the day side is exposed to the solar wind and experiences greater disturbance in the frequency range being considered (see previous section).

Figure 8 is based on a detailed study of one day's records and may not be typical. To check this, vectorgrams were also drawn for a number of other part-days during which fast-run data were available: *Oamaru*, May 28–29, June 1, June 4, June 20, July 9; *Cold Bay*, July 5, July 9. Figure 9 shows the total data, plotted in the same way.

The conclusion remains that the polarizations are fairly consistently opposite in the two hemispheres on the night side, but less so on the day side. The Oamaru diagram (Fig. 9) suggests that the polarization on the day side is opposite to that on the night side, in the same hemisphere. The evidence on this point from Cold Bay is less definite (rather contrary, if anything) but the micropulsation amplitude is much smaller at Cold Bay and the chance of error is greater.

If it is correct that the polarization pattern for the 40-s oscillations in the same hemisphere divides approximately on the line perpendicular to the Sun-Earth line, this behaviour is at variance with the results of Sugiura (1961) and Wilson and Sugiura (1961) for longer period (several hundred seconds) oscillations, which they attribute to hydromagnetic waves. However, the results presented here for Oamaru and Cold Bay are insufficient to establish the case firmly.

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