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Abstracts of ULF Conference Papers Not Published in This Issue

Magnetospheric turbulence and electron precipitation, C. F. Kennel and H. E. Petschek, *Avco-Everett Research Laboratory, Everett, Mass.*

In this paper, we consider weak turbulence in the magnetosphere. Plasmas are subject to microscopic instabilities, involving secular exchanges of energy between electromagnetic fields and groups of resonant particles. Stability properties are determined by distribution function gradients in velocity space of resonant velocities. In general, growth times are rapid relative to other times of interest in the magnetosphere (10^{-2} sec). If such an instability wants to occur, it will, quickly, and the distribution of velocities will adjust until it is no longer unstable. Conversely, if there is a source of waves, distributions that initially absorb wave energy adjust themselves to transparency via resonant interactions. This marginal stability state we call the "$\gamma=0$ configuration" (γ is the growth rate) and represents the steady state distribution function of a weakly turbulent plasma. For noise in the whistler mode, this involves a sensitive adjustment of parallel and perpendicular pressures.

The electron precipitation data of O'Brien et al. [1964][1] suggest that the magnetosphere is turbulent, since 50 keV electrons are continually scattered into auroral regions at a rapid rate. We suggest that wave diffusion may account for this steady precipitation background or "drizzle." From O'Brien's high latitude pitch angle data, we can obtain the rate of change with pitch angles of the equatorial distribution function for a given line of force. If we assume particles diffuse in pitch angle until they reach the dumping cone where they are lost in about a second, we can estimate an angular diffusion coefficient. Extrapolating this argument to angles far from the dumping cone, we find that the time to random walk 1 radian in pitch angle is 3×10^{4} sec, in agreement with O'Brien's lifetimes for trapping calculated independently from precipitation rates and observed equatorial plane particle densities. This suggests that the diffusion argument is consistent. The wave amplitude required to provide this diffusion is 2×10^{-8} gauss in the VLF frequency band, which is not inconsistent with Injun 3 observations. If the plasma is at $\gamma=0$, very small perturbations of the distribution function can be converted efficiently to VLF noise. Increased noise in turn implies an increased diffusion rate, and hence violent precipitation events or "splashes." Thus these events may be caused by traveling hydromagnetic fronts, which produce a small increase in perpendicular particle energies. The semi-periodic balloon x-ray events associated with ULF magnetic field fluctuations can probably be explained in the same way.

The sources of turbulence and its relation to the acceleration of particles to high energy may be discussed.

Similar concepts have been developed for fusion plasmas by others.

Origin and propagation characteristics of geomagnetic micropulsations, T. J. Herron, *Lamont Geological Observatory, Columbia University, New York, N.Y.*

Evidence is presented that micropulsations in the 15 to several hundred second period range are waves propagating in a predominantly horizontal, east-west direction through a dispersive upper atmospheric region, away from the dark hemisphere of the earth toward the sunlit face, in a pattern of motion similar to that of auroral displays and ionospheric irregularities. The delays in arrival times of micropulsation signals at stations separated several hundred kilometers in a north-south and east-west direction are shown to be a function of station separation and of the period of the signal. An apparent phase velocity curve shows that velocity decreases with increasing period. Evidence from the published literature is quoted to support the hypothesis that a source of geomagnetic disturbances exists whose effects on the surface of the earth are first observed in the dark hemisphere, predominantly near and symmetrically about the 11 P.M. solar time meridian.

ULF environment of the ocean floor, L. Launay, *Institut de Physique du Globe, Paris, France,* S. W. Lichtman, *Hughes Aircraft Co., Los Angeles, Calif., and E. Selzer, Institut de Physique du Globe, Paris, France.*

During dives with the French bathyscaphe "Archimède" observations were made of the electromagnetic spectrum below 300 c/s, on the floor of the Puerto Rico Trench, to depths ranging between 6 and 8 kilometers, at detection thresholds estimated to have been of the order of 2.10^{-15} watts/meter^2 at 60 c/s.

Listening tests disclosed that quiet magnetical conditions prevailed on the ocean floor (when of sedimentary structure). Electrical conditions were found noisier (telluric registrations), in the same situation. Magnetic tape recordings that were taken, some of them on a rock floor, are at present under analysis for more subtle evidence of environmental contributions.

Evidence has been collected for the existence of a steady, telluric (d-c), field-alined potential gradient near the ocean floor. The gradient attained several tenths of mV/m at 7 kilometers depth.

The upper atmosphere; airglow and aurora, D. M. Hunten, *Kitt Peak National Observatory, Tucsón, Ariz.*

A review is given of the factors that control the composition of the atmosphere at various heights, with special emphasis on photochemical reactions. Night, twilight, and day airglows are described, and their excitation is discussed. A brief account is given of the aurora, its spectrum, and the particle fluxes responsible. An introduction to auroral theory ends the paper.

A review of the IAGA resolutions on the classification of geomagnetic rapid variations, V. P. Hessler, *Geophysical Institute, University of Alaska, College, Alaska, and* J. B. Townshend, *U.S. Coast and Geodetic Survey, College Magnetic Observatory.*

Classification of geomagnetic rapid variations has been on the IAGA agenda more or less continuously since the Rome Assembly in 1954. A new definition of micropulsations was approved by IAGA in Berkeley, which it appears may be subject to variations in interpretation. All IAGA actions from the Rome assembly to date are reviewed in some detail. Recommendations for improvements and clarification in the reporting technique are given.

ULF propagation along clad wires, L. M. Vallese, A. M. Passalaqua, G. Rakowsky, *International Telephone and Telegraph Federal Laboratories, Nutley, N.J., and* A. Shostak, *Office of Naval Research, Washington, D.C.*

A study is developed of the propagation of ULF electromagnetic waves guided by a long metallic cable, clad with lossless uniform material of high permittivity and high permeability, and located in a lossless medium. Equations for the computation of the axial propagation constant and for the transversal decay constant are derived and plotted for various cases.

Regular oscillations with periods of 5 seconds to 7 minutes: the experimental approach, J. R. Heirtzler, *Lamont Geological Observatory (Columbia University), Palisades, N.Y.*

Experimental methods have not yielded well defined characteristics of micropulsations with periods greater than 5 seconds. A new approach, using a carefully designed array of instruments, may provide less ambiguous characteristics. The initial results of this type of observational program substantiate this suggestion.

A theory of the Dst main phase and certain associated phenomena based on geomagnetic fluctuations, K. D. Cole;

[1] O'Brien, B. J., C. D. Laughlin, and D. A. Gurnett (1964), High-latitude geophysical studies with satellite Injun 3, 1. Description of the satellite, J. Geophys. Res. **69**, 1–12.

Department of the Geophysical Sciences, University of Chicago, Chicago, Ill.
A new theory is outlined which consistently relates (i) geomagnetic fluctuations, (ii) the depletion of plasma in the outer magnetosphere during storms, (iii) the main phase of *Dst*, (iv) the occurrence and properties of the stable auroral red arc, and (v) the "*Dst* variation" of the mid latitude *F*2 region.

Preliminary report on the observations of ELF waves, Michiko Yamashita, Hidehiko Jindo, and Kazuo Sao, *The Research Institute of Atmospherics, Nagoya University, Japan.*
From the records of ELF electromagnetic waves obtained through simultaneous observations, we found that lightning discharges emitted ELF atmospherics and that most ELF sources were lightning discharges.
The sonagraphic curves for the waves below 40 c/s showed rising and falling whistlers. However, because of the weakness of intensity, the ELF emissions supposed to be of magnetospheric origin were found to be rather scarce.

An ultralow frequency electromagnetic wave force mechanism for the ionosphere, J. M. Boyer, *Northrop Space Laboratories,* and W. T. Roberts, *George C. Marshall Space Flight Center, Huntsville, Ala.*
Present theoretical explanations of the ionospheric behavior encounter certain difficulties in accounting for observed geographic, diurnal, and seasonal anomalies. The first author discusses, in particular, the two nocturnal maximum electron density concentrations which occur approximately 12 degrees above and below the geomagnetic equator, their seasonal variation and the sudden height increases which occur in the *F*2 layer soon after twilight. In section 2 a theoretical force mechanism for ionospheric matter, originated by the first author, is briefly described. Such a model uses a mechanical potential geometry derived from electromagnetic standing waves generated by Mie scattering of ultralow frequency energy from the sun incident on the earth. The importance of the $1/\omega^2$ dependence of the time average Lorentz force on charged matter within such a standing wave gradient is emphasized, weighing first order effects toward the first few dipole/multipole resonances of the earth in the region 7.0 to 70.0 c/s. Some computer results for plane wave scattering from the earth in the above spectral region are displayed to show that the result is the erection of a complex wave geometry of three-dimensional potential wells for charged matter. Anomalies in the standing electromagnetic wave field are found to correspond well with observed ionosphere anomalies in the *F*2 region, when translation between the wave coordinate frame and the geographic frame is made.

Ultralow frequency effects provoked by high altitude nuclear explosions, E. Selzer, *Institut de Physique du Globe de Paris.*
At the occasion of the presentation of this paper at the ULF Symposium, the author felt that he should try a synthetic approach to the subject, rather than more or less duplicating recent review papers just published on the same subject.
For this reason, this paper, while recalling the basic data and experimental facts, will put the stress on their main characteristics and attempts to bring out the few definite general laws governing the phenomena.

Regular oscillations with periods of 5 seconds to 7 minutes, Yoshio Kato, *Geophysical Institute, Tohoku University, Sendai, Japan.*
The characters of pc 2, pc 3, pc 4, and pc 5 were discussed, and the rules of polarization vector of pc 5 pulsations were investigated using the cylindrical model.

Results of simultaneous ELF measurements at Brannenburg (Germany) and Kingston, R.I., T. J. Keefe, C. Polk, *Dept. of Electric Engineering, University of Rhode Island, Kingston, R.I. and* H. L. König, *Elektrophysikalisches Institut der Technischen Hoschule, Munich, Germany.*
Between May 1963 and June 1964 a series of measurements of the horizontal magnetic field in the 5 to 15 c/s frequency range were performed in Kingston, R.I., and Brannenburg, Germany. These two locations are separated in distance along the earth's surface by approximately 4000 miles; their respective coordinates are lat. 41°30′ North, long. 71°32′ West (Kingston) and lat. 47°26′ North, long. 12°03′ East (Brannenburg).
Simultaneous readings on paper tape running at 25 mm/sec obtained on 30 different dates for a total of approximately 321 minutes indicate that some ELF bursts were received simultaneously and must have originated from a common source; most of the time, however, the records at the two stations were not similar in appearance.
The rectified output of a narrow band filter about the frequency range of the first Schumann resonance (7.5–10 c/s) was recorded continuously at both stations over periods of several months. Recordings at the two locations exhibit very similar diurnal variation if the data are referred to *local* time.

The polarization of giant pulsations at Kiruna, K. V. Paulson,[1] A. Egeland, *Kiruna Geophysical Observatory, Kiruna C, Sweden, and* F. Eleman, *Swedish Board of Shipping and Navigation, Stockholm, Sweden.*
The polarizations of four of the five giant pulsations recorded during 1963 at Kiruna ($\theta = 67.8°$ N., $\lambda = 20.4°$ E.) have been analyzed by a method which has not been used in previous geomagnetic investigations. This method of analysis gives a quantitative measure of the type and degree of polarization and the principal directions of the resultant vectors in each of three orthogonal planes. In addition, the phase differences between each of the three orthogonal components and the mean period of the quasi-periodic time variation in each component have been derived. For these giant pulsations, attention is drawn to the variance of the vertical component which is of the same order and often larger than the variance of the corresponding geomagnetic north component.

Observations of 8 c/s radiation, William R. Barron, *Air Force Cambridge Research Laboratories, Bedford, Mass., and* Alan H. Katz, *Boston University, Boston, Mass.*
Eight-cycle electromagnetic radiation in a band one cycle wide, has been observed continuously since September 1963 at the Sagamore Hill Radio Observatory, Hamilton, Mass. The observing system consisted of a vertical whip antenna and a fixed tuned amplifier.
At the start of the observing period, no distinct diurnal variation was present, and the signal level was low. During the winter months of 1963–1964, the signal level increased generally by a factor of 1.5 and a very definite diurnal pattern appeared. This diurnal variation consisted of the signal level being high during the night and low during the day. The nighttime level averaged about 1.2 times the daytime level. In the Spring of 1964, the general level decreased to the pre-winter level, but the wintertime diurnal pattern continued, accompanied by a gradual increase in signal intensity around local noon.
If the observed diurnal variation is due to thunderstorm activity, it would appear to take the following form:
1. The high nighttime level occurs closest to the time of peak thunderstorm activity in Australia and southeast Asia.
2. The noontime level increase in the Spring correlates best with activity in the Americas, presumably equatorial South America.

During a 56-day interval in September–November, 1963, approximately 25 percent of the observations were made during times of magnetic storms. Comparing the stormy periods with the quiet periods in the same interval, it was found that the diurnal pattern of the radiation did not change, but the signal level was about 15 percent higher during the stormy periods than during the quiet periods.
Observations, with a bandwidth of two cycles, were also made from July 16–29, 1963. During this period, high nighttime levels and low daytime levels, similar to the Winter, 1963 period, were observed. During the solar eclipse of July 20, 1963, which was 95 percent at maximum phase on the ground, the low daytime signal level increased to a normal nighttime level as the sun was eclipsed, and then returned to the prior daytime level as the sun was again uncovered by the moon. The observed signal level started to increase when the sun was approximately 15 percent covered, and it had returned to pre-eclipse levels when the sun was approximately 85 percent uncovered by the moon.

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ELF spectrum measurements of the earth-ionosphere cavity modes, Martin Balser, *Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Mass.*

The first observations on the detailed structure of the ELF noise spectrum that indicated the modes of the earth-ionosphere cavity were made in 1960. At that time, the peak of the dominant mode was found to be close to 8 c/s, and the next several modes were located at frequencies consistent with the expected relationship for the spherical cavity. Later observations revealed that the measured power undergoes distinct diurnal variations that are correlated with the expected worldwide thunderstorm activity. In some cases, differences among modes of these diurnal varations can be ascribed to the different geometric configurations of the source and receiver with respect to the mode fields. The diurnal variations themselves change with the season as the source distribution changes. When the frequency of the mode peak is measured accurately, it is found that the frequency also undergoes diurnal variations, presumably connected with asymmetries in the cavity not yet included in analytic treatments. A specific asymmetric perturbation is introduced into the cavity by a high-altitude nuclear detonation. Following such a detonation, the peak frequencies have been observed to change suddenly, and several hours are required for the cavity to return to its unperturbed state.

On the latitude-dependence of pc-type micropulsations: Results of observations on a north-south profile through Europe, Hans Voelker, *Geophysikalisches Institut der Universität Göttingen, Gottingen, Germany.*

A direct comparison of geomagnetic pulsations simultaneously recorded with standardized equipment at five observatories on a north-south profile through Europe gives as the most important finding a systematic increase of the periods of pc's and pse's with increasing geomagnetic latitude. A statistic analysis of the data shows one characteristic pc-period predominating at each of the German observatories, Wingst, Göttingen, and Fürstenfeldbruck. For Enköping the spectrum of pc-periods contains two maxima near 75 sec and about 30 sec. Here the pulsations with the longer periods correspond to the pc's with latitude-dependent periods at the German stations, while there are no equivalent effects at lower latitude for the maximum at shorter periods. At Kiruna the period-spectrum covers a wide range. Here also appears a peak near 30 sec as was found for Enköping, but for longer periods the spectrum is nearly white.

An explanation of these pulsations can be given in terms of field-alined hydromagnetic oscillations in the magnetosphere under the additional assumption that the plasma density in the magnetosphere has a lamellar structure. The distribution of the pulsation periods, computed by Siebert, as a function of the geomagnetic latitude shows a good agreement with the observed data.

The ionosphere, T. E. VanZandt., *National Bureau of Standards, Boulder, Colo.*

The structure and physics of the ionosphere are briefly reviewed. The ionospheric regions are named. Then for each region are given: its height range, ionic composition, electron concentration, causes of ionization, and loss processes. Transport of ionization is mentioned. Sporadic *E* and spread *F* are briefly described.

A review of seven studies of geomagnetic pulsations associated with auroral zone disturbance phenomena, W. H. Campbell, *National Bureau of Standards, Boulder, Colo.*

A resume is given of seven studies of geomagnetic field pulsations in the frequency range of 2.0 c/s to 0.005 c/s that demonstrate a close relationship to upper atmospheric auroral zone phenomena. The ultra-low frequency pulsations of irregular amplitude appearance are shown to be related to the disturbed ionosphere, as evidenced by the auroral luminosity fluctuations, the electrojet behavior, the vertical incidence soundings of the *E* region, the cosmic noise absorption, high latitude infrasonic pressure waves, and balloon observations of electron bremsstrahlung. Simultaneous measurements at a number of world stations indicate the characteristic hemispherical behavior of the signals as well as the uniqueness of conjugate locations.

Preliminary results of polarization studies of certain type Pc 1 micropulsations recorded at Boulder, J. H. Pope, *National Bureau of Standards, Boulder, Colo.*

Studies of a particular type of micropulsation event which fits the category "Pc 1," recorded at College, Alaska, have shown interesting results with respect to their polarization patterns. In general they show an elliptically polarized wave in a plane perpendicular to the magnetic field line at the station. The sense of rotation, while complicated by superposition of a number of signals, shows a counter-clockwise sense of rotation as viewed in the direction of propagation.

The purpose of this paper is the presentation of preliminary results obtained from similar recordings made at Boulder, Colo. In particular, it is important to determine if the inclination of the plane of polarization is perpendicular to the field line at Boulder and if the sense of rotation is the same as at higher latitudes.

Simultaneous measurement of micropulsation activity, R. L. Komack, and A. S. Orange, *Air Force Cambridge Research Laboratories, Bedford, Mass.*

Earth current micropulsations were recorded simultaneously at Trinidad, Puerto Rico, and Austin, Tex., during the Fall of 1962 by workers from the Air Force Cambridge Research Laboratories and the University of Texas. Signals were continuously recorded on paper chart in the frequency band 0.01 to 1.5 c/s at a chart speed of 1 mm/sec. Timing accuracy was maintained to better than 0.05 seconds at all locations. Twelve selected portions of the data averaging about 3/4 hour in length were digitized and machine computation was employed to compute power spectra, coherencies, and the direction of the resultant electric vector.

The power spectra exhibit large peaks in the 0.01 to 0.07 region, normally considered the region of PC type activity. In this frequency region, power spectra of data obtained simultaneously at the three locations are virtually identical; no variations with latitude or longitude are observed.

The coherency of two signal channels is defined here as a normalized cross power spectrum of the two channels and is a measure of the linear relationship between them. Coherencies above 0.7 were consistently found between signals in the PC frequency region recorded more than 2,000 miles apart. The coherency data exhibit unexplained "dips" in the PC frequency region that appear in may of the data samples.

The investigation of the directional properties of the resultant electric field vector illustrates the strong dependence of this vector on local geology. The vector is seen to be essentially stationary with respect to time and oriented roughly parallel to the dominant geographical feature in the vicinity of the location.

"V" Phenomena in micropulsations, Elwood Maple, *Air Force Cambridge Research Laboratories (OAR), Bedford, Mass., and* John H. Frey, *Physics Research Division, Emmanuel College, Boston, Mass.*

A representative "V" signal (named for its appearance on a Sonagram) may have a duration of about 15 minutes, start at about 10 c/s or higher, decrease in frequency to about 2 c/s, then rise again to 5 c/s or more. This dominant frequency variation is usually modulated by a quasi-sinusoidal frequency variation having a period of about 1 minute and a peak-to-peak amplitude of about 3 c/s. Considerable variation in duration is observed, a slow rate of decrease of the V frequency being followed by a correspondingly slow increase. The frequency range covered also varies, and in the present study, the highest frequency observed is often limited by the recording equipment. During active times, ten to twenty modulated V's per day may occur. Unmodulated V's, having purer tones and longer durations than the modulated V's, are less frequently observed. Other characteristics of the V's and their morphology will be discussed.

Preliminary results of micropulsation measurements at near-conjugate stations of Byrd and Great Whale River, C. S. Wright, *Pacific Naval Laboratory, Esquimalt, British Columbia, Canada.*

The paper deals with selected micropulsation data recorded at these places in the Southern and Northern Auroral Zones. The difficulty of displaying the similarities and dissimilarities without bias is discussed. Brief mention is made of associations with magnetic data measured in satellites.

The coast-line effect on rapid geomagnetic variations, Attia A. Ashour, *High Altitude Observatory, Boulder, Colo., and*

Geophysical Institute, College, Alaska.
Calculations are made for the magnetic field of the induced currents in a hemispherical ocean by a uniform inducing field which is either parallel or normal to the axis of the ocean. The conductivity of the ocean is assumed infinite, an assumption permissible when rapid variations are considered.
The results show that a large concentration of induced currents exists near the coast, and that the effect of this concentration of currents is to reverse the direction of the vertical component on land and that of the horizontal component at sea near the coast. This is the effect noted by Parkinson at Watheroo.
It is shown that the oceanic shielding is reduced due to currents induced in the earth's core. However, the enhancement of the field near the coast remains.

Cyclotron excitation of hydromagnetic emissions, Lee Tepley and R. C. Wentworth, *Research Laboratories, Lockheed Missiles and Space Company, Palo Alto, Calif.*
A new model for the production of hydromagnetic emissions is presented. The model is based on the interaction between proton streams moving in the magnetosphere and the ambient plasma. Hydromagnetic emissions are typically characterized by two frequencies: the emission frequency on the order of 0.2–5.0 c/s, and the repetition frequency of the fine-structured elements on the order of 0.2–1.0 c/min (periods of 1 to 5 minutes). The model associates these two characteristic frequencies with two natural parameters of the motion of proton streams in the magnetosphere. The emission frequency is the anomalously Doppler shifted proton cyclotron frequency in the vicinity of the equatorial plane, and the period of the fine-structured elements, observed experimentally to be received alternately in the two hemispheres, is determined by the bounce period of the proton stream as it mirrors successively above the northern and southern hemispheres. The model shows that the rising-frequency emission fine structure may be produced by a small velocity spread in the proton stream. It also predicts the experimentally observed latitude dependence of hm emission frequency. This paper will be presented in two parts: the first part deals with theoretical concepts of the proton stream plasma interaction; the second part describes the model calculations relating physical parameters of the magnetosphere to the relevant frequencies of the hm emissions.

Hydromagnetic whistlers, J. A. Jacobs and T. Watanabe, *Department of Geophysics, University of British Columbia, Vancouver, British Columbia, Canada.*
Of the two modes of hydromagnetic waves propagating in a magneto-active plasma, it is shown that only one mode is likely to be guided by the magnetic field. For this mode the wave energy is propagated with a faster velocity at a lower frequency. This dispersion characteristic gives support to the view that a series of rising tones on a dynamic spectrum of signals of the so-called "pearl" type micropulsations is caused by a hydromagnetic wave packet which is guided by a magnetic line of force of the Earth echoing between the two conjugate points. The possibility that such a hydromagnetic wave packet is generated by a traveling-wave tube (T.W.T.) amplification process is discussed.

The effects of ionospheric inhomogeneities on the Schumann resonances, T. Madden, *Institute of Geophysics and Planetary Physics, University of California, La Jolla, Calif.*
A full three-dimensional treatment of the earth-ionosphere resonant cavity is carried out in order to study the splitting effects of the day-night and magnetic field variations on the resonant modes and to investigate the sensitivity of the resonant frequencies to changes in various segments of the ionosphere.

Optical pulsations in the aurora, T. Neil Davis, *NASA-Goddard Space Flight Center, Greenbelt, Md.*, and George Cresswell, *Geophysical Institute, College, Alaska.*
Regular and irregular variations in the luminosity of auroras are observed at College, Alaska, in the post-midnight hours. These optical pulsations have been recorded by the television cinemaphotography technique and with an array of extremely narrow-field photometers. Preliminary study of the data indicates that several types of visual and sub-visual pulsations are occurring in the frequency range 0.1 to 10 c/s. A part of the observed luminosity variation is in the form of waves propagating through the aurora with apparent speeds in excess of 100 km/sec. A film strip demonstrating the optical pulsations and the preliminary analysis results are presented.

A sudden reversal of polarity of ULF field and impulsive VLF hiss, aurora and aurora zone absorption, H. Morozumi, *Radioscience Laboratory, Stanford University, Stanford, Calif.*
In this note some new features of the relation between micropulsation phenomena and other geophysical phenomena are described. Micropulsations were recorded simultaneously with VLF, ELF, aurora and cosmic noise absorption (CNA). Relative timing of events on these records could be measured to better than ½ minute. It was found that VLF impulsive hiss was related to the initial positive change in ULF field, and that cosmic noise absorption does not commence until the first reversal of polarity of the ULF field.
During a little more than two month's observations (July 31 to October 8) at Byrd Station, Antarctica, 23 well-defined cases of this relationship were observed. A similar trend was noted on many other records which were too complex to permit clear interpretation. This type of event is usually observed near 0400 UT (magnetic midnight is 0615 UT), when background activity tends to be low. However, when an event is observed, it is usually large and stands out clearly from the background noise. The onset of such an event is quite sudden. The event attains its maximum amplitude within a few minutes. A typical sequence of this type of event is as follows.
At about 0300 UT, VLF hiss of relatively constant amplitude variations are observed. This type of hiss usually does not accompany a large event. Aurora at this time is composed of arcs and bands. VLF hiss observed near 0400 UT is of a more impulsive nature and the amplitude of the entire noise band fluctuates very rapidly. With this impulsive hiss, the vertical component of the ULF field starts to increase. When the VLF hiss signal attains maximum amplitude, the ULF field starts to decrease. This reversal in the direction of change usually takes place within 1 minute. A sudden commencement of CNA is also observed when the ULF field starts to decrease. The beginning of a CNA event also coincides with the breakup stage of auroras. At the beginning of the third reversal of polarity of the ULF field, the VLF hiss intensity usually drops almost to the background noise level. The time interval between the first and the third reversal of ULF field is typically a few minutes. After the third reversal of polarity of ULF, except for envelope variations, we did not find any outstanding relation between the ULF field and other geophysical phenomena. The above described phenomena usually lasted 1 to 2 hours.
These observational facts suggest that two different particle energies may be involved in the initial and secondary stages of the event.

Brightness fluctuations in quiet-form aurora, K. V. Paulson and G. G. Shepherd, *Institute of Upper Atmospheric Physics, Saskatoon, Canada.*
Observations have been made from Saskatoon of brightness fluctuations in quiet-form aurora. The analysis of these fluctuations, on the assumption that they may be regarded as second-order stationary processes, shows that certain frequencies are dominant. Spectral density estimates invariably show one, and sometimes two, pronounced peaks having reciprocal frequency values of 3 to 20 seconds. The spatial extent of these fluctuations has been examined, and a scale size of about 40 km found for a vertical direction, and values scattered between 20 and 100 km for the horizontal direction. At times, these brightness fluctuations were observed to propagate within the form. For five cases in which speeds were measured, the values varied from 1.7 to 17 km/sec, and the directions of motion were eastward in three cases, westward in one, and downward in one. An attempt was made to determine the variation of the fluctuation spectral content with height above the earth's surface. The heights were estimated from the apparent lifetimes of the ^1S state of OI, which in turn were determined by cross-spectral analysis of OI 5577A and N_2^+ 3914A radiation. It was concluded that the median reciprocal frequency increases with increasing height.
Fluctuations in H_β emission were also observed, and found to be identical with those from N_2^+. These observations will be reported, and a comparison made with what might be expected on the basis of a simple bounce mechanism.

Slow fluctuations of absorption ratio between conjugate points, J. J. A. Chivers and J. K. Hargreaves, *National Bureau of Standards, Boulder, Colo.*

Ionospheric absorption is being measured with riometers at three pairs of conjugate points, respectively outside, on, and inside the auroral zones. When the ratio of absorption at a northern site to that at its southern conjugate is calculated for selected periods, it is found that the absorption ratio often exhibits slow fluctuations. Sometimes these assume a quasi-sinusoidal appearance having a period of about 2 hours. They tend to be stronger and more frequent at the higher latitudes, and are seen more often by night than by day. Some statistics will be presented of the occurrence of these fluctuations, and the available evidence of their spatial properties over the surface of the earth will be discussed. They will be compared and contrasted with other known oscillations of ionospheric absorption.

Geomagnetic fluctuations—a prime contributor to the depletion of plasma from the outer magnetosphere, the main phase of D_{st}, and high red auroral arcs, K. D. Cole, *Department of the Geophysical Science, University of Chicago, Chicago, Ill.*

A theory of the depletion of plasma in the outer geomagnetic field, and main phase of $D_{st}(h)$ is presented. It is argued that random geomagnetic fluctuations with periods in excess of about 200 sec contribute significantly and directly to both these phenomena.

Random electrostatic fields (**E**) associated with geomagnetic noise in the magnetosphere, such that $\mathbf{E}\cdot\mathbf{B}=0$, cause the random interchange of tubes of force and the plasma in them. This changes the gross distribution of plasma density (n) from the quiet $n \propto R_E^{-3}$ (in the equatorial plane) to $n \propto R_E^{-4}$ (approx.) within the noise region of the magnetosphere. The noise region appears to be several earth radii thick during storms. This may be inferred from the latitude distribution of amplitude of geomagnetic fluctuations as observed at the ground. The change of n profile represents a first order decrease in n in the outer parts of the noise region and would account for the loss of plasma there observed by whistler techniques.

The coefficient of diffusion applicable is

$$D = 2\frac{\overline{E^2}}{\overline{B^2}}\tau$$

where $\overline{E^2}$ is the variance of the noise field and τ its correlation time. The time (t_D) required to change the distribution within a noise region of equatorial radial dimension ΔR is $t_D=(\Delta R)^2D^{-1}$; during magnetic storms t_D is about the time difference between the onset of the initial phase and the trough of the main phase of $D_{st}(H)$.

Corresponding to the loss of plasma from the outer part of the noise region there is a gain at the inner part. In a typical magnetic storm there is thus a net energization of the plasma in the noise region by a factor of about 10. The plasma beyond 5 R_E normally has a temperature of 10–100 eV. The plasma redistributed by storm noise in the region 3 R_E (say) to about 10 R_E has an energy of about 200–2000 eV per particle. This is sufficient to cause the main phase of D_{st}.

The energy flux in the magnetosphere in geomagnetic fluctuations appears sufficient, during the time available before the main phase trough, to account for the energy involved in the main phase of D_{st}. It has been shown elsewhere that the heat losses to the atmosphere from hot F-region electrons which are assumed to excite the mid-latitude red arc are comparable to the decay of magnetic energy of the main phase of D_{st}. Since geomagnetic fluctuations contribute a significant component to D_{st} energy, they are an indirect contributor to the formation of the red arcs, by virtue of heat transfer from the hot magnetospheric plasma to F-region electrons.

Oscillatory phenomena in laboratory simulation of the magnetosphere, M. P. Bachynski, J. V. Gore, and F. J. F. Osborne, *RCA Victor Co., Ltd., Research Laboratories, Montreal, Canada.*

Laboratory experiments have been performed, scaled to simulate the interaction of the solar wind with the earth's magnetic field, or the case where there is no interplanetary magnetic field. As in nature the solar wind is considered as a magnetohydrodynamic medium. Thus the interaction is designed to correspond to the concepts of a magnetic field frozen to the plasma so that a simple form of Ohm's Law ($\mathbf{E}+(\mathbf{V}\times\mathbf{B})=0$) is applicable, where **E** is the vector electric field, **V** the plasma velocity, and **B** the vector magnetic field. Effects of thermal pressure, resistivity, and Hall currents must be minimized in order for this to be the case in the laboratory. The scaling of the experiment is selected on this basis within the limits of attainable laboratory parameters. Further, the interaction requires that the magnetic pressure of the model magnetic field be equal to the wind kinetic pressure at some suitable distance from the model earth, thus placing constraints on the velocity of the medium, the terrella magnetic field, and the size of the interaction volume. Finally, the time for development of the physical processes involved must be taken into account. All these requirements appear to be fulfilled in the laboratory model experiments.

Two distinct forms of interaction have been delineated by photographic and magnetic observations, the determining factor being the solar wind properties.

The "standoff" interaction shows the virtual exclusion of the impinging solar wind plasma from the geomagnetic cavity. The magnetic cavity formed shows a well defined steep gradient boundary to windward at the position of the visible standoff.

The "injection" interaction shows a poorly defined slow gradient boundary as determined both by photographic and magnetic measurement. In addition, cavity penetration by the solar wind plasma is observed in the regions associated with the Chapman-Ferraro horns. These injections near the poles follow converging paths moving to leeward and merging in the equatorial plane to form a single tail. The magnetic evidence suggests that the injection interaction may be associated with a lower plasma conductivity.

Both types of interaction show a clearly separable interior phenomenon resembling in many ways the Van Allen belt in space. The laboratory belt shows well defined latitude limits as modified by the distortion of the dipole magnetic field. The belt shows a predominant westward motion of the ions at a velocity lower than that of the incident solar wind.

Spatially resolved measurements in the quasi Van Allen belts by means of electrostatic and magnetic probes have shown the presence of several types of electromagnetic oscillations. These signals are observed at several distinct frequencies below 1 Mc/s which scale to low-frequency emission signals observed by some satellites, and are possibly associated with hydromagnetic waves generated during the interaction. The spatial distribution of these oscillations within the quasi Van Allen belts suggests that they are associated with the mechanisms generating the belts and their subsequent motions.

Electromagnetic disturbances associated with high altitude nuclear weapons tests, R. D. Elliott, R. A. Fowler, D. T. Hodder, J. Kert, and B. J. Kotick, *Space and Information Systems Division, North American Aviation, Inc., Downey, Calif.*

Worldwide effects observed in magnetic and earth current records from the Argus and Starfish Test series are summarized and compared to natural disturbance data.

A preliminary comparison of natural and *blast* produced wave forms is presented and distinctions discussed in terms of simultaneity of arrivals and morphology or latitude effects. The results of those studies are briefly summarized. Instrumental distortions are analyzed and corrections including time series reconstruction by Fourier Transform methods are introduced. Three distinct regions of *blast* effects are identified and related to observed phenomena.

To permit phenomenological studies and evaluation of propagation characteristics above the ionosphere, such as dispersion, harmonic analysis of the corrected signals is performed. This includes use of advanced power, coquadrature and cospectral analysis techniques. The mathematical techniques employed are identified. These analyses aid in the identification of unique spectral resonances in the blast perturbation with definite harmonic structure. Comparisons to harmonic analysis of natural micropulsation disturbances are presented.

The unusual significance of these effects for study of the exosphere and interpretation of natural phenomena is indicated.

Magnetospheric resonance, J. W. Dungey, *Imperial College, London.*

An elementary account is presented of the propagation of hydromagnetic waves when the plasma pressure is negligible. Equations are also derived for waves in axially symmetric fields, and particular kinds of mode are described. Numerical values are given for the magnetosphere and the variation of the wave amplitude with distance is discussed. The effect of the ionosphere is described and shows the need for combining observations from a triangle of stations. Other aspects such as dispersion and guidance are outlined.

Nuclear explosions as sources for ULF electromagnetic fields, W. J. Karzas, *The RAND Corporation, Santa Monica, Calif.* The emissions from a nuclear explosion (γ rays, x rays, etc.) are described. The interaction of these products with the atmosphere is discussed, with particular attention to the different effects expected as the altitude of the explosion is varied.

The associated currents and conductivities are described and are grouped into two classes: (1) Those which are limited in extent and rapid in time variation (compared to the wavelengths and frequencies in the ULF region); for these the character of the observed EM fields is determined primarily by the nature of the earth-atmosphere medium and propagation in it; (2) those which have wavelengths and/or frequencies in the ULF range; for these the observed EM fields will be more closely related to the explosion history.

Estimates are made for the magnitude of the expected ULF fields and compared with experimental results.

The magnetosphere, Laurence J. Cahill, Jr., *Physics Department, University of New Hampshire, Durham, N.H.*
Experimental evidence obtained by the Pioneer 1 and 5 space probes, the Explorer 12 and 14 satellites and, recently, the IMP 1 satellite, have defined the location and the nature of the sunlit portion of the magnetosphere. The boundary is a thin layer, less than 100 km thick, in which field direction reverses. It is located near 10 earth radii at the subsolar point, but its distance increases to 14 earth radii near the dawn meridian. Movement of the boundary may be inferred from the observations on about half of the passes. Motions of several hundred km are common. Large motions of several earth radii occur more infrequently. The boundary of the magnetosphere does not close immediately behind the earth, but extends in a long tail at least beyond 30 earth radii. The diameter of this cylindrical tail, apparently nearly symmetrical about the anti-solar direction, is 30 to 40 earth radii. The postulated ring current responsible for the main phase of geomagnetic storms has not been identified positively. Significant distortions of the magnetosphere near 3 earth radii in the sunlit hemisphere and near 8 earth radii in the dark hemisphere have been observed. These distortions are apparently due to inflation of the magnetosphere by large numbers of low-energy particles, since observed higher energy protons and electrons are not sufficient to produce the distortions observed. Fluctuations in the field have been observed which may be interpreted as hydromagnetic waves propagating through the magnetosphere. Compressional and transverse waves have been observed with amplitudes of 5 to 20 gammas and with periods varying from one to many minutes.

Auroral zone effects, J. E. Lokken, *Pacific Naval Laboratory, Defence Research Board of Canada, Victoria, B.C., Canada.*
Geomagnetic micropulsations, as observed at auroral latitudes, and associated phenomena, are discussed in a descriptive way. The most characteristic feature of auroral zone micropulsations is the occurrence of impulsive events, recently called Pi 1 and Pi 2. These often, but not always, occur near the onset of magnetic bays, usually near midnight, and exhibit a high degree of conjugacy. They occur in conjunction with fluctuating aurora, x-ray emission, cosmic noise absorption, and immediately on termination of VLF auroral hiss. Recent satellite measurements confirm the presence of precipitated particles. Long period (Pc 5) regular micropulsations are also an auroral zone feature. One outstanding example lasted for 12 hours, maintaining phase coherence between Byrd and Great Whale River during the entire interval. Fluctuating riometer absorption and auroral intensity fluctuations are sometimes known to accompany some types of regular micropulsations.

A review of solar wind-magnetospheric interactions, A. J. Dessler, *Department of Space Science, Rice University, Houston, Texas.*
The solar wind is a magnetized plasma whose magnetic field, in general, makes an oblique angle with the solar wind velocity vector. G. K. Walters (1964, J. Geophys. Res. **69,** 1769–1783) has shown that the effect of this angle is an easterly deflection of the solar wind as it traverses the standing hydromagnetic shock wave a few earth radii upstream of the magnetosphere. The calculated deflection angle lies between 5 and 20 degrees, and disappears completely when the interplanetary field is either parallel to or normal to the solar wind velocity. The magnetosphere will tend to aline itself along the direction of the local solar wind flow. Changes in the direction of the interplanetary field will thus result in changes in the shape of the magnetosphere, which can be detected at the earth's surface as hydromagnetic perturbations. Thus, the changing direction of the interplanetary magnetic field offers a mechanism whereby energy can be transferred from the solar wind into magnetic activity detectable at the earth's surface as measured by *Kp* or *Ap* indexes (A. J. Dessler and G. K. Walters, Planet. Space Sci. 1964 **12,** 227–234; and K. Maer and A. J. Dessler, 1964, J. Geophys. Res. **69,** 2846). Another interaction effect is that hydromagnetic shock waves in the magnetospheric tail may drag it out for distances of the order of 30 A.U. (A. J. Dessler, 1964, J. Geophys. Res. **69,** 3913–3918).