Preface

Since the International Geophysical Year, there has been a rapid and significant growth in the number of scientists studying the natural electromagnetic signals in the frequency range between 30 c/s and 0.001 c/s. Sufficient progress was made in the understanding of the geophysical sources and their propagation characteristics to consider it an appropriate time to pause, reevaluate the research, summarize the work, and delineate the pressing needs for future studies. The Symposium on Ultra Low Frequency Electromagnetic Fields was held in Boulder, Colo., on August 17–20, 1964. The conference consisted of three tutorial sessions on the environment, signal sources, and observations, and one session for presentation of contributed papers regarding recent research. The conference was arranged by the National Bureau of Standards and the National Center for Atmospheric Research and cosponsored by the American Geophysical Union, the Office of Naval Research, the Air Force Cambridge Research Laboratories, and the International Association of Geomagnetism and Aeronomy. Approximately three hundred international scientists were in attendance. The papers presented in this issue of Radio Science were selected from the large number of manuscripts submitted by the participants at the symposium. Abstracts of other contributions are listed at the end of this issue. Papers prepared for this symposium by researchers in Japan have appeared in the *Report of Ionosphere and Space Research in Japan*, Volume 18, No. 3, 1964. It is hoped that this publication of the symposium highlights will expose the reader to the present level of understanding in this interesting field of research and stimulate further productive studies.

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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, Tucsòn, 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.