Ionospheric Radio Communications

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PREFACE

Essentially three groups of research workers are concerned with ionospheric radio communications. Radio physicists engaged in a study of the propagation medium, equipment and system designers, and technical personnel responsible for operating terminal facilities. The success of endeavours to solve the numerous challenging problems which still remain depends upon the ability of the groups to coordinate their efforts and functions. The present situation leaves much to be desired. Physicists in particular, in treating the experimental material at hand have been inclined to restrict their research in pursuit of purely scientific goals. Their formulation of problems and terms of analysis have often been poorly matched to the requirements of the users and the design engineers.

A record of a NATO Advanced Study Institute this volume brings together representatives of the above groups to exchange experiences and viewpoints.

This volume emphasizes the phenomena and problems associated with the arctic environment. However, contributions representing novel techniques and advanced system refinements have been included even if they are not particularly related to the high latitude domain. Nearly all the papers are based on experimental research, either in the form of measurements of ionospheric characteristics and properties of propagated signals or as laboratory investigations to optimize system performances.

Features of the physics of the arctic ionosphere, required as a basis for meaningful discussions, are reviewed in the introductory chapter. Outstanding phenomena bound to the complex mechanisms in the sun-earth relationship are described and their significance for practical communication stressed. Several contributions are devoted to transmissions in the spectrum ranging from the VLF- to the VHF-band. Of particular interest among the multitude of subjects are navigational applications of VLF, aspects of ionospheric and meteor scatter propagation, temporal and spatial characteristics of HF-transmissions, description of modulation techniques, air-to-ground communication, prediction of HF working frequencies and use of anomalous ionozation structures, such as E_s and field-aligned irregularities for practical communication purposes.

Practical engineers will find the section dealing with system techniques particularly important. Features of modern design philosophy are considered, including adaptive transmitting and receiving equipment, methods for avoiding or reducing the effects of frequency and time dispersion, system applications based on electronic computers and employment of artificial ionization in establishing useable channels in operating high priority projects.

Other papers survey the communication facilities in the Canadian and Norwegian Arctic.

A summary of the sessions is given in the final chapter, together with a stimulating panel discussion on future developments.

As a whole, the book provides a comprehensive picture of the present state of affairs in the field of ionospheric communication. Throughout the volume the need for extended cooperation among all groups of communication workers is repeatedly stressed.

Progress presupposes a desire to establish a common language, understood and accepted by all people involved: physicists, designers, and operators. If the book helps to further this view to a broader audience, it will have fulfilled a worthwhile purpose.

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Coll, D.C., Adaptive receivers for multipath channels

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Daly, R.F., see Vincent

Davies, K., Physicist's contribution to panel discussion

Egeland, A., Discussion of VLF records obtained during polar cap absorption and auroral disturbances

Folkestad, K., Results from stepped frequency oblique soundings at high latitudes

Hartz, T.R., The general pattern of auroral particle precipitation and its implications for high latitude communication systems

Hartz, T.R., Summary of sessions

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Holt, O., Characteristics of polar cap absorption

Jespersen, M. and B. Landmark, Electron density observations during auroral absorption related to radio wave communication problems

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Kulinyi, R.A., Notes on a multi-mode communication system

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Lange-Hesse, G., VHF bistatic auroral backscatter communication

Maynard, L.A., Meteor burst communications in the Arctic

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Meek, J.H., Bridging the gap between physicist, engineer and the user and the needs for the future

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Piggott, W.R., Normal and abnormal absorption at high latitudes
Pratley, P.J., Some experiences with military communications in the Canadian Arctic
Probst, S.E., The CURTS concept and current status of development
Probst, S.E., Users viewpoint contribution to the summary panel discussion
Powers, C.F. and C.M. Rush, The ionization maximum in polar latitudes
Ringereide, T., Existing communications facilities and user problems in the Canadian Arctic
Rush, C.M., see Powers
Sifford, B.M., see Vincent
Stevens, E.E., The significance of sporadic E propagation in determining the MUF
Stevens, E.E., The CHEC sounding system
Thrane, E.V., Collision frequency in the high latitude D-region
Veastad, J.R., Survey of the user problems and existing communication facilities in the Norwegian Arctic
Vincent, W.R., R.F. Daly and B.M. Sifford, Modeling communication systems
Warren, E.S., see Petrie
Watt, A.D., A note regarding the performance of various communications systems in a noisy background
Westerlund, S., Periodic fading of VLF signals received over a polar path during sunset and sunrise
Wright, P.J., Royal Air Force Coastal Command Maritime air/ground communications to and from auroral regions

CONTENTS

HF Communications

Communication System Techniques

Survey of Existing Communication Facilities and User Problems in the Arctic

Panel Discussion of Future Developments

OPENING SPEECH

Finn Lied

Director, Norwegian Defence Research

Establishment

1. GENERAL

The noticeable trend in our days to exploit the arctic for industrial, military and scientific purposes has led to an increasing demand for extended and improved communications in that part of the world.

Unfortunately the communication technique most extensively employed hitherto, that of ionospheric HF-propagation, has proved to be rather susceptible to disruption and impairments caused by dynamic processes frequently occurring in the polar ionosphere. The recognized unreliability of propagation at high frequencies in the polar regions naturally has stimulated the interest for transmission systems less critically dependent upon the state of the intervening medium, such as tropospheric scatter circuits, microwave links and the novel technique based on use of artificial satellites.

In spite of the difficulties associated with HF-operation at high latitudes and the persistent efforts to establish more reliable ways of communicating, it is reasonable to believe that this range of the spectrum still for many years will carry a substantial part of the radio-traffic in these regions. Whenever primary importance is placed on simplicity of installations, moderate power consumption and economy, none of the other modes of RF-operation really can compete with an HF-arrangement.

The LF- and VLF-bands have nowadays become firmly established as working domains for several navigational networks, among them the most advanced global system termed OMEGA.

In these frequency ranges it is often convenient to consider a signal as a combination of modes propagated in a spherical wave-guide formed by the earth's surface and the low boundary of the ionosphere. The characteristics of reception are largely determined by the properties of the ionospheric strata involved.

At this NATO Institute we shall confine our interest to a study of ionospheric transmissions only. We are convinced that the part of arctic communication concerned with ionospheric radio propagation is of sufficient future importance to justify such a restriction of the subject.

The arrangement of the Institute should be regarded as an attempt to establish a forum where the significant physical and practical aspects of ionospheric radio communication in the Arctic will receive due attention.

It may be appropriate at the outset, for the sake of perspective to briefly outline some basic concepts pertinent to the polar ionosphere and its relation to solar and interplanetary processes.

2. MAIN PROBLEMS

Generally the electron distribution N(h) in the lower part of the ionosphere, the D- and the E-regions, say between 50 and 95 km, has a profound influence on the propagation of electromagnetic energy at radiofrequencies. Considering waves in the LF- and VLF-ranges the primary effect of an increase in the ionization in the D-layer is a downward displacement of the reflection points with an alteration of the effective signal paths. The resulting changes in the phase patterns on the ground may completely mask the regular diurnal variations. Usually, departures from the normal signal strength levels, detected in conjunction with a disturbance in the lower ionosphere, do not seriously affect the circuit behaviour.

Ionospherically propagated rays in the HF-band suffer energy loss in traversing the D-layer on the way to or from the reflection regions in the higher strata. In this part of the spectrum the attenuation is essentially determined by the product of electron density and electron collision frequency, $N \times \nu$. As the collision frequency increases downward in approximate correspondence with an exponential law, one might infer that a given change ΔN at low altitudes leads to a more severe attenuation than a similar deviation in the ionization at larger heights.

Since the propagational difficulties encountered are inherently associated with spatial and temporal changes in the content of free electrons in the ionosphere, a broad understanding of the nature of the disturbances implies a consideration of the mechanisms responsible for the production and maintenance of the ionization involved.

At low and middle latitudes N is predominantly caused by electromagnetic radiation from the sun. In the polar ionosphere incoming charged particles constitute production agencies equally or even more important than the ultra-violet source. The particles are known to be of solar or galactic origin. They cover a broad spectrum of energies and exhibit intensities which depend upon the conditions on the sun. During periods succeeding solar eruptions the particle flux may increase considerably.

As the particles approach the earth's surroundings, they are acted upon by the geomagnetic field and guided into the polar areas. The resulting spatial distribution pattern is determined by the energy of the impinging particles. The most serious category of disturbances which may occur, termed Polar Cap Absorption, is accompanied by an influx of rather energetic particles distributed across the entire polar cap. In the majority of events, though, the impact tends to concentrate in restricted areas, in geophysical parlance denoted Auroral Zones. Here they give rise to a multitude of phenomena, such as magnetic storms, auroral displays and to the formation of certain types of Es-ionization.

3. HISTORICAL BACKGROUND AND DEVELOPMENT

The pioneering experimental work conducted by Birkeland, and the subsequent extensive theoretical analyses by Størmer of trajectories of charged particles in a dipole field, mark the starting point of later extensive research of polar disturbances. Størmer's theories are still found valuable in the study of the behaviour of cosmic rays. To explain the dynamics of auroral impacts associated with auroral disturbances, more refined models have to be invoked. It is interesting to note in passing that Størmer more than 50 years ago showed that charged particles actually could remain trapped in the earth's magnetic field. As many will know, the existence of regions with geomagnetically trapped particles was drastically demonstrated in 1958 through the measurements of Van Allen in Explorer I.

For several decades the lack of experimental data served to give theories concerned with the solar-terrestrial relationship a conspicuous character of speculation. The situation is now in the process of being radically changed, first of all through the use of rockets and exploring satellites. There are still a variety of unsolved questions which undoubtedly will challenge the scientists in years to come. However, from the available elements of information obtained through active research in recent years, a fairly coherent pattern for the structure of the terrestrial environment is slowly beginning to manifest itself.

Soundings of the ionosphere conducted from the top-side by the Canadian satellites Alouette I and II and the American space vehicle Explorer XX have yielded a wealth of information on the spatial, diurnal and annual variations of the electron distribution, on field aligned irregularities, resonance phenomena and guided propagation at low frequencies. The output from numerous experiments designed to measure angular spectra and energy distributions of charged particles, has greatly advanced our knowledge of the dynamics of particle movements in the earth's field. Our present picture of the geomagnetic field, its boundaries, intensity and directional properties, is in large based on measurements of magnetic sensors in orbiting satellites.

4. PATTERN FOR THE TERRRESTRIAL SURROUNDINGS

The main features of our present-day concept of the earth's environment may conveniently be displayed in connection with a representation given by Ness (1), based on measurements of the IMP satellite.

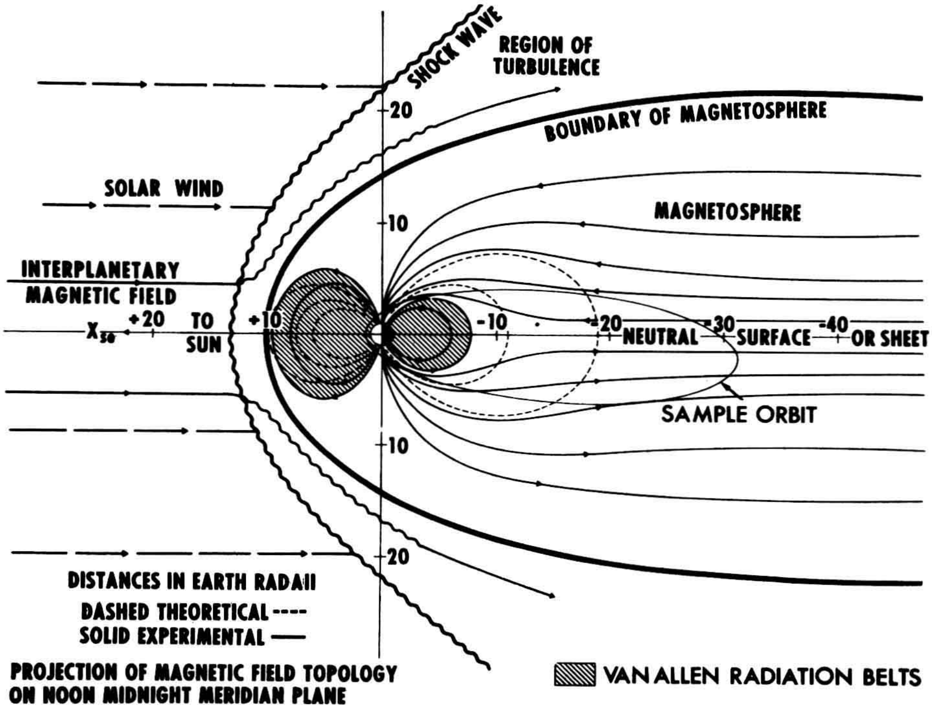

Figure 1. Earth's environment

A highly tenuous plasma blowing radially outward from the sun at a speed of 3-500 km/s at 1 AU constitutes a "solar wind". Embedded in the plasma, and moving with it, is a magnetic field whose order of magnitude is about $5 \cdot 10^{-5}$ Gauss. Due to the interaction of the earth's magnetic field and the streaming plasma flux, a cavity is created inside which the earth's field is confined. Ahead of the cavity boundary a detached shock wave is produced. Between the shock wave and the magnetosphere is a transition region characterized by a turbulent, disordered field configuration. The dimensions of the cavity depend upon the intensity of the streaming jet. The distance to the magnetopause in the solar direction is typically about 10 earth radii. In the direction away from the sun the cavity has been found to stretch out to very great distances, probably to more than 60 earth radii.

The central part of the magnetic tail is made up of a neutral sheet. It is highly probably that this restricted part of the tail plays an important role as a coupling domain where the solar particles are injected into the geomagnetic confinements. From the sheet the particles are constrained to move, under the influence of electrodynamical forces, into the high latitude regions.

The dashed parts in the figure represent radiation belts consisting of magnetically trapped particles. The displayed unsymmetry is easily explained in terms of invariant properties governing this type of particle drift. There are experimental indications that particles in the radiation belts, at times of disturbances, may be released from their confined orbits and penetrate into the lower polar ionosphere. Exact details of the nature of the mechanisms initiating such a dumping of particles remain unknown.

5. CONCLUDING REMARKS

With the rapid expansion in space research in our days, and the resulting steady accumulation of new data, it is unlikely that each detail in the model just described will remain unchanged. It is thought, however, that essential features in the solar-terrestrial relationship are adequately represented. The model does explain the strong linkage of the polar ionosphere to corpuscular interplanetary processes and the observed latitudinal cutoff in precipitation. This is a property which any model pretending to describe the earth's surroundings has to possess.

In the coming week we will hear lecturers supplementing and extending this somewhat sketchy presentation. Several papers will deal with particular forms of particle influx and their implication for arctic communication, the morphology of magnetic disturbances and theoretical aspects of wave-propagation. Other lectures will be devoted to a description of communication techniques, practical results from radio-operation in the Arctic, users problems and prediction methods.

Participants engaged in practical work, as operators or technical administrators, will have an opportunity of broadening their concepts and clarifying their notions of the physical processes causing disruption of their circuits. The physicists on their side may obtain a clearer understanding of the problems and demands of practical communication services. It is our ambitious hope that the interchange of information and experience conveyed through lectures and discussions at this symposium may serve to focus and concentrate our interests and engagements in the field of arctic ionospheric communication on those problems where future efforts may be of greatest benefit.

With these words I would like to open this NATO Study Institute.

6. REFERENCE

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