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DEFENCE RESEARCH BOARD, DEPARTMENT OF NATIONAL DEFENCE, OTTAWA, CANADA

DRTE REPORT NO. 1192-U

FEBRUARY 1968

DEFENCE RESEARCH BOARD

DEPARTMENT OF NATIONAL DEFENCE
CANADA

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INTRODUCTION

by

F. T. Davies - Chief Superintendent

At the end of 1966 DRTE staff numbered 444 in establishment positions, including 106 Scientific Officers, 59 Technical Officers, 106 Technicians, and 173 in support roles. CEMS had in addition 44 casuals. This represents a regular DRTE employee total of 488.

During 1966 ten Scientific Officers left DRTE and twenty-three joined. Three left for educational leave and L.A. Maynard returned from university.

A.W. Adey and B.C. Blevis joined the Canadian Defence Research Staff in Washington; R.F. Nikkel joined DSIS as information officer; J.W. Cox was appointed to a special HQ assignment for long range studies; G.W. Morton retired; D.L. Matthews and J.L. McAlpine left for university posts and J.P. Murray joined IBM, Toronto.

J.S. Belrose and G.W. Jull were posted to UK for a year, the former at RSRS (Slough) and the latter at Imperial College. G.H. Booth took a post with the European Space Research Organization (ESRO) and W. Threinen is at M.I.T. for a year.

J.H. Crysdale, D.R. McCaskill joined DRTE from HQ, W.C. Collins from NRC, and C.V. Rayment from HQ to become Scientific Staff Officer DRTE.

Eleven University Professors acted as consultants during 1966—Dr. T.A. Clark of U. of Calgary, Dr. A.H. Manson of Canterbury University, New Zealand, and Dr. R.A. Smith of the University of New England, Australia, spent some months at DRTE.

M.R. Knoll and M.M. Auger returned to Le Centre National d'Études Spatiales, Paris, after a year with the Satellite team; Major J. Blachon returned to France; Dr. O. Sletvold returned to Norway; Major A.N. Yazar returned to Turkey; and Dr. R.B. Harvey to SES after a year in DRTE. Three new NATO/DRB fellows have recently joined DRTE for a year, T. Endresen (Norway), N K. Hansen (Denmark) and M.A. Sencer (Turkey).

S/L G.W. Tahirali returned to the RCAF and was replaced by S/L J.A. Heal. F/O C.B.D. Bunner joined DRTE to replace F/L Bauer who returns to the RCAF in January, 1967. F/L S. Chute is attached to DRTE from CFHQ. F/L E.J. Gaines and six NCO's (RCAF) left PARL for RCAF postings. Cdr. R.D. Wilson (RCN) and Capt. E.W. Halayko (Can. Army Signals) continue at DRTE.

TTCP Sub-Group, K9 Panel and TTCP Sub-Group M met at DRTE during September.

A Board meeting of DRB met at DRTE on 1 June after which Dr. A.H. Zimmerman, assisted by Mr. A.B. Hunt, Vice-President, Northern Electric and Mr. E.H. Higgins, Vice President, Canadair, officially opened the new Satellite Communications Facility. This is a great acquisition for DRTE in Communications Research.

The Science Council of Canada held a meeting on Space Research at DRTE on 28 November and inspected DRTE Space Research Facilities in the afternoon.

Mobile Force Command held a very useful two day discussion at DRTE in December on Communications problems.

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J.W. COX

DEPUTY CHIEF SUPERINTENDENT
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Liaison-Policy-Plans

ADMINISTRATION WING
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  - H.F. Pragnell
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  - J.S. Belrose *
- PLASMA PHYSICS SECTION
  - R.E. Barrington
- CONSULTANTS
  - T.R. Hartz
  - L. Herzberg (Mrs.)

* Acts for Superintendent in his absence.
† Acts for Scientific Staff Officer in his absence.
1966

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Five DRTE officers attended Canadian Army Brigade exercises in Germany. This was the third year in which a DRTE team, led by Capt. Halayko, was privileged to see communications operations during extensive exercises. Other small teams participated in Maritime equipment tests and in radar evaluation at No. 3 Wing RCAF. The increasing direct links with active Service units during the past three years has been very useful and necessary to DRTE, and will be further increased in future.

A certificate of merit was won by the DRTE Fire Prevention and Protection Group. CDRB accepted this on behalf of DRTE at a ceremony arranged by the National Fire Protection Association.

Theoretical research in Field Theory and Gravitation has been pursued intensively by James C. W. Scott during the past three years. It is perhaps the most difficult type of research which one can tackle. The response to his published papers is a credit to Mr. Scott which is fully appreciated by his colleagues in DRTE.

John H. Chapman, Deputy CS/DRTE, was presented with the first Dellinger Gold Medal of the International Union of Radio Science at Munich in September, an honour not only to himself but to Canada.

ALOUETTE/ISIS SATELLITE PROGRAM

The two Defence Research Board satellites, Alouettes I and II, continue to function well. Alouette I has completed over four years of operation and records data at a rate of 2 to 3 hours per day, depending on the fraction of time it is in direct sunlight. The quality of the sounder records is still excellent, see Figure 1, and there are no signs of a reduction in sensitivity. Alouette II has completed over one year of successful operation, and it records data from 4.5 to 7 hours per day, again depending on the fraction of time it is in direct sunlight.

Performance figures for the two satellites are:

(a) Orbital Elements	**Alouette I**	**Alouette II**
Height of apogee	642 miles	1,850 miles
Height of perigee	616 miles	311 miles
Inclination	80.5 degrees	79.8 degrees
Period	105.4 minutes	121.3 minutes
(b) Operations (to 31 Dec/66)		
Number of orbits	21,217	4,716
Number of commands executed (approx.)	48,000	12,200
Total telemetry transmission time	7,400 hours	2,100 hours
Number of ionograms recorded (approx.)	1,590,000	353,000.

Integration of the engineering model of the third satellite in the series, identified as ISIS-A (International Satellite for Ionospheric Studies) is nearing completion and flight hardware construction is underway. Experiments for the ISIS-B satellite have been selected.

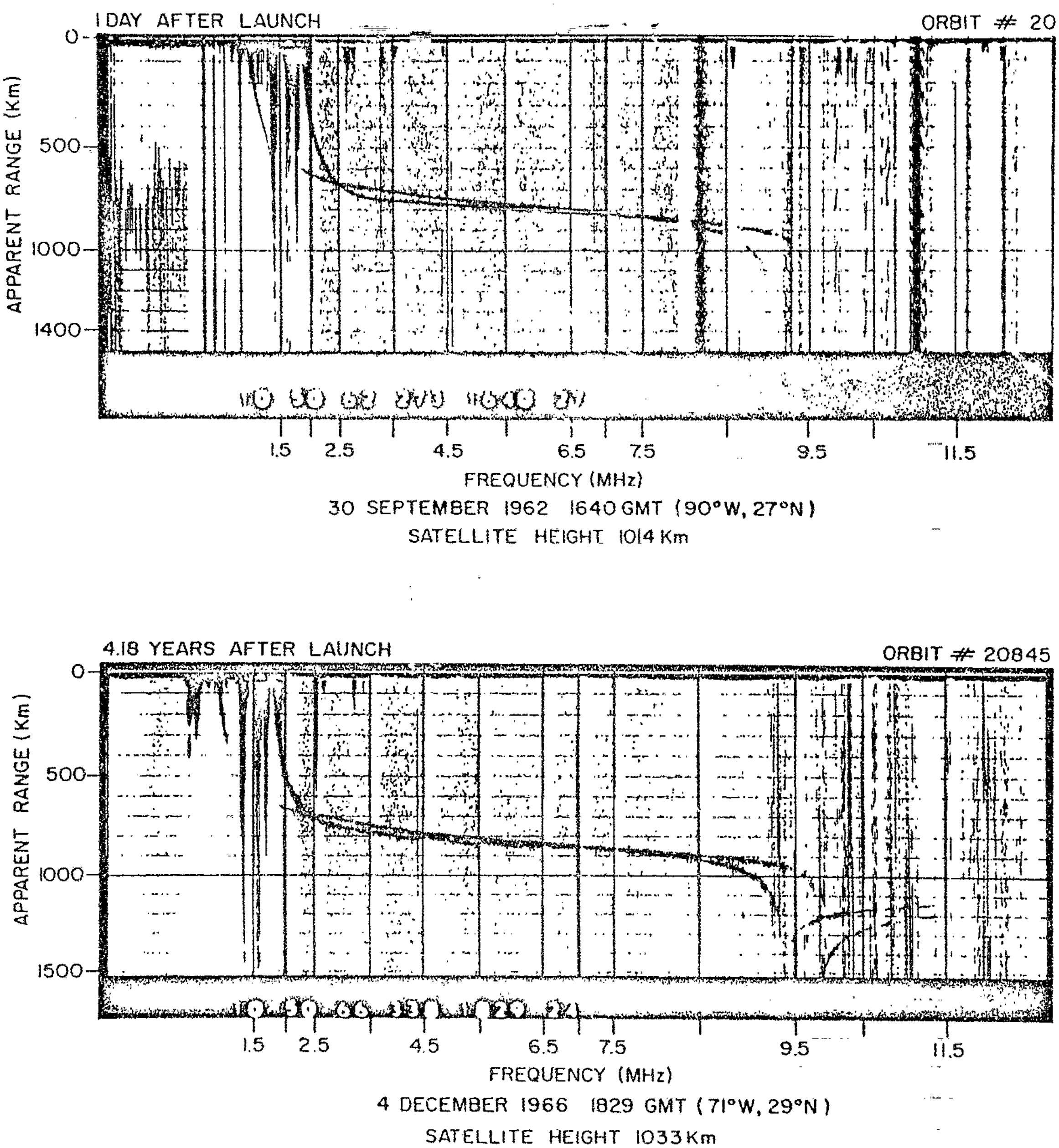

Fig. 1. Alouette I ionograms indicating little degradation of equipment performance after more than four years in orbit.

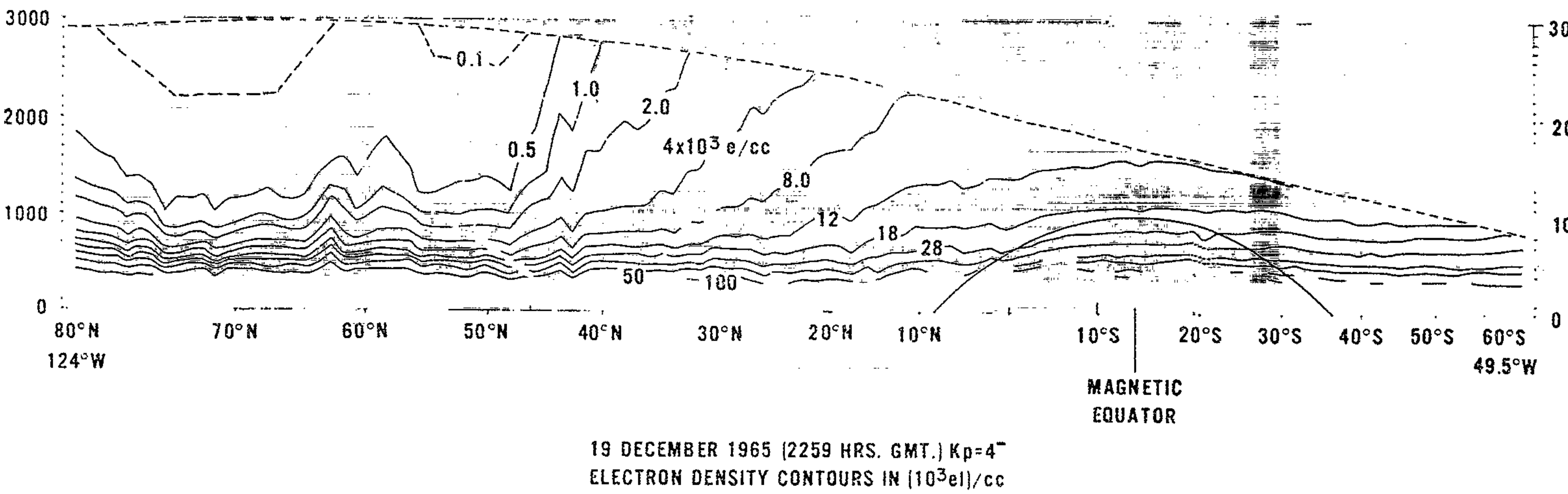

Fig. 2. Electron density contours in the earth's ionosphere derived from Alouette II measurements.

ANALYSIS OF ALOUETTE I AND ALOUETTE II DATA

(a) ELECTRON NUMBER DENSITY OVER THE POLAR REGIONS

Analysis of the topside sounder data from Alouette II has revealed unexpectedly low electron densities over large regions of the polar cap, at heights between 2000–3000 km (Fig. 2). This discovery is highly significant for the development of theories of ionospheric formation, since these low densities are comparable to typical values for interplanetary space at a distance of one astronomical unit from the sun.

(b) A NEW RADIOWAVE METHOD FOR MEASURING VERY LOW ELECTRON DENSITIES

The normal topside sounding technique for measuring electron number density is limited by the low-frequency end of the frequency sweep. The lowest densities that can normally be measured by the Alouette I sounder are about 1500 electrons/cm^3, and by Alouette II about 300 electrons/cm^3. This sensitivity is not adequate for studies of the very low density of ionization in the polar regions. Fortunately, a new plasma resonance effect was observed on the Alouette II ionograms, and this effect has been used to measure very low electron densities.

When two fundamental plasma resonances, the electron gyrofrequency (f_H) and the "upper hybrid" resonance (f_T), are sufficiently close together in frequency, both resonances are stimulated simultaneously by the sounder pulse transmissions. A beat frequency is produced between these two resonances, and this beat is observed in the sounder receiver output as a modulation on the resonance spikes, (Fig. 3). From this difference frequency and the application of plasma theory, the electron number density at the satellite can be computed to an accuracy of a few per cent, even for densities as low as 8 per cm^3.

(c) SATELLITE MEASUREMENTS OF RADIO NOISE

Measurements in the Alouette II satellite of the amplitude of radio noise have revealed unexpected HF noise bands that appear to originate in the ionosphere or the magnetosphere. These noise bands all appear below a specific plasma resonance frequency (the local "upper-hybrid" resonance), which is usually in the range 1 to 2 MHz. Between this resonance and the low frequency limit (100 kHz) of the satellite receiver at least four distinct bands of noise have been identified. Depending on circumstances, any or all of these bands may be very intense, and on some occasions they saturate the receiver.

Analysis of these noise data is still in progress, but certain tentative conclusions have already been reached. One of the noise bands appears to be generated by some local process such as electrostatic oscillations in the satellite wake. The occurrence patterns of the other noise bands suggest a relationship to auroral-zone phenomena, such as "auroral" electrons. Suggested explanations for two of these bands are Doppler-shifted cyclotron radiation and Cerenkov radiation due to the energetic electrons. No completely satisfactory explanation of the remaining noise band has yet been found.

(d) SATELLITE OBSERVATIONS OF VERY LOW FREQUENCY (VLF) RADIO EMISSIONS

Radio emissions in the frequency range 50 Hz to 30 kHz are recorded by the Alouette satellites. Analysis of these data are providing vital new information on the properties of the earth's upper atmosphere.

Certain VLF emissions originate in lightning flashes and arrive at the satellites in the form of gliding tones, or "whistlers". Alouette I discovered a new type of VLF whistler whose properties are largely determined by the concentration of protons along the path. These signals are called "proton whistlers". Alouette II, because of its extended frequency coverage at the low end of the VLF band, provided the first observations of "helium whistlers".

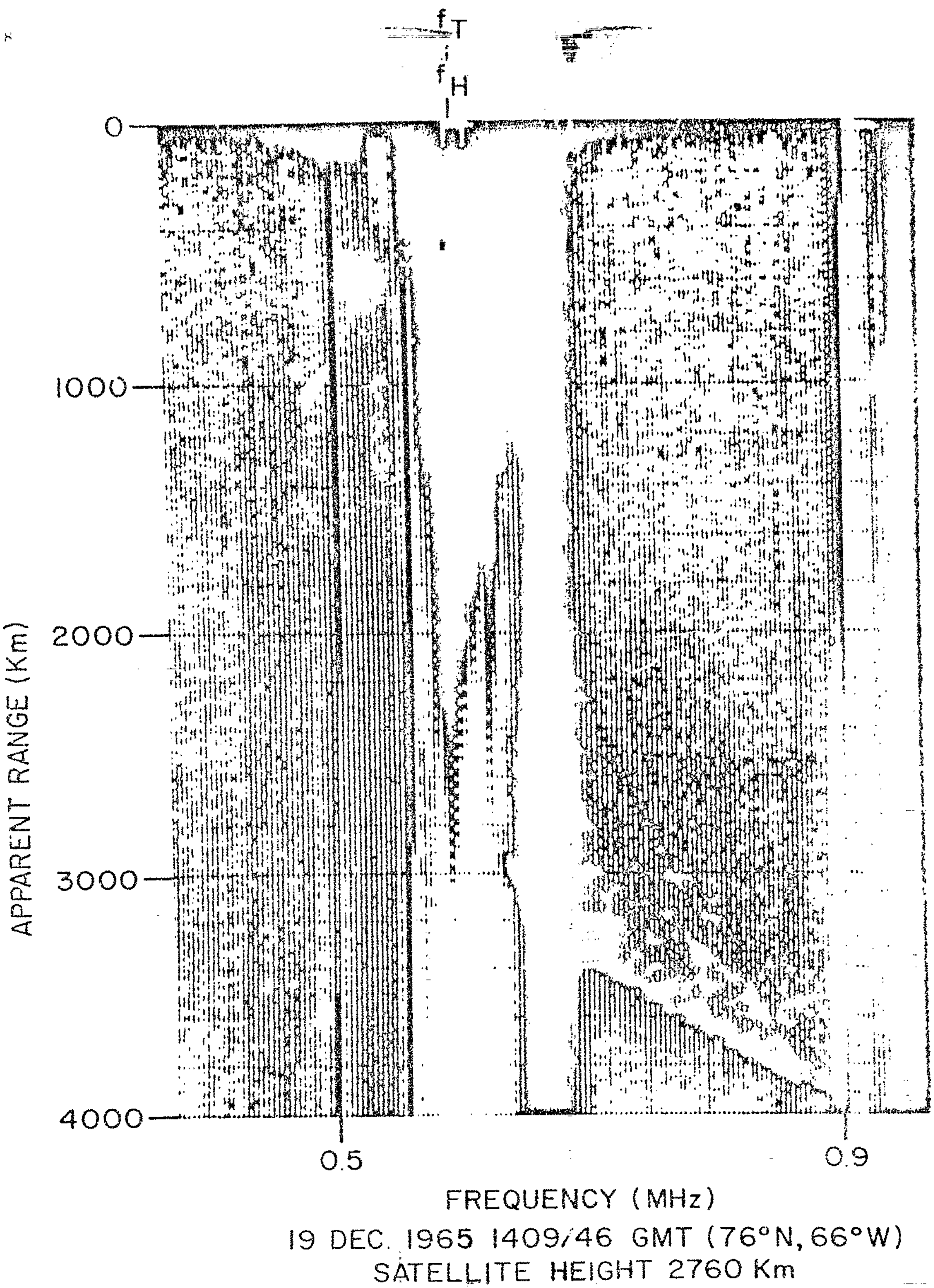

Fig. 3. An example of Alouette II ionograms used to compute very low electron densities.

To date, the Alouette helium whistler observations are still unique. Simultaneous recordings of helium and proton whistlers provide a direct and accurate means of measuring the concentration of protons, helium ions and oxygen ions at great heights above the earth's surface. Figure 4 shows a theoretical picture of an ordinary fractional-hop whistler, converted into both a proton and helium whistler, together with an Alouette II recording of such an event.

One significant result of the analysis is the discovery that the concentration of oxygen ions is unexpectedly large in the height range from 1000–2000 km at mid latitudes. Another result is the development of a method for measuring the temperature of ions. On the satellite recordings, the amplitude of a proton whistler decreases rather abruptly (i.e., is cut off) at a wave frequency slightly less than the proton gyrofrequency at the satellite. A theory of this effect has been developed in which the difference between the wave frequency at cutoff and the proton gyrofrequency is related to the proton temperature.

On many occasions VLF noise bands recorded by the Alouette satellites have a well-defined low-frequency limit which occurs at the frequency of a theoretical natural plasma resonance and is known as the "lower-hybrid resonance" (LHR). At high latitudes the LHR noise is observed over the entire height range (500–3000 km) of Alouette II. This noise, however, is absent in a belt centered on the equator and extending to the magnetic field lines that intersect the earth's surface at about 30° latitude.

At great heights, where the ionosphere consists almost entirely of protons, the LHR frequency provides a direct measure of the electron density at the height of the satellite. These LHR observations complement the swept-frequency sounder measurements of electron density, since the LHR frequency can be observed continuously. In addition, this LHR technique can be used to measure the extremely low electron densities of about 100 electrons/cm^3 found at great heights in the polar regions.

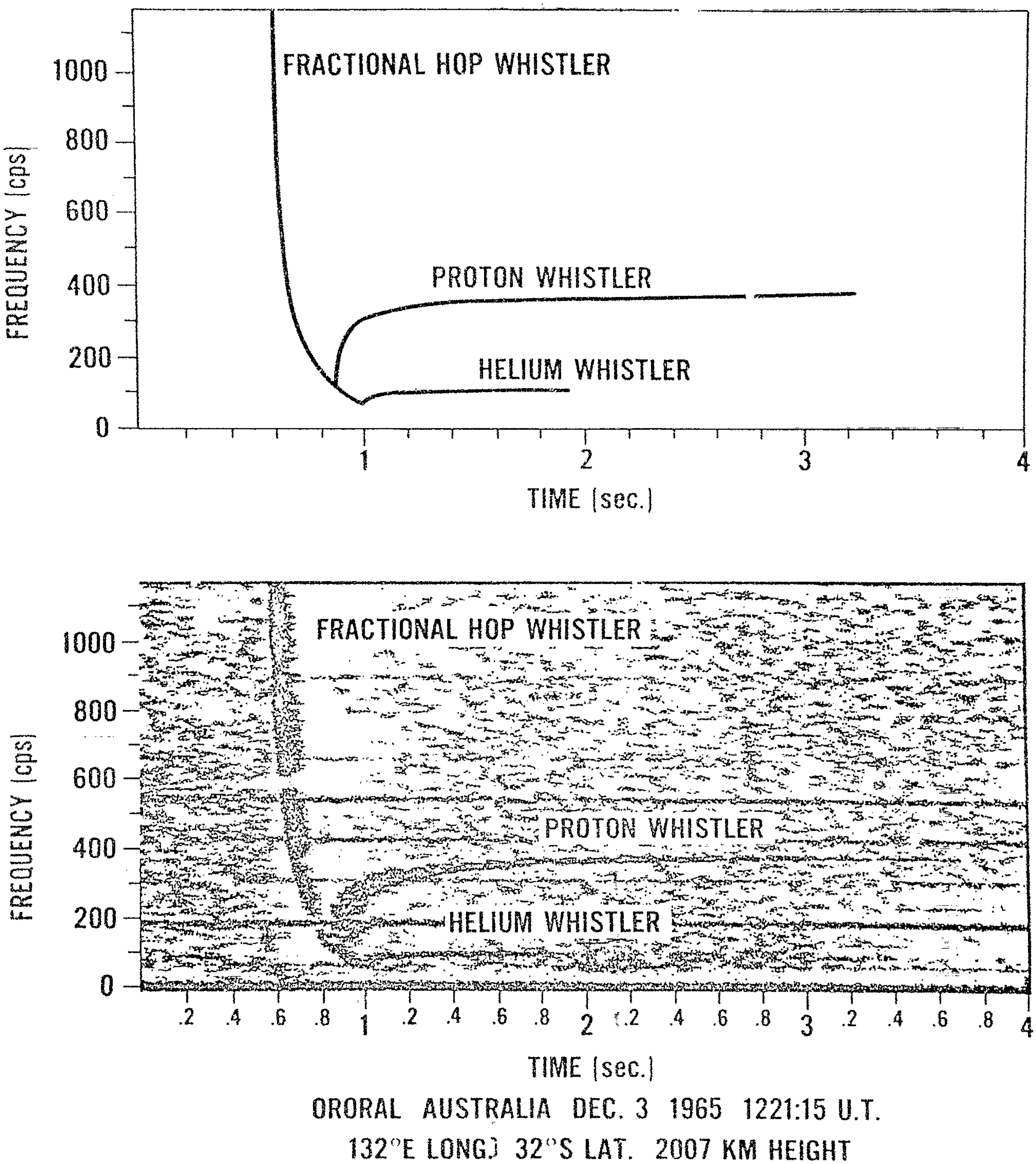

Fig. 4. Comparison of a theoretical fractional hop whistler signal and an actual Alouette II recording.

SATELLITE COMMUNICATIONS

Research has continued on modulation systems to provide multiple random access in satellite communication systems and on microwave propagation at frequencies which are expected to be used in the future for satellite communications. A Memorandum of Understanding between the U.S. Department of the Army and the Defence Research Board which was signed in November, 1966, provides for experimental use by DRTE of repeater satellites launched for the United States Initial Defense Communication Satellite Project (IDCSP).

(a) MULTIPLE ACCESS

In the 1965 Annual Report, a description was given of the features of communications by means of an active satellite repeater. Tactical and point-to-point military communications were discussed and the capacity of a hypothetical satellite communications link for ground terminals of various antenna sizes was estimated. On June 16, 1966, the United States Department of Defense launched seven active repeater satellites in a near synchronous equatorial orbit as the first of several satellite launches of the IDCSP. These satellites have been used to gather experimental evidence of the value to the military of satellite communications. The satellites have functioned reliably in orbit and, in U.S. tests with ground terminals located around the world, the high reliability and quality of this communications method have been demonstrated. However, a modulation technique to provide multiple access has not been selected. The DRTE research program of communications experiments is being carried out to investigate the use of spread spectrum and adaptive variable rate techniques for multiple access to the satellite repeater.

The Adaptive Systems Group at DRTE has built a modulation and demodulation equipment, based on spread spectrum techniques. Through the use of these techniques, it is anticipated that one pair of terminals will be able to communicate teletype messages, data and vocoded speech while many other terminals are also using the repeater. A unique feature of the DRTE modulation and demodulation equipment is a facility to change the message rate rapidly to adjust for changes in signal strength due to variations in the use of the satellite. In an adaptive mode, the highest message rate that is satisfactory for the instantaneous condition of satellite sharing will be selected automatically. The Memorandum of Understanding, referred to above, provides for exclusive and shared experimental use of satellites during 1966-1969 to test this system.

The communications experiment is being carried out with the DRTE thirty-foot precision tracking antenna. The terminal was used with an interim transmitter and receiver beginning in December, 1966 and preliminary experiments with the communications system were carried out successfully. A low noise receiver, a diplexer and a 10 kw power amplifier have been ordered and installation should be completed in February, 1967. During 1967, all communications tests will be loop tests, in which the DRTE terminal will monitor its own signals as relayed by the satellite. Link tests, between two ground terminals, may be carried out later to test the performance of the communications system. The region of the globe over which signals from the Ottawa terminal can be received is indicated in Figure 5.

(b) MICROWAVE PROPAGATION

The first phase of the program, measurements of attenuation due to rain along a terrestrial path, has been successfully completed. The measurements were made at 8 and 15 GHz, using a 16 km line-of-sight transmission path. Rainfall rates were measured by six rain gauges distributed along the path. Recordings of signal strength were obtained for 92% of the 1965-66 period. Analysis of the data obtained in 1965 showed that the observed values of attenuation tended to exceed the theoretically predicted values, particularly at low values of rainfall rate (Fig. 6). The observations showed no tendency to exceed the maximum values which are theoretically possible. Computation, based on the observations, were made to relate attenuation to rainfall rate for the Ottawa area. A study of the cumulative distribution of signal level at 15 GHz showed that rain caused a significant change in signal strength (3 dB) less than one per cent of the time. Also, it has been

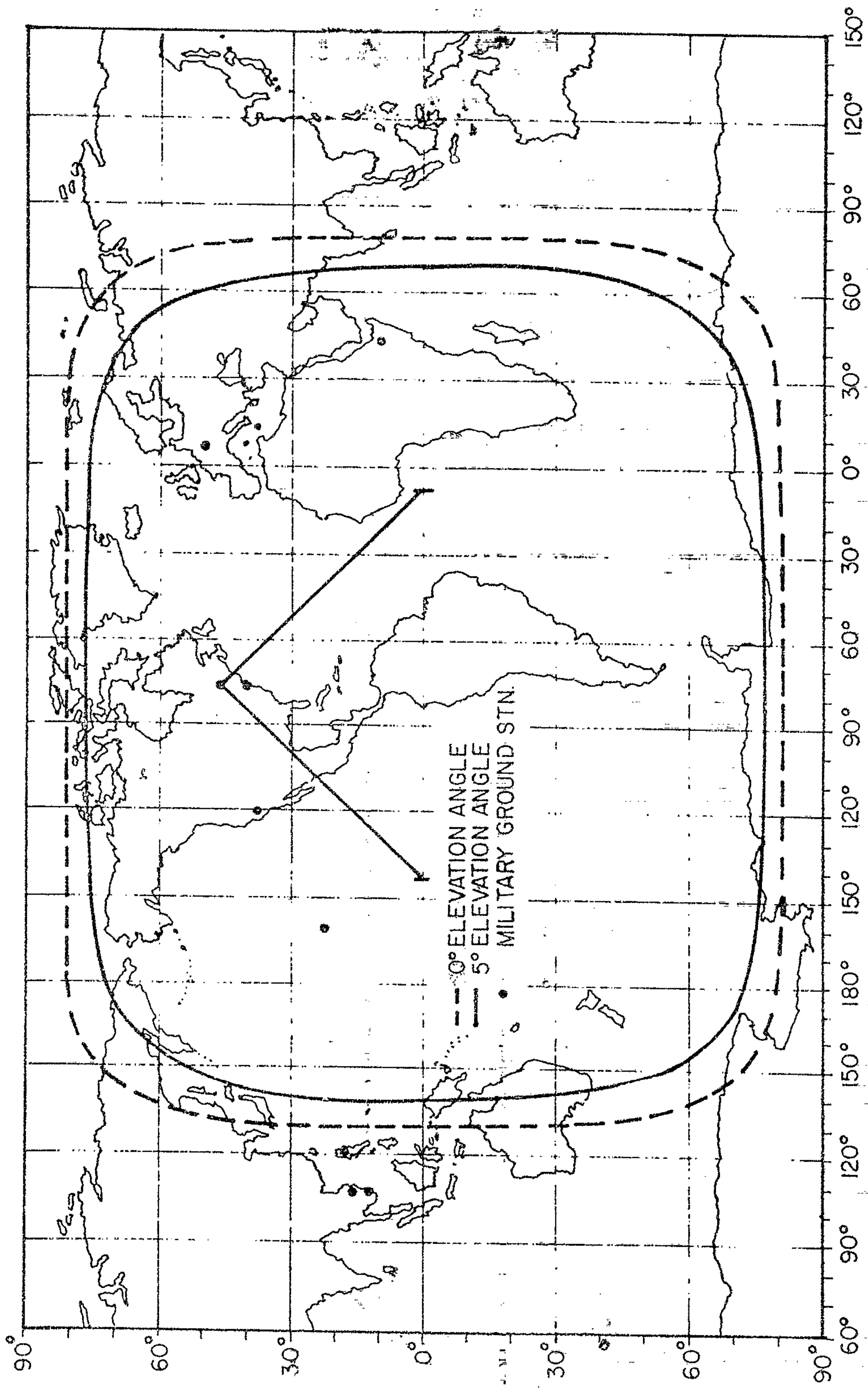

Fig. 5. Satellite communications coverage from Ottawa.

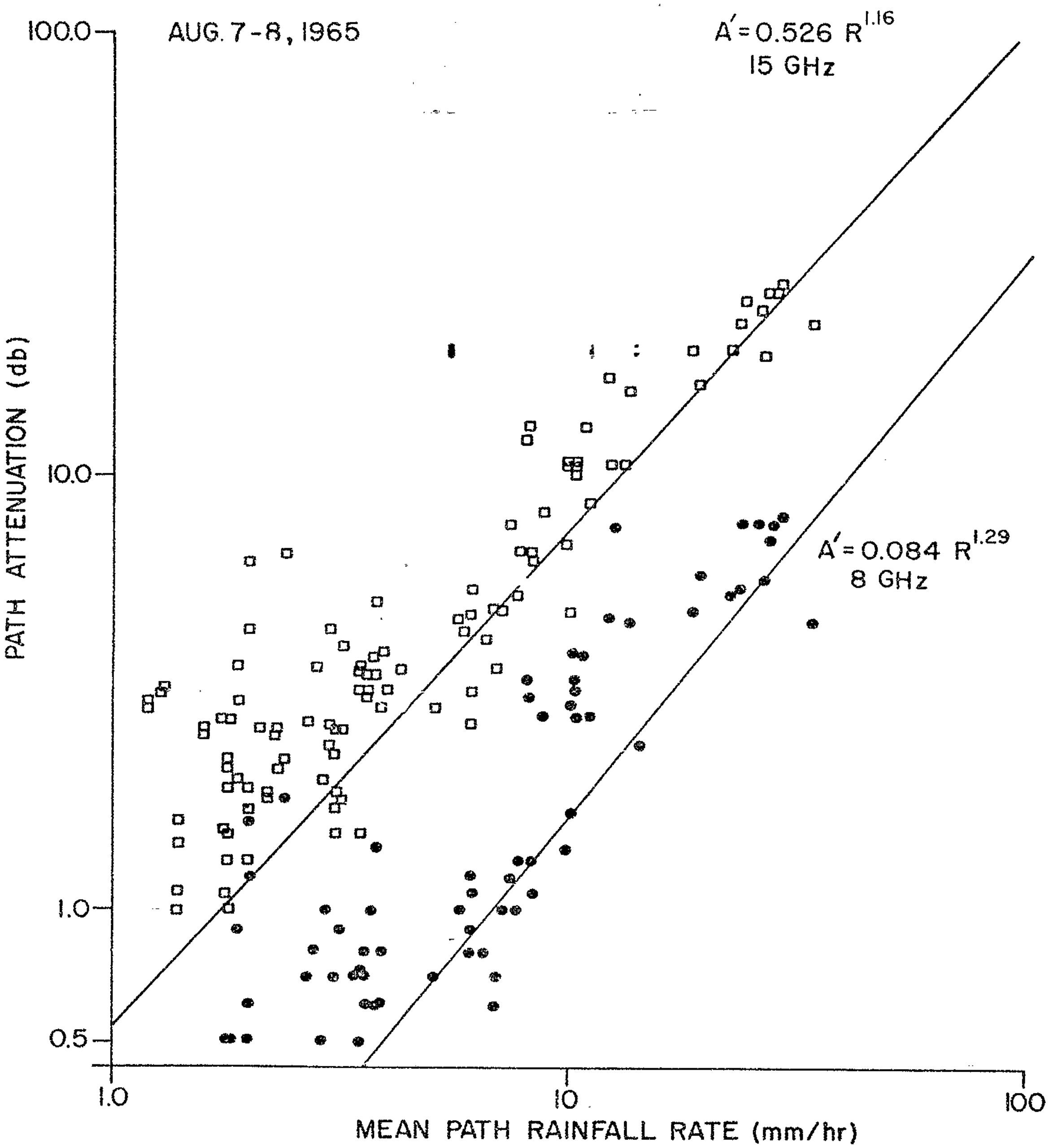

Fig. 6. Correlation of rainfall rate and signal attenuation over a 16 km terrestrial path.

confirmed that, on a long-term basis, the cumulative distribution of attenuation along the propagation path can be predicted from a knowledge of the rainfall statistics at a point in the Ottawa area.

The 30-foot precision tracking antenna (Fig. 7) was completed in the spring of 1966. The ground station was officially opened by the Chairman, DRB, on 1 June. Acceptance tests included tracking of the U.S. satellite RELAY II. In November, initial rain attenuation measurements at 7 GHz were made using the IDCSP satellites.

The start of the measurements using airborne beacons was delayed by difficulties associated with modifications of the wing-tip tank which carries the beacon package and transmitting antennas (Fig. 8). These difficulties were resolved late in the year. The first successful flights in which the aircraft was tracked by the ground antenna were achieved in December. This phase of the measurement program will begin in April of 1967.

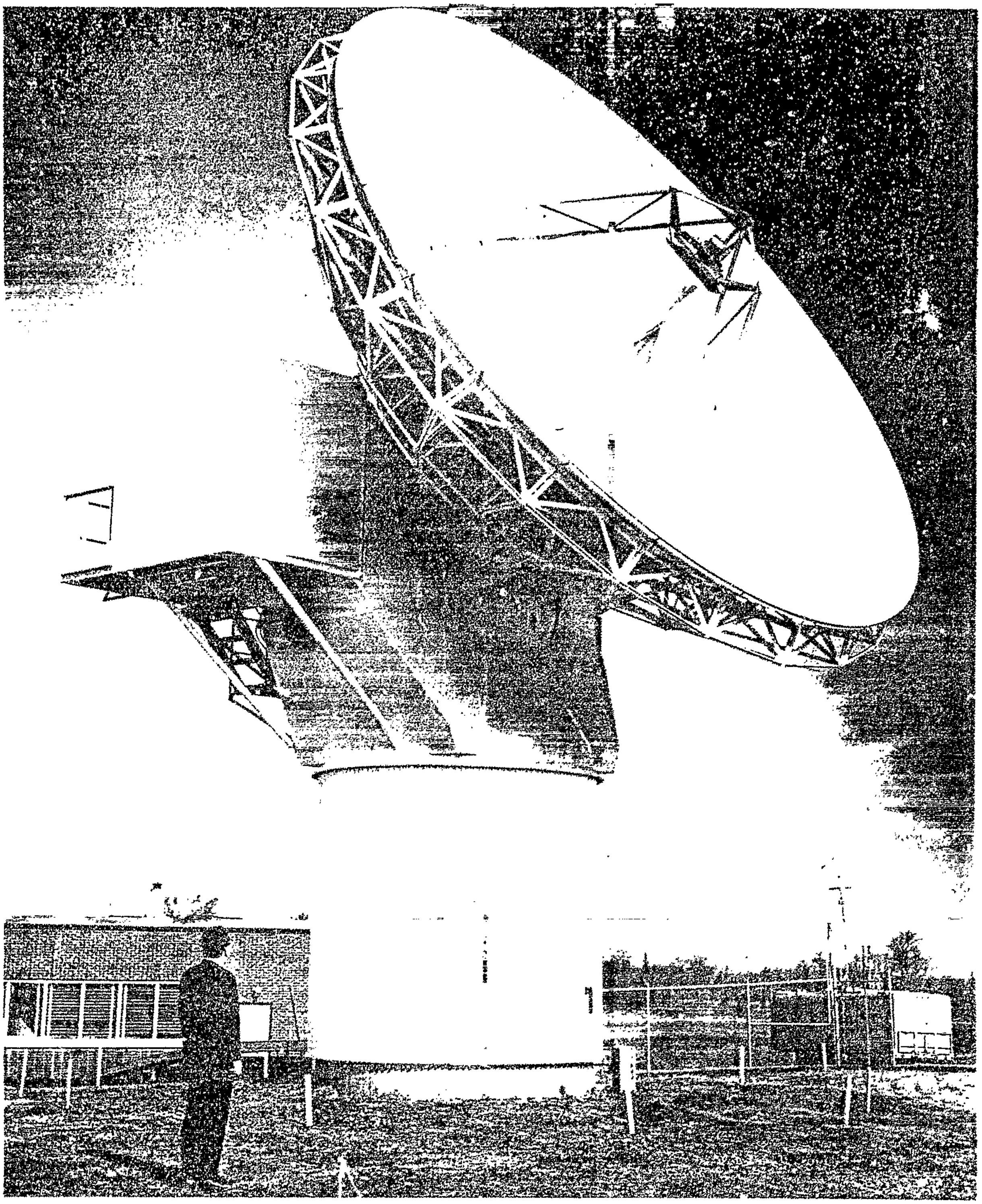

Fig. 7. The DRTE [illegible] tracking antenna used to study propagation effects [illegible] SHF [illegible]

[illegible]

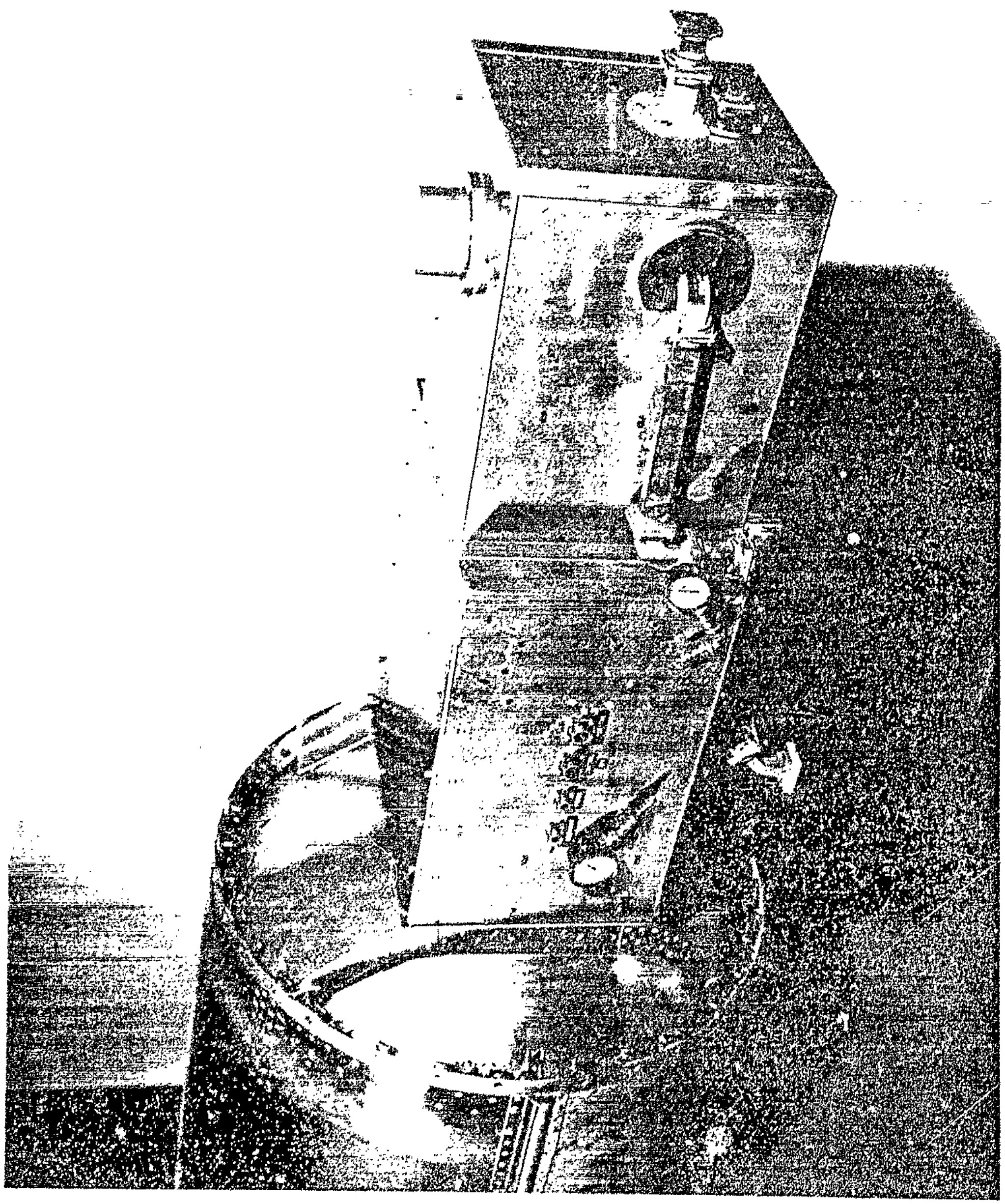

Fig. 8. Beacon package in wing-tip pod of CF-100 aircraft.

COMMUNICATIONS RESEARCH FOR THE CANADIAN ARMED FORCES

(a) THE CHANNEL EVALUATION AND CALLING (CHEC) SYSTEM

The CHEC system, formerly called the airborne channel sounder, has been developed at DRTE as an aid to HF communications. The CHEC system produces a current and past record of the signal to interference ratio at each of the frequencies allocated to the communications link. This information allows the operator to select, from all the assigned channels, the most reliable working frequency. CHEC also provides a highly reliable two-way calling system.

CHEC-aided communications trials, between an RCAF ARGUS aircraft and a DRTE ground station over ranges up to 2500 miles, were conducted during the summer of 1966. These trials were, from a technical point of view, highly successful and clearly demonstrated the advantages of the CHEC system.

As a result of the additional experience gained during the airborne trials, the CHEC system has been modified considerably and a simplified version of the airborne equipment will undergo further evaluation on a long distance point-to-point circuit during the fall of 1967.

(b) OPTIMUM RECEIVER DESIGN

Recent research at DRTE in the field of optimum receiver design for Pulse Amplitude Modulation (PAM) communication systems with intersymbol interference has led to the derivation of methods for the automatic adjustment of linear filters. In particular, techniques have been developed for the setting of tapped delay-line filters to minimize the mean-square-error between a received signal and reference signal. These techniques are being studied with a computer-controlled experimental system.

Previously, explicit analytical expressions had been derived for the form of the optimum receiver to use in situations in which PAM signals had been corrupted by intersymbol interference and additive noise. An experimental receiver was built using these principles, and tests were carried out on a number of simulated channels. To counteract slowly-varying changes in the signal distortion, iterative search procedures were evolved whereby the receiver response could be varied automatically to optimize the performance continuously.

Lucky and Rudin have shown that the direction in which the tap values on a tapped delay-line filter should be changed can be derived from measurements of the receiver output when a reasonable estimate of the transmitted signal can be made. The present DRTE research on adaptive procedures resulted from a generalization of the preceding DRTE work, and includes the Lucky-Rudin scheme. More extensive use is made of the information available from the system to enable the optimum filter to be set directly, rather than approached through a hill-climbing search procedure.

In general, it is possible to determine how a postulated modification to a linear system will affect the mean-square-error. Further, for a given change, it is possible to determine what magnitude that change should be to minimize the mean-square-error. This determination is particularly useful when the system in question is a tapped delay-line filter.

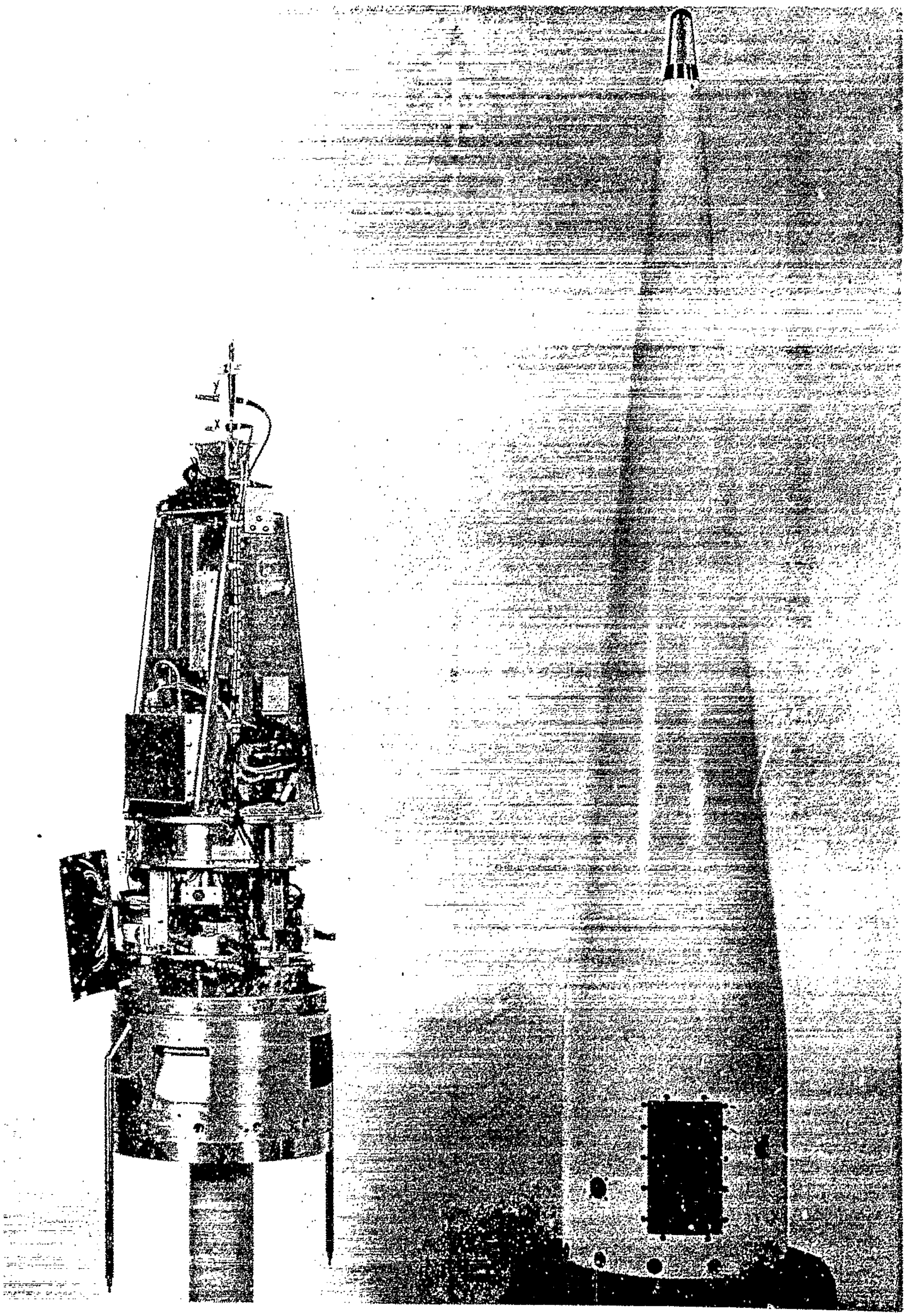

Fig. 9. Payload and nose cone of Black Brant IV rocket.

ROCKET EXPERIMENTS

The objective of the DRTE program of very-low-frequency (VLF) rocket experiments is to assist the design of future VLF equipment in the ISIS satellite program. In September, a VLF experiment was performed at Wallops Island, Virginia, using a NASA Javelin rocket. The experimental equipment, designed at DRTE performed completely as planned and provided valuable information and experience in conducting such experiments. Work is currently in progress on equipment for a similar experiment, but two large extendible dipole antennas will be used. The Javelin rocket that will carry this equipment is to be launched by NASA from the Churchill Research Range in the spring of 1967. This payload will complement a similar payload under construction at DRTE for launch on a Black Brant IV rocket at the same range in the summer of 1967. (See Fig. 9.)

Work is continuing on the development and building of instruments to study the nature of incoming energetic particles in the auroral zone and their interaction with the ionosphere. A soft electron spectrometer was flown in March at Fort Churchill to study the flux and spectrum of incoming electrons during a radio-wave absorption event and a second spectrometer is scheduled for flight in December to observe background particle fluxes during quiet ionospheric conditions. The instrument is undergoing some design changes to provide more reliable operation.

An experiment designed to measure particular auroral emissions in the vacuum ultraviolet region was developed and flown for the first time in March. A number of such detectors for monitoring specific auroral emissions in the region 1000—2000 Å are presently being built for rocket flights into aurora to measure the intensity of emissions in this wavelength region relative to that of visible emissions and to the total energy flux of incoming electrons.

MEASUREMENT OF CARBON ISOTOPES IN THE SOLAR PHOTOSPHERE

The abundance ratio R of the stable isotopes of carbon C^{12} and C^{13} in the solar photosphere is of importance in solar studies, because this ratio gives an indication of the degree of mixing that occurs in the body of the sun. The $R = C^{12}/C^{13}$ ratio is also pertinent to hypotheses on the history of the solar system. A marked difference between the photospheric value of R and the values of R determined for the earth and other orbiting bodies would suggest either that the planets and the photosphere originated in different parts of the solar nebula, or that nuclear reactions have taken place outsde the sun at a comparatively late epoch.

Prior to the work reported below, the generally accepted value of the photospheric carbon isotope ratio was $R \approx 10^4$. This is about one hundred times as large as values obtained for the earth and for other bodies in the solar system (Venus, meteorites, one comet). Consequently, there has been speculation that, at an early stage of solar evolution, an excess of C^{13} was produced in solids near the sun by neutron irradiation of C^{12}. Later, this material would somehow have been incorporated into the solar orbiting bodies.

The abundance ratio $R = C^{12}/C^{13}$ has recently been redetermined in co-operation with the Institute of Astrophysics, University of Liege. This Belgian group, with USAF financial support, has obtained solar spectra superior to any previously available. An example is shown in Figure 10. From analysis of such spectra in the 3874/3875 Å region, a lower limit of $R \approx 40$ has been determined. While this result does not actually exclude the possibility of a much higher value of R, the most straightforward interpretation of the available data leads to the conclusion that there is no significant difference between the values of R for the sun and for other bodies in the solar system.

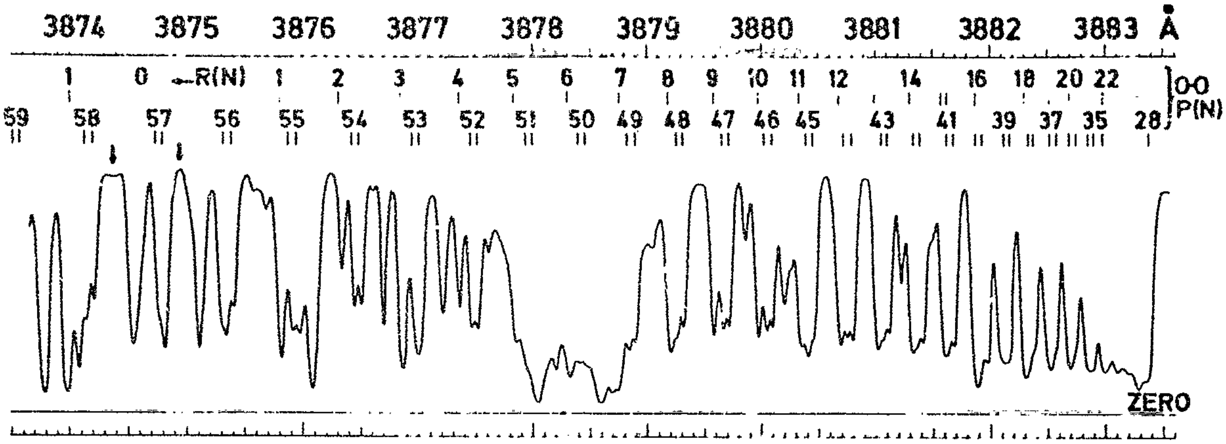

Fig. 10. Typical Solar Spectra used to determine the ratio of C^{12}/C^{13} in the solar photosphere.

SOLID STATE PHYSICS

The activities in solid state physics lie in the areas of bulk properties of semiconductors with particular emphasis on reactions between impurities in germanium, and on the fluorescent properties of doped crystals suitable for optically-pumped lasers.

Some specially prepared germanium was presented to a commercial organization and fabricated into detectors for nuclear radiation using lithium drift techniques. The germanium is of the same quality regularly prepared in DRTE for the impurity reaction research, but is especially well suited for these devices because it contains agents to inhibit the effects of traces of oxygen. The preliminary results of these trials indicate a dramatic improvement in yield for the technology. Government scientists at Chalk River are awaiting delivery of a large single crystal of this germanium which must be grown to an unusually large diameter for their tests.

Several single crystals of a calcium salt, $Ca_3(VO_4)_2$, have been fabricated in an attempt to elucidate growth parameters which would be involved in growing neodymium crystals for lasers. The final form of the crystal and a complete phase diagram for the original melt have been proposed and verified, marking an important milestone in this programme. The doped crystals which have been prepared so far show an anomolous fluorescent line-width which makes them unsuitable for lasers although there is no discernible reason why this should be so. There is still reason to hope that this material will prove to be superior to other calcium salts and certain glasses as a laser host and the work will continue in that direction.

The Solid State Physics Laboratory is now equipped to prepare and study a great variety of crystals of regular or unusual composition for many applications. Spectroscopic facilities are extensive enough to permit study of the optical properties into the infrared spectrum well beyond the 8 to 14 micron atmosphere "window" and the determination of the relations between the physical processes in the material and infrared or nuclear detectors or other electronic devices is a prime commitment for the staff.

RADIOWAVE PROPAGATION OVER ICE-COVERED SEA WATER

During 1966 the Polar Continental Shelf Project (PCSP) of the Department of Energy, Mines and Resources, experienced major difficulties in its survey operations near Alert, N.W.T., and requested DRTE assistance. Their survey and navigation system, Decca Hi-Fix operating at 1.7 MHz, had apparently performed satisfactorily in earlier years in other ice-covered areas near Devon Island. Accordingly DRTE carried out a ten-day field operation at Alert in co-operation with PCSP, using the station shown in Figure 11.

The experimental data were then analyzed at DRTE, and compared with a theoretical model of propagation over uniform ice of constant thickness lying on the surface of the sea. The theory shows that when a wave propagates over such a stratified medium it is no longer sufficient to consider only the usual "surface" wave. The analysis indicates the existence of an additional wave, called a "trapped" wave, and the combined effect of the two waves must be taken into account. This effect has a strong dependence on the ice thickness.

Reasonable agreement was obtained between the experimental data and these computations (Fig. 12). The theoretical curves are for propagation over ice-covered sea water having assumed conductivities of 10 mhos/metre and 5 mhos/metre (ice and sea). The numbers 0, 2, 4, 5 marked on the curves are the thickness of ice in metres. All the experimental data were recorded over ice-covered surfaces. Curves A and B were obtained for ice which was about 2 metres thick. Curves C and D are for ice estimated to be 4–5 metres thick.

If the theoretical model is valid, a decrease in operating frequency from 1.7 MHz to 0.8 MHz would extend the useful range of the survey system at Alert from 10 kilometers to about 70 kilometers.

BASIC ELECTRONIC CIRCUITS

The insulated-gate field-effect transistor (MOSFET) is potentially a very important electronic component in military and space systems for several reasons. These include its low noise, its capability of operation at low power levels, and its simplicity of manufacture. However, it is by far the most sensitive of all modern electronic components to the effects of radiation. A study has been made at DRTE of the mechanisms causing the characteristic shift of MOSFET parameters under irradiation, and this has led to the development of a method of hardening these devices. This work has led in turn to a consideration of the use of MOSFETs as very simple radiation dosimeters.

A major circuit study has concerned the ability of transistors to deliver very high power at high frequencies using the switched-mode (Class-D) technique. The potentialities of this technique have been demonstrated by the development of a 500 kHz induction furnace that operates with an efficiency of greater than 90% under all load conditions up to a maximum power delivery of 1 kilowatt. The furnace is small, rugged and reliable, and is in daily use as a new tool for materials research.

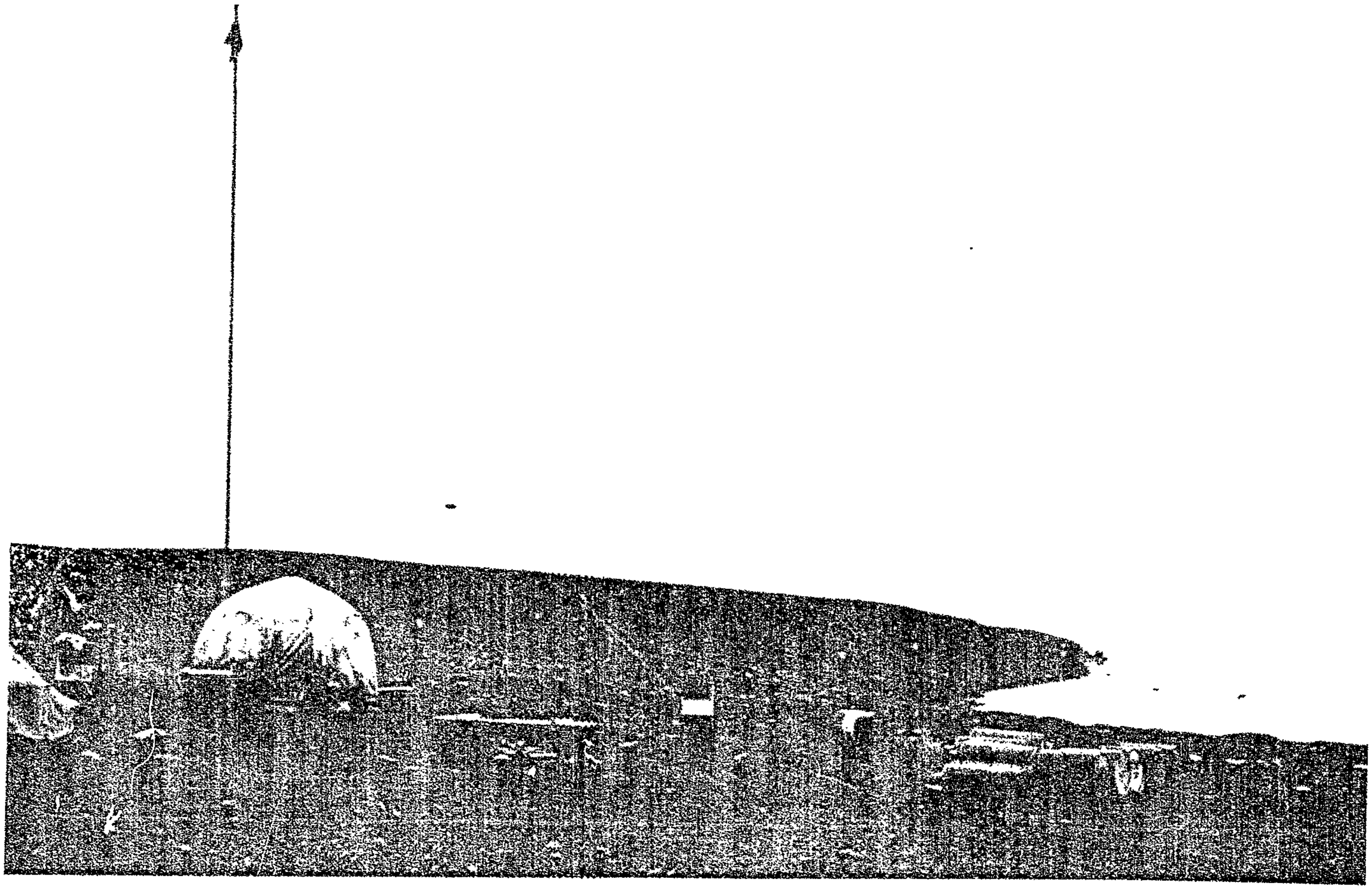

Fig. 11. Base camp near Alert, NWT, employed in measurements of radiowave propagation over ice-covered sea water.

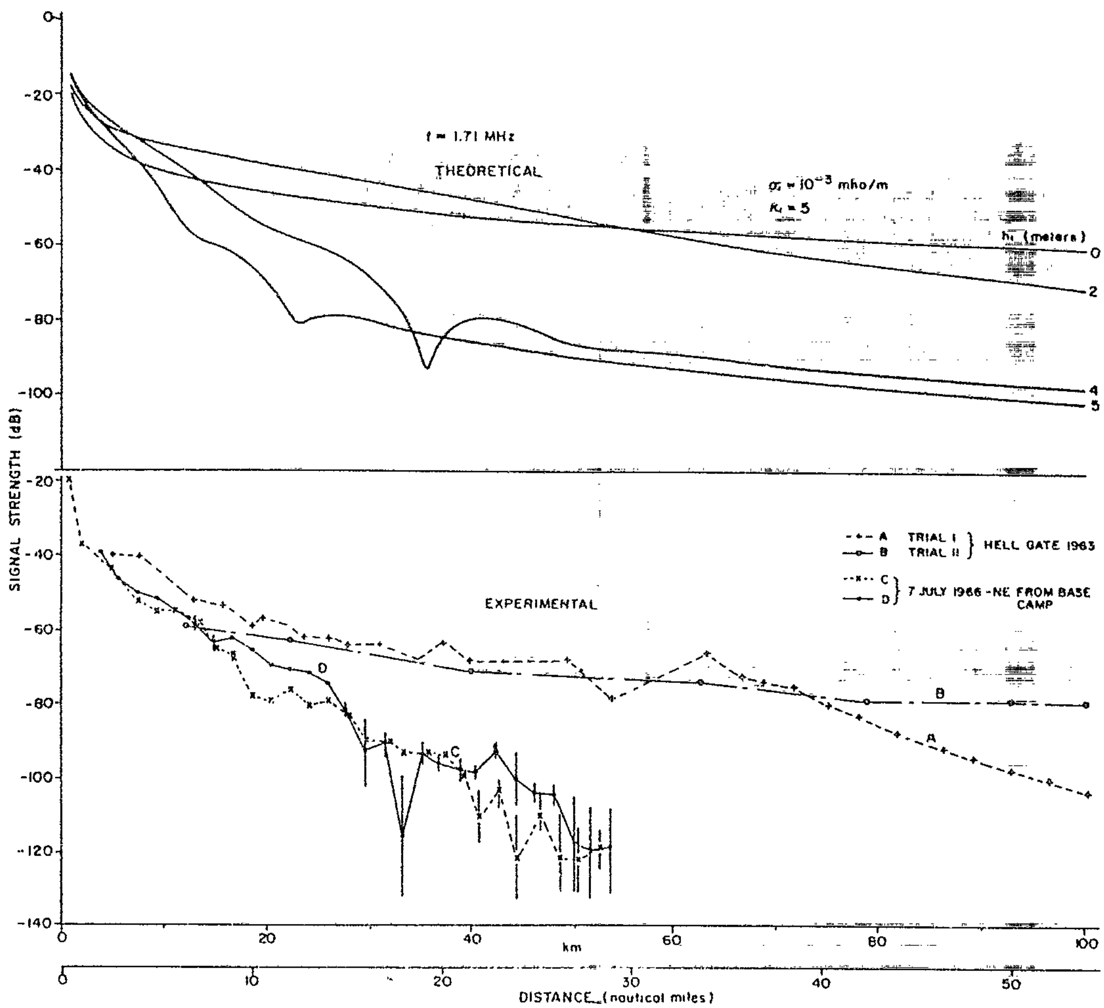

Fig. 12. Comparison between theoretical and experimental signal strength variations with distance at 1.71 MHz. The position of the zero dB level for the theoretical curves has been chosen arbitrarily.

DRTE COMPUTING CENTRE

In May, 1966, the DRTE-built computer was retired after 5 1/2 years of service and was replaced by a Control Data 3200 system. This system has 3200 words of random access core memory, a 64-word register file, 48-bit double precision and floating-point hardware, 3 index registers, and up to 8 independent Input/Output channels. Typical instruction cycle times are about 1 to 3 μsec for integer operations and 10 to 20 μsec for floating point.

The peripheral equipment includes the following:

- 500 line/min printer
- 1200 card/min reader
- 100 card/min punch
- 350 character/sec paper tape reader
- 120 character/sec paper tape punch
- 4 magnetic tape units
- 2 disk memory units
- 1 digital CRT with light pen
- 1 special purpose Input/Output buffered channel for real time experiments and data transfer.

RESEARCH IN FIELD THEORY AND GRAVITATION

A new theory of gravitation has been developed which is much simpler than Einstein's General Theory and yet meets successfully all known experimental tests.

Thus the precession of the orbit of the planet Mercury, the deflection of a light ray in the gravitational field of the sun and the gravitational red shift are all correctly predicted by the new theory. In addition the theory requires that gravitational acceleration be independent of the mass of the moving body as any valid theory must. An important feature is that space is not curved in a gravitational field as it is in Einstein's theory. As a consequence the speed of light, as distinct from its direction, remains constant. This makes it possible to discover which theory is correct, by comparing radar measurements of the time taken for a light ray to be reflected from the planet Venus, when the light must pass close to the sun and when the light track is more distant from the sun. This experiment is being prepared by the Lincoln Laboratory of M.I.T. under the direction of Dr. I.I. Shapiro and should be carried out next year. If the light is not slowed down by the sun's gravitational field Einstein's general theory will be proven wrong and the new theory will be placed on firm ground.

Another important feature of this theory is that it explains Mach's principle. This principle is merely the statement that acceleration is relative to the fixed stars, so that inertia is determined by the motion of the remote universe. Einstein unsuccessfully tried to incorporate this principle into his theory and considered that a satisfactory theory of relativity must account for this basic fact of nature.

During 1966 two papers on the new theory were published in the Canadian Journal of Physics. Two other papers have been submitted for publication and a fifth is in preparation.

Seminars and lectures on the theory have been given at a number of Canadian universities and also at King's College, London and at Mexico City.

Requests for reprints of published papers are being received from all over the world including such places as Hungary, Singapore, Israel and Yugoslavia as well as North America and Western Europe.

Fig. 13. DRTE 'Control Data 3200' computing system.

APPENDIX A

PUBLICATIONS

REPORTS PUBLISHED IN 1966

PCC No.	Report No.	Author	Title
C98-38-01-21	1156	Cross, F.R. Barnes, D.C.	A Logarithmic IF Amplifier for CW or Pulse Type Signals. February, 1966.
D48-95-11-29	1160	Lacey, W.K. Cebuliak, S.E.	A Digital Control and Data Processing System for Rocket Experiments. April, 1966.
D48-02-04-02	1161	Lake, G.T.	Signal Processing for the Alouette Satellites. May, 1966.
D48-38-01-17	1164	Werstiuk, H.L. Maynard, L.A.	A Synoptic Study of Electron and Ion Temperature in the Quiet Ionosphere. October, 1966.
D48-95-11-29	1165	Lacey, W.K. Cebuliak, S.E.	DRTE Radio Frequency Electron Density Probes. October, 1966.

PAPERS PUBLISHED IN 1966

PCC No.	Author	Title
D48-02-04-02	Chapman, J.H., et al.	Alouette II. Sentinel, Vol. 2, No. 1, 8-13, 1966.
D48-02-04-02	Maclean, M.A.	A period modulated carrier technique for data recording. Supplement to IEEE Trans., Vol. AES-2, No. 6, 119-124, 1966.
D48-28-01-07	Davis, W.A. Brzozowski, J.A.	On the linearity of sequential machines. IEEE Trans., Vol. EC-15, No. 1, 21-29, 1966.
D48-28-01-07	Davis, W.A.	Generation of delayed replicas of maximal-length linear binary sequences. Proc. IEEE, Vol. 113, No. 2, 295-296, 1966.
D48-28-01-07	Davis, W.A.	Automatic delay changing facility for delayed m-sequences. Proc. IEEE, Vol. 54, No. 6, 913-914, 1966.
D48-28-01-14 D48-28-01-13	Coll, D.C. Storey, J.R.	A note on the application of pulse compression techniques to ionospheric sounding. Radio Science, Vol. 69D, No. 8, 1191-1193, 1965.
D48-28-01-19	Serson, H., et al.	Electronic components and apparatus for use in polar field operations. The Polar Record, Vol. 13, No. 82, 37-43, 1966.
D48-38-80-05	Royer, G.M.	Directive gain and impedance of a ring array of antennas. IEEE Trans. Vol. AP-14, No. 5, 566-573, 1966.
D48-55-03-08	Cox, C.D. Surek, T.	Growth of single crystal calcium orthovanadate. Can. Ceramic Soc. Jour., 1966.
D48-95-10-27	Chapman, J.H.	The topside ionosphere. Electron density profiles in ionosphere and exosphere, ed. by J. Frihagen, North-Holland Pub. Co., 264-269, 1966.
D48-95-10-27	Scott, J.C.W.	The gravitokinetic field and the orbit of Mercury. Can. Jour. of Physics, Vol. 44, 1147-1156, 1966.
D48-95-10-27	Scott, J.C.W.	Photons in the gravitational field. Can. Jour. of Physics, Vol. 44, 1639-1648, 1966.
D48-95-11-01	Barrington, R.E. Herzberg, Luise	Frequency variation in ionospheric cyclotron harmonic series obtained by the Alouette I satellite. Can. Jour. of Physics, Vol. 44, 987-994, 1966.
D48-95-11-01	Herzberg, L.	An unpredicted period in the orbital motion of the Alouette I artificial earth satellite. Planetary and Space Science, Vol. 14, No. 6, 451-4, 1966.
D48-95-11-01	Delbouille, L. Herzberg, Luise Roland, G.	A new determination of the C^{12}/C^{13} abundance ratio in the solar photosphere. Astronomical Jour., Vol. 71, No. 6, 1966. (Abstract only)

PCC No.	Author	Title
D48-95-11-30 D48-95-11-40	Nelms, G.L. Barrington, R.E. Belrose, J.S. Hartz, T.R. McDiarmid, I.B. Brace, L.H.	The Alouette I satellite. Can. Jour. of Physics (letter to Editor). Vol. 44, 1419-1430, 1966.
D48-95-11-34	Barrington, R.E. Belrose, J.S.	Ion composition and temperature at 1000 Km as deduced from VLF resonances and topside ionograms. Electron density profiles in ionosphere and exosphere, ed. by J. Frihagen, North-Holland Pub. Co., 387-396, 1966.
D48-95-11-34	Barrington, R.E. Belrose, J.S. Mather, W.E.	A helium whistler observed in the Canadian satellite Alouette II. Nature, Vol. 210, No. 5031, 80-81, 1966.
D48-95-11-36	Paghis, I.	The earth's outermost atmosphere. Jour. of the Royal Astronomical Soc. of Canada, 1966.
D48-95-11-40	Nelms, G.L.	Seasonal and diurnal variations of the distribution of electron density in the topside of the ionosphere. Electron density profiles in ionosphere and exosphere, ed. by J. Frihagen, North-Holland Pub. Co., 358-386, 1966.
D48-95-11-40	Muldrew, D.B.	Delayed cyclotron pulse generation in the topside ionosphere deduced from Alouette I data. Nature, Vol. 210, No. 5035, 471-473, 1966.
D48-95-11-40	Muldrew, D.B.	A novel ionospheric cyclotron resonance phenomenon observed on Alouette I data. Can. Jour. of Physics, Vol. 44, 925-939, 1966.
D48-95-11-40	Hagg, E.L.	Remote cyclotron resonance phenomenon observed by the Alouette satellite. Nature, Vol. 210, No. 5039, 927-929, 1966.
D48-95-11-57	Belrose, J.S. Bourne, I.A. Hewitt, L.W.	The winter variability of electron number density in the lower ionosphere over Ottawa - A discussion of results and possible cause. Electron density profiles in ionosphere and exosphere, ed. by J. Frihagen, North-Holland Pub. Co., 48-60, 1966.
D48-95-11-57	Belrose, J.S. Bode, L.R. Hewitt, L.W.	A preliminary investigation of diurnal and seasonal changes in electron number density over Resolute Bay as observed by partial reflections. Electron density profiles in ionosphere and exosphere, ed. by J. Frihagen, North-Holland Pub. Co., 37-47, 1966.

PAPERS PRESENTED IN 1966

PCC No.	Author	Title
D48-55-66-02	Barry, A.L. Bingham, J.A. Page, D.F.	Ionizing radiation effects in insulated-gate transistors. 18th DRB Symposium. 14-16 Dec. 1966.
D48-02-04-02	Huva, J.	Non-linear dynamic instability of fin stabilized rockets. 18th DRB Symposium. 14-16 Dec. 1966.
D48-02-04-02	Franklin, C.A.	Wideband transmitters for ISIS-A. 18th DRB Symposium. 14-16 Dec. 1966.
D48-02-04-02	Molozzi, A.R. Hitchcock, N.S.	A milliwatt digital clock and programmer for satellite use. 18th DRB Symposium. 14-16 Dec. 1966.
D48-02-01-02	Vigneron, F.	Elastic stability and equilibrium configuration of earth pointing non-rigid satellites. 18th DRB Symposium. 14-16 Dec. 1966.
D48-02-01-03	Beshara, J.N. Skafel, M.G.	Use of scale models for determining response of spacecraft launch vibrations. 18th DRB Symposium. 14-16 Dec. 1966.
D48-95-11-33	Belrose, J.S. Ross, D.B.	Some remarks on ionization changes in the lower ionosphere inferred from the propagation of long radio waves. DRTE/AFCRL Conf. on Ground-Based Radio Wave Propagation Studies of the Lower Ionosphere, Ottawa. 11-15 Apr. 1966.
D48-95-11-57	Belrose, J.S. Bourne, I.A. Hewitt, L.W.	A critical review of the partial reflection experiment. DRTE/AFCRL Conf. on Ground-Based Radio Wave Propagation Studies of the Lower Ionosphere, Ottawa. 11-15 Apr. 1966.
D48-95-11-57	Belrose, J.S. Bourne, I.A. Hewitt, L.W.	A preliminary investigation of diurnal and seasonal changes in electron distribution over Ottawa, Churchill and Resolute Bay. DRTE/AFCRL Conf. on Ground-Based Radio Wave Propagation Studies of the Lower Ionosphere, Ottawa. 11-15 Apr. 1966.
D48-97-52-01	Davies, F.T.	Arctic communications. Symposium of Commonwealth Defence Science Organization, Ottawa. 14-19 Sept. 1966.
D48-55-66-02	Barry, A.L. Page, D.F.	A study of ionising radiation effects in MOS transistors with applications to radiation hardening. Nuclear & Space Radiation Effects Conf., Stanford, Calif. 8-22 July 1966.
D48-95-11-01	Chapman, J.H.	Radio waves in the ionosphere and plasma resonances. Royal Society of Canada, Quebec, P.Q. June 1966.
D48-02-04-01	Molozzi, A.R. Richardson, J.R.	The measured impedance of a dipole antenna in the ionosphere. COSPAR Vienna, Austria. 12 May 1966.
D48-95-11-01	Herzberg, L. Delbouille, L. Roland, G.	A new determination of the C^{12}/C^{13} isotopic abundance ratio in the solar photosphere. 121st Meeting of Amer. Astron. Society, Hampton Va. 28 March - 1 April 1966.

PCC No.	Author	Title
D48-95-11-54	Rice, D.W.	Some observations of ground sidescatter at 20 Mc/s. CAP Meeting, Sherbrooke, P.Q. June 1966.
D48-95-11-34	McEwen, D.J. Barrington, R.E.	Ionospheric irregularities as deduced from Alouette VLF data. CAP Meeting, Sherbrooke, P.Q. June 1966.
D48-95-11-40	Nelms, G.L. Lockwood, G.E.K.	Early results from the topside sounder in the Alouette II satellite. COSPAR, Vienna. 9-18 May 1966.
D48-28-01-19	Blevis, B.C.	Rain effects on radomes and antenna reflectors. Conf. on Large Steerable Aerials for Satellite Communications, Radio Astronomy and Radar, London, England. 6-8 June 1966.
D48-95-11-54	Caldwell, J.D. Stevens, E.E. Warren, E.S.	The reflection coefficient of an ionosphere containing large scale irregularities. AGARD Meeting, Leicester, England. 25-29 July 1966.
D48-95-11-54	Petrie, L.E. Hagg, E.L. Stapley, A.G.	The vertical and oblique incidence reflection coefficients of the ionosphere. AGARD Meeting, Leicester, England. 25-29 July 1966.
D48-95-11-57	Barrington, R.E.	Harmonic generation in the ionosphere. DRTE/AFCRL Conf. on Ground-Based Radio Wave Propagation Studies of the Lower Ionosphere, Ottawa. 11-15 Apr. 1966.
D48-95-11-57	Belrose, J.S.	Ionospheric sounding of the E-region. DRTE/AFCRL Conf. on Ground-Based Radio Wave Propagation Studies of the Lower Ionosphere, Ottawa. 11-15 Apr. 1966.
D48-95-11-57	Jelly, D.H.	Some remarks on the valley between the F-layer and thick E_s (Night E) determined from simultaneous bottomside and topside ionograms. DRTE/AFCRL Conf. on Ground-Based Radio Wave Propagation Studies of the Lower Ionosphere, Ottawa. 11-15 Apr. 1966.
D48-95-11-57	Belrose, J.S. Bourne, I.A.	The electron distribution and collision frequency height profile for the lower part of the ionosphere (the D- and lower E-regions). DRTE/AFCRL Conf. on Ground-Based Radio Wave Propagation Studies of the Lower Ionosphere, Ottawa. 11-15 Apr. 1966.
D48-95-11-33	Belrose, J.S. Segal, B.	Some comments on the determination of D-region electron density distributions from the reflection of long radio waves. DRTE/AFCRL Conf. on Ground-Based Radio Wave Propagation Studies of the Lower Ionosphere, Ottawa. 11-15 Apr. 1966.
D48-95-11-34	Barrington, R.E. McEwen, D.J.	Ion composition from VLF phenomena observed by Alouette I and II. COSPAR, Vienna. 10-18 May 1966.
D48-95-11-01	Chapman, J.H.	Address to XV General Assembly of URSI. XV General Assembly of URSI, Munich, Germany. 7 Sept. 1966.

PCC No.	Author	Title
D48-95-11-34	Barrington, R. E. McEwen, D.J.	Lower hybrid resonance observations of Alouette II. Fall URSI, Palo Alto, Calif. 7-9 Dec. 1966.
D48-28-01-07	Jull, G. W.	Short-term and averaged characteristics of nonreciprocal HF ionospheric paths. 11th Symposium, AGARD, Leicester, England. 25-29 July 1966.
D48-28-01-14	Coll, D.C.	An adaptive receiver for multipath channels. Fourth Canadian Symposium on Communications, Montreal. 13-14 Oct. 1966.

APPENDIX B

1966 INTERNATIONAL SCIENTIFIC CONFERENCES ATTENDED

Title	Date
American Physical Society, Physics Conference, New York, N.Y.	January
International Symposium on Information Theory, IEEE, Los Angeles, Calif.	January/February
1966 International Solid State Circuits Conference (ISSCC), University of Pennsylvania, Philadelphia, P.A.	February
Conference of Optical Society of America, Washington, D.C.	March
Meeting of the American Physical Society, Durham, North Carolina.	March
Meeting of the American Astronomical Society, Hampton, Va.	March/April
4th International Quantum Electronics Conference, IEEE/American Physical Society, Pheonix, Arizona.	April
AGU/URSI, Washington, D.C.	April
20th Annual Frequency-Control Symposium, U.S. Army Electronics Command, Atlantic City, N.J.	April
Spring Joint Computer Conference, Boston, Mass.	April
American Institute of Aeronautics and Astronautics and IEEE, Washington, D.C.	May
International Convention Society of Technical Writers and Publishers, Fort Worth, Texas.	May
1966 DECUS Symposium, Boston, Mass.	May
Conference on VLF Propagation, NRL, Washington, D.C.	June
IEEE International Communications Conference, Philadelphia, P.A.	June
International Conference of Crystal Growers, AFCRL, Boston, Mass.	June
IEEE Conference on Nuclear & Space Radiation Effects, San Francisco, Calif.	July
Meeting of American Physical Society, Mexico City, Mexico.	September
Symposium on Optical Properties of Transition-Metal and Rare-Earth Ions in Solids, ONR, Baltimore, Md.	September
8th Annual NORAD Electronic Warfare Conference, Washington, D.C.	September

Title	Date
International Solid State Circuits Conference, Program Committee Meeting, New York, N.Y.	September
First Marine Geodesy Symposium, N.U.S.P. Coast Geodesy Society (ESSA), Battelle Memorial Institute, Columbus, Ohio.	September
Annual Symposium British Research and Development Society, Imperial College, London, England.	September
1966 Aerospace and Electronic Systems Convention (IEEE), New York, N.Y.	October
Special Meeting on Solar Astronomy, American Astronomical Society, University of Colorado, Boulder, Colorado.	October
IEEE Conference on Communications, Montreal, P.Q.	October
12th Conference on Radar Meteorology, American Meteorological Society, Oklahoma City, Oklamhoma.	October
Control Data Users Group Organization (SWAP) Conference, Cleveland, Ohio.	October
Annual Symposium on Switching Circuit Theory and Logical Design (IEEE), Palo Alto, Calif.	October
National Safety Congress and Exposition (ANSC), Chicago, Illinois.	October
International Solid State Circuits Conference, Program Committee Meeting, New York, N.Y.	October
Fall Joint Computer Conference, American Federation of Information Processing Societies, San Francisco, Calif.	November

APPENDIX C

DRTE PROFESSIONAL STAFF

#Adey, A.W.
Atkins, E.A.
Barrington, R.E.
Barry, A.L.
Barry, J.N.
Bedal, G.K.
Belrose, J.S.
Bennett, J.P.
Beshara, J.N.
Bibby, R.J.
#Blevis, B.C.
Bloom, J.N.
Bode, L.R.
* Bonnycastle, R.J.
#Booth, G.H.
Boulding, J.D.R.
Bourne, I.A.
Bowen, R.R.
* Brown, H.G.
* Bridgewater, A.W.
Brown, J.W.
Burns, D.W.
* Butterworth, J.S.
Caldwell, J.D.
Campbell, W.S.
Chambers, J.G.
Chapman, J.H.
Checkley, H.E.
Chudobiak, W.J.
* Clowes, G.J.
* Colclough, J.P
Coll, D.C.
* Collins, W.C.
Cox, C.D.
#Cox, J.W.
Craig, A.J.
Cross, F.R.
* Crysdale, J.H.
Czaharynski, M.
Davies, F.T.
Davies, N.G.
Davis, L.S.
Davis, W.A.
Day, J.W.B.
* Dingle, B.K.
Dohoo, R.M.
Edwards, W.D.
Else, J.
Faire, D.F.
Field, P.A.
Fisher, J.F.
Florida, C.D.
Franklin, C.A.
Frayn, H.C.
Fujaros, R.G.
Garland, M.G.
Garrett, T.
Gilchrist, A.W.R.
Gordon, B.A.
Goeres, R.
Grosvenor, K.D.J.
Hagg, E.L.
Hansen, D.R.
Hara, E.H.
Harrison, N.A.
* Hartman, W.A.
Hartz, T.R.
Hatton, W.L.
Henderson, D.P.
Herzberg, L.H. (Mrs.)
Hewitt, L.W.
Hindson, W.D.
Hitchcock, N.S.
Hoyt, D.P.
Hutchison, R.L.
Huva, J.
Irvine, G.W.
Jacques, P.
Jelly, D.H. (Miss)
Judd, D.L.
Jull, G.W.
Kennedy, J.D.
Keys, J.E.
Kirkpatrick, J.
Kowalik, H.
Lacey, W.K.
Lake, G.T.
Langille, R.C.
Lockwood, G.E.K.
Lusick, P.J.
McAlpine, J.L.
McCormick, S.
McEwen, D.J.
McKerrow, C.A.
Mackie, G.H.C.
Maclean, M.A.
Mar, J.
Matsushita, J.S.
Matthews, D.L.
Maynard, L.A.
Meek, J.H.
Mills, S.T.
* Milne, R.M.T.
Molozzi, A.R.
Montribriand, L.E.
Morton, G.W.
Muldrew, D.B.
Murray, J.P.
Nelms, G.L.B.
Nikkel, R.F.
Nishizaki, T.
Northey, G.R.
Nuspl, P.P.
Orosz, J.
Osborne, T. (Miss)
Page, D.F.
Paghis, I.
* Pawziuk, W.J.
Petrie, L.E.
Poaps, G.E.
Poirier, A.L.
Pope, W.A.
Pragnell, H.F.
Psutka, M.E.
Raine, H.R.
* Rayment, C.V.
* Reynaud, A.H.
Rice, D.W.
Rolfe, W.
Roscoe, O.S.
Ross, D.B.
Royer, G.M.
Scott, J.C.W.
Seaman, E.A.
Segal, B.

Selin, D.L.
Selwyn, D.M.
Serson, H.V.
* Sewards, A.
* Skafel, M.G.
Smith, F.E.
Stapley, A.G.
Stevens, F.E.
Storey, J.R.
Strickl[illegible]d, J.I.
Sturro[illegible], R.F.
Symons, F.W.
Tennuci, J.E.
Thompson, W.E.
Threinen, W.E.
Vail, F.T.
Venier, G.O.
Vigneron, F.R.
Walker, E.A.
Warren, E.S.
Warwick, J.A.
Watanabe, A.
Werstiuk, H.L.
* Webber, R.V.
Winacott, E.L.
* Wohlberg, D.B.
Zhignesse, J.P.

Chudobiak, W.J. (Carleton)
Hara, E.H. (Toronto)
Montbriand, L.E. (Saskatchewan)
Nuspl, P.P. (Michigan)
Vigneron, F.R. (Illinois)
Bridgewater, A.W. (Birmingham)

* Arrivals during 1966
# Departures during 1966

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