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RESEARCH IN AERONOMY

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ABSTRACT

This document comprises Semiannual Progress Report 66-1 of the Aeronomy Laboratory of the University of Illinois Department of Electrical Engineering, and covers the period from October 1, 1965 through March 31, 1966. The activities of the laboratory during this period are divided into the following topics:

(a) Direct measurements of ion and electron densities
(b) Vertical incidence absorption measurement
(c) Rocket propagation experiment
(d) VLF studies
(e) Cross modulation
(f) Field station development and operations
(g) Ionospheric drifts
(h) Direct Measurements conference
(i) Partial reflection experiment

Progress is reported by the individuals concerned.

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The following is a list of the various contracts supporting the activities of the Aeronomy Laboratory, together with the sections of the report pertaining to each of these contracts.

Air Force Electronics System Division contract AF 19(628)-3900

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1. DIRECT MEASUREMENTS OF ELECTRON AND ION DENSITY

1.1 IQSY Measurements

S.A. Bowhill
E.A. Mechtly
C.F. Sechrist, Jr.

Tasks included under this topic pertain to the planning of rocket experiments, as conducted under NASA grant NsG-511.

Various changes have been necessitated in the rocket firing schedule due to the change in the date of the Ft. Churchill experiment. The revised schedule is therefore as follows:

December 15, 1965:	Final Quarterly World Day measurement during IQSY, Wallops Island. Type A payload, 3.385 mc, zenith angle 60° afternoon.
January 4, 1966 onwards:	Daytime (60° zenith angle) shot to detect sporadic D-layer, to await winter day of high absorption, if December 15 shot was on day of low absorption; alternately to await day of low absorption in event December 15 shot was on day of high absorption. Type A payload, 3.385 mc.
March 15, 1966:	Radio experiment only in Black Brant rocket at Ft. Churchill. Firing will await a 1.5 db daytime absorption event.
June 6-7, 1966:	Two shots, one Type A daytime 60° zenith angle; one night Type B, in Puerto Rico. One standby Type A payload will be instrumented.

June 15, 1966:	Pre-sunrise rocket, zenith angle 95° to detect visible radiation effects on the C-layer. Shot will await pre-sunrise VLF absorption, occurring at 98° zenith angle of 2 db or more. Type B payload, 2.225 mc.
September, 1966:	Two or three rockets around sunset carrying ion mass spectrometer instruments by Goddard Space Flight Center, Wallops Island, Virginia, to study E-layer decay.
November, 1966:	Eclipse program in Argentina or Brazil.

Discussions with Dr. Hendricks of the Charged Particle Research Laboratory (CPRL) have revealed the possibility of CPRL undertaking the design and engineering of a Paul type mass spectrometer for the measurement of E-region positive ion composition. The suggestion was to have CPRL furnish a detailed set of working drawings for construction of the instrument by GCA, and a completely engineered electronics package for mounting in the payload. A six-month period was estimated as necessary for the execution of this project. Conversations with Dr. Smith of GCA indicated that this arrangement would be agreeable to him, and that perhaps the test rounds could be fired in July. For further implications of this, as far as the eclipse program is concerned, see section 3.6.

In discussions with Dr. Schmerling of NASA concerning the Paul massenfilter, an additional cost estimate of $20,000 was submitted by GCA for construction of the quadrupole instrument and integration of it into 2 payloads. Dr. Schmerling indicated this would be acceptable, and that a proposal should be submitted by Dr. Hendricks for design and construction of two instruments. This proposal is now being prepared, and is expected to be sent to NASA shortly.

It is planned, therefore, to prepare two mass spectrometer payloads containing the following instruments:

Paul ion mass spectrometer

Smith dc probe (on nose cone, jettisoned at 100 km)

Radio propagation experiment antenna and receiver

Magnetic aspect sensor

Baroswitch

This would be designated as the "Type C" payload.

In the light of this development, the September shots are being cancelled. The tentative date for the July shots is July 15.

In the event the July shots are successful, the plan will be to have one or more ion mass spectrometer rounds as part of the eclipse program.

Following is an excerpt from a letter dated Nov. 29, 1965, received from L.G. Smith, GCA Corporation, Bedford, Mass., which pertains to Type A and Type B payloads.

"Some preliminary work has been done on the specifications for the two types of payloads. We propose to change the telemetry channel assignments as shown in Table One.

Table 1: Telemetry Channel Assignments

Channel	Information Bandwidth	Type A(Mod 3) Payload	Type B(Mod 3) Payload
19(93 kHz)	1395 Hz	Solar Aspect (5V)	Ion Trap. #1
18(70 kHz)	1050	Propagation, mod(5V)	Same as A
17(52.5 kHz)	790	Probe, Linear(± 2.5)	Same as A
16(40 kHz)	600	Probe, Log(±2.5)	Same as A
15(30 kHz)	450	UV, high gain(5V)	Temp. Probe
14(22 kHz)	330	UV, low gain(-5V)	Ion Trap. #2
13(14.5 kHz)	220	Magnetometer(5V)	Same as A
12(10.5 kHz)	160	Propagation, AGC(5V)	Same as A

Channel 19 has only recently been added to the IRIG standard. The propagation experiment is assigned to Channel 18. This is 70 kHz center frequency with ±7½% deviation so that one can still use the Channel E discriminator.

The nose probe is assigned two channels. This represents the addition of the fine structure measurement.

In the Type B payload, Nagy's ion trap is assigned Channels 19 and 14. Channel 15 will be used to transmit a continuous measurement of electron temperature obtained by a modification of the Boyd-Druyvesteyn method. The sensing electrode will be insulated from the rocket body and allowed to attain floating potential. The two small ac signals of the Boyd method will be applied to the electrode through a capacitor. The amplitude modulation of the higher frequency by the lower is a measure of the curvature of the current-voltage characteristic and is inversely proportional to electron temperature. With this modification the increased time resolution of the temperature measurement is obtained at the expense of a scan of electron energy. However, no deviations from a Maxwellian energy distribution have been found in previous observations. This experiment should enable us to determine the temperature profile of a sporadic E layer, which would be a most interesting observation".

The December 15, 1965 rocket experiment occurred on the final Quarterly World Day of the IQSY at Wallops Island. A type A payload was flown and the rocket propagation experiment operated on a frequency of 3.385 MHz. The firing time corresponded to a solar zenith angle of 60° (noon).

Because the December 15th rocket experiment was not conducted on a day of high absorption, it was necessary to conduct a comparison experiment on a day of anomalous winter absorption. An investigation was undertaken to determine the occurrence frequency of winter days of high absorption. A.H. Shapley (ESSA) was contacted and he informed us that summer noon absorption is comparable to that on a winter day of high absorption, that six to eight consecutive days of high absorption in December would be typical, and that there is probably a longitudinal dependence for the anomalous winter absorption.

On the basis of Wallops Island f-plots for the period from November, 1964 to January, 1965, f_{min} values were plotted, revealing that two or three consecutive days of high absorption tend to recur at 10 day intervals.

In another effort to determine the occurrence frequency and duration of anomalous absorption at Wallops Island, f-plots were ordered from the

Data Center at ESSA (Boulder, Colorado); these covered the months of October and November, 1965, and examination of them revealed a fair amount of solar activity. Based on these f-plots, it was rather difficult to differentiate between days of anomalous absorption and days of high solar activity. Also, it was determined that scaling of the f_{min} values from the ionograms is a very subjective process; for best results the f_{min} values should be determined by actual inspection of the ionograms. Also, it was discovered that D-region reflections tend to occur at the lower ionosonde frequencies on days of anomalous absorption. In order to substantiate this, ionograms obtained at Wallops Island during the winter of 1964-65 were examined; these showed that D-region reflections were accompanied by high values of f_{min}.

Concerning the rocket firing at Wallops Island in January, 1966 on a day of anomalous absorption, it was agreed that the earliest firing date would be January 5th. The firing would be scheduled each day for 1300 EST and the decision to fire or not would be made by 1100 EST on the basis of the vertical incidence absorption measurements complemented by the Wallops ionosonde observations. For a more complete description of the means employed to determine whether the firing criteria were met, see section 2.2. Preliminary information concerning the launch and subsequent data retrieval may be found in section 3.1.

Plans and schedules have been made for rocket firings during June, July, and November, 1966.

1.2 DC Probe Theory

R.J. Cicerone

This task includes the theoretical investigations of ion collection and their relation to ionospheric measurements. It is supported in part by the Air Force Electronics Systems Division under contract AF 19(628)-3900 and in part by the National Aeronautics and Space Administration under grant NsG-511.

The direct measurement of positive ion concentrations at D-region altitudes is required for a better understanding of the formation and dynamics of this part of the earth's ionosphere. The electrostatic probe is one possible way to make such measurements. Any complete theory of collection of positive ions by an electrostatic probe in an environment such as the D region must include the effects of negative ions, the collision-dominated motion of all the particles, and probably must consider the situation where the plasma has a net macroscopic motion relative to the probe.

In the present work the theory of a stationary spherical electrostatic probe is studied for the case of one positive and one negative charged specie in the plasma surrounding the probe. Ultimately it is hoped that these efforts can be extended to include translating probes, such as one mounted on a small rocket.

Following the method of Su and Lam (1963), the equations governing the behavior of a collision-dominated spherical probe in the steady state were written using the theory of statistical mechanics. The expressions for the current densities of positive and negative species are,

$$\vec{J}_+ = e\left[-\vec{\nabla}\ (D_+N_+) - \mu_+N_+\ \vec{\nabla} V\right] \tag{1}$$

$$\vec{J}_- = -e\left[-\vec{\nabla}\ (D_-N_-) - \mu_-N_-\ \vec{\nabla} V\right] \tag{2}$$

where N_+, N_-, μ_+, μ_-, D_+, D_-, are the number densities, mobilities, and diffusion constants for the positive and negative species. In the absence of production and loss of charged particles each specie obeys an equation of charge continuity:

$$\nabla \cdot J+ = 0 = \nabla \cdot J- \tag{3}$$

Also, the electrostatic potential V must obey Poisson's equation

$$\nabla^2 V(r) = -\frac{e}{\varepsilon_0}(N+ - N_-) \tag{4}$$

in rationalized MKS units.

The boundary conditions imposed on this set of equations are that infinitely far away from the probe the positive and negative number densities are equal to the quiescent plasma density, N_o, and are zero at the probe surface, $r=r_p$, and that the electrostatic potential of the quiescent plasma is taken to be zero and that of the probe to be V_p. Mathematically,

$$\begin{aligned} N_+(\infty) &= N_o , & N_+(r_p) &= 0 \\ N_-(\infty) &= N_o , & N_-(r_p) &= 0 \\ V(\infty) &= 0 , & V(r_p) &= V_p \end{aligned} \tag{5}$$

For the case of highly negative probe potentials

$$J_- = 0 \tag{6}$$

Using this condition and introducing dimensionless variables

$$n_+ = \frac{N_+}{N_o}$$

$$n_- = \frac{N_-}{N_o} \tag{7}$$

$$\phi = - \frac{eV}{kT_-}$$

where k=Boltzmann's constant, T_-=temperature of negative specie we can write the system of equations as

$$I_+ = 4\pi r^2 N_o D_+ e \left[\frac{dn_+}{dr} - \varepsilon\, n_+ \frac{d\phi}{dr} \right] \tag{8}$$

$$n_- = e^{-\phi} \tag{9}$$

$$\frac{d^2\phi}{dr^2} + \frac{2}{r}\frac{d\phi}{dr} = \frac{N_o e^2}{\varepsilon_o kT_-} (n_+ - n_-) \tag{10}$$

where $\varepsilon = \frac{T_-}{T_+}$ and we have used the Einstein relations

$$D_+ = \frac{\mu_+ kT_+}{e}$$

$$D_- = \frac{\mu_- kT_-}{e} \tag{11}$$

Introducing the dimensionless spatial variable $s=\frac{r}{r_p}$ we get

$$\frac{dn_+}{ds} - \varepsilon\, n_+ \frac{d\phi}{ds} = \frac{I}{4\pi r_p N_o e D_+} \cdot \frac{1}{s^2} \tag{12}$$

$$n_- = e^{-\phi} \tag{13}$$

$$\frac{d^2\phi}{ds^2} + \frac{2}{s}\,\frac{d\phi}{ds} = \frac{r_p^{\,2} N_o e^2}{kT_-} \quad (n_+ - n_-) \tag{14}$$

with the boundary conditions

$$\begin{array}{ll} n_+ (\infty) = 1 & n_+ (1) = 0 \\ n_- (\infty) = 1 & n_- (1) = 0 \\ \phi \ (\infty) = 0 & \phi \ (1) = -\dfrac{eV}{kT_-} \end{array} \tag{15}$$

Seeing the random current

$$I_r = 4\pi r_p N_o \; e \; D_+ \tag{16}$$

and defining $\alpha = \frac{I_+}{I_d}$ (17)

and recognizing the Debye length squared

$$\lambda_D{}^2 = \frac{\varepsilon_o kT_-}{N_o e^2} \tag{18}$$

we use the inversion transformation $t=\frac{1}{s}$ to simplify the left hand side of (14). Making one further transformation $x=\alpha t$ moves the probe surface out to $x=\alpha$, infinity corresponding to $x=0$.

The resulting equations are

$$\frac{dn+}{dx} = \epsilon n+ \frac{d\phi}{dx} - 1 \tag{19}$$

$$n_- = e^{-\phi} \tag{20}$$

$$x^4 \frac{d^2\phi}{dx^2} = \frac{\alpha^2 r_p^2}{\lambda_D^2} (n+ - n-) \tag{21}$$

with the boundary conditions

$$\begin{aligned} n+ (0) &= 1 & n+ (\alpha) &= 0 \\ \phi (0) &= 0 & \phi (\alpha) &= \frac{-eVp}{kT} \end{aligned} \tag{22}$$

These equations are highly non-linear and require numerical solution. Still following Su and Lam, but assuming no relationship between the relative magnitudes of r_p and λ_D we have attempted numerical solution. The general method is to perform a numerical integration from $x=0$ to $x=\alpha$, the probe surface, on the electrostatic potential. The final result is the potential on the probe.

In specifying the first and second derivatives of the potential at the origin the quasi-neutral solution is utilized, that is $n_+ = n_-$. However, since the second derivative of the potential is singular at the origin we may not begin precisely at the origin. Instead we start at some value of x, small enough that the quasi-neutral solution still holds. Starting values for n_+ and ϕ, and $\frac{d\phi}{dx}$ are provided by the quasi-neutral solution. The first derivative of ϕ is not directly specified, however. Only a lower bound can be deduced. The behaviour of the system of equations depends very strongly on the starting value for the derivative of the potential; the system is highly unstable if a value too small or too great is chosen. Incorporated into the computer program is an iterative procedure to choose the correct value of $\frac{d\phi}{dx}$. Tests for instability are included.

When solutions with $V_p > \frac{10kT_-}{e}$ were sought it was found that the starting value for $\frac{d\phi}{dx}$ had to be determined more precisely than the eight-significant figures possible on the IBM 7094. Instead of completely reformulating the problem it was decided to continue with the same method using either double precision accuracy on the IBM 7094 (16 significant places) or the 13 significant digit accuracy of Illiac II, a computer used in the Department of Computer Science at the University of Illinois. Illiac II was chosen because it is faster than the 7094, and hence more economical.

Although the calculations on Illiac II are not yet complete it appears that solutions for probe potentials up to approximately $20 \frac{kT_-}{e}$ can be found for ion number densities between 10^3 and 10^4 per cm^3.

Reference

Su, C.H., and S.H. Lam (1963), The continuum theory of electrostatic probes, Physics of Fluids 6, 1479-1491.

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2. VERTICAL INCIDENCE ABSORPTION MEASUREMENT

2.1 Instrumentation

G.W. Henry, Jr.
T.W. Knecht

Tasks included under this topic pertain to the design, construction, and maintenance of instrumentation for use with vertical incidence sounding systems for study of the ionosphere, as conducted under NASA grant NsG-511.

Receivers

The DC amplifier stage of the ionospheric sounding receiver was redesigned to improve the temperature stability and bandwidth. The new design utilizes two direct-coupled differential amplifiers with approximately 24 db overall feedback. This new amplifier circuit has been incorporated into one receiver and will be added to the others as time permits.

Transmitters

The final amplifier and driver stages of the Wallops Island 50 kw pulse transmitter were installed in the former shipboard van at the Aeronomy Laboratory. The necessary patch cords were made up to operate these units with the power supplies and pulser used in the shipboard experiment. Upon testing, the poor operation of the Wallops transmitter was traced to the following defects:

1. The 7094 tube used as a screen-pulse amplifier in the final amplifier stage had low emission. It has been replaced.
2. The two 7214 tubes used as final amplifiers had low emission. They have also been replaced.

3. The high concentration of salt- and dirt-saturated air at Wallops Island deposited enough impurities on the components to cause arcing wherever high voltages were present. All high voltage points were cleaned as well as possible without disassembling the units.

After the above corrections were made, the Wallops Island transmitter components functioned well. Arrangements were then made to transport these units to Wallops Island for use during the Nike-Apache shot on December 16, 1965, and during the shot in January, 1966.

A few problems were encountered in returning the Wallops transmitter and receiving systems to operation. These problems were:

1. Both the transmitting and receiving arrays were broken and down. The repair of the transmitting array was quite simple, but repair of the receiving array required replacement of all feedlines and repair of all dipole elements. The 300-ohm heavy duty twin-lead was replaced with double RG-62/U coaxial cable in a balanced configuration. The resulting installation is much stronger.

2. The transmitting array was no longer matched to the feedline. Evidently the leakage across the feedlines at the wooden supports was sufficiently capacitive to mismatch the system. Inductors placed at the center of the array were found to be sufficient to return the impedance at the transmitter location to 500 ohms per line. This mismatch problem was probably the cause of many transmitter failures last summer. It is essential that the feed impedance of the system be checked, and adjusted if necessary, before operation of the transmitter. The transmitter only operates correctly if matched, and the

phase-shift network acts as an impedance transformer if mismatched, further increasing the mismatch to the transmitter as well as giving the wrong value of phase-shift. If continued use of the Wallops Island absorption / partial-reflection sounder is contemplated, the antenna systems should be redesigned to reduce or eliminate this problem of leakage across the feedlines. A solution would be to replace all open-wire feedlines with RG-17/U coaxial cable as is being done at the Urbana field installation.

Automatic Absorption Recording System

The automatic absorption recording system designed by R. Appel was set up in the Urbana van and tested at the Aeronomy Laboratory using one dipole for receiving and transmitting. A minor change was found to be necessary in the 2E gate timing system to permit a wider range of height variation, but otherwise the system operated quite well. A major problem was confronted when calibration of the system was attempted. The nature of the sampling, integrating, and comparing circuits required that the signal input be of pulsed nature, rather than CW. It was therefore necessary to design and construct a pulse modulator system to use in conjunction with a signal generator to calibrate the system. The calibration system was devised during the last few days before leaving for Wallops Island. While sufficiently accurate for limited calibrations such as those needed for the Wallops installation, a calibration system of wider dynamic range should be designed and constructed in the near future. In addition, the receiver should be modified to permit a wider range of signal amplitudes that may be controlled directly by the automatic system.

The complete automatic absorption recording system was transported to Wallops Island. It was installed and operated there during December, 1965. The system performed well except for a drift problem in the DC and RF amplifiers of the receiver and control system. The system was returned to Urbana from Wallops Island on January 13, 1966. At this time the equipment was set up in the Aeronomy Laboratory for a closed-loop test using a simulated signal to observe system drift. Testing showed the system drift to be 1.5 db/hr with the same gain-control settings as used at Wallops Island. A stage-by-stage check proved that the drift was due mainly to temperature instability of the receiver RF amplifier and the DC amplifier following the integrator circuit. By simply readjusting the RF amplifier gain control, the system drift was reduced to 0.4 db/hr. Any further improvement in the system stability requires redesign of several circuits. This will be worked out as time allows. One possibility for reduction of temperature drift of the RF amplifier is the use of N-channel tetrode field-effect transistors for gain control.

System Operations

Preliminary observations of ionospheric absorption, drift, partial reflections and noise levels were initiated at the Aeronomy Field Station near Urbana in February, 1966. The entire vertical incidence sounding system was operated at the increased pulse repetition rates set up for partial reflection measurements (see section 10.2). All experiments connected with the sounding system were found to function well at the higher prf, but increased heat dissipation in the final amplifier caused oxidation of the soldered connections to the final amplifier tubes. The problem was somewhat alleviated by use of high-temperature solder and clamp-type connectors, but final amplifier instabilities still prevented resumption of measurements at the field station through the month of March, 1966. New tube sockets and larger blowers are on order and will be incorporated in an improved final amplifier design upon arrival.

2.2 Wallops Island Measurements

G.L.N. Rao
J.S. Shirke

Tasks performed under this topic pertain to ionospheric measurements by vertical incidence sounding techniques at Wallops Island, Va., as conducted under NASA grant NsG-511.

Plans were formulated for making vertical incidence ionospheric absorption measurements at Wallops Island during the winter of 1965-66, with the following aims:

1. To provide a criteria for the launching of rockets in the midst of the so-called "winter anomaly" phenomena, whereby increased absorption of RF waves is noticed on some days in winter at middle and high latitudes.
2. To link up the rocket measurements with the large amount of data obtainable from ground-based measurements.

The winter anomaly is known to have a large latitudinal dependence, with no perceptible effects at latitudes of 23° north and maximum effect at 58° north. For higher latitudes the particle effects start becoming predominant and large variability in ionospheric absorption of radio waves is noticeable.

The excess absorption is known to build up gradually following sunrise, being very low for large solar zenith angles. There is no day-to-day correlation of the anomaly with the magnetic index. The phenomena depends largely on the sunspot cycle. As many as 80 percent of the days are anomalous at the latitude of Slough during the peak of activity.

It may thus be seen that there is no clear-cut criteria existing for the detection of the anomaly at a given epoch and location. When it was decided to launch a rocket under the anomalous conditions, it became imperative to establish a criteria from vertical incidence absorption measurements. December 15, 1965 was the final IQSY world day and, as a part of the U.S. program for the synoptic measurement of the mid-latitude ionosphere, a rocket was scheduled for launching from Wallops Island, equipped with a payload suitable for deriving the electron density as well as collision frequency profiles in the lower ionosphere.

In order to take the greatest advantage of this rocket launching, it was decided to start making observations of vertical incidence absorption five days prior to the launch date and to continue the observations for five days afterwards. The aim was to find out whether the launch took place under the normal or anomalous conditions. Since the ground-based measurements showed that the day was not of the anomalous type, another set of similar measurements was conducted commencing on January 4, 1966. A rocket was held ready for launch each day until Jaunary 10, 1966, when a day of the anomalous winter type was encountered, as determined on the basis of criteria established from ground-based measurements. The rocket was launched at about the same solar zenith angle as that of the earlier shot. The rocket showed more than tenfold enhancement in electron density at altitudes close to 82 kilometers, justifying the enhanced attenuation measured at the ground station.

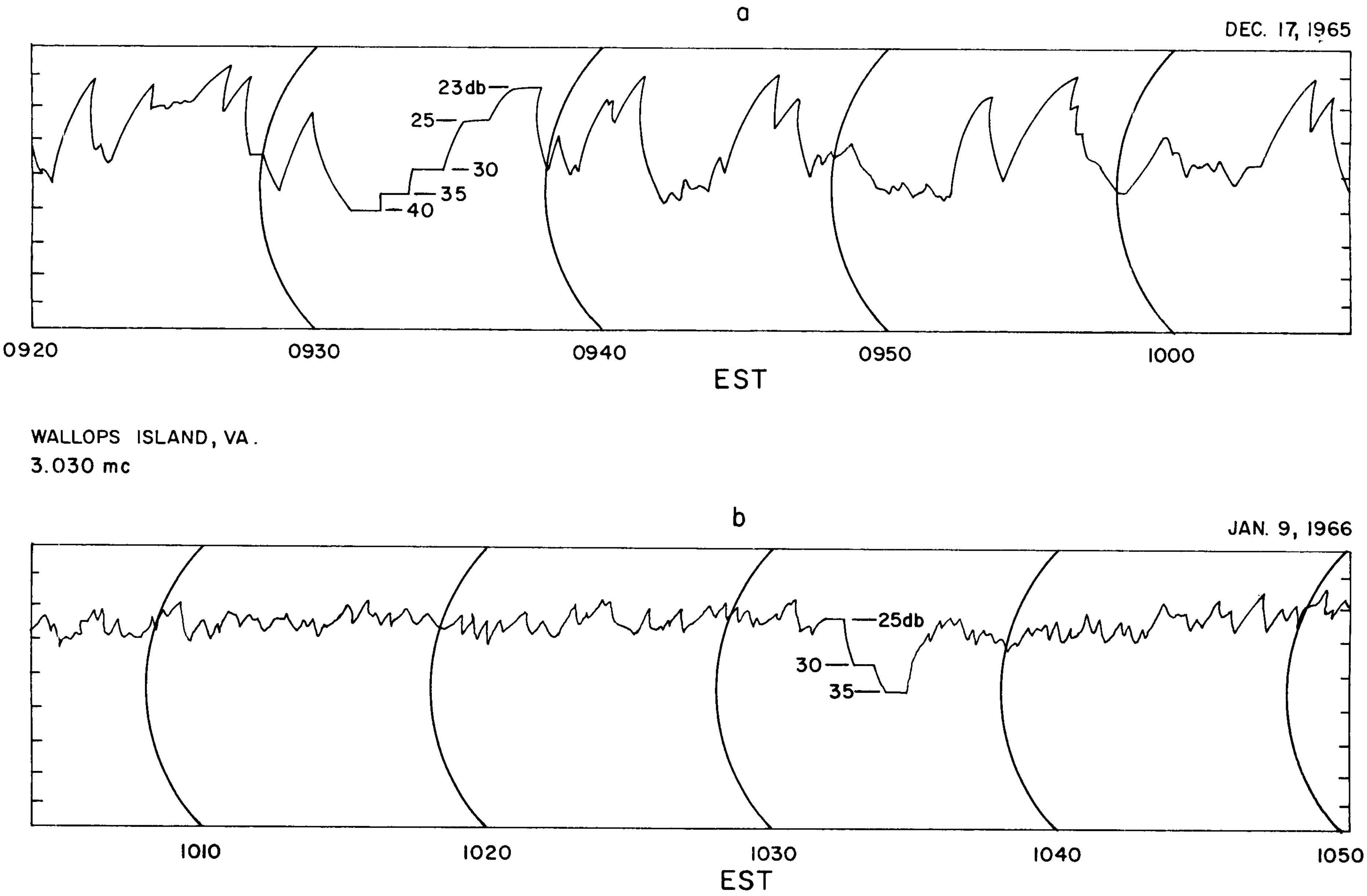

Figure 2.2.1 A pair of typical records showing the amplitude fluctuations in the first order echo (a) from the F layer in the absence of any intervening E_s layer, and (b) from a blanketing type E_s layer.

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The ground station set-up consisted in essence of a pulse transmitter at 3030 kHz with a 50 kw peak power and a pulse width of about 50 μsec. The pulse repetition frequency was 2 pulses per second. The antenna system consisted of four half-wave dipoles situated as four arms of a square array. The opposite arms of the array were connected in parallel. The outputs from the two pairs of antennas were combined after adding a phase delay in one of the outputs. Circular polarization of either polarity was achieved by the appropriate choice of the delay. Similar but independent antenna systems were used for transmission and reception.

A specially-designed high gain receiver was used, the output being displayed on a monitor oscilloscope. The desired echo was selected by a variable-position gate. The gated output was integrated in a circuit having a time constant of 45 seconds and fed to an Amprobe chart recorder. To accomodate a larger range of echo variation the integrated output was fed back as AGC to the previous stages of the receiver.

The system was calibrated using signals from a standard Hewlett-Packard signal generator. The CW output from the signal generator was modulated using a low frequency pulse, simulating the ionospheric echo. The pulsed output from the signal generator was fed into the receiver through an RF attenuator. The recorder output was calibrated in terms of this attenuator in the range of variation normally expected from the ionosphere.

The accompanying Figure (2.2.1) shows some of the typical records taken during the observations. Usually the echo amplitudes were undergoing large fluctuations with periods ranging from one to ten minutes. For computation of absorption a period of ten minutes was found suitable in most

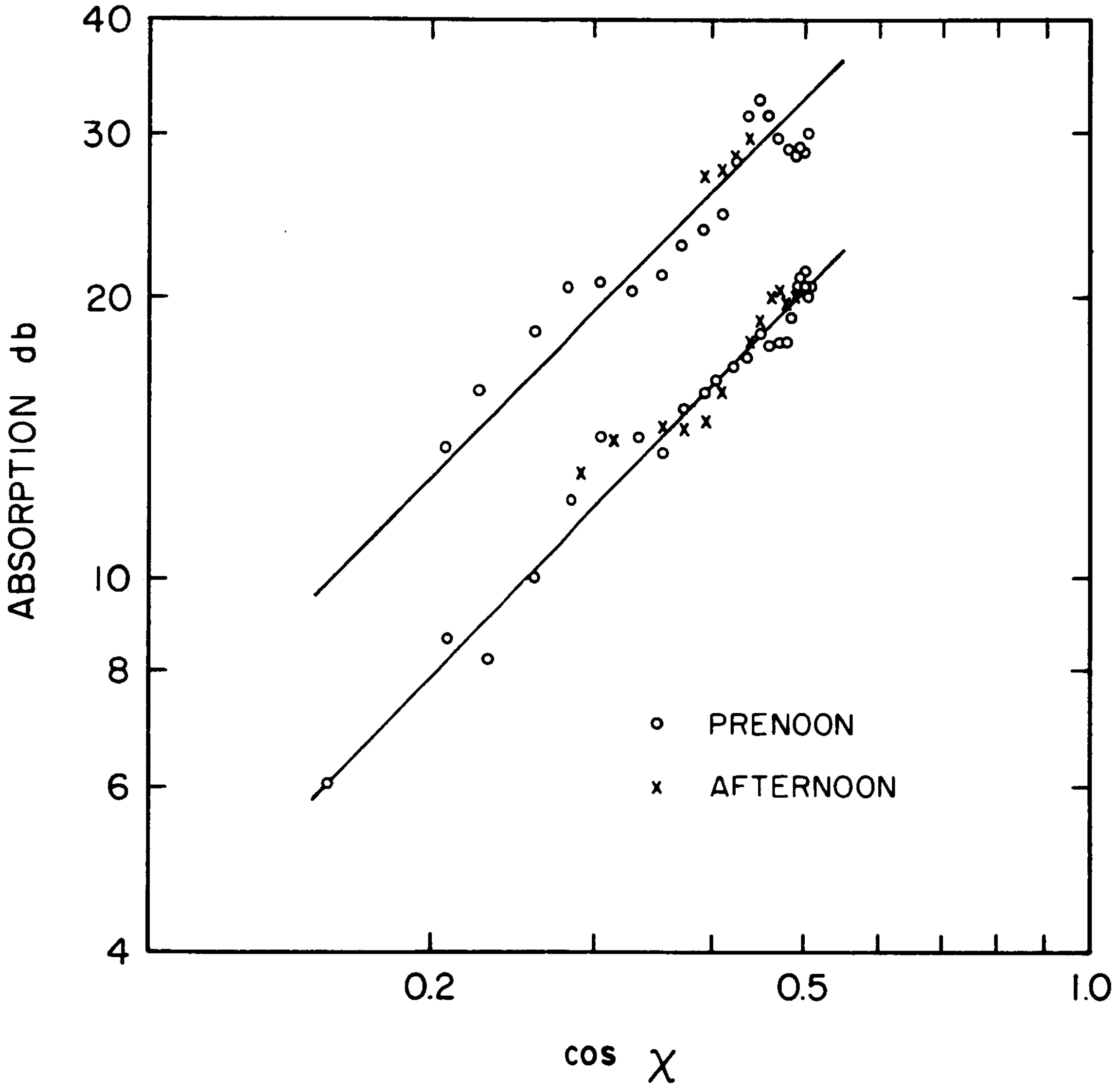

Figure 2.2.2 A plot of the diurnal variation of absorption on the control days and on 10 January 1966.

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cases to give a reasonable estimate of the median echo amplitude. The conversion of the recorded echo amplitude on the chart to actual dissipative ionospheric attenuation was made by noting the level of the median amplitude below the reference level of the signal generator and by substituting this quantity in the usual formula used for these calculations. The equipment constant was derived from several sets of measurements made by gating the 1F and 2F echoes in succession. This permitted using the measurements of 1F alone to give the absorption values at times when the 2F echo was not available due to increased absorption. The height of the reflection of the echo was noted each time so that appropriate correction for the spatial attenuation could be enforced.

Generally the F layer was gated, since the E layer critical frequency was normally lower than the operating frequency. Occasionally, however, the appearance of an intervening E_s layer affected the intensity of the F region echo. Under such circumstances the E_s layer was gated instead. As seen in Figure 2.2,1, it may be noticed that the fading characteristics vary widely between the E_s and F echoes, the actual absorption values also being different in the two cases. In fact, a large dependence of absorption on the height of the echo was also noticeable, suggesting that a large part of the observed attenuation was originating from levels above 95 km. Since the winter anomaly phenomena was recognized as originating below this level, account had to be taken of the type of reflecting layer, its altitude and the characteristics of any intervening layers such as E_s.

Figure 2.2.2 shows a plot of the diurnal variation of absorption on the control days and on January 10, 1966. It may be noted that all of the control days were not normal and the comparison is not strictly between normal and abnormal conditions. The lower heights of reflection has compensated for the increase of the attenuation in the lower ionosphere on some of these days. December 20, 1965 was an anomalous winter day with heights of reflection exceeding those on the 10th of January. This day has been excluded in evaluating the control day mean.

Based on these measurements it was decided that the rocket should be fired when the absorption exceeded 25 db for each ten minute period between 10:00 and 11:00 a.m. EST. The criteria does not cover all of the winter anomaly days, such as those on which a blanketing type E_s is present, but those are special cases and have to be treated independently. Several other aspects of the winter anomaly are under investigation, using the above data. The relative roles of the electron density and electron collision frequency in producing the winter anomaly are being studied, as is the development of the anomaly with the changes in the solar zenith angle.

Supporting ground-based measurements were made using a J-5 ionosonde prior to and during the rocket launches. An increase in f_{min}, the minimum frequency recorded in the ionosonde, has often been used as a rough index of absorption. With increased sensitivity in the ionosonde of the type available, a lower layer with a base altitude variable from 85 to 100 km is often found in the ionogram. Since this layer is not always adversely affected due to the absorption originating in the vicinity, the layer is often found to be enhanced rather than depleted when the layer above shows increased f_{min} (i.e., increased absorption). The lower layer has to be eliminated in considering the f_{min} for the detection of the anomalous days. Even so, the f_{min} index is rough and is affected greatly by broadcast interference. On the event under consideration, the f_{min} values had gone to as high as 1.8 MHz around noon, confirming that the attenuation in the lower ionosphere had increased substantially.

Arrangements were made to switch the transmitter polarization from one polarity to the other in quick succession. Corresponding alterations were made in the receiver antenna. The receiver outputs on the ordinary and extraordinary modes were displayed on an A-scope in opposite polarities above and below the base line, and photographs were made of the traces. Partial reflections from much lower altitudes were observed around noon on the day the anomalous absorption was noticed.

An analysis made of the relative amplitudes of ordinary and extraordinary modes of propagation on this occasion indicates a changeover in the ratio of these amplitudes rather suddenly between 80 and 85 km, confirming the large enchancement of ionization observed by the rocket instruments.

A paper giving the results obtained during these measurements is being prepared by Dr. J.S. Shirke and G.L.N. Rao, and will be duly published.

2.3 Urbana Measurements

G.W. Henry, Jr.
G.L.N. Rao
J.S. Shirke

Tasks performed under this topic pertain to ionospheric measurements by vertical incidence sounding techniques at the Aeronomy Field Station near Urbana, Illinois, as conducted under NASA grant NsG-511.

It is planned that routine measurements be made of the vertical incidence ionospheric absorption at the University of Illinois. The diurnal and seasonal aspects of ionospheric absorption under normal and disturbed ionospheric conditions will be investigated. The relative amplitudes of the deviative and non-deviative attenuations, the role of the electron-ion collisions in producing ionospheric attenuation, and the frequency dependence of absorption will be studied.

A set of frequencies will ultimately have to be used to clear up some of the problems associated with the ionospheric measurement. It is planned to start measurements on a single frequency. Discussion concerning the fixed frequency to be chosen for the operation of the vertical incidence absorption experiment, preliminary ionospheric drift measurements, and partial reflection measurements resolved that a frequency of 2660 kHz should be used in order to be compatible with other measurements of a similar nature being conducted at other locations throughout the world at that frequency.

Accordingly, the necessary forms were completed and submitted to the Federal Communications Commission in Washington, D.C. for authorization of transmitter construction and operation at a frequency of 2660 kHz. The pertinent specifications submitted were as follows:

Transmitter Specifications:

Frequency - 2660 kHz.
Power - 50,000 watts (peak - pulse mode).
Type of emission - 24 P0.
Bandwidth - 24 kHz (as defined by FCC).
Pulse Duration - 50 microseconds.

Pulse Rep. Rate -	60 pps maximum, also use 30, 10, 5, 2, 1, and ½ pps.
Transmission speed -	120 bauds max. (as defined by FCC).
Hours of operation -	unlimited.

General Specifications:

Location - fixed near Urbana, Illinois in Champaign County at $40^{\circ}10'10''$ N. Latitude and $88^{\circ}09'36''$ W. Longitude.

Sponsoring Agency - NASA - contract NsG-511.

Purpose of transmitter - Vertical incidence ionospheric sounding.

Height of antenna system above ground - 60 ft.

Elevation of ground at antenna site - 725 ft.

Distance to nearest airport runway - 12,000 ft.

Antenna directivity - vertical only.

Antenna 3 db beamwidth - approximately 15°.

Complete drawings of the proposed large antenna arrays were submitted with the applications. As of March 31, 1966, FCC authorization has not yet been received.

An automatic recording system described in Aeronomy Report No. 7 has been constructed for use with the pulse transmitter. The receiver pulses are integrated over a 65 second period and the output is fed to a recorder. The recording system was built and tested in the laboratory and then at Wallops Island for over two weeks. The following improvements of the system should be made:

1. The dynamic range of operation must be increased so that less monitoring is required.
2. The stability of recording and calibrating systems should be improved.
3. Provisions should be made for recording the height of the gated echo.

The long-term stability of the recording system was found to be poor. The instability was traced to the RF amplifier of the receiver and the DC amplifier preceding the recorder. For further information on these problems and solutions presently being considered, see section 2.1.

Regarding calibration of the system, a CW signal output from a standard signal generator originally was fed into the receiver through an attenuator, and the system was calibrated in terms of the attenuator settings. With this system, the constancy of measurements was found to be limited, especially for lower levels of CW signals. To avoid this trouble, a modulating pulse generator was added to the circuitry to simulate the ionospheric echo as far as calibration was concerned. This improved the situation considerably.

A preliminary testing of the system was made at the Aeronomy Field Station located near the Urbana campus. Since the building which is to house the equipment was incomplete, the equipment was operated from a mobile van. The design details of the transmitter and antenna system used are described in Aeronomy Report No. 7.

The method of measurement was identical to that used at Wallops Island during the winter of 1965-66 as described in section 2.2. The frequency was 3.030 MHz and the ordinary mode of propagation was used for the measurements.

Currently the final amplifier chassis of the transmitter, which has a peak pulse power of 50 kw and a pulse repetition frequency of 30 or 60 pps, is being rewired, using new power amplifier tube sockets and adequate ventilation.

The buildings at the Aeronomy Field Station are nearly complete. The experiment will be resumed after shifting the equipment from the van to the laboratory building.

2.4 Carrier Experiment

G.W. Henry, Jr.
J.S. Shirke

Tasks performed under this topic pertain to ionospheric sounding measurements undertaken aboard the USNS Croatan during the NASA mobile launch expedition, as conducted under NASA grant NsG-511.

In order to study the latitudinal variation in ionospheric absorption, vertical incidence ionospheric soundings were carried out on board the aircraft carrier during April and May, 1965. Data for over two days was collected, during which time the ship covered latitudes from 25° S to 25° N geographic.

A frequency of 3.030 MHz was used. A transmitter with a peak pulse power output of 50 kw and a pulse width of 50 μsec was connected to an antenna array composed of two horizontal dipoles crossed at right angles at their centers. Suitable phase delay networks were added in the feedlines to give circular polarization of the ordinary mode of propagation. The same antenna was employed for reception and was connected to a receiver by means of a TR gate. The receiver output was displayed on an A-scope once every 2 seconds in synchronization with the transmitter pulse repetition frequency. A camera unit was attached to the oscilloscope screen to photograph each set of traces as they appeared.

Each run of operation consisted of a ten minute period beginning at twenty minute intervals. External attenuation had to be put in manually to prevent the echo amplitudes from going into the saturation level. The height of the reflecting level could be noted from the time base scale factor.

When multiple echoes were available, suitable calibration runs were made by noting the relative amplitudes of these echoes on successive sets of frames. This was possible by adjusting the gain of the receiver and by adding known external attenuation on the strong echoes. Knowing the calibration constant of the equipment, it was possible to deduce the attenuation at any given instant from the amplitude measurements on a single echo.

The reduction of the data proved to be an enormous task, as each frame had to be projected to make measurements of the echo amplitudes. The external attenuation associated with each of the frames had to be varied from time to time to prevent echo amplitudes from going into saturation. This involved considerable computation in finally converting the measured amplitudes to ionospheric attenuation. The height of reflection of the echo in each frame being different, the correction to be applied for the spatial attenuation in each frame was also different.

In view of the large number of frames available it was decided to sample only 10 percent of the data. Every tenth frame in succession was therefore used for the final analysis. A preliminary plot of these values showed that besides a quick period of fading, a slow fading with a period of the order of ten minutes was often present. A median value for the absorption for each ten minute period was therefore evaluated.

An analysis of the computed data has been undertaken. In spite of the large scatter in individual readings, certain trends in latitudinal variation are noticeable. One of the major tasks was to evaluate the solar zenith angle corresponding to various locations of the aircraft carrier. The ship had not moved appreciably from the 75° W meridian during the period of observation. Even so, the appropriate time shifts due to the changes in the longitude of the carrier had to be noted.

For a given solar zenith angle the latitude variation of absorption was estimated throughout the latitude range of 25° N to 25° S. The procedure was repeated for solar zenith angles of 30, 40, 50, 60, 70, and 80 degrees.

A decrease in attenuation with increasing latitudes is noticeable for all the solar zenith angles. A subsidiary peak is noticed around 15° N. It may be that a peak of this nature can arise due to faulty readings on a single day.

Diurnal variation of absorption with corresponding solar zenith angle dependence for specific zones is under investigation. This should give a clue as to how much reliance may be placed on a particular day's readings.

Associated features such as the critical frequency of the E layer will have to be taken into consideration before giving a final interpretaion of the data.

A complete description of all instrumentaion designed and constructed for use in this experiment, as well as a discussion of preliminary data analyzed will be duly presented in the forthcoming Aeronomy Report No. 13.

3. ROCKET PROPAGATION EXPERIMENT

3.1 Wallops Island Measurements

S.A. Bowhill
E.A. Mechtly
C.F. Sechrist, Jr.

Tasks included under this topic pertain to the planning, coordination, and execution of rocket propagation experiment launchings from Wallops Island, Va., as conducted under NASA grant NsG-511.

Transfer of the CSL ground station equipment to the Aeronomy Laboratory was completed. Eventually (probably by June 30, 1966) the CSL data analysis setup will also be transferred to AL. CSL will have completed analysis of all rocket shots at 100 points per second by that time.

In addition, Morrison will have completed a computer program to determine Faraday rotation directly from the 10 Hz signals. While this does not satisfy the criteria set up for the experiment, it may be possible to develop it at a later stage to cope with the 500 Hz signals.

A program is to be initiated of constructing engineering versions of those elements of the automatic Faraday rotation system at CSL which currently exist only in breadboard form, together with a program to test these in the entire CSL system. In this way, by the time the CSL work is completed, a complete FR system will be available for transfer to the Aeronomy Laboratory.

In view of the difficulties involved in manning two stations simultaneously, at Ft. Churchill and Wallops Island, consideration was given to postponing the February Wallops measurements to early March. However, postponement of the Ft. Churchill program to March by AFCRL removed the need for this.

In an endeavor to evaluate the low altitude (namely, below 90 km) electron densities for the July 1964 shots, it was decided to plot the differential absorption against the indefinite integral of the electron current times the pressure. This plot should be a straight line if the electron current is proportional to the electron density, and the absorption is entirely non-deviative.

The effect of the standing wave pattern on the differential absorption measurement is being investigated. An examination of the pattern for 14.146 has revealed the following three types of pattern, each of which can be used for the determination of electron density:

1. Interference between the direct and reflected ordinary wave.
2. Interference between the direct and reflected extraordinary wave, below the level of extraordinary wave reflections.
3. Interference between the direct ordinary wave radiated at the extraordinary frequency, and the constant-phase extraordinary present at, and slightly above, the extraordinary reflection level.

These are in addition to the Z-trace standing wave which is seen when the ordinary wave reflection is located below the rocket apogee.

Nike-Apache 14.247

Dr. C.F. Sechrist, Jr. spent several days at Wallops Island in connection with the rocket firing on September 15, 1965. This afforded him an opportunity to observe the adjustment of the ground-based portion of the rocket propagation experiment.

Personnel assignments were made for the final IQSY Quarterly World Day rocket firing at Wallops Island on December 15, 1965; these were as follows:

Dr. Sechrist, overall direction; Dr. J.S. Shirke and G.L. Narayana Rao, vertical incidence absorption; Dr. Mukunda Rao, G.W. Henry, and L.A. Schick, rocket propagation experiment; and J. Strong, payload. Letters were sent to the Security Officer and Project Engineer (Mr. R. Pless) at Wallops concerning the names of these scientific personnel from the Aeronomy Laboratory who would be participating.

Drs. M. Rao and Sechrist discussed the rocket propagation experiment with H.V. Krone and D. Skaperdas at the Coordinated Science Laboratory at the University of Illinois. Because Dr. Rao is very interested in equatorial rocket experiments, problems associated with the propagation experiment when used at the geomagnetic equator were discussed.

In connection with the December 15th rocket firing at a solar zenith angle of 60° (1200 EST), Henry and Strong arrived at Wallops Island on December 7 and activated the vertical incidence absorption experiment at the old Coast Guard building on the north end of the island. This experiment was turned over to Dr. Shirke and N. Rao, who arrived at Wallops on December 10. L.A. Schick joined Henry and Strong on that date, and they then activated the ground instrumentation for the rocket propagation experiment. On December 13, Drs. M. Rao, Mechtly, and Sechrist arrived at Wallops. M. Rao and Mechtly observed the adjustment and operation of the rocket propagation experiment, while Sechrist was responsible for the overall scientific direction of the firing.

According to Dr. L. Smith, the non-availability of the Spandar and FPQ-6 radars for the December shot would result in a track only to 100 km (from the FPS-16 radar). This, however, is adequate to permit extrapolation on the basis of a vacuum trajectory.

Rocket 14.247 was launched at Wallops Island on December 15, 1965 at 1200 EST as scheduled. Instrumentation performance was satisfactory except for non-function of the 1450 Å ion chamber. The DC probe and the propagation experiment indicated the presence of two sporadic E-layers, the lower at about 96 km being about 4 km thick, and the upper layer at 112 km being about 1 km thick. Both the rocket propagation and the vertical incidence absorption experiments suffered radio-teletype interference; however, much useful data will be obtained. Based on the vertical incidence absorption measurements, this firing occurred on a day of low or normal absorption.

Nike-Apache 14.248

Nike-Apache 14.248 was launched at Wallops Island on January 10, 1966 at 1714 GMT during a day of "anomalous high winter absorption" as required by mission objectives. For a discussion of the criteria chosen for determining a day of anomalous absorption, see section 2.2.

Unfortunately, the telemetry receiver signal levels dropped to 10 microvolts at T+3 seconds as the result of a partial failure of the payload telemetry transmitter. Preliminary evaluation of telemetry records suggested that little useful data could be recovered.

However, Dr. E.A. Mechtly worked with A.A. Gault at the Goddard Space Flight Center, Information Processing Division, Data Processing Branch on January 21, February 8, February 10, and March 1, 1966, to extract as much data as possible from the original telemetry tapes. The tape from Telemetry Station A was of better quality than the Wallops Main Base Telemetry Station tape. All final data processing was done with the Station A tape.

Mechtly and Gault used an Electro-Mechanical Research, Inc. Model 229 phase-locked discriminator, an Interstate Series 450 Model 8 signal tracking filter, and an Electrac, Inc. Model 215T phase-lock tracking filter.

The EMR 229 phase-locked discriminator is designed for use with the IRIG telemetry bands. It held phase lock better than the Interstate tracking filter, which is a general purpose instrument, and better than the Electrac 215T, which has a relatively fixed tracking bandwidth of 300 Hz. For example, the DC probe data was recovered by setting the EMR 229 "loop width" (i.e., deviation ratio) at 100, providing narrow band tracking, setting the cutoff frequency at 100 Hz., and carefully tuning the discriminator.

Combinations of variable frequency high- and low-pass SKL filters were tried to precondition signals. However, they were not sufficiently sharp to help.

Using the EMR 229 discriminator, Mechtly and Gault successfully recovered the DC probe and receiver AGC data and greatly improved the signal-to-noise ratio of the aspect magnetometer, ultraviolet, and receiver detector data.

The recovered data are of sufficient quality to provide a basis for a paper on what is probably the first rocket probe of the ionosphere on a day of "high winter absorption." The results are scheduled to be presented in preliminary form at the COSPAR meeting in Vienna, Austria on the week of May 8, 1966.

3.2 Data Analysis - Standing Wave

G.L.N. Rao

Tasks included under this topic pertain to the determination of electron densities in the E region of the ionosphere through analysis of standing wave patterns encountered in the rocket propagation experiment, conducted under NASA grant NsG-511.

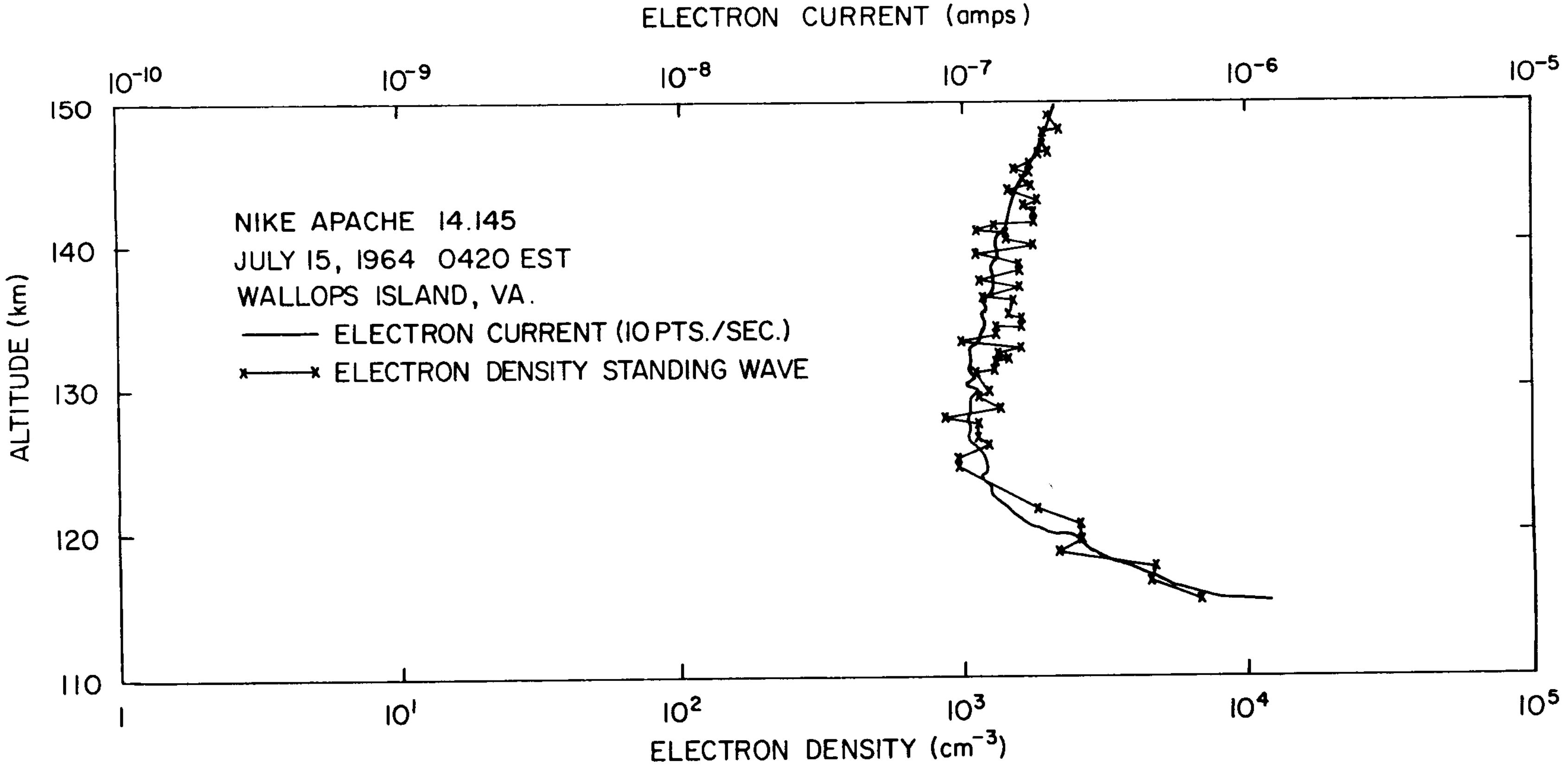

Figure 3.2.1 Electron densities in E-region levels for rocket 14.145.

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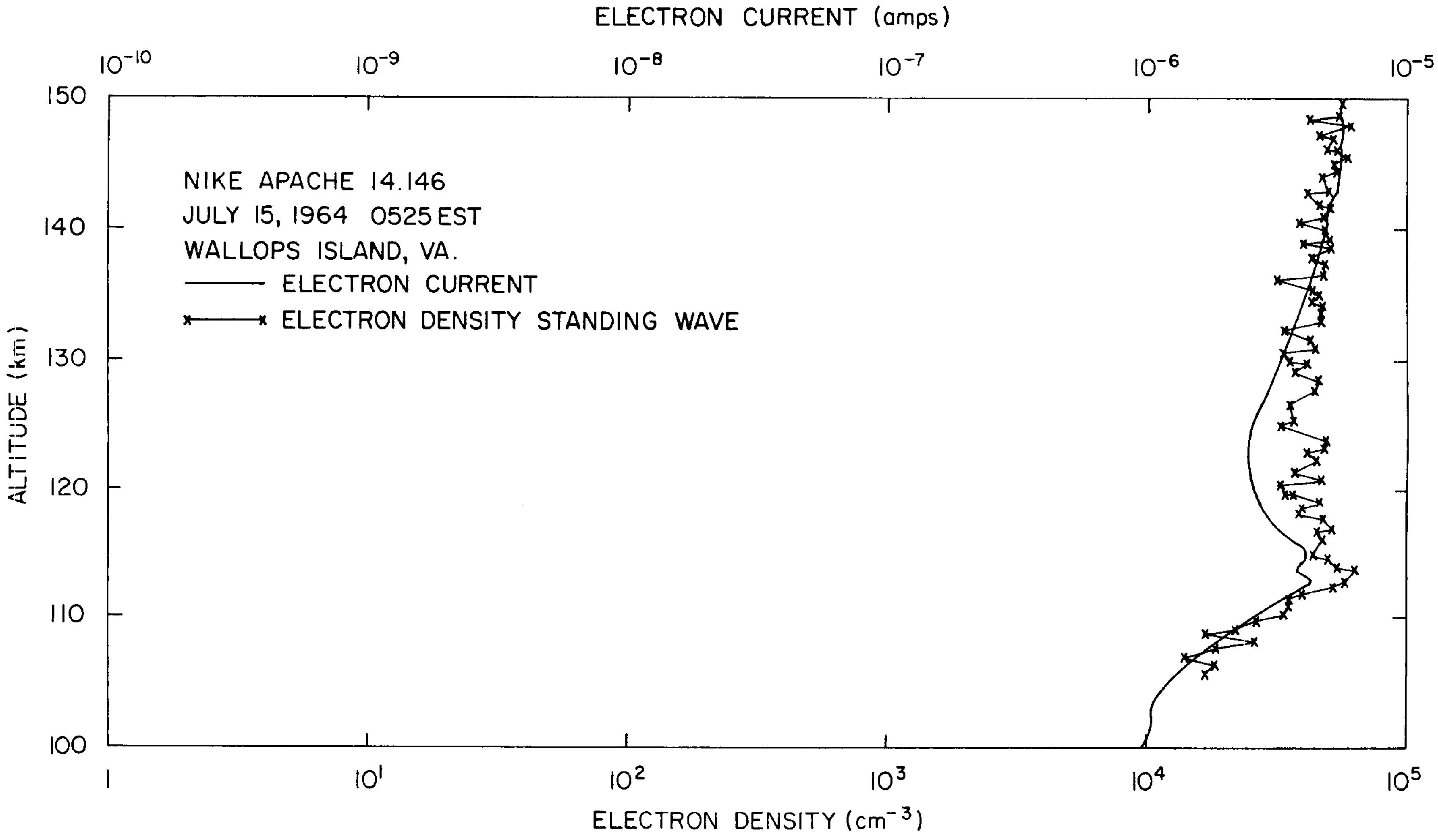

Figure 3.2.2 Electron densities in E-region levels for rocket 14.146.

Standing wave analysis techniques were applied to data from rocket shots 14.145 and 14.146. The details of instrumentation and launching of these rocket are as follows:

GSFC Model	Date	Location	Time	f	χ	Payload type
14.145	July 15, 1964	Wallops Island	0920Z	2.225 MHz	94.12°	A
14.146	July 16, 1964	Wallops Island	1025A	2.225 MHz	83.1°	A

The type A payload consists of a nose-tip DC probe for measuring electron densities and temperatures in the region above 100 km, and electron and ion currents below that height; a radio propagation experiment for measuring the differential absorption, Faraday rotation, and standing waves of CW radio signals transmitted from the ground, and hence the electron density and collision frequency over a wide range of heights; ultraviolet photometers at 1216 Å and 1450 Å for the measurement of molecular oxygen density and ionizing flux; and optical and magnetic aspect sensors.

The electron densities obtained in the E-region levels for rockets 14.145 and 14.146 are presented in Figures 3.2.1 and 3.2.2.

Some theoretical analysis has been carried out of the type of phase interference to be anticipated between the direct and reflected ordinary components and on the effect of rocket aspect on this standing wave. A preliminary conclusion is that deep nulls can be expected in the ordinary wave interference region only when the angle between the direct and reflected is less than 90°.

3.3A Data Analysis - Electron Densities and Collision Frequencies

J. Salah

Tasks included under this topic pertain to the analysis of data obtained from the rocket propagation experiment, conducted under NASA grant NsG-511.

Some of the results of experiments conducted to study the diurnal, seasonal, and latitudinal variations of the lower regions of the ionosphere are presented here.

Electron density profiles have been obtained from several measurements. In the altitude range above 100 km, the ordinary refractive index is computed from the standing wave produced by the direct and reflected waves. This normally agrees very well with the DC probe electron current. The mean value from the standing wave has often been used to calculate aspect correction factors for the probe current. In that region, the ratio of electron density to probe current is about 10^{10} amps^{-1} cm^{-3} and stays almost constant.

Between 80 and 100 km, the electron density, N, is obtained from the measurement of the Faraday rotation. Since N is proportional to the rate of change of Faraday rotation, this is an absolute measure, independent of collisions. This technique presented essentially no problems and yielded good results.

Another measurement is that of differential absorption, proportional to $\int N\nu dz$, where ν is the collision frequency. With N known from Faraday rotation, a collision frequency model may be constructed. The collision model is obtained from Appleton-Hartree equations and is assumed to be directly proportional to pressure, P. The ratio $\frac{\nu_{AH}}{P}$ varied from $2x10^8$ to $3x10^8$, depending on ionospheric effects. Below 82 km, the Sen and Wyller generalized equations have been used to calculate N. It was found that on the average this altitude may be safely used as an index for the collision frequency to be neglected in the quasi-longitudinal Appleton-Hartree equations. To the densities around 80 km an error of 10% is ascribed due to continuity.

In the asymptotic limits given by Sen and Wyller, multiplicative factors may be applied to obtain the monoenergetic collision frequency. Furthermore, at low altitude, where differential absorption plots do not show monotonically increasing values, a current calibration method has been used to obtain N. The collision frequency model calculated above 80 km is extrapolated to these lower altitudes. A smoothed absorption vs. the integral of pressure times current yields one slope factor and a point-by-point slope yields the other factor, thus allowing us to calculate the range of N at low levels.

Below 100 km, the ratio of electron density to probe current was computed using instantaneous values of current, compared with average values of density. A great deal of scatter was observed. Probe current readings were then made by GCA at 0.1 sec intervals and weighting functions were introduced to calculate the calibration constants. The scatter problem was corrected.

In the calibration constant evaluation remarkable changes in the slope have been noticed for one of the shots that showed sporadic E layer. This density effect was later dismissed because it did not appear for other experiments which yielded the same results.

Above 100 km, electron current and electron density are in a one-to-one correspondence. Between 80 and 100 km the ratio varies from shot to shot, but definitely decreases. Below 80 km, the probe current leads to an overestimated electron density by almost an order of magnitude. The technique used for obtaining electron density at these altitudes is still under study.

Final form and tabulation requirements have been set for the density results. The form will be an electron density profile derived from the smoothed N/I calibration constant and the electron current. Tabulated data will be given at 1 point/km for slow gradients of density and at 10 points/km for the fast gradients. Upper and lower limits of densities will be given for low altitude range. These will be available for every experiment.

The above has been a general presentation of the method of analysis and the manner in which the data was interpreted.

Although preliminary results have been obtained for most of the rockets launched so far, only seven will be presented here. Table 1 gives the pertinent data and information.

Table 1

FLIGHT	DATE	TIME	LAT.	LONG.	PROPAG. FREQUENCY	ZENITH ANGLE	TYPE OF PAYLOAD
14.144	15 July 64	0800 Z	Wallops		2.225 MHz	105°	B_1^*
14.145	15 July 64	0920 Z	Wallops		2.225 MHz	94.12°	A
14.146	15 July 64	1025 Z	Wallops		2.225 MHz	83.1°	A
14.149	19 Nov 64	2020 Z	Wallops		2.225 MHz	77°	B_2^*
14.230	5 April 65	1345:53 Z	29°32'S	75°13'W	3.385 MHz	58°	A
14.231	9 April 65	1918:15 Z	44°15'S	77°40'W	3.385 MHz	60°	A
14.232	12 April 65	1714:02 Z	58°19'S	78°W	3.385 MHz	67°	A

$^*B_1$ Sayers Probe and Hirao Probe

$^*B_2$ Sayers Probe and Nagy Probe

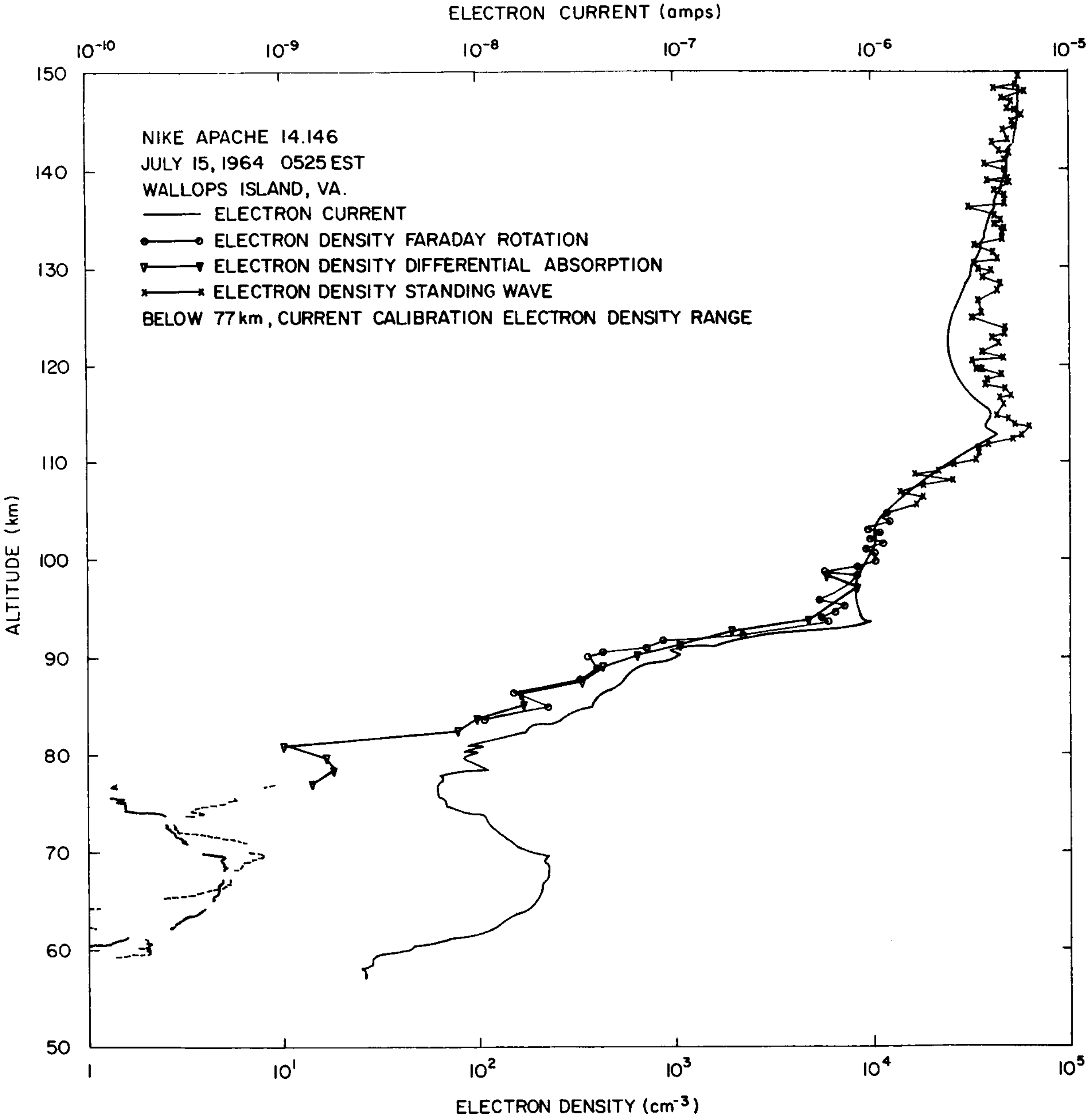

Figure 3.3.1 Electron density derived from radio propagation data as compared to probe current for rocket 14.146.

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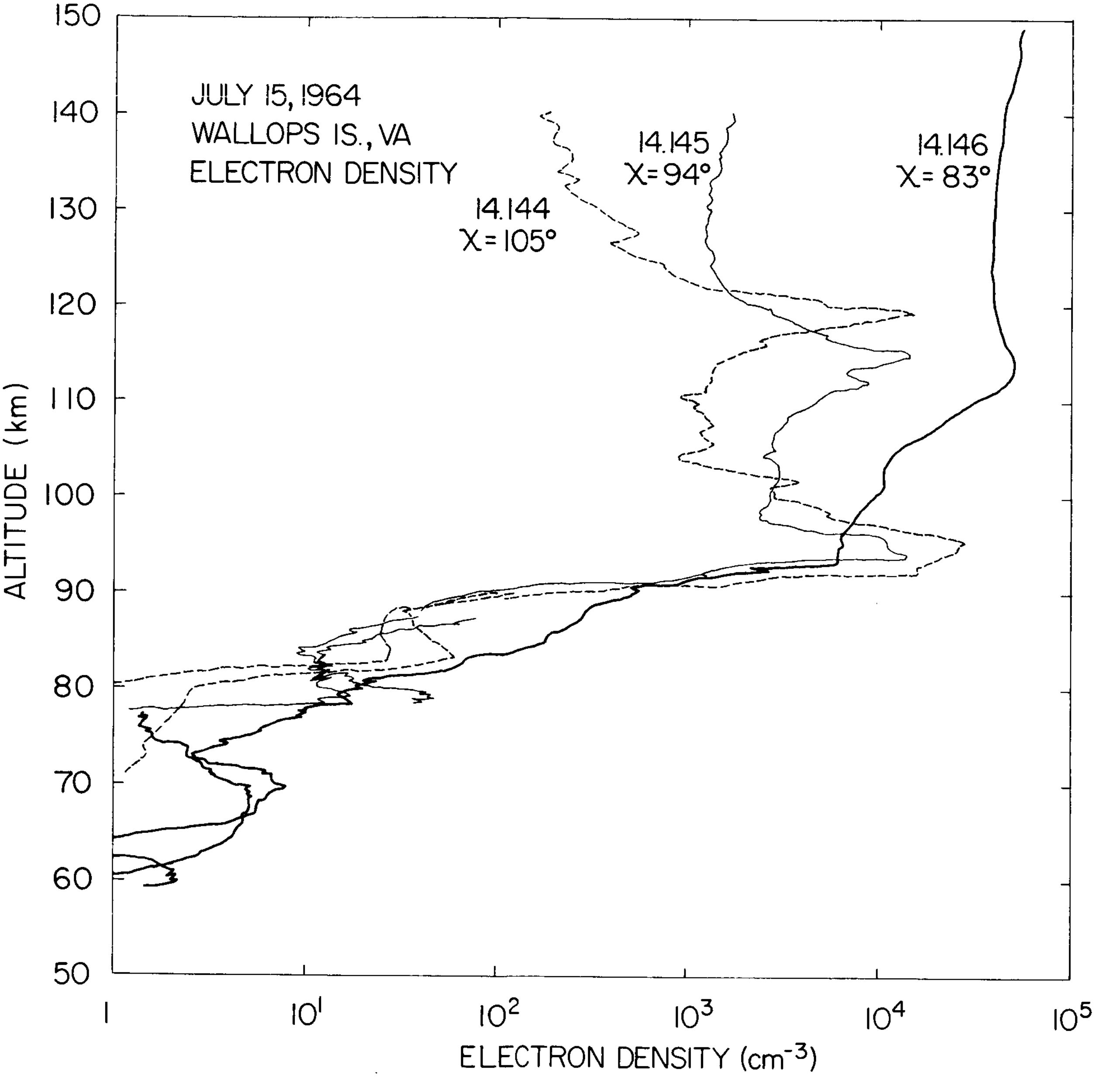

Figure 3.3.2 Final electron density profiles for rockets 14.144, 14.145, and 14.146.

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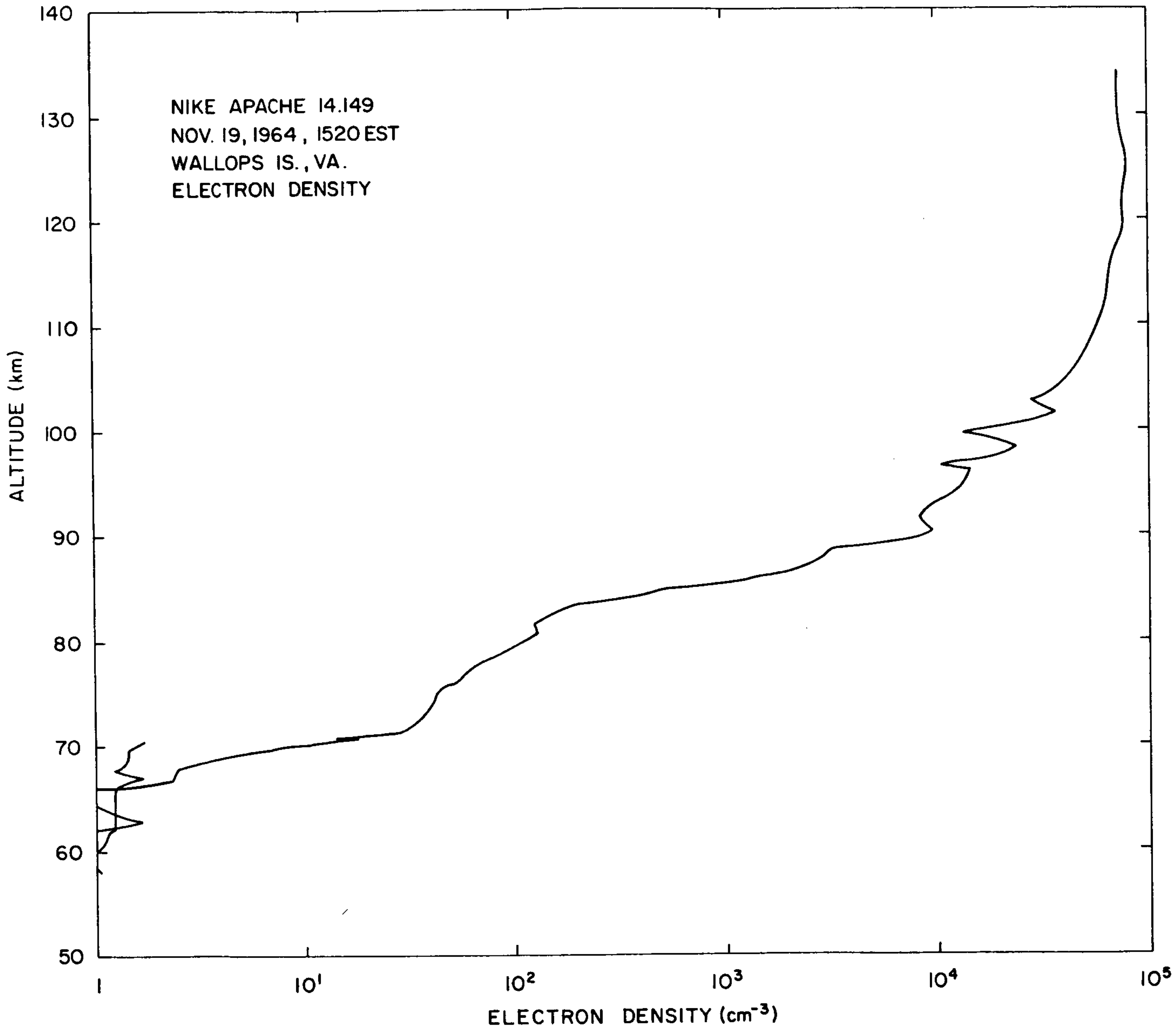

Figure 3.3.3 Electron density profile for rocket 14.149.

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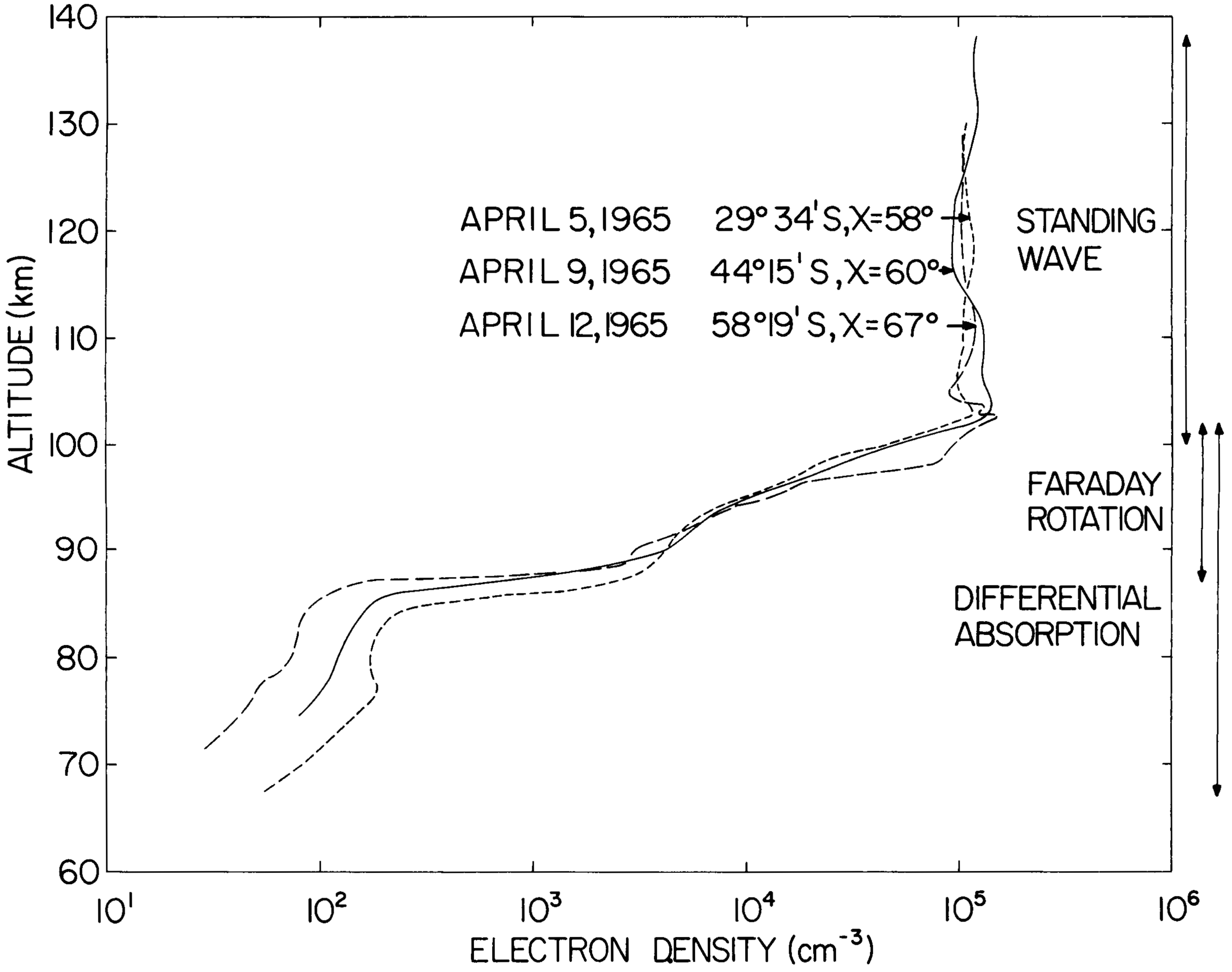

Figure 3.3.4 Radio propagation electron density profiles obtained at various latitudes during the Mobile Launch Expedition.

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Two shots launched in November, 1964 (14.147 and 14.148) were analyzed to the maximum extent. Faraday rotation was limited to a sudden increase over a few kilometers and very little absorption was recorded. Reduction is still pending on these experiments.

As an example, Figure 3.3.1 is presented to show the electron density derived from the radio propagation data for 14.146 as compared to probe current. Good agreement is evident.

Figure 3.3.2 shows the final electron density profiles for rockets 14.144, 14.145, and 14.146 respectively. Strong sporadic E layers, with densities of the order of 10^5 cm^{-3} are in evidence. Bowhill (1966) concluded from these observations that the diffuse non-blanketing sporadic E layer consists of an "assembly of under-dense ionization irregularities having a vertical correlation distance of about 25 m." He distinguishes between this phenomenon and the intense blanketing sporadic E.

Based upon the low altitude density measurement and the development of the C-layer, Bowhill and Smith (1965) have confirmed that O_2^- is not the dominant negative ion in the twilight D-region as had been previously assumed.

The November (14.149) results are shown in Figures 3.3.3, where the ionization increase occurs between 85 and 90 km compared with the 90-95 km increase for 14.146. Above 90 km, the standing wave analysis shows the same general profile shape as the current profile but there is not a one-to-one correspondence as observed in earlier shots. The several ledges occurent as these altitudes have not been explained yet.

Figure 3.3.4 shows the radio propagation electron density profiles

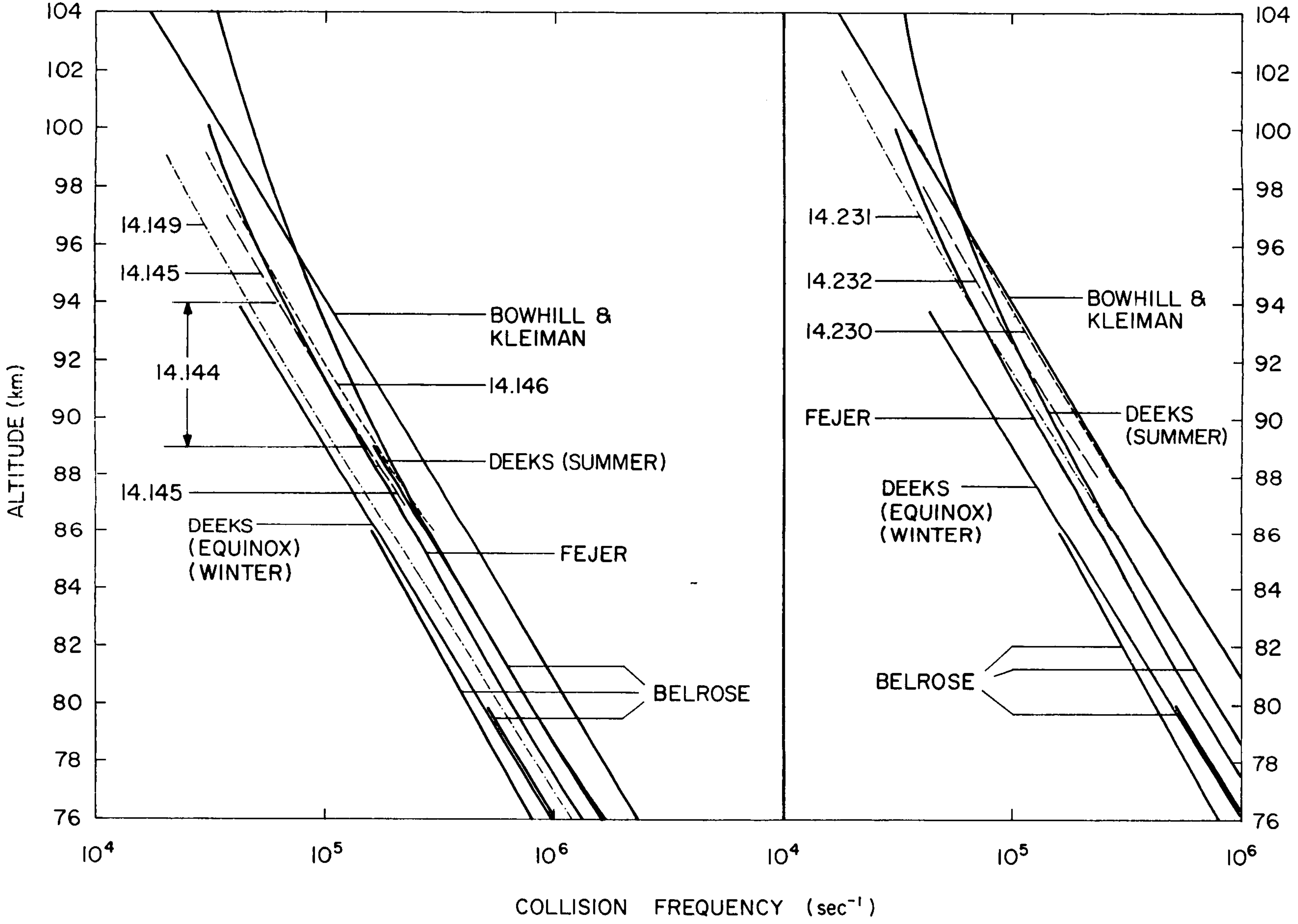

Figure 3.3.5 The various monoenergetic collision frequencies obtained from the rocket described in the test. Superimposed are the collision frequencies obtained by Belrose (1962) and Fejer (1962).

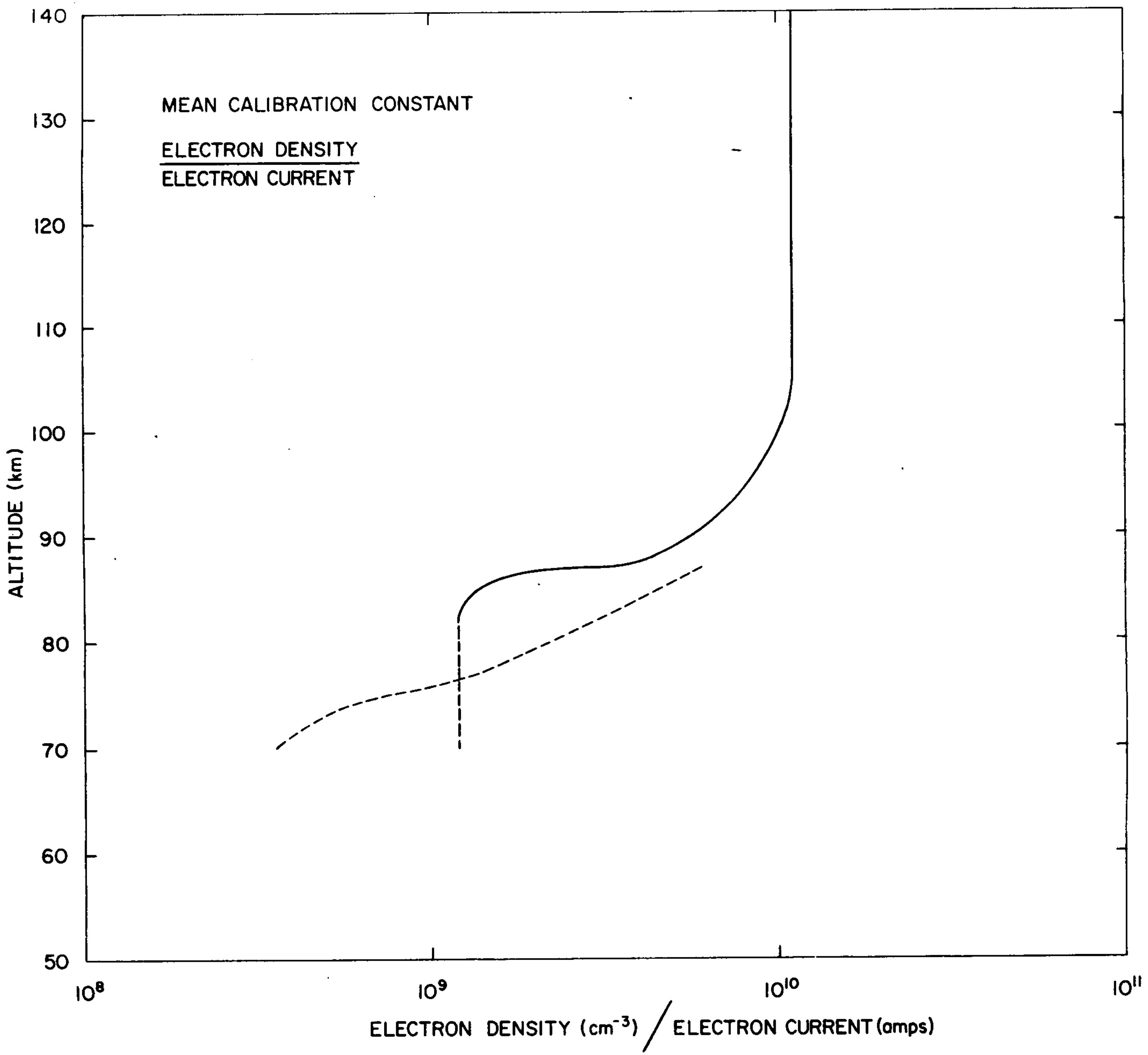

Figure 3.3.6 Mean calibration constant vs altitude, as obtained from the ratio of electron density and probe current for the various shots.

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at different latitudes during the Mobile Launch Expedition. Above 100 km, the electron density is about 10^5 cm^{-3} and stays constant. No latitudinal variation is observed in density except at the lower altitudes (below 80 km).

Figure 3.3.5 shows the various monoenergetic collision frequencies obtained for the rockets described above. These have been obtained by applying the asymptotic multiplicative factor of $\frac{2}{5}$ to the Appleton-Hartree collision frequency. Superimposed is shown the collision frequency obtained by Belrose (1962) from his and other experimenters' observations. Another profile is that of Fejer (1962).

Finally Figure 3.3.6 shows the calibration constant versus altitude, obtained from the ratio of electron density and probe current for the various shots. The curve shown is a smoothed mean value of this ratio, whereas the straight line below 80 km is an average value.

The main difficulties encountered in the analysis were the following:

1. Radar trajectories for the mobile launch gave some inconsistent parameters which had to be corrected.
2. In some experiments, Faraday rotation and differential absorption seemed to indicate different reflection heights for the extraordinary wave. Often the signals were noisy and it was difficult to determine where the real data had stopped. Other techniques of reduction had to be explored and used at the Coordinated Science Laboratory.
3. High resolution readings of Faraday rotation and differential absorption were difficult at the lower altitudes because of the sensitivity of the reduction system.

4. The standing wave cycle count was always hampered by noise in the receiver output channel, but criteria were set to make the count accurate.

References

Belrose, J.S., and L.W. Hewitt (1962), Variation of collision frequency in the lowest ionosphere with solar activity, Nature 202, 267-269.

Bowhill, S.A. (1966), A rocket experiment on the structure of sporadic E, Radio Science 1, 187-190.

Bowhill, S.A., and L.G. Smith (1965), Rocket observations of the lowest ionosphere at sunrise and sunset, COSPAR, Buenos Aires, May, 1965.

Fejer, J.S. (1962), Radio Wave Absorption in the Ionosphere, ed. N.C. Gerson, Pergamon Press, Oxford, 260-274.

3.3B Electron Temperatures in the D and Lower E Regions

J. Salah

This topic includes indirect measurements of electron temperature deduced from collision frequency measurements. It is supported by the National Aeronautics and Space Administration under grant NsG-511.

Whether or not thermal equilibrium conditions exist at D-region altitudes is a question which has led to conflicting theories. This research project has attempted to demonstrate how an average value of electron temperature may be calculated from radio absorption measurements in the D region for several experiments conducted at various solar zenith angles, and to compare the results with neutral temperatures calculated from the observed scale height of molecular oxygen density.

The laboratory measurements of Phelps and Pack (1959) have shown that the electron collision frequency in nitrogen is directly proportional to electron energy, or electron temperature. With very little error incurred, this result may be generalized for air.

Both collision frequency and number density are measured by the rocket experiment.

One measurement of the collision frequency may be extracted from the absorption data and may be corrected by the Sen and Wyller asymptotic factors.

The number density may be calculated from the Lyman-α radiation flux and the molecular oxygen concentration. The value of optical depth factor to be used in this analysis is that at one scale height above the lower altitude in the valid range. For near grazing incidence angles and for $\chi > \pi$, values tabulated by Swider will be used. For $\chi < 70^\circ$, sec χ may be adequately used with less than 1% error.

A knowledge of both these parameters then allows for a formulation of the electron temperature. The electron temperature has been found directly proportional to the product of H, the scale height and the ratio $\nu/\int Jdz$ where ν is the collision frequency, J is defined as $\frac{1}{I}\frac{dI}{dz}$ and I is the Lyman-α radiation flux.

From the reduced formula an average electron temperature may be calculated, limited in altitude range by the collision model and the Lyman-α radiation. A reasonable estimate would be from 80 to 100 km.

Calculation of neutral temperature from the scale height of molecular oxygen has been based on the fact that below 100 km, the atmospheric constituents are in a well-mixed state. The values obtained have yielded temperatures slightly higher than standard atmosphere values. This may be expected especially since we are dealing with an average neutral temperature at mesopause altitudes.

The following table gives the results of these calculations. Reference should be made to section 3.3A for exact launch conditions.

Flight	Zenith Angle	Altitude Range	T_e	T_n	CIRA 1965 at 80 km
14.145	96^o	90-98 km	208^oK	201^oK	185^oK
14.146	85^o	80-100 km	222^oK	218^oK	185^oK
14.230	60^o	86-92 km	223^oK	206.1^oK	218^oK
14.231	67^o	88-98 km	284.2^oK	285.9^oK	218^oK
14.246	60^o	80-96 km	203^oK	196.1^oK	182.5^oK

CIRA 1965 at 100 km: $T_n=213^oK$ with $T=\pm 50^oK$.

The CIRA 1965 temperature values are given at 80 km for the exact month and latitude.

It is seen that all except 14.232 agree well with model atmosphere temperature. Together with 14.232, and to within experimental accuracy, they confirm the experience of thermal equilibrium in the D and lower E regions.

These results support Dalgarno and Henry's (1965) theory and calculation.

Despite equilibrium conditions, 14.232 shows a rather high temperature. This is due to the increased scale height of molecular oxygen which will affect both T_e and T_n. An error of 10^oK should be ascribed to this result because it is based on descent values for Lyman-α flux. In addition, the sensitivity of the photometer was low for that shot.

Based upon this information, the new temperature will be within the quoted CIRA variation range.

Since 14.232 was launched in spring in the southern hemisphere at 60^o latitude, this would correspond to a high latitude northern hemisphere winter shot. The anomalies in temperature are well known for these conditions.

Heat sources are now being studied to explain this increase in temperature and possible evidence in its favor is being sought.

References

Dalgarno, A., and J.W. Henry (1965), Electron temperatures in the D-region, Proc. Roy. Soc. A288, 521-530.

Phelps, A.V., and J.L. Pack (1951), Electron collision frequncies in nitrogen and in the lower ionosphere, Phys. Rev. 3, 340-342.

3.4 Fort Churchill Experiment

E.A. Mechtly
Mukunda Rao
L.A. Schick

Tasks included under this topic pertain to the planning, coordination, and execution of the rocket propagation experiment at Fort Churchill, Manitoba, as conducted under Air Force Electronics System Division contract AF 19(628)-3900.

The Fort Churchill experiment for studying the lower ionosphere at auroral latitudes, which was originally scheduled for January 20, 1966, has been postponed to March 15. The criterion for launching set by AFCRL was that a daytime auroral absorption event of 1.5 db as observed on a 30 MHz riometer should occur. For this reason a study has been made of the theory and operation of the riometer.

Some time was spent in collecting literature on aurora and auroral absorption events. In studying the literature on high latitude absorption, some points of interest became apparent. The high latitude absorption events may be divided into three categories, as follows: (1) Sudden Ionospheric Disturbances (SID), which are mainly daytime phenomena; (2) auroral absorption, which occurs both during the night and day; and (3) Polar Cap Absorption (PCA), which is more intense during the daytime.

The occurrence of auroral-zone absorption events was studied by continuous riometer measurements on a world-wide basis. In general, the lower level events (less than 1 db) are not expected to differ significantly in frequency from those observed during solar maximum. On the other hand, the larger absorption events (greater than 2 db) are practically nonexistent during solar minimum. Using the data reported by Basler, the frequency of occurrence for events between 0.5 and 1.0 db for the Fort Churchill latitude is given as 5 percent. Events of this type may be expected to occur with a rather high probability within a 48 hour period. It has been observed that the occurrence of these high-absorption events is greater during the equinox months. As the Fort Churchill experiment was scheduled for March, it is expected that the chances of finding the desired absorption event are fair.

In preparation for the Fort Churchill experiment, much of the equipment used in the rocket propagation experiment had to be modified or reconstructed because of the change of operating frequency. The system used at Fort Churchill operates at 7.9225 MHz, whereas the frequencies normally used are 3.385 and 2.225 MHz. See section 3.8 for details on the preparation of the instrumentation to be used.

It was decided that the former shipboard sounder van was much better suited for travel because of its large stock of spare parts and equipment. Accordingly, the equipment for use at Fort Churchill was transferred to the sounder van, and the sounder instrumentation was installed in the van originally used for the rocket experiment instrumentation.

The rocket payload receivers supplied by Space Craft, Inc. were calibrated and the payload package was sent to AFCRL for integration into the Black Brant. Testing of the payload at AFCRL was conducted in early March. A 7.9225 MHz carrier was modulated 30 percent with a 400 Hz signal and transmitted to the receiver. The receiver output was observed on an oscilloscope while other experiments included in the payload were switched on individually. A few of the experiments were found to cause definite interference with the received signal. These were (1) The University of Utah's scintillator, (2) Utah's radiometer, and (3) The University of Maryland's retarding potential probe. Some of the interference was eliminated by shielding the wires running through the University of Illinois deck of the payload. However, the experiments mentioned above had to be modified slightly to reduce the interference to an acceptable level. All interference problems were cleared up before the payload was shipped to Fort Churchill.

Prior to departing for Fort Churchill, a general agreement had been reached that calibration of the AGC signal would be attempted with the rocket in flight rather than on the ground, as had been done previously. This is to be accomplished by keeping the ordinary power from the ground transmitters constant and varying the extraordinary power in discrete steps. This process must be completed before the rocket reaches 40 km (at approximately T+35 seconds) so that the loop lock may be restored before the rocket enters the ionosphere. It was also suggested that the ordinary power be decreased to 30 db when the extraordinary attenuator hit the end of its range. It was thought that additional useful data might be obtained by this technique, which will be tried during the Fort Churchill firing.

The University of Illinois team arrived at Fort Churchill on March 15, 1966.

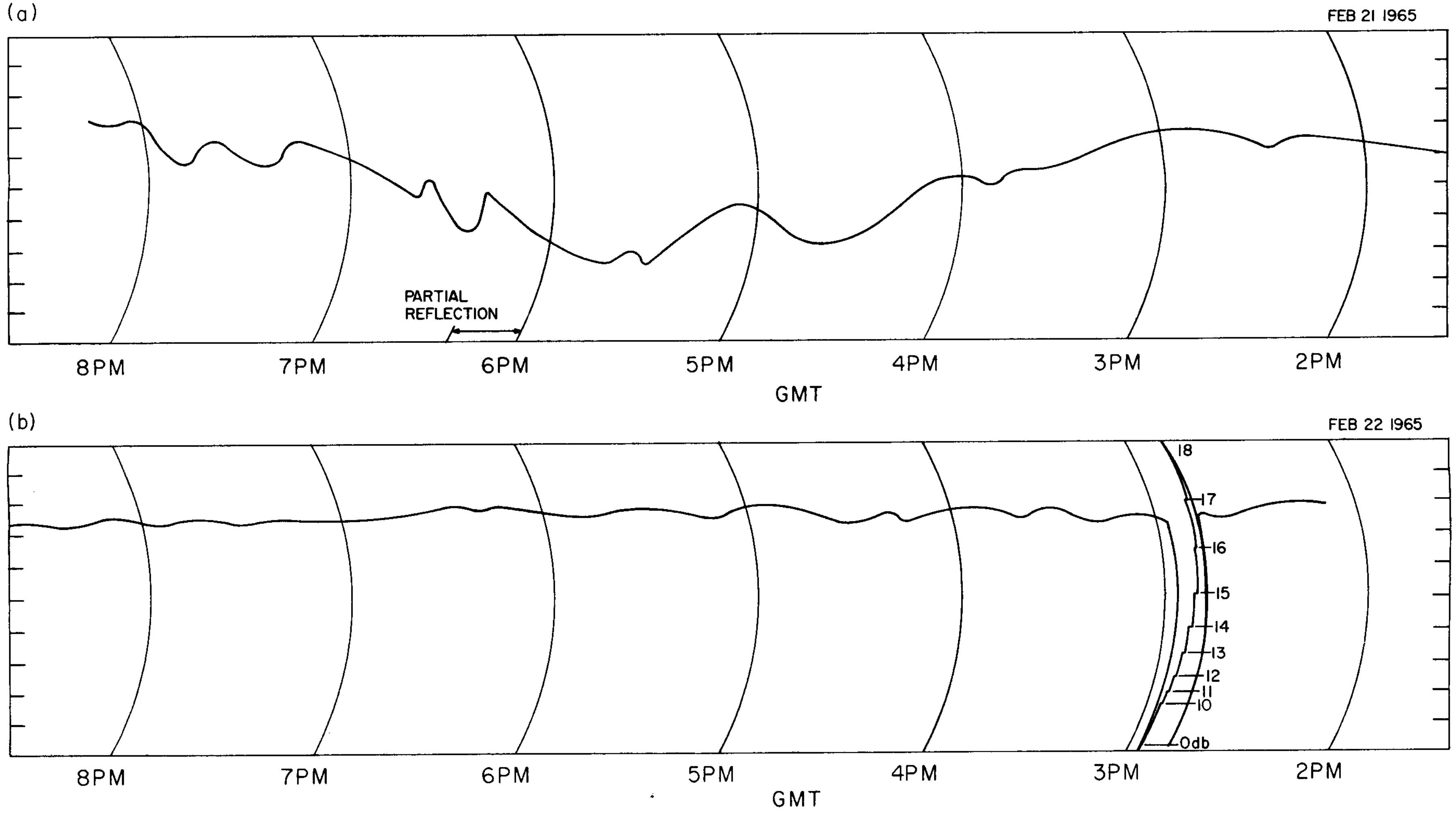

Figure 3.4.1 Fort Churchill 30 MHz riometer records showing (a) a day when an auroral absorption event of 3 db occurred, as compared to (b) a normal quiet day.

NOT CITABLE

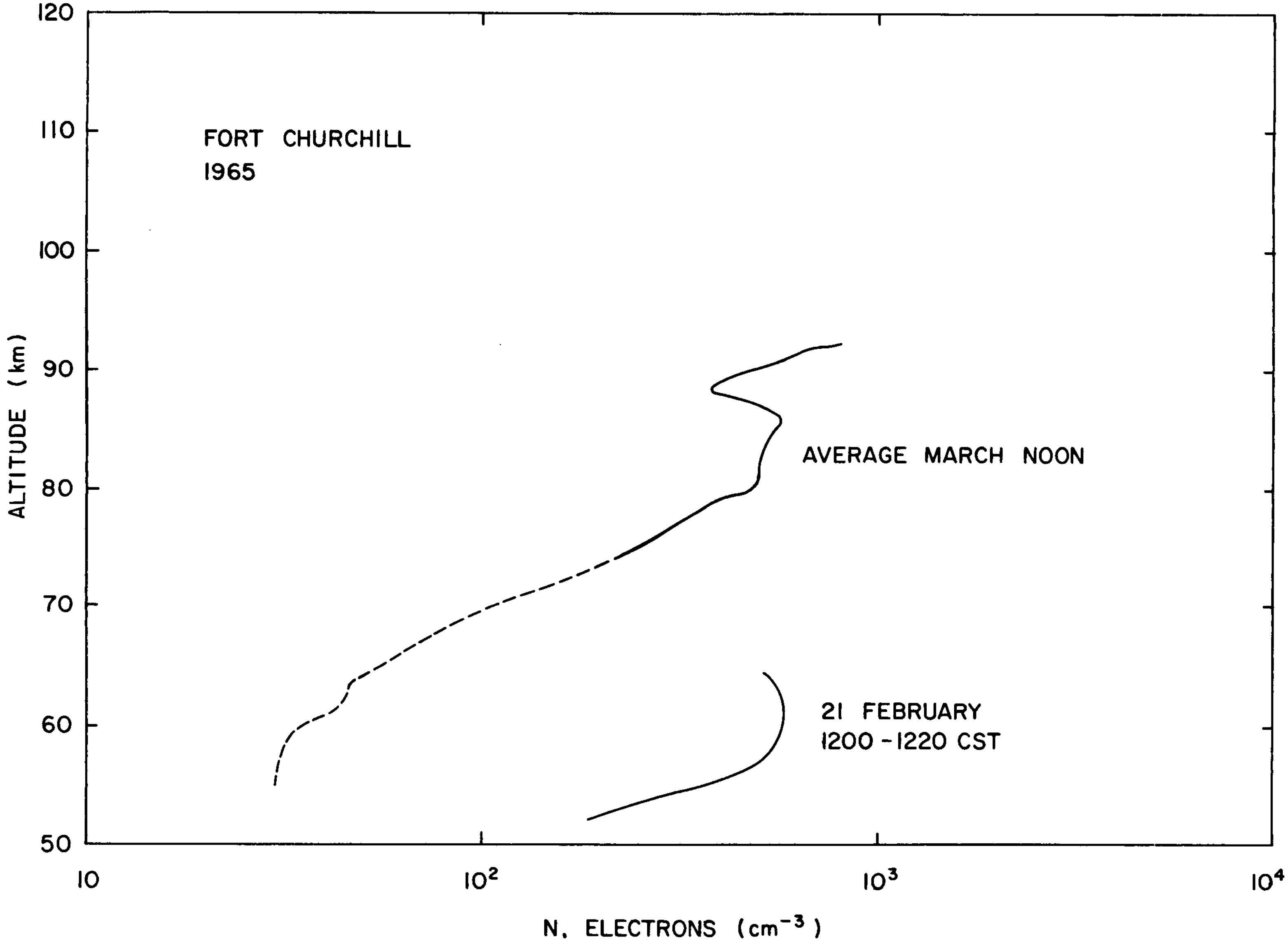

Figure 3.4.2 Electron density profile obtained during the auroral absorption event on 21 February 1965, compared with a quiet day profile.

NOT CITABLE

The instrumentation van also arrived on that date and was pulled out to the launch area. The equipment was tested for normal operation. Most of the equipment functioned properly, although some minor difficulties were encountered (see section 3.8 for details). Most of the week was spent in preparing the van for the firing.

On March 22, Dr. Sandock, the project scientist, and his team arrived from AFCRL. A meeting was convened between the range personnel and the project personnel on March 23 to discuss the requirements for the experiment. It was decided that the first attempt at firing into the daytime auroral absorption event should be made on April 1, 1966. The launch window requested was between 8:00 A.M. and 2:00 P.M. local time.

A preliminary analysis of the riometer charts for February, 1966 indicated a strong correlation between f_{min} values and cosmic noise absorption. It was therefore decided to look into f_{min} values before making a decision to fire, as a check on the occurrence of the desired event. According to the instructions of Dr. J.S. Belrose, Mr. Albert Maoine, who is operating the partial reflection equipment at Fort Churchill, was contacted and he was requested to take the records during the time of the shot.

The criterion set for the Fort Churchill experiment is that a daytime auroral absorption event of greater than 1½ db as observed on a 30 MHz riometer should occur. To illustrate the desired event, in Figure 3.4.1 the riometer record is shown when an event of 3 db occurred as compared with a normal quiet day record during the same time. In Figure 3.4.2 is given the electron density profile obtained during the above said event and it is compared with a quiet day profile to show the order of increase

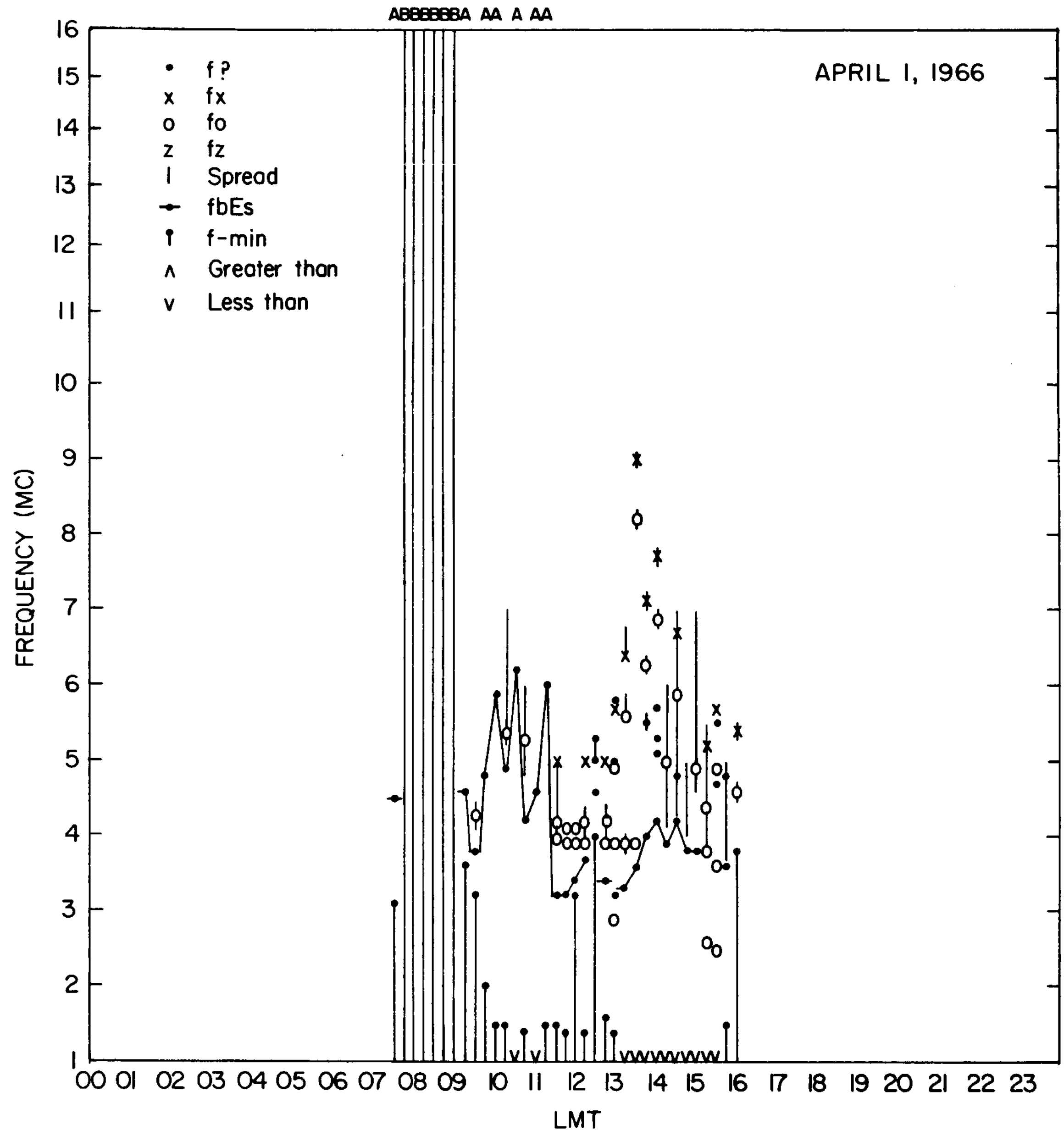

Figure 3.4.3 An f-plot of the various ionospheric parameters during a day when a auroral absorption event occurred. Notice that the diurnal variation of f_of_2 is completely different from a normal day.

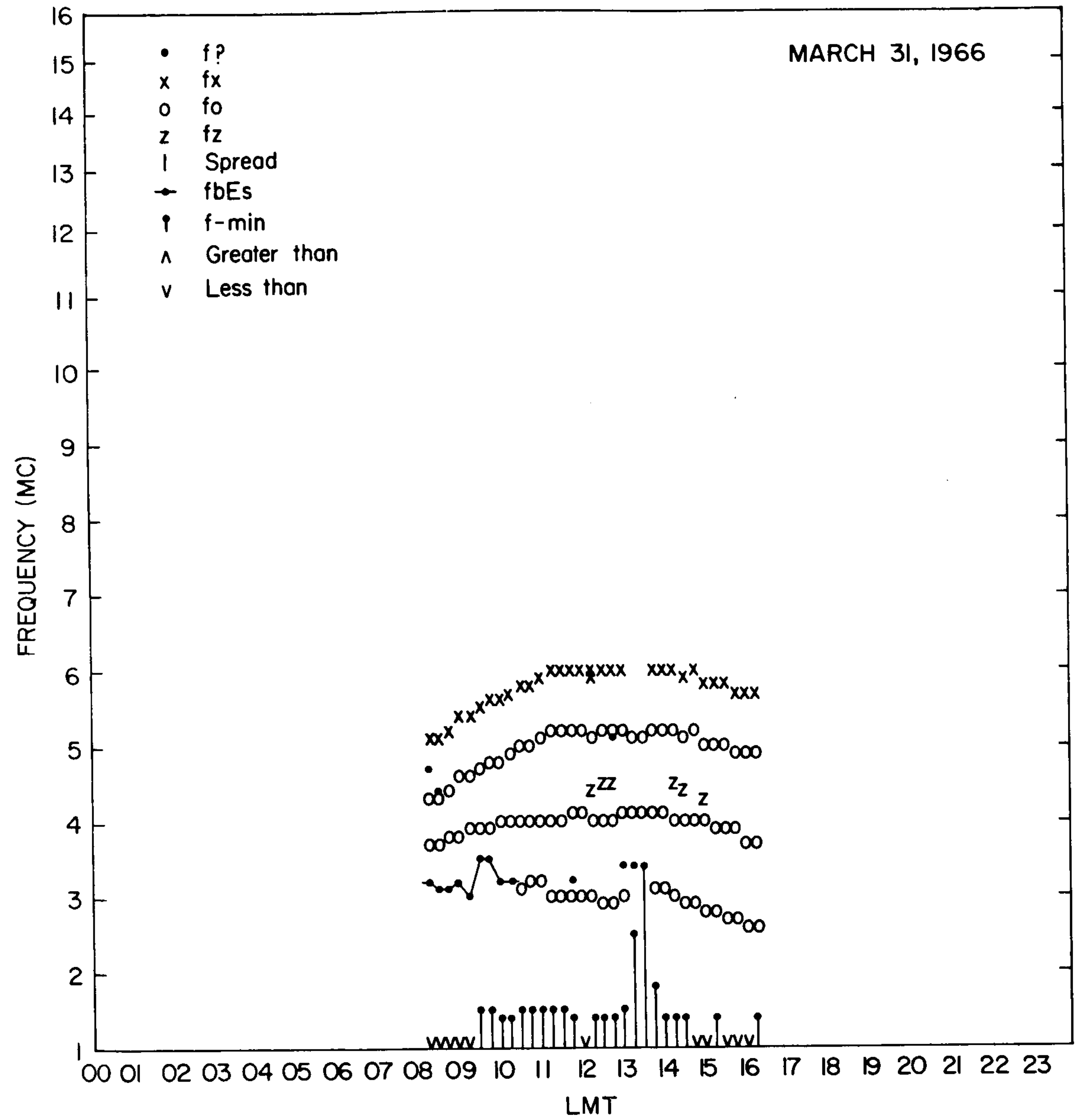

Figure 3.4.4 An f-plot taken at Fort Churchill on a quiet day.

NOT CITABLE

of ionization (after Belrose). In Figure 3.4.3 a plot of the different ionospheric parameters is shown during a day when an absorption event occurred and in Figure 3.4.4 a quiet day plot is given for comparison. It can be clearly noticed in Figure 3.4.3 that at the time when the event occurred (between 0730-0930 L.T.) the f_{min} values (the continuous lines) show an abnormal increase even to the point of blacking out the F_2 region reflections. During such events the magnetometer also records large changes of the order of 500γ. So before making a decision to fire the rocket, in order to hit at a daytime auroral absorption event, the riometer, the ionosonde, and the magnetometer located at the launch site are consulted.

3.5 Puerto Rico Experiment

E.A. Mechtly
Mukunda Rao
L.A. Schick

Tasks included under this topic pertain to the planning, coordination, and execution of the rocket propagation experiment at Camp Tortuguero, Puerto Rico, as conducted under NASA grant NsG-511.

The launching of two Nike-Apache rockets on the afternoon and after sunset of June 6 or 7, 1966 was conceived for the purpose of comparing rocket measurements with incoherent backscatter data to be obtained simultaneously from the Arecibo Ionospheric Observatory at Arecibo, Puerto Rico.

R.T. Long (of NASA-Wallops Station), D.C. Tackett (of NASA-Goddard Center), and E.A. Mechtly (of the University of Illinois) visited Puerto Rico on March 27-29, 1966 for planning of the Nike-Apache shots scheduled for June.

J.W. Findlay, Director of the Arecibo Ionospheric Observatory, was informed of the June 6 target launch date. He stated that there would be no problem scheduling ionospheric backscatter observations for this date.

Mechtly agreed to forward plans for the rocket experiments to AIO as they are developed.

Col. Rafael Gorbea of the P.R. Army National Guard approved use of the Camp Tortuguero military base as a launch site, with the provision that the approaches to the landing strip would not be obstructed. Examination of aerial photographs indicates that this requirement can easily be satisfied. The plan is to use the Nike launch pad, located on an aircraft parking circle, which was used by AFCRL earlier this year.

Donald Ross, of the FAA in San Juan, showed maps of the impact zone used for the AFCRL shots. The plan is to use the same zone with its center line azimuth of 315° from the pad at Camp Tortuguero.

Navy Captain Collingwood agreed to provide surveillance of the impact zone, probably by a P2-V aircraft.

Major Lilley, Signal Officer of the U.S. Army Antilles Command in San Juan, assisted by Capt. Wootan, and Lt. Conrey, were authorized by their commanding officer to serve as operations coordinators for these shots. Major Lilley agreed to provide all necessary radio communications. However, the Antilles Command is being dissolved and its communications support will not be available after June 31.

Navy Commander Windahm cleared the frequency of 3.385 MHz ± 10 kHz for the radio experiments, and 231.4 MHz for telemetry. The 240.2 MHz telemetry frequency is already allocated. The specification of several alternate telemetry frequencies is necessary to assure that at least one is available.

Mr. A.E. Ehlers, of Eglin AFB, Fla., launch control officer for the AFCRL shots, has stored a Nike Launcher, a van with equipment, two 5 kva generators, and several other items of launch equipment at Camp Tortuguero. If Mr. Ehlers approves, this equipment could be used to advantage.

Guards to protect the launch equipment from vandalism, and a tractor for towing vans from San Juan to Tortuguero were not available from the government agencies represented above.

It has been decided that both rocket propagation experiment payloads for the Puerto Rico shots will operate at 3.385 MHz. GCA Corporation, which will construct the payloads, has been notified of this decision.

Present plans call for the use of the van presently at Fort Churchill for the Puerto Rico experiment. Some thought has been given to the problem of converting the instrumentation van back to operation at 3.385 MHz from the 8 MHz frequency to be used at Fort Churchill. There are two possibilities:

1. Have the van shipped to Wallops after the Fort Churchill shot and send a team from the Aeronomy Laboratory to Wallops Island to perform the necessary modifications.
2. Ship the van back to the Aeronomy Laboratory at Urbana for the conversion.

Assuming that the van will be shipped to Puerto Rico from Wallops Island, the first suggestion seems to be better because of the time saved in shipping as well as the cost of shipping the van back to Urbana.

Some thought has also been given to the problem of constructing antennas at Puerto Rico. The Aeronomy Laboratory apparently has some telescoping poles that could be used and thereby perhaps eliminate the setting of telephone poles. A transit would probably be needed to assure a square array if the telescoping poles were used.

3.6 1966 Eclipse Experiment

S.A. Bowhill
E.A. Mechtly

Tasks included under this topic pertain to the planning, coordination, and execution of the rocket propagation experiment under total eclipse conditions in South America on November 12, 1966, as conducted under NASA grant NsG-511.

A project description was initiated in November, 1965 with Dr. R. Fleischer of NSF, in charge of coordination of all eclipse projects in the USA, for a relatively modest program of 6 or 8 rocket firings close to totality from S. Brazil or N. Argentina. The purpose of the program is to accomplish measurements of lower ionosphere rate coefficients during the November 12, 1966 solar eclipse.

Contact was established with Dr. S. Radicella of the National University of Tucuman, Argentina, who expressed great interest in a cooperative rocket experiment for the 1966 eclipse; he is exploring this matter with the Argentine Space Committee.

A letter was subsequently received from Col. Fernando de Mendonca, in charge of the Brazilian National Space Effort. He made the suggestion that the 1966 eclipse experiments either be carried out from a Brazilian ship or from a Brazilian Air Force site fairly close to Rio Grande. Consideration will be given to this suggestion, as soon as a reply is received from Dr. Radicella.

A letter was also received from Dr. Padula-Pintos, Chairman of the Argentine Commission 3 of URSI offering to assist in any way possible with eclipse measurements.

Initial contacts with Dr. Schmerling of NASA indicated a considerable interest by NASA in carrying out the proposed program. He indicated that he would be quite agreeable to such a program provided we regarded it as coming out of our 1966-67 allowance of rockets (approximately 8). In view of this, it is suggested that the September program be scrubbed, and that the aim be to have several mass spectrometer rounds in the eclipse, as well as the Type A payloads already planned for the study of the lowest ionosphere. In the event that the July mass spectrometer round is not successful, the ms payloads would be simply scrubbed from the eclipse program.

L.G. Smith and E.A. Mechtly attended a meeting on Wednesday, February 9, 1966 at the National Science Foundation in Washington, D.C. on planning of the 1966 Eclipse Experiment.

Dr. Robert Fleischer, NSF chairman, limited the discussions primarily to coordination of contemplated rocket launchings by Cambridge Research Laboratory, Ballistics Research Laboratory, AEC-Sandia Corp., Illinois-GCA, and possibly Pa. State Univ. Most of the groups considered Rio Grande (Southern Brazil) the most desirable launch site, and there was considerable discussion on the merits of central communications and control versus independent operations. E.R. Schmerling, J.R. Holtz, and R.J.H. Barnes represented NASA (Illinois-GCA) interests. All groups agreed that a delegation consisting of spokesmen from each group would survey the Rio Grande site on March 14. A preliminary meeting of the delegation members was scheduled for Washington, D.C. on February 28. NASA-Illinois-GCA had not yet taken a position favoring location in Brazil or Argentina, and received the consent of Dr. Fleischer to visit Argentina before the March 14 meeting in Brazil.

Dr. L.G. Smith provided the following summary of the 1966 Eclipse Planning Meeting in Washington on February 9, 1966:

"Dr. Robert Fleischer, National Science Foundation, arranged this meeting to discuss the international requirements relating to rocket program planned for the eclipse of 12 November 1966. The path of totality passes through Northern Argentina and Southern Brazil.

"There are five programs of rocket launches: two are sponsored by DASA, one by AEC, and two by NASA.

"The two DASA programs are under the overall supervision of Warran Berning of BRL. The DASA 6.3 program is run by Mester of BRL and will consist of our Hydac rockets to study the D region; rocket apogee is 85 km. Electron density will be measured on ascent using a Langmuir probe. A parachute will be released at 80 km and mobility measurements will be made during the parachute descent. The mobility instrument is being developed by AVCO.

"The DASA 6.4 program is run by J. Ulwick of AFCRL. Three Nike Hydac (or Nike Javelin III) rockets are instrumented to investigate the ionosphere to 110 km. These are the payloads to be integrated by GCA Engineering Operations and for which G. Accardo and L. Weeks will be supplying the solar radiation experiment.

"The AEC program is run by Argo of LASL with the assistance of Sandia Corporation. Five Nike Tomahawk rockets will be used to observe 8 preselected lines in the solar x-ray spectrum between 16 and 40 A.

"The two NASA programs both involve GCA experiments. One is the joint University of Illinois-GCA investigation of the D- and E-regions of the ionosphere. Four Nike-Apache rockets are to be launched with two more being available as backups. E.R. Schmerling is the NASA technical monitor.

"The other NASA program is a proposed wind measurement by the vapor trail method. One Nike-Apache rocket will be used with one more as backup. Photographs of the trail are to be made from the NASA aircraft as well as from ground stations. M. Dubin is the NASA technical monitor.

"It has apparently been decided that the NASA aircraft will be flying over Northern Argentina during totality which therefore restricts the launch site for the wind measurement to the same area. Otherwise the programs can be carried out in either Argentina or Brazil; the latter is preferred for logistic as well as scientific reasons. The final decision will, however, probably depend on diplomatic factors.

"The sponsoring agencies appear ready to support their respective programs once permission to launch rockets is granted by Argentina or Brazil. As yet no response (positive or negative) has been received in Washington but this is probably because details of the program had not been communicated to the respective countries.

"Fleischer is to make the next move. He is taking a group, representative of the scientific and engineering aspects of the rocket launches as well as the diplomatic aspects, down to Brazil, leaving on March 14, 1966. This trip is conditional on word being received that the Brazilians are interested in discussing the possibility of rocket launches.

"The meeting achieved its primary objective which was to spell out the scope of the total U.S. rocket effort for the November eclipse."

Dr. Lic. Sandro M. Radicella of the Universidad Nacional de Tucuman, Argentina, indicated by a cable of February 16 that Argentina will support the NASA-UI-GCA eclipse experiments in Argentina. A letter from Dr. Radicella followed, elaborating on his cable of February 16. The letter extended an invitation to the NASA-UI-GCA group to conduct its 1966 eclipse experiments in Argentina.

E.A. Mechtly attended a meeting at the National Science Foundation on Monday, February 28, concerned with plans for the visit of a U.S. delegation to Brazil and Argentina for the survey of sites for eclipse rocket experiments.

A revision of the description of the NASA-UI-GCA Eclipse Experiments was drafted and mailed to Dr. Robert Fleischer (of NSF) for up-dating the Eclipse Manual. The revised description, distributed to Eclipse Manual addressees by Dr. Fleischer, may be found on the following pages.

1966 ECLIPSE MANUAL

Institution:	University of Illinois, Aeronomy Laboratory
Investigator:	S. A. Bowhill
Title:	Lower Ionosphere Rocket Measurements
Purpose:	Determination of lower ionosphere constituents, and their reaction rates
Description:	Measurements of atmosphere density, ion composition, ion density, electron density, and electron temperature will be made by Nike-Apache payloads including a radio propagation experiment, a DC probe, an ion collector, a mass spectrometer, and ultraviolet photometers.
Reference:	University of Illinois Coordinated Science Laboratory Report R-273, December 1965 GCA Corporation Technical Report No. 65-25-N, October 1965 GCA Corporation Technical Report No. 65-21-N, April 1965
Location:	Brazil, Rio Grande
Dates:	October 1 through November 15, 1966
Number of People:	12

Equipment: 100,000 kg (220,000 lb), 170 cubic meters (220 cubic yards), $2,650,000

Cooperating: Charles D. Hendricks, Univ. of Illinois, mass spectrometer; Leslie G. Smith, GCA Corporation, D.C. probe, and photometers

Power: 25 kW

Special Needs:

1. Six Nike-Apache rockets shall be on internal power, ready for launch at $T_o -400$ seconds, where T_o is the time of center of total eclipse at the launch site.

2. Rockets 1 through 4 inclusive shall carry type A payloads.

3. Rockets 5 and 6 shall carry type C payloads (i.e. with ion mass spectrometers).

4. Each of the six payloads shall radiate on a separate telemetry carrier frequency.

5. Two independent telemetry receiver facilities shall be operated. They shall record telemetry from the two most important payloads at any given time.

6. Two independent tracking radar facilities shall be operated. Radar tracking requirements shall be relaxed at 100 km to permit tracking of the next rocket as necessary.

7. All six payloads shall use the same frequency for the radio propagation experiment, about 3 MHz (probably 3.385 MHz).

8. The launch schedule is as follows:

Rocket Number	Launch Time (in seconds) with respect to time of center of total eclipse
1	-390
5	-150
2	+ 30
6	+7200

Rocket No. 3 and Rocket No. 4 shall be launched only if rockets 1, 5, 2, and 6 are not completely successful.

Status: 0.8

Funds: $300,000, NASA, 0.6

On Saturday, March 12, E.A. Mechtly and S.A. Bowhill left Champaign for Rio de Janeiro, arriving March 13. The purpose of the visit to Brazil, and subsequently to Argentina, was to determine the feasibility of a program of rocket and ground-based measurements in South America during the total solar eclipse of November 12, 1966. The inspection team consisted of the following: M. Kramm, P.D. Seward, and W.E. Walker of Sandia Corporation; W. Berning, J. Linberg, and B. Porter of DASA; J. Morrison, R.K. Long, and C.D. Tackett of NASA; S.A. Bowhill and E.A. Mechtly of the University of Illinois. The Sandia, DASA, and NASA programs are, of course, quite separate, each involving between five and ten rockets.

Eclipse Site Survey in Brazil

Discussions were held Monday morning with the Science Attache at the U.S. Embassy in Rio de Janeiro, Mr. Simonpietri, and other Embassy personnel; and in the afternoon with Dr. F. de Mendonca and other officials of the Brazilian Space Commission. The scientific and technical requirements for the program were presented to them in outline. Detailed discussions were held Monday afternoon and Tuesday morning with Dr. de Mendonca. He had made a very detailed survey of a possible launch site near Rio Grande, which appeared to fulfill most of the requirements for a rocket program. He also offered to make available NASA equipment from his present launch range in Natal. However, it appears that the scientific participation of his group would be limited. He has carried out several ionospheric rocket experiments recently using an ultraviolet spectrometer consisting of a photoemissive surface combined with an electron retarding potential analyzer, together with a Langmuir probe on the same payload.

He indicated that he might be interested in putting a spectrometer of this kind on one of our payloads to be fired during totality, to study the ionization from scattered Lyman lines of hydrogen (which he believes responsible for the ionization in the night E-layer).

The Brazilian officials were receptive and offered general cooperation and support for the conduct of the eclipse rocket programs in Brazil.

Monday night, Delegation Members had detailed discussions with Dr. de Mendonca who gave the following information in answer to questions:

1. Any frequency above 2 MHz is available for eclipse experiment.
2. There are two stations in the broadcast band at Rio Grande.
3. There is about 1 ship per day entering Rio Grande port.
4. The line power in Rio Grande is 50 Hz, 3 phase, 13 kV, with 90 to 129 V fluctuations.
5. There is one new hotel in Rio Grande.
6. There is ample local labor available.
7. Rental trucks are available.
8. The port-to-site distance is about 20 km.
9. Docks and heavy cranes are available.
10. About 8 cars can be rented at Rio Grande, and 50 at Pelotas.
11. There would be difficulty buying radio silence, but there is no problem above 2 MHz.
12. The required concrete pads are no problem.
13. Poles are not available at Rio Grande.
14. A 70 km radius impact zone is no problem.

15. A C-130 cargo aircraft could be flown to Washington D.C. and then to Porto Alegre with equipment for eclipse experiments.

16. Rio Grande can be used as port of entry.

The Delegation arrived in Rio Grande on Wednesday, 16 March via Brazilian Air Force DC-3 piloted by Lt. Col. Freitas. Mr. Luiz Gylvan Meira of CNAE escorted the Delegation and acted as interpreter.

Photographs of the proposed launch site were taken from the aircraft before it landed at the Rio Grande airport (which is no longer in commerical service).

The Mayor of Rio Grande provided vehicles in which he and the Delegation Members were transported to the proposed launch sites on the Rio Grande beach. Close up photographs were taken. The beach is about 3 km in length and 150 to 200 meters in width. High tide sweeps in over the sand a distance of about 50 meters and at the boundary of the high tide level there are sand dunes ranging from small mounds to hills as high as 15 or 20 meters. The dunes fall off sharply on the west side into an impenetrable swamp. The sand is fine grained and well compacted and apparently capable of supporting heavy vehicles. Automobiles and trucks drive on it without difficulty.

On Thursday, the Delegation met with the Rio Grande Mayor and City Engineer for detailed discussion of operational requirements and available resources. Some of the many facts provided are:

1. The road to the beach via Cassino, the small town south of Rio Grande, will bear 17 ton loads.
2. The railroad to the beach from the port will also bear 17 ton loads. It is controlled by the port authority.

3. The cost of concrete is about $35.00 per cubic meter.

4. The cost of concrete forms is about $.25 per square meter.

5. The cost of a building is about $48 per square meter with brick wall, wood roof covered with asbestos sheets, and with lights and windows.

6. Diesel fuel costs about $.07 per liter.

In summary, the Rio Grande beach is entirely satisfactory as a launch site for the eclipse programs. Supporting facilities appear to be available or can be delivered by ship with little difficulty.

Eclipse Site Survey in Argentina

On March 15 Dr. Bowhill left Rio for Buenos Aires, and made an appointment with the AEC representative in the U.S. Embassy, Mr. Lester Rogers, for the following day (Dr. Woodruff, the Science Attache, being out of town until March 18).

After a telephone conversation Wednesday with Commodore Riccardi, Chairman of the Argentine Eclipse Committee, and Mr. S. Radicella, Director of the Ionosphere Station at Tucuman, it was determined that Bowhill should meet with Mr. Rogers. Bowhill mentioned comments made by our Embassy in Rio that a sharing of the program between Brazil and Argentina might be desirable. He agreed whole heartedly with this (as did Dr. Woodruff later).

In the meeting with Commodore Riccardi, he drew attention to two possible launch sites:

1. Ciro Echesortu, 10 miles south of Tartagal, firing southeast across the eclipse path into an uninhabited area. The suggested launch site is adjacent to a 2 km airstrip operated by YPF, the nationalized petroleum

combine, to service the surrounding oilfield area. YPF power lines are available close by. The area proposed would be for the meteorological rocket site to be at one end of the runway, and the NASA site at the other . This would permit common meteorological and range safety support. The disadvantage of this site is its distance (about 1800 km) from Buenos Aires. The nearest jet service is to Salta (about a three-hour drive); direct service by Avro prop-jet is available 3 times per week in each direction to Tartagal (whose airstrip is not as elaborate as that at Ciro Echesortu).

2. Corrientes, a city of substantial size in northeast Argentina on the Parana river, firing again to the southeast. Direct jet service is available from Buenos Aires.

He indicated that both sites seemed acceptable from the scientific standpoint, permitting the upleg and downleg to be in the zone of totality at 50-170 km. After considerable discussion, it was determined that a full scientific partnership between the U.S. and Argentina would best meet the desires of the Argentine group. It appears that Argentina would be able to make available very considerable logistic and personnel support for the operation. However, the feasibility of an eclipse program in Argentina was evidently contingent on an inspection of the available sites by the NASA team.

On Thursday, March 17, Dr. Bowhill proceeded to Tucuman and met with Mr. Radicella. He seemed most enthusiastic concerning the program, and indicated a strong desire to participate scientifically. They then outlined 13 problems which might be studied in using results from the program:

1. Heat transfer between electrons, ion, and neutrals in the eclipsed E-layer.
2. Ion species and recombination coefficients.
3. Neutral density variations in eclipse.
4. Attachment rate in D-layer.
5. Photodetachment rate in D-layer.
6. Ion current very low down for cosmic ray production.
7. Sporadic E phenomena.
8. Stratification in upper E- or lower F-layer--comparison with sounder data.
9. Variations of x-ray emission through eclipse.
10. Possible negative ions in E-layer.
11. Use of N-h profiles and collision frequencies to give integrated conductivity and compare with S_q through eclipse from magnetometer.
12. Comparison of VLF and N-h profiles and full wave solutions.
13. Sodium cloud experiment and ionospheric drift.

Radicella indicated his prime interest was in topics 1, 7, 8, and 11; and Bowhill indicated prime interest in 2, 4, 5, and 6. The remaining problems are of a more speculative kind.

In the event that it was decided to go ahead with the experiment in Argentina, it was resolved that both Radicella and the UI group would work out the exact time of totality for altitudes of 60, 120, and 180 km, using rocket trajectories with a permissible sets of azimuths and ranges. This would then enable determination of exact time of launch for various contingencies. Radicella would scale from his ionospheric routes at Tucuman, the ordinary blanketing frequency distribution, for each hour for the combined months of November 1963, 1964, and 1965; and the distribution of foE and fEs on the same basis. This will permit a determination of the frequency to be used.

On March 18, Dr. Bowhill returned to Buenos Aires and met the NASA and Sandia teams who had just arrived from Brazil. On Saturday morning they conferred with N.H. Woodruff, Scientific Attache of the U.S. Embassy. Bowhill returned to New York on Saturday evening, March 19. Members of the Delegation representing the Berning and Ulwick experiments had returned to the U.S. after having chosen the Rio Grande, Brazil launch site. On Monday, March 21, and Tuesday, March 22, the Delegation met at the office of Commodore Humberto Jose Ricciardi, President of Argentina Eclipse Coordinating Committee.

Present were:

Tabenera	(Argentina Space Commission)
Ricciardi, H.J.	(Argentina Eclipse Committee)
Radicella, S.M.	(Tucuman University)
Technical personnel from the Argentina launch crew	
Morrison, J.R.	(NASA Office of International Affairs)
Tackett, C.D.	(NASA Goddard Rocket Sounding Branch)
Long, R.T.	(NASA Wallops Station)
Mechtly, E.A.	(University of Illinois)
Woodruff, N.H.	(U.S. Embassy)
Kramm, M.L.	(Sandia Corp.)
Walker, W.E.	(Sandia Corp.)

All present became convinced that the Nike-Tomahawk rockets specified for the Argo experiments require a larger impact zone than is available in Argentina. After the group arrived at this conclusion, M.L. Kramm and W.E. Walker returned to the U.S., and further discussions were focused on the Bowhill and Webb experiments.

Ricciardi stated that the resources of the Resistencia-Corrientes area are fully committed to the support of Blamont's experiments and can not support a second rocket program. Attention was then concentrated on the Tartagal area for the NASA-Bowhill program.

Maps of the Tartagal district were distributed and examined for adequacy of impact zone. Ricciardi assured the group that he would be fully responsible for range safety, and asserted that the impact zone is virtually uninhabited jungle. Later examination of the area from the air verified this fact.

Preliminary sketches of launch site layouts were made. They included four main groups; launch pads and control van, two telemetry and one Univ. of Ill. van, two MPS-19 radars, storage and assembly buildings. One Nike launcher, one MPS-19 radar, and one telemetry station are available in Argentina with crews.

A set of deadline target dates was established as a framework for operators.

April 15 - a decision to conduct or not to conduct the NASA eclipse experiments in Argentina

August 15 - on-site construction to begin

October 15 - all shipped equipment received in Buenos Aires

October 15 - completion of on-site construction and occupancy

Morrison, Tacket, Long, and Mechtly had an additional discussion with Radicella and it was apparent that full scientific and technical cooperation and support is available from the University of Tucuman.

On Wednesday, March 23, the group flew from Buenos Aires to Salta, and on March 24 from Salta to Tartagal in an Argentina Air Force DC-3.

In Tartagal the group was well escorted, housed, and fed by representatives of YPF, Argentina's nationalized oil industry.

The YPF air strip at Ciro Echesortu is 3 km in length, and 30 m in width and is construct of compacted-asphalted earth. The airstrip lies on a clearing of 200 m width cut out of the jungle. YPF has offered the airstrip for the location of all launch facilities required by the NASA-Bowhill program. Ricciardi can provide a determination of the location of the YPF airstrip to within 2 or 3 arc seconds.

YPF is currently drilling nine oil wells in the Tartagal area to depths of about 4 km. The associated heavy machine shops, light machine, carpentry shops, and associated cranes, forklifts, etc. are all available in support of NASA within about 3 km of the Ciro Echesortu airstrip. YPF can provide two 27 kva diesel generators at the airstrip.

The YPF operates a radio-teletype system between Tartagal and Buenos Aires which would be at NASA's disposal for the eclipse program.

There are three adequate, although not plush, hotels in Tartagal for launch crew housing. There is also a nearby military base with available quarters. YPF operates a community of its own which offers a swimming pool, tennis courts, movie theater, club house, etc. for recreation.

In summary, Tartagal-Echesortu is well suited as the launch site for the NASA-Bowhill 1966 Eclipse Program. The principal obstacle in using the site is the distance of about 1500 km from port facilities in Buenos Aires. However, the highways are excellent and transportation by truck can be accomplished.

After careful consideration of the many factors involved, E.R. Schmerling and J.R. Holtz made the decision to launch the NASA-UI-GCA rockets for the November 12, 1966 Eclipse from Rio Grande, Brazil.

3.7 Equatorial Experiment

Mukunda Rao

Tasks included under this topic pertain to the interpretation of data obtained from Nike-Apache 14.228, fired at the geomagnetic equator during the NASA Mobile Launch Expedition. This project is being conducted under NASA grant NsG-511.

The magneto-ionic theory has been studied in detail and the equations for differential absorption and Faraday rotation using the quasi-transverse approximation have been derived. The method for analyzing the rocket data to obtain the electron density and collision frequencies has been studied and the analysis of the equatorial shot 14.248 has been started.

The variations of differential absorption and Faraday rotation for 14.248 show many anomalies. First of all, the differential absorption shows an increase up to 80 seconds after launch and then decreases, whereas it is expected to increase still further. However, using these values, electron densities were deduced between 76 and 96 km. Utilizing these electron density values the Faraday rotation angles at different heights were calculated and compared with the observed values. From this comparison many disparities were observed, the most important one being that the observed FR values show a decrease of height up to the 78th second after launch, whereas the reverse is expected according to theory. From an examination of the telemetry record it has been observed that the rocket receiver detector output is very noisy up to the 78th second and from that time on it improved. So it is necessary to discard the observed FR and DA data before this time. The data were processed again, this time introducing noise filters and observing carefully for the possibility of the phase detector registering an extra 180°

under noisy conditions. Upon examining the new computer output, it has been observed that at about the 78th second after launch, the Faraday rotation began to increase at a very fast rate. Within less than two seconds it had increased from 110° to 2580°. Using the usual formula for N and the observed values of FR, a very high value of N was derived. However, Prof. Bowhill has pointed out the possibility of observing such large values for FR if that particular point is an extraordinary reflection point. However, it was thought that it would be better to confirm the reliability of the data by observing the computer output again, this time with 100 points per second. Meanwhile, Mr. J. Gooch of the Coordinated Science Laboratory is working on improving the existing analog Faraday rotation data reduction system to yield more reliable results under noisy conditions.

The standing wave analyses have been started for obtaining the electron density profile above 100 km. The actual number of cycles has been counted between 98 and 138 km, but for calculating the number of geometric cyles, the trajectory supplied to us does not contain the slant range (SR) and the elevation angles (EL). Hence a letter was addressed to Mr. Robert T. Long of Wallops Station, requesting that he send new trajectory data which include both SR and EL values. However, it is possible to calculate the SR values from the available trajectory data.

In conclusion, it must be mentioned that the data are noisy at many points and this might be due to the interference of broadcast stations. Therefore, great care must be exercised in drawing any definite conclusions from these data.

3.8 Instrumentation Design

G.W. Henry, Jr.
T.W. Knecht
J.E. Russell
L.A. Schick

Tasks included under this topic pertain to the design, construction, and maintenance of instrumentation for use in the rocket propagation experiment, as conducted under NASA grant NsG-511 and Air Force Electronics Systems Division contract AF 19(628)-3900 (the latter applies only to operations in connection with the Fort Churchill project).

I. Instrumentation for Fort Churchill

In preparation for the rocket propagation experiment to be conducted at Fort Churchill, Manitoba it was necessary to modify all RF components of the system to operate at 7.9225 MHz. The system was originally designed for use in the 2 to 3 MHz range. In many cases, it was only necessary to change tuned circuits to the higher frequency. However, some circuits required extensive modification or rebuilding. The major changes are indicated below.

Exciter

An 8 MHz exciter for use with the rocket propagation experiment at Fort Churchill has been constructed and tested. This unit contains two crystal-controlled oscillators to generate the circularly-polarized signals which drive the one kilowatt linear amplifiers. It was found that the system used previously, in which the tank circuits of the exciter amplifier stages were located at the piston attenuators, was not satisfactory. At 8 MHz the length of the line from the exciter to the attenuators had too much capacitance to allow the attenuator input to be tuned to the operating frequency.

A pi-network for the exciter amplifier output was breadboarded and tested. The use of this network allows one to match the amplifier output to a 50-ohm load, and consequently the length of cable to the attenuator is no longer critical. A resonant autotransformer was added to the attenuator input to match the 50-ohm line to the input link impedance.

The original design for this unit also failed to give an adequate range of control of output amplitude, thereby making accurate adjustment of modulation percentage difficult in some cases. In the new model, the original AGC system used in the exciter amplifier stages was left intact, but control of output amplitude was accomplished by means of an adjustable series resistor in the amplifier screen lead. This method has the added advantage that full AGC action is available at any setting of the output amplitude controls, whereas the pervious system reduced the effect of the AGC system in inverse proportion to the output level.

Initial testing of the unit revealed that the 8 MHz crystals could be varied in frequency over a much wider range than 3 MHz crystals in the original circuit. Thus it was possible to substantially reduce the number of crystals required to cover the possible range of rocket receiver center frequencies. Also discovered during the testing procedure, however, was the fact that the amplifier stages were rather unstable and tended to interact, resulting in a very undesirable modulation of the outputs at the difference frequency. These problems were solved by additional shielding, and bypassing, by improved matching of the output stages to the 50-ohm lines, and by inserting a small resistance in series with the grid lead of each of the amplifier tubes. The performance of the completed unit was checked and compared against a unit of the earlier design being operated at Wallops Island, Va. It was found that the 8 Mhz exciter surpassed the original unit in output, stability, and control capability.

Hybrid Polarizer

The hybrid polarizer unit, which divides the power between the transmitters and provides a means of adjusting signal phase relationships so that circularity of the transmitted signal may be achieved, was originally designed to operate in the 2 to 3 Mhz range. It was found to be practically inoperative at 8 MHz. The pulse transformers used were very inefficient at the higher frequency, and the GR delay lines exhibited severe standing waves and large attenuations. It was also discovered that the linear amplifiers incorporated on the chassis were non-linear above 6 volts peak-to-peak output, a condition which destroys the validity of piston attenuator settings between 0 and 10 db. In addition, impedance mismatches at the output of the hybrid power dividers used resulted in a rather severe deterioration of interchannel isolation, thereby making adjustment for true circularity virtually impossible.

Some consideration was given to using Ad-Yu high frequency delay lines in place of the GR devices, but it was discovered that the Ad-Yu lines could be varied only in fairly large discrete steps, a fault which the GR units did not exhibit. It was decided that the losses in the delay lines could be tolerated, since redesign of the linear amplifier stages was mandatory in any event, and additional gain could then be included to make up for other circuit losses. Accordingly, the one-stage amplifiers were removed and replaced by two-stage amplifiers with higher plate voltage and regulated screen supplies. The higher gain of the new amplifiers also made it possible to omit the pulse transformers originally used for impedance matching at the amplifier inputs.

The interaction between channels was reduced to an inconsequential amount by inserting a resistive matching system at the hybrid power divider outputs. It was discovered that the impedances at the input of the power dividers affected feedthrough very little. Consequently, no matching devices were needed at the step attenuator or delay line outputs, although some experimental work had been done on developing an active matching device to be incorporated at these points. Better matching of the delay line output impedances will still be considered as a possible future modification, however, as it would tend to reduce the large fluctations of the delay line output amplitudes caused by standing waves on the lines.

The final unit, although more complicated to adjust, should prove much more satisfactory than the original, especially at higher frequencies. Consideration might well be given to rebuilding the polarizer unit at Wallops Island to incorporate these improvements, since it has often been difficult to achieve and maintain good polarization of the antennas there.

Pulsed R.F. Generator

It was also necessary to modify the pulsed RF generator for use at 8 MHz. This unit provides a pulsed signal to drive the transmitters when making ionospheric soundings, a procedure used to double check the adjustment of the antenna polarization. The original unit when modified did not exhibit good suppression of unwanted signals, probably because of the physical layout, which was adequate for operation at lower frequencies. Some effort was devoted to development of a transistorized replacement of this unit, since the circuit design of such a unit would find application in several other projects being conducted by the laboratory. A germanium diode balanced modulator was developed which gave excellent carrier suppression. Sufficient time has not been available to continue work on this system, however. It will be necessary to design a successful transistor RF power amplifier, and a means of gating the balanced modulator properly before the system will be operational. Meanwhile, efforts will be made to improve the characteristics of the vacuum-tube model.

Antennas

Operation at 8 MHz required the construction of four new dipole antennas for the ground station transmitting box array. These antennas were measured and cut at the laboratory. Insulating hardware was attached and the entire antenna assembly was erected at the Urbana field station. Measurements made of each of the four antennas showed them to have electrical characteristics very close to the desired values. The antennas were then removed from the field station and packed for shipment to Fort Churchill.

A shielded loop is used as a receiving antenna when making pulse soundings to double-check antenna circularity. This unit was modified to operate at 8 MHz and was considerably ruggedized to withstand the Fort Churchill environment.

The "whirly", a motor-driven spinning dipole antenna which is placed in the center of the transmitting array to test for signal circularity, was also modified and ruggedized for operation at Fort Churchill. The loop dipole antenna was retuned and a matching network introduced to permit 8 MHz operation. The entire unit was enclosed in an insulated wooden cabinet along with two heating elements to prevent the motor and gear train from stalling at extremely low temperatures.

Payload

A full-size model of the rocket receiver antenna assembly was constructed and shipped to AFCRL. This model was used in the design of mounting hardware necessary for installing our payload in the Black Brant rocket to be launched from Fort Churchill. The rocket-borne receivers supplied by Spacecraft, Inc. were calibrated and the payload package was shipped to AFCRL for integration into the Black Brant rocket.

Miscellaneous Equipment

A modified version of our standard broad-band ionospheric sounding receiver has been constructed to operate at 7.9225 MHz. It will be used at Fort Churchill in making ionospheric soundings as a check on antenna polarization characteristics. The only modification is that of center frequency. The IF amplifier, DC amplifier, and power supply are identical with previous receivers.

A new dual phase detector has been constructed identical with the unit employed at Wallops Island. This device samples the telemetered rocket receiver output and the 500 Hz reference frequency generated by the exciter unit to give an in-flight indication of Faraday rotation. A DC amplifier for the phase detector output has been designed and constructed. The design is essentially the same as that used for the new DC amplifier in the sounding receivers (see section 2.1, Receivers) but incorporates a self-contained power supply and gain control system.

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4. VLF STUDIES

4.1 Full Wave Solutions

C.F. Sechrist, Jr.

Tasks included under this topic pertain to the study of VLF propagation theory and full-wave solutions of the coupled wave equations, as conducted under NASA grant NsG-511.

Dr. Sechrist worked with R. Kubala in connection with his studies of VLF propagation theory and experiments. Plans were made to implement a steep-incidence VLF experiment at Wallops Island in the future, and to develop a computer program suitable for obtaining full-wave solutions.

During January, 1966, Mr. Kubala left the Aeronomy Laboratory and this problem is now in abeyance. Emphasis is being placed on the steep-incidence VLF experiment which will be carried out in June, 1966 in connection with the pre-sunrise rocket shot.

Mr. Richard Smirl, research assistant, will be responsible for the design and development of the VLF instrumentation. A report of his work is covered under section 4.2.

4.2 VLF Experiment

R.A. Smirl

Tasks included under this topic pertain to the design and instrumentation of the VLF experiment, as conducted under NASA grant NsG-511.

In this experiment the relative amplitude and phase of the sky wave from the U.S. Navy VLF transmitter, NSS, at Annapolis, Maryland will be measured at Wallops Island, Va., about 150 km south-southeast of NSS.

In particular, the component having an electric vector perpendicular to the plane of incidence will be measured. Past experience indicates that

Power - operate from a standard 115 volt, 60 Hz single phase power source.

Weight - not critical.

Size - not critical.

this measurement is a sensitive indicator of small changes in the electron density near the base of the D region (60 to 70 km). This region is of interest because during the pre-sunrise period a layer of ionization, the C layer,is formed there. The rocket propagation experiment will make direct measurements of this region during the formative period.

Work on this experiment was begun when R.A. Smirl arrived in February. The progress to date is as follows:

1. Reports of previous work have been studied.
2. The overall design of the measuring system was determined.
3. Suppliers were selected and orders placed for a loop antenna and a phase comparator.
4. Receiver design experience was gained through experiments carried out on a 20 kHz receiver available in the laboratory.

5. AERONOMIC THEORY

5.1 Protonosphere

J.E.C. Gliddon
S.A. Bowhill

This topic includes investigation of the thermal and ionization economy of the ionosphere. It is sponsored by the National Science Foundation under grant NSF-GP 866.

Some time has been spent on the contents of Chapter II of Aeronomy Report No. 12, "Some considerations of the steady motion and equilibrium of plasma in the F-2 region and in the protonosphere". There is some doubt as to the sense in which the two invariants of the Chew-Goldberger-Low theory are adiabatic in the limit of zero fluid motion. We have previously assumed these quantities constants along a line of force. However, if analogy can be made with gas dynamics, it may be permissible to treat quantities as constants throughout the protonosphere. The situation may be comparable to the assumption of constant entropy in the adiabatic model of the neutral atmosphere. We are also considering a different model, in which the kinetic temperatures (parallel and perpendicular to the magnetic field) are constant.

The associated problem of the equilibrium confinement of plasma by magnetic fields has received considerable attention in recent years. These investigations suggest that the state of knowledge concerning plasma equilibria is still incomplete but they may be of help in our problem.

A seminar was presented by Dr. Bowhill at the Center for Radiophysics and Space Research, Cornell University on January 20, on the topic "Thermal Structure of the Protonosphere". It was pointed out that conductivity considerations ruled out electron temperatures greater than 7000 deg K in the equatorial plane at geocentric distances of two to three Earth radii.

Dr. Bowhill prepared an article "The Ionosphere" for the Encyclopedia of Earth Sciences.

5.2 F Region

J.E.C. Gliddon

This topic includes theoretical studies of the ion distribution in the F-region, and is supported by the National Science Foundation under grant NSF-GP 866.

Proofs of the paper "Ambipolar Diffusion and Drift Motions in the F-2 Region", have been corrected and returned to the publisher. Reprints were ordered on behalf of the Laboratory. The paper appeared in volume 13, pp. 959-967 of Planetary and Space Science.

The effect of ion drag in the F-region, allowing for viscosity of the neutral air, has been a matter for conjecture for the past few years.

The problem has been discussed recently by Rishbeth, Mcgill, and Cahn in Ann. de Geophysique 21, 2, 1965. They derive an equation of motion for the neutral air but their conclusions are based only on a qualitative discussion.

Dr. Gliddon is trying to find solutions of the equations which may permit numerical discussion of this problem.

The differential equation

$$\frac{d^2y}{dz^2} - \lambda(C_o + C_1 z + C_2 z^2)y = 0, \qquad y(0) = 1, \; y^1(0) = 0 \qquad (1)$$

has been investigated in connection with E-region theory (see section 5.3), If $C_2z + C_1z + C_o = 0$ has real roots α, β, then if the origin is moved to $\frac{1}{2}(\alpha+\beta)$ by the substitution

$$z - \tfrac{1}{2}(\alpha+\beta) = (\lambda C_2)^{-\frac{1}{4}} x \qquad (2)$$

the equation takes the standard form of Weber's equation

$$\frac{d^2y}{dx^2} + (n + \tfrac{1}{2} - \tfrac{1}{4}x^2)y = 0 \qquad (3)$$

where $n + \frac{1}{2} = \frac{\lambda C_2}{8}(\alpha-\beta)^2$ (4)

The solutions of (3) are the parabolic cylinder functions $D_n(x)$ (expressible in terms of Hermite polynomials), see Whitaker and Watson, Modern Analysis, p. 347. The above transformation may need modification, depending upon the signs of the parameters and of α, β. It is always valid but the practical usefulness may be restricted, for example if α, β, are complex.

The last section (4.5) of the report "Theoretical investigations of the structure of the protonosphere and upper F-region" has been completed, and the report will be issued as Aeronomy Report No. 12.

5.3 E Region

P. Paramasivaiah

This topic includes theoretical investigations relevant to the development and refinement of E-region theory, as conducted under NASA grant NsG-511 and NSF GP-866.

The possibility of charged particles and dust particles serving as sources of ionization and of selective heat input to the ambient electrons in the E region was studied. Investigations show that these sources can provide a small amount of ionization, but by themselves cannot furnish the heat input necessary to sustain the electron temperature observed in the E region. Likewise, the Joule heating computed on the basis of magnetic field variations with height in the E region, as reported by Hall and Burrows, is inadequate to maintain the temperatures observed, except on the bottom side of the E region below about 110 km.

A method has been developed to evaluate the electron production rate during sunrise in terms of the production rate sometime during midafternoon at another altitude. For any altitude during sunrise for a given solar zenith angle, the midafternoon altitude is identified by equating the optical depths at the two altitudes. The optical depth is calculated assuming O_2 as the most effective absorbing constituent of the solar radiation in the upper atmosphere. Ionization rates are calculated in terms of O_2^+ rates and the assumption is made that the total rate of ions produced at any level in the E region bears a constant ratio to the production rate of O_2^+. If a photoequilibrium condition is assumed to prevail during midafternoon, the total rate of ion production is found in terms of the electron density and the effective recombination coefficient at that altitude and at that time. Thus the electron production rate for any zenith angle during sunrise is calculated in terms of an unknown recombination coefficient and the electron density profile.

Now the continuity equation for electron density during sunrise consists of two unknowns, the recombination coefficient during sunrise and the recombination coefficient during midafternoon. The continuity equation is solved exactly, and for five altitudes in the range from 125 to 160 km, plots of $\alpha_{\text{midafternoon}}$ vs α_{sunrise} are obtained. These plots are seen to converge to within a small area, indicating that perhaps the E region can be characterized by almost constant value of $\alpha_{\text{midafternoon}}$ and another value for α_{sunrise}. The computed values are:

$$\alpha_{\text{midafternoon}} = 2.7 \times 10^{-8} \text{cm}^3 \text{sec}^{-1}$$

$$\alpha_{\text{sunrise}} = 0.7 \times 10^{-8} \text{cm}^3 \text{sec}^{-1}$$

Futher analysis is being undertaken.

5.4 D Region

C.F. Sechrist, Jr.
J.S. Shirke

This topic includes theoretical and experimental investigations for the development and refinement of D-region theory, as conducted under NASA grant NsG-511.

Theoretical Investigations

C.F. Sechrist, Jr.

The problem of pre-sunrise ionization in the D-region has been explored. Because O_3^- has been suggested as a dominant negative ion in the D-region, the ozone layer formation and its variations in the mesosphere were studied. A non-equilibrium investigation into the diurnal photochemical atomic oxygen and ozone variation in the mesosphere was carried out by B.G. Hunt (JATP, 27 1965, 133-144). One result obtained was that photochemical equilibrium does not exist in the atmosphere above 60 km; Hunt illustrates the diurnal varition of the atomic oxygen and ozone concentrations. The implications of Hunt's work, and the pre-sunrise ionization in the D-region were considered.

In connection with winter days of high absorption, disturbances of stratospheric and mesospheric circulation in winter were considered. It is possible that transport processes redistribute photochemical constituents such as O, O_2, and O_3; consequently, negative ions of these constituents may be redistributed. It is possible that sunrise variability observed with VLF measurements is explainable in terms of the redistribution of negative ions also. Kellogg (1961) accounted for winter mesospheric heating by assuming that a meridional circulation transports atomic oxygen at heights of 110 to 120 km from southerly latitudes towards the pole. He showed that heat would be realized through chemical energy release due to atomic oxygen recombining to form molecular oxygen.

The important processes for the destruction of atomic oxygen are:

$$O + O + M \longrightarrow O_2 + M$$
$$O + O_2 + M \longrightarrow O_3 + M$$

However, as far as D-region ionization is concerned, the reactions producing nitric oxide are most important, namely:

$$N + O + M \longrightarrow NO + M$$
$$NO_2 + O \longrightarrow NO + O_2$$

During the period March 3-8, 1966, Dr. Sechrist visited the World Data Center at ESSA (Boulder, Colorado) to examine F-plots and ionograms obtained at Wallops Island and Ft. Belvoir during the interval 1961-1964; in particular, data were inspected for those months during which rocket-grenade measurements of temperature were carried out at Wallops, to determine whether or not f_{min}

values were higher on days when the grenade measurements revealed D-region warming. Also, visits were made at NCAR with Dr. W.W. Kellogg and Dr. Paul Julian to discuss the subjects of mesospheric and stratospheric warmings and their relationships.

Essentially, it is believed that D-region warmings are responsible for the anomalous winter absorption, because the concentration of nitric oxide in the D-region is temperature dependent. In particular, examination of mesospheric temperature profiles obtained by the rocket-grenade technique at Wallops Island revealed the occurrence of mesospheric warming on certain winter days. A preliminary investigation indicated that f_{min} values observed with ionosondes at Wallops Island and Ft. Belvoir, Virginia, tend to be higher on days when the mesospheric temperatures are abnormally high. Because higher values of f_{min} may be associated with enhanced ionization in the D-region, it is believed that the increased values of f_{min} are caused by a sporadic D layer.

A theory of the formation of a sporadic D layer at middle latitudes in winter was developed. Use was made of the experimental temperature profiles to obtain estimates of the nitric oxide distribution in the D region on an average winter day and on a nontypical winter day at Wallops Island. The temperature and nitric oxide distributions were utilized to calculate the electron production rate profiles; electron density distributions were derived from these assuming an effective recombination coefficient of $5 \times 10^{-7} cm^3 sec^{-1}$.

On the basis of the calculated nitric oxide and electron density distributions, and examination of f_{min} values from ionograms, it was concluded that the "winter anomaly" in ionospheric radio absorption may be caused by a temperature inversion in the D region on certain winter days at middle latitudes.

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Also, examination of f_{min} values and stratospheric temperatures during November, 1963 indicated that November 17, 1963 was a nontypical winter day at Wallops Island; and it was suggested that the D-region nitric oxide concentration measured by Barth on that date was abnormally high because of a sporadic warming in the D region.

Dr. Sechrist attended the following conferences and meetings in connection with our D-region studies: Second Conference on Direct Aeronomic Measurements, September 27-30, 1965; URSI Meetings, October 4-6, 1965; Solar Eclipse Workshop, October 11-12, 1965.

A paper entitled "The Sunrise Variability of VLF Radio Waves Ionospherically Reflected Near Vertical Incidence" was presented at the Aeronomy Conference. This paper was co-authored by J.M. Musser.

Two papers were presented at the URSI meeting held at Dartmouth College: "A Co-ordinated Experiment to Study the Effects of Solar Proton Events on VLF Radio Wave Propagation," and "Time History of High-Latitude Electron Density Profiles during the 10 November 1961 PCA Event Derived from Explorer XII Proton Spectral Data." The second paper was co-authored by P.M. Banks.

Experimental Investigations — J.S. Shirke

A study of the "winter anomaly" in ionospheric absorption was undertaken, Data obtained on vertical incidence absorption measurements at Wallops Island during December, 1965 and January, 1966 were used for this purpose. The primary aim of the experiment was to provide a criteria for the launching of rockets during the anomalous and the normal ionospheric conditions. The above task was accomplished successfully as verified from the rocket data acquired during this period. A subsequent analysis of the data from ground-based sounding measurements in conjunction with some of the rocket measurements has provided information on several aspects of the wintertime ionosphere, some of which is outlined below.

Measurements at 3030 kHz showed a dependence of the noon vertical incidence absorption on the altitude from which the echo return was taking place. The observed attenuation increased with increasing echo altitude up to 200 km.

The period and amplitude of fading of the received echo were found to be different in nature when the echo was received from a sporadic E layer rather than from a regular ionospheric layer. Much larger amplitudes as well as periods were noticed in the latter case. There is reason to believe that these large amplitude fadings are originating at levels above the normal E_s layer.

The absence of appreciable retardation effects associated with the E_s-type reflections in some of the cases indicated that there was very little deviative attenuation associated with these reflections. The nondeviative attenuation measured at noon (corresponding to a solar zenith angle of 60^o) was of the order of 11 db for an echo altitude of 110 km.

The noon absorption on all the days for which data was available when plotted against the virtual height of reflection of the echo showed two sets of cruves displaced from each other by about 8 db. The curve with lower absorption values in general has been identified as that corresponding to normal days and the one with larger values as that pertaining to the abnormal winter anomaly days. The noon abnormal winter absorption corresponding to 60^o solar zenith angle was therefore estimated to be of the order of 8 db and originating below the lowest recorded reflecting level of 110 km.

Each of the two curves mentioned above showed an increase in absorption with an increase in the virtual height of reflection at least up to an altitude of 200 km. This was presumably due to the increase in group retardation with the associated increase in the virtual height of reflection of the echo. The major portion of the attenuation originating in the region above 110 km was therefore believed to be deviative in nature.

The rocket launched under the anomalous conditions has shown large increases in electron density close to 82 km and persisting to a certain extent up to an altitude of close to 92 km over the normal day profile. Calculations using these values of electron density are underway to estimate the electron neutral particle collision frequency profile which would adequately explain the ground-based measurements. The results are by no means final as the rocket trajectory information is incomplete at this time.

Partial reflections from altitudes as low as 60 km were also noticed around noon on the anomalous day as well as on the previous day, which was also of the anomalous type. It has been shown by Piggott and Thrane (1966) that gradients in the collision frequency of electrons can just as well cause these reflections as the electron density gradients. Whichever of these phenomena may be responsible for the observed backscatter echoes, caution must be used in treating the profiles of electron density or collision frequency as typical of a normal ionosphere, as they have been derived under abnormal circumstances.

An association of the appearance of low altitude echoes around 80 km and the enhancement of ionospheric absorption on levels above has been noted by several investigators. A study of some of these cases shows that while the appearance of low altitude echoes always puts increased attenuation on layers above, the converse is not always true. For instance, no low altitude echo around 80 km was noticed in the ionosonde record taken during the January rocket launch.

The diurnal variation of the absorption on the anomalous and other days has also been investigated and the relationship between the solar zenith angle and the total absorption measured at the ground has been established. The absorption has been shown to be a linear function of the cosine of the solar zenith angle.

A paper giving some of the results noted above has been prepared and will soon be sent in for publication.

5.5 Dynamics

S.A. Bowhill

This topic includes the initiation of studies of the dynamics of the upper atmosphere under the sponsorship of the National Science Foundation under grant NSG-GP 866.

An examination was begun of the theory of acoustic-gravity (Martyn-Hines) waves, to see if seasonal changes above the turbopause might be explained on this basis.

N67 14647

6. CROSS MODULATION

J.S. Shirke

Tasks included under this topic pertain to the study of cross modulation effects in the ionosphere, conducted under NASA grant NsG-511.

During June, 1965 an experiment was undertaken at the time of the launching of rocket 14.245 (Wallops Island; June 14, 1965; 0913Z; $\chi = 94^{\circ}$) to study cross modulation effects in the ionosphere. The aim was to deduce, if possible, the collision frequency profile of the electrons in the ionosphere which could then be compared with that obtained from other experiments included in the same rocket payload.

A ground-based transmitter with approximately 62 kw output power operating on 1.4 MHz and modulated 80% by a 155 Hz signal was operative during the launch period.and served as the disturbing transmitter. The antenna directivity covered the rocket trajectory.

Another pair of transmitters was also operative at this time. They transmitted both ordinary and extraordinary propagation modes differing in frequency by 500 Hz with a mean frequency of 3.385 MHz. The beat signal of 500 Hz as observed at the rocket receiver output was telemetered to the ground station. A servo system to correct for the differential absorption of the extraordinary wave over the ordinary was also attached to the ground transmitter. This system has a servo time constant of the order of 1 sec, much too large to affect seriously the 155 Hz cross modulation in the ionosphere. For convenience of measurement on other experiments a difference of 10 db between the ordinary and extraordinary power levels was maintained throughout the experiment.

Earlier efforts to detect cross modulation effects on the 500 Hz beat note due to the 155 Hz modulation of the disturbing wave had not borne fruit. Since the ordinary and extraordinary signal levels were not identical, it was felt to be desirable to use a half wave detector to be followed by a 500 Hz rejection circuit with sharp bandpass characteristics, thereby preserving only the 155 Hz component which could then be amplified for recording purposes. It was felt that using alternately the positive and negative waveforms would provide an additional confirmation of the cross modulation effect if they exhibited the expected differences. Calculations to estimate the order of cross modulation indicated that the effects would be less then one percent maximum, as the expected electron densities (and hence the absorption of the wanted wave) would be low in view of the large solar zenith angle at the time of launch.

A circuit using a half wave detector and a bandpass filter was designed and constructed by Mr. Knecht. It was tested in the laboratory with a simulated signal. Since the modulating frequencies of the circularly polarized and disturbing signals were fairly close to each other, the filter circuit posed severe design problems. The circuit was tested for detecting less than one percent changes in the modulating levels. This circuit, however, failed to show detectable output at 155 Hz when the taped telemetry output from the launch was fed in.

It was realized that to achieve the best results the circuit might have to be tuned over a small range around the expected frequency to take into account any possible variations in frequency caused by rocket roll, etc. At this stage a commercially manufactured wave analyzer became available which could be tuned over a wide range of frequencies and still retain a narrow detecting bandwidth.

The taped data output from the rocket was subjected to a spectrum analysis using this instrument. No systematic perceptible output around the 155 Hz modulating frequency could be detected. However, outputs at other frequencies in the range of 270-310 Hz were noticed. A systematic recording of the outputs at 155, 275, and 310 Hz were made over the entire rocket trajectory using a dual channel recorder to give simultaneously the real time code recording as well.

Calculations undertaken at this stage indicated that a second harmonic of the modulating frequency of the disturbing transmitter could be expected in the output as a component inherent in the cross modulation phenomena. However, the amplitude of the second harmonic component would be about $\frac{1}{4}$ that of the fundamental, corresponding to a collisional frequency of 10^7 electrons/sec. The ratio would decrease to 1/10 at 10^5 electrons/sec. These calculations were made neglecting the effects due to the earth's magnetic field.

A detailed study of the recordings has yet to be undertaken. The observed results are at this stage difficult to understand. It is hard to believe that the output around 310 Hz is appearing as a consequence of the cross modulation effect. It has been suggested that this signal may have been the result of an interfering carrier falling within the rocket receiver passband, although this is difficult to determine definitely. The high chart speed necessary to accomodate the time code output is itself rendering difficult a quick survey of the records. The spectral characteristics of the wave analyzer must also be taken into account before final conclusions may be drawn.

It is planned that a fresh attempt be made to look for cross modulation effects using low speed recordings and with certain modifications of the present arrangement. Even so, considering the relatively low power of the disturbing transmitter, these effects are expected to be small.

N67 14648

7. AERONOMY FIELD STATION

7.1 Construction

R. Davis

Tasks included under this topic pertain to the construction of the Aeronomy Field Station near Urbana, Illinois, under NSF grant GP-2918.

The past six months were spent primarily in overseeing the construction of the field station buildings. Concrete work was completed in early November, 1965. Structural steel work was completed late in December, and installation of exterior and interior sheeting continued through January, 1966. Interior carpentry, plumbing, and electrical work extended through March. Although there were numerous delays caused by the shipment schedules for the prefabricated buildings, by March 31, 1966, the entire structure was almost 100 percent complete.

7.2 Field Site - Antennas

G.W. Henry, Jr.
J.S. Shirke

Tasks included under this topic pertain to the design and construction of antenna systems at the Aeronomy Field Station near Urbana, Illinois, under NASA grant NsG-511.

The antenna systems required for operation of the field station are designed to operate in conjunction with instruments for measurement of vertical incidence absorption (see section 2), ionospheric drifts (section 8), and partial reflections (section 10). Antenna work at the field station consisted of three major projects: (1) design and erection of a four-dipole circularly polarized array for use in absorption, drift, and partial reflection measurements, (2) design and construction of three coaxial loop antennas for use as receiving antennas for drift measurements, and (3) design and initial construction phase of very large high gain antenna arrays for use in measurement of partial reflections.

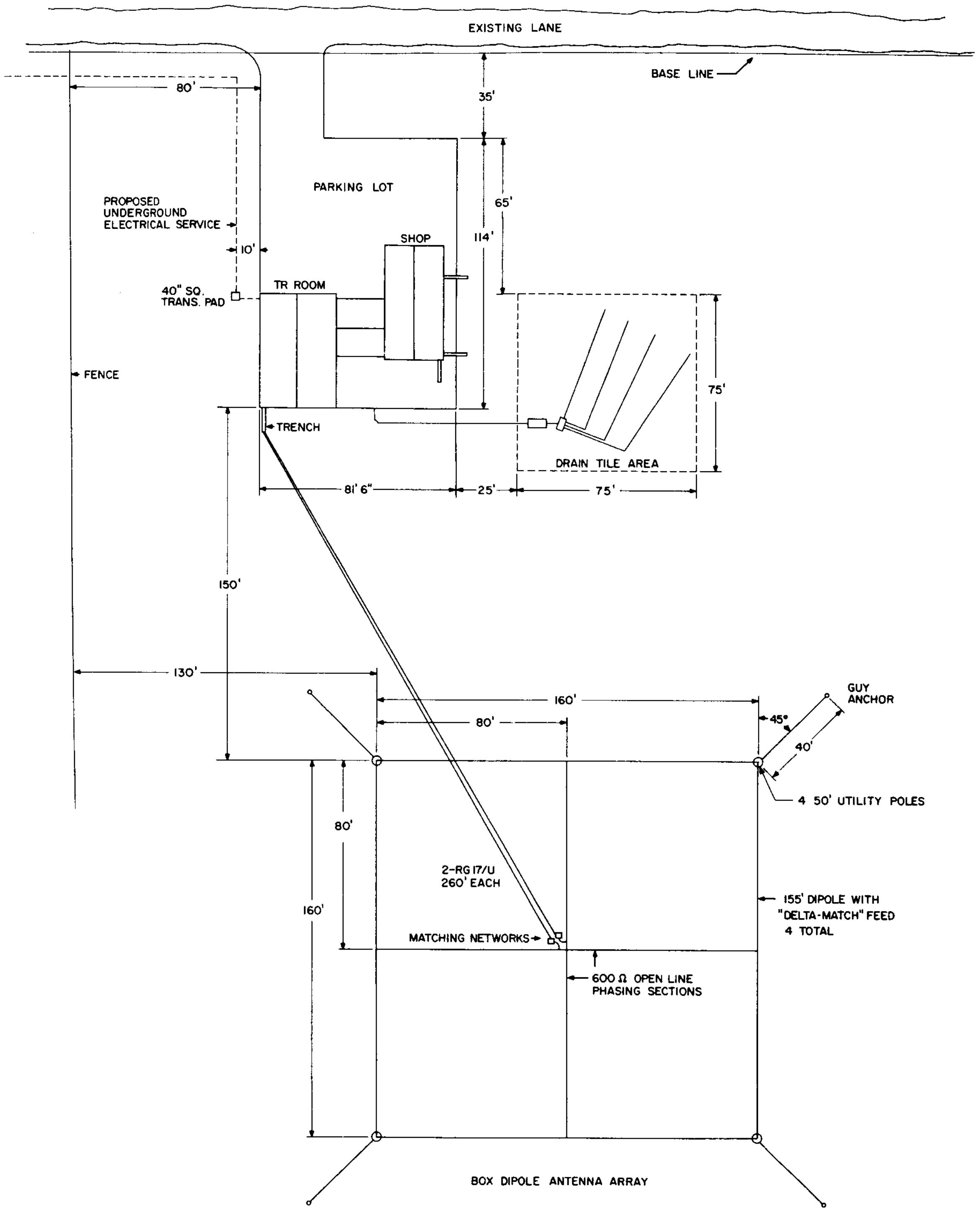

Figure 7.2.1 Four-dipole box array installed at the Aeronomy Field Station.

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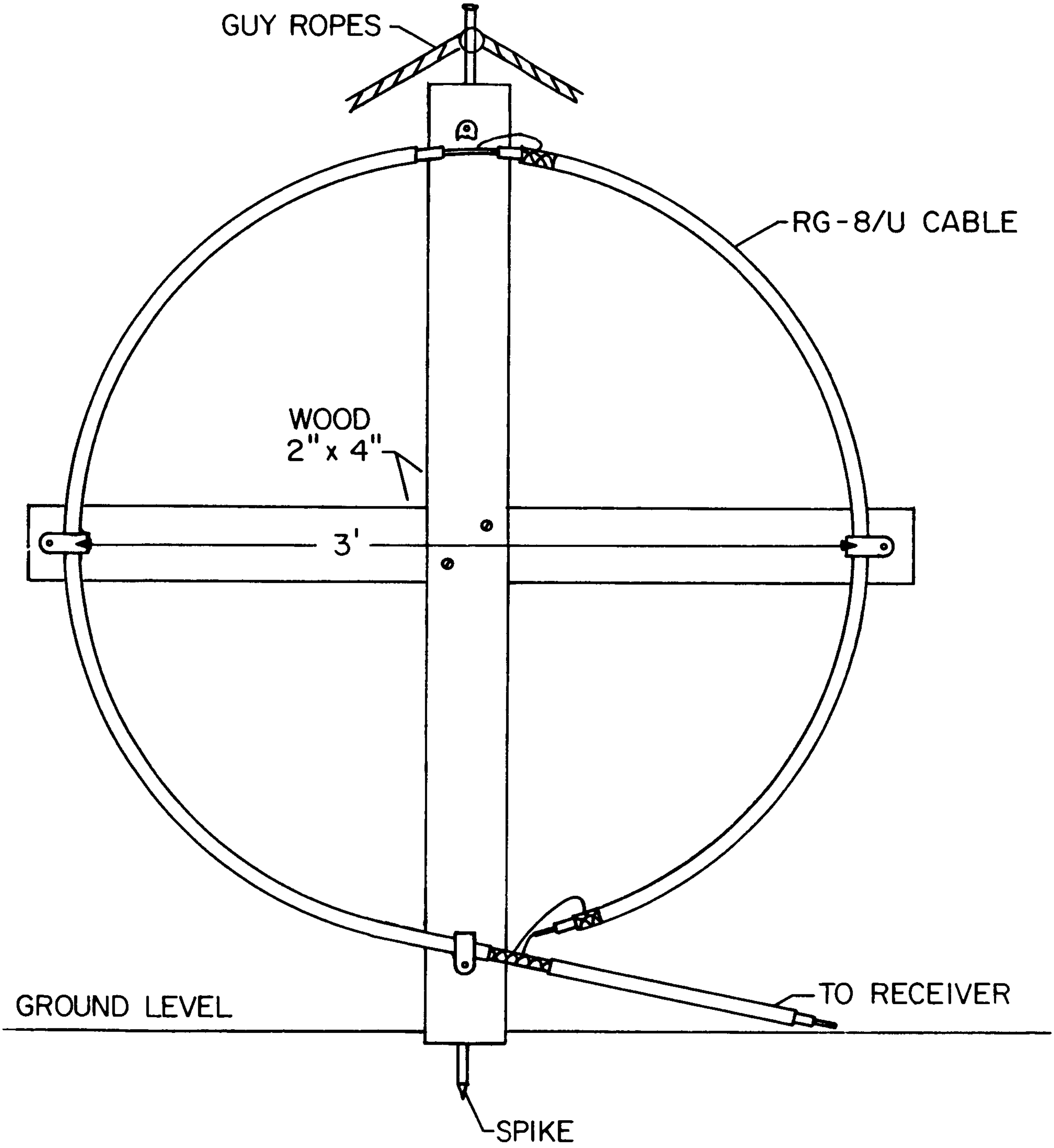

Figure 7.2.2 Detail of the coaxial loop antennas designed for ionospheric drifts measurements.

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Four 70 ft, class-2 utility poles were set in a 160 ft square on November 19, 1965 to support a four dipole square antenna array for use at 3030 kHz for measurement of absorption and drift, and for preliminary observation of partial reflections. The poles were installed with 7½ ft of the bottom end in the earth and the holes around the poles were back-filled with dirt. Unfortunately, power tamping was not used on the back-fill and a combination of heavy rains and high winds soon after erection caused the poles to settle considerably out of plumb. The poles were manually pulled back into position with the ½-inch guy rope installed at the top of each pole.

The antenna elements mounted on these poles are half wavelength dipoles for 3030 kHz with a "Delta-match" feed system much like that in use on a similar array at Wallops Island. In order to avoid interference with ground maintenance, feedlines to all four dipoles were routed directly to the center of the square, eliminating the feedline support stakes that the Wallops antenna array incorporates. The antenna matching networks used aboard the ship during the Mobile Launch Expedition were installed at the center of the array to match the high-impedance antenna feedlines to the 50 ohm coaxial cables from the transmitter. A diagram of the antenna array appears on the following page (Figure 7.2.1).

Three coaxial loop antennas of approximately one square meter area were constructed during January of 1966 for use as receiving antennas for ionospheric drift measurements (8.2). The loops were constructed of RG-8/U coaxial cable and were impedance matched at the end of the 333 ft. feedline at the receiver terminals. Figure 7.2.2 shows a diagram of the construction of the coaxial loop antennas.

Observation of signal-to-noise ratios with the sounder from the ship experiment and the first four-dipole array at the field station demonstrated the need for at least 25 db of additional system gain for partial reflection measurements. Various proposals for means to achieve this additional system gain were considered (see 10.2), the main difference between proposals being whether the additional gain should be achieved by increasing the transmitter power, antenna gain, or a combination of both.

A cost analysis of the situation yielded the following results:

1. The effective gain of the system is directly proportional to transmitter power as is cost of construction.
2. The effective gain of the system is proportional to the square of the effective antenna area whereas cost is directly proportional to land area occupied by the antenna.
3. Cost analysis based upon previous costs of construction of transmitters and antennas and rental of land demonstrated that the most economical design of the system would be that in which 2/3 of the available capital is invested in the antenna system and 1/3 of the available capital in transmitter design and construction.

It was therefore decided that a much larger antenna system was the logical method to achieve the additional gain.

4. Availability of land dictated that the maximum dimensions of the antenna system could not exceed a 1000 ft square, or an antenna of 5/2 wavelengths square for operation at 2660 kHz.

Further discussion of the physical characteristics of the antenna array yielded the following considerations and results:

1. A transmit-receive switch adequate for the high power level used and with sufficiently fast recovery time for reception of partial reflections would require considerable expense for design and development time. A simpler and more reliable approach of constructing identical antenna arrays for transmitting and receiving was chosen.
2. The antenna arrays would consist of 50 collinear dipole elements, arranged in two sets of 25 each with one set physically perpendicular to the other. All 25 elements in one set would be fed in phase with each other and the two sets would be phased in quadrature to achieve either mode of circular polarization. The lines of half-wavelength dipole elements would be separated by one-half wavelength at 2660 kHz.
3. Choice of a method of feeding the transmitted power to each of the dipoles involved considerable discussion. The methods advocated were the corporate structure feed system or the phased-array feed system. The main advantage of the corporate structure feed system is that of inherently balanced power division to all elements. The phased-array feed system is much simpler mechanically. The phased-array feed system was chosen because of the extreme complication of mechanical placement and erection of a corporate structure feed system for an array of 25 dipoles.
4. A total of 80 class-2 70 ft treated southern yellow pine utility poles would be required to support two 50 element arrays. The poles would be set nine ft in the ground and small traffic-bound gravel

would be used exclusively for back-fill to avoid settling problems such as those experienced with the four poles set in November, 1965.

5. Physical guying of the poles would be achieved by guying the outside lines of poles around the array to expanding guy anchors installed six feet in the ground. Guying of the interior poles of the array would be accomplished by tensioning the antenna elements themselves, much the same procedure as is commonly used in power distribution lines. The antenna elements would therefore have to be of sufficient strength to withstand this tension plus their own wind-load and the wind-load of the poles.

6. Actual installation of the tensioned antenna elements and guys would be sub-contracted to experienced power company linemen. Construction and installation of the phasing stubs as well as procurement of all hardware required for the installation of the antenna elements would be undertaken by the technical services division of the Aeronomy Laboratory.

7. The projected date of completion of the arrays to avoid interference with the farmers' crops would be May 15, 1966 for the eastern array and June 1, 1966 for the western array, barring an unusual amount of bad weather.

Negotiations have been completed with the University of Illinois Foundation for rental of a 24-acre tract immediately to the west of the Field Station, and with Mr. Hill, a neighboring farmer, for placing some additional poles on his land immediately to the east of the tract we currently rent from him.

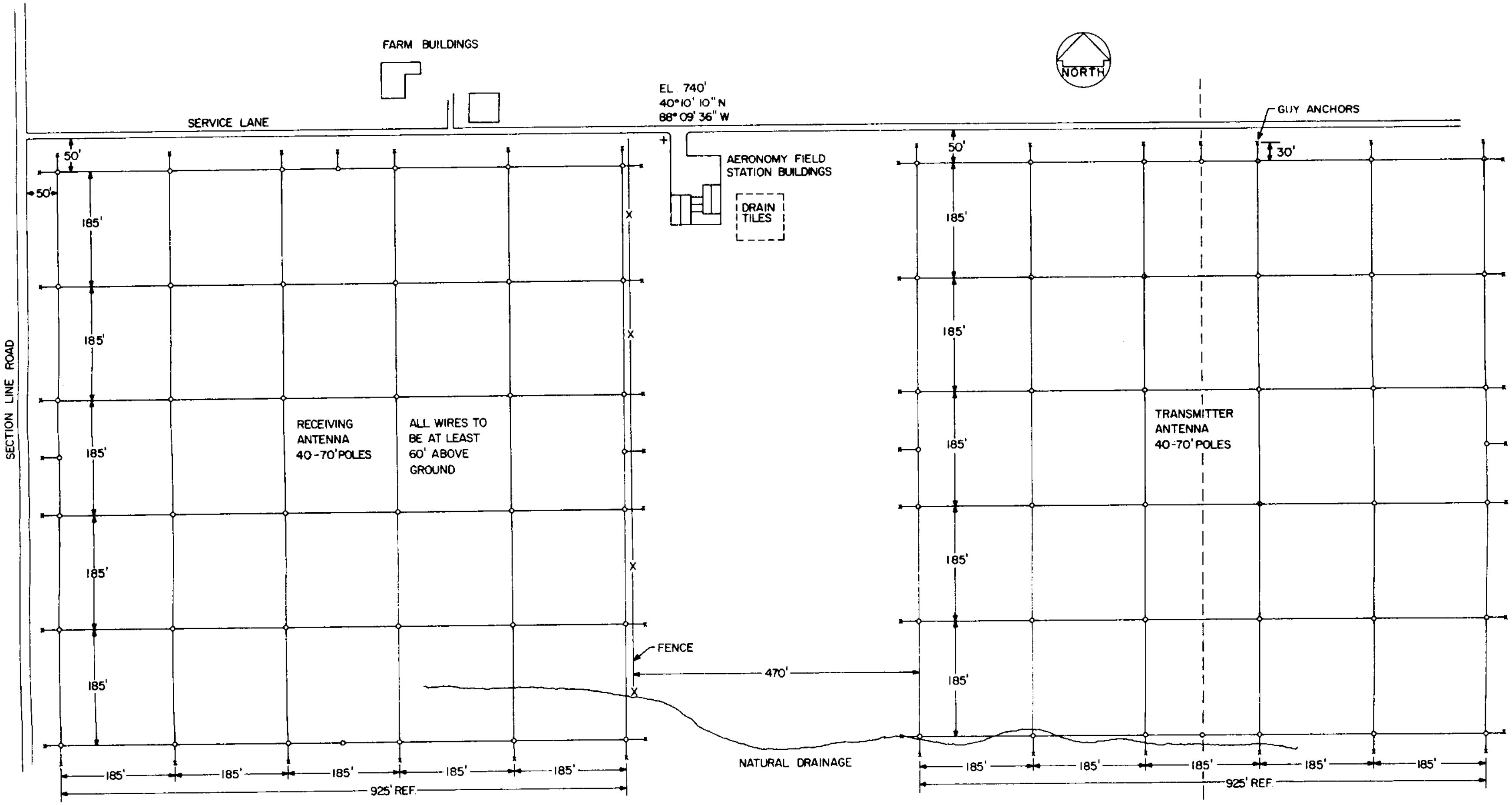

Figure 7.2.3 Location of the two 50-element dipole arrays at the Aeronomy Field Station.

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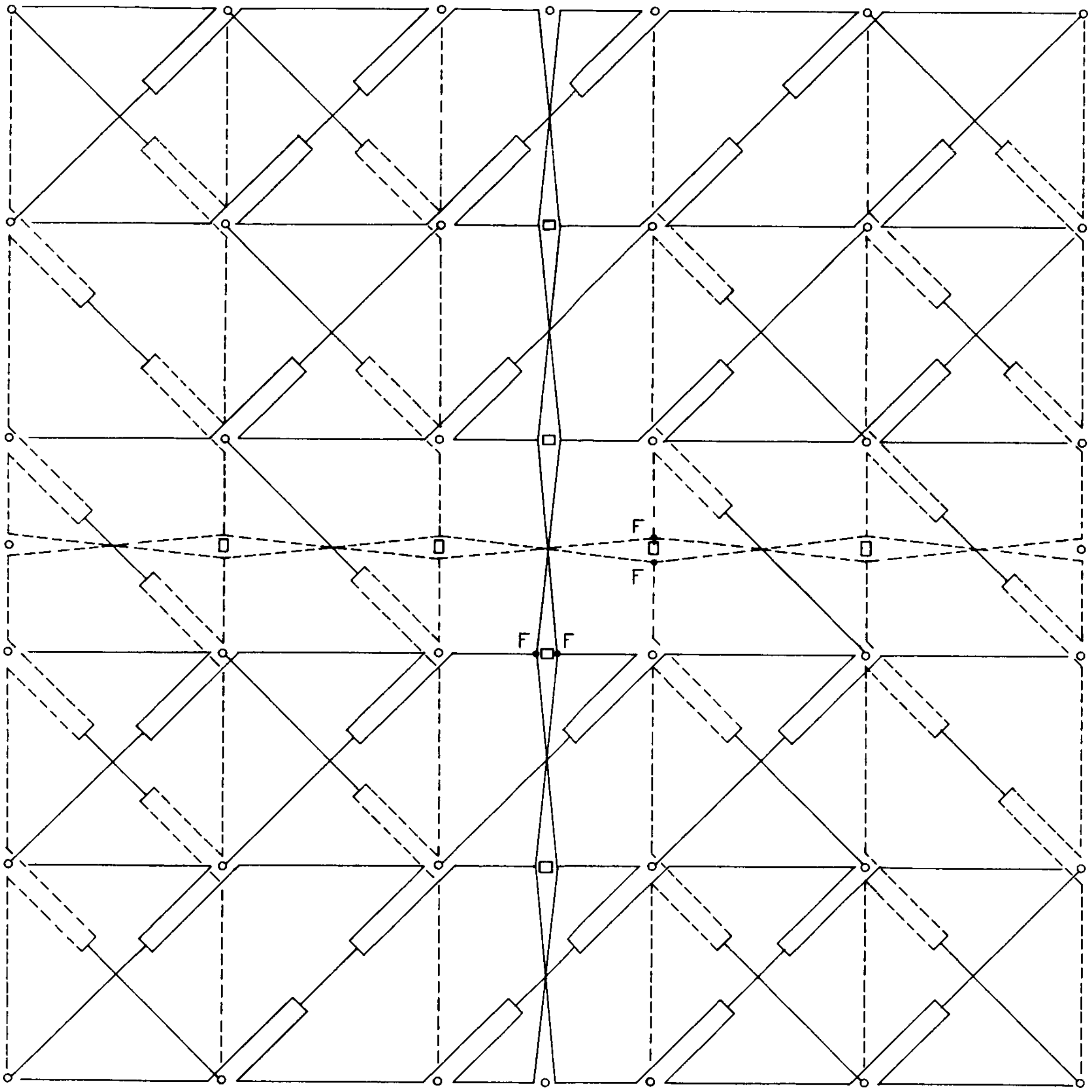

Figure 7.2.4 Electrical feed and phasing systems to be used in the 50-element arrays.

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The arrangement worked out with the University of Illinois Foundation is that they will place the 24 acres in the soil bank for the current year, and that we will compensate them for about $700 of preparatory work they put in in the fall with a view to raising a corp of corn. As part of the soil bank arrangement, they will need to seed a soil conservation crop (probably oats) in June or July. For the next year, they will attempt to induce the tenant to farm 20 of the 24 acres between our rows of antenna poles, whereupon we will be charged rental only for the 4 acres taken out of cultivation. As far as Mr. Hill is concerned, there will be no change in the present financial arrangements; the transmitting dipole array will be placed straddling the east boundary line of the presently rented tract. Mr. Marriott, the tenant, will then farm between the antenna poles in addition to the area he currently farms. This will give him approximately an extra 6 acres of land, as compensation for the inconvenience of having 3 rows of poles on the property he was formerly farming.

As of March 31, 1966, the poles for both arrays were ordered and delivery was specified for May 1, 1966 to the railroad siding at Leverett, Illinois, approximately two miles from the field station. Selection and procurement of the necessary hardware for the antenna installation is under active consideration and positive action will be taken to procure all necessary supplies for the installation by May, 1966.

Figures 7.2.3, 7.2.4, and 7.2.5 outline the basic design of the antenna arrays. Figure 7.2.3 illustrates the location of the two arrays with respect to the field station, roads, and farm house. Figure 7.2.4 is a schematic diagram of the electrical feed and phasing system to be used in the array.

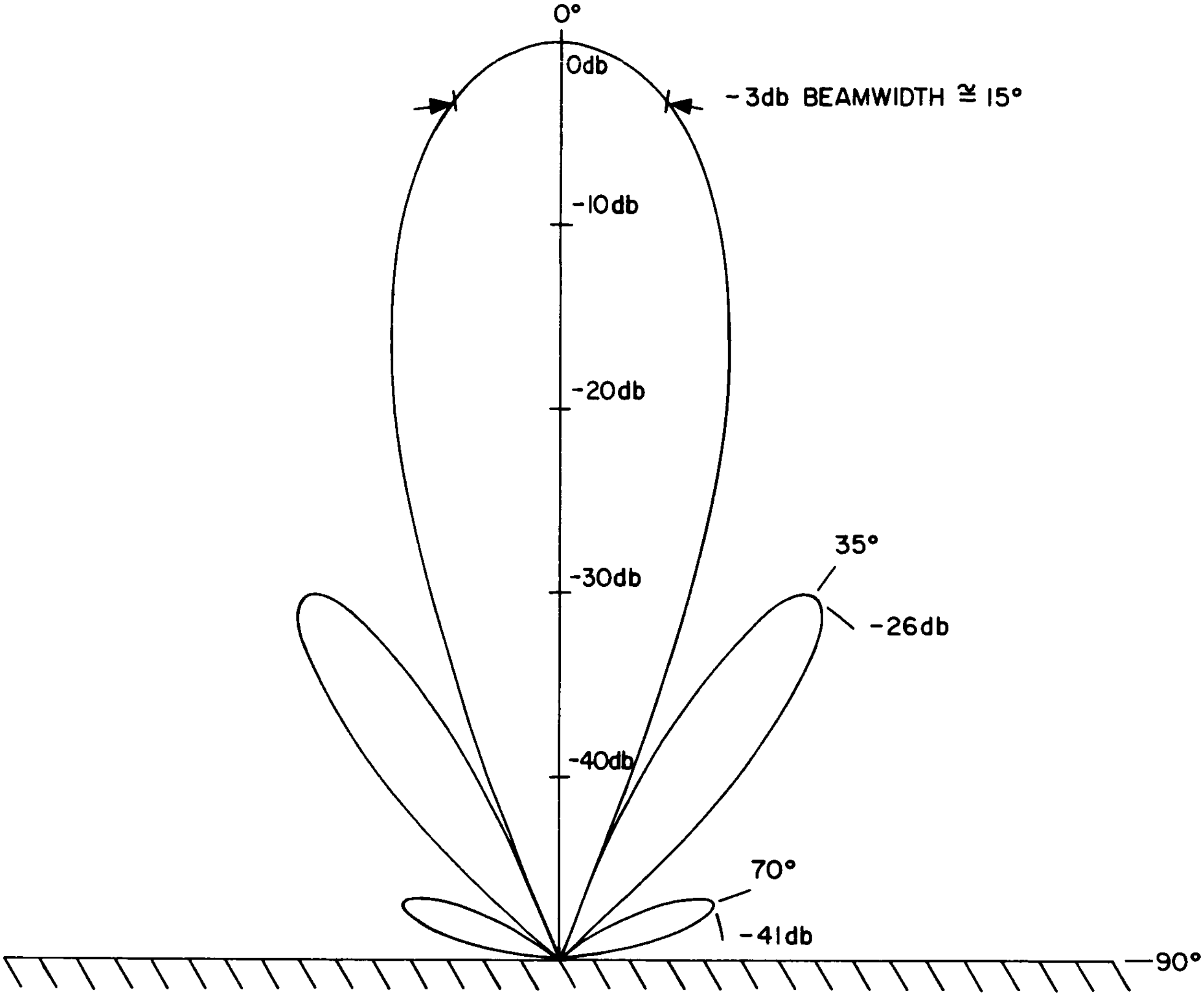

Figure 7.2.5 Polar diagram of the calculated antenna pattern of one 50-element dipole array.

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Figure 7.2.5 is a polar diagram of the calculated antenna pattern for one array assuming a perfectly reflecting flat ground under the antennas, complete matching of the amplitude and phases of all voltages distributed to the antenna elements, and negligible losses in all feedlines and insulators. A calculation of directive gain of the array based upon effective antenna area predicts that a gain of approximately 28 db over an isotropic radiator may be achieved with each antenna array.

7.3 Ionosonde

S.A. Bowhill

In view of the strong need for a vertical incidence ionosonde at the field station, a proposal was prepared and submitted to the National Science Foundation under their atmospheric science facilities program. It called for a type J-5 ionosonde, 250 kHz to 20 MHz, with associated antennas and switching equipment. An installation comparable to the Wallops Island instrument of NASA is envisaged. This proposal was funded by NSF under grant GA-374.

N67 14649

8. IONOSPHERIC DRIFTS

8.1 Program Planning

G.L.N. Rao

Tasks included under this topic pertain to the planning of a systematic study of horizontal drifts in the lower and upper ionosphere on a world-wide scale, and to a program for measurement of these drifts at the Aeronomy Field Station, as conducted under NSF grant GP-866.

In order to acquire the horizontal drift data from various investigators around the globe, a letter was addressed to Prof. R.W.H. Wright, University of West Indies, Kingston, Jamaica, who is the coordinator of the drift measurements during the IQSY. The following is an excerpt of the letter received from him:

"I am extremely interested in your research and your proposed study. I am preparing a catalog of ionospheric stations which are making drift measurements. I hope this will be ready shortly and as soon as it is, I will send you a copy. I am afraid this will not be as useful as I would like it because it is so difficult to acquire the details. I think your best bet would be to take this catalog, which will contain addresses, and contact stations direct. I am hoping that we shall be able to get a working group of people together at the next general assembly of URSI, which will be held in Europe next summer."

Details of the ionospheric drift stations around the globe were collected from World Data Center catalogs, and a preliminary assessment was made of how much data would be required for the study.

The purpose of the investigation is to study seasonal, diurnal, latitudinal, and sunspot cycle variations of the drift parameters. A world-wide distribution of ionospheric drifts as obtained by the spaced receiver method will be given and this may perhaps be very useful in understanding the more intricate behavior of the ionosphere.

The following drift data for the lower and upper ionosphere was obtained from the World Data Center:

STATION	LATITUDE	YEARS OF DATA
Tomsk	56° 29' N	Sept. 1957 - May 1964
Irkutsk	52° 16' N	April 1958 - May 1964
Rostov	47° 00' N	July 1958 - June 1964
Ashkhabad	37° 57' N	Jan. 1958 - June 1964
Yamagawa	31° 00' N	July 1959 - Dec. 1964
Waltair	17° 30' N	Jan. 1958 - Dec. 1964

This data is in the form of microfilm rolls. Prints will be made from these rolls to do the analysis.

Measurements of horizontal drifts at the Aeronomy Field Station will be made on 3030 kHz on a routine basis. The receiving antennas were placed at the corners of an equilateral triangle as opposed to the conventional placement of the antennas at the vertices of a right triangle. The reason is that each side of the triangle can be used to give the width of the spatial auto-correlation function in a direction parallel to the side. While both geometric arrangements effectively give the structure in six directions, an equilateral triangle must be used for these directions to be spaced uniformly in azimuth (Sales and Bowhill, 1962). The following is the future program on the study of ionospheric drifts at the field station:

1. An investigation on the height gradient in horizontal drifts will be made. This investigation requires the measurement of drifts on multiple frequencies during short intervals. It is planned to accomplish this by using the transmitter of the ionosonde during the interval between ionograms.

2. A study of E_s drift will be undertaken after the ionosonde is installed.

3. A study of F2-region drifts will be made to understand the morphology of the F2 region.

4. Measurements of winds in D-region levels will be undertaken after the installation of the partial reflection sounder.

Reference

Sales, G.S., and S.A. Bowhill (1962), Apparent ionospheric motion in the nighttime D-region, J. Atmosph. Terrest. Phys. 24, 451-465.

8.2 Instrumentation Design

G.W. Henry, Jr.

Tasks included under this topic pertain to the design and preparation of instrumentation to be used for measurement of ionospheric drifts at the Aeronomy Field Station, as conducted under NASA grant NsG-511.

The preliminary design of a system for measurement of ionospheric drifts has been planned to give maximum utilization of instrumentation already designed and constructed for use on the shipboard experiment. The system requirements were:

1. Transmitter power - at least 5 kw peak pulse power.

2. Pulse requirements - 50 microsecond pulse, pulse repetition rate of at least 30 pps and preferably 60 pps.

3. Receiver requirements - Sensitivity of at least 100 μV . Bandwidth of at least 30 kHz. Three channel input with identical gain on each channel and electronic switching between channels so that the channels are individually activated every third transmitter pulse in sequence. Three channel output synchronized with input switching to provide a DC offset of each channel with respect to the others.

4. Antenna requirements - Three identical loop antennas of 1 square meter area spaced in an equilateral triangle 100 meters on a side, apex to the north or south (see section 7.2).

The ship board transmitter and receiver were capable of the above operations except for the transmitter power output, which was greater than necessary (50 kw), slower pulse repetition rate, and only single channel receiver capability. It was therefore decided to modify the existing system to fulfill the necessary requirements. The steps necessary to modify existing equipment or to design new instruments in order to adapt the original system were:

1. Either operate the 5 kw driver-amplifier stage as an output stage coupled directly to the antenna system or design and construct a new high-voltage power supply to permit operation of the final amplifier at the higher pulse repetition rates. Construction of the new power supply was chosen because it also fulfilled requirements of the expanded partial reflection experiment (see section 10.2).

2. Design and construct a new pulse generator capable of pulse repetition rates of 30 and 60 pps, preferably synchronized to the power line. This unit, when constructed, also proved quite useful in conjunction with partial reflection measurements (see section 10.2).

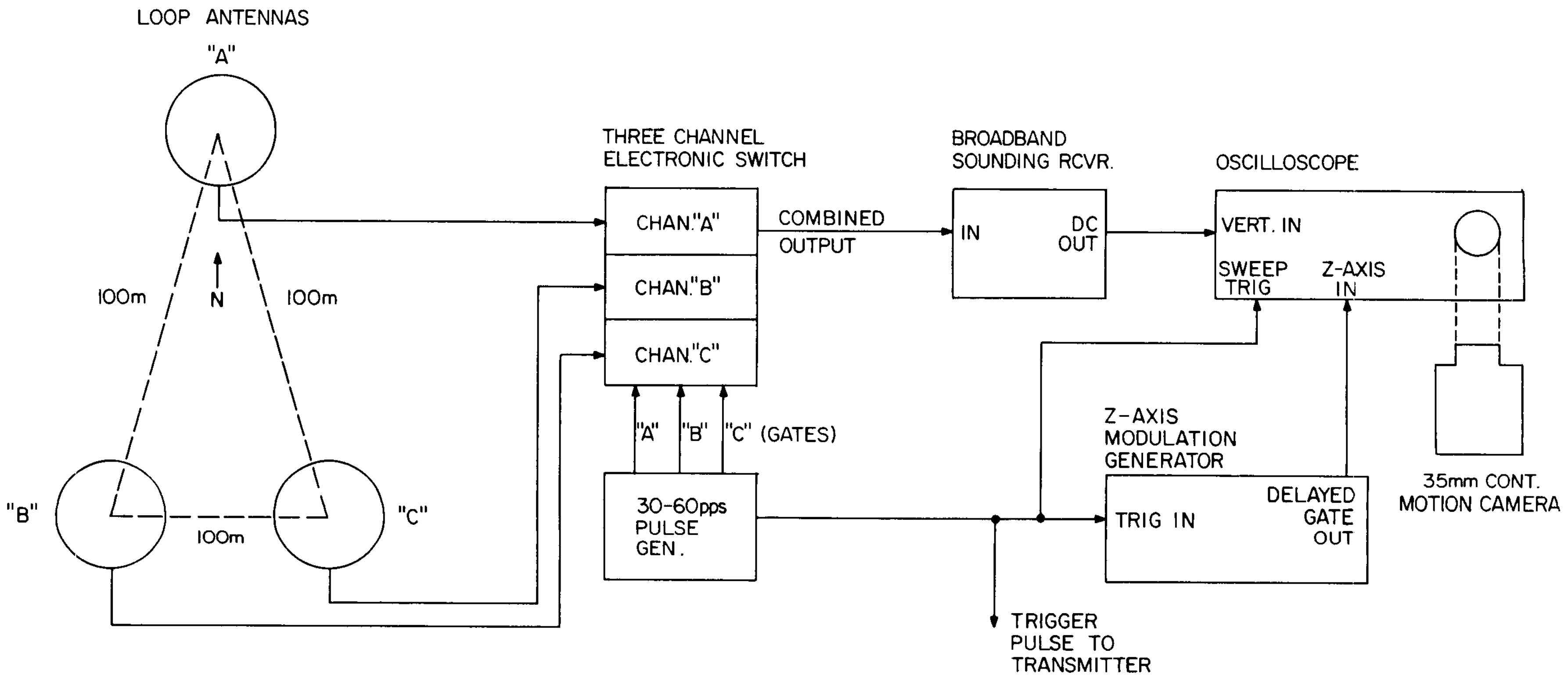

Figure 8.2.1 Block diagram of the instrumentation designed for ionospheric drifts measurements.

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3. Design and construct a three-channel electronically-switched preamplifier to be used in conjunction with the broadband ionospheric sounding receiver designed for absorption and partial reflection measurements.

4. Design and construct a DC level shifting circuit to adapt the DC amplifiers of the receiver for three-channel operation.

5.. Convert various metering circuits of the transmitter to accomodate operation at the increased pulse repetition rates.

6. Design and construct three identical loop antennas.

7. Obtain a continuous-motion 35 mm film magazine for the data recording camera used for partial reflection recording, and adapt the control system to operate it.

8. Design and construct a time marker generator to provide time reference marks on the data record at five-second intervals. The unit designed uses a synchronous timing motor and simple logic circuits to blank the oscilloscope input at the appropriate time for a period of 100 ms.

All of the above construction and modification projects were completed, tested, and installed at the field station during January, 1966. Preliminary ionospheric drift recordings were filmed during February, but transmitter failures due to increased heat generated because of the higher pulse repetition rates prevented any further measurements during the month of March (see section 2.1). Figure 8.2.1 shows a block diagram of the instrumentation used for ionospheric drifts measurements.

8.3 Data Analysis and Review

G.L.N. Rao

Tasks included under this topic pertain to the review of published studies on ionospheric drifts measurements and to the analysis of drifts data, as conducted under NSF grant GP-866.

A number of geophysical problems--such as motions of noctilucent clouds, meteor trails, the appearance and motion of sporadic E, and seasonal changes in geomagnetic diurnal variation--all make it possible to postulate the existence of wind circulation systems in the ionosphere. The study of horizontal drifts in the ionosphere has gained considerable importance during the last several years. The IGY committee on ionospheric drifts designed a systematic program of measurements during the IGY of ionospheric drifts in the lower and upper ionosphere, and several people were involved in these measurements around the globe. The most general and widely used method of observation of drifts is that employing spaced receivers (Mitra, 1941). The results obtained by various investigators prior to the IGY were carefully summarized and reviewed by Briggs and Spencer (1954).

The IGY program on ionospheric drifts made it possible to understand the world-wide variation of drifts. The wealth of data collected during the IGY-IGC was used by the present author to study the parameters of ionospheric drifts in the E and F2 regions and their latitude variation. Experimental results published by various investigators at different locations were carefully collected. In all, about seventy research papers in lower ionospheric drifts and about eighty research papers in upper ionospheric drifts were published. The large number of papers published in this area of research demanded a consolidating and reviewing of the current state of affairs on drifts in the lower and upper ionospheres. Accordingly, an extensive and thorough investigation into this aspect was undertaken and a review on ionospheric drift parameters was made.

These investigations were divided into two parts: drifts in the lower ionosphere and drifts in the upper ionosphere. Comparisons of the results obtained by various investigators were made and these are published as Aeronomy Reports 6 and 9.

Some of the very interesting results obtained by this review work are summarized below:

Lower Ionosphere

1. The nighttime average drift velocities were greater than the average daytime drift velocities, but the difference in magnitude was more at higher latitudes.
2. The magnitude of steady drift was found to increase with increase of latitude. From this behavior, it appears that there is a uniform system of motions in the lower ionosphere.
3. A fundamental change in drift direction was noticed with the presence sporadic E.
4. The Fourier analysis showed that the rotation of diurnal and semi-diurnal drift vectors with time was clockwise, in general, in the northern hemisphere and anticlockwise in the southern hemisphere.
5. The diurnal drift vector was large at low latitudes and it decreased in magnitude with increase of latitude.
6. The parameters of the spatial correlation ellipse were found to decrease in magnitude with increase of latitude.

Upper Ionosphere

1. The variation in the drift velocities at the equator was largely diurnal and west by day and east by night.

2. The diurnal component of the drift velocity decreased in magnitude with increase of latitude from the equator up to middle latitudes and then started increase toward high latitudes.

3. The magnitudes of the drift velocities were largest at the equator, decreased with increase of latitude up to 45°, and then increased toward higher latitudes.

4. The effect of magnetic activity on ionospheric drifts was significant. The drift velocities were found to decrease with increase of k-index values at the equatorial latitudes, and at higher latitudes the effect was opposite. The change from negative to positive correlation occurred around 30° geomagnetic latitude.

N67 14650

9. DIRECT MEASUREMENTS CONFERENCE

9.1 Administration

Mrs. Belva Edwards

This topic includes arrangements for the Second Conference on Direct Aeronomic Measurements in the Lower Ionosphere sponsored by Ballistics Research Laboratories under grant AMC-862.

After preliminary correspondence with Dr. W.W. Berning, Dr. Bowhill prepared a proposal for submission to the Ballistics Research Laboratories for support of the Second Conference on Direct Aeronomic Measurements in the Lower Ionosphere, to be held September 27-30, 1965, at the University of Illinois. The proposal outlined objectives of the meeting and a budget, prepared in collaboration with Mr. Lawler and Mr. J.W. Seyler of the University of Illinois Extension Division.

In May, 1965, the First Notice and Call for Papers was prepared and approximately 750 copies were sent to scientists all over the world.

Dr. Bowhill selected a Program Committee; copies of abstracts of all contributed papers were sent to them together with an evaluation sheet for their classification of the paper. These evaluation sheets were returned and the selection of papers was made from them. The authors were notified of acceptance or rejection.

In June approximately 175 personal letters of invitation were sent to outstanding individuals. Those from overseas indicating an interest in attending were sent letters offering financial assistance from the University Extension office.

In August a second circular and registration card (prepared in collaboration with Mr. R.C. Wicklund, Short-Courses and Conferences) were sent to each of the invitees. The second circular contained a general outline of topics on the program and requested that summaries of papers to be presented be sent in for inclusion in the Conference Digest. The registration card was to be returned to Mr. Wicklund's office for registration purposes and hotel reservations.

In September, the Conference Digest was compiled from the summaries and diagrams received, under the supervision of Dr. J.S. Shirke and Mrs. Howard of the Publications Office.

The Program was finalized by Dr. Bowhill; session chairmen appointed and opening speakers selected by Dr. Bowhill were contacted for their consent to give the opening paper in their specialized field. A copy of the program together with a "Final Instructions to Authors" memorandum were sent to all authors, opening speakers and session chairmen.

Arrangements were made through Mr. Wicklund's office and G.L.N. Rao, for use of the Illini Union facilities including reservations for meeting rooms, the ballroom, hotel rooms, telephone installation, and meals and coffee for morning and afternoon sessions. Also, arrangements were made with the Urbana-Lincoln for rooms and the conference banquet.

Arrangements were made with the Physical Plant for a projectionist to be present at all sessions and with WILL for microphones and recording equipment.

G.L.N. Rao compiled a complete list of reservations (from the cards returned to Mr. Wicklund's office) showing times of arrival and hotels so that our couriers would know when and where to deliver the attendees. Three

University cars and drivers were available during the week of the Conference for the convenience of the attendees. A bus was used on the night of the banquet to take people to and from the Urbana-Lincoln Hotel.

Dr. Sechrist was in charge of reporting for the conference. He selected reporters, scheduled their times to work and issued special instructions for them. The entire conference was tape recorded and three reporters were present at each session to take notes and handle special visual aid material speakers might have. A copy of papers and diagrams presented were to be furnished by the participant for inclusion in the Conference Record, but the discussion which followed each paper was transcribed from the tape by the reporters for their particular sessions. These were typed in rough, then edited by Dr. Sechrist and Dr. Shirke and incorporated with the papers for the Conference Record. Final typing of the Record is to be done by the Publiciations Office and will be issued as Aeronomy Report No. 10, a copy of which will be sent to each attendee.

Registration for the Conference was handled by Mr. Wicklund's office. They received money for meals and handed out copies of the Conference Digest. Registration was held on Sunday evening and again on Monday and Tuesday mornings.

A total of 105 persons attended the conference, including

2 from U.K.

2 from India

1 from Ceylon

1 from Norway

1 from France

4 from Canada

Travel vouchers were prepared for those from overseas and reimbursement for these has been made.

Letters of appreciation from Dr. Bowhill have been sent to all opening speakers.

9.2 Reporting

C.F. Sechrist, Jr.

Tasks included under this topic pertain to arranging reporting coverage of the Second Conference on Direct Aeronomic Measurements, and to the preparation of the Conference Record, as conducted under Ballistics Research Laboratory grant AMC-862.

The Second Conference on Direct Aeronomic Measurements in the Lower Ionosphere was held at the University of Illinois during September 27-30, 1965. All proceedings of this conference were tape recorded and several members of the Aeronomy Laboratory served as conference reporters.

Following the conference, the reporters transcribed the discussions which followed virtually every paper presented. The co-editors (C.F. Sechrist and J.S. Shirke) assembled, edited, and proofread each conference paper. The transcribed discussions were also edited and proofread.

Several speakers did not submit written papers, and it was necessary to have these transcribed by Stenographic Services. Some of the transcribed papers required extensive editing.

The Publications Office in the Department of Electrical Engineering typed all papers and discussions on multilith masters, and these were proofread by the co-editors. During March, Dr. Shirke prepared the Table of Contents, author index, and list of attendees. The Conference Record will be issued as Aeronomy Report No. 10.

10. PARTIAL REFLECTION EXPERIMENT

10.1 System Study

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Tasks included under this topic pertain to the estimation of the system gain required to obtain satisfactory performance of the partial-reflection sounder, as conducted under NASA grant NsG-511.

According to A. Von Viel and W. Flood of the Cornell Aeronautical Laboratory, the E-layer echo amplitude observed with their 2.4 MHz partial reflection experiment was 60 to 70 db above noise; this was obtained on an island in the South Pacific during May, 1965. Also, the partial reflections from the 50 km altitude were roughly 20 to 30 db above the noise level. Hence partial reflection amplitudes are of the order of 50 db below the amplitude of the E-layer echo.

According to J.S. Belrose (1964), amplitudes of partial reflections at 2.66 MHz are of the order of 50 to 70 db below the E-region echo amplitude.

A-scope recordings from the partial reflection experiment were inspected. E-layer echo amplitudes were roughly 30 db above noise peaks and 40 db above the average noise level. This suggests that we need at least 20 db additional system gain.

Following the installation of the partial reflection experiment at the Urbana field station in February, 1966, noise measurements were conducted in order to estimate more accurately the system gain required for successful operation of the experiment. It was confirmed that at least 20 db additional gain is necessary.

It appears that the amplitudes of D-region partial reflections are enhanced on winter days of high absorption, based on results obtained by J.E. Gregory in New Zealand (1965); therefore, attempts were made to obtain partial reflections on these days before March 1st. Unfortunately, the results were negative.

10.2 Instrumentation

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Tasks included under this topic pertain to the design, construction and maintenance of instrumentation for use in making partial reflection measurements, as conducted under NASA grant NsG-511

The technique originally given by Gardner and Pawsey relies on the determination of the relative amplitudes of radio waves back-scattered from the transmission of the ordinary and extraordinary modes of propagation from the ground. These measurements in turn may be used to determine the electron density profile at a given time, provided that the electron collision frequency model is known.

Instrumentation was designed during the months from June to December, 1964 for use in measurement of vertical incidence absorption and partial reflections on board the NASA Mobile Launch Research Expedition to the south Pacific in the spring of 1965 (see 2.4). After use on this expedition, the van containing the entire system was returned to the campus of the University of Illinois for further use in measurement of ionospheric absorption and partial reflections. This system has been used as the basis for all instrumentation for ionospheric measurements at the University of Illinois from September, 1965 to the present. The system incorporates a pulsed transmitter capable of delivering a peak pulsed power of 50 kw to the antenna, a very high gain, wide bandwidth receiver, and the associated power supplies, pulse generators, and oscilloscope monitoring equipment necessary to display and record the data. All of the above instrumentation is described in detail in forthcoming Aeronomy Report No. 13.

Measurements of noise levels vs amplitudes of reflected signals demonstrated the need for additional system gain for reliable partial reflection recording (see 10.1). The following five proposals were considered for system improvement:

1. Increase the pulse repetition rate of the existing transmitter from a maximum of 5 pps to 60 pps to achieve signal integration on the records, thereby giving an apparent improvement in signal to noise ratio for repetitive signals recorded on the film.
2. Modify the existing transmitter for 100 kw output by adding two additional final amplifier tubes to the existing push-pull final amplifier stage.
3. Construct a high power (500 to 800 kw) amplifier using the existing 50 kw transmitter as a driver stage.

4. Construct a completely new 800 kw transmitter following the general design used in the existing 50 kw transmitter, but designed to be more easily operated over a wide range of frequencies and at greater pulse repetition rates.

5. Design and construct a high gain antenna system.

Initial discussions led to the choice of proposal No. 1 so that additional measurements of signal-to-noise ratios could be made for accurate determination of exactly how much improvement in the system gain was required.

To modify the existing transmitter for operation at the increased pulse repetition rates it was necessary to design and construct the following instrumentation:

1. A 5,000 volt - 100 ma power supply to provide the increased average power required by the final amplifier and driver amplifier stages of the transmitter.

2. A pulse generator capable of generating trigger pulses for the transmitter at pulse repetition rates of 30 and 60 pps, synchronized with the power line. This pulse generator was also required for use with the ionospheric drifts experiment and therefore served a dual function (see 8.2).

3. Modify the metering circuits of the transmitter to accomodate the increased average power.

The above instrumentation was completed and installed in the van at the Aeronomy Field Station during January, 1966. Additionally, it was necessary to design and construct some instrumentation that had not been required for the Mobile Launch Expedition. This instrumentation was:

1. A coaxial delay-line type of phase-shifter to give the required 90 degree phase shift to generate circular polarization.
2. Two coaxial attenuators to allow adjustment of the amplitudes of the signals fed to the two antenna elements for circular polarization alignment of the antennas.
3. An impedance-matching diplexer to couple equal amounts of power to the two 50 ohm coaxial antenna feedlines from the 50 ohm transmitter output.

This instrumentation was also installed in the system at the field station during January, 1966.

The entire system was coupled to the four-dipole antenna array at the field station in February, 1966 and signal-to-noise measurements were made. These measurements indicated that approximately 20 to 30 db additional system gain was required for observation of partial reflections (see 10.1) and that the recovery time of the transmit-receive switch was not sufficiently short for partial reflection measurements.

Further discussion and a cost analysis of increasing transmitter power vs increasing antenna gain demonstrated the desirability of a larger antenna system (see 7.2). Therefore, it was decided to proceed with proposal No. 5 as discussed in section 7.2 and to suspend further transmitter improvement until after the larger antenna system had been constructed and tested. It was also decided to construct a second antenna system for receiving to avoid the extensive and expensive redesign of the transmit-receive switch system to achieve the faster recovery time.

Operation of the transmitter at the increased pulse repetition rates caused considerable trouble with increased heat generation and failures in the transmitter as noted in section 2.1. These problems are to be alleviated by incorporation of new air-system tube sockets and larger blowers for cooling of the final amplifier tubes.

Consideration is being given to the design of a height marker generator for use with the partial reflection data recording system. An intensified dot is to be superimposed on the oscilloscope trace at intervals of one kilometer of virtual height. The design problem hinged primarily on finding a means of keying a multivibrator in such a way that its period of oscillation would be constant from the instant of turn-on. Base gating of one of the multivibrator transistors has provided the desired uniformity. This multivibrator stage will now be incorporated into the remainder of the triggering circuitry necessary to synchronize the height marks with the transmitted pulses.

It is planned that a frequency of 2.66 MHz will be used for the partial reflection experiment in the future, which hopefully will be more effective, especially for routine low altitude measurements.