Ionospheric Research

NASA Grant NsG-114-61

Scientific Report

on

Instrumentation for Continuous Polarimetry

Measurements of Satellite Transmissions
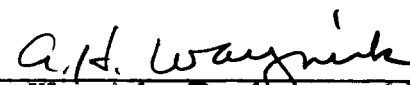
by

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ABSTRACT 29303

The development of a continuous polarimeter applicable
to Faraday rotation investigation of satellite transmissions is
presented. The system is designed to overcome ambiguities in
determination of the Faraday rotation at the ground, under condi-
tions which are likely to produce fluctuations or changes in the
direction of rotation. This is accomplished by resolving the
linearly polarized wave into its component oppositely sensed
circularly polarized modes using a fixed-geometry antenna system.
The component modes are phase compared to determine contin-
uously the position and sense of the plane of polarization of the
wave.

I. INTRODUCTION

1. Satellites in Ionospheric Research

The satellite has proved to be an extremely useful tool for the investigation of the upper atmosphere. In the study of the ionosphere, satellites have provided many types of information. For example, a satellite may act as a probe, yielding a wide variety of environmental data; it may act as a sounder by transmitting radio waves downward and measuring the echo range; or the satellite may act as a beacon, transmitting directly to the ground where the radio waves can be analyzed having passed through the ionosphere.

The satellite's primary advantage is its long-term high altitude operation. In this respect, it increases the range of sounding studies to the top half of the electron density profile and overcomes some of the difficulties encountered with the short lifetime of a rocket, which has been the primary vehicle for probe investigation. In addition, a satellite, depending upon its orbit, can provide worldwide coverage thus furnishing data for all types of geographic and geomagnetic conditions.

2. Beacon Satellite Investigations

As a beacon, a satellite transmits linearly polarized waves directly to the ground. Usually these waves are unmodulated and at frequencies somewhat greater than the critical reflection frequency. Ground stations are prepared to analyze the incoming waves for the effects of passage through the ionosphere.

One principal technique involves measurement of the Doppler frequency shift resulting from the satellite's high lateral velocity. At two harmonically related frequencies, the ratio of the observed frequency shifts at the ground usually does not coincide with the ratio of the frequencies, as would be expected in free space. It has been shown that this deviation is dependent upon the integrated electron density along the wave's path.

A second major method of investigation involves observation of Faraday rotation, which can be briefly described as follows. In passage through a medium such as the ionosphere in the presence of a magnetic field, a linearly polarized electromagnetic wave will experience a rotation of its plane of polarization about the axis of propagation. The amount of rotation is dependent upon the total electron content in a narrow column between the satellite and receiver. Instrumentation to measure Faraday rotation is the primary purpose of this investigation.

The satellite's orbit has a pronounced effect on the Faraday rotation observed at a ground station. Steady rotation of uniform direction requires only simple instrumentation; however, several factors may lead to variations in the rotation rate and direction which will be discussed more fully in Chapter II. The most important factor in considering the rotation for a particular orbit is the spatial variation with satellite direction of the earth's magnetic field component longitudinal to the wave normal.

Consequently, a polar satellite is unlikely to produce changes in rotation direction and the Faraday rotation can be

detected by amplitude variations from a linear antenna. However, a satellite with an inclination of 40° passes over a mid-latitude station in a West to East direction and rotation direction changes are common. Therefore, if unambiguous rotation data are to be obtained for an inclined satellite, the instrumentation must be capable of continuously monitoring the angle of the wave's plane of polarization.

A continuous polarimeter could take many forms all a great deal more complex than the linear antenna which detects amplitude nulls every half rotation. To determine the sense of rotation unambiguously, the system must include at least two antennas and related receiving equipment for two channels. Several antennas could be oriented at different angles and the null's progress observed by commutating these, but this system has a resolution limited by the number of antennas.

The best system appears to be one which mechanically follows the rotation; however, the system complexity and size limit its general use. The basic cost and time to construct and maintain such a system make consideration of a simpler system a certainty. Therefore, fixed geometry has been chosen as a system require-ment of the polarimeter.

3. Statement of the Problem

A system is to be developed to obtain unambiguous Faraday rotation data from a satellite pass under conditions which are likely to produce fluctuations or changes in the direction and rate of rotation. More explicitly, a fixed-geometry continuous polarimeter of reasonable simplicity with a resolution on the order

of 5° is required to monitor satellite transmissions for all satellite positions up to about 45° from zenith as viewed from the receiving station. Fixed geometry has been chosen for reasons of size, cost, and maintenance. The resolution of 5° or better has been selected on the basis of the resolution required for a paper chart record at normal chart speeds for satellite data reduction (about 5-15 mm/sec). The 45° angle from zenith corresponds to the normal range of reception for a satellite orbiting at 1000 km with a power output of 100-200 mw and a wave frequency of 20 MHz.

II. THEORY OF FARADAY ROTATION

1. First-Order Theory

In propagating through a magnetoionic medium such as the ionosphere, a linearly polarized plane wave may be considered as the resultant of two oppositely sensed characteristic waves having equal amplitudes but different phase velocities. In general, these waves are elliptically polarized, but may be considered to be circular if the wave frequency is much greater than the plasma frequency. Since the phase velocities of the characteristic modes are unequal, the linearly polarized resultant is seen to rotate about the axis of propagation as the wave traverses the ionosphere. This phenomenon is generally known as Faraday rotation.

It can be shown, in general, that a linearly polarized plane wave is formed by the vector summation of two oppositely sensed circularly polarized waves of equal amplitude. Equations for circularly polarized waves, with left-handed and right-handed senses respectively, may be written as follows,

LEFT HANDED: $\quad \overline{E}_L = E_o \cos \omega t \, \overline{a}_x + E_o \sin \omega t \, \overline{a}_y \qquad (1)$

RIGHT HANDED: $\quad \overline{E}_R = E_o \cos (\omega t + \psi) \overline{a}_x - E_o \sin (\omega t + \psi) \overline{a}_y \qquad (2)$

where:

$\quad \overline{E}_L, \overline{E}_R$ = the electric field vector in the plane of polarization for each sense

$\quad E_o$ = the electric field magnitude of each circularly polarized component wave

$\overline{a}_x, \overline{a}_y$ = unit vectors in the x-, y- direction

ω = the wave angular frequency

ψ = the spatial angle between the field vectors for the opposite senses at t = 0.

Let the vector sum of the two modes $(\overline{E}_L + \overline{E}_R)$ be given as $\overline{E}_T$. Then an expression for $\overline{E}_T$ can be written by vector summation of equations (1) and (2).

$$\overline{E}_T = \overline{E}_L + \overline{E}_R = E_o [\cos \omega t + \cos (\omega t + \psi)] \, \overline{a}_x +$$

$$E_o [\sin \omega t - \sin (\omega t + \psi)] \, \overline{a}_y$$

$$= 2E_o \cos (\omega t + \psi/2) [\cos \tfrac{\psi}{2} \, \overline{a}_x - \sin \tfrac{\psi}{2} \, \overline{a}_y] \qquad (3)$$

Equation (3) can be seen to be the equation of a linearly polarized wave of magnitude $2E_o$ with its plane of polarization oriented at an angle of $\psi/2$ in the right-handed direction from the x-z plane as shown in Figure 1. If the angle ψ should increase steadily while the wave is propagating, it is obvious that the plane of polarization for the linearly polarized resultant wave will appear to rotate. The rate of rotation will proceed at half the rate of change in ψ.

To show that the two modes have different phase velocities, producing variation in ψ, it is necessary to consider their indices of refraction. Assuming negligible attenuation, a wave frequency much greater than the plasma frequency, and for propagation quasi-longitudinal to the earth's magnetic field, an expression for the index

PLANE OF POLARIZATION OF THE RESULTANT WAVE
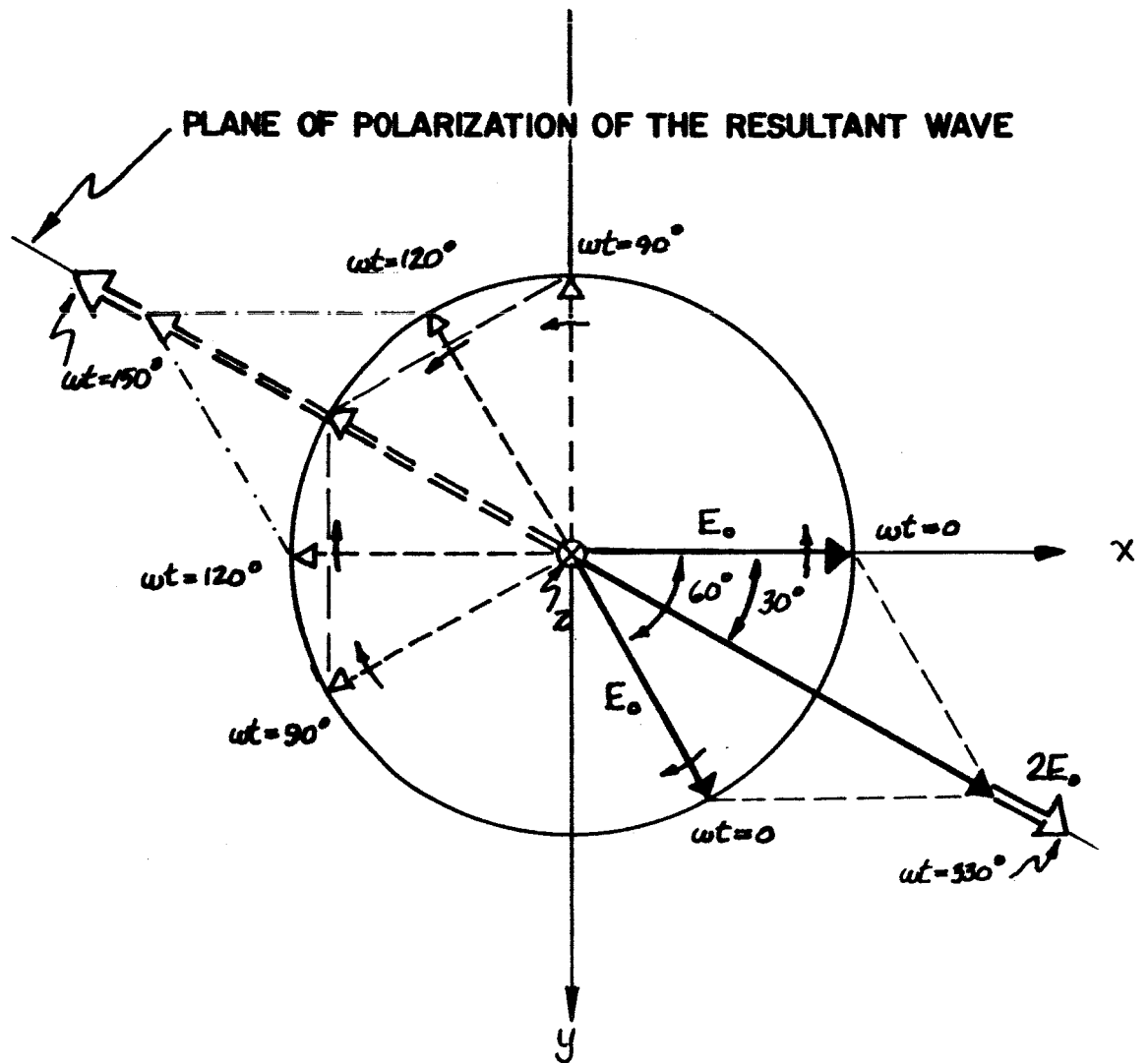
LINEAR POLARIZATION AS THE RESULTANT OF TWO
OPPOSITELY SENSED CIRCULARLY POLARIZED MODES
FOR $\psi = 60°$

FIGURE I

of refraction may be written in the form, [4, 10]

$$\mu^2 = 1 - \frac{X}{1 \pm Y_L} \quad ,$$

which reduces to

$$\mu = 1 - \frac{1}{2} X \pm \frac{1}{2} X Y_L \qquad (4)$$

where,

μ = the index of refraction

$X = \dfrac{(\text{plasma frequency})^2}{(\text{wave frequency})^2} = \dfrac{f_N^2}{f^2} = \dfrac{N e^2}{4 \pi^2 \varepsilon_o m f^2}$

$Y_L = \dfrac{\text{longitudinal gyro frequency}}{\text{wave frequency}} = \dfrac{f_L}{f} = \dfrac{B_o e \cos \theta}{2 \pi m f}$

ε_o = permittivity of free space

N = electron density

θ = the angle between the wave normal and the
earth's magnetic field

B_o = the earth's magnetic flux

m = electron mass

e = electron charge

For a wave frequency of 20 MHz, the ratio f_N is greater than 3:1.
This means that the quasi-longitudinal approximation[4, 10]

$$\left| \frac{Y_T^2}{2 Y_L} \right| \ll |1 - X|$$

is valid with an inequality better than 10:1 for all angles of θ except for the small range of angles $90 \pm 2°$ which, however, cannot be observed in the ionosphere at mid-latitudes.

The Faraday rotation is simply the difference, in radians, between the phase path lengths for the two modes from the satellite to the receiver.

$$\Omega = \frac{\pi}{\lambda} \int \mu_{(+)} ds - \frac{\pi}{\lambda} \int \mu_{(-)} ds \tag{5}$$

phase   phase
path   path
(+) mode   (-) mode

where,

Ω = the Faraday rotation angle

ds = an element of path length

λ = the free space wavelength of the wave

$\mu_{(+)}, \mu_{(-)}$ = the indices of refraction from equation (4)

The two terms in equation (5) may be combined, to a first-order approximation, by performing each integration over the straight line path between the satellite and the receiver.

Since

$$\mu_{(+)} - \mu_{(-)} \approx XY_L$$

Therefore,

$$\Omega = \frac{e^3 \overline{B}_L}{8\pi^3 \varepsilon_o Cm^2 f^2} \int Nds \tag{6}$$

straight line
path

where $\overline{B}_L = \overline{B_o \cos \theta}$ is the mean value for the component of the earth's magnetic field in the direction of the wave normal, and C is the velocity of light in free space. For a horizontally stratified ionization distribution equation (6) becomes

$$\Omega = \frac{K\overline{M}N_T}{f^2} \tag{7}$$

where,

$$\overline{M} = \overline{B_o \cos \theta \sec \chi}$$

$$K = \frac{e^3}{8\pi^3 \, \varepsilon_o Cm^2}$$

χ = the angle between zenith and the straight line ray path

$$N_T = \int_o^h Ndh \ (h = \text{height})$$

For the case when the ionization is not horizontally stratified, equation (6) can still be written in the form of equation (7), but the quantity N_T must then be interpreted as an "equivalent" vertical column integral. In fact, since the ionization is heavily concentrated about the level of peak density, and lateral variations in N are generally small, this equivalence is found to be physically significant. In this study, it is intended to invoke this interpretation only for purposes of qualitative discussion.

2. Satellite Applications

Equations (6) and (7) describe, to a first-order approximation, the total angle of Faraday rotation experienced by an electromagnetic

wave in propagation from the satellite to the ground. However, the ground observer can only detect changes in rotation. Increases or decreases in the total angle appear as rotation of the wave's plane of polarization at the ground. Consequently, it is the rate of rotation that is measured rather than the total angle. Taking the time derivative of equation (7) produces,

$$\frac{d\Omega}{dt} = \frac{K}{f^2} \overline{M} \frac{dN_T}{dt} + \frac{K}{f^2} N_T \frac{d\overline{M}}{dt}$$

which written in terms of spatial gradients becomes,

$$\frac{d\Omega}{dt} = \frac{K}{f^2} \overline{M} \frac{\partial N_T}{\partial t} + \frac{K}{f^2} \overline{M} \frac{\partial N_T}{\partial x} \overline{V} + \frac{K}{f^2} N_T \frac{d\overline{M}}{\partial x} \qquad (8)$$

where, $\overline{V}$ = the horizontal component of velocity for the straight line ray path at the mean ionospheric height.

If a horizontally stratified ionosphere is assumed, the second term in equation (8) vanishes. The first term is usually very small since time variation of N_T is diurnal. However, if the third term is small, the relative importance of any horizontal or time variations is magnified and the first two terms may not be neglected.

The spatial gradient of $\overline{M}$ is highly dependent upon the satellite orbit. Figure 2 shows the distribution of $\overline{M}$ around State College (40.8 °N, 77.9°W) as a function of satellite position for a satellite height of 1000 km. It is easily seen that a satellite with a near polar orbit will have a large $\overline{M}$ gradient, whereas one inclined 40° from the equator will have a very small gradient (see Figure 3)

X STATE COLLEGE

30000
35000
40000
45000
50000
55000
60000
65000
70000
75000
80000

SATELLITE LATITUDE (°N)

55 50 45 40 35 30 25 20 15

SATELLITE LONGITUDE (°W)

95 90 85 80 75 70 65 60
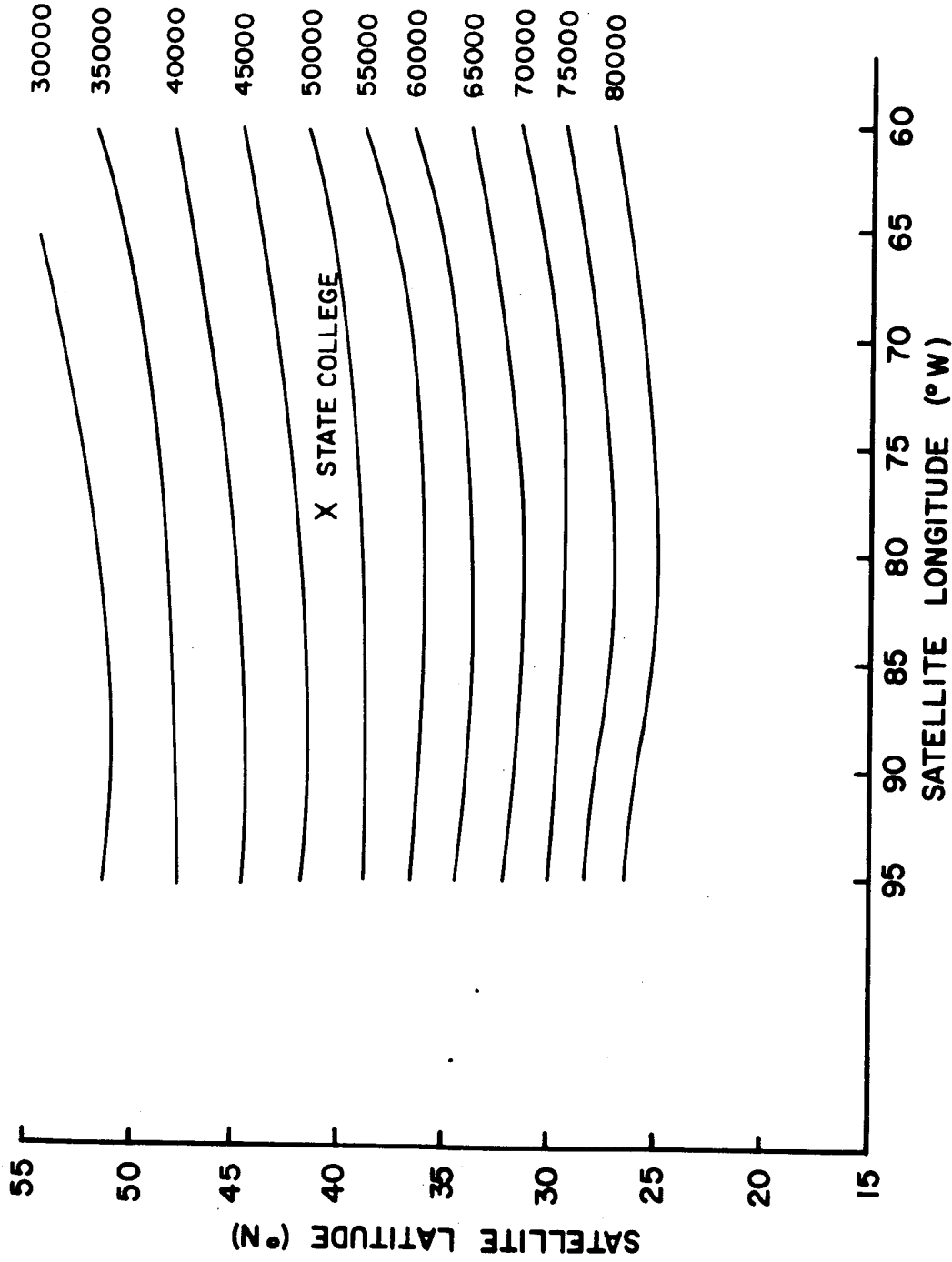
VARIATION OF THE PARAMETER $\bar{M}$ WITH SATELLITE
POSITION ($M = B_L \cos\theta \sec\chi$)
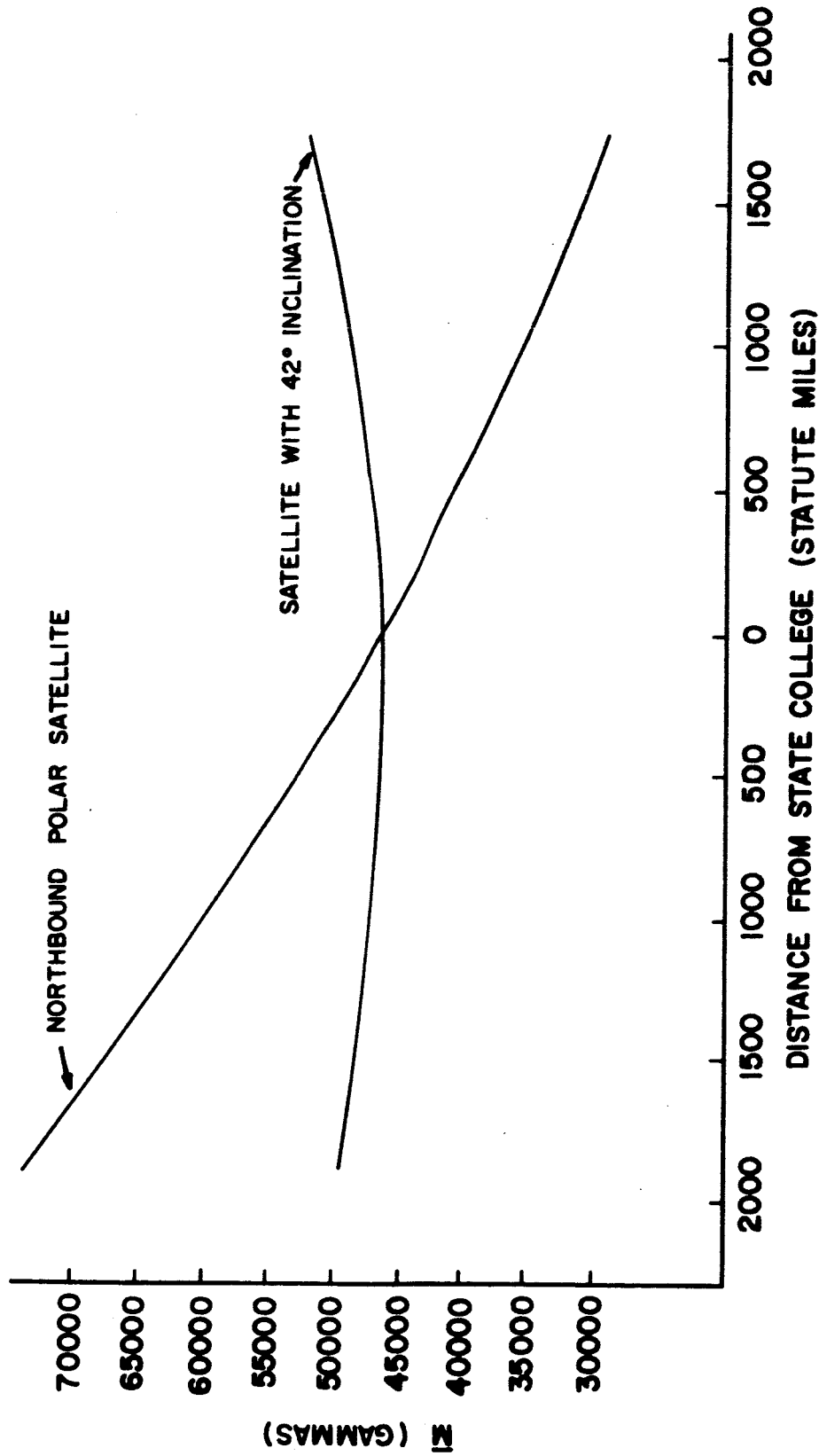
FIGURE 2

VARIATION OF THE PARAMETER $\bar{M}$ WITH DISTANCE FROM STATE COLLEGE
FOR OVERHEAD PASSES OF A POLAR AND 42° INCLINED SATELLITE
ORBITING AT 1000 KM.

FIGURE 3

since it passes over State College along a West-East path as demon-
strated in Figure 4.

For the satellite with 41° inclination, any one of the three
terms in equation (12) could result in a change of sign corresponding
to a change in the rotation direction as seen on the ground. For
example, the satellite moving into the sunlit hemisphere will
encounter gradients in integrated electron density resulting from
increased ionization. Further, careful study of Figures 2, 3, and
4 reveals that the $\overline{M}$ gradient will change sign for an inclined
satellite.

It may be concluded that a satellite with an inclination of about
41° is very likely to transmit signals which will result in fluctuations
or changes in Faraday rotation direction at a mid-latitude ground
station. On the other hand, signals from a near polar satellite are
unlikely to change rotation direction for such a station, although the
possibility does exist and in reality occurs occasionally in the
presence of a large gradient of electron content.
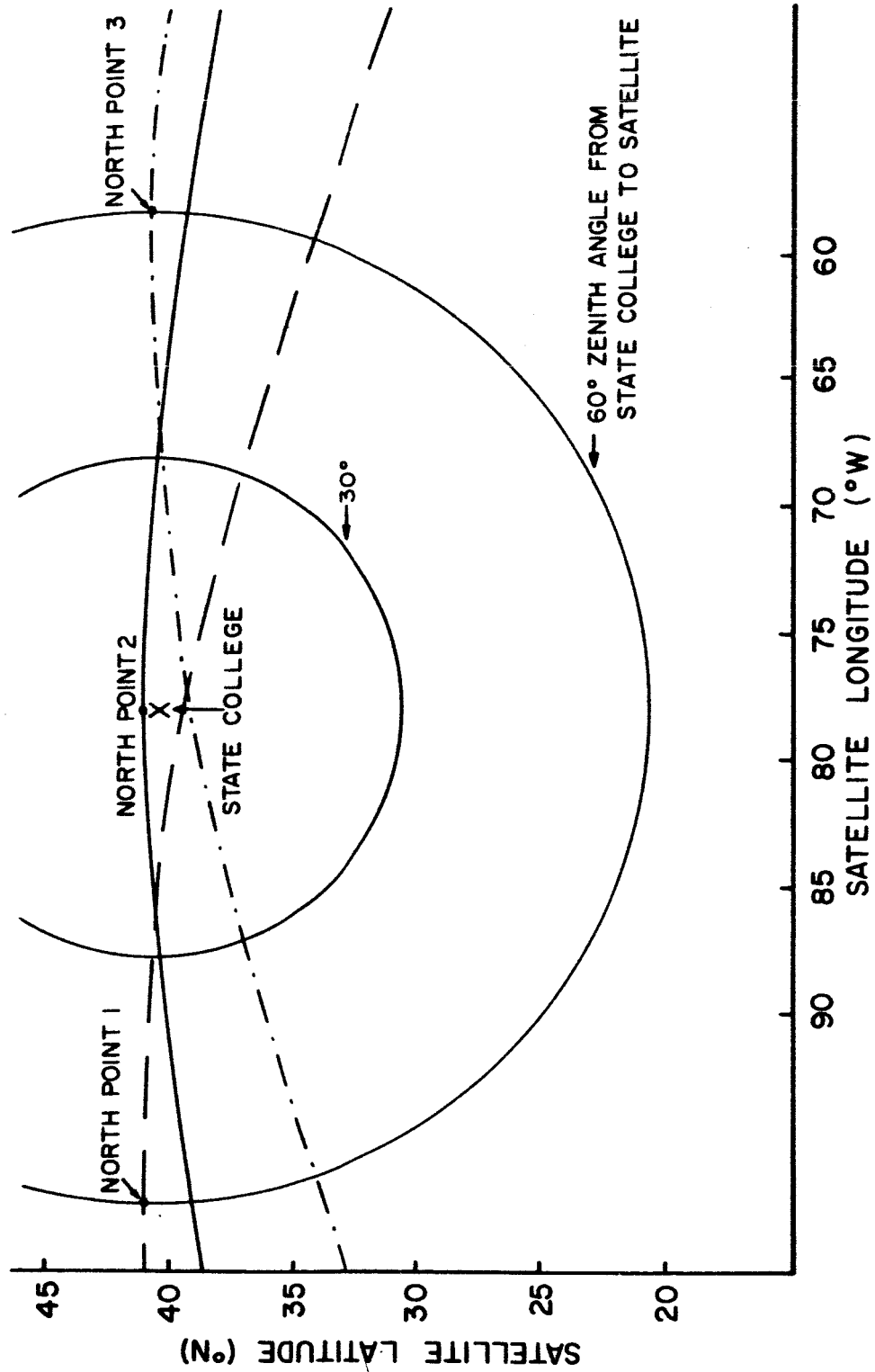
THREE SUCCESSIVE PASSES OF THE BEACON C SATELLITE

FIGURE 4

III. DEVELOPMENT OF THE INSTRUMENTATION

1. The Satellites

Two ionospheric research beacon satellites have been available for this study, S-66 Beacon B which has a near polar orbit, and S-66 Beacon C which has an inclination of 41°. Both have near circular orbits and a nominal altitude of 1000 km. Typical orbit parameters for the two satellites are as follows:

	Beacon B	Beacon C
Nodal Period (minutes)	104.8	107.7
Inclination (degrees)	79.7	41.2
Perigee Height (kilometers)	890	940
Apogee Height (kilometers)	1070	1320

Both satellites transmit continuous unmodulated linearly polarized waves at 20 MHz, 40 MHz, and 41 MHz with power out- puts of 250 mw. The satellite antennas are dipoles oriented normal to the axis which is magnetically stabilized; therefore, only one end of the satellite is presented to a mid-latitude receiving station.

2. The Antenna System

Continuous polarimetry can be achieved if the linear polar- ization of the wave is considered as the phase difference between its two oppositely sensed, circularly polarized components as discussed in Chapter II. Development of a circularly polarized

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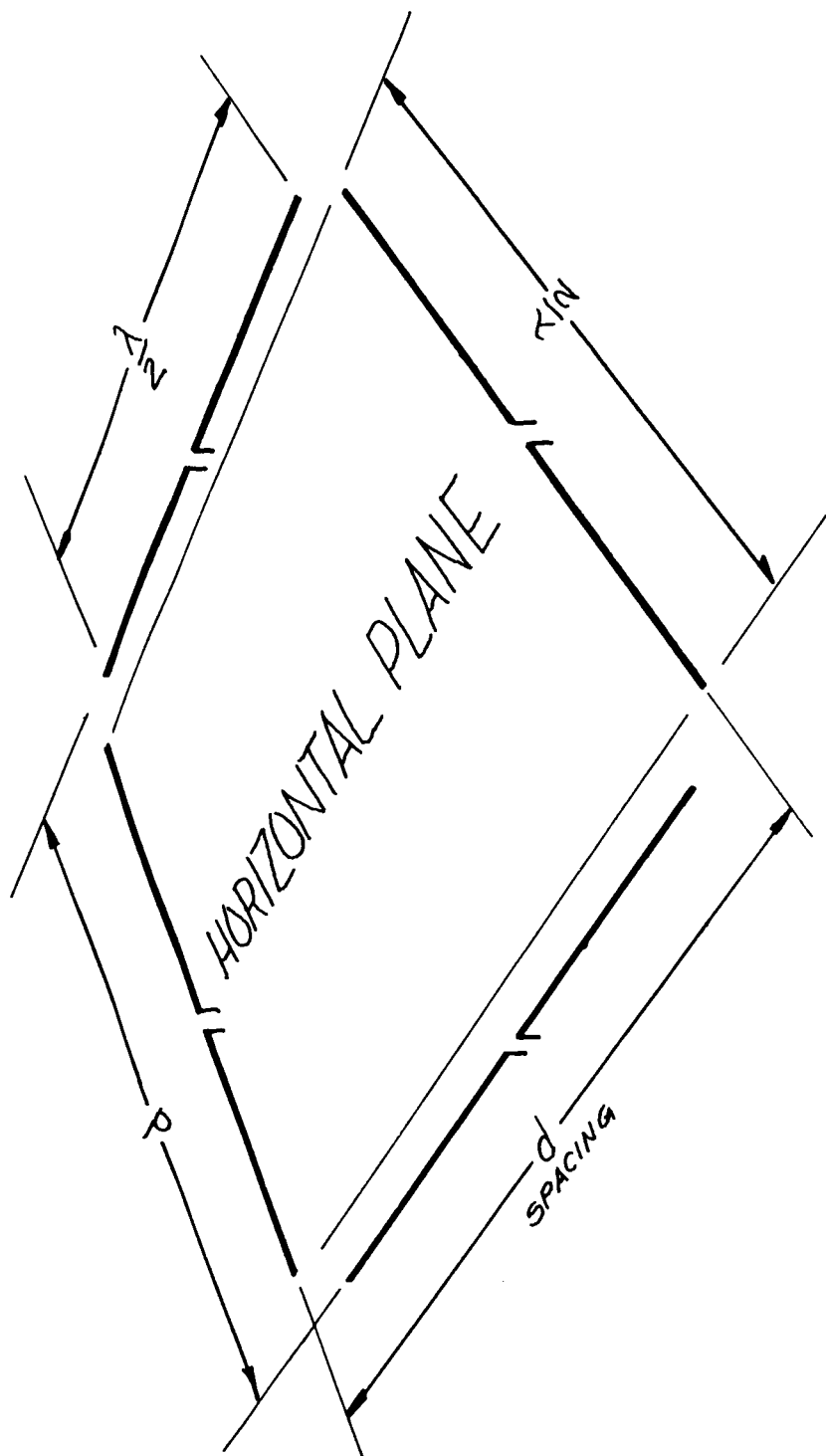
ANTENNA CONFIGURATION

FIGURE 5
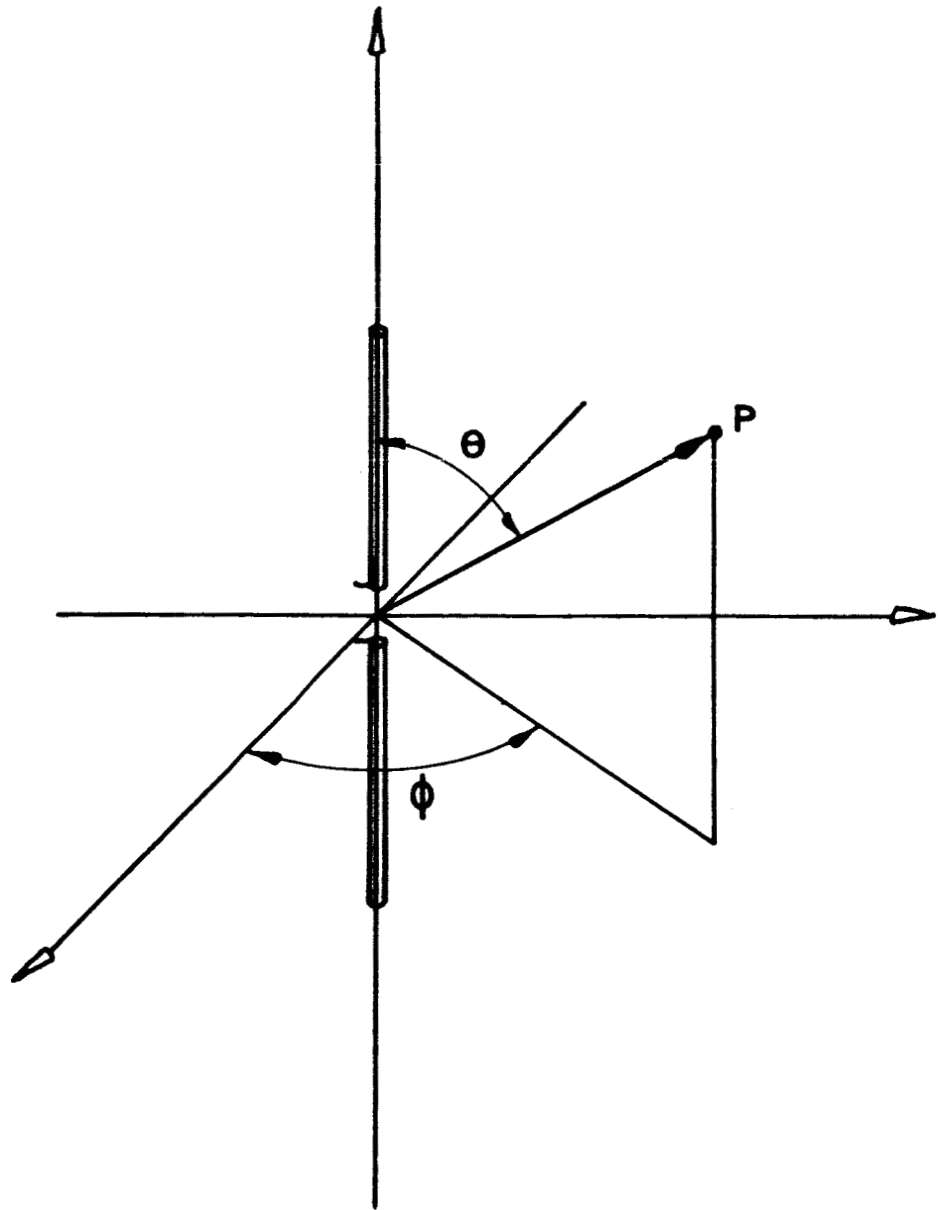
GEOMETRY FOR THE PATTERN OF A DIPOLE ANTENNA

FIGURE 6

phasor sum of the fields from each point source. The phase
difference, using the array mid-point as reference, is given by
$\pm\, kd/2 \cos \alpha$, where $k = 2\pi/\lambda$ and α is the angle between the path
and the array axis as defined in Figure 7. But $\cos \alpha = \sin \theta \cos \phi$,
and the total field is given by the cosine of the mid-point phase
difference, therefore the relative field pattern is given by

$$E_2 = \cos\left(\frac{kd}{2} \sin \theta \cos \phi\right) . \tag{10}$$

The relative field pattern for two parallel dipoles driven equally,
in-phase, and spaced d wavelengths apart is given as the product of
equations (9) and (10) following the principle of pattern multiplication.

$$E = \frac{\cos\left(\frac{\pi}{2} \cos \theta\right) \cos\left(\frac{kd}{2} \sin \theta \cos \phi\right)}{\sin \theta} \tag{11}$$

The antenna geometry is shown in Figure 8. The broadside pattern,
$E(\phi)$, can be obtained from equation (11) by setting $\theta = 90°$ in
equation (11).

Since, the antennas are separated into opposite pairs, each
pair should be omnidirectional to obtain the desired coverage; that
is, the end-on pattern of one pair should match the broadside
pattern of the other. This sets the criterion for element spacing.
It can be seen from Figure 9 that a spacing of 1/3 wavelength pro-
duces a very close pattern match up to about 45° from zenith. It
should also be noted that the diagonal patterns match through
symmetry; therefore, it would appear that the antennas are almost
perfectly omnidirectional within the region of interest. This is
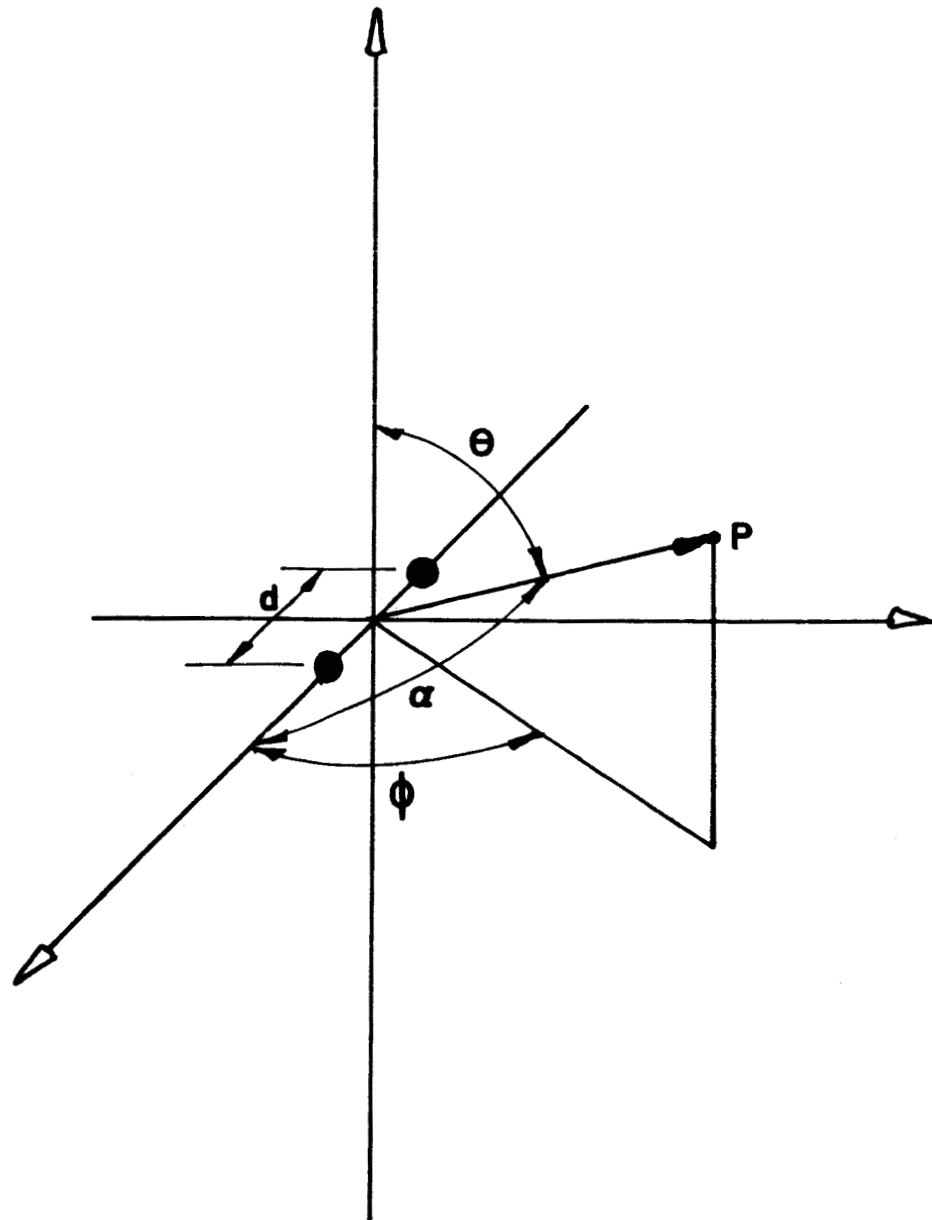
GEOMETRY FOR THE PATTERN OF AN ARRAY OF
TWO ISOTROPIC POINT SOURCES

FIGURE 7
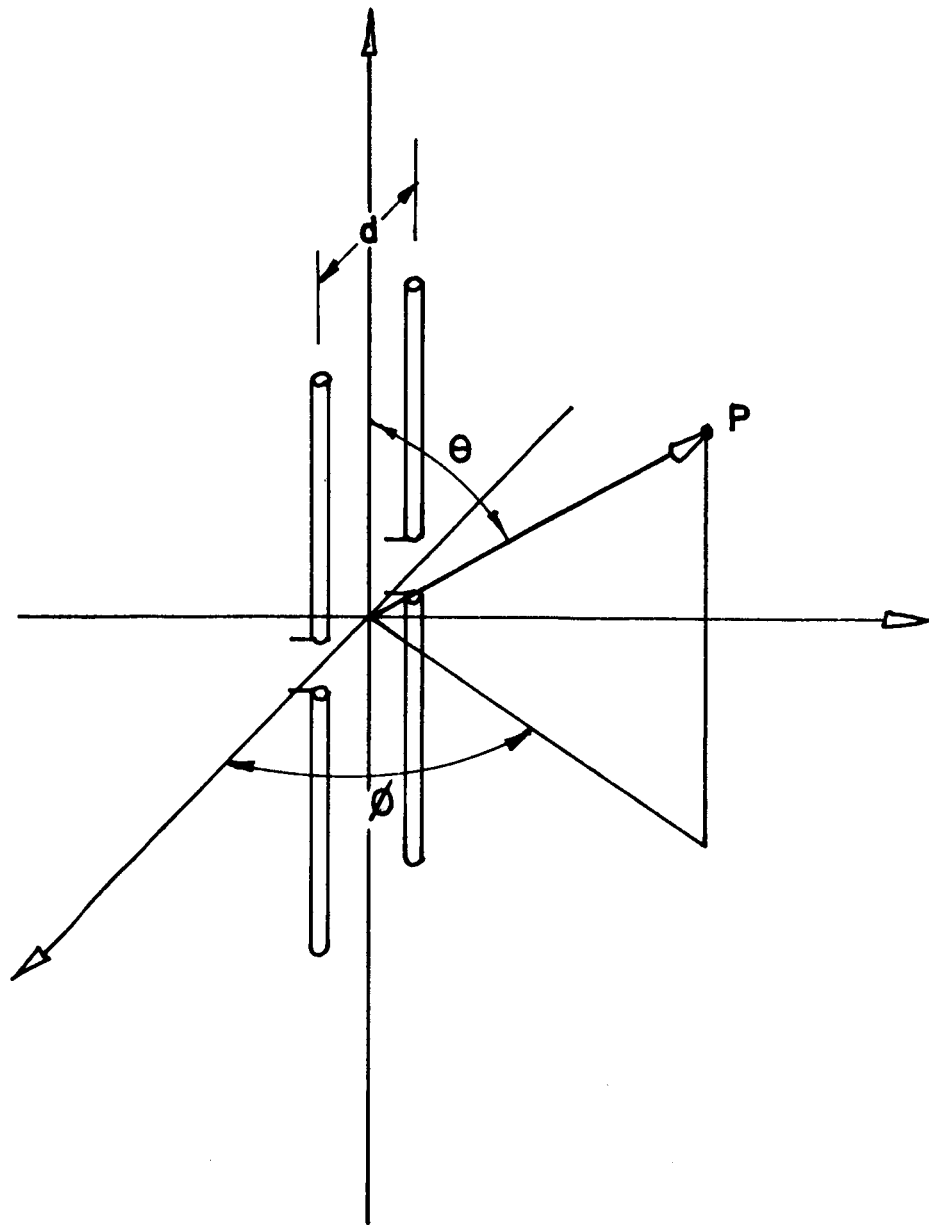
GEOMETRY FOR THE PATTERN OF TWO
PARALLEL DIPOLES SPACED d WAVELENGTHS

FIGURE 8
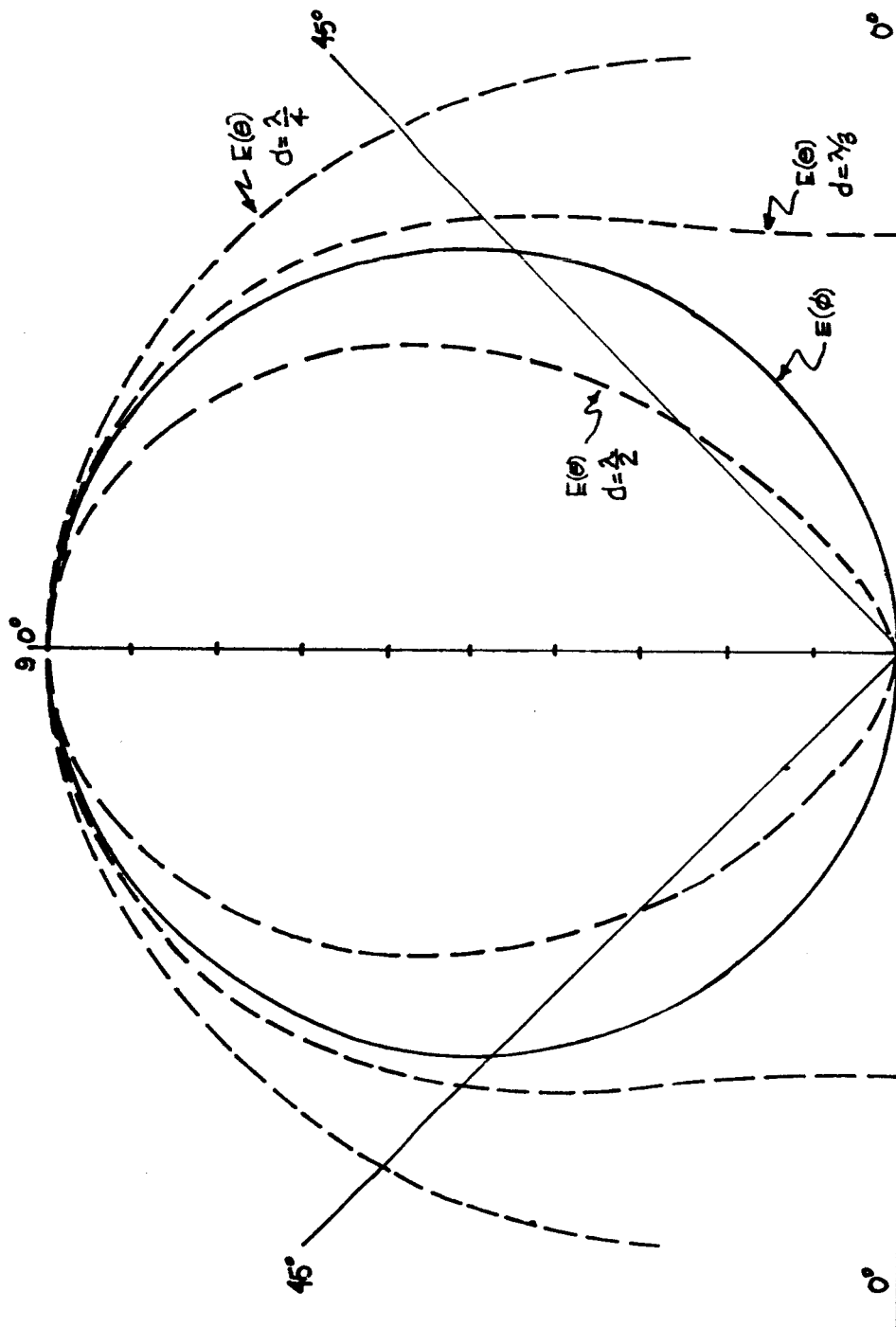
BROADSIDE RELATIVE FIELD PATTERNS FOR DIFFERENT
SPACINGS OF TWO PARALLEL DIPOLE ANTENNAS AND THE
END·ON PATTERN

FIGURE 9

shown to be true by equation (11) which is plotted in Figure 10.

Degradation of the free space field pattern occurs when the antennas are mounted horizontally above a ground plane. For an antenna height of 1/4 wavelength, the broadside pattern of a single dipole nulls at $\phi = 0$; whereas, it was independent of ϕ in free space. This pattern is plotted in Figure 11 along with the pattern for two isotropic point sources in free space. The resultant pattern has been obtained by pattern multiplication and is also shown. The resultant end-on pattern appears in Figure 12; comparison with Figure 11 shows that the patterns are still almost identical.[1]

It may be observed that the element lengths, 1/2 wavelength, are greater than the element spacing, 1/3 wavelength. This results in an overlapping at the ends of the opposite pairs. Empirically, it was decided to separate the pairs vertically by 1/16 wavelength. It can be seen that 1/16 wavelength is slightly longer than the distance of overlap. The mean element height was chosen at 1/4 wavelength.

Achievement of circular polarization has been accomplished by connecting opposite elements in phase and phase shifting the perpendicular pairs by 1/4 wavelength. Utilizing the same two pairs and phasing their outputs properly, both senses of circular polarization have been obtained. Each mode then forms a separate channel. Description of the phase shifting system has been deferred to a later section (Section 3.4).
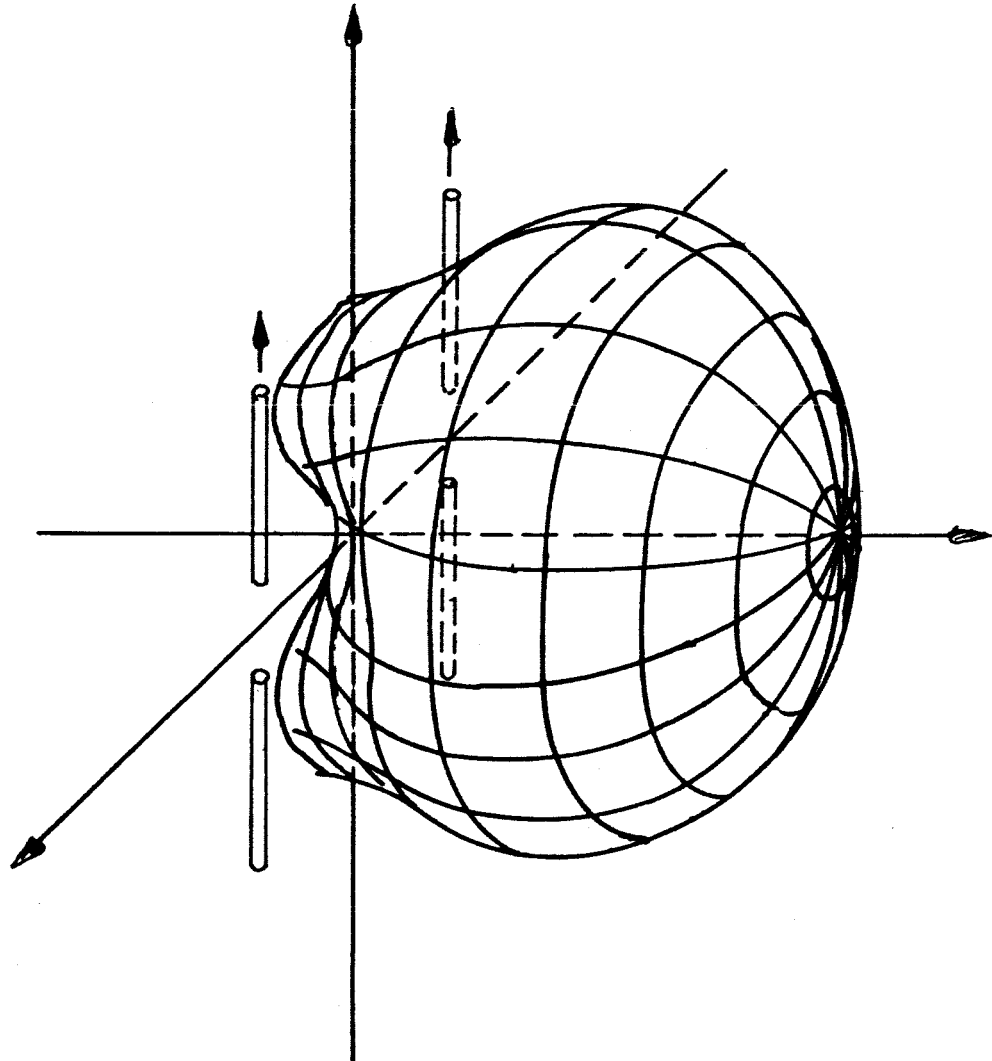
THE THREE DIMENSIONAL FIELD PATTERN OF TWO
PARALLEL DIPOLES SPACED $\frac{1}{8}$ WAVELENGTH APART

FIGURE 10
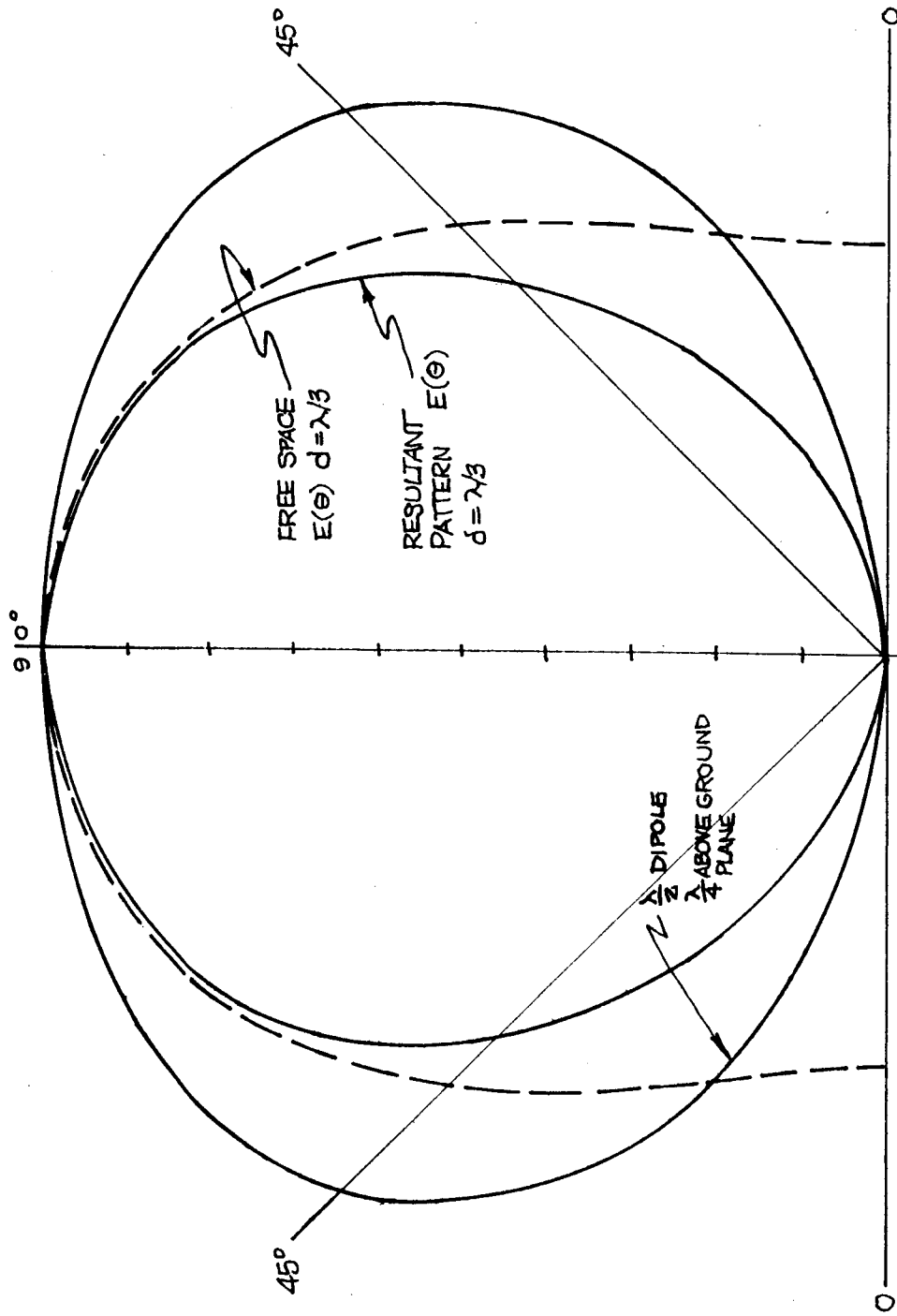
PATTERN MULTIPLICATION TO OBTAIN THE RESULTANT FIELD
PATTERN FOR PARALLEL DIPOLES 1/4 WAVELENGTH ABOVE A
PERFECT GROUND PLANE

FIGURE 11
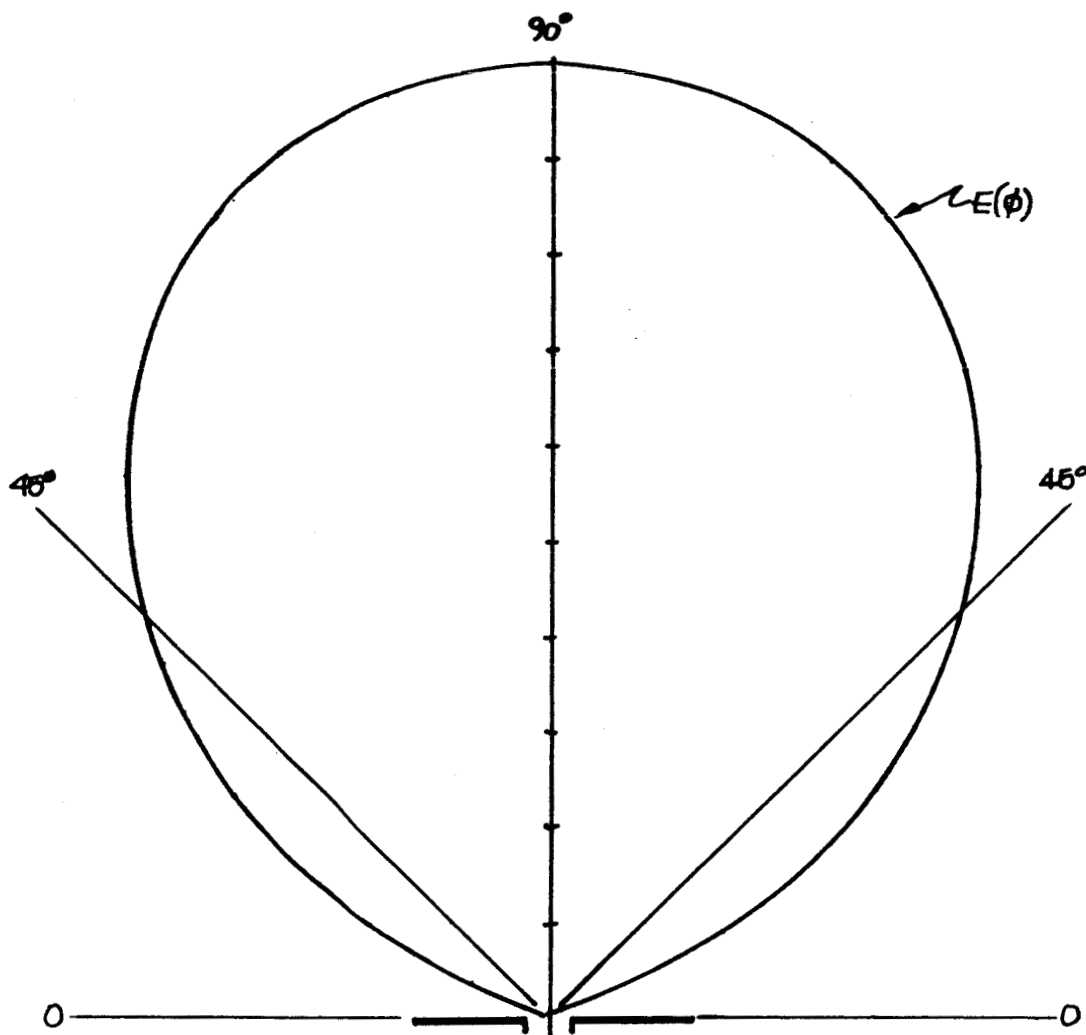
THE END·ON FIELD PATTERN FOR PARALLEL DIPOLES 1/4 WAVELENGTH ABOVE A PERFECT GROUND PLANE

FIGURE 12

3. Antenna Matching

The antennas, being folded half-wavelength dipoles made from 300 ohm twin-lead, have balanced terminal impedances of about 300 ohms each, and must be matched to 75 ohm unbalanced coaxial cable. In addition cables of equal length from opposite antennas must be joined and matched to a 75 ohm unbalanced line.

The balanced to unbalanced conversion has been accomplished using half-wave 75 ohm coaxial cable baluns as shown in Figure 13. An impedance match of two joined 75 ohm lines to 75 ohm line has been provided by a quarter-wavelength section of 52 ohm cable. This was derived from the impedance transformation equation for odd multiples of quarter wavelengths,

$$Z_s = \frac{Z_o^2}{Z_L}$$

where Z_s and Z_L are the terminal impedances and Z_o is the characteristic line impedance.

4. The Antenna Phasing Network

The phasing system must properly phase and isolate the two pairs of linearly polarized antennas to produce the equivalent of two oppositely sensed circularly polarized antennas. The phasing requirements can be seen more readily by considering a pair of crossed dipoles as illustrated in Figure 14. If terminal 1 is connected directly to the lead-in cable and terminal 2 is connected to the same lead-in cable through a 1/4 wavelength phasing section, the resulting antenna system will be circularly polarized from above
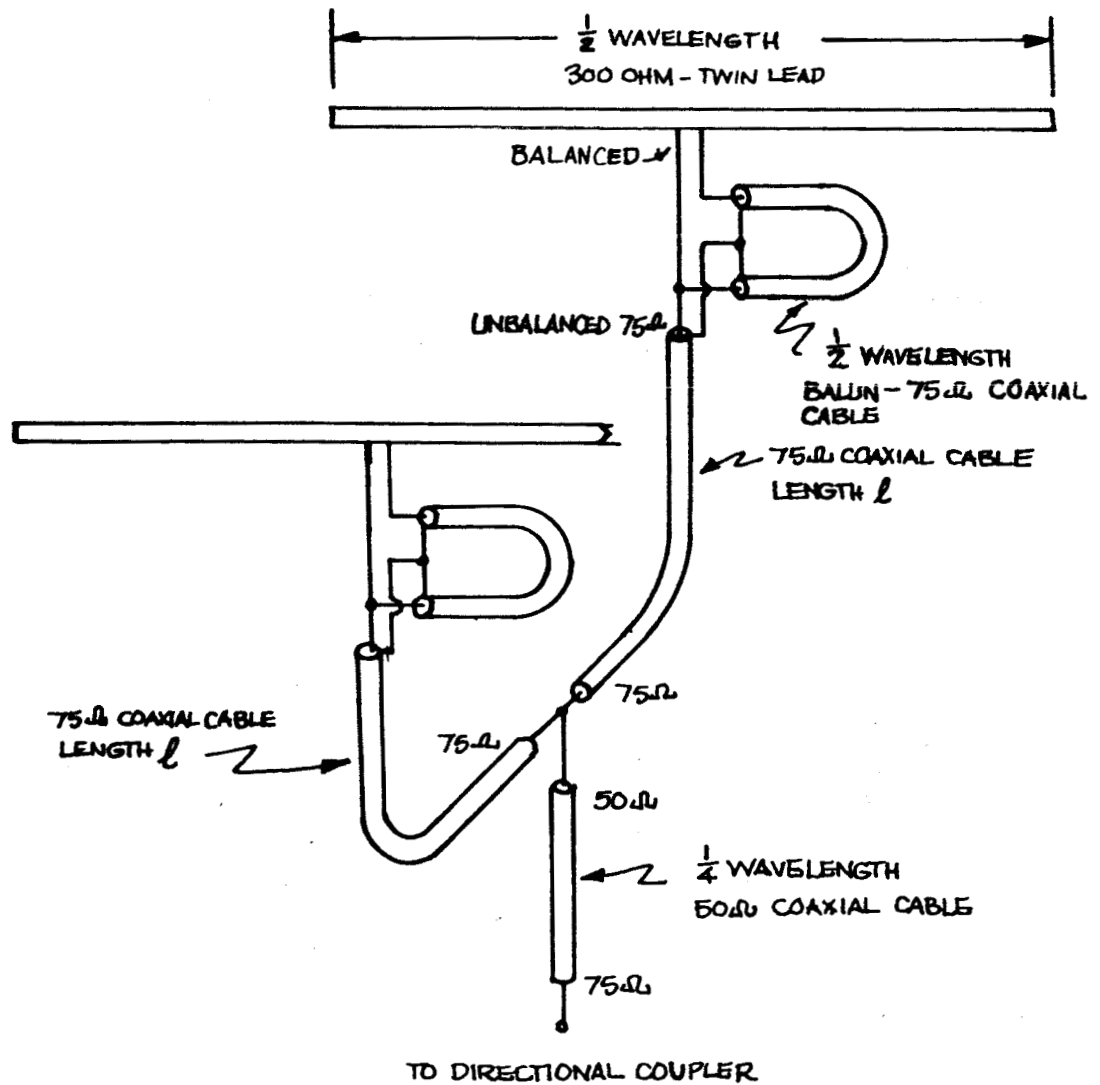
ANTENNA MATCHING

FIGURE 13
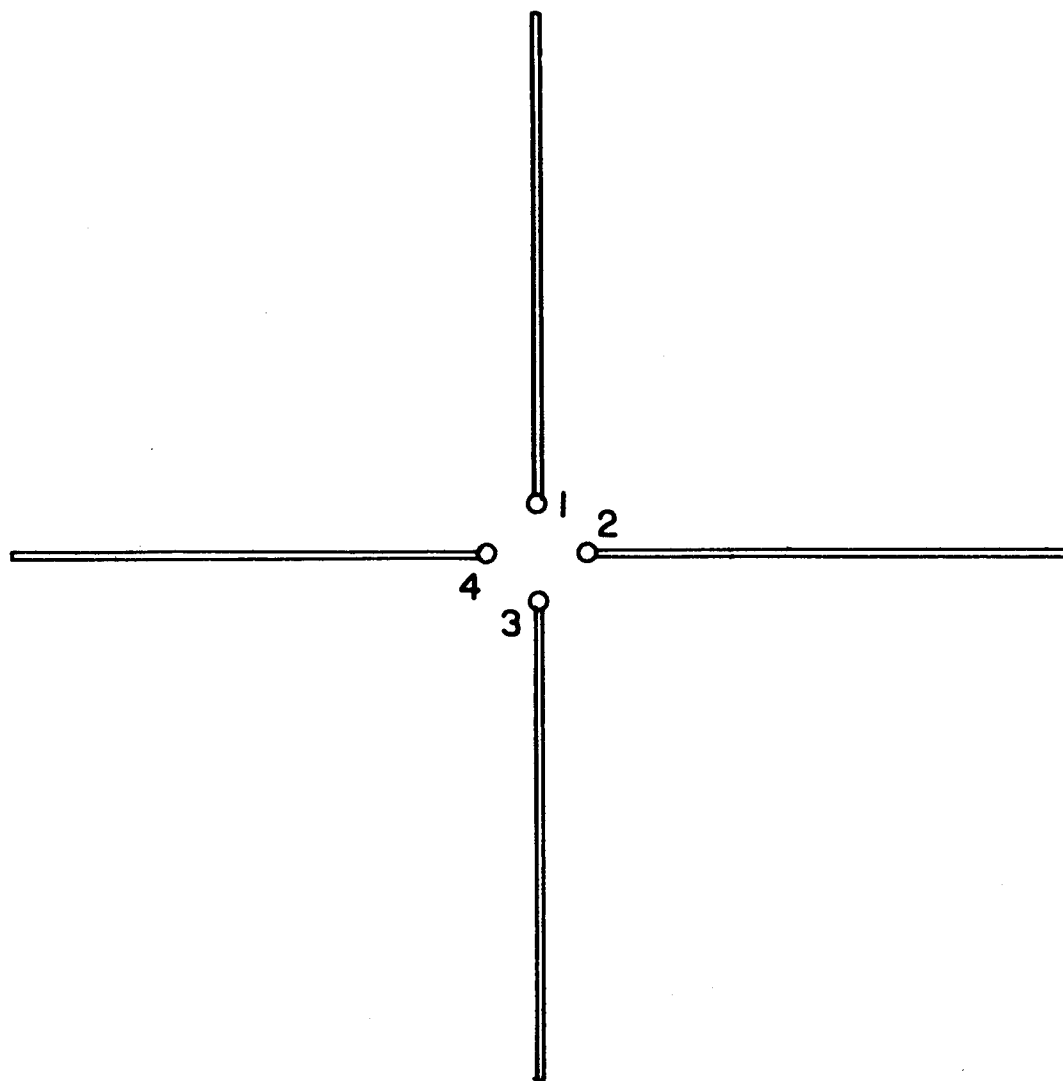
CROSSED DIPOLE ANTENNAS

FIGURE 14

with right-handed sense. Left-handed sense is possible by driving terminal 2 directly and terminal 1 through a 1/4 wavelength phasing section.

Since the antenna system has its opposite elements connected together, its phasing requirements are identical to those for the crossed dipoles. The pairs of elements are oriented North-South (NS) and East-West (EW) respectively, and the right-handed and left-handed polarizations are labelled polarimeter channels A and B respectively.

Consequently, the NS pair must drive the A receiver directly and the B receiver with a 1/4 wavelength lag. Conversely, the EW pair must drive the B receiver directly and the A receiver with a 1/4 wavelength lag. Also, the NS pair must be electrically isolated from the EW pair and receiver A isolated from receiver B.

The phasing could be accomplished through the use of isolation amplifiers and 1/4 wavelength phasing lines; however, a passive configuration exists which will fill the need with only four 1/4 wavelength sections of line. This configuration is usually called a magic-T or hybrid-T. Obtained from waveguide theory, the coaxial line magic-T which is shown in Figure 15 has an extremely complicated derivation which can be found in the microwave literature. [2, 9]

The constructed magic-T functioned in the laboratory according to the theory. With all terminals properly loaded and one input, half the power appeared at each output and no measurable signal appeared at the second input. The system operated well
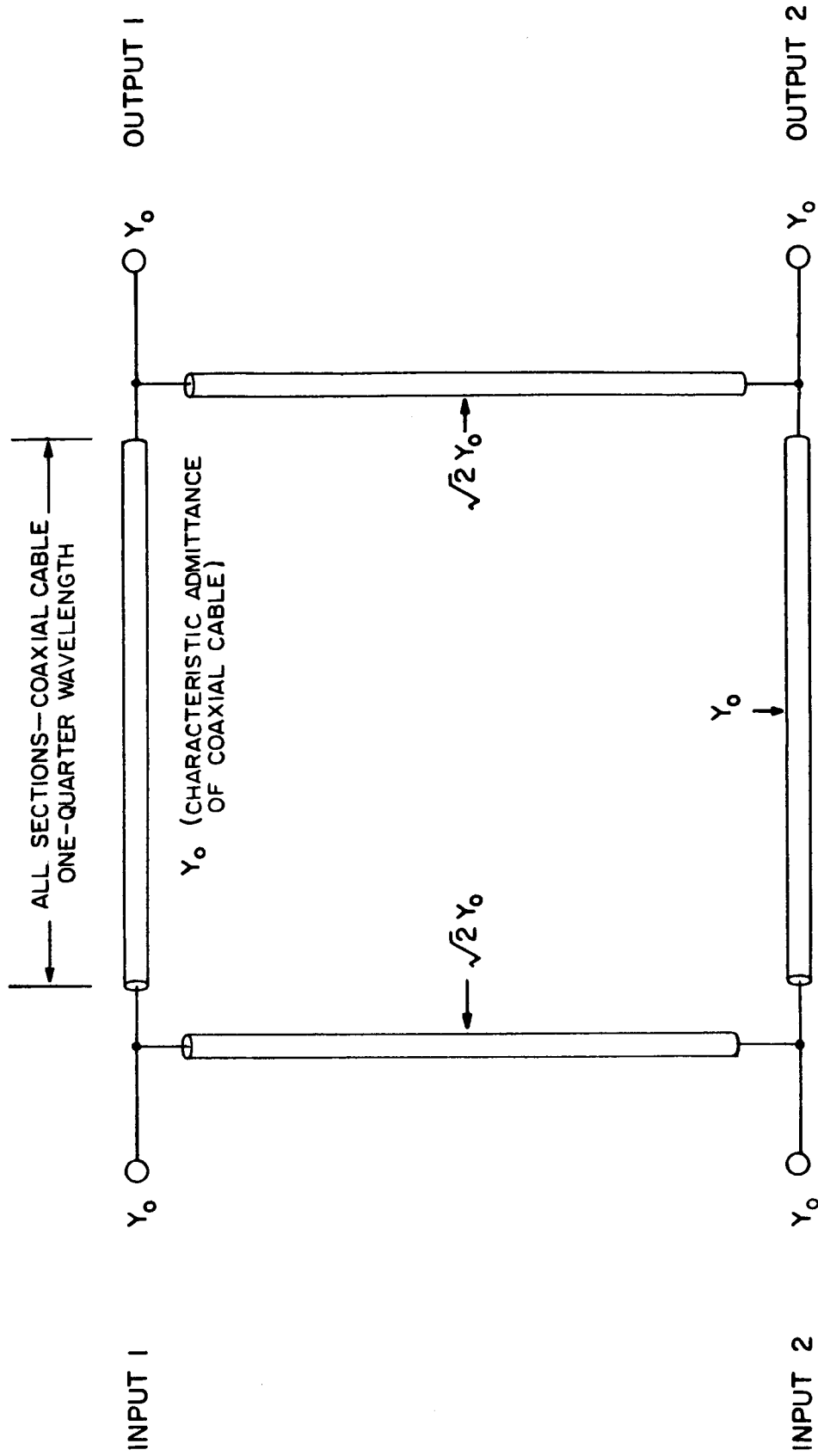
MAGIC-T DIRECTIONAL PHASING COUPLER USING
QUARTER-WAVELENGTH SECTIONS OF COAXIAL CABLE

FIGURE 15

within about 20% of the design frequency; outside this range some signal began to appear at the second input. The phase shifting operated as expected with negligible phase shift between the 1 input and the 1 output and 90° phase shift between the 1 input and 2 output. The signal was then applied to input terminal 2 and similar results were obtained as would be expected from the symmetry of the system.

5. The Receiving System

Since the polarimeter operation depends upon phase information between the two circularly polarized channels, the receiving system must be capable of preserving relative phase. Further, it is desirable to have an audio frequency at the receiver output whose amplitude and phase correspond to those at the input. As audio frequency signals, the receiver outputs can be easily handled and recorded on magnetic tape. An additional problem is presented by the Doppler frequency shift resulting from the satellite's motion relative to the receiving station. The receiver bandwidth must be wide enough to accommodate the frequency shift, but it should be as narrow as possible to limit received noise levels and station interference.

Preservation of the phase relationship between the polarimeter channels requires the use of receivers with a common frequency reference. Usually, this is achieved through the use of a stable master oscillator for all of the receivers; however, the Doppler frequency shift requires a tracking oscillator if a constant

- 34 -

frequency audio output is to be obtained. The Doppler frequency

shift for a close pass of a satellite of 1000 km altitude transmitting

has a maximum of about 500 Hz from the nominal 20 MHz. This

requires about 1 KHz tracking and receiver bandwidth.

The tracking oscillator is a voltage controlled crystal

oscillator capable of about 500 Hz deviation from a nominal 1 MHz.

The audio output from a receiver for a circularly polarized

channel is filtered and used to drive the tracking oscillator. The

output of the tracking oscillator contains selected harmonics of a

nominal 10 MHz. The first harmonic, which is 250 Hz higher in

frequency than the incoming signal at 20 MHz, is then mixed with

the antenna signal. Thus the receiver output is at a constant

250 Hz for 20 MHz with amplitude and phase corresponding to the

polarimeter signal.

The signals from the receivers are transmitted via

telephone line to the recording site. After selective filtering to

remove excess noise, the signals are recorded at 3-3/4 i.p.s. on

magnetic instrumentation tape. The tapes are played back at the

same speed and the signals are again selectively filtered before

further analysis. A block diagram of the receiving system is

shown in Figure 16.

6. The Comparator and Display System

The output of the polarimeter system is to appear on a chart

record simultaneously with a number of other satellite information

channels. It is desired to have a readout which displays directly the

POLARIMETER
CHANNEL A

$+$

RECEIVER A

BANDWIDTH
1.5KHz

$K_1 A(t)\cos(2\pi 250 t + \alpha)$

$A(t)\cos(2\pi f_{IN} t + \alpha)$ $+$

$f_{IN} =$ nominal 20Hz

$f_{IN} + 250Hz$

TRACKING
OSCILLATOR

$f_{IN} + 250Hz$

DISCRIMINATOR
250Hz

250Hz

$B(t)\cos(2\pi f_{IN} t + \beta)$ $+$

RECEIVER A

BANDWIDTH
1.5KHz

POLARIMETER
CHANNEL B

$+$

$K_2 B(t)\cos(2\pi 250 t + \beta)$
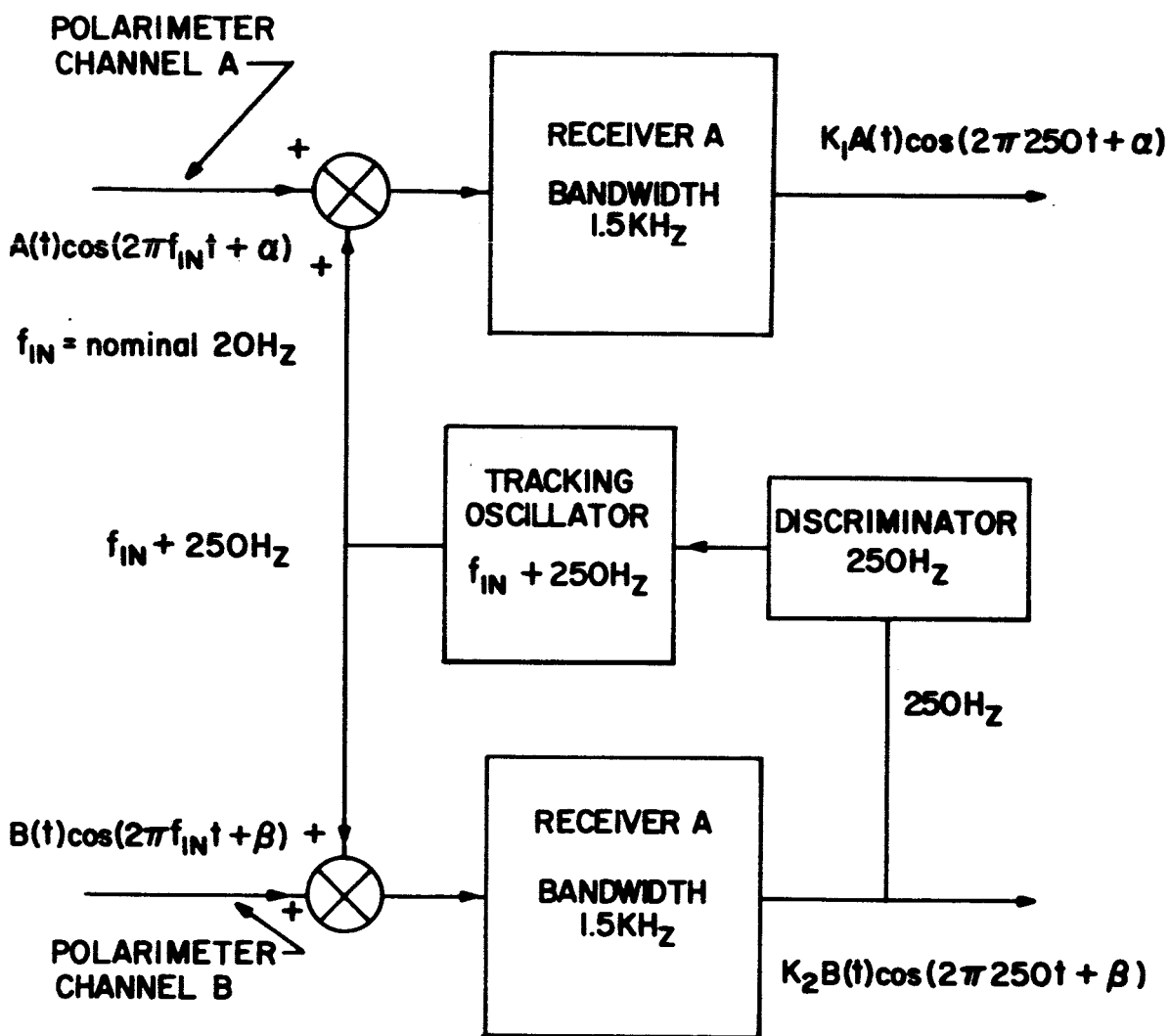
THE RECEIVING SYSTEM
FIGURE 16

continuous angle of rotation in a manner requiring a minimum of subjective interpretation. In addition, restriction of the output to one chart channel is preferred to allow other information to be simultaneously displayed on the limited number of channels available.

The plane of polarization of the incoming wave can be determined from the phase relationship between the two characteristic modes as discussed in Chapter II. Using one mode as reference, the rotation direction is determined by the direction of the change of phase for the second mode; therefore, a linear phase detector is sufficient since the slope of its output corresponds to the rate of change of phase.

Each 250 Hz signal is clipped at about 10% of its peak value and the resulting almost perfect square wave is amplified and selectively differentiated to provide positive pulses. The time of the pulse corresponds to the leading edge of the square wave which in turn corresponds to the positive going zero crossing of the 250 Hz signal. The two sets of pulses from the differentiators each drive a logic level of a flip-flop. The output of the flip-flop is then a rectangular wave with width corresponding to the phase difference between the 250 Hz signals. This is then integrated with appropriate time constants to produce an output whose slope is proportional to the rate of change of phase. That is, a positive going ramp for clockwise Faraday rotation and a negative going ramp for counterclockwise rotation. This ramp function recycles every 2π radians of phase difference, i.e. every half-rotation of the plane

of polarization.

      The time constants were chosen for the integrators using the following criteria. The Faraday rotation period as observed on the ground is seldom less than 3 seconds per rotation. Then 1-1/2 seconds corresponds to the minimum time lapse for the phase between the 250 Hz signals to proceed from zero to 2π radians phase difference. The period for the signal, however, is only .004 seconds. This sets the minimum allowable time constant. The desired 5° angular resolution of the system corresponds to a time .05 seconds which sets the maximum allowable time constant for the integrator. The comparator diagram is shown in Figure 17.
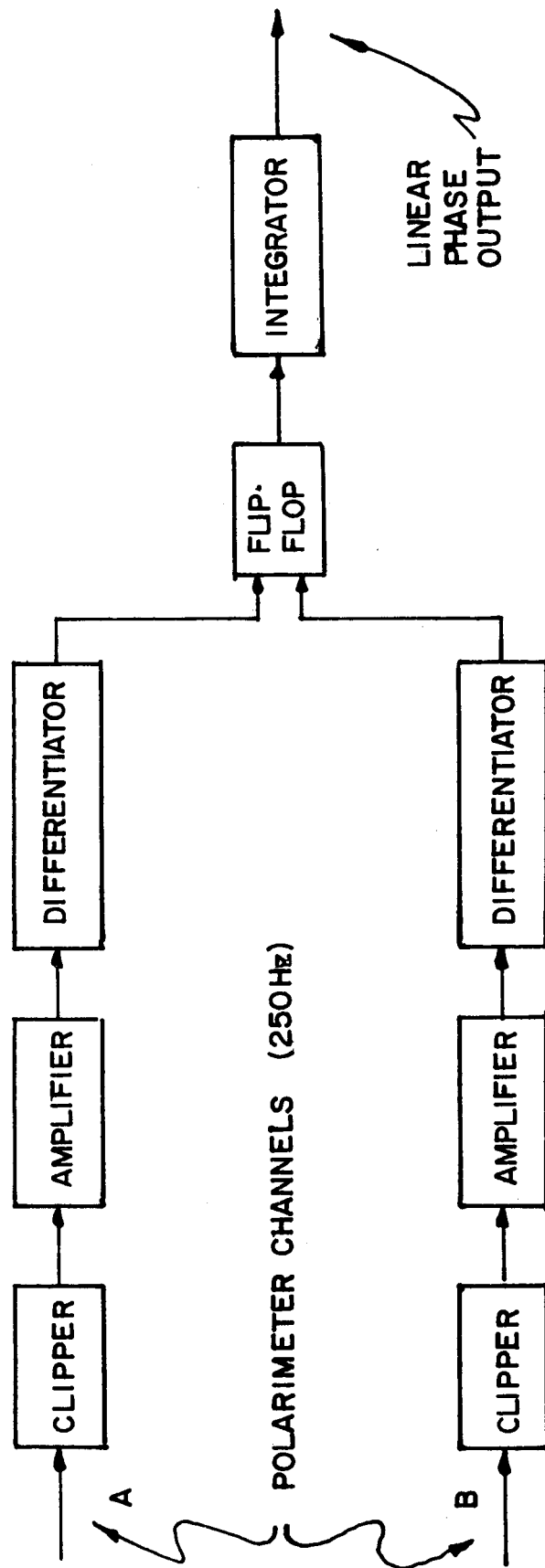
THE PHASE COMPARATOR

FIGURE 17

IV.   THE POLARIMETER OPERATION

A block diagram of the polarimeter system is shown in Figure 18.   The accuracy and linearity of the system are determined primarily by the antenna system, its related phasing equipment, and the phase comparator system.   Any phase differential between the channels resulting from components other than those listed above will be constant.   Consequently, it will not affect the rate of change of phase, but simply shift the zero point at the output. Amplitude inequalities between channels do not noticeably affect the system since the only measurement is of phase, not amplitude. This is not to say, however, that amplitude fluctuations with rotation are tolerable, since these correspond to ellipticity in the antenna system.

The antenna is the source of greatest error.   Limited by fixed geometry, the development of an antenna that appears circularly polarized from all directions is an extremely difficult task, conse- quently ellipticity usually exists and, in this case, is more noticeable at larger angles from zenith.   Also, the antenna system appears more elliptical as viewed from the diagonal than when viewed end-on or broadside.   The axial ratio has been calculated and plotted in Figure 19 for various angles from zenith.   A plot is also shown for simple crossed dipoles to show the improvement in using the four dipole arrangement.

A circulary polarized wave approaching at an angle $\chi = 45°$ on the antenna diagonal will appear elliptically polarized with an axial ratio of 1.4:1.   In this case, which is considered as the worst
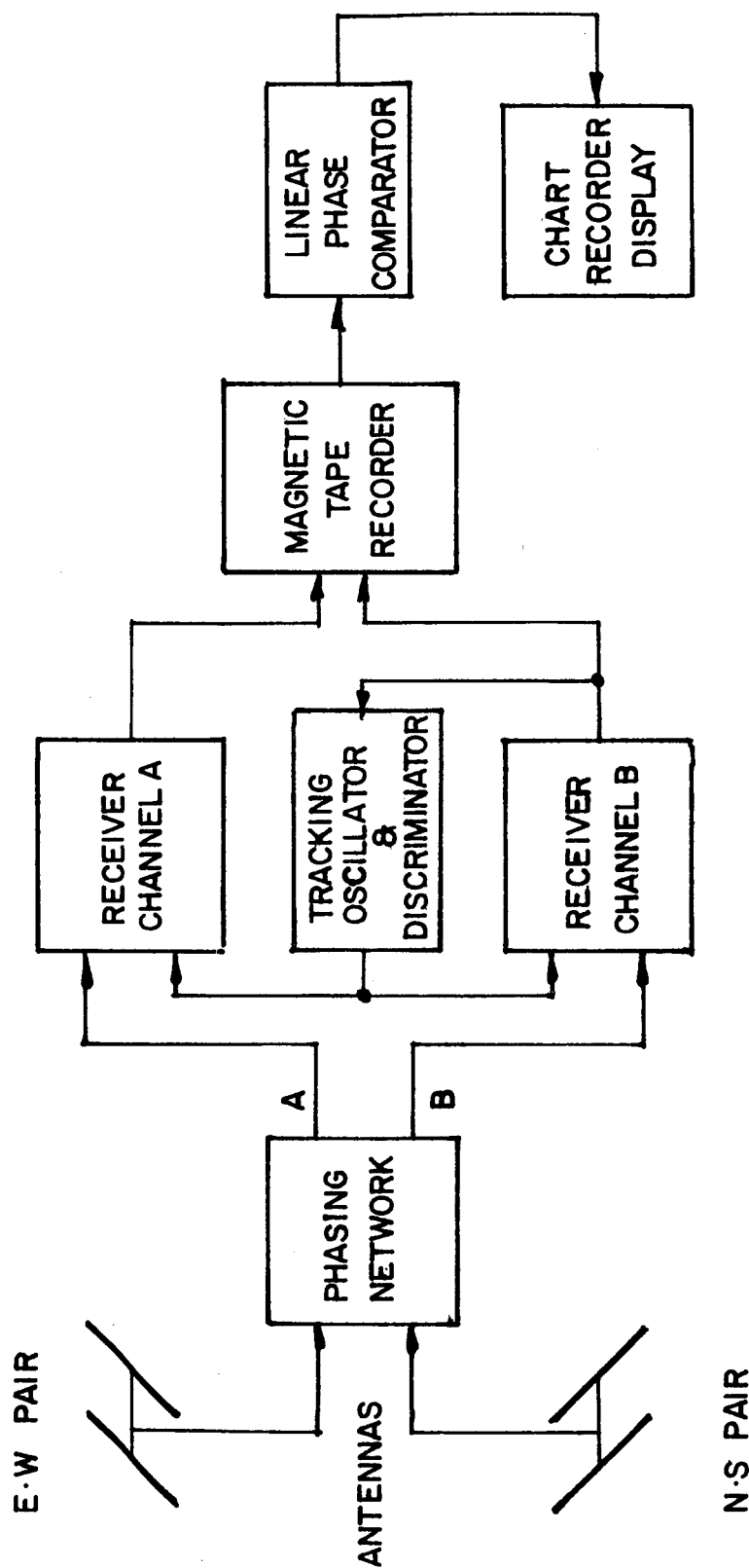
THE POLARIMETER BLOCK DIAGRAM

FIGURE 18
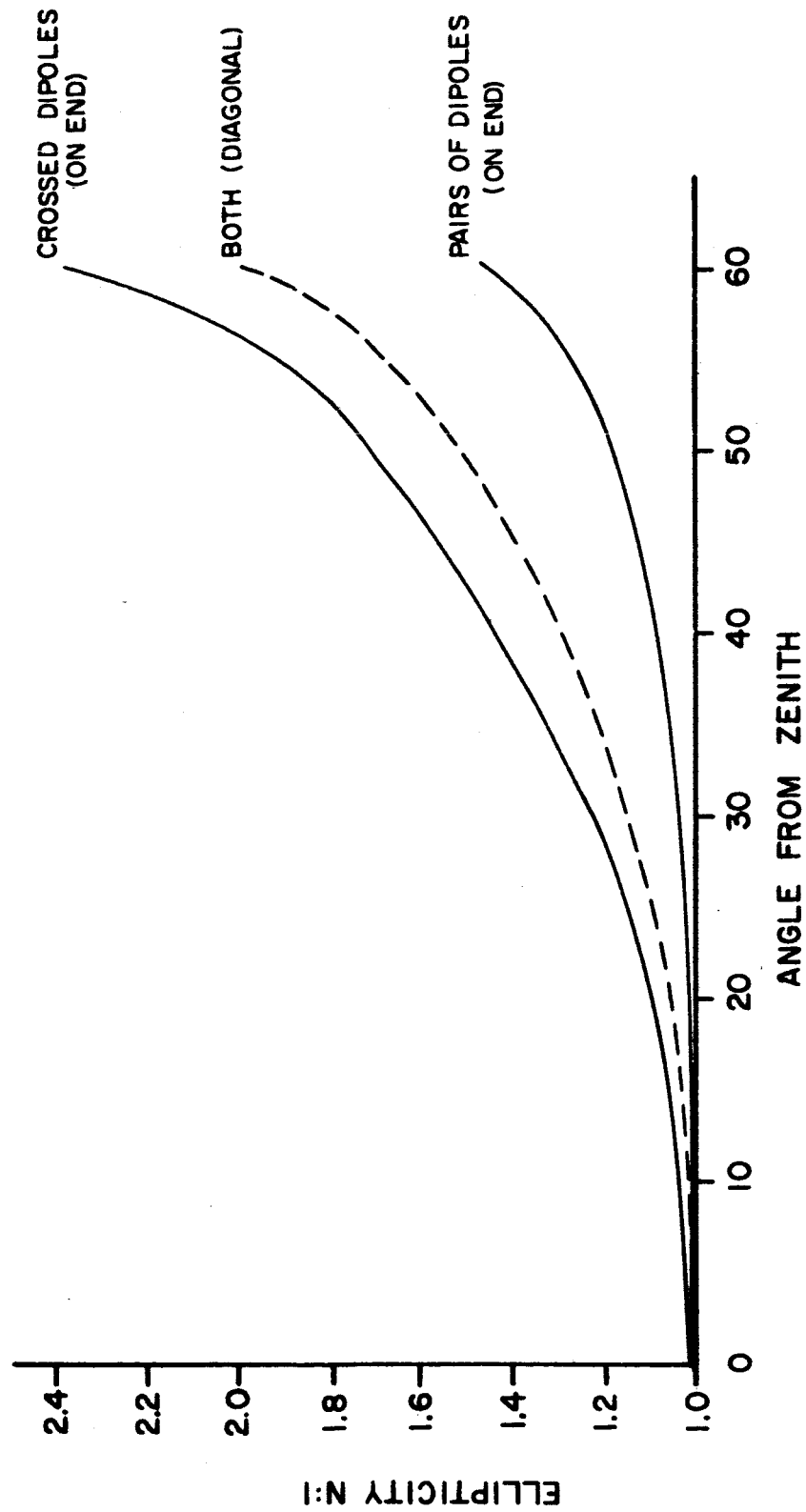
ELLIPTICITY OF THE ANTENNA SYSTEM FOR POSITION AND ZENITH ANGLE OF THE SATELLITE COMPARED TO CROSSED DIPOLES

FIGURE 19

case, the maximum absolute scale error is 10° occurring when the wave polarization is 45° from vertical. The maximum differential error is 1.4°/degree occurring for vertical wave polarization and 0.7°/degree for horizontal polarization. This means that the remainder of the system must have no worse than 3.5° phase change resolution if 5° overall is required for the system. A plot of the polarimeter channel phase difference versus incoming signal polarization angle is shown in Figure 20 for different degrees of ellipticity.

It should be remembered, moreover, that development of this system follows the need for a continuous polarimeter created by the Beacon-C satellite. By the nature of the satellite's orbit, signals from Beacon-C usually approach the antenna diagonal with small zenith angles. Since antenna ellipticity diminishes near zenith, the characteristic modes of the signal from Beacon-C will usually appear nearly circularly polarized for the entire pass. A plot of the axial ratio of the ellipticity versus satellite position is shown in Figure 21.

The related matching and phasing networks associated with the antennas form a major possibility for error. Any phase differential introduced in the system between the antennas and the phasing network will lead to ellipticity in the system, beyond the phasing network it will result in a scale shift at the output. Consequently, extreme care has been taken to ensure that the cables from all antennas are of equal length and that the related matching networks are as nearly identical as possible. The magic-T phasing
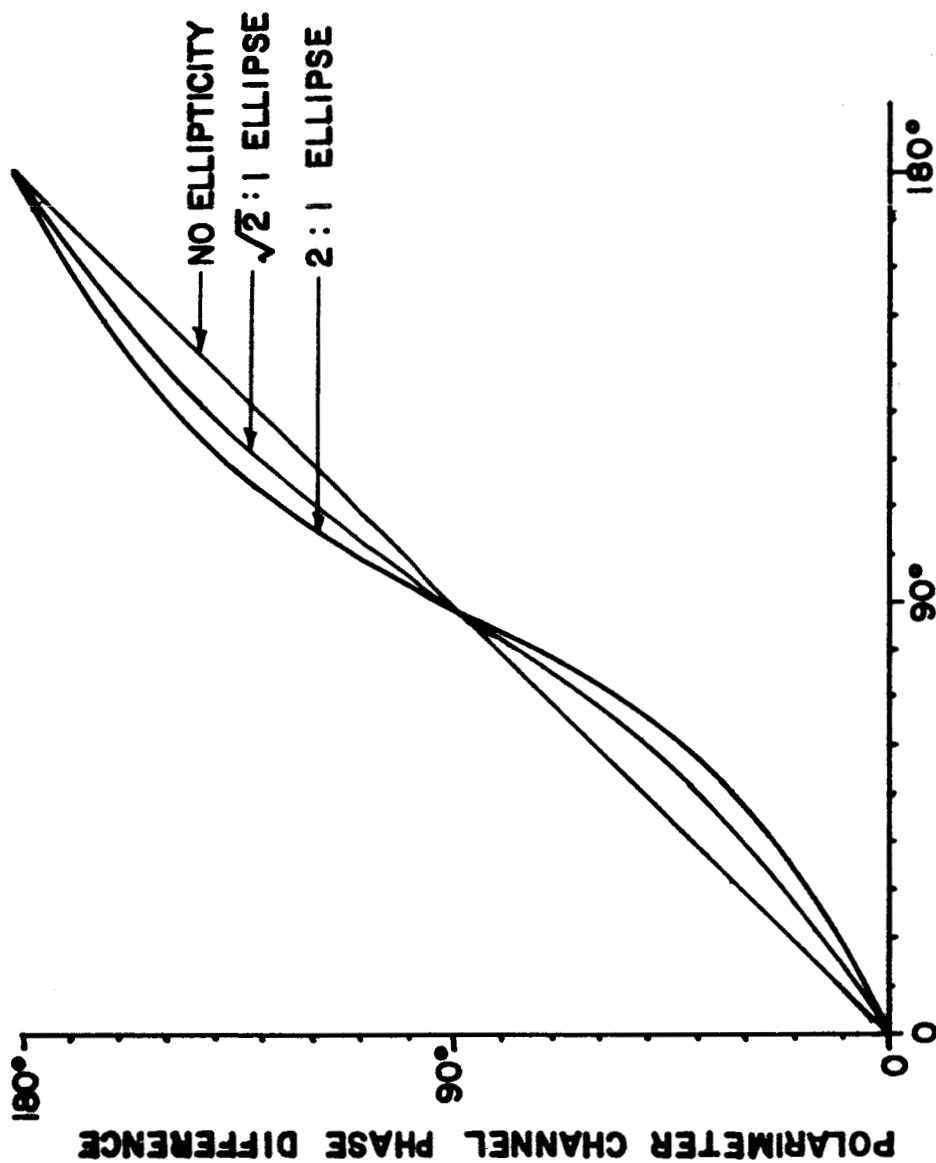
ANGLE OF WAVE POLARIZATION

POLARIMETER CHANNEL PHASE DIFFERENCE VS. ANGLE OF WAVE
POLARIZATION FOR DIFFERENT VALUES OF SYSTEM ELLIPTICITY

FIGURE 20

- 44 -
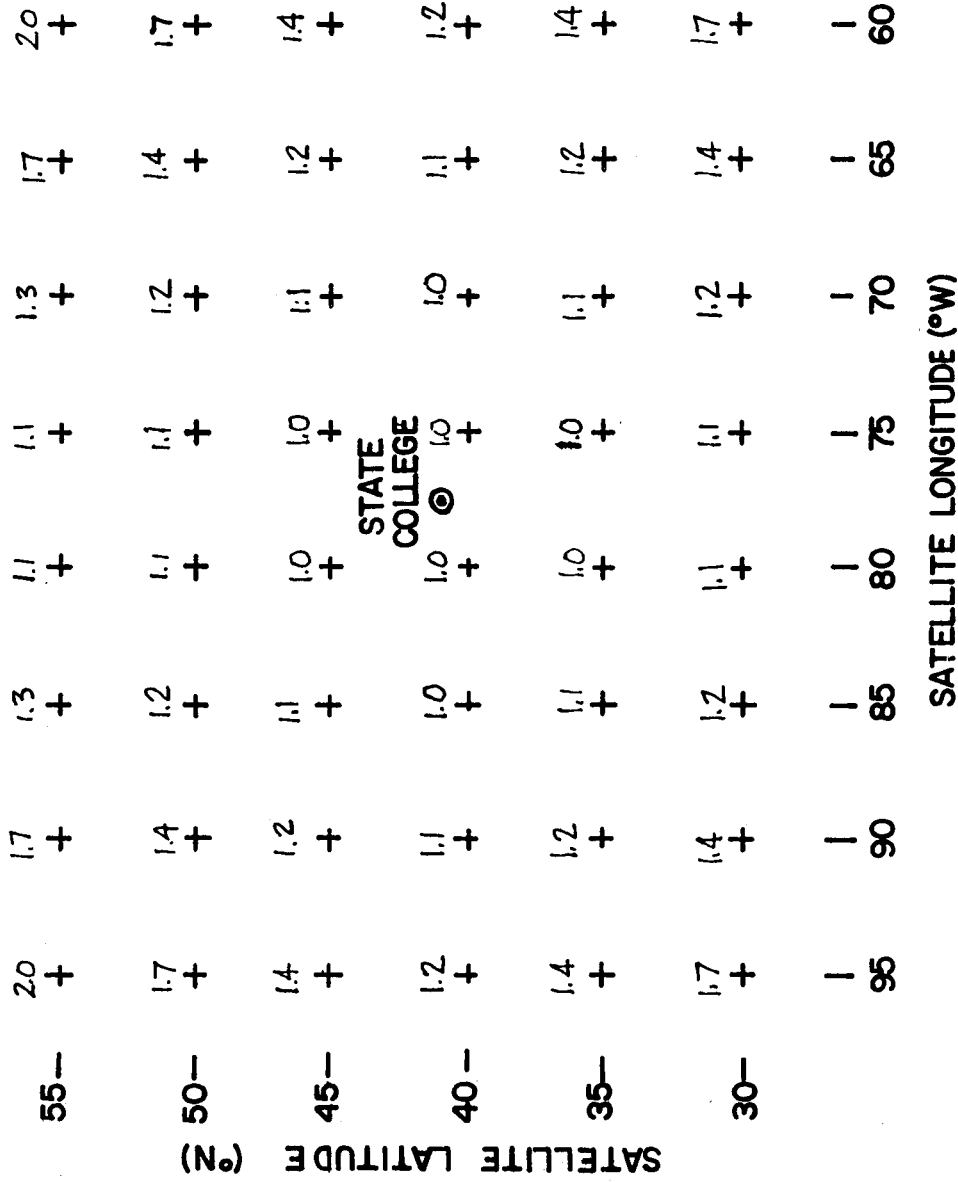
AXIAL RATIO OF ANTENNA ELLIPTICITY VS. SATELLITE POSITION

FIGURE 21

SATELLITE LATITUDE (°N)

	95	90	85	80	75	70	65	60
55	2.0	1.7	1.3	1.1	1.1	1.3	1.7	2.0
50	1.7	1.4	1.2	1.1	1.1	1.2	1.4	1.7
45	1.4	1.2	1.1	1.0	1.0	1.1	1.2	1.4
40	1.2	1.1	1.0	1.0	1.0	1.0	1.1	1.2
35	1.4	1.2	1.1	1.0	1.0	1.1	1.2	1.4
30	1.7	1.4	1.2	1.1	1.1	1.2	1.4	1.7

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SATELLITE LONGITUDE (°W)

network has been laboratory tested and found to be balanced. It, therefore, has been assumed that no appreciable errors exist resulting from the phasing and matching networks.

Polarimeter amplitude records shown in Figures 22 through 26 give some indication as to the circularity of the antenna system. It can be seen that slight amplitude variations resulting from rotation of the plane of polarization appear early and late in the pass. The existence of variation indicates ellipticity in the system with an axial ratio corresponding to the degree of variation. During most of the pass, however, the amplitude does not vary significantly indicating antenna circularity.

The only other major source of error is the phase comparator system. Tested in the laboratory where the phase of two input signals could be controlled, it was found to be quite linear over most of its range of operation. However, phase scintillations produced by the wave's passage through the ionosphere cause slight distortion of the output as the phase difference between the polarimeter channels approaches 360°. At this point the phase comparator is faced with a decision whether to display maximum or minimum output since this is the reset value of phase. Further complicated by phase scintillation, the comparator displays a slightly ambiguous output until the fluctuations no longer pass through zero phase. This type of distortion appears more predominately when the rotation is very slow, and usually results in only a few degrees of ambiguity near the reset position.

Typical chart records produced by the polarimeter are
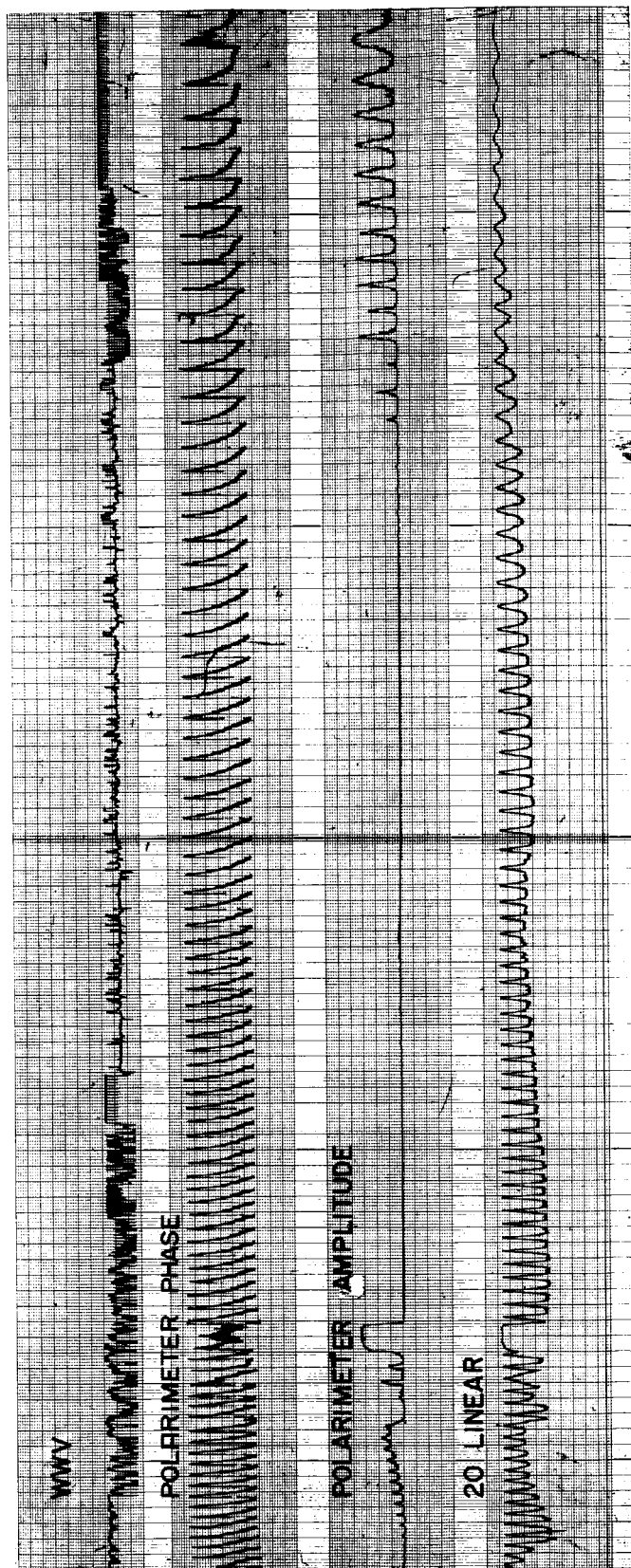
A NORMAL PASS OF BEACON B SATELLITE

FIGURE 22
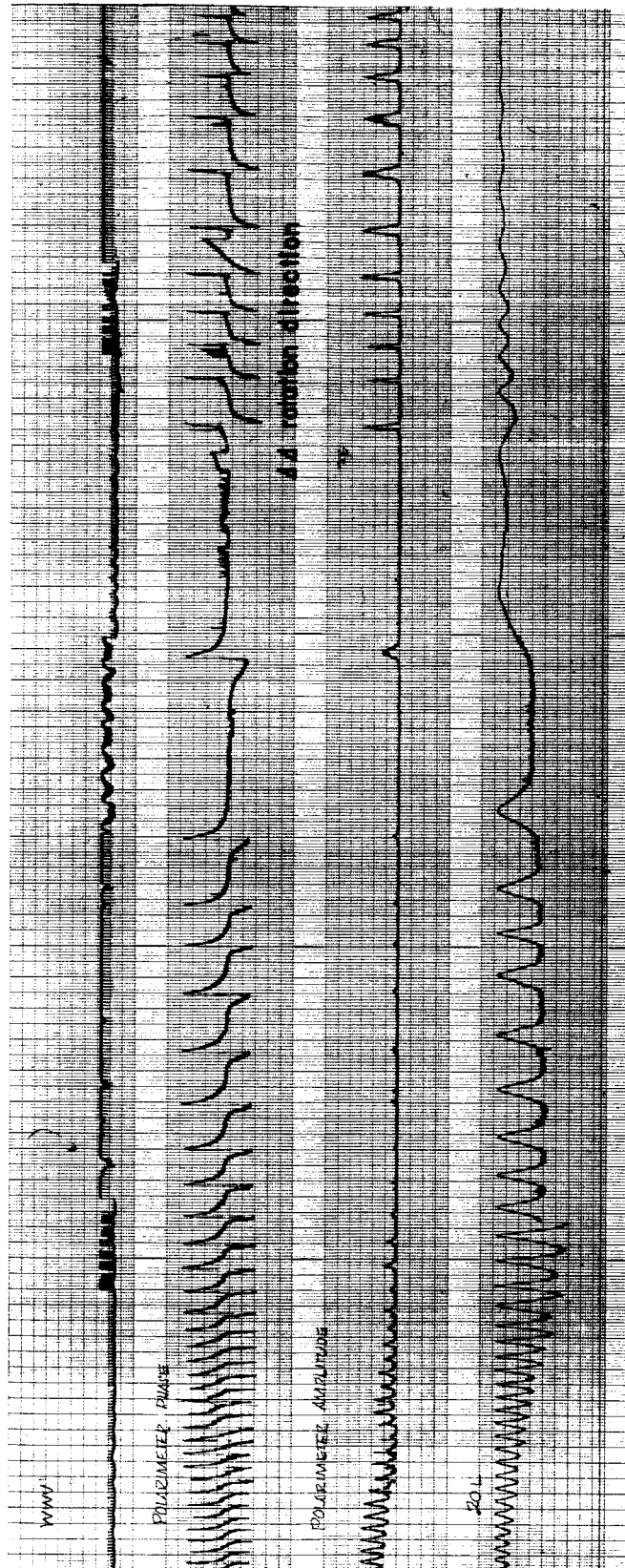
A TYPICAL PASS OF BEACON C SATELLITE

FIGURE 23
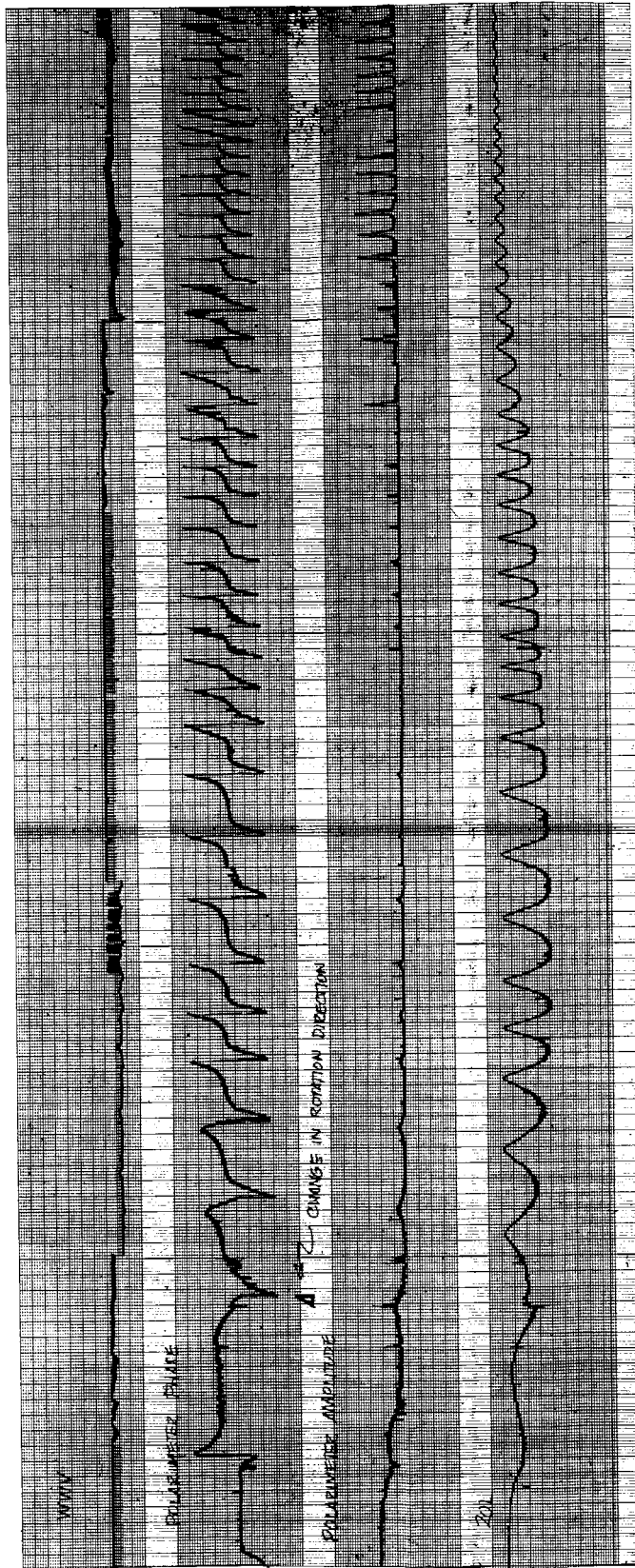
A PASS OF BEACON C REVEALING SLIGHT PHASE SCINTILLATION

FIGURE 24

-49-
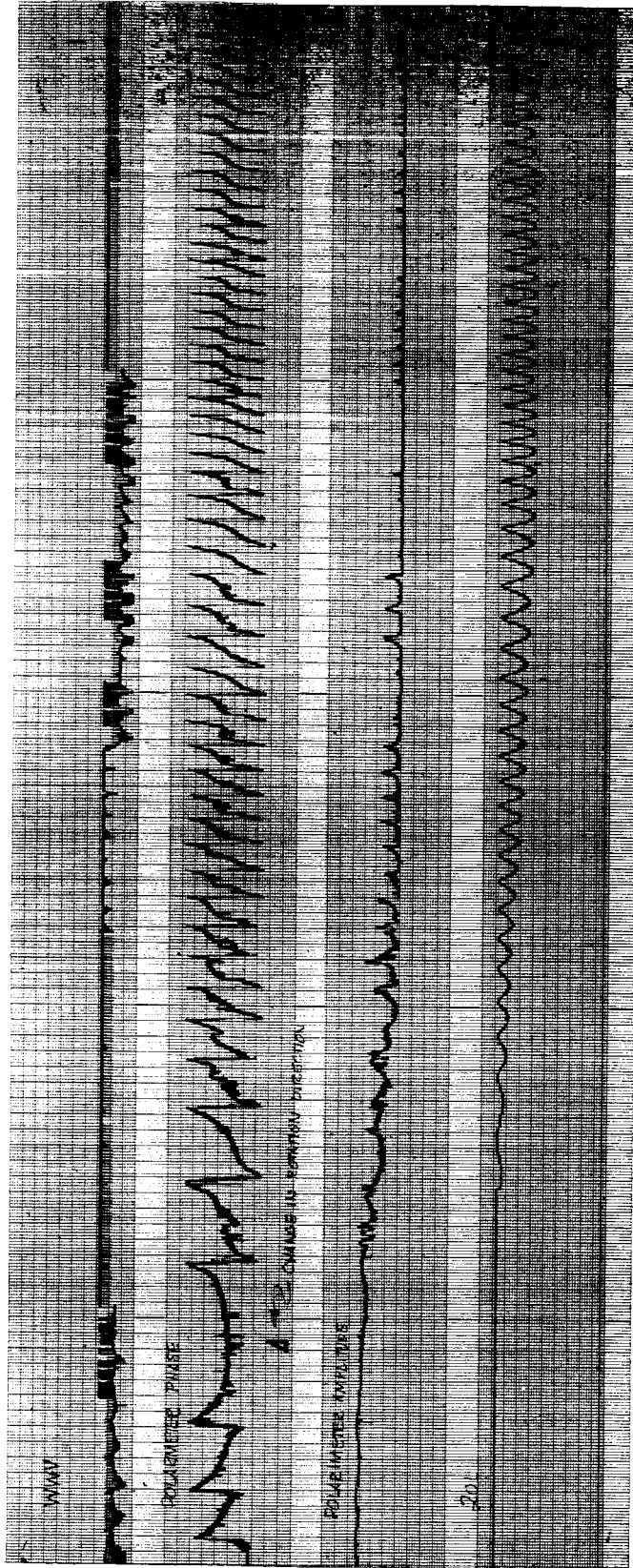
A PASS OF BEACON C WITH PHASE SCINTILLATIONS

FIGURE 25
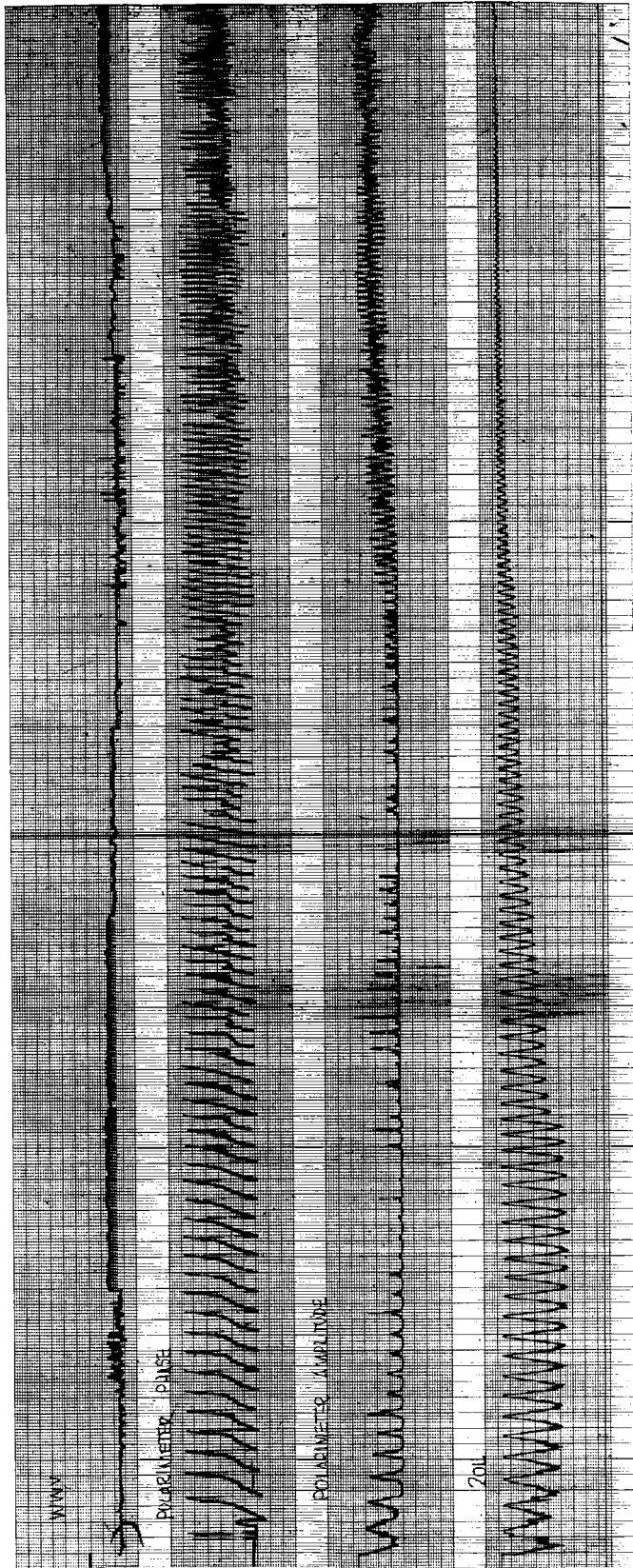
A PASS OF BEACON B WITH PHASE SCINTILLATION

FIGURE 26

shown in Figures 22 through 26. Figure 22 shows a normal pass of Beacon-B satellite. It can be seen that all of the ramps on the polarimeter display channel slope in the same direction; this corresponds to constant rotation direction. Figure 23 displays a typical record for a daytime pass of Beacon-C. Notice that the ramp display changes its direction of slope at the point indicated by an arrow. A pass of Beacon-C in which there was some signal scintillation appears in Figure 24, and a pass with considerable scintillation is displayed by Figure 25. In both cases, the polarimeter shows the general trend of the rotation and it is possible to count the number of half rotations unambiguously in a given direction. Figure 26 is the record of a nighttime pass of Beacon-B showing scintillation. Even though the rotation does not change direction in Figure 26, valuable information about scintillation and the uniformity of the rotation is obtained.

Figures 22 through 26 also display the modulation from the standard time station WWV for time reference, the amplitude output of a linear E-W antenna for 20 MHz, and the amplitude from one of the polarimeter channels. The amplitude record from the 20 MHz linear antenna shows a null every half rotation, which corresponds to the plane of polarization of the wave being oriented in a North-South direction. This channel serves, in this case, to set the zero point for the polarimeter. It can be seen that for uniform rotation, this channel alone could serve to provide the necessary information for Faraday rotation study.

V. SUMMARY

1. Conclusions

Evolving from a need for more complete knowledge of the Faraday rotation of a linearly polarized satellite transmission, a continuous polarimeter has been developed and constructed. Essentially, the polarimeter independently receives the two oppositely sensed circularly polarized component modes of the 20 MHz linearly polarized wave. It then performs phase measurements between the component modes to determine unambiguously the rate and direction of the polarization rotation. This has been accomplished using a fixed geometry of four half-wavelength dipole antennas. Both senses of circular polarization are received by the same antennas and separated using a directional coupling and phasing network. The component modes are compared using a linear phase comparator such that the slope of the output reveals the rate and direction of the Faraday rotation.

The system is capable of measurements for all sources up to 45° from zenith and is at least capable of detecting all 5° or greater changes in rotation and of absolute angle within 10°. The display output shows continuously the rotation direction and rate as the slope of a linear phase plot.

The experimental system has been used to interpret records of polarization rotation from a number of satellite passages under varying conditions of aspect and for both quiet and disturbed ionospheric conditions. Its performance is found to be generally as

predicted from a theoretical analysis.

2. Suggestions for Further Investigation

The greatest room for improvement in the existing system is the antenna. A marked decrease in the error for absolute angle determination, from its worst case value of 10° to 5°, could be gained from an antenna system half as elliptical at large zenith angles. This could possibly be accomplished by phase measurements from three radially oriented dipoles or by deviating from horizontal plane orientation of the antenna elements. Such a system has been suggested by Brown (1949)[3] but it is limited to one sense of polarization.

If a technique could be developed to remove the systematic Faraday rotation from the output, the display would reveal only fluctuations in the plane of polarization. This would enable phase scintillation studies to be performed using the polarimeter system. Preliminary investigation suggests that this could be accomplished using a mechanical resolver with a slow response. Driving the resolver with the phase comparator output and subtracting its output from its input should reveal only fluctuations in the rotation. An electrical analog could produce the same results.

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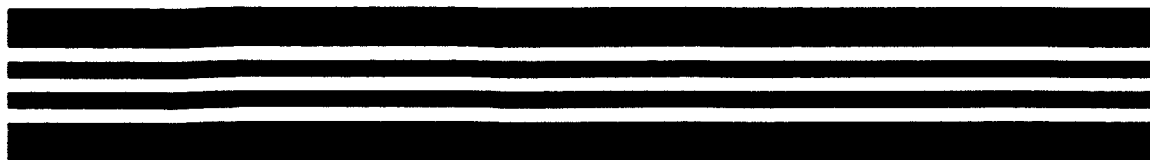
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JUNE 1966

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METEOROLOGICAL DATA REPORT

AEROBEE NASA 4.51 UG
(23 May 1966)

BY

GORDON L. DUNAWAY

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METEOROLOGICAL DATA REPORT

AEROBEE NASA 4.51 UG
(23 May 1966)

By

Gordon L. Dunaway

DR-36   June 1966

DA Task IV650212A127-02

ATMOSPHERIC SCIENCES LABORATORY
WHITE SANDS MISSILE RANGE, NEW MEXICO

ABSTRACT

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Meteorological data gathered for the launching of Aerobee NASA 4.51 UG are presented for the National Aeronautics and Space Administration, Princeton University and for ballistic studies. The data appear, along with calculated ballistic data, in tabular form.

CONTENTS

INTRODUCTION

Aerobee NASA 4.51 UG was launched by Naval Ordnance Missile Test Facility personnel, White Sands Missile Range (WSMR), New Mexico, at 2207 hours MST, 23 May 1966.

Meteorological data used in conjunction with theoretical calculations to predict rocket impact were collected by the Meteorological Support Division, Atmospheric Sciences Laboratory, White Sands Missile Range, New Mexico. The Ballistic Meteorologists for this firing were Gordon L. Dunaway and Ivan I. Layton.

DISCUSSION

Wind data for the first 4,000 feet above the surface were obtained from a Double-Theodolite Wind Velocity Computer System (1). Balloons released at the launch site were observed and tracked from a 2,000-foot baseline. Continuous angular data were transmitted from two electrically instrumented theodolites to a computer where the data were reduced to obtain a velocity-vs-height relationship. The computer output drives two recorders which trace north-south and east-west components on a specially designed wind velocity computer ballistic chart. It is possible to read directly from the chart both the mean wind component values and the mean ballistic wind components in the various ballistic layers.

Temperature, pressure and humidity data, along with upper wind data from 4,000 to approximately 100,000 feet above the surface, were obtained from standard rawinsonde operations.

Mean wind component values in each ballistic zone were determined from vertical cross sections by equal-area method.

Data appearing in Tables IX, X and XI, are based on the L. D. Duncan (2) theory. The "Predicted Impact" includes, when applicable, an adjustment of impact based on the experience of the Ballistic Meteorologists and the forecast of firing time wind conditions.

1

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   Stabilized Rockets." ERDA-196, Environmental Sciences
   Directorate, United States Army Electronics Research and
   Development Activity, White Sands Missile Range, New Mexico.

2

PAYLOAD	Includes Nosecone Weight	300.5	Pounds
*UNIT WIND EFFECT	Cross	3.45	Miles/MPH
	Range	4.06	Miles/MPH
TOWER TILT EFFECT		18.28	Miles/Degree
BURNOUT	Velocity	5,399	Feet/Second
	Altitude	121,100	Feet MSL
	Time	51.8	Seconds
PEAK	Altitude	113.0	Miles MSL
	Time	224.0	Seconds
TOTAL FLIGHT TIME		525.0	Seconds
CORIOLIS EFFECT	West	5.35	Miles

TABLE I.   THEORETICAL ROCKET PERFORMANCE VALUES
AEROBEE NASA 4.51 UG

* An empirical correction (85 percent of the total) has been made to the cross-unit wind effect. This correction was determined from statistical studies.

LAYERS IN FEET ABOVE GROUND	BALLISTIC FACTOR
143- 250	.185
250- 400	.115
400- 600	.100
600- 800	.062
800-1200	.053
1200-1600	.031
1600-2000	.025
2000-2500	.029
2500-3000	.023

LAYERS IN FEET ABOVE GROUND	BALLISTIC FACTOR
3000- 3500	.019
3500- 4000	.016
4000- 5000	.031
5000-10000	.096
10000-15000	.056
15000-20000	.033
20000-25000	.023
25000-30000	.017
30000-35000	.014

LAYERS IN FEET ABOVE GROUND	BALLISTIC FACTOR
35000- 40000	.009
40000- 45000	.006
45000- 50000	.012
50000- 60000	.010
60000- 70000	.009
70000- 80000	.007
80000- 90000	.008
90000-100000	.010

TABLE II.   BALLISTIC FACTORS
AEROBEE NASA 4.51 UG

4

TIME IN MINUTES	ANEMOMETER-MEASURED WIND	
	Speed (Knots)	Direction (Degrees)
T - 15	3.0	356
T - 10	2.0	358
T - 5	1.0	348
T - Time	0.5	330
T + 5	0.5	360
T + 10	1.0	360
T + 15	0.5	358

TABLE III. ANEMOMETER-MEASURED WIND SPEED AND DIRECTION
AEROBEE NASA 4.51 UG

NOTE: Wind speeds and directions are 5-minute averages
centered at indicated times.

MEAN WIND COMPONENTS IN MILES PER HOUR

LAYERS IN FEET ABOVE GROUND	1 1907 MST		2 1937 MST		3 2007 MST		4 2027 MST		5 2047 MST		6 2107 MST	
	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W
143- 250	5.5N	9.0W	5.0N	6.0W	4.5N	7.0W	10.5N	6.0W	9.0W	6.0W	7.5N	4.0W
250- 400	4.5	11.0	7.0	10.0	5.5	8.5	12.5	8.0	10.0	10.0	11.5	6.0
400- 600	5.5	11.5	7.0	13.0	4.5	12.0	14.0	11.0	11.0	11.0	12.5	8.5
600- 800	3.0	19.0	7.5	15.0	7.5	14.5	12.5	13.5	13.5	13.0	15.5	9.0
800-1200	5.5	17.0	3.5	19.0	7.5	16.0	10.5	15.0	6.5	15.0	11.5	13.0
1200-1600	1.0	14.5	0.5	19.0	4.0	19.0	12.0	15.5	12.5	15.0	7.5	14.0
1600-2000	3.0	16.5	1.0	20.0	4.0	25.5	11.5	17.0	13.0	18.0	8.5	15.0
2000-2500	5.0	19.0	4.5	19.0	3.5	27.5	7.5	16.0	11.5	19.0	7.0	17.0
2500-3000	1.5	19.0	6.5	24.5	5.5	39.5	6.5	16.5	16.5	21.0	6.5	17.5
3000-3500	5.0	21.0	4.5	23.0	2.0	38.5	11.5	20.5	6.0	21.0	10.0	19.0
3500-4000	8.0	21.0	7.0	21.5	0.0	39.0	11.5	18.0	6.0	22.0	8.5	20.5

TABLE IV.   PILOT-BALLOON-MEASURED WIND DATA
(DOUBLE-THEODOLITE METHOD)
AEROBEE NASA 4.51 UG

MEAN WIND COMPONENTS IN MILES PER HOUR

LAYERS IN FEET ABOVE GROUND	7 2122 MST		8 2135 MST		9 2147 MST		10 2157 MST		11 2208 MST			
	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W
143- 250	6.0N	1.0W	6.0N	0.0	6.0N	0.0	3.5N	0.0	1.0N	0.5W		
250- 400	11.5	3.0	10.5	1.0W	11.0	2.0W	3.5	2.0W	2.0	0.5		
400- 600	8.5	7.0	7.5	4.0	11.0	4.0	8.5	7.0	9.5	4.0		
600- 800	7.5	9.0	8.5	9.0	8.0	9.0	10.5	9.5	8.0	8.0		
800-1200	11.5	10.5	7.0	11.0	6.0	13.0	6.5	11.0	3.0	13.0		
1200-1600	7.0	13.5	5.5	14.0	4.5	15.0	6.0	17.0	3.0	15.0		
1600-2000	6.0	11.5	4.5	15.0	4.0	15.0	2.5	17.0	2.0	15.5		
2000-2500	8.5	12.0	2.5	16.0	3.0	19.0	5.0	19.0	3.0	22.0		
2500-3000	6.5	13.5	4.0	19.0	2.0	23.0	2.5S	22.0	4.0S	21.5		
3000-3500	10.5	22.0	13.0	28.5	1.0	24.0	1.0N	23.0	0.5N	24.0		
3500-4000	8.5	24.0	9.5	31.0	8.5	31.0	5.5	28.5	1.0	30.5		

TABLE IV.   PILOT-BALLOON-MEASURED WIND DATA (Cont)
(DOUBLE-THEODOLITE METHOD)
AEROBEE NASA 4.51 UG

LAYERS IN FEET ABOVE GROUND	MEAN WIND COMPONENTS IN KNOTS					
	1 1630 MST		2* 1905 MST		3 2207 MST	
	N-S	E-W	N-S	E-W	N-S	E-W
4000- 5000	3.0S	17.5W	0.0	16.0W	4.0S	21.5W
5000- 10000	8.0	21.5	4.0S	23.5	6.5	18.0
10000- 15000	6.5	18.0	13.5	22.5	16.0	13.5
15000- 20000	10.0	28.0	5.5	30.5	18.5	22.0
20000- 25000	0.0	44.0	7.5	41.5	15.0	41.5
25000- 30000	11.0S	64.0	23.5	65.0	23.0	63.0
30000- 35000	15.0	87.0	15.5	88.0	16.0	89.5
35000- 40000	0.0	98.0	16.5	94.0	16.0	89.5
40000- 45000	0.0	68.0	0.0	64.0	10.5N	59.0
45000- 50000	8.0N	46.5	4.5S	26.5	9.0S	52.0
50000- 60000	0.0	23.0	2.0	11.0	0.0	30.0
60000- 70000	5.0S	6.0	12.5N	7.0E	0.0	14.0E
70000- 80000	15.0N	2.5E	0.0	15.0	3.0N	16.5
80000- 90000	2.5	15.0	3.5N	18.5	0.0	12.0
90000-100000	3.0	16.5	BALLOON BURST		2.5N	13.0

TABLE VI.   UPPER AIR DATA (4,000-100,000 FT) AEROBEE NASA 4.51 UG

* Rawin, telecompute data not available.

LAYERS IN FEET ABOVE GROUND	MEAN WIND COMPONENTS IN KNOTS	
	1 2110 MST	
	N-S	E-W
4000- 5000	3.0N	16.5W
5000-10000	7.5S	20.5
10000-15000	13.5	16.0
15000-20000	15.5	18.5

TABLE V.   UPPER AIR DATA (4,000-20,000 FT) AEROBEE NASA 4.51 UG

8

UPPER AIR DATA
3914309
WHITE SANDS SITE
TABLE VII

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	DEWPOINT DEGREES CENTIGRADE	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
3989.0	874.3	33.7	1.5	13.0	989.8	683.1	250.0	9.9	1.000248
4000.0	874.0	33.7	1.5	13.0	989.6	683.0	250.0	9.9	1.000248
4500.0	858.9	32.0	0.9	13.7	977.8	681.2	252.2	11.2	1.000244
5000.0	844.1	30.4	0.3	14.4	966.2	679.4	254.3	12.5	1.000241
5500.0	829.6	28.8	-0.3	15.1	954.8	677.5	256.4	13.8	1.000238
6000.0	815.3	27.1	-1.0	15.8	943.5	675.6	257.3	14.8	1.000234
6500.0	801.3	25.5	-1.7	16.5	932.4	673.8	257.6	15.6	1.000231
7000.0	787.5	23.9	-2.5	17.2	921.5	671.9	257.9	15.9	1.000227
7500.0	773.9	22.2	-3.3	17.9	910.7	670.0	258.3	15.4	1.000224
8000.0	760.6	20.6	-4.1	18.6	900.1	668.1	258.3	15.6	1.000220
8500.0	747.5	19.0	-4.9	19.3	889.6	666.2	257.6	16.9	1.000217
9000.0	734.6	17.4	-5.8	20.0	879.3	664.4	256.3	18.4	1.000214
9500.0	721.5	16.0	-6.1	21.4	867.7	662.8	256.6	18.2	1.000211
10000.0	708.6	14.6	-6.4	22.8	856.3	661.2	257.3	19.3	1.000208
10500.0	696.0	13.2	-6.8	24.2	845.1	659.5	257.7	19.5	1.000205
11000.0	683.5	11.8	-7.3	25.6	834.1	657.9	257.0	19.5	1.000202
11500.0	671.0	10.4	-7.8	27.1	823.1	656.2	255.6	19.4	1.000199
12000.0	658.7	8.9	-8.4	28.7	812.2	654.5	252.4	18.6	1.000196
12500.0	646.6	7.4	-9.0	30.2	801.5	652.8	249.8	18.7	1.000194
13000.0	634.7	6.0	-9.6	31.8	790.9	651.1	247.7	19.5	1.000191
13500.0	623.0	4.5	-10.3	33.3	780.5	649.4	246.2	20.7	1.000188
14000.0	611.5	3.0	-11.0	34.9	770.2	647.6	245.3	21.7	1.000185
14500.0	600.3	1.6	-11.8	36.4	760.1	645.9	246.4	21.9	1.000182
15000.0	589.1	0.2	-12.6	37.6	749.7	644.2	246.8	21.8	1.000179
15500.0	577.9	-1.1	-13.5	38.5	739.2	642.6	246.6	21.2	1.000176
16000.0	567.0	-2.5	-14.4	39.5	728.8	641.0	247.0	21.1	1.000173
16500.0	556.2	-3.8	-15.4	40.4	718.6	639.4	247.7	21.1	1.000170
17000.0	545.6	-5.1	-17.0	39.0	708.4	637.9	248.8	21.0	1.000166
17500.0	535.1	-6.3	-19.6	34.1	697.9	636.4	250.4	20.6	1.000162
18000.0	524.7	-7.4	-22.4	29.2	687.6	634.9	252.0	20.3	1.000159

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STATION ALTITUDE 3989.0 FEET MSL
23 MAY 66   1630 HRS MST
ASCENSION NO. 31

UPPER AIR DATA
3914309
WHITE SANDS SITE
TABLE VII (Cont)

WSTM SITE COORDINATES
E 488,580 FEET
N 185,045 FEET

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	DEWPOINT	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
18500.0	514.6	-8.6	-25.5	24.3	677.4	633.5	254.1	20.4	1.000155
19000.0	504.6	-9.7	-28.1	20.9	667.1	632.1	256.2	20.6	1.000152
19500.0	494.7	-10.7	-29.1	20.5	656.4	630.9	257.6	23.4	1.000149
20000.0	484.9	-11.7	-30.1	20.2	645.9	629.8	258.7	26.1	1.000147
20500.0	475.4	-12.6	-31.1	19.9	635.6	628.6	257.9	28.8	1.000144
21000.0	466.0	-13.6	-32.1	19.5	625.4	627.4	257.2	31.5	1.000142
21500.0	456.8	-14.6	-33.1	19.2	615.4	626.2	257.5	34.1	1.000139
22000.0	447.8	-15.8	-34.1	19.2	606.0	624.8	258.2	36.0	1.000137
22500.0	438.8	-17.3	-35.1	19.8	597.3	622.9	260.0	36.2	1.000135
23000.0	430.0	-18.3	-36.1	19.6	587.8	621.6	262.0	36.7	1.000133
23500.0	421.3	-19.1	-37.1	18.8	577.6	620.7	264.2	37.7	1.000130
24000.0	412.8	-19.8	-38.2	18.0	567.6	619.8	266.3	38.6	1.000128
24500.0	404.2	-21.1	-39.2	18.2	558.7	618.2	268.2	39.3	1.000126
25000.0	395.7	-22.4	-40.2	18.4	549.9	616.6	269.0	40.7	1.000124
25500.0	387.5	-23.7	-41.2	18.6	541.2	615.0	269.3	42.4	1.000122
26000.0	379.4	-25.0	-42.2	18.7	532.7	613.4	269.5	43.9	1.000120
26500.0	371.5	-26.3	-43.2	18.9	524.3	611.8	269.7	45.5	1.000118
27000.0	363.8	-27.6	-44.2	19.1	516.1	610.2	269.9	47.0	1.000116
27500.0	356.2	-28.9	-45.3	19.3	508.1	608.5	270.1	48.6	1.000114
28000.0	348.7	-30.2	-46.3	19.5	500.1	606.9	269.6	50.2	1.000112
28500.0	341.5	-31.5	-47.3	19.7	492.3	605.3	268.8	51.8	1.000110
29000.0	334.4	-32.8	-48.3	19.8	484.7	603.7	268.0	53.6	1.000108
29500.0	327.4	-34.1	-49.6	19.5**	477.1	602.0	267.1	55.6	1.000107
30000.0	320.3	-35.4	-53.3	14.2**	469.2	600.5	265.7	58.0	1.000105
30500.0	313.3	-36.6	-58.1	8.9***	461.5	598.9	263.7	61.1	1.000103
31000.0	306.5	-37.9	-65.9	3.6***	453.9	597.3	261.8	63.9	1.000101
31500.0	299.9	-38.9	0.	-0.**	445.9	596.0	260.1	66.7	1.000099
32000.0	293.3	-39.4	0.	-0.**	437.1	595.4	258.2	68.4	1.000097
32500.0	286.8	-39.9	0.	-0.**	428.4	594.7	256.4	69.8	1.000095
33000.0	280.5	-40.4	0.	-0.**	419.9	594.1	256.0	72.3	1.000094

** AT LEAST ONE ASSUMED RELATIVE HUMIDITY VALUE WAS USED IN THE INTERPOLATION.

STATION ALTITUDE 3989.0 FEET MSL
23 MAY 66   1630 HRS MST
ASCENSION NO. 371

UPPER AIR DATA
3914309
WHITE SANDS SITE
TABLE VII (Cont)

WSTM SITE COORDINATES
E 488,580 FEET
N 185,045 FEET

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	TEMPERATURE DEWPOINT DEGREES CENTIGRADE	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
33500.0	274.4	-40.9	0.	-0.**	411.6	593.4	256.1	74.4	1.000092
34000.0	268.2	-41.6	0.	-0.**	403.7	592.5	257.3	75.4	1.000090
34500.0	262.3	-42.4	0.	-0.**	396.0	591.5	259.0	78.8	1.000088
35000.0	256.4	-43.2	0.	-0.**	388.5	590.4	261.1	84.6	1.000087
35500.0	250.7	-44.0	0.	-0.**	381.1	589.4	262.7	90.0	1.000085
36000.0	245.1	-44.8	0.	-0.**	373.9	588.4	264.1	95.2	1.000083
36500.0	239.6	-45.6	0.	-0.**	366.9	587.3	264.9	95.1	1.000082
37000.0	234.2	-46.4	0.	-0.**	359.9	586.3	265.6	93.1	1.000080
37500.0	228.8	-47.7	0.	-0.**	353.6	584.7	265.7	94.4	1.000079
38000.0	223.5	-49.1	0.	-0.**	347.6	582.8	265.7	96.7	1.000077
38500.0	218.3	-50.5	0.	-0.**	341.6	581.0	265.9	96.6	1.000076
39000.0	213.3	-51.9	0.	-0.**	335.8	579.2	266.1	95.8	1.000075
39500.0	208.3	-53.3	0.	-0.**	330.1	577.3	266.2	100.0	1.000074
40000.0	203.5	-54.7	0.	-0.**	324.5	575.5	266.3	106.0	1.000072
40500.0	198.7	-56.1	0.	-0.**	319.1	573.6	266.4	103.7	1.000071
41000.0	194.1	-57.5	0.	-0.**	313.7	571.8	266.5	98.4	1.000070
41500.0	189.6	-58.6	0.	-0.**	307.9	570.3	266.2	93.7	1.000069
42000.0	185.0	-59.0	0.	-0.**	301.1	569.8	265.6	89.2	1.000067
42500.0	180.6	-59.4	0.	-0.**	294.5	569.2	265.2	84.4	1.000066
43000.0	176.3	-59.1	0.	-0.**	287.0	569.7	264.8	79.5	1.000064
43500.0	172.1	-58.6	0.	-0.**	279.5	570.3	265.7	78.1	1.000062
44000.0	168.0	-58.1	0.	-0.**	272.2	571.0	266.7	77.0	1.000061
44500.0	164.0	-58.4	0.	-0.**	266.0	570.6	268.1	77.5	1.000059
45000.0	160.0	-59.4	0.	-0.**	260.8	569.2	269.6	78.1	1.000058
45500.0	156.1	-60.5	0.	-0.**	255.7	567.9	270.3	77.5	1.000057
46000.0	152.3	-61.5	0.	-0.**	250.7	566.5	271.0	76.8	1.000056
46500.0	148.6	-62.5	0.	-0.**	245.9	565.1	271.2	75.3	1.000055
47000.0	145.0	-63.5	0.	-0.**	241.1	563.8	271.2	73.4	1.000054
47500.0	141.5	-64.5	0.	-0.**	236.4	562.4	271.4	71.3	1.000053
48000.0	138.1	-65.6	0.	-0.**	231.8	561.0	272.0	68.8	1.000052

** AT LEAST ONE ASSUMED RELATIVE HUMIDITY VALUE WAS USED IN THE INTERPOLATION.

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STATION ALTITUDE 3989.0 FEET MSL
23 MAY 66   1630 HRS MST
ASCENSION NO. 371

UPPER AIR DATA
3914309
WHITE SANDS SITE
TABLE VII (Cont)

WSTM SITE COORDINATES
E 488,580 FEET
N 185,045 FEET

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	DEWPOINT DEGREES CENTIGRADE	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
48500.0	134.7	-65.9	0.	-0.**	226.5	560.6	272.7	66.4	1.000050
49000.0	131.4	-65.9	0.	-0.**	220.9	560.6	273.8	64.4	1.000049
49500.0	128.1	-65.9	0.	-0.**	215.4	560.6	274.9	62.4	1.000048
50000.0	125.0	-65.9	0.	-0.**	210.1	560.6	276.0	58.1	1.000047
50500.0	121.9	-65.9	0.	-0.**	204.9	560.6	277.1	53.2	1.000046
51000.0	118.9	-65.9	0.	-0.**	199.9	560.6	276.5	46.9	1.000045
51500.0	116.0	-65.9	0.	-0.**	194.9	560.6	275.0	40.0	1.000043
52000.0	113.1	-65.9	0.	-0.**	190.1	560.6	271.0	35.3	1.000042
52500.0	110.3	-64.2	0.	-0.**	184.0	562.8	265.9	31.7	1.000041
53000.0	107.6	-64.6	0.	-0.**	179.8	562.3	261.7	30.0	1.000040
53500.0	104.9	-65.4	0.	-0.**	176.0	561.2	258.2	29.5	1.000039
54000.0	102.3	-66.2	0.	-0.**	172.3	560.1	256.2	29.1	1.000038
54500.0	99.8	-67.0	0.	-0.**	168.7	559.0	256.2	28.8	1.000038
55000.0	97.4	-67.8	0.	-0.**	165.2	558.0	256.5	28.4	1.000037
55500.0	94.9	-68.5	0.	-0.**	161.7	557.0	258.5	26.9	1.000036
56000.0	92.6	-66.2	0.	-0.**	155.9	560.2	260.5	25.4	1.000035
56500.0	90.3	-66.3	0.	-0.**	152.1	560.1	261.5	23.7	1.000034
57000.0	88.1	-67.1	0.	-0.**	148.9	558.9	262.2	22.0	1.000033
57500.0	85.9	-68.0	0.	-0.**	145.8	557.7	262.0	19.5	1.000032
58000.0	83.7	-68.9	0.	-0.**	142.8	556.5	260.1	15.9	1.000032
58500.0	81.6	-69.4	0.	-0.**	139.6	555.7	258.3	12.2	1.000031
59000.0	79.6	-69.8	0.	-0.**	136.4	555.2	262.3	10.9	1.000030
59500.0	77.6	-70.2	0.	-0.**	133.2	554.7	266.6	9.8	1.000030
60000.0	75.6	-69.9	0.	-0.**	129.7	555.1	273.5	11.6	1.000029
60500.0	73.8	-67.1	0.	-0.**	124.7	558.9	281.3	14.6	1.000028
61000.0	71.9	-67.2	0.	-0.**	121.7	558.8	287.8	16.1	1.000027
61500.0	70.1	-67.3	0.	-0.**	118.7	558.7	293.4	16.8	1.000026
62000.0	68.4	-66.5	0.	-0.**	115.3	559.8	310.9	14.9	1.000026
62500.0	66.7	-64.1	0.	-0.**	111.2	562.9	339.9	10.8	1.000025
63000.0	65.1	-63.2	0.	-0.**	108.0	564.2	10.4	9.2	1.000024

** AT LEAST ONE ASSUMED RELATIVE HUMIDITY VALUE WAS USED IN THE INTERPOLATION.

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STATION ALTITUDE 3989.0 FEET MSL
23 MAY 66   1630 HRS MST
ASCENSION NO. 371

UPPER AIR DATA
3914309
WHITE SANDS SITE
TABLE VII (Cont)

WSTM SITE COORDINATES
E 488,580 FEET
N 185,045 FEET

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	DEWPOINT DEGREES CENTIGRADE	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
63500.0	63.5	-63.4	0.	-0.**	105.5	564.0	43.6	12.0	1.000023
64000.0	62.0	-63.6	0.	-0.**	103.0	563.7	69.1	13.2	1.000023
64500.0	60.5	-63.7	0.	-0.**	100.6	563.5	69.6	8.9	1.000022
65000.0	59.0	-63.9	0.	-0.**	98.2	563.3	62.1	6.0	1.000022
65500.0	57.6	-62.5	0.	-0.**	95.2	565.1	348.4	14.3	1.000021
66000.0	56.2	-61.2	0.	-0.**	92.3	566.9	274.7	22.5	1.000021
66500.0	54.8	-61.0	0.	-0.**	90.0	567.1	299.0	13.3	1.000020
67000.0	53.5	-61.0	0.	-0.**	87.8	567.1	326.4	3.5	1.000020
67500.0	52.2	-61.0	0.	-0.**	85.7	567.1	0.4	2.1	1.000019
68000.0	50.9	-61.0	0.	-0.**	83.7	567.1	35.9	2.6	1.000019
68500.0	49.7	-60.8	0.	-0.**	81.6	567.4	62.9	6.0	1.000018
69000.0	48.5	-60.1	0.	-0.**	79.4	568.4	84.2	11.4	1.000018
69500.0	47.4	-59.4	0.	-0.**	77.2	569.3	112.6	15.8	1.000017
70000.0	46.3	-58.6	0.	-0.**	75.1	570.3	173.3	15.2	1.000017
70500.0	45.1	-57.9	0.	-0.**	73.1	571.3	234.1	14.5	1.000016
71000.0	44.1	-57.2	0.	-0.**	71.1	572.3	259.6	11.6	1.000016
71500.0	43.0	-56.4	0.	-0.**	69.2	573.2	262.1	7.3	1.000015
72000.0	42.0	-56.5	0.	-0.**	67.6	573.1	265.7	3.0	1.000015
72500.0	41.0	-56.6	0.	-0.**	66.0	572.9	318.3	5.4	1.000015
73000.0	40.1	-56.8	0.	-0.**	64.5	572.8	10.9	7.7	1.000014
73500.0	39.1	-56.9	0.	-0.**	63.0	572.6	36.6	8.4	1.000014
74000.0	38.2	-57.0	0.	-0.**	61.5	572.5	26.5	6.8	1.000014
74500.0	37.3	-57.1	0.	-0.**	60.1	572.3	16.4	5.3	1.000013
75000.0	36.4	-57.2	0.	-0.**	58.7	572.1	19.4	5.9	1.000013
75500.0	35.5	-56.2	0.	-0.**	57.1	573.5	25.1	6.8	1.000013
76000.0	34.7	-54.2	0.	-0.**	55.3	576.1	29.0	7.6	1.000012
76500.0	33.9	-52.6	0.	-0.**	53.6	578.3	26.9	7.4	1.000012
77000.0	33.1	-53.4	0.	-0.**	52.5	577.2	24.8	7.2	1.000012
77500.0	32.3	-54.2	0.	-0.**	51.5	576.2	32.9	10.2	1.000011
78000.0	31.6	-55.0	0.	-0.**	50.4	575.2	47.6	15.3	1.000011

** AT LEAST ONE ASSUMED RELATIVE HUMIDITY VALUE WAS USED IN THE INTERPOLATION.

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UPPER AIR DATA
3914309
WHITE SANDS SITE
TABLE VII (Cont)

STATION ALTITUDE 3989.0 FEET MSL
23 MAY 66   1630 HRS MST
ASCENSION NO. 371

WSTM SITE COORDINATES
E 488,580 FEET
N 185,045 FEET

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	DEWPOINT DEGREES CENTIGRADE	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
78500.0	30.9	-55.5	0.	-0.**	49.4	574.5	62.4	20.5	1.000011
79000.0	30.1	-54.9	0.	-0.**	48.1	575.2	66.1	20.3	1.000011
79500.0	29.4	-54.4	0.	-0.**	46.9	575.9	69.5	20.1	1.000010
80000.0	28.8	-53.8	0.	-0.**	45.7	576.7	72.8	19.5	1.000010
80500.0	28.1	-53.3	0.	-0.**	44.5	577.4	75.9	18.3	1.000010
81000.0	27.4	-52.7	0.	-0.**	43.4	578.1	79.1	17.1	1.000010
81500.0	26.8	-52.1	0.	-0.**	42.3	578.9	81.4	17.3	1.000009
82000.0	26.2	-51.6	0.	-0.**	41.2	579.6	83.4	18.0	1.000009
82500.0	25.6	-51.0	0.	-0.**	40.1	580.3	85.2	18.1	1.000009
83000.0	25.0	-50.5	0.	-0.**	39.1	581.1	85.2	13.6	1.000009
83500.0	24.4	-49.9	0.	-0.**	38.1	581.8	85.2	9.1	1.000008
84000.0	23.9	-49.5	0.	-0.**	37.2	582.3	85.2	8.4	1.000008
84500.0	23.3	-49.4	0.	-0.**	36.3	582.4	85.2	11.5	1.000008
85000.0	22.8	-49.3	0.	-0.**	35.5	582.5	85.2	14.7	1.000008
85500.0	22.3	-49.3	0.	-0.**	34.6	582.6	85.2	15.0	1.000008
86000.0	21.8	-49.2	0.	-0.**	33.8	582.7	85.2	14.7	1.000008
86500.0	21.3	-49.1	0.	-0.**	33.1	582.8	85.2	14.8	1.000007
87000.0	20.8	-49.0	0.	-0.**	32.3	582.9	85.2	16.7	1.000007
87500.0	20.3	-48.9	0.	-0.**	31.5	583.0	85.2	18.7	1.000007
88000.0	19.8	-48.3	0.	-0.**	30.7	583.9	84.1	18.6	1.000007
88500.0	19.4	-46.6	0.	-0.**	29.8	586.1	81.8	16.5	1.000007
89000.0	19.0	-45.0	0.	-0.**	28.9	588.1	79.6	14.4	1.000006
89500.0	18.5	-45.0	0.	-0.**	28.3	588.1	79.1	13.9	1.000006
90000.0	18.1	-45.0	0.	-0.**	27.7	588.1	79.1	13.8	1.000006
90500.0	17.7	-45.0	0.	-0.**	27.1	588.1	78.9	13.9	1.000006
91000.0	17.3	-45.0	0.	-0.**	26.4	588.1	77.6	15.1	1.000006
91500.0	16.9	-45.0	0.	-0.**	25.9	588.1	76.2	16.3	1.000006
92000.0	16.6	-45.0	0.	-0.**	25.3	588.1	76.1	16.9	1.000006
92500.0	16.2	-45.0	0.	-0.**	24.7	588.1	77.8	16.7	1.000005
93000.0	15.8	-45.1	0.	-0.**	24.2	588.1	79.6	16.5	1.000005

** AT LEAST ONE ASSUMED RELATIVE HUMIDITY VALUE WAS USED IN THE INTERPOLATION.

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UPPER AIR DATA
3914309
WHITE SANDS SITE
TABLE VII (Cont)

STATION ALTITUDE 3989.0 FEET MSL
23 MAY 66   1630 HRS MST
ASCENSION NO. 371

WSTM SITE COORDINATES
E 488,580 FEET
N 185,045 FEET

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	DEWPOINT DEGREES CENTIGRADE	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
93500.0	15.5	-45.1	0.	-0.**	23.6	588.1	78.5	15.6	1.000005
94000.0	15.1	-45.1	0.	-0.**	23.1	588.1	75.5	14.1	1.000005
94500.0	14.8	-45.1	0.	-0.**	22.6	588.0	72.6	12.6	1.000005
95000.0	14.5	-45.1	0.	-0.**	22.1	588.0	72.8	11.5	1.000005
95500.0	14.1	-45.1	0.	-0.**	21.6	588.0	74.5	10.5	1.000005
96000.0	13.8	-45.1	0.	-0.**	21.1	588.0	76.1	9.5	1.000005
96500.0	13.5	-45.1	0.	-0.**	20.6	588.0	74.7	9.6	1.000005
97000.0	13.2	-44.3	0.	-0.**	20.1	589.0	72.3	10.0	1.000004
97500.0	12.9	-43.6	0.	-0.**	19.6	590.0	70.0	10.4	1.000004
98000.0	12.6	-42.8	0.	-0.**	19.1	590.9	72.7	11.9	1.000004
98500.0	12.3	-42.1	0.	-0.**	18.6	591.9	76.3	13.6	1.000004
99000.0	12.1	-41.3	0.	-0.**	18.1	592.9	79.9	15.3	1.000004
99500.0	11.8	-41.1	0.	-0.**	17.7	593.2	80.2	15.2	1.000004
100000.0	11.5	-41.1	0.	-0.**	17.3	593.2	80.0	14.8	1.000004
100500.0	11.3	-41.0	0.	-0.**	17.0	593.2	79.9	14.5	1.000004
101000.0	11.0	-41.0	0.	-0.**	16.6	593.3	80.2	15.2	1.000004
101500.0	10.8	-41.0	0.	-0.**	16.2	593.3	80.5	16.0	1.000004
102000.0	10.6	-41.0	0.	-0.**	15.9	593.3	80.8	16.8	1.000004
102500.0	10.3	-40.9	0.	-0.**	15.5	593.4	80.5	15.8	1.000003
103000.0	10.1	-40.9	0.	-0.**	15.2	593.4	80.1	14.7	1.000003
103500.0	9.9	-40.9	0.	-0.**	14.8	593.4	79.7	13.6	1.000003
104000.0	9.7	-40.8	0.	-0.**	14.5	593.5			1.000003
104500.0	9.5	-40.8	0.	-0.**	14.2	593.5			1.000003
105000.0	9.3	-40.5	0.	-0.**	13.9	593.9			1.000003
105500.0	9.0	-39.5	0.	-0.**	13.5	595.2			1.000003
106000.0	8.9	-38.5	0.	-0.**	13.1	596.5			1.000003
106500.0	8.7	-37.4	0.	-0.**	12.8	597.8			1.000003

** AT LEAST ONE ASSUMED RELATIVE HUMIDITY VALUE WAS USED IN THE INTERPOLATION.

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UPPER AIR DATA
3914310
WHITE SANDS SITE
TABLE VIII

WSTM SITE COORDINATES
E 488,580 FEET
N 185,045 FEET

STATION ALTITUDE 3989.0 FEET MSL
23 MAY 66   2207 HRS MST
ASCENSION NO. 374

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	DEWPOINT CENTIGRADE	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
3989.0	876.0	22.0	-1.3	21.0	1031.6	669.7	0.	0.	1.000254
4000.0	875.7	22.2	-1.2	20.9	1030.4	670.0	359.6	0.1	1.000254
4500.0	860.6	28.3	1.5	17.8	991.8	677.0	340.3	3.9	1.000249
5000.0	845.8	27.3	0.2	17.1	978.1	675.9	320.9	7.8	1.000244
5500.0	831.3	26.4	-1.1	16.4	964.5	674.8	301.6	11.6	1.000239
6000.0	817.1	25.4	-2.5	15.7	951.2	673.6	282.3	15.5	1.000234
6500.0	803.1	24.5	-3.8	15.0	938.0	672.5	269.7	18.2	1.000229
7000.0	788.9	23.1	-4.5	15.6	926.0	670.9	267.7	19.0	1.000225
7500.0	775.1	21.6	-5.1	16.2	914.3	669.2	266.0	19.6	1.000222
8000.0	761.5	20.2	-5.8	16.7	902.7	667.5	264.5	20.1	1.000219
8500.0	748.1	18.7	-6.6	17.3	891.3	665.9	263.3	20.2	1.000215
9000.0	734.9	17.3	-7.3	17.9	880.0	664.2	262.2	20.3	1.000212
9500.0	722.0	15.9	-8.1	18.5	869.0	662.5	260.0	20.1	1.000209
10000.0	709.3	14.4	-8.8	19.2	858.0	660.8	257.7	19.9	1.000206
10500.0	696.4	13.0	-8.9	20.9	846.6	659.2	253.8	19.9	1.000203
11000.0	683.8	11.5	-9.2	22.6	835.5	657.5	249.7	20.0	1.000200
11500.0	671.3	10.0	-9.5	24.2	824.6	655.8	245.7	20.1	1.000198
12000.0	659.1	8.6	-9.9	25.9	813.8	654.1	241.7	20.3	1.000195
12500.0	647.2	7.1	-10.4	27.6	803.2	652.4	237.3	20.2	1.000192
13000.0	635.4	5.7	-10.9	29.2	792.7	650.7	232.8	19.9	1.000190
13500.0	623.7	4.2	-11.2	31.6	782.2	649.0	229.9	20.1	1.000187
14000.0	612.0	2.7	-11.4	34.7	771.6	647.3	227.8	20.5	1.000185
14500.0	600.5	1.3	-11.6	37.7	761.2	645.5	226.2	20.8	1.000182
15000.0	589.2	-0.2	-12.0	40.8	751.0	643.8	224.8	21.0	1.000180
15500.0	578.2	-1.7	-12.4	43.8	740.9	642.0	223.6	21.4	1.000177
16000.0	567.3	-3.2	-12.9	46.9	731.0	640.3	222.4	21.8	1.000175
16500.0	556.5	-4.6	-13.1	51.4	720.8	638.6	220.3	22.2	1.000172
17000.0	545.8	-6.0	-13.4	55.9	710.6	636.9	216.3	22.7	1.000170
17500.0	535.3	-7.4	-13.8	60.5	700.7	635.2	212.2	23.1	1.000167
18000.0	525.0	-8.8	-14.3	65.0	690.9	633.5	209.3	24.5	1.000165

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STATION ALTITUDE 3989.0 FEET MSL
23 MAY 66   2207 HRS MST
ASCENSION NO.   374

UPPER AIR DATA
3914310
WHITE SANDS SITE
TABLE VIII (Cont)

WSTM SITE COORDINATES
E 488,580 FEET
N 185,045 FEET

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	DEWPOINT DEGREES CENTIGRADE	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
18500.0	514.7	-10.1	-16.3	60.9	680.8	632.0	206.4	25.9	1.000161
19000.0	504.6	-11.3	-18.3	56.9	670.8	630.4	206.8	26.7	1.000157
19500.0	494.7	-12.6	-20.3	52.8	661.0	628.8	207.9	27.4	1.000154
20000.0	485.0	-13.5	-23.9	41.6	650.4	627.6	212.8	26.9	1.000150
20500.0	475.4	-13.8	-32.5	19.0	638.3	627.2	219.0	26.2	1.000144
21000.0	465.8	-14.8	-33.3	19.2	628.1	625.9	228.1	25.9	1.000142
21500.0	456.5	-15.9	-34.1	19.3	618.0	624.7	236.6	26.5	1.000140
22000.0	447.3	-16.9	-34.9	19.5	608.1	623.4	243.9	27.9	1.000137
22500.0	438.4	-18.0	-35.7	19.6	598.3	622.1	247.8	30.6	1.000135
23000.0	429.6	-19.0	-36.5	19.8	588.7	620.8	251.8	32.0	1.000133
23500.0	420.9	-20.0	-37.4	19.9	579.3	619.5	255.5	33.0	1.000130
24000.0	412.4	-21.2	-38.1	20.3	570.0	618.2	256.0	35.4	1.000128
24500.0	403.9	-22.3	-38.9	20.8	560.9	616.7	256.8	37.1	1.000126
25000.0	395.5	-23.5	-39.7	21.3	551.9	615.3	257.7	38.1	1.000124
25500.0	387.4	-24.7	-40.5	21.8	543.1	613.8	256.5	41.8	1.000122
26000.0	379.4	-25.8	-41.3	22.3	534.4	612.4	255.0	45.7	1.000120
26500.0	371.6	-27.0	-42.1	22.8	525.9	610.9	254.0	49.2	1.000118
27000.0	363.8	-28.3	-42.0	26.1	517.7	609.3	253.2	52.6	1.000116
27500.0	356.1	-29.8	-41.7	30.9	509.7	607.5	253.2	56.0	1.000115
28000.0	348.6	-31.2	-41.6	35.6	501.8	605.8	253.0	58.6	1.000113
28500.0	341.2	-32.6	-41.7	40.3	494.1	604.0	252.7	60.1	1.000111
29000.0	334.0	-34.0	-42.0	45.0	486.5	602.2	252.9	60.4	1.000109
29500.0	326.7	-35.3	-43.9	41.4	478.6	600.6	253.4	60.0	1.000107
30000.0	319.7	-36.6	-45.9	37.9	470.8	598.9	253.7	61.6	1.000106
30500.0	312.8	-37.3	-47.4	34.6	461.9	598.0	254.1	63.6	1.000103
31000.0	305.9	-37.8	-48.7	31.4	452.8	597.4	254.4	68.0	1.000101
31500.0	299.3	-38.3	-51.6	23.6**	444.0	596.7	254.6	71.8	1.000099
32000.0	292.7	-38.8	-57.6	12.1**	435.3	596.0	254.4	74.4	1.000097
32500.0	286.3	-39.4	-79.2	0.6***	426.7	595.4	254.0	76.0	1.000095
33000.0	280.0	-40.6	0.	-0.**	419.5	593.8	253.3	76.4	1.000093

** AT LEAST ONE ASSUMED RELATIVE HUMIDITY VALUE WAS USED IN THE INTERPOLATION.

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STATION ALTITUDE 3989.0 FEET MSL
23 MAY 66   2207 HRS MST
ASCENSION NO. 374

UPPER AIR DATA
3914310
WHITE SANDS SITE
TABLE VIII (Cont)

WSTM SITE COORDINATES
E 488,580 FEET
N 185,045 FEET

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	DEWPOINT	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
33500.0	273.8	-41.8	0.	**	412.4	592.2	253.7	76.3	1.000092
34000.0	267.7	-42.5	0.	**	404.5	591.3	254.9	76.0	1.000090
34500.0	261.8	-43.0	0.	**	396.2	590.8	256.5	79.9	1.000088
35000.0	255.9	-43.4	0.	**	388.1	590.2	258.3	84.9	1.000086
35500.0	250.2	-44.1	0.	**	380.5	589.4	260.6	90.1	1.000085
36000.0	244.5	-45.2	0.	**	373.6	587.9	262.5	94.1	1.000083
36500.0	238.9	-46.3	0.	**	366.9	586.4	263.3	94.6	1.000082
37000.0	233.4	-47.5	0.	**	360.3	585.0	263.7	94.7	1.000080
37500.0	228.0	-48.6	0.	**	353.8	583.5	263.8	94.2	1.000079
38000.0	222.8	-49.7	0.	**	347.5	582.0	263.4	93.7	1.000077
38500.0	217.7	-50.9	0.	**	341.3	580.5	262.6	93.4	1.000076
39000.0	212.7	-52.0	0.	**	335.2	579.0	262.2	95.3	1.000075
39500.0	207.9	-53.2	0.	**	329.2	577.5	261.9	98.0	1.000073
40000.0	203.1	-54.3	0.	**	323.3	576.0	261.8	94.9	1.000072
40500.0	198.4	-55.4	0.	**	317.5	574.6	261.8	91.2	1.000071
41000.0	193.7	-56.2	0.	**	311.1	573.5	261.3	88.4	1.000069
41500.0	189.1	-57.0	0.	**	304.8	572.5	260.9	85.7	1.000068
42000.0	184.6	-57.8	0.	**	298.7	571.4	260.7	86.8	1.000067
42500.0	180.2	-58.6	0.	**	292.7	570.3	260.6	88.2	1.000065
43000.0	176.0	-59.4	0.	**	286.8	569.3	261.3	90.6	1.000064
43500.0	171.8	-59.1	0.	**	279.6	569.7	262.3	90.7	1.000062
44000.0	167.7	-58.8	0.	**	272.5	570.1	263.9	86.6	1.000061
44500.0	163.6	-58.8	0.	**	266.0	570.0	266.6	78.2	1.000059
45000.0	159.7	-59.5	0.	**	260.4	569.2	269.9	67.1	1.000058
45500.0	155.8	-60.2	0.	**	254.9	568.3	273.5	61.0	1.000057
46000.0	152.1	-60.8	0.	**	249.5	567.4	276.2	57.1	1.000056
46500.0	148.4	-61.5	0.	**	244.3	566.5	277.3	57.4	1.000054
47000.0	144.8	-62.2	0.	**	239.1	565.6	277.7	58.2	1.000053
47500.0	141.3	-62.8	0.	**	234.1	564.7	277.1	59.7	1.000052
48000.0	137.9	-63.5	0.	**	229.1	563.8	276.4	60.8	1.000051

** AT LEAST ONE ASSUMED RELATIVE HUMIDITY VALUE WAS USED IN THE INTERPOLATION.

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STATION ALTITUDE 3989.0 FEET MSL
23 MAY 66   2207 HRS MST
ASCENSION NO. 374

UPPER AIR DATA
3914310
WHITE SANDS SITE
TABLE VIII (Cont)

WSTM SITE COORDINATES
E 488,580 FEET
N 185,045 FEET

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	DEWPOINT DEGREES CENTIGRADE	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
48500.0	134.5	-64.2	0.	-0.**	224.3	562.9	275.2	60.8	1.000050
49000.0	131.3	-64.7	0.	-0.**	219.4	562.2	274.0	60.8	1.000049
49500.0	128.0	-65.0	0.	-0.**	214.3	561.7	272.2	59.9	1.000048
50000.0	124.9	-65.4	0.	-0.**	209.4	561.3	270.3	59.1	1.000047
50500.0	121.8	-65.6	0.	-0.**	204.5	560.9	268.0	57.3	1.000046
51000.0	118.8	-64.5	0.	-0.**	198.5	562.4	265.4	55.2	1.000044
51500.0	115.9	-63.5	0.	-0.**	192.6	563.9	262.6	53.1	1.000043
52000.0	113.1	-63.5	0.	-0.**	187.9	563.9	259.4	51.0	1.000042
52500.0	110.3	-64.0	0.	-0.**	183.7	563.2	256.9	49.7	1.000041
53000.0	107.6	-64.5	0.	-0.**	179.6	562.5	255.0	49.1	1.000040
53500.0	104.9	-65.0	0.	-0.**	175.7	561.8	254.4	50.8	1.000039
54000.0	102.4	-65.5	0.	-0.**	171.8	561.1	254.5	53.5	1.000038
54500.0	99.8	-66.0	0.	-0.**	168.0	560.4	255.1	55.1	1.000037
55000.0	97.4	-66.6	0.	-0.**	164.2	559.7	255.8	56.3	1.000037
55500.0	95.0	-67.1	0.	-0.**	160.6	559.0	256.4	55.1	1.000036
56000.0	92.7	-66.6	0.	-0.**	156.3	559.6	256.7	51.2	1.000035
56500.0	90.4	-66.0	0.	-0.**	151.9	560.5	257.1	47.2	1.000034
57000.0	88.1	-66.9	0.	-0.**	148.8	559.2	258.1	40.3	1.000033
57500.0	85.9	-67.8	0.	-0.**	145.7	558.0	259.1	33.4	1.000032
58000.0	83.8	-68.7	0.	-0.**	142.7	556.7	261.8	29.5	1.000032
58500.0	81.7	-69.6	0.	-0.**	139.8	555.5	265.3	27.0	1.000031
59000.0	79.6	-70.6	0.	-0.**	136.9	554.2	269.0	25.5	1.000030
59500.0	77.6	-71.1	0.	-0.**	133.9	553.4	273.0	25.0	1.000030
60000.0	75.7	-70.2	0.	-0.**	130.0	554.7	277.9	23.3	1.000029
60500.0	73.8	-69.2	0.	-0.**	126.2	556.0	284.2	19.5	1.000028
61000.0	72.0	-68.3	0.	-0.**	122.5	557.3	295.5	15.6	1.000027
61500.0	70.2	-67.3	0.	-0.**	118.9	558.6	321.6	11.5	1.000026
62000.0	68.5	-66.4	0.	-0.**	115.4	559.9	342.9	7.9	1.000026
62500.0	66.8	-65.4	0.	-0.**	112.1	561.2	336.0	8.0	1.000025
63000.0	65.2	-64.5	0.	-0.**	108.8	562.5	328.3	8.4	1.000024

** AT LEAST ONE ASSUMED RELATIVE HUMIDITY VALUE WAS USED IN THE INTERPOLATION.

STATION ALTITUDE 3989.0 FEET MSL
23 MAY 66   2207 HRS MST
ASCENSION NO. 374

WSTM SITE COORDINATES
E 488,580 FEET
N 185,045 FEET

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	DEWPOINT DEGREES CENTIGRADE	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
63500.0	63.5	-63.5	0.	-0. **	105.6	563.7	311.5	11.0	1.000024
64000.0	62.0	-62.6	0.	-0. **	102.6	565.0	297.0	13.2	1.000023
64500.0	60.5	-61.9	0.	-0. **	99.7	566.0	312.4	10.4	1.000022
65000.0	59.0	-61.6	0.	-0. **	97.2	566.4	328.2	7.8	1.000022
65500.0	57.6	-61.3	0.	-0. **	94.7	566.8	14.1	12.8	1.000021
66000.0	56.2	-60.9	0.	-0. **	92.3	567.2	60.1	17.9	1.000021
66500.0	54.9	-60.6	0.	-0. **	90.0	567.6	69.1	15.3	1.000020
67000.0	53.6	-60.3	0.	-0. **	87.7	568.1	75.3	12.0	1.000020
67500.0	52.3	-60.0	0.	-0. **	85.5	568.5	90.9	11.1	1.000019
68000.0	51.0	-59.7	0.	-0. **	83.3	568.9	108.3	10.5	1.000019
68500.0	49.8	-59.4	0.	-0. **	81.2	569.3	127.8	10.3	1.000018
69000.0	48.6	-59.0	0.	-0. **	79.2	569.7	148.2	10.1	1.000018
69500.0	47.5	-58.7	0.	-0. **	77.2	570.2	152.6	11.7	1.000017
70000.0	46.3	-58.4	0.	-0. **	75.2	570.6	137.7	15.2	1.000017
70500.0	45.2	-58.1	0.	-0. **	73.3	571.0	126.3	17.5	1.000016
71000.0	44.2	-57.8	0.	-0. **	71.4	571.4	131.7	13.8	1.000016
71500.0	43.1	-57.5	0.	-0. **	69.6	571.8	137.1	10.0	1.000015
72000.0	42.1	-57.2	0.	-0. **	67.9	572.3	145.2	7.8	1.000015
72500.0	41.1	-56.8	0.	-0. **	66.2	572.7	153.5	5.8	1.000015
73000.0	40.1	-56.5	0.	-0. **	64.5	573.1	135.9	6.8	1.000014
73500.0	39.1	-56.6	0.	-0. **	63.0	573.0	101.6	9.7	1.000014
74000.0	38.2	-56.6	0.	-0. **	61.5	572.9	76.3	11.1	1.000014
74500.0	37.3	-56.7	0.	-0. **	60.1	572.8	71.0	9.4	1.000013
75000.0	36.4	-56.8	0.	-0. **	58.7	572.7	65.8	7.7	1.000013
75500.0	35.6	-56.9	0.	-0. **	57.3	572.6	68.6	11.3	1.000013
76000.0	34.7	-56.9	0.	-0. **	56.0	572.5	71.4	15.0	1.000012
76500.0	33.9	-57.0	0.	-0. **	54.7	572.4	70.1	13.5	1.000012
77000.0	33.1	-57.1	0.	-0. **	53.4	572.3	67.0	9.8	1.000012
77500.0	32.4	-56.8	0.	-0. **	52.1	572.7	65.8	8.0	1.000012
78000.0	31.6	-56.5	0.	-0. **	50.8	573.1	70.8	12.5	1.000011

** AT LEAST ONE ASSUMED RELATIVE HUMIDITY VALUE WAS USED IN THE INTERPOLATION.

STATION ALTITUDE 3989.0 FEET MSL
23 MAY 66   2207 HRS MST
ASCENSION NO. 374

WSTM SITE COORDINATES
E 488,580 FEET
N 185,045 FEET

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	DEWPOINT DEGREES CENTIGRADE	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
78500.0	30.9	-56.2	0.	-0.**	49.6	573.5	75.9	16.9	1.000011
79000.0	30.2	-55.9	0.	-0.**	48.4	573.9	78.1	17.5	1.000011
79500.0	29.5	-55.6	0.	-0.**	47.2	574.3	78.1	15.2	1.000011
80000.0	28.8	-55.3	0.	-0.**	46.1	574.7	78.1	12.8	1.000010
80500.0	28.1	-55.0	0.	-0.**	45.0	575.1	78.1	12.3	1.000010
81000.0	27.5	-54.7	0.	-0.**	43.9	575.5	78.1	12.2	1.000010
81500.0	26.9	-54.4	0.	-0.**	42.8	575.9	78.3	12.2	1.000010
82000.0	26.2	-54.1	0.	-0.**	41.8	576.3	80.8	12.5	1.000009
82500.0	25.6	-53.8	0.	-0.**	40.7	576.7	83.4	12.8	1.000009
83000.0	25.1	-53.5	0.	-0.**	39.7	577.1	86.4	13.3	1.000009
83500.0	24.5	-53.2	0.	-0.**	38.8	577.5	90.2	14.2	1.000009
84000.0	23.9	-52.9	0.	-0.**	37.8	577.8	94.1	15.2	1.000008
84500.0	23.4	-52.6	0.	-0.**	36.9	578.2	97.1	14.7	1.000008
85000.0	22.8	-52.3	0.	-0.**	36.0	578.6	99.3	13.4	1.000008
85500.0	22.3	-52.0	0.	-0.**	35.1	579.0	101.5	12.0	1.000008
86000.0	21.8	-51.7	0.	-0.**	34.3	579.4	102.1	11.6	1.000008
86500.0	21.3	-51.4	0.	-0.**	33.5	579.8	102.3	11.4	1.000007
87000.0	20.8	-51.1	0.	-0.**	32.6	580.2	102.0	11.3	1.000007
87500.0	20.3	-50.8	0.	-0.**	31.8	580.6	96.1	11.0	1.000007
88000.0	19.9	-50.5	0.	-0.**	31.1	581.0	90.1	10.8	1.000007
88500.0	19.4	-50.2	0.	-0.**	30.3	581.4	86.9	11.7	1.000007
89000.0	19.0	-49.9	0.	-0.**	29.6	581.8	88.9	14.9	1.000007
89500.0	18.5	-49.6	0.	-0.**	28.9	582.2	90.8	18.1	1.000006
90000.0	18.1	-49.3	0.	-0.**	28.2	582.6	90.8	18.9	1.000006
90500.0	17.7	-49.0	0.	-0.**	27.5	583.0	89.6	18.0	1.000006
91000.0	17.3	-48.7	0.	-0.**	26.8	583.4	88.3	17.2	1.000006
91500.0	16.9	-48.4	0.	-0.**	26.2	583.8	88.3	16.7	1.000006
92000.0	16.5	-48.1	0.	-0.**	25.5	584.2	88.5	16.4	1.000006
92500.0	16.1	-47.8	0.	-0.**	24.9	584.5	88.2	16.2	1.000006
93000.0	15.7	-47.5	0.	-0.**	24.3	584.9	84.1	16.7	1.000005

** AT LEAST ONE ASSUMED RELATIVE HUMIDITY VALUE WAS USED IN THE INTERPOLATION.

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STATION ALTITUDE 3989.C FEET MSL
23 MAY 66   2207 HRS MST
ASCENSION NO. 374

UPPER AIR DATA
3914310
WHITE SANDS SITE
TABLE VIII (Cont)

WSTM SITE COORDINATES
E 488,580 FEET
N 185,045 FEET

GEOMETRIC ALTITUDE MSL FEET	PRESSURE MILLIBARS	TEMPERATURE AIR DEGREES CENTIGRADE	DEWPOINT DEGREES CENTIGRADE	RELATIVE HUMIDITY PERCENT	DENSITY GM/CUBIC METER	SPEED OF SOUND KNOTS	WIND DATA DIRECTION DEGREES(TN)	SPEED KNOTS	INDEX OF REFRACTION
93500.C	15.4	-47.2	0.	-0. **	23.7	585.3	80.1	17.3	1.000005
94000.0	15.0	-46.9	0.	-0. **	23.1	585.7	77.5	18.4	1.000005
94500.C	14.7	-46.6	0.	-0. **	22.6	586.1	77.5	20.4	1.000005
95000.0	14.3	-46.3	0.	-0. **	22.0	586.5	77.5	22.4	1.000005
95500.C	14.0	-46.0	0.	-0. **	21.5	586.9	77.5	23.0	1.000005
96000.C	13.7	-45.7	0.	-0. **	21.0	587.3	77.5	22.6	1.000005
96500.0	13.4	-45.4	0.	-0. **	20.5	587.7	77.5	22.3	1.000005
97000.C	13.1	-45.1	0.	-0. **	20.0	588.1	77.5	21.3	1.000004
97500.C	12.8	-44.8	0.	-0. **	19.5	588.4	77.5	20.2	1.000004
98000.0	12.5	-44.6	0.	-0. **	19.0	588.7	77.5	19.1	1.000004
98500.0	12.2	-44.3	0.	-0. **	18.6	589.0	77.5	17.1	1.000004
99000.0	11.9	-44.1	0.	-0. **	18.2	589.3	77.5	15.0	1.000004
99500.C	11.7	-43.8	0.	-0. **	17.7	589.7		12.8	1.000004
100000.0	11.4	-43.6	0.	-0. **	17.3	590.0			1.000004
100500.C	11.2	-43.3	0.	-0. **	16.9	590.3			1.000004
101000.0	10.9	-43.1	0.	-0. **	16.5	590.6			1.000004
101500.0	10.7	-42.8	0.	-0. **	16.1	590.9			1.000004
102000.0	10.4	-42.6	0.	-0. **	15.8	591.3			1.000004
102500.C	10.2	-42.3	0.	-0. **	15.4	591.6			1.000003

** AT LEAST ONE ASSUMED RELATIVE HUMIDITY VALUE WAS USED IN THE INTERPOLATION.

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TABLE IX. IMPACT PREDICTION DATA AEROBEE NASA 4.51 UG

TIME: 2207 MST
DATE: 23 MAY 1966

RELEASE TIME (MST)		IMPACT DISPLACEMENT IN MILES DUE TO WIND								THEORETICAL IMPACT IN MILES FROM LAUNCHER	
RAWINSONDE	PIBAL	143-4000 FT		4000-20000 FT		20000-100000 FT		TOTAL			
		N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W	N-S	E-W
R₁ 1630 / R 1630	P 1907	12.5N	29.7W	7.3S	18.0W	0.9S	20.4W	4.3N	68.1W	54.2N	20.7W
R₂ 1905 / R 1630	P 1937	14.3N	29.5W	6.2S	19.9W	0.9S	20.4W	7.2N	69.8W	57.1N	22.4W
R₂ 1905 / R 1630	P 2007	13.0N	30.8W	6.2S	19.9W	0.9S	20.4W	5.9N	71.1W	55.8N	23.7W
R₂ 1905 / R 1630	P 2027	30.0N	24.7W	6.2S	19.9W	0.9S	20.4W	22.9N	65.0W	72.8N	17.6W
R₂ 1905 / R 1630	P 2047	27.2N	25.9W	6.2S	19.9W	0.9S	20.4W	20.1N	66.2W	70.0N	18.8W
R₂ 1905 / R₃ 1905	P 2107	27.1N	19.9W	6.2S	19.9W	4.3S	17.9W	16.6N	57.7W	66.5N	10.3W
R₂ 1905 / R₃ 1905	P 2122	22.9N	15.5W	6.2S	19.9W	4.3S	17.9W	12.4N	53.3W	62.3N	5.9W
R₂ 2110 / R₃ 1905	P 2140	19.1N	15.0W	8.9S	15.8W	4.3S	17.9W	5.9N	48.7W	55.8N	1.3W
R₂ 2110 / R₃ 1905	P 2147	19.3N	16.1W	8.9S	15.8W	4.3S	17.9W	6.1N	49.8W	56.0N	2.4W
R₂ 2110 / R₃ 1905	P 2157	14.3N	16.1W	8.9S	15.8W	4.3S	17.9W	1.1N	49.8W	51.0N	2.4W
*R₁ 2207 / *R 2207	*P 2208	9.2N	15.7W	10.5S	15.4W	5.2S	20.3W	6.5S	51.4W	43.4N	4.0W

* = Post-Shoot Data
P = Double Theodolite Winds (143-4,000 FT)
R = Rawinsonde Winds (Above 20,000 FT)
R₁= Rawinsonde Winds (4,000-20,000 FT)
R₂= Rawin Winds (4,000-20,000 FT)
R₃= Rawin Winds (Above 20,000 FT)

JACK SETTINGS FOR LAUNCHER B	West leg	28	inches
	East leg	8	inches
LAUNCHER SETTING	Tilt	3.97	degrees
	Azimuth	046.7	degrees
TILT COMPONENTS	North	2.73	degrees
	East	2.89	degrees
NO WIND IMPACT FROM LAUNCHER	North	49.9	miles
	East	47.4	miles

PREDICTED IMPACT FROM LAUNCHER	North	55.0	miles
	West	2.0	miles
PREDICTED BOOSTER IMPACT FROM LAUNCHER	Azimuth	050	degrees
	Distance	1,500	feet
RECOMMENDATION - Fire, with 90% confidence of impacting on range, based upon: wind correction of 1-hr wind variability		49 miles 14 miles	
23 May 1966/2153 MST			

TABLE X.   ACTUAL AND PREDICTED LAUNCH DATA
AEROBEE NASA 4.51 UG

RADAR IMPACT FROM LAUNCHER	North	24.1	miles
	West	6.9	miles
ACTUAL BOOSTER IMPACT FROM LAUNCHER	Azimuth	N/A	degrees
	Distance	N/A	feet

TABLE XI.   IMPACT DATA
AEROBEE NASA 4.51 UG

NOTE: The peak altitude of the rocket was only 87 miles. Therefore, the rocket impacted short of the prediction.

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
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	2b. GROUP

3. REPORT TITLE

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5. AUTHOR(S) (Last name, first name, initial)

Dunaway, Gordon L.

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	U. S. Army Electronics Command Atmospheric Sciences Laboratory White Sands Missile Range, New Mexico

13. ABSTRACT

Meteorological data gathered for the launching of Aerobee NASA 4.51 UG are presented for the National Aeronautics and Space Administration, Princeton University and for ballistic studies. The data appear, along with calculated ballistic data, in tabular form.

DD FORM 1 JAN 64 **1473**

UNCLASSIFIED
Security Classification

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1. Ballistics 2. Meteorology 3. Wind						

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