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D REGION RADIO MEASUREMENTS AT THE MAGNETIC EQUATOR

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ABSTRACT

This note reports electron density measurements from two ARCAS rocket flights at Thumba, India on 8 March 1968. D region electron density profiles were obtained from absorption measurements of C. W. radio transmissions propagating transversely to the earth's magnetic field.

I. INTRODUCTION

The electron density in the lower ionosphere is fairly well known at middle latitudes. This is due to the efforts of numerous workers using various radio techniques both ground based and rocket borne. By comparison, the lower ionosphere at equatorial latitudes has not received much attention.

From the theoretical stand point equatorial measurements should be of prime interest. It is well established that mesospheric air pressures, densities and temperatures undergo significant seasonal variations. These variations however are smallest at lowest latitudes. This meteorological stability together with the absence of particle precepitation removes from the equatorial D region two of the most unpredicable variables of the mid-latitude D region. The equator is therefore the ideal place from which to study the buildup and decay of a D region under a simple solar zenith angle control.

Another interesting point about the equator concerns the so called C Region. Below about 65 km it is generally believed that all normal day ionization is produced by cosmic rays. Since the latitude dependence of the cosmic ray ionization source is known, comparisons between equatorial and mid-latitude C region electron density profiles should provide some simple tests of current theory. In Section VI of this report some evidence is presented which seems to indicate that a simple theory of the C region is inadequate.

II. EXPERIMENTAL CONSIDERATIONS

One of the reasons why the equatorial D region has received little experimental attention is the fact that the radio techniques employed at mid-latitudes are inappropriate near the magnetic equator. Mid-latitude radio techniques are all based on the so called quasi-longitudinal or Q.L. approximation to the Appleton-Hartree formula. Near the magnetic equator the Q. L. approximation breaks down for the radio frequencies (~ 2-3 MHz) required for D region measurements. However at the magnetic equator (within $\pm$ 1 or 2 degrees) it is possible with a vertically propagating radio wave to satisfy the conditions of the other extreme of the Appleton-Hartree formula, namely to quasi-transverse or Q.T. approximation.

A unique experimental advantage accures to the Q.T. condition, namely the fact that the two characteristic waves are linearly polarized. To transmit either mode one simply radiates from a horizontal linear dipole antenna oriented parallel (ordinary mode) or perpendicular (extraordinary mode) to the magnetic meridian. Compare this with the mid-latitude case where the transmission of a characteristic mode requires a pair of crossed dipoles combined in a precise phase and amplitude relation. In the Q.T. regime there occurs no Faraday rotation (in the normal meaning of the term).

However differential absorption is operative and the absorption indices are related to the electron density and collison frequency in a straight forward manner. This is the basis of the experimental technique described in the following section.

III. EXPERIMENTAL METHOD

On the ground the output of a 100 watt CW transmitter was alternately switched between a North-South (ordinary) and an East-West (extraordinary) half wave dipole antenna. See Appendix A for details of the switching technique. In the rocket the amplitude of the arriving wave was sampled at a 40 cycle/sec rate by a linearly polarized receiving antenna, the sampling frequency frequency being twice the rocket spin frequency. In addition to a pre-flight calibration of the receiver characteristic, an in-flight calibration was obtained by manually stepping the transmitter output through 40 db of attenuation.

A sample of the telemetry flight record is shown in figure 1. Here is seen the amplitude of the received signal strengths of two CW transmissions as the ordinary and extraordinary modes are alternately transmitted from the ground. Differential absorption is clearly visable. A plot of absorption observed for both modes is shown versus altitude in figure 2 for a transmission frequency of 1865 khz.

IV. DATA REDUCTION

From the altitude derivative of the differential absorption the electron density profile was deduced by means of the Generalized Appleton-Hartree formula (see Sen and Wyler, 1960). A model collision frequency profile was assumed. The model used was taken from the pressure measurements made at 0^{o} latitude, 8 March 1965 (Smith et al, 1967) together with the expression Phelps (1960)

$$\nu = 6.28 \times 10^{-7} p \text{ (millibars)}$$

relating the collision frequency to atmospheric pressure p given in millibars.

By performing the absorption measurements on more than one frequency, the requirement of internal consistancy provides a check on the appropriateness of the choice of collision frequency model.

V. ELECTRON DENSITY RESULTS

In table I are listed the electron densities derived for the two rocket shots labled Brahma I and Brahma II. Brahma I was fired near local noon (solar zenith angle, $\chi = 12^{o}$), while Brahma II was fired near sunset of the same day ($\chi = 86^{o}$). Included in table I is the model collision frequency profile applied to both rocket shots.

For comparison these results are plotted as BI and BII in figure 3 together with results at middle latitudes obtained by other workers. The curves labled S are results from a ground based cross modulation experiment by Smith (1967) at zenith angles 15.5^{o} and 85^{o}. The curve labled M is a rocket result by Mechley (1968) at $\chi = 85^{o}$, while the curve labled KI is a rocket result at $\chi = 84^{o}$ by Kane and Troim (1967). The solid portion of the curve labled ZVI is from a Faraday rotation measurement at $\chi = 18^{o}$ by Kane (1969).

VI. DISCUSSION

Generally speaking the agreement among the profiles of figure 3 is good although the sunset BII profile shows electron densities somewhat larger than the comparable sunrise profiles. At this point however it cannot be said whether or not this is a real effect.

The agreement between the profiles BI and ZVI is very good down to 67 km which is the extent of the ZVI data. Below this altitude it is reasonable to assume that the ion production function q is that due to cosmic rays only and is given by the expression (Quenby and Webber, 1959) $q = q_o \cos^{-4}\lambda$ where λ is the magnetic latitude. If the BI profile below 67 km is extropolated to the latitude of the ZVI shot using the well known relationship between electron density N_e and the ion production function $q = \alpha N_e^{2}$, the result is the unlikely values shown as the dashed line portion of the ZVI profile. The reason for this peculiar situation might be due to treating α, the effective recombination coefficient, as a latitude independent in this extropolation.

By the same reasoning, the agreement of the BI and ZVI profile above 67 km would suggest that there the effective recombination coefficient is latitude independent.

VII. CONCLUSION

A fairly simple radio propagation experiment has been devised to obtain daytime D region electron density profiles at the magnetic equator. A comparison with results from mid-latitude profiles has revealed some evidence for a latitude dependent effective recombination coefficient in the altitude region dominated by cosmic rays.

The Q.T. propagation conditions at the magnetic equator offer some interesting experimental possibilities for precision measurements of the C region; measurements which would be impractical at mid-latitudes.

ACKNOWLEDGEMENTS

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APPENDIX A

The transmitter is alternately switched between the N-S and E-W dipole antennas by the arrangement shown in figure 1A. The total length of feed line from transmitter to antenna is chosen to be a convenient multiple of half wave lengths. Each antenna feed line is alternately shorted at its quarter wave point by a current operated relay. The coax feed line itself provides the current path for the relay. The impedance seen by the transmitter looking into a line whose length is an odd number of quarter wave lengths is given by $Z = Z_o^2/Z_L$ where Z_o is the characteristic impedance of the line and Z_L is the load impedance. Thus the line which is shorted at the quarter wave point presents a high impedance to the transmitter while the unshorted line presents the antenna as a load to the transmitter.

Figure 1B shows the schematic diagram of a pair of of unijunction transistors connected as a multivibrator by means of a latching relay. This same latching relay commands the r.f. switch at the quarter wave point.

TABLE I

Z	ν	BRAHMA I N_e	BRAHMA II N_e
58	2.20^{7}	65 $\pm$ 35	
60	1.70	75 $\pm$ 35	
62	1.30	100 $\pm$ 50	
64	1.00	130 $\pm$ 65	
66	7.50^{6}	160 $\pm$ 80	
68	5.60	250 $\pm$100	
70	4.10	375 $\pm$100	
72	3.00	600 $\pm$150	
74	2.15	630 $\pm$150	
76	1.55	790 $\pm$150	40 $\pm$ 50
78	1.12	1030 $\pm$200	85 $\pm$ 50
80	8.10^{5}	1025 $\pm$200	120 $\pm$ 60
82	5.80	1000 $\pm$200	160 $\pm$ 80
83	4.90	1650 $\pm$350	200 $\pm$ 90
84	4.10	2300 $\pm$500	240 $\pm$100
85	3.45		350 $\pm$150
86	2.90		680 $\pm$200
87	2.50		1920 $\pm$500

FIGURE CAPTIONS

Figure 1 - Sample of telemetry flight record for Brahma I showing received signal strengths of two transmission as ordinary and extraordinary modes as alternately transmitted from the ground.

Figure 2 - Absorption versus altitude for both modes observed at 1865 khz on Brahma I.

Figure 3 - Comparison of Brahma I and Brahma II electron densities profiles with results from mid latitudes.

Figure 1-A - Scheme for switching transmitter between N-S and E-W antennas.

Figure 2-A - Multivibrator circuit used to command r.f switch.

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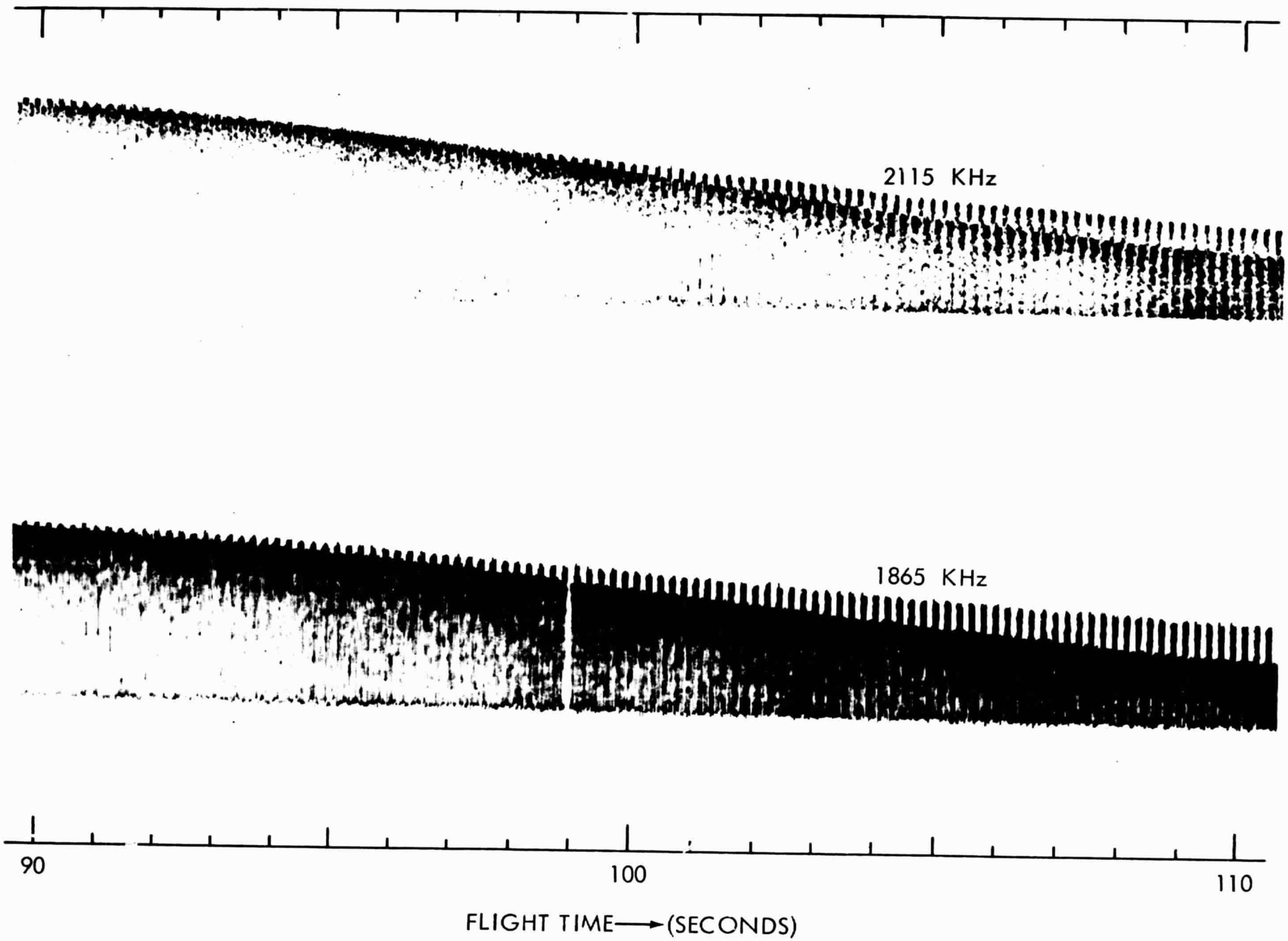
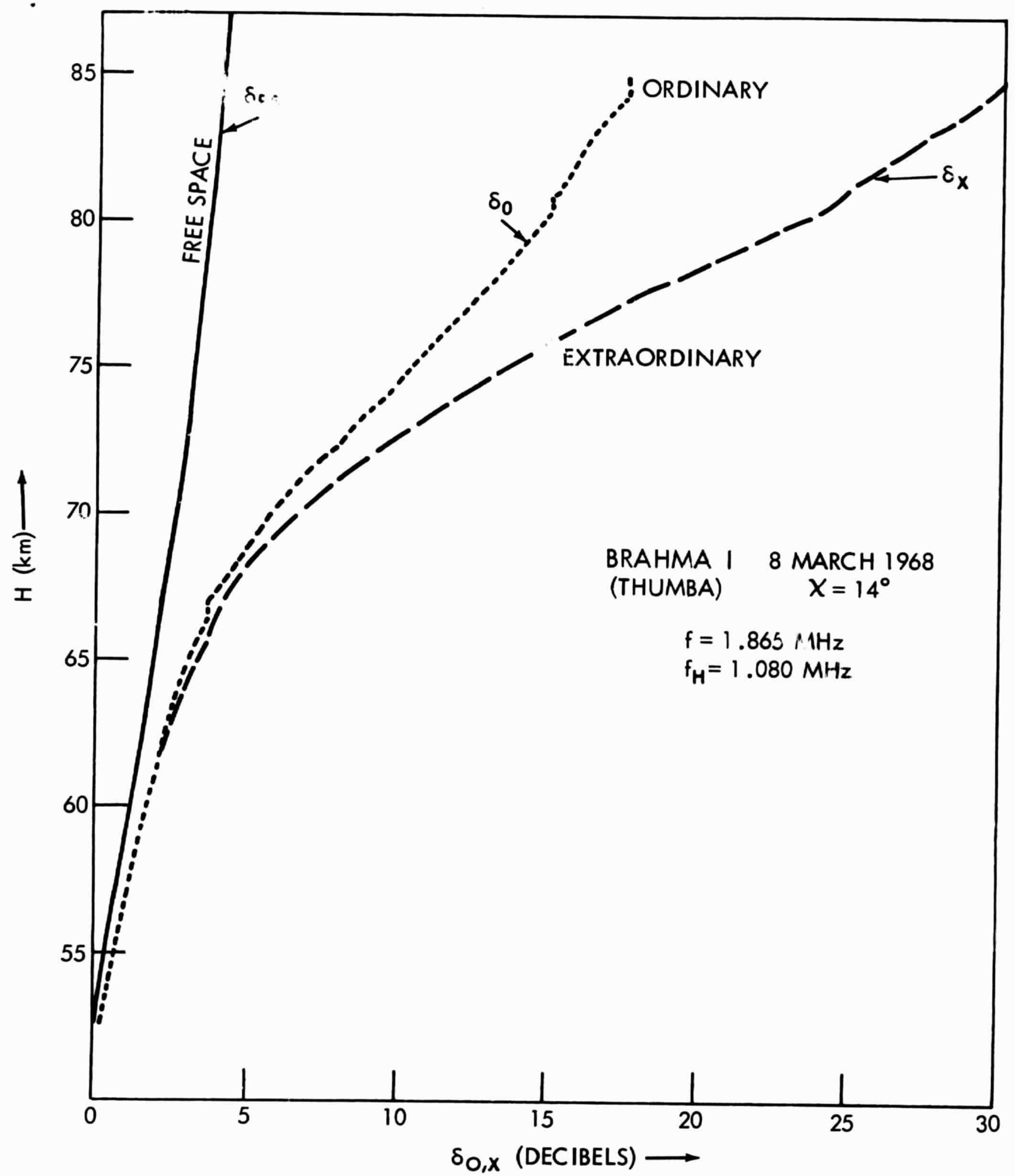


Figure 1



85
80
75
70
65
60
55
H (km)
FREE SPACE
ORDINARY
EXTRAORDINARY
δ_0
δ_X
BRAHMA I 8 MARCH 1968
(THUMBA) X = 14°
f = 1.865 MHz
f_H = 1.080 MHz
0
5
10
15
20
25
30
$\delta_{O,X}$ (DECIBELS)

Figure 2

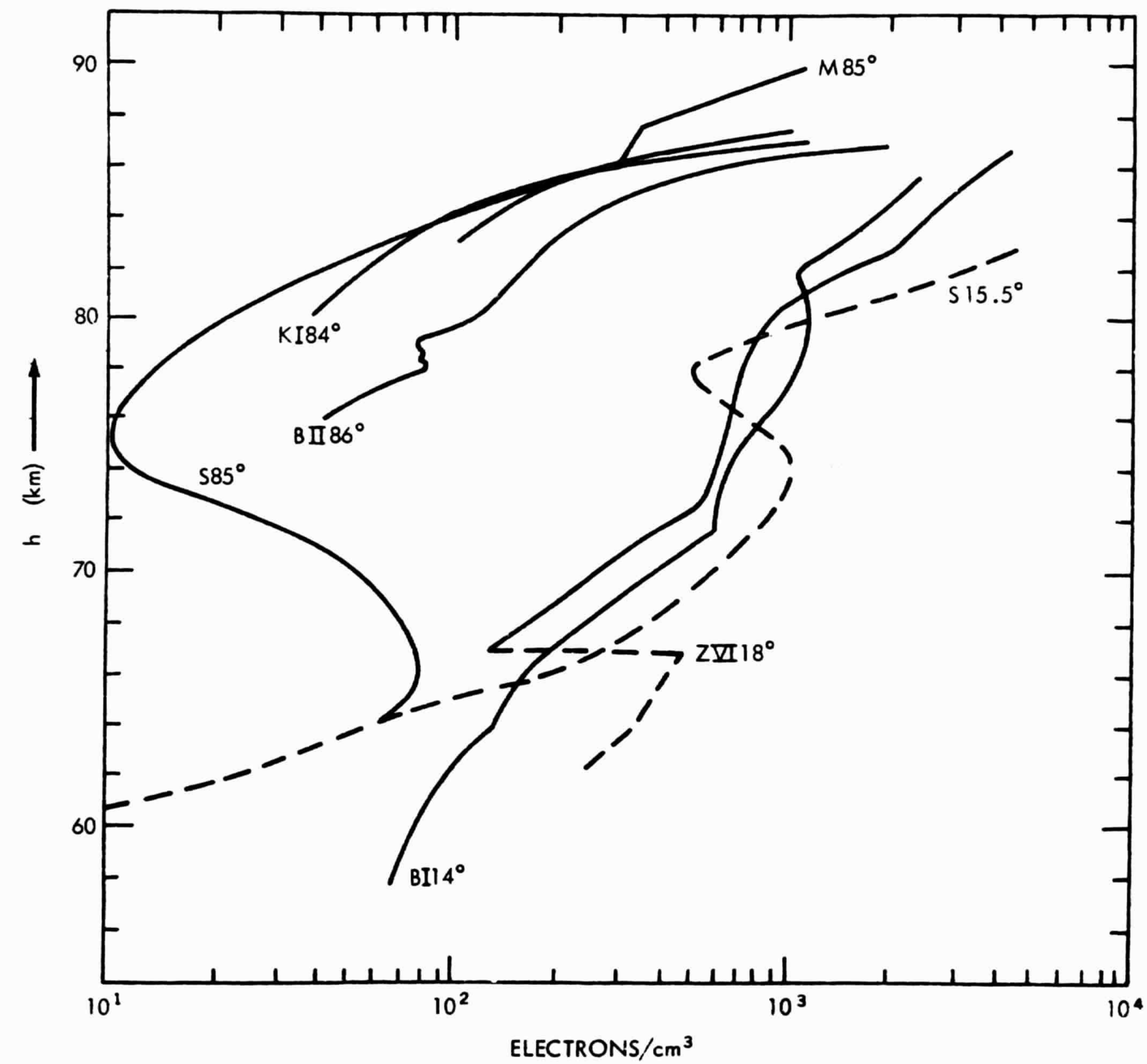
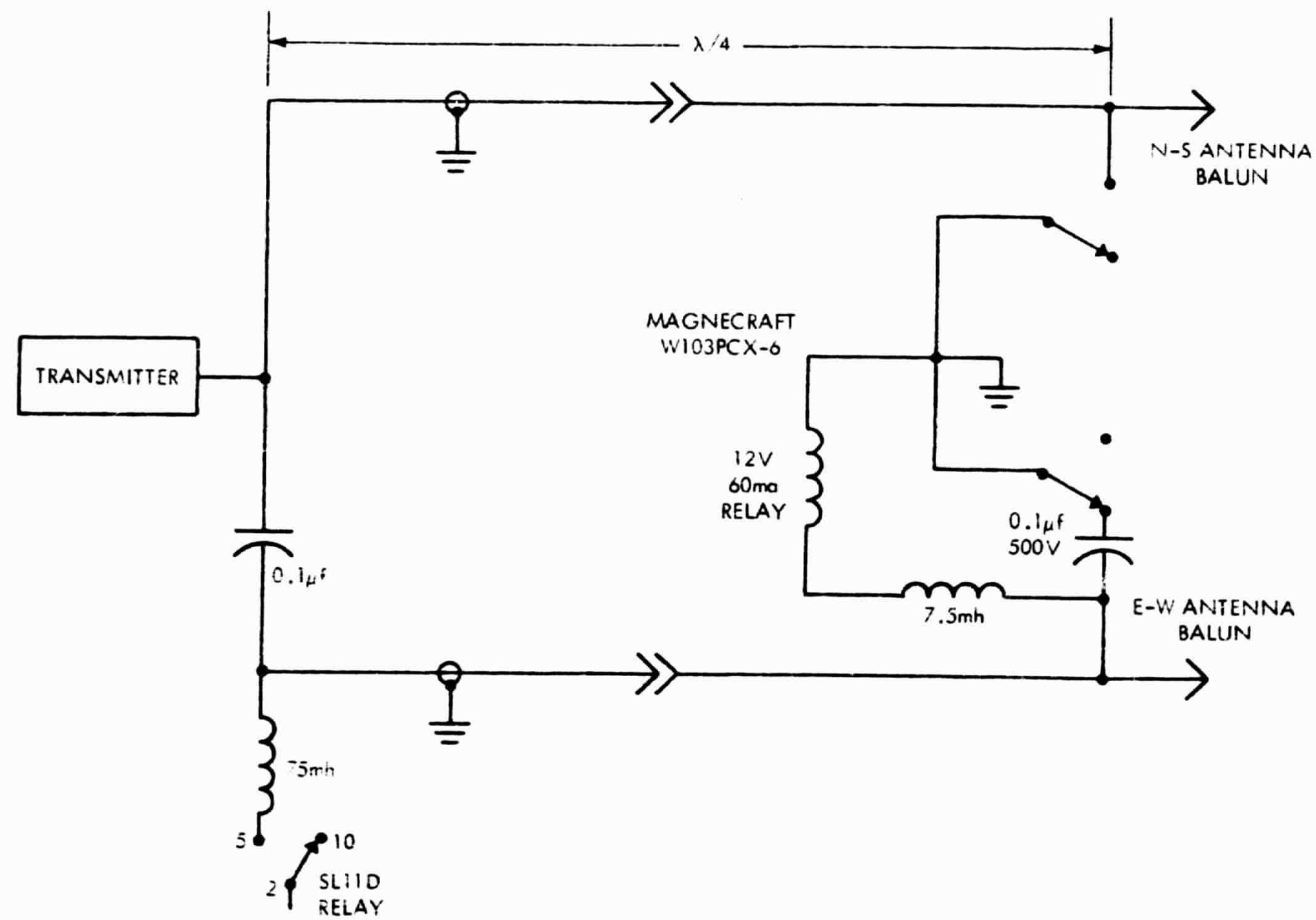

90
80
70
60
h (km)
M85°
KI84°
BII86°
S85°
S15.5°
ZVI18°
BI14°
10^1
10^2
10^3
10^4
ELECTRONS/cm³

Figure 3



λ/4
N-S ANTENNA
BALUN
MAGNECRAFT
W103PCX-6
TRANSMITTER
12V
60ma
RELAY
0.1μf
500V
0.1μf
E-W ANTENNA
BALUN
7.5mh
75mh
5
10
2
SL11D
RELAY

Figure 1-A

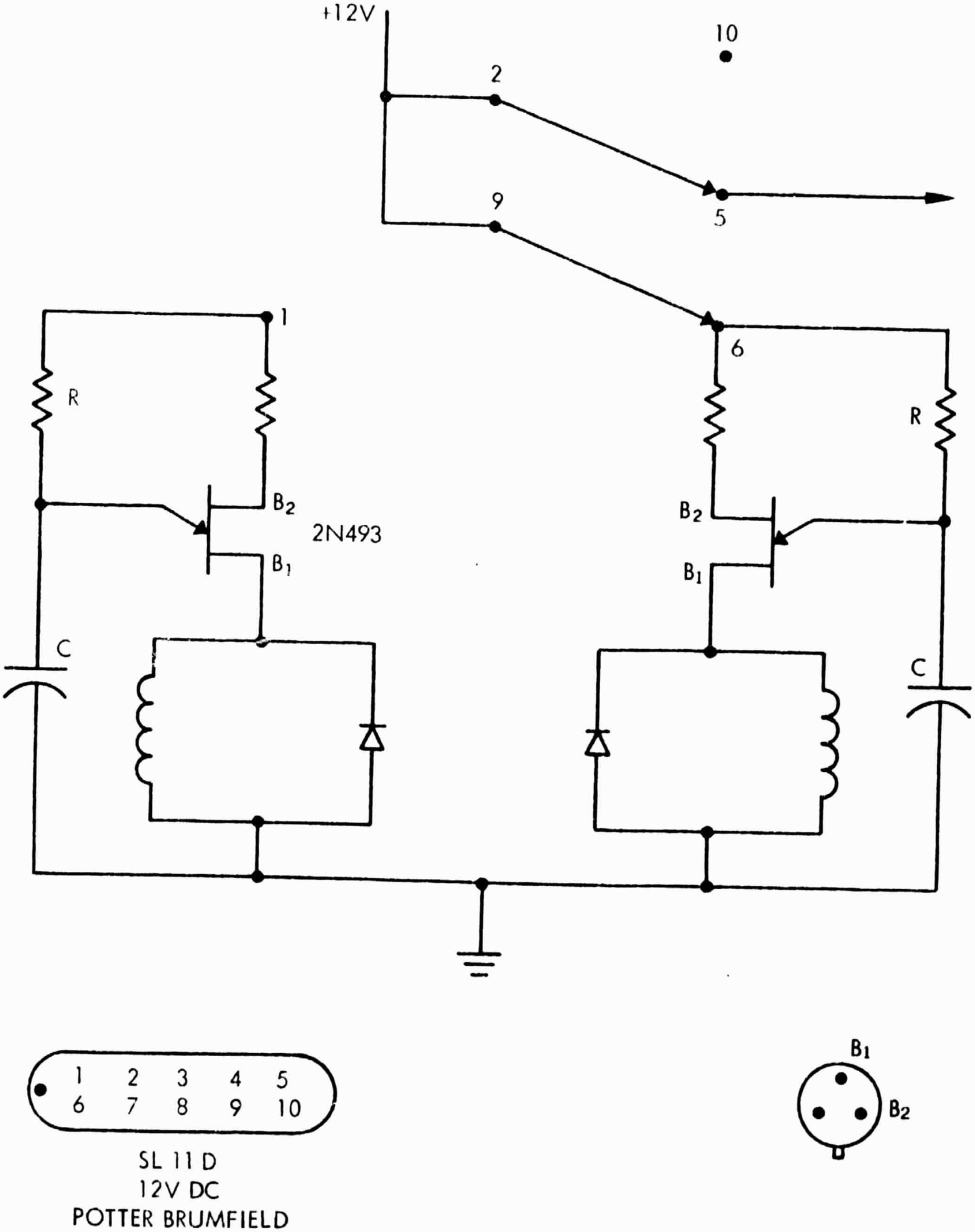

+12V
10
2
9
5
1
6
R
R
B2
B1
2N493
C
C
1 2 3 4 5
6 7 8 9 10
SL 11 D
12V DC
POTTER BRUMFIELD
B1
B2

Figure 2-A