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LARGE SCALE PLASMA IRREGULARITIES OBSERVED IN THE NIGHTTIME IONOSPHERE OVER NATAL USING A ROCKET-BORNE LANGMUIR PROBE

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RESUMO-NOTAS/ABSTRACT-NOTES

Measurements of the spectral distribution of plasma density irregularities, in the ionospheric E and F regions over Natal, were made on the night of 11 December 1985 using a rocket-borne Langmuir Probe payload, designed and developed at the Instituto de Pesquisas Espaciais (INPE/MCT). Height resolution for the irregularity measurements was better than 3 meters. Plasma density irregularities of scale sizes extending from a few meters to several tens of kilometers were observed during both the ascent and descent of the rocket. The rocket reached an apogee of about 516 km. Observation of certain large scale electron density structures during both the ascent and descent of the rocket, in spite of the 400-500 km horizontal separation in the upleg and downleg of the rocket trajectory, indicates the large horizontal scale sizes of the large scale plasma irregularities. These results are analysed and discussed here in the light of the existing plasma instability mechanisms responsible for the generation of both small scale and large scale plasma irregularities. At the time of the rocket flight, spread-F echoes were recorded by ground based ionosonde, enabling the study of plasma irregularities that give rise to the equatorial spread-F echoes.

OBSERVAÇÕES/REMARKS

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LARGE SCALE PLASMA IRREGULARITIES OBSERVED IN THE NIGHTTIME IONOSPHERE OVER NATAL USING A ROCKET-BORNE LANGMUIR PROBE

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This work will be presented in 2º Encontro Regional de Geofísica, 25-27 de novembro de 1987, Salvador-BA.

ABSTRACT

Measurements of the spectral distribution of plasma density irregularities, in the ionospheric E and F regions over Natal, were made on the night of 11 December 1985 using a rocket-borne Langmuir Probe payload, designed and developed at the Instituto de Pesquisas Espaciais (INPE/MCT). Height resolution for the irregularity measurements was better than 3 meters. Plasma density irregularities of scale sizes extending from a few meters to several tens of kilometers were observed during both the ascent and descent of the rocket. The rocket reached an apogee of about 516 km. Observation of certain large scale electron density structures during both the ascent and descent of the rocket, in spite of the 400-500 km horizontal separation in the upleg and downleg of the rocket trajectory, indicates the large horizontal scale sizes of the large scale plasma irregularities. These results are analysed and discussed here in the light of the existing plasma instability mechanisms responsible for the generation of both small scale and large scale plasma irregularities. At the time of the rocket flight, spread-F echoes were recorded by ground based ionosonde, enabling the study of plasma irregularities that give rise to the equatorial spread - F echoes.

INTRODUCTION

Electron density irregularities present in the ionosphere manifest themselves in different forms at different heights and at different times of the day. Sporadic-E, Spread-F, radio star scintillations, VHF scatter are a few of such phenomena, familiar to ionospheric physicists for quite some time. The basic knowledge of the plasma irregularities, responsible for these phenomena, has progressed considerably both in theory and observation since the discovery of the strong VHF radar echoes from the equatorial ionosphere (Bowles et al., 1960, 1963). Balsley (1969), from their spectral characteristics as observed by the VHF radar, classified the plasma irregularities into two groups, namely Type I and Type II. While type I irregularities are now seen to be consistent with the two stream instability mechanism operating in the equatorial electrojet (Farley, 1963; Sato, 1972), the type II irregularities are due to the nonlinear crossfield instability mechanism (Rogister and D'Angelo, 1970, 1972, Balsley and Farley, 1973). Direct observations by Prakash et al. (1970, 1971a,b), using rocket-borne Langmuir Probes flown from India, support the existance of type II irregularities in the equatorial E-region. Type II irregularities are characterized by scale sizes extending from as low as few meters up to a few tens of kilometers or more. The short wavelength irregularities apparently seem to be generated from larger scale sizes by nonlinear coupling or cascading processes (Rogister, 1972, Rogister and D'Angelo, 1970, 1972; Sato, 1971, 1973; Sudan et al., 1973). Neutral turbulence also seems to be another probable mechanism for the generation of plasma irregularities (Prakash et al., 1970). The spectral characteristics of the different types of irregularities have been studied in detail (Prakash et al., 1970; Ott and Farley, 1974).

With the ultimate objective of studying the electron density and temperature variations and the spectral distribution of plasma irregularities in the equatorial ionosphere over Natal in Brazil, in situ measurements of the electron density and temperature were made using a rocket-borne Langmuir probe on the night of 11 December 1985. Observations related to the large scale plasma irregularities and probable plasma instability mechanisms responsible for their generation are presented and discussed here. The Langmuir probe, capable of measuring electron density in the range of a few tens of electrons up to more than 10^6 electrons/cm^3, was designed and developed at the Instituto de Pesquisas Espaciais (INPE/MCT) and was launched aboard a SONDA III rocket provided by the Instituto de Atividades Espaciais (IAE/CTA) from the Centro de Lançamento da Barreira do Inferno (CLBI) in Natal-RN; under collaboration between INPE and IAE. The rocket was launched under conditions favourable for the generation of "plasma bubbles". The experiment functioned satisfactorily during both the ascent and descent of the rocket, and in fact passed through at least a couple of plasma bubbles, giving valuable information about the nighttime ionospheric E and F-regions over Natal, under conditions favourable for the existence of plasma bubbles.

EXPERIMENT DETAILS

A new Langmuir probe (LP) sensor geometry was tested for the first time during the studies reported here. This was necessitated by the fact that one of the conventional sensor locations, namely the nose tip of the rocket, was occupied by a High Frequency Capacitance (HFC) probe sensor (see Figure 1) and hence was not available for mounting the LP sensor. Separated from the HFC sensor by a teflon ring, the LP sensor with an approximately cylindrical shape was mounted below the HFC sensor. The stainless steel LP sensor was guarded on both sides along the rocket axis by a pair of stainless steel guard rings. The rings were maintained at the same electrical potential as the LP sensor.

The block diagram of the LP electronics system is shown in Figure 2. A sweep voltage, varying from -1V to +4V in a time period of about 2.6 seconds, is applied to the sensor through a high input impedance amplifier. This preamplifier converts the current collected by the LP sensor into a varying voltage. The same sweep voltage is applied to the guard rings to make the electric field near the sensor uniform, as also to reduce the A.C. leakage and capacitive effects. The preamplifier can operate in two different gain modes, the higher gain being about 50 times the lower gain. This is to accommodate the large dynamic range (> 5 decades) of the sensor current. In order to obtain information about both the height profile of electron density and the small scale fluctuations in it, the output of the preamplifier is processed through three different channels before being sent to the telemetry system for transmission to the ground station. In one of the channels the signal is amplified by a constant gain dc amplifier. In the second channel, the signal is amplified by a multiple gain dc amplifier with automatic gain control. The gain of the amplifier is so selected that the amplifier output is maintained at the maximum level between 0 and 5V. In the third channel the a.c. fluctuations in the signal are separated out using a high pass filter, and the a.c. signal is amplified by a multiple gain a.c. amplifier, and then level shifted to bring the output in the range of 0-5V suitable for transmission. Other housekeeping information such as the sweep voltage, gain level, and calibration status are also transmitted to the ground station along with the outputs of the three data channels by an on board PCM/FM telemetry system.

RESULTS AND DISCUSSION

The launch time of the rocket was so chosen that, when the rocket traverses the ionospheric regions, the conditions there are favorable for the presence of plasma bubbles. These conditions could be predicted by ground based observations using ionosondes and polarimeters near the launch site, as well as at stations away from the launch site. As could be seen from the results, the rocket, in fact, passed through at least a couple of large plasma depletions or plasma bubbles. The flight and trajectory details are given below.

INPE 002 - SONDA III FLIGHT DETAILS

Station	-	CLBI, Natal-RN
Day	-	11 Dec. 1985
Time	-	2330 Hrs (U.T)
Rocket Apogee	-	524 km
Horizontal Range	-	540 km
Flight Duration	-	725 seconds
Azimuth (Trajectory)	-	74.4^{o}

The electron density profiles estimated from the LP current variations, during the ascent and descent of the rocket are shown in Figure 3. A quick examination of the two profiles will show the following dominant features

(i) There exists a sharp E layer peak around the altitude region of 100 km in the region of rocket ascent. In the region of rocket descent, the peak is seen around 90 km altitude, with considerably less amplitude.

(ii) A large electron density valley is seen extending from about 140 km up to about 260 km in the upleg profile. This valley region is much less predominat in the downleg profile.

(iii) Two large plasma bubbles are observed in the F region around 370 km and 420 km altitudes. While the bubbles can be dominantly seen in the upleg profile, their presence can be just identified in the downleg profile.

(iv) Large scale plasma irregularities are present in the valley between the E and F regions in both the upleg and downleg profiles, while in the topside F region large scale irregularities are observed only in the downleg profile.

Observations (i) and (ii), namely a sharp E-layer and the presence of a deep valley above about 120km, are features that have been observed earlier from both rocket-borne and ground based experiments (see Prakash et al., 1970). Though these are now considered to be the characteristic features of the nighttime lower ionosphere, some of these features are neither completely understood on theoretical basis, nor the existing models explain their presence. Some of the observations like multiple Sporadic-E layers though could find explanation at mid latitudes, the explanation fails over equatorial latitudes. Prakash et al. (1970) discuss the possibility of windshear mechanism to be responsible for the generation of some of the large scale structures observed in the E-region.

The observation of bubble structures in the nighttime ionosphere has been a rather familiar feature. We will not go into the details of these observations in this report, and confine ourselves to the observations of large scale plasma irregularities.

The generation of large scale plasma irregularities by the mechanism of cross-field instability is now reasonably well-understood (Reid, 1968; Tsuda et al., 1969). A necessary condition for the mechanism to operate is that there should exist an electron density gradient in the direction of the ambient electric field. In the nighttime ionosphere, the polarization electric field is generally downwards and so the height regions favourable for the operation of the cross-field instability mechanism are those where the ambient electron density gradients are downwards. The present observation of large scale irregularities in the valley between the E and F regions, and in the topside F region, where the electron density gradients are downwards, can be attributed to the operation of cross-field instability mechanism.

A puzzling feature that is difficult to explain is the observation of large scale plasma irregularities on the topside of the F-region only during the descent of the rocket, the electron density profile being rather smooth in this height region during the ascent of the rocket. The amplitude of the irregularities observed in the downleg profile are so large that it cannot be attributed to the rocket wake effect, on the contrary, we have just seen that these irregularities could be generated by the mechanism of cross-field instability. One should remember here that, in the height region concerned, the upleg and downleg of the rocket are separated by a distance of about 150-200 km; and perhaps irregularities are really absent in the region of the upleg trajectory.

As can be seen in Figure 3, the large scale plasma irregularities range in scale sizes from a few kilometers up to about 50 km. Several of these structures have amplitudes of greater than 50%, especially in the topside F-region. In the valley between the E and F regions, some of the large scale electron density structures observed in the upleg profile are also observed in the downleg profiles. This indicates the large horizontal extension of these plasma irregularities with dimensions of a few hundred kilometers even in the east-west direction.

CONCLUSIONS

The nighttime E region over Natal, observed on 11.Dec.1985, is characterised by a sharp E layer around the altitude of about 100 km, with a valley region above it extending up to 260 kms.

Large scale plasma irregularities apparently generated by the cross-field instability mechanism are observed in the valley between the E and F regions during both ascent and descent of the rocket. In topside F region cross-field irregularities of large vertical scale sizes were observed only during the downleg of the rocket. The absence of such irregularities in the upleg profile is not easily understandable.

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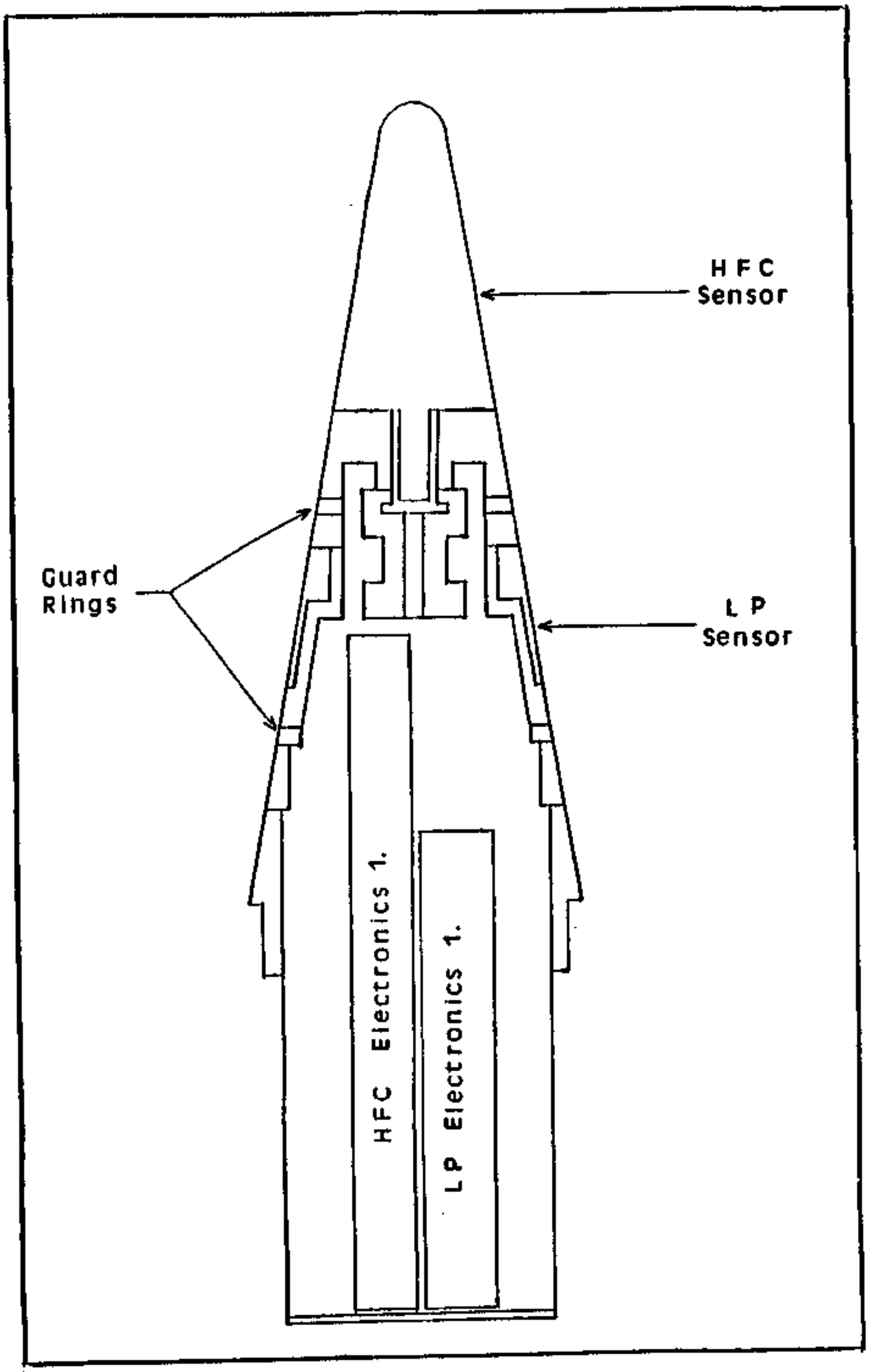
FIGURE CAPTIONS

Figure 1 - Schematic of the LP and HFC sensors mounted on the rocket nose cone.

Figure 2 - Block diagram of the Langmuir probe payload electronics.

Figure 3 - The electron density profiles estimated from the LP current variation observed during the ascent and descent of the rocket. The lower scale is for the upleg profile and the upper scale is for the downleg profile.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Sensor
Guard
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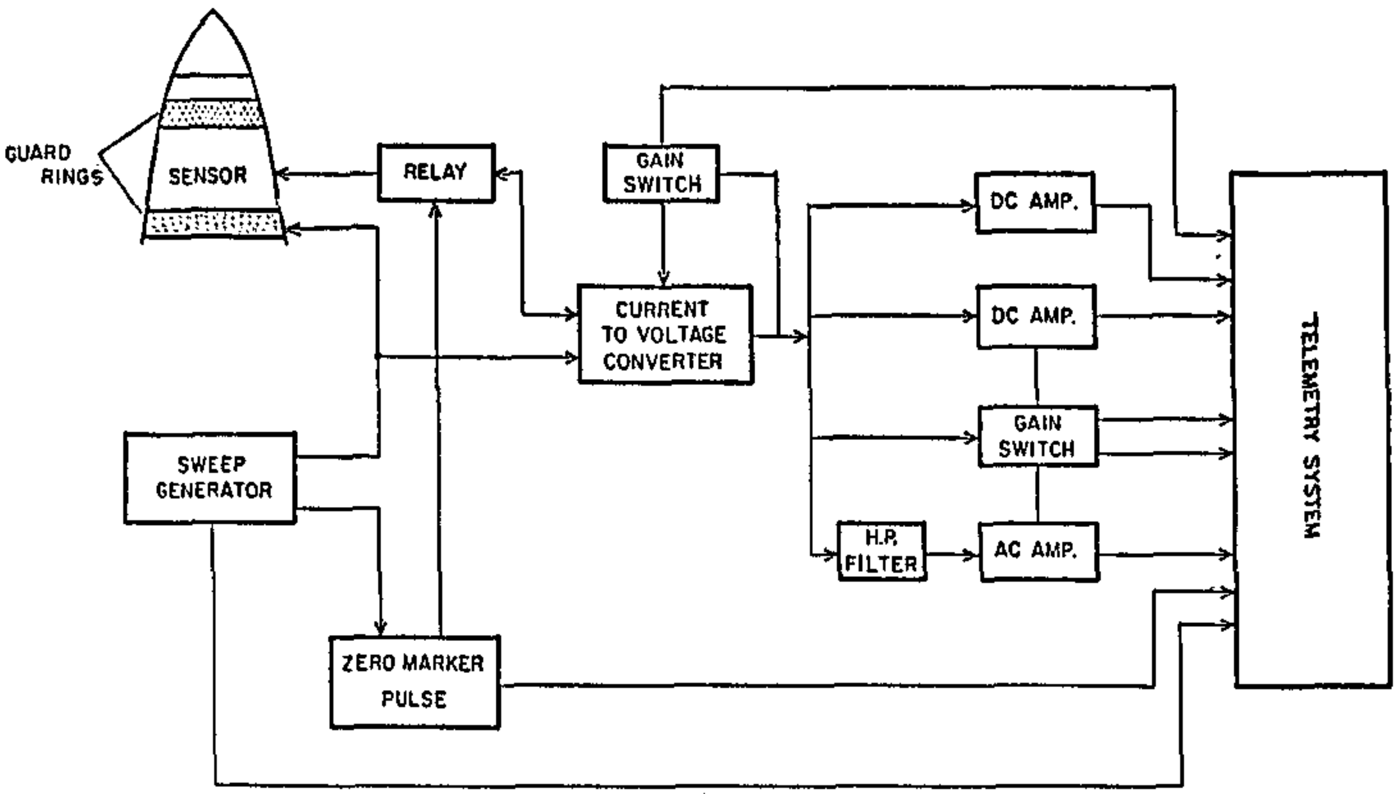
LP
Sensor
HFC Electronics 1.
LP Electronics 1.

Fig. 1


GUARD RINGS
SENSOR
RELAY
GAIN SWITCH
CURRENT TO VOLTAGE CONVERTER
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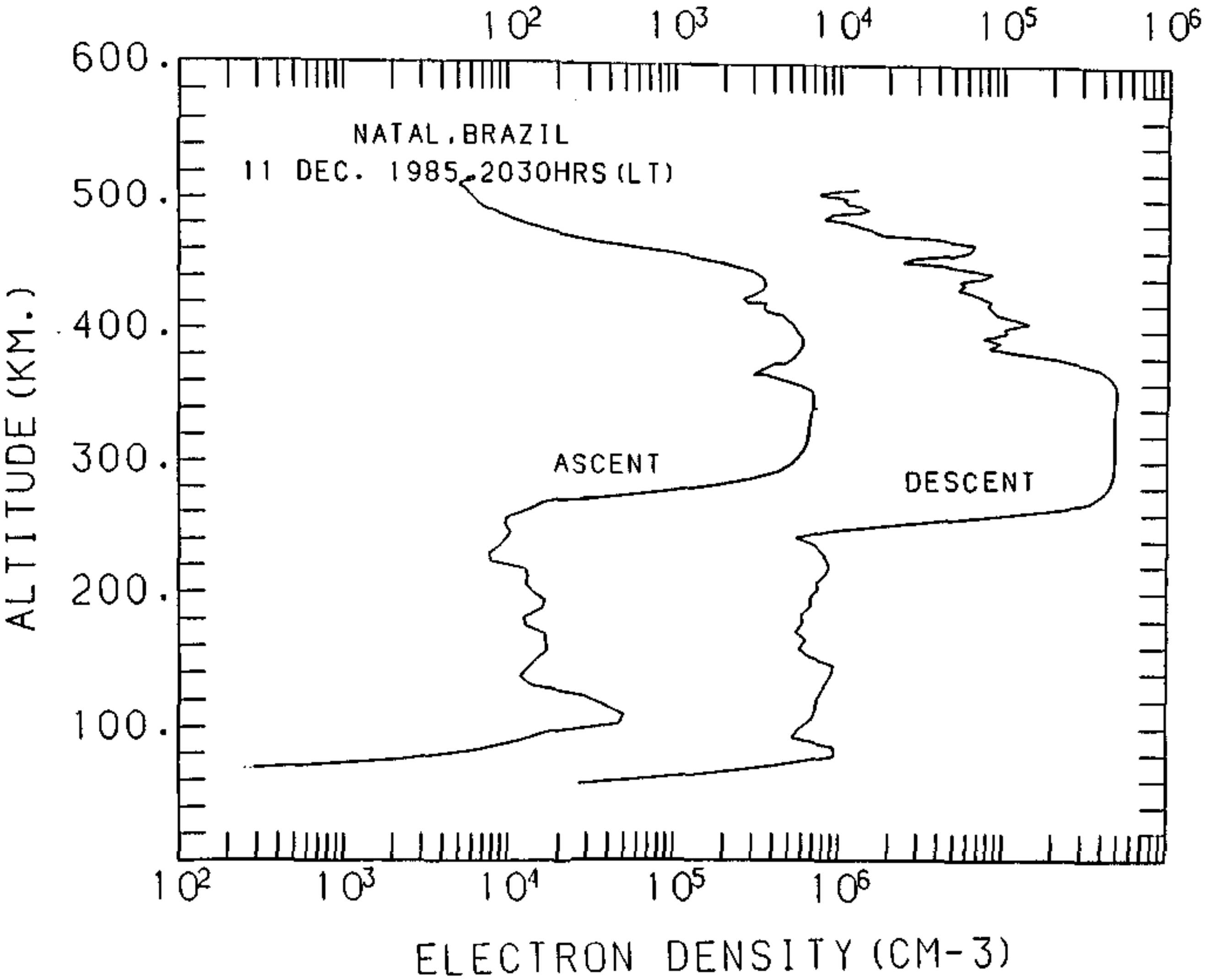
DC AMP.
GAIN SWITCH
H.P. FILTER
AC AMP.
TELEMETRY SYSTEM
SWEEP GENERATOR
ZERO MARKER PULSE

Fig. 2



NATAL, BRAZIL
11 DEC. 1985, 2030HRS (LT)
ASCENT
DESCENT
ALTITUDE (KM.)
ELECTRON DENSITY (CM-3)
600.
500.
400.
300.
200.
100.

Fig. 3