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A plasma diagnostics package for low-latitude observations on board the French-Brazilian microsatellite

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RESUMEN

El microsatélite Francés-Brasileño (FBM) está programado para lanzarse en el año 2004. Será colocado en una inclinación baja (cercana a 6 grados) en una órbita circular ecuatorial a una altura de 700 km. Entre varios experimentos, llevará un Paquete de Diagnóstico de Plasma (PDP) consistente de 3 experimentos, una Prueba de Capacitancia de Alta Frecuencia (HFC) para medir la densidad absoluta electrónica a lo largo de la trayectoria del satélite, una Prueba de Langmuir (LP) para medir la variación relativa y la distribución espectral de la densidad electrónica y una Prueba de Temperatura Electrónica (ETP) para medir la variación en la temperatura electrónica y el potencial espacial. El principal objetivo del experimento PDP es realizar observaciones globales de las principales características de las burbujas de plasma de bajas latitudes, y por tanto estudiar la dinámica y electrodinámica que controla la generación, desarrollo y decaimiento de estas burbujas. Estas observaciones satelitales se complementarán con observaciones provenientes de una red de equipos tales como ionosondas, digisondas, polarímetros y radares VHF operados simultáneamente por un grupo selecto de estaciones de tierra en Brasil y otros países colaboradores. La operación de los experimentos brasileños a bordo del FBM se controlarán por una computadora especial. Esta computadora estará asociada con la computadora principal que controla la operación del satélite. Los datos del experimento LP se pueden procesar también a bordo para reducir los requerimientos de memoria.

PALABRAS CLAVE: Ionosfera, burbujas de plasma, inestabilidad de plasma, densidad electrónica, temperatura electrónica.

ABSTRACT

A French-Brazilian micro satellite (FBM) is scheduled to be launched in 2004. It will be placed in a low inclination (about 6 degrees) equatorial circular orbit at a height of 700 km. Among other French and Brazilian experiments, it will carry a Plasma Diagnostics Package (PDP) consisting of three experiments. A High Frequency Capacitance probe (HFC) to measure the absolute electron density along the satellite trajectory; a Langmuir Probe (LP) to measure the relative variation and the spectral distribution of electron density, and an Electron Temperature Probe (ETP) to measure the variations in the electron temperature and the space potential. The main objective of the PDP experiments is to make global observations of the characteristic features of low-latitude plasma bubbles, and to study the dynamic and electrodynamic processes that control the generation, development and decay of plasma bubbles. These satellite observations will be complemented by observations from a network of Ionosondes, Digisondes, Polarimeters, and VHF radars operated simultaneously from selected ground stations in Brazil and in other collaborating countries. The Brazilian experiments on board FBM will be controlled by the Brazilian Payload Computer (BPC), linked with the main computer that controls the functioning and operations of the satellite. Data from the LP experiment can be processed on board to save data memory.

KEY WORDS: Ionosphere, plasma bubble, plasma instability, electron density, electron temperature.

1. INTRODUCTION

In the low latitude region where the geomagnetic field lines are primarily horizontal, plasma instabilities are driven by gravitational forces and by the electric fields and current systems. Observed phenomena include the equatorial spread-F/ plasma bubbles and the electrojet current instabilities. Plasma bubbles are geomagnetic field-aligned depleted flux tubes with plasma density orders of magnitude lower than the ambient density, stretching a few thousands of kilometers between conjugate points north and south of the magnetic equator. Since their discovery in the 70's by radar, satellites and rockets (Kelly *et al*., 1976, Woodman and La Hoz, 1976), ionospheric plasma bubbles have been the subject of scientific and technological investigations by international groups. Over the equator they are distributed from ~300 km where their seeding occurs reaching to ~1500 km or more in their vertical growth process. The nighttime Brazilian low latitude ionosphere is strongly controlled by plasma bubble phenomena. They present significant longitudinal and seasonal dependence, as the Brazilian Atlantic longitude is a region of globally highest occurrences observed so far. The equatorial ionospheric plasma is highly unstable to nonlinear plasma processes, such as the Rayleigh-Taylor mechanism, that are responsible for the generation of plasma bubbles (Haerendal, 1974).

Plasma irregularities produce significant modifications of the phase and amplitude of radio waves in different bands used in wide ranging space applications (telecommunications, geodesy, remote sensing by space shuttle based radars, etc.,). Their investigation is considered to be a priority topic in space research activities by international scientific bodies.

Ionospheric conditions and electrodynamics responsible for the large variability in the occurrence frequency and intensity of occurrence of plasma bubbles remain unknown. A better understanding of these aspects is fundamental for improving the predictability of the occurrence of these phenomena. A low-inclination, low-altitude satellite carrying a plasma diagnostics package will substantially improve the observational foundation for investigation of these phenomena. The *in situ* measurement of critical parameters to be realized on board the French-Brazilian Micro satellite (FBM), promises to offer important data for the detailed study of electrodynamic processes.

The FBM is scheduled to be launched in the year 2004. It will be placed in a low inclination (about 6 degrees) equatorial circular orbit at a height of about 700 km with the following multi discipline experiments.

- Plasma Diagnostic Package - PDP
- Astrophysics Experiments - APEX
- Boiling Under Microgravity - CEBMG
- Capillary Heat Transfer - CPL
- Radiation Flux - FLUXRAD
- French Experiments

The Plasma Diagnostics Package (PDP) is being developed at the Instituto Nacional de Pesquisas Espaciais – INPE, Brazil. Its purpose is investigating the electrodynamics and nonlinear processes of the equatorial ionosphere-thermosphere system (EITS) by global observations of the characteristic features of low-latitude plasma bubbles, and studying the dynamic and electrodynamic processes that control their generation, development and decay. This investigation intends to elucidate the strong influence of the plasma bubble and the associated plasma turbulence in several space application systems like trans-ionospheric telecommunication, space geodesy, remote sensing with radar etc.

The satellite observations will be supported by ground-based ionospheric and thermospheric measurements in Brazil and at selected locations in other countries using a network of diagnostic instruments that include radars, digisondes/ionosondes, optical imagers and interferometers and the available GPS satellites.

2. SCIENTIFIC AND TECHNICAL OBJECTIVES

The Plasma Diagnostics Package (PDP) consists of three different plasma diagnostic experiments aimed at measuring the ionospheric plasma parameters with the objective of studying the electrodynamics and non-linear plasma processes in the Equatorial Ionosphere – Thermosphere System (EITS). The plasma parameters measured are:

- the number density of electrons and ions in the ambient plasma using a High Frequency Capacitance Probe (HFC Probe) and a Langmuir Probe (LP)
- the spectral distribution of fluctuations in the ambient electron number density using the Langmuir Probe and
- the kinetic temperature of the ambient electrons using an Electron Temperature Probe (ETP).

2.1 PLASMA BUBBLE STUDIES

Plasma bubbles are observed dominantly in the post sun set period extending till midnight, though at times they are observed even during the post midnight period but with less frequency. To study the nature of the plasma bubbles it is essential to make measurements of the electron density (using LP and HFC experiments) and of the electron temperature (using the ETP experiment) continuously and simultaneously during the post sunset period. As mentioned above the bubble formation has the maximum frequency of occurrence during this period. The HFC experiment can provide practically the absolute values of the electron density (except for a plasma sheath factor that is known to have an empirical value of 0.5). The LP experiment can provide the variations in the ambient plasma density on a relative scale with high spatial resolution needed for the study of the plasma irregularities. These measurements can be calibrated by comparison with the HFC measurements.

It should be mentioned here that the LP and HFC measurements are scalar measurements and the data obtained from them are contaminated mainly by the emission of photoelectrons from the sensor surface and by the falling of vehicle wake on the sensor. The mean thermal velocity of the electrons in the height region of measurement is much higher than the vehicle (satellite) velocity, thereby practically eliminating the effect of the changing direction of the satellite motion (or the electron flux direction) on the measured electron density.

The ETP experiment has always been tested in the past and used widely by the group in Japan (ISAS) under conditions where the electron flux collected by the ETP sensor has a direction within 10 degrees from the perpendicular to the sensor surface. The effect of larger angles of approach caused by the changing orientations of the satellite has not been studied so far. But as given below this is one of the technical objectives of the present ETP experiment.

2.2 STUDY OF THE PLASMA INSTABILITY PROCESSES

Here the main objective is to study the plasma instability processes responsible for the generation of electron density irregularities observed both in the day time as well as the night time low latitude ionosphere. It is now rather well established that the low latitude ionospheric plasma is highly unstable to non-linear plasma instability processes. Several linear and non-linear theories have been invoked to explain the wide spectrum of electron density irregularities observed in the nighttime F-region (Reid, 1968, Hudson *et al.*, 1973, Sudan *et al.,* 1973). The post-sunset equatorial F-layer can become unstable under the influence of any disturbance produced by gravity waves, neutral winds or electric fields, and can generate plasma irregularities through the R-T instability mechanism (Hysell *et al.*, 1990, Singh *et al.*, 1997). Steep plasma density gradients associated with the long wavelength R-T mode, create a condition which leads to the hierarchy of plasma instabilities giving rise to a wide spectrum of irregularities. These irregularities produce significant modifications to the phase and amplitude of radio waves in different bands used in wide ranging space application areas (telecommunications, geodesy, remote sensing by space shuttle based radars, etc.

To achieve this objective it is necessary to operate the LP, HFC and ETP experiments simultaneously. If due to some technical reason it is not possible to obtain reliable electron temperature measurements continuously in time, one can make use of the available ETP measurements to compliment the continuous LP and HFC measurements.

2.3 OBTAINING A WIDER DATA BASE

It is intended to measure the ionospheric plasma parameters like electron number density and electron temperature for providing a wider data base for the low latitude ionosphere with the ultimate objective of improving the existing ionospheric models. To achieve this objective it is necessary to operate the LP, HFC and ETP experiments simultaneously. If due to some technical reason it is not possible to obtain reliable electron temperature measurements continuously in time, one can make use of the available ETP measurements to compliment the continuous LP and HFC measurements.

2.4 CRITICAL STUDY OF PROBLEMS

It is proposed to make a critical study of some of the problems known to be associated with some of the plasma measurement techniques (Muralikrishna and Abdu, 1991). Some of the problems envisaged are:

The effect of the formation of plasma sheath surrounding the sensor on the measurement of electron number density using the HFC probe technique.

It is possible to study the effect of the formation of plasma sheath surrounding the HFC sensor on the measured electron number density by comparing the amplitudes of the slow varying components in the electron density as measured by the HFC and LP experiments. In addition to achieving this objective the comparison between the HFC and LP measurements will be used to calibrate the LP data once in a while.

The effect of the incoming electron flux being nonperpendicular to the sensor surface on the accuracy of the ETP technique.

To achieve this technical objective as also to increase the period of data reliable data acquisition it is planned to use to ETP sensors mounted in such away as to make an angle of 20 degrees between their surfaces. This will ensure that the electron flux that arrives within a cone of vertical angle of 40 degrees will be incident on at least one of the sensor surfaces at an angle of less than 10 degrees from the perpendicular to the sensor surface thus providing reliable electron temperature data. However knowing the attitude of the satellite and the velocity vector one can compare the measurements made by the two sensors and develop an analytical method to correct (if at all found necessary) the data from the sensor which receives the electron flux (as indicated by the satellite velocity vector) at angle higher than 10 degrees. In fact once a correction method is developed one can extend it even for higher electron flux angles stage by stage. However this needs continuous measurement by the two ETP sensors along with reliable data on the satellite attitude and the satellite velocity vector.

The effect of high electron number density on the temperature measured by the ETP technique.

Earlier satellite observations have shown that when the electron number density is very high and the electron flux falls vertically on the ETP sensor surface it affects the electron temperature measurements. Under such conditions it is better to avoid the condition of perpendicularity of the electron flux (satellite velocity) direction and the sensor surface. By continuous observation using the two ETP sensors that have sensor surfaces at an angle of 20 degrees one develop a method to study the effect of high electron number density on the electron temperature when the electron flux is perpendicular to the sensor surface.

3. EXPERIMENT DETAILS

3.1 HIGH FREQUENCY CAPACITANCE PROBE

This experiment is projected to measure, with high precision, the distribution of electron number density along the trajectory of the satellite. The results from this experiment will also be used for comparison with and to normalize the measurements made with the Langmuir probe. The technique is based on the determination of the capacitance of a spherical electrode of diameter about 60 mm, mounted on the satellite such that the sensor is exposed to the ambient plasma. The capacitance of the sensor is a function of the dielectric constant of the plasma and the dielectric constant depends on the number density of electrons. Thus the determination of the sensor capacitance enables the determination of the electron number density.

The sensor electrode of the HFC experiment is used as a capacitance element in the tank circuit of a "Clapp" type oscillator. The capacitance varies with the electron density along the trajectory of the satellite, varying the frequency of oscillation of the oscillator that is measured on board the satellite. From the change in the oscillator frequency it is possible to determine the number density of electrons through the approximate relation (Heikkila *et al.*, 1968):

$$n = \frac{2.f^2.\Delta f(C_S + C_0)}{81.f_0.S.C_0} , \qquad (1)$$

where

n is the number density of electrons
f is the oscillator frequency in the plasma
f_0 is the oscillator frequency in free space
Δf is the variation in the oscillator frequency
C_0 is the capacitance of the sensor in free space
C_S is the stray capacitance of the oscillator
S is the plasma sheath factor.

The variation in the oscillator frequency for a given ambient plasma density is inversely proportional to the oscillator frequency (Equation 1). Lower the oscillator frequency higher is the sensibility of measurement. But the Equation 1 is valid only when the oscillator frequency is well above the local ionospheric plasma frequency that can vary by orders of magnitude between outside and inside the plasma bubbles. From these considerations and also from the point of view of reducing the operational complexity of the experiment the HFC probe is projected to operate at a frequency of about 8 MHz. To obtain the free space oscillator frequency negative bias pulses of 100 V is applied to the HFC sensor for a short time (128 ms in the present case) at regular intervals of time. This repels the ambient plasma from the neighborhood of the sensor and the oscillator frequency measured during this period is very close to the free space oscillator frequency. Changes (up to about 10% from the mean value) in the frequency of oscillation is measured and later converted into the ambient electron number density within the measurable range of 103 to 5x106 electrons per cubic centimeter. 4 digital data words of 8bits each sampled at 16 per second represent the HFC oscillator frequency variation and the experiment mode of operation. The measurement accuracy of the experiment is about 17 Hz in the frequency. This gives an estimated accuracy of about 10^8 electrons per m^3 in the electron number density.

Figure 1 shows the block diagram of the oscillator module (Module A) of the HFC experiment. The mechanical design of this module is shown in Figure 2. The oscillator output from module A is processed in Module B of the experiment whose block diagram is shown in Figure 3. The oscillator signal appears at the HFC sensor and its amplitude is controlled to be always at a low level less than 100mV for not perturbing the ambient plasma surrounding the sensor. The counter circuit counts the number of the arriving pulses through a preset time gate of approximately 60 ms. This count information is sent to the on board experiment interface BPC by the formatter circuit. The pulse count is represented by 20 binary bits of three 8 bit words, HFC1, HFC2 and HFC3, only 4 low significant bits of the word HFC3 (HFC3 represents the highest significant bits of the pulse count) and 8 bits each of the words HFC2 and HFC1 being used for this purpose. The bias (-100 V) status is monitored through one of the bits.

3.2 LANGMUIR PROBE

The Langmuir Probe (LP) is used to measure the ambient plasma parameters like the number density of electrons and the spatial fluctuations in it. The LP consists of a metal-

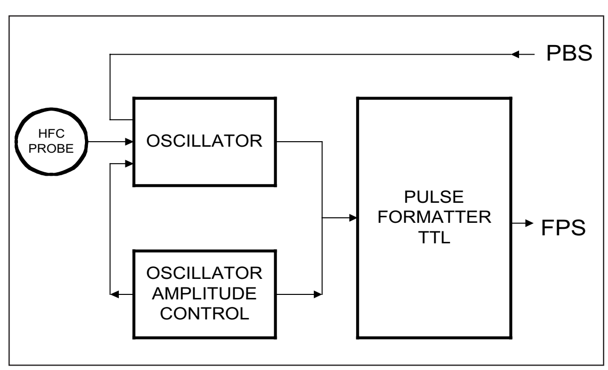


Fig. 1. The HFC MODULE-A showing the oscillator, its amplitude control unit and the pulse formatter.

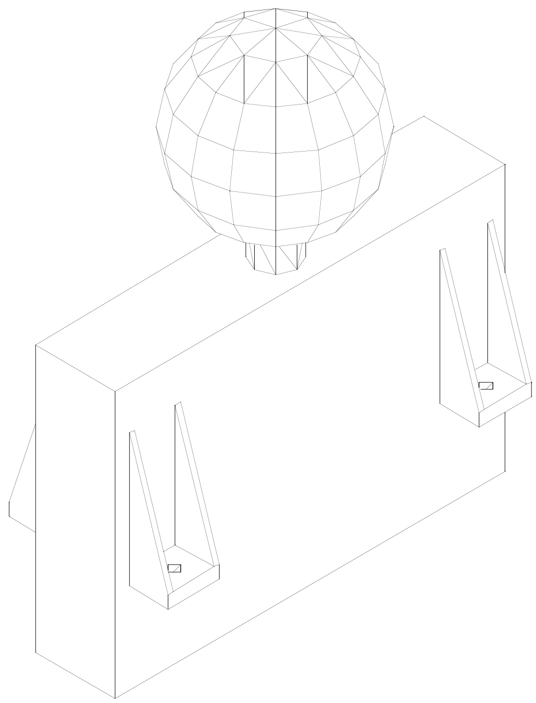


Fig. 2. Mechanical design of the Module A of the HFC (LP) experiments.

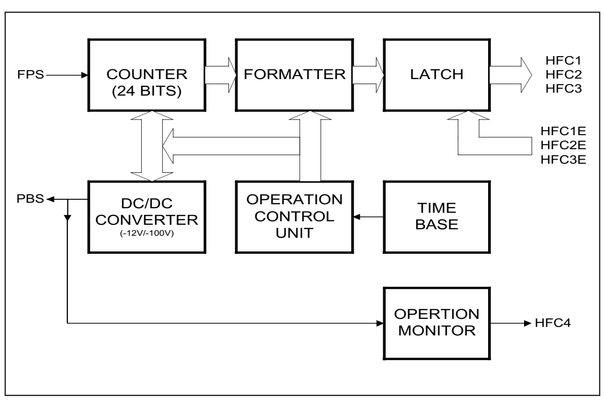


Fig. 3. HFC MODULE-B block diagram.

lic sensor in the form of a sphere of about 60 mm diameter mounted on the satellite such that the sensor is fully immersed in the ambient plasma The current of electrons and ions collected by the sensor depends very much on the geometric form of the sensor, the potential applied to the sensor, the physical characteristics of the ambient plasma and the sensor speed. The sensor current, measured for a properly chosen bias potential applied to the sensor can give the ambient electron density. It can be shown that for a negative potential V of the sensor (measured with respect to the ambient plasma potential) the current collected by it is given by the approximate relation:

$$I = enA[V_s - V_e \exp(-eV/kT_e)] \,, \tag{2}$$

where

e is the electronic charge
n is the number density of electrons (or ions)
V_s is the satellite velocity
V_e is the mean thermal velocity of electrons
T_e is the kinetic temperature of the electrons
k is the Boltzmann constant and
A is the surface area of the sensor
V is the potential applied to the sensor.

For positive sensor potentials the current collected by the sensor is given by the approximate relation

$$I = enA\left\{ V_s \exp(eV/kT_i) - V_e[1-\exp(eV/k_e)] \right\}, \tag{3}$$

where T_i -is the kinetic temperature of the ions.

The sensor can be maintained at the ambient plasma potential (V = 0) or at a negative potential to collect predominantly positive ions or at a positive potential to collect predominantly electrons. The potentials applied to the LP sensor can be selected in a preprogrammed mode or by telecommands as -1V, 0V, +1V, or +2V depending on the specific scientific objectives.

In the Langmuir Probe experiment the current collected (in the range of 1na to 20 ma) by the metallic sensor is measured and later converted into electron number density in the range of 10^8 to $5x10^{12}$ electrons per m^3. 3 digital data words of 8 bits each sampled at 16 per second represent the LP current variations (monitored through three different channels) and 1 digital data word of 8 bits sampled at a minimum rate of 2048 per second represents the ac fluctuations in the LP current. The ac fluctuations in the current collected by the sensor in the frequency range of about 10 Hz to 1000 Hz (upper limit imposed by the maximum sampling rate possible) is thus measured. The accuracy of measurement of the LP experiment varies almost logarithmically in the measurement range. At low electron densities the accuracy of measurement is about 10% (corresponding to about 100 electrons per cc while at higher electron densities one can obtain an accuracy of about 2% comparing the dc measurements with the corresponding ac measurements.

The block diagrams of the Langmuir Probe electronics subsystem are shown in Figures 4 and 5. The mechanical designs of the Modules A and B of the LP experiment are similar to those of the HFC experiment. A negative, zero or positive potential is applied to the LP sensor (selected in a preprogrammed mode or through a telecommand) and the current collected by the sensor is converted to a varying voltage using a high input impedance preamplifier (Figure 4). To study the fluctuations in the electron density an FFT spectral analysis method is used. The potential applied to the sensor, the preamplifier gain and the dc and ac amplifier gains as well as the status of the onboard FFT analysis performed on the ac signal are all monitored through an 8 bit digital word LP1.

On board processing of LP data

In order to obtain the maximum possible information from the collected data on a global scale the analog ac data from the LP experiment that is sampled at a rate of 2048 samples per second is subjected to an on board processing, especially when the satellite is outside the visibility range of the ground telemetry station. This helps in reducing the data volume to a level acceptable for on board storage. When the satellite is in the telemetry visibility the LP ac signal is transmitted without any onboard processing. But when the satellite is off the telemetry visibility, to reduce the amount of the data stored FFT analysis is made of the ac data and the average of a predetermined number of the FFT spectra thus obtained is stored in the place of raw data. The average spectra are estimated as follows:

Assuming that 32 spectra estimated from 32 blocks of 256 samples each of LP ac data are to be averaged, first the 32 spectra are stored in 128 words of 4 bytes (32 bits) each in a cumulative mode. The 32 spectra are thus summed into one spectrum of 128 words. Each of these 128 spectral values of the integrated spectrum is represented by 32 bits (4 bytes of 8 bits each) as B_0, B_1, B_2, B_3,…………B_{31} (B_0 being the least significant and B_{31} the most significant bits). Of these 32 bits one may choose 8 bits, say B_8 to B_{15} to represent the average spectrum.

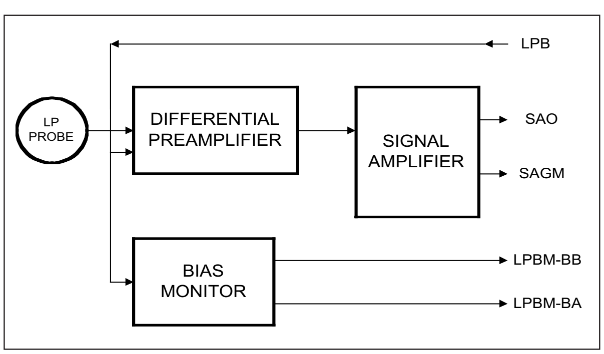
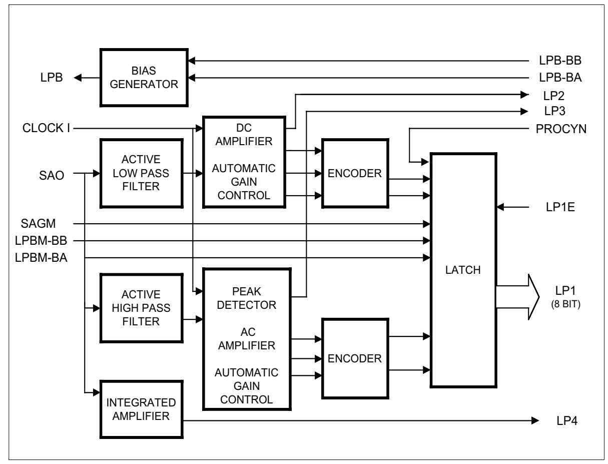


Fig. 4. Block Diagram of the LP MODULE-A.



LP - B MODULE

Fig. 5. Block Diagram of the LP MODULE-B.

In the normal mode of operation the FFT processing can be programmed and it may not be necessary to send any telecommand to change this cycle. But, when one needs to collect the data over a certain geographic region this operation cycle may have to be interrupted by a telecommand and the onboard analysis command has to be generated in the BPC following a different cycle. The bias level of the LP sensor also can follow a preprogrammed cyclic change in the normal mode of operation. The telecommand is needed only when one wants to interrupt this normal mode of operation.

3.3 ELECTRON TEMPERATURE PROBE

In the Electron Temperature Probe (ETP) the current-voltage characteristic curve of a conventional Langmuir probe is deformed by superposing a radio frequency (RF) signal of 30 kHz on the sensor bias. During one operation cycle lasting about 800 ms, this RF signal is maintained at an amplitude 2↦ (about 500 mV) for the first 400 ms and then at an amplitude of a (about 250 mV) for the next 200 ms and finally at an amplitude of 0mV (no RF signal) for the next 200 ms. The frequency of this RF signal is so chosen as to be sufficiently below the electron plasma frequency and sufficiently above the ion plasma frequency. The deviations in the I-V characteristic curves introduced by this RF signal are measured in terms of the variations in the floating potential of the sensor (potential at which the current collected is zero). The ratio R between the measured deviations in the floating potential corresponding to the periods when the RF signal amplitude is 2↦ and ↦ respectively, is used to determine the electron temperature. R is related to the electron kinetic temperature through the approximate relation:

$$R = \frac{I_0(2ea/kT_e) - 1}{I_0(ea/kT_e) - 1} \,, \tag{4}$$

where

- $\mapsto$ is the amplitude of the RF signal applied to the sensor
- e is the electronic charge
- k is the Boltzmann constant
- T_e is the kinetic temperature of electrons
- I_0 is the modified Bessel function of the first order.

In the ETP experiment the kinetic temperature of the electrons in the approximate range of 10 – 2000 degree Kelvin and the space potential in the range of 0 to 2V are measured. 4 digital data words (2 from each of the 2 ETP sensors) of 8 bits each, sampled at the rate of 16 per second represent these parameters. The ETP experiment has an estimated approximate measuring accuracy of about 10 degrees in the electron temperature and about 50 mV in the space potential.

Figures 6 and 7 show the block diagrams of the ETP electronics subsystem. It is proposed to use two ETP sensors mounted with an angle of about 20 degrees between them so as to increase the effective time of measurement for the experiment. Each ETP sensor is made out of a printed circuit board cut in the form of a disc of 100 mm diameter (Figure 6). The metallic part of the disc along one diameter of the disc is removed and the disc is transformed into two semicircular sensors. A RF signal of 30 kHz is generated in an oscillator and modulated to amplitudes $\mapsto$ and $2\mapsto$ alternately. This modulated signal is applied to one of the semicircular sensors of the ETP. No potential is applied to the other semicircular sensor and therefore provides the variations in the floating potential of the sensor. The difference in the potential between the two sensors is amplified in a differential amplifier. This potential difference can be related to the electron kinetic temperature.

4. PHYSICAL AND ELECTRICAL REQUIREMENTS

4.1 POWER BUDGET:

The electrical power requirement of the PDP Experiments is summarized in Table 1.

4.2 MASS BUDGET

The PDP experiment mass specification is shown in Table 2. It should be noted here that the values given are estimated values from the earlier experiments and depending on the location of mounting and other restrictions imposed may vary them slightly.

Table 1

Power Budget for PDP

EXPT.	MODULE	V (VOLTS)	I (mA)	POWER (mW)
	HFCMA	+ 12	30	360
HFC	(0.60W)	- 12	20	240
(2.080W)	HFCMB	+ 12	20	240
	(1.48W)	- 12	20	240
		+ 5	200	1,000
	LPMA	+ 12	25	300
LP	(O.66W)	- 12	30	360
(1.920W)	LPMB	+ 12	55	660
	(1.26W)	- 12	50	600
	ETP-N	+ 12	35	420
ETP	(0.72W)	- 12	25	300
(1.440W)	ETP-I	+ 12	35	420
	(0.72W)	- 12	25	300
	TOTAL			5,440

Table 2

Mass Budget for PDP

EXPERIMENT	MASS (kg)
LP MODULE-A	0,700
HFC MODULE-A	0,700
ETP MODULES	0,600
ELECTRONICS	1,200
TOTAL	3,200

4.3 MECHANICAL DIMENSIONS

The electronic circuits of the three PDP experiments are mounted on a single printed circuit board on one of the segments of the satellite. The mechanical dimensions of the different experiment units and the main electronics box are given in Table 3. These are to be considered the upper limits of the dimensions.

Table 3

Mechanical Dimensions

EXPERIMENT UNIT	DIMENSIONS(mm^3)
LP MODULE-A	184,5x150x65,2
HFC MODULE-A	184,5x150x65,2
ETP MODULES	250x150x125
HFCMB	270x150x21
LPMB	270x150x20
BPC (Micro)	270x150x20
BPC (Acquisition)	270x150x20
ENERGY (DC/DC C)	270x150x21

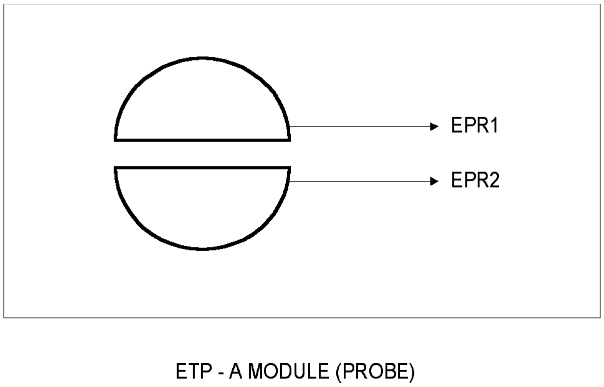


Fig. 6. ETP MODULE-A showing one of the ETP Sensors.

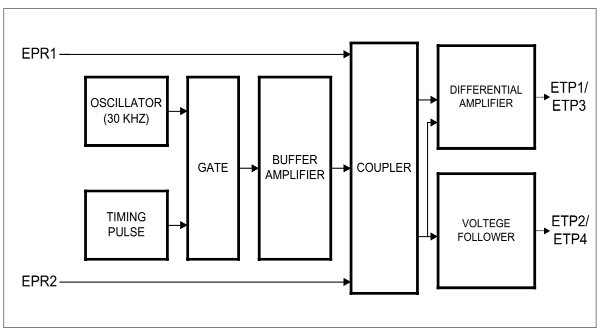


Fig. 7. ETP MODULE-B Block Diagram.

The operation of the PDP experiments will be controlled by the Brazilian Payload Computer (BPC) through an interface shown schematically in Figure 8. BPC will function as the interface between the PDP and the On Board Computer (OBC) and will take care of all the experiment operations and data transfer receiving commands from OBC whenever needed.

The sensors of the HFC and the LP experiments and their Modules-A electronics as well as the sensors and the electronic module of the ETP experiment are mounted at properly selected locations on board the satellite, as shown in Figure 9. permitting their uninterrupted exposure to the ambient plasma. As can be seen from the figure the HFC and LP sensors, spherical in shape are mounted at the extremities of two rectangular boxes that contain the sensor electronics (Module-A) of the two experiments. This is to reduce the interference of variations in the satellite potential on the sensor characteristics. The two ETP sensors (circular in shape) are mounted on the satellite such that their planes are at an angle of about 20 degrees. This angle between the sensor planes and the orientation of the perpendiculars to the sensor planes are so chosen as to maximize the duration of reliable electron temperature measurements. It should be mentioned here that the ETP makes reliable measurements of the electron temperature when the sensor plane is perpendicular to the velocity vector of the satellite. The main electronics subsystems of the HFC and LP experiments and the BPC are mounted in one of the main segments of the satellite.

5. TELEMETRY AND TELECOMMAND

The incoming and outgoing signals for the HFC experiment are shown in Table 4. The three 8 bit digital words HFC0, HFC1 and HFC2 and the analog signal HFC3 are sent to the Micro controller interface (MCI) wherein the analog signal HFC3 is digitized into an 8 bit word. All the signals have a uniform sampling rate of 16 per second.

An operation cycle of the HFC experiment is initiated by the interrupter pulse INT0 generated by the HFC experiment. Based on this pulse INT0 the pulses HHFC0, HHFC1 and HHFC2 shown in Table 4 that are the read enable pulses received by the HFC experiment. An additional command pulse provided by the MCI is the pulse OSCONOFF that has the function of switching ON or OFF the oscillator unit of

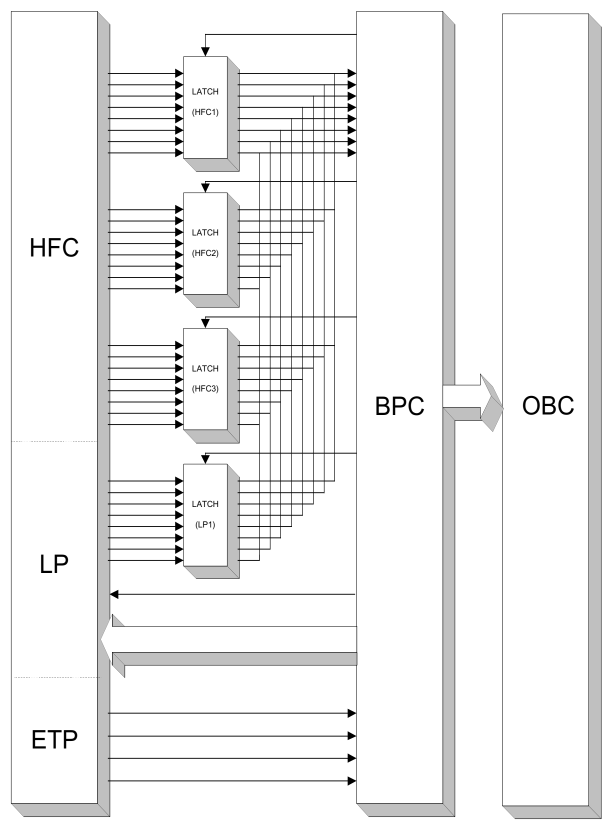


Fig. 8. PDP-BPC Inter-Connection

the HFC experiment whenever needed. This pulse does not form part on a normal operation cycle of the experiment but is activated by a specific telecommand whenever needed.

The incoming and outgoing signals of the LP experiment are shown in Table 5. The signal levels as well as their sampling rates are also shown in Table 5. The current from the LP sensor is converted into a correspondingly varying voltage and processed through the electronics system. The analog signals from this experiment namely the multiple gain dc signal LP0, the multiple gain ac signal LP1 and the integral signal LP2 are passed on to the MCI for conversion into digital 8 bit words. While the ac signal LP1 is sampled at 2048 samples per second the other signals are sampled at a uniform rate of 16 samples per second. Two digital 8 bit words LP3 and LP4 are also formed to monitor the gains of the preamplifier (1 bit MGSPA), the dc amplifier (2 bits MGSDC) and the ac amplifier (2 bits MGSAC) as also to monitor the LP sensor biases (3 bits) and the status of the on board FFT analysis. While the gains of the three amplifiers change automatically depending on the level of the sensor signal, the LP sensor bias and the status of the onboard FFT analysis are changed only on command (which depends on commands received from the OBC).

The incoming and outgoing signals of the Electron Temperature Probe are shown in Table 6. The analog signals of the experiment namely the differential amplifier output ETP0 and the floating potential ETP1 are forwarded to the MCI for being digitized into two 8 bit digital words. The two signals from the ETP experiment are sampled at a rate of 16 samples per second.

As mentioned in the respective sections earlier the operation of the HFC and LP experiments and the on board spectrum analysis of the ac data from the LP experiment are controlled by 3 commands namely, OSCONOFF, YNPROC and LPBIAS1. These commands may be given online during the satellite visibility and/or generated in the On Board Computer (OBC) through a program loaded on to it which may be altered by specific telecommands at a later stage if needed.

Table 4

Input/Output Signals - HFC Experiment

SIGNAL	D/A	RANGE	RATE	DESCRIPTION
HFC0	D	8 BIT-TTL	16	Counter Bits - LSB
HFC1	D	8 BIT-TTL	16	Counter Bits – INTER.
HFC2	D	8 BIT-TTL	16	Counter Bits - MSB
HFC3	A	0 TO 5V	16	Oper. Monitor
OSCONOFF	D	1 BIT-TTL	-	HFC Osc. ON/OFF Comd.
INT0	D	1 BIT-TTL	16	Interruption
HHFC0	D	1 BIT-TTL	16	Read Enable (HFC0)
HHFC1	D	1 BIT-TTL	16	Read Enable (HFC1)
HHFC2	D	1 BIT-TTL	16	Read Enable (HFC2)

Table 5

Input/Output Signals - LP Experiment

SIGNAL	D/A	RANGE	RATE	DESCRIPTION
LP0	A	0 TO 5V	16	LPSDC - DC SIGNAL
LP1	A	0 TO 5V	2048	LPSAC - AC SIGNAL
LP2	A	0 TO 5V	16	LPINT - INTEG. SIGNAL
HLPSGB	D	1 BIT-TTL	16	READ ENABLE
				GAIN MON.
LP3, LP4				BIAS MON
(LPMGB)	D	8 BIT-TTL	16	MPROC- PROC. MON.
TELE. CMDS	D	TTL	-	PROC Y/N
				LPBIAS

- OSCONOFF command switches the oscillator of the HFC experiment ON/OFF.
- YNPROC command initiates/stops the onboard FFT analysis done on the LPSAC signal of the DLP experiment.
- LPBIAS1 alters the voltage bias on the LP sensor to one of the 6 preset levels.

Table 6

Input/Output Signals - ETP Experiment

SIGNAL	D/A	RANGE	RATE	DESCRIPTION
ETP0	A	0 TO 5V	16	TEMP. ELEC
ETP1	A	0 TO 5V	16	FLOAT POT.

When the satellite is in the telemetry visibility the LP ac signal is transmitted without any onboard processing. But when the satellite is off the telemetry visibility, to reduce the amount of the data stored FFT analysis is made of the ac data and the average of a predetermined number of the FFT spectra thus obtained are averaged and stored in the place of raw data. Thus in the normal mode of operation the FFT processing can be programmed and it may not be necessary to send any telecommand to change this cycle. But, when one needs to collect the data over a certain geographic region this operation cycle may have to be interrupted by a telecommand and the onboard analysis command has to be generated in the OBC following a different cycle. The bias level of the LP sensor also can follow a pre programmed cyclic change in the normal mode of operation. The telecommand is needed only when one wants to interrupt this normal mode of operation.

6. BRAZILIAN PAYLOAD COMPUTER

The operation of the PDP experiments will be controlled by the Brazilian Payload Computer (BPC) which will function as the interface between the Brazilian scientific experiments and the On Board Computer (OBC) and will take care of all the experiment operations and data transfer receiving commands from OBC whenever needed. The interface details are shown schematically in Figure 8 and are summarized in Table 7.

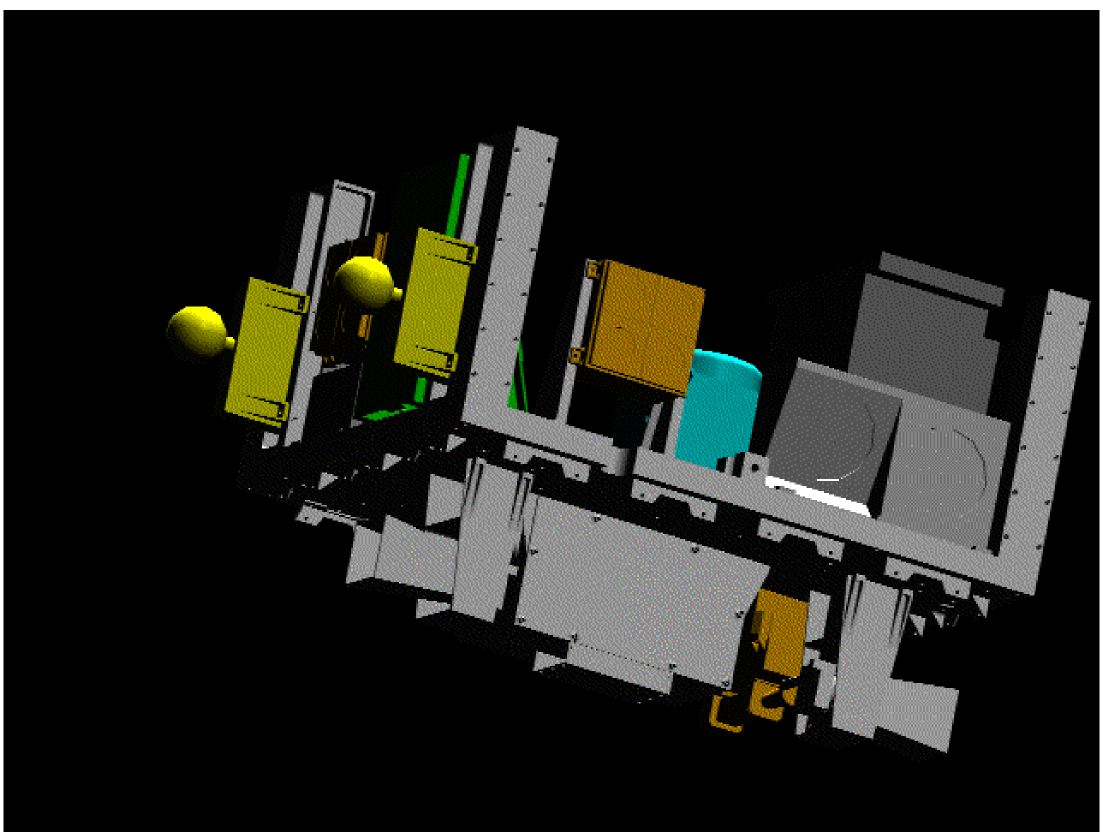


Fig. 9. Artists view of the FBM Platform with experiments mounted.

Table 7

Specifications of PDP-BPC Interface Connection

FROM	SIGNAL	D/A	RANGE (V)	RATE(1/S)	DESCRIPTION	NOTE
ETP	ETP1	A	0 to +5	16	Electron Temperature	ETPN0
(TLM)	ETP2	A	0 to +5	16	Floating Potential	ETPN1
	ETP3	A	0 to +5	16	Electron Temperature	ETPI0
	ETP4	A	0 to +5	16	Floating Potential	ETPI1
HFC	HFC1	D	TTL	16	Counter Bits (LSB)	HFC1
(TLM)	HFC2	D	TTL	16	Counter Bits (Intermediate)	HFC2
	HFC3	D	TTL	16	Counter Bits (MSB) + OP. Mon. Bits	HFC3
	HFC4	A	0 to+5	16	HFC Operation Monitor	HFCMO
7. LP	LP1	D	TTL	16	Gain, Bias and operation Monitor	LPGBOM
(TLM)	LP2	A	0 to+5	16	DC Sensor Signal	LPDCS
	LP3	A	0 to+5	2028	AC Sensor Signal	LPACS
	LP4	A	0 to+5	16	INT Sensor Signal	LPINTS
BPC	HFC1E	D	TTL		HFC1 - Enable	HFC1E
(ENABLE)	HFC2E	D	TTL		HFC2 – Enable	HFC2E
	HFC3E	D	TTL		HFC3 - Enable	HFC3E
	LP1E	D	TTL		LP1 – Enable	LP1E
BPC	LPB-BA	D	TTL		Telecommand Bias	LPBIAS-A
(TLC)	LPB-BB	D	TTL		Telecommand Bias	LPBIAS-B
	PROCYN	D	TTL		On board processing YES/NO Monitor	PROCYN

8. SUMMARY AND CONCLUSIONS

The French-Brazilian micro satellite (FBM) designed and developed under collaboration between the Brazilian Space Agency –AES and the French Space Agency CNES is expected to be launched in the year 2004, on board a Brazilian Satellite Launch Vehicle VLS. The Plasma Diagnostic Package PDP is being fabricated and mounted at the Brazilian National Institute for Space Research – INPE/MCT. The final integration of the Brazilian experiments on board the satellite platform is expected to be done in France in the month of January 2003.

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