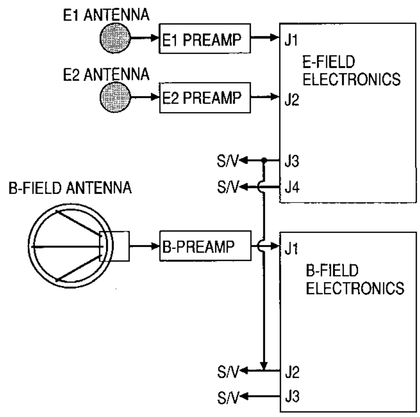

Fig. 1 Block diagram of the LASSII ELFWA.

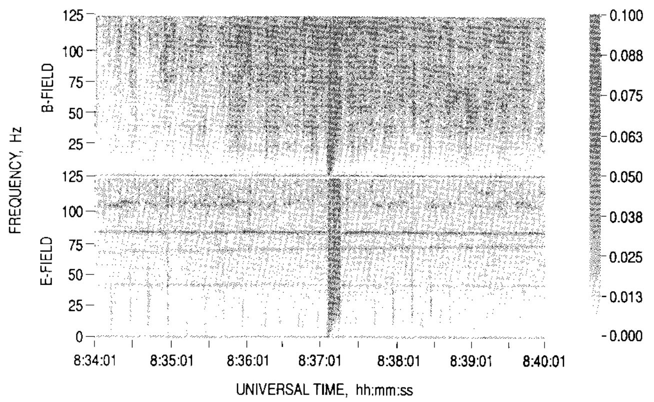

Fig. 2 Picture of a model of the CRRES spacecraft identifying the E-field and B-field antennas for the ELFWA experiment.

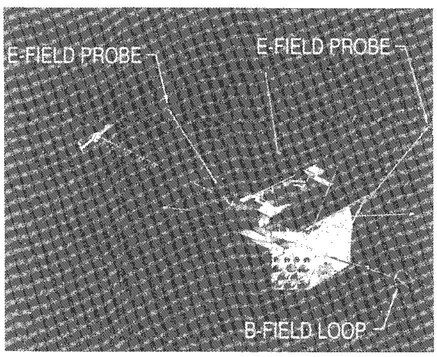

Fig. 3 Spectrograms of the signals from the magnetic (top) and electric (bottom) antennas during the barium chemical release from the CRRES spacecraft at 08:37:07 UT on July 19, 1991.

axis magnetic field measurement is also made in the spin plane of the spacecraft.

The two electronics packages, E-field and B-field, condition the antenna signals for data storage and telemetry. Each signal is amplified into the range 0 to 5.1 V. They are then sampled at evenly spaced intervals at 250 samples/s providing a 125 Hz Nyquist frequency for the signal from each antenna. Each of the electronics packages has independent gain settings of 0, −20, and −40 dB, and two modes, linear and automatic gain control (AGC). The dynamic range is 48 dB in the linear mode and approximately 90 dB in the AGC mode at one gain setting. The experiment normally takes data in the AGC mode with the gain set at 0 dB. Then the sensitivity corresponding to 0.02 V (1 bit) output from the electronics packages is 9.9×10^{-7} V/m from the electric antenna and 0.2 pT from the magnetic antenna. The total signal in-band is also averaged and recorded each second. In a separate mode, the signal from the electric antenna is passed from the E-field electronics package to the B-field electronics package as well as to the E-field electronics package as shown in Fig. 1. The combined output then doubles the sampling rate of the signal from the electric antenna to 500 samples/s for a Nyquist frequency of 250 Hz.

Data

At perigee, the spectrum detected by both antennas is characterized by electromagnetic impulses across the entire frequency range from 10 to 250 Hz. These impulses are most likely generated by lightning. At higher altitudes there is a hiss-like spectrum extending from 50 Hz to above the bandpass of the analyzer. This may be the lowest spectral component of plasmaspheric hiss. Figure 3 shows spectrograms of the signals from the magnetic and electric antennas during the barium chemical release from the CRRES spacecraft at 08:37:07 UT on July 19, 1991. The electromagnetic signal has spectral components across the entire band from 10 to 125 Hz and lasts approximately 10 s from the time of the release.

Flight Operations

Because the LASSII telemetry format is incompatible with the format used by the wave and particle instruments which are part of the Space Radiation Effects experiment on the same spacecraft, LASSII is duty cycled using the following scheme. When perigee is between 1730 and 0230 LT (i.e., dusk to postmidnight), LASSII operates below 3000 km during every other orbit. When perigee is between 0230 and 1730 LT, LASSII operates below 1000 km every fourth orbit. During low-altitude chemical release campaigns LASSII monitors the ionosphere for four orbits before and after each chemical release. The ELFWA instrument has been operating successfully throughout its first year on orbit.

Acknowledgments

This work was supported by the U.S. Air Force's Space Systems Division under Contract F04701-88-C-0089. We wish to express our appreciation to P. Rodriguez, LASSII Principal Investigator, for the opportunity to fly the ELFWA instrument as part of the LASSII experiment. We also acknowledge the efforts of S. Imamoto, D. Katsuda, P. Lew, D. Mabry, and W. Wong in the fabrication, testing, and integration of the ELFWA instrument.

LASSII Pulsed Plasma Probe on CRRES

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Introduction

THE CRRES includes as part of its scientific payload the Low Altitude Satellite Study of Ionospheric Irregularities (LASSII) experiment. One of the LASSII instruments is the pulsed plasma probe (P^3), which is used to study plasma

Received Aug. 3, 1991; revision received Aug. 7, 1991; accepted for publication Aug. 7, 1991. This paper is declared a work of the U.S. Government and is not subject to copyright protection in the United States.

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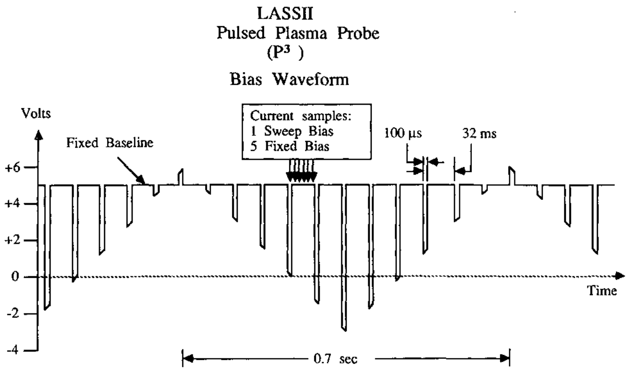

Fig. 1 Normal pulsed bias mode for the E-probe.

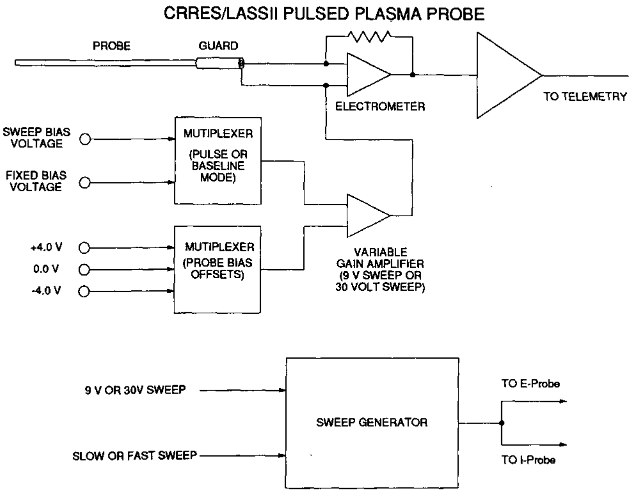

Fig. 2 Block diagram of the P^3 instrument.

irregularities caused by natural perturbations of the ionosphere, such as spread-F, and artificial modifications caused by chemical releases from the satellite. We present a description of the pulsed plasma probe instrument, its modes of operation, and an example of initial measurements obtained.

The F-region of the ionosphere is known to exhibit both large-scale and small-scale electron density irregularities, which in some cases can lead to density variations of more than three orders of magnitude. The phenomenon known as spread-F is the most dramatic example of large-scale irregularities occurring at low latitudes. This instability is observed in the nightside of the ionosphere, preferentially at local times of 1800 to 2300 h, and is associated with the formation of large-scale density depletions rising to high altitudes from the bottomside of the ionosphere. The distributions and scale sizes of electron density irregularities in spread-F have been measured with instruments on previous satellite and rocket experiments[1]; however, it is only until CRRES was launched that it has become possible to conduct several different experiments from the same spacecraft to compare naturally occurring instabilities with artificial electron density irregularities created by chemical releases. The Naval Research Laboratory's P^3 has been used on several previous rocket and one satellite experiment to study ionospheric density irregularities, both at high and low latitudes.[2,3]

Instrument Description

The P^3 is one of three diagnostic instruments which together comprise the LASSII experiment on CRRES. The P^3 is designed to measure the electron density and temperature, and fluctuations of the ambient ionospheric plasma. The experiment consists of two cylindrical Langmuir probes, two preamplifiers, and a main electronics box. Each of the Langmuir probes is made of tungsten wire 20 cm long and 0.09 cm in diameter, mounted on the end of a boom about 2 m in length. The base of each boom is attached near an outer corner of the solar array panels of the CRRES spacecraft; the booms are deployed opposite each other at a 45-deg angle to the plane of the solar panels. Figure 1 (from Ref. 4) is a schematic showing the deployment of the P^3 booms. The Langmuir probes are designated as E- and I-probes, with the E-probe biased for measuring electron currents and the I-probe usually biased for measuring ion currents; however, for some modes of operation, the I-probe can be biased to measure electron currents.

Two basic types of measurements can be made with the LASSII P^3 instrument: the traditional probe current as a function of probe bias voltage (the "*I-V*" curve) and the saturation current when the probe is held at a constant bias in the current-limited region of the *I-V* curve.[5] Analysis of the *I-V* curve provides electron temperatures and densities of the plasma, whereas the fixed baseline probe simultaneously provides higher time resolution of the electron density fluctuations.

The design of the P^3 experiment provides two basic types of instrument modes, the pulsed mode or the fixed baseline mode, by applying different bias waveforms to the probe. The pulsed mode is achieved by multiplexing a standard sawtooth (sweep) bias waveform with a fixed voltage bias. The resulting waveform for the normal E-probe pulsed mode of operation is shown in Fig. 1. This mode is referred to as "pulsed" because the sweep voltage is applied to the probe as a 100-μs pulse. In the pulsed mode of operation, one current sample is taken with the probe biased at the pulsed sweep voltage, followed by five current samples with the probe biased at the baseline voltage. With the fixed baseline mode, the probe is biased with a fixed voltage (no sweep voltage applied).

For normal operations, the E-probe is commanded to the pulsed mode, with a fixed bias voltage of + 5.5 V, and the sweep bias voltage sweeping from − 3.0 to + 6.0 V; the I-probe is commanded to the fixed baseline mode with bias voltage of − 2.5 V. Both E- and I-probes have various commandable amplitude and time scales for biasing. Table 1 shows the baseline voltages, sweep voltage ranges, and sweep periods that each probe may have. Note that there are two sweep voltage ranges, 9.0 and 30.0 V; when the sweep range is 30.0 V, the only possible fixed biases for the pulsed and baseline mode are + 13.3 V for the E-probe, and − 13.3 V for the I-probe. Each probe is configured independently with the

Table 1 P^3 bias mode

Baseline				Sweep period, s	
E- and I-probes, V	I-probe only, V	Sweep bias, V	Sweep range, V	Fast	Slow
−1.5		−7.0 to +2.0	9.0	0.7	2.5
+5.5		−3.0 to +6.0	9.0	0.7	2.5
+9.5		+1.0 to +10.0	9.0	0.7	2.5
	+1.5	+1.0 to +10.0	9.0	0.7	2.5
	−2.5	−3.0 to +6.0	9.0	0.7	2.5
	−6.5	−7.0 to +2.0	9.0	0.7	2.5
+13.3		−15.0 to +15.0	30.0	2.3	8.0
	−13.3	−15.0 to +15.0	30.0	2.3	8.0

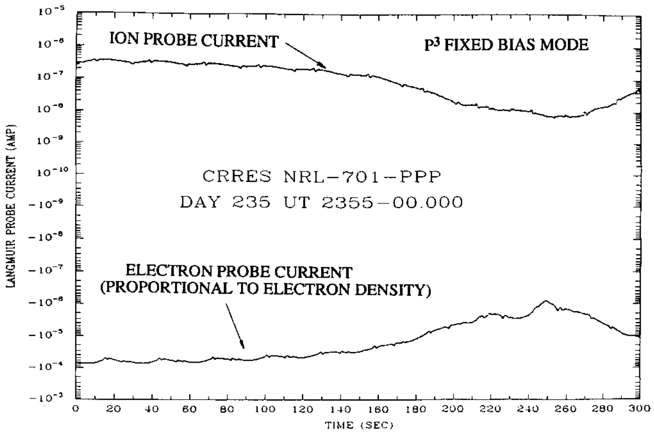

Fig. 3 Measured electron and ion currents near CRRES perigee.

following exception: if both probes have a sweep voltage applied, the bias waveforms must be identical, and in this case, both probes must have the same sweep period. The probe biases are measured with respect to the spacecraft, therefore any variation in spacecraft potential is imposed on the probes.

There are several additional modes of operation which combine pulsed and baseline mode. The first combined mode cycles both probes through four sweep periods of pulsed mode, followed by four sweep periods of baseline mode. The second combined mode cycles the instrument through two sweep periods of pulsed mode, followed by six sweep periods of baseline mode. When the instrument is in baseline mode, measurements from both probes are taken with fixed baseline voltages applied to the probes. There is also a mode in which a given probe can be pulsed between two different baseline voltages, one baseline being in the electron saturation region and the other baseline in the ion saturation region.

The pulsed bias technique has the added advantage of reducing the effects of probe contamination on the measured current. Surface contamination results in unknown probe capacitances which if allowed to fully charge will interrupt current flow to the probe; by pulsing the probe bias, these unknown capacitances do not fully charge within the time resolution of the current measurement. In addition, since the plasma density may be fluctuating during the time of the measurements required to construct the *I-V* curve, saturation current measurements from the fixed baseline are used to correct for current variations on the slope of the *I-V* curve. Correlation with the fixed plasma baseline I-probe, which is sampling ion currents, helps separate plasma density variations from other effects, such as spacecraft wakes and magnetic field anisotropies.

Figure 2 shows a block diagram of the P³ instrument. Note that there is one sweep voltage generator, with two possible voltage ranges (-3 to $+6$ V and -15 to $+15$ V) and two possible time constants for integration (producing four distinct sweep periods). If the instrument is being operated in pulsed mode, either the sweep voltage or a baseline voltage is multiplexed on the output. Note that the output of the amplifier can be shifted by ± 4 V. Also note that the fundamental difference between the E-probe and the I-probe is that the I-probe is capable of being biased at either the electron saturation current baseline voltage or at the ion saturation current baseline voltage. The instrument can measure currents between $\pm 10^{-10}$ and $\pm 10^{-3}$ A. With a sampling rate of about 6.3 kbps, the instrument spatial resolution depends on the spacecraft velocity and ranges from about 50 m at 350 km altitude (perigee) to approximately 40 m at an altitude of 3000 km.

Initial Measurements

The P³ experiment was turned on and successfully completed its orbital checkout procedure within weeks after the launch of CRRES on July 25, 1990. All instrument functions are working normally and the instrument was used to provide ionospheric background electron density measurements in support of the first chemical release campaign in September of 1990. An example of the current measurements from both E- and I-probes is shown in Fig. 3, which plots data from a 5-min interval as the spacecraft approaches perigee. For the time period shown, the instrument was in a fixed bias mode in which the E-probe was at a fixed baseline of $+5.5$ V and the I-probe was at a fixed baseline of -2.5 V. Current polarity is included in the plot of Fig. 3, so that the minimum current level on the logarithmic scale is at the midpoint of the vertical axis. Thus, plasma density increases are associated with increases in positive ion current and increases in negative electron current. The relative minimums observed in both probes at about 250 s on the time axis correspond to a decrease in plasma density. The measurement plots also indicate periodic "blips" that appear at periods equal to the spin period of the CRRES spacecraft (about 30 s early in the mission). The spin-modulated currents result from the probes passing through the wake region of the spacecraft, in which relative density decreases occur because the spacecraft is moving at a velocity greater than the thermal ion velocity of the background ionosphere. This effect is observed to varying degrees depending on P³ instrument modes, and will provide a data base from which to study the structure of the satellite wake.

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Electron and Proton Wide-Angle Spectrometer (EPAS) on the CRRES Spacecraft

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Received May 24, 1991; revision received July 29, 1991; accepted for publication July 29, 1991. Copyright © 1992 by A. Korth. Published by the American Institute of Aeronautics and Astronautics, Inc. with permission.

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