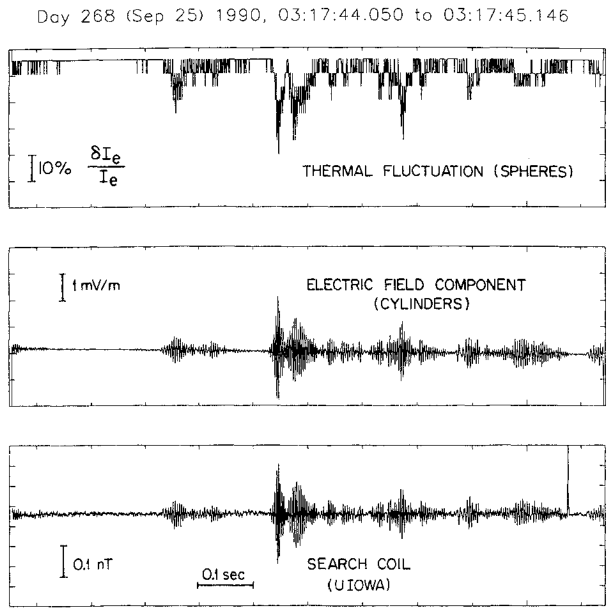

Fig. 4 High time resolution measurement from burst memory of a modulated whistler wave.

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NRL-701 LASSII/QIMS Quadrupole Ion Mass Spectrometer on CRRES

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THE quadrupole ion mass spectrometer (QIMS) on the CRRES is one of the three instruments that make up the low altitude satellite studies of ionospheric irregularities (LASSII) investigation. Along with the other LASSII instruments, the goals of QIMS are to investigate the dynamics of naturally occurring irregularities in the equatorial ionosphere (e.g., spread-F plumes) and to diagnose the low altitude chemical releases from the CRRES satellite.

QIMS measures the identities and relative concentrations of ionospheric positive ions, both ambient and those produced by photoionization of the released chemicals. The mass spectrometer is designed to be sensitive to thermal ions in the stationary ionosphere and to the ions formed following chemical releases. These ions have energies in the range of 0–100 eV in the instrument's frame of reference. This is a very different operation regime than the other ion mass spectrometers onboard CRRES. For example, the ONR-307-3 low energy ion mass spectrometer measures the fluxes of radiation belt ions in the energy range of 500 keV to 100 MeV.

The design of the QIMS mass spectrometer was adapted from similar instruments that have been flown successfully on many sounding rockets.[1-3] QIMS consists of a sensor and an electronics box. The sensor, shown in Fig. 1, incorporates a circular, motor-driven cover that maintains a high vacuum in the instrument during ground testing and is opened by command once the satellite is in orbit. Immediately underneath the cover is the aperture plate that is biased at -10 V to draw ions into the instrument, and the quadrupole rods, which run down the axis of the cylindrical front part of the sensor. The electron multiplier, the high voltage power supply, the radio frequency (rf) amplifier, and the logarithmic current amplifier for the aperture plate are contained in the back half of the sensor package. The electronics box contains the low voltage power supplies, programming circuitry, pulse counter, and command and telemetry systems. The sensor is 14 in. long, the electronics box is a 6-in. cube, and the weight of the instrument is 28 lb.

The mass range of the spectrometer is 4–155 amu. All ambient ions (with the exception of H^+) and all ions derived from the chemical releases fall into this range. The resolution of the instrument was adjusted to give the mass peaks a full width at half-maximum of ~ 2 amu across the entire mass range. This is sufficient resolution to separate the two O^+ isotopes at masses 16 and 18, to separate the ambient molecular ions at masses 28, 30, and 32, and to differentiate between all of the metal ions (Li^+, Sr^+, Ca^+, Ba^+, and Eu^+) derived from the chemical releases. Because the total ion density is measured by the aperture plate and the LASSII P^3 Langmuir

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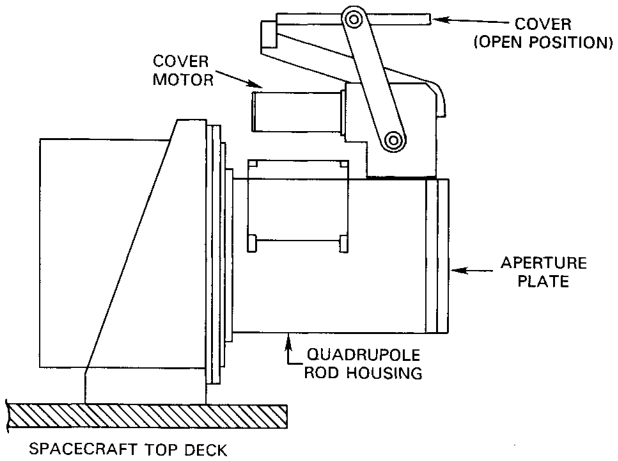

Fig. 1 Outline drawing of QIMS sensor.

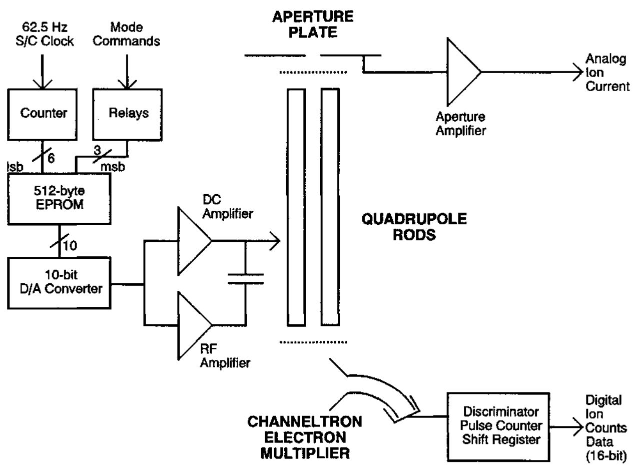

Fig. 2 Block diagram of QIMS electronics.

probe, a very high sensitivity for the instrument was chosen during calibration to maximize detection of trace species. A first look at flight data from the instrument indicates that the detection limit may be as low as 0.05 ion/cm^3.

The block diagram of the QIMS electronics in Fig. 2 indicates how the instrument is controlled. The passband of the quadrupole mass filter is determined by the values of the rf and dc voltages applied to the rods. The amplitudes of these voltages set the center of the passband and the ratio between them controls the width. Preprogrammed sequences of measurements are stored in a 512 address EPROM memory. Each address contains a 10-bit code for the particular mass to be measured. This code is converted into a control voltage for the rf and dc amplifiers by a 10-bit digital-to-analog converter.

The EPROM memory is functionally divided into eight octants by directly controlling the three most significant bits of the address word with latching relays. The six mode commands for the QIMS are three groups of "set" and "reset" commands for these relays. These are the only commands, other than power on/off and cover open commands, that are sent to the instrument in flight. The six least significant bits of the address are controlled by a binary counter that is advanced by a 62.5-Hz spacecraft clock synchronized with the telemetry system. The clock cycles the instrument through one of the eight sets of 64 measurements selected by the mode commands.

Each of the eight measurement sequences steps the instrument from the top of one mass peak to the top of another rather than mapping out the full shape of each peak and valley. Peak stepping is chosen to maximize the temporal and spatial resolution of the measurements. The eight sequences are listed in Table 1. Sequence 7 is for low spatial resolution measurements of ionospheric composition and the spacecraft environment. Sequences 2 and 5 are used for measurements of equatorial spread-F dynamics. Two sequences, 1 and 6, are set aside for the frequent Ba/Sr chemical releases. Sequence 1 favors temporal and spatial resolution by minimizing the number of measurements made, and sequence 6 increases the dynamic range of the Ba ion measurements. In case the mass 138 Ba^+ signal saturates, sequence 6 includes measurements of Ba^{++} (which should be approximately a factor of 10^4 lower in concentration than Ba^+; see Ref. 3) and the less prevalent ^{135}Ba isotope, which will be a factor of 10 lower in density than ^{138}Ba. To increase the instrument sensitivity, sequence 6 also includes measurements in the high pass mode of the mass filter, which has a greater throughput. The total concentration of ions greater than mass 70, called the total ions or TI(70) measurement, will give a high sensitivity measurement of the combined concentrations of Sr^+ and Ba^+, whereas TI(100) will include only Ba^+. Sequences 3 and 4 are for the specialized Ba/Ca and Ba/Li or Ba/Eu releases. Finally, sequence 0 is a multipurpose sequence designed as a backup for the others.

The block diagram also shows the two types of science data provided by the instrument: 1) the total ion current collected on the aperture plate and 2) the number of ion counts at each measurement mass. The QIMS telemetry also includes a number of instrument health and status monitors.

The mass spectrometer is mounted on the top deck of the CRRES spacecraft, directly over compartment 4. The sensor is perpendicular to and pointed radially outward from the spin axis of the satellite. This mounting position is shown schematically in Fig. 3. When the spin axis is aligned with the velocity vector, QIMS has a constant attack angle of 90 deg. When the spin axis is perpendicular to the velocity vector (CRRES trav-

Table 1 QIMS measurement sequences

Sequence no.	Ion masses measured[a]					Sequence use
0	4	7	13	14	16	Multipurpose
	18	28	30	32	40	
	88	138	TI(1)			
1	16	88	138			Ba/Sr chemical release (short)
2	4	16	18	30		Plume dynamics
3	7	16	138	151		Ba/Li/Eu chemical release
4	16	40	138			Ba/Ca chemical release
5	4	16	30			Plume dynamics
6	16	69	88	135	138	Ba/Sr chemical release (long)
	TI(70)	TI(100)				
7	4	13	14	16	18	Ionospheric composition
	28	30	32	TI(1)		

[a]Species identities are 4(He^+), 7(Li^+), 13(background), 14(N^+), 16(O^+), 18($^{18}O^+$, H_2O^+), 28(N_2^+), 30(NO^+), 32(O_2^+), 40 (Ca^+), 69 (Ba^{++}), 88(Sr^+), 135($^{135}Ba^+$), 138 ($^{138}Ba^+$), 151(Eu^+). TI(1) TI(70), and TI(100) are total ions measurements.

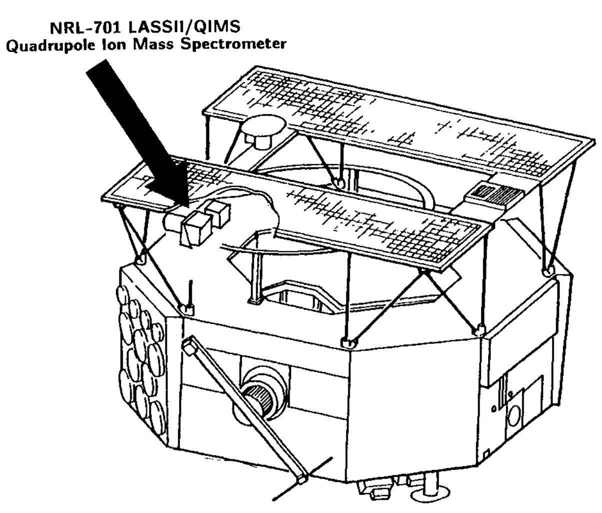

Fig. 3 Location of QIMS on CRRES spacecraft.

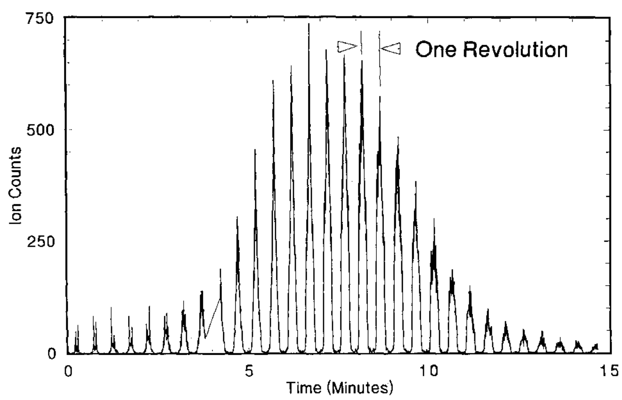

Fig. 4 Sample of flight data showing NO^+ current as a function of time during a CRRES perigee pass.

eling "sideways"), QIMS sees a strong ram/wake modulation as the attack angle varies from 0 to 180 deg.

Because QIMS is an ionospheric instrument, it is operated only at perigee of the highly elliptical CRRES orbit. A sample of mass spectrometer data from such a perigee pass is shown in Fig. 4. QIMS was turned on when CRRES was at about 1000 km in altitude ($T = 0$ min in Fig. 4), remained on as the satellite went through perigee at about 400 km ($T = 7$ min), and was turned off when CRRES again reached 1000 km. The overall envelope of the NO^+ count rate shows the altitude variation of this low altitude molecular ion, which peaks at perigee. The sharp spikes in the count rate are due to ram/wake spin modulation as the spacecraft spins at 2 rpm. The QIMS sensitivity is highly attitude dependent and is greatest when pointing close to the velocity vector direction.

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Extremely Low Frequency Wave Analyzer

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Introduction

THE Space and Environment Technology Center of The Aerospace Corporation has provided an extremely low frequency wave analyzer (ELFWA) for the Low Altitude Satellite Study of Ionospheric Irregularities (LASSII) instrument complement on the CRRES spacecraft. The objectives of the LASSII experiment are to understand the effects of naturally occurring and artificially created irregularities in the ionosphere on communication, navigation, and radar signals propagating through the ionosphere. LASSII will also determine the threat of ionospheric modification by chemical releases and high-power radio transmitters to various communication, command, control, and intelligence systems.

The ELFWA instrument measures electrostatic and electromagnetic ion waves in the ambient ionosphere and during active experiments involving chemical releases and the ionospheric heater at Arecibo, Puerto Rico. It also measures long-wavelength (> 100 m) electron density irregularities. These irregularities degrade communication, navigation, and radar signals that propagate through the ionosphere.

Description

The ELFWA measures single-axis electric field spectra and amplitudes from 10 to 250 Hz and single-axis magnetic field spectra and amplitudes from 10 to 125 Hz. The instrument consists of two antennas, two preamplifiers, and two electronics boxes connected as shown in Fig. 1. The electric field antenna consists of two spherical probes, each 6.35 cm in diameter, deployed on booms 190.5 cm long above the spacecraft as shown in Fig. 2. The probes are coated with Acheson Electrodag 121 graphite semicolloidal dispersion in an organic binder. The probes are separated by 4.5 m. Preamplifiers at the base of each boom have unity gain. The signals from the two probes are differenced in the E-field electronics package to provide a single-axis measurement of the electric field in the spin plane of the spacecraft.

The magnetic field antenna is a 50-cm diam, 1600-turn loop of AWG36 copper wire. The antenna is deployed on a 2-m boom as shown in Fig. 2. The boom consists of hinged tube assemblies constructed in two segments. It is canted slightly upward to clear the canister ejection trajectories for the chemical canisters used for the chemical release experiments. The resistance of the antenna wire is 3500 Ω, and the inductance is 4.5 H. The preamplifier input impedance is 30 kΩ at 2200 Hz. An external load resistance is adjusted to 20 kΩ to provide 10 mV out from the antenna for a 10-nT field at 2200 Hz. At 100 Hz, a 5-nT field produces 1 mV out of the antenna. The preamplifier at the base of the boom has a gain of 100. The B-field antenna signal output frequency response is −6 dB per octave in the 125 to 12.5 Hz frequency range. The preamplifier has been frequency compensated with 6 dB per octave bass boost to produce a flat frequency response from the antenna and preamplifier combination from 10 to 125 Hz. The single-

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