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FOR THE PERIOD AUGUST 1, 1965 THROUGH OCTOBER 31, 1965

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COMPARISON OF ROCKET-BORNE PROBES FOR ELECTRON DENSITY MEASUREMENTS

J. A. FEJER, W. J. HEIKKILA, O. HOLT
PRINCIPAL INVESTIGATORS

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Construction and testing of all three flight units was completed on schedule, and the final checkout and test of each flight unit was made at the Goddard Space Flight Center from August 18 through August 27, 1965. The rockets were launched on schedule; NASA 14.213UA was launched on August 31, 1965, and NASA 14.214UA was launched on September 1, 1965. The backup rocket, NASA 14.76, was not launched.

NASA 14.213UA was a successful flight with the only failure being the breaking off of the 20 ft. antennas as they unreeled from the rocket. However, the instrument from CRPL (Central Radio Propagation Laboratory, Boulder, Colorado) did receive good data before the antennas broke. Telemetry received during the flight indicated no other electrical or mechanical failure, and with the exception of the antennas, all experiments performed satisfactorily.

NASA 14.214UA had a major failure in the clamshell system; the clamshell failed to deploy at the scheduled time. Therefore, no data was received from those experiments using probes housed within the clamshell. However, data was received from the CRPL experiment using the 20 ft. antennas before they broke off during deployment.

The backup payload to be launched on NASA 14.76 was returned to the Graduate Research Center to await further data analysis and to make necessary design changes. Before launching NASA 14.76 the following steps are being planned: (1) redesign of the CRPL antenna system, (2) revaluate the clamshell design both electrically and mechanically, and test for cause of failure, and (3) make any necessary instrument design changes which are indicated by the data received from the two previous flights. Telemetry received during the flight indicated all instruments functioned properly throughout the complete flight.

The firing data for NASA 14.76 has been tentatively set for the first quarter of 1966.

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REPORT ON A MULTIPLE IONOSPHERIC PROBE ROCKET EXPERIMENT

W. J. Heikkila

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SOUTHWEST CENTER FOR ADVANCED STUDIES
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REPORT ON A MULTIPLE IONOSPHERIC PROBE ROCKET EXPERIMENT

While radio wave propagation methods have considerable merit in ionospheric studies, nevertheless, it is often found desirable or necessary to use probe methods for local measurements near the rocket or satellite. This need arises partly out of the presence of space-time variations in the electron concentration. Unfortunately, many probe methods are subject to error due to the interaction between the probe and the ionospheric plasma. A program for the careful evaluation and comparison of different probe techniques has, therefore, been undertaken. This program is based on the philosophy that the ionosphere provides the best possible plasma laboratory, and the several probes have, therefore, been instrumented into a rocket payload. Each payload, called a "Multiple Ionospheric Probe" includes five different types of probes for electron density measurements, four of these being instrumented by the Southwest Center for Advanced Studies, Dallas, Texas, and one by the Central Radio Propagation Laboratory, Boulder, Colorado. The experiments are listed on the first slide.

The first of these instruments is the "Resonance Relaxation Probe", a low-power radar sweeping the frequency range from 3.0 down to 0.1 MHz in 0.5 seconds; it is designed to detect slowly decaying plasma oscillations of the types observed with the Alouette and Topsy satellites. Such plasma resonances occur near the plasma frequency ω_N, the electron cyclotron frequency ω_H and its harmonics, and the upper hybrid frequency $\omega_T = \sqrt{\omega_N^2 + \omega_H^2}$. Particular objectives were the measurement of the intensity of the resonances as a function of electron concentration, collision frequency, and length of antenna. This experiment was also included in the payload for the purpose of providing a calibration for the other probes, since this probe is not as likely to be influenced by sheath effects. This probe was instrumented by W. Calvert and J. Hugill of CRPL.

A second instrument, the Variable Frequency Impedance Probe, was designed by J. A. Fejer and K. Tipple to measure the real and imaginary parts of the impedance of an 11.6 cm diameter sphere. The experiment was designed to show the nature of this impedance over a broad frequency range (3.0 to 0.1 MHz) on either side of the plasma frequency.

The third instrument, also due to J. Fejer and K. Tipple, is the "Resonance Rectification Probe", similar to probes first used by Japanese workers. This probe measures the floating DC potential of the same 11.6 cm sphere, while the swept frequency RF voltage is applied. The negative floating potential of such a probe shows a resonant maximum near a certain frequency. It was at first thought that this frequency is the plasma frequency, but recent theoretical considerations indicate that the maximum occurs below the plasma frequency. The experiment provides for a test of this theory.

The fourth instrument, designed by W. J. Heikkila and N. Eaker, is a capacitance probe operating at a frequency well above the plasma frequency; in this case, two separate frequencies in turn, 5 and 10 MHz. The same 11.6 cm sphere is used on a time shared basis with the previous experiments. This spherical capacitor serves as the tuning element in an oscillator circuit, the oscillator frequency being then a convenient measure of the dielectric constant of the plasma. In the absence of ion sheath effects, a change in oscillator frequency would be directly proportional to a change in electron concentration; however, the ion sheath effects are significant and difficult to evaluate. The primary purpose of this experiment is to evaluate the ion sheath effect quantitatively, making use of the accurate determination of electron concentration provided by the resonance relaxation probe.

The fifth, and final type of experiment in the payload, again due to W. J. Heikkila and N. Eaker, is a DC probe. Two different instruments were included; one, the so-called "Electrostatic Probe" measured the ion current to the large sphere, while the other was a conventional Langmuir Probe, using both a spherical, and a cylindrical collector in turn. These measurements were intended to test electrostatic probe operation, and to measure the vehicle potential.

The different experiments were programmed to operate on a time-shared basis in order to avoid mutual interference. A total of eight telemetry channels were utilized, including one with a bandwidth of 10 KHz.

Figure 2 is a typical portion of the flight record, obtained at an altitude of 146 kilometers. Three different modes of operation are shown labeled Periods IIB and IIIB of Frame No. 46 and Period IA of Frame No. 47. Only four of the telemetry channels are shown. During Period I, channel H of the telemetry carried the A-scan for the resonance relaxation experiment as shown on the right hand side of the slide. In this scan, the frequency is swept from 3.0 MHz down to 0.1 MHz in about 1/2 second. The responses at the extreme beginning and end of this sweep are instrumental and should be ignored. During the actual sweep several resonances are apparent, including the one at the electron cyclotron frequency, one at the plasma frequency, one at the upper hybrid frequency, and one at the second harmonic of the cyclotron frequency. At times, the resonances are broad and poorly formed; at other times, they are clean and symmetrical. It is possible that ionospheric reflections are present; these cannot be resolved on this presentation. In general, the resonances occur at the expected frequencies and with the expected relationships throughout the flight, so that identification of the resonances is reasonably conclusive. Channels 12CW and 10CW carried information on the impedance of the antennas. Unfortunately, parts of the antennas broke off and only weak responses on the impedance channels were obtained. Channel 8CW carried Langmuir Probe sensitivity range information during Period I, the main Langmuir probe data being carried on another telemetry channel not shown on this slide.

During Period II, the transmitter for the resonance relaxation experiment was turned off, but the receiver was left on with its output on Channel II. At this time, it was receiving a signal from the variable frequency impedance and resonance rectification probes, whose outputs are carried on the next three channels. The receiver output showed a strong signal with a smooth frequency dependence in the absence of the plasma; in the ionosphere, however, this signal was reduced considerably at several distinct frequencies. Four of these resonances could be identified as being the same resonances as shown during Period I; namely, ω_H, ω_N, ω_T, and $2\omega_H$. Two other resonances were observed fairly consistently throughout the flight, one near the cyclotron frequency, and one near the plasma frequency. These two resonances have not yet been identified.

The impedance of the sphere did show a resonant behavior at a frequency which was in general not the plasma frequency. When the plasma frequency was appreciably greater than the cyclotron frequency, as in the case shown, the resonance occurred at a frequency below the plasma frequency. When the plasma frequency decreased below the cyclotron frequency, the resonance remained above the cyclotron frequency. This resonance appeared to be controlled by some combination of the cyclotron and plasma frequencies, such as perhaps the hybrid frequency.

The sphere potential was telemetered on Channel 8 CW. During much of the flight the apparent potential was off-scale indicating that the vehicle potential was more negative than had been anticipated, in excess of 0.5 volts. For this reason, no rectification effect is indicated during this sweep, but the next slide shows such an effect, for Frame No. 70B at an altitude of 146 km. during descent. The evidence is conclusive that the resonance rectification does not occur at the plasma frequency. To this extent, the theory mentioned earlier was corroborated; however, the theory did not take the effect of the magnetic field into account and the results show clearly that the magnetic field influence is strong.

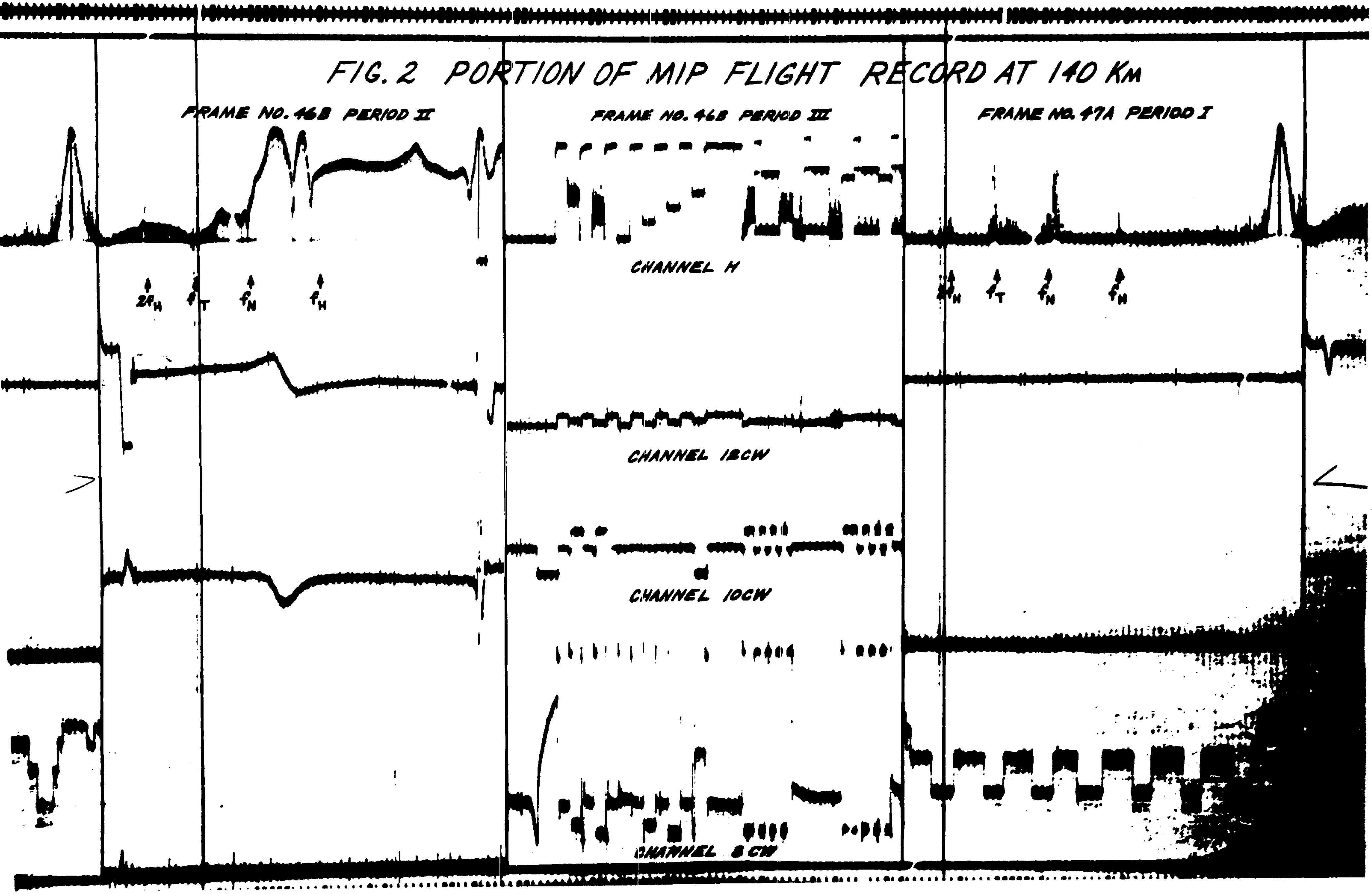
During Period 3, the sphere was switched to the high frequency capacitance probe experiment. During this period, a complex bias program was played on the sphere, consisting of a swept portion, six different steps ranging from -250 volts to -1 volt alternated with +1.4 volts and finally, four broader steps of 1.4 volts and -100 volts. Throughout this time, the probe oscillator frequency was measured by means of a discriminator, with the data carried on Channel H. The frequency was also determined by a counting technique during four 32 ms. intervals during the latter half of the bias program, with a digitally coded result read in four short bursts as shown. The RF excitation was not applied while the swept bias was applied in the example shown; it was applied on alternate frames. The tops of the pedestals are a measure of the sphere capacitance with +1.4 volts applied relative to the rocket body. Under this condition, it may be assumed that the large sphere was only slightly negative with respect to the plasma. The ramp steps indicate the dependence of the capacity on (negative) sphere potential. The measured capacitance as a function of potential will permit a complete evaluation of the ion sheath behavior as a function of probe potential. During Period 3, Channels 12 CW and 10 CW carried ranging information for other channels and need not be described here. Channel 8 CW carried the electrostatic ion current to the large sphere. The combined measurements of ion current and high frequency capacitance will permit a complete and quantitative test of electrostatic probe theory, such as that of Bernstein and Rabinowitz.

Only a very preliminary analysis of this data has thus far been performed. The qualitative conclusions just presented are probably reliable; however, further detailed reduction and analysis must be carried out. Some of the results of the early analysis are shown in Figure 3, in the form of an electron concentration profile. These results were obtained by means of the resonance relaxation, the high frequency capacitance, and the electrostatic probes, these last two being normalized to agree with the resonance relaxation result at the peak of the E-layer. This comparison should be taken as qualitative only since the ion sheath effects are not independent of height. The E-region critical frequency indicated by the ionogram taken just before the flight at Wallops Island is also shown on the slide.

EXPERIMENT	METHOD	PROBE	OBJECTIVES
1. Resonance Relaxation	Sounder 3.0 to 0.1 MHz swept	Dipole 12 m	(a) Dependence on N, ν, L (b) Accurate N
2. Variable Frequency Impedance	Quadrature currents 3.0 to 0.1 MHz	Sphere 11.5 cm	Z over large frequency range about f_N
3. Resonance Rectification	Floating potential 3.0 to 0.1 MHz		Compare resonant frequency with f_N
4. High Frequency Capacitance	Frequency shift of oscillator 5 and 10 MHz		Evaluate sheath effect
5. D.C. probes a) Electrostatic	Ion current		Test electrostatic probe theory
b) Langmuir (2)	Electron and ion currents	Small wire and sphere	Vehicle potential

Figure 1. MIP Rocket Experiments

FIG. 2 PORTION OF MIP FLIGHT RECORD AT 140 KM



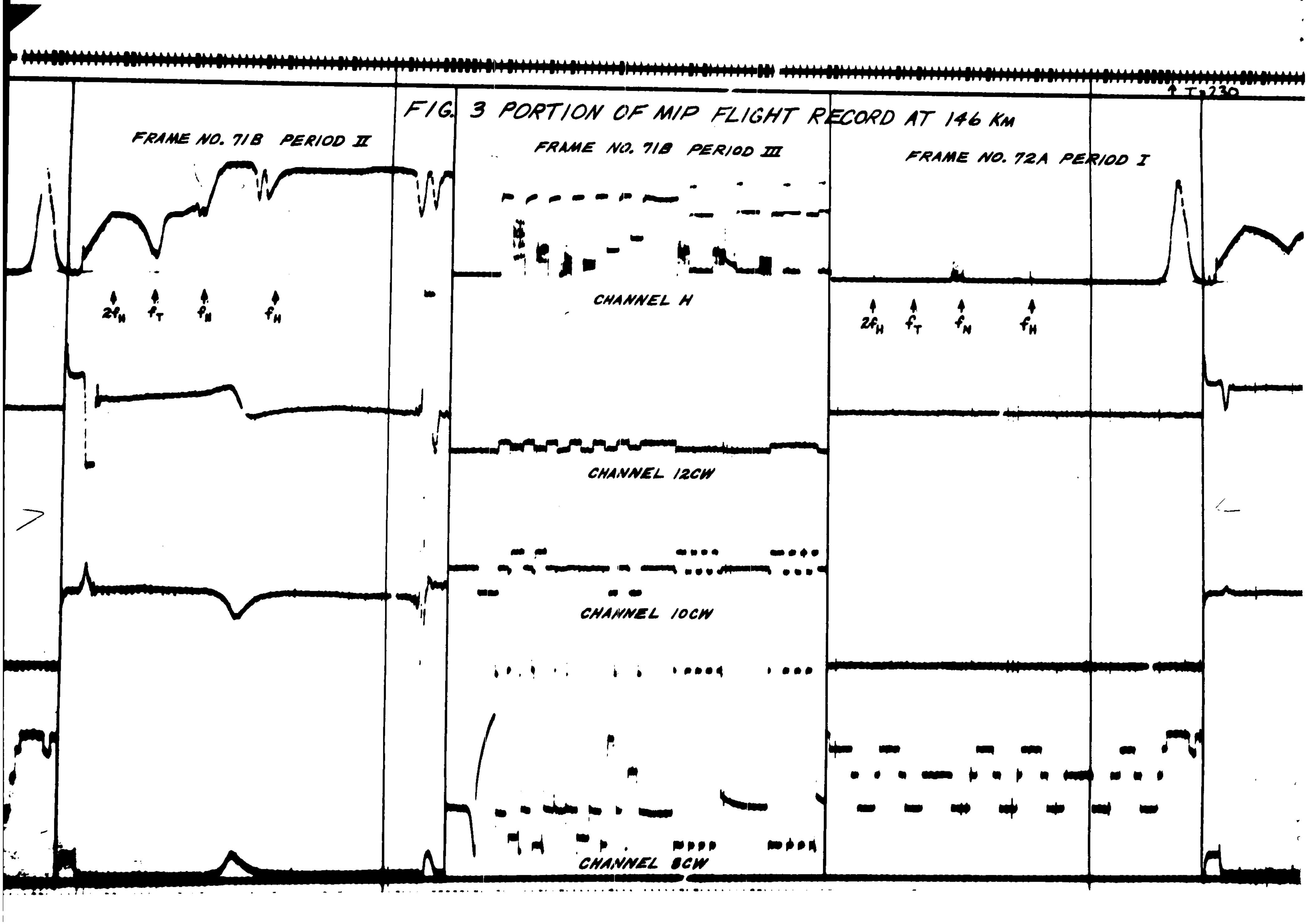


FIG. 3 PORTION OF MIP FLIGHT RECORD AT 146 KM

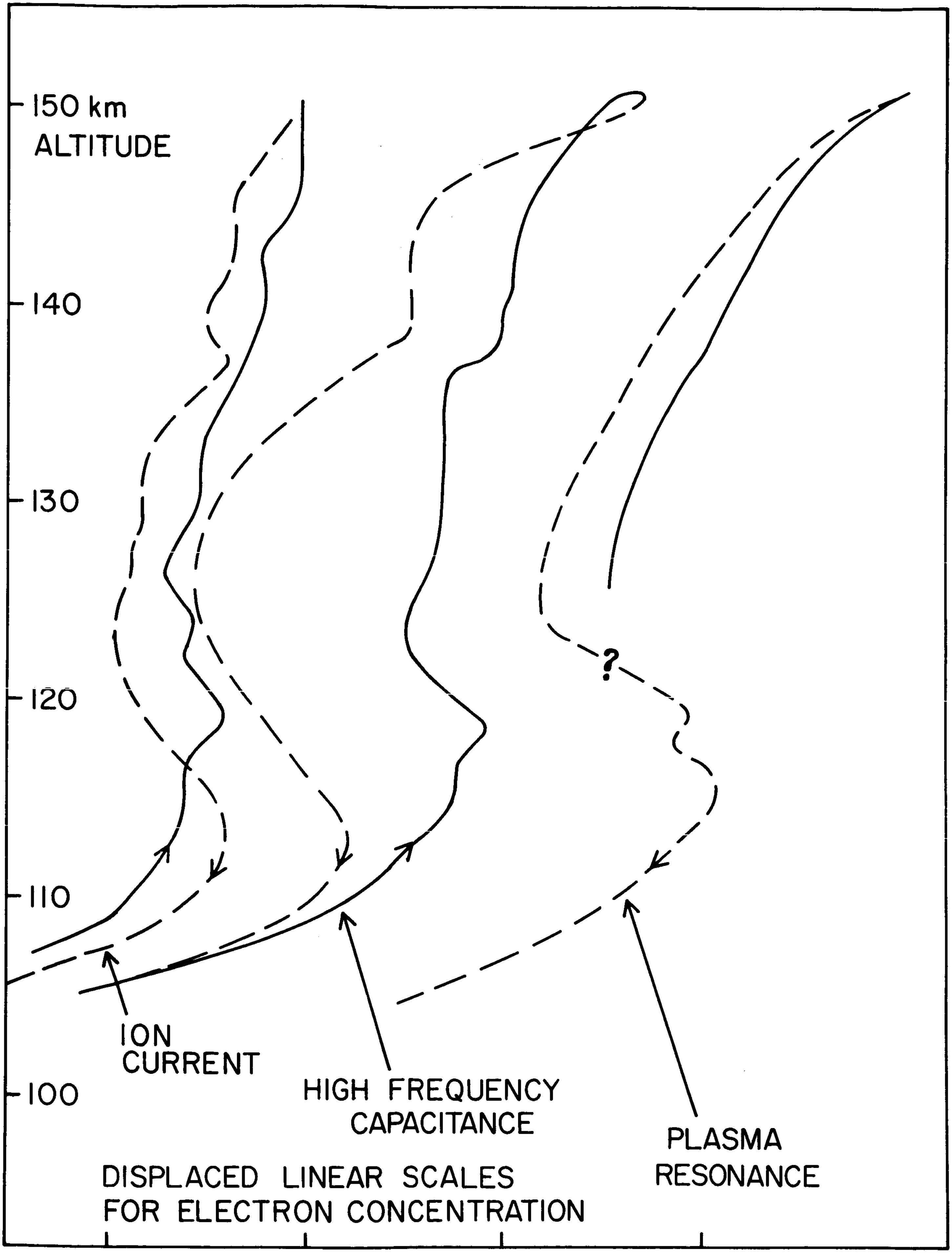


FIG. 4 PRELIMINARY RESULTS OF MIP 14.213