



#420

ESRO-4

POSITIVE ION DATA

72-092A-01A

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1. INTRODUCTION:

The documentation for this data set was originally on paper, kept in NSSDC's Data Set Catalogs (DSCs). The paper documentation in the Data Set Catalogs have been made into digital images, and then collected into a single PDF file for each Data Set Catalog. The inventory information in these DSCs is current as of July 1, 2004. This inventory information is now no longer maintained in the DSCs, but is now managed in the inventory part of the NSSDC information system. The information existing in the DSCs is now not needed for locating the data files, but we did not remove that inventory information.

The offline tape datasets have now been migrated from the original magnetic tape to Archival Information Packages (AIP's).

A prior restoration may have been done on data sets, if a requestor of this data set has questions; they should send an inquiry to the request office to see if additional information exists.

2. ERRATA/CHANGE LOG:

NOTE: Changes are made in a text box, and will show up that way when displayed on screen with a PDF reader.

When printing, special settings may be required to make the text box appear on the printed output.

Version	Date	Person	Page	Description of Change
01				
02				

3 LINKS TO RELEVANT INFORMATION IN THE ONLINE NSSDC INFORMATION SYSTEM:

<http://nssdc.gsfc.nasa.gov/nmc/>

[NOTE: This link will take you to the main page of the NSSDC Master Catalog. There you will be able to perform searches to find additional information]

4. CATALOG MATERIALS:

- a. Associated Documents To find associated documents you will need to know the document ID number and then click here.
<http://nssdcftp.gsfc.nasa.gov/miscellaneous/documents/>

- b. Core Catalog Materials

ESRO-4

POS. ION DATA, TAPE

72-092A-01A SPMS-00064

THIS DATA SET HAS BEEN RESTORED. ORIGINALLY IT CONTAINED THREE 9-TRACK, 1600 BPI TAPES WRITTEN IN BINARY. THERE IS ONE RESTORED TAPE. THE DR TAPE IS 3480 CARTRIDGE AND THE DS TAPE IS 9-TRACK, 6250 BPI. THE ORIGINAL TAPES WERE CREATED ON AN IBM 360/65 COMPUTER AND WERE RESTORED ON THE MRS COMPUTER. THE DR AND DS NUMBERS ALONG WITH THE CORRESPONDING D NUMBERS AND TIME SPANS ARE AS FOLLOWS:

DR#	DS#	D#	FILES	TIME SPAN
DR005273	DS005273	D030957	1	11/22/72 - 05/10/73
		D030958	2	05/11/73 - 11/04/73
		D030959	3	11/04/73 - 04/14/74

REQ. AGENT
CMP

RAND NO.
RC9052

ACQ. AGENT
RNH

ESRO-4

POSITIVE ION DATA

72-092A-01A

This data set catalog contains 3 tapes. They are 9 track, Binary, 1600 BPI, and created on an IBM 360/65 computer. Also included in this catalog is a listing supplied by the experimenter of D-30957. Each tape has 1 file. The tape format is on page VI-2 of the Post Launch Report.

<u>D#</u>	<u>C#</u>	<u>TIME SPAN</u>
D-30957	C-19813	11/22/72 - 05/10/73
D-30958	C-19814	07/17/73 - 11/04/73
D-30959	C-19185	11/04/73 - 04/14/74

72 - 092A - 01

**ESRO-4 EXPERIMENT
S45
TECHNICAL DESCRIPTION**

**MULLARD SPACE SCIENCE LABORATORY
UNIVERSITY COLLEGE LONDON**

EXPERIMENT S45 TO BE FLOWN ON ESRO SATELLITE ESRO - 4

An experiment to measure the structure of the major ionic species in the topside ionosphere over a height range of 350 - 1000 km at latitudes from -90° to $+90^{\circ}$ geographic.

**W.J. Raitt
Mullard Space Science Laboratory
University College London
April, 1970**

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1. Purpose of Experiment

The purpose of the experiment is to investigate the properties of the major ion species of the topside ionosphere with particular attention to ionic species, energy distribution and drift velocity. The main sensor will be backed up by other sensors to assist in the analysis, and as a by-product these other sensors will provide information on electron temperature, electron density and irregularities in the total ion density as small as a change of 0.5%.

2. Method Used

All of the sensors referred to above will consist of electrodes immersed in the ionospheric plasma attached to suitable electronic analysers so that functions of the current flowing to the electrodes in terms of the voltage applied to them may be studied. This type of sensor is known as the Langmuir probe after the American physicist Irving Langmuir (1926) who did much to develop both the theoretical and practical aspects of probes during the 1920's and 1930's.

The biasing voltages for the electrodes are chosen so that measurements may be made on both negative and positive charge carriers.

The main sensor consists of a large, spherical ion collecting probe of 19 cms diameter. This is supplemented by an electron collecting spherical probe to ascertain vehicle potential, and a spherical probe monitoring total ion current mounted on the spin axis of the vehicle to avoid spin modulation effects on this current.

3. Outline of Theory

The work of Langmuir has been extended by Medicus (1961, 1962) who has, in particular, applied the theory to the case of a plasma-consisting of ions having a Maxwellian velocity distribution due to their temperature superimposed on a steady drift velocity. This is, in fact, the situation applicable to a probe mounted on a spacecraft, the drift velocity being the spacecraft velocity relative to the plasma.

3.1. Spherical ion probe

This probe will be referred to henceforth as a mass spectrometer because of its ability to resolve different ion species. This may be understood qualitatively by considering that an ion of species i will have an energy in the frame of reference of the spacecraft of

$$E_i = \frac{1}{2} m_i V_s^2 \dots \dots \dots (1)$$

where V_s is the spacecraft velocity.

Thus, in order to prevent ions of this species reaching the probe, a voltage V given by

$$eV_i = \frac{1}{2} m_i V_s^2 \dots \dots \dots (2)$$

must be applied to the probe.

Thus, in principle, by observing discontinuities in the current collected by the probe as the applied voltage is changed, the presence of various species may be detected. In practice, the ions have a random velocity distribution superimposed on this drift so the discontinuities are not sharp; however, provided

$$V_t \ll V_D$$

the discontinuities can be separated, where V_t = thermal vel.

V_D = drift vel.

It can be seen that this is a positive voltage, therefore to prevent the ion current being swamped by an electron current a grid biased to a negative potential must surround the probe surface. It can be shown from considerations of the conservation of angular momentum, that as far as the ion current collected by a spherical probe is concerned the grid has no effect other than to introduce a transparency factor.

Druyvesteyn (1930) has shown that the energy distribution of the ions is related to the current J collected by a Langmuir probe at potential V is given by

$$N(V) dV = \frac{d^2 J}{dV^2} / V^{\frac{1}{2}} \dots \dots \dots (3)$$

where $N(V)$ is the number of particles having energy $V \rightarrow V + dV$
Medicus (1962) gives the expression

$$\frac{d^2J}{d\eta^2} = K \left[\frac{\exp(-\eta - \eta_0) \sinh(2(\eta \eta_0)^{\frac{1}{2}})}{(\pi \eta \eta_0)^{\frac{1}{2}}} \right] \dots \dots \dots (4)$$

- where
- $\eta = V/kT$
 - $\eta_0 = V_0/kT$
 - $K = \pi n e n \left(\frac{2kT}{m}\right)^{\frac{1}{2}} \cdot r^2$
 - $e =$ electron charge
 - $n =$ ion density
 - $m =$ ion mass
 - $r =$ probe radius
 - $V_0 =$ drift energy of ion species when thermal velocity is zero
 - $T =$ ion temperature.

This expression is for one ion species assuming a Maxwellian velocity distribution.

If we write

$$S_1(\eta) = \frac{\exp(-\eta - \eta_{0i}) \sinh(2(\eta \eta_{0i})^{\frac{1}{2}})}{\eta^{\frac{1}{2}}} \dots \dots \dots (5)$$

We can write the second derivative of current as a function of voltage for the *i*th species as

$$\frac{d^2J}{dV^2} = \frac{nAe}{kT m_i v_s \pi^{\frac{1}{2}}} S_1(\eta) \dots \dots \dots (6)$$

where $A = \pi r^2$

Thus, if there are *P* ion species of fraction *f_i*

$$\frac{d^2J}{dV^2} = \frac{nAe}{k m_p^{\frac{1}{2}} v_s \pi^{\frac{1}{2}}} \cdot \frac{1}{T} \cdot \sum_{i=1}^P \frac{f_i}{M_i} S_1(\eta) \dots \dots \dots (7)$$

- where $m_p =$ proton mass
 $M_i =$ mass number of *i*th species.

Theoretical curves for this function have been evaluated and are shown in fig. 1.

It can be seen from the diagram that for the ion species expected in the topside F-region identification can be made, but complete resolution of

H^+ and He^+ is not possible. However, the resolution of the instrument should be sufficiently high for the two peaks to be distinguished in most of the circumstances when both H^+ and He^+ ions are present.

For the peak of a given ion species we have the relations:

$$V_m = f_1 (V_s, M_i, T_i)$$

$$W = f_2 (V_s, M_i, T_i)$$

$$A = f_3 (V_s, M_i, T_i, n_i)$$

where

V_m = Voltage at which peak maximum occurs

W = Width of peak at say half amplitude

A = Amplitude of peak

In fact V_m varies rather slowly with T_i and since the major ions present in the F-region are known to be H^+ , He^+ or O^+ this provides a positive identification of M_i providing the potential of the vehicle relative to the ambient plasma is known. Having determined M_i , T_i can be found from W and then n_i from A .

The functions f_1 , f_2 and f_3 are determined by evaluating the expression (7) for the particular species of ion expected.

3.2 Electron collecting probe

For the electrons, their thermal velocity is much greater than their drift velocity, so we can use the theory for a Langmuir probe immersed in a plasma at rest which gives the current to the probe as

$$J(v) = 2\pi^{1/2} r^2 en \left(\frac{2kT_e}{m} \right)^{1/2} \exp \frac{v}{kT_e} \dots \dots \dots (8)$$

in the retarding region.

Now for a small spherical probe when the radius of the charge sheath around the probe is large compared with the probe radius Medicus (1961) shows that

$$J(v) = a + b V$$

in the accelerating region where for a Maxwellian velocity distribution

$$a = 2\pi^{1/2} r^2 en \left(\frac{2kT_e}{m} \right)^{1/2}$$

$$b = a/kT_e$$

That is, the variation of $J(v)$ for the accelerating region is linear and tangential to the variation in the retarding region.

This is illustrated in fig. 2. It can be seen that as a means of defining space potential, the current characteristic is not very suitable. However, if the first derivative is observed on a semi-logarithmic plot, it can be seen that it is possible to locate the point at which the probe and the plasma are at the same potential.

A further reason for measuring the first derivative of the current voltage relationship is that the effects of photo-electric currents are eliminated. In fact, the negative current to the probe is given fully by

$$J(v) = J_e(v) - J_p - J_i(v)$$

where J_e is given by equation (8)
 J_p is photo-electric current
 J_i is positive ion current

Now, $J_i = J_e$ (see section 5) and J_p is constant.

$$\therefore \frac{dJ}{dV} = \frac{dJ_e}{dV} \text{ only}$$

$$= 2enr_p^2 \frac{2}{km} \frac{1}{T_e^{1/2}} \cdot \exp(-v/kT_e)$$

in the retarding region

and $\frac{dJ}{dV} = 2enr_p^2 \frac{2}{km} \frac{1}{T_e^{1/2}}$ in the accelerating region.

Therefore, in the retarding region a plot of $\log \left(\frac{dJ}{dV} \right) v. V$ results in a straight line of slope $-\frac{1}{kT_e}$, from which the electron temperature T_e may be found, while in the accelerating region $\log \left(\frac{dJ}{dV} \right)$ remains at a constant value depending on $\frac{n}{T_e^{1/2}}$ from which n may be determined when T_e is known.

Thus, although the electron probe is primarily for location of vehicle potential, it also gives supplementary information on electron density and temperature.

3.3 Total ion density probe

For a spherical probe moving through the ionosphere of a velocity of V_g and biased -ve with respect to the plasma, the ion current collected is largely independent of attitude and given by:

$$I_p = N^+ e A V_s$$

where

N^+ = total ion density

e = electronic charge

A = probe cross sectional area

V_s = satellite velocity

The only attitude dependence is caused by the probe passing into the wake of the spacecraft.

Changes in I_p are therefore a direct monitor of fluctuations in the ambient positive ion density N^+ .

Since the emission of photo electrons from the probe surface adds to I_p the probe must be surrounded by a grid biased more negatively than the energy of the peak flux of photo-electrons from the surface. In this way the photo-emission current is reduced to a low value compared with the ion current.

4. Description of Sensors

4.1 Ion mass spectrometer and electron probe

As mentioned previously, this sensor consists of a sphere 19 cm in diameter to collect positive ions, and surrounded by spherical grid 20 cm in diameter biased negatively to prevent electrons reaching the probe surface. The stem supporting the grid is also at grid potential to avoid any high field strength areas in the immediate vicinity of the probe. Integral with the probe assembly is a pre-amplifier occupying one half of a cylindrical container mounted at the end of the grid supporting stem.

The pre-amplifier case also serves to support the electron probe on a short stem at right angles to the axis of the case, and the other half of the container is used as a preamplifier for this probe.

The detail assembly is shown in figure 4. The surface of both the large and small spheres are to be rhodium plated using plating techniques as similar as possible. This is to ensure that the contact potential between the two probes is low. Rhodium is chosen for the surface because of its durability, freedom from atmospheric corrosion and constancy of contact potential over a large plated area.

The two probes must be in close proximity so that the measurement of vehicle potential by the small probe is that applicable to the large probe.

and this is achieved by the mounting arrangement described above. The other criteria for positioning the probes is that they should be clear of the charge sheath surrounding the satellite, and also that they should have a field of view of as near 4π steradians as possible. These are achieved by mounting the probe assembly on a boom 1.2 metres long which is deployed to have its axis in the direction of the satellite coordinate system.

4.2 Total ion density probe

This probe consists of a rhodium plated sphere 9.0 cms in diameter surrounded by a spherical grid 10.0 cms in diameter. The sensor is mounted on a boom projecting from the spacecraft skin aligned with the spin axis. The assembly is shown in figure 5.

The probe is biased to a negative potential to collect positive ions and the surrounding grid to a more negative potential to suppress photo-electrons emitted from the probe surface.

There are no preamplifiers associated with this probe, the only electrical components in the vicinity of the probe being those to decouple R.F. signals picked up by the probe.

5. The Problem of Spacecraft Potential

In making probe measurements one is eventually faced with making voltage biasing measurements relative to the spacecraft as a reference. However, this is not tied to a large capacity body such as the earthing used in ground-based observations, and since we need to know these potentials relative to the ionosphere, it is important that the spacecraft adopts a potential not far removed from the ionosphere, and also that it remains stable.

When a satellite is moving through the ionosphere it tends to become negatively charged due to collection of electrons and positively charged due to collection of positive ions and photo-emission. If no point on the satellite generates an electric field from an internal source of potential, the spacecraft normally stabilises its potential at about one volt negative

to the ionosphere, at which potential the electron current equals the ion current plus the photo-electric current. If, however, there are any surfaces at positive potentials, they collect electrons, and unless this electron current is neutralised by providing sufficient clean metal for an increased ion current, the satellite will charge up to a relatively high negative potential.

The ratio of the electron current when a probe is at space potential to the ion current when an area of metal is also at space potential is given by

$$\frac{J_e}{J_i} = \frac{A_e}{A_i} \sqrt{\frac{m_i}{m_e}}$$

where A_e = area collecting electrons
 A_i = area collecting ions
 m_i = mass of ion
 m_e = mass of electron.

$\frac{J_e}{J_i}$ must be unity at equilibrium

$$\therefore A_i = A_e \sqrt{\frac{m_i}{m_e}}$$

$$= 170 A_e \text{ for } O^+ \text{ ions}$$

Now, if A_i is chosen to be this value the potential of the satellite will stabilise at some point about midway between zero and the maximum negative charge attained with equal ion and electron collecting areas. Furthermore, any variation of electron current collected will cause large variations in the spacecraft potential acting to counteract the sweep voltage being applied to the probe which would cause these changes in electron current.

We, therefore, make the ion collecting area

$$A_i \gg 170 A_e$$

so that the potential stabilises quite close to zero and changes in electron current have a very small effect on the satellite potential.

Thus, for the S45 experiment we have specified a clean area of 5000 sq. cm. to compensate for the current collected by a spherical electron probe of 1 cm. in diameter.

The calculations presented above are not exact because, of course, the ratio of J_e/J_i is for space potential surfaces, whereas a different potential is reached by the spacecraft. Accurate calculation is difficult because the current collecting characteristics of an irregular body such as the clean areas of the spacecraft is not readily predictable. However, the calculation serves to give an indication of the minimum clean area required.

6. Description of Electronics

The overall block diagram of the electronics is shown in fig. 7.

6.1 Mass spectrometer signal processing

The mass spectrometer probe has a varying sweep voltage applied to it in a manner described below, and added to this relatively slowly varying voltage are two alternating voltages at frequencies f_1 and f_2 and equal amplitudes the value of which is of the order of kT_i where T_i is the mean ion temperature expected (about 1000°K), and can be commanded to a lower amplitude. Non-linearities in the probe current/voltage relationship cause mixing of the two a.c. signals, the degree of mixing depending on the second derivative of the $i-v$ characteristic. Thus, by observing the amplitude of the current at the difference frequency ($f_1 - f_2$) a measure of the second derivative of the probe characteristic is obtained as the sweep voltage changes.

$$J(f_1 - f_2) = v_1 v_2 \frac{d^2 J_1}{dV^2}$$

where v_1 and v_2 are the amplitudes of the f_1 and f_2 signals. By filtering the current flowing to the probe the difference frequency component may be selected and rectified to obtain a measure of the value of $\frac{d^2 J_1}{dV^2}$.

In fact, the expected dynamic range of $J(f_1 - f_2)$ is about $\frac{d^2 J_1}{dV^2}$

80 db, so to obtain measurements over all conditions likely to be encountered in orbit the current is monitored by a logarithmic amplifier having four overlapping ranges. The form of the calibration curves for the amplifiers being as shown in fig. 8. During any one sweep two of the ranges only are used, either the high or low sensitivity pair, selection of the pairs being automatic and alternated from sweep to sweep of the probe voltage. A monitor of which sensitivity range is being used is kept by altering one of the experiment housekeeping channels to a preset value during one

sensitivity mode and monitoring the housekeeping signal during the other sensitivity mode.

6.2 Electron probe signal processing

The electron probe also has a sweep voltage applied to it and, in addition, a single alternating voltage f_3 of small amplitude less than or equal to kT_e where T_e is the smallest value of electron temperature expected to be encountered. The amplitude of the probe current at this frequency is, therefore, a measure of the mean value of $\frac{dJ_e}{dv}$ over the voltage defined by the amplitude of the a.c. signal. This component is filtered from the probe signal by using an a.c. bridge technique to prevent the applied signal reaching the input of the analysing amplifier when no probe current is flowing, and then using a selective amplifier to measure the off-balance component at f_3 when the probe is taking current.

Again, to cope with the wide dynamic range a logarithmic amplifier is used, but in this case only one range is used to cover a dynamic range of about 60 db. A further reason for using a logarithmic amplifier in this case is that the variation of $\log \frac{dJ_e}{dv}$ in the retarding region is a linear function of voltage as explained earlier.

6.3 Generation of sweep voltages

Previous experience in this type of probe has shown that the caution necessary to cope with unexpected variations in spacecraft potential has often led to considerable fractions of the data being transmitted when both electron and ion probes were so negative with respect to space potential that no useful information was obtained. To improve this situation a new technique has been adopted in sweeping the potential.

If we consider the start of a sweep cycle when both mass spectrometer and electron probes are at about -5 volts relative to spacecraft ground. The sweep generator produces a rapid increase in voltage on both probes until the signal from the electron probe rises above a certain threshold. At this time the sweep rate reduces to about 1 volt per second for both probes, and the electron probe changes the origin of its slowly rising region of sweep voltage. This is illustrated in fig. 9.

The effect of this is to bring the probes rapidly to about 1 volt below space potential, then to allow the mass spectrometer to increase slowly from that point, while the electron probe sweep voltage is reduced in order that

signals below the threshold may be studied.

When the ion probe voltage reaches a certain preset level both sweep voltages fly back to the starting point of about -5 volts.

It is not possible to specify an exact sweep period, the period is a function of electron temperature and spacecraft potential, but it is of the order of 10 seconds when operating in the searching mode.

Should the electron probe become faulty it is possible to change the mode of the sweep voltages to that of a normal repeating sawtooth waveform between defined voltage limits, on issuing one of the commands allocated to this experiment.

6.4 Total ion density probe signal processing

The current flowing to the total ion density consists of a relatively steady level (on a time scale of a few seconds) superimposed on which may be small fairly rapid variations caused by the spacecraft passing through irregularities in the ionosphere.

The circuitry separates these two components of the probe current in order that both the ambient ion density and small fluctuations may be observed. The mean d.c. current is amplified by a logarithmic amplifier and its output is presented to one of the low speed telemetry channels.

The fluctuating component is treated in a somewhat different manner. A circuit has been devised which gives an output to the telemetry

$$V = \frac{5}{\left(\frac{I_0}{I_p}\right)^\alpha + 1} \text{ volts}$$

where I_0 = current to probes at beginning of mass spectrometer sweep
 I_p = current measured during the course of the sweep
 α = preset sensitivity constant

Now the circuit automatically sets $I_0 = I_p$ at the beginning of each mass spectrometer sweep, so

$$V = 2.5 \text{ volts,}$$

then, depending whether I_p increases or decreases, the output voltage varies in a manner shown in figure 10.

It is planned to set α to a value greater than 10 so that very small fluctuations in (I_0/I_p) of 1% or less may be detected. The circuit will then

provide a measure of the small fluctuations which will have only a minor effect on the mass spectrometer, but are of geophysical interest; however, if a large fluctuation in ion density should occur this will be indicated by a zero or full scale reading of the output which will be an indication that the mass spectrometer data is suspect.

6.5 Electronics housing

Most of the electronics described is housed in a single electronics box located in the experimental area of the satellite. In addition, there is an AC/DC convertor to provide the voltage rails for the electronics from the spacecraft AC power supply. The whole unit weighs 1.9 Kg and consumes 400mW of electrical power.

The only electronics separate from this unit are two preamplifiers housed in a case on the boom containing the mass spectrometer.

6.6 Telemetry channels

The experiment uses 15 telemetry channels of which four are sampled at 0.15 sec intervals, two at 1.2 sec intervals and nine at 4.8 sec intervals. The quantities being measured are shown in fig. 7 and tabulated in Table I.

6.7 Command facilities

There are six commands used by the experiment to change sweep mode, bias voltages and a.c. amplitudes. These are tabulated in Table II.

7. Laboratory Stimulation of Probes

7.1 Mass spectrometer and electron probes

The current voltage characteristic of a diode is similar to that of a Langmuir probe in the ionosphere, and for this reason a diode with a suitable series resistance to limit the conduction current is connected to the probe. As the probe voltage is swept, the analysers then produce outputs of similar form to those expected in the ionosphere.

Precautions have to be taken in shielding the diodes to avoid unwanted signal pick-up, and also it is necessary to use a series combination of a point contact diode and a junction diode to give both low capacitance and low leakage current. In the case of the mass spectrometer two diodes will be used and by applying different bias voltages the situation of two ion species can be simulated.

The diode stimulation for both the mass spectrometer and electron probes will be housed in a shielded container mounted on the boom assembly with connections taken to the probe through contacts specially provided on the two probes.

7.2 Total ion density probe

In order to stimulate the steady current to the total ion density probe it is only necessary to connect a resistor between the probe and spacecraft ground. The fluctuating component of the ion current will be simulated by a low frequency oscillator powered by the voltage on the guard ring of the probe assembly.

The components to achieve this will be mounted on the protective covering of the probe surfaces which will have contacts on to the probes in addition to providing protection.

References

1. Mott Smith, H.M. and Langmuir, I. 1926, Phys. Rev. 28, 727.
2. Druyvesteyn, M.J. 1930, Z. Phys. 64, -790.
3. Medicus, G. 1961, J. Appl. Phys. 32, 2512.
4. Medicus, G. 1962, J. Appl. Phys. 33, 3094.
5. Norman, K. and Willmore, A.P. 1965, Planet. & Spa. Sci. 13, 1.

TABLE I

Telemetry channel	Sample Interval (sec)	Measured parameter
1	0.15 0.2	Ion probe 2nd derivative (high sensitivity)
2	0.15 0.2	Ion probe 2nd derivative (low sensitivity)
3	0.15 0.2	Electron probe 1st derivative
4	0.15 0.2	Plate probe fluctuations
5	1.20	Ion probe sweep monitor
6	1.20	Electron probe sweep monitor
7	4.80	^{Total ion} Plate probe mean current
8	4.80	a.c. amplitude monitor (f_1)
9	4.80	a.c. amplitude monitor (f_2)
10	4.80	a.c. amplitude monitor (f_3)
11	4.80	d.c. supply monitor A
12	4.80	d.c. supply monitor B
13	4.80	main package temperature
14	4.80	bias monitor
15	4.80	preamplifier package temperature

TABLE II

Command.	Function
1	a.c. level, sweep, bias all mode 1
2	a.c. level 2
3	sweep mode 2
4	bias level 2

List of figures

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2. First derivative function for S45/2.
3. General assembly of S45/1 and S45/2.
4. General assembly of S45/3.
5. Electronics block diagram.
6. S45/1 calibration curves.
7. S45/1 and S45/2 sweep waveforms.
8. S45/3 calibration curves.

SPHERICAL ION PROBE - 2nd DERIVATIVE FUNCTION

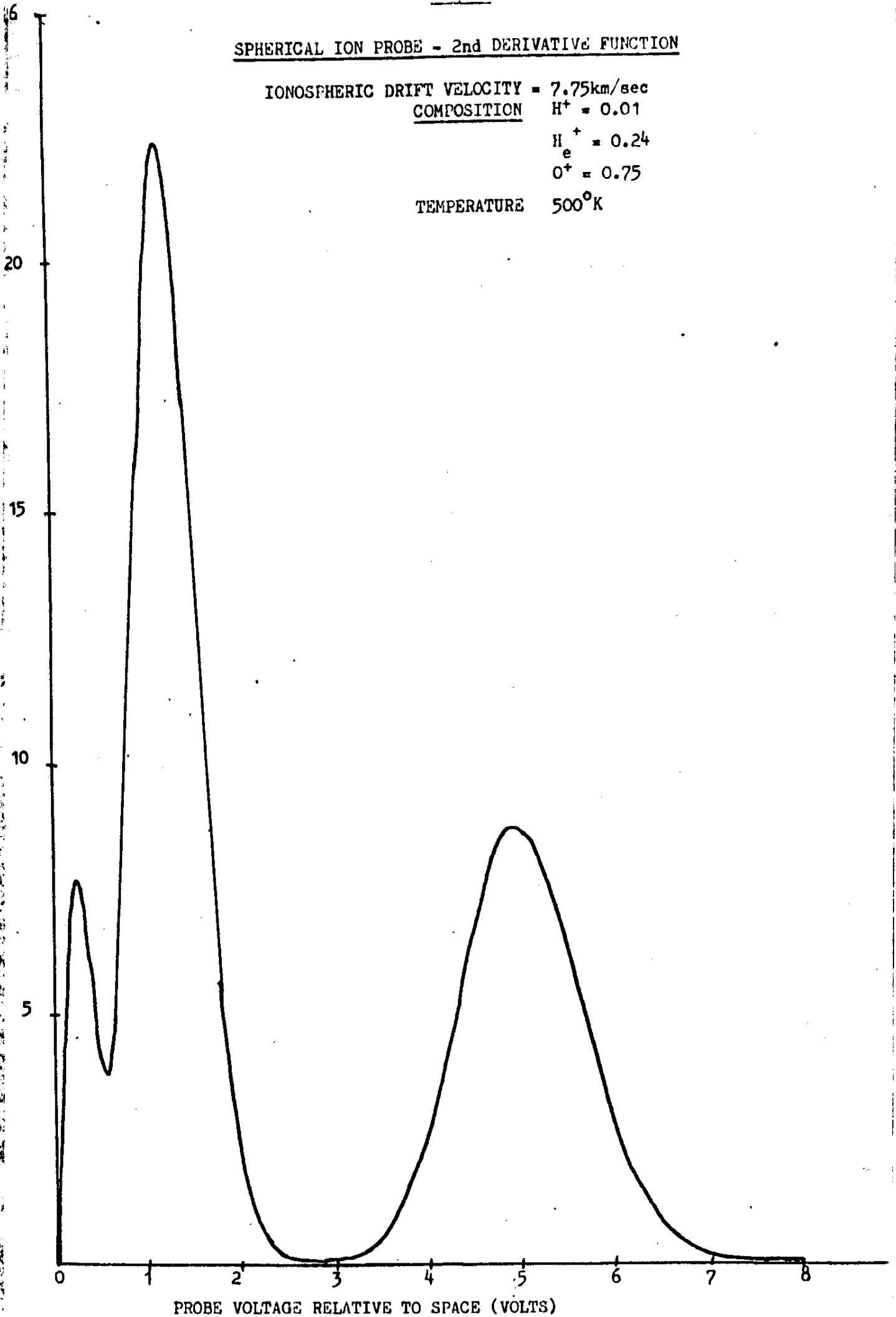
IONOSPHERIC DRIFT VELOCITY = 7.75km/sec

COMPOSITION H⁺ = 0.01

H_e⁺ = 0.24

O⁺ = 0.75

TEMPERATURE 500°K



PROBE VOLTAGE RELATIVE TO SPACE (VOLTS)

Fig. 2

Variation of electron probe current and its first derivative

$T_e = 1500^\circ\text{K}$

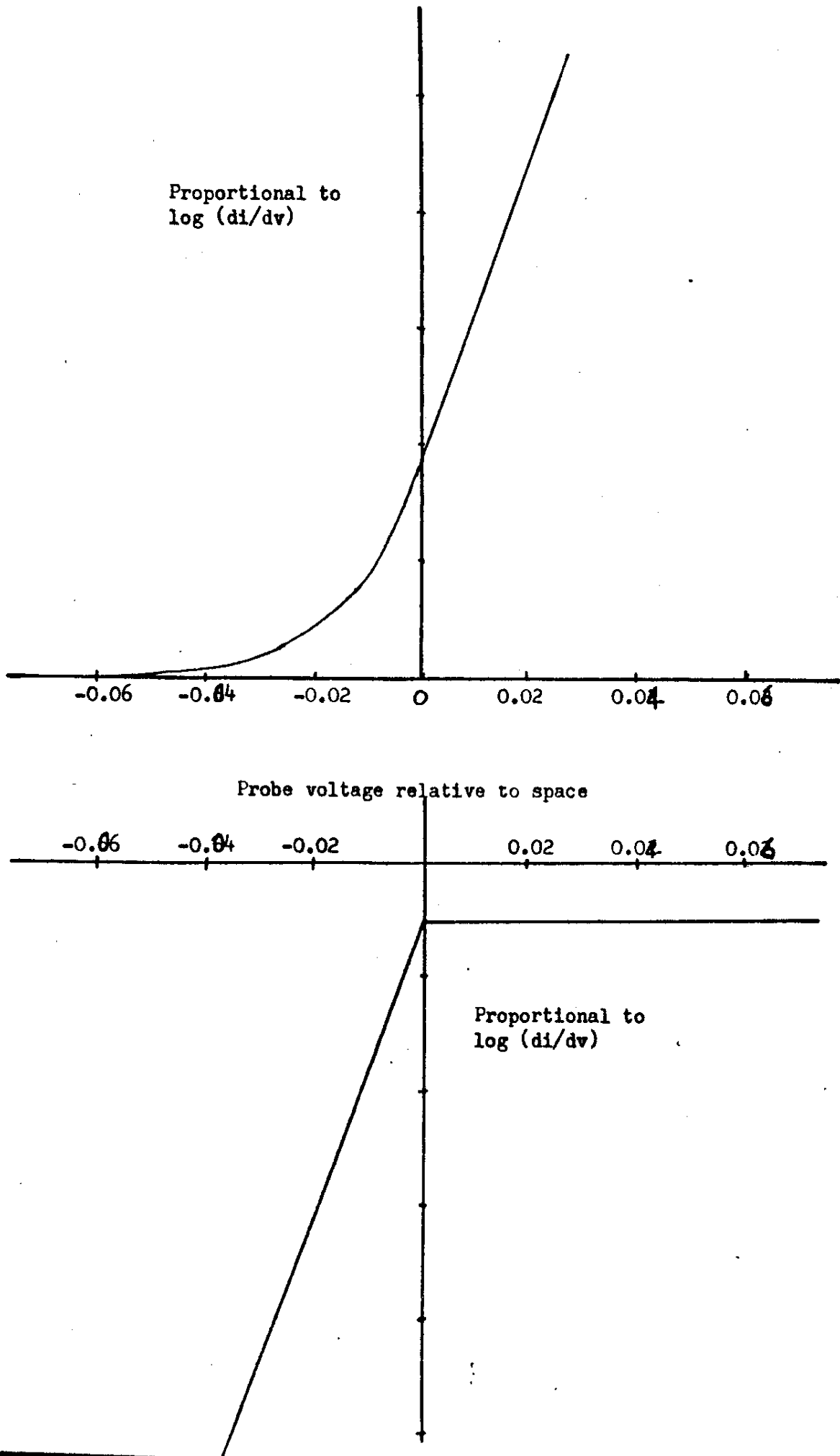
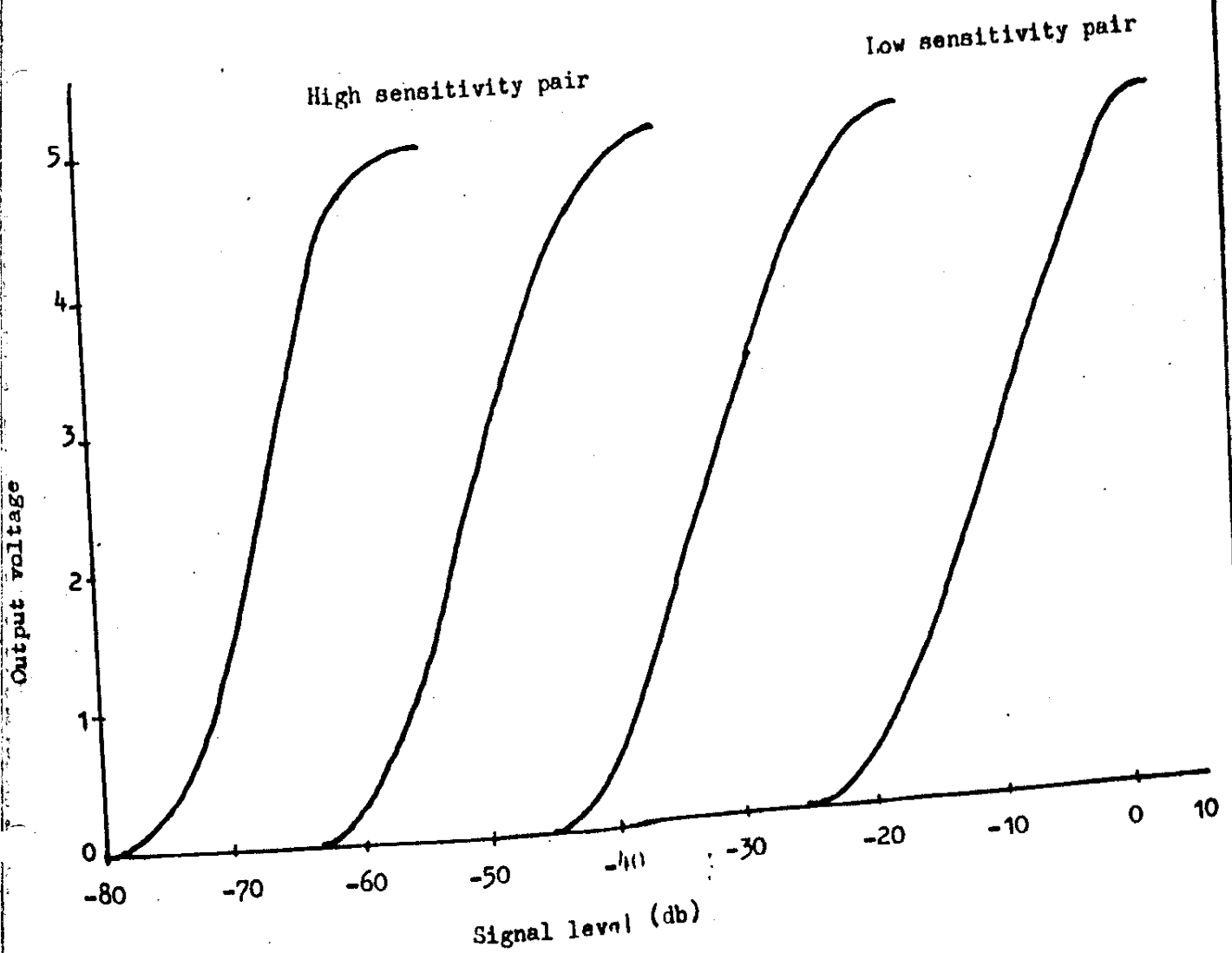


Fig. 6

Form of Ion Probe calibration curves



Ion and electron probe sweep waveforms

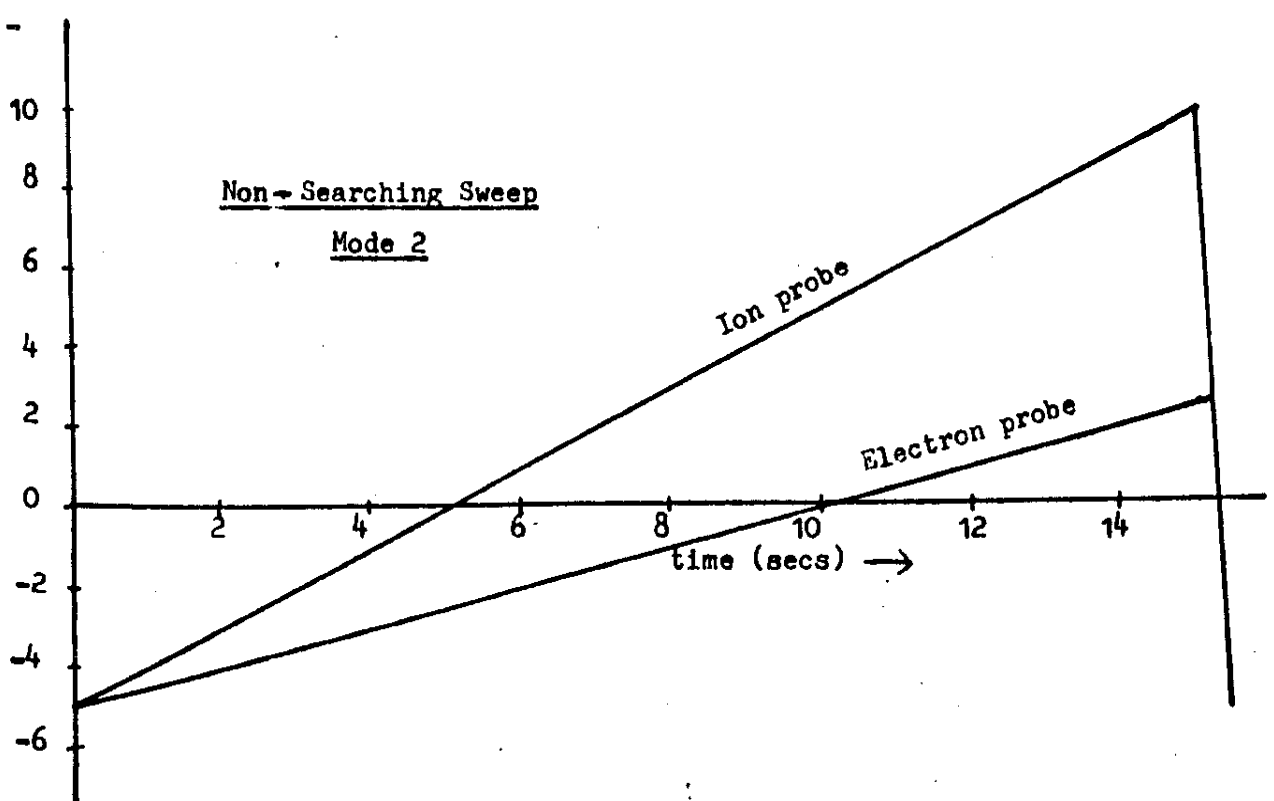
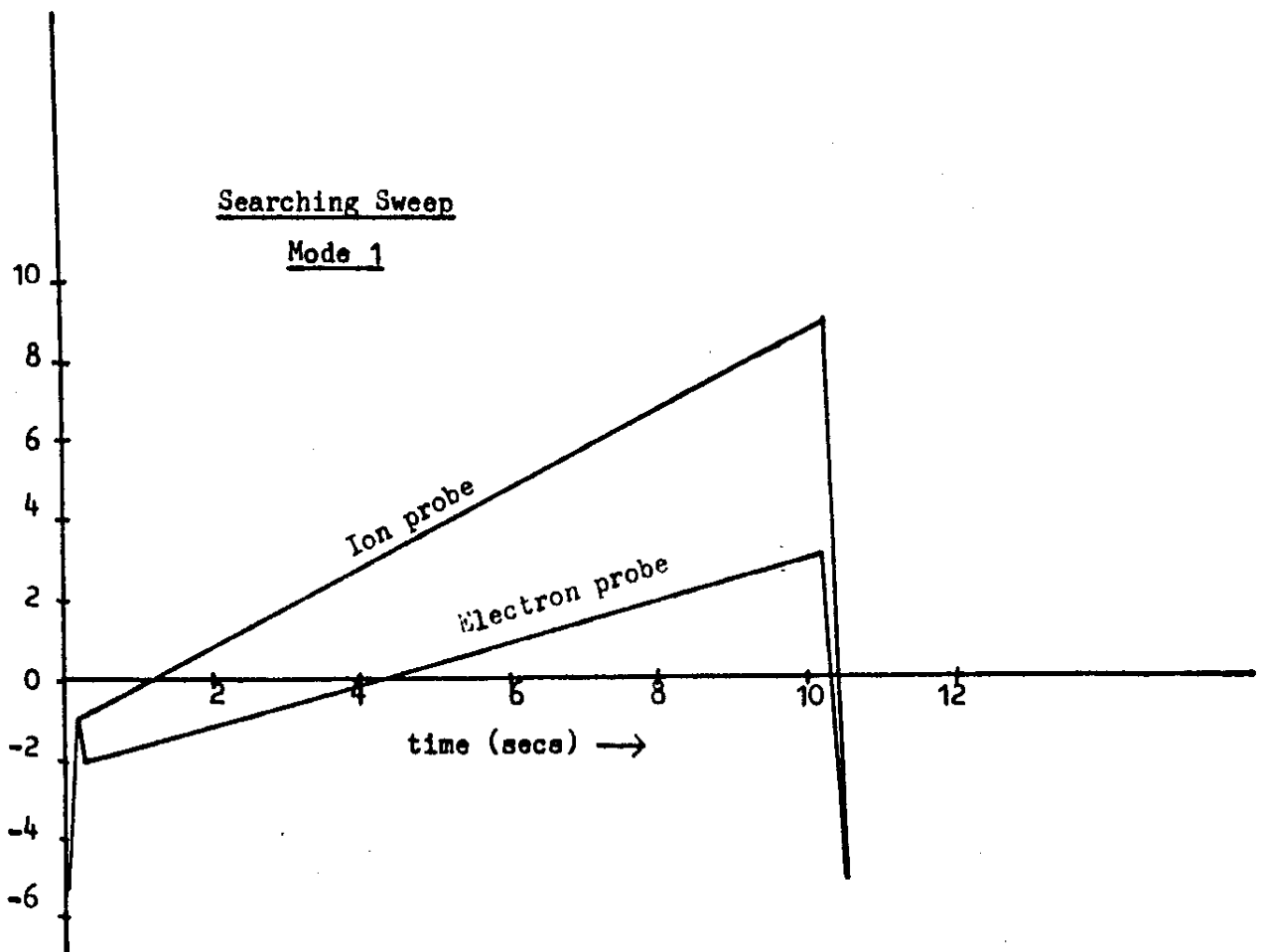
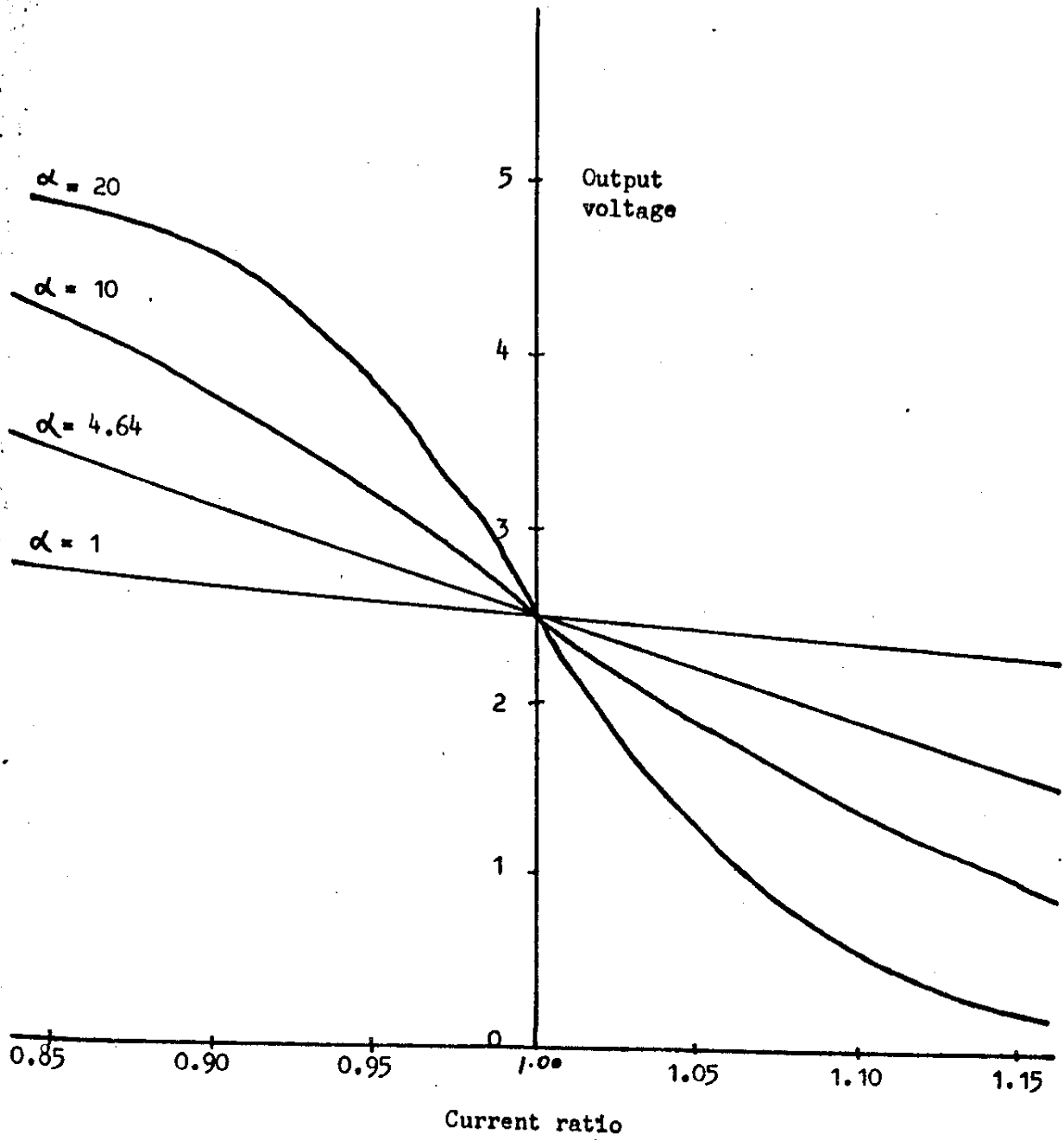


Fig. 8

Transfer characteristic of circuit for monitoring
Small fluctuations in plate probe current



72-092A-01

ESRO-4 - EXPERIMENT S45

POST LAUNCH REPORT

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24th August 1973

Summary

The report describes the form of the S45 raw data and the format of the data tapes received from ESOC. The procedures to handle this data both from a routine administrative point of view and the reduction to geophysical parameters is described. A preliminary description of the type of results obtained at this early stage is given together with an outline of the larger scale scientific analysis which could commence in the near future.

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POST LAUNCH REPORTAUGUST 19731. Introduction

The satellite ESRO-4 was launched at 00.17 U.T. on 22nd November 1972 from the Western Test Range at Vandenberg Air Force Base, California. It successfully achieved an orbit of the earth but the apogee of 1100 km was about 100 km high and the perigee of 250 km was about 30 km low from the nominal orbit specifications. The inclination and time of launch met the scientific requirements. The nominal spin rate of about one revolution per second was achieved after boom deployment. The moment of inertia of the spinning satellite constituted the means of its stabilisation, although, as will be mentioned later the direction in which the spin axis points can be changed by commands sent from the ground.

The experiments carried by the satellite were as follows:-

Code	Institution	Objectives
1. S45	MSSL, London	Thermal plasma parameters of ionosphere
2. S80	Univ. of Bonn	Neutral mass spectra of atmosphere
3. S94	Kiruna Geophys. Obs.	Particle fluxes 0.5-150keV, electrons and protons
4. S99	Univ. of Utrecht	Proton fluxes 2-100MeV, Alpha particles 4-240MeV
5. S103	MPI, Garching	Proton fluxes 0.2-90MeV, Alpha particles 2.5-360MeV
6. HCI	Estec, Noordwijk	Assess operation of Infra red horizon detector

The satellite subsystems included a tape recorder, a high and low bit rate encoder with separate transmitters and a magno-torquer to re-orient the spin axis of the satellite.

The S45 experiment consists of three sensors and associated electronics packages designated as follows:-

Code	Function
S45/1	Spherical ion mass spectrometer (20 cms diameter)
S45/2	Spherical electron Langmuir probe (1 cm)

Code	Function
S45/3	Gridded spherical total ion current collector (10 cms)
S45/4	Main electronics package inside spacecraft
S45/5	S45/1, S45/2 preamplifier package (boom mounted)

The positions of the probes relative to the spacecraft is shown in fig 1.

The satellite was launched with S45 switched on, and as soon as the nose-cone had been ejected telemetry signals received at the range showed characteristic curves from the S45 electron probe. The other experiments were switched on in sequence during the first week of orbital operation and all were found to function satisfactorily.

There are a number of standard spin axis pointing directions which are normally such that the spin axis lies in the orbital plane of the satellite. On one occasion it was 30° out of plane to improve the collection of energy by the solar cells. A list of the standard attitude and the transition dates is given in Appendix I.

Further information on the facilities of the satellite and the operational programme can be obtained from the ESTEC documents:-

E4/PD/06	Issue 3	Mission and Operational Programme
E4/PD/10	Issue 3	General Description of the ESRO-4 Satellite

2. General Characteristics of the Data

The general form of the received data will be made with reference to copies of Sanborn chart records made at ESOC and supplied on a routine basis to enable rapid assessment of the operation of the experiment on a quick-look basis.

2.1 S45/1 Data

The peak in the second derivative of the probe current-voltage characteristic as ions of differing mass are retarded is shown in fig 2. These plots show the automatic change in operations range occurring at each fly-back and flagged in one of the housekeeping data samples.

The rapid motion of the satellite through the earth's magnetic field causes a voltage to be induced in the boom given by

$$V_{ind} = (v \times B) \cdot L$$

where

v	= satellite velocity vector	} all in same coordinate system
B	= magnetic field vector	
L	= boom vector	

During one sweep v and B remain sensibly constant, however L is a rotating vector at the spin rate of 1 revolution per second. Thus the induced voltage is oscillatory and, being added to the probe sweep voltage, it causes a modulation in the signal received by the probe current analyser.

The induced voltage disappears at the magnetic equator when v and B are virtually parallel and is maximum at the polar regions when v and B are perpendicular. The effect of this on the S45/1 data is shown in fig 3.

The general noise level shows similar characteristics to the ESRO-I results, in the regions of the characteristic when the second derivative should be very small the output signal shows a higher noise level before the ions are retarded, that is if i is large there is a larger 2 kHz component than if i is small after the ions have been retarded. The latter level has changed negligibly since the pre-launch measurements, a contrast to ESRO-I when the residual electronics noise level steadily increased over the first 6 months in orbit.

A feature of the ESRO-I data which has not been observed in ESRO-4 is the large increase in noise level such as to swamp the characteristic peaks which occurred when ESRO-I left the polar regions and progressed towards the equator. It may be that sufficient orbits in the right sort of altitude/local time conditions have not yet been studied, however my feeling at present is that if the effect is there at all it is at a much lower level than was observed on ESRO-I.

There is a small amount of RFI observed when the high power transmitter is operating, this is a surprising result since the last three RFI checks on the ground showed no interference at all. The form of this interference is shown in fig 4. The high power transmitter is used most during attitudes favourable to the S94 experiment and then only over the northern auroral and polar cap regions. It is also used for tape recorder dumps which last about three minutes.

In general the S45/1 data is free from disturbance due to the satellite wake, however in certain attitudes the boom passes through the wake of the satellite and when this occurs in equatorial regions a drop in signal once per spin can be seen in the ion peaks. An example of the effect on the O^+ ion peak is shown in fig 5. This data is potentially very interesting for wake-effect studies since with careful analysis a comparison between H^+/He^+ depletions and O^+ depletions could be made. The amount of data on the ion density in satellite wakes is very sparse so it would seem worthwhile to try

and produce not only ion-wake measurements, but also profiles for different ion species.

2.2 S45/2 Data

The S45/2 probe has its first derivative measured and the typical forms of the characteristics are shown in fig 6. Again this probe suffers from the induced $v \times B$ voltage on the boom causing a pronounced spin modulation of the data.

The sensitivity of this probe was set rather high so that useful measurements could be obtained down to considerably lower densities than on earlier flights of the sensor. Also since in one mode of operation of the experiment it controlled the sweep generator it was felt that we should maintain the sweeping potentials to the probes for as much of the orbit as possible.

The result of this as far as the data is concerned is that at low latitudes near perigee during the day the probe current analyser saturates and there is no electron density measurement, however we can still measure electron temperature, and the vehicle potential measurement is not in error by more than about 200-300 mV. This latter figure could be corrected by use of the measured electron temperature and the ion density measured by S45/1.

The sweep generator stops when the instrument is operated in the scanning mode when the value of N_e falls below a value in the range 200 to 500 cm^{-3} depending on the prevailing electron temperature.

2.3 S45/3 Data

The direct ion current flowing to this fixed bias sensor is analysed in two ways on board the satellite. At every flyback the current is sampled and telemetered at relatively infrequent intervals (about 3 times during a sweep). At the instant of sampling a channel with a much faster sampling rate is set to midscale and it then monitors changes in the ion current from the sampled value with a full scale range of about $\pm 30\%$. Thus it is possible to study quite fine detail in ion density structure over a wide dynamic range.

The steady current shows orbital variations which reflect the change in ion density with altitude and latitude which will be referred to later. The profiles obtained are, however, greatly modified by the passage of the probe through the wake of the satellite which occurs once per orbit at a relatively slow speed since the probe is on the spin axis, and the spin axis is in the orbital plane.

The fluctuations in ion current have three typical types of signal shown

in fig 7. Fig 7a is typical of an undisturbed region and the general variation over the sweep is probably a combination of altitude and latitude variations of density occurring during the sweep period. The small residual spin modulation is thought to be due to transparency fluctuations in the grid surrounding the probe. When the probe is over the auroral and polar regions the data shows large and random variations indicating either temporal or spatial fluctuations in ion density due to incoming charged particles. A typical section of this data is shown in fig 7b. Another characteristic form of the data is shown in fig 7c which was taken as the S45/3 probe was entering the wake of the satellite. The large ion density gradient in this region will cause severe modulation of the ion current if the probe is slightly off the spin axis causing it to effectively oscillate in the region of high density gradient at the spin rate. During static ground deployment tests the alignment of the probe to the spin axis was always estimated to be better than 1 degree, thus if this figure can be relied upon in orbit it would enable a measurement of the density gradient in the flanks of the ion wake to be made.

3. Modifications of Experiment Mode of Operation by Telecommand

There are three parameters of the experiment which can be altered by telecommand to one of two states and any combination can be set up by sending a particular grouping of the four commands available to the S45 experiment. The commandable functions are:-

	Normal	Alternate
1. S45/1 ac voltages	200 mV	50 mV
2. Sweep mode	Fixed period and voltage range	Controlled by S45/2 signal
3. S45/1 & S45/3 Bias	-6 volts	-10 volts

The satellite was launched with everything in normal mode, then during the early orbit phase each of the three alternate modes was tested for one complete orbit on two successive days.

The behaviour of the instrument was as expected and after assessment of the data it was decided to operate the instrument with the S45/1 ac voltages at 200 mV, the sweep mode in the alternate condition and the S45/1 grid and S45/3 bias at -6 volts.

The ac voltage control is rather historic than useful since at the time of proposal for TD2 we were concerned about the effect of finite ac voltage on the shape of the light ion peaks, however since then we feel that a complete Fourier analysis of the probe signal can completely take care of the distorting effect of the ac voltage. Thus it is better to use the 200 mV level to obtain the best sensitivity for the probe.

The alternate sweep mode enables the period of the sweep generator to be changed from about 18 secs to 12 secs so improving the spatial resolution of the measurements. This mode does cause the sweep generator to stop when the electron density falls below about 500 cm^{-3} , however by this time the S45/1 and S45/3 probes are giving no data.

The control of the grid bias was put on to see what effect this bias had on the operation of the S45/1 mass spectrometer. The initial experiments and subsequent experiments have shown that this has no measurable effect on the peak being observed and furthermore it demonstrates that the S45/2 probe is sufficiently far from the S45/1 grid not to be influenced by its potential. This is shown in fig 8 which is quite a convincing demonstration of the Debye shielding effect in a plasma.

The only other commanding activity has been to revert to normal sweep mode for occasional orbits to enable a check to be made on the residual noise level of S45/2 which is otherwise not monitored when operating in the alternate sweep mode.

4. General Survey of Data Processing Procedures

The agreed procedure for distribution of ESRO-4 data to the experimenters was that each experimenter would receive magnetic tapes containing his own data and any other relevant measurements stripped from the telemetry encoder format merged with various orbital and attitude measurements and flagged with the Universal Time of the observations. The principle was adopted that in general orbit, attitude and associated parameters such as the magnetic field would be given in terms of basic vectors in a unified coordinate system, namely Geocentric Equatorial Inertial (GEI). The subroutines to manipulate these vectors into the more usual coordinates were supplied by ESOC.

Experimenters had the option of having their data in binary or BCD format on the magnetic tapes. Since the tapes were being produced on an IBM 360 computer we would have no difficulty in handling the data in internal binary form so we decided to use this tape format with its advantages in reduction of total tape volume and speed of input to data processing programmes.

The content and format of the tapes are given in Appendix II copied from information supplied by ESOC.

The only data medium we initially received was magnetic tape, so the first priority was to produce indexing and listing programmes to present the data in an easily readable form with the position coordinates reduced to conventional parameters. Also the calibration tables produced from the calibration measurements made by Pys Ltd. were used to enable the printouts to be produced in engineering units. These programmes exist to produce listings both on the line printer and on microfilm for use in the routine processing to be described later.

At the same time routines were developed to analyse the data to produce geophysical parameters from the raw data and these routines have been incorporated in a variety of programmes to make individual analyses of specific time periods from the accumulating store of data tapes. The general methods employed will be described later in sections 5 and 6.

Once sufficient data had been analysed to gain confidence in the automatic analysis procedures adopted the various routines were incorporated into the main data reduction programme which analyses complete or part data tapes and builds up a master tape of the reduced geophysical parameters. Details of this programme will be given in section 6.

Having referred to the various categories of programme, the general procedures adopted in handling the data can now be outlined.

The tapes arrive by post from ESOC and are logged into a tape receipt form. The tape is then labelled Qxxxxx and a blank tape labelled Bxxxxx where xxxxx is the ESOC tape number. At the next available opportunity the tapes, together with an equal number of blank tapes, are sent to the UCL Computer Centre to be stored in tape racks which have previously been vacated by shipping tapes not immediately needed back to the tape store at Flaxman Terrace. There is no paperwork with the ESOC tapes so the first job is to index the tape to find how many files are written on it, this being done the Q-tape is then copied to the B-tape using a UCLCC programme which makes a "carbon copy" of the original tape. When the copy has been made the Q-tapes are then stored at Flaxman Terrace and the B-tapes at UCL as far as is possible within the limited tape storage space available at UCL.

The tape indexes are then used to select files which enable routine listing programmes to be run in which a few sweeps are listed once per day and about two thirds of an orbit once per week. The latter printout is produced on micro-

film using the SD 4020 plotter situated at the Atlas Computer Laboratory, Chilton. These printouts are archived for reference purposes. Each tape is also run with a programme which produces a chronological file of all available data. This file is stored on disc and can optionally be listed from time to time to produce an index of where data for specific time can be located on the original data tapes.

Within the last month we have begun running the main production programme to build up the master data tapes. Since it is planned to reduce all data by this programme we are analysing the data tape by tape in numerical order of ESOC tape numbers, in fact it turns out that this is approximately in chronological data order. This is proving to be quite a time consuming process because of the large amount of data available. Each tape recorder playback of one orbit's worth of data takes about 1.5 minutes of computer time to process and we are nearly up to orbit 4000 with 80-85% data recovery. It is hoped that operations can be transferred to the RHEL computer which should improve the time by a factor of 4-5 since the programme is compute-bound rather than I/O-bound.

At present this phase of the processing is proceeding rather slowly because we cannot get about 1 hour per night every night due to the unusually high work-load at UCL this summer. However, we have managed to make a good start on the processing by making use of a whole shift on two Sundays recently.

A list of all data processing programmes produced to date is included in Appendix III.

5. Problem Areas

In general there have not been many purely data processing problems, the tape reading procedures have been quite straightforward, thanks largely to a very useful routine MULTIR developed by the UCLCC for handling multi-file tapes which is otherwise rather cumbersome on the IBM 360. The greatest difficulties in analysing the data have arisen from the radial boom-mounted position we had to accept and from a basic limitation of the S45/1 probe in analysing the light H^+/He^+ ions.

5.1 Spin modulation corrections

The cause and effect of spin modulation in the S45/1 and S45/2 data has been described earlier in section 2.1. Sufficient attitude information is supplied with the data such that, in conjunction with the spin phase monitor data, it is possible to compute the induced voltage ($v \times B$). L at any sample time of the S45/1 or S45/2 data in order that the monitored probe voltage

can be corrected. The mathematical method to make this correction has been developed by J. Sojka and is described in Appendix IV. The amplitude of the oscillating voltage was calculated satisfactorily, but the phase gave us the greatest difficulty. It proved impossible to get the best cancellation of the spin effects using the nominal boom position and data time reference, so it was necessary to introduce a variable phase offset and inspect the data plots to see which was the best phase offset from nominal to use. It appeared that this figure should be about 12° phase offset. Examples of the spin modulation correction to the S45/2 data is shown in fig 9.

When the spin voltage correction is applied to the S45/1 data the removal of the modulation is not so effective as is shown in fig 10. One possible cause of this is due to the overall time constant of the S45/1 circuit from probe to telemetry output which would cause an additional phase lag in the signal. This parameter was deliberately reduced during the circuit development in anticipation of this problem. However, noise considerations prevented Pye from reducing the time constant below about 50 m sec. This figure is still small compared with the interval between samples of 200 m sec and the spin period of 500 m sec so I think we are still talking of a relatively small correction.

The response of each of the four operating ranges of the instrument was measured on the bench and it is hoped that the effect of this correction on the S45/1 data can be studied in the near future if the manpower to do so is available.

The procedure outlined above is only applicable when the satellite is in sunlight. In darkness there is no spin phase measurement available from the sun sensor and in this case we resort to our own data to obtain the spin induced voltage oscillation. As explained in section 6.2 the oscillating probe voltage component can be derived from a function fit to the retarding region of the S45/2 output, then providing the data and hence the fit is good this function can be used to correct the probe voltage monitored for the S45/1 probe. The transition from sun to dark and vice-versa is automatically detected by analysing the spin phase output and the method of correcting the S45/1 voltage automatically selected in the programme.

5.2 Analysis of Light Ions

This is a problem which has really been carried over from the ESRO-I data analysis. The basic problem is the low mass resolution of the instrument causing the H^{+} and He^{+} peaks to overlap thus making peak width measurements a

function of both H^+/He^+ ratio and ion temperature. A relatively fast method of reducing this data was developed to a certain stage for the ESRO-I data and has been described in a recent paper in the Journal of Physics E: Scientific Instruments (Raitt et al, A satellite-borne positive ion mass spectrometer, 6, 443, 1973). However, it has not yet been possible to refine this procedure to the stage at which it can be incorporated into routine processing. I think again it is time and effort which is required rather than a basic difficulty, and I am hopeful that J. Sojka who started to look into the analysis method will be able to return to it when the pressure of round development, testing and launching has eased after the High Latitude Campaign.

6. Procedures to Reduce Data to Geophysical Parameters

The basic subdivision of the data for all three probes are the sweeps of voltage applied to the S45/1 and S45/2 probes which are synchronized but are of different voltage range. All of the data reduction programmes therefore use the basic structure outlined by the flow diagram shown in fig 11. The box labelled "Process one sweep of data" can then represent procedures of varying complexity to analyse some or all of the probe data. The skeleton show is the logic to select all of the probe data relevant to one sweep bearing in mind the data is blocked on the magnetic tape in an asynchronous manner relative to the sweep generator which itself is not of constant repetition rate due to the control of the generator by the S45/2 signal.

6.1 S45/1 Data to Ion temperature, density and composition

After calibration and probe voltage correction for spin induced voltage peaks in the data are searched for in the two voltage ranges $V_p > 4.0$ volts, $V_p \leq 4.0$ volts, it having been found that the spacecraft potential is stable enough for this voltage to be used as a divider between the H^+/He^+ peaks at lower voltages and the O^+ peaks at higher voltages.

As far as the H^+/He^+ peak is concerned only, the amplitude and position of the peak is monitored. This is sufficient to determine whether the major light ion is mainly H^+ or mainly He^+ and by using a typical ion temperature it is possible to deduce a representative ion density.

If an O^+ peak above a certain cut-off level is detected, first its amplitude and the voltage at which the peak occurs is recorded, then an attempt is made to measure its width and /or half-width to obtain a measurement of the ion temperature and density by a double interpolation in tables of theoretical widths and amplitudes of O^+ peaks as described in the paper referred to in section 5.2.

6.2 S45/2 Data to Electron Density, Electron Temperature and Vehicle Potential

The calibrated sweep's worth of data is put through a selection procedure to obtain data from the retarding region of the probe characteristic, that is the ascending section of the probe signal as shown, for example, in fig 9. A simple selection between two levels offset from the signal levels at the beginning and end of the sweep is first used, then if either too few or too many points are selected various modifications are made to endeavour to get a number of selected points between 5 and 25 in number. Should this prove impossible the temperature measurement is abandoned, Te is set to a flag value of 600 and the upper level of the signal at the end of the sweep is used to give a density value computed as if the value of Te was 6400°K.

If, however, sufficient points are selected a function of the form

$$E = A + B V_p + C \sin \omega t + D \cos \omega t$$

is fitted to the retarding region where

- E is the log of di/dV expressed in db
- B is the slope of the characteristic in db/volt
- C and D are related to the amplitude of the spin induced voltage
- ω is the satellite spin rate

Details of the deduction of the parameters listed in the sub-heading from the coefficients of this fitted function are given in Appendix V.

6.3 S45/3 Data to ion density fluctuation figures

It can be seen from fig 7 that in many circumstances it is difficult to define a key parameter to specify the behaviour of the fluctuations measured by this probe. However, it was decided that the data could best be fitted by a spin modulated straight line during one sweep period and this is done giving a mean slope and the amplitude of the spin component. Away from the polar regions the mean slope can be combined with the change in attitude during the sweep period to deduce a value for the scale height assuming that the change in probe current from start to end of the sweep is due solely to the change in satellite attitude. However this only gives reasonable figures over small parts of the orbit, in the majority of the lower latitude regions the latitudinal change appears to be as great as or greater than the altitude effect giving unreasonably high or low values for scale height depending whether the two effects are working together or not.

The spin rate modulation is a useful parameter since it characterises the approach to the satellite wake where it becomes very much enhanced in value as described previously.

The final parameter of the fit is the rms deviation and without looking for specific event effects in the polar region, the sudden onset of structure in the ionosphere is shown by a marked increase in the rms deviation of the fit of the function.

Preliminary data for this probe and the other probes will be presented and discussed in more detail in section 7.

6.4 The Geophysical Data Master Tape

As mentioned earlier in section 4 the parameters computed are written onto a master tape together with position, attitude and other data. The format, content and method of reading the master tape is described in Appendix VI.

7. Scientific Results Obtained

At present no large scale scientific analysis has been made due to most of the available effort being put into getting the data reduction programmes running reliably. However, as a by-product of checking the reduction programmes a certain amount of scientific analysis of the data has been made.

7.1 S45/2 Measurements of Electron Temperature, Electron Density and Spacecraft Potential

Three parameters are extracted from the measurements of the S45/2 electron temperature probe, electron temperature (T_e), electron density (N_e) and spacecraft potential (V_{sp}).

Electron temperature . In general this is the most accurately determined parameter, once corrections for spin modulation have been made. Our analysis programme lists T_e for each voltage sweep. Figure 12 shows the variations of electron temperature around a typical orbit.

Spacecraft Potential Spacecraft potential V_{sp} is determined by finding the voltage at which the exponential portion of the characteristic changes to a constant slope, or, in terms of the first differential which is the parameter that is telemetered, the voltage at which the idealised fixed slope of the retarding portion intersects the idealised constant level of the non-retarding portion. In practice the fixed slope has to be synthesized from the spin-modulated data, and the constant level has to be selected from a level which falls from a maximum value, and not always at the same rate. Because of these uncertainties in slope and constant level, V_{sp} is uncertain too, and we have to be alert to the possibility that any variations in V_{sp} that we may detect are in some way creations of the analysis routine rather than real effects. We expect to begin quite soon to extract V_{sp} from the S45/1 data, so as to have a separate and hopefully independent measurement of V_{sp} against which

to check the S45/2 measurements.

Meanwhile we are continuing to study the Spacecraft potential measurements, such as the example given in Figure 12, where both V_{sp} and T_e are plotted against latitude; apogee, perigee, dark period and attitude relative to the velocity vector are all indicated. Broadly speaking V_{sp} follows T_e as would be expected from Whipple's expression

$$\begin{aligned} V_{sp} &= \frac{k T_e}{e} m \left(\frac{T_+}{T_e} \cdot \frac{m_e}{m_+} \right)^{-\frac{1}{2}} \\ &\approx \text{constant} \cdot \frac{k T_e}{e} \end{aligned}$$

but there are significant departures in detail.

For the case when O^+ dominates, we can write

$$V_{sp} \approx 4.5 \times 10^{-4} \cdot T_e$$

but we find that, around any orbit, the constant in this expression may change by as much as an order of magnitude, from say 0.5×10^{-4} to 5×10^{-4} . In order to find out more about this variation we are listing as part of our routine analysis the ratio V_{sp}/T_e and will look for possible correlations with other parameters.

One feature already noticed, and one which appears particularly well in Figure 12, is the dip in V_{sp} which occurs at or near to the equator crossings. So far we have established no rules for the occurrence and we have to be careful to disentangle it from other related effects such as changes in T_e , and N_e and also changes in the position of perigee, apogee, the daylight/dark periods and spacecraft attitude. The position of the dip appears to move in relation to the equator but just what governs the movement is not yet clear; geomagnetic control so far seems unlikely.

Electron Density The electron density is calculated from a measurement of the slope of the current-voltage characteristic at space potential, and hence relies on the location of this latter parameter. Because of the lack of precision, N_e is not obtained with any very good accuracy. We are however able to compare values with the nO^+ ion concentrations given by the S45/1 probe, at least to the extent of requiring that N_e be no smaller than nO^+ . Such checks have lead to the discovery that, for any reasonable criterion for determining space potential, the values of N_e during any one orbit are sometimes less than nO^+ , sometimes the same and sometimes greater. As part of our current investigations we are listing the ratio nO^+/N_e in order to look for consistent trends

and for correlations with other parameters, with the hope that we may in time throw some light on this puzzling inconsistency.

7.2 Calibrations against radar incoherent scatter measurements

We have made comparisons between our determinations of Ne and Te (and nO^+) with those made by RRE Malvern using the incoherent scatter technique, on four dates in December and January last. On three of these occasions our Te and nO^+ measurements agreed well with theirs, but on the fourth a x2 discrepancy in density occurred. As far as we can tell it was due to the existence of a mid-latitude trough with its Southern edge lying in a roughly SW/NE direction, in such a position as to put Malvern outside the trough but the spacecraft inside it when crossing the Malvern latitude only 3° to the west in longitude. Taylor at Malvern has questioned the likelihood of the trough being so far south when the Kp index was fairly low, so we are checking adjacent orbits to verify its presence. A complicating factor was the occurrence of dawn at the magnetic conjugate point just before the RRE measurements began. This produced a steady decay in Ne over a period of $1\frac{1}{2}$ hours or so which can, if one isn't alerted to its existence, give the impression that the trough was moving slowly southwards.

7.3 Wake Effect Observed by S45/3 probe.

The S45/3 probe passes through the wake of the satellite once per orbit at a distance of about one equivalent satellite radius. The geographic position of this passage through the wake depends to which of the standard attitudes the satellite is set, thus in attitudes 5. and 6. the wake passage occurs over one of the poles, while in attitudes 3. and 4. it occurs over the equator.

Figure 13 shows two examples of the wake as observed by this probe in which the current to S45/3 is plotted against angle of attack, and since the probe is in the -Z direction in the satellite coordinate system the maximum wake effect occurs at 0° angle of attack. The angle is given a sign to distinguish entry of the probe into the wake when θ is decreasing (180° to 0°) from the exit case when θ is increasing (0° to -180°). Figure 13a is a plot of a wake passage over the North Pole, while 13b is a plot of the wake passage over the Equator.

The two examples shown have been chosen because of the structure which appears on one side of the wake. This has been observed on a number of passes about similar times to these plots but with varying degrees of intensity.

The geometric width of the wake indicates that for parallel flow of the ions without any convergence the probe should encounter the edge of the wake

at attack angles of $\pm 42^\circ$, it can be seen that this is not what is observed indicating a convergence of the flow lines. It is not yet clear however how much this apparent convergence is affected by the negative bias on the grid of S45/3 distorting the flow as the probe approaches the wake edge.

In association with these wake profiles the fluctuations output of S45/3 shows the increased spin modulation at the edges of the wake, however as mentioned earlier in section 2.3 it is necessary to make some assumptions about the boom axis-spin axis alignment before any qualitative use can be made of the data. It is possible that this can be done by comparing the slope of the wake profile as measured by the steady current to S45/3 with the amplitude of the spin rate oscillations. A typical profile of the amplitude of these oscillations is shown in fig 14.

7.4 Location of particle precipitation zones from S45/3 data

It was described in section 2.3 that over the auroral and polar regions the characteristic appearance of S45/3 data shows large amplitude apparently random fluctuations which reveal themselves as an increase in the rms deviation of a line fitted to the data as described in section 6.3. Providing the ambient density in the altitude range in which the satellite passes over the polar cap is not too low to prevent a signal being measured the effect of the particle precipitation can be observed as shown in fig. 15.

The figure shows the orbital variation of the rms deviation during a magnetically quiet period (orbit 295) and a magnetically active period (orbit 301) about 1 day later so that the two orbits cover approximately the same geographical sub-orbital track. The main feature of both plots is the sudden increase in rms deviation at the S. Pole at the invariant latitudes marked on the diagram. The effect is rather masked at the N. Pole due to the satellite attitude causing the S45/3 probe to pass through the wake. The large amplitude spin modulations referred to earlier do seem to cause an increase in the rms deviation of the fit.

The satellite passed through its apogee of about 1100 km at the S. Pole at this time.

It can be seen that there is a significant widening of the precipitation zone when the magnetic activity is higher showing the penetration of charged particle fluxes to lower invariant latitudes, that is lower L-shells. This effect has been observed by particle experiments although there are considerable differences in the low latitude cut-off depending on particle energy, and it would be interesting to see which boundary our measured boundary agrees with most closely.

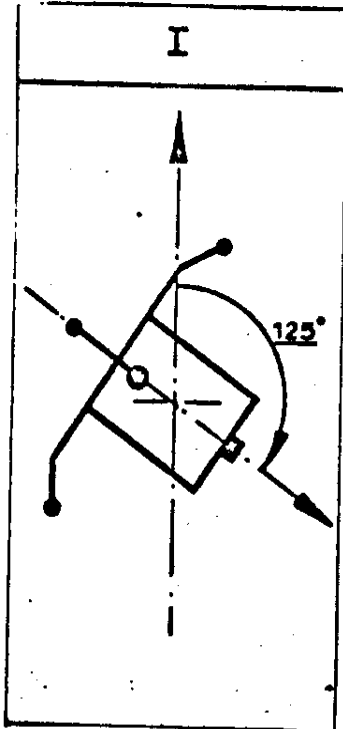
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- II ESRO 4 Experimenter Tapes Final Record Format) MISSING
- III Synopsis of IBM/360 Orientated Programs.
- IV Vector Manipulation for correcting spin modulation.
- V Reduction of Electron Probe Data to Geophysical Parameters.
- VI Format of ESRO-4 Master Tapes.

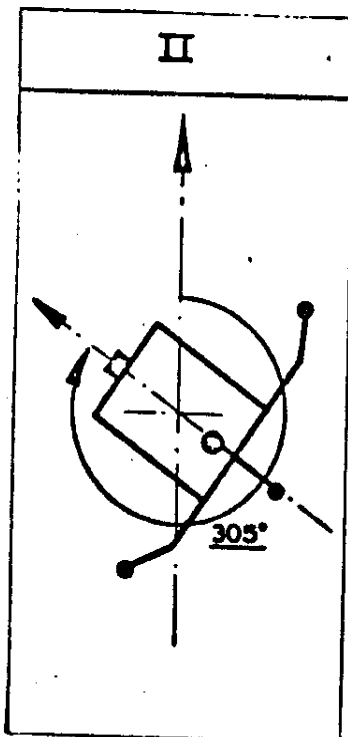
Appendix I

ESRO-4 Standard Attitudes

It is easier to describe the standard attitude pictorially as shown below. The vertical line with the arrowhead towards the top of the page represents the direction of the earth's spin axis. In all cases the satellite spin axis lies in the plane of the orbit except one attitude referred to later as IA when it was set with a skew angle to bring it 30° out of the orbital plane for better collection of solar energy.

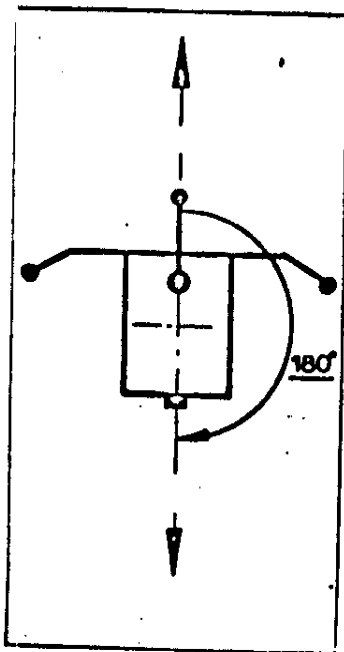


1. Designed to make satellite perpendicular to the magnetic field over Tromso for S94, also ram direction suitable for S80 when perigee near S. Pole.



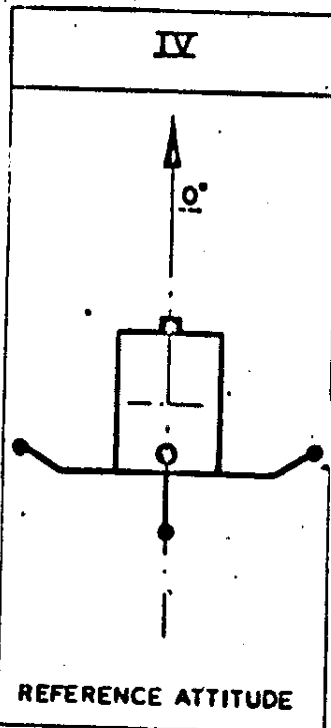
2. Designed to make satellite perpendicular to the magnetic field over Tromso for S94, also ram direction suitable for S80 when perigee near N. Pole.

III



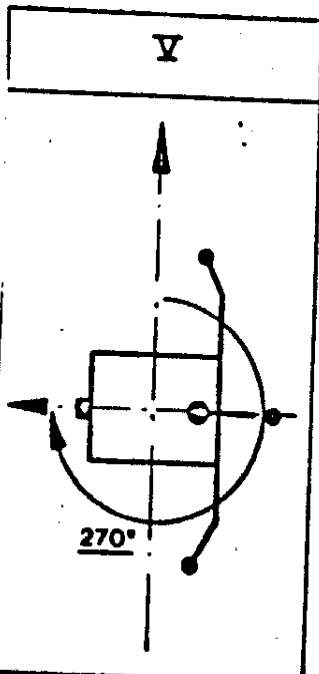
3. S80 ram direction over equator when perigee near descending node. Also S99 viewing out at S. Pole, S103 at N. Pole

IV



4. S80 ram direction over equator when perigee near ascending node. Also S99 viewing out at N. Pole, S103 at S. Pole.

V



5. Designed to give good S80 dat when perigee is over the N. Pole.

(Additional attitude - 6 sometimes used when manoeuvring which is as 5. but spin axis turned through 180° - i.e. S80 data when perigee over S. Pole)

Manoeuvre No.	Start		Stop		Attitude	
	Orbit	Date/Time	Orbit	Date/Time	From	To
1	105	29/11/72	166	3/12/72	L	5
2	402	20/12/72	478	25/12/72	5	4
3	928	24/1/73	993	29/1/73	4	1A
4A	1566	9/3/73 09.31	1595	11/3/73 00.37	1A	6
4B	1610	12/3/73 22.01	1654	15/3/73 21.44	6	
4C	1669	16/3/73 21.58	1713	19/3/73 21.21		5
5	1934	3/4/73 20.23	1979	6/4/73 15.06	5	4
6	2556	15/5/73 06.41	2616.	19/5/73	4	6
6A	2660	22/5/73	2705	25/5/73 06.40	6	3
7	3181	26/6/73			3	5
8*	3494	17/7/73			5	4
9*	4019	21/8/73			4	3

* Confirmation of these dates not received at present

Appendix IVVector Manipulation for correcting spin modulation

Definition of the G.E.I. reference frame.

The origin is taken as the centre of the earth, the X direction is taken as the first point of Aries, the Z being perpendicular to the plane of the ecliptic to the north celestial pole and the y axis completes a right handed set of cartesian axes.

Then for every satellite data format (4.8 seconds) the following vectors in G.E.I. are known.

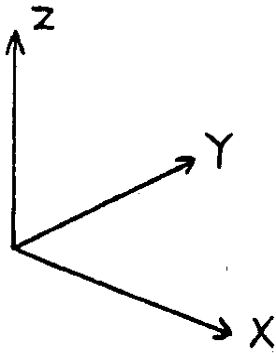
- a) sun vector, $\underline{S}_{G.E.I}$
- b) magnetic field vector, $\underline{B}_{G.E.I}$
- c) satellite velocity vector, $\underline{V}_{G.E.I}$
- d) spin axis vector, $\underline{SA}_{G.E.I}$

To enable the induced $\underline{V} \times \underline{B} \cdot \underline{L}$ potential on the probe to be calculated the boom position vector in G.E.I. must be known. The satellite in question spins about an axis which is parallel to the spin axis vector. A spin rate of approx. 1 r.p.s. and voltage sweep duration of 10 seconds are the two important time periods. Thus the spin modulation for a sweep is of the order of 10 cycles, this is clearly illustrated on Fig. 8.

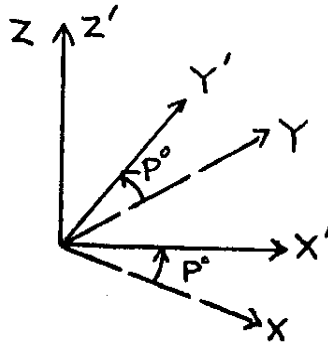
Before setting up the necessary transformation from the centre of the satellite frame, in which the boom spins, to G.E.I. a number of approximations are made.

- 1) Over the duration of a sweep the spin axis vector remains constant.
- 2) The sun sensor placed on the satellite sees the sun every 360° of rotation. This holds good because in a spin period the satellite can be regarded as stationary relative to the sun. Hence, we can regard sun sensor period equivalent to the spin rate.
- 3) Using the fact that the satellite-earth distance is very small compared to the earth-sun distance assume that the sun vector in G.E.I. is the same as the satellite-sun vector in G.E.I.

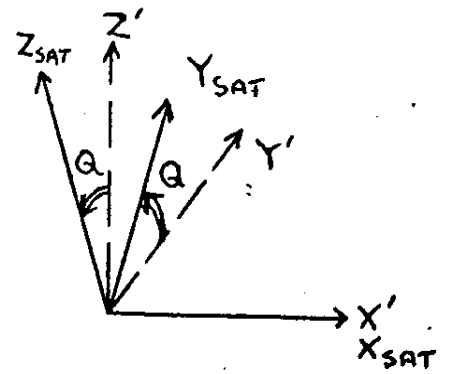
The problem now reduces to the point where the satellite can be regarded as spinning at the G.E.I. origin about the spin axes. Then the sun vector, which is known in the satellite frame and G.E.I. frame is used to get the spin phase between the two frames correct. Define the satellite frame as having its Z axis along the spin axis and a X,Y plane that contains both the sun sensor and boom. A general cartesian transformation between the two frames can be achieved by using two angles P and Q. P is a positive rotation about the G.E.I. Z axis and Q a positive rotation about the new X axis.



G.E.I.



rotate by P



rotate by Q
to get satellite frame

Writing this in matrix form

$$\begin{aligned} \underline{R}_{G\text{E.I.}} &= \begin{bmatrix} \cos P & -\sin P & 0 \\ \sin P & \cos P & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos Q & -\sin Q \\ 0 & \sin Q & \cos Q \end{bmatrix} \underline{R}_{\text{SAT}} \\ &= \begin{bmatrix} \cos P & -\cos P \sin Q & \sin P \sin Q \\ \sin P & \cos P \cos Q & -\sin Q \cos P \\ 0 & \sin Q & \cos Q \end{bmatrix} \underline{R}_{\text{SAT}} \\ &= A \underline{R}_{\text{SAT}} \end{aligned}$$

To evaluate the components of the transformation matrix A the spin vector, which is common to both frames, is used.

$$\underline{S}_{\text{A}_{G\text{E.I.}}} = (S_{Ax}, S_{Ay}, S_{Az})$$

$$\underline{S}_{\text{A}_{\text{SAT}}} = (0, 0, 1)$$

$$\Rightarrow S_{Ax} = \sin P \sin Q, \quad S_{Ay} = -\sin Q \cos P, \quad \text{and} \quad S_{Az} = \cos Q$$

hence we can find coefficients of A in terms of known vector components. The sun sensor sees the sun at a time T_0 so that by transforming the Sun vector from G.E.I. to the Satellite frame the sun sensor position is known. However, since the rotation is about the z axis the position of the sensor in the spin plane (x,y) is required. This is obtained by projecting the sun vector in the satellite frame on to the x,y plane. The position in the x,y plane is given by an angle R as follows.

$$\underline{S}_{\text{SAT}} = A^T \underline{S}_{\text{G\text{E.I.}}}$$

$$\underline{S}_{\text{SAT}} = (S_x, S_y, S_z)$$

$$\tan R = \frac{S_y}{S_x}$$

hence the sun sensor position at a subsequent time t is given by:

$$x = \cos (w (t - T_0) + R)$$

$$y = \sin (w (t - T_0) + R)$$

where w is the spin rate. The boom is at a further 100° in the positive rotation sense to the sun sensor.

$$\therefore x_{\text{BOOM}} = \cos (w (t - T_0) + R + 100)$$

$$y_{\text{BOOM}} = \sin (w (t - T_0) + R + 100)$$

Then the third component z_{BOOM} is set to 0. In actual fact the boom ends are tilted at 17° to the spin plane. Now the transformation A can be used on \underline{L} satellite, stated in component form above, to obtain the required G.E.I. boom position vector.

$$\underline{L}_{\text{GEI}} = A \underline{L}_{\text{SAT}}$$

Thus by making use of the given $\underline{B}_{\text{GEI}}$ and $\underline{V}_{\text{GEI}}$ vectors the voltage induced on the boom can be calculated by evaluating the vector expression

$$\underline{V}_{\text{GEI}} \times \underline{B}_{\text{GEI}} \cdot \underline{L}_{\text{GEI}}$$

giving the scalar potential induced on the boom.

Appendix VReduction of Electron Probe Data to Geophysical Parameters

The programmes to date have used the straightforward electron Langmuir probe theory for spherical probes using the following relations:

$$\text{In retarding region} \quad i = i_0 e^{-\frac{|V|}{kT}} \quad \dots\dots\dots 1.$$

where i_0 = probe current when $V = 0$
 V = probe - plasma potential
 k = Boltzmann's Constant
 T = electron temperature

$$\text{In accelerating region} \quad \frac{di}{dV} = \left| \frac{di}{dV} \right|_{V=0} = \frac{i_0}{kT} \quad \dots\dots\dots 2.$$

The current to the probe at plasma potential is given by

$$i_0 = \frac{1}{4} A e n \left(\frac{8kT}{\pi m} \right)^{\frac{1}{2}} \quad \dots\dots\dots 3.$$

where A = probe area
 e = electronic charge
 n = electron density
 m = electron mass

We can deduce the electron temperature from 1. as follows:-

$$\left| \frac{di}{dV} \right| = \frac{i_0}{kT} e^{-\frac{|V|}{kT}}$$

$$\therefore \ln \left| \frac{di}{dV} \right| = -\frac{V}{kT} + K \quad \dots\dots\dots 4.$$

The experiment measures a parameter which is dependant on the $\log \left| \frac{di}{dV} \right|$ in the following way:-

$$\frac{i_{ac}}{v_{ac}} \approx \frac{di}{dV}$$

where i_{ac} = ac current flowing in probe
 v_{ac} = ac voltage applied to probe

We measure i_{ac} in db

$$\text{i.e. db} = 20 \log \left(\frac{i_{ac}}{i_{ref}} \right)$$

$$\therefore \log i_{ac} = \frac{db}{20} + \log(i_{ref})$$

$$\begin{aligned} \therefore \log \left(\frac{di}{dV} \right) &= \log(i_{ac}) - \log(V_{ac}) \\ &= \frac{db}{20} + \log(i_{ref}) - \log(V_{ac}) \dots 5. \end{aligned}$$

but from 4.

$$\log \left| \frac{di}{dV} \right| = \frac{-V}{\ln 10 \cdot (kT)} + K' \dots 6.$$

Equating 5. & 6.

$$\frac{db}{20} + \log(i_{ref}) - \log(V_{ac}) = \frac{-V}{\ln 10 \cdot (kT)} + K' \dots 7.$$

From 4. we can see that it is the derivative of $\left| \frac{di}{dV} \right|$ wrt V which is a measure of T, thus if we differentiate 7. wrt V we can obtain an expression for the relation between the slope of the measured signal in db/volt to the electron temperature.

Substitution of constants gives

$$T = \frac{1.00803 \times 10^5}{S} \dots 8.$$

Where S is the slope of the retarding region of the characteristic expressed in db/volt.

Having ascertained T we can then use equation 2, and 3. to deduce the electron density n.

$$\left| \frac{di}{dV} \right|_{V=0} = \frac{\frac{1}{4} A e n \left(\frac{8k}{\pi m} \right)^{\frac{1}{2}} \cdot T^{\frac{1}{2}}}{kT}$$

Note in substituting for the constants the 'k' in the numerator is in J deg⁻¹, while in the denominator it is in eV deg⁻¹.

Substituting for the constants gives

$$\left| \frac{di}{dV} \right|_{V=0} = 9.0717 \times 10^{-16} \left(\frac{n}{T^{\frac{1}{2}}} \right) \dots 9.$$

Where n is in m⁻³

and T in degrees Kelvin

The determination of S and $\left| \frac{di}{dV} \right|_{V=0}$ is made in the subroutine DEKINK. This subroutine selects the data for curve fitting also sets up the data to fit a straight line plus a spin modulation component in the subroutine SPINLN.

Let E be the experimental db value of i_{ac} , then in the retarding region, from equation 7., we wish to fit the function

$$E = \alpha V_{ps} + \beta \quad \dots 10.$$

Where V_{ps} = probe to spacecraft ground voltage

(Note the constant bias due to the spacecraft-plasma potential can be ignored in this application because it has been taken care of in the way in which the data has been selected to be in the retarding region. Mathematically it would represent part of the constant β in 10)

Now V_p is made up of a bias voltage generated by the sweep voltage generator (V_p), and an induced voltage due to the $v \times B$ potential along the boom. The latter can be represented as the sum of a sine and cosine term to represent an orbital amplitude and phase.

$$\therefore V_{ps} = V_p + (a \sin \omega t + b \cos \omega t)$$

$$\omega = \text{satellite spin rate}$$

$$V_p = \text{Voltage output of sweep generator}$$

$$\therefore E = \alpha V_p + \alpha a \sin \omega t + \alpha b \cos \omega t + \beta$$

$$\text{or } E = A + B V_p + C \sin \omega t + D \cos \omega t \quad \dots 11.$$

$$\text{Where } B = \text{slope in db/volt}$$

$$a = \frac{C}{B}, \quad b = \frac{D}{B}$$

We may fit such a function by the method of least squares which is done in SPINLN by forming the coefficients of the four simultaneous equations generated and solving them by use of the IBM/SSP routine SIMQ.

The value of B deduced may then be used in 8. to obtain the electron temperature. The values of a and b enable the spin modulation correction to be made for S45/1 when the satellite is in darkness.

The electron density is computed from the maximum value of $\frac{di}{dV}$ which generally occurs near space potential.

The actual space potential is deduced by finding the intersection of the non-oscillating part of 11. with the line.

$$\left| \frac{di}{dV} \right|_{\max} = \text{const.}$$

I	Contents
1	Julian Day number, origin 1950.00
2	Day of Month
3	Number of Month
4	Year
5	HH
6	MM
7	SS
8	Orbit Number
9	Sidereal angle (deg. x 10 ⁻¹)
10	Spin axis X
11	Spin axis Y
12	Spin axis Z
13	Spin rate deg. x 10 ⁻¹ /sec
14	Sun Vector X
15	Sun Vector Y
16	Sun Vector Z
17	S45/1 8.5 kHz amplitude (mV)
18	S45/1 10.5 kHz amplitude (mV)
19	Positive 6 volt monitor (mV)
20	Preamp. Temperature (deg. x 10 ⁻¹)
21	Negative 6 volt monitor (mV)
22	Package Temperature (deg. x 10 ⁻¹)
23	Bias voltage (mV)
24	S45/2 3.2 kHz amplitude (mV)
25	Spare

} Time origin of pass (U.T.)

} Normalised to 10⁴ (GEI)

} Normalised to 10⁴ (GEI)

Contents of OUT (I,J), I = 1,25, J = 2, NSW

I	Contents
1 I5	Amplitude of light ion peak (amps x 10^{-11})
2 I6	Voltage of light ion peak (mV)
3 I5	Amplitude of heavy ion peak (amps x 10^{-11})
4 I6	Voltage of heavy ion peak (mV)
5 I6	Electron Temperature (deg.K)
6 I4	Electron Density (cm^{-3} x 10^2)
7 I5	Space Potential (mV)
8 I5	Elapsed Orbital time of sweep (at VSP) (secs)
9 I5	S45/3 current (μA)
10 I6	S45/3 fluctuations spin modulation amplitude
11 I6	S45/3 fluctuations derived scale height
12 I6	S45/3 rms deviation of fit
13 I5	Longitude (deg. x 10^{-1})
14 I5	Latitude (deg. x 10^{-2})
15 I6	Altitude (km x 10^{-1})
16 I6	Angle of Attack of Spin Axis (deg. x 10^{-2})
17 I5	Invariant Latitude (deg. x 10^{-2})
18 I5	Velocity (m/s)
19 I5	Experiment Status (coded)
20 I4	Kp at sweep time (ESOC code)
21 I5	Temperature of O^+ ion (deg. K)
22 I5	Density of O^+ ion (cm^{-3} x 10^3)
23 I4	Temperature computation status flag
24	Spare
25 I2	Sunlight/Darkness Flag

Definition of Status Flags1. OUT (19,N)

This number is computed as follows:-

$$1000 * KSENS + 100 * IVCOR + 10 * STATB(4) + 4 * STATB(3) + 2 * STATB(2) + STATB(1)$$

Where

KSENS	is S45/1 sensitivity flag	= 1 High sensitivity
		= 2 Low sensitivity
IVCOR	is S45/1 spin modulation correction flag	
	= 0	Correction by using attitude solution and spin phase monitor
	= 1	Correction by fit to S45/2 data (used in darkness)
STATB(4)	= 1	Experiment on
	= 0	Experiment off
STATB(3)	= 1	Bias = -10 volts
	= 0	Bias = - 6 volts
STATB(2)	= 1	Scanning sweep mode
	= 0	Normal sweep mode
STATB(1)	= 1	S45/1 ac voltages \approx 200mV
	= 0	S45/1 ac voltages \approx 50mV

2. OUT (23,N)

This number is computed as:-

$$100 * IVCOR + 10 * MAD + KX$$

Where

IVCOR	is S45/1 spin modulation correction flag	
	= 0	Correction using attitude solution and spin phase monitor
	= 1	Correction by fit to S45/2 data
MAD	= 0	Good fit to S45/2 data
	= 1	Bad fit to S45/2 data
KX	= 0	Peak not usable
	= 1	Lower half width of 0 ⁺ peak used
	= 2	Upper half width of 0 ⁺ peak used
	= 3	Total width of 0 ⁺ peak used

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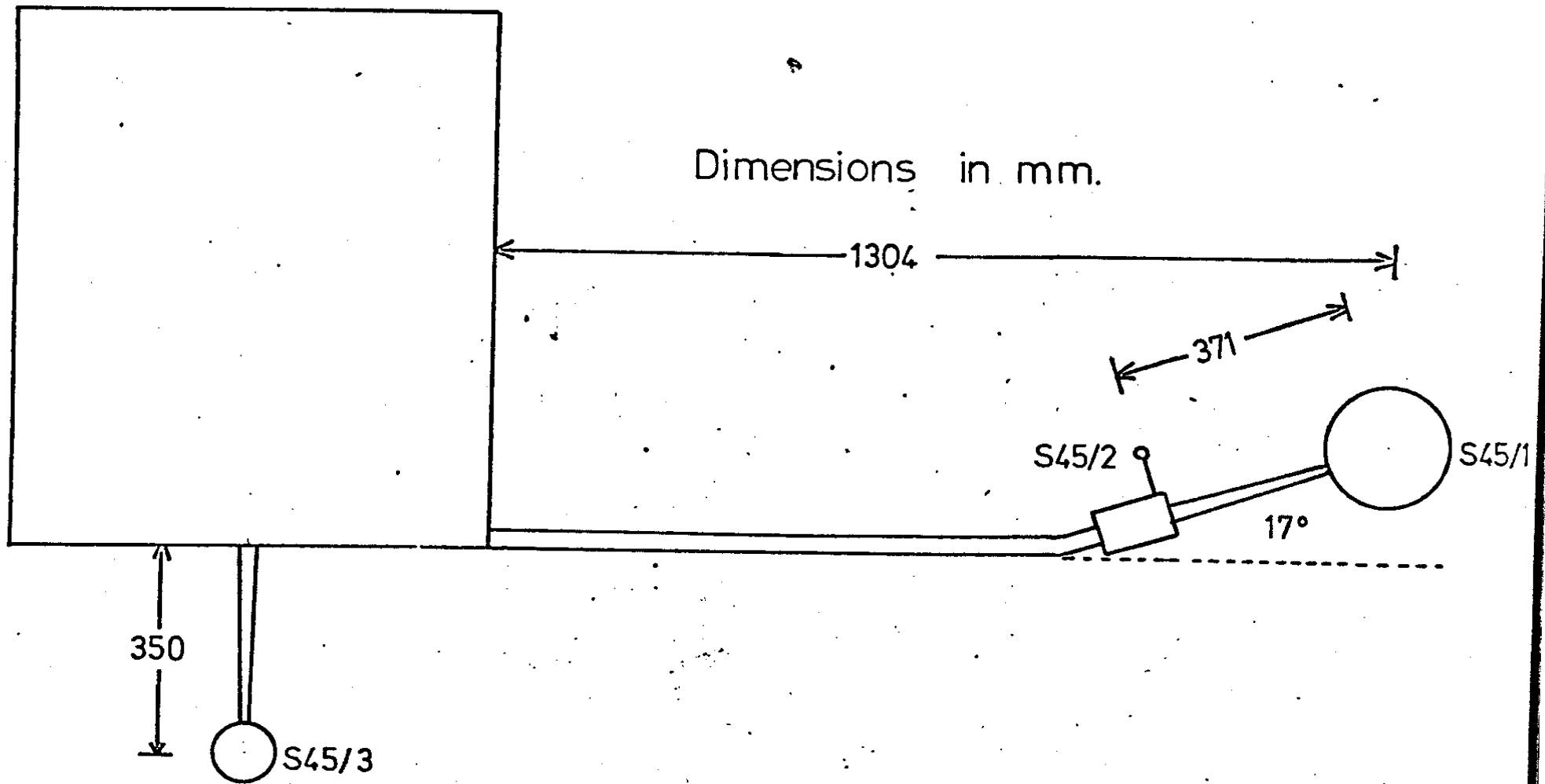


fig. Schematic Diagram Showing Positions of S45 Probes.

He⁺ He⁺ O⁺

Low Sensitivity Sweep High Sensitivity Sweep

5.12

Chan.
127
(T/M volts)

Orbit 824
18th Jan. 1973
Satellite in
attitude 4

0

5.12

Chan.
126
(T/M volts)

0

Time → (6.4 mm ≡ 1 sec)

fig 2. S45/1 Raw Data showing peaks in second derivative as He⁺ and O⁺ ions are retarded.
Data taken over the magnetic equator

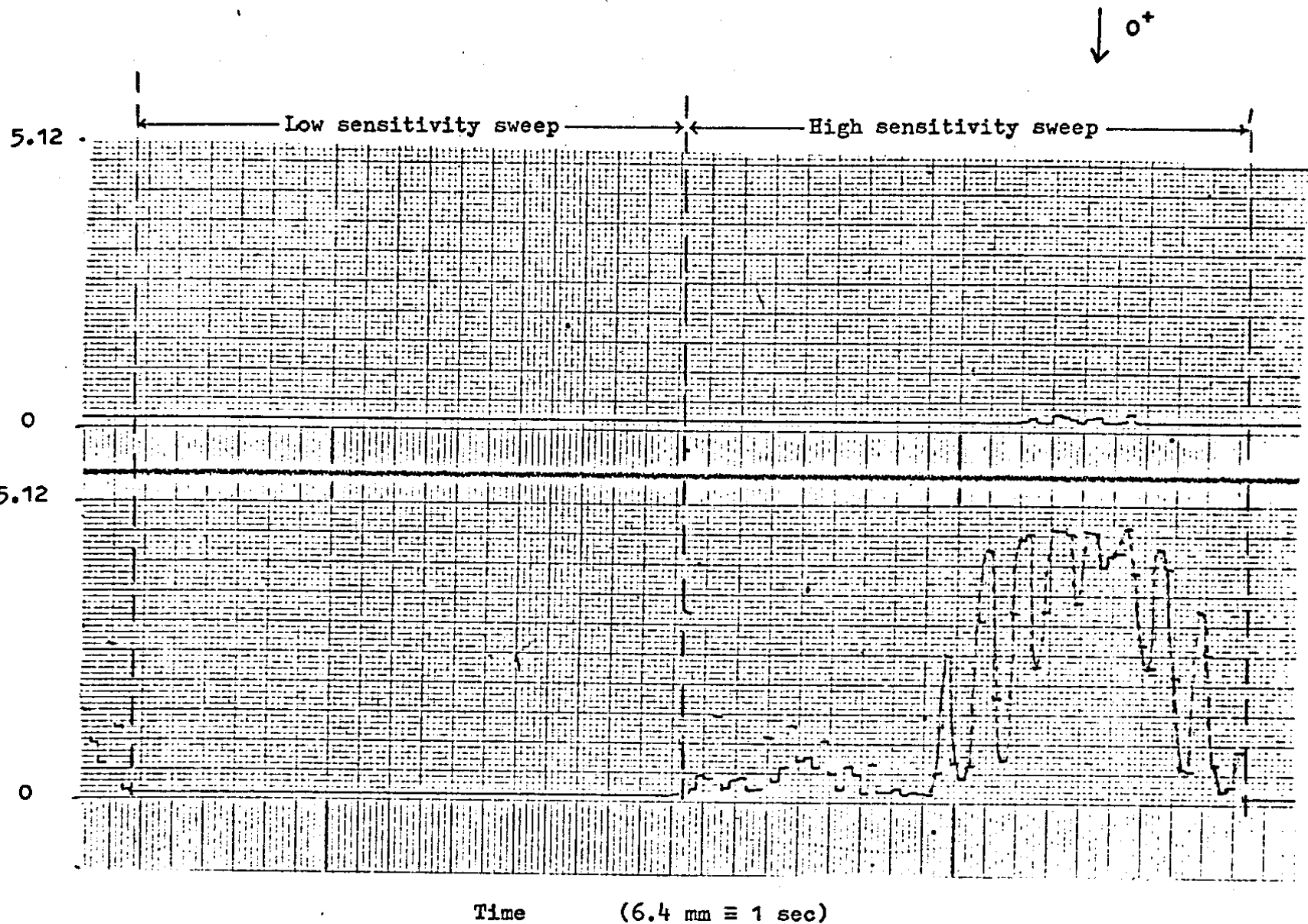


fig 3. Example of S45/1 raw data showing spin modulation due to $v \times B$

Orbit 1000 29th Jan. 1973

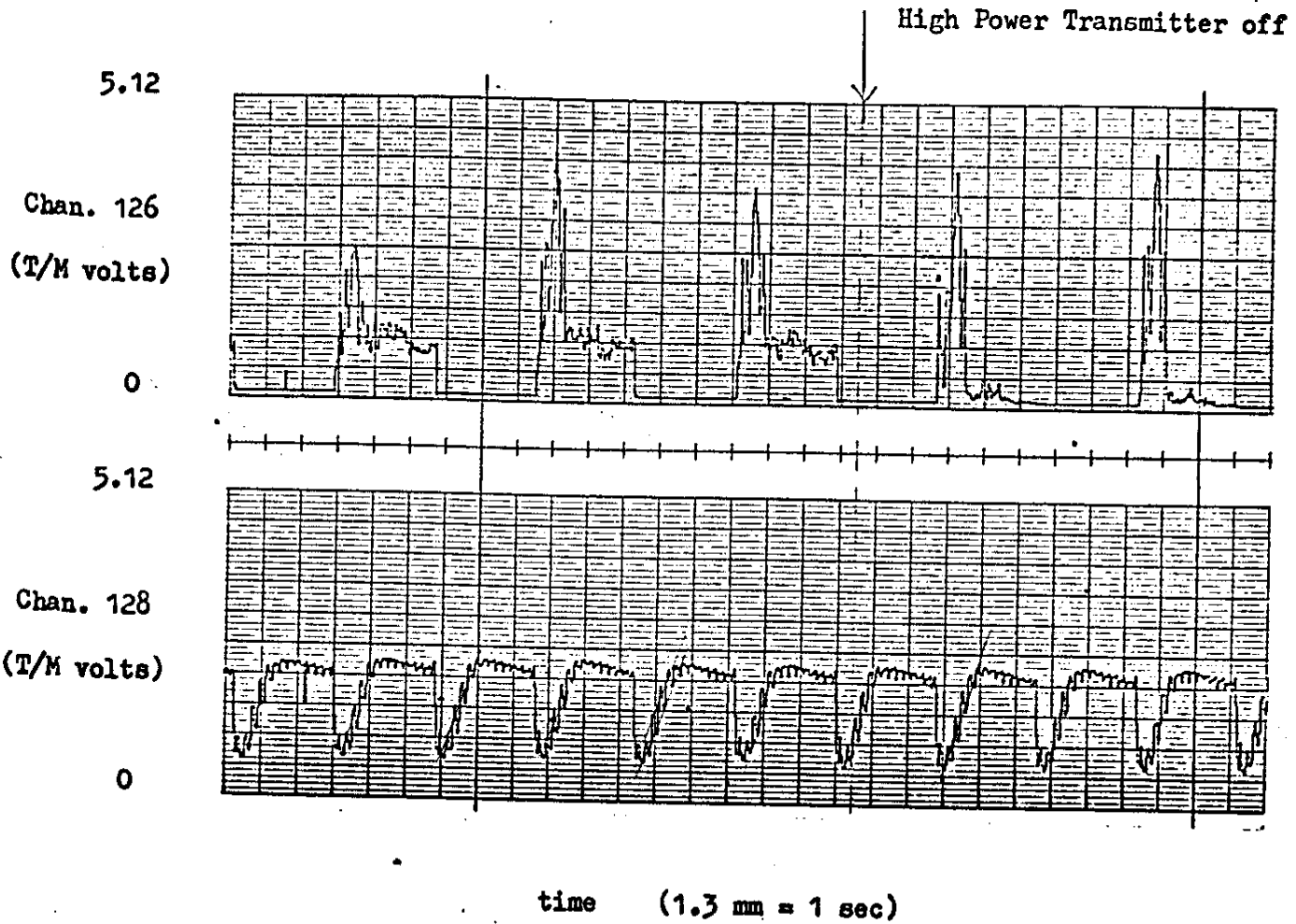


fig. 4 Interference to S45/1 data from High Power Transmitter

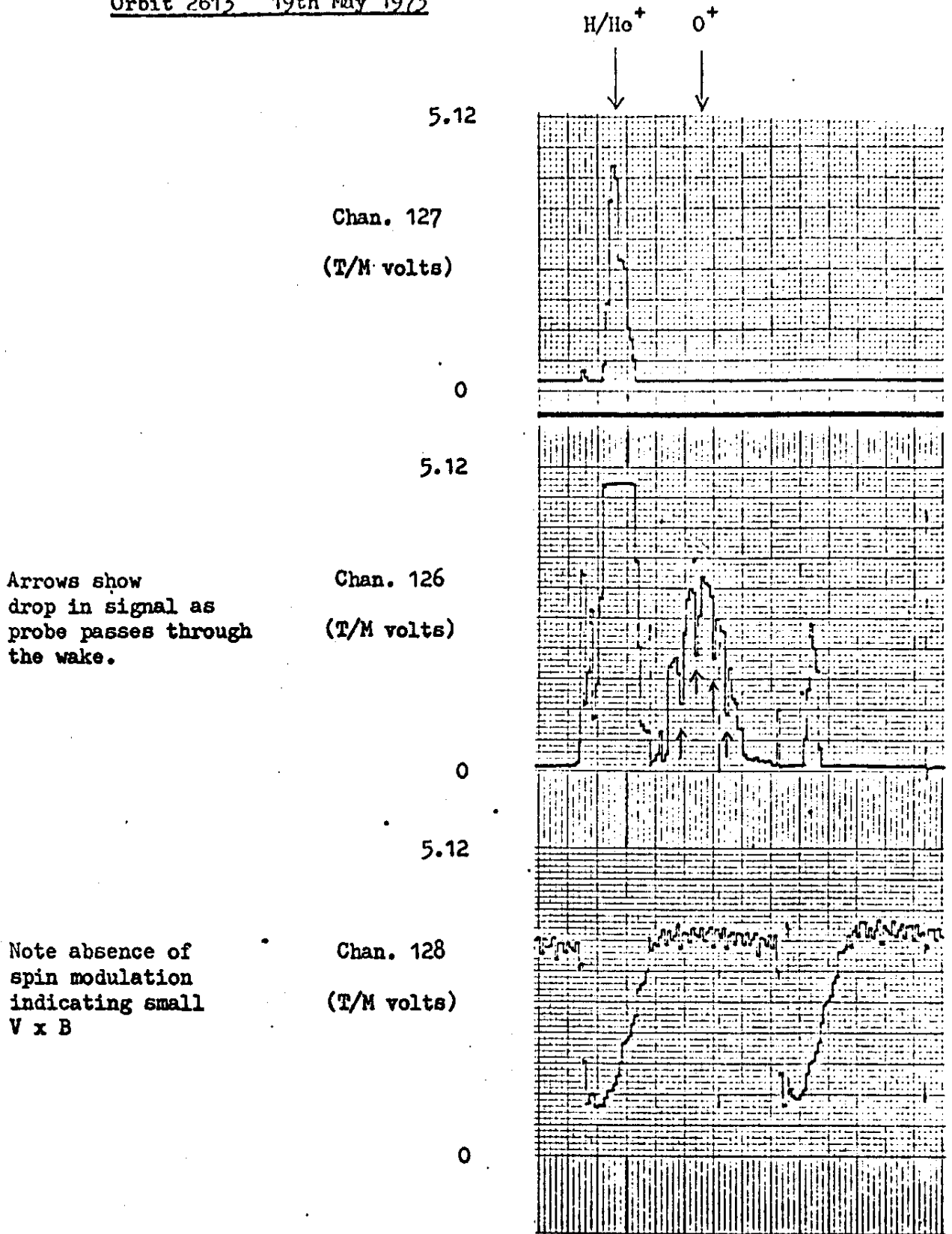
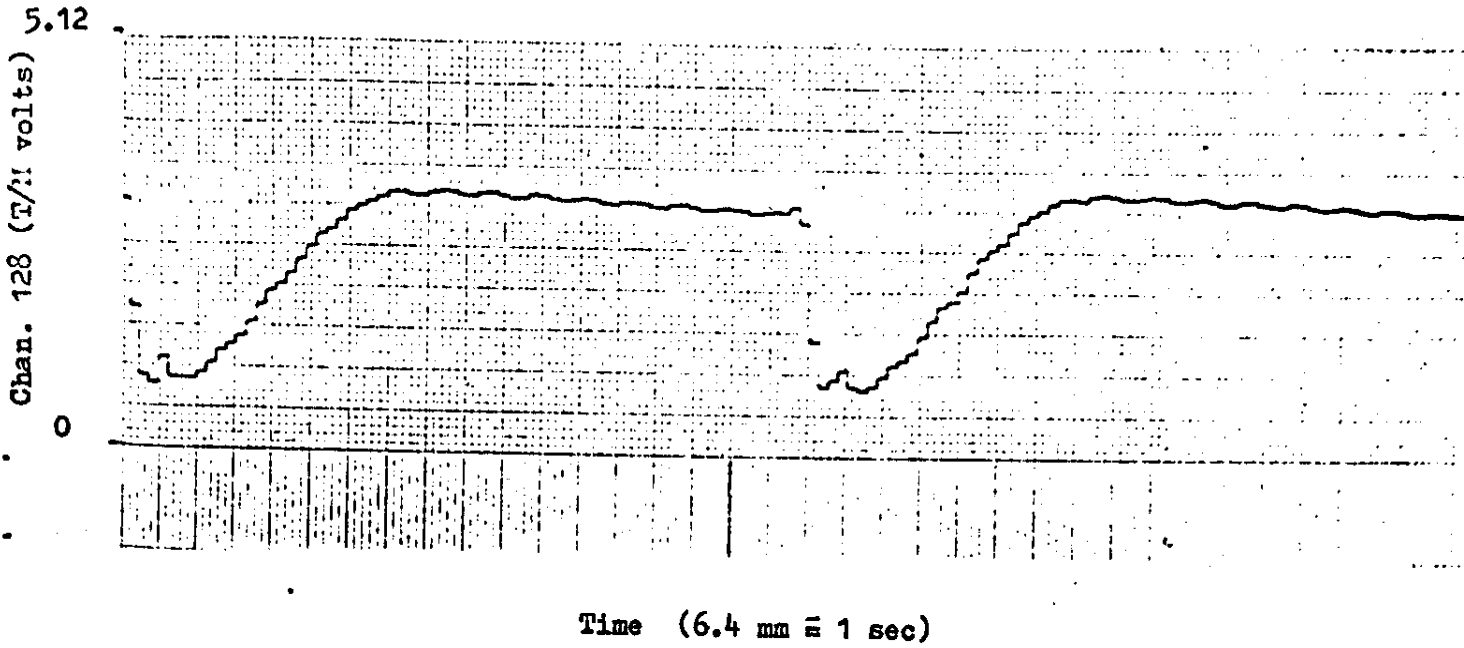
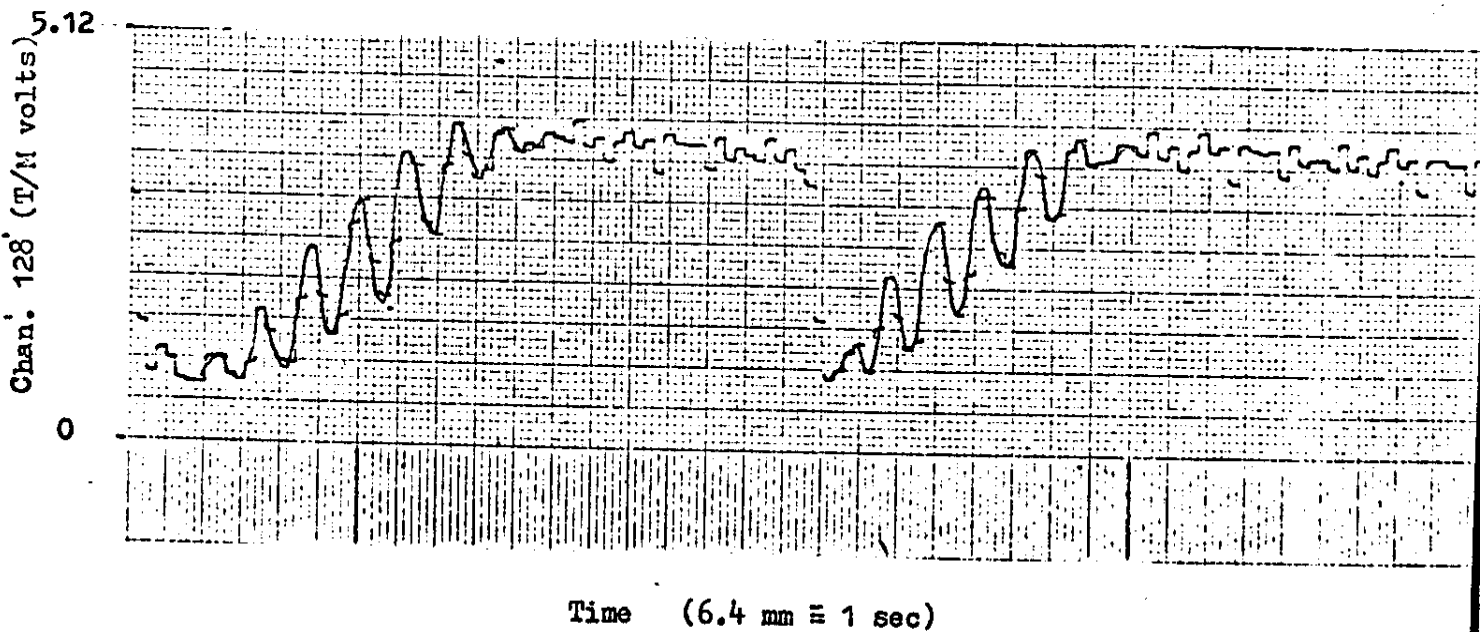


fig 5. Wake effect observed by S45/1 Probe



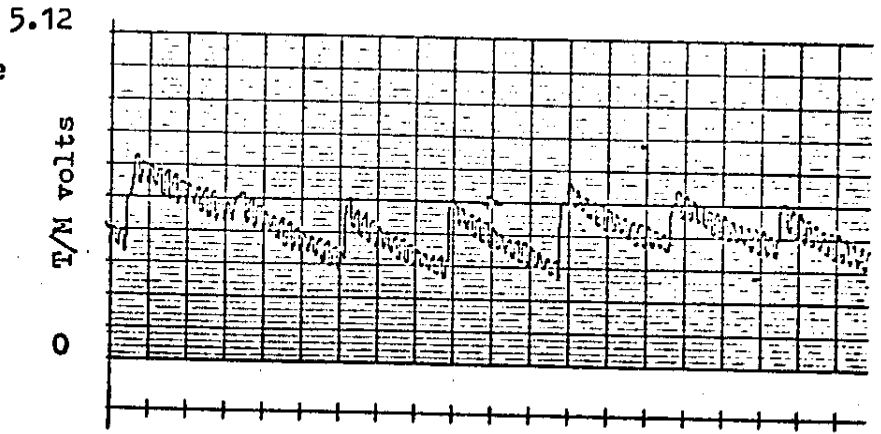
a) Data taken near equator when $v \times B$ tends to zero



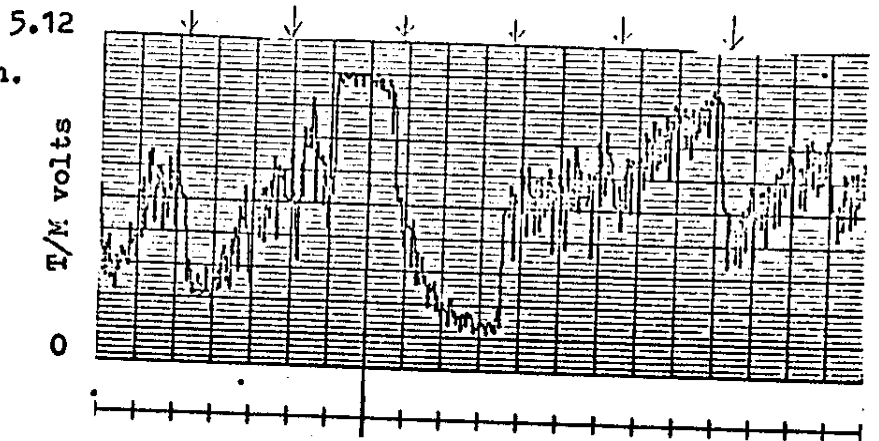
b) Data taken at higher latitude showing spin modulation

fig 6. Example of raw S45/2 Data

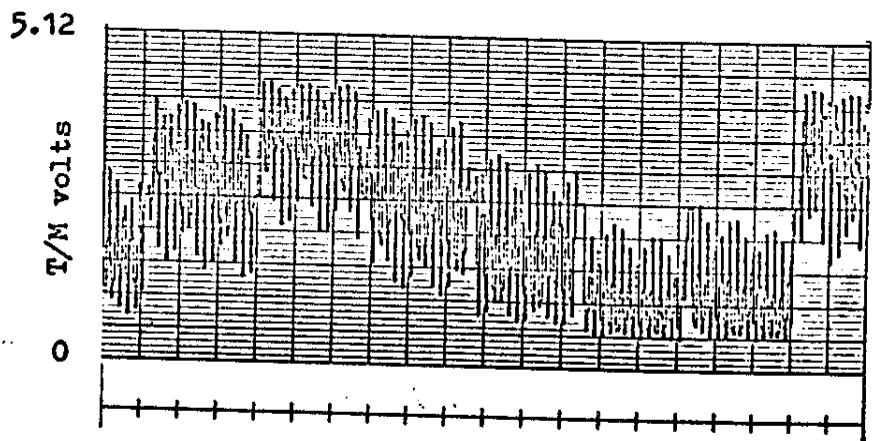
a) Undisturbed ionosphere showing regularly changing ion density



b) Disturbed polar region. Large amplitude rapid fluctuations. Arrows show reset times.



c) Spin rate modulation as S45/3 enters or leaves the wake of the satellite.



time (1.3 mm = 1 sec)

fig 7. Characteristic Forms of S45/3 Fluctuations Output

Chan
127

Chan
126

Chan
128

Chan
129

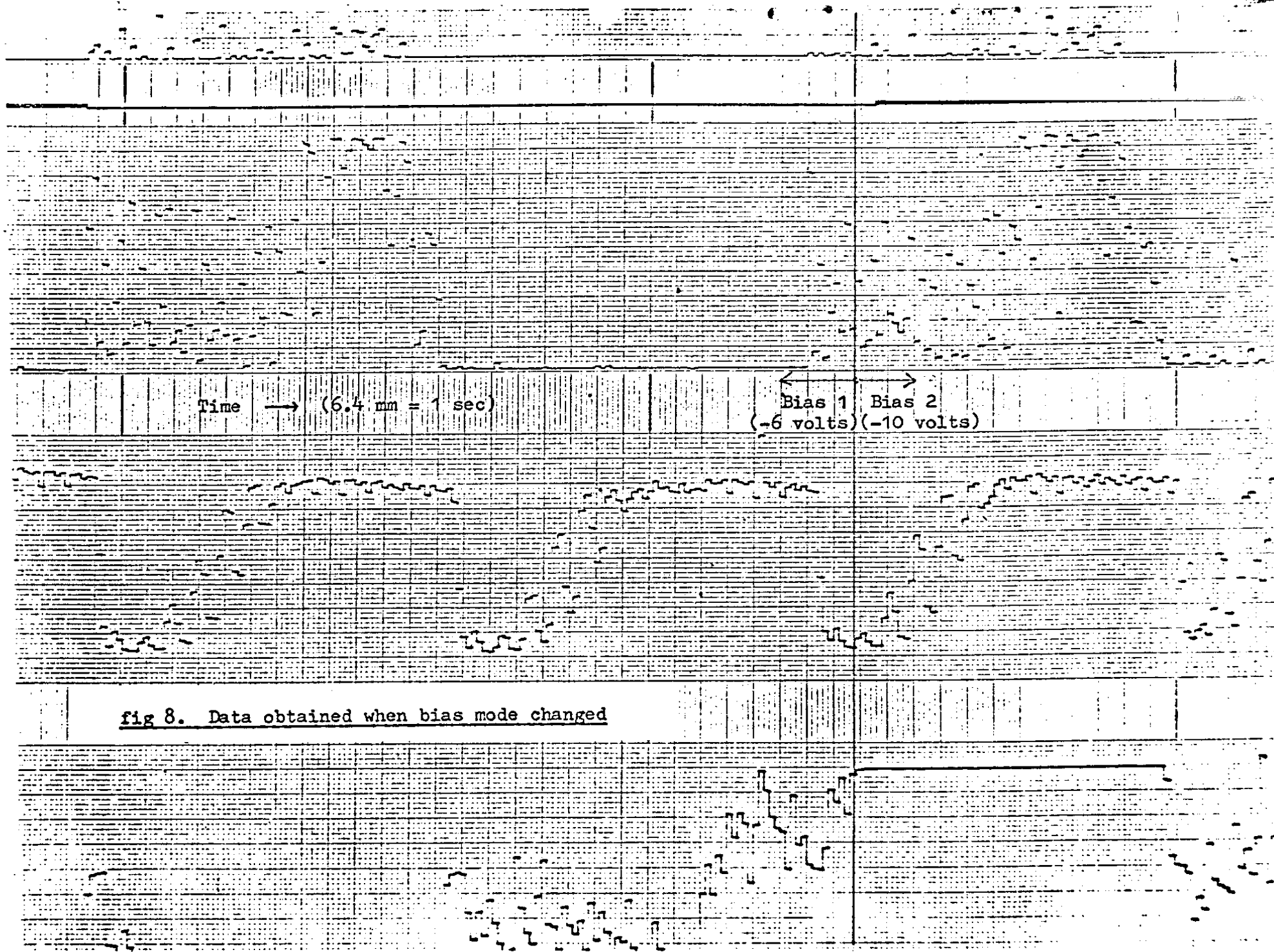
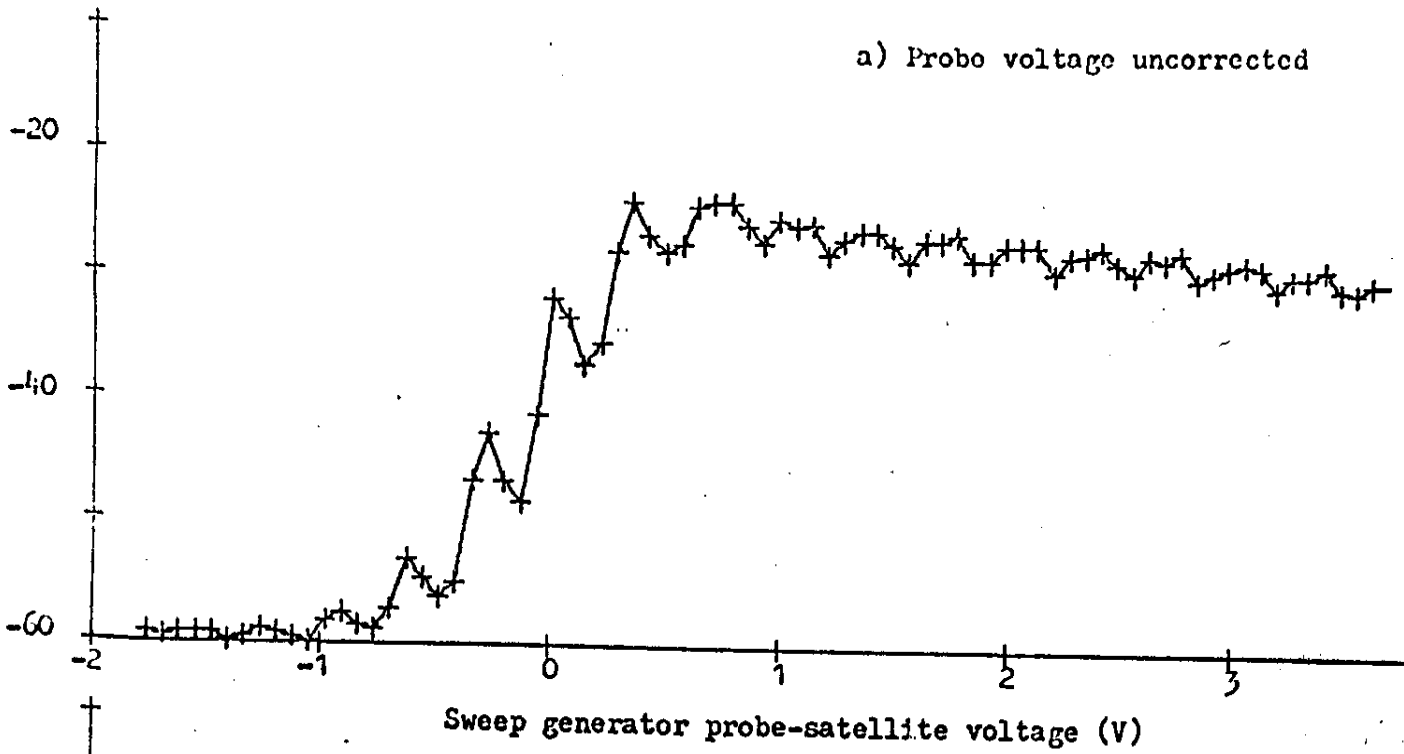
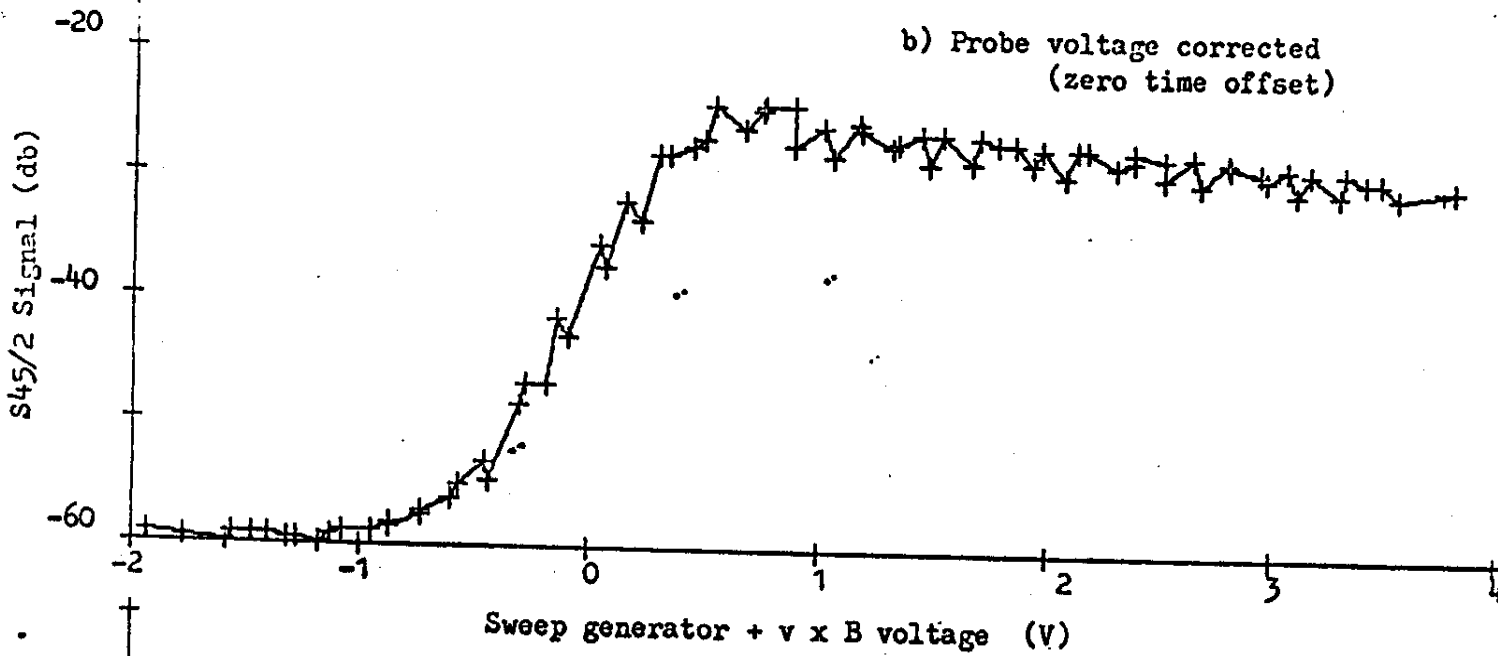


fig 8. Data obtained when bias mode changed

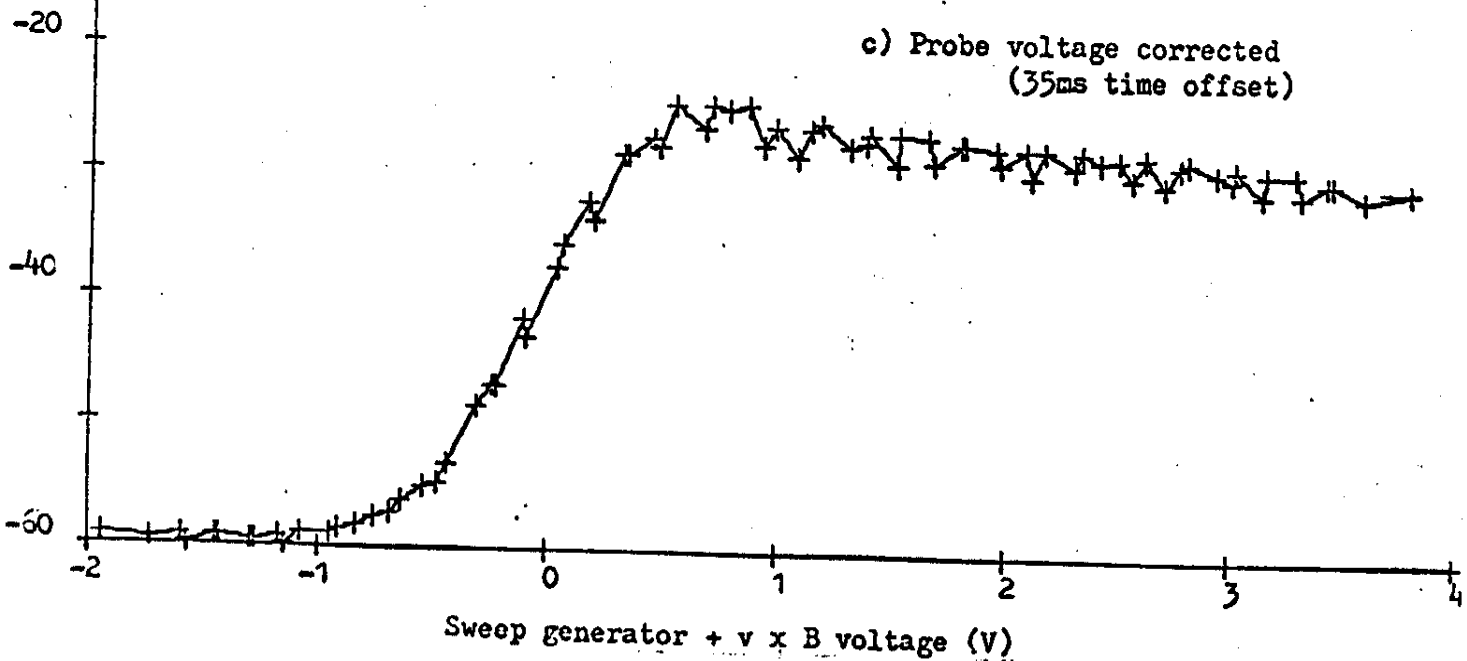
a) Probe voltage uncorrected



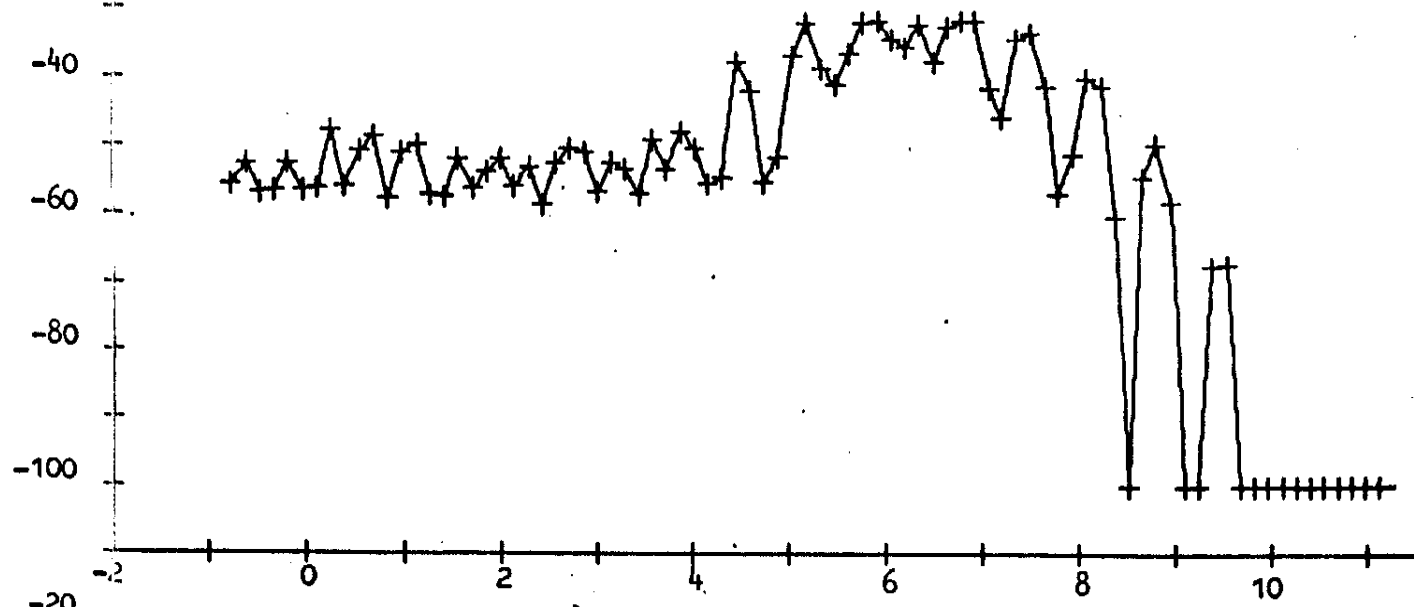
b) Probe voltage corrected (zero time offset)



c) Probe voltage corrected (35ms time offset)

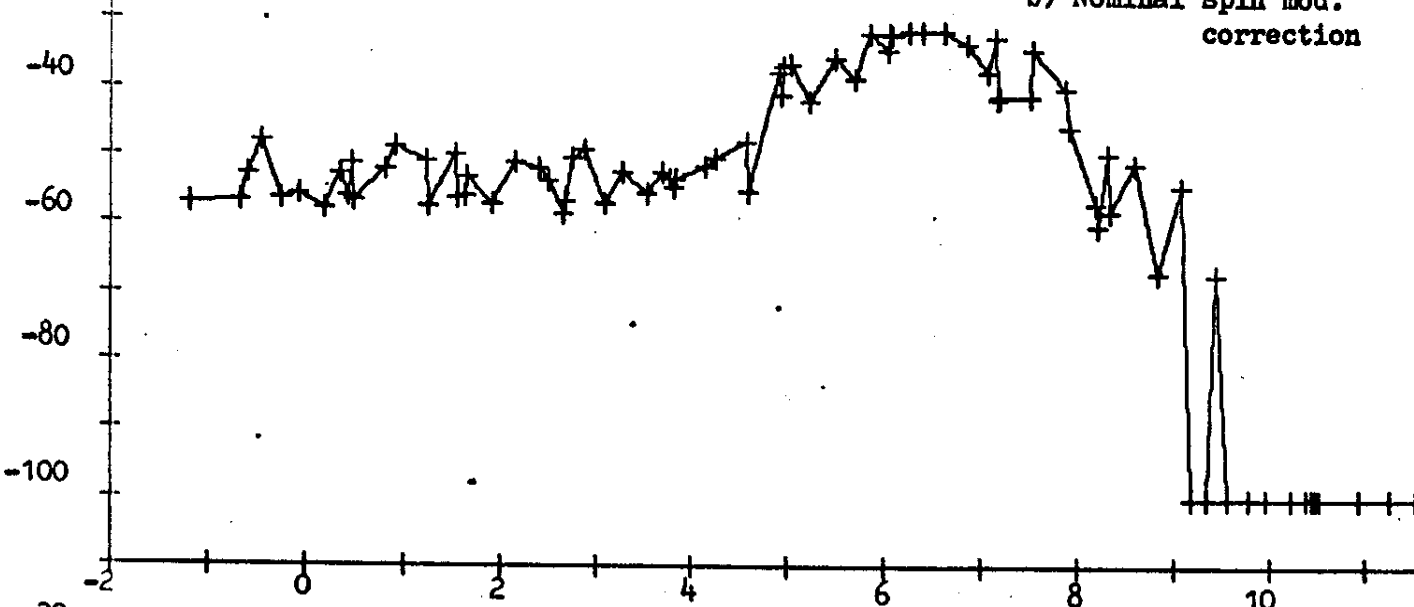


S45/1 signal (db rel 10^{-7} amp rms)



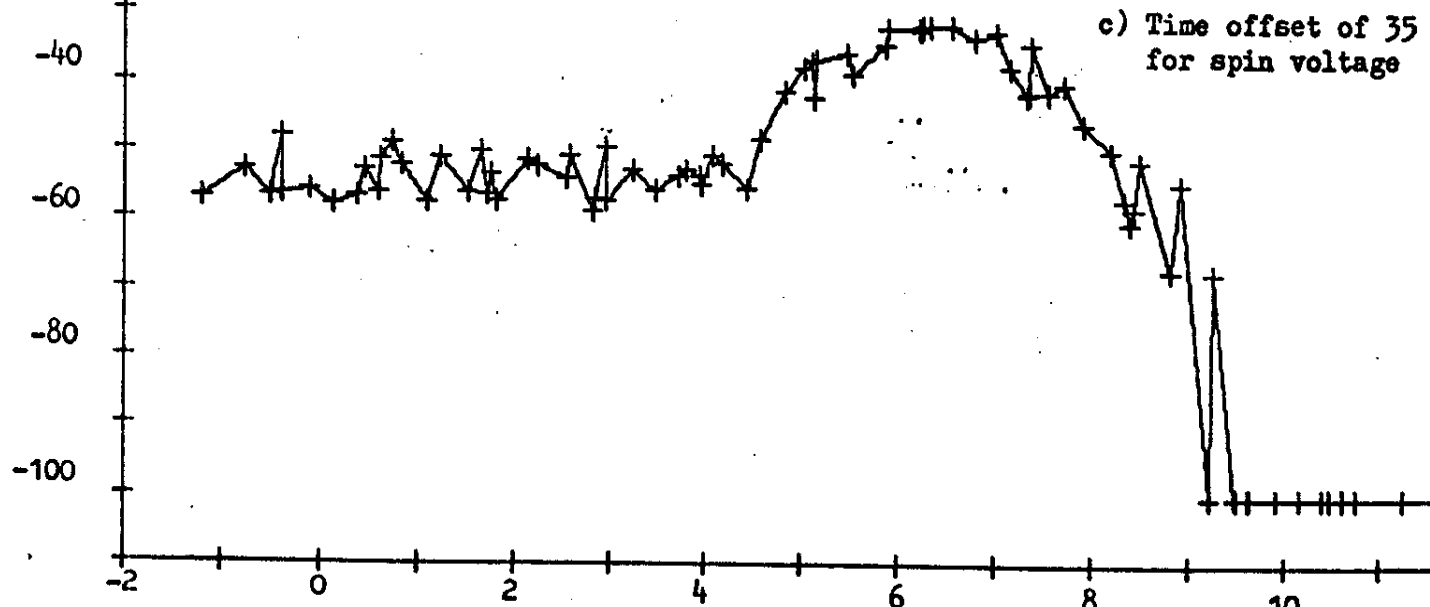
Uncorrected Probe-satellite voltage (V)

b) Nominal spin mod. correction



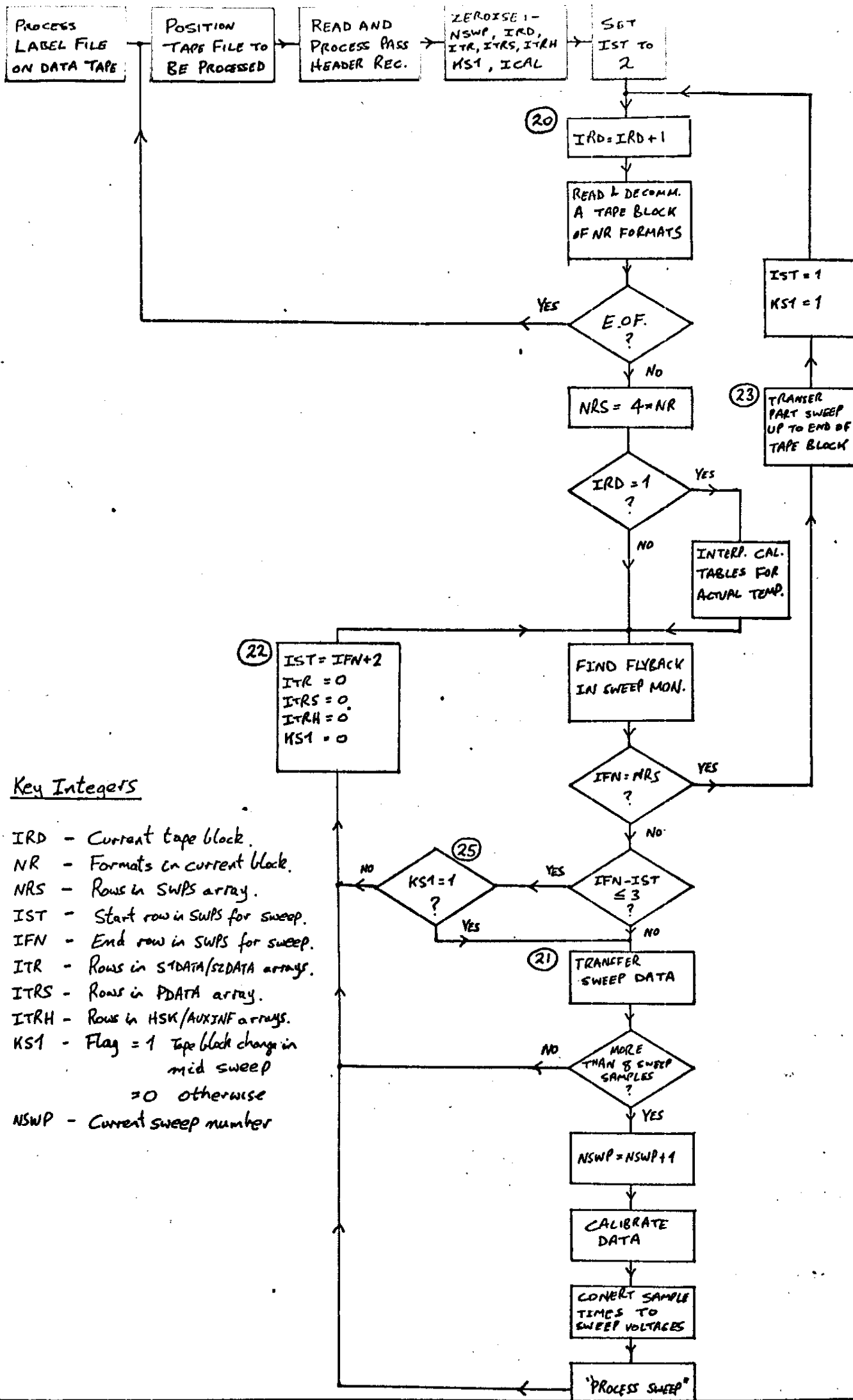
Probe-satellite voltage corrected for spin modulation (V)

c) Time offset of 35 mS for spin voltage



Probe-Satellite voltage corrected for spin modulation

fig 10 Spin modulation correction for S45/1

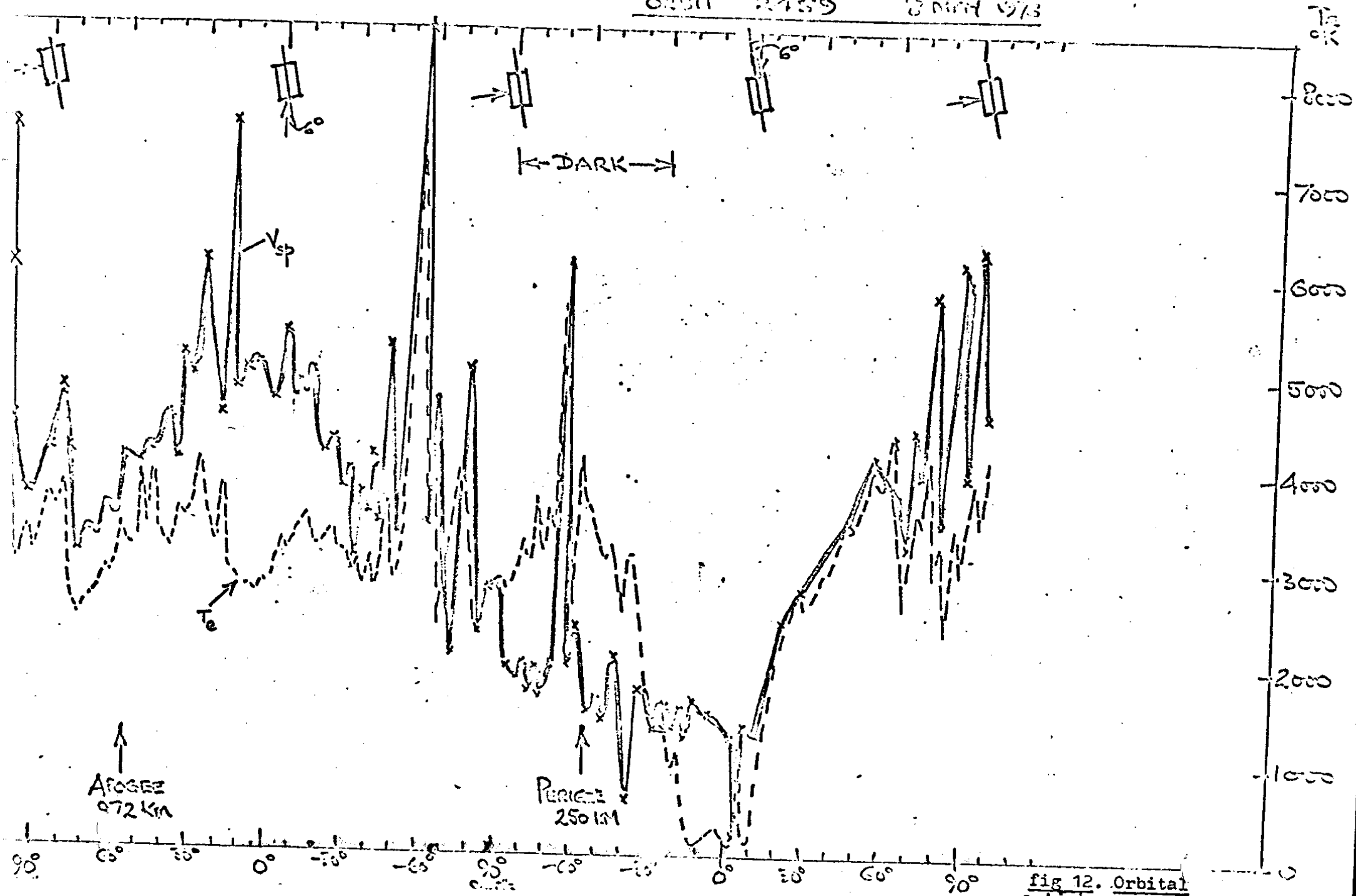


Key Integers

- IRD - Current tape block.
- NR - Formats in current block.
- NRS - Rows in SWPS array.
- IST - Start row in SWPS for sweep.
- IFN - End row in SWPS for sweep.
- ITR - Rows in S1DATA/S2DATA arrays.
- ITRS - Rows in PDATA array.
- ITRH - Rows in HSK/AUXINF arrays.
- KST - Flag = 1 Tape block change in mid sweep
= 0 otherwise
- NSWP - Current sweep number

ESD-4. T_e AND V_{sp} v. Latitude

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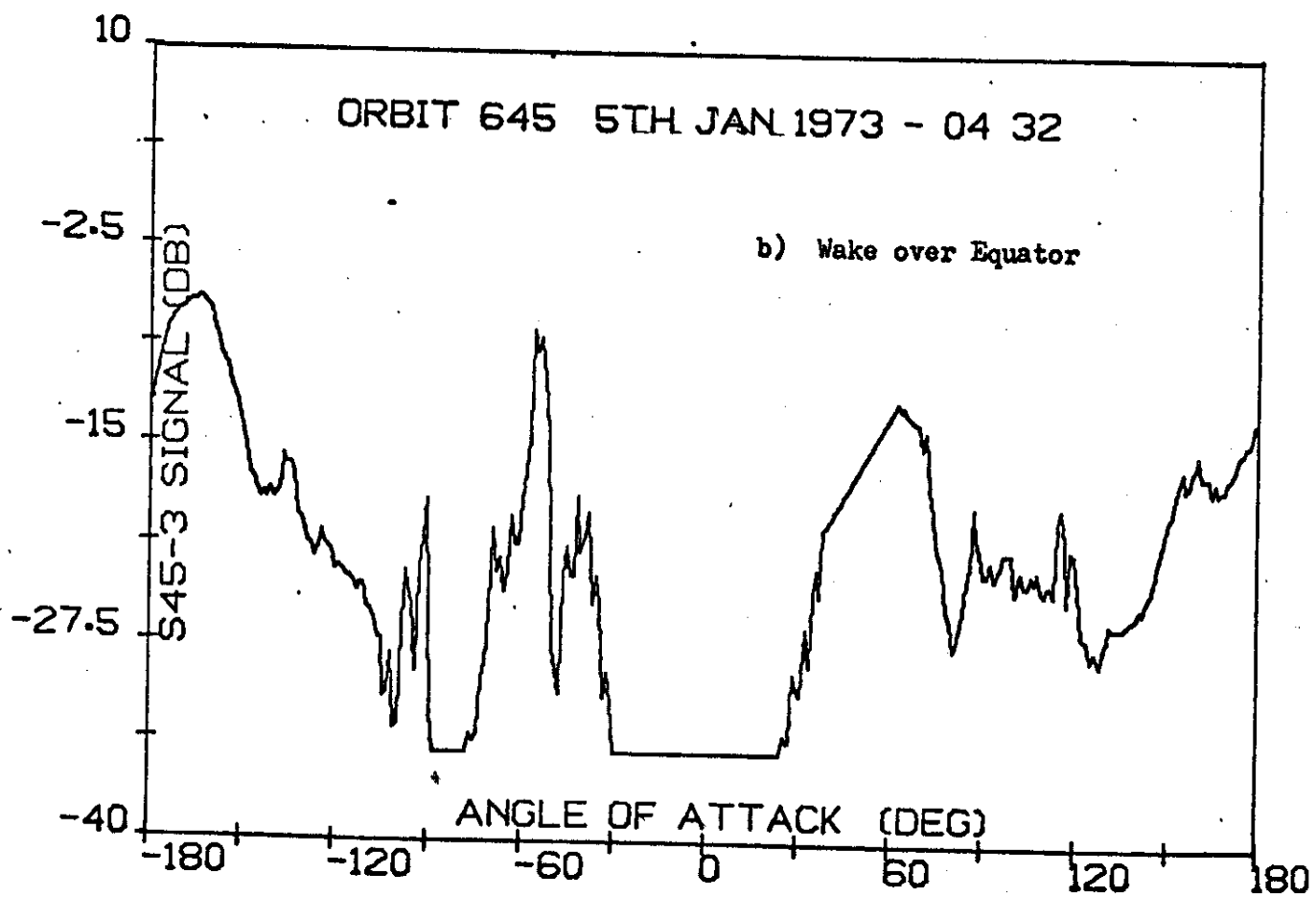
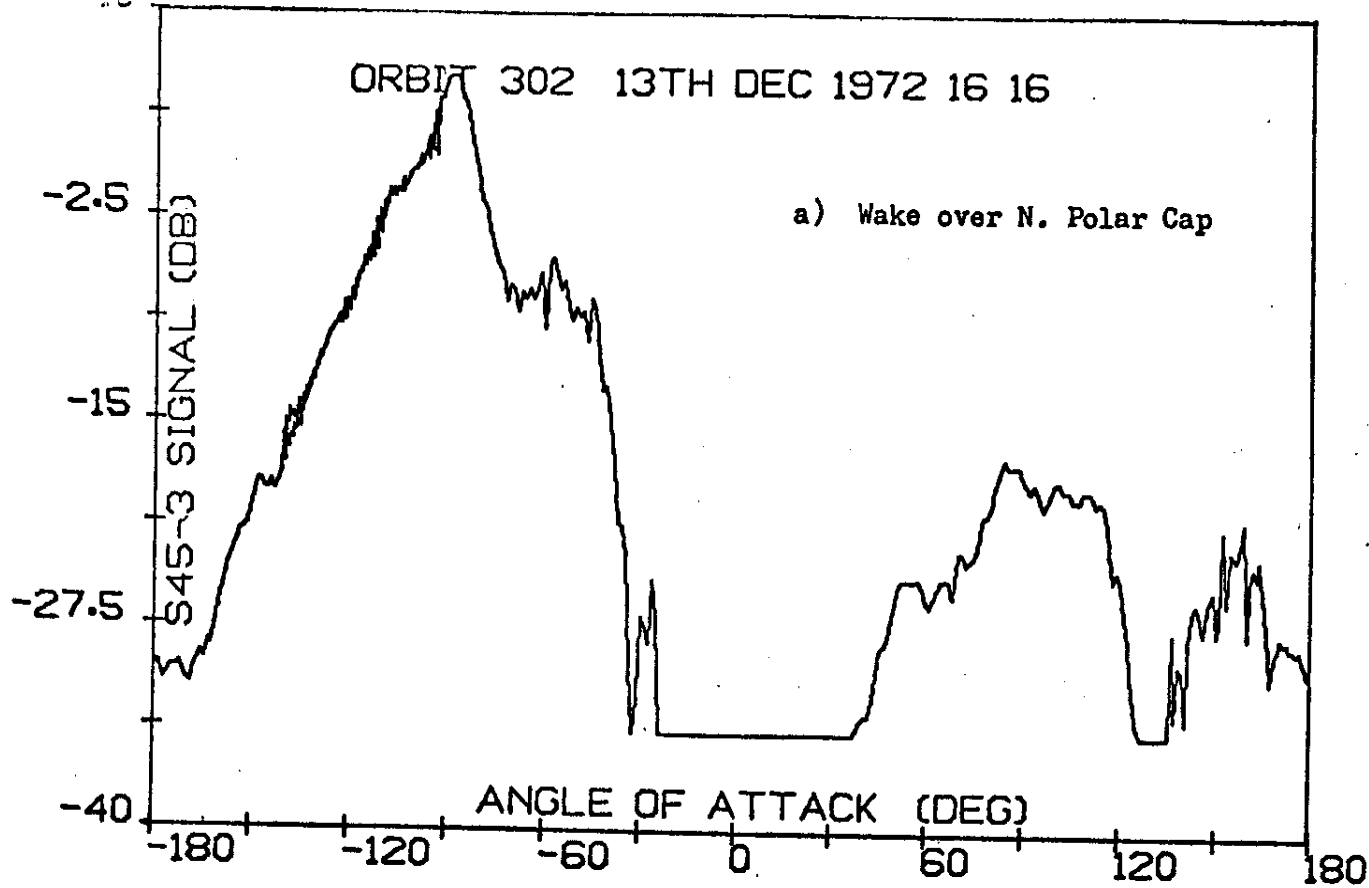


fig. 13 Plots of S45/3 data showing the satellite wake

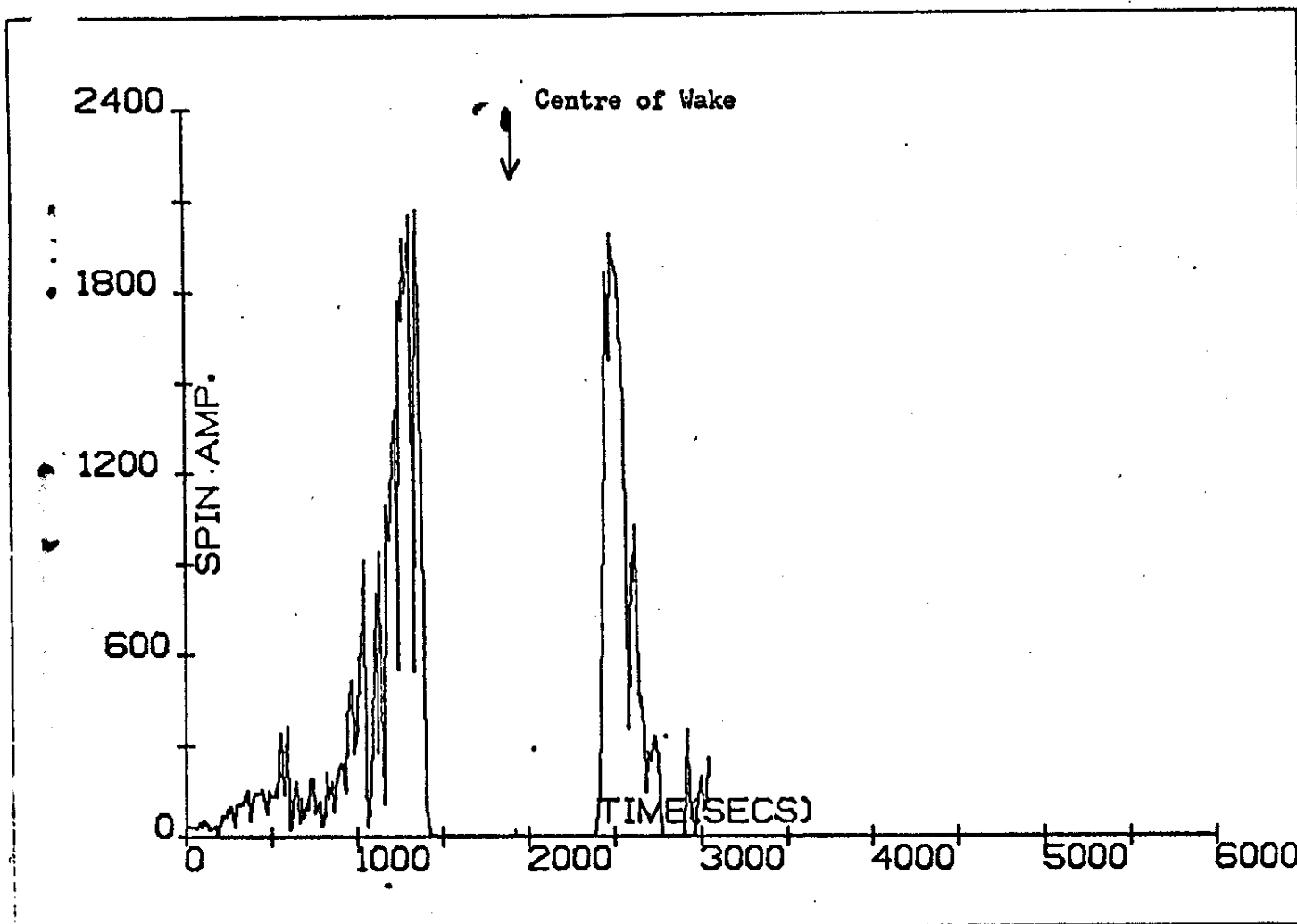


fig 14 Spin modulation on S45/3 fluctuations channel

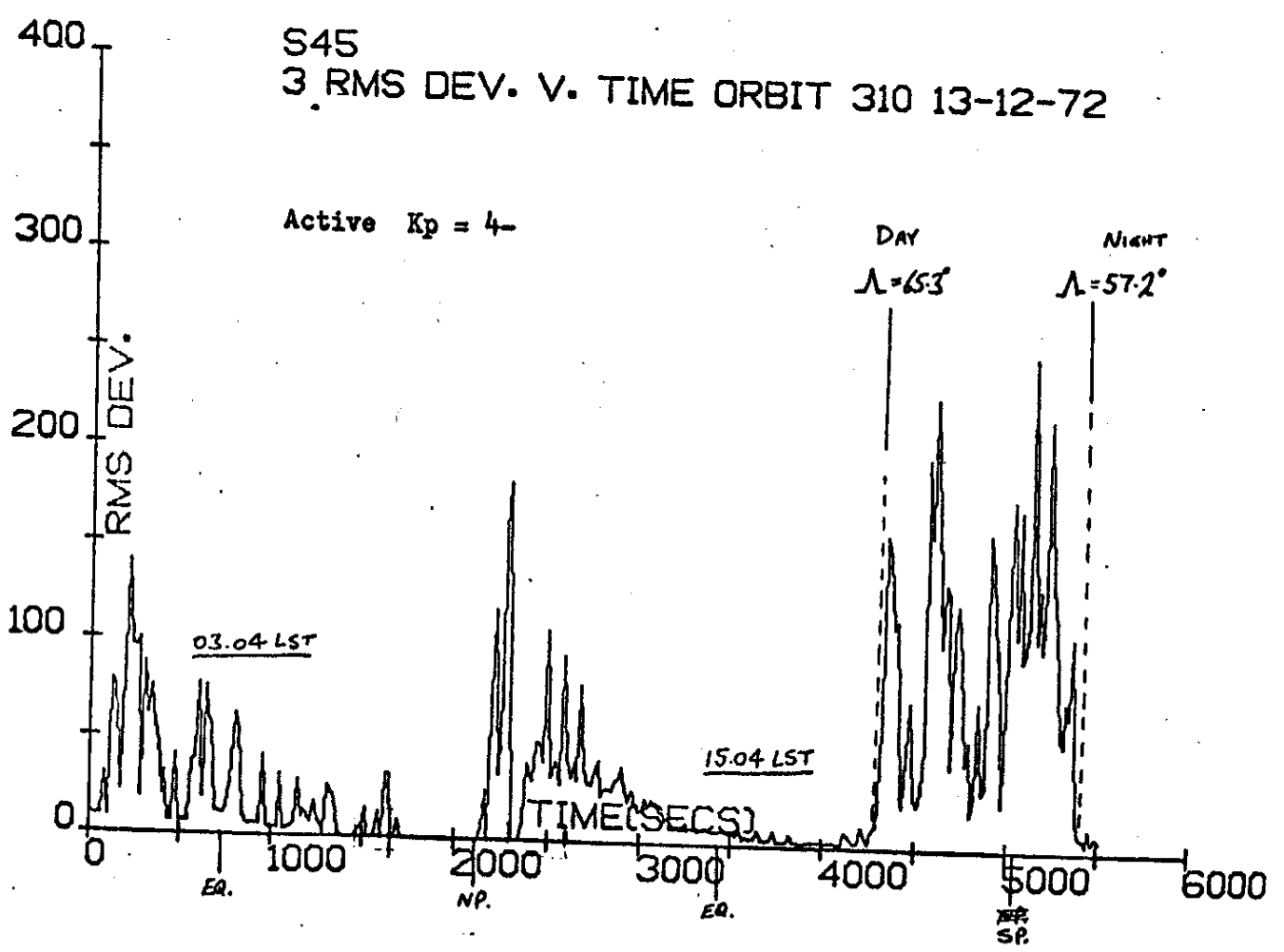
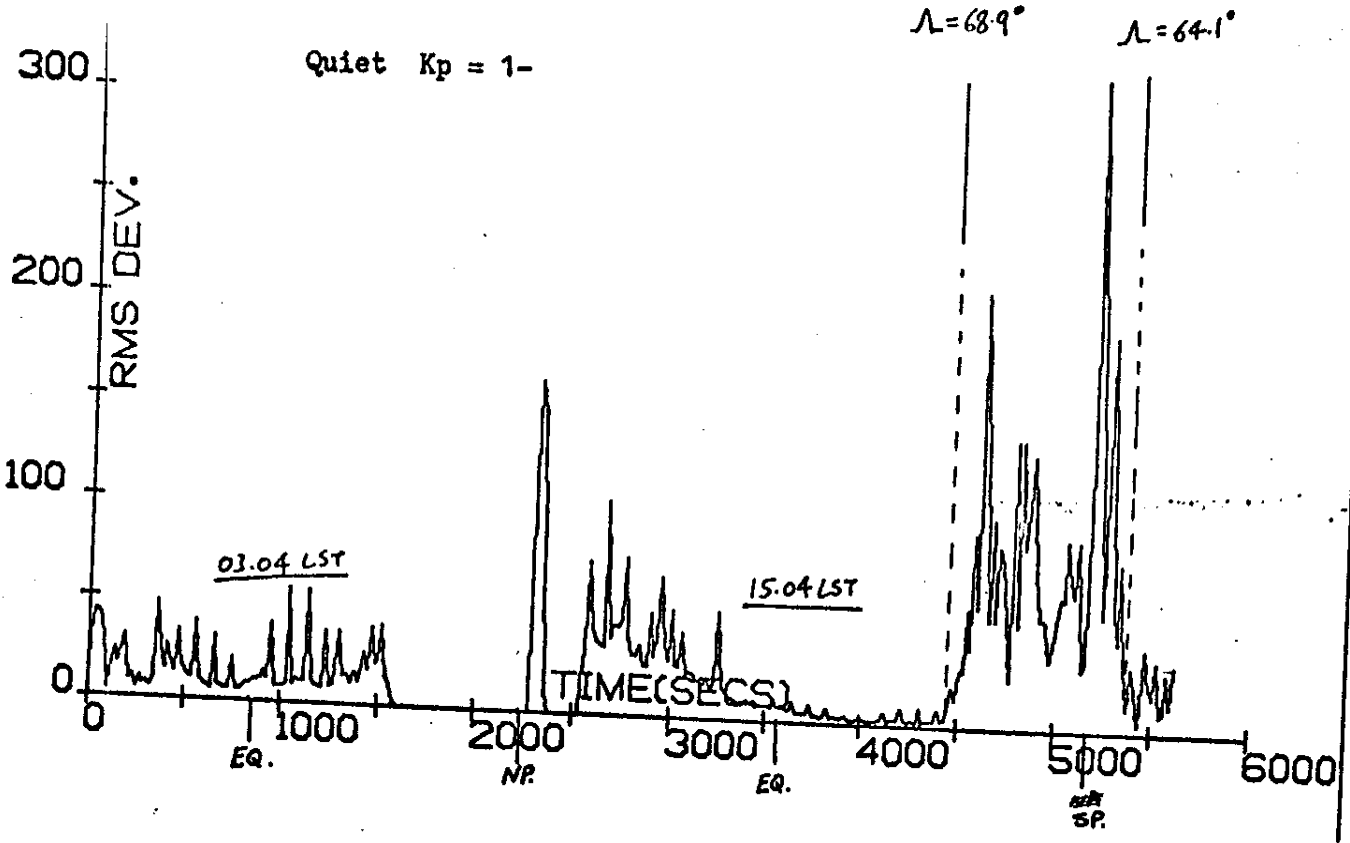


fig 15. Rms deviation showing particle precipitation boundaries at S.Pole

