ELECTRON IRRADIATION TESTS ON EUROPEAN METEOROLOGICAL SATELLITE

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SUMMARY

The observation of in orbit anomalies on **Meteosat** resulted in a test being performed to establish the charging and discharging characteristics of a flight configured engineering model when irradiated with electrons. Surface potentials were measured together with discharge rates and amplitudes.

INTRODUCTION

Following the launch of Meteosat 1 in 1978, a number of in flight anomalies associated with the radiometer, power and other subsystems were observed (ref. 1). Consideration of the satellite external surface configuration suggested that the most likely cause of the anomalies was the effect on sensitive electronic circuitry of electrostatic discharges. Subsequently a series of discharge tests, using spark gaps, were performed on the electrical model P1, to try to reproduce the effects seen in orbit (ref. 2). At the same time samples of materials i.e. radiometer mirror, thermal shield and SSM were irradiated to establish their charging characteristics (ref. 3).

The results of these studies confirmed the original idea that charging of the satellite due to the electron (1-20 keV) environment was responsible for the anomalies. Previously a large scale irradiation facility had been developed by SOPEMEA for ESA suitable for simulating the electron environment in geostationary orbit inside a large vacuum chamber (ref. 4).

It was therefore decided to perform a full scale test on the Meteosat P1 model, with fully representative external surfaces (i.e. thermal shield, solar panels, etc.) reflecting both the present in flight configuration and the proposed modifications.

Meteosat 1 has thermal shields and SSM's which are externally aluminized. However the conductive coating is not connected to the satellite ground. It was proposed that Meteosat 2 should have these surfaces grounded.

TEST OBJECTIVES

In view of the cost and problems of operating a complete ground station, the test was made on an electrically inert satellite. The test objectives may be summarised as follows:

a) to measure the induced satellite potentials as a function of incident electron energy
b) to measure the E-field produced by the discharges
c) to observe any physical degradation
d) to observe and locate discharges
e) to measure the radiometer mirror potential
f) to observe the variation of charging/discharging characteristics with inclination of the satellite with respect to the incident electron beam
g) to compare the above measurements for two configurations i.e. satellite external surfaces floating with respect to satellite ground and grounded with respect to satellite ground
h) finally it was hoped to measure the current discharge by having the possibility of grounding or floating the entire satellite itself

From the above measurements it was hoped to establish whether or not the satellite surface would charge differentially and to define culprit surfaces together with likely amplitudes of discharges.

TEST CONFIGURATION AND INSTRUMENTATION

General

A schematic of the test set up is shown in fig. 1. The satellite was mounted on an isolating adaptor ring in the solar simulation facility SIMLES at CNES, Toulouse. The satellite structure was connected to the facility ground by means of a high voltage relay. Switching the relay allowed two satellite configurations to be established i.e. floating and grounded.

Externally the satellite was initially the configuration of F1, with thermal shields isolated from satellite structure and with the F2 flight spare solar panels mounted. Subsequently the satellite was reconfigured to F2 by connecting the external thermal shields to the satellite structure.

The facility instrumentation can be divided into four categories:

a) Electron source and monitor
b) Satellite surface potential monitors
c) Radiometer surface potential monitor
d) E-field antennas

Electron source and Monitor

The electron source consists of a conventional electron gun providing a beam of electrons which is diffused by a thin aluminium foil in order to provide an homogeneous beam.

The homogeneity of the beam in the plane of the test object was measured and is shown in figure 2. The electron flux is measured by means of a fixed Faraday cup which is calibrated with respect to given levels in the plane of the test sample. This is monitored continuously during the irradiation.

During the test it was possible to interchange the diffusion foil by means of a simple crank. It should be noted here that after diffusion the electron beam is not monoenergetic. Measurements made at DERTS indicate that the electron energy spectrum will be that shown in figure 3. In this report all electron energy levels are given as the monoenergetic electron energy incident on the diffusion foil.

Satellite surface potential monitors

To measure the satellite surface potential six TREK potential monitors were installed as shown in figure 4. These probes were mounted on the SIMAT (acronym for the system allowing the satellite to be rotated and tilted simultaneously) and therefore allowed a continuous measurement of the external potential of the satellite as it rotated.

The probes themselves consist of a vibrating fork which samples the electric field and nulls it. Consequently high voltage feed-throughs were required together with intermediate line drivers, in view of the large (14m) separation of the probes from the external equipment.

In principle the separation of the probe from the charged surface is immaterial up to a maximum of 1 cm. However due to the topography of the satellite it was necessary to have a larger separation for which the probes were calibrated (fig. 5).

Radiometer potential probe

In order to monitor the radiometer mirror surface potential a simple capacitive divider with FET amplifier was used. The instrument, developed by DERTS, was mounted close to the mirror and had a shutter mechanism connected to the satellite ground to provide a reference datum after each measurement.

Data from the sensor was relayed to external monitor using a simple VHF transmitter powered by a battery. Switching of the battery was by means of the solar array.

Because the potential measured is referenced to the satellite ground point the results obtained with this sensor were difficult to interpret and this work is continuing.

E-field antennas

To monitor the E-fields produced by the discharges six antennas were installed around the satellite. Of these antennas one was calibrated and the resulting E-fields monitored on a BIOMATION 8100 transient recorder.

The other antennas were simple rod antennas mounted on the base of the chamber as shown schematically in figure 6. Four of these antennas were connected to simple detection circuitry to give a count of the number of discharges and to give some idea of the location on the satellite. The fifth antenna was connected to the input of an EMI receiver in an attempt to count only those discharges of high energy i.e. to integrate the pulse height-width product.

TEST PROCEDURE

The detailed test procedure was defined in ref. 5 and subsequently modified during the test in light of experience gained. Briefly, the test was divided into three phases as follows:

PHASE A: Satellite vertical and stationary with the radiometer facing the electron gun. After irradiation of duration 1, 2, 4, etc. minutes the satellite was rotated to allow measurement of the potential profile and the radiometer mirror potential. The above performed with the satellite grounded and floating.

PHASE B: Satellite inclined at + 23° and rotating at ± 1 turn/min. After ten minutes satellite tilted to - 23°. The objective here was to simulate the inclination of the satellite w.r.t. the sun at soltices. Again the test was performed floating and grounded.

PHASE C: Satellite inclined at + 23° or - 23° and irradiated for a fixed period and orientations of α = 0, 60, 120, 180, 240, 300 w.r.t. to the electron gun.

For each of the above phases the irradiations were performed with electron energies of 10, 15, and 20 keV.

Phase B and C were performed in both satellite configurations i.e. thermal shields floating and thermal shields grounded to satellite structure.

PRELIMINARY OBSERVATIONS

Before starting the test a series of tests and controls were made.

A flasher test was performed on each solar panel to ensure each was functionning correctly. This test was repeated after the completion of the whole test and verified that there was no measureable change in the performance of the solar panels. The isolation of the thermal blankets was verified, one was repared and one correctly isolated after it was found to be arcing at 100v.

No observable degradation was seen as a result of the test. The isolation of the satellite mounting ficture in SIMLES was measured at 500v only and found to be greater than 10 MΩ. This being the limit of the test equipment.

TEST RESULTS

The results obtained during the various test phases are summarised in Table 1. Figures 8-10 show the actual surface potential. In view of the fact that the probe separation in the satellite was only measured at intervals of 30° the fine structure of the profile is lost and therefore the original plots are included.

The orientation angle α is referred with $\alpha = 0$ as the position where the radiometer mirror is facing the electron gun. Therefore, in view of the position of the probes, i.e. on opposite side of satellite, the plot α □ 180° would correspond to the radiometer facing the probes. (Fig. 7)

Potential plots are only shown for the probe monitoring the satellite circumference. This is due to the fact that considerable difficulty was had in maintaining the correct operation of the probes at all times during the test. During the test some probes became noisy and stopped functionning, other probes started discharging. Unfortunately it was not possible to resolve these problems and the cause of malfunction is being investigated.

It should be pointed out that across the face of the radiometer aperture was placed a metal band connected to satellite structure. Values of α □ $180^\circ \pm 5^\circ$ correspond to this band.

Clearly evident in these plots are the large potential gradients which can exist together with the relatively low value of satellite structure potential.

The variation of circumferential potential with incident energy is clearly shown in Figure 11.

The discharge activity was assessed quantitively by the number of counts on the four antenna monitors. With the satellite in the vertical position there is no apparent difference between the antenna readings (Fig. 12). However with the satellite inclined there is clearly a correlation with antenna position and angle of inclination (figs. 13 and 14).

The measurements of electronic field showed wide differences with a maximum measured field of about 5000 v/m although typical values were between 500 v/m and 1500 v/m. These are shown in figures 15 and 16.

After modifying the external surfaces by grounding them to the satellite the discharge activity was greatly reduced as shown by comparing the antenna readings before and after (fig. 17).

The measurement of generated electric field indicate that the magnitude of the field was reduced by about 20 dB. However, it should be remembered that the grounding of the shields will also improve the r.f. attenuation characteristics should the field be generated inside the satellite structure. This apparent improvement in the generated electric field must be treated with some caution.

FINAL OBSERVATIONS

The satellite surfaces were closely inspected before and after the electron bombardment. No visible degradation or effects of any kind were noticeable.

Due to the fact that the satellite was electrically inert it was not possible to see the effects of discharges on the satellite electronics. However, a post check system test verified that no damage was sustained in the electronics during this test.

During the test it was possible to see the discharges occurring over a large part of the satellite. From observations and photos it is clear that the majority of these take place on or around the solar cells with other discharges occurring at the edges of the thermal shield (fig. 18).

CONCLUSIONS

It is clear from the foregoing test results that a large number of discharges are possible on the satellite whether or not the external surfaces are grounded.

For the initial measurements we can see that there are very high potential gradients around the satellite which obviously contribute largely to the discharging behaviour.

Results show that the time constant for charging is very small, indicating also that equilibrium conditions are achieved very quickly as the local ambient changes in orbit.

Of particular interest in this test is the comparison between the results obtained with the satellite floating and grounded to the facility.

From a simplistic consideration of the charge-discharge mechanism it would be expected that with the satellite floating no discharges would occur since the satellite should reach equilibrium with the incident electron beam. Where the satellite is grounded a reference plane is obtained which should then propagate discharges.

What has been observed is the opposite. No discharges have been observed when the satellite was grounded and the most intense discharge activity has been obtained with the satellite floating. No explanation of this effect is offered here but the phenomenum will have to be investigated in the future.

There is no indication that the test on P1 with flight solar panels has degraded in any way the optical, thermal, or electrical performance of the satellite. We therefore recommend that this type of test be included as an "acceptance test" for satellites likely to undergo electrostatic charging, to be performed as part of the normal thermal vacuum testing.

In light of experience gained during this test a number of recommendations can be made to improve the quality of data. The most obvious improvement concerns the measurement of surface potential. The inability to measure the potential at all times restricted the scope of the test considerably.

The use of rod antennas to locate the discharges could be extended by employing a matrix of identical antennas.

The auxiliary recording equipment for monitoring the data should be expanded to allow simultaneous records of all parameters to be made. This will allow much better correlation of events during the test.

Finally the addition of on-board satellite monitors will improve the knowledge of coupling mechanisms into the satellite even on an electrically passive model.

REFERENCES

1. "METEOSAT Spacecraft Charging Investigation" Final Report ESA Contract 3561/78 F/GG/SC.

2. "Programme d'Essais 'Arcing' METEOSAT P1". Doc 2606/83 TCA May'78 - Aerospatiale/Cannes.

3. "Essais d'Irradiation d'un Miroir de METEOSAT". Etude CERT 4081.

4. "The Qualification of a Large Electron Irradiation Facility for Telecommunications - Satellite - Differential - Charging Simulation". Sérène, Reddy; ESA Journal 1979, Vol. 3.

5. "METEOSAT Irradiation Test Procedure". ESA EOPO OS/3109-78/DH-JM.

TEST SUMMARY

Phase	Satellite configuration	Incident energy	Antenna acount	Potentials	E-Field
A1	Floating	10 keV	Few	1 kV	40 v/M
A2	Grounded	10 keV	Nil	1 kV	-
A3	Floating	15 keV	60	3,5 kV	400 v/M
A4	Floating	20 keV	40	6 kV	500 v/M
B1	Floating	15 keV	30	6,5 kV	100 v/M
B2	Floating	20 keV	30	4,5 kV	1200 v/M
C1	Floating	20 keV	20	-	5000 v/M
C2	Floating	20 keV	20	-	5000 v/M
C1.1	Floating	20 keV	Few	4 kV	50 v/M
C2.1	Floating	20 keV	20	4 kV	400 v/M
B1	Floating	20 keV	60	6 kV	150 v/M
EXTERNAL SURFACES MODIFIED					
C1.1	Floating	20 keV	Few L.L	-	40 v/M
C2.1	Floating	20 keV	10	-	400 v/M
B1	Floating	20 keV	Few L.L	-	400 v/M
B2	Grounded	20 keV	Few L.L	-	200 v/M
B3	Floating	15 keV	Few L.L	-	40 v/M
B4	Grounded	15 keV	Few L.L	-	10 v/M
B5	Floating	10 keV	Nil	-	-
B6	Grounded	10 keV	Nil	-	-
B7	Floating	- keV	Nil	-	-
B8	Grounded	- keV	Nil	-	-
C1.2	Floating	20 keV	Nil	-	-
C2.2	Grounded	- keV	Nil	-	-

TABLE 1

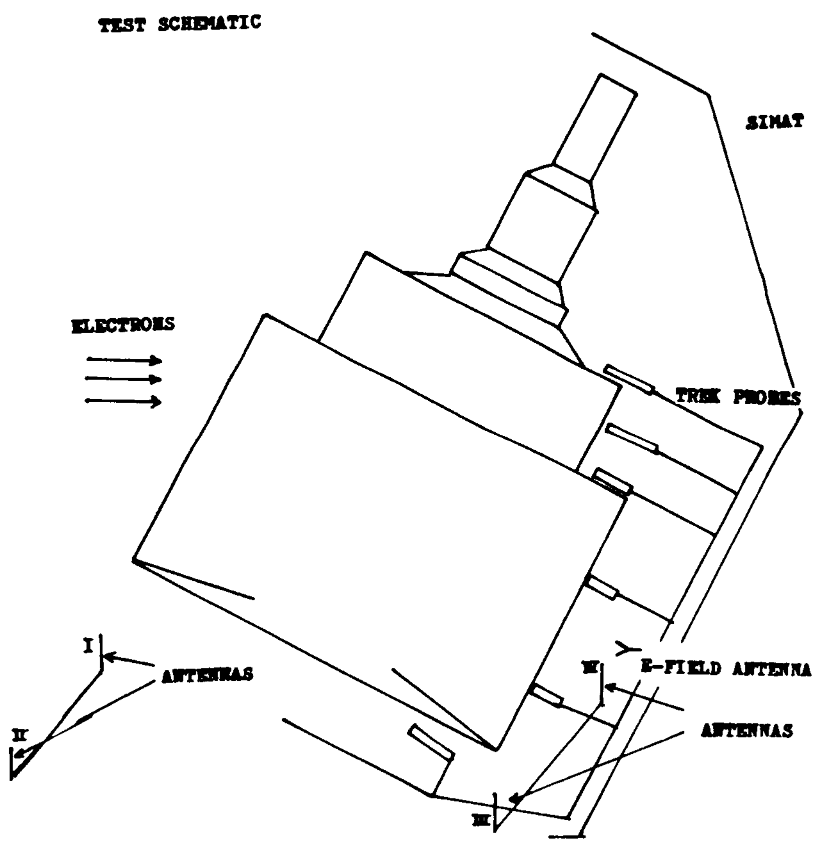
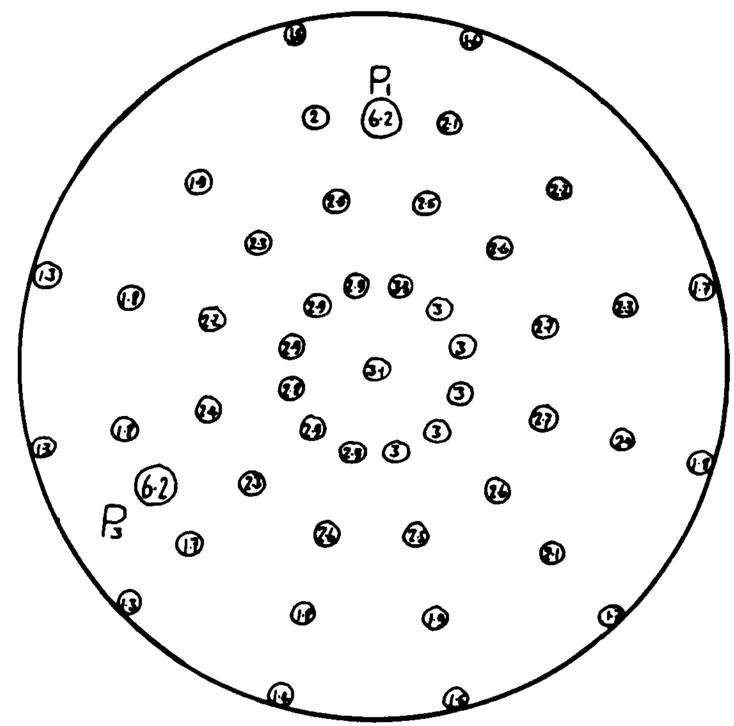
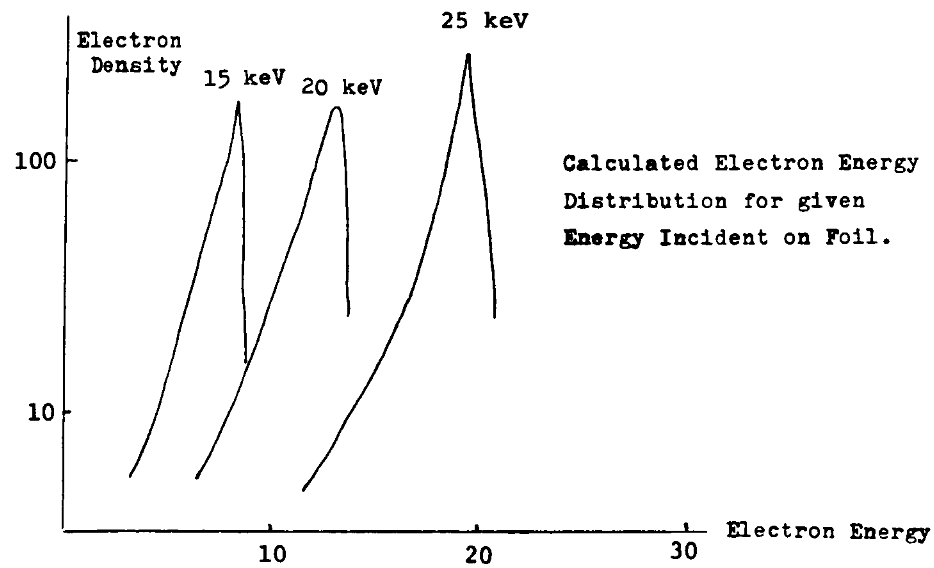


Figure 1



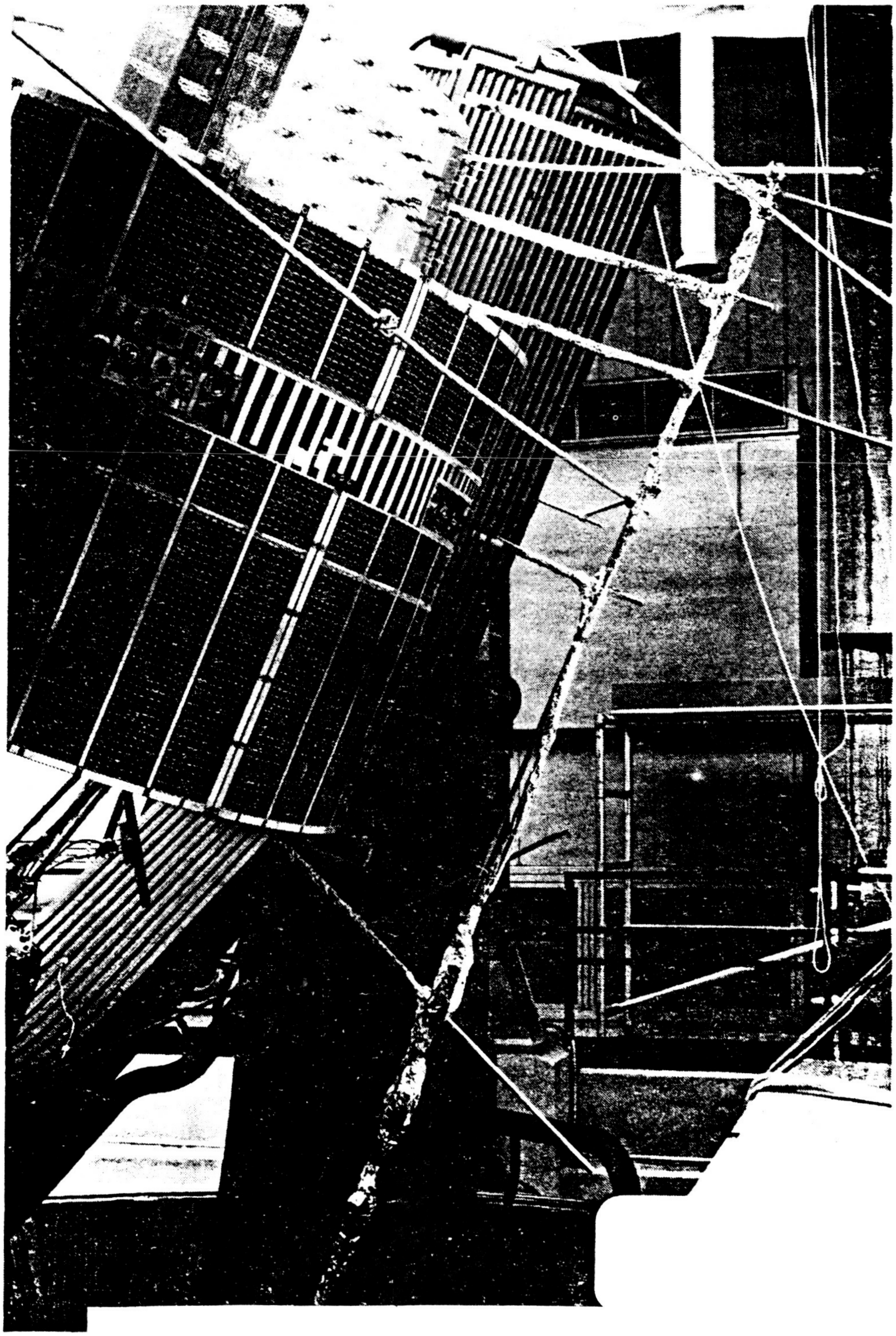
HOMOGENEITY IN PLANE OF SATELLITE ($nAcm^{-2}$)
$E_1 = 20keV$
$I_1 = 600\mu A$

Figure 2



Calculated Electron Energy Distribution for given Energy Incident on Foil.

Figure 3



PROBE INSTALLATION RELATIVE TO SATELLITE
Figure 4

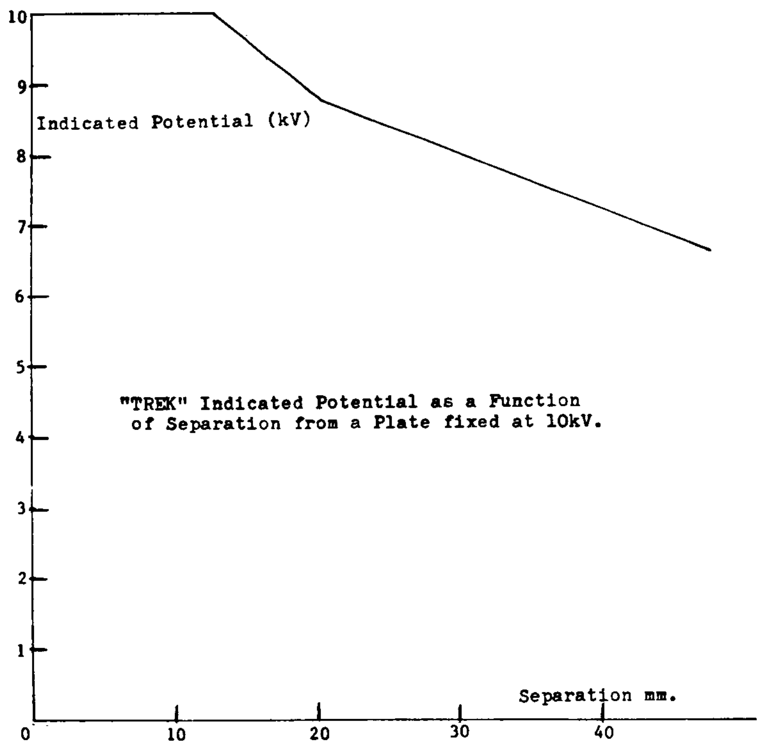
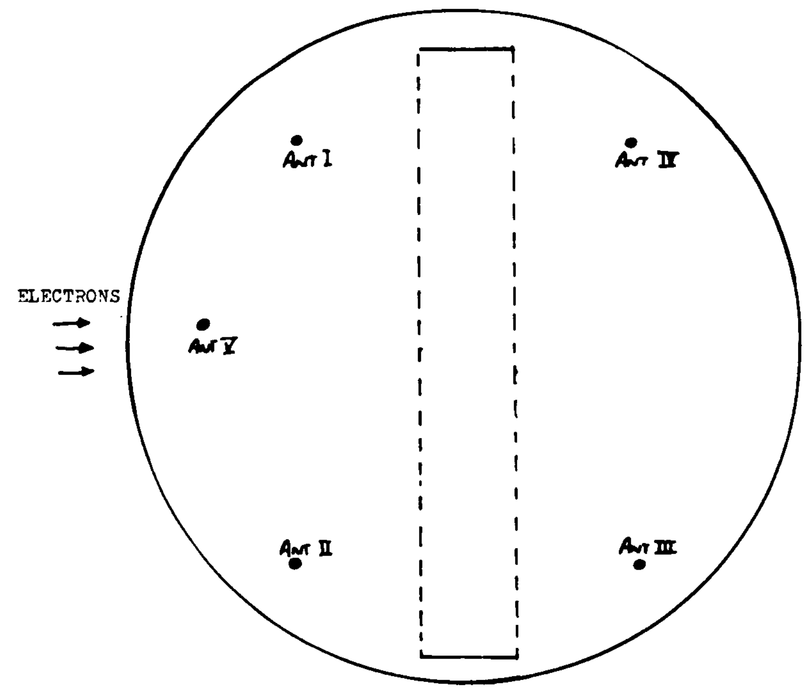


Figure 5



ANTENNA SCHEMATIC

Figure 6

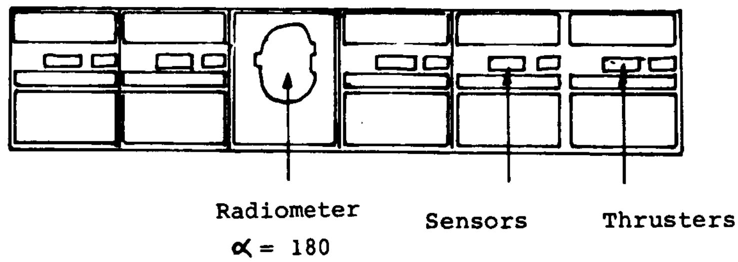


Figure 7

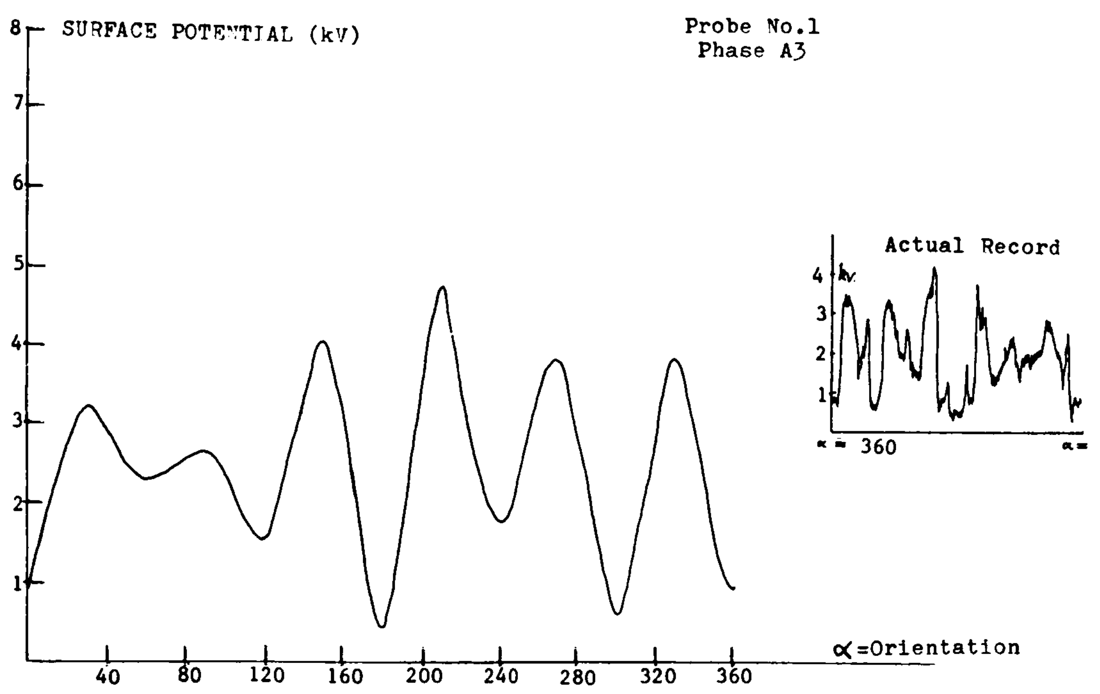


Figure 8

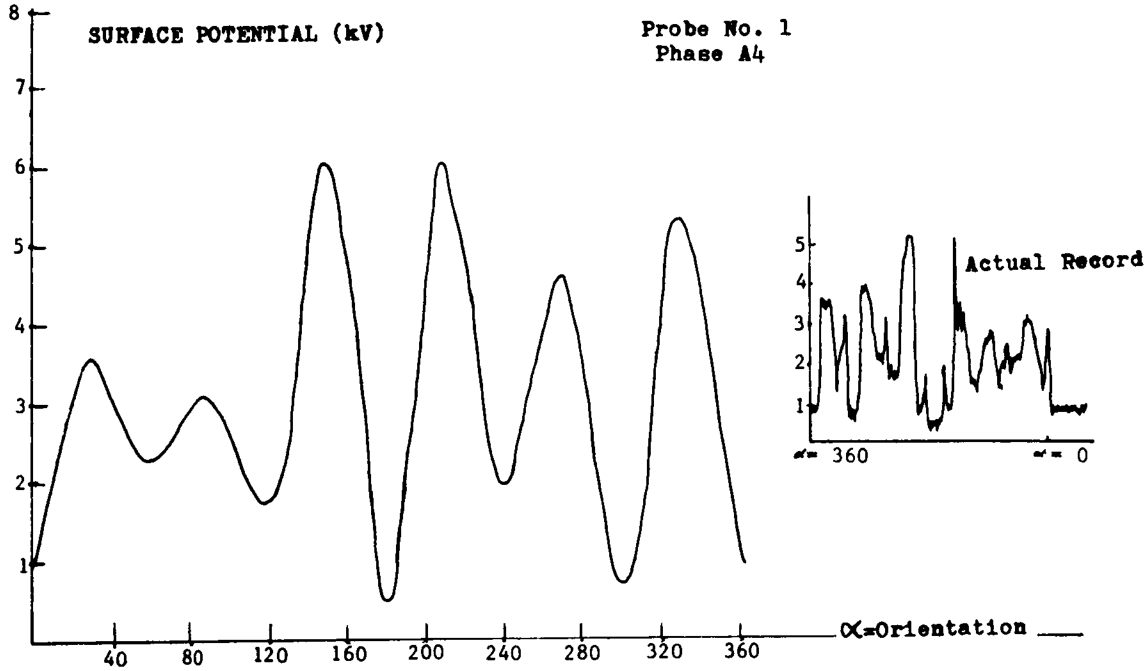


Figure 9

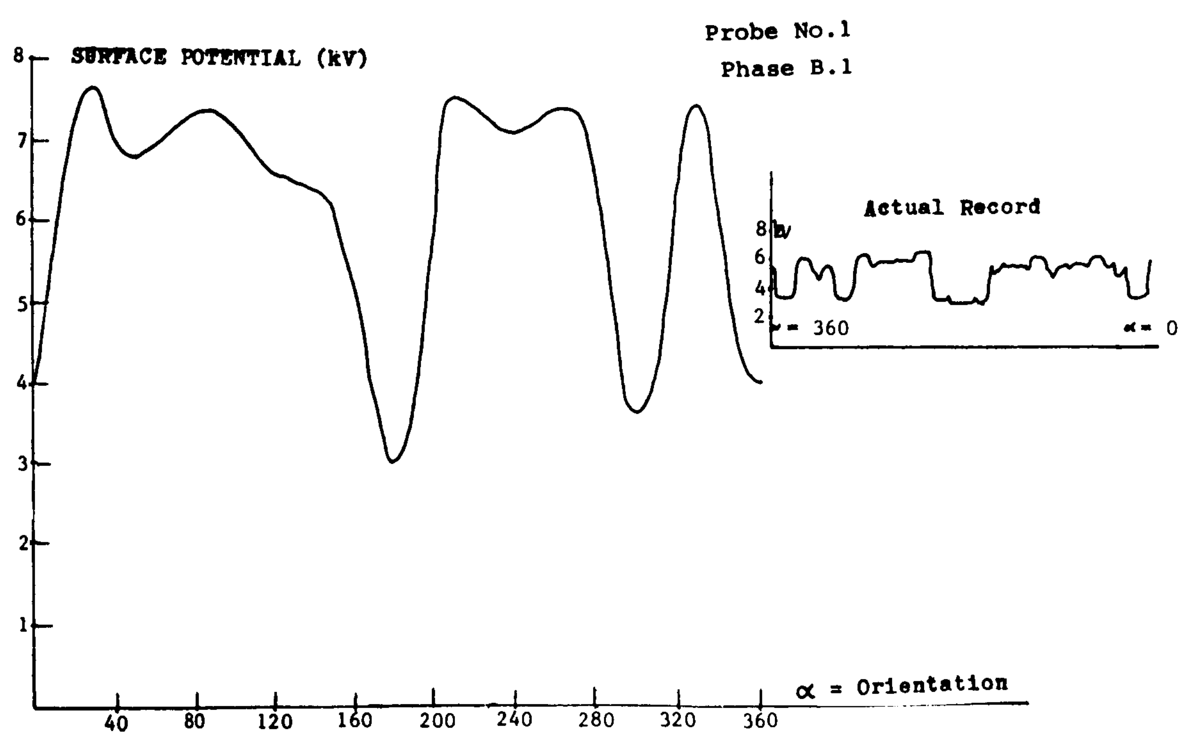
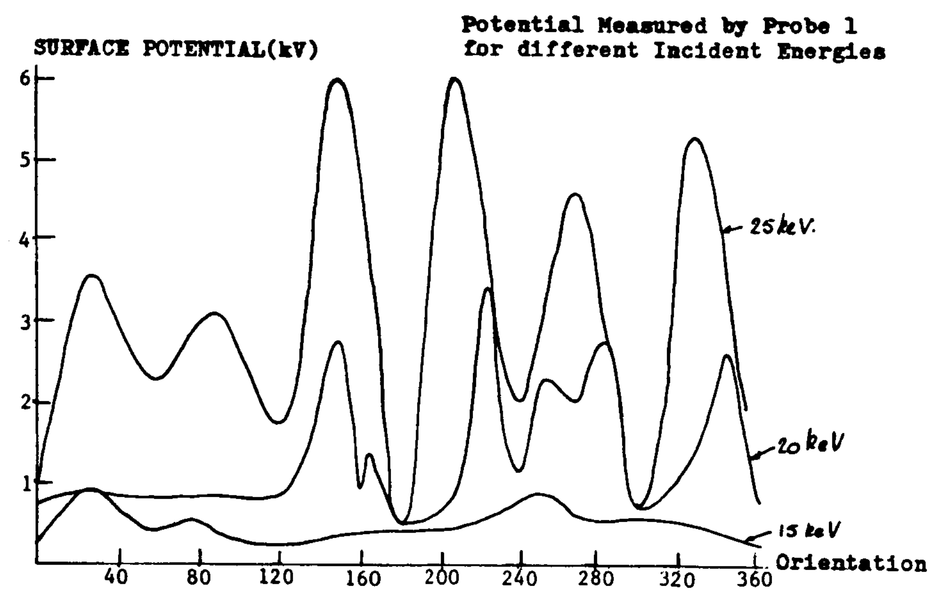
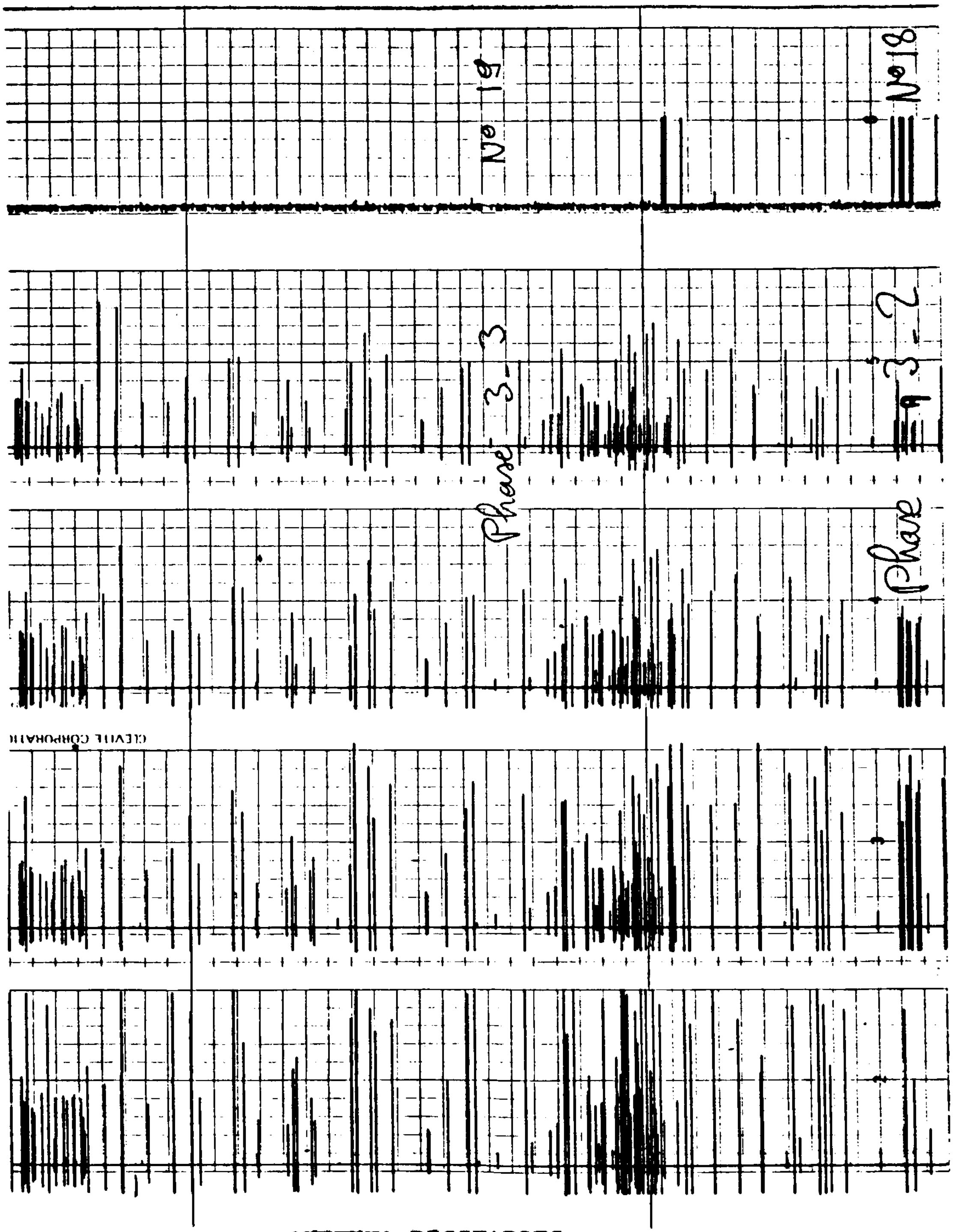


Figure 10



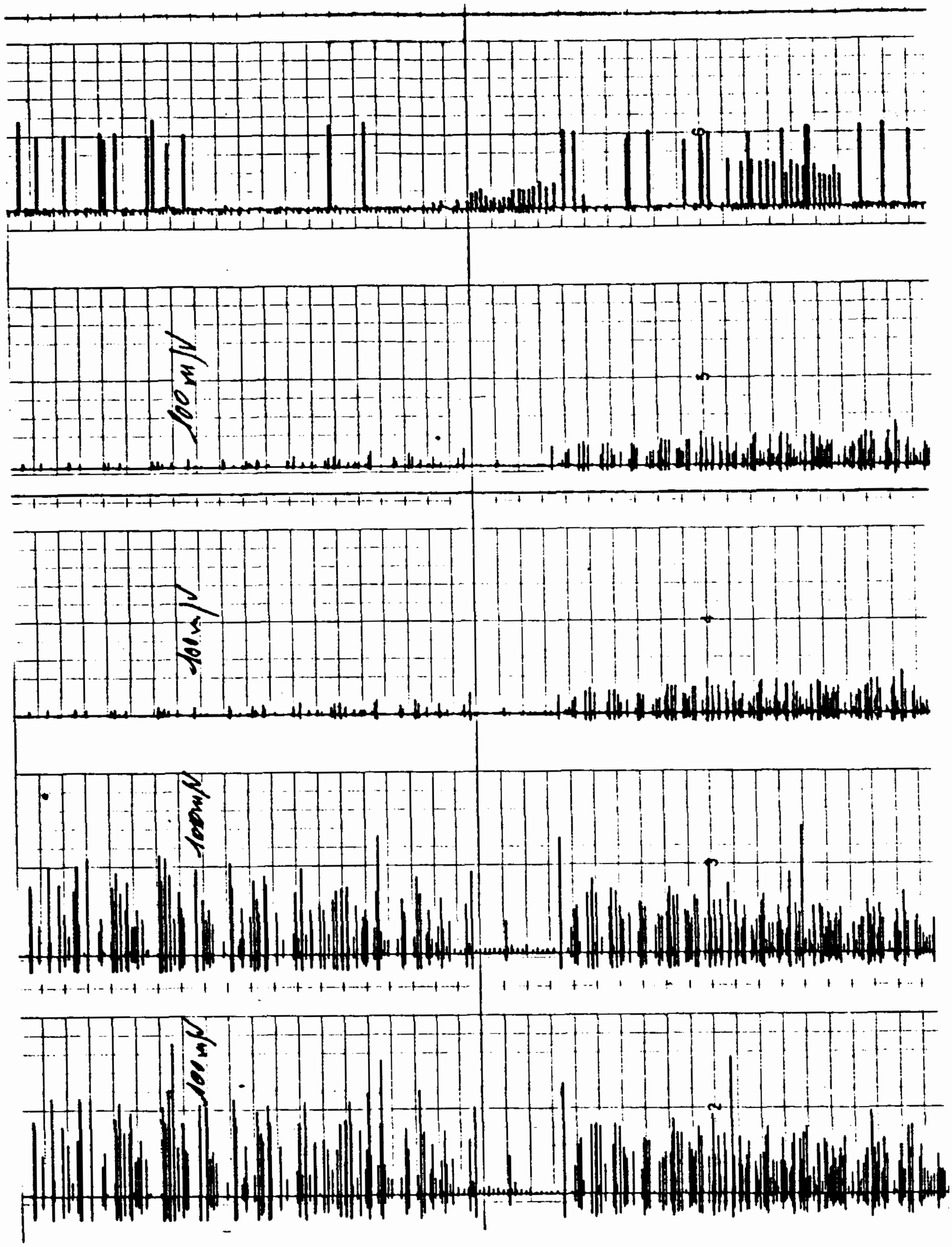
SURFACE POTENTIAL(kV)
Potential Measured by Probe 1
for different Incident Energies
6
5
4
3
2
1
25keV.
20keV
15keV
40
80
120
160
200
240
280
320
360
Orientation

Figure 11



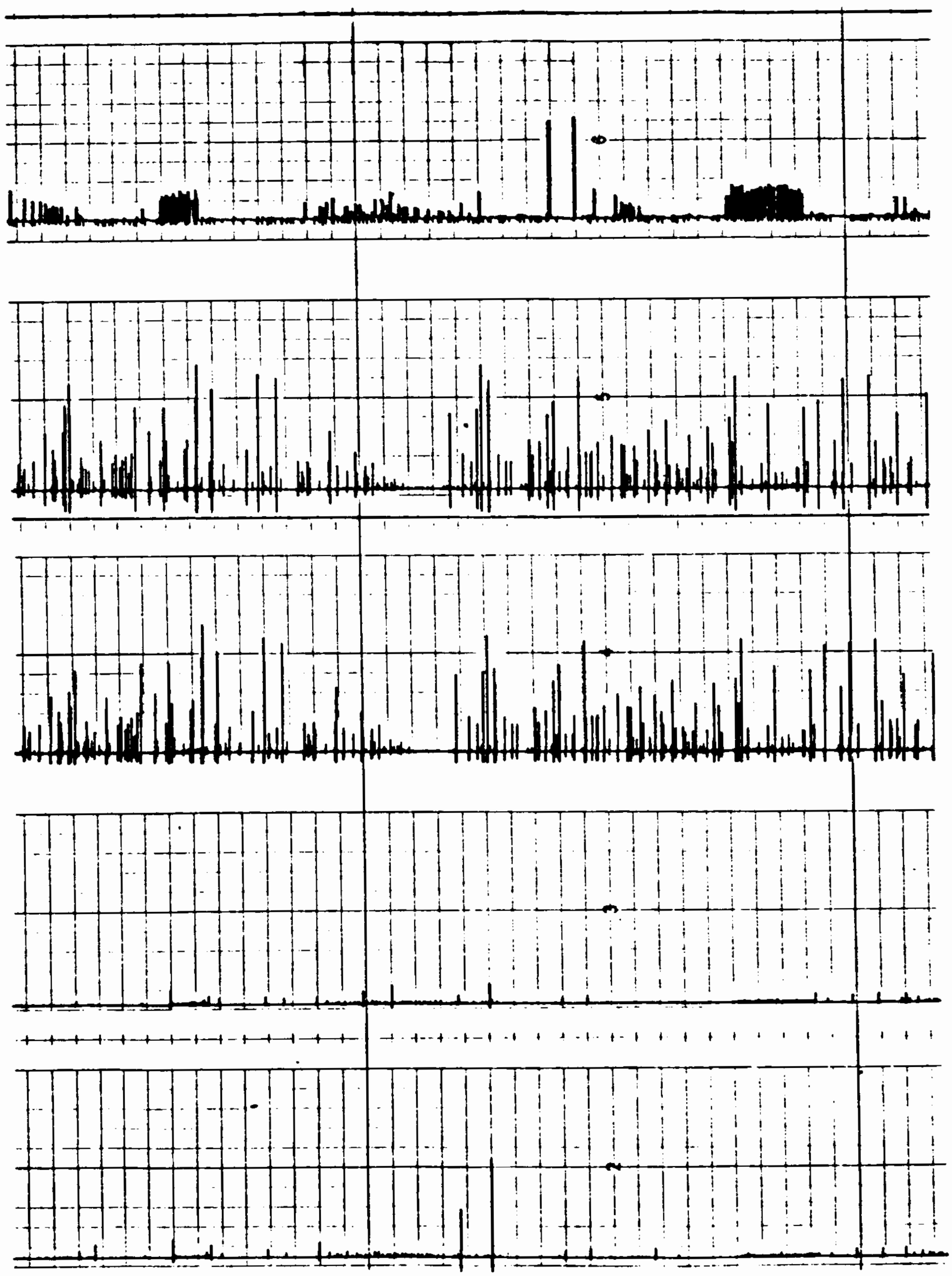
ANTENNA DISCHARGES
PHASE A3

Figure 12



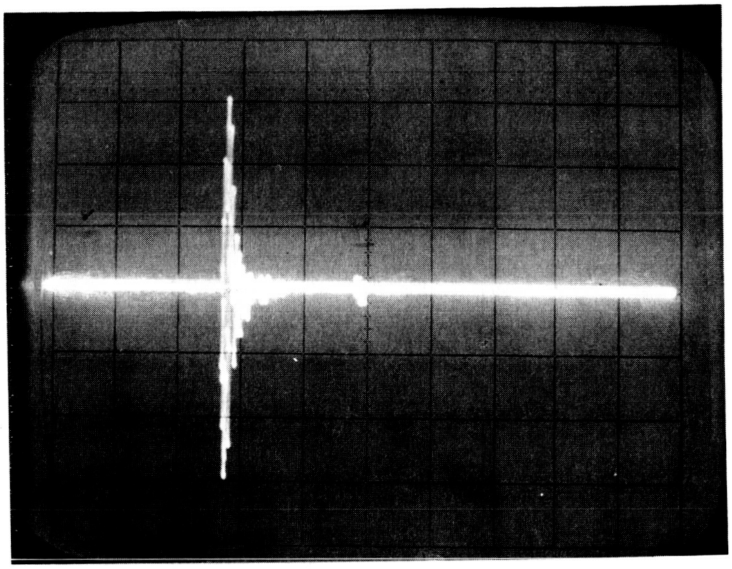
ANTENNA DISCHARGE PATTERN
$\beta = +23$

Figure 13



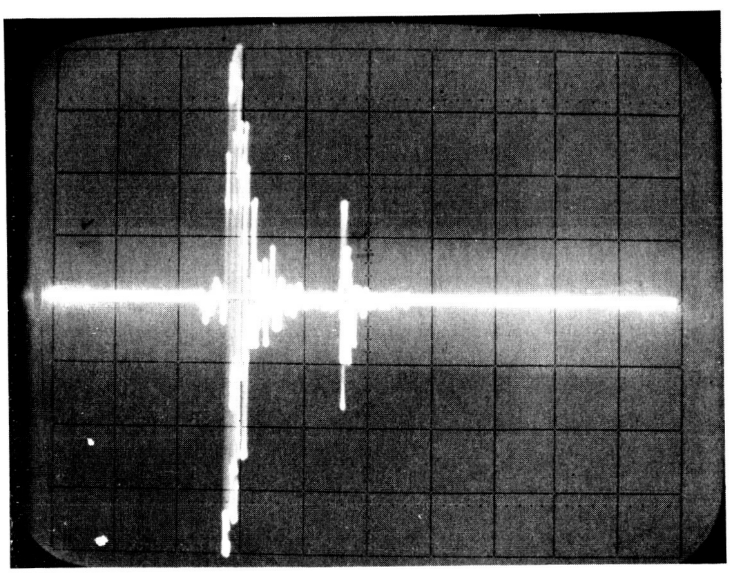
ANTENNA DISCHARGE PATTERN
$\beta = -23$

Figure 14



E-Field Discharge
500 V/m full scale
2 usecs/div
Phase B1-4

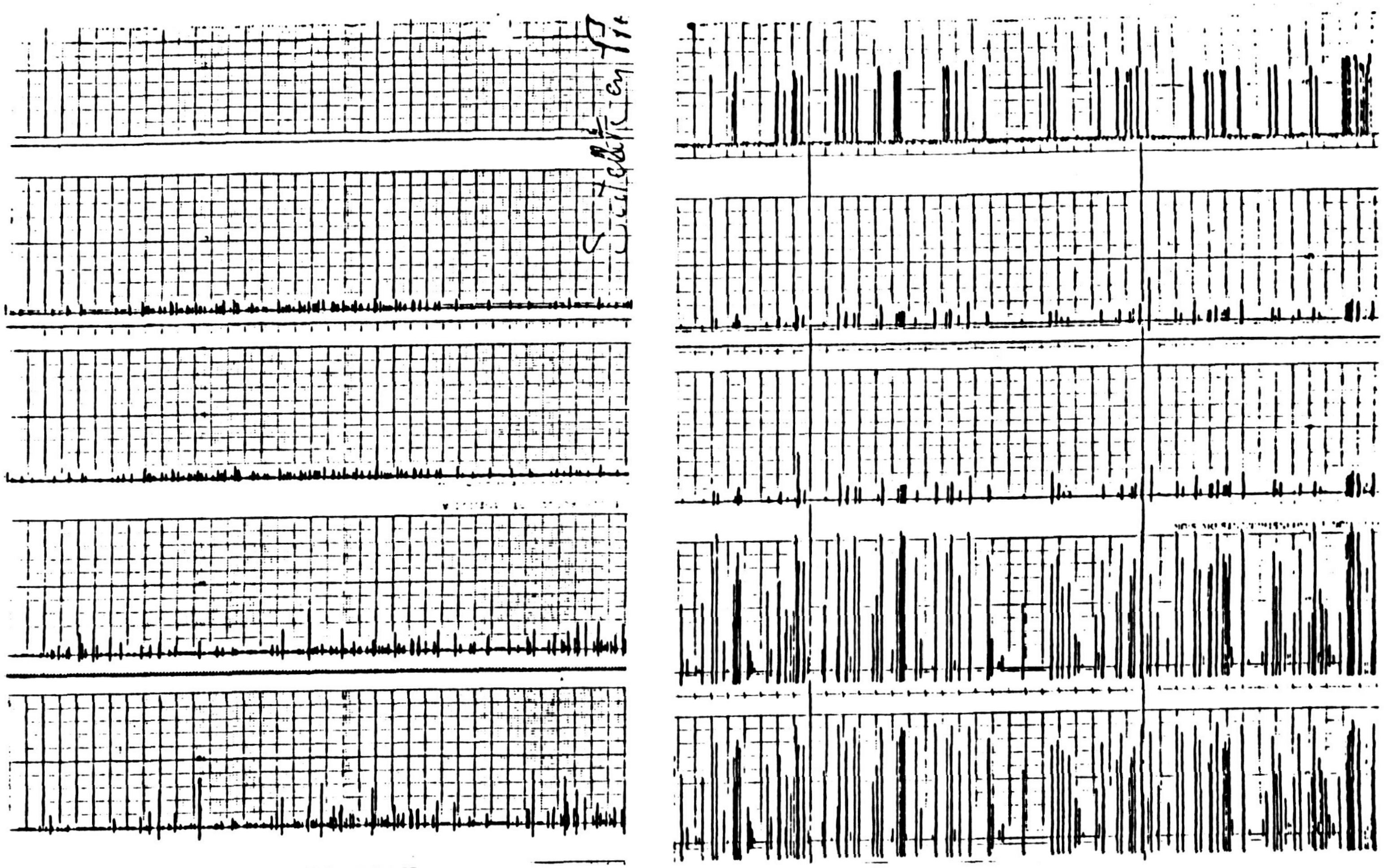
Figure 15



E-Field Discharge
1000 V/m full scale
2 usecs/div
Phase B2

Figure 16

TYPICAL DISCHARGE PATTERNS



AFTER MODIFICATION

BEFORE MODIFICATION

Figure 17

DISCHARGES ON SATELLITE

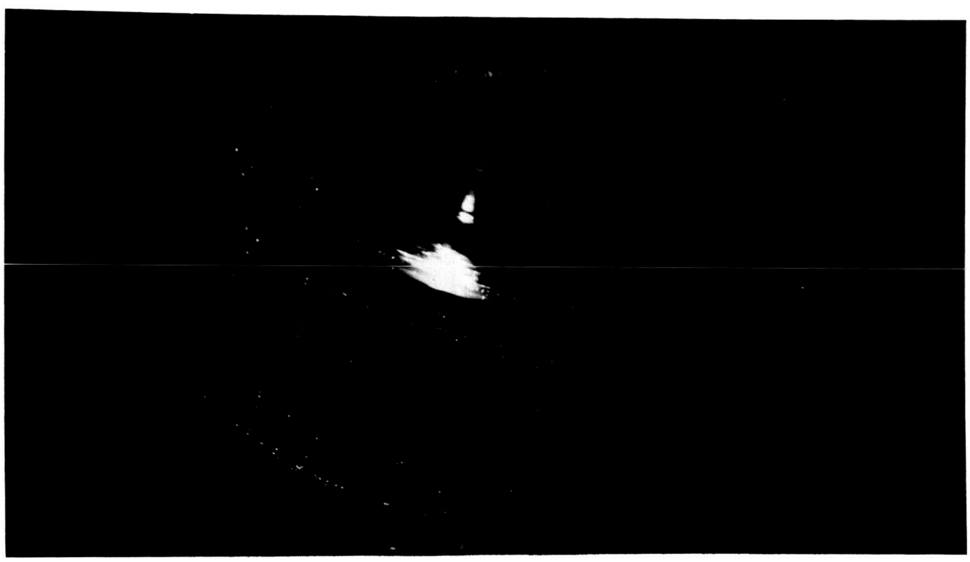


Figure 18