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DESCRIPTION AND CHARGING RESULTS FROM THE RSPM*

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SUMMARY

Representative satellite materials, to be flown on STP-78-2 in 1979 on the SSPM instruments, were included as part of the AFGL Rocket payload flown from White Sands Missile Range on January 21, 1978. Potentials as high as ~ +1100 volts on the conductor and ~ +400 volts on the insulator were recorded by the RSPM near the minimum in the electron density vs altitude profile. In addition to the charging potentials measured during ion gun operation, sample charging currents also were recorded with time resolutions near 30 milliseconds. These results demonstrate the validity of the experiment concept of the SSPM on SCATHA.

INTRODUCTION

Spacecraft charging during natural and artificial events including solar eclipse will be studied in detail on the STP 78-2 (SCATHA) satellite. The charging of various thermal control materials [Al/kapton, OSR, Astroquartz, Ag/Teflon] will be measured by three Satellite-Surface-Potential-Monitors (SSPM), each capable of making measurements on up to four different samples. Specifically, each SSPM contains separate electronics to provide the back surface potential and associated bulk or induced currents of individual samples. The Rocket-Surface-Potential-Monitor (RSPM) is essentially one-half of an SSPM containing two samples, a gold plated magnesium conductor and an aluminized kapton insulator.

One of our primary purposes for including a modified version of the SSPM instrument on the AFGL rocket was to verify the concept of measuring back surface potentials to provide front surface values during artificial charging events. It was not feasible to directly measure the front surface potential of a sample material in space. The major design effort for the SSPM/RSPM was the development of a technique for measuring the rear surface potential of the samples so that the front surface potential could be derived.

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Physical Description

The RSPM is packaged in a rectangular, gold-plated, magnesium box, 33 cm by 16.5 cm by 5.1 cm and weighs 1.6 Kg (Fig. 1). The box, machined from a single piece of magnesium, contains four cells for housing circuitry, instrumentation and samples. Two adjacent cells on one side (each approximately 16 by 16 by 2.5 cm) contain potential and current measurement instrumentation and provide mounting for the samples. The signal conditioning circuitry, power supplies and interface hardware are behind the sample assemblies.

Sample Materials

The two samples used on the RSPM were a sheet of 5 mil kapton, aluminized on one surface, and a gold plated magnesium plate electrically isolated by a polycarbonate frame.

The aluminized back surface of the kapton sample was attached to a copper clad fiberglass sample board (Fig. 2) using conductive epoxy as an adhesive. The sample board contained a centrally located hole (.635 cm dia.) concentric with a circular area of the same size etched free of aluminum on the kapton sample. The Monroe electrostatic field sensor was mounted with its sensitive aperture centered under the hole in the sample board. This sensor was spaced about .25 mm from the back surface of the kapton sample. Surface charging on the kapton sample induced a corresponding potential on the back surface (cleared of aluminum) which was detected by the electrostatic sensor.

Bulk and induced currents, on the back side of the kapton sample, were collected by the rear surface electrode system (Fig. 3). They were conducted to ground through a sensitive electrometer.

The gold/magnesium sample plate was mounted in a Lexan 500 frame 2 mm above the Monroe sensor holder assembly. The plate, being an isolated conductor, allowed simple calibration by direct voltage stimulation of the front surface. The currents appearing in the sample board electrometer circuit were limited to capacitively induced currents since the sample was electrically isolated.

Signal Conditioning

The RSPM outputs were analog 0 to 5 volt DC signals. Since the SSPM outputs are digital, modification of the telemetry interface was required. A fresh approach was needed for the problem of a logarithmic current amplifier covering in excess of four decades of positive and negative current with the resulting output spanning zero to +5 volts DC (Fig. 4). The small temperature changes forecast allowed a simple diode feedback to be used for the logarithmic function. The second stage op-amp is driven to the rails by small current signals. Larger currents cause the drop across the feedback diodes to increase into the conduction region thereby reducing the voltage to the final amplifier. This results in an output at zero or +5 volt, depending on polarity, for zero input current. Larger currents cause the output to go toward +2.5 V. The positive and negative current curves cross each other at the 2.5 V line when the input is 5×10^{-7} A. (Fig. 5). This circuit provides a very sensitive indication of small currents, and allows sufficient dynamic range.

Temperature Measurements

Temperature measurements of each sample board were provided by a standard thermistor whose resistance was converted to a 0 to 5 volt output. Temperature ranged from ~16°C down to 6°C for kapton and remained relatively constant at ~18°C for the gold plate sample assembly.

Sample Calibration

The potential calibration was made using direct contact of an electrode on the front surface of the sample. The calibrating voltage was incremented in 100 volt steps between -3000 volts and +3000 volts (Fig. 6). A nonlinear calibration curve was used to provide more sensitivity to small potentials while still preserving the anticipated dynamic range requirement.

Current calibration was made by directly injecting a known current from a constant current source into the input of the electrometer circuit. The range for both positive and negative currents was 10^{-6} A to 10^{-10} A.

Temperature calibration was performed by taking numerous measurements after non-operating soaking periods at each temperature. The calibrated linear range was -10°C to +25°C.

RESULTS

The primary purpose for including the RSPM on the Air Force Geophysics Laboratory (AFGL) rocket was to test the feasibility of monitoring a conductor and an insulator with Monroe electrostatic sensors during gun operations. The flight also provided a qualification for the non-standard Monroe flight assembly on STP 78-2. In the previous paper given by Cohen et al., it was clearly shown that the upper stage of the rocket achieved negative potentials as high as 1000-1100 volts near electron densities of 10^{3}/cm^{3}. These calculated densities were for altitudes near 150 km and corresponded to flight times near 111 sec and 418 sec.

For display purposes, we need to compare the RSPM measurements with a potential and a current monitor that describes the incident flux on the samples. The outer Thermal Emissive Probe (TEP) was used as a potential monitor and the Retarding Potential Analyzer (RPA) 2 was used as a current monitor.

Figure 7 shows these two measurements for the downleg low altitude portion of the flight. The top curve is the calculated electron density described in the previous presentation. RPA 2 is in units of nanoamperes and the TEP is in volts. The bottom two curves are the back-surface potentials of the gold plated magnesium sample and the aluminized kapton sample. During the time following ~395 seconds, the xenon ion source went through its pre-programed cycle that was discussed in the previous paper. In summary: ions are emitted at ~9 μamps with energy near 840 eV for 1 second, 12 μamps at

1.7 keV for 1.5 seconds, 80 eV electrons at approximate 10 milliamps for .5 seconds, ions at 840 eV at 9 μamps for .5 seconds followed by ≤200 volt ions at 1 μamp for 2.5 seconds to complete the cycle.

Both the conductor and insulator sample track the potential monitor throughout this time period. Average potentials are indicated. The time constants for the RSPM voltage sensors are much faster than the 0.5 sec averages shown in Fig. 7. The slow increase in voltage for the highest ion step (1.7 keV) is duplicated by the steady increase in RPA current. The most significant aspect of the potential profiles is when the ion gun cycles to low voltage for ~2.5 sec. The potential monitors (including the TEP) indicate a drop in potential of the rocket chassis. The sample potentials, measured by the RSPM remain at the initial value. If the potentials measured from the RSPM samples were due only to changes in the reference level in the circuitry, then the potential would drop when the chassis swings toward zero. The observations that the potentials remain up until a negative current is emitted from the gun (that drives the chassis positive to ~80 volts) is definitive proof that both the gold magnesium and kapton RSPM samples were charged during this flight. [A detailed description of the charging profiles has not been done at this time.]

Figure 8 shows the same measurements as the previous figure but for the upleg portion of the flight where the calculated density is a minimum. During the initial stages of the flight, the response to the ion gun was different. For example at T = 103 sec into the flight, the TEP measured values near 1000 volts with a collecting current in the RPA greater than 10 namps. As the gold magnesium conductor recorded values near 1100 volts, the kapton averaged ~300 volts. A thorough analysis of ion produced secondary electron production would have to be performed to compare with these numbers. Another interesting aspect of this data shows the first 0.5 sec average to be the highest value attained by the kapton back surface. While the gold sample continued to increase for the next second, the kapton potential decreased. This example will be addressed in more detail in Figure 9.

Another region of interest occurred near 108 sec. Negative current was recorded in the RPA between 10-30 namps for ~8 sec. The TEP monitor measured a negative potential change on the rocket chassis from -60 to -250 volts. The kapton potential changed from -3 to -15 volts. The gold plated magnesium sample, however, remained at -25 volts. A preliminary interpretation is that secondary electrons, produced by electron fluxes impinging on the sample, prevents significant charging. Laboratory measurements using electron beams show that significant charging on gold doesn't occur until electron energies greater than ~4 keV are reached.

One of the longest charging profiles in the entire flight occurs near 123 sec. The gold magnesium reached equilibrium in one second as does the TEP monitor. However, kapton continues to increase for several seconds.

Figure 9 shows the high resolution data from the RSPM. Each point is a 30 millisecond sample of the kapton potential and current on the left side and the gold plated magnesium voltage and induced current on the right side. This figure gives an indication of the time resolution of the RSPM to charging in space. For example the decay of the charging current on the gold sample falls by 1/e in less than 20 milliseconds. The rise time (1/e) of the kapton sample is approximately the sampling time. This example was shown in the previous figure and showed a drop in the kapton voltage after the initial 0.5 sec. or so. From the bulk current monitor on kapton, there is no obvious reason why the back surface voltage should decrease.

The final figure shows the RSPM instrument parameters. Based on our preliminary analysis, the major objectives were met with complete success. We would like to suggest that operational programs concerned with material charging in orbit should consider flying such a monitor for a direct in situ measurement. If the SSPM instruments on SCATHA perform as well as the RSPM instrument did then we can expect a wealth of useful material charging data in the coming year.

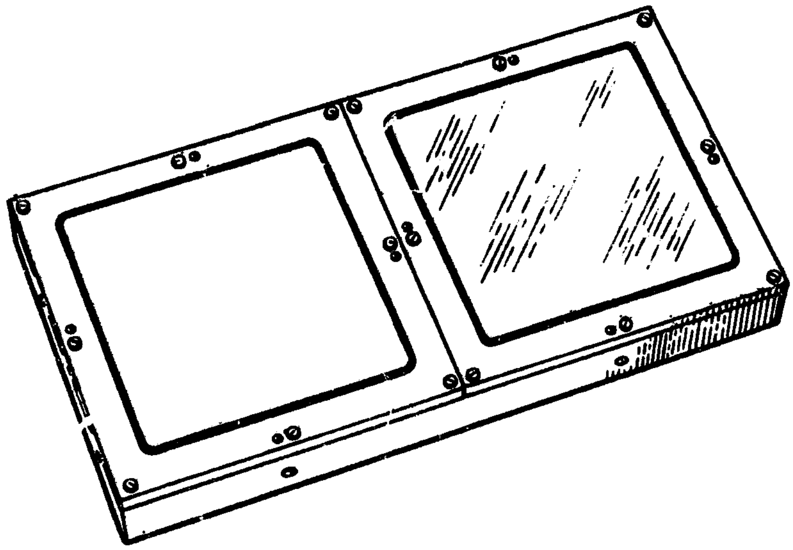


Figure 1 A sketch of the Rocket Surface Potential Monitor with aluminized kapton and gold plated magnesium samples

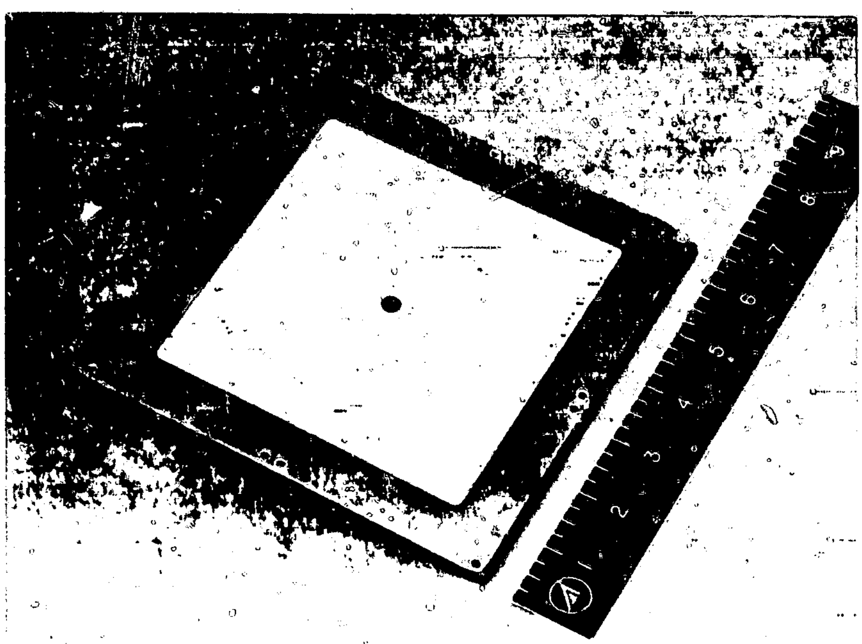


Figure 2 Typical SSPM sample board on which the RSPM kapton sample was mounted. Active current collecting area is approximately 5 inches square or $\sim 160\ cm^2$.

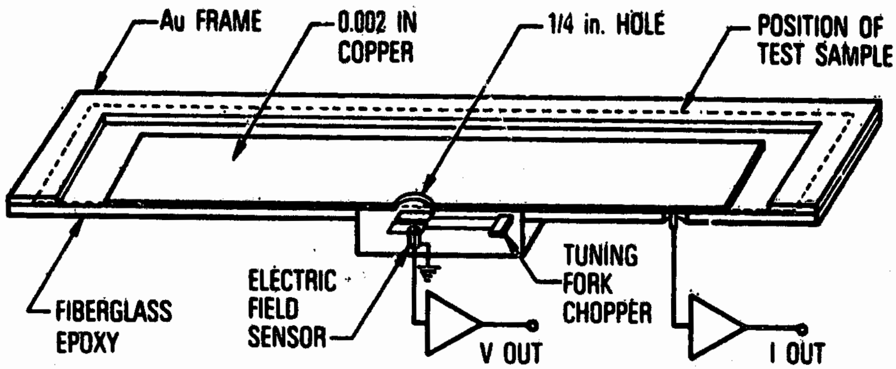


Figure 3 Schematic representation of the dielectric sample holder and associated sensors. The electric field sensor is positioned under the back surface of kapton with a 0.25 inch diameter aluminum etched region.

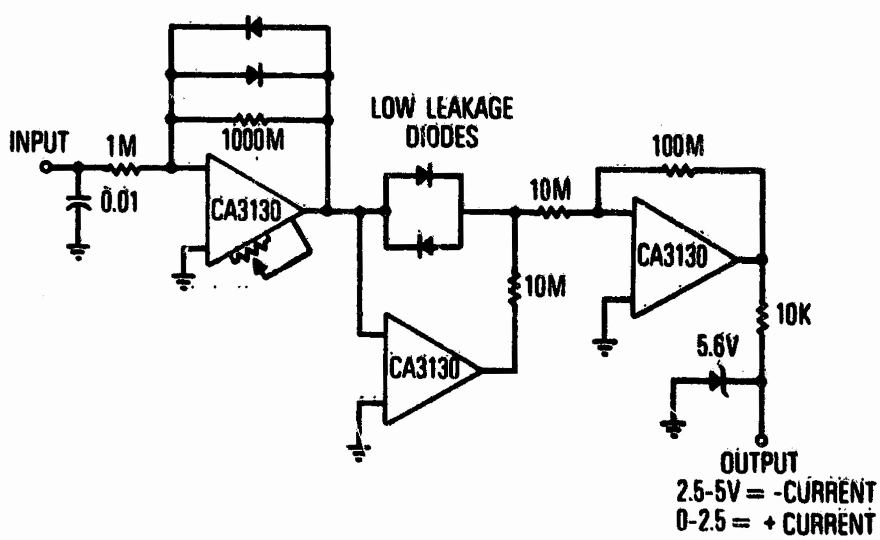


Figure 4 Schematic diagram of the logarithmic current amplifier designed for the RSPM that takes the digital electrometer outputs and converts them to analog T/M.

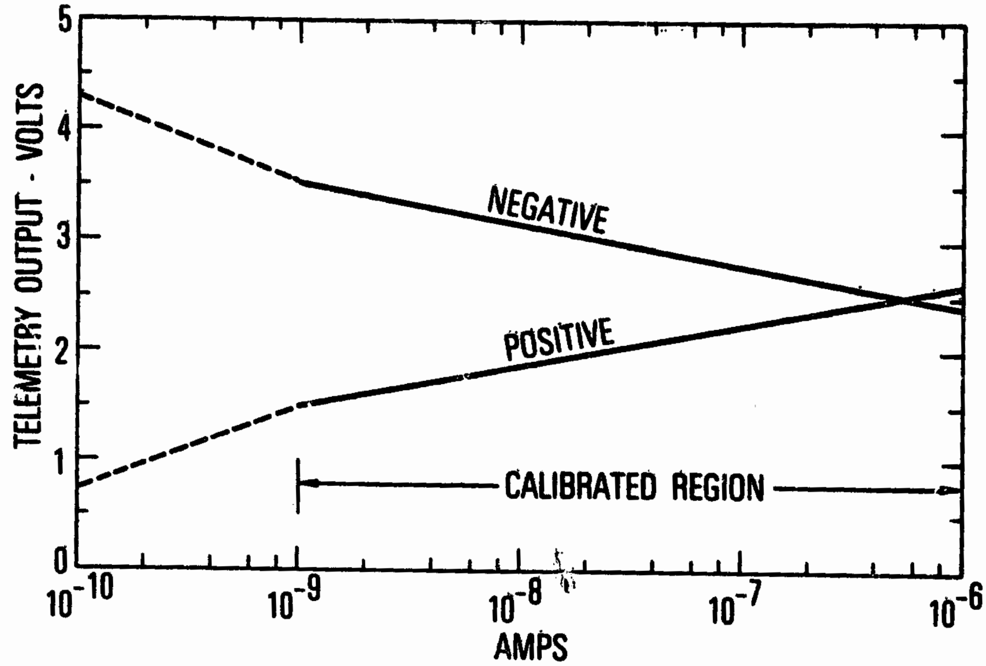


Figure 5. - RSPM current calibration.

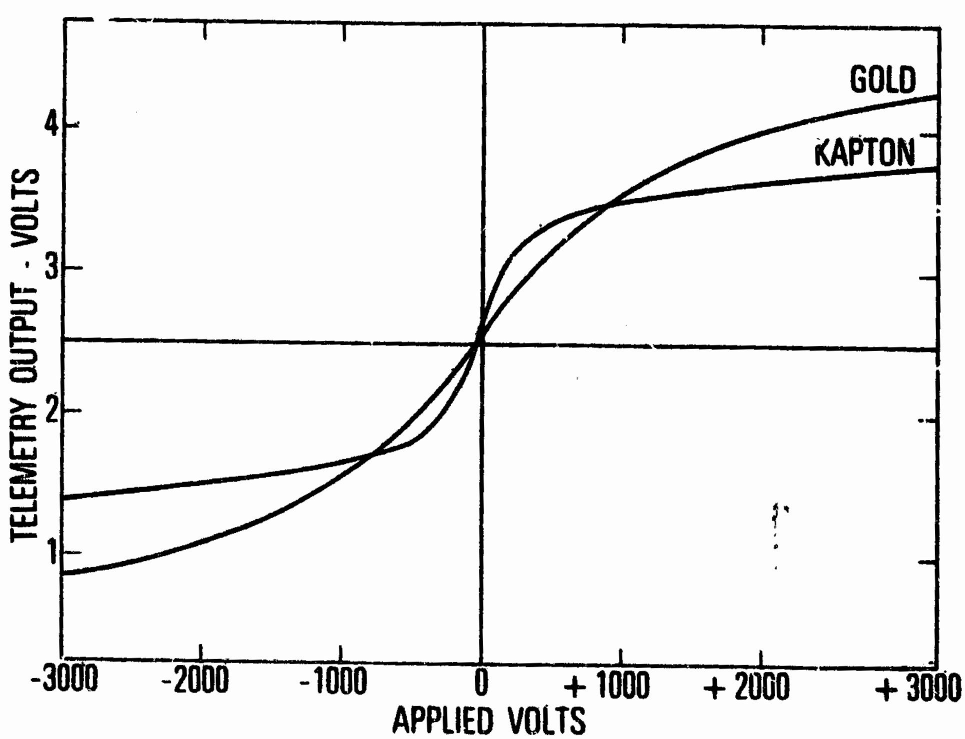
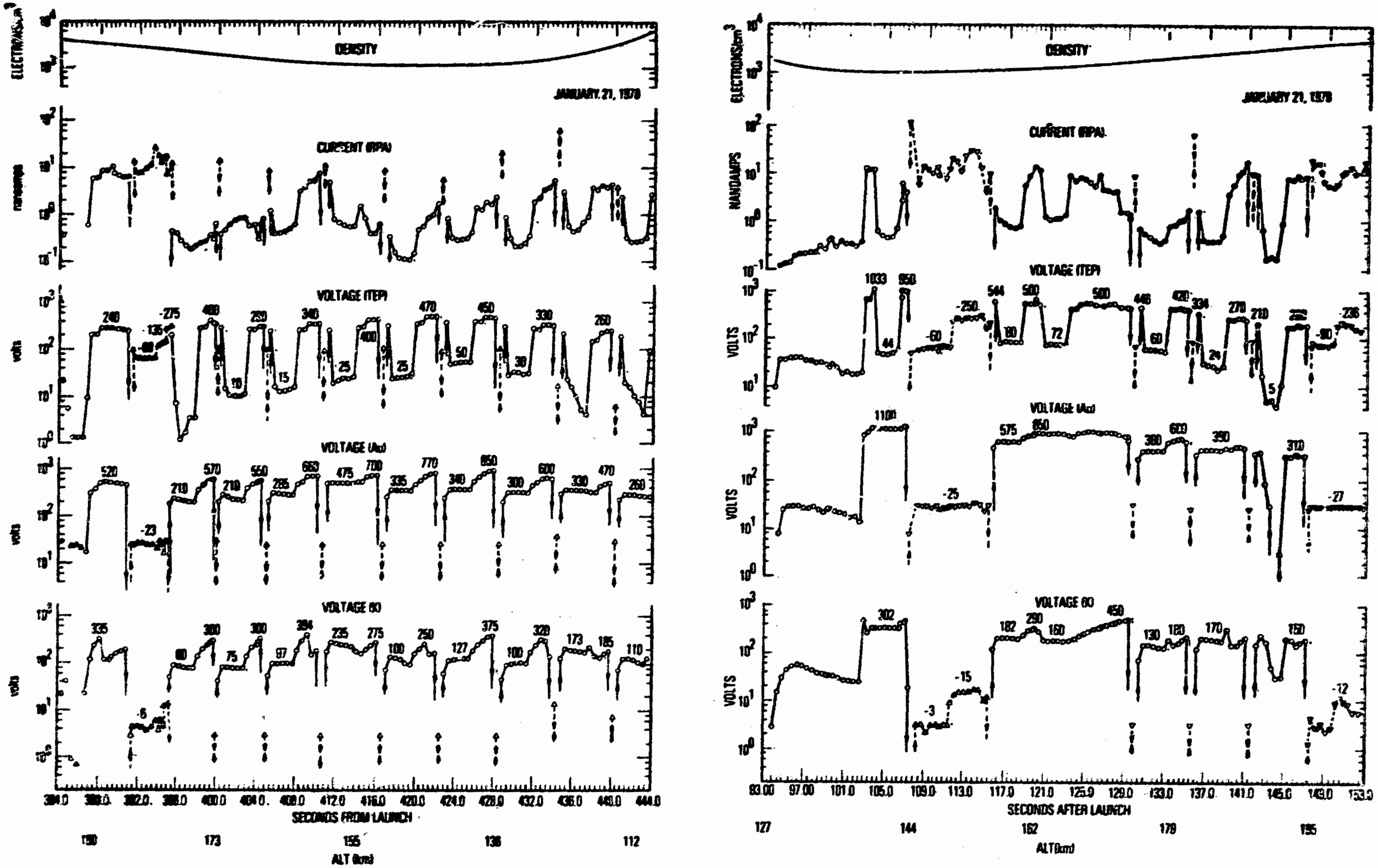


Figure 6. - RSPM voltage calibration.



Downleg (Figure 7) and Upleg (Figure 3) charging results from the rocket flight showing estimated electron density at the top as a function of flight time and altitude. Return current to the rocket is measured by a Retarding Potential Analyzer (RPA) and the potential difference between the environment and the rocket chassis is provided by the Thermal Emissive Probe (TEP). Back surface voltages are shown for the gold sample and kapton sample from the RSPM.

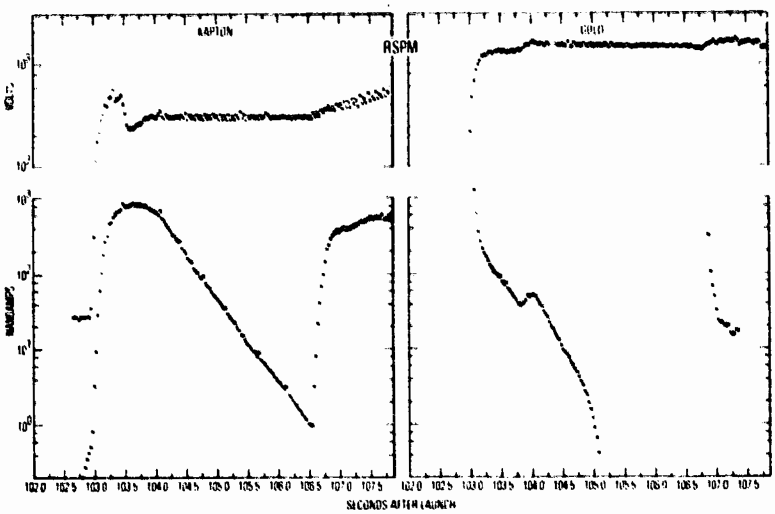


Figure 9 High resolution (~30 m sec/sample) data from potential and current outputs of the RSPM. The charging times of the kapton and the isolated gold plated conductor can be easily resolved.

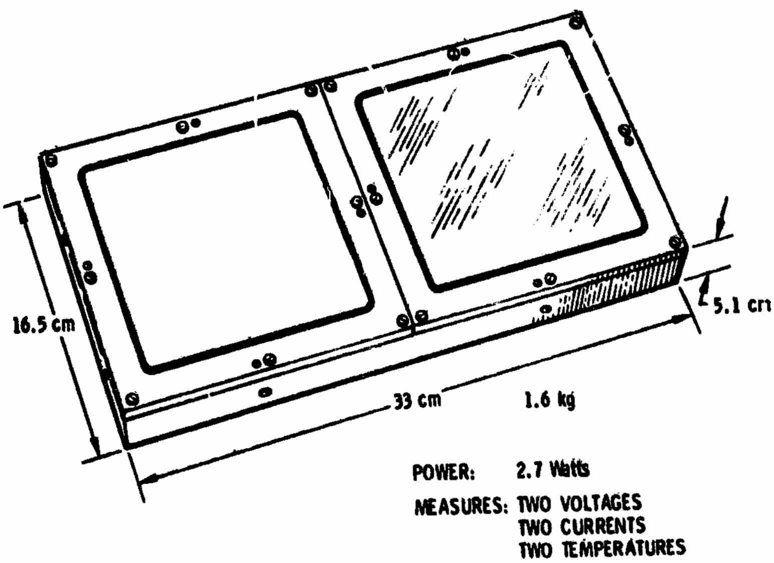


Figure 10 Characteristics of the RSPM.