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ELECTRICAL BREAKDOWN OF ANODIZED STRUCTURES IN A LOW EARTH ORBITAL ENVIRONMENT

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SUMMARY

A comprehensive set of investigations involving arcing on a negatively biased anodized aluminum plate immersed in a low density argon plasma at low pressures ($P_0 \approx 7.5\times10^{-5}$ torr) have been performed. These arcing experiments were designed to simulate electrical breakdown of anodized coatings in a Low Earth Orbital (LEO) environment. When electrical breakdown of an anodized layer occurs, an arc strikes, and there is a sudden flux of electrons accelerated into the ambient plasma. This event is directly followed by ejection of a quasi-neutral plasma cloud consisting of ejected material blown out of the anodized layer. Statistical analysis of plasma cloud expansion velocities have yielded a mean propagation velocity, $v = (19.4\pm3.5)$ km/s. As the plasma cloud expands into the ambient plasma, energy in the form of electrical noise is generated. The radiated electromagnetic noise is detected by means of an insulated antenna immersed in the ambient plasma. The purpose of the investigations is (1) to observe and record the electromagnetic radiation spectrum resulting from the arcing process. (2) Make estimates of the travel time of the quasi-neutral plasma cloud based on fluctuations to several Langmuir probes mounted in the ambient plasma. (3) To study induced arcing between two anodized aluminum structures in close proximity.

NOMENCLATURE

C capacitance, F

D plate separation, m

E electrical field strength, V/m

f frequency, Hz

L antenna length, m

N_e electron number density, m^{-3}

OD outer diameter, m

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P_o neutral gas pressure, torr

R resistance, Ω

r probe and plate distance, m

T_e electron temperature, eV

V bias potential, V

v average velocity, m/s

W width, m

$\Delta\tau$ propagation time, s

Δx thickness of anodized layer, m

ν mean velocity, m/s

ϕ_b plate bias potential, V

INTRODUCTION

The trend for modern day satellite payloads is for more robust, higher voltage power systems. Where older payloads typically operated at less than 80 V, newer payloads currently operate at just under 200 V. The higher voltages have placed a heavier demand on spacecraft power systems, and the trend is ever increasing as payloads become more complex. Historically spacecraft have incorporated a negative grounding scheme into their structures in order to provide a single point ground connection for electrical components. The typical way of providing a negative ground is to tie the negative end of the solar array directly to the structure of the spacecraft. The negative grounding scheme has led to other potentially hazardous problems involving arcing. Furthermore it has been found that both the solar arrays and the structure are vulnerable to arcing. These arcing concerns has led to other matters involving electromagnetic interference (EMI) with scientific payloads which also need to be addressed. For example, in order to provide the required power for the International Space Station (ISS), the operating voltage was set to 160 V (ref. 1). This 160 V, coupled with the negative grounding scheme, has unfortunately placed the ISS in a region where there are significant physical interactions with the LEO plasma (refs. 1 to 3). The series of experiments will focus on one such interaction, the electrical breakdown of anodized coatings (i.e., structures) in a Low Earth Orbit (LEO) environment.

Insulating paints are often used to passively regulate the surface temperature of spacecraft structures in LEO (refs. 4 and 5). More recently several types of anodized coatings have been developed for use on the ISS. A chromic acid anodized coating, produced by the type I or type IB process, with a thickness between 1.3 to 5.1 μm was finally decided upon for the ISS (refs. 1 and 6). The thickness of these coatings has been manufactured to supply the needed thermal properties for temperature stabilization of external surfaces, as well as providing protection against atomic oxygen degradation.

It has been shown that the 160 V solar array of the ISS will cause the structure to charge between −120 and −140 V relative to local plasma potential (refs. 1 and 2). Unfortunately the thickness of the anodized surfaces specified for the ISS do not have sufficient dielectric strength to be able to stand off the −120 to −140 V they may acquire (refs. 1, 7 and 8). In order to fix its problems the ISS has basedlined the use of a plasma contactor. Depending on the design voltage specified for new high voltage power systems, future spacecraft may need to use thicker anodized coatings to protect against such interactions.

EXPERIMENTAL TEST APPARATUS

Ground tests were performed at NASA's Glenn Research Center (GRC) Plasma Interaction Facility (PIF). All the experiments were conducted in the 1.8-m diameter by 3.0-m high vertical vacuum chamber. Two Penning discharge sources, equipped with a 0.25-mm diameter tungsten filament, were used to ionize argon gas molecules and provide plasma for the experiments. Neutral gas pressures were carefully monitored and maintained at $P_0 = 7.5\times10^{-5}$ torr throughout the tests with the plasma sources operating. Plasma densities (N_e) ranged between 1.8 to 8.6×10^5 [electrons/cm^3] and electron temperatures (T_e) were on the order of 1.2 to 1.3 eV.

For these experiments several type II, class 1, sulfuric acid anodized aluminum plates, with an alloy designation of 6061–T6 (having a specified minimum coating thickness of 2.5146 μm (ref. 1) and conforming to MIL-A-8625E, were procured. The T6 coating designation calls for tempering an aluminum alloy by heat treatment prior to anodizing a coating electrolytically in a sulfuric acid bath.

The anodized aluminum plates arrived as six precut 30.48×30.48 cm plates and one large 60.96×60.96 cm plate which were anodized on both sides. The center conductor of a shielded coaxial cable (RG-58/U, 50Ω) was attached to each plate and terminated with a standard BNC connector on the other end. The anodized plates were prepared by covering the sides and back with a 0.05-mm kapton sheet. The plates were then cleaned with an isopropyl alcohol wash and allowed to air dry prior to mounting them in the tank. The BNC's were attached to an insulated electrical feedthrough rated at 1000 V breakdown potential.

Diagnostic equipment consisted of two spherical Langmuir probes (1.9-cm diameter) and two cylindrical wire probes (0.32-cm diameter × 5.08-cm long). Two antennae were constructed, each with 0.32-cm diameter × 56.56-cm long insulated whips, and identical 47×47-cm hexagonal ground planes which were fashioned from 0.32-cm aluminum sheet metal. A very sensitive current probe amplifier and current probe were also used. Dual channel (300 and 330 MHz) digitizing oscilloscopes, each equipped with an IEEE-488 bus, were also used to capture and store measurements in a very short time interval.

The mounting positions of the probes inside the vacuum chamber are shown in figure 1. All probes, with the exception of antenna B, are mounted at a height of 59.69 cm high off the subfloor of the vacuum tank. Table I identifies the measured distance of each probe with respect to the center of the anodized plate.

Figure 2 shows a pictorial diagram of experimental apparatus used in obtaining the electromagnetic frequency spectrum, and for the plasma cloud propagation tests. The diagram shows an anodized aluminum plate biased negative of tank ground by a high voltage DC power supply. The DC power supply charges a 0.47 μF capacitor, which is mounted in parallel with the DC power supply and the anodized plate. The value of the capacitor is used to represent the capacitance of a typical satellite in space. Note that when electrical breakdown of the anodized coating occurs, an arc strikes, and the arc return path is through the plasma and back to tank ground. In order for charge to be conserved, the same current must flow from the negative terminal of the capacitor and back to the anodized plate. A current probe is placed between the negative capacitor terminal and the plate in order to detect an arc. When the current probe detects an arc, the signal is amplified, and sent to channel 2 which has been set to trigger at a given current level. Channel 2 of the first scope then simultaneously triggers channel 1 and both channels on the second scope via an external trigger. In this way 4 channels of information are gathered at once.

The diagram in figure 3 depicts the experimental setup used for the induced arcing experiments. For these experiments identical pairs of anodized aluminum plates were mounted in parallel (with the exposed anodized surfaces of the plates facing one another) and floated in the ambient plasma. Note that there are two arcing circuits shown and each plate is independently biased negative relative to tank ground through a separate DC power supply. An initial arc on plate A simultaneously triggers both channels on the LeCroy 4950A scope.

EXPERIMENTAL RESULTS

Measurements of the electromagnetic radiation spectrum resulting from the arcing process were obtained. Being only interested in obtaining electromagnetic interference (EMI) measurements generated by the arcing process, the antenna whips needed to be insulated, thereby passing all radiated emissions and effectively blocking the conducted emissions caused by the expansion of the plasma cloud into the ambient plasma. Both antennae were cut to a resonant frequency of 500 MHz in order to give a broad band behavior at the measured frequencies. The antenna leads were cut according to the equation: $L = (299.8)(0.95)/f$, where L is the length in meters and f is the frequency in megahertz. All data were obtained in digital form with a sampling interval of 2.5-ns. This sampling rate yields a maximum bandwidth of 200 MHz for the tests. A Fast Fourier Transform was applied to the data in order to map signals from the time domain to a frequency domain for comparison against the SSF specification for electromagnetic interference (EMI).

Two perpendicular antennae were used to find the direction and strength of the electromagnetic field. Thus antennae A and B were mounted in orthogonal directions, to measure the components (signal strength versus time) of arc induced electromagnetic radiation generated in each of the respective directions. Which explains why there are two sets of results shown for each antenna.

Figures 4(a) and (b) show typical electromagnetic signatures picked up by the horizontally mounted insulated antenna, as well as the resultant electromagnetic frequency spectrum obtained by the horizontal antenna.

Similar data were recorded for the vertical antenna (see figs. 5(a) and (b)). Note that the magnitude of the frequency plots is in relative units. The E-field strength was estimated as 0.5 [V/m/MHz]. The EMI standards for the ISS, are given in units of dB [μV/m/MHz] (refs. 9 and 11).

It was found that the EMI levels for the horizontal and vertical antennae exceed the EMI standards set fourth for Space Shuttle (refs. 9). Figures 6(a) and (b) show the EMI level of arcs on an anodized aluminum plate converted to units of decibels. Figure 6(a) demonstrates quantitatively the safe EMI level specified for the Space Shuttle is exceeded. Figure 6(b) shows similar data for payloads in the Shuttle payload bay, which are held to a more rigorous EMI standard. Note that data plotted in figures 6(a) and (b) are the result of 34 separate ground based antennae measurements of EMI levels due to arcs on anodized aluminum plates. The next set of measurements involved determining the travel time of the expanding plasma cloud caused by the arcing process. Noninsulated probes were used in order to pass the conducted emissions. As previously discussed when an arc strikes, a quasi-neutral cloud of material is ejected into the ambient plasma. Experiments have shown that a single arc on an anodized aluminum plate may generate as many as 10^{15} atoms of aluminum into the surrounding plasma (ref. 10).

It is possible to measure the overall time response of the probe to the arcing process and hence make travel time estimates based on the difference in time Δt between when an arc event initially occurs and when the wire probe finishes sensing the perturbations causing the arc. (See fig. 7.) The upper trace displays the initial arc event, which is initially triggered by an arc on plate Ny1. The lower trace, which was simultaneously triggered, displays what is sensed by the wire probe. It is important to note that the plasma cloud first begins to sense the wire probe, approximately 10 μs later than the initial arc trigger at point (A). The plasma cloud oscillations are fully developed by the time point (P) is reached. Point (B) designates the time just before the rise of the small pulse at point (E) is sensed. The small oscillation at Point (E) is due to electrical field fluctuations generated by breakdown of the anodized coating. This pulse at point (E) marks the end of the arcing process. Hence, the travel time is equal to difference in time Δt between points (A) and (B). Table II tabulates the plasma cloud travel times for various probes. Because the distance from the plate to each probe are known (see table I) the average velocity of expanding plasma cloud can be calculated. These values are shown in table II. A statistical analysis of the plasma cloud expansion velocities shown in table II yield a mean propagation velocity, $v = (19.4 \pm 3.5)$ km/s. Note that one could have judiciously chosen the peak values at points (P) and (E) for the travel time estimates. In this case the travel time estimate would have been shorter.

The final set of experiments involved induced arcing between two parallel plates of anodized aluminum in close proximity. The purpose of these experiments was to verify that an initiating arc on plate, A, would cause an arc to be triggered on plate B. Plate A was negatively biased at a potential above the arcing threshold. Plate B was set to a less negative potential, just under the arcing threshold. It was felt an arc triggered on plate A, could temporally pull plate B more negative than the bias potential set on plate B. The net voltage drop could cause electrical breakdown of the anodized coating on plate B.

For these tests the sulfuric acid anodized coatings (Type II, MIL-A-8265E) were abandoned for some of the chromic acid anodized coatings (Type I, MIL-A-8265E) used in the previous summer's experiments. The chromic acid anodized plates arced at nearly half the voltage (–200 V) that of the sulfuric acid anodized plates. (The sulfuric acid anodized samples were found to arc at approximately –400 V.) Since the chromic acid anodized plates were manufactured to the same coating thickness, $\Delta x = 2.5$ μm, this equates to a 50 percent reduction in the E-field strength, or $E = 7.9 \times 10^7$ V/m, before arcing can occur in the chromic acid anodized coatings. As a result the chromic acid anodized coatings better represent the actual charging potentials that may be seen on ISS when no plasma contactor is present. Because only a small amount of the anodized material was available at the time of these tests, the samples were cut into smaller 18×18-cm plates for these experiments. Sample pairs were mounted in the tank with a separation of 25 and 50 cm between each parallel plate pair. One parallel plate in each pair was biased at –250 V potential. The remaining plate in each pair biased at –300 V.

Figures 8(a) and (b) show the current registered by two independently biased parallel plates separated by 50 cm. Figures 9(a) and (b) demonstrate induced arcing between two independently biased parallel plates at a distance of 25 cm from one another. Note that the arc pulses are of comparable height here. The delay time could not be measured due to the time scale of the waveforms. What is certain is that the time delay is not due to influences caused by expansion of the plasma cloud, which is on the order of 20 to 40 μs. Hence arcs on plate A and plate B appear to be simultaneously triggered. In figures 8 and 9 the initiating arc is believed to be occur on plate A, since plate B is below the arcing threshold.

CONCLUSION

Much valuable information important to the ISS, spacecraft designers and the scientific community in general has been obtained as a result of these tests. With the current setup we have been able to successfully record the electromagnetic radiation spectrum resulting from the arcing process. It was found that the frequency spectrum peaks between 8 and 10 MHz and that the magnitude of interference exceeds the EMI the technical specifications set for Space Shuttle operation. Accurate estimates of the time of travel of the expanding plasma cloud resulting from the arcing process were also made. Measurements have ascertained the velocity of the expanding plasma cloud (19.4±3.5) km/s is somewhat lower than earlier estimates of (25 to 30) km/s[1]. These velocities are highly dependent on the points chosen for the travel time estimates. Finally, it has been demonstrated that induced arcing between two independently biased anodized plates is possible. Induced arcing could have serious consequences for high power instrument payloads operating in the Shuttle payload bay.

REFERENCES

1. Vaughn, J.A., Carruth Jr., M.R., Katz, I., Mandell, M.J., and Jongeward, G.A.: "Electrical Breakdown Currents on Large Spacecraft in Low Earth Orbit," Journal of Spacecraft and Rockets, Vol. 31, No. 1, 1994, pp. 54–59
2. Kennerude, K.L.: "High Voltage Array Experiments," NASA CR–121280, March 1994
3. McCoy, J.E., and Konradi, A.: "Sheath Effects Observed on a 100 Meter High Voltage Panel in Simulated Low Earth Orbit," Proceedings of Spacecraft Charging Technology 1978, NASA CP–2071, Oct.-Nov. 1978 pp. 201–210
4. Robinson, P., and Whittlesey, A.: "Electrostatic Charging Characteristics of Thermal Control Paints as a Function of Temperature," Proceedings of Space Charging Technology 1980, NASA CP–2182, Nov 12-14, 1980 pp. 309–319.
5. Leung, P.: "The Electrical Conductivity of ZOT After a Long Term Exposure to Thermal Vacuum Environment," Proceedings of Spacecraft Charging Technology Conference 1989, Oct-Nov 1989, pp. 166–173
6. Military Specification MIL-A-8625E: "Anodic Coatings for Aluminum and Aluminum Alloys," Navy-AS MFFP-0368, April 25, 1988, pp. 1–18
7. Carruth, M.R. Jr., Vaughn, J.A., and Gray, P.A.: "Experimental Studies of Spacecraft Arcing," AIAA Paper 92–0820 Jan. 1992
8. Carruth, M.R. Jr., Vaghn, J.A., Holt, J.M., Werp, R., and Sudduth, R.D.: "Plasma Effects on Passive Thermal Control Coatings of Space Station Freedom," AIAA Paper 92–1685, March 1992
9. Vayner, B.V., Doreswamy, C.V., Ferguson, D.C., Galofaro, J, and Snyder, D.B.: "Arcing on Aluminum Anodized Plates Immersed in Low-Density Plasmas," Journal of Spacecraft and Rockets, Vol. 35, No. 6, September-October 1998, pp. 805–811
10. B.V. Vayner, B.V., Ferguson, D.C., and Galofaro, J.: "The Spacecraft Surfaces Degradation and Contamination Caused by Arcing in Low Density Plasmas," XVIII ISDEIV Conference, Eindhoven, Netherlands, Aug 17-21, 1998 pp. 824–827
11. Vayner, B.V., Ferguson, D.C., and Snyder, D.B.: "Electromagnetic Radiation Generated by Arcing in Low Density Plasma," NASA TM–107217, July 1996.

TABLE I.—PROBE DIMENSIONS AND MOUNTING POSITIONS SPECIFIED FOR THE VERTICAL CHAMBER TESTS

[Note: All radii (r) measured from center of plate 1, D = plate separation distance, OD = outer diameter.]

Probe number	Probe type	Dimension	Distance
LP1	Wire probe 1	0.3175 cm OD × 5.08 cm L	r = 57.15 cm
LP2	Spherical probe 2	1.905 cm OD	r = 48.89 cm
LP3	Wire probe 2	0.3175 cm OD × 5.08 cm L	r = 77.47 cm
LP4	Spherical probe 1	1.905 cm OD	r = 78.74 cm
A&B	Antenna lead	0.3175 cm OD × 56.96 cm L	r = 100 cm
	Hexagonal ground plane	47 cm × 47 cm	
Plate 1	Large anodized plate	60.96 cm L × 60.96 cm W	
	Parallel anodized plates	18 cm L × 18 cm W	D = 25, 50 cm

TABLE II.—TABULATED RESULTS FOR PLASMA CLOUD TRAVEL TIMES, VELOCITY AND FREQUENCY

Probe type	$\Delta t = (\tau - \tau_0)$	$v = (\Delta x/\Delta t)$	$f = 1/\Delta t$
Wire probe 1	28.8 μS	19.8 km/S	34.7 kHz
Wire probe 1	34.1 μS	16.8 km/S	29.3 kHz
Wire probe 1	28.7 μS	19.9 km/S	34.7 kHz
Wire probe 1	30.9 μS	18.5 km/S	32.4 kHz
Wire probe 2	37.3 μS	20.8 km/S	26.8 kHz
Wire probe 2	34.2 μS	22.7 km/S	28.2 kHz
Wire probe 2	32.5 μS	23.8 km/S	30.8 kHz
Wire probe 2	35.0 μS	22.1 km/S	28.6 kHz
Sphere LP2	31.3 μS	15.6 km/S	31.9 kHz
Sphere LP2	34.1 μS	15.6 km/S	29.3 kHz
Sphere LP2	34.3 μS	14.3 km/S	29.2 kHz
Sphere LP2	20.3 μS	24.1 km/S	49.3 kHz

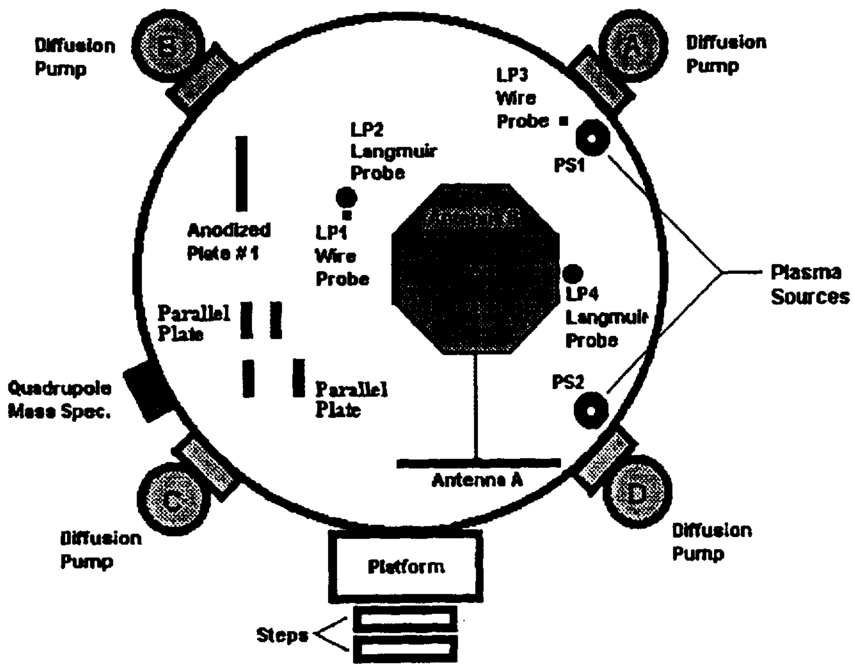


Figure 1.—Top down cutaway view of vertical Chamber,
(Dimensions: 1.8 μm diameter x 3.0 μm high)

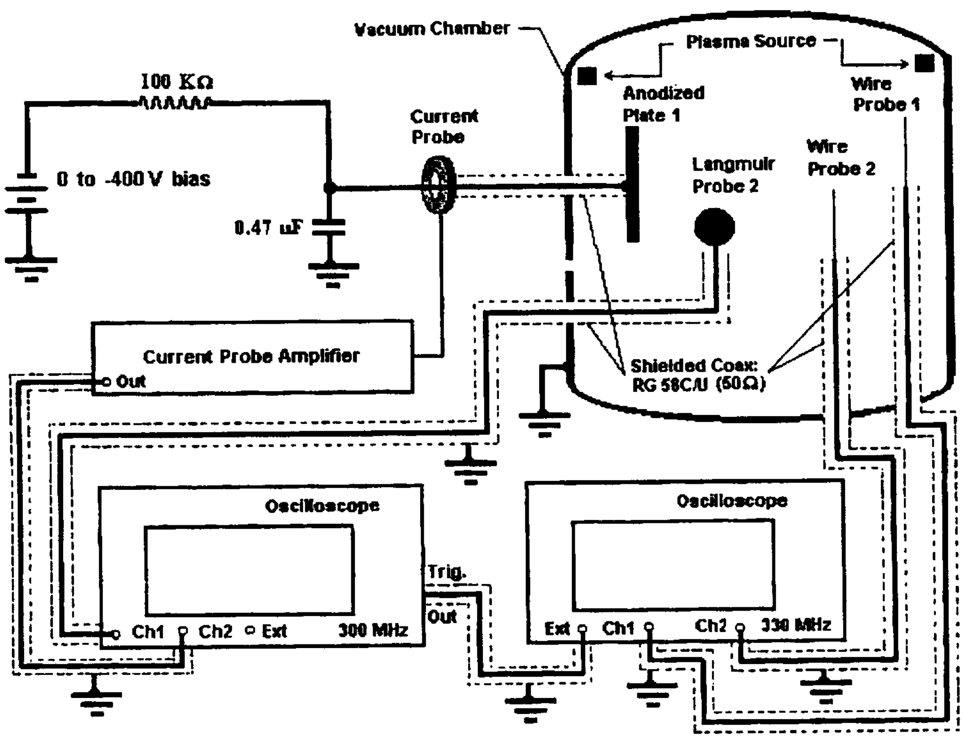


Figure 2.—Experimental apparatus for the electromagnetic frequency spectrum measurements and plasma cloud propagation experiments.

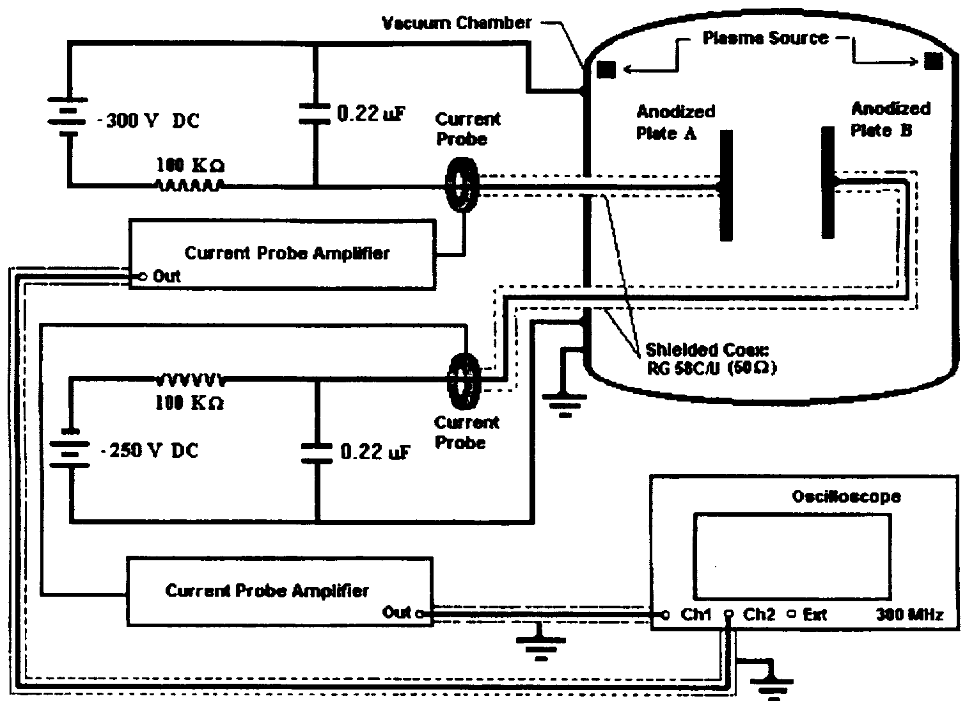


Figure 3.—Experimental apparatus for the induced arcing experiments.

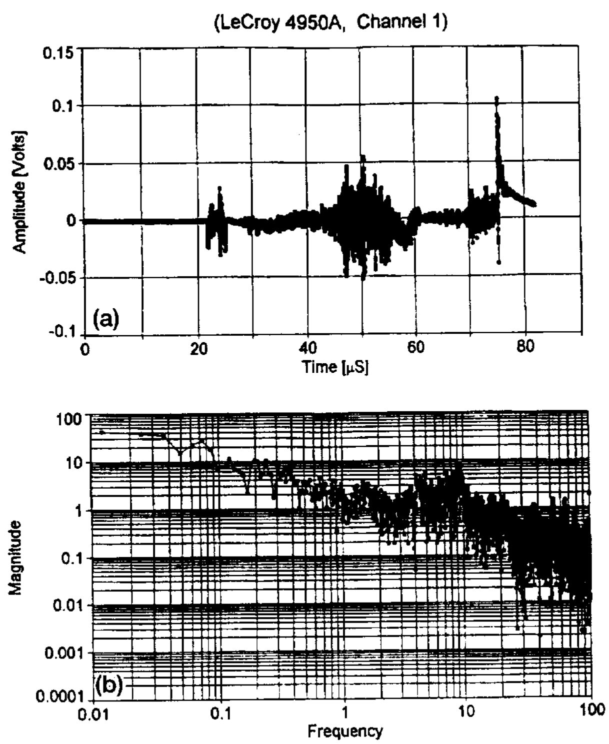


Figure 4.—(a) Electromagnetic signature resulting from arc. Signal trace shown was acquired from the horizontal antenna (Antenna A). (b) Resultant electromagnetic frequency spectrum for the horizontal antenna. Displayed waveform was obtained from the Fourier Transform of signal trace in figure (a) (note: frequency in MHz and vertical scale is given in relative units).

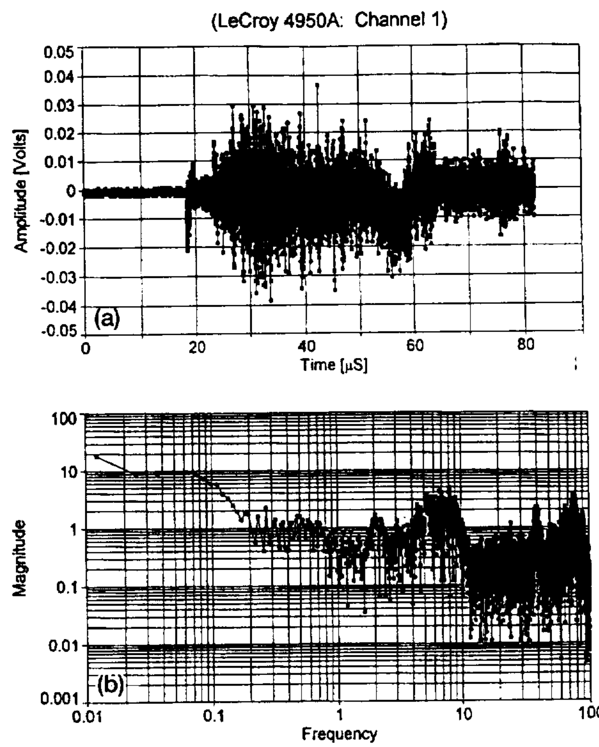
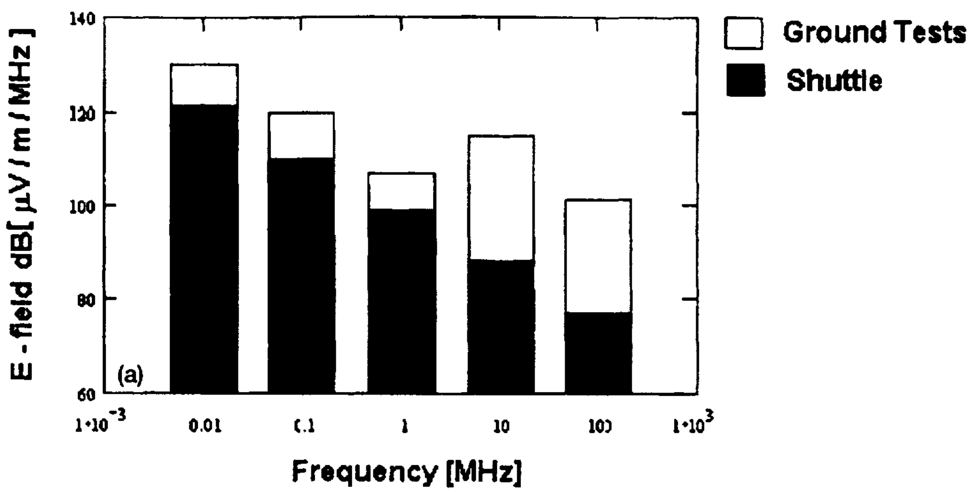


Figure 5.—(a) Electromagnetic signature resulting from arc. Signal trace shown was acquired from the vertical antenna (Antenna B). (b) Resultant electromagnetic frequency spectrum for the vertical antenna. Displayed waveform was obtained from the Fourier Transform of signal trace in figure (a) (note: frequency in MHz and vertical scale is given in relative units).



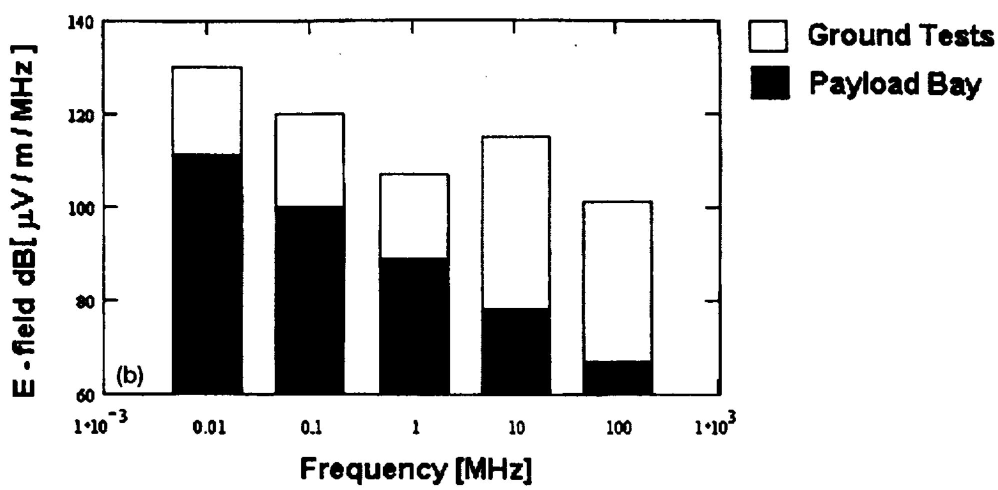


Figure 6.—(a) Comparison of max EMI levels set for Shuttle and EMI levels obtained from arcs at approximately 1 m distance in ground testing at LeRC. (See ref. 11 for details). (b) Comparison of max EMI levels set for payload in Shuttle payload bay and EMI levels obtained from arcs at ≈ 1 m distance from plate at LeRC. (See ref. 11 for details).

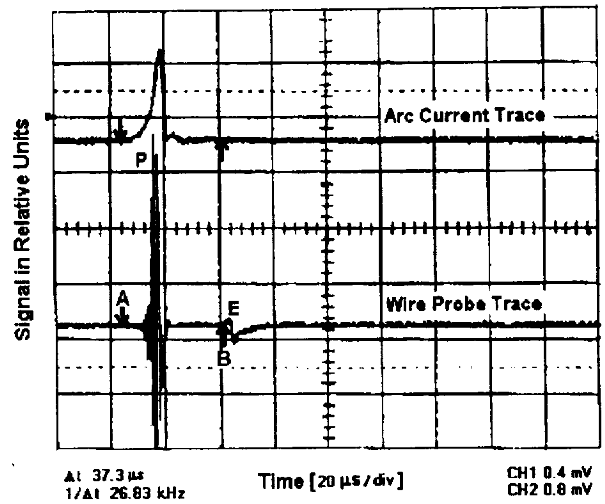


Figure 7.—Typical signal traces obtained from plasma cloud propagation tests. (Plate #1: ϕ_b = –400 V, C = 47 μF, R = 100 kΩ).

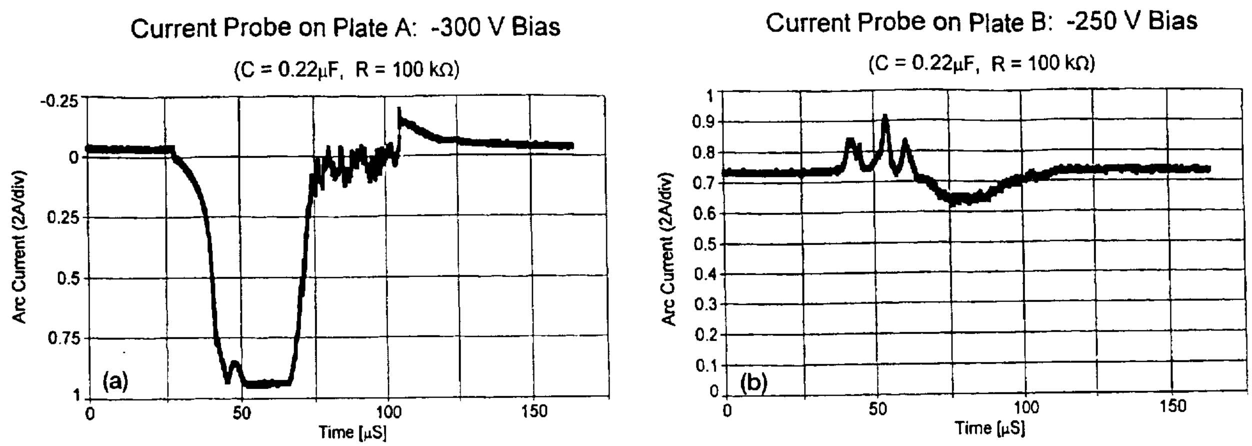


Figure 8.—Are pulses recorded on two independently biased parallel plates. Note: distance between plates in 50 centimeters. (No measured delay was observed.)

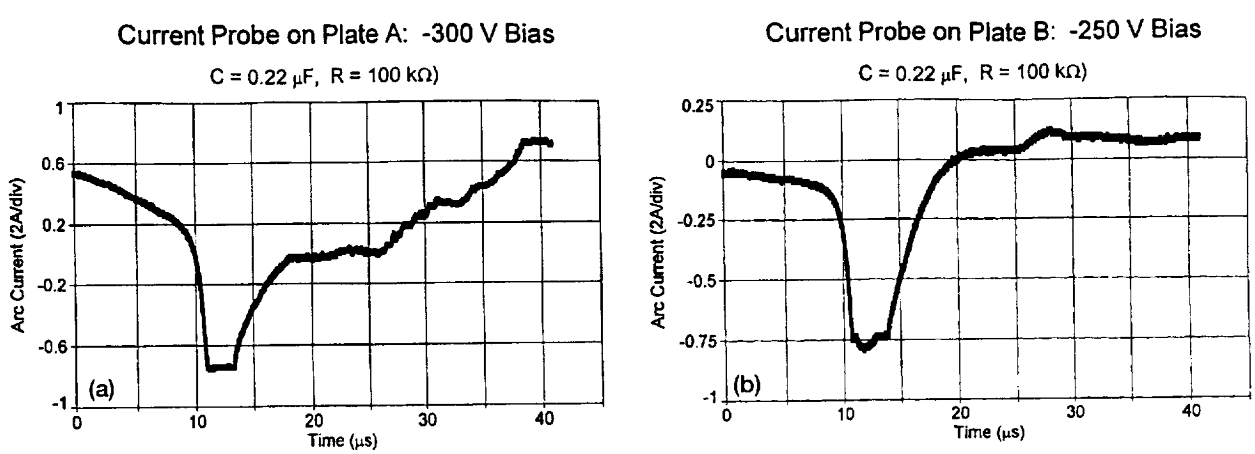


Figure 9.—Induced arcing between two independently biased parallel plates. Note: distance between plates in 25 centimeters. (No measured delay was observed.)

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13. ABSTRACT ***(Maximum 200 words)***

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