

# Comment on "Theory and Observation of Triple-Root Jump in Spacecraft Charging" by Shu T. Lai

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Lai [1991] has developed the basis of multiple roots for the zero net current condition on high-altitude satellites. This work is then compared to an example of observations from the SCATHA satellite during an eclipse transition. This temporal dependence of the illumination makes the application of the theory developed by Lai to the SCATHA example somewhat difficult to follow. An alternate example is pro-posed here, which may better illustrate the points made in his paper.

The example is chosen from a charging event analyzed by *Olsen and Whipple* [1988], from the ISEE satellite. This example was a daylight charging event, observed with the ion mass spectrometer and the two electric field experiments. During most of the period for this work, there was good agreement among the three instruments (refer to Figure 1 of Olsen and Whipple). For 15-30 min following perigee, however, there was a disagreement. The Goddard Space Flight Center (GSFC) electric field experiment probes were found to float as much as 20 V below the satellite potential (Figure 11 of Olsen and Whipple). There was then a sharp increase in the boom potential over the period of 1 potential measurement (1/4 s). After this point, the GSFC electric field experiment was apparently floating at a potential similar to the University of California, Berkeley (UCB), probe, indicating a potential similar to that inferred from the ion data.

Figure 1 shows the GSFC electric field data in detail. The top panel is the differential (end-to-end) measurement, which reflects the ambient electric field (distorted by satellite charging effects). The bottom panel shows the common mode voltage, the potential of the probes with respect to the satellite. Prior to 1158:44 UT the boom potential is oscillating between near zero and -20 V. If the satellite potential is -10 V at this time, as indicated by the other instruments, the probes are oscillating between -10 and -30 V potential with respect to the ambient plasma.

A modest change in the environment apparently occurs at this point ( $L \sim 6.6$ , 22 MLT), and the probe potential snaps upward, such that the spin modulation is between +5 and +30 V with respect to the satellite. This means the probe potential with respect to the ambient plasma is oscillating between a value near zero and +25 V. This is closer to the behavior observed prior to the gradual drop in potential at ~1150 UT and prior to perigee. The sign of the inferred satellite potential comes into agreement with the other two instruments. Note that the UCB probes have a bias current applied which normally reduces the floating potential of that probe to near zero with respect to the ambient plasma.

There are no obvious changes in the electric field measurement, in the top panel, indicating that whatever changes occurred at ~1158:44 occurred at both of the booms. That is, there was not some sort of arc discharge affecting only one boom; there was a change in the equilibrium current balance for both probes.

There was no obvious explanation for this change at the time the data were published. The work by *Lai* [1991] suggests that these data could be interpreted as a shift in equilibrium, associated with the triple-root phenomenon. Figure 2 shows inferred current-voltage curves for the beryllium-copper (Be-Cu) probes, following the example of Lai. (Detailed calculations using the ambient environment and probe secondary emission characteristics have not been done.) Following Figure 2a, the initial behavior of the probes can be followed. The probes alternate between being fully illuminated (sunlight) and being pointed to at the Sun, at which point they are effectively in eclipse (shadow). The potential oscillates between the single negative root of the "shadow" curve and the negative root of the "sunlight" curve. With a modest shift in the environment, there is apparently an increase in the net (positive) probe current. Figure 2b illustrates one scenario for the revised equilibrium states of the GSFC probe. The probe is now oscillating between the single roots, with the sunlight root now being positive.

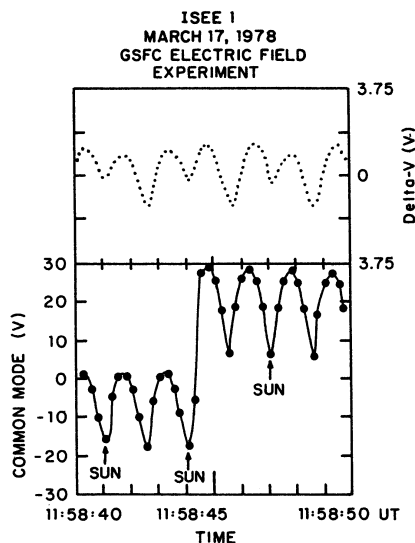


Fig. 1. Data from the GSFC electric field experiment. (Top) Electric field data, the end-to-end potential. (Bottom) Common mode potential, or boom potential with respect to the satellite.

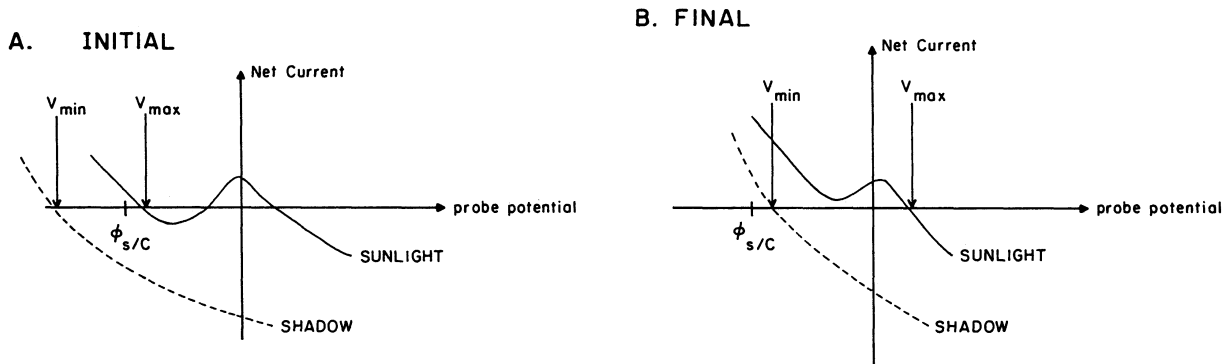


Fig. 2. (a) Current-voltage relation where multiple roots exist in sunlight. (b) Current-voltage relation where only single roots exist.  $V_{min}$  and  $V_{max}$  represent the equilibrium potential of the GSFC antenna probes when they are parallel and perpendicular to the satellite-Sun line, respectively.

The existence of multiple roots for satellite potential Olsen, R. C., and E. C. Whipple, An unusual charging event on appears to be on firm ground theoretically. These data from ISEE 1 now have at least a plausible explanation, albeit not yet based on detailed calculation. As a possible example, they provide additional evidence for the phenomena described by Lai.

#### REFERENCES

- Lai, S. T., Theory and observation of triple-root jump in spacecraft charging, *J. Geophys. Res.*, 96, 19,269-19,281, 1991.  
 Olsen, R. C., and E. C Whipple, An unusual charging event on ISEE 1, *J. Geophys. Res.*, 93, 5668-5578, 1988.

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