PLASMA NOISE IN EMI DESIGN

Practice:

Missions with payloads that can interact strongly with the ambient plasma, such as a high power electron beam, a high power RF source, or an ion engine, may require a structural current test for conducted susceptibility and higher radiated susceptibility test levels. The practice is to perform an analysis early in such a program to estimate the amplitude of plasma noise induced electromagnetic interference (EMI). This may identify potential adverse effects on operational reliability.

Benefits:

Potential EMI sources are identified in time so that appropriate measures can be incorporated into the electromagnetic compatibility (EMC) program. If the high predicted levels turn out to be a problem, the early identification allows time to develop a solution.

Programs That Certified Usage:

Atmospheric Trace Molecules Observed by Spectroscopy (ATMOS) mission in the ATLAS series.

Center to Contact for Information:

Jet Propulsion Laboratory (JPL).

Implementation Method:

Perform a comprehensive survey of the mission environments and payload characteristics, then determine the possible sources of plasma generated noise. If the source of plasma noise is from the natural occurring space plasma or arises from the motion of a spacecraft through the earth's geomagnetic field, the radiated susceptibility (RS03) test levels specified in MIL-STD-461C will be adequate. The magnitude of plasma waves in the natural space environment is usually limited by the thermal energy of the ambient plasma. Due to the low plasma densities of the earth and other planets, the energy content of the naturally occurring space plasma is relatively low. It can easily be shown that the MIL-STD-461C radiated susceptibility RS03 limits are adequate to demonstrate a spacecraft's immunity to EMI generated by natural plasma noise.

The RS03 specifications are:

Frequency Range	E-Field (Volts/meter)
14 kHz to 30 MHz	10
30 MHz to 10 GHz	5
Above 10 GHz	20

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For large conducting structures moving across the geomagnetic field, additional plasma noise is generated as a result of wave emission due to the motion induced VxB electric field. In low earth orbit, the noise level generated by a typical space station structure is estimated to be 10^{-3} V/m per ampere current (ref. 1) and that of a tethered satellite system is 10^{-1} V/m (ref. 2). Since the typical current flow for the space station and the tethered satellite is less than 1 Amp, the electric field generated by motion of a space structure will also be enveloped by the MIL-STD-461C RS03 limits.

Plasma can also cause structure current (conducted emission) to flow in the spacecraft. In the absence of any externally induced events, the net current to the spacecraft structure is always zero. When the spacecraft goes in and out of eclipse, a transient current would be induced on the spacecraft structure. Since the time scale of this type of transition is relatively long, on the order of seconds, and the current involved is the plasma current that can be collected by a spacecraft (which is on the order of 0.1A), this transient current will not be a EMI source of any concern.

Technical Rationale:

Electron beam experiments can generate high levels of conducted and radiated EMI. When an electron beam is injected into the plasma from a spacecraft, a return current must be present in order for the current loop to be completed. The rise time of this return current is determined by the transit time of thermal electrons through the sheath surrounding the spacecraft. This time scale is >0.1 µs (ref. 3 and 4). The upper bound value of the peak return current is given by the peak injected electron beam current. Therefore, the dI/dt of the structure current will be in the range of 108 A/s (assuming a peak current of 10 Amp). For programs that have tests to demonstrate immunity against lightning or ESD inducted structure current, the dI/dt of those test specifications are usually > 10^4 A/µs and thus they envelope the dI/dt induced by electron beam. For a program that has no test specifications for structure current, it should be added to the EMC program if an electron beam experiment is on-board. This is particularly important when the beam current exceeds 10 Amp.

The injected electron beam also generates large amplitude waves in the ambient plasma (ref. 5). A comprehensive analysis is needed to determine the maximum amplitude of the beam generated plasma noise. This analysis involves an estimate of the conversion efficiency of the beam energy into electromagnetic wave energy. Usually this conversion efficiency has an upper bound value of 1% (ref. 6). Once the amplitude of the EMI produced by beam generated waves has been determined, the adequacy of the MIL-STD-461C RS03 specifications can be evaluated. Similar approaches can be applied to determine the EMI resulting from the interaction of an ion engine plume and the ambient plasma.

Impact of Non-Practice:

Unpredictable operational anomalies and compromised science data may result.

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References:

1. Hastings, D. and Wang J. (1989), "Induced Emission of Radiation from a Large Space-Station-Like Structure in Ionosphere," AIAA Journal, 27, N4.

2. Wang, J. and Hastings, D. (1991), "A Dynamic Analysis of the Radiation Excitation from the Activation of a Current Collecting System in Space", Journal of Geophysical Research, 93, A3.

3. Singh, N. and Hwang, K. (1988), "Electric Potential Structures and Propagation of Electron Beams Injected From a Spacecraft Into a Plasma", Journal of Geophysical Research, 93, A9.

4. Neubert, T., et al. (1986), "Waves Generated During Electron Beam Emissions from the Space Shuttle", Journal of Geophysical Research, 91, A10.

5. Wincler, J., et al. (1989), "Echo 7: An Electron Beam Experiment in the Magnetosphere," Eos, Transactions, American Geophysical Union, 70, 657.

6. Winglee, R. and Kellog, P. (1990), "Electron Beam Injection During Active Experiments, 1, Electromagnetic Wave Emissions", Journal of Geophysical Research, 95, A5.