EU ASRG Electromagnetic Interference Test Summary

EU ASRG testing was performed in accordance with MIL-STD-461E, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment. The test consisted of the following:

- Radiated E-field emissions, 10 KHz to 18 GHz (RE102)
- Radiated Susceptibility, 14 KHz to 18 GHz (tailored RS103)
- Conducted Emissions, 30 Hz to 150 KHz (CE102)
- Conducted Susceptibility, 30 Hz to 150 KHz (tailored CS101)

Per MIL-STD-461E, CE102 and CS101 are required only for those that obtain power from another source, thus are not applicable to ASRG, being a power source. These tests, however, were performed to characterize EU ASRG and define preliminary bounds for spacecraft integration.

In addition, AC and DC magnetic field emissions with and without the controller due to AC current flow and the presence of permanent magnets in the ASC, respectively, were performed. The table below summarizes the EU compliance to the requirements.

In summary, both AC and DC magnetic field emissions exceeded requirements as expected, though the AC requirement was “To Be Resolved”. Both can be mitigated with minor generator modifications that are mission dependent. Radiated and conducted emissions exceeded requirements, though conducted emissions will meet when the proper spacecraft bus impedance is taken into consideration. Additional testing is being considered to further characterize radiated emissions. Radiated and conducted susceptibility test results were within specification.

Test	Requirement	Test Results
DC Magnetic Field Emissions	25 nT at 1 m from center of EU	84.5 nT at 1 m from center of EU
AC Magnetic Field Emissions	80 (TBR) dBpT at 1 m from center of ASRG	119 dBpT at 1 m from center of ASRG
Radiated Emission, E-Field	Derived from MRO and X2000 specifications	Out of spec. at 7 to 30 MHz range
Radiated Susceptibility, E-Fields (tailored)	No degradation in performance when subjected to an applied field of 20 V/m (14 KHz to 1 GHz) and 100 V/m (>1 GHz)	Passed, no performance change observed
Conducted Emissions, E-Field	CE102 limits, MIL-STD-461E	Out of spec. at 20 KHz and its harmonics
Conducted Susceptibility CS101 (tailored)	No degradation in performance when subjected to injection of 1 amp pk-to-pk ripple on the bus	Passed, no performance change observed

DC magnetic Field Emissions

The DC magnetic field emissions come from the 12 permanent magnets in each ASC alternator. Figure 1 shows the data taken at various distances from the unpowered EU ASRG. The requirement for DC magnetic field emissions is mission dependent. Galileo/Ulysses missions specified 30 nT emissions while 78 nT was specified for the Cassini mission. As a comparison, the GPHS-RTG typically emits >100 nT at 1 m from the generator center due to DC current loops. GPHS-RTG F5 was measured at 134 nT in 1985 after fueling.

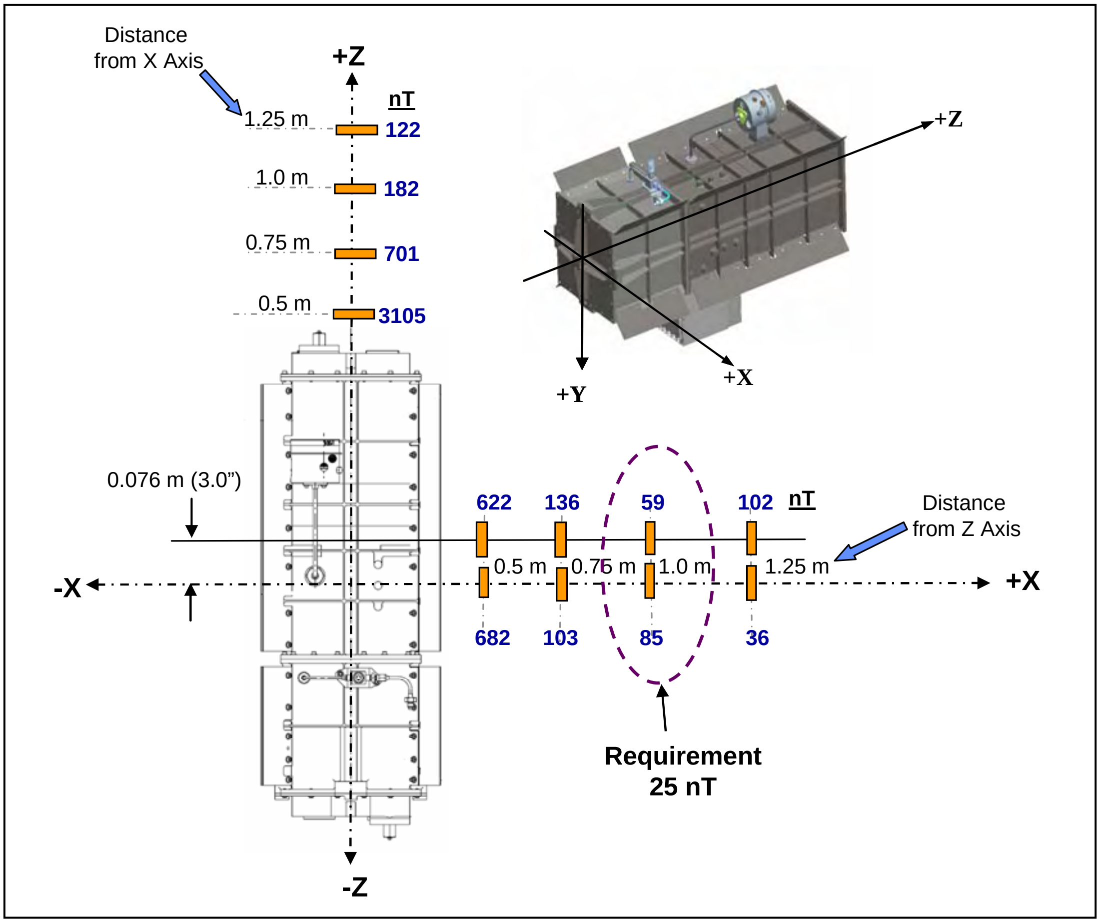

Figure 1. DC Magnetic Field Emissions Test Results.

To meet the emissions requirement, compensating permanent magnets were located externally on the GPHS-RTG housing for Galileo/Ulysses missions. A similar technique is expected to be applied to ASRG when mission demands the lower requirement. Using the test data from the EU ASRG, analysis will be performed to define compensating magnet strength, quantity and mounting locations. These activities are to be conducted and demonstrated for the qualification ASRG.

AC Magnetic Field Emissions

Majority of the AC magnetic field emissions come from the AC current loops in the ASC alternators. The TBR requirement of 80 dBpT originated from SRG110 that used the Technology Development Convertor (TDC) having lower power, higher voltage and lower current output. Figure 2 shows the typical output measurement with ASC emissions at its operating frequency of 102 Hz and its harmonics. Also measured are the emissions from the controller that operates at the 20 kHz frequency.

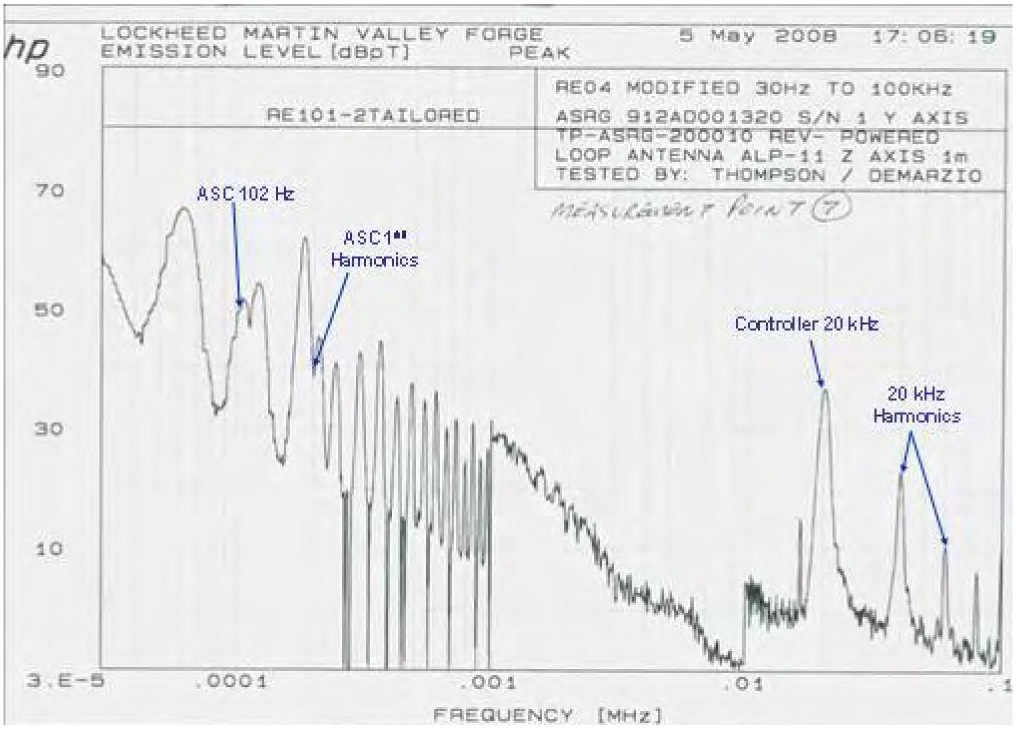

Figure 2. Typical AC Magnetic Field Emissions Test Output.

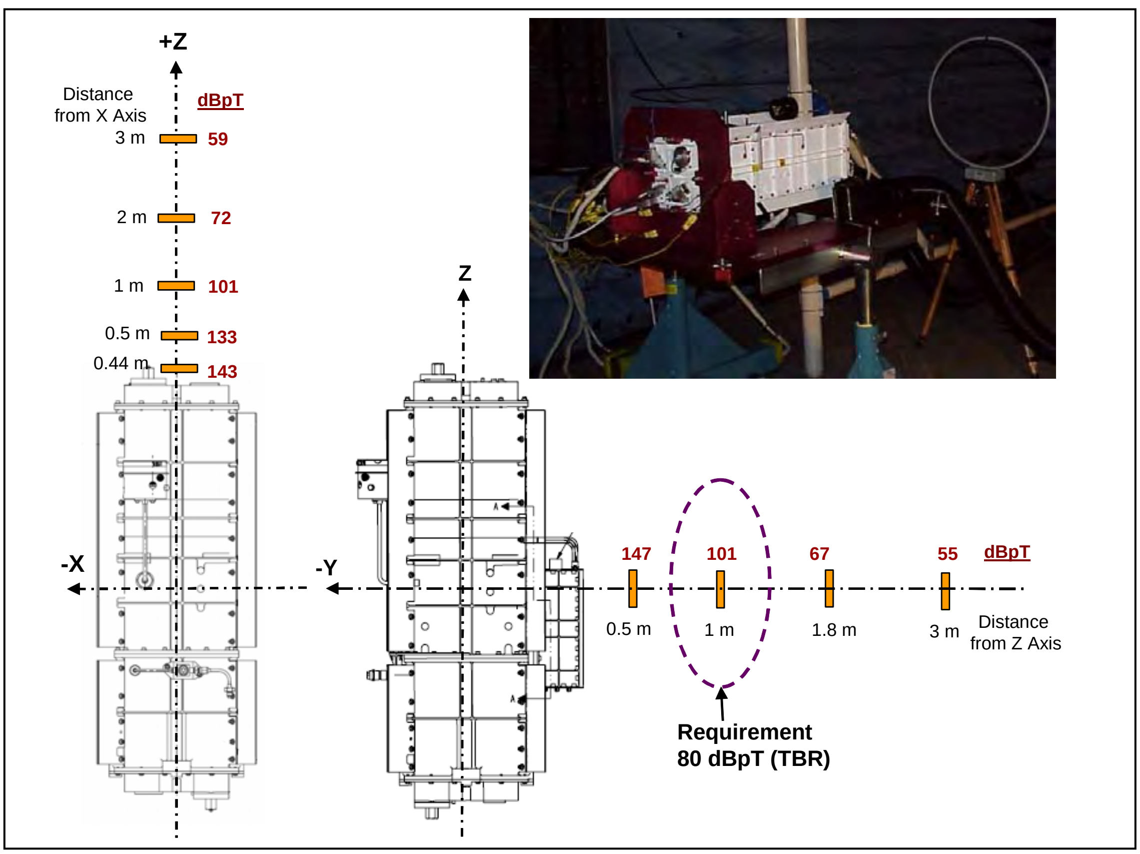

Figure 3. AC Magnetic Field Emission Test Results.

Radiated Emissions, E-Field

An out-of-specification condition was observed in the region from 7 to 30 MHz during test, as shown in Figure 4. The exceeded range coincided with the background noise measured with the uninterruptable power supply (UPS) turned on. However, this noise cannot be simply subtracted from the powered reading nor would it significantly reduce the result measured in dB scale.

An RF sniffer was used to monitor the EGSE during full power operation. It was observed to strongly emanate in the 10 MHz region from the electric heat source (EHS) power supplies, as called out in Figure 4. The controller H-bridge switches at 20 kHz at high currents with sub-microsecond rise-times. This may create frequencies in the out-of-specification band. Thus the source of the emanations cannot be determined from the data available; it may be the controller or the UPS and ground support equipment.

A simple test will be performed during the final electrical performance. An RF sniffer will be used on the controller and generator assembly at full power. Then the measurement is repeated with no power supplied to the EHS. This is not a calibrated test but would help troubleshoot the source.

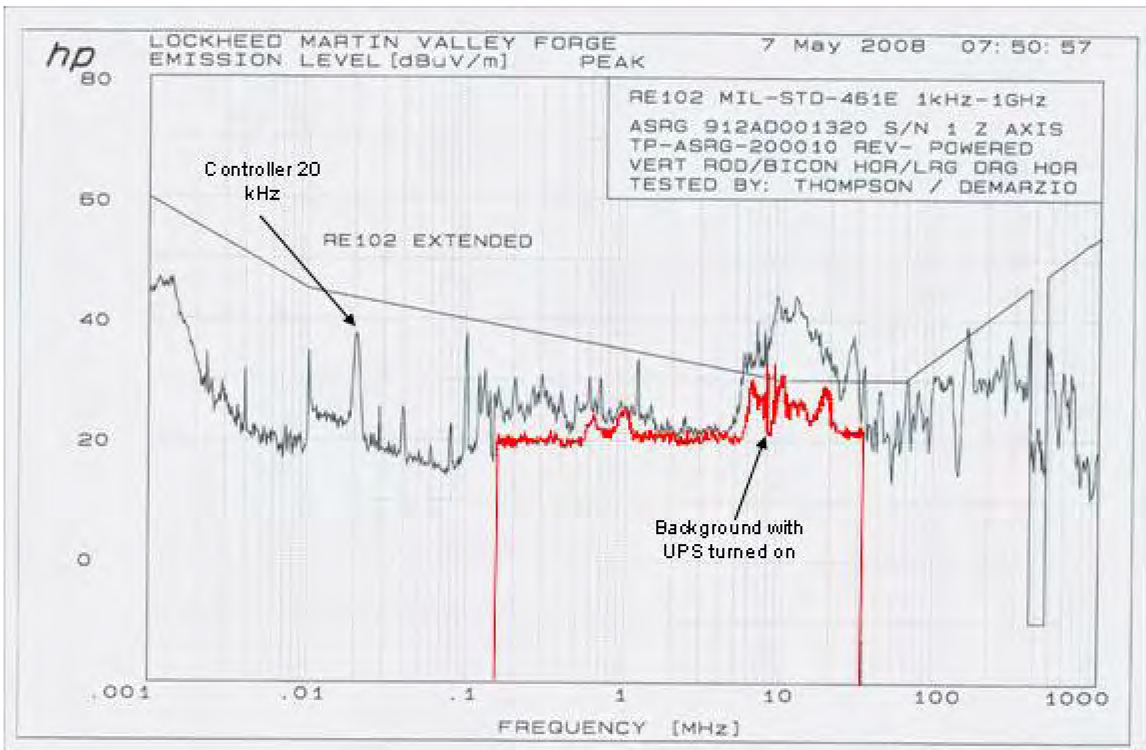

Figure 4. Radiated Emission Limits and Measurements.

Conducted Emissions

The conducted emissions requirement is applicable to assemblies that obtain power from another source, such as the ASRG, and thus is not a Generator Specification requirement. The CE102 test was performed, however, to characterize the emissions and the potential interaction for multiple ASRG missions. The test results in accordance with CE102 test setup are provided in Figure 5. The emissions exceed the limit at 20 KHz switching frequency of the controller.

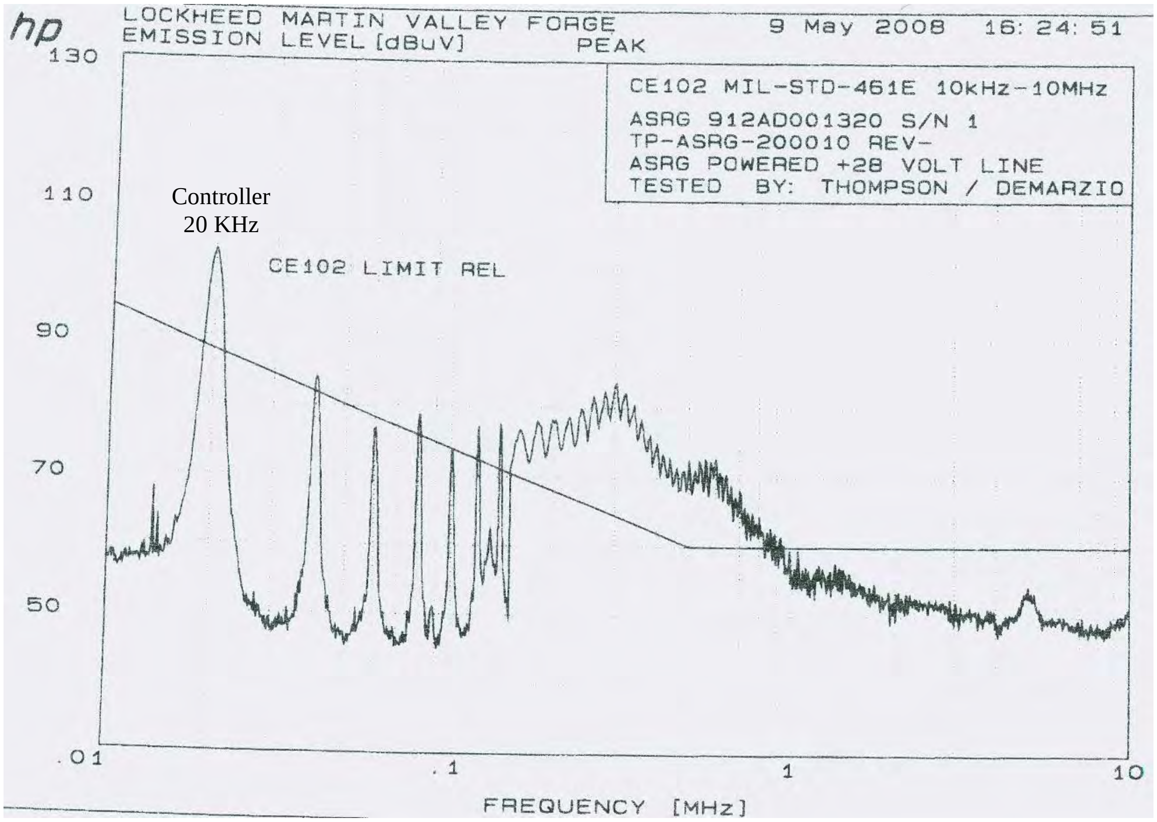

Figure 5. Conducted Emission Limits and Measurements

Further evaluation shows that a 50 µH inductor is specified for the Line Impedance Stabilization Network (LISN) in CE102 per MIL-STD-461E. The resulting bus impedance with 50 µH inductor increases by about 23.5 Ohms between 10 KHz and 200 KHz. This translates to about a 20 dB increase in bus impedance. Changing the 50 µH LISN to 5 µH LISN will be more representative of most system bus impedance. This change will reduce the measured voltage by 20 dB and fall below the CE102 limit of 88 dBµV.