APPLICATION		REVISIONS			
NEXT ASSY	USED ON	REV	DESCRIPTION	DATE	APPROVED
	FAME	-	Release to Production per ERN	6/19/01	

ORGINATED BY	DATE
APP'D TEST MANAGER	DATE
APP'D ELECTRICAL ENGINEER	DATE
APP'D PROD. ASSURANCE	DATE
APP'D PROGRAM MANAGER	DATE

NAVAL RESEARCH LABORATORY

SPACE SYSTEMS DEVELOPMENT DEPARTMENT
WASHINGTON, D.C. 20375

TITLE: FAME
Electromagnetic Compatibility (EMC)
Control Plan

CODE IDENT. NO.	DRAWING NO.	REV
#####	NCST-D-FM018	-
	SHEET 1 OF 25	

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1 INTRODUCTION

1.1 Purpose. This document implements the Naval Research Laboratory's Electromagnetic Compatibility Control Plan (EMCCP) for the Full-sky Astrometric Mapping Explorer (FAME). Contained within this plan are the detailed requirements for the electromagnetic compatibility, including Electromagnetic Interference (EMI), electrical bonding, grounding, referencing/isolation, electrostatic discharge and cabling applicable to FAME.

1.2 Scope. Requirements and information presented in this EMCCP are applicable at the Spacecraft and at the component level. This document establishes requirements, their interpretation and provides design guidance useful to vendor and subcontractor hardware as well as in-house build items.

1.3 Management Controls. Responsibility for the overall System EMC resides with the Naval Research Laboratory. The requirements at the space segment level, through the Prime Item Development Specification (PIDS), address subsystem and component EMC. These PIDS requirements include bonding, referencing, EMC Control Plans, and MIL-STD-461 implementations. Requirements are allocated to the applicable subsystems and components by this EMC Control Plan. The allocated requirements are contractually imposed on subcontractors by the Procurement Documents (PDs) and other contractual vehicles. These organizations are responsible to support the EMC program.

1.4 EMC Control Board. The purpose of the EMC Control Board (EMCCB) is to ensure that the mechanisms and procedures exist and are implemented so that electromagnetic compatibility is achieved at the integration of the Spacecraft. Assistance is provided by advising affected contractors, subcontractors, and Government agencies of the appropriate methods for identifying and correcting EMC deficiencies. It is the responsibility of the EMCCB to direct studies, make recommendations, and otherwise assist in achieving electromagnetic compatibility of the System with its expected and operational environments. Therefore, the EMCCB is composed of representatives qualified to make appropriate decisions and recommendations on EMC problem solutions.

The members of the EMCCB are the Naval Research Laboratory Code 8100, 8200 and the subcontractor agencies. Meetings of the EMCCB are scheduled approximately quarterly as called by the EMCCB chairman. Special meetings may be called by the chairman.

2 APPLICABLE DOCUMENTS

The documents referenced herein form a part of this EMCCP to the extent referenced. In case of conflict between this document and any referenced document, this EMCCP shall take precedence.

2.1 Compliance Documents. The following Government specifications and standards are applicable to the program to the extent referenced herein. These "compliance" documents are listed by specification or standard number, including the applicable issue letter designator, (i.e., MIL-STD-461C), and their title. Additional documents referenced in any of the following documents are applicable only as directly specified in the citing document. Lower tier referenced documents provide guidance information, not additional requirements and are listed in the Other Documents section, with references noted.

TABLE 2-1: COMPLIANCE DOCUMENTS

Document Number	Title
MIL-STD-461C 04 AUG 1986	MILITARY STANDARD – Electromagnetic Emissions and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-462, Notice 5 04 AUG 1986	MILITARY STANDARD – Measurement of Electromagnetic Interference Characteristics
MIL-B-5087 (superseded by MIL-STD-464)	MILITARY SPECIFICATION – Bonding, Electrical, and Lightning Protection for Aerospace Systems
MIL-STD-464 18 MAR 1997	MILITARY STANDARD – Electromagnetic Environmental Effects Requirements for Systems
MIL-STD-1541A 30 DEC 1987	MILITARY STANDARD – Electromagnetic Compatibility Requirements for Space Systems

2.2 Other Documents. The following are referenced as design guidance and compliance verification support documents only.

TABLE 2-2: OTHER DOCUMENTS

Document Number	Title
DI-EMCS-80199	Data Item Description – EMC Control Plan
NTIA Manual	Manual of Regulations and Procedures for Federal Radio Frequency Management, National Telecommunications and Information Administration, U.S. Department of Commerce

3 REQUIREMENTS

3.1 System Requirements. Requirements for EMC Design are derived from MIL-STD-1541A and MIL-STD-461C, Part 3 as tailored herein, and are detailed in this section. EMC test requirements are shown in section 4. The test matrix in Table 3-2 specifies which tests apply to FAME subsystems and equipment within the spacecraft.

3.2 EMC Design Requirements. Electrical and electronic equipment will be designed to operate compatibly when operated independently, and when operating in the spacecraft configuration. This requires that the operation of all such equipment will not be adversely affected by interference voltages, currents, and fields generated by spacecraft sources, and also requires that the individual equipment will not be a source of interference which adversely affects the operation of other spacecraft-related equipment. The EMC design objective is to establish a safety margin on critical circuits. The equipment characteristics will be such that a margin will exist between the critical circuit response threshold and the noise energy present on the circuit due to the spacecraft operation and test bed environment. The requirements of this EMCCP are chosen to support a minimum 6 dB EMI safety margin for the spacecraft and a 20 dB EMI safety margin for ordinance, in accordance with MIL-STD-1541A.

Design consideration will be given to: conservation of spectrum bandwidth; control of operating frequencies and associated harmonics; sidebands and spurious products; control of pulse amplitudes and rise times; and other factors affecting interference.

The application of interference control components used, as in filtering, shielding, and bonding, will conform to good aerospace engineering practice and will be an integral part of the equipment. Separately installed external suppression components will not be used. Power neutral or return leads will not be switched where the neutral will isolate the unpowered circuit from the single point ground reference.

Each subcontractor equipment design effort shall prepare the following equipment level documents to delineate compliance approaches to requirements of this document: EMC Control Plan, EMC Test Plans, EMC Test Procedures and Reports. These plans and reports shall be in the contractor format.

3.2.1 Electromagnetic Environments

3.2.1.1 Launch Site. Requirements caused by being in a launch site environment are included in this EMC control plan.

3.2.2 Lightning. Equipment and spacecraft designs shall prevent overstress or damage induced by a lightning strike to the nearest facility lightning protection device, by a lightning strike just outside the zone of protection, or by a lightning strike near or above underground cables which are part of the system. The lightning current waveform is 200,000 amperes peak, a width of 5 to 10 microseconds at the 90% point, not less than 230

microseconds width at the 50% point, and a rate of rise of at least 100,000 amperes per microsecond. The requirements for the vehicle shall be satisfied by analysis in accordance with MIL-STD-1541.

3.3 EMC Program Requirements. The system shall meet the requirements of MIL-STD-1541A and MIL-STD-461C, Part 3 as tailored herein. Each of the spacecraft subsystems is listed in the EMC test matrix in Table 3-2 which shows which tests are to be performed for each of the subsystem components.

3.3.1 Conducted Emissions Requirements. As specified in Table 3-2, electronic equipment shall be designed to limit the conducted emissions on all power leads, including return lines, specified in the following subparagraphs.

3.3.1.1 Power Leads – 30 Hz to 15 kHz, (CE01). Components shall comply with the CE01 narrowband emission requirement of MIL-STD-461C, Part 3. The narrowband limit for power leads is shown in Figure 3-1. This requirement applies to the input power leads only. Any component that provides power to other subsystems shall meet the power quality requirements of section 3.3.5 on the output power leads. Measurements shall be conducted in accordance with MIL-STD-462.

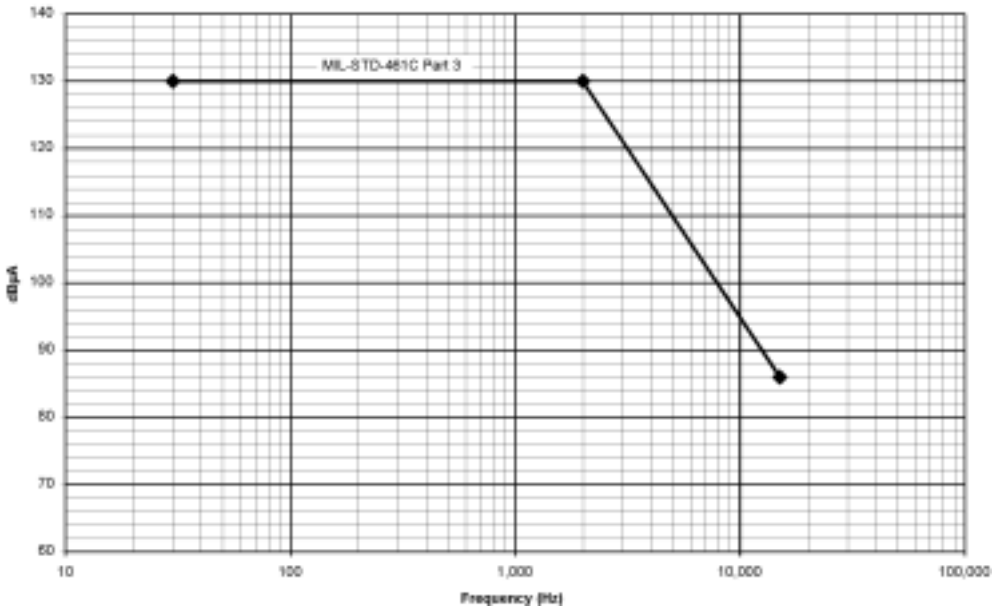

FIGURE 3-1: CE01 NARROWBAND TEST LIMIT

3.3.1.2 Power Leads – 15 kHz to 50 MHz, Narrowband (CE03). Components shall comply with the modified CE03 narrowband emission requirement of MIL-STD-461C, Part 3. The modified narrowband limit for power leads is shown in Figure 3-2. This requirement applies to the input power leads only. Any component that provides power to other subsystems shall meet the power quality requirements of section 3.3.5 on the output power leads. Measurements shall be conducted in accordance with MIL-STD-462.

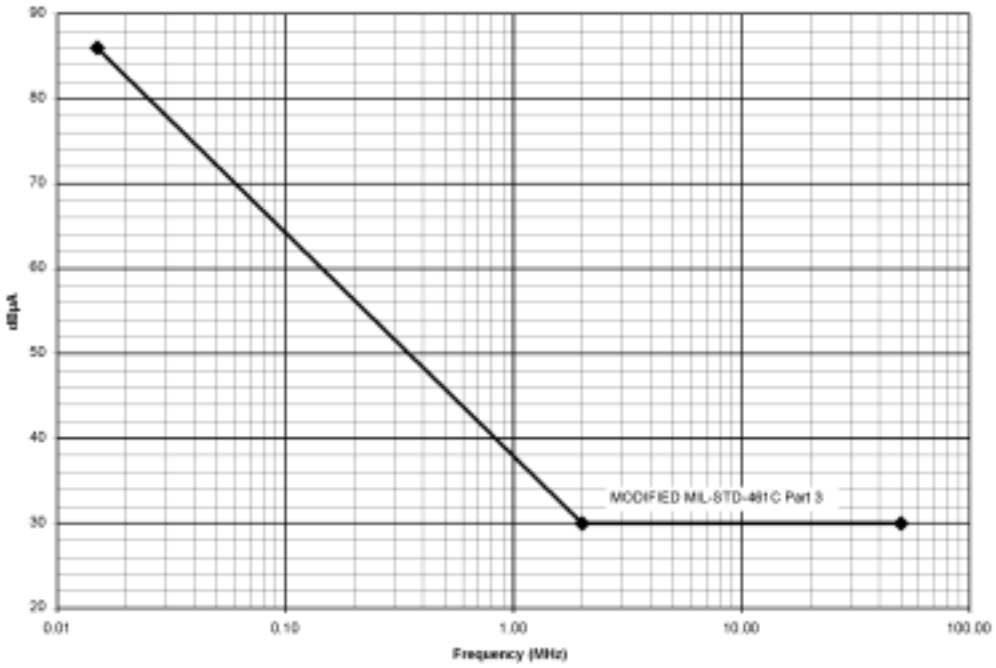

FIGURE 3-2: MODIFIED CE03 NARROWBAND TEST LIMIT

3.3.1.3 Antenna Terminals – 10 kHz to 100 GHz, Narrowband (CE06). This requirement is applicable only for those equipment and subsystems with antenna leads or those designed to be connected to antennas. Components shall comply with the CE06 narrowband emission requirement of MIL-STD-461C, Part 3.

Measurements shall be conducted in accordance with MIL-STD-462. The frequency range specified in MIL-STD-462 shall be extended to the thirtieth harmonic or 100 GHz, whichever is less, for equipment operating frequencies greater than 30 megahertz (per MIL-STD-1541) The tailored CE06 requirement does not relax or modify any requirement specified by the National Telecommunications and Information Administration (NTIA) unless a written waiver of those limits is obtained from NTIA.

3.3.2 Conducted Susceptibility Requirements. As specified in Table 3-2, electronic equipment shall be designed to operate without malfunction, undesired response or degradation of performance beyond the tolerances given its design specification or source control drawing when the power input is subjected to the signals specified in the following subparagraphs.

3.3.2.1 Power Leads – 30 Hz to 50 kHz, (CS01). Components shall comply with the modified CS01 susceptibility requirement of MIL-STD-461C, Part 3. The power leads shall be subjected to a continuous wave (CW) of RMS voltage equal to or greater than that shown in Figure 3-3. The requirement is also met if the power source, adjusted to dissipate 50 Watts into a 0.5 ohm load, cannot develop the required injected voltage and the test sample is not susceptible. This requirement applies to the input power leads only. Any component that provides power to other subsystems shall meet the power quality requirements of section 3.3.5 on the output power leads. The test method shall be conducted in accordance with MIL-STD-462.

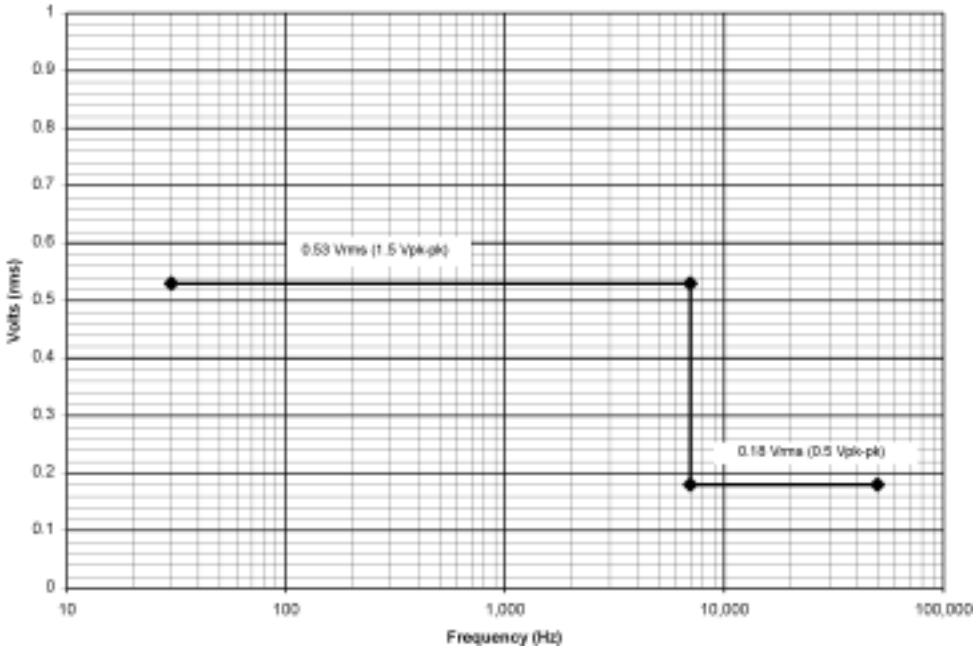

FIGURE 3-3: MODIFIED CS01 SUSCEPTIBILITY REQUIREMENT

3.3.2.2 Power Leads –50 kHz to 400 MHz, (CS02). Components shall comply with the modified CS02 susceptibility requirement of MIL-STD-461C, Part 3. The power leads shall be subjected to a modulated RMS voltage equal to or greater than 0.18 Vrms from a 50 ohm source. The requirement is also met if the power source, adjusted to dissipate 1 Watt into a 50 ohm load, cannot develop the required injected voltage and the test sample is not susceptible. The modulation characteristic shall be chosen which has the maximum affect on the test sample as shown by analysis. A standard 1 kHz Pulse modulation with 50% duty cycle, shall be used if there is no reason to expect the test sample

having sensitivity to a unique modulation type. This requirement applies to the input power leads only. Any component that provides power to other subsystems shall meet the power quality requirements of section 3.3.5 on the output power leads. The test method shall be conducted in accordance with MIL-STD-462.

3.3.2.3 Antenna Terminals –Intermodulation, 15 kHz to 10 GHz (CS03). This requirement is applicable only to receiving equipment and subsystems such as receivers, transceivers, and the like. The applicable frequency range of this requirement is dependent of the operating frequency of the test sample and shall be extended to the tenth harmonic or 10 GHz, whichever is less. Components shall comply with the CS03 susceptibility requirement of MIL-STD-461C, Part 3. The test method shall be conducted in accordance with MIL-STD-462.

3.3.2.4 Antenna Terminals – Rejection of Undesired Signals, 30 Hz to 20 GHz (CS04). This requirement is applicable only to receiving equipment and subsystems such as receivers, transceivers, and the like. The applicable frequency range of this requirement is dependent of the operating frequency of the test sample and shall be extended to the twentieth harmonic or 20 GHz, whichever is less. Components shall comply with the CS04 susceptibility requirement of MIL-STD-461C, Part 3. The test method shall be conducted in accordance with MIL-STD-462.

3.3.2.5 Antenna Terminals – Cross Modulation, 30 Hz to 20 GHz (CS05). This requirement is applicable only to receiving equipment and subsystems such as receivers, transceivers, and the like that normally process amplitude-modulated RF signals. The applicable frequency range of this requirement is dependent of the operating frequency of the test sample, not to exceed 20 GHz. Components shall comply with the CS05 susceptibility requirement of MIL-STD-461C, Part 3. The test method shall be conducted in accordance with MIL-STD-462.

3.3.2.6 Power Leads – Spike, (CS06). Components shall comply with the modified CS06 susceptibility requirement of MIL-STD-461C, Part 3. The power leads shall be subjected to test spikes having a waveforms and amplitudes as shown in Figure 3-4A for the +28 Volt power lead and Figure 3-4B for the Return lead. Each Spike shall be superimposed on the powerline voltage. This requirement applies to the input power leads only. Any component that provides power to other subsystems shall meet the power quality requirements of section 3.3.5 on the output power leads. The test method shall be conducted in accordance with MIL-STD-462.

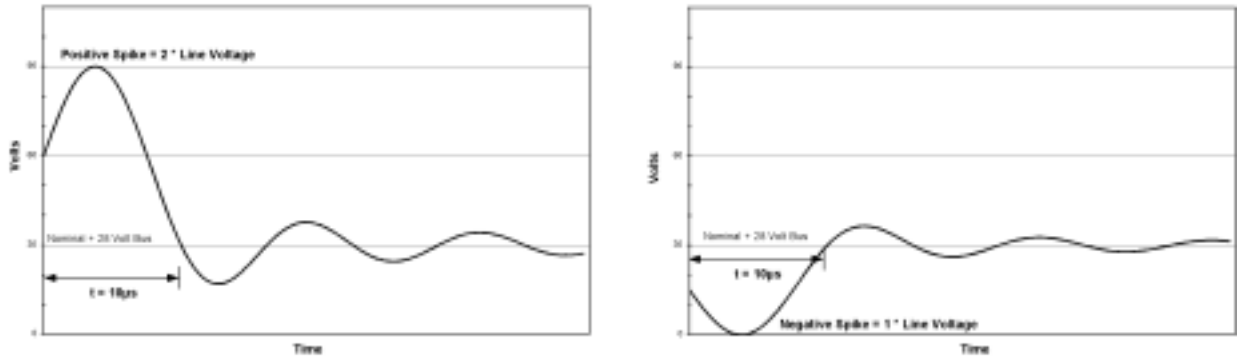

FIGURE 3-4A: MODIFIED CS06 WAVEFORMS FOR +28 VOLT LEAD

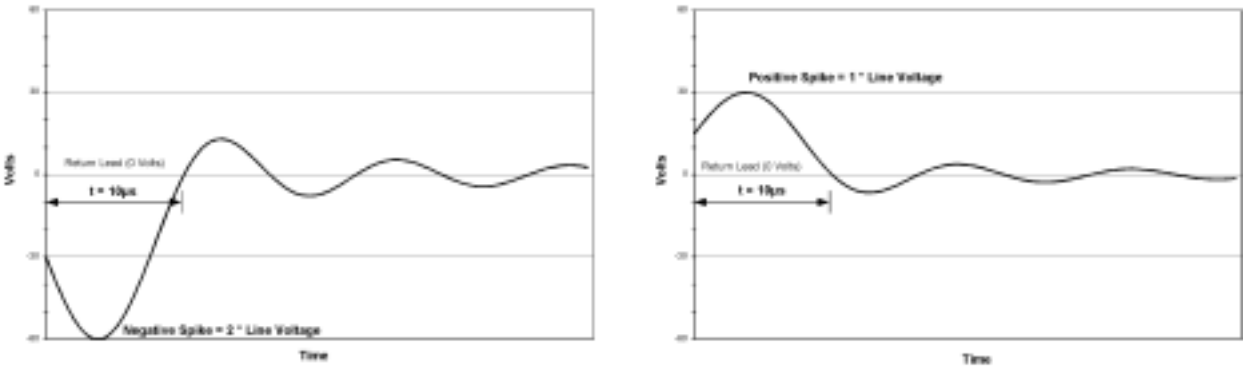

FIGURE 3-4B: MODIFIED CS06 WAVEFORMS FOR RETURN LEAD

3.3.2.7 Power Leads – Electrical Power Surges. Components shall comply with the susceptibility requirements of MIL-STD-1541 as specified in the following sections. The components shall withstand positive and negative input voltage surges which are sustained for at least 10 and 200 milliseconds, respectively. This requirement applies to the input power leads only. Any component that provides power to other subsystems shall meet the power quality requirements of section 3.3.5 on the output power leads. The test method for this requirement shall be established by the contractor.

3.3.2.7.1 General Surge Response. Components shall remain undamaged when subjected to step changes of the input voltage from 0% to 175% (not to exceed 50 Volts) and from 120% to 0% of the nominal load voltage. With step changes from 0% to 100% of the nominal load voltage, the instantaneous inrush current shall not exceed 2 times the average steady-state input current.

3.3.2.7.2 Surge Response for Essential Equipment. Essential components shall satisfy their performance requirements when subjected to input voltage step changes from 100% to 65% and from 100% to 130% of the nominal load voltage.

3.3.2.8 Signal and Control Circuits. Signal and control circuits shall conform to the emission and susceptibility limits in the project peculiar Prime Item Development Specification (PIDS). The test method for these requirements shall be established by the contractor.

3.3.3 Radiated Emissions Requirements. As specified in Table 3-2, electronic equipment shall be designed to limit the radiated emissions as specified in the following subparagraph.

3.3.3.1 Electric Field – 14 kHz to 18 GHz, Narrowband (RE02). Components shall comply with the modified RE02 narrowband emission requirement of MIL-STD-461C, Part 3. The modified narrowband limit is shown in Figure 3-5. The two notches for the RF uplinks of the spacecraft are: S-Band Uplink (2015 – 2130 MHz), and the C-Band Beacon (5640 – 5740 MHz). The notch for the S-Band Uplink shall apply to all equipment. The C-Band Beacon is part of the launch vehicle RF system. This notch, from 5640 to 5740 MHz, shall not apply to equipment that is completely powered off during vehicle integration testing, launch pad checkout, and launch. Above 30 MHz, the requirements shall be met for both vertically and horizontally polarized fields. Measurements shall be conducted in accordance with MIL-STD-462.

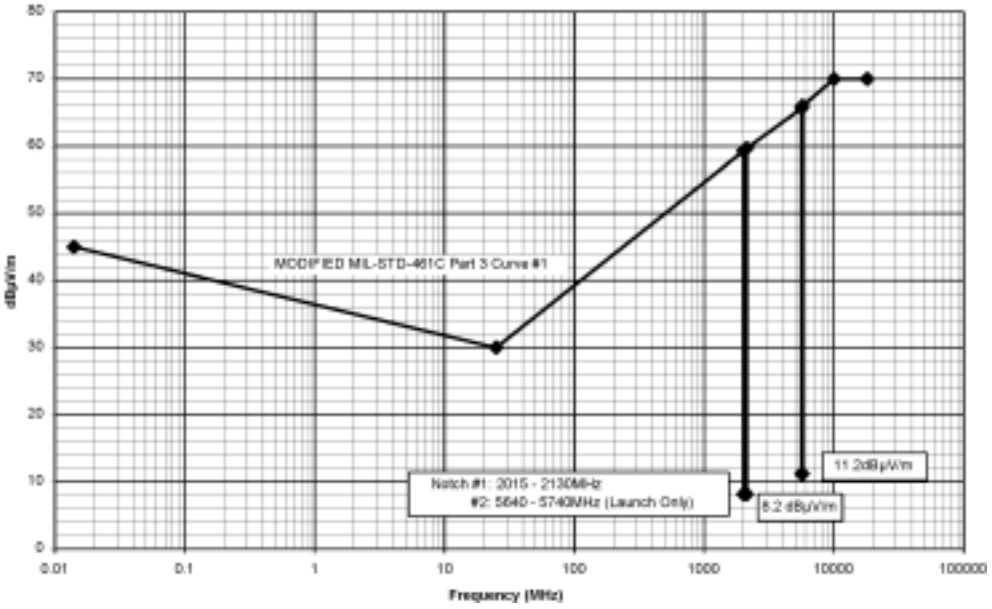

FIGURE 3-5: MODIFIED RE02 NARROWBAND TEST LIMIT

3.3.4 Radiated Susceptibility Requirements. As specified in Table 3-2, electronic equipment shall be designed to operate without malfunction, undesired response or degradation of performance beyond the tolerances given its design specification or source control drawing when subjected to the radiated environment specified in the following subparagraphs.

3.3.4.1 Electric Field – 10 kHz to 18 GHz, (RS03). Components shall comply with the modified RS03 susceptibility requirement of MIL-STD-461C, Part 3. The modified requirement is a modulated electric field level equal to or greater than 20 Volts/meter over the frequency band of 10 kHz to 18 GHz. In addition, testing shall be performed at the spacecraft downlink frequencies at the levels determined from these transmitters, as shown in Table 3-1. Receivers are exempt from RS03 testing within the 66 dB passband frequencies. Above 30 MHz, the requirements shall be met for both vertically and horizontally polarized fields. The test method shall be conducted in accordance with MIL-STD-462.

The modulation characteristic shall be chosen which has the maximum affect on the test sample as shown by analysis. A standard 1 kHz Pulse modulation with 50% duty cycle, shall be used if there is no reason to expect the test sample having sensitivity to a unique modulation type.

TABLE 3-1: MODIFIED RADIATED SUSCEPTIBILITY REQUIREMENTS

Description	Frequency	Level
Modified RS03	10 kHz to 18 GHz	20 V/m
S-Band Transmitter	2200 MHz to 2300 MHz	40 V/m
C-Band Beacon Transmitter	5715 MHz to 5815 MHz	40 V/m

3.3.4.2 Electrostatic Discharge (ESD). Components shall comply with the ESD requirement of MIL-STD-1541A. The equipment shall not be disturbed by arc discharge voltages of 10 kilovolts. The test method shall be conducted in accordance with MIL-STD-1541A.

3.3.5 DC Electrical Power Quality. The source generated power quality at the output of electrical power subsystems shall conform to the emission and susceptibility limits in the project peculiar Prime Item Development Specification (PIDS). The test method for these requirements shall be established by the contractor.

3.4 Mechanical Design Requirements

3.4.1 Electrical Grounding, Bonding, and Isolation. Components shall comply with the grounding, bonding, and isolation requirements of MIL-STD-1541A and MIL-STD-464. Compliance shall be verified by test, analysis, inspections, or a combination thereof, for the particular bonding provision. The electrical bonding of the equipment and structure shall:

a. Prevent the accumulation of static charge on any structure, equipment case, metal part, conductor or semiconductor material

and prevent damage of equipment due to lightning discharge or electrostatic discharge.

b. Provide a low impedance path to the electrical reference point for the conduction of fault currents, instrumentation currents, and electromagnetic currents.
c. Prevent electromagnetic wave or current nonlinear rectification.
d. Reduce to a minimum any shock hazard to personnel
e. Provide a uni-potential mass that can be used as a reference point for electrical measurements

3.4.1.1 Electrical Ground Network. The conductive and semiconductive parts of the vehicle structures and component enclosures shall be electrically connected to form a vehicle ground network (potential reference). These conductive connections may be provided by separate bonding conductors or by the bundle shields for interconnecting cables. A suitable terminal shall be provided for connection to the facility ground during assembly and test activities.

3.4.1.2 Electrical Power Subsystem Referencing and Ground Isolation. The return or neutral conductor of each isolated segment of the power subsystem shall be conductively connected to the ground network so as to control the differential voltage between the circuits and metallic elements of the vehicle. Primary power circuits shall be so connected near the source to maintain a single point ground concept. The connection location for secondary power shall be selected so as to minimize common-mode effects on the signal circuits. The case (chassis) or mounting structure shall not be used as a path to conduct power currents. The main single point ground node shall not be used as an intentional circuit return.

Primary input power and returns shall be isolated from the case (chassis) by a minimum of 1 megohm DC resistance. Primary input power and returns shall be isolated from the secondary power circuitry by a minimum of 1 megohm DC resistance. Primary input power and returns shall be isolated from signal returns by a minimum of 1 megohm DC resistance.

3.4.1.3 Bonding. Bonding between the conductive parts of the vehicle structure, component enclosures, and cable shields shall conform to the requirements for Class R of MIL-B—5087 (DC resistance of 2.5 milliohms). Conductive films on or imbedded in dielectric materials (such as thermal blankets) shall be bonded to the ground network with a resistance equal to or less than 10 ohms. Bonding resistance between the conductive and semiconductive items of the vehicle system shall be less than 1 ohm. Other applications of bonds shall conform to MIL-STD-464.

The surface finish for electrical bonding shall be bare metal or a qualified conductive finish such as Iridite 14 or Alodine 1000. Nonconductive coatings such as anodized aluminum shall not be used. If abrasives or scrapers are used to remove any protective finish, they shall be the kind that produces a clean,

smooth surface without removing excessive materials under the finish. Abrasive that would cause corrosion if imbedded in the metal shall not be used.

3.4.2 Equipment Enclosures. The equipment enclosures shall be electrically conductive and shall be designed to minimize electromagnetic propagation and pickup from external sources. The enclosure shall be designed to provide adequate shielding effectiveness to reduce the interference sources within the enclosure to levels below the radiated emissions requirements. Provisions for installation shall be such that there will be a continuous, low impedance path from the equipment enclosure to the basic structure of the spacecraft to permit (Class R) bonding of the equipment. Mechanical discontinuities in the enclosure, such as covers, inspection plates and joints, shall be kept to a minimum. A low impedance path shall be provided across the interface of each discontinuity so as not to degrade the electromagnetic shielding effectiveness of the enclosure. Covers shall be secured by methods that prevent conductive metal particles generated from screw threads or EMI gaskets from becoming mobile within the enclosure. All joints shall conform to the requirements for Class R bonds.

3.4.3 Interconnecting Cables. Wiring and cabling carrying electrical signals will couple that energy onto other wires and cables. Cable separation and shielding treatments can be used to reduce the coupling effects. Design analysis and correction of problems cannot be implemented without identification of wire and cable bundles. No verification will be required, however this section is provided to assist the designer to meet the radiated emission and susceptibility requirements.

3.4.3.1 Cable Categories. External interconnecting cables are classified, categorized, and identified by the following characteristics: frequency or rise/fall time, impedance, voltage, sensitivity, and signal type. The appropriate wiring treatment shall be assigned to each circuit as determined by their classification. The wire type, twisting, shielding, and shield ground requirements shall be reflected on all schematics, wiring diagram and Interface Control Documents (ICD). Circuits of different categories shall be physically separated to provide electromagnetic coupling isolation. Circuits of the same category may be bundled and routed together. Circuits of the same category that provide redundancy of the circuit shall be routed separately.

3.4.3.2 Shield Termination. All cable connectors shall have backshells suitable for terminating all shields. The preferred method is to connect the shield peripherally (360-degree) to the backshell of the connector. Where grounding provisions are required for multiple shield terminations within a backshell, the shields shall be broken out such that no more than 2 inches of wiring is exposed, and the wiring must be contained within the connector metal backshell. Shields of different categories shall be terminated separately. Shields shall not pass through connectors into the case (chassis).

Shielded cables shall have their shields grounded at each end of the cable and at multiple intermediate points as practical. Certain signal types, such as low level analog signals, may require grounding at one end only.

TABLE 3-2: EMC TEST MATRIX

EQUIPMENT		FAME Instrument	ACS	OCU	CT&DH (FSC)	RF Subsystem	EPS	System Level (Vehicle)
TEST	**Ref.**							
Lightning	3.2.2	N	N	N	N	N	N	A
CE01	3.3.1.1	Y	Y	Y	Y	Y	Y	N
CE03	3.3.1.2	Y	Y	Y	Y	Y	Y	N
CE06	3.3.1.3	N	N	N	N	Y_L	N	N
CS01	3.3.2.1	Y	Y	Y	Y	Y	Y	N
CS02	3.3.2.2	Y	Y	Y	Y	Y	Y	N
CS03	3.3.2.3	N	N	N	N	Y_L	N	N
CS04	3.3.2.4	N	N	N	N	Y_L	N	N
CS05	3.3.2.5	N	N	N	N	Y_L	N	N
CS06	3.3.2.6	Y	Y	Y	Y	Y	Y	N
Electrical Power Surge	3.3.2.7	Y	Y	Y	Y	Y	Y	N
Signal/Control Circuits	3.3.2.8	Y	Y	Y	Y	Y	Y	N
RE02	3.3.3.1	Y	Y	Y	Y	Y	Y	Y
RS03	3.3.4.1	Y	Y	Y	Y	Y	Y	Y
ESD	3.3.4.2	Y	Y	Y	Y	Y	Y	Y
DC Power Quality	3.3.5	N	N	N	N	N	Y	Y*
Grounding, Bonding, Isolation	3.4.1, and 3.4.2	T/A/I	T/A/I	T/A/I	T/A/I	T/A/I	T/A/I	T/A/I

Notes: Y = Required
Y_L = Limited Applicability
Y* = Required, Self Compatibility Test Only
N = Not Required
A = Verify by Analysis
T/A/I = Test, Analysis, Inspection, respectively

4 TEST REQUIREMENTS

4.1 Test Objective. All equipments, subsystems, and spacecraft are required to meet the limits as specified herein in accordance with Table 3-2. The objective of the EMC test program is to verify the electromagnetic compatibility of the subsystems and of spacecraft.

4.2 Test Requirements. Test requirements are shown in Table 3-2. All equipment shall be tested with cables of flight like configuration. Test failure due to leakage or susceptibility at the cables is a failure of the equipment. It is incumbent on the designers to assure that the cable design supports the EMC requirement of the particular equipment.

4.2.1 General Requirements. All equipments having active electric/electronic circuitry are to be EMC tested at least once for each representative type of equipment prior to installation for vehicle level testing. The exact configuration of equipments shall be delineated in a test plan. Should single configurations be tested to represent other configurations, a rationale shall be provided to support the applicability of testing to the other configuration. This rationale shall be agreed to by the cognizant system/sub-system engineer and the EMC engineer.

4.2.2 Prerequisites. Verification shall be made that the equipment has successfully completed the Performance Tests specified in the appropriate PD, ICD, or Contract End Item (CEI) specification. An interactive verification functional test of the equipment shall be performed prior to EMC testing to ensure proper operation of the equipment in the test configuration. Documentation of bonding compliance and method shall be presented prior to beginning of EMC testing.

4.2.3 Cable and Ground Plane Requirements

4.2.3.1 Component Level Testing. Each EMC test shall simulated the actual flight configuration as closely as possible. Cabling external to test units shall simulate the flight configuration for average length, wire size, shielding, shield termination and twisting. When cable lengths are not specified for the installation, cables shall be sufficiently long to satisfy the conditions specified below. At least 2 meters (except for cables which are shorter in actual installation) of each interconnecting cable shall be run parallel to the front boundary of the setup. Remaining cable lengths shall be routed to the back of the setup in a zigzagged arrangement. For bench top setups using ground planes, the cable closest to the front boundary shall be placed 10 centimeters from the front edge of the ground plane. All cables shall be supported 5 centimeters above the ground plane.

Two meters of input power leads, including return, shall be routed parallel to the front edge of the setup in the same manner as the interconnecting leads (Note: 1 meter cable length is required for CE01 and CE03). The power leads shall be connected to the 10 microfarad capacitors. Power leads that are part of an interconnecting cable shall be separated out. If power leads are twisted

in actual system installation, they shall be twisted as close to the 10 microfarad capacitors as practical.

4.2.3.2 System Level Testing. The configuration during the system level EMC test is the actual flight configuration. All cabling will be flight configuration. Any external cabling to the spacecraft during system level testing, such as umbilical cables, shall be kept to a minimum. These cables are not considered part of the Equipment Under Test and shall be constructed such that they do not introduce any electromagnetic radiation to the EMI test ambient. No input powerline 10 microfarad capacitors are required. The floor of the EMI chamber will act as the ground plane for the spacecraft.

4.2.4 Bonding. Bonding (including bonding of the structure), grounding, isolation, and shielding shall be inspected, or tested (when measurements criteria exists) during assembly at the contractors facility to verify these requirements. The equipment under test shall be bonded to the ground plane by the same or similar method that will be used for component installation in the spacecraft.

4.3 EMC Test Facilities and Environment. EMC tests shall be performed at facilities approved by Naval Research Laboratory through test plan approval. It is recommended that shielded enclosures have RF absorber/anechoic materials for radiated emissions and susceptibility testing.

All tests shall be performed at room ambient pressure and temperature. Controlled relative humidity during EMC testing is not required. The electromagnetic environment shall be a minimum of 6 dB below the required measurement level. Test personnel and equipment in the area of RF measurements shall be kept to a minimum.

4.4 EMC Test Plan. An EMC Test Plan shall be developed for the spacecraft system level testing, as well as for each equipment/component within the spacecraft. EMC Test Plans shall address the required tests as specified by Table 3-2: EMC Test Matrix. EMC Test Plans shall, at a minimum, address the following topics for each Equipment Under Test (EUT):

- Specific EMI Tests to be performed
- Applicable Tests limits for each EMI Test
- EMI Test facility requirements
- Support equipment and test setups to be used to conduct each test
- EUT bonding considerations and requirements
- Construction and arrangement of interconnecting cables
- Operation of the EUT during emissions and susceptibility testing
- EMI test data requirements
- EMI test equipment calibration requirements
- EMI measurement techniques and procedures
- Scanning speeds, measurement bandwidths
- EMI test Pass/Fail Criteria
- Submission of an EMI Test Report following completion of testing

4.5 Conducted Emissions

4.5.1 Power Leads – 30 Hz to 15 kHz, (CE01)

4.5.1.1 Configuration. Measurements shall be conducted in accordance with section 4.2 and MIL-STD-462.

4.5.1.2 EUT and Test System Operation. The component shall tested when operated in a steady state mode(s) determined to produce the worst case emissions.

4.5.1.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents.

4.5.2 Power Leads – 15 kHz to 50 MHz, Narrowband (CE03)

4.5.2.1 Configuration. Measurements shall be conducted in accordance with section 4.2 and MIL-STD-462.

4.5.2.2 EUT and Test System Operation. The component shall tested when operated in a steady state mode(s) determined to produce the worst case emissions.

4.5.2.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents.

4.5.3 Antenna Terminals – 10 kHz to 100 GHz, Narrowband (CE06)

4.5.3.1 Configuration. Measurements shall be conducted in accordance with section 4.2 and MIL-STD-462.

4.5.3.2 EUT and Test System Operation. The component shall tested when operated in a steady state mode(s) determined to produce the worst case emissions.

4.5.3.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents.

4.6 Conducted Susceptibility

4.6.1 Power Leads – 30 Hz to 50 kHz, (CS01)

4.6.1.1 Configuration. Measurements shall be conducted in accordance with section 4.2 and MIL-STD-462.

4.6.1.2 EUT and Test System Operation. The component shall tested when operated in a steady state mode(s) determined to be the most susceptible to CS01 energy.

4.6.1.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents.

4.6.2 Power Leads –50 kHz to 400 MHz, (CS02)

4.6.2.1 Configuration. Measurements shall be conducted in accordance with section 4.2 and MIL-STD-462, and having the modulation characteristics as defined in section 3.3.2.2.

4.6.2.2 EUT and Test System Operation. The component shall tested when operated in a steady state mode(s) determined to be the most susceptible to CS02 energy.

4.6.2.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents.

4.6.3 Antenna Terminals –Intermodulation, 15 kHz to 10 GHz (CS03)

4.6.3.1 Configuration. Measurements shall be conducted in accordance with section 4.2 and MIL-STD-462.

4.6.3.2 EUT and Test System Operation. The component shall tested when operated in a steady state mode(s) determined to be the most susceptible to CS03 energy.

4.6.3.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents.

4.6.4 Antenna Terminals – Rejection of Undesired Signals, 30 Hz to 20 GHz (CS04)

4.6.4.1 Configuration. Measurements shall be conducted in accordance with section 4.2 and MIL-STD-462.

4.6.4.2 EUT and Test System Operation. The component shall tested when operated in a steady state mode(s) determined to be the most susceptible to CS04 energy.

4.6.4.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents.

4.6.5 Antenna Terminals – Cross Modulation, 30 Hz to 20 GHz (CS05)

4.6.5.1 Configuration. Measurements shall be conducted in accordance with section 4.2 and MIL-STD-462.

4.6.5.2 EUT and Test System Operation. The component shall tested when operated in a steady state mode(s) determined to be the most susceptible to CS05 energy.

4.6.5.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents.

4.6.6 Power Leads – Spike, (CS06)

4.6.6.1 Configuration. Measurements shall be conducted in accordance with section 4.2 and MIL-STD-462.

4.6.6.2 EUT and Test System Operation. The component shall tested when operated in a steady state mode(s) determined to be the most susceptible to CS06 transients.

4.6.6.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents.

4.6.7 Power Leads – Electrical Power Surges

4.6.7.1 Configuration. Measurements shall be conducted in accordance with the test method established by the contractor to meet the requirements of section 3.3.2.7.

4.6.7.2 EUT and Test System Operation. The component shall tested when operated in all modes determined by the contractor to verify the requirements of section 3.3.2.7.

4.6.7.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents. If this data is published in another document as required by the contractor, it may be included by reference with the exact location of the documentation for purposes of review.

4.6.8 Signal and Control Circuits

4.6.8.1 Configuration. Measurements shall be conducted in accordance with the test method established by the contractor to meet the requirements of section 3.3.2.8.

4.6.8.2 EUT and Test System Operation. The component shall tested when operated in all modes determined by the contractor to verify the requirements of section 3.3.2.8.

4.6.8.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents. If this data is published in another document as required by the contractor, it may be included by reference with the exact location of the documentation for purposes of review.

4.7 Radiated Emissions

4.7.1 Electric Field – 14 kHz to 18 GHz, Narrowband (RE02)

4.7.1.1 Configuration. Measurements shall be conducted in accordance with section 4.2 and MIL-STD-462.

4.7.1.2 EUT and Test System Operation. The component shall tested when operated in a steady state mode(s) determined to produce the worst case emissions.

4.7.1.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents.

4.8 Radiated Susceptibility

4.8.1 Electric Field – 10 kHz to 18 GHz, (RS03)

4.8.1.1 Configuration. Measurements shall be conducted in accordance with section 4.2 and MIL-STD-462, and having the modulation characteristics as defined in section 3.3.4.1.

4.8.1.2 EUT and Test System Operation. The component shall tested when operated in a steady state mode(s) determined to be the most susceptible to RS03 energy.

4.8.1.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents.

4.8.2 Electrostatic Discharge (ESD)

4.8.2.1 Configuration. Measurements shall be conducted in accordance with section 4.2 and MIL-STD-1541. A suggested arc discharge source is shown in MIL-STD-1541. Any other equivalent device may be used provided it meets the minimum voltage and minimum dissipated energy, and shall be fully described in the EMI test plan. The ESD arc discharge specified in section 3.3.4.2, at a rate of 1 per second for a period of 30 seconds, shall be established at a distance of 30 centimeters. The test shall be repeated by one of the following methods:

a. Using a direct discharge from one test electrode of the arc source to each top corner of the test sample for equipment exposed to the direct space environment, or
b. Impressing the series current from the arc discharge source through the mounting surfaces of the test sample for equipment installed within the shielded space vehicle.

4.8.2.2 EUT and Test System Operation. The component shall tested when operated in a steady state mode(s) determined to be the most susceptible to ESD.

4.8.2.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents.

4.9 Other Tests

4.9.1 DC Electrical Power Quality

4.9.1.1 Configuration. Measurements shall be conducted in accordance with the test method established by the contractor to meet the requirements of section 3.3.5.

4.9.1.2 EUT and Test System Operation. The component shall tested when operated in all modes determined by the contractor to verify the requirements of section 3.3.5.

4.9.1.3 Data Requirement. Data shall be presented in accordance with section 4.11 EMC Test Report Contents. If this data is published in another document as required by the contractor, it may be included by reference with the exact location of the documentation for purposes of review.

4.10 Post Tests. EMC test equipment shall be left in place until completion of a quick-look data review to determine that all necessary data and quality control verifications have been obtained.

After successfully completing all EMI/EMC test, conduct a functional performance test to ensure proper operation of the equipment under test prior to breaking down the test configuration. Record the results in the EMI test log.

4.11 EMC Test Report Contents. The test report shall be in a format consistent with the contractor documentation. The EMC Test Report shall contain the factual data in accordance with the requirement of this document. If technical support data required for the EMI Test Report is published in another document as required by the contractor, it may be included by reference with the exact location of the documentation for purposes of review. The report shall include but is not limited to the following. If these data are contained in the approved test procedure, it shall be referenced as such in the test report. A separate appendix shall be used for each test required. Each appendix shall include the applicable test procedure, data sheets, graph, illustrations, photographs, and printouts for that test. Copies of the log book entries, equipment list/calibration, and troubleshooting data shall each be included as separate sections in the appendix.

a. Nomenclature of EMI measurement equipment
b. Serial numbers of EMI measurement equipment
c. Date of next calibration of EMI measurement equipment
d. Measured line voltage of the EUT
e. Ground plane DC bonding resistance
f. Descriptions of test procedures used
g. Any deviation from the test procedure
h. Emissions versus limit plots over the applicable frequency range

i. Susceptibility thresholds, frequency ranges, symptoms of susceptibility, if applicable
j. Details of any Troubleshooting Investigations
k. Photographs of each test setup
l. Description and size of shielded enclosure
m. Description of ground plane used
n. Characteristics of current probes, antenna and other transducers used during the test