SECTION 2.5

EMC

2.5 ELECTROMAGNETIC COMPATIBILITY (EMC) REQUIREMENTS

The general requirements for electromagnetic compatibility are as follows:

a. The payload (spacecraft) and its elements shall not generate electromagnetic interference that could adversely affect its own subsystems and components, other payloads, or the safety and operation of the launch vehicle (STS or ELV) and launch site.

b. The payload (spacecraft) and its subsystems and components shall not be susceptible to emissions that could adversely affect their safety and performance. This applies whether the emissions are self-generated or emanate from other sources, or whether they are intentional or unintentional.

2.5.1 Requirements Summary

The EMC test requirements herein when performed as a set are intended to provide an adequate measure of hardware quality and workmanship. The tests are performed to fixed levels which are intended to envelope those that may be expected during a typical mission and allow for some degradation of the hardware during the mission. The levels should be tailored to meet mission specific requirements, such as, the enveloping of launch vehicle and launch site environments, or the inclusion of very sensitive detectors or instruments in the payload.

Thus tailored, the requirements envelope the environments usually encountered during integration and ground testing. However, because some payloads may have sensors and devices that are particularly sensitive to the low-level EMI ground environment, special work-around procedures may have to be developed to meet individual payload needs.

2.5.1.1 The Range of Requirements - Table 2.5-1 is a matrix of EMC tests that apply to a wide range of hardware intended for launch either by the STS or an expendable launch vehicle (ELV). Tests are prescribed at the component, subsystem, and payload levels of assembly. Not all tests apply to all levels of assembly or to all types of payloads. The project must select the requirements that fit the characteristics of the mission and hardware, e.g. a transmitter would require a different group of EMC tests than a receiver. Symbols in the hardware levels of assembly columns will assist in the selection of an appropriate EMC test program.

Once the program is selected, all flight hardware shall be tested. The EMC test program is meant to uncover workmanship defects and unit-to-unit variations in electromagnetic characteristics, as well as design flaws. The qualification and flight acceptance EMC programs are the same. Performance of both will provide a margin of hardware reliability.

A specific group of EMC requirements are imposed by Johnson Space Center (JSC) on STS payloads that operate on orbiter power or that operate on their own power within or near the orbiter. Those requirements, which are defined in the ICD 2-19001 document (1.7.), are partially included here for the convenience of the user; however the user is responsible for obtaining those requirements from ICD 2-19001, which is the controlling document.

Table 2.5-1
EMC Requirements per Level of Assembly

Type	Test Spacecraft	Paragraph Number	STS	ELV	Component	Subsystem/ Instrument	Payload*
CE	Dc power leads	2.5.2.1.a&c	X	X	Sb,Rb,R	Sb,Rb,R	Sb
CE	Ac power leads	2.5.2.1.a&c	X		Sb,Rb	Sb,Rb	Sb
CE	Power Leads	2.5.2.1.b	X	X	Rb,R	Rb,R	-
CE	Transients on orbiter dc power lines	2.5.2.1.d	X		Sb	Sb	Sb
CE	Spikes on orbiter ac power lines	2.5.2.1.e	X		Sb	Sb	Sb
CE	Antenna terminals	2.5.2.1.f	X	X	R	-	-
RE	Magnetic field (STS payloads)	2.5.2.2.a	X		-	-	Sd
RE	Ac magnetic field	2.5.2.2.b	X	X	Rb,R	Rb,R	Rb,R
RE	E-fields	2.5.2.2.c&d	X	X	Rb,R	Rb,R	Sd,Rb,R
RE	Payload transmitters	2.5.2.2.e	X	X	-	-	Sd,**
RE	Spurious (transmitter antenna)	2.5.2.2.f	X	X	-	Rb,R	-
CS	Power line	2.5.3.1.a	X	X	Rb,R	Rb,R	Rb
CS	Intermodulation products	2.5.3.1.b	X	X	Rb,R	-	-
CS	Signal rejection	2.5.3.1.c	X	X	Rb,R	-	-
CS	Cross modulation	2.5.3.1.d	X	X	Rb,R	-	-
CS	Power line transients	2.5.3.1.e	X	X	Rb,R	Rb,R	Rb
RS	E-field (general compatibility)	2.5.3.2.a	X	X	Rb,R	Rb,R	Rb,R
RS	Compatibility with orbiter transmitters	2.5.3.2.b	X		-	-	Rb
RS	Orbiter unintentional E-field	2.5.3.2.c	X		-	-	Rb
RS	Magnetic-field susceptibility	2.5.3.2.d	X	X	Rb,R	Rb,R	Rb,R
	Magnetic properties	2.5.4	X	X	R	R	R

CE - Conducted Emission
CS - Conducted Susceptibility
R - Test to ensure reliable operation of payload, and to help ensure compatibility with the launch vehicle and launch site
Rb - Test to ensure reliable operation of orbiter attached payloads
RE - Radiated Emission
RS - Radiated Susceptibility
Sb - Items interfacing with orbiter power in payload bay or in the cabin; required by ICD 2-19001
Sd - Items operating on or near orbiter; required by ICD 2-19001
* - Payload, Mission, or highest level of assembly
** - Must meet any unique requirements of launch vehicle and launch site for transmitters that are on during launch

A wide range of EMC test requirements are provided to cover a variety of free flyer and shuttle-attached payload operating modes. For example, some free flyers will be operated with the orbiter during prerelease and checkout procedures and must be tested to ensure EMC with the orbiter. The more stringent EMC environment occurs after the free flyer moves away from the orbiter when it becomes more susceptible to the operations of its own subsystems and sensitive instruments. Because some free flyers will not be operated or checked out before release from the orbiter, they will not have to meet the JSC EMC requirements and the tests need only ensure self-compatibility and survival after exposure to the high-level emissions from the orbiter's transmitters. Requirements are also provided for attached payloads that may be subjected throughout the mission to EMI from the orbiter and from other attached payloads.

The EMC tests are intended to verify that:

(1) The hardware will operate properly if subjected to conducted or radiated emissions from other sources that could occur during launch or in orbit (susceptibility tests).

(2) The hardware does not generate either conducted or radiated signals that could hinder the operation of other systems (emissions tests).

2.5.1.2 Testing at Lower Levels of Assembly - It is recommended that testing be performed at the component, subsystem, and payload levels of assembly. Testing at lower levels of assembly has many advantages: it uncovers problems early in the program when they are less costly to correct and less disruptive to the program schedule; it uncovers problems that cannot be detected or traced at higher levels of assembly; it characterizes box-to-box EMI performance, providing a baseline that can be used to alert the project to potential problems at higher levels of assembly; and it aids in troubleshooting.

2.5.1.3 Basis of the Tests - A description of the individual EMC tests listed in Table 2.5-1, including their requirement limits and test procedures, are provided in paragraphs 2.5.2 through 2.5.4.7 Most of the tests are based on the requirements of MIL-STD-461C and 462, as amended by Notice 1, and MIL-STD-463A (1.7.8). Note: all references in this document to MIL-STD-462 assume reference to Notice 1.

The tests and their limits are to be considered minimum requirements; however, they may be revised as appropriate for a particular payload or mission if GSFC project approval is obtained.

The MIL-STD limits have been modified as appropriate to meet the EMC requirements for STS payloads as defined by ICD 2-19001 and also to meet the STS reliability requirements specified herein.

For ELV launch, additional EMC requirements may be placed on the spacecraft by the launch vehicle or launch site or in consideration of the mission launch radiation environment. Those requirements shall be established during coordination between the spacecraft project and the launch vehicle program office.

More stringent requirements may be needed for payloads with very sensitive electric field or magnetic field measurement systems. The tests and their limits shall be documented in the verification plan, specification, and procedures.

2.5.l.4 Safety and Controls - During prelaunch and prerelease checkout, sensitive detectors and hardware may require special procedures to protect them from the damage of high-level radiated emissions. If such procedures are needed, they should also be applied during EMC testing. Operational control procedures should also be instituted for EMC testing during prerelease checkout to minimize interference with the orbiter and other payloads as appropriate.

Except for bridgewires, live electroexplosive devices (EEDs) used to initiate such payload functions as boom and antenna deployment shall be replaced by inert EEDs. When that is not possible, special safety precautions shall be taken to ensure the safety of the payload and its operating personnel.

Spurious signals that lie above specified testing limits shall be eliminated. Spurious signals that are below specified limits shall be analyzed to determine if a subsequent change in frequency or amplitude is possible; if it is possible, the spurious signals should be eliminated to protect payload and instruments from the possibility of interference. Retest shall be performed to verify that intended solutions are effective.

2.5.2 Emission Requirements

The following paragraphs on emission tests shall be used to implement the emission requirements of Table 2.5-1.

2.5.2.l Conducted Emission Limits - Conducted emission limits and requirements on power leads, as well as on antenna terminals, shall be applied to payload hardware as defined below. The requirements do not apply to secondary power leads to subunits within the level of assembly under test unless they are specifically included in a hardware specification.

a. Narrowband conducted emissions on power, and power-return leads (both dc and ac for STS) shall be limited to the levels specified in Figure 2.5-1.

   Testing shall be in accordance with MIL-STD-461C and 462, test numbers CE01 and CE03, as applicable, with limits as shown in Figure 2.5-1.

b. A Conducted Emissions (CE) test to control Common Mode Noise (CMN) shall be required at the subsystem/component level. This frequency domain current test shall be performed on all non-passive components which receive or generate spacecraft primary power.

   The purpose of the test is to limit CMN emissions that flow through the spacecraft structure and flight harness which result in the generation of undesirable electrical currents, and electro-magnetic fields at the integrated system level.

   Specific CMN requirements must be determined carefully from spacecraft hardware designs or mission scenario. Spacecraft which have analog or low level signal interfaces, low level detectors, and instruments that measure electromagnetic fields may be particularly sensitive to CMN. If mission requirements do not place stricter control on CMN, the limits of Figure 2.5-1a are suggested.

   The CMN test procedure is the same as narrowband CE01/03 except that the current probe is placed around both the plus and return primary wires together.

c. Broadband conducted emissions on power, and power-return leads (both dc and ac for STS) shall be limited to the levels specified in Figure 2.5-2. Testing shall be in accordance with MIL-STD-461C and 462, test number CE03, with limits as shown in Figure 2.5-2.

d. Transients produced by orbiter payloads on dc powerlines interconnecting to the orbiter, caused by switching or other operations, shall not exceed the limits defined in Figure 2.5-3 when fed from a source impedance close to but not less than the values defined in Figure 2.5-4 (The use of a battery cart is preferable to regulated dc power supplies). Each non-overlapping transient is considered independent of prior or post transients. Rise and fall times shall be greater than 1.0 microsecond. The steady state ripple voltage in the time domain (starting approximately one second after the transient) shall not exceed 28.45 volts nor go below 27.55 volts (28 ± 0.45 volts). A network for simulating the orbiter power source impedance is shown in Figure 2.5-5.

e. Transient spikes produced by orbiter payloads on ac powerlines from the orbiter to the payloads shall not exceed the limits defined in Figure 2.5-6 when they are fed from a source impedance not greater than 10 ohms. Peak spikes below 10 microseconds duration shall be limited to 60 volts superimposed on the 400 Hz sine wave. Rise and fall times shall be greater than 1.0 microsecond.

f. Conducted emissions on the antenna terminals of payload receivers, and transmitters in key-up modes shall not exceed 34 dB μV for narrowband emissions and 40 dB μV/MHz for broadband emissions.

Harmonics (greater than the third) and all other spurious emissions from transmitters in the key-down mode shall have peak powers 80 dB down from the power at the fundamental. Power at the second and third harmonics shall be suppressed by {50 + 10 Log(Peak Power in watts at the fundamental) dB}, or 80 dB whichever requires less suppression.

Testing shall be in accordance with MIL-STD-462, test number CE06. The test is conducted on receivers and transmitters before they are integrated with their antenna systems. Refer to MIL-STD-461C and MIL-STD-462 for additional details concerning this requirement.

2.5.2.2 Radiated Emission Limits - Radiated emission limits and requirements shall be applied to payload hardware as defined in sections 2.5.2.2.a through 2.5.2.2.f below. Additional tests or test conditions should be considered by the project if it appears that this may be necessary, for example, if the spacecraft receives at frequencies other than S-band (1.77 - 2.3 GHz).

a. Radiated ac magnetic field levels produced by orbiter payloads at distances of 1 meter from the payload shall not exceed 130 dB above 1 pico-tesla over the frequency range of 20 Hz to 2 kHz, then falling 40 dB per decade to 50 kHz as shown in Figure 2.5-8. Testing shall be in accordance with MIL-STD-462 test number RE04.

The dc magnetic field generated by orbiter payloads shall not exceed 170 dB pT at the payload envelope. This limit applies to electromagnetic and permanent magnetic devices.

b. Radiated ac magnetic field levels produced by STS free flyer (or ELV-launched) payloads and their subsystems shall be limited to 60 dB pT from 20 Hz to 50 kHz. This requirement may be deleted with project approval if subsystems or instruments are not inherently susceptible to ac magnetic fields; however, the requirements in paragraph a, above, still apply for STS payloads.

If the free flyer payloads or their instruments contain sensitive magnetic field detectors or devices with high sensitivities to magnetic fields, more stringent limits on magnetic field emission may be required. Testing shall be in accordance with MIL-STD-462, test number RE04, with limits as defined above.

c. Unintentional radiated narrowband electric field levels produced by payloads shall not exceed the levels specified in Figure 2.5-9. Testing shall be in accordance with MIL-STD 461C and 462, test number RE02, with the test frequency range and limits revised as defined in Figure 2.5-9. In addition, STS payloads shall not exceed the limits of Figure 2.5-9a.

d. Unintentional radiated broadband electric field levels produced by payloads shall not exceed the levels specified in Figure 2.5-10. Testing shall be in accordance with MIL-STD-461C and 462, test number RE02, with the test frequency range and the limits revised as defined in Figure 2.5-10.

e. Allowable levels of radiation from payload transmitter antenna systems depend on the launch vehicle and launch site.

For an ELV launch, any unique requirements of the launch vehicle and launch site for transmitters that will be on during launch must be met.

For STS applications, the allowable levels of radiation from orbiter payload transmitter antenna systems are shown in Figure 2.5-11. The radiation limits apply at surfaces defined as follows:

(1) The allowable payload-to-payload (cargo element-to-cargo element) limit is defined as the radiation impinging upon imaginary planes (orbiter y, z) located at the smallest and largest X_o allocated to the radiating payload, or upon the imaginary planes (orbiter x, z) located at the smallest and largest ± Y_o allocated to the radiating payload. The limits have been established to permit flexibility in manifesting payloads. However, the limits can be waived by JSC for individual payloads (cargo elements) with selective mixing of payloads in flight manifesting.

(2) The allowable payload-to-orbiter limit is defined as the radiation impinging upon an imaginary surface 7.6 cm (3 inches) beyond the payload allowable envelope for envelope Z_o of 410 or less. This does not limit radiation at higher levels with a directional antenna through open cargo bay doors (Z_o 410).

(3) The allowable payload-to-remote manipulator system (RMS) limit for payloads attached to the RMS is defined as the radiation impinging upon an imaginary plane containing the RMS wrist roll joint end face, which is the mating interface for the standard end effector to the RMS.

(4) The allowable payload-to-RMS limit for payloads intentionally producing radiated fields while mounted in the cargo bay is defined as the radiation impinging on an imaginary surface 7.6 cm (3 inches) beyond the envelope of the actual surface of the payload in the ± X, ± Y, and +Z direction during RMS operation.

The above is in reference to radiation with the cargo bay doors open. No intentional radiation will be permitted with the doors closed.

Allowable levels of radiation from orbiter cabin payload or experiment transmitter systems are specified in section 10.7.3.2 of ICD 2-19001.

f. Radiated spurious and harmonic emissions from payload transmitter antennas shall have peak powers 80 dB down from the power at the fundamental (for harmonics greater than the third). Power at the second and third harmonics shall be suppressed by {50 + 10 Log(Peak Power in watts at the fundamental) dB}, or 80 dB whichever requires less suppression. These are the same limits as those for conducted spurious and harmonic emissions on antenna terminals in paragraph 2.5.2.1.f. When the MIL-STD-462 test CE06 for conducted emissions on antenna terminals cannot be applied, test RE03 for radiated spurious and harmonic emissions shall be used as an alternative test. Refer to MIL-STD-461C and 462 for details.

2.5.2.3 Acceptance Requirements - The emission requirements of 2.5.2 shall also apply to all previously qualified hardware.

2.5.3 Susceptibility Requirements

The following paragraphs on susceptibility tests shall be used to implement the susceptibility requirements of Table 2.5-1. Additional tests or test conditions should be considered by the project if the operational scenario, the launch site environment, or the design suggests such additions may be necessary. The worst-case levels of shuttle-produced emissions in the payload bay, as defined in ICD 2-19001, have been incorporated into the following requirements where applicable.

2.5.3.1 Conducted Susceptibility Requirements - The following conducted susceptibility design and test requirements shall be applied to power leads (both dc and ac for STS) and to antenna terminals of payload hardware:

a. Conducted Susceptibility CS01-CS02 (Powerlines) - The tests should be conducted over the frequency range of 30 Hz to 400 MHz in accordance with the limit requirements and test procedures of MIL-STD-461C and 462. If degraded performance is observed, the signal level should be decreased to determine the threshold of interference. Above 50 KHz, modulation of the applied susceptibility signal is required if appropriate. If the appropriate modulation has not been established by component design or mission application, the following guidelines for selecting an appropriate modulation will apply:

(1) AM Receivers - Modulate 50 percent with 1000-Hz tone.

(2) FM Receivers - While monitoring signal-to-noise ratio, modulate with 1000-Hz signal using 10-kHz deviation. When testing for receiver quieting, use no modulation.

(3) SSB Receivers - Use no modulation.

(4) Components With Video Channels Other Than Receivers - Modulate 90 to 100 percent with pulse of duration 2/BW and repetition rate equal to BW/1000 where BW is the video bandwidth.

(5) Digital Components - Use pulse modulation with pulse duration and repetition rate equal to that used in the component under test.

(6) Nontuned Components - Use 1000-Hz tone for amplitude modulation of 50 percent.

For STS payloads, the conducted susceptibility tests of paragraphs 2.5.3.1.a are performed on applicable hardware in keeping with two operational requirements derived from ICD 2-19001. The first requirement applies to payload hardware that operates on +28 volt power originating from one of the orbiter's dc power buses. The requirement is met with sawtoothed transient oscillations (between 500 and 700 Hz) on the powerlines with a maximum voltage envelope shown in either Figure 2.5-12a or Figure 2.5-12b depending on which orbiter bus is supplying the power. The bus voltage transients (caused by activation of the hydraulic circulation pump connected to the bus) may occur at any time during on-orbit operations, plus activation at touchdown, and are not subjected to preflight scheduling.

The second requirement applies to equipment which operates on orbiter-supplied ac power. The requirement is met with transient spikes on the ac buses as defined in Figure 2.5-13. For payload testing purposes, the impedance into which the spikes are generated is 50 ohms minimum for significant frequency components of the spikes.

b. Conducted Susceptibility CS03 (Two-Signal Intermodulation) - This test, which determines the presence of intermodulation products from two signals, should be conducted on receivers operating in the frequency range of 30 Hz to 18 GHz where this test is appropriate for that type of receiver. The items should perform in accordance with the limit requirements and the test procedures of MIL-STD-461C and 462 except that the operational frequency range of equipment subject to this test should be increased to 18 GHz and the highest frequency used in the test procedure should be increased to 40 GHz.

c. Conducted Susceptibility CS04 (Rejection of Undesired Signals) - Receivers operating in the frequency range from 30 Hz to 18 GHz should be tested for rejection of spurious signals where this test is appropriate for that type of receiver. The items should perform in accordance with the limit requirements and the test procedures of MIL-STD-461C and 462 except that the frequency range should be increased to 40 GHz.

d. Conducted Susceptibility CS05 (Cross Modulation) - Receivers of amplitude-modulated RF signals operating in the frequency range of 30 Hz to 18 GHz should be tested to determine the presence of products of cross modulation where this test is appropriate for that type of receiver. The items should perform in accordance with the limit requirements and test procedures of MIL-STD-461C and 462 except that the operational frequency range of equipment subject to this test should be increased to 18 GHz and the highest frequency used in the test procedure should be increased to 40 GHz.

e. Conducted Susceptibility CS06 (Powerline Transient) - A transient signal should be applied to powerlines in accordance with the procedures of MIL-STD-461C and 462. Because the applied transient signal should equal the powerline voltage, the resulting total voltage is twice the powerline level. The transient should be applied for a duration of 5 minutes at a repetition rate of 60 pps. The test should be applied to the input power leads of all payloads.

Changes in the method of describing powerline transients (line-to-line in lieu of line-to-structure) in JSC ICD-2-19001 reveal that STS payloads could be exposed to powerline transient voltages in excess of these levels. (Refer to paragraphs 7.3.7.2 and 7.3.7.4 of ICD-2-19001.) Payloads should be designed with this in mind, and tested to these ICD levels at the STS interface.

2.5.3.2 Radiated Susceptibility Requirements - The following tests shall be applied to individual payloads and payload subsystems. The tests are based on MIL-STD-461C and 462, as supplemented.

a. Radiated Susceptibility Test RS03 (E-field) - The payload shall be exposed to external electromagnetic signals in accordance with the requirements and test methods of test RS03. Intentional E-field sensors on payloads that operate within the frequency range of the test shall be removed or disabled without otherwise disabling the payload during the test. The test shall demonstrate that spacecraft (exclusive of E-field sensors) can meet their performance objectives while exposed to the specified levels. Modulation of the applied susceptibility signal is required. If the appropriate modulation has not been established by hardware design or mission scenario, then 50% amplitude modulation by a 100 Hz square wave should be considered. When performing additional testing at discrete frequencies of known emitters, the modulation characteristics of the emitter should be simulated as closely as possible.

(1) ELV-launched spacecraft or STS payloads not operated or checked out before release from the orbiter:

o 2 V/m over the frequency range of 14 kHz to 2 GHz.

o 5 V/m over the frequency range of 2 to 12 GHz.

o 10 V/m over the frequency range of 12 to 18 GHz; applicable only to spacecraft with a Ku band telemetry system.

(2) Orbiter attached payloads and free flyers operated or checked out before release from the orbiter:

o 2 V/m over the frequency range of 14 KHz to 2 GHz. (Other payloads are permitted to radiate in excess of these levels after the payload bay doors are opened. Refer to 2.5.2.2.e and Figure 2.5-11. If it is determined that the payload will be exposed to higher levels than 2 V/m, the requirements should be revised to reflect those higher levels at the specific frequencies involved.)

o 20 V/m over the frequency range of 2 to 18 GHz. The 20 V/m level is required since other payloads are permitted to radiate these levels after the payload bay doors are opened; refer to 2.5.2.2.e and Figure 2.5-11. Also, a payload element could be exposed to these levels at S-band if it is within 2 meters of the payload bay forward bulkhead; refer to Figure 2.5-14a.

For both STS and ELV payloads, the EMI test levels (or frequency range) should be increased if it is determined that onboard telemetry systems, another payload, or other signals in space could expose a payload to higher levels than the above test levels. Systems such as ground based radars are known to produce signals in space in excess of 2 V/m at frequencies at least as low as 400 MHz.

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Payloads not operated or checked out before release from the orbiter shall be tested to ensure proper performance after a 6-minute minimum exposure to E-field levels of 20 V/m during which the frequency is uniformly swept from 2 to 18 GHz. This test shall be conducted with the payload powered down.

Free flyers could be exposed to the main beam of the orbiter's Ku-band transmitter after being released from the orbiter, or an attached payload could be exposed after deployment. Refer to paragraph 10.7.2.2 of the ICD 2-19001 for the Ku-band levels. Projects may choose to negotiate operational constraints with JSC to avoid exposure of the payload rather then design and test to those high Ku-band levels. Any agreements with JSC shall be defined in the payload integration plan.

During deployment, after release, or during retrieval, payloads could be exposed to levels greater than 20 V/m from the orbiter's S-band transmitters or the ERPCL S-band transmitter. Refer to paragraph 10.7.2.2 of the ICD-2-19001 and Figures 2.5-14a through 2.5-14e.

The maximum field intensities associated with the transmitters supporting an EVA crewman are 6.5 volts per meter at one meter from the TV antenna of the EMU and 3.8 volts per meter at one meter from the EMU EVA voice antenna. Transmitter characteristics associated with EVA activities are given in Table 2.5-2. Payloads that could be exposed to these EVA emissions shall be designed to meet these induced environments. [Note: The TV antenna and the voice antenna are both located on the man.]

There is also a Wireless Crew Communications System (WCCS) operating in the orbiter crew compartment at frequencies between 338.0 MHz and 392.0 MHz. (Refer to paragraph 10.7.2.2 of the ICD-2-19001).

b. Operational Compatibility of Attached Payloads with the Orbiter's Intentional (Transmitter) Emissions - Payloads designed to operate in the orbiter bay that contain sensors or devices that are inherently susceptible to EMI shall be tested to demonstrate that they can meet their performance requirements while exposed to the radiated emissions from the orbiter's transmitters. The levels, defined in Figure 2.5-14a, are worst-case values in the upper (+Z) quadrant of the payload envelope with the bay doors open. Although reduced levels can usually be expected in the lower levels of the bay, the levels are dependent on the geometry of the payload. Table 2.5-2 gives the frequency range and modulation associated with the orbiter transmitter field strengths, which are given in Figure 2.5-14a.

Testing shall be in accordance with test RS03 utilizing the actual orbiter, adjacent payload, and EVA transmitter frequencies and levels as applicable. All payload sensory devices shall be connected and operating. Appropriate modulation of the test signals shall be based on the modulation types defined in Table 2.5-2. The test signal antenna shall be positioned to provide appropriate simulation of the operation of the payload while it is exposed to intended emissions from the orbiter's transmitters.

Table 2.5-2
Frequency Range and Modulation Associated
With Orbiter Transmitters

Transmitter	Frequency	Modulation
S-Band Hemi	2000-2300 MHz	FM
S-Band Quad	2200-2300 MHz	PSK,PM
S-Band Payload	2000-2200 MHz	PSK,PM,FM/P
Ku-Band	13-15 GHz	PSK,FM,Pulse
UHF-(EVA)	259.7, 279.0 MHz	AM Voice and Data

c. Operational Compatibility of Attached Payloads With the Orbiter's Unintentional Emissions - Payloads that are designed to operate in the payload bay of the orbiter and that contain sensors or devices that are inherently susceptible to EMI shall be tested with their sensors operating in order to demonstrate that they can meet performance requirements while exposed to unintentional radiated emissions from the orbiter. The test levels shall be in accordance with the orbiter's radiated narrowband E-field limits given in Figure 2.5-15 and the orbiter's broadband emission limits given in Figure 2.5-16.

The tests shall be in accordance with RS03. The test signal antenna shall be located so as to simulate payload operation while it is exposed to the orbiter's radiated emissions.

d. Magnetic Field Susceptibility - Payloads that could be susceptible to the magnetic field levels generated by their own subsystems and components, or STS payloads that could be susceptible to the magnetic fields generated by the STS, shall be tested for susceptibility in a suitable test facility. The tests shall be performed to expected/acceptable levels from 30 Hz to 50 KHz and/or in a static (dc) field.

This requirement may be deleted with project approval for payloads that do not include subsystems or instruments that are inherently susceptible to magnetic fields.

The minimum test levels to satisfy STS requirements are given in paragraph 10.7.2.2. of ICD 2-19001. The magnetic field susceptibility portion may be deleted with project approval.

2.5.3.3 Acceptance Requirements - The susceptibility requirements of 2.5.3 shall apply to all previously qualified hardware.

2.5.4 Magnetic Properties*

A spacecraft whose magnetic properties or fields must be controlled to satisfy operational or scientific requirements, shall be tested at the component, subsystem, and spacecraft levels of assembly, as appropriate, and shall meet the following magnetic requirements (spacecraft with magnetic sensors, e.g., magnetometers, may have more stringent requirements):

2.5.4.l Initial Perm Test - The maximum dc dipole moment produced by a spacecraft and by each of its components following manufacture shall not exceed 3.0 and 0.2 AM^2 (dipole moment), respectively.

2.5.4.2 Perm Levels After Exposure to Magnetic Field - The maximum dipole moment produced by a spacecraft and each of its components after exposures to magnetic field test levels of 15×10^{-4} tesla shall not exceed 5.0 and 0.3 AM^2, respectively.

2.5.4.3 Perm Levels After Exposures to Deperm Test - The maximum dipole moment produced by a spacecraft and each of its components after exposures to magnetic field deperm levels of 30×10^{-4} tesla for spacecraft and 50×10^{-4} tesla for components shall not exceed 2.0 and 0.l AM^2, respectively.

2.5.4.4 Induced Magnetic Field Measurement - In order to obtain information for spacecraft magnetic design and testing, the induced magnetic field of components shall be measured while the components are turned off and exposed to a magnetic field test level of 0.6×10^{-4} tesla. The measurement shall be made by a test magnetometer that can null the magnetic test field.

2.5.4.5 Stray Magnetic Field Measurements - A spacecraft and each of its components shall not produce dipole moments due to internal current flows in excess of 0.5 and 0.05 AM^2, respectively.

2.5.4.6 Subsystem Requirements - Subsystems shall also be tested in accordance with the above requirements; however, the requirement limits shall be determined on a per case basis. The limits shall be designated between the levels for the spacecraft and those for components and shall depend upon the number of components in a subsystem and the number of subsystems in the spacecraft. Subsystem limits shall be designated such that the fully integrated spacecraft can meet its magnetic requirements.

2.5.4.7 Acceptance Requirements - The provisions for magnetic testing (2.5.4) shall apply to all previously qualified hardware.

* Dc magnetics testing should be performed after vibration testing. This provides an opportunity to correct for any magnetization of the flight hardware caused by fields associated with the vibration test equipment.

2.5.4.8 Notes on Magnetics Terminology and Units Used In GEVS

Induced Field - If a low level magnetic field is applied to the hardware, the measured change in the magnetic field may be different from the applied field. This difference is called the induced field. The induced field disappears when the applied field is turned-off. The induced field is measured with the hardware turned-off. The low level applied field is approximately equal to the Earth field.

Stray Fields - Magnetic fields that are generated by current flowing within the spacecraft and its experiments.

Perm Levels - This is the permanent magnetic field of the hardware. This permanent magnetic field is actually a function of its history of exposure to magnetic fields.

Deperm - The process of demagnetizing the hardware with the purpose of reducing the effects of any previous environmental field exposures.

The product of the area of a plane loop of wire and the dc current flowing in the loop is called the magnetic dipole moment. At distances sufficiently removed from the hardware, the magnetic flux density (B-field) can approximately be modeled as if it were produced by such a loop. Under such conditions, the magnetic dipole moment becomes a measure of the B-field.

Comparison of the "Perm Levels After Exposure to Deperm Test" with the "Perm Levels After Exposure to Magnetic Field" gives an indication of the amount of soft magnetic material present in the s/c hardware.

Induced magnetism has historically, been the major factor preventing accurate calculation of the s/c dipole moment from the measured dipole moments of all of the major subunits of the s/c.

The 15 gauss exposure level in the GEVS is based on worst case field levels expected in the vicinity of shaker tables used during environmental testing.

The stray field measurements are designed so that it is possible to differentiate between the power-on vs. power-off conditions of operation as well as shifts in the stray-field levels during operation of the equipment.

The magnetic flux density (B) is expressed in units of Tesla (Weber/meter-squared) in the mks system.

The magnetization M of a material is defined as the magnetic (dipole) moment per unit volume. In the mks system, the units of M are ampere/meter.

The magnetic field strength (H) is often expressed in units of ampere/meter; this is the same units as M. But it is also often expressed in the units of B in lieu of the units of M; this is one of the sources of ambiguity in magnetics units.

Historically "magnetic charge" was defined as an analog to "electric charge." The magnetic "pole" is a unit of "magnetic charge." Even the existence of magnetic charges has not been established, but this mathematical analog sometimes proves useful.

Examples Of Considerations And Situations That Occur

Measurement of hysteresis and eddy current losses can be performed in a test facility that can produce a rotating magnetic field.

Hysteresis effects - The (irreversible) magnetic field characteristics of ferromagnetic materials (hysteresis) result in energy dissipation in the materials under conditions of spacecraft hardware spinning in a magnetic field. The disturbance torques produced in the process can act to despin the spinning part of a spacecraft. On Transit 1B, this effect was used to despin the satellite. Eight 31 inch long rods mounted orthogonal to the spin axis were used to accomplish this. (The rods were made of a soft magnetic material).

Eddy Currents - Eddy currents in a material are caused by time-varying magnetic fields. These currents may act to despin the spinning part of a spacecraft. Eddy currents would be possible even in the absence of spacecraft generated magnetic fields.

Disturbance torques can result from spacecraft hardware that rotates relative to other hardware on the spacecraft.

The magnetic disturbance torque acting on a spacecraft is equal to the cross product of the magnetic dipole moment of the spacecraft and the magnetic flux density.

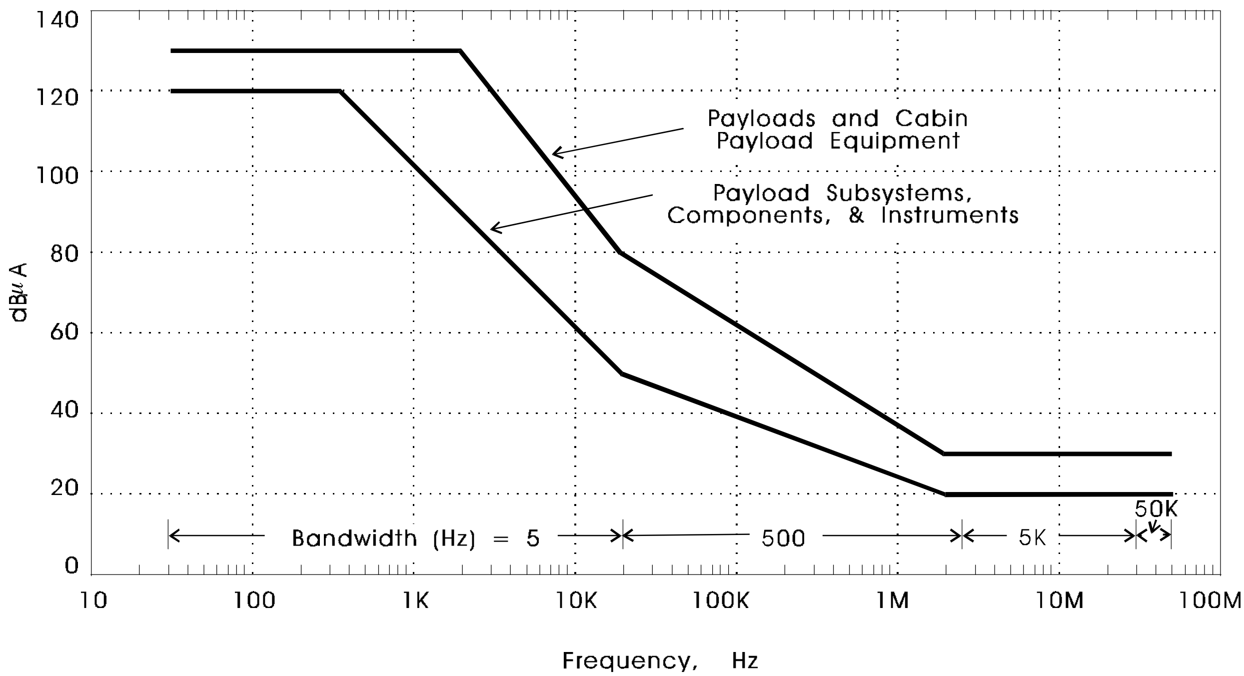


Figure 2.5-1 Narrowband Conducted Emission Limits on Payload Power Lines

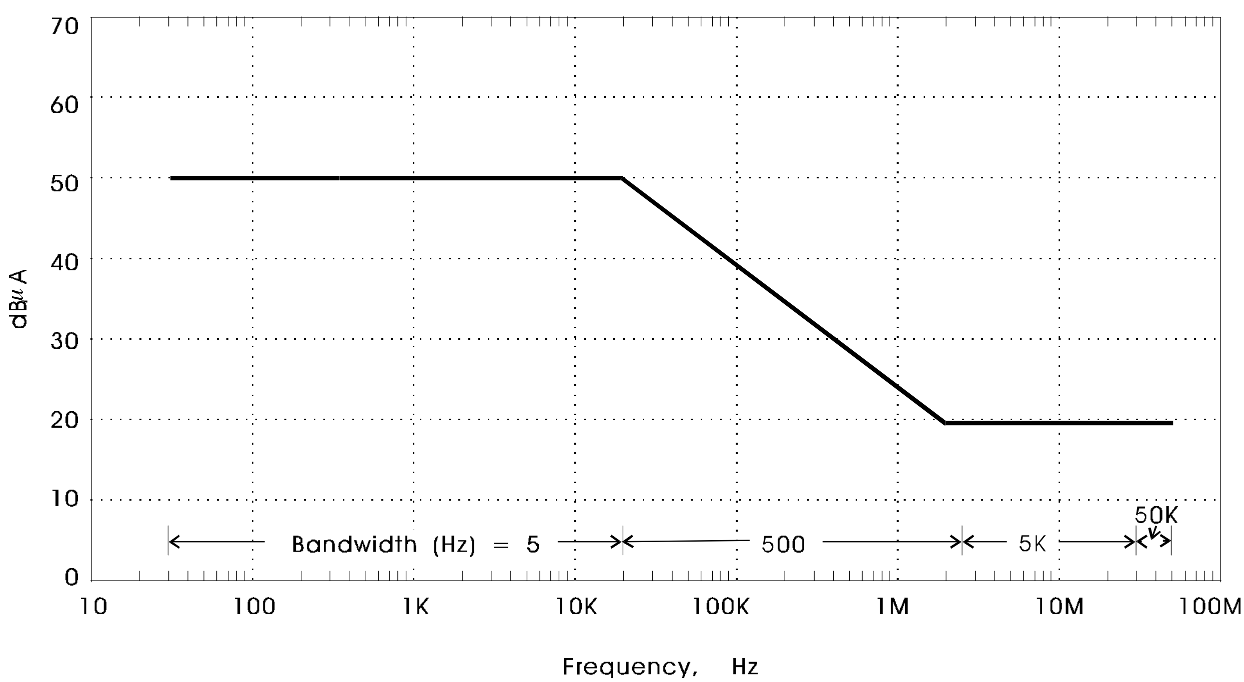


Figure 2.5-1a Common Mode Conducted Emission Limits on Primary Power Lines

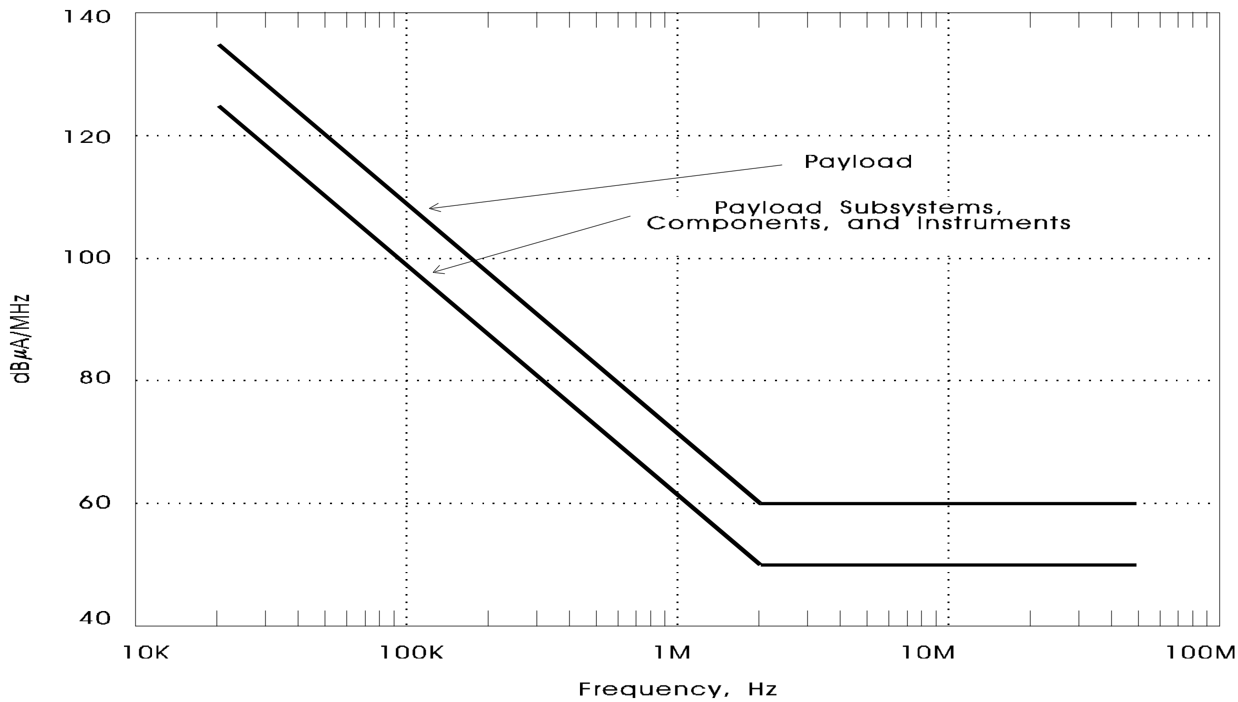


Figure 2.5-2 Broadband Conducted Emission Limits on Payload Power Lines

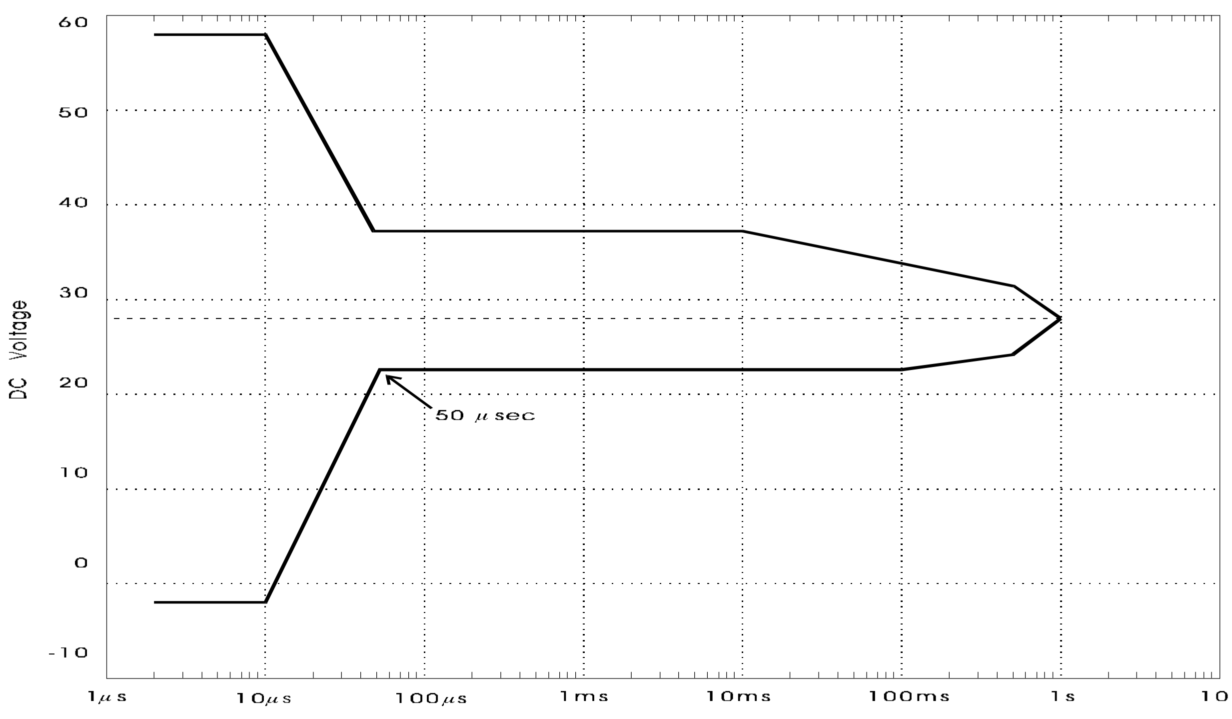


Figure 2.5-3 Limit Envelope of Cargo-Generated Transients (Line-to-Line) on DC Power Busses for Normal Electrical System

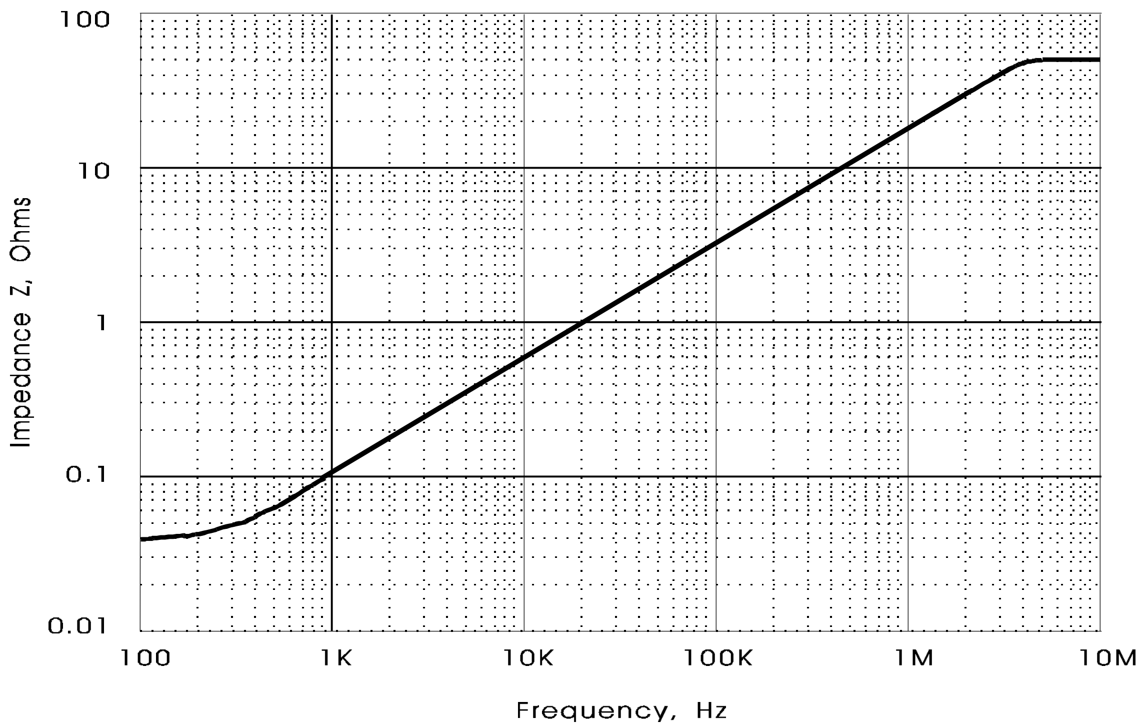
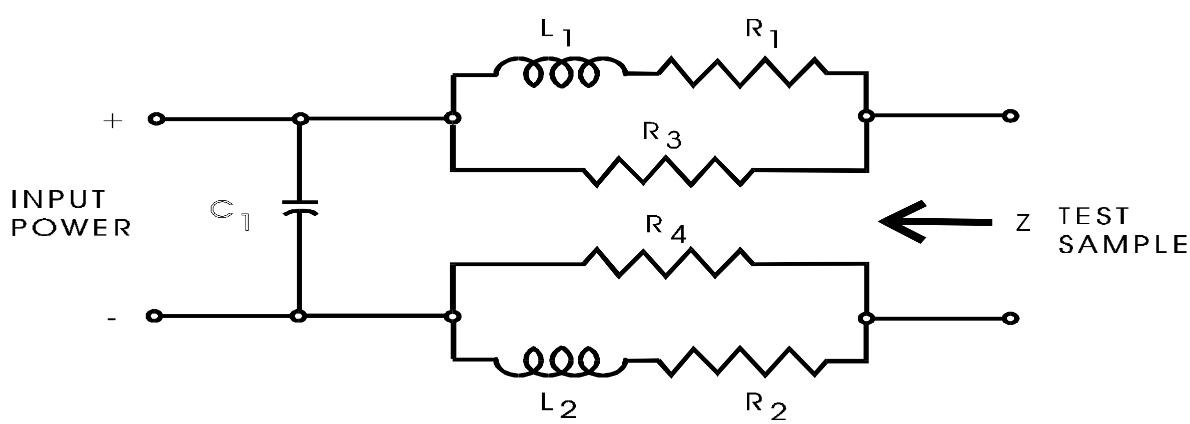


Figure 2.5-4 Orbiter DC Powerline Impedance



R1,R2	=	0.25 ohm*
R3,R4	=	25 ohm
C1	=	19,000 μ F (75 V ELECTROLYTIC)
L1,L2	=	4 μ H

* Value of resistors may be reduced to 0.025 ohms or lower for hardware requiring high levels of power currents.

Figure 2.5-5 Network Schematic for Simulating Impedance of Orbiter Power System

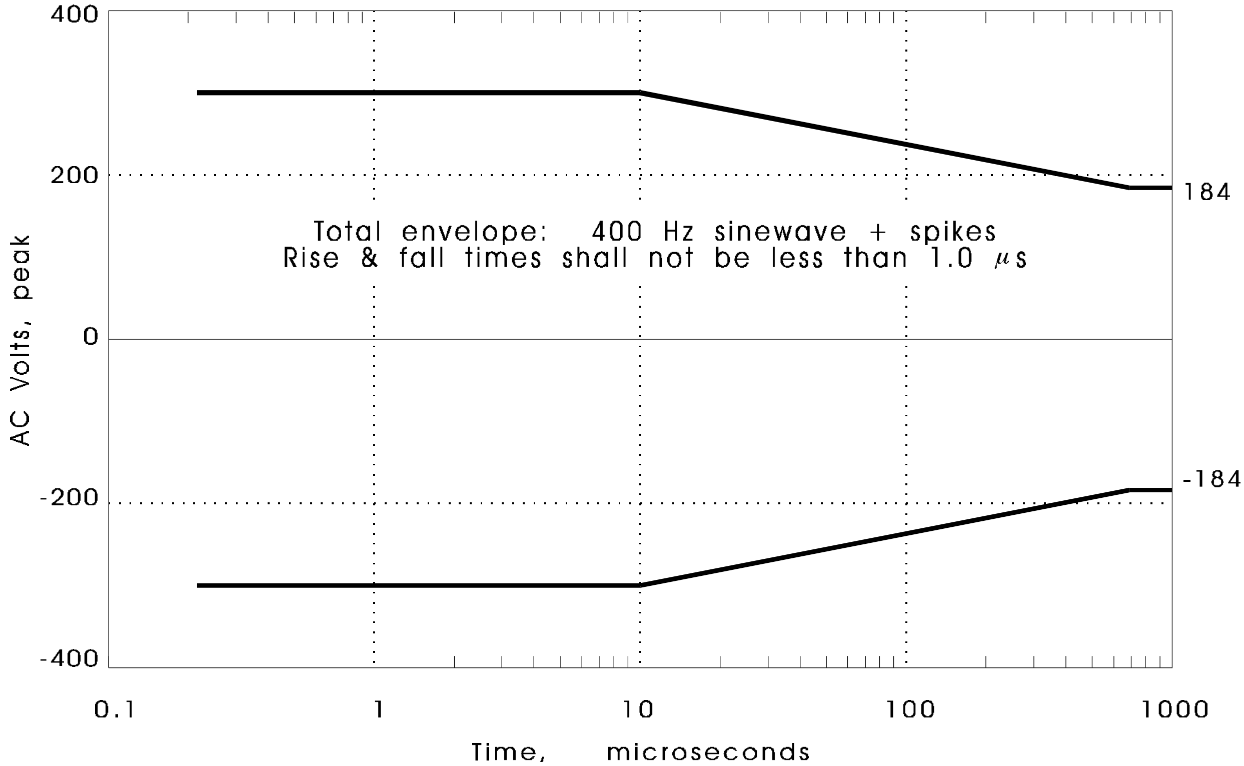


Figure 2.5-6 Limits of Payload-Produced Spikes on Orbiter AC Power Leads

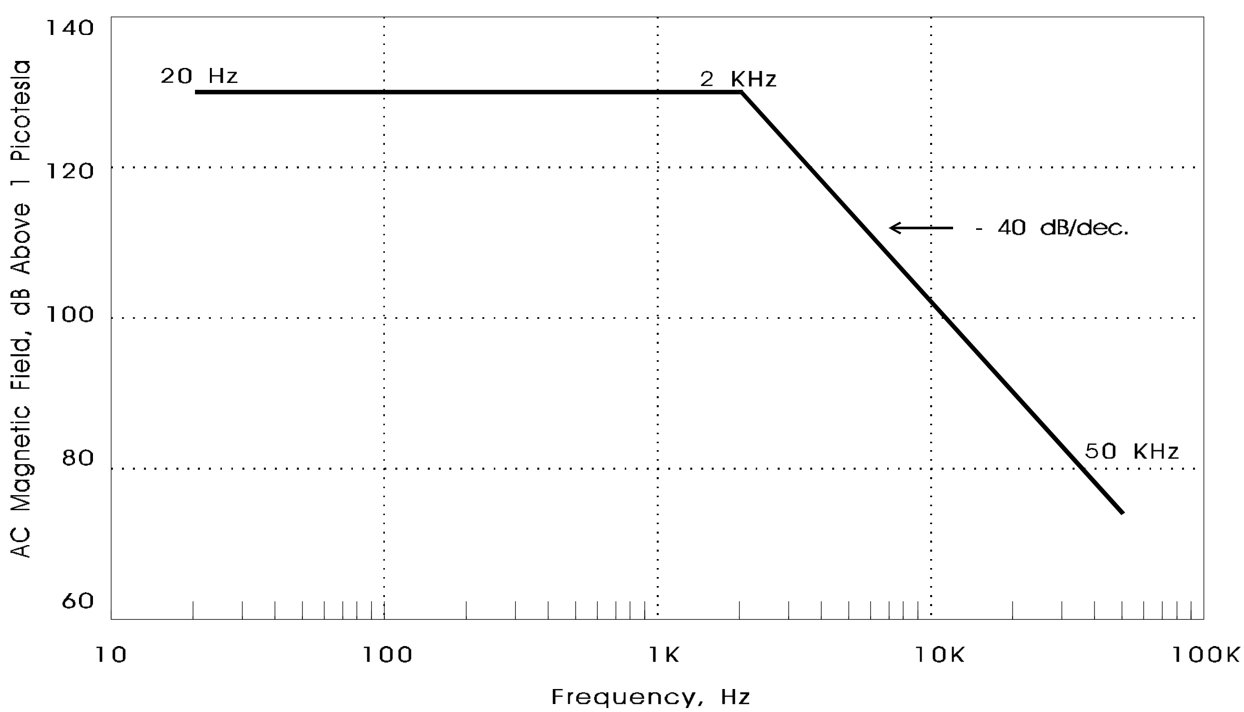


Figure 2.5-8 Limits of Radiated AC Magnetic Field at 1 Meter From Orbiter Payload

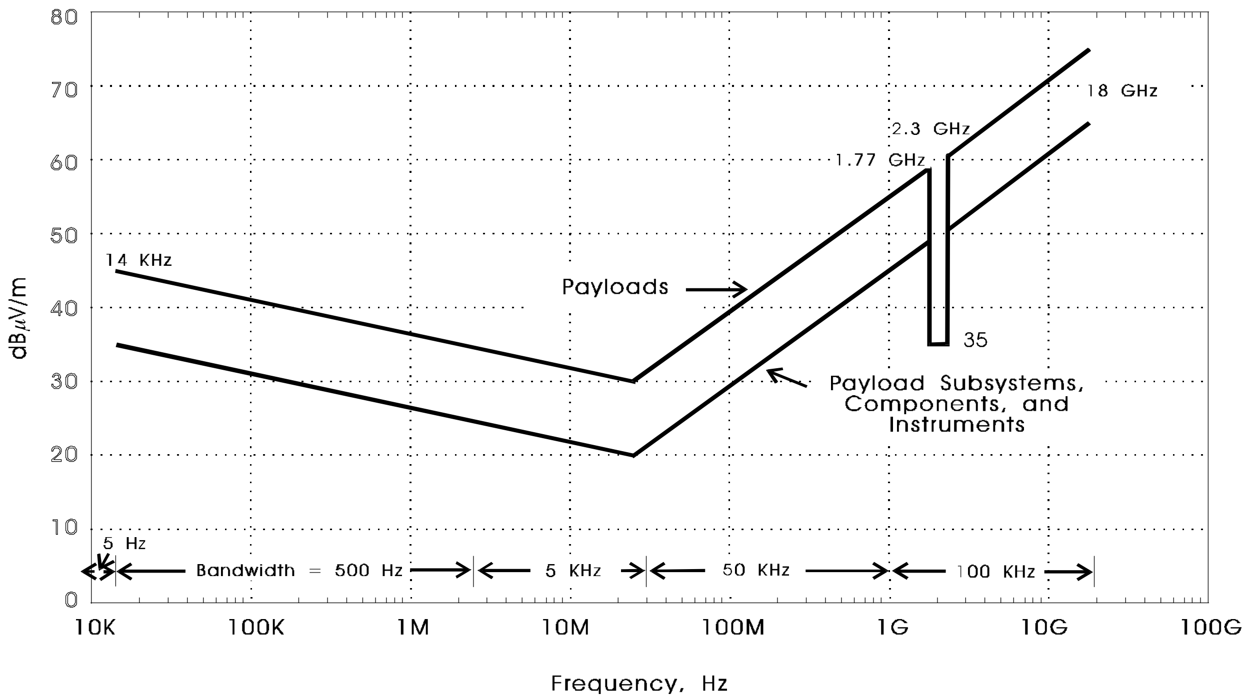
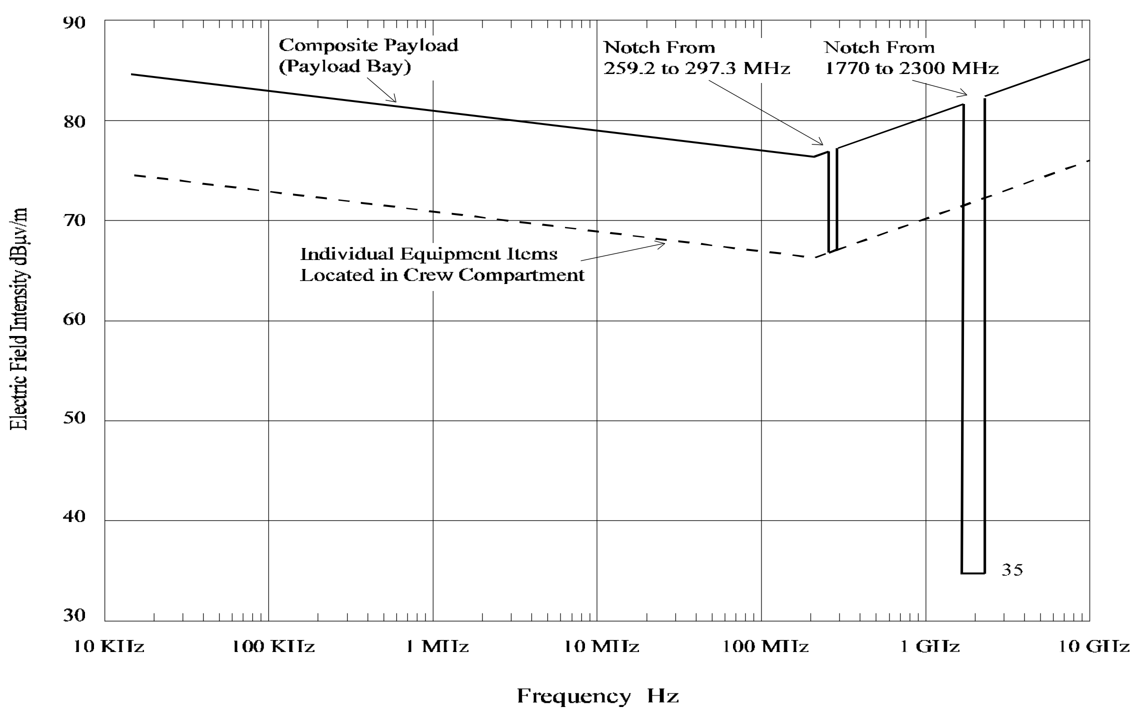


Figure 2.5-9 Unintentional Radiated Narrowband Limits for Electric Field Emission Produced by Payloads and Payload Subsystems



.Figure 2.5-9a Allowable Unintentional Radiated Narrowband Emissions Limits in Orbiter Cargo Bay

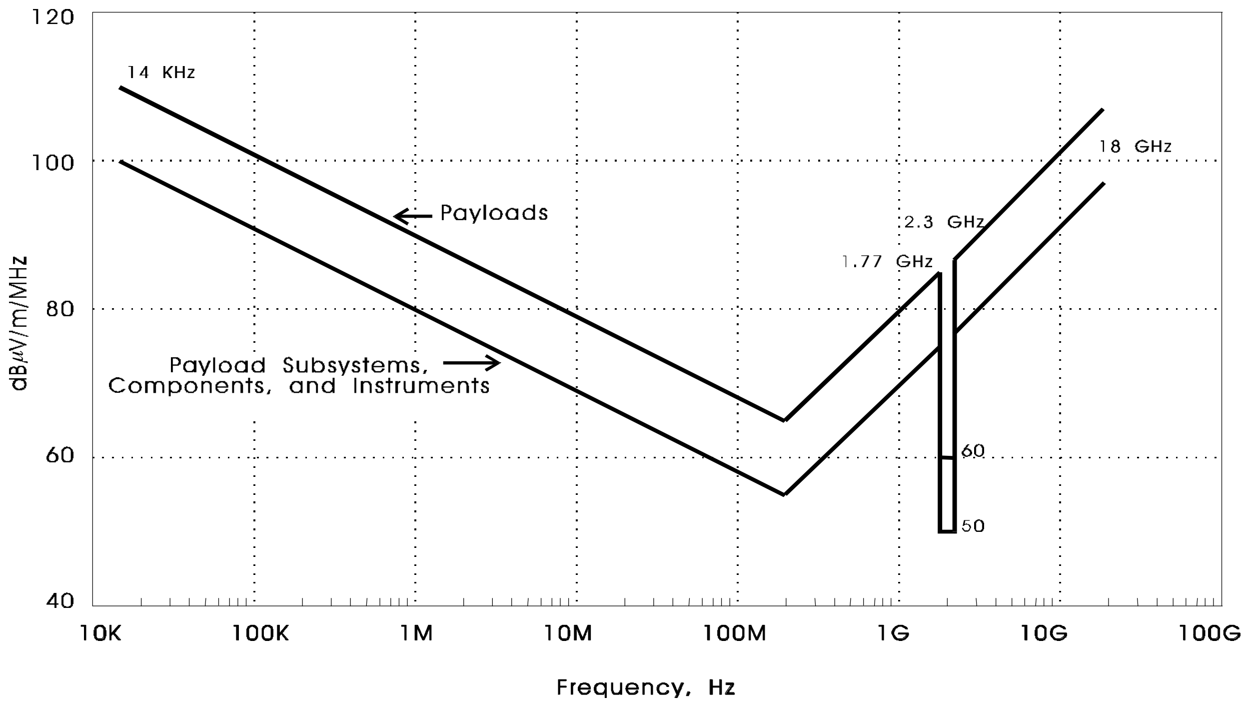


Figure 2.5-10 Unintentional Radiated Broadband Limits for Electric Field Emissions Produced by Payloads and Payload Subsystems

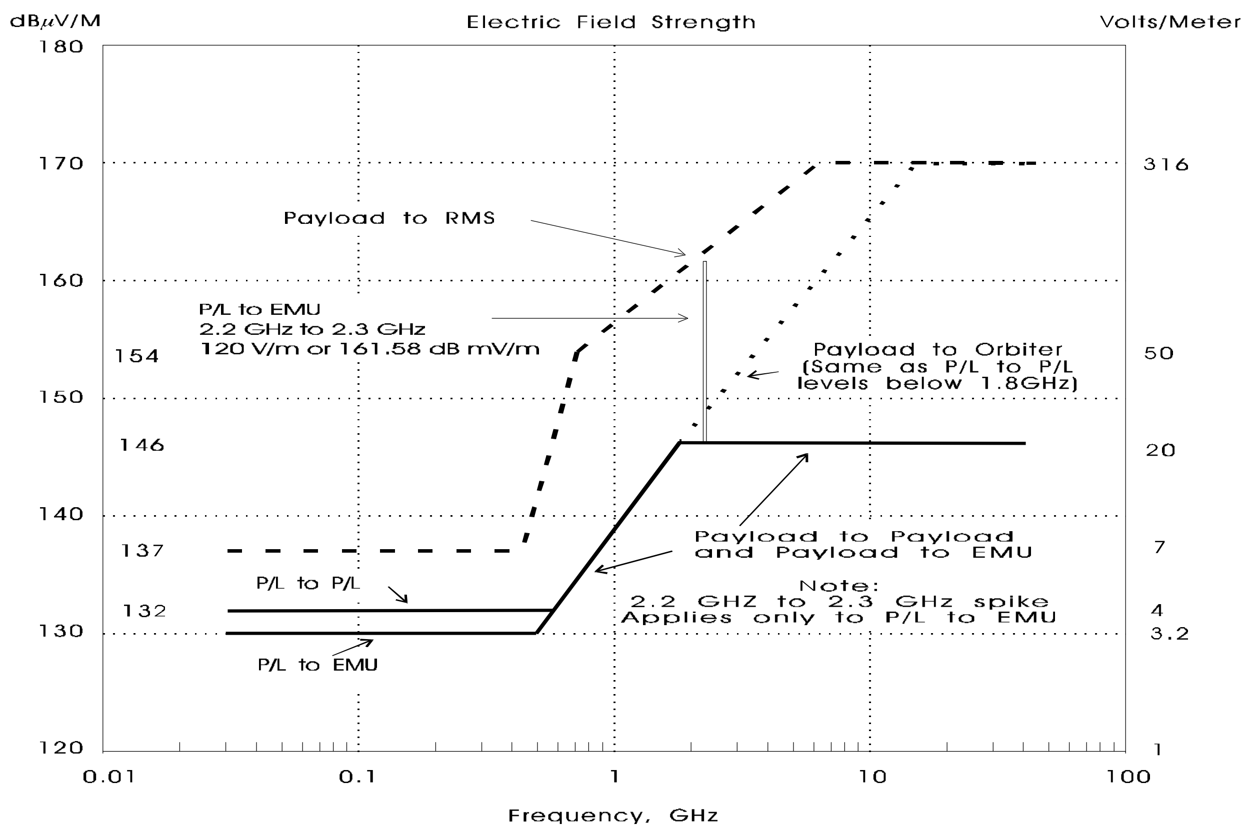


Figure 2.5-11 Allowable Intentional Field Strength in Orbiter Cargo Bay

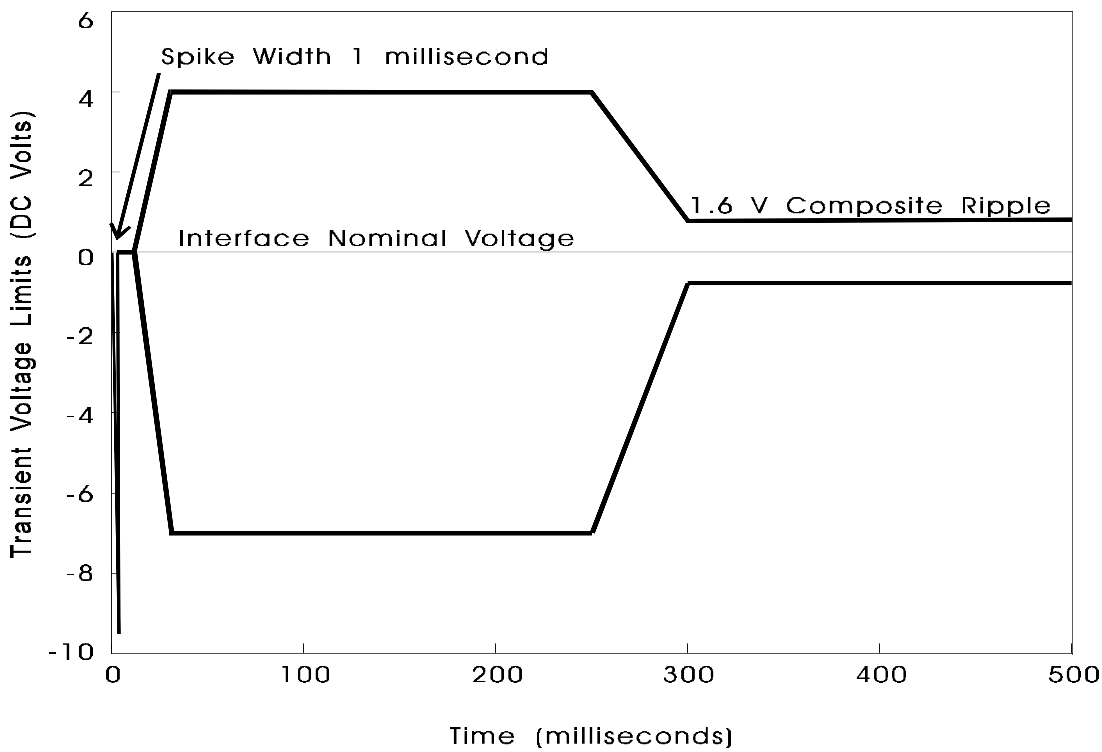


Figure 2.5-12a Transient Voltage on the Aft Payload B and C DC Buses Produced by Operation of the Hydraulic Circulation Pump

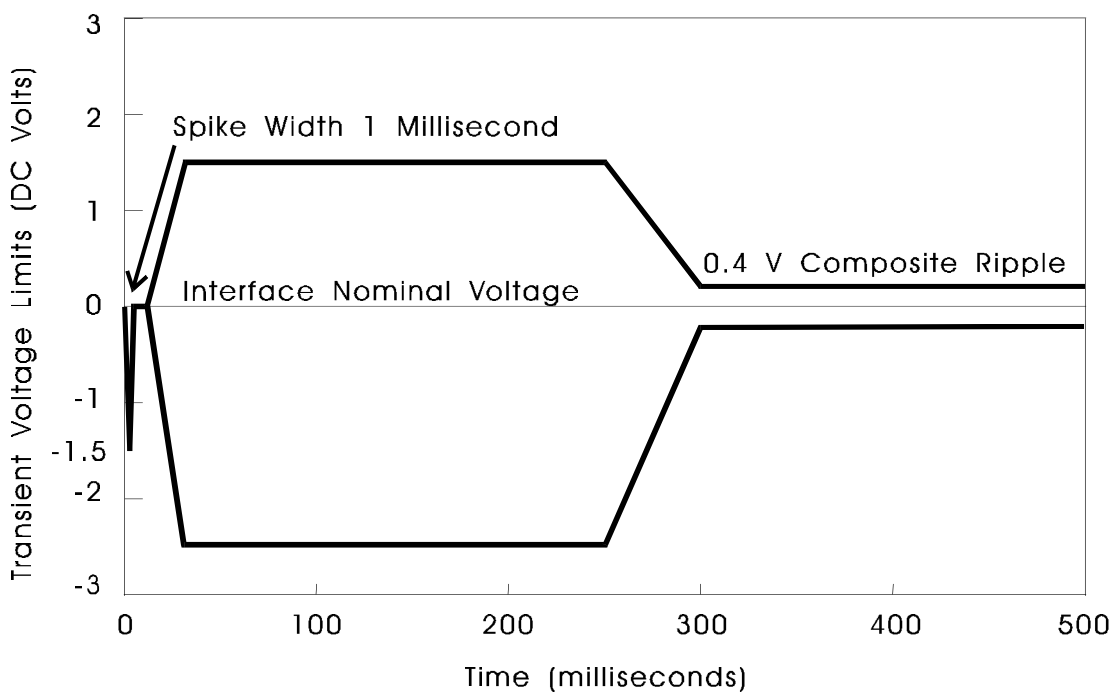


Figure 2.5-12b Transient Voltage on the Primary P/L Bus, Aux P/L A, AUX P/L B, and the Cabin P/L Bus at the Cargo Element Interface Produced by Operation of the Hydraulic Circulation Pump

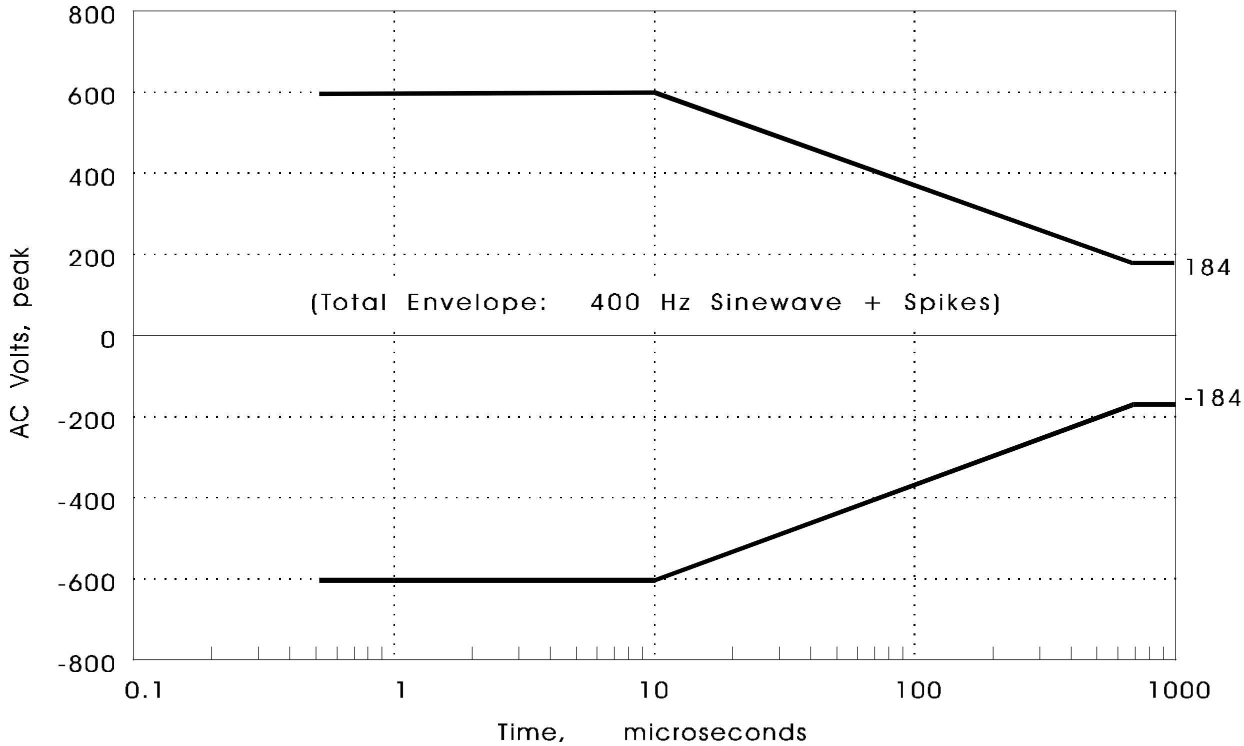


Figure 2.5-13 Envelope of Spikes on the Orbiter AC Power Bus

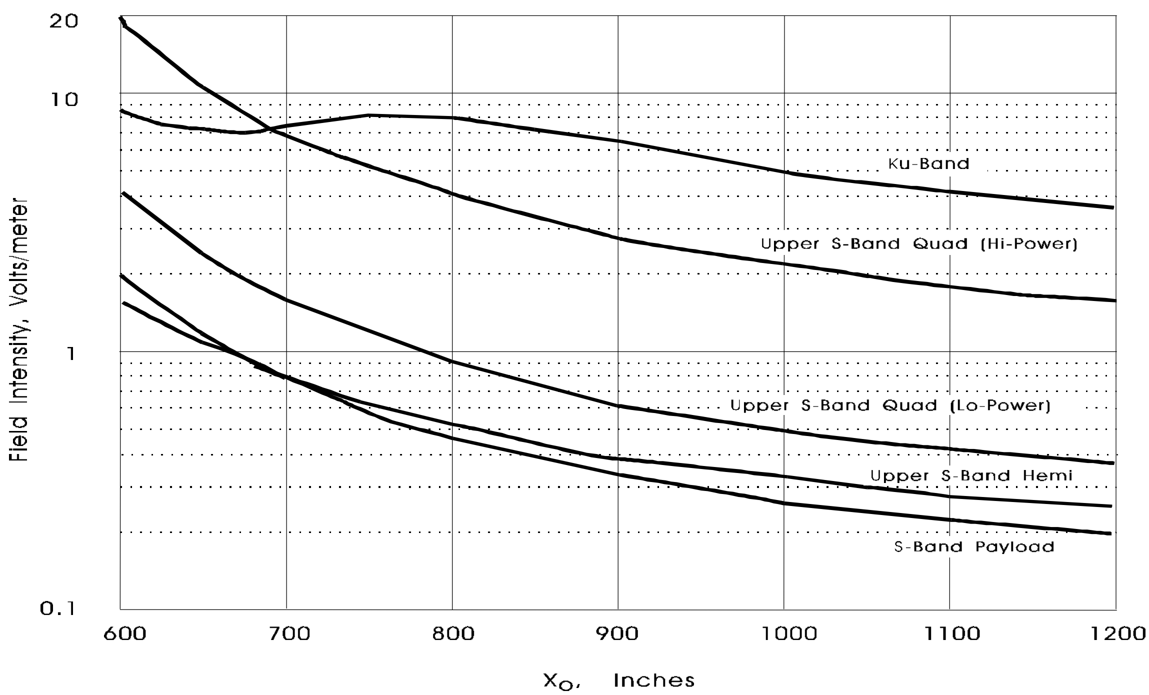
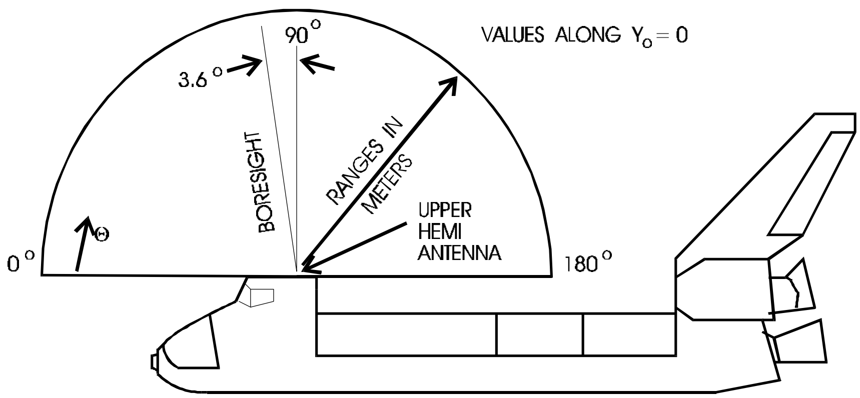


Figure 2.5-14a Maximum Field Intensities on Payload Envelope Produced by Orbiter Transmitters



For ranges greater than 1 meter:

$$\text{Volts/meter @ Desired Range} = \frac{\text{Volts/meter @ 1 meter}}{\text{Range in meters}}$$

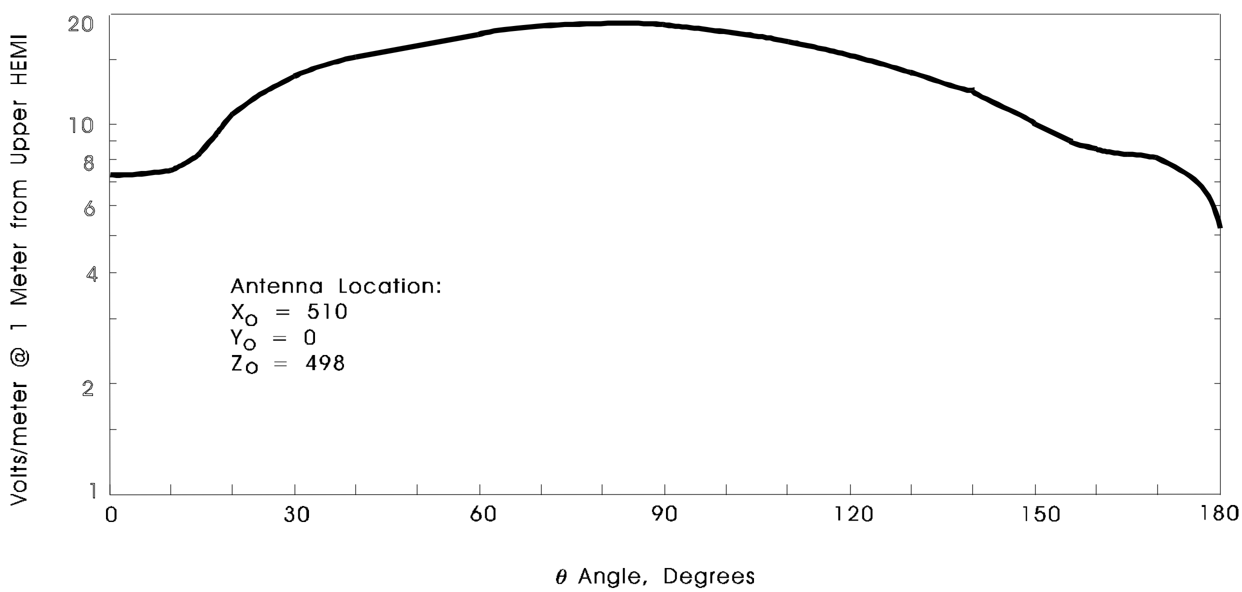
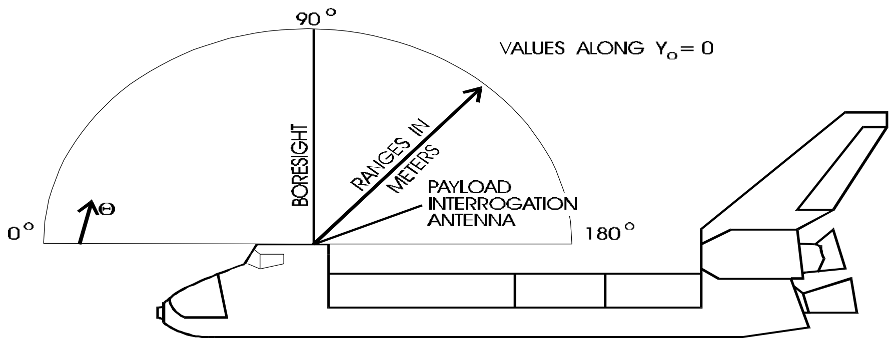


Figure 2.5-14b S-Band FM Transmitter, Upper HEMI Antenna, Maximum Field Intensities



For ranges greater than 1 meter:

$$\text{Volts/meter @ Desired Range} = \frac{\text{Volts/meter @ 1 meter}}{\text{Range in meters}}$$

For the medium power mode multiply volts/meter by 0.316 (-10 dB)

For the low power mode multiply volts/meter by 0.071 (-23 dB)

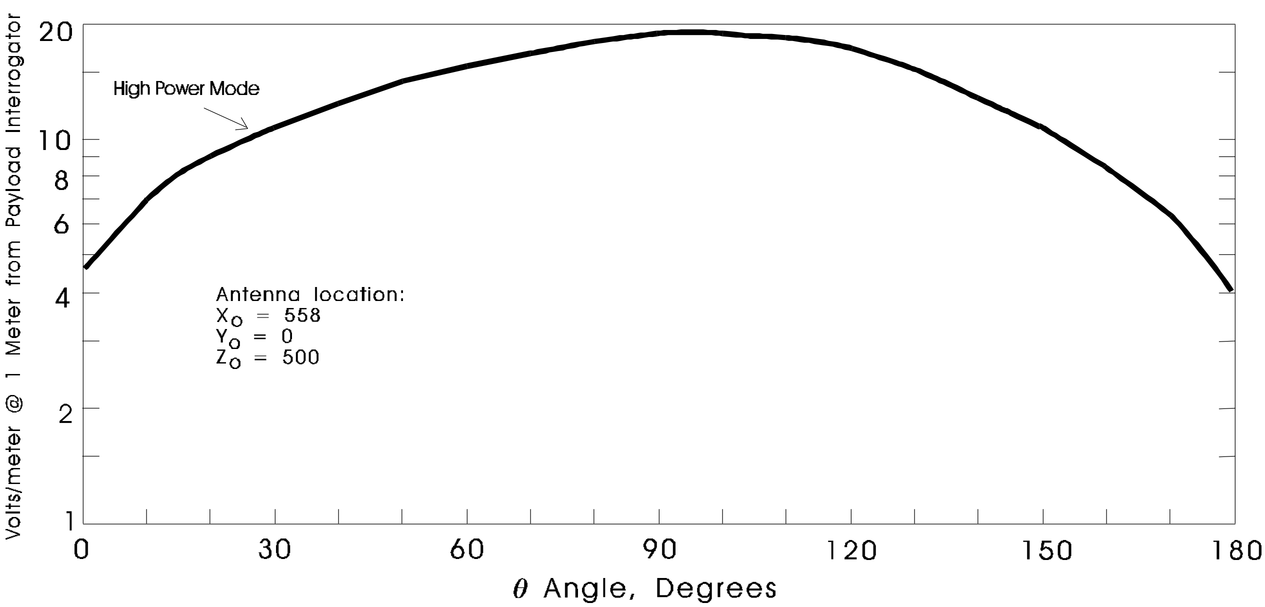


Figure 2.5-14c S-Band Payload Interrogator, Maximum Field Intensities

For ranges greater than 1 meter:

Volts/meter @ Desired Range	=	Volts/meter @ 1 meter / Range in meters	For the low power mode multiply Volts/meter by 0.158 (-16 dB)

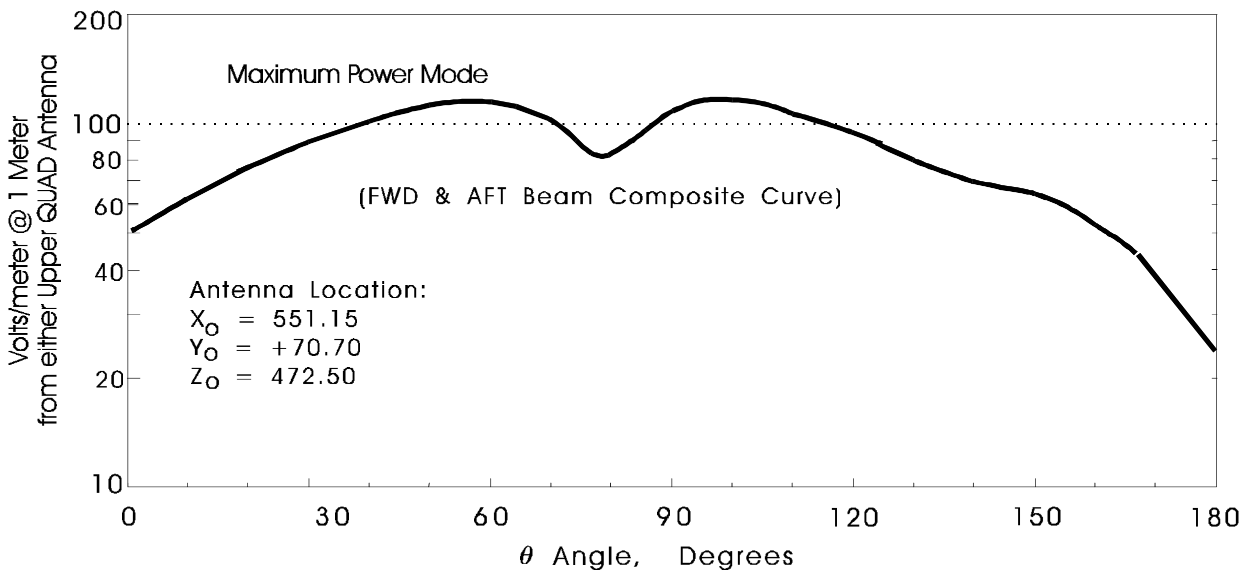


Figure 2.5-14d S-Band Network Transponder, Upper Quad Antennas, Maximum Field Intensities

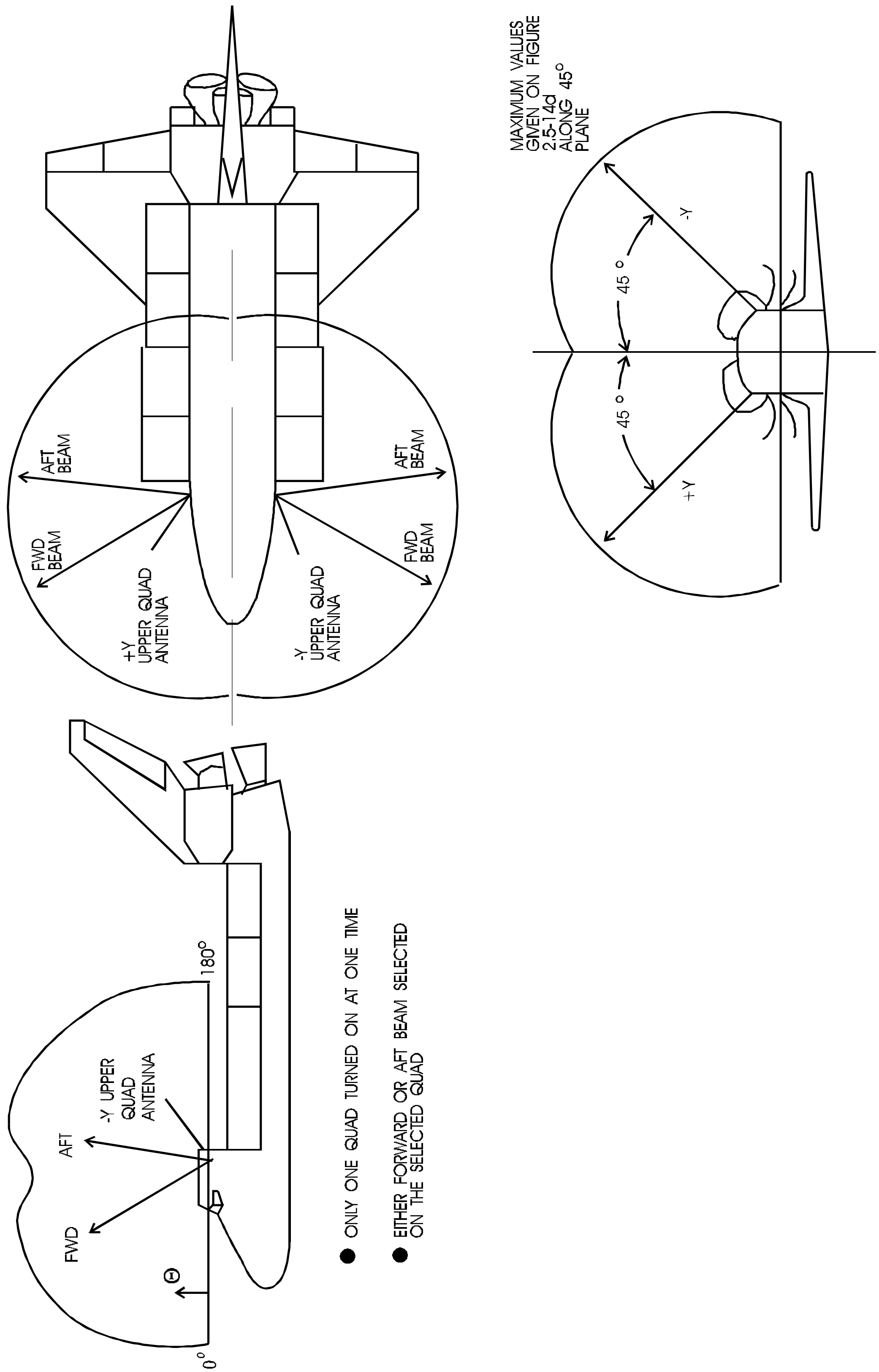


Figure 2.5-14e. S-Band Network Transponder, Upper Quad Antennas, Beam Configuration

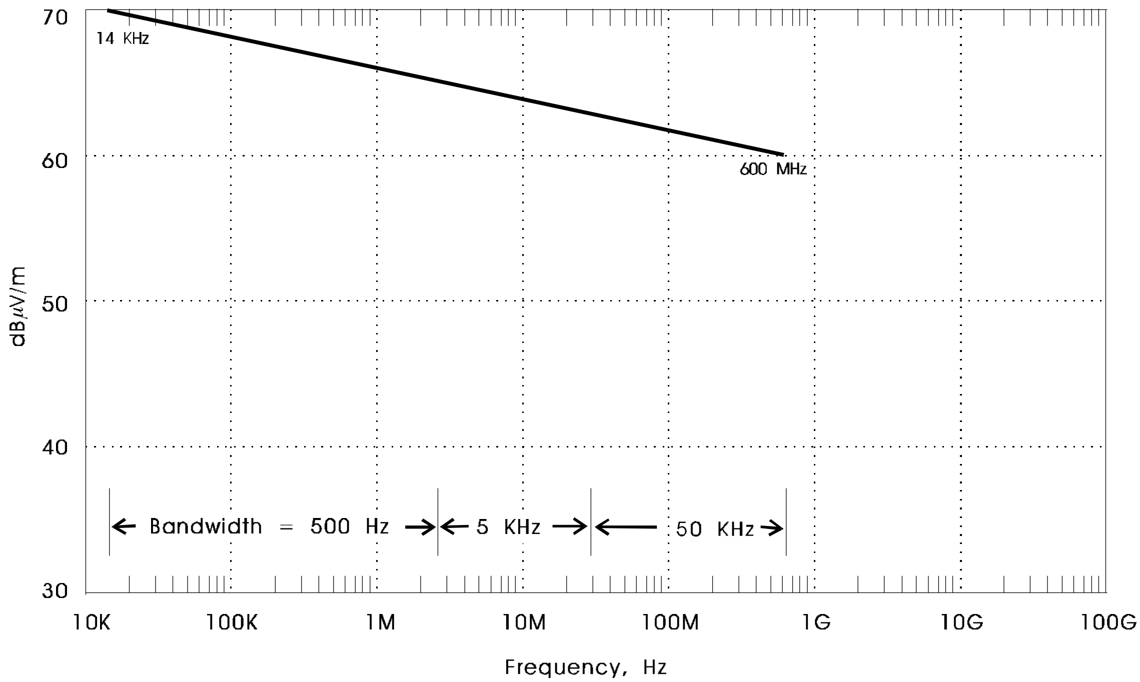


Figure 2.5-15 Orbiter Produced Radiated Narrowband Emissions in Payload Bay

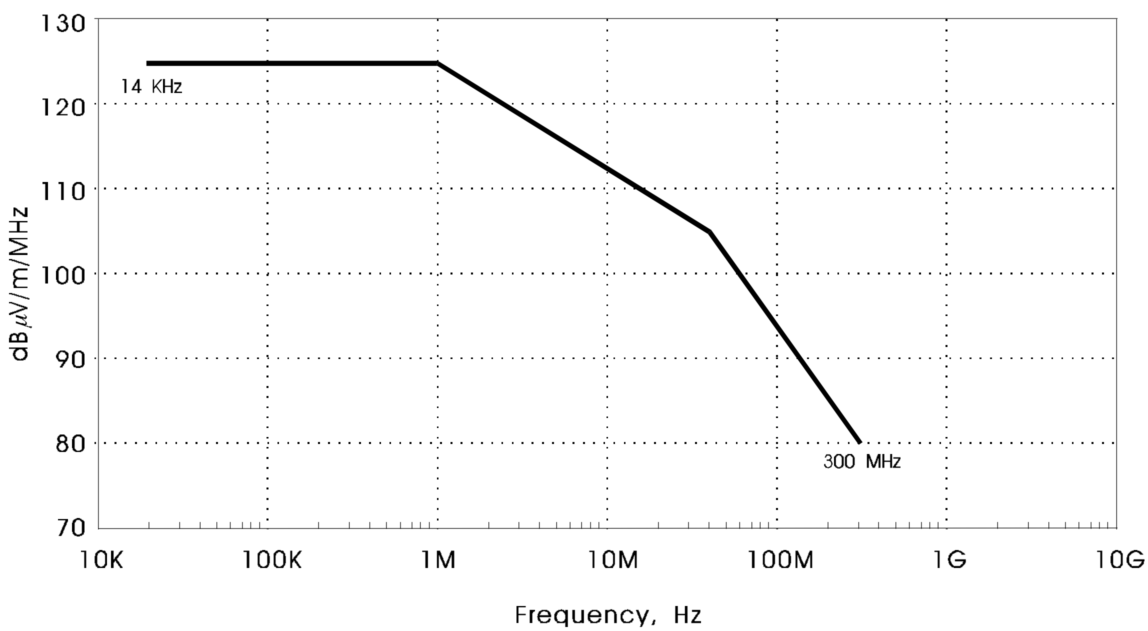


Figure 2.5-16 Orbiter Produced Radiated Broadband Emissions in Payload Bay