

Standard

Electromagnetic Compatibility Requirements for Space Equipment and Systems

AIAA standards are copyrighted by the American Institute of Aeronautics and Astronautics (AIAA), 1801 Alexander Bell Drive, Reston, VA 20191-4344 USA. All rights reserved.

AIAA grants you a license as follows: The right to download an electronic file of this AIAA standard for storage on your computer for purposes of viewing, and/or printing one copy of the AIAA standard for individual use. Neither the electronic file nor the hard copy print may be reproduced in any way. In addition, the electronic file may not be distributed elsewhere over computer networks or otherwise. The hard copy print may only be distributed to your employees for their internal use within your organization.



Standard

Electromagnetic Compatibility Requirements for Space Equipment and Systems

Sponsored by

American Institute of Aeronautics and Astronautics

Approved

4 September 2009

Abstract

This document, when followed in its entirety, will yield a robust electromagnetic capability design suitable for high-reliability space missions. This document specifies general design practices and sets recommended verification and validation requirements for space vehicles and launch vehicles.

Library of Congress Cataloging-in-publication data on file

Published by
American Institute of Aeronautics and Astronautics
1801 Alexander Bell Drive, Reston, VA 20191

Copyright © 2009 American Institute of Aeronautics and
Astronautics
All rights reserved

No part of this publication may be reproduced in any form, in an electronic retrieval system
or otherwise, without prior written permission of the publisher.

Printed in the United States of America

Contents

Foreword.....	ix
1 Scope.....	1
2 Tailoring.....	1
3 Applicable Documents.....	1
4 Vocabulary.....	2
4.1 Acronyms and Abbreviated Terms.....	2
4.2 Terms and Definitions.....	4
5 General Requirements.....	5
5.1 System.....	6
5.2 Units and Subsystems.....	6
5.3 Ground Equipment.....	6
5.4 Limits.....	6
6 Detailed Requirements—System.....	6
6.1 EMI Safety Margins (EMISMs).....	6
6.2 Intrasystem Electromagnetic Compatibility.....	7
6.3 External Electromagnetic Environment.....	8
6.4 Lightning.....	9
6.5 Electromagnetic Pulse (EMP).....	12
6.6 Subsystems and Equipment Electromagnetic Interference (EMI).....	12
6.7 Non-Developmental Items (NDI), Government Furnished Equipment (GFE), and Commercial Items.....	12
6.8 Magnetic Field Environment.....	13
6.9 Electrostatic Charge Control.....	13
6.10 Electromagnetic Radiation Hazards (EMRADHAZ).....	13
6.11 Life Cycle, E3 Hardness.....	14
6.12 Electrical Bonding.....	14
6.13 TEMPEST.....	15
6.14 EM Spectral Compatibility.....	15
6.15 System Circuit and Structure Reference.....	15
6.16 Return Current Control.....	15
6.17 Wiring.....	16
6.18 Material Properties.....	16
6.19 Data Formats.....	16
6.20 Tailoring Guidance for Contractual Application.....	16
7 General Requirements—Units and Subsystems.....	16
7.1 Filtering (Navy Only).....	19

7.2	Non-Developmental Items (NDI).....	19
7.3	Selected by Contractor	19
7.4	Procurement of Equipment or Subsystems Having Met Other EMI Requirements	19
7.5	Government Furnished Equipment (GFE)	19
7.6	Switching Transients.....	19
7.7	Measurement Tolerances	19
7.8	Ambient Electromagnetic Level	19
7.9	Power Source Impedance.....	19
7.10	Input Power Leads.....	21
7.11	Susceptibility Monitoring	21
7.12	Detector	21
7.13	Computer-Controlled Receivers.....	21
7.14	Emission Identification	22
7.15	Frequency Scanning.....	22
7.16	Emission Data Presentation.....	22
7.17	Susceptibility Scanning (Reference 4.3.10.4.1 of MIL-STD-461F).....	22
7.18	Calibration of Measuring Equipment.....	22
8	Detailed Requirements—Units and Subsystems	23
8.1	Operating Modes	23
8.2	EMI Control Requirements, Intended Installations.....	23
8.3	Emission and Susceptibility Requirements, Limits, and Test Procedures.....	23
8.4	Power Bus Conducted Interference, Load-Induced, Frequency Domain	25
8.5	RF Common Mode Conducted Emissions, Power and Signal Cables.....	27
8.6	Conducted Emissions, Antenna Terminal.....	30
8.7	Conducted Emissions, Differential Mode, Time Domain, Load-Induced Voltage Transients	30
8.8	Audio Frequency Conducted Susceptibility, Power Leads.....	32
8.9	Conducted Susceptibility, Antenna Port, Intermodulation	34
8.10	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals.....	34
8.11	Conducted Susceptibility, Antenna Port, Cross Modulation	34
8.12	Conducted Susceptibility, Bulk Cable Injection, Swept Frequency	34
8.13	Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation	35
8.14	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power.....	35
8.15	Conducted Susceptibility, Ground Plane Injection, Spike	35
8.16	Conducted Susceptibility, Ground Plane Injection, Audio Frequency	37
8.17	Conducted Susceptibility, Ground Plane Injection, Radio Frequency	40
8.18	Susceptibility to Switching Transients, Power Leads, Time Domain.....	41

8.19	Radiated Emissions, Magnetic Field.....	44
8.20	Radiated Emissions, Electric Field.....	44
8.21	Radiated Emissions, Antenna Spurious and Harmonic Outputs, 10 kHz to 40 GHz.....	45
8.22	Radiated Susceptibility, Magnetic Field.....	45
8.23	Radiated Susceptibility, Electric Field.....	45
	Annex A Requirements Rationale	47
A.1	General.....	47
A.2	Tailoring (see Section 2).....	47
A.3	System (see Section 5.1).....	47
A.4	Limits (see Section 5.4).....	47
A.5	EMI Safety Margins (see Section 6.1).....	48
A.6	Passive Intermodulation (see Section 6.2.1).....	49
A.7	Multipaction (see Section 6.2.2).....	49
A.8	Deployment, Staging, and Separation Events (see Section 6.2.3).....	50
A.9	Plugs-Out Test (see Section 6.2.4).....	50
A.10	RF Front-End Margin Assessment (see Section 6.2.5.1).....	51
A.11	Base Band Margin Assessment (see Section 6.2.5.2).....	51
A.12	External Electromagnetic Environment (see Section 6.3).....	51
A.13	Ground Support Equipment (see Section 6.3.1).....	52
A.14	Lightning (see Section 6.4).....	52
A.15	Magnetic Field Environment (see Section 6.5).....	53
A.16	Magnetic Dipole Moment (see Section 6.5.1).....	53
A.17	Electrostatic Charge Control (see Section 6.5.9).....	54
A.18	Triboelectric Charging (see Section 6.9.1).....	54
A.19	Electro-Explosive Device (see Section 6.9.2).....	55
A.20	Electromagnetic Radiation Hazards (EMRADHAZ) (see Section 6.10).....	56
A.21	Hazards of Electromagnetic Radiation to Personnel (HERP) (see Section 6.10.1).....	56
A.22	Hazards of Electromagnetic Radiation to Fuel (HERF) (see Section 6.10.2).....	56
A.23	Hazards of Electromagnetic Radiation to Ordnance (HERO) (see Section 6.10.13).....	56
A.24	Life Cycle, E3 Hardness (see Section 6.11).....	56
A.25	Electrical Bonding (see Section 6.12).....	56
A.26	Power Current Return Path (see Section 6.12.1).....	57
A.27	Antenna Installations (see Section 6.12.2).....	57
A.28	External Grounds (see Section 6.12.7).....	57
A.29	Servicing and Maintenance Equipment Grounds (see Section 6.12.8).....	57
A.30	TEMPEST (see Section 6.13).....	57

A.31	EM Spectrum Compatibility (see Section 6.14).....	57
A.32	System Circuit and Structure Reference (see Section 6.15).....	57
A.33	Return Current Control (see Section 6.16).....	58
A.34	Wiring (see Section 6.17).....	58
A.35	Data Formats (see Section 6.19).....	58
A.36	Tailoring Guidance for Contractual Application (see Section 6.20).....	59
A.37	Non-Developmental Items (see Section 7.2).....	60
A.38	Selected by Contractor (see Section 7.3).....	60
A.39	Measurement Tolerances (see Section 7.7).....	61
A.40	Ambient Electromagnetic Level (see Section 7.8).....	61
A.41	Power Source Impedance (see Section 7.9).....	62
A.42	Input Power Leads (see Section 7.10).....	62
A.43	Susceptibility Monitoring (see Section 7.11).....	62
A.44	Thresholds of Susceptibility (see Section 7.11.1).....	63
A.45	Detector (see Section 7.12).....	63
A.46	Computer-Controlled Receivers (see Section 7.13).....	64
A.47	Bandwidths (see Section 7.13.1).....	64
A.48	Emission Identification (see Section 7.14).....	64
A.49	Frequency Scanning (see Section 7.15).....	64
A.50	Emission Data Presentation (see Section 7.16).....	65
A.51	Susceptibility Scanning (see Section 7.17).....	66
A.52	Calibration of Measuring Equipment (see Section 7.18).....	66
A.53	Operating Modes (see Section 8.1).....	66
A.54	Power Bus Conducted Interference, Load Induced, Frequency Domain (see Section 8.4).....	66
A.55	Test Technique (see Section 8.4.2.1).....	68
A.56	RF Common Mode Conducted Emissions, Power and Signal Cables (see Section 8.5).....	69
A.57	Conducted Emissions, Antenna Terminal (see Section 8.6).....	70
A.58	Conducted Emissions, Differential Mode, Time Domain, Load-Induced Voltage Transients (see Section 8.7).....	71
A.59	Audio Frequency Conducted Susceptibility, Power Leads (see Section 8.8).....	72
A.60	Conducted Susceptibility, Antenna Port, Intermodulation (see Section 8.9).....	74
A.61	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals (see Section 8.10).....	74
A.62	Conducted Susceptibility, Antenna Port, Cross Modulation (see Section 8.11).....	75
A.63	Conducted Susceptibility, Bulk Cable Injection (see Section 8.12).....	75
A.64	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power (see Section 8.14).....	76
A.65	Conducted Susceptibility, Ground Plane Injection, Spike (see Section 8.15).....	77

A.66	Conducted Susceptibility, Ground Plane Injection, Audio Frequency (see Section 8.16)	77
A.67	Conducted Susceptibility, Ground Plane Injection, Radio Frequency (see Section 8.17)	78
A.68	Susceptibility to Switching Transients, Power Leads, Time Domain (see Section 8.18)	79
A.69	Radiated Emissions, Magnetic Field (see Section 8.19)	80
A.70	Radiated Emissions, Electric Field (see Section 8.20)	81
A.71	Radiated Susceptibility, Magnetic Field (see Section 8.22)	81
A.72	Radiated Susceptibility, Electric Field (see Section 8.23)	81
	Bibliography	82
Figures		
Figure 1	— Lightning direct effects environment	11
Figure 2	— Lightning indirect effects environment	12
Figure 3	— LISN schematic	20
Figure 4	— LISN impedance	20
Figure 5	— Power bus conducted interference limits, load induced, audio frequency, 30 Hz–150 kHz	25
Figure 6	— RF conducted emission limit curve	26
Figure 7	— Common mode CE limit	27
Figure 8	— Measurement system check	28
Figure 9	— Measurement setup	29
Figure 10	— DC signal injection	33
Figure 11	— Ground Plane Injection (GPI) spike potential waveform	35
Figure 12	— GPI spike test setup	36
Figure 13	— Current limit for audio frequency ground plane injection	38
Figure 14	— GPI audio frequency test setup	39
Figure 15	— GPI radio frequency test setup	41
Figure 16	— Calibration test setup	43
Figure 17	— Test setup	44
Figure 18	— Radiated emission limit	44
Figure A.1	— Shunt source impedance resulting from the insertion of 10 μ F feed-through capacitors in power feeder and return	67
Figure A.2	— Verification of adequately stiff source impedance	68
Figure A.3	— Load-induced voltage transient switching and test integrity circuit	72
Figure A.4	— Bulk cable injection, tailored limit	76
Figure A.5	— Conducted susceptibility, damped sinusoidal transients, tailored limit	77
Figure A.6	— Transient generator schematic (slightly modified solid-state switch from requirement in Figure A.3)	80

Tables

Table 1 — EMI safety margins.....	7
Table 2 — Ground operations through launch and SV/LV separation.....	9
Table 3 — On-orbit.....	9
Table 4 — Lightning stroke waveform parameters.....	10
Table 5 — Exceptions to MIL-STD-461F Section 4.....	17
Table 6 — Requirement applicability matrix.....	2
Table 7 — Default requirements	25
Table 8 — Radiated emission notches.....	45
Table 9 — Ground operations through launch and SV/LV separation.....	46
Table 10 — On-orbit.....	46
Table A.1 — Multiple scan option.....	65
Table A.2 — Ground plane injection audio frequency limits for AC power systems.....	78

Foreword

This standard has been developed under the sponsorship of the Chief Engineer's office of the United States Air Force Space and Missile Systems Center (SMC) and under the auspices of the AIAA Electromagnetic Compatibility (EMC) Committee on Standards. It is one in a series of standards planned to codify industry best practices to ensure the very highest level of performance and reliability for the next generation of high-reliability space systems. It follows in the footsteps of MIL-STD-1541A, "Electromagnetic Compatibility Requirements for Space Systems and Equipment," but has been thoroughly updated to reflect current industry design practices.

The starting point for this document was "Electromagnetic Compatibility Requirements for Space Systems and Equipment," TOR 2005(8583)-1, 8 August 2005, developed by Mark W. Dunbar of the Electrical and Electronic Systems Engineering Department, Electronics Engineering Subdivision at The Aerospace Corporation. However, as a result of committee deliberations, this standard draws most of its content from MIL-STD-461F and MIL-STD-464A. Additional requirements deemed necessary for high-reliability space systems have been added by the committee.

The intent is to address approximately 80% of space systems. For missions that do not require all the provisions of this standard, or which may need additional requirements, it is understood that tailoring may be performed to balance performance, risk, and cost to suit the needs of a particular program.

The final product reflects the best EMC design and verification practices for high-reliability space systems.

At the time of approval, the members of the AIAA EMC Committee on Standards were:

David Brumbaugh, Co-Chair	The Boeing Company
James Lukash, Co-Chair	Lockheed Martin
Karen Barker	Boeing Corporation
Leard Bell	The Aerospace Corporation
Larry Campbell	MEI Technologies
Joe Chott	General Dynamics
Mark Dunbar	The Aerospace Corporation
Glen Gassaway	General Dynamics
Grant Hellings	Ball Aerospace & Technologies Corp
Ken Jav	EMC Compliance
Haris K...	Honeywell
Alex Crystalinski	Aerojet
Deede Luong	The Boeing Company
Matt McCollum	NASA
Elias Moawad	United Technologies
Paul St Jean	ATK Thiokol
Noel Sargent	Analex Corporation
Bob Shappell	Honeywell

Carl Vogelsang

The Boeing Company

Les Warboys

Northrop Grumman

Ed Whitcomb

United Technologies

Albert Whittlesey

Jet Propulsion Laboratory

The above consensus body approved this document in September 2009.

The AIAA Standards Executive Council (Mr. Amr El Sawy, Chairman) accepted the document for publication in October 2009.

The AIAA Standards Procedures dictate that all approved Standards, Recommended Practices, and Guides are advisory only. Their use by anyone engaged in industry or trade is entirely voluntary. There is no agreement to adhere to any AIAA standards publication and no commitment to conform to or be guided by standards reports. In formulating, revising, and approving standards publications, the committees on standards will not consider patents that may apply to the subject matter. Prospective users of the publications are responsible for protecting themselves against liability for infringement of patents or copyright or both.

1 Scope

This standard is applicable for the procurement of space systems, including spacecraft, space vehicles, launch vehicles, ground systems, and associated equipment/subsystems.

This standard establishes performance and verification requirements for the purpose of ensuring space systems electromagnetic compatibility (EMC), including all electromagnetic environmental effects. Engineering issues that must be addressed in order to achieve system-level EMC are identified herein, with guidance and rationale toward achieving specification compliance.

2 Tailoring

When viewed from the perspective of a specific program or project context, the requirements defined in this standard may be tailored to match the actual requirements of the particular program or project. Tailoring of requirements shall be undertaken in consultation with the procuring agency where applicable.

NOTE Tailoring is a process by which individual requirements or specifications, standards, and related documents are evaluated and made applicable to a specific program or project by selection, and in some exceptional cases, modification and addition of requirements in the standards.

3 Applicable Documents

The following documents contain provisions that, through reference in this text, constitute provisions of this standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies.

AFSPCMAN 9-710, Vol. 3	<i>Range Safety User Requirements Manual, Volume 3 – Launch Vehicles, Payload, and Ground Support Systems Requirements</i>
AFSC DH 1-4 (4 th Ed, Rev 1)	<i>AFSC Design Handbook 1-4</i>
AIAA S-113-2005	<i>Criteria for Explosive Systems and Devices on Space Launch Vehicles</i>
ANSI/IEEE C95.1-2005	<i>Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz</i>
JSC-28596 (2000)	<i>NASA Standard Initiator User's Guide</i>
MIL-HDBK-83575 (1998)	<i>General Handbook for Space Vehicle Wiring Harness Design and Testing</i>
MIL-STD-331C	<i>Fuse and Fuse Components Environmental and Performance Tests</i>
MIL-STD-461F	<i>Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment</i>
MIL-STD-464A	<i>Electromagnetic Environmental Effects Requirements for Systems</i>
MIL-STD-889B	<i>Dissimilar Metals</i>
MIL-STD-1576 Valid Notice 1	<i>Electroexplosive Subsystem Safety Requirements and Test Methods for Space Systems</i>