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Space systems — Electromagnetic interference (EMI) test reporting requirements

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National foreword

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Space systems — Electromagnetic interference (EMI) test reporting requirements

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ISO 24637 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

Throughout this International Standard, the minimum essential criteria are identified by the use of the key word “shall”. Recommended criteria are identified by the use of the key word “should”, and while not mandatory, are considered to be of primary importance in providing serviceable, economical and practical designs. Deviations from the recommended criteria are only permissible after careful consideration, extensive testing and thorough service evaluation have shown alternative methods to be satisfactory.

INTERNATIONAL STANDARD **ISO 24637:2009(E)**

Space systems — Electromagnetic interference (EMI) test reporting requirements

1 Scope

This International Standard provides specific requirements for the content of equipment-level electromagnetic interference (EMI) test report documentation to ensure that sufficient data is provided for subsequent integration analysis of complex space systems. Emphasis is placed on necessary test report augmentation to include additional test data reporting when specifically needed to document any EMI test limit failures for spaceflight hardware.

The requirements presented in this International Standard apply only to EMI test reports at the equipment level. These requirements are particularly important when an EMI test limit non-conformance waiver is requested for spaceflight equipment in lieu of re-design.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14302, *Space systems — Electromagnetic compatibility requirements*

ISO 15864, *Space systems — General test methods for space craft, subsystems and units*

ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories*

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
degradation criteria
minimum performance criteria required for acceptance of the product as specified in the electromagnetic interference test plan

3.1.2
hard upset
degradation of product performance that requires manual (non-automatic) issuance of a reset command or intervening procedure to restore product nominal performance without removal from the system

3.1.3
onset of susceptibility
degradation in product performance of at least one functional characteristic beyond equipment under test parameter tolerance

3.1.4
product specification
equipment under test functional minimum performance requirements with associated accuracy parameters

3.1.5
soft upset
degradation in product performance where that product returns to normal with no operator intervention immediately following the removal of the immunity test stimulus

3.2 Abbreviated terms

EMI electromagnetic interference

EMC electromagnetic compatibility

EUT equipment under test

IF intermediate frequency

LISN line impedance stabilization network

NE network equivalent

4 Equipment-level EMI test reporting requirements

4.1 General reporting requirements

4.1.1 General

The general content of the EMI test report shall be in accordance with ISO/IEC 17025:2005, 5.10.

System-level electromagnetic compatibility (EMC) test reporting shall comply with ISO 15864 and ISO 14302.

4.1.2 Description of the test article

The test article shall be identified by model and serial number. A short functional description of the EUT shall be provided to enable the EMC systems analyst to understand the criticality of function, operating modes and, if known, the significance of interfaces with other equipment in the complete operating system.

This requirement may be met with an associated reference which includes the equipment's functional design description, containing an explanation of nominal signal parameters such as data rate, clock speed, frequency list, IF with bandwidths, and voltage input and output characteristics. A complete description of the test setup shall be supplied in the form of photos and individual wiring harness schematics, including shielding, twisting and grounding/isolation with respect to structure for primary power, secondary power and signal wiring including that of external test loads.

It is expected that the EUT will be tested using cabling and connectors either pre-defined by the test method or that agreed to by the customer, i.e. flight harness configuration. Any deviation from either standard test method wiring configuration or flight harness configuration shall be noted in the test report. Setup, operation, and control settings of any video display that is part of the EUT shall be described.

4.1.3 Supporting documentation

The standard(s) to which the EUT was tested shall be clearly described in the test report. The EMI test report shall reference other supporting documentation containing the functional description and interface wiring, the EMI test plan, EMI test specifications, techniques, "as run" procedures and the daily test log.

4.1.4 Signature information

The EMI test report shall contain the names of the EUT product engineer and the EMI test engineer, including sufficient information so that they may be contacted by telephone or e-mail. The location of the test site shall be identified in the test report.

4.1.5 Summary conclusions

The EMI test report shall contain a summary conclusion narrative, stating either complete compliance with each of the EMI test requirements, or describing any non-conformance with the test limits or approved test procedure, in such cases giving a list of non-conformance reports issued throughout the test.

4.1.6 Modifications to the EUT

A description shall be provided to explain any modification to the EUT during the course of performing the test plan. It shall be made clear in the test report which corrective actions (modification of the EUT during the test) will become part of the flight article, with those test results clearly marked as such.

4.1.7 Procedure variation

A description shall be provided to explain any modification to the test procedure during the course of performing the test plan. Procedure variations shall be made clear in the test report to differentiate between multiple test results, and clearly marked as such.

4.2 Specific reporting requirements

4.2.1 General

The test report shall contain:

a) all the information necessary to reproduce the test;

b) the EUT operating modes in which the emission and susceptibility tests have been performed.

4.2.2 EMI measurement system information

The following EMI measurement system detail shall be included in the EMI test report:

a) test equipment used, software support programme, and calibration certification;

b) photograph and drawings of each unique test setup, including EUT and interfacing cabling;

c) antenna factors and frequency ranges of magnetic and electric field antennas;

d) antenna distance from EUT;

e) transfer impedance of current probes and/or termination impedances provided by LISNs;

f) LISN (NE) transfer function as a function of frequency;

g) description of software operations/calculations used to produce measurement output (scan averaging or peak-hold, antenna factors, cable loss, attenuators, and amplifiers): this description shall include the means used to verify each test method's end-to-end accuracy; if data quality has been compromised due to test conditions, the reason and impact on results shall be stated;

h) measurement system scan speeds, step sizes, and measurement bandwidths as a function of frequency;

i) antenna polarizations used;

j) EUT power source frequency, voltage, nominal operating current, and facility temperature and relative humidity;

k) compression level of active devices (amplifiers) in measurement chain;

l) facility limitations from that requested or required by the test plan and procedures;

m) method of radiated susceptibility field determination and modulation type;

n) grounding configuration of EUT and test support equipment.

4.2.3 EMI measurement reporting resolution

EMI test data shall be reported in graphic form with frequency resolution of 1 %, and decibel notation within 1 dB. For test limit failure conditions, improved data resolution shall be provided as further explained in 4.3.

4.3 Reporting emissions test results

4.3.1 General

Data output of the EUT test result shall be in the form of amplitude over time (for the time domain plots) and amplitude over frequency (for frequency domain plots), superimposed with the EMI test limit. Conducted and radiated interference background plots shall be included for each test configuration unless all emission data are 6 dB below the limit. Test data shall include X and Y legend, date and time recorded and the respective EUT operational mode.

4.3.2 Conducted interference test results

4.3.2.1 General

Each conducted interference test measurement result shall be clear in its intent to measure common-mode or differential-mode current or voltage.

4.3.2.2 Power bus conducted interference, load induced, frequency domain

Data presentation shall be a graphic output of amplitude versus frequency. Units of measurement for frequency domain conducted emissions measurements shall be reported in units of dB referenced to one microvolt (dBuV), or referenced to one microampere (dBuA), depending on which transducer is specified by the test method and its associated limit.

4.3.2.3 Power bus conducted interference, load induced, time domain ripple

Data presentation shall be a graphic output of amplitude versus time, at a time base that best displays the voltage ripple frequency. Oscilloscope plots shall include the amplitude physical unit (V or A) conversion factors V into A, if applicable, and the oscilloscope sensitivity, time base settings and measurement bandwidth. Amplitude resolution shall be within 3 % and time base within 5 %.

4.3.2.4 Power bus load induced switching transients

Data presentation shall be a graphic display of voltage amplitude versus time, or current versus time for in-rush at a time base that best displays the transient characteristic with respect to the applicable limit. Amplitude resolution shall be within 3 % and time base within 5 %.

4.3.2.5 Antenna connection port spurious emissions

4.3.2.5.1 Receivers and transmitters (in standby mode)

Data presentation shall be a graphic output of amplitude versus frequency. Minimum frequency resolution shall be twice the measurement receiver bandwidth, with a minimum amplitude resolution of 1 dB for each graph.

4.3.2.5.2 Transmitters (in transmit mode)

Data presentation shall be graphical, indicating power amplitude within ±1 dB for fundamental transmit frequency, and frequencies of all harmonics and spurious emissions detected by the applicable test method.

4.3.3 Radiated emissions test results

4.3.3.1 Steady state radiated emissions

4.3.3.1.1 a.c. magnetic field

Data presentation shall be a graphic output of amplitude versus frequency. Magnetic field radiated emissions measurements shall be reported in units of dB relative to one picotesla (dBpT). In the event of a non-conformance, the distance at each face shall be recorded at which the EUT meets the emissions limit.

4.3.3.1.2 Electric field

Data presentation shall be a graphic output of amplitude versus frequency. Electric field radiated emissions measurements shall be reported in units of dB relative to one microvolt per metre (dBuV/m). In the event of any emissions test result above 100 MHz that is over the EMI test limit, greater accuracy of its frequency shall be reported with resolution equal to twice the measurement bandwidth.

4.3.3.2 Transient radiated emissions

If an EUT is capable of creating short-duration transients, data output shall report the transient pulse repetition rate, and the broadband frequency distribution over the steady state limit. For a single-event pulse exceeding the steady state limit, the pulse duration at the failed frequency with highest amplitude shall be reported.

4.3.3.3 d.c. magnetic field

For applications requiring a d.c. magnetic cleanliness programme to protect an attitude control system or scientific instruments, static magnetic field test results shall be included in the test report. The data shall be presented graphically in units of magnetic field strength for a 360° rotation about each of the three axes of the EUT, with resolution of 1° (20 mrad).

4.4 Reporting immunity test results

4.4.1 General

A description shall be provided explaining which EUT functional outputs were monitored to verify immunity, including a list of the degradation criteria. If the EUT uses a built-in-test for this function, its operation and thresholds shall be described. The susceptibility criteria defined in the EMI test procedure shall be repeated in the test report, or the “as run” EMI test procedure shall be an annex to the EMI test report. If or when susceptibility is observed, multiple levels of susceptibility shall be determined and recorded in the EMI test report in accordance with 4.4.2 to aid the systems analysis.

4.4.2 Determination of susceptibility

At each frequency, or band of frequencies, the immunity input test level shall be determined as defined by the three categories listed below, with a description of the EUT response(s) recorded for the following conditions:

a) onset of susceptibility indicated by degradation in EUT performance beyond product specification limits or levels;

b) EUT transition from soft upset to hard upset, should it occur at or below full test level;

c) description of degradation of performance with full test level applied.

It is also extremely important to record the immunity test level that would result in the EUT issuing a command (e.g. to a caution and warning system), even though this could be classified as a soft upset for the EUT itself.

4.4.3 Conducted immunity

Data presentation shall be a graphic or tabular output of injected amplitude at each frequency tested. If the EUT does not meet the specified limit for conducted immunity, the failure amplitude test levels and product performance shall be determined and recorded in accordance with 4.4.2 for each failed frequency (or band of frequencies) and for each power lead.

4.4.4 Antenna port immunity

Data presentation shall be a graphic or tabular output of injected amplitude at each frequency tested. If the EUT does not meet the specified limit for antenna port immunity, the failure amplitude test levels and product performance shall be determined and recorded in accordance with 4.4.2.

4.4.5 Radiated immunity, electric and magnetic field

Data presentation shall be a graphic or tabular output of field amplitude at each frequency tested. If the EUT does not meet the specified limit for radiated immunity, the failure amplitude test levels and product performance shall be determined and recorded in accordance with 4.4.2 for each failed frequency (or band of frequencies).

4.4.6 Pulse immunity, lightning and electrostatic discharge

Data presentation shall be a graphic or tabular output of amplitude at each impulse tested. If the EUT does not meet the specified limit, the failure amplitude test levels and product performance shall be determined and recorded for each failure condition in accordance with 4.4. The requirements of 4.4.2 do not apply to electrostatic discharge testing.

Annex A
(informative)

Rationale behind EMI test report requirements

A.1 General

This annex provides an explanation as to why the required information is important to the system analyst, i.e. why is it needed and how will it be used.

This International Standard places emphasis on test reporting in those cases where full compliance cannot be achieved after appropriate re-design efforts. This International Standard requires that additional data be provided to aid in system-level EMC analysis to substantiate granting a waiver to non-compliant spaceflight equipment. In most cases, the additional data required by this International Standard is normally obtained during the course of attempting to determine what re-design efforts are needed to ensure full compliance; however, that data is seldom recorded or reported in an archival way that includes it in the final EMI test report.

Testing of any EUT requires the preparation of a written and approved EMI test plan, as specified in ISO 14302, or other contract requirements for EMI equipment-level testing. This test plan should provide for, and anticipate, what actions will be taken should any test method not result in full compliance. The purpose of this annex is to explain the rationale behind this thought process, in order to help ensure that the data and documentation are complete.

A.2 Rationale for requirements

Many spaceflight programmes contain equipment that is non-critical. Generally speaking, these are one-of-a-kind instruments or elements of a science payload, however, this equipment should not interfere with critical and essential systems (or neighbouring non-critical equipment) on board the same platform. For this reason, it is mandatory that EMI data be acquired and archived in a document that allows for this system-level EMC analysis. This is particularly important when equipment exhibits an over-the-limit radiated emission at a frequency that has the potential to interfere with a victim receiver, or when a combination of equipment could adversely affect power quality. These potential incompatibilities are almost never known by the EUT test laboratory, but are discovered during the EMC analysis process after equipment-level testing is complete. The requirements in this International Standard are intended to provide all the necessary data that is needed to resolve these potential incompatibilities without the need, or limited need, for additional integrated EMC testing. It is not expected that the immunity reporting requirements of this International Standard apply to systems. Requirements in 4.4 could be potentially damaging or degrading at the system level.

A.3 The EMC systems analysis process

Except for on-board intentional emitters, the electromagnetic environment definition is composed of a worst-case envelope of a great variety of radio frequency sources that are possible to be encountered during payload processing, pre-launch operations, launch and ascent, and on-orbit operations. The probability of encountering the maximum defined electromagnetic field at any instant is quite small, but it is possible. It is more likely that the system will encounter a lower “ambient” field which is largely undefined, but can be estimated by the EMC system analyst. For this reason, it is probable that a non-critical EUT that fails to meet the susceptibility test limit at select frequencies at amplitudes not far below that limit may be shown to meet the programme objectives for the system when the proper supporting data required by this International Standard is available. It should be emphasized that equipment which is part of a critical system should meet all EMI test limits.

A.4 Equipment-level EMI test reporting requirements

A.4.1 General reporting requirements

A.4.1.1 General

The EMC system analyst is usually not familiar with the design and functional output characteristics of every EUT comprising the system. For this reason, it is mandatory to include in the EMI test report a sufficient description of the EUT, so that the effect (degradation of performance) on the system caused by any EMI test failure can be evaluated. The test report should contain easily obtainable references that would serve this function like the functional requirements document.

A.4.1.2 Description of the test article

Space systems usually require the use of a single-point grounding power system to minimize intentional current flow through structure. This usually results in a requirement on the EUT to have the power leads isolated from structure. The grounding/isolation configuration of the power return lead should be verified prior to the test and documented in the test report. EMI test results can also be skewed significantly by cabling configuration (shielded versus unshielded wire, foil shield versus braid, pigtail termination versus 360° back shell). Flight-like cabling and connectors should be used to the maximum extent possible and documented in the EMI test report. Video display settings can have a profound effect on both emissions and susceptibility. The video display contained in a EUT should be operated in its most sensitive mode. Contrast controls should be set at maximum, and brightness at maximum or at raster extinction. Colour displays should use white letters on a black background, with character size and characters per line set at the typical number of maximum characters to be displayed. The configuration of video system control settings that are part of the EUT should be reported.

A.4.1.3 Supporting documentation

Requirements for supporting documentation in this International Standard may be satisfied by submission of the EMI test plan and other information as an appendix to the test report. A description of differences between any intended operational configuration and the EMI test configurations needs to be made clear. If a modified or alternate test method was used, the EMI test report shall identify and describe that method, provide justification for its use, and describe how the results obtained through its use correlate with the methods and limits specified by the standard to which the EUT was to be tested.

A.4.1.4 Summary conclusions

It is necessary for the EMI test report to include a concise summary indicating whether the EUT passes or fails each test, and giving margins with respect to the limits to which it was tested. All non-compliances shall be identified such that this information may be used as a reference to review the detailed data provided later in the report. This summary provides the EMC systems analyst with an explanation from the EUT point of view on the severity of the non-compliance, if it should occur in only certain operating modes. If the EUT only passes with specific modifications or special attributes (such as shielded cables), this information shall be included in the summary results.

A.4.1.5 Modifications to the EUT

The test report should be clear as to what configuration applies to the flight hardware when multiple sets of data are included. If modification of the EUT is required to improve its performance, these modifications shall be explained in the test report.

A.4.2 Specific reporting requirements

A.4.2.1 General

EMI test measurement systems are usually operated by computer-controlled software. The measurement data collection, manipulation and output format are typically similar, but are not exactly the same for each system manufacturer. For this reason, this International Standard does not impose specific data presentation formats.

A.4.2.2 Test setup documentation

It is necessary to document the test measurement setup and associated parameters in sufficient detail that the test may be accurately repeated, or in order that the EUT may be integrated into a subsystem or system test, as outlined below.

a) A complete list of all test equipment used should be included in the test report. This information shall include manufacturer's model number and date of last calibration.

b) Photographs and drawings showing each wire (length and placement) of the measurement configuration should be included; do not use one-line diagrams. Block system diagrams are required to show interconnection of EUT loads and other functional units necessary for the test.

c) Antenna factors and frequency ranges for all antennas used during each test are required. This information can aid in determining if output data is noise-floor limited.

d) The required measurement distance/placement of antennas and other transducers should be reported. If this placement is different from the requirement in the test standard, the reason for such a deviation shall be reported. Radiated emissions measurements taken at alternative distances should be reported at the actual distance used.

e) Transducer factors and frequency ranges for all current probes used during each test are required. The termination impedance of all LISNs used in the test setup shall be reported.

f) Transducer factors and frequency ranges for all LISNs used during each test are required.

g) The description of software operations/calculations used to produce measurement output (scan averaging or peak-hold, antenna factors, cable loss, attenuators, and amplifiers) are required to ensure all loss/gain characteristics of the measurement network have been properly accounted for in the data reduction and reporting process. This description should include the means (e.g. current probe calibration fixture) used to verify each test method's end-to-end accuracy.

h) Measurement system scan speeds, step sizes and measurement bandwidths should be documented in the test report to aid in the EMC system analysis process.

i) All radiated emissions data should be accompanied by a description of the antenna polarization position.

j) Overload of the measurement system input is possible when a strong signal compresses either the active transducer (e.g. active rod antenna) or the measurement receiver or spectrum analyzer itself. For transducers, this saturation level should be known and documented in the EMI test report, particularly when measurement data is over the limit.

k) Any compromise of the required EMI test methods, as-written test plan or facility operation should be adequately described in the EMI test report.

l) There are a number of EMI test method standards that are acceptable for determining the radiated immunity applied field, such as E-field probes adjacent to the EUT or the use of a predetermined calibrated volume. The method used should be documented in the EMI test report.

m) It is mandatory that the grounding configuration of the EUT and test support equipment be understood, documented and reported. This information becomes necessary when further integrated testing is required and is used to ensure that ground reference connections of the EUT and its wiring are understood relative to that of the integrated system.

A.4.2.3 EMI measurement reporting resolution

Resolution of 1 dB is required on all plots of amplitude versus frequency. This does not mean (or require) that the data presented are accurate to within 1 dB. Resolution is the capability to distinguish between the relative values on a given graphic output.

When an emission test limit cannot be met, greater frequency resolution is required to assess the compatibility with intentional receivers in the complete system. This resolution should ideally be less than or equal to the victim receiver bandwidth.

A.4.3 Reporting emissions test results

A.4.3.1 Transient radiated emissions

If an EUT produces short-duration radiated emission pulses in excess of the steady state limit, its characteristics should be reported in both the time domain (for duration and pulse repetition rate) and in the frequency domain (for its broadband characteristic). Typical sources of single-event transient electric and magnetic field radiated emissions might include spark igniters, pulsed thrusters, or when switching high inductance loads.

A.4.3.2 Reporting immunity test results

Most EMI test method standards only require that the onset of susceptibility be reported in the event of degradation of performance. For spaceflight equipment, it is essential to understand the response of the EUT in detail, and its possible effect on the system, when any susceptibility is observed during immunity testing. In those cases where the immunity test requirement cannot be met, this International Standard requires that multiple levels of susceptibility be reported as the immunity test level is increased from the initial observed response through full test level. If an EUT is expected to apply for a waiver of non-compliance when used in a spaceflight system, one measurement of susceptibility alone is insufficient. Data should be supplied not only to report the onset of interference, but also to report the EUT response at the conditions in 4.4.2 up to the full immunity test level, even if that response is limited to a soft upset. It is extremely important to report any immunity test level that results in a transition from a soft upset to a hard upset, which requires an external command or action to restore the EUT to nominal performance once the immunity stimulus is removed.

A.4.3.3 Determination of susceptibility

In order to accurately report the onset of susceptibility, the immunity test signal shall be reduced until the EUT susceptibility response disappears, continuing to reduce the immunity input signal by an additional 6 dB. The immunity test signal shall then be increased slowly until the response threshold re-occurs, and this value shall be recorded.

A.4.3.4 Electric field

This test data is required primarily to protect receiver in-band sensitivity. In order to evaluate the interference to a receiver properly, it is necessary to know the EUT interfering frequency more precisely. If the victim receiver bandwidth is not known, reporting frequency resolution equal to twice the measurement bandwidth is usually sufficient (for EUT test results over the radiated emissions limit). Ideally, the measurement bandwidth should be equal to the victim receiver bandwidth.

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