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MIL-STD461G: Introduction and Differences from Previous Versions

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MIL-STD, changes in the last 2 decades

- 1993: MIL-STD-461D and MIL-STD-462D: remain the major "revolution" in military EMI standards
- 1999: MIL-STD-461E combined MIL-STD-461 and MIL-STD-462 into a single standard
- 1999: MIL-STD-462 obsolete
- 2007: MIL-STD-461F, and provided a number of changes from MIL-STD-461E, but the changes were minor in nature when compared to the changes between revisions D and E.

MIL-STD-461F requirement applicability

Equipment and Subsystems Installed In, On, or Launched From the Following Platforms or Installations	Requirement Applicability																	
	CE101	CE102	CE106	CS101	CS103	CS104	CS105	CS106	CS109	CS114	CS115	CS116	RE101	RE102	RE103	RS101	RS103	RS105
Surface Ships	A	A	L	A	S	S	S	A	L	A	S	A	A	A	L	A	A	L
Submarines	A	A	L	A	S	S	S	A	L	A	S	L	A	A	L	L	A	L
Aircraft, Army, Including Flight Line	A	A	L	A	S	S	S			A	A	A	A	A	L	A	A	L
Aircraft, Navy	L	A	L	A	S	S	S			A	A	A	L	A	L	L	A	L
Aircraft, Air Force		A	L	A	S	S	S			A	A	A		A	L		A	
Space Systems, Including Launch Vehicles		A	L	A	S	S	S			A	A	A		A	L		A	
Ground, Army		A	L	A	S	S	S			A	A	A		A	L	L	A	
Ground, Navy		A	L	A	S	S	S			A	A	A		A	L	A	A	L
Ground, Air Force		A	L	A	S	S	S			A	A	A		A	L		A	

Legend:

A: Applicable
L: Limited as specified in the individual sections of this standard
S: Procuring activity must specify in procurement documentation

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Minor changes in MIL-STD-461F

More details about cable layout:

- shall always be based on actual installation, and
- when unknown, 2 m aligned with EUT

CS116: More details about probe positioning

RE102: Rod antenna:

- bonding the cable to the ground plane and using a common mode choke to reduce cable currents influencing the test results

RE102: 20dB higher level for below deck equipment

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MIL-STD-461G

11 December 2015: MIL-STD-461G

Most structural changes:

- Two new requirements
  - CS117: lightning indirect effects based on the RTCA DO160
  - CS118: personnel electrostatic discharge based on AECTP 501
- One requirement deleted
  - CS106: removed also in E, added in MIL-STD-461F, but removed again in G

MIL-STD-461G requirement applicability

Equipment and Subsystems Installed In, On, or Launched From the Following Platforms or Installations	Requirement Applicability																		
	CE101	CE102	CE106	CS101	CS103	CS104	CS105	CS109	CS114	CS115	CS116	CS117	CS118	RE101	RE102	RE103	RS101	RS103	RS105
Surface Ships	A	A	L	A	S	L	S	L	A	S	A	L	S	A	A	L	L	A	L
Submarines	A	A	L	A	S	L	S	L	A	S	L	S	S	A	A	L	L	A	L
Aircraft, Army, Including Flight Line	A	A	L	A	S	S	S		A	A	A	L	A	A	A	L	A	A	L
Aircraft, Navy	L	A	L	A	S	S	S		A	A	A	L	A	L	A	L	L	A	L
Aircraft, Air Force		A	L	A	S	S	S		A	A	A	L	A		A	L		A	
Space Systems, Including Launch Vehicles		A	L	A	S	S	S		A	A	A	L			A	L		A	
Ground, Army		A	L	A	S	S	S		A	A	A	S	A		A	L	L	A	
Ground, Navy		A	L	A	S	S	S		A	A	A	S	A		A	L	L	A	L
Ground, Air Force		A	L	A	S	S	S		A	A	A		A		A	L		A	

Legend:

A: Applicable

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Changes MIL-STD-461G

Definition on 'exposed below deck' added

Calibration (F) **is now 'Measurement system integrity check'**

More details, which should have been known by test engineers:

4.3.6 Power source impedance.

- **LISNs shall be electrically bonded to the test ground plane or facility ground as required and the bond resistance shall not exceed 2.5 milliohms.**

4.3.7.2 Excess personnel and equipment

- **All equipment and ancillary gear including antennas that are not being actively used for a particular subset of radiated tests shall be removed from the test area or shielded enclosure**

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Changes MIL-STD-461G

4.3.8.2 Bonding of EUT

- **Bonding of the EUT to the ground plane shall be verified to be in accordance with the installation drawings or equipment specification before connecting cables and EMI testing.**

4.3.8.6.1 Interconnecting leads and cables.

- Remaining cable lengths shall be routed to the back of the setup, **positioned 5 cm above the ground plane**, and shall be placed in a zigzagged arrangement, **minimizing cable overlap or crossing. ……** All cables shall be supported 5 cm above the ground plane **with non-conductive material such as wood or foam. If the EUT is a tall cabinet and the cables are routed from top or near the top, then the cables shall be routed down to the bench ground plane and then 2 meters shall be run parallel to the front edge of the boundary. If the EUT is a floor standing unit and the cables are routed from the top, then the cables shall be routed down to the bench ground plane and then 2 meters shall be run parallel to the front edge of the boundary. If the cables are routed from the bottom, then the cables shall be routed up to the bench ground plane and then 2 meters shall be run parallel to the front edge of the boundary**

Changes MIL-STD-461G

4.3.8.6.2 Input (primary) power leads.

- The total length of power lead from the EUT electrical connector to the LISNs shall not exceed 2.5 meters, **except for large EUTs, where the cables are routed from the top of a tall EUT or bottom of a floor standing cabinet, then the total length may exceed 2.5 meters, but shall be kept at a minimum.** All power leads shall be supported 5 cm above the ground plane **with non-conductive material such as wood or foam.**

Changes MIL-STD-461G

4.3.10 Use of measurement equipment.

- Measurement receivers using Fast Fourier Transform (FFT) time domain measurement techniques are acceptable for use, as long as Table II parameters are directly user accessible and can be verified.

- Note: FFT Receivers. FFT measurement techniques may be used provided that FFT operation is in accordance with ANSI C63.2. The user interface of the measurement receiver must allow for the direct input of the parameters in Table II for both FFT Time Domain and Frequency Stepped modes of measurement in the same manner, without the necessity or opportunity to control FFT functions directly.

Changes MIL-STD-461G

Frequency Range	6 dB Resolution Bandwidth	Minimum Dwell Time		Minimum Measurement Time Analog-Tuned Measurement Receiver [1/]
		Stepped-Tuned Receiver [1/] (Seconds)	FFT Receiver [2/] (Seconds/ Measurement Bandwidth)	
30 Hz - 1 kHz	10 Hz	0.15	1	0.015 sec/Hz
1 kHz - 10 kHz	100 Hz	0.015	1	0.15 sec/kHz
10 kHz - 150 kHz	1 kHz	0.015	1	0.015 sec/kHz
150 kHz - 10 MHz	10 kHz	0.015	1	1.5 sec/MHz
10 MHz - 30 MHz	10 kHz	0.015	0.15	1.5 sec/MHz
30 MHz - 1 GHz	100 kHz	0.015	0.15	0.15 sec/MHz
Above 1 GHz	1 MHz	0.015	0.015	15 sec/GHz

Changes MIL-STD-461G

4.3.10.4.3 Thresholds of susceptibility

- **Determine the worst-case failure frequency within the failure bandwidth by manually tuning the frequency, iteratively reducing the step size by a factor of two until the lowest threshold is determined.**

4.3.11 Calibration of measuring equipment.

- **Primary measurement devices** and accessories required for measurement in accordance with this standard shall be calibrated in accordance with ISO/IEC 17025 or ISO 10012 or under an approved calibration program traceable to the National Institute for Standards and Technology.
- **After the initial calibration passive devices such as measurement antennas, current probes, and LISNs, require no further formal calibration unless the device is repaired. The measurement system integrity check in the procedures is sufficient to determine acceptability of passive devices.**

Changes MIL-STD-461G, CE101

F: 5.4 CE101, conducted emissions, power leads, 30 Hz to 10 kHz

G: 5.4 CE101, conducted emissions, audio frequency currents, power leads.

- For Navy aircraft, this requirement is applicable only if the platform contains **equipment, which operate between 30 Hz and 10 kHz, such as Acoustic (Sonobouy) Receivers or Magnetic Anomaly Detectors (MAD).**
- **Some minor details, including renaming** Calibration (F) **to Measurement system integrity check (G)**

Changes MIL-STD-461G, CE102

F: 5.5 CE102, conducted emissions, power leads, 10 kHz to 10 MHz.

- Calibration
- Ensure that the EUT power source is turned off.

G: 5.5 CE102, conducted emissions, radio frequency potential, power leads.

- **Measurement system integrity check**
- **Ensure that the LISN power source is disconnected.**

Changes MIL-STD-461G, CE102

Calibration(F) **is now Measurement system integrity check(G)**

- Apply a signal level **of 90 dBµV at 10.5 kHz** and 100 kHz to the power output terminal of the LISN. At 10.5 kHz and 100 kHz, use an oscilloscope, **in high impedance mode, to verify that there is a proper signal level at the LISN and** verify that it is sinusoidal. **After establishing the proper signal at the LISN, disconnect LISN and measure resulting voltage using an oscilloscope with 50 ohm input impedance. The ratio of the LISN voltage to the 50 ohm voltage measurement must be within the following tolerances: at 10.5 kHz = -14 dB (+1 dB/-2 dB) and at 100 kHz = -3 dB (+1 dB/-2 dB)**
- Apply a signal level that is at least 6 dB below the limit at **10.5 kHz**, 100 kHz, **1.95 MHz and 9.8 MHz** to the power output terminal of the LISN. **At 10.5 kHz** and 100 kHz, use an oscilloscope to calibrate the signal level. **At 1.95 MHz and 9.8 MHz,** use a calibrated output level directly from a 50 Ω signal generator.

Changes MIL-STD-461G, CE106

F: 5.6 CE106, conducted emissions, antenna terminal, 10 kHz to 40 GHz.

G: 5.6 CE106, conducted emissions, antenna port.

Added:

- The transmit mode portion of this requirement is not applicable within the bandwidth of the EUT transmitted signal or within ±5 percent of the fundamental frequency, whichever is larger. **For Navy shipboard applications with peak transmitter power greater than 1 kW, the 5% frequency exclusion will be increased by an additional 0.1% of the fundamental frequency for each dB above 1 kW of peak power. Frequency Exclusion = ± f * (0.05 + (0.001/dB) * (PtPk [dBm] – 60 [dBm]))**

Changes MIL-STD-461G, CE106

And also the requirement changed:

- Transmitters and amplifiers (transmit mode): Harmonics, except the second and third, and all other spurious emissions shall be at least 80 dB down from the level at the fundamental. The second and third harmonics shall be suppressed to a level of -20 dBm or 80 dB below the fundamental, whichever requires less suppression. **For Navy shipboard applications, the second and third harmonics will be suppressed to a level of -20 dBm and all other harmonics and spurious emissions shall be suppressed to -40 dBm, except if the duty cycle of the emissions are less than 0.2%, then the limit may be relaxed to 0 dBm.**

Changes MIL-STD-461G, CS101

F: 5.7 CS101, conducted susceptibility, power leads, 30 Hz to 150 kHz.

G: 5.7 CS101, conducted susceptibility, power leads.

- This requirement is applicable from 30 Hz to 150 kHz for equipment and subsystem AC, limited to current draws ≤ 30 amperes per phase, and DC input power leads, not including returns. **This is also applicable to systems that draw more than 30 amps if the system has an operating frequency 150 kHz or less and an operating sensitivity of 1 µV or better (such as 0.5 µV).**

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Changes MIL-STD-461G, CS101

And in test procedure:

- This test procedure is used to verify the ability of the EUT to withstand signals coupled onto input power leads. **There are two methods provided for making measurements of the applied signal. The first uses an oscilloscope with a power input isolation transformer. The second uses a measurement receiver together with a transducer. The transducer electrically isolates the receiver from the EUT power and reduces the levels to protect the receiver.**

In Appendix:

- **See next page**

Changes MIL-STD-461G, CS101

In Appendix:

- Below 10 kHz there is a possibility that a portion of the injected signal will drop across the power source rather than the test sample power input. Therefore, below 10 kHz when the specification limit potential cannot be developed across the test sample power input and the precalibrated power limit has been reached, it is incumbent on the tester to check that the missing signal level is not being dropped across the power source. If the missing potential is there (usually due to high impedance test facility EMI filters), then steps should be taken to lower the source impedance. This can be done on DC power by using a larger capacitor (~10,000 µF) in parallel with the 10 µF capacitor. With AC power, this isn't possible and the best approach is to bypass facility EMI filters entirely, bringing unfiltered power into the room.

Changes MIL-STD-461G, CS103, CS104

- F: 5.8 CS103, conducted susceptibility, antenna port, intermodulation, 15 kHz to 10 GHz.
- **G: 5.8 CS103, conducted susceptibility, antenna port, intermodulation.**
- F: 5.9 CS104, conducted susceptibility, antenna port, rejection of undesired signals, 30 Hz to 20 GHz.
- **G: 5.9 CS104, conducted susceptibility, antenna port, rejection of undesired signals.**
  - **For Navy ships and submarines, this requirement is applicable for all receivers. The applicable frequencies are a function of the front-end design of the unit being evaluated.**

Changes MIL-STD-461G, CS105, ~~CS106~~, CS109

- F: 5.10 CS105, conducted susceptibility, antenna port, cross modulation, 30 Hz to 20 GHz.
- **G: 5.10 CS105, conducted susceptibility, antenna port, cross modulation.**
- F: 5.11 CS106, conducted susceptibility, transients, power leads.
- **G: deleted**
- F: 5.12 CS109, conducted susceptibility, structure current, 60 Hz to 100 kHz.
- **G: 5.11 CS109, conducted susceptibility, structure current.**

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Changes MIL-STD-461G, CS114

F: 5.13 CS114, conducted susceptibility, bulk cable injection, 10 kHz to 200 MHz.

G: 5.12 CS114, conducted susceptibility, bulk cable injection.

- **For EUTs intended to be installed on ships or submarines, an additional common mode limit of 77 dBµA is applicable from 4 kHz to 1 MHz on complete power cables (highs and returns - common mode test): was in F in body text**

Changes MIL-STD-461G, CS114

- Requirements are also met if the EUT is not susceptible at forward power levels sensed by the directional coupler that are below those determined during calibration provided that the actual current induced in the cable under test is ~~6 dB or greater than the calibration limit.~~ **Curve 5 = 115 dBµA, Curve 4 = 103 dBµA, Curve 3 = 95 dBµA, Curve 2 = 89 dBµA and Curve 1 = 83 dBµA across the frequency range.**

Changes MIL-STD-461G, CS114

- It is important to note that the test signal is inductively coupled and that Faraday's law predicts an induced voltage in a circuit loop with the resultant current flow and voltage distribution dependent on the various impedances present. **For this reason, the test method under MIL-STD-461G reverts to an older method that was used in MIL-STD- 461D and MIL-STD-462D. Instead of leveling primarily on the cable-induced current, the precalibrated forward power is the primary target, with only a frequency-independent induced cable current limit equal to 6 dB above the flat (maximum) portion of the applicable limit. With this older method, which is found in SAE ARP1972, and RTCA DO-160C/D, the relationship between the Bulk Cable Injection (BCI) cable currents and those induced by radiated fields will agree more closely for shielded cables, while being no different for unshielded cables. It should be noted that the method used for MIL-STD-461E and MIL-STD-461F works well with heuristically determined cable currents such as in DEF STAN 59-411, because there the previously measured cable current is in fact the target, not the precalibrated forward power. With limits based on the physics of field-to-wire coupling as described in previous paragraphs, controlling the induced potential and allowing the current to be determined by the cable impedance is the proper technique.**

Changes MIL-STD-461G, CS114

- Ideal bulk cable monitor probes would have no effect on the circuit under test. In reality, there is a transfer function associated with insertion into the calibration or test circuit (not to be confused with insertion loss). However, a well-engineered probe might introduce only a 1 dB response change after introduction into the 100 Ω calibration circuit. There are other problems that may be encountered when conducting a bulk cable test (e.g. loose or damaged connections and center pins, damaged cables, bad attenuators, bad terminations, overheated injection or monitor probe and incorrect monitor probe factors). In computer controlled systems, it is possible to cross the two spectrum analyzers or use of the probe outside of an appropriate band without realizing it. These will never be discovered while conducting the test. Therefore, revision G adds the monitoring probe to the calibration step and a new verification step was added.

Changes MIL-STD-461G, CS115, CS116

- F: 5.14 CS115, Conducted susceptibility, bulk cable injection, impulse excitation.
- **G: 5.13 CS115, Conducted susceptibility, bulk cable injection, impulse excitation.**

- F: 5.15 CS116, conducted susceptibility, damped sinusoidal transients, cables and power leads, 10 kHz to 100 MHz.
- **G: 5.14 CS116, conducted susceptibility, damped sinusoidal transients, cables and power leads.**

Changes MIL-STD-461G, CS117, New

5.15 CS117, conducted susceptibility, lightning induced transients, cables and power leads.

- This requirement is applicable to all safety-critical equipment interconnecting cables, including complete power cables, and individual high side power leads.
  This requirement also has limited applicability to surface ship equipment which have *cables routed above deck*.

- The CS117 test is based on the RTCA, Section 22, Lightning Induced Transient Susceptibility.

Changes MIL-STD-461G, CS118, New

G: 5.16 CS118, personnel borne electrostatic discharge.

- Already in the NATO AECTP, based on the IEC 61000-4-2 ESD test

Changes MIL-STD-461G, RE101, RE102

F: 5.16 RE101, radiated emissions, magnetic field, 30 Hz to 100 kHz.

G: 5.17 RE101, radiated emissions, magnetic field.

- **Using an ohmmeter, verify that the resistance of the loop sensor winding is between 5 and 10 ohms. (**was: approximately 10 ohms.)

F: 5.17 RE102, radiated emissions, electric field, 10 kHz to 18 GHz.

G: 5.18 RE102, radiated emissions, electric field.

- Topside: **now Above deck and exposed below deck**

Changes MIL-STD-461G, RE103, RS101

- F: 5.18 RE103, radiated emissions, antenna spurious and harmonic outputs, 10 kHz to 40 GHz.
- **G: 5.19 RE103, radiated emissions, antenna spurious and harmonic outputs.**
- F: 5.19 RS101, radiated susceptibility, magnetic field, 30 Hz to 100 kHz.
- **G: 5.20 RS101, radiated susceptibility, magnetic field.**

Changes MIL-STD-461G, RS103

F: 5.20 RS103, radiated susceptibility, electric field, 2 MHz to 40 GHz.

G: 5.21 RS103, radiated susceptibility, electric field.

- **For receiver EUTs having permanently attached antennas only, unless otherwise stated in the system specification, reduced performance over the intended receiver band of operation is allowed. The receiver shall meet its performance requirements after in-band exposure to the radiated field.**
- **Position sensors at same distance as the EUT is located from the transmit antenna and in the plane of the test setup boundary edge closest to the antenna.**

In appendix:

- **See next page**

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Changes MIL-STD-461G, RS103

In appendix:

- When testing large equipment, there may be a need to use antennas with wider beamwidths so that the EUT and sensor are within the 3dB beamwidth. It may also be achieved by moving the antenna farther away to satisfy the requirement. This may require the use of more powerful amplifiers to achieve the required field strength.

Changes MIL-STD-461G, RS105

- F: 5.21 RS105, radiated susceptibility, transient electromagnetic field.
- **G: 5.22 RS105, radiated susceptibility, transient electromagnetic field.**

Changes MIL-STD-461G, Appendix

Appendix, filtering:

- **Additionally, this requirement is used as a control to limit the total line to ground capacitance of the ungrounded electrical distribution system for the performance of the ground fault detection circuitry and for the restraint of hull currents and line to ground voltages. Excessive line to ground capacitance will desensitize the ground fault detectors and may cause erroneous ground fault indications in some cases. If unbalanced, line to ground capacitance may produce unwanted hull currents and can form a resonant L-C circuit when combined with inductances from motors, transformers, and cabling for damaging overvoltage to ground. It should be noted that this requirement is applicable to all line to ground capacitance that is not transformer isolated from primary power.**
- **Text** "This will, in turn, limit the power line current to 5 mA which is consistent with leakage current (safety) requirements." **removed because it is not correct**

Changes MIL-STD-461G, Appendix

Appendix, modulation of susceptibility test signals

- Starting in MIL-STD-461G, verification of the presence of correct modulation by monitoring output signals is specified in the CS114 and RS103 sections. Correct modulation is essential for evaluating EUT performance. Many items will respond readily to a modulated signal and not to a continuous wave source. Modulation sources are internal to some signal generators. Other signal generators require an external source. Simple forget fulness to apply modulation, improper settings, or lack of visible indications of modulation on instrumentation displays can all result in deficient testing.

Questions?