



MIL-STD-461G

Highlights & Under-the-Radar Subtleties



Ken Javor
EMC Consultant

MIL-STD-461G

METRIC

MIL-STD-461G
11 December 2015
SUPERSEDING
MIL-STD-461F
10 December 2007

DEPARTMENT OF DEFENSE INTERFACE STANDARD

REQUIREMENTS FOR THE CONTROL OF
ELECTROMAGNETIC INTERFERENCE
CHARACTERISTICS OF SUBSYSTEMS AND
EQUIPMENT



- USAF is the preparing activity for MIL-STD-461 (and MIL-STD-464). A Tri-Service Working Group (TSWG = Army, Navy, Air Force, industry representatives) is convened on a five-year cycle to review the standard and make recommendations as to whether to keep as-is or revise.
- Released 11 December 2015
- Applies to programs let after 11 December 2015.

In depth review in this year's recent ITEM publication, and here:

<http://www.interferencetechnology.com/mil-std-461g-compleat-review/>

MIL-STD-461G

- The most change in the standard since the C→D revision process.
- But still nothing like that revolutionary change. Still an evolutionary process.
- Two “brand new” (okay borrowed) requirements. One deleted requirement.
 - CS117 Indirect lightning effects added
 - CS118 PEsD added
 - CS106 deleted
- Several themes run through MIL-STD-461D/E/F/G:
 - Measurement system integrity checks, which attain a greater recognition/importance in “G” than ever before.
 - Balance between technically correct and what a majority of test labs can properly perform on a regular basis.
 - Responding to abuses of the clear technical intent of the standard by “EMC lawyers.”
 - Fixing abuses – “come on, people!”

4.3.11 Equipment Calibration

Added verbiage: ““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.”

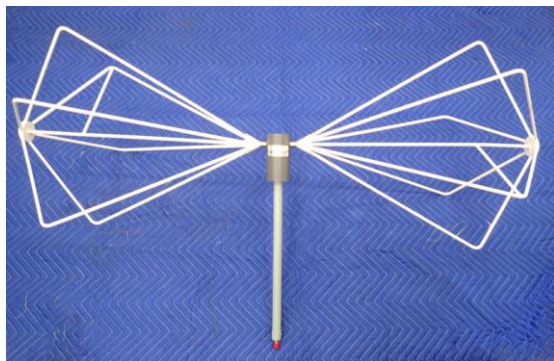
Section 4.3.11 only requires routine NIST traceable calibration for devices such as EMI receivers, spectrum analyzers, oscilloscopes, and electric field strength meters. Passive devices and even items like low noise preamplifiers and rod antenna electronics can be verified by the measurement system integrity check and the test facility can verify proper operation in accordance with SAE AIR 6236.

Measurement system integrity checks, unique to MIL-STD-461, attain a greater recognition/importance in “G” than ever before, because of this change. The CE102 measurement system integrity check is augmented, and CS114 adds a measurement system integrity check



SAE AIR 6236

<http://www.interferencetechnology.com/air-mil-std-461g/>



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AEROSPACE INFORMATION REPORT



AIR6236™

REV. A

Issued 2015-12

Revised
Proposed
Draft
2016-01-06

Superseding AIR6236

In-House Verification of EMI Test Equipment

RATIONALE

MIL-STD-461 no longer requires the routine calibration of many types of EMI test equipment. This AIR provides the EMI test facility with procedures that can be performed in-house using their own EMI test equipment to check that the devices no longer requiring calibration nevertheless are performing properly to manufacturer's specifications. These procedures can be performed to check that the transducer factors entered into EMI test software haven't changed, or in the case where a MIL-STD-461 measurement system integrity check indicates a problem, they serve as a quick check of the transducer's integrity.

INTRODUCTION

MIL-STD-461G does not require certain types of test equipment to be periodically calibrated in a traceable manner. This aerospace information report provides guidance on how to self-check such devices, using equipment commonly found in EMI test facilities. The purpose is not to calibrate these devices, but to check that they have not varied significantly from manufacturer's specifications.

1. SCOPE

This AIR provides guidance to the EMI test facility on how to check performance of the following types of EMI test equipment

- Current probe
- Line Impedance Stabilization Network (LISN)
- Directional coupler
- Attenuator
- Cable loss
- Low noise preamplifier
- Rod antenna base
- Passive antennas

All performance checks can be performed without software. A computer may be required to generate an electronic or hard copy of data. This is not to say that custom software might not be helpful; just that the procedures documented herein specifically eschew the necessity of automated operation.

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Abuse of MIL-STD-461 intent by “EMC lawyers.”

MIL-STD-461G forbids the use of pre-calibrating the RS103 electric field above 1 GHz. It used to be allowed above 1 GHz, but no longer.

Section 5.17.1 RE102 applicability under MIL-STD-461F:

“... The requirement does not apply at the transmitter fundamental frequencies and the necessary occupied bandwidth of the signal.”

Section 5.18.1 RE102 applicability under MIL-STD-461G:

“... this requirement does not apply at the transmitter fundamental frequency and the necessary occupied bandwidth of the signal.”

Wise guy lawyer type



Crotchety old
EMC engineer
type

Come on, people!

MIL-STD-461G Section 4.3.8.2 formalizes a requirement to perform bond checks on the test sample enclosure prior to EMI testing, *and prior to cable connection.*

Section 4.3.6 requires LISNs to be bonded to the ground plane with a 2.5 milliohm resistance.

Section 4.3.7.2 requires that only the antenna in use be located in the test chamber during RE/RS testing. Translation: the anechoic-lined shield room is a test chamber, not a broom closet.

Sections 4.3.8.6.1 and 4.3.8.6.2 require the 5 cm above ground cable standoff be achieved using “non-conductive material such as wood or foam.” And that the entire length of the cable, not just the two meters exposed to the antenna, be so-supported above the ground plane. So no more using rf absorber material for that purpose, folks!



“Doh!”

Requirement frequency ranges moved from title to applicability sub-section

An editorial change is that frequency ranges are no longer listed in the individual requirement titles, but rather moved to the applicability subsection, where they more naturally belong.

Many requirements have different start and stop frequencies depending on Service and application.

MIL-STD-461G

5.21 RS103, radiated susceptibility, electric field.

5.21.1 RS103 applicability.

This requirement is applicable for equipment and subsystem enclosures and all interconnecting cables. The requirement is applicable as follows:

- a. 2 MHz to 30 MHz Army, Navy and optional* for all others
- b. 30 MHz to 18 GHz All
- c. 18 GHz to 40 GHz Optional* for all

*Required only if specified in the procurement specification

For Army and Air Force: there is no requirement at the tuned frequency of antenna-connected receivers.

MIL-STD-461F

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

5.20.1 RS103 applicability.

This requirement is applicable to equipment and subsystem enclosures and all interconnecting cables. The requirement is applicable as follows:

- a. 2 MHz to 30 MHz Army ships; Army aircraft, including flight line; Navy (except aircraft); and optional* for all others
- b. 30 MHz to 100 MHz all (except Navy aircraft)
- c. 100 MHz to 1 GHz all
- d. 1 GHz to 18 GHz all
- e. 18 GHz to 40 GHz optional* for all

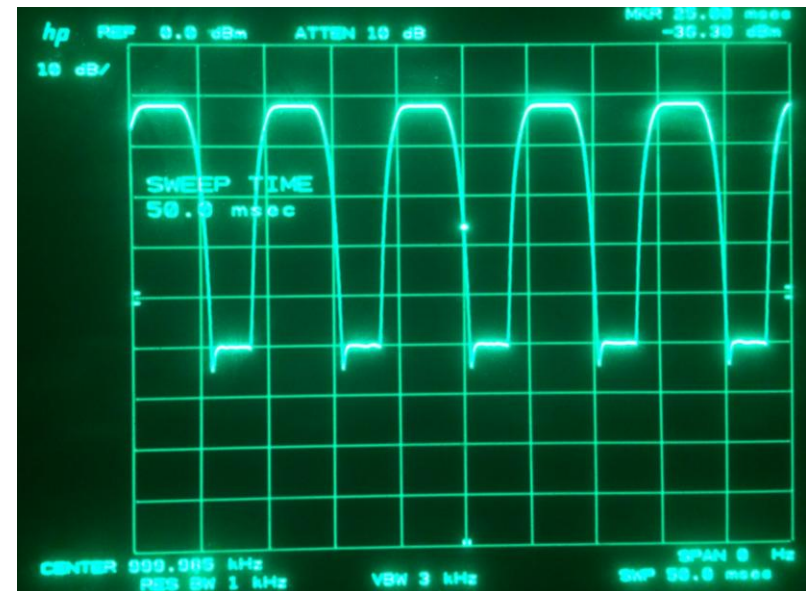
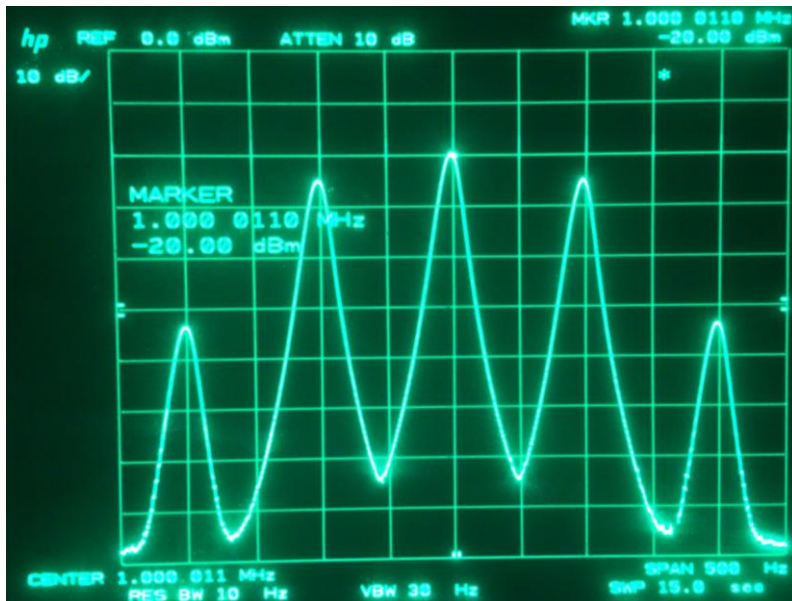
*Required only if specified in the procurement specification

There is no requirement at the tuned frequency of antenna-connected receivers except for surface ships and submarines.

Changes to susceptibility procedures

Section 4.3.10.4.2 (modulation of susceptibility signals) doesn't say so, but now both CS114 and RS103 both require demonstration that the required modulation has been applied. This is most easily done in zero-span mode and measuring the correct on-off timing and also the 40 dB on-to-off ratio.

Section 4.3.10.4.3 (thresholds of susceptibility) now requires “zeroing in” on the frequency of greatest susceptibility within the susceptibility band.



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Stepping through
the standard...



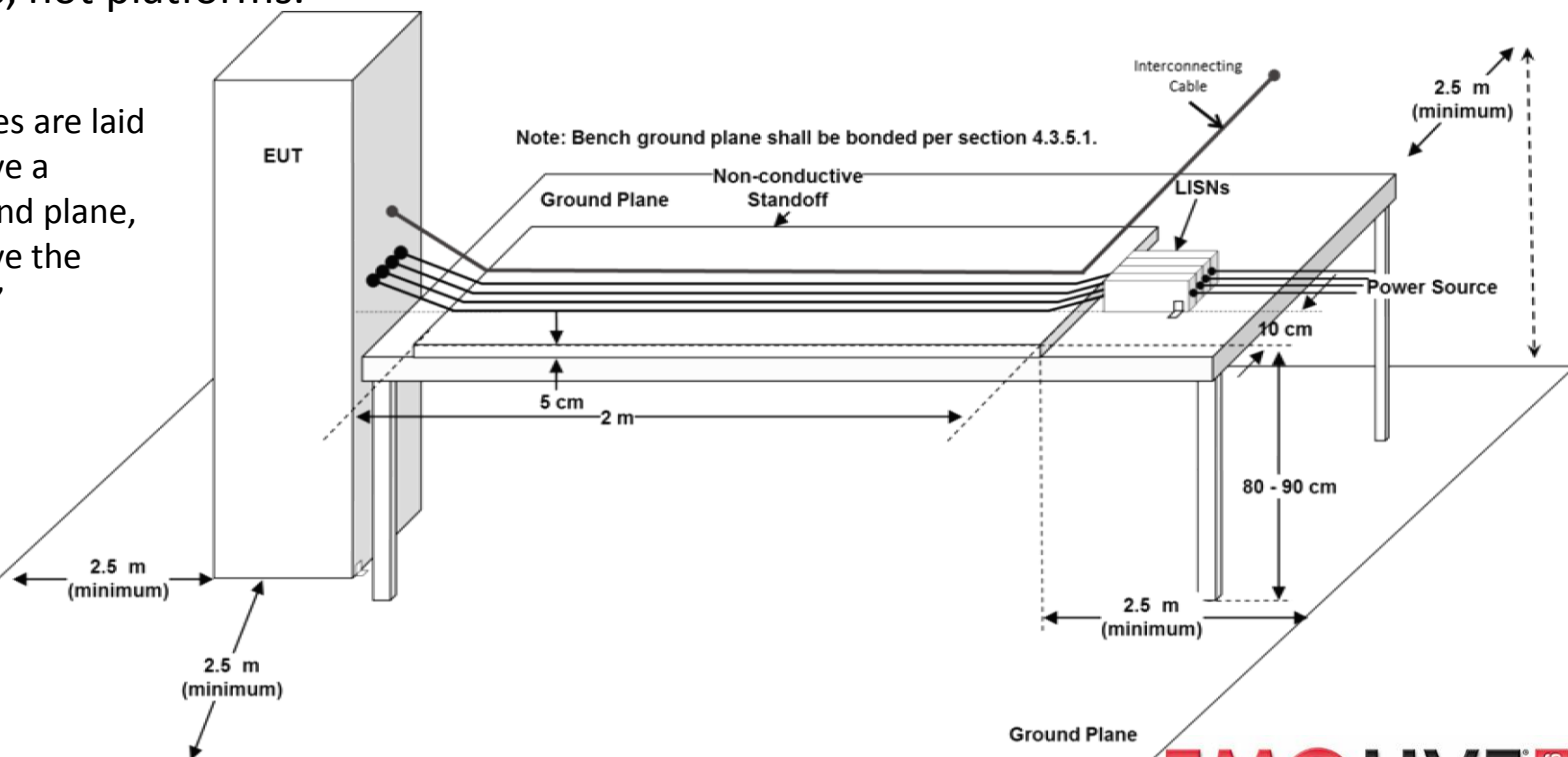
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AREA EMCS

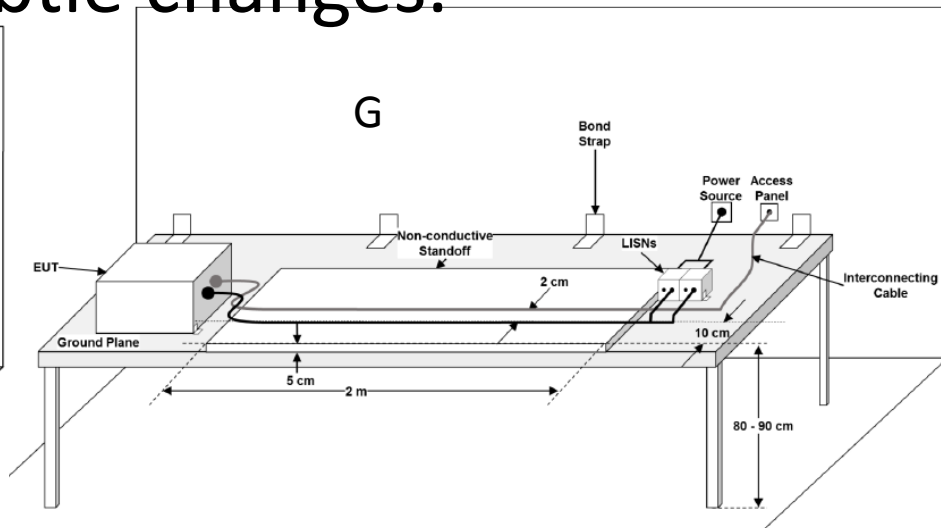
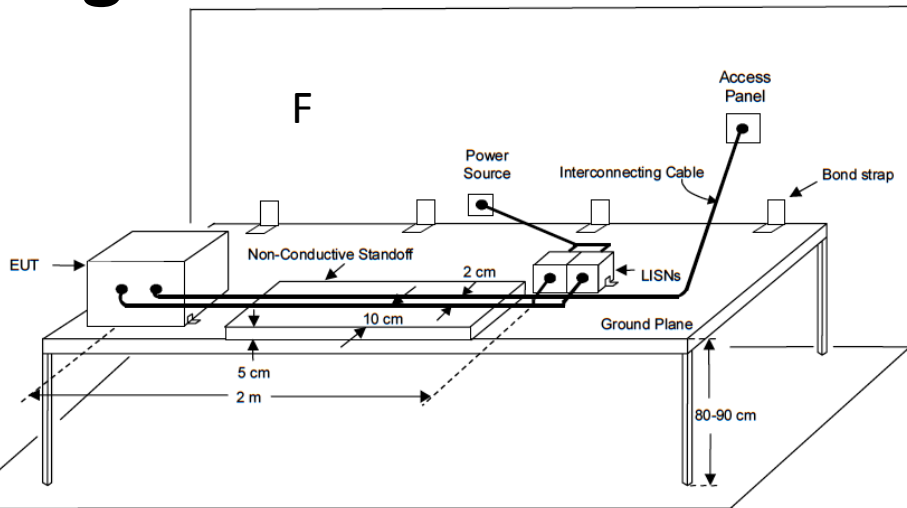
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Section 4.3.5.1 (metallic ground plane) , augmented by brand new Figure 5 requires 2.5 meters in any direction from the edge of the test set-up boundary to the edge of the ground plane, as compared to 1.5 meters in earlier versions of the standard. The change was based on the desire to have the ground plane underneath the entire set-up, antennas used in various tests, and distance beyond the backside of any such antenna still covered with ground plane. Also note Figure 5 replaces what looked like a truck or other wheeled vehicle (but wasn't supposed to) with something that looks like an electronics enclosure. It is important to always reinforce that MIL-STD-461 applies to equipments and subsystems, not platforms.

Also, the cables are laid out 5 cm above a tabletop ground plane, not 5 cm above the floor, as in "F."



Figures 2 – 5 have two subtle changes.



1 – Test sample enclosures are oriented so that the connector side faces the way the cables are laid down the length of the tabletop, as opposed to in previous versions, where the connector side faces the front of the table.

2 - These figures are now titled “general.” Complex enclosures with lots of cables and/or long EMI backshells with large cable bend radii will follow the new setup, but paragraph 4.3.8.5 Orientation of EUTs is unchanged and still requires surfaces which produce maximum radiation to face the measurement antenna.

So nothing to fear here, **EMC lawyers**: there is still plenty of opportunity to ply your craft.

Radiated testing must now cover entire test set-up area, not just horizontal extent



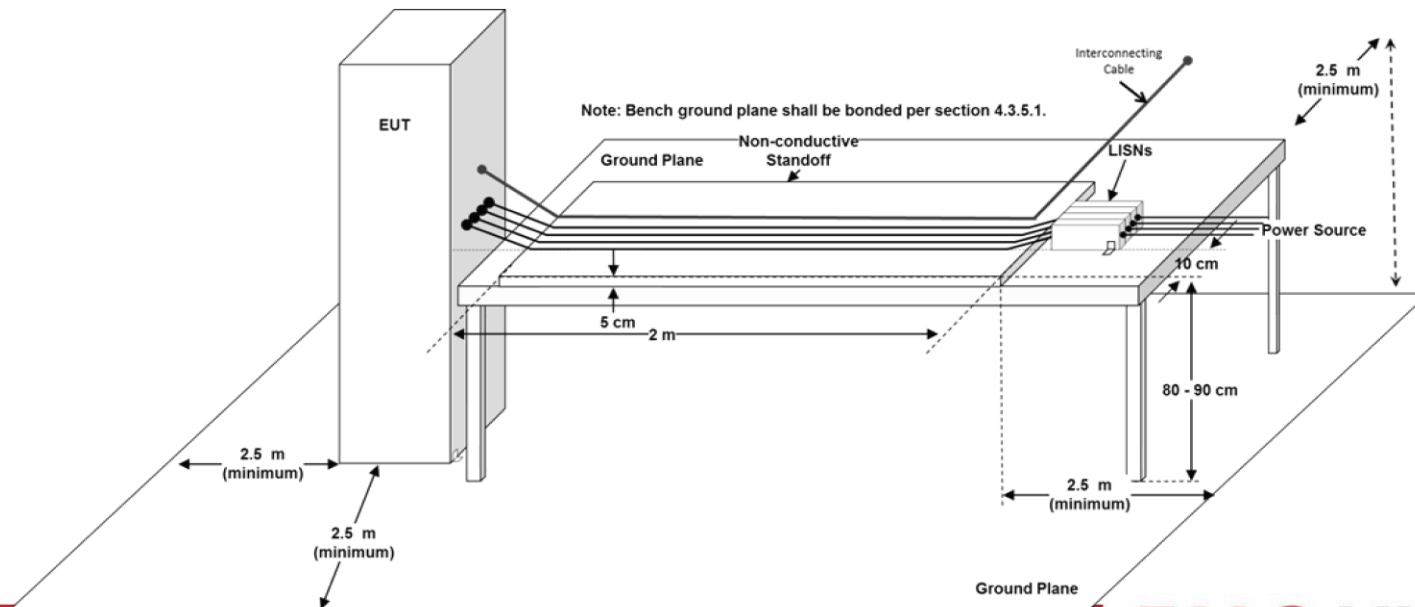
Added emphasis on the testing of large, floor standing test samples whose height approaches the horizontal extent of the test set-up.

In previous versions (“D” through “F”) there was plenty of information on how to set up RE102/RS103 antenna positions for test set-ups with extended horizontal dimensions, but no corresponding information for vertically large enclosures, such as 19” racks.

The RE102 and RS103 sections of this version of the standard now require a sufficient number of antenna positions such that the entire *area* of the test set-up has been interrogated/illuminated.

Large test items – continued.

Another issue is cable length. There has always been a limit of 2.5 meters maximum between test sample and LISNs, in order to allow the LISN to control the line impedance (the reason why CE102 stops at 10 MHz). But with a large test sample like a floor-standing rack, especially if the cables exit near the top and a power strip runs down the height of the rack powering loads near the bottom, the 2.5 meters gets used up very quickly and a strict adherence to that limit would mount the LISNs very near the rack itself, limiting RE/RS interaction with power lines. Given the MIL-STD-462D decision to have a single power wire length for all tests, as opposed to short cables for CE testing and long cables for RE/RS as previously, it was decided to require two meters of power wiring exposed 5 cm above the tabletop ground plane regardless of where the wires emanate from the test sample, nor how long the cables are within the test sample.



New equipment recognized for use in MIL-STD-461G:

Time Domain Receivers

The TSWG wrestled with how to specify the use of time domain EMI receivers in the revised standard. These are machines that look at very wide frequency bands and then use FFT software routines to show the signature that would have been obtained with a traditional receiver tuned to a specific frequency using a Table II bandwidth.

Identical responses are obtained for a cw signal, but unless dwell times are carefully controlled, an intermittent (broadband) signal can be missed. On the plus side, if the dwell times are properly specified, then the TD machine gives a true representation vs. the sampled response of the traditional machine.

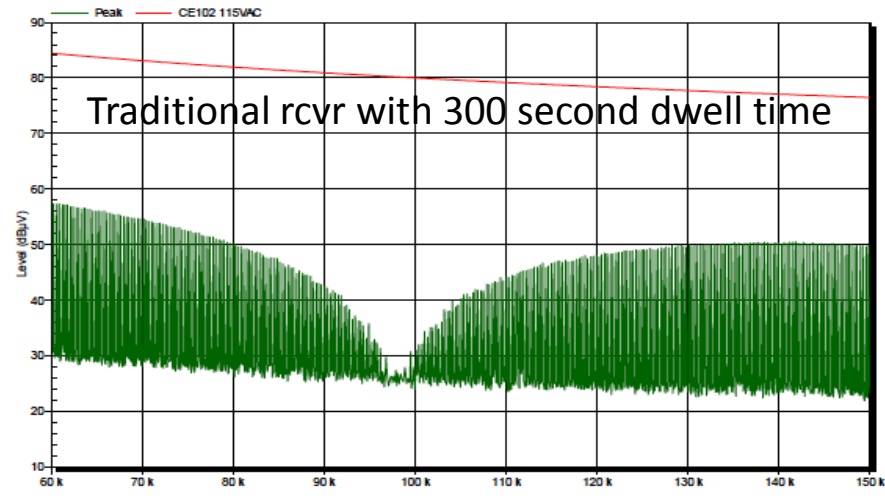
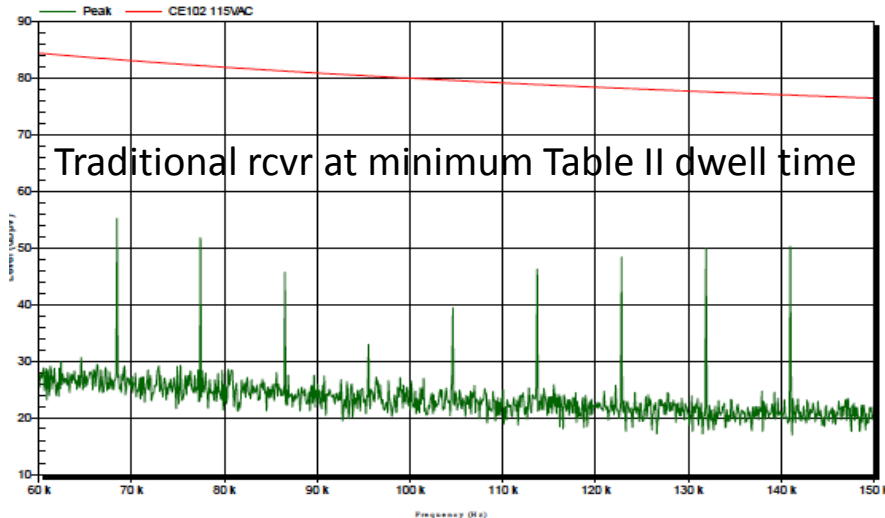
Frequency Range	6 dB Resolution Bandwidth	Minimum Dwell Time		Minimum Measurement Time Analog-Tuned Measurement Receiver ^{1/}
		Stepped-Tuned Receiver ^{1/} (Seconds)	FFT Receiver ^{2/} (Seconds/ Measurement Bandwidth)	
30 Hz - 1 kHz	10 Hz	0.15	1	0.015 sec/Hz
1 kHz - 10 kHz	100 Hz	0.015	1	0.15 sec/kHz
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

1/ Alternative scanning technique. Multiple faster sweeps with the use of a maximum hold function may be used if the total scanning time is equal to or greater than the Minimum Measurement Time defined above.

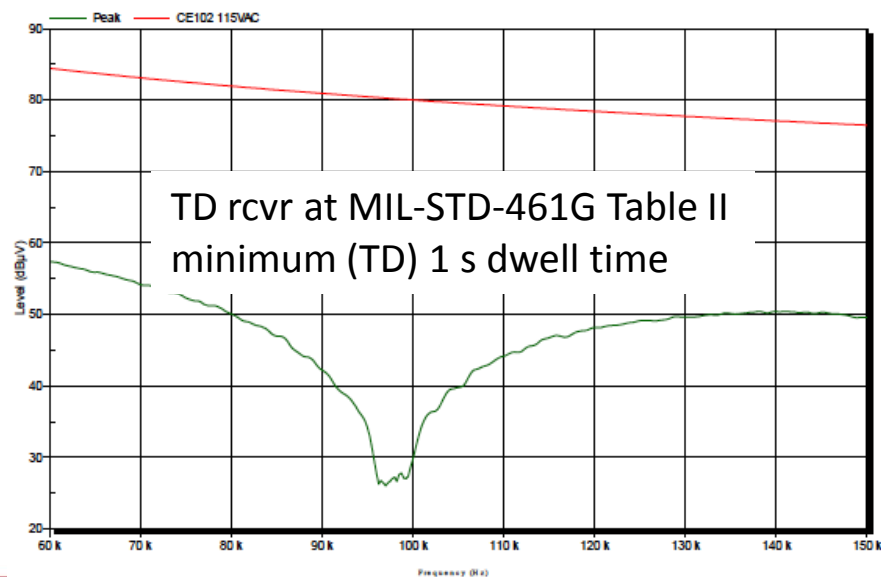
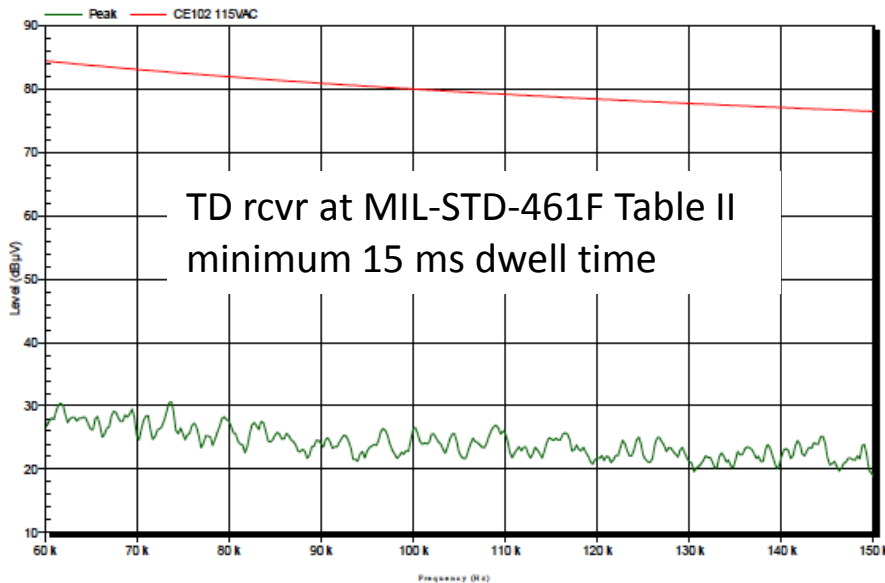
2/ FFT Receivers. FFT measurement techniques may be used provided that FFT operation is in accordance with ANSI C63.2. **The user interface of the measurement receiver must allow for the direct input of the parameters in Table II for both FFT Time Domain and Frequency Stepped modes of measurement in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

New equipment recognized for use in MIL-STD-461G:

Time Domain Receivers



Time domain vs. traditional EMI receivers responding to 1 pps 10 us long pulse

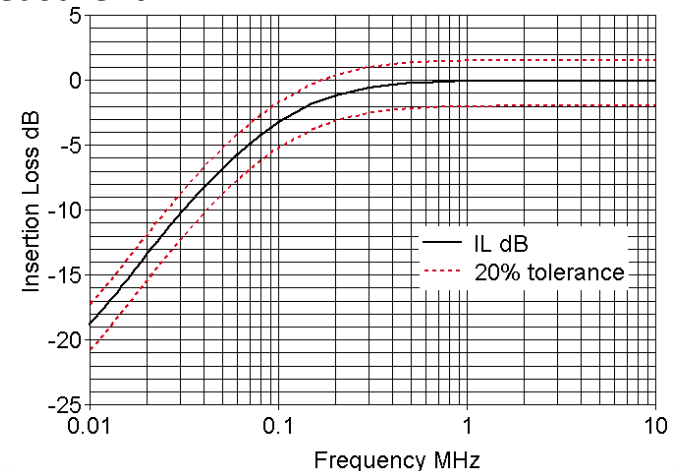


CE102 Measurement System Integrity Check

Section 5.5.3.4.a.2 is the expansion on the basic CE102 measurement system integrity check that verifies the LISN impedance at 10.5 and 100 kHz.

Previous (“D” through “F”) technique verified impedance at 2 and 10 MHz, but not at lower frequencies where LISN impedance is low relative to 50 ohms, and with elimination of a requirement to regularly calibrate LISNs, the expanded measurement system integrity check fills that gap.

There is little extra effort besides record keeping. Because the LISN is a low impedance relative to 50 Ohms, the signal source output amplitude must be increased above the actual level resulting across the LISN. The extra effort is simply to document the required increase (in dB) and compare that to what is theoretically required per the LISN impedance curve of Figure 7, including both the 20% tolerance of that figure, plus the losses associated with the LISN 0.25 uF blocking capacitor. This section says what the decibel difference is supposed to be at the measurement system integrity test frequencies of 10.5 and 100 kHz. SAE AIR 6236 shows the LISN insertion loss curve with tolerances over the entire 10 kHz to 10 MHz frequency range, and how to measure it.



Changes to CE106

Section 5.6.1 CE106 has been modified for NAVSEA (surface ship) transmitter procurements. The traditional 5% exclusion zone surrounding the transmit frequency is increased according to a formula given in this section for transmitters operating above 1 kW (60 dBm).

There is also a modification of the criterion for the highest required test frequency. The effect of the change is that the test must always be run to at least 10 GHz, with a maximum frequency of 40 GHz. The modification is that under MIL-STD-461F, the upper frequency was stated to be:

“The end frequency of the test is 40 GHz or twenty times the highest generated or received frequency within the EUT, whichever is less.”

Under the “G” change, the end frequency criterion depends on whether the highest generated or received frequency is above or below 1 GHz. If the highest generated or received frequency is below 1 GHz, the end frequency is twenty times that frequency or 18 GHz, whichever is greater. If the highest generated or received frequency is equal to or above 1 GHz, then the end frequency is ten times the highest frequency, or 40 GHz, whichever is less.

The benefit of this approach is a lot of devices will only need to be tested to 18 GHz, instead of higher. Every test facility can test to 18 GHz because of RE102, but often testing beyond that requires the rental of a special receiver, so overall this modification is beneficial.

Changes to CE106 & RE103



Section 5.6.2 CE106 has been modified for NAVSEA (surface ship) transmitter procurements. The relative limit in decibels below the carrier (e.g., -80 dBc) has been changed to a fixed level of -40 dBm. This was done to aid in co-location of high power transmitters and sensitive receivers. Note that for any transmitter power level above 10 Watts (40 dBm) this represents a more stringent limit than previously. There is a relaxation of this -40 dBm level to 0 dBm if the transmitter duty cycle is below 0.2%, which would take care of many radar systems.

New equipment recognized for use in MIL-STD-461G:

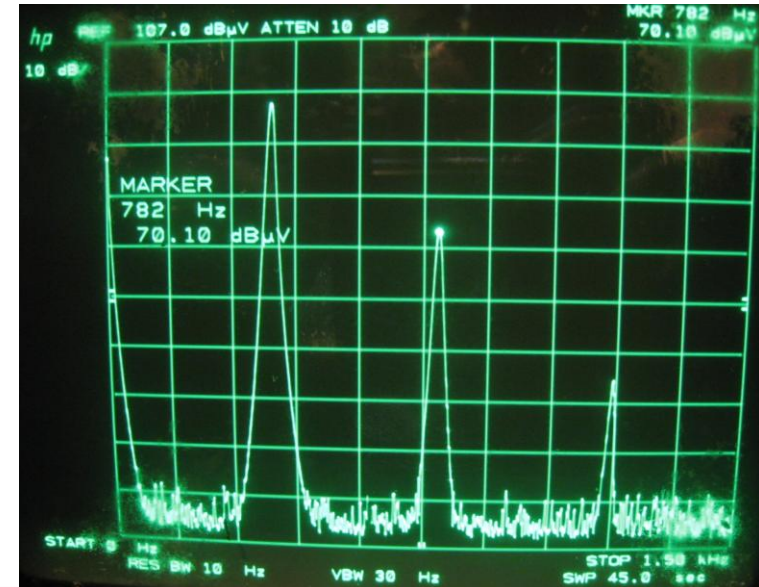
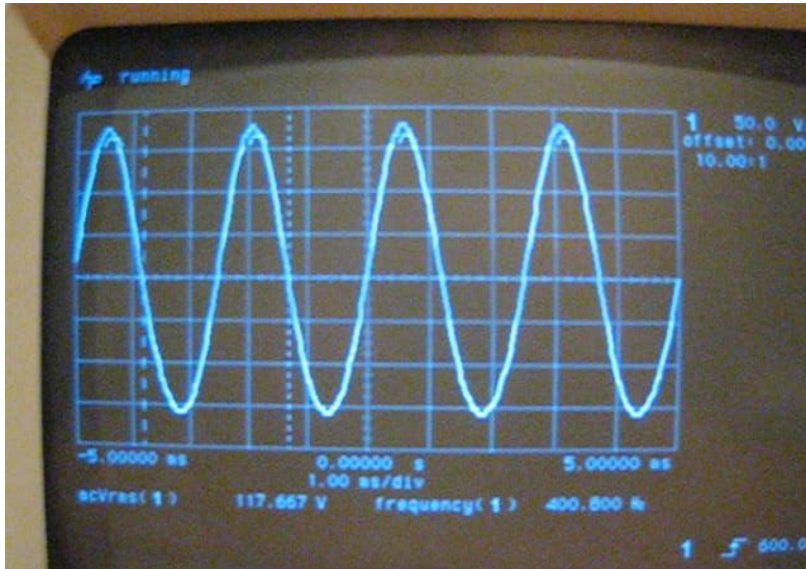
CS101

Section 5.7.3 CS101 test procedure allows for the use of a power line ripple detector (PRD) to measure ripple induced on an ac power line, which is very difficult to monitor.

The PRD contains an isolation transformer so that connection of the ac neutral to the PRD maintains isolation between the neutral and the grounded EMI receiver or spectrum analyzer chassis. That isolation is required by paragraph 5.7.3.1 of MIL-STD-461G.

CS101 figures are updated to show either the traditional measurement with floated oscilloscope or the new measurement with PRD and grounded receiver.

The PRD functions as an interface between the power line and the 50 Ohm input of a spectrum analyzer or EMI receiver, allowing the measurement to be made in the frequency domain so that the ripple component can be seen entirely separately from the power line frequency.

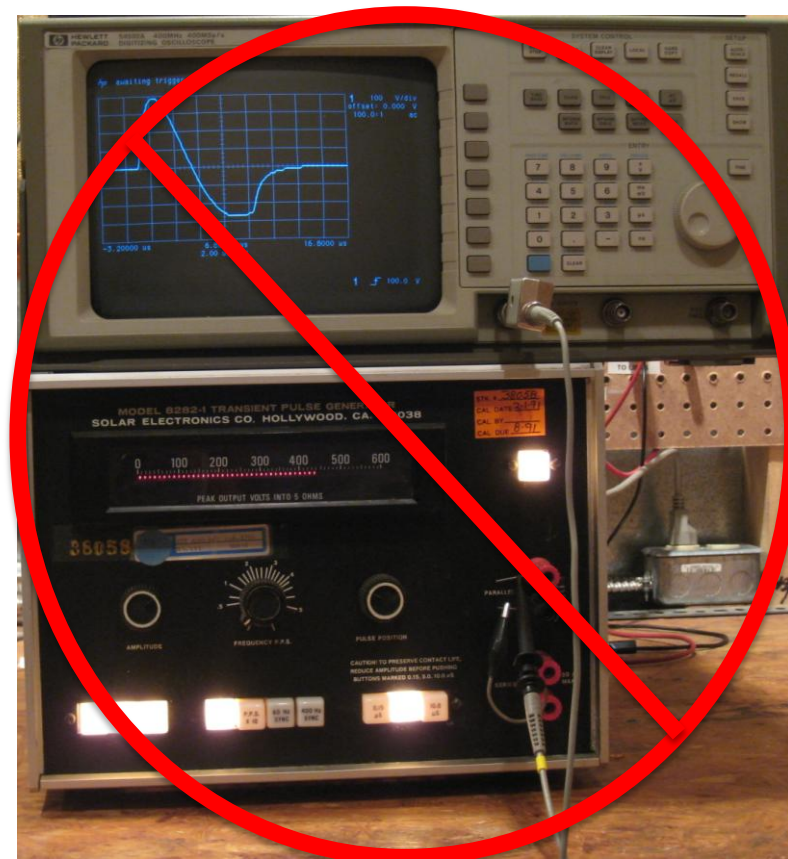


CS106 – gone.

The underlying issue in MIL-STD-461F CS106 was not the response of the power supply to the transient, but crosstalk within an equipment between the transient on the power wiring and signals carried on wiring adjacent to the power wires without adequate protection. The very purpose of the requirement was to force adequate segregation between power and signal circuitry.

However, CS115 was designed specifically to represent the coupling of transients on a power bus into cables run adjacent to it. The very short 30 ns duration and even shorter 2 ns rise and fall times represent the leading edge of a waveform such as CS106 on a power bus inductively coupling into an adjacent cable. Measurements on a one foot section of ribbon cable modeling an unprotected connection between a connector and motherboard revealed that injecting CS115 on the simulated signal wires looked very similar to the cross-coupling from injecting CS106 on the simulated power wires.

It was concluded that CS115 already meets the intent behind the reintroduction of CS106.



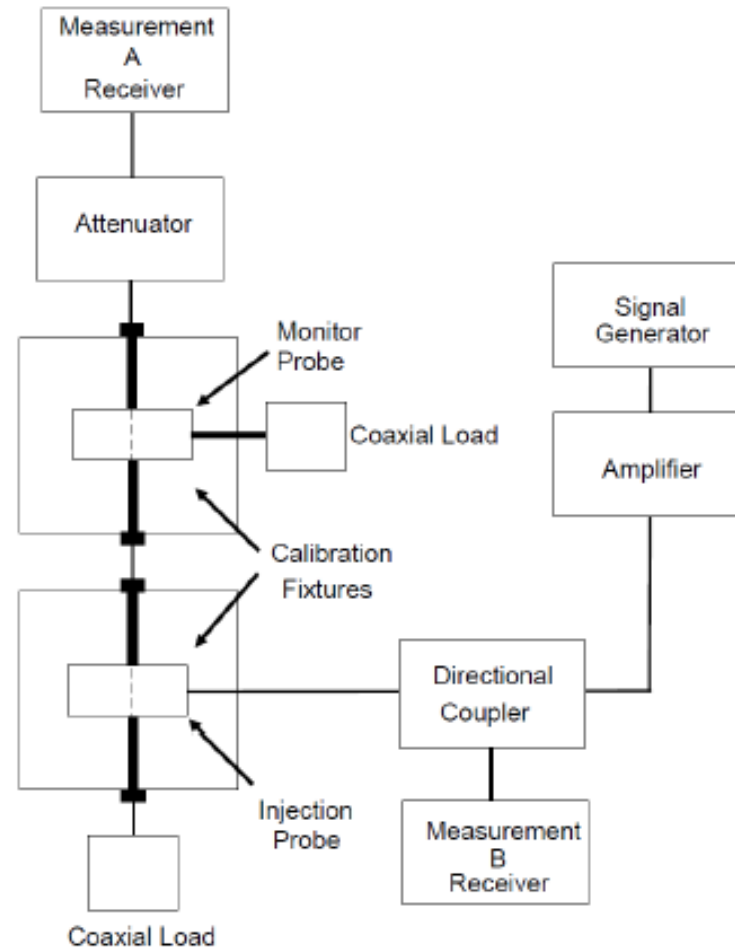
CS114 changes

Two changes, one to limit, one to procedure.

The limit reverts back to that of MIL-STD-461D, where the primary limit is the forward power recorded in the calibration fixture when the appropriate specification limit (Curve 1 – 5) is induced in the fixture, with the only current limit being 6 dB higher than the current in the plateau region of the curve.

The reason behind the reversion to MIL-STD-461D is explained in “(More) On Field-To-Wire Coupling Versus Conducted Injection Techniques,” in the October 2014 issue of IN Compliance magazine.

The procedural change is that in addition to the traditional measurement of the forward power required to induce the specification limit current in the calibration fixture, the current in the fixture must be measured using the current probe that will be used to monitor current on the cable-under-test. This is an augmentation of the measurement system integrity check, because again a current probe will not require periodic calibration.



CS117 – New Requirement

CS117 (lightning induced transients on cables and power leads) is one of the two new requirements in MIL-STD-461G.

Borrowed from RTCA/DO-160 section 22

A subset of RTCA/DO-160 section 22.

There is nothing in CS117 that doesn't exist in section 22, but many aspects of section 22 were left out of CS117. There was a desire to simplify, but the simplification was not performed for its own sake, but rather in keeping with two philosophical tenets of MIL-STD-461 since the "D" revisions in 1993.

These are that cable-related tests are performed at the bulk cable level, no pin injection, and second that platform installations are divided into two categories, internal and external (relative to a metallic platform). [In 1993, all pin-type tests were removed in the C → D transition.]

CS117 – New Requirement

CS117 has six waveforms borrowed from section 22, but only two levels, internal and external.

In addition to that simplification vs. five different levels in RTCA/DO160G section 22, another simplification is that there is no separate table for a single stroke application. Instead, the single stroke levels of section 22 Table 22-3 have been incorporated into the multiple stroke Table VII of CS117.

Table 22-3 levels 3 and 4 become the first stroke of the multiple stroke requirement in CS117 Table VII. Level 3 maps to internal, and level 4 maps to external. Subsequent strokes in CS117 Table VII are from section 22 Table 22-4, except that for Waveforms 4/5A, there was some mixing and matching from levels under Waveform 4/1 in section 22 Table 22-4.

Multiple bursts in the same CS117 Table VII are exactly the same as section 22 Table 22-5 levels 3 & 4, again mapping to internal and external installations, respectively.

CS118 – New Requirement

CS118 (personnel borne electrostatic discharge) is the second new requirement in MIL-STD-461G.

Background. In the run-up to the MIL-STD-461G revision process, proponents of including an ESD requirement discussed failures in the field and how those could be tied to ESD problems. Such damage would most likely occur during remove-and-replace operations, not during powered up use, else the failures would be much more dramatic and noticeable (i.e., hardware working during a mission and suddenly failing, as opposed to installing hardware and running a built-in test - BIT - and with a BIT failure, installing a different box).

The application of ESD pulses to an unpowered box and then subsequently running BIT or some other acceptance test procedure (ATP) was argued to not fit within MIL-STD-461, just like lightning direct effects doesn't, but rather to belong in MIL-STD-810. But this argument didn't fly, not least because the candidate test methods were based on RTCA/DO-160 section 25 and IEC 61000-4-2, which apply ESD pulses to fully operational hardware and look for *malfunction*.

CS118 – New Requirement

Test set-up and “gun” are based largely on RTCA/DO-160 Section 25, with the addition of a “target” borrowed from IEC 61000-4-2 for calibrating the current discharge waveform, and a contact discharge electrode design not found in RTCA/DO-160 because it only requires air discharge.

The section 25 set-up was chosen over IEC 61000-4-2 because of the obvious similarities in a metal vehicle application, with the test sample enclosure directly grounded to structure, as opposed to the 61000-4-2 approach with a nonconductive table top 80 cm removed from ground, with at most a green wire ground connection.

Use of the 61000-4-2 target prior to each test is part of the measurement system integrity check philosophy, rather than relying solely on a “gun” calibration sticker. Likewise CS118 requires an electrostatic assessment of the gun potential prior to the discharge.

Applicability is to non-ordnance connected electronics; ordnance ESD is covered elsewhere.

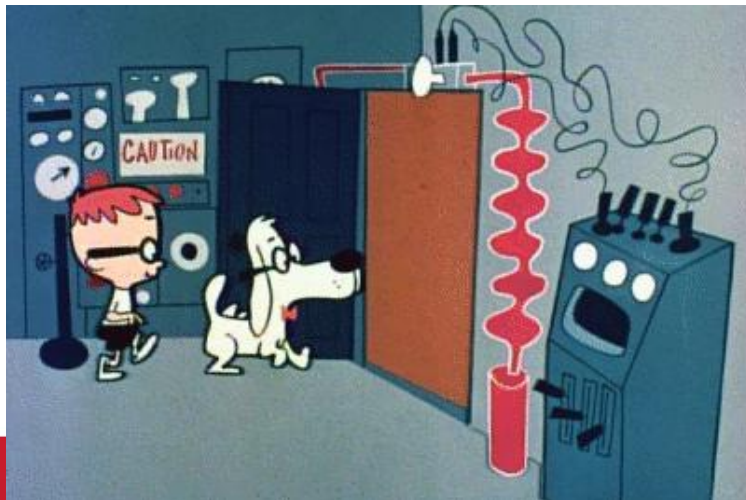
Limits are 8 kV for contact, 15 kV for air discharge. Contact discharge is the preferred method unless the test item has nonconductive surfaces requiring an air discharge approach. Air discharges are performed not only at the 15 kV limit, as per RTCA/DO-160 section 25, but also at 2, 4, and 8 kV. This is because air discharge current waveforms can have higher amplitudes at lower potentials, due to smaller arc distances and hence lower arc resistance. It is most often the coupling from the radiated field of the ESD event that causes upset, and the higher the waveform di/dt , the larger the transient coupled to (potential) victim circuits.

Test Equipment for CS117 & CS118

CS117 and CS118 require no test equipment different from RTCA/DO-160 sections 22 and 25, with one exception. CS118 requires a contact discharge “target” as per EN 61000-4-2.

If a test house has these test capabilities at present, they need buy no new test equipment.

On the other hand, if these remind you of your high voltage capability, it might be time to upgrade...



RE102 Changes

Section 5.18.1 RE102 applicability removes the conditional limit on the upper test frequency and makes it 18 GHz, regardless of test sample clock speeds. It was deemed that the time saved not testing to 18 GHz was insignificant.

The most notable RE102 changes relate to illuminating/interrogating the entire test set-up area, as opposed to width.

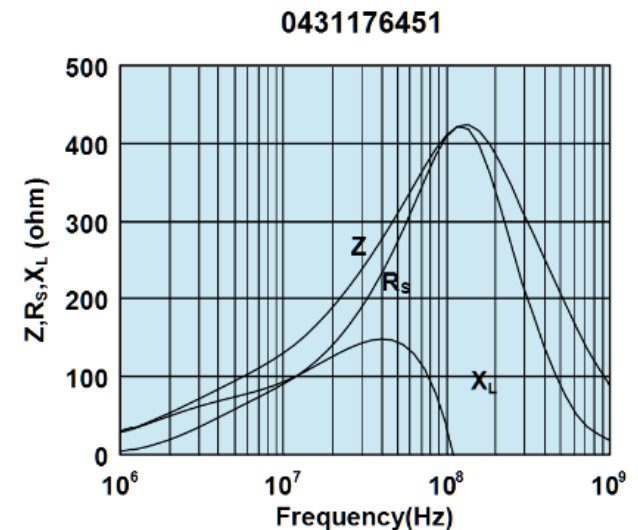
A change in the RE102 measurement system integrity check for the 41" rod antenna acknowledges that the assumed Thevenin model output impedance of a 41" rod is not always 10 pF, because some large diameter rods have larger output capacitance. The standard now invokes the manufacturer's suggested value.

5.18.3.3 Setup.

The test setup shall be as follows:

- a.
- b. ...
- c. EUT testing.

(1) For rod antenna measurements, electrical bonding of the counterpoise is prohibited... A ferrite sleeve with 20 to 30 ohms impedance (lossy with minimal inductance) at 20 MHz shall be placed near the center of the coaxial cable length between the antenna matching network and the floor.



Impedance, reactance, and resistance vs. frequency.



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