MIL-STD-461G Overview

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MIL-STD-461G

Electromagnetic Environmental Effects (E^3)

- The terms Electromagnetic Environment (EME) and the EME Effects (E^3) are used to describe the potential EM sources and characteristics present within a specific installation site or platform.

- This is intended to establish a realistic baseline to evaluate EMC risks prior to product deployment.

- Product industries world-wide use a similar approach to establish EMC for their particular EM environments.

- Therefore, the severity of EMI/EMC regulatory requirements for a home office will differ extensively from an aircraft, automobile, or a US Aircraft carrier.

- These differences pose significant challenges for multiplatform integration of equipment designed for use in specific environments. (i.e., DoD integration of COTS equipment).

EMI Case Study- U.S.S. Forrestal

- In 1967, the USS Forrestal Aircraft Carrier was involved in one of the worst cases of EMI ever documented.

- During combat maneuvers off the gulf coast of Northern Vietnam, one the carrier's staged aircraft was exposed to the ship's high power radar signal which accidentally fired one of the aircraft's air-to-surface rockets.
- The rocket hit another staged, fully armed, and fueled aircraft on the deck, resulting in systematic chain of explosions and massive fire.

- This incident caused catastrophic damage to the carrier, resulting in the loss of 134 lives, as well as 161 injuries.

- The forensic investigation discovered that a poor cable shield termination on the first aircraft reduced the firing systems RF immunity to EMI and was ultimately was the cause of the accident.

U.S. Navy aircraft carrier USS *Forrestal* (CVA-59)

- **On July 31, 1967 MIL-STD-461 The electromagnetic Interference Requirements for Military equipment was issued.**

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Department of Defense Testing -MIL-STD-461G

- MIL-STD-461G provides the EMI/EMC verification requirements of all equipment and subsystems deployed by the U.S. Department of Defense.
- MIL-STD-461G is an “inclusive” document providing the EMI/EMC test methods, control limits, and susceptibility evaluated test levels for every major product type deployed by the US military.
- Environmental, vibe/shock, safety, etc.. are not covered by this standard. They are addressed by other MIL-STD test methods, and are usually specified in the SOW.
- The test criteria for each method is determined by the DoD Tri-Services committee consisting of representatives from each of the primary military service branches (Army, Navy, and Air Force) to best represent the EME’s for each installation platform type (land, sea, air, and space).

Tests are based upon particular installation platforms, and their corresponding electromagnetic environments.

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- **Test procedure Requirements**
  - An approved Electromagnetic Interference Test Procedure (EMITP) is REQUIRED by MIL-STD-461 prior to conducting formal testing. The test procedure shall meet the Device Information Document requirements of DI-EMCS-80201C.
- **Product Specifications**
  - **Intended platforms the product will be used on & End users (Army, Navy, Air Force).**
  - **Parametric information (Power, size, weight, etc…).**
  - **Intended operational functions, cycle times & pertinent features of the EUT that will be tested.**
  - **Latest revision electrical and mechanical schematics.**
  - **Cabling type, length, function.(Shielded/Unshielded, twisted pair, coax, fiber optic, etc…).**
  - **Actual or Representative loads that will be used for each interface during testing.**
  - **Stimulation and Monitoring hardware and software.**
  - **Electrical Bonding/Grounding scheme (Chassis, cable shields, etc…).**
  - **Test methods, limits, levels, and any tailored exceptions or deviations or modifications and justifications made.**

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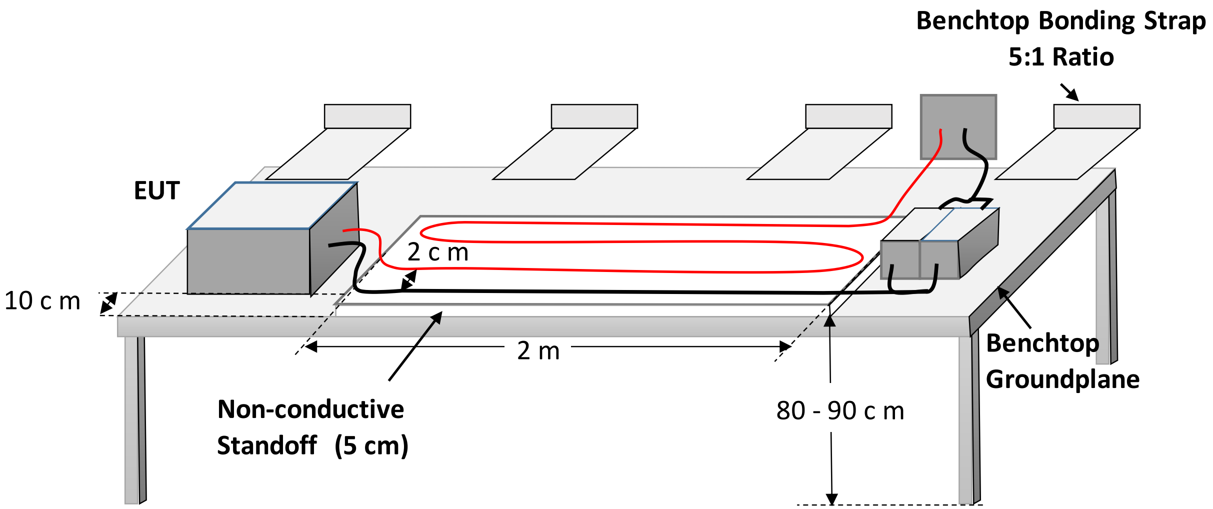
Test Setup (Table Top Equipment)-

All cabling shall be elevated above the ground plane by 5 cm using non-conductive stand off material.

Individual cabling shall be separated by 2 cm from one another, minimizing cross over as a best practice.



Power Cables-

- *Power leads shall be routed to the front edge of the test setup boundary for 2 meters, not exceeding a total length of 2.5 meters from the EUT to the LISNs.*

Interconnecting Cables-

- *Actual installation lengths up to 10 meters shall be used for testing.*
- *If unknown at least 2 meters shall be provided.*
- *All cables shall be routed for 2 meters to the front edge of the test setup boundary with excess cabling routed to the back in a "zig-zagged" arrangement.*

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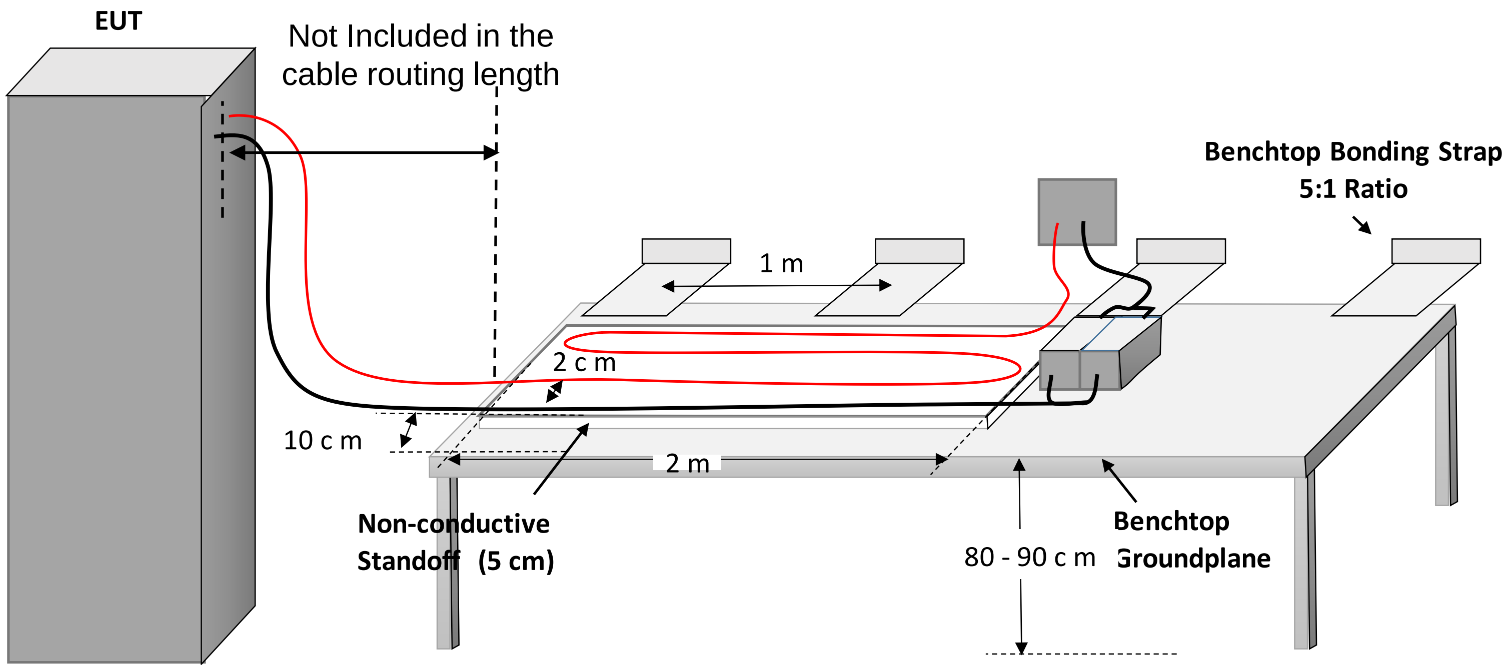
Test Setup (Free Standing Equipment in EMI chamber)-

- Large free standing equipment shall be positioned on the floor of the EMI chamber next to the benchtop ground plane.
- 2 meters of each cable type shall be routed to the front edge.
- The length of cable from the free standing EUT to the benchtop is not included in the 2 meter cable routing length.



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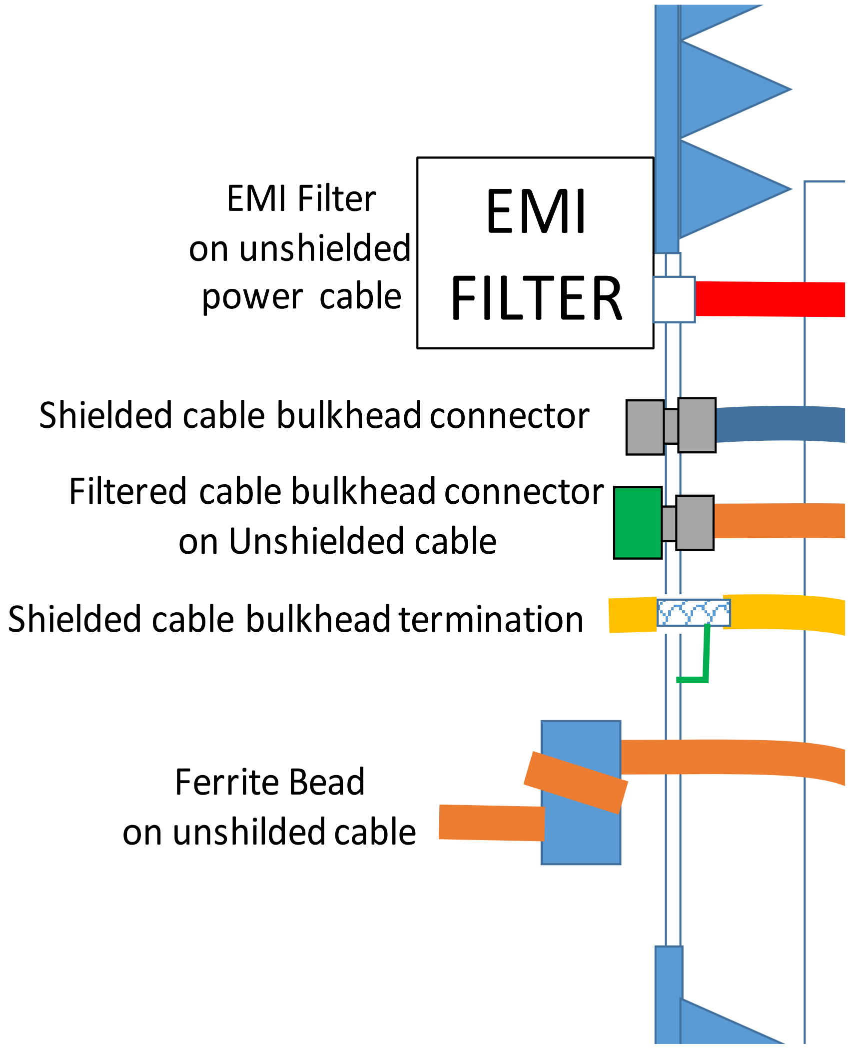
Test Setup (Cable filtering and shielding)-

- Cables with shields should be terminated at the feedthrough panel through a bulkhead mounted connector if possible. Otherwise, by stripping back the cable insulation, and bonding the shield to the bulkhead.

- A 360 degree shield termination around the cable will provide the best performance especially at high frequencies.

- Unshielded communication/signal, or alarm cables should be filtered using either a filtered connector or EMI connector insert if possible.
- However, filtering may affect the performance and/or operation of high frequency communication circuits and cannot be used. In these cases, a shielded cable may be the best option.

- A ferrite bead can also be added to the cable just outside the chamber bulkhead feedthrough for moderate CM filtering. In most cases, up to four turns of cable through the ferrite acceptable.
  - The specific type of ferrite material should be selected based on the highest impedance provided within the frequency range of interest.



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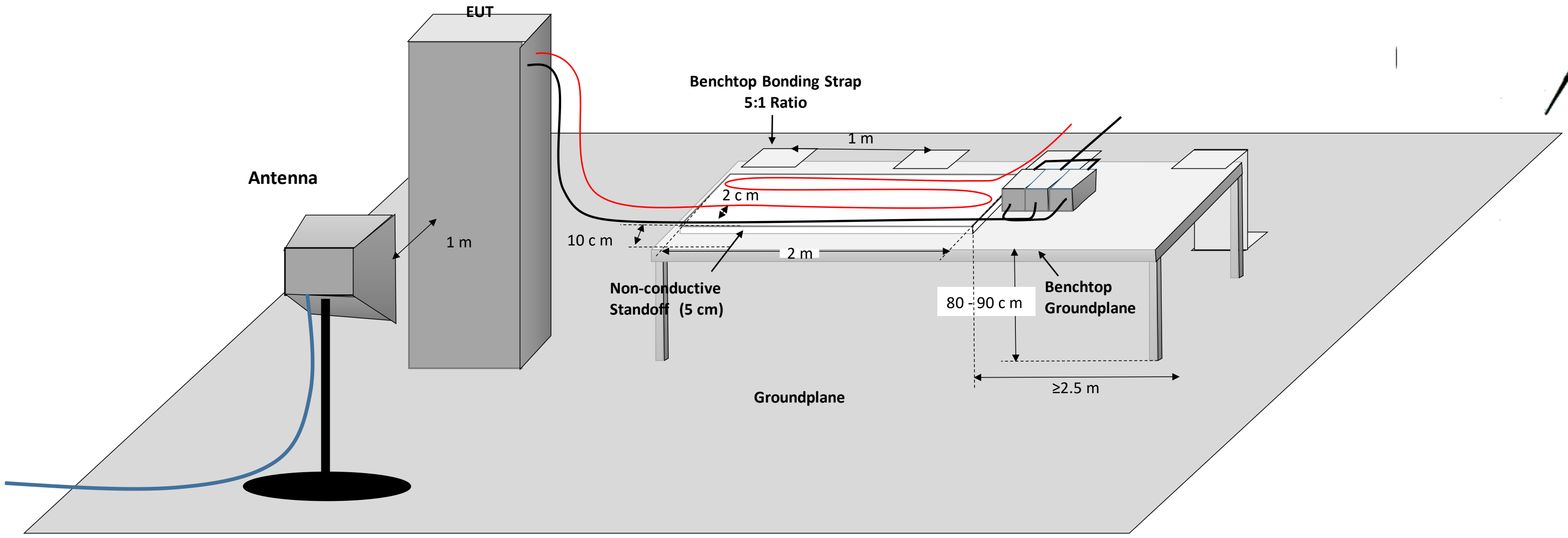
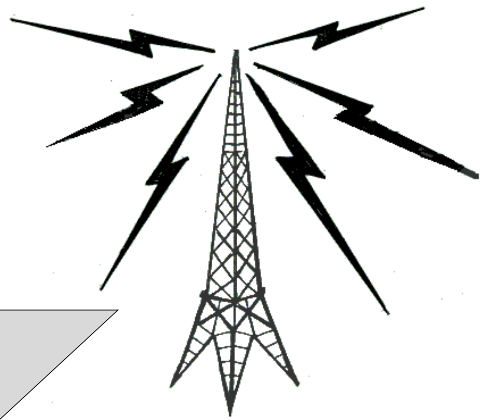
Radiated Emissions Testing- Open Area Test Site

- In cases where the Equipment Under Test (EUT) is too large or complex to be tested at an NTS Lab, or a site survey is being conducted, measurements are made outdoors.

- When measurements are made outside a shielded enclosure, the tests shall be performed during times and conditions when the ambient is at its lowest level. The ambient shall be recorded in the EMITR and shall not compromise the test results.





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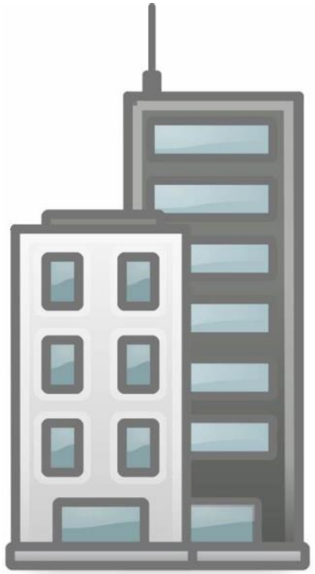
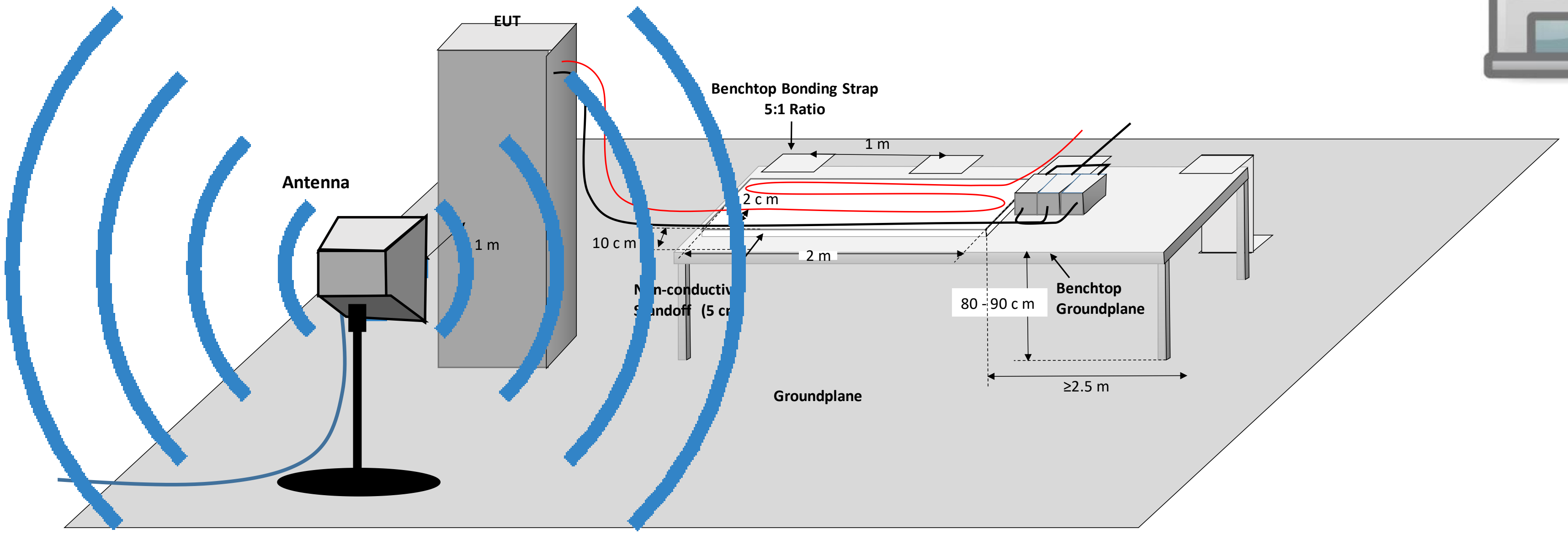
Radiated Immunity/Susceptibility Testing – Open Area Test Site

- Radiated susceptibility tests generate high field levels that could interfere with normal FCC approved frequency assignments. Therefore, testing should be conducted in a shielded enclosure. Some open site testing may be feasible if prior FCC coordination is accomplished.
- These electromagnetic fields may also be potentially dangerous to personnel. The permissible exposure levels in DoDI 6055.11 shall not be exceeded in areas where personnel are present. Safety procedures and devices shall be used to prevent accidental exposure of personnel to RF hazards.





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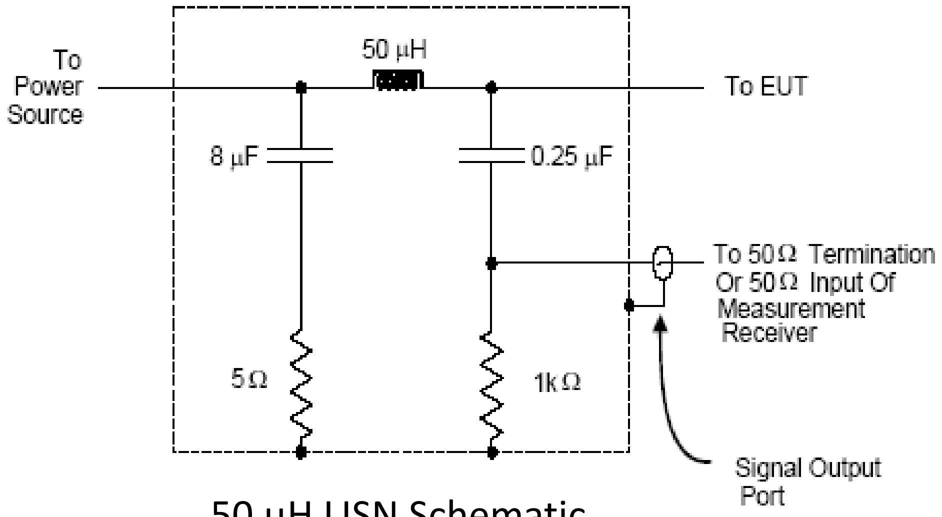
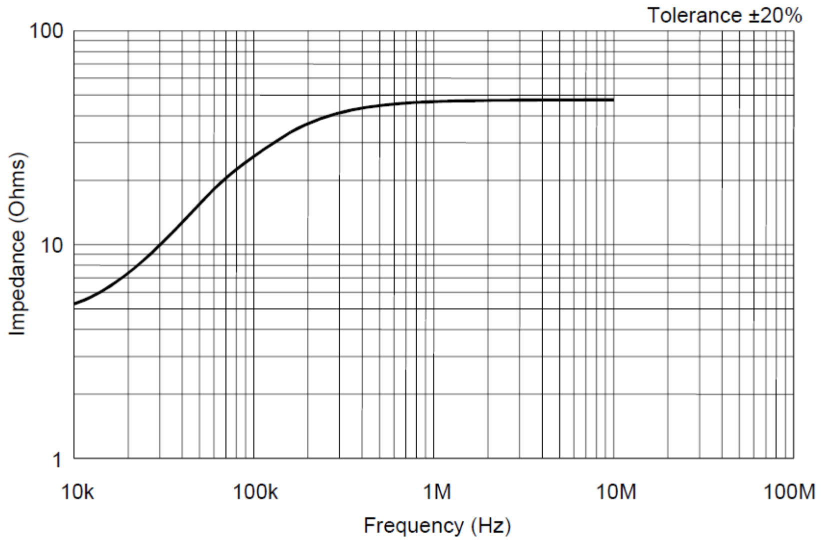
Line Impedance Stabilization networks (LISNs)-

- 50 µH LISNs shall be installed on each primary input power line to control the impedance of the power source during testing.
  - *Simulates 50 meters of power distribution wiring*.
- The 50 µH LISN circuit is selected from ANSI C63.4 to maintain a standardized impedance down to 10 kHz.
- At 10 kHz, the reactance of the 50 µH inductor is cancelled with the addition of the 8 µF capacitor, effectively providing a 5 ohm resistive load to ground.
- The 0.25 µF capacitor is provided for emissions voltage measurements discussed in test method CE102.



50 µH LISN Schematic



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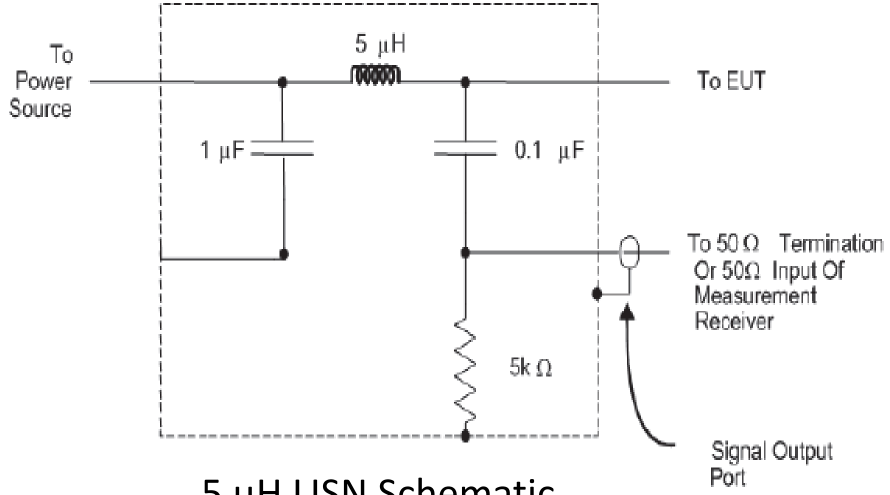
Line Impedance Stabilization networks (LISNs)-

- Applications where 50 µH is not representative of the installation environment, the EUT operation may be affected.
  - *issues with switching power supply stability and the power source impedance seen by the power supply.*

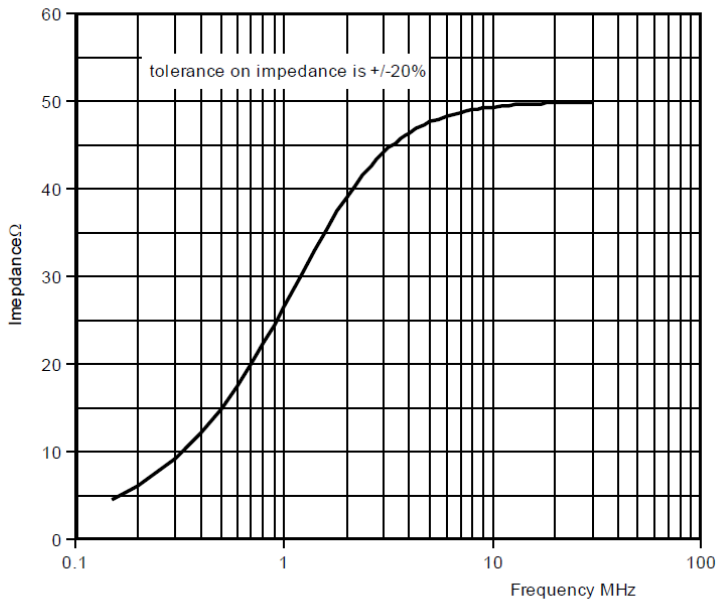
- The 50 µH inductor is representative of 50 meters of power distribution wiring in a large platform, such as a ship or cargo aircraft.

- However, for smaller platforms such as fighter aircraft, or vehicle platform, a 5 µH LISN may be more appropriate.

- The use of 5 µH must be approved by the procuring activity prior to testing.



5 µH LISN Schematic



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CE101- Audio Frequency Current Conducted Emissions

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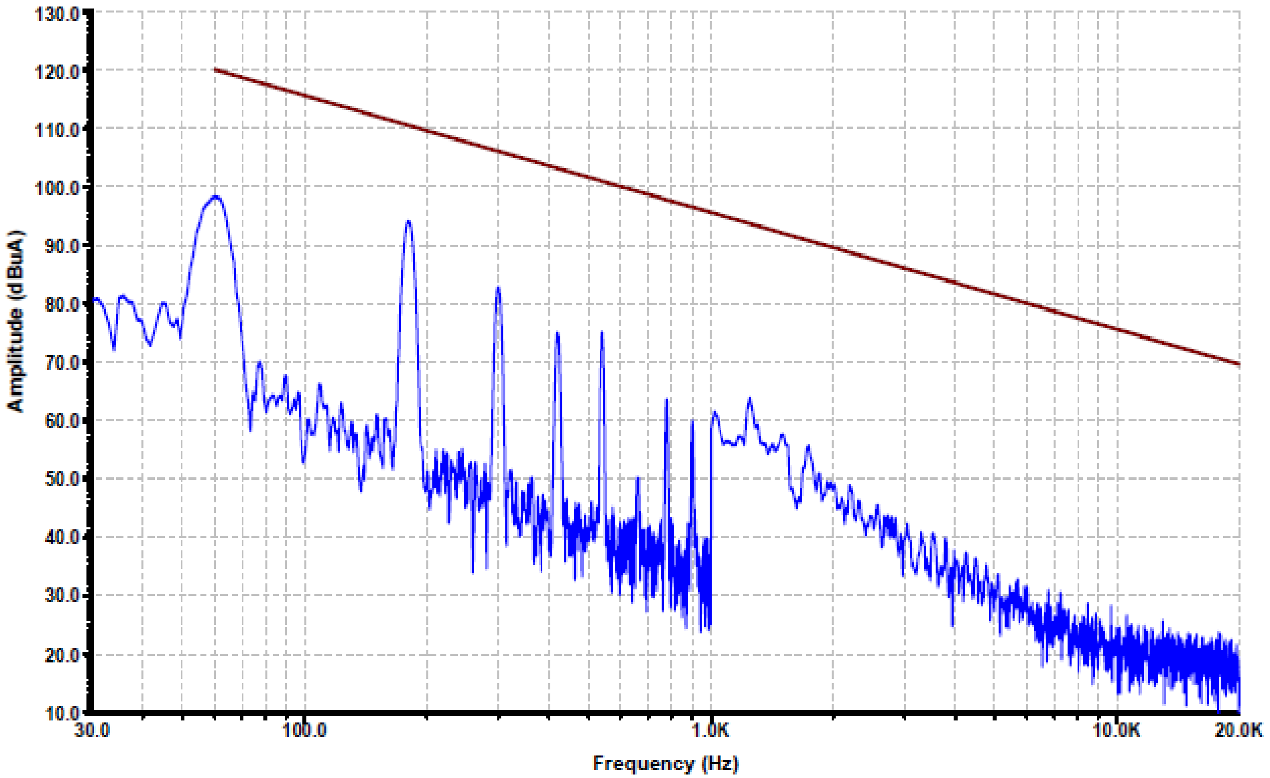
Test Method CE101 Power Line *Conducted Emissions*

- Evaluates noise and harmonic currents (dBµA) from 30 Hz – 10 kHz.
  - *Commonly extended to 20 kHz to cover MIL-STD-1399 section 300 power criteria (when applicable)*
- Performed on AC or DC power leads that obtain power from sources not part of the EUT.
  - *Connections to platform utilities, power bus, or shared power sources.*
- Applicable for Navy Surface Ships & submarines, and Army Aircraft
- “Limited” applicability for Navy Aircraft.



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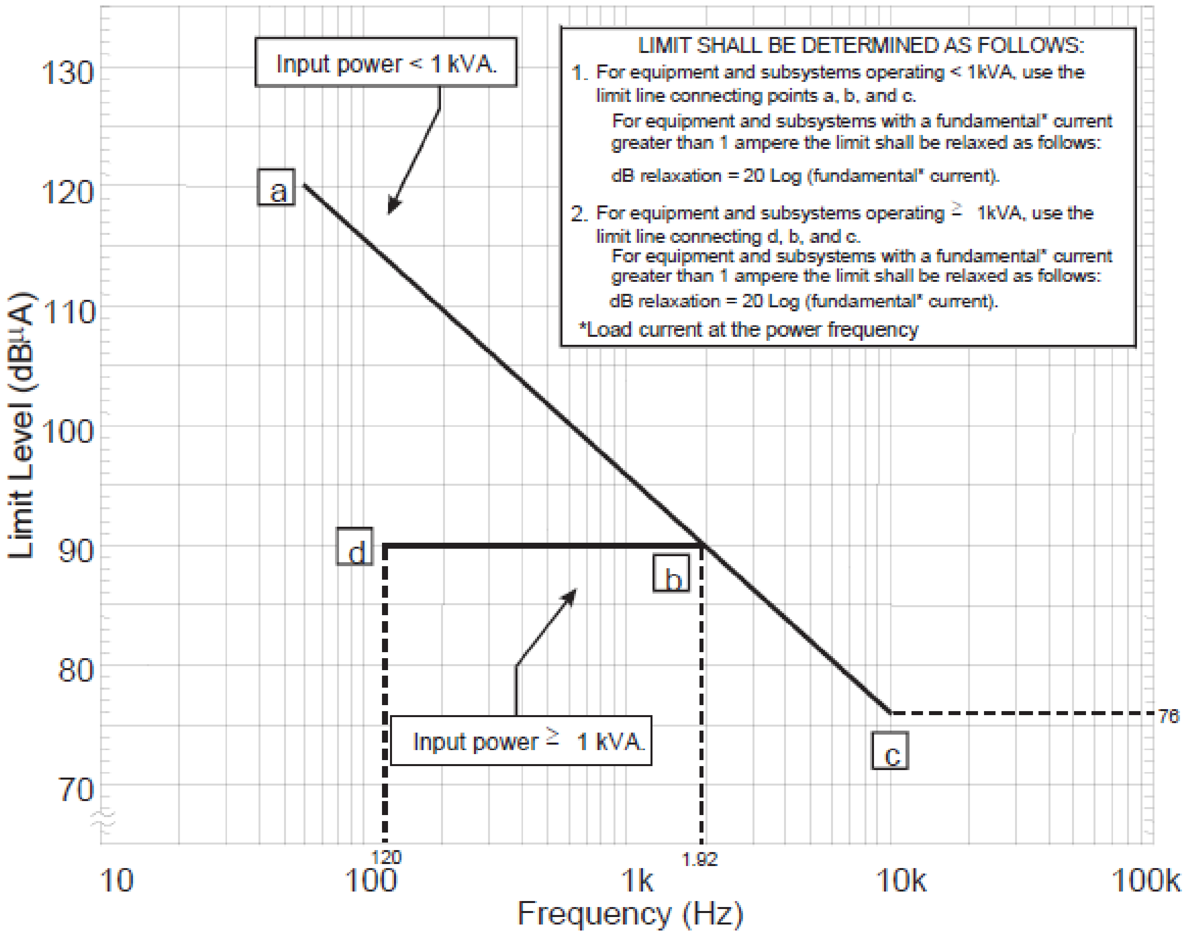
Test Method CE101 Power line *Conducted Emissions*

- *Shipboard & Submarine limits are based on MIL-STD-1399 section 300.*
- Basic Limits are provided for 60 Hz power draws.
    - *< 1 kVA use points a & b.*
    - *≥ 1 kVA use points d, b & c*
- *Basic limits are relaxed by 20 Log(fundamental current) when exceeding 1 amp.*



Limits for Surface Ship & Submarines 60 Hz power

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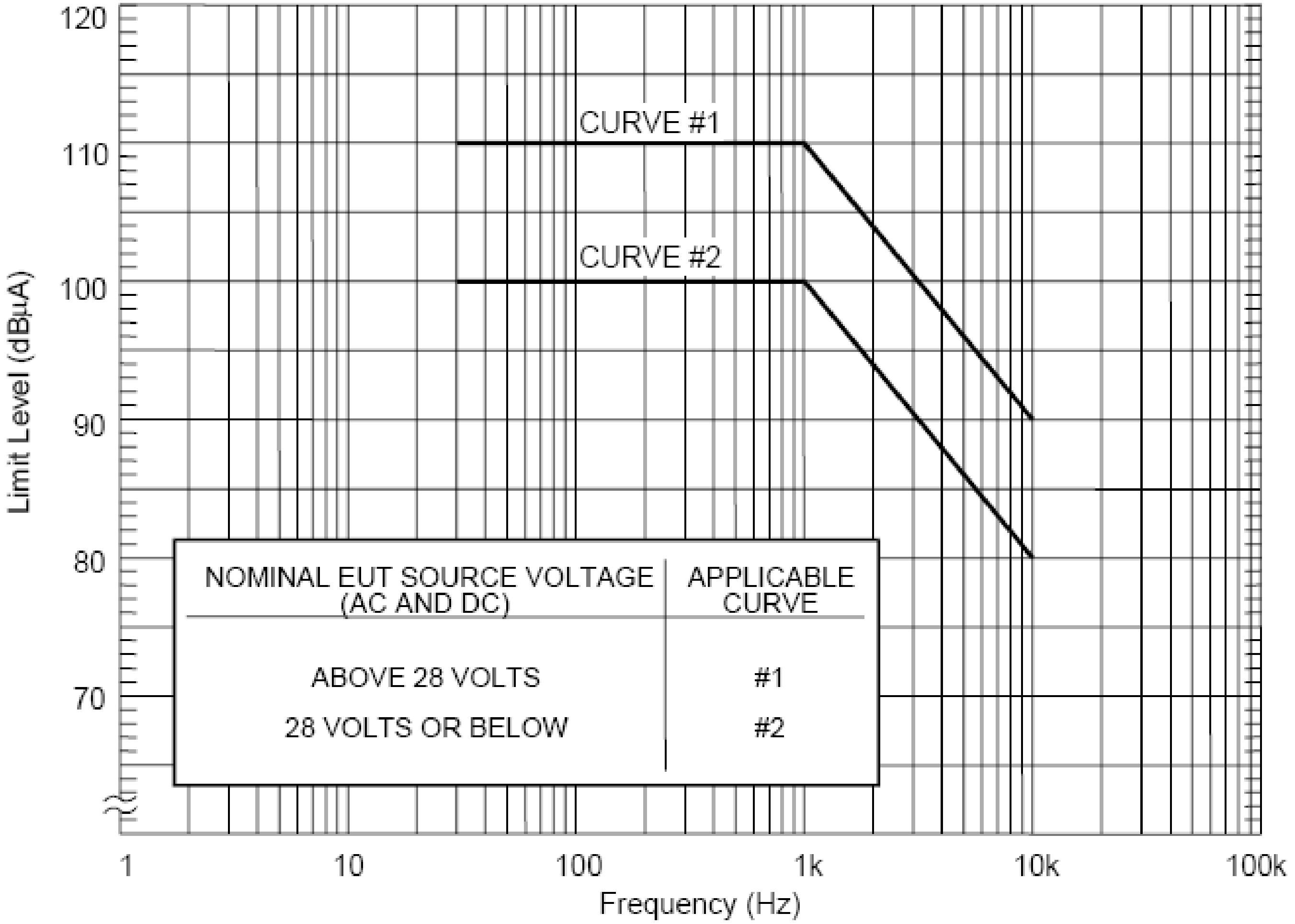
Test Method CE101 Power line *Conducted Emissions*

- Limit selection is based on voltage level (≤28Volts or >28 Volts).
- Applicable to start test at the second harmonic of the AC fundamental frequency.
- No limit relaxation is allowed.



Limits for Navy ASW aircraft and Army aircraft (including flight line) applications.

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Test Method CE101 Power line *Conducted Emissions*

Test Setup and measurement Process

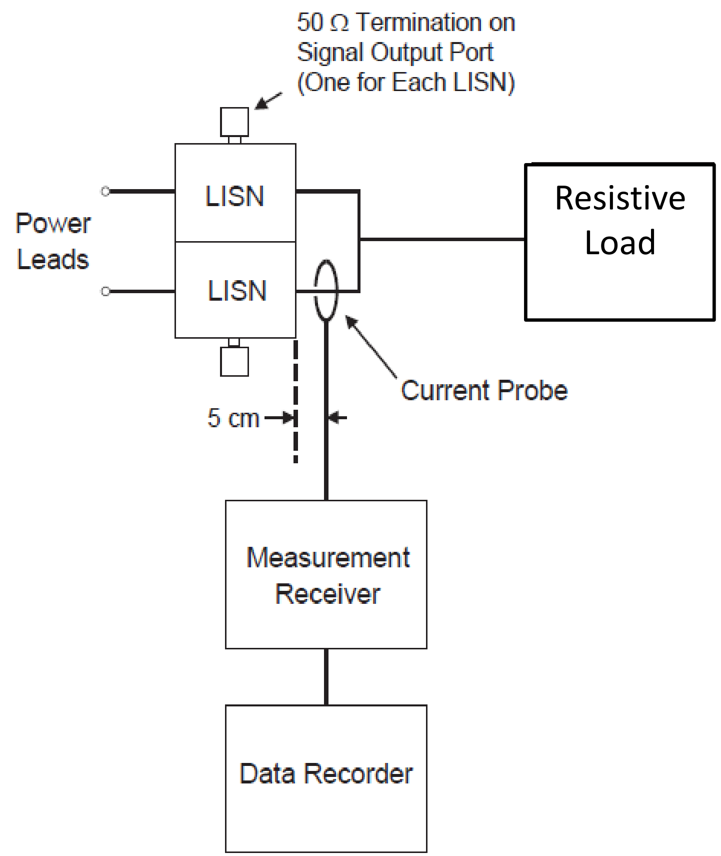
Ambient background Checks are generally performed to ensure external electromagnetic noise sources have been controlled prior to testing.

- The ambient measurement setup shall be nearly identical to that of an actual test, except that a resistive load shall be used that represents the EUT load current while operating.

- When tests are performed in a shielded enclosure and the EUT is in compliance with required limits, the ambient profile need not be performed.

- When measurements are made outside a shielded enclosure, the tests shall be performed during times and conditions when the ambient is at its lowest level. The ambient shall be performed in the EMITR and shall not compromise the test results. .

- Ambient data shall be at least 6dB below the test limit prior to testing.



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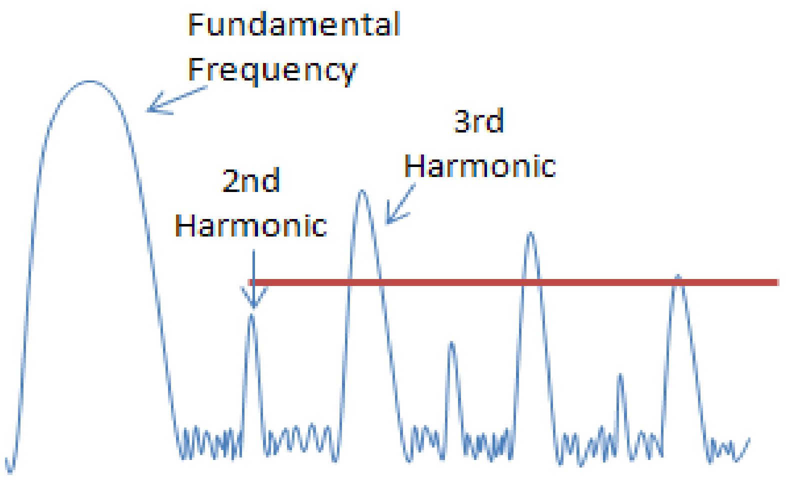
CE101 Test FAILING Design Solutions



Verify the EUT is fully loaded

- Most systems have designed internal harmonic filtering for the maximum load demand.

Passive Harmonic Trap Filtering

- Tuned for discrete frequencies
- ~ good for 20 dB.
- Bulky depending on the number of stages.
- performance dependent on load.
- Can lead to high leakage currents.

Inductive/Reactive Filtering

Uses series inductance to suppress harmonic noise.

- Inexpensive.
- Bulky & heavy due to required inductance.
- Must be rated to handle load.
- Performance highly dependent on load.
- Can impact AC voltage level at fundamental frequency.

Active harmonic Filtering

uses power electronics to introduce current components, which “cancel” the harmonic components of the non-linear loads.

- ~ good for 60 dB
- Bulky, expensive, and limited in high frequency range, generally needs a low pass filter.
- Can lead to high leakage currents.

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CE102- RF Conducted Emissions Power Leads

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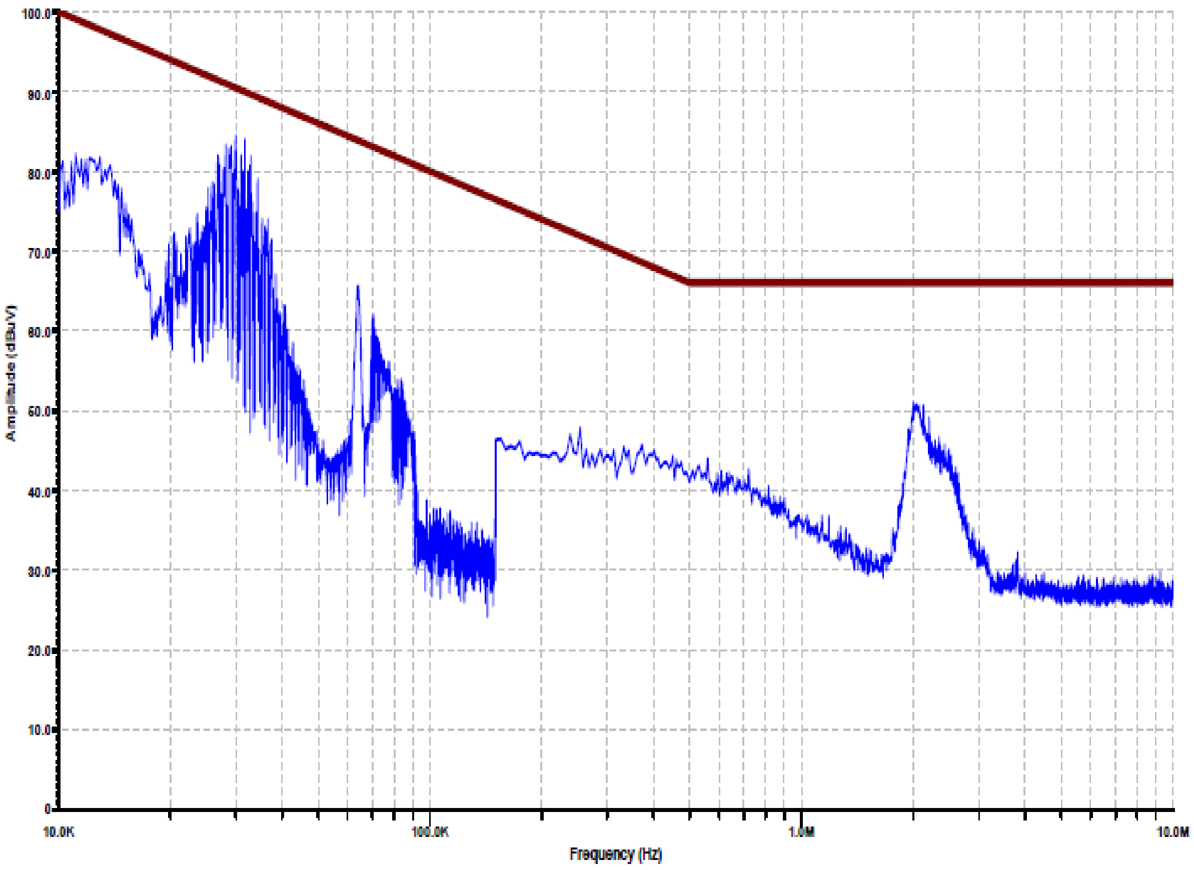
Test Method CE102 *Conducted Emissions*

- Evaluates Voltage noise (dBµV) from 10 kHz to 10 MHz.
- Performed on AC or DC power leads that obtain power from sources not part of the EUT.
  - *Connections to platform utilities, power bus, or shared power sources.*
- *Applicable to equipment deployed on all platforms and all procurement agencies.*



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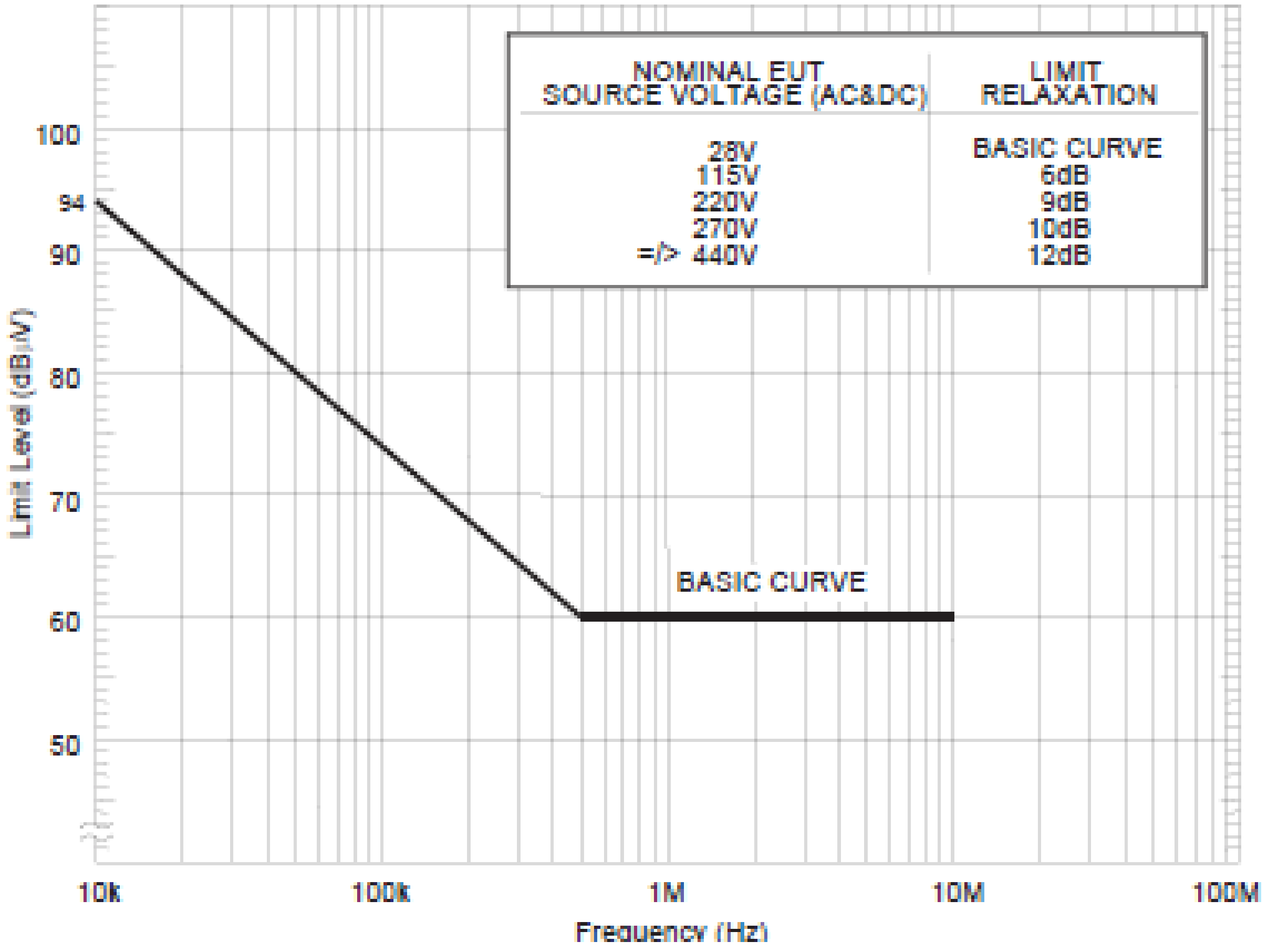
Test Method CE102 *Conducted Emissions*

- One basic curve is used for all applications starting at 28V and relaxed based upon the specific operating voltage.

- The relaxation for higher operating voltages is based on the relative levels of the power quality seen on board aircraft *(MIL-STD-704)* and ships/submarines *(MIL-STD-1399).*



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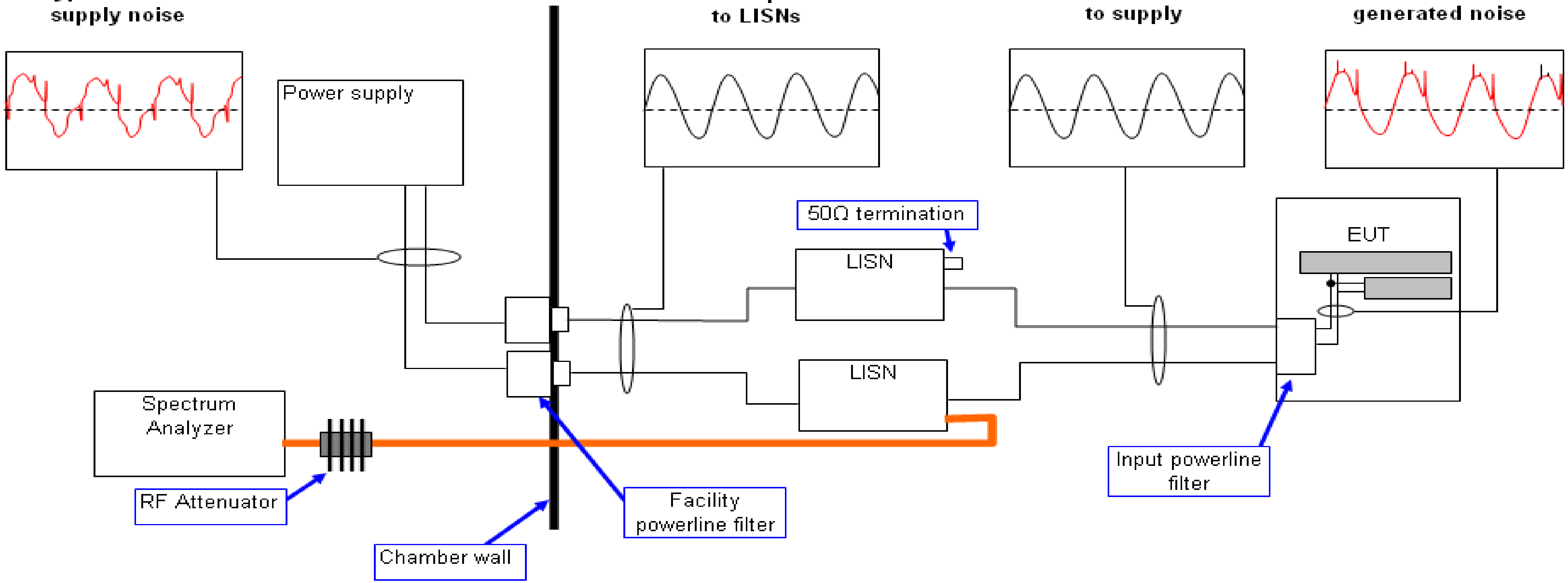
Test Method CE102 *Conducted Emissions*



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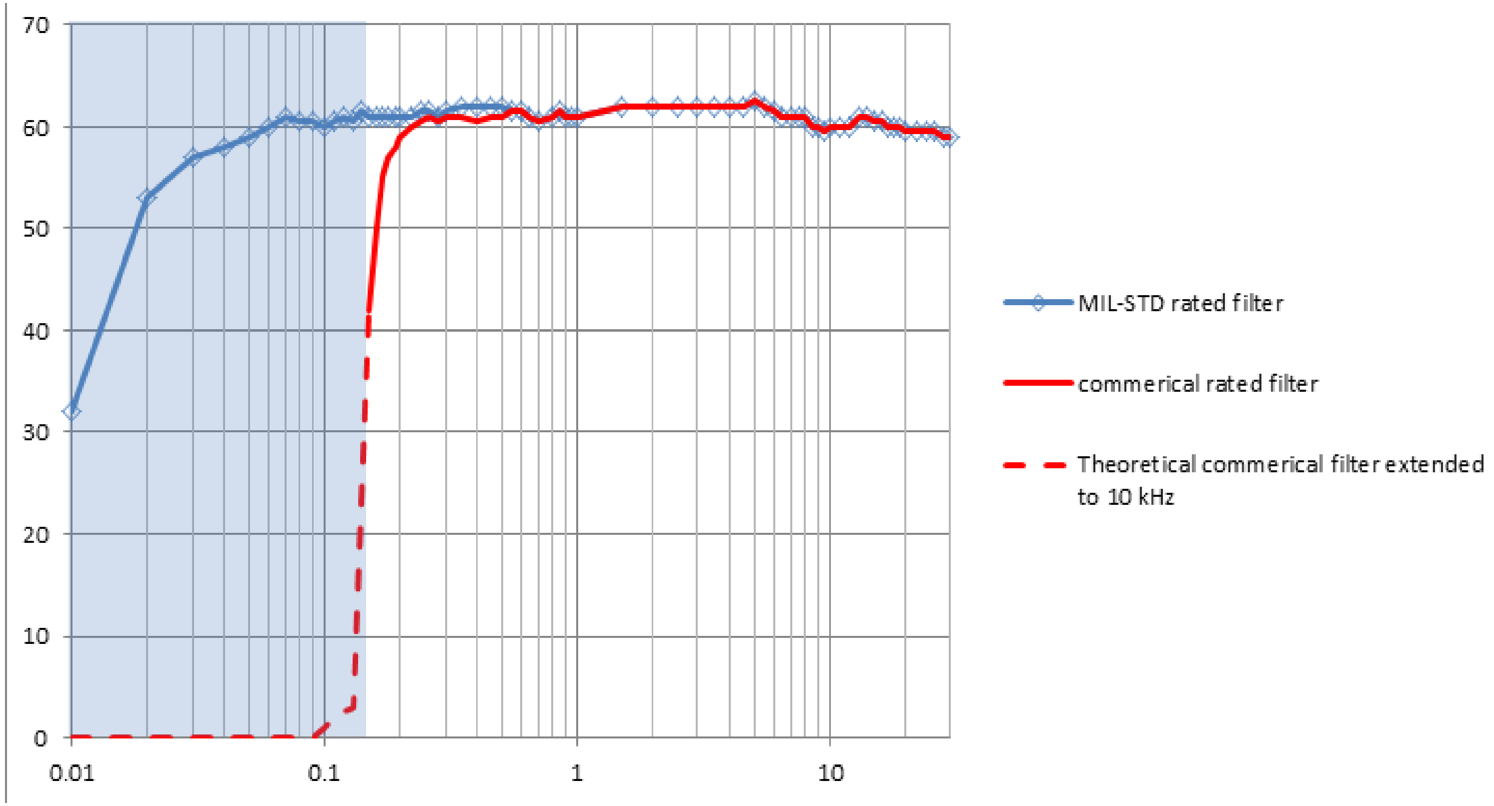
Test Method CE102 *Conducted Emissions- COTS EMI filters*

- Commercial (EN, & FCC) rated filters may not be suitable for defense, applications due to a designed frequency range of 150 KHz to 30 MHz, since CE102 testing is performed from 10 kHz to 10 MHz.

- Manufacturers using must be aware of low frequency operating frequencies to ensure potential noise in the 10 kHz to 150 kHz will not be an issue.
  - Primary concerns: *Variable frequency drives (operating in the 4 kHz to 12 kHz range).*



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CE106- Antenna Port Conducted Emissions

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Test Method CE106 conducted emissions, antenna terminal

- Evaluates the spurious and harmonic voltage (dBµV) content produced at the antenna terminals of transmitters, receivers & RF amplifiers.
- Not applicable for permanently mounted antennas (*this is covered under RE103*)
- Frequency range dependent on the Tx, or Rx frequencies. Up to 20X the highest freq. or 40GHz.
    - Performed on both transmit and receive modes of operation, and transmitters and amplifiers in standby mode.

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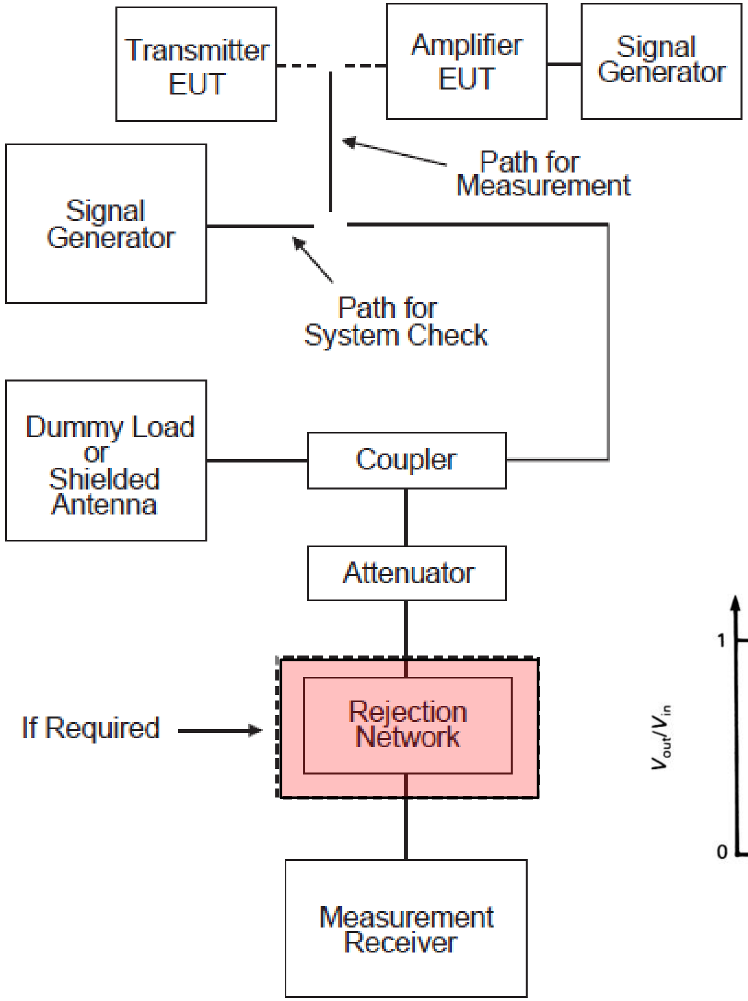
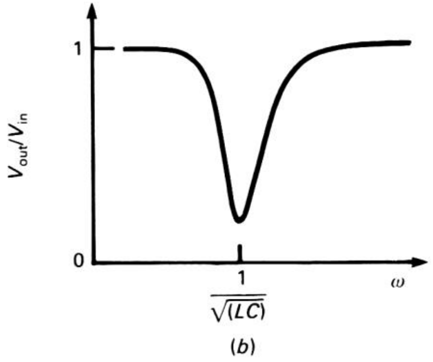
Test Method CE106 conducted emissions, antenna terminal

- Rejection Networks (Notch Filter) may be required in order to achieve the required dynamic measurement range.
    - *Protects the measurement receiver from overload damage similar to a broadband RF attenuator.*
    - *However, it is designed to only attenuate the high power transmit signal and associated harmonics while allowing the spurious noise to pass freely.*
    - *The notch filter must be characterized prior to conducting the test, then the insertion loss factors are added to the measured results.*





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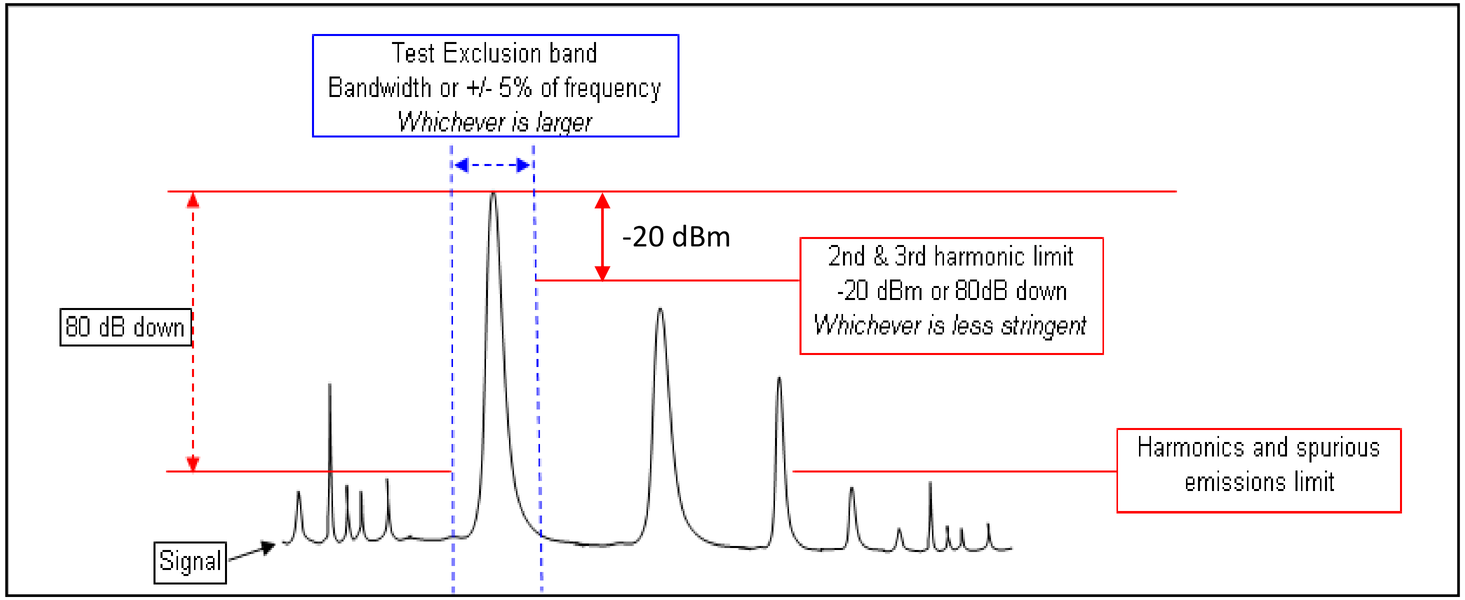
Test Method CE106 conducted emissions, antenna terminal

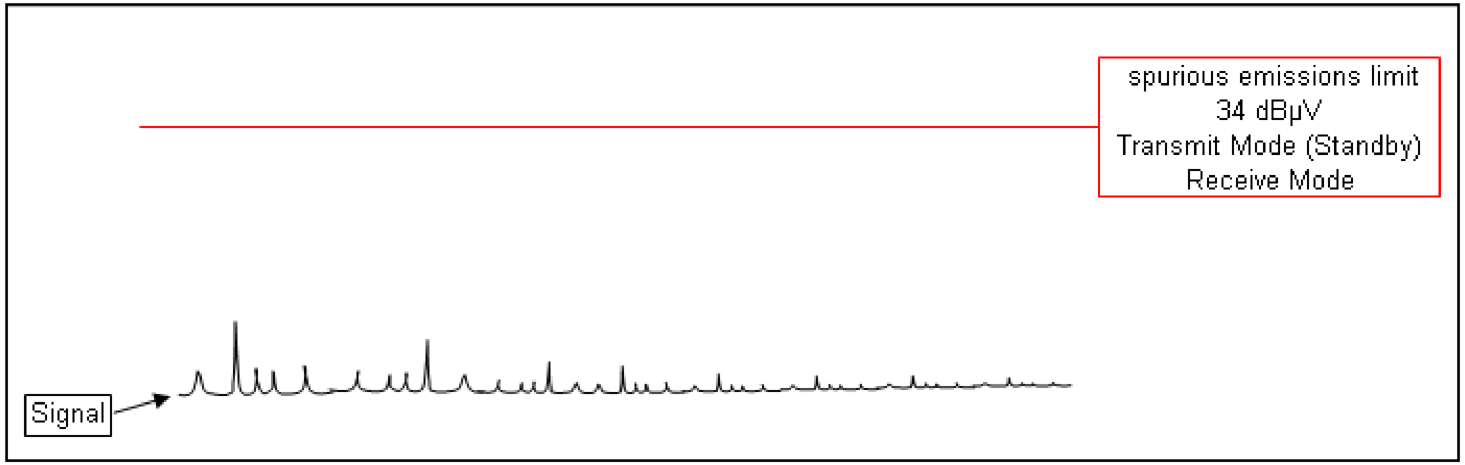
Transmit Mode Limits-

- Transmit Signals are excluded from testing.
- 2nd & 3rd harmonics shall be -20dBm or 80dB down from transmit signal which ever is less stringent.
  - *All other harmonics and spurious signals shall be 80dB down from peak.*
- Navy Applications require the 2nd & 3rd harmonics to be limited to -20 dBm, with all other spurious noise limited to -48 dBm.
  - *When the duty cycle of the emissions is < 0.2%, the limit is relaxed to 0 dBm.*

Standby & Receive mode Limits-

- All spurious noise shall be limited to 34 dBµV.





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CS101- Conducted Susceptibility Power Leads

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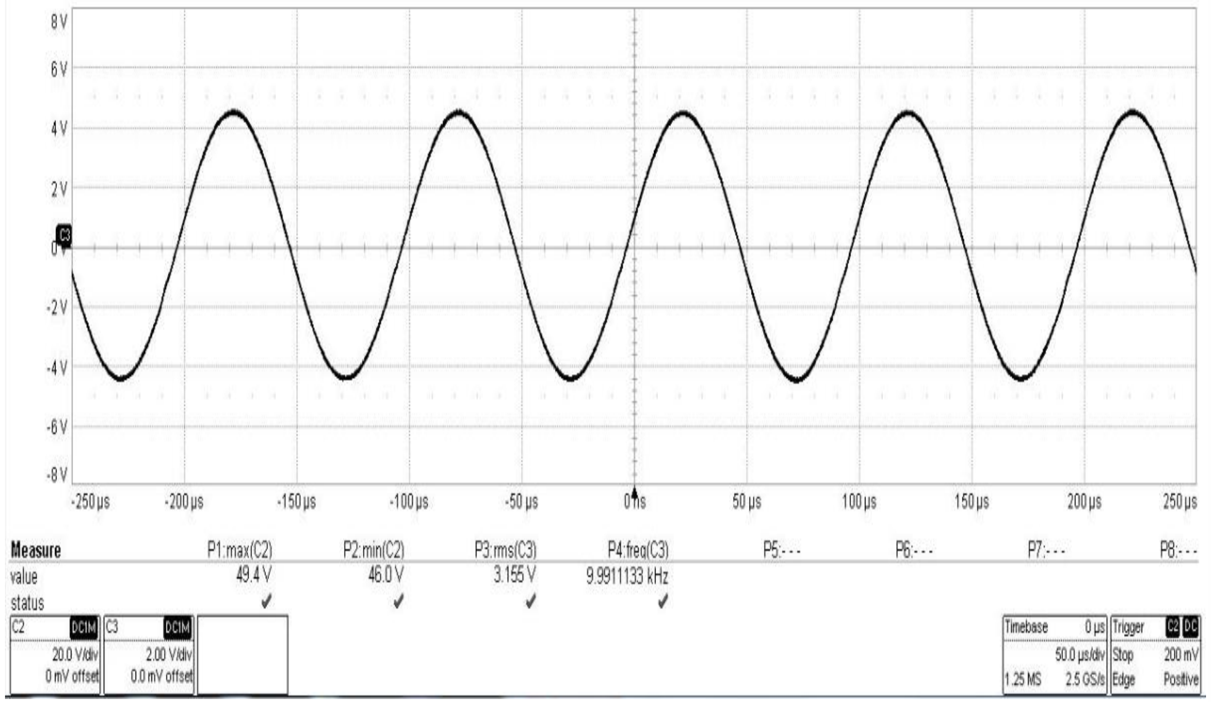
Test Method CS101 Low frequency *conducted susceptibility*

- Evaluates that EUT performance is not degraded from ripple voltages associated with allowable distortion of power source voltage waveforms.

- Applicable to all equipment platform deployments and for all procurement agencies.

- Performed on power input lines High sides only (not on returns).
  - Low frequency coupling 30 Hz – 150 kHz (DC power leads).
  - Low frequency coupling 2nd harmonic – 150 kHz (AC leads).



- Equipment shall not be damaged or show signs of degraded performance.

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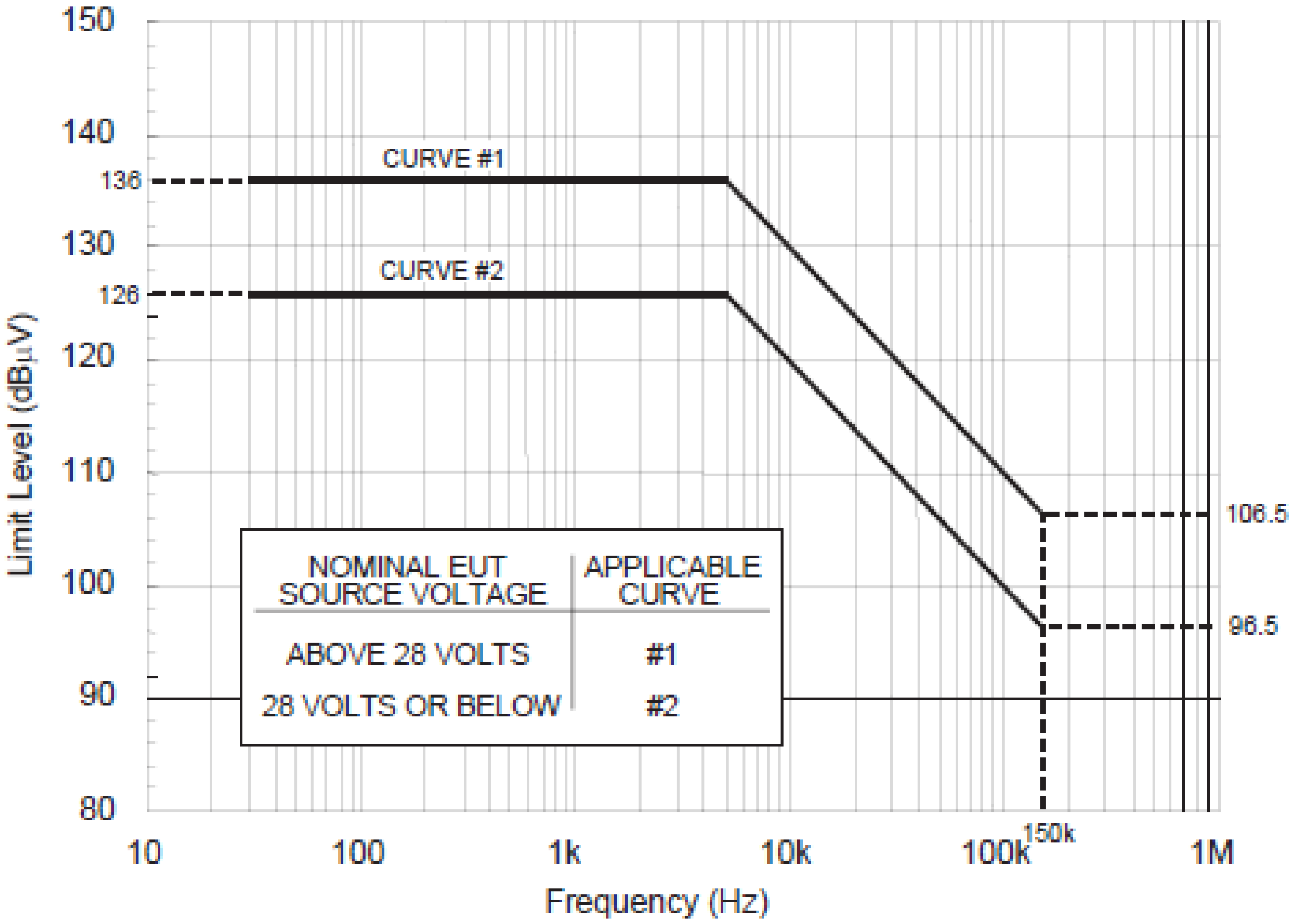
Test Method CS101 Low frequency *conducted susceptibility*

Test Limits-

- Limits are based upon the EUT's primary input voltage level.
- Limits are based on the power quality requirement of MIL-STD-704.
- The voltage amplitude specified is approximately 6 dB above typical power quality limits, although the limit has been somewhat generalized to avoid complex curves.



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Test Method CS101 Low frequency *conducted susceptibility*

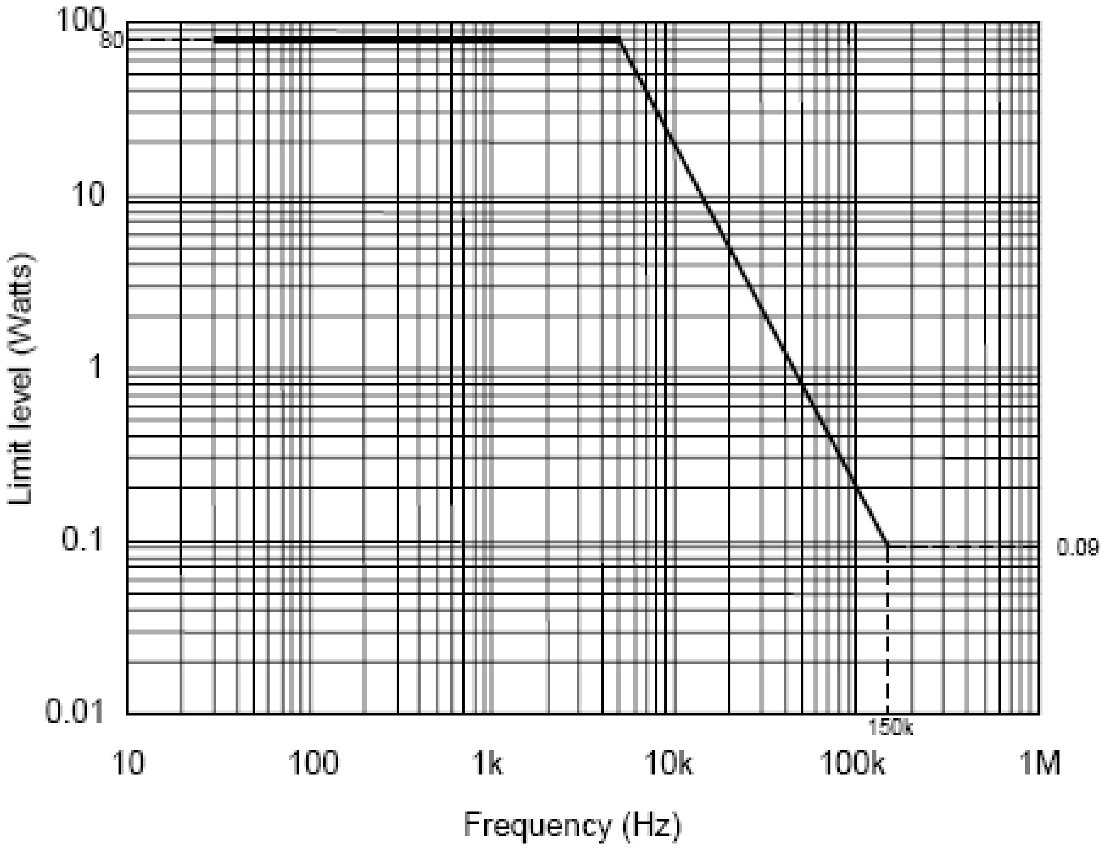
Secondary Power Limit-

- Power is limited to 80 Watts into 0.5 ohms to prevent an excessive over current from being developed on low impedance circuits.

- Bulk capacitors can provide low impedance path for low frequency currents.

EUT Current Limit-

- Testing is limited to systems drawing ≤ 30 amps per phase.
  - *Devices drawing over 30 amps are exempt from CS101 testing, unless load currents can be reduced in normal operating conditions.*
  - *Reduced from 100 amps* because above 30 amps the expected ripple is higher than the CS101 test level.



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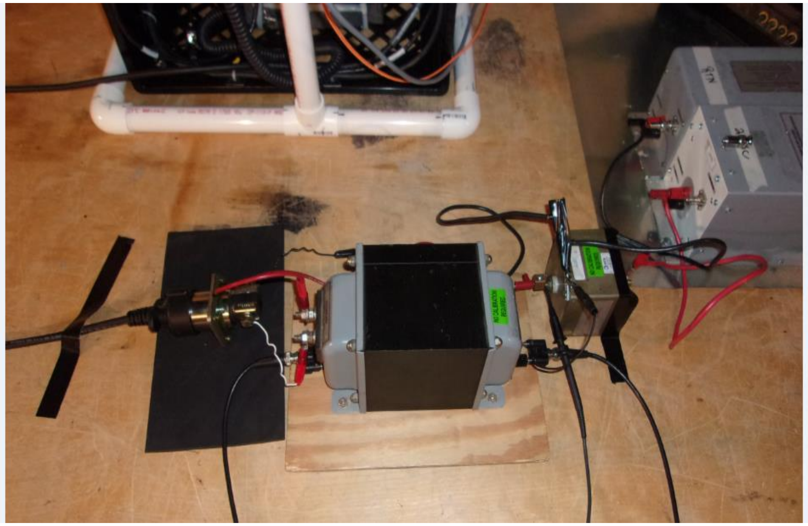
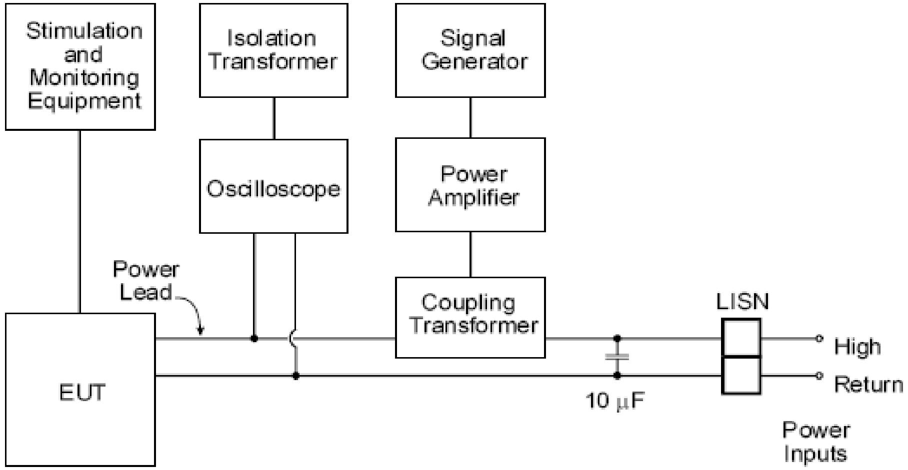
CS101 Test Setup for Single Phase Systems

Test Setup-

- AC signals are coupled onto the EUT’s input power lines (high sides only) using a broadband coupling transformer.
- Voltage is measured differentially and increased until either the voltage test limit or secondary power limit is reached (whichever comes first).
- The test frequency range is either stepped or swept while monitoring EUT operational performance.





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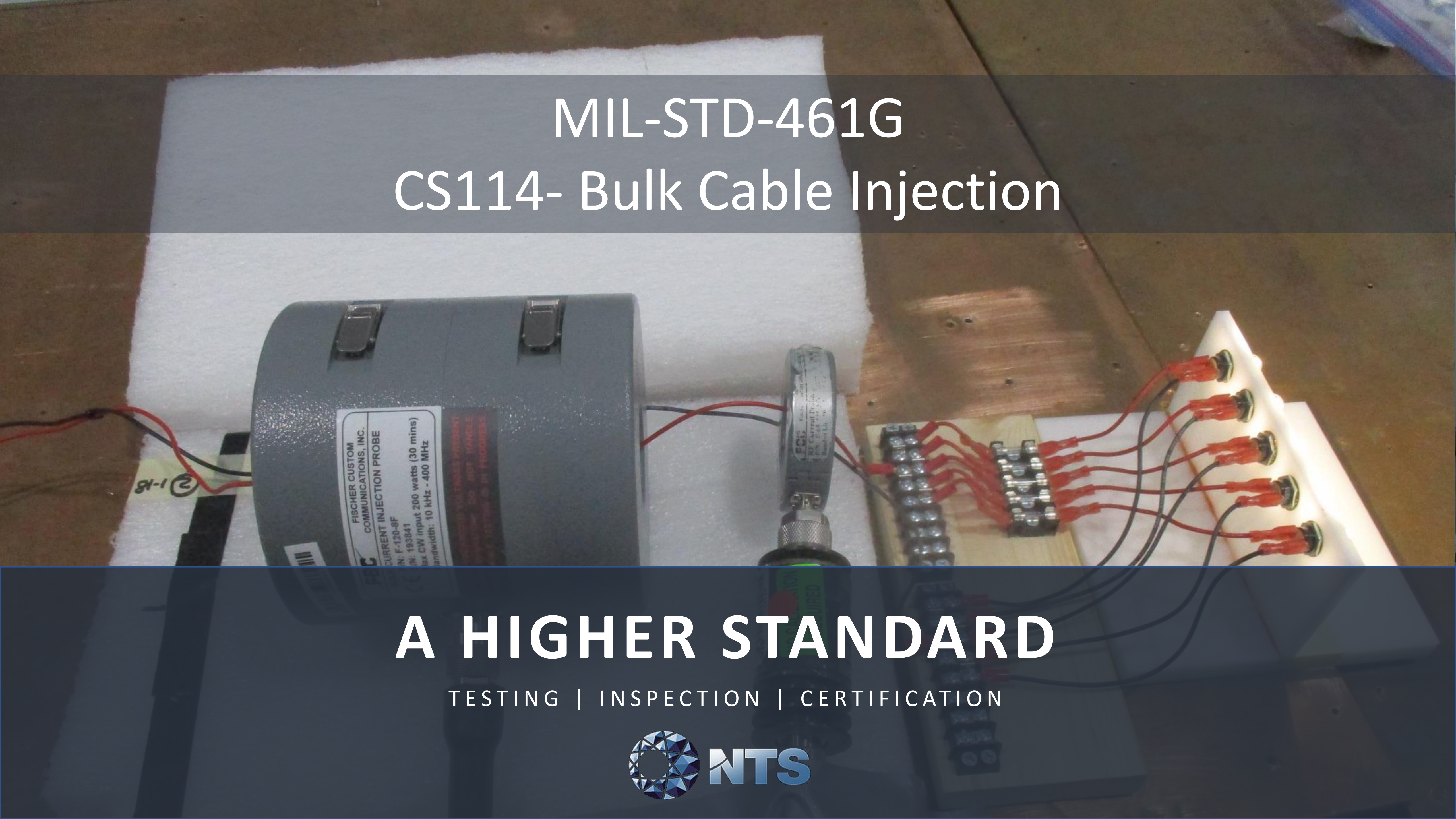
CS114- Bulk Cable Injection



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Test Method CS114 Bulk cable injection

- Simulates currents that will be developed on platform cabling from EMI fields generated by antenna transmissions (RS103) both on and off the platform.
- CS114 provides data that can be directly related to induced current levels measured during platform-level evaluations.
- Testing is performed on all power & signal cables that interface with the EUT from 10 kHz to 200 MHz.

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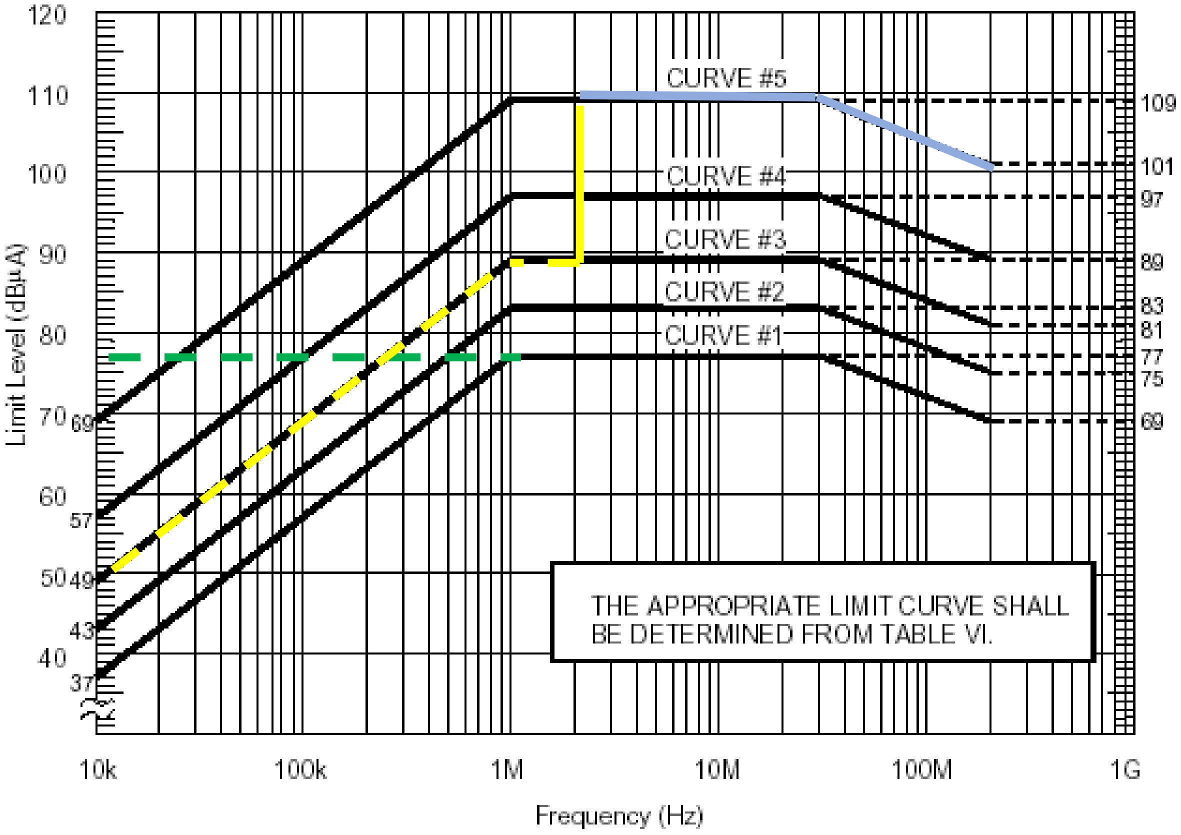
Test Method CS114 Bulk cable injection

FREQUENCY RANGE	PLATFORM	LIMIT CURVE NUMBERS SHOWN IN FIGURE CS-114-1 AND LIMITS							
		AIRCRFAFT (EXTERNAL OR SAFETY CRITICAL)	AIRCRAFT INTERNAL	ALL SHIPS (ABOVE DECK & EXPOSED BELOW DECK) AND SUBMARINES (EXTERNAL)*	SHIPS (METALLIC) (BELOW DECKS)	SHIPS (NON-METALLIC) (BELOW DECK)**	SUBMARINE (INTERNAL)	GROUND	SPACE
4 kHz to 1MHz	N	-	-	77 dBµA	77 dBµA	77 dBµA	77 dBµA	-	-
10 kHz to 2 MHz	A	5	5	2	2	2	1	3	3
	N	5	3	2	2	2	1	2	3
	AF	5	3	-	-	-	-	2	3
2 MHz to 30 MHz	A	5	5	5	2	4	1	4	3
	N	5	5	5	2	4	1	2	3
	AF	5	3	-	-	-	-	2	3
30 MHz to 200 MHZ	A	5	5	5	2	2	2	4	3
	N	5	5	5	2	2	2	2	3
	AF	5	3	-	-	-	-	2	3

KEY: A= Army
N= Navy
AF= Air Force

* For equipment located external to the pressure hull of a submarine but within the superstructure, use SHIPS (METALLIC) (BELOW DECKS)
** For equipment located in the hangar deck of Aircraft Carriers



Example: All Ships Above Decks & Submarines External-

- 77 dBµA from 4 kHz – 1 MHz
- Curve#2 from 10 kHz – 2 MHz
- Curve#5 from 2 MHz – 30 MHz
- Curve#5 from 30 MHz to 200 MHz

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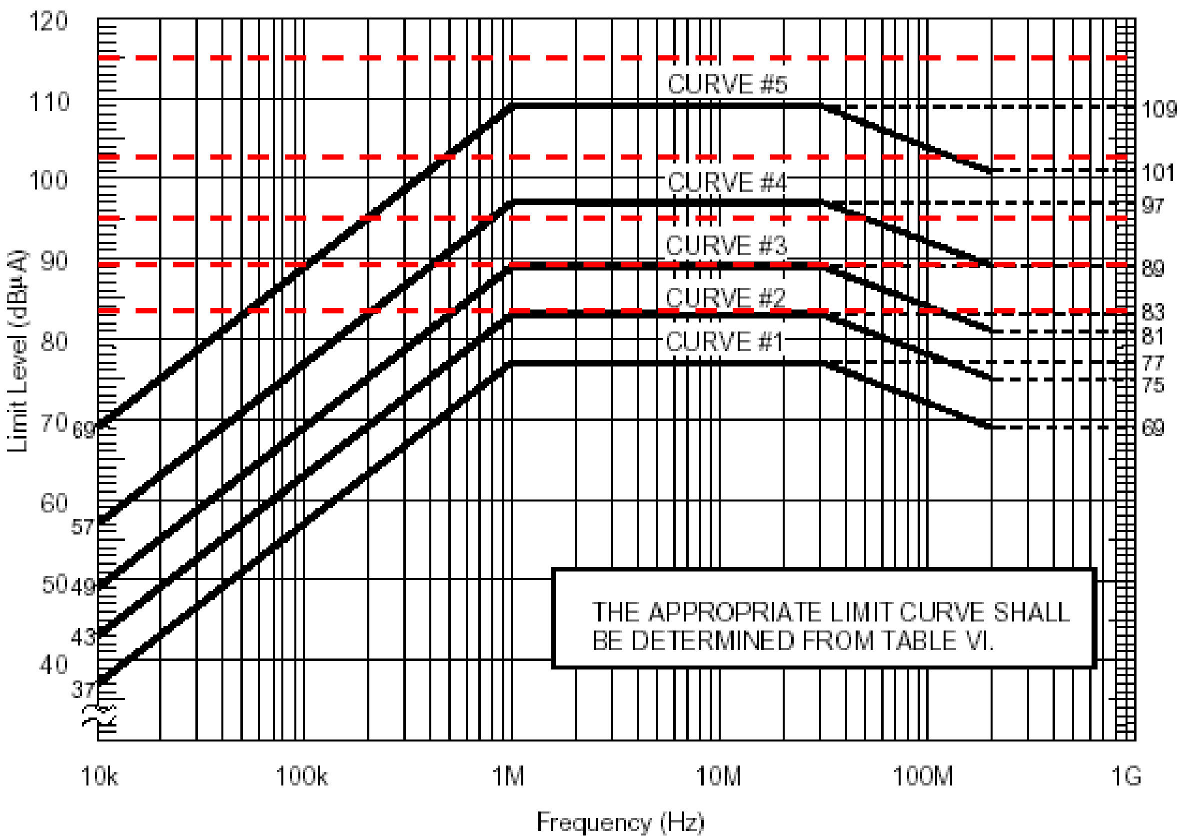
Test Method CS114 Bulk cable injection

- The CS114 test requirements are considered met when the EUT is not susceptible at the pre-calibrated forward power levels required to achieve the appropriate test current limit.
- The CS114 requirements are also met if the EUT is not susceptible at forward power levels that are below those determined during calibration as long as the minimum current for each curve is met:

  - Curve 5 = 115 dBµA,
  - Curve 4 = 103 dBµA,
  - Curve 3 = 95 dBµA,
  - Curve 2 = 89 dBµA
  - Curve 1 = 83 dBµA.

Note minimum current levels are +6 dB over the applicable test limit curve.



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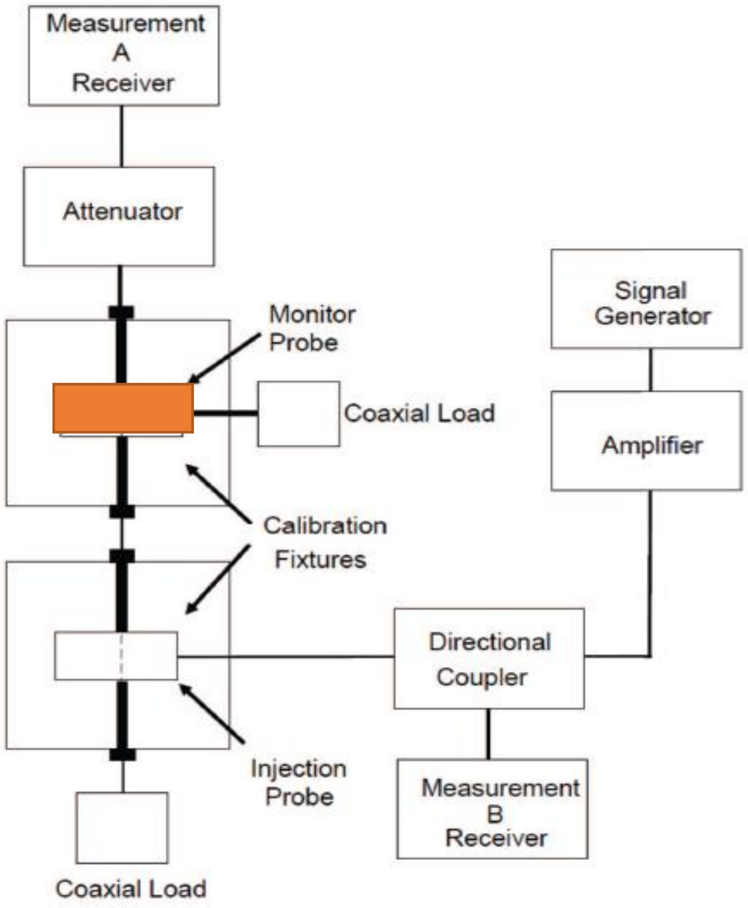
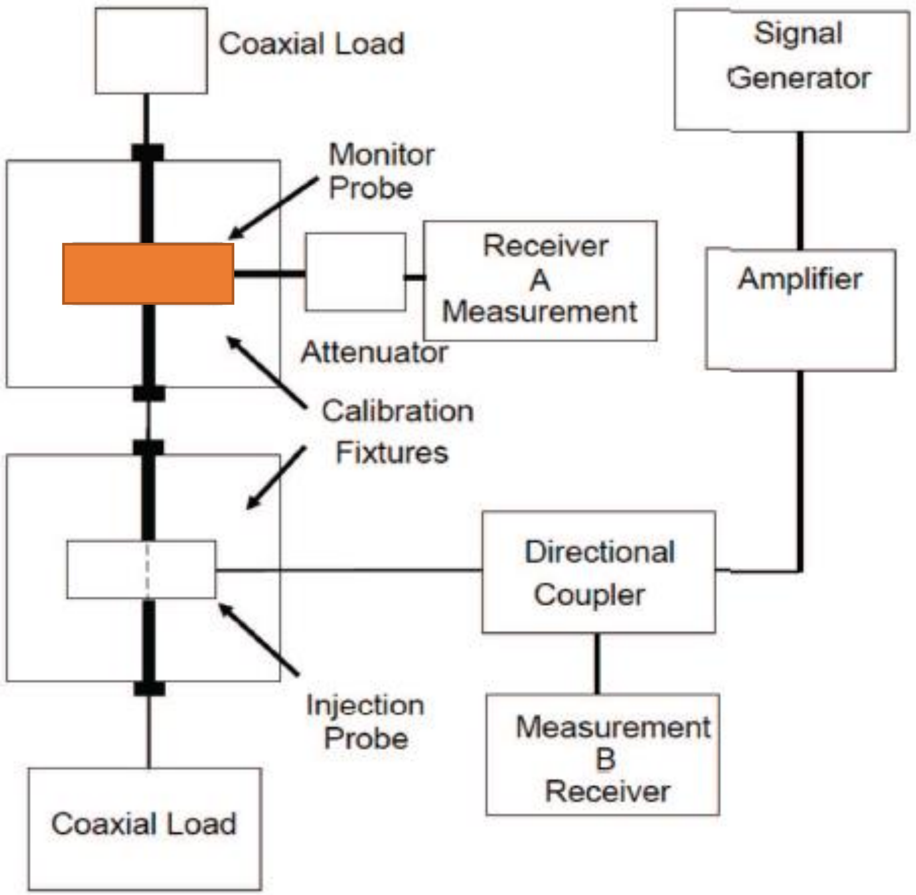
Test Method CS114 Bulk cable injection





- Calibration is now performed with the current monitor clamp in circuit to account for potential signal attenuation effects.

The calibration levels are then verified using the current monitor versus the voltage measurement used in previous versions.

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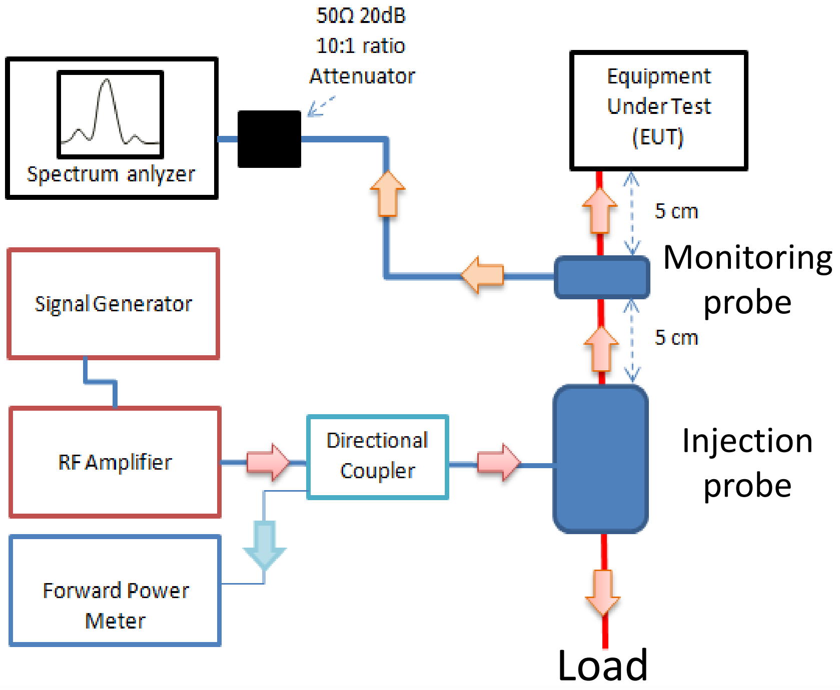
Test Method CS114 Bulk cable injection

- Current monitoring probe positioned 5 cm from EUT.
  - *Injected test current is monitored to prevent excessive current from being developed*.
- Injection Probe positioned 5 cm from monitoring probe.

- The test signal is modulated with 1kHz PM 50% duty cycle 40dB depth.
- At each frequency, the signal amplitude is increased until either the calibrated forward power, or the minimum current level is reached (*whichever is less stringent*).
- A threshold analysis is required at each frequency whenever susceptibility is observed.



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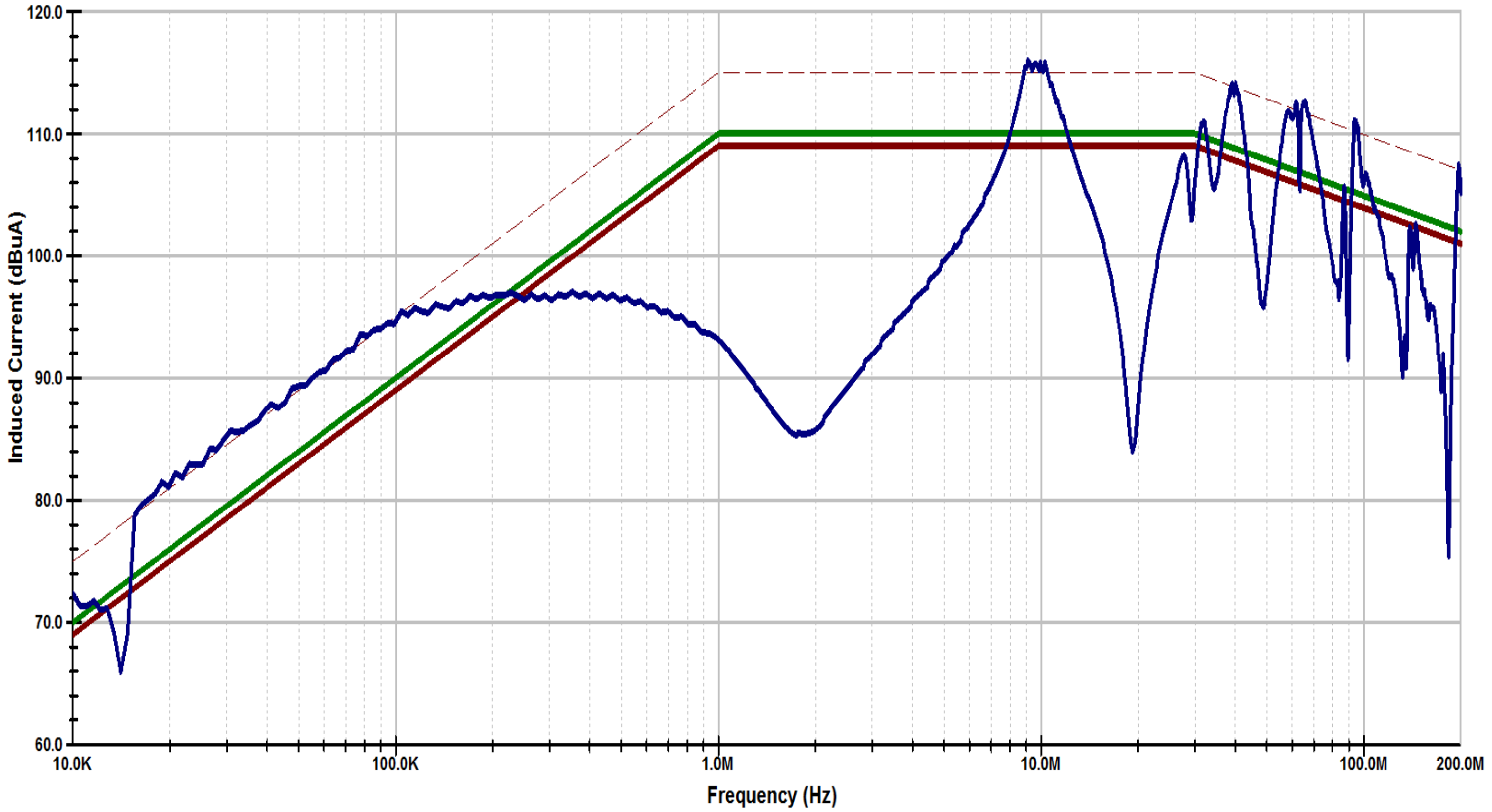
Test Method CS114 Bulk cable injection

- Cable Impedance will determine the amount of current or voltage induced on to the cable at a given frequency..
- High impedance cables (>50 ohms) will induce high voltages and reach the calibrated FWD PWR before the maximum current test level.
- Low impedance cables (shielded lines, common mode filtering, etc…), will reach the maximum current test level before the calibrated FWD PWR.



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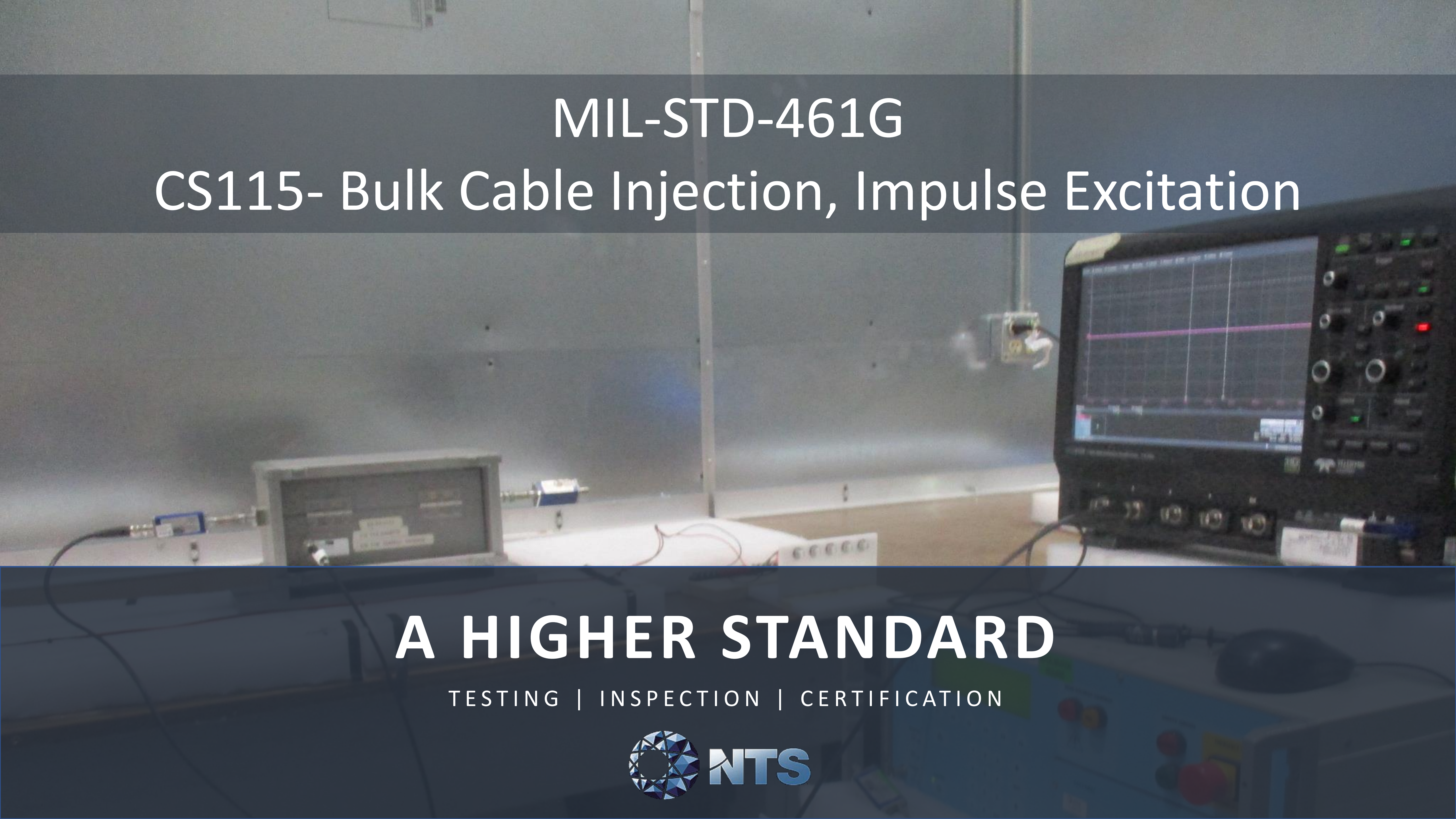
CS115- Bulk Cable Injection, Impulse Excitation



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Test Methods CS115 Bulk cable injection impulse excitation

- Simulates fast rise and fall time transients developed by platform switching operations, and external transient environments (lightning & EMP).
  - *Intended to excite natural resonances on each cable*.
- Performed on all interconnecting including power lines.
  - *Entire power bundle, then repeated with returns and grounds removed*.
- Applicable to all aircraft, space, and ground system applications
  - *Applicable for surface ship and submarine platforms when specified by the procuring activity.*

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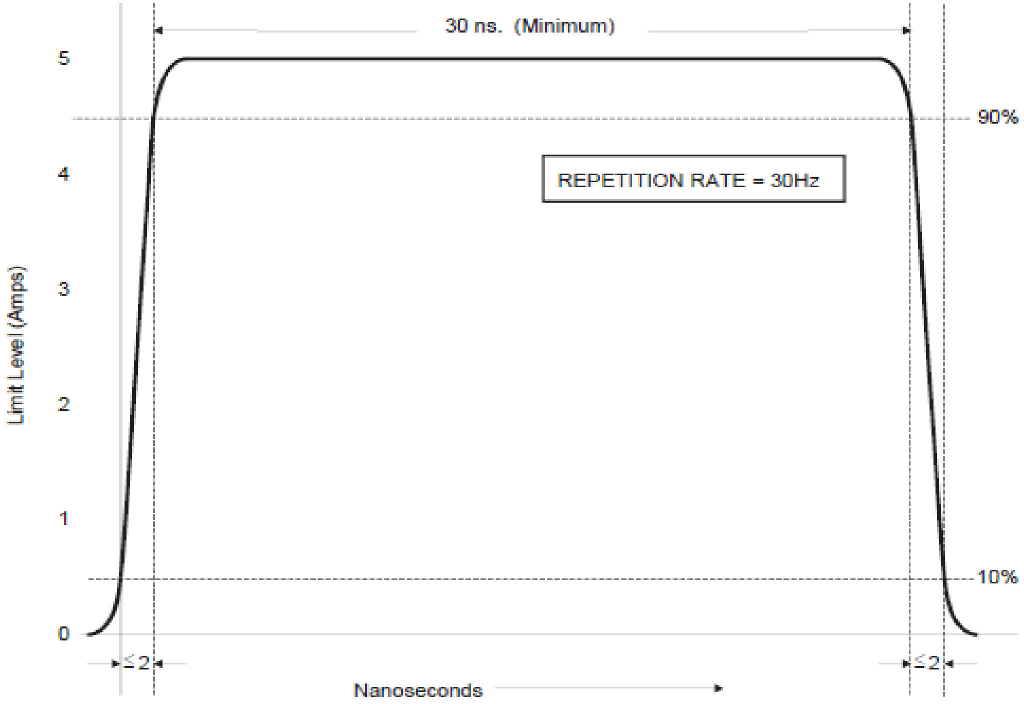
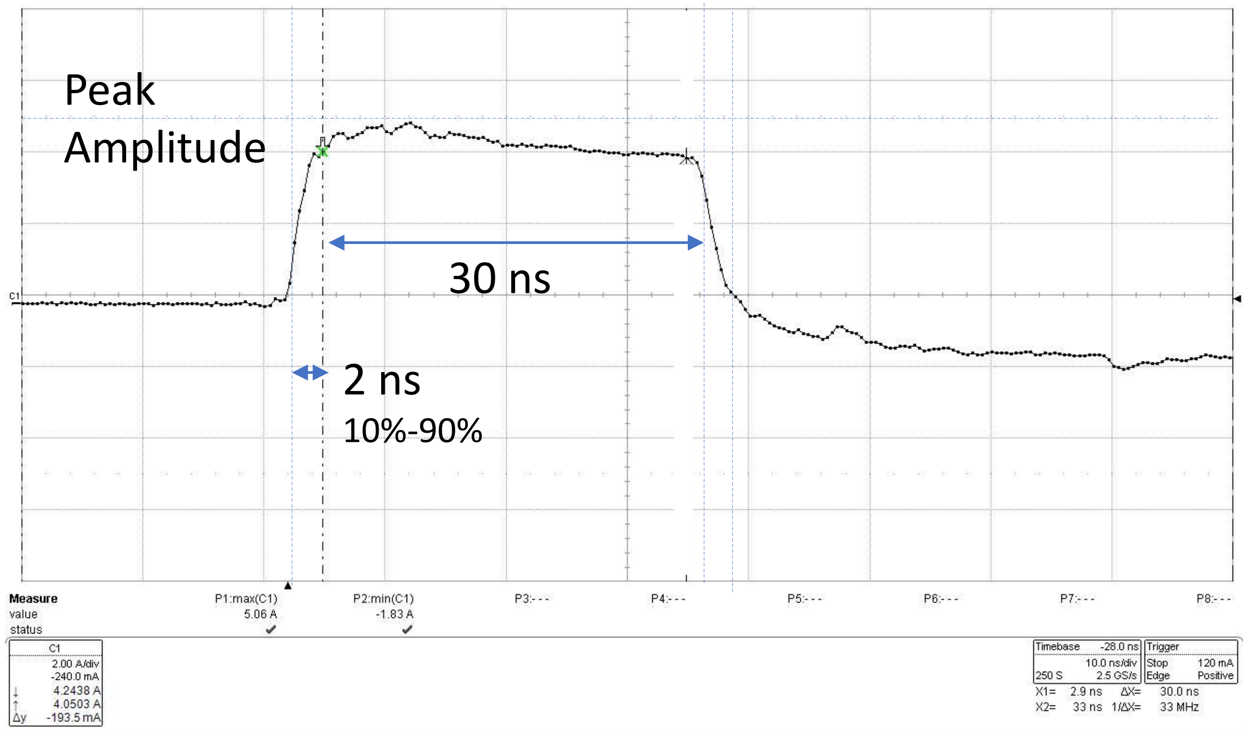
Test Methods CS115 Bulk cable injection impulse excitation

- Rise time, fall time, and pulse width are verified prior to testing.
  - *The precise pulse shape will not be reproduced due to the inductive coupling mechanism.*
- Pulse amplitude of 5 amps peak, 500V (*into 100 Ω*).
- Pulses are applied at a 30 Hz rate for 1 minute.





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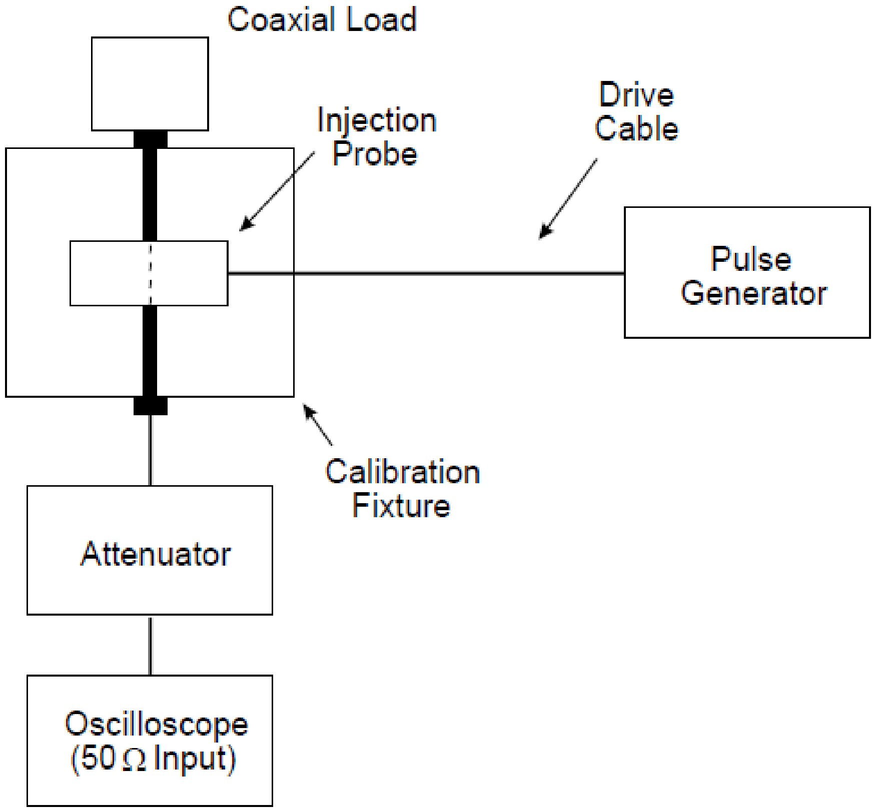
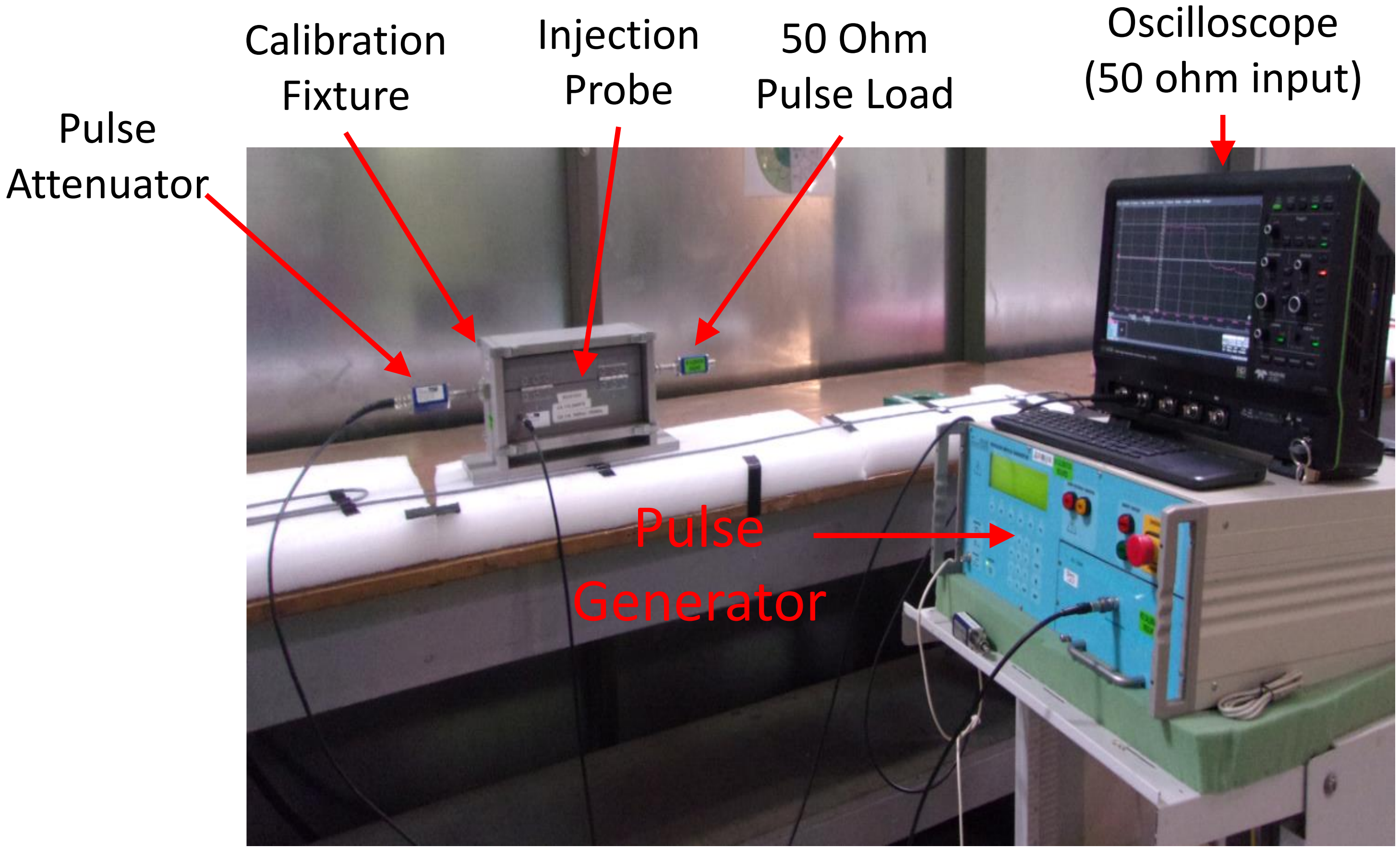
Test Methods CS115 Bulk cable injection impulse excitation

- Pulse amplitude is gradually increased until test level (5 amps) is reached.
- Waveform parameters are verified, and generator setting are recorded.






MIL-STD-461G
CS116- Damped Sinusoidal Transients
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Test Methods *CS116* Damped sinusoidal transients

- Simulates the excitation of natural cable resonances induced by platform
  - *Caused by both external stimuli (lightning and electromagnetic pulse) and from platform electrical switching phenomena.*
- Applicable to all platform applications and procurement branches. However, CS116 it is only applicable for submarines applications where cabling is routed external to the pressure hull.

- CS116 Pulses are generally applied at discrete frequencies 10 kHz, 100 kHz,1 MHz, 10 MHz, 30 MHz, and 100 MHz to cover a wide range of coupling scenarios.
- CS116 shall also be performed at other critical installation frequencies such as platform electrical resonance frequencies (if known).

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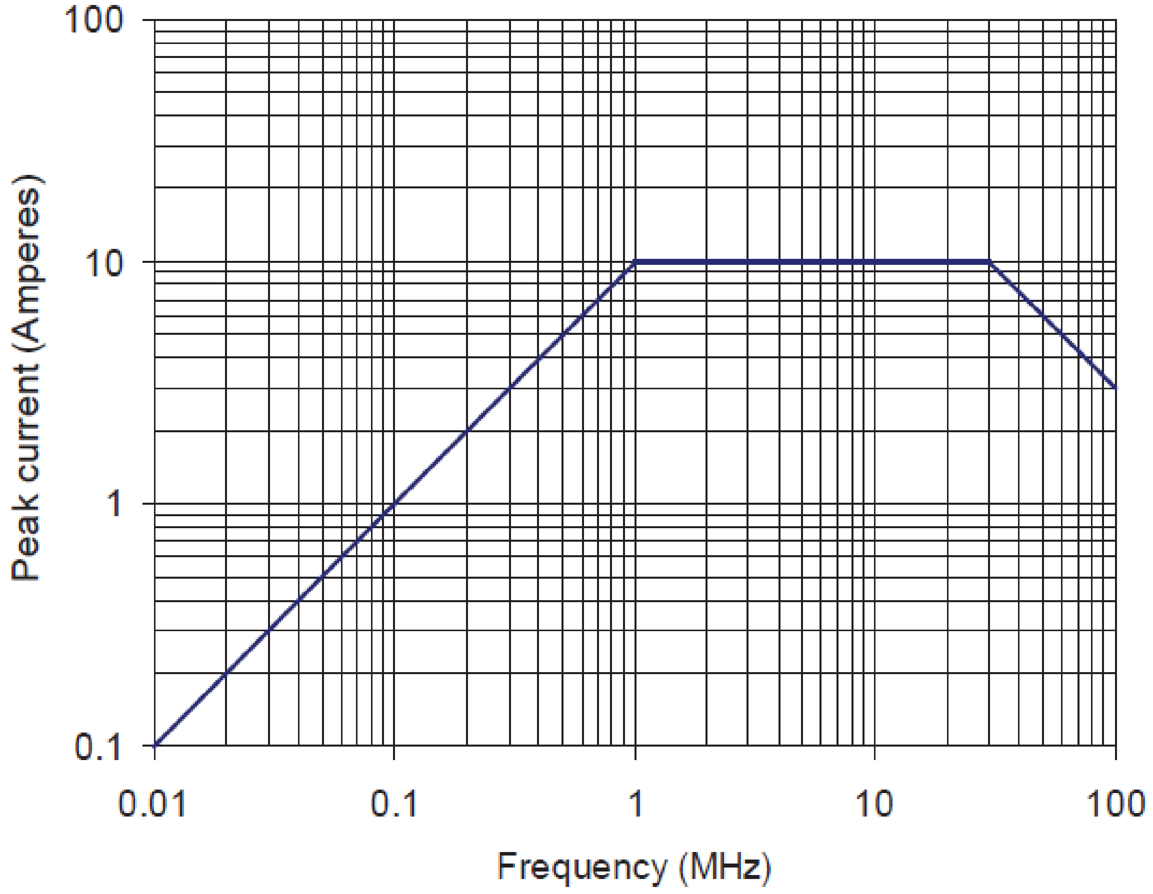
Test Methods *CS116* Damped sinusoidal transients

CS116 Test Limit- All applications

- 100mA peak test level at 10 kHz increasing at a rate of 20 dB per decade to 1 MHz
- 10 Amp peak test level between 1 MHz and 30 MHz.
- 10 Amp peak test level at 30 MHz decreases at a rate of 20 dB per decade to a 3 Amp peak test level at 100 MHz.
- Theses current limits represent induced levels typically found in platforms during system-level testing to external transient environments.
  - *The lower frequency breakpoints represent the worst-case platform resonant frequencies which have a consistent response fall off of 20 dB/decade.*
  - *The upper frequency breakpoint is located where the spectral content of the transient environments falls off also at a rate of 20dB/decade.*



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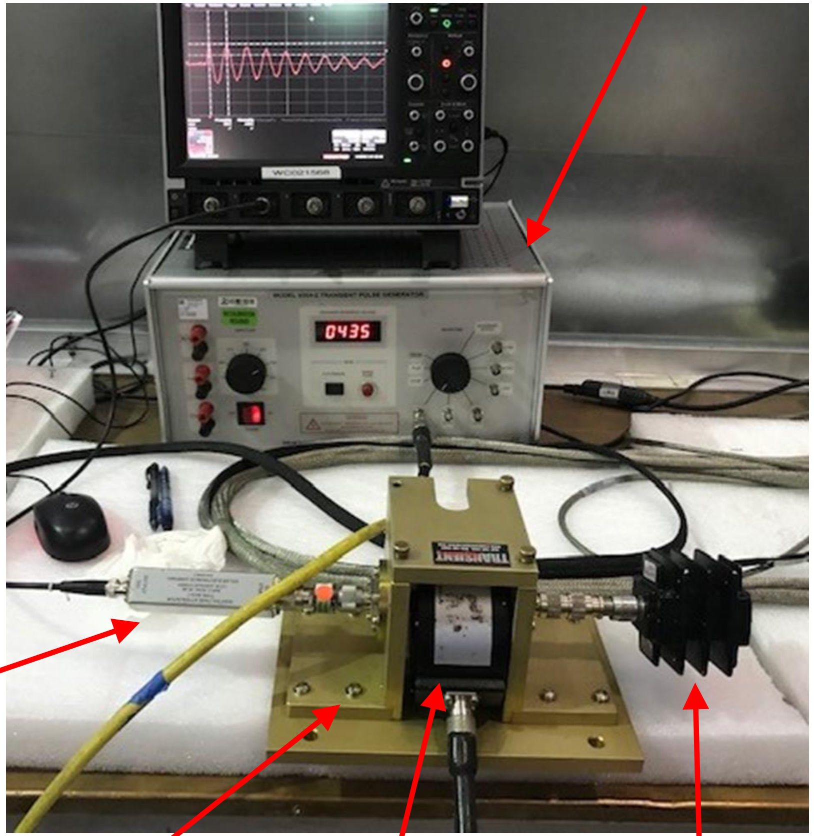
Test Methods *CS116* Damped sinusoidal transients

CS116 Waveform Verification

- Turn on the measurement equipment and allow sufficient time for stabilization.
- The Waveform verification setup is similar to CS116.
- The amplitude of damped sine generator is gradually increased until the appropriate peak current level is reached.
- The test generator settings are recorded, and the waveform parameters are verified for amplitude, frequency, and damping factor (Q).
- This is repeated for each test frequency from 10 kHz to 100MHz,



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Test Methods *CS116* Damped sinusoidal transients

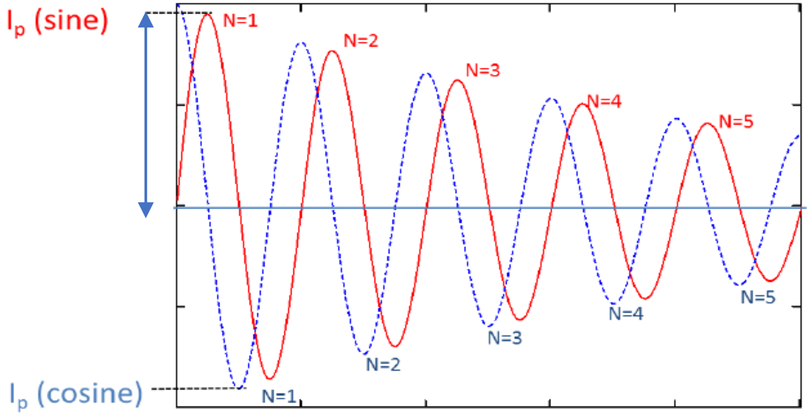
Damping Factor

- Q of the injected waveform is measured to ensure the proper energy is contained in the damped waveform.
- This is determined at the peak of the first half-sine wave and the associated peak closest to being 50% down in amplitude.

Sine Vs. Cosine Waveforms

- It is acceptable to use a damped cosine waveform rather than a damped sine waveform. However damped cosine is considered more severe than the damped sine because of the fast rise time on the leading edge, and may result in EUT failures.

- The first peak should not be used to determine Q for damped cosine waveforms due to potential leading edge noise issues.
- The next half peak (negative going) should be used together with the associated negative peak closest to 50% down.



Normalized Waveform: $e^{-(\pi f t)/Q}\sin(2\pi f t)$

Where:
f = Frequency (Hz)
t = Time (sec)
Q = Damping Factor, 15 ±5

Damping Factor Calculation: $Q = \dfrac{\pi(N-1)}{\ln\left(\frac{I_P}{I_N}\right)}$

Where:
Q = Damping Factor
N = Cycle number (i.e. N= 2, 3, 4, 5, …)
I_P *= Peak current at 1st cycle*
I_N *= Peak current at cycle closest to 50% decay*
In = Natural log

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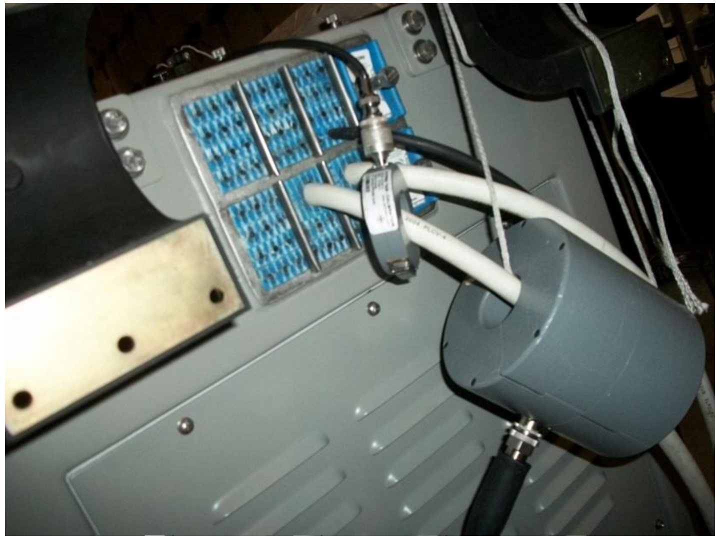
Test Methods CS116 Damped sinusoidal transients

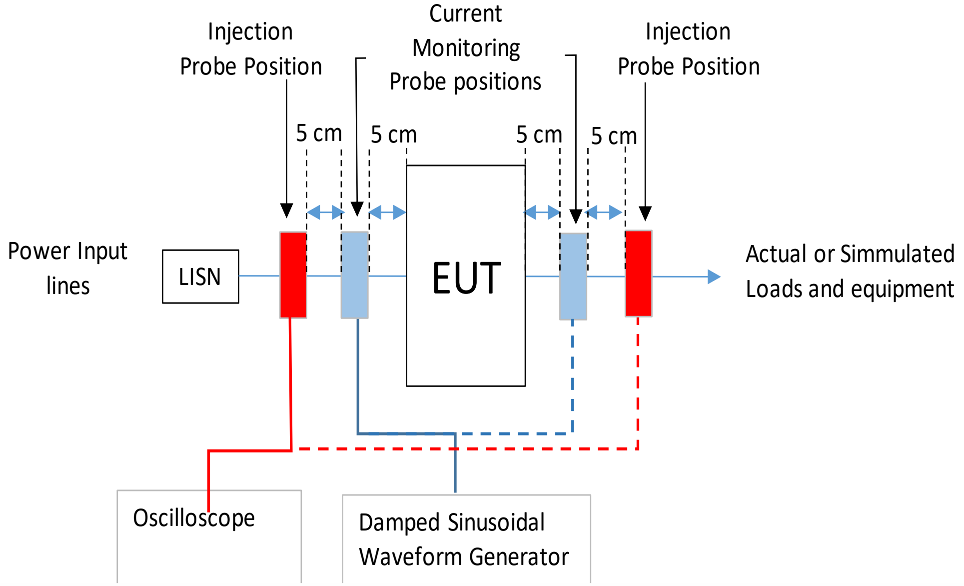
- The injection and monitor probes are positioned around a cable bundle interfacing an EUT connector.
- monitor probe 5 cm from the connector, and the injection probe 5 cm from the monitor probe.
  - *If the overall length of the EUT connector, backshell exceeds 5 cm, position the monitor probe as close to the connector's backshell as possible.*

- Apply the calibrated test signals to each cable or power lead of the EUT sequentially at a repetition rate no greater than one pulse per second and no less than one pulse every two seconds, for a period of five minutes.
  - *In an effort to avoid over current testing of low impedance cables, It is preferred to gradually increase the signal until either the generator's calibration setting or peak current test level is reached (whichever is less).*

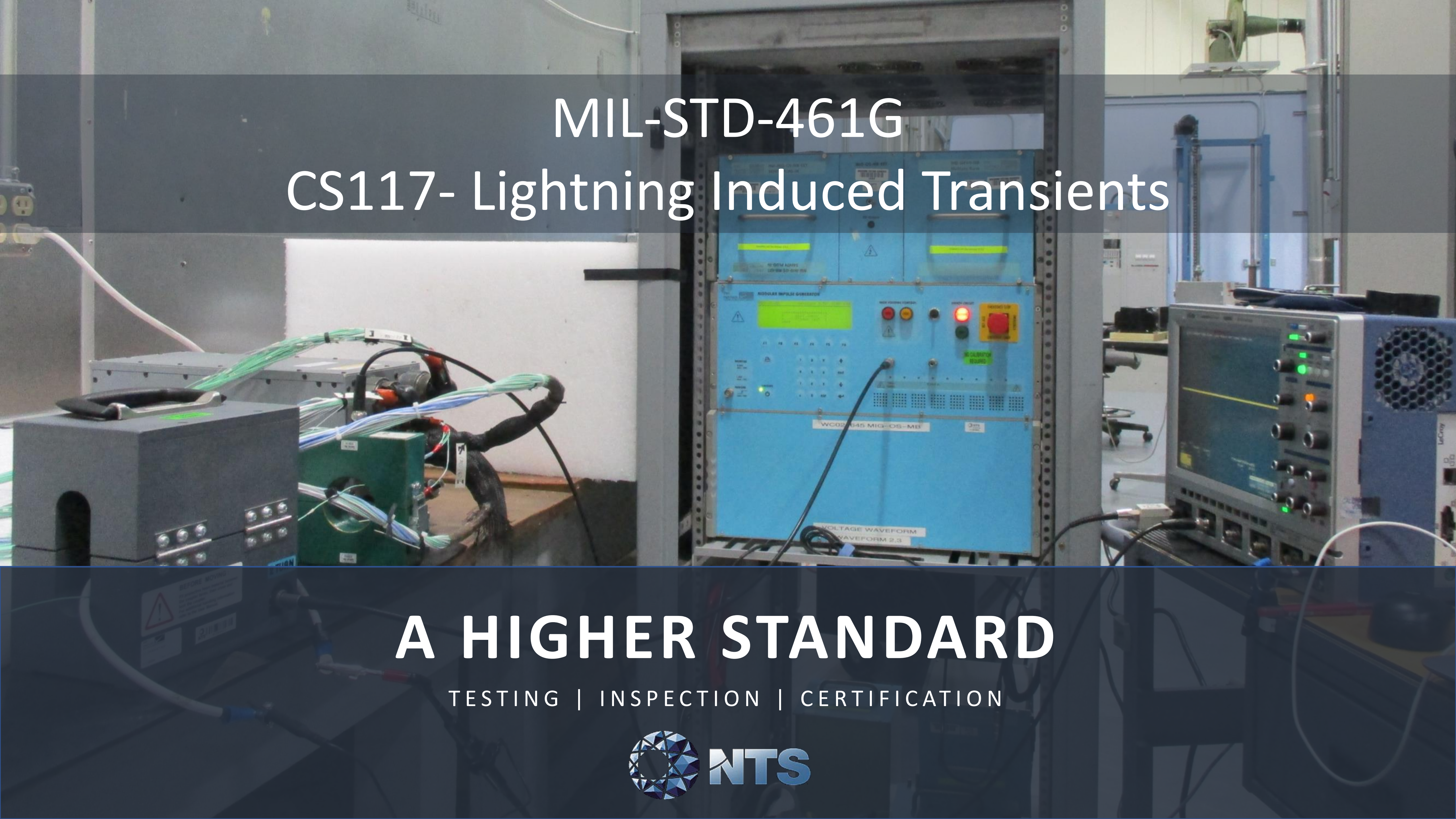
- Since the quality factor (Q) of the damped sine waveform results in both positive and negative peaks of significant value regardless of the polarity of the first peak, there is no requirement to perform testing in both polarities. Either polarity will suffice.



- *Similar Injection technique as CS114 and CS115.*



MIL-STD-461G
CS117- Lightning Induced Transients



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Test Methods *CS117* Lightning Induced Transients conducted susceptibility

- CS117 Evaluates withstand capability of lightning induced voltages and currents inductively coupled to a device's power and signal lines.

- Limited applicability to aircraft, surface ships (above decks applications), and space systems. May be elected in special circumstances for Army ground applications.

    - Performed on all aircraft safety-critical related equipment interconnecting cabling as well as non-safety critical equipment and cabling which is connected to equipment performing safety critical functions.

    - Additional guidance can be found in the FAA AC 20-136B, as well as SAE ARP5412 and RTCA DO160.

MIL-STD-461G

Test Methods *CS117* Lightning Induced Transients conducted susceptibility

- The transient waveforms and specified test levels provided are considered generic, are to be selected by default when actual data does not exist.

- When platform data is available it should be used to tailor the test conditions pending approval.

Default Test Level selection-

- Default Test levels are segregated into two categories, **internal equipment** and **external equipment** environments.

  - Equipment that is installed within the aircraft fuselage but have wire bundles routed through exterior portions of the aircraft, should be tested to external levels.

  - Equipment installed on aircraft with portions of structure that are constructed of non-conductive materials are tested to external environments.

Test Number	Test Description/Applicability	Internal Equipment Limits [1/]	External Equipment limits [1/]
1	Multiple Stroke –Waveforms 1 and 2. Applicable to all aircraft.	Initial Stroke V_L = 300 volts (WF #2) I_T = 600 amps (WF #1) I_L = 60 amps [2/] Subsequent Strokes V_L = 150 volts (WF #2) I_T = 150 amps (WF #1) I_L = 30 amps [2/]	Initial Stroke V_L = 750 volts (WF #2) I_T = 1500 amps (WF #1) I_L = 150 amps [2/] Subsequent Strokes V_L = 375 volts (WF #2) I_T = 375 amps (WF #1) I_L = 75 amps [2/]
2	Multiple Stroke – Waveform 3, (apply at both 1 and 10 MHz) Applicable to all aircraft.	Initial Stroke V_T = 600 volts (WF #3) I_L = 120 amps (WF #3) I_T = 12 amps [2/] Subsequent Strokes V_T = 300 volts (WF #3) I_L = 60 amps (WF #3) I_T = 12 amps [2/]	Initial Stroke V_T = 1500 volts (WF #3) I_L = 300 amps (WF #3) I_T = 60 amps [2/] Subsequent Strokes V_T = 750 volts (WF #3) I_L = 150 amps (WF #3) I_T = 30 amps [2/]
3	Multiple Stroke – Waveform 4 and 5. Applicable to aircraft with composite skin/structure. Not applicable to an all-metal skin/structure aircraft.	Initial Stroke V_L = 300 volts (WF #4) I_T = 1000 amps (WF #5) I_L = 300 amps [2/] Subsequent Strokes V_L = 75 volts (WF #2) I_T = 200 amps (WF #1) I_L = 150 amps [2/]	Initial Stroke V_L = 750 volts (WF #4) I_T = 2000 amps (WF #5) I_L = 750 amps [2/] Subsequent Strokes V_L = 187.5 volts (WF #2) I_T = 400 amps (WF #1) I_L = 375 amps [2/]
4	Multiple Burst –Waveform 3, (apply at both 1 and 10 MHz). Applicable to all aircraft.	V_T = 360 volts (WF #3) I_L = 6 amps (WF #3) F = 1 MHz, 10 MHz	V_T = 900 volts (WF #3) I_L = 15 amps (WF #3) F = 1 MHz, 10 MHz
5	Multiple Burst –Waveform 6. Applicable to low impedance bundles only.	V_T = 600 volts (WF #6) I_L = 30 amps (WF #6)	V_T = 1500 volts (WF #6) I_L = 75 amps (WF #6)

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Test Methods *CS117* Lightning Induced Transients conducted susceptibility

- Each waveform is identified as a “voltage waveform”, or a “current waveform” based on the anticipated platform coupling mechanism.
- Waveform test characteristics are identified as “V_T” or “I_T” respectively.

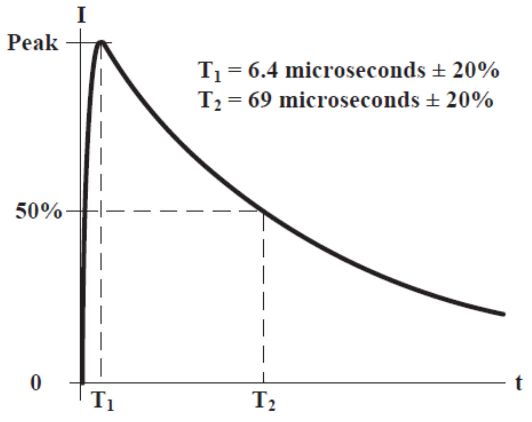


FIGURE CS117-1. Current Waveform 1.

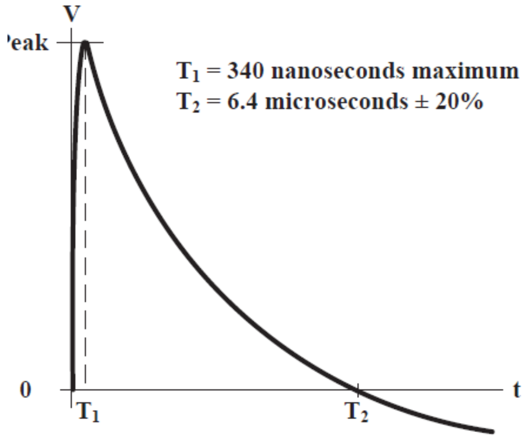
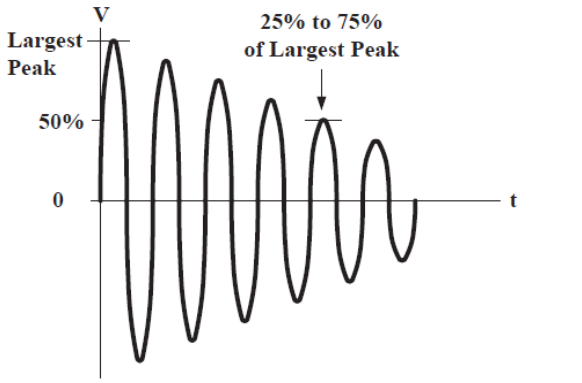


FIGURE CS117-2. Voltage Waveform 2.



NOTE: The waveshape may have either a damped sine or cosine waveshape.

FIGURE CS117-3. Voltage Waveform 3.

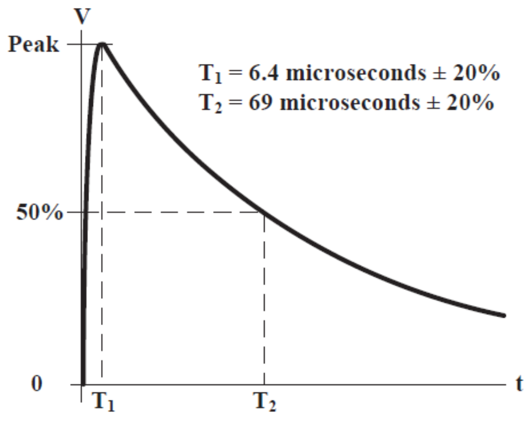


FIGURE CS117-4. Voltage Waveform 4.

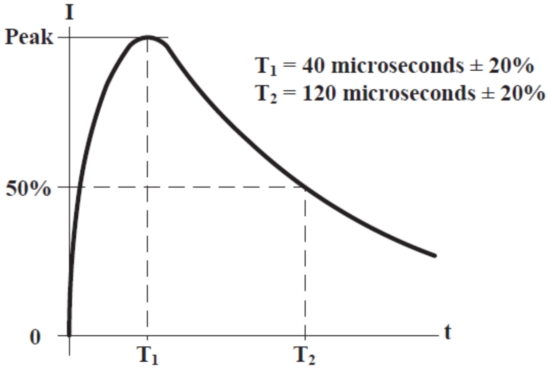


FIGURE CS117-5. Current Waveform 5A.

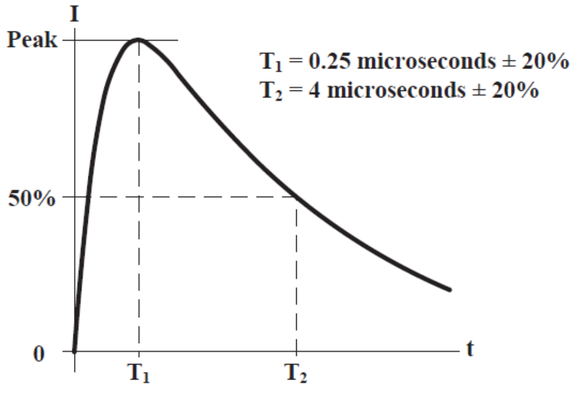


FIGURE CS117-6. Current Waveform 6.

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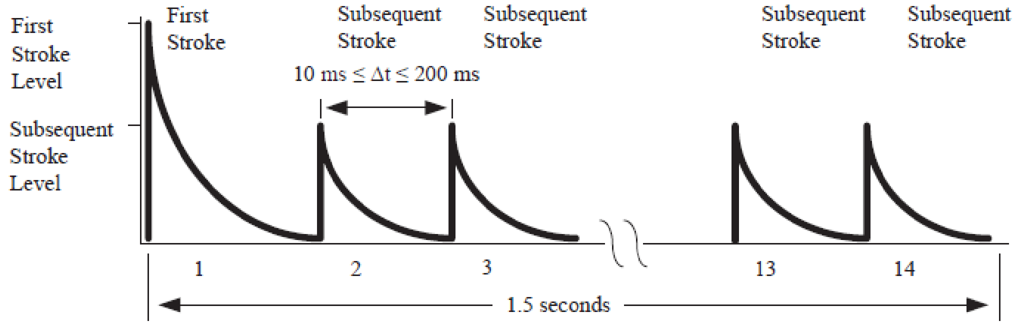
Test Methods *CS117* Lightning Induced Transients conducted susceptibility

Waveform Applications

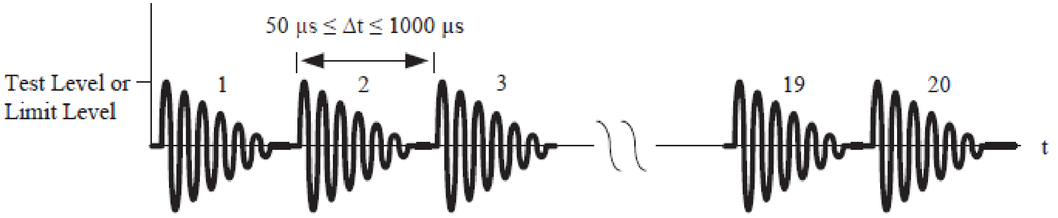
- **Single Stroke**
  - First initial lightning stroke (single pulse).

- **Multi-Stroke**
  - Typically performed immediately following the single stroke
  - 13 subsequent stokes (at half power of the single stroke) randomly spaced over a 1.5 second period.
  - A minimum of 10 applications are applied in each polarity (as applicable).

- **Multi-Burst.**
  - Transients are spaced randomly between 50µs and 1ms, in groups of 20 to form a Burst.
  - Bursts are then randomly spaced between 30 ms and 300 ms, and applied every 3 seconds (3 seconds between the start of each set of three bursts) continuously for a minimum of 5 minutes.



One first transient followed by thirteen subsequent transients distributed over a period of up to 1.5 seconds.



One burst is 20 transients spaced 50-1000 microseconds

One burst application is 3 sets of bursts spaced 30-300 milliseconds

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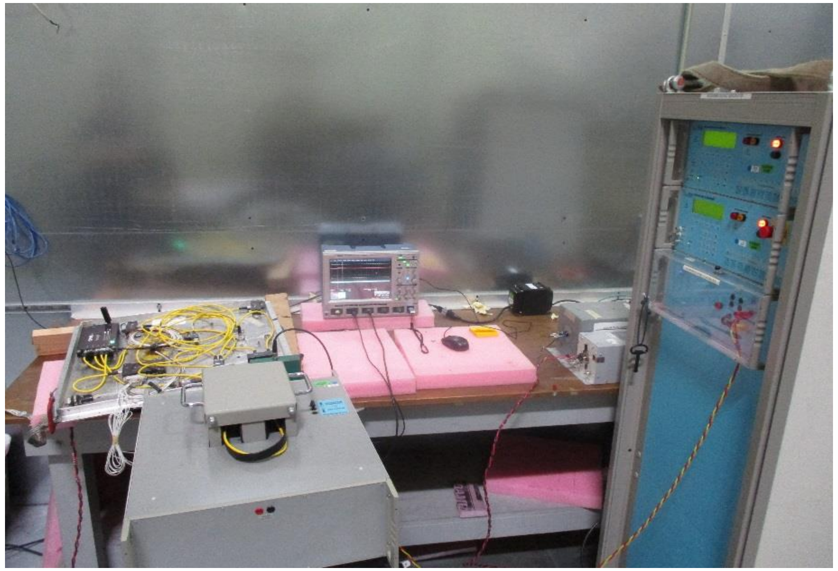
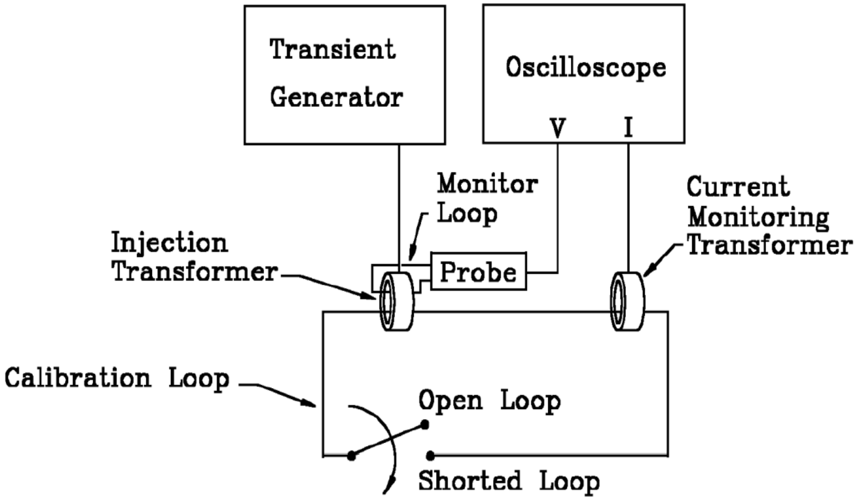
Test Methods *CS117* Lightning Induced Transients conducted susceptibility

- Waveforms parameters verified at the coupling transformer prior to testing.

- Based on the selected waveform test level (V_T or I_T), Either the Open Circuit Voltage waveform or the Short Circuit Current waveform parameters must be verified.

- It is not necessary for the transient generator to produce the associated voltage or current limit level (V_L or I_L) and waveshape. However, limit level waveform should be recorded at the generator setting used to achieve the test level.





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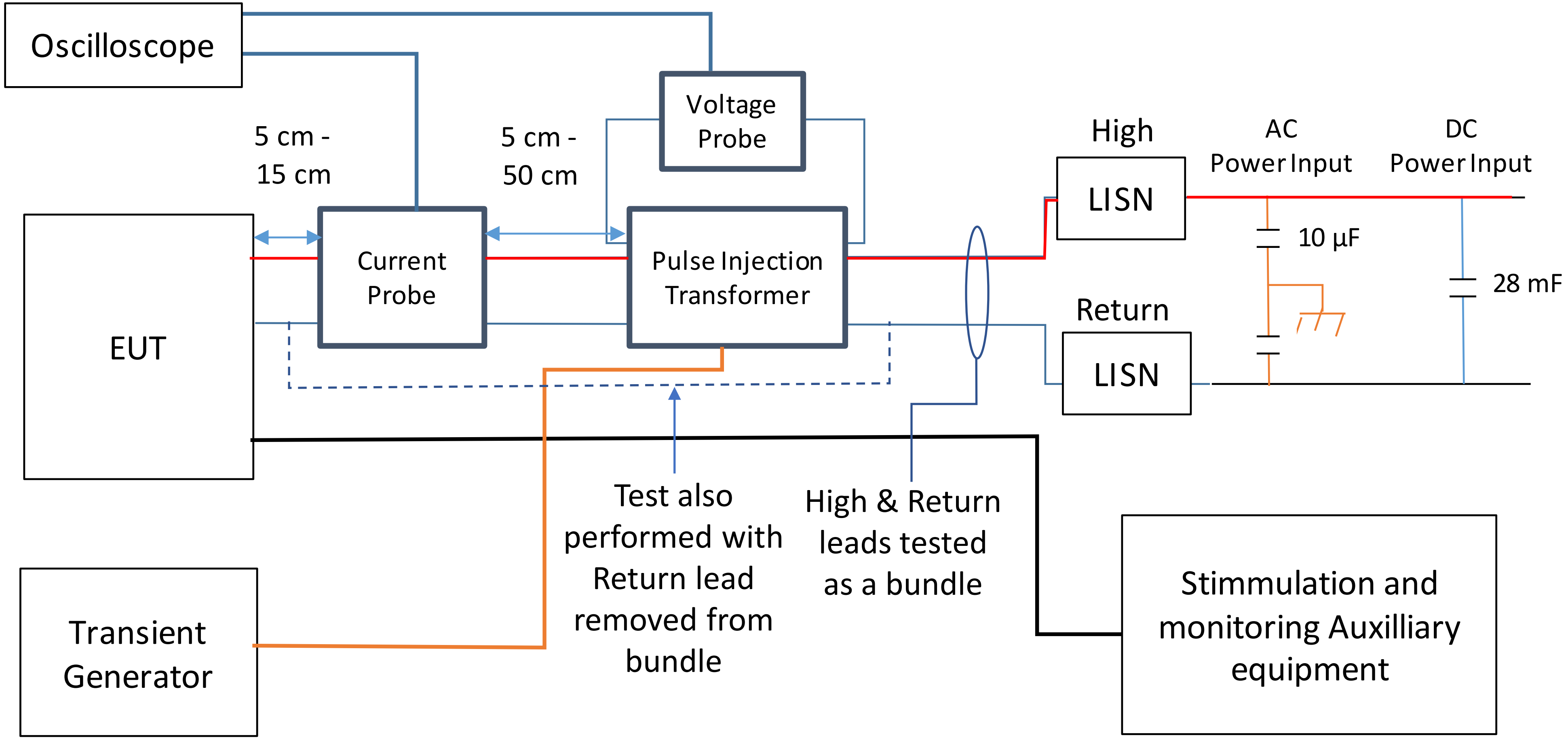
Test Methods *CS117* Lightning Induced Transients conducted susceptibility



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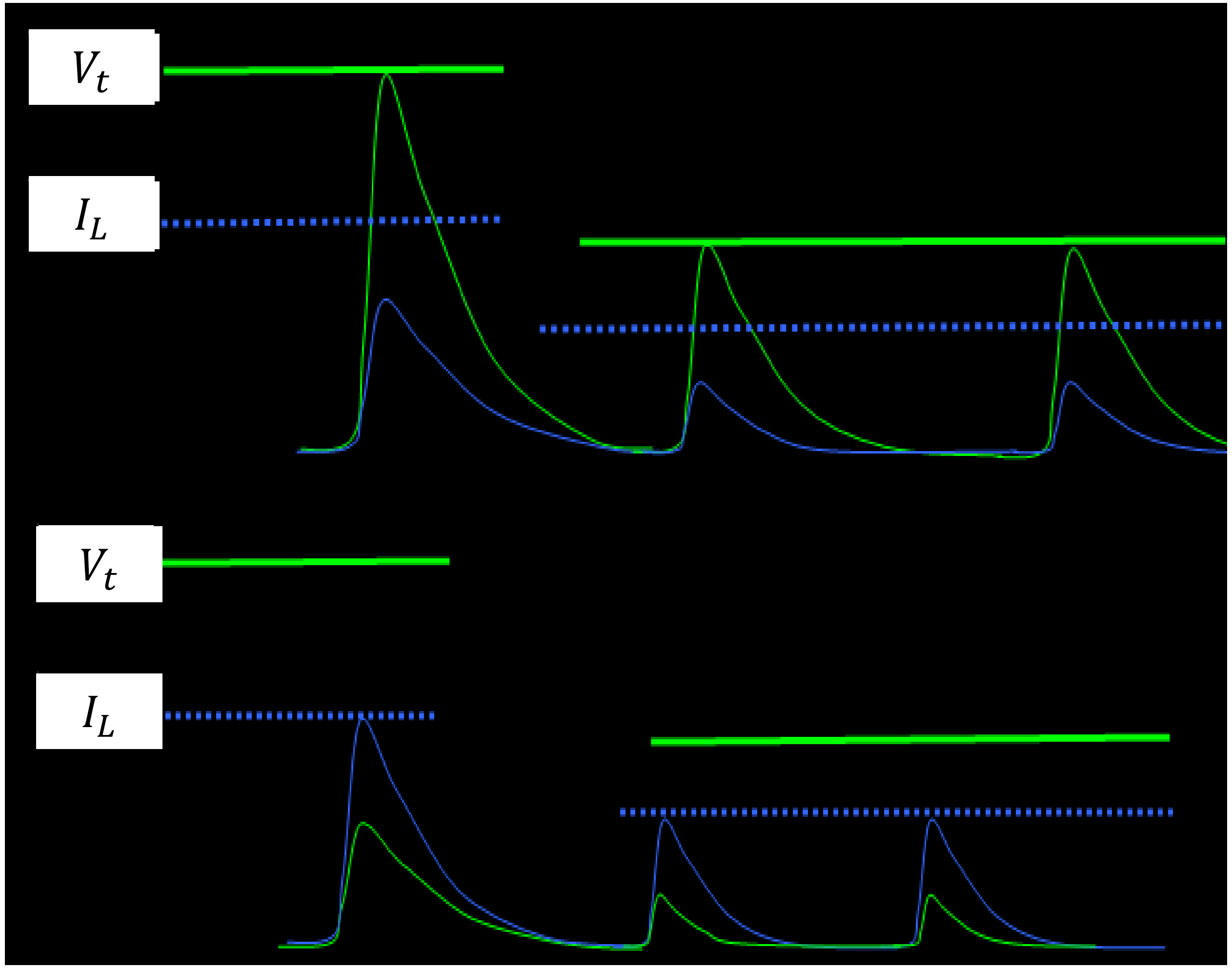
Test Methods *CS117* Lightning Induced Transients conducted susceptibility

Test Level vs. Test Limit

- Test Level (V_t or I_t) = Test criteria
- Limit Level (V_L or I_L) = Not to exceed value

- While transients are being applied to the cable, the pulse amplitude will be slowly increased until either the **test level**, or the **limit level** is met.

- If the **Limit level** is reached before the Test level, a reevaluation of the generator or waveform set may be required.



MIL-STD-461G
CS118- Personnel Borne Electrostatic Discharge

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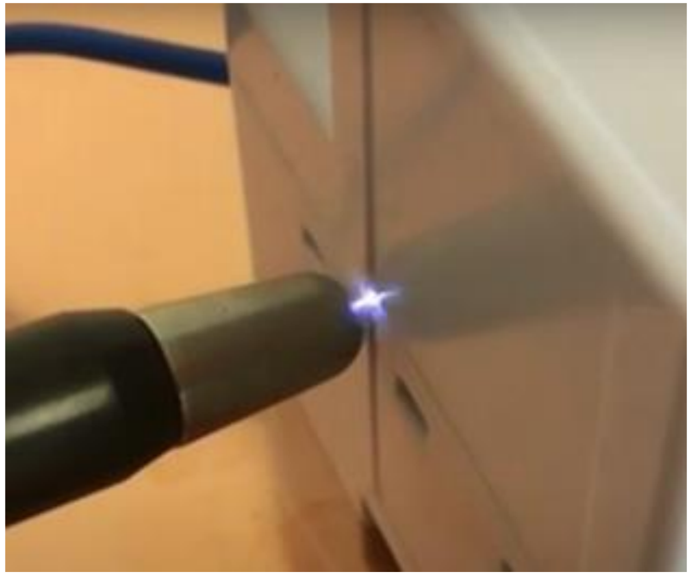
Test Methods *CS118* Personnel Borne Electrostatic Discharge (ESD)



- The CS118 test presents a controlled method to evaluate the susceptibility of electrical and electronic subsystems exposed to human body electrostatic discharges.
- The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, when subjected to Electrostatic Discharges.
- ESD testing is performed on electrical, electronic, and electromechanical subsystems and equipment except for those which interface with or control ordnance/munitions.
- Ordnance and munitions are covered under standards such as MIL-STD-331, derived from the system level qualification requirements (MIL-STD-464C).
- CS118 is applicable to all equipment installation platforms, and all procurements, except for space systems and launch vehicles.

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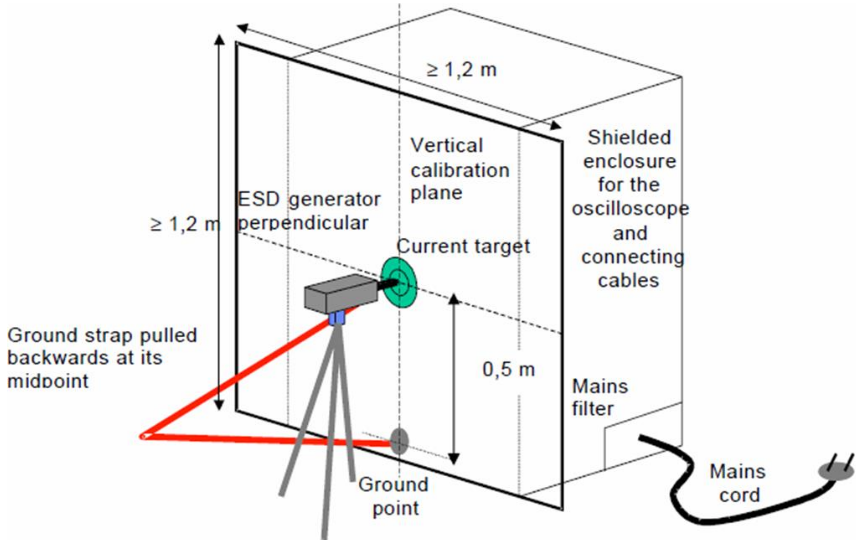
Test Methods *CS118* Personnel Borne Electrostatic Discharge (ESD)

- The CS118 test equipment and procedures are based on internationally-recognized standards such as IEC 61000-4-2.
- The ESD current waveform is verified using a 2 ohm coaxial resistor as part of the test setup.
- ESD Voltage level is also verified using an electrostatic voltmeter.



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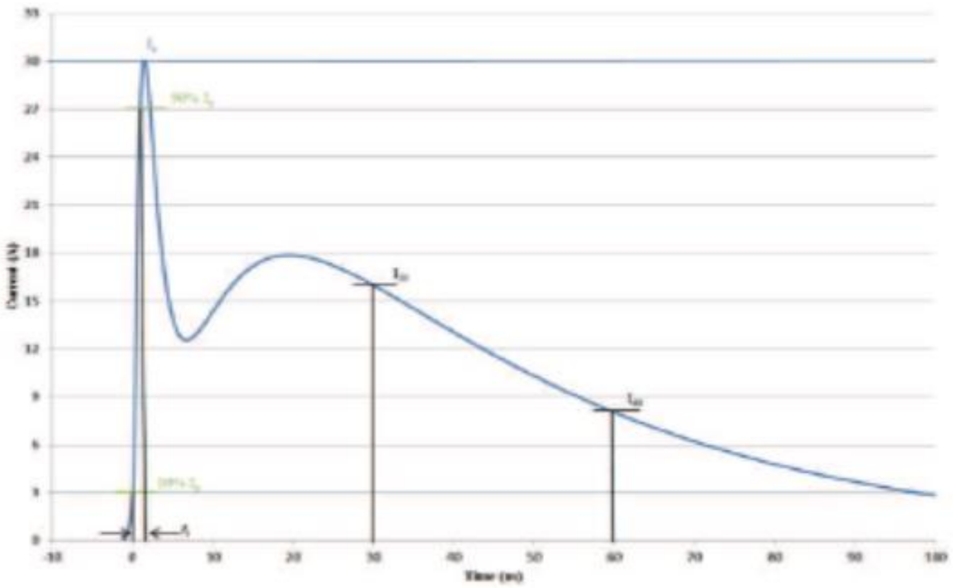
Test Methods *CS118* Personnel Borne Electrostatic Discharge (ESD)

- Four ESD current waveform parameters are checked prior to testing to ensure the proper amount of energy will be delivered to each test point.
- Rise time (between 10% and 90%).
- First peak current
- Current Peak at 30 ns
- Current peak at 60 ns



Displayed Voltage (KV)	First Peak Current, ±15% (A)	Rise time [1/] (ns)	Current I_1, ±30% (A) at t_1 = 30 ns	Current I_2 ±30% (A) at t_2 = 60 ns
±2	7.5	$0.6 \leq t_r \leq 1.0$	4	2
±8	30		16	8

1/Rise time is defined as the time from 10% to 90% of the peak value of the current waveform.

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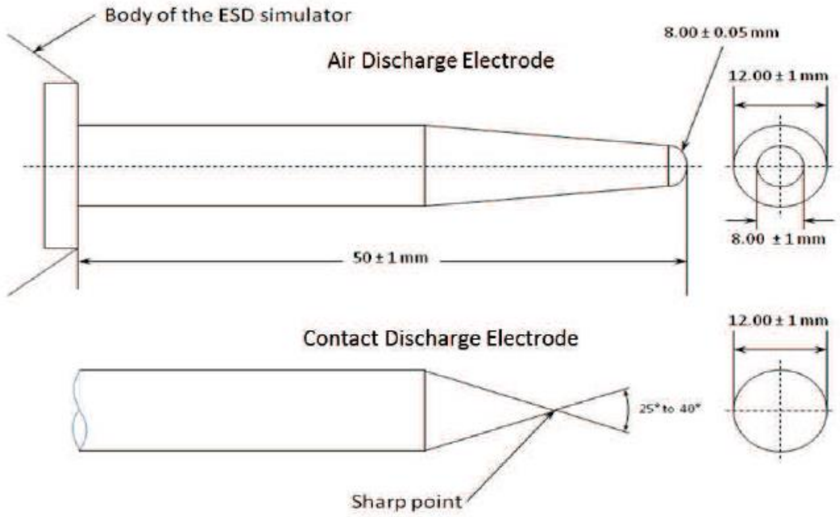
Test Methods *CS118* Personnel Borne Electrostatic Discharge (ESD)

- 5 positive and 5 negative discharges are applied to each test point using either Contact or Air discharge methods (depending on the material).
- Contact discharges are applied to all conductive surfaces accessible by a human fingertip.
- Air discharges are applied to test points that will not except a contact discharge.
  - Residual charge is drained off between discharges to prevent excessive build up.
  - The repetition time between discharges shall be long enough for EUT settling and to determine if susceptibility to ESD has occurred.

Level	Test Voltage (kV)	Method
1	±2	Contact
2	±4	Contact
3	±6	Contact
4	±8	Contact
5	±15	Air only



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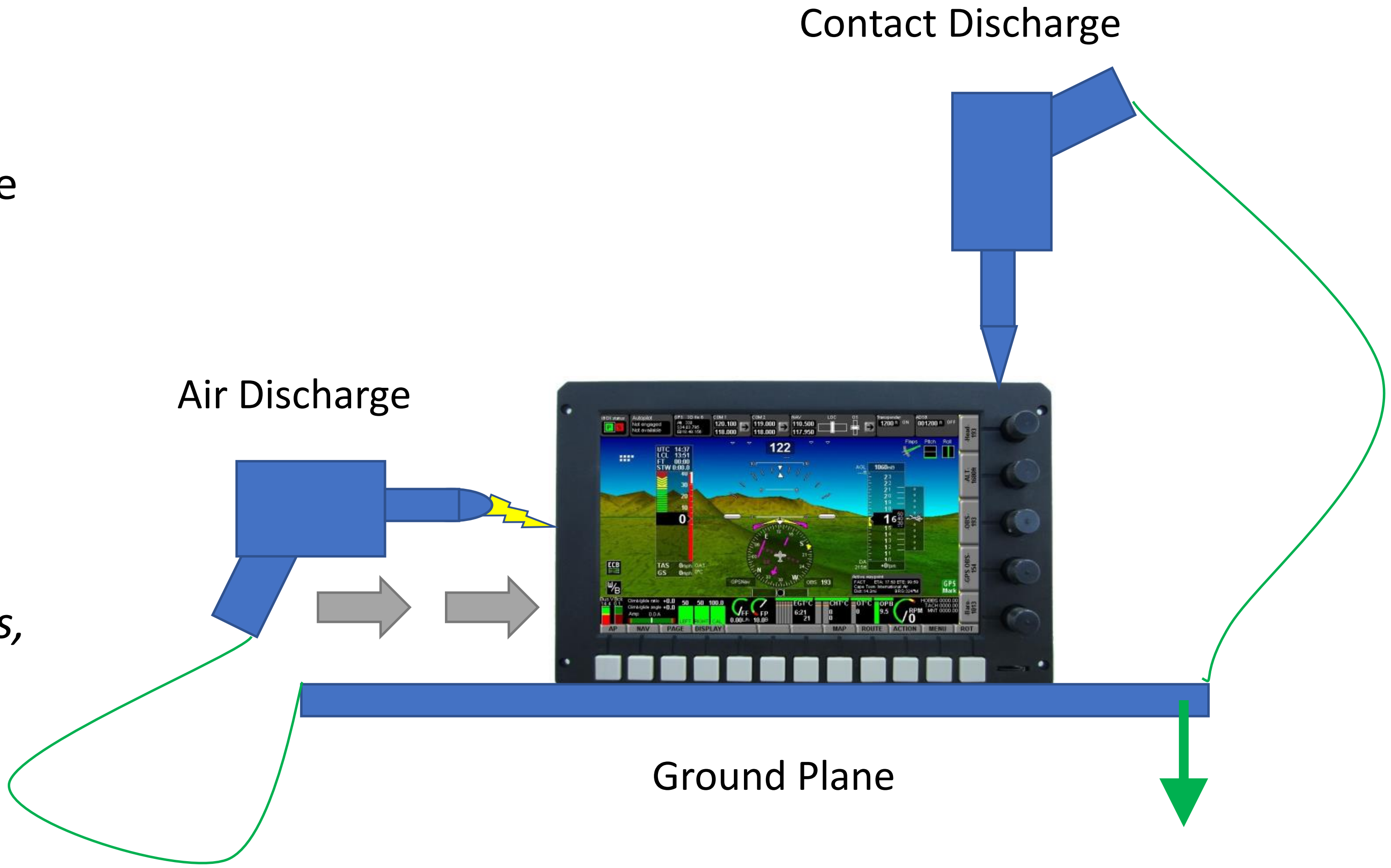
Test Methods CS118 Personnel Borne Electrostatic Discharge (ESD)

Testing

- ESD test locations shall be selected based on points and surfaces accessible by personnel during normal operation.
- **Typical test point locations:**
  - *Mounting points*
  - *handles*
  - *LED's,*
  - *ventilation ducts,*
  - *displays, keyboards and punch pads, connector shells,*
  - *knobs, switches, and buttons.*



MIL-STD-461G
RE101- Radiated Emissions, Magnetic Field

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Test Method RE101 radiated emissions magnetic field

- RE101 measures the Magnetic field emissions produced by the EUT at near field distances.
- *Determines the magnetic safe installation distance between the EUT and potentially magnetic sensitive equipment.*
- Applicable to Surface Ships, Submarines and Army Aircraft platforms.

- Limited applicability to Navy Aircraft equipped with magnetic sensitive Anti-Submarine Warfare (ASW) technology:
  - Acoustic Sonobouy Receivers
  - Magnetic Anomally Detectors (MAD).

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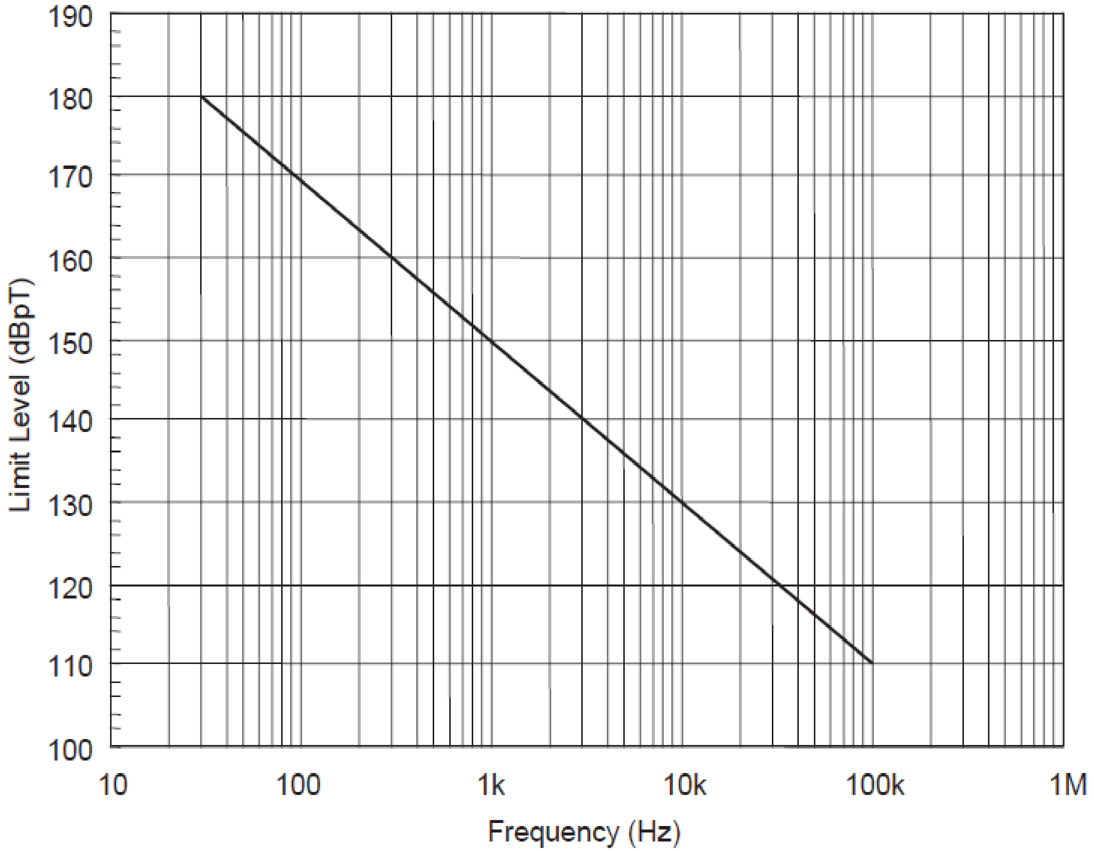
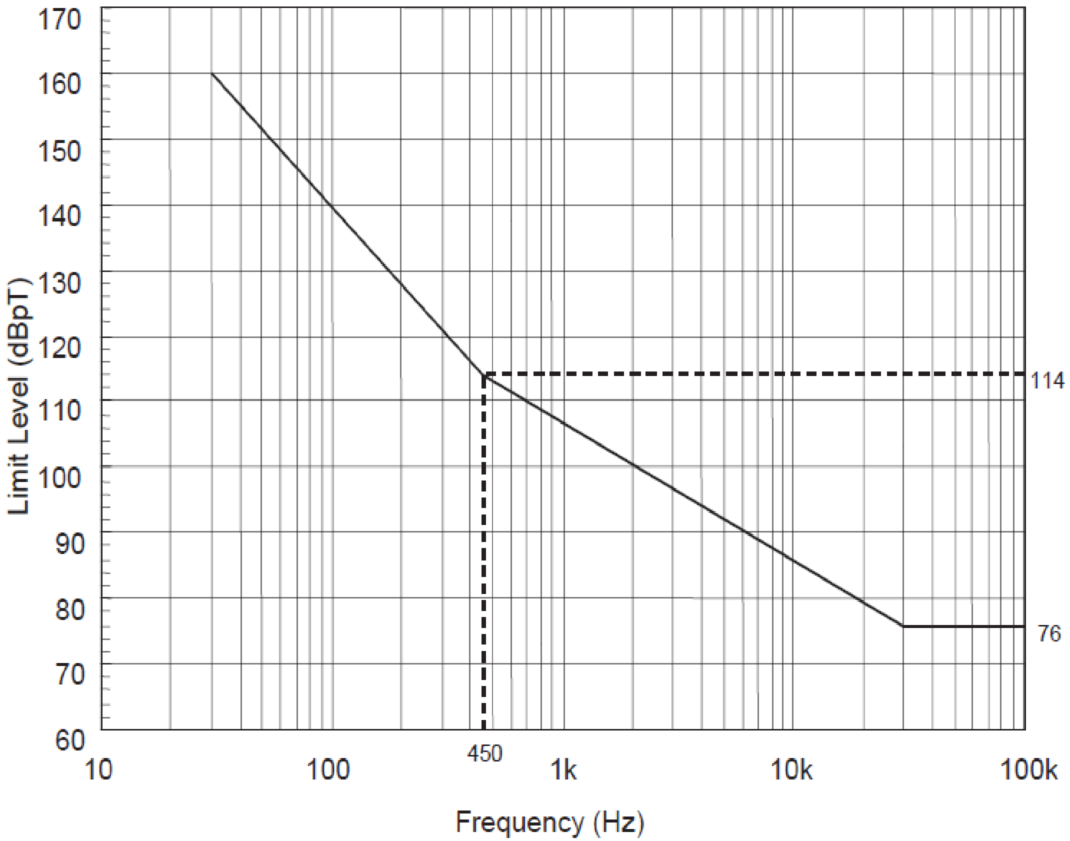
Test Method RE101 radiated emissions magnetic field



Army Limit

Navy Limit is more stringent



Navy Limit

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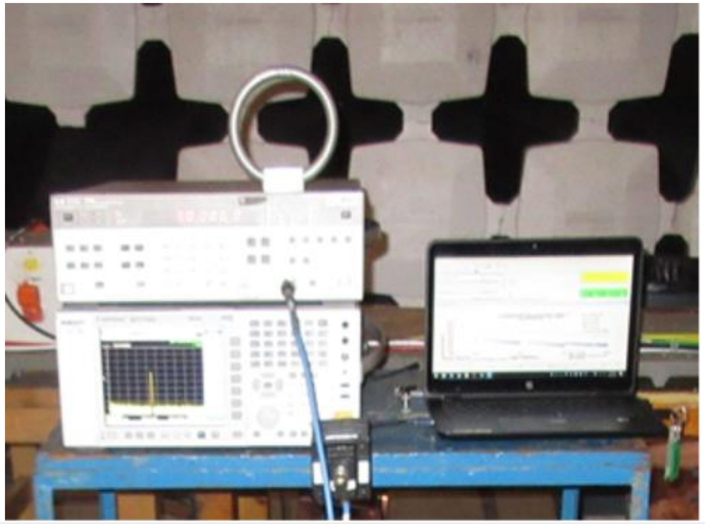
Test Method RE101 radiated emissions magnetic field

- Magnetic field measurements made with a electrostatically shielded loop antenna (13.3cm diameter).
- The DC Resistance of the measurement loop is checked prior to testing to be within 5 to 10 ohms.
- A measurement path system check is performed prior to testing by applying a signal into the 6 dB below the limit (limit minus the loop sensor correction factor), at a frequency of 50 kHz.
- The measurement receiver is tuned to a center frequency of 50 kHz, and the measured level is recorded.
- The measured value must be within ± 3dB of the injected signal level to ensure the integrity of the measurement path.



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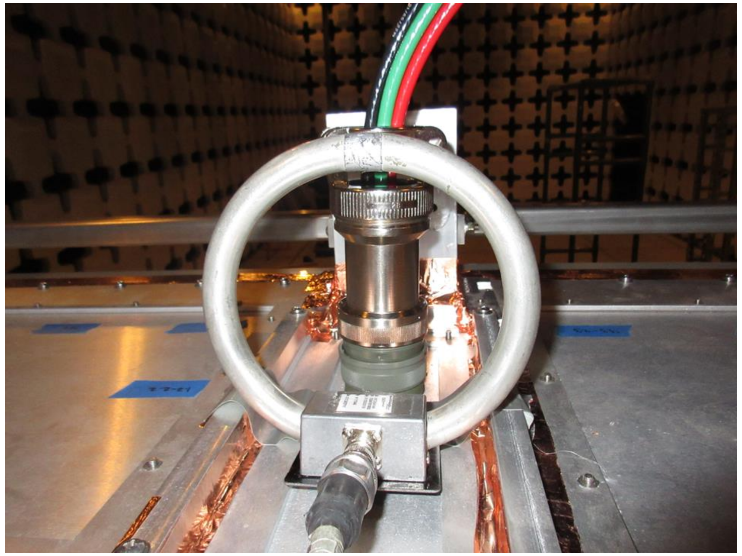
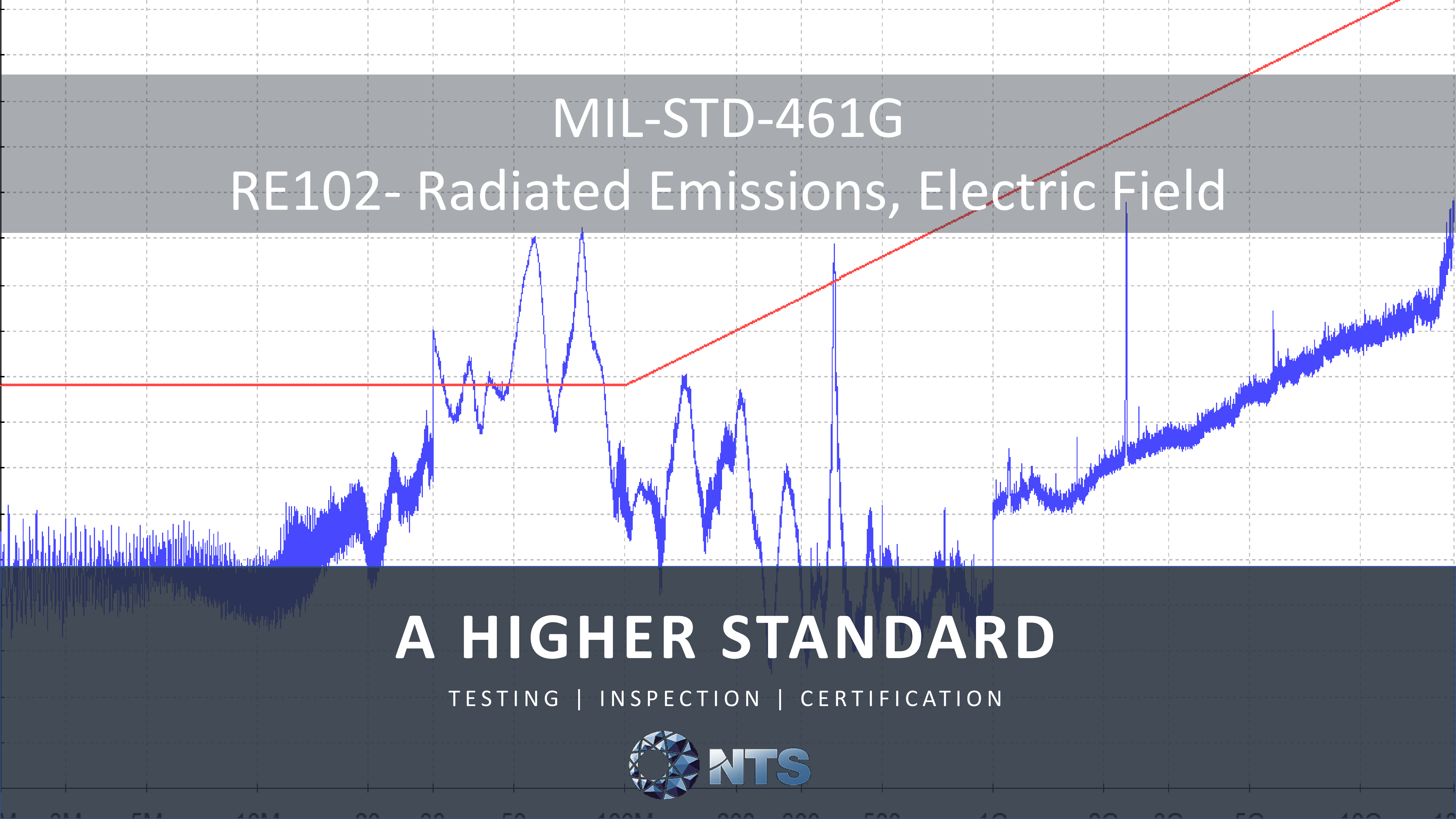
Test Method RE101 radiated emissions magnetic field

- The loop sensor will be oriented parallel to and positioned 7 cm from the EUT face and electrical interface connectors
- Measurements are performed from 30 Hz to 100 kHz in order to locate the frequencies of maximum radiation.
- A minimum of 2 frequencies per octave below 200 Hz, and 3 frequencies per octave above 200 Hz shall be maximized over the entire surface of the EUT.
- If the magnetic emissions exceed the 7 cm limit, the measurement distance will be increased until the emissions fall below the test limit. Data is recorded and provided in the report for assessment purposes. However, the EUT still needs to meet the 7 cm limit to pass RE101.

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RE102- Radiated Emissions, Electric Field
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Test Method RE102 Radiated Emissions electric field

- RE102 measures the radiated electromagnetic emissions from equipment and subsystem enclosures, and their associated interconnecting cables.
- For equipment with permanently mounted antennas this requirement does not apply at the transmitter fundamental frequency and the necessary occupied bandwidth of the signal.
- The RE102 test range varies based on platform and procurement branch requirements:

•Ground	**2 MHz to 18 GHz**
•Ships, surface	**10 kHz to 18 GHz**
•Submarines	**10 kHz to 18 GHz**
•Aircraft (Army and Navy)	**10 kHz to 18 GHz**
•Aircraft (Air Force)	**2 MHz to 18 GHz**
•Space	**10 kHz to 18 GHz**

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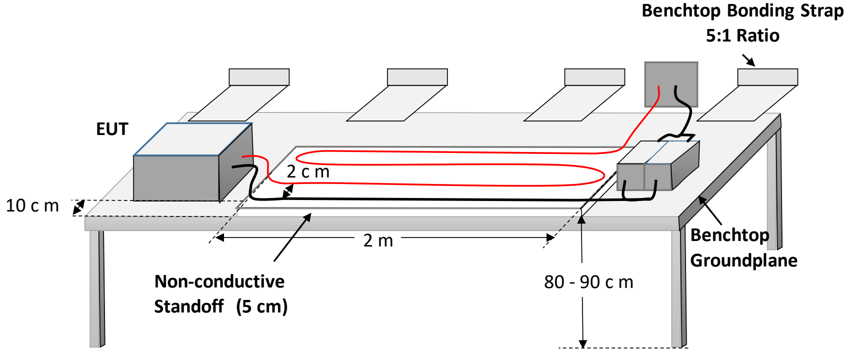
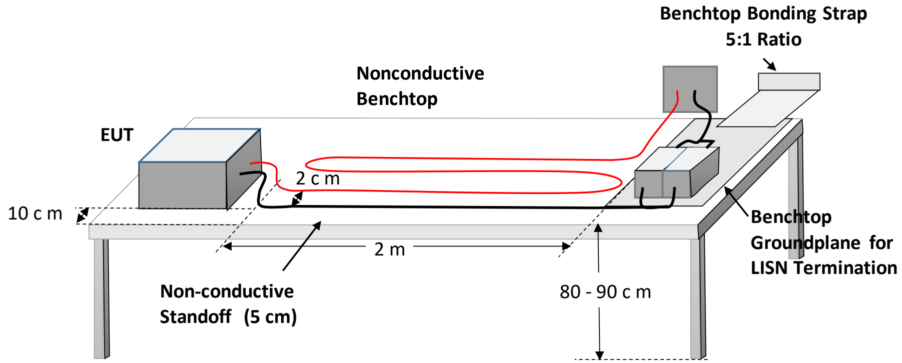
Test Setup-

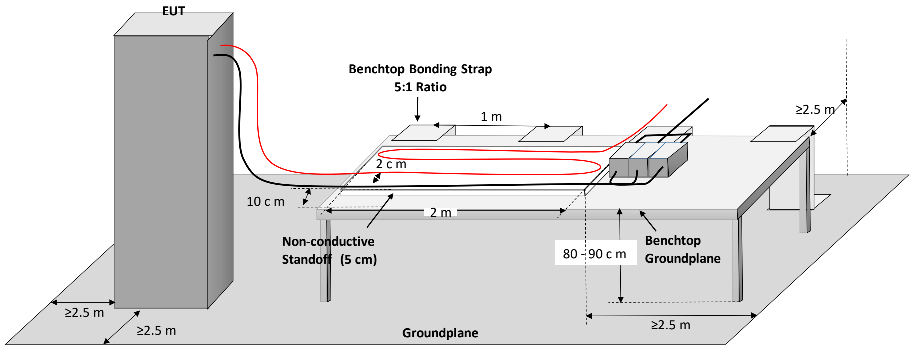
- Regardless if testing is performed in a laboratory environment or not, the equipment configuration setup and operation is very important for all radiated type tests.

- These details and test instructions must be carefully documented in the EMITP, and implemented during testing in order to provide consistent, repeatable, and meaningful test results:

  - Cable layout (routing paths, spacing, isolation, shield terminations, filtering, etc…).
  - EUT orientation (mounting, grounding, positioning, mode(s) of operation).
  - Electrical bonding and grounding scheme.
  - Operational Safety measures.







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Test Method RE102 Radiated Emissions electric field

Antenna Positioning

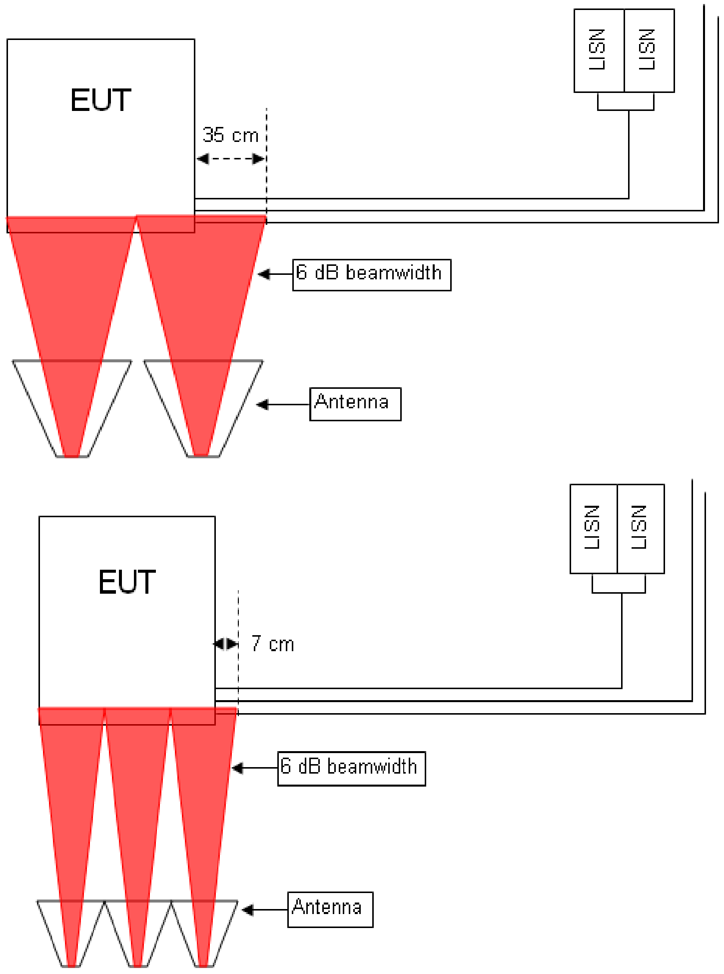
- RE102 measurements are made at a 1 meter distance.

- The number of antenna positions are determined, by frequency range, size of EUT, and beam width coverage of the measurement antenna as follows:

  - **Below 200 MHz-** the test boundary is divided by 3 and rounded up to nearest integer.

  - **Between 200 – 1000 MHz-** The entire AREA of EUT enclosure, plus first 35 cm of cables must be within 3 dB beam width.

  - **Above 1 GHz-** The entire AREA of EUT enclosure, plus first 7 cm of cables must be within 3 dB beam width.



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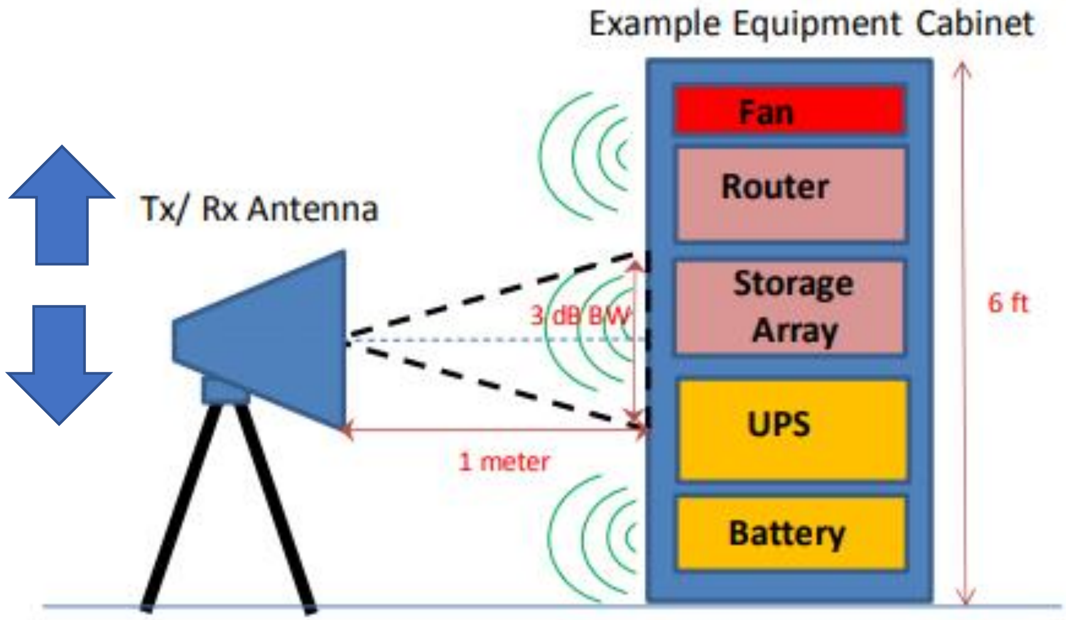
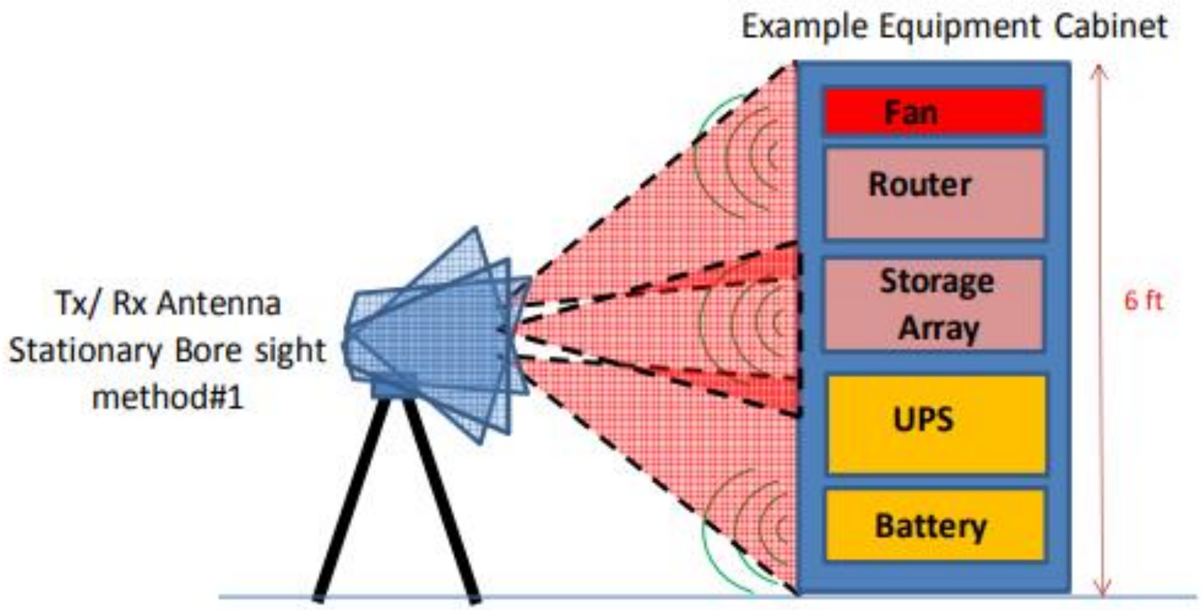
Test Method RE102 Radiated Emissions electric field

- For testing above 200 MHz the entire area of each EUT enclosure must fall within the ½ power beam width of the receive antenna.
- For large EUT's exceeding the measurement antenna's ½ power beam width, multiple antenna positions may be required vertically as well as horizontally to cover the entire surface area.





MIL-STD-461G
RS101- Radiated Susceptibility, Magnetic Field

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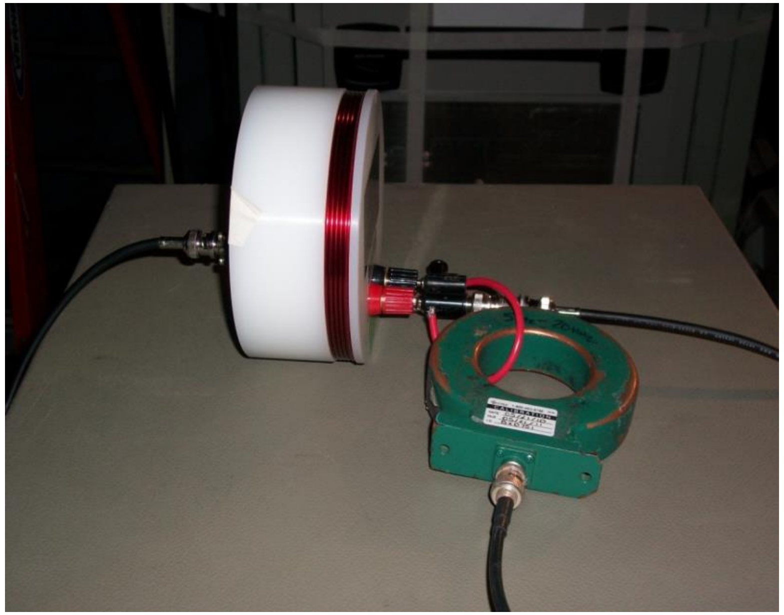
Test Method RS101 Radiated Susceptibility Magnetic field

- RS101 is intended to verify the ability of the EUT to withstand radiated magnetic fields from 30 Hz to 100 kHz.
- RS101 is only applicable where magnetically sensitive equipment may be exposed to unintentional magnetic fields .
  - **Army and Navy ground equipment-** the requirement is applicable only to vehicles having a minesweeping or mine detection capability.
  - **Navy ships and submarines-** RS101 is only applicable to equipment and subsystems that have an operating frequency of 100 kHz or less and an operating sensitivity of 1 µV or better (such as 0.5 µV).
  - **Navy aircraft-** RS101 is only applicable to equipment installed on ASW capable aircraft, and external equipment on aircraft that are capable of being launched by electromagnetic aircraft launching systems (EMALS).



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Test Method RS101 Radiated Susceptibility Magnetic field

RS101 Radiating loop has the following specifications:

- Diameter: 12 cm
- Number of turns: 20
- Wire: No. 12 insulated copper
- Magnetic flux density: 9.5x10$_7$ pT/ampere of applied current at a distance of 5 cm from the plane of the loop.

RS101 Loop sensor has the following specifications:

- Diameter: 4 cm
- Number of turns: 51
- Wire: 7-41 Litz wire (7 Strand, No. 41 AWG)
- Shielding: Electrostatic

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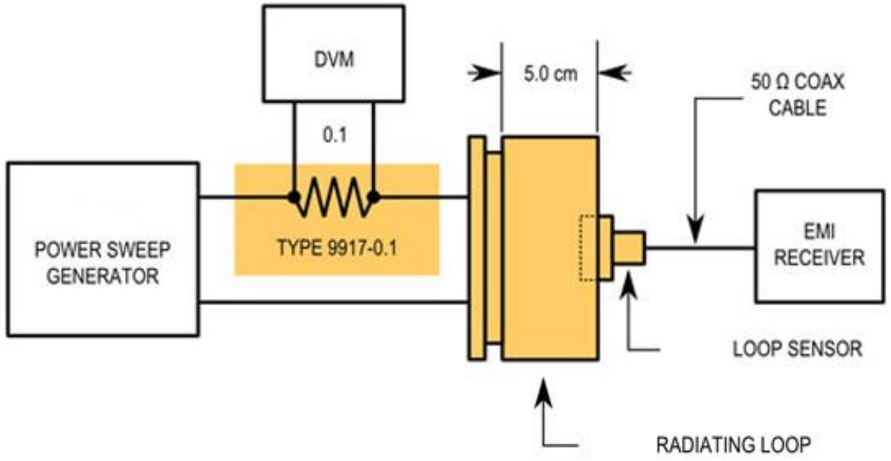
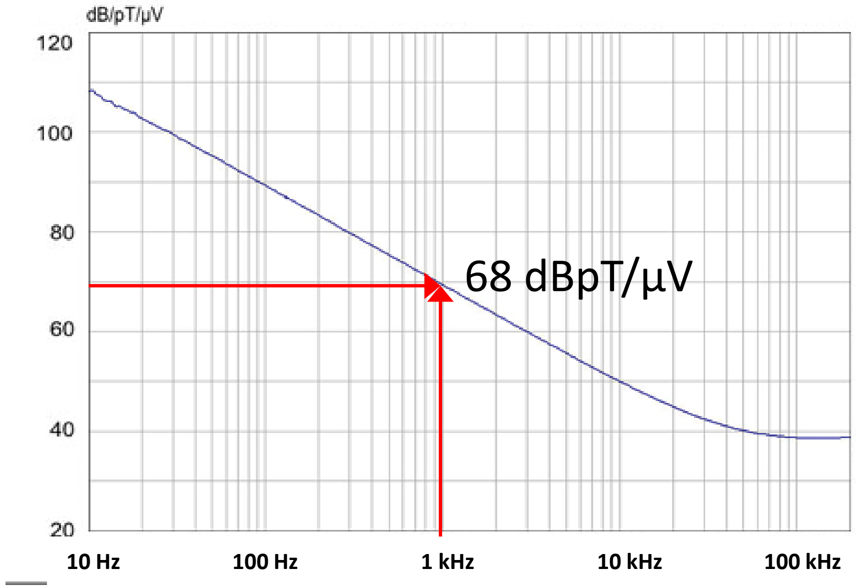
Test Method RS101 Radiated Susceptibility Magnetic field

- A loop verification is performed to validate the magnetic field prior to testing.
- A 1 kHz signal is injected into the Radiated Loop and set to produce a field intensity of 110 dBpT.
- The voltage induced into the loop sensor will be measured determine the appropriate level is reached ± 3dB.
- In this case, the loop sensors correction factor at 1 kHz is 68 dB.
- This factor is subtracted from the required field intensity level (110 dBpT) which determines a target voltage level of 42 dBµV to be measured at the Loop sensor output.





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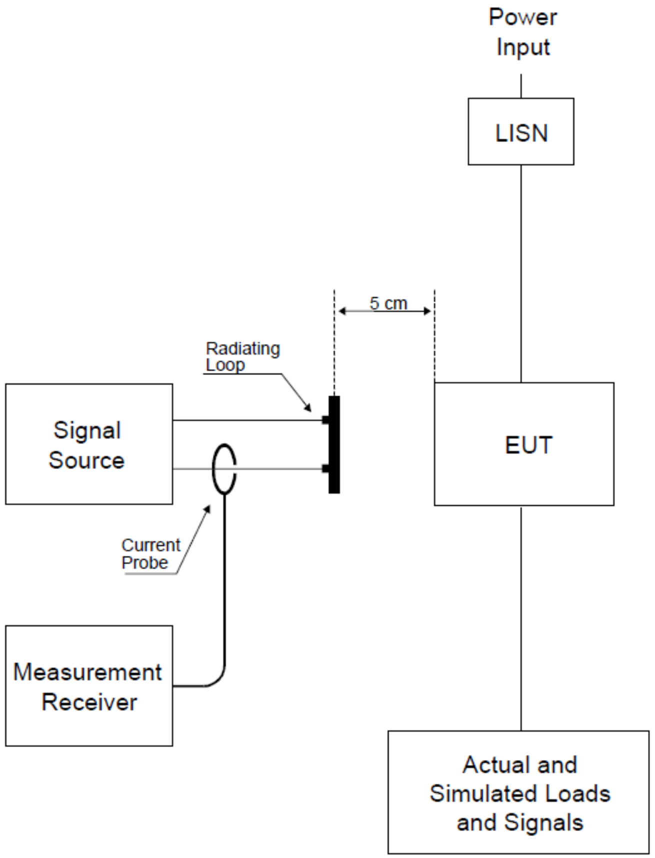
Test Method RS101 Radiated Susceptibility Magnetic field

Test Method

- The Radiating loop is located 5 cm from the EUT.
- Oriented in the parallel axis
- Positioned every 30 cm x 30 cm area over each face including each connector interface.
- Initially field levels 10 dB greater than specified are produced (not to exceed 15 amps) to quickly detect potential susceptibility issues.
- The signal is the swept or stepped from 30 Hz to 100 kHz at the specified rate while the EUT is monitored for indications of susceptibility.
- If susceptibility is noted, select no less than three test frequencies per octave at those frequencies where the maximum indications of susceptibility are present.



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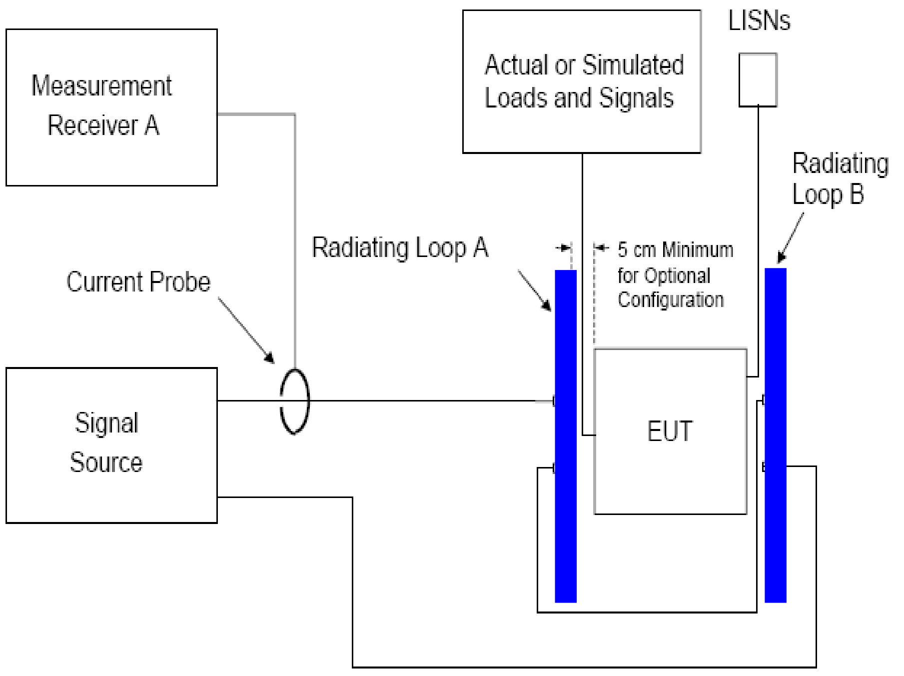
Test Method RS101 Radiated Susceptibility Magnetic field

AC Helmholtz coil test method

- Alternatively, Helmholtz coils can be used.
- AC Helmholtz coil test option is preferred for submarine applications.
- Large loops generate a relatively uniform magnetic field that is more representative to field environments.
- Reduced test time compared to 12 cm loop test method.
- Initially field levels 6 dB greater than specified are produced (Vs. 10 dB for 12 cm loop method)
- The signal is the swept or stepped from 30 Hz to 100 kHz at the specified rate while the EUT is monitored for indications of susceptibility.
- If susceptibility is noted, select no less than three test frequencies per octave at those frequencies where the maximum indications of susceptibility are present.



MIL-STD-461G
RS103- Radiated Susceptibility, Electric Field

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Test Method RS103 Radiated Susceptibility electric field

- RS103 verifies the ability of the EUT and associated cabling to withstand the effects of radiated electric fields.
- There is no implied relationship between this requirement and RE102. The RE102 limit is placed primarily to protect antenna-connected receivers while RS103 simulates fields resulting from antenna transmissions.

Test Frequency Range

- 30 MHz to 18 GHz testing required for all applications.
- 2 MHz to 30 MHz testing is required for Army & Navy, Optional for Air Force.
- 18 GHz to 40GHz test is optional for all branches.
  - *40 GHz testing can be driven by system level E^3 risk assessment.*

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Test Method RS103 Test Levels

PLATFORM / FREQUENCY RANGE		LIMIT LEVELS (VOLTS/METER)							
		AIRCRFAFT (EXTERNAL OR SAFETY CRITICAL)	AIRCRAFT INTERNAL	ALL SHIPS (ABOVE DECK & EXPOSED BELOW DECK) AND SUBMARINES (EXTERNAL)*	SHIPS (METALLIC) (BELOW DECKS)	SHIPS (NON-METALLIC) (BELOW DECK)**	SUBMARINE (INTERNAL)	GROUND	SPACE
2 MHz to 30 MHz	A	200	200	200	10	50	5	50	20
	N	200	200	200	10	50	5	10	20
	AF	200	20	-	-	-	-	10	20
30 MHz to 1 GHz	A	200	200	200	10	10	10	50	20
	N	200	200	200	10	10	10	10	20
	AF	200	20	-	-	-	-	10	20
1 GHz to 18 GHz	A	200	200	200	10	10	10	50	20
	N	200	200	200	10	10	10	50	20
	AF	200	60	-	-	-	-	50	20
18 GHz to 40 GHZ	A	200	200	200	10	10	10	50	20
	N	200	60	200	10	10	10	50	20
	AF	200	60	-	-	-	-	50	20

KEY: A= Army
N= Navy
AF= Air Force

* For equipment located external to the pressure hull of a submarine but within the superstructure, use SHIPS (METALLIC) (BELOW DECK)

** For equipment located in the hanger deck of Aircraft Carriers

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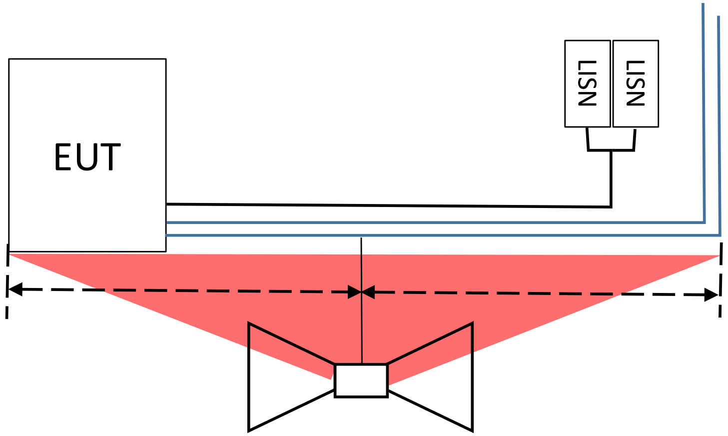
Test Method RS103 Radiated Susceptibility electric field

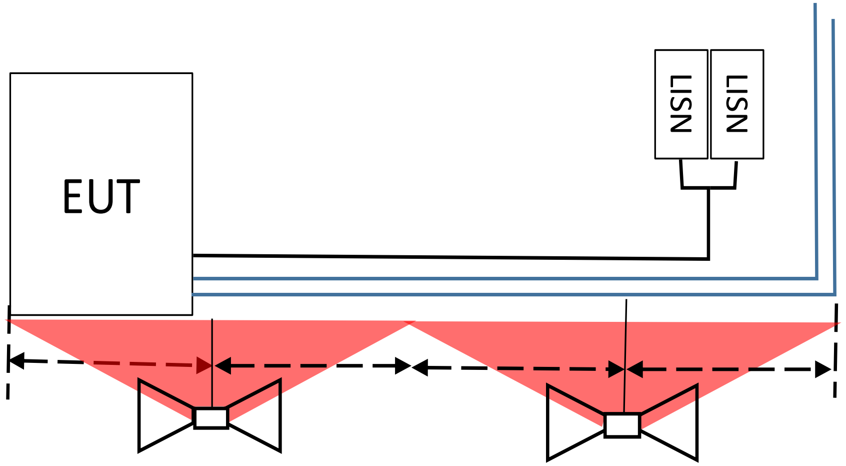
- Similar to RE102, the EUT surface area must be testing within the effective beam width of the transmit antenna.



2 MHz – 200 MHz

- **Test Boundaries ≤ 3 meters**
- Center the antenna between the edges of the test setup boundary. The boundary includes all enclosures of the EUT and the 2 meters of exposed interconnecting and power leads

- **Test setup boundaries > 3 meters**
- Multiple antenna positions are calculated by dividing the edge-to-edge boundary distance (in meters) by 3 and rounding up to an integer.



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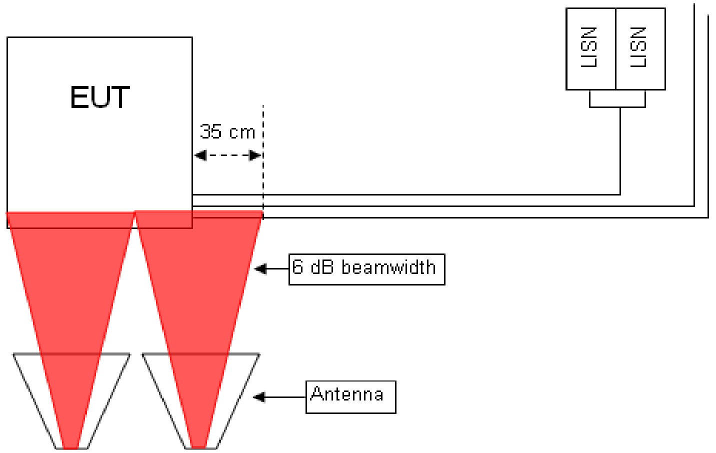
Test Method RS103 Radiated Susceptibility electric field

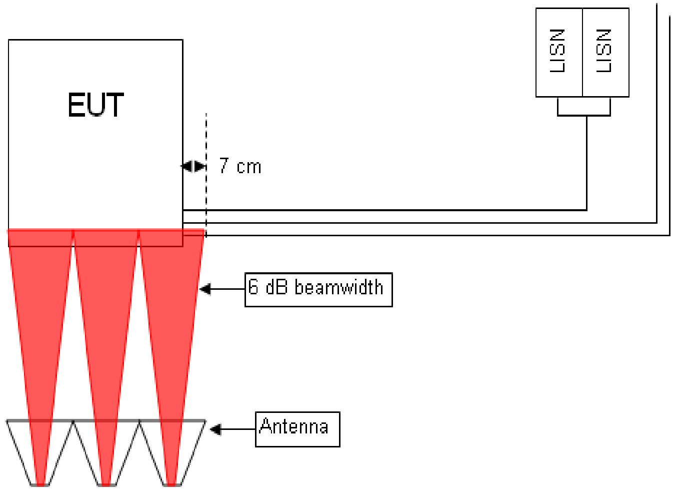
200 MHz to 1 GHz

- The antenna is positioned such that the entire area of each EUT enclosure and the first 35 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.



> 1 GHz

- The antenna is positioned such that the entire area of each EUT enclosure and the first 7 cm of cables and leads interfacing with the EUT enclosure are within the 3 dB beamwidth of the antenna.



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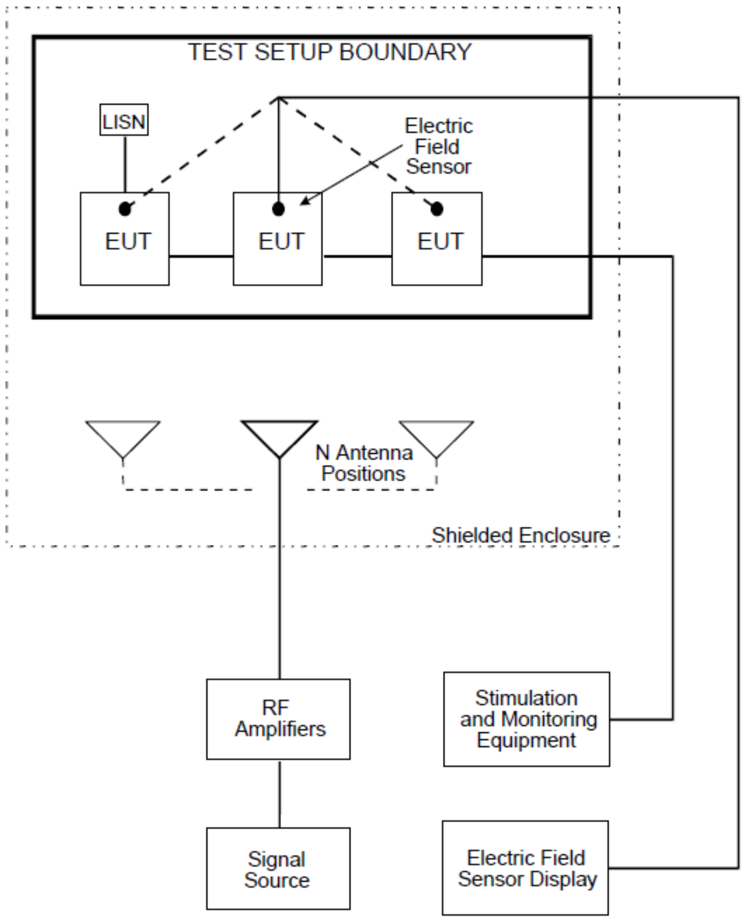
Test Method RS103 Radiated Susceptibility electric field

RF Field Sensors

- RS103 testing fields are typically monitored using isotropic electric field sensors and meters positioned directly opposite the transmit antenna and at a minimum of 30 cm above the ground plane at or below 1 GHz.
- Above 1 GHz, sensors are positioned at a height corresponding to the area of the EUT being illuminated.
- Avoid placing sensors directly at corners or edges of EUT components.
- Different sensors may use various techniques to measure the field. Sensors that detect magnetic field or power density and convert to electric field are not acceptable since most to the testing will be performed in the near field environment.



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Test Method RS103 Radiated Susceptibility electric field

RF Field Sensors

- Field Sensor correction factors must be applied during RS103 testing to determine equivalent peak detection of modulated signals
- An unmodulated field is applied and measured with the sensor.
- The signal is then modulated using 1 kHz pulse, 50% duty cycle, at 40 dB depth and measured with the sensor.
- The unmodulated reading is then divided by the modulated reading to determine the correction factor.
- The sensor modulation factor is applied to the reading as a multiplier (for linear V/m readings).

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Test Method RS103 Radiated Susceptibility electric field

- RF Fields are either swept, or incremental stepped over the required test frequency range.
- Stepped frequency testing requires a minimum dwell time of 3 seconds per tuned test frequency to observe signs of susceptibility.
- Above 30 MHz, test is repeated for both horizontal and vertical linear polarizations.
- Test is also repeated for all required antenna positions.
- Test times can be significant

Frequency Range	Analog Scans Maximum Scan Rates	Stepped Scans Maximum Step Size
30 Hz - 1 MHz	0.0333 f/sec	0.05 f
1 MHz – 30 MHz	0.00667 f/sec	0.01 f
30 MHz - 1 GHz	0.00333 f/sec	0.005 f
1 GHz - 40 GHz	0.00167 f/sec	0.0025 f

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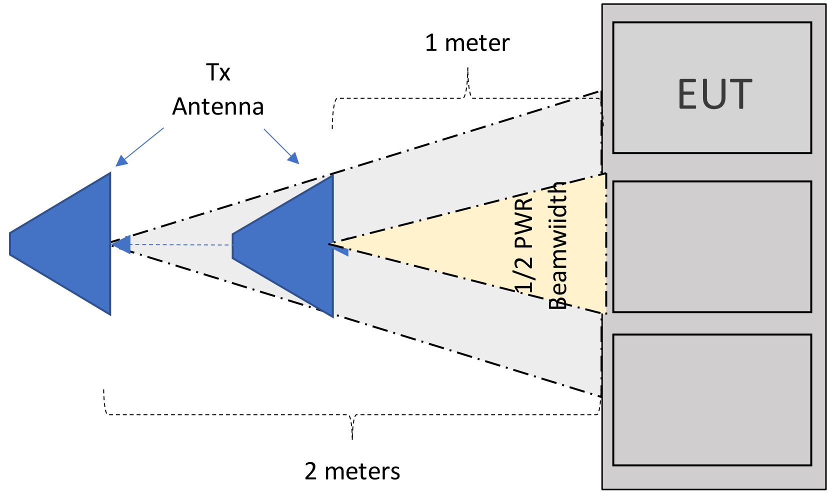
Test Method RS103 Radiated Susceptibility electric field

RS103 Time reduction Trade Off:

- MIL-STD-461G allows for testing at greater transmit distances (> 1 meter) as long as the field level can still be achieved.
  - Antenna beamwidth increases with Tx distance
  - Electric field strength reduces with Tx distance



Electric Field Strength Formula (V/m):

$$\sqrt{\frac{Tx\ Power_{(W)} * 10^{(Gain_{(dBi)}/10)} * 30}{Tx\ Distance_{(m)}}}$$

- *Field strength is divided by the distance:*
  - 1 meter Tx distance = 274.8 V/m
  - 2 meter Tx distance = 137.4 V/m
  - 3 meter Tx distance = 91.6 V/m

½ Pwr Beamwidth Coverage Formula (cm):

$$2 * Tx\ Distance_{(cm)} * \tan\frac{BW\ angle_{(\theta)}}{2}$$

- *Beamwidth Coverage is multiplied by the distance:*
  - 1 meter Tx distance = 125.1 cm
  - 2 meter Tx distance = 250.2 cm
  - 3 meter Tx distance = 375.3 cm

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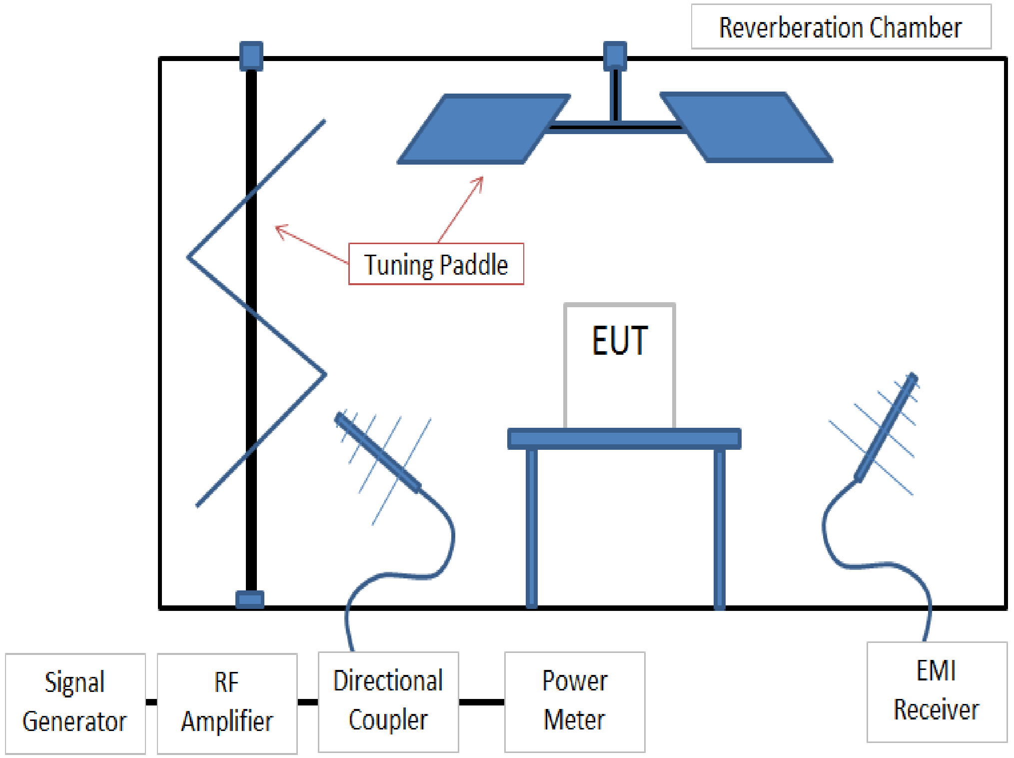
Radiated Susceptibility Testing – Reverberation chamber

- A reverberation chamber is essentially a large cavity resonator (*like a microwave oven*) used to perform Electromagnetic (EM) measurements (both emissions and immunity).
  - It is comprised of a highly conductive inner cavity (copper, aluminum, or steel) with no RF absorber installed.
  - A Tuner paddle either vertically or horizontally mounted or moving wall.
  - A transmit antenna, and a receive antenna facing away from the equipment being tested.



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Radiated Susceptibility Testing – Reverberation chamber

- Generates fields in all directions and field polarizations
  - Does not require multiple EUT orientations, antenna positions or polarity changes.
  - Much faster test time for large integrated systems.
  - However, this can make pinpointing areas of EUT susceptibility difficult.

- Chamber geometry defines the lowest usable test frequency (LUF).
  - Direct Illumination testing may still be required at lower frequencies.
  - Chamber geometry also limits the usable test volume and overall size of EUT that can be tested.
- Highly efficient field generator (high “Q”), achieving high field strengths at moderately low power levels.

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- **Radiated Susceptibility Testing –Reverberation chamber**

RS103 Mode Tuning Method-

- RF source is modulated with 1 kHz pulse modulation, 50 % duty cycle.
- The amount of RF power needed to achieve the desired field strength is calculated using the chambers calibration factor.
- The tuner is rotated 360 degrees using the minimum of steps required by the standard, and dwell at each position for a minimum of 3 seconds per tunned frequency.
- The test is performed over the required frequency range while the EUT is monitored for signs of susceptibility.

MIL-STD-461G
RS105- Radiated Susceptibility, Transient Electromagnetic Pulsed Field

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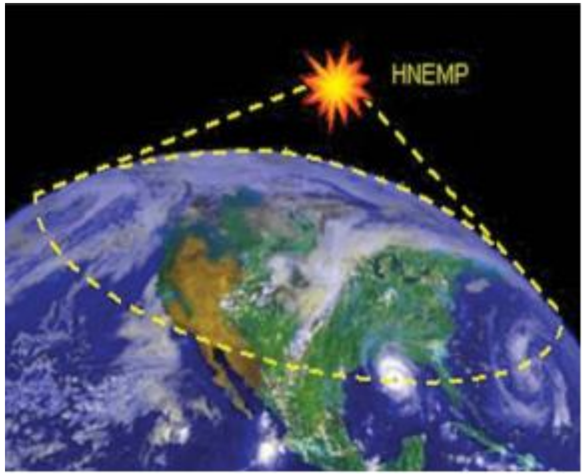
Test Method RS105 Radiated Susceptibility, Electromagnetic Pulse



- RS105 is used to evaluate the ability of equipment and subsystems to withstand the transient electromagnetic effects of a high-altitude nuclear payload detonation.

- **Applicable to equipment enclosures:**
  - Located external to a hardened (shielded) platform or facility.
  - in poorly shielded or unshielded platforms (hanger decks, etc…)
  - Or equipment intended solely for use on non-metallic platforms when specified by the procuring activity.

- RS105 is not meant to evaluate the effects of EMP voltages and current induced on to cabling shields, internal filtering or surge protection.
- Responses due to cable coupling are controlled under other conducted type test methods such as CS115 and CS116.

Test Method RS105 Radiated Susceptibility, Electromagnetic Pulse

History-

- *July 1962* a series of high-altitude nuclear detonation tests were conducted by the United states.
- The Starfish Prime Nuclear test was detonated at an altitude of 250 miles over the pacific ocean.
- The explosion caused a severe electromagnetic pulse (EMP) that was much larger than expected.
- The EM effects the detonation was reported to have caused electrical damage including blowing out streetlights and damaging a telecom microwave link which shut down calls across the Hawaiian islands over 900 miles away from the detonation.

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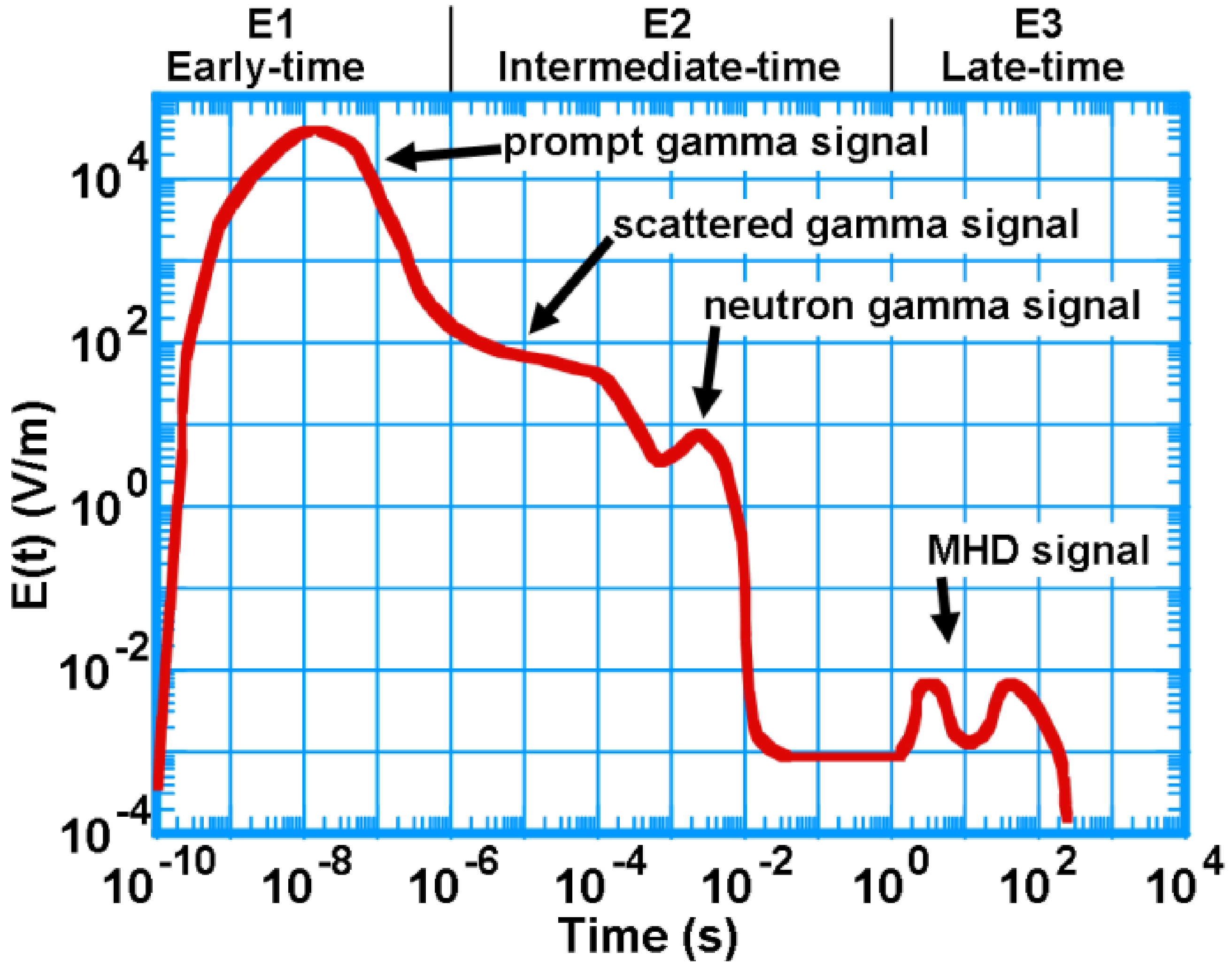
Test Method RS105 Radiated Susceptibility, Electromagnetic Pulse

- A High altitude nuclear EMP is a complex multi-pulse waveform defined in terms of three components.
- Although the actual characteristics of these components are classified under MIL-STD-2169, the unclassified version has been developed by the IEC (IEC 61000-2-9).
- The three components have been defined as:
  - **E1 Early Time**
  - **E2 Intermediate Time**
  - **E3 Late Time**



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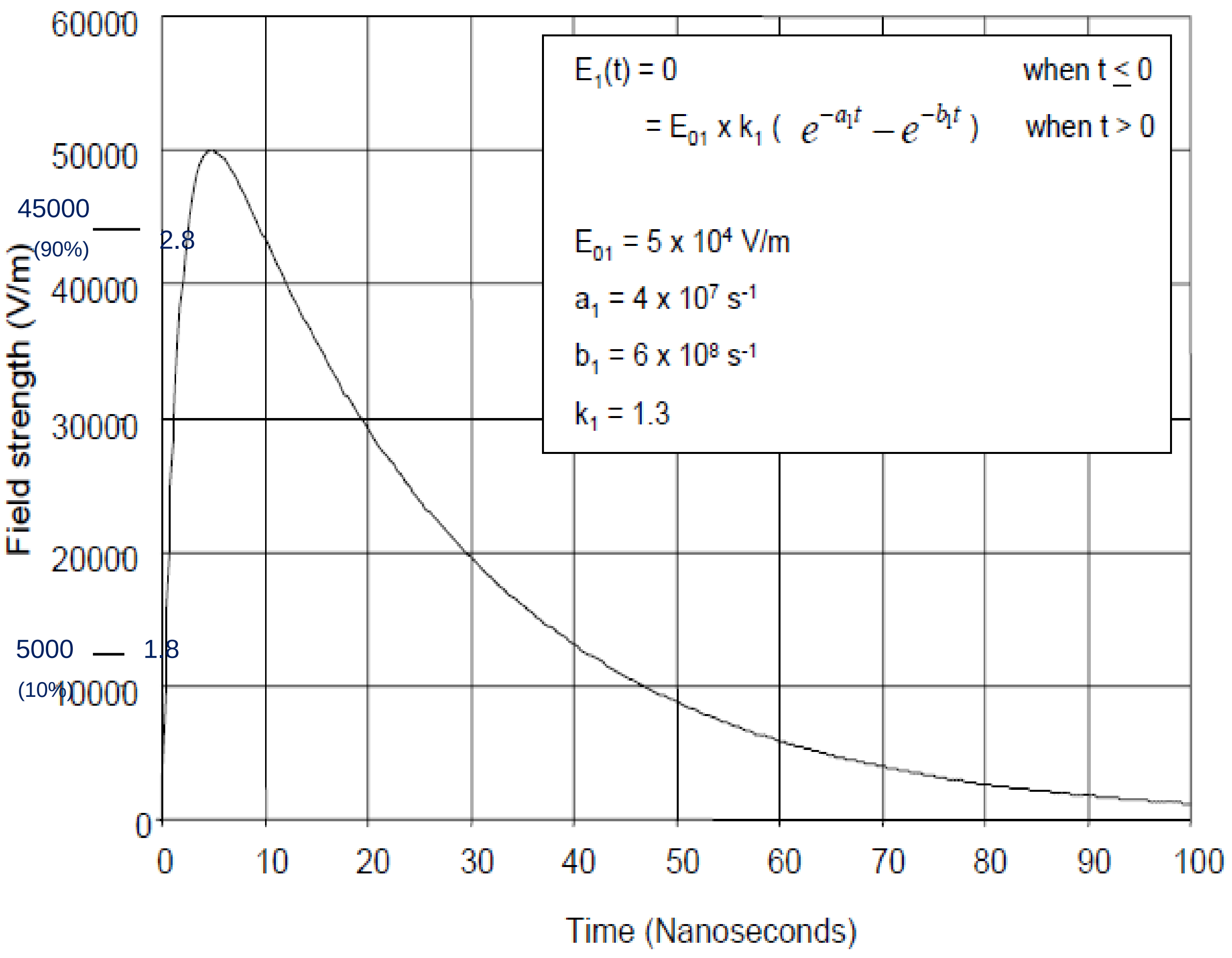
Test Method RS105 Radiated Susceptibility, electromagnetic pulse

- The RS105 Pulse represents the characteristics of the E1 early time portion of a high altitude EMP.
    - Test level = 50,000 V/m.
    - Rise time = 2.8 ns at 90% of peak
    - Fall time = 25 ns at 50% of peak
- The fast rise time and high amplitude can disrupt, degrade, and even damage sensitive electronic equipment and components if not adequate protection is not implemented.



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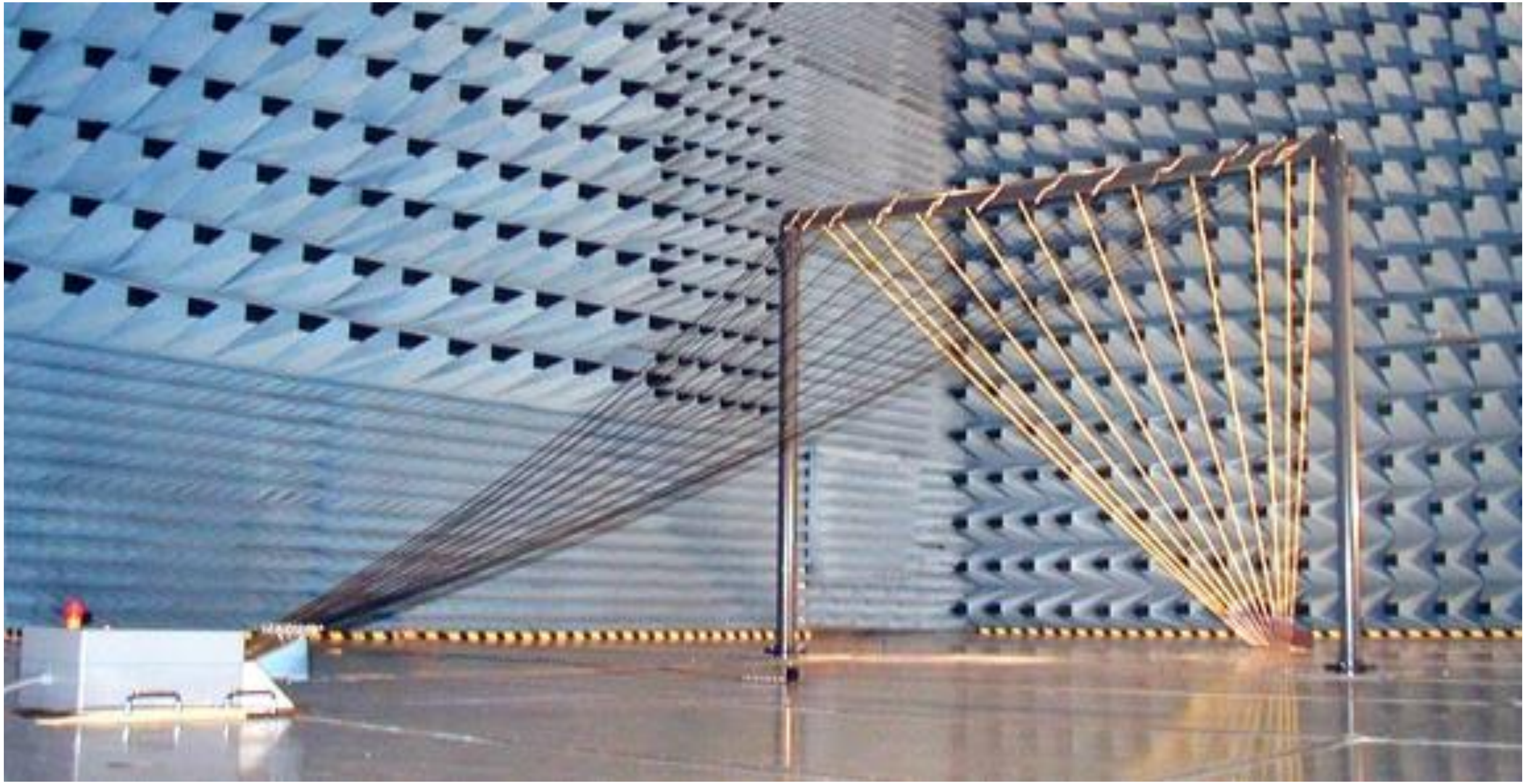
Test Method RS105 Radiated Susceptibility, Electromagnetic Pulse



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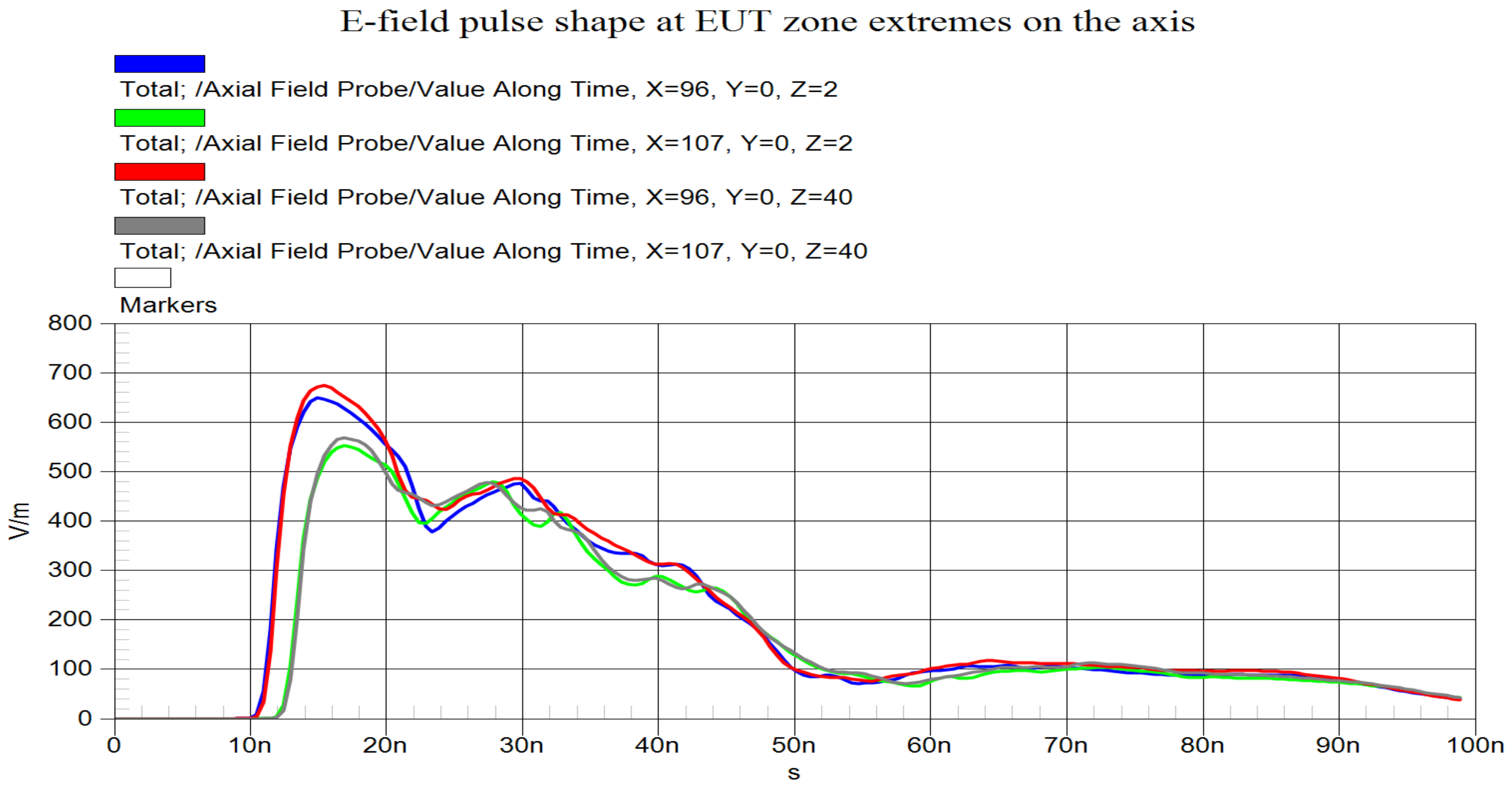
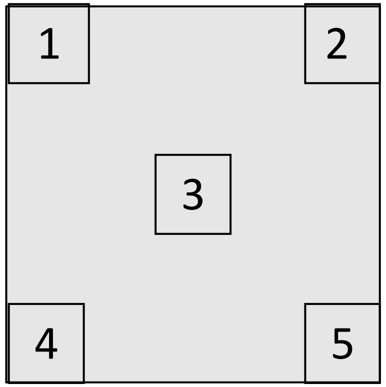
Test Method RS105 Radiated Susceptibility, Electromagnetic Pulse

Field Uniformity-

- 5 point verification grid.
- Results taken at each point shall be within 6dB of each other.
- No less than 50,000 v/m at any point.





Vertical Face of the EUT

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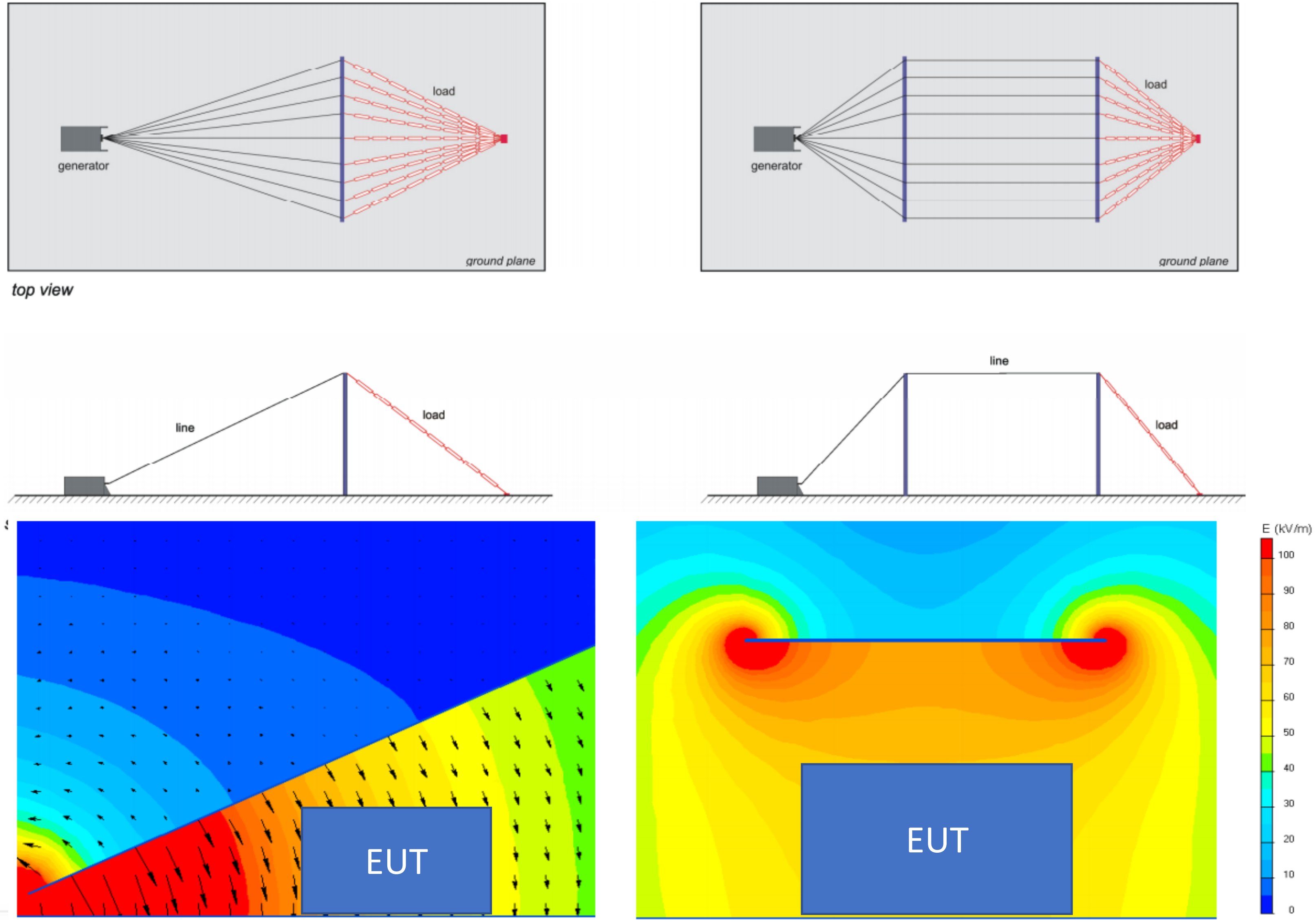
Test Method RS105 Radiated Susceptibility, Electromagnetic Pulse

- The EUT is then centered within the working volume of the radiation system.
- Usable volume of the radiation system requirements
- (h/3, B/2, A/2)/(EUT dimensions x,y,z)

- The pulse level is incrementally increased until 50 kV/m is reached or signs of degraded performance are observed (whichever comes first).

Testing is repeated in all axis.



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Thank You For Your Time!

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