Electromagnetic Interference and Compatibility (EMI/EMC)

Overview of MIL-STD-461

presented by
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Latest & Greatest: MIL-STD 461G

- MIL-STD 461 released in 1967
- MIL-STD-461G released 11 December 2015
  - Added CS117 – Induced Lightning
  - Added CS118 – Personnel Borne ESD
  - Deleted CS106 – Power line transient
  - Several significant changes to other tests
- Added General requirements (section 4)
  - Configuration management
  - Test equipment / measurement methods
  - Calibration requirements
  - Threshold measurements

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Organization

- 1. Scope
- 2. Applicable Documents
- 3. Definitions
- 4. General Requirements (service-specific)
- 5. Detailed requirements (test methods)
- 6. Notes (including tailoring)
- Appendix A (~100 pages of application guidance)

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Test Lists

- CE: Conducted Emissions (three flavors)
- RE: Radiated Emissions (three flavors)
- CS: Conducted Susceptibility (ten flavors)
- RS: Radiated Susceptibility (three flavors)

- These tests represent a mix of CW, modulated, transient and pulse tests

- Intended to simulate the environment and to measure the effect of equipment on the environment

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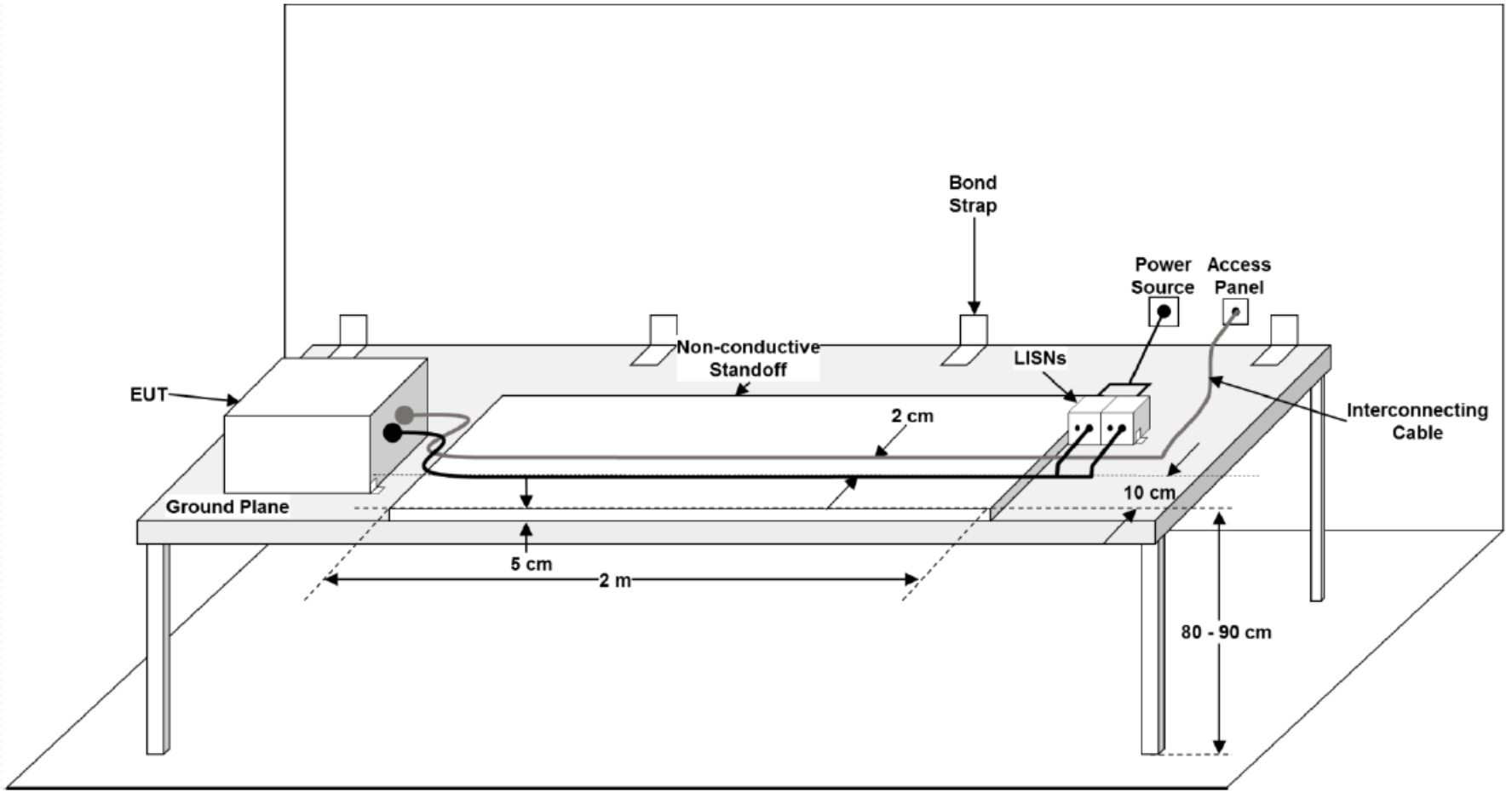
Configuration – general



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Configuration - general

- Ground plane
  - Bond to enclosure - <2.5 mΩ
  - Diagram omits absorber (compared to “F”)
  - Straps 5:1 (L/W) ratio to reduce inductance
- Cable arrangements
  - Retract from front – 10-cm
  - Elevate 5-cm
  - Expose 2-m
  - 2.5-m – power (unshielded)
  - Up to 10-m signal (not exceed actual)
- Consider a tailored configuration to match actual

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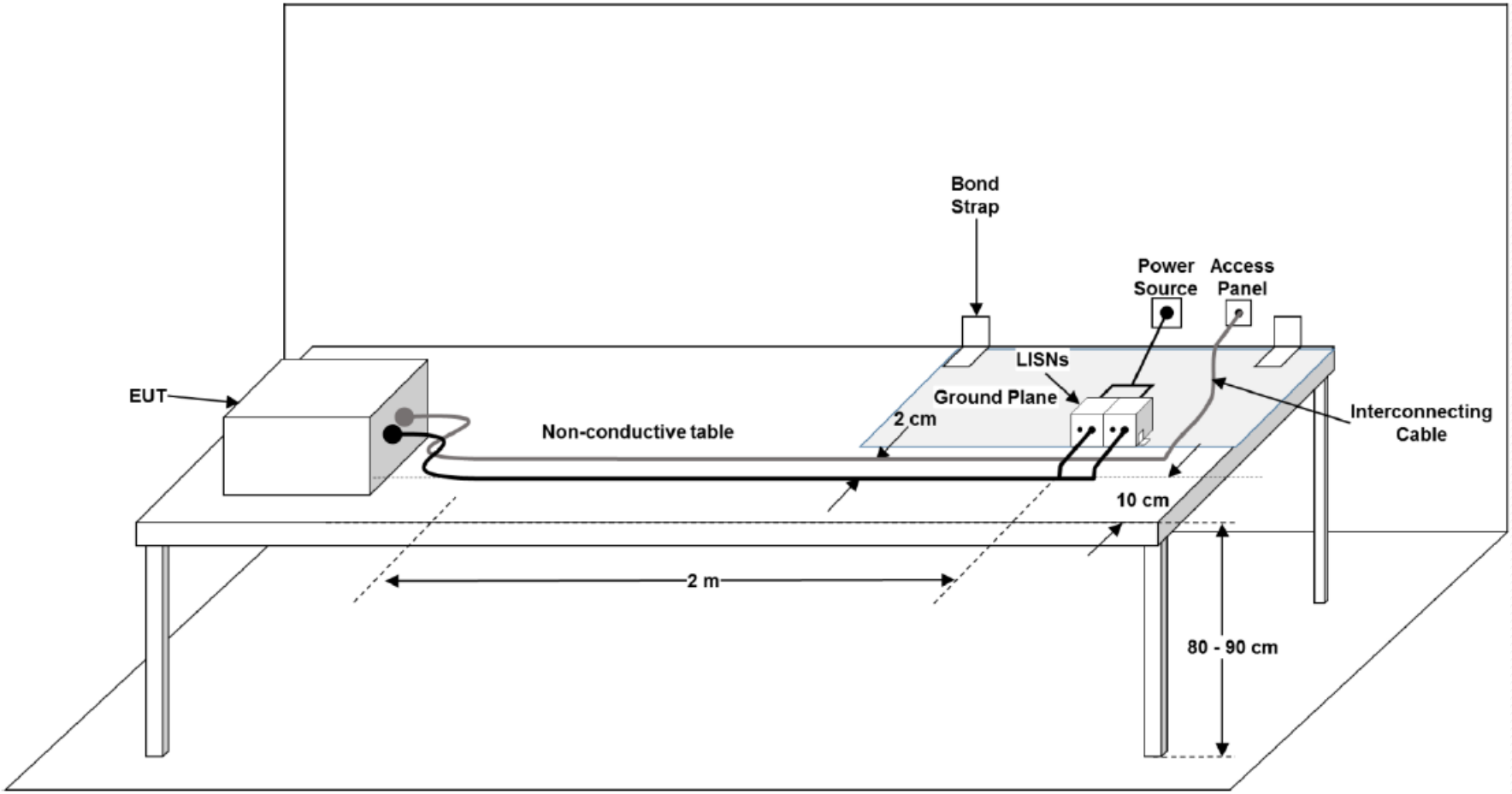
Configuration – non-conductive



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Configuration – non-conductive

- Same as general configuration except
- Ground plane
  - Short to provide for LISN bonding
  - Cable routes not above ground plane

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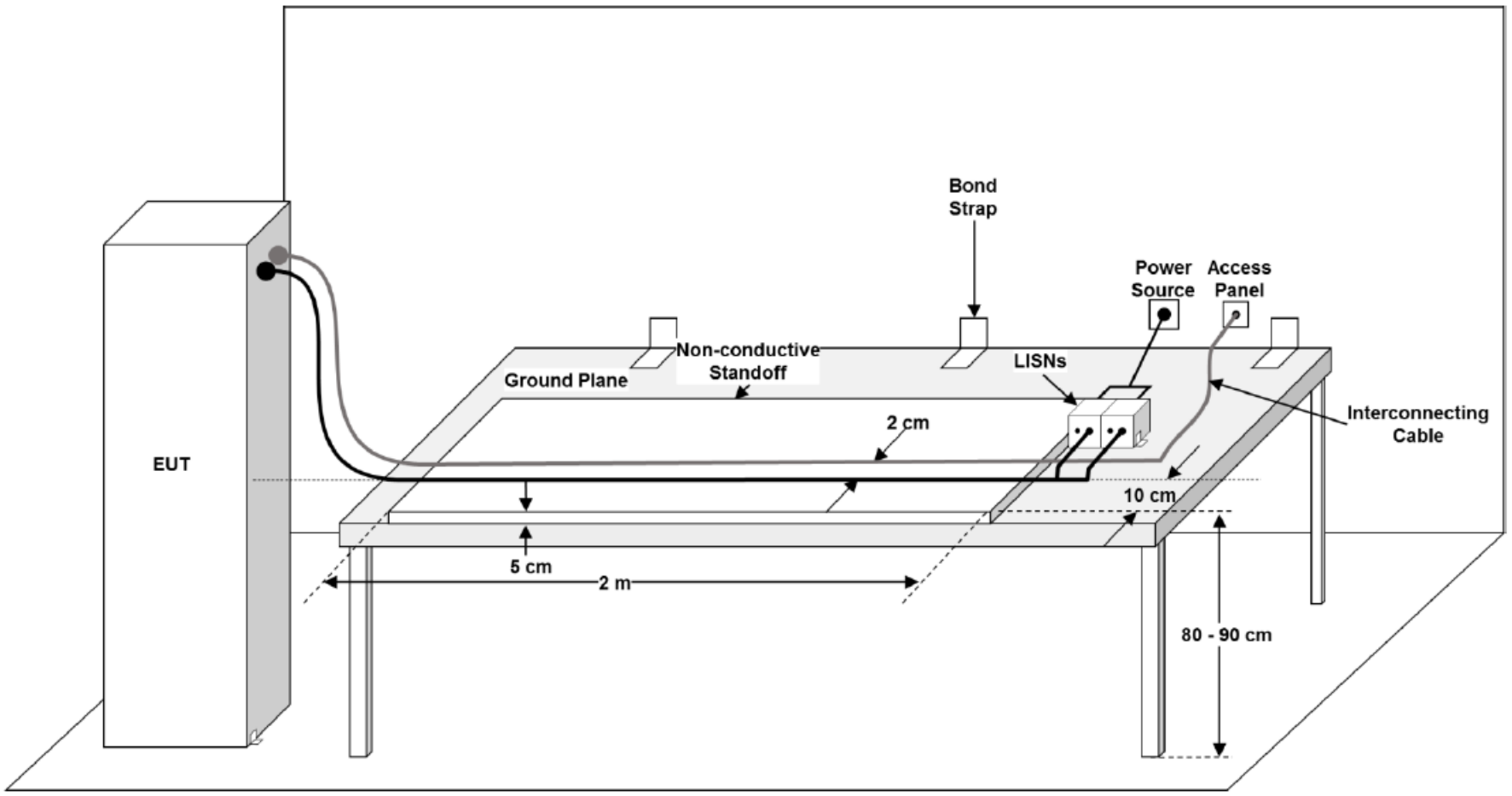
Configuration – free standing



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Configuration – free standing

- Same as general configuration except
- Table-top cable routing
  - Table ground plane attached to enclosure
  - Vertical cable not part of 2-m exposed
- EUT ground to enclosure
  - EUT strap indicated (restricted if not part of installation)
- Rotation of the EUT presents cable routing challenges that are not discussed

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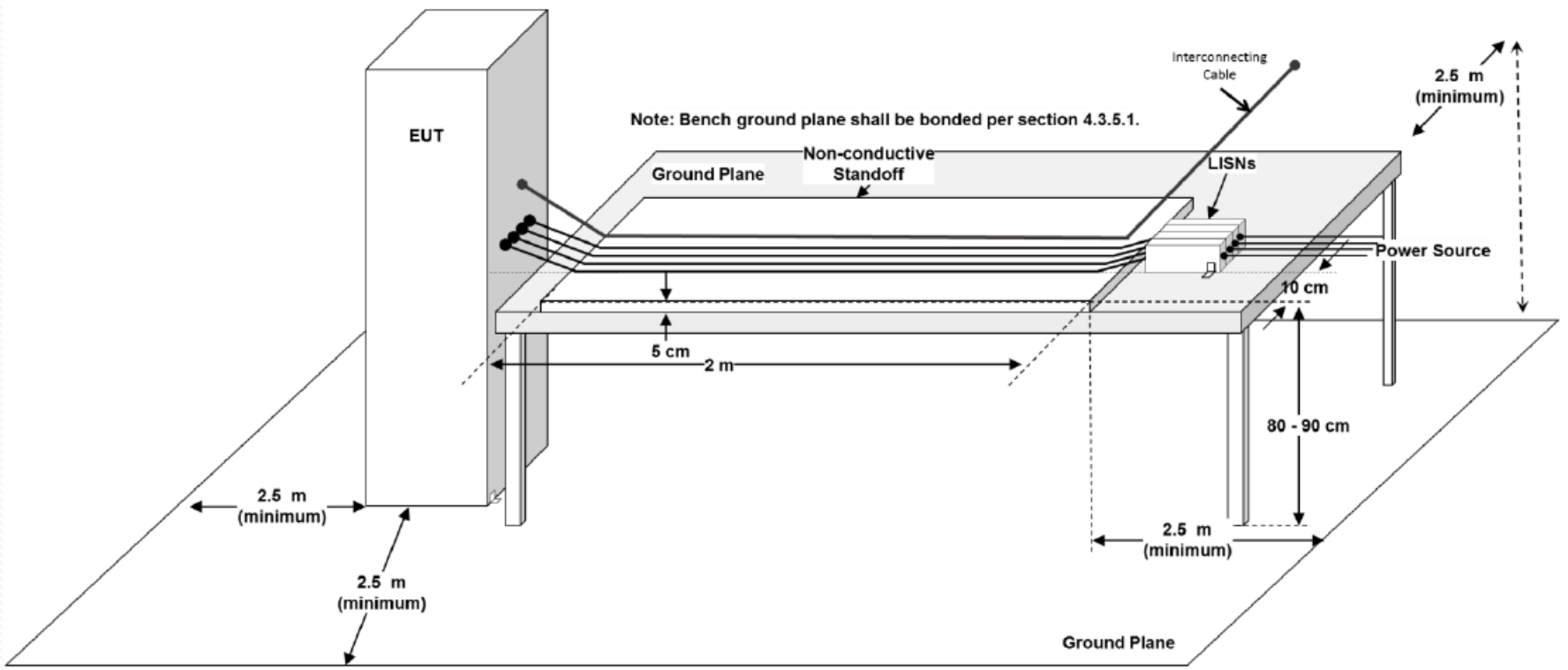
Configuration - outdoor



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Configuration – outdoor

- Basically the same as general configuration
- Table-top cable routing
  - Table ground plane attached to floor ground plane
  - Vertical cable not part of 2-m exposed
- EUT ground to ground plane
  - EUT strap indicated (restricted if not part of installation)

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Bonding

- Verify bonding of ground plane to enclosure
- EUT bonding
  - Section 4.3.8.2
  - Only the provisions included in the design shall be used
  - Applies to multiple module interfaces
  - Applies for ground plane connection
  - Verification results recorded in test report
    - 2.5 mΩ may get mis-applied
    - Use installation guide and record measurement

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Threshold measurements

- Previously – quantity not defined
  - Approval could require measurement at each frequency step
- Section 4.3.10.4.3
  - Determine worst-case
  - Record frequency range, frequency & level of greatest susceptibility
- Personal thoughts
  - Assumes gaussian distribution
  - Prefer range, greatest and 2-3 points per octave over range of susceptibility

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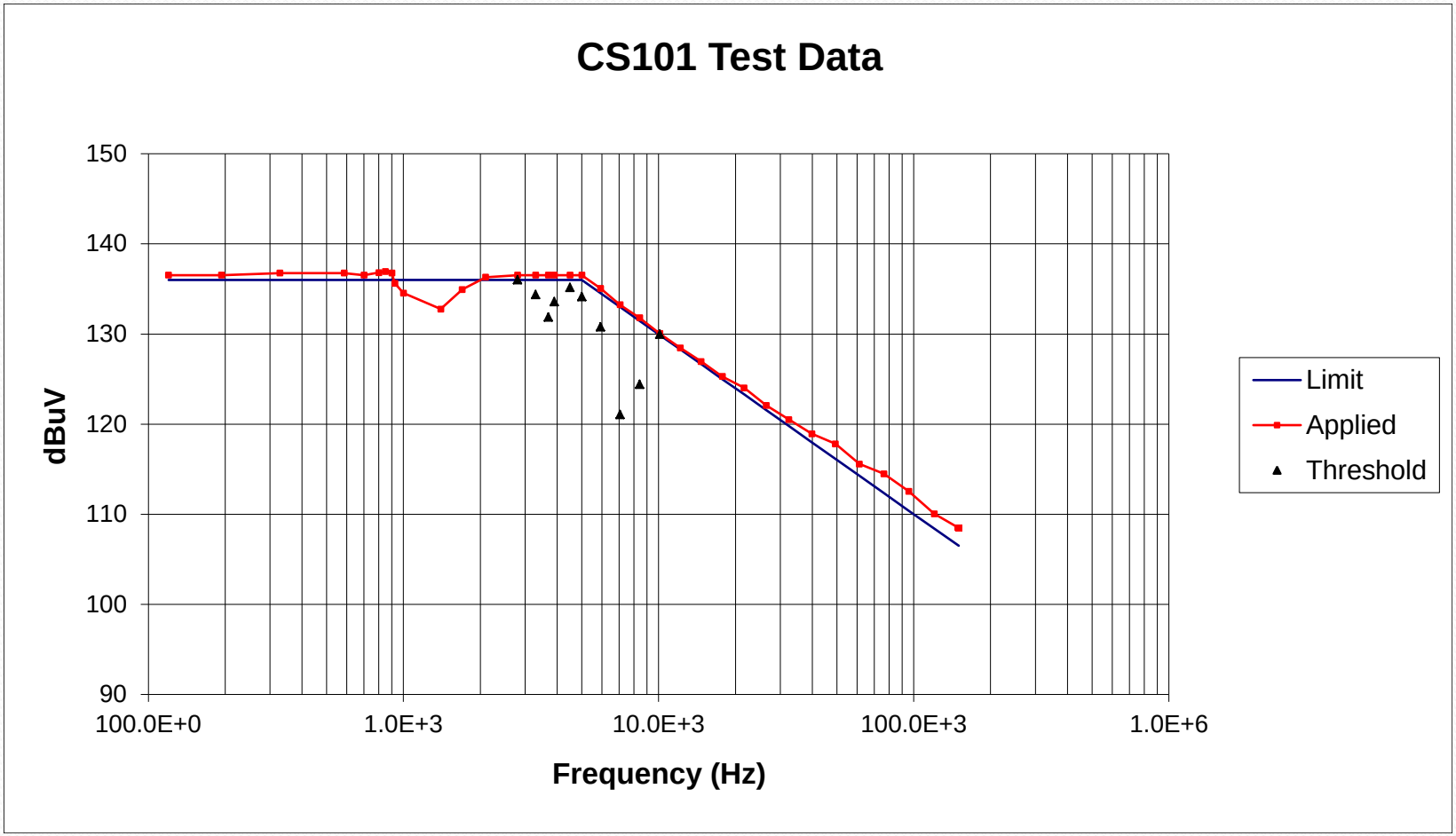
Threshold chart



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FFT Receiver

- Previously – stepped tuned
  - Measure time minimum (EUT cycle time)
  - ½ BW measurements to meet 2dB accuracy
- FFT receiver
  - Must meet ANSI C63.2 requirements
  - Time/BW minimum defined (EUT cycle time)

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Bandwidth / Measurement time

Frequency Range	IF Bandwidth	Dwell Time Stepped - Tuned	Dwell Time FFT Receiver	Minimum Measurement Time
30Hz – 1kHz	10Hz	0.15 sec	1 sec/BW	0.015 sec/Hz
1kHz – 10kHz	100Hz	0.015 sec	1 sec/BW	0.15 sec/kHz
10kHz – 150kHz	1kHz	0.015 sec	1 sec/BW	0.015 sec/kHz
150kHz – 10MHz	10kHz	0.015 sec	1 sec/BW	1.5 sec/MHz
10MHz – 30MHz	10kHz	0.015 sec	0.15 sec/BW	1.5 sec/MHz
30MHz – 1GHz	100kHz	0.015 sec	0.15 sec/BW	0.15 sec/MHz
> 1GHz	1MHz	0.015 sec	0.015 sec/BW	15 sec/GHz

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Loading/Connections

- All electrical input and output interfaces shall be terminated
- EUTs with mechanical outputs shall be suitably loaded. When variable electrical or mechanical loading is present in the actual installation, testing shall be performed under expected worst case conditions

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CE101 Limit relaxation

- Ship-board limits are relaxed based on the power draw
  - DC – if >3A then relax 20 log (I/3) (max 35dB)
  - 60 Hz – if > 1A then 20 log (I)
  - 400 Hz – if > 1A then 20 log (I)

  Aircraft
  - No relaxation provided

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CE101/CE102 High Current

- LISN Issue
  - Installation of LISN may produce voltage drops from the impedance of the LISN inductor preventing proper operation of high current test articles
  - Voltage drops are more significant with 400Hz power (greater inductance at higher freqs)

  Alternate LISN
  - MIL-STD-461G appendix discusses use of 5µH LISN for situations
  - Overall tailoring of the test plan is needed
    - CE101 frequency range and limit adjusted for alternate LISN
    - CE102 frequency range adjusted for alternate LISN

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CE102 Calibration

- Calibration verification at 10.5 kHz, 100 kHz, 1.95 MHz & 9.8 MHz
- Determine oscilloscope voltages to be set ($10^{dB/20}$/1E6) for 10.5 kHz and 100 kHz
- Set the signal generator levels based on oscilloscope measurements
- Ratio of signal generator output with/without LISN load
  - -14 dB (+1/-2 dB) @ 10.5 kHz; -3 dB (+1/-2 dB) @ 100 kHz

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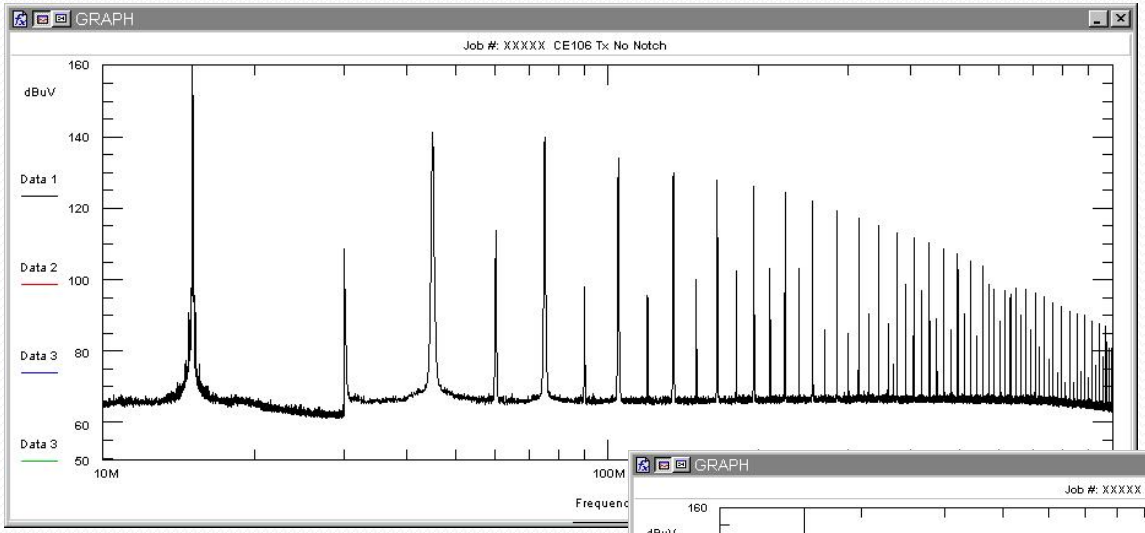
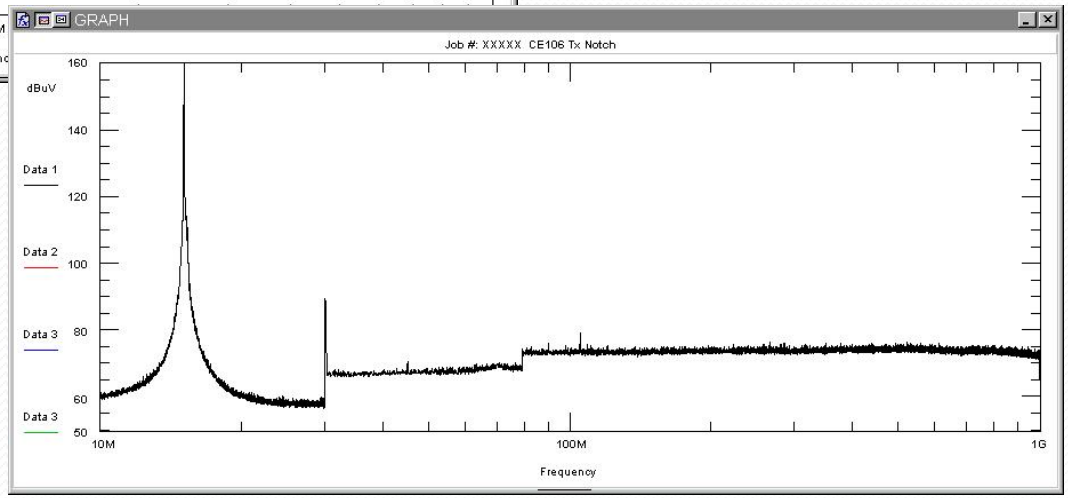
CE106 TX Over-drive

- Transmit level attenuated below max input with and without a notch filter providing 20dB





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CS101

- Conducted susceptibility, power leads, 30Hz-150kHz
  - Applicable for power loads
    - ≤ 30A per phase (previous 100A)
    - > 30A per phase if F_o <150 kHz and sensitivity ≤ 1μV
- Measurement receiver
  - Receiver transducer
- Receiver transducer
  - Isolate the power line from the power line
  - Attenuates the power frequency to prevent damage to the receiver
  - Characterization transfer characteristics for amplitude vs. frequency required for correction factors
- Phase shift networks not permitted as transducer

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CS101 <10 kHz

- Below 10 kHz voltage drop across power source may dominate
  - 10 μF feedthrough inadequate for series source/LISN inductance
  - Enclosure filter components may drop the voltage
- If voltage is not attained with the pre-calibrated power:
  - Tester is to locate missing potential
  - If drop is across power source – correction is needed
- Correction measures
  - DC can use a large capacitor in parallel with the 10 μF
  - AC – bypass facility filter

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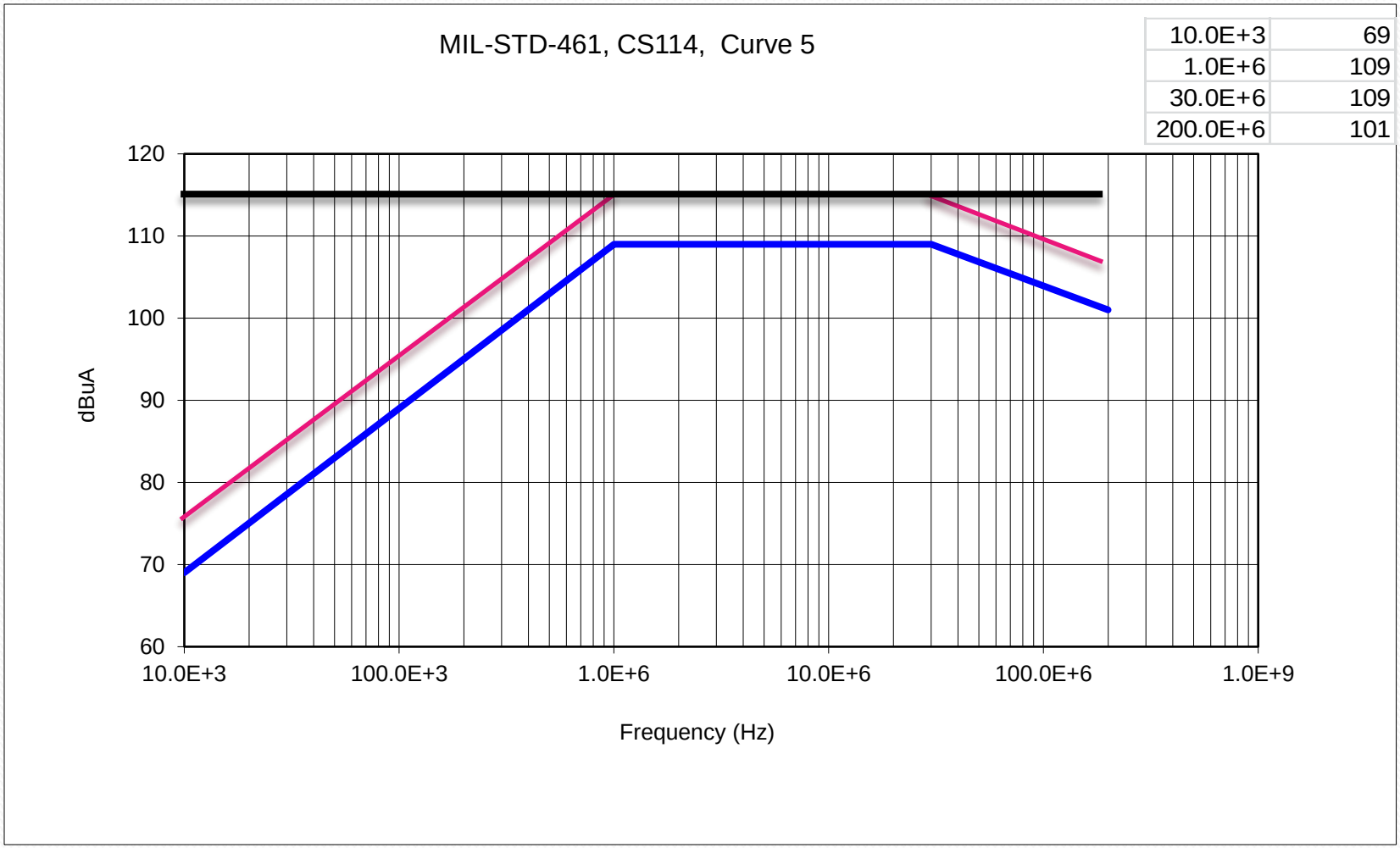
CS114 Test Current



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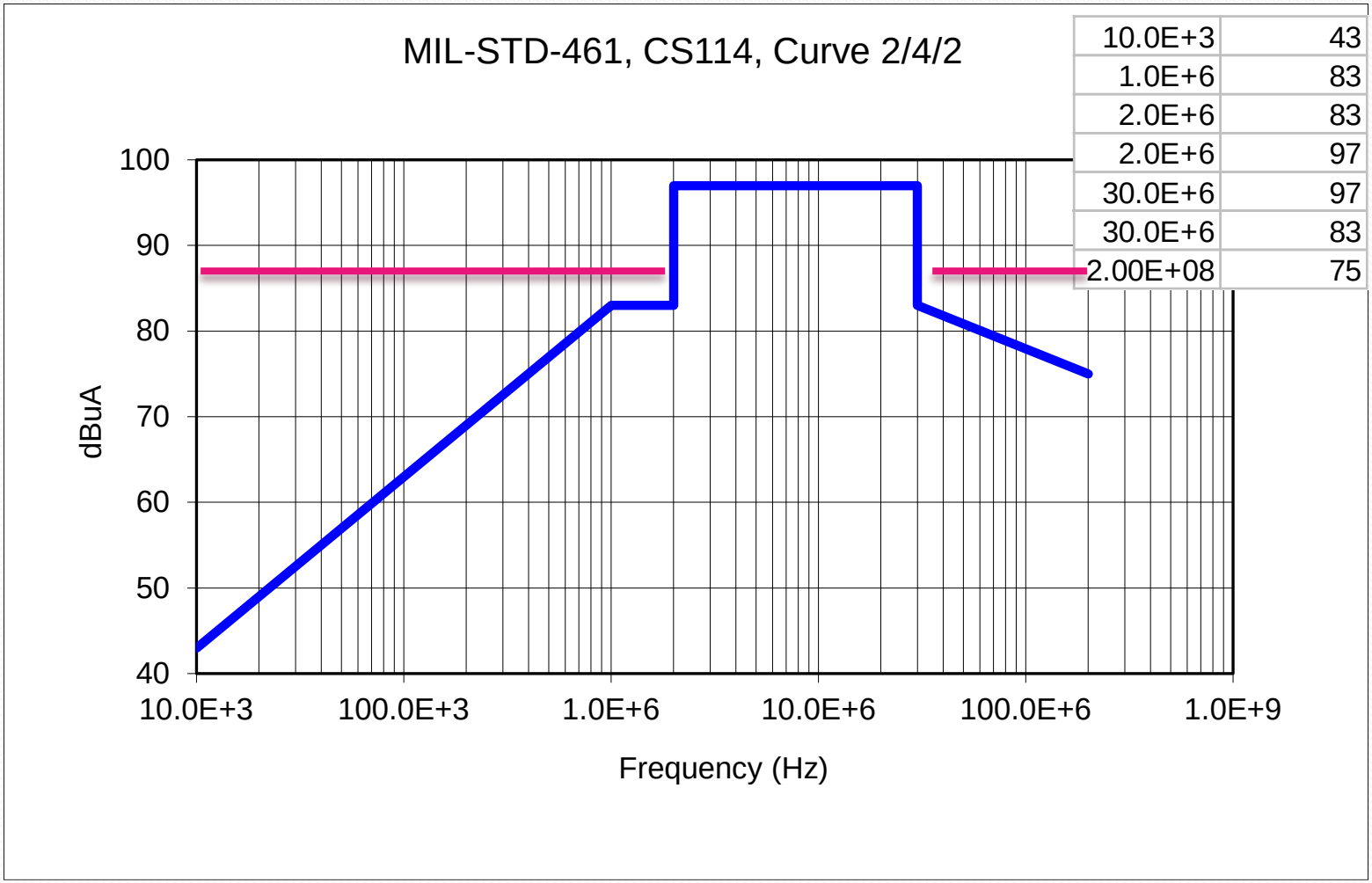
CS114 Test Current 2/4/2



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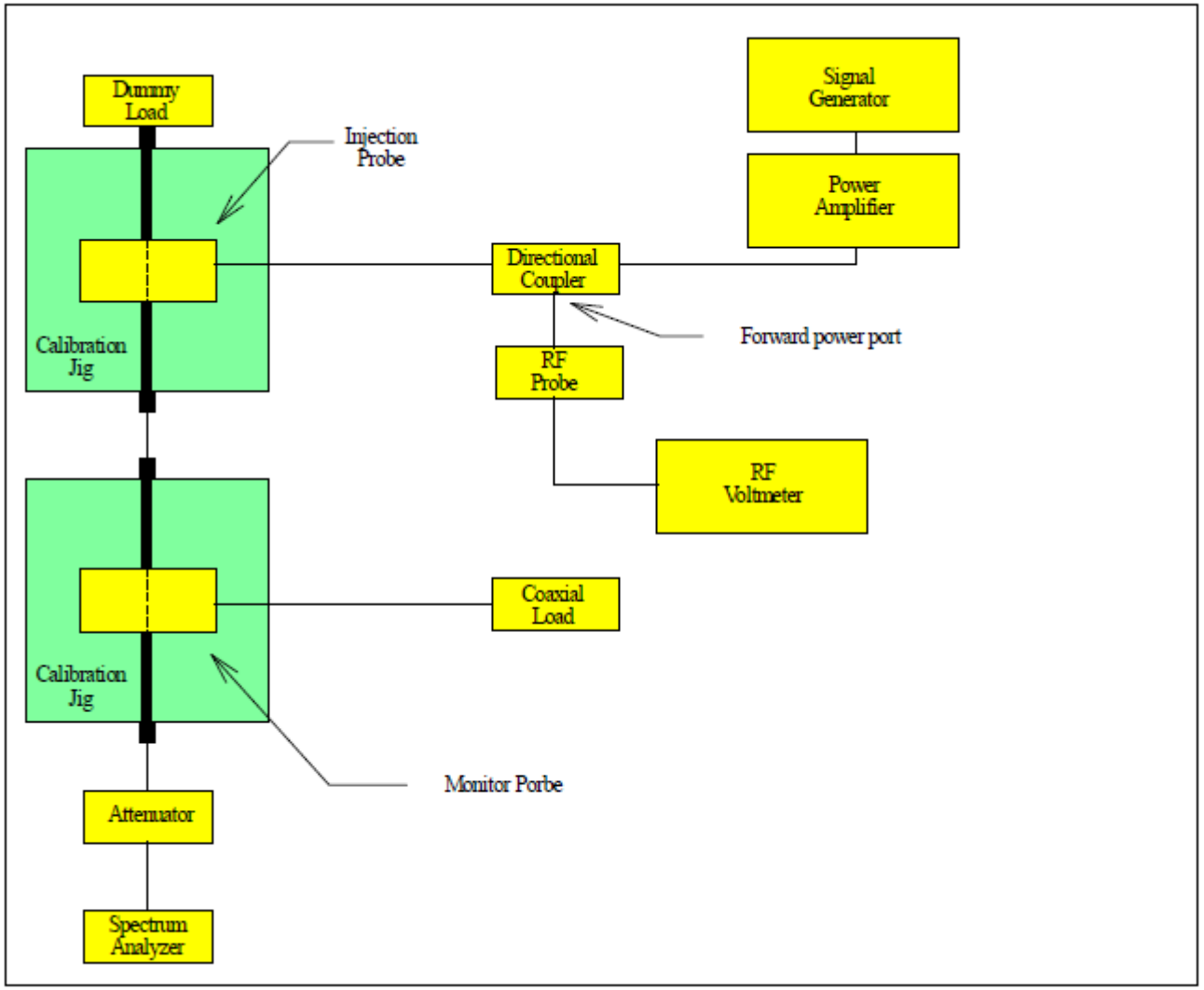
CS114 Pretest Calibration



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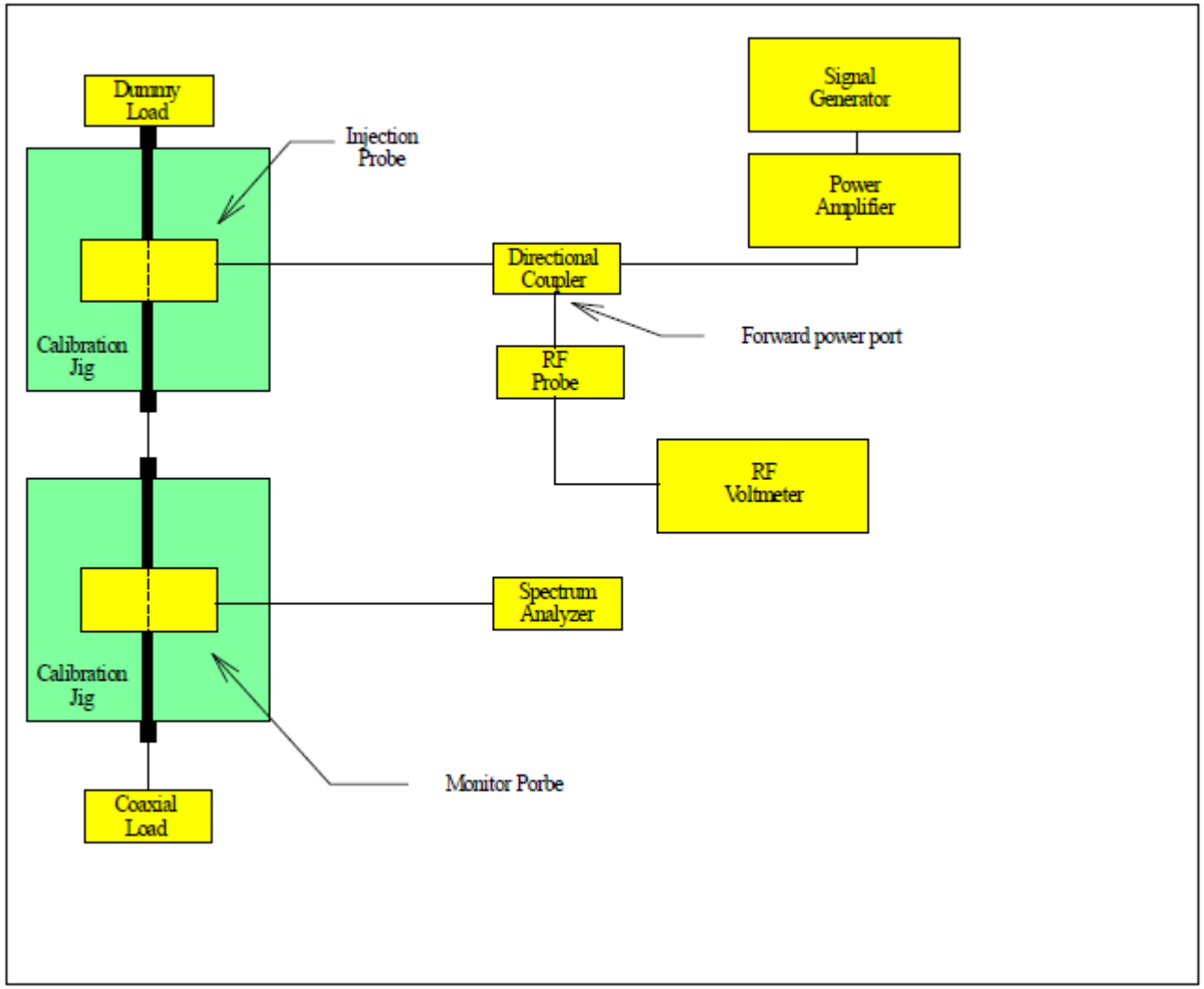
CS114 Calibration Verification



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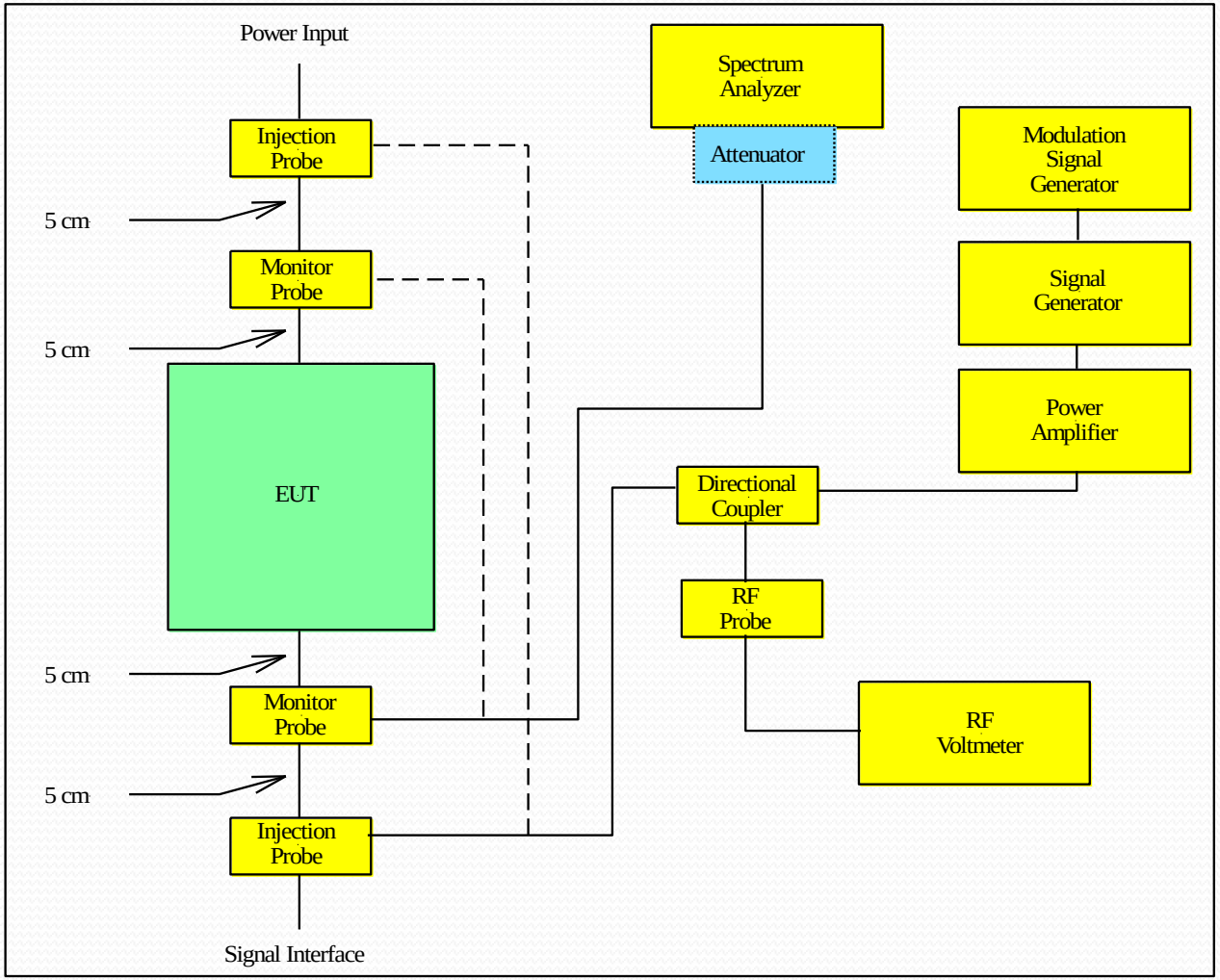
CS114 Test Configuration



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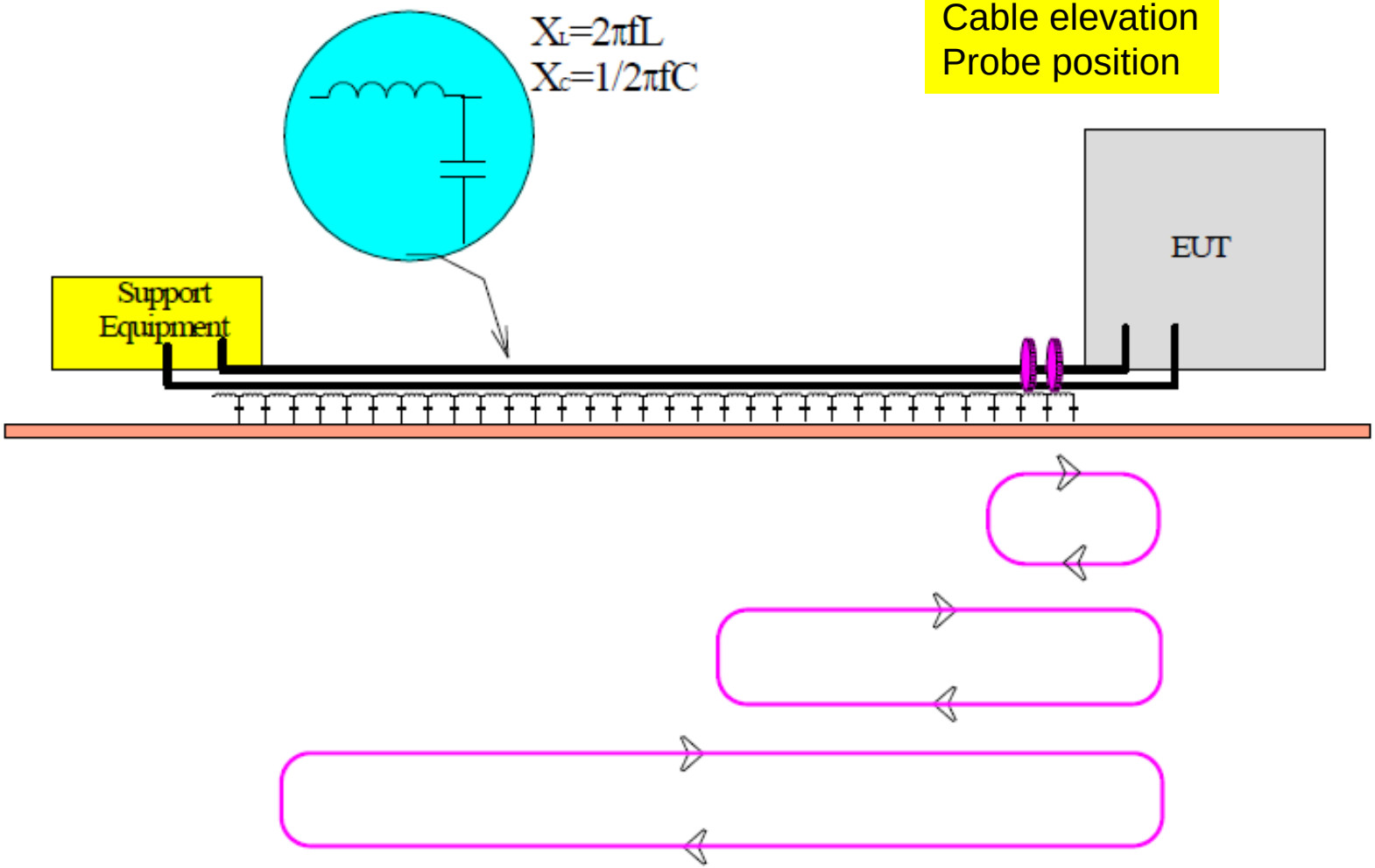
CS114 Current

Current flow
Cable coupling
Cable radiation
Cable elevation
Probe position



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CS117

- Conducted susceptibility, lightning induced transients, cables and power leads
  - Limited applicability or specified in procurement requirements
    - Safety critical
    - Non-safety critical that are part of or connected to safety critical
    - Non-safety if specified in procurement
    - Surface ship above deck or with cables routed above deck
  - Test accomplished by bulk cable injection
    - Cable bundles
    - Power cables & high side leads (grouped)
  - Limits defined but specific platform data takes precedence

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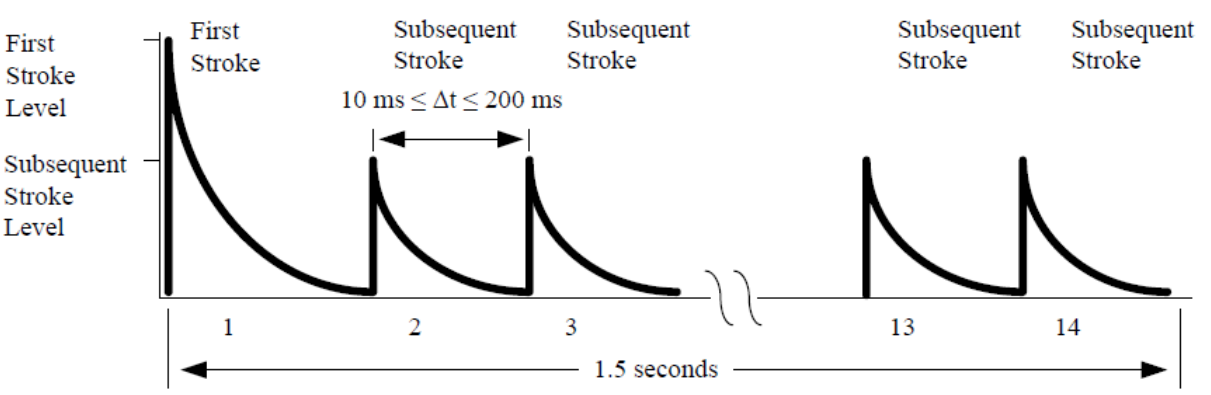
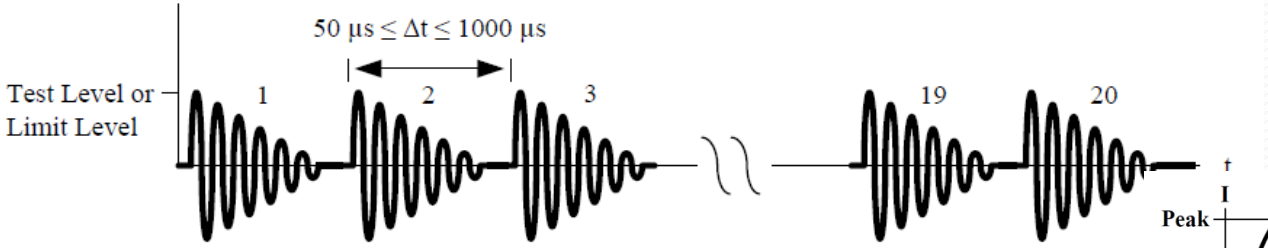
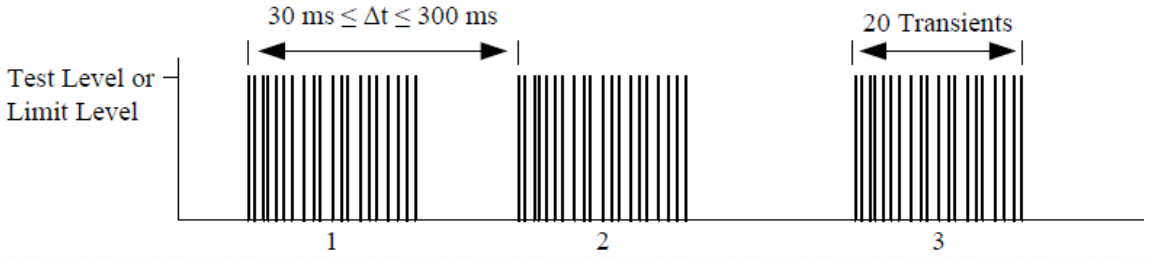
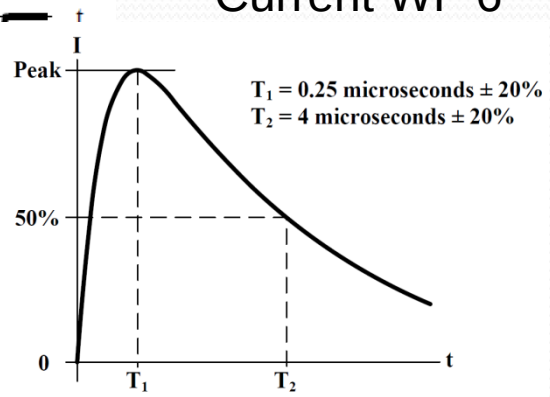
CS117 Waveforms







Current WF 6



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CS117 Test Levels

All equipment installations	Waveform 2 (WF2)/ Waveform 1 (WF1)	First Stroke V_L = 300 V (WF2) I_T = 600 A (WF1) I_T = 60 A* Subsequent Strokes V_L = 150 V (WF2) I_T = 150 A (WF1) I_T = 30 A*	First Stroke V_L = 750 V (WF2) I_T = 1500 A (WF1) I_T = 150 A* Subsequent Strokes V_L = 375 V (WF2) I_T = 375 A (WF1) I_T = 75 A*
Equipment installations routed in areas with composite skin/structure.	Waveform 4 (WF4)/ Waveform 5A (WF5A)	First Stroke V_L = 300 V (WF4) I_T = 1000 A (WF5A) I_T = 300 A* Subsequent Strokes V_L = 75 V (WF4) I_T = 200 A (WF5A) I_T = 150 A*	First Stroke V_L = 750 V (WF4) I_T = 2000 A (WF5A) I_T = 750 A* Subsequent Strokes V_L = 187.5 V (WF4) I_T = 400 A (WF5A) I_T = 375 A*
Equipment installations that utilize short, low impedance cable bundle installations.	Waveform 6 (WF6)	V_L = 600 V (WF6) I_T = 30 A (WF6)	V_L = 1500 V (WF6) I_T = 75 A (WF6)

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CS118

- Conducted susceptibility, personnel borne electrostatic discharge
  - Applicability - equipment with man-machine interface
    - Ordnance excluded (MIL-STD-331 would apply)
  - Test accomplished by contact or air discharge
- Acceptability - no malfunction, performance degradation or deviation from specified indications beyond specification tolerances
- Test levels

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

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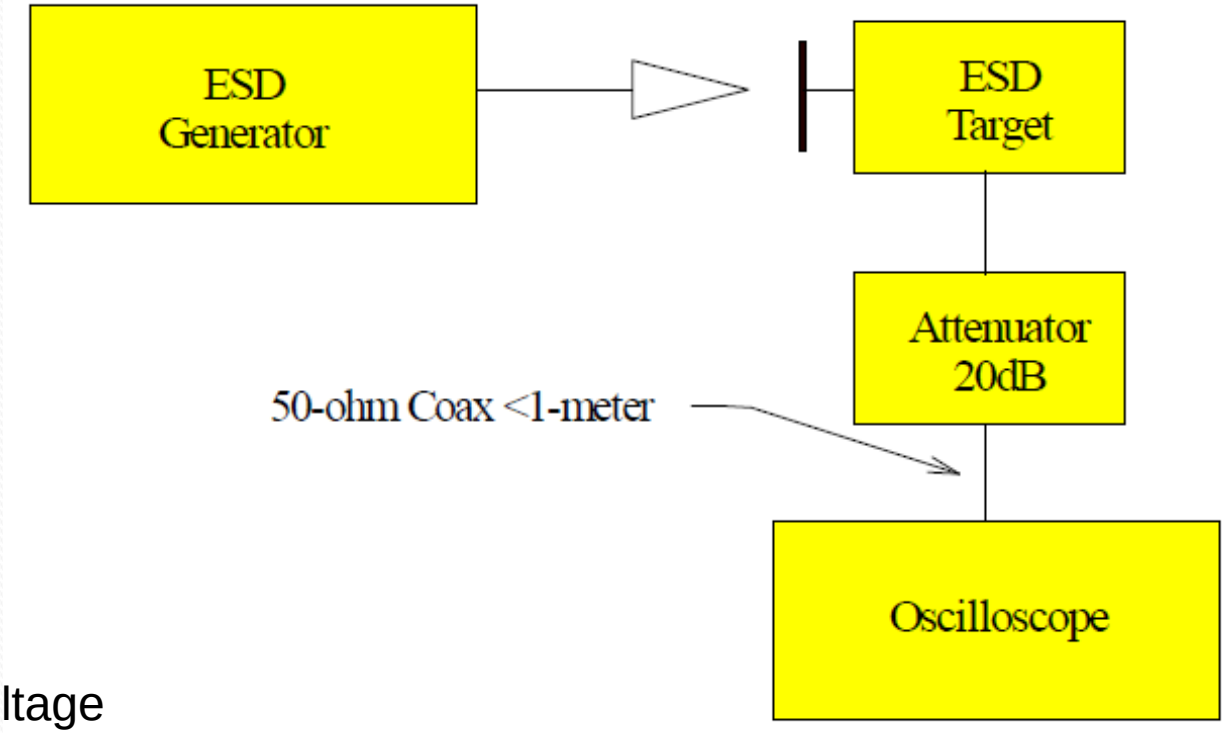
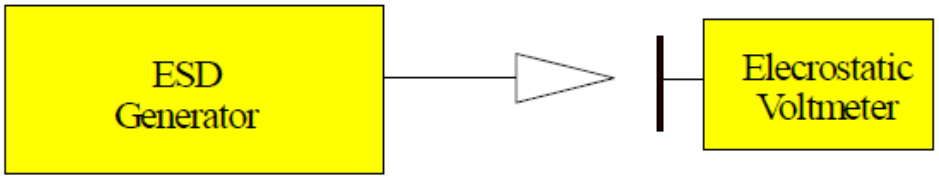
CS118 Calibration

Waveform



Tip voltage



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RE102

- Radiated emissions, electric field, 10kHz-18GHz
  - Applicable to all services/applications
  - Test performed on all EUT face with maximum emissions (determined by analysis typically)
  - Test start frequency depend on application
  - Upper test frequency is 18GHz
  - Horizontal and vertical antenna polarizations at frequencies above 30MHz
  - Not required at transmit fundamental frequency and occupied bandwidth for antenna connected transmitters (deleted standby mode only test) ***OVERLOAD CAUTION***

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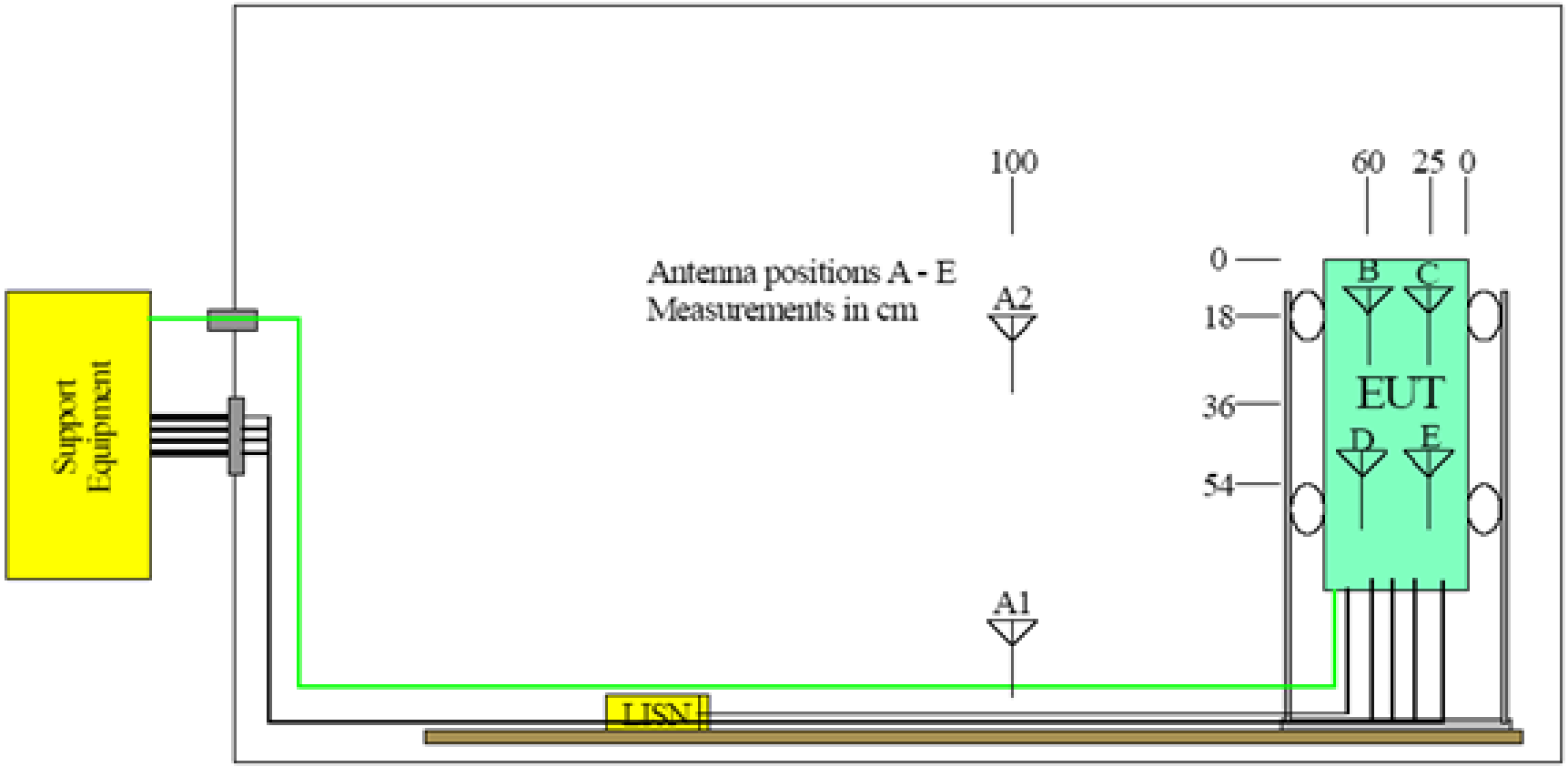
RE102 Antenna beam-width



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Summary

- Tests are comprehensive and have evolved considerably over the various versions of MIL-STD 461
- More complex environments simulated
- Tailoring may be considered (for certain environments) to either expand or reduce a test program's scope

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Websites

- MIL-STDs:
  - quicksearch.dla.mil
- WLL:
  - http://www.wll.com/
- Contact:

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Questions

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