Mil Std 461E

CS-115
CS-116
RS-105

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MIL STD 461E
CS-115 CS-116 RS-105

- **Purpose of Test**
- **History**
- **Type of Test**
- **What Is To Be Tested**
- **Calibration Setup**
- **Calibration Data**
- **Test Setup**
- **Test Procedure/Data**
- **Test Considerations/Limitations/Comments**

CS-115

- **<u>Purpose of Test:</u> Simulate fast rise and fall time transients induced on cables from electromagnetic fields generated by power switching apparatus as well as from EMP and lightning**
- **<u>History:</u> Replaces "chattering relay" of RS-06 in Mil Std 461C**

CS-115

- **Type of Test:**
  - **Square pulse with fast rise and fall time inductively coupled onto cabling**
  - **Tested with EUT power on**
  - **Detection of functional upset and damage**
- **What is Tested:**
  - **All aircraft, space, and ground system interconnecting cables including power (may be applied to surface ship and submarine subsystems)**
  - **Each cable bundle interfacing with each EUT electrical connector**
    - **-Testing of complete power cable bundle including power returns and grounds**
    - **- Testing of power cable bundle without returns and grounds**

CS-115 Waveform

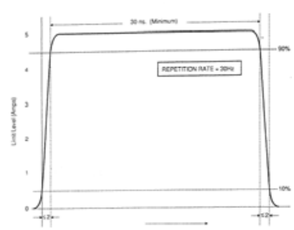


FIGURE CS115-1. CS115 signal characteristics for all applications.

CS-115 Calibration Setup

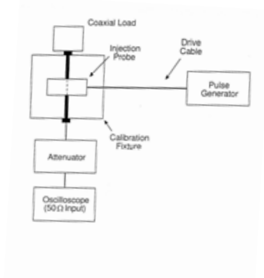


FIGURE CS115-2. Calibration setup.

CS-115 Calibration Data

- Set Pulse Generator drive level to achieve 5 amps flowing in 100 ohm calibration loop
  - "Loop" is formed by two 50 ohm loads in series, cal fixture, and ground return
  - Implies 500 volts induced across 100 ohm load
  - Will measure 500 volts/2 across one of the 50 ohm loads
- Verify rise time and fall times (10% to 90%) are <= 2ns, pulse width (at 90% points) is >= 30 ns
  - Waveshape of inductively coupled current will be different from spec due to coupler characteristics (not spec'd)
  - Pulse generator would give spec waveshape as direct drive of 50 ohm load
- Record the pulse generator drive level setting

CS-115 Calibration Data (cont)

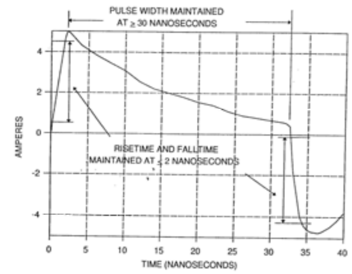


FIGURE A-13. Typical CS115 calibration fixture waveform.

CS-115 Test Setup

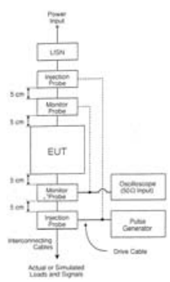


FIGURE CS115-2. Bulk cable injection.

CS-115 Test Conduct/Data

- Test Conduct (for each cable bundle)
  - Set pulse generator to level determined during calibration
  - Install inductive coupler on cable bundle
  - Turn on pulse generator and run for 1 minute at 30 pps
  - Monitor EUT for degradation of performance
  - Note peak current induced and record waveform
- If EUT degradation of performance is noted for any cable bundle, pulse generator drive level is to be lowered to determine degradation threshold

CS-115 Considerations/Limitations

- Need to define performance degradation (upset) prior to testing
- Simulated loads attached to EUT are also being "tested" - if performance degradation (upset) is noted, determining if was the EUT or was the simulated load that upset can be problematic – may need to consider/define upset for simulated loads, diagnostic equipment, etc connected to bundle under test
- If performance degradation (upset) is noted, determining which wire upset can be problematic – may require additional inductive or direct pin injection on individual wires to isolate
- No voltage monitoring on cabling or wires
- Can drive >> 5 amps into <<100 ohm loads
- Can drive >500 volts into >>100 ohm loops
- Shielded cable may protect cable
  - Pigtailed ground could compromise shielding – circumferential shield termination better
  - Filtering a possible mitigation approach

CS-116 and RS-105: Some Background

- Both have origins in EMP
- OLD APPROACH: Pin and cable bundle specs derived from coupling of EMP free field threat to specific system configuration including coupling and shielding characteristics of system. Qual testing to pin/bundle/free field for specific system/subsystem/LRU. Originally not in Mil Std 461/462. Many pin/bundle specs in existence beyond 461
- NEW APPROACH: Standardized pin and bundle spec in Mil Std 461/462 (pin spec dropped after 461C), as well as standardized free field test. NOT system dependent – "qualifies" EUT independent of system it is used on.
- Ramifications discussed later

CS-116

- **Purpose of Test:** **Simulate damped sinusoid transients induced on cables from electromagnetic fields from EMP, lightning, and electrical switching. Damped sinusoids are typical waveshapes resulting from natural resonance phenomena.**
- **History:** **Roots in EMP**

CS-116

- **Type of Test:**
  - **Damped sinusoid inductively coupled onto cabling**
  - **Multiple damped sine frequencies to cover possible ranges and conditions of EUT installations**
  - **Tested with EUT power on**
  - **Detection of functional upset and damage**
- **What is Tested:**
  - **All interconnecting cables including power interfacing with each EUT electrical connector**
  - **Testing of individual high side of power cables (returns, neutrals "not required to be tested")**

CS-116 Waveform

NOTES: 1. Normalized waveform: $e^{-(\pi f t)/Q}\sin(2\pi f t)$

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

2. Damping factor (Q) shall be determined as follows:

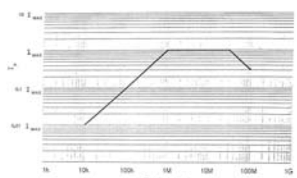
$$Q = \frac{\pi(N-1)}{\ln(I_P/I_N)}$$

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
ln = Natural log

3. I_P as specified in Figure CS116-2

FIGURE CS116-1. Typical CS116 damped sinusoidal waveform.

CS-116 Test Frequencies/Levels



NOTES:
1. For Army and Navy procurements, I_{max} = 10 amperes
2. For Air Force procurements, I_{max} = 5 amperes

FIGURE CS116-2. CS116 limit for all applications.

CS-116 Calibration Setup

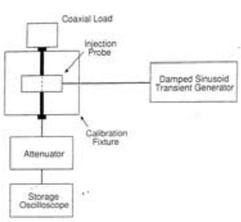


FIGURE CS116-3. Typical test setup for calibration of test waveform.

CS-116 Calibration Data

- **Set pulse generator drive to get spec current (for damped sine frequency of test) level into 100 ohm calibration loop**
  - **"Loop" is formed by two 50 ohm loads in series, cal fixture, and ground return**
  - **Implies Ispec x 100 ohm volts induced across 100 ohm load**
  - **Will measure (Ispec x 100 ohms)/2 across one of the 50 ohm loads**
- **Record pulse generators settings**
- **Verify waveform (frequency, Q, amplitude)**
- **Six mandatory frequencies plus any known frequencies critical to equipment installation**
- **NOTE: It is possible for procuring activity to set current levels higher or lower, and to change frequency break points**

CS-116 Test Setup

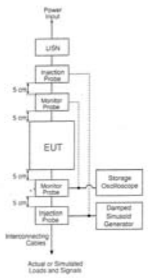


FIGURE CS116-4. Typical set up for bulk cable injection of damped sinusoidal transients.

CS-116 Test Procedure/Data

- Start with pulse generator set to low output
- Increase drive level until spec current level (for damped sine frequency of test) is measured on bundle under test or the pulse generator setting determined during calibration is reached (whichever occurs first)
- Pulse for 5 minutes (one pulse every 1 to 2 sec)
- Monitor EUT for upset or damage
- Note test frequencies and current amplitudes reached including recording of waveform
- If upset or functional degradation noted at lower level, so document

CS-116 Considerations/Limitations

- Need to define performance degradation (upset) prior to testing
- Simulated loads attached to EUT are also being "tested" - if performance degradation (upset) is noted, determining if was the EUT or was the simulated load that upset can be problematic – may need to consider/define upset for simulated loads, diagnostic equipment, etc attached to cable under test
- If performance degradation (upset) is noted, determining which wire upset can be problematic – may require additional inductive or direct pin injection on individual wires to isolate
- No voltage monitoring on cabling or wires
- Can drive >> Ispec into <<100 ohm loads
- Can drive >(Ispec x 100 ohm) volts into >>100 ohm loops

CS-116 Considerations/Limitations
(continued)

- Levels cover expected upper bound from real tests. HOWEVER:
- There is nothing in the Mil Std that specifies shielding external to the EUT that will assure external EMP impinging on system will be reduced to CS-116 levels
- CS-116 states that "equipment should not be expected to provide the total protection" and " platform designer should be required to share in the burden of the hardening process…"

CS-116 Design Considerations

- Shielded cable may protect cable
  - Pigtailed ground could compromise shielding – circumferential shield termination better
- Filtering a possible mitigation approach
- Spec says 5 amp level should be low enough to avoid use of Transient Protection Devices (TPDs), but…….TPDs are a possible mitigation approach

RS-105

- <u>Purpose of Test:</u> Subject EUT to an electromagnetic plane wave field approximating a High Altitude EMP to verify that the EUT does not sustain functional upset or damage
- <u>History:</u>
  - Roots in EMP
  - Waveform modified as theoretical weapon yields updated
  - Waveform used to be much slower (risetime and width)

RS-105

- **Type of Test:**
  - **- Electromagnetic plane wave field illumination**
  - **- Simultaneous exposure to both Electric (E) and Magnetic (H) fields**
  - **- Double exponential waveform having very fast risetime (1.8-2.8ns), fast decay time (23+/-5 ns), and high amplitude (50 kV/m and 133 A/m)**
  - **- Detection of functional upset and damage**
  - **- Tested with EUT power on**
- **What is Tested:**
  - **- EUTs exposed directly to EMP or located in poorly shielded area**
  - **- Intended primarily to be test of EUT, versus system/subsystem test**
  - **- Cables connected to EUT not (deliberately) intended to be tested**

RS-105 Waveform

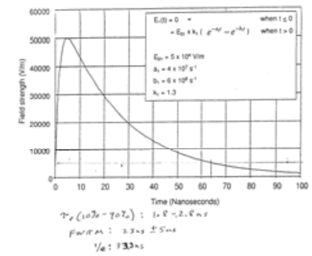


FIGURE RS105-1. RS105 limit for all applications.

RS-105 Calibration Setup

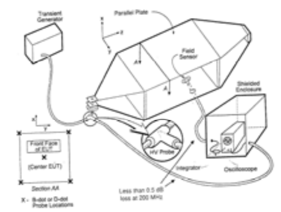


FIGURE RS105-2. Typical calibration setup using parallel plate radiation system.

RS-105 Calibration Data

- **Probes**
  - **- Spec cites using E or H field derivative probes**
    - **- Derivative probes need to be integrated real time using an integrator – integrator bandwidth can be problematic (too narrow to completely integrate derivative waveform)**
    - **- Self integrating broadband H sensors available**
  - **- Spec cites using High Voltage probe to look at drive to simulator**
    - **- For 1 meter simulator, would need probe to handle 50 kV**
    - **- Special, expensive probe, difficult to do – not recommended**
- **Field map at 5 points where EUT front face will be**
  - **- All 5 points must be >= spec, <= 2x spec**
- **Record the field waveform at all 5 points**

RS-105 Test Setup

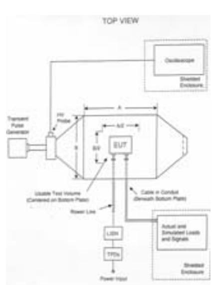


FIGURE RS105-3. Typical test setup using parallel plate radiation system.

RS-105 Test Procedure/Data

- **Start at 10% of spec level**
- **Increase in 2-3x steps**
- **Check waveform (Note: scattering from EUT may result in field waveform distortion)**
- **At spec level, pulse EUT 5 times**
- **Rotate EUT 90 degrees, and pulse 5 more times**
- **Rotate another 90 degrees and pulse 5 times**
- **Monitor for upset/damage throughout pulsing – stop testing if upset noticed and document test level**
- **Photos of test setup**
- **Written documentation of test setup**
- **Record waveforms of all pulses**

RS-105 Considerations/Limitations

- **Spec says to ground EUT as done in installation**
  - **- If simulated loads on other end of cable connected to EUT are grounded, this allows simulator return current to flow down cable – may introduce measurement errors**
  - **- Ferrite chokes on this cable may mitigate**
- **Spec says to orient cable to minimize electromagnetic field interaction**
  - **- Difficult to completely eliminate this interaction – opens possibility of field interaction with cable of inducing upset on simulated loads, diagnostic equipment, etc**
- **This is a "bounded wave" simulator**
  - **- Hard to find**
  - **- Horizontally polarized EMP simulators are not equivalents**

RS-105 Design Considerations

- **Apertures (seams, deliberate holes, etc) on EUT need to be considered**
  - **- Electromagnetic field coupling analysis and internal buried circuit analysis may be needed to identify vulnerability during design phase**
  - **- May need to consider conductive film windows, wire mesh over air ducts, etc to seal apertures to fields**
- **Conundrum:**
  - **- Spec address testing of EUT exposed to EMP, but deliberately excludes cabling**
  - **- But cabling will likely also "see" EMP**
  - **- What assures that EMP induced transient on cabling will be below CS-116 levels?**

Bruce Harlacher Biography

Mr. Harlacher is a Program Manager for Fischer Custom Communications, Inc.'s (FCC) design center in San Diego, CA. His primary duties include supporting FCC activities related to custom EMP testing for the US Defense Threat Reduction Agency (DTRA), and EMP test related activities for US Government Contractors. His other duties include commercial product development support for FCC. Mr. Harlacher is NARTE certified EMC engineer.

Prior to joining FCC, Mr. Harlacher was the Manager of Maxwell Laboratories S-Cubed Division Electromagnetic Test Section, where he was responsible for the overall operation of this business unit, and served a similar function while with IRT Corp. As part of this responsibility, he has served as Program Manager on a wide variety of programs. These include the design and construction of a 10-meter high EMP simulator (for Mil Std 461/462C RS-05) using a 600 kV Marx Generator for the Naval Weapons Center (China Lake, CA), and on the design and construction of a 2-meter high EMP simulator for the South Korean Government for Mil Std 461D RS-105 testing.

Mr. Harlacher has participated in more than dozens field tests involving either frequency domain (CW) and/or time domain (pulse) testing. In addition, he has planned, executed, and documented over 100 laboratory EMP tests on military and commercial equipment.