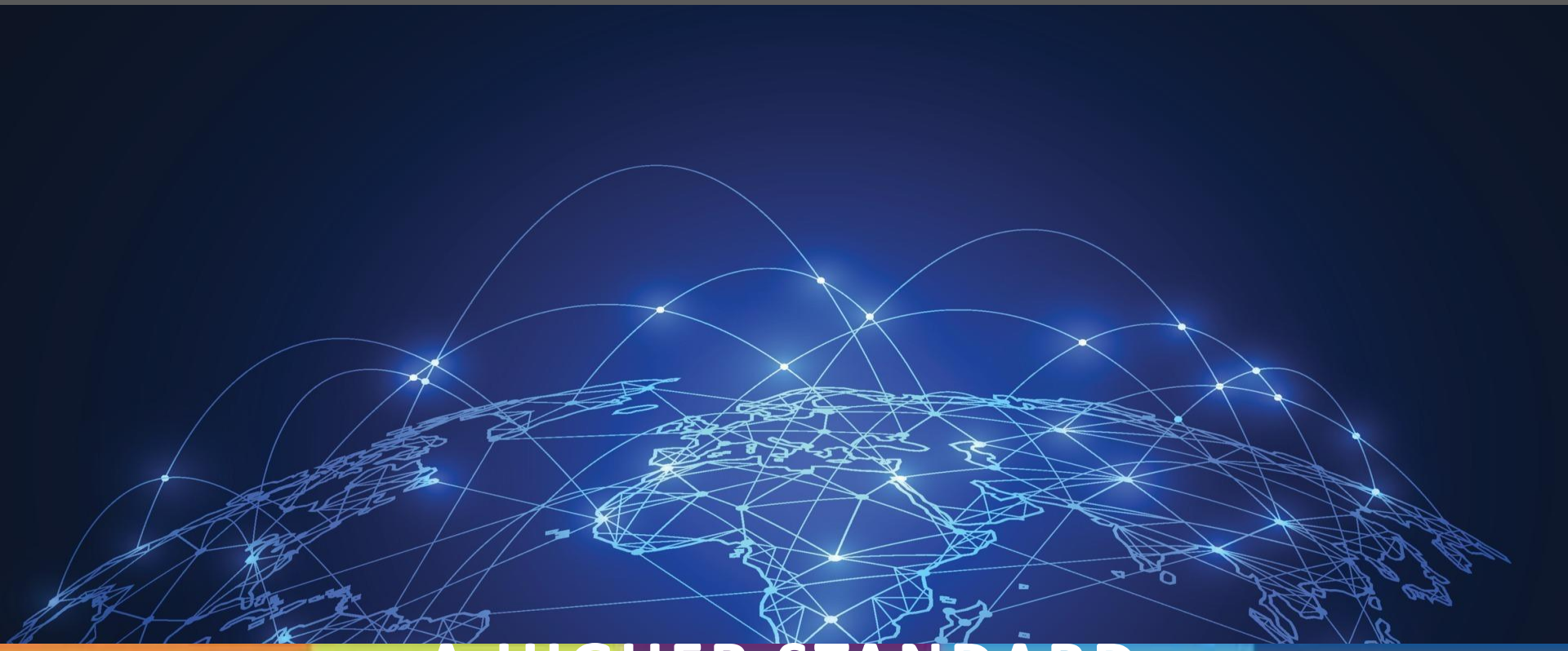
INTERNATIONAL EMI/EMC STANDARDS COMPARISON



A HIGHER STANDARD

TESTING | INSPECTION | CERTIFICATION

Jeffrey Viel
Chief Engineer
Jeffrey.Viel@nts.com
978-727-3793

NTS

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

- Technology is embedded into nearly every aspect of our lives.

- Technological advancements in electronics have allowed us to perform tasks in new and innovative ways never before thought possible.
  - From simplifying mundane tasks, eliminating universal communication barriers, and providing hours of entertainment, to conducting highly complex, mission critical functions and processes.

- However, as the adaption of increases, so does the risk of electromagnetic interference of these function

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

- EMI regulatory test standards are developed to ensure that products will operate as intended, and not interfere with the operation of other products within their intended installation environment and platform.
- A platform is anywhere a product may be installed and operated.
- This can be anything from a plane, train, ship, or even your home, or office.

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

- Product compliance tests are developed to simulate real-world environments-

  - **Immunity/Susceptibility tests**

  (Evaluates the ability to operate as intended when subjected to external EM environments)

    - *Radiated EM fields*
    - *Conducted EM voltages/currents*
    - *Surges, switching transients, lightning*
    - *power quality (drop outs, sags, variations, etc…)*

  - **Emissions Tests**

  (Ensures that proper EMI controls have been implemented, minimizing the potential for operational interference of nearby equipment).

    - *Radiated EM emissions*
    - *Conducted EM emissions*

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

No single standard covers every market!

- Modern Industry test standards address similar EMI/EMC concerns.
  - In some instances this results in overlapping test conditions.
  - Some standards allow you to take credit for tests performed in accordance with other standards were conditions are aligned.

- However, the Electromagnetic Environment of each installation platform and its effects on locally installed equipment often times vary.
  - These variances result in changes to test conditions (limits, levels, frequencies, etc…) causing gaps.
  - Gaps are considered Risk Areas which usually require testing to ensure compliance.

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Defense Vs. Commercial

Commercial Off the Shelf (COTS)

- The integration of COTS equipment in the DoD has been increasing exponentially of the past decade.
  - ***More cost effective***
  - ***Improved deployment time***
- However, COTS equipment is generally not designed or intended for Combat EME's.
  - Equipment is commonly qualified to commercial industry standards not MIL-STD.
  - Occasionally, Risk Analysis Assessments and certain test requirements are waived in an effort to support rapid deployments (on a case-by-case basis).
  - In most cases, COTS equipment will require some modification to meet MIL-STD test criteria.

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Defense Vs. Commercial

MIL-STD-461	IEC/EN/CISPR
RE101 Magnetic Field Emissions 30 Hz – 100 kHz	No equivalent test required
RE102 Electric Field Emissions 10 kHz – 18 GHz	**CISPR 16 Electric Field Radiated Emissions** 30 MHz – 1 GHz
CE101 Conducted Emissions (Current) Power leads Only 30 Hz – 10 kHz	**IEC 61000-3-2 Current Harmonics <16Amps** **IEC 61000-3-12 Current Harmonics <75Amps** Fundamental to 50th harmonic
CE102 Conducted Emissions (Voltage) Power leads Only 10 kHz – 10 MHz	**CISPR /IEC/EN Conducted Emissions** **Power** 150 kHz – 30 MHz **Communications (I/O)** 150 kHz – 30 MHz

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Defense Vs. Commercial

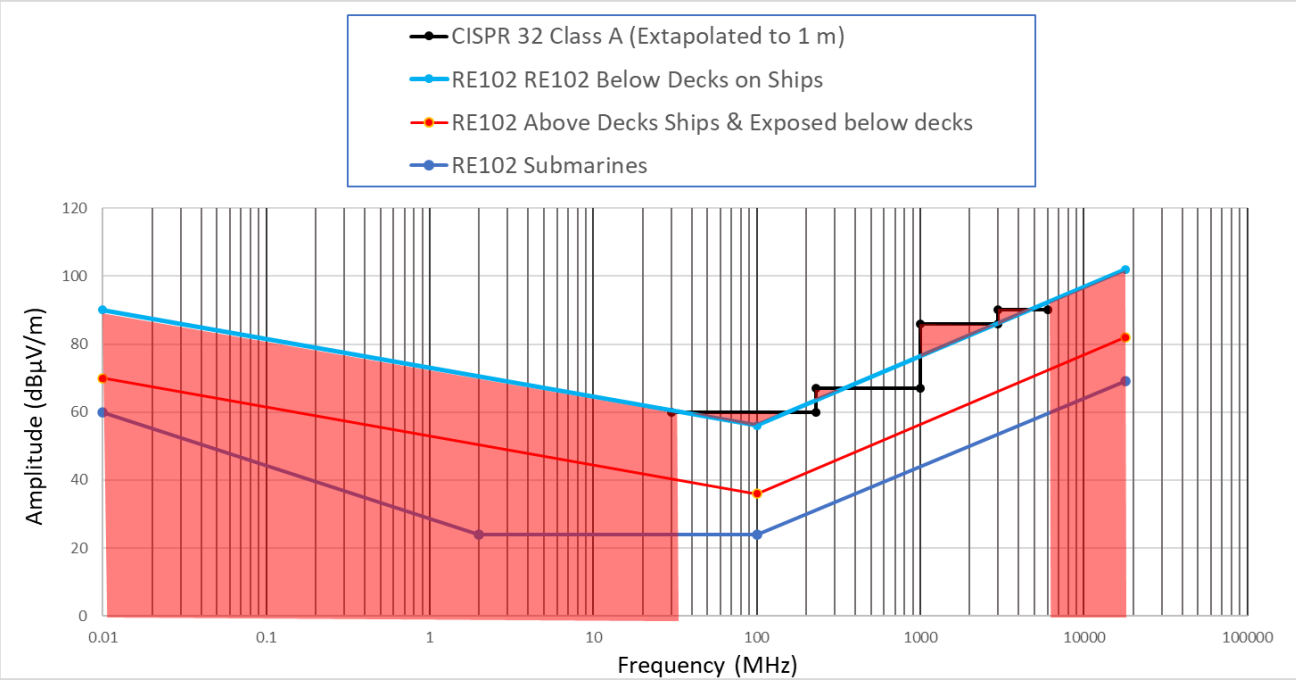
MIL-STD RE102 to CISPR32 Comparison

Major Differences

- Frequency Range
- *Measurement Distance*
- *Resolution BW*
- *Peak Vs. Quasi-Peak & Average Measurements*

Other Considerations:

- *Near Field Vs. Far Field*
- *Maximization routine*
- *Mode(s) of operation*
- *Equipment Configuration*



INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Defense Vs. Commercial

Common Issues: CE101 Current Harmonic Control

- Current Harmonics Emissions produced by a commercial off the shelf UPS, and other power conversion technologies commonly have problems meeting MIL-STD-461's CE101 while previously complying with the IEC's 61000-3-2, or 3-12 harmonics control criteria.

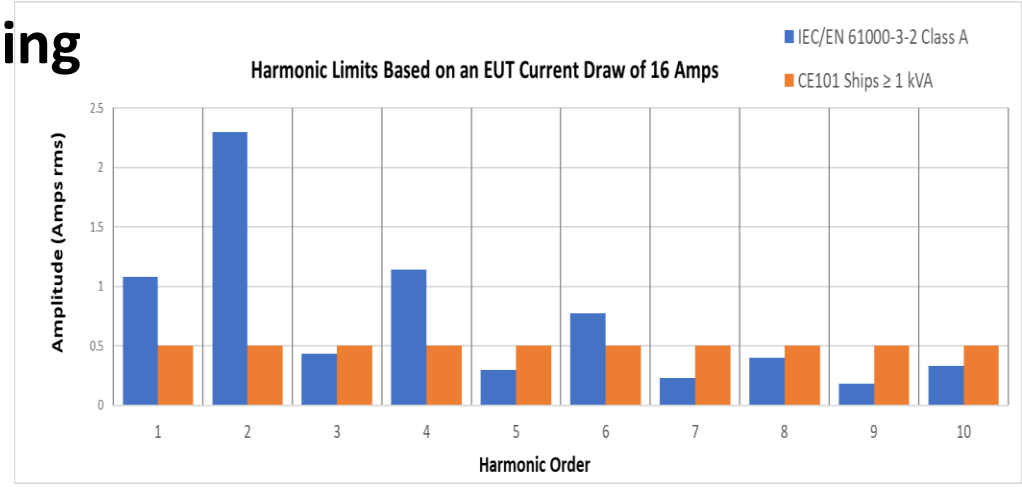
- The CE101 ≥ 1kVA limit was derived from MIL-STD 1399 section 300A Shipboard and submarine power quality requirements.
  - Although the CE101 limit is relaxed based on the fundamental current draw but it regulates single harmonic currents to 3% from the 2nd to the 32nd.

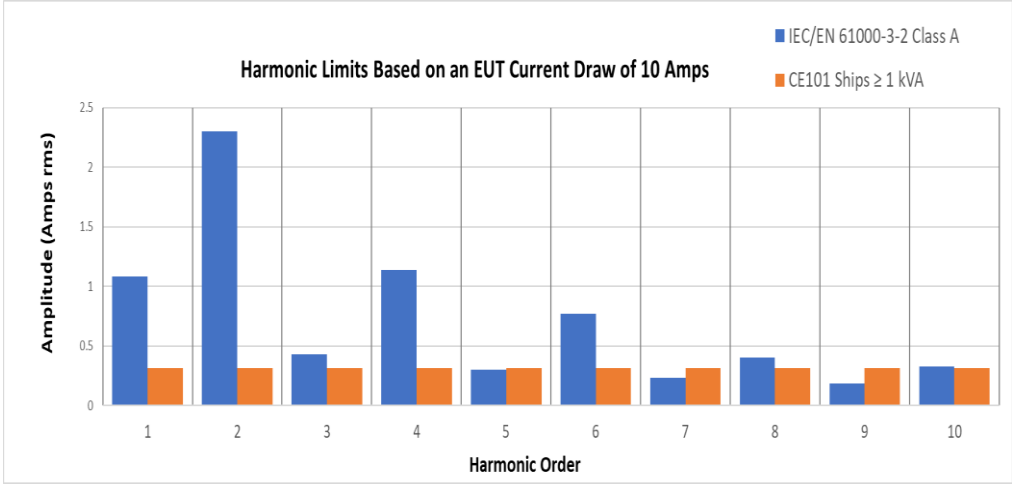
INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Defense V.s. Commercial

Common Issues: Harmonics Testing

- Commercial UPS equipment is typically tested at full load. It's Internal Inductive filtering "DC Link Choke" is sized to provide adequate harmonic control at the highest rating of the supply without causing significant voltage drop.
- Defense System integrators will generally oversize their UPS to allow for equipment expansion; resulting in a load size lower than the UPS full rating.
- The lower the current draw, lower the harmonic control provided by the UPS's internal filtering.
- **It is common for COTS UPS at < 65% of it's maximum current rating, to exceed the CE101 Navy shipboard ≥ 1kVA test criteria.**





INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Common Solutions: Harmonics Testing

- It is most likely that the COTS UPS Manufacturer will not modify their equipment for free.
- The cheapest solution is to establish a load rating that works for the application and is compliance with the standard.
- External filtering can be big, heavy, expensive, and can generate heat! This approach is not favorable, but if it's the only option then a design review is needed.
- Adding harmonic control filtering also cause other EMI/EMC test issues (RE101, High Temp Testing, etc…). Retesting may be required.

NTS

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Defense V.s. Commercial

Common Issues: Conducted Emissions Testing

- Conducted Emissions compliance issues are common for COTS variable frequency drives, and motor controllers.

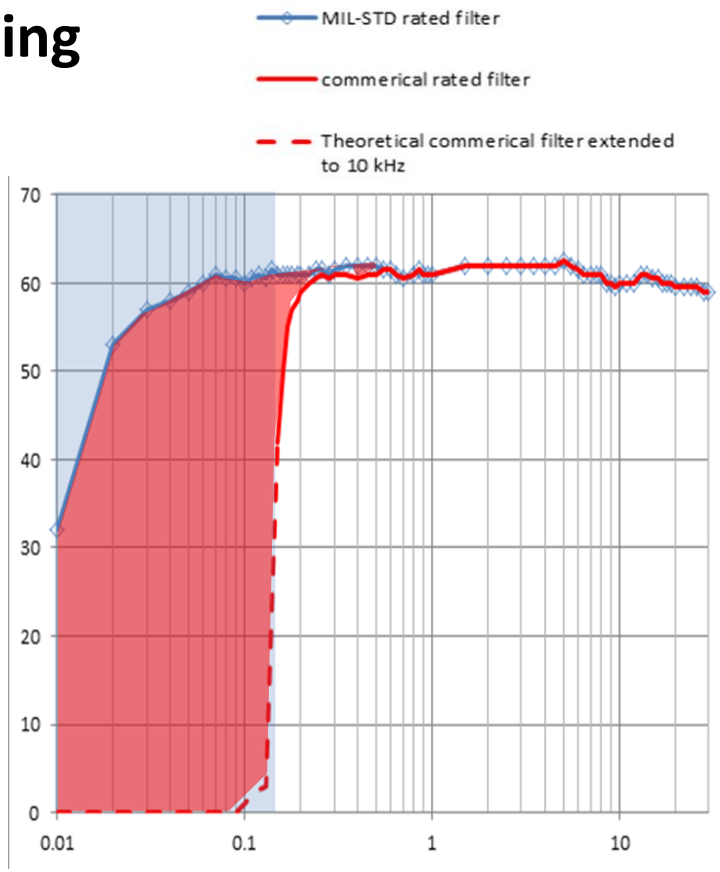
- Carrier frequencies generally found between 4 kHz & 22 kHz.
- In some cases, COTS inverts will come with their own EMI filter to meet the standard FCC or CE Mark commissions requirements.
    - FCC & CE Mark conducted emissions testing starts at 150 kHz, whereas MIL-STD-461 starts at 10 kHz.
    - Input filtering loss pass cutoff is usually tuned for 150 kHz allowing carrier frequency to freely conduct back onto the utility.
    - Filter modifications or replacements typically occur during qualification testing

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Defense V.s. Commercial

Common Issues: Conducted Emissions Testing

- The FCC & CE Mark conducted emissions test starts at 150 kHz, whereas MIL-STD-461 starts at 10 kHz.
- COTS input power filtering is designed to meet the commercial standards with a low pass cutoff frequency usually tuned for 150 kHz.
- In this case, the Inverter's carrier frequency and other internal RF noise below 150 kHz may freely conduct back power system which can result in CE102 non- compliance issues.
- Modifications or replacement of the filter is typically required during qualification testing.



INTERNATIONAL EMI/EMC STANDARDS COMPARISON

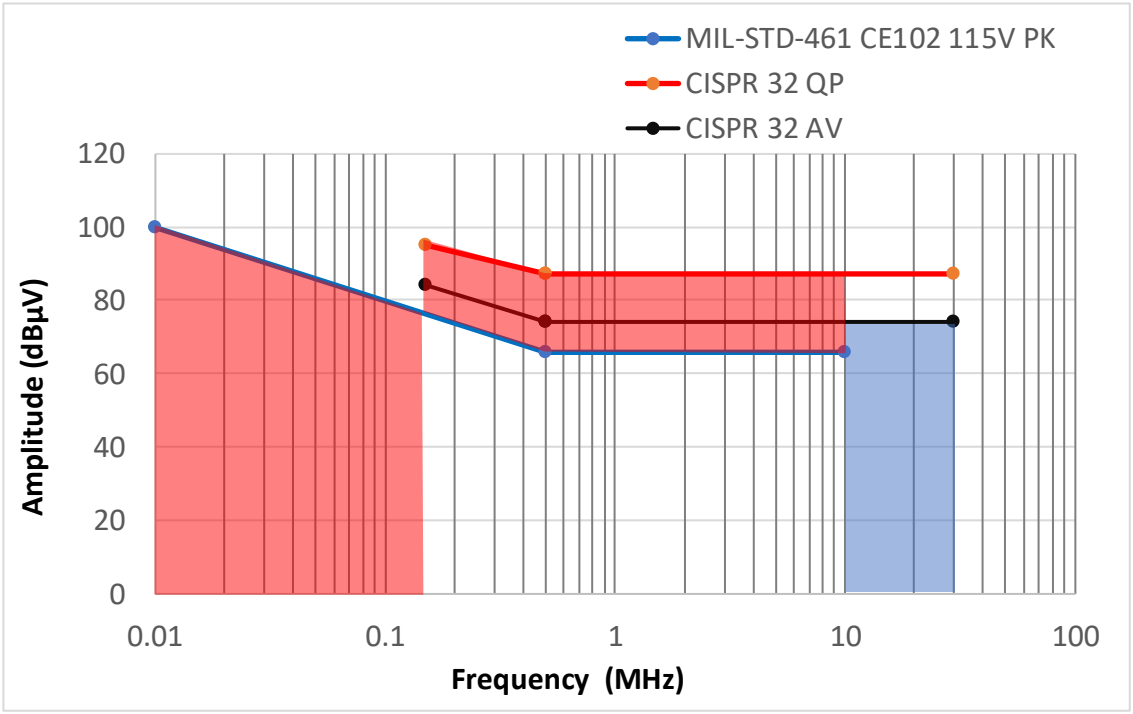
Defense V.s. Commercial

Common Issues: Conducted Emissions Testing

- Additional COTS compliance gaps to consider:

- The CISPR 32 Quasi-Peak limit exceeds the CE102 115V limits by 21 dBµV.
- The CISPR 32 Average limit exceeds the CE102 115V limits by 8 dBµV.

- Since CE102 limit is based on peak detection measurements, the levels are not directly comparable. However, it's safe to say the CE102 Limit is far more stringent.



INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Defense V.s. Commercial

MIL-STD-461	IEC/EN/CISPR
RS101 Magnetic Field Susceptibility 30 Hz – 100 kHz	**IEC 61000-4-8 Power frequency Magnetic Field** 50 Hz & 60Hz
RS103 Electric Field Susceptibility 2 MHz – 18 GHz up to (40 GHz)	**IEC 61000-4-3 Electric Field Radiated Immunity** 80 MHz – 2.7 GHz
CS101 Conducted Susceptibility (Voltage Ripple) Power leads Only 30 Hz – 150 kHz	**IEC 61000-4-13** 16 Hz – 2.4 kHz **IEC 61000-4-16** 15 Hz – 150 kHz
CS114 Conducted Susceptibility **Power** (4 kHz) 10 kHz – 200 MHz **Communications(I/O)**10 kHz – 200 MHz	**IEC 61000-4-6 Conducted Immunity** **Power** 150 kHz – 80 MHz **Communications (I/O)** 150 kHz – 80 MHz

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Defense V.s. Commercial

MIL-STD-461	IEC/EN/CISPR
CS106 Transient Susceptibility Power lines only	**IEC 61000-4-5 Electrical Surges** All Lines
CS115 Impulse excitation All Lines	**IEC 61000-4-4 Electrical Fast Transients** All Lines
CS116 Damped sinusoidal Transients All Lines 10 kHz – 100 MHz	**IEC 61000-4-12 Damped sinusoidal Transient** All Lines 100 kHz Ring wave
RS101 Radiated Susceptibility Magnetic field 30 Hz – 100 kHz	**IEC 61000-4-9 Magnetic Pulse** 50/60Hz to 50 kHz **IEC 61000-4-10 Damped Sinusoidal Mag. Pulse** 100kHz & 1 MHz
CS117 Lightning Induced Transients	**EUROCAE ED-14** Environmental conditions and test procedures for airborne equipment
CS118 Electrostatic Discharge (ESD) Harmonized	**IEC 61000-4-2 Electrostatic Discharge (ESD)** Harmonized
RS105 Electromagnetic Pulse (EMP) 50 kV 2/50ns	**IEC 61000-4-23** Test methods for protective devices for HEMP and other radiated disturbances

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Nuclear Industry

- **NRC REGULATORY GUIDE 1.180**
  - *Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety Related Instrumentations and Control Systems.*
- **EPRI TR-102323 Rev 5**
  - *Guidelines for Electromagnetic Interference Testing of Power Plant Equipment .*

- The NRC and EPRI leverage test methodologies from MIL-STD-461 and IEC to ensure equipment EM compatibility in Nuclear Power plants.
  - Test criteria has been tailored to best represent the nuclear power plant EM environment.
- Manufacturers may select either industry to show compliance, but generally test a combination of the two in an effort to minimize risk due to compliance gaps.

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Aerospace

- RTCA DO160 provides test procedures and criteria for evaluating airborne equipment for all types of commercial aircraft ranging from general aviation aircraft and helicopters to "jumbo jets".
- It is comprised of 26 test procedure sections and three appendices, 9 of which are classified as electrical/EMI type test methods.
- Most test methods, and criteria are based on DoD requirements, but tailored to best represent the Airframe EM environment.

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Defense Vs. Aerospace

Defense	DO160
RE101 Magnetic Field Radiated Emissions 30 Hz – 100 kHz	**Section 15 DC Magnetic Field**
RE102 Electric Field Radiated Emissions 10 kHz – 18 GHz	**Section 21 Electric Field Radiated Emissions** 100 MHz – 6 GHz
CE101 Conducted Emissions (Current) Power leads Only 30 Hz – 10 kHz	**Section 16 Power Input** Harmonic Content
CE102 Conducted Emissions (Voltage) Power leads Only 30 Hz – 10 kHz	**Section 21 Conducted Emissions (current)** Power 150 kHz – 152 MHz Communications (I/O) 150 kHz – 152 MHz

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Defense Vs. Aerospace

MIL-STD-461	DO160
RS101 Magnetic Field Susceptibility 30 Hz – 100 kHz	**Section 19** Induced Signal Susceptibility Equipment 350 Hz & 800 Hz 20 Arms Cabling 350 Hz up to 32 kHz
RS103 Electric Field Susceptibility 2 MHz – 18 GHz up to (40 GHz)	**Section 20 Radiated Susceptibility** 100 MHz – 18 GHz Includes CW, SW, and PM (HIRF)
CS101 Conducted Susceptibility (Voltage Ripple) Power leads Only 30 Hz – 150 kHz	**Section 18 Audio Signal Susceptibility (Voltage Ripple)** Power Leads Only 10 Hz to 150 kHz
CS114 Conducted Susceptibility Power (4 kHz) 10 kHz – 200 MHz Communications(I/O)10 kHz – 200 MHz	**Section 20 Conducted Susceptibility** Power 10 kHz – 400 MHz Communications (I/O) 10 kHz – 400 MHz

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

MIL-STD-461	RTCA DO160
CS106 Transient Susceptibility Power lines only 2usec/10usec	**Section 17 Voltage Spike** Power Lines Only 2usec/10usec
CS115 Impulse excitation All Lines	**Section 19 induced signal susceptibility** All Lines
CS116 Damped sinusoidal Transients All Lines 10 kHz – 100 MHz	**Section 22 Lightning Induced Transients** All Lines 1 MHz & 10 MHz
RS105 Electromagnetic Pulse (EMP) 50 kV 2/50ns	**Not Covered**
Not Covered	**Section 23 Lightning Direct Effects** Magnetic Component
Not Covered	**Section 16 Power Input Characteristics** **AC & DC**
Not Covered	**Sections 25 Electrostatic Discharge**

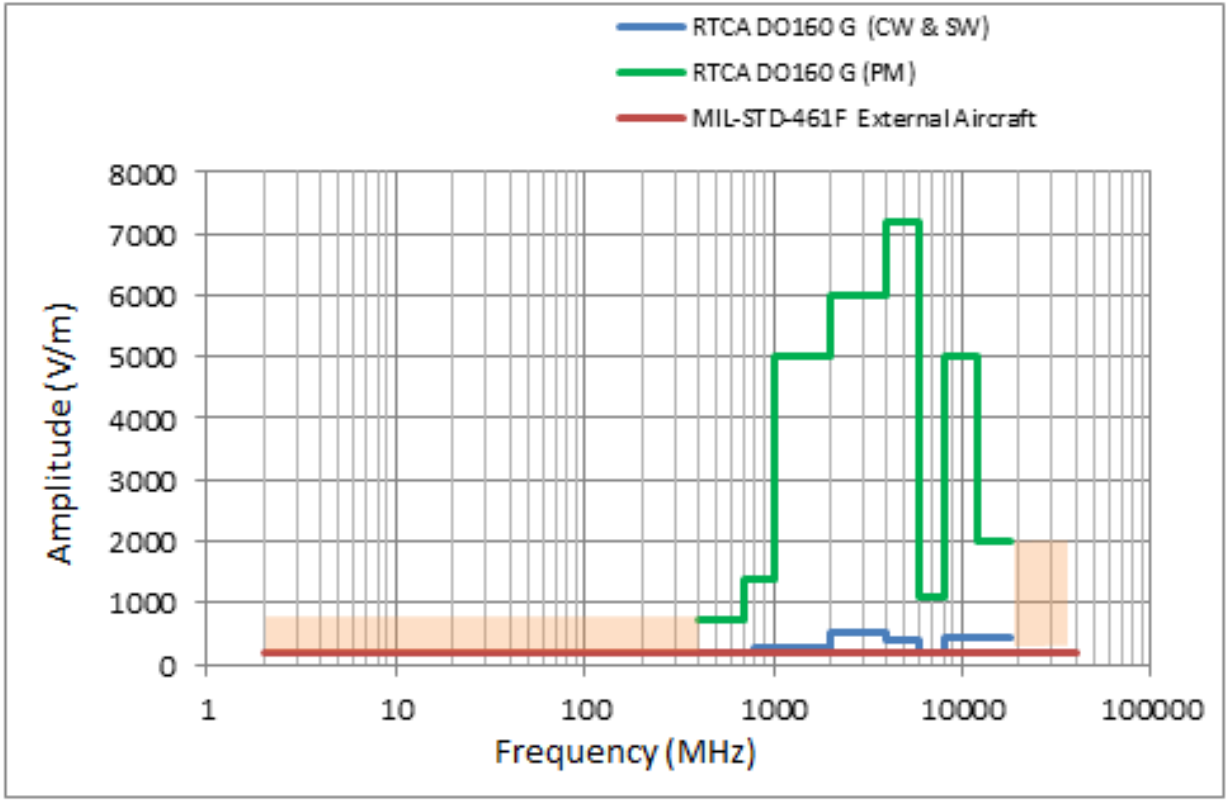
INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Defense V.s. Aerospace

Radiated Susceptibility Comparison

- Frequency Range
- *Step Size*
- *Modulation*
- *HIRF*

Other Considerations:
DoD generally adresses the Electromagnetic Environment at the system level (MIL-STD-464).



INTERNATIONAL EMI/EMC STANDARDS COMPARISON

Summary

- Differences in test methodology and Test Criteria may exist between standards which usually requires additional qualification testing to enter a product into new markets.

- A Risk analysis should be performed prior to testing to determine if design modifications are needed.

- Combine the most severe test criteria when qualifying a product for deployment into multiple platforms under the same market to save time and money.

  Examples:
  - Combining Ships above decks and below decks criteria
  - Combining fixed wing aircraft, and helicopter criteria

INTERNATIONAL EMI/EMC STANDARDS COMPARISON

THANK YOU FOR YOUR TIME!

A HIGHER STANDARD

TESTING | INSPECTION | CERTIFICATION

Jeffrey Viel
Chief Engineer
Jeffrey.Viel@nts.com
978-727-3793

NTS