RTCA DO160G
Overview

A HIGHER STANDARD

TESTING | INSPECTION | CERTIFICATION

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

NTS

What is RTCA?

- *RTCA is the* **Radio Technical Commission for Aeronautics**
  - *DO160 is managed by the SC-135 committee comprised of*
    - *manufacturers, government, and test laboratories.*
    - Founded in 1935, provided the foundation for virtually every technical advancement in modern civil aviation.

- RTCA is sponsored as a Federal Advisory Committee by the US DOT Federal Aviation Administration, but not an official agency of the United States Government.

- RTCA standards align with the European Organization for Civil Aviation Equipment (EUROCAE).

- DO-160G is also recognized by the International Organization for Standardization (ISO) international standard ISO-7137

Technical sections covered:

Purpose-

- Provides standard test procedures and criteria for evaluating airborne equipment for all types of aircraft ranging from general aviation aircraft and helicopters to "jumbo jets".

- *DO160 G is comprised of 26 test procedure sections including appendices, 10 of which are categorized as electrical/EMI type test methods.*

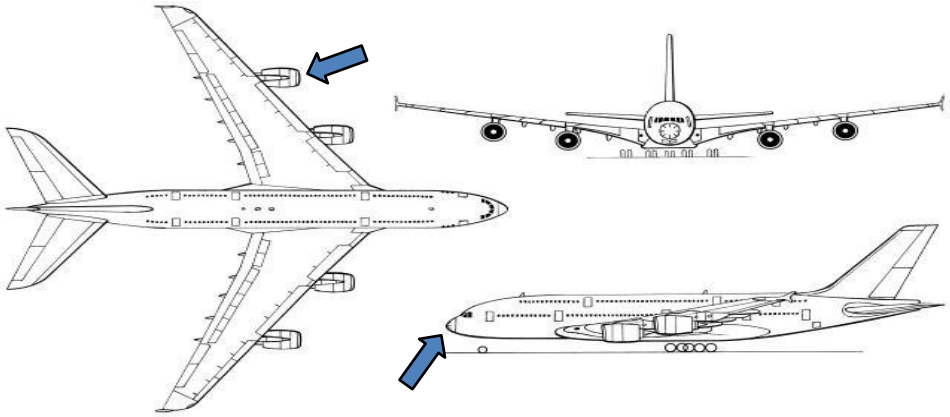
Electrical Test Sections covered today

Section 15.0	Magnetic Effect
Section 16.0	Power Input
Section 17.0	Voltage Spike
Section 18.0	Audio Frequency Conducted Susceptibility - Power Inputs
Section 19.0	Induced Signal Susceptibility
Section 20.0	Radio Frequency Susceptibility (Radiated and Conducted)
Section 21.0	Emission of Radio Frequency Energy
Section 22.0	Lightning Induced Transient Susceptibility
Section 23.0	Lightning Direct Effects
Section 25.0	Electrostatic Discharge

RTCA Applicability-

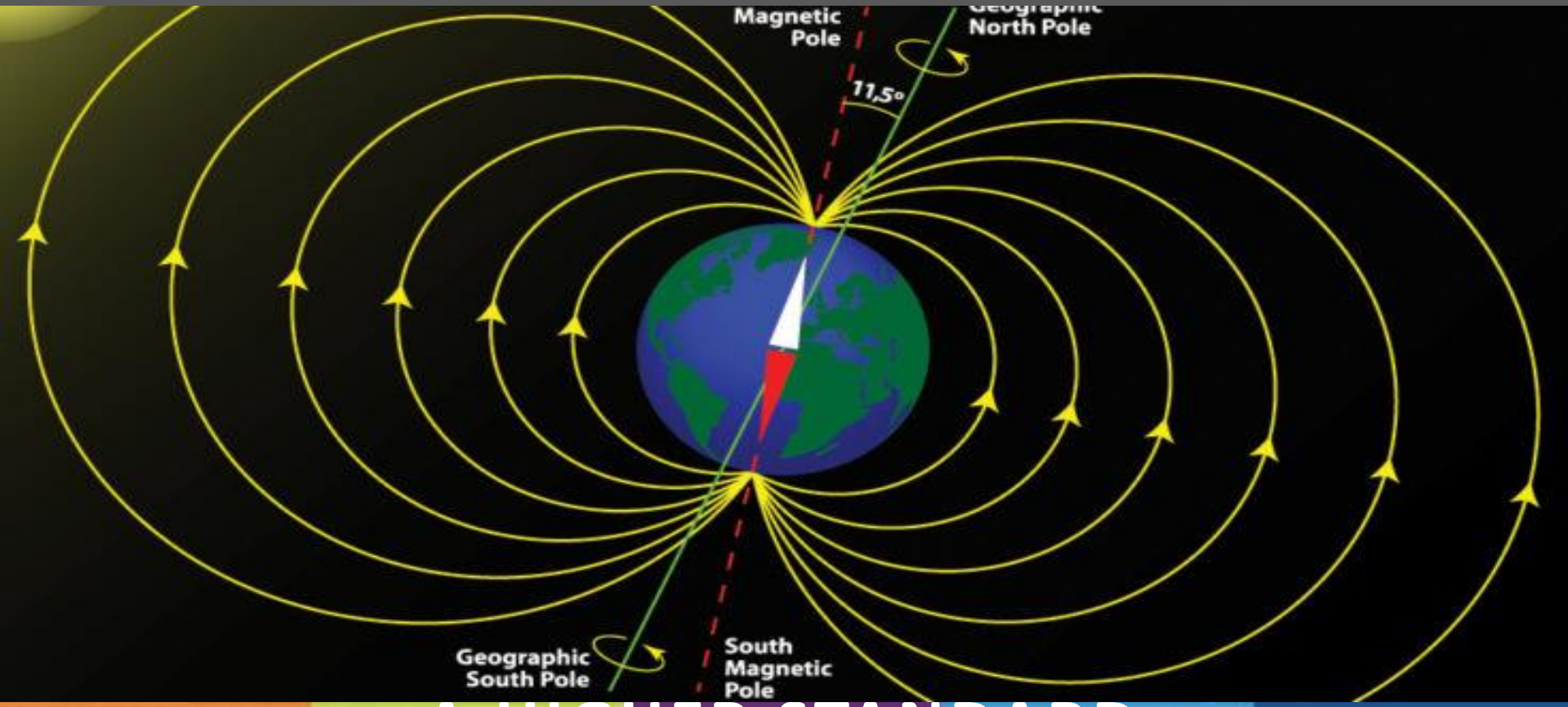
- **Test procedures and conditions are not applicable to all airborne equipment.**
  The selection of the appropriate conditions (categories) and test procedures are based on the type of device and its intended installation on the airframe.

- **Category of Tests and Declarations-**
  Categories are selected to best represent the most severe environment which the equipment is expected to be regularly exposed to during its service life for each applicable test section



  - Category classifications are specific to each test section (definitions change based on the test method).
  - If a category is found insufficient for a specific aircraft certification, then additional testing may be required.

SECTION 15 MAGNETIC EFFECTS



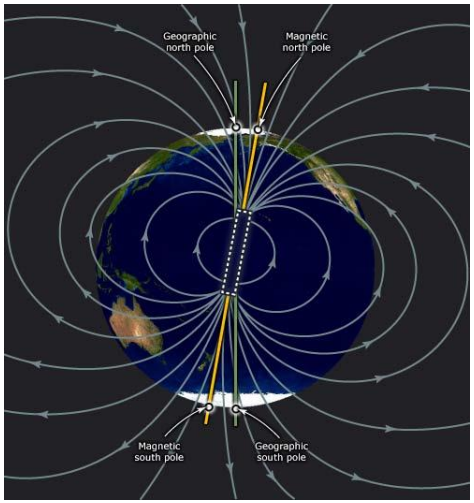
A HIGHER STANDARD

TESTING | INSPECTION | CERTIFICATION

NTS

Section 15 – Magnetic Effects

Purpose of the Test-



- To determine the magnetic safe installation distance from the equipment under test and assists equipment installers with choosing the proper location of the equipment in the aircraft.
- Validates the distance at which the equipment can operate properly without interfering with operation of nearby magnetic sensitive equipment.

Test Description-

- Magnetic effects are determined in terms of the deflection of a free magnet in a uniform magnetic field (*produced by the earth*) having a horizontal intensity of 14.4 A/m ±10%.
- The equipment under test is positioned on the east-west line through the pivot of a magnet.
- Performed with either an uncompensated compass or an equivalent DC magnetic sensor.

Section 15 – Magnetic Effects

Test Categories-

- Based on the distance at which one angular degree of deflection (Dc=1°) is observed.

Category Y: ≤1° Dc measured immediately adjacent to the equipment.
equipment whose installation is placed between 0.0m and 0.3m from the magnetic compasses or flux gates.

Category Z: 1° Dc measured >0.0m to ≤0.3m from the equipment.
equipment whose installation is ≥ 0.3m to magnetic compasses or flux gates.

Category A: 1° Dc measured >0.3m to ≤1.0 m to the equipment.
equipment whose installation is ≥ 1m to magnetic compasses or flux gates.

Category B: 1° Dc measured >1.0m to ≤3.0 m to the equipment.
equipment whose installation is ≤3m to magnetic compasses or flux gates.

Category C: 1° Dc measured >3.0 m to the equipment.
equipment whose installation is >3m to magnetic compasses or flux gates.

NTS

Section 15 – Magnetic Effects

Determining the degree of deflection-

- When the measured Horizontal Component of the Ambient magnetic Field Strength (HCAFS) at the location of the test is within tolerance (14.4 A/m ±10%), the angular deflection will be one degree of deflection (Dc = 1°).
- If the measured HCAFS at the location of the test exceeds the stated tolerance, the angular deflection shall be adjusted using the following formula:

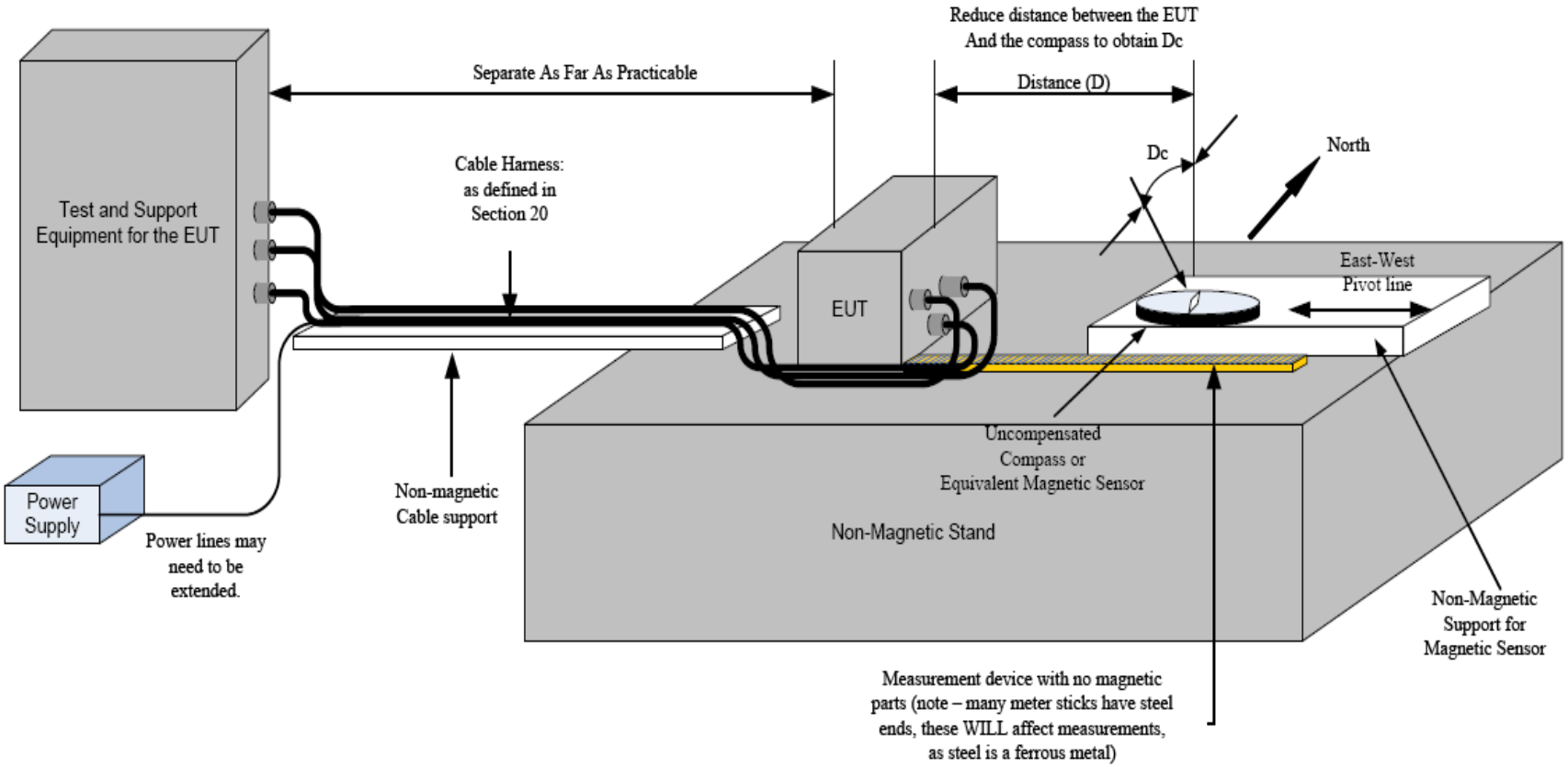
$$Dc = \frac{14.4\ A/m}{\text{Measured HCAFS}}$$

Example:

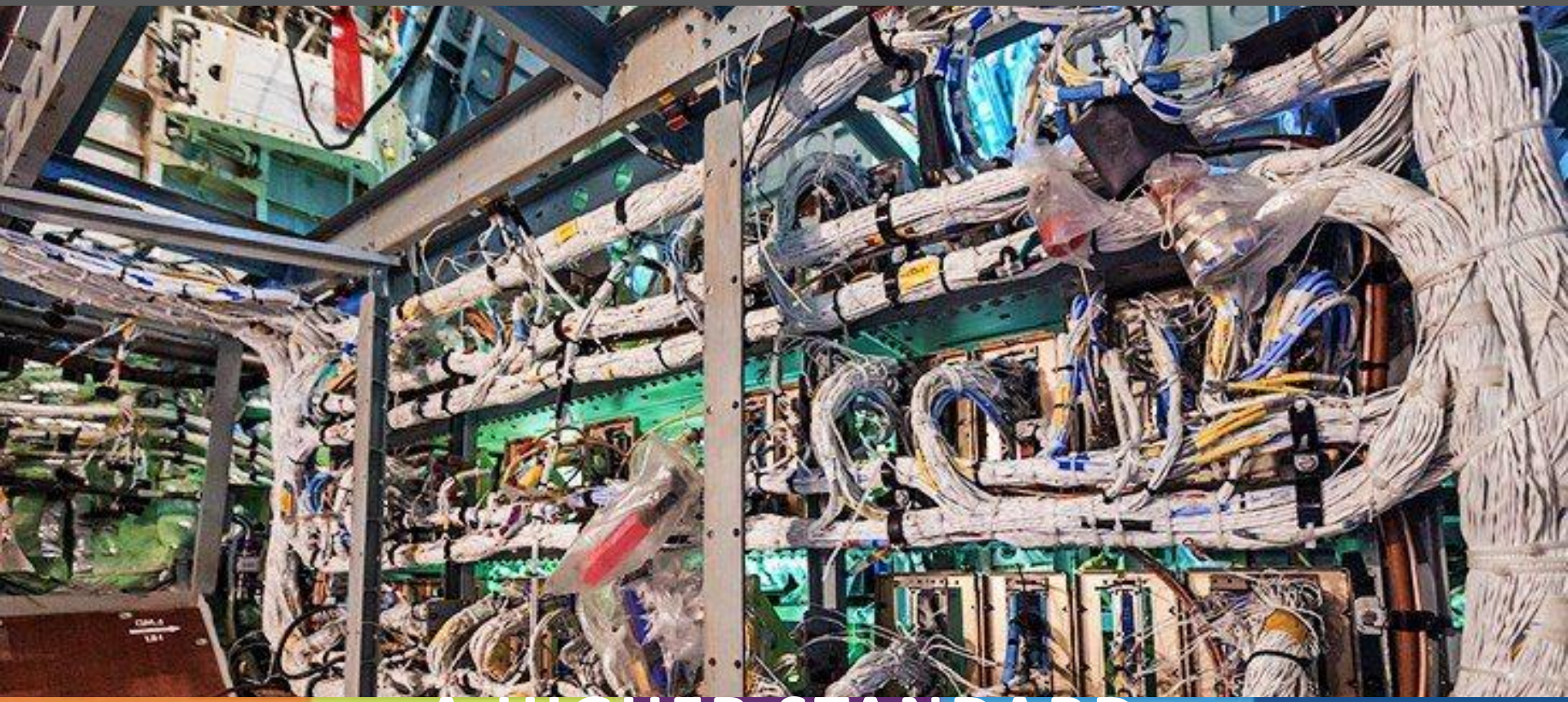
Measured HCAFS = 7.2 A/m

(14.4/7.2) = 2 ° of angular deflection

Section 15 – Magnetic Effects



SECTION 16 POWER INPUT



A HIGHER STANDARD

TESTING | INSPECTION | CERTIFICATION

NTS

Section 16 – Power Input

Purpose of the Test-

- Evaluates equipment operability when exposed to normal, abnormal, and emergency power conditions which can occur on aircraft power systems.
- Test methods adopted from Department of Defense test standards (MIL-STD-704) but tailored for typical civil aircraft power system conditions.

Applicable to all Power types:

AC Equipment

A(CF): Constant Fundamental Frequency of 400Hz
A(NF): Narrow Variable Fundamental Frequency range of 360 Hz to 650 HZ
A(WF): Wide Variable Fundamental Frequency range of 360 Hz to 800 Hz

DC Equipment

A: 28 VDC sources derived from constant or variable frequency AC systems
B: 14 VDC or 28 VDC sources derived from engine driven alternator/rectifiers or DC generators with a floating battery source that is present at all times.
D: 270 VDC sources derived from constant or variable frequency AC systems
Z: 28 VDC sources derived from all other electrical system types. More Severe requirements.

Section 16 – Power Input

Additional AC Test Applicability:

AC Harmonics Test Applicability

- Applicable for equipment with a single unit power consumption greater than 35VA
- or installations where the combined power consumption of multiple units exceed 150 VA.

AC Modulation Test Applicability

- Applicable for equipment where the current modulation (ripple) drawn from the device is to be controlled.
- Testing is required and levels are reported for all AC equipment regardless of its classification.

AC Power Factor Test Applicability

- Applicable for equipment where the power factor drawn from the device is to be controlled.
- Testing is required and levels are reported for all AC equipment regardless of its classification.

Section 16 – Power Input

Additional DC test applicability:

DC Current Ripple Test Applicability

Applicable for equipment with a single unit power consumption greater than 400 W for 28V, or 35 W for 270 V, or installations where the combined power consumption of multiple units exceed 400W for 28V or 150W for 270 V systems.

AC or DC Inrush Test Applicability

Applicable for equipment intended to control startup in rush currents.

Section 16 – Power Input

AC Normal Operating Conditions

- Voltage & Frequency variations encountered during “normal aircraft operation”.
- Equipment under test must operated as intended without degraded performance.

- 30 minute applications
- Test levels can be substituted with Abnormal Operating Conditions to satisfy both Requirements.

	EQUIPMENT CATEGORY		A(CF)	A(NF)	A(WF)
MAX	VOLTAGE (Vrms)	Highest phase	122	122	122
		Average of three phases	120.5	120.5	120.5
	FREQUENCY (Hz)	Normal	410	650	800
		Emergency	440	650	800
MIN	VOLTAGE (Vrms)	Lowest phase	100	100	100
		Average of three phases	101.5	101.5	101.5
	FREQUENCY (Hz)	Normal	390	360	360
		Emergency	360	360	360

Voltage at Equipment Terminals	28 V dc	270 V dc
Maximum	30.3 V	285 V
Minimum	22.0 V	235 V
Emergency Operation	18.0 V	235 V

Section 16 – Power Input

Abnormal Operating Conditions

- More severe levels than Normal Op Conditions.
- Typically 5 minute applications or 30 minutes if conducted in place of normal op testing.
- Does not include emergency Conditions testing

	EQUIPMENT CATEGORY		A(CF)	A(NF)	A(WF)
MAX	VOLTAGE (Vrms)	Highest phase	134	134	134
		Average of three phases	132.5	132.5	132.5
	FREQUENCY (Hz)		430	N/A	N/A
MIN	VOLTAGE (Vrms)	Lowest phase	97	97	97
		Average of three phases	98.5	98.5	98.5
	FREQUENCY (Hz)		370	N/A	N/A

Increased by 20 Hz

Increased by 12 V

Decreased by 20 Hz

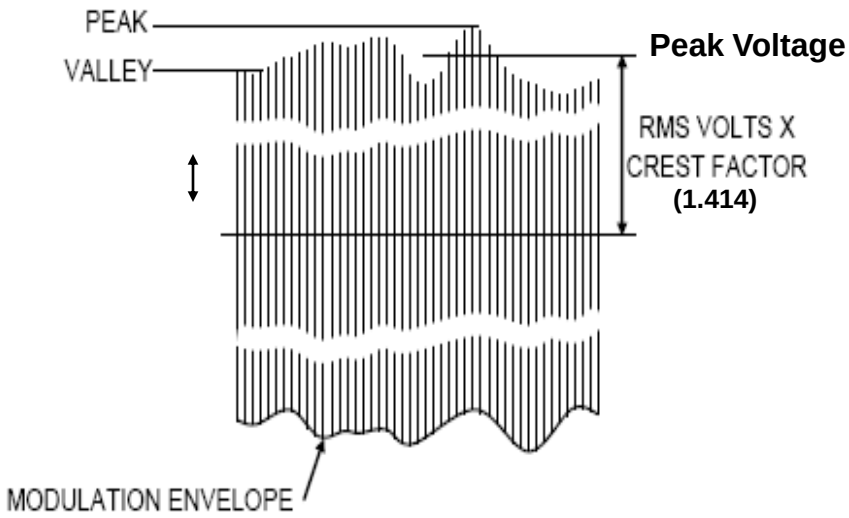
Decreased by 3 V

Voltage at Equipment Terminals		28 V dc	270 V dc	
Maximum	Increased by 2.2 V	32.2 V	320 V	Increased by 35 V
Minimum	Decreased by 1.5 V	20.5 V	220 V	Decreased by 15 V

Section 16 – Power Input

Voltage Modulation (AC)

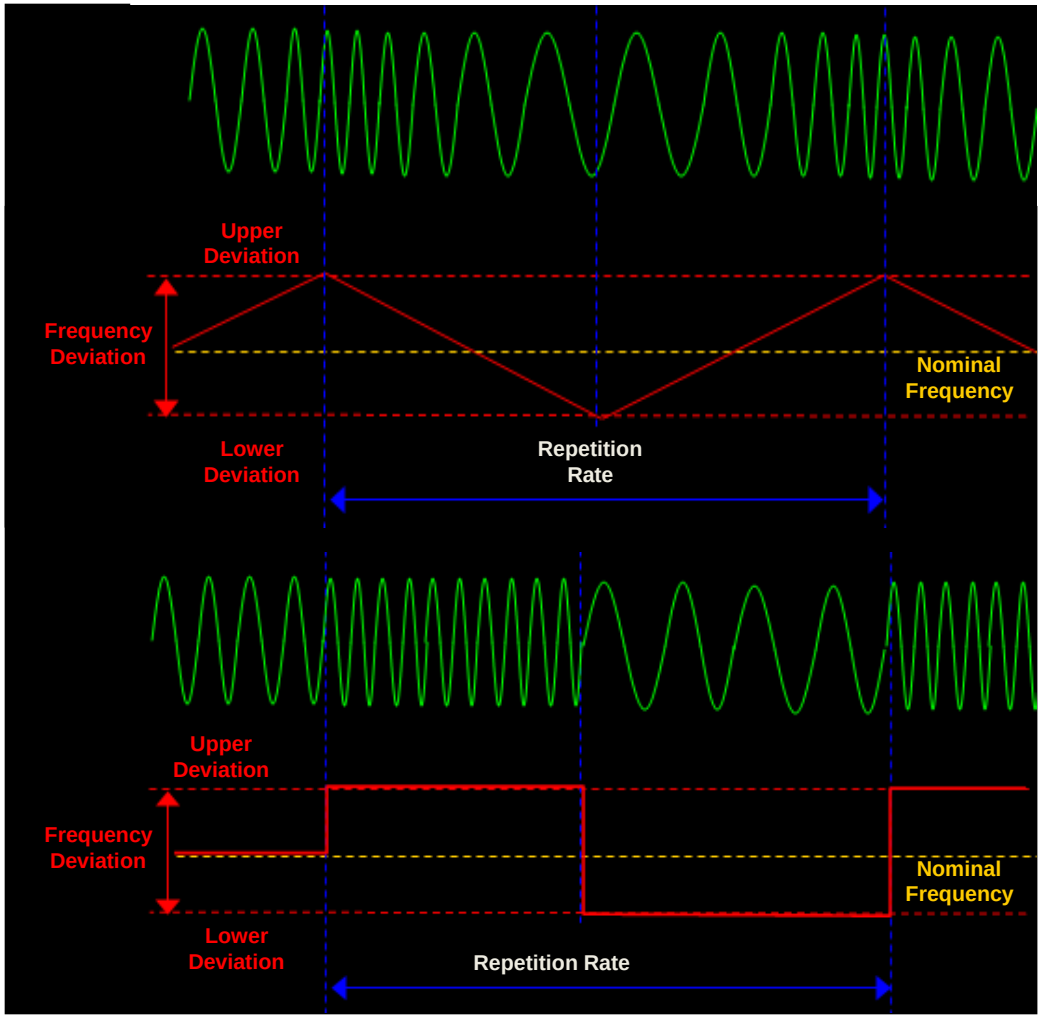
- Voltage modulation is the cyclic variation, random voltage variation of the mean level ac peak voltage encountered during steady state operation.
- Caused by voltage regulation variations and speed variations.
- Voltage is Modulated by 5 volts (*peak to valley*) between the minimum and the maximum voltage reached on the modulation envelope or higher as indicated in the equipment specification.
- This value is doubled for 230VAC systems.



Section 16 – Power Input

Frequency Modulation (AC)

- Frequency modulation occurs as a result of speed variations in a generator coupling or drive speed regulation.
- Frequency modulation is the cyclic or random frequency variation of the mean frequency during steady-state electrical system operation.
- Each repetition rate test point, dwelled at for 30 seconds or for a time indicated in the equipment specification.



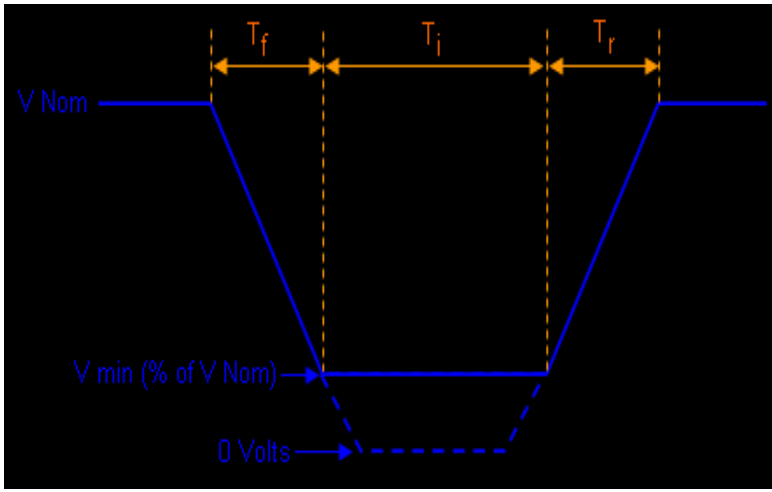
Section 16 – Power Input

Momentary Power Interruptions

- Power interruptions occur during the transfer switching of power sources ranging from 50 milliseconds to 1 second.

DC Equipment

Applicable Category	A, B, D, Z				A, D, Z			D, Z.	A, B, D, Z.		A, D, Z				D, Z.	A, B, D, Z			
Test Condition	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
T_f (ms)	<1	10	17	18	19	20	20	20	10	25	50	43	48	50	50	18	20	13	5
T_i (ms)	<1	0	8	32	56	80	180	980	0	0	0	33	53	150	950	13	15	27	20
T_r (ms)	2	3	4	5	5	5	5	5	4	10	20	17	19	20	20	7	2	13	5
% V_{NOM} (V_{MIN})	0	50	15	10	5	0	0	0	80	50	0	15	5	0	0	65	60	35	0



AC Equipment

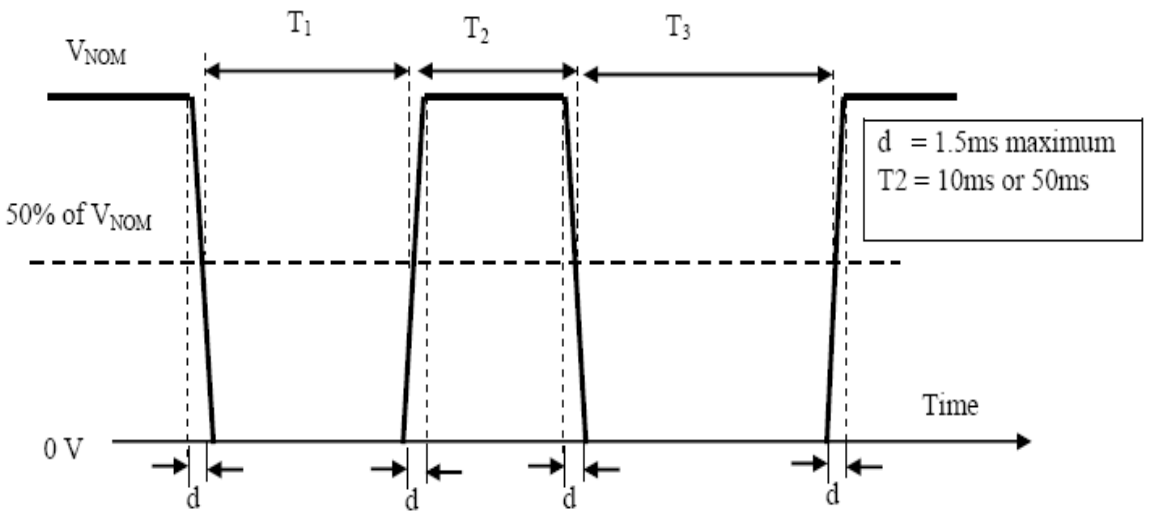
Test Condition	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
T_f (mS)	<1	10	17	18	19	20	20	10	25	50	43	48	50	18	20	13	5	<1	<1
T_i (mS)	2	0	8	32	56	80	180	0	0	0	33	53	150	13	15	27	20	50	200
T_r (mS)	<1	3	4	5	5	5	5	4	10	20	17	19	20	7	2	13	5	<1	<1
% V_{NOM} (V_{MIN})	0	50	15	10	5	0	0	80	50	0	15	5	0	65	60	35	0	0	0

Not every test condition interruption reaches 0 volts

Section 16 – Power Input

Interruptions (DC Equipment with Memory Circuits)

- Applicable to equipment that incorporates digital circuitry and/or memory devices, and delay circuits.
- This type of equipment is sensitive to momentary power interruptions that can cause aberrations in performance.
- This test procedure selects discrete values that are considered effective for determining equipment performance.

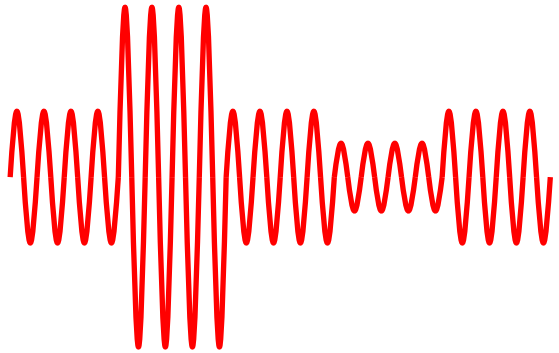


Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Cat A, D, Z	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Cat B	**Y**	**Y**	**Y**	**Y**	N/A	**Y**	N/A	N/A	N/A	**Y**	**Y**	N/A	N/A	N/A	N/A	N/A	N/A
T1 (ms)	9000	9000	10	10	10	20	20	20	20	50	50	50	50	100	100	150	150
T3 (ms)	20	50	10	50	100	10	50	100	170	10	50	100	140	50	90	10	40

Section 16 – Power Input

Normal & Abnormal Surge Voltages

Voltage surges caused inherent regulation of the electrical power system in response to disturbances and remedial action by the regulator, such as load switching, and system fault clearing actions.



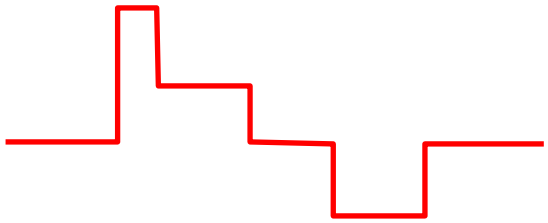
AC Equipment- *upper and lower surge levels*

- 160 Volts for 30 msec, 70 Volts for 30 msec
  to 180 Volts for 100 msec, 148 Volts for 1 second.

DC Equipment- *upper and lower surge levels*

- 28 VDC - 12 Volts for 30 msec, 50 Volts for 50 msec,
  to 80 Volts for 100 msec, 48 Volts for 1 second.

- 270 VDC - 400 Volts for 30 msec, 160 Volts for 30 msec,
  to 425 VDC for 100 msec, 345 Volts for 1 second.



Section 16 – Power Input

Normal & Abnormal Frequency Transients (AC)

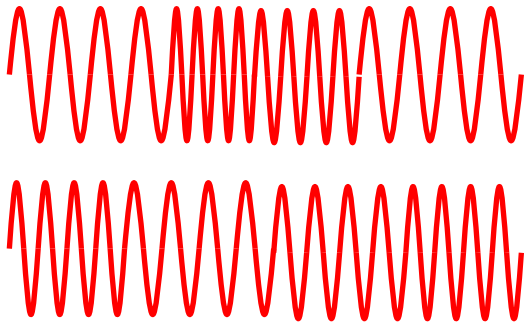
- Frequency transients result from the regulation of the electrical power supply system in response to disturbances imposed by system operations, such as normal and abnormal engine speed changes and remedial action by the regulator.

Normal Frequency Transients

All AC Categories:

High frequency: 440 Hz for 150 msec, then 420 Hz 1.5 seconds.

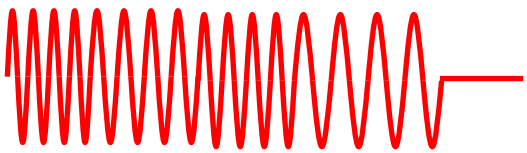
Low frequency: 350 Hz for 150 msec, then 380 Hz for 1.5 seconds.



Abnormal Frequency Transients

All AC Categories:

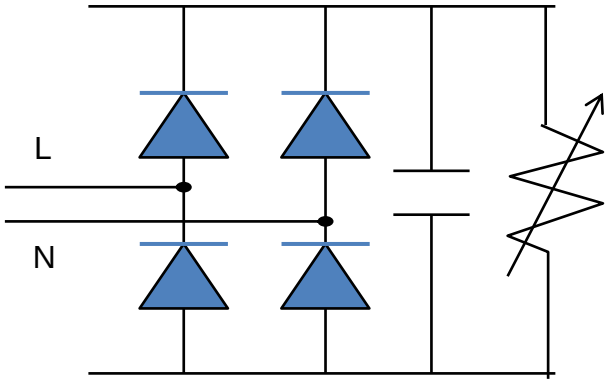
- 350 Hz for 5 seconds, followed by 320 Hz for 200 msec,
- Then followed by a 0 Volt reduction for 200 msec.



Section 16 – Power Input

Total Harmonic Distortion (AC)

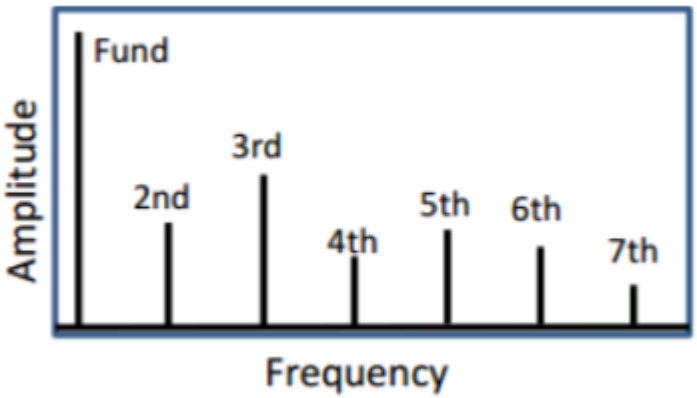
- Current draw from non-linear ac loads will cause distortion in the ac voltage waveform under normal conditions.



- The level of voltage distortion is controlled by varying the load on the rectifier(s), and source impedance.
- Or clipping the supply voltage AC sinewave. The equipment shall operate in these conditions for at least 30 minutes.

This THDV limits are as follows:

- 8 % for category A(CF) and A(NF) equipment
- 10 % for category A(WF) equipment



Section 16 – Power Input

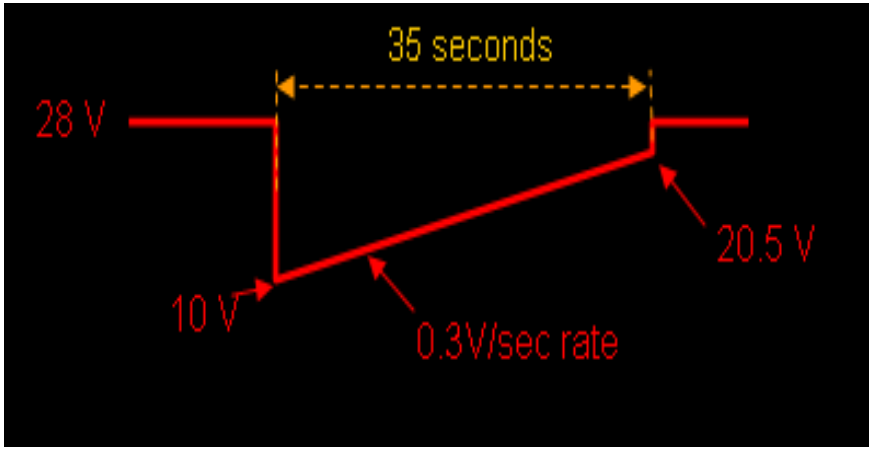
Engine Starting Under Voltage (DC)

- During engine starting, momentary voltages in the range from 10.0 to 20.5 V dc may occur for any duration up to 35 seconds or as indicated in the equipment specification

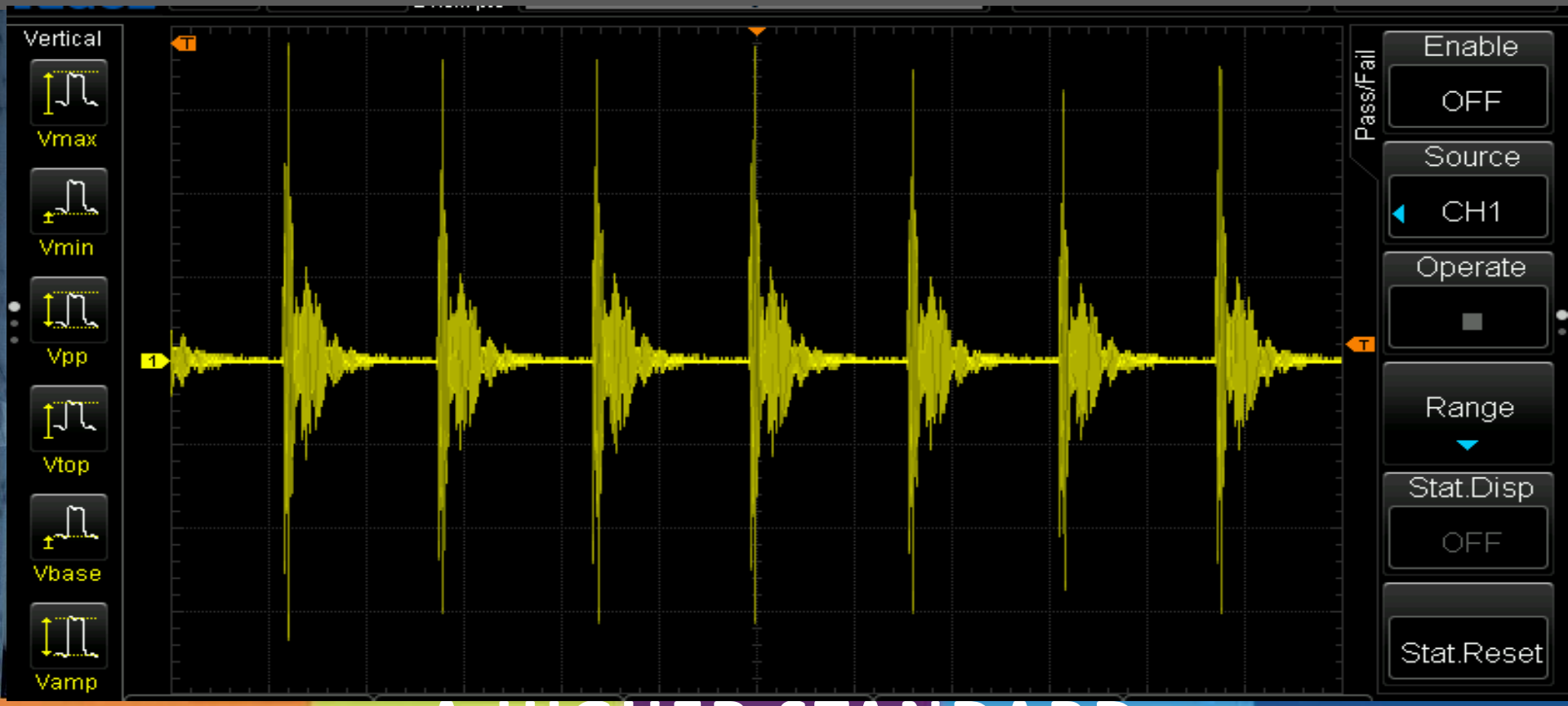
- Applicable to Category Z and 28 volt Category B equipment.

- Voltage is reduced to 10.0 V dc and increased by 0.30 volts per second for 35 seconds, then returned to rated voltage.

- During this period the equipment performance can fall to a level stipulated in the equipment specification.



SECTION 17 VOLTAGE SPIKE



Section 17 – Voltage Spike

Purpose:

- Evaluates the effects of voltage spike transients caused by load switching, and other events.
- Voltage spikes are fast, short duration electrical transients coupled onto equipment power cabling which can result *in equipment performance issues, component failure and insulation breakdown.*
- **Voltage spike test levels are based on Equipment Location Category**

Category A- To be installed in areas where a high degree of protection against damage from voltage spikes is required.
Amplitude: 600V zero to peak

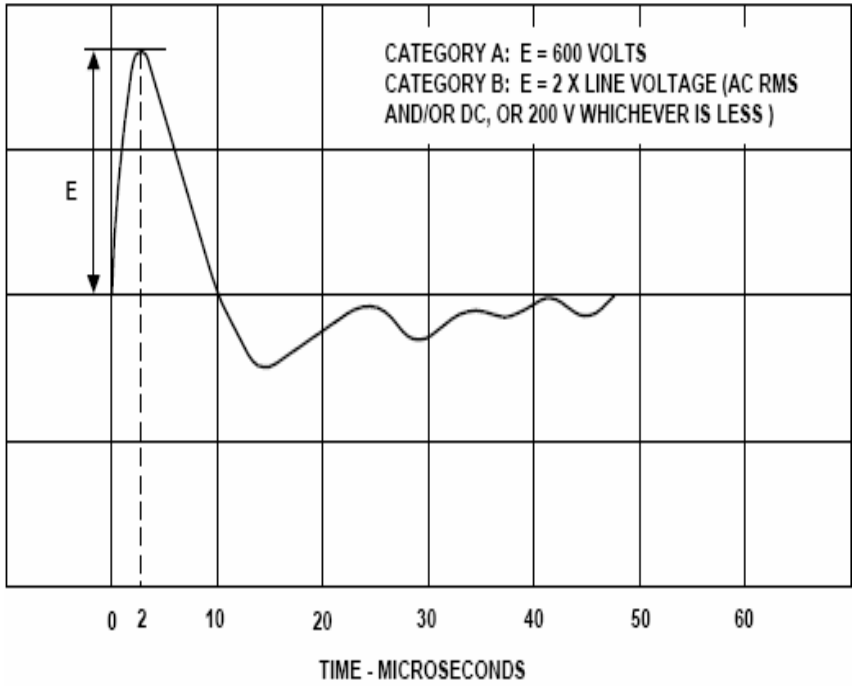
Category B- To be installed in areas where a lower standard of protection against damage from voltage spikes is acceptable.
Amplitude: 2x line voltage or 200V whichever is less

Section 17 – Voltage Spike

Voltage Spike Characteristics

- Any spike generation method can be used if the waveform parameters are met.
  - *Pulse rise time ≤2 µs*
  - *Total pulse duration 10 µs.*
  - *Source impedance 50Ω.*
  - Similar to CS106 per MIL-STD-461F.

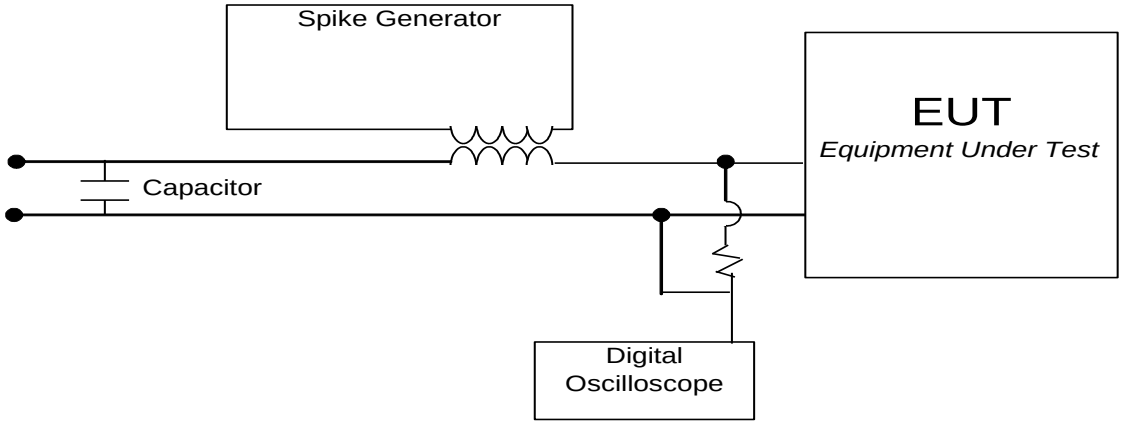
    Source impedance of 5Ω versus 50Ω
- 50 pulses in a one minute period is applied in each polarity.
- Applied to all ungrounded primary input power lines (high sides only).



Section 17 – Voltage Spike

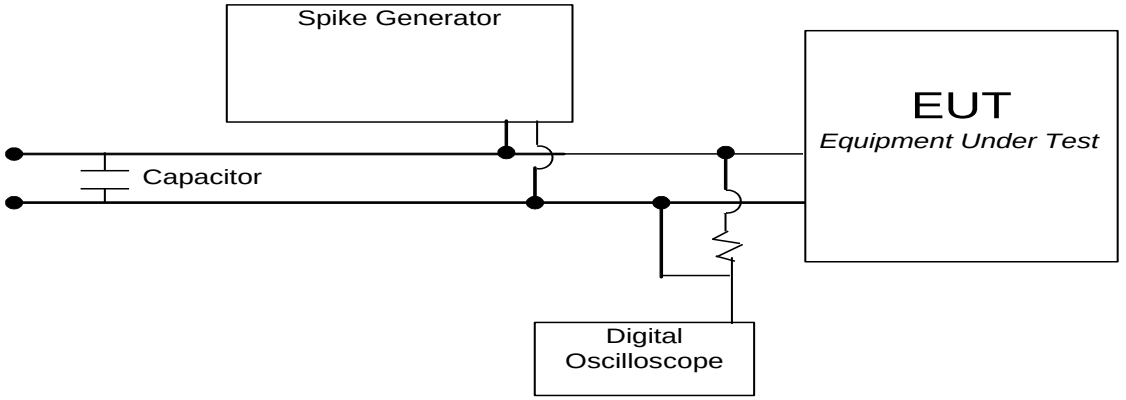
Series Coupling Mode-

- Preferred Setup for AC systems, and low to moderate current draws



Parallel Coupling Mode-

- Alternative Setup for DC systems, and moderate to high current draws.



SECTION 18 AUDIO FREQUENCY SUSCEPTIBILITY

A HIGHER STANDARD

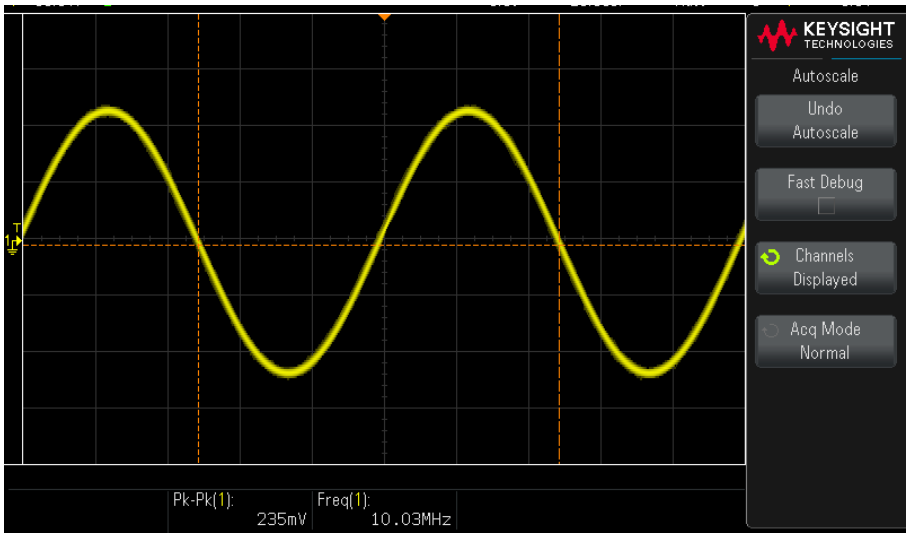
TESTING | INSPECTION | CERTIFICATION

NTS

Section 18 – Audio Frequency Conducted Susceptibility

Purpose:

- Simulates low frequency AC voltages coupled to power lines expected when the equipment is installed in the aircraft.
- These frequency components are normally harmonically related to the power source fundamental frequency.



- Test method is similar to MIL-STD 461 CS101, A few notable differences:
  - DO160 tests 30 frequencies per decade, with a dwell time of 1 minute per freq.
  - DO160 current limit of 36 amps pk-pk Vs. MIL-STD-461's limit of 80W.
  - DO160 includes a Common Mode injection test for 270 VDC lines.

Section 18 – Audio Frequency Conducted Susceptibility

Test Levels:

- Performed on AC and DC equipment power lines only.

AC Equipment:

- Test levels vary but are between 6% - 8% of nominal line voltage.

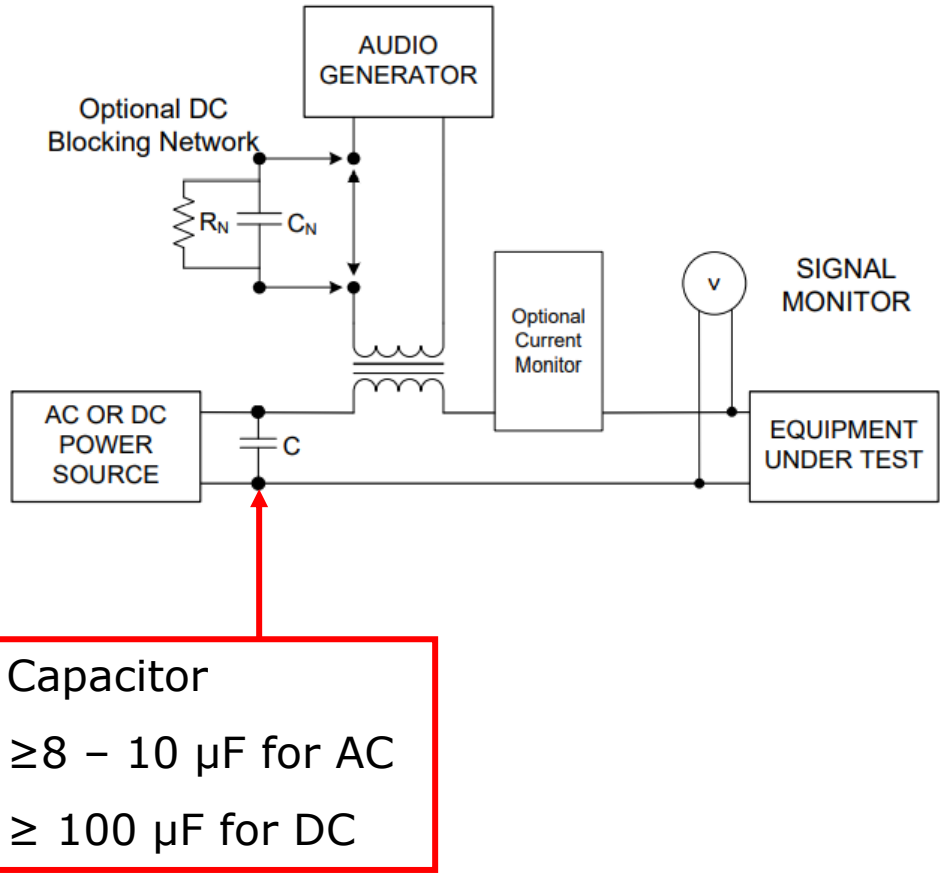
DC Equipment:

- Test levels vary up to 4 VDC pk-pk for 28 VDC systems
- Up to 16 VDC pk-pk for 270 VDC systems tested in Differential Mode
- Up to 32 VDC pk-pk for 270 VDC systems tested in Common Mode.

Section 18 – Audio Frequency Conducted Susceptibility

Setup:

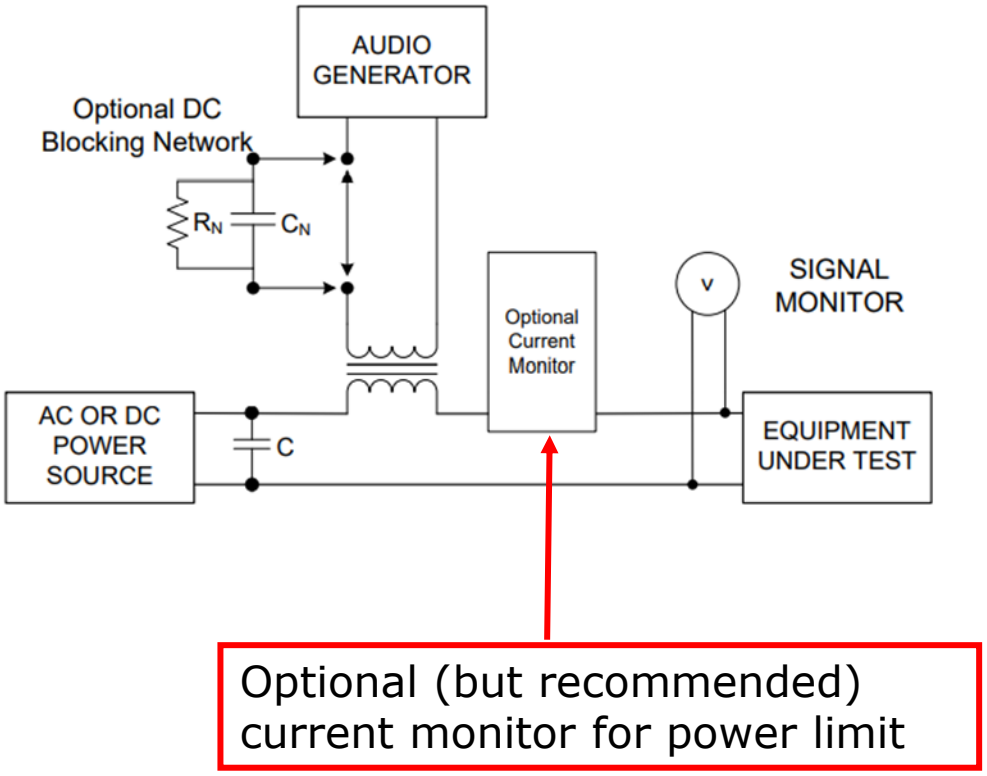
- An audio isolation transformer is used to couple the audio frequency components onto the AC or DC power lines differentially.
- The transformer impedance shall be 0.6Ω ± 50% *(as specified in Rev F.)*
- 10 µF differential capacitor is installed on AC lines (like CS101).
- 100 µF differential capacitor is installed on DC lines.



Section 18 – Audio Frequency Conducted Susceptibility

Current Limit:

- Excessive current shall be limited to at least **36 amps pk-pk** (*in addition to EUT draw*) when test voltage cannot be achieved.
- This requires the use of a current monitor to ensure the EUT is not over tested.

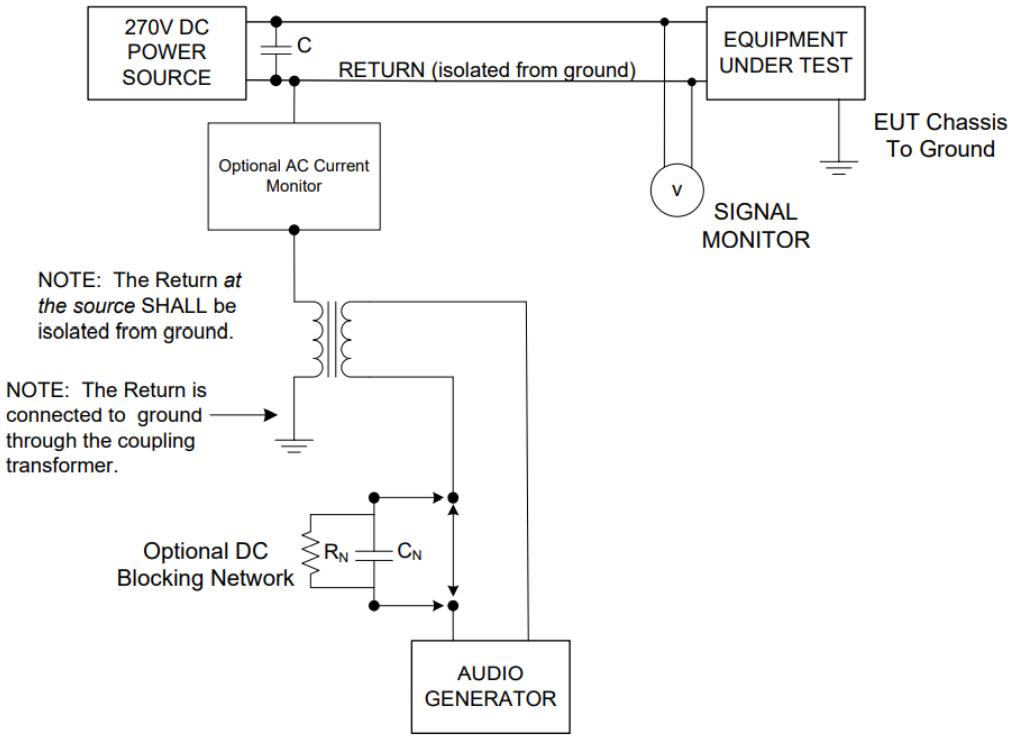


Section 18 – Audio Frequency Conducted Susceptibility

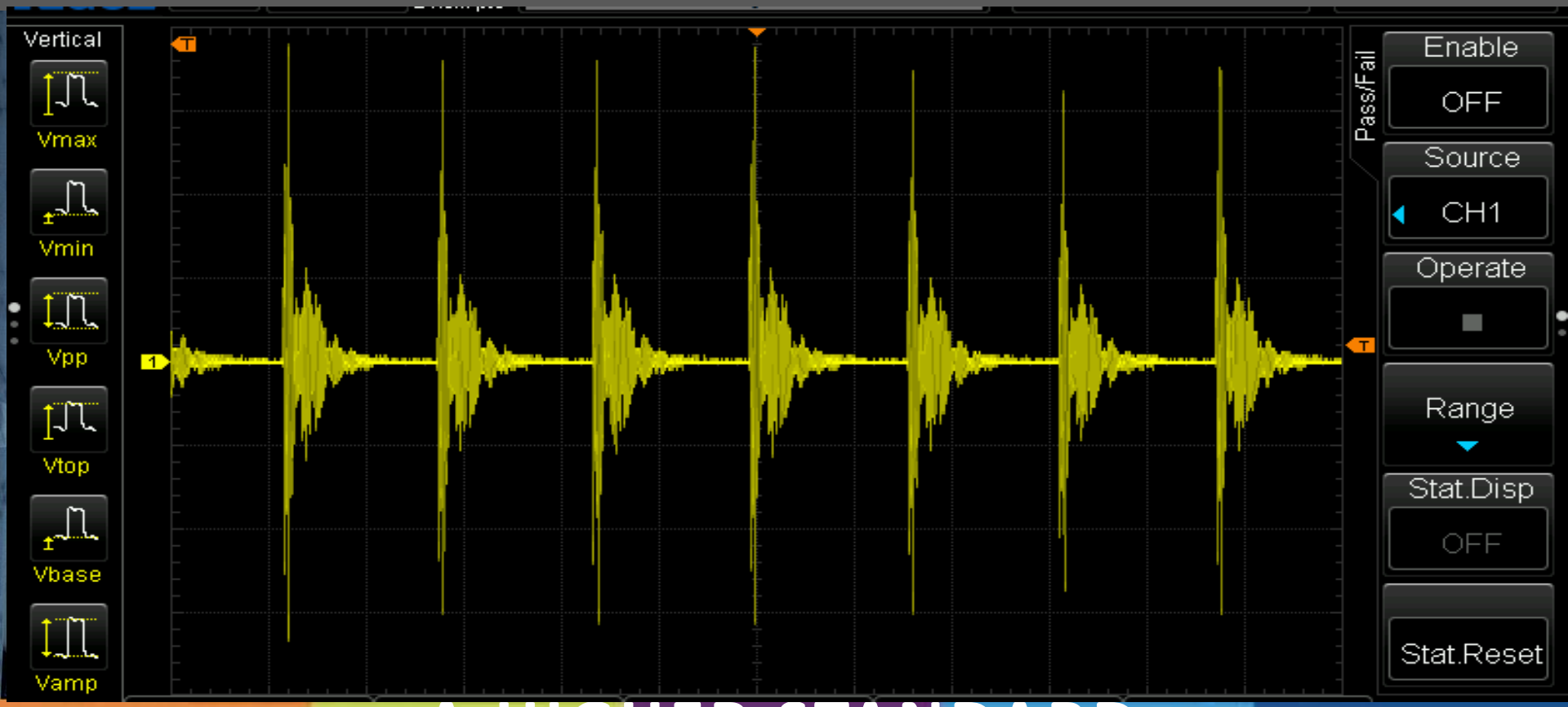
270VDC common Mode Test:

- A common mode injection test is applicable for 270VDC.
- Tested at twice the voltage level of the differential test.

Freq. (kHz)	270Vdc Limit Differential Mode	270Vdc Limit Common Mode
0.01	2.4	4.8
0.2	2.4	4.8
0.2	6.4	12.8
1	6.4	12.8
1	16	32
15	16	32
15	2.4	4.8
148.5936	0.016	0.032

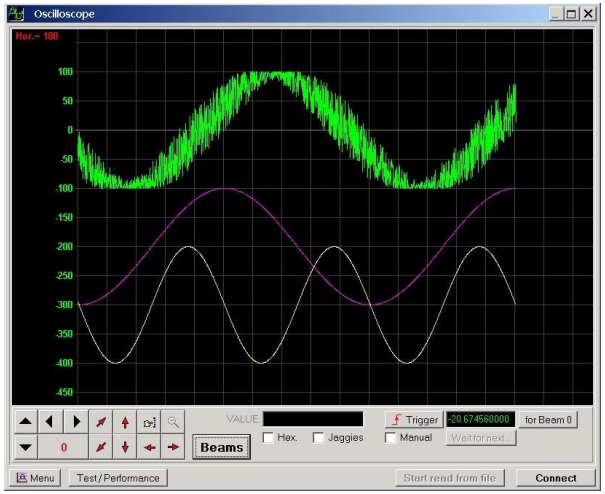


SECTION 19 INDUCED SIGNAL SUSCEPTIBILITY



Section 19- Induced Signal Susceptibility

Purpose:



- Simulates electromagnetic interference signals generated by power frequencies, and harmonics, as well as electrical transients sourced by onboard equipment or systems.

- **Five test methods** are used to determine the EUT's ability to withstand or accept a level of induced voltage and current present in the installation environment.

1) Magnetic Fields induced Fields into equipment.

2) Magnetic Fields induced Fields into interconnecting cables.

3) Electric Fields Induced into equipment.

4) Electric Fields induced into interconnecting cables.

5) Spikes induced into interconnecting cables.

Section 19- Induced Signal Susceptibility

Equipment Categories

- 3 letter designation: **(Test level) - (Power type) - (E-field Test applicability)**

Test Level:
Category C: Interference free operation is required in severe coupling environments.
Category Z: Interference free operation is required in all environments.
Category A: Interference free operation is desired.
Category B: Interference is controlled to a tolerable level.

Power Type:
Category C: Continuous frequency Equipment 400 Hz or DC.
Category N: Narrow Frequency AC Equipment 350 Hz – 650 Hz.
Category W: Wide Frequency AC Equipment 350 Hz – 800 Hz.

E-field test applicability:
E: Applicable
X: Not applicable

NTS

Section 19- Induced Signal Susceptibility

Test Levels, Methods & Categories

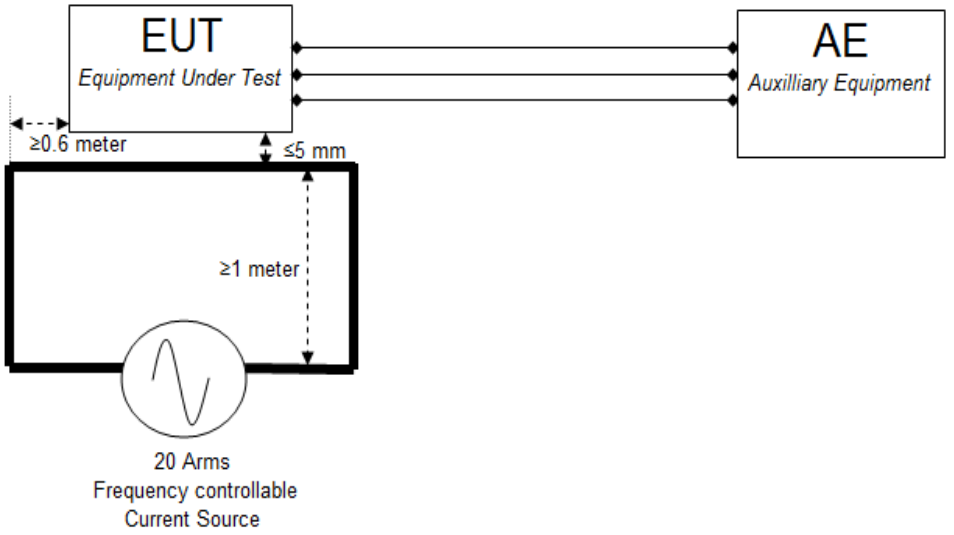
Paragraph	Test	Category ZW	Category AW	Category BW	Category CW
19.3.1	Magnetic Fields induced into the equipment	20 A rms at 350 Hz and 800 Hz	20 A rms at 350 Hz and 800 Hz	20 A rms at 350 Hz and 800 Hz	20 A rms at 350 Hz and 800 Hz
19.3.2	Electric Fields induced into the equipment	170 V rms at 400 Hz	170 V rms at 400 Hz	170 V rms at 400 Hz	170 V rms at 400 Hz
19.3.3	Magnetic fields induced into interconnecting cables	IxL=30 A-m from 350 to 800 Hz and reducing to 0.8 A-m at 32 kHz	IxL=18 A-m from 350 to 800 Hz	Not Applicable	IxL=120 A-m from 350 to 800 Hz reducing to 1.6 A-m at 32 kHz
19.3.4	Electric Fields induced into interconnecting cables	VxL=1800 V-m from 350 to 800 Hz	VxL=360 V-m from 350 to 800 Hz	Not Applicable	VxL=5400 V-m from 350 to 800 Hz reducing to 135 V-m at 32 kHz
19.3.5	Spikes induced into interconnecting cables	Figure 19-4 L=3.0 m	Figure 19-4 L=3.0 m	Figure 19-4 L=1.2 m	Figure 19-4 L=3.0 m

NTS

Section 19- Induced Signal Susceptibility

Magnetic fields induced into equipment-

- 20Arms is applied to a straight wire radiator.
- Loop axis is perpendicular and spaced 5 mm from each face.
  - *The loop must extend at least 60cm beyond each lateral boundary.*
- Applied 5 minutes each side of



- Repeated at each frequency determined by the equipment category (400Hz, 350Hz, 650 Hz, 800Hz).
  - ***Not synchronized with the power line frequency.***

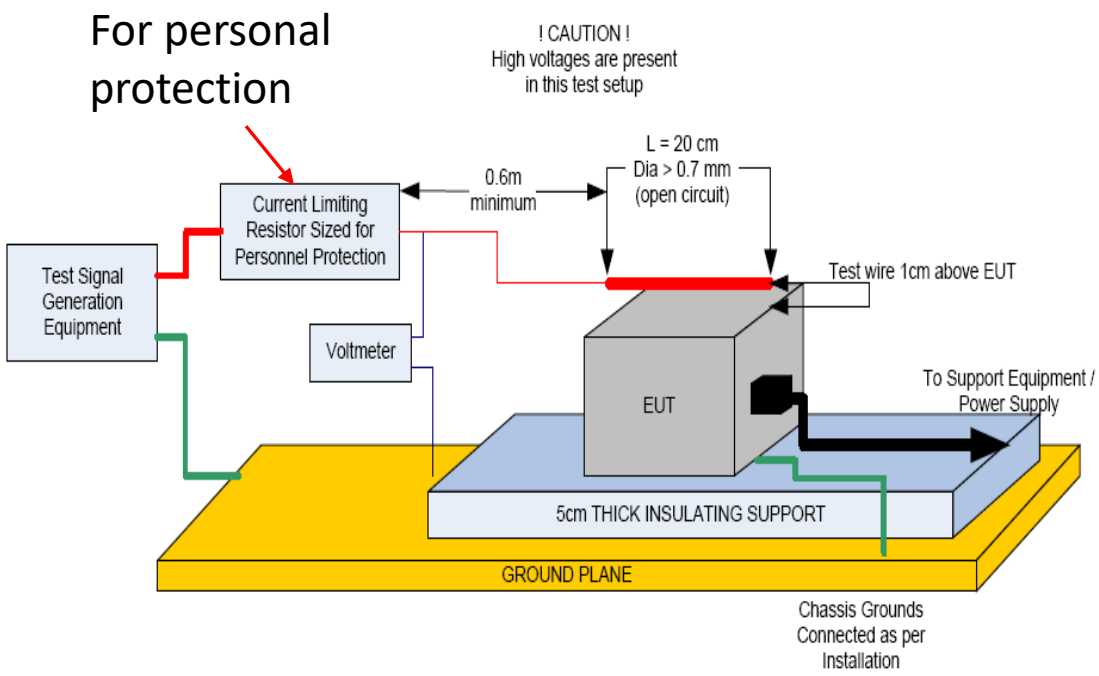
Section 19- Induced Signal Susceptibility

Electric fields induced into Equipment-

- Strait wire radiator slowly waved over each face maintaining 1 cm separation distance. *Slower than the response time of the EUT*

- 170 Vrms at 400 Hz (open circuit).

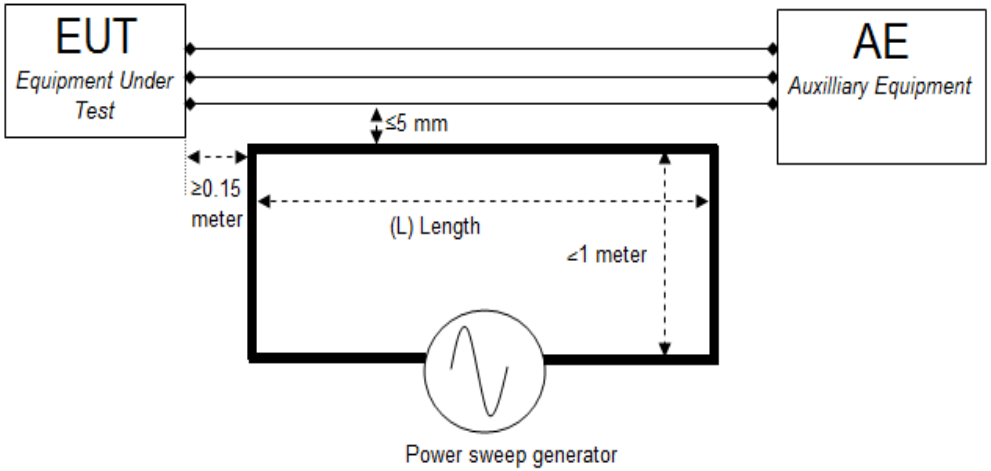
- Each face is tested using Horizontal sweeps on 0 and 90 degree axis.



Section 19- Induced Signal Susceptibility

Magnetic fields induced into interconnecting cables-

- Current is applied to a straight wire radiator.
- Amplitude (A-m) is dependent on equipment category but is calculated by length of radiator in meters (L) multiplied by current (Arms).
  - *30 A-m = 3 meters * 10 Arms*
  - *30 A-m = 1.5 meters * 20 Arms*



- Frequency range is also dependent on equipment category, but can range from 350 Hz up to 15kHz.
- Test can be swept or stepped across the frequency applicable range:

Step rate

- *30 frequencies per decade with a 10 second dwell per frequency (5 minute test)*

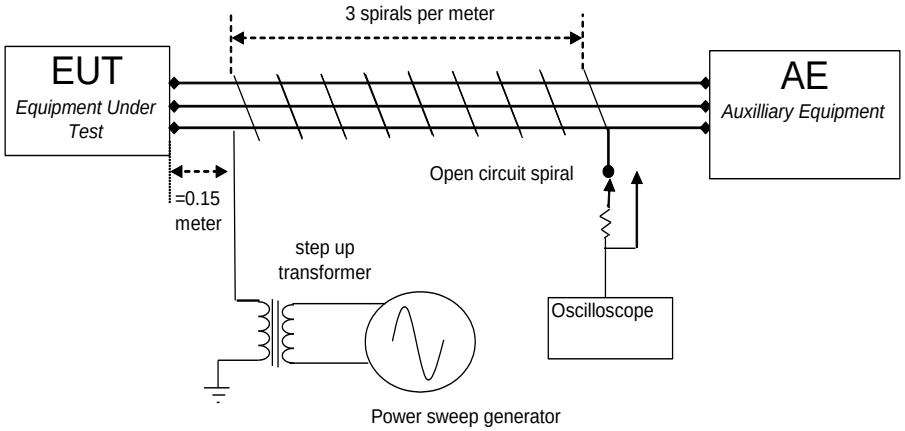
Sweep Rate

- *swept at a rate no less than the step rate test time (5 minutes).*

Section 19- Induced Signal Susceptibility

Electric fields induced into interconnecting cables-

- Open circuit wire is spiraled around each interconnecting cable bundle.
  - *Maintaining 3 spirals/meter.*



- Amplitude (V/m) is dependent on equipment category but is calculated by length of radiator in meters (L) multiplied by voltage (Vrms).

Examples:

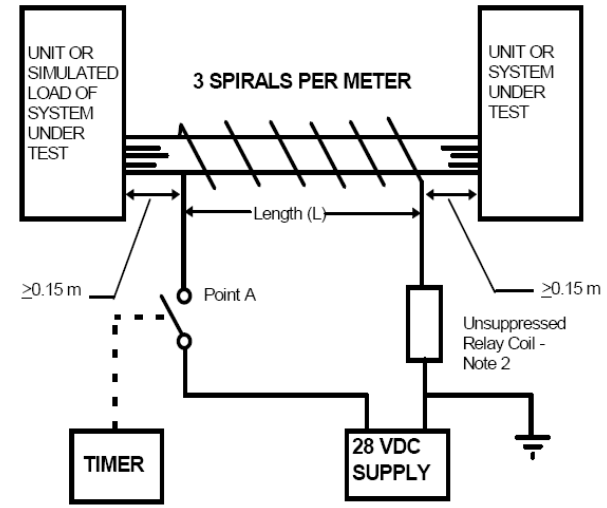
- ***5400 V/m = 3 meters * 1800 Vrms***
- ***5400 V/m = 1.5 meters * 3600 Vrms***

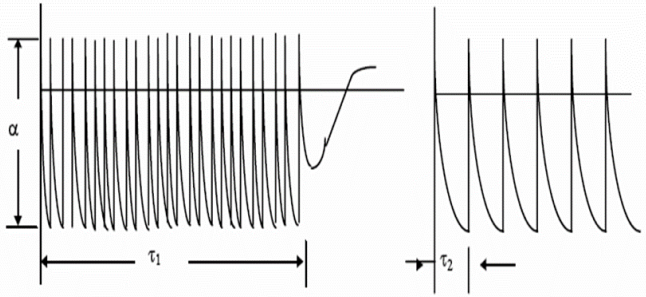
- Frequency range is also dependent on equipment category but can range from 350 Hz up to 15kHz.

Section 19- Induced Signal Susceptibility

Spikes induced into interconnecting cables-

- The same spiral loop radiator is used, except it's terminated through a high inductance coil (~1.5 H), in series with a switching contacts.
- The collapse of the V field across the inductive coil produces a spike reaching 600Vpk-pk.
- Pulse Repetition between 200 ns -10 µs
- Total Duration between 50 - 1000 µs
- The test duration for each polarity ≥2 minutes





α Amplitude ≥ 600 v p-p
τ1 Total Duration 50 to 1000 microseconds
τ2 Repetition Period 0.2 to 10 microseconds

SECTION 20 RADIO FREQUENCY SUSCEPTIBILITY

A HIGHER STANDARD

TESTING | INSPECTION | CERTIFICATION

NTS

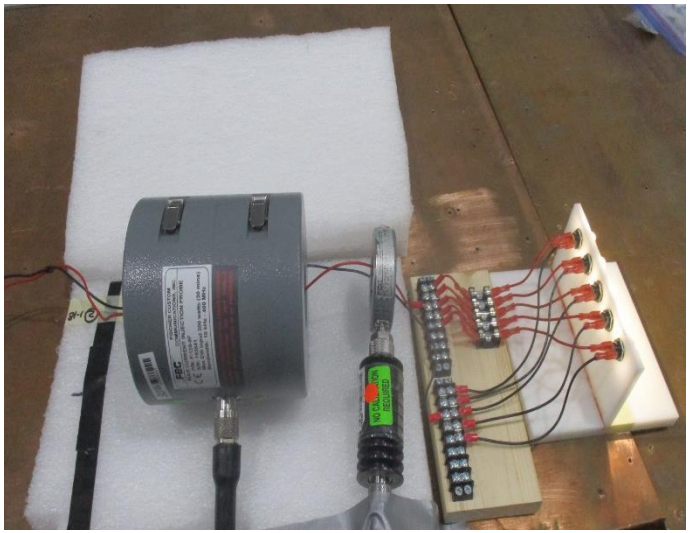
Section 20- Radio Frequency Susceptibility

Purpose of RF Susceptibility testing:

- Similar to RS103 and CS114, Section 20 testing evaluates the equipment's ability to operate as intended when exposed to a steady state electromagnetic environment (conducted & Radiated).

- **Conducted susceptibility-**
  Tested from 10kHz to 400MHz

- **Radiated susceptibility-**
  Tested from 100MHz up to 18 GHz



Section 20- Radio Frequency Susceptibility

Aircraft HIRF Environment

- The commercial aircraft HIRF environment is comprised of high-powered radio and television frequency transmitters, radar and satellite uplink transmitters, and large microwave communications systems.

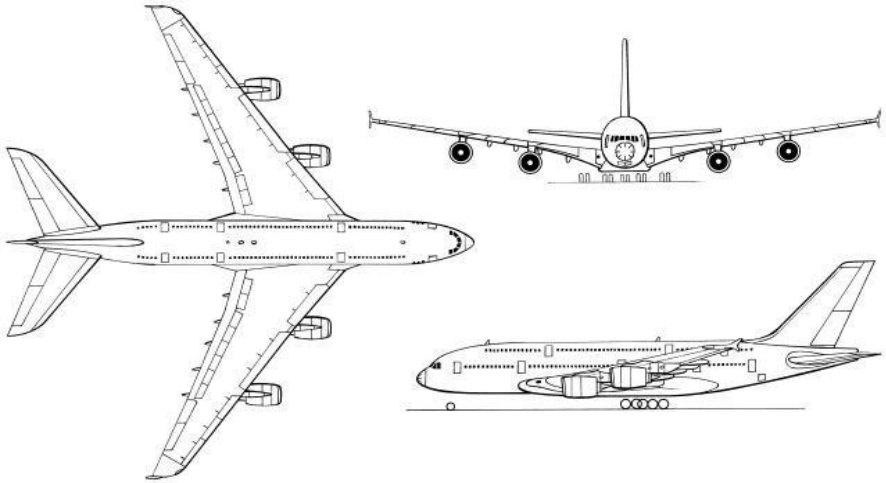
- There are more than 500,000 emitters across the U.S. and Western Europe contributing to the aircraft electromagnetic environment. The number of emitters, frequency range, and HIRF field exposure levels are increasing each year.

- Additionally, HIRF addresses low power transmitting portable electronic devices (T-PEDs) such as cell phones, and other mobile electronics that can be located very close to aircraft systems and wiring are also considered part of the HIRF environment.

Section 20- Radio Frequency Susceptibility

Equipment Categories:

- Test categories directly relate to the expected RF exposure level and operational criticality of the EUT.
- In many cases, a category level must be selected before the internal RF environment on the aircraft is known. *(HIRF certification has not been performed yet -SAE ARP 5583A /EUROCAE ED-107A).*



- Therefore, testing may/should be performed to the most severe applicable HIRF exposure levels.
  - *These tests are sufficient to obtain equipment certification of RF susceptibility.*

NTS

Section 20- Radio Frequency Susceptibility

Equipment Categories:

Categories	Description
B,D,G,L,M,O	Tests levels that directly relate to HIRF with the highest criticality.
R	Bench testing is allowed to meet for systems with high criticality, and tolerance to T-PED.
S	Minimum Test Level where external RF environment is minor, and interference free operation is desirable but not required.
W, Y	Bench testing supporting HIRF special conditions, and T-PED Tolerance
Q	Test conducted with modulations other than those specified by RTCA DO160

NTS

Section 20- Radio Frequency Susceptibility

Frequency Scan Rates

- Much less stringent than MIL-STD-461.
- Frequency sweeping, or discrete frequency stepping methods are accepted.
- Scan rates should be no less than 100 frequencies per decade above 100kHz, 10 frequencies per decade below 100kHz (*logarithmically spaced*).
- Dwell time per tuned frequency shall at least 1 second, but dependent on equipment cycling time, and modulation duty cycle.

Section 20- Radio Frequency Susceptibility

Signal Modulation

CS Tests-

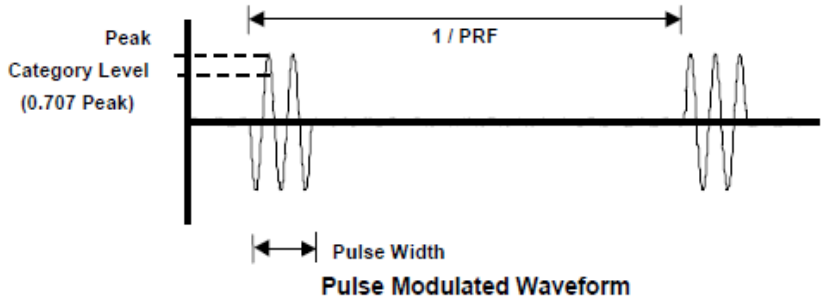
- CW (unmodulated)
- SW (1 kHz 50% duty cycle >90% depth)

RS Tests-

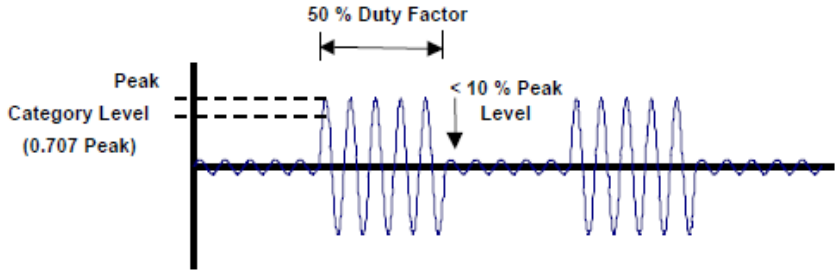
- Modulations vary on applicable Category.

Example: TEST CATEGORY R

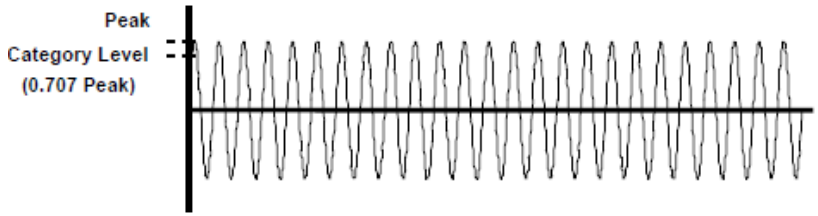
- CW and SW (1 kHz, 50% >90%) used from 100 MHz to 400 MHz
- PM (1 kHz 4% duty cycle) from 400 MHz to 8 GHz. This is cycled at a 1 Hz rate to simulate the rotational effects of a Radar source.



Pulse Modulated Waveform



Square Wave (SW) Modulated Waveform



Unmodulated (CW) Waveform

Section 20- Radio Frequency Susceptibility

Conducted Susceptibility:

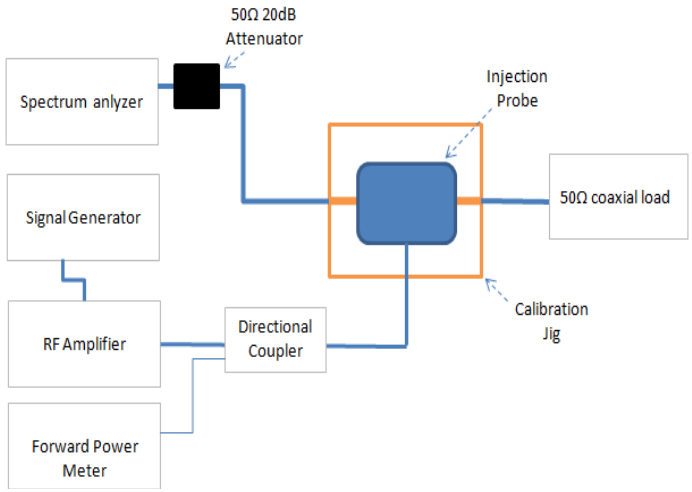
- Interconnecting power leads, I/O cables are subjected to induced RF currents, similar to MIL-STD-461 CS114 Test Method.
- Interconnecting wiring and harnesses can be tested as a whole or as individual wires.
- Simultaneous injection with separate probes on several bundles may be used, especially for equipment with built-in redundancy. Also used for system level HIRF Testing.
- Power return leads or ground leads are excluded from the bundle under test and are tested.

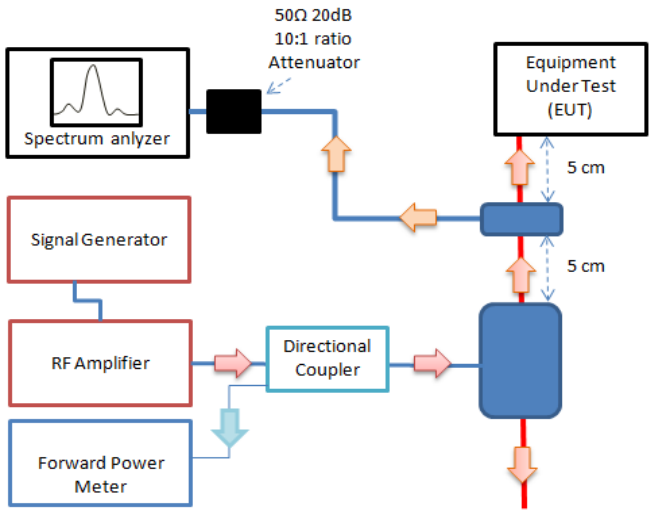
NTS

Section 20- Radio Frequency Susceptibility

Conducted Susceptibility Calibration:

- Induced current levels are calibrated into a 50 ohms load prior testing.
- The drive signal forward power level is recorded at each frequency once the test current is achieved.
- For ALL categories, the induced current on the cable is used to establish the test level, and the calibrated forward power level is used as test limit.

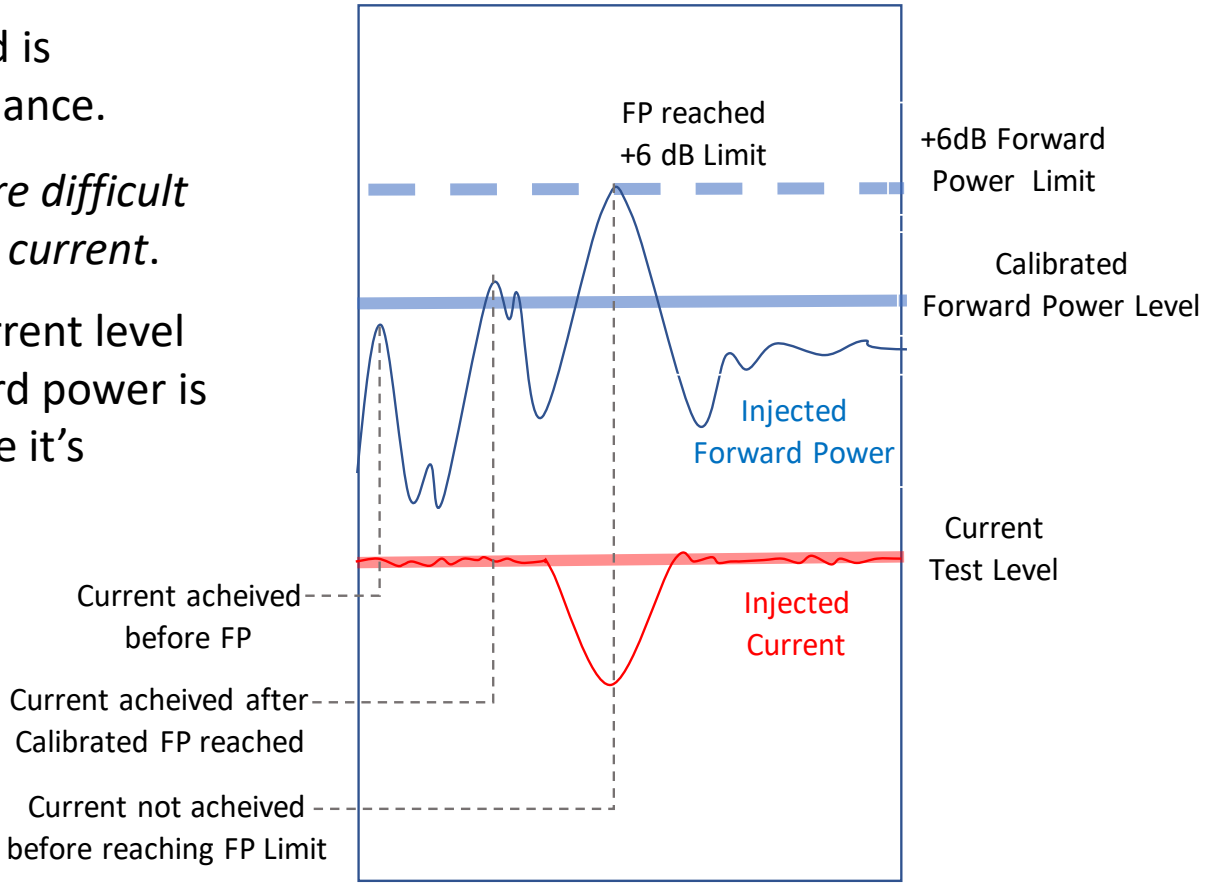




Section 20- Radio Frequency Susceptibility

Conducted Susceptibility Test Criteria:

- The amount of current injected is dependent on the cable impedance.
- *Higher the impedance, the more difficult it will become to achieve inject current*.
- In cases where the induced current level cannot be achieved, the forward power is may be increased to 6 dB above it's calibrated FP level.
- **This Methodology Differs from MIL-STD-461G CS114 (+6dB current**



Section 20- Radio Frequency Susceptibility

Radiated Susceptibility-

Purpose:

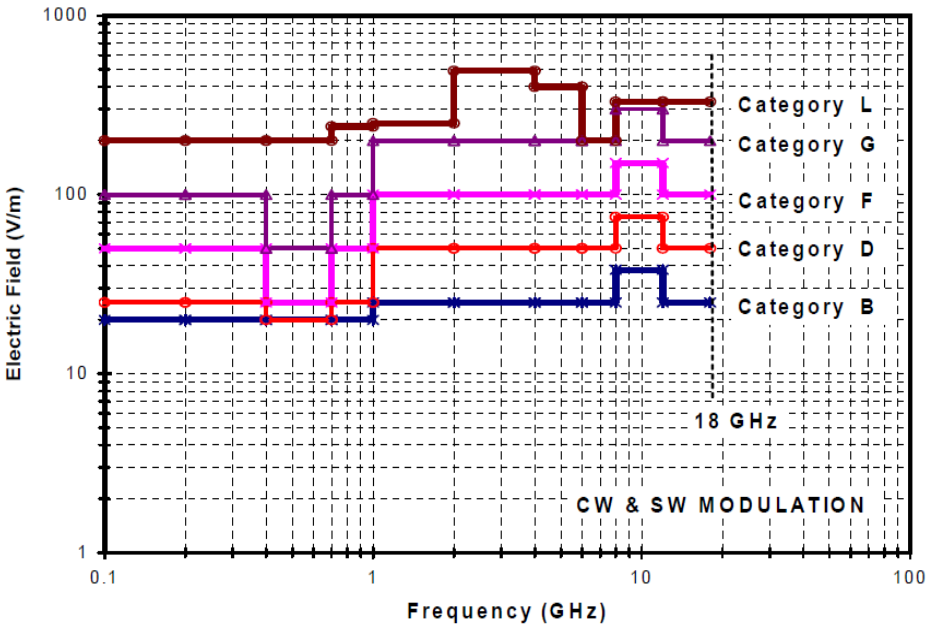
- Evaluates the performance of equipment when exposed to Radiated fields.

- Test Results cab be used to determine equipment response to a variety of EM threats:
  - HIRF
  - T-PED

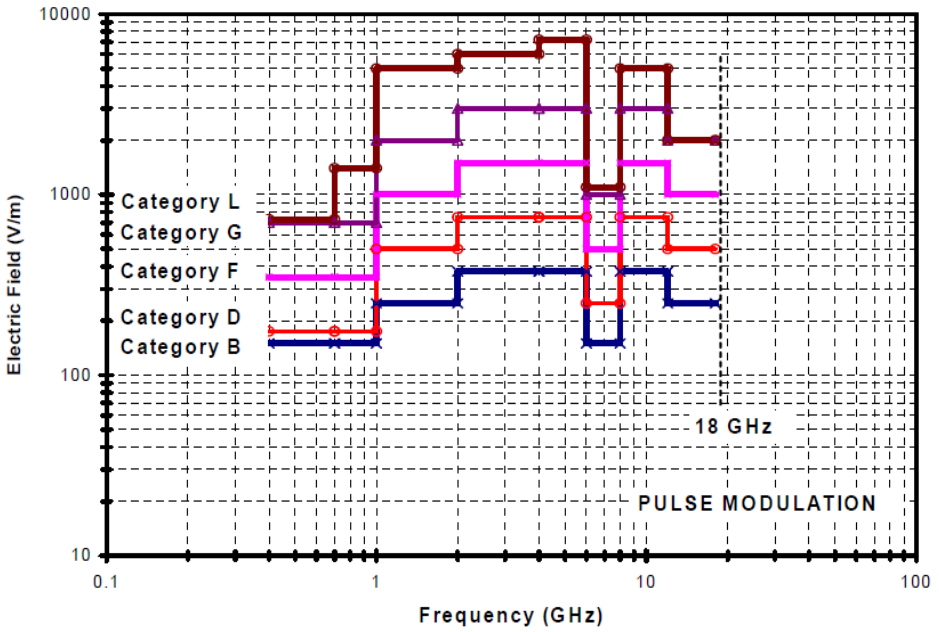
- The test methods used are similar to those found in MIL-STD-461G.

Section 20- Radio Frequency Susceptibility

Radiated Susceptibility Category Test LImits



CW & SW Modulated Signals



Pulse Modulated Signals

Section 20- Radio Frequency Susceptibility

Radiated Susceptibility-

- Two test methods can be used:

Direct Illumination Method

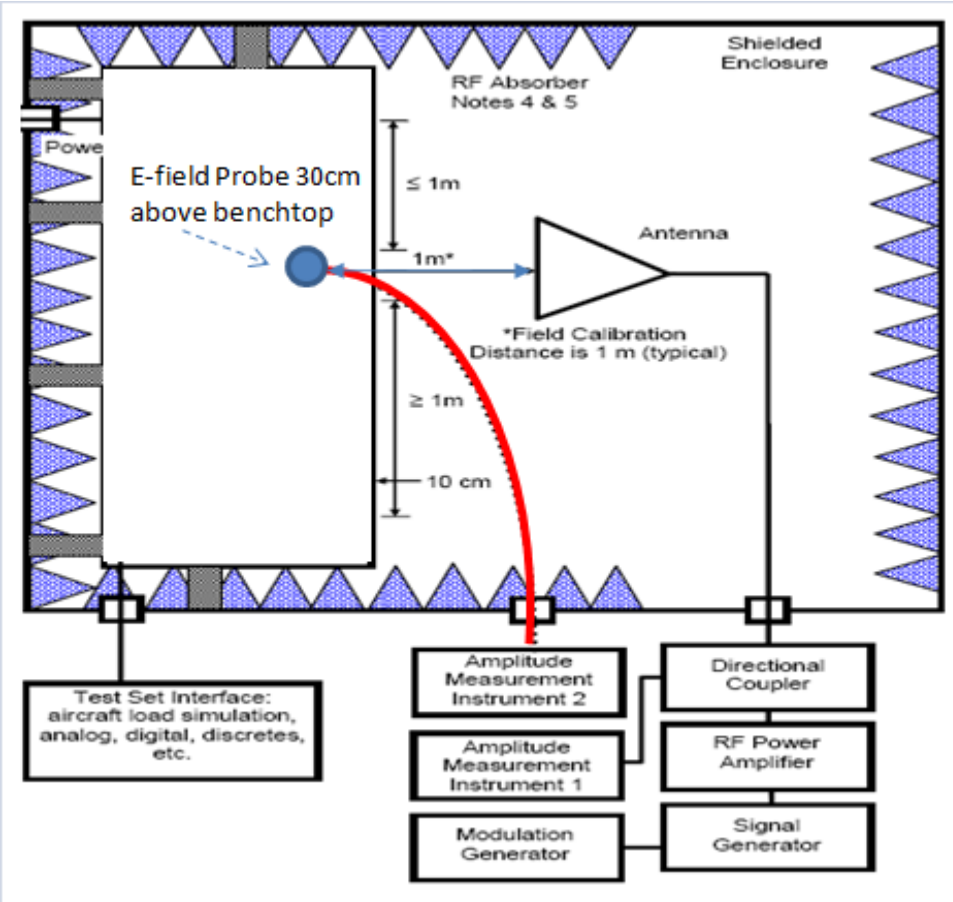
Reverberation Chamber method

Section 20- Radio Frequency Susceptibility

Radiated Susceptibility- Direct Illumination

Calibration-

- Performed immediately prior to EUT testing.
- performed using a 3 axis omni directional electric field sensor (Isotropic probe) or receive antenna.
- The probe is placed at the location where the EUT will be installed, and elevated 30cm above the bench top.
- Each tuned frequency is radiated at the field probe, where the signal amplitude is increased until the desired test level is met.

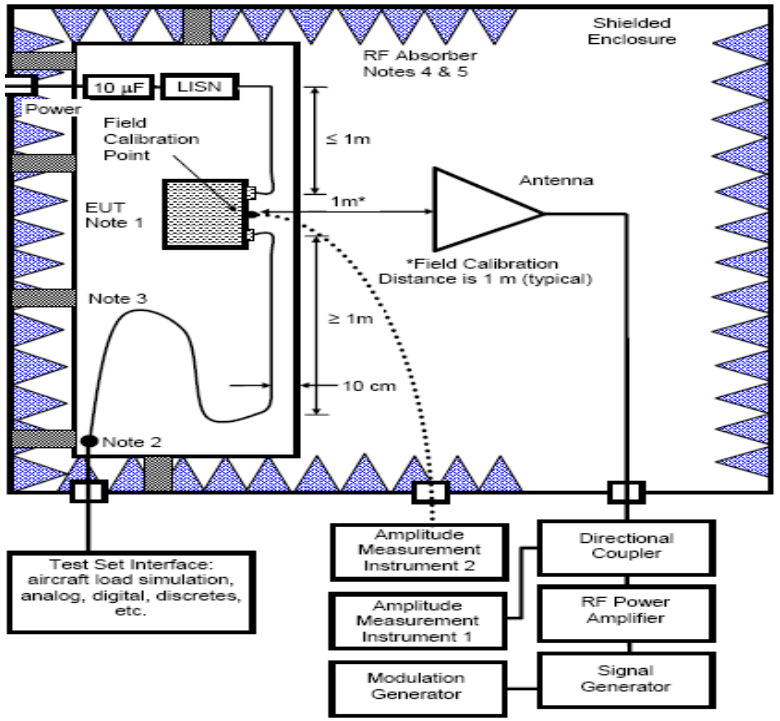


Section 20- Radio Frequency Susceptibility

Radiated Susceptibility-

Direct Illumination Test Method

- Antennas will be centered 30 cm above and the ground plane at 1 meter distance from the EUT.
- It is permissible to move the antenna closer to the EUT than the one meter as long as the distance between the transmit distance remains equal to or greater than the far field boundary conditions. ***(Differs from MIL-STD-461 RS103)***.
- It is also allowable to move the antenna farther than one meter from the EUT.



$$x = \frac{2 * D^2}{\lambda}$$

$X =$ *Far field boundary distance in meters*

$D =$ *Largest dimension of the transmitting aperture*

$\lambda =$ *Wavelength of the frequency of interest in meters*

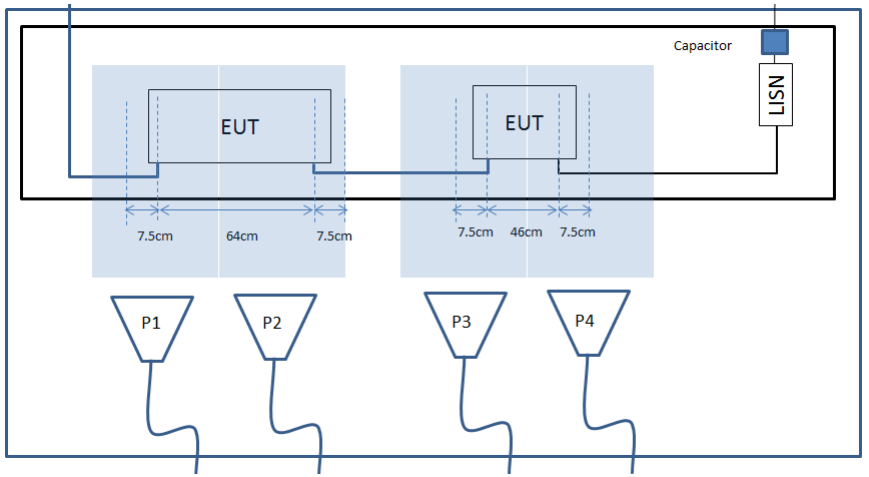
Section 20- Radio Frequency Susceptibility

Radiated Susceptibility- Illumination Method

EUT and cabling Illumination

- The entire width of the EUT and at least one-half wavelength of wiring of that shall fall within the ½ power beam width of the transmit antenna.

- When the ½ power beam width of the antenna does not totally cover the system under test, multiple area scans are required.



Section 20- Radio Frequency Susceptibility

Radiated Susceptibility- Illumination Method

EUT and cabling Illumination

- All faces of the EUT are expected to be illuminated by the transmitted field.

- ANY face not directly exposed/tested must be justified in the report.
    - **The FAA mandates that this justification is to be made by the manufacturer, not the test lab.**

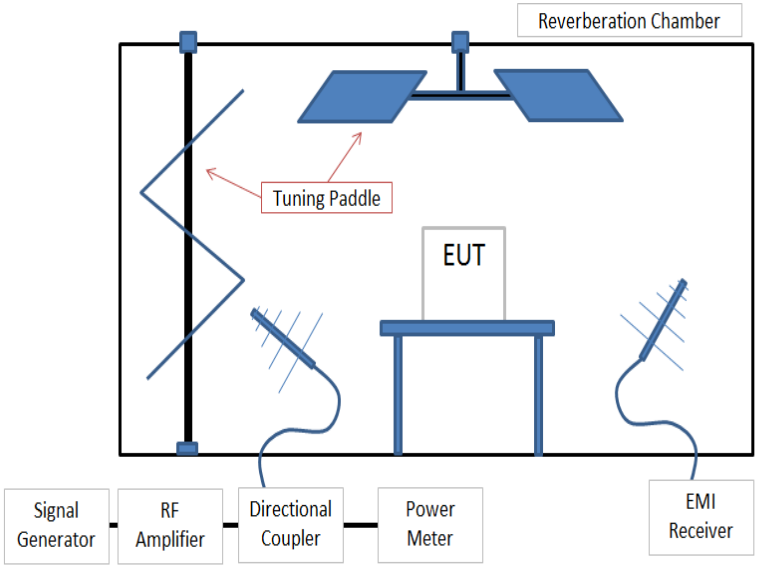
Example:

Complex systems with entry exit points on multiple sides will typically require multiple EUT orientations during testing to ensure each surface has been properly illuminated.

Section 20- Radio Frequency Susceptibility

Radiated Susceptibility- Reverberation Method

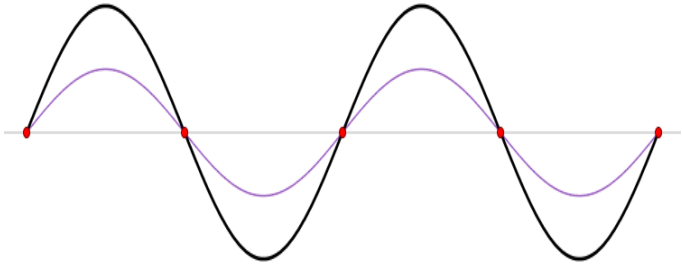
- A reverberation chamber is essentially a large cavity resonator (*like a microwave oven*) used to perform Electromagnetic (EM) measurements (both emissions and immunity).
- It is comprised of a copper, aluminum, or steel inner cavity (with no RF absorber installed).
- A Tuner paddle either vertically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



Section 20- Radio Frequency Susceptibility

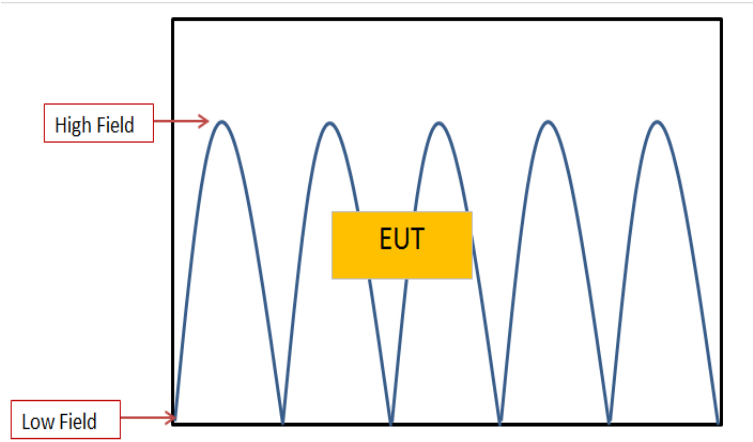
Radiated Susceptibility- Reverberation Method

- Due to the chamber's low RF absorption/highly reflective nature, strong standing waves can be developed producing high field levels at relatively low input power levels.



Standing Wave

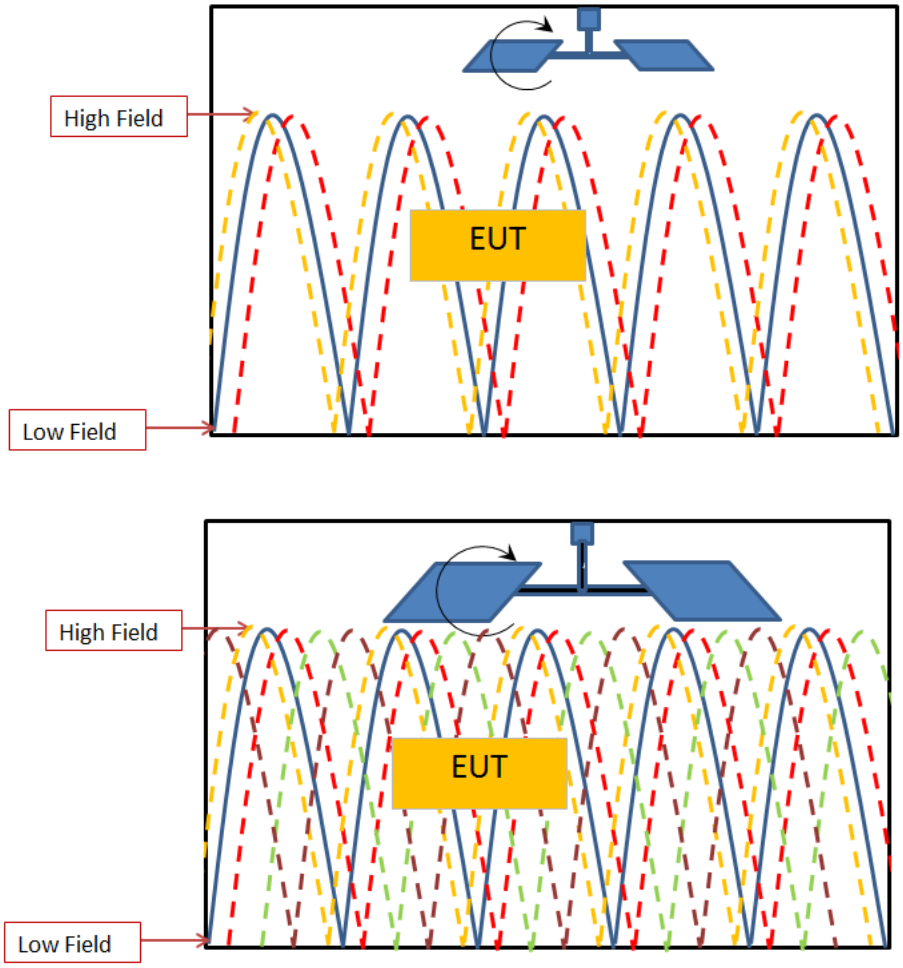
- Standing waves occur inside the chamber due to interference between waves reflected back and forth at the chamber's resonant frequency (*determined by the parametric dimensions of the chamber*).



Section 20- Radio Frequency Susceptibility

Radiated Susceptibility- Reverberation Method

- Uniform field (spatial distribution) is required to ensure that the EUT and cabling is properly illuminated.
- This is achieved by rotating a conductive paddle to disturb the standing wave pattern. This repositions “stirs” the modal fields over the inner volume of the chamber.
- The size of the paddle must be large enough to sufficiently stir the field.



Section 20- Radio Frequency Susceptibility

Radiated Susceptibility- Reverberation Method

Loaded Chamber Calibration

- Required before every test.
- Used to determine the RF loading effects on field strength .
- Performed with the EUT and associated cabling installed in the chamber.
- Performed at reduced input power level, and number of test frequencies.
- Used to establish the square law ratio between forward power and field strength.

For every 6dB change in field, there will be a 6 dB change in Power.

$$P_{Target} = 20*\log\left(\frac{E_{Desired}}{E_{Max}}\right) + P_{FWD}$$

P_{Target}= Target Forward power (dBm)
$E_{Desired}$= Desired field strength in the chamber (V/m)
E_{Max}= Field strength measured during the loaded chamber calibration
P_{FWD}= Forward power measured during loaded chamber calibration

Section 20- Radio Frequency Susceptibility

Radiated Susceptibility- Reverberation Method

Pros-

- Measures total radiated power in all directions & Polarizations (emissions).
- Generates fields in all directions and polarizations (immunity).
- Highly efficient field generator (high “Q”), achieving high field strengths at moderately low power levels.

Cons-

- Field measurements are averaged over many paddle positions or slow continuous paddle rotations.
- There is no easy way to pinpoint areas of EUT susceptibility.
- Lowest usable frequency is limited largest chamber dimension.
- EUT’s with significant amounts of RF absorber material will suppress the maximum achievable field level.
- EUT must fit within the uniform field volume of the chamber.

Either method can be used. The selection should be based on the project objectives.

SECTION 21 EMISSIONS OF RF ENERGY

A HIGHER STANDARD

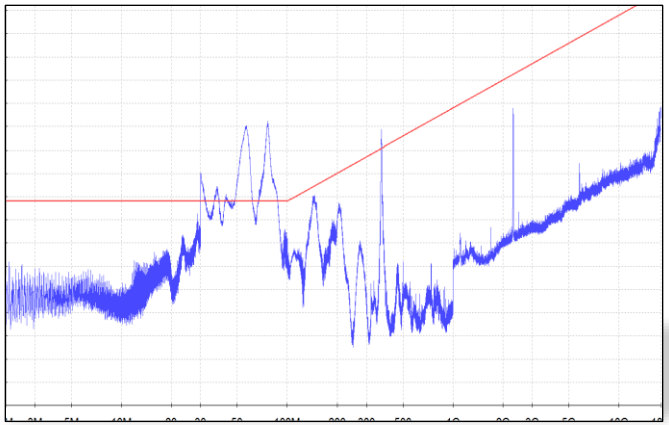
TESTING | INSPECTION | CERTIFICATION

NTS

Section 21- Radio Frequency Emissions

Purpose:

- Emissions testing measures the level of electromagnetic interference generated by a device.
- Equipment categories are defined in terms of location and separation between equipment and aircraft radio antennas.

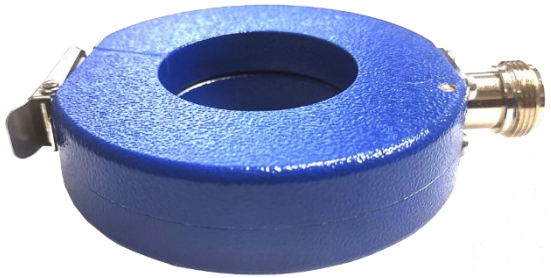


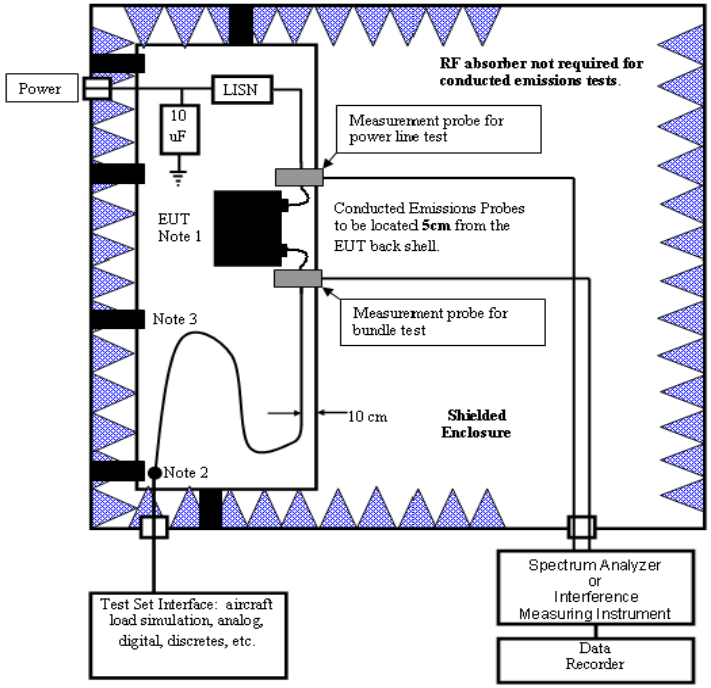
- Two Test methods are used to evaluate the control of Electromagnetic Emissions:
  - Conducted Emissions Testing
  - Radiated Emissions Testing

Section 21- Radio Frequency Emissions

Conducted Emissions

- Current measurements are made from 150kHz to 152MHz.
- A wideband current clamp is positioned around each power and interconnecting cable bundle 5cm from the EUT connector.
- Power return wires tied locally to the ground plane are not tested.
- Significantly differs from MIL-STD-461 methodologies.



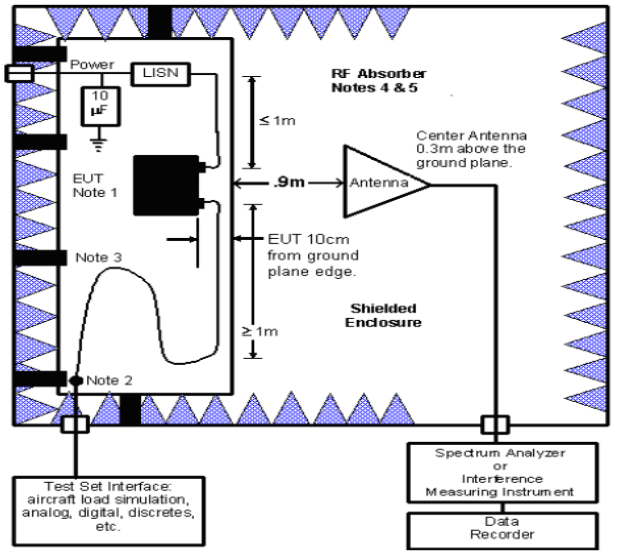


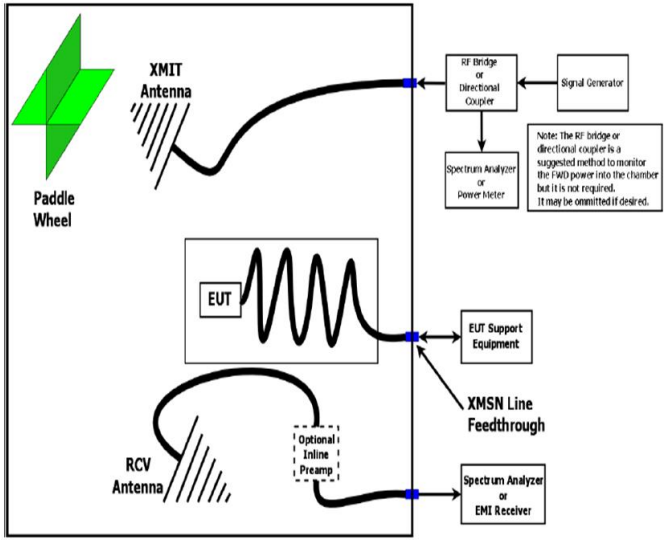
Section 21- Radio Frequency Emissions

Radiated Emissions

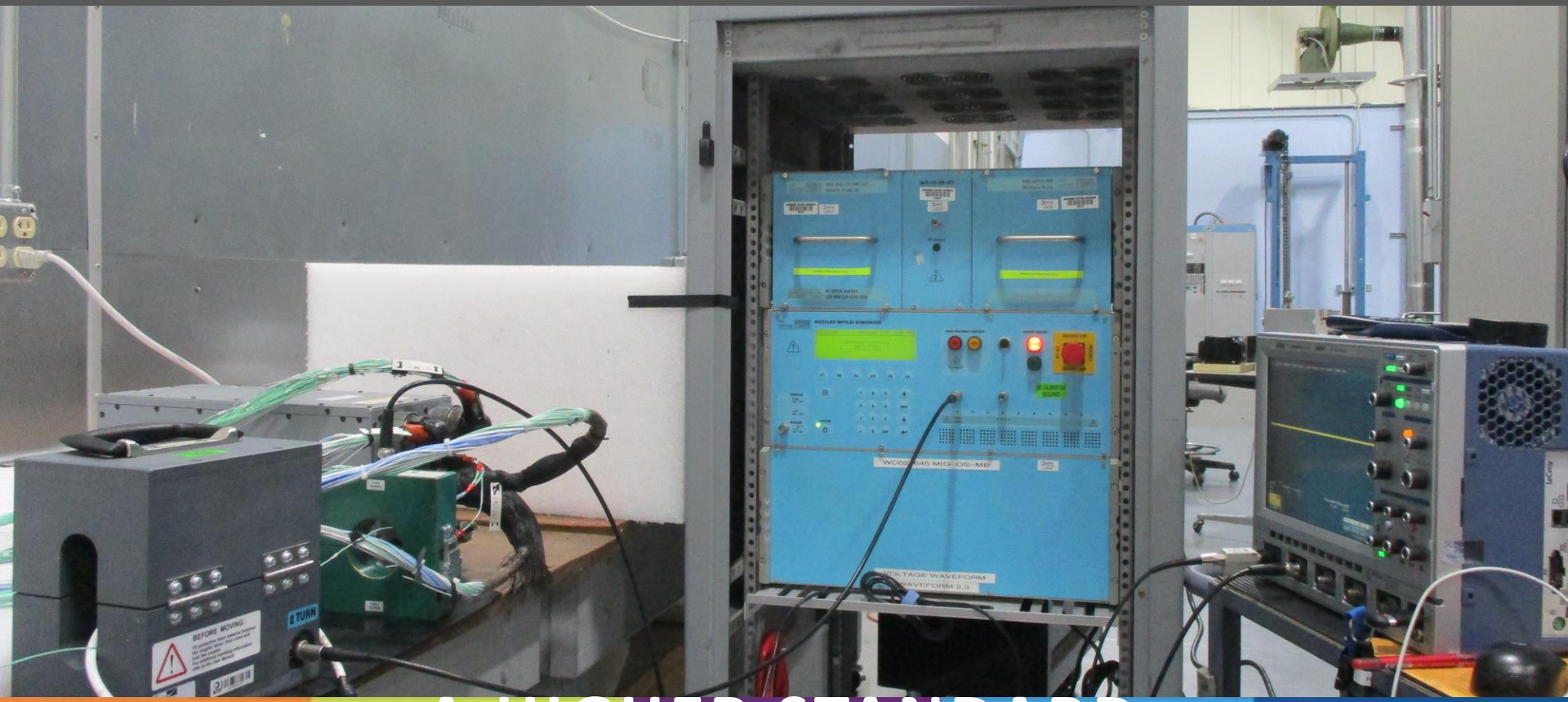
Purpose:

- Used to measure the unintentional electromagnetic signature of the EUT from 100 MHz to 6 GHz.
- Two Emissions Methods can be selected:
  - **Direct Illumination**
  - **Reverberation Chamber**
- Direct Illumination method is similar to RE102, but no method for Reverb emissions testing in 461G.





SECTION 22 LIGHTNING INDUCED TRANSIENTS



A HIGHER STANDARD

TESTING | INSPECTION | CERTIFICATION

NTS

Section 22- Lightning Induced Transient Susceptibility

Purpose:

- Simulates voltages and currents induced onto equipment cabling when in flight aircraft is struck by lightning.
- Verifies the EUT's ability to withstand cable induced electrical transient effects caused by lighting.
- Testing is segregated into two groups:
  - **Pin Injection Tests –** Damage assessment
  - **Cable Induced transient tests** -Functional Upset Tolerance

NTS

Section 22- Lightning Induced Transient Susceptibility-

Waveform Set Designators

- Waveform sets are selected based on the aircraft design and EUT cable routing scheme.
- Induced lighting waveforms are categorized as either Voltage driven, or Current driven.

Waveform sets A, C, E, G, and J (metal aircraft)

- Equipment interconnecting wiring installed within airframes where apertures are the cause of induced transients.
- Airframes with metal framework, and composite skin panels.
- Also applies to Carbon Fiber Composite (CFC) airframes where major surface areas are protected with metal meshes or foils.

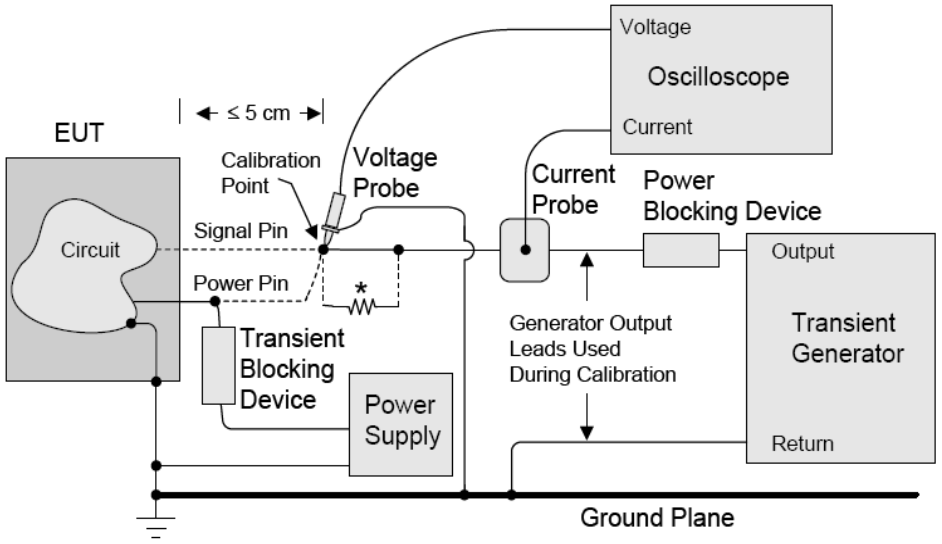
Waveform sets B, D, F, H and K (composite or non-conductive aircraft)

- Airframes where structural resistances are the cause of induced transients.
- *Airframes with Carbon Fiber Composite structures*.

Section 22- Lightning Induced Transient Susceptibility-

Pin Injection

- Transients applied directly to the designated pins of the connector.
- Used in damage assessment of dielectric withstand voltage or damage tolerance of interface circuitry.



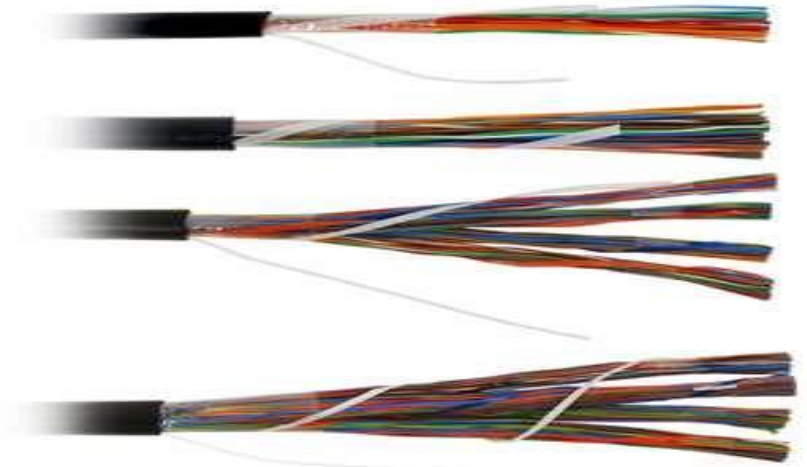
- **HI POT** testing may be performed in lieu of pin injection, on simple electric or electromechanical devices electrically isolated from case ground.
  - *Pin Injection tests are required for all devices containing electronic components.*
- *T*esting is performed at the peak pin injection test category level for 60 seconds.
  - *HI POT Test levels on power lines also include the line voltage potential.*

Section 22- Lightning Induced Transient Susceptibility-

Pin Injection

Group Testing/Qualification through Similarity

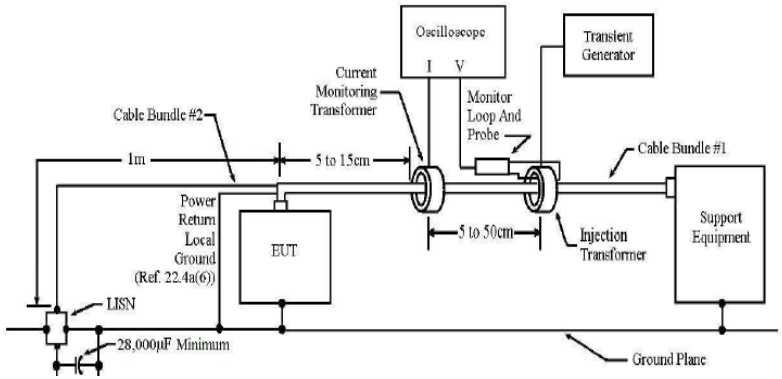
- 4 or more pins with identical circuit design for both operation and protection may be qualified by similarity.
- Testing can be performed on 3 representative pins of each group.
- High impedance input/output circuits with multiple pins may be tested simultaneously given that the test voltage amplitude and wave shape characteristics remain in tolerance.



Section 22- Lightning Induced Transient Susceptibility-

Cable Induction Method

- Waveforms are inductively coupled onto the interconnecting lines while the EUT is operating normally.
- A coupling transformer and current monitoring clamp are placed around the selected cable to be tested.
- Applicable for single stoke, multi stroke, and multi burst tests.
- Several power protection schemes used, for AC & DC configurations.



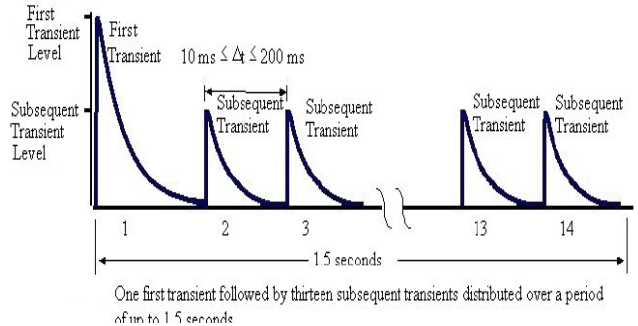
Section 22- Lightning Induced Transient Susceptibility-

Single Stroke

- A single transient applied by cable induction or ground injection.
  - *Representative of cloud to ground lightning strike.*

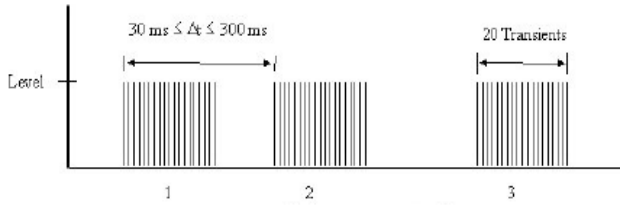
Multiple Stroke

- A Single stoke waveform followed by 13 subsequent strikes at half amplitude randomly spaced over a 1.5 second period.
  - *Represents the induced effects of a cloud to ground lightning strike on an aircraft in flight.*



Multiple Burst

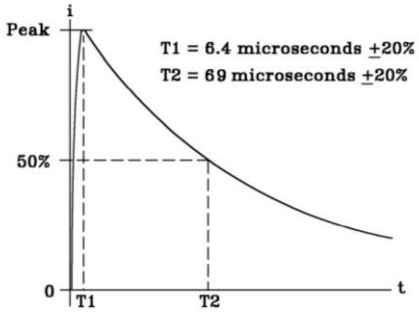
- The application of damped sinusoidal transients randomly spaced in groups of 20 (bursts) spaced over a period of 5 minutes.
  - Represents electricity passing between the negatively charged base of the cloud and its positively charged upper levels.



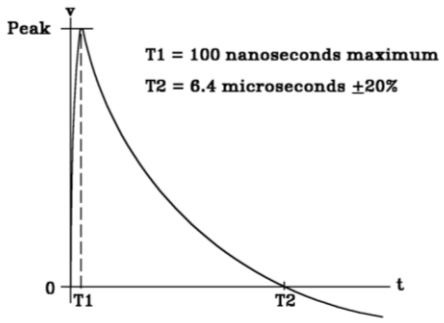
Section 22- Lightning Induced Transient Susceptibility-

Test Level Vs. Limit Level

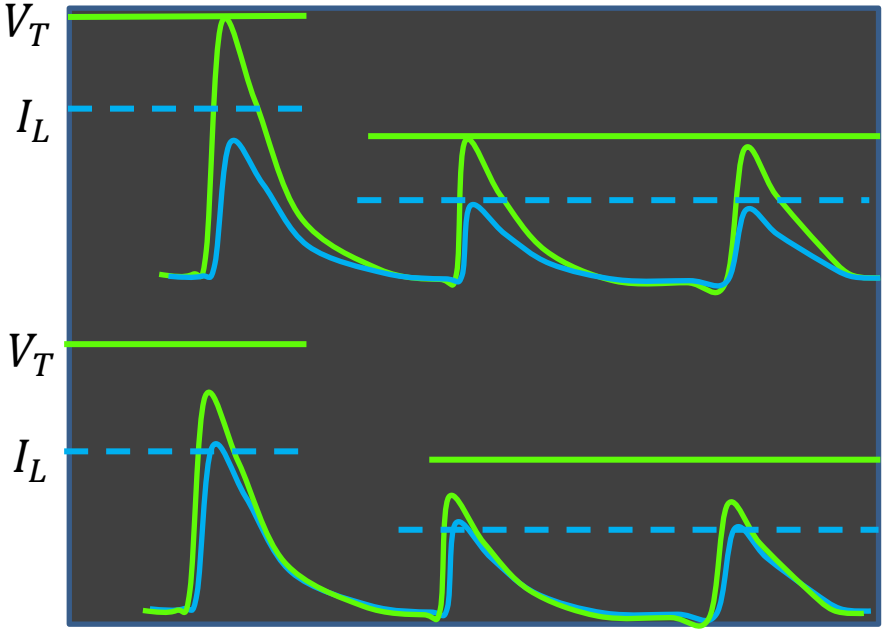
- Waveform sets are either Voltage driven or Current driven based on the aircraft design. This is indicated as either $\boldsymbol{V_T}$ or $\boldsymbol{I_T}$.
- Impedance of the cable under test will drive either Voltage or Current so a Limit Level is implemented to prevent excessive over testing. This is indicated as either $\boldsymbol{V_L}$ for Current waveforms or $\boldsymbol{I_L}$ for Voltage waveforms.
- Initially, the test level is gradually increased until either the **Test Level** or the **Limit Level** is reached (*whichever comes first*).
- However, if the Limit Level is reached before the Test Level, a re-evaluating the generator or selected waveform set may be required.



Current Waveform 1



Voltage Waveform 2



SECTION 23 LIGHTNING DIRECT EFFECTS

A HIGHER STANDARD

TESTING | INSPECTION | CERTIFICATION

NTS

Section 23 -Lightning Direct Effects

- It may **shock** you to learn, *no pun intended*, that 25,00 aircraft are struck by lightning each year. This equates to every aircraft around the world being struck by lightning once a year.

- Fortunately, it has been nearly 60 years since the last major accident caused by a lightning strike**. (*Pan Am Flight 214 -1963*)**

- Lightning damage accounts for more than $2 billion annually in airline operating costs and passenger delays.

NTS

Section 23 -Lightning Direct Effects

- Evaluates the effects of a direct lightning strike on Aeronautical equipment.

- Testing includes all equipment covered only by a dielectric skin or fairing including interconnecting cables furnished as part of the equipment.
  - **Antenna arrays,**
  - ***Exterior lightning,***
  - ***Air data probes & other external sensors,***
  - ***Anti-ice and de-ice equipment mounted external to the structure.***
  - ***Magnetic fluid level indicators,***
  - ***Fuel filler caps and drain valves.***

- Not intended for mechanical devices, equipment that are an integral part of the aircraft, or equipment protected by the aircraft radome.

Section 23 -Lightning Direct Effects

- There are numerous effects lightning can have on Aircraft skins (metallic & composite)

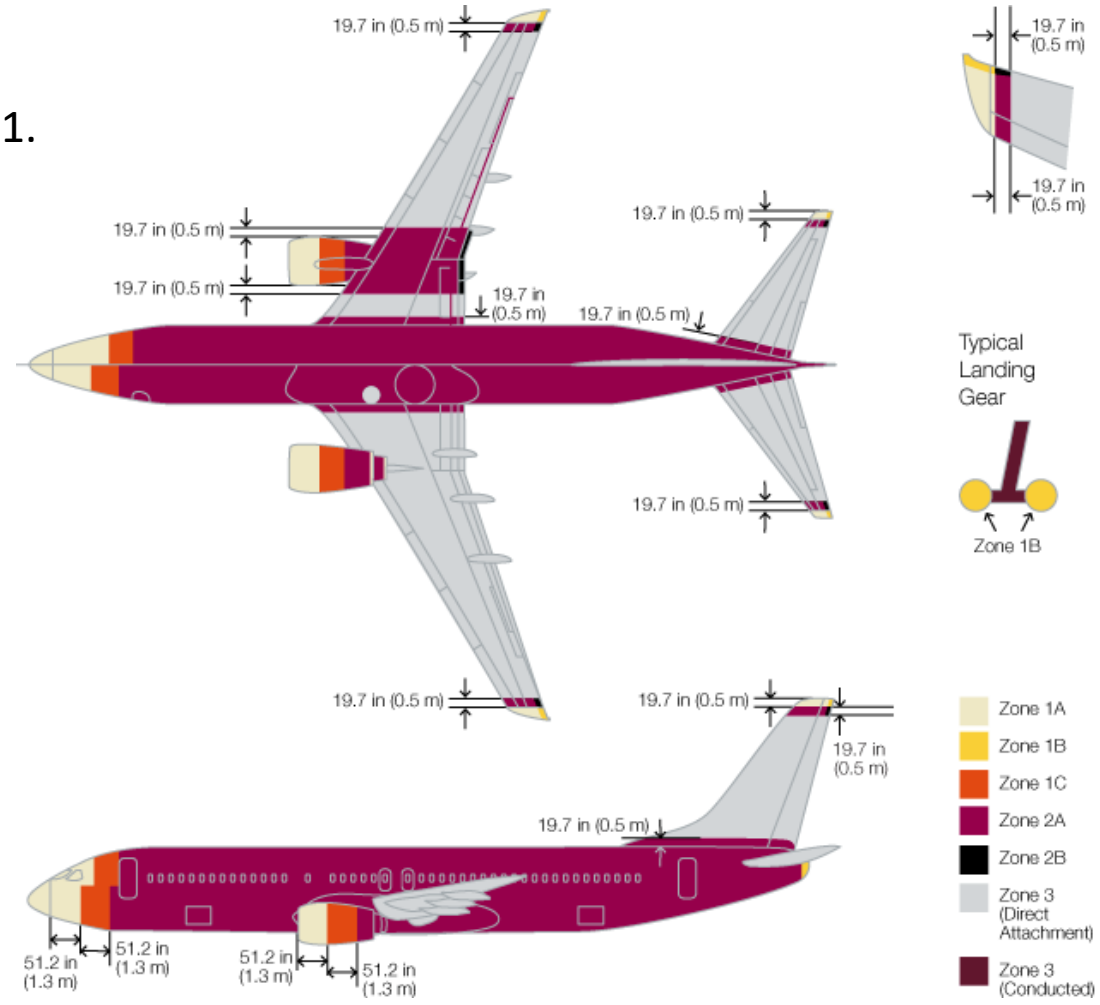
- **Melting or burning at lightning attachment points.**
- **Resistive temperature rise.**
- **Magnetic force effects.**
- **Acoustic shock effects.**
- **Arcing & sparking at bonds hinges & joints.**
- **Ignition of combustible vapors within fuel tanks.**

NTS

Section 23 -Lightning Direct Effects

Lightning Zones

- Zones are defined in ARP 5414/ED91.
- Lightning zones are probable strike areas on a specific aircraft, areas most likely to be hit.
- Zones also define the probability of the type of hit for a specific area.
- Areas appropriate to these zones on a particular aircraft must be agreed upon between the airframe manufacturer and the certifying authority (FAA).



Section 23 -Lightning Direct Effects

High Current Waveforms and Levels

- The natural lightning environment is represented by 4 current test components:

Component A

- 3 test levels
- Rise time (10%-90%) 50 µs.
- 500µs total duration.

Component A – *First Return Stroke Current*

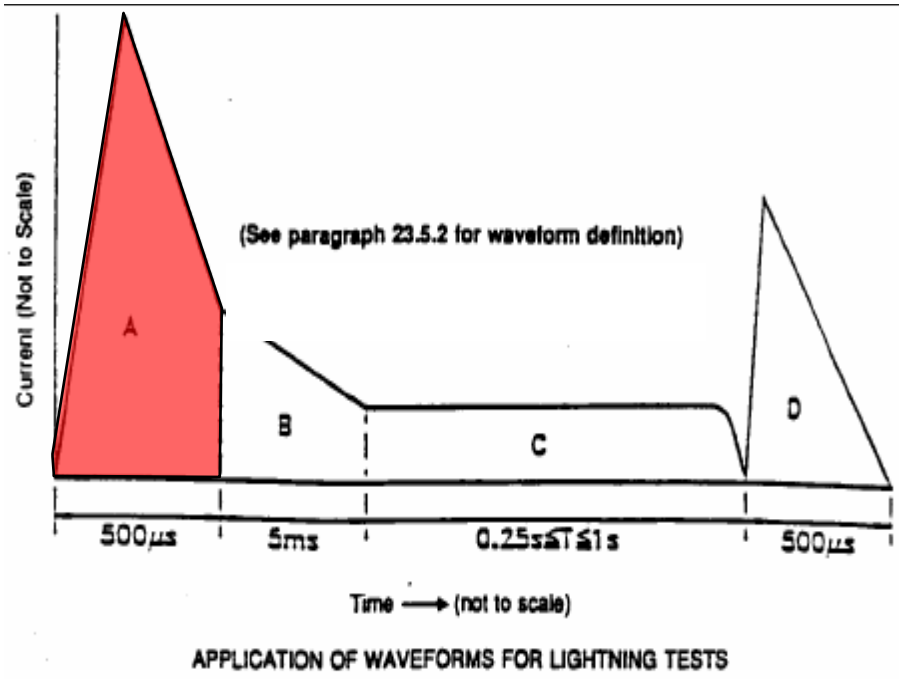
- Peak Amplitude of 200kA ±10%

Component Ah - *Transition Zone Current*

- Peak amplitude of 150 kA ±10 %

Component A5 – *Zone3 Arc Entry*

- Peak amplitude of 400 kA ±10 %



APPLICATION OF WAVEFORMS FOR LIGHTNING TESTS

Zone 3

Intended for equipment which have **new or novel design features** that could significantly reduce the level of protection provided by traditional designs, or which **have no proven service history**.

Section 23 -Lightning Direct Effects

High Current Waveforms and Levels

Component B – *Intermediate Current*

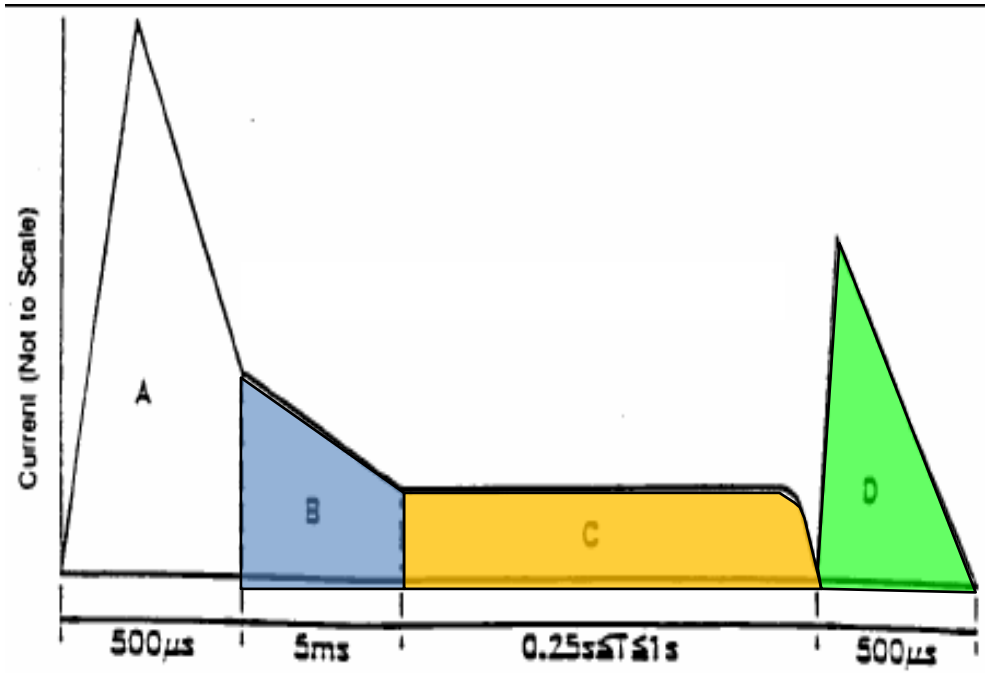
- An average of 2kA ±10%
- Total duration 5 ms.
- Unidirectional, rectangular, exponential, or linearly decaying.

Component C – *Continuing Current*

- A total or 200 coulombs ±20%
- Amplitude 200 to 800 amps
- Between 0.25 and 1 second
- Unidirectional, rectangular, exponential, or linearly decaying.

Component D – *Re-Strike Current*

- Peak Amplitude of 100kA ±10%
- Total duration 500µs.
- Rise time (10%-90%) 25 µs.
- Unidirectional or oscillatory.



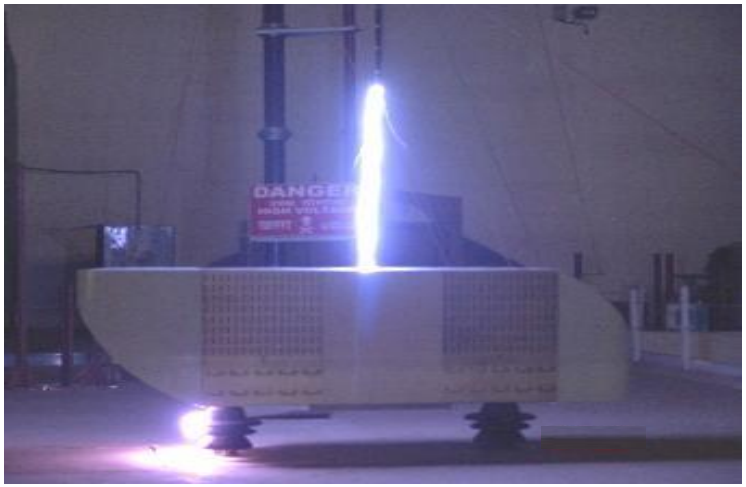
APPLICATION OF WAVEFORMS FOR LIGHTNING TESTS

Section 23 -Lightning Direct Effects

Test Types

- **High Voltage strike**
  - Typically performed first to determine likely attachment & Detachment points on the test object.

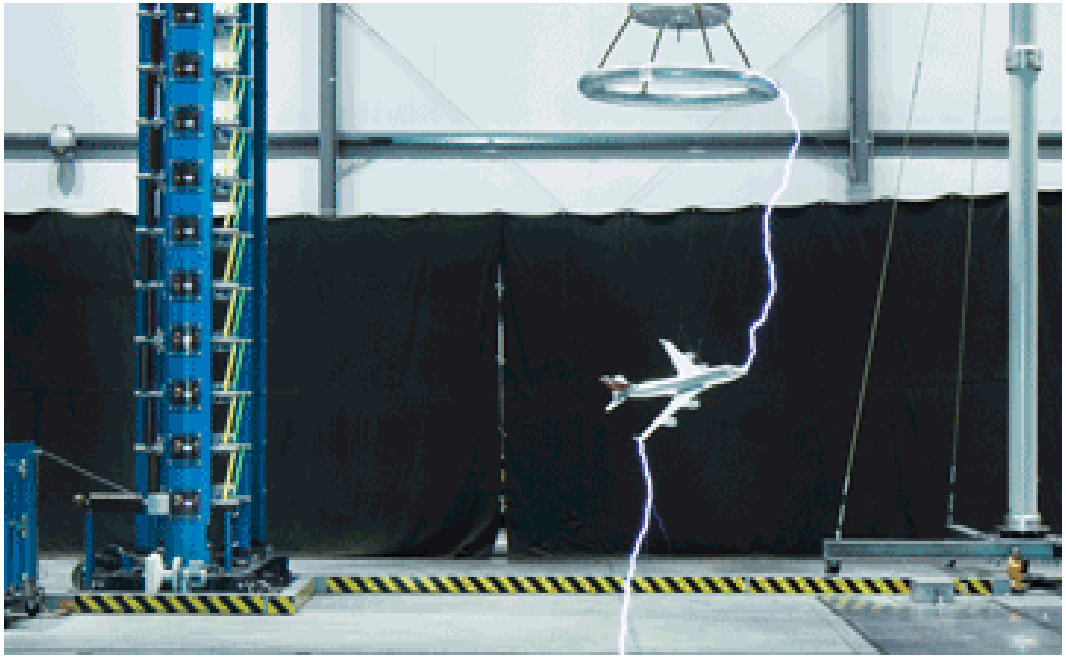
- **High Current physical damage-**
  - Used to evaluate the damage to equipment that may be exposed to the direct injection of Lighting current.
  - *Performed at the locations identified during HV testing.*



NTS

Section 23 -Lightning Direct Effects

High Voltage Testing



- The type of high voltage test performed is dependent upon its test category requirement.

- **Initial leader attachment tests**
  - Determines likely lightning attachment locations for a piece of equipment due to an approaching lightning leader.

- **Swept channel attachment tests**
  - Determines the likely lightning attachment locations for a piece of equipment due to a lightning channel sweeping across equipment.

NTS

Section 23 -Lightning Direct Effects

High Voltage Test Waveforms and Levels

High Voltage Strike Attachment Test Category	Test Type	High Voltage Waveform	
		A	D
1A	Initial Leader Attachment Test (23.4.1.2)		X
1B	Initial Leader Attachment Test (23.4.1.2)		X
1C	Swept Channel Attachment Test (23.4.1.3)	X	
2A	Swept Channel Attachment Test (23.4.1.3)	X	
2B	Swept Channel Attachment Test (23.4.1.3)	X	
3N	Swept Channel Attachment Test (23.4.1.3)	X	

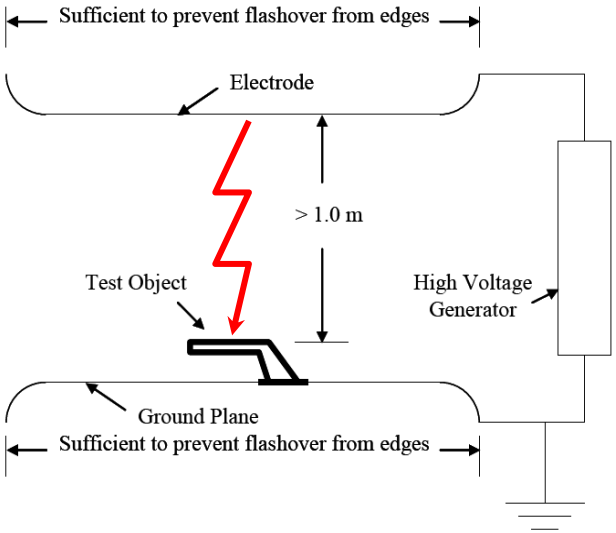
- **Voltage Waveform A**
  - Voltage Waveform A is a voltage rising at the rate of 1000 kV/µs ±50 percent.
  - The rate of rise shall be measured from 30% to 90% of the peak voltage.

- **Voltage Waveform D**
  - Voltage Waveform D is a voltage rising to peak in between 50 µs and 250 µs with a time to 50% of peak of approximately 2000 µs.

Section 23 -Lightning Direct Effects

Initial Leader Test

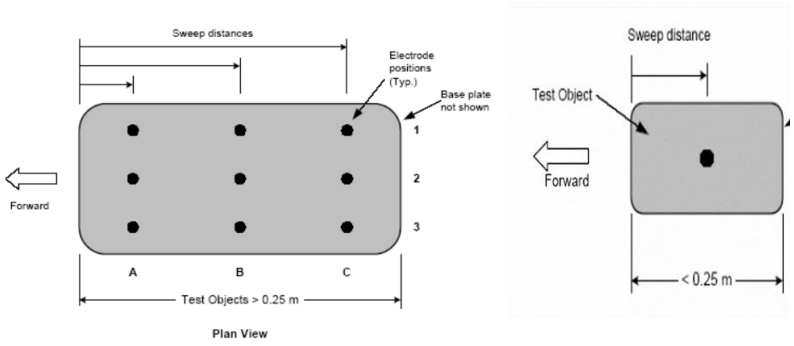
- Identifies likely lightning attachment points on the equipment and breakdown paths across or through the dielectric covers.
- A minimum of two strikes are performed.
  - *Should be performed at different electrode positions.*
- High speed photography and physical inspection techniques are used to determine compliance.

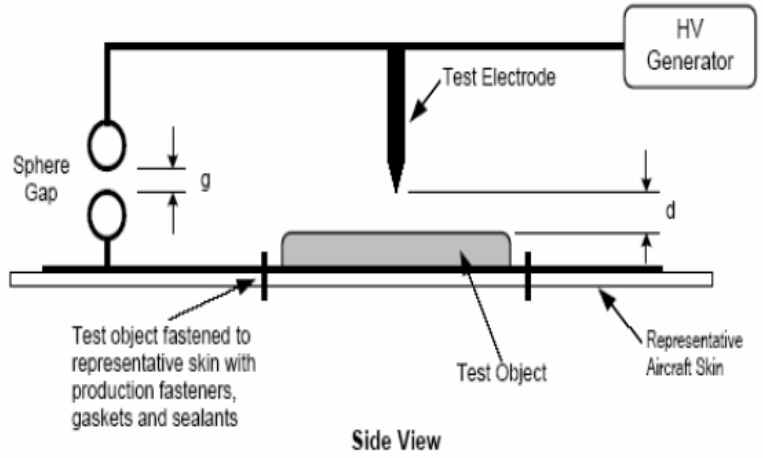


Section 23 -Lightning Direct Effects

Swept Channel Attachment Test

- Determines the likely lightning attachment locations for a piece of equipment due to a lightning channel sweeping across equipment.
    - Test item is placed on a base plate constructed of the same material as the aircraft.
    - Test voltage level is based on 140 kV/m * sweep distance.
    - Spark gap is set to discharge at 120% of the test voltage.
    - Electrode is positioned ≤ 50 mm from the EUT.
    - High speed photography and physical inspection techniques are used to determine compliance.

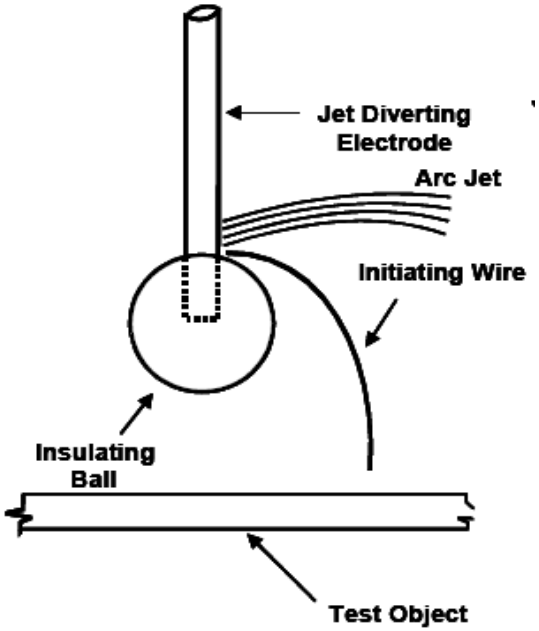




Section 23 -Lightning Direct Effects

Arc Entry Test- High Current

- Used to evaluate the damage to equipment that may be exposed to the direct injection of Lighting current.
- Full scale production or representative prototype testing.
- A “jet-diverting” type electrode is positioned ≥ 50 mm above the area of the test object. This allows lightning currents to be conducted away from the test object in a manner representative of when the aircraft is struck by lightning.



- Alternatively, a salient lead wire (0.1 mm diameter) may be used to direct the arc to a specific point of interest on the test object.

SECTION 25 ELECTROSTATIC DISCHARGE TESTING

A HIGHER STANDARD

TESTING | INSPECTION | CERTIFICATION

NTS

Section 25 –Electrostatic Discharge (ESD)

- Evaluates the EUT's ability to withstand static electricity discharges from human contact.

- The equipment performance shall not be permanently degraded or suffer damage as a result of air ESD.

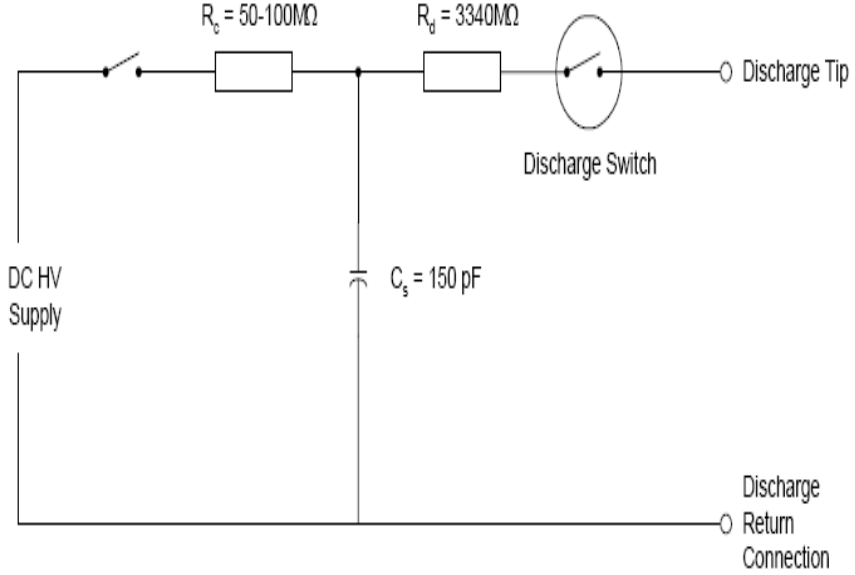
Category A Equipment

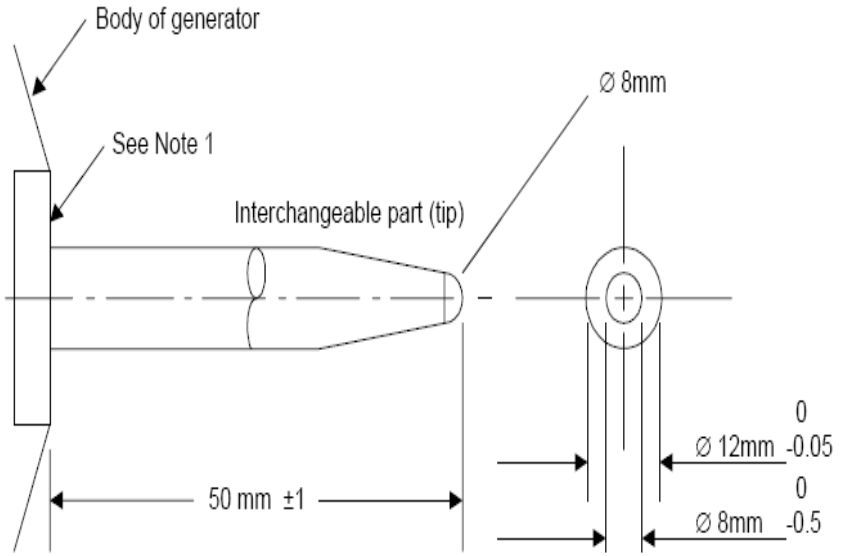
- ESD testing is applicable to all equipment installed, repaired, or operated in an aerospace environment.

Section 25 –Electrostatic Discharge (ESD)

Generator

- The generator is fitted with a beveled air discharge tip that simulates the tip of a finger.
- The generator utilizes a resistive/capacitive “RC” network (330 Ω (±20%) 150pF (±20%)) which is representative of a human body.

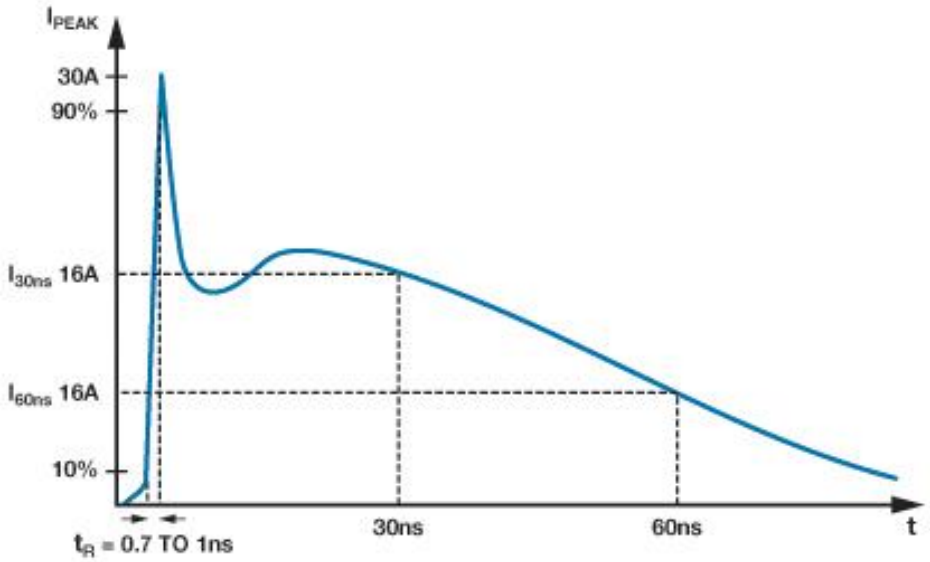




Section 25 –Electrostatic Discharge (ESD)

ESD Waveform

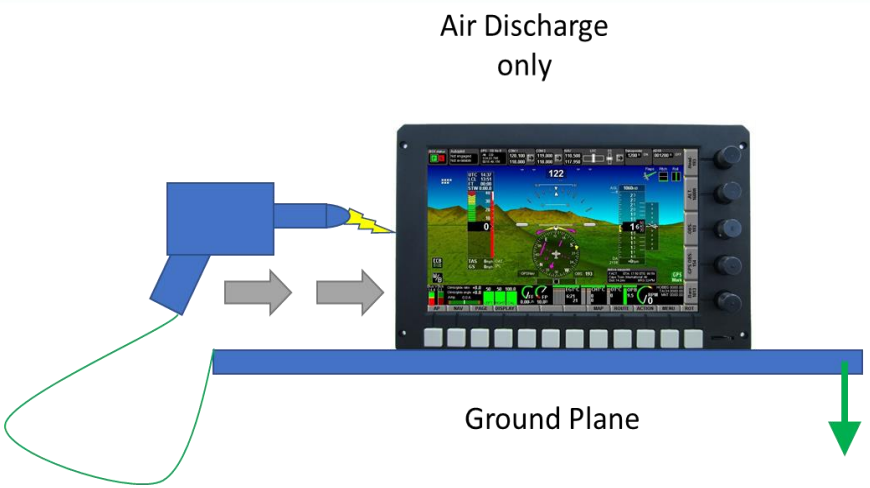
- Four ESD current waveform parameters are checked as part of the ESD gun Calibration routine to ensure the proper amount of energy will be delivered to each test point.
  - Rise time (between 10% and 90%).
  - First peak current
  - Current Peak at 30 ns
  - Current peak at 60 ns



Section 25 –Electrostatic Discharge (ESD)

Testing

- EUT is bonded to the ground plane as to replicate its intended installation practices.
- The ESD generator is moved towards the EUT at a rate of 0.3 m/sec to emulate the speed of a typical hand.
- 10 repetitions +/- 15 kV air discharges (each polarity) will be applied to all test points.
- In the event of no discharge, another test point in the area will be selected.
- ESD test locations are selected based on points and surfaces accessible by personnel during normal operation as installed in the aircraft only



THANK YOU
FOR YOUR TIME!

A HIGHER STANDARD

TESTING | INSPECTION | CERTIFICATION

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

NTS