IEEE EMC Society
Plano, TX
January 15, 2008

MIL-STD-461E/F

MIL-STD-461E/F

- MIL-STD-461 provides limits
  - Original issue 1967
  - 416A 1973 minor changes
  - 461B 1980 minor changes
  - 461C 1986 added EMP (Electro Magnetic Pulse)
  - 461 D 1994 major change no Narrow or Broad Band
  - 461E 1999 combined with 462
  - 461F 2007

MIL-STD-461E/F

- MIL-STD-462 provides test methods
- 462 changed by Notices
- Each service had their own Notice
  - Notice 1 General 1968
  - Notice 2 Air Force 1970
  - Notice 3 Army 1971
  - Notice 4 Navy 1980
  - Notice 5 Navy 1986
  - Notice 6 Air Force 1987

MIL-STD-461E/F

- When 461D was developed 462 was updated to 462D (no 462 A,B, or C)
- 461/462D eliminated Notices
- 461/462D added appendix
- 461E pulled 462 into same document
- We will discuss 461E (very similar to 461/462D)
- MIL-STD-461F date Dec. 2007
- Expect “G” version in a year – ESD and Lightning

MIL-STD-461E/F

- Facility Requirements
  - Absorbers required
  - Frequency Minimum absorption
  - 80 MHz - 250 MHz - 6 dB
  - Above 250 MHz - 10 dB
  - Shielded room and ground plane
  - Must meet setup and antenna position requirements

MIL-STD-461E/F

- Facility Requirements
  - Ambient 6 db below limit
  - Ground plane 2.25 sq. m (>76 cm)
  - LISNs (Line Impedance Stabilization Network) (50 uH) (older versions have 10uF feedthrough & 5 uH)
  - EUT (Equipment Under Test) in contact w/ground plane
  - Cables actual length (if > than 10 m then use 10m; if unknown use 2 m)
  - 5 cm above ground; 10 cm from edge

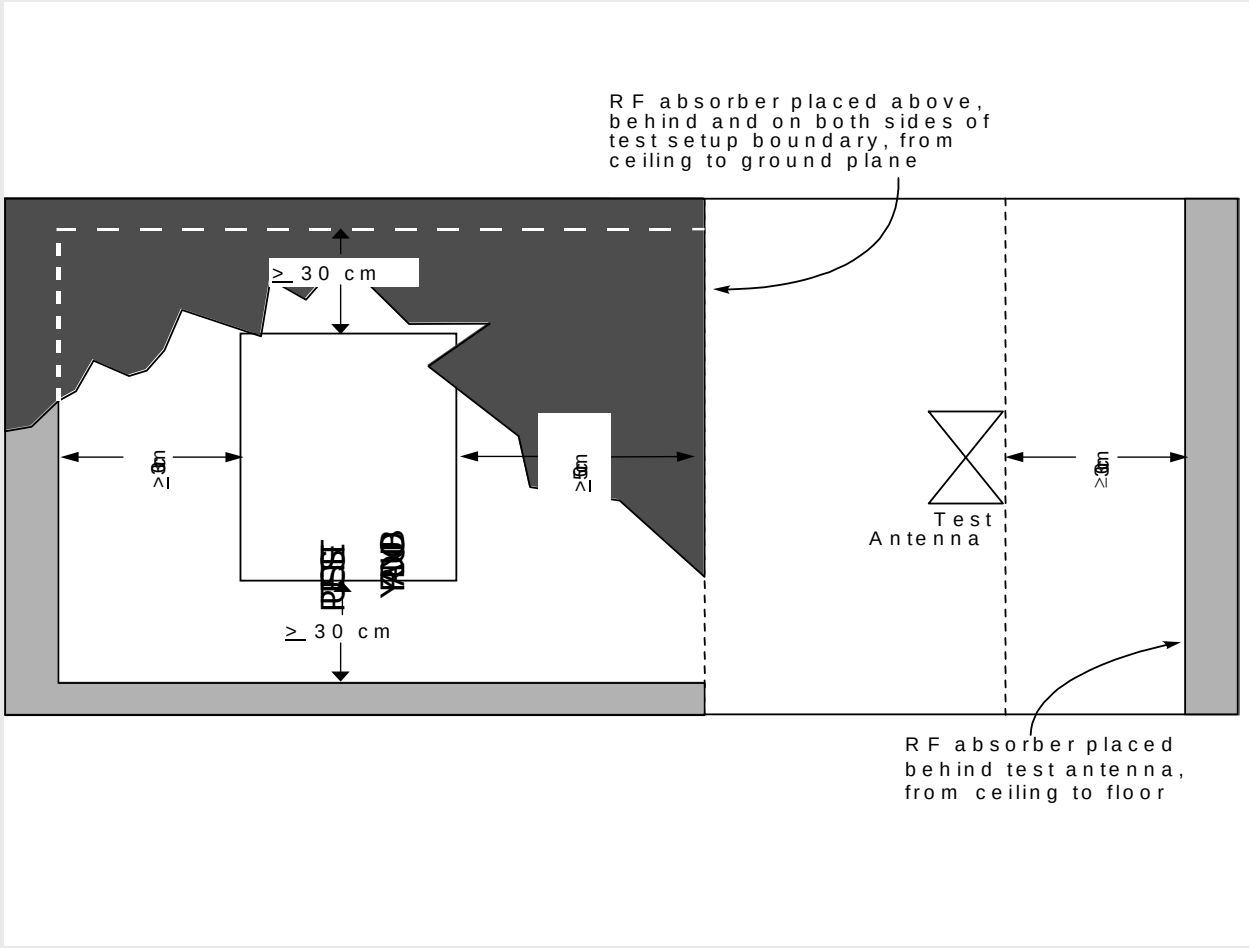
MIL-STD-461E/F

- EUT Operation
  - Test Plan is required
  - Most susceptible and maximum emissions mode defined
  - Multiple modes may be required
  - Operation plan must be justified
  - Frequency tuning for transmitters and receivers
  - Susceptibility monitoring method described in test plan

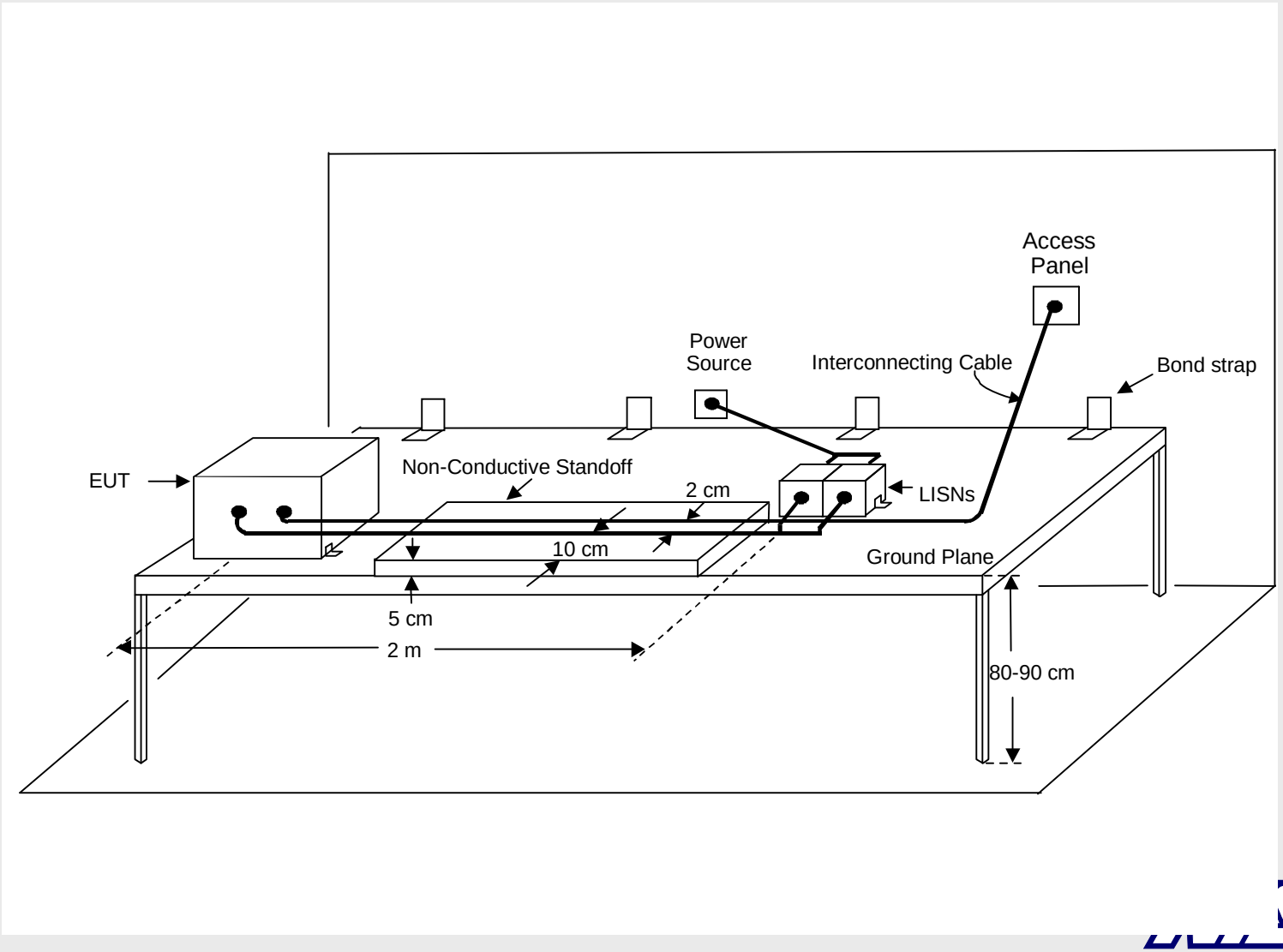
MIL-STD-461E/F

- Equipment Required
  - Analyzer per ANSI C63.2 (CISPR 16)
  - Peak Detector (no quasi-peak)
  - 6 dB RBW Filter (higher RBW allowed but no limit change)
  - Receiver software described in Test Plan
  - Emission plots required in Test Report

MIL-STD-461E/F
Facility



MIL-STD-461E/F
Test Setup



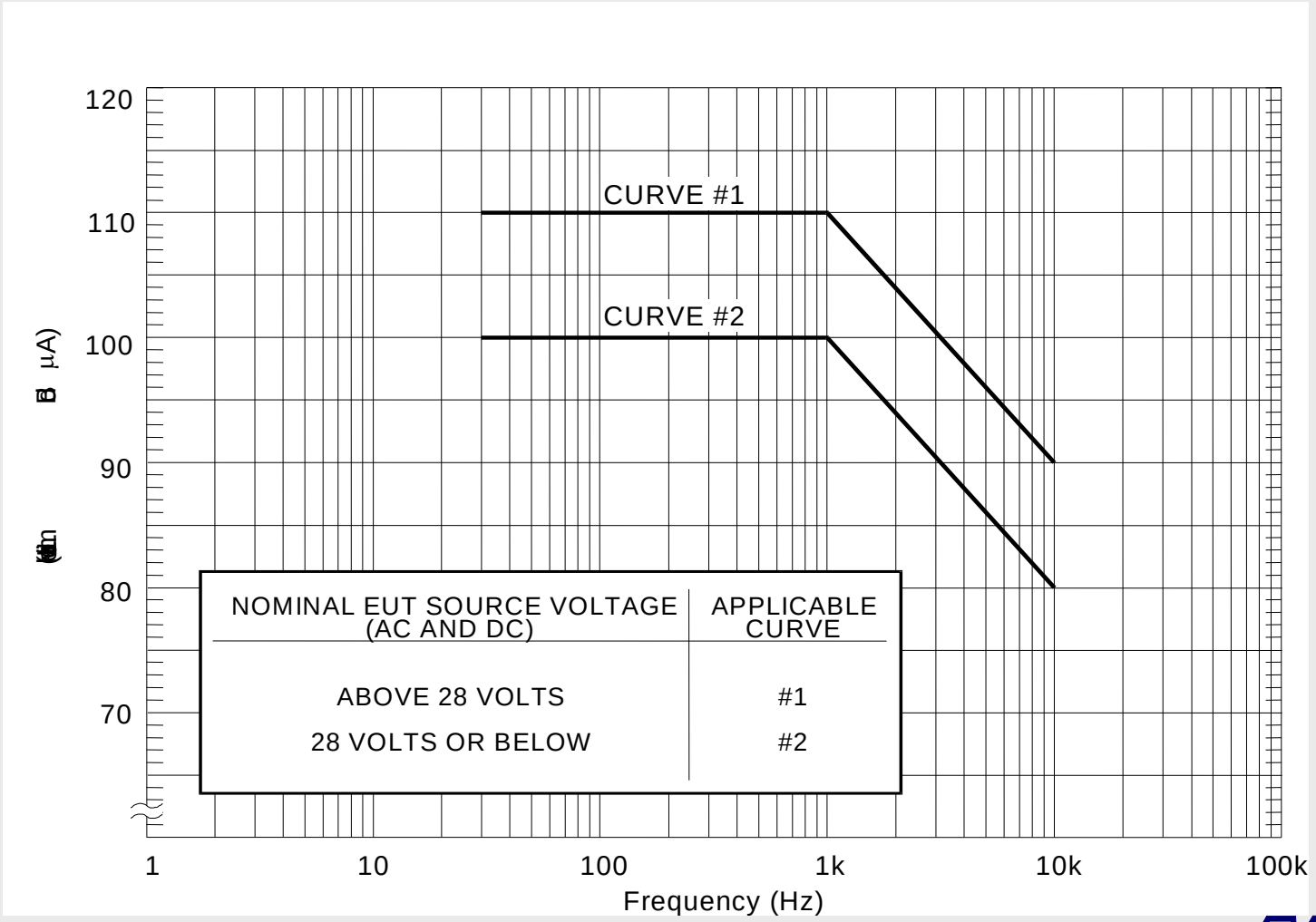
MIL-STD-461E/F Tests

Requirement	Description
CE101	Conducted Emissions, Power Leads, 30 Hz to 10 kHz
CE102	Conducted Emissions, Power Leads, 10 kHz to 10 MHz
CE106	Conducted Emissions, Antenna Terminal, 10 kHz to 40 GHz
CS101	Conducted Susceptibility, Power Leads, 30 Hz to 150 kHz
CS103	Conducted Susceptibility, Antenna Port, Intermodulation, 15 kHz to 10 GHz
CS104	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals, 30 Hz to 20 GHz
CS105	Conducted Susceptibility, Antenna Port, Cross-Modulation, 30 Hz to 20 GHz
CS109	Conducted Susceptibility, Structure Current, 60 Hz to 100 kHz
CS114	Conducted Susceptibility, Bulk Cable Injection, 10 kHz to 400 MHz
CS115	Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation
CS116	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads, 10 kHz to 100 MHz
RE101	Radiated Emissions, Magnetic Field, 30 Hz to 100 kHz
RE102	Radiated Emissions, Electric Field, 10 kHz to 18 GHz
RE103	Radiated Emissions, Antenna Spurious and Harmonic Outputs, 10 kHz to 40 GHz
RS101	Radiated Susceptibility, Magnetic Field, 30 Hz to 100 kHz
RS103	Radiated Susceptibility, Electric Field, 10 kHz to 40 GHz
RS105	Radiated Susceptibility, Transient Electromagnetic Field

MIL-STD-461E/F

- Requirements CE101
  - Conducted Emissions (CE) low frequency 30 Hz – 10 kHz (power leads only)
  - Test is to verify that the Equipment Under Test (EUT) does not conduct electrical noise above the specified limit onto the power buss in the 30 Hz – 10 kHz frequency range
  - Measured in dBuA using a current probe and spectrum analyzer

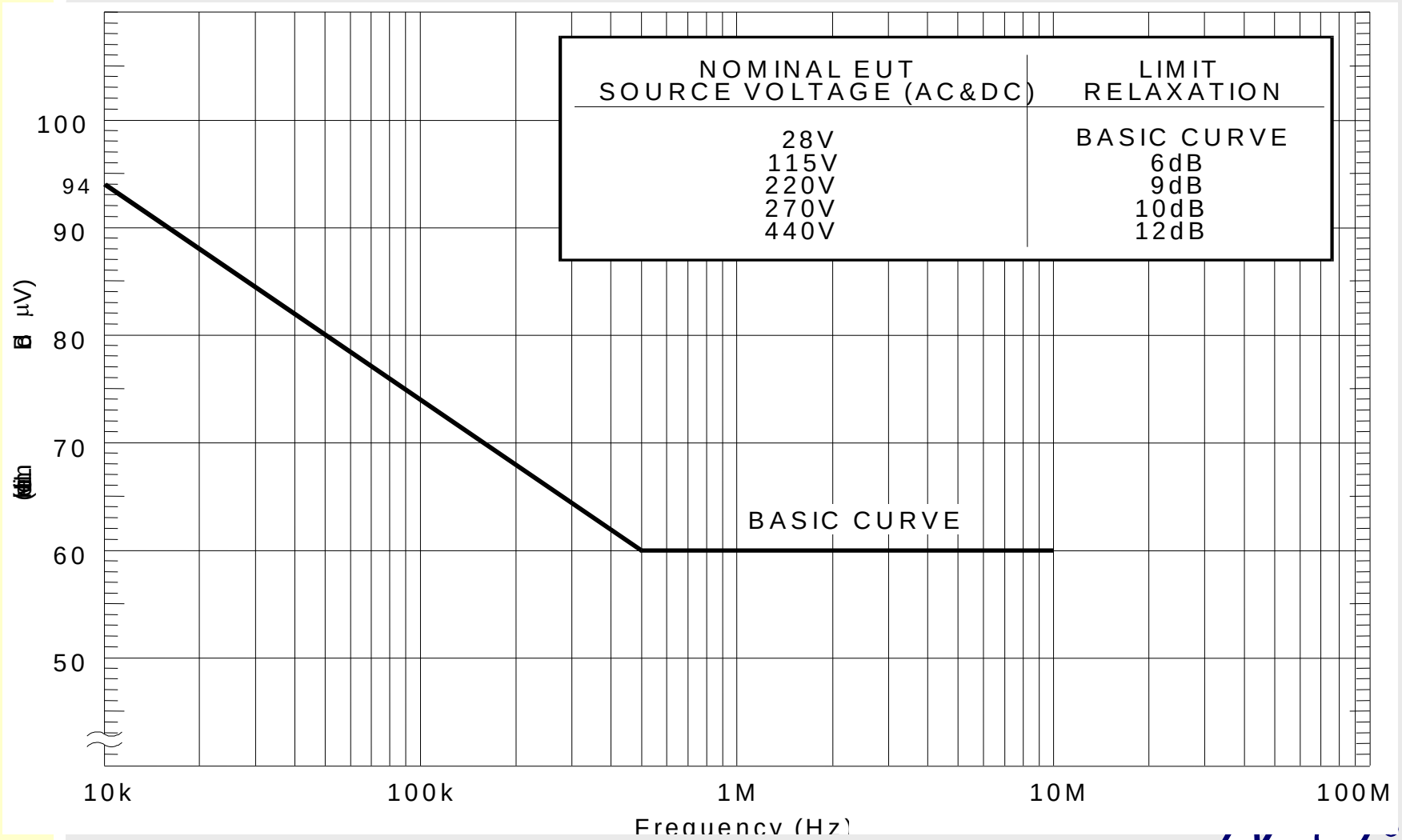
MIL-STD-461E/F
Limit (Typical) CE101



MIL-STD-461E/F

- Requirements CE102
  - Conducted Emissions (CE) - high frequency 10 kHz – 30 MHz (power leads)
  - Test is to verify that the Equipment Under Test (EUT) does not conduct electrical noise above the specified limit onto the power buss in the 10 kHz – 30 MHz frequency range
  - Measured in dBuV using a voltage probe, Line Impedance Stabilization Network (LISN) and spectrum analyzer

MIL-STD-461E/F
Limit (Typical) CE102



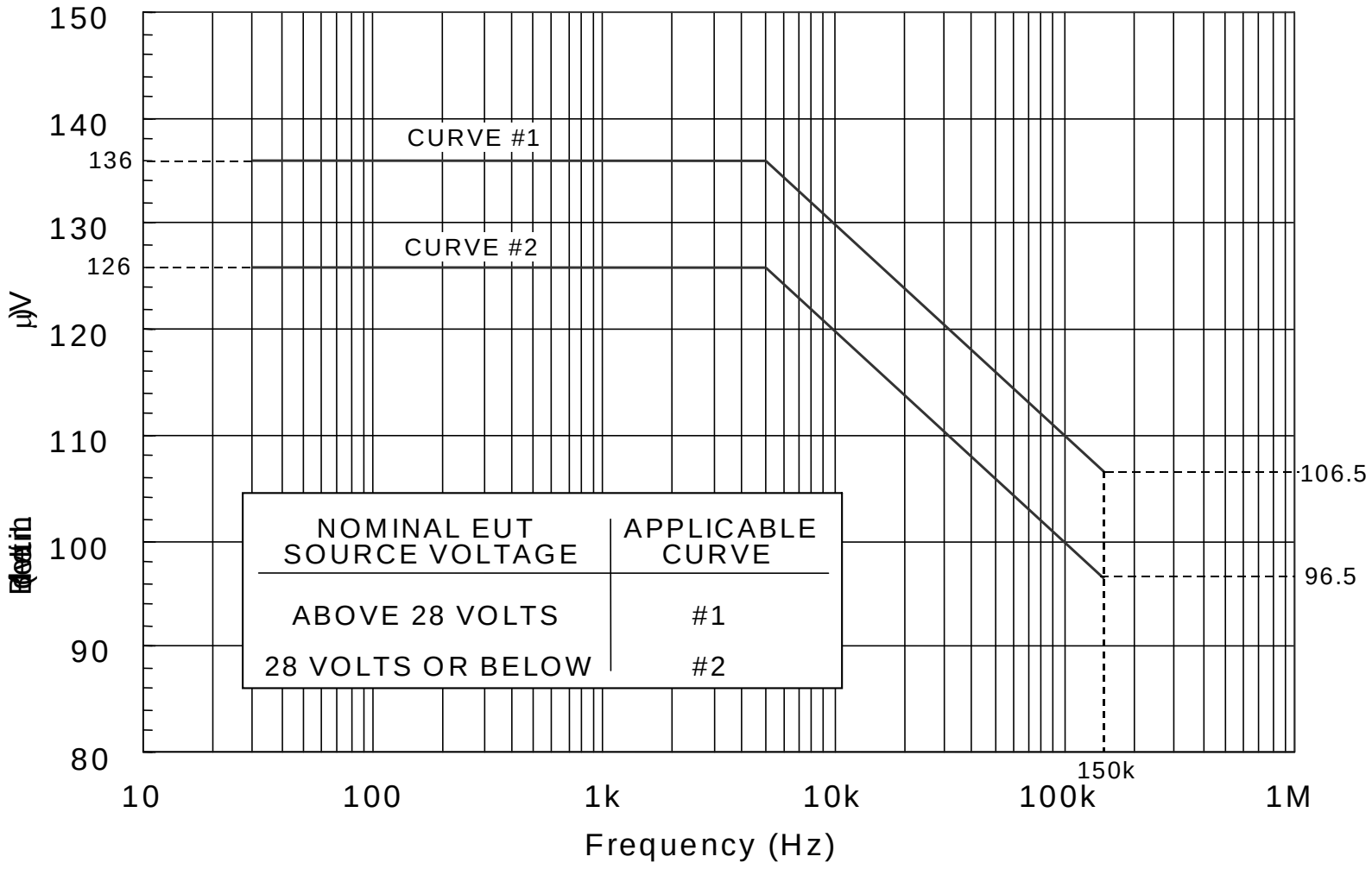
MIL-STD-461E/F

- Requirements CE 106
  - Applicable to transmitters, receivers & RF amplifiers
  - Test is to verify that the (EUT) does not conduct electrical noise above the limit onto antenna ports in the 10 kHz – 40 GHz frequency range
  - Measured in dBuV using a spectrum analyzer

MIL-STD-461E/F

- Requirements CS101
  - Conducted Susceptibility (CS) - Low frequency 30 Hz – 150 kHz (power leads)
  - Test is to verify that the (EUT) can operate safely when conduct electrical noise is injected onto the power buss in the 30 Hz – 150 kHz frequency range
  - Limit in dBuV
  - Performed using a signal generator, audio amplifier, voltage probe and oscilloscope

MIL-STD-461E/F
Limit (Typical) CS101



MIL-STD-461E/F

- CS103 – antenna port intermodulation
- CS104 – antenna port rejection of undesirable signal
- CS105 – antenna port cross modulation
- No test methods – case-by-case basis
- See appendix in Mil-Std 461E for guidance
- Unit specific

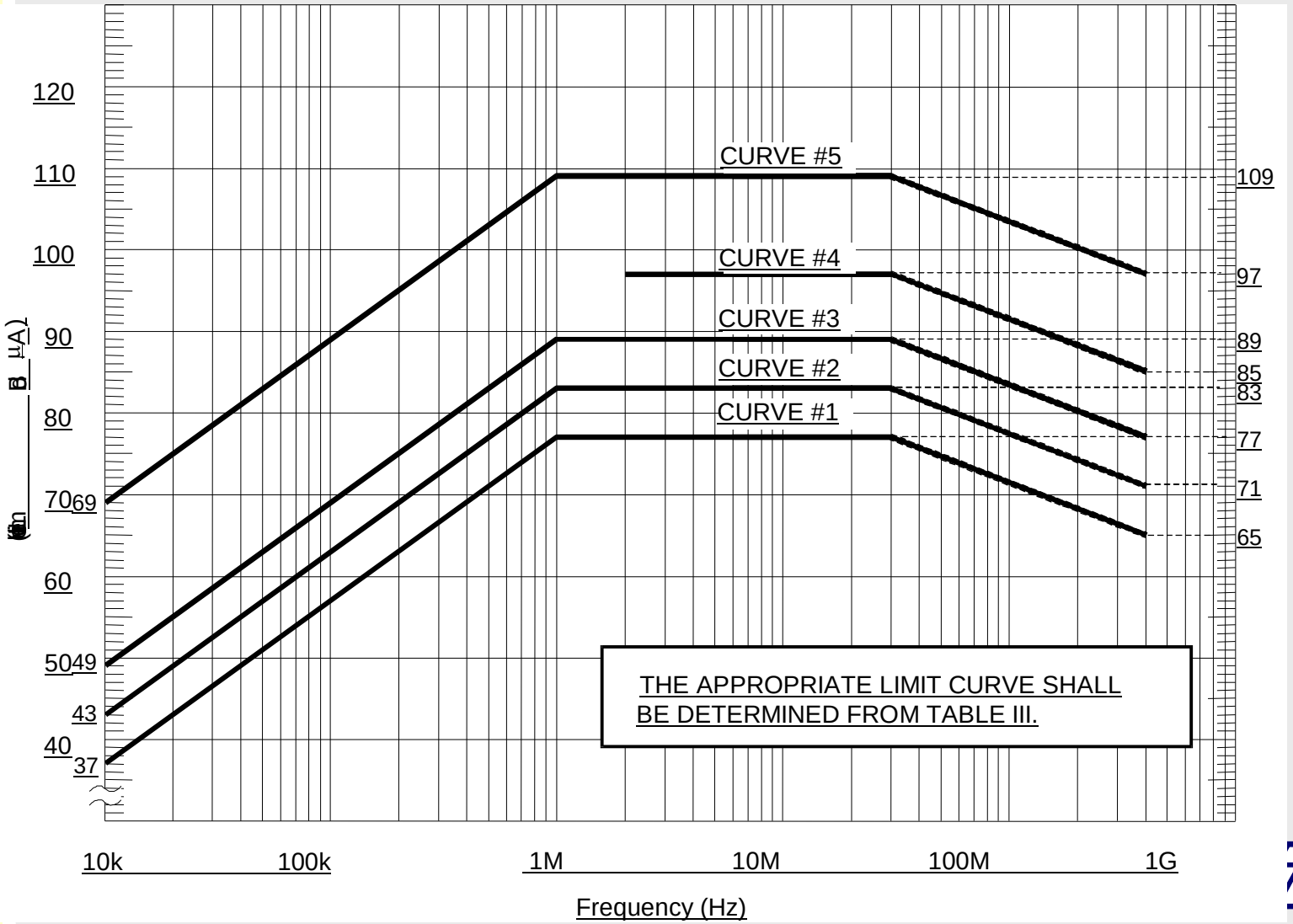
MIL-STD-461E/F

- Requirements CS109 (Not used on NYCT)
  - Conducted Susceptibility (CS) - structure currents 60 Hz – 100 kHz (submarines and low frequency application only)
  - Test is to verify that the (EUT) can operate safely when conducted electrical noise is injected onto the chassis in the 60 Hz – 100 kHz frequency range
  - Limit in dBuA
  - Performed using a signal generator, audio amplifier, current probe and oscilloscope

MIL-STD-461E/F

- Requirements CS114
  - Conducted Susceptibility (CS) - bulk cable (all leads) 10 kHz – 200 MHz (some Equipment Requirements go to 400 MHz)
  - Test is to verify that the (EUT) can operate safely when conducted electrical noise is injected onto the power buss and all signal lines (metallic) in the 10 kHz – 200 MHz frequency range
  - Limit in dBuA
  - Performed using a signal generator, RF power amplifier, coupling probe, power meter, directional coupler and spectrum analyzer

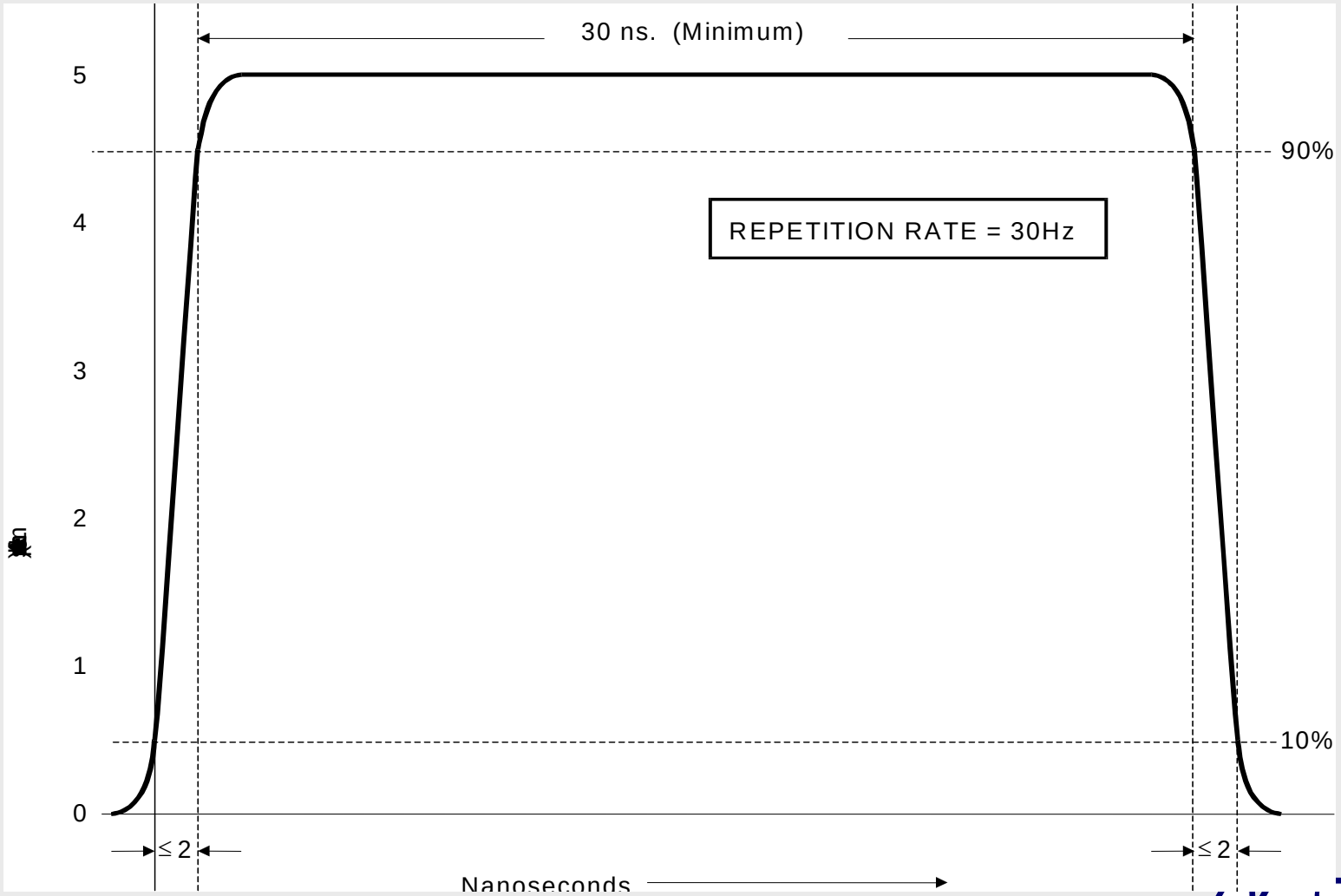
MIL-STD-461E/F
Limit CS114



MIL-STD-461E/F

- Requirements CS115
  - Conducted Susceptibility (CS) - bulk cable (all leads) impulse
  - Test is to verify that the (EUT) can operate safely when conducted electrical transient noise is injected onto the power buss and all signal lines (metallic).
  - Transient is a pulse with 2 ns rise and fall and a 30 ns width
  - Limit in A & V
  - Performed using a pulser, voltage probe and oscilloscope

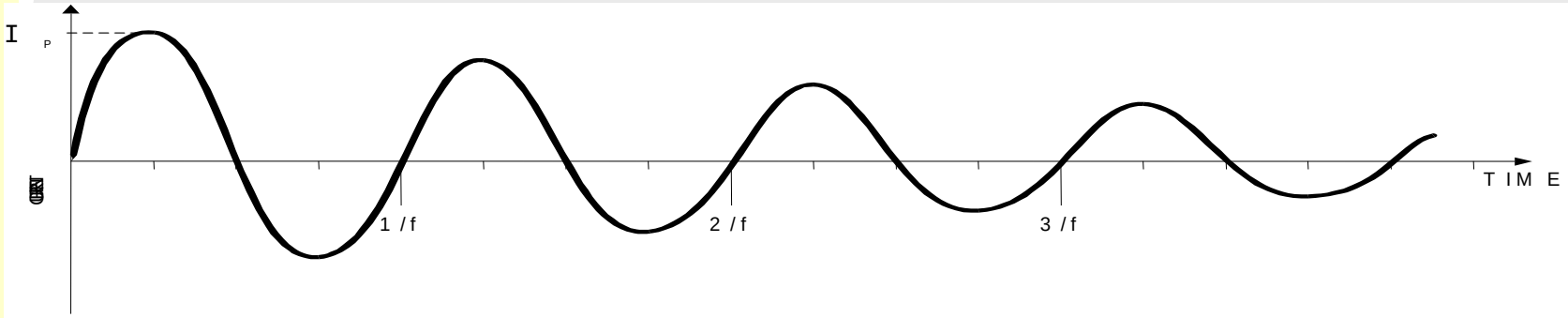
MIL-STD-461E/F
Limit CS115



MIL-STD-461E/F

- Requirements CS116
  - Conducted Susceptibility (CS) - damped sine (all leads) impulse
  - Test is to verify that the (EUT) can operate safely when conducted transient electrical noise is injected onto the power buss and all signal lines (metallic). Transient is a damped sine wave
  - Limit in A
  - Performed using a pulser, coupler, current probe, and oscilloscope

MIL-STD-461E/F
Limit CS116



NOTES:

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

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

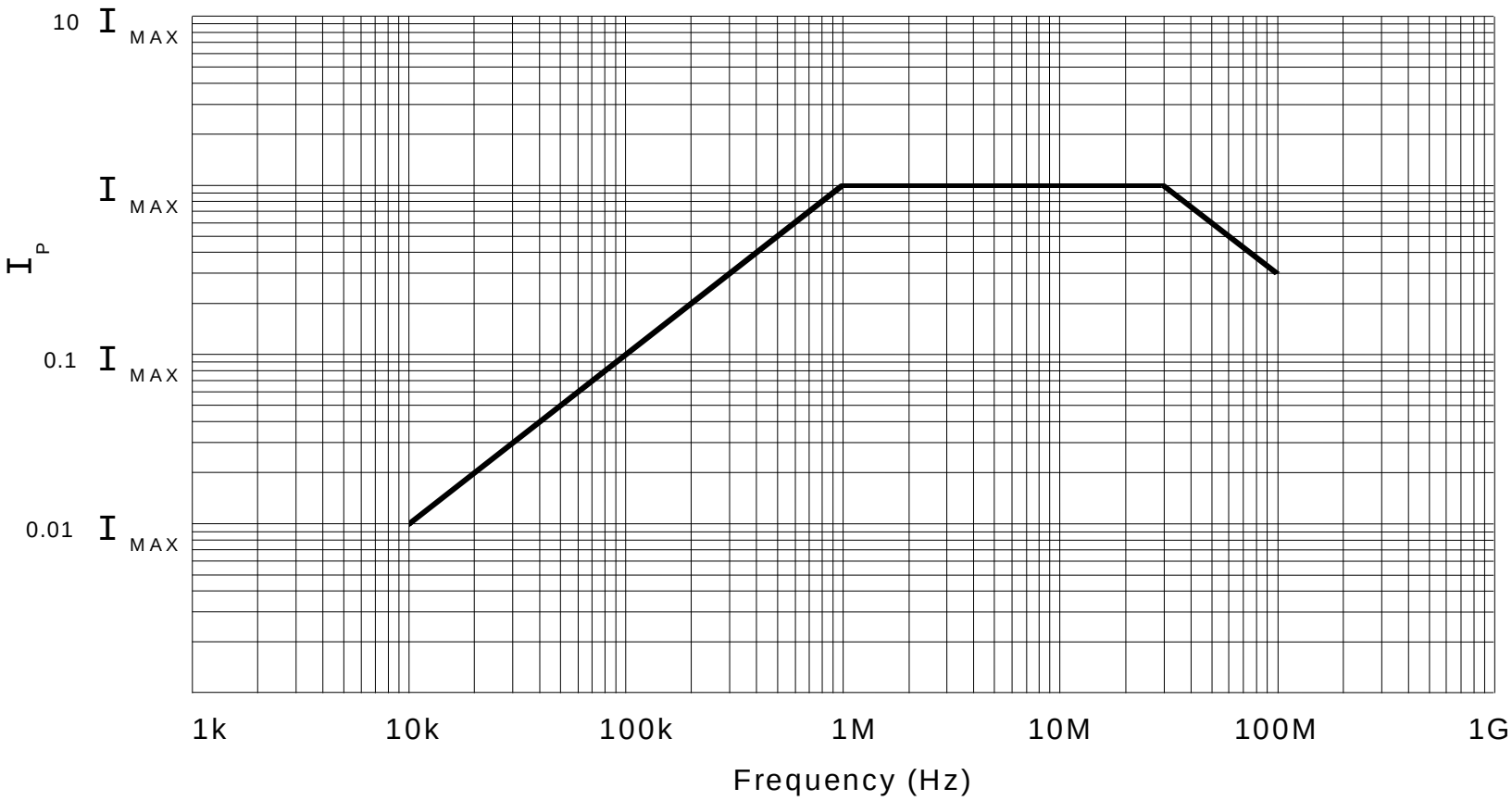
2. Damping factor (Q) shall be determined as follows

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

   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 Nth cycle
   ln = Natural log

3. I_P as per figure CS116-2

MIL-STD-461E/F
Limit CS116



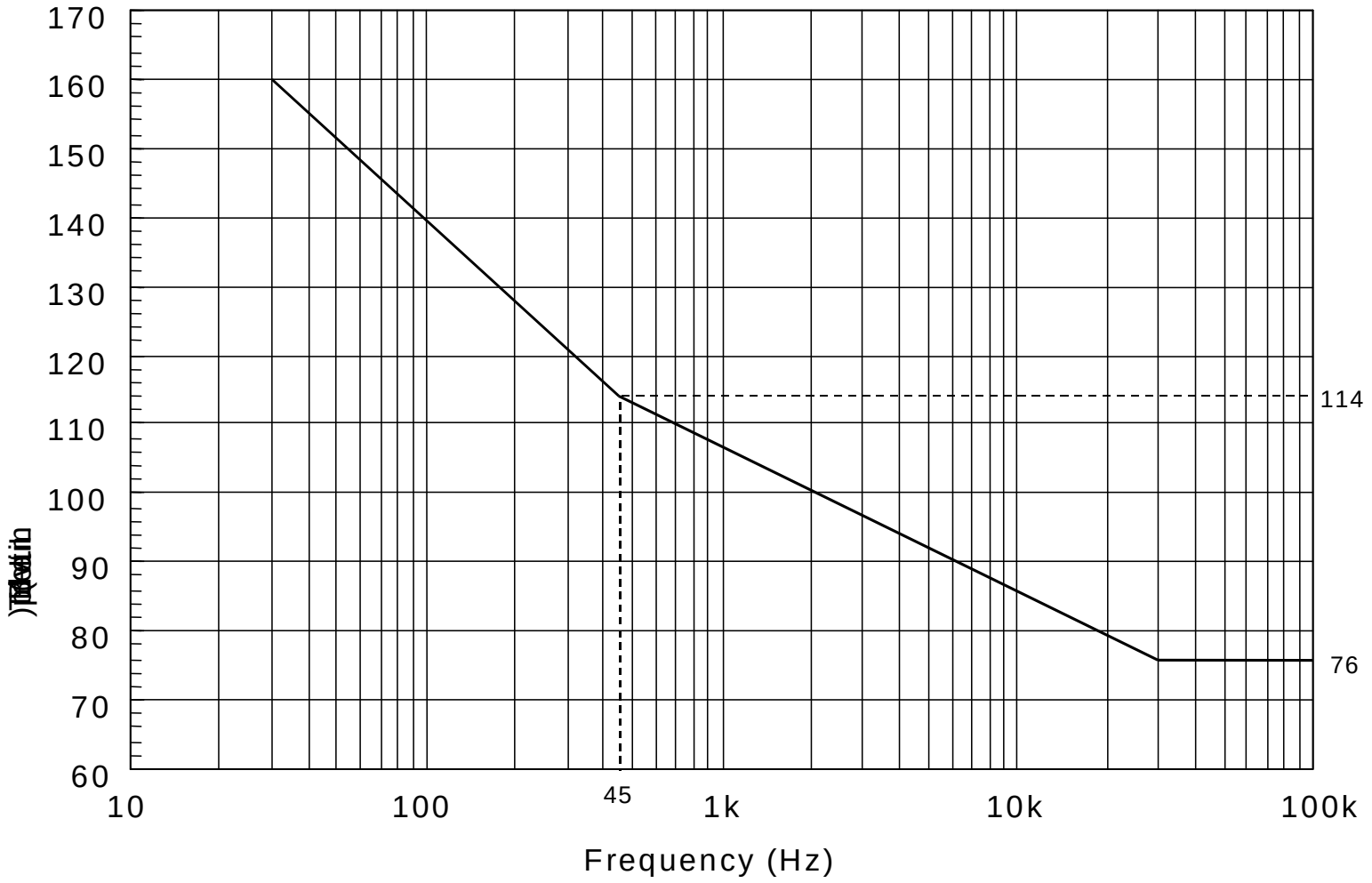
NOTES:

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

MIL-STD-461E/F

- Requirements RE101
  - Radiated Emissions (RE) - magnetic field 30 Hz – 100 kHz
  - Test is to verify that the (EUT) does not radiate magnetic noise above the limit in the 30 Hz – 100 kHz frequency range
  - Measured in dBpT (unit of Magnetic density)
  - Performed using a loop antenna and spectrum analyzer

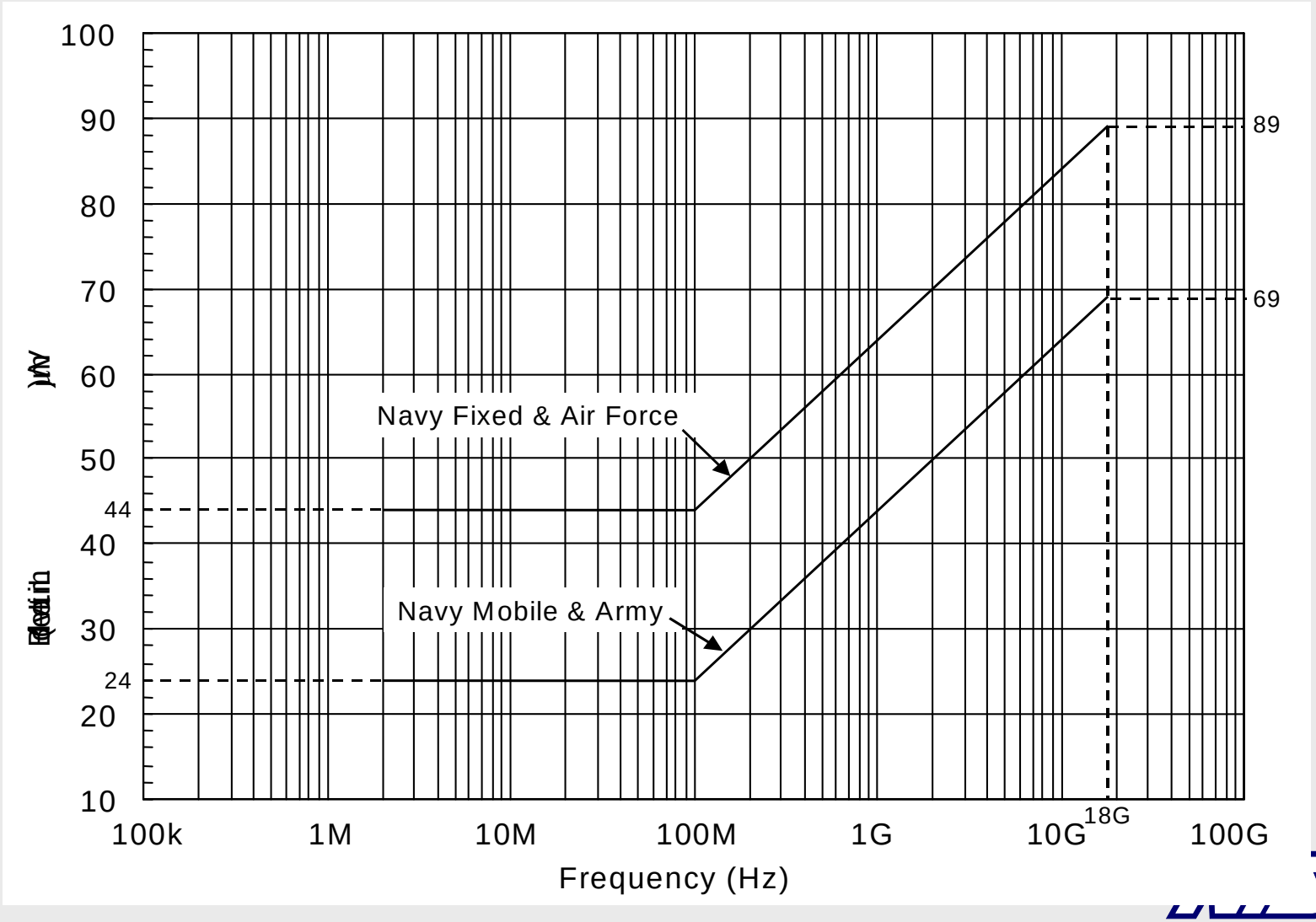
MIL-STD-461E/F
Limit(Typical) RE101



MIL-STD-461E/F

- Requirements RE102
  - Radiated Emissions (RE) - Electric field 10 kHz – 40 GHz
  - Test is to verify that the (EUT) does not radiate electrical noise above the limit in the 10 kHz – 40 GHz frequency range
  - Measured in dBuV/m
  - Performed using five or six antennas (to cover full range) and spectrum analyzer

MIL-STD-461E/F
Limit(Typical) RE102



MIL-STD-461E/F

- Requirements RE 103
- Rarely performed – use CE106

MIL-STD-461E/F

- Requirements RS101
  - Radiated Susceptibility (RS) - Magnetic field 30 Hz – 100 kHz
  - Test is to verify that the (EUT) can operate with radiated magnetic noise in the 30 Hz – 100 kHz frequency range
  - Unit is dBpT (unit of Magnetic density)
  - Performed using a loop antenna and spectrum analyzer

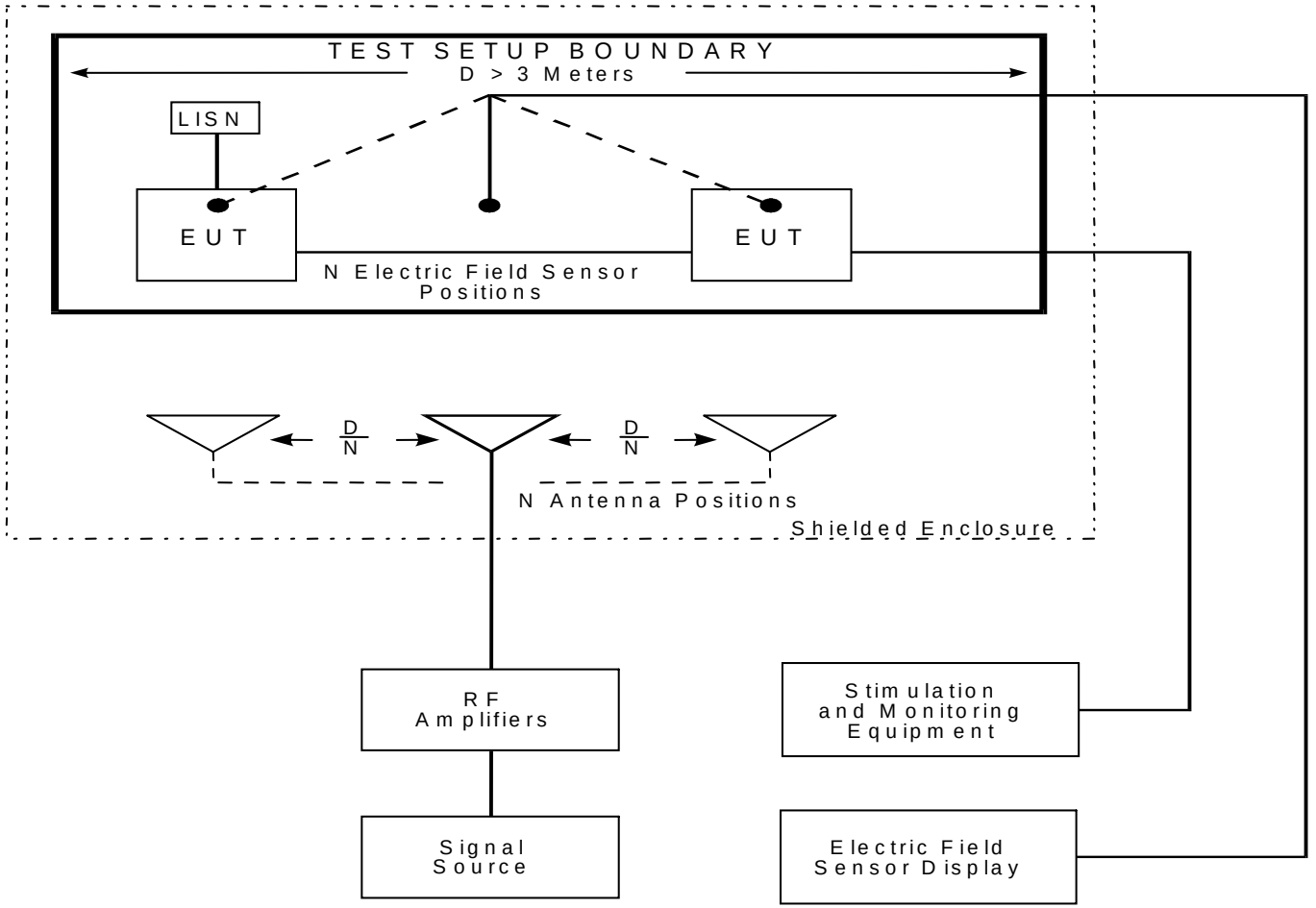
MIL-STD-461E/F

- Requirements RS103
  - Radiated Susceptibility (RS) - electric field 2 MHz – 40 GHz
  - Test is to verify that the EUT can operate with radiated electrical noise in the 2 MHz – 40 GHz frequency range (if CS114 is performed)
  - Unit is V/m
  - Performed using various RF power amplifiers, antennas, and field sensors

MIL-STD-461E/F

- Verification RS103
  - Verification is accomplished during testing
  - Place field sensor 1 m from Transmit antenna and at least 30 cm above the ground plane
  - Do not place at edge of EUT boundary
  - Produce field required by limit and sweep thru a section of frequency
  - Note gain required to meet level

MIL-STD-461E/F
Test RS103 > 3 m



MIL-STD-461E/F
Limit RS103

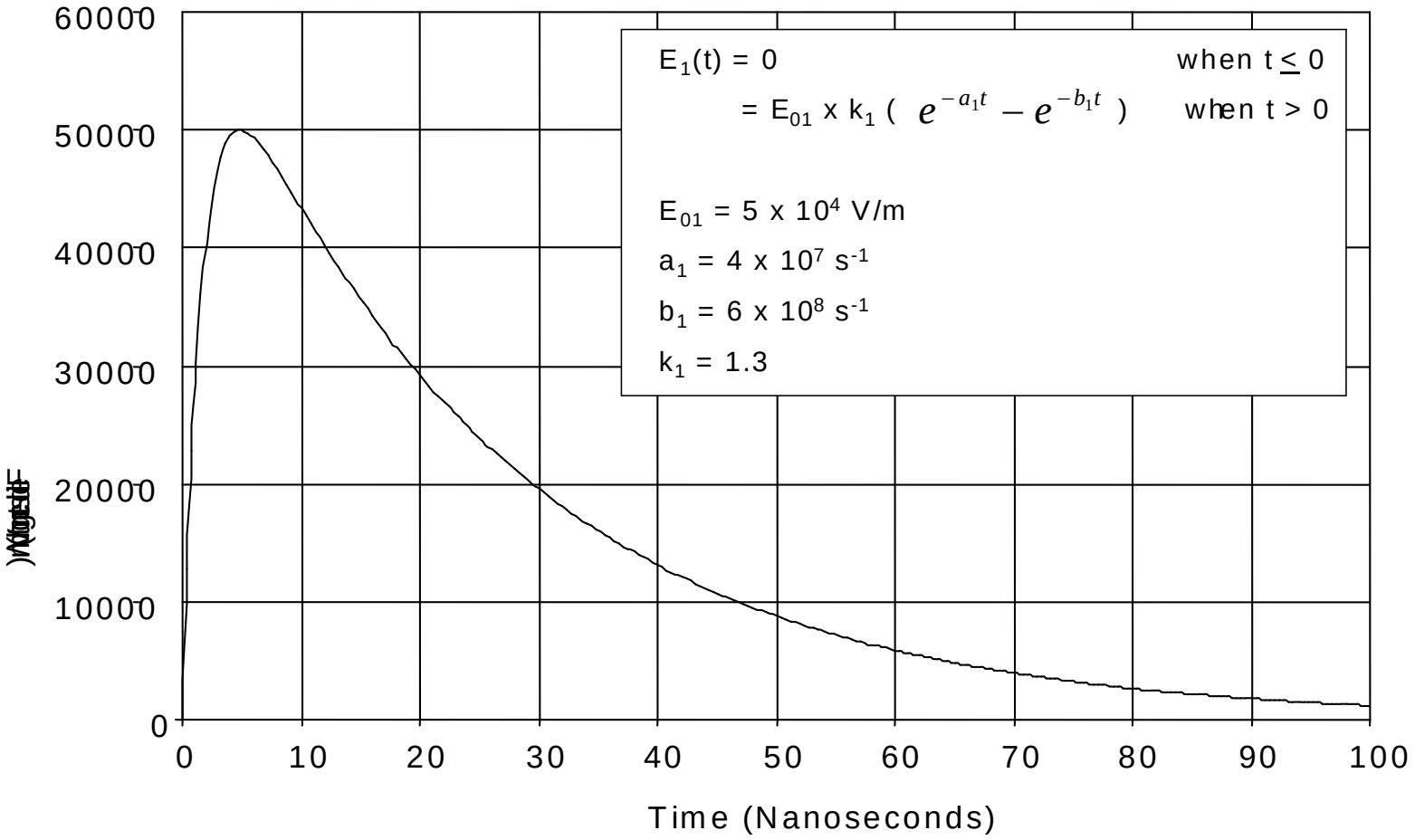
FREQ. RANGE / PLATFORM		LIMIT LEVEL (VOLTS/METER)							
		AIRCRAFT (EXTERNAL OR SAFETY CRITICAL)	AIRCRAFT INTERNAL	ALL SHIPS (ABOVE DECKS)	SHIPS (METALLIC) (BELOW DECKS)	SHIPS (NON-METALLIC) (BELOW DECKS)	SUB-MARINES	GROUND	SPACE
10 kHz	A	200	200	10	10	10	5	20	20
↓	N	200	20	10	10	10	5	10	20
2 MHz	AF	200	20	-	-	-	-	10	20
2 MHz	A	200	200	200	10	50	5	50	20
↓	N	200	200	200	10	50	5	10	20
30 MHz	AF	200	20	-	-	-	-	10	20
30 MHz	A	200	200	200	10	10	5	50	20
↓	N	200	200	200	10	10	5	10	20
1 GHz	AF	200	20	-	-	-	-	10	20
1 GHz	A	200	200	200	10	10	5	50	20
↓	N	200	200	200	10	10	5	50	20
18 GHz	AF	200	60	-	-	-	-	50	20
18 GHz	A	200	200	200	10	10	5	50	20
↓	N	200	60	200	10	10	5	50	20
40 GHz	AF	200	60	-	-	-	-	50	20

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

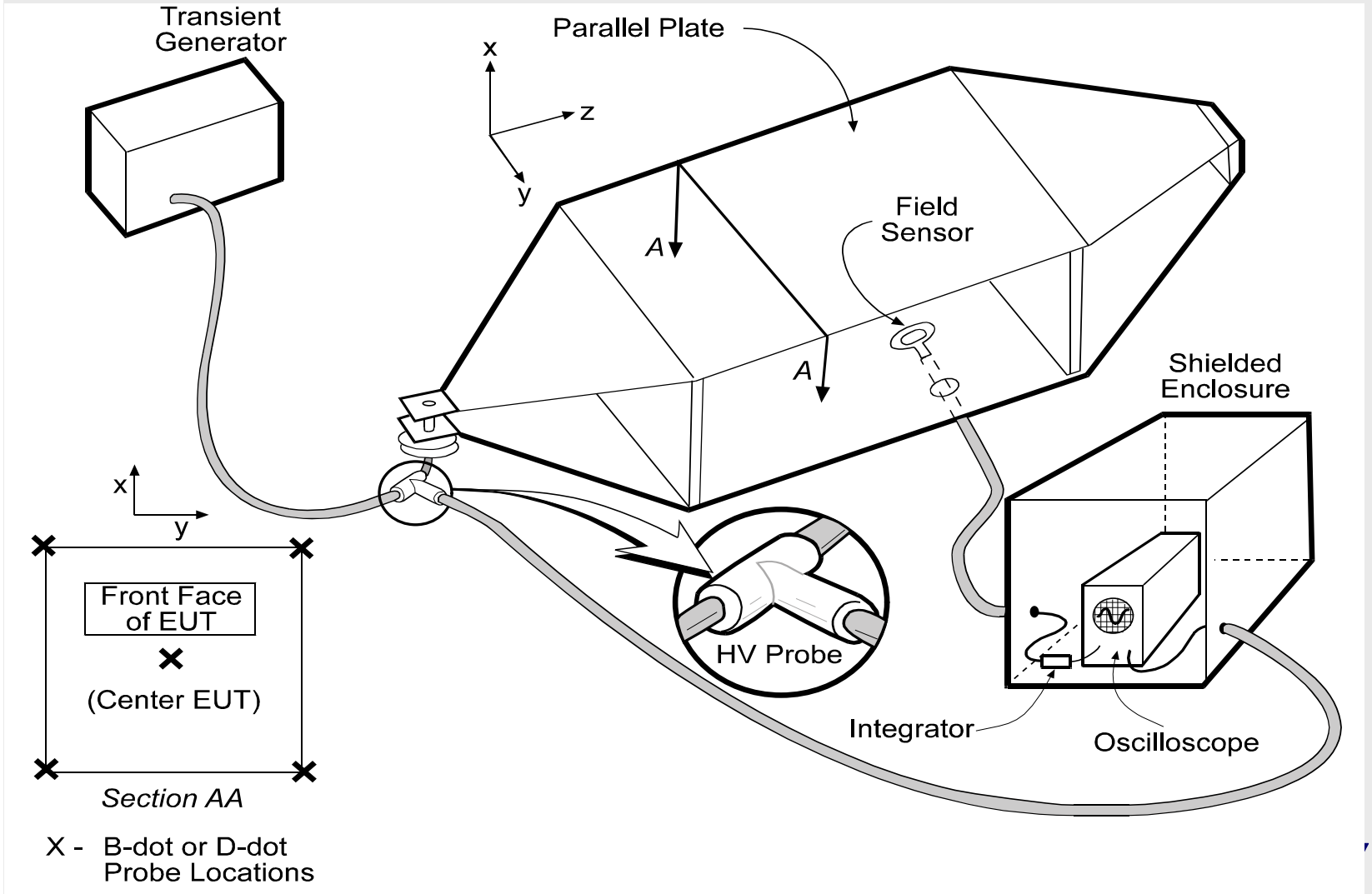
MIL-STD-461E/F

- Requirements RS105
  - Radiated Susceptibility (RS) - Transient electric field (EMP)
  - Test is to verify that the (EUT) can operate with radiated transient electrical noise produce by EMP
  - Signal is a pulse 2.5 x 25 nsec
  - Unit is V/m (50,000 V/m)
  - Performed using a HV pulser and a parallel plate antenna

MIL-STD-461E/F



MIL-STD-461E/F



MIL-STD-461E/F

- Conclusion
  - During CS and RS testing, always monitor for susceptibility
  - If susceptibility occurs, determine thresholds
  - LISNs always used
  - Setup is never changed
  - DID EMCS 80199A, 80200A & 80201A defines Test Procedure, Test Report, & EMC Control Plan
  - (Read Appendix of Mil-Std 461E when you have questions)

Mike Wozniak

Thanks to

Mike Wozniak,

NTS Regional Sales Manager, who ran the slide show and edited it.

MIL-STD-461E/F

- Changes to MIL-STD-461F
- December 10, 2007
- Changes are smallest
- RE101 – need to determine at what distance unit meets spec – not just 50 cm.
- RE102 – rod antenna is lower, no bonding strap, bond shield, add 20 Ohms of Ferrite load

MIL-STD-461E/F

- RE102 con't – new below deck limit
- CS106 – new requirement but same as old CS06
- CS114 77 dBuA 4 kHz – 1 MHz for Ships and Subs
- RS103 – need to check harmonic content
- Faster sweep from 1 – 40 GHz

MIL-STD-461E/F

- Application changes
  - CE101 - Ships
  - CE106 – Ships and Subs
  - CS109 - limited application to Ships
  - CS115 – ships and subs are limited application
  - RS101 and CS116 – limited application for subs

MIL-STD-461E/F

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THANK YOU