



Electromagnetic Compatibility (EMC) for Equipment Qualification EPRI TR-102323 R4

presented by
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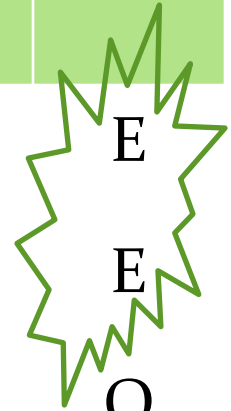
Administrative

- The basis of today's discussion is EPRI TR-102323 R4 released in December 2013.
 - A short review of the test methods used for equipment qualification including noted changes from the previous revision is presented.
- Please note that this presentation is the opinion of the presenter and not endorsed by EPRI as an official position
- EMI
 - A conducted interfering (EMI) signal defined by an undesirable voltage or current coupled into a signal, power, or other pertinent conductor
 - A radiated interfering (EMI) signal is defined as a time-changing electromagnetic field that couples into system circuitry, thereby inducing undesirable voltage or currents that result in degraded performance.
- EMC
 - The capability of electronic systems to operate in the intended electromagnetic environment at designed levels of performance and efficiency



Susceptibility

	Susceptibility Tests						
	Conducted		Radiated		Surge	EFT	ESD
	Low Frequency	High Frequency	Low Frequency	High Frequency			
Safety Related	A	A	E	A	A	A	E
Important to Power Production	R	R	E	R	R	R	E
Non-Safety Related	O	O	O	O	O	O	O



A	Applicable
R	Recommended
E	Evaluate
O	Optional



Emissions

	Emission Tests			
	Conducted		Radiated	
	Low Frequency	High Frequency	Low Frequency	High Frequency
Safety Related	E	A	E	A
Important to Power Production	E	A	E	A
Non-Safety Related	E	A	E	A



EMC Compliance Standards

- Susceptibility (aka Immunity)
 - Low frequency conducted (CS101, IEC 61000-4-13, -4-16)
 - High frequency conducted (CS114, IEC 61000-4-6)
 - Low frequency radiated (RS101, IEC 61000-4-8, -4-9, -4-10)
 - High frequency radiated (RS103, IEC 61000-4-3)
 - Surge (CS116, IEC 61000-4-5, -4-12, -4-18, IEEE 62-41)
 - EFT (CS115, IEC 61000-4-4, IEEE C63-41)
 - ESD (IEC 61000-4-2)
- Emissions
 - Low frequency conducted (CE101)
 - High frequency conducted (CE102, IEC 61000-6-4, FCC Part 15)
 - Low frequency radiated (RE101)
 - High frequency radiated (RE102, IEC 61000-6-4, FCC Part 15)

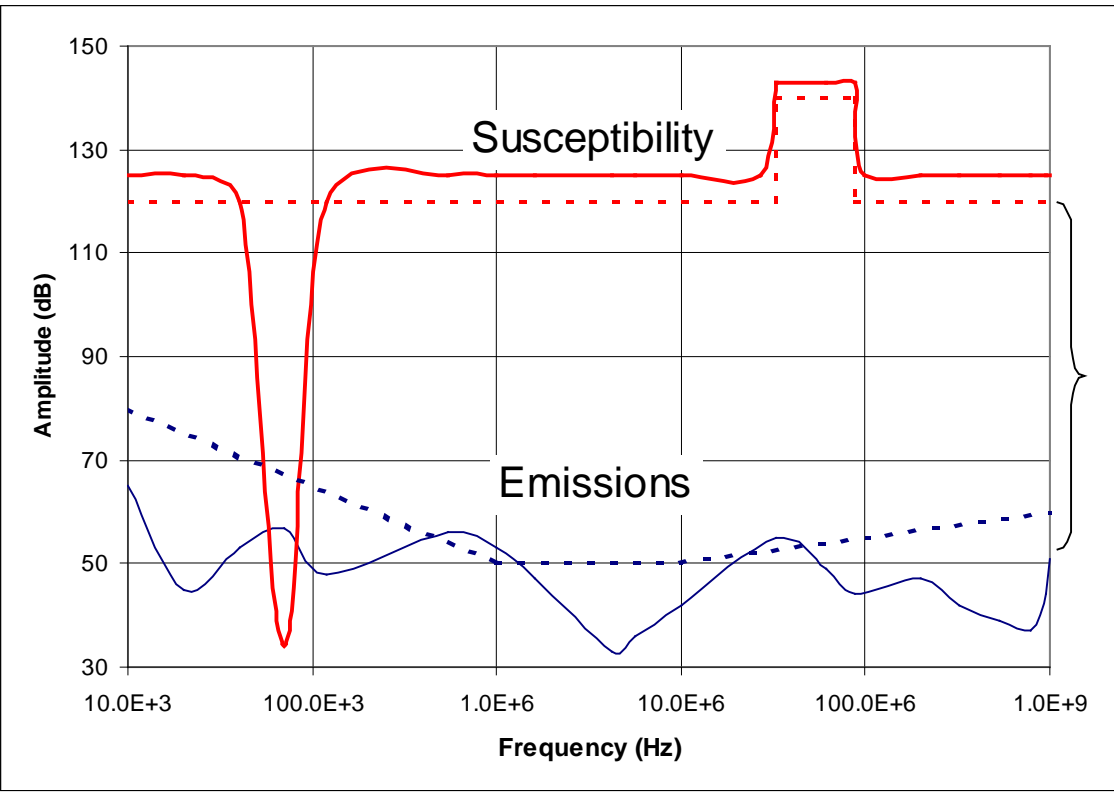


Acceptance categories

- Plants should not support these acceptance categories – these are associated with CE Marking – Acceptance should be in the procurement specification
- Category A
 - Performance as specified during exposure to interference
- Category B
 - Loss of performance during event
 - No loss of data
 - Return to normal operation at the point where the interruption occurred without operator intervention
- Category C
 - Loss of function or temporary degradation
 - Operator intervention permitted to restore operation
 - Repair of the unit not required
- Category D
 - Repair allow to restore operation



Emissions & Susceptibility



Emissions

Intentional or unintentional signal radiated or conducted from an electronic or natural source

Susceptibility

Reception of emissions leading to degradation of performance



Threshold measurements

- Threshold measurements provide data on the amplitude and frequency of interference that produces susceptibility
 - This is the lowest level that produces unacceptable results
 - Frequency ranges of susceptibility need to be identified
- Why?
 - Absence of information makes acceptance of a deviation nearly impossible
 - Solutions need the data to support design



Low frequency conducted susceptibility

- Purpose is to evaluate performance in the presence of low frequency interference conducted via the power or signal lines
- MIL-STD-461
 - CS101, Conducted susceptibility, low frequency, 30 Hz to 150 kHz
 - R4 deleted measurement in current terms
 - Power lines test – not signal
- IEC 61000-4
 - IEC 61000-4-13, Conducted susceptibility, low frequency, 16 Hz to 2.4 kHz
 - Class 2 or higher
 - IEC 61000-4-16, Conducted susceptibility, low frequency, 15 Hz to 150 kHz
 - Level 3 (applicability notes)



High frequency conducted susceptibility

- Purpose is to evaluate performance in the presence of RF signals inducing currents into the equipment via the cables
- MIL-STD-461
 - CS114, Conducted susceptibility, high frequency, 10 kHz to 200 MHz (may exempt >30 MHz if RS103 is tested)
- IEC 61000-4
 - IEC 61000-4-6, Conducted susceptibility, disturbances induced by radio-frequency fields, 150 kHz – 80 MHz



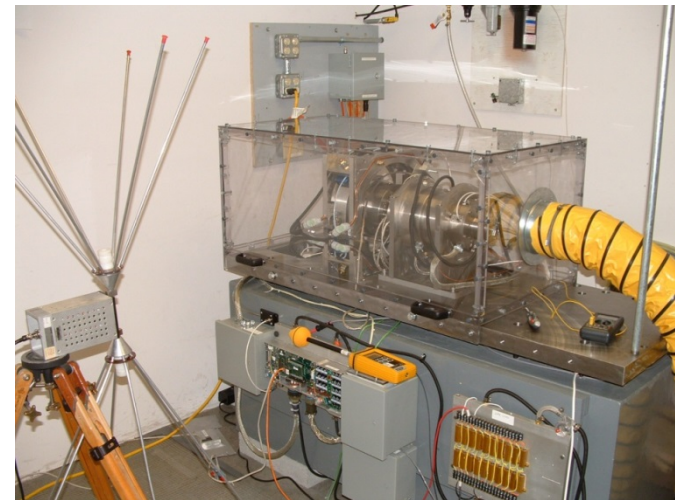
Low frequency RS (magnetic field)

- Purpose is to evaluate performance in the presence of magnetic fields (typically from high current devices or transients)
- Exempt test if equipment is not near sources of large magnetic fields and limiting practices are used
 - R4 indicates <1-m from >300A/m sources
- Test methods:
 - MIL-STD-461 RS101, Radiated susceptibility, magnetic field, 30 Hz to 100 kHz
 - IEC 61000-4-8, Radiated susceptibility, magnetic field, 50 Hz and 60 Hz
 - Continuous and short duration
 - IEC 61000-4-9, Radiated susceptibility, magnetic field, pulse
 - Deleted reference to frequency range aligning to standard IEC test
 - IEC 61000-4-10, Radiated susceptibility, magnetic field, 100 kHz and 1 MHz
 - IEC 61000-4-10 has additional limiting applicability to high current switching sources (bus bar switching)



High frequency RS (electric field)

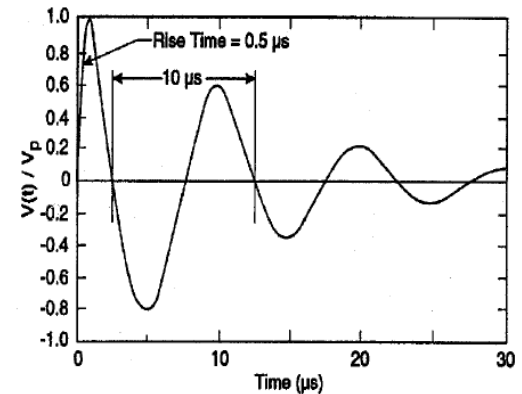
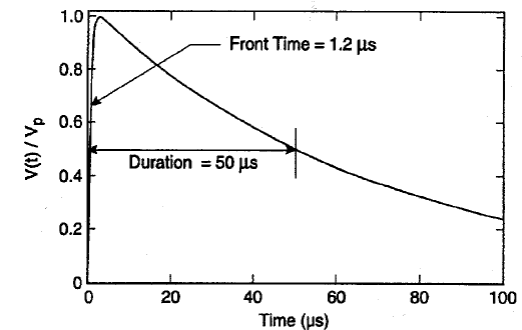
- Purpose is to evaluate performance in the presence of high level electric fields (typically intentional transmitters or uncontrolled emitters)
- MIL-STD-461, Radiated susceptibility, electric field, 30 MHz* to 10 GHz
 - Modulation with a 1 kHz square wave
 - Testing for RS103 in the 10 kHz to 30 MHz frequency range if CS114 is not performed
 - (* Initial R4 release stated 26 MHz in error)
- IEC 61000-4-3, Radiated susceptibility, electric field, 26 MHz to 10 GHz
 - Modulation with a 1 kHz sine wave
 - Deletion of 30 MHz to 80 MHz if IEC 61000-4-6 testing is performed





Surge

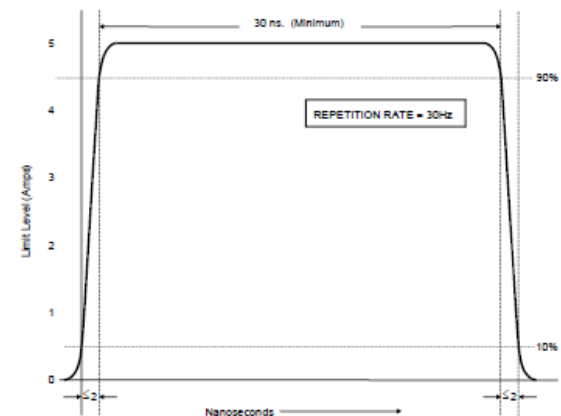
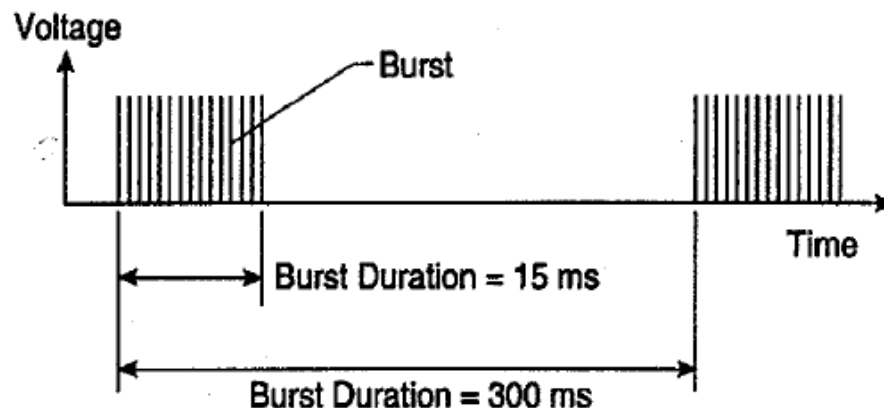
- Purpose is to evaluate performance in the presence of transient events (typically associated with lightning coupled onto power or signal lines)
- Combination wave
 - IEC 61000-4-5, Surge immunity test (1.2/50 μ S)
- Ring wave
 - IEC 61000-4-12, Damped sine wave or
 - IEEE C62.41, Damped sine wave
 - 100 kHz
- Oscillatory wave
 - IEC 61000-4-18, Oscillatory waves
 - 100 kHz @ 40 Hz and
 - 1 MHz @ 400 Hz
- CS116 removed
- Removed confusion about the 61000-4-12 waveform
- Established different levels for L-E and L-L tests





Electrically Fast Transients/Bursts (EFT)

- Purpose is to evaluate performance in the presence of transient events (typically associated with switching (bus bar load switching, relays, etc.) coupled onto power or signal lines)
- MIL-STD-461, CS115, Conducted susceptibility, bulk cable injection, impulse excitation
- IEC 61000-4-4, Electrically Fast Transient/Bursts
- C62.41-1991, Electrically Fast Transient/Bursts





Electrostatic Discharge (ESD)

- Purpose is to evaluate performance in the presence of transient events (typically associated with human body charges equalizing to equipment)
- Optional switched to:
 - Evaluate for safety related
 - Evaluate for important to power production
 - Optional for non-safety related
- IEC 61000-4-2 is the test standard
 - Level 4 testing (8kV contact; 15kV air)
 - Test points selected based on accessibility



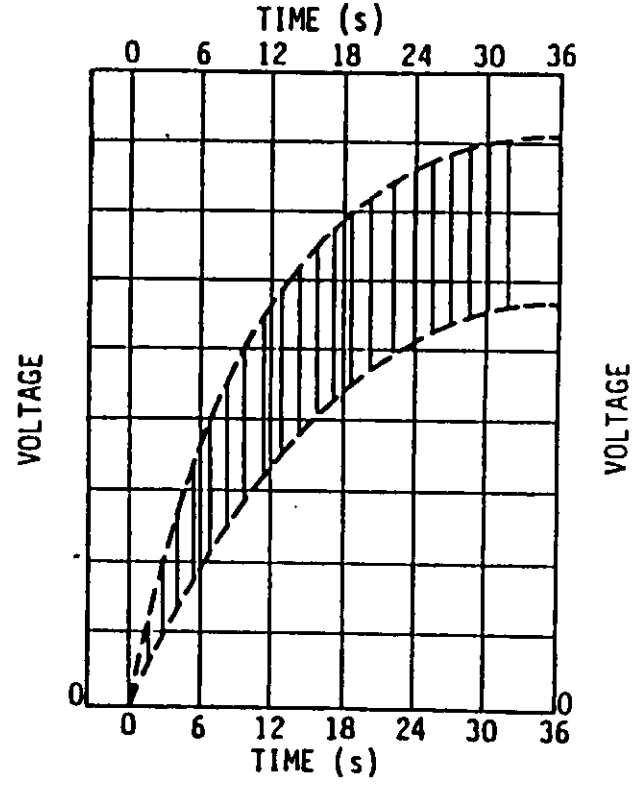
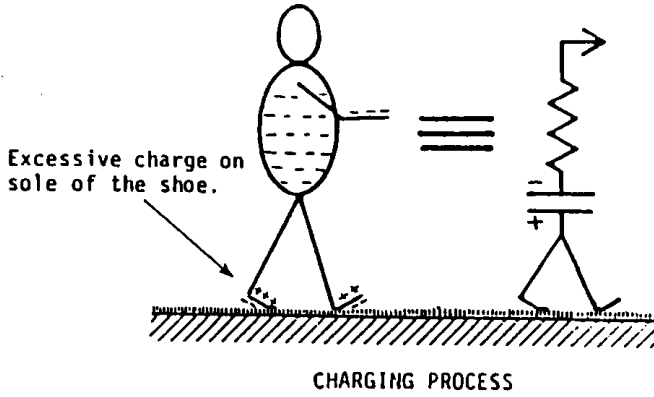


Electrostatic Discharge

- ESD is the sudden transfer of electric charge between two or more bodies of different electrostatic potentials
- ESD field intensity is produced which exceeds the breakdown level causing ionization and a conduction discharge in the medium between the two oppositely charged bodies
- Electrostatic generation is the result of charge transfer and buildup. The charge transfer is mainly electronic with some ionic contribution. "Trapped" charges, usually in non-conductors, result in potential build-up.



Charge Build-Up



GRAPH OF VOLTAGE BUILD-UP



Typical ESD Levels

Means of Generation	RH 10-20%	RH 65-90%
Walking across carpet	35kV	1.5kV
Walking on vinyl floor	12kV	0.25kV
Moving on work area seat	6kV	0.1kV
Handling an envelope	7kV	0.6kV
Handling polyethylene bag	20kV	1.2kV
Moving on padded poly chair	18kV	1.5kV

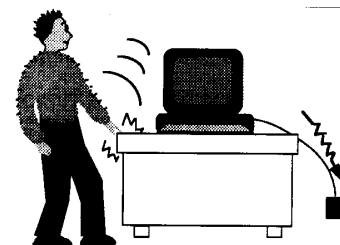
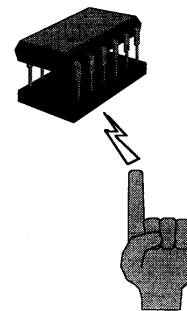


Type of Discharge

- Air discharge
 - Discharge is actuated by a spark in ionized air upon approach and prior to contact between charge objects
- Contact discharge
 - Discharge is actuated by breakdown of a dielectric between conductors

ESD Coupling

- Direct
 - Discharge current is injected directly into components, cables, switches, circuits, etc.
- Indirect
 - Discharges produce pulse-type, time-varying, EM fields that couple into circuit loops and cable inducing currents and voltages



Metallic desk supporting plastic encased equipment



ESD Effects

- Upset
 - Operation interrupt
 - Reset (automatic or by operator intervention)
- Damage
 - Operation interrupt
 - Restored by repair
- Latent issue
 - Reliability
 - MTBF degradation
 - Static circuit impaired





Conducted emissions

- Purpose is to evaluate potential interference conducted via power lines
- Low frequency
 - MIL-STD-461, CE101, 30 Hz – 10 kHz
 - Exempt equipment from test if
 - Power quality requirements are consistent with existing power supply and design practices include power quality controls
 - New equipment will not impose additional harmonic distortion exceeding 5% THD or other power quality criteria with a valid technical basis
 - Limit relaxation allowed for high current AC power
- High frequency
 - CE102, 10 kHz to 10 MHz or
 - CISPR 11, 150 kHz to 30 MHz
 - Measurement in current terms deleted

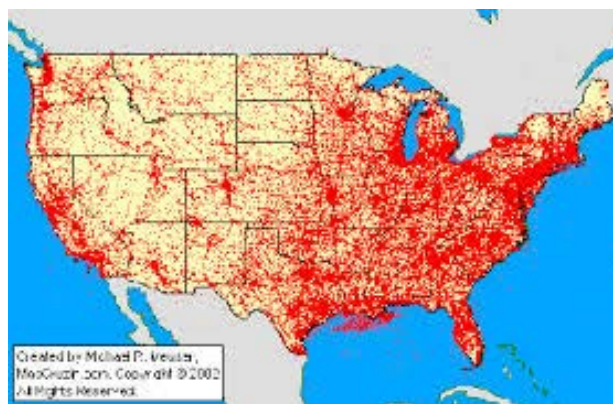


Radiated emissions

- Purpose is to evaluate potential interference from radiated fields
- Low frequency
 - RE101, 30 Hz – 100 kHz
 - Applicable if
 - New equipment is a source of large magnetic fields ($>300\text{A/m}$) that is installed $<1\text{m}$ from magnetically sensitive equipment
 - Equipment and cable separation of EMI limiting practices (defined Section 4) are not satisfied
- High frequency
 - RE102, 2 MHz to 10 GHz
 - CISPR 11, 30 MHz to 1 GHz
 - FCC 47 Part 15, 30 MHz to 1 GHz
 - QP emission measurements

Facility mapping

- Facility mapping is used to identify locations where interference potential exists
- Equipment that complies with the required qualification tests presents a low risk of impact to facility compliance but the on-going mapping identifies EMI control deterioration and introduction of EMI sources that have not been evaluated





Mapping process

- Mapping process
 - Prior to and subsequent to installation of new equipment the facility is evaluated for EMI potential
 - Locations within the facility are identified for radiated evaluation
 - Circuits and interface cables are selected for evaluation
 - Emission levels are measured at the selected test points and the results are analyzed to ensure that the new equipment immunity is adequate
 - Post installation tests are frequently used to verify that the new equipment did not introduce emissions that could impact existing equipment
 - Radiated tests are accomplished with receive antennae placed at central locations
 - Conducted measurements are accomplished with a RF probe attached to selected conductors
 - Transients – difficult to capture





Plant limits

- TR-102323 includes a section on plant limits
- Plant limits are based on the composite measurements for several facilities studied
 - The plant limits help ensure that susceptibility test levels are greater than potential interference
- Radio transmitters are a part of the overall plant emissions profile that are **NOT** always included in the facility map
 - This is prevalent when mobile RF transmitters are used in the facility or open areas near the facility
 - Fixed commercial RF transmitters are included in the mapping but a particular facility may have a close transmission antenna and with that a unique risk





Personal portable transceivers

- Section 4.2 provides guidance on exclusion zone for portable transceivers
 - Calculation of field intensity based on FCC certification ERP or EIRP
 - Basis assumes peak power is reported in FCC certification
 - Caution – other than peak power may be reported depending on the particular rule part associated with certification
- Error in formulas in original release – correction notification issued in February and download version corrected
 - Verify that Equation 4-1b is:
 - **$G = 10^{(dBd/10)}$ (where $dBd = dBi - 2.15$ when gain is reported in units of dBi)**





Risk assessment

- Risk assessments are integral to a safety analysis report
- Risk assessment documents should include:
 - EMC qualification test reports
 - EMI facility mapping reports
 - EMC control measures for the facility and associated equipment



Installation

- Site plan considering EMC
- Location of sensitive devices
- Grounding scheme – not left to chance
- Verify product qualification
- Understand installation requirements
- Cables – Cables - Cables

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PRACTICES TO ENSURE EMC



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