Overview of EMC Regulations and Testing

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What is EMC

Electro-Magnetic Compatibility

EMC

- **EMI** (Interference)
- **EMS** (Susceptibility)

Conducted Emission

Radiated Emission

Conducted Susceptibility

Radiated Susceptibility
Natural
Terrestrial
Atmospheric
Sun
.
.
Man-Made
Broadcast
Radar
Fluorescent lights
Computing devices
Microwave Ovens

Radiation
Far-Field
Plane Wave
Near-Field
Capacitive cross-talk
Inductive cross-talk
Conduction
Power distribution
Signal distribution
Ground loops

Biological
Man
Animal
Plants

Man-Made
Broadcast receivers
Navigation receivers
Radar receivers
Computing devices
Biomedical sensors
How EMC

• Suppress the emission at its source
• Make the coupling path as inefficient as possible
• Make the receptor less susceptible to the emission
How EMC

Product Slippage

- EMC test failure forces product redesign
- Product launch delayed to achieve compliance
- Product’s time in market reduced
- Potential sales and profit reduced

Time lost to achieve EMC compliance

Cost to implement product redesign

Freedom to implement redesign

Cost to implement product redesign
How EMC

An example: for PC

- Suppress the emission:
  - Proper layout with EM concept
  - Using component with low edge rate as possible

- Reduce coupling path
  - Using shielded enclosure

- Less susceptible receptor
  - Differential pairs
  - Error-correcting code
EMC Regulations

CISPR 11 : Limits and methods of measurements of radio disturbance characteristics of industrial, scientific and medical (ISM) radio-frequency equipment
CISPR 13 : Limits and methods of measurements of radio disturbance characteristics of broadcast receivers and associated equipment
CISPR 14 : Limits and methods of measurements of radio disturbance characteristics of household electrical appliances, portable tools and similar electrical apparatus
CISPR 19 : Guidance on the use of the substitution method for measurements of radiation from microwave ovens for frequencies above 1GHz
CISPR 22 : Limits and methods of measurements of radio disturbance characteristics of information technology equipment
IEC 61000-3-2 : Limits for harmonic current emissions (equipment input current <16A per phase)
EMC Regulations

IEC 61000-4-2: Testing and measurement techniques - Electrostatic discharge immunity test
IEC 61000-4-3: Testing and measurement techniques - Radiated, radio-frequency, electromagnetic field immunity test
IEC 61000-4-4: Testing and measurement techniques - Electrical fast transient/burst immunity test
IEC 61000-4-5: Testing and measurement techniques - Surge immunity test
IEC 61000-4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields
IEC 61000-4-8: Testing and measurement techniques - Power frequency magnetic field immunity test
IEC 61000-4-11: Testing and measurement techniques - Voltage dips, short interruptions and voltage variations immunity
EMC Regulations : CISPR 22

Test Levels
Test Setups and Illustrations
## EMC Regulations: Levels

### Limits for conducted disturbance at the mains ports of Class A

<table>
<thead>
<tr>
<th>Frequency range MHz</th>
<th>Quasi-peak dB(μV)</th>
<th>Average dB(μV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.15 to 0.50</td>
<td>79</td>
<td>66</td>
</tr>
<tr>
<td>0.5 to 30</td>
<td>73</td>
<td>60</td>
</tr>
</tbody>
</table>

*Note – The lower limit shall apply at the transition frequency.*

### Limits for conducted disturbance at the mains ports of Class B

<table>
<thead>
<tr>
<th>Frequency range MHz</th>
<th>Limits dB(μV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.15 to 0.5</td>
<td>66 to 56</td>
</tr>
<tr>
<td>0.5 to 5</td>
<td>56</td>
</tr>
<tr>
<td>5 to 30</td>
<td>60</td>
</tr>
</tbody>
</table>

*Notes*
1. The lower limit shall apply at the transition frequencies
2. The limit decreases linearly with the logarithm of the frequency in the range 0.15 MHz to 0.50 MHz
# EMC Regulations : Levels

## Limits for radiated disturbance of Class A ITE at a measuring of 10 m

<table>
<thead>
<tr>
<th>Frequency range MHz</th>
<th>Quasi – peak limits dB(μV/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 to 230</td>
<td>40</td>
</tr>
<tr>
<td>230 to 1000</td>
<td>47</td>
</tr>
</tbody>
</table>

### Notes
1. The lower limit shall apply at the transition frequency
2. Additional provisions may be required for cases where interference occurs

## Limits for radiated disturbance of Class B ITE at a measuring of 10 m

<table>
<thead>
<tr>
<th>Frequency range MHz</th>
<th>Quasi – peak limits dB(μV/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 to 230</td>
<td>30</td>
</tr>
<tr>
<td>230 to 1000</td>
<td>37</td>
</tr>
</tbody>
</table>

### Notes
1. The lower limit shall apply at the transition frequency
2. Additional provisions may be required for cases where interference occurs
Measured with LISN

Class B (QP)

Class A (QP)

Voltage (dB\(\mu\)V)

150 KHz  500 KHz  5 MHz  30 MHz

Voltage (dB\(\mu\)V)

150 KHz  500 KHz  30 MHz
Measurement distance 10 m

Class B
(Quasi-peak limits)

Electric field (dB\text{\greek{u}V/m})

30 MHz  230 MHz  1 GHz

30 MHz  230 MHz  1 GHz

Class A
(Quasi-peak limits)

Measurement distance 10 m
Open Area Test Site (OATS)

RE measurement (EN55022)

- OFTS
- elliptical boundary
- common distance 3m, 10m & 30m ($\lambda/3$ for 3m)
- size of DUT = $2D^2/\lambda$ (Rayleigh Range criterion)
- ground plane roughness $\pm$ 20mm
- Ground plane conductor (max mesh size 20mm)
- site attenuation $\pm$ 3db
- antenna positioned at 1-4m for maximum field strength
Open Area Test Site (OATS)

Plan View of an OFTS
elliptical boundary
common distance 3m, 10m & 30m (λ/3 for 3m)
Open Area Test Site (OATS)

OFTS Groundplane Minimum Area

ground plane roughness ± 20mm
Ground plane conductor (max mesh size 20mm)

equipment under test  aerial
Open Area Test Site (OATS)

Side View of an OFTS
antenna positioned at 1-4m for maximum field strength
Semi-Anechoic Chamber

- Shielded room
- EUT
- Ground plane
- Absorber
- 3 m or 10 m
- Scan height 1 - 4 m vertical and horizontal polarization
- S.A. or Receiver
Measurement: EMI

System Level
Fully Anechoic Chamber

EMI Measurement Environment
Shielding Effectiveness (EN50147-1)

\[
SE = 20 \log |E_i / E_t|
\]
Shielding Effectiveness (EN50147-1)
Shielding Effectiveness (EN50147-1)

![Graph showing shielding effectiveness across different frequencies](image)

$\alpha_s = \text{shield attenuation in dB}$

- curve A: defined performance of the door seams for high performance shielded enclosures
- curve 1: high performance of a shielded enclosure
- curve 2: standard performance of a shielded enclosure

**Figure 2:** Typical shield attenuation values
Line Impedance Stabilization Network (LISN)

Impedance characteristic of the LISN at EUT port
Test Setups and Illustrations

Test configuration: tabletop equipment (conducted measurement)

AMN = Artificial mains network
AE = Associated equipment
EUT = Equipment under test

Rear of EUT to be flushed with rear of table top

40 cm min.

80 cm to ground plane

Non-conductive table

Bounded to horizontal ground plane

Bounded to horizontal ground plane

40 cm to vertical reference plane
If cables, which hang closer than 40 cm to the horizontal metal ground plane, cannot shortened to approximate length, the excess shall be folded back and forth forming a bundle 30 cm to 40 cm long. Excess mains cord shall be bundled in the center or shortened to appropriate length. EUT connected to one AMN. All AMNs may alternatively be connected to the vertical reference plane or metal wall.

3a) All other units of a system powered from a second AMN. A multiple outlet strip can be used for multiple mains cords.
3b) AMN 80 cm from EUT and at least 80 cm from other units and other metal planes.
3c) Mains cords and signal cables shall be positioned for their entire lengths, as far as possible, at 40 cm from the vertical reference plane.

Cables of hand operated devices, such as keyboards, mouses, etc. shall be placed as for normal usage.

Peripherals shall be placed at a distance of 10 cm from each other and from the controller, except for the monitor which, if for an acceptable installation practice, shall be placed directly on the top of the controller.

I/O signal cable intended for external connection.
The end of the I/O cables which are not connected to an AE may be terminated if required using correct terminating impedance.
Test configuration: tabletop equipment (radiated measurement)

- Non-conductive table
- EUT
- 10 cm
- 80 cm to ground plane
- 40 cm min.
If cables, which hang closer than 40 cm to the horizontal metal ground plane, cannot shortened to approximate length, the excess shall be folded back and forth forming a bundle 30 cm to 40 cm long. The end of the I/O cables which are not connected to a peripheral may be terminated if required for proper operation using correct terminating impedance.

Mains junction box(s) shall be flush with and bonded directly to the metal ground plane.

NOTE - If used, the AMN shall be installed under the horizontal metal ground plane.

Cables of hand operated devices, such as keyboards, mouses, etc. shall be placed as for normal usage. Peripherals shall be placed at a distance of 10 cm from each other and from the controller, except for the monitor which, if for an acceptable installation practice, shall be placed directly on the top of the controller.

Mains cables shall drape to the floor and then routed to receptacle. No extension cords shall be used to mains receptacle.
## Typical Characteristics of Pulsed EMI

<table>
<thead>
<tr>
<th>Feature</th>
<th>ESD</th>
<th>EFT</th>
<th>Surge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waveform</td>
<td>See the next page</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rise time</td>
<td>less than 1 ns</td>
<td>~ 5 ns</td>
<td>μs</td>
</tr>
<tr>
<td>Energy</td>
<td>low ( mJ )</td>
<td>medium ( mJ )</td>
<td>high ( J )</td>
</tr>
<tr>
<td>Duration</td>
<td>ns</td>
<td>ns, and repeating</td>
<td>ms</td>
</tr>
<tr>
<td>Peak voltage</td>
<td>up to about 15 kV</td>
<td>kV</td>
<td>several kV</td>
</tr>
<tr>
<td>( into high impedance)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peak current</td>
<td>medium ( A )</td>
<td>low ( A )</td>
<td>high ( kA )</td>
</tr>
<tr>
<td>( into low impedance)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sources</td>
<td>accumulation of static electricity</td>
<td>activation of gaseous discharge, make / break of electrical circuits</td>
<td>lightning, power switching</td>
</tr>
</tbody>
</table>
Waveforms of pulsed EMI

ESD

Rise time = 0.5 $\mu$s

10 $\mu$s

Surge

Several nanosecond-duration pulses in a burst

Rise time = 0.5 $\mu$s
# Test Levels and Test Result Classifications

<table>
<thead>
<tr>
<th>Level</th>
<th>Test voltage (kV)</th>
<th>Level</th>
<th>Test voltage (kV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>x</td>
<td>Special</td>
<td>x</td>
<td>Special</td>
</tr>
</tbody>
</table>

“x” is an open level. The level has to be specified in the dedicated equipment specification. If higher voltages than those shown are specified, special test equipment may be needed.

<table>
<thead>
<tr>
<th>Level</th>
<th>Indicated voltage (kV)</th>
<th>First peak current of discharge ± 10% A</th>
<th>Rise time $\xi$ with discharge switch ns</th>
<th>Current (± 30%) at 30 ns A</th>
<th>Current (± 30%) at 60 ns A</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>7.5</td>
<td>0.7 to 1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>15</td>
<td>0.7 to 1</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>22.5</td>
<td>0.7 to 1</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>30</td>
<td>0.7 to 1</td>
<td>16</td>
<td>8</td>
</tr>
</tbody>
</table>
### Test levels for radiated immunity
(80 MHz to 1000 MHz)

<table>
<thead>
<tr>
<th>Level</th>
<th>Test field strength V/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>x</td>
<td>Special</td>
</tr>
</tbody>
</table>

**NOTE** – x is an open test level. This level may be given in the product specification. The signal is 80% amplitude modulated with 1 kHz sinewave to simulate actual treats.

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### Test levels for EFT test

<table>
<thead>
<tr>
<th>Level</th>
<th>On power supply port, PE</th>
<th>On I/O (input/output) signal data and control ports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Voltage peak kV</td>
<td>Repetition rate kHz</td>
</tr>
<tr>
<td>1</td>
<td>0.5</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>2.5</td>
</tr>
<tr>
<td>x</td>
<td>Special</td>
<td>Special</td>
</tr>
</tbody>
</table>

X is an open level. The level has to be specified in the dedicated equipment specification.
Test Result Classifications

Normal performance within the specification limits
Temporary degradation or less of function or performance which is self-recoverable
Temporary degradation or loss of function or performance which requires operator intervention or system reset
Degradation or loss of function which is not recoverable due to damage of equipment (components) or software, or loss of data
Test Setups and Illustrations
Example of test set-up for table-top equipment, laboratory for ESD tests

- Typical position for indirect discharge to HCP
- Typical position for direct application
- Typical position for indirect discharge to VCP
- Horizontal coupling plane 1.6m × 0.8m
- Wooden table 0.8 m high
- Ground reference plane
- Power supply
- 470 KΩ Resistor
- 0.1m
- PCV 0.5m × 0.5m VCP
- Support isolation Insulation
Example of suitable test facility for radiated immunity

- Interconnection filter
- Field generation antenna
- Incoming mains power filter
- Area of uniform field (1.5m x 1.5m)
- Field generation equipment
- Interconnecting cables
- Chamber penetration cables
- 3 m
- 0.8 m
General EFT test set-up for laboratory type tests

$ l = $ length between clamp and EUT to be tested, should not be more than 1 m

( A ) = location for supply line coupling

( B ) = location for signal coupling