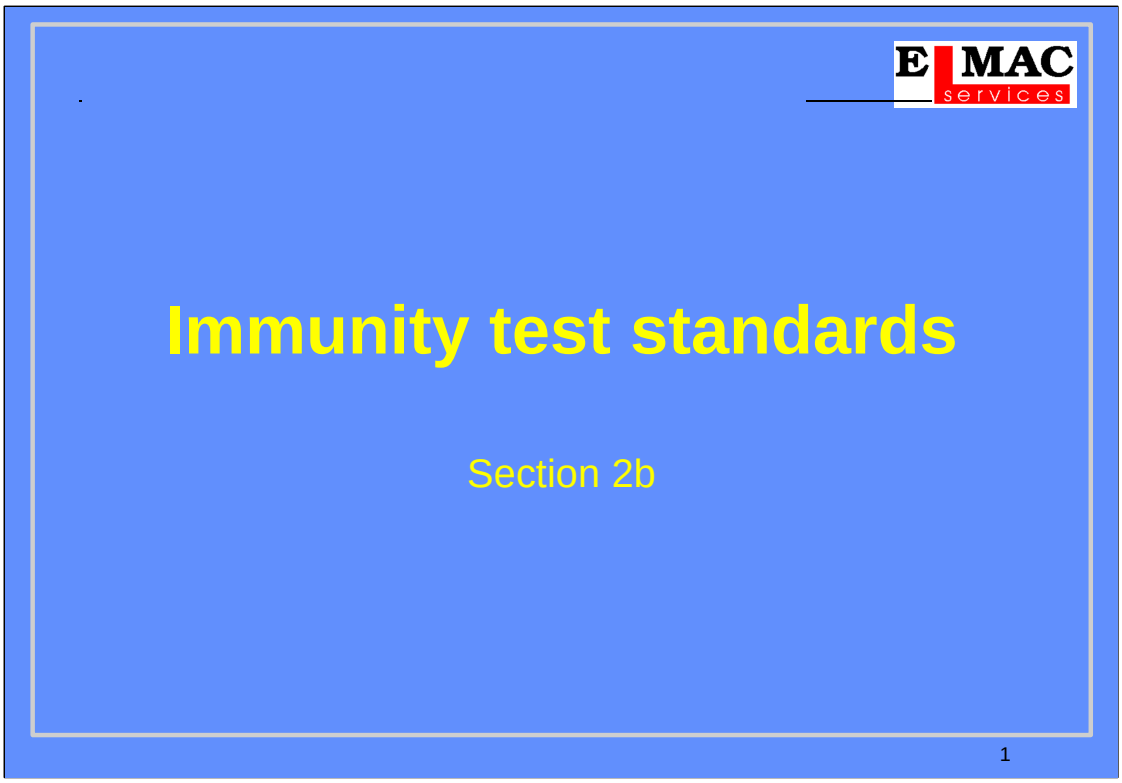
EMAC
services
Immunity test standards
Section 2b
1

Outline

- Content of IEC 61000-4 immunity standards
- Description of IEC 61000-4-2, 3, 4, 5, 6, 11

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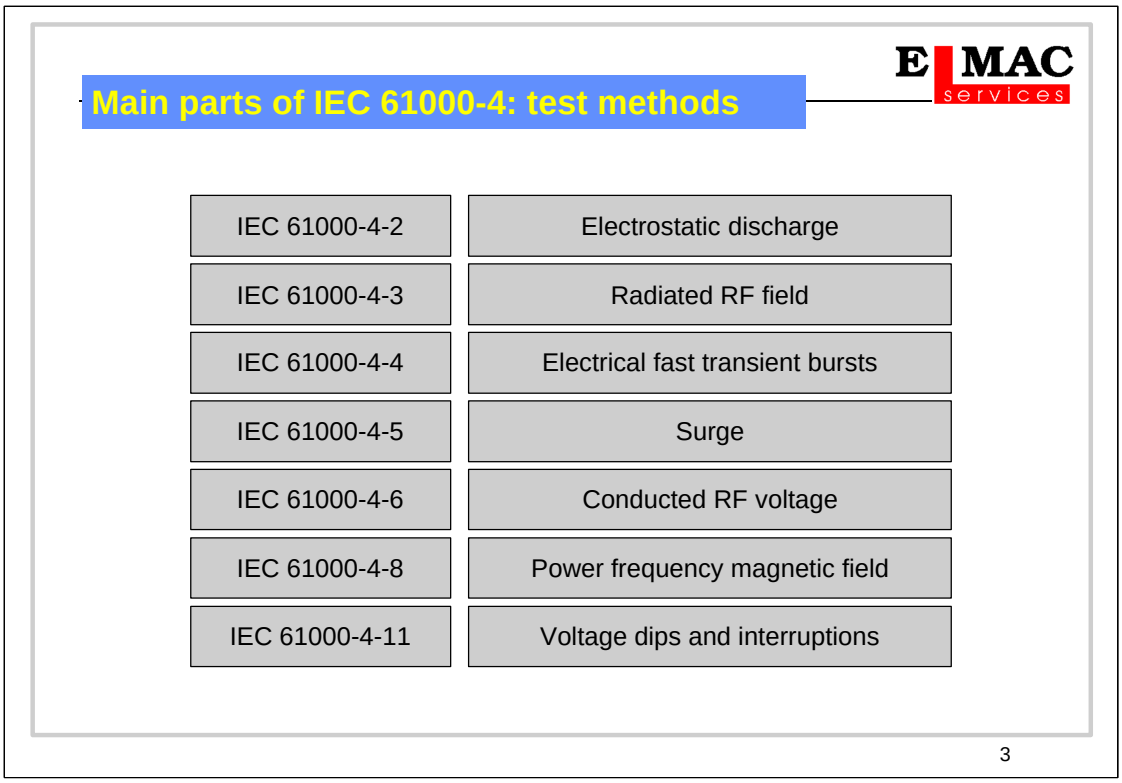
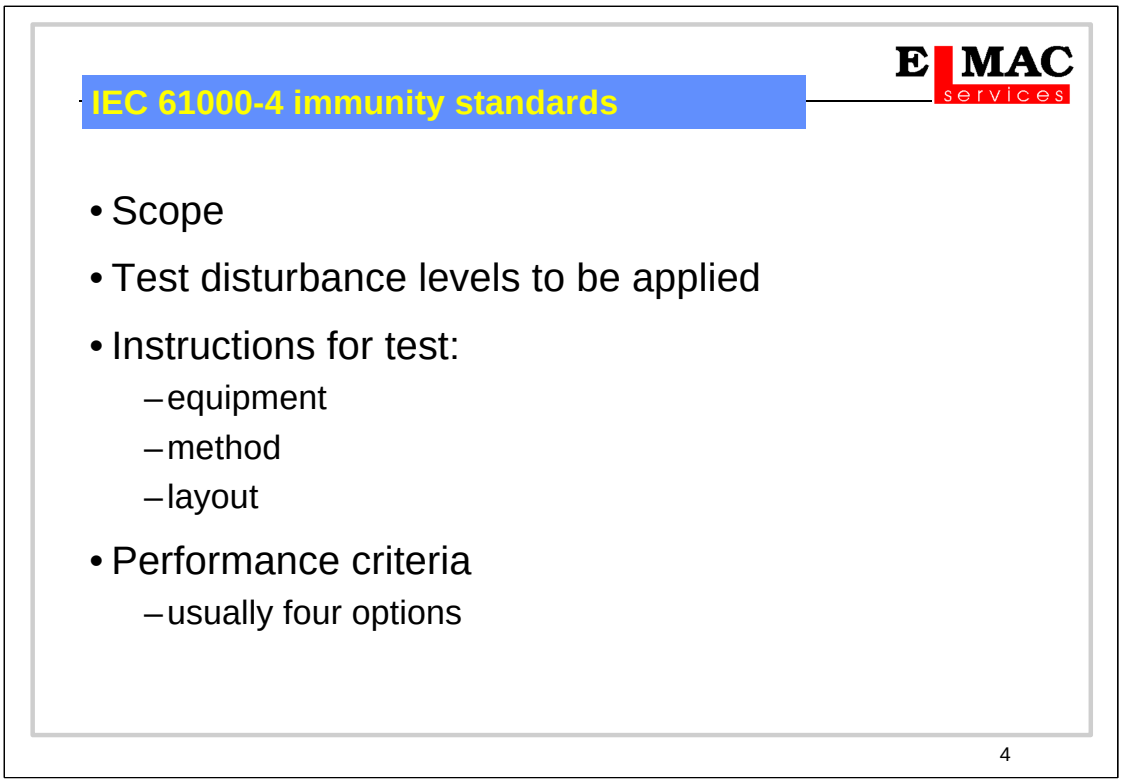


The IEC 61000-4 series of standards are primarily, but not exclusively, concerned with immunity test methods. There are around 25 parts either published or in draft form. The majority of these concern phenomena or techniques which are not relevant to most products presently being tested.

The parts listed above are those which are referenced most broadly in the product and generic standards. The power frequency magnetic field test (IEC 61000-4-8) is normally only applied to products which are likely to be affected by such fields, such as CRT-based monitors.



EMC immunity standards have many similarities to emission requirements. These standards also define the construction (in some cases) and calibration of the test disturbance generators and facilities. The amplitudes of the applied disturbance levels are defined.

A major difference with respect to emissions standards is in the definition of the criteria for pass or fail. For emissions it is relatively straightforward to compare a result to a limit and apply the 80/80 rule. For immunity, checking compliance is far from straightforward since the actual response of an EUT to a disturbance must be compared against its expected operation. Individual product standards should lay down more detailed performance criteria than is possible in the generic standards.

The options offered in the IEC 61000-4 series are:

- normal performance within the specification limits;
- temporary degradation or loss 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.

IEC 61000-4-2 Electrostatic discharge

- Calibrated generator, human body model
- direct discharge:
  - air discharge applied to non-conducting parts
  - contact discharge applied to conducting parts
  - only parts accessible to personnel in normal operation
- indirect discharge:
  - contact discharge applied to vertical and horizontal coupling planes
- levels 2kV-8kV contact, 2kV-15kV air

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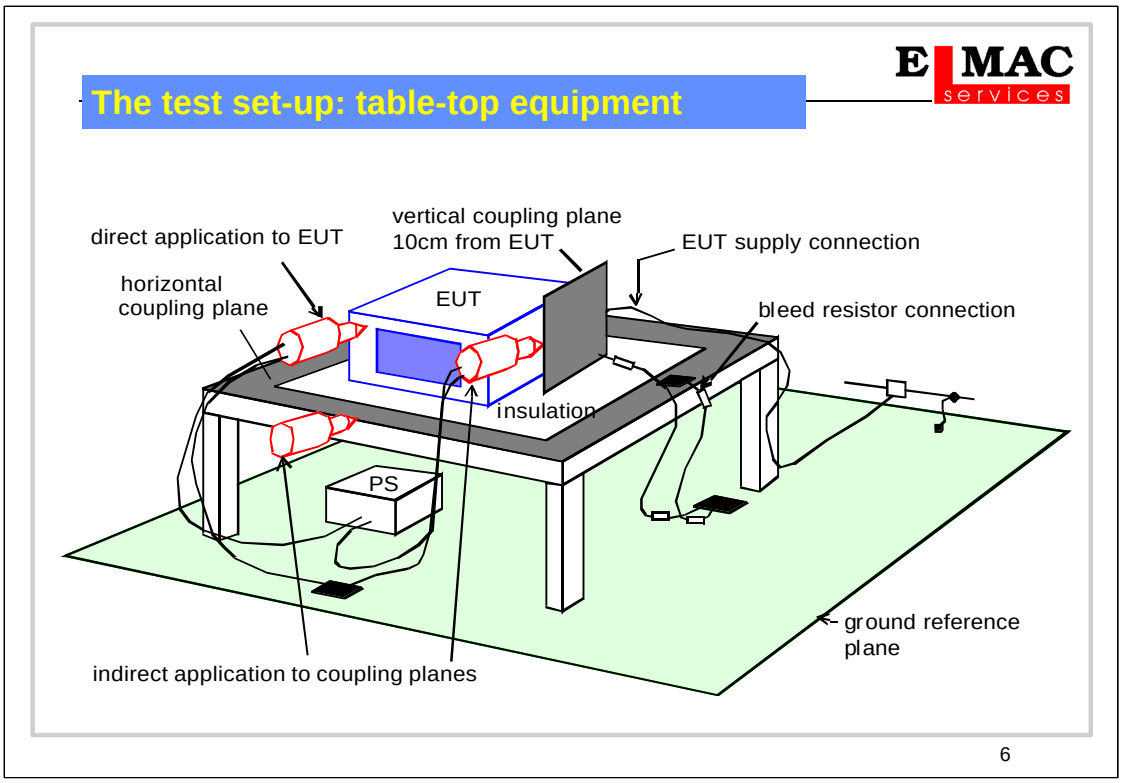
The ESD test is intended to simulate the threat from a local or direct discharge from a charged person. It does not represent other sources, such as furniture or vehicles. The severity levels offered represent four categories of environment, depending on their likely minimum relative humidity and the presence or absence of static generative materials.

Two direct discharge methods (air and contact) are specified. These are complementary rather than alternative. The contact method is preferred for accessible conducting parts, since it is much more repeatable; the air method is still necessary to stress those parts of the apparatus that are insulating but with potential spark propagation paths. The indirect contact method is specified to represent discharges to nearby objects rather than direct to the apparatus.



Because of the very fast edges associated with the ESD discharge, high frequency techniques are essential in ESD testing. The use of a ground reference plane to regularize the EUT-to-ground capacitance is mandatory. Without it, the discharge current return path would be uncontrolled, the rise time and routes of the return currents would vary from test to test and there would be no repeatability. The EUT must be spaced a defined distance from the plane but not earthed to it, unless this would be representative of true installation practice. Normally EUT earthing would be provided by its supply cable green/yellow wire, or not at all in the case of Class II insulated or battery-powered equipment. The ground plane should be at least $1m^2$, and should project beyond the EUT by 0.5m, and for safety purposes should be separately connected to the safety earth. The discharge return cable is always connected to the ground plane and kept well away from the EUT.

Table-top equipment is placed on a wooden table with a horizontal coupling plane on its surface, connected to the ground plane via isolating bleed resistors of 470kΩ at each end. The EUT is insulated from the coupling plane. Discharges are applied to appropriate points on the EUT and also to the horizontal coupling plane. In addition, contact discharges to a vertical coupling plane, spaced 10cm from the EUT, are required.

Note that the EUT is well spaced from the ground reference in this set-up. Although the standard does not require it, it may also be advisable to apply discharges to the EUT on a metallic table to which the simulator is directly grounded.

IEC 61000-4-3 radiated RF

- RF field swept or stepped
  - from 80MHz to 1GHz (+1.4 to 2GHz)
  - amplitude modulated 80% @ 1kHz
  - field set by substitution method
  - field uniformity in EUT area +6 -0dB
- each face of EUT subjected to vertical and horizontal polarizations
- chamber method preferred, TEM cell allowed
- levels from 1V/m to 10V/m and above

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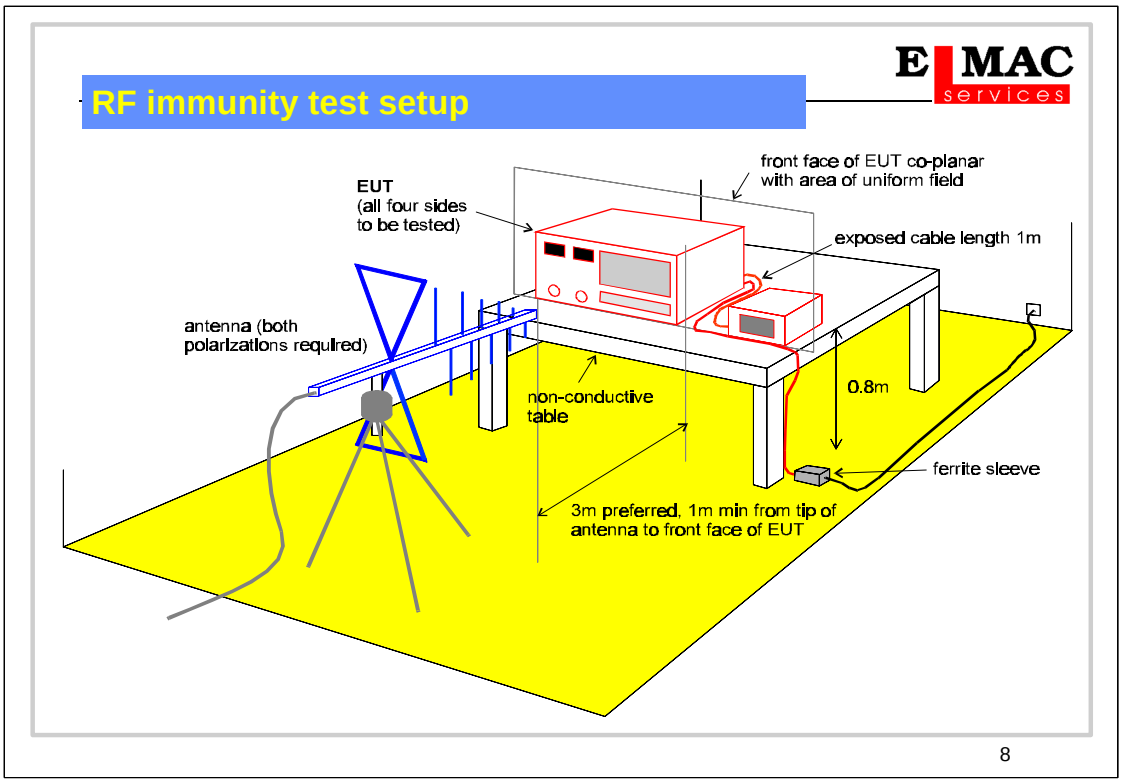
The radiated RF field test is the most complex and expensive, in terms of test method and equipment, of all the parts of IEC 61000-4. It represents the threat from radio transmitters that may be found in the vicinity of the apparatus; principally portable transmitters that can be brought close, but also more distant high-power sources that cause a more pervasive field. The severity levels represent three grades of environment, depending mostly on the likelihood of portable or high power fixed transmitters being nearby. The approach to setting the environmental levels is essentially broad brush, with little account taken of the spectrum occupancy in any particular band. Surviving this test does not necessarily mean that equipment will be fit for purpose in a given location, nor vice versa for that matter.

Because it is illegal in most countries to transmit high field strengths indiscriminately across a broad frequency range, the test must be done inside a screened enclosure. This has led, as with radiated emissions tests, to an unavoidably complicated and involved method. Unfortunately, shortcuts in this method do not give repeatable or representative results.

The frequency range has been extended by Amendment 1 to the standard up to 2GHz, but few product standards yet reflect this requirement.



The EUT is placed on the usual 0.8m high wooden table (for table top devices) with its front face in the same plane as the uniform field area that has been previously calibrated. The calibration records the forward power necessary to achieve the required field strength *without* the EUT present, and this is then re-played during the actual test, without the field strength being monitored. Both the antenna position and the uniform area will be fixed with respect to the chamber. The standard requires at least 1m of connected cable length to be exposed to the field, and recommends the use of ferrite chokes to decouple longer cables. The cable layout cannot be generally specified, but at least some of the length should be in the same plane as one of the polarizations of the antenna.

The EUT is rotated on the table so that each of its four sides, and the top and bottom if it may be used in any orientation, face the antenna in turn, and are coplanar with the uniform area. For each orientation, two sweeps are performed across the frequency range, one in each antenna polarization. For every sweep, it is necessary to monitor and record the EUT's response. If the frequency is swept from 80 to 1000MHz in 1% steps with the conventional minimum dwell time of 3 seconds per step, each sweep will take about 15 minutes, and the whole test takes over two hours.

IEC 61000-4-4 EFT bursts

- Generator produces fast transient bursts:
  - 15ms duration every 300ms
  - each burst has 5/50ns pulses at 5kHz
- coupled with respect to ground plane:
  - to mains live, neutral and earth via coupling/decoupling network
  - to signal cables via capacitive coupling clamp
- standard duration, 1 minute each polarity
- levels into open circuit, 0.5kV to 4kV

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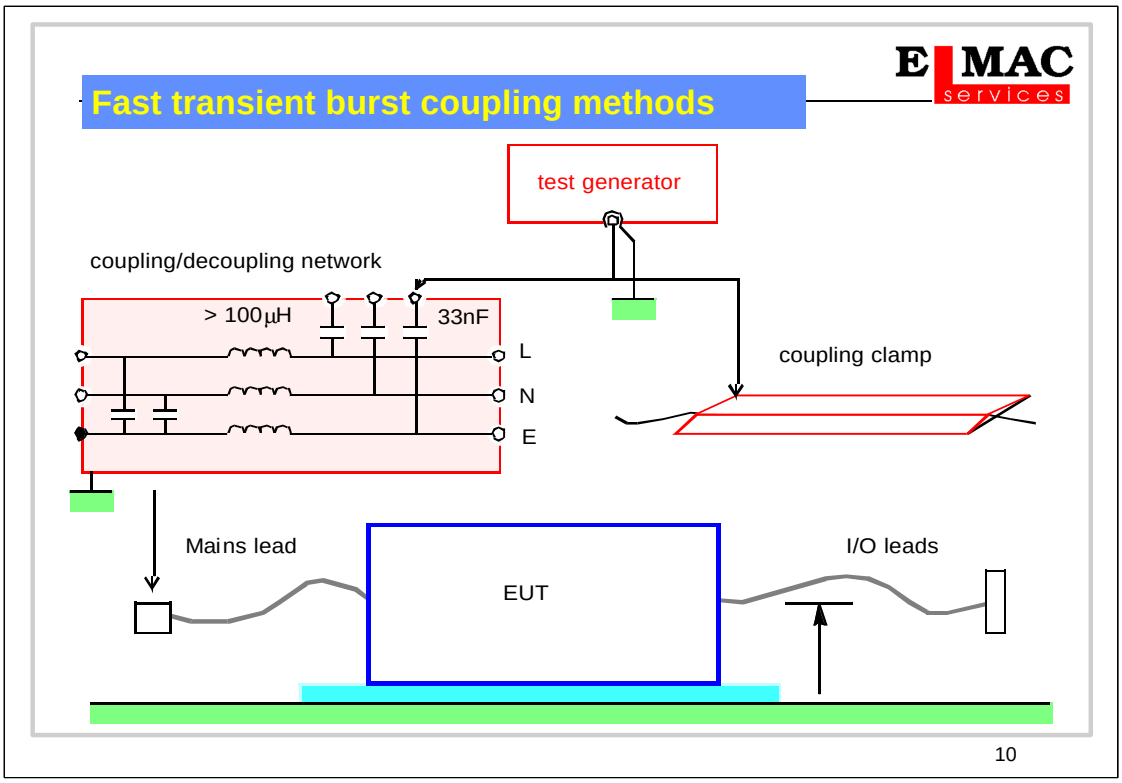
The Electrical Fast Transient (EFT) burst test subjects the EUT to bursts of transients that test its immunity to environmental disturbances caused mainly by local power switching operations. The transients are called “fast” to distinguish them from lower-frequency surges caused by distant disturbances outside the immediate environment. The carefully specified spike waveform and burst composition do not directly represent the wide variety of switching disturbances found in real life; the justification for the test is that apparatus that survives it is likely to be more immune to such real transients.

The test is exclusively cable-coupled. There are no radiated transient tests in the IEC 61000-4 series. The pulse waveform is wideband, with frequency components only 20dB down at 50MHz, and is invariably applied with respect to a ground reference plane. The open circuit voltage stress levels represent four degrees of environmental classification, as follows:

- Level 1: well-protected environment
- Level 2: protected environment
- Level 3: typical industrial environment
- Level 4: severe industrial environment.

For testing I/O, signal, data and control ports, half the voltage values applied to power supply ports are recommended.



Because the transients have a very high frequency spectral content, the test set up and coupling methods must use RF techniques as with the electrostatic discharge set up. A ground reference plane is mandatory and the test waveform generator and coupling network must be referred to it, as should the protective earth. It should project beyond the EUT by at least 10cm on all sides. As with the ESD test, the EUT must only be earthed according to its normal installation practice; free standing items should be spaced from the ground plane by an insulating support 10cm thick, while table-top equipment should be 0.8m above it.

Power leads (less than 1m long) are connected to the test pulse generator via a coupling/decoupling network which capacitively couples the transient burst onto each individual line. The coupling point is isolated from the supply by an L-C decoupling network in each line. This includes the protective earth conductor, which therefore is able to have transients applied to it as well. Thus unless the EUT's enclosure is normally separately bonded to installation earth, it too will have transient voltages coupled to it.

I/O cables are subjected to transient coupling via a capacitive coupling clamp spaced 10cm above the ground plane, which sandwiches the cable in question between two flat metal plates, both of which carry the test pulse burst referred to the ground plane. The distributed capacitance of this arrangement is 50–200pF. For in-situ tests, it can be simulated by wrapping foil around the cable bundle for a suitable length, if there is insufficient room to use the clamp.

IEC 61000-4-5 surge

- Generator produces single-shot surges:
  - 1.2/50µs voltage waveform
  - 8/20µs current waveform
- coupled differentially or with respect to earth:
  - to mains live and neutral via coupling/decoupling network
  - to signal cables via capacitive or spark gap coupling
- standard number, 5 pulses each polarity
- levels into open circuit, 0.5kV to 4kV

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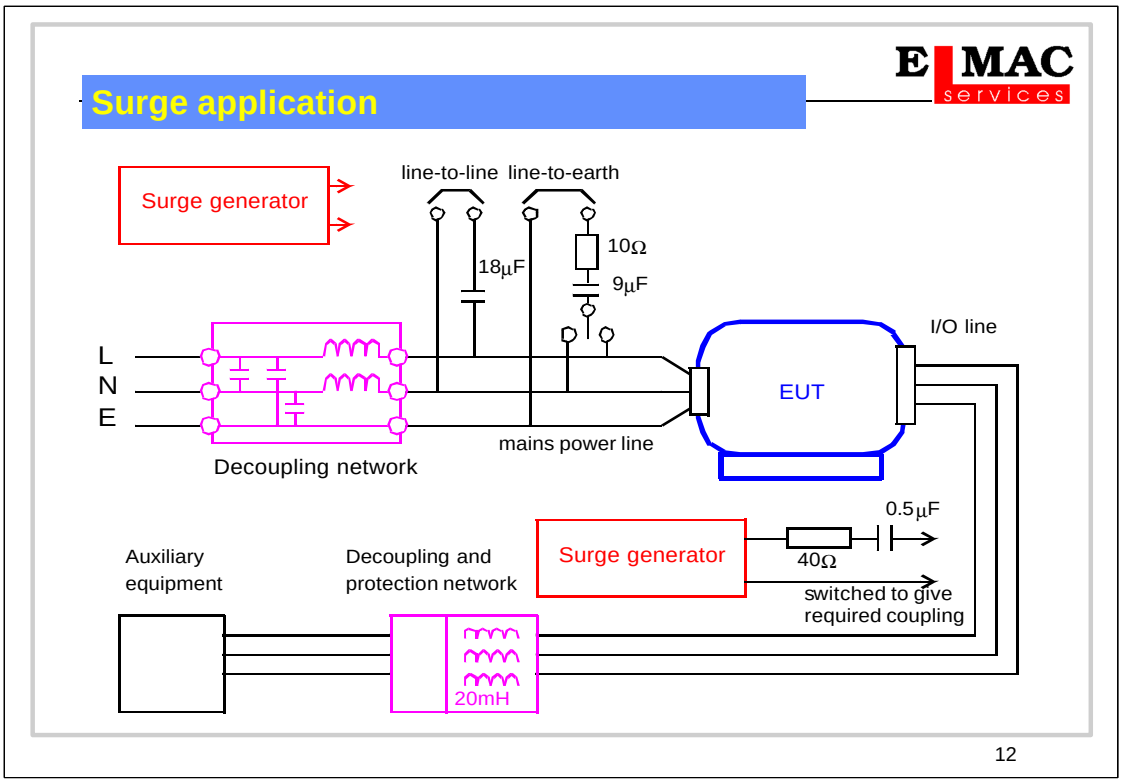
The surge test applies high energy but relatively low bandwidth transients, particularly representing those that may be attributable to nearby lightning strikes. The specification of the unipolar surge combines different voltage and current waveforms (so that the source impedance has reactive components) and it therefore is known as the “combination wave”. This means that a single pulse appears as a different waveform depending on whether it is applied to an open or a short circuit; most EUT impedances will lie somewhere in between, and may be non-linear.

Coupling can be either differential (symmetrical) between lines, or asymmetrical against one or more lines with respect to earth. The test levels should be based on installation conditions, particularly with regard to cable layout, and the type of line being tested: power supplies and long distance lines being subjected to greater stress levels.

Some telecommunication port tests reference another waveform, also mentioned in IEC 61000-4-5, which is the CCITT 10/700µs waveform. This is intended to be more representative of lightning surges induced directly onto outdoor telephone lines.



High energy surges are applied to the power port between phases and from phase to ground. For input/output lines, again both line-to-line and line-to-ground surges are applied, but from a higher impedance. 2Ω represents the differential source impedance of the power supply network, 12Ω represents the line-to-ground power network impedance while 42Ω represents the source impedance both line-to-line and line-to-ground of all other lines.

Power line surges are applied via a coupling/decoupling network incorporating a back filter, which avoids adverse effects on other equipment powered from the same supply, and provides sufficient impedance to allow the surge voltage to be fully developed. For line-to-line coupling the generator output must float, though for line-to-ground coupling it can be grounded. A 10Ω resistor is included in series with the output for line-to-ground coupling.

I/O line surges are applied in series with a 40Ω resistor either via capacitive coupling with a decoupling filter facing any necessary auxiliary equipment, or by spark-gap coupling where the bandwidth of the I/O line is wide enough that capacitive coupling would affect its operation. Note that testing with differential mode surges is only intended for unbalanced circuits in critical applications, i.e. ports intended for process measurement and control.

Long-distance telecommunication lines require special treatment, involving the CCITT 10 x 700μs waveform applied at up to 4kV.

IEC 61000-4-6 conducted RF

- RF voltage or current swept or stepped
  - from 150kHz to 80MHz (230MHz)
  - amplitude modulated 80% @ 1kHz
  - level set by substitution method
- applied to each relevant port of EUT
- coupled by coupling/decoupling network, EM clamp or current probe
- common mode source impedance 150Ω to ground reference plane
- levels from 1V to 10V emf and above

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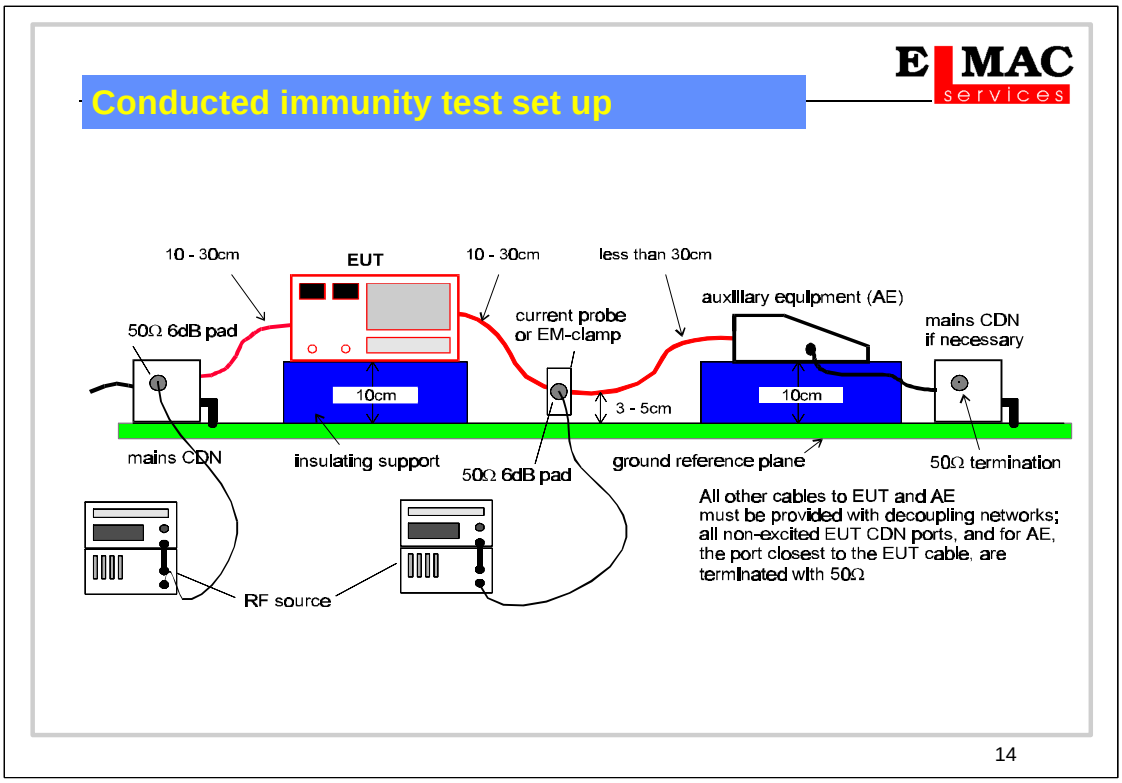
The conducted RF immunity test is complementary to IEC 61000-4-3 for radiated RF. Interference at lower frequencies is generally coupled through connected cables, whilst at higher frequencies coupling is more likely to be radiated directly via the enclosure. The breakpoint for testing was set by the IEC committee at 80MHz, analogous (but not identical) to the CISPR emission breakpoint at 30MHz. In fact, the optimum breakpoint rather depends on the dimensions of the EUT, with larger products favouring lower frequencies and vice versa. The text of IEC 61000-4-6 leaves the way open for product committees to set an alternative breakpoint between conducted and radiated testing at 230MHz.

The stress signal is always applied onto connected cables one at a time in common mode with respect to the ground reference plane. In this sense it is similar to the EFT burst test, but in the RF test the common mode source impedance is set to 150Ω across the frequency range. For common cable types (mains, one- or two-twisted pair, some screened cables) this can be achieved in a straightforward way by coupling/decoupling networks (CDNs), but less usual cables must be tested by a non-invasive method. There is a choice of EM-clamp or current probe, but neither of these give an accurate 150Ω impedance.

The stress levels are specified in terms of the open circuit voltage at the output of the test generator/transducer with the EUT absent. They correspond to those offered in IEC 61000-4-3, but it should not be deduced from this that there is a one-to-one correspondence between field strengths and induced cable voltage: there is still much controversy on that subject.



The IEC/EN 61000-4-6 test requires the application of an RF voltage swept at slower than 1.5 x 10^{-3} decades/s, or with a step size not exceeding 1% of fundamental and dwell time sufficient to allow the EUT to respond, over the frequency range 150kHz to 80MHz or 230MHz. The range 80MHz to 230MHz overlaps with IEC 61000-4-3 and these tests may be used instead of the radiated tests, depending on the EUT dimensions.

The signal is applied via coupling/decoupling networks (CDNs) to cable ports of the EUT. When CDNs are not suitable, the alternative methods of EM-clamp or current injection probe can be used. Cables leaving the EUT in close proximity or in conduit are treated as one cable. EUTs with many ports need only be tested on between 2 and 5 ports, selecting the most sensitive configurations

The standard gives severity levels of 1, 3 or 10V emf unmodulated; actual applied signal is modulated to 80% with a 1kHz sinewave.

IEC 61000-4-11 voltage dips/interrupts

- Applied to mains supply input
  - usually uses programmable waveform generator
  - may also used switched variac
- interruptions to 0% voltage from half a cycle to 50 cycles (1 second)
- dips to 40% or 70% of nominal voltage from half a cycle to 50 cycles

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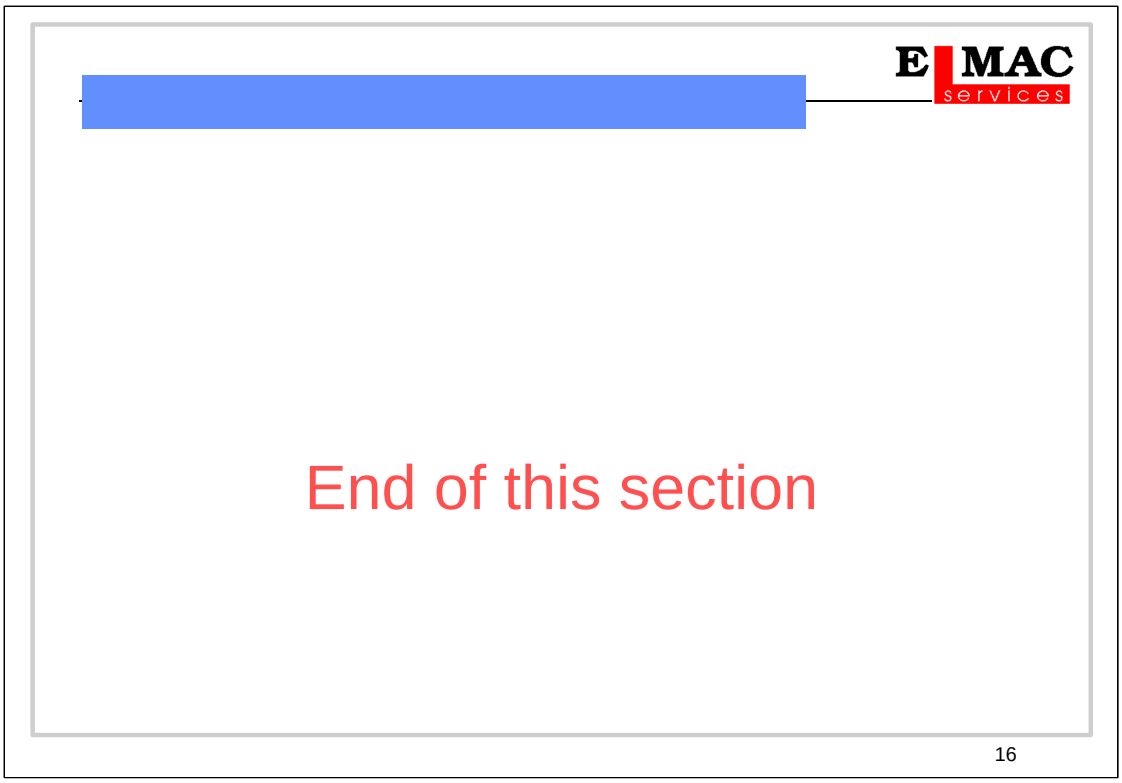
LF power supply compatibility is also regarded as an EMC phenomenon. Disturbances of the supply voltage itself (sometimes known as Power Quality, or PQ) are of course varied; the standard test simply specifies some standard dips and interruptions on the mains supply, in order to give repeatable and universal testing. Dips and interruptions are abrupt changes. The standard also offers an optional test against voltage variations with a defined transition period, but these are rarely used by product committees.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