TÜBİTAK

UME

EMC TESTING

ELECTROMAGNETIC LABORATORY

TÜBİTAK Ulusal Metroloji Enstitüsü

Gebze/Kocaeli

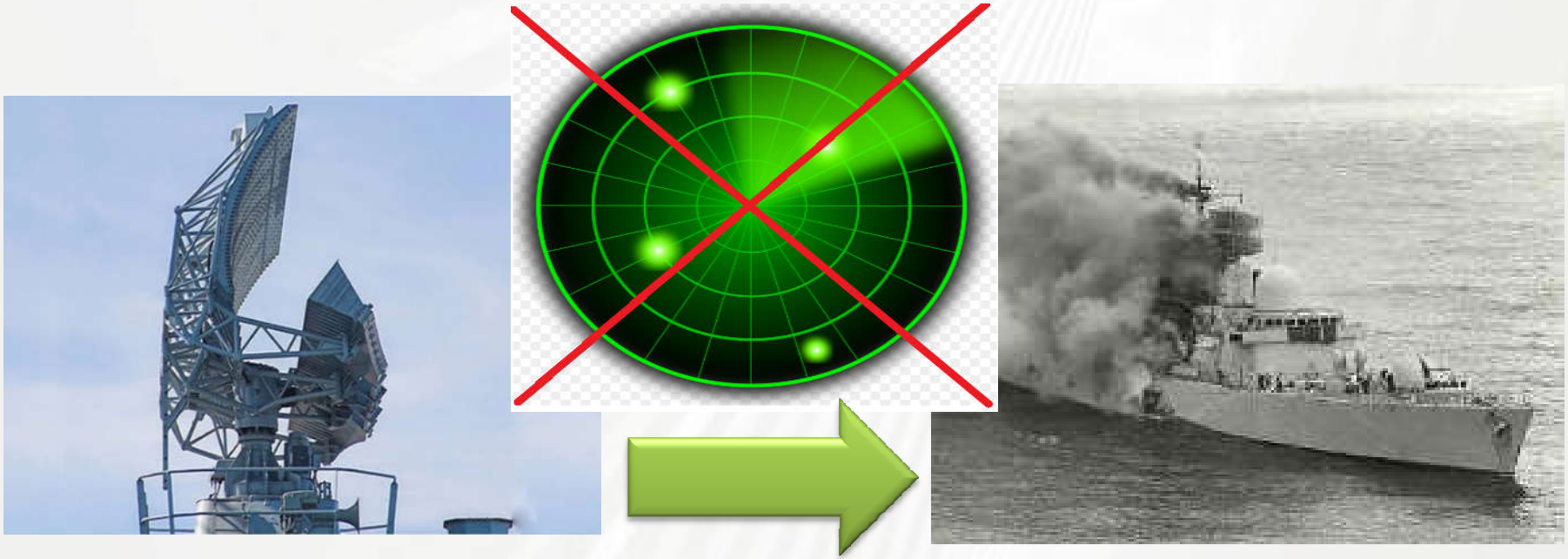
EMC Problems in Real Life

EMC Problems in Real Life

In the Gulf of Tonkin on 29 July, Forrestal had been launching aircraft from her flight deck. For four days, the Planes of Attack Carrier Air Wing 17 flew about 150 missions against targets in North Vietnam from the ship.On 29 July 1967, during preparation for another strike, a Zuni rocket installed on an F4 Phantom, misfired, impacting an armed A-4 Skyhawk, parked on the port side. The rocket's impact dislodged and ruptured the Skyhawk's 400-gallon external fuel tank. Fuel from the leaking tank caught fire, creating a serious conflagration that burned for hours, killing 134, injuring 161, destroying 21 aircraft and costing the Navy US$72 million. The accidental firing is believed to have been triggered by a combination of the powerful fields at deck level from the ship’s radar and an incorrectly fitted shielded cable connector.

EMC Problems in Real Life

The HMS Sheffield was a Type 42 guided missile destroyer and was fitted with the Type 965 radar system. This was an old system that was due to be upgraded to the Type 1022 system. Two Argentine Navy Super Étendards (3-A-202 and 3-A-203) both armed with Exocets fired two missiles and one of them hit the HMS Sheffield. The Sheffield's search radar was switched off when the satellite communication system was used, because of interference from the radar. Without its search radar the Sheffield's anti-missile defences could not be used, and this allowed an Exocet missile to hit the ship on 4th May 1982.



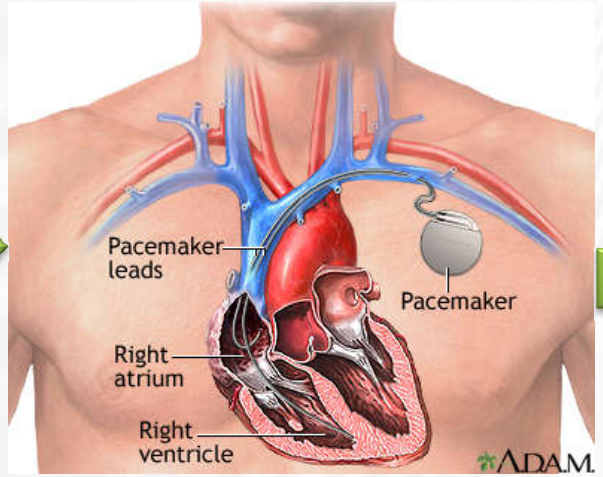
EMC Problems in Real Life

On July 17, 1996, TWA Flight 800, a Boeing 747 bound for Paris, exploded shortly after takeoff from New York's JFK International airport, killing all 230 people on board. The National Transportation Safety Board concluded that the probable cause of the accident was an "explosion of the center wing fuel tank" resulting from an ignition of the fuel/air mixture inside the tank.

The likely source of the ignition was an arc generated in the wiring associated with the fuel quantity indication system.

EMC Problems in Real Life

Pacemakers can mistakenly detect electromagnetic interference from smartphones as a cardiac signal, causing them to briefly stop working. This leads to a pause in the cardiac rhythm of the pacing-dependent patient and may result in syncope. For implantable cardioverter defibrillators, the external signal mimics a life threatening ventricular tachyarrhythmia, leading the ICD to deliver a painful shock.

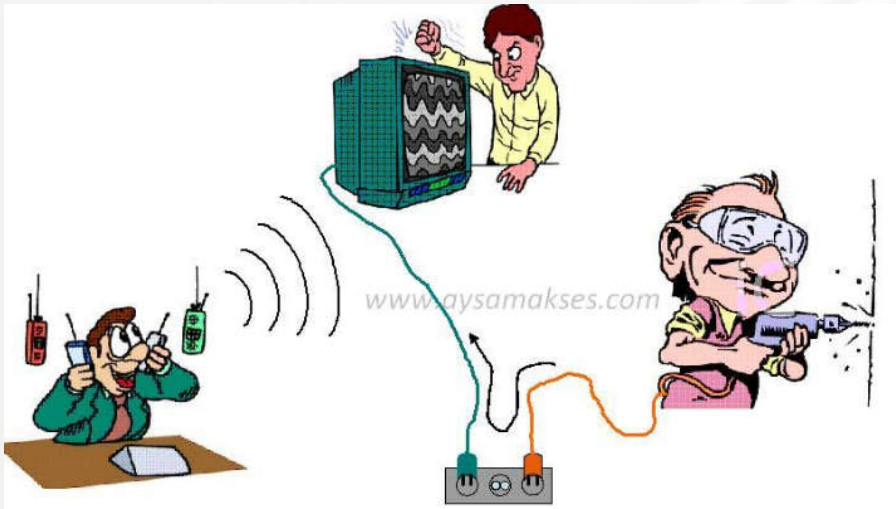


https://incompliancemag.com/studies-confirms-smartphones-interfere-with-pacemakers/

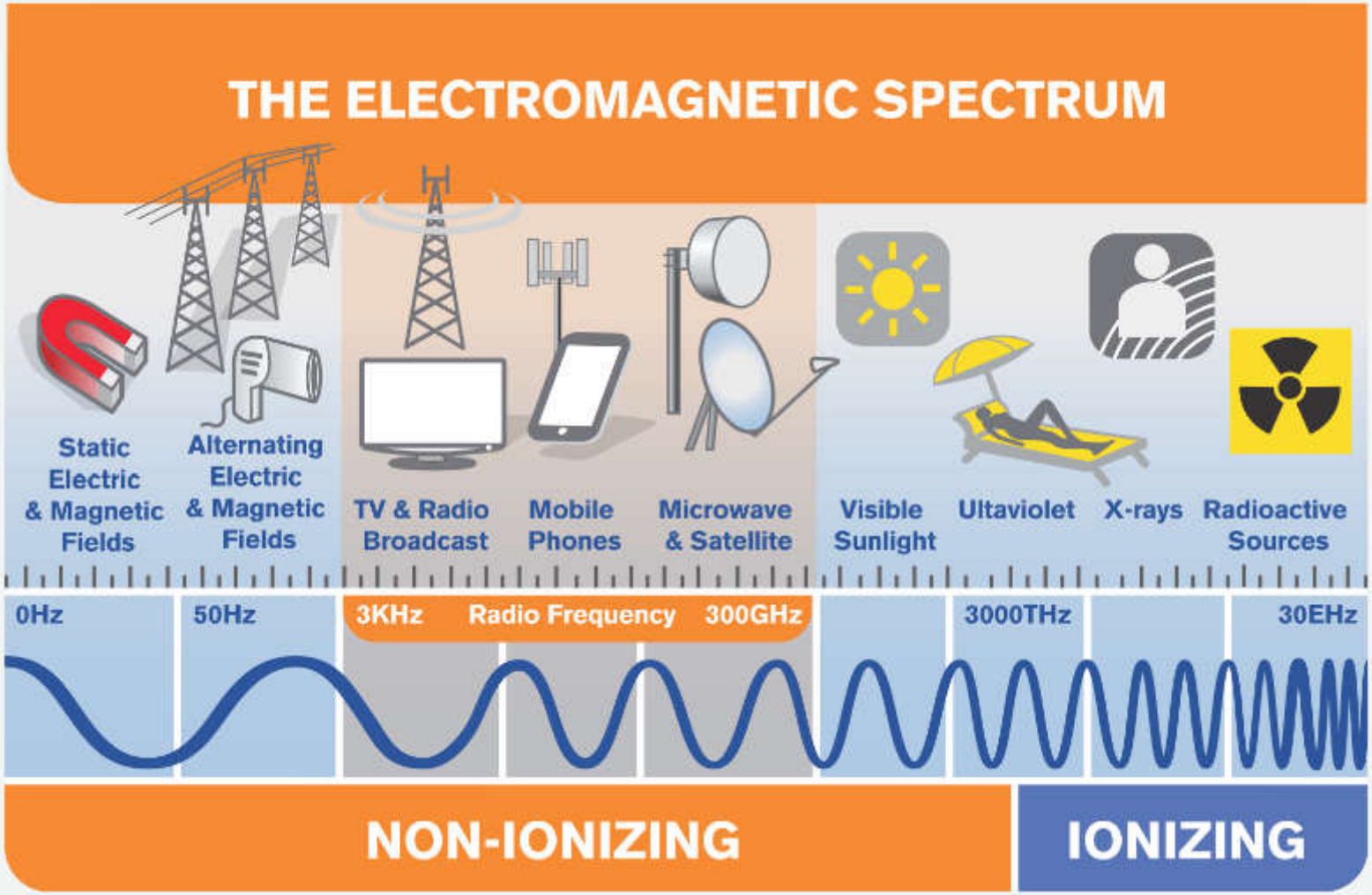
Definition of EMC

➢ Electromagnetic compatibility (EMC) is defined as the ability of a device, equipment, or system to function satisfactorily in its electromagnetic environment without producing intolerable electromagnetic disturbances to anything in that environment.

➢ EMC is achieved when a device functions satisfactorily without introducing intolerable disturbances to the electromagnetic environment

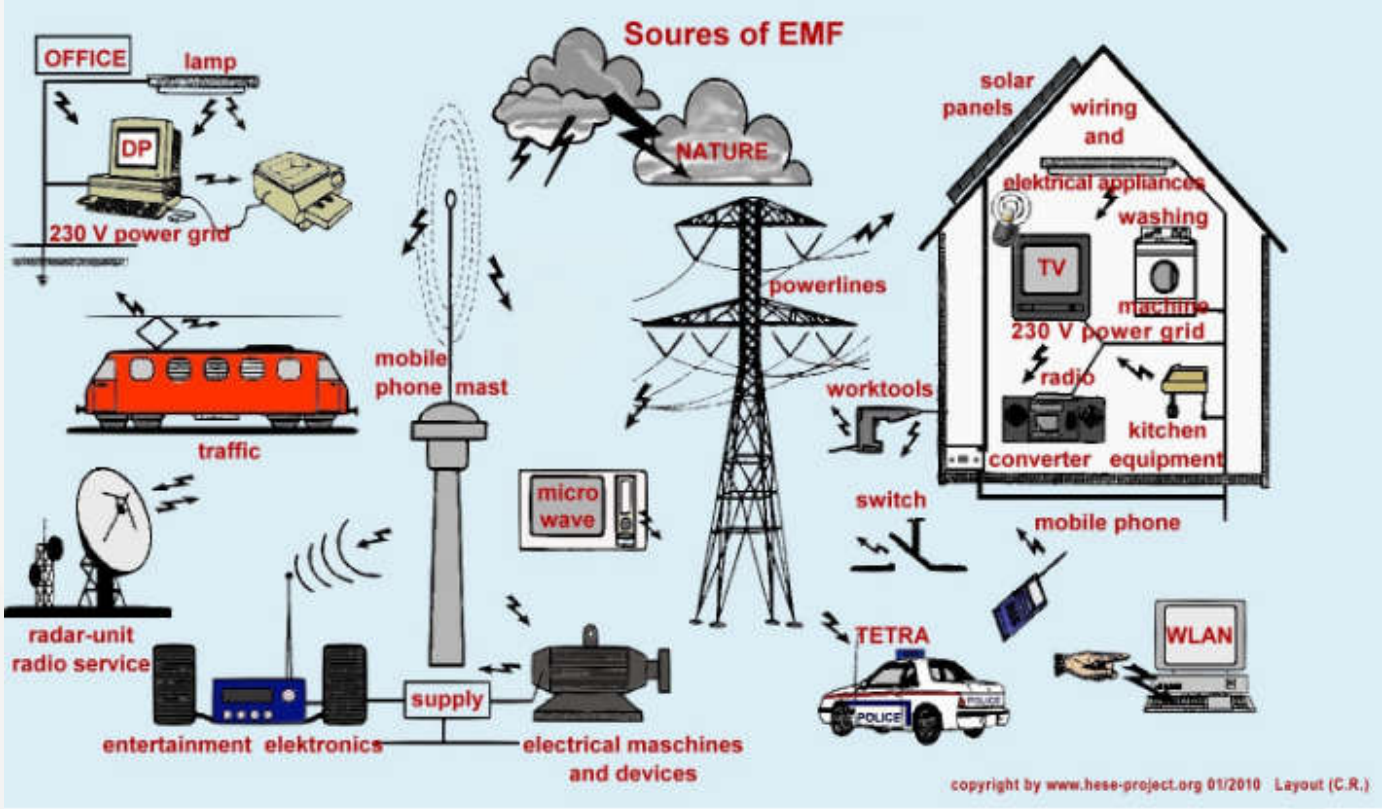


Electromagnetic Spectrum



http://emfguide.itu.int/emfguide.html

EMI/EMC Sources

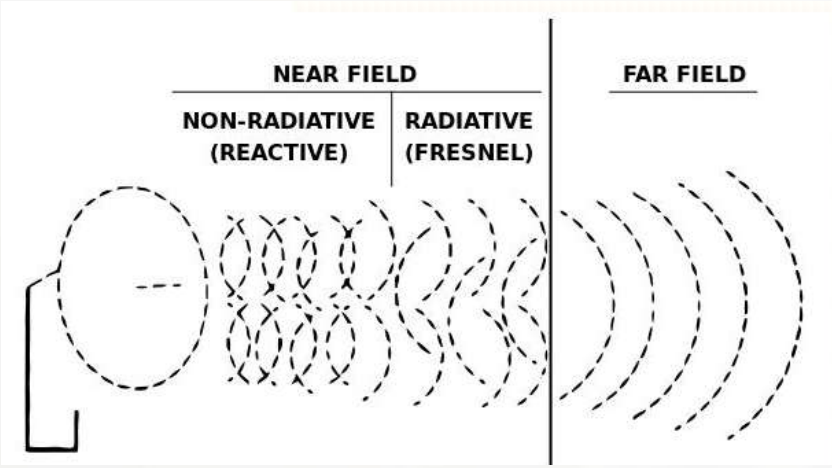


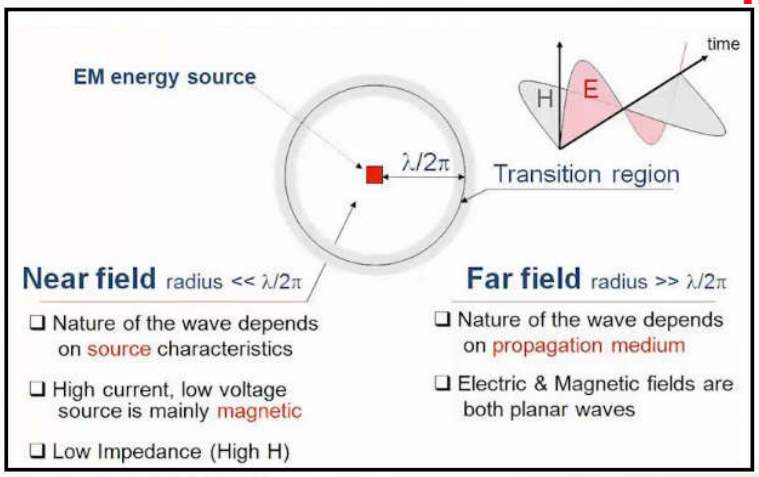
- Natural sources: Lightning, Sun Spots

- Unintentional emitting products: Power lines, Motors (Mixer, Hair Dryers etc)

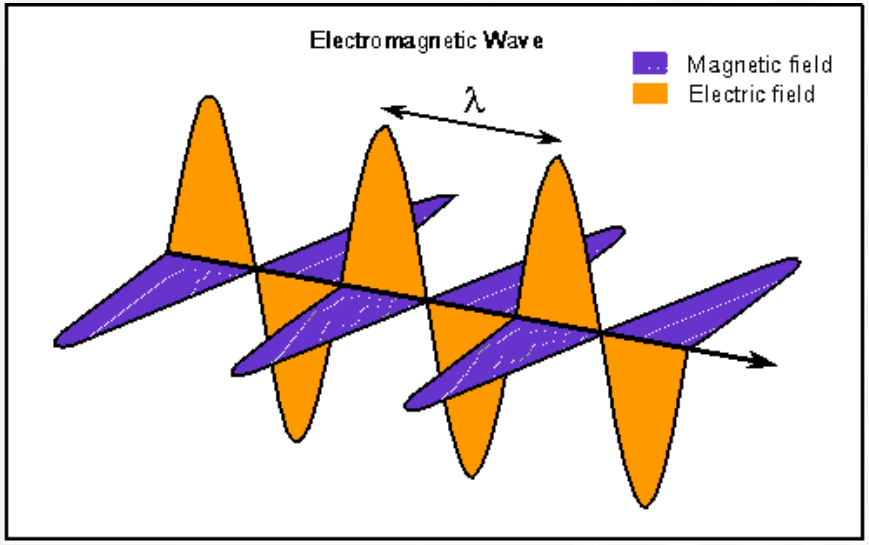
- Devices that intentionally emit signals: Computers, Radar, Transmitters, Broadcast Equipment etc.

Definiton of Far Field and Near Field

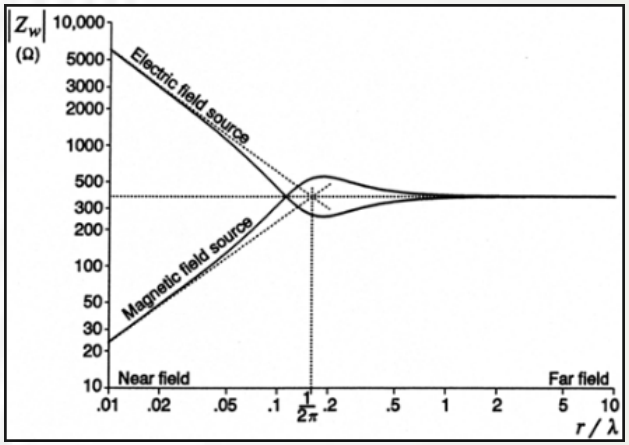




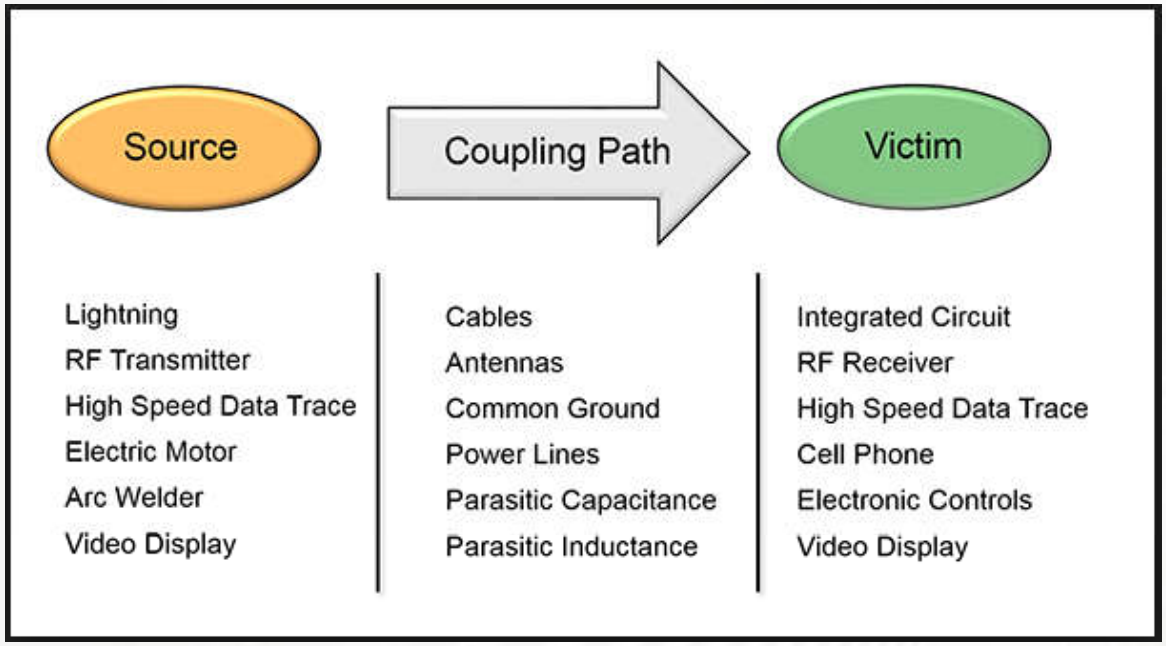
	near field	*far field*
Situation of the zone	close to the antenna	far from the antenna
Distance	$0 – 2D^2/\lambda$	$2D^2/\lambda$ - ∞
E perpendicular to H	no	yes
E and H perpendicular to S[1]	no	yes
Evolution of the field in 1/r	no	yes
Wave impedance (Z=E/H)	≠ 377 Ω	377 Ω
Field distribution	very complex and inhomogeneous	easy and monotone (spherical waves)

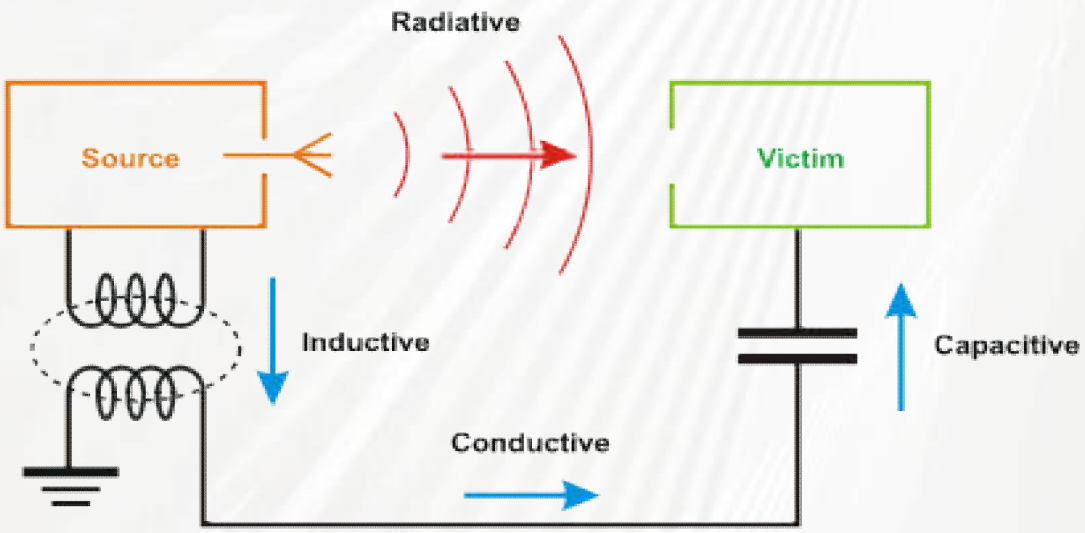


http://www.astronomynotes.com

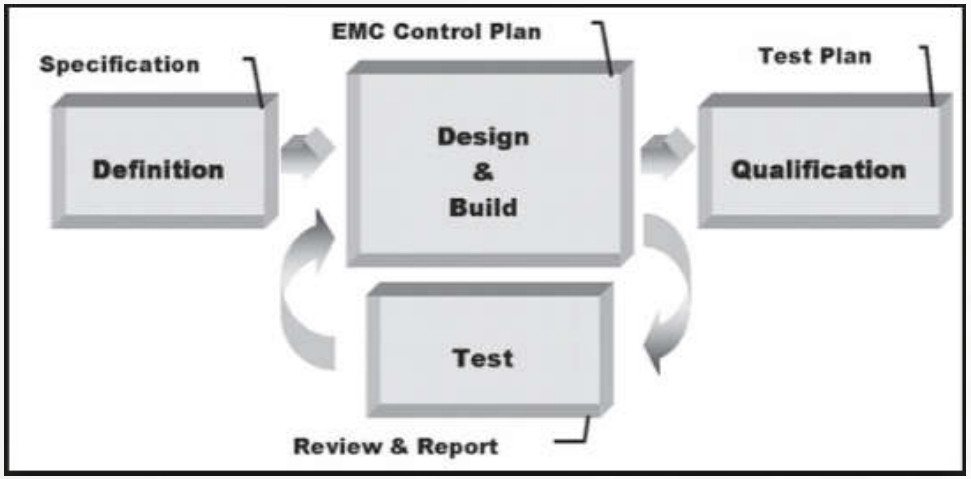


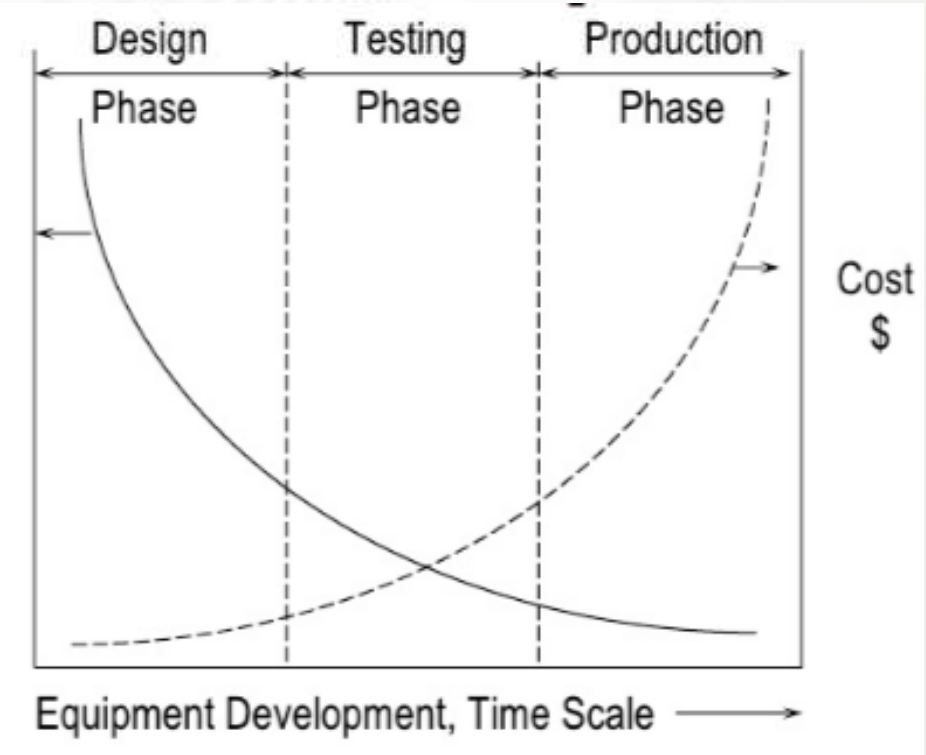
EMC Phenomenon



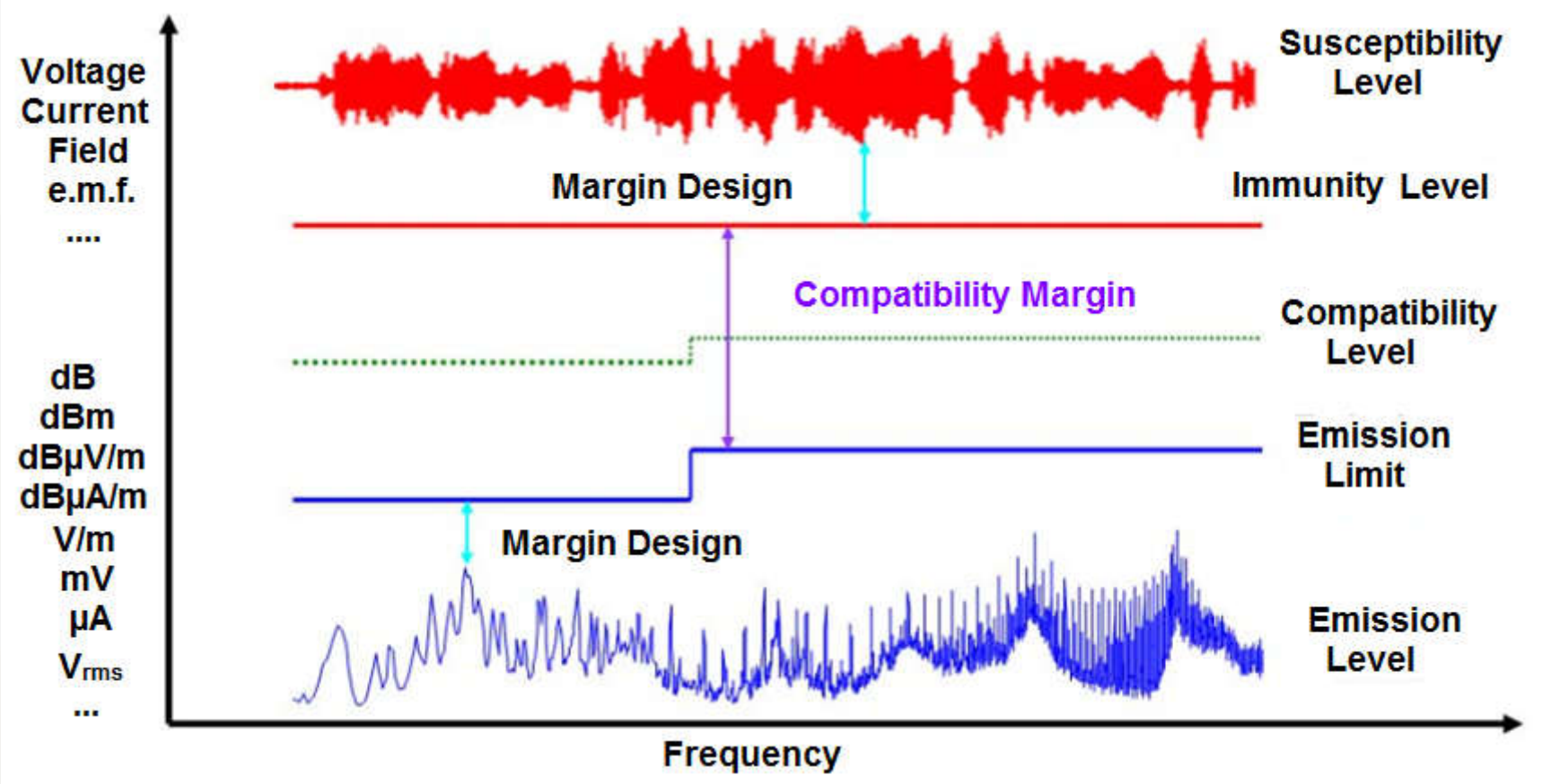


The Importance of EMC





EMC Test Levels



https://wpo-altertechnology.com

Definition of decibel (dB)

dB is a logarithmic unit expressing the ratio of two quantities.

- In power measurement, the relative power is defined as

$$dB_{ref} = 10\ log_{10} \frac{P_1}{P_{ref}}$$

dBm represents the power level P_1 with reference to 1 mW

- in voltage measurement, the relative voltage is defined as

$$dB_{ref} = 20\ log_{10} \frac{V_1}{V_{ref}} \Big| if\ R_1 = R_{ref}$$

dBμV represents the power level V_1 with reference to 1 μV rms

- in current measurement, the relative current is defined as

$$dB_{ref} = 20\ log_{10} \frac{I_1}{I_{ref}} \Big| if\ R_1 = R_{ref}$$

dBμA represents the power level I_1 with reference to 1 μA rms

dBm to dBμV and dBμV to dBμA

dBm to dBμV conversion only for 50 Ω system

$$P = \frac{V^2}{R} \rightarrow P = \frac{V^2}{50} \rightarrow 10logP = 20\ logV - 10log50$$

$$dBW = dBV - 17 \rightarrow (dBm - 30) = (dB\mu V - 120) - 17 \rightarrow 0\ dBm = 107\ dB\mu V$$

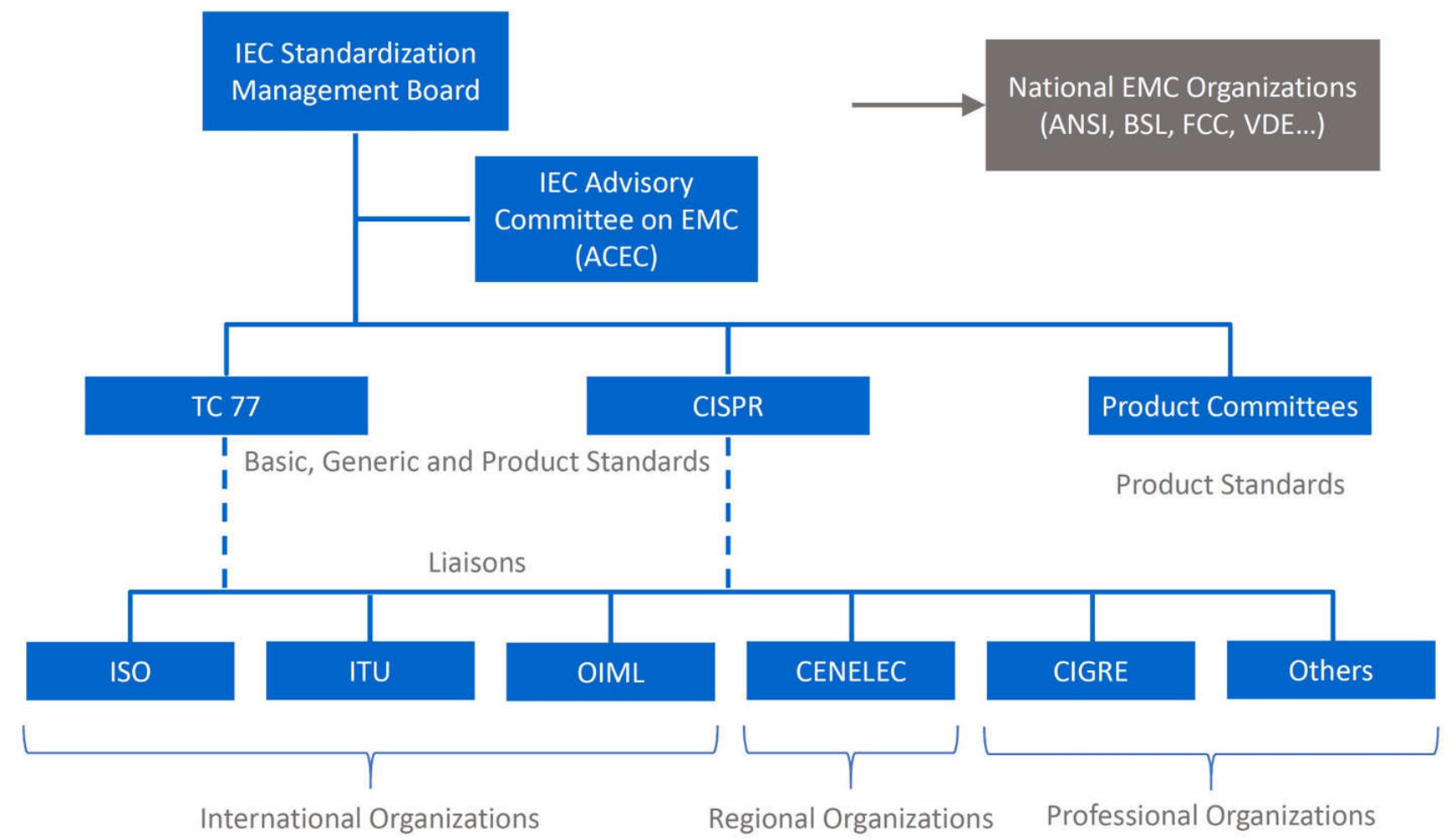
dBμV to dBμA conversion only for 50 Ω system

$$V = I * R \rightarrow V = I * 50 \rightarrow dBV = dBA + 34dB\Omega$$

$$dB\mu V - 120 = (dB\mu A - 120) + 34dB\Omega \rightarrow 20logV = 20logI + 20log50$$

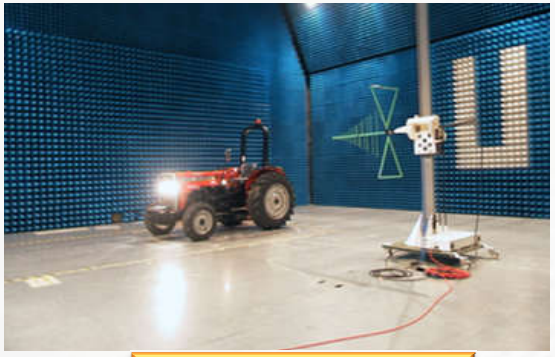
$$\rightarrow dB\mu V = dB\mu A + 34dB\Omega$$

EMC Standardization, Organization

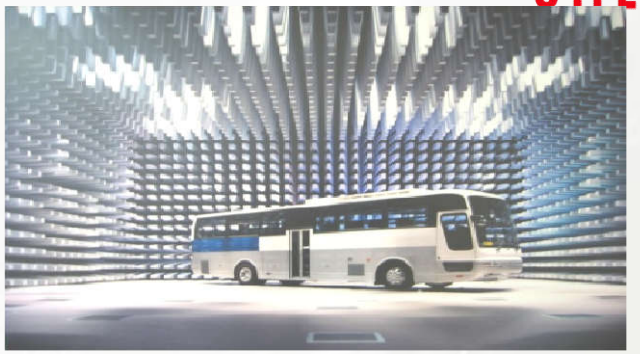


EMC Test Enviroments

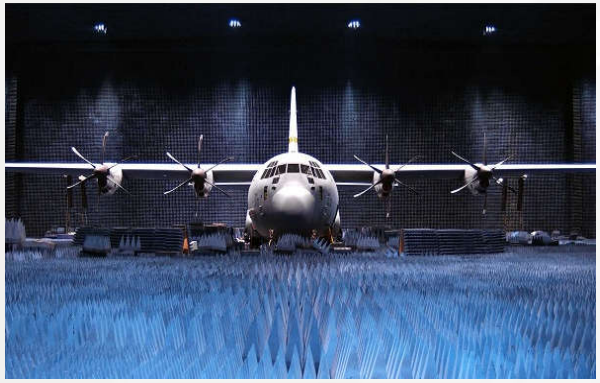
3m EMC Chamber



10m EMC Chamber



30m EMC Chamber



Full EMC Chamber

OATS

Screen Chamber

EMC Test Equipment

Commercial EMC Standards

Basic Standards

Examples

IEC/EN 61000-3-XX

IEC/EN 61000-4-XX

Product Specific

Examples

EN 50199

EN 50293

EN 50270

Product Family

Examples

EN 55011

EN 55022

EN 55024

Generic

IEC/EN 61000-6-XX

Examples

IEC/EN 61000-6-1

IEC/EN 61000-6-4

Basic EMC Standards

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Immunity Standards

- ***IEC 61000-4-2**, Electrostatic discharge immunity test*
- ***IEC 61000-4-3**, Radio frequency, electromagnetic field immunity test*
- ***IEC 61000-4-4,** Electrical fast transient/burst immunity test*
- ***IEC 61000-4-5,** Surge Immunity Test*
- ***IEC 61000-4-6,** Immunity to conducted disturbances, induced by radio-frequency fields*
- ***IEC 61000-4-8,** Power Frequency Magnetic Field Immunity Test*
- ***IEC 61000-4-11,** Voltage dips, short interruptions and voltage variations immunity tests*

Emission Standards

- ***CISPR 11,** Industrial, scientific and medical equipment*
- ***CISPR 12,** Vehicles, boats and internal combustion engines*
- ***CISPR 13,** Sound and television broadcast receivers and associated equipment*
- ***CISPR 14,** Household appliances, electric tools and similar apparatus*
- ***CISPR 15,** Electrical lighting and similar equipment*
- ***CISPR 22,** Information technology equipment*
- ***CISPR 25,** Vehicles, boats and internal combustion engines*
- ***CISPR 32,** Electromagnetic compatibility of multimedia equipment*
- ***IEC 61000-3-2,** Harmonic current emissions (equipment input current ≤16 A per phase)*
- ***IEC 61000-3-3,** Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16 A per phase*

General Test Conditions - I

- The Equipment Under Test (EUT) shall be fully operational during testing. The electronics shall be exercised in a way simulating actual / worst case usage.

- If needed, special test firmware/software can be loaded to simulate worst case scenarios. The special loads and equipment shall be provided by the customer.

- It is the customers responsibility to provide a test PC/laptop if this is required to exercise the EUT in full.

- The tests configuration shall be as close to typical actual operation state as possible. If the EUT is capable of various modes of operation (for instance GSM band 1/2/3) that cannot be activated and tested simultaneously. it is required to select sufficient number of modes to simulate actual situation and ensure that different types of modes can be tested.

General Test Conditions - II

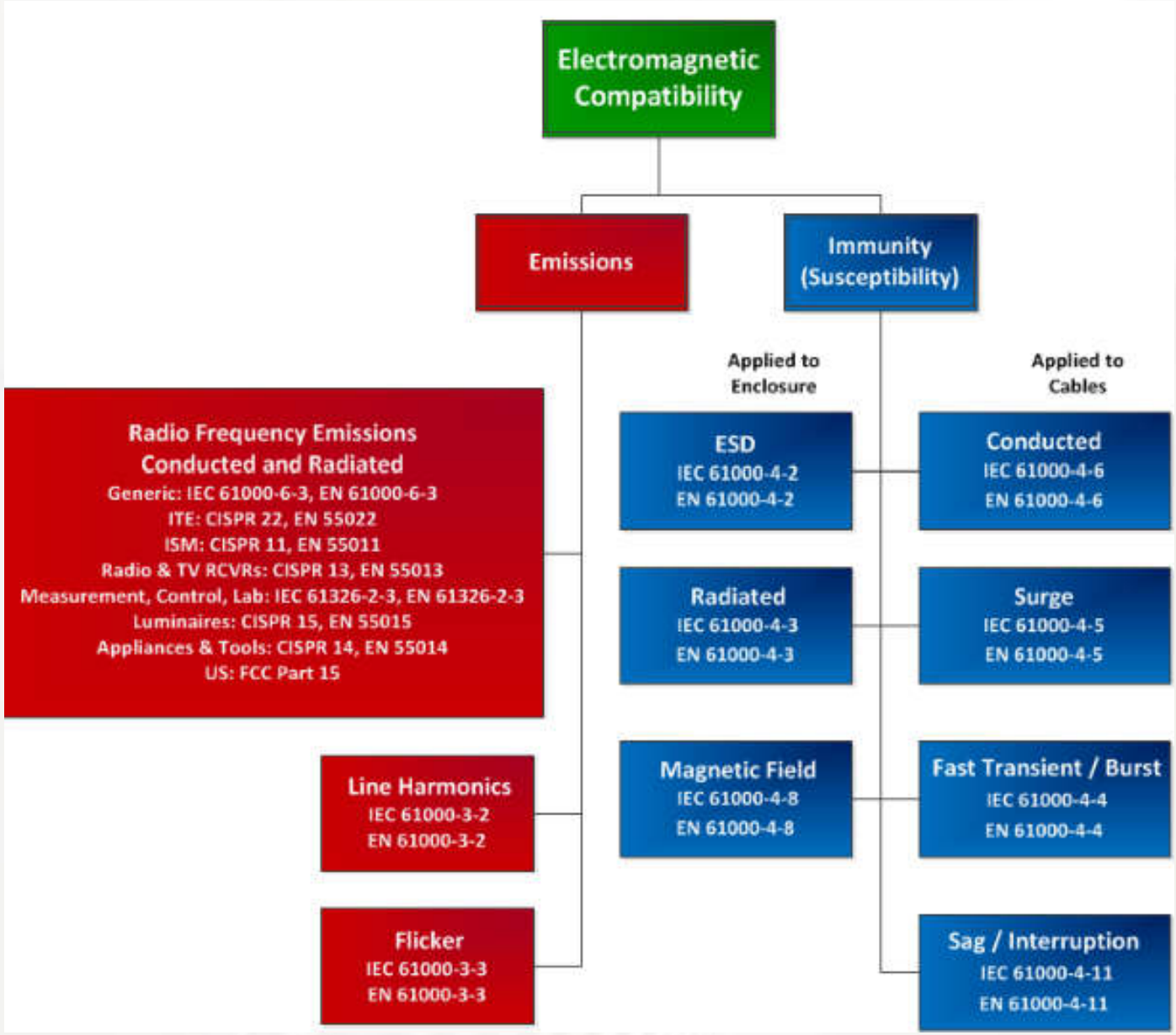
- If the EUT can operate from different supply voltages, the tests must be repeated for the different voltages.

- If the EUT has lots of ports, it is required to select sufficient number of ports to simulate actual situation and ensure that different types of ports can be tested.

- The customer shall clearly indicate the required standards and modes to be tested against otherwise the testing laboratory shall revert to the setup in the generic / product standard(s) applicable to the device.

- The test conditions, operating mode and test configuration shall be properly recorded in the test report.

General EMC Tests

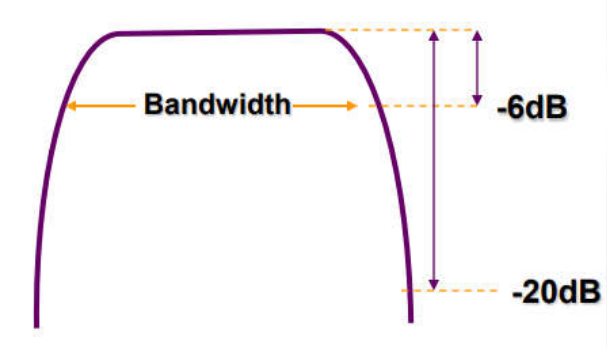


http://www.power-supply-designer.com

EMISSION TESTS

CISPR Bandwidth and Detector Requirements

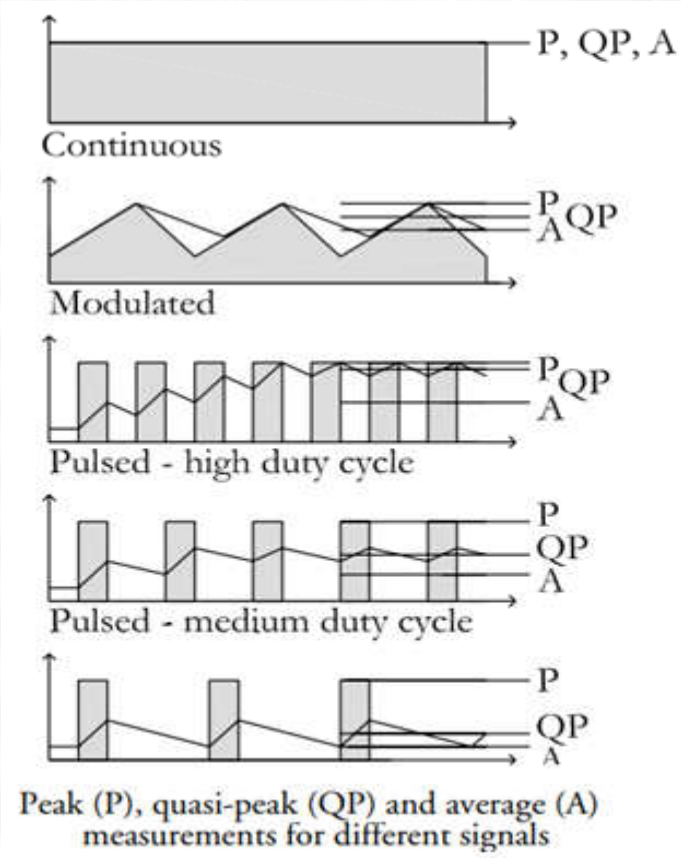
Frequency Range	CISPR Band	CISPR 6dB Bandwidth	Step Size
9 kHz – 150 kHz	A	200 Hz	≤ 100 Hz
150 kHz – 30 MHz	B	9 kHz	≤ 4.5 kHz
30 MHz – 1 GHz	C/D	120 kHz	≤ 60 kHz
Above 1 GHz	E	1 MHz	≤ 500 kHz



Peak Detector
- Initially used
- Faster than QP and Average modes
- If all signals fall below the limit, then the product passes and no future testing is needed.

Quasi-Peak Detector
- For CW signal, Peak = QP
- Much slower by 2 or 3 order magnitude compared to using Peak detector
- Charge rate much faster than discharge rate – the higher repetition rate of the signal, the higher QP reading

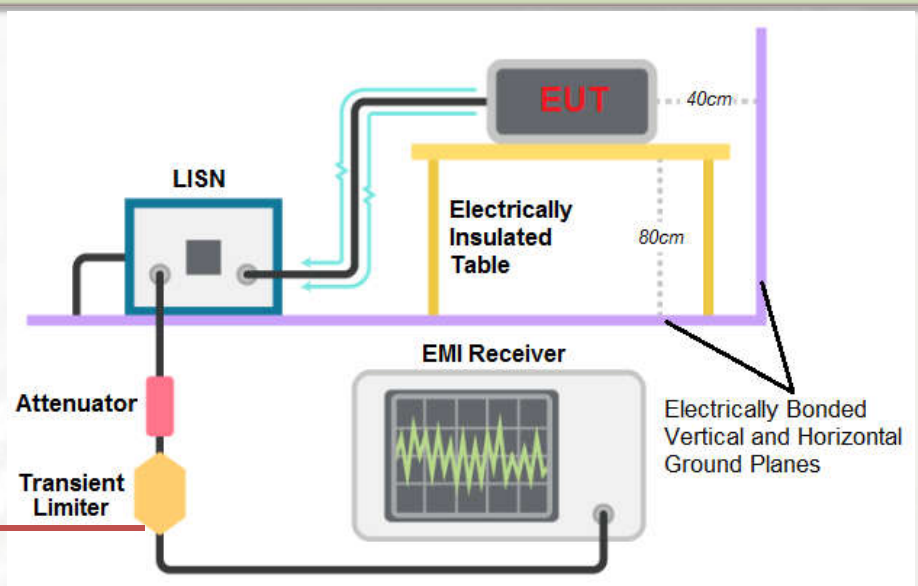
Average Detector
- Radiated emissions measurements above 1 GHz are performed using average detection



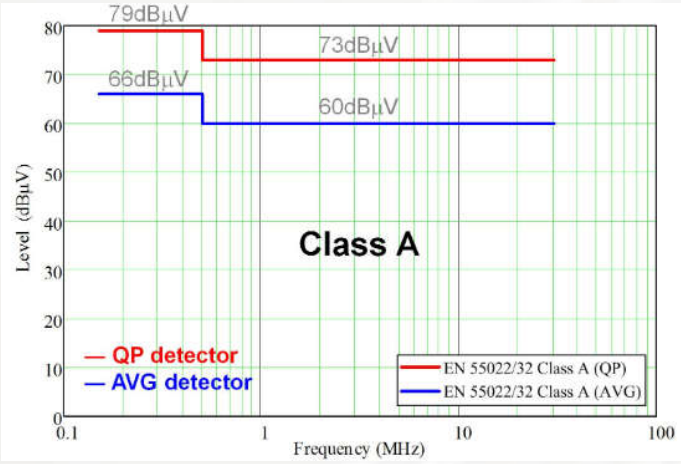
Conducted Emission Test for Power Lines By Using LISN

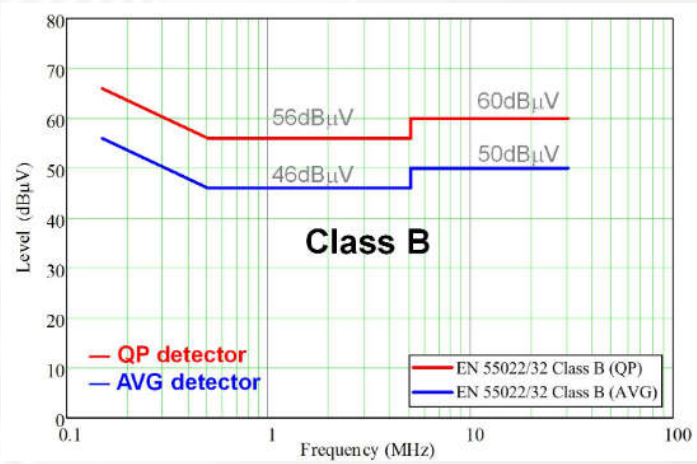
The aim of this test is to measure the levels of disturbance conducted by electrical and/or electronic equipment through its power supply cables in the frequency range from 150 kHz to 30 MHz.

The purpose of the transient limiter is to protect the input of the EMI receiver from large transients when connected to a LISN. Switching EUT power on or off can cause large spikes generated in the LISN.



https://www.cui.com/blog/importance-of-electromagnetic-compatibility-testing

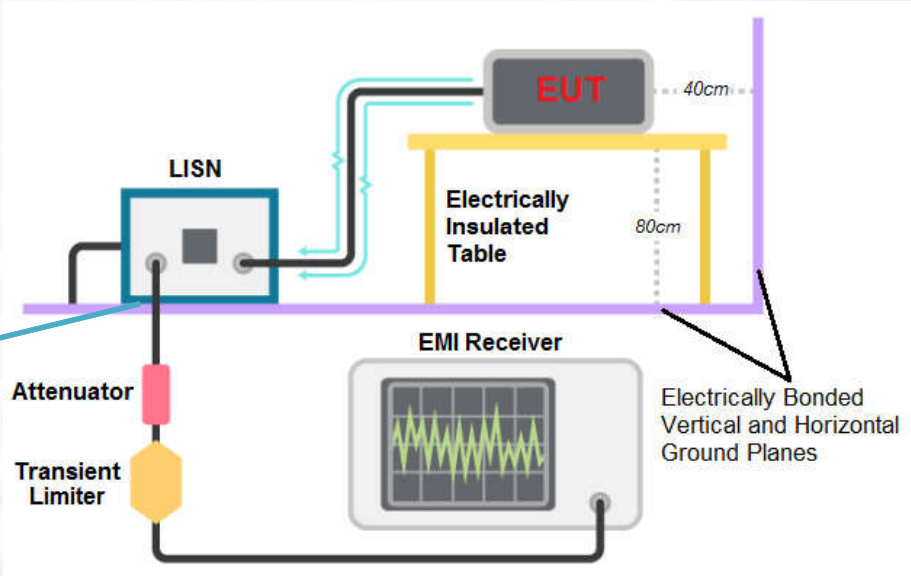




Conducted Emission Test for Power Lines By Using LISN

The LISN's earth is connected to the ground reference plane (GRP) of the test setup. Since this is the ground reference for the measurement, no extra RF impedance should be introduced by this connection because it would affect both the impedance seen by the EUT and the voltage developed across the LISN's impedance. This means that wires or straps of more than a few inches must not be used, since their inductance is unacceptable. The best connection here is a solid metal bracket, firmly bonding the LISN to the GRP, as shown below.

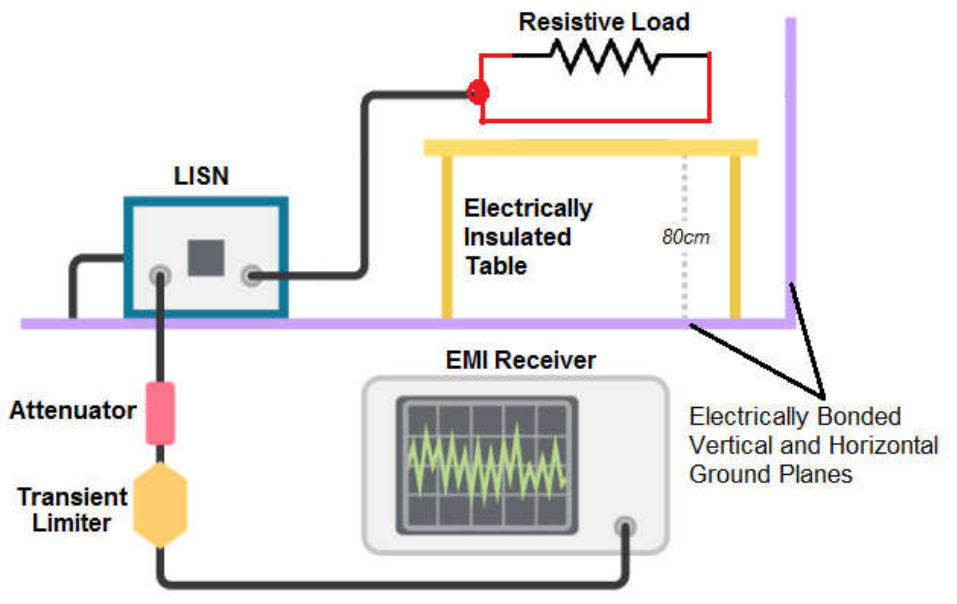
https://www.emcstandards.co.uk/files/calibration_and_use_of_amns_lisns_and_absorbing_clamps_tim_williams.pdf

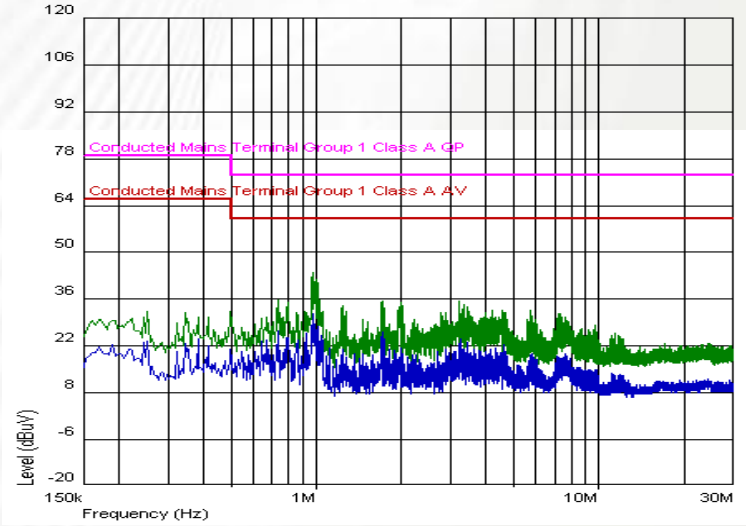


EMI Receiver/Spectrum Analyser shall be compatible with CISPR 16-1-1.

Background Noise Measurement for Conducted Emission Test

Before the conducted emission testing, the background noise level measured with the EUT de-energized and all auxiliary equipment turned on shall be at least 6 dB below the allowable specified limits when the test is performed in a shielded enclosure. The background conducted levels on power leads shall be measured with the leads disconnected from the EUT and connected to a resistive load which draws the same rated current as the EUT.

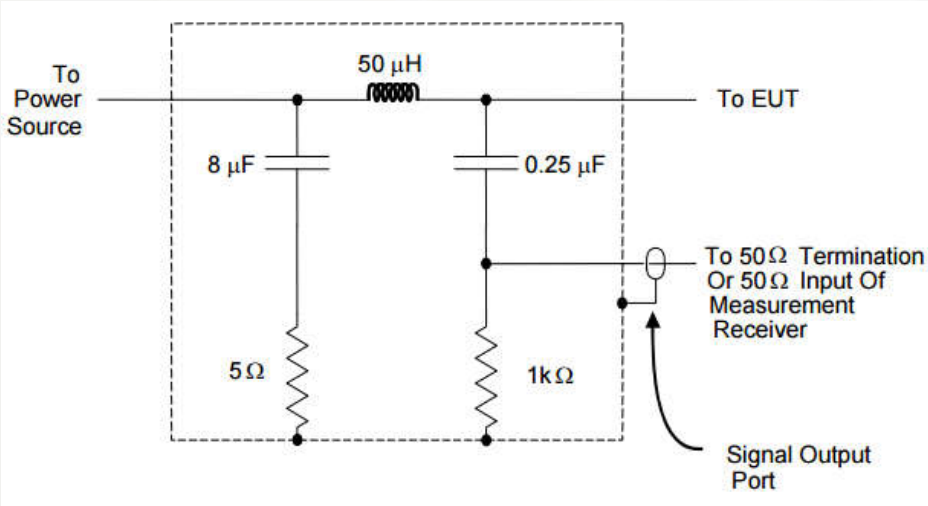


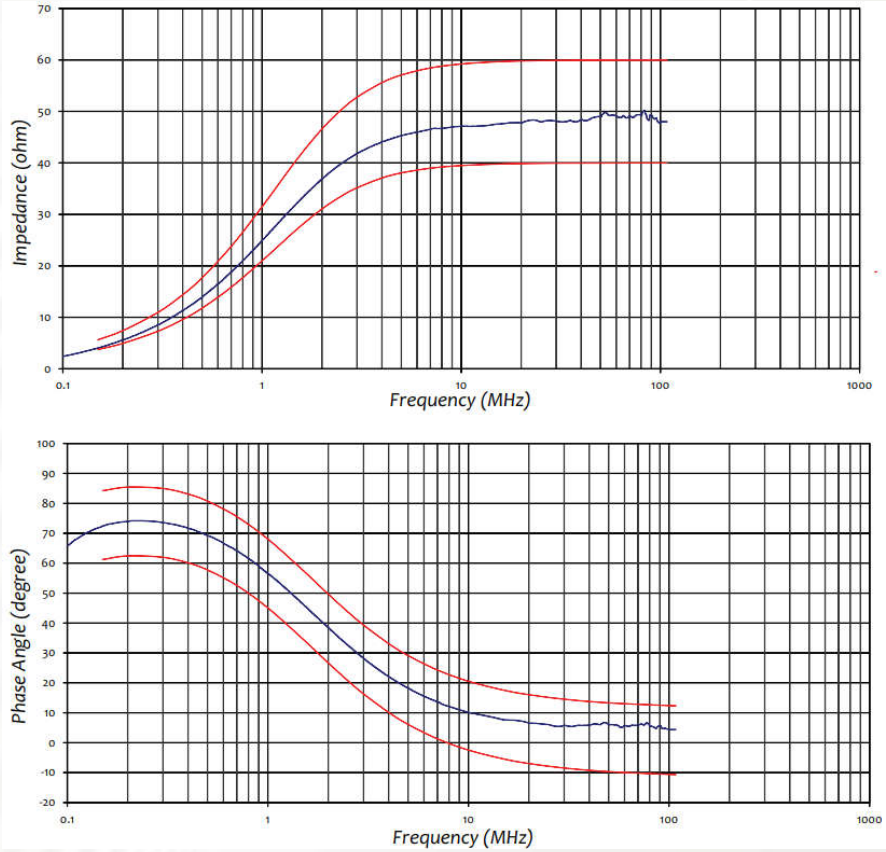


Purpose of a LISN

- The LISN isolates the power mains from the EUT. The power supplied to the EUT must be as clean as possible.
- The LISN isolates any noise generated by the EUT from being coupled to the power mains.
- To provide a defined impedance impedance to measure the conducted emission test and to provide a measurement port to determine the conducted emission levels.

Schematic of LISN circuit

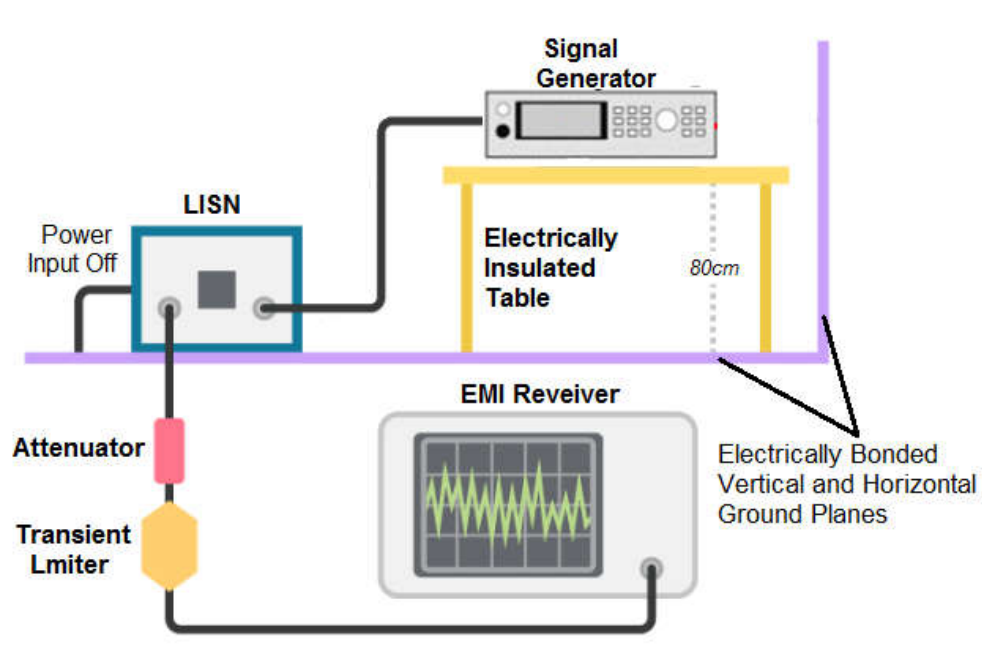




https://www.com-power.com/datasheets/LI-550A.PDF

Verification Measurement for Conducted Emission Test

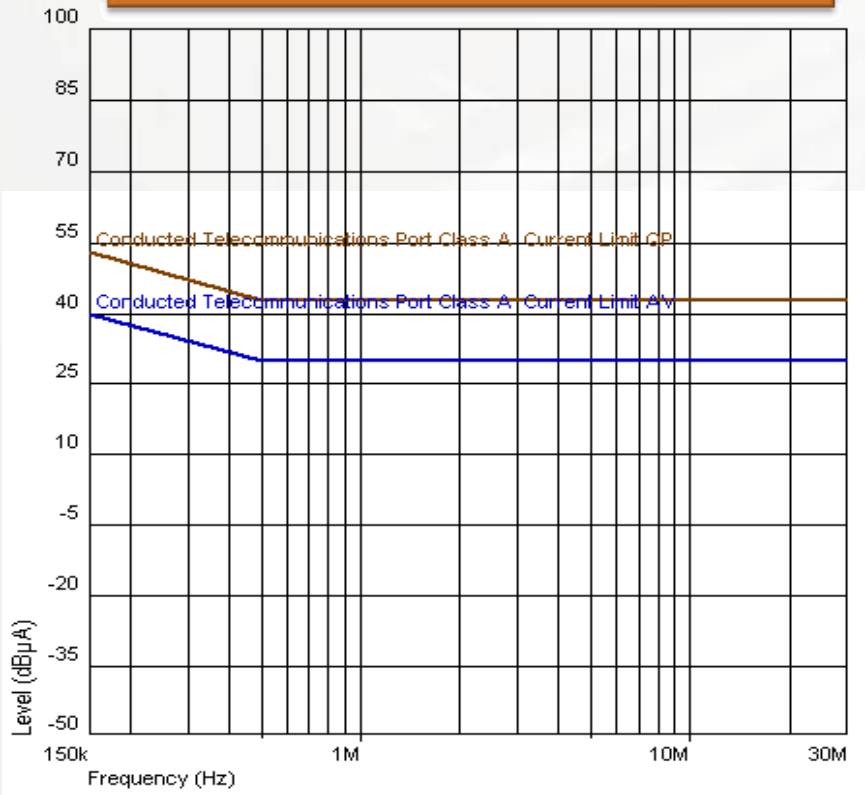
- Before conducted emission testing, test laboratory must perform verifications to ensure the quality and precision of test results by means of verification as the verification can detect errors beforehand in the test setup and prevent wrong testing.
- A known signal that is 6 dB below the limit to the input of the LISN at 150 kHz, 15 MHz and 30 MHz in turn as shown. Thereafter, the measurement receiver is scanned for each frequency in the same manner as a test scan and it is expected that the test software must indicate a level within ± 3 dB of the injected level. If the measured signal levels deviate by more than ± 3 dB, the test is not continued and the error must be rectified in the test system.



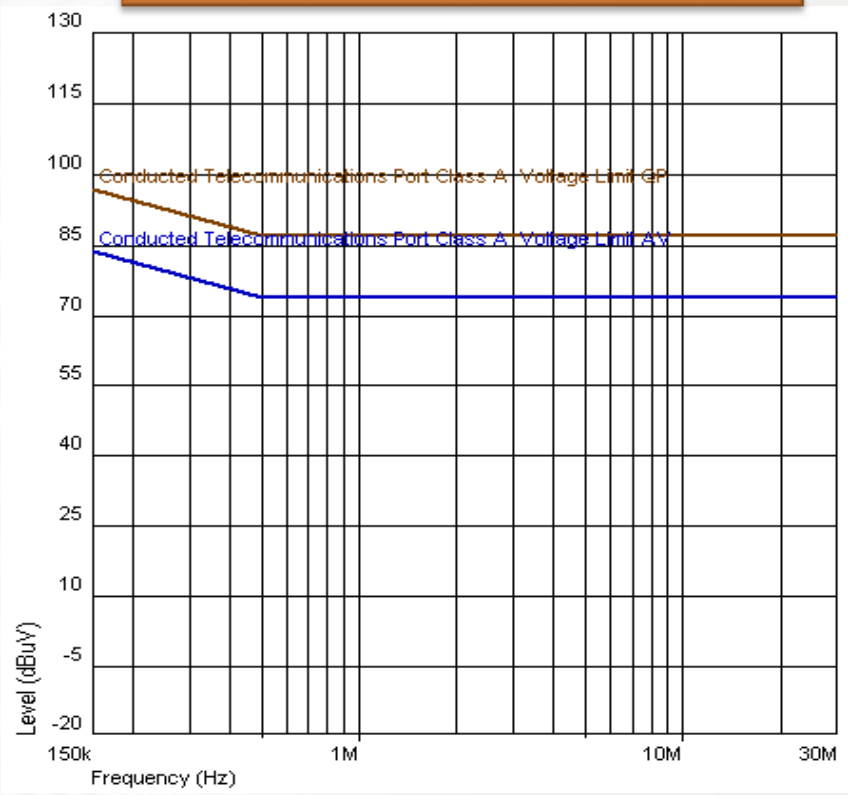
Conducted Emission Test for Signal Lines

The aim of this test is to measure the levels of disturbance conducted by electrical and/or electronic equipment through its signal lines in the frequency range from 150 kHz to 30 MHz.

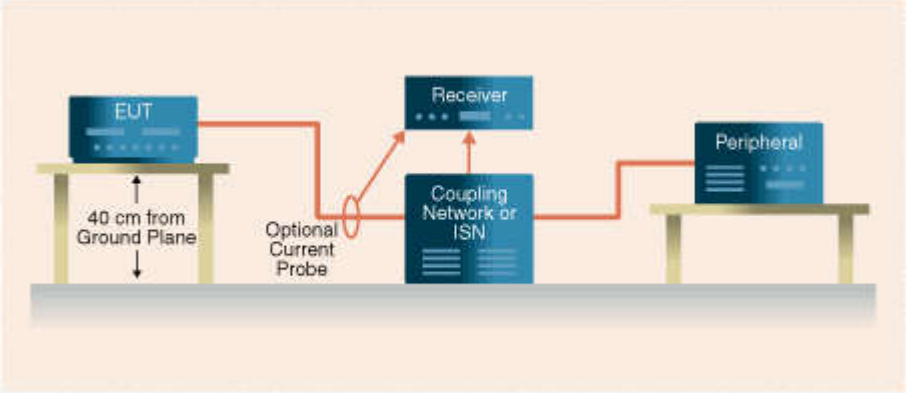
CE Test limit for Current Measurement

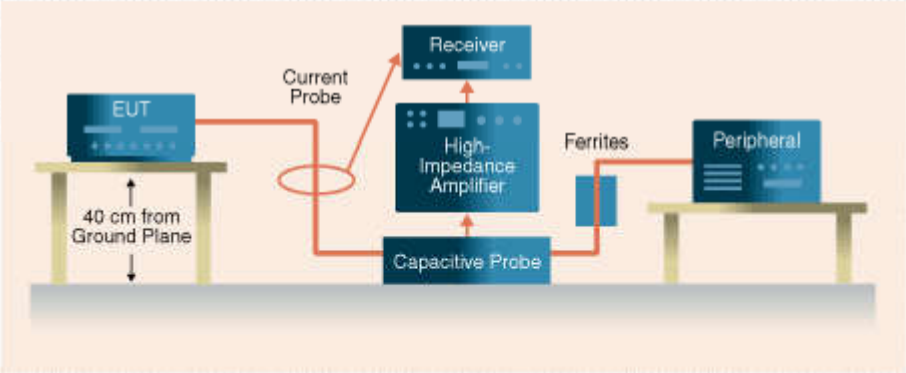


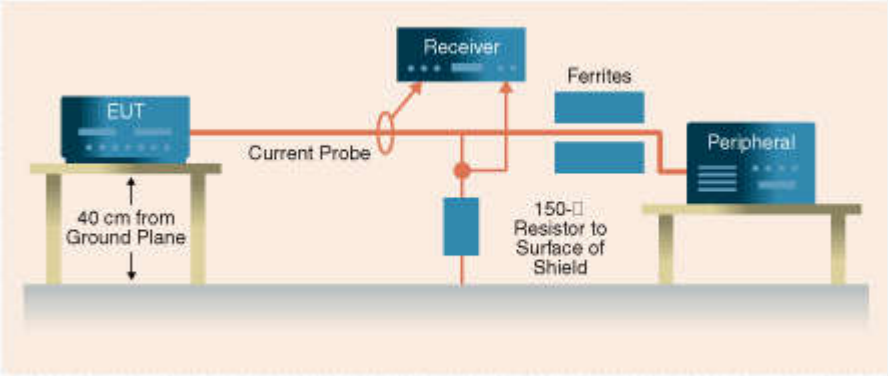
CE Test limit for Voltage Measurement (ISN)



Conducted Emission Test Setups for Signal Lines



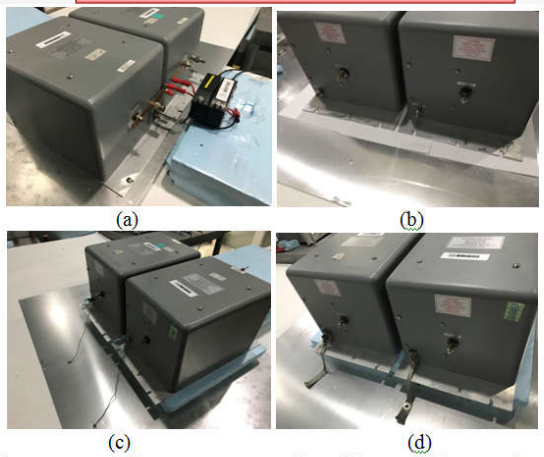




https://www.edn.com/electronics-news/4384663/Test-EMI-Emissions-on-Telecom-Test-Ports

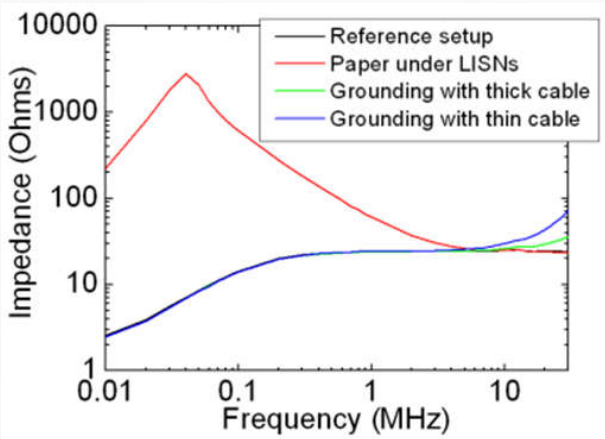
50Ω Load and Grounding Effect on Conducted Emission Testing

Grounding scenarios setups

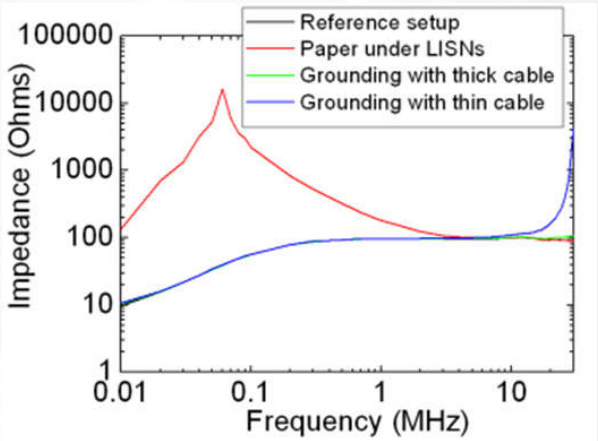


(a) reference setup, (b) very poor grounding with paper, (c) grounding with thin cable, (d) grounding with thick cable

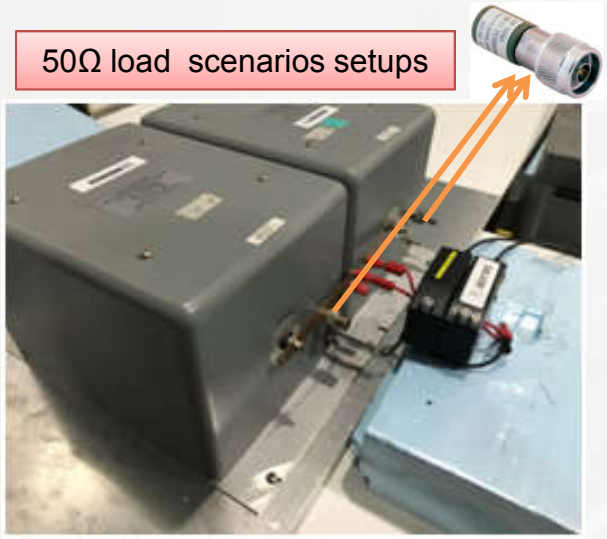
Common Mode Impedance



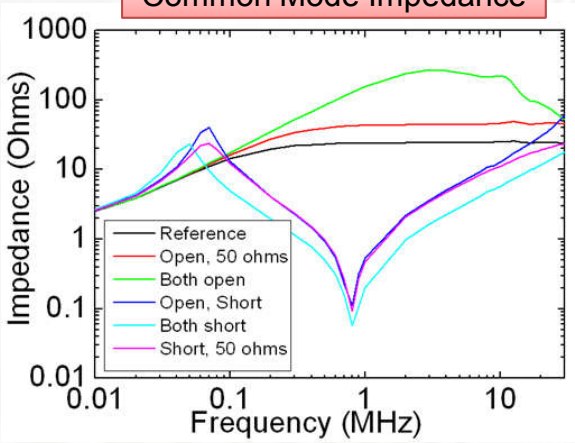
Differantial Mode Impedance



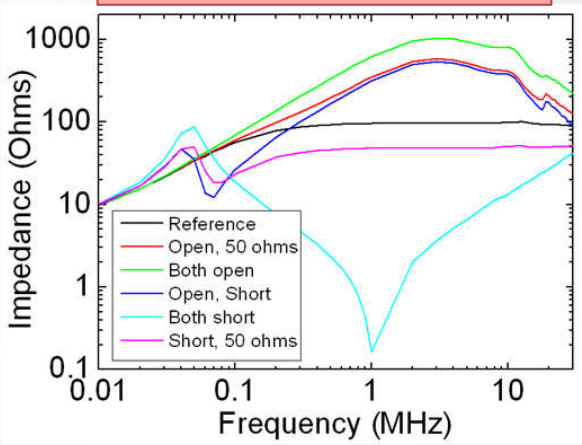
50Ω load scenarios setups



Common Mode Impedance



Differantial Mode Impedance



Sen, O., Cakir, S. "Improved Just-Before-Test Verification Methods with VNA for Conducted EMC Tests ", IEEE International Symposium on Electromagnetic Compatibility 2018, August:art. no. 8485179 (2018) : 488-493

Conducted Emission Test for Power Lines By Using Voltage Probe

The EUT has large dimensions or requires high input current (> 200 A), it is not, for most of the time, possible to send it to an EMC laboratory or to use LISNs (the commercial LISNs may not be available) during the conducted emission test. CISPR, ANSI, and the FCC all describe a voltage probe which can be used to measure the conducted emissions on power terminals as an alternative method. If the conducted emission test is performed without LISN, the uncertainty value arising from the mains shall be taken into account when evaluating the test result.

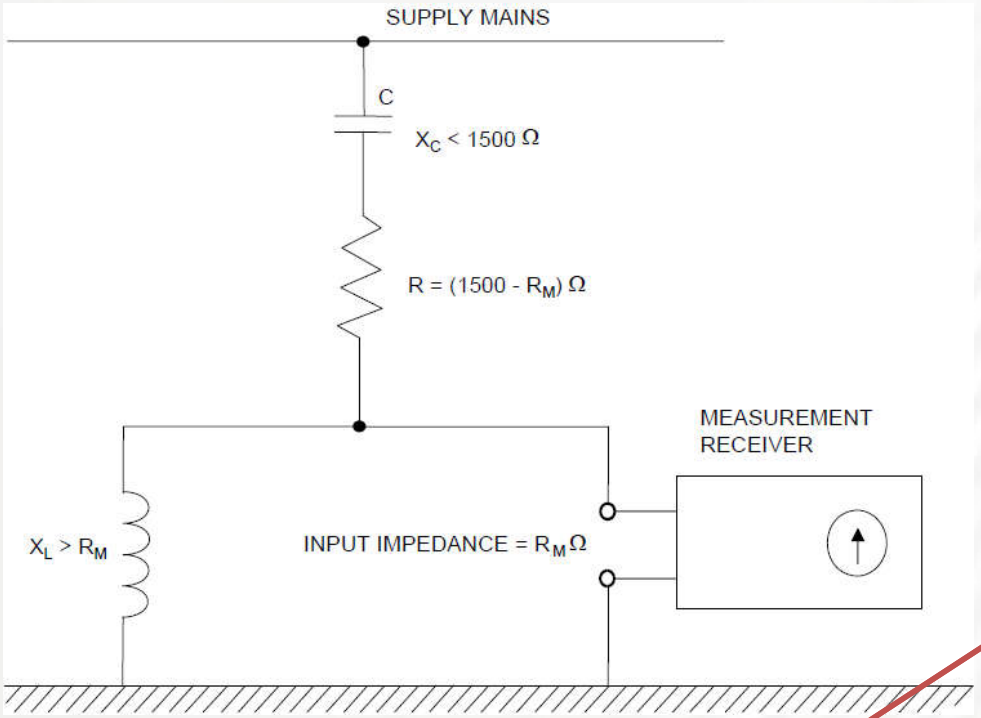


Table B.3 – Conducted disturbance measurements from 9 kHz to 30 MHz using a VP

Input quantity [a]	X_i	Uncertainty of x_i		$c_i\,u(x_i)$ [b]
		dB	Probability distribution function	dB
Receiver reading [A1)]	V_r	± 0,1	k = 1	0,10
Attenuation: VP-receiver [A2)]	a_c	± 0,1	k = 2	0,05
VP voltage division factor (VDF) [B3)]	F_{VP}	± 0,2	k = 2	0,10
Receiver corrections:				
Sine wave voltage [A3)]	δV_{sw}	± 1,0	k = 2	0,50
Pulse amplitude response [A4)]	δV_{pa}	± 1,5	Rectangular	0,87
Pulse repetition rate response [A4)]	δV_{pr}	± 1,5	Rectangular	0,87
Noise floor proximity [A5)]	δV_{nf}	± 0,0		0,00
VP VDF frequency interpolation [A6)]	δF_{VPf}	± 0,1	Rectangular	0,06
Mismatch: VP - receiver [A7)]	δM	+0,7/−0,8	U-shaped	0,53
VP impedance [B4)]	δZ_{VP}	± 0,5	Triangular	0,20
Effect of mains disturbances [B5)]	δD_{mains}	-	-	-
Effect of mains impedance when compared with AMN [B5)]	δZ_{mains}	± 30,0	Triangular	12,24
Effect of the environment [B19)]	δV_{env}	-	-	-

[a] Superscripts [e.g. [A1)]] correspond to numbered comments in the annexes (see A.2 and B.6).

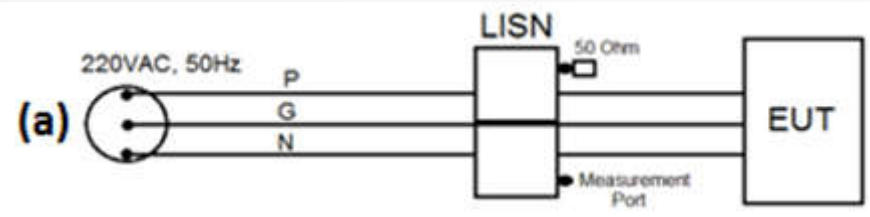
[b] All c_i = 1 (see A.1).

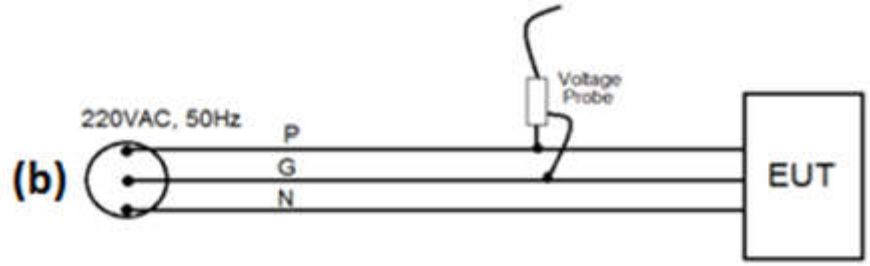
Hence, expanded uncertainty

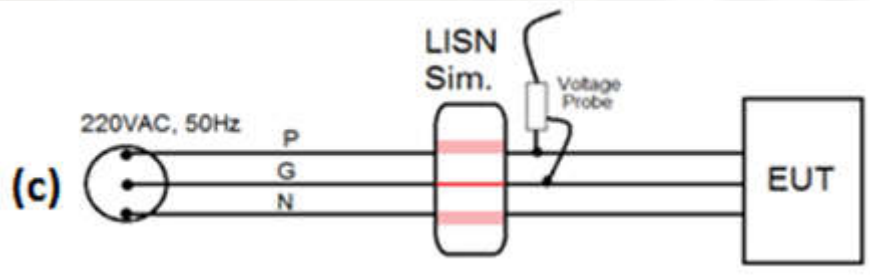
$U(V) = 2u_c(V) =$ 2,91dB / 24,65 dB considering the effect of mains impedance when compared with AMN

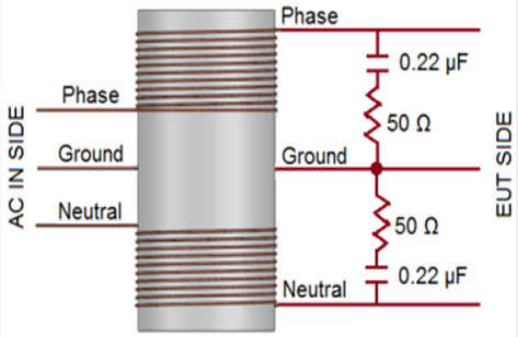
The uncertainty value arising from the mains

Comparison of Conducted Emission Test Methods





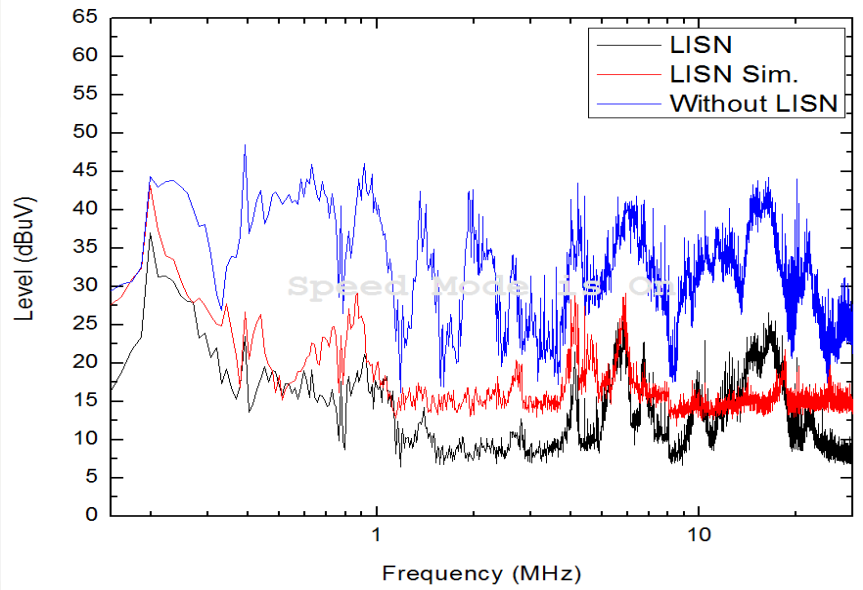




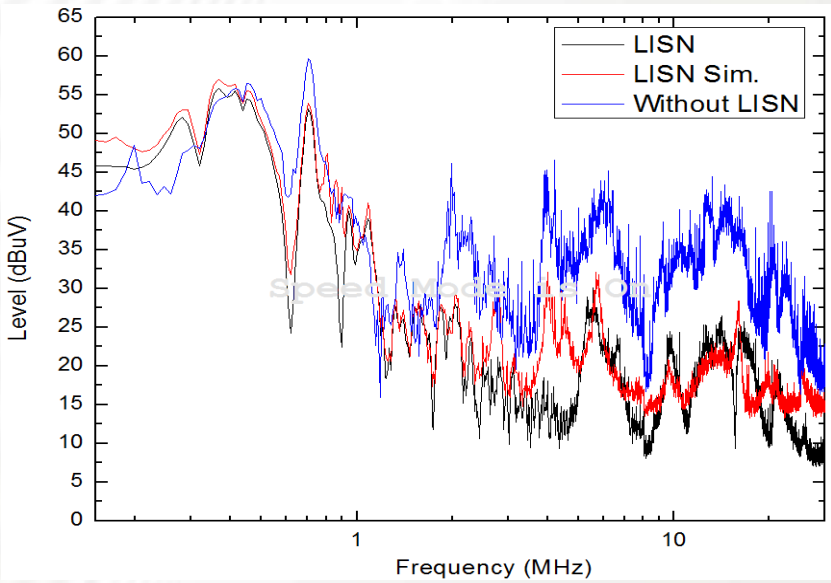
Sen, O., Cakir, S., Acak, S., Cetintas, M. "Alternative Conducted Emission Measurements with LISN Simulation & CISPR 16 Voltage Probe", IEEE International Symposium on Electromagnetic Compatibility (EMC Europe 2015), Dresden (16-22/08/2015) : 5 p

Comparison of Conducted Emission Test Methods

Conducted emission backround measurement results



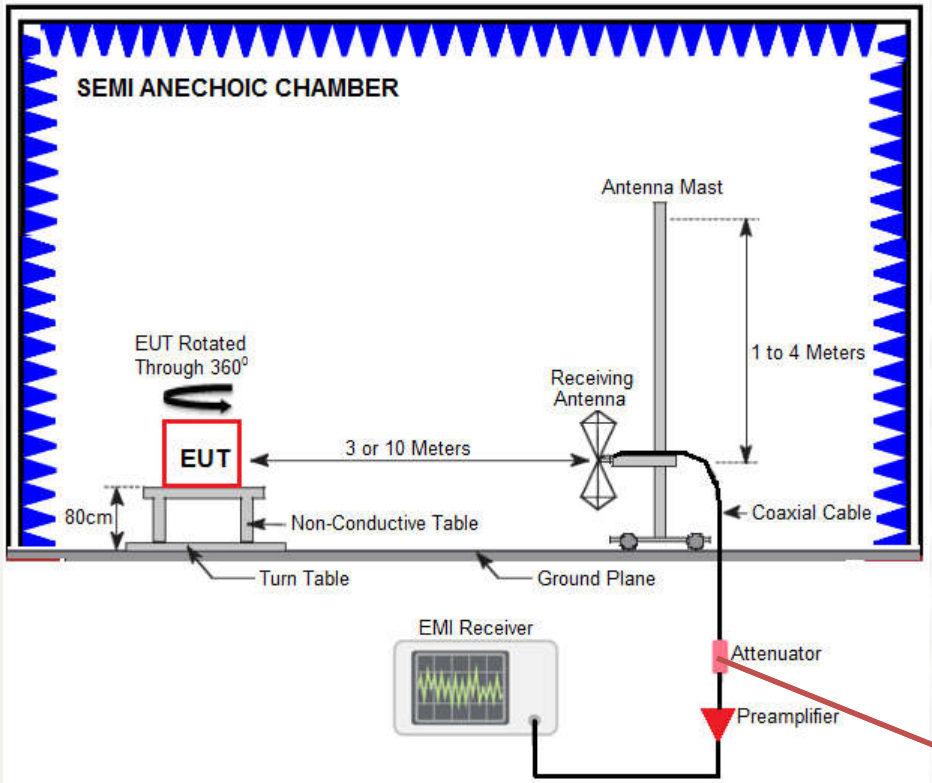
Conducted emission measurement results for actual EUT



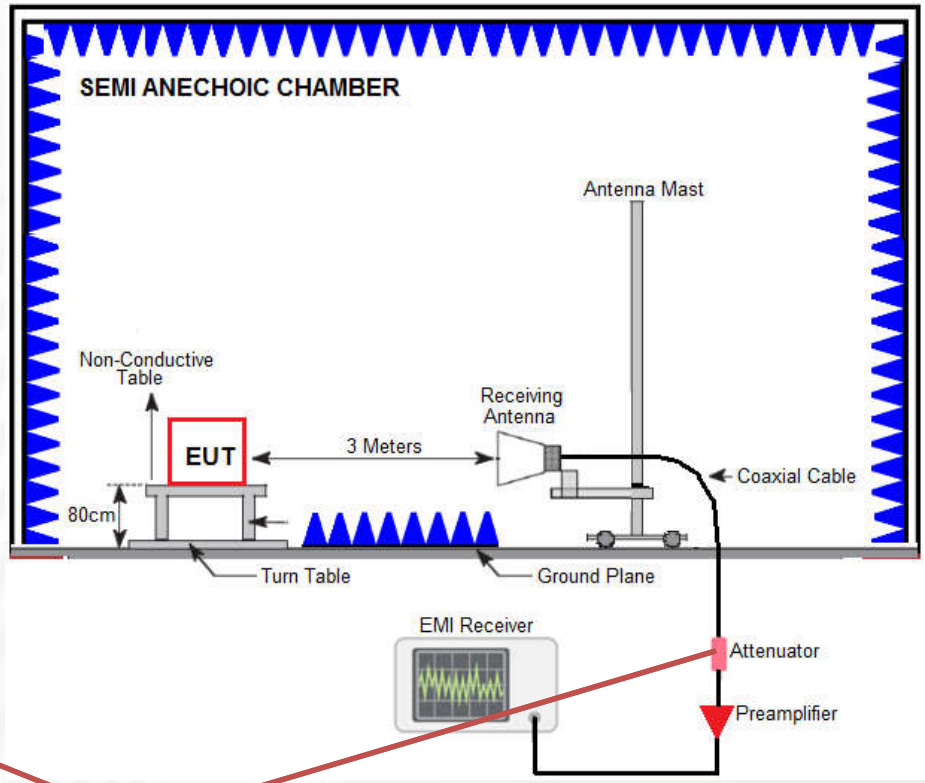
Radiated Emission Test

The aim of this test is to measure the levels of disturbance radiated by electrical and/or electronic equipment through its enclosure and input/output cables in the frequency range from 30 MHz to 6 GHz.

Radiated Emission Test Setup for 30 MHz – 1 GHz



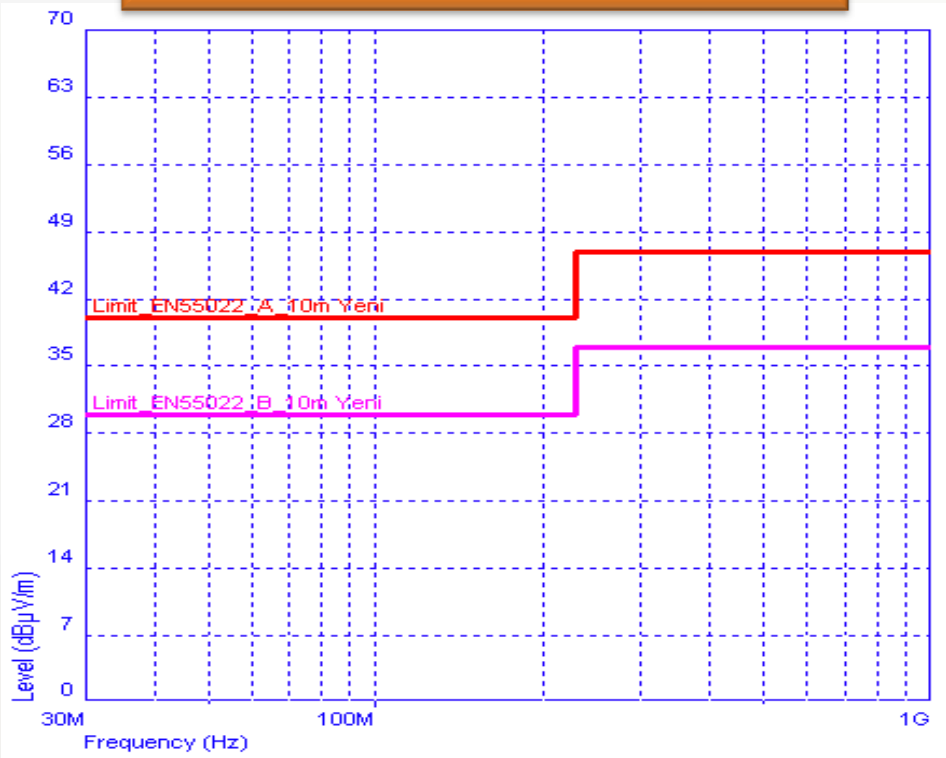
Radiated Emission Test Setup for 1 GHz – 6 GHz



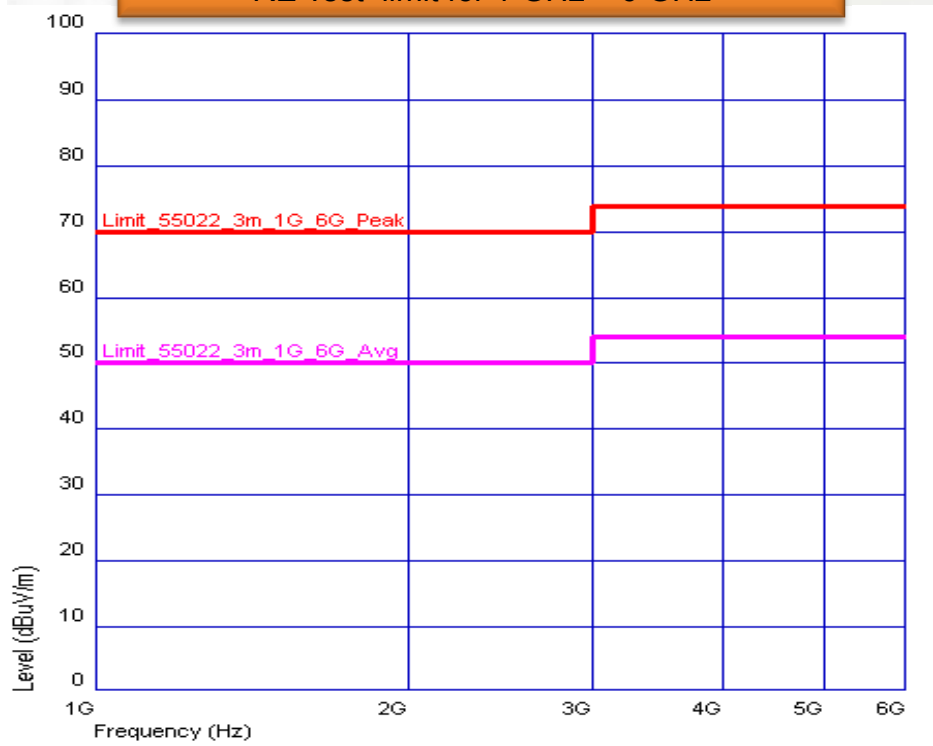
The attenuator (at least 6 dB) shall be used between the output of receiving antenna and the input of the preamplifier in order to minimize the mismatch of impedance.

Radiated Emission Testing Limits

RE Test limit for 30 MHz – 1 GHz (10m)

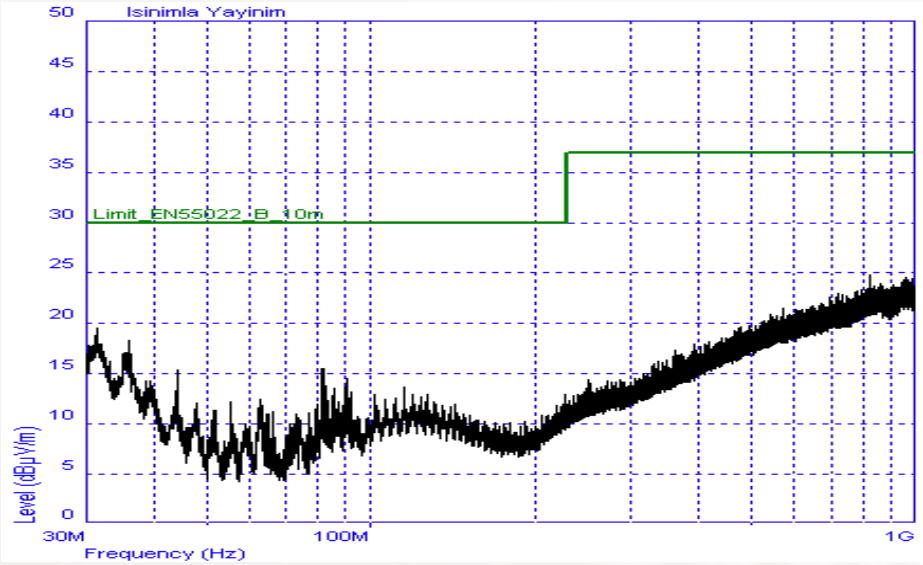


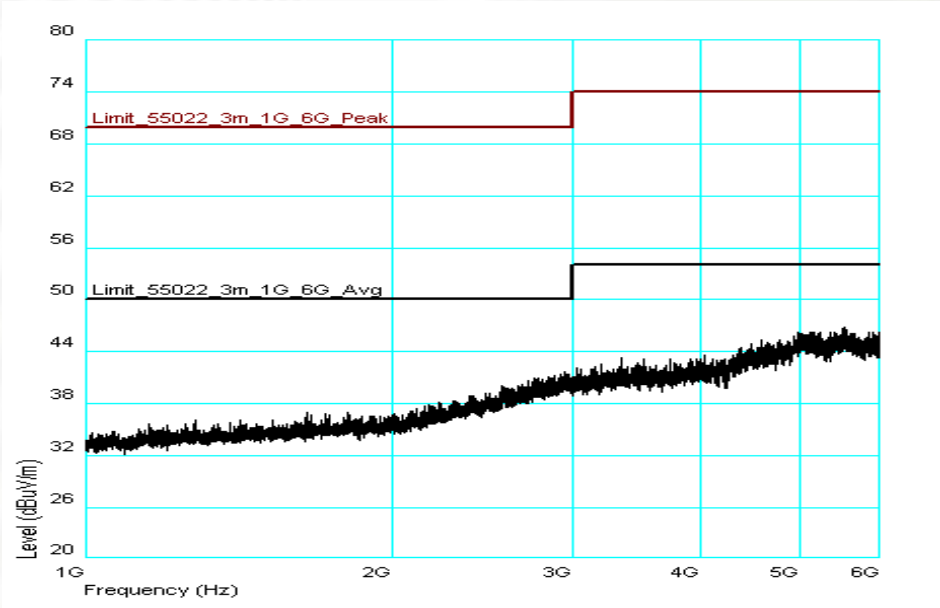
RE Test limit for 1 GHz – 6 GHz



Background Level for Radiated Emission Testing Limits

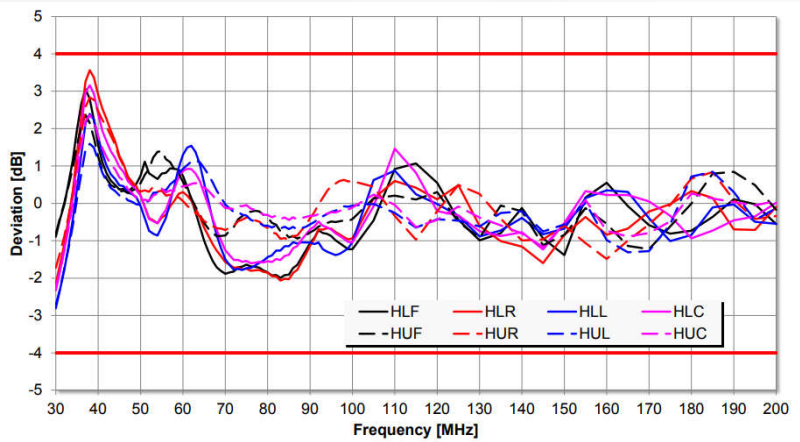
During radiated emission testing, the ambient electromagnetic level measured with the EUT de-energized and all auxiliary equipment turned on shall be at least 6 dB below the allowable specified limits when the test is performed in a semi anechoic chamber.

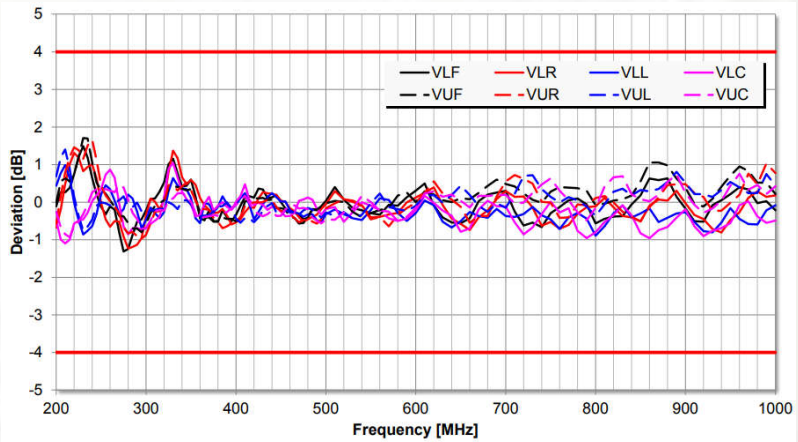


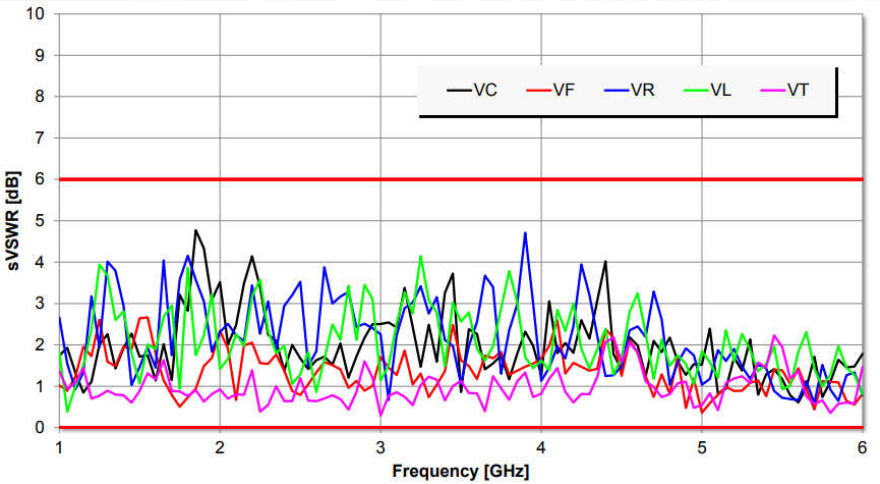


Requirements of Test Chamber

The OATS or the Semi-Anechoic Chamber facilities used at the radiated emission testing shall meet the site validation criteria (NSA and S_{VSWR}) requirements of CISPR 16-1-4.

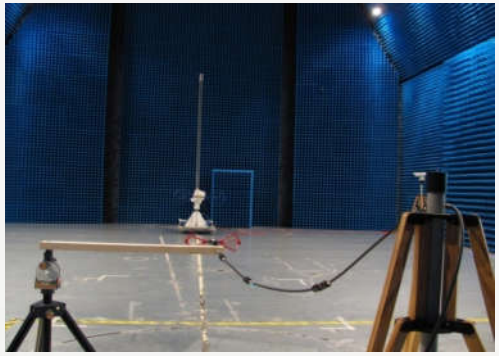




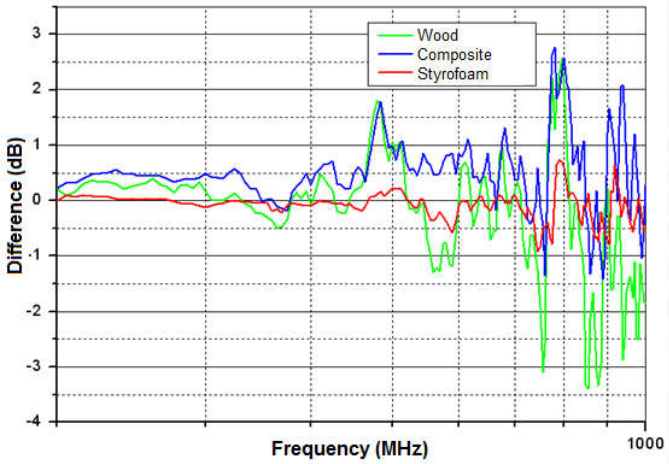


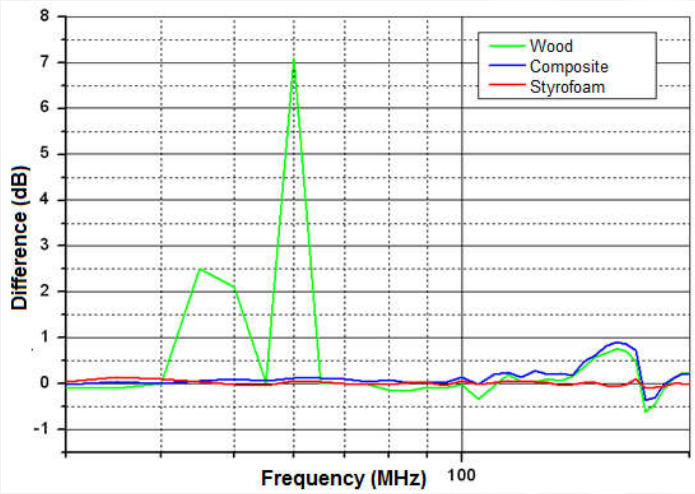
http://dmas.eu/docs/SeibersdorfgraphsNSA.pdf

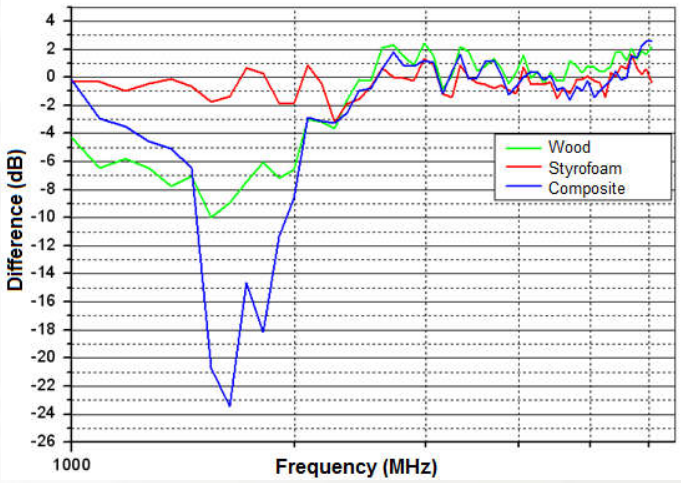
Test Table Effect on Radiated Emission Testing



The impact on the test results of the test tables used at the radiated emission measurement shall be measured as per CISPR 16-1-4 in the frequency range 30 MHz – 6 GHz.

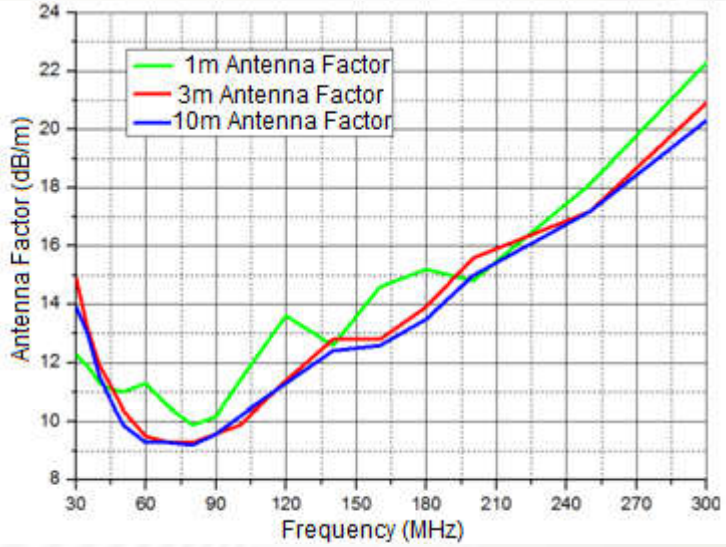


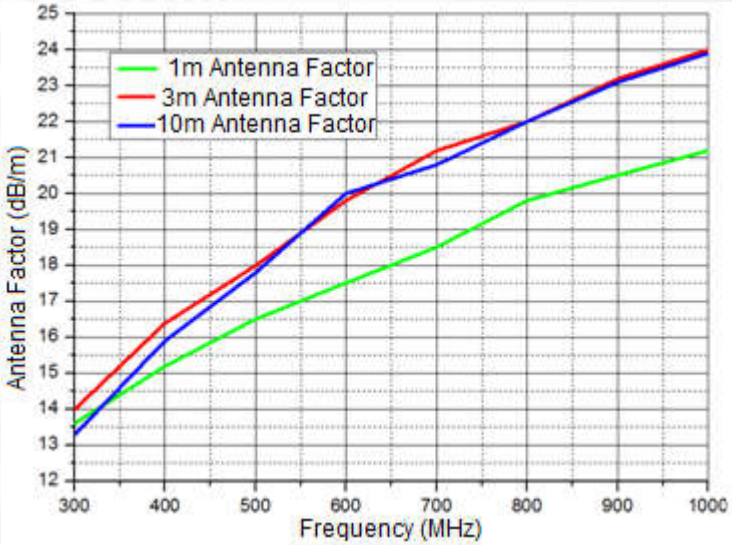




Effect of Antenna Calibration Method and Distance on Radiated Emission Testing

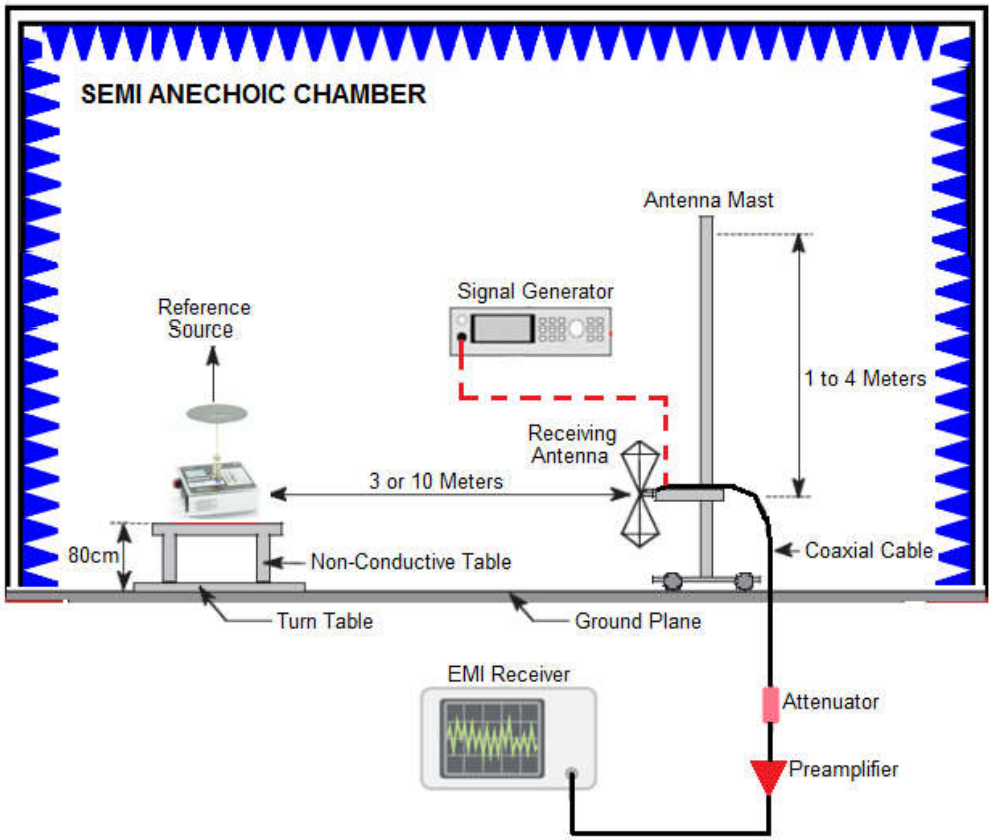
The receiving antennas shall be calibrated in accordance with the distance to be used at radiated emission testing in order to avoid wrong testing.





Verification Measurement for Radiated Emission Testing

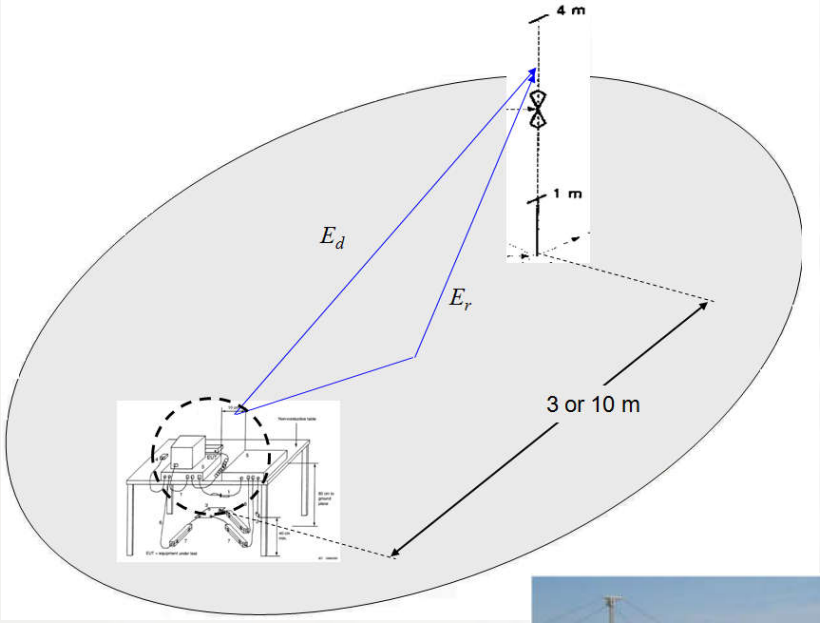
- Before radiated emission testing, test laboratory must perform verifications to ensure the quality and precision of test results by means of verification as the verification can detect errors beforehand in the test setup and prevent wrong testing.
- A known signal that is 6 dB below the limit to the input of the receiving antenna at the lowest frequency of test, at a mid-band frequency, and at the highest frequency of test. Thereafter, the measurement receiver is scanned for each frequency in the same manner as a test scan and it is expected that the test software must indicate a level within ± 3 dB of the injected level. If the measured signal levels deviate by more than ± 3 dB, the test is not continued and the error must be rectified in the test system.
- Moreover, the reference source should be utilized before radiated emission testing in order to check all the test system including the test chamber and the receiving antenna.

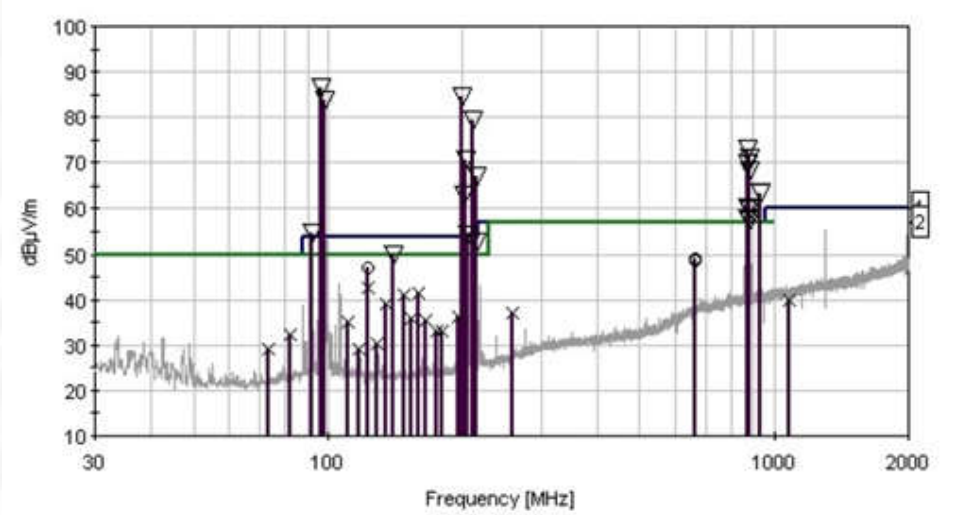


Radiated Emission Testing at OATS

The background noise is at least 6 dB below the limit line specified by the customer when the EUT is switched off.

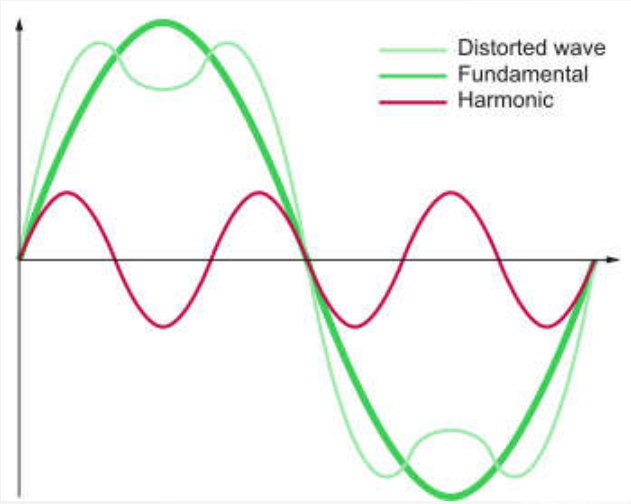
Due to many RF noise sources such as FM, TV and GSM, in the outdoor environment, the radiated emission measurement is not able to be performed properly at OATS for all frequency range.





https://emcfastpass.com/emc-testing-beginners-guide/emissions/

Description of Harmonic



In a linear system (e.g. a circuit, with ideal resistors, capacitors and/or inductors), the characteristics of the voltage and the current are sinusoidal in nature. The current contains only one frequency, the mains frequency or the so called fundamental. Beside this 50 Hz component there are no other frequencies and therefore there are no harmonic components.

Harmonics are produced by not-linear loads that absorb non-sinusoidal current. The most common loads, both in industrial surroundings and domestic ones, are the following ones:

- ✓ Frequency / Variable speed drives
- ✓ Discharge lamps (high pressure sodium vapour lamp, mercury vapour lamp, low consumption, fluorescent, etc.)
- ✓ Rectifiers
- ✓ AC/DC Converters
- ✓ Arc welding
- ✓ Induction ovens
- ✓ UPS
- ✓ Computers and laptops

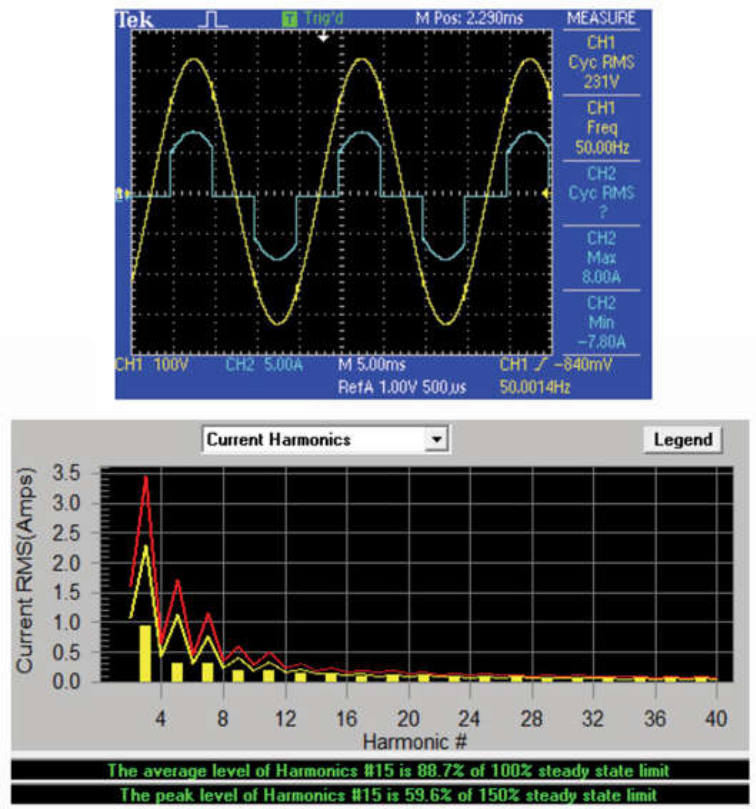
Effects of Harmonics on Mains supplies

- ➢ Distortion of main supply voltage, unwanted currents flowing in the supply network generate additional energy losses.
- ➢ Defective operation of regulating devices, disturbed operation of florescent lamps, television receivers or other equipment.
- ➢ Malfunction of ripple control and other mains signaling systems, protective relays and, possibly, other of control systems.
- ➢ Additional acoustic noise from motors and other apparatus, reducing the efficiency of motors.
- ➢ High harmonic amplitudes may not only cause malfunctions, additional losses and overheating, but also overload the power distribution network and overheat the neutral conductor and cause it to burn out.

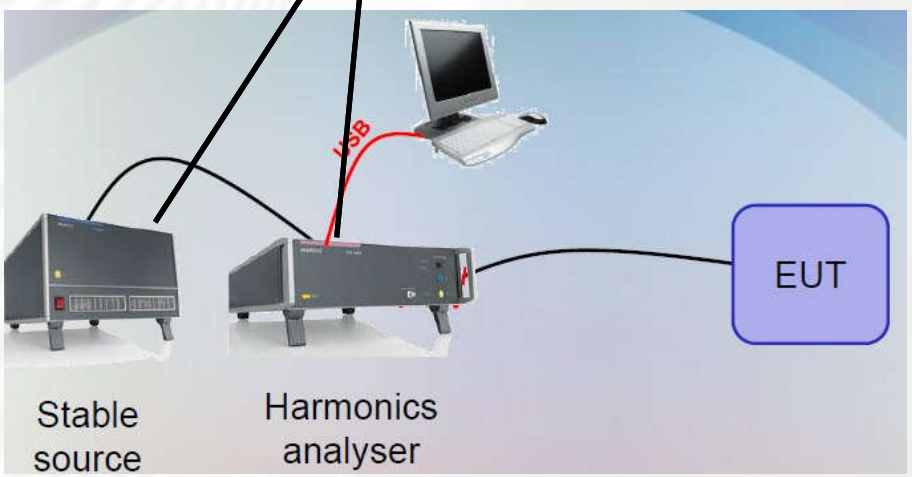
Harmonic Current Emission Testing

➢The aim of this test is to measure the harmonic currents injected into the public supply system by electrical and/or electronic equipment.

➢ This standard is applicable for all electric and electronic equipment that has an input current of up to 16A per phase, suitable for connection to the low-voltage AC public mains distribution network.



The stable power source and the harmonic analyser shall meet requirements of IEC/EN 61000-3-2.

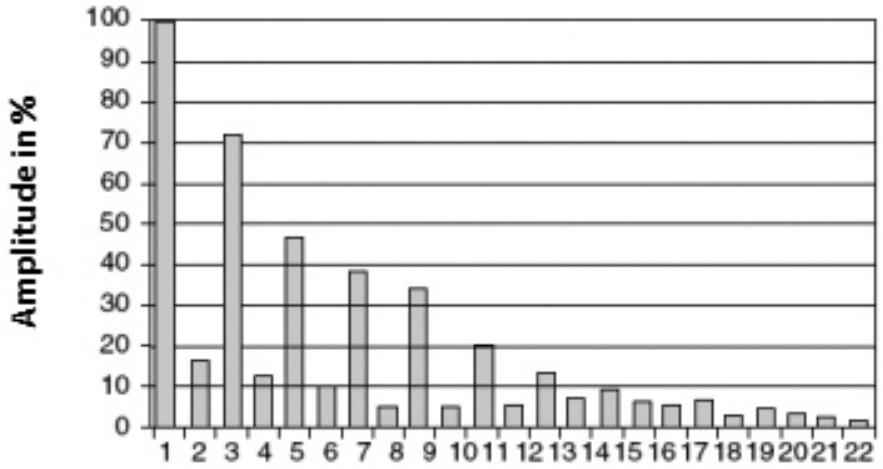


Harmonic Limits and Equipment Classification

Harmonics [n]	Class A [A]	Class B [A]	Class C [% of fund]	Class D [mA/W]
Odd harmonics				
3	2.30	3.45	30 x λ	3.4
5	1.14	1.71.	10	1.9
7	0.77	1.155	7	1.0
9	0.40	0.60	5	0.5
11	0.33	0.495	3	0.35
13	0.21	0.315	3	3.85/13
15≤n≤39	0.15 x 15/n	0.225 x 15/n	3	3.85/n
Even harmonics				
2	1.08	1.62	2	-
4	0.43	0.645	-	-
6	0.30	0.45	-	-
8≤n≤40	0.23 x 8/n	0.345 x 8/n	-	-

Class A	➢ Balanced three-phase equipment ➢ Household appliances excluding equipment identified as Class D ➢ Tools excluding portable tools ➢ Dimmers for incandescent lamps ➢ Audio equipment ➢ Equipment not specified one of the three other classes shall be considered as Class A equipment
Class B	➢ Portable tools
Class C	➢ Lightning equipment
Class D	➢ Equipment having a specified power ≤ 600W of the following types: ✓ Personal computers and personal monitors ✓ Television receivers

Example Test Result for Harmonic Current Measurement



Example of Harmonic frequency distribution

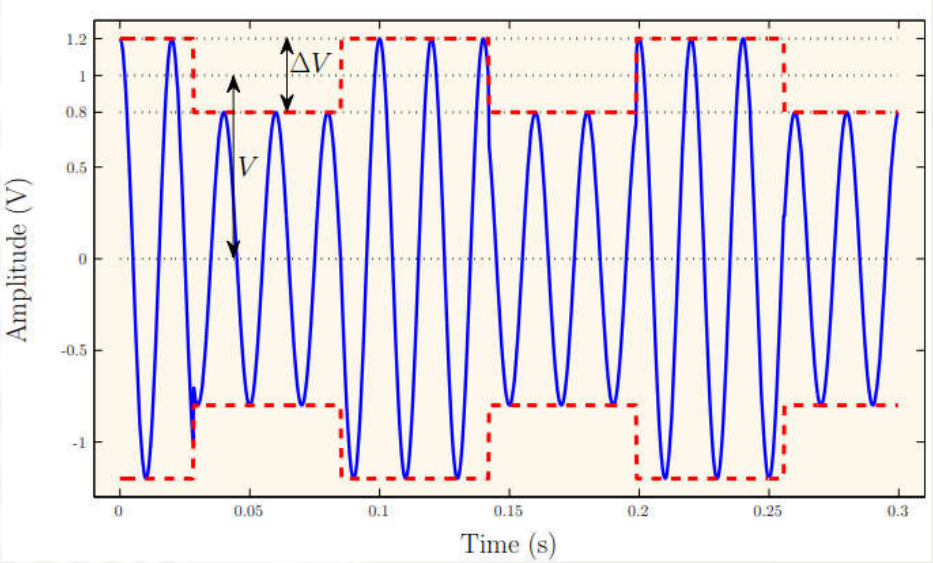
Data for a newly introduced 200 watt power supply with PFC						
Power	530.2	Watt				
PF	0.986					
If	2.289	Amp-rms				
Harmonic	Harmonic current limits					Actual PS
order	Class-A	Class-B	Class-C	Class-D	ANSI	emissions
2	1.080	1.620	0.046	n/a	0.114	0.038
3	2.300	3.450	0.677	1.803	0.687	0.264
5	1.140	1.710	0.229	1.007	n/a	0.175
7	0.770	1.155	0.160	0.530	n/a	0.106
9	0.400	0.600	0.069	0.265	< 30 %	0.034
11	0.330	0.495	0.114	0.186	n/a	0.040
13	0.210	0.315	0.114	0.157	0.160	0.020
15	0.150	0.225	0.114	0.136	0.160	0.027
17	0.132	0.199	0.114	0.120	0.160	0.035
19	0.118	0.178	0.114	0.107	0.160	0.025
21	0.107	0.161	0.114	0.097	0.160	0.031
23	0.098	0.147	0.114	0.089	0.160	0.040
25	0.090	0.135	0.114	0.082	0.160	0.036
27	0.083	0.125	0.114	0.076	0.160	0.031
29	0.078	0.116	0.114	0.070	0.160	0.037
31	0.073	0.109	0.114	0.066	0.160	0.034
33	0.068	0.102	0.114	0.062	0.160	0.028
35	0.064	0.096	0.114	0.058	0.160	0.025
37	0.061	0.091	0.114	0.055	0.160	0.024
39	0.058	0.087	0.114	0.052	0.160	0.027

Voltage Changes, Voltage Fluctuations and Flicker

Voltage fluctuations can be described as repetitive or random variations of the voltage envelope due to sudden changes in the real and reactive power drawn by a load. The fluctuating current that is drawn from the supply causes additional voltage drops in the power system leading to fluctuations in the supply voltage. The characteristics of voltage fluctuations depend on the load type and size and the power system capacity.

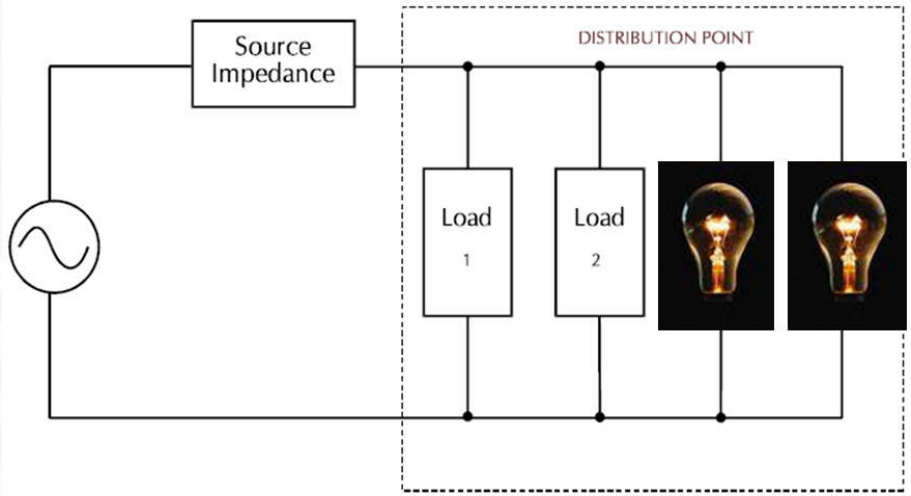
Examples of loads that may produce voltage fluctuations in the supply include

- Arc furnaces
- Arc welders
- Installations with frequent motor starts (air conditioner units, fans)
- Motor drives with cyclic operation (mine hoists, rolling mills)
- Equipment with excessive motor speed changes (wood chippers, car shredders)

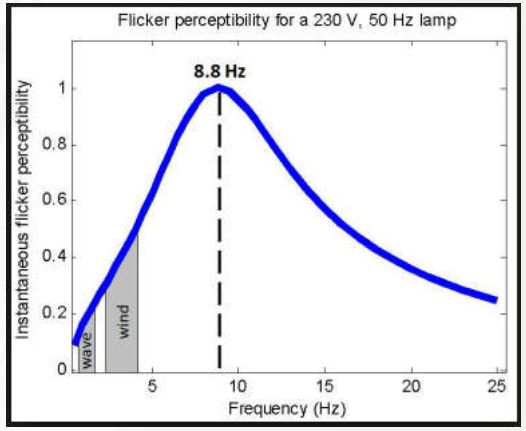


Voltage Changes, Voltage Fluctuations and Flicker Testing

- Based on IEC standard, the critical flicker frequency which is the most sensitive to human eyes is located at 8.8 Hz.
- Since this flicker in the lamps affects the nervous system of people, it may cause the following effects



* Severe headache
* Seizures
* Nausea or vomiting
* Eye strain



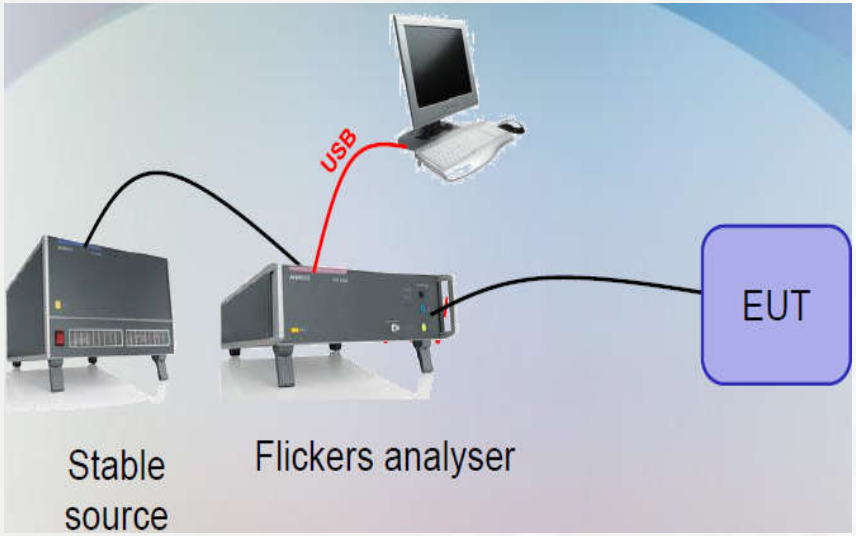
Voltage Changes, Voltage Fluctuations and Flicker Testing

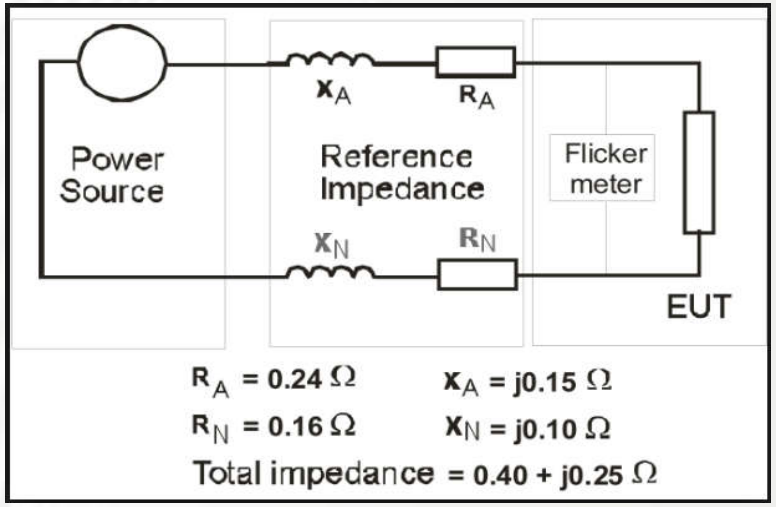
➢The aim of this test is to measure the voltage fluctuation caused by electrical and/or electronic equipment.

➢ This standard is applicable for all electric and electronic equipment that has an input current of up to 16A per phase, suitable for connection to the low-voltage AC public mains distribution network

✓ The value of the short-term light flicker severity index Pst ≤ 1.0
✓ The value of the long-term light flicker severity index Plt ≤ 0.65
✓ The stationary relative voltage change d (t) ≤ 3%
✓ The maximal relative voltage change dmax ≤ 4%
✓ The d value during the voltage change should not exceed 3% for a duration longer than 200 ms

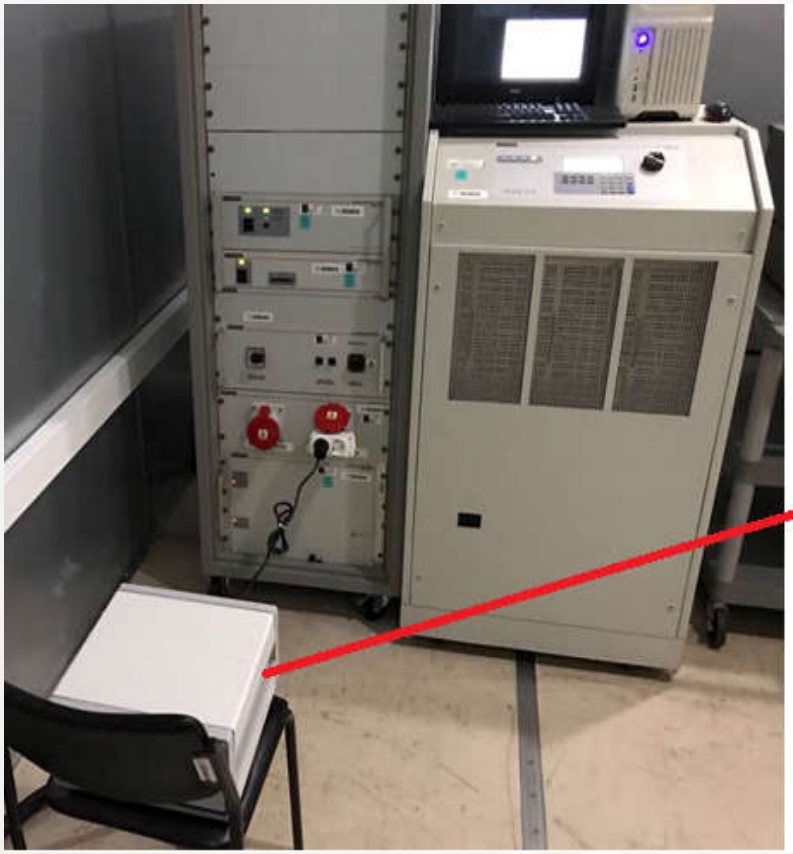
In order to obtain comparable measured results, a **reference impedance** must be inserted between the power source and the EUT when measuring flicker





Verification of Voltage Changes, Voltage Fluctuations and Flicker Testing System

➢ Before harmonic current emission and flicker testing, test laboratory must perform verification measurement to ensure the quality and precision of test results by means of the reference source as the verification measurement can detect errors beforehand in the test setup and prevent wrong testing.

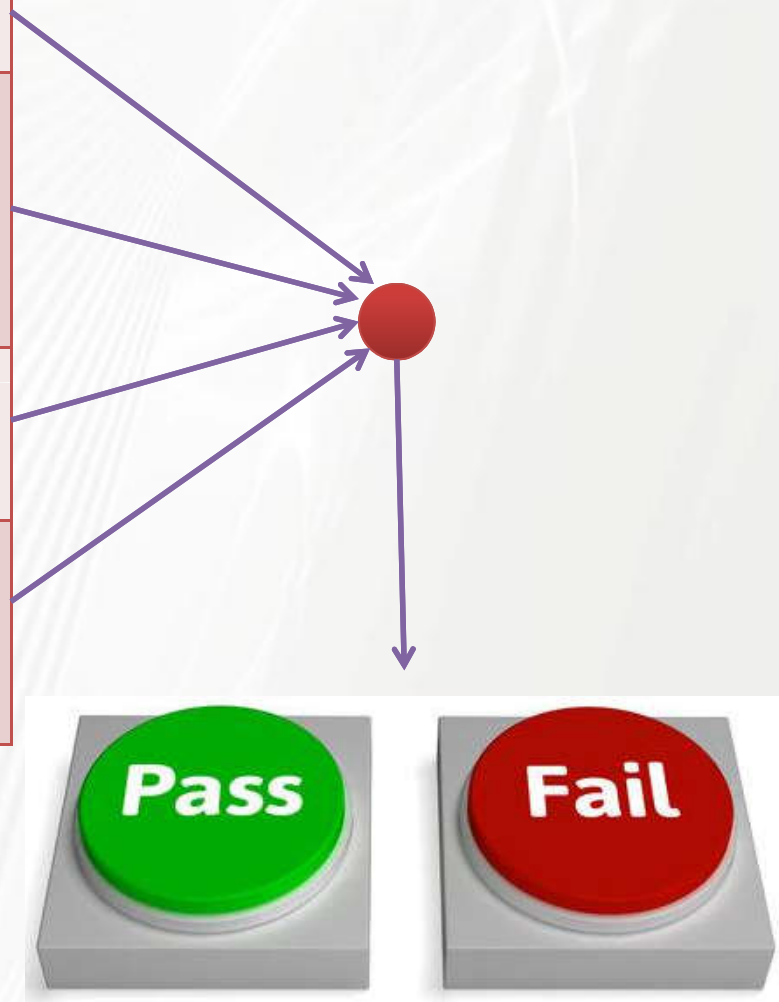


IMMUNITY TESTS

Performance Criteria for Immunity Tests

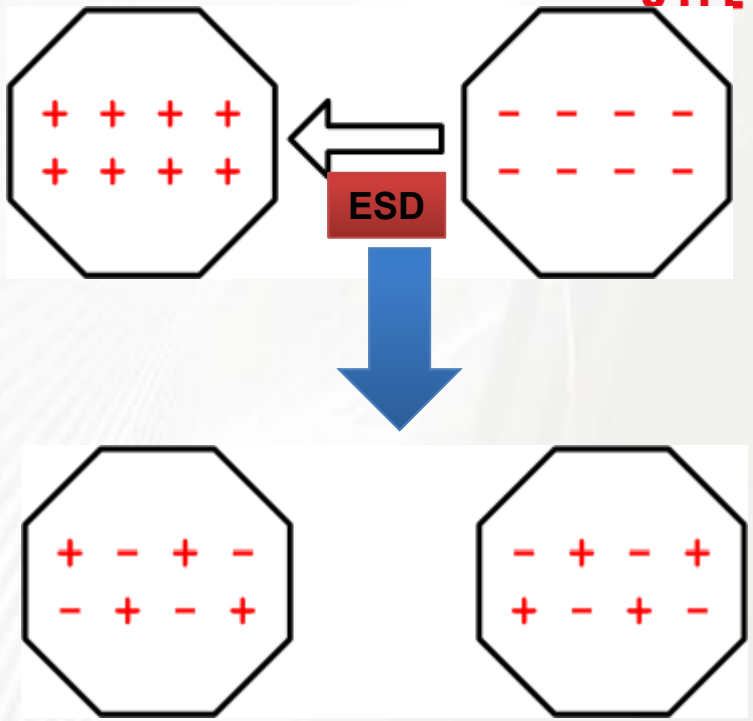
Results of immunity tests are classified into four categories. These categories are as follows.

Class A	Normal performance within limits specified by the manufacturer, requestor or purchaser.
Class B	Temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the equipment under test recovers its normal performance, without operator intervention
Class C	Temporary loss of function or degradation of performance, the correction of which requires operator intervention.
Class D	Loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss of data.

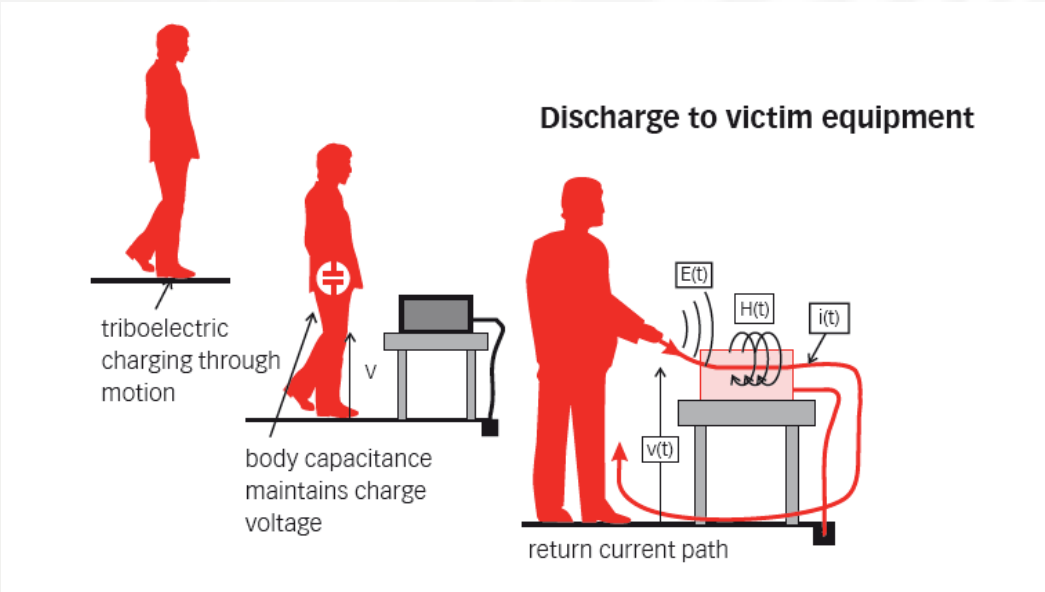


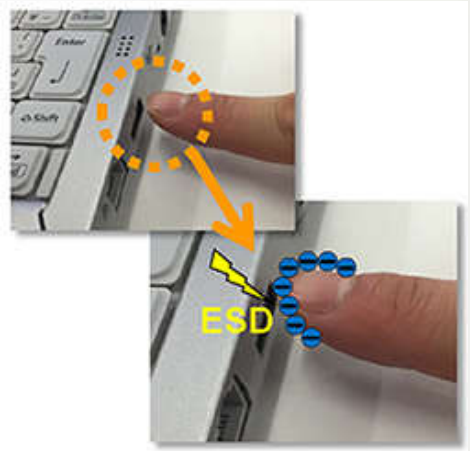
What is Electrostatic Discharge (ESD)?

When two electrically charged objects, such as the human body and an electronic device come into contact with each other, static electricity is discharged. This phenomenon is called ESD (Electrostatic Discharge). ESD generated from the human body can be of the order of several thousand volts. This high voltage pulse enters the electronic device that is touched, resulting in a malfunction or destruction of the IC circuits inside it.



http://www.ee.cityu.edu.hk/~emc/20150418P2.pdf

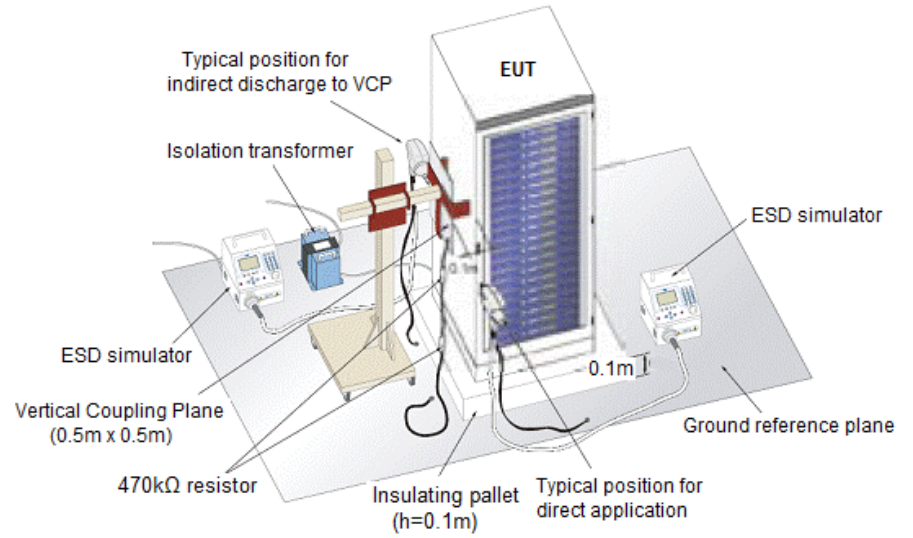




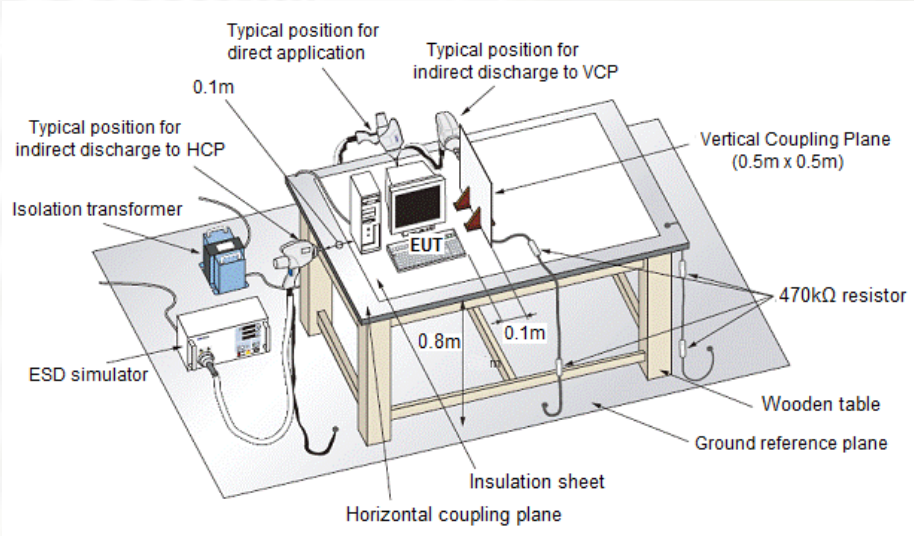
ESD Testing

- The purpose of the ESD immunity testing is to determine the effects of unwanted ESD pulses caused by users on the EUT.
- During the ESD immunity testing, the EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual when subjected to the ESD pulse.

Test set-up for floor-standing EUT



Test set-up for table top EUT



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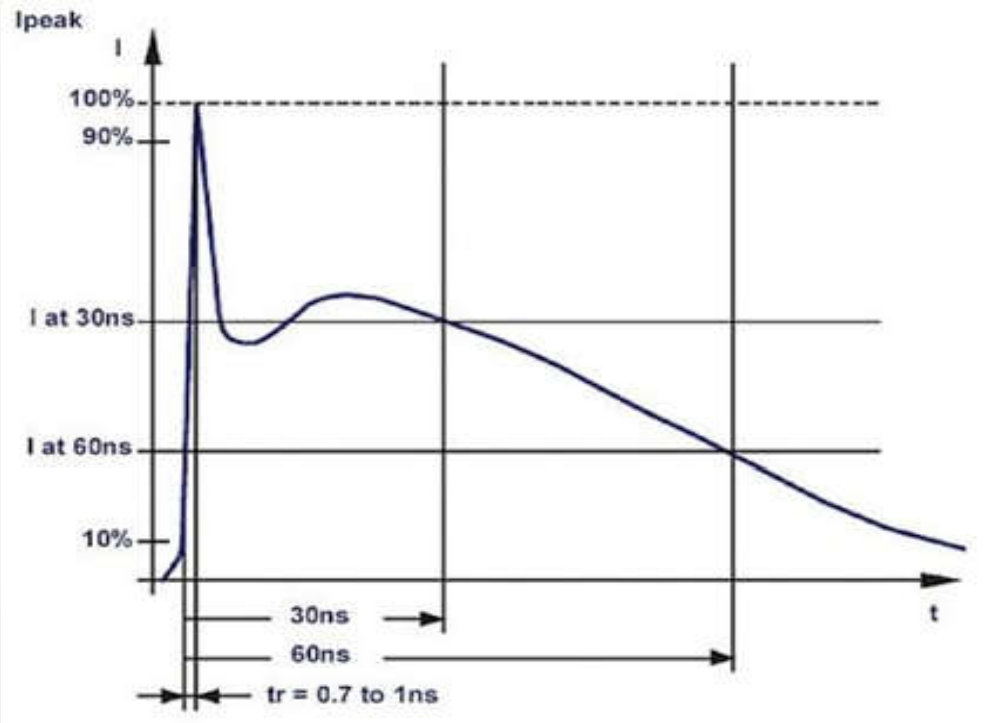
ESD Waveform

ESD waveform



In the case of air discharge testing, the climatic conditions shall be within the following ranges:

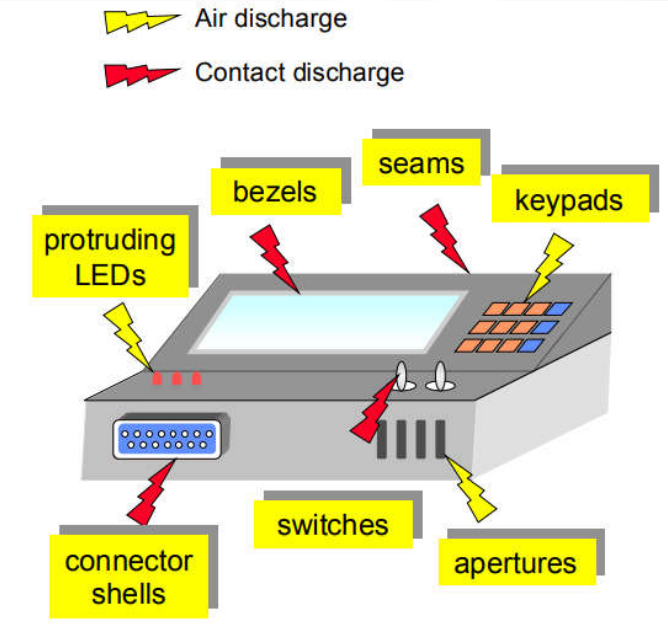
- Ambient temperature: 15 °C to 35 °C;
- Relative humidity: 30 % to 60 %;
- Atmospheric pressure: 86 kPa (860 mbar) to 106 kPa (1060 mbar).

Level	Indicated Voltage kV	First Peak Current of Discharge ±10 % A	Rise Time t_r with Discharge Switch ns	Current (±30 %) at 30 ns A	Current (±30 %) at 60 ns A
1	2	7.5	0.7 to 1	4	2
2	4	15	0.7 to 1	8	4
3	6	22.5	0.7 to 1	12	6
4	8	30	0.7 to 1	16	8

ESD Testing ve Levels

- Application of discharge:
  - ✓ Direct: on the surface of the EUT
  - ✓ Indirect: in the coupling planes
- Types of discharges:
  - ✓ In contact: the conductive surface (head pointed gun)
  - ✓ In air: on insolating surfaces (gun head rounded)
- One discharge each 3 sec
- 10 discharges + and - by point of application
- 4 test levels
- For high levels we must pass by intermediate levels

Test levels shall be selected according to specific product standards or generic standards that defines levels in accordance with electromagnetic environment.



http://www.elmac.co.uk/ESD_considerations.pdf

Test Levels for ESD Test

Contact Discharge		Air Discharge	
Level	Test Voltage kV	Level	Test Voltage kV
1	2	1	2
2	4	2	4
3	6	3	8
4	8	4	15
x[a]	Special	x[a]	Special

[a] "X" can be any level, above, below or in between the others. The level shall be specified in the dedicated equipment specification. If higher voltages than those shown are specified test equipment may be needed.

Cases for application of ESD on connectors

Case	Connector shell	Cover material	Air discharge to:	Contact discharge to:
1	Metallic	None	–	Shell
2	Metallic	Insulated	Cover	Shell when accessible
3	Metallic	Metallic	–	Shell and cover
4	Insulated	None	[a]	–
5	Insulated	Insulated	Cover	–
6	Insulated	Metallic	–	Cover

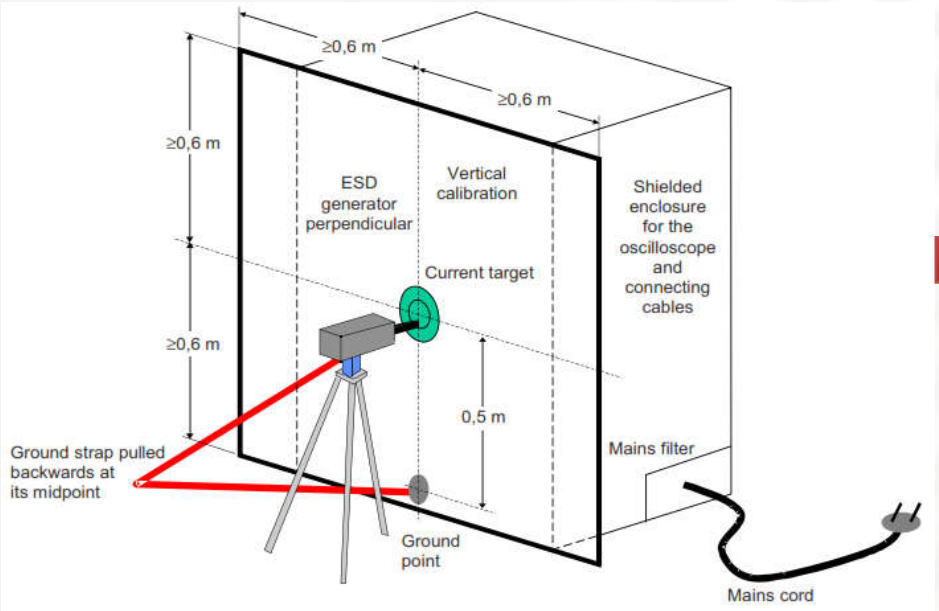
NOTE In case a cover is applied to provide (ESD) shielding to the connector pins, the cover or the equipment near to the connector to which the cover is applied should be labelled with an ESD warning.

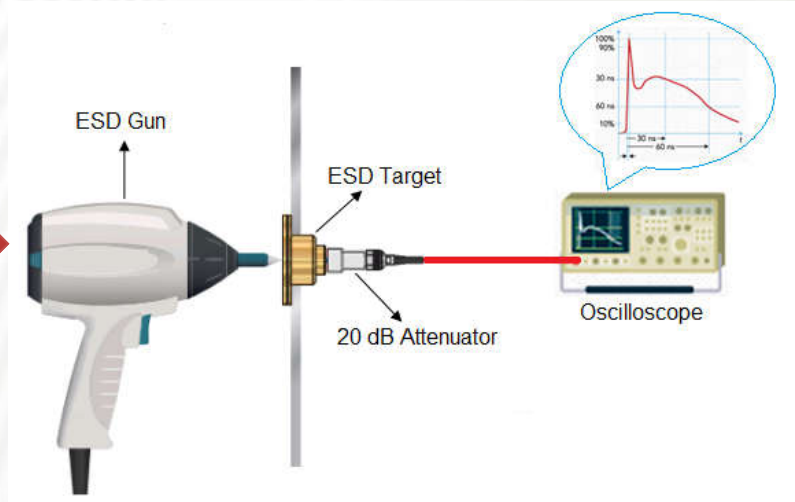
[a] If the product (family) standard requires testing to individual pins of an insulated connector, air discharges shall apply.

Verification of the ESD Test System

The purpose of verification is to ensure that the ESD simulator's tip voltage is operating correctly before ESD testing. The 470 kΩ bleeder resistors shall also be checked before ESD testing.

- Before ESD immunity testing, the verification setup is established.
- Any channel of the oscilloscope is connected to output of the ESD target including 20 dB.
- The ESD pulse is applied by using ESD gun on the ESD target as if the ESD immunity testing was performed.
- The values (voltage and time parameters) to be read on the oscilloscope shall be a level within ±10% of the target level
- Otherwise, the test is not started before the problem is solved.

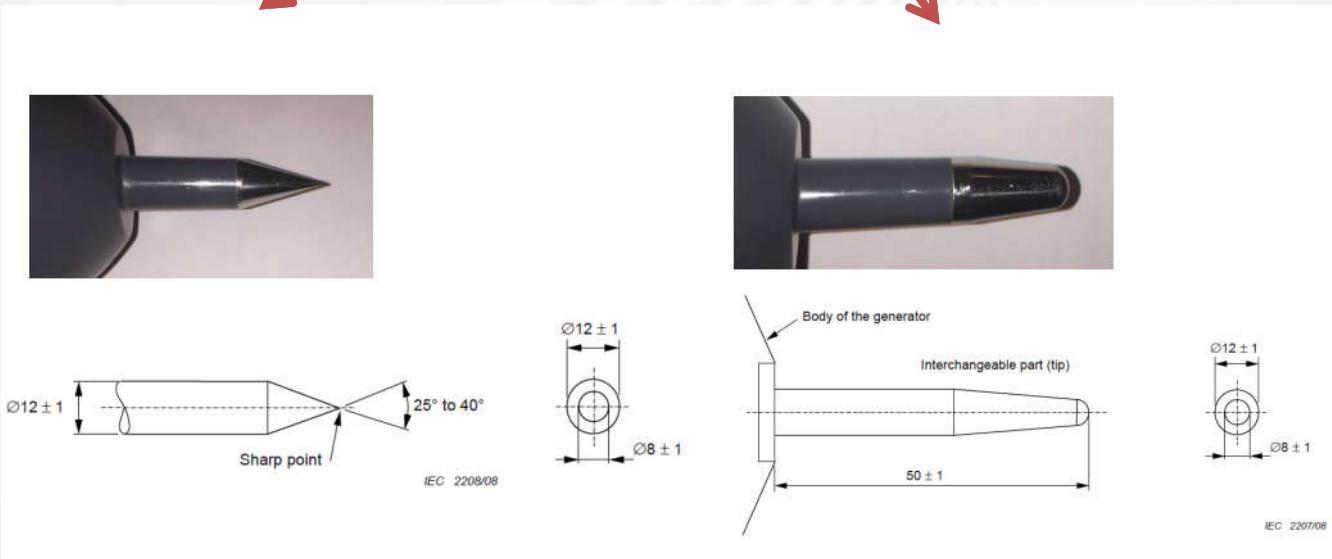




ESD Gun and Discharge Tips

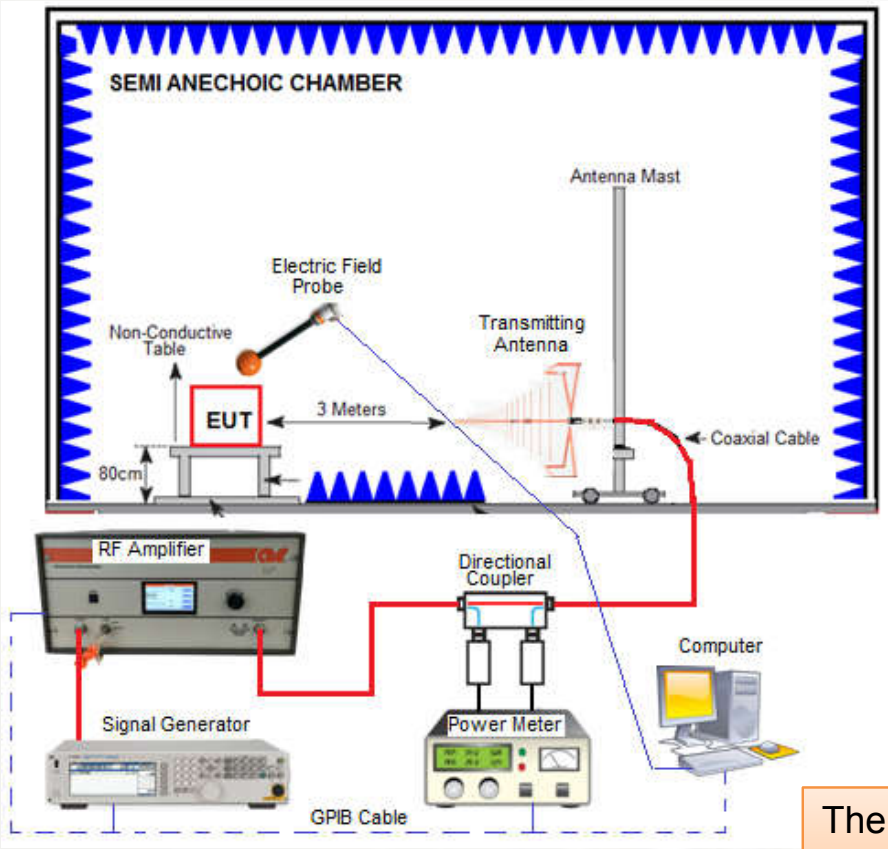
For contact discharge

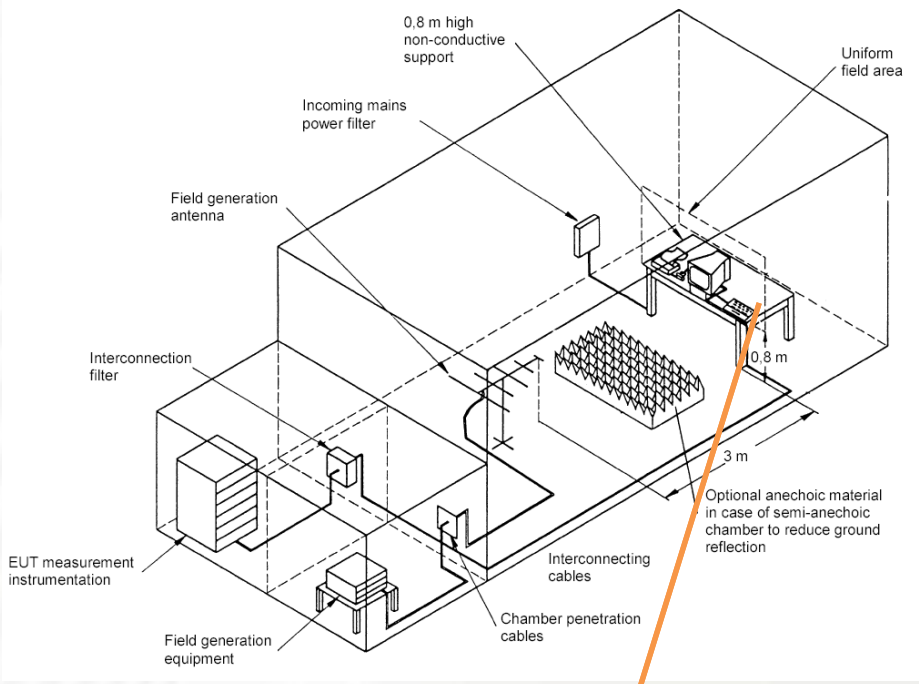
For air discharge



Radiated Immunity Testing

- The purpose of the radiated immunity testing is to determine the effects of radiated electromagnetic field such as might be created by cell phones and other intentional radiators on the EUT.
- During the the radiated immunity testing, the EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual when subjected to the radiated electromagnetic fields in the frequency range 80 MHz – 6 GHz.





The test table to be used at the radiated immunity testing shall be made of the none conductive material with a low permeability.

Test Levels and Modulation Types

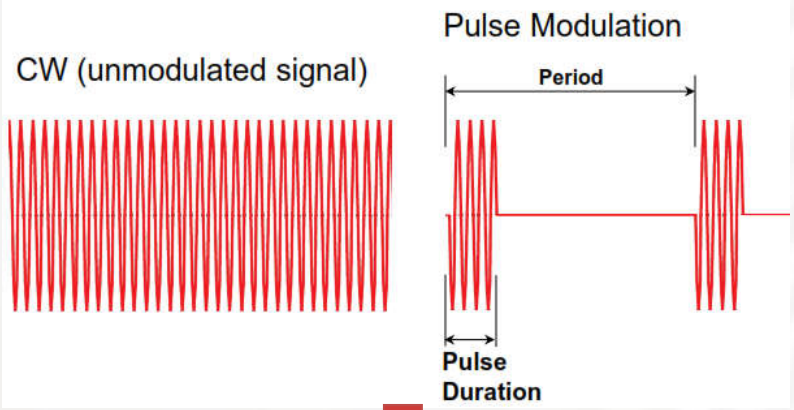
Level	Test field strength (V/m)
1	1
2	3
3	10
4	30
x	Special
NOTE x is an open test level and the associated field strength may be any value. This level may be given in the product standard.	

The dwell time of the amplitude modulated carrier at each frequency shall not be less than the time necessary for the EUT to be exercised and to respond, but shall in no case be less than 0,5s.

The modulation type(s) and the test level to be applied at the radiated immunity testing shall be chosen in accordance with the product standard .

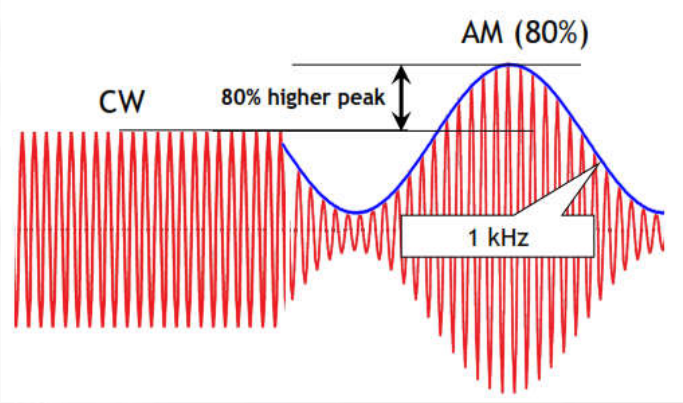
The step size shall not exceed 1% of the preceding frequency value.

Pulse modulation for 800 MHz to 960 MHz and 1.4 GHz to 6.0 GHz



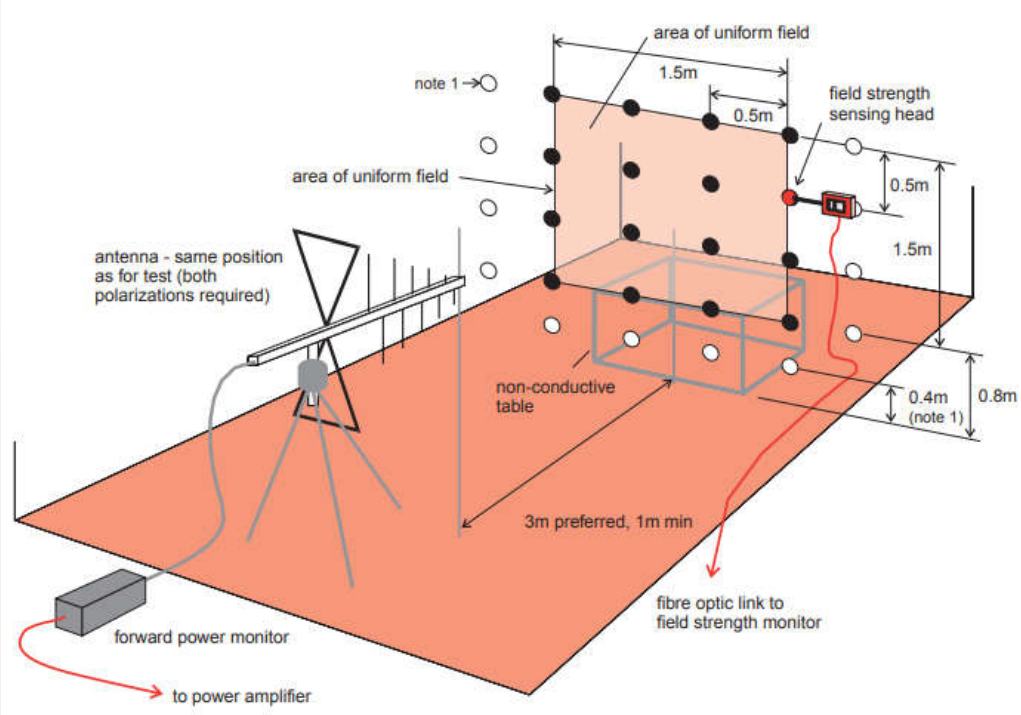
* “GSM-like” pulsed RF, duty cycle 1:8 at 200 Hz
* “DECT-like” pulsed RF, duty cycle 1:2 at 100 Hz (Base station)
* “DECT-like” pulsed RF, duty cycle 1:2 at 100 Hz (Portable)

80% AM Modulation for 80 MHz to 1000 MHz



Verification of the Radiated Immunity Test System I

➢ Before radiated immunity testing, test laboratory must perform verifications to ensure the quality and precision of test results by means of verification as the verification can detect errors beforehand in the test setup and prevent wrong testing.



➢ The location and height of the transmitting antenna are adjusted as the field uniformity calibration.

➢ The electric field probe is placed at any point in the uniform area

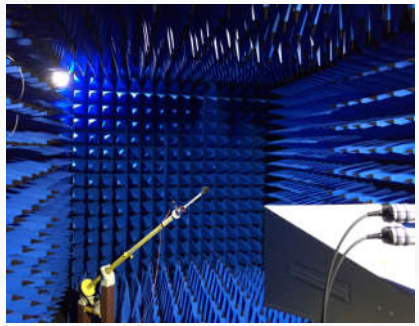
➢ The test is started as if the radiated immunity test was performed but the modulation is chosen 0%.

➢ The values to be read on the electric field probe must be between the target electric field and the target electric field + 6 dB.

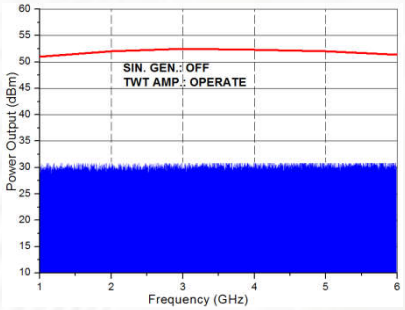
➢For example, for 3 V/m the electric field probe placed in uniform area shall be read values between 3 V/m and 6 V/m. Otherwise, the test is not started before the problem is solved.

Verification of the Radiated Immunity Test System II

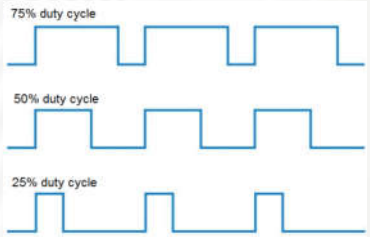
- The calibration of electric field probe shall be performed according to IEC/EN 61000-4-3 (frequency response, linearity, isotropy) by an accredited calibration laboratory and the calibration factors shall be entered into the test software.

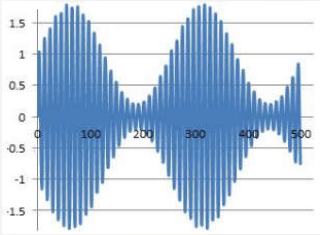


- If the TWT Amplifier is used at the test, the internal noise of the TWT Amplifier should be considered.

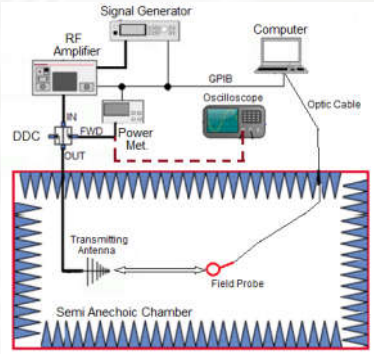


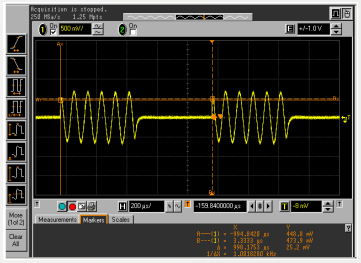
- The calibration of the signal generator shall be performed by an accredited calibration laboratory according to the modulation types to be used in the radiated immunity test.





- The correctness of modulations (AM, PM) which are applied in the radited immunity test and generated by the software shall be checked with an oscilloscope.

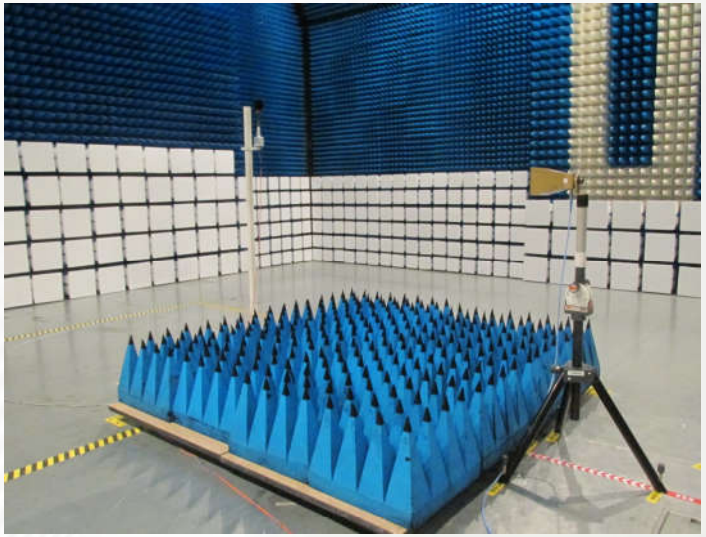


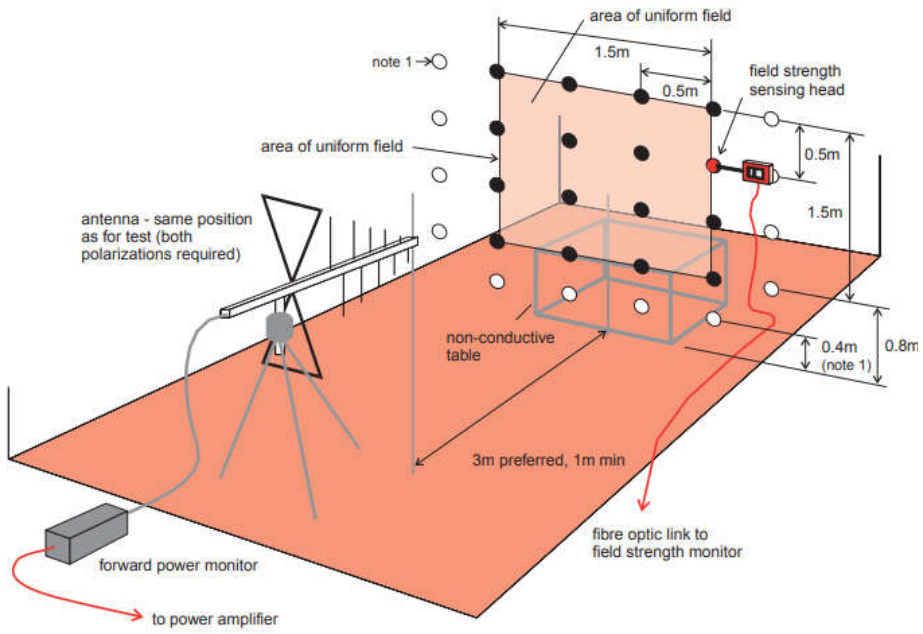


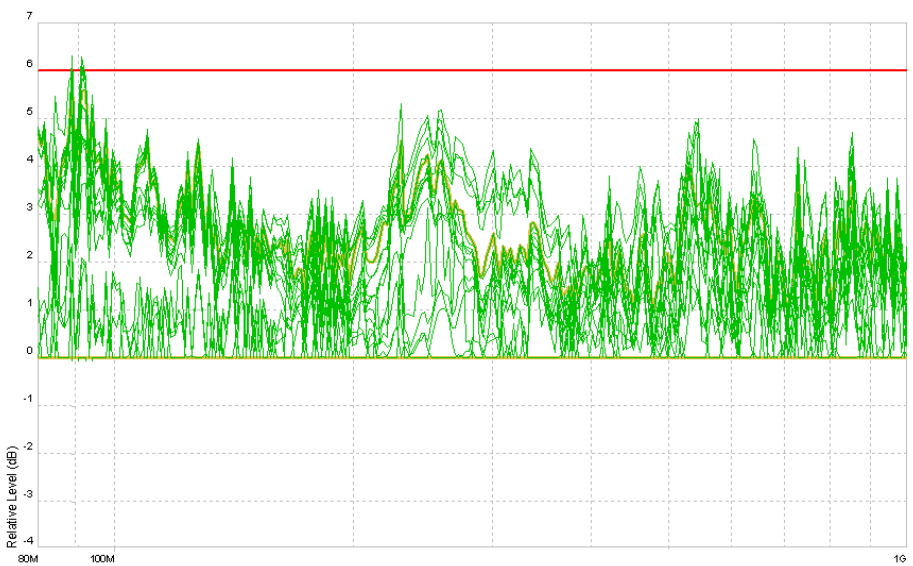
Field Uniformity Measurements

- Size: 1.5 m × 1.5 m (16 points)
- –0 dB/+6 dB variation over UFA plane
- More than 75 % of points have to be within tolerance
- Larger sizes and partial illumination allowed for larger EUT
- Smaller sizes allowed for smaller EUT (including cabling)
- Located 0.8 m above floor
- Distance from antenna tip: minimum 1 m, preferred 3 m

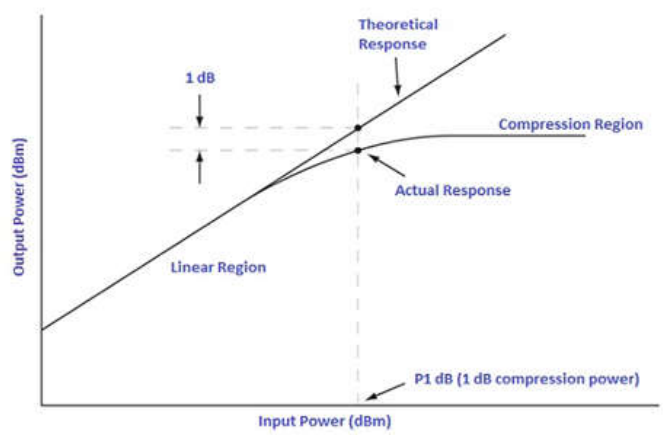
The field uniformity calibration shall be performed at a level 1.8 times the specified test level; that is, for 10 V/m test, the calibration is carried out at 18 V/m to verify the RF amplifier has the ability to reach the required field when the 80% 1kHz modulation.



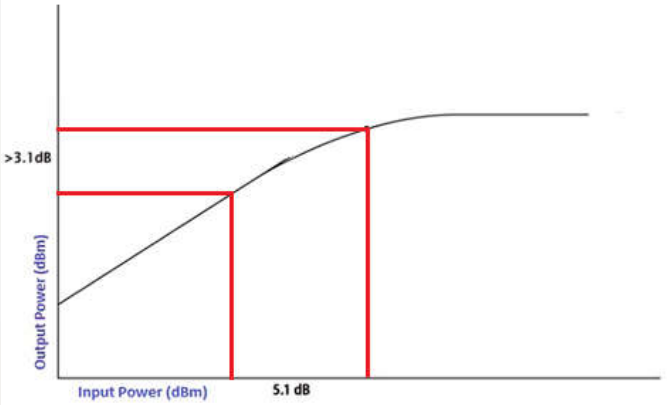




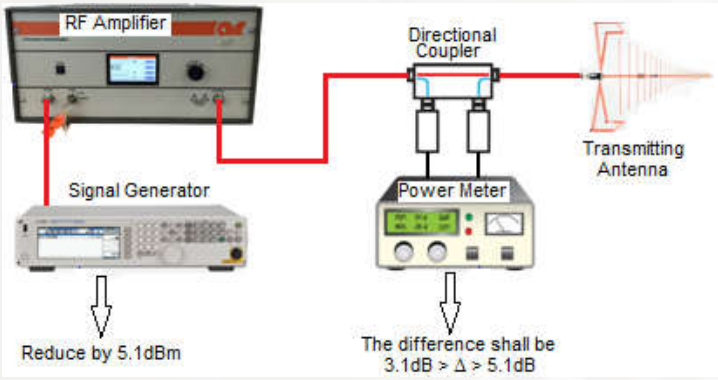
Saturation Measurements



A linear relationship exists between the input power and the output power over most of the operating range of an amplifier. However, as the power level rises, limitations in the supply voltage and current cause the output power to increase at a slower rate than the input. This initiates amplifier saturation



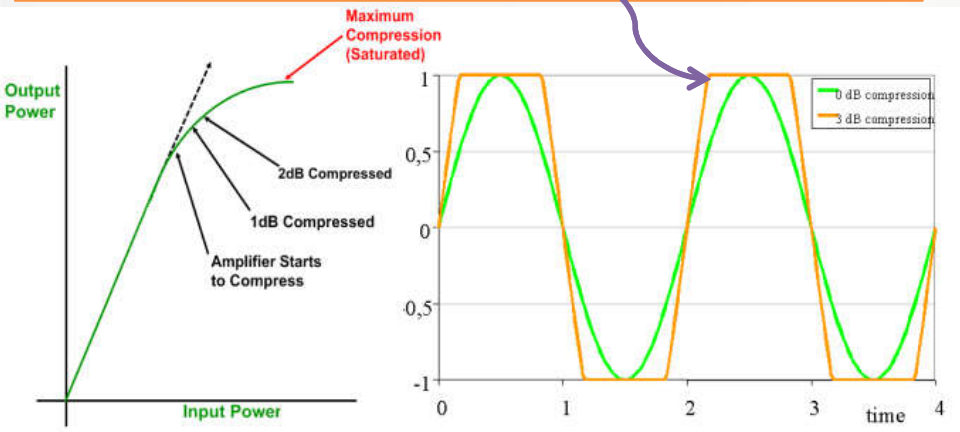
The chamber shall first be calibrated with the at a level 1.8 times the target test level that will be used for the EUT testing. This calibration produces a list of powers required at each frequency to achieve at 1.8 times the specified test level in the uniform field. Subsequently, at each frequency, the calibration power level is generated by the amplifier, and then the signal-generator level is reduced by 5.1 dB. The amplifier power level must fall by at least 3.1 dB for the amplifier to meet the 2-dB linearity criteria and be considered linear.



Frekans (MHz)	Sinyal Seviyesi (dBm)	Uygulanan Sinyal Seviyesi (dBm)	F-PWR (dBm)	PC (dBm)	FPWR-PC (dB)	Limit (dB)	Doyum Sonucu
80,00	-13,30	-18,40	44,97	49,85	4,88	3.1 dB - 5.1 dB	PASS
80,80	-13,80	-18,90	44,71	49,59	4,88	3.1 dB - 5.1 dB	PASS
81,61	-16,50	-21,60	43,07	48,33	5,26	3.1 dB - 5.1 dB	PASS
82,42	-12,20	-17,30	46,43	51,41	4,98	3.1 dB - 5.1 dB	PASS
83,25	-14,60	-19,70	43,11	48,33	5,22	3.1 dB - 5.1 dB	PASS
84,08	-14,00	-19,10	45,74	50,84	5,09	3.1 dB - 5.1 dB	PASS
84,92	-15,90	-21,00	44,34	49,36	5,03	3.1 dB - 5.1 dB	PASS
85,77	-12,30	-17,40	45,79	50,79	5,00	3.1 dB - 5.1 dB	PASS
86,63	-14,30	-19,40	42,39	47,19	4,80	3.1 dB - 5.1 dB	PASS
87,49	-12,80	-17,90	44,50	49,43	4,93	3.1 dB - 5.1 dB	PASS
88,37	-14,80	-19,90	43,93	48,88	4,96	3.1 dB - 5.1 dB	PASS
89,25	-15,00	-20,10	43,95	49,02	5,07	3.1 dB - 5.1 dB	PASS
90,15	-16,20	-21,30	41,80	46,93	5,12	3.1 dB - 5.1 dB	PASS
91,05	-15,20	-20,30	41,26	46,47	5,21	3.1 dB - 5.1 dB	PASS
91,96	-11,40	-16,50	44,83	49,85	5,02	3.1 dB - 5.1 dB	PASS
92,88	-16,30	-21,40	41,17	46,37	5,20	3.1 dB - 5.1 dB	PASS
93,81	-13,90	-19,00	44,22	49,25	5,02	3.1 dB - 5.1 dB	PASS
94,74	-14,60	-19,70	42,33	47,16	4,84	3.1 dB - 5.1 dB	PASS

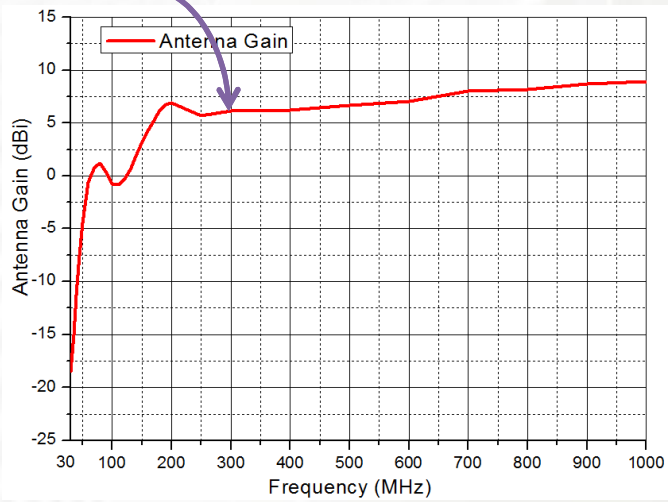
Harmonic Mesurements I

All amplifiers produce the harmonics unwanted frequencies generated by system nonlinearities. The level of these harmonics is dependent on the design and quality of the amplifier and worsens as the amplifier approaches saturation.



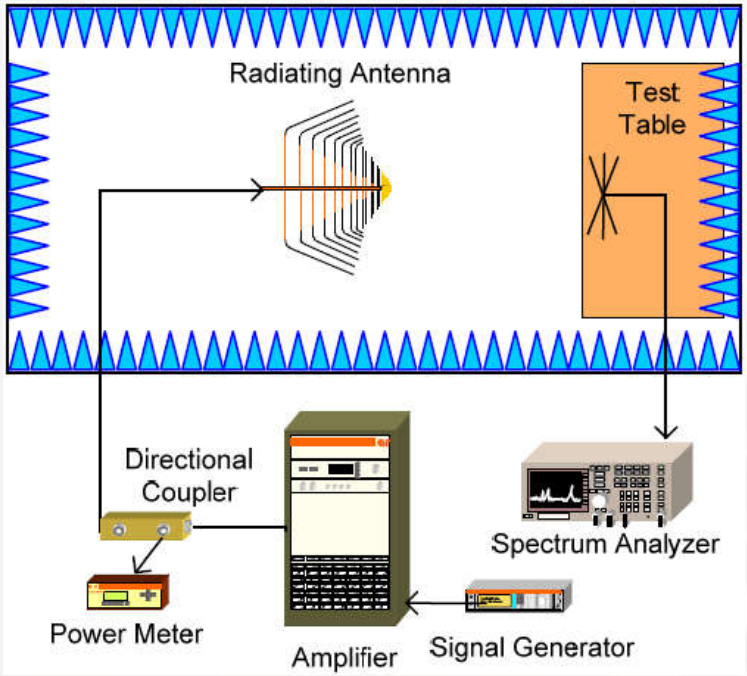
https://www.testforce.com/testforce_files/Seminars/SpirentMedicalSeminar2016/SpirentMedicalSystemsMed.pdf

The use of the broadband transmitting antennas also leads to a harmonics problem because the gain of the broadband transmitting antennas usually has better gain at higher frequencies. This can increase the level of the harmonics compared to the fundamental signal.



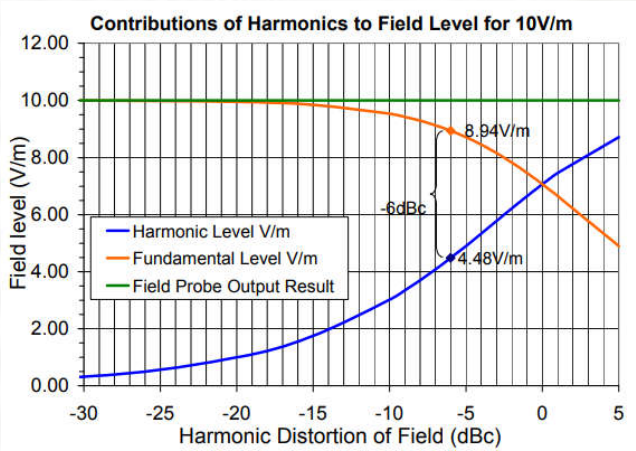
- When using a broadband receiving device for field calibration such as a field probe, it is not distinguish between different signals (fundamental or harmonic)
- High harmonics can contribute to the readings of the field probe and produce error in the reading.
- This error will cause testing at the intended fundamental frequency to be incorrect.

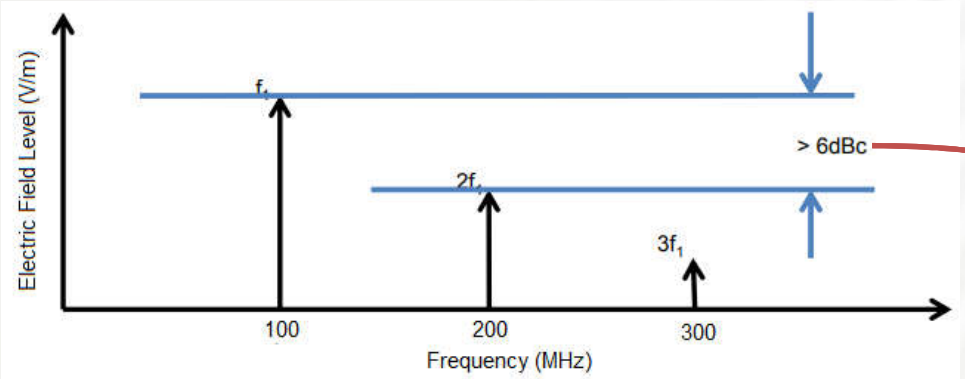
Harmonic Mesurements II



http://www.microwavejournal.com/ext/resources/BGDownload/8/7/AppNote60.pdf?1520938749

- The harmonic measurements shall be performed at a level 1.8 times the specified test level.
- The receiving antenna factors and RF cable factors must be taken into account to obtain the 2th&3th harmonic levels of the RF amplifier.

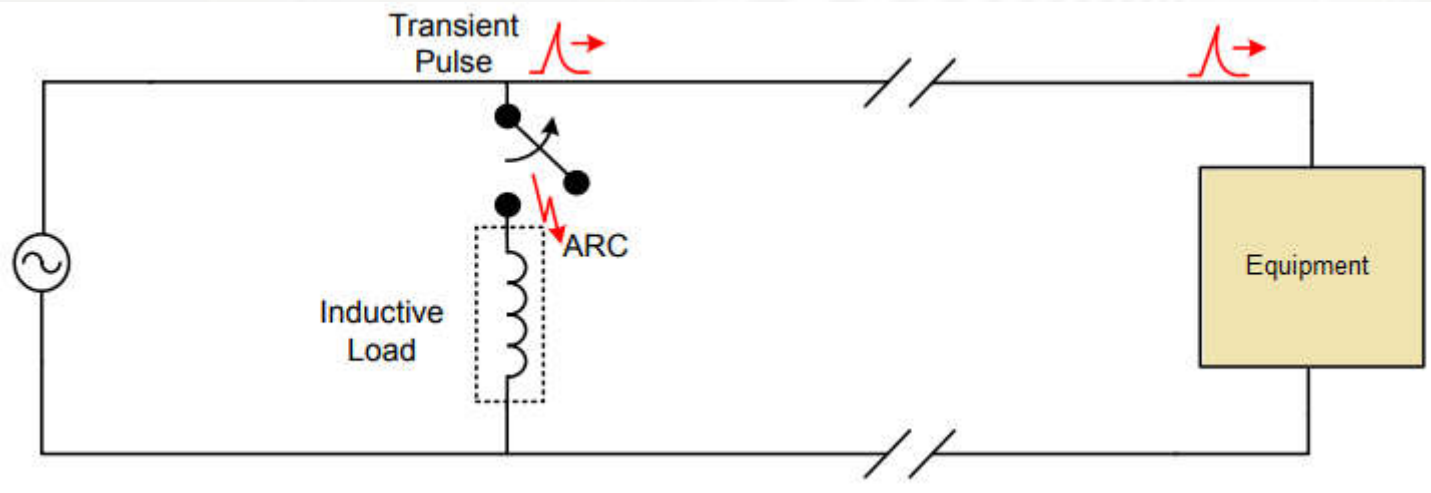




IEC 61000-4-3 requires that the level of the fundamental signal measured at the uniform plane is 6 dB more than the harmonics.

What is Electrical Fast Transient (EFT)?

Inductive loads such as relays, switch contactors, or heavy-duty motors when de-energized produce bursts of narrow high-frequency transients on the power distribution system. These fast transients can also be produced when the utility provider switches in or out the power factor correction equipment. A common cause of power line transients is sparking that occurs whenever an AC power cord is plugged in, equipment is switched off, or when circuit breakers are opened or closed. Figure given below shows how transients are generated and coupled to end equipment over power lines.

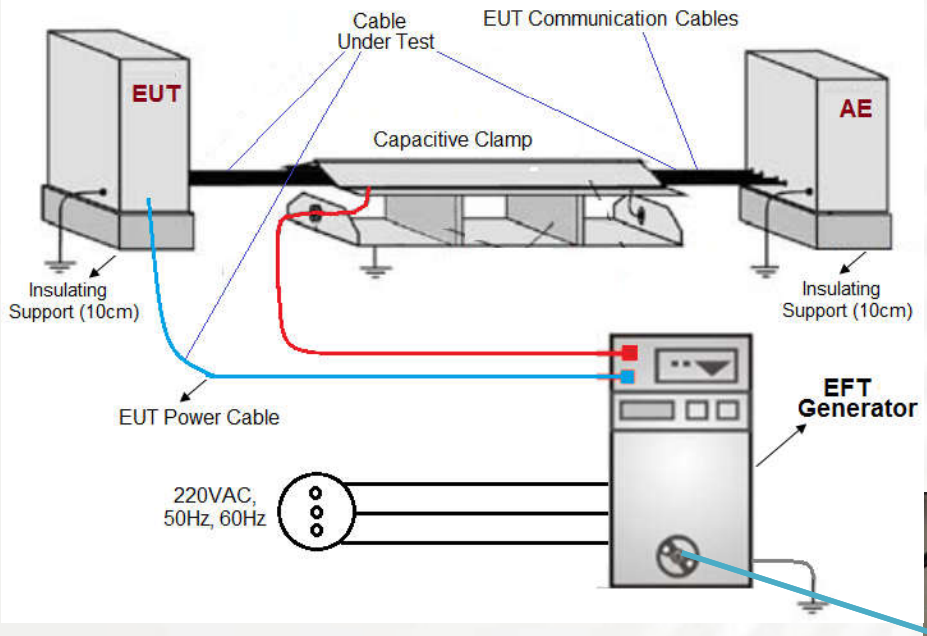


http://www.cypress.com/file/138636/download

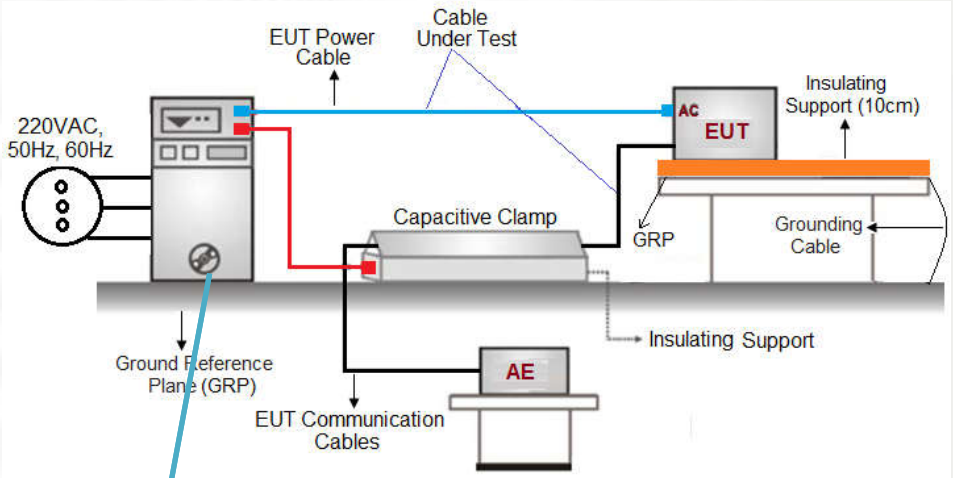
EFT/Burst Testing

- The purpose of the EFT/Burst immunity testing is to determine the effects of switching transients caused by the interruption of inductive loads, relays, switch contactors, or heavy-duty motors on the EUT.
- During the EFT/Burst immunity testing, the EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual when subjected to the EFT/Burst pulse.

Test set-up for floor-standing EUT



Test set-up for table top EUT



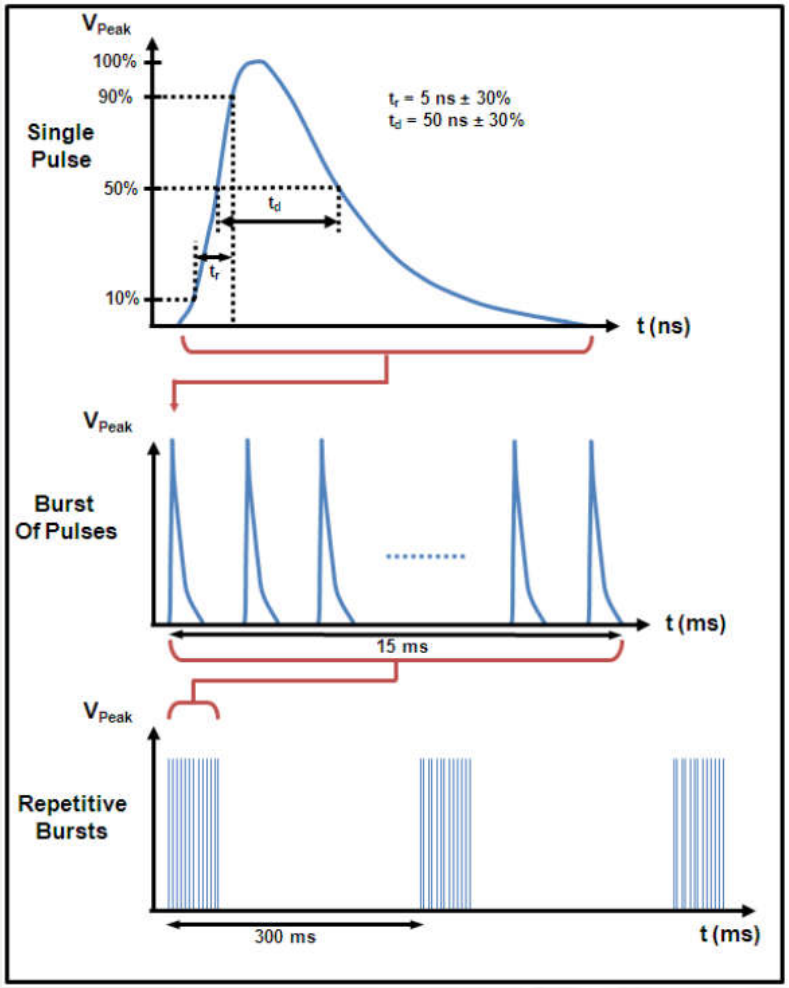
The EFT Generator and CDN has to be connected with the reference ground in low impedance manner.

The connection between the output of the CDN and the coaxial adapter should be as short as possible; but not to exceed 0,1 m

EFT/Burst Test Levels and Pulse Shape

The EFT/Burst test is performed on power lines, I/O data lines, I/O control lines and earth wires of EUT

Test levels shall be selected according to specific product standards or generic standards that defines levels in accordance with electromagnetic environment.



Test Levels for EFT/Burst Test

Open Circuit Output Test Voltage and Repetition Frequency of the Impulses				
Level	Power Supply Terminal		I/O Signals/Data Terminals	
	Peak Voltage (kV)	Repetition Rate (kHz)	Peak Voltage (kV)	Repetition Rate (kHz)
1	0.5	5 or 100	0.25	5 or 100
2	1	5 or 100	0.5	5 or 100
3	2	5 or 100	1.0	5 or 100
4	4	5 or 100	2.0	5 or 100
X[a]	Special	Special	Special	Special

The use of 5 kHz repetition frequency is traditional, however, 100 kHz is closer to reality. Product committees should determine which frequencies are relevant for specific products or product types.

With some products, there may be no clear distinction between power ports and signal ports, in which case it is up to product committees to make this determination for test purposes.

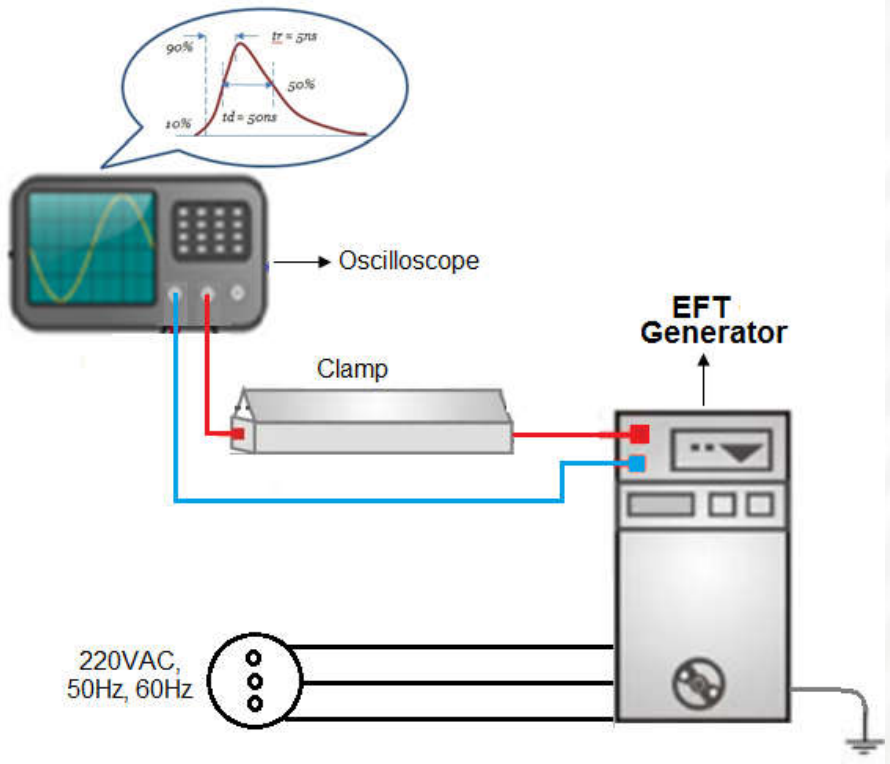
[a] "X" can be any level, above, below or in between the others. The level shall be specified in the dedicated equipment specification

Verification of the EFT/Burst Test System

➢ The purpose of verification is to ensure that the EFT/Burst test setup is operating correctly between calibrations. The EFT/Burst test setup includes the EFT/Burst generator, CDN, capacitive coupling clamp, interconnection cables.

➢ To verify that the system functions correctly, the following signals should be checked.

* EFT/Burst signal present at the output terminal of the CDN,
* EFT/Burst signal present at the capacitive coupling clamp.



➢Before EFT/Burst immunity testing, the verification setup is established.

➢ Any channel of the oscilloscope is connected to outputs of the EFT generator.

➢ The EFT/Burst pulse is applied by using clamp or directly on any input channel of the oscilloscope as if the EFT/Burst immunity testinf was performed.

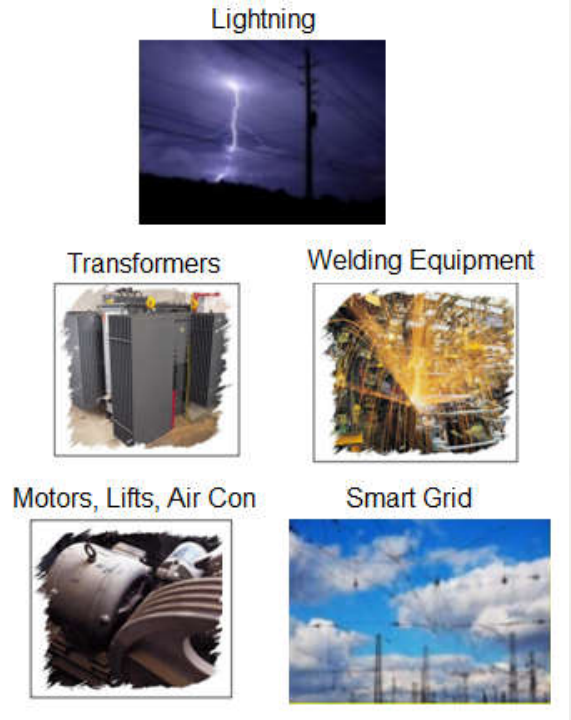
➢ The values (voltage and time parameters) to be read on the oscilloscope shall be a level within ±10% of the target level.

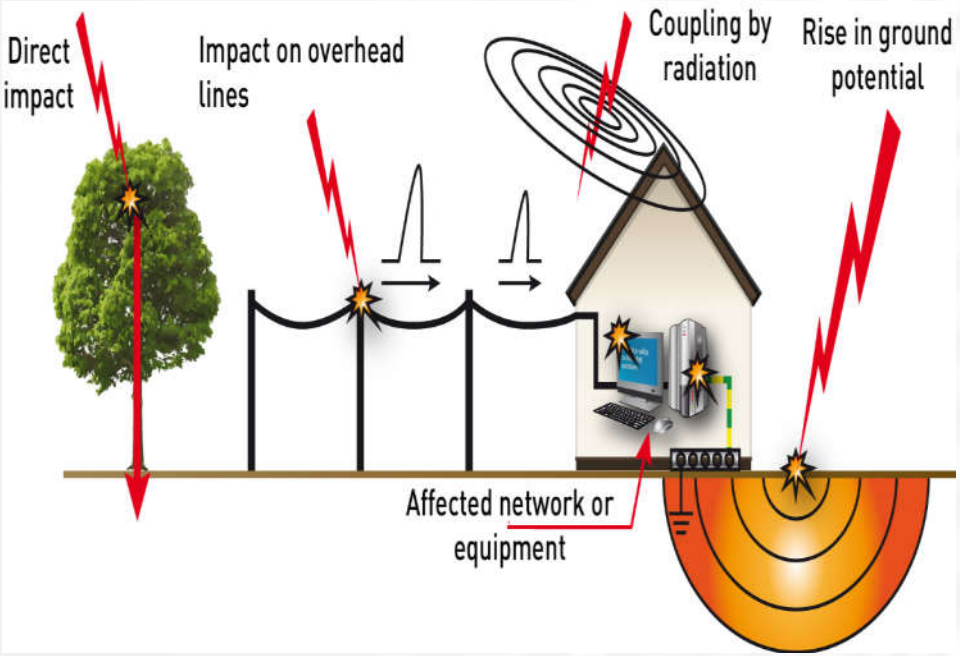
➢ Otherwise, the test is not started before the problem is solved.

What is Surge?

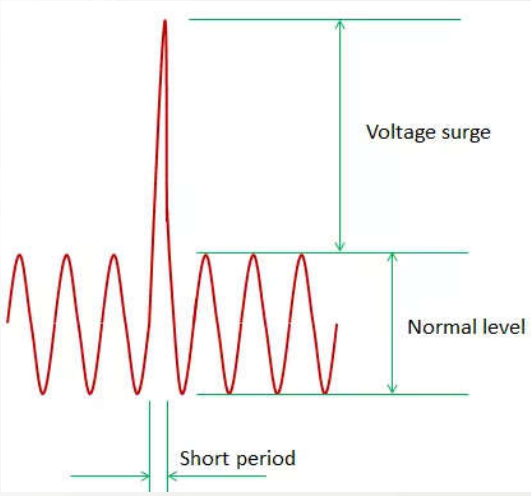
Surge is an unexpected, temporary, uncontrolled increase in current or voltage in an electrical circuit. Transient overvoltages on the ac power system are produced by events such as

- Lightning strikes
- Load switching (Motors, Large loads, Capacitor bank switching)
- Source switching (Smart grid, Gensets, PV, Wind turbine)
- Faulty electrical wiring,
- Short circuits etc.





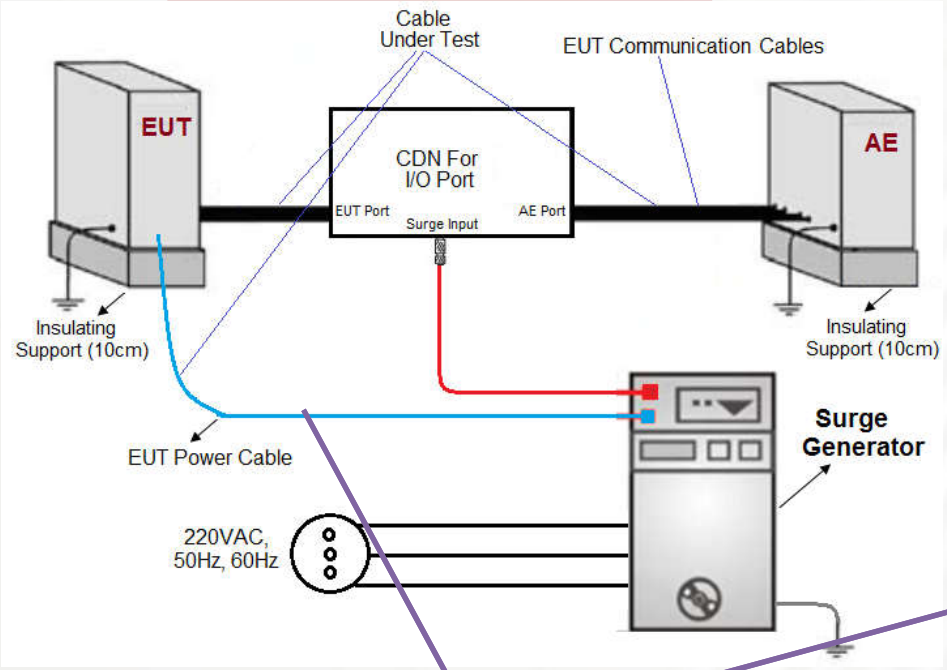
http://www.citel.in/in/origin-of-overvoltages.html



Surge Testing

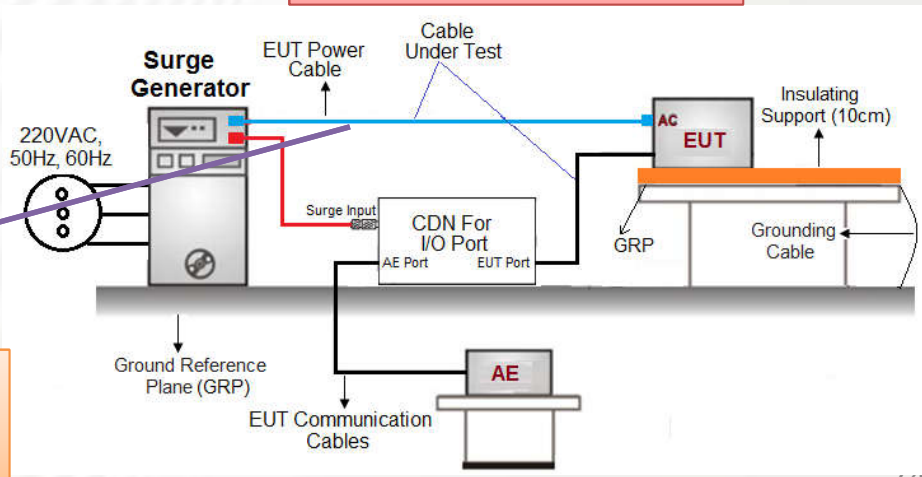
- The purpose of the surge immunity testing is to determine the effects of the unidirectional surges caused by over voltages from switching and lightning transients on the EUT.
- During the surge immunity testing, the EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual when subjected to the surge pulse.

Test set-up for floor-standing EUT



The surge test is performed on power lines, I/O data lines, I/O control lines and earth wires of EUT

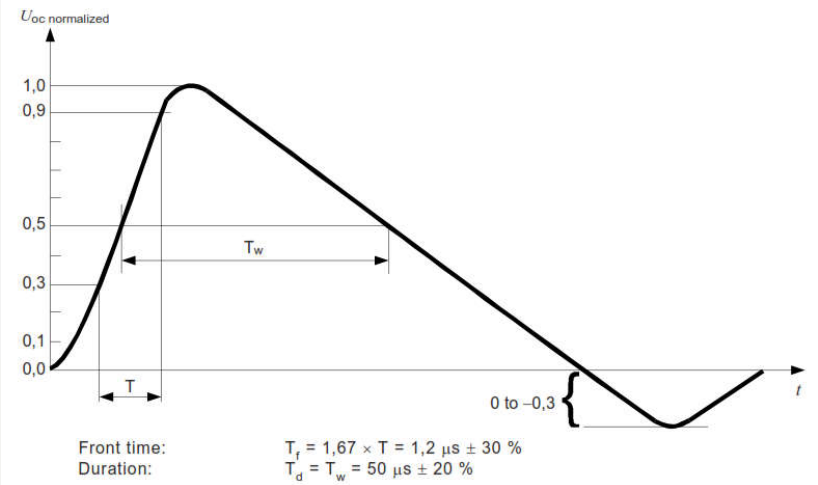
Test set-up for table top EUT



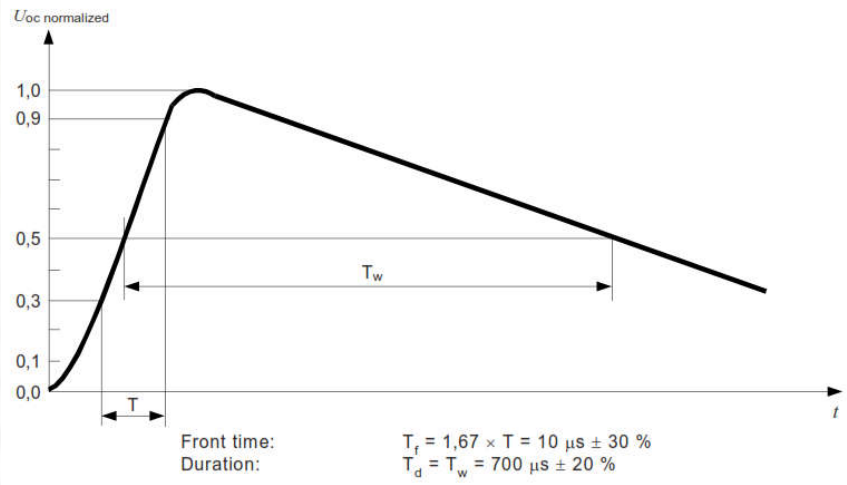
If not otherwise specified the power cable between the EUT and the coupling/decoupling network shall not exceed 2 m in length.

Surge Testing Waveforms

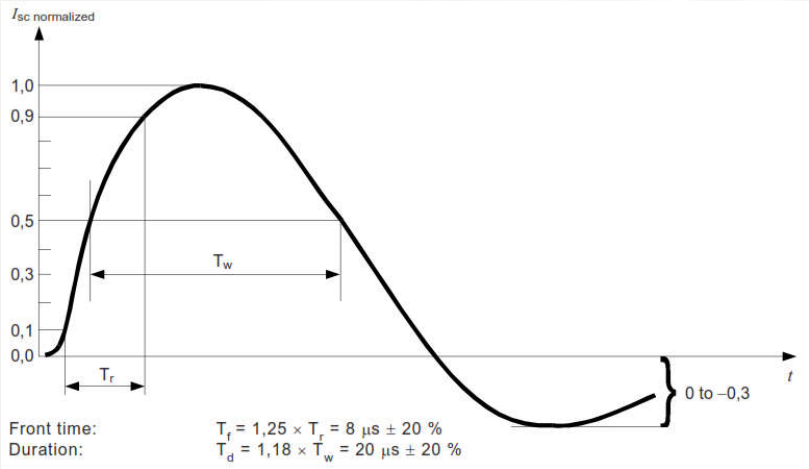
Waveform of open-circuit voltage (1,2/50 µs) at the output of the generator with no CDN connected



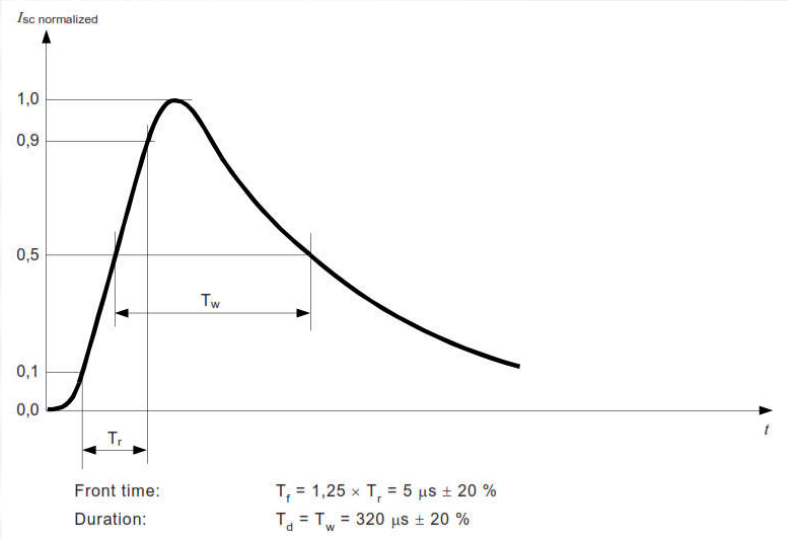
Waveform of open-circuit voltage (10/700 µs)



Waveform of short-circuit current (8/20 µs) at the output of the generator with no CDN connected



Waveform of the 5/320 µs short-circuit current waveform



Surge Testing Levels and Application

- Test levels shall be selected according to specific product standards or generic standards that defines levels in accordance with electromagnetic environment.

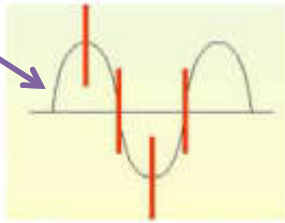
Test Levels for Surge Test

Level	Open-circuit test voltage kV	
	Line-to-line	Line-to-ground [b]
1	-	0.5
2	0.5	1
3	1	2
4	2	4
X [a]	Special	Special

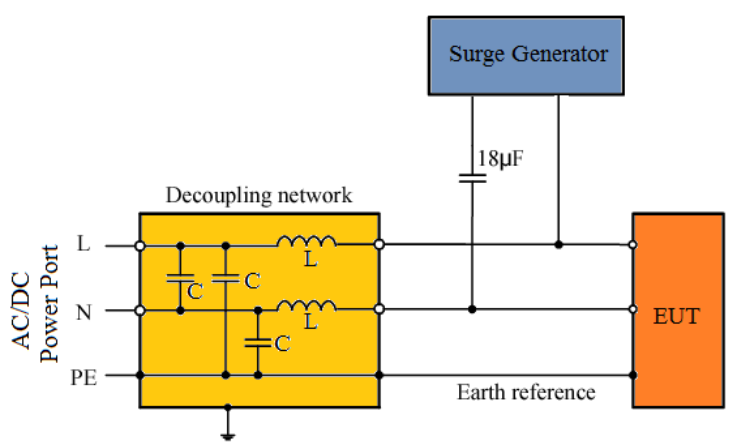
[a] "X" can be any level, above, below or in between the others. The level shall be specified in the dedicated equipment specification.

[b] For symmetrical interconnection lines the test can be applied to multiple lines simultaneously with respect to ground, i.e. "lines to ground".

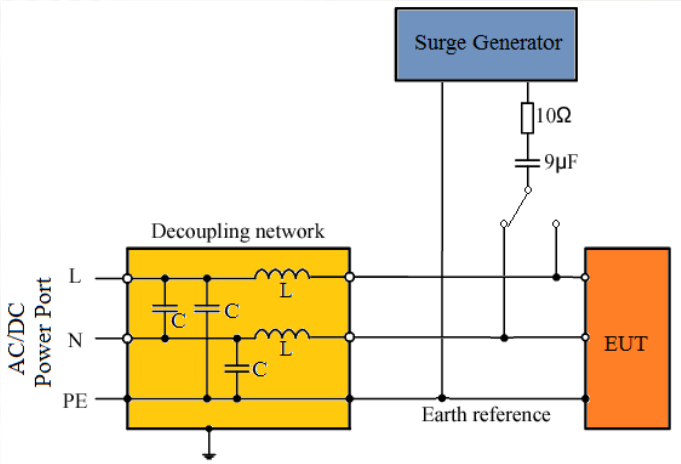
- Coupling: Line to line (differantial mode) and line to ground (common mode)
- Polarity: Positive and negative
- Repetition rate: 1 per minute or faster
- Number of pulses: 5 (for each polarity)
- Phase angles: 0°, 90°, 180°, 270°



Line to line coupling



Line to ground coupling

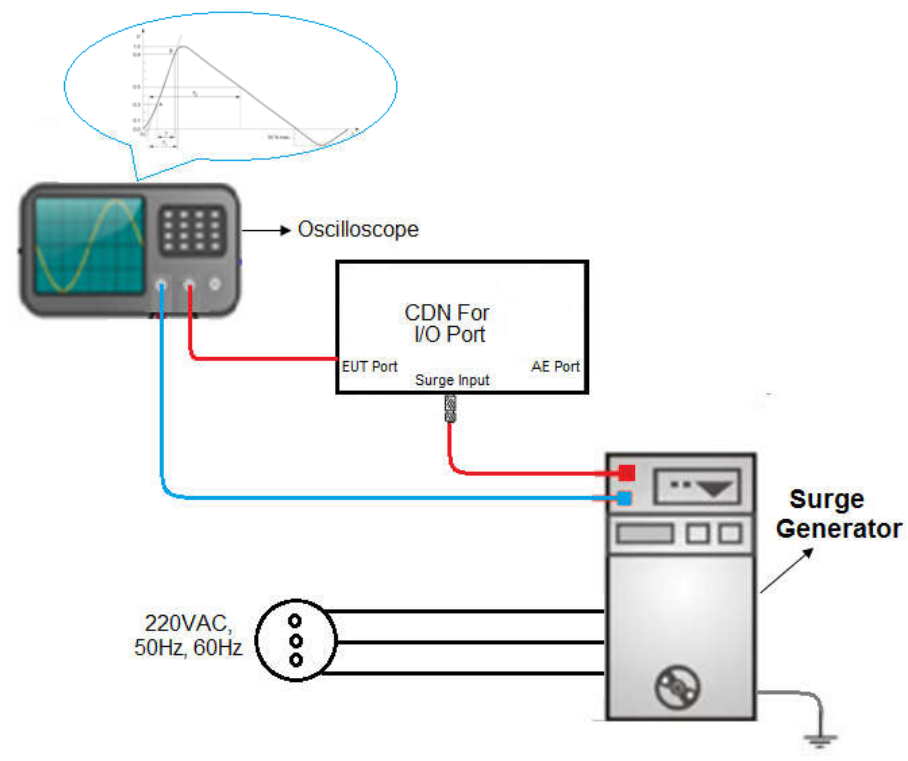


Verification of the Surge Testing System

➢ The purpose of verification is to ensure that the test setup is operating correctly. The test setup includes the combination wave generator, the CDN, the interconnection cables of the test equipment.

➢ To verify that the system functions correctly, the following signal should be checked.

* Surge impulse present at the output terminal of the CDN



➢Before the surge immunity testing, the verification setup is established.

➢ Any channel of the oscilloscope is connected to outputs of the surge generator.

➢ The surge pulse is applied by using CDN or directly on any input channel of the oscilloscope as if the surge immunity testinf was performed.

➢ The values (voltage and time parameters) to be read on the oscilloscope shall be a level within ±10% of the target level.

➢ Otherwise, the test is not started before the problem is solved.

Conducted Immunity Testing

- The purpose of this test is to determine the effects of electromagnetic disturbances coming from intended RF transmitters in the frequency range 150 kHz – 80 (230) MHz on the EUT.
- During the the conducted immunity testing, the EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual when subjected to radio frequency voltage or current on interconnecting cables (mains, communication lines, interface cables).

CDNs (Direct capacitive coupling)

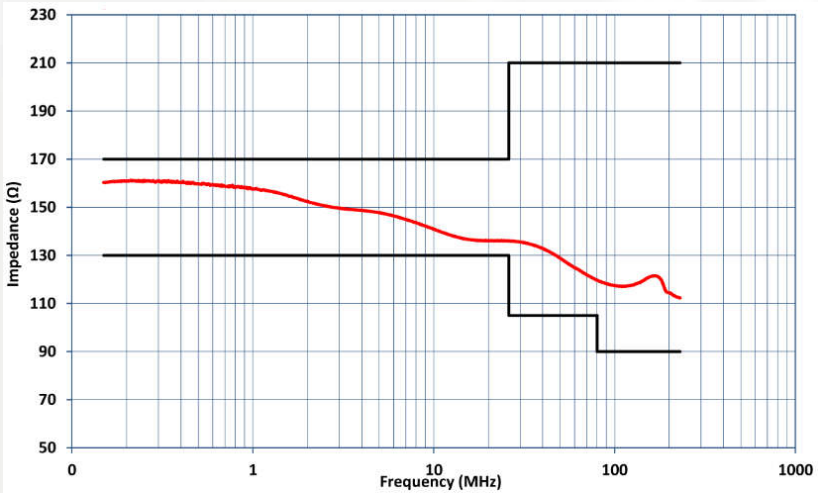
Current Clamp (Inductive coupling)

EM Clamp (Capacitive and inductive coupling)

General Information About CDN

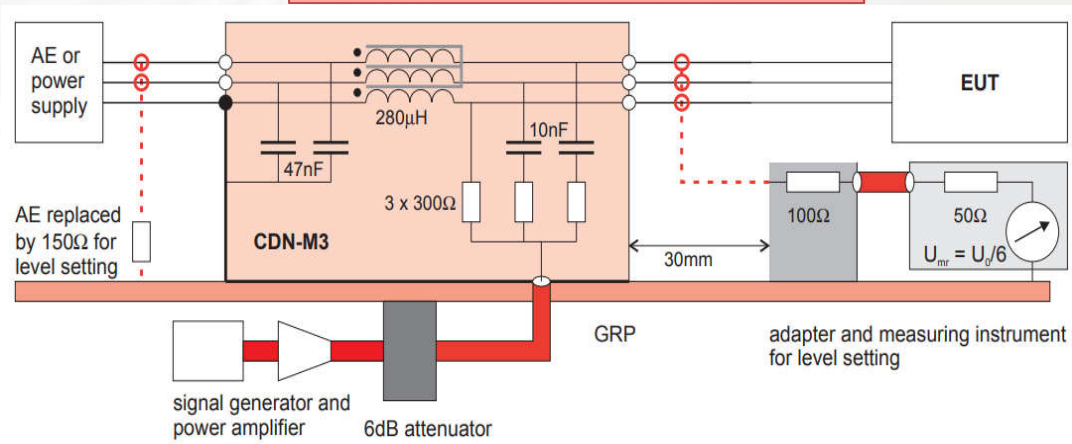
- The CDNs provide the appropriate common-mode impedance (150 Ω) in order to obtain more repeatable results.
- The CDN is used for appropriate coupling of the disturbing signal to the various cables connected to the EUT and for preventing applied test signals from affecting other devices, equipment and systems that are not under test.
- The calibrations of the CDNs and adapters to be used in the conducted immunity testing shall be performed an accredited calibration laboratory at specified intervals.

CDN common mode impedance



https://www.com-power.com/cdn-m325e.html

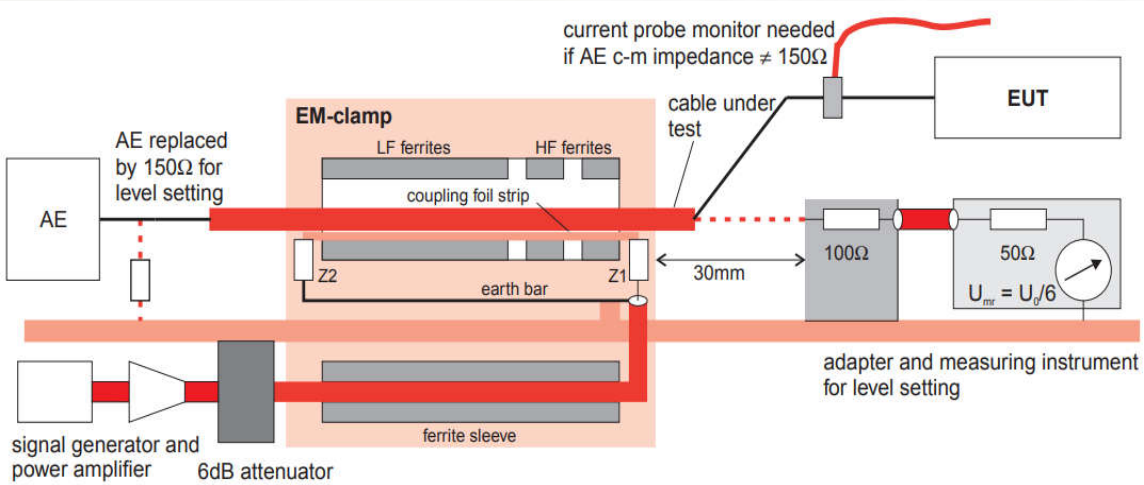
The circuit diagram for M3 type CDN



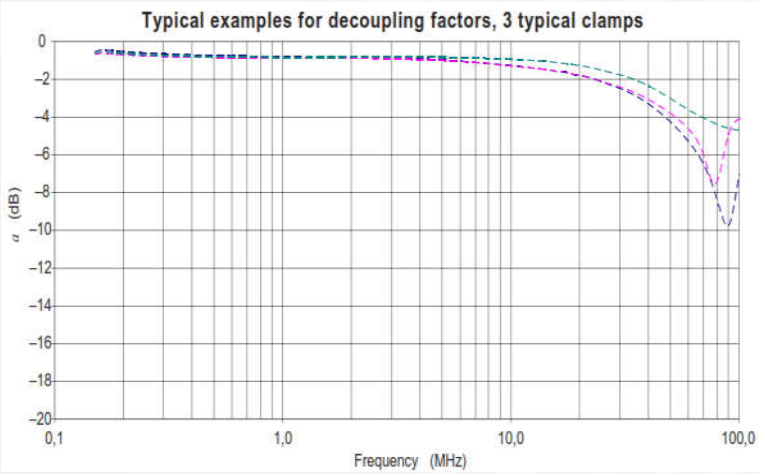
CDN	Type of Cable
M Series	Power Line
C Series	Shielded Coax
AF Series	Unshielded Signal Cables
S Series	Shielded Signal Cables
T Series	Unshielded Balanced Pairs

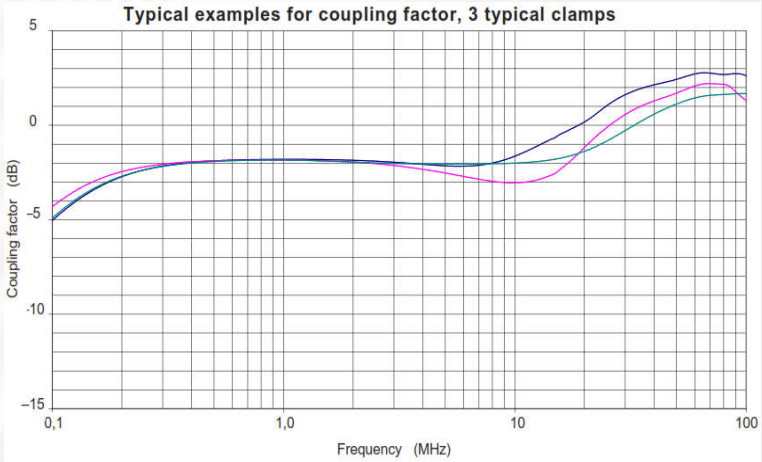
General Information About EM Clamp

➢ The electromagnetic (EM) clamp is a high efficiency broadband clamp-on injection device developed to test the immunity of electronic equipment when the standard IEC 61000-4-6 CDN using the direct capacitive coupling technique is not possible nor appropriate. The EM clamp is often used to test unshielded multiple conductor cables. The EM-Clamp is used, when a CDN is not possible, e.g. for shielded or complex cables. The clamp and the separate decoupling clamp are placed around the cable.



http://www.teseq.com/media/docs/support_downloads/technical-information/wallcharts/LF_and_RF_immunity.pdf



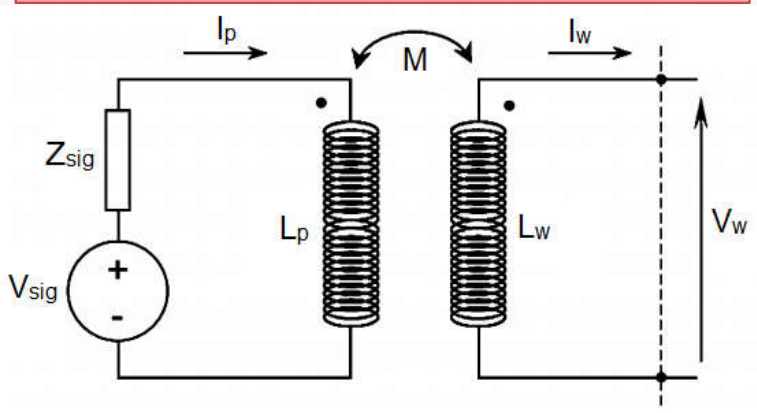


General Information About Current Clamp

➢ As per IEC 61000-4-6, an injection clamp should be used only when there is no commercially available CDN for the type of port(s) to be tested. Unlike the CDN, a clamp does not provide the decoupling functions or establish the required impedance. Therefore, the flow of current is not controlled, and a current monitoring probe must also be installed on the line(s) under test to ensure that the current does not exceed the maximum required current.

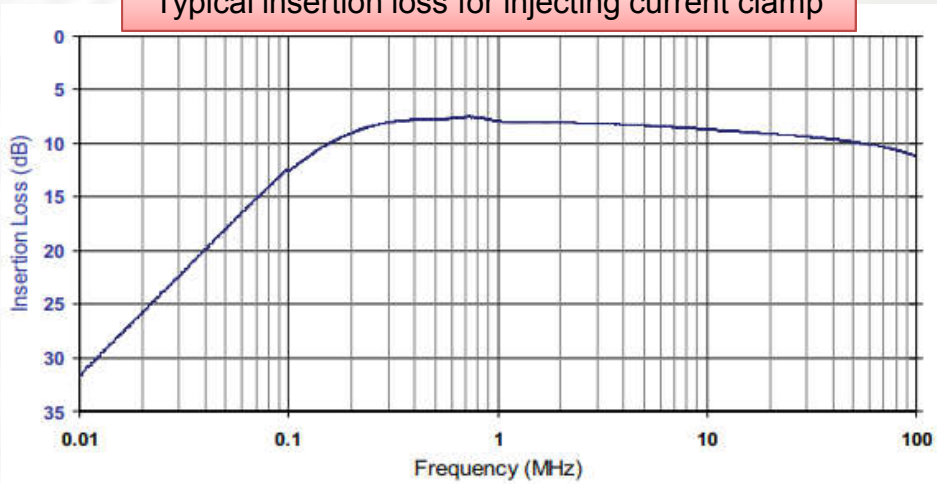
Injecting current clamp with test jig

Equivalent circuit of the injecting current clamp



The required performance of the current clamp is such that the increase of the transmission loss of the test jig, produced by the insertion of the current clamp, shall not exceed 1,6 dB.

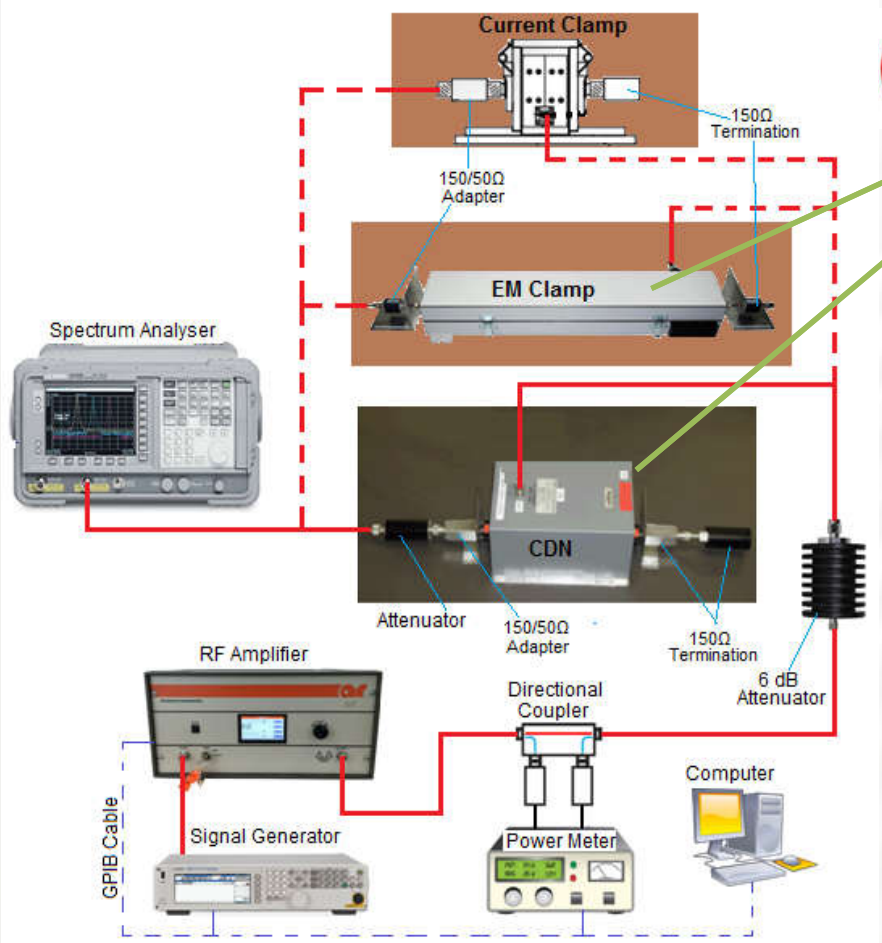
Typical insertion loss for injecting current clamp



https://assets.tequipment.net/assets/1/26/Com-Power_CLCI-100_-_Data_Sheet.pdf

Calibration Setups for CDN, EM Clamp and Current Clamp

- Before conducted immunity testing, a calibrated drive levels corresponding to the test levels as per the table below shall be established on the suitable coupling device (CDN, EM clamp or current clamp) to be used at test.
- The open circuit test levels (e.m.f.) of the unmodulated disturbing signal, expressed in r.m.s., are given in table below.



The CDN including adapters and the adapters of the EM clamp have to be connected with the reference ground in low impedance manner.

Test levels shall be selected according to specific product standards or generic standards that defines levels in accordance with electromagnetic environment.

Test Levels

Frequency range 150 kHz to 80 MHz		
Level	Voltage level (e.m.f.)	
	U_O V	U_O dB(μV)
1	1	120
2	3	129.5
3	10	140
x[a]	Special	

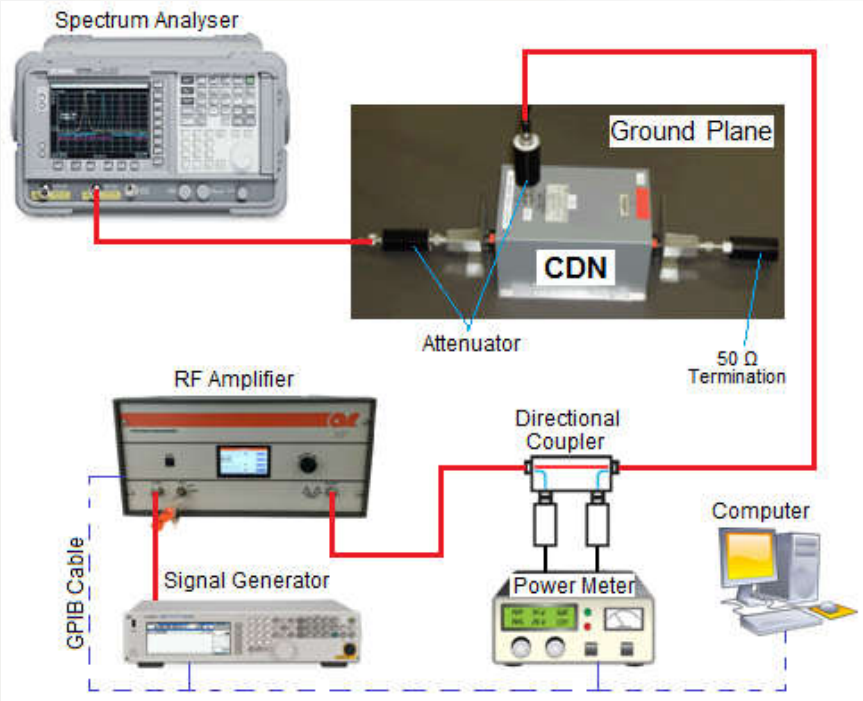
[a] "X" can be any level, above, below or in between the others. The level has to be specified in the dedicated equipment specification.

Verification Setup for CDN

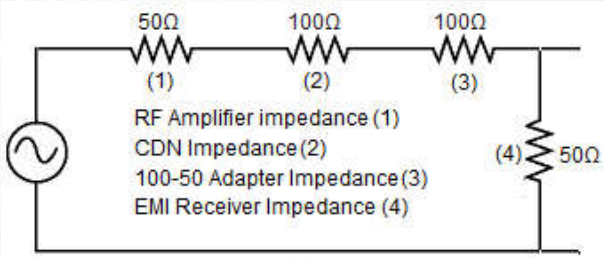
- The purpose of verification is to ensure that the test setup is operating correctly.
- To verify that the system functions correctly, the following equipment should be checked.

* The signal generator, the RF amplifier, the CDN+adapter, and the RF path (cable and attenuator).

Verification setup for CDN



- Before conducted immunity testing, the verification setup is established for each CDN.
- The test is started as if the conducted immunity testing was performed but the modulation is chosen 0%.
- The values to be read on the spectrum analyser or the EMI receiver shall be a level within ±20% of the target level (The RF cable loss and the attenuator factors shall be taken into account).
- For example, for 10 V the spectrum analyser or the EMI receiver shall be read values between 2V (126dBµV) and 1.3V (122.5dBµV). Otherwise, the test is not started before the problem is solved.



$$I = \frac{V}{50 + 100 + 100 + 50}$$

$$V_{EMI} = \frac{V}{300} x50 \qquad V_{EMI} = \frac{V}{6}$$

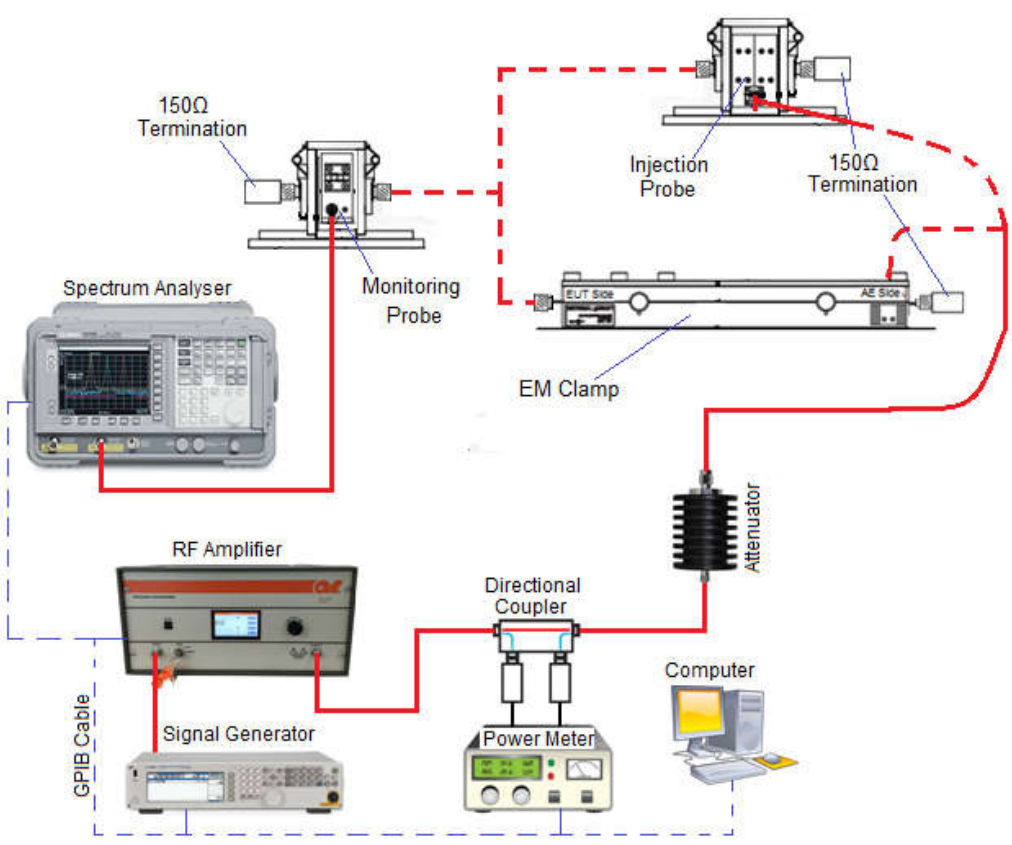
$$20log(V_{EMI}) = 20log(Vx10^6) - 20log(6)$$

Verification of the Test System for EM Clamp or Current Clamp

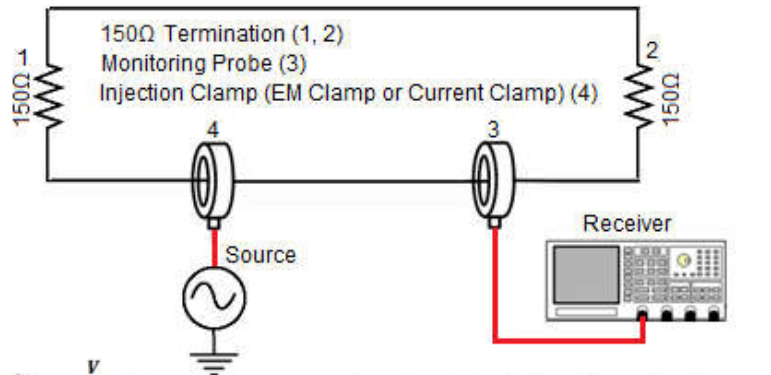
- The purpose of verification is to ensure that the test setup is operating correctly.
- To verify that the system functions correctly, the following equipment should be checked.

* The signal generator, the RF amplifier, the EM clamp, the injection and monitoring probe, and the RF path (cable and attenuator).

Verification setup for EM Clamp or Current Clamp



- Before conducted immunity testing, the verification setup is established for the EM clamp or the current clamp.
- The test is started as if the conducted immunity testing was performed but the modulation is chosen 0%.
- The values to be read on the software shall be shall be a level within ±20% of the target level.
- For example, for 10 V the test software shall indicate the values between 40mA (92dBµA) and 26mA (88.5dBµA). Otherwise, the test is not started before the problem is solved.



$$I = \frac{V}{150 + 150}$$

$$V_{EMI} = \frac{V}{300} x50$$

$$V_{EMI} = \frac{V}{6}$$

$$20log(V_{EMI}) = 20log(Vx10^6) - 20log(6)$$

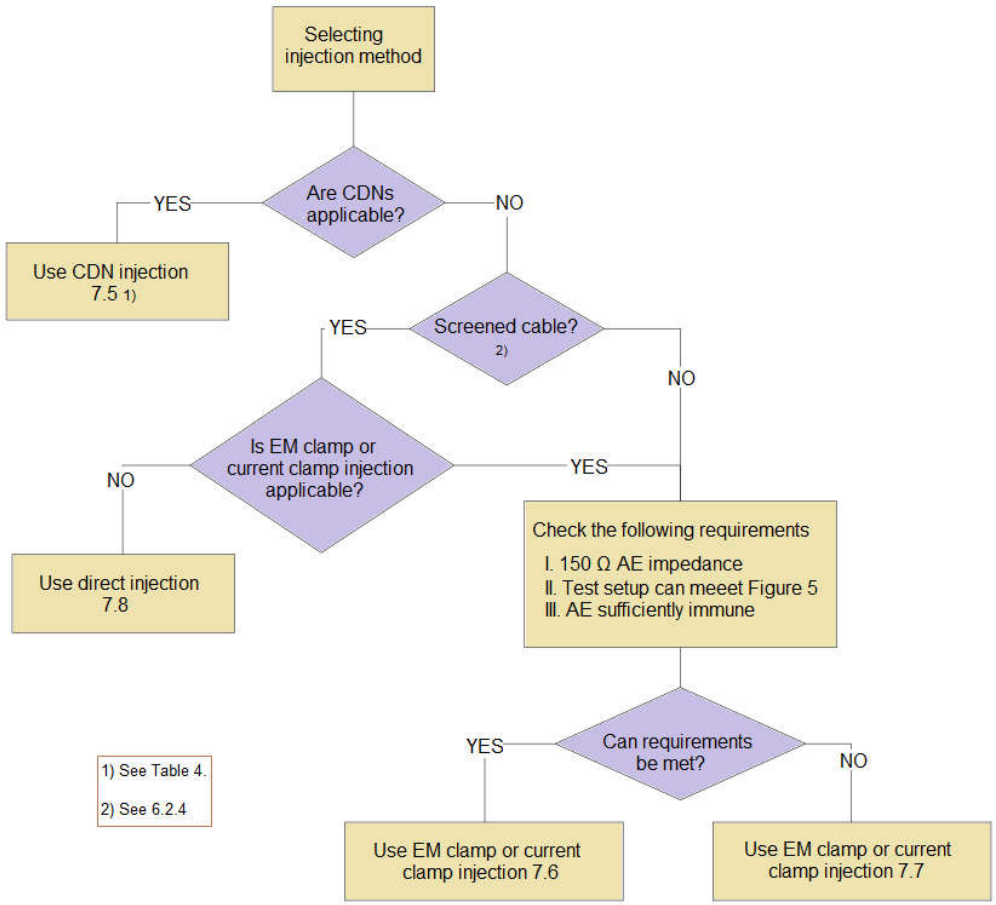
$$V = IxR = Ix50\Omega$$

$$20log(I_{EMI}) = 20log(Vx10^6) - 20log(6) - 20log(50)$$

$$20log(I_{EMI}) = 20log(Vx10^6) - 49.6$$

Performing of Conducted Immunity Testing

The appropriate injection method given following is chosen for the EUT to be tested.

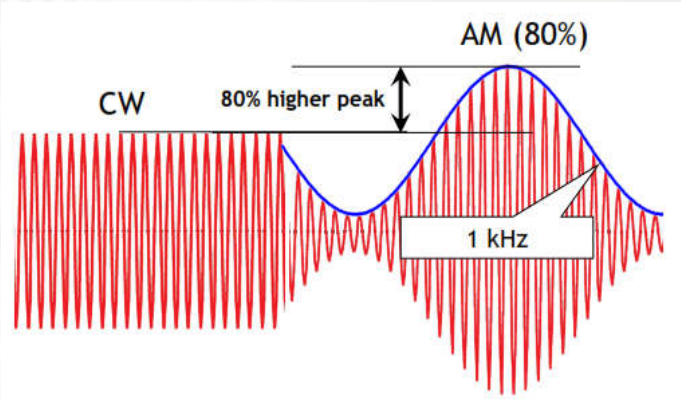


The sensitive frequencies (e.g. clock frequencies or frequencies identified by the manufacturer or obtained as outcome of the test) shall be analyzed in addition to the stepped frequencies.

The frequency range is swept from 150 kHz to 80 (230) MHz, using the signal levels established during the setting process, and with the disturbance signal 80 % amplitude modulated with a 1 kHz sine wave, pausing to adjust the RF signal level or to change coupling devices as necessary.

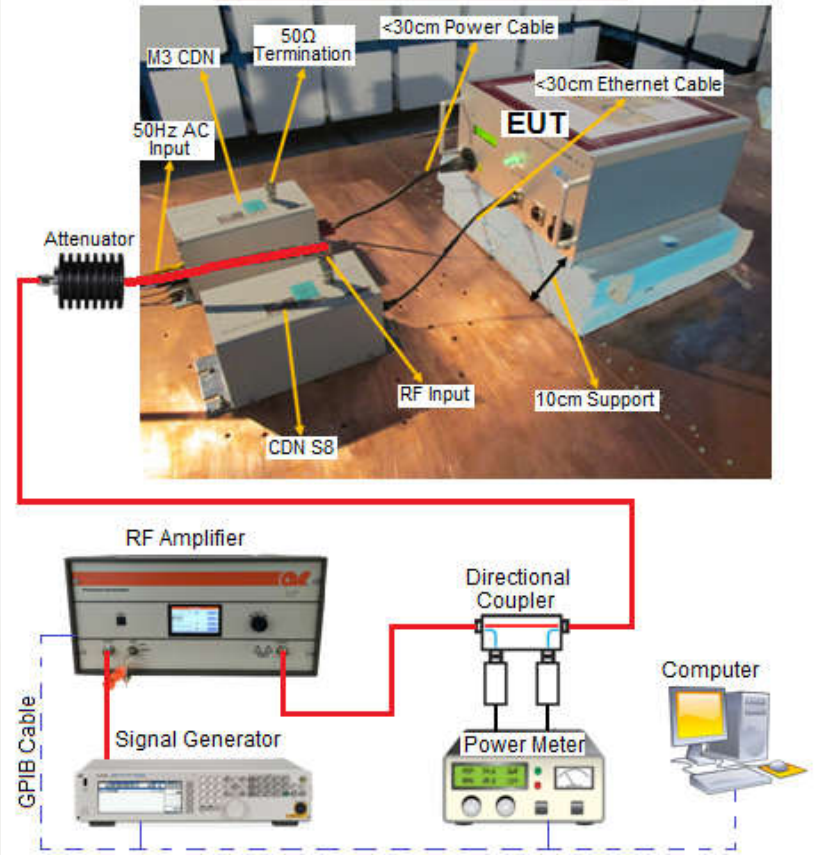
Where the frequency is swept incrementally, the step size shall not exceed 1 % of the preceding frequency value. The dwell time of the amplitude modulated carrier at each frequency shall not be less than the time necessary for the EUT to be exercised and to respond, but shall in no case be less than 0,5 s.

80% AM Modulation for 150 kHz to 230 MHz

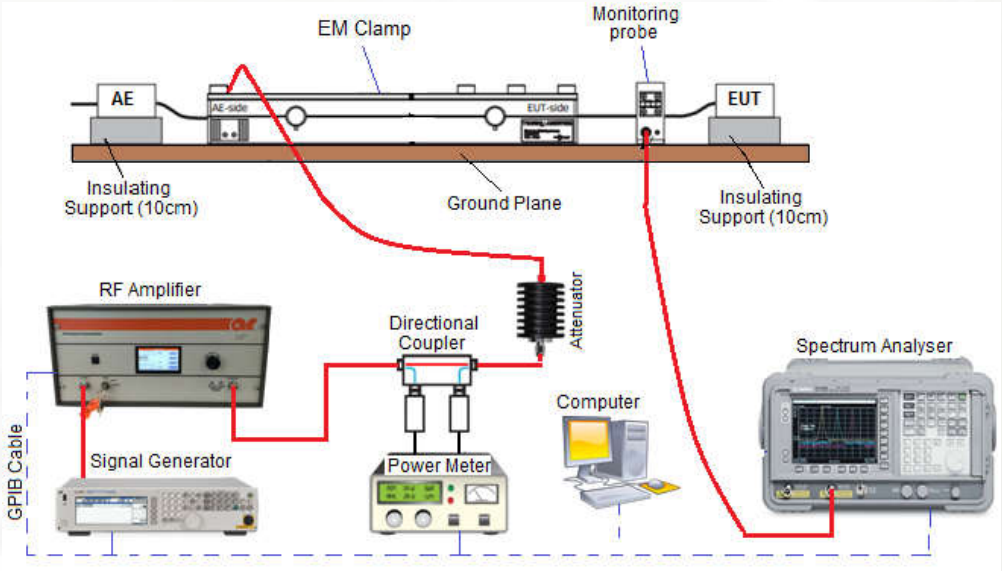


Conducted Immunity Testing

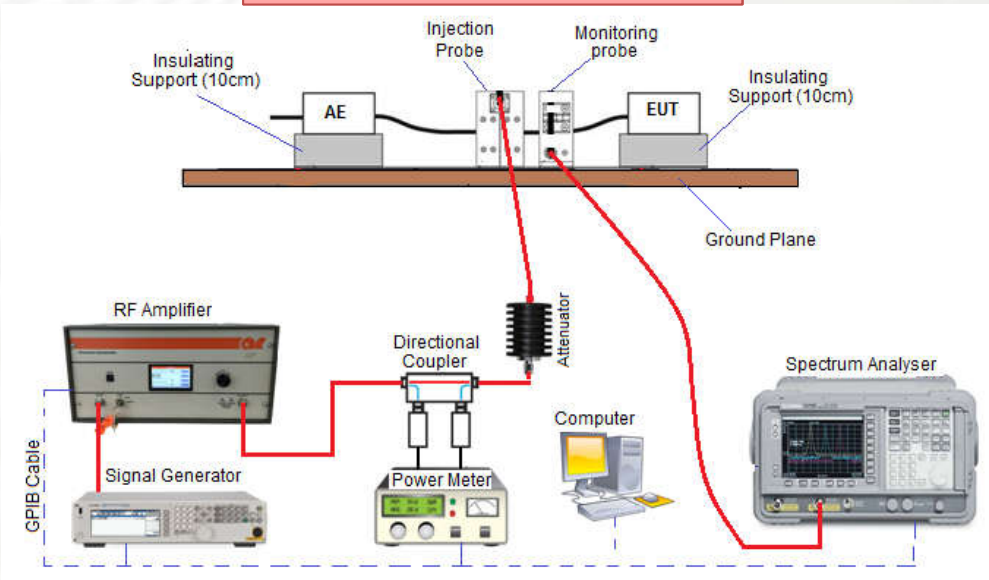
Test Setup for CDN



Test Setup for EM Clamp



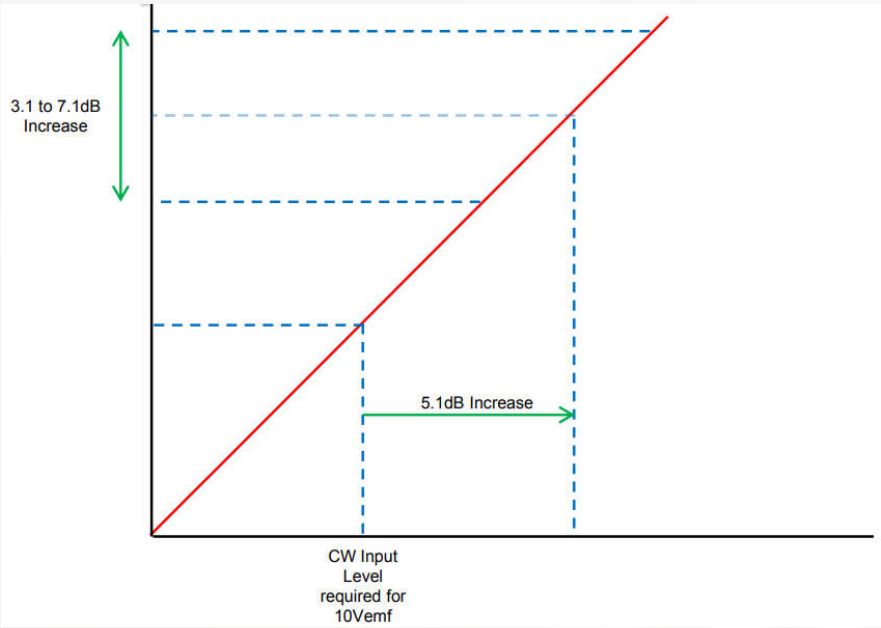
Test Setup for Current Clamp



The current monitoring probe shall be used in between the injection clamp (EM clamp or current clamp) and the EUT, and current shall be monitored. If the current exceeds the nominal circuit value, the test generator level shall be reduced until it reaches max value.

$I_{max} = U_0/150\Omega$

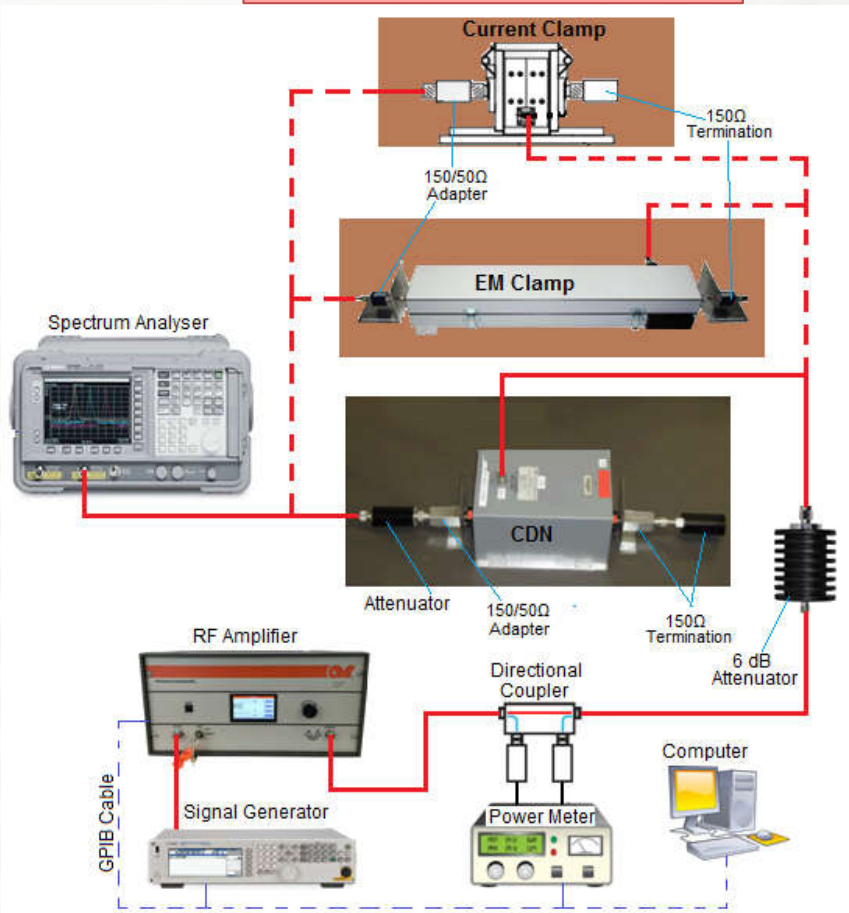
Saturation Measurements



Target (dBµV)	Output of Signal Generator (dBm)	Level of Power Meter (dBm)	Level of EMI Receiver (dBµV)
X (140)	A	B	C
Y (145.6)	D (A+5.6)	E	F
Y – X=5.6	D –A= 5.6 dB	E –B= Δ 3.1<Δ<7.1	F –C= Δ 3.1<Δ<7.1

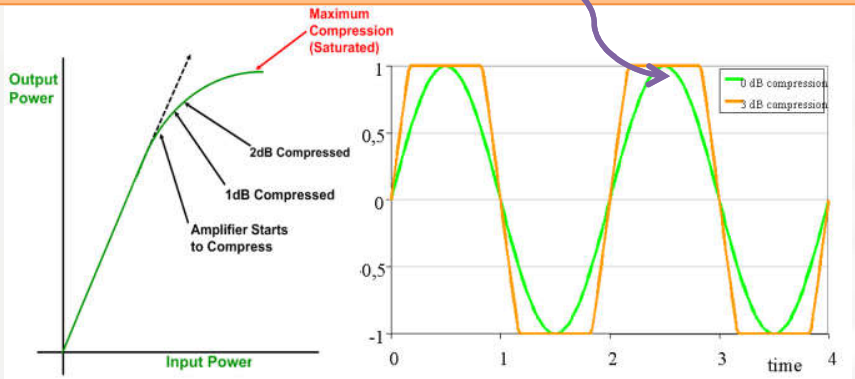
If the difference is between 3,1 dB and 7,1 dB then the amplifier is in tolerance and the test system is sufficient for testing at the selected test level. If the difference is less than 3,1 dB or more than 7,1 dB then the amplifier is non linear and is not suitable for testing.

Linearity Measurement Setup



Harmonic Mesurements

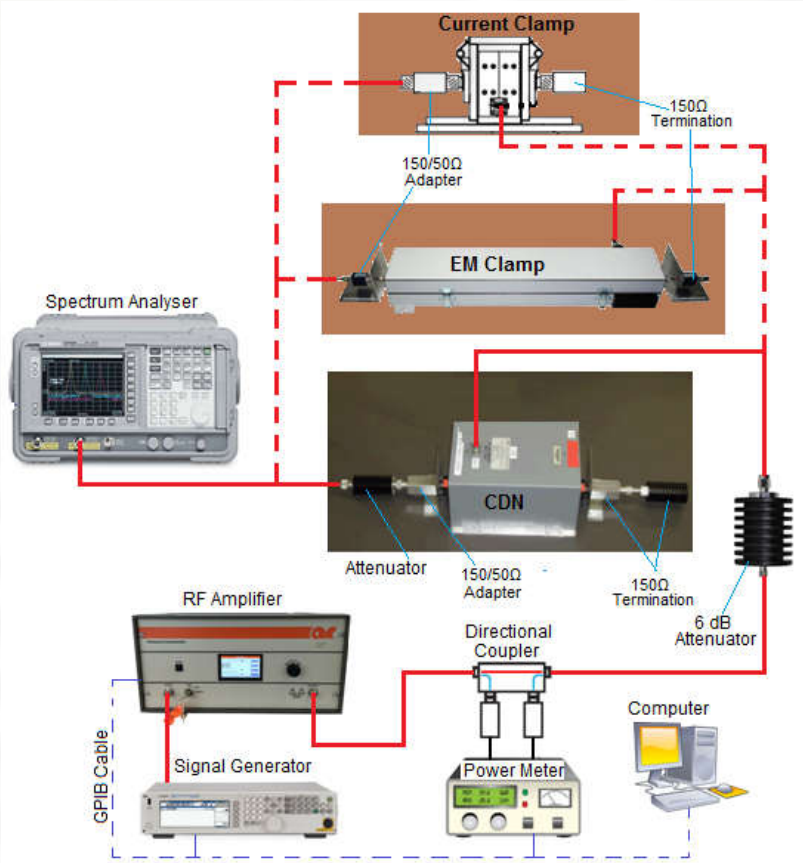
All amplifiers produce the harmonics unwanted frequencies generated by system nonlinearities. The level of these harmonics is dependent on the design and quality of the amplifier and worsens as the amplifier approaches saturation.

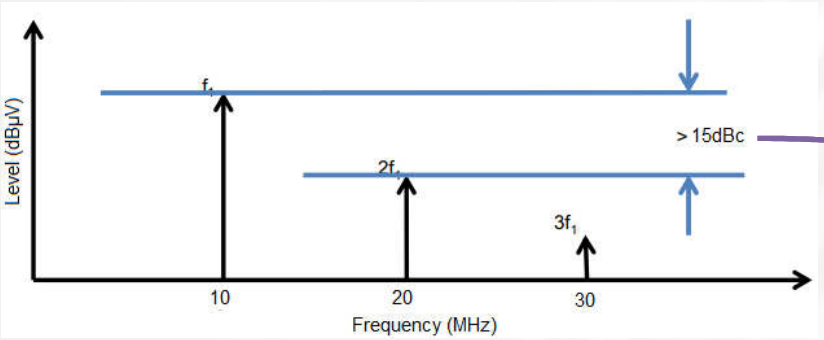


https://www.testforce.com/testforce_files/Seminars/SpirentMedicalSeminar2016/SpirentMedicalSystemsMed.pdf

Harmonics may cause an EUT failure where the EUT is robust at the intended fundamental frequency but not robust at the harmonic frequency. The false failure would be recorded incorrectly and may lead to an incorrect redesign.

Harmonic Measurement Setup

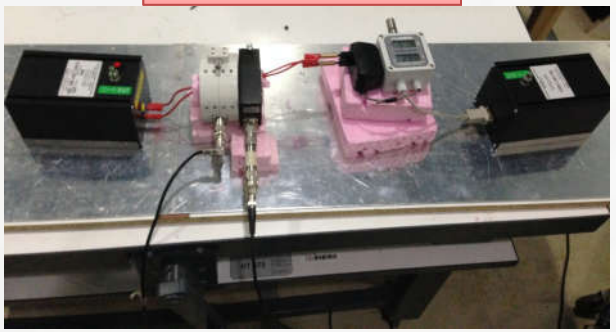




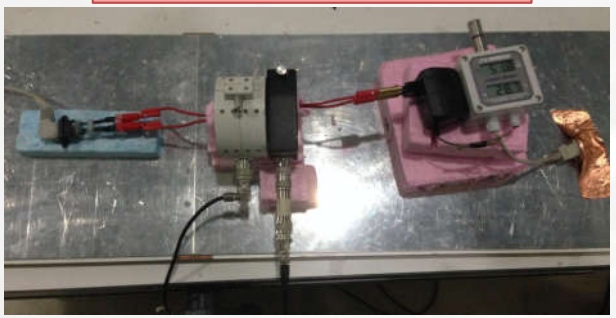
IEC 61000-4-6 requires that within 150 kHz and 80 (230) MHz, any spurious signal shall be at least 15 dB below the carrier level, measured at the EUT port of the coupling device. The harmonics and distortion are measured in continuous wave (CW) at 1,8 times the test level without modulation.

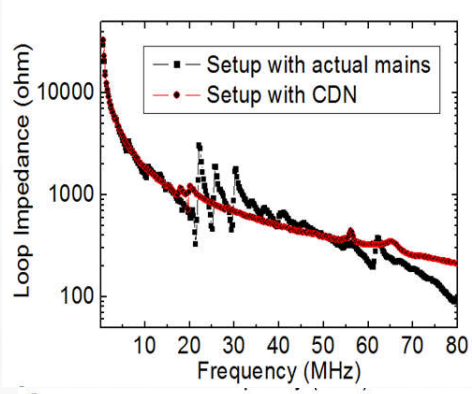
Effect of Common Mode Impedance on Conducted Immunity Testing

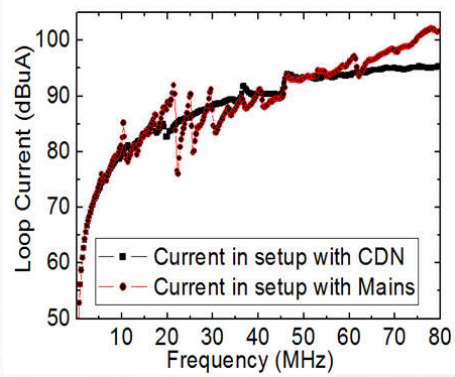
CDN Method

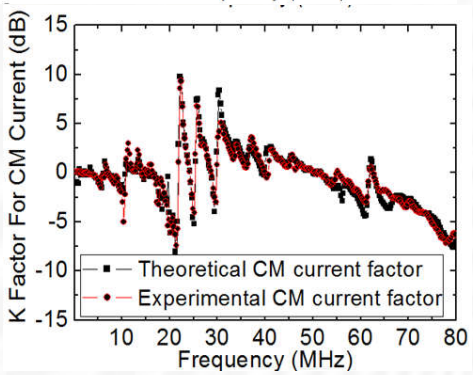


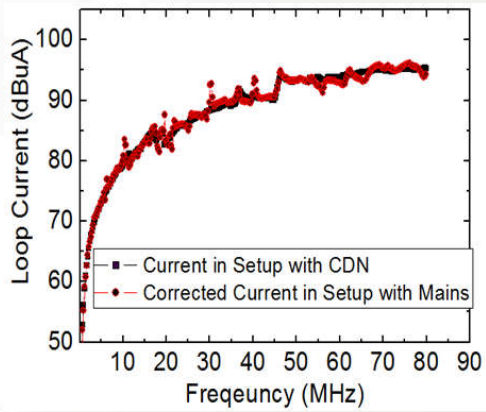
Current Clamp Method

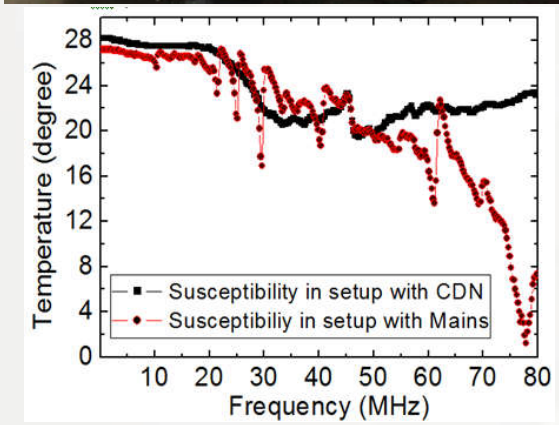


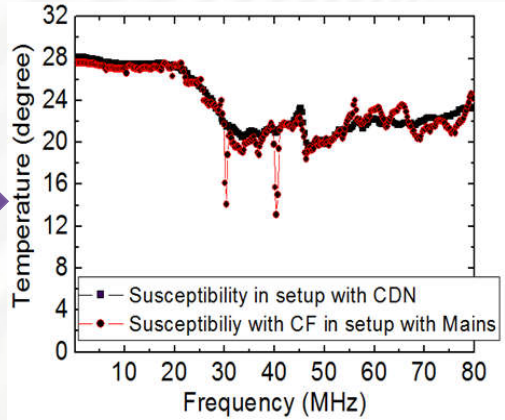






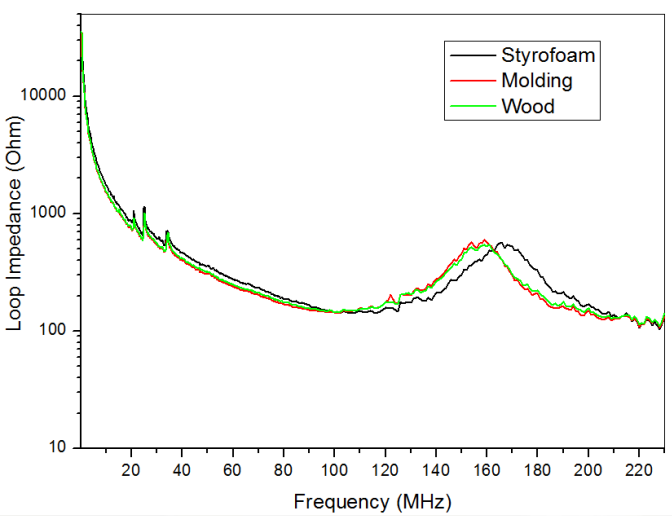


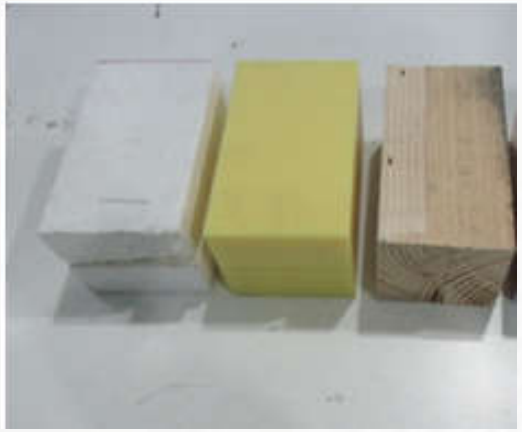


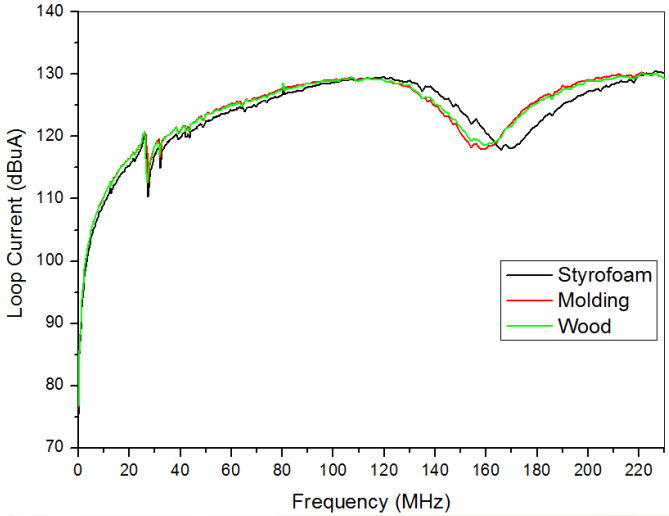


Cakir, S., Sen, O., Acak, S., Azpúrua, M., Silva, F., Cetintas, M. "Alternative Conducted Immunity Tests", IEEE Electromagnetic Compatibility Magazine, 5:3 (2016) : 45-51

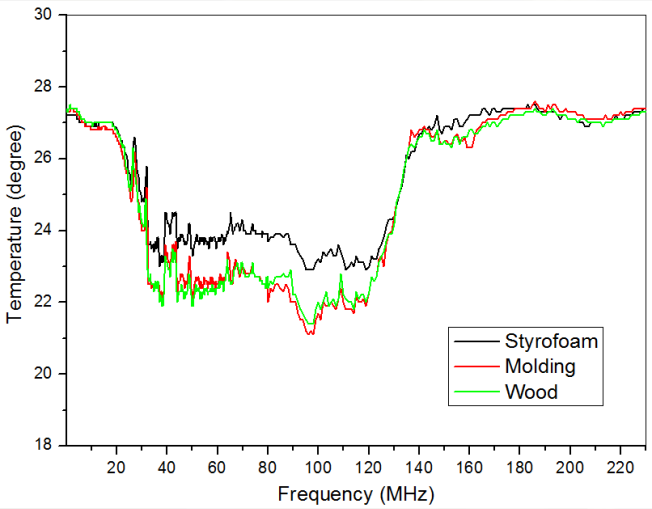
Support Effect on Conducted Immunity Testing

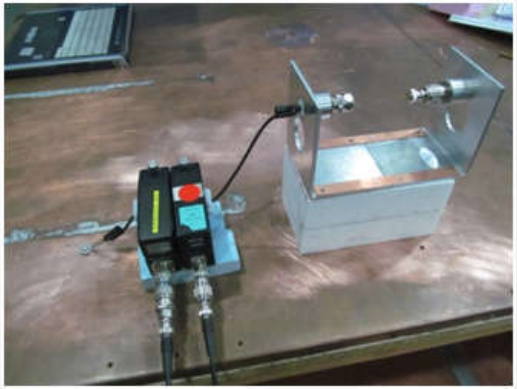






The support to be used at the conducted immunity testing shall be made of the none conductive material with a low permeability.

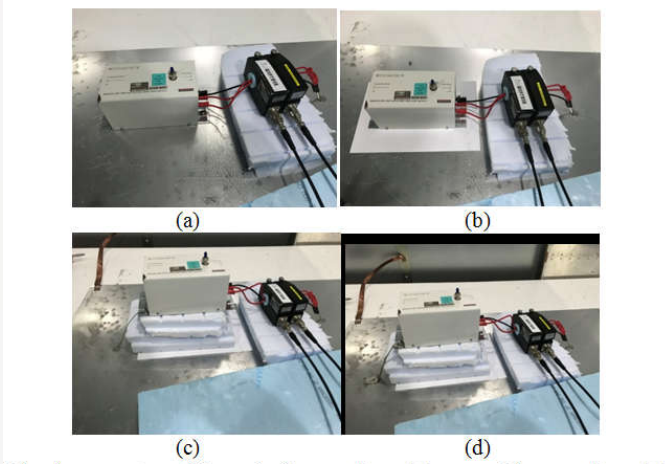




Sen, O., Cakir, S., Acak, S. "More Insight into Conducted Immunity Tests and Investigation of Support Influences", Asia-Pacific International Symposium on Electromagnetic Compatibility (APEMC), Seul (20-23/06/2017) : 3 p.

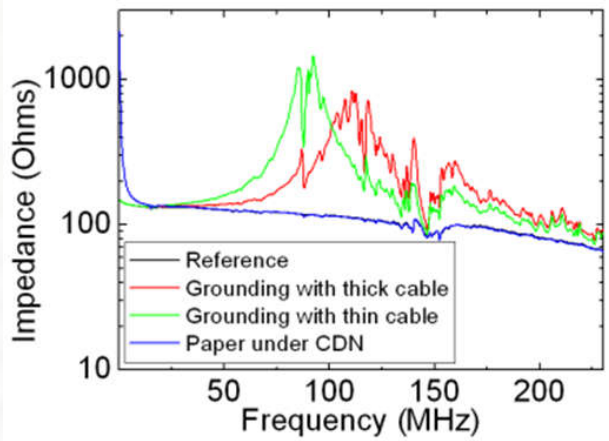
50Ω Load and Grounding Effect on Conducted Immunity Testing

Grounding scenarios setups

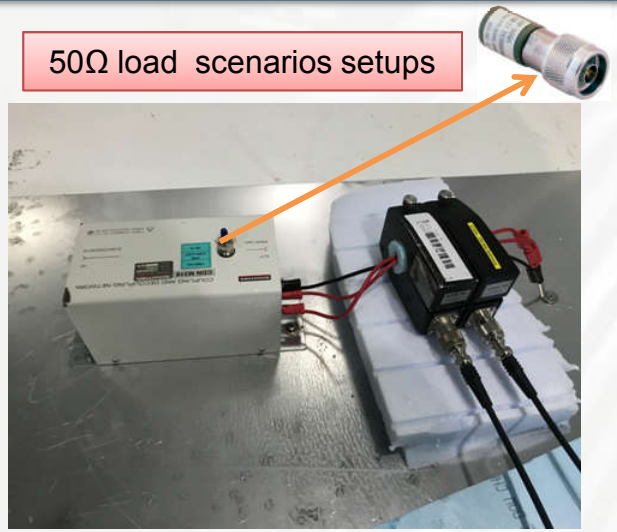


(a) reference setup, (b) very bad grounding with paper, (c) grounding with thin cables, (d) grounding with thick cables

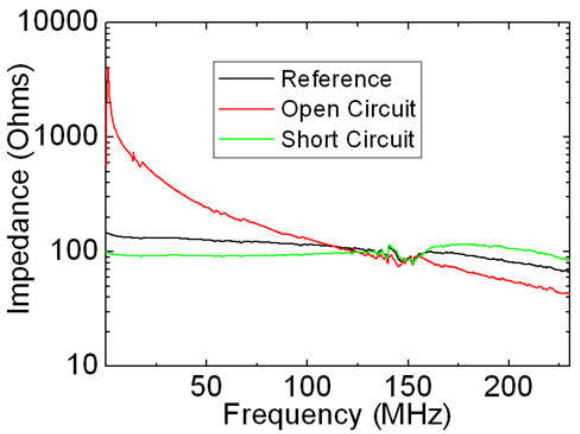
Common Mode Impedance



50Ω load scenarios setups



Common Mode Impedance



Sen, O., Cakir, S. "Improved Just-Before-Test Verification Methods with VNA for Conducted EMC Tests ", IEEE International Symposium on Electromagnetic Compatibility 2018, August:art. no. 8485179 (2018) : 488-493

Magnetic Immunity Testing

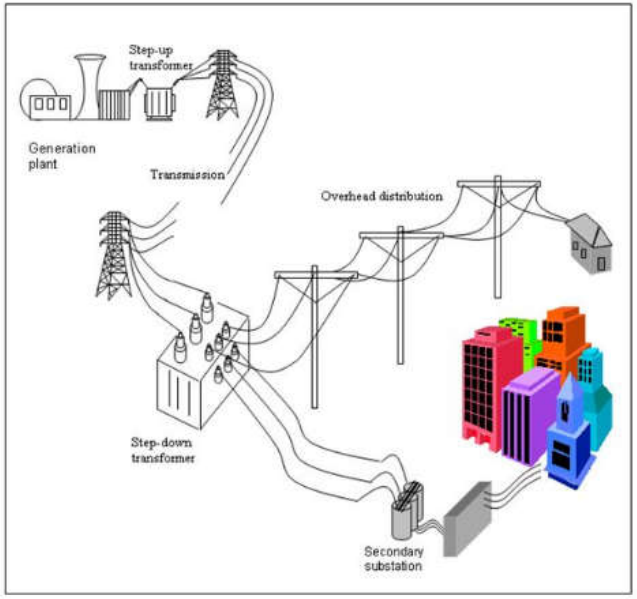
➢Electronic products are often subjected to magnetic fields at AC mains frequencies. These fields are frequently produced in the vicinity of power transformers and can cause problems with video displays, Hall effect sensors, and other electronic products having a sensitivity to magnetic fields

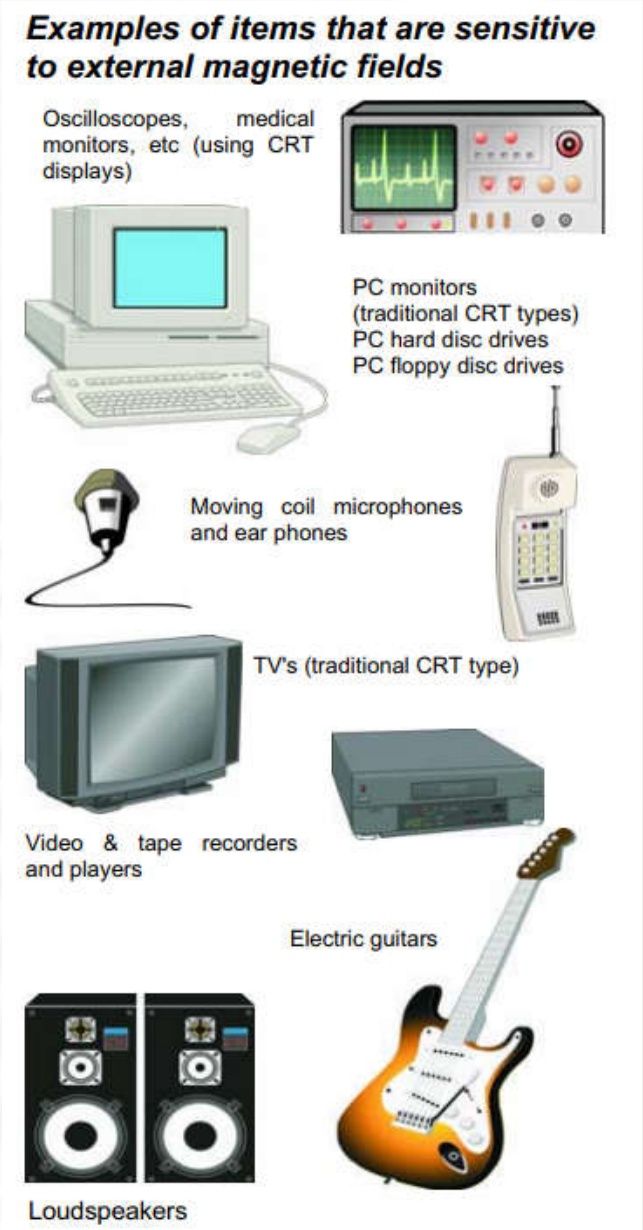
The flow of electrical energy from the generation plant to the customer.

Along the way there are different types of sources of power-frequency magnetic fields

The PFMFs sources and techniques can be classified according to their origin:

- Power lines
- Underground cables
- Complex sources (e.g. substations)





https://emcfastpass.com/wp-content/uploads/2017/04/61000-4-8_guide.pdf

Performing of Magnetic Immunity Testing and Test Levels

➢The purpose of this test is to determine the effects of magnetic fields coming from AC mains frequencies (50Hz or 60Hz) on the EUT.

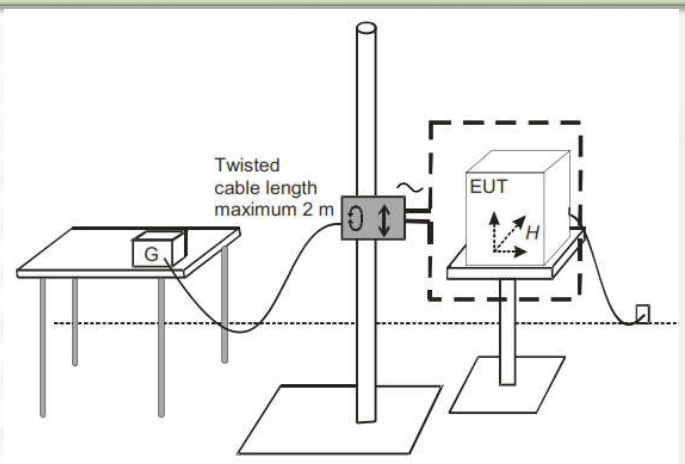
➢ During the the magnetic immunity testing, the EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual when subjected to magnetic fields.

Test Levels for Contionus and Short Duration

Level	Magnetic Field Strength for Continuous Field (A/m)	Magnetic Field Strength for Short Duration:1s to 3 s (A/m)
1	1	n.a.[b]
2	3	n.a.[b]
3	10	n.a.[b]
4	30	300
5	100	1000
x[a]	Special	Special

[a] "x" can be any level, above, below or in between the other levels. This level can be given in the product specification.

[b] "n.a." not applicable



Floor-standing equipment

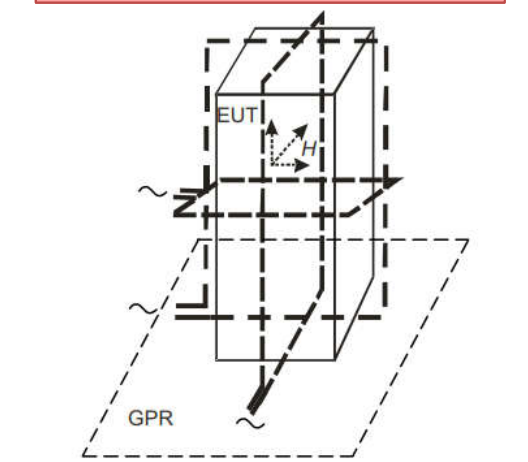
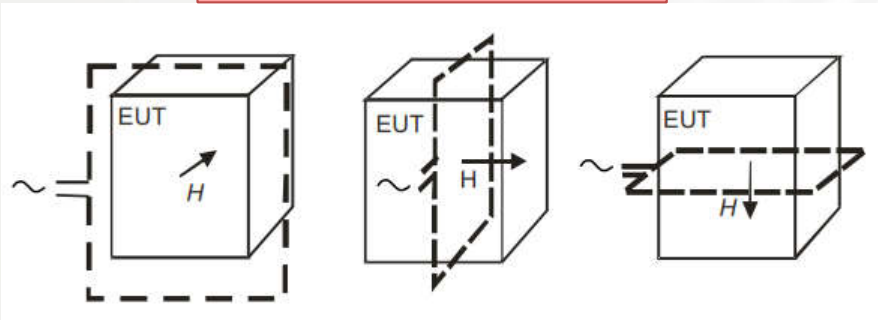
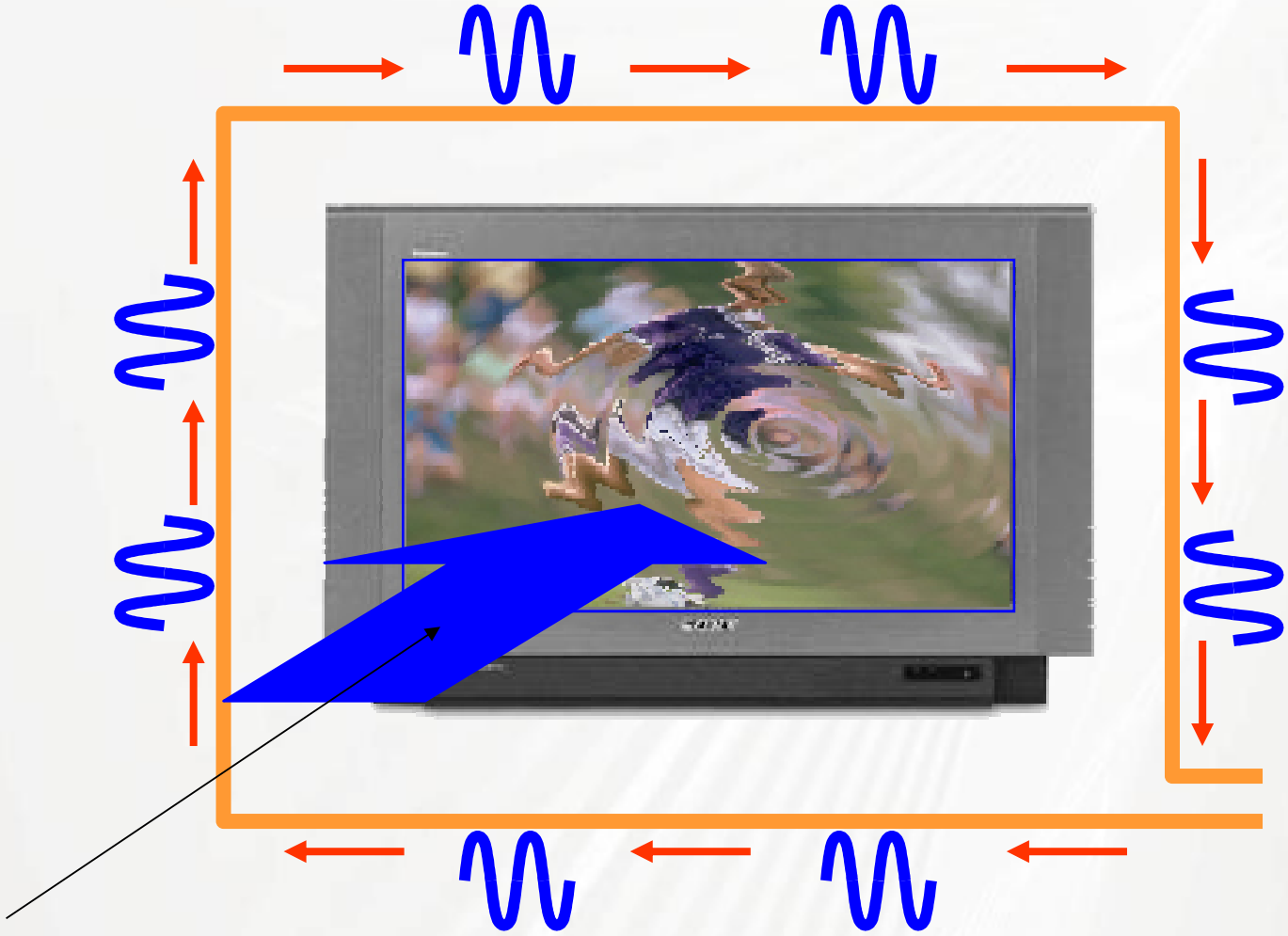


Table-top equipment



Typical Effect of Magnetic Immunity Testing on EUT

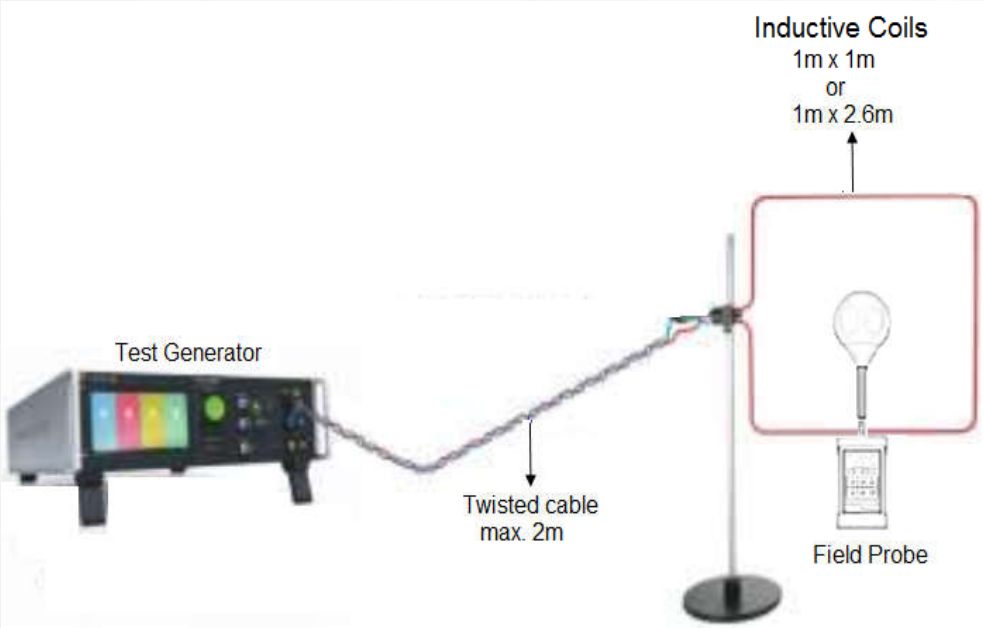


Verification of the Magnetic Immunity Test System

- The purpose of verification is to ensure that the test setup is operating correctly.
- To verify that the system functions correctly, the following equipment should be checked.

* The test generator, the twisted cable and the inductive coil.

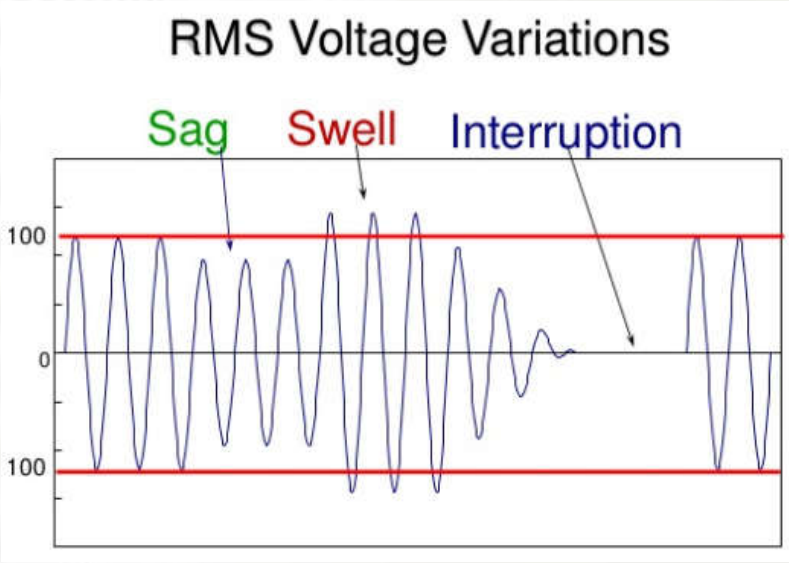
Verification setup for Magnetic Immunity Test System



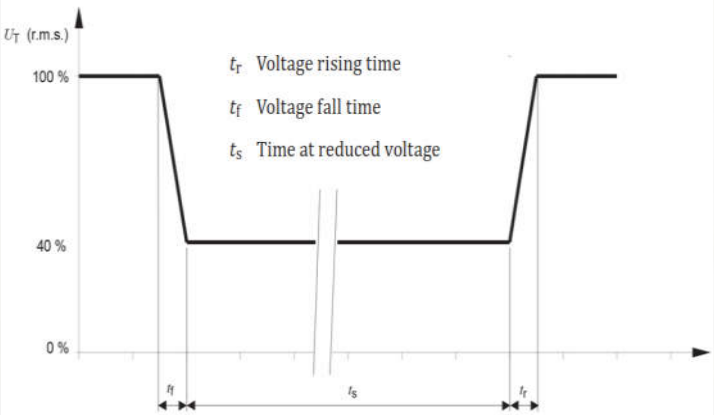
- An appropriate magnetic field sensor shall be used to verify the magnetic field strength generated by the inductive coil.
- Before magnetic immunity testing, the verification setup is established.
- The magnetic field sensor shall be positioned at the centre of the inductive coil (without the EUT) and with suitable orientation to detect the maximum value of the field.
- The test is started as if the magnetic immunity testing was performed.
- The values to be read on the magnetic field sensor shall be a level within ±10% of the target level
- For example, for 10 A/m the magnetic field sensor shall be read values between 9 A/m and 11 A/m. Otherwise, the test is not started before the problem is solved.

Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests

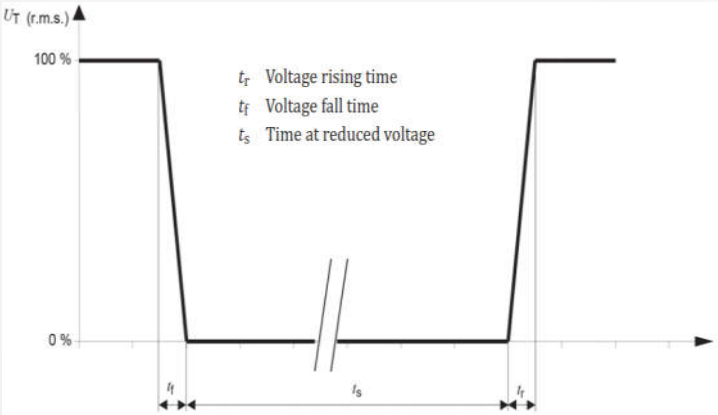
The voltage dips and the short interruptions can be caused by a wide variety of phenomena and can cause equipment to operate unreliability, and in some cases, can damage the equipment. Faulty loads on an adjacent branch circuit, for example, can cause a circuit breaker to trip, and high-power loads such as welders, motors and electric heaters can cause voltage variations. Natural events, such as power lines downed by storms or lightning strikes, may also disrupt mains power.



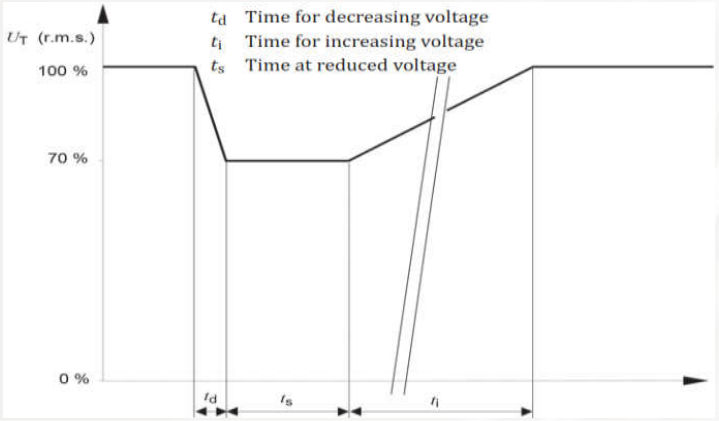
Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests



The voltage dip is a sudden reduction of the supply voltage below a certain voltage level (the dip threshold, the common values are 40 %, 70 % and 80 % of the rated voltage) followed by recovery after a short time interval



The short interruption is a sudden reduction of the supply voltage on all phases below a certain voltage level (the interruption threshold, a common value is 0 % of the rated voltage) followed by restoration after a short interval.



The voltage variations are caused by fault conditions, the energization of large loads which require high starting currents, or intermittent loose connections in power wiring. Depending on the fault location and the system conditions, the fault can cause either temporary voltage drops (sags), voltage rises (swells).

Voltage Dips, Short Interruptions and Voltage Variations Immunity Tests

- The purpose of this test is to determine the effects of voltage dips, short interruptions or voltage variations occuring at the AC power mains (50Hz or 60Hz) on the EUT.
- During the the voltage dips and/or interrupts immunity testing, the EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual when subjected to dips and/or interrupts on the AC power mains.

Preferred test level and durations for voltage dips

Class[a]	Test level and durations for voltage dips (t_s) (50 Hz/60 Hz)				
Class 1	Case-by-case according to the equipment requirements				
Class 2	0 % during ½ cycle	0 % during 1 cycle	70 % during 25/30[c] cycles		
Class 3	0 % during ½ cycle	0 % during 1 cycle	40 % during 10/12[c] cycles	70 % during 25/30[c] cycles	80 % during 250/300[c] cycles
Class X[b]	X	X	X	X	X

[a] Classes as per IEC 61000-2-4; see Annex B.

[b] To be defined by product committee. For equipment connected directly or indirectly to the public network, the levels must not be less severe than Class 2.

[c] "25/30 cycles" means "25 cycles for 50 Hz test" and "30 cycles for 60 Hz test".

Preferred test level and durations for short interruptions

Class[a]	Test level and durations for short interruptions (t_s) (50 Hz/60 Hz)
Class 1	Case-by-case according to the equipment requirements
Class 2	0 % during 250/300[c] cycles
Class 3	0 % during 250/300[c] cycles
Class X[b]	X

[a] Classes as per IEC 61000-2-4; see Annex B.

[b] To be defined by product committee. For equipment connected directly or indirectly to the public network, the levels must not be less severe than Class 2.

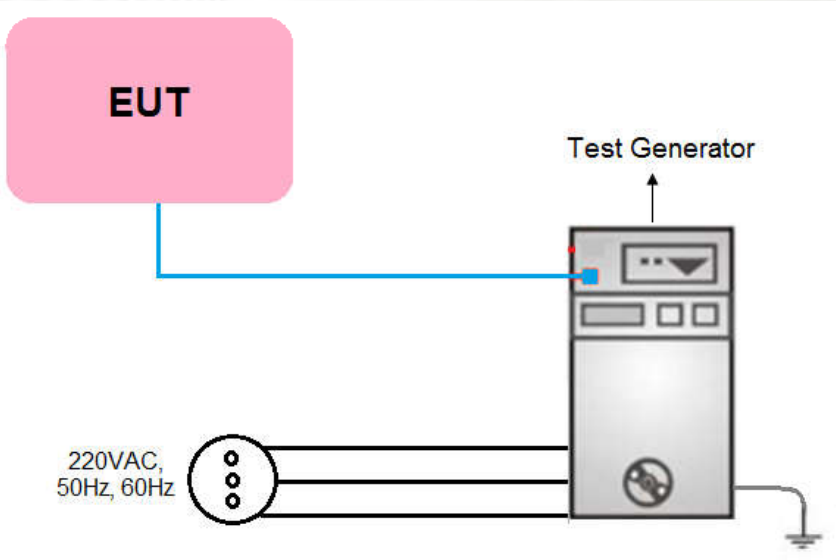
[c] "250/300 cycles" means "250 cycles for 50 Hz test" and "300 cycles for 60 Hz test".

Timing of short-term supply voltage variations

Voltage test level	Time for decreasing voltage (t_d)	Time at reduced voltage(t_s)	Time for increasing voltage (t_i) (50 Hz/60 Hz)
70 %	Abrupt	1 cycle	25/30[b] cycles
X[a]	X[a]	X[a]	X[a]

[a] To be defined by product committee.

[b] "25/30 cycles" means "25 cycles for 50 Hz test" and "30 cycles for 60 Hz test".

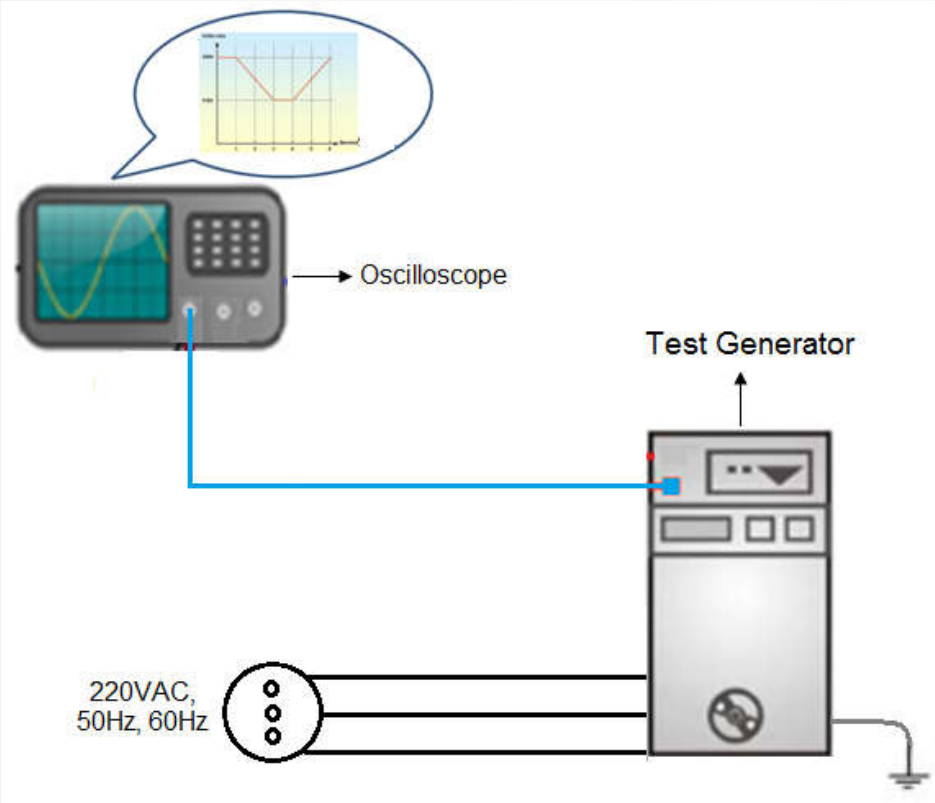


Verification of the Test System

- The purpose of verification is to ensure that the test setup is operating correctly.
- To verify that the system functions correctly, the following equipment should be checked.

* The test generator

Verification Setup for Voltage Dips, Short Interruptions and Voltage Variations Immunity Test System



- Before voltage dips, short interruptions and voltage variations immunity testing, the verification setup is established.
- Any channel of the oscilloscope is connected to L – N ports of the test genetaor.
- The test is started as if the voltage dips, short interruptions and voltage variations immunity testing was performed.
- The values (voltage and time parameters) to be read on the oscilloscope shall be a level within ±10% of the target level
- Otherwise, the test is not started before the problem is solved.

Thank you for Your Attention

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