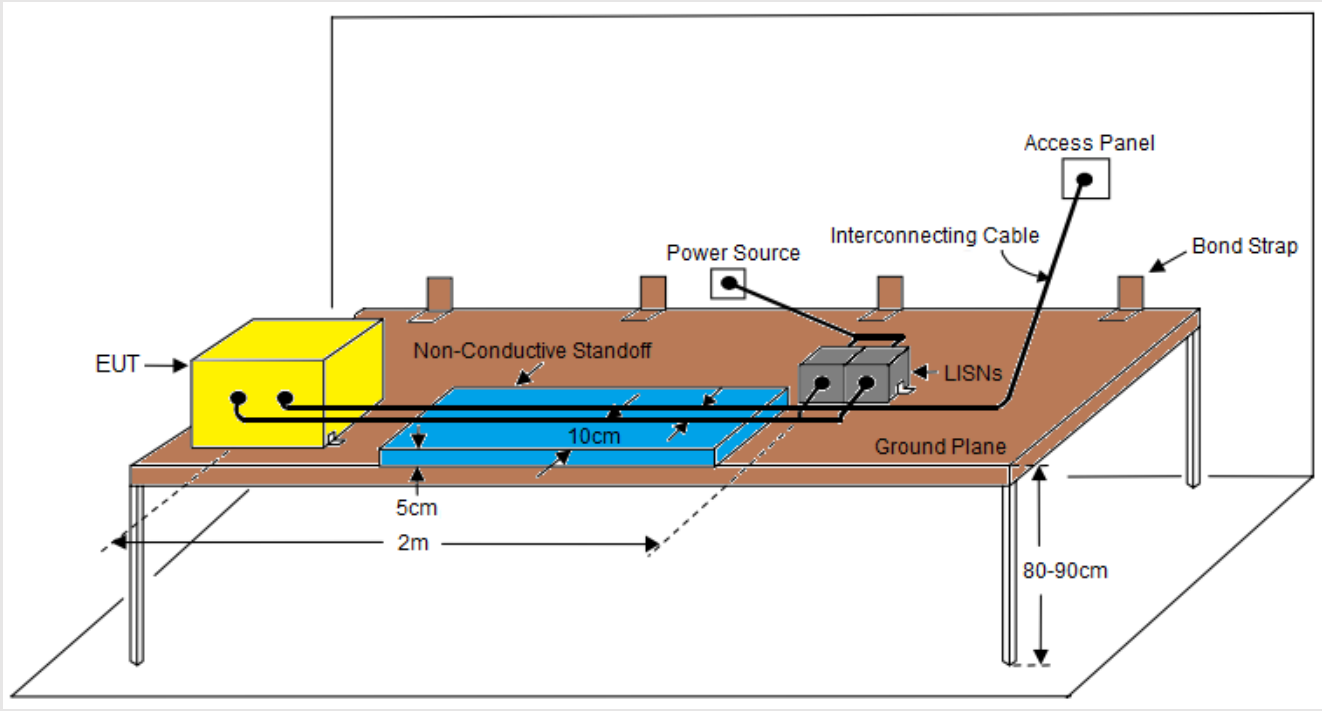
Military Conducted Emission Tests: CE101, CE102

Osman ŞEN

05 September 2019
Barcelona, Spain

MIL STD 461F General Test Setup I

MIL-STD-461 is the standard that defines the test limits, test levels, and test procedure for various electromagnetic phenomena for electronic equipment used for military purpose (Army, Navy, and Air Force on all platforms).



- Unless otherwise specified, the EUT shall be installed on a ground plane that simulates the actual installation.
- If the actual installation is unknown or multiple installation are expected, then a metallic ground plane shall be used.
- When a ground plane is not present in the EUT installation, the EUT shall be placed on a non-conductive table.

The EUT should be tested in all possible operating modes, but at a minimum shall be tested under following conditions.

- Operating modes which will produce maximum emissions shall be chosen for RE and CE tests.

During the emission testing,

- Measures the electromagnetic energy emitted from the EUT enclosure and interconnecting cabling.
- Validates that the EUT will not cause operational problems in other subsystems or equipment while performing its intended functions.

TÜBİTAK UME

MIL STD 461F General Test Setup II

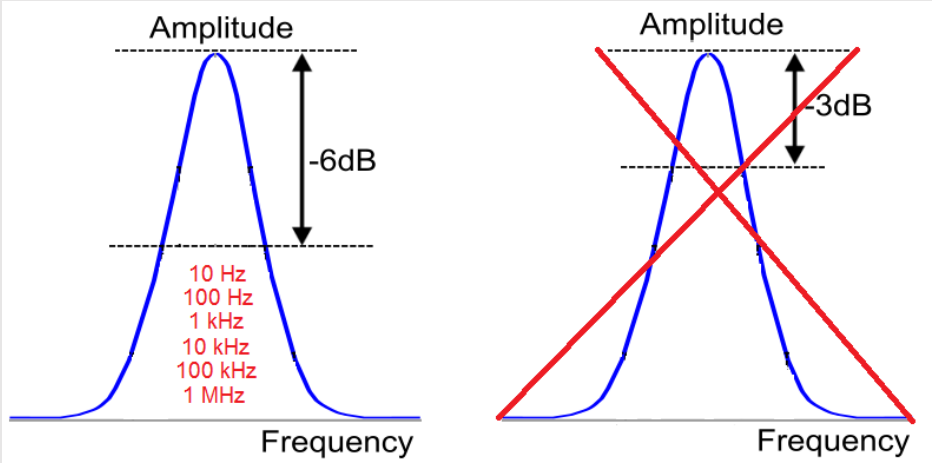
EUTs shall be operated in modes that will draw maximum current or voltage in order to determined maximum emission levels.

All EUT electrical interfaces shall be terminated with either the actual equipment from the platform installation or representative loads which simulate the electrical properties

A peak detector shall be used for all frequency domain emission and susceptibility measurements.

The measurement receiver bandwidths listed in Table given below shall be used for emission testing. These bandwidths are specified at the 6 dB down points for the overall selectivity curve of the receivers. Video filtering shall not be used to bandwidth limit the receiver response.

Frequency Range	6 dB Bandwidth	Dwell Time	Minimum Measurement Time Analog Measurement Receiver
30 Hz – 1 kHz	10 Hz	0.15 sec	0.015 sec/Hz
1 kHz – 10 kHz	100 Hz	0.015 sec	0.15 sec/kHz
10 kHz – 150 kHz	1 kHz	0.015 sec	0.015 sec/kHz
150 kHz – 30 MHz	10 kHz	0.015 sec	1.5 sec/MHz
30 MHz – 1 GHz	100 kHz	0.015 sec	0.15 sec/MHz
1 GHz – 18 GHz	1 MHz	0.015 sec	15 sec/GHz



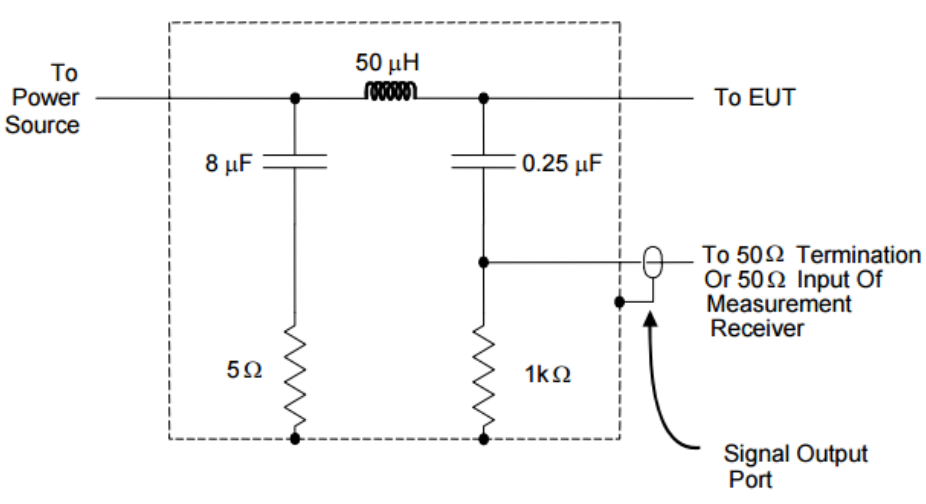
TÜBİTAK UME

Purposes of Use of LISN

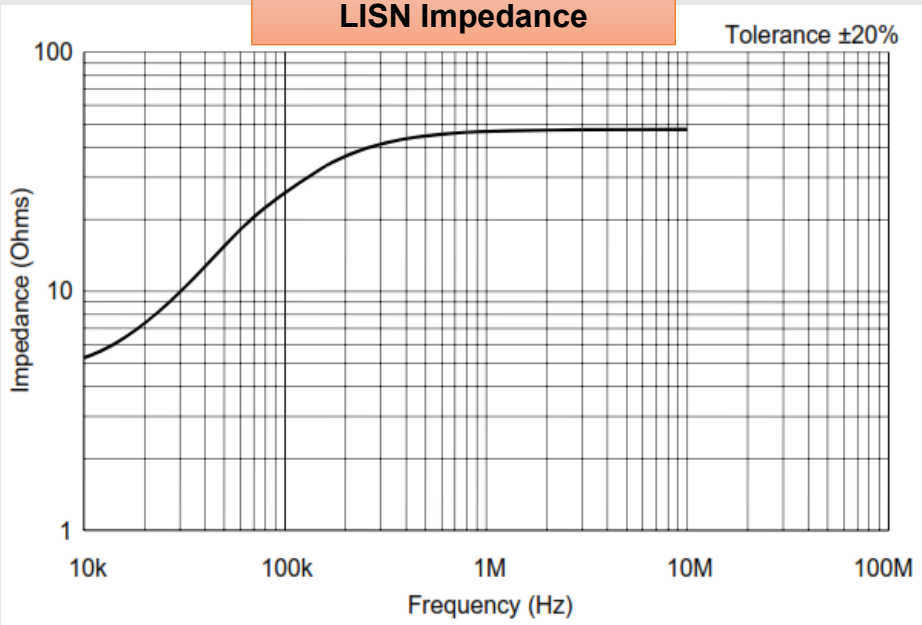
The impedance of power sources providing input power to the EUT shall be controlled by Line Impedance Stabilization Networks (LISNs) for all tests unless otherwise stated in a particular test procedure.

- 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 to measure the conducted emission test and to provide a measurement port to determine the conducted emission levels.

Schematic of LISN circuit



LISN Impedance



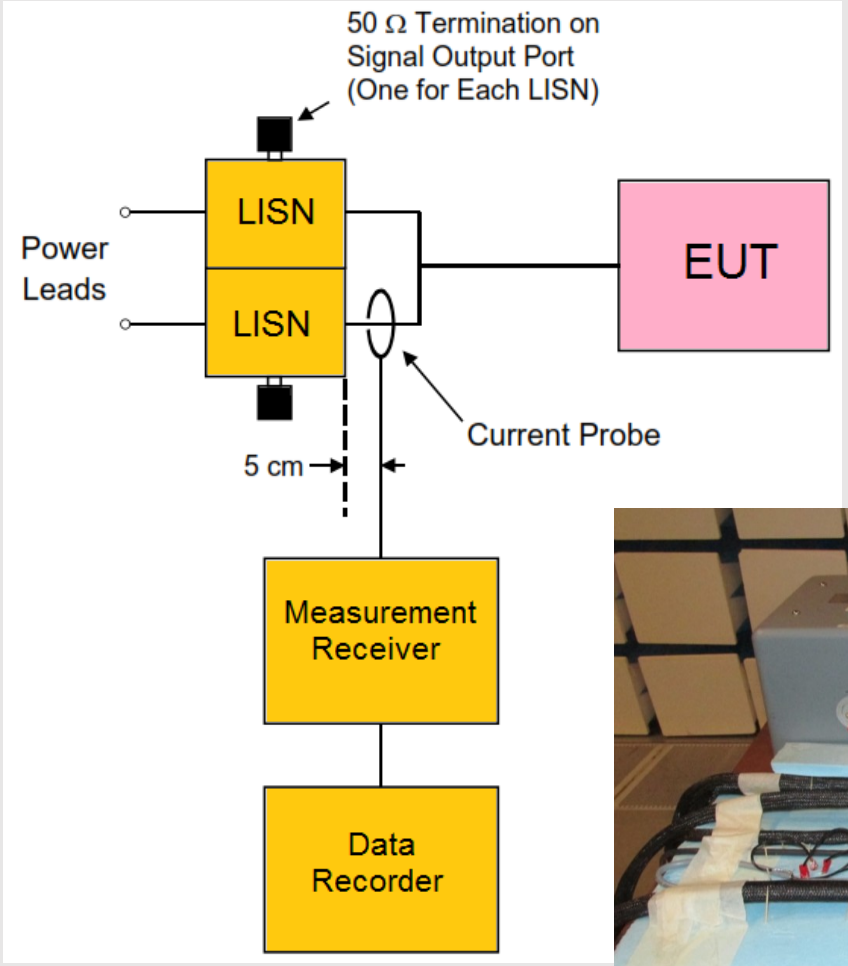
CE101 Test Method

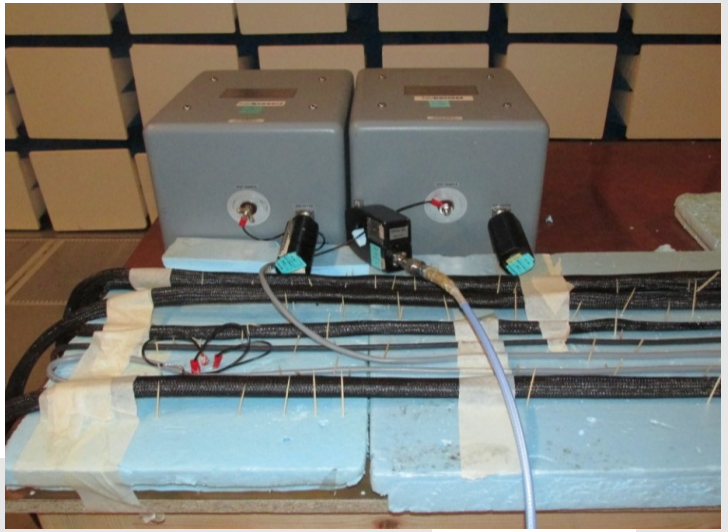
CE101 testing is performed to verify that electromagnetic emissions from the EUT with AC or DC power inputs do not exceed the specified requirements for power input leads including returns.

This test is applicable in the frequency range 30 Hz – 10 kHz (AC start frequency second harmonic of the supply frequency of the EUT)

CE101 testing is a low frequency current (dBμA) measurement test. The emission levels are determined by measuring the current present on each power lead. The limits are based on the current or the source voltage of the EUT.

The Pass/Fail ciriterion depends on for the EUT specified limit.

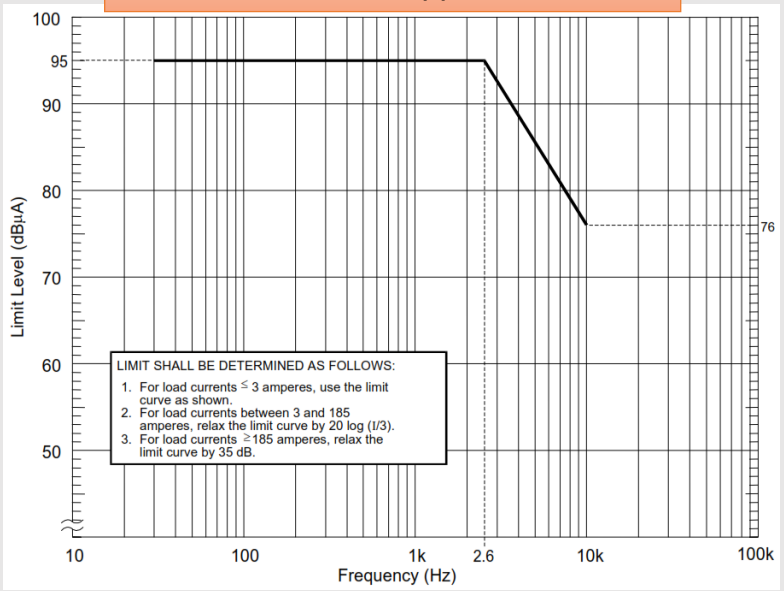




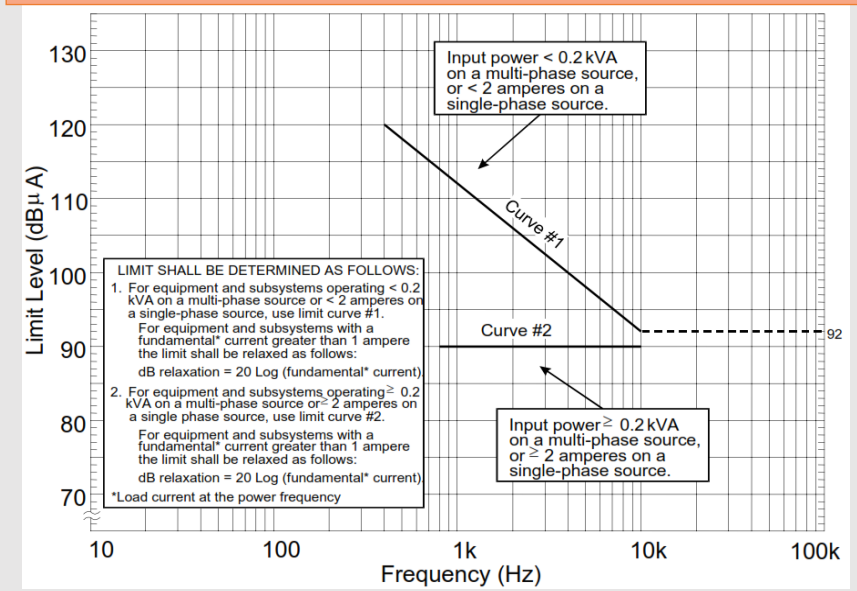
UME

CE101 Test Limits

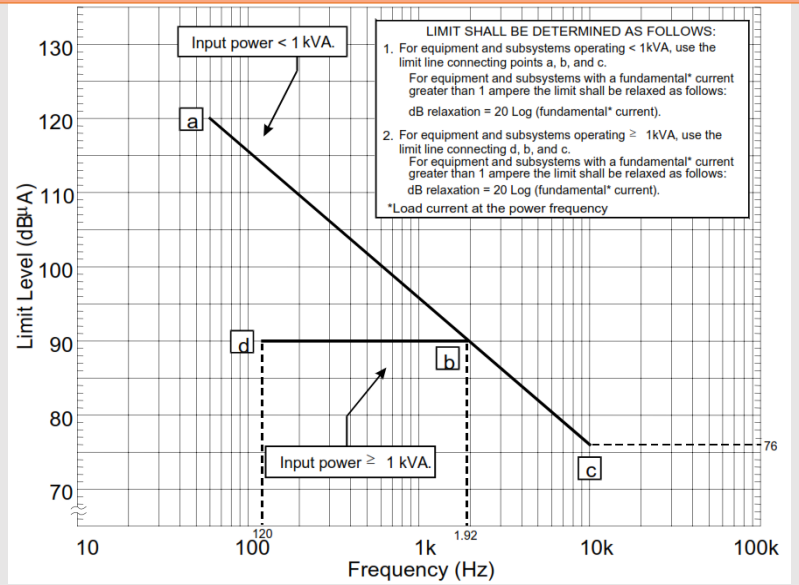
Limit for submarine applications, DC.



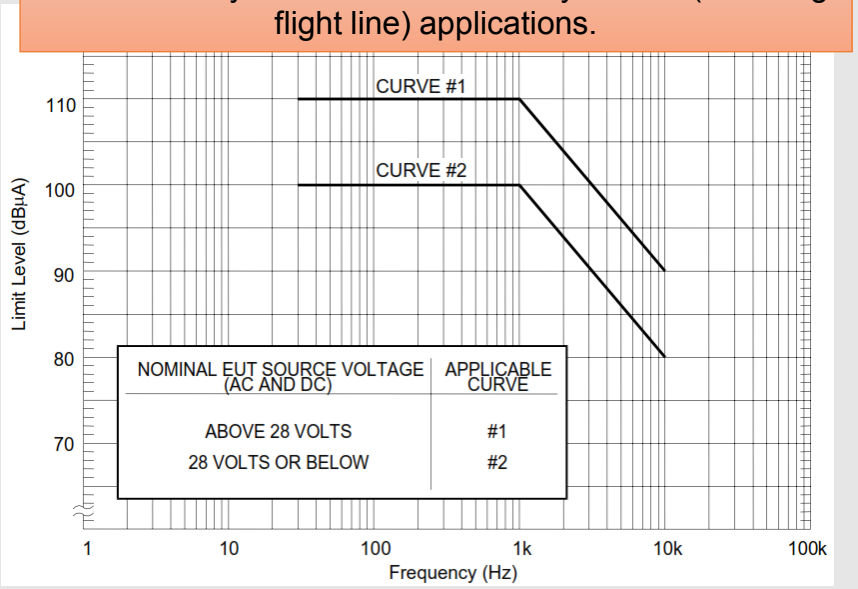
Limit for surface ships and submarine applications, 400 Hz.



Limit for surface ships and submarine applications, 60 Hz.



Llimit for Navy ASW aircraft and Army aircraft (including flight line) applications.



Verification of CE101 Test System

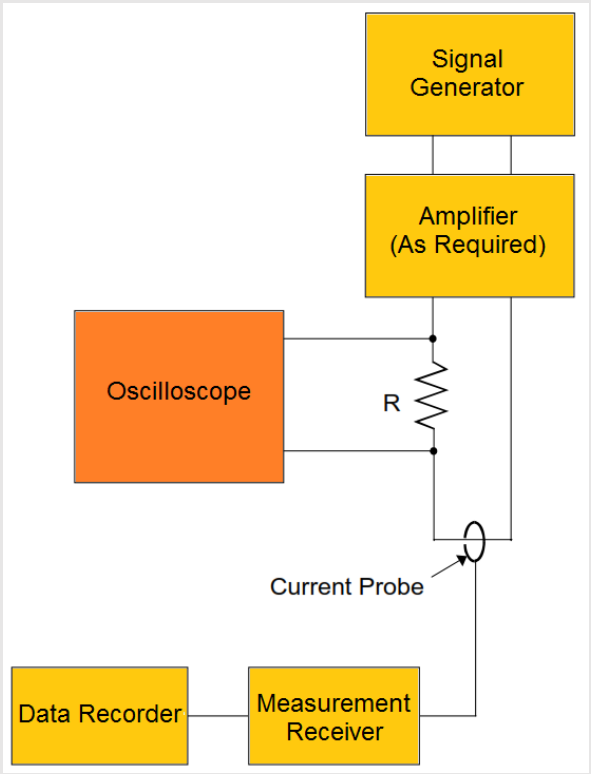
Before CE101 testing, test laboratory must perform verifications to ensure the quality and precision of test results by means of verification as the verification can detect errors beforehand in the test setup and prevent wrong testing.

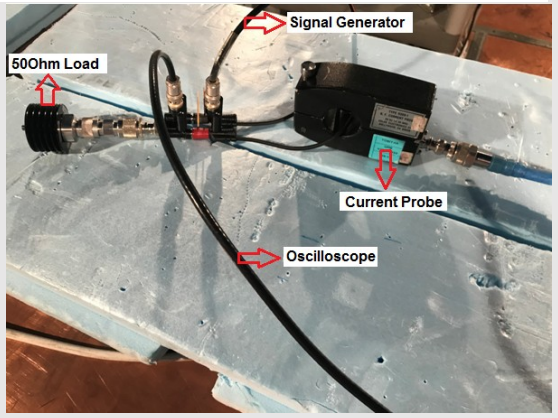
Apply a calibrated signal level, which is at least 6 dB below the applicable limit at 1 kHz, 3 kHz, and 10 kHz, to the current probe.

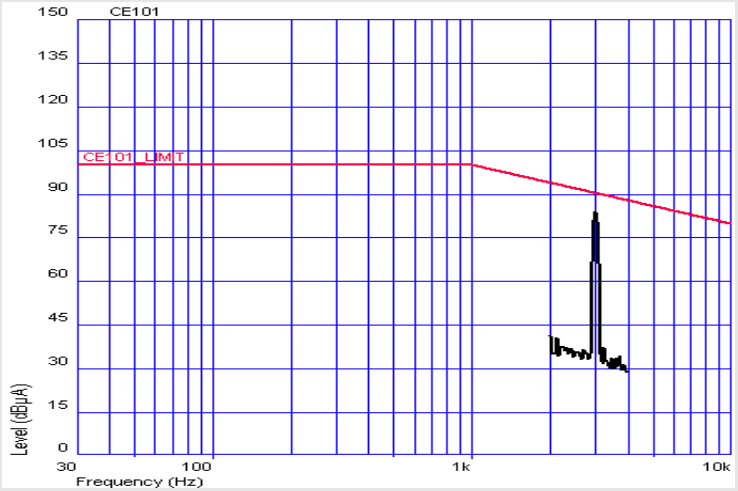
Verify the current level, using the oscilloscope and load resistor; also, verify that the current waveform is sinusoidal.

Scan the measurement receiver for each frequency in the same manner as a normal data scan. Verify that the data recording device indicates 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.







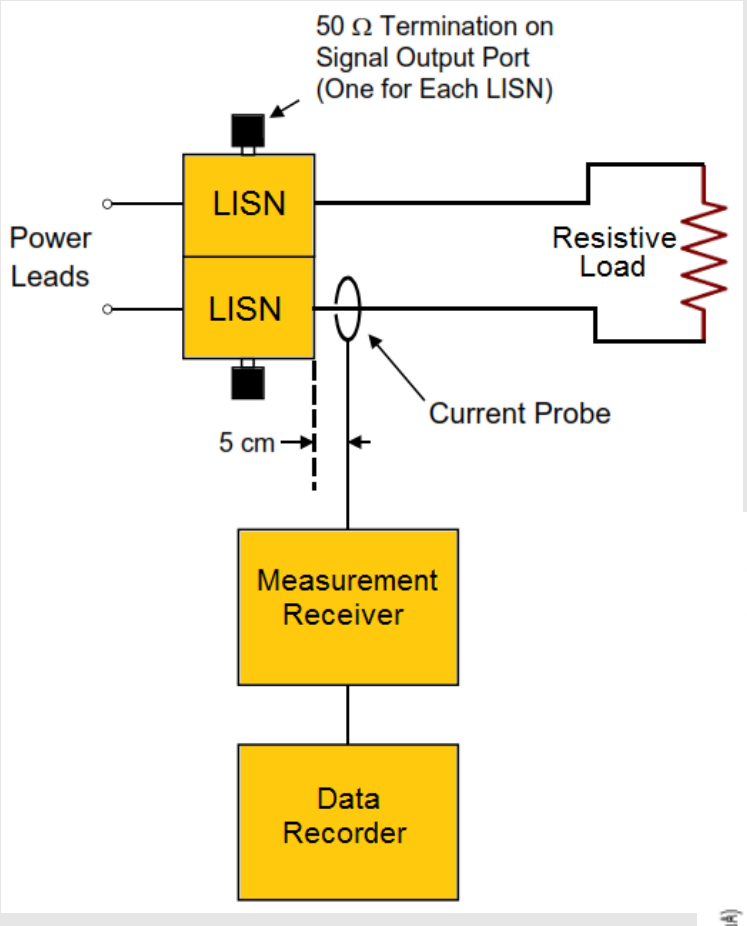
Frequency (kHz)	Expected level (dBµA)	Measurement level (dBµA)	Difference (dB)	Limit (dB)	Result
1	94	95,01	-1,01	± 3	Pass
3	84	84,03	-0,03	± 3	Pass
10	74	74,43	-0,43	± 3	Pass

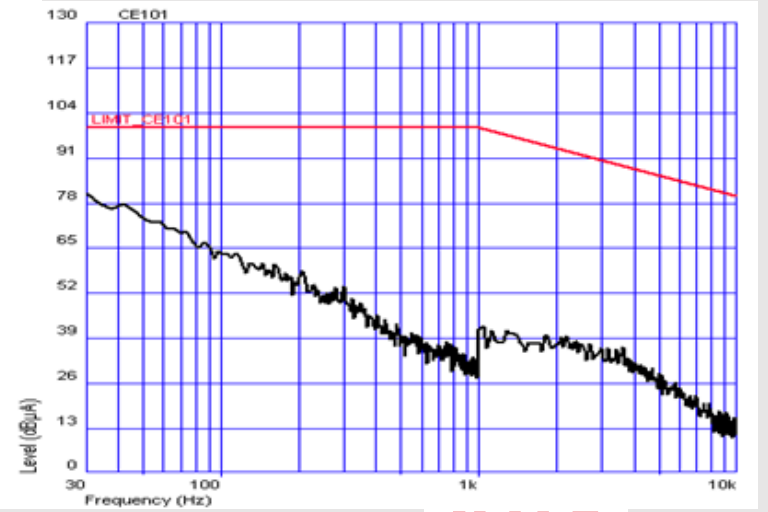
TÜBİTAK UME

Background Noise (BN) Measurement for CE101 Testing

Before the CE101 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.





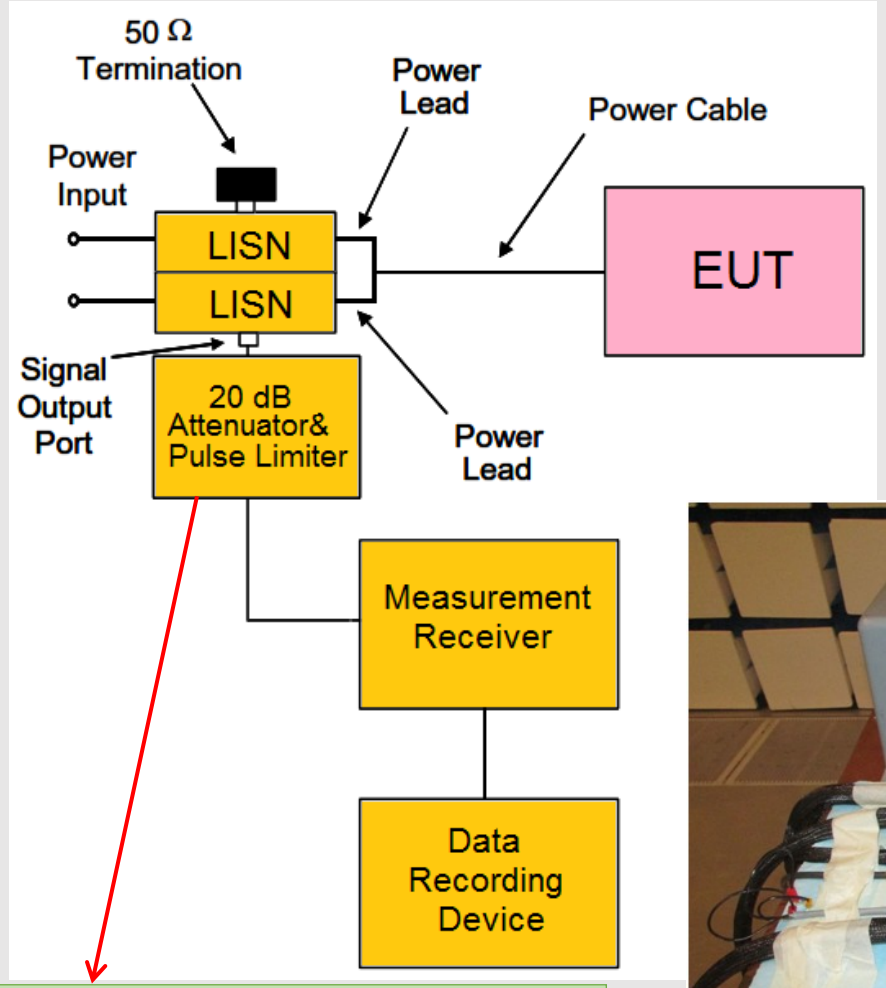
CE102 Test Method

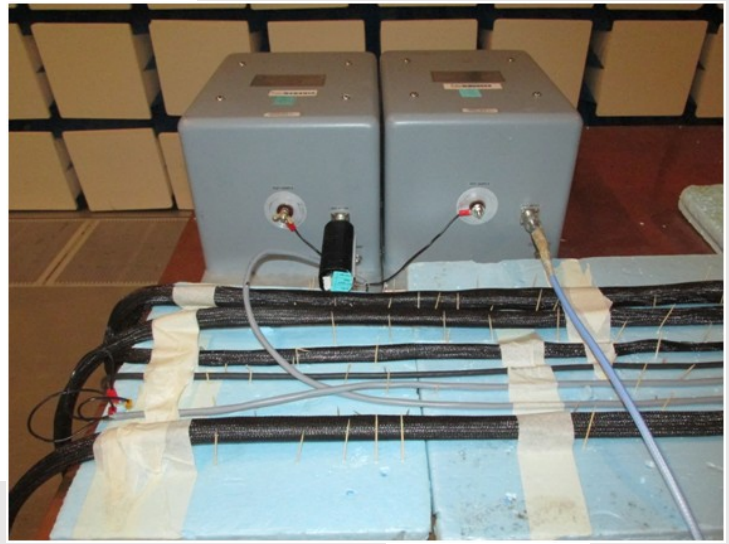
CE102 testing is performed to verify that electromagnetic emissions from the EUT with AC or DC power inputs do not exceed the specified requirements for power input leads including returns.

This test is applicable in the frequency range 10 kHz – 10 MHz.

CE102 testing is a medium frequency voltage (dBµV) measurement test. The emission levels are determined by measuring the voltage present at the output port of the LISN. The limits are based on the source voltage of the EUT.

The Pass/Fail ciriterion depends on for the EUT specified limit.



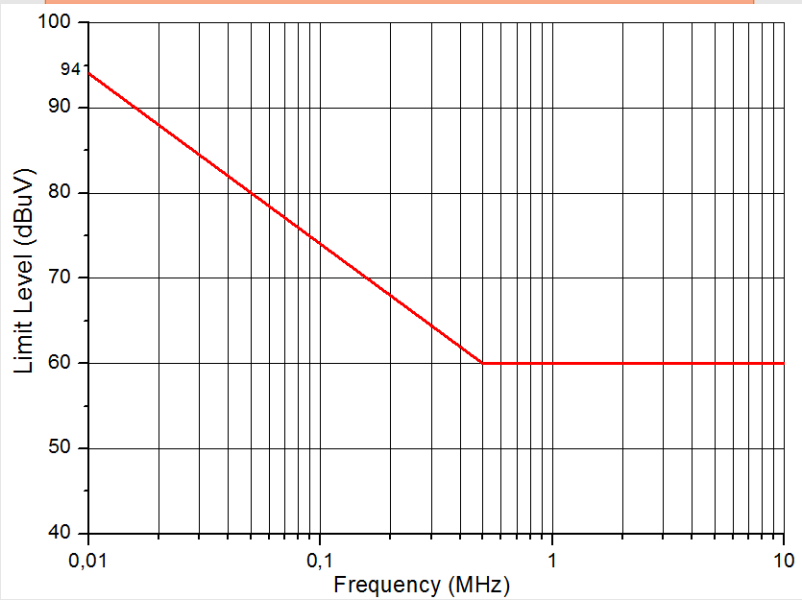


The 20 dB attenuator & the pulse limiter is essential for protecting the EMI receiver, and also providing a better impedance match between the signal output of the LISN and the input of the EMI receiver.

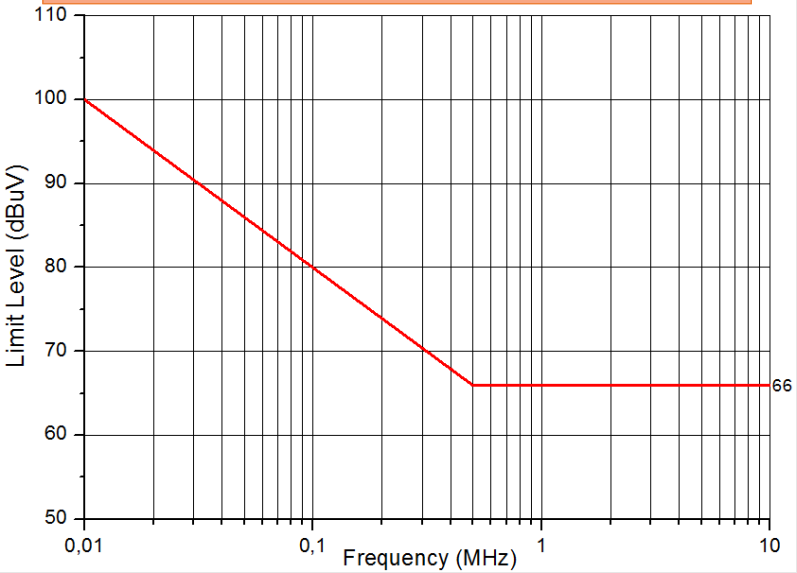
UME

CE102 Test Limits

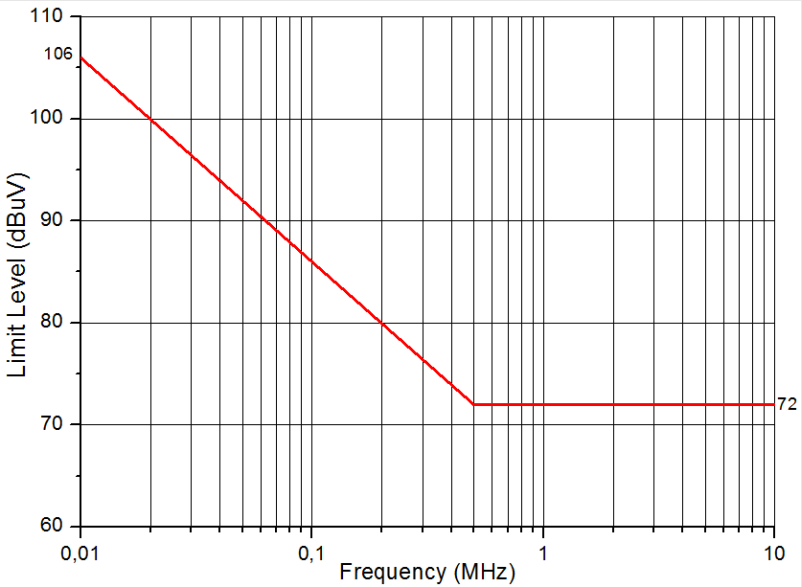
Limit for EUT with a supply voltage of 28V



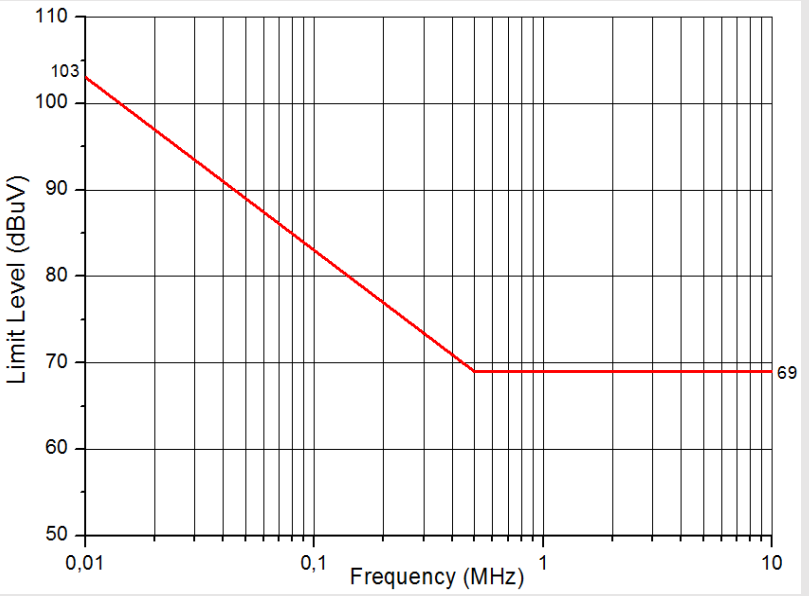
Limit for EUT with a supply voltage of 115V



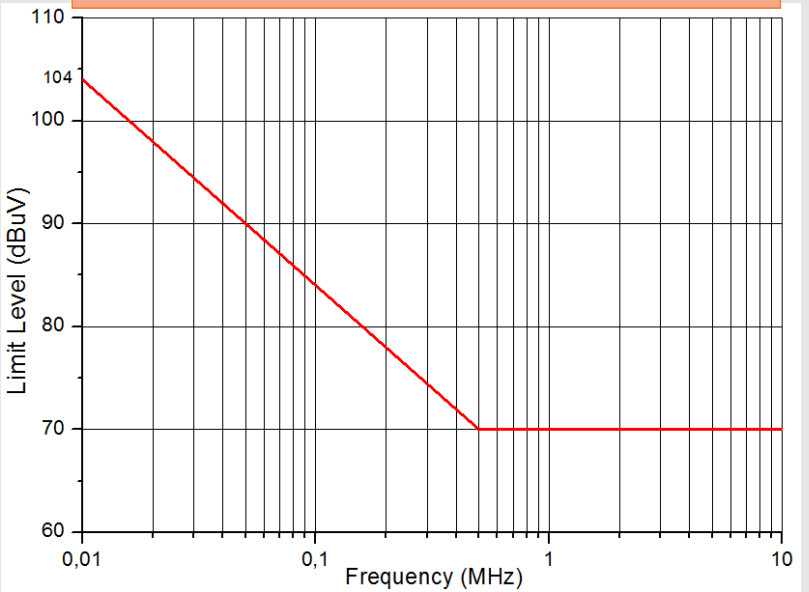
Limit for EUT with a supply voltage of 440V



Limit for EUT with a supply voltage of 220V



Limit for EUT with a supply voltage of 270V



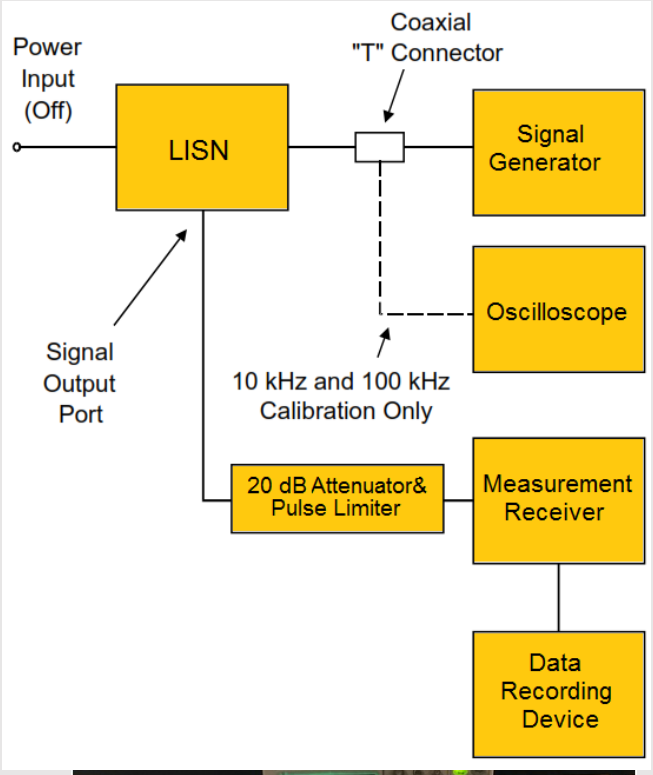
Verification of CE102 Test System

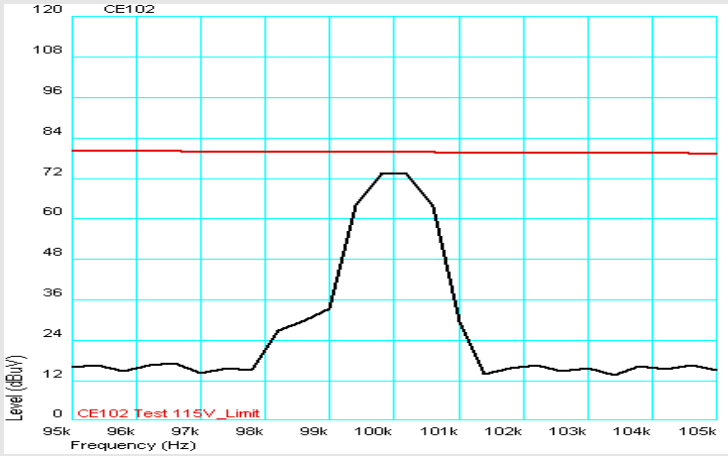
Before CE102 testing, test laboratory must perform verifications to ensure the quality and precision of test results by means of verification as the verification can detect errors beforehand in the test setup and prevent wrong testing.

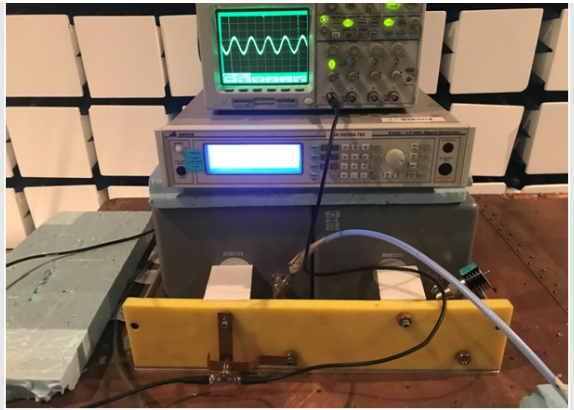
Apply a signal level that is at least 6 dB below the limit at 10 kHz, 100 kHz, 2 MHz and 10 MHz to the power output terminal of the LISN. At 10 kHz and 100 kHz, use an oscilloscope to calibrate the signal level and verify that it is sinusoidal. At 2 MHz and 10 MHz, use a calibrated output level directly from a 50Ω signal generator.

Scan the measurement receiver for each frequency in the same manner as a normal data scan. Verify that the data recording device (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.







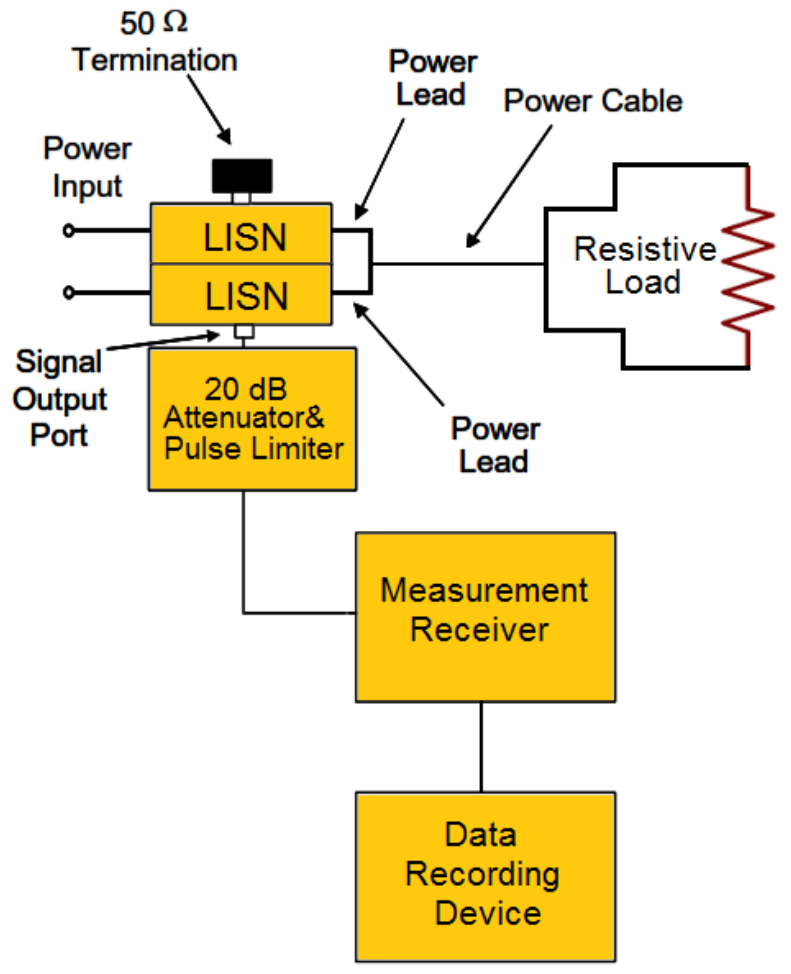
Measured line	Frequency (MHz)	Expected level (dBµV)	Measurement level (dBµV)	Difference (dB)	Limit (dB)	Result
Phase Line	0,01	94,0	94,2	0,2	± 3	Pass
Phase Line	0,1	74,0	74,7	0,7	± 3	Pass
Phase Line	2	60,0	59,9	- 0,1	± 3	Pass
Phase Line	10	60,0	59,2	- 0,8	± 3	Pass
Neutral Line	0,01	94,0	93,1	- 0,9	± 3	Pass
Neutral Line	0,1	74,0	73,6	- 0,4	± 3	Pass
Neutral Line	2	60,0	59,7	- 0,3	± 3	Pass
Neutral Line	10	60,0	59,1	- 0,9	± 3	Pass

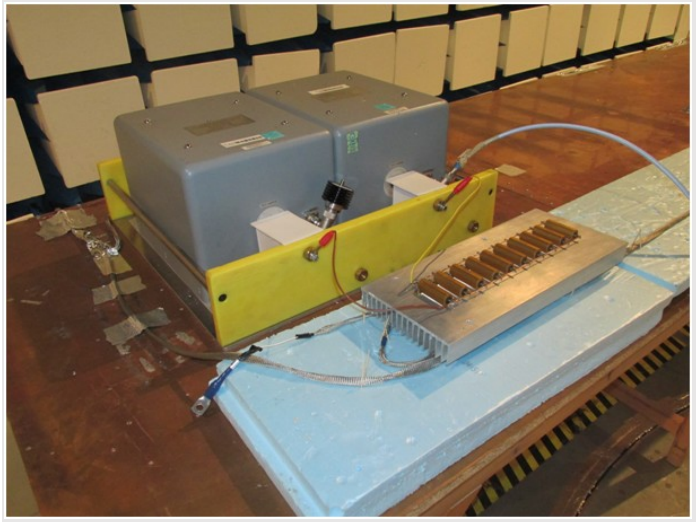
TÜBİTAK UME

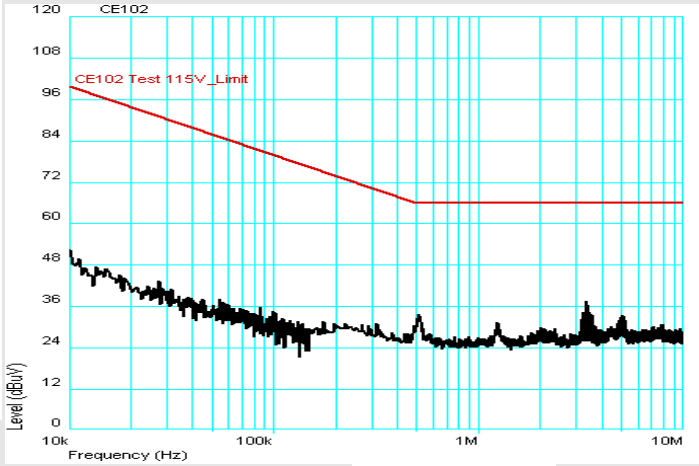
BN Measurement for CE102 Testing

Before the CE102 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.





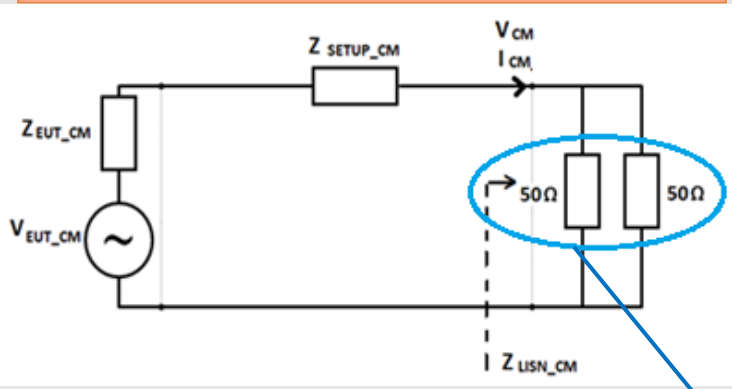


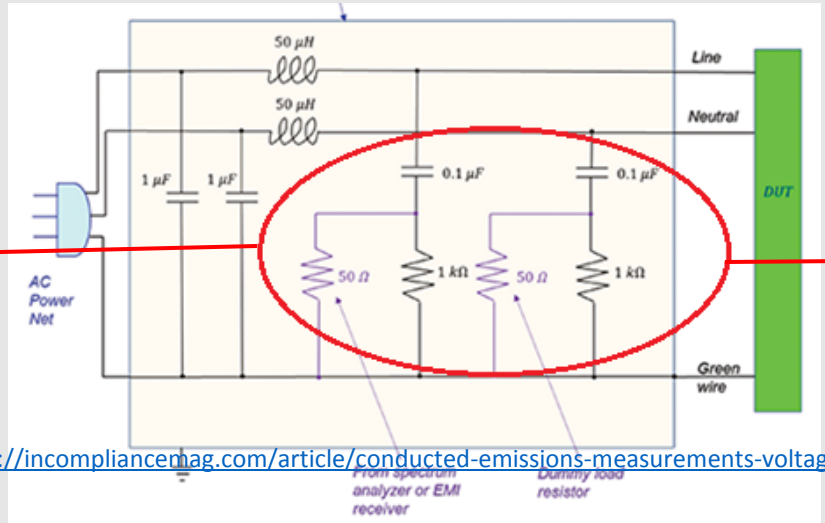
UME

Proposed Just Before Verification Method for CE102 Testing

We have proposed additional just-before test verification method based on impedance measurement as the current verification in the standard may not be enough to catch all the issues such as LISN ground issues.

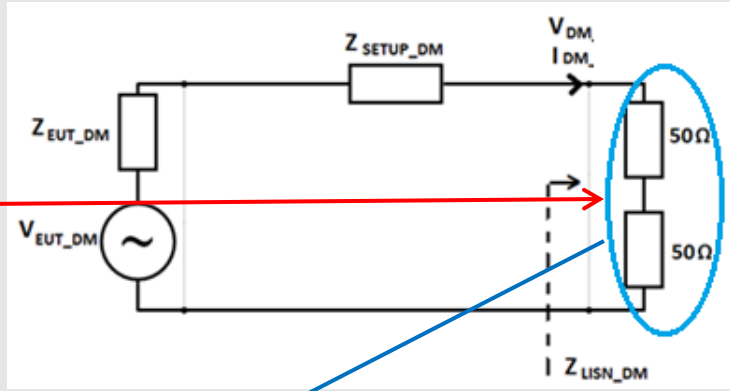
LISN Common Mode (CM) Circuit

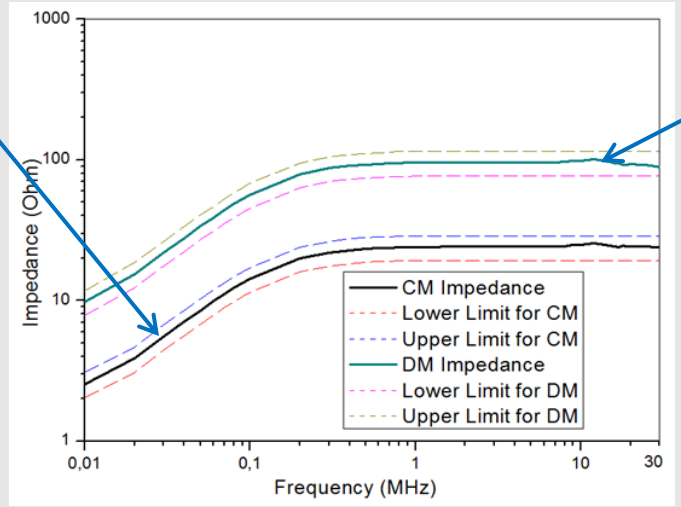




https://incompliancemag.com/article/conducted-emissions-measurements-voltage-method

LISN Differential Mode (DM) Circuit

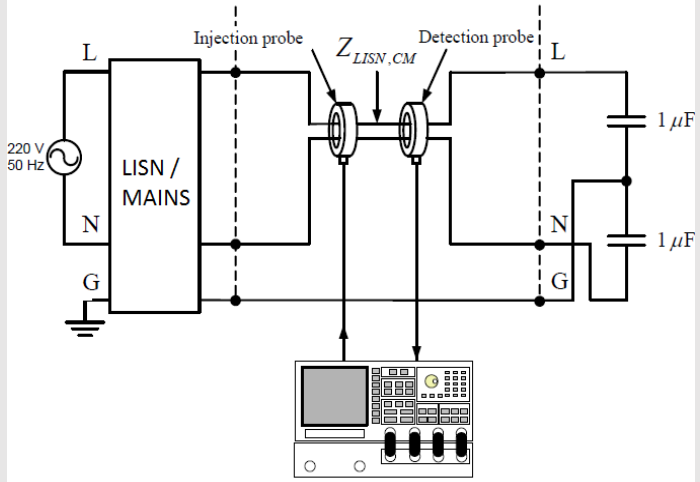




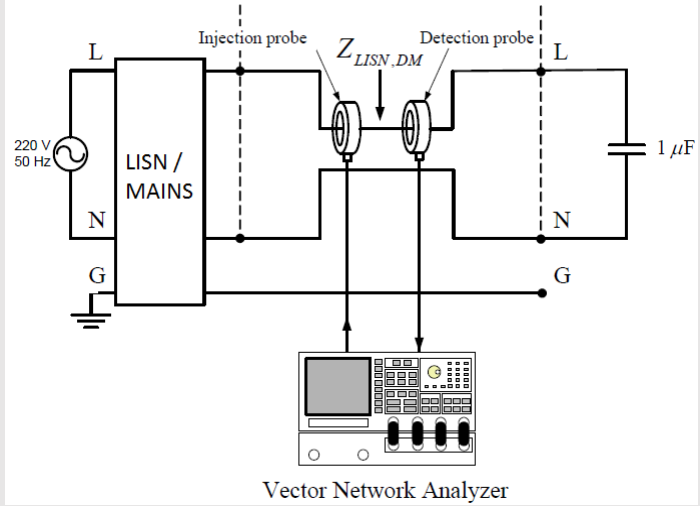
TÜBİTAK UME

Impedance Measurement Setup

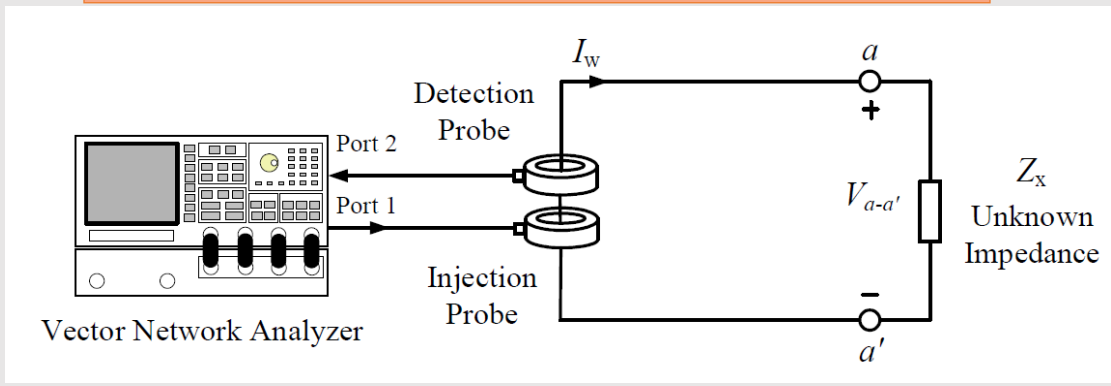
LISN CM Impedance Measurements Setup



LISN DM Impedance Measurements Setup



Impedance Measurement Setup with Two Current Probes



$$\frac{V_{p1}}{V_{p2}} = \frac{S_{11}+1}{S_{21}}$$

$$R_{std} = K\left(\frac{V_{p1}}{V_{p2}}\right)|_{Z_x=R_{std}} - Z_{setup}$$

$$0 = K\left(\frac{V_{p1}}{V_{p2}}\right)|_{Z_x=short} - Z_{setup}$$

$$Z_x = K\left(\frac{V_{p1}}{V_{p2}}\right) - Z_{setup}$$

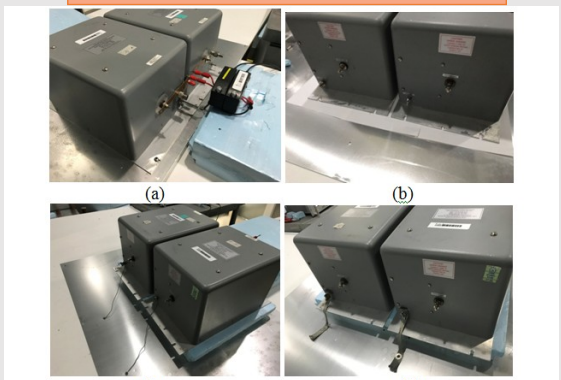
S_{11} = the measured reflection coefficient at port 1

S_{21} = the measured forward transmission coefficient at port 2

Tarateeraseth V., Bo Hu ; Kye Yak See, Canavero F.G., "Noise Source Impedance Measurement in SMPS", Electromagnetic Interference Issues in Power Electronics and Power Systems, 2010, pp. 1-20.

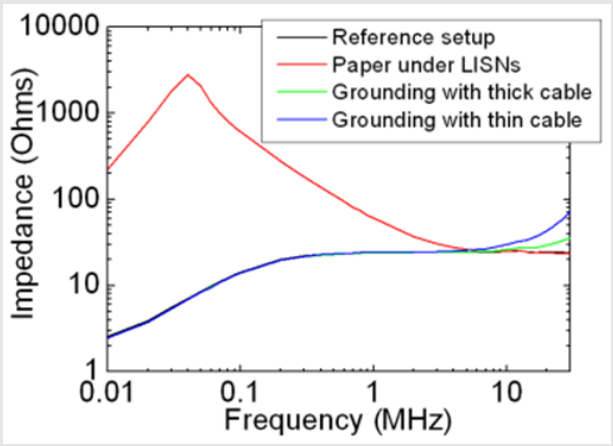
Measurement Results

Grounding scenarios setups

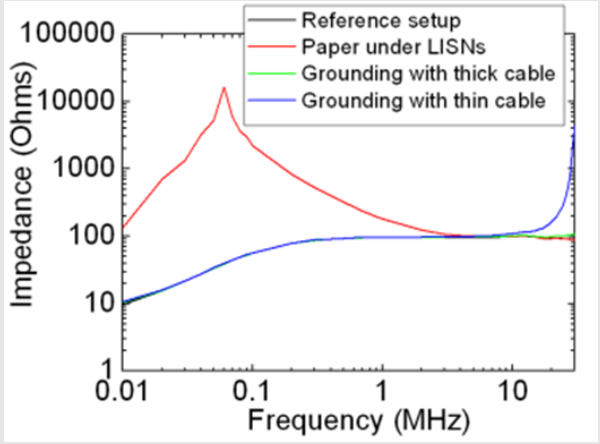


(a) reference setup, (b) very poor grounding with paper, (c) grounding with thin cable, (d) grounding with thick cable

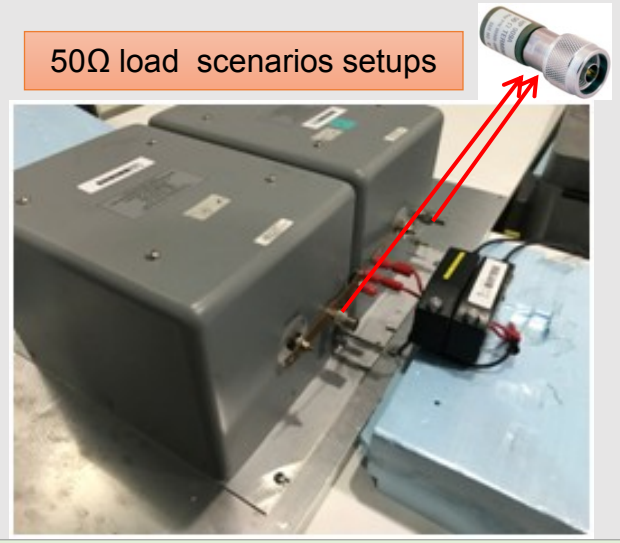
Common Mode Impedance



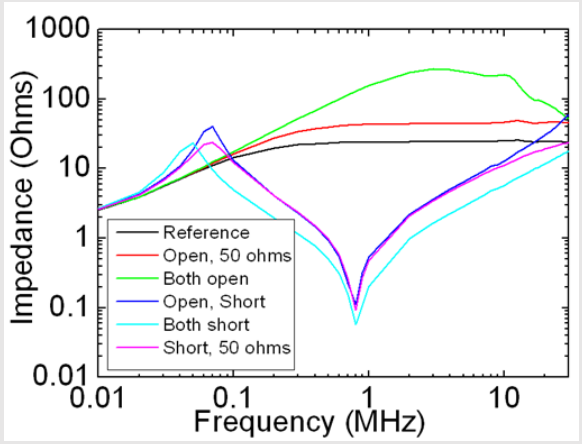
Differantial Mode Impedance



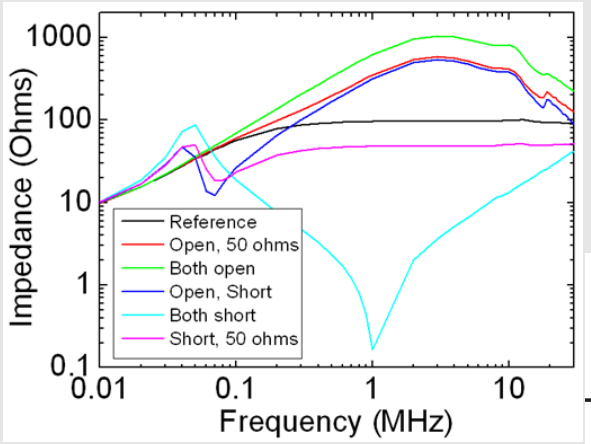
50Ω load scenarios setups



Common Mode Impedance



Differantial Mode Impedance



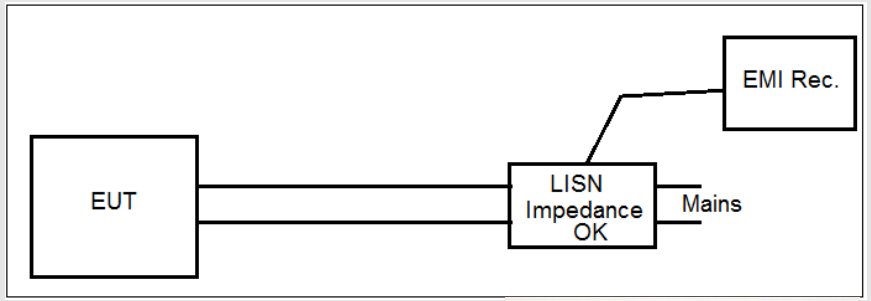
Sen, O., Cakir, S. "Improved Just-Before-Test Verification Methods with VNA for Conducted EMC Tests ", IEEE International Symposium on Electromagnetic Compatibility 2018, August:art. no. 8485179 (2018) : 488-493

TÜBİTAK UME

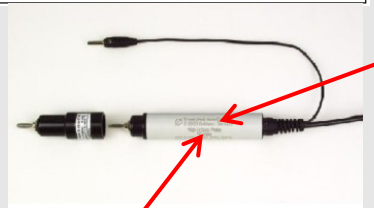
CE102 Testing With Voltage Probe

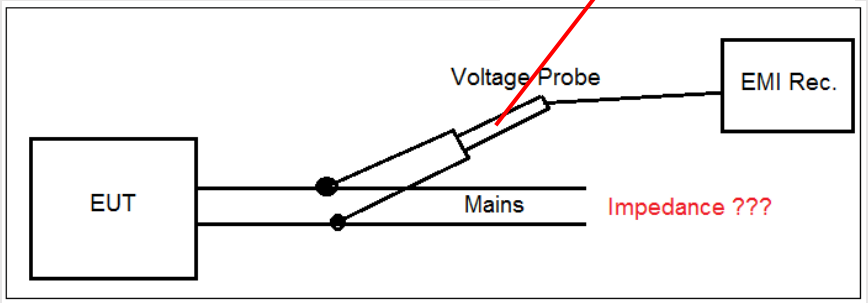
The EUT has large dimensions or requires high input current (> 200 A), it is not, for most of the time, possible to send it to an EMC laboratory or to use LISNs (the commercial LISNs may not be available) during the CE102 testing. CISPR, ANSI, and the FCC all describe a voltage probe which can be used 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.



http://www.schwarzbeck.de/en/component/content/article/69-voltage-probe/539-tk-9420-voltage-probe.html





CE102 test setup for voltage probe

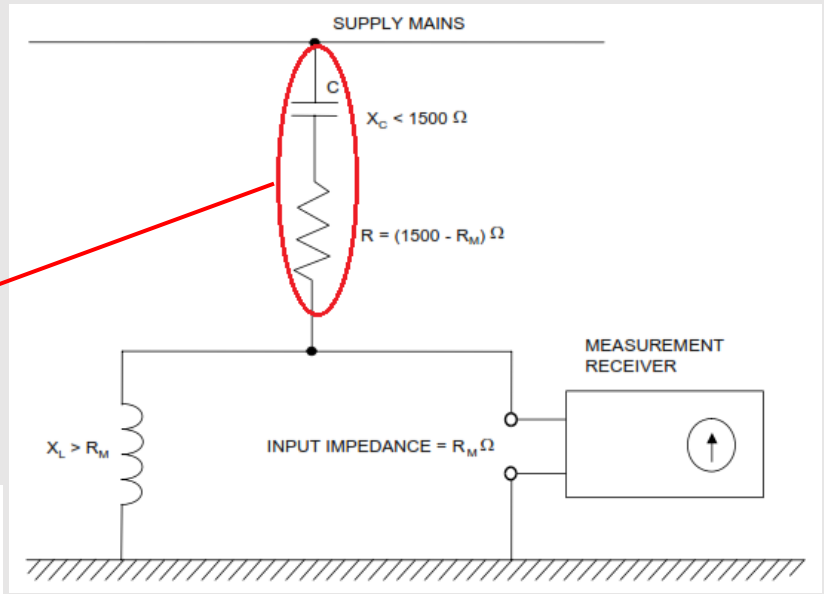


Table B.3 – Conducted disturbance measurements from 9 kHz to 30 MHz using a VP

Input quantity [a]	X_i	Uncertainty of x_i dB	Probability distribution function	$c_i\,u(x_i)$ [b] 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

Time-Varying Signals in CE102 Testing

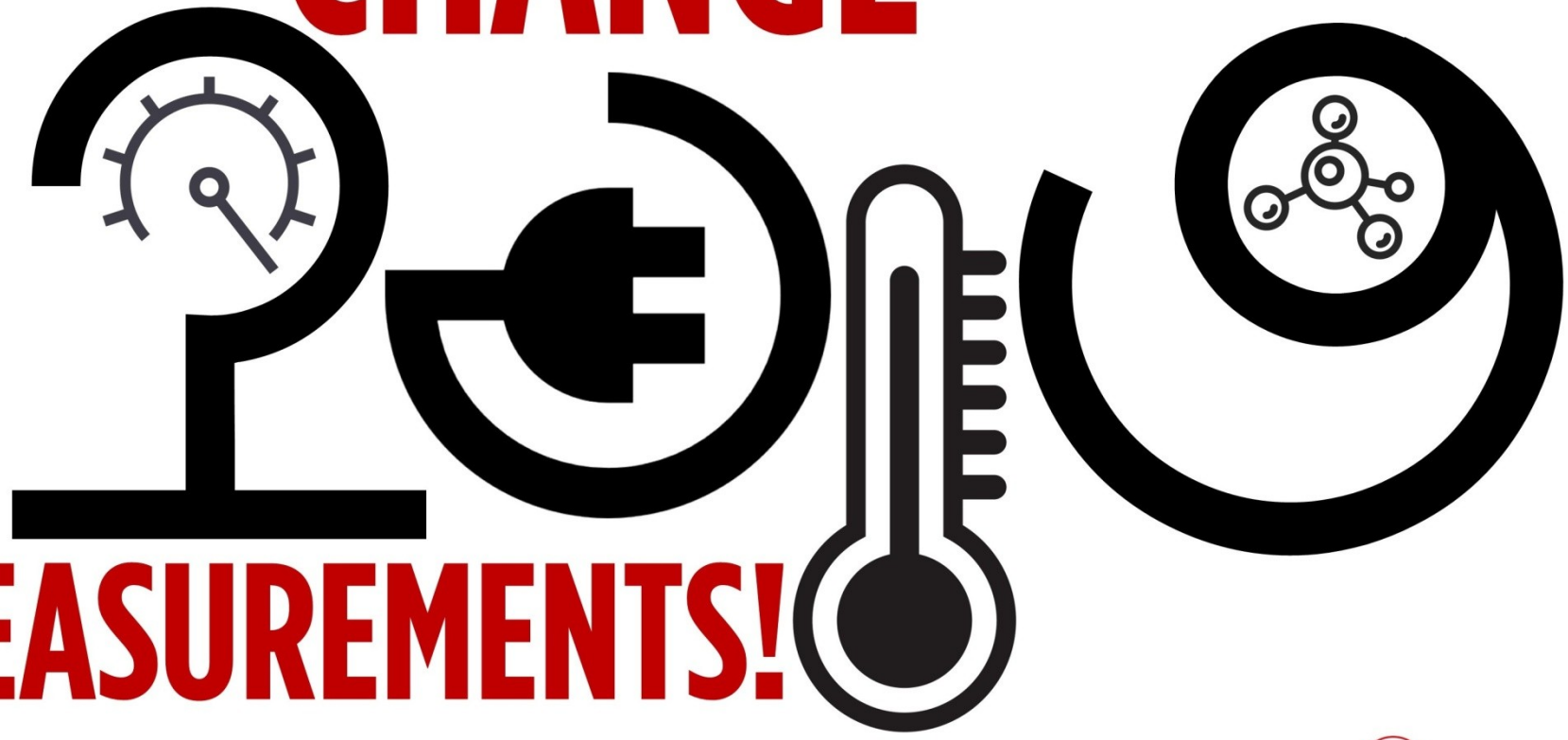
As per MIL STD 461F, for equipment that operates such that potential emissions are produced at only infrequent intervals, times for frequency scanning shall be increased as necessary to capture any emissions

Example CE102 Measurement Result

Phase Line	Measurement Frequency (MHz)	Measurement Results with 15ms (dBµV)	Measurement Results with Increased Measuring Time (>15ms) (dBµV)	Limit (dBµV)	Difference (dB)	Result
Line A	1	45,83	62,33	66	-3,67	Pass
Line B	1	62,66	71,05	66	5,05	**Fail**
	4	53,14	69,85	66	3,85	**Fail**
Line C	4	43,46	64,16	66	-1,84	Pass

TÜBİTAK UME

CHANGE THROUGH



MEASUREMENTS!

TRUE MEASUREMENT EXCELLENCE

THANK YOU

TÜBİTAK UME