



LISN-CISPR16-32A

Artificial Mains Network

Users Manual





The LISN-CISPR16-32A is a Line Impedance Stabilization Network for the measurement of line-conducted interference within the range of 9 kHz to 30MHz, according to the CISPR 16-1-2 standard. The device is designed for testing 3-phase and single phase, AC-powered equipment with supply voltages up to maximum 450V/260V and 16A. Conducted noise can be measured on each phase and on the neutral conductor. The LISN-CISPR16-32A has separate RF outputs for each phase and neutral and consequently can be coupled with the TBLM1 to split the emissions in its common mode and differential mode components. The LISN-CISPR16-32A has no integrated high pass filter at the RF outputs, but comes with an external 9 kHz coaxial high pass instead.

The single phase DUT socket is available in country-specific variants.

FEATURES

Frequency range:	9 kHz to 30 MHz
Impedance:	50 Ω (50 μH + 5 Ω)
Artificial hand:	220 pF + 511 Ω
Switchable PE: 50 Ω 50 μH	250μH pre-filter
Separate RF outputs for each line and neutral	
Air core inductors	
Line voltage:	max 540V/260V / 50 – 60 Hz
Max. current per line and neutral:	16A @ 23°C each
3-phase DUT socket:	CEE / IEC60309, 3L+N+PE, 16A, female
Single phase DUT socket:	country specific
Power connector:	CEE / IEC60309, 3L+N+PE, 16A, male
Measurement connectors:	50 Ω BNC
External 9 kHz high pass filter, N-male / N-female	
Operating Temperature Range:	+5°C ... + 40°C; 5% to 80% RH

APPLICATION

- EMC CONDUCTED NOISE MEASUREMENTS

SAFETY

Operating an AC LISN involves dealing with potentially lethal voltages and high ground leakage currents. The LISN shall only be operated by qualified staff.



Read this manual carefully and be sure to understand the operation of an AC LISN. Make sure that the conducted noise pre – compliance test equipment is set up correctly and that the necessary earth connections are reliably bonded to avoid the risk of lethal electric shocks. The ground strap must be securely connected to the protective earth conductor available on site, before making any other electrical connection. This connection must not be separated, until the mains supply is disconnected from the LISN setup.

Always supply the LISN only through an isolation transformer.

Always use the LISN together with the supplied 9 kHz high pass attached to the input of the spectrum analyzer / EMI receiver.

Take precautions, such as validating the signal amplitude at the RF output prior to connecting a spectrum analyzer or using attenuators and/or limiters to prevent damage to your test receiver or spectrum analyzer.

Do not carry out any modifications or manipulations of the LISN-CISPER16-32A.

Avoid touching the housing, when operating the LISN at maximum current over extended time. The housing temperature may rise up to 50°C. Turn off the DUT after measurements to avoid unnecessary dissipation.

1. INTRODUCTION

A line impedance stabilization network (LISN) is a device used in conducted and radiated radio-frequency emission and susceptibility tests, as specified in various EMC/EMI test standards. LISN are also sometimes referred to as artificial networks (AN) or artificial mains networks (AMN).

In conducted emission measurements, LISN are inserted into the supply lines of the equipment under test and provide an RF output to measure conducted emissions.

In many other test set-ups, LISN are inserted into the EUT supply lines just for the purpose of creating a defined source (supply) impedance.

The output impedance of a power supply (source) is hardly ever known and varies from source to source. EMC testing requires a well-defined and repeatable set up, which is created by placing a LISN in series with the source. The equipment under test does no longer see the output impedance of the source, but instead the specified impedance of the LISN.

1.1 Pre-compliance testing of conducted emissions

Full compliance measurement of AC mains supplied products requires a high end set up consisting of an anechoic or screened chamber, a measurement receiver that complies with the requirements of CISPR 16, a 50µH LISN and a suitable table for the measurement setup. Great effort and cost ensures optimum accuracy and repeatability.

Pre-compliance measurements target to give a very close approximation of the EMC performance of the Device Under Test at a fraction of the cost of full compliance testing. The measurement receiver can be replaced by a spectrum analyzer with suitable sensitivity, bandwidth and detectors. The advent of affordable spectrum analyzers with EMI IF filters and Quasi-Peak detectors made EMC pre-compliance testing affordable for any company which develops electronic products. Together with test accessories from Tekbox, EMC pre-compliance set-ups cost hardly more than a standard oscilloscope a few years ago.

Eliminate uncertainty before going to the test house for compliance testing. There is hardly anything that can give you a return on invest as quickly as EMC pre compliance test equipment.

1.2 Line Impedance Stabilization Networks

A LISN is a device inserted between a power source and the supply terminals of a DUT (Device Under Test). It presents a defined impedance for the emissions produced by the DUT and emitted via the supply cables of the Device Under Test. The impedance seen by the RF emissions is $50\ \Omega \parallel 50\ \mu\text{H} + 5\ \Omega$ which results in 50 Ohms for the most part of the specified frequency range. Only at the lower edge of its bandwidth, the impedance decreases. This impedance curve is specified in the corresponding test standards such as CISPR 16-1-2. Having a defined impedance for the emissions at the DUT terminals eliminates any influence of the power source impedance. Consequently, the measured amplitudes of the noise spectrum become independent of the power source characteristics:

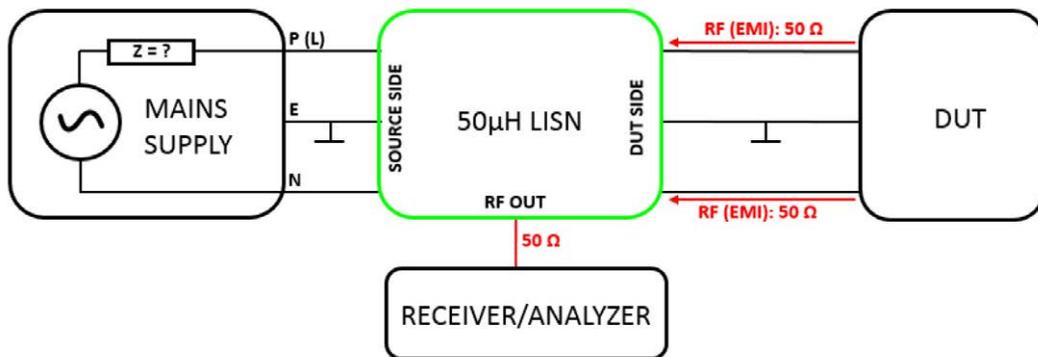


Figure 1 – Basic AC LISN set up: impedance levels

Furthermore, the AC LISN attenuates noise originating from the incoming mains supply towards the Receiver/Analyzer and DUT. For detailed information, refer to the LISN overview document, which can be downloaded from the Tekbox website.

1.3 RF output

The LISN-CISPER16-32A provides separate RF outputs for L1, L2, L3 and Neutral. Consequently, a complete conducted emission measurement consists of four separate measurements in case of a DUT supplied in Y-configuration, three separate measurements in case of DUTs supplied in Delta-configuration, or two separate measurements in case of single phase supplied DUTs. L1 is connected both to the 3-phase DUT socket, as well as to a country specific single phase socket to simplify connectivity of single phase supplied products. When measuring conducted emissions on any of the four paths, the three unused RF outputs have to be terminated with 50 Ohm.

As the LISN-CISPER16-32A provides separate outputs for each path, it can be connected to a TBLM1 LISN mate in order to split the output signal into its common mode and differential mode components.

The LISN-CISPER16-32A RF paths do not provide any built in attenuators / filters / limiters.

Always connect the supplied TBHPF1-9kHz low pass filter to the RF input of your spectrum analyzer / measurement receiver, unless you don't use external attenuators which provide a 50 Ohm impedance down to DC or an external attenuator / limiter/filter such as the Tekbox TBFL1.

Take precautions, such as validating the signal amplitude at the RF output prior to connecting a spectrum analyzer or using attenuators and/or limiters such as the Tekbox TBFL1 to prevent damage to your test receiver or spectrum analyzer.

WARNING: Ensure that the spectrum analyzer RF input is disconnected when powering on or powering off the DUT. Use an attenuator/limiter, if the DUT switches inductive loads during operation or in case of any uncertainty concerning the DUT characteristics. After ensuring that the spectrum analyzer is not over-driven, you may remove or reduce external attenuation.

1.4 Informative schematic

The simplified schematic below shows the basic topology and the values of the main components of the LISN-CISPER16-32AAC LISN. It consists of four identical LISN paths.

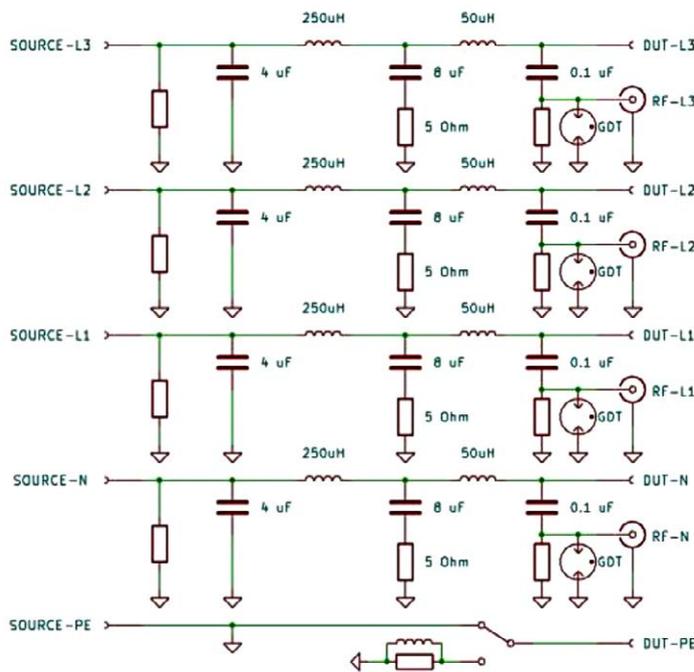


Figure 2 – 3-phase LISN, simplified schematic

NOTE the high capacitor values, which cause considerable blind current at 50Hz/60Hz line voltages. Direct connection to the mains outlet would cause tripping of the ground fault switch. Refer to the next chapter on how to set up the AC LISN in a standard laboratory environment.

1.5 Laboratory set up

Always refer to the set-up specified in the applicable standard for your product. If it cannot be implemented in your available laboratory environment, refer to the set up below.

The DUT shall be isolated and elevated from the ground plane. The spectrum analyzer shall measure the conducted emissions on both line and neutral.

The value of the parallel combination of the capacitors is 12µF from each line and neutral to ground. This causes around 0.75A flowing into the earth connection and would trip the ground fault switch. Hence, an insulation transformer is required for any mains supply which is protected by a residual current device or ground fault (earth leakage) circuit breaker and good grounding is essential for safety.

The set up below is just informative. For the exact details of the set up and for the limits of conducted emissions refer to the relevant applicable standard or the examples in the LISN overview document, which can be downloaded from our website.

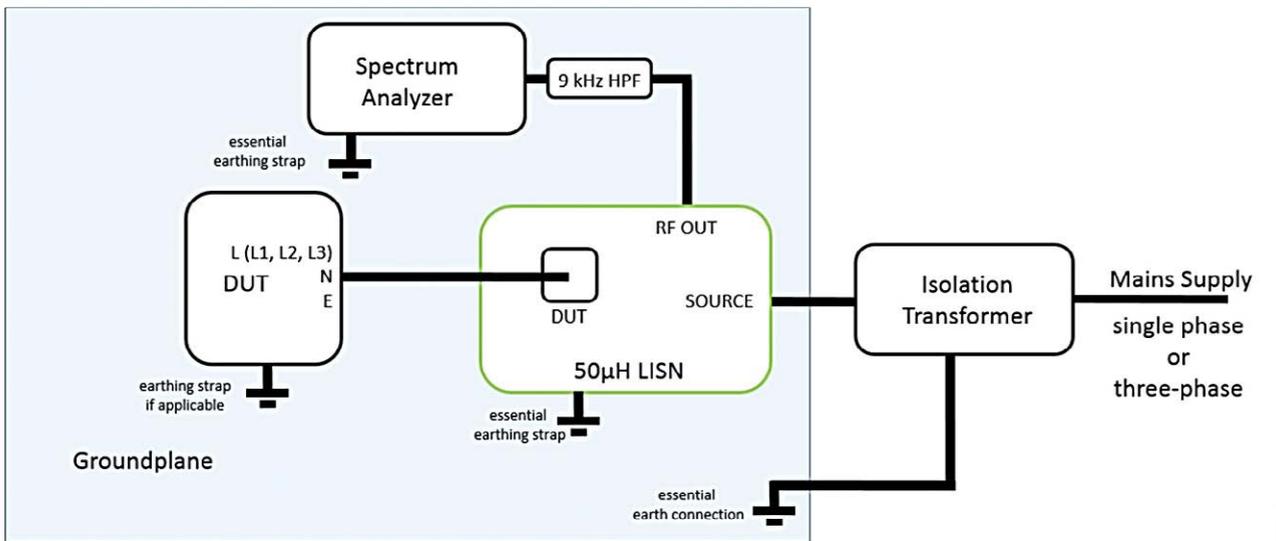


Figure 3 – Conducted noise pre-compliance measurement setup

SAFETY: Ensure that all required earth connections are reliably bonded and that the isolation transformer can supply the required load current.

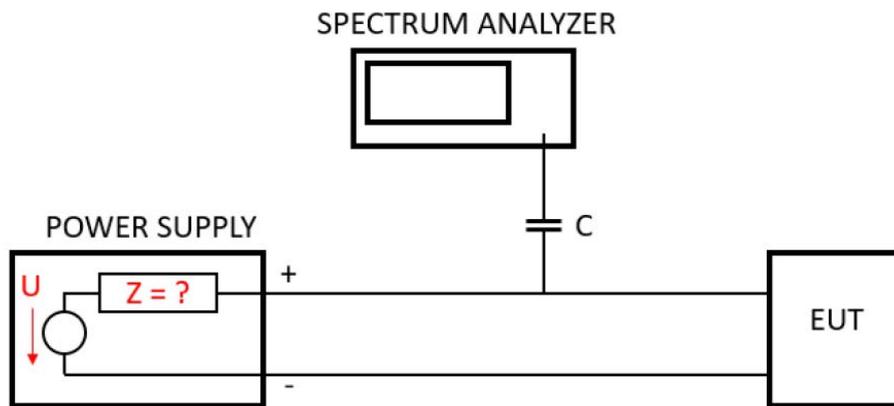
1.6 Ground plane

Any voltage measurement must be made against a common circuit node which can be referred to as the “zero volt” reference. In order to provide a low impedance zero volt reference for RF measurements, a metal sheet must be provided as ground plane. All ground straps between equipment and ground plane shall be as short as possible and fastened with screws. Exact details on the size of the ground plane and the arrangement of the equipment and interconnecting cables are described in the applicable standards.

In a pre-compliance test set up, as a rule of thumb, the size of the ground plane shall be large enough to accommodate all involved equipment and exceed at least 10cm each side.

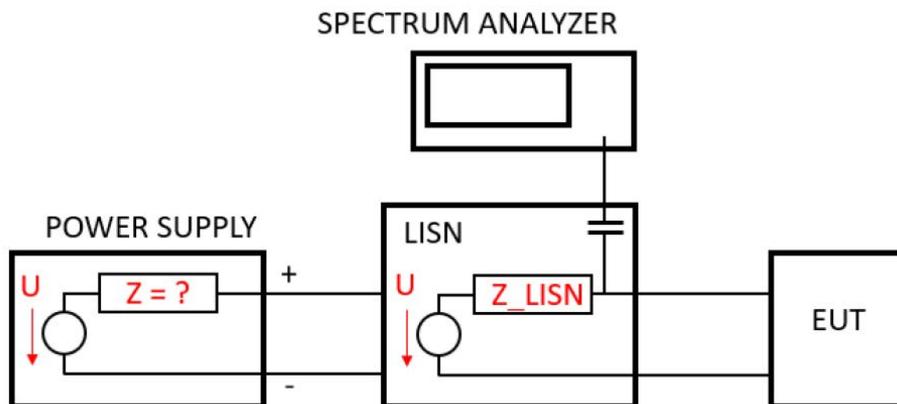
How does it work?

If you want to measure conducted noise emissions, you could do it as simple as below:



It is definitely possible, to measure conducted emissions produced by the EUT, using this simple set up. However, the amplitude of the conducted emissions will be influenced by the impedance of the source. The source impedance is part of a voltage divider in the overall system and has a significant influence on the amplitude of the measured amplitude of the conducted emissions. As it is necessary to get the same results for the same EUT in any lab, anywhere, it is necessary to remove the impedance of the supply source from the equation.

The picture below shows how a LISN is inserted into the setup, in order to provide a defined impedance for the conducted emissions travelling on the supply lines of an equipment under test:



A LISN can be connected to any power supply and provide the same voltage and current capability as the power supply at the EUT terminals. However, the source impedance of the LISN is specified by EMC standards and enables repeatable conducted emission measurements in any laboratory.

How is it implemented?

The below impedance curve of a 5µH LISN is copied from CISPR 25, Annex C, one of the EMC standards that specifies LISN:

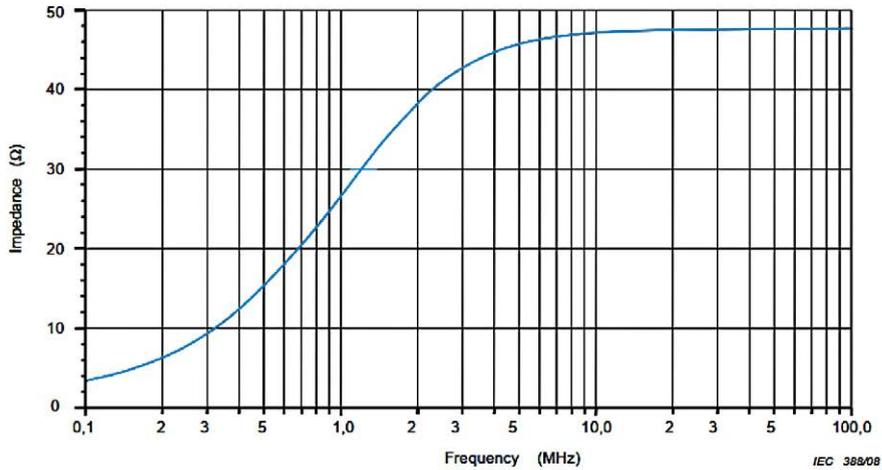


Figure E.1 – Characteristics of the AN impedance

For the most part of the specified frequency range, the LISN impedance is close to 50 Ohm. At frequencies below 5 MHz, the impedance starts to decrease and at DC, the impedance will be close to 0 Ohm.

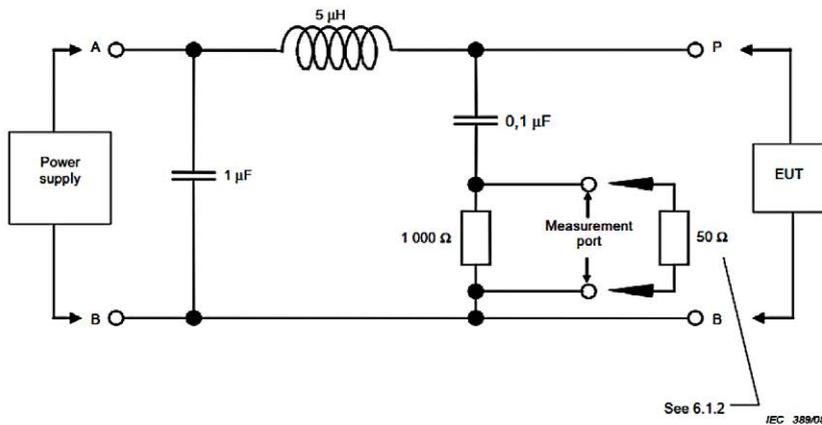


Figure E.2 – Example of 5 µH AN schematic

The simplified schematic reveals, how the LISN is implemented. At frequencies above 5 MHz, the impedance of the 5µH inductor is high. The LISN impedance at the EUT port is dominated by the 50 Ohm load resistance. In fact, when the LISN is used for conducted noise measurement, the 50 Ohm impedance is actually the input impedance of the connected spectrum analyzer or measurement receiver. This also explains, why the RF output of a LISN has to be terminated with 50 Ohm, when used without measurement equipment connected.

At frequencies below 5 MHz, the impedance of the inductor combined with the 1µF capacitor starts loading the 50 Ohm resistor and the overall LISN impedance decreases according to the specified impedance curve.

The LISN impedance must follow the specification independently of the source terminals shorted or open or whatever impedance connected to it. The impedance of the connected power supply does not have any influence on the impedance of the LISN within its specified frequency range.

This is just an example of a LISN. There are several specified variants, but the underlying principle is same for all.

2 SPECIFICATIONS

2.1 Conformity

The LISN-CISPER16-32A is compliant with CISPR 16-1-2.

In line with the CISPR 16-1-2 standard compliant design and setup specification, the LISN-CISPER16-32A V-LISN exhibits high ground leakage currents and non-standard isolation and consequently cannot meet the safety requirements of EN 61010-1.

Furthermore CISPR 16-1-2 specifies high capacitance values for the capacitors from Line1/2/3 and from Neutral to Ground (PE). These capacitance values are not commercially available in Y2 rating and are implemented using AC rated capacitors with suitable voltage rating.

In order to prevent the danger of lethal electric shock, the operator is responsible for ensuring protective measures in line with IEC 60364-4-41 and IEC 60364-5-54 and to follow all safety related information of this manual.

2.2 Safety

In order to ensure safe operations, the user must follow all safety relevant information of this manual. All housing parts are connected with the earth conductor of the power cable, DUT socket, yellow banana receptacle and with the ground strap of the housing. It is not allowed to carry out any modifications or manipulations of the LISN-CISPER16-32A. The LISN-CISPER16-32A shall be operated by qualified laboratory staff only.

2.3 Specifications

- Frequency range: 9 kHz to 30 MHz
- Impedance: $50 \Omega \parallel (50 \mu\text{H} + 5 \Omega)$
- Artificial hand: $220 \text{ pF} + 511 \Omega$
- Switchable PE: $50 \Omega \parallel 50 \mu\text{H}$
- 250 μH pre-filter
- Air core inductors
- Line voltage: max. 540V/260V, 50 – 60 Hz
- Max. current: 16A @ 23°C for each phase and neutral
- 3-phase DUT socket: CEE / IEC60309, 3L+N+PE, 16A, female
- Single phase DUT socket: country specific, note country specific DUT socket limits (see chapter 4)
- Power connector: CEE / IEC60309, 3L+N+PE, 16A, male
- Measurement connector: 50 Ω BNC, separate outputs for each line and phase; external 9 kHz HPF
- Operating Temperature Range: +5°C ... + 40°C; 5% to 80% RH
- Weight: 21 kg, length: 520mm, width: 470 mm, height: 180 mm

2.4 Supply voltage

The LISN-CISPER16-32A does not require any particular voltage settings. It can be operated with any supply voltage which does not exceed 540V/260V, 50Hz/60Hz. It is also suitable for DC operation.

2.5 Front Panel

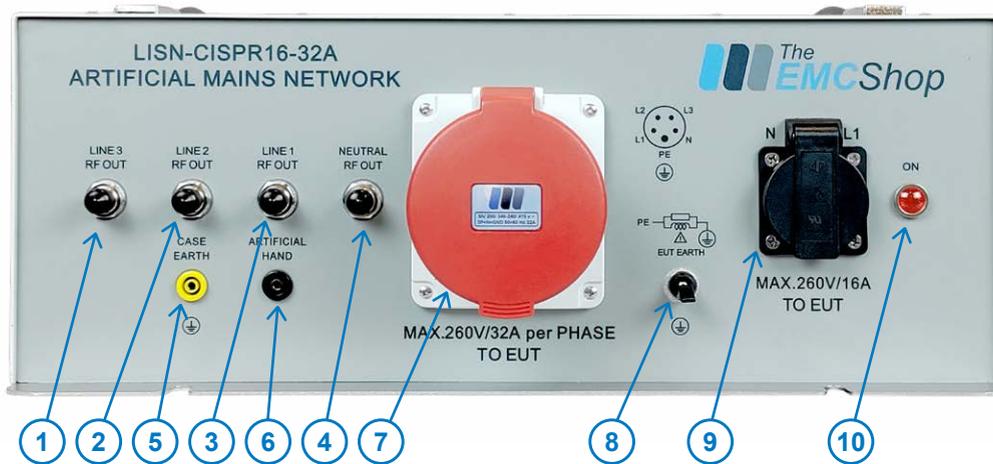


Figure 4 – Front panel layout

- 1) Line 3 BNC RF output
- 2) Line 2 BNC RF output
- 3) Line 1 BNC RF output
- 4) Neutral BNC RF output
- 5) Auxiliary case earth connector, safety banana jack
- 6) Artificial hand connector, safety banana jack
- 7) Three phase DUT socket, IEC60309, 3L+N+PE, 16A, female
- 8) Protective Earth switch to connect DUT earth either directly to case earth, or via $50\mu\text{H} \parallel 50\ \Omega$
- 9) Single phase DUT socket, country specific
- 10) Power On indicator

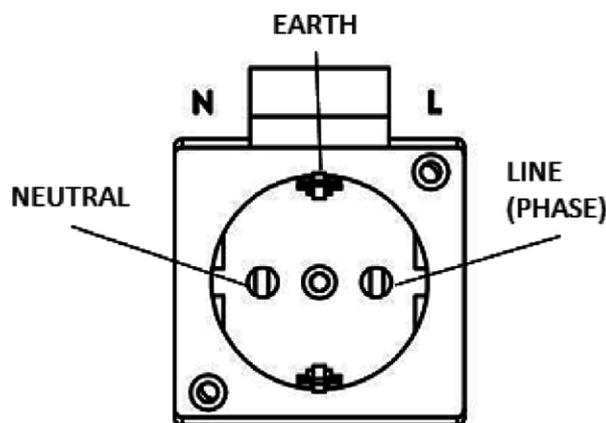


Figure 5 – DUT socket, pin assignment with reference to the rear power connector
For the pin-assignment of the three phase socket, refer to the graphics on the front panel

2.6 Rear Panel

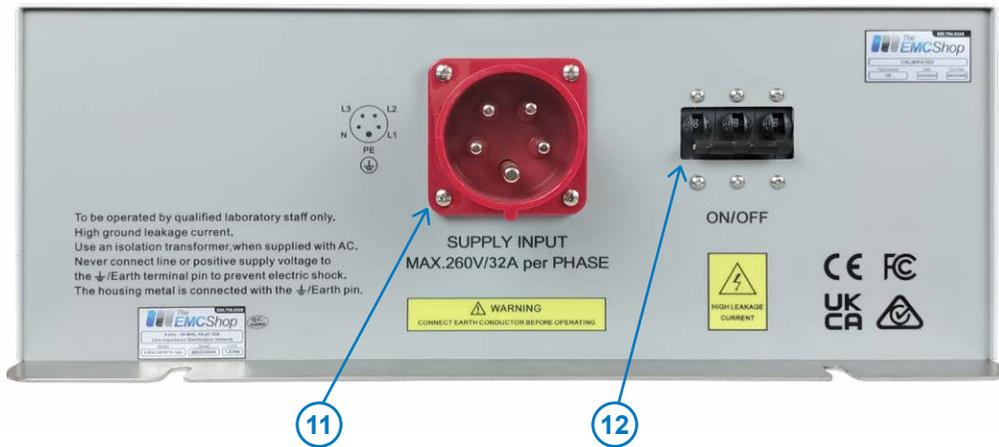
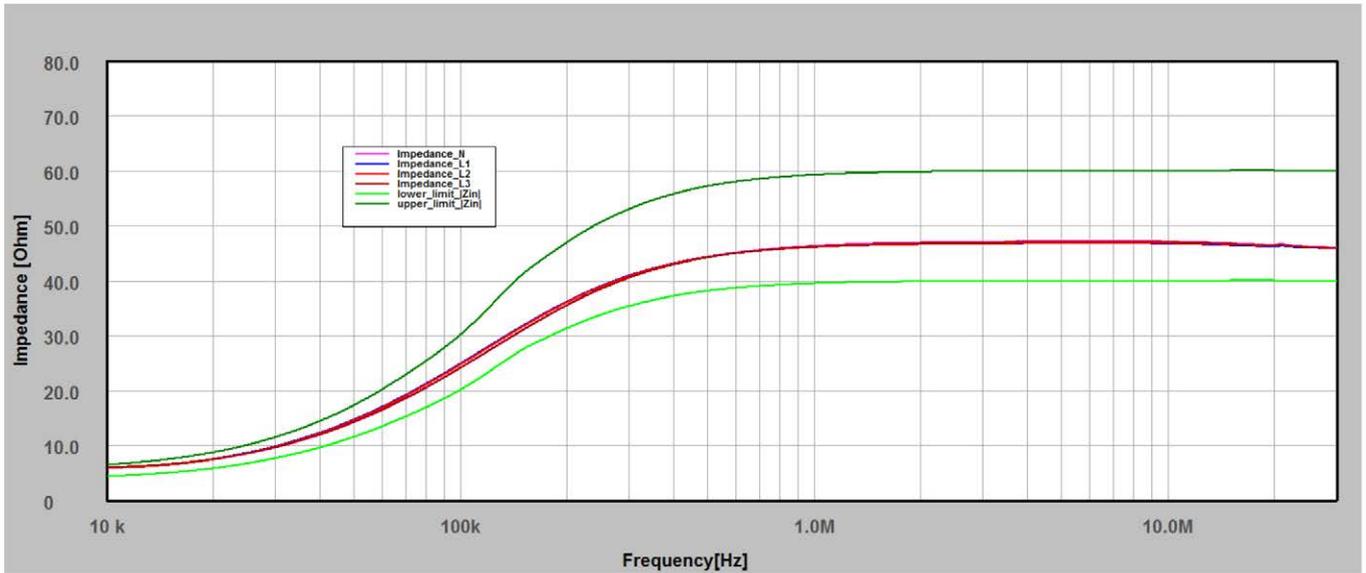


Figure 6 – Rear panel layout

- 11) Three phase power (source) socket, IEC60309, 3L+N+PE, 16A, male
- 12) Power switch

For the pin assignment of the power socket, refer to the graphics on the rear panel.

2.7 Impedance



*) BNC connectors terminated with 50 Ohm. Impedance measured at the DUT terminals on the PCB. The wiring from DUT connector to the PCB can be considered as an additional 20 cm of DUT supply cable length.

2.8 Phase

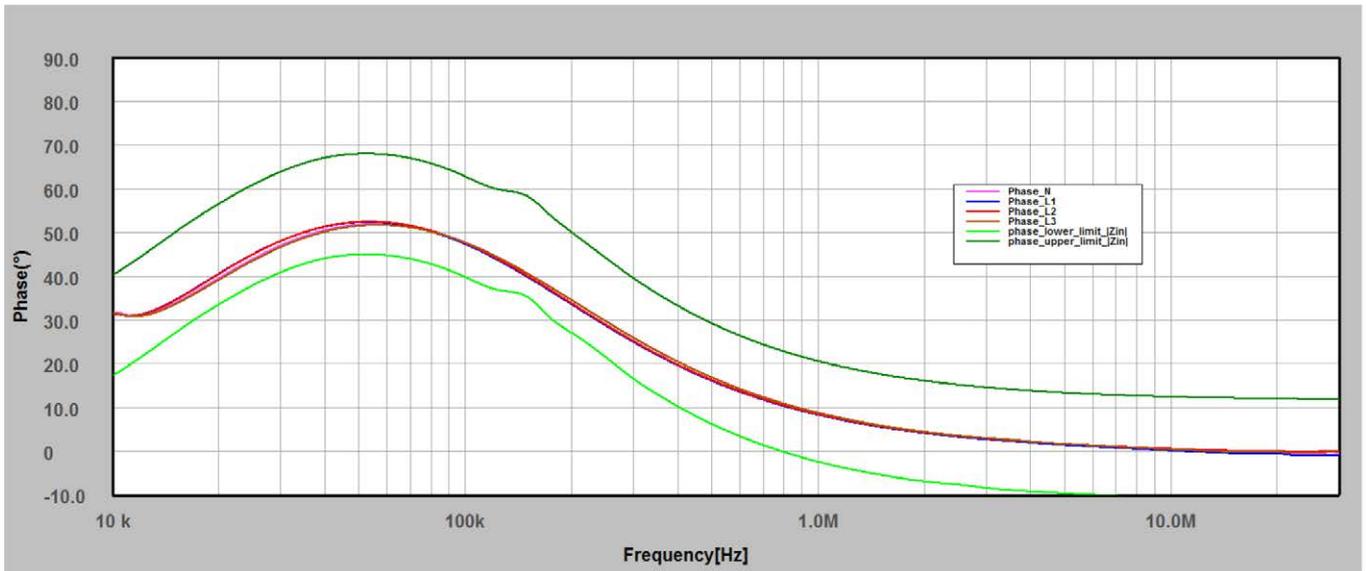


Figure 8 – Phase angle vs. frequency at DUT terminals, limit lines according CISPR 16-1-2*

*) BNC connectors terminated with 50 Ohm. Phase angle measured at the DUT terminals on the PCB. The wiring from DUT connector to the PCB can be considered as an additional 20 cm of DUT supply cable length

2.9 Frequency response, S21 from DUT port to RF port

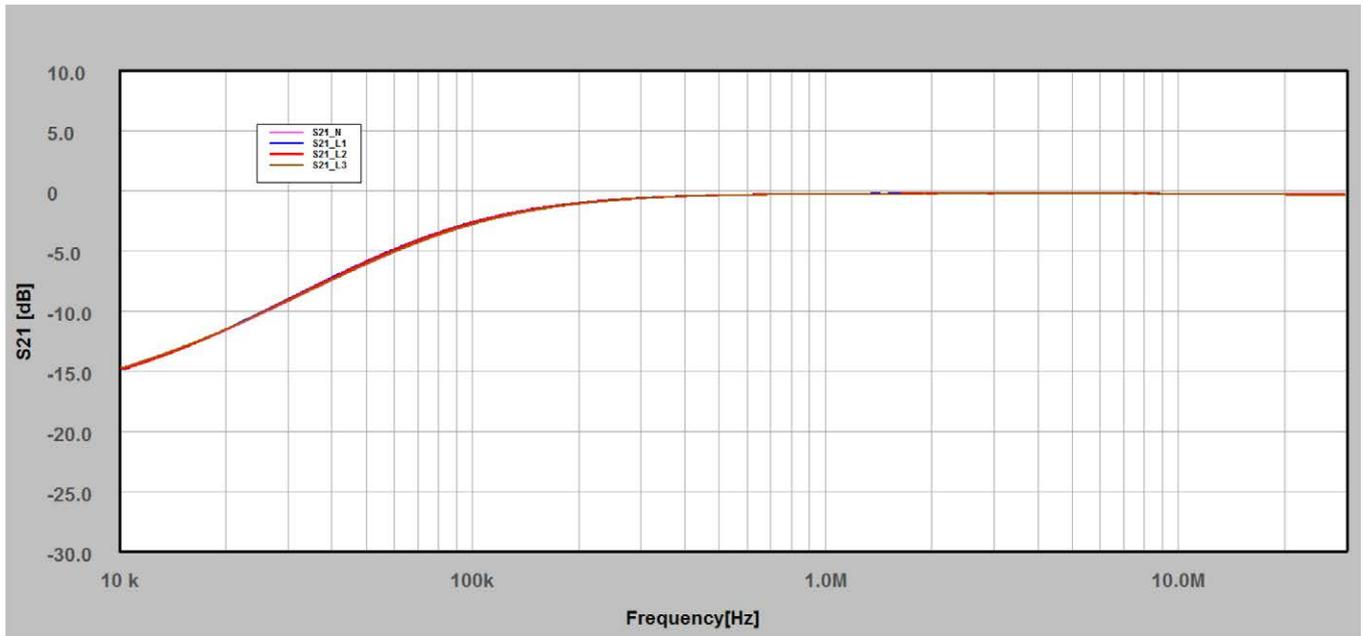


Figure 9 – Frequency response, S21, DUT terminals to BNC connector

Table 1 – Frequency response, PCB DUT terminals to BNC, typical data

Frequency [MHz]	Transmission Neutral / ATT_OFF [dB]
0.009	-15,76
0.015	-13.17
0.02	-11.57
0.03	-9.07
0.05	-5.93
0.07	-4.14
0.1	-2.67
0.15	-1.55
0.2	-1.11
0.3	-0.66
0.5	-0.42
0.75	-0.35
1	-0.32
1.25	-0.31
2.5	-0.30
5	-0.29
7.5	-0.30
10	-0.31
20	-0.36
30	-0.38

2.10 Calibration data according to CISPR 16 -1-2 Annex A8

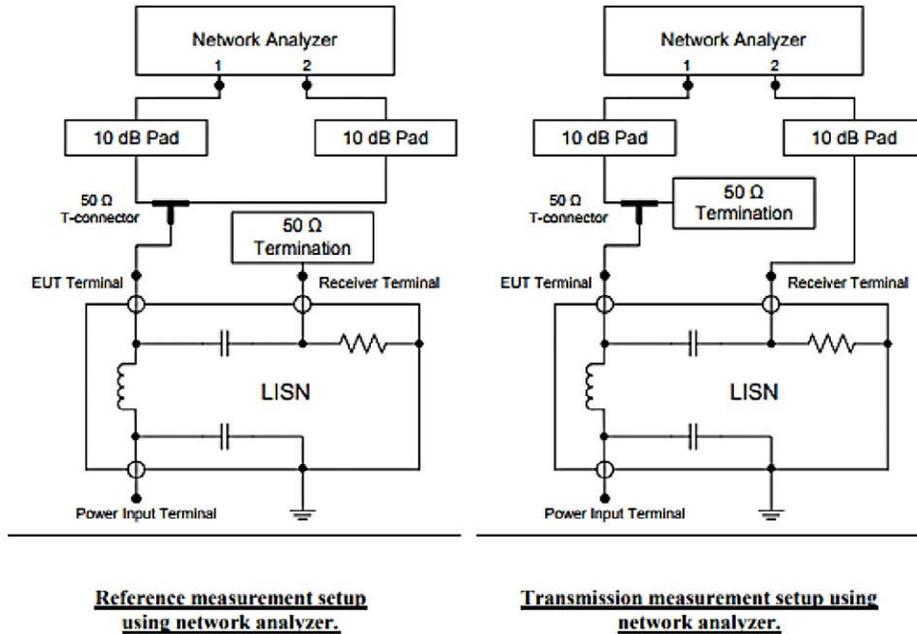


Figure 70 – Calibration set up according to CISPR 16-1-2 Annex A.8.

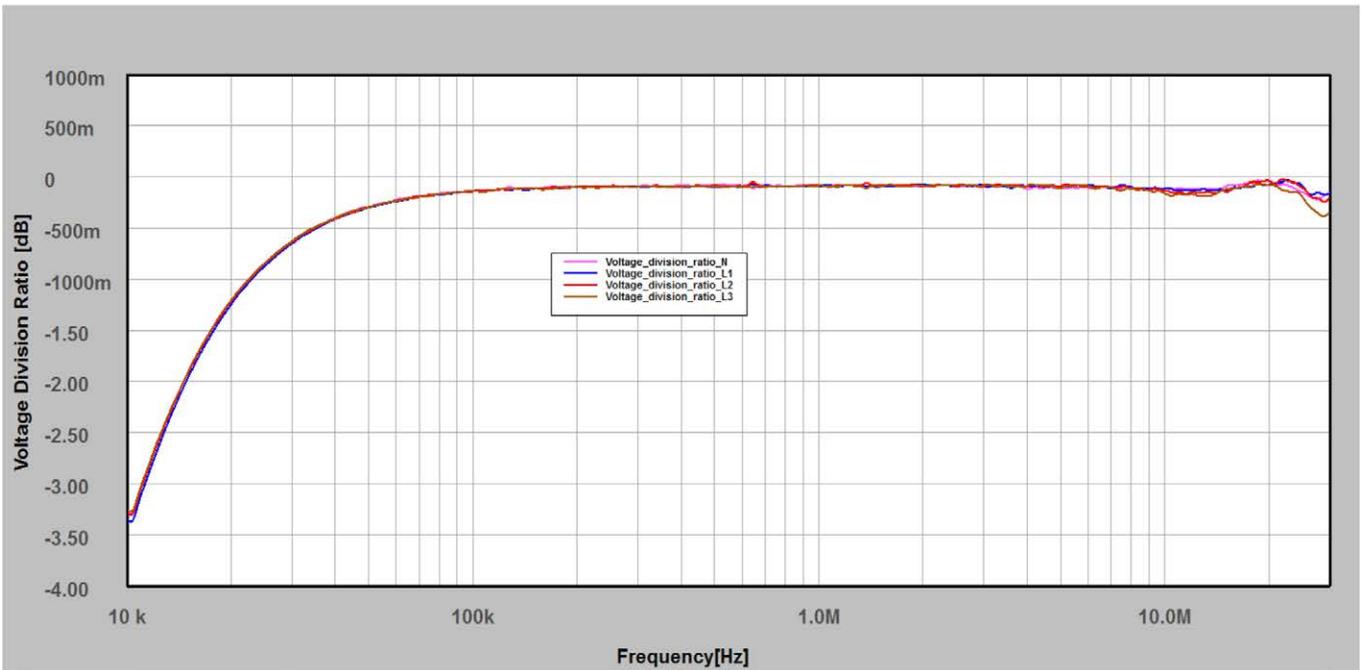


Figure 81 – Voltage Division Ratio versus frequency

Frequency [MHz]	Typical Voltage Division Ratio [dB], L1, L2, L3, N
0.009	-3.48
0.015	-1.92
0.02	-1.21
0.03	-0.64
0.05	-0.31
0.1	-0.14
0.15	-0.11
0.2	-0.097
0.3	-0.096
0.5	-0.085
0.75	-0.091
1	-0.083
2.5	-0.095
5	-0.091
7.5	-0.11
10	-0.13
20	-0.22
30	-0.21

Table 2, LISN-CISPER16-32A LISN voltage division ratio, typical calibration data*

*) measured from DUT terminals on the PCB to BNC

2.11 Isolation

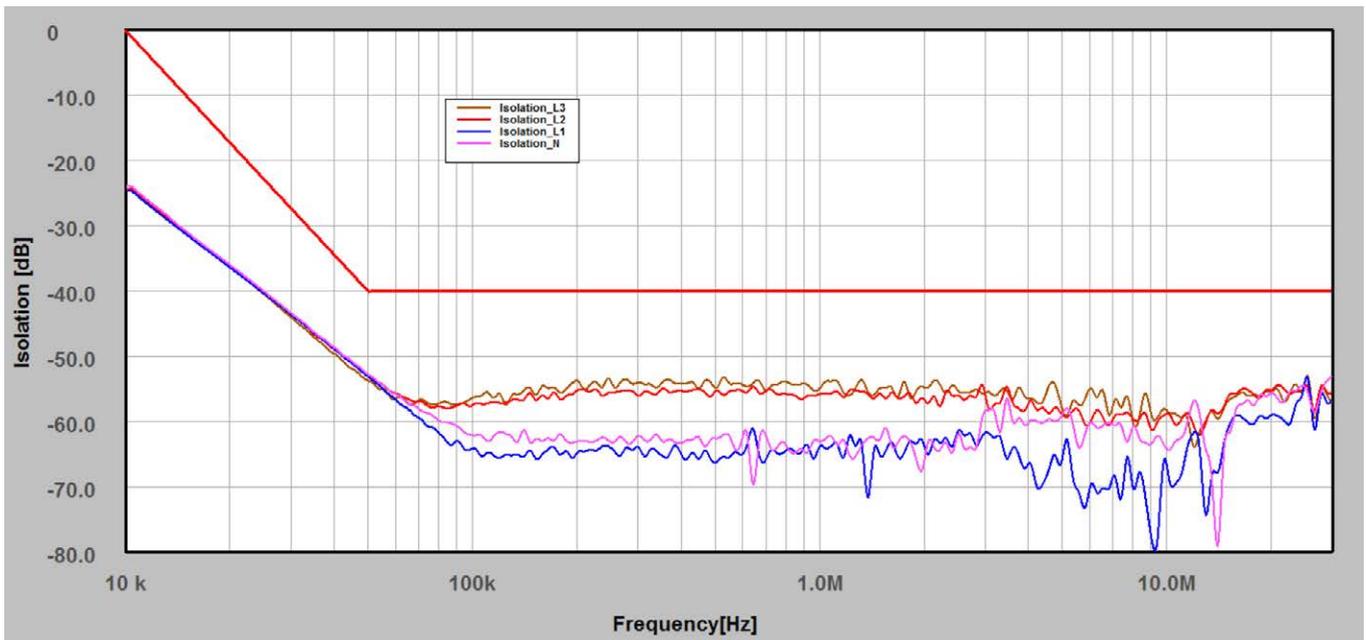


Figure 92: LISN Isolation, Source to RF out, limit line according CISPR 16-1-2

The isolation is measured between the mains (source) connector and RF port, with the DUT port terminated with 50 Ohm.

2.12 Thermal characteristics

Avoid touching the housing, when operating the LISN at maximum current over extended time. Typical conducted noise measurements take less than 10 minutes per line. Turn off the DUT after measurements to avoid unnecessary dissipation.

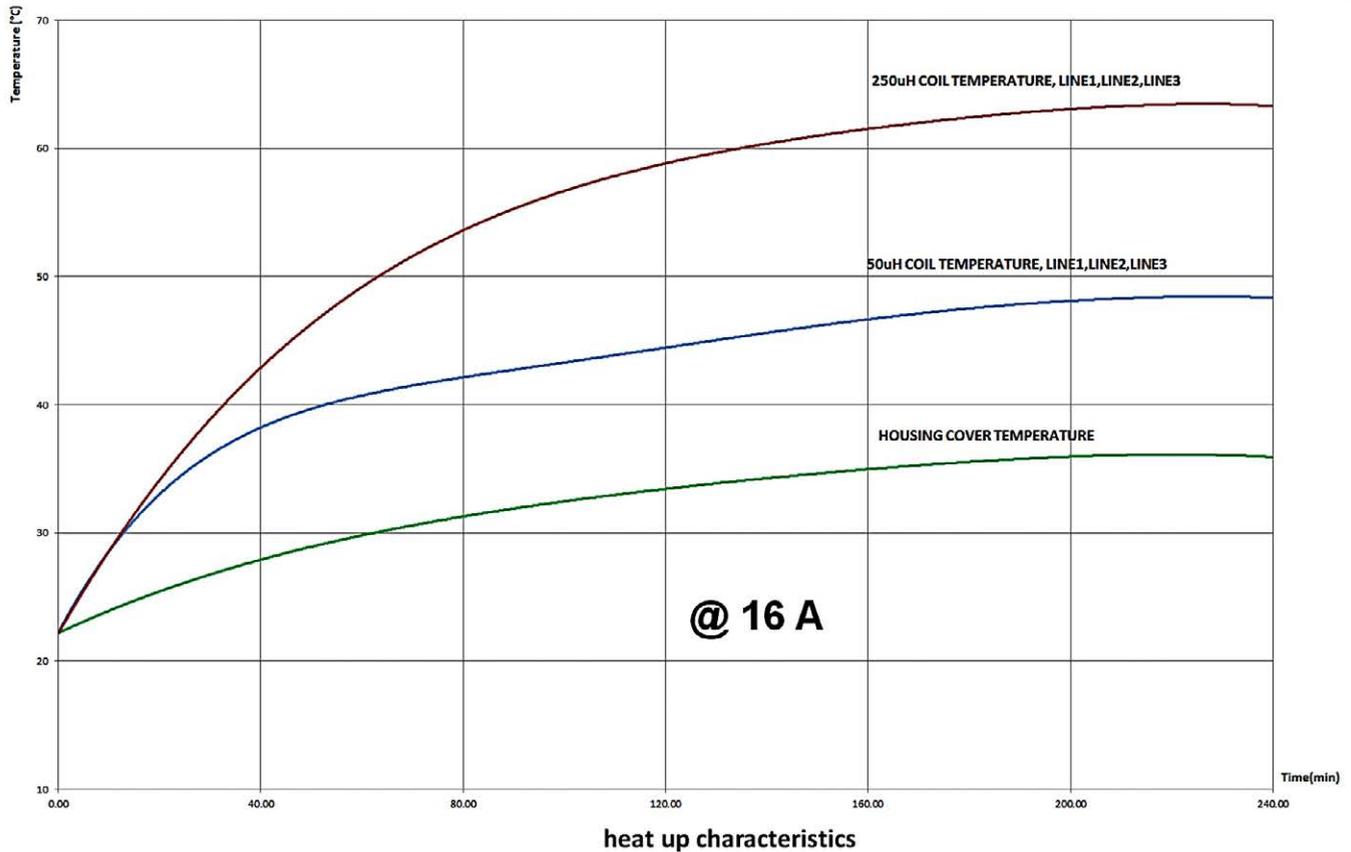


Figure 103: Coil and housing temperature at 16 A DUT current @ 22 °C ambient temperature

2.13 Spectrum analyzer / emi receiver RF input protection

The LISN-CISPER16-32A offers only limited protection to prevent surges appearing at the input of the measurement receiver or analyzer.

All lines and neutral are equipped with a 275V varistor to ground. All four RF paths are protected by a 50V gas discharge tube. In order to suppress residual 50Hz AC from the RF output, the supplied external TBHPF1-9kHz high pass filter always has to be connected to the RF input of the connected spectrum analyzer / EMI-receiver, unless external attenuators or an external combined attenuator / filter / limiter such as the TBFL1 is used.

Find more details in the TBHPF1-9kHz datasheet that can be downloaded from our website.

Additional protection using a combined attenuator/ highpass filter / limiter at the spectrum analyzer RF input is recommended. Tekbox offers a range of suitable attenuators and a combined attenuator / filter / limiter.

2.14 Artificial hand

When performing conducted noise measurements with devices which are held in hand, the artificial hand network mimics the influence of the human hand. Examples for such devices are power tools, hair driers, kitchen tools and similar equipment. Insulated housing sections that are touched by the hand when operating the equipment are covered with metal foil and connected to the artificial hand jack.

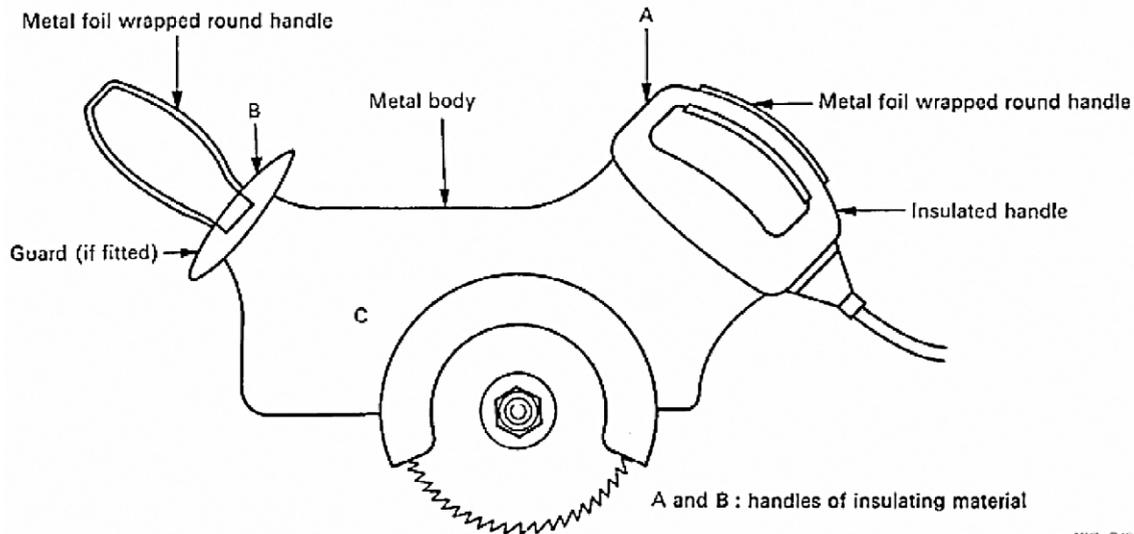


Figure 114 – Example from CISPR 16, portable electric saw with artificial hand

3 OPERATION CHECKLIST

- Setup the isolation transformer, LISN-CISPER16-32A , DUT and spectrum analyzer according to Figure 3.
- Before powering the isolation transformer, measure the connectivity between each equipment chassis and ground plane.
- Ensure that the supply cable of the isolation transformer, the supply cable of the LISN, the supply cable of the spectrum analyzer and if applicable the supply cable of the DUT contain a ground conductor.
- Ensure, that the RF cable is not yet connected
- Ensure that the Protective Earth switch is set to direct ground position
- Ensure that the 9 kHz high pass filter or a Limiter/Attenuator is attached to the RF input of the analyzer.
- Ensure that the power switch of the LISN-CISPER16-32A is in “OFF” position.
- Ensure that the DUT power switch is in “OFF” position.
- Power on the isolation transformer
- Power on the spectrum analyzer, set frequency, bandwidth, amplitude etc.
- Power on the LISN-CISPER16-32A
- Power on the DUT
- Connect the RF cable to carry out the conducted noise measurements. If the conducted noise is not exceeding the analyzer input limits, remove the Limiter/Attenuator for better sensitivity and in order to avoid potential intermodulation. However, never use the analyzer without the 9 kHz HPF
- After finishing the measurement, proceed in reverse order. Take special care to disconnect the RF cable before powering off the DUT.

4 TBHPF1-9KHZ HIGH PASS FILTER

4.1 Technical Data

High Pass Filter, reflective, 50 Ohm

3dB bandwidth: 9 kHz – 3 GHz

Maximum input voltage: 100V; 250V for < 5 sec.

Maximum permitted input current at frequencies < 9kHz and open output: 160 mA

Maximum input power at frequencies 20 kHz – 1 GHz: 10W

Resistive dampening to prevent pulses with high rise time cause excessive ringing.

Connectors: N-Male / N-Female

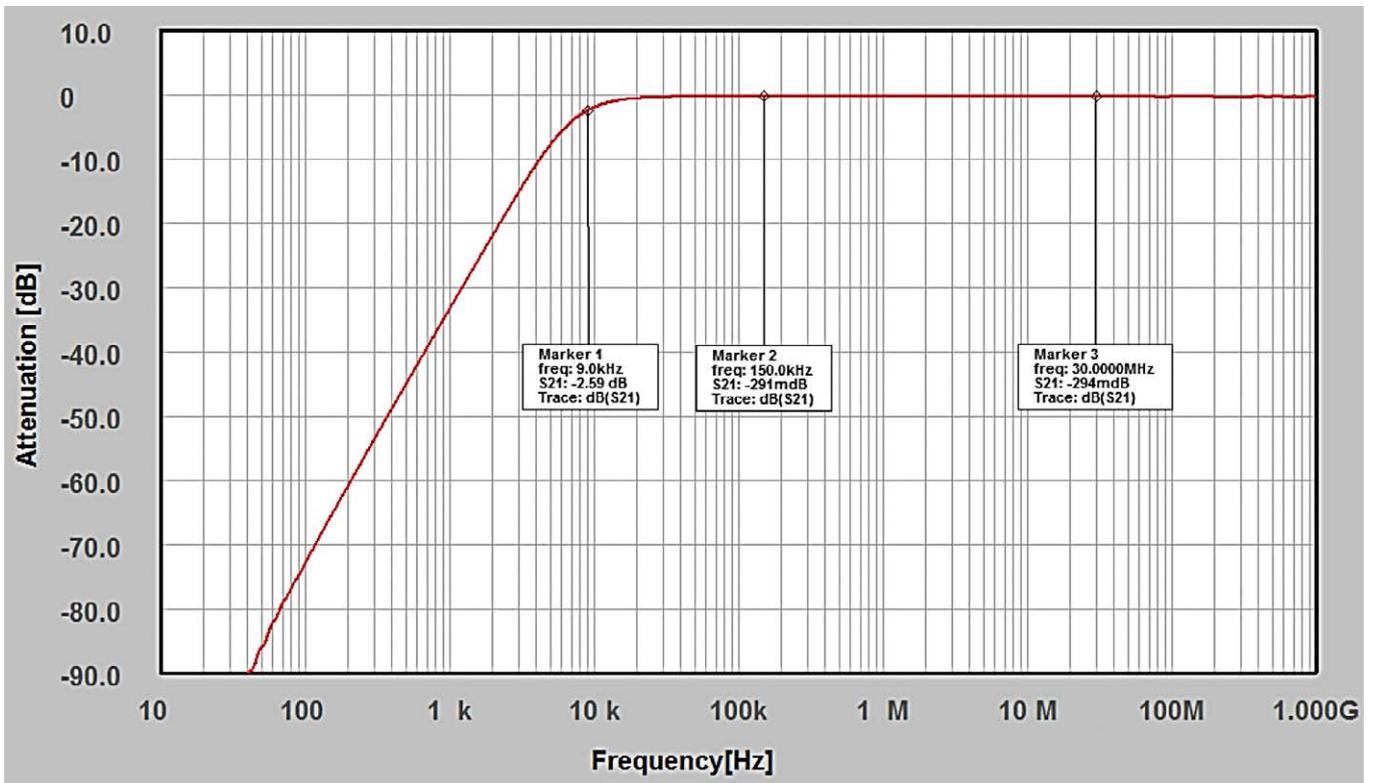
Dimensions: 26 x 26 x 82 mm

Weight: ca. 100g



4.2 Frequency response

Typical data, 50 Ohm system



TBHPF1-9kHz: Attenuation 10 Hz to 1 GHz, typical data

Attenuation table, 50 Ohm system:

Frequency [Hz]	Attenuation [dB]	Frequency [Hz]	Attenuation [dB]
30	97.13	13000	1.15
40	89.93	14000	1.02
50	85.91	15000	0.91
100	73.25	20000	0.61
250	57.30	25000	0.49
500	45.27	50000	0.33
750	38.20	100000	0.29
1000	33.20	250000	0.27
2500	17.59	500000	0.27
5000	7.31	1000000	0.27
6000	5.29	10000000	0.27
7000	3.92	30000000	0.28
8000	2.99	100000000	0.41
9000	2.35	250000000	0.53
10000	1.90	500000000	0.39
11000	1.57	750000000	0.43
12000	1.33	1000000000	0.46

TBHPF1-9kHz: Attenuation 10 Hz to 1 GHz, typical data

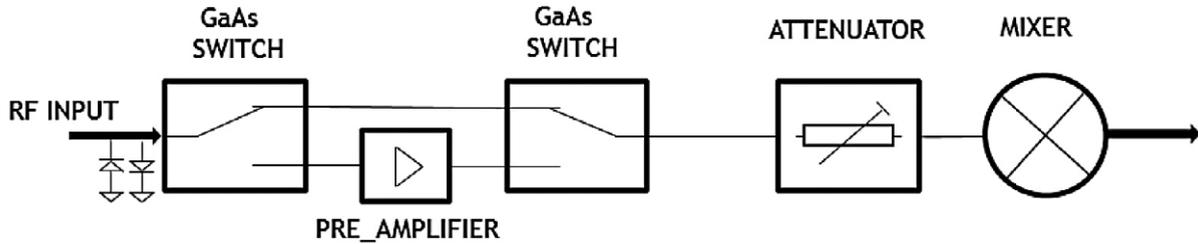
Voltage attenuation table, 1 MΩ load impedance:

Frequency [Hz]	Vout/Vin [dB]	Frequency [Hz]	Vout/V in [dB]
30	>60	7000	1.92
40	>60	8000	0.43
50	>60	9000	0.085
100	>60	10000	0.25
250	>60	20000	0.47
500	58.6	25000	0.56
750	53.9	50000	0.42
1000	48.4	100000	0.17
2500	20.1	250000	0.083
5000	9.93	500000	0.042
6000	6.11	1000000	0.034

4.3 Application

Analyzer RF frontend limitations:

Whenever working with spectrum analyzers, be aware that excessive input power, voltage transients or ESD can damage the RF-frontend. Spectrum analyzers typically have a maximum CW input rating in the range of +20 dBm to +30 dBm. Unlike oscilloscopes, spectrum analyzer inputs are not protected or only vaguely protected. A simplified RF frontend looks as below:



The diodes at the input typically serve as ESD protection diodes. In order to fully protect the input with a limiter, shunt diodes would need to be combined with a series resistor to limit forward current in case of excessive input signal. Consequently, a classic current limiting resistor solution cannot be implemented, as it would increase the input impedance of the analyzer.

A limiter could be implemented by combining it with an attenuator, however this would degrade the sensitivity of the analyzer and limit its use.

The first weak link of the input chain is the RF switch. Typical EMI spectrum analyzers use integrated GaAs switches. GaAs switches are inherently weak at low frequencies. Many GaAs switches are not even specified with respect to maximum input power at low frequencies, down to 9 kHz.

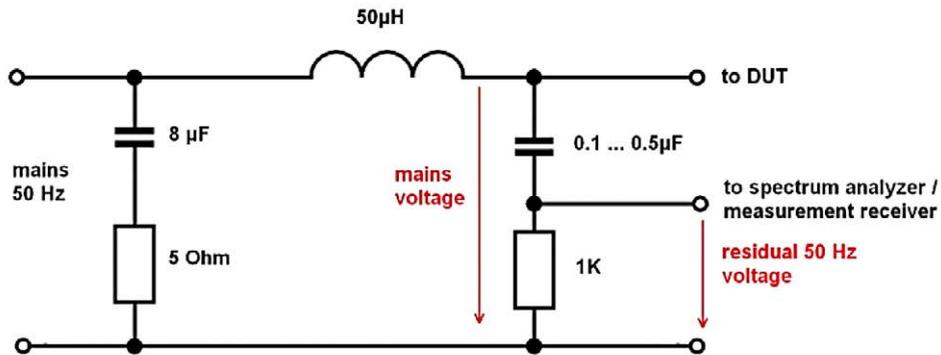
Below is an example data sheet of a typical GaAs switch:

HMC221B	
ABSOLUTE MAXIMUM RATINGS	
Table 2.	
Parameter	Rating
Control Voltage Range (A and B)	-0.2 V dc to 12 V dc
RF Input Power Level (CW Peak, $V_{CTL} = 0\text{ V}/5\text{ V}$)	0.36 W
10 kHz to 10 MHz	8 dBm
10 MHz to 20 MHz	10 dBm
20 MHz to 30 MHz	11 dBm
30 MHz to 250 MHz	14 dBm
250 MHz to 3.0 GHz	31 dBm
Hot Switching RF Input Power Level (CW Peak, $V_{CTL} = 0\text{ V}/5\text{ V}$)	
10 kHz to 250 MHz	6 dBm
250 MHz to 3.0 GHz	20 dBm

The maximum RF input power ratings versus frequency clearly show the degradation at low frequencies.

Residual 50 Hz voltage at the RF output of LISN:

The picture below shows the basic circuit diagram of an AC LISN:



The full AC mains voltage is present at the DUT terminals of the LISN. The RF coupling capacitor and the 1K resistor form a voltage divider, which determines the amplitude of the 50 Hz voltage at the RF connector.

Considering a 0.1 μF capacitor, which has an impedance of 32K at 50 Hz. Together with the 1K resistor, the resulting 50 Hz voltage at the RF terminal of the LISN is approximately 6.6V in the absence of any load. Assuming a 50 Ohm load in parallel to the 1K resistor, the residual 50 Hz voltage would become negligible.

Some LISN may need to use a higher value, in order to meet the impedance specifications at lower frequencies. Assuming a 0.5 μF capacitor, the residual 50 Hz voltage at the RF terminal of the LISN would be as high as 31V. This still would become reduced to a negligible value, if a 50 Ohm load in parallel to the 1K resistor is present.

However, it is unlikely that a low cost analyzer has an input impedance of 50 Ohm at 50 Hz. Typically the input impedance is not specified for frequencies below 9 kHz. Furthermore, as already mentioned, low cost analyzers use GaAs switches at the RF input, which are inherently vulnerable at low frequencies.

Consequently, placing a 9 kHz high pass filters, or 150 kHz high pass filters at the RF input of a spectrum analyzer or measurement receiver will offer good protection against residual 50 Hz voltage. Due to its very low insertion loss in the pass band, it will not reduce the dynamic range of the measurement.

Sub-harmonics of switched mode regulators:

When carrying out conducted noise tests of switched-mode power supplies, the highest spurious levels occur at relatively low frequencies. Sub-harmonics are even more critical. These are typically at frequencies significantly below 100 kHz and unless they produce audible noise due to magnetostriction of the power inductors, they often go completely unnoticed, as most tests start at 9 kHz or 150 kHz. You may carry out a conducted noise test and wonder, why the analyzer beeps and displays an ADC overflow warning, despite all spurious being well below limits. What drives the attenuator into saturation may be a very high amplitude sub-harmonic at e.g. 6 kHz.

In case that you notice that your signals are in the range of 20 dB lower than what they actually are, disaster already happened. The first GaAs switch is already damaged. In most cases, it fails with a short on the RF path and protects the following components, but in extreme cases, the damage will reach as far as the first mixer.

In order to prevent such things happen, you always should start investigating any new DUT using external attenuators, high pass filters or a combined attenuator/filter/limiter. With an external 20 dB attenuator or limiter attached to the analyzer input, have a look at the spectrum at very low frequencies and ensure that there are no signals with critically high amplitude. Alternatively, you can first connect an oscilloscope to the LISN RF output and check the DUT emissions in the time domain. In order to establish the same impedance level as with a connected spectrum analyzer, terminate the oscilloscope input with a 50 Ohm feed through or switch the input to 50 Ohm, if the scope offers this feature.

5 LISN LIMITATIONS

LISN are limited with respect to its frequency range, both on the low end and towards higher frequencies. Consequently LISN cannot be used to measure conducted emissions on most data lines. This is the domain of RF current monitoring probes.

LISN are limited with respect to current and voltage ratings. LISN cannot be practically implemented for very high voltages and high currents. LISN for currents up to 800A and voltages up to 1500 V is about as far as you can go. In cases where LISN cannot be applied or suitable LISN are not available, capacitive voltage probes (CVP), capacitive foil probes (CFP), EFT and current probes may be used instead.

6 SPECTRUM ANALYZER / EMI RECEIVER RF INPUT PROTECTION

High amplitude spurious, sub harmonics, high voltage transients and residual 50Hz voltage may potentially damage the RF input of connected spectrum analyzers or EMI receivers. Consequently, it is recommended to apply protective measures such as attenuators, high pass filters or combined attenuator / filter / limiters such as the TBFL1, when operating LISN.

Read our How to use spectrum analyzers for EMC testing application note for more details on this subject.

7 LISN APPLICATIONS

LISN are not only used for conducted emission measurement, but for establishing a defined supply line impedance in numerous measurement set ups. The following examples are just a few out of many.

7.1 Conducted emission measurements, voltage method

In EMC pre-compliance testing, LISN are primarily used for conducted emission measurements on supply lines.

Chapter 6 shows examples of conducted emission measurement set-ups for various standards.

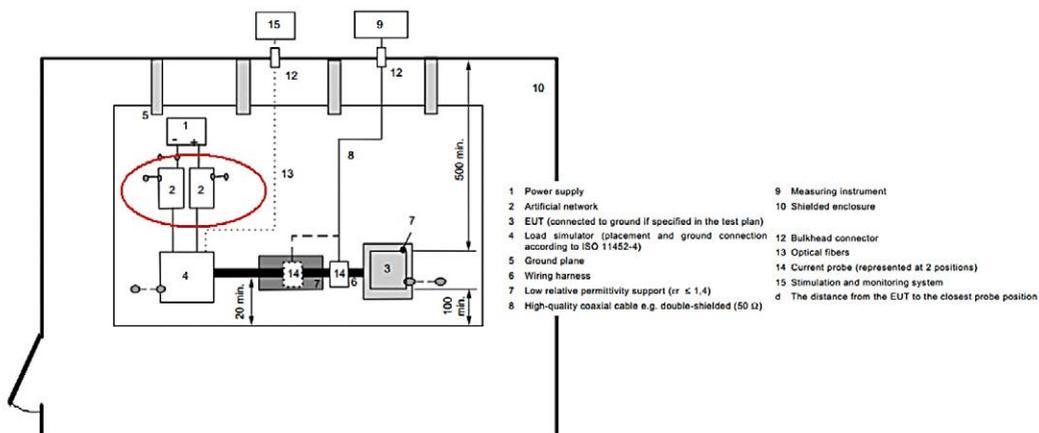
DC powered equipment is measured on its DC supply lines and AC-mains powered equipment is measured on its mains supply lines.

In case of a device with an external power supply, such as a laptop, a 3D-printer or a mobile phone with charger, just to name a few, the standard only requires testing at the AC-mains side and does not bother the interconnecting supply cable from the power supply or charger to the connected device. This does not mean that noise on these lines will go unpunished. Noise on any interconnecting supply lines will radiate from the cable and potentially cause failing the radiated noise tests of the product.

Hence it is good practice to insert a pair of 5µH LISN in between the power supply and the attached device and to check conducted emissions on the interconnecting cable. As both the power supply and the associated device may produce conducted emissions, make a first measurement with the EUT terminals connected to the power supply terminal and thereafter flip the LISN to check the emissions on the supply input terminals of the connected device. There are no limits specified for this case, so apply the limits specified for the mains powered side and ensure that the emissions are within limits to avoid a bad surprise at the test house.

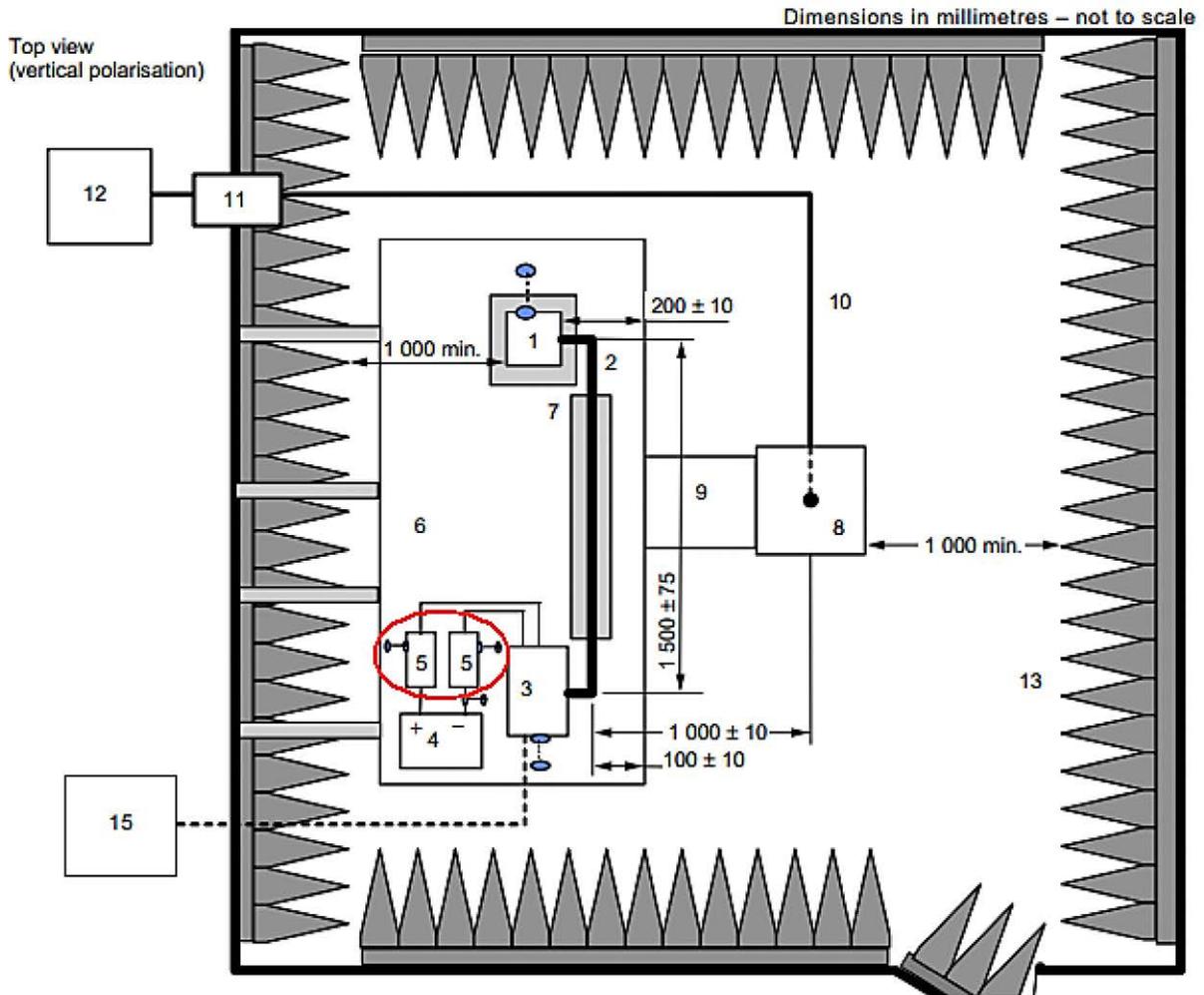
7.1 Conducted emission measurements, current method

Example set up from CISPR 25. LISN in the supply lines create a defined impedance level. The LISN RF outputs are terminated with 50 Ohm and not used for conducted noise measurement:



7.1 Radiated emission measurements

Example set up from CISPR 25. LISN in the supply lines create a defined impedance level. The LISN RF outputs are terminated with 50 Ohm.



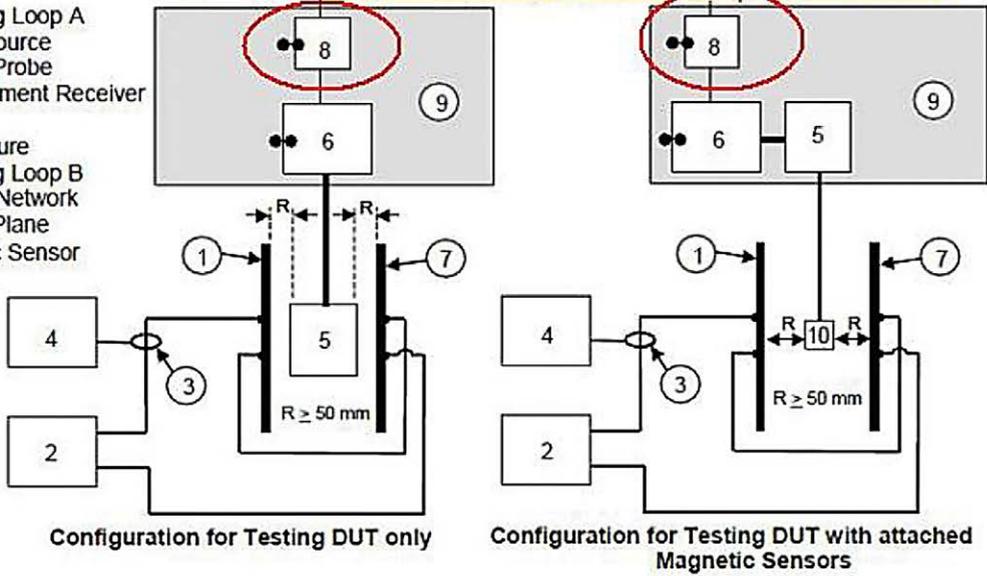
- | | |
|---|--|
| <ul style="list-style-type: none"> 1 EUT (grounded locally if required in test plan) 2 Test harness 3 Load simulator (placement and ground connection according to 6.4.2.5) 4 Power supply (location optional) 5 Artificial network (AN) 6 Ground plane (bonded to shielded enclosure) 7 Low relative permittivity support ($\epsilon_r \leq 1,4$) 8 Rod antenna with counterpoise (dimensions: 600 mm by 600 mm typical) $h = (900 \pm 100)$ mm $h_{cp} = h + (+10 / -20)$ mm | <ul style="list-style-type: none"> 9 Grounding connection (full width bond between counterpoise and ground plane) 10 High-quality coaxial cable e.g. double-shielded (50 Ω) 11 Bulkhead connector 12 Measuring instrument 13 RF absorber material 14 Antenna matching unit (the preferred location is below the counterpoise; if above the counterpoise then the base of the antenna rod shall be at the height of the ground plane) 15 Stimulation and monitoring system |
|---|--|

7.1 Immunity testing

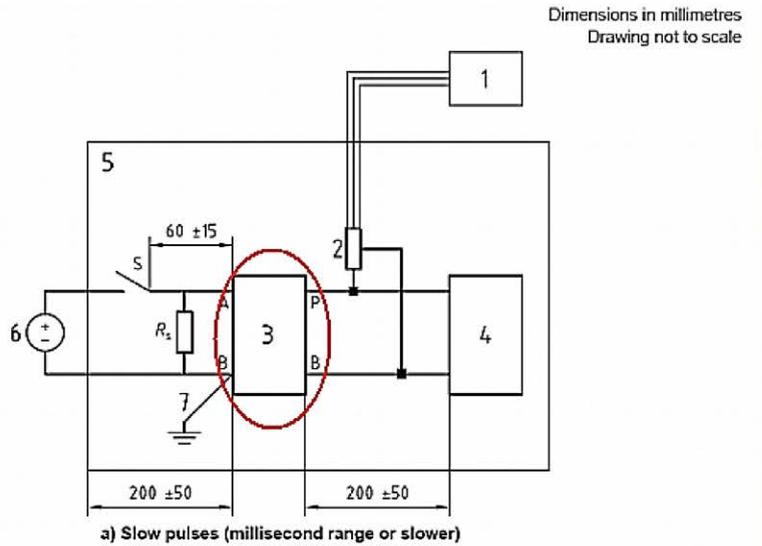
Immunity to magnetic field:

Figure 11- 2: Magnetic Immunity Test Set-ups for Helmholtz Coil

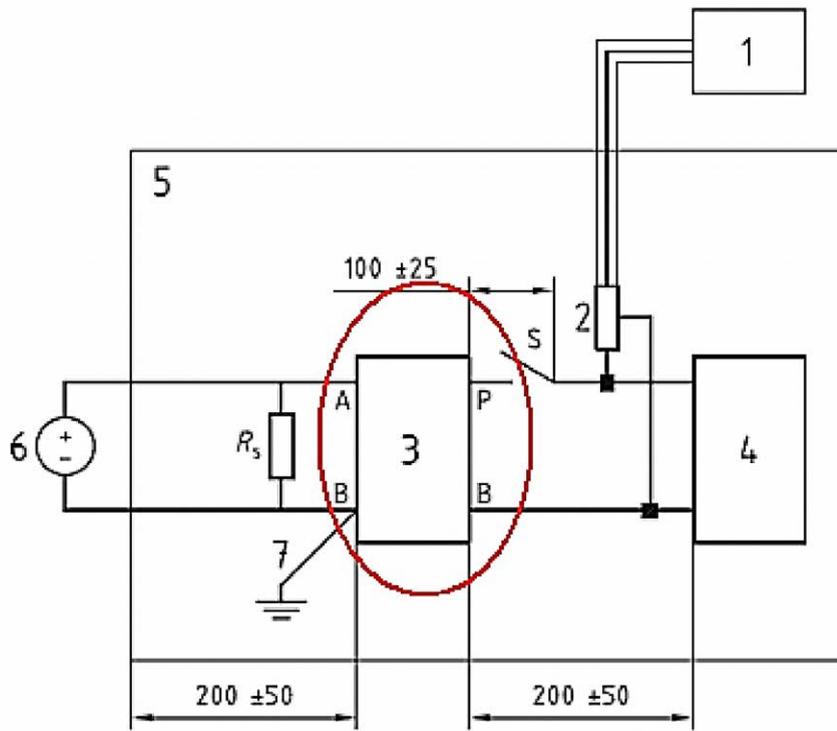
- 1 Radiating Loop A
- 2 Signal Source
- 3 Current Probe
- 4 Measurement Receiver
- 5 DUT
- 6 Test Fixture
- 7 Radiating Loop B
- 8 Artificial Network
- 9 Ground Plane
- 10 Magnetic Sensor



Immunity to voltage transients:



- Key**
- | | |
|------------------------------|--------------------------------------|
| 1 oscilloscope or equivalent | 5 ground plane |
| 2 voltage probe | 6 power supply |
| 3 artificial network | 7 Ground connection; length < 100 mm |
| 4 DUT (source of transient) | |



b) Fast pulses (nanosecond-to-microsecond range)

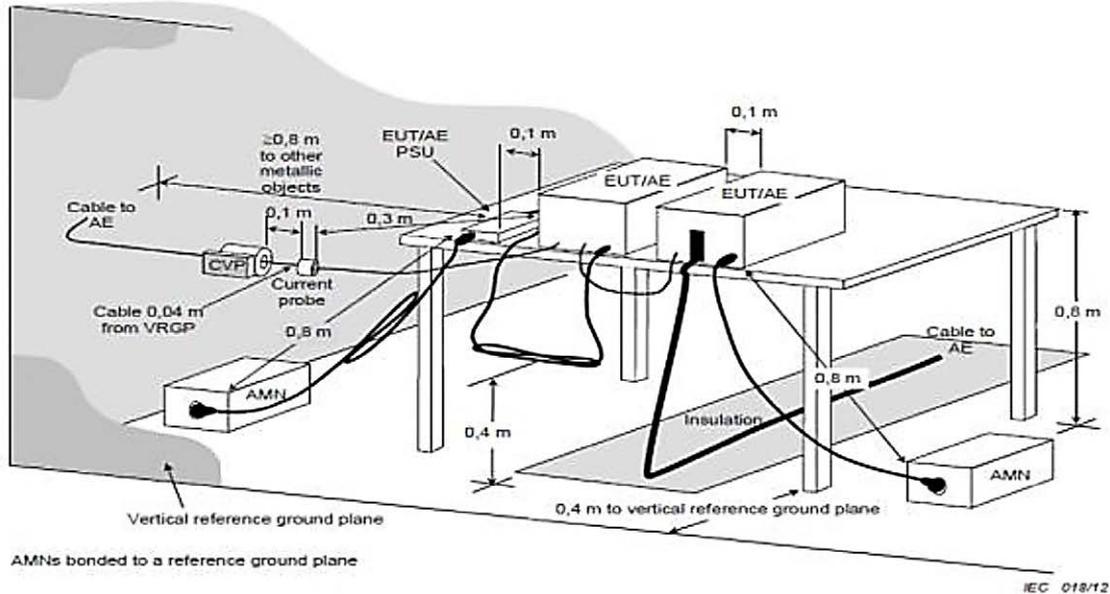
Key

- | | | | |
|---|----------------------------|---|------------------------------------|
| 1 | oscilloscope or equivalent | 5 | ground plane |
| 2 | voltage probe | 6 | power supply |
| 3 | artificial network | 7 | Ground connection; length < 100 mm |
| 4 | DUT (source of transient) | | |

Note that some immunity standards have special requirements with respect to the LISN capacitors.

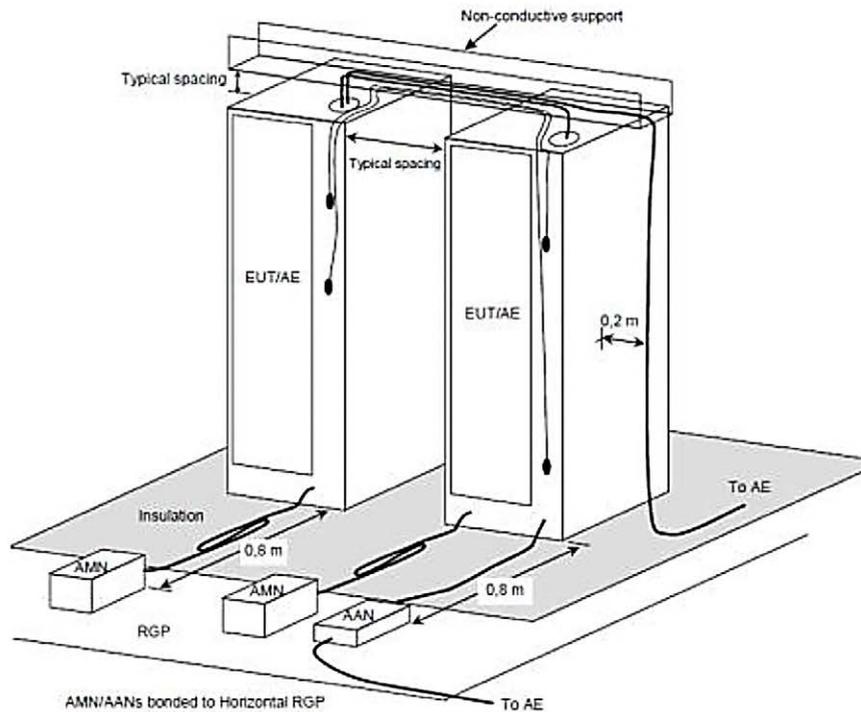
8 LISN SET-UP EXAMPLES FOR CONDUCTED EMISSION MEASUREMENTS

CISPR xx, other than CISPR 25

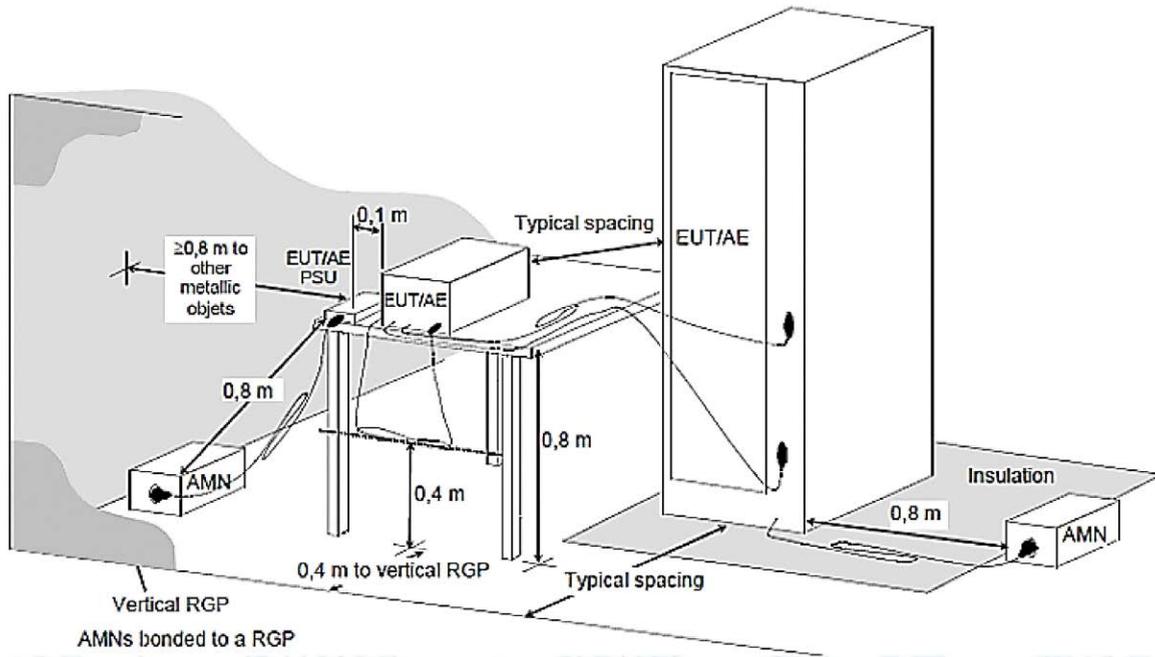


IEC 018/12

Set up for table top equipment

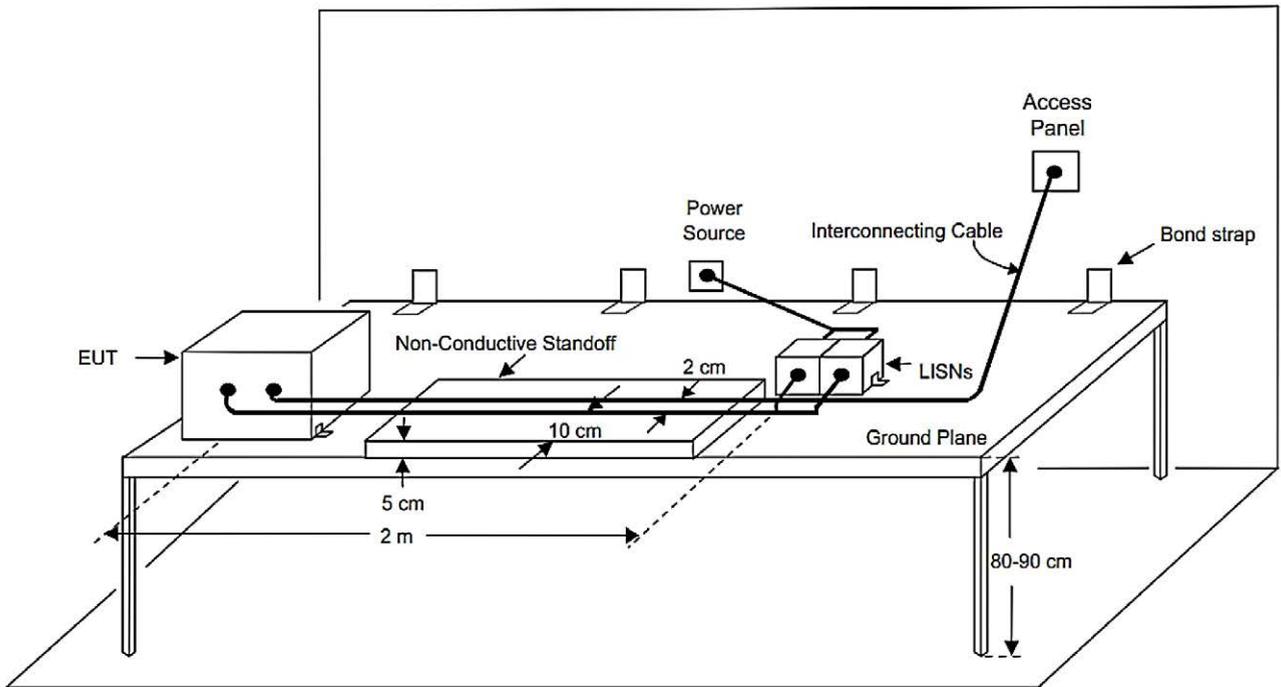


Set up for floor standing equipment

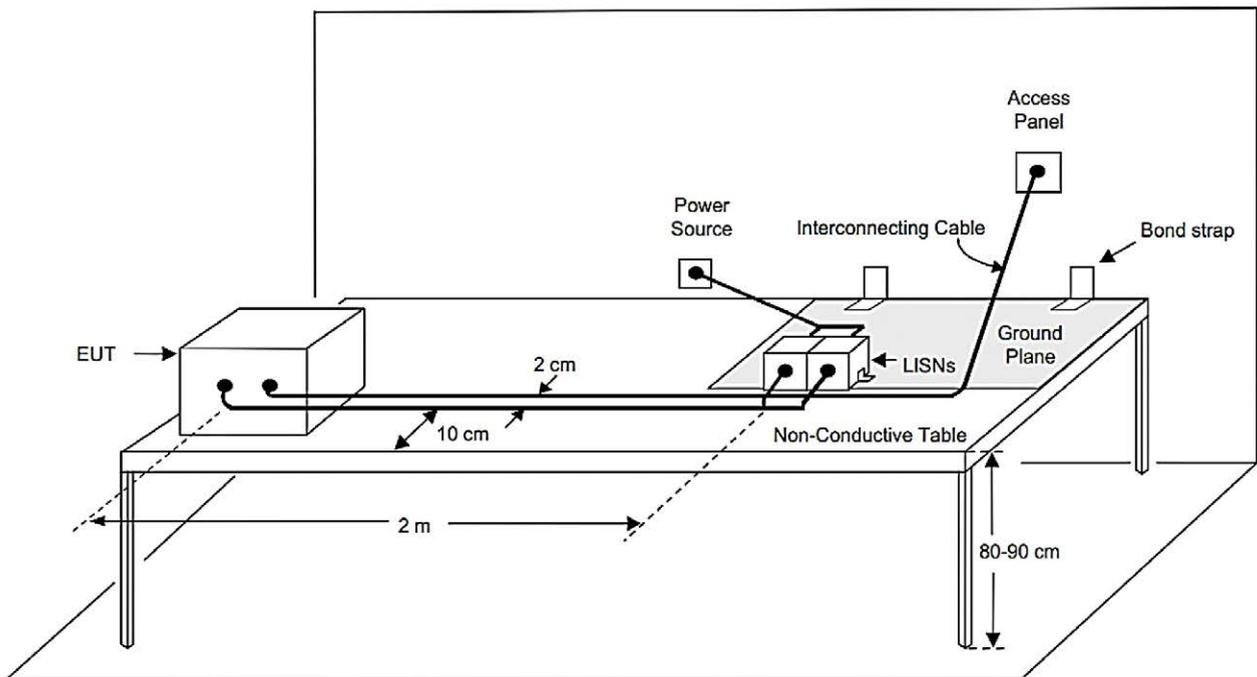


Set up for combination equipment

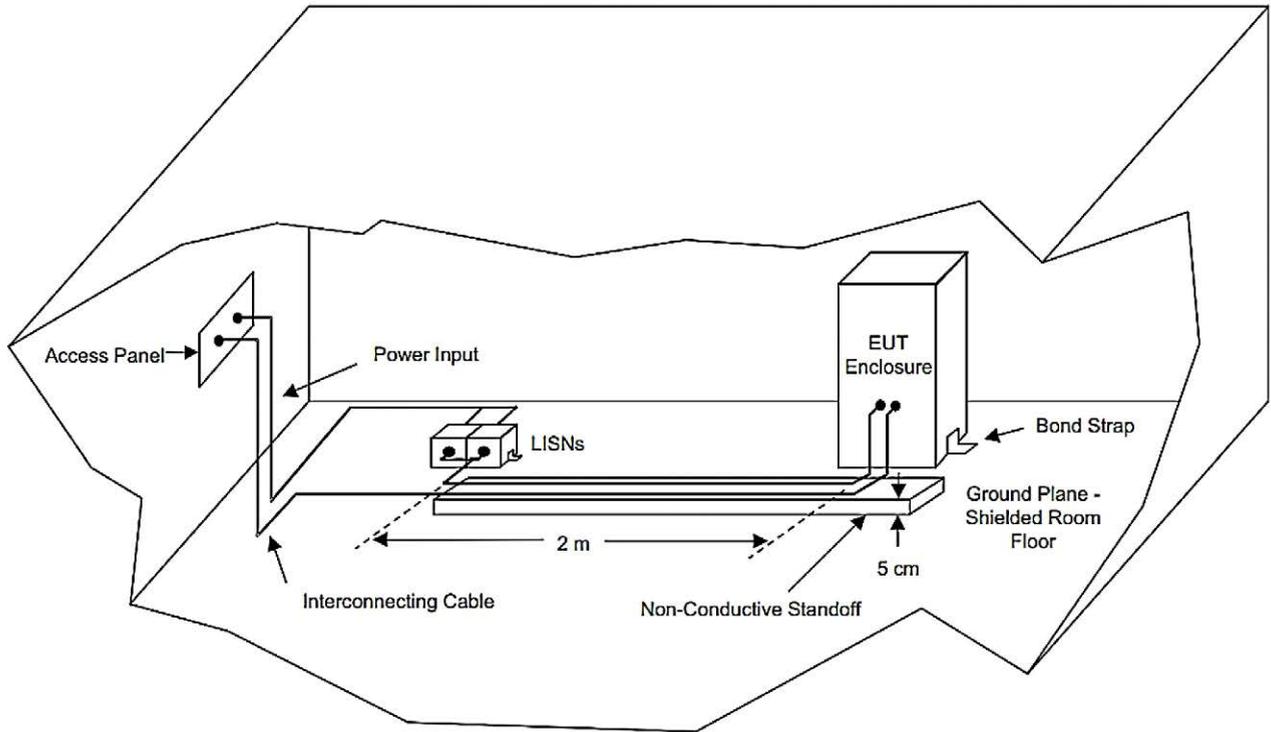
MIL-STD-461F



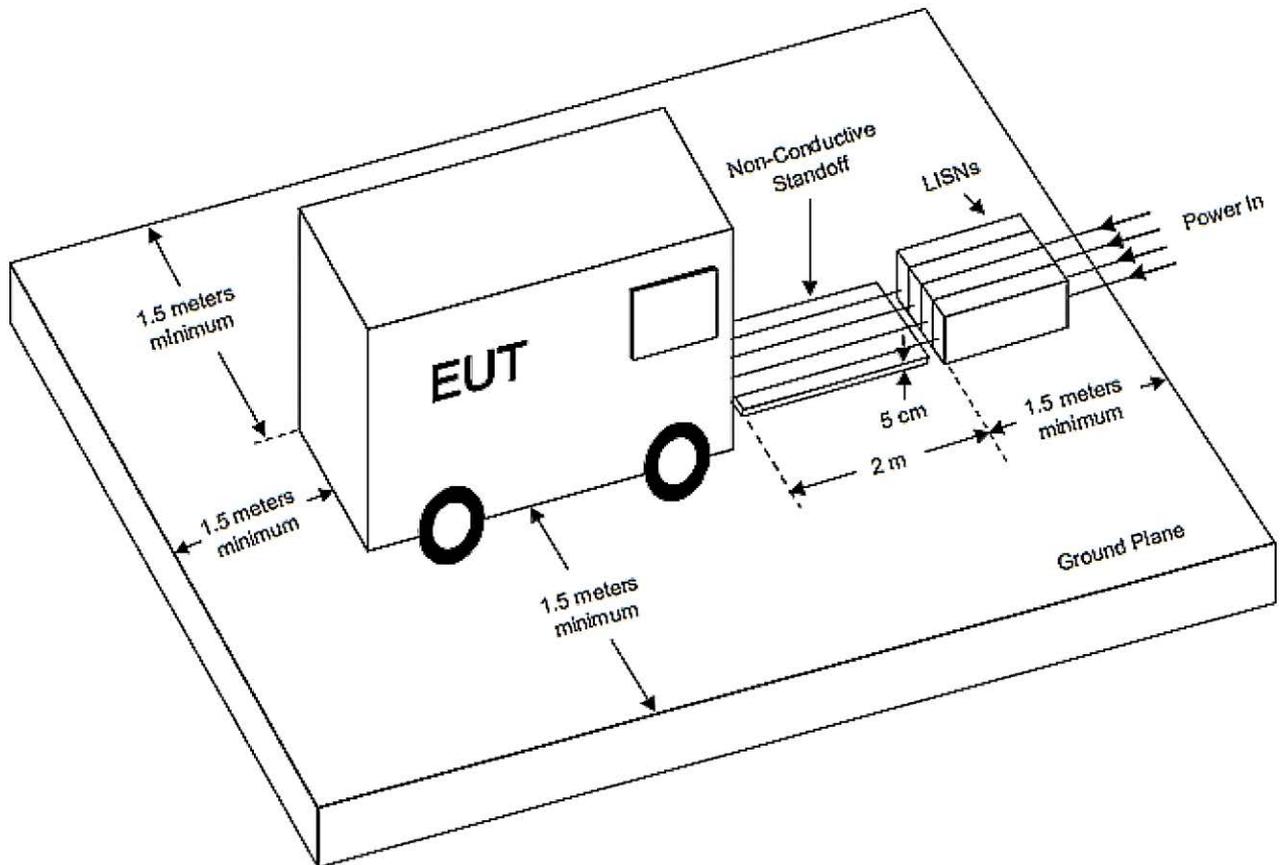
MIL-STD-461F general test setup



MIL-STD-461F setup for non-conductive surface mount EUT



MIL-STD-461F setup for free standing EUT in shielded enclosure



9 INPUT PROTECTION

When carrying out conducted noise tests of switched mode power supplies, the highest spurious levels occur at relatively low frequencies. Sub-harmonics are even more critical. These are typically at frequencies significantly below 100 kHz and often go completely unnoticed, as most tests start at 150 kHz. You may carry out a conducted noise test and wonder, why the analyzer beeps and displays an ADC overflow warning, despite all spurious being well below limits. What drives the attenuator into saturation may be a very high amplitude sub harmonic at 6 kHz.

In case that you notice that your signals are in the range of 20 dB lower than what they actually are, disaster already happened. The first GaAs switch is already damaged. In most cases it fails with a short on the RF path and protects the following components, but in extreme cases, the damage will reach as far as to the first mixer.

In order to prevent such things happen, you always should start investigating any new EUT, using external attenuators or a combined attenuator / limiter, both also available from Tekbox. With an external 20 dB attenuator or limiter attached to the analyzer input, have a look at the spectrum at very low frequencies and ensure that there are no signals with critically high amplitude. Alternatively, you can first connect an oscilloscope to the LISN RF output and check the EUT emissions in the time domain. In order to establish the same impedance level as with a connected spectrum analyzer, terminate the oscilloscope input with a 50 Ohm feed-through or switch the input to 50 Ohm, if the scope offers this feature.

Follow following sequence, when doing conducted emission measurements with a LISN:

- 1) Leave the RF output of the LISN unconnected
- 2) Connect the EUT to the LISN
- 3) Connect the LISN to the isolation transformer
- 4) Power on the EUT
- 5) Check the RF output of the LISN using a scope and / or the analyzer with an external 20 dB attenuator or combined attenuator/limiter
- 6) Connect the RF cable from LISN output to the spectrum analyzer input
- 7) Carry out the conducted noise scan
- 8) Disconnect the RF cable
- 9) Power off the EUT

Purpose of having the analyzer disconnected during powering ON/OFF the EUT is avoiding voltage transients due to back EMF, especially of highly inductive loads such as motors or switched mode power supplies.

In case that your EUT produces sub-harmonics, place a suitable high pass filter at the RF input of the spectrum analyzer. The Tekbox TBFL1 transient limiter not only contains a combined attenuator / limiter, but also a 9 kHz high pass filter. If the sub-harmonic frequency is above 9 kHz, connect a 150 kHz high pass.