emtest MILMEGA TESEQ

CONDUCTED RF EQUIPMENT POWER AMPLIFIERS



IEC 61000-4-6
Conducted Immunity Testing

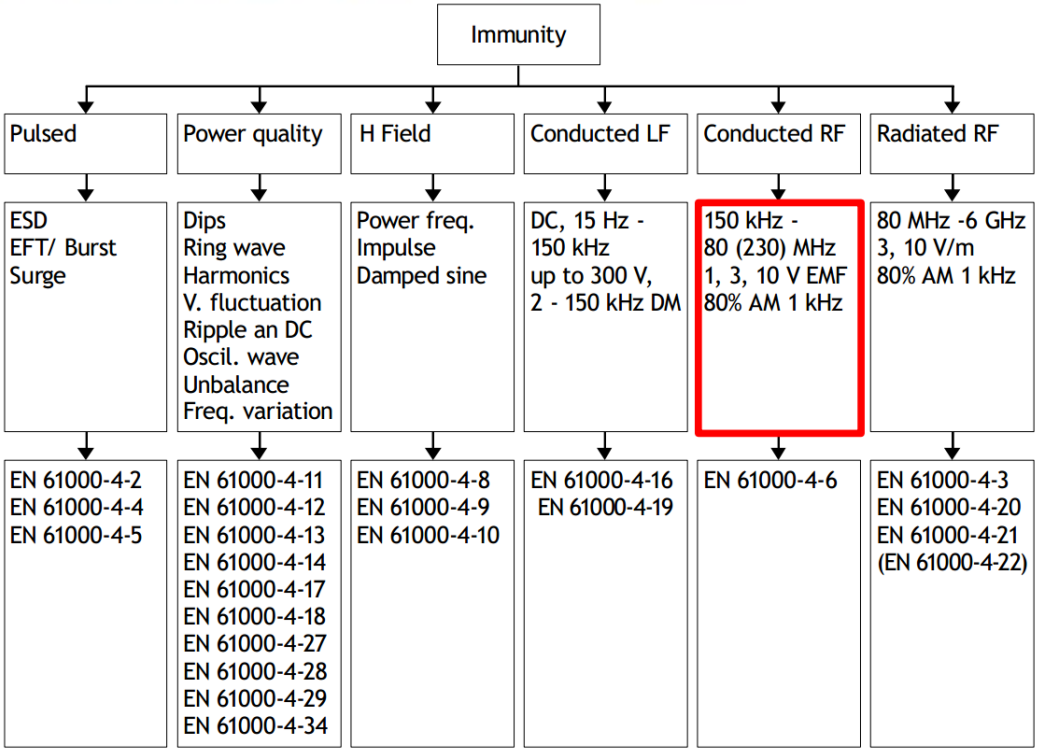
Accelonix EMC workshop 17-9-2019

Accelonix keeping you ahead.

Overview

- IEC/EN 61000-4-6
  - Basics about the standard, standard development
  - Challenge
  - Other points
  - Solutions
  - Setups and Coupling devices

Orientation



BASICS ABOUT THE STANDARD

Standard requirements

Frequency range	150 kHz … 80 (230) MHz
Common mode impedance	150 Ω (in exception 50 Ω)
Test level (EMF)	1 V, 3 V, 10 V and level X, tolerance +19% / -16%
Modulation	1 kHz sinus, tolerance ±100 Hz, AM, 80%, tolerance +5% / -20%
Dwell time	1 s
Step size	max. 1% of the preceding frequency value

Standard requirements

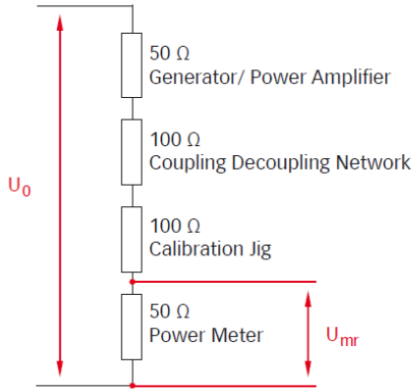
Method for the system calibration	Set-up the coupling device with the 150 Ω calibration jig, adjust the unmodulated test level (U0/6) and measure on the 50 Ω output of the jig
Test method	Using the signal levels established during the system calibration process, switch on the modulation
Power limitation if the 150 Ω can not be meet	Monitoring of the disturbance current and limiting the signal level as follows: Imax = U0/150 Ω
Attenuator	≥ 6 dB
Output impedance of the test generator	50 Ω
Harmonics and distortion below the carrier level	≥ 15 dB (The harmonics and distortion are measured in continuous wave (CW) at 1.8 times the test level without modulation.)

Standard requirements

- U0 the open-circuit test levels (e.m.f.) of the unmodulated disturbing signal, expressed in r.m.s. are 1 V, 3 V or 10 V. The test levels are set at the EUT port of the coupling devices.
- For equipment testing, this signal is 80 % amplitude modulated with a 1 kHz sine wave to simulate actual threats.

Disturbance signal

$U_{mr} = U_0/6$ +19% / -16%, in linear quantities, or
$U_{mr} = U_0$ – 15.6 dB ± 1.5 dB in logarithmic quantities.



$$\frac{U_{mr}}{U_0} = \frac{50}{50+100+100+50}$$

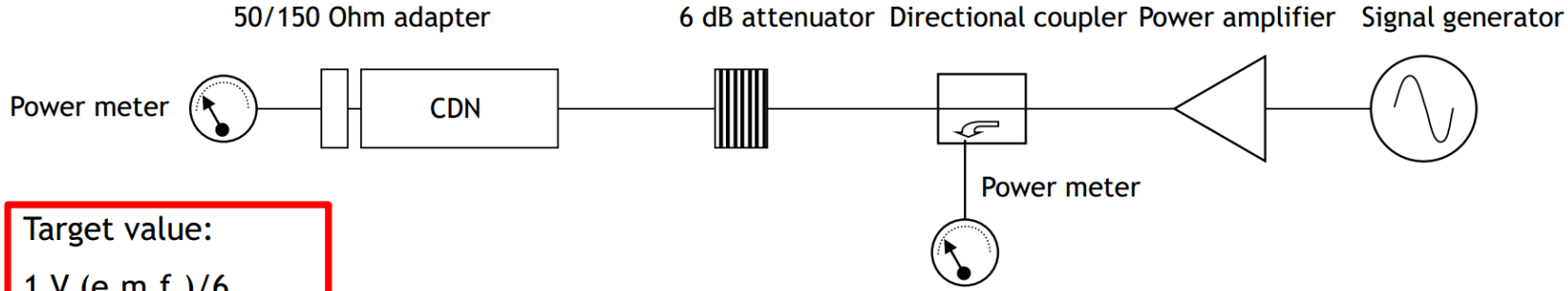
$$U_{mr} = \frac{U_0}{6}$$

Disturbance signal

$$U_{mr} = \frac{U_0}{6}$$

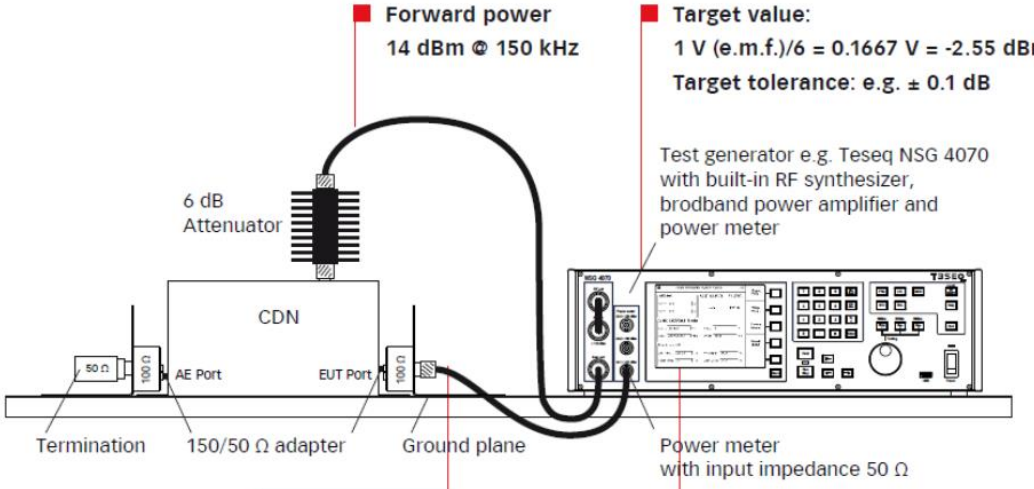
Test level U_0 in V	Measured voltage U_{mr} in V	Measured power on the 50 Ω power meter in dBm
1	0.1667	-2.55
3	0.5	6.99
10	1.667	17.45
20	3.33	23.47
30	5.00	26.99

Calculation example



Target value: 1 V (e.m.f.)/6 = 0.1667 V (at 50 Ω) = -2.55 dBm	Insertion loss	Insertion loss	Forward power	Gain	Output power
	-9.6 dB	-6 dB	+13 dBm	+49 dB	- 36 dBm
-2.55 dBm =	-9.6 dB	-6 dB	+13.05 dBm		
			+13.05 dBm =	+49 dB	-35.95 dBm

Example NSG4070 “system calibration”



Example of calibration file:

Test level: 1 V (e.m.f.)

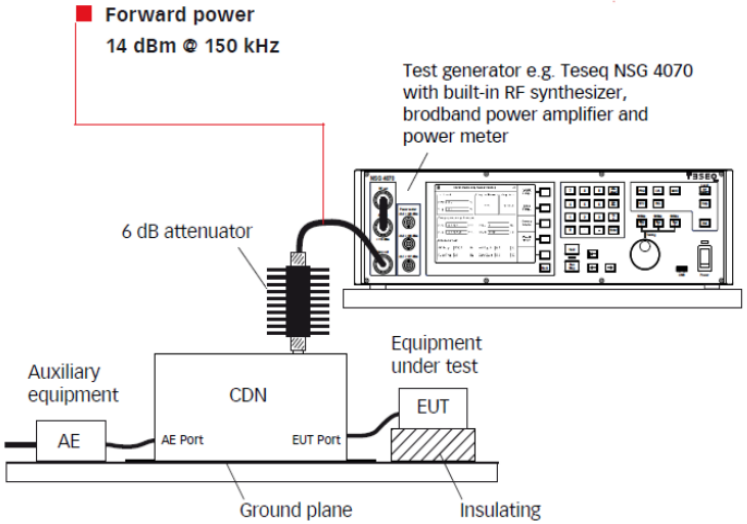
Step: 1%

Frequency	Forward power
150 kHz	14.0 dBm
151.5 kHz	14.15 dBm
153.015 kHz	14.13 dBm

Example NSG4070 Testing

Testing procedure

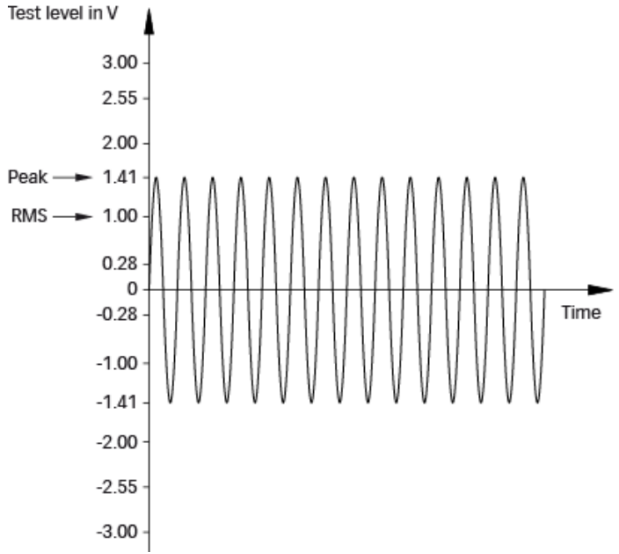
1. Adjust frequency
2. Adjust forward power as given in the calibration file
3. Switch on modulation
4. Check monitoring ports before the dwell time ends
5. Switch off after dwell time and go to next frequency step



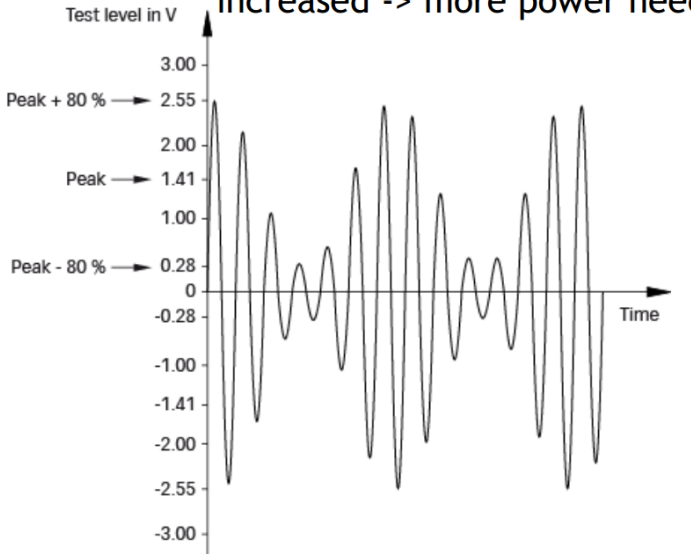
CHALLENGE

AM according IEC/EN 61000-4-6

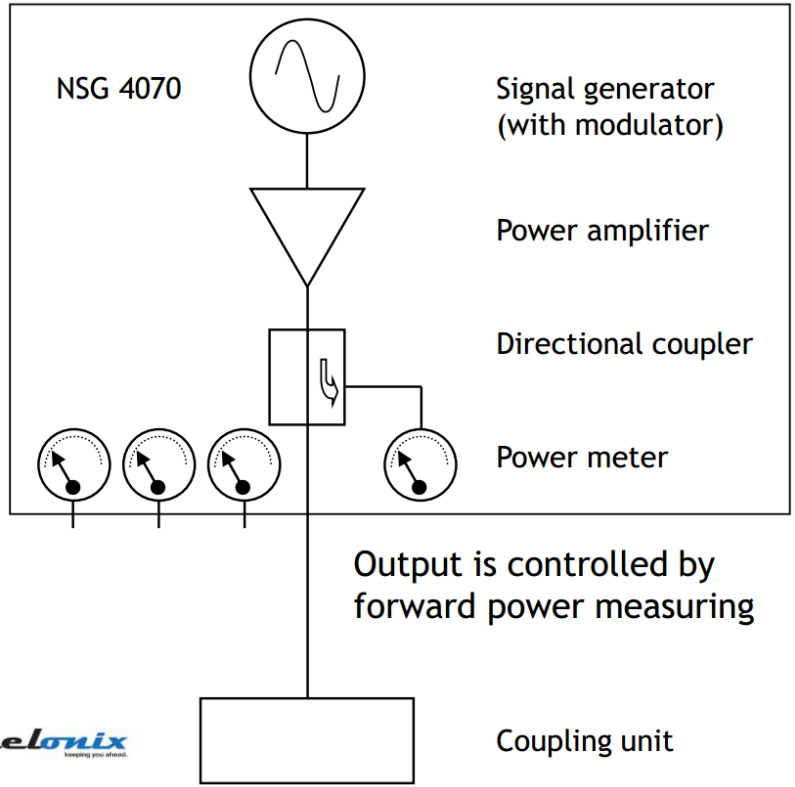
Calibration with CW

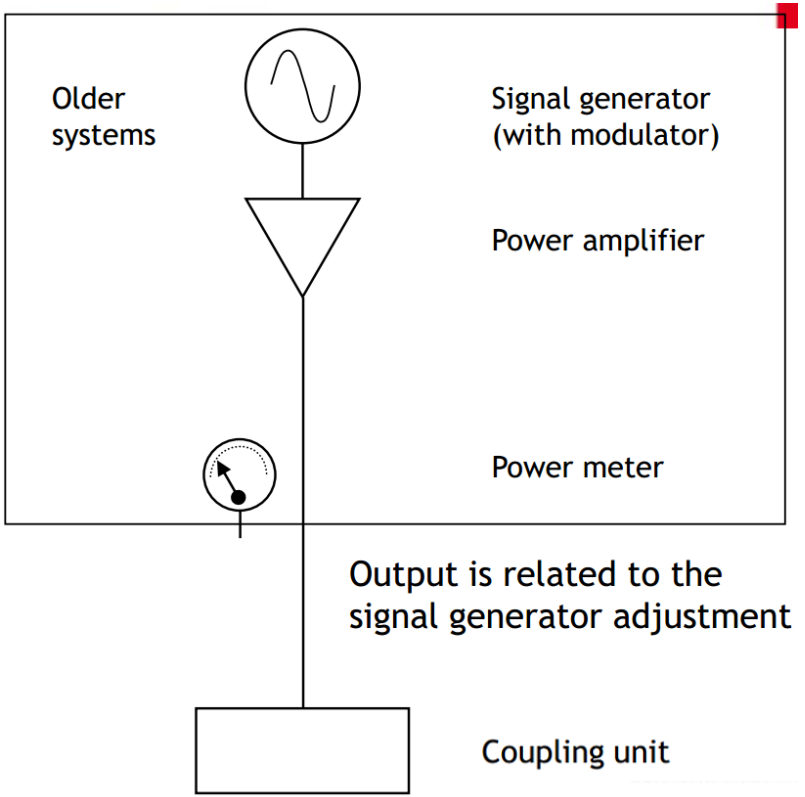


Test with AM 80 % (peak value increased -> more power needed)

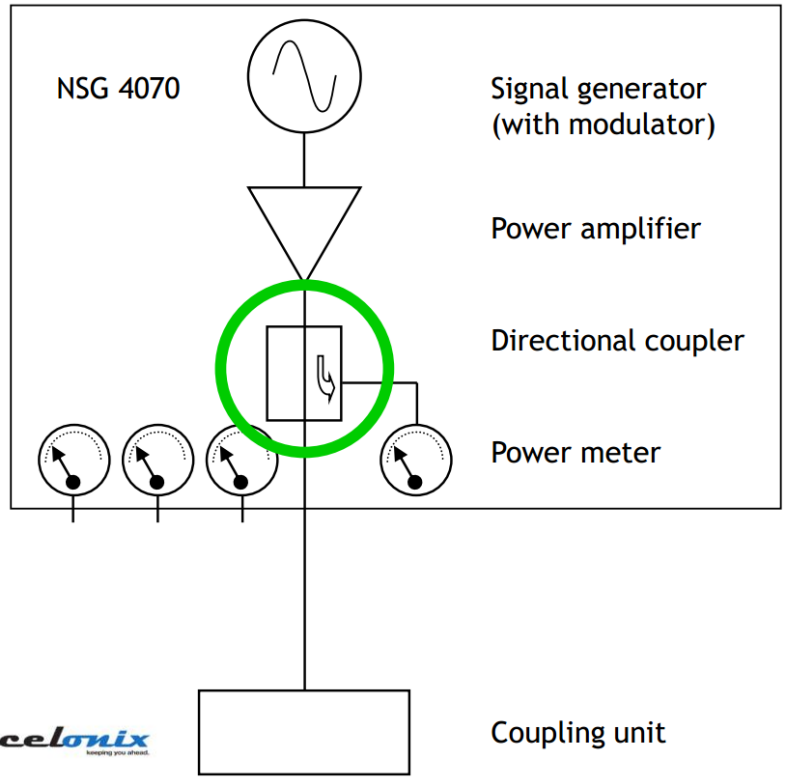


System differences





The big difference



Advantages of “Back to forward power”

- Excludes possible non-linearity of the system (power amplifier)
- Amp saturation will be seen /can be avoided
- Procedure according IEC/EN 61000-4-6:
  - Calibration with CW
  - Testing with modulation required e.g. 5.1 dB more power (80 % modulation depth)

- No chance to be standart compliant with a saturated amplifier

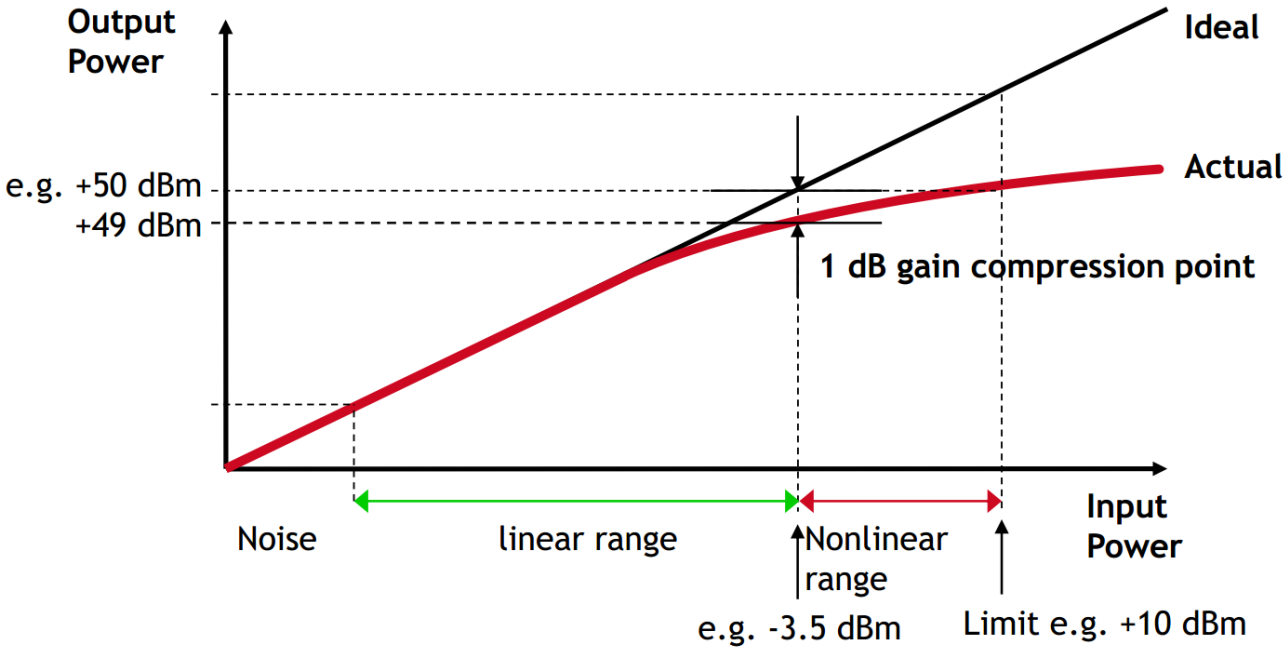
Power requirements IEC/EN 61000-4-6

System calibration with CW → Testing with AM 80 % (increased peak values -> more power needed

U EMF	Forward power		Forward power	
Stress level	calibration		with modulation 80% AM	
V	dBm	Watts	dBm	Watts
1	14,4	0,03	19,5	0,1
3	24,0	0,3	29,1	0,8
10	34,4	2,8	39,5	9,0
30	44,0	25,1	49,1	81,1

Typical power requirements with 6 dB attenuator, 0.5 dB cable loss, 10.5 dB insertion loss of the CDNs and AM with 80%

Problem: PA power



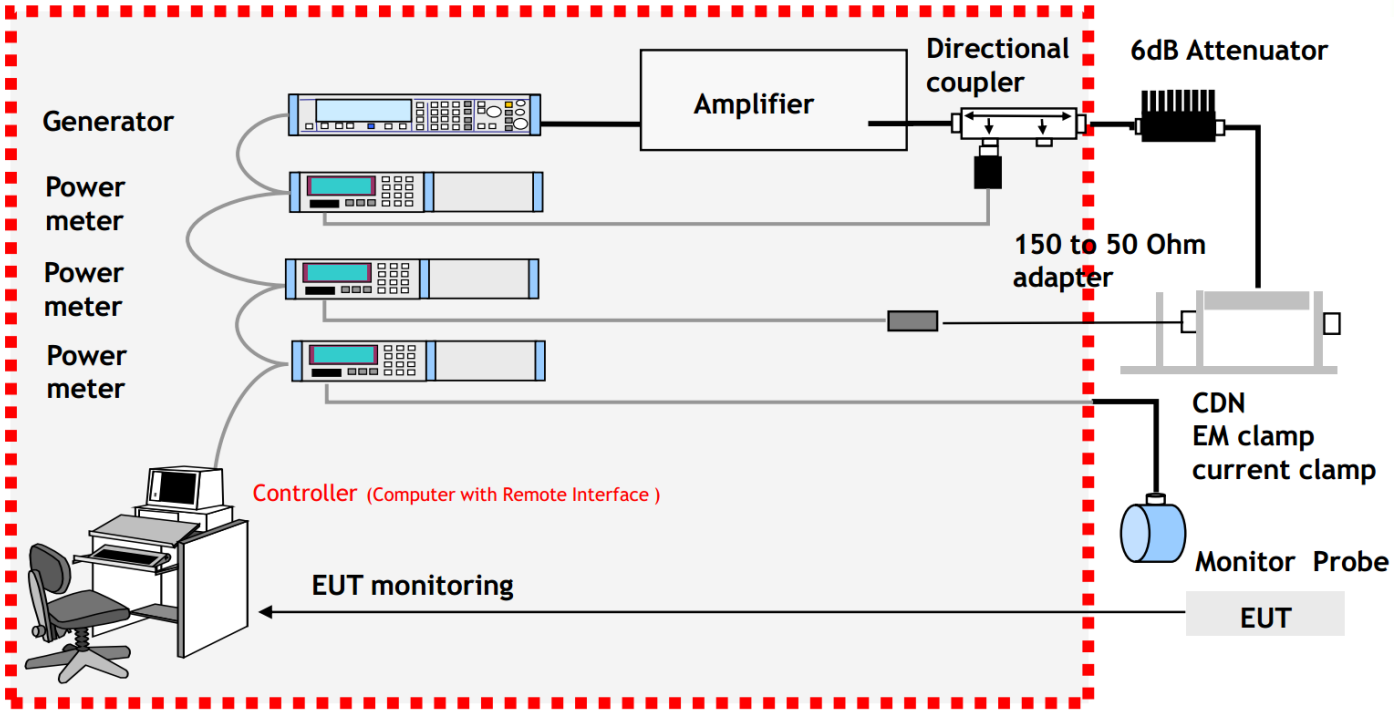
Attenuator for improving VSWR

An attenuator which halves the input voltage, reduces the reflected voltage by 4.

Ametek (Teseq) equipment ?

- Teseq provides full compliant test equipment for conducted immunity applications
- Equipment ensures low uncertainty
- Some important system components for conducted immunity will be presented on the following slides

Tradition


Generator
Power meter
Power meter
Power meter
Amplifier
Directional coupler
6dB Attenuator
150 to 50 Ohm adapter
CDN
EM clamp
current clamp
Monitor Probe
EUT
Controller (Computer with Remote Interface)
EUT monitoring

NSG 4070 functions

Modulator
AM, PM, external

Signal generator
4 kHz - 1 GHz

Power amplifier:
several models

3 power meters:
4 kHz - 1 GHz
Version with internal amplifier: (+1 inside and built-in directional coupler)

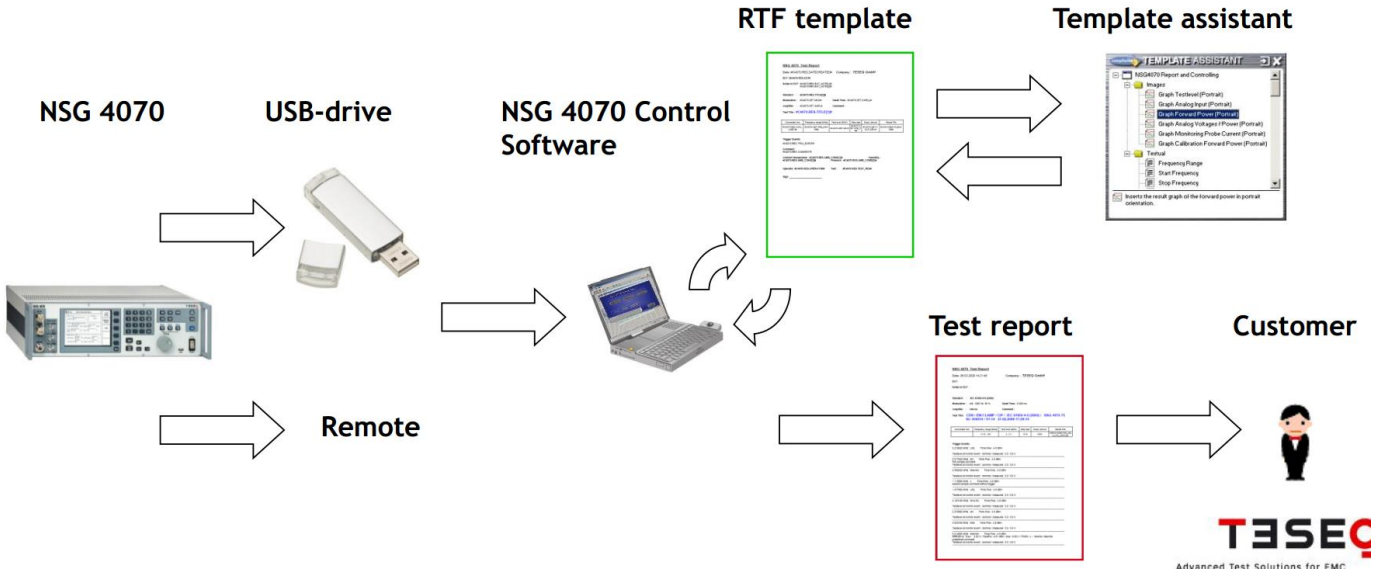
Remote connection:
LAN, USB, opt. RS232
or electr. RS232

EUT monitoring:
8 inputs, 4 outputs

Picture includes option: Rack mounting kit for NSG 4070 (red handles)

Report generation

NSG 4070 control program



Optional windows software icd.control

EUT monitoring

- 1 analog, 1 optical input
- 2 digital inputs
- User port (4 TTL in, 4 TTL out)

- 4 analog inputs 0-24V
- 4 digital inputs 0-24 V
- 8 TTL inputs, 1 optical input
- 8 low level TTL outputs
- IOB 4000 recommended for more complex applications

Features

- Integrated signal generator 4 kHz – 1 GHz
- AM (IEC 61000-4-6) and AM PC (Automotive) 1 Hz to 50 kHz, PM 0.01 Hz to 1 MHz or via external input
- 4 Power meters (thereof 1 for internal use), NSG 4070C-60: 5 Power meters (thereof 2 for internal use)
- Use of external amplifiers and directional couplers possible
- 5,7“ TFT color display as well as hard and soft keys for easy stand alone operation
- Multiple EUT monitoring options
- Several integrated power amplifier modules available

Selection of Power Amplifier

Product	Power amplifier nominal power	Power amplifier frequency range	Immunity testing IEC/EN 61000-4-6)[1] 150 kHz to 230 MHz			Immunity testing Namur)[1] 10 kHz to 80 MHz			Automotive BCI testing)[2] ISO 11452-4: 2011		Automotive BCI testing Ford FMC1278)[2]		MIL-STD-461G CS114)[2]	RTCA DO-160G CS Test)[2]
			CDN	EM clamp	Current injection probe	CDN	EM clamp	Current injection probe	Substitution	Closed loop with k = 4	Substitution	Closed loop with k = 4	Substitution	Closed loop with k = 4
NSG 4070C-0		-	*	*	*	*	*	*	*	*	*	*	*	*
NSG 4070C-0 + external amp	260 W (>10 W at 4 kHz)	10 kHz (4 kHz) to 400 MHz	30 V	30 V	15 V	30 V	11 V	3 V	600 mA > Level IV	300 mA > Level IV	115 dBµA Level 2	109 dBµA Level 2	114 dBµA Level 5	300 mA Level M, Q, R, S, T, W, Y
NSG 4070C-110)[3]	110 W (>10 W at 4 kHz)	10 kHz (4 kHz) to 400 MHz	30 V	26 V	10 V	30 V	7 V	2 V	400 mA > Level IV	200 mA > Level IV	112 dBµA Level 2	106 dBµA Level 2	114 dBµA Level 5	200 mA Level M, R, S, T, W
NSG 4070C-80	80 W	150 kHz to 230 MHz	30 V	22 V	8 V	*	*	*	*	*	*	*	*	*
NSG 4070C-60)[3]	60 W (>10 W at 4 kHz)	10 kHz (4 kHz) to 400 MHz	27 V	19 V	7 V	27 V	5 V	1 V	300 mA > Level IV	150 mA Level III	109 dBµA Level 2	103 dBµA Level 1	109 dBµA Level 5	150 mA Level M, R, S, T, W
NSG 4070C-45	45 W	9 kHz to 1 GHz	24 V	17 V	6 V	24 V	5 V	1 V	260 mA > Level IV	130 mA Level III	108 dBµA Level 2	102 dBµA Level 1	108 dBµA Level 5	130 mA Level M, R, S, T
NSG 4070C-40	40 W	10 kHz to 400 MHz	22 V	16 V	6 V	22 V	4 V	1 V	240 mA > Level IV	120 mA Level III	108 dBµA Level 2	102 dBµA Level 1	108 dBµA Level 5	120 mA Level M, R, S, T
NSG 4070C-35	35 W	150 kHz to 230 MHz	21 V	15 V	5 V	*	*	*	*	*	*	*	*	*

All level calculated in relation to the standard requirements with typical values of the coupling device.

[1]) Calculated with 6 dB attenuator and AM with 80% modulation depth.

[2]) Calculated with highest test level in the frequency range and related typical insertion loss of the BCI probe Teseq CIP 9136A.

[3]) NSG 4070C-60 and NSG 4070C-110 measure the reverse power also with selected internal power amplifier (5 channel power meter and bidirectional coupler) as may required by the BCI standard.

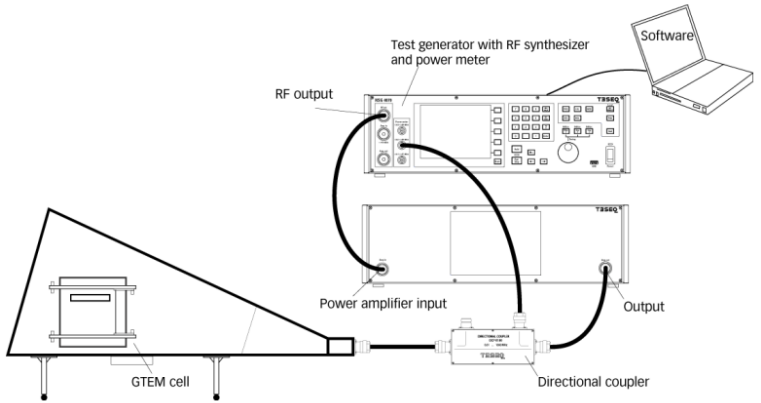
*) Requires external directional coupler and external power amplifier for the frequency range and test level.

Advantages NSG 4070

- Compact generator which replaces a couple of standalone units with no technical disadvantage but more value for money
- USP against other compact generators
  - Class A amplifier (forward power is independent of the load's impedance)
  - Back to forward power controlling (improves systems linearity)
  - Saturation check implemented
  - Report generator which is based on templates (time advantage)
  - Multiple EUT monitoring with 7 inputs and 4 outputs (flexibility, time advantage)

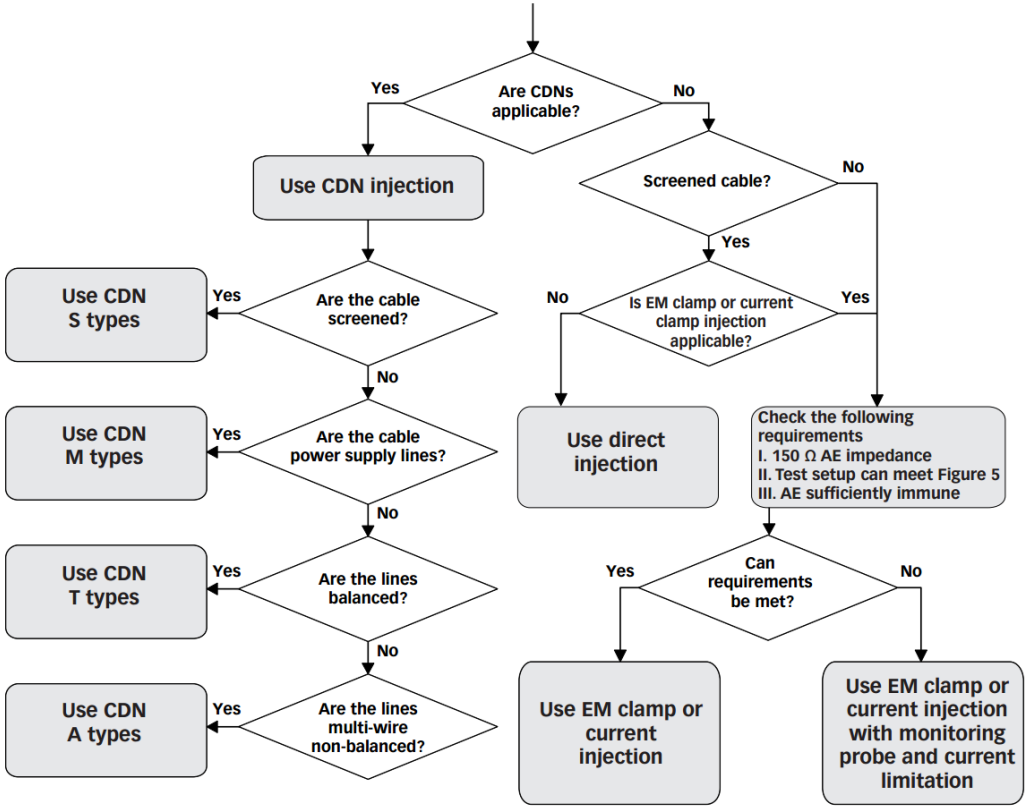
Advantages NSG 4070

- System concept for R&D:
  1. Establishing of own test possibility for IEC/EN 61000-4-6
  2. Upgrade with amplifier, directional coupler, GTEM and control software for testing 80 to 1000 MHz



Coupling devices and setups

IEC/EN 61000-4-6 Rules for selecting the injection method



The right coupling device?

- EMC phenomena: Immunity to conducted disturbances, induced by RF fields
- Frequency range: 150 kHz … 80 (230) MHz
- Level: 1, 3 or 10 V EMF, 150 Ohms system
- Test site: Screened room
- Equipment: Signal generator, power amplifier, power meter, directional coupler, 6 dB attenuator, software
- Coupling device: CDN (M-, AF-, T-, S-types), EM-clamp, current injection clamp (CIP)
- Additional: Calibration sets for level setting

Coupling devices

CDN M

CDN A

CDN S

CDN T

Current injection probe

EM clamp

Calibration adapters

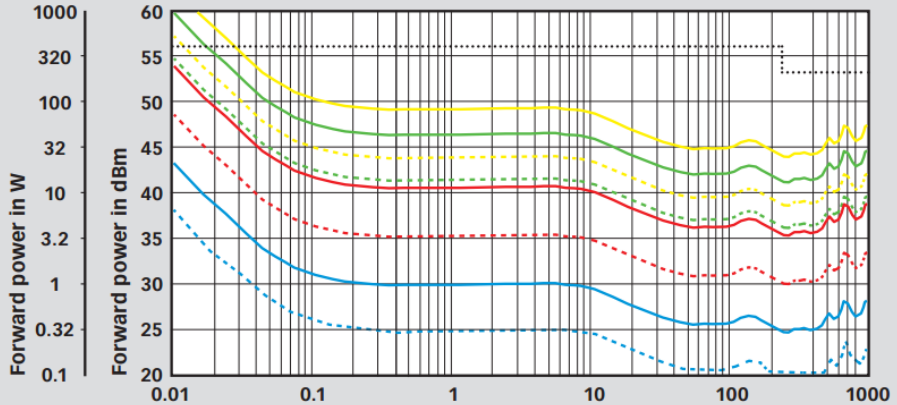
Attenuation clamp
(decoupling only)

KEMZ 801A

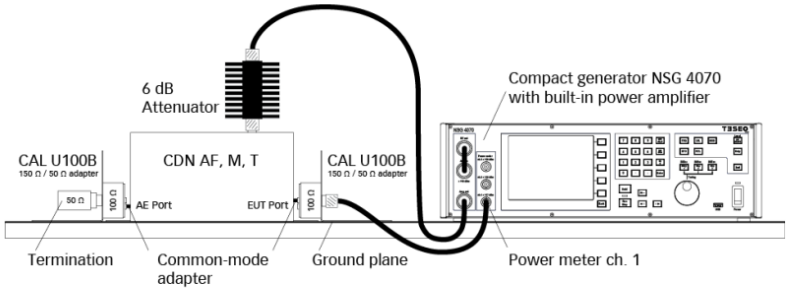
- If CDNs cannot be used: EM clamp
- KEMZ 801A: Improved design for better RF performance – flat frequency response
- Suitable for 10 kHz applications up to 10 V EMF

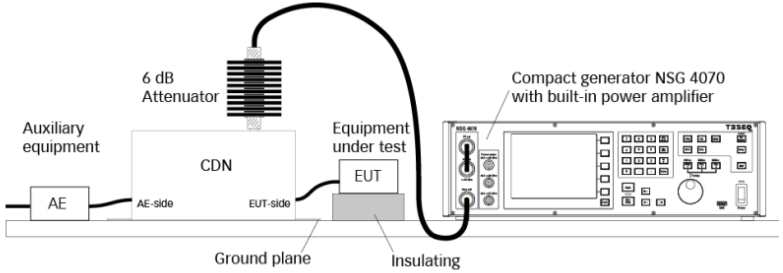
KEMZ 801A

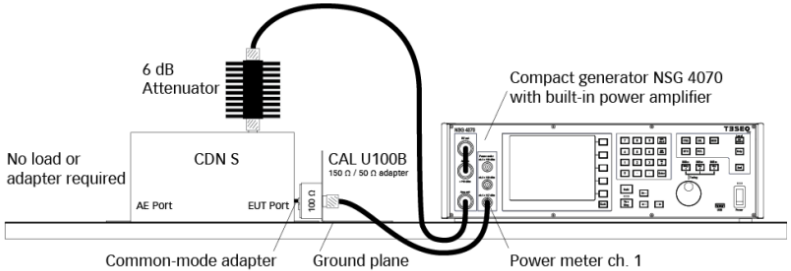
Power requirements in accordance with IEC/EN 61000-4-6
(6 dB attenuator, 0.5 dB cable loss, typical insertion loss of KEMZ 801A)
- 3 V EMF without modulation (stress level setting), 3 V EMF with AM 80%,
- 10 V EMF without modulation (stress level setting), 10 V EMF with AM 80%,
- 20 V EMF without modulation (stress level setting), 20 V EMF with AM 80%
- 30 V EMF without modulation (stress level setting), 30 V EMF with AM 80%
- ····· Max. forward power on the 6 dB attenuator input



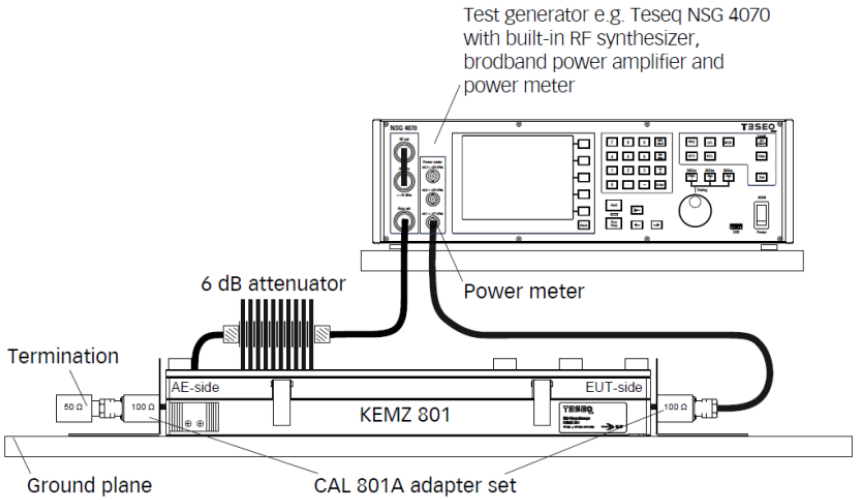
Typical setups for IEC/EN 61000-4-6

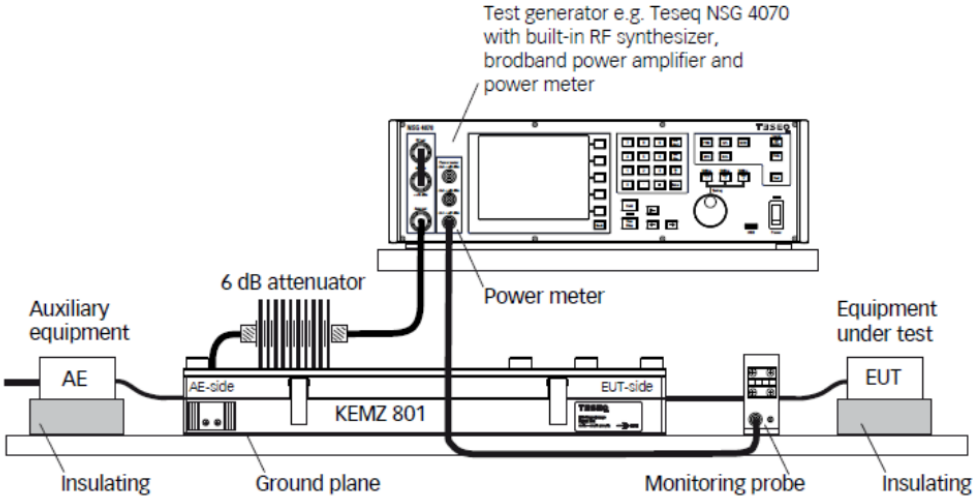




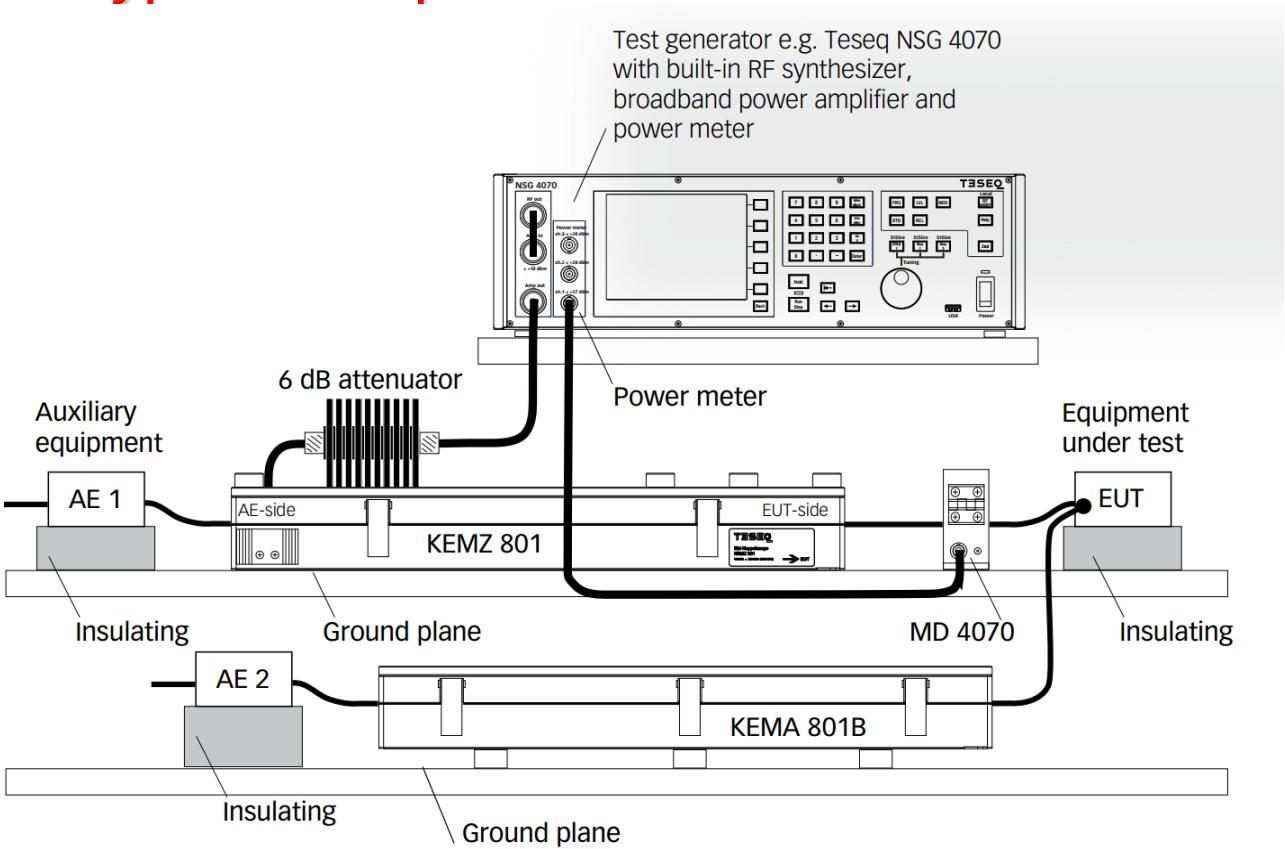


Typical setups for IEC/EN 61000-4-6





Typical setups for IEC/EN 61000-4-6



Accessories / system components

6 dB attenuator

RF Cable set

Monitoring probe

RF switch

MD4070 monitoring probe

- 10 kHz to >400 MHz
- Active and passive operation (30 dB)
- Remote controlled and manual operation
- Passive:
  - Flat frequency response (+/-1.5 dB) from 100 kHz to 230 MHz
  - max. 1 A
- Active:
  - 1 dB compression >27 dBm
  - max. 30 mA (linear)
- Dynamic range matched to NSG 4070

Test setup example

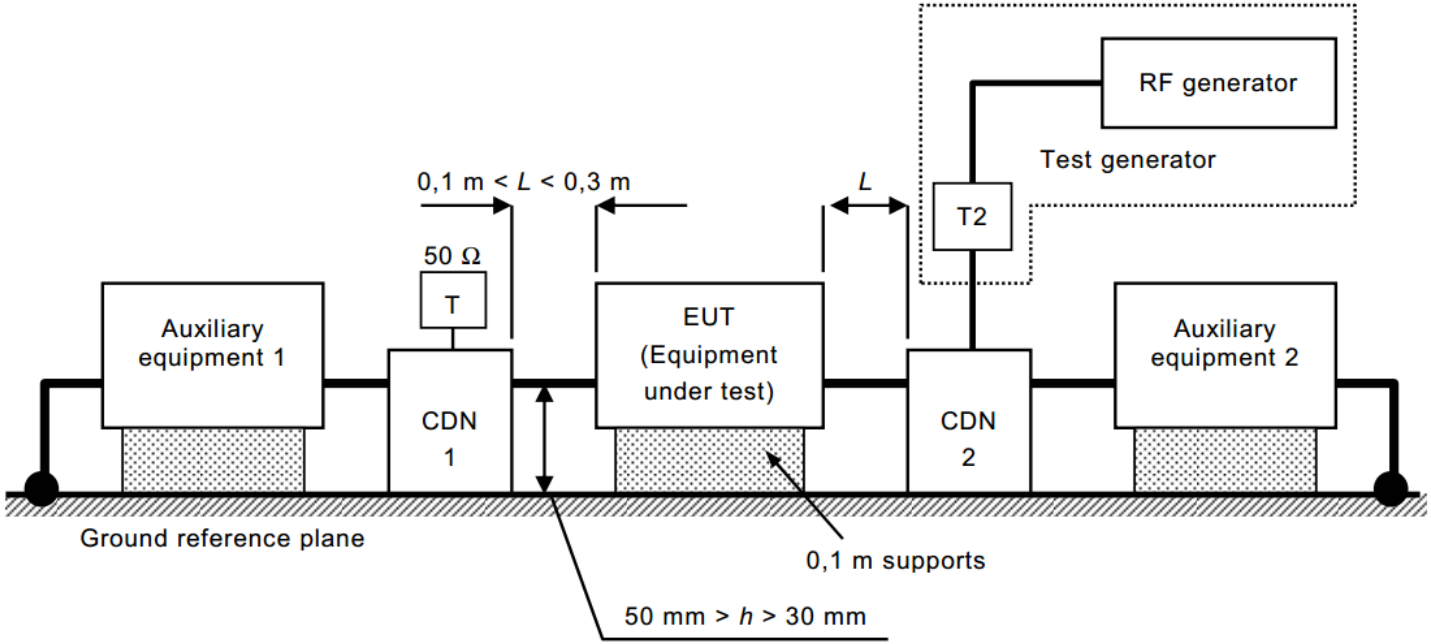


Figure 2b – Schematic set-up for immunity test to RF conducted disturbances

Test setup example

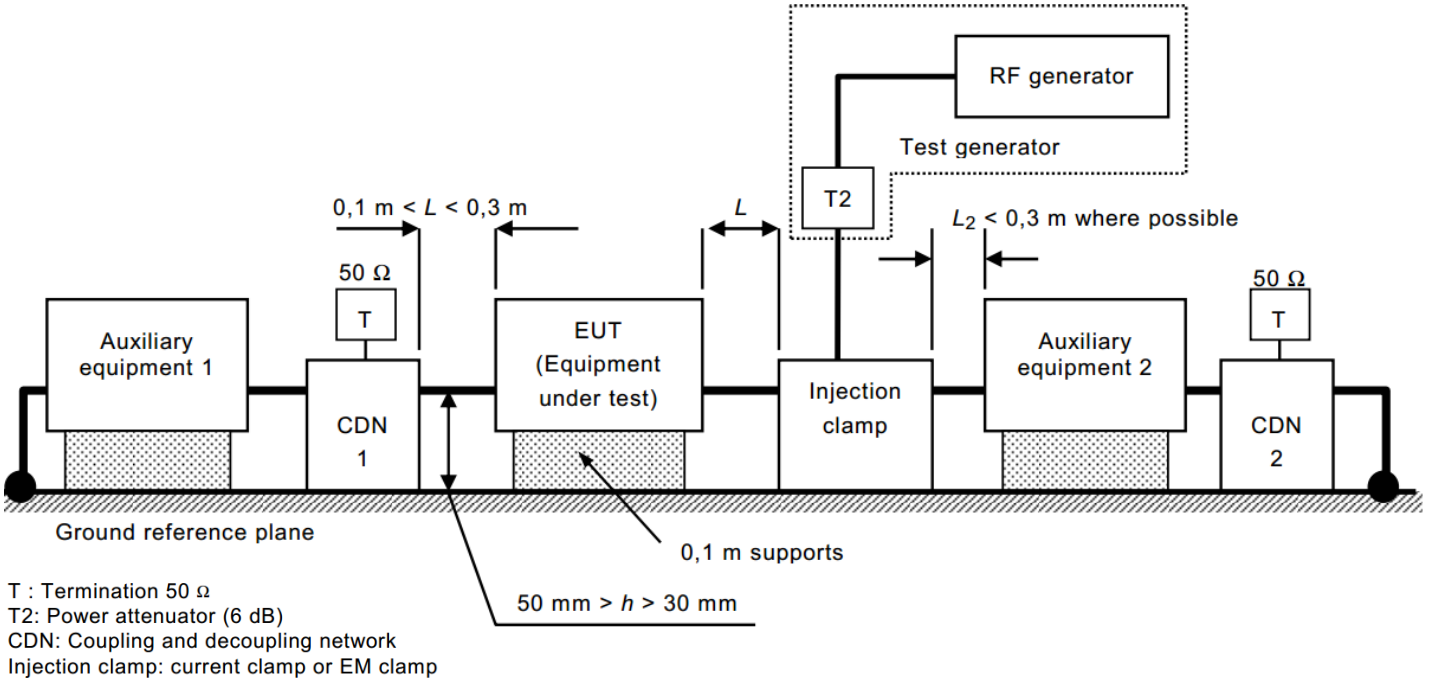


Figure 2b – Schematic set-up for immunity test to RF conducted disturbances

Test setup example

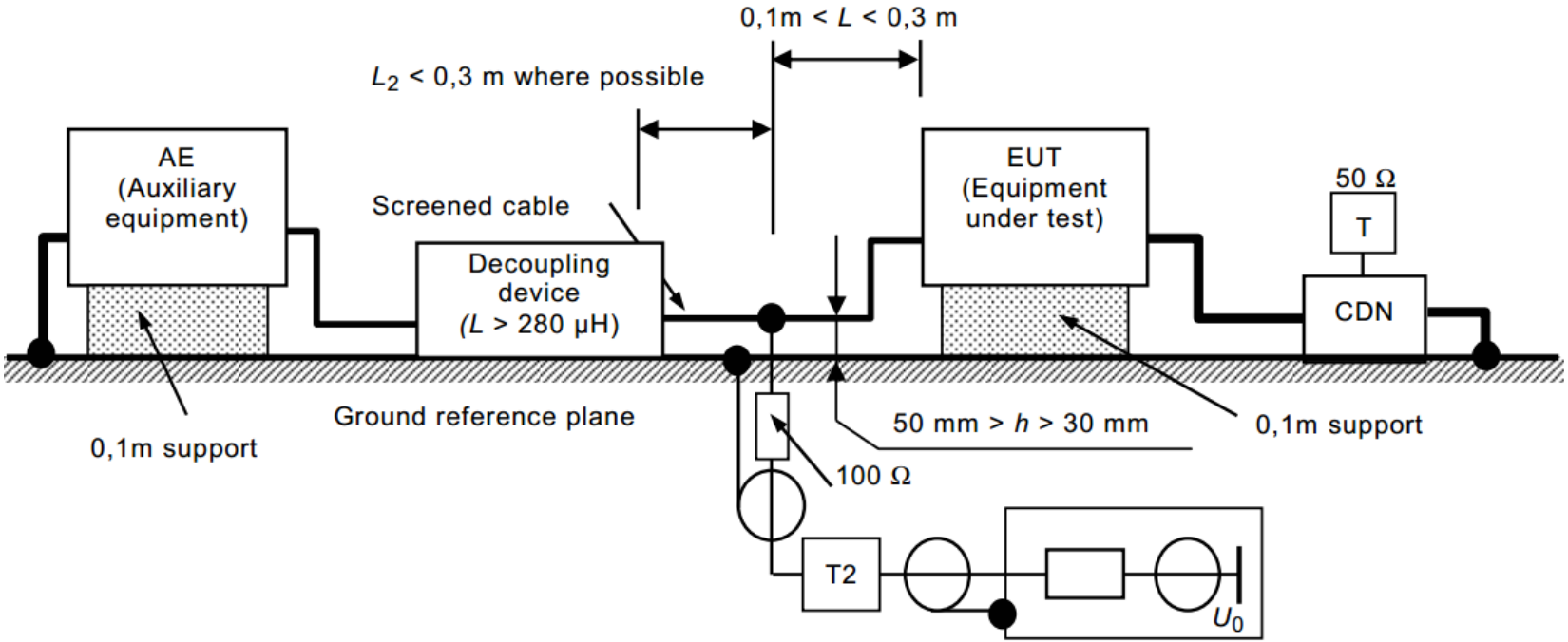


Figure 5b – Principle of direct injection to screened cables

Test setup example

Procedure for Direct Injection

- The EUT should be placed on an insulating support of 0.1m above the ground reference plane
- On the cable being tested, a decoupling network should be located between the injection point and the AE, as close as possible to the injection point
- All other cables should have decoupling networks
- Injection point should be located between 0.1m-0.3m from the geometric projection of the EUT on to the ground reference plane
- Test signal should be injected directly on to the shield of the cable through a 100Ω resistor

Test setup example

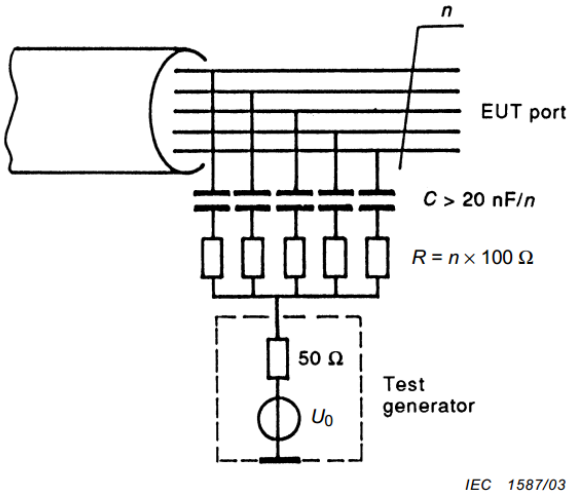
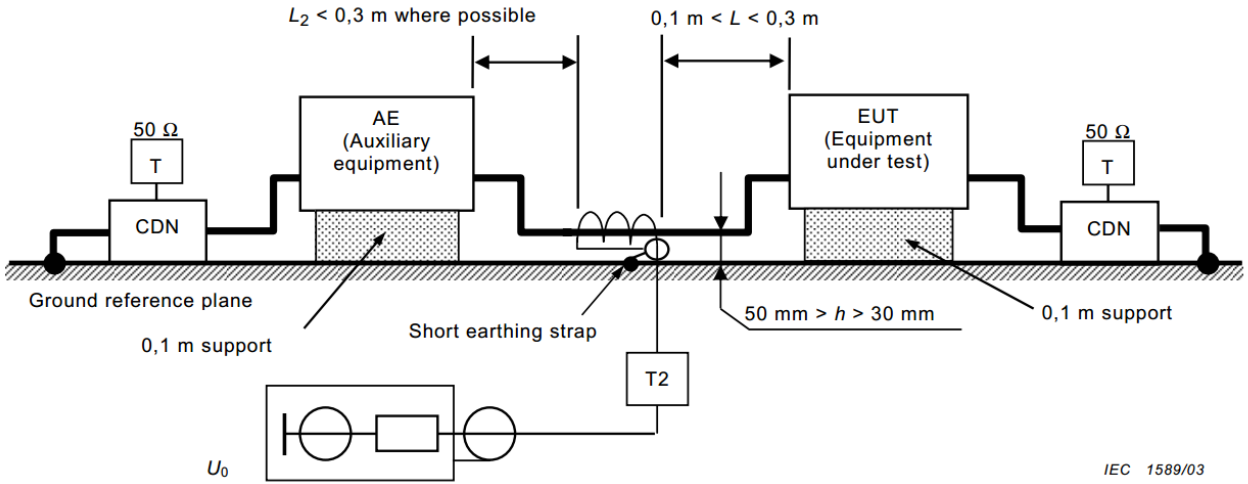


Figure 5c – Principle of coupling to unscreened cables

Test setup example



The CDN connected to the AE, e.g. CDN-M1 connected to the dedicated earth terminal or CDN-M3, shall be terminated with 50 Ω at the input port (see 7.4).

Figure 6 – Principle of coupling and decoupling according to the clamp injection method

Test setup example

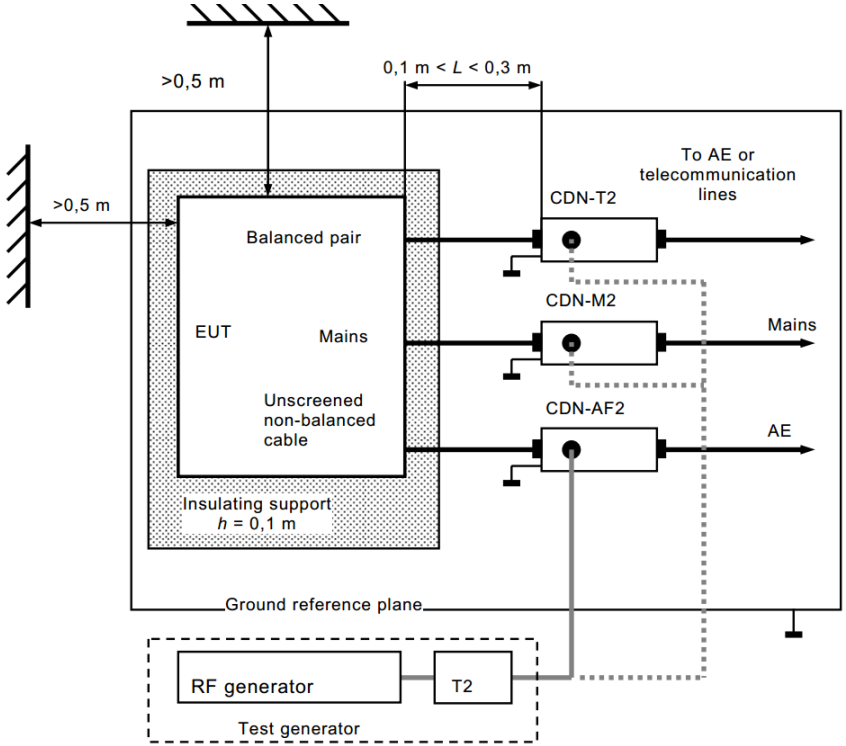


Figure 9 – Example of test set-up with a single unit EUT

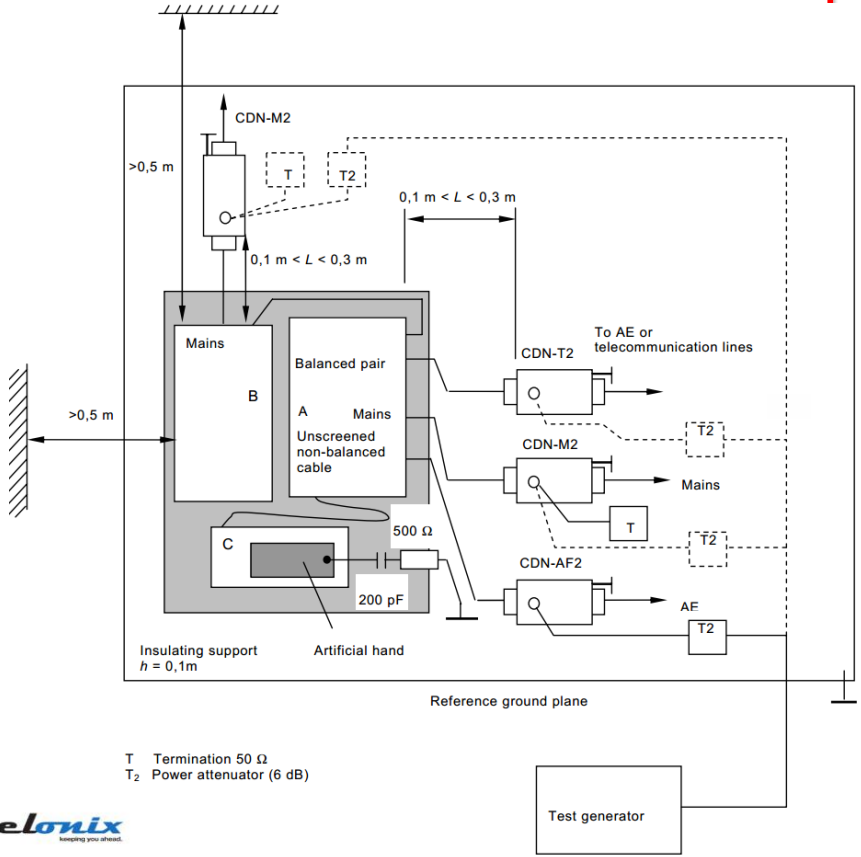
Test setup example

EUT comprising of a single unit

- EUT should be placed on an insulating support 0.1m above the ground reference plane
- On all cables being tested, coupling/decoupling devices should be placed on the ground reference plane, making direct contact at a distance of 0.1m-0.3m from the EUT
- If the EUT is provided with other earth terminals, they should be connected to the ground reference plane through CDN-M1
- If the EUT has a keyboard or handheld accessory, then an artificial hand should be placed on the device and connected to the ground reference plane

- All AE should be connected before testing, through a coupling/decoupling device

Test setup example



The EUT clearance from any metallic obstacles shall be at least 0,5 m

Only one of the CDNs not used for injection shall be terminated with 50 Ω, providing only one return path. All other CDNs shall be coupled as decoupling networks.

Interconnecting cables (≤ 1 m) belonging to the EUT shall remain on the insulating support.

Preferred Method: each sub unit is treated and tested separately as the EUT, with the other units considered an AE. CDNs are placed on the cables of the sub unit that is considered the EUT during the test, and each sub unit should be tested in turn

Figure 10 – Example of a test set-up with a multi-unit EUT

Test setup example

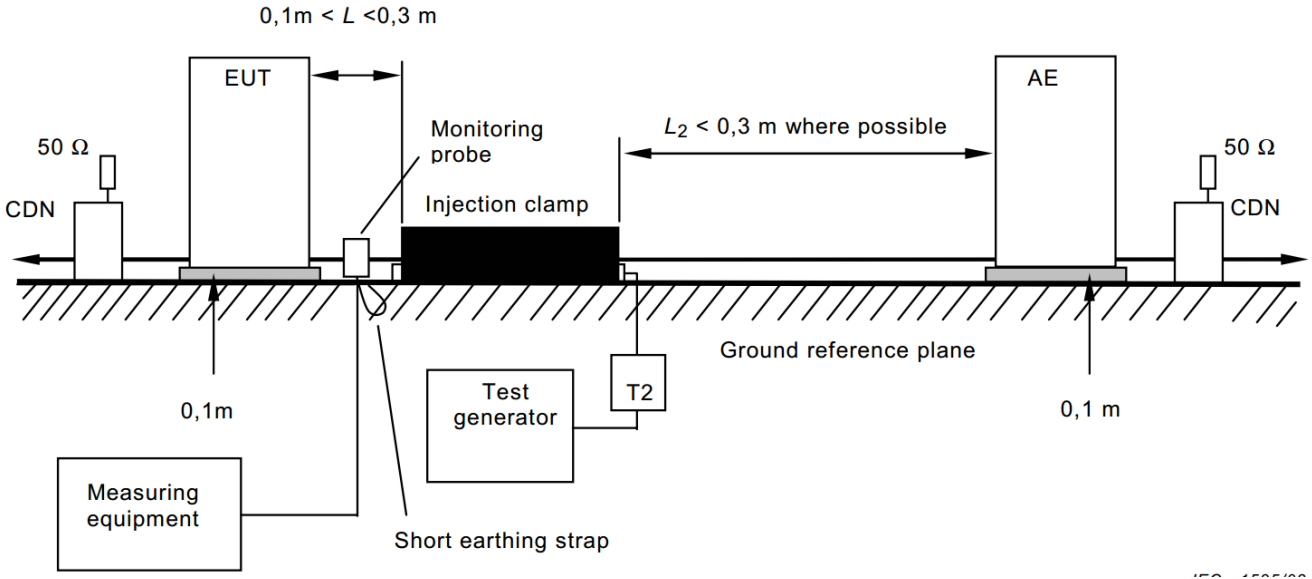


Figure A.6 – General principle of a test set-up using injection clamps

Test setup example

Procedure for Clamp Injection

- Each AE should be placed on an insulating support of 0.1m above the ground reference plane
- A decoupling network should be installed on each cable between the EUT and AE, except the cable under test
- All cables connected to each AE but not the EUT should have decoupling networks attached
- The decoupling networks connected to each AE should be no further than 0.3m from the AE, and be kept between 30mm -50mm above the ground reference plane
- Only one CDN on each of the EUT and AE should be terminated in 50Ω
- When several clamps are used, the injection is carried out on each cable one by one

Test setup example

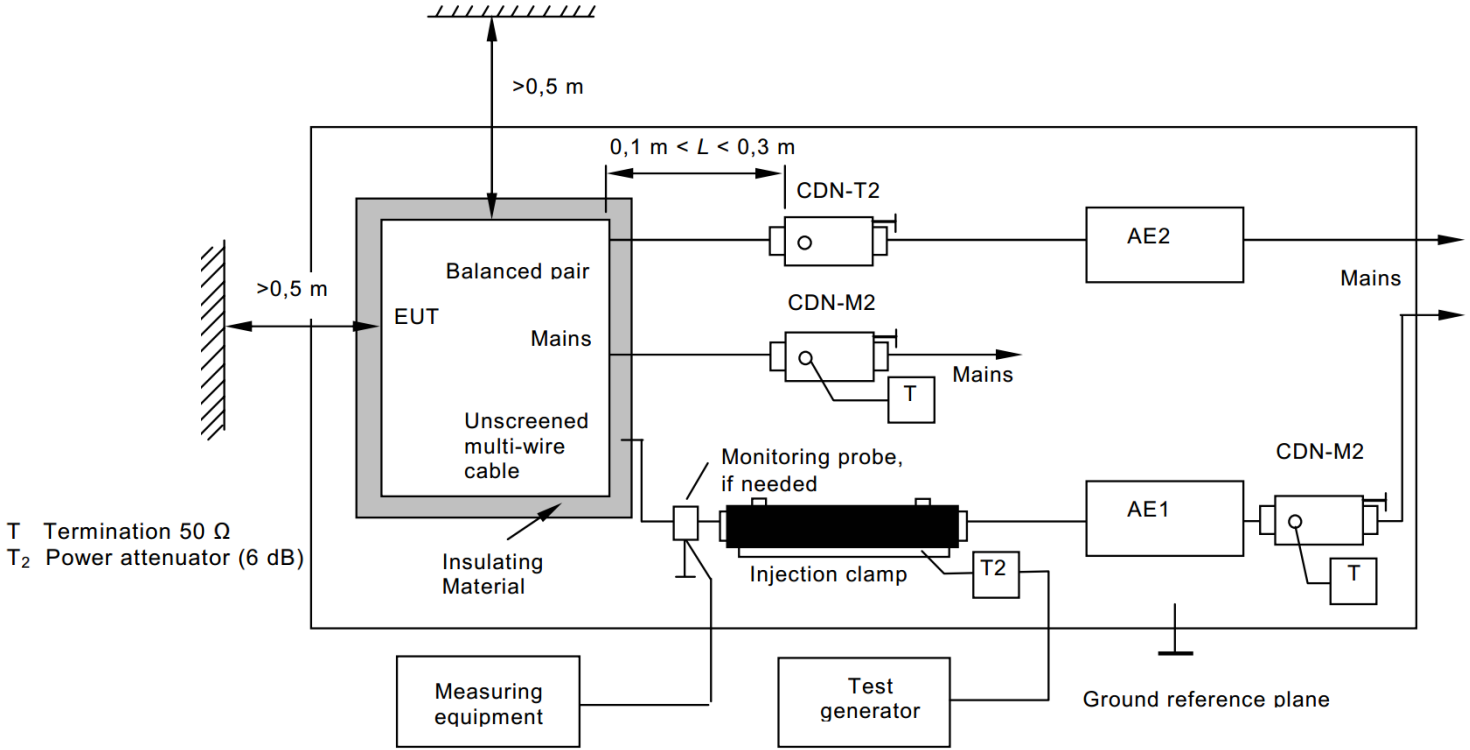


Figure A.7 – Example of the test unit locations on the ground plane when using injection clamps (top view)

Test setup example

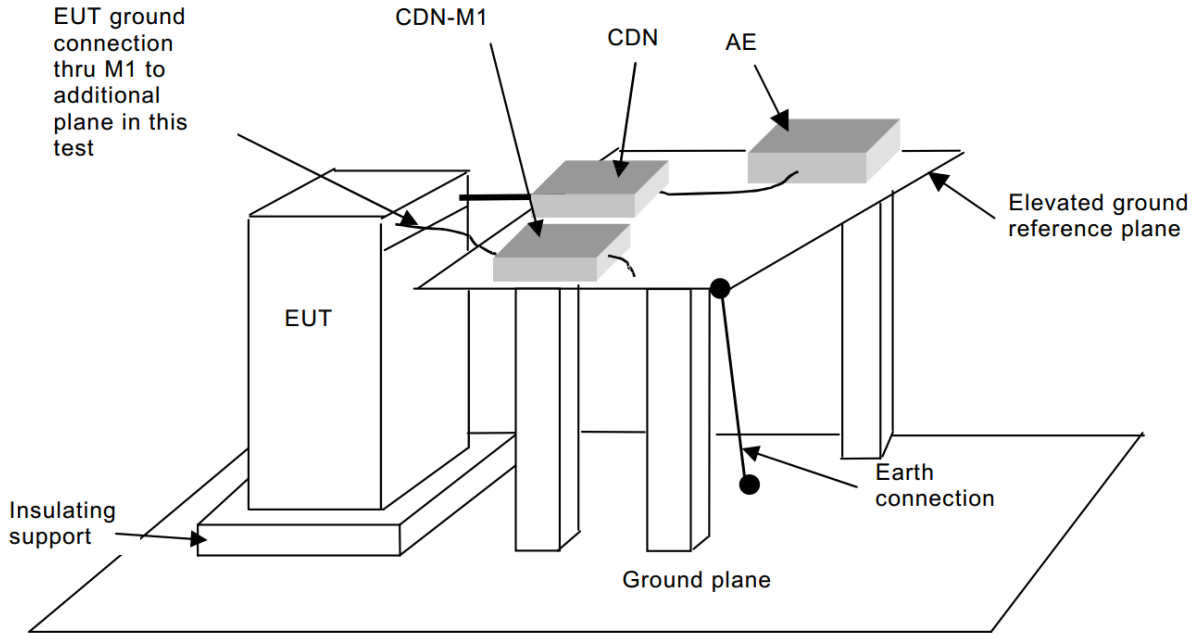


Figure F.1 – Example of large EUT test set-up with elevated horizontal ground reference plane

Test Report

Evaluation of Test Results

The test results should be classified in terms of the loss of function or degradation of performance of the EUT, relative to the performance level defined by its manufacturer

Classifications:

- Normal performance within limits specified by the manufacturer
- Temporary loss of function or degradation of performance which ceases after the disturbance ceases, and EUT recovers to normal performance, without operator intervention
- Temporary loss of function or degradation of performance, correction requires operator intervention
- Loss of function or degradation of performance which is not recoverable

Test Report

Test Report

Should contain all information necessary to reproduce the report, and the following should be recorded:

- Identification of EUT and any associated equipment
- Size of the EUT
- Representative operating conditions of the EUT
- Test performed as single or multiple units
- Types of interconnecting cables, their length and interfacing port of EUT which they connect to
- Any specific conditions for use, which are required to achieve compliance
- Recovery time of EUT, if necessary
- Type of test facility used and position of EUT, AE and coupling/decoupling devices
- Identification of test equipment
- The coupling and decoupling devices used on each cable and their length
- Description of EUT exercising method
- Any specific conditions necessary to enable the test being performed
- The frequency range of application of the test
- Rate of sweep frequency, dwell time and frequency steps
- The applied test level
- Performance level and criteria
- Any effects on the EUT observed during or after testing
- The rationale for pass/fail decision

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RF EQUIPMENT

POWER AMPLIFIERS

Thank you!

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