IEC 61000-4-4

Electrical fast transient / Burst immunity test

AMETEK®

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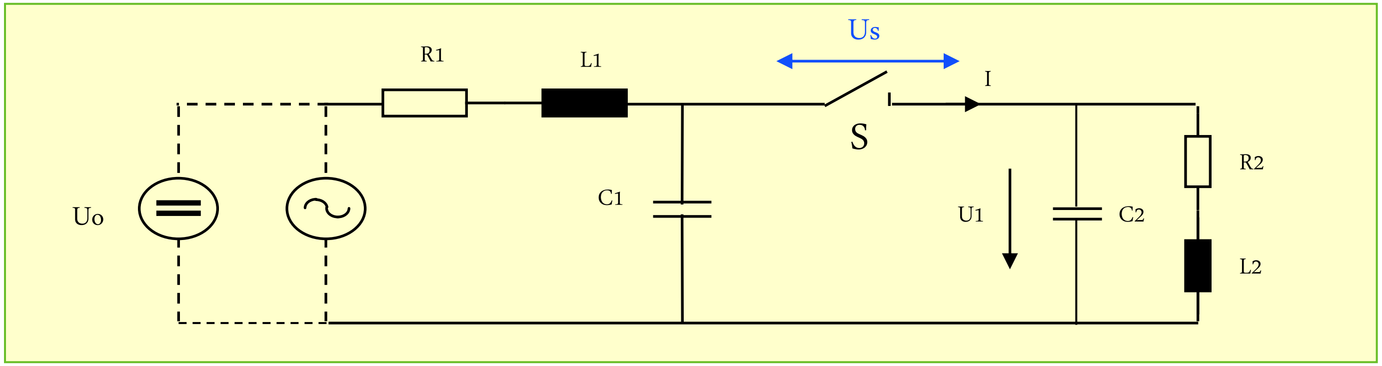
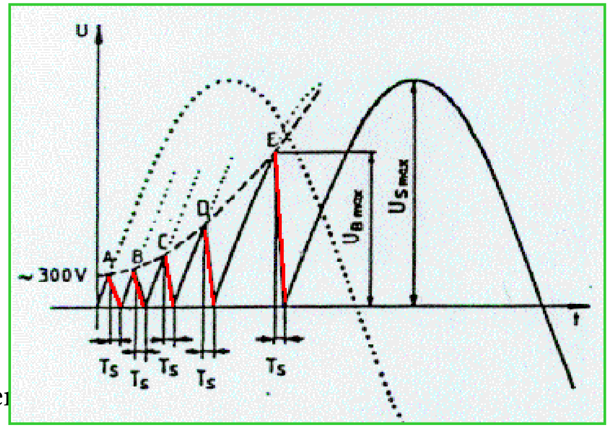
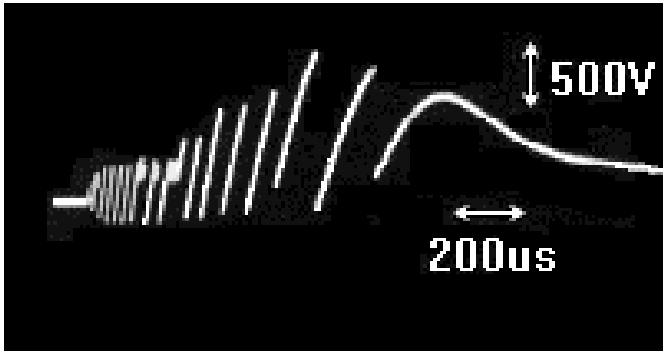
Phenomenom open a contact

Equivalent diagram of a switching circuit



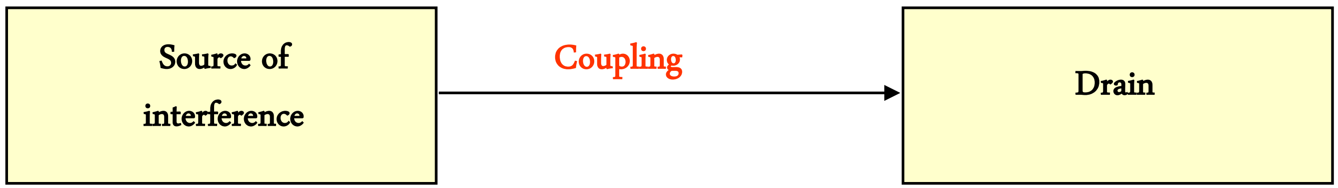
Typical voltage waveform across an opening switch





230V Power

EMC Model for fast transients



- **Source of interference**
  - Circuit breaker in electric circuits
  - High voltage switchgears
  - 110/230V power supply systems
  - 24V control lines

- **Characteristics**
  - Impulse with rise time in nanoseconds
  - Broadband interference spectrum up to 400 MHz
  - Amplitudes up to some kV

- **Coupling**
  - Capacitive (du/dt) to parallel lines
  - Inductive by magnetic fields (di/dt) to earth leads
  - Radiation in the near field by arcs

- **Migration**
  - Conducted in the cable system
  - Asymmetrical resp. Line to Earth

Test level since EN 61000-4-4:2004

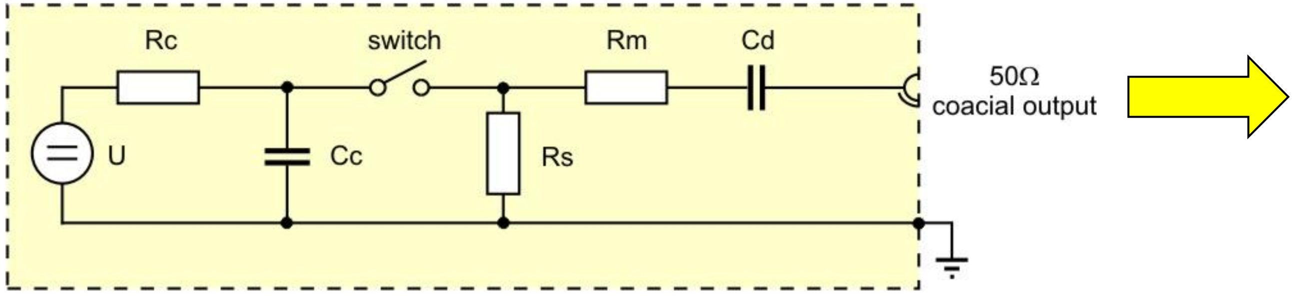
Open circuit test voltage			
Level	**Power line**	**I/O line**	
	Peak voltage [kV]		Repetition rate [kHz]
1	0,5	0,25	5 or **100**
2	1	0,5	5 or **100**
3	2	1	5 or **100**
4	4	2	**5 or 100**
X (1)	special	special	

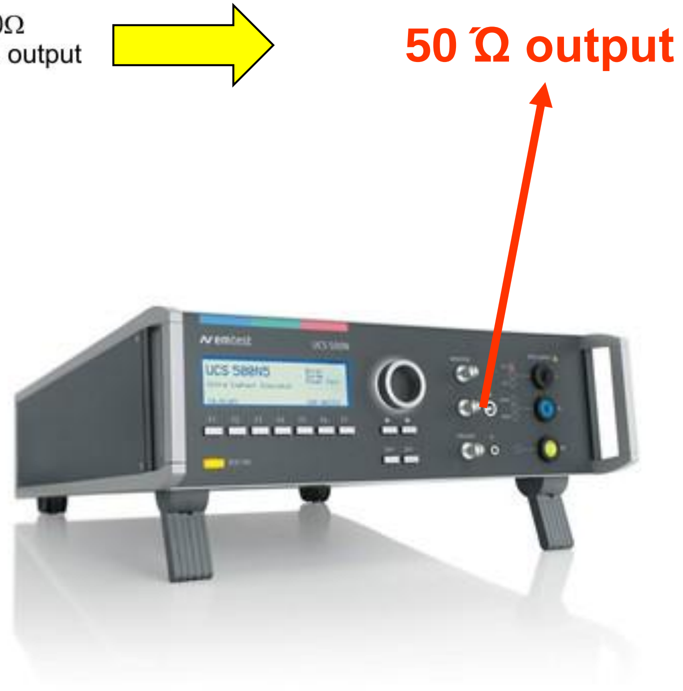
Table 1- Test levels

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

In Annex B1 you will find representative values from real installations for your assistance.

Test equipment simplified circuit diagram of EFT / burst generator





Components

U	High-voltage source
*R*c	Charging resistor
*C*c	Energy storage capacitor
*R*s	Impulse duration shaping resistor
*R*m	Impedance matching resistor
*C*d	DC blocking capacitor
Switch	High-voltage switch (electronic switch)

NOTE: The characteristics of the switch together with stray elements (inductance and capacitance) of the layout shape the required rise time.

Characteristic waveform (New in Edition 3)

New in Ed 3

Output voltage range with 1000 Ω load:	min. 0.24 kV up to 3.8 kV;
Output voltage range with 50 Ω load:	min. 0.125 kV up to 2 kV;
Pulse repetition frequency:	5 kHz and 100 kHz ± 20 %
Burst duration (see 6.1.2 and fig. 2):	(15 ± 3) ms at 5 kHz (0.75 ± 0.15) ms at 100 kHz
Burst period	(300 ± 60) ms

Pulse shape:

Termination at coaxial output (with 50 Ω load)	Rise time tr = (5 ± 1.5) ns Pulse duration (50 %-value) td = (50 ± 15)ns Peak value of voltage; Table 2 ± 10 %
Termination at coaxial out (with 1000 Ω load)	Rise time tr = (5 ± 1.5) ns Pulse duration (50 %-value) td = 50 ns with a tolerance of – 15 ns to + 100 ns Peak value of voltage; Table 2 ± 20 %

Parameter of the actual interferences

Single pulse

Rise time tr = 5ns

Pulse duration td = 50ns

Pulse packet (Burst)

Repetition time Tr = 300ms

As formerly:

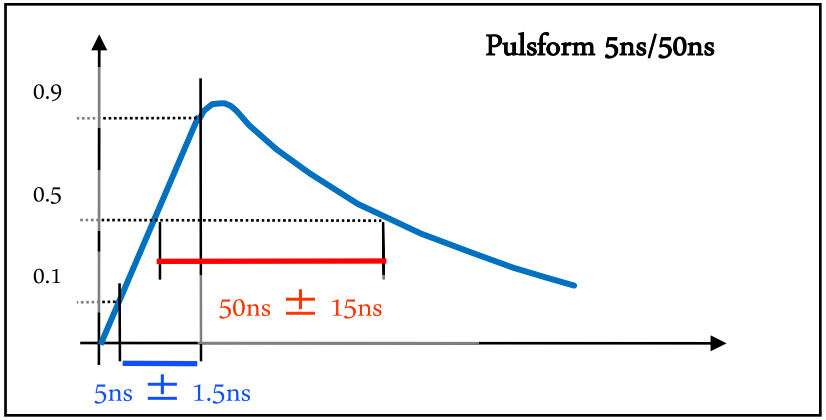
Duration burst packet Td = 15ms

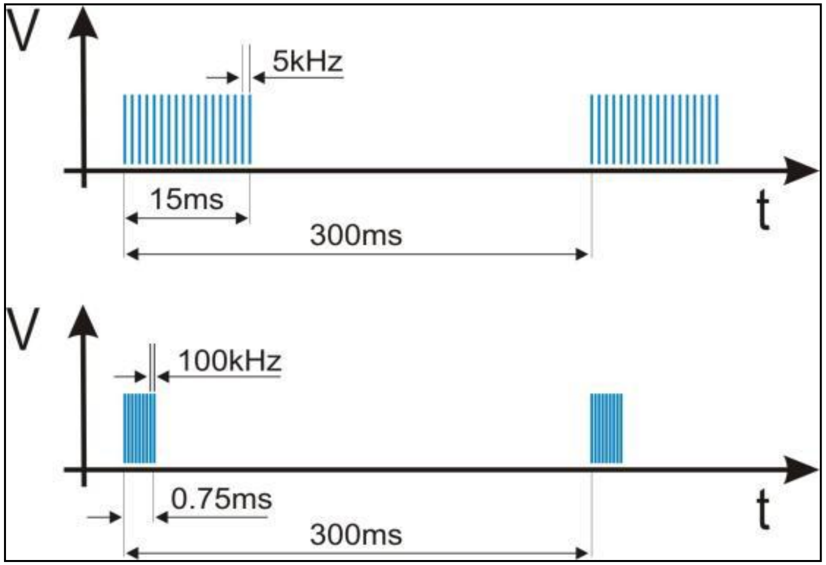
at spike frequency f=5kHz

<u>Added in 2004:</u>

Duration burst packet Td = 0,75ms

At spike frequency f = 100kHz





Mathematical modeling of Burst waveforms new in Edition 3

Figure 3 shows the ideal waveform of a signal pulse into a 50 Ω load with nominal parameters

t_r = 5 ns and

t_w = 50 ns

Formula of the ideal waveform per Figure 3, $v_{EFT}(t)$

$$v_{EFT}(t) = k_v \left[\frac{v_1}{k_{EFT}} \cdot \frac{\left(\frac{t}{\tau_1}\right)^{n_{EFT}}}{1+\left(\frac{t}{\tau_1}\right)^{n_{EFT}}} \cdot e^{\frac{-t}{\tau_2}} \right]$$

where

$$k_{EFT} = e^{-\frac{\tau_1}{\tau_2} \cdot \left(\frac{n_{EFT} \cdot \tau_2}{\tau_1}\right)^{\frac{1}{n_{EFT}}}}$$

k_v is max. or peak value of the open-circuit voltage (k_v = 1 means normalized voltage)

v_1 = 0,92 τ_1 = 3,5 ns τ_2 = 51 ns n_{EFT} = 1,8

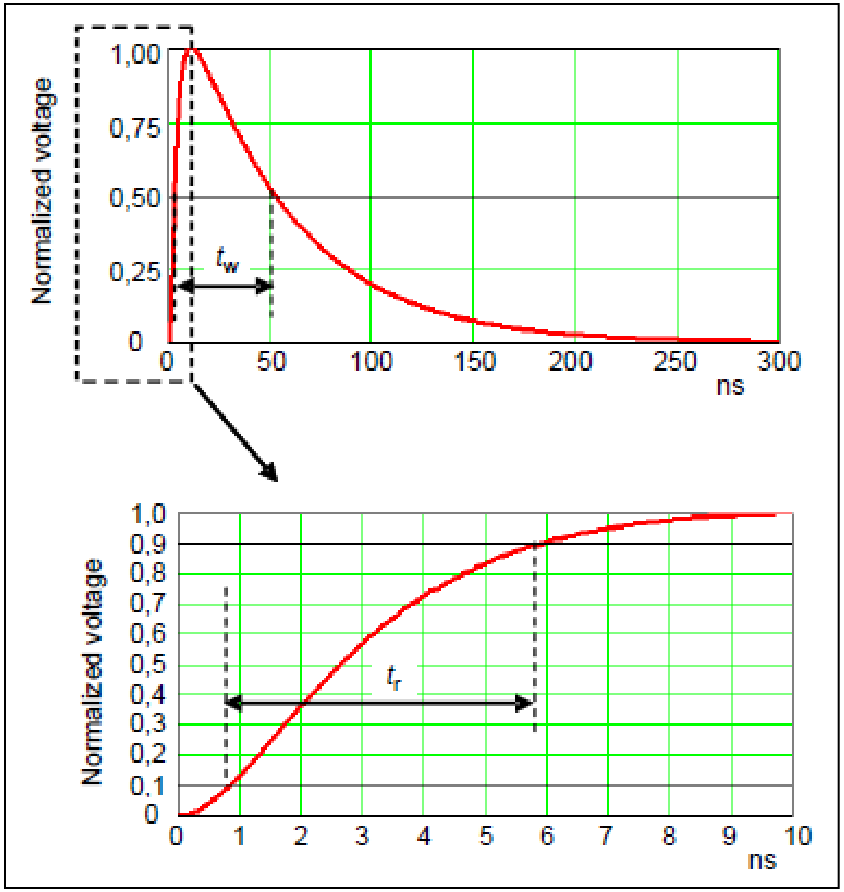


Figure 3

Characteristics - output voltage peak -

New repetition frequency of burst pulses is introduced in table 1!

Table 2 – Output voltage peak values and repetition frequencies

Set voltage kV	V_p (open circuit) kV	V_p (1 000 Ω) kV	V_p (50 Ω) kV	Repetition frequency kHz
0,25	0,25	0,24	0,125	5 or 100
0,5	0,5	0,48	0,25	5 or 100
1	1	0,95	0,5	5 or 100
2	2	1,9	1	5 or 100
4	4	3,8	2	5 or 100
Measures should be taken to ensure that stray capacitance is kept to a minimum.				

NOTE 1 Use of a 1 000 Ω load resistor will automatically result in a voltage reading that is 5 % lower than the set voltage, as shown in column V_p (1 000 Ω). The reading V_p at 1 000 Ω = V_p (open circuit) multiplied times 1 000/1 050 (the ratio of the test load to the total circuit impedance of 1 000 Ω plus 50 Ω).

NOTE 2 With the 50 Ω load, the measured output voltage is 0,5 times the value of the unloaded voltage as reflected in the table above.

Calibration at the coaxial output

In order to provide a common supply basis for all test simulators, the characteristics of the test simulators have to be proved.

The verification at coaxial output has to be carried out as follows:

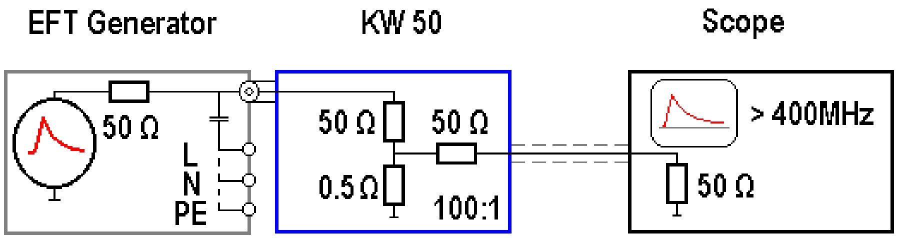
1. The demanded test voltage is set at the simulator.

2. The curve progression is measured at the coaxial output of the simulator. The Peak value of the voltage has to be 50% of the set voltage at the simulator .

3. The curve progression is measured at constant simulator settings at 1000 Ω The peak value of the voltage has to be Up (open circuit) corresponding (±20%)

Calibration routine no.: 1

Calibration at coaxial 50 Ohm output of the simulator with a 50 Ohm load

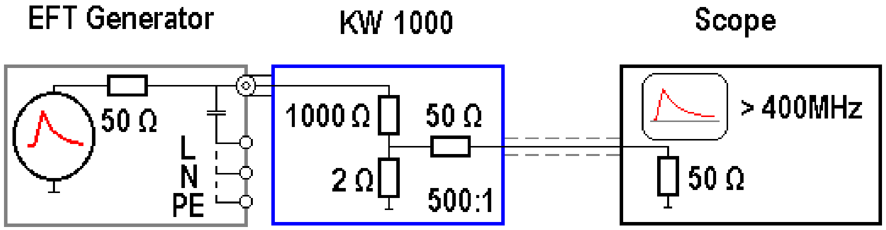


Ratio with KW50 -> 1:400

Example: 2000V Burst = 5V on scope

Calibration routine no.: 2

Calibration at coaxial 50 Ohm output of the simulator with a 1000 Ohm load



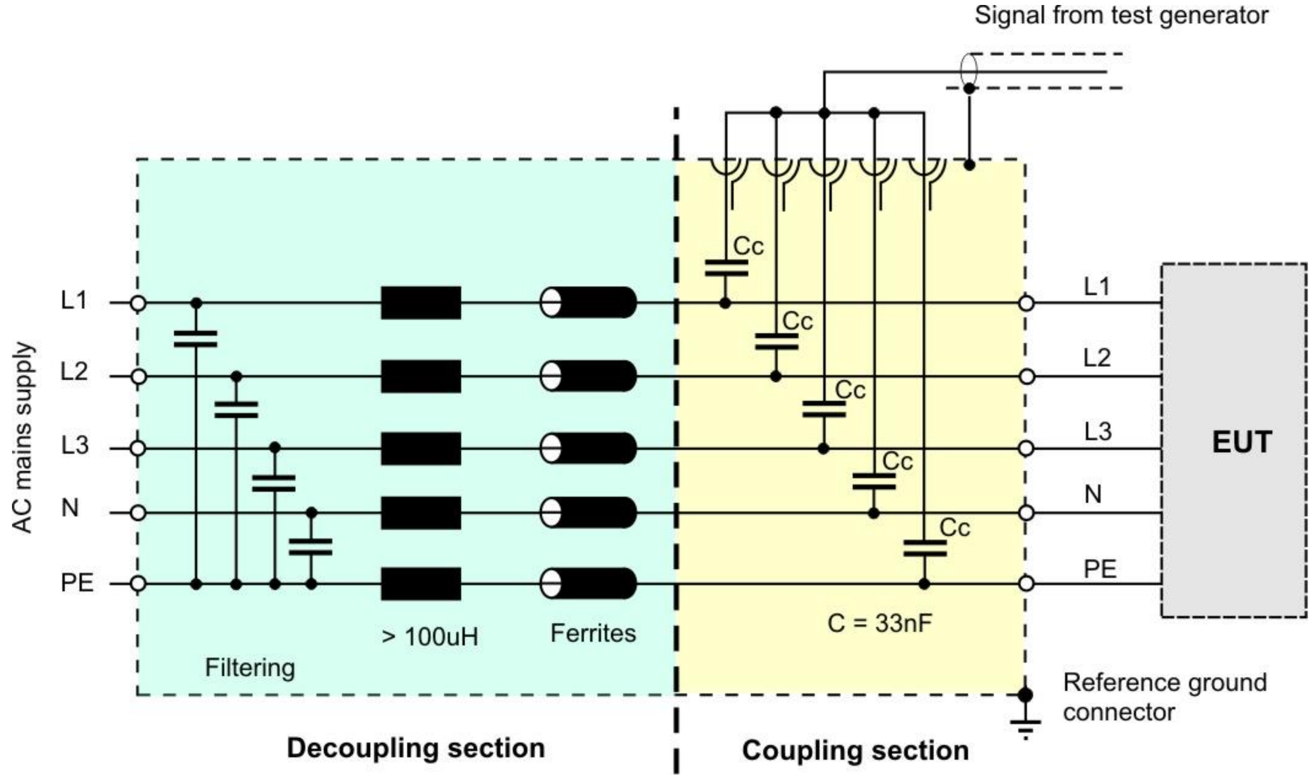
Ratio with KW1000 -> 1:1000

Example: 2000V Burst = 2V on scope

Coupling/Decoupling network for mains connectors (IEC 61000-4-4:2012)

Coupling capacitors: 33 nF

Insertion loss: asymmetric (all lines against reference earth)



Calibration of the CDN for mains supply

Proof of characteristics of coupling/decoupling network:

The pulse shape has to be proved at each output/path of coupling-/decoupling network

- Therefore all coupling paths are set simultaneously (Common Mode)
- The output of the coupling network is terminated with a coaxial load of 50 Ω

The calibration has to be provided with a voltage setting of 4kV as follows:

	since EN 61000-4-4:2004	**New:** EN 61000-4-4:2012
Rise time **tr**	5 ns ± 30%	5,5ns ± 1,5ns
Pulse duration **td**	50 ns ± 30%	45ns ± 15ns
peak value of voltage	± 10% of the voltage according to table	

Calibration of the CDN for mains supply

Procedure since Amendment A1 to IEC61000-4-4 ed.2 of 01/2010

The calibration is performed with the generator output at a set voltage of **4 kV**.

The generator is connected to the input of the coupling/decoupling network. **Each individual output** of the CDN (normally connected to the EUT) is terminated in sequence with a 50 Ω load while the other outputs are open. The peak voltage and waveform are recorded for each polarity.

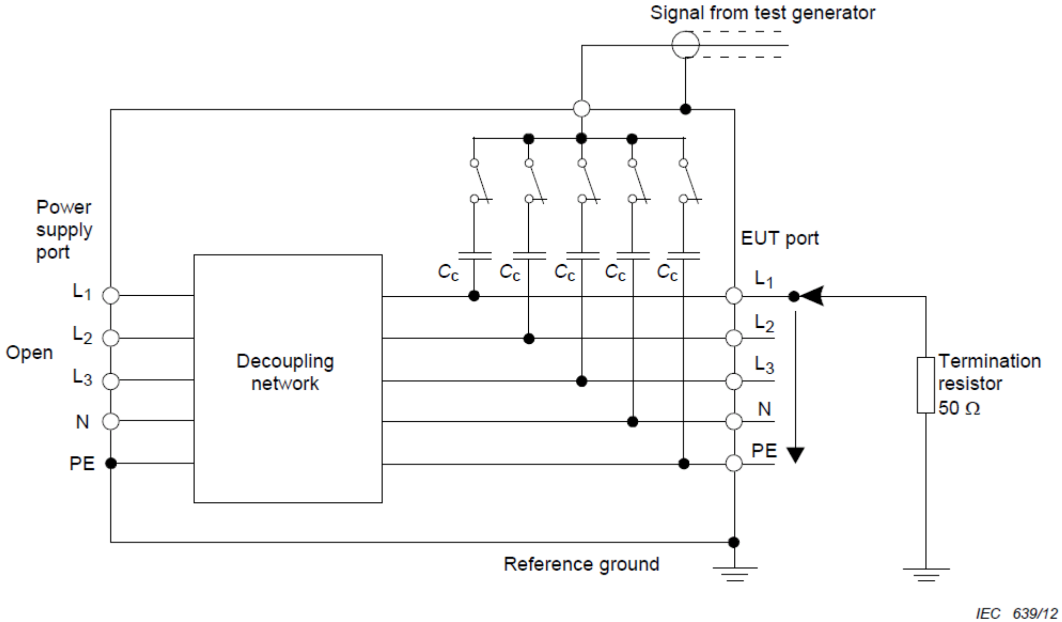


Figure 5 – Calibration of the waveform at the output of the coupling/decoupling network

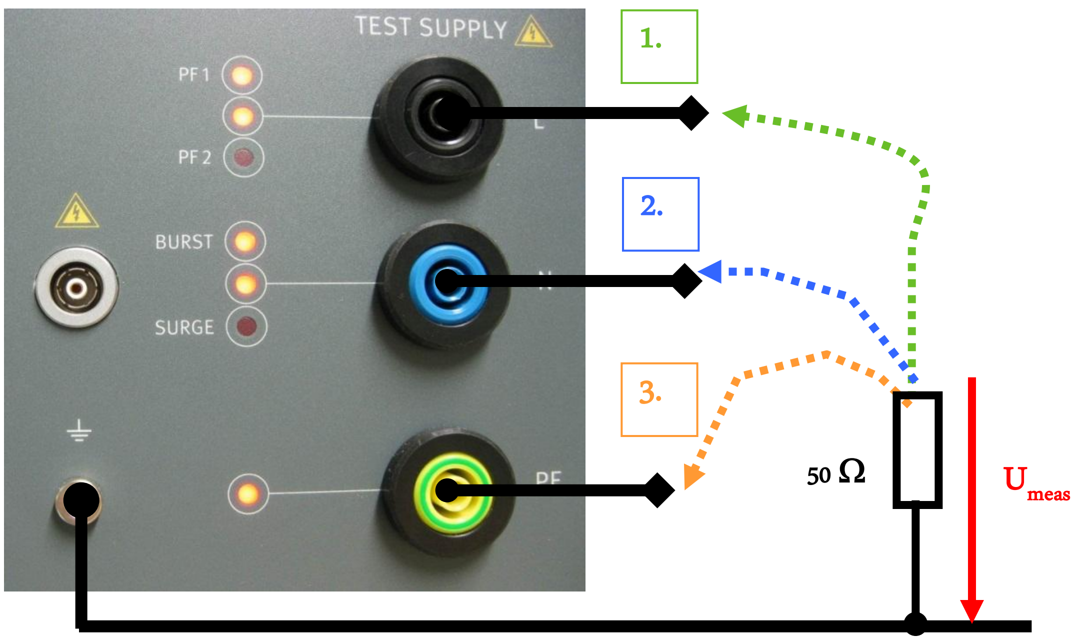
Rise time of the pulses shall be (5,5 ± 1,5) ns.

Pulse width shall be (45 ± 15) ns.

NOTE: With the CDN the rise time has been increased from 5ns to 5.5ns and the pulse width has been reduced from 50ns to 45ns

Calibration routine no.: 3

- The EFT transients are coupled to all CDN lines **simultaneously** (CM).
- The output of the CDN shall not be short circuited.
- The EFT transients shall be measured **at each individual output** of the CDN with 50Ω load, while the **other outputs are open**.
- Each individual output must show the transients within the tolerances as specified.



1.

2.

3.

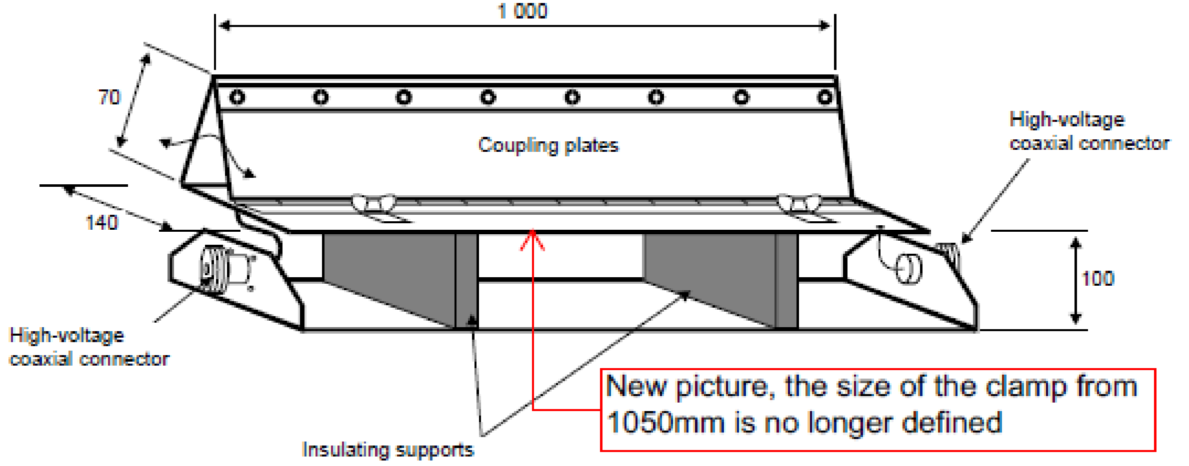
Capacitive Coupling Clamp

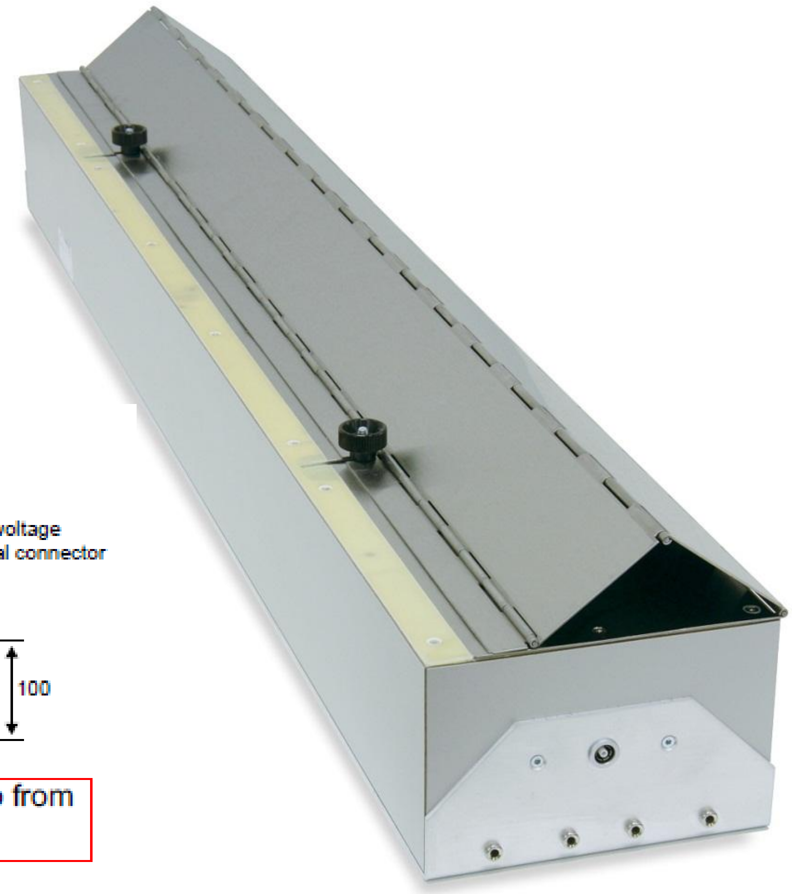
Dimensions have now tolerances

Lower coupling plate height: (100 ± 5) mm

Lower coupling plate width: (140 ± 7) mm

Lower coupling plate length: (1 000 ± 50) mm

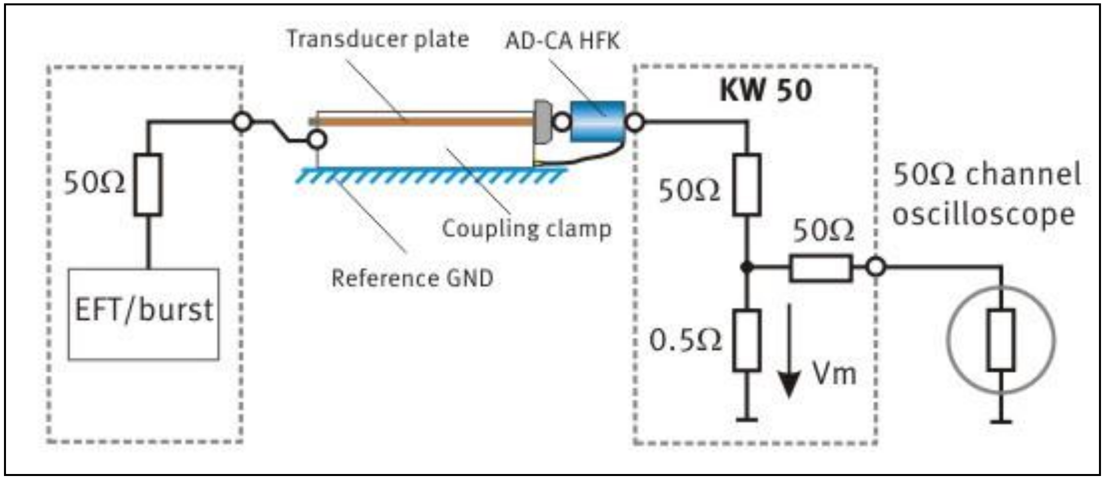


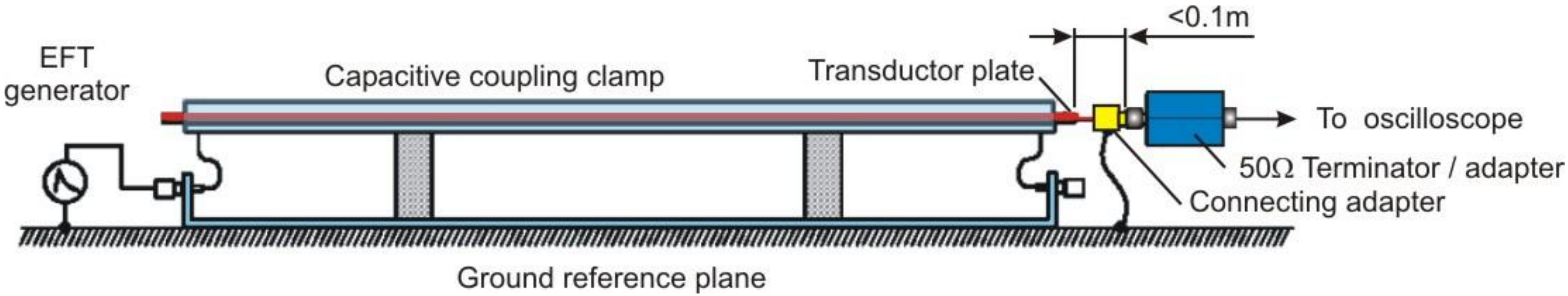


Calibration of capacitive coupling clamp per EN61000-4-4:2012

In a new chapter the edition 3 describes the calibration method of the capacitive coupling clamp with a transducer plate.

The transducer plate consists in a metallic sheet of 120 mm x 1050 mm of max 0.5 mm thickness, isolated on top and bottom by a dielectric foil of 0.5 mm. Isolation for 2.5 kV on all sides must be guaranteed in order to avoid the clamp to contact the transducer plate.

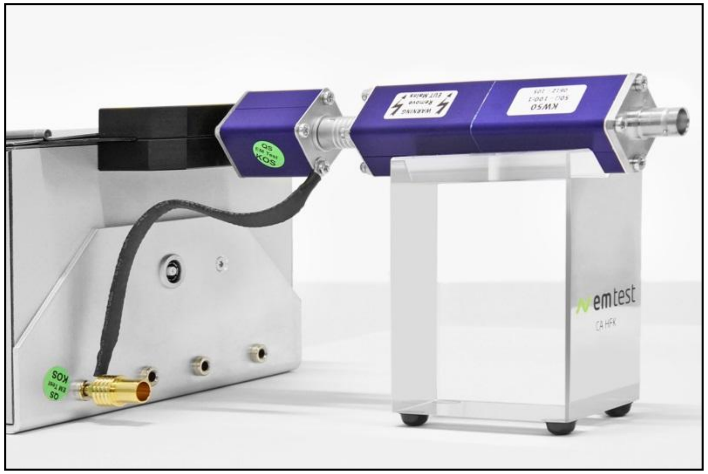




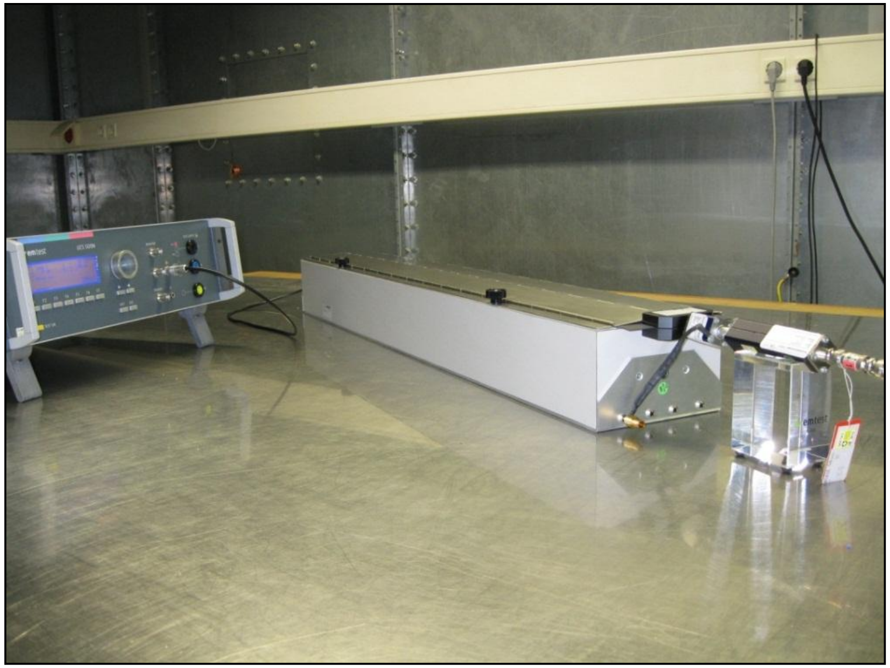
Calibration setup of capacitive coupling clamp per EN61000-4-4:2012

- The transducer plate is to be inserted into the coupling clamp and must be terminated at the opposite end of the generator connection with a coaxial load of 50 Ω.
- The calibration is performed with the generator output voltage set to **2 kV**. The calibration have to meet the following requirements:

Rise time **tr**	5ns $\pm$ 1,5ns
Pulse duration **td**	50ns $\pm$ 15ns
peak value of voltage	1kV $\pm$ 200V

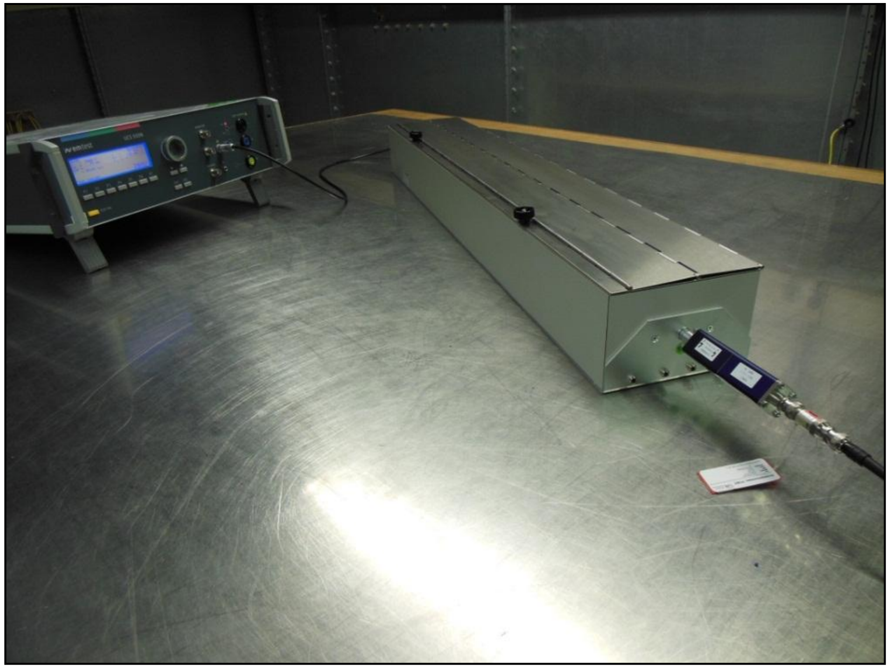


Calibration of capacitive coupling clamp per EN61000-4-4:2012



Calibration setup

of a capacitive coupling clamp using the transducer plate acc. to figure 8 of EN61000-4-4:2012



Verification setup

of the system functions with Generator and capacitive coupling clamp acc. to figure 10 of EN61000-4-4:2012

Test setup and test execution

Coupling mode: „all lines against ground reference “

So, the coupling mode is a pure „Common Mode testing“. This means that the testing of single lines, line after line, is not demanded any more, but only all lines simultaneously have to be supplied with burst pulses.

Components

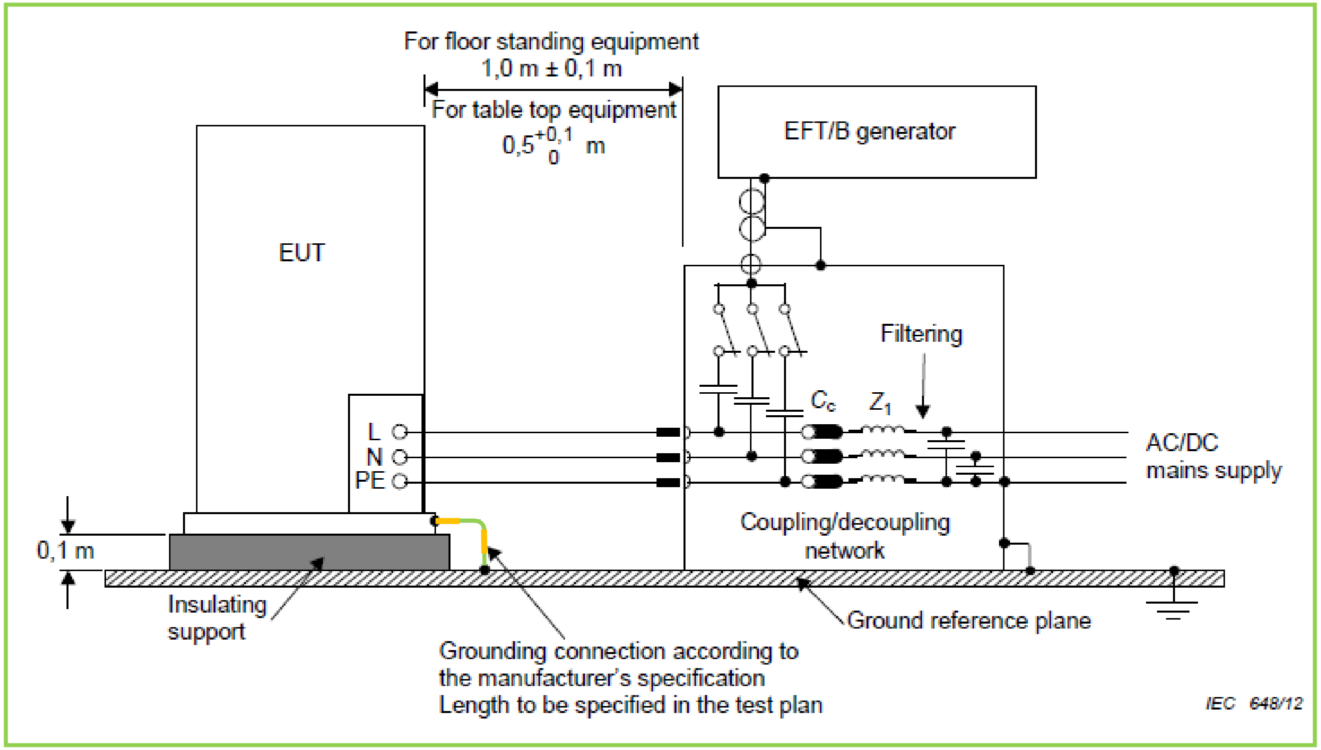
PE protective earth

N neutral

L phase

*Z*1 decoupling inductive

*C*c coupling capacitor



Test setup and test execution

Coupling mode: „all lines against reference ground "

Remark:

A large number of experts is convinced that the testing of single lines is still reasonable, because the pure Common Mode testing cannot simulate all phenomena that appear in reality.

Existing coupling/decoupling networks support both coupling modes, so that it is the user´s responsability to decide if testing of single lines is reasonable for his use.

Legally, it is enough to do the Common Mode testing. However, in the field of quality assurance it makes sense to do also the tests of single lines (e.g. during development). Thereby, useful test experience and knowledge of the EUTs behavior can be obtained.

General tests set-up acc. to EN 61000-4-4:2012

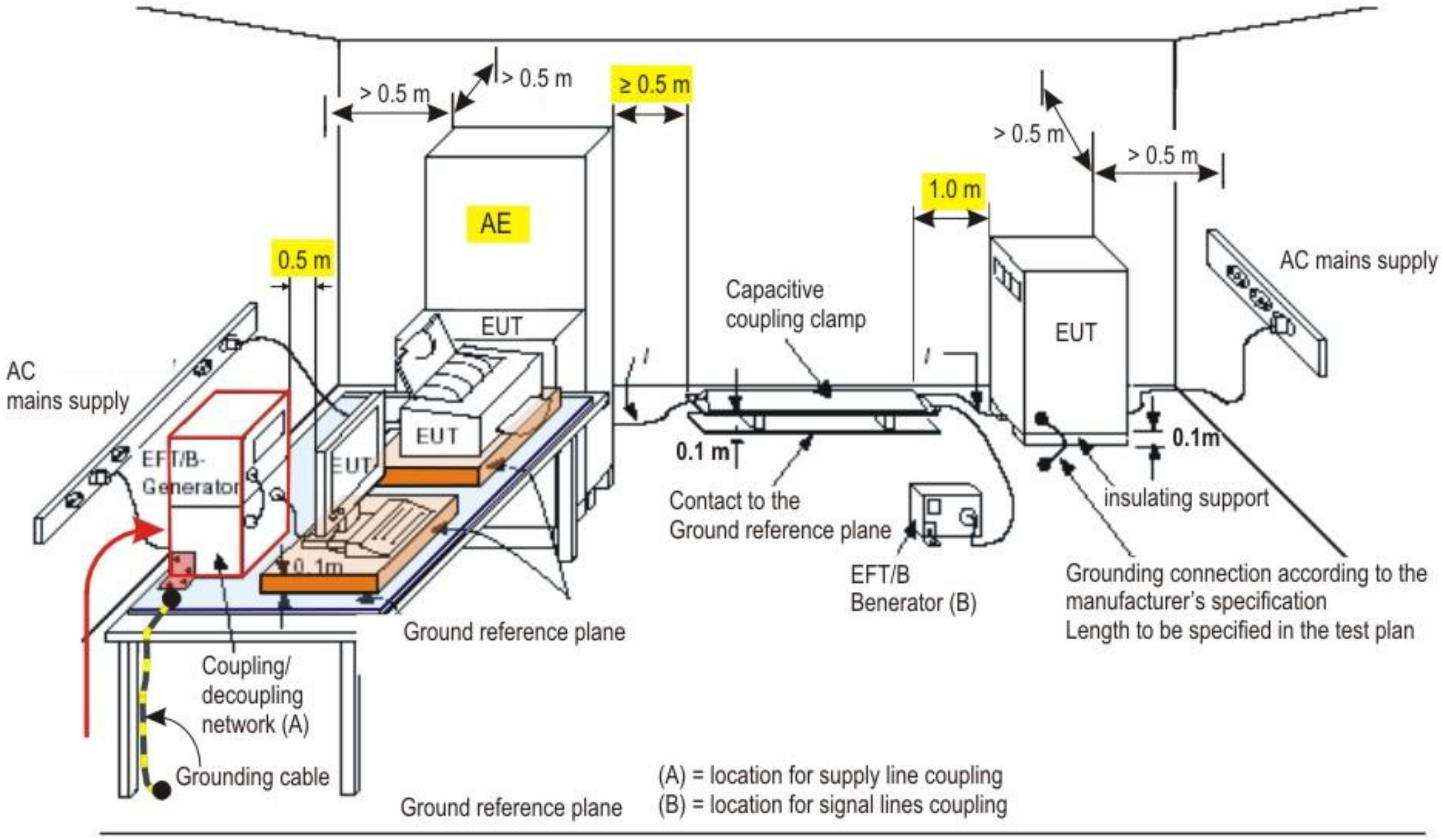
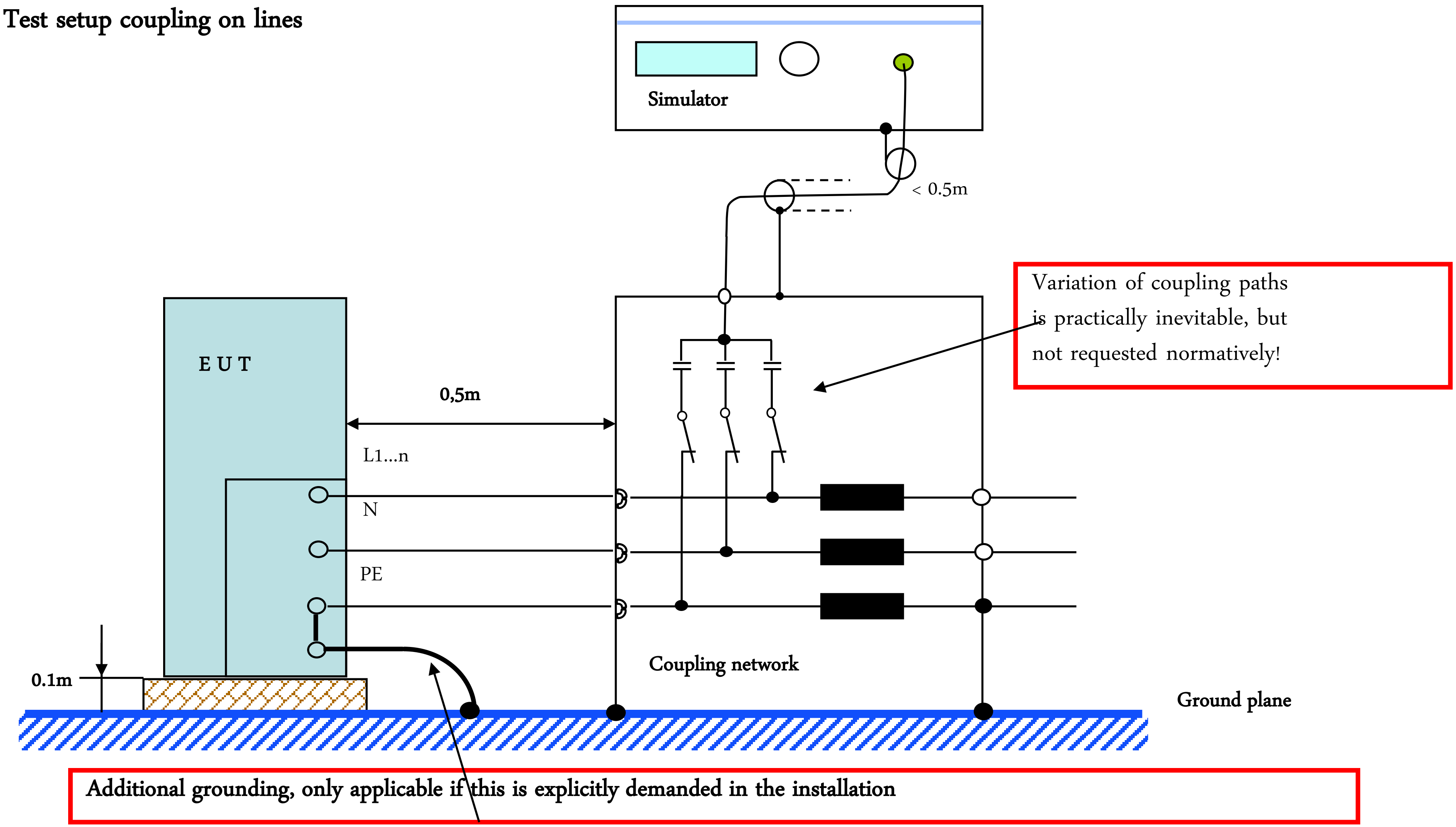
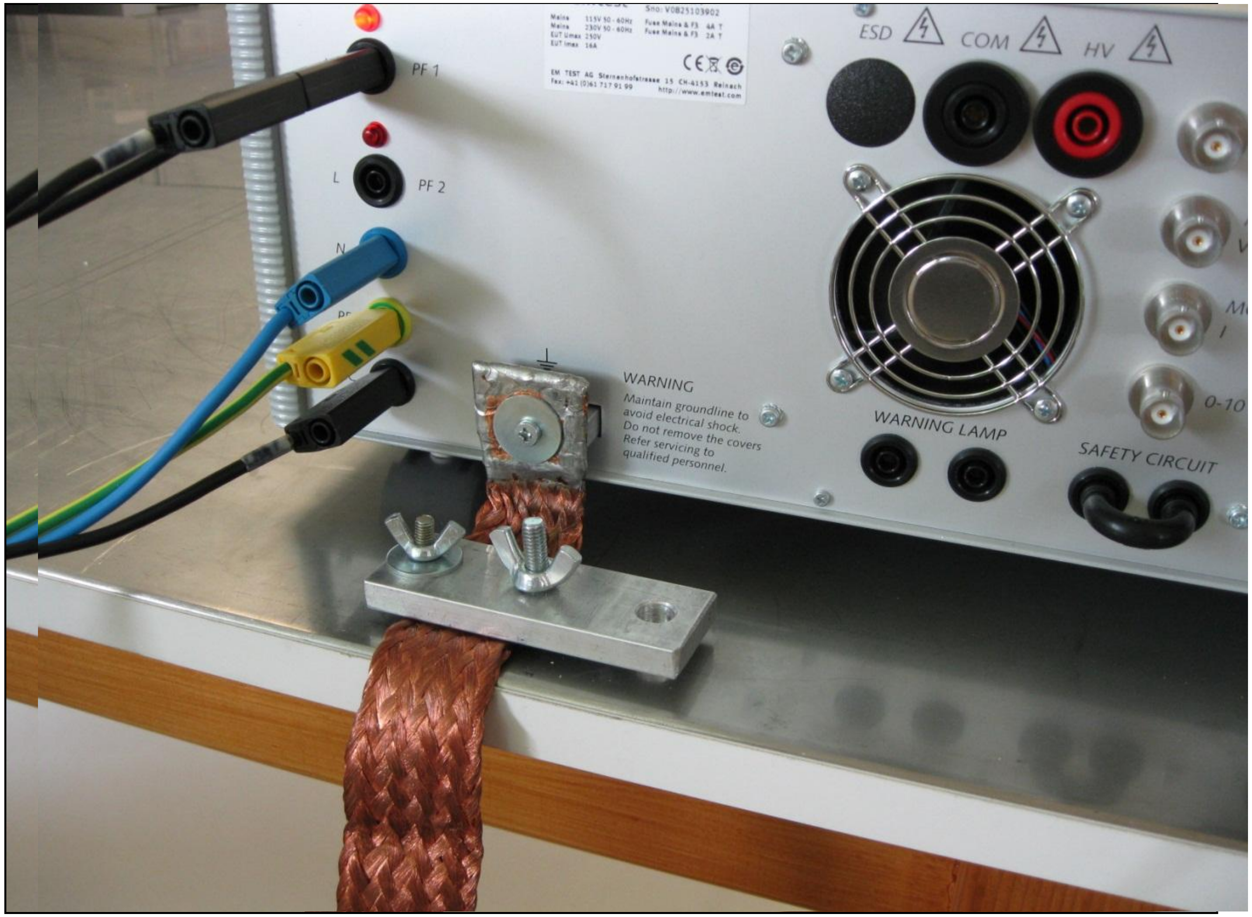


Figure 11: Example of a test setup for laboratory type tests

Test setup coupling on lines



Test setup: Connection of coupling network

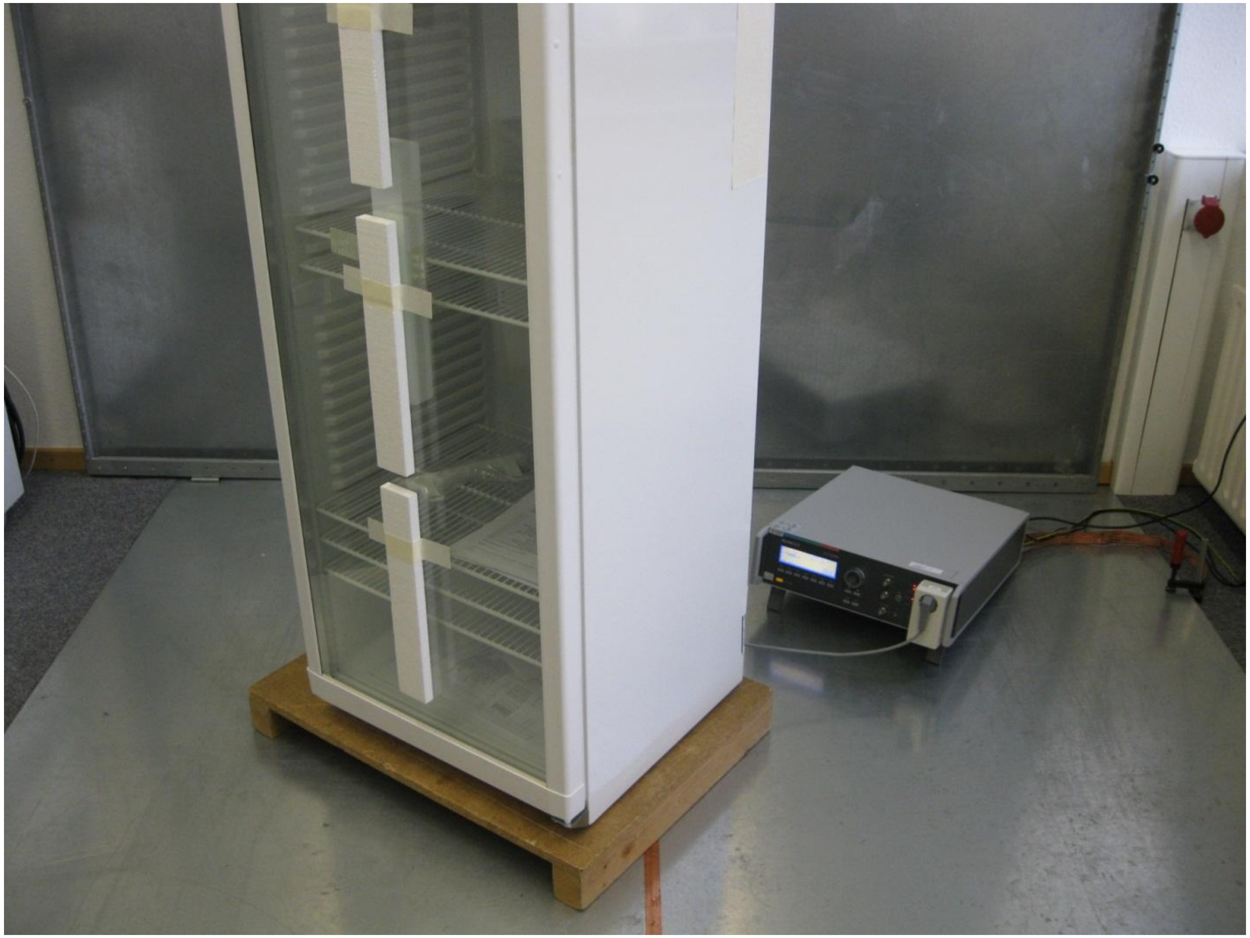


The coupling network has to be connected with the reference ground in low impedance manner!

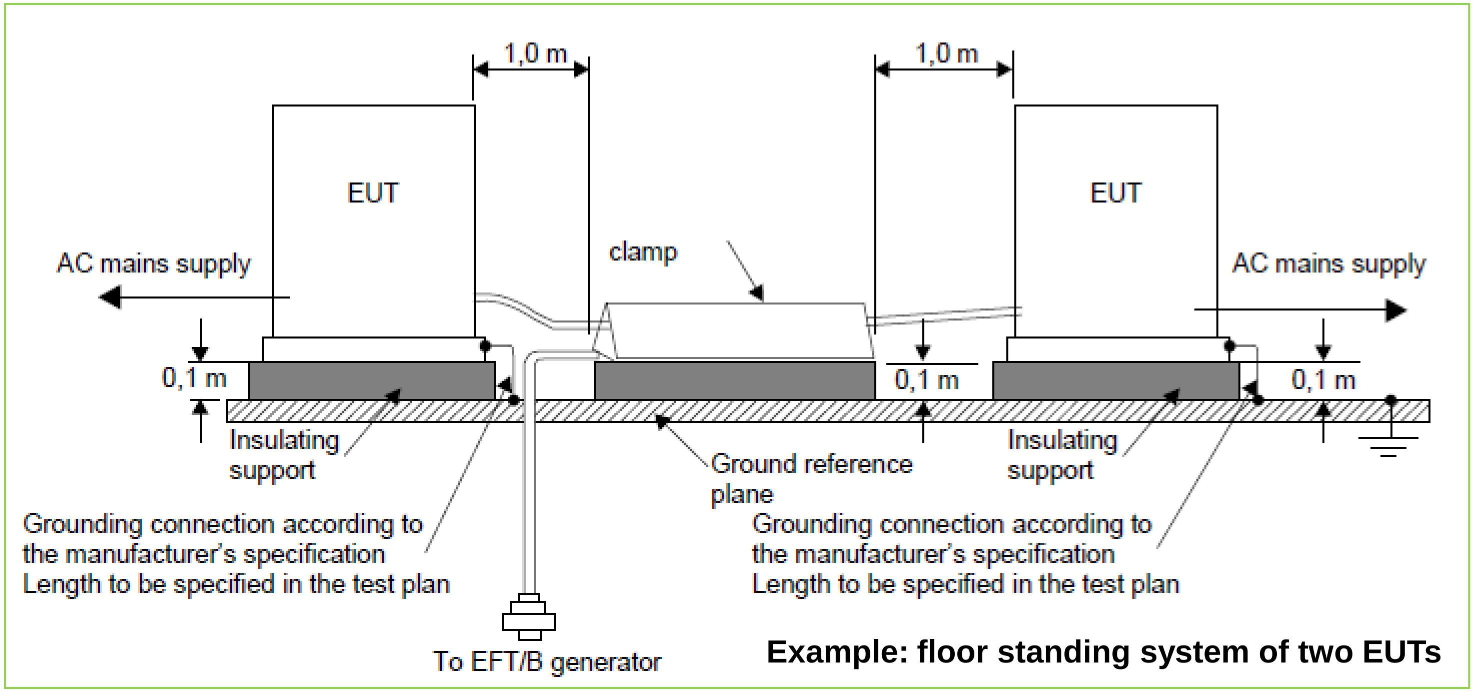
Test setup: Coupling on supply lines

Burst to AC supply lines EUT on insulated support distance generator to EUT =0.5m

Test setup: Coupling on supply lines (floor standing device) old standard!



Test setup: signal lines with capacitive coupling clamp



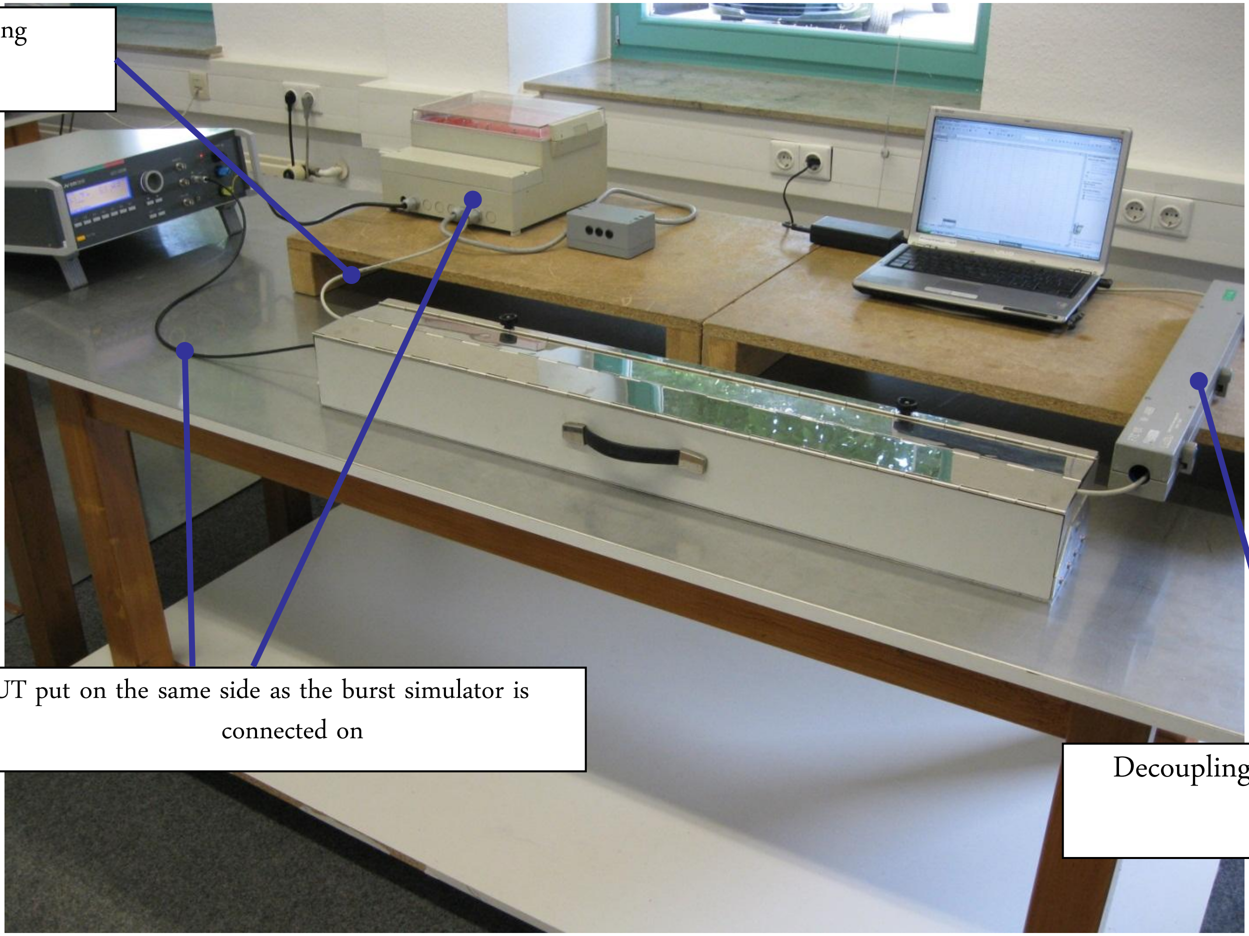
According to EN 61000-4-4:2012

The distance between any coupling devices and the EUT shall be

- **Table top equipment** testing: (0,5 - 0/+ 0,1) m
- **Floor standing equipment** : (1,0 ± 0,1) m

Test setup: capacitive coupling clamp

Distance of coupling 0.5m



EUT put on the same side as the burst simulator is connected on

Decoupling network to the AE port

Test setup: capacitive coupling clamp

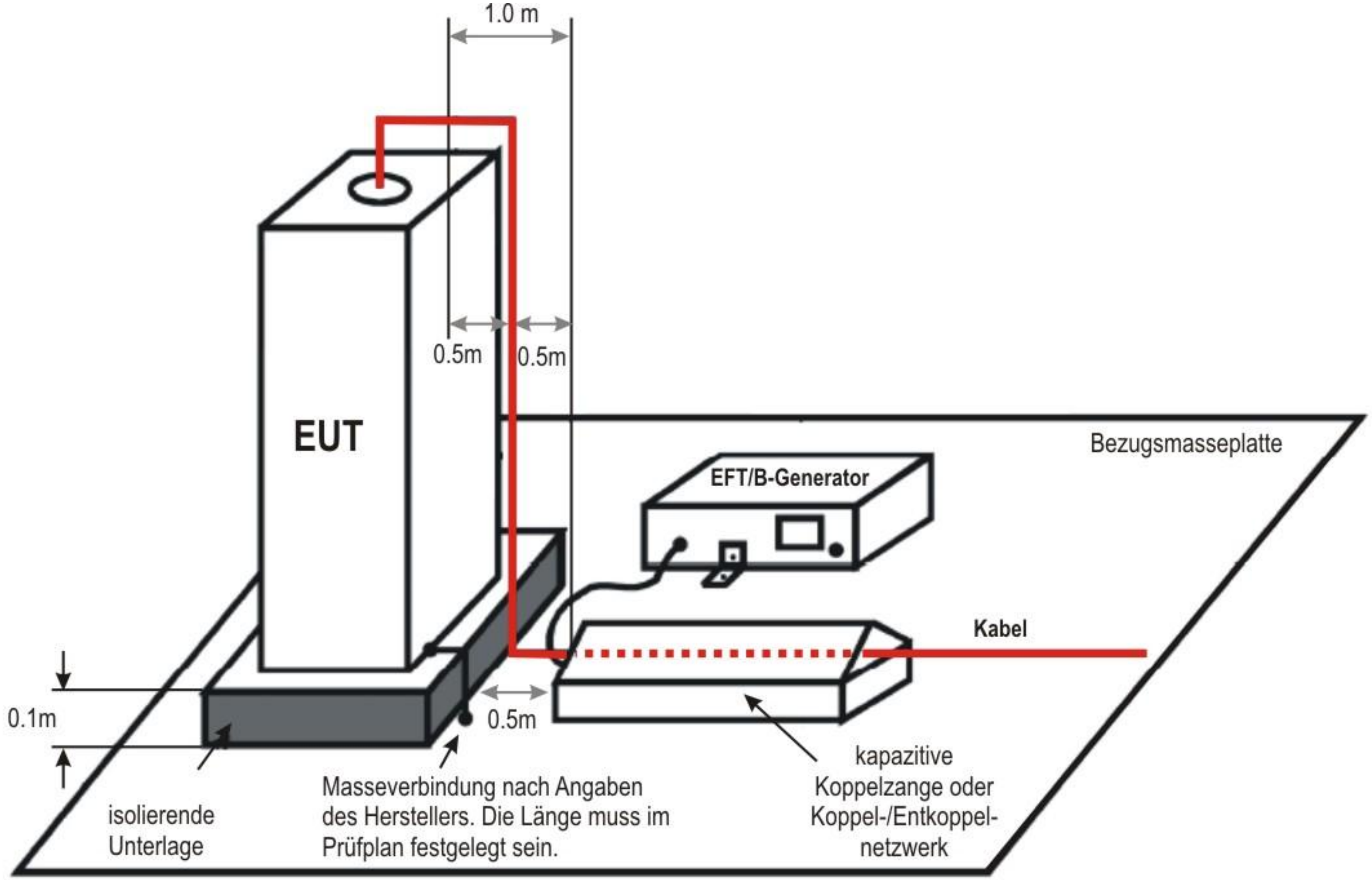


Figure 13 Example of a test setup for equipment with elevated cable entries

Example for in situ test on a.c./d.c. power ports and PE

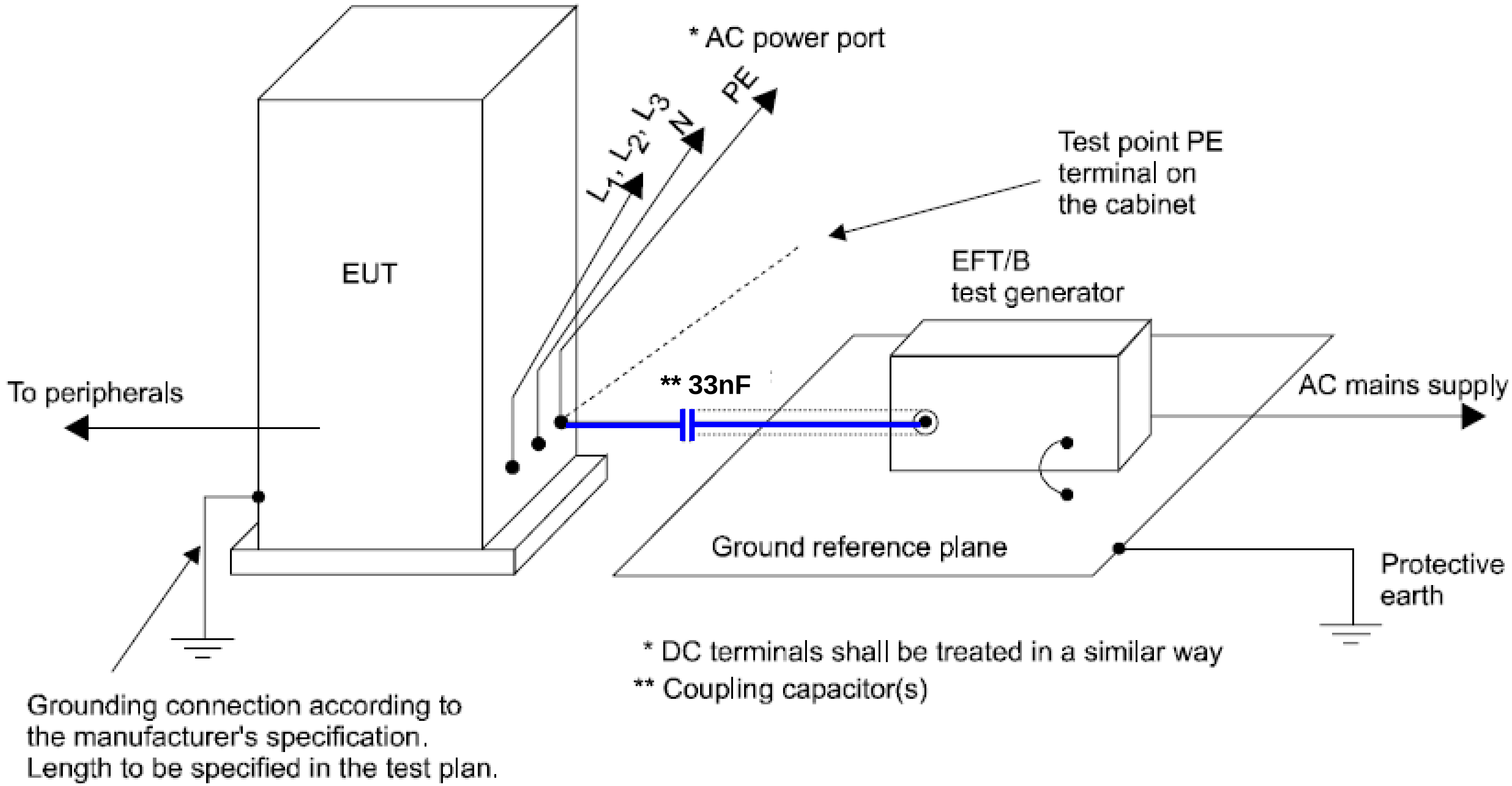


Figure 13 Example of a test setup for equipment with elevated cable entries

Alternative method for coupling to signal lines without a CCC

The capacitive coupling clamp is the preferred method for coupling the test voltage into signal and control ports. If the clamp cannot be used due to mechanical reasons (e.g. size, cable routing) in the cabling, it shall be replaced by,

a. a tape or a conductive foil enveloping the lines under test.

or alternatively

b. via discrete (100 ± 20) pF capacitors

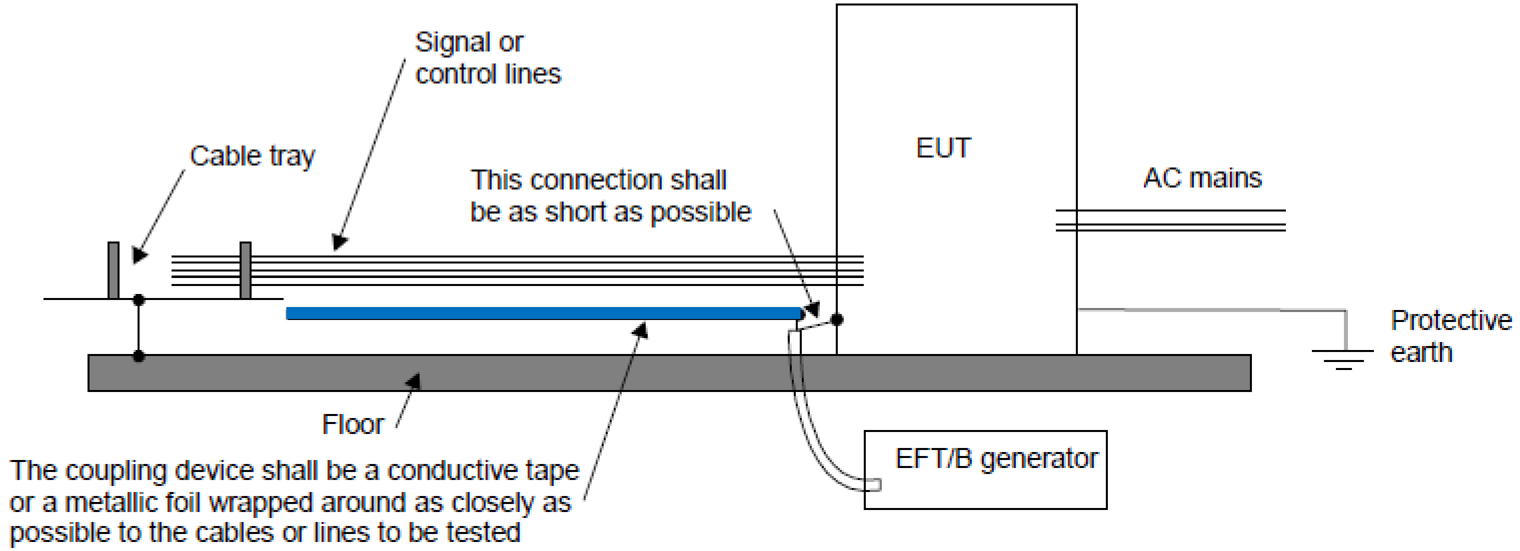


Table C.1 – Example of uncertainty budget for voltage rise time (*tr*)

Symbol	Estimate	Unit	Error bound	Unit	PDF [a]	Divisor	$u(x_i)$	c_i	Unit	$u_i(y)$	Unit
$T_{10\,\%}$	0,85	ns	0,10	ns	triangular	2,45	0,041	−1,02	1	0,041	ns
$T_{90\,\%}$	6,1	ns	0,10	ns	triangular	2,45	0,041	1,02	1	0,041	ns
δR	0	ns	0,15	ns	normal (k = 1)	1,00	0,150	1,02	1	0,152	ns
A	360	ns·MHz	40	ns·MHz	rectangular	1,73	23,09	$-44\cdot10^{-5}$	1/MHz	0,010	ns
B	400	MHz	30	MHz	rectangular	1,73	17,32	$39\cdot10^{-5}$	ns/MHz	$6,78\cdot10^{-3}$	ns
[a] Probability Density Function							$u_c(y) = \sqrt{\Sigma u_i(y)^2}$			0,16	ns
							$U(y) = 2\,u_c(y)$			0,33	ns
							Y			5,33	ns
							Expressed in % of 5,33 ns			6,2	%

New in edition 3

Table C.2 – Example of uncertainty budget for EFT/B peak voltage value (*VP*)

Symbol	Estimate	Unit	Error bound	Unit	PDF [a]	Divisor	$u(x_i)$	c_i	Unit	$u_i(y)$	Unit
V_{PR}	3,75	V	0,007 3	V	triangular	2,45	0,003 0	1 000	1	2,99	V
A	1 000	1	50	1	rectangular	1,73	28,9	3,75	V	108	V
δR	0	1	0,03	1	normal (k = 1)	1,00	0,030	3 751	V	112,5	V
δV	0	1	0,02	1	rectangular	1,73	0,012	3 751	V	43,3	V
β	7,0	MHz	0,8	MHz	rectangular	1,73	0,462	0,328	V/MHz	0,152	V
B	400	MHz	30	MHz	rectangular	1,73	17,32	−0,005 8	V/MHz	0,099 5	V
[a] Probability Density Function							$u_c(y) = \sqrt{\Sigma u_i(y)^2}$			0,162	kV
							$U(y) = 2\ u_c(y)$			0,32	kV
							y			3,75	kV
							Expressed in % of 3,75 kV			8,6	%

New in edition 3

Table C.3 – Example of uncertainty budget for EFT/B voltage pulse width (*tw*)

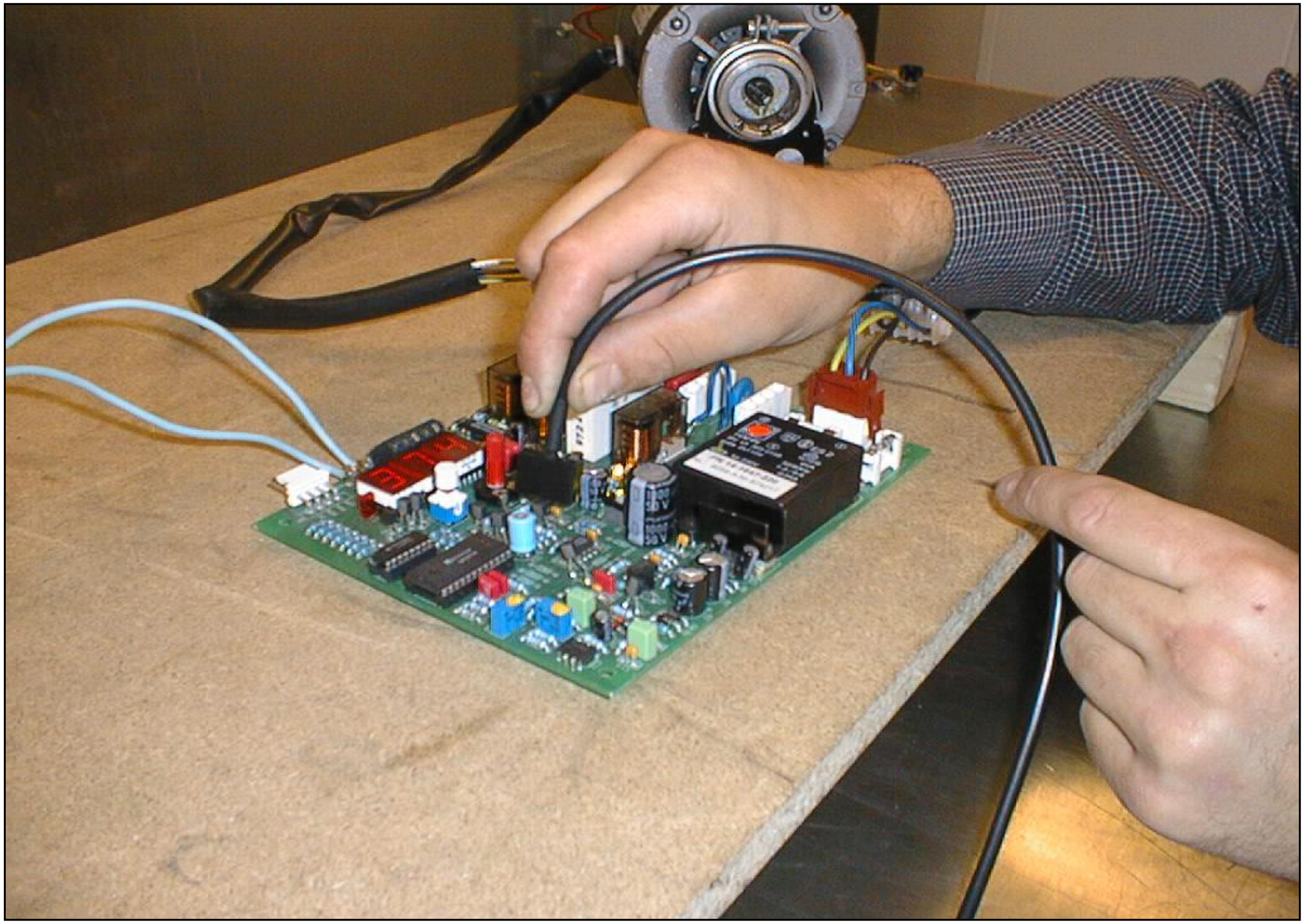
Symbol	Estimate	Unit	Error bound	Unit	PDF [a]	Divisor	$u(x_i)$	c_i	Unit	$u_i(y)$	Unit
$T_{50\ \%,R}$	3,5	ns	0,10	ns	triangular	2,45	0,041	−1,00	ns	0,040 8	ns
$T_{50\ \%,F}$	54,5	ns	0,10	ns	triangular	2,45	0,041	1,00	ns	0,040 8	ns
δR	0	ns	1,5	ns	normal (k = 1)	1,00	1,50	1,00	ns	1,50	ns
$ß$	7,0	MHz	0,8	MHz	rectangular	1,73	0,462	−0,004 5	ns/MHz	0,002 1	ns
B	400	MHz	30	MHz	rectangular	1,73	17,32	$8{,}0\cdot10^{-5}$	ns/MHz	0,001 4	ns
[a] Probability Density Function							$u_c(y) = \sqrt{\Sigma u_i(y)^2}$			1,502	ns
							$U(y) = 2\ u_c(y)$			3,00	ns
							Y			51,0	ns
							Expressed in % of 51,0 ns			5,9	%

New in edition 3

During development: Immunity in layout

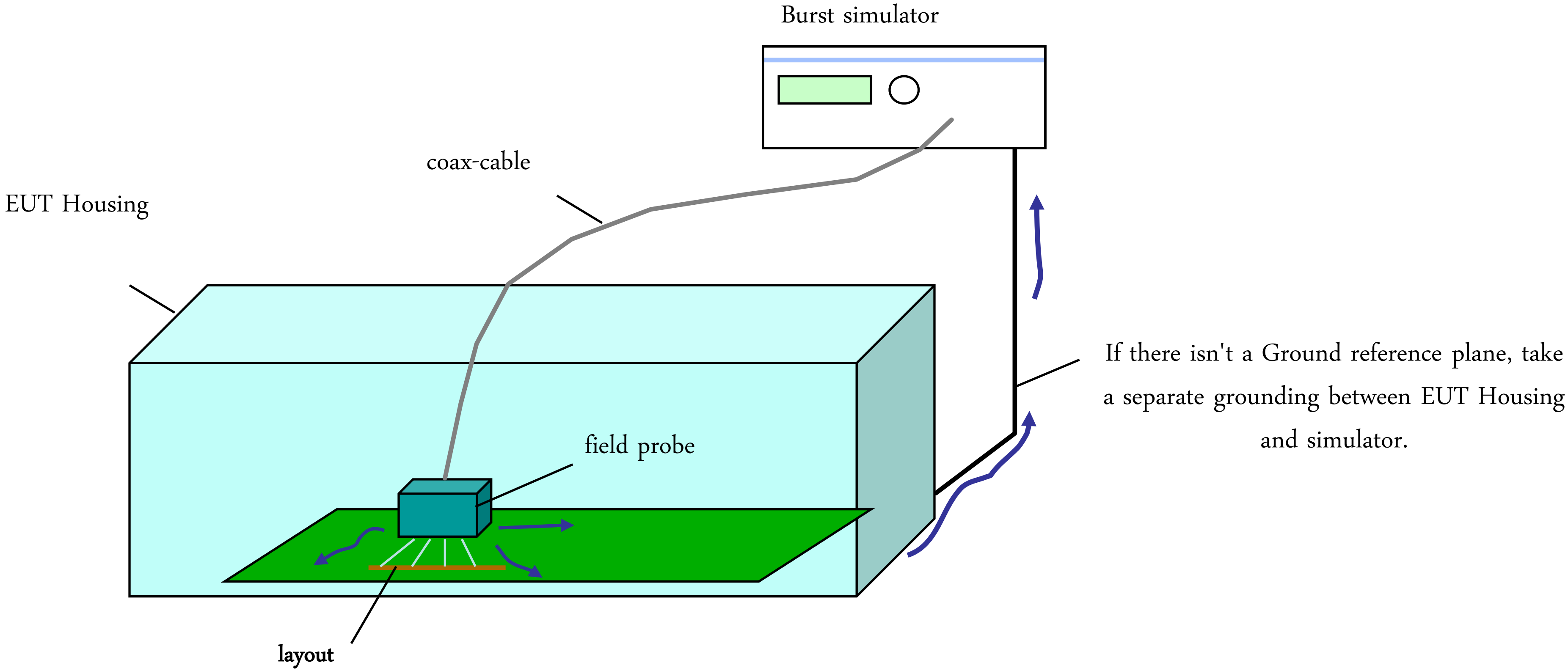
ITP set

Immunity Test Probe



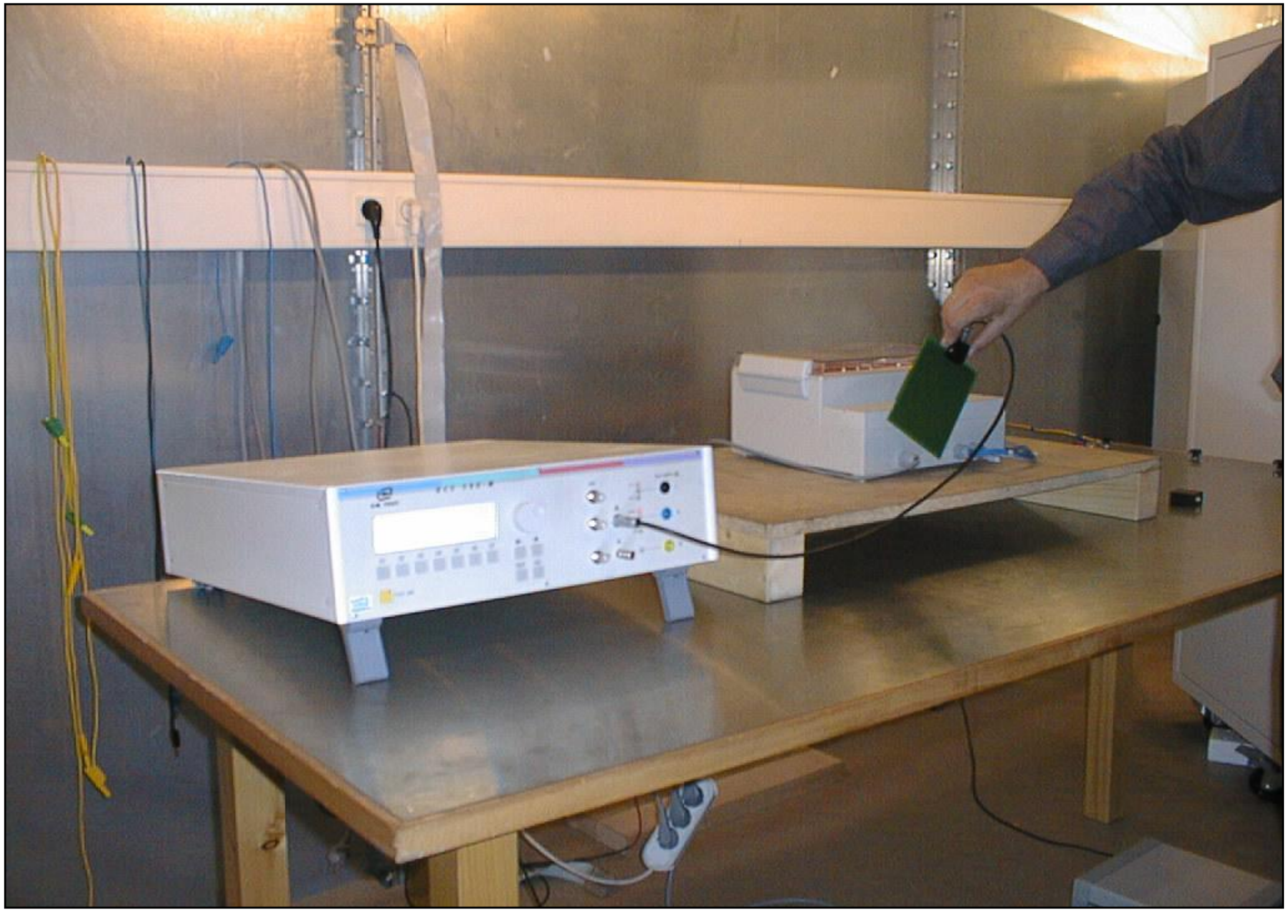
Immunity in layout - capacitive with an E - fieldprobe

Example for radiated field immunity test inside the EUT



During development: Radiated immunity

Example for radiated field immunity test



Any questions? We are at your disposal!

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Thank you for your attention!