EMC

EMC of Power Converters

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Electromagnetism is just electricity

Converters are particularly concerned with EMC:

- **Conducted disturbances (Mainly by large converters)**
  - For the converter itself (self immunity)
  - For the environment (common mode disturbances)

- **Radiated disturbances (even by small converters)**
  - Near fields couplings
  - Far field radiation (mainly for radio receivers)

Beware of unreasonable EMC Standards!

Conducted emission limits of EMC standards for large equipment (inverters, speed drives, arc welders, lifts…) are really too high:

Mains terminal disturbance voltage limits for class A equipment measured on a test site

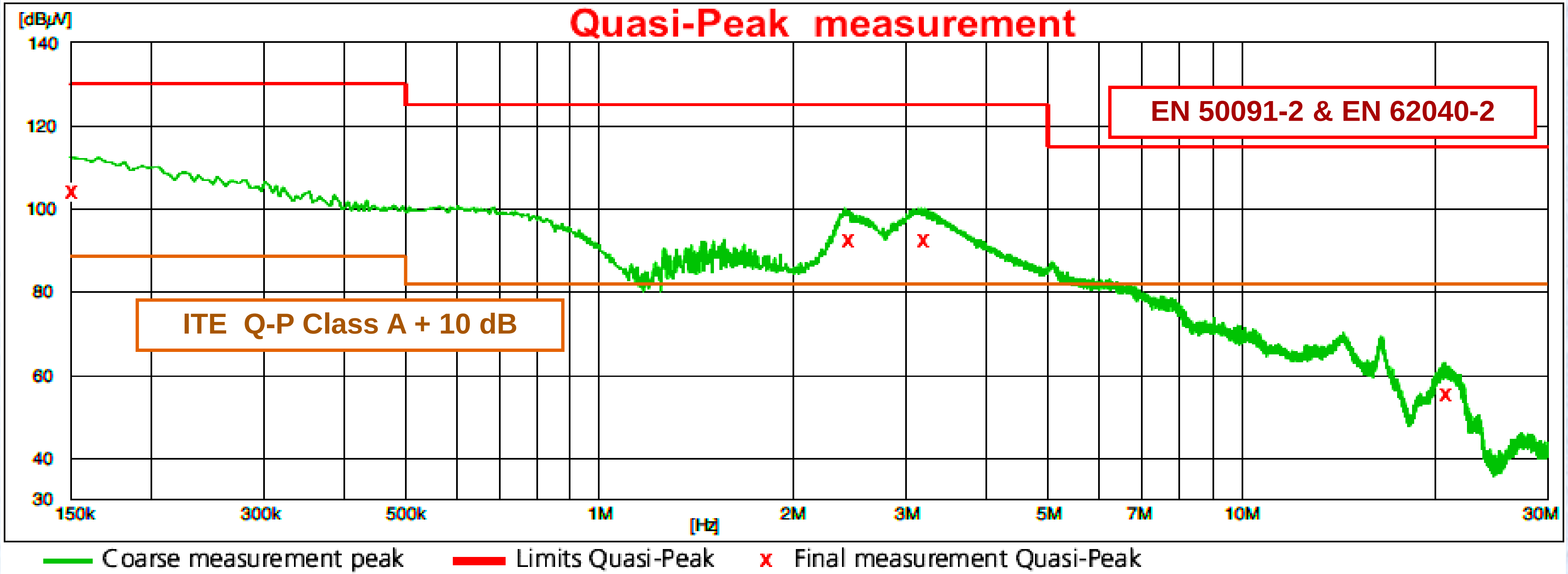
Frequency band MHz	Class A equipment limits dB(µV)					
	Group 1		Group 2		Group 2 [a]	
	Quasi-peak	Average	Quasi-peak	Average	Quasi-peak	Average
0,15 – 0,50	79	66	100	90	130	120
0,50 – 5	73	60	86	76	125	115
5 – 30	73	60	90 Decreasing linearly with logarithm of frequency to 70	80 Decreasing linearly with logarithm of frequency to 60	115	105

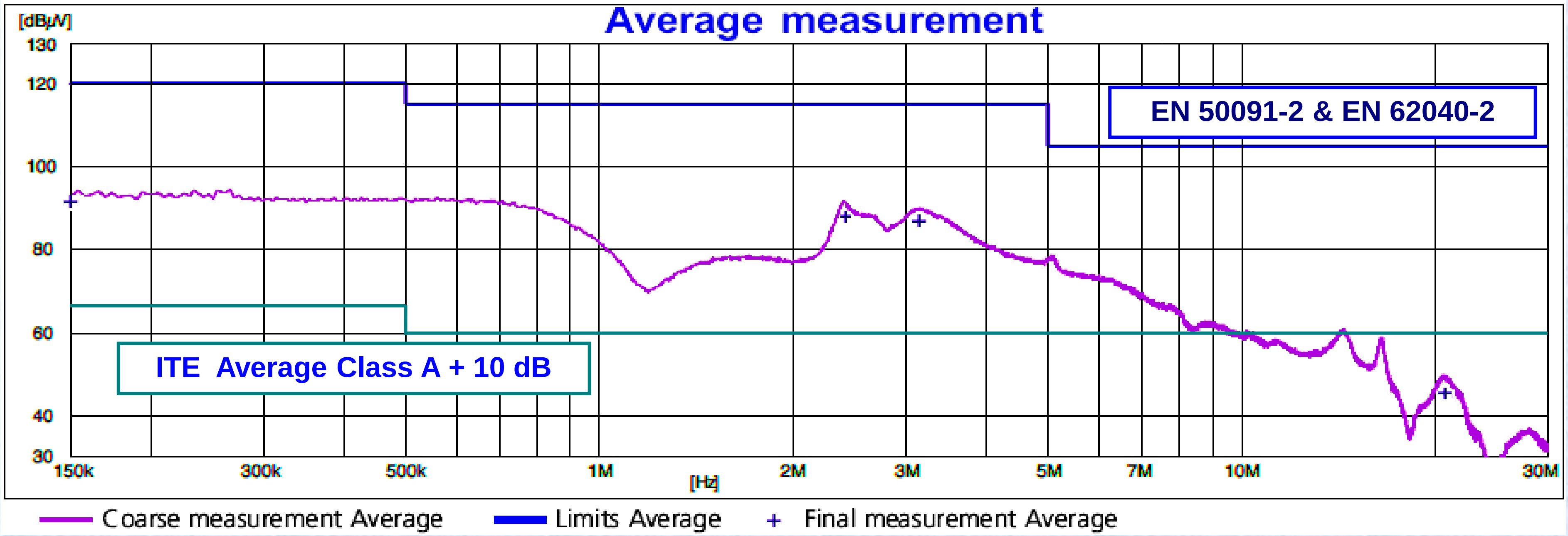
a Mains supply currents in excess of 100 A per phase when using the CISPR voltage probe or a suitable V-network (LISN or AMN).

115 $dB_{\mu V}$ into 9 kHz **= 126 $dB_{\mu V}$** into 120 kHz **equivalent to 40 mA into 50 Ω**

While the limit corresponding to the **radiated emission** according to **Class A + 10 dB** from 30 MHz to 230 MHz is smaller than **30 µA** (in common mode for any cable)!

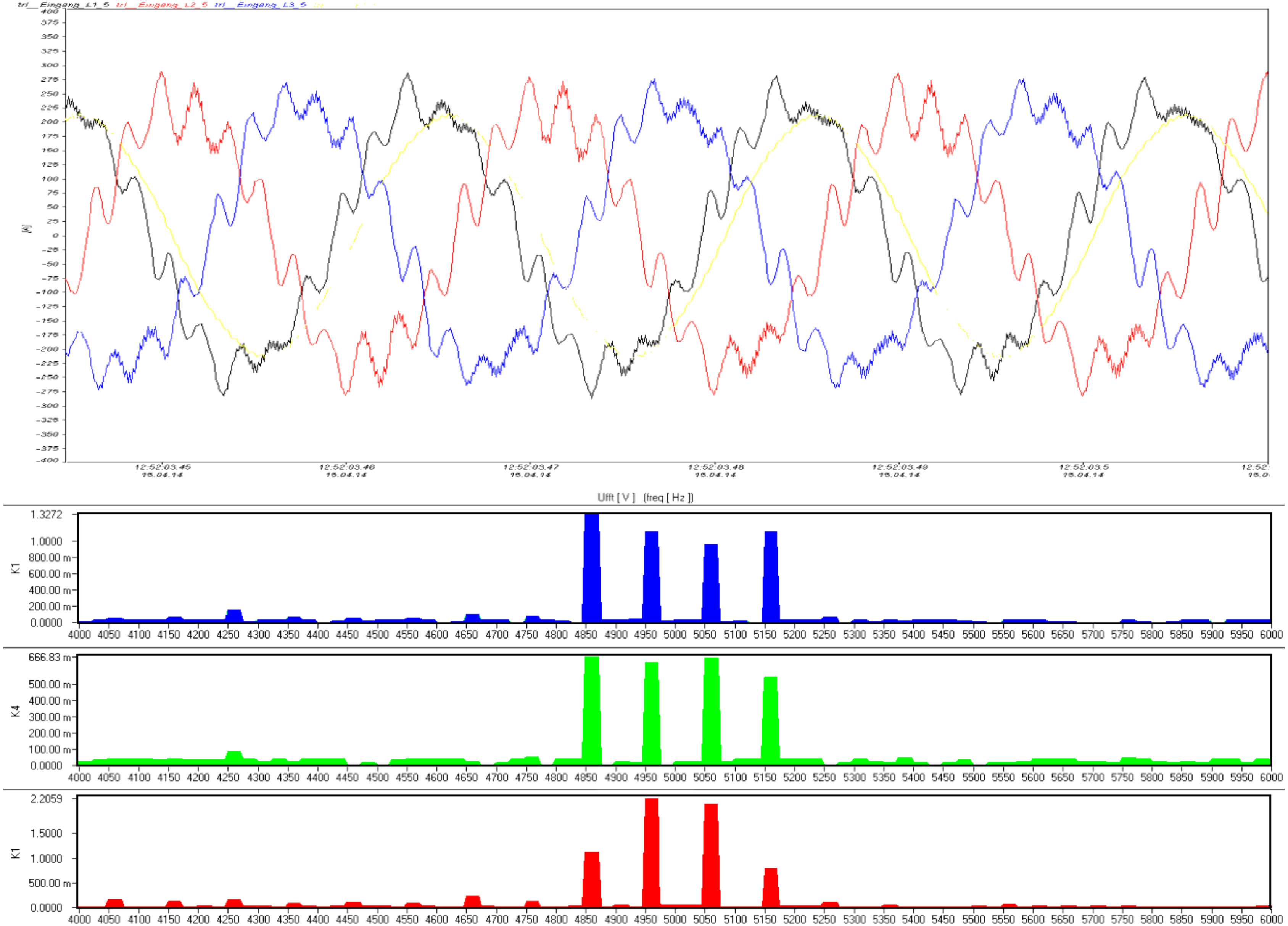
Poorly filtered 300kVA inverter conducted spectrum





Beware of 2 kHz to 150 kHz band !

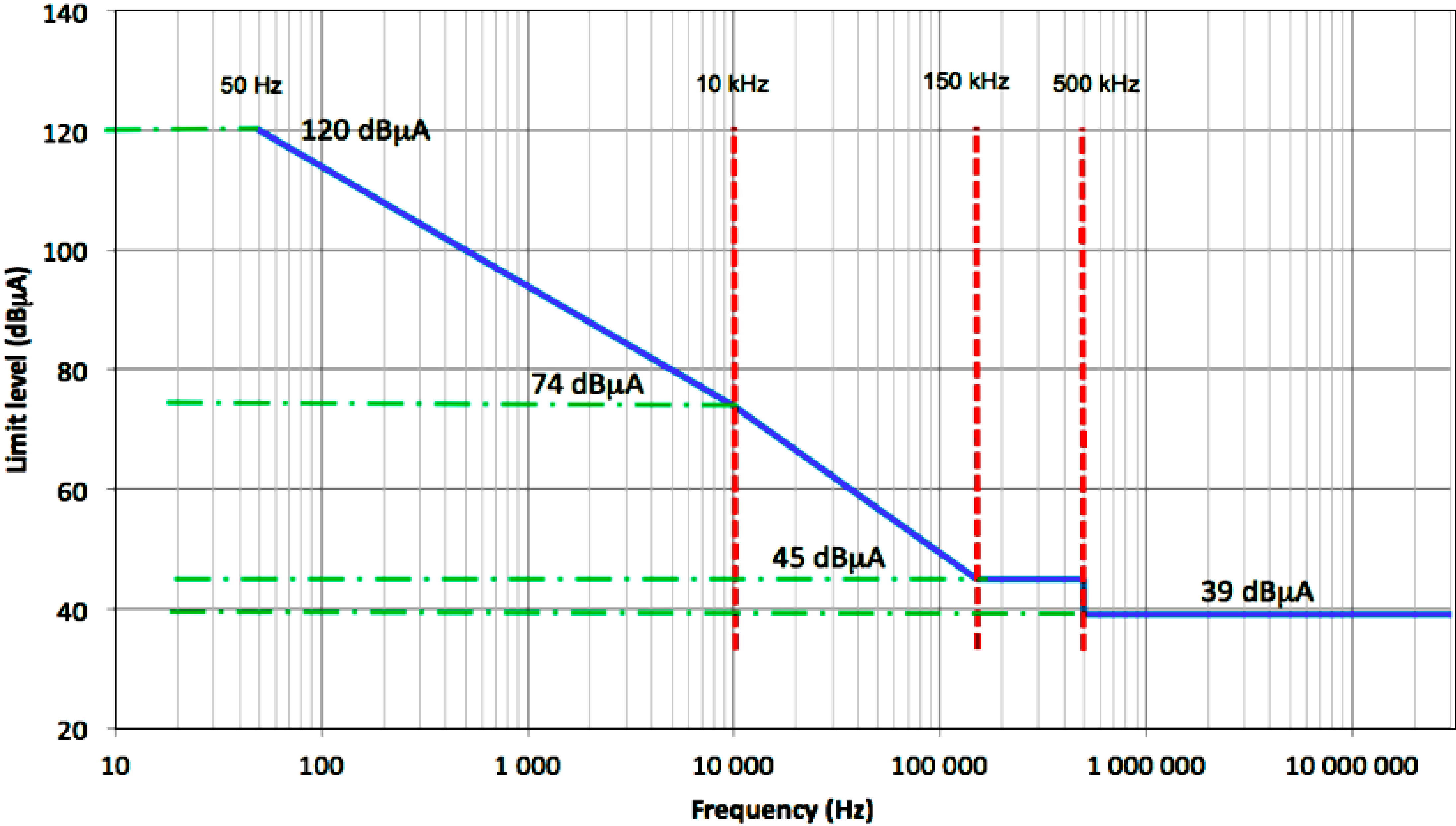
Inverter currents in time & frequency domain (currently, no CISPR limit apply)



Suggested specification for immunity testing: IEC 61000-4-16

Let’s specify modified EMC Standards !

Conducted emission limits for ITER Facility



DC / DC Converter instability

A switch-Mode Converter at low frequency introduces a **negative incremental impedance**

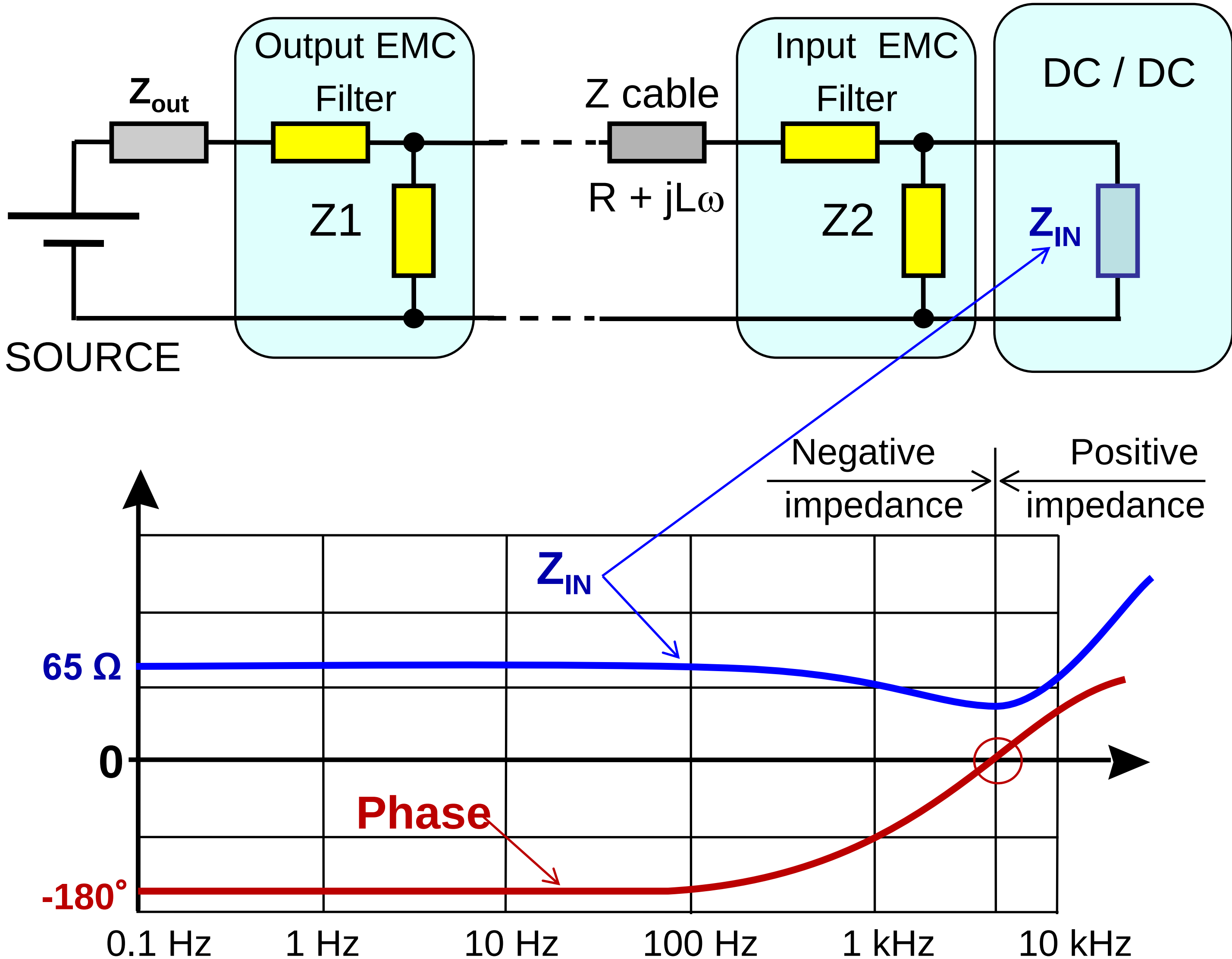
$Z_{IN} = \Delta V / \Delta I$ (for P = constant, when U decreases, I increases).

Risks :

- No start.
- Start but wrong output voltage.
- Output voltage instability.
- Destruction of the converter.

Solutions :

- Add a large (larger) capacitor at the DC/DC converter input.
- Reduce the source impedance (example: several pairs in //).
- Reduce the converter bandwidth.

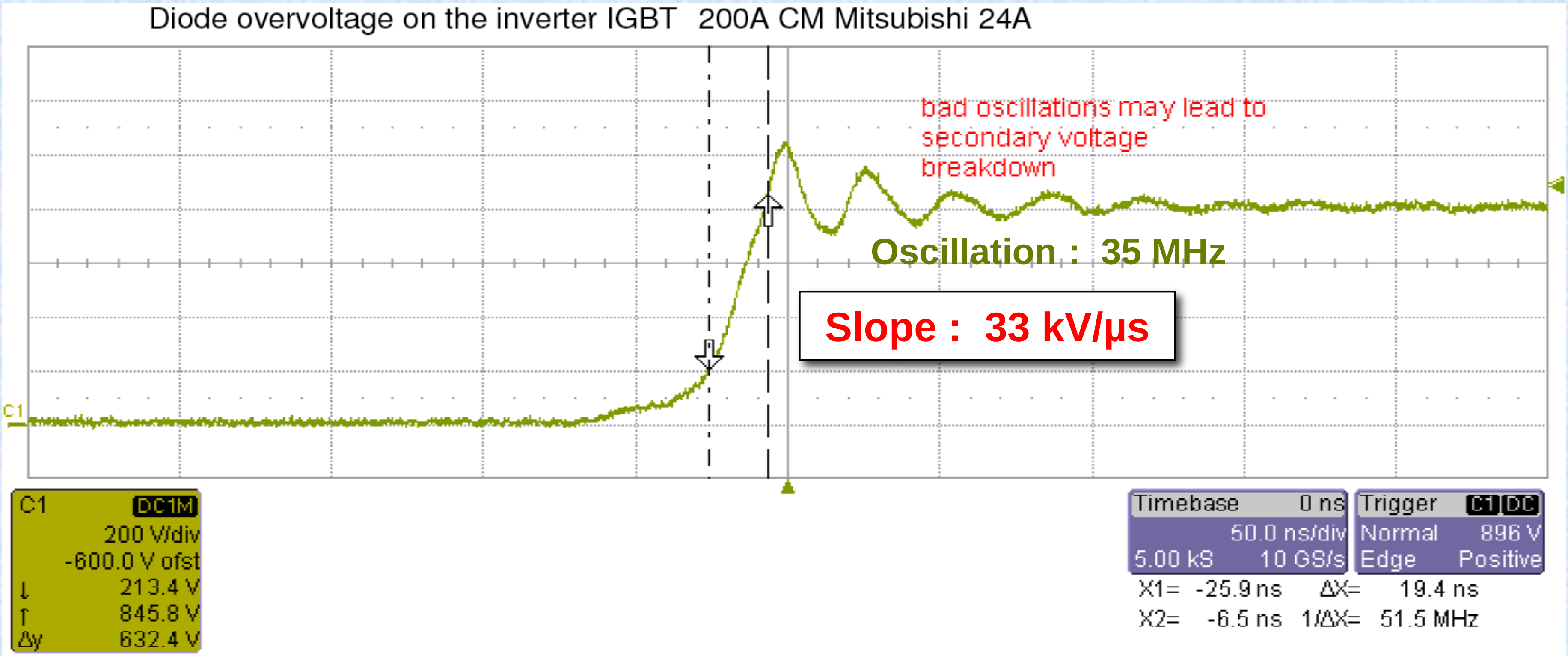


Let's read and uphold data-sheets !

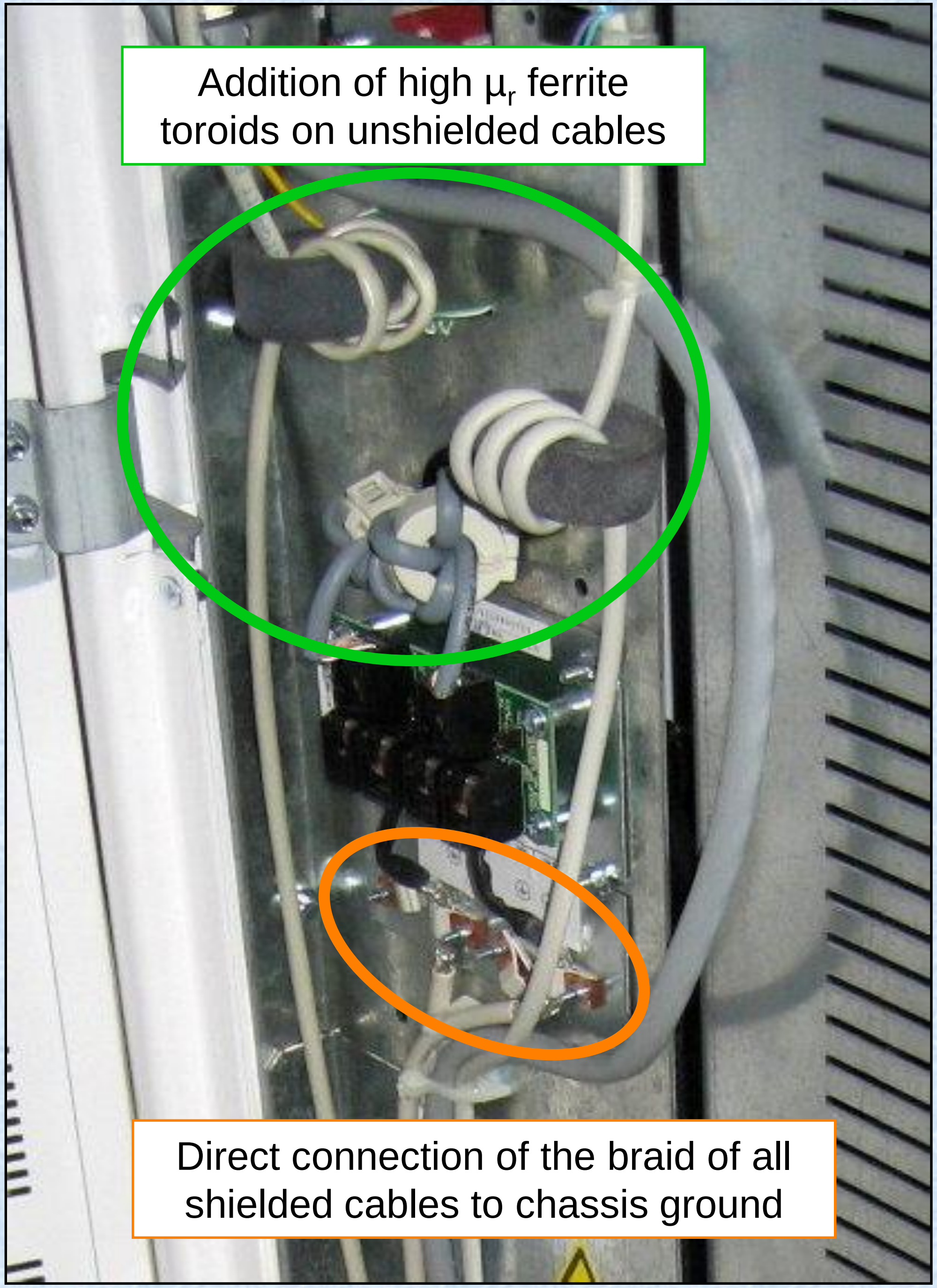
Parameter	Symbol	Min.	Typ.*	Max.	Units	Test Conditions
Output High Level Common Mode Transient Immunity	$\|CM_H\|$	15	30		kV/µs	T_A = 25°C, I_F = 10 to 16 mA, V_{CM} = 1500 V, V_{CC} = 30 V
Output Low Level Common Mode Transient Immunity	$\|CM_L\|$	15	30		kV/µs	T_A = 25°C, V_{CM} = 1500 V, V_F = 0 V, V_{CC} = 30 V

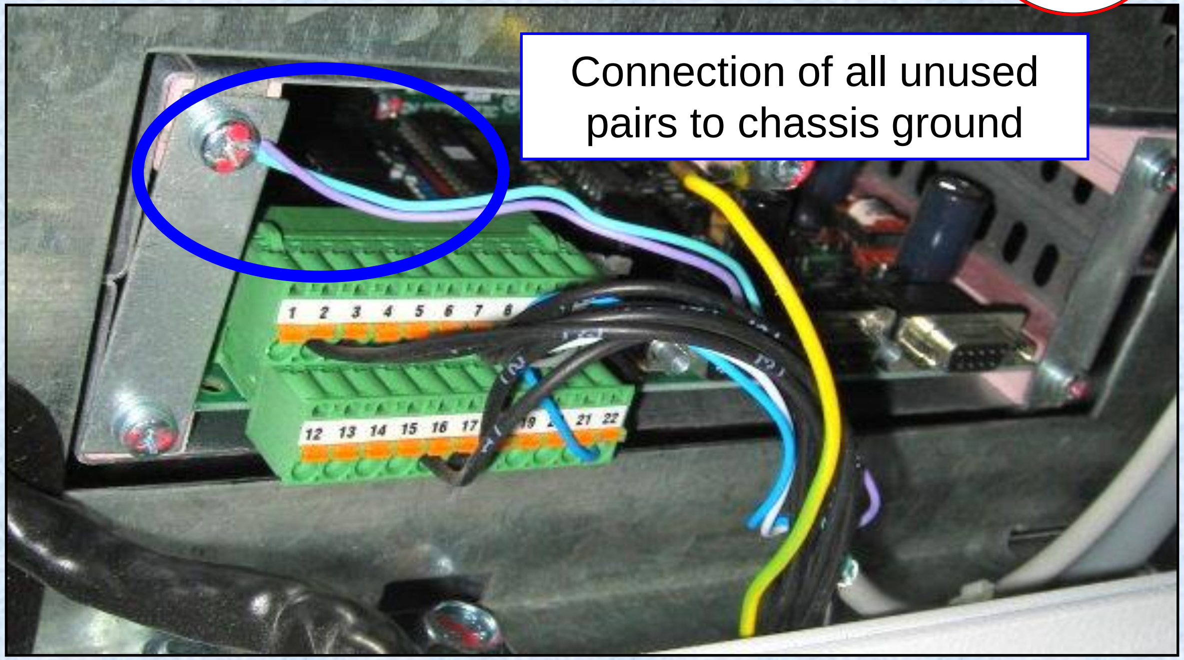
* typical values at T_A = 25°C

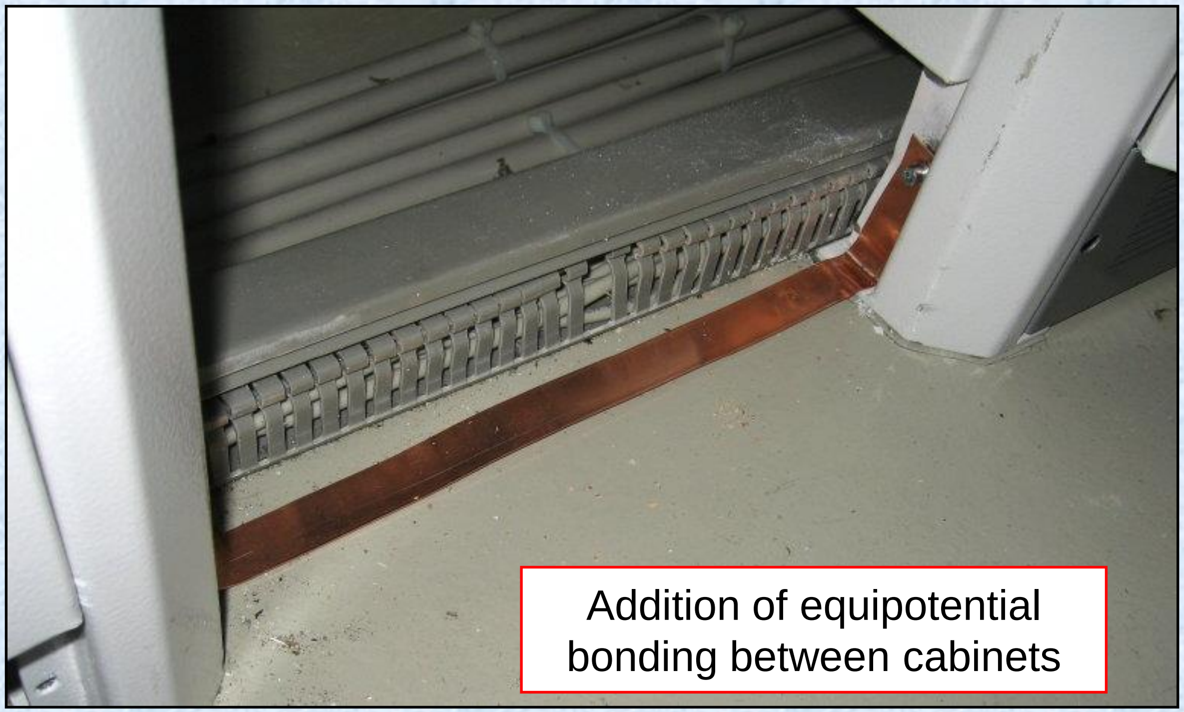
Gate Drive Optocoupler HCPL 3120 Technical Data



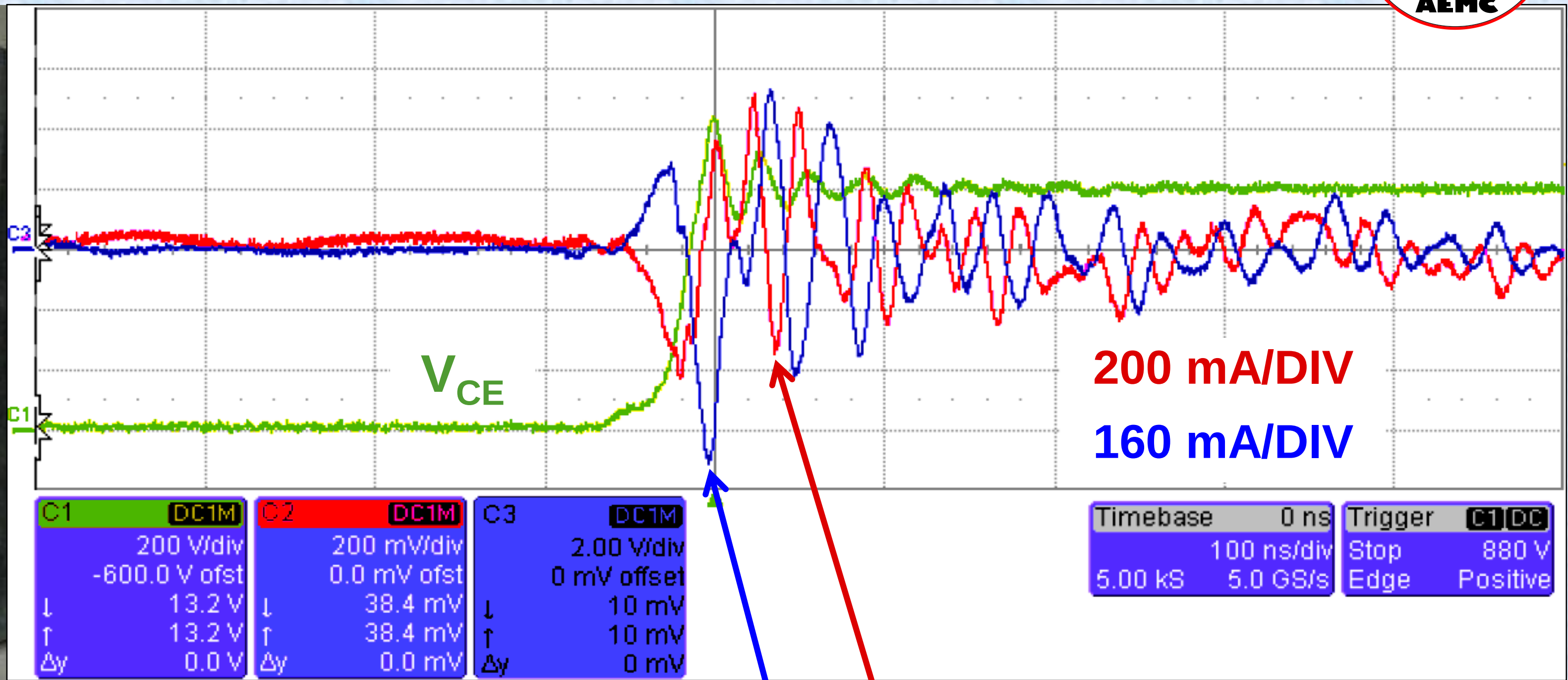
EMC on-site mitigation







Maximal CM current over internal cables



Wide-band clamp : Zt = 1 Ω (from 0,03 to 100 MHz)

Sensitive current clamp : Zt = 12 Ω (5 to 230 MHz)

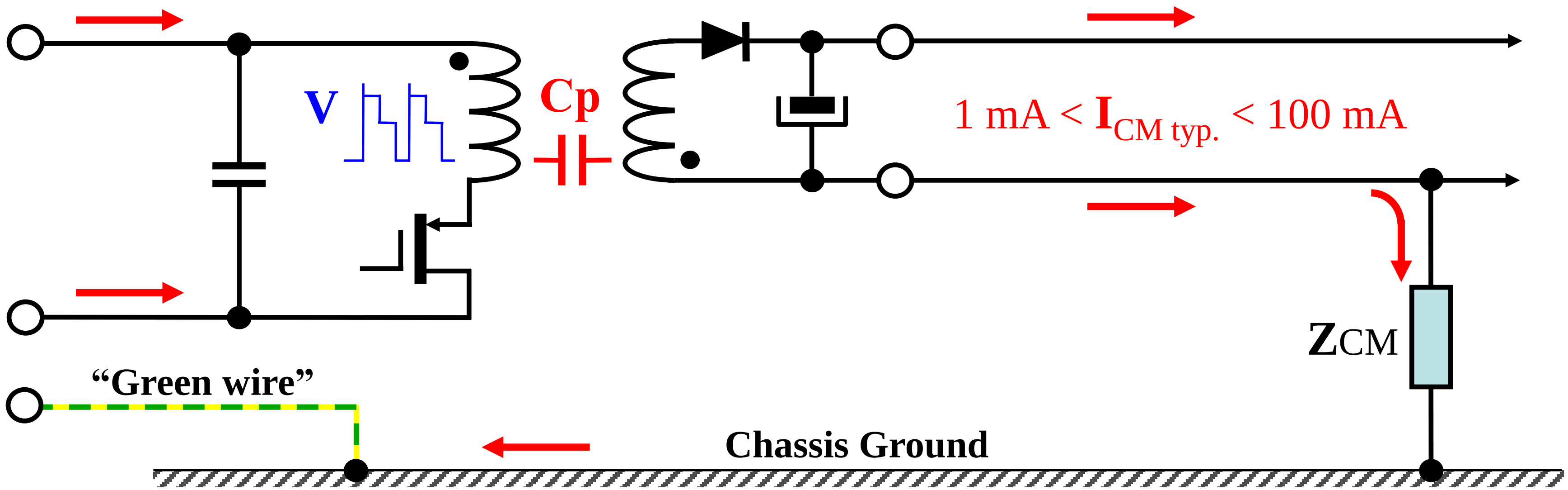
EMC recommendation :

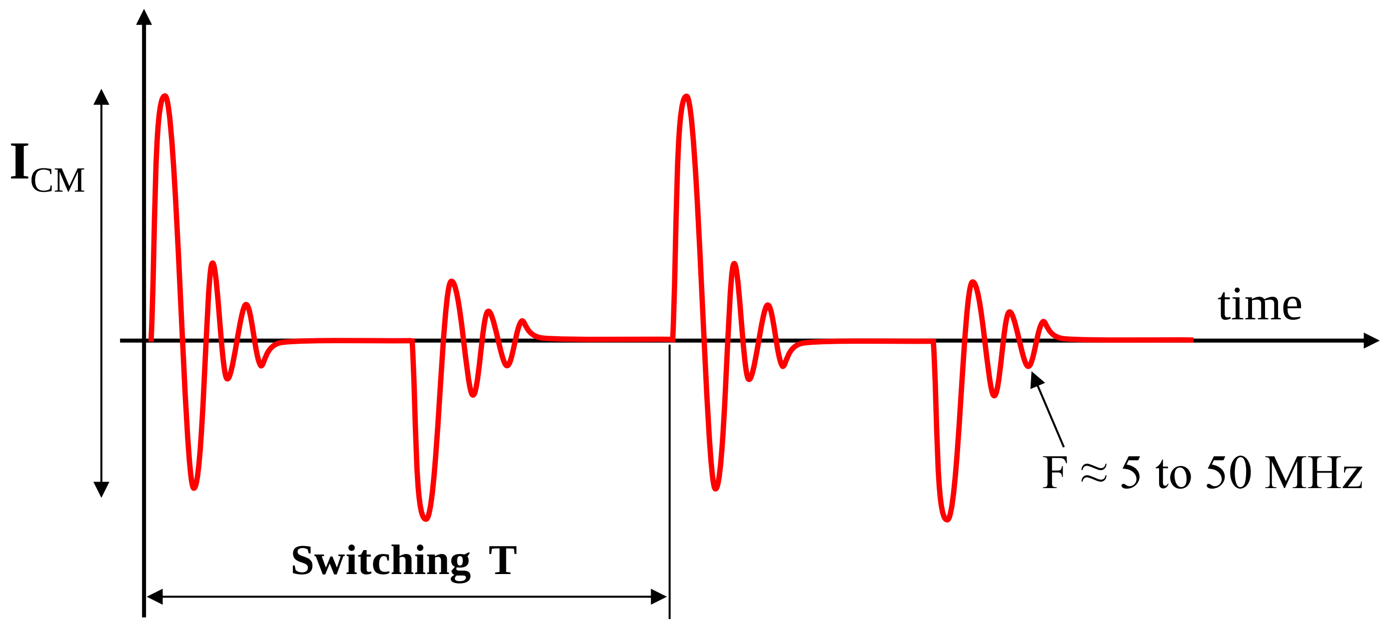
I_{CM} on IGBT control cable: < 5 A peak-to-peak

I_{CM} on any internal cable: < 2 A peak-to-peak

Comfortable EMC margin : 0.2 x those values

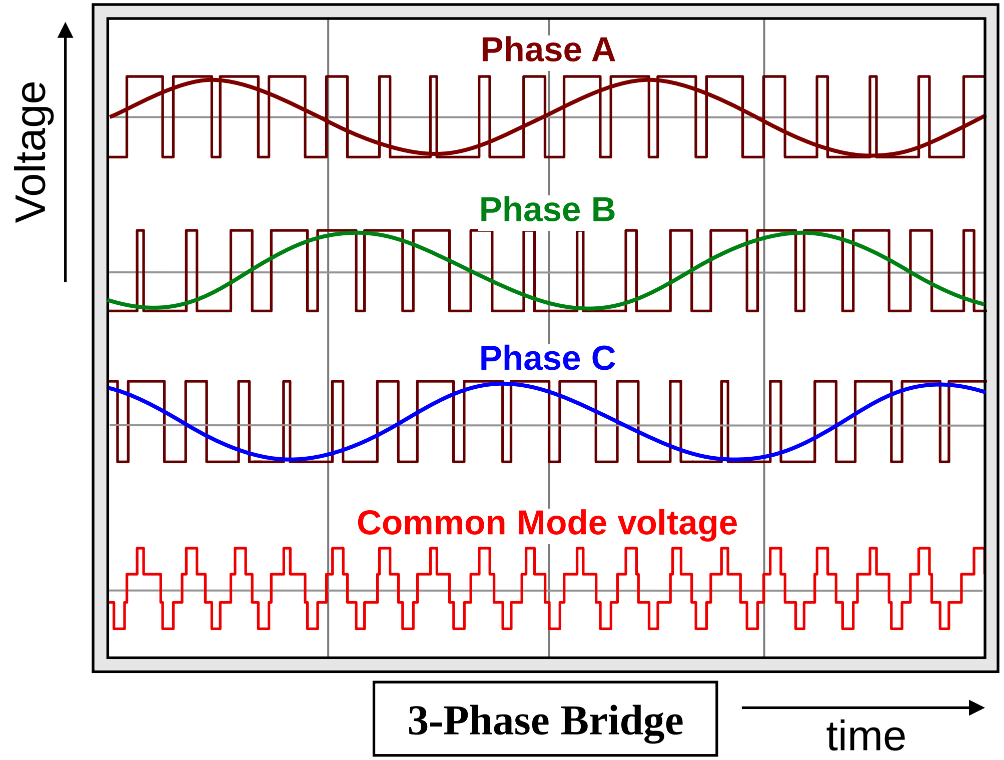
DC/DC Input to output common mode



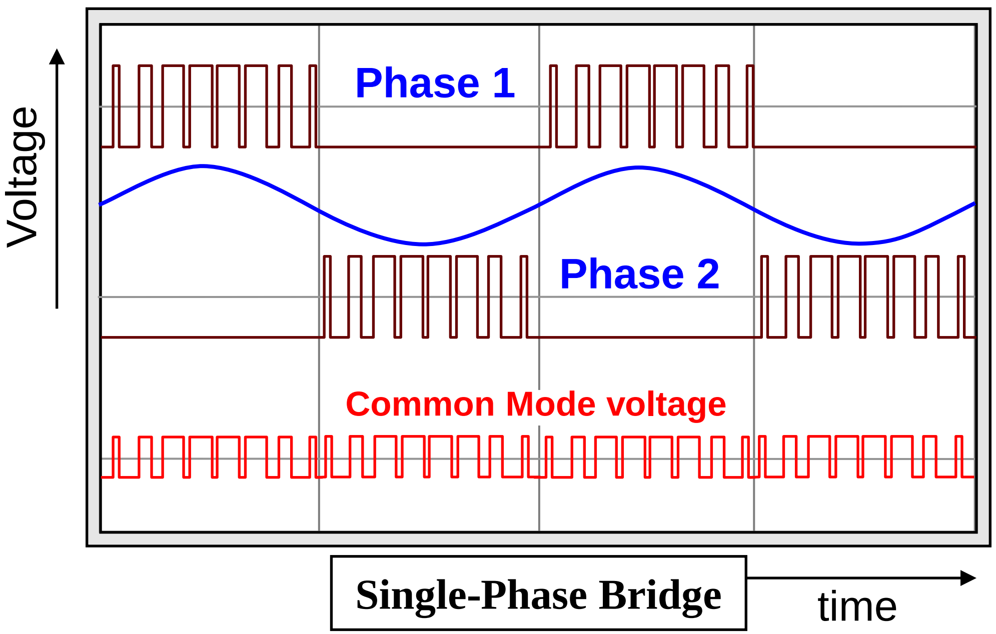


DC/AC Input to output common mode

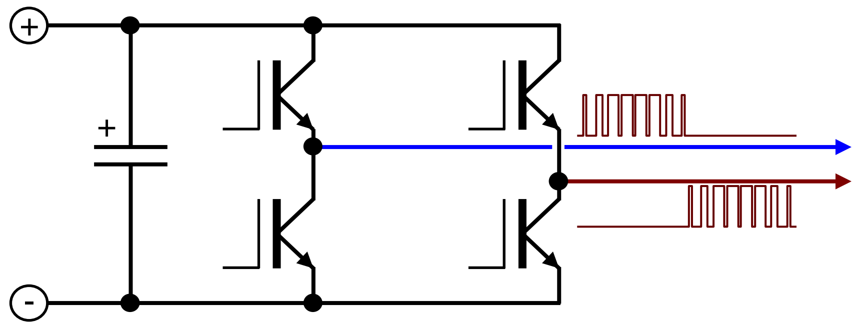
Switching inverters and motor drives are noisy sources in common mode



3-Phase Bridge

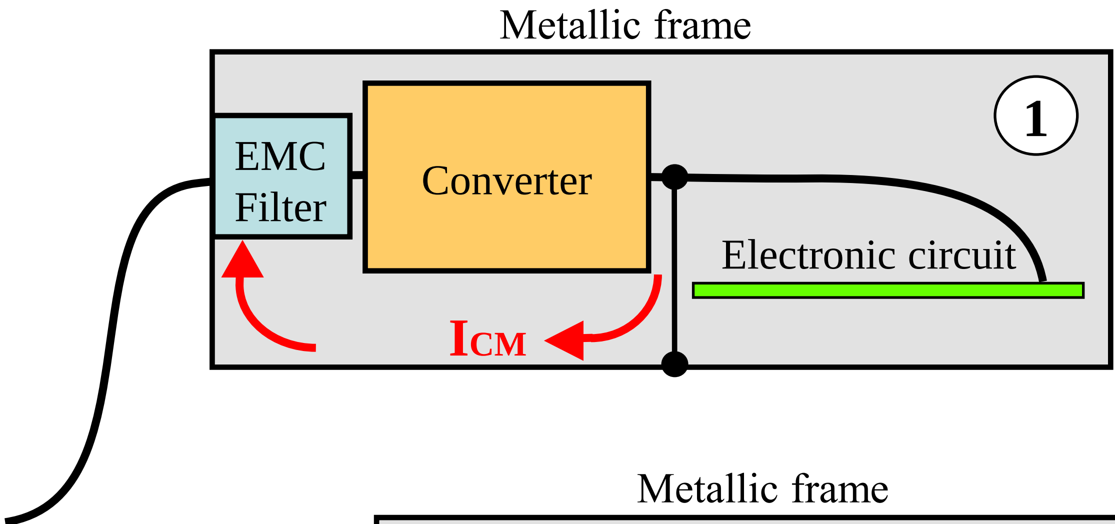


Single-Phase Bridge

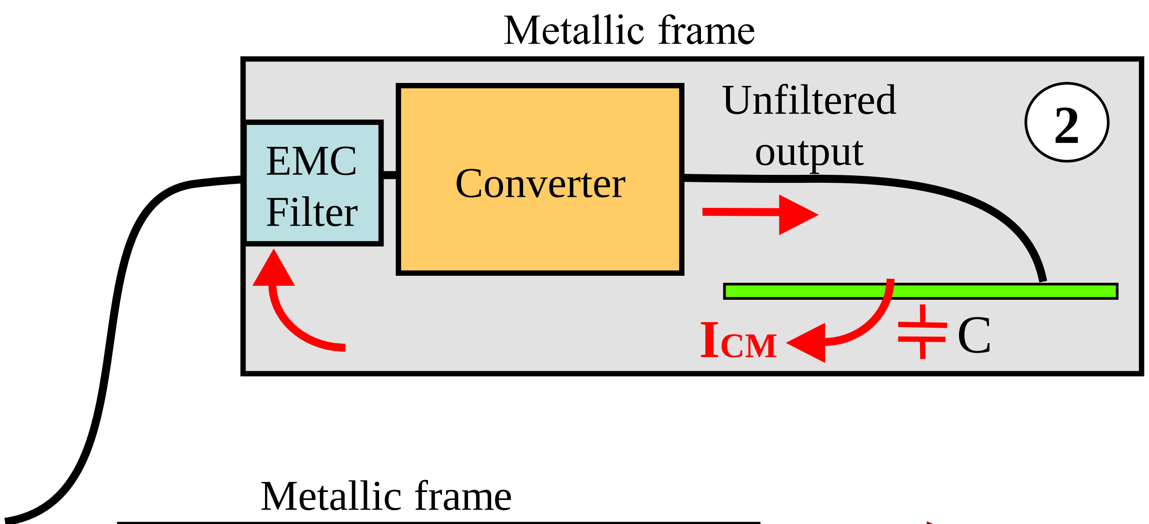


Principle schematics of a H-Bridge
(here a Single-Phase Bridge)

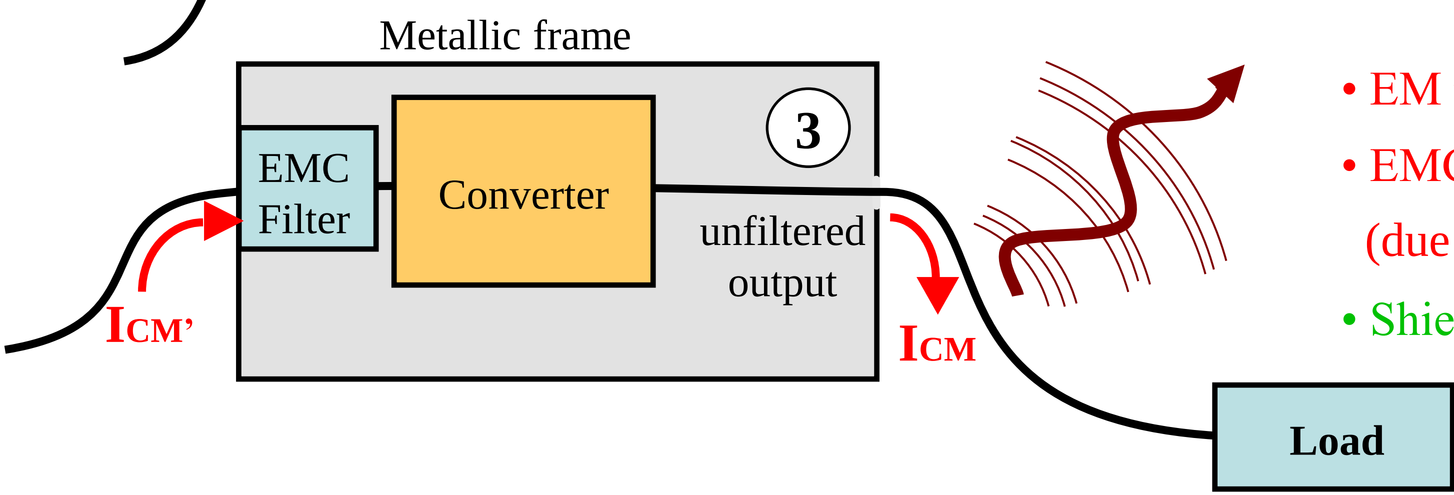
3 cases of input - output common mode



- No disturbance out of the frame
- No CM noise through electronic circuits
- EMC filter easy to optimise

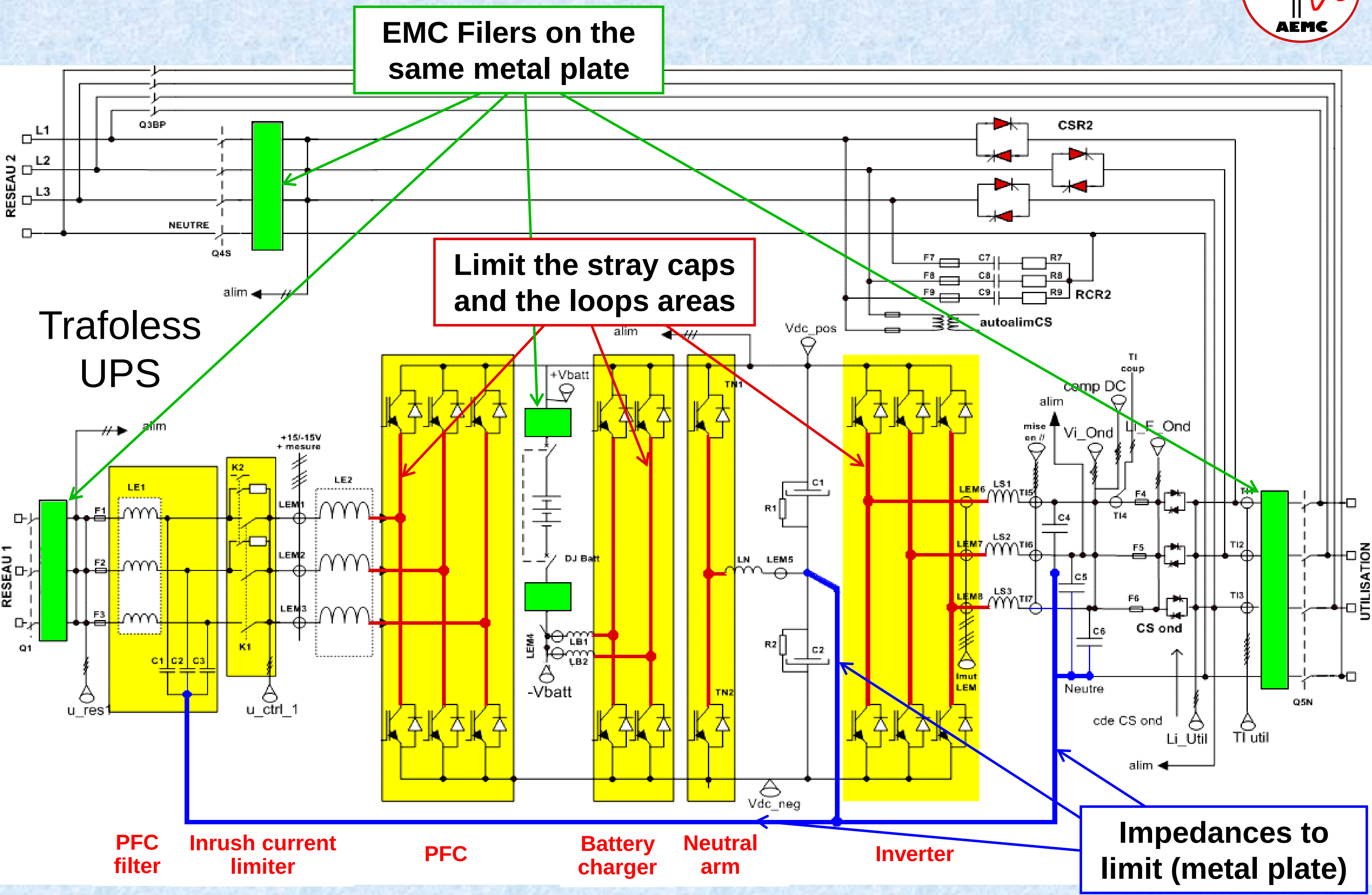


- No disturbance out of the frame
- CM current through electronics
- EMC filter more difficult to optimise (due to resonant frequencies)



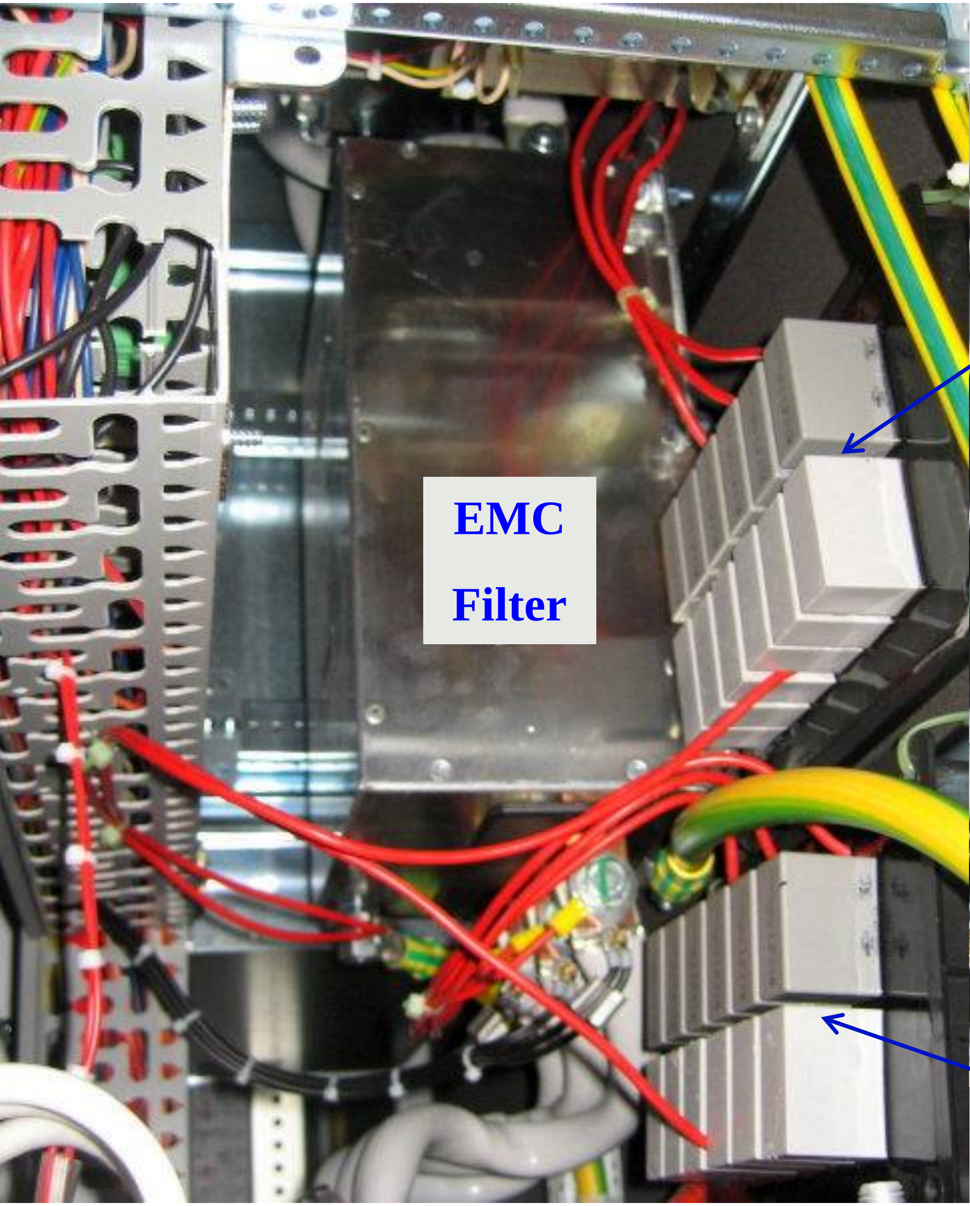
- EM radiation out of the frame
- EMC filter impossible to optimise (due to ICM')
- Shield or filter the output cable...

EMC overview of a large UPS

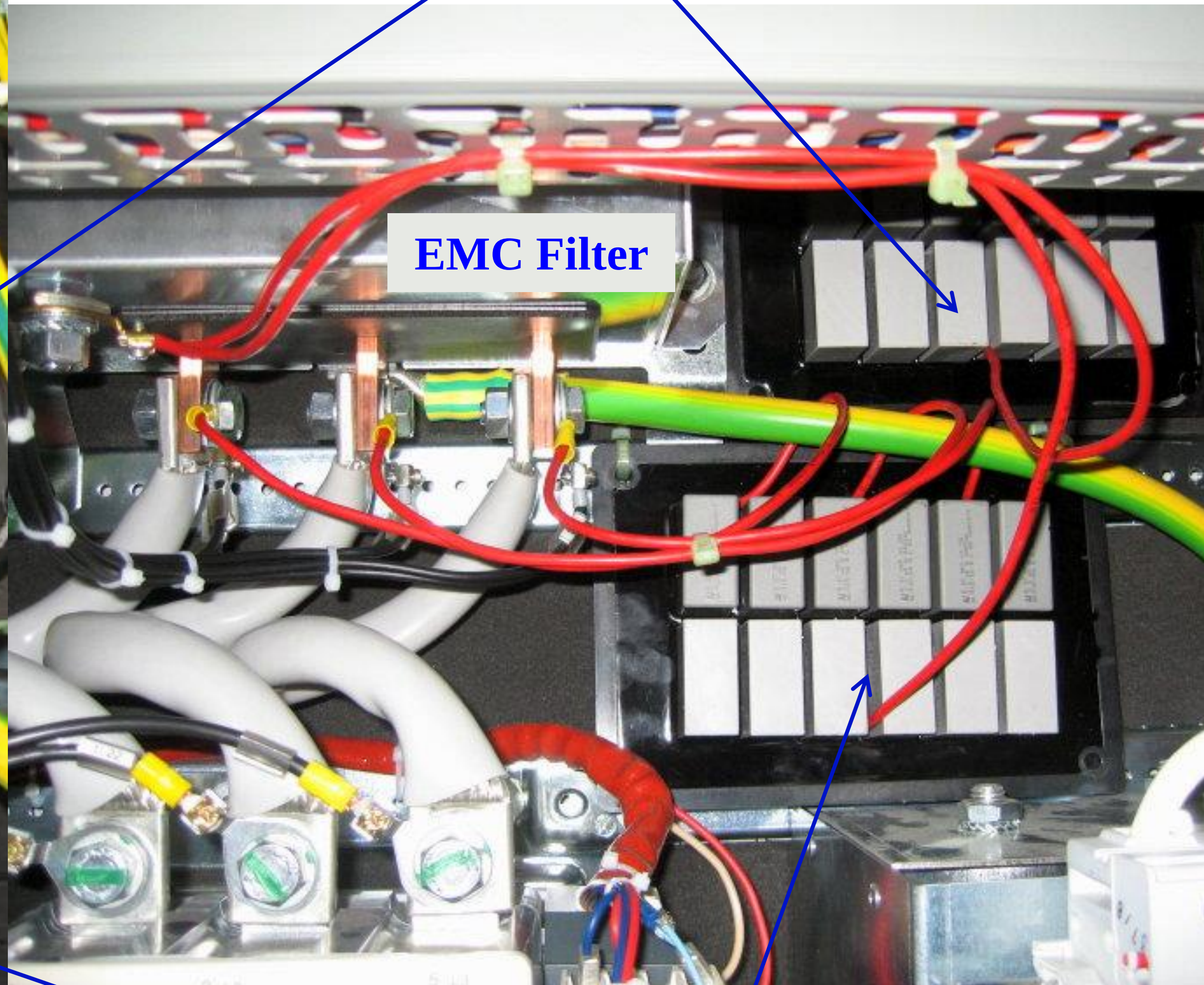


Will you find the errors of this assembly?

Capacitors: 3 x 2,2 µF (Mains side)



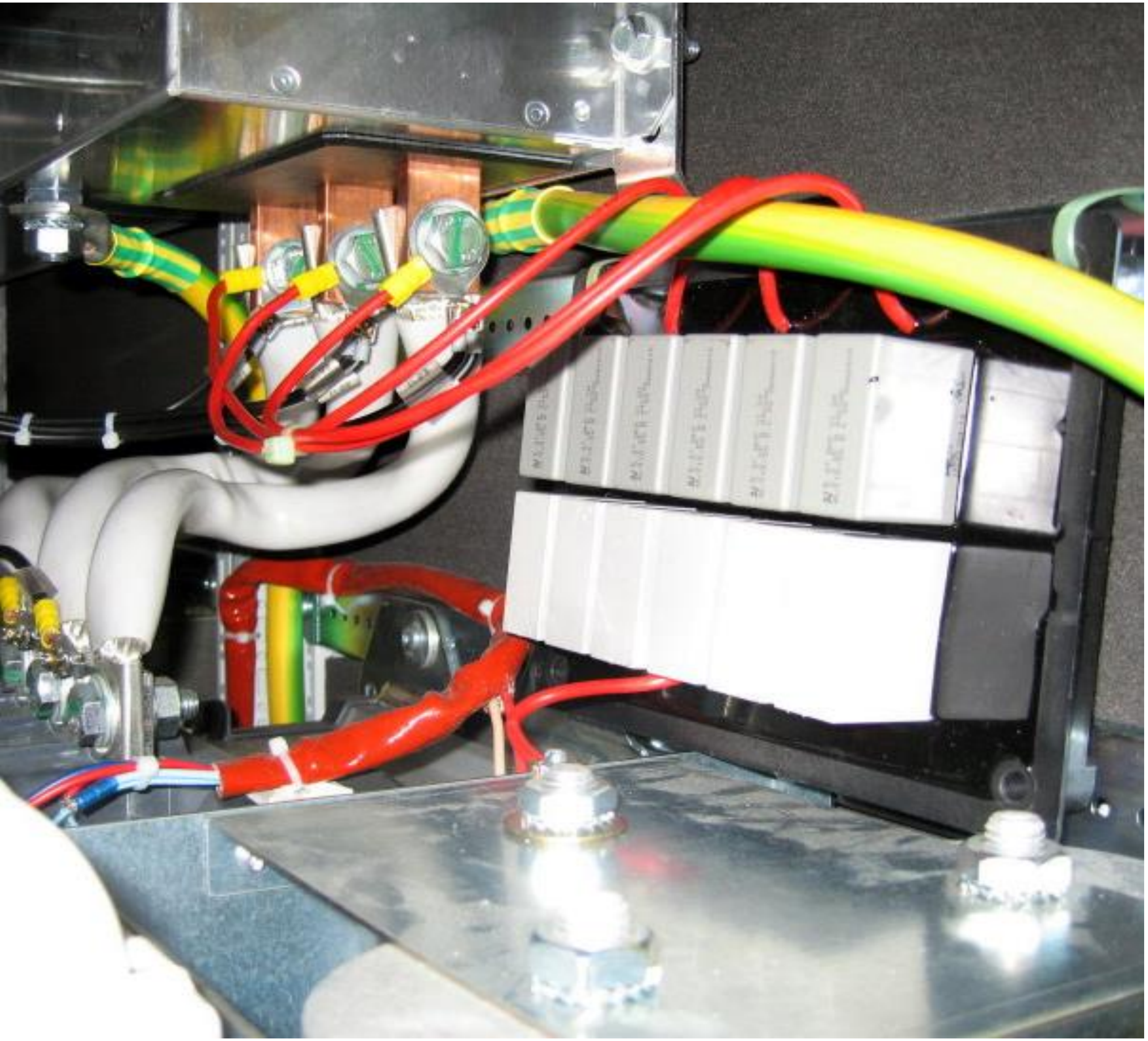
Side view



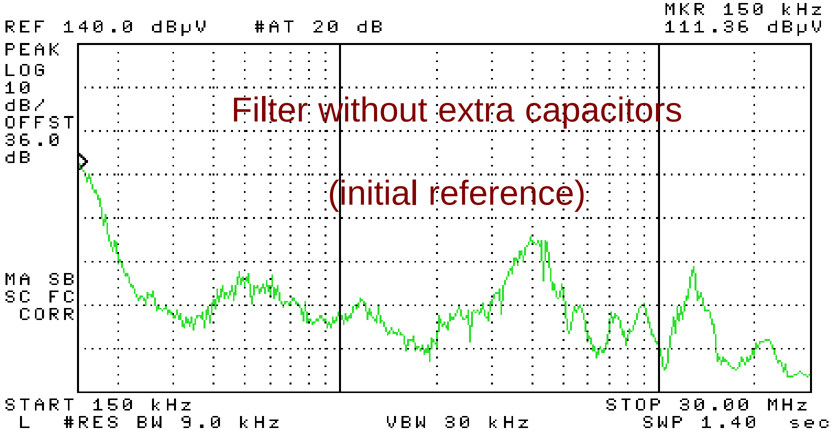
Front view

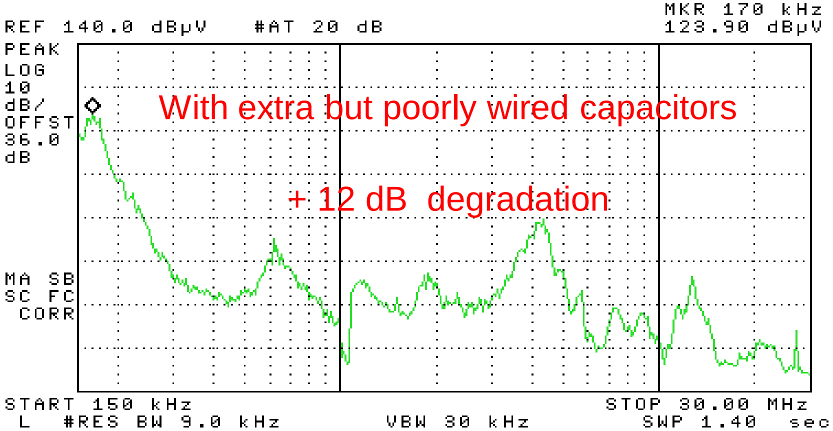
Capacitors: 3 x 2,2 µF (Internal side)

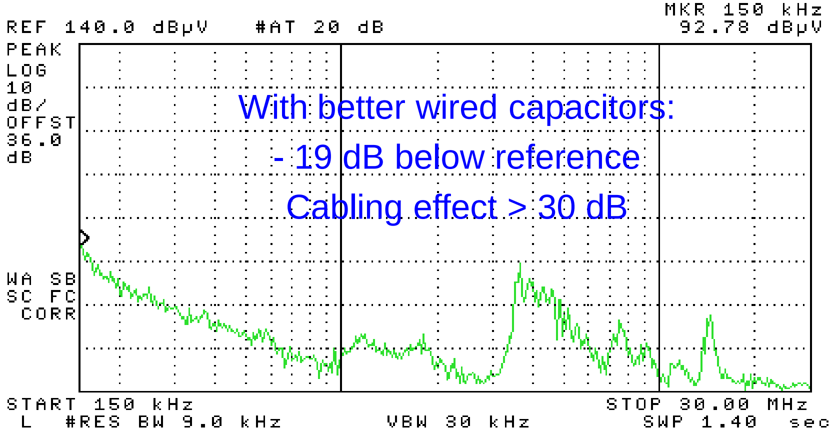
Cabling effects



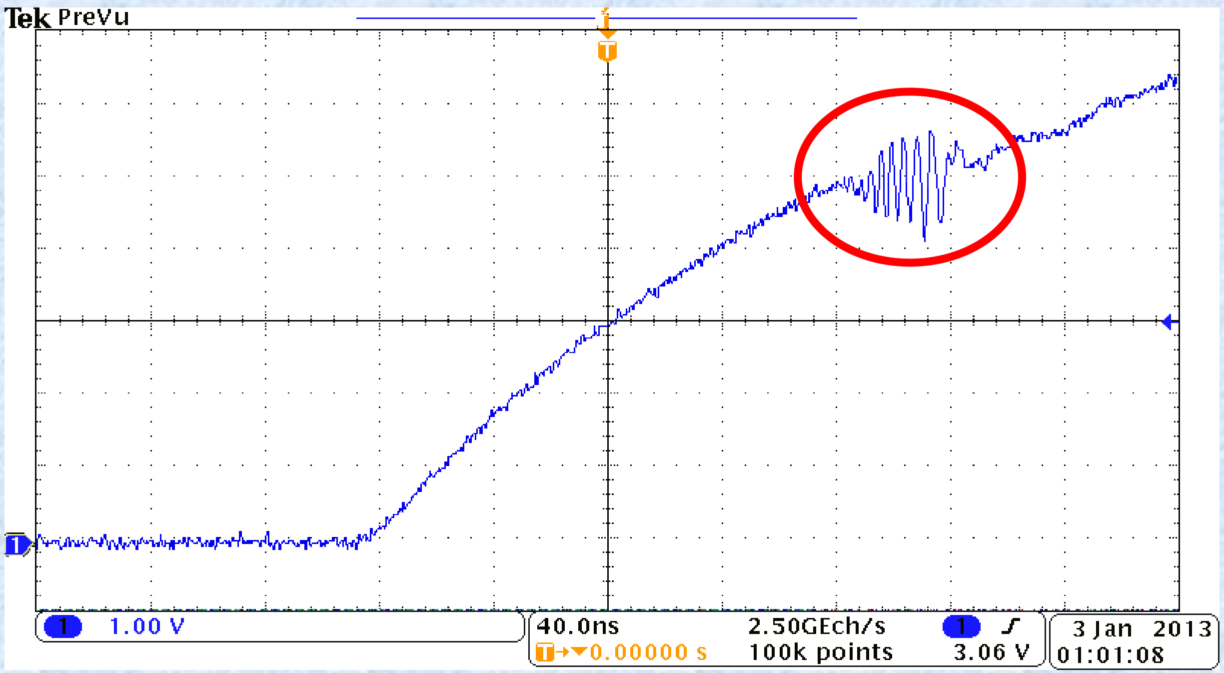
Better wiring (still perfectible)

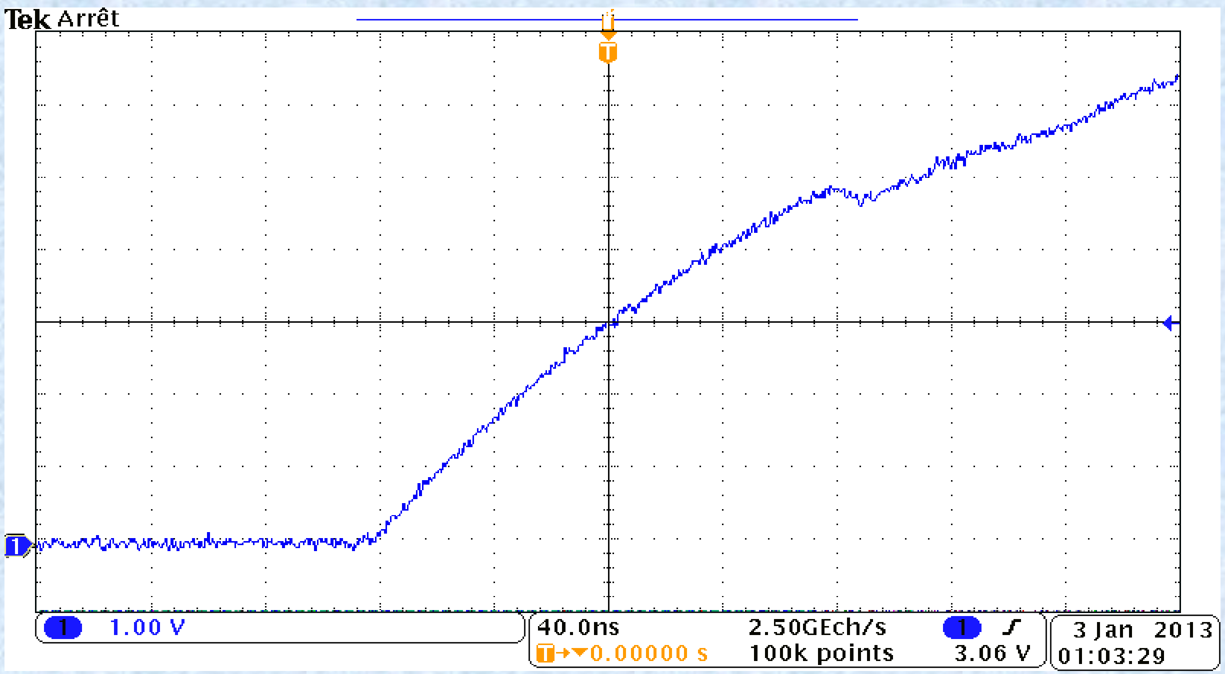






Oscillations of an H-Bridge





Re-lightning of the opposite MOS or IGBT V_{GS} via the Miller capacitance.

Causes :

- $V_{DC\ bus} \geq 100$ V (400 V here).
- Driver with zero voltage blocking.
- Too long gate trace (within 5 cm).

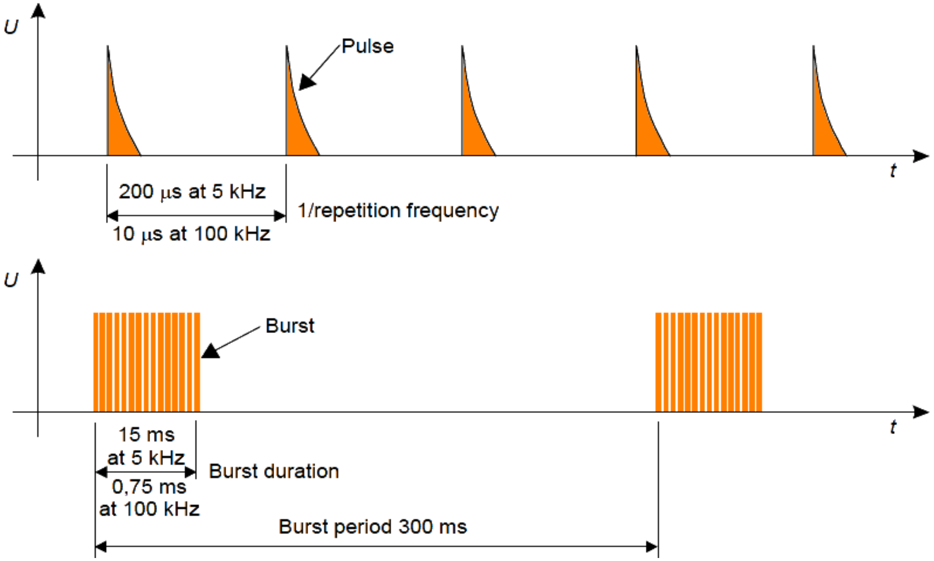
Effect :

- Radiated emission (here ≈ 200 MHz).

Fixes:

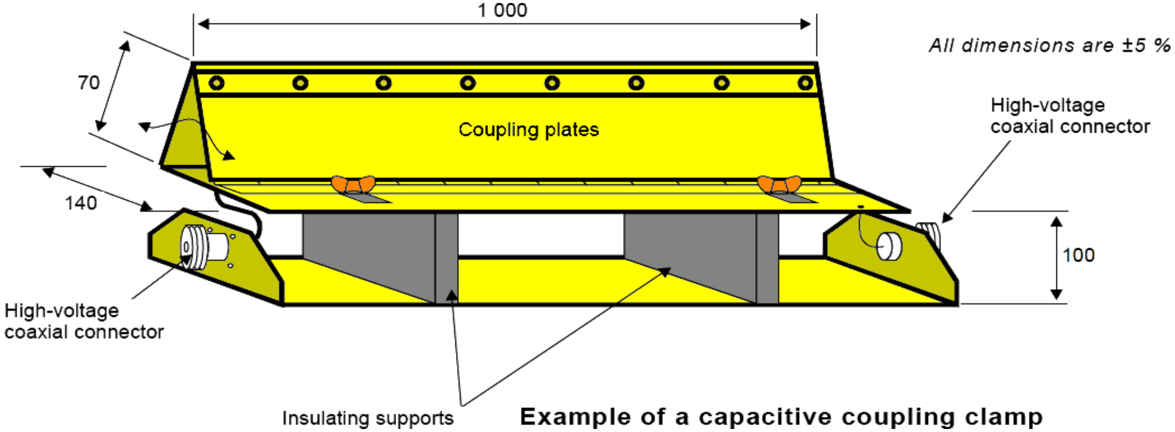
- Addition of a push-pull near the gate.
- Negative voltage blocking.
- Control with a pulse transformer.

Electrical Fast Transient in Burst (EFT/B)

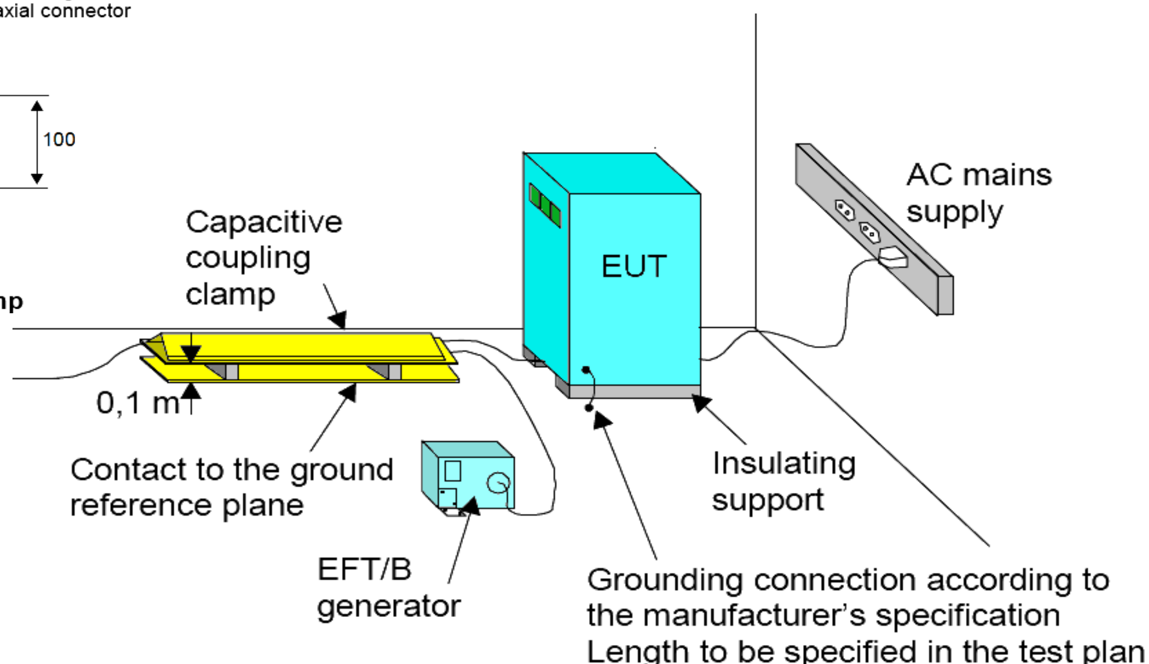


Characteristics:

– polarity:	positive/negative
– output type:	coaxial, 50 Ω
– d.c. blocking capacitor	(10 ± 2) nF
– repetition frequency:	5 kHz or 100 kHz ±20 %
– relation to a.c. mains:	asynchronous
– burst duration:	(15 ± 3) ms at 5 kHz (0,75 ± 0,15) ms at 100 kHz
– burst period:	(300 ± 60) ms
– wave shape of the pulse	rise time t_r = (5 ± 1,5) ns
• into 50 Ω load	pulse width t_w = (50 ± 15) ns
	peak voltage = ±10 %



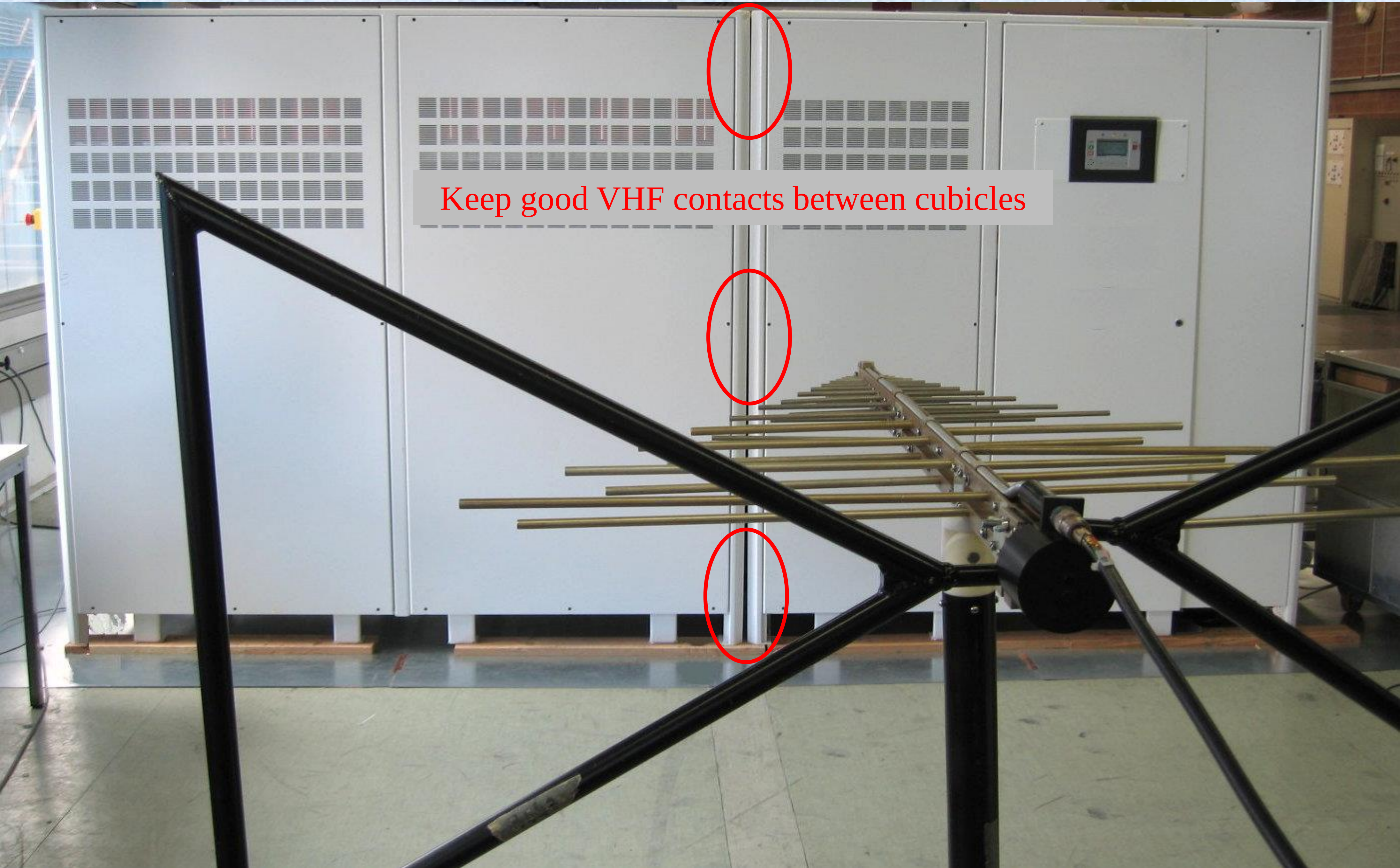
Example of a capacitive coupling clamp



IEC 61000-4-4 Immunity Test

Power converters may radiate in excess

(Both large and small cabinets and attached cables)



Selection of a differential probe

To measure voltages on an H-bridge (V_{GS} or blocking overvoltage), use a differential probe with at least:

Bandwidth ≥ 100 MHz

CMRR ≥ 50 dB @ 1 MHz

Suggested models:

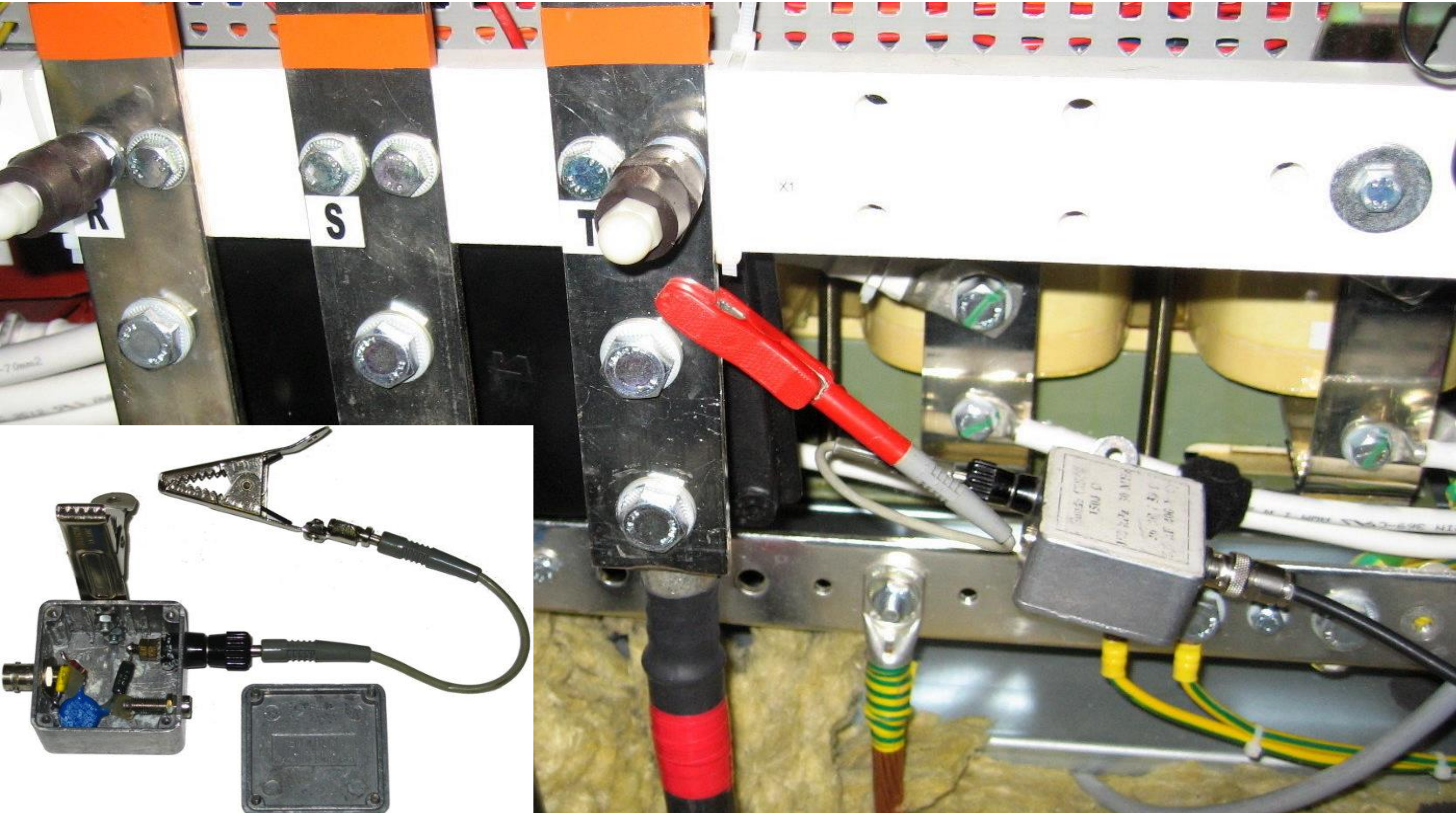
4233 or 4234 (Probe Master) or

SI-9110 (Sapphire Instruments)

To measure peak overvoltage, trigger the oscilloscope in "normal" mode on the signal peak.

Example of Home–Made Voltage Probe

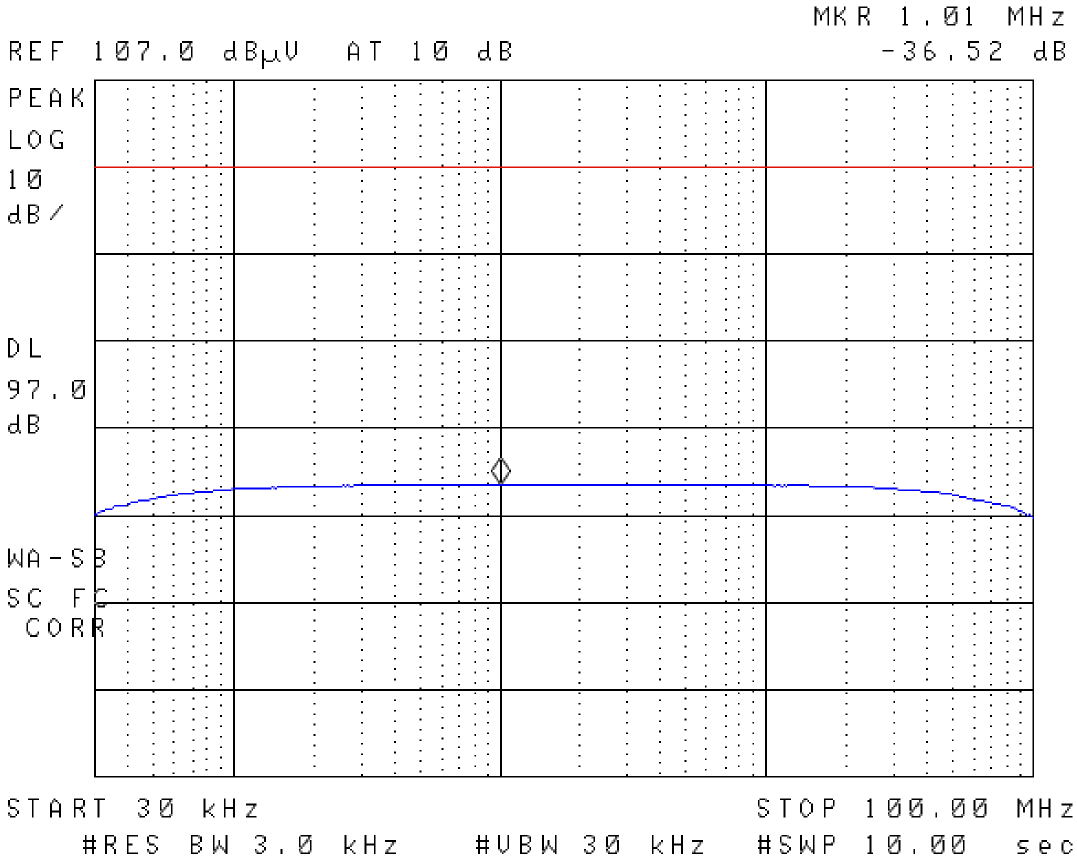
1500 Ohm Probe (150 kHz to 30 MHz)



Example of Home–Made Current Probe

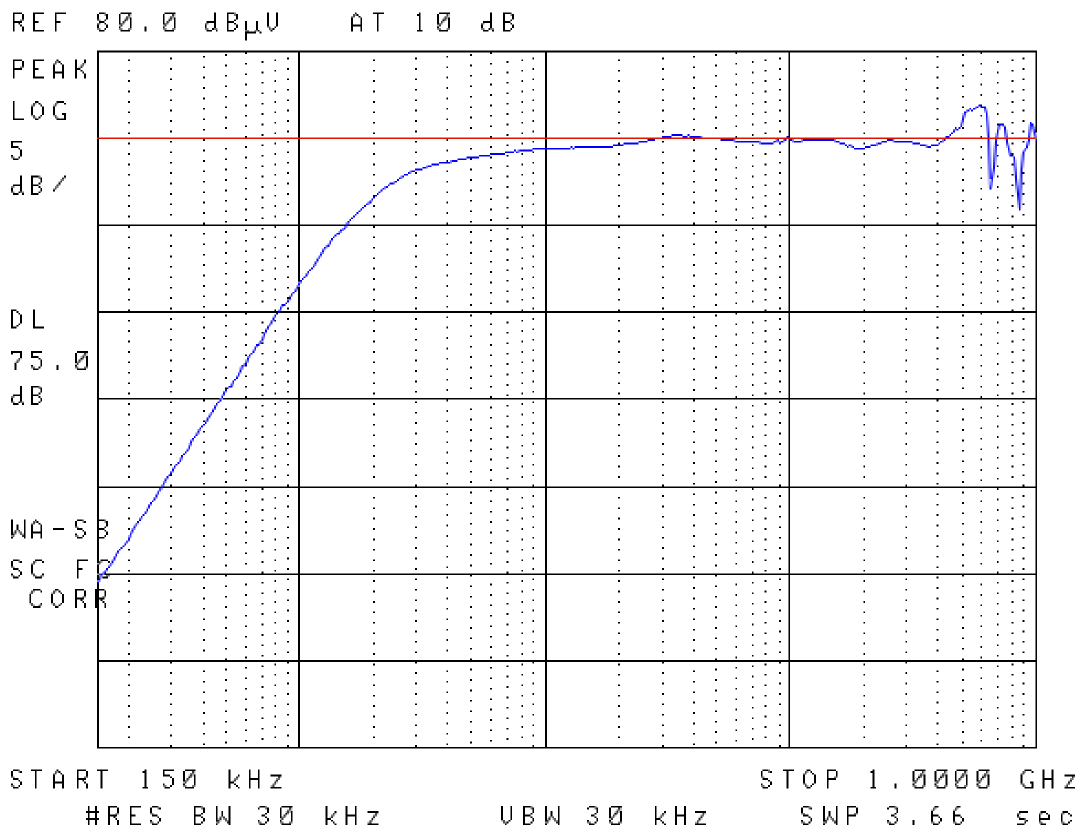
$Z_t = 10\ \Omega$ (+1 / - 2 dB from 3 MHz to 300 MHz)

Let's check Home - Made Probes



Frequency response of a home-made
1500 Ω Voltage Probe

Nominal insertion loss = 36 dB
+ 0 / -1 dB from 150 kHz to 30 MHz



Frequency response of a home-made
10 Ω Current Probe

Nominal Transfer Impedance = 20 dB_{Ω}
In-band Output SWVR ≤ 1.5
Nominal primary circuit load = 5 Ω

Examples of Home-Made probes

ΔV/Δt - 1 pF probe

(50 mV / V/ns up to 1 GHz)

ΔB/Δt passive probe

BNC Shunt for current injection

(for Zt of Coaxial cable assessment)

Questions ?