EMC and Power Electronics Workshop

EMI/EMC Debugging with Oscilloscopes

Part 1: **Conducted Emissions**

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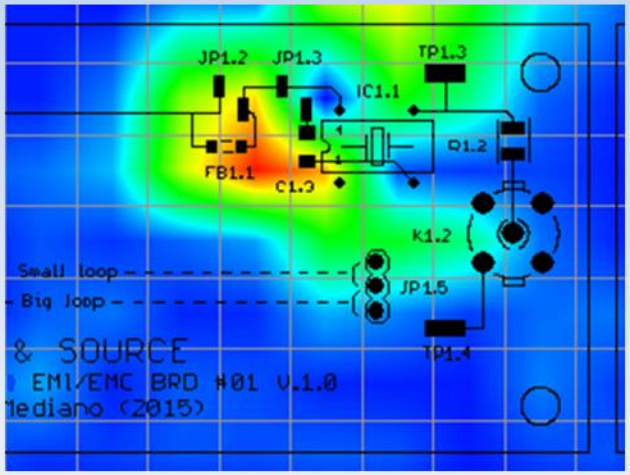
Organized by:

March 2024

The HF Magic Lab(R)

A High Frequency Lab for design, diagnostic, troubleshooting and training



Interferences (**EMI**)
Electromagnetic Compatibility (**EMC**)
Signal Integrity (**SI**)
Radiofrequency(**RF**)

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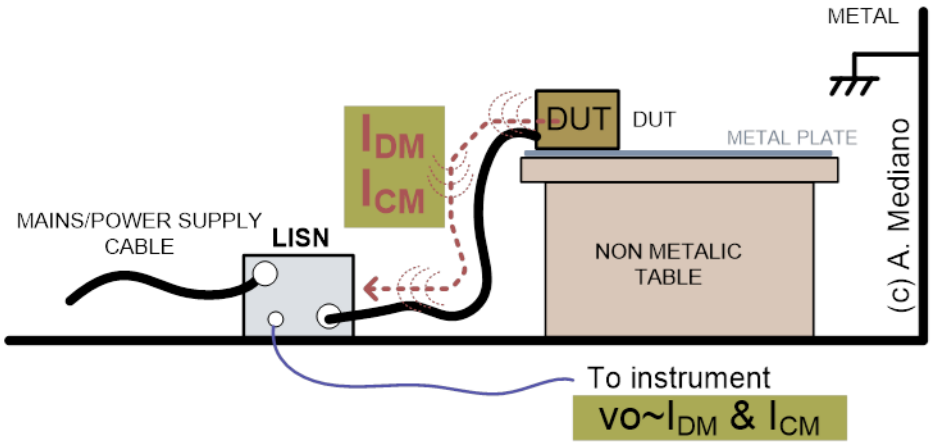
www.cartoontronics.com

ASK FOR YOUR FREE CATALOG!

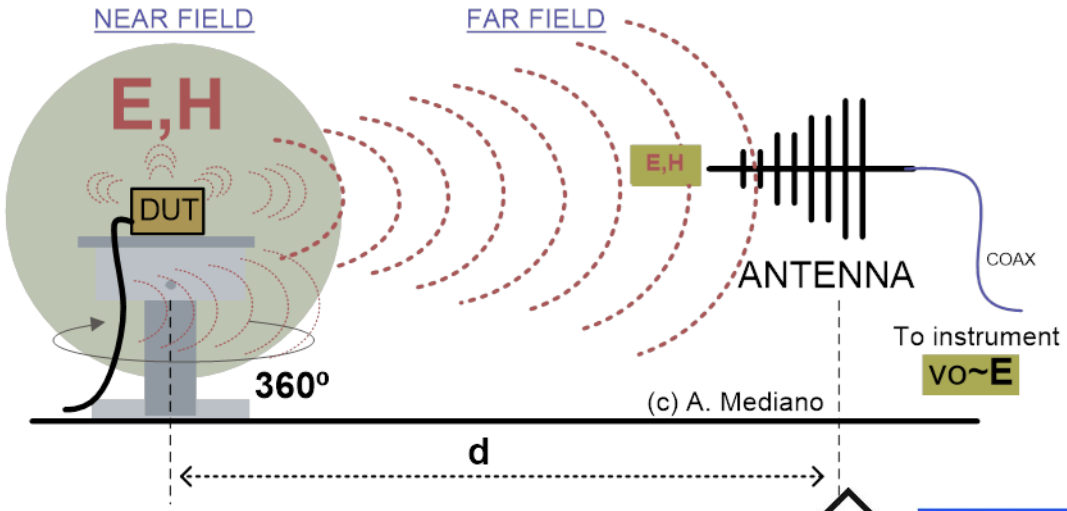
Debugging strategy

EMI/EMC: tests

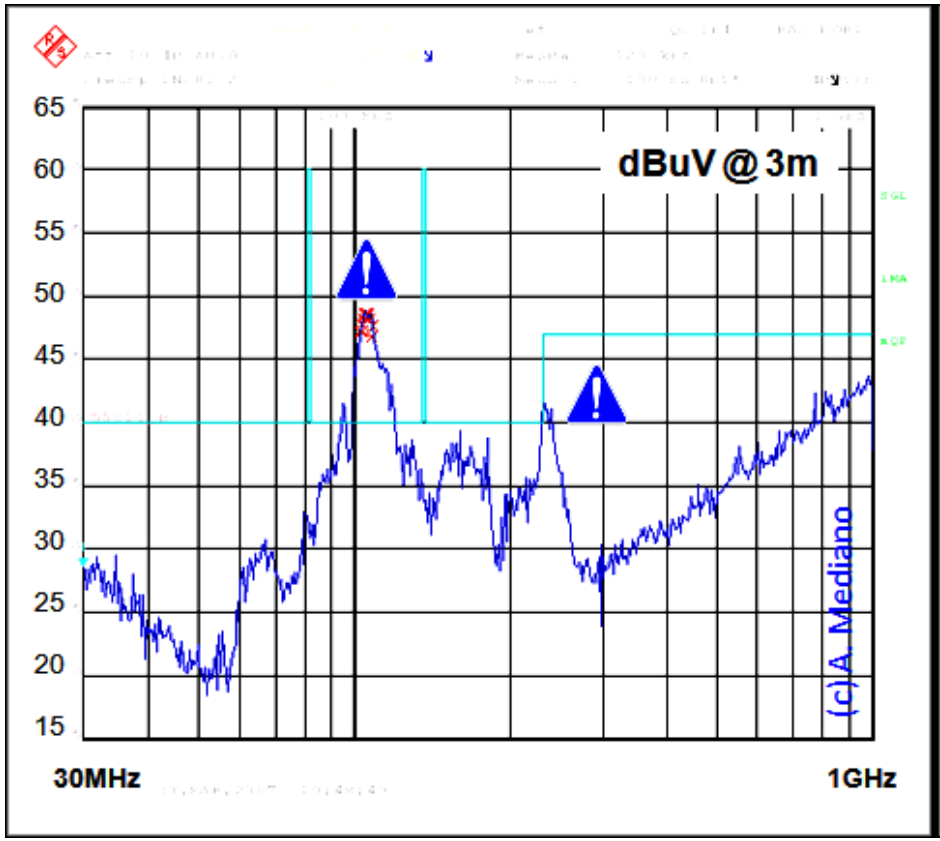
CONDUCTED EMISSIONS

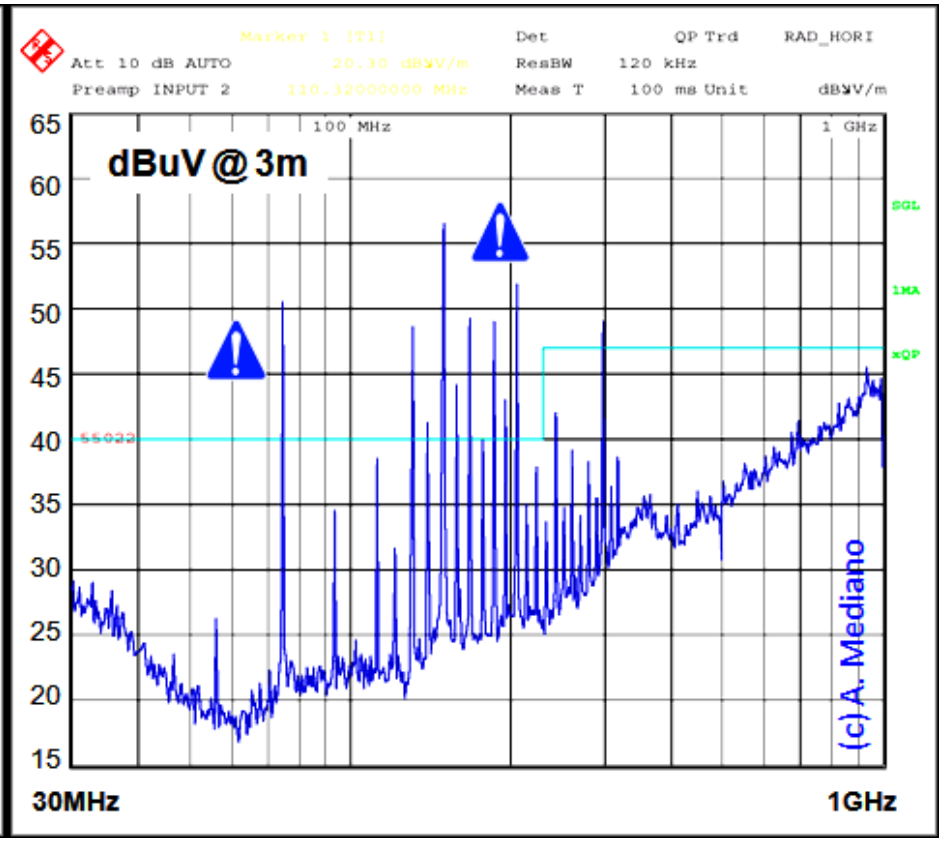


RADIATED EMISSIONS



EMC: failing in tests





Testing: strategy

www.incompliancemag.com

EMI Debugging: if you can see it you can fix it
by Arturo Mediano.

(c) A. Mediano

SCOPE with FFT
Picture R&S RTO6

(c) A. Mediano

Testing: instrumentation

R&S **Scope**

R&S **HL562E** antenna

R&S **ENV216** LISN

R&S **HM6050-2**
LISN

R&S **RT-ZP10**
Voltage probe

R&S **EZ – 17**
Current Probe

R&S **ESH3-Z2**
pulse limiter

R&S **HZ – 15**
Near Field Probe

R&S **HZ-16**
Preamplifier

RTO 6: scope

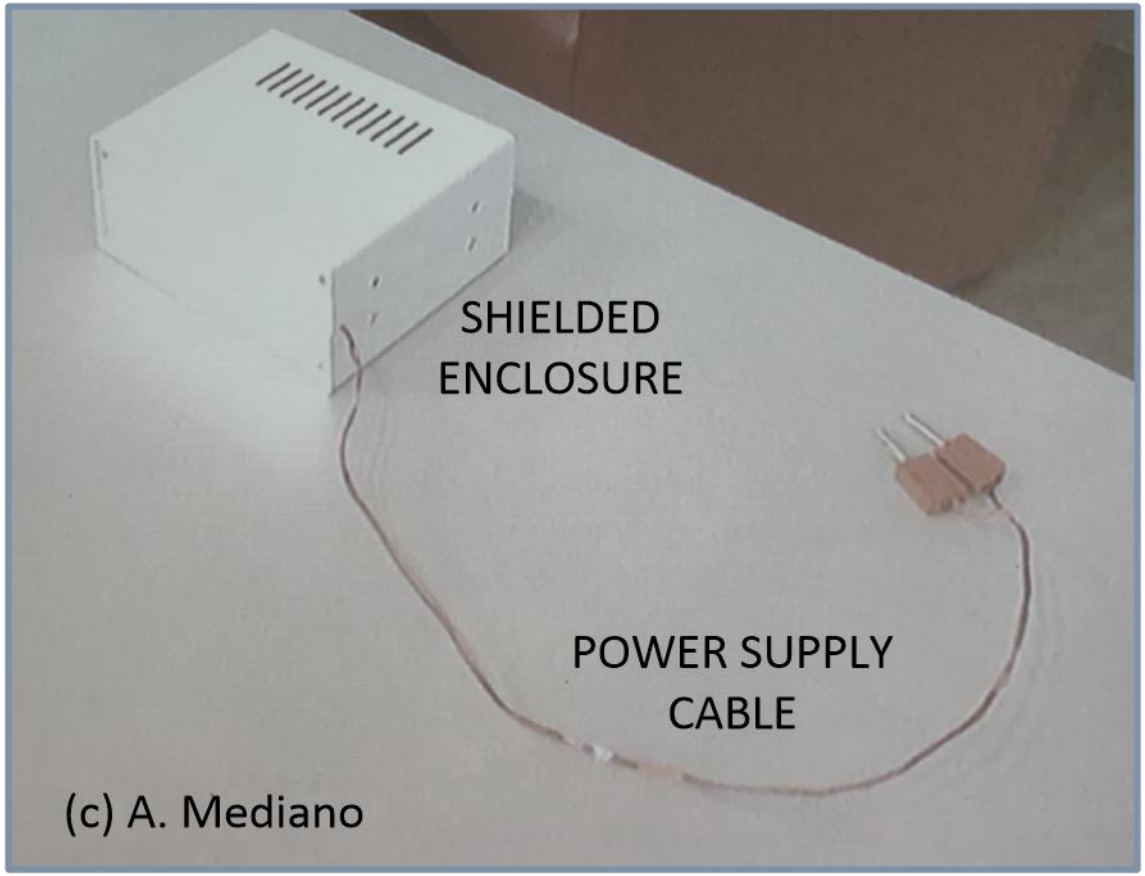
RTO 6 scope by

ROHDE&SCHWARZ
Make ideas real

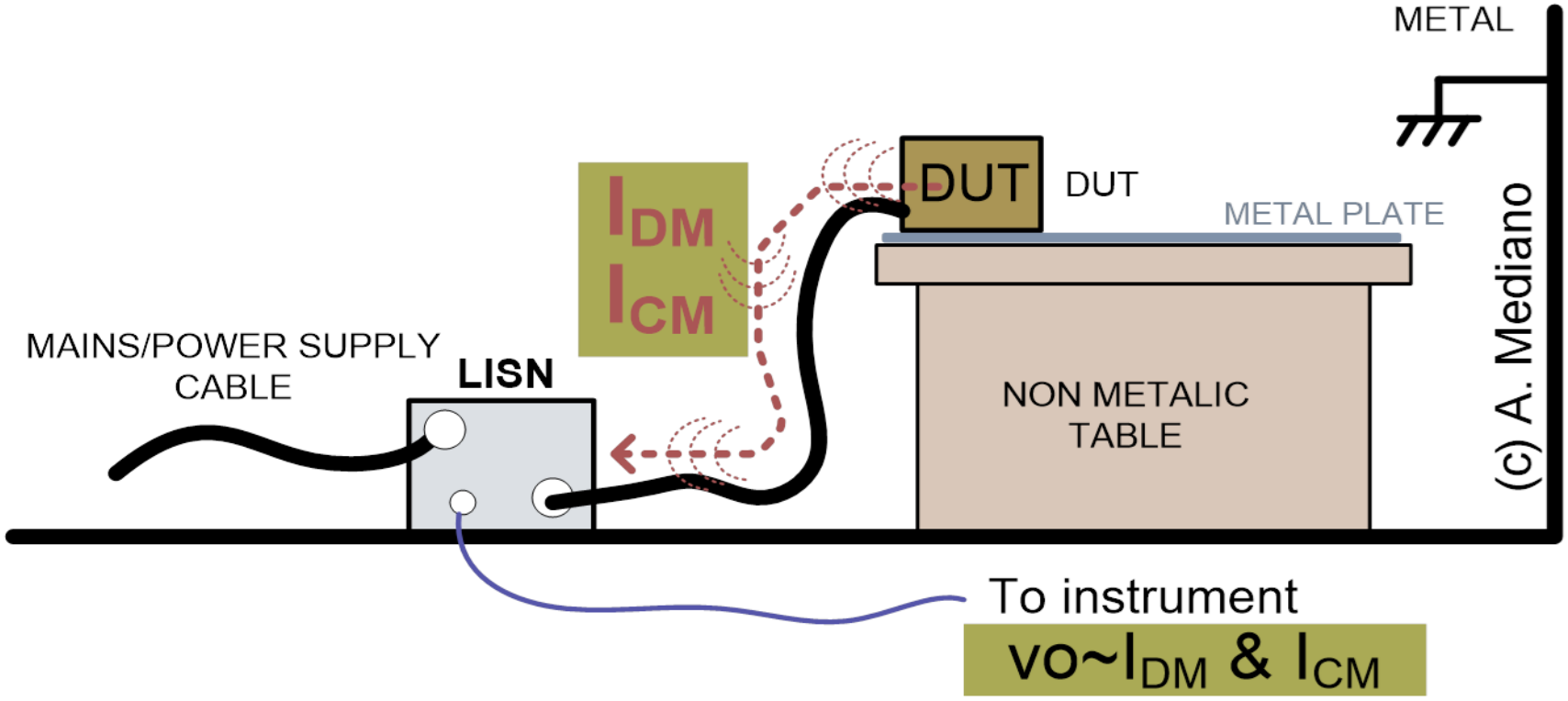
- **Four channels**
- **Time domain** and **frequency domain**
  - … in one instrument (synchronized!!).
  - … spectrum analyzer "style": CENTER FREQ, SPAN.
  - … FFT with GATING technique.
- **High bandwidth.**
  - … 600MHz to 6GHz.
- **Inputs**: **"High" impedance 1MΩ and 50Ω.**
  - … critical for some probes (i.e. NFP) and BW
- **Vertical scale/resolution**: **good sensitivity**
  - … (i.e. dynamic range): 1mV/DIV
  - … 16 bits
- **Sampling rate**
  - … up to 10Gsamples/sec
- **Big record length**
  - … 1 million waveforms/second.
- **Big color Display**:
  - … persistence mode to detect CW signals vs burst

Our product (demo)

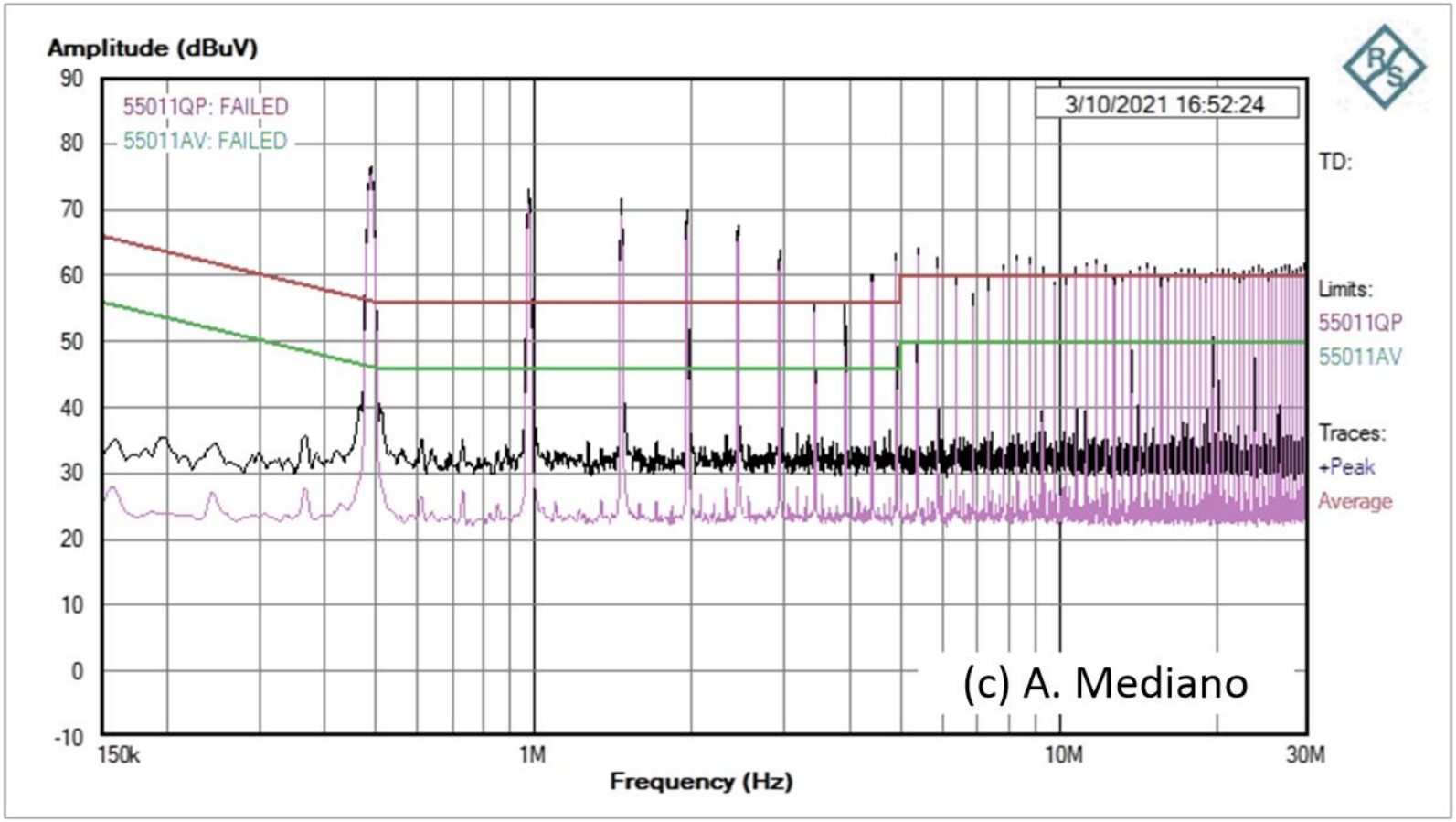
EMI/EMC debugging: demo ...



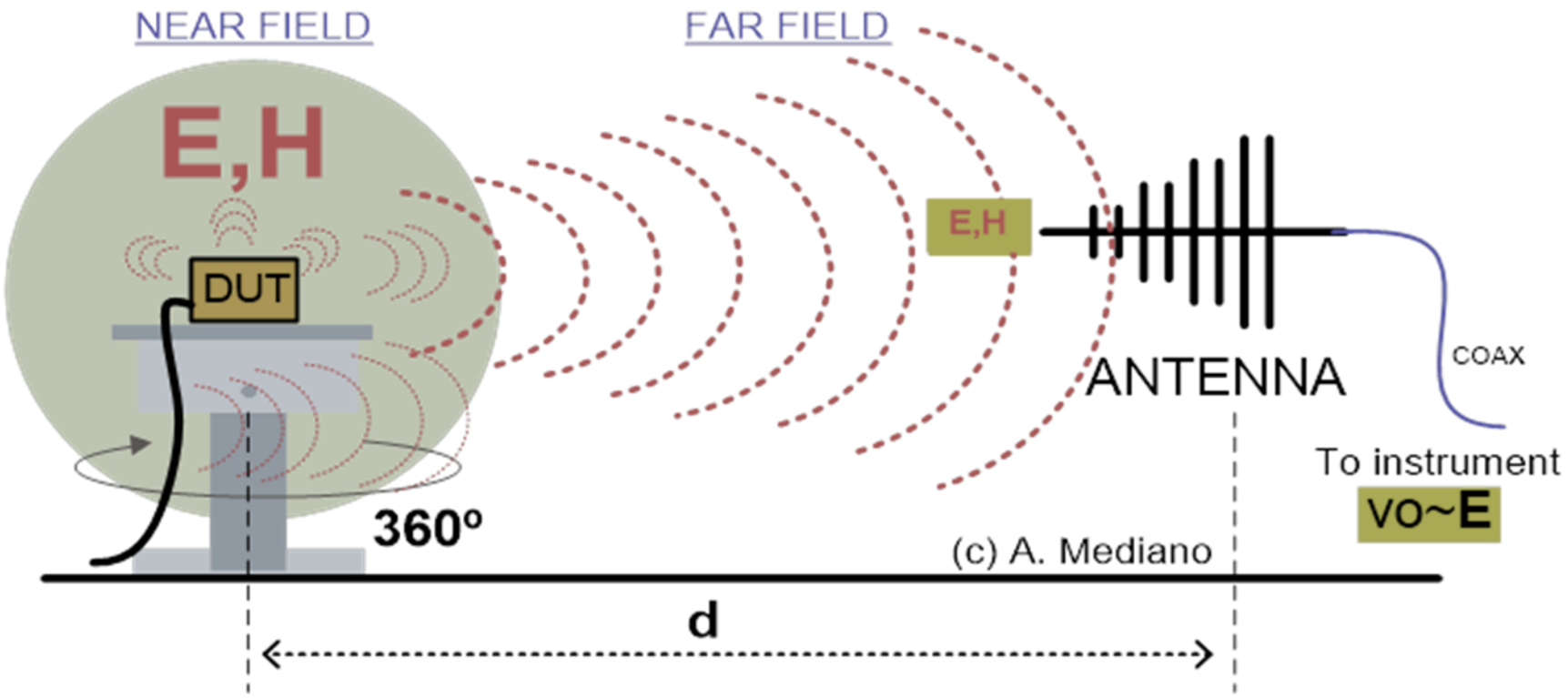
EMC: fail in conducted emissions



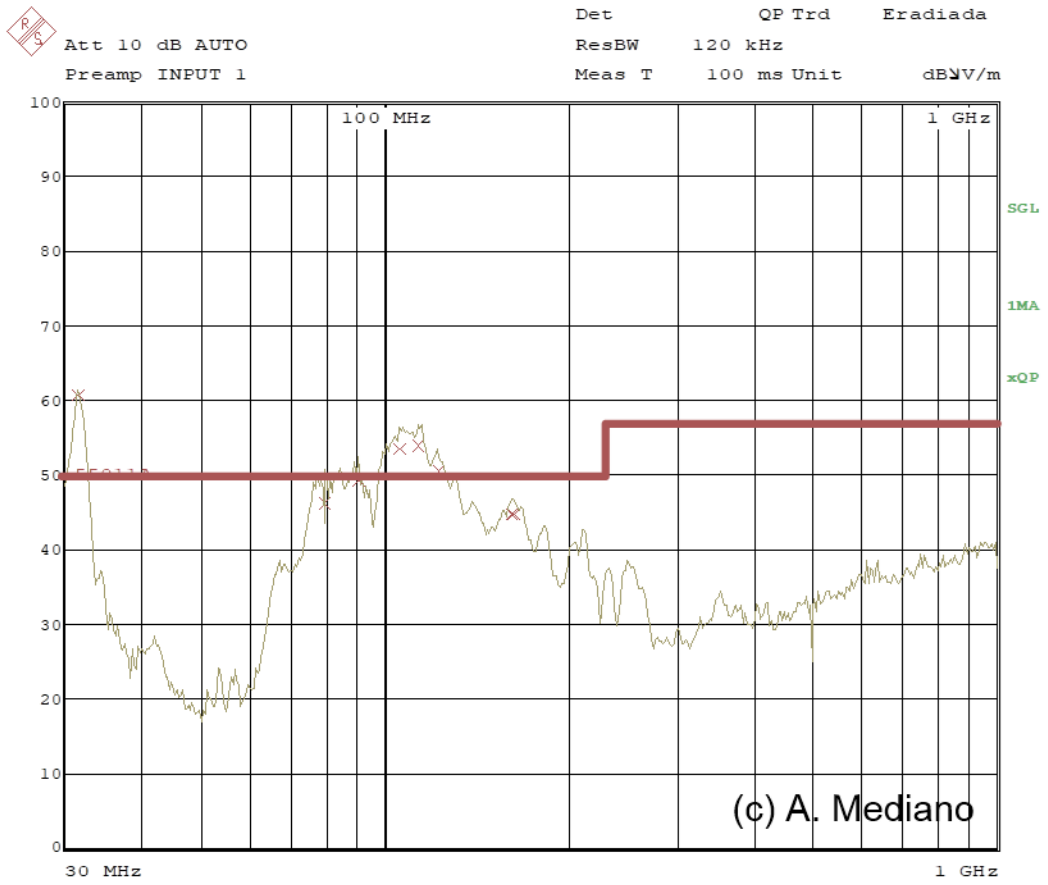
EMC: fail in conducted emissions



EMC: fail in radiated emissions

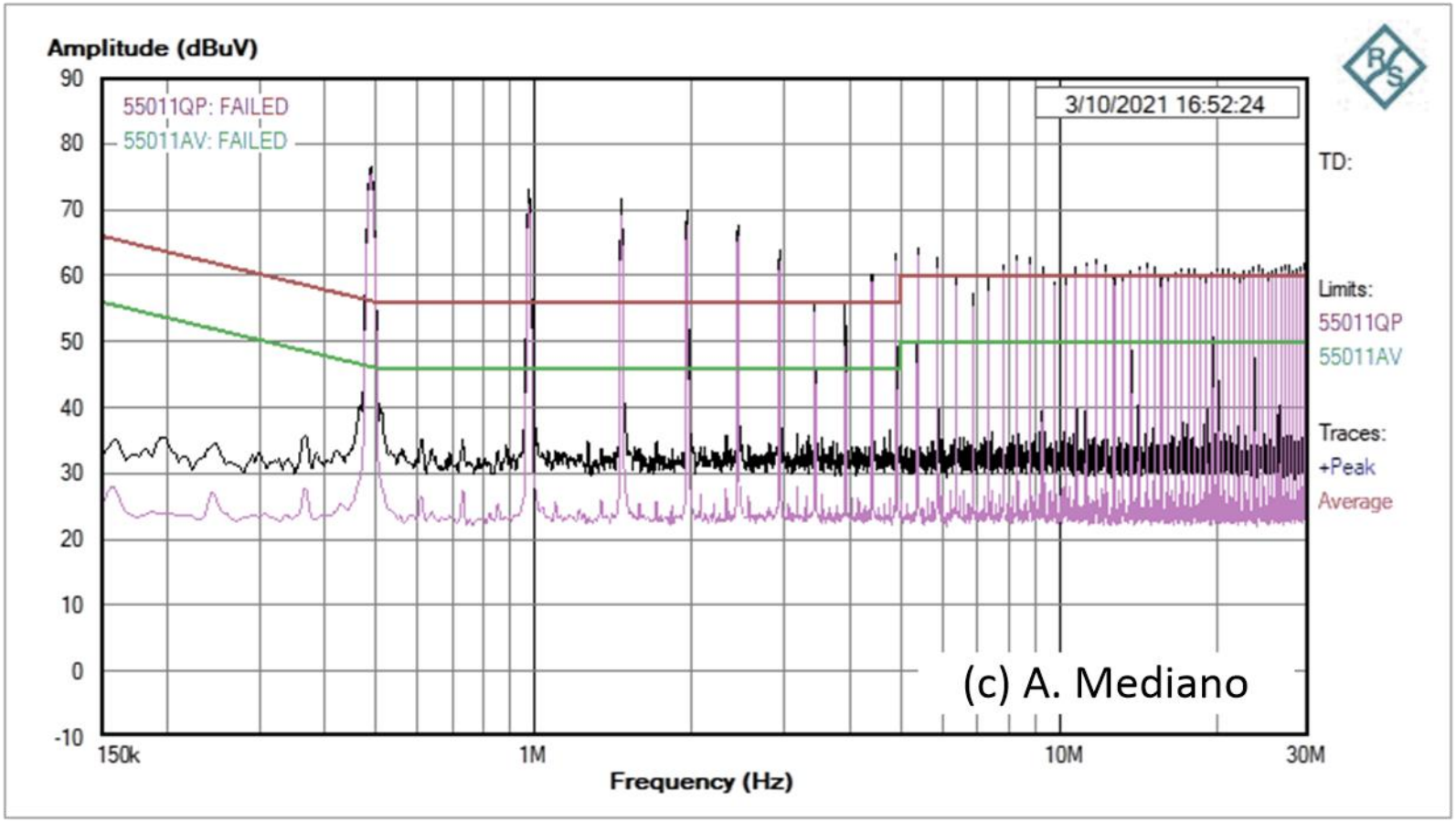


EMC: fail in radiated emissions

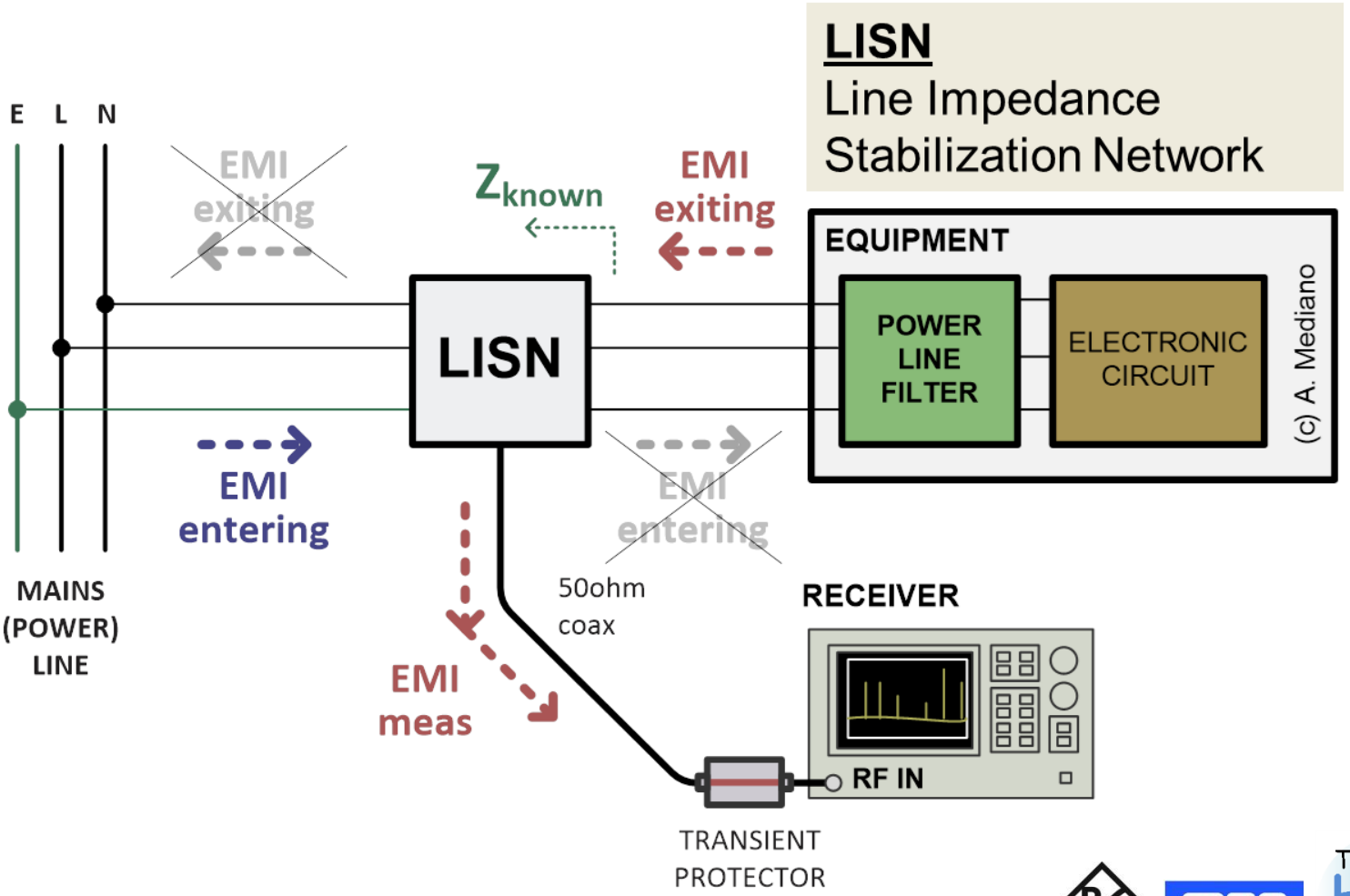


Conducted emissions

EMC: fail in conducted emissions



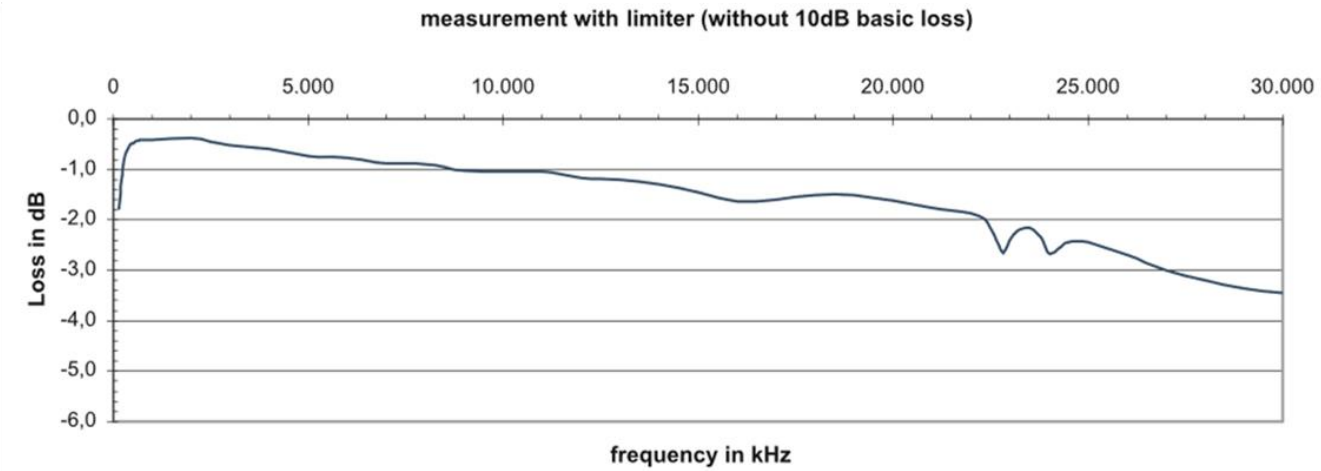
EMC: measuring conducted emissions



LISN: example R&S HM6050-2

10kHz-30MHz

Line Impedance Stabilization Network HM6050-2 All data valid at 23°C after 30 minutes warm-up.	
Frequency Range:	10 kHz to 30 MHz
Impedance Characteristics:	Z = 50Ω || (50 µH + 5Ω), Error <20% under terms of VDE 876T1
Max. Current:	16A
Line Voltage/Frequency:	230V/50…60Hz, CAT II
Artificial Hand:	220pF + 511Ω
PE (selectable):	50µH || 50Ω



Pulse limiter example: R&S ESH3-Z2

R&S®ESH3-Z2 Pulse Limiter

order number 0357.8810.54

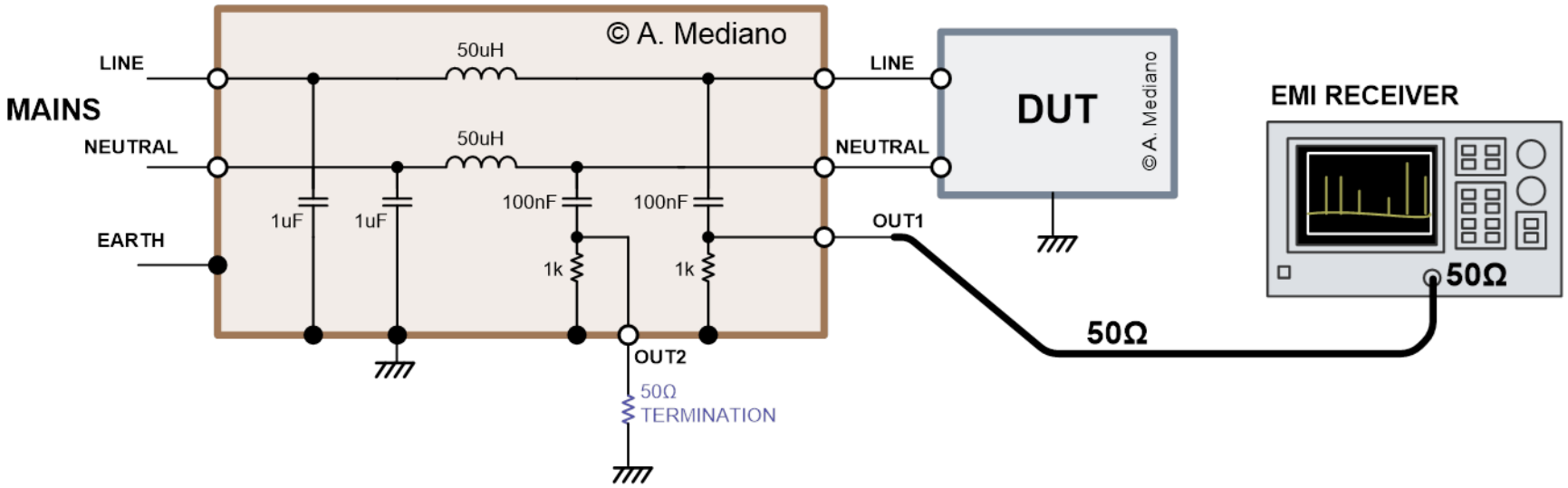
High RF input levels and high-energy disturbance pulses generated on artificial mains networks when the DUT is switched on and off can damage the RF input circuits of test receivers. The R&S®ESH3-Z2 pulse limiter limits and reduces the disturbance level.

Specifications in brief

- Frequency range: 0 Hz to 30 MHz
- Insertion loss: 10 dB ± 0.3 dB
- Frequency response: ≤ ±0.3 dB
- SWR with 50 Ω termination, input/output: ≤ 1.06/≤ 1.25
- Power handling capacity in continuous mode: 1 W
- Pulse power handling capacity: E = 0.1 Ws (8 ms)
- RF connectors (input/output): N (female/male

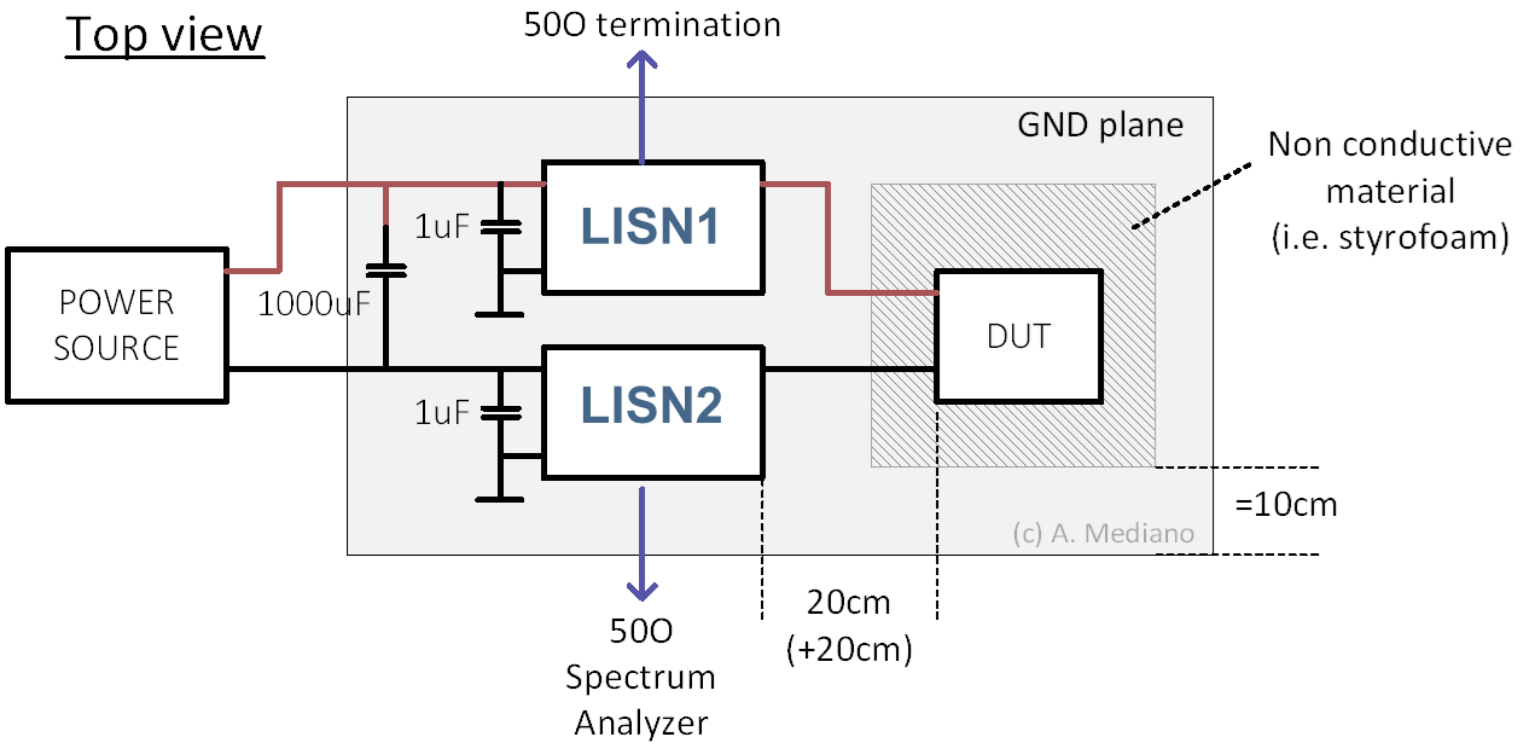
LISNs: why two LISNs are used ...

- Before designing filter we need to **understand measurement setup**.
- For conducted emissions we need a LISN and some kind of EMI receiver.

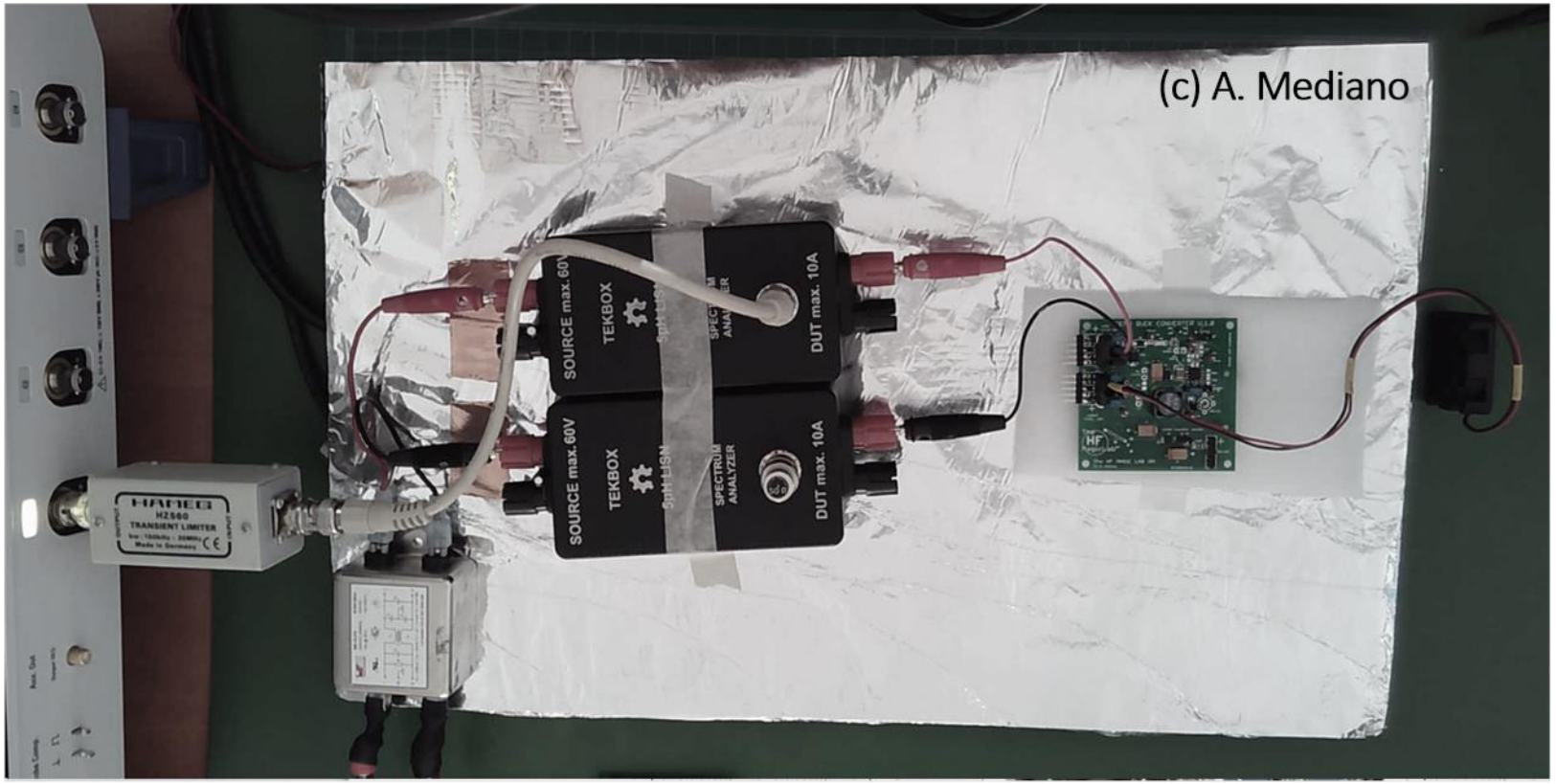


Example: two LISNs setup

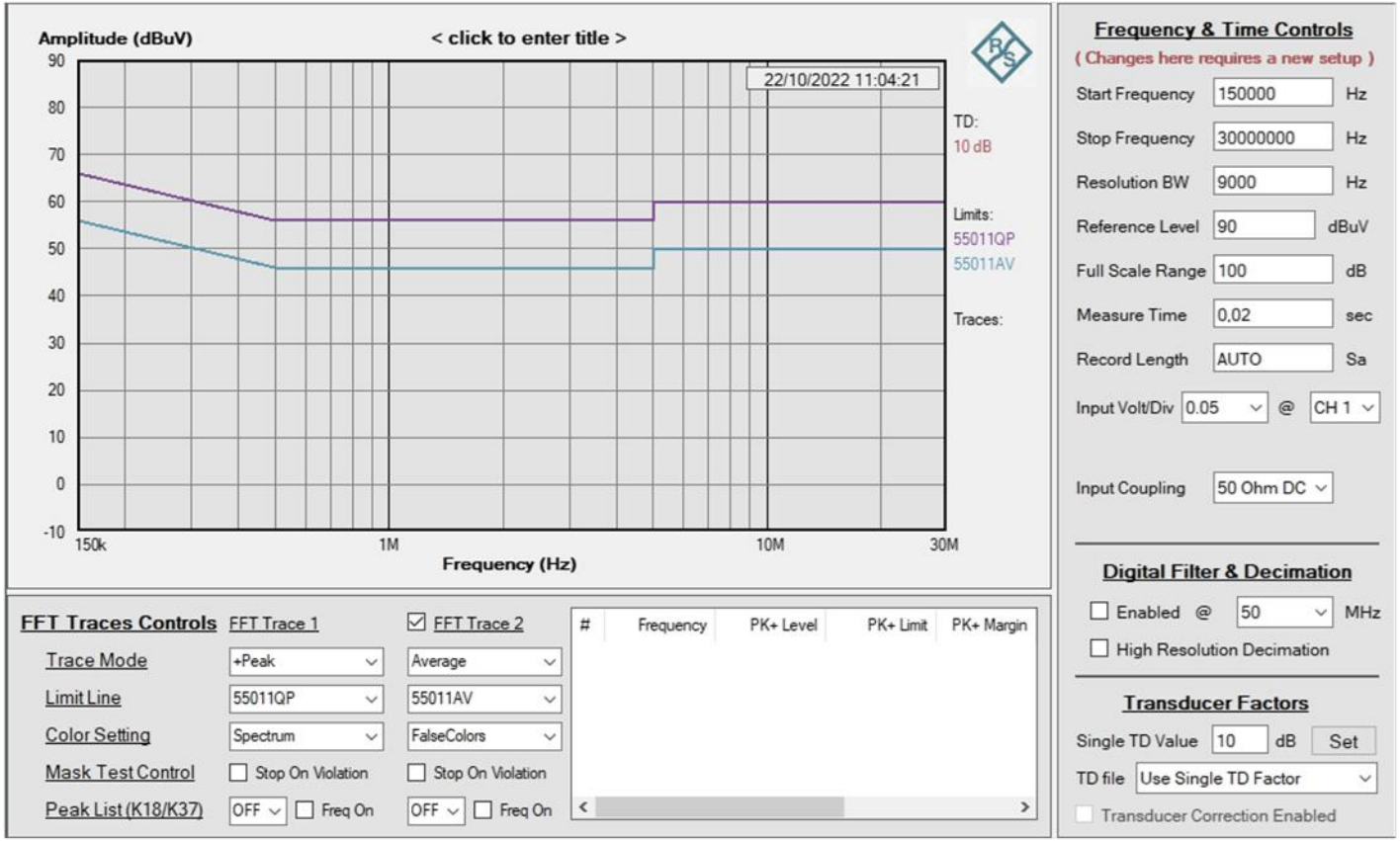
Example for CISPR-25:



Demo: general view of experiment

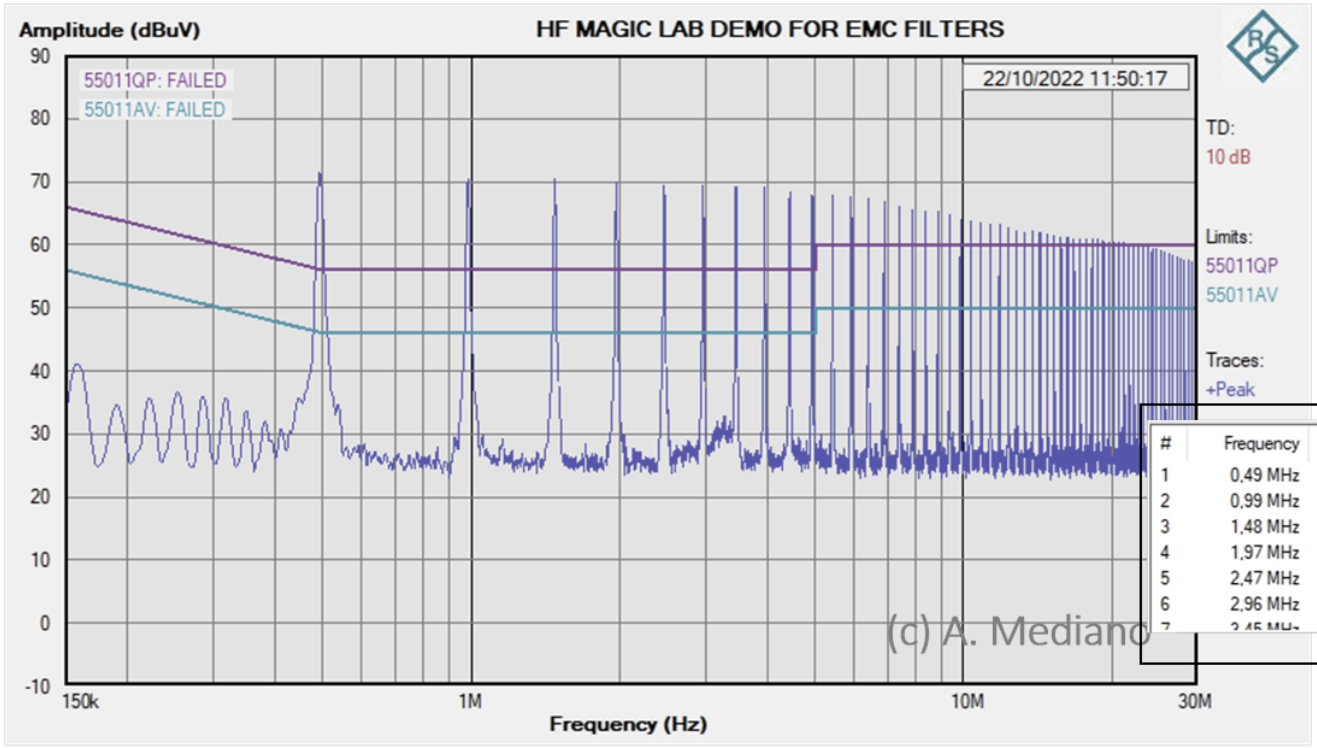


Demo: general view of software



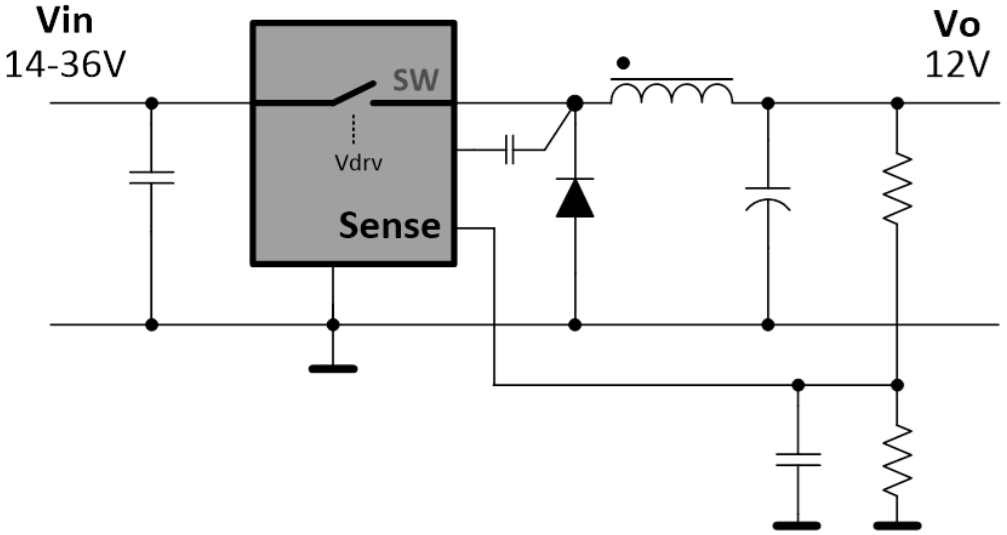
Demo: measuring only peak

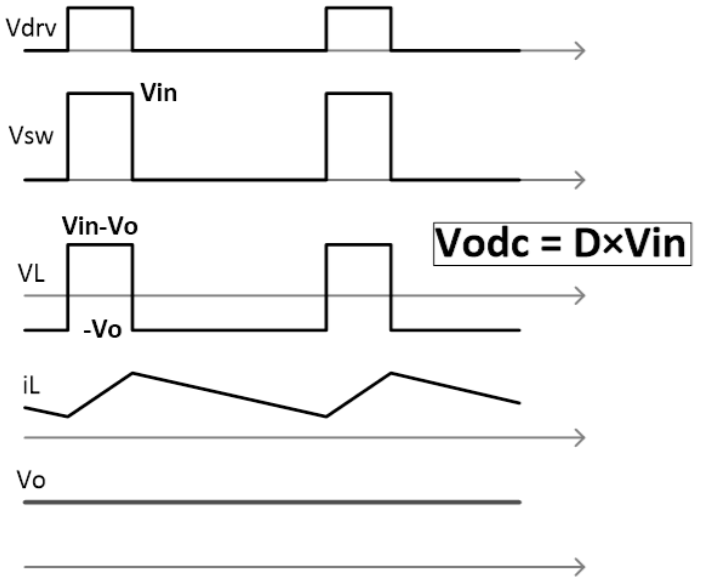
Emissions are out of the limits …



#	Frequency	PK+ Level	PK+ Limit	PK+ Margin
1	0,49 MHz	71,5 dBuV	56,1 dBuV	-15,4 dB
2	0,99 MHz	70,5 dBuV	56,0 dBuV	-14,5 dB
3	1,48 MHz	70,3 dBuV	56,0 dBuV	-14,3 dB
4	1,97 MHz	69,9 dBuV	56,0 dBuV	-13,9 dB
5	2,47 MHz	69,5 dBuV	56,0 dBuV	-13,5 dB
6	2,96 MHz	69,4 dBuV	56,0 dBuV	-13,4 dB

Demo circuit: DC/DC converter



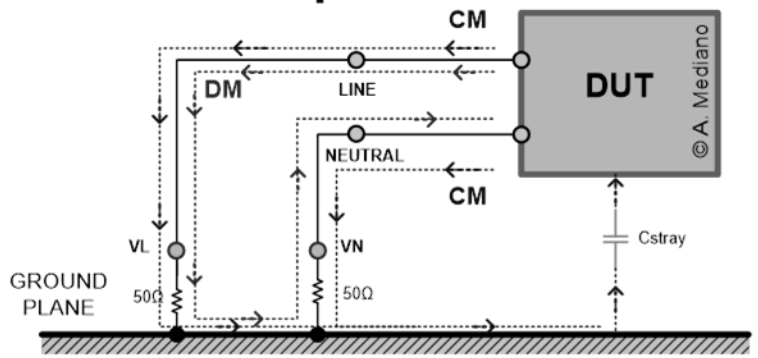


Step-down buck converter
PWM control
fsw = 500kHz

Conducted emissions: DM and CM

- DM and CM can be separated:

DM and CM separation



VL = Vcm + Vdm
VN = Vcm - Vdm

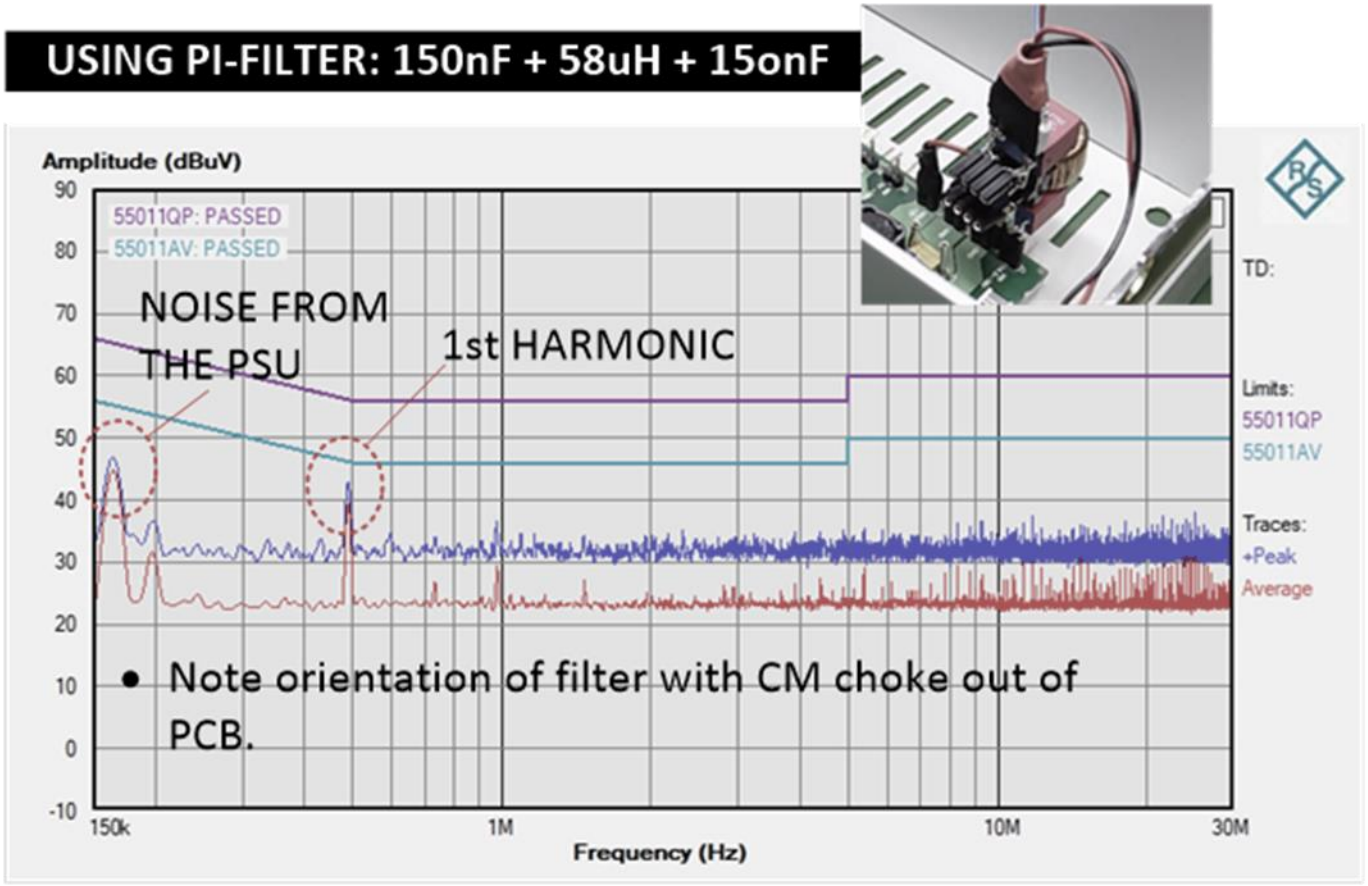
→ Vdm = (VL-VN)/2
Vcm = (VL+VN)/2

EXAMPLES:

- Scope: 2 channels and math
- Transformers
- Splitters
- Resistor networks

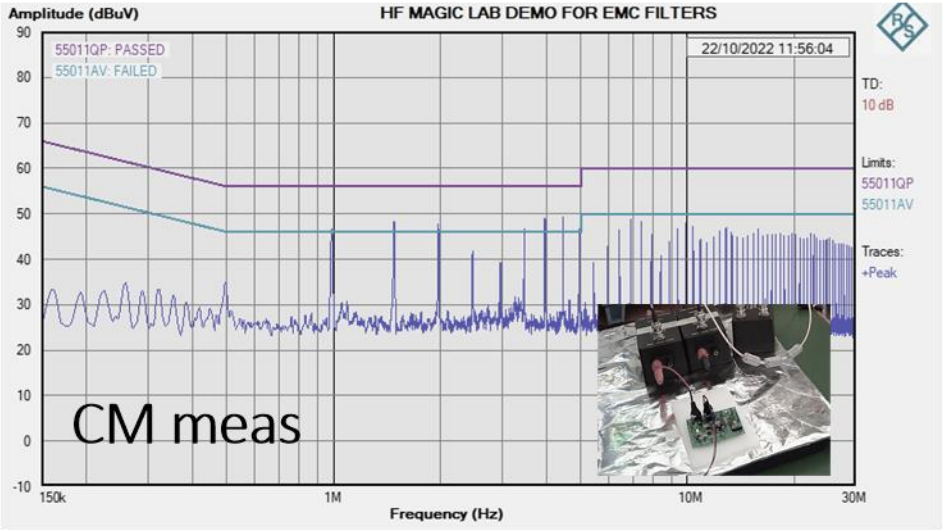
Note 6dB factor to include to obtain VDM and VCM

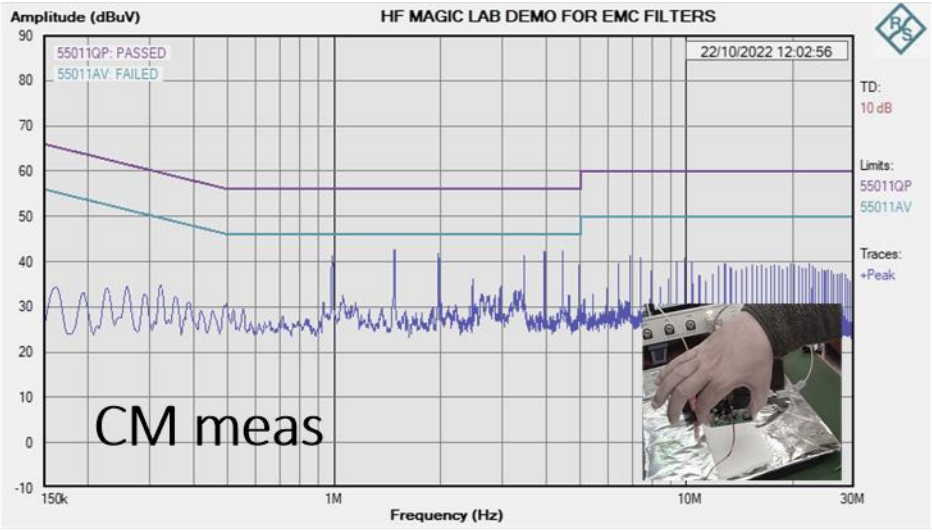
Conducted emissions: filtering



Conducted emissions: changing CM emissions

Separate the DC/DC board from metal plane to see how CM decrease:

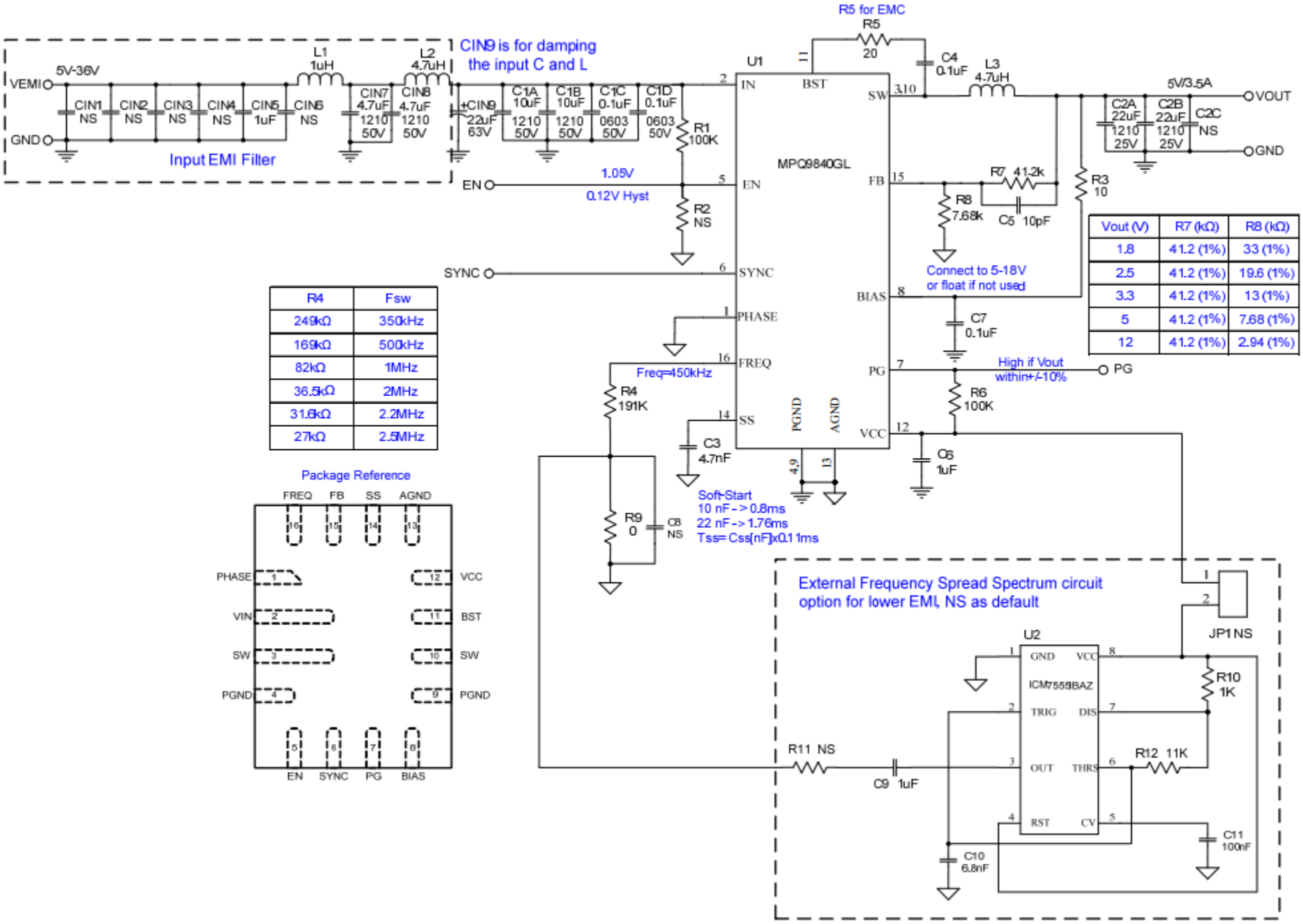




An optimized design from MPS

MPS Eval board: EVQ4431-L-00A

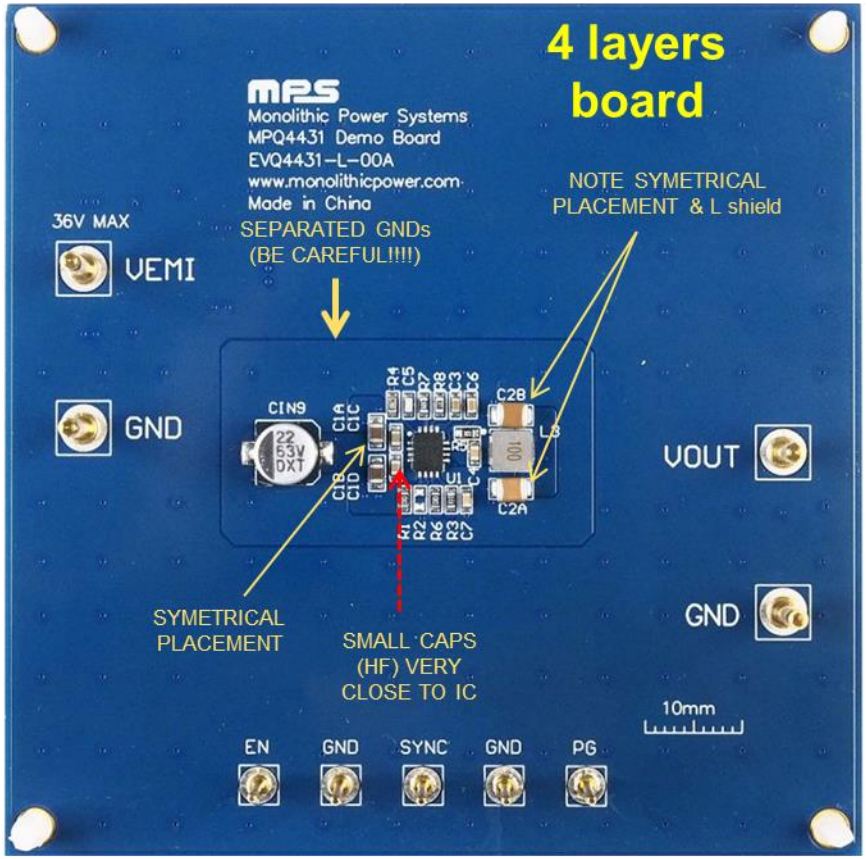
36V, 1A, Low I_Q, Synchronous Step-Down Converter Evaluation Board

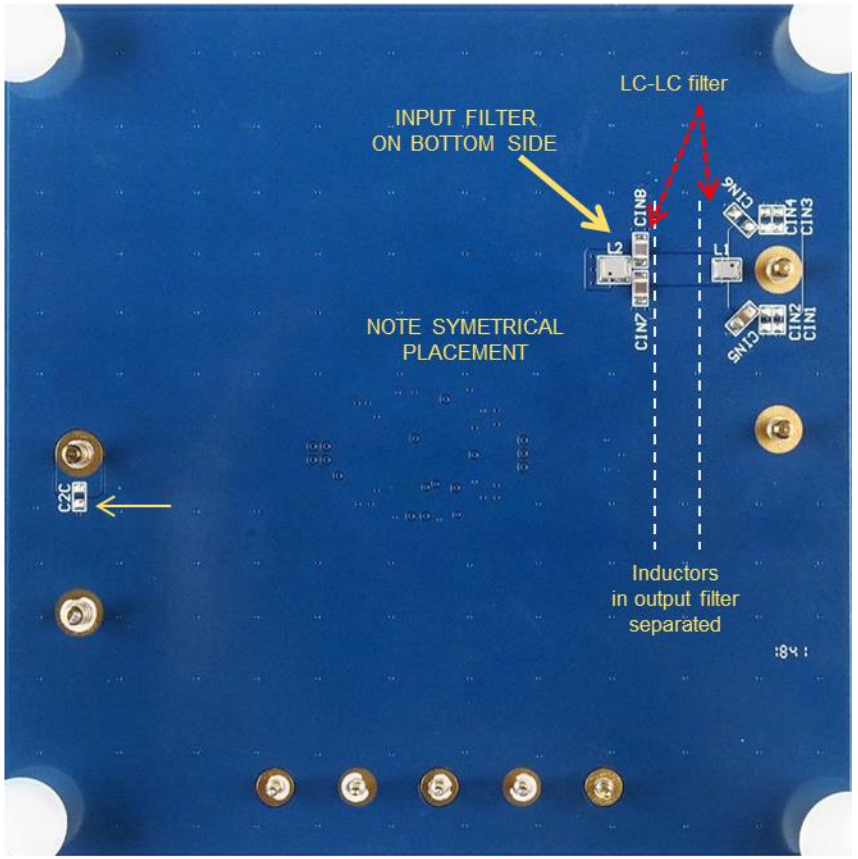


R4	Fsw
249kΩ	350kHz
169kΩ	500kHz
82kΩ	1MHz
36.5kΩ	2MHz
31.6kΩ	2.2MHz
27kΩ	2.5MHz

Vout (V)	R7 (kΩ)	R8 (kΩ)
1.8	41.2 (1%)	33 (1%)
2.5	41.2 (1%)	19.6 (1%)
3.3	41.2 (1%)	13 (1%)
5	41.2 (1%)	7.68 (1%)
12	41.2 (1%)	2.94 (1%)

MPS Eval board: EVQ4431-L-00A

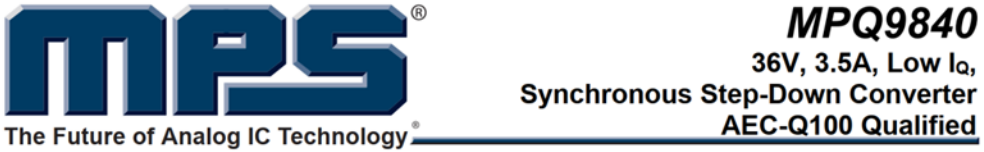




Credit for the techniques: MPS

REFERENCES: … from MPS

Datasheets:



Presentations:

- *EMI Sources on Step-Down Converters*, Ralf Ohmberger, MPS Staff Apps Enginer, Jun 2023.
- *Automotive EMI Demystified: Part 1. Black Magic Busted*, Christian Kueck, Oct. 2018.
- *Automotive EMI Demystified: Part 2. Pursuing an Ideal Power Supply Layout*. Jens Hedrich, Senior FAE, Central Europe MPS, Dec. 2018

THANK YOU!

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