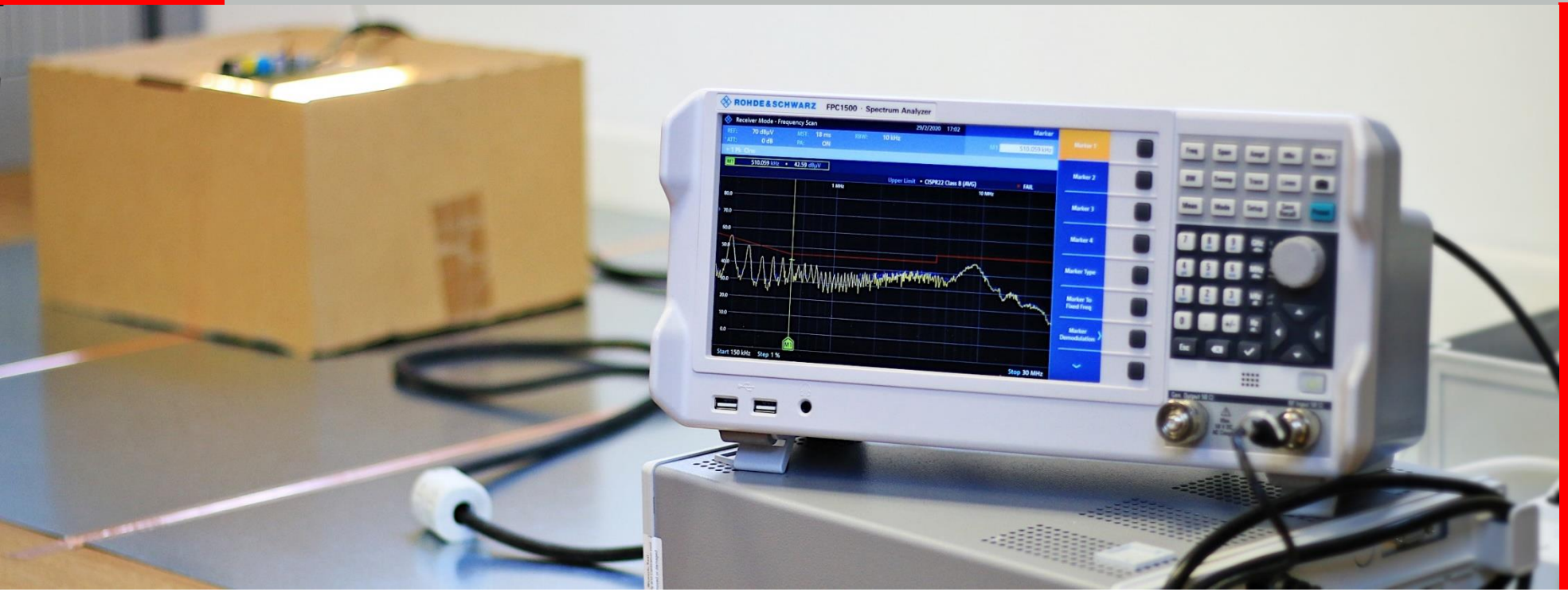
TECHNICAL ACADEMY

WÜRTH ELEKTRONIK

Build your EMC Lab from Scratch

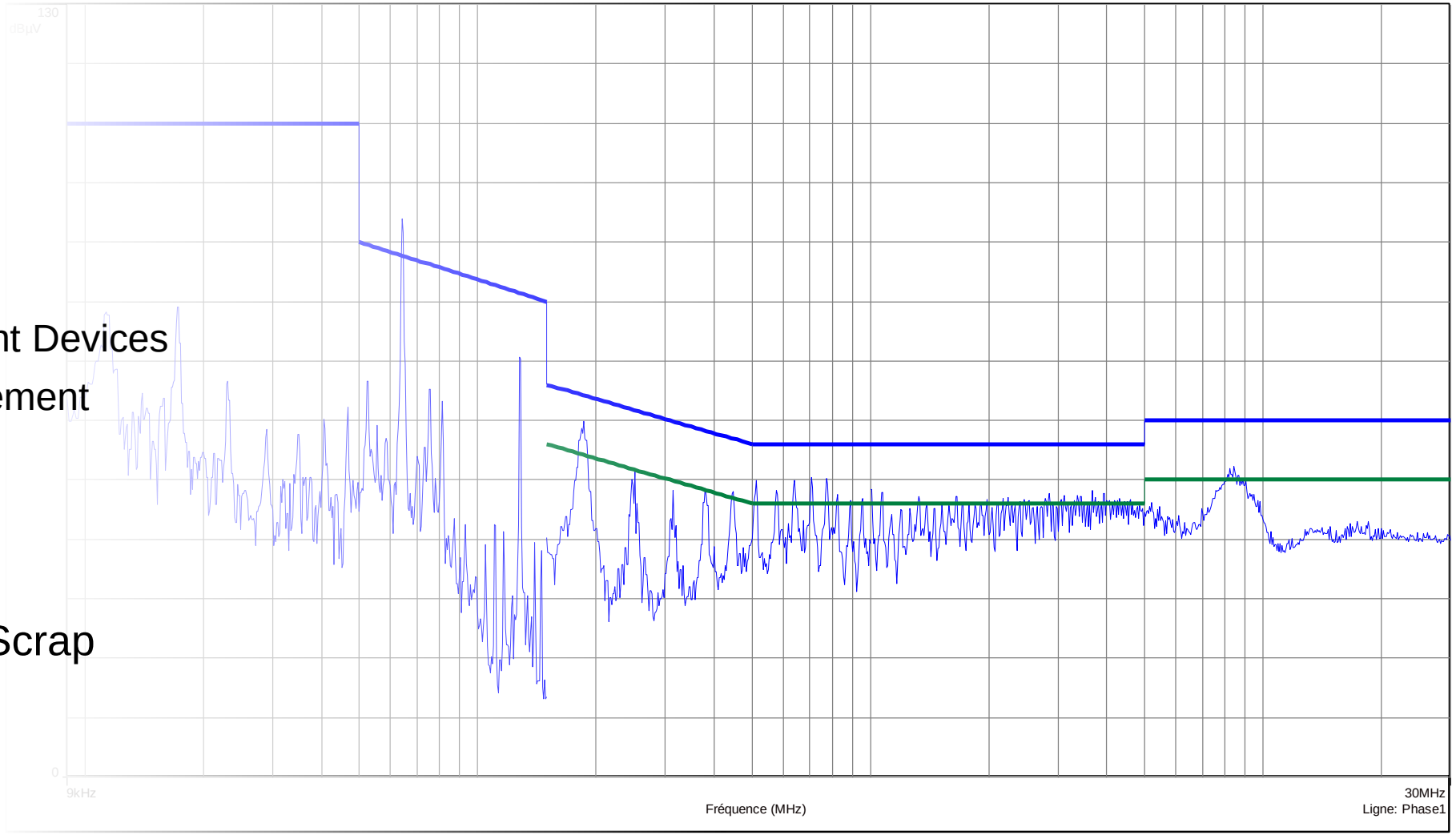


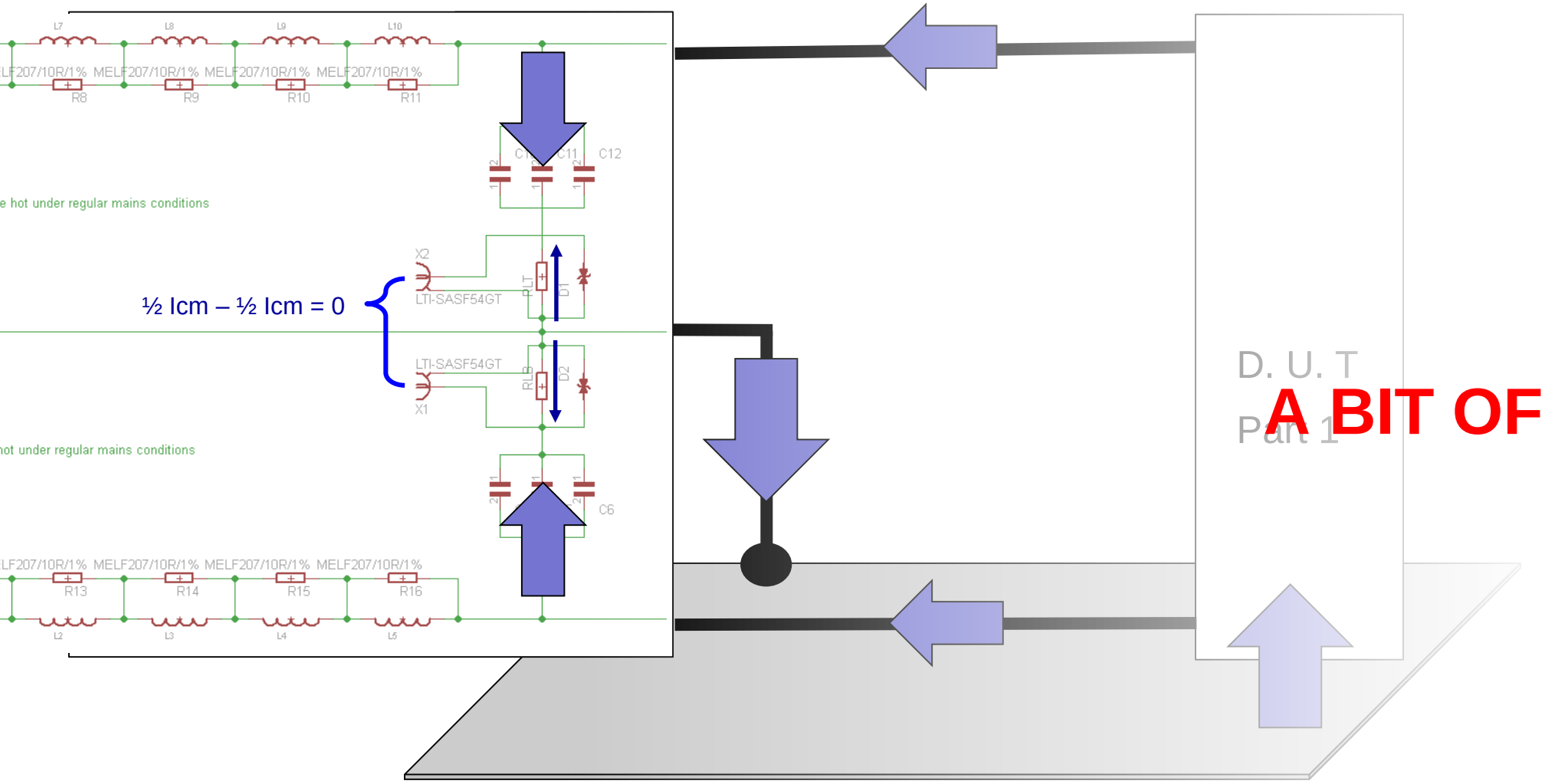
Sylvain LE BRAS

Wurth Elektronik eiSos

Build your EMC Lab from Scratch

- A bit of theory
  - Power path
  - Signal path
  - Safety
- A bit of hardware
  - Shopping list
  - Applicable Measurement Devices
  - Enabling EMC measurement
- A bit of Manual Labor
  - Assembly
  - Test
- Build you EMC lab from Scrap
  - Cost optimization
- Extra hardware

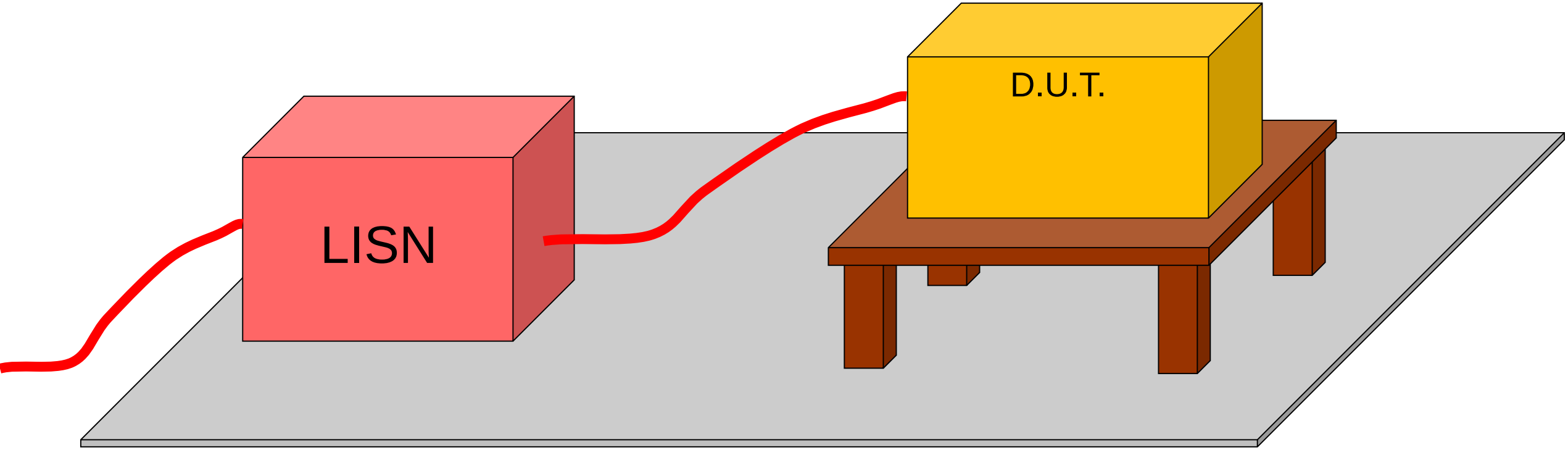




A BIT OF THEORY

Part 1

Conducted EMI Test Setup

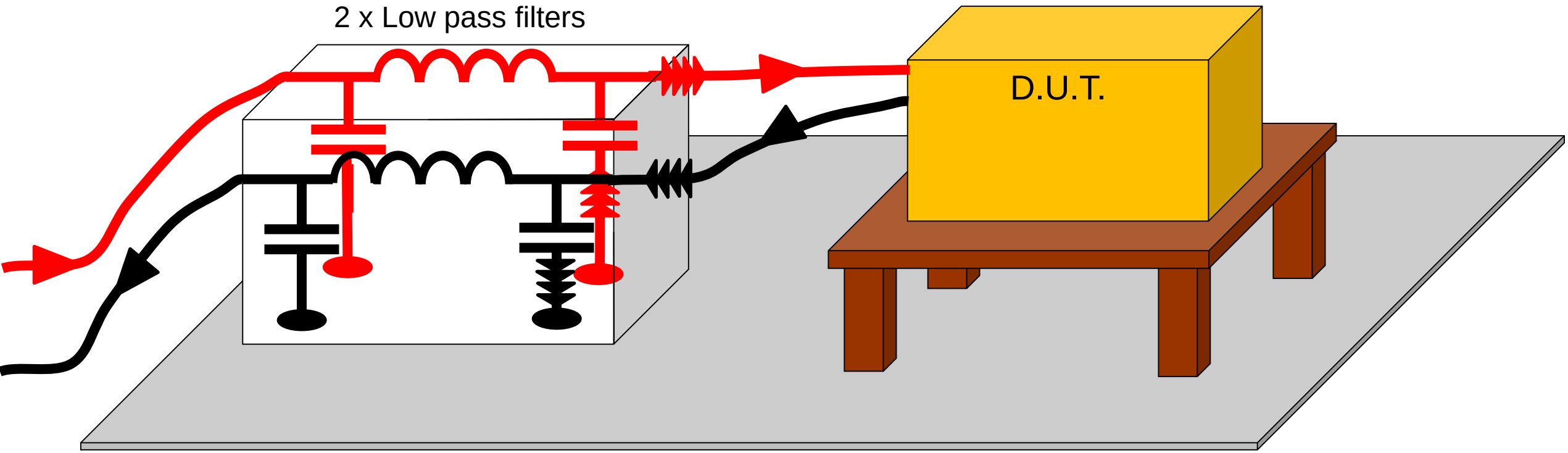


A bit of theory

The power Path

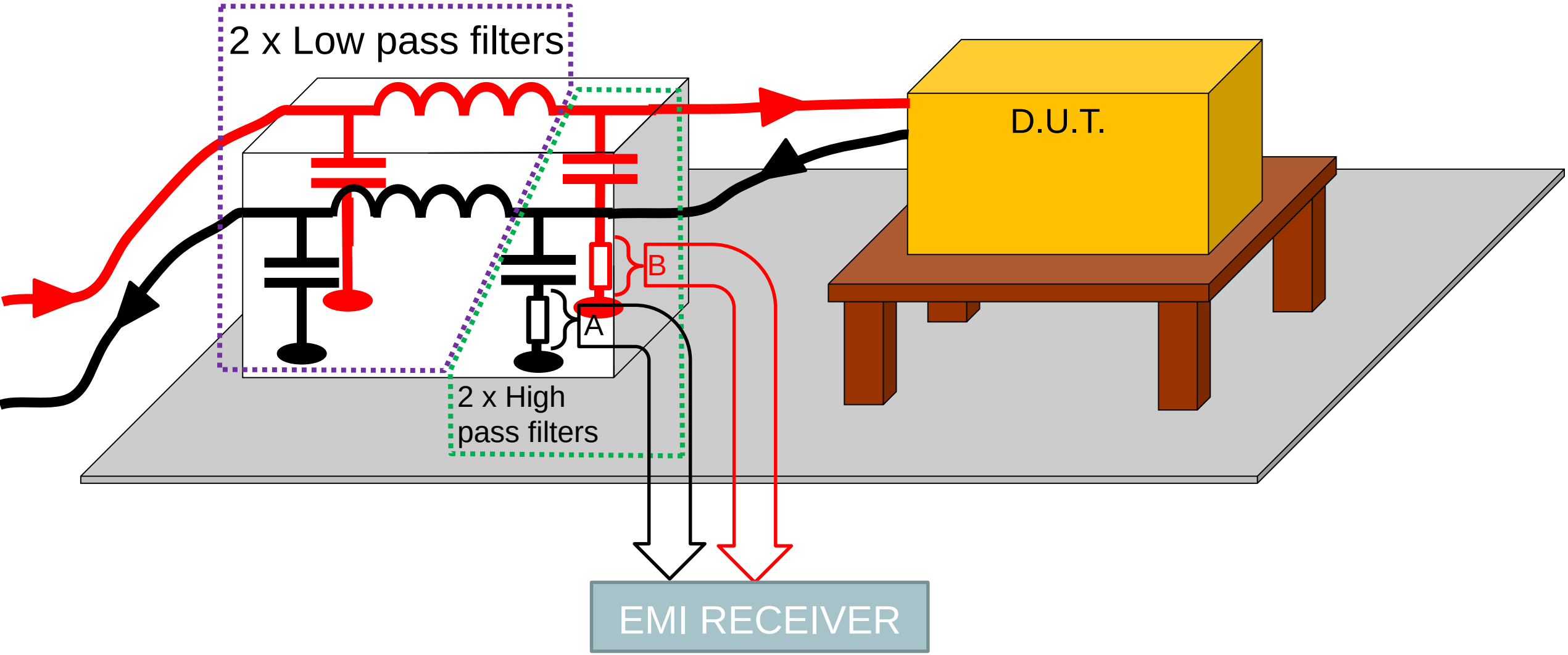
Low Frequency

High Frequency



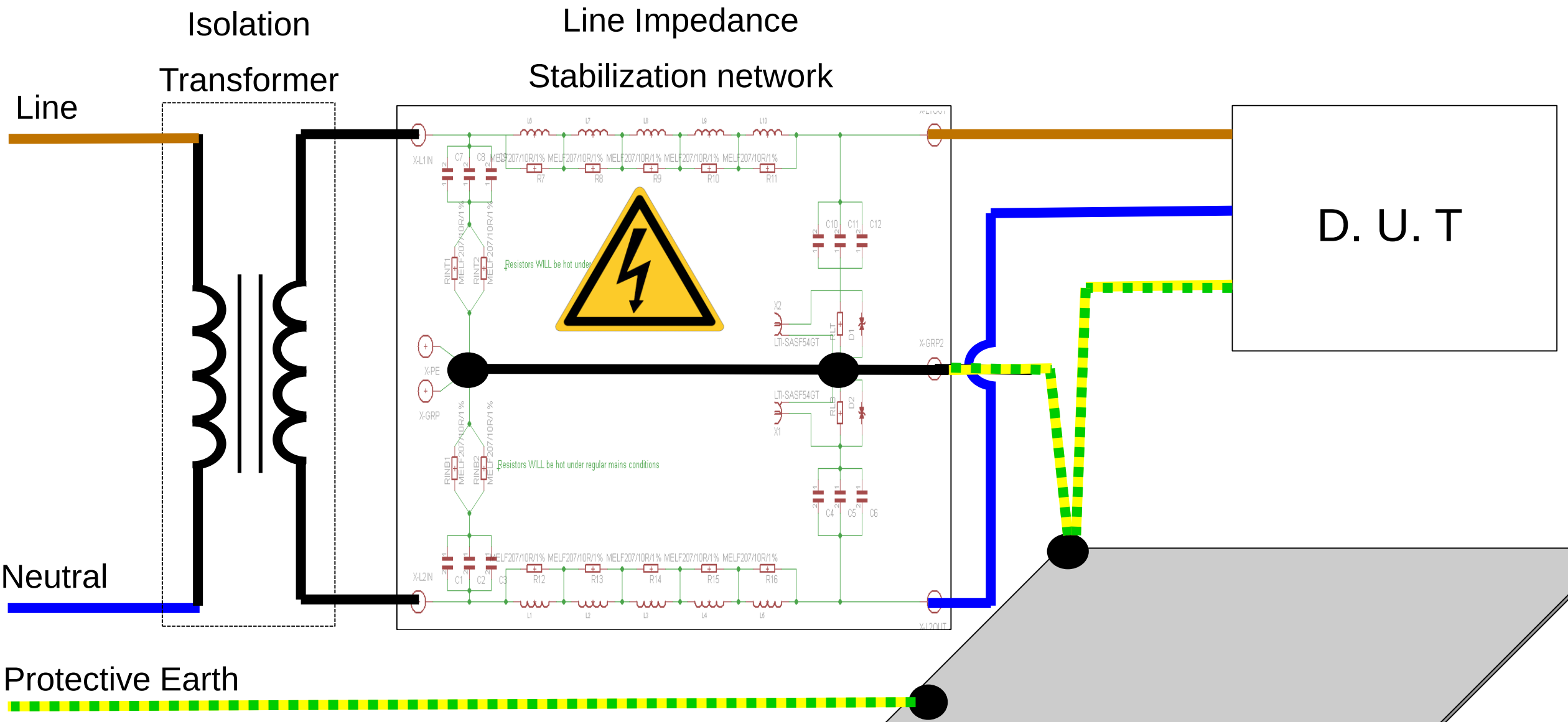
A bit of theory

The signal Path



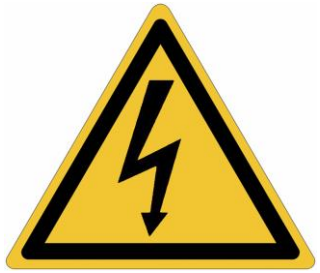
Safety

Conducted EMI Test Setup



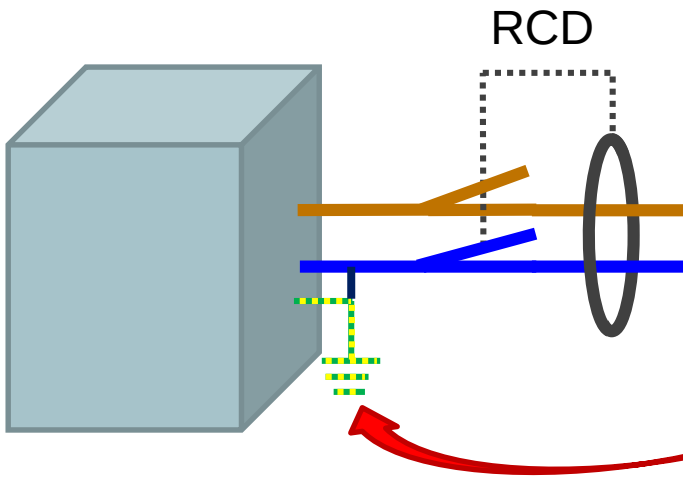
Safety

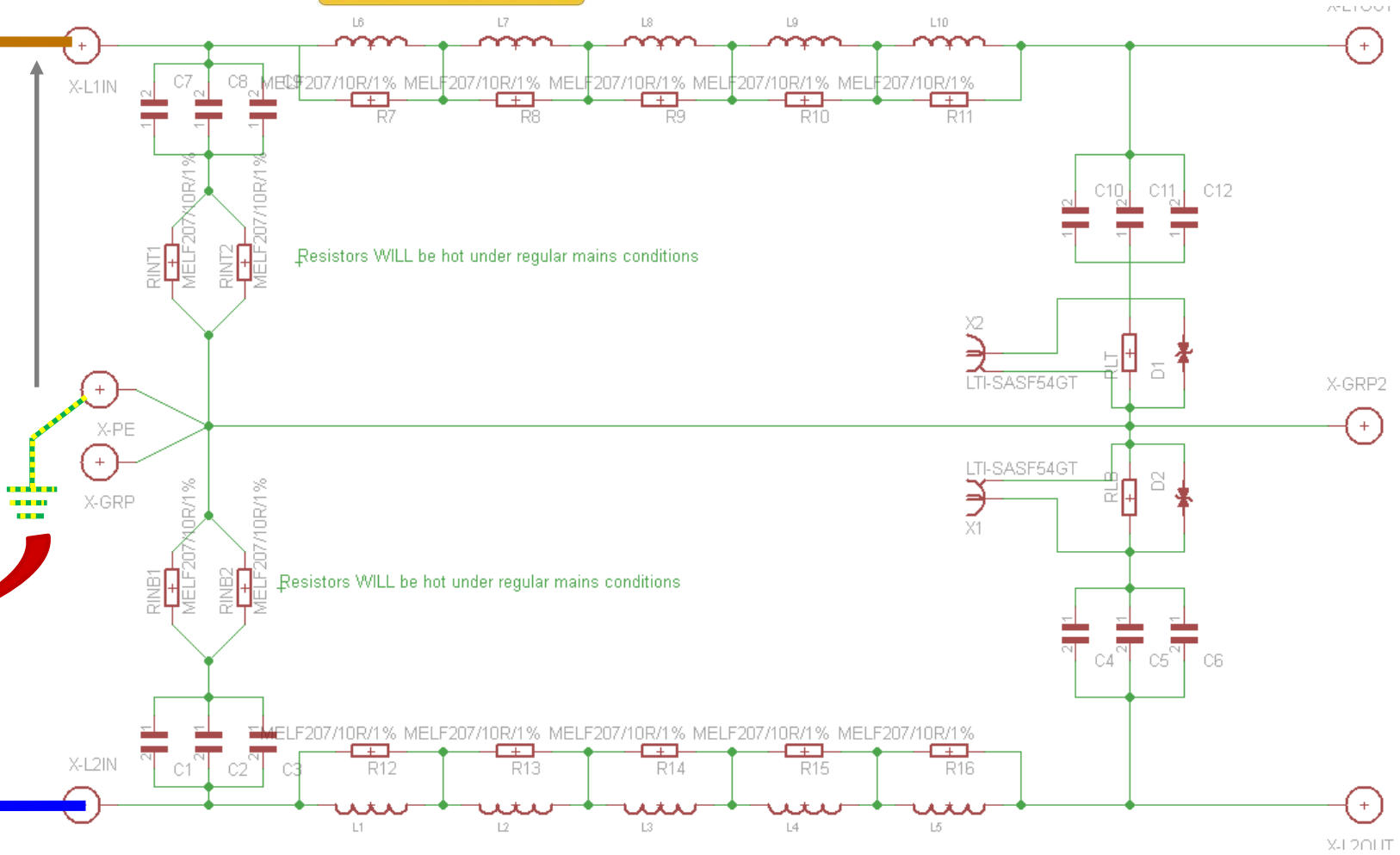
Why do we need an Isolation transformer



$$I_{Leak} = \frac{V_{mains}}{Z_{Lisn} + Z_{Earth}}$$

$$Z_{Lisn} = 5 + \frac{1}{8\mu \times 2\pi \times F_{mains}}$$





$$Z_{Lisn@50Hz} = 5 + 400 = 405$$

$$I_{Leak} = \frac{230 \times \sqrt{2}}{405} = \textbf{0,803 A}$$

A BIT OF HARDWARE

Shopping List

- Line impedance stabilization network
- Isolation transformer
- Multi socket mains extension
- Crimping tools
- Power cord
- Circuit Breaker
- Plastic cabinet
- Bolts, Nuts, Screws
- Cable Lugs
- EMC filter
- Copper Wire
- Copper Tape
- Metal sheet (~ 3 m²)

Price of an EMC Lab

Without LISN and Spectum Analyzer

158,95 €

+ 287,90 €

446,85 €

Applicable Measurement Devices : Spectrum Analyzer

Key facts

- RF performance engineered in Germany
- 10.1" WXGA (1366 × 768 pixel) display – largest and highest resolution in class
- Tracking generator and independent CW signal generator
- Built-in VSWR bridge
- One port vector network analyzer with Smith chart display

Applicable Measurement Devices : Picoscope ?

PicoScope® 3000 Series

Power, portability and performance

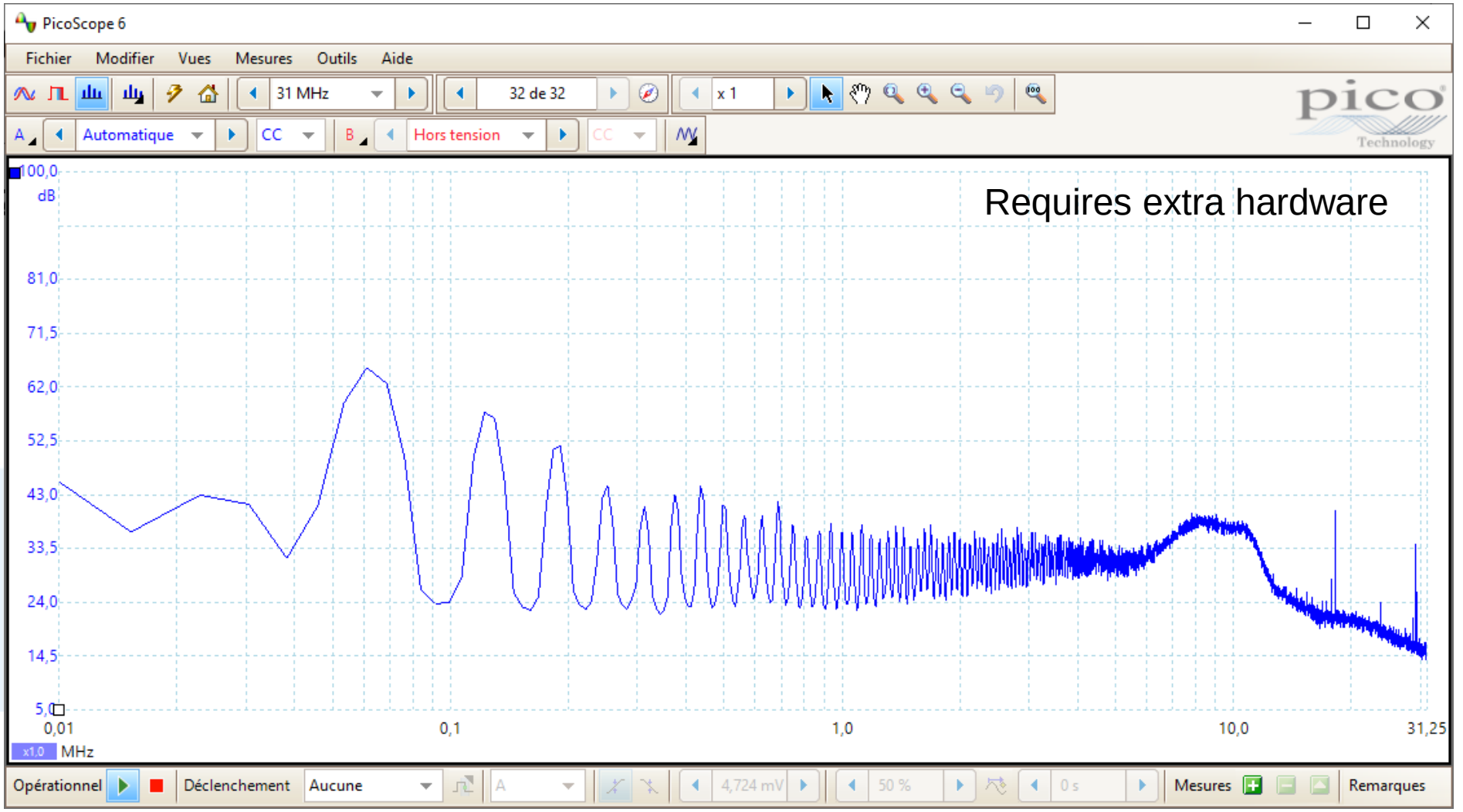
CONFIGURE YOUR SCOPE

BANDWIDTH (MHz)

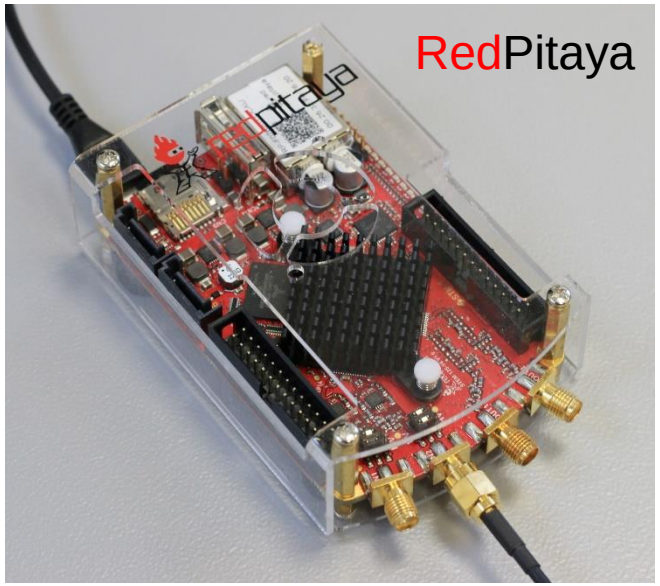
50 70 100 200

CHANNELS 2 4

MSO MSO

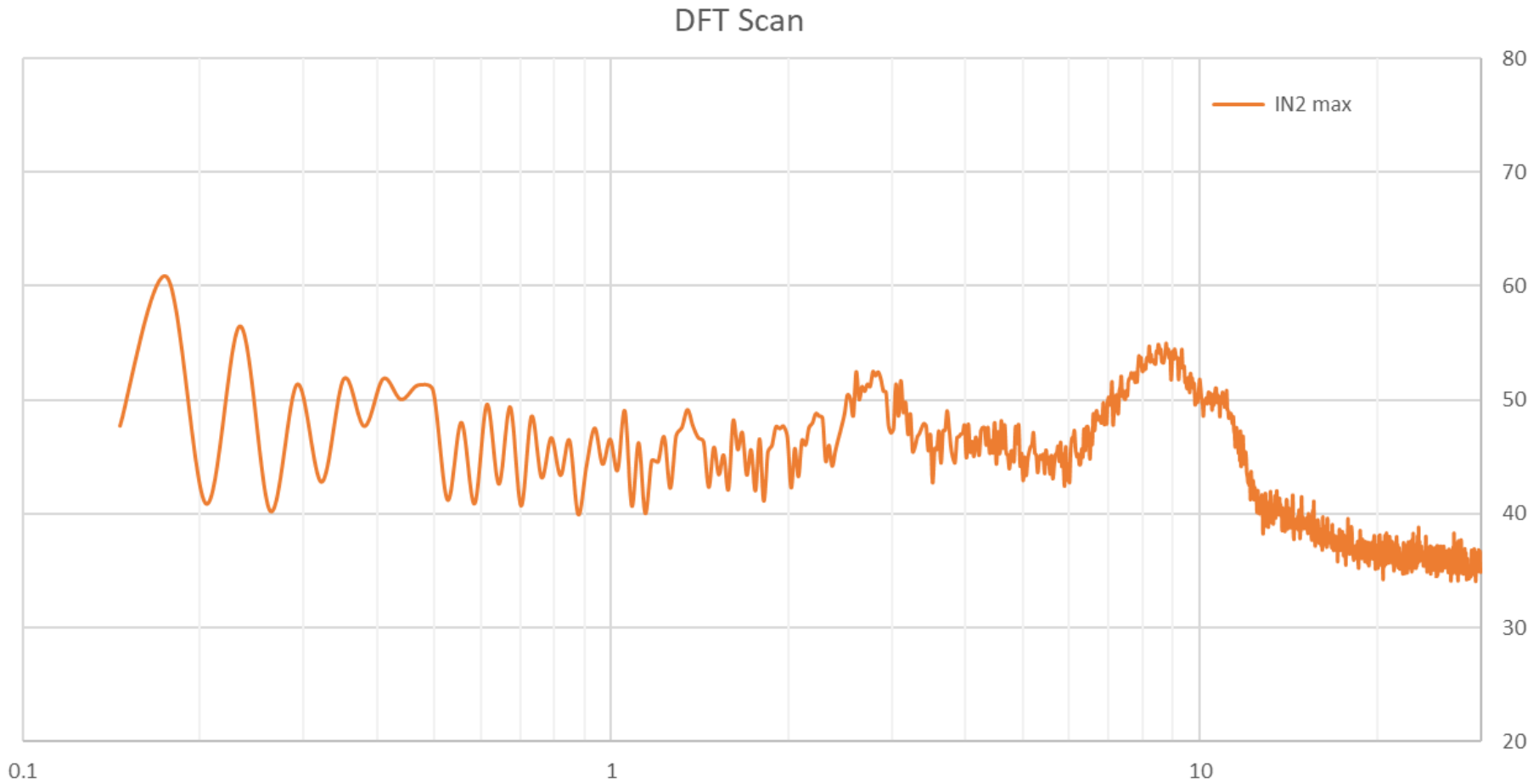


Applicable Measurement Devices : RedPitaya



STEM^{lab} 125-14

Starter kit



Oscilloscope, Spectrum Analyzer and EMI Receiver

	Input	High Pass Filter	Variable RBW	Peak, RMS, Qpeak detector	Normative Limit lines
EMI Receiver	50Ω / 75Ω	Yes (AC coupled)	Yes Normative	Yes Normative	Yes
Spectrum Analyzer	50Ω / 75Ω	Yes (AC coupled)	Yes	Mostly Yes	Mostly Yes
Oscilloscope	1MΩ / 10MΩ	No	No	No	No

Enabling EMC pre-compliance on Oscilloscopes

	Input	High Pass Filter	Variable RBW	Peak, RMS, Qpeak detector	Normative Limit lines
Oscilloscope	1 Meg / 10 Meg	No	No	No	No

Terminated Transient limiter

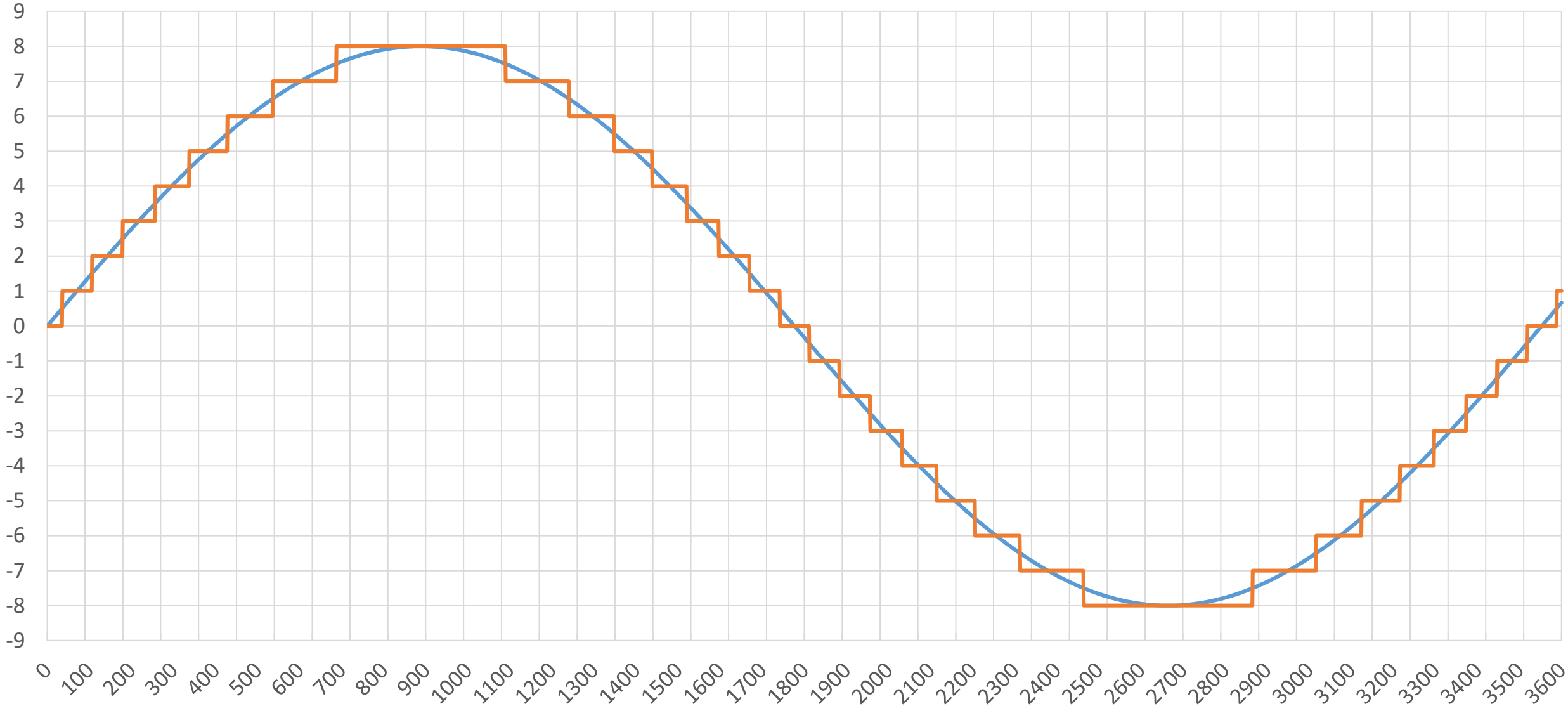
Do we really care ?
Or
Downscale DTF / FFT

≈ max hold and mean

Steal them there's always a workaround to display them

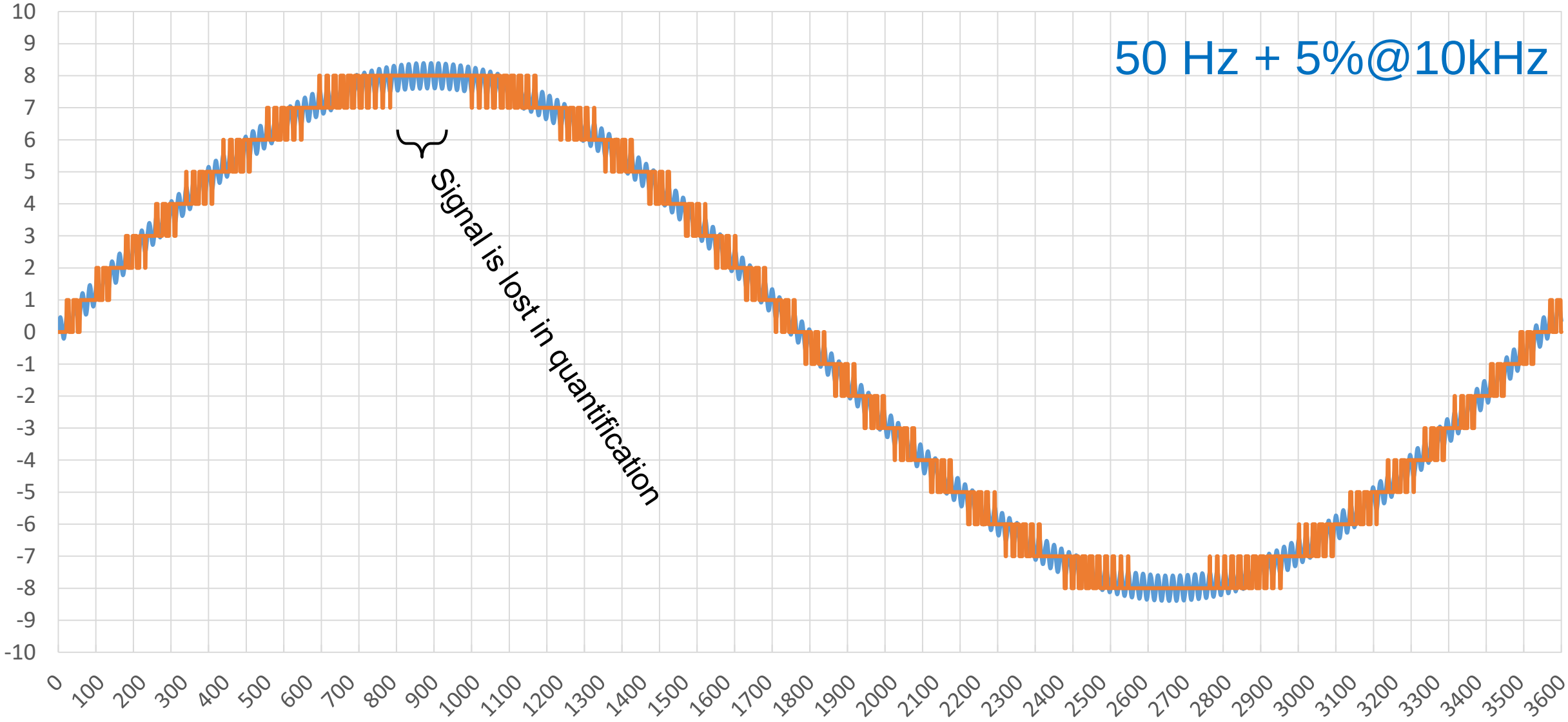
ADC Vertical Quantification reminder

Why do we need a High pass filter ?



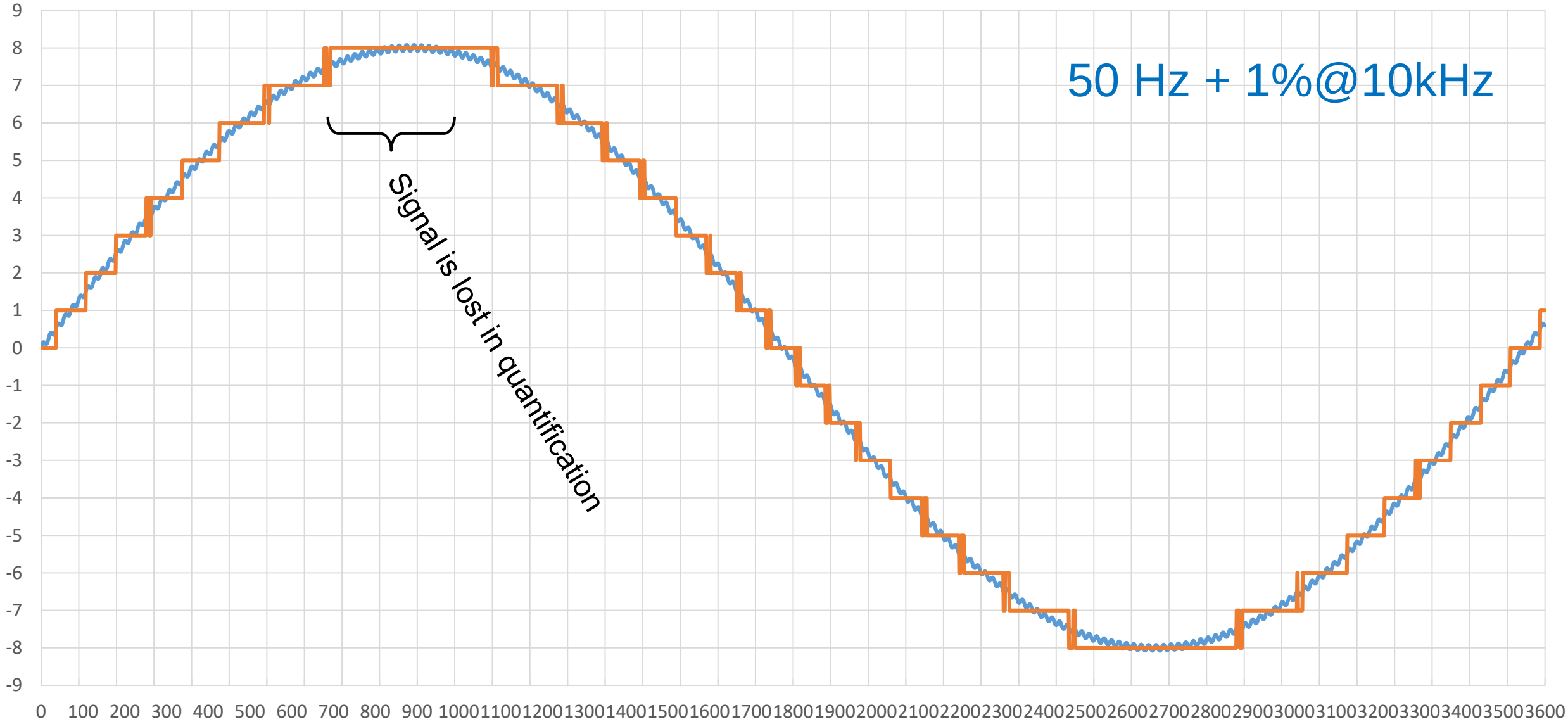
ADC Vertical Quantification reminder

Why do we need a High pass filter ?

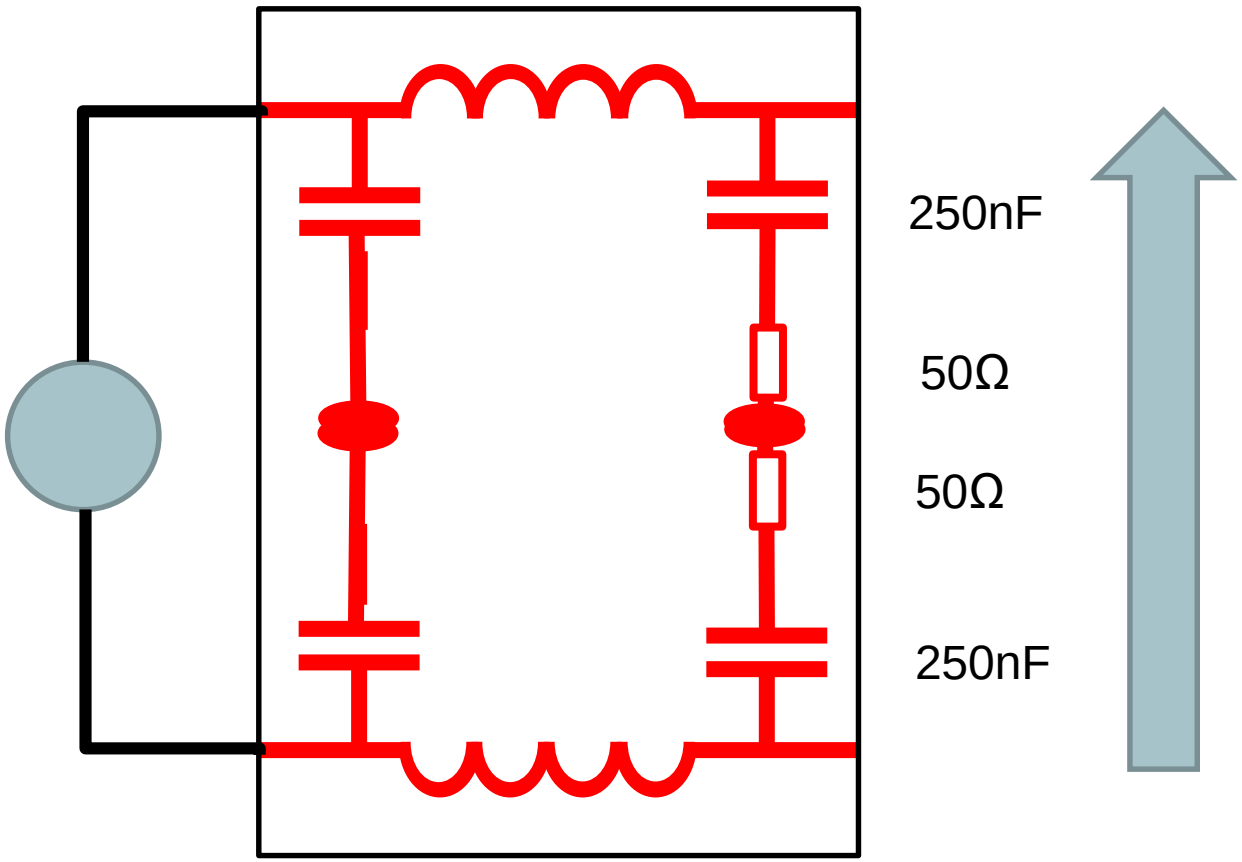


ADC Vertical Quantification reminder

Why do we need a High pass filter ?



High pass filter example



$$V_A = \frac{Vout}{2} \times \frac{Zr}{Zc + Zr}$$

$$Z_C = \frac{1}{C \times \omega} = \frac{1}{250 \times 10^{-9} \times 2 \times \pi \times 50}$$

$$Z_C = \frac{1}{C \times \omega} = \frac{1}{250 \times 10^{-9} \times 2 \times \pi \times 50} = 12.7k$$

$$V_A = \frac{50 \times 230\sqrt{2}}{2 \times (12.7k + 50)} = 0{,}64V$$

Full scale of oscilloscope will be ±1V

Sensitivity VS Full scale

With a full scale of ±1V

1V

100 mV

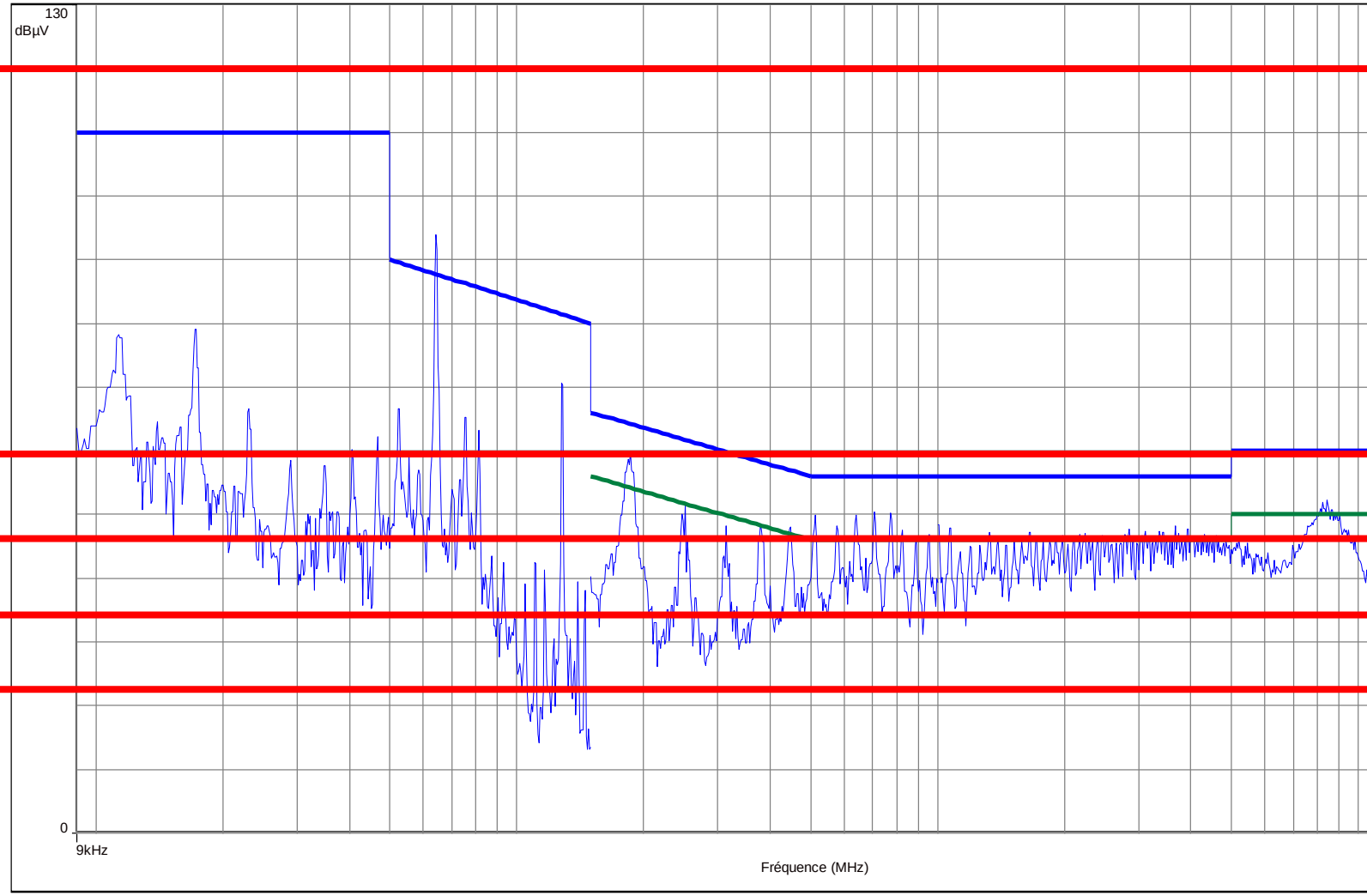
10 mV

10 bit quantification limit 60 dBµV =1 mV

12 bit quantification limit 48 dBµV = 250 µV

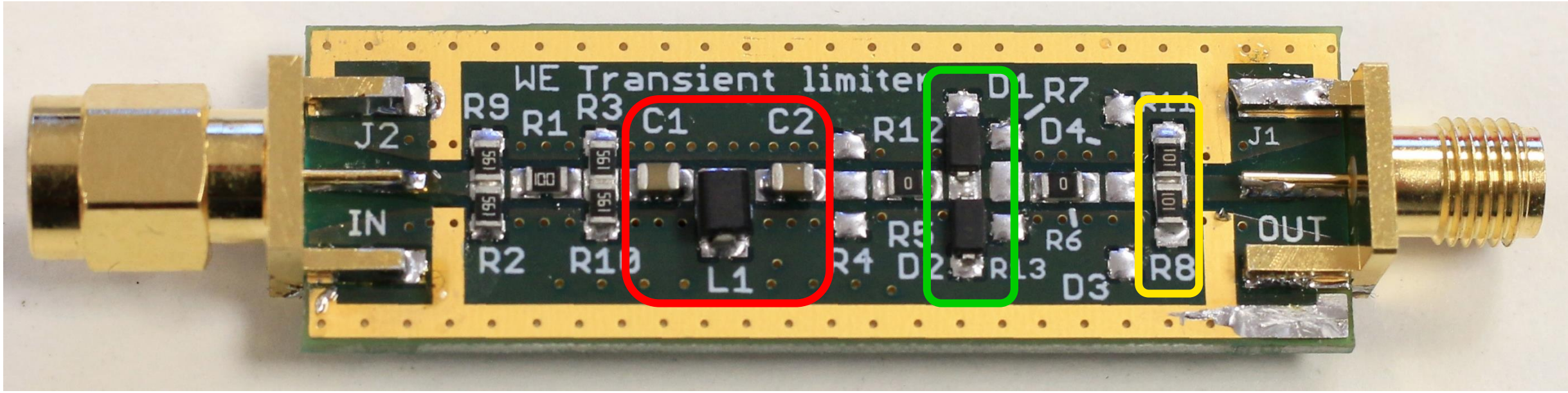
14 bit quantification limit 36 dBµV = 62,5µV

16 bit quantification limit 24 dBµV = 15 µV



Terminated transient limiter

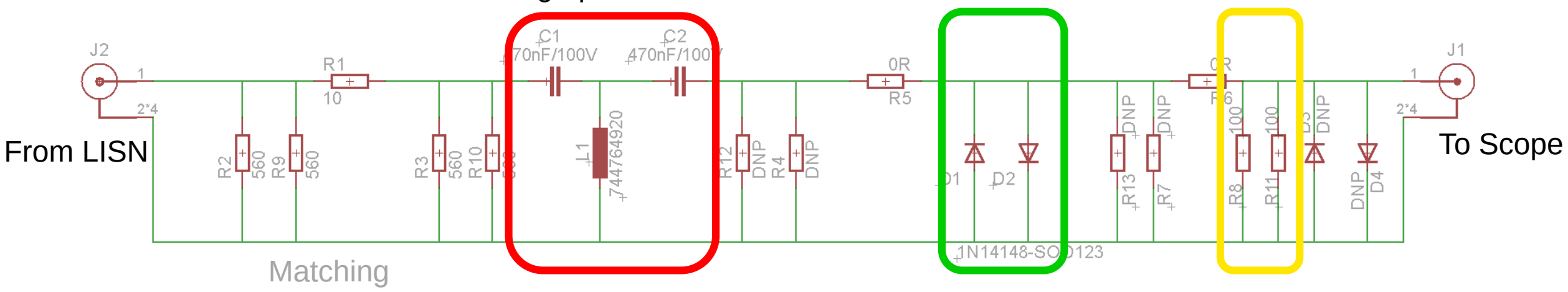
Turning any Oscilloscope into a EMC pre-compliance receiver



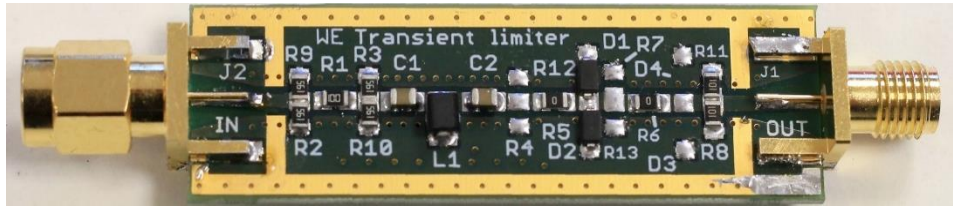
High pass filter

Transient limiter

50 Ω Termination



Insertion Loss of transient limiter



WÜRTH ELEKTRONIK

Suppression of Unwanted Low frequency

Typical conducted EMC range
150 kHz – 30 Meg

-3 dB cutoff
42 kHz – 58 Meg

Insertion Loss (dB)

0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110

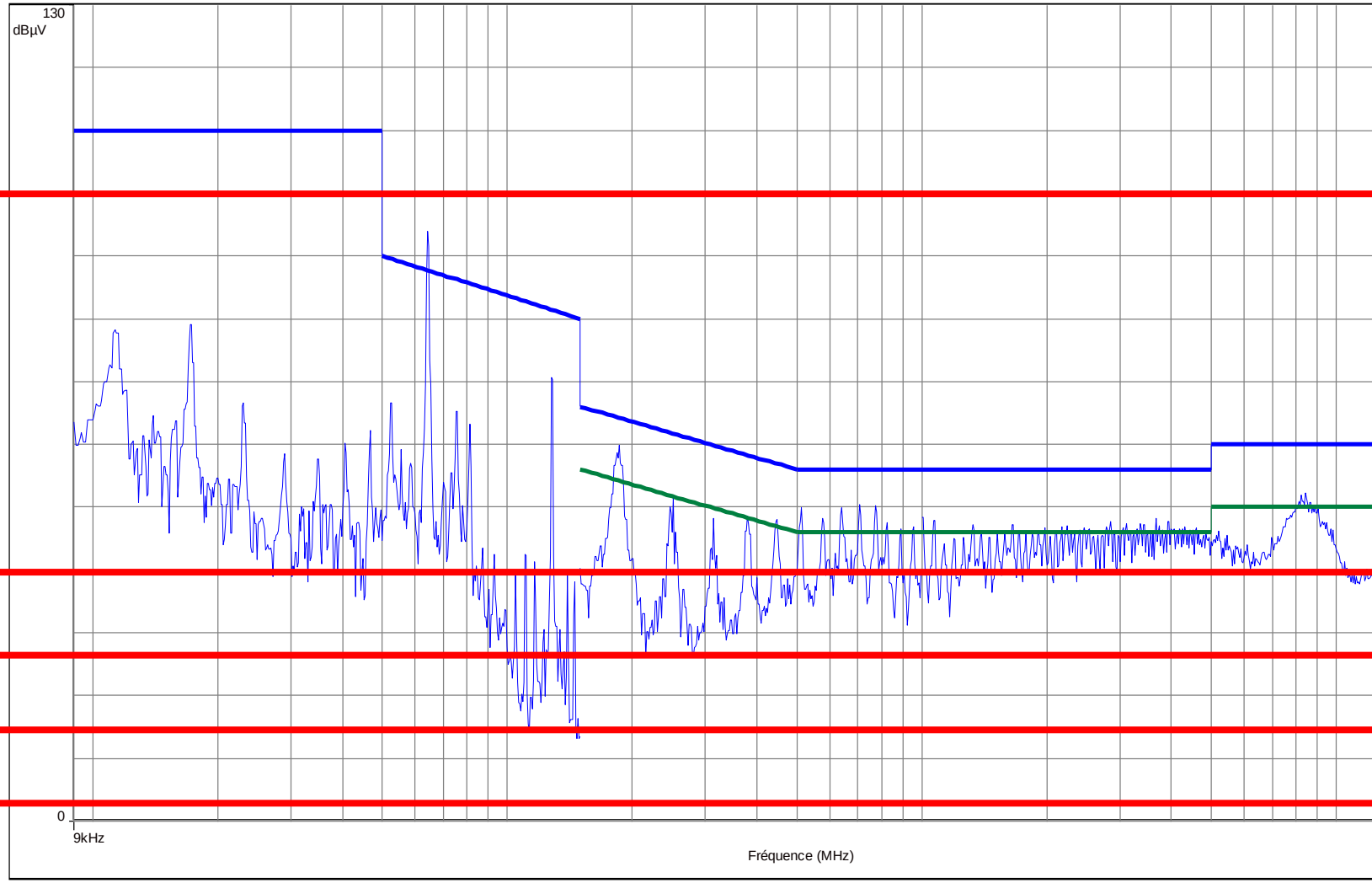
100 Hz
1kHz
10kHz
100kHz
1MHz
10MHz

Transient Limter WE 150kHz-30Meg

Sensitivity VS Full scale with Transient Limiter

Turning any Oscilloscope into a EMC pre-compliance receiver

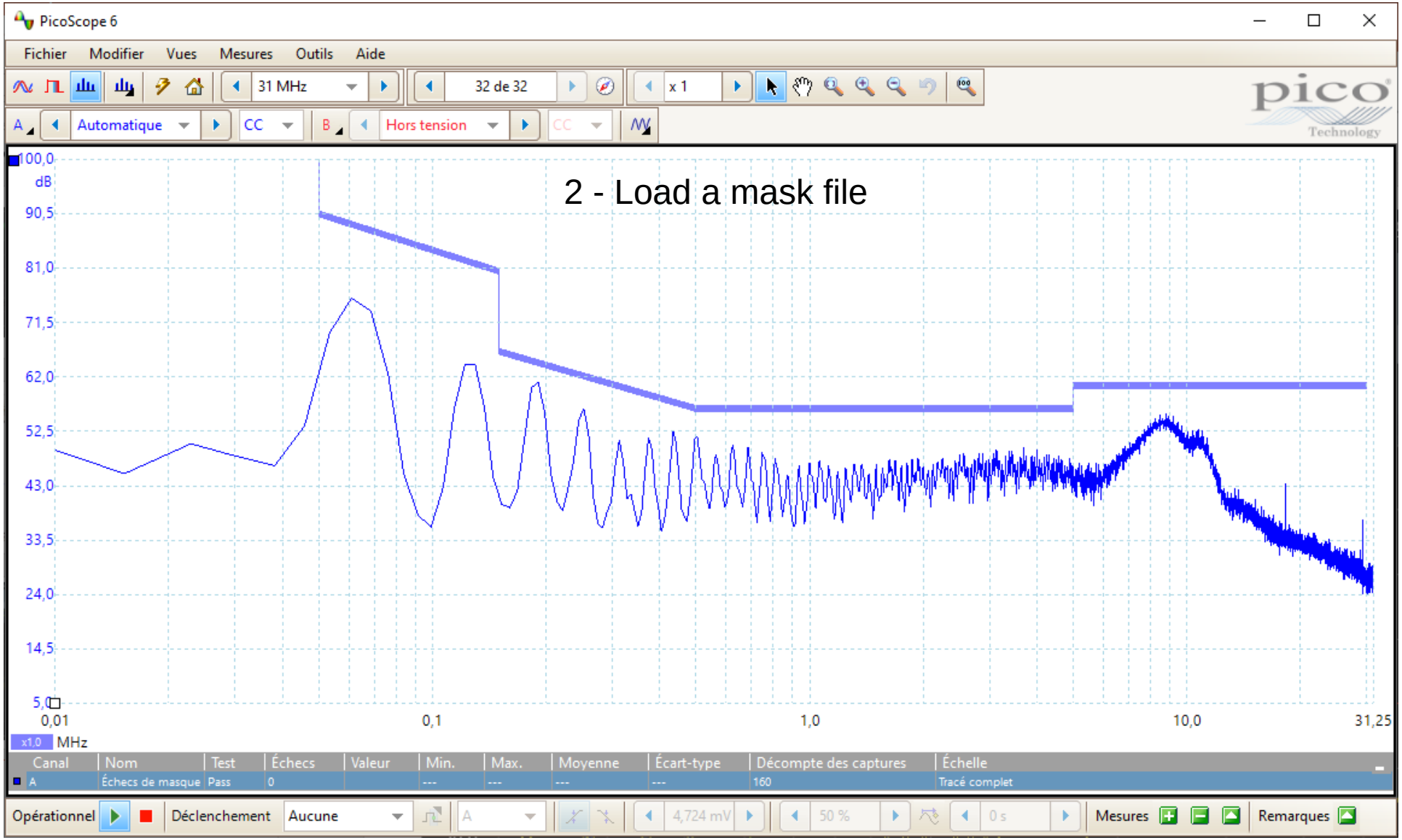
> 90dB suppression
@ 50Hz enables
a full scale of ±100mV



Loading limit lines on Picoscope

1 - Edit a mask file

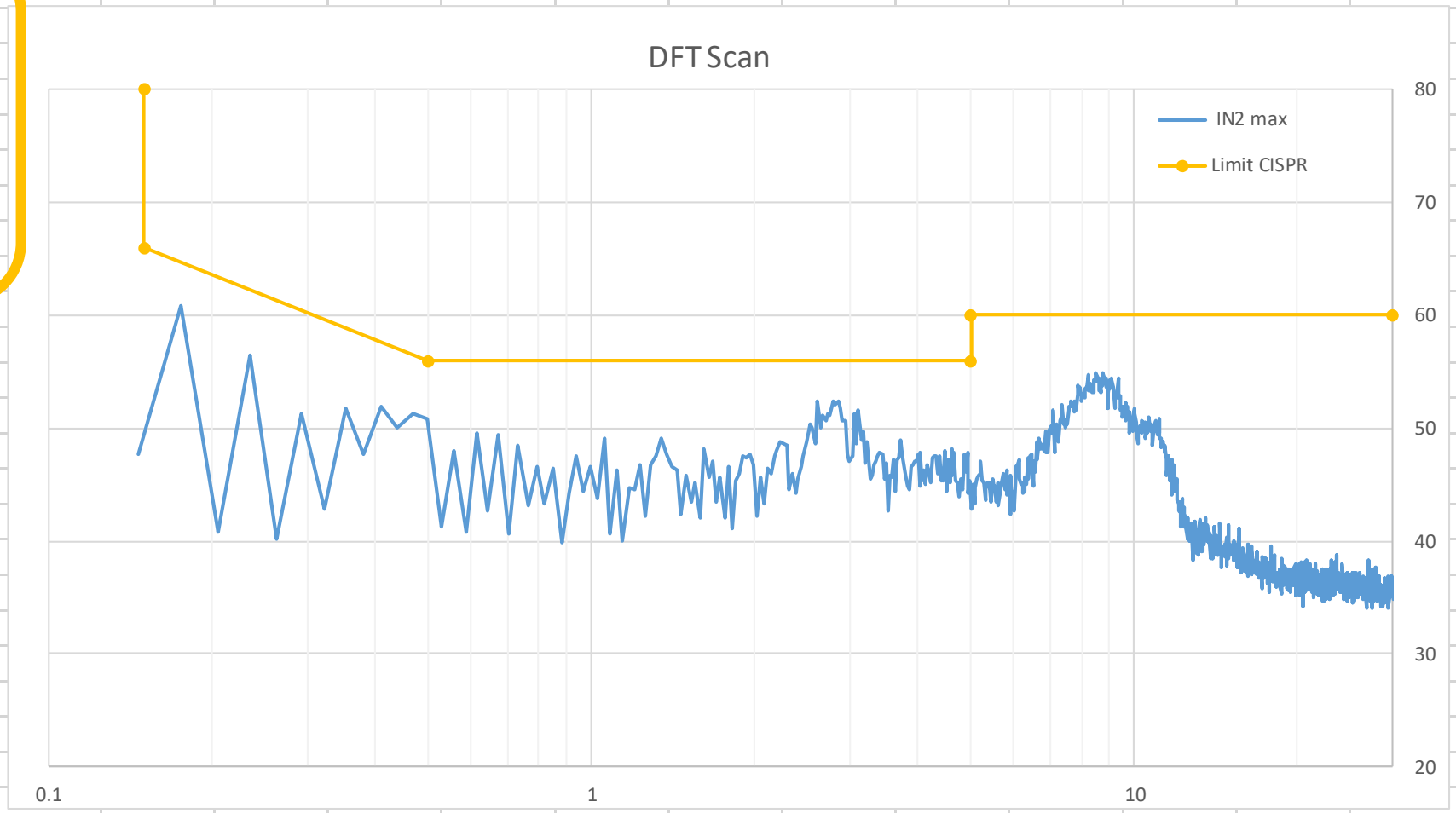
```
<Mask>
  <polygons collection="True">
    <polygon>
      <points collection="True">
        <point>
          <x value="9000" />
          <y value="110" />
        </point>
       // Lots of points
        <point>
          <x value="9000" />
          <y value="111" />
        </point>
      </points>
    </polygon>
  </polygons>
  <masksize value="2000" />
  <minx value="0" />
  <maxx value="31250000" />
  <name value="Limit line CISPR32" />
  <readonly value="False" />
  <unitx>
    <unittype value="Hertz" />
  </unitx>
  <unity>
    <unittype value="Decibel" />
  </unity>
</Mask>
```



Loading limit lines on Red Pitaya

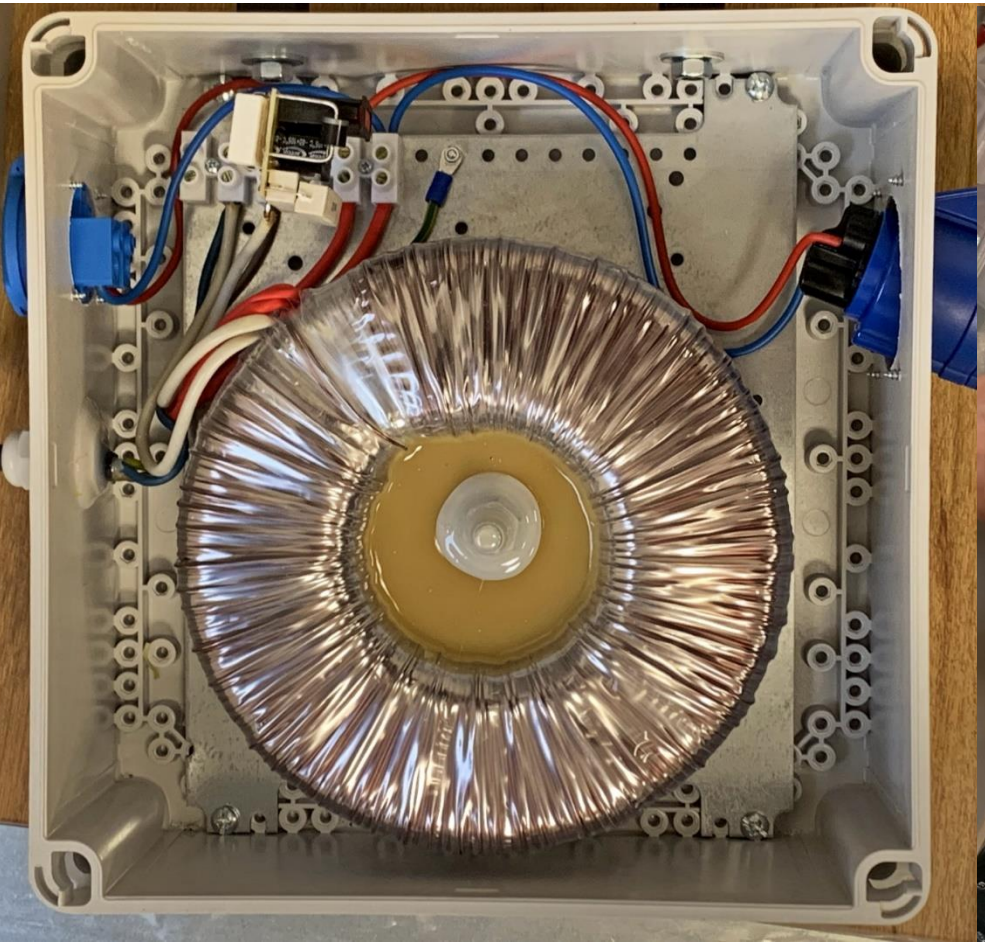
Export data to Excel

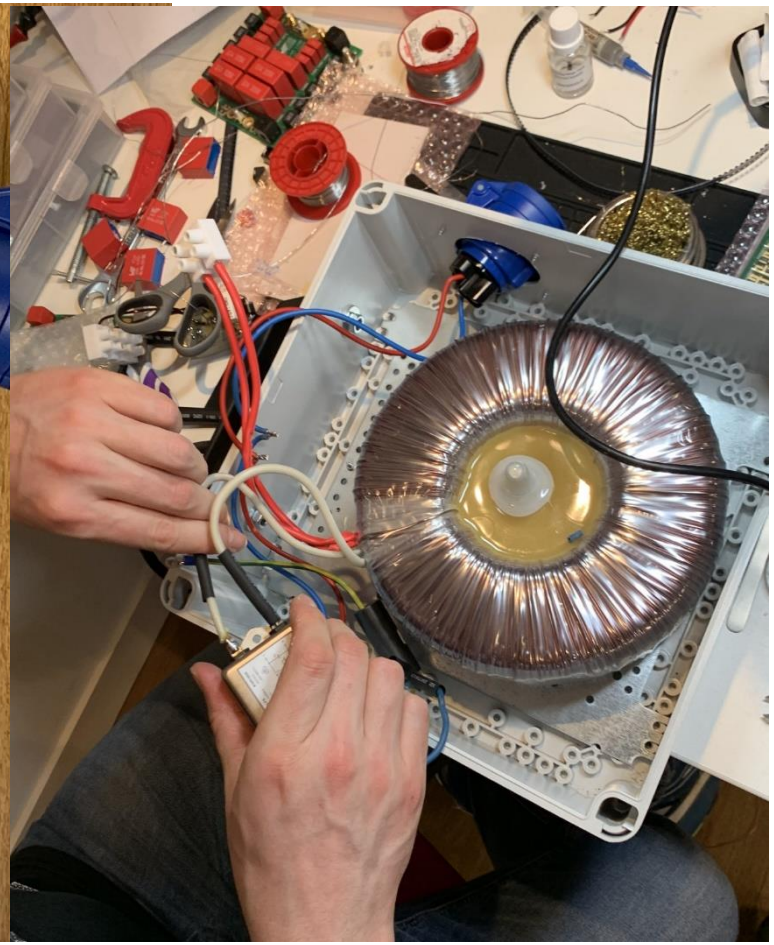
Frequency [MHz]	IN2 max	Frequency [MHz]	Limit CISPR
0.146627566	47.6962	0.009	110
0.175953079	60.78936	0.05	110
0.205278592	40.87318	0.15	80
0.234604106	56.4705	0.15	66
0.263929619	40.22402	0.5	56
0.293255132	51.3560	5	56
0.322580645	42.78056	5.01	60
0.351906158	51.842659	30	60
0.381231672	47.672752		
0.410557185	51.850319		
0.439882698	50.028267		
0.469208211	51.265526		
0.498533724	50.855293		
0.527859238	41.211853		
0.557184751	48.003532		
0.586510264	40.870407		
0.615835777	49.594872		
0.64516129	42.614082		
0.674486804	49.363373		
0.703812317	40.701797		
0.73313783	48.55323		
0.762463343	43.160782		
0.791788856	46.657547		

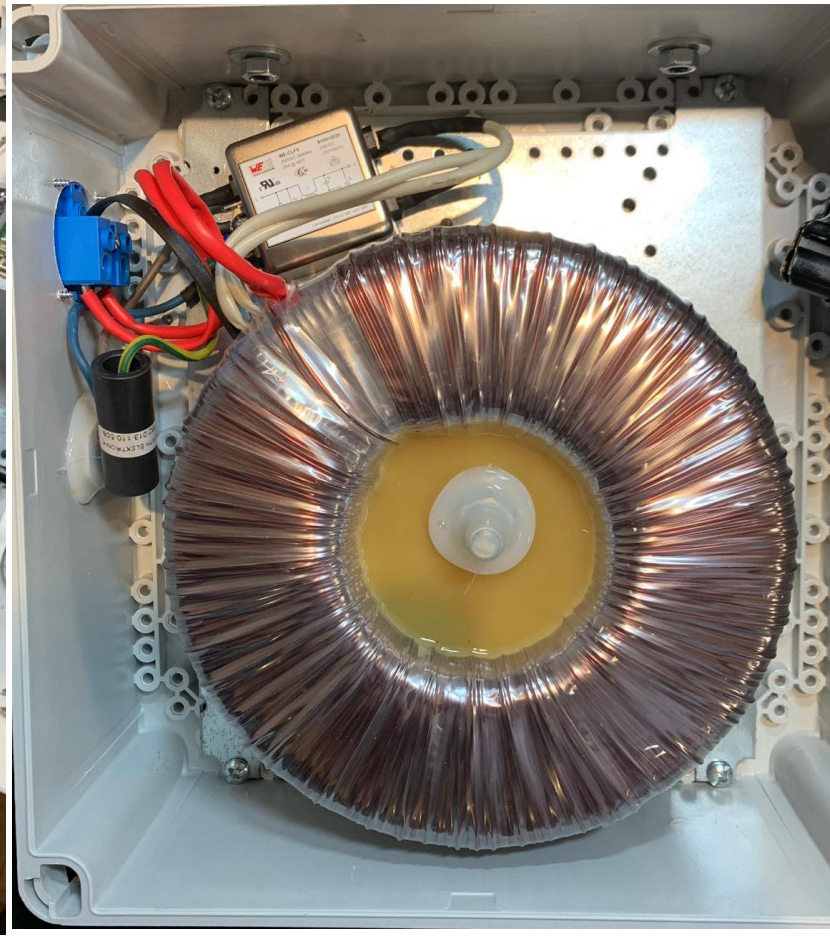


A BIT OF LABOR

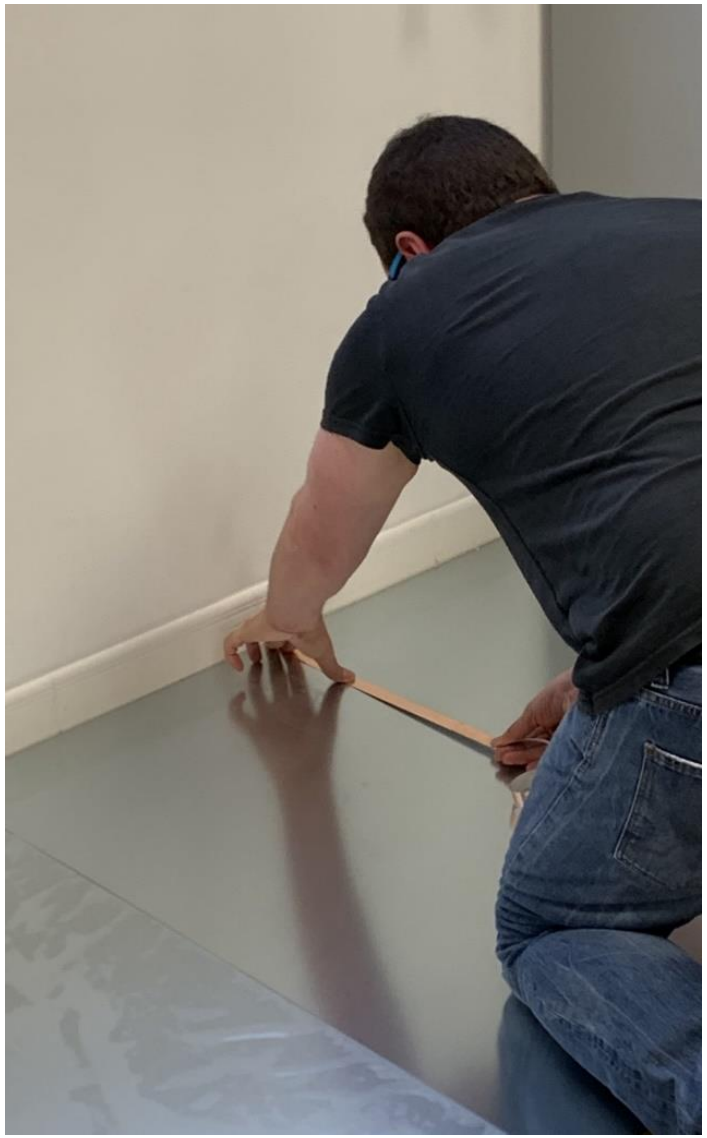
Re-Wiring the isolation transformer





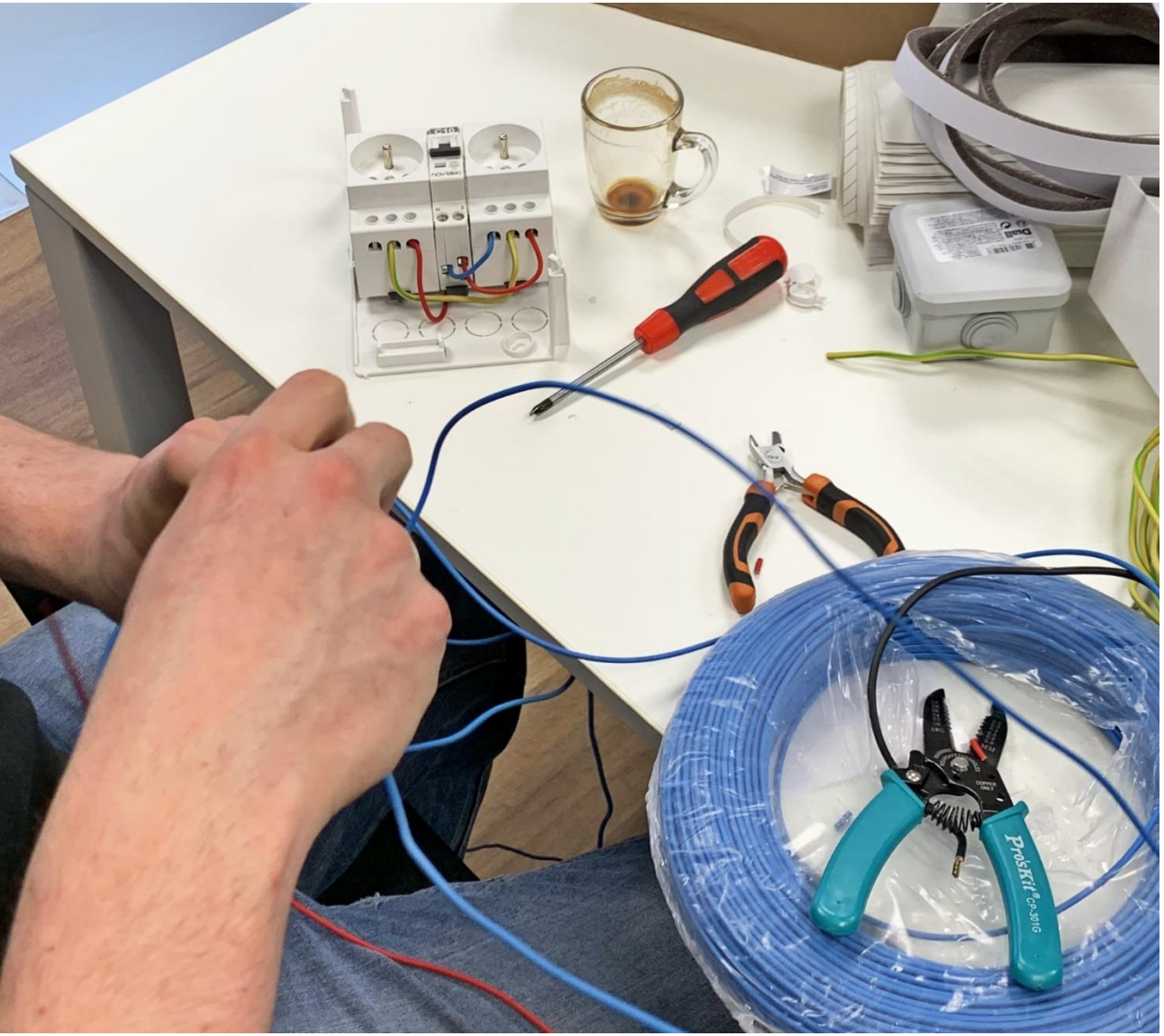


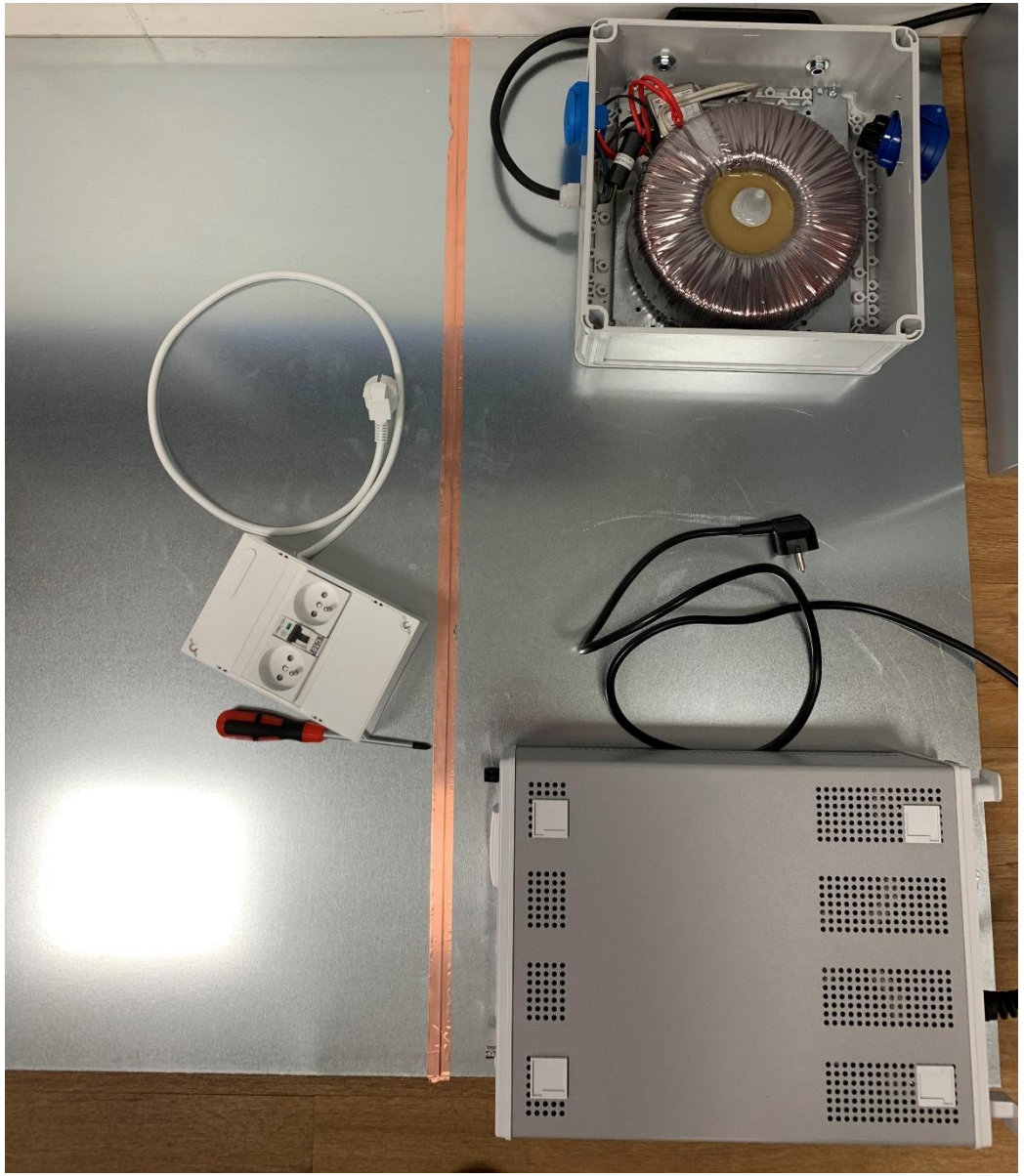
Assembling GRP



Bonding to the GRP

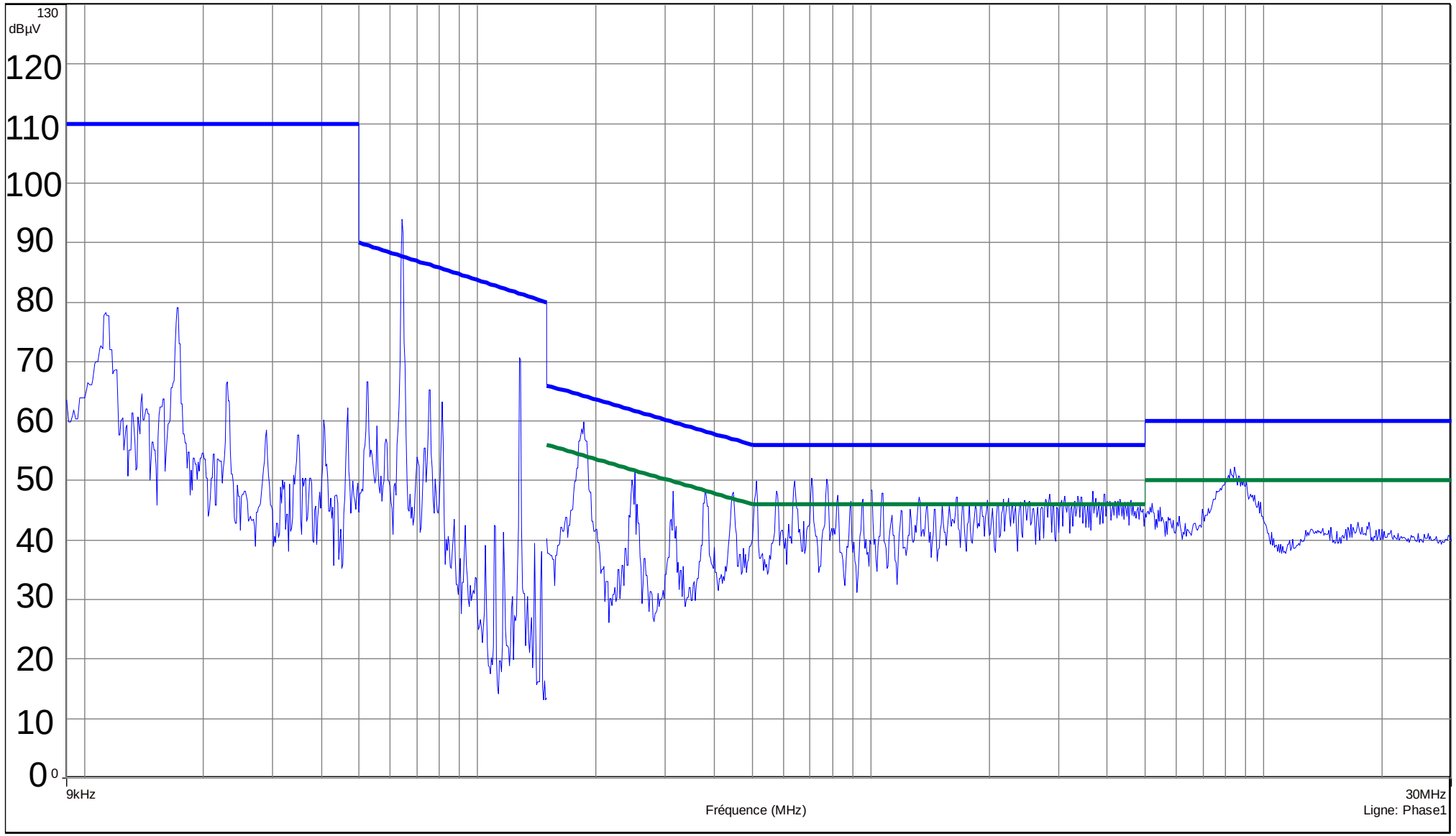
Distribution Box Wiring and Installation



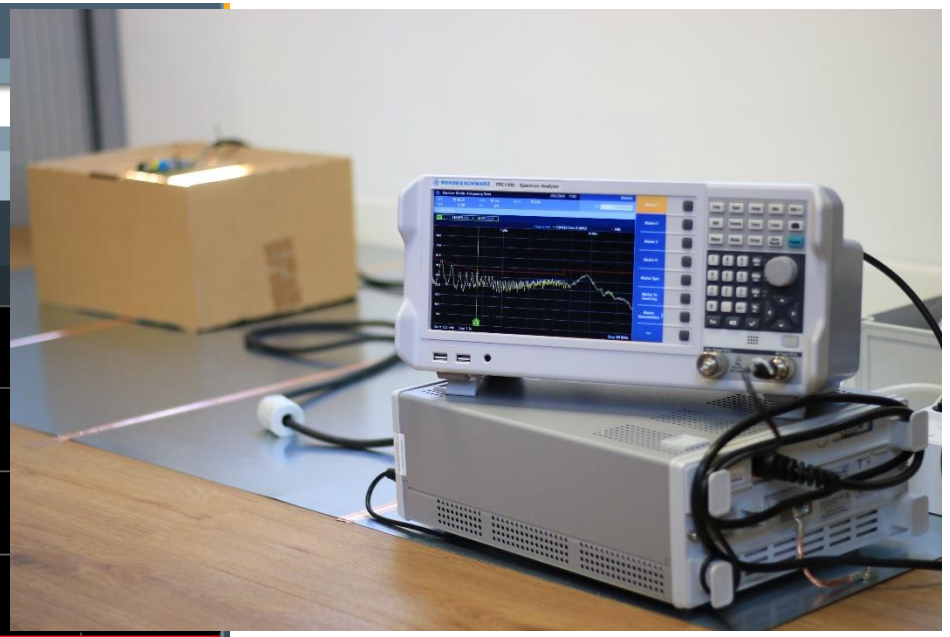


BENCHMARKING

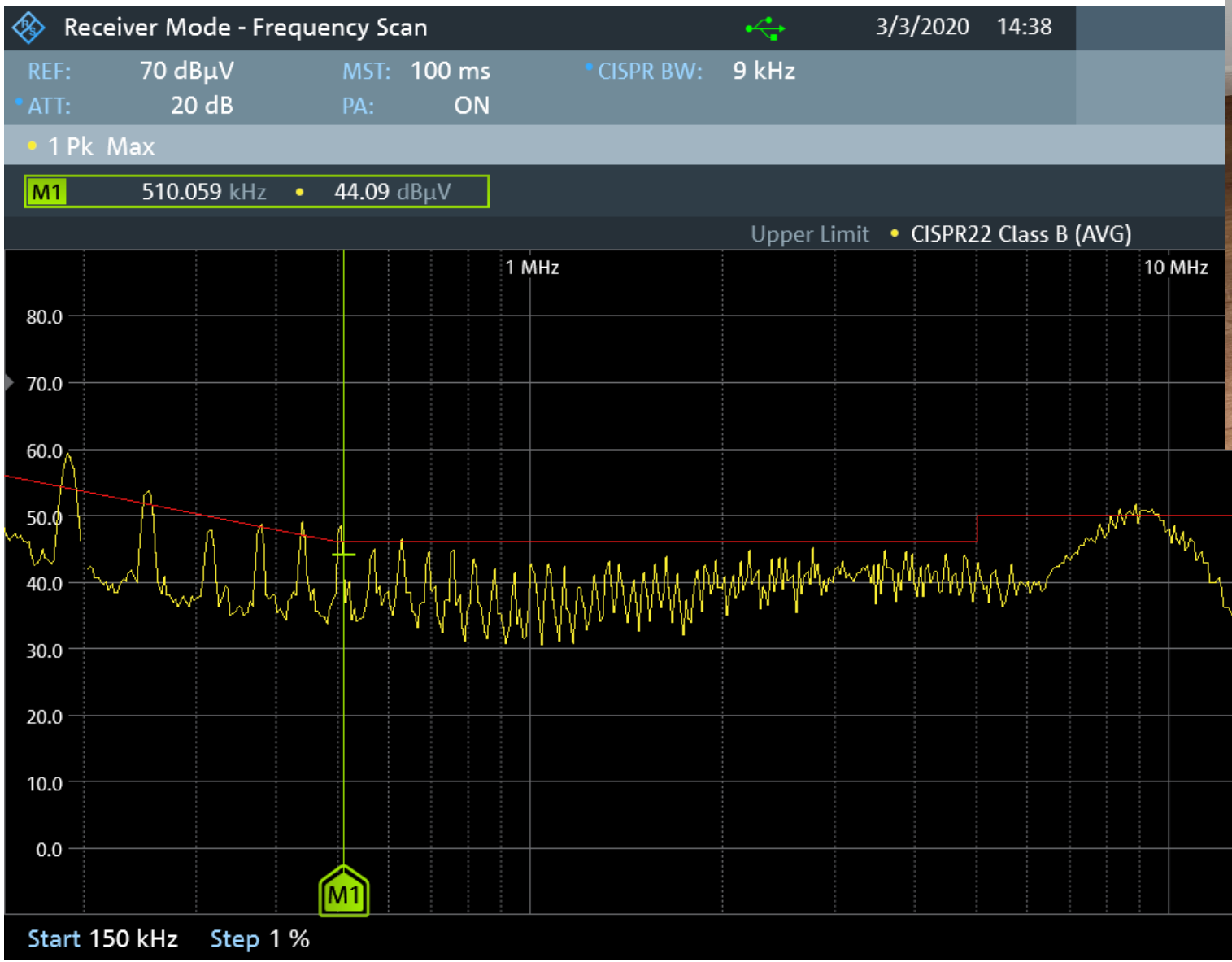
The result in a commercial EMC LAB

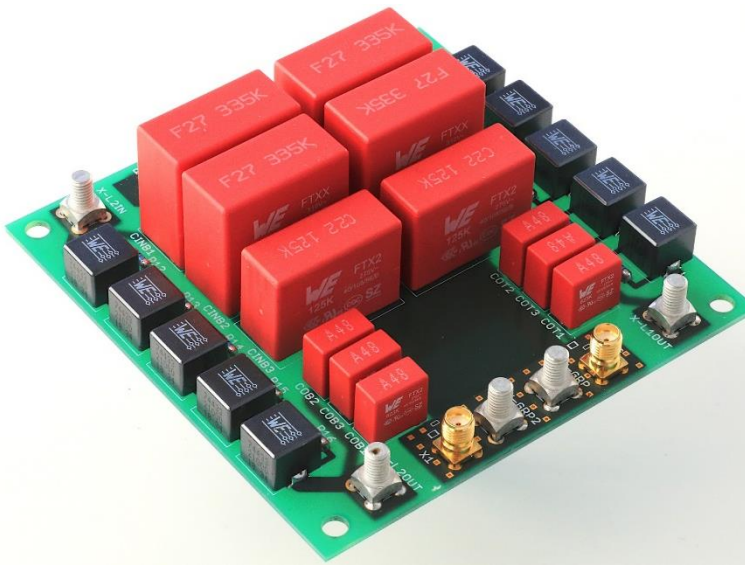


The result in a less than 2000€ Lab

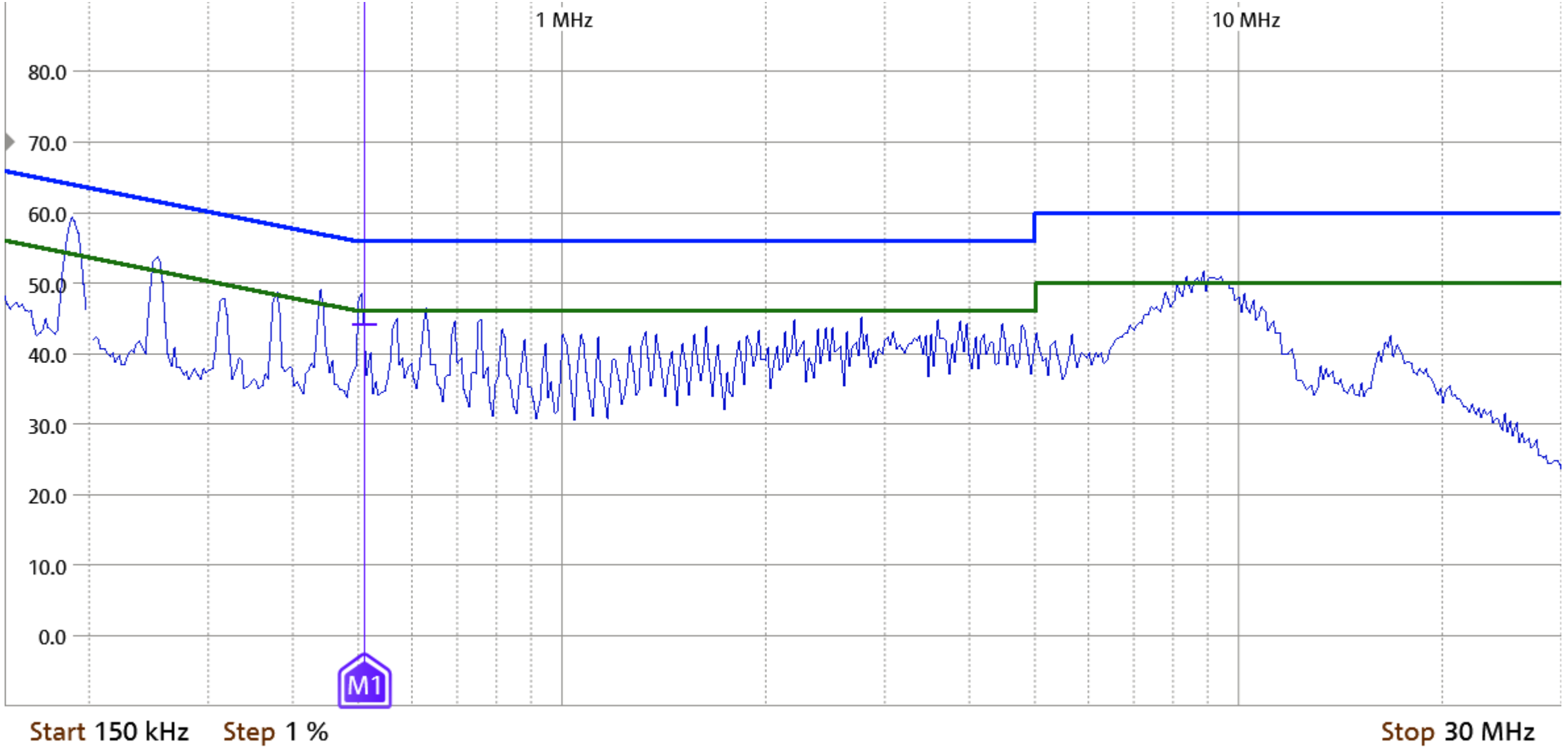


The result in a less than 1000€ Lab

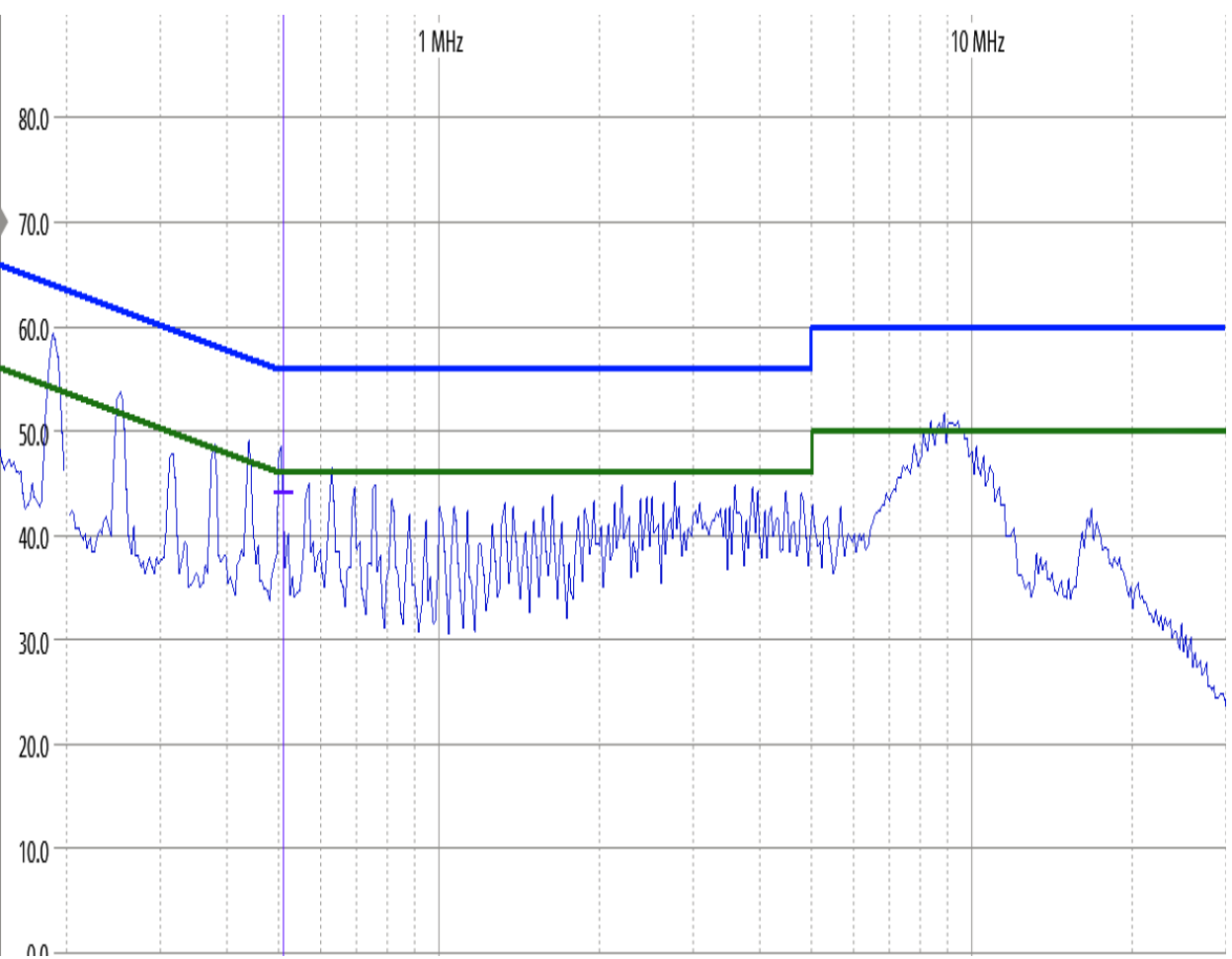


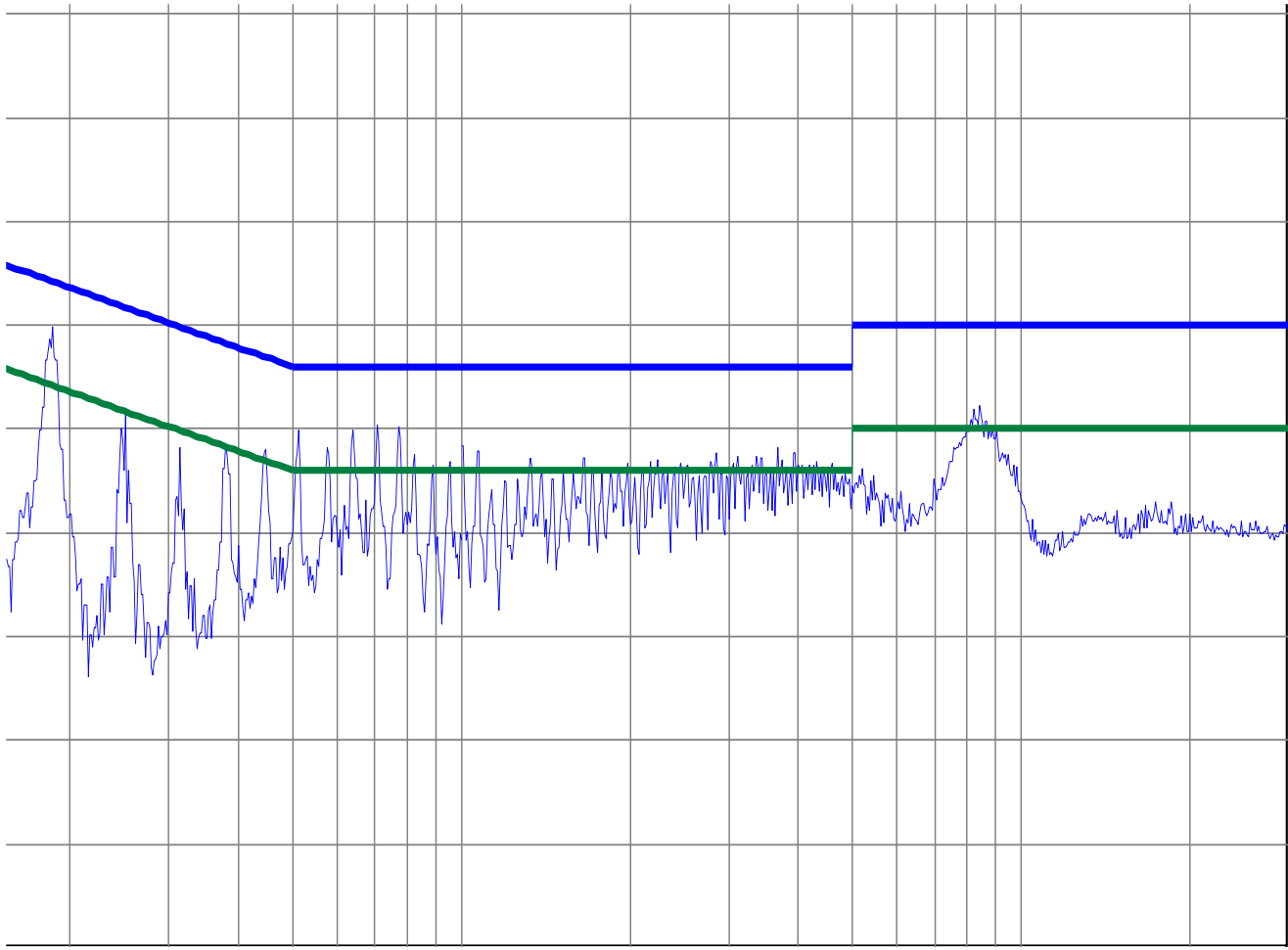


The result in a less than 1000€ Lab (with the right color)



The result



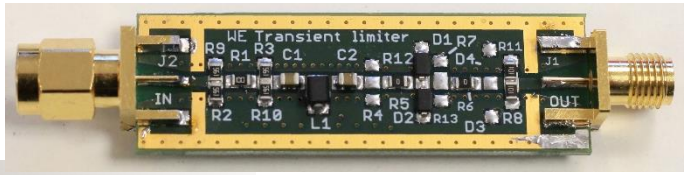


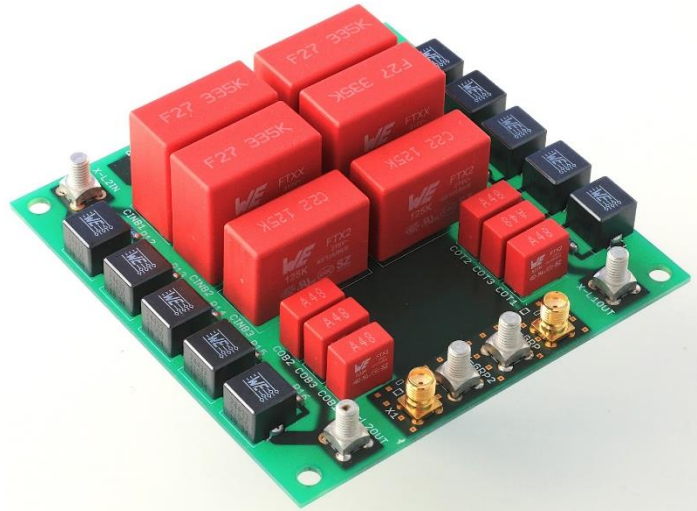
A 1000€ Lab

A commercial Lab

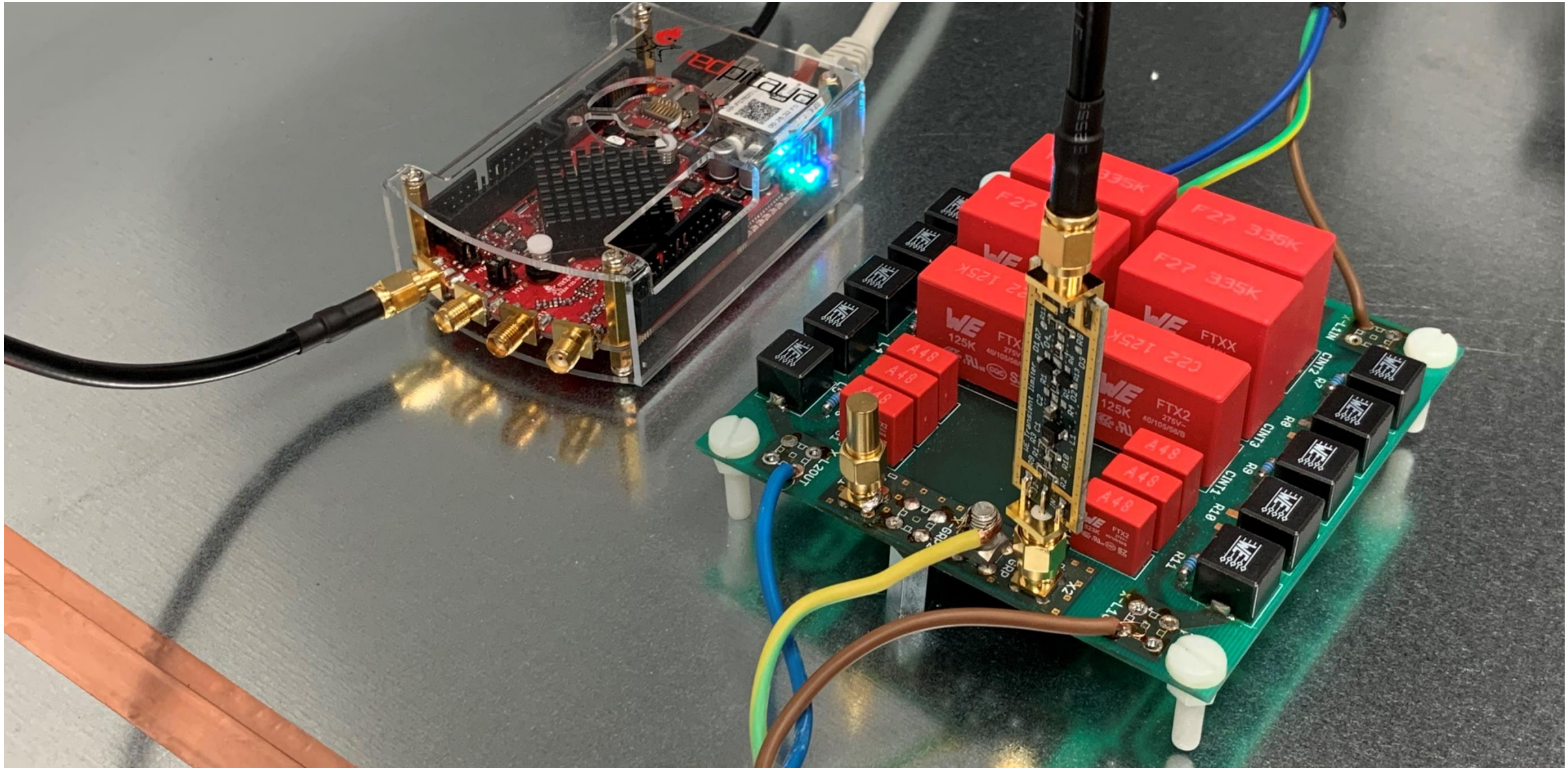
BUILD YOUR EMC LAB FROM (S)CRAP

The Cheapest LAB (< 500 €)

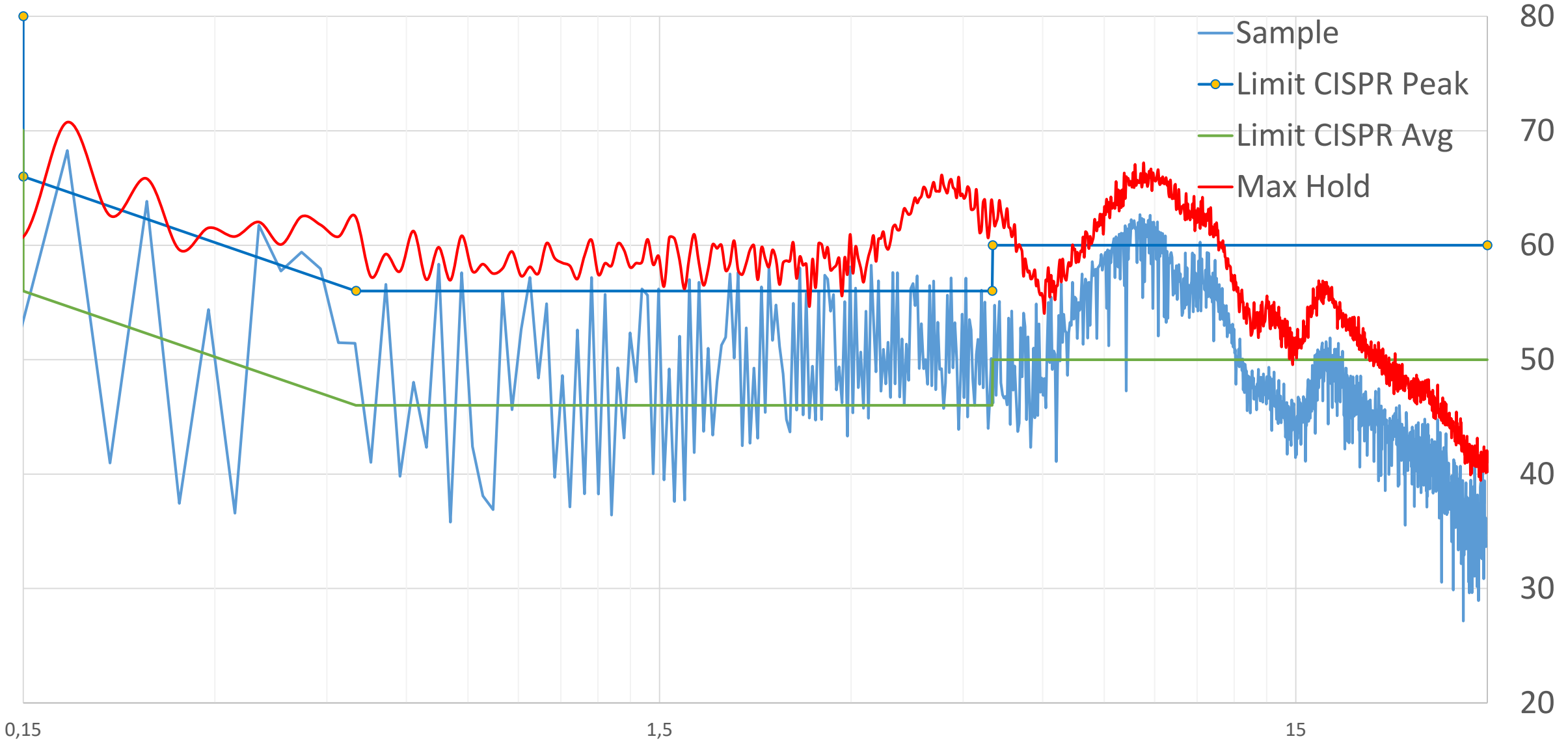




The Cheapest LAB (< 500 €)



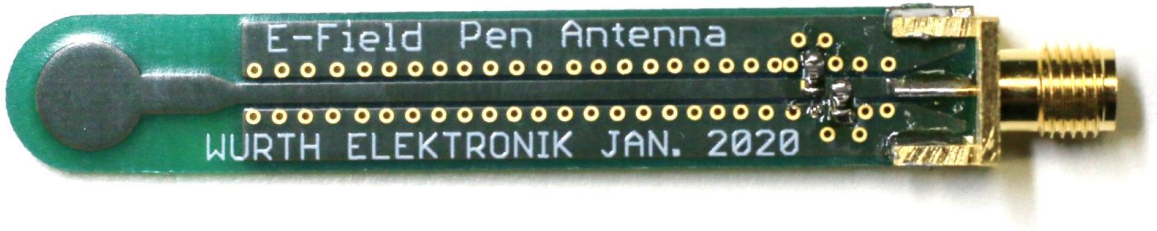
The Cheapest LAB (< 500 €)

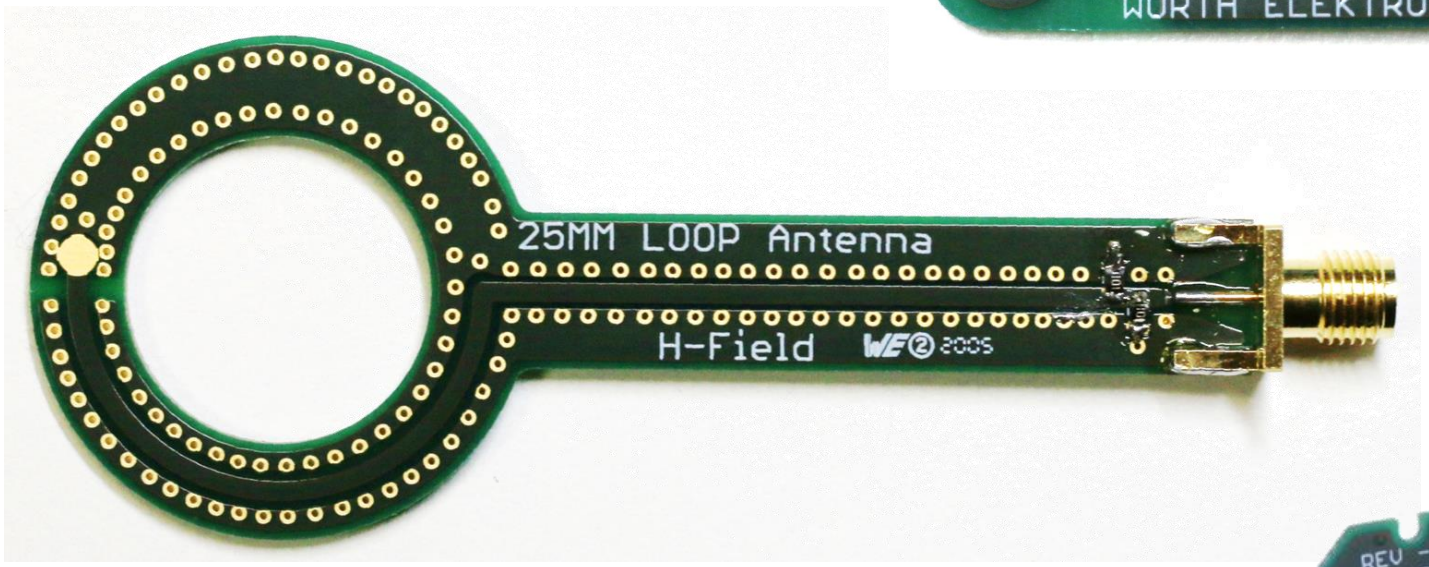


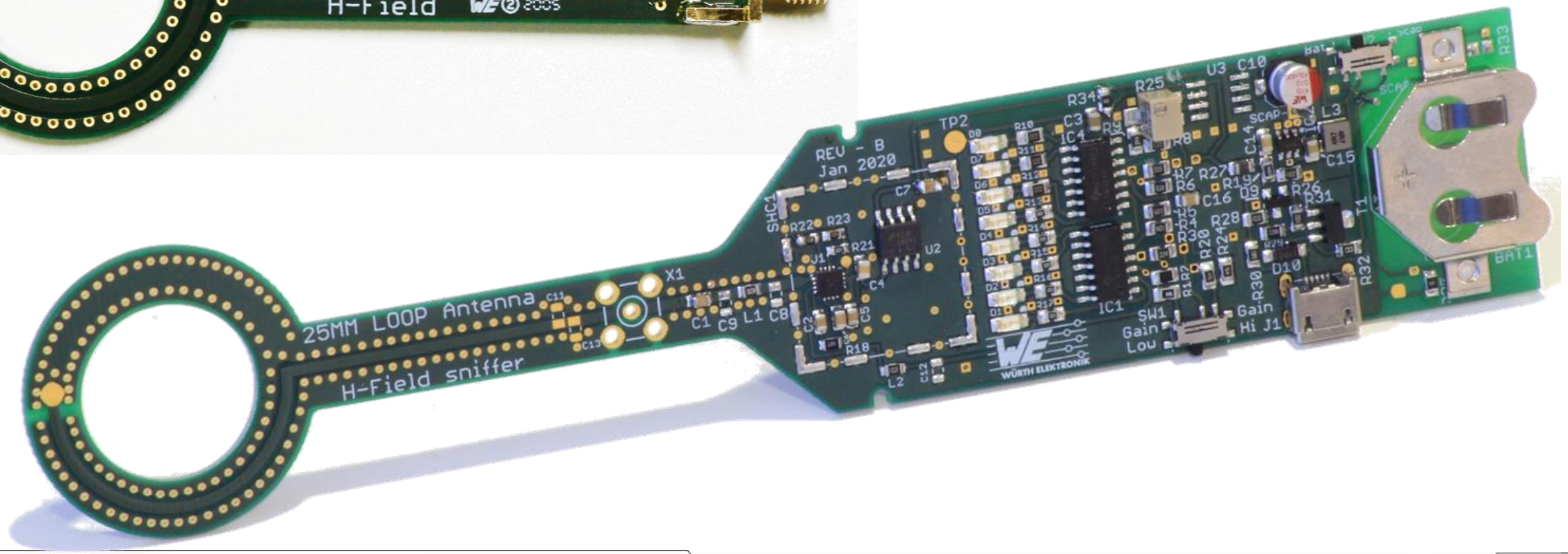
Open Hardware / Open Source / Free Samples

https://github.com/sylvainlebras/EMC-Tools

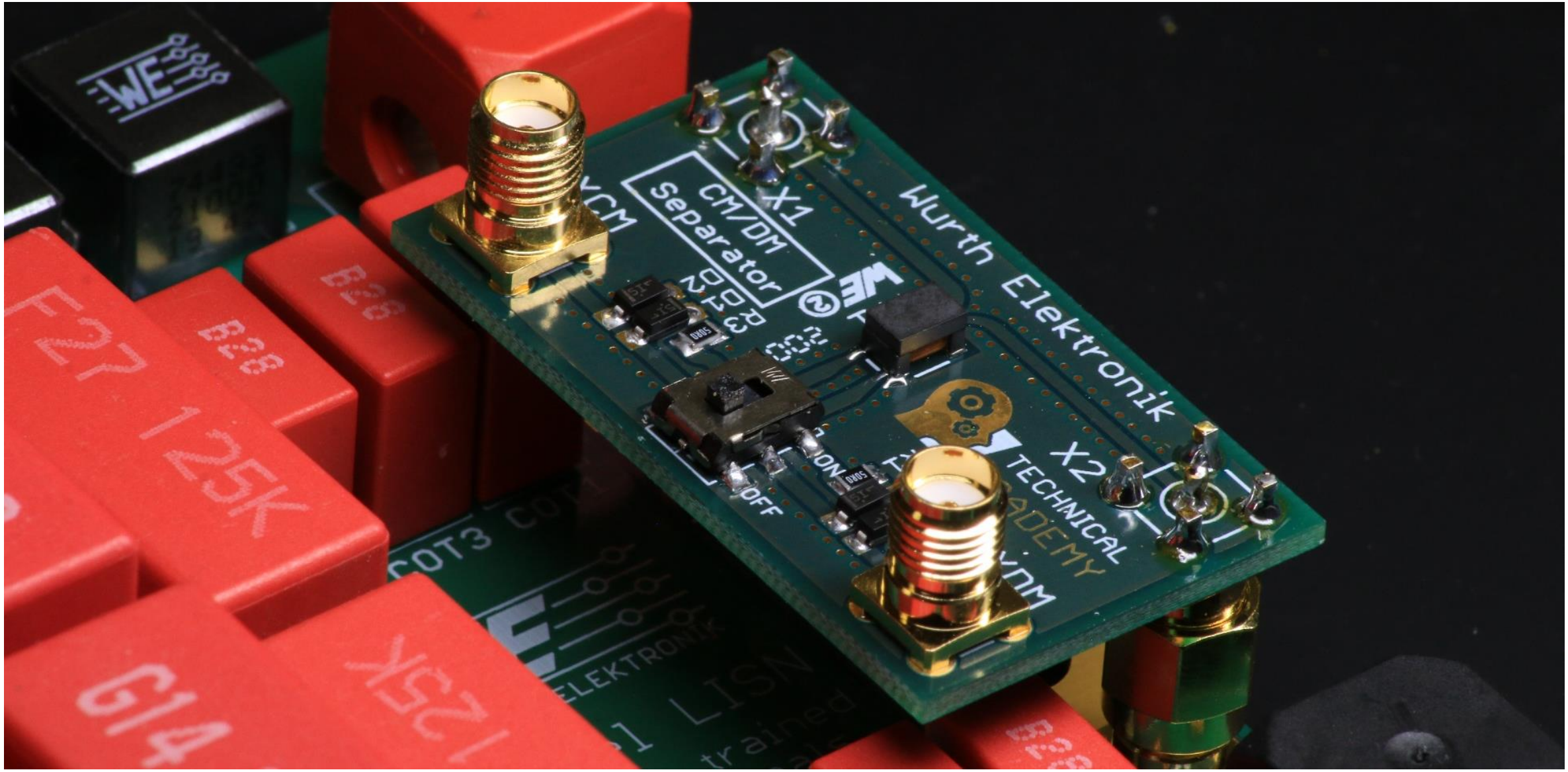
Extra Hardware :







Extra Hardware :



Thank you, any question ?