The secrets of EMI/EMC debugging … with high-end oscilloscopes!

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How state of the art scopes can help in debugging EMI/EMC problems.

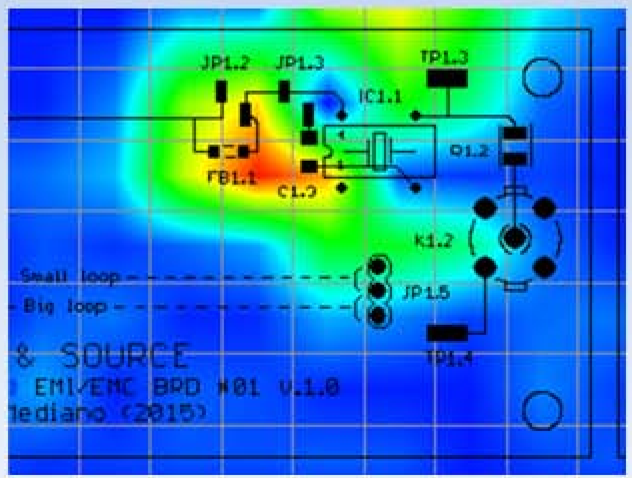
Organized by:

ROHDE & SCHWARZ

Dec 2017

A High Frequency Lab

for **design, diagnostic, troubleshooting and training**



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

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Outline: for this session.

Failing in EMC

Radiated and **conducted emissions/immunity**

Source – **Coupling** mechanism – **Victim**

Voltage-Current vs **Electric-Magnetic** fields.

Time domain vs **frequency domain.**

The **EFFT**. **dV/dt** vs **dI/dt**.

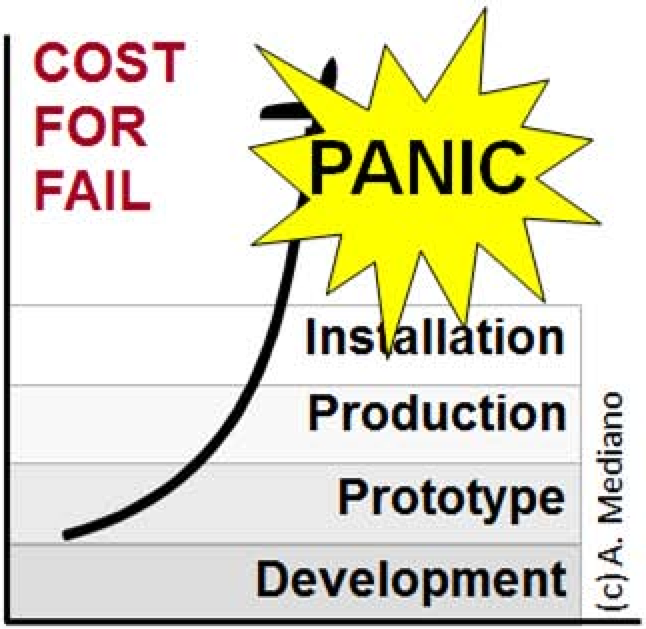
Loops vs **dipoles** and **monopoles**.

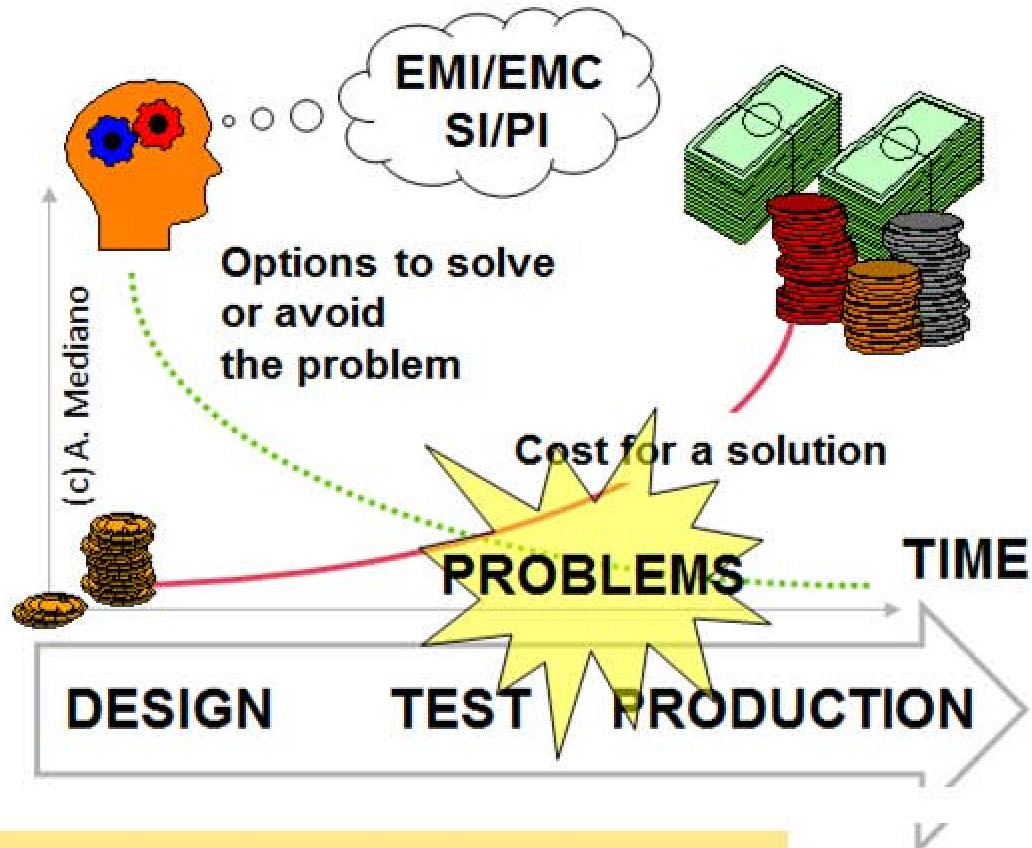
The **strategy** …. TOOLS!

Demos with some circuits

Your **questions**!

It is time for failures: too late?

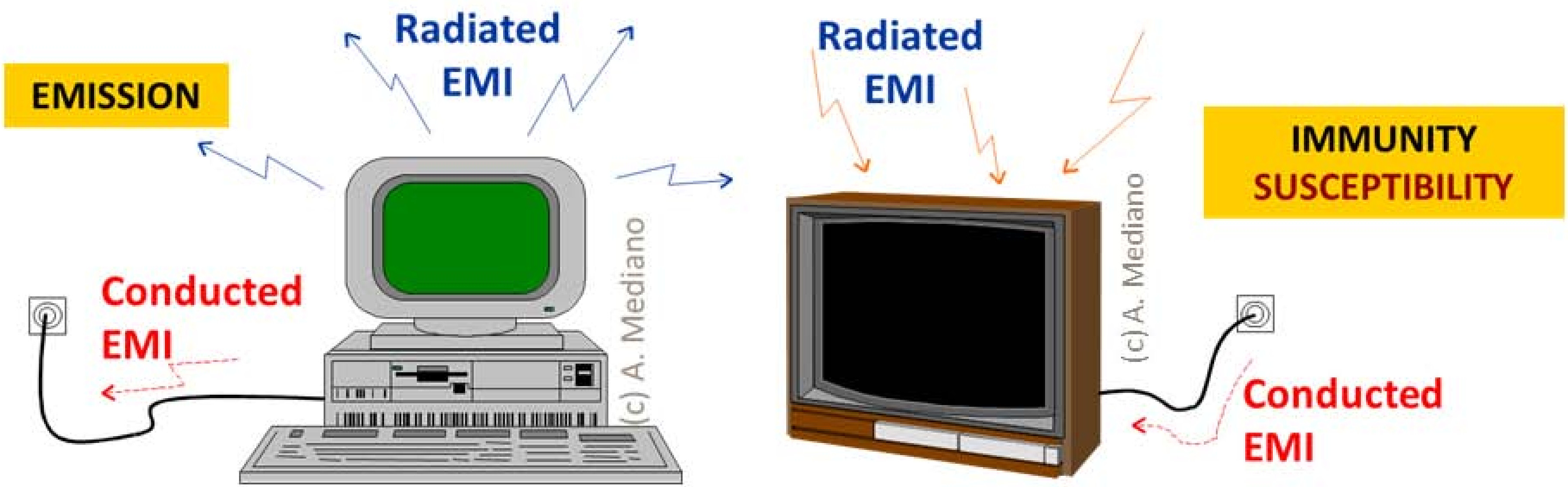




Time · Cost · Size · Stress

Classification: radiated-conducted

Radiated and conducted **emissions/immunity**



EMI/EMC troubleshooting: philosophy

"... a significant part of effective trobleshooting lies en <u>the way that you think</u> about the problem!"; Bob Pease.

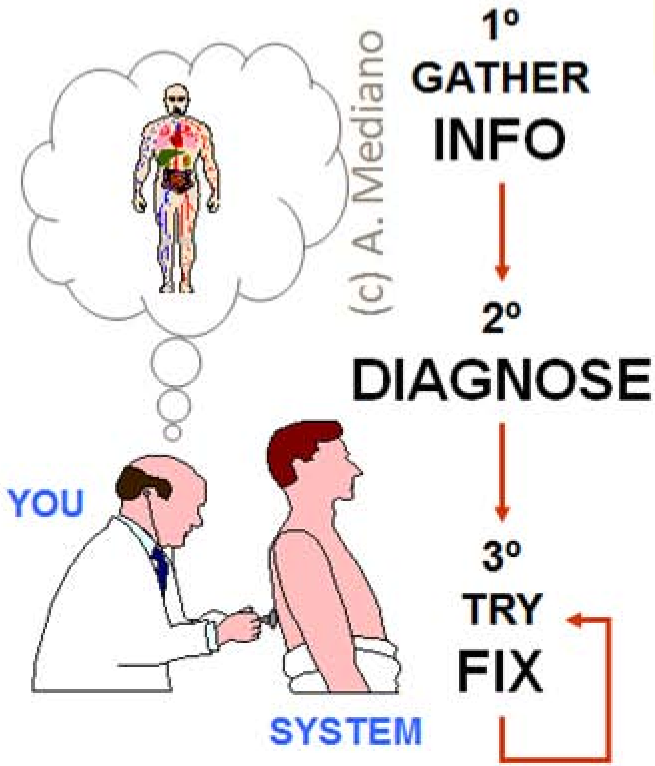
1) EMI is COMPLEX. Not COMPLICATED.
2)EMI = exception to rules.
3)EMI is not comfortable.
4) EMI requires different point of view.

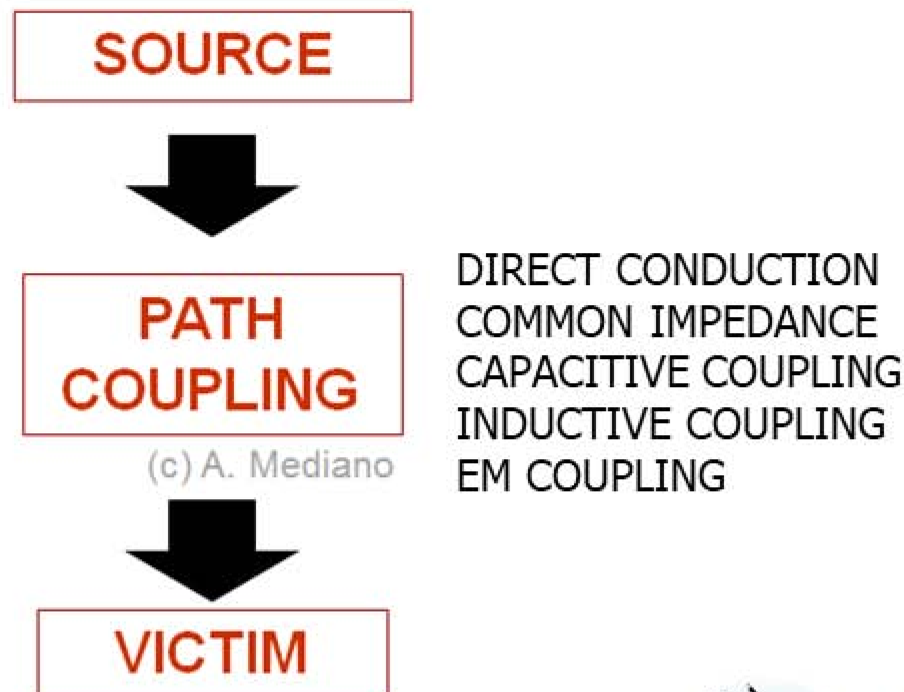
Gerke & Kimmel

Key parameters: S-CM-V

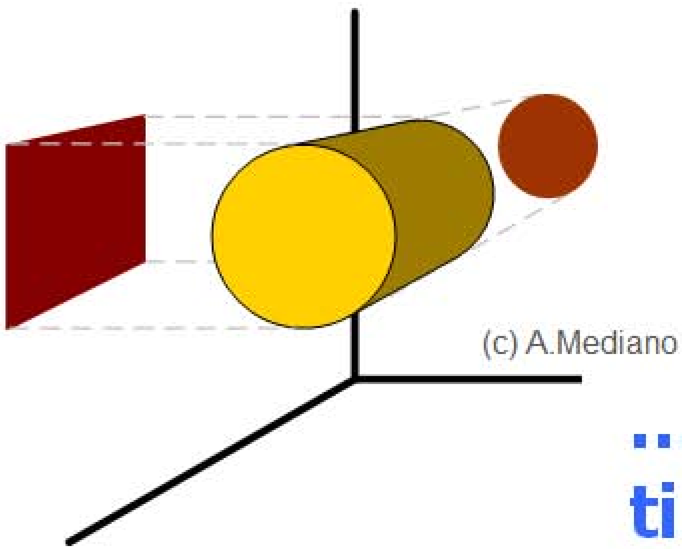
Source – Coupling mechanism – Victim

It is harder to ask the rigth questions than to find answers for the wrong questions

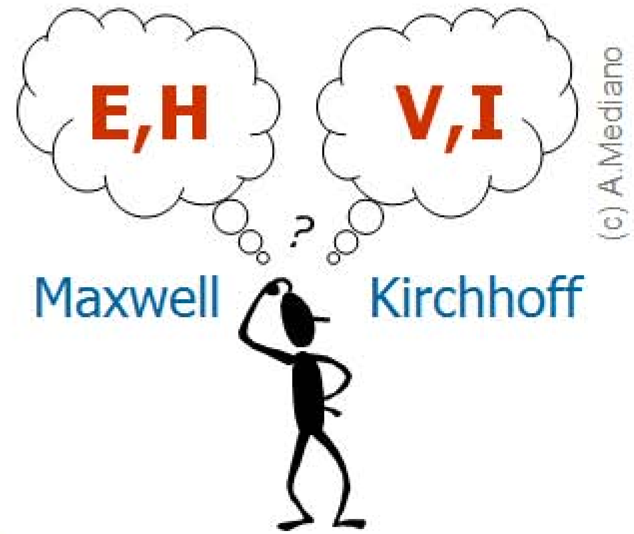




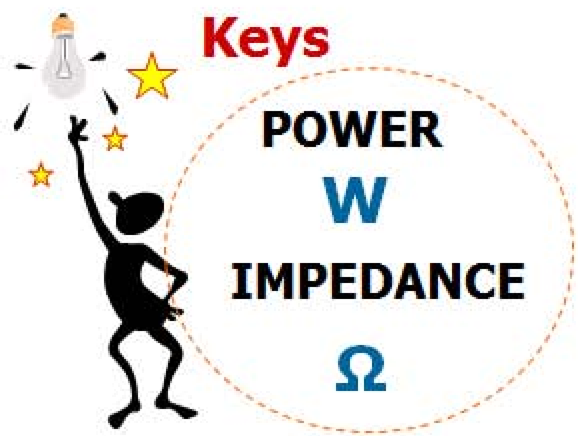
Points of view: try many!



Two points of view ...



... and many times:



Point of view: .. Frequency vs Wavelength

Two related parameters ...

FREQUENCY

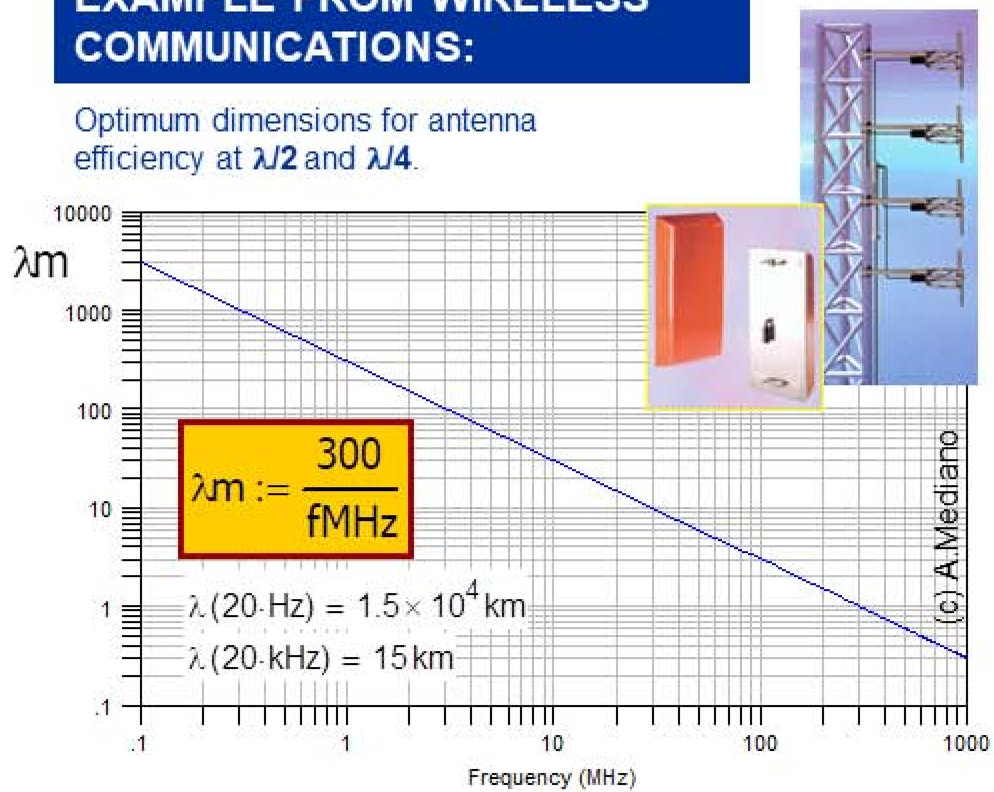
Hz

WAVELEGTH (SIZE)

m

EXAMPLE FROM WIRELESS COMMUNICATIONS:

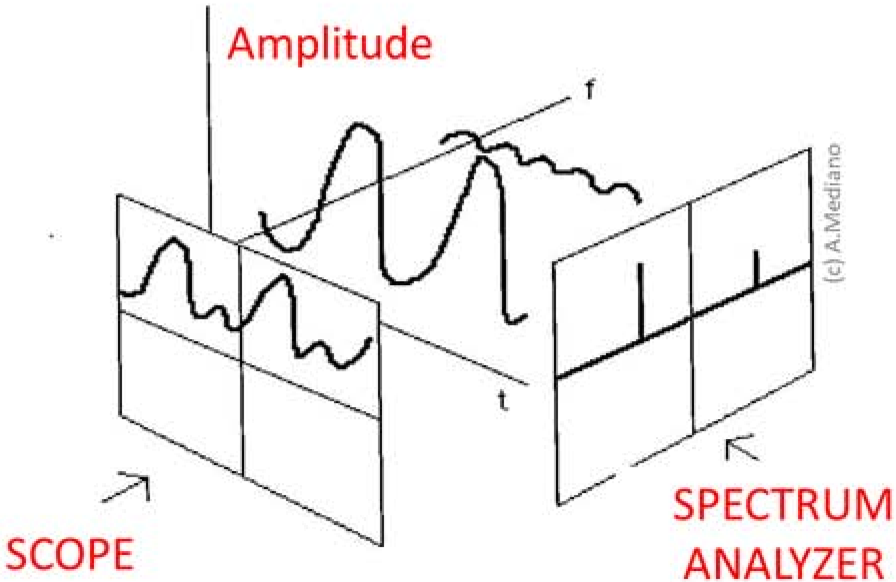
Optimum dimensions for antenna efficiency at **λ/2** and **λ/4**.



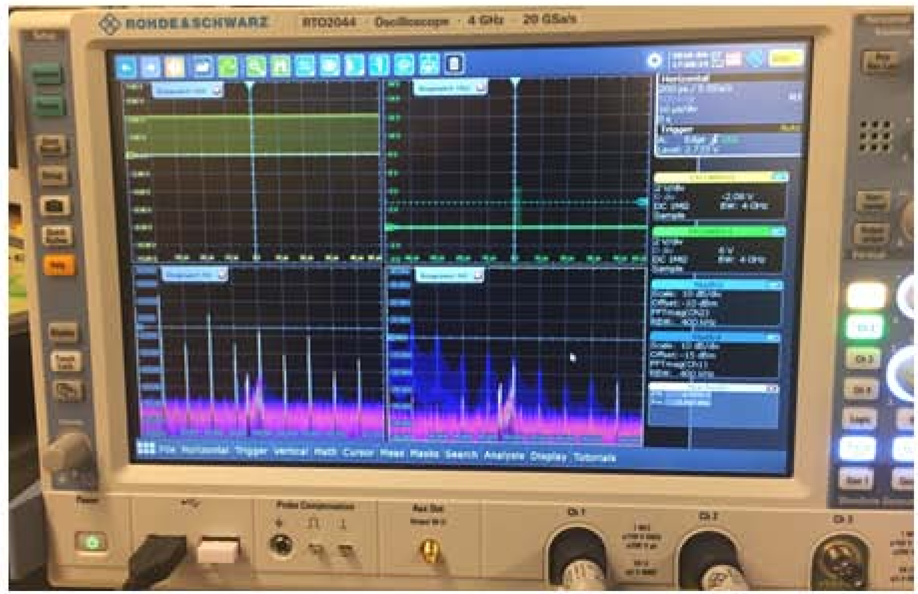
BIG or SMALL?

Two sides: time-frequency

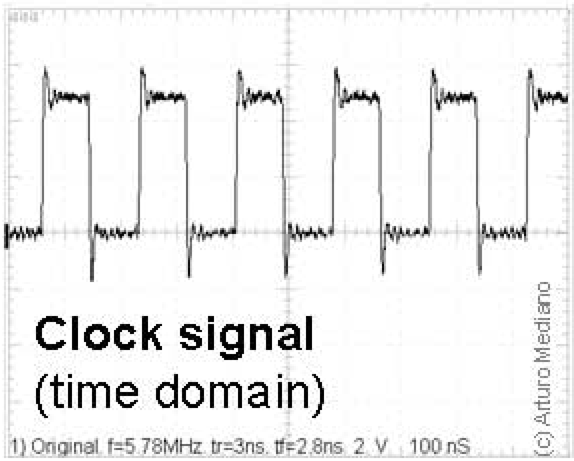
Time domain vs frequency domain.

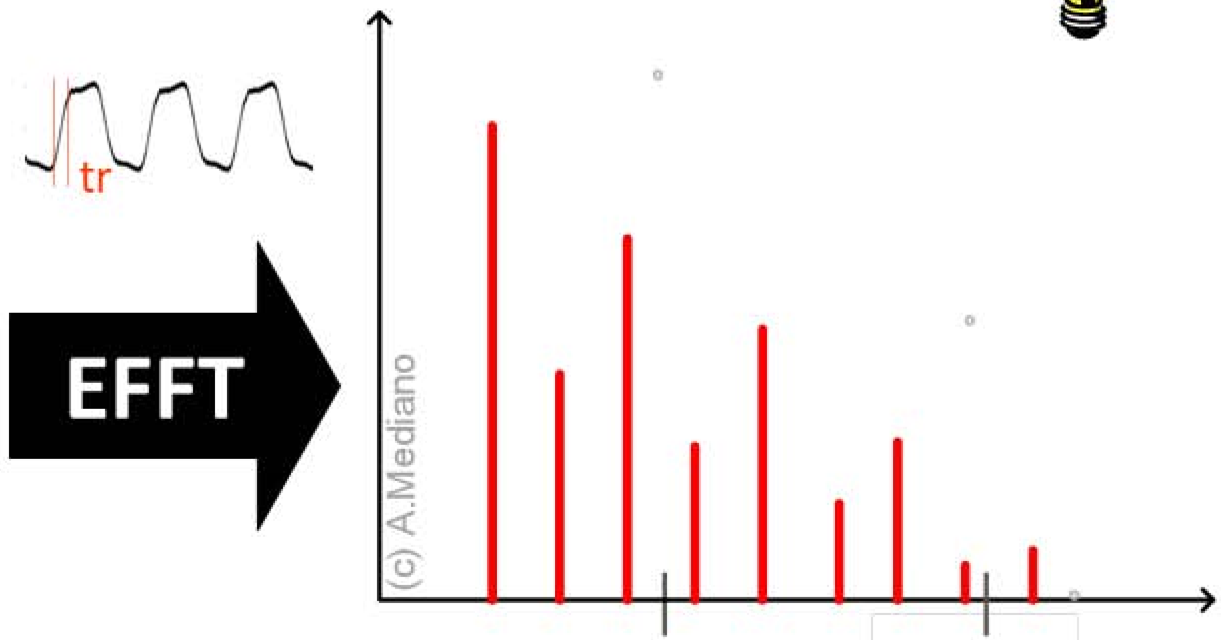


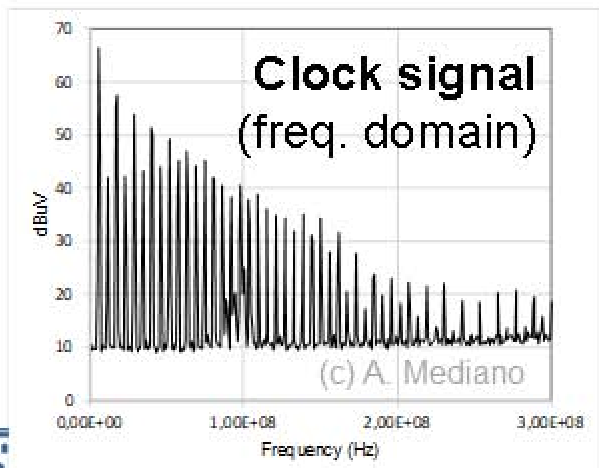
Your "eyes":



Spectrum: the EFFT







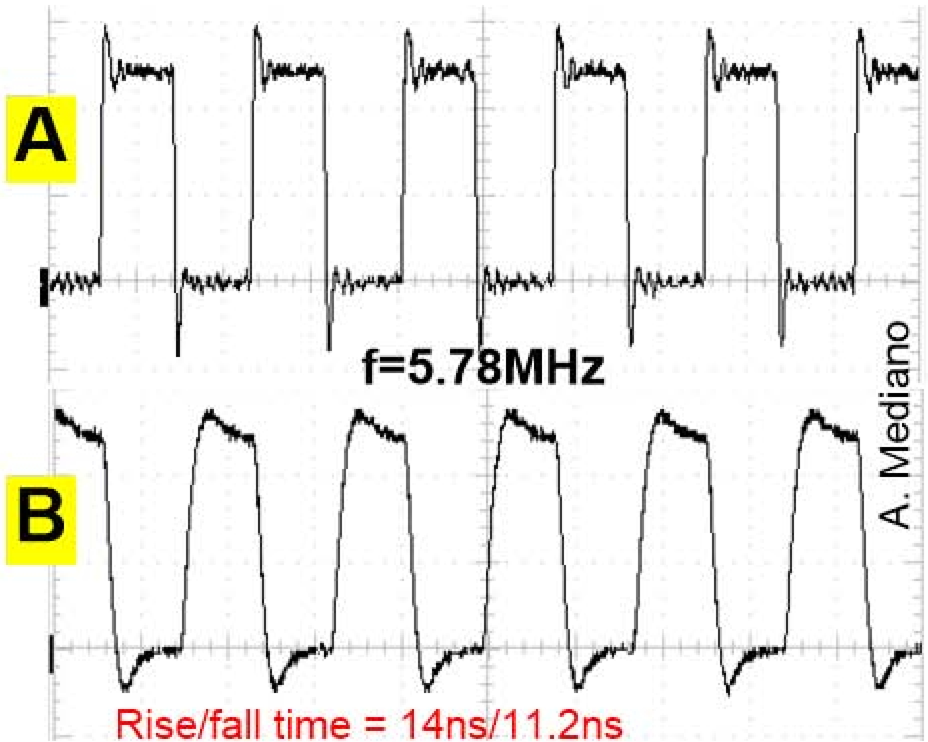
Example:

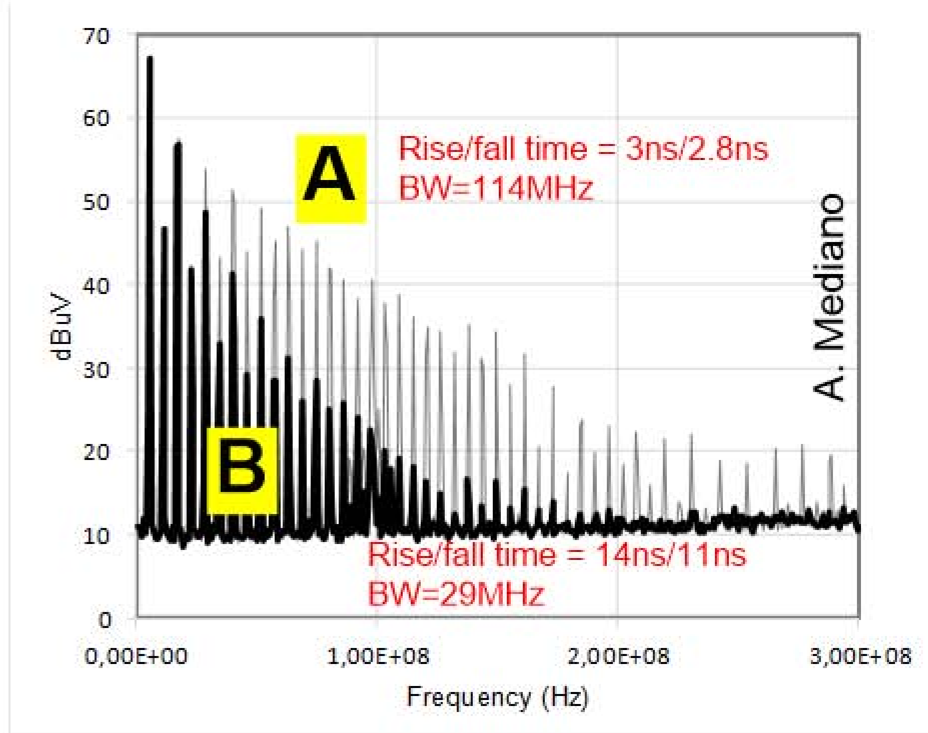
1ns → 300MHz

Same thing for non periodic signals (e.g. ESD).

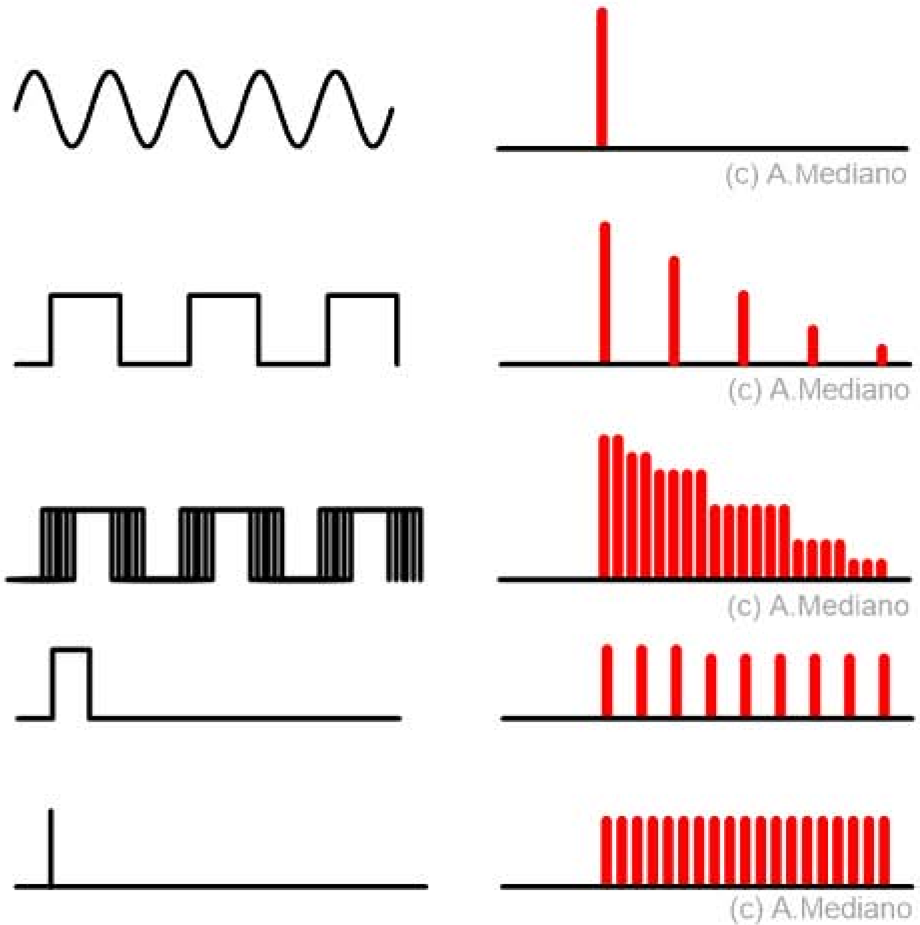
$\frac{dv}{dt}\uparrow\uparrow \quad \frac{di}{dt}\uparrow\uparrow$ **= DANGER!!!**

Spectrum: EFFT example in digital data





Signals: "Broadband" vs "Narrowband"



CW narrowband
E.g.: oscillators and RF

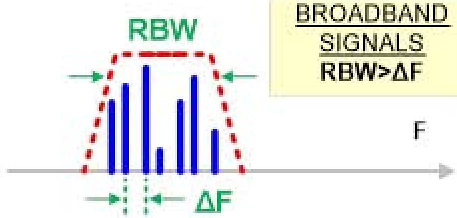
Continous narrowband
E.g. digital or power

Continous broadband
E.g.: power electronics

Discontinous broadband
E.g.: power electronics

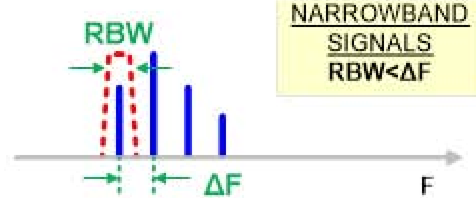
Discontinous broadband
E.g.: ESD and sparks. ON/OFF situations

Signals: "Broadband" vs "Narrowband"



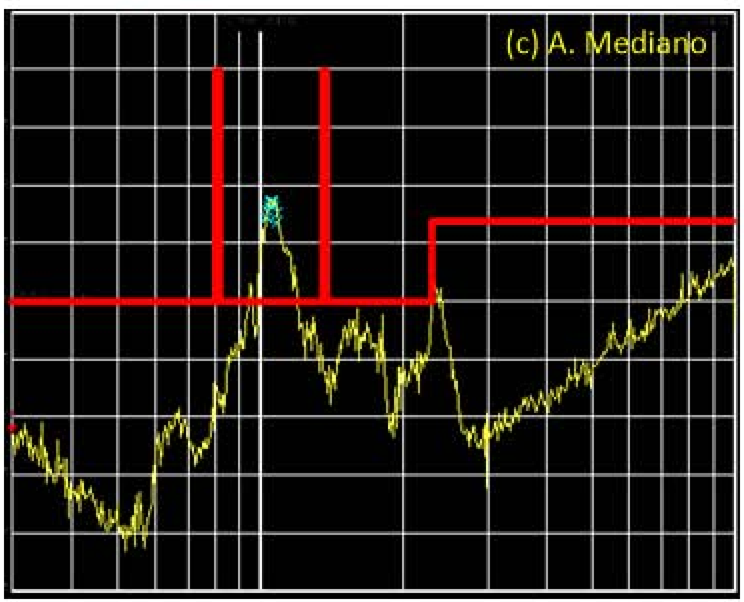
BROADBAND SIGNALS
RBW>ΔF

- MOTORs
- SPARKs
- SMPS
- SPREAD SPECTRUM POWER
- ETC.

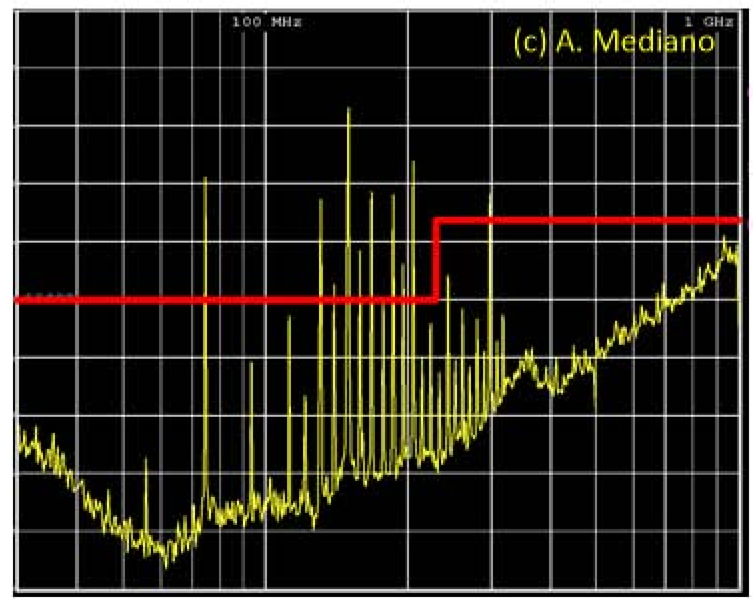


NARROWBAND SIGNALS
RBW<ΔF

- CLOCKS
- DC/DC converters
- POWER inverters
- OSCILLATORS
- ETC



30MHz 1GHz

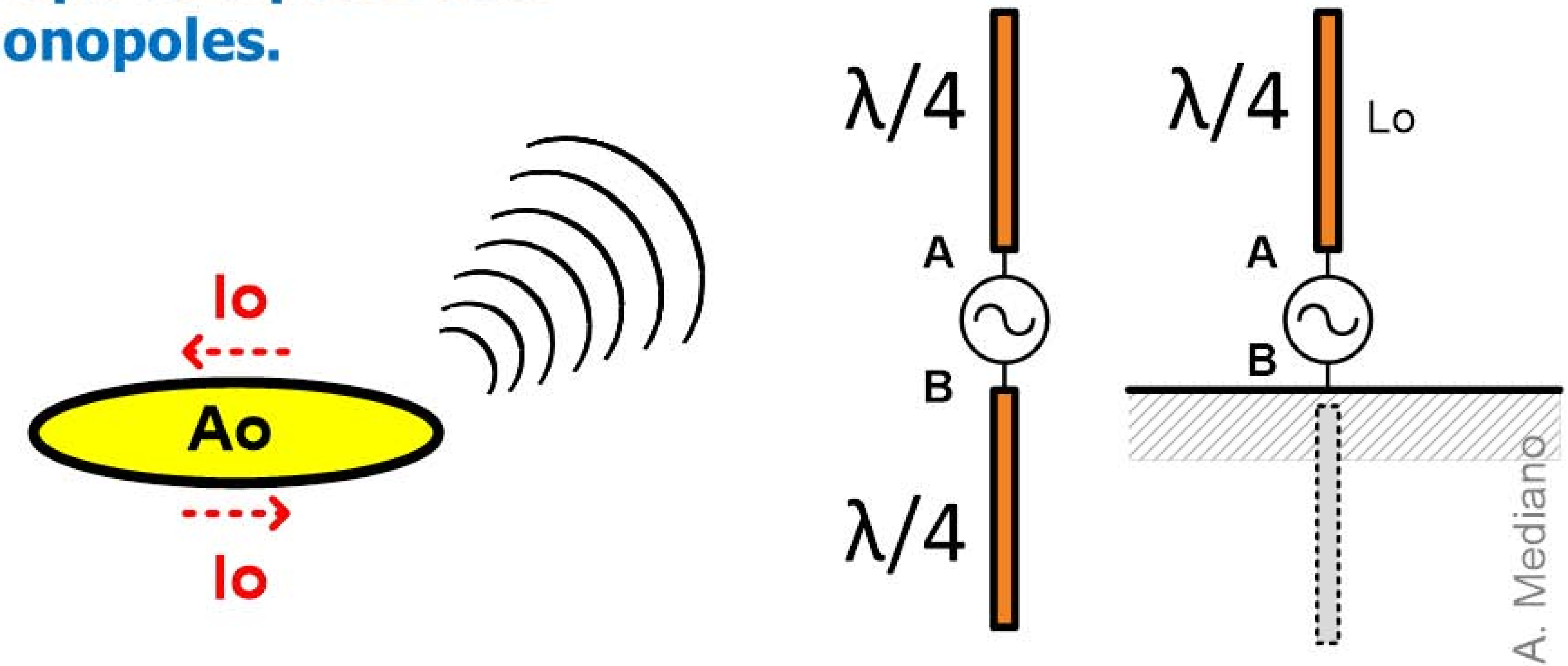


30MHz 1GHz

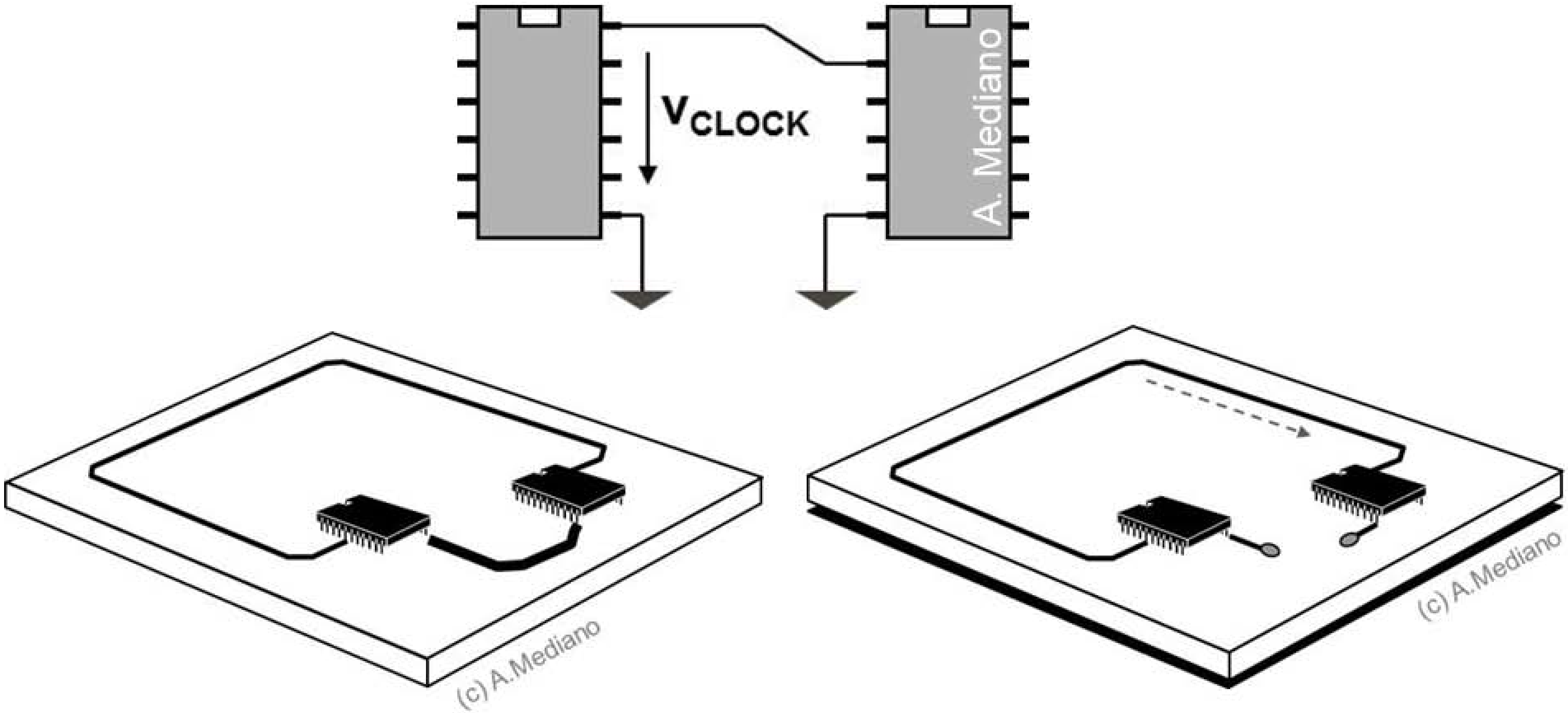
IMPORTANT NOTE: RBW↓ = NOISE↑ & MEASURED VALUE = f(RBW)

Troubleshooting: intro

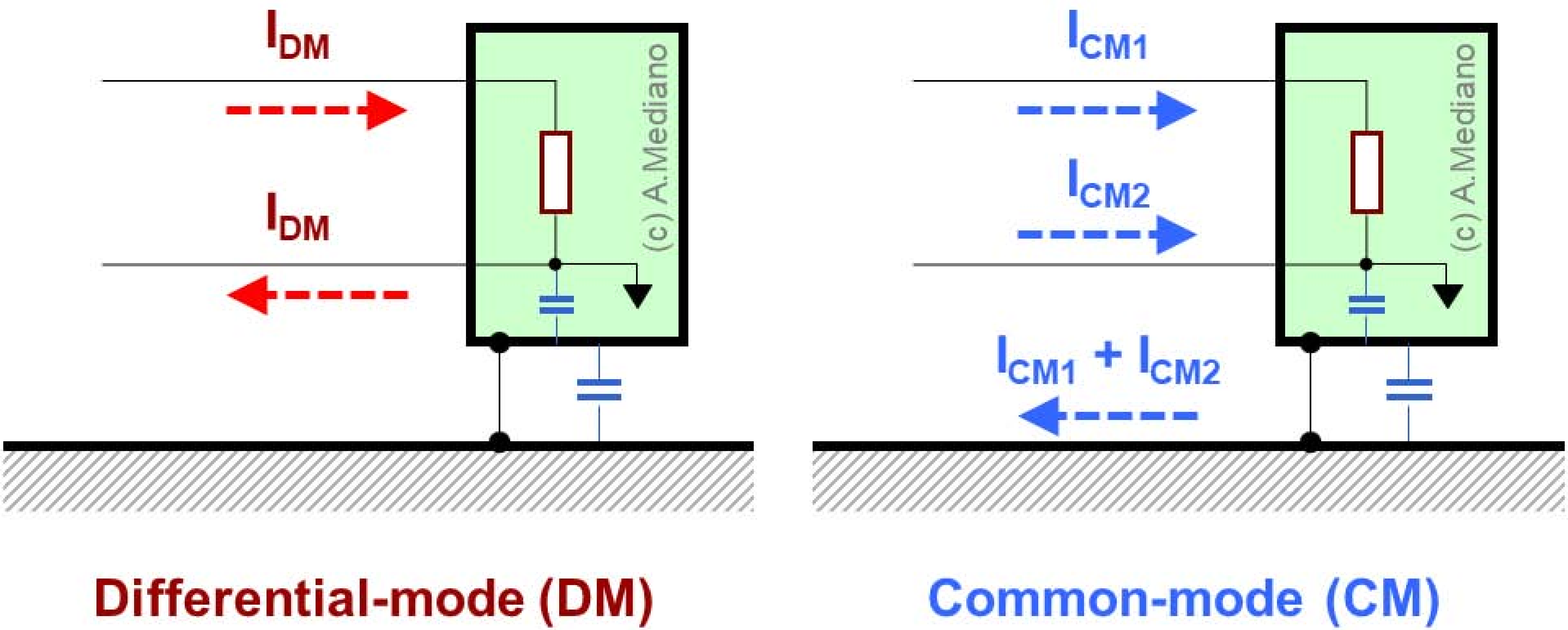
Loops vs dipoles and monopoles.



Key factor: current path.



Current modes: DM vs CM



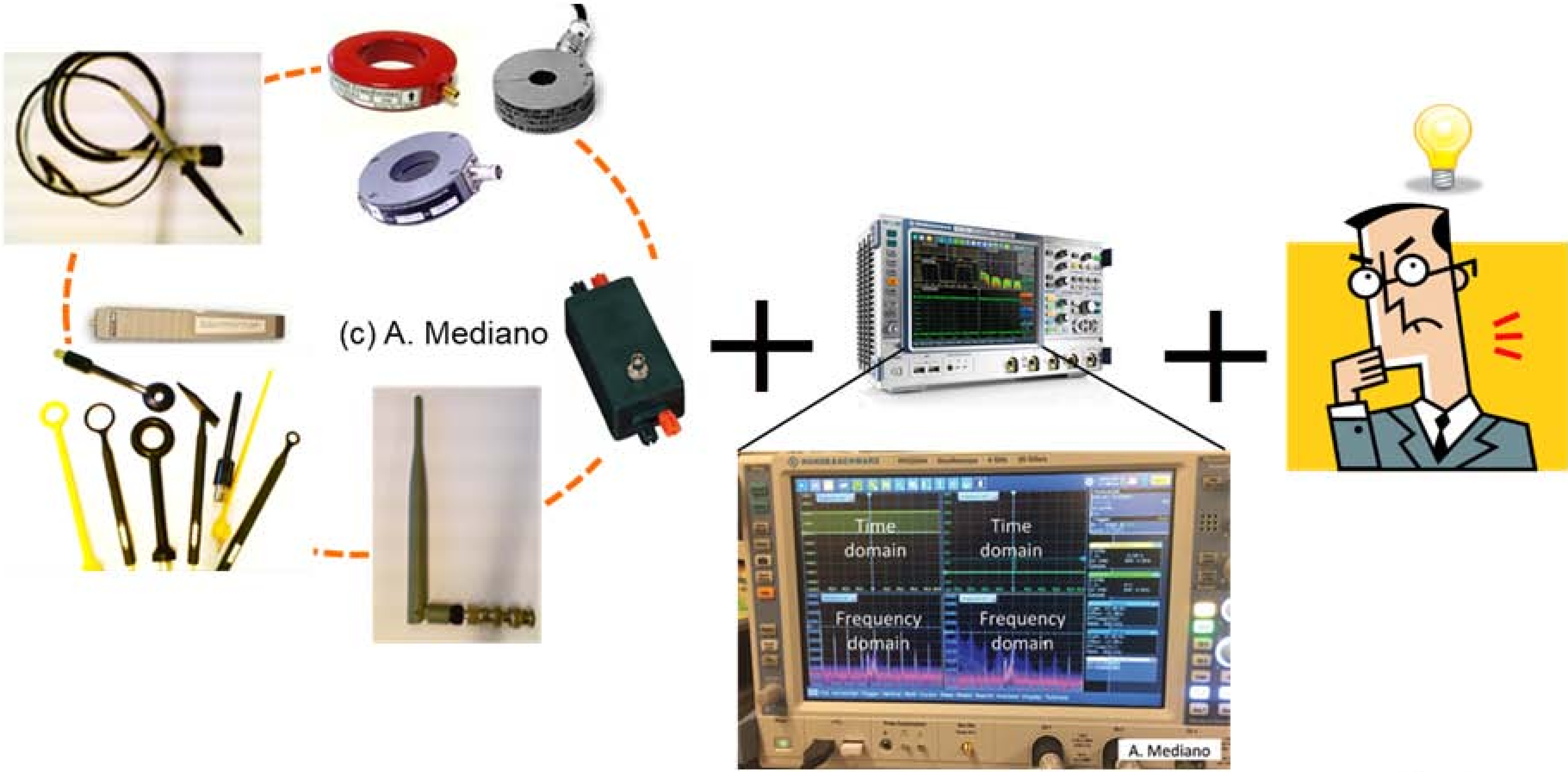
Testing: strategy

Typical scenery …

+

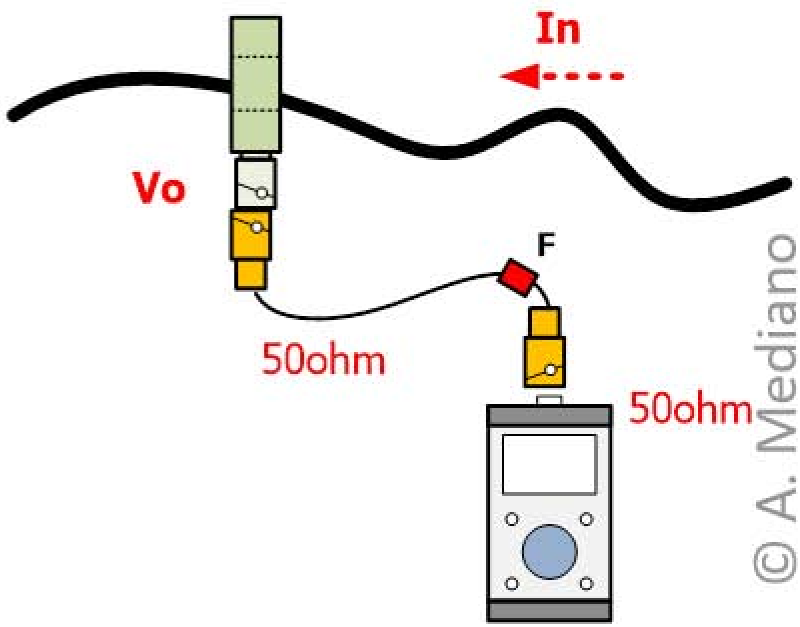
+

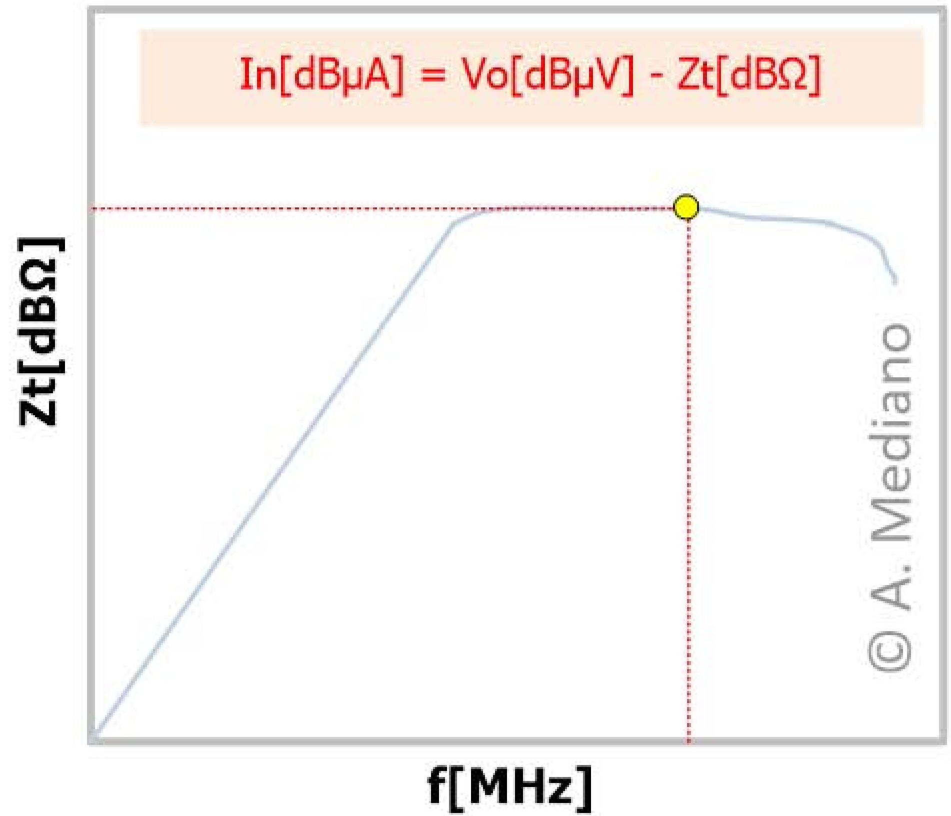
Testing: strategy



Troubleshooting: intro

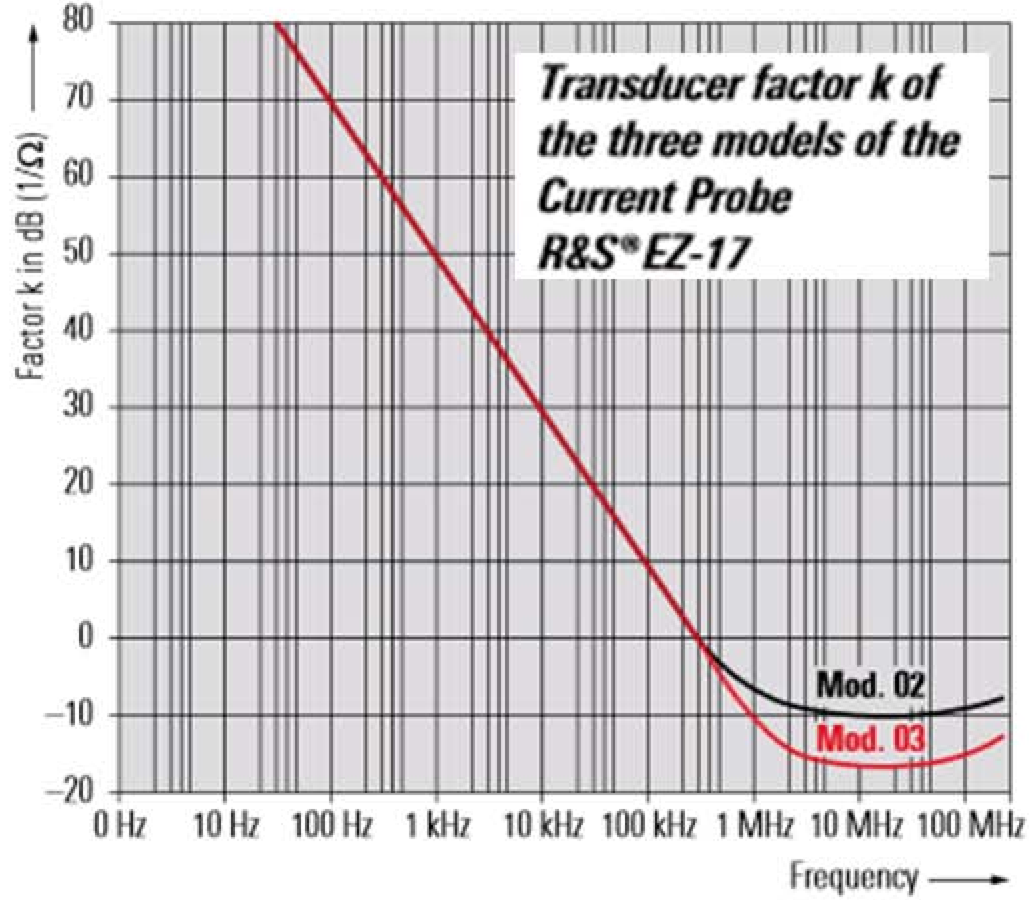
Current probes



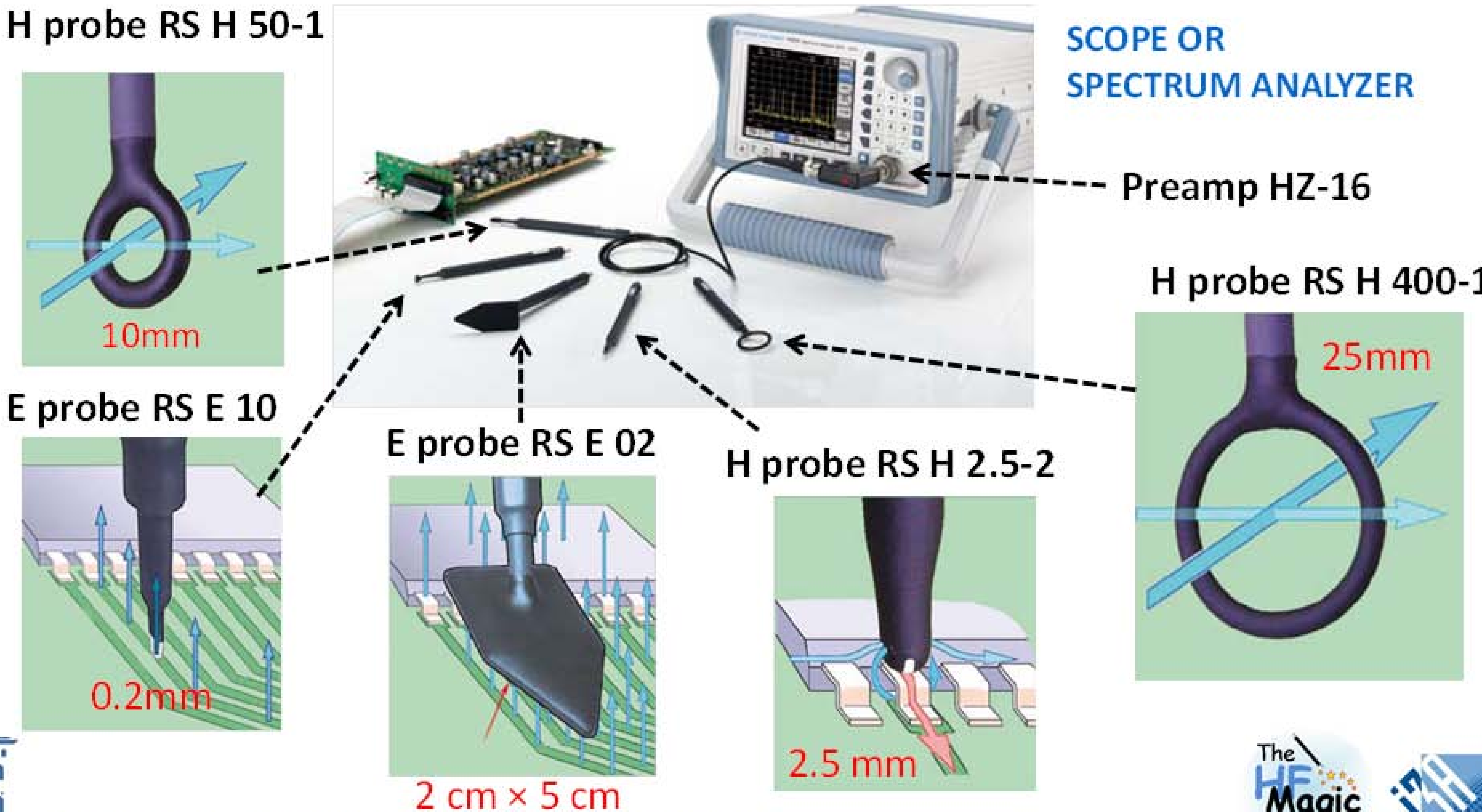


Testing: R&S EZ-17

R&S **EZ – 17**
Current Probe
50Hz - 200MHz



Testing: R&S HZ-15 Near field probes



Scopes and EMI debugging: state of the art

CRITICAL FOR EMI DEBUGGING:

High sample rates + fast waveform update rates + stable triggers + deep memory

STATE OF THE ART SCOPES CAN HELP WITH THIS:

Example:

RTO/RTE scopes by

ROHDE&SCHWARZ

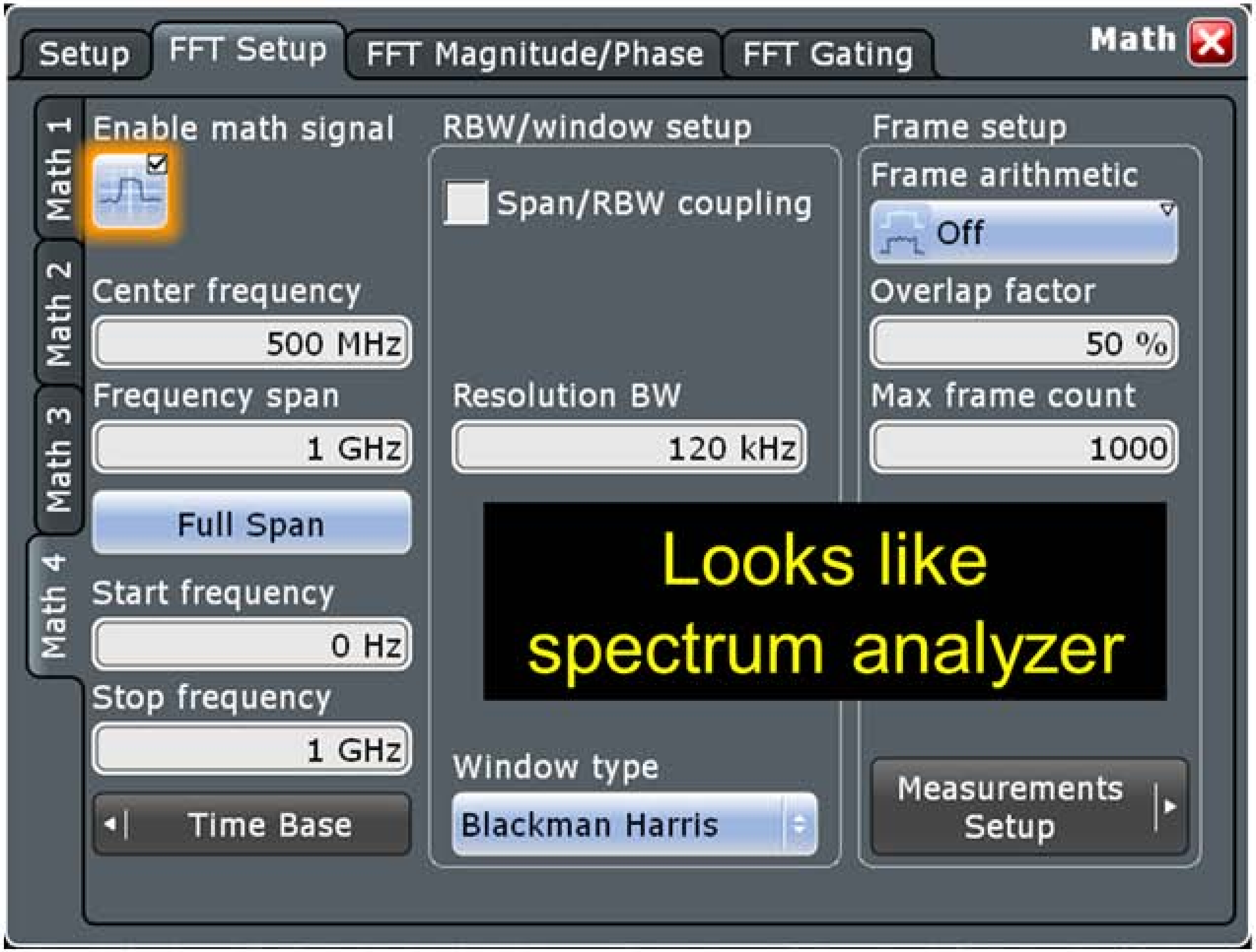
Scopes and EMI debugging: state of the art

- **Time domain** and **frequency domain**
  … in one instrument (synchronized!!).
- **Big record length**
  … ensuring that you capture enough information.
- **Sample rate >2 x f_{MAX}**
  … e.g. 2.5 GS/s in DC to 1GHz
  … RTO 10Gs/sec = 1E6 waveforms/second!!!!!
- **Inputs**: **"High" impedance and 50Ω.**
  … critical for some probes (i.e. NFP) and BW
- **Vertical scale**: **good sensitivity**
  … (i.e. dynamic range) 1 - 5mV/DIV

Scopes and EMI debugging: state of the art

- **Powerful frequency analysis**:
  - … Advanced FFT ≠ Traditional FFT
  - … Spectrum analyzer "style":
    - CENTER FREQ, SPAN and RBW.
    - FFT analysis not time domain setup configuration dependence.
  - … FFT with ZOOM.
  - … FFT with GATING technique:
    - Easy to identify spurious EMI in time domain.
- **Display**:
  - … color table
  - … persistence mode to detect CW signals vs burst
- **Masks** with configurable actions !!!!

Scopes: FFT analysis



<u>Conventional FFT</u>: **displayed SPAN and RBW controlled by TIME DOMAIN settings**.

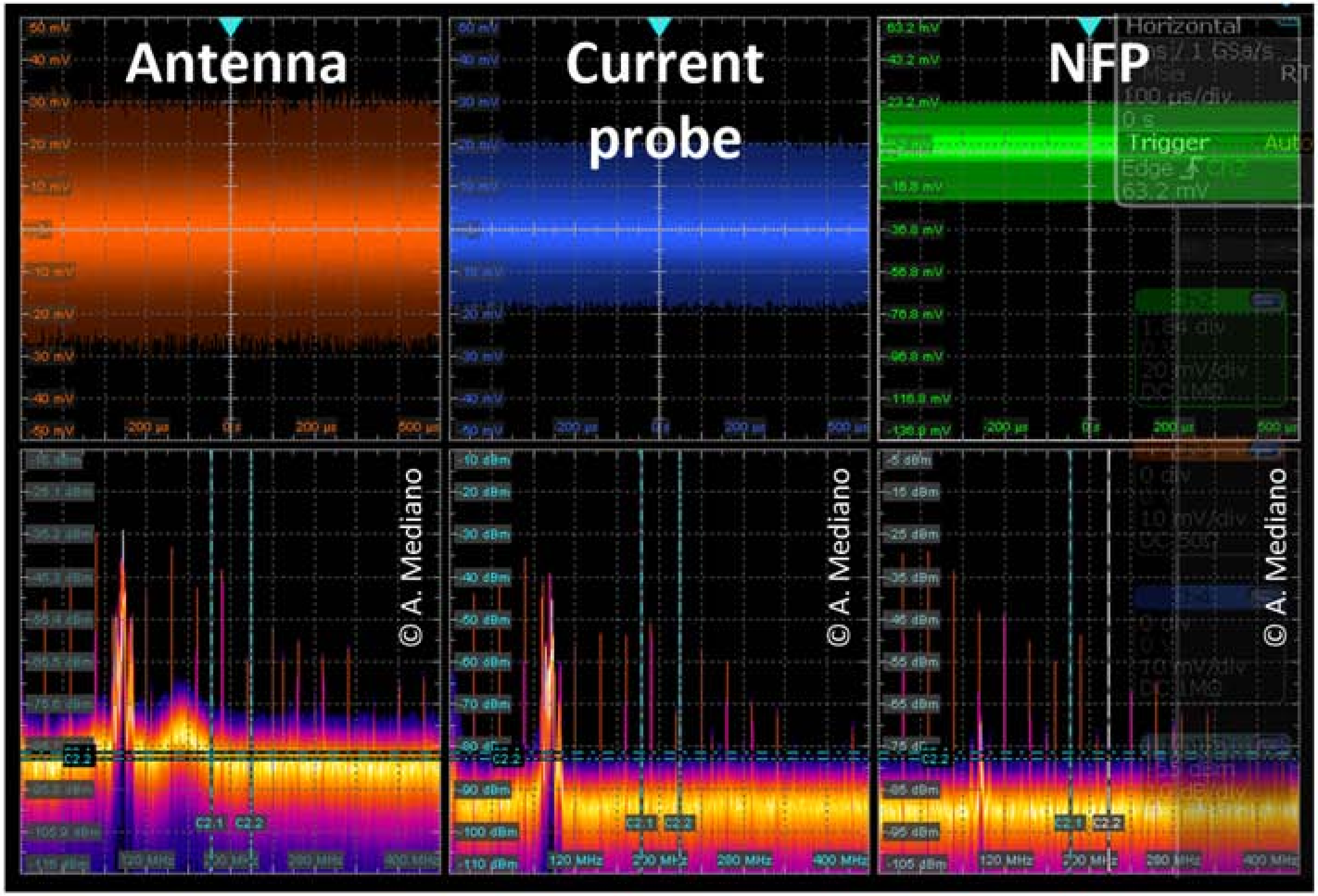
- Difficult to navigate in FREQ domain
- Slows down signal analysis in SPECTRUM DOMAIN

RTO/RTE scopes

ROHDE&SCHWARZ

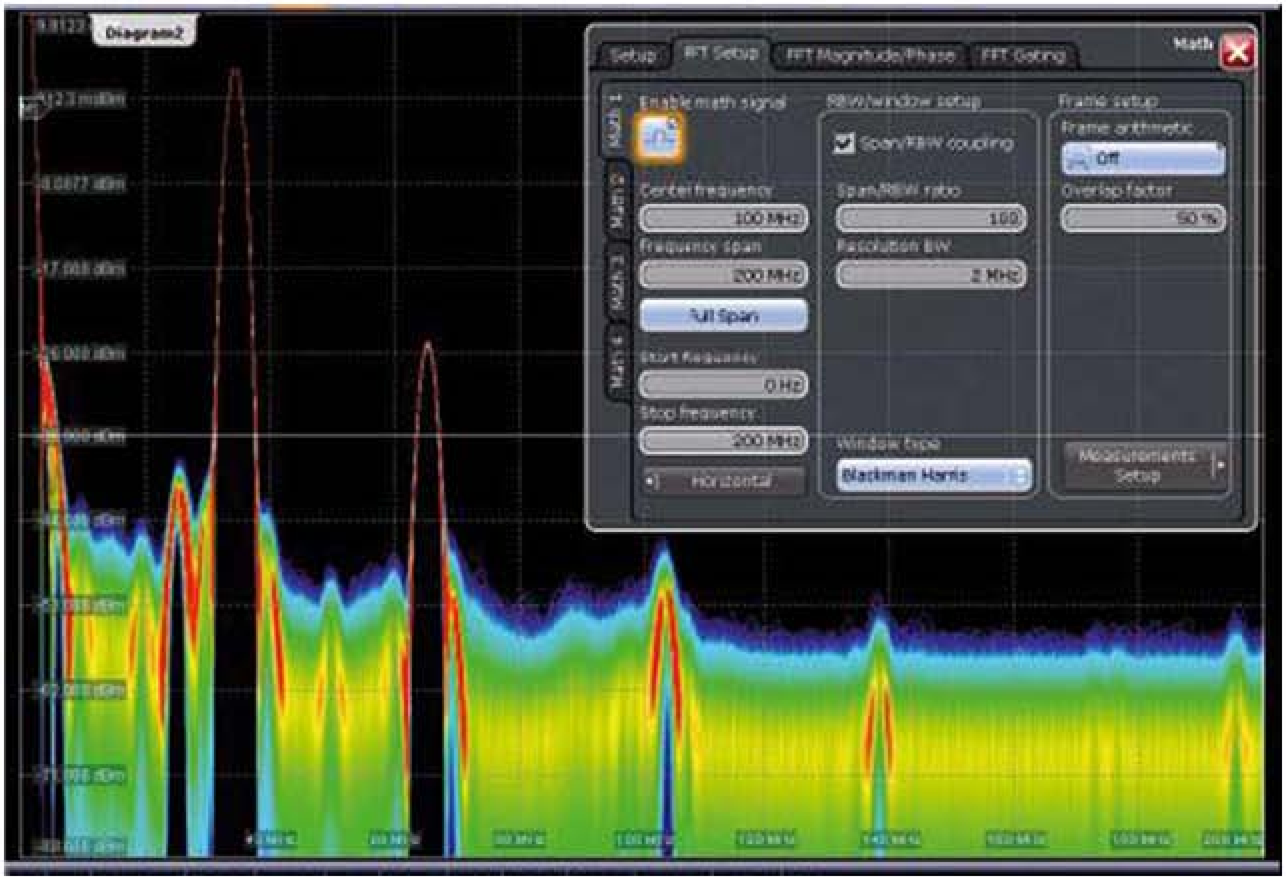
The HF Magic Lab®

Scopes: Time and Frequency domains



Scopes: FFT display

HW overlapping FFT implementation



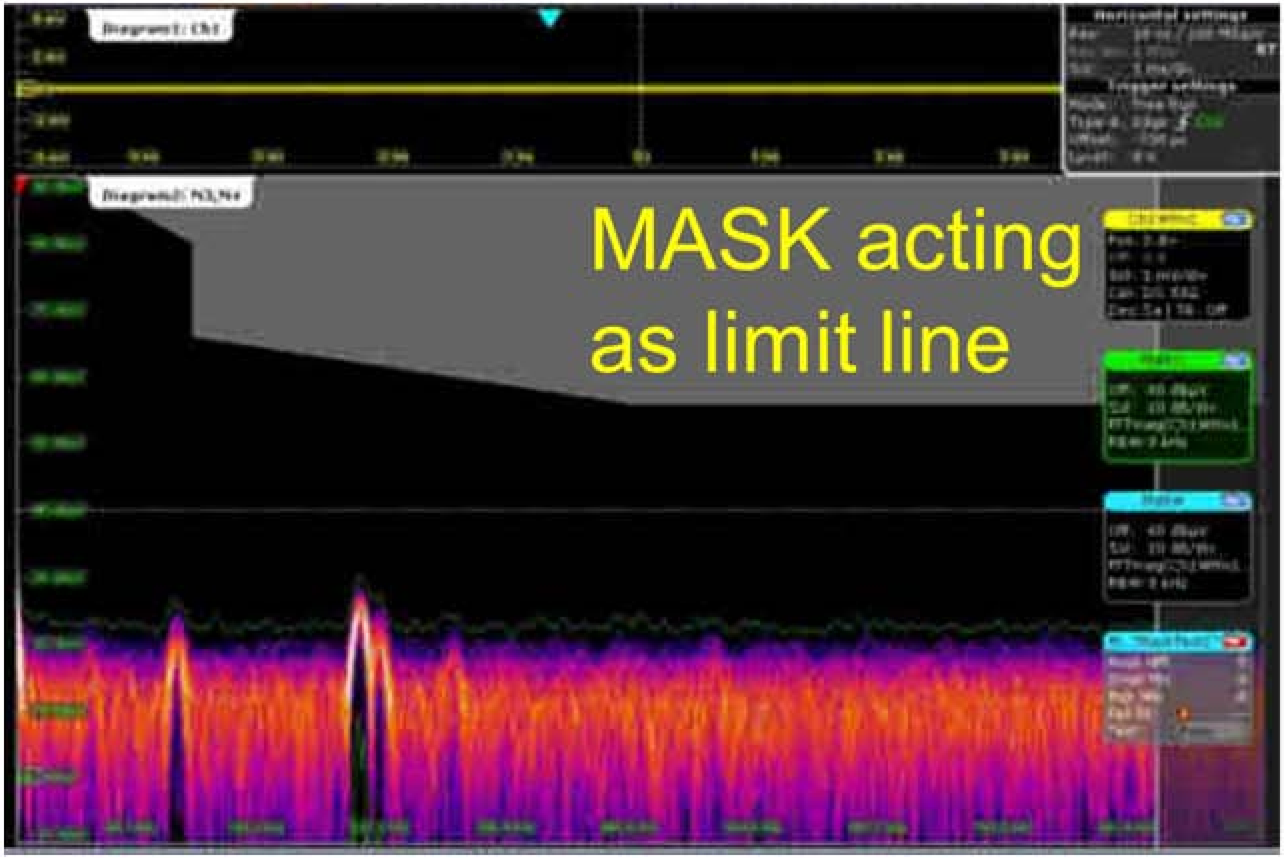
- Powerful
- User-friendly
- Very responsive
- Intensity modulated color display
- Not neccesary "MAX-HOLD mode"

RTO/RTE scopes

ROHDE&SCHWARZ

The HF Magic Lab®

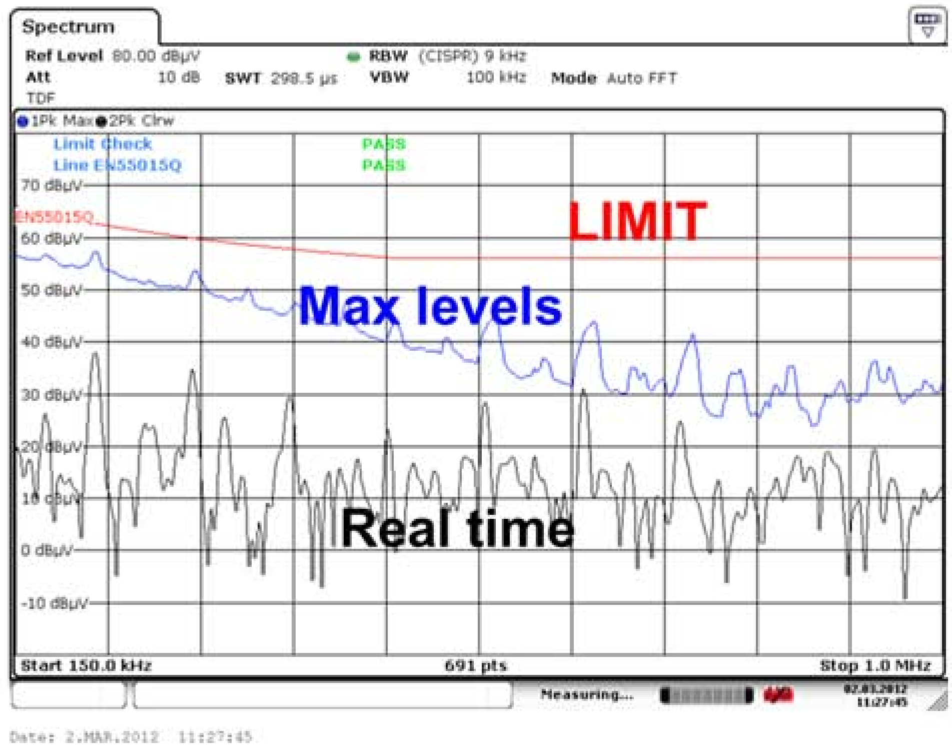
Scopes: EMI debugging and masks



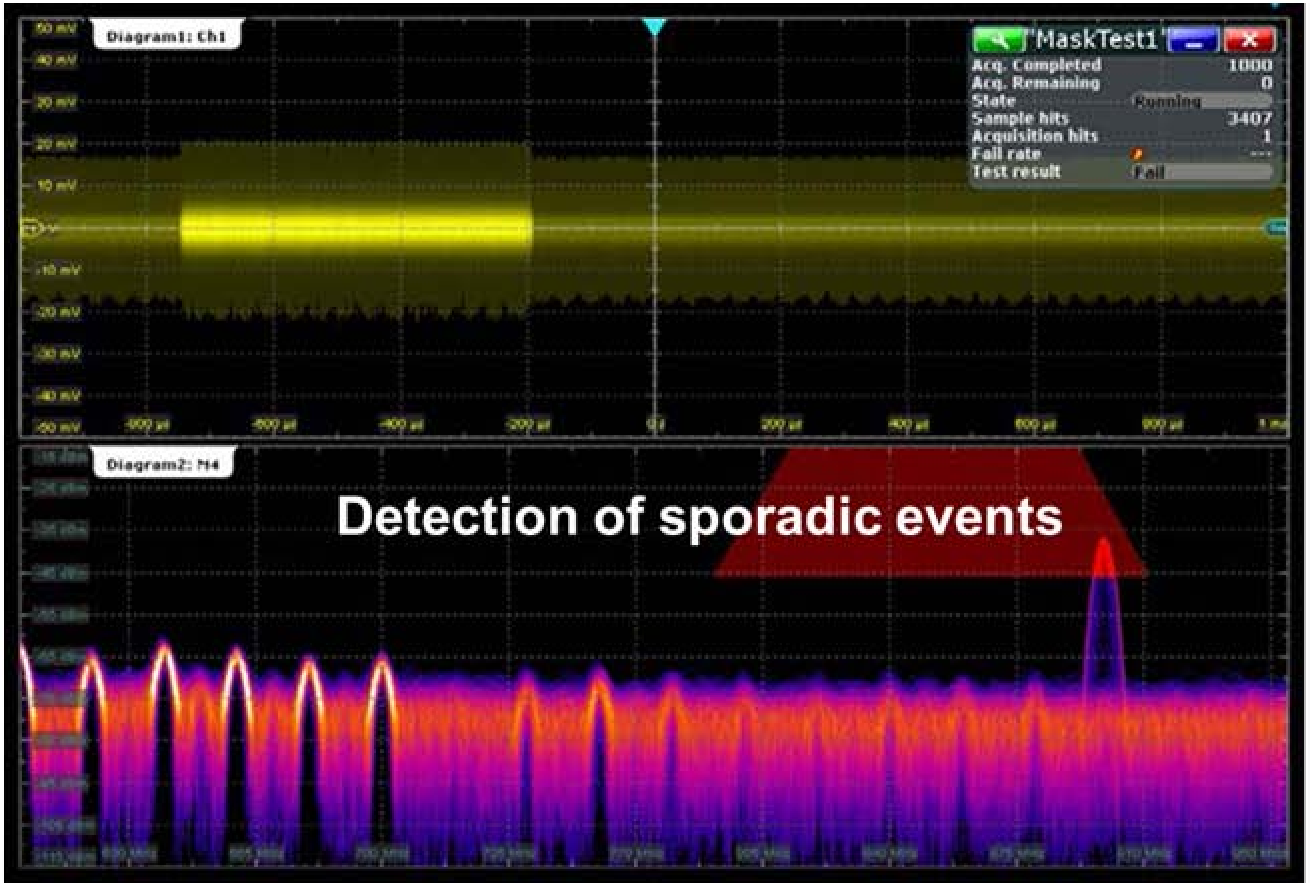
Stop-on mask violation setting !!!

Scopes: Conducted emissions example

Conducted Emissions using LISN. Range: 9 kHz – 1 MHz



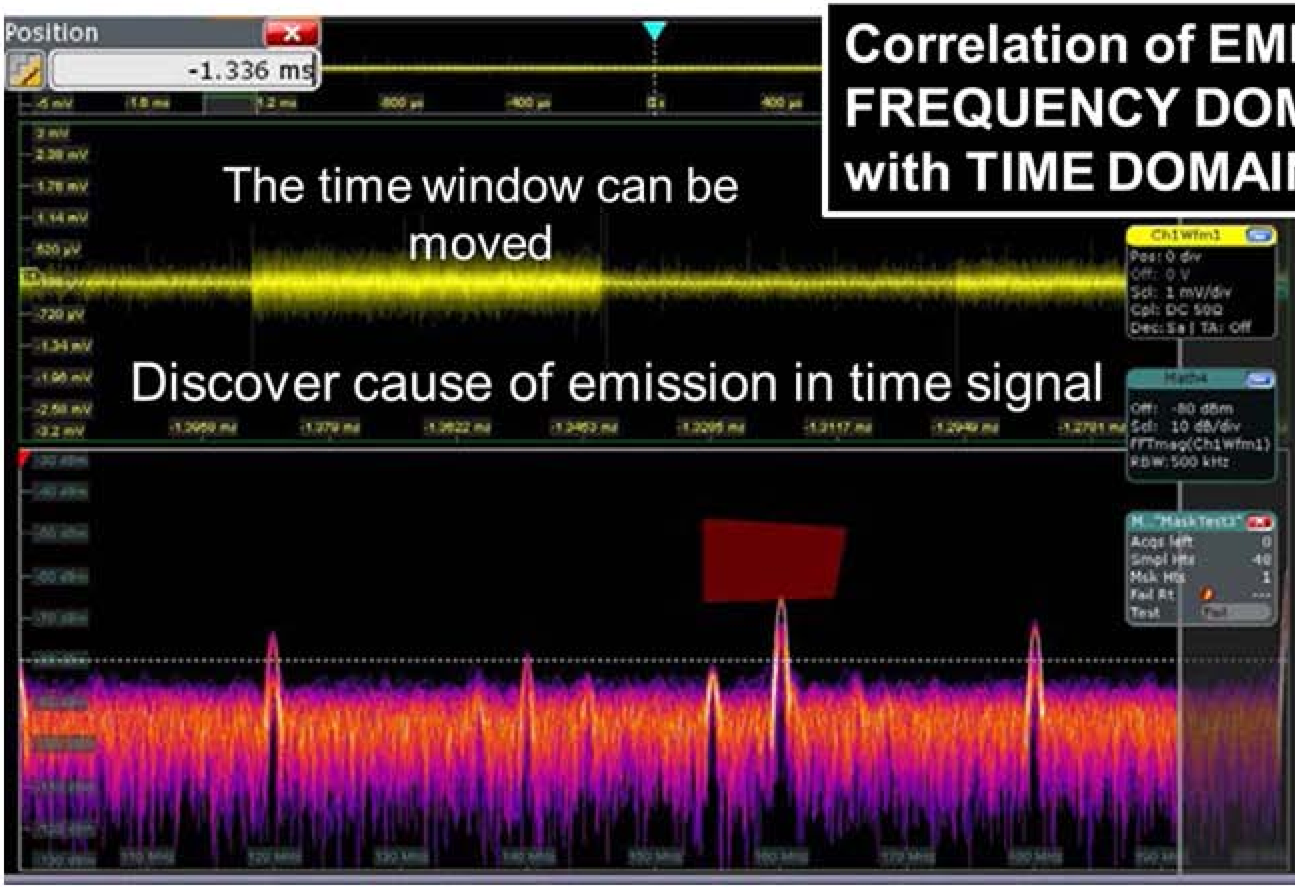
Scopes: Frequency Mask Triggering



Use "Stop-On-Violation" function

Scopes: FFT gating

The FFT is restricted to a specific interval in the acquired time domain signal



Correlation of EMI signals from FREQUENCY DOMAIN with TIME DOMAIN