KONFERENCJA
EMC FOR BUSINESS
PRAKTYCY DLA PRAKTYKÓW
11-12.10.2018

Zakłócenia promieniowane ograniczanie i przeciwdziałanie

Autor: Piotr Gierwiatowski, Würth Elektronik Polska Sp. z o.o.

Field Application Engineer

Sponsorzy

Główny patronat medialny

Patronat medialny

Frequency Range for Conducted and Radiated Noise

Conducted noise

Differential Filters

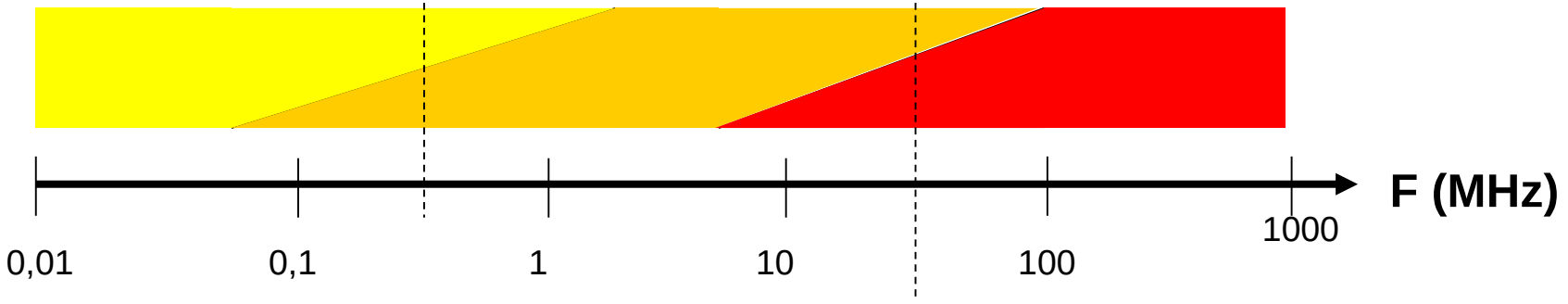
Coupled noise

Common Mode Chokes(*)

Radiated noise

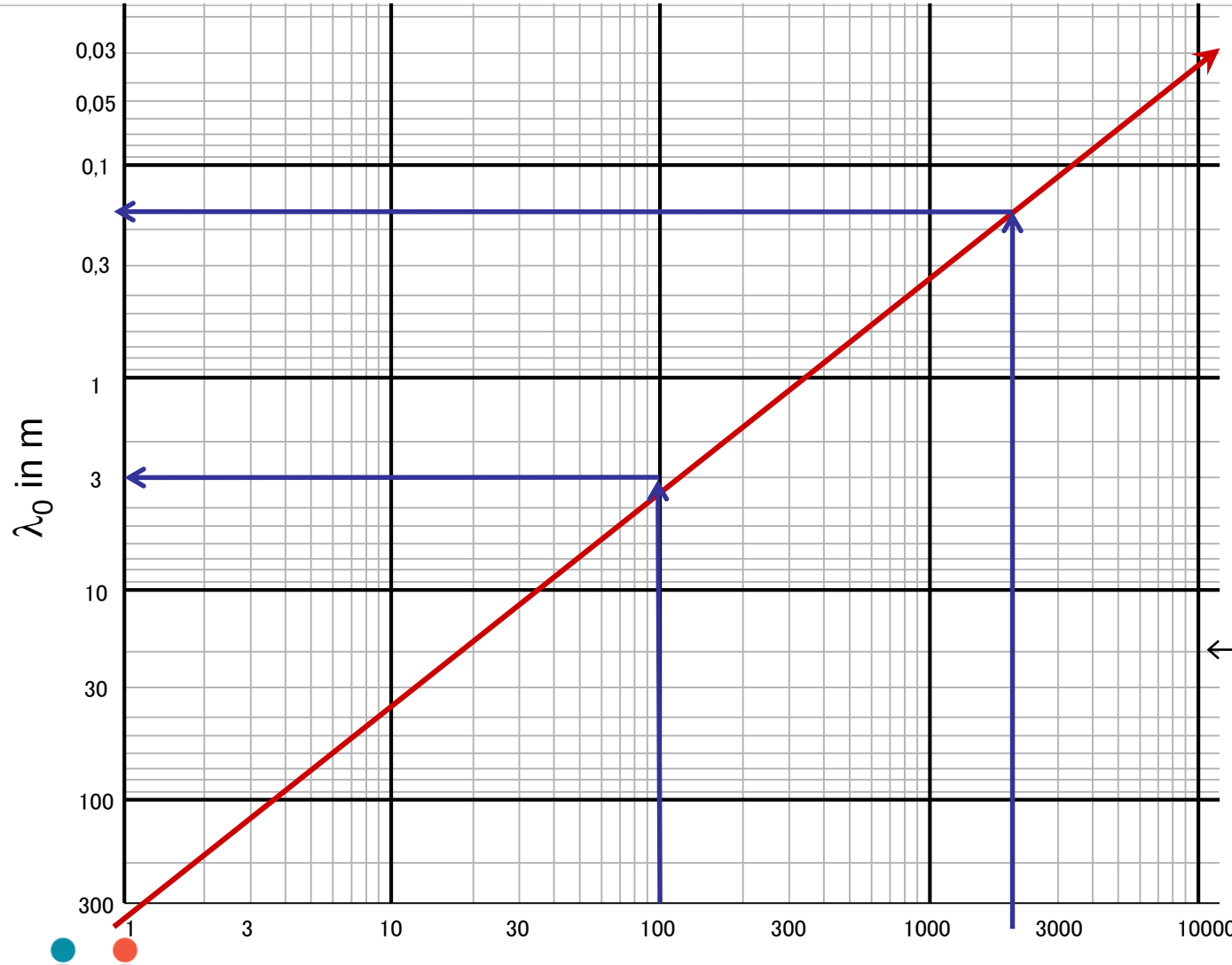
Metal or ferrite foils: *Shielding*

chip bead ferrites



30 MHZ

Frequency relations – Wavelength



$$\lambda_0 = \frac{c_0}{f} = \frac{1}{f \cdot \sqrt{\varepsilon_0 \cdot \mu_0}}$$

physical constant

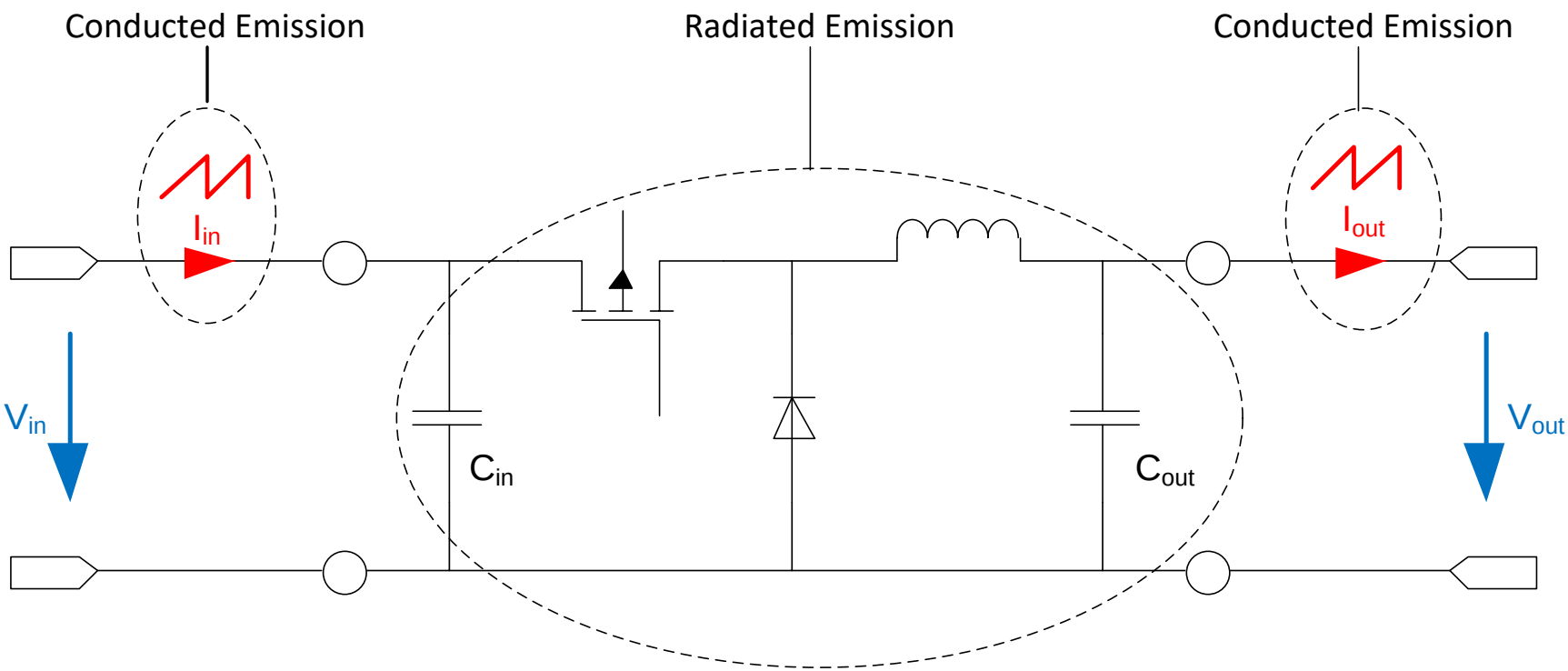
Examples:

VHF @ 100MHz →
$\lambda_0/4$ = 75cm (FM Antenna)

WLAN @ 2.45 GHz →
$\lambda_0/4$ = 3.125cm

↔

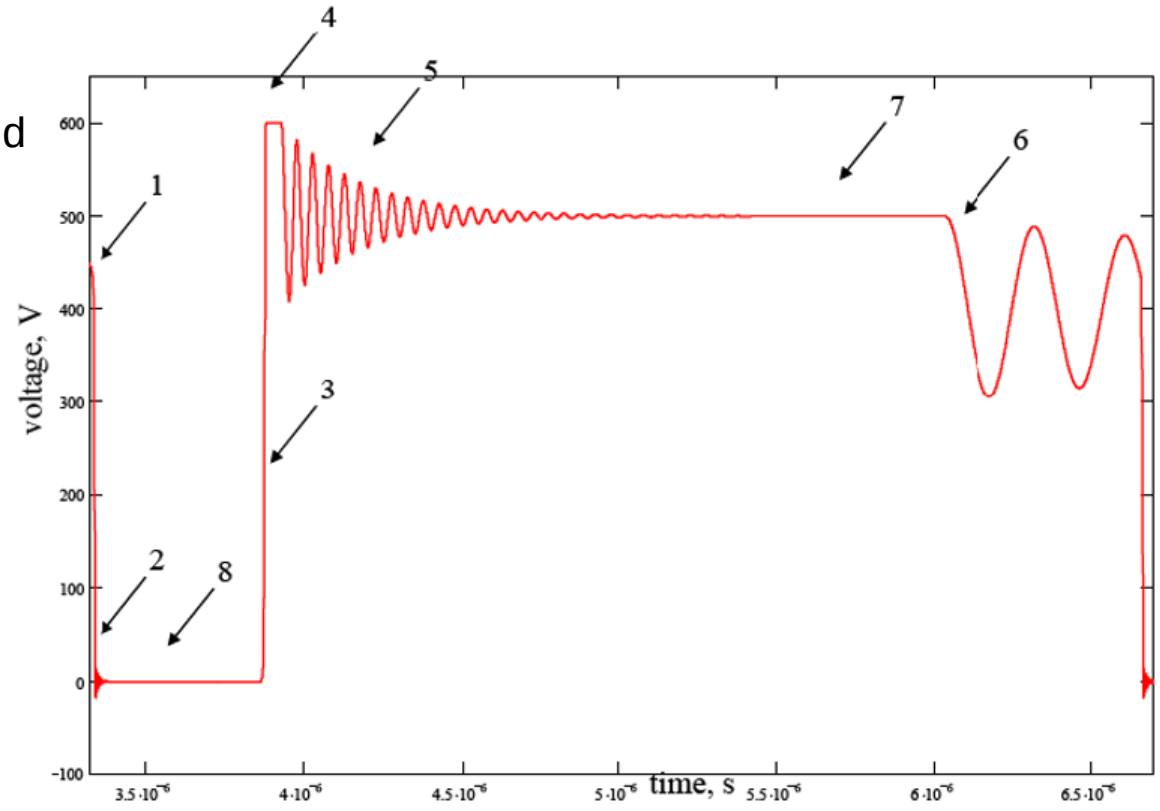
Potential interference sources



Potential interference sources

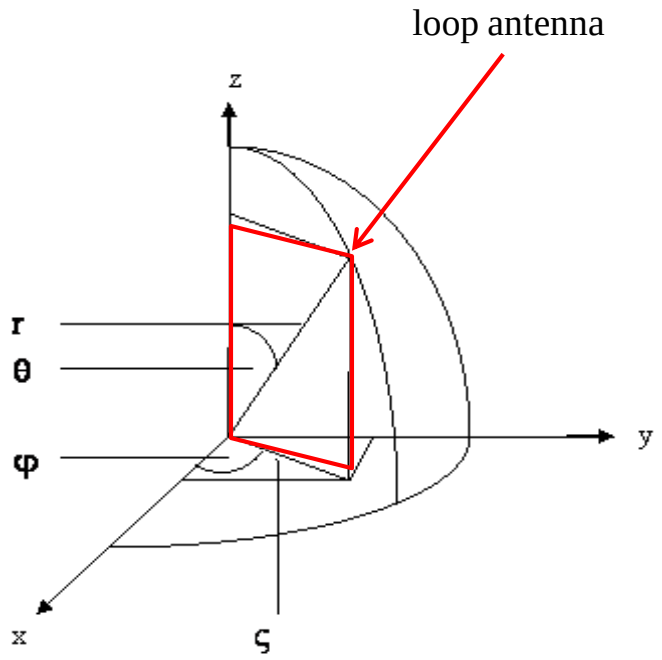
e.g. Flybuck™ DCDC or Flyback ACDC

- Oscillation due to parasitic MOSFET output capacitance and leakage inductance of the transformer
- High frequency content
- Voltage overshoot



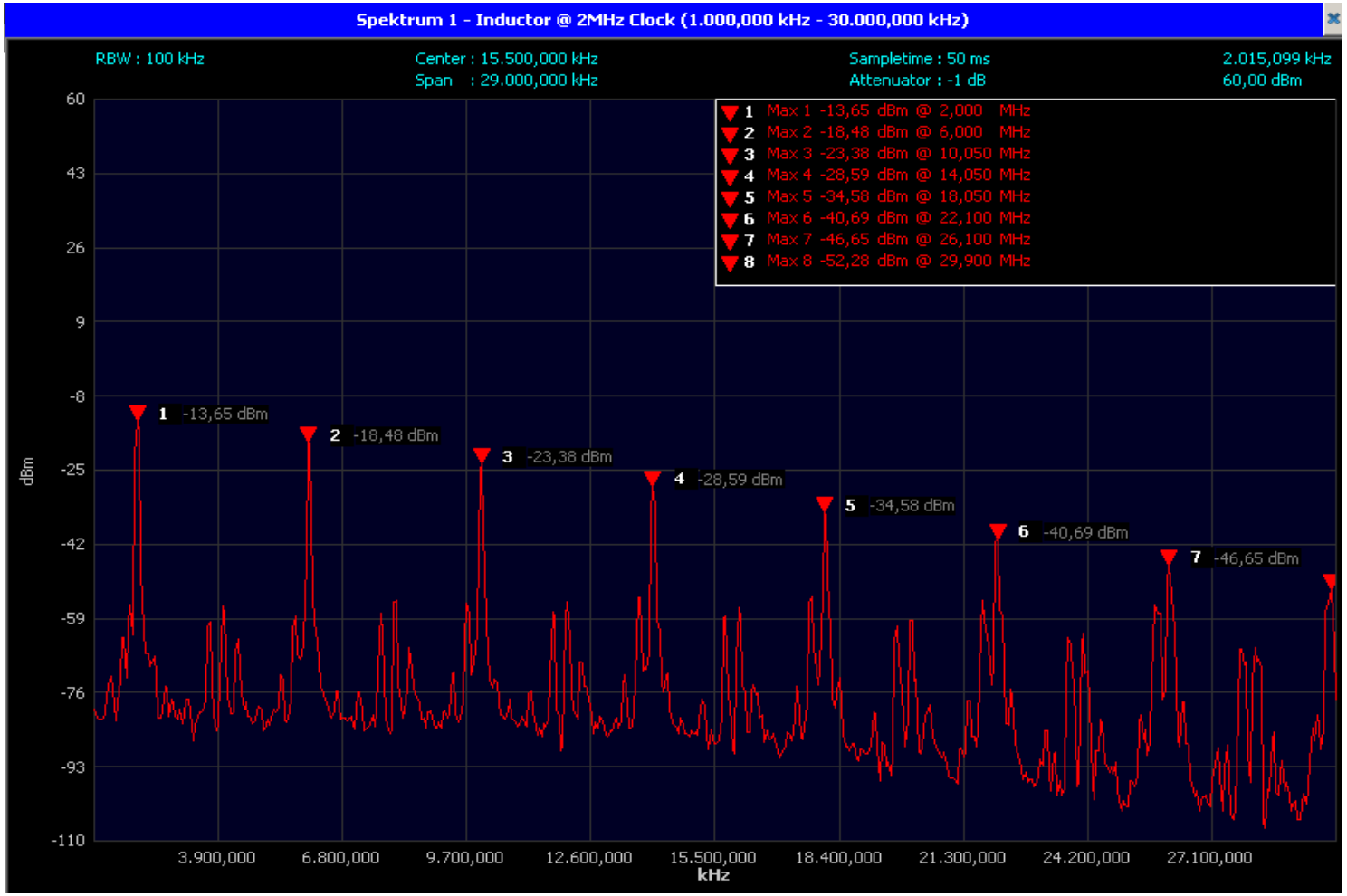
Potential interference sources

- Power and signal loops have antenna characteristics
- Radiation over all power and signal loops
- Field strength depends on :
  - Loop size
  - Amplitude of I_{AC}
  - Frequency
  - Distance between noise source and noise sink



Potential interference sources

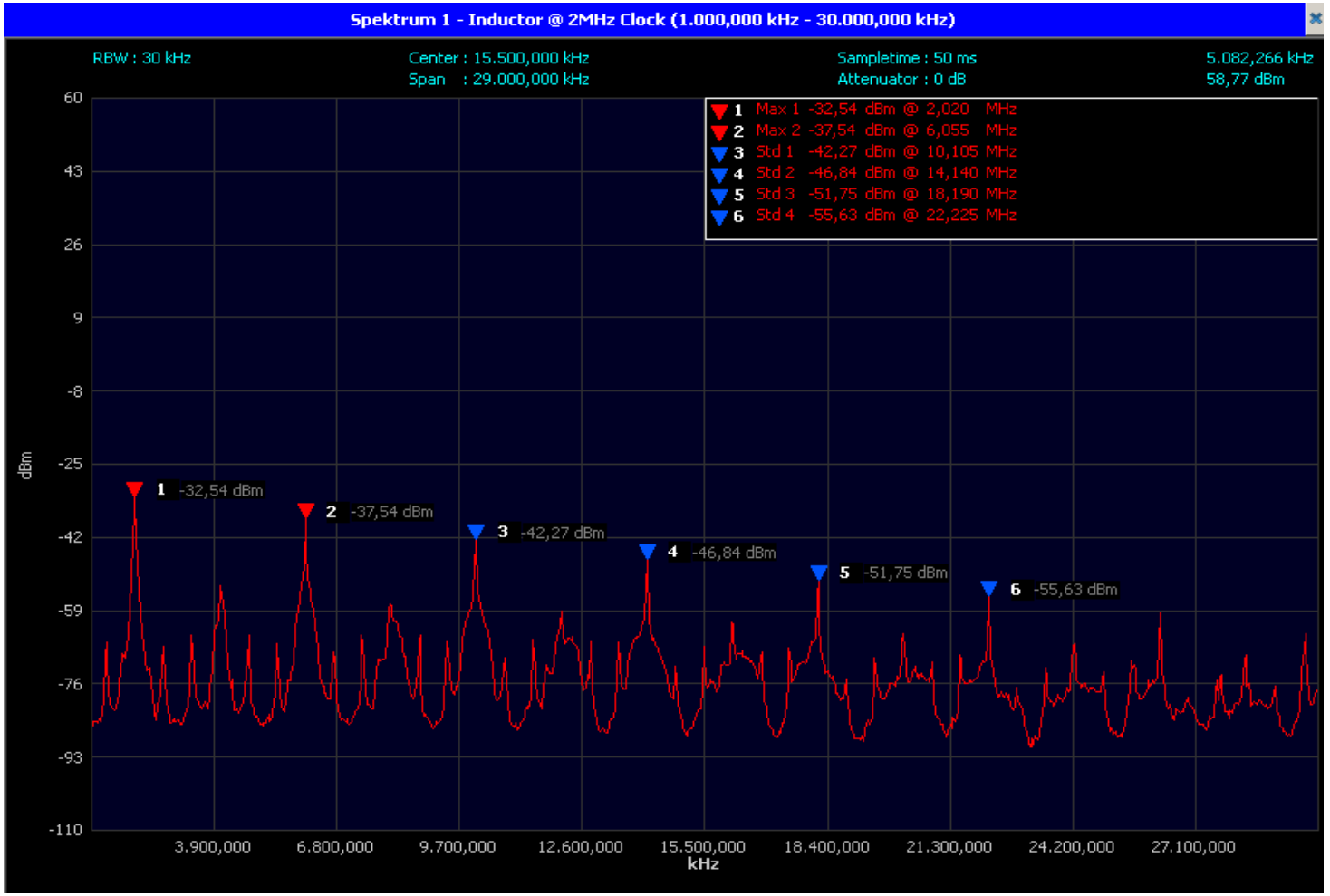
- WE - PD2 **unshielded**
- 10µH, 2MHz, 1A



Potential interference sources

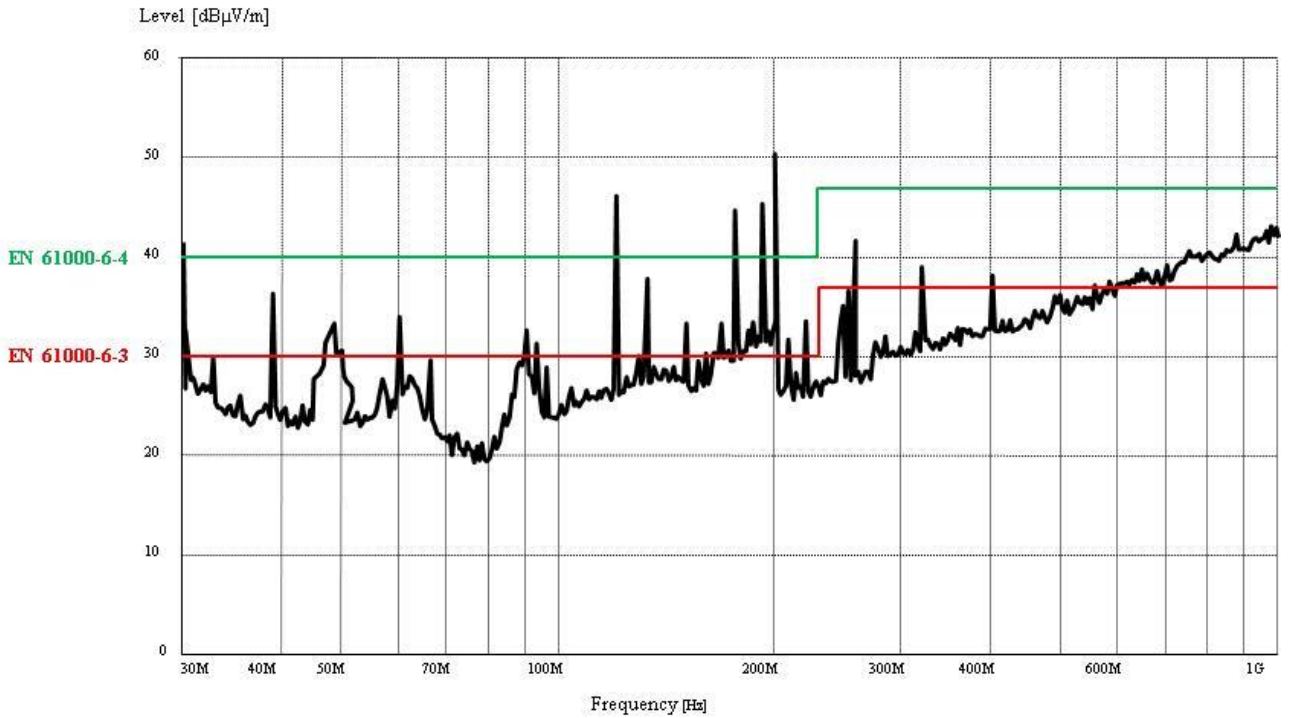
WE - PD **shielded**
10µH, 2MHz, 1A

19dBm
Improvement

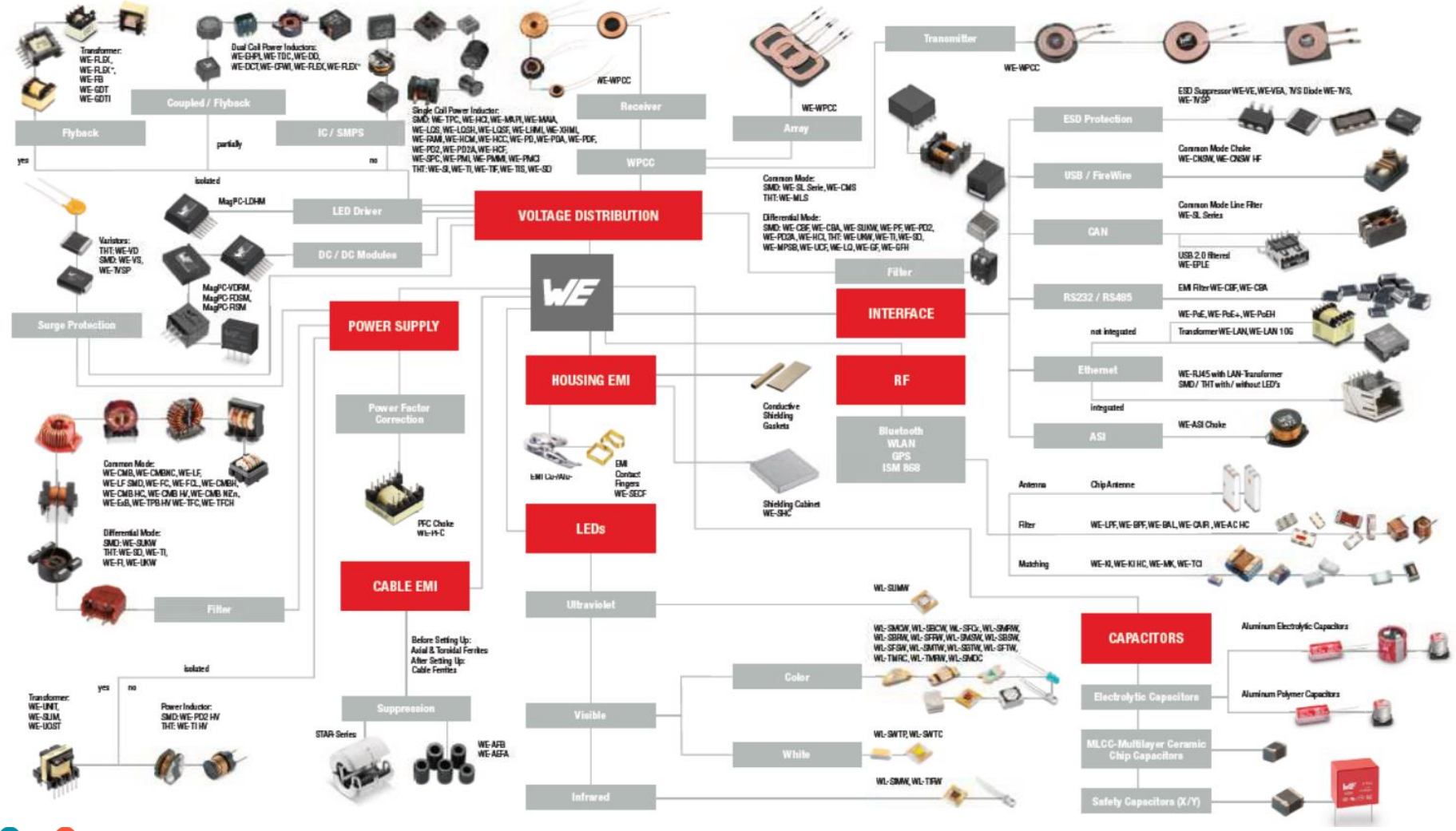


Radiated Emission

- Main sources:
  - Copper traces on PCBs
  - SMPS power chokes
- e.g.: EN 61000-6-4 (Industry) QP
- e.g.: EN 61000-6-3 (Home) QP

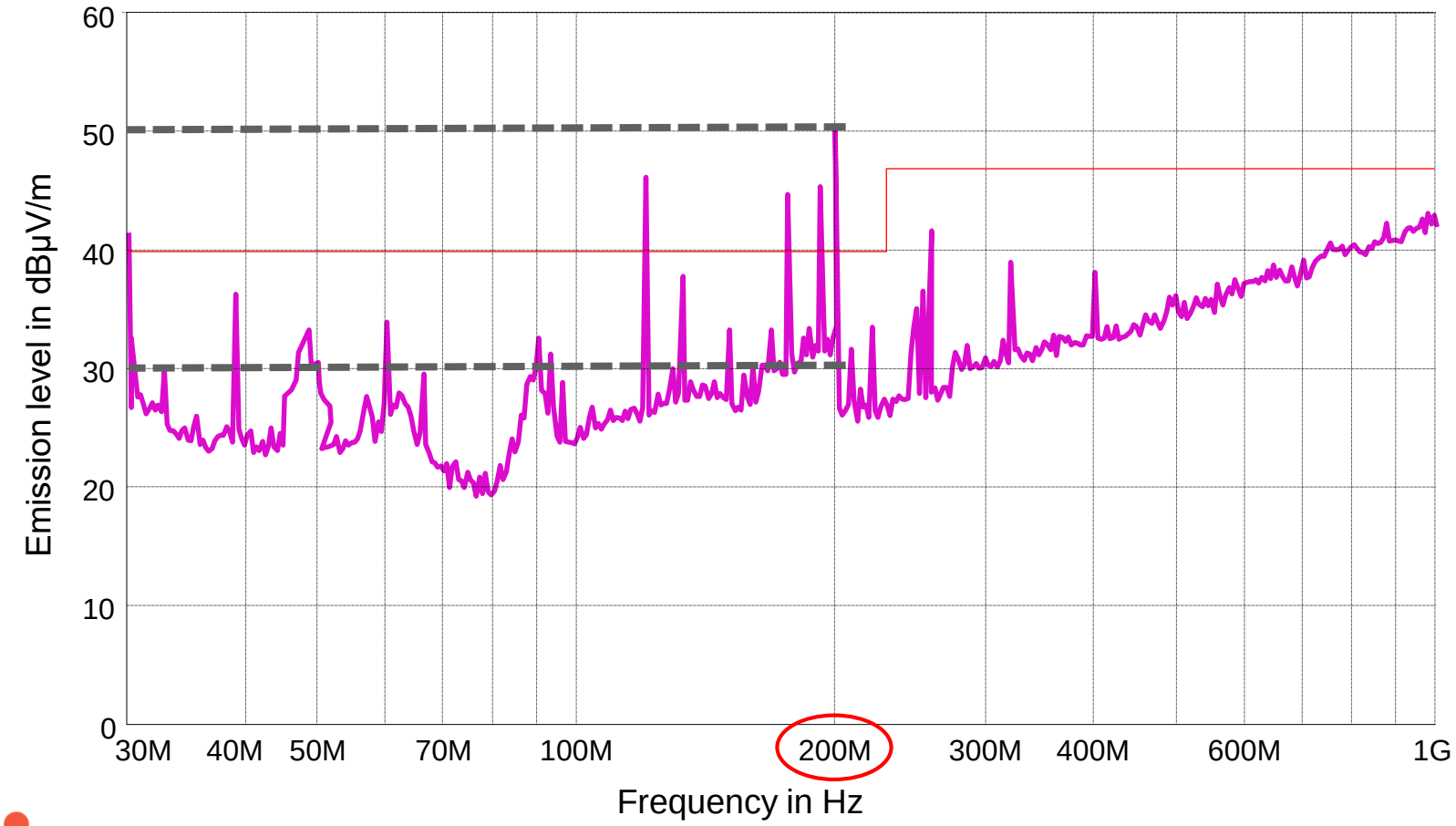


What we have:


Transformer: WE-FLEX, WE-FLEX+, WE-FBI WE-GDT WE-GDTI
Dual Coil Power Inductors: WE-EHPI, WE-TDC, WE-DD, WE-DCT, WE-CFWI, WE-FLEX, WE-FLEX+
Coupled / Flyback
Flyback
IC / SMPS
yes
partially
no
isolated
Single Coil Power Inductor: SMD: WE-TPC, WE-HCI, WE-MAPI, WE-MAIA, WE-LQS, WE-LQSH, WE-LQSF, WE-LHMI, WE-XHMI, WE-FAMI, WE-HCM, WE-HCC, WE-PD, WE-PDA, WE-PDF, WE-PD2, WE-PD2A, WE-HCF, WE-SPC, WE-PMI, WE-PMM, WE-PMCI THT: WE-SI, WE-TI, WE-TF, WE-TIS, WE-SD
WE-WPCC
Receiver
WPCC
WE-WPCC
Array
Transmitter
WE-WPCC
MagPC-LDHM
LED Driver
DC / DC Modules
MagPC-VDRM, MagPC-FDSM, MagPC-RSM
VOLTAGE DISTRIBUTION
Common Mode: SMD: WE-SL Serie, WE-CMS THT: WE-MLS
Differential Mode: SMD: WE-CBF, WE-CBA, WE-SUKW, WE-PF, WE-PD2, WE-PD2A, WE-HCI, THT: WE-UMW, WE-TI, WE-SD, WE-MPSB, WE-UCF, WE-LQ, WE-GF, WE-GFH
Filter
Varistors: THT: WE-VD SMD: WE-VS, WE-TVSP
Surge Protection
POWER SUPPLY
INTERFACE
HOUSING EMI
RF
Power Factor Correction
PFC Choke WE-MAPI-C
Conductive Shielding Gaskets
Shielding Cabinet WE-SHC
EMI Contact Fingers WE-SECF
Bluetooth WLAN GPS ISM 868
ESD Protection
ESD Suppressor WE-VE, WE-VEA, TVS Diode WE-TVS, WE-TVSP
USB / FireWire
Common Mode Choke WE-CNSW, WE-CNSW HF
CAN
Common Mode Line Filter WE-SL Series
USB 2.0 filtered WE-EPLE
RS232 / RS485
EMI Filter WE-CBF, WE-CBA
WE-PoE, WE-PoE+, WE-PoEH
not integrated
Transformer WE-LAN, WE-LAN 10G
Ethernet
WE-RJ45 with LAN-Transformer SMD / THT with / without LED's
integrated
ASI
WE-ASI Choke
Common Mode: WE-CMB, WE-CMBNC, WE-LF, WE-LF SMD, WE-FC, WE-FCL, WE-CMBH, WE-CMB HC, WE-CMB HV, WE-CMB NZn, WE-ExB, WE-TPB HV WE-TFC, WE-TFCH
Differential Mode: SMD: WE-SUKW THT: WE-SD, WE-TI, WE-FI, WE-UKW
Filter
CABLE EMI
Before Setting Up: Axial & Toroidal Ferrites After Setting Up: Cable Ferrites
Suppression
STAR Series
WE-AFB WE-AEFA
isolated
yes
no
Transformer: WE-UNIT, WE-SLIM, WE-UCST
Power Inductor: SMD: WE-PD2 HV THT: WE-TI HV
LEDs
Ultraviolet
Visible
Infrared
Color
White
WL-SUMW
WL-SMCW, WL-SBCW, WL-SFCx, WL-SMRW, WL-SBRW, WL-SFRW, WL-SMSW, WL-SBSW, WL-SFSW, WL-SMTW, WL-SBTW, WL-SFTW, WL-TMRC, WL-TMRW, WL-SMDC
WL-SWTP, WL-SWTC
WL-SMW, WL-TFW
Antenna
Chip Antenne
Filter
WE-LPF, WE-BPF, WE-BAL, WE-CNR, WE-AC HC
Matching
WE-KI, WE-KI HC, WE-MK, WE-TCI
CAPACITORS
Aluminum Electrolytic Capacitors
Electrolytic Capacitors
Aluminum Polymer Capacitors
MLCC-Multilayer Ceramic Chip Capacitors
Safety Capacitors (X/Y)

Practical example:

Measurement of the radiated emission:

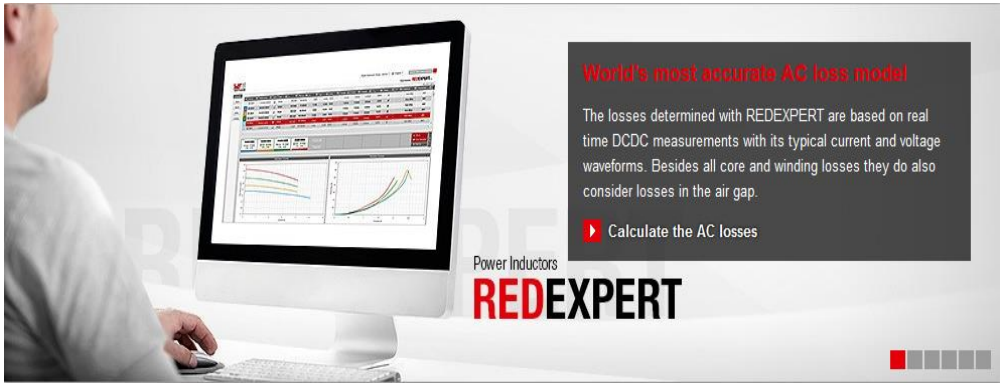


Available tools: RedExpert

REDEXPERT: What is it?

Würth Elektronik - www.we-online.com/ToolBox

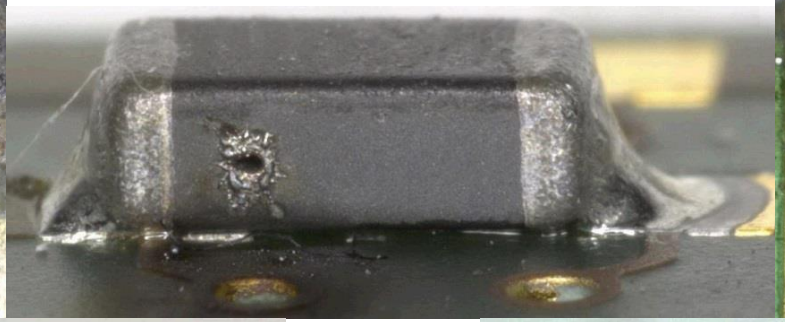
- online usable
- live update
- real time calculation
- easy component comparison
- several design tools integrated



No Calculation
Smart Determination

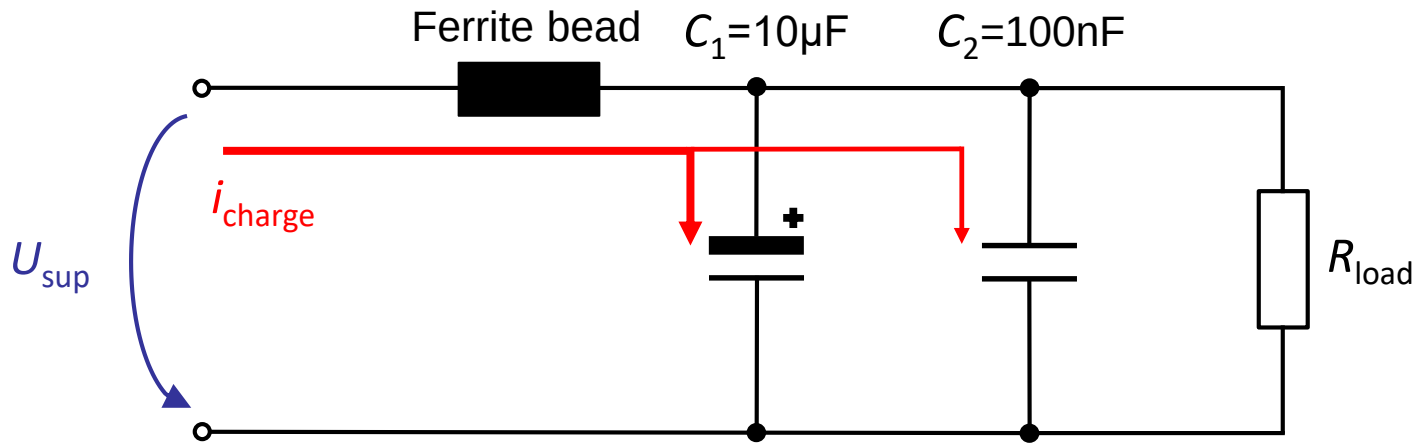
REDEXPERT

Practical example:



Pulse current capability

- The specified rated (DC) current given in the datasheet is guaranteed.
- Pulse currents due to charging of uncharged capacitors can cause thermal stress on a ferrite bead.
- Multilayer ferrites are endangered.
- Statistically based pulse testing can determine the breakdown level of the filter component.



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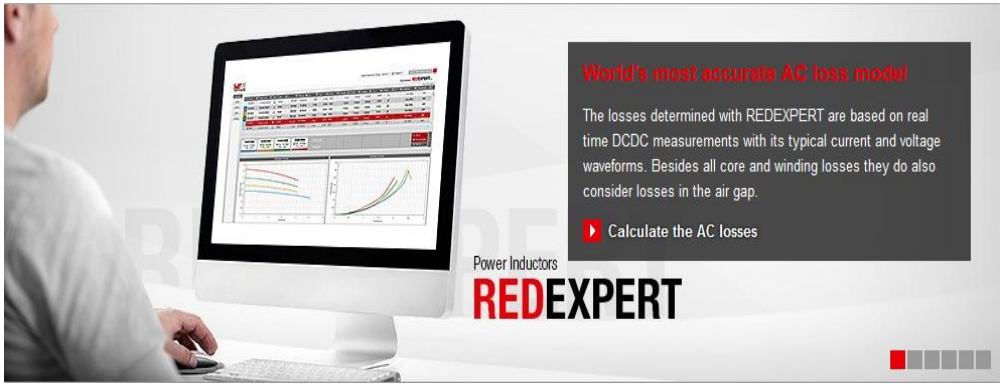
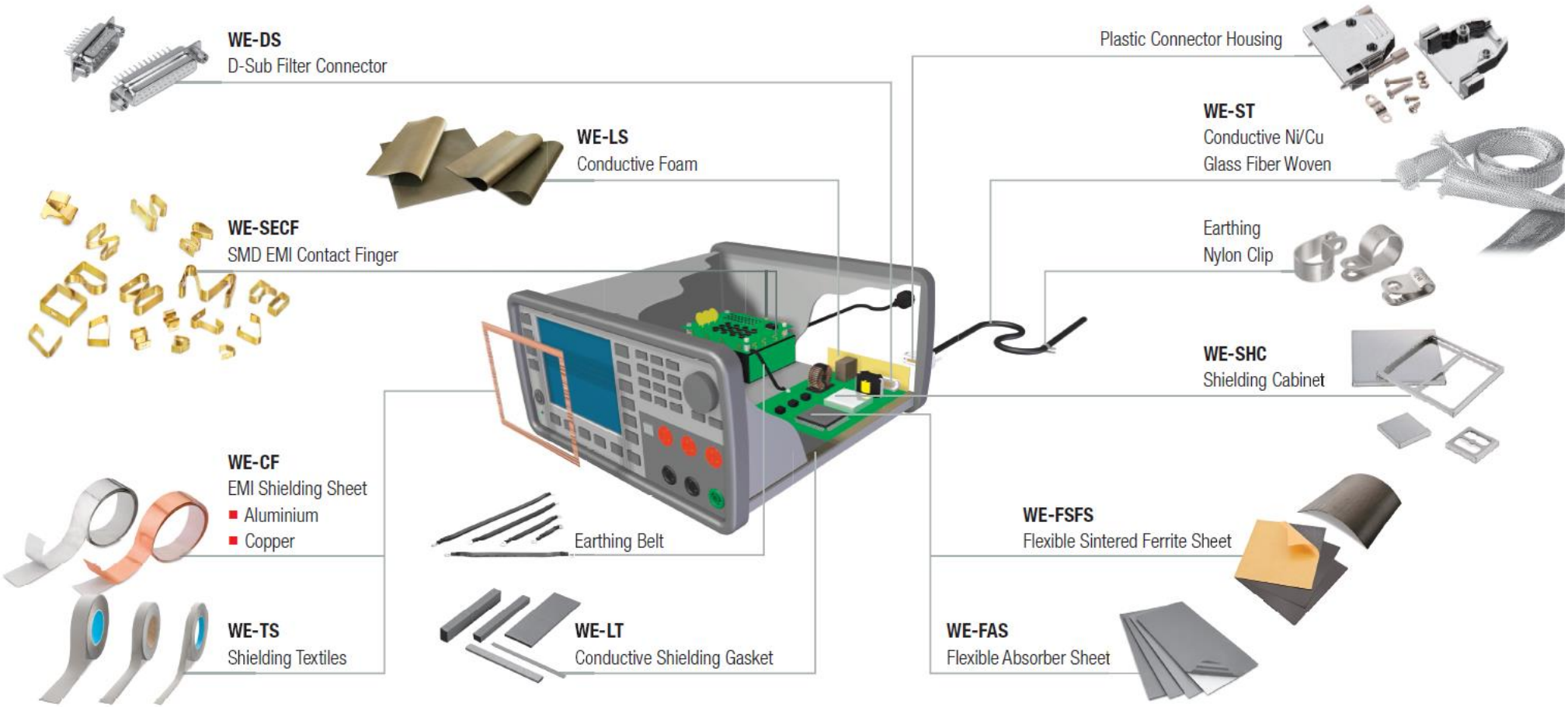


No Calculation
Smart Determination

REDEXPERT

Shielding: what WE have

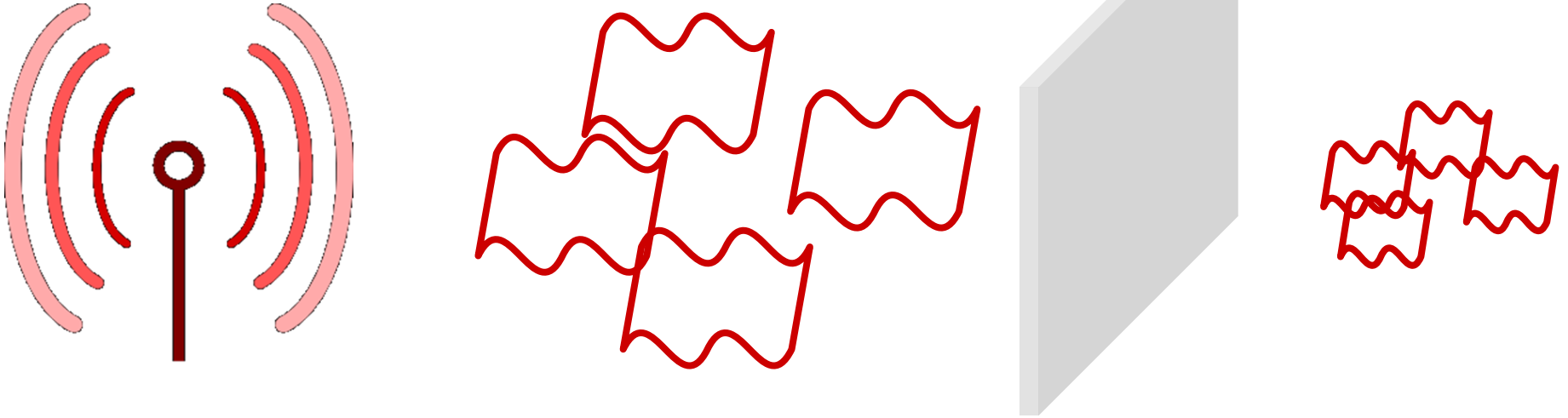


Shield Behavior Modes - Absorption mode

Source

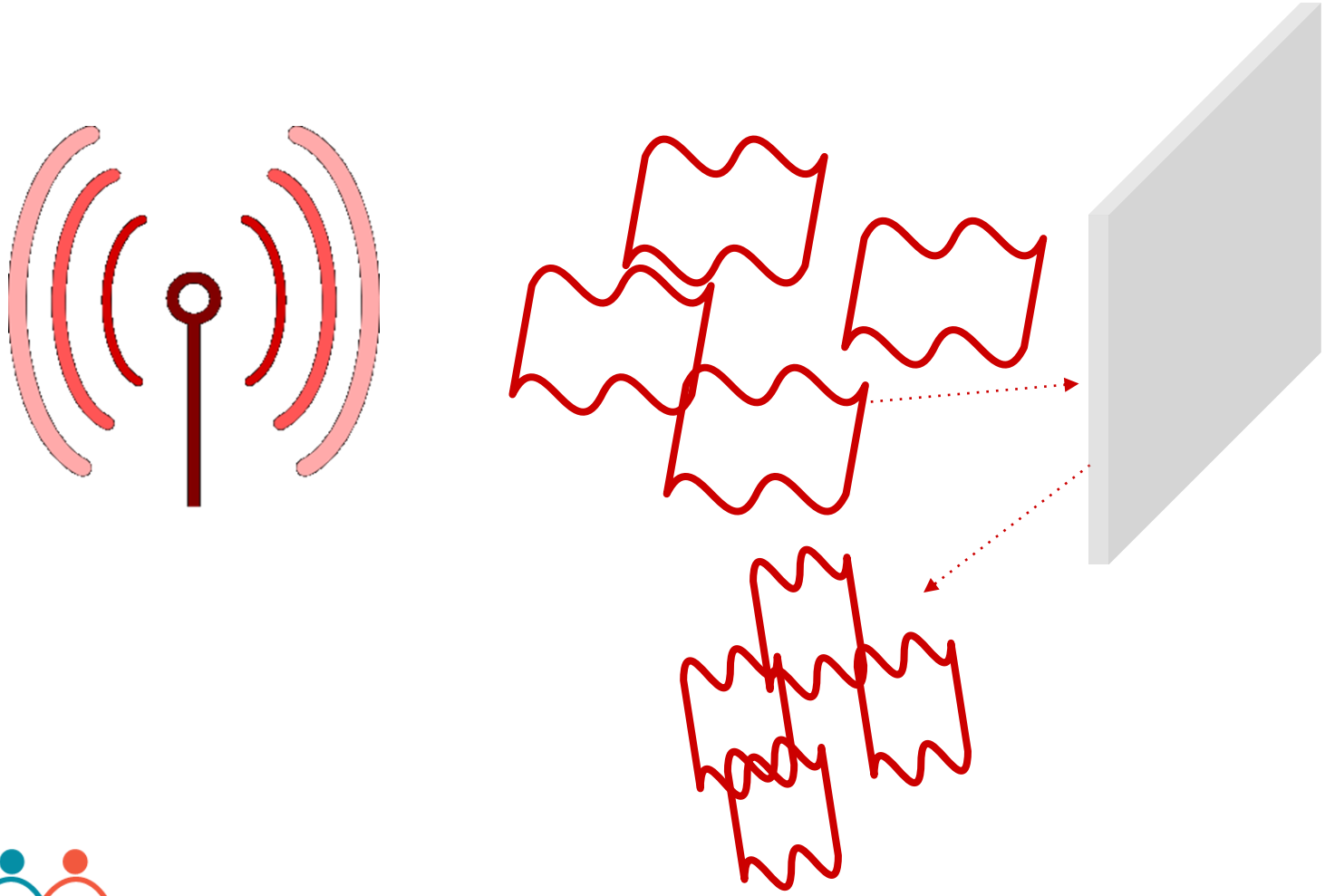
Before

Shield

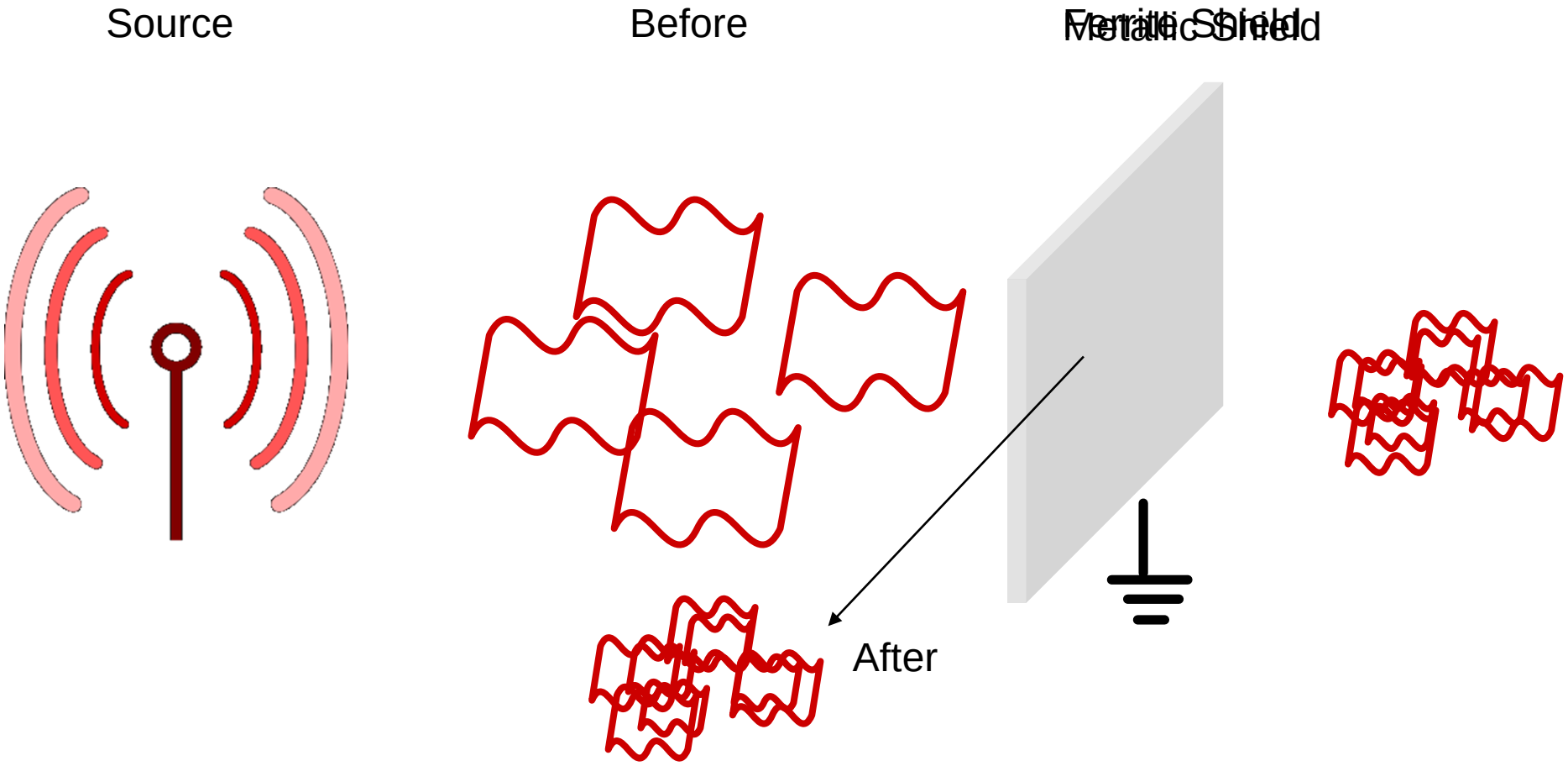


Shield Behavior Modes - Reflection mode

Source Before Shield After

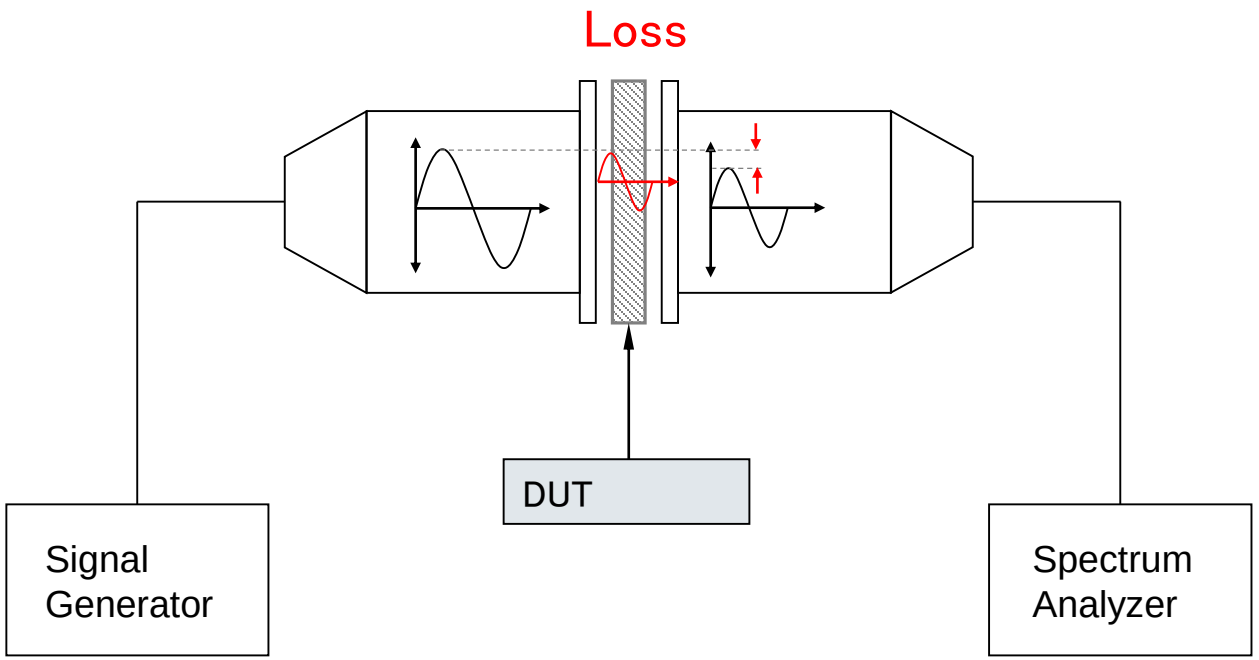


A realistic scenario: Absorption + Reflection Mode

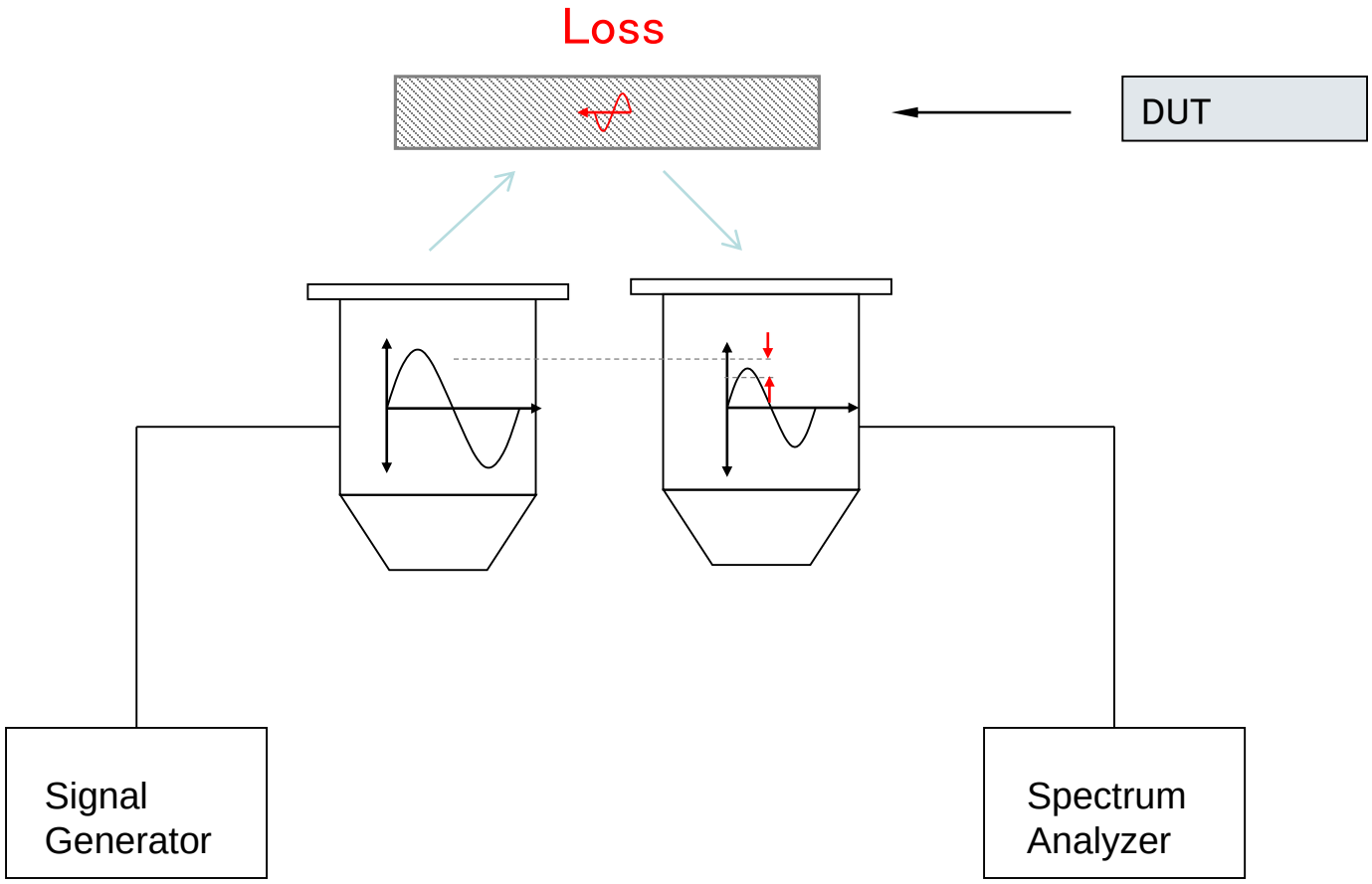


Metal need to be grounded in some cases! But a ferrite does not.

How is Attenuation Measured (Absoprtion Mode)

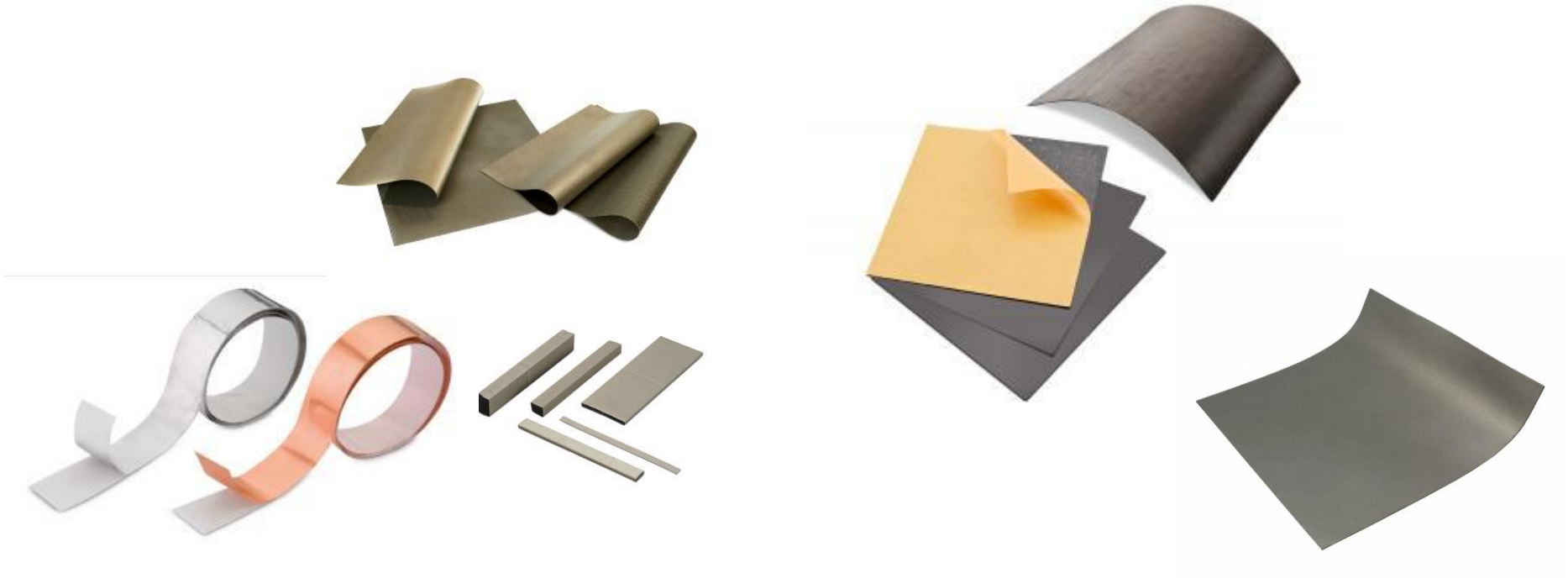


How is Attenuation Measured (Reflection Mode)



Types of shielding materials

Two main types: **Metallic** (Cu, Al, Steel) and **Ferrites** (NiZn, MnZn or other materials)



Characterization of Shields

Resistivity – a measure of ability to conduct current

Permeability – a measure of abilitiy to concentrate a magnetic field

Thickness – a measure of the Z dimension in 3D space

Weight – a measure of mechanical mass and density

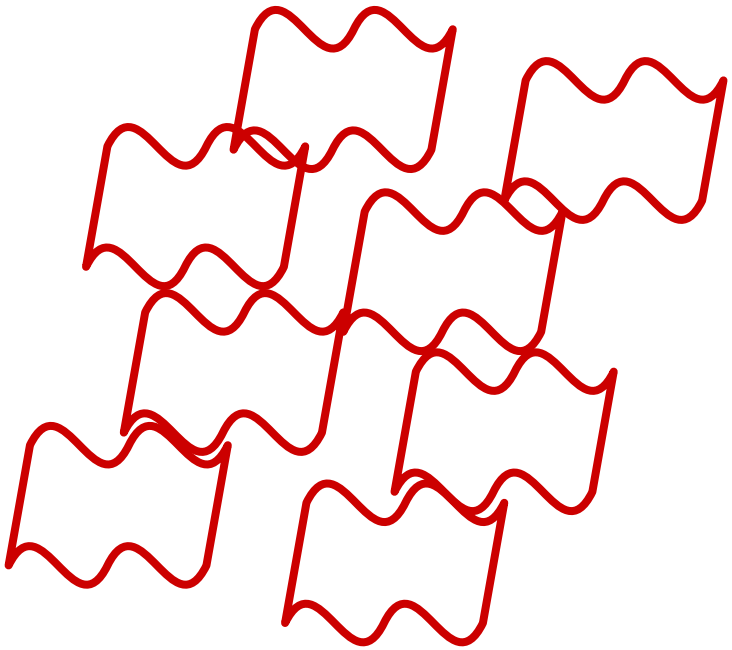
Melting Point – a measure of ability to resist heat

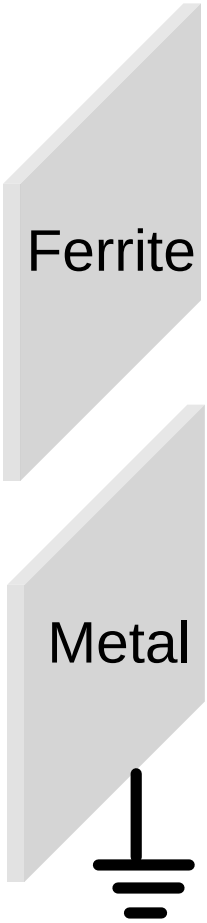
Flammability – a measure of ability to catch fire

Insertion Loss – a measure of how much noise is reduced

(this last parameter is the most important one)

How Shields affect each component of EM waves

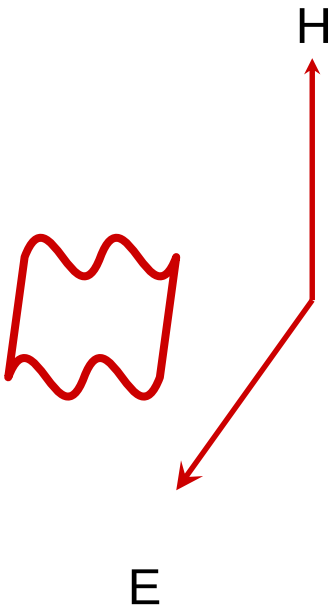


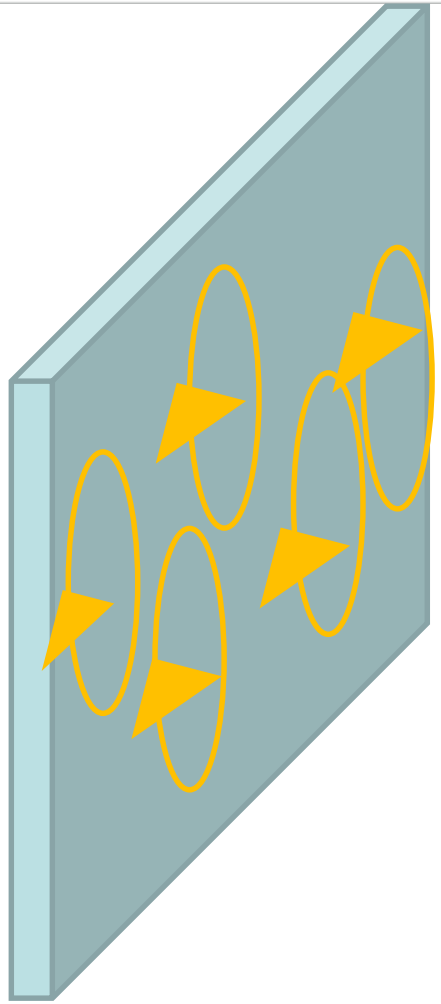


Ferrite works better at short distances and it affects more significantly the magnetic field

Metal works at any distance and it affects more significantly the electric field

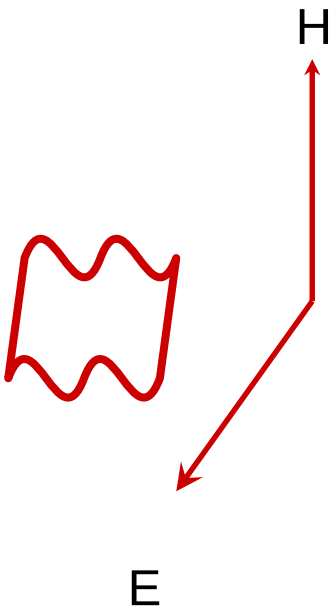
Metallic Shielding: In more detail

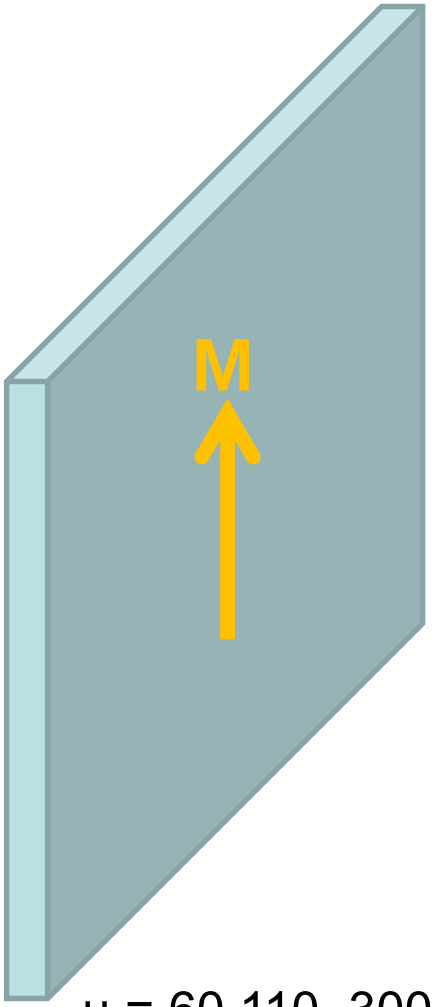


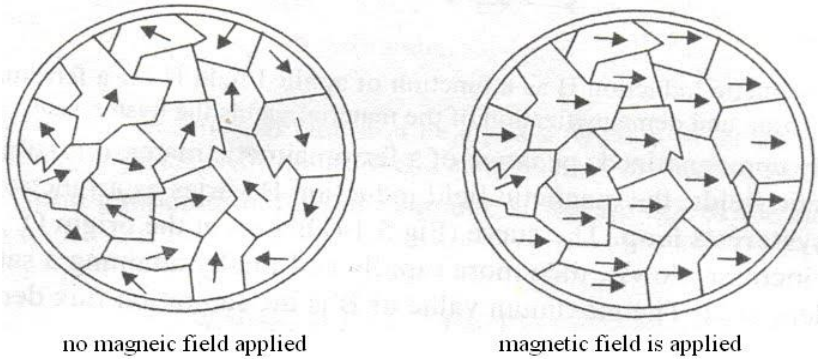


Eddy currents account for the majority of the attenuation

Ferrite shields in more detail





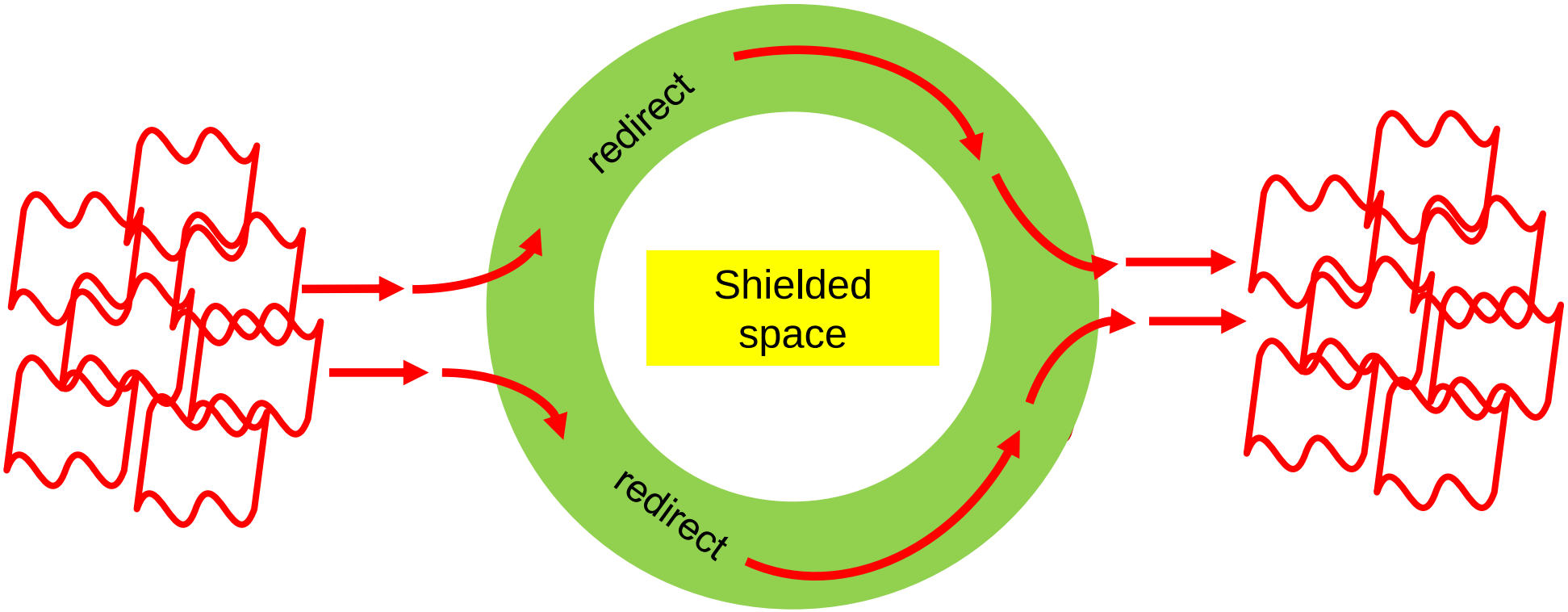


Low Remanence
High Permeability

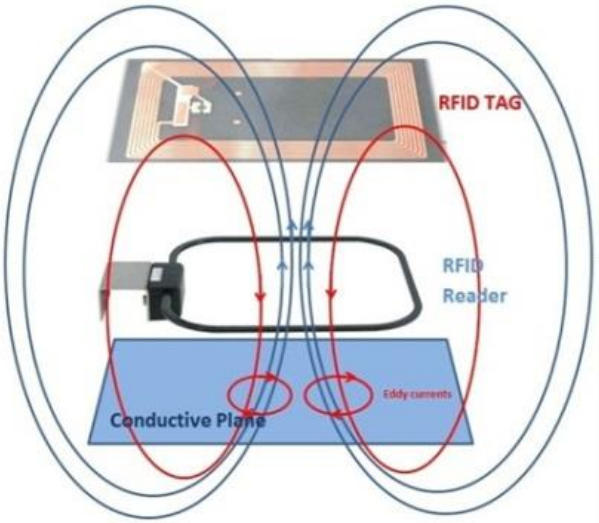
The magnetic moments of each magnetic domain try to align with the incoming magnetic field. Energy is lost due to both Mechanical **torque** and **phase lag.**

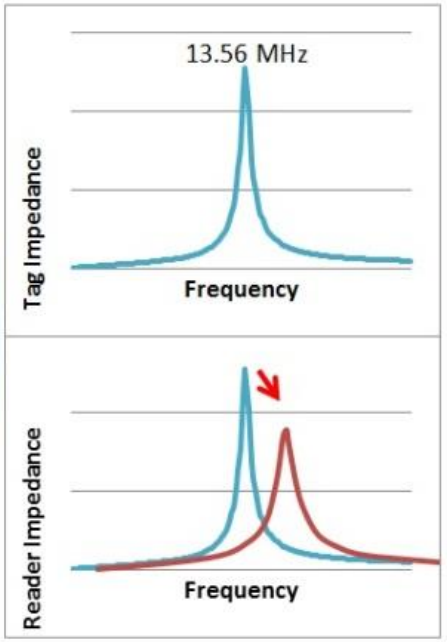
μ = 60,110, 300 typically.

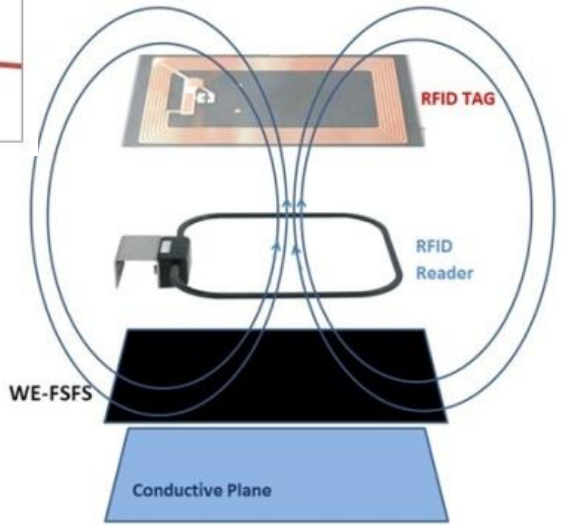
Shielding by magnetic re-direction

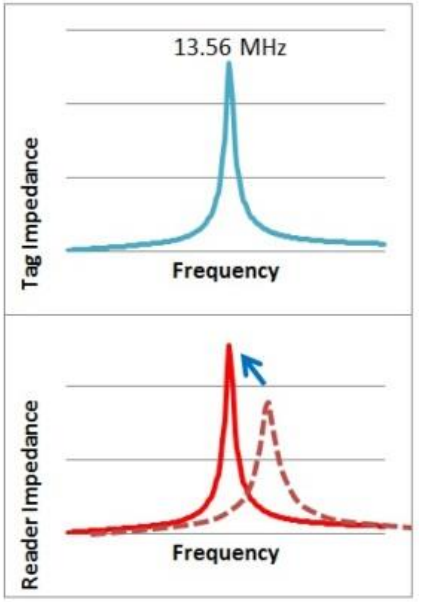


WE-FSFS Flexible Sinterted Ferrite Sheet



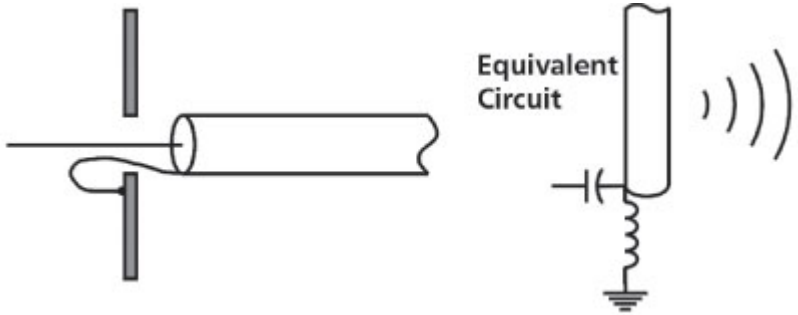






Cable shielding – closer look

- Cable shield is part of the product shield
- Surface conductivity must be high
- Most important is cable termination: The connection between the cable shield and the enclosure must be 360°
- Unproperly terminated cables behave like an antenna

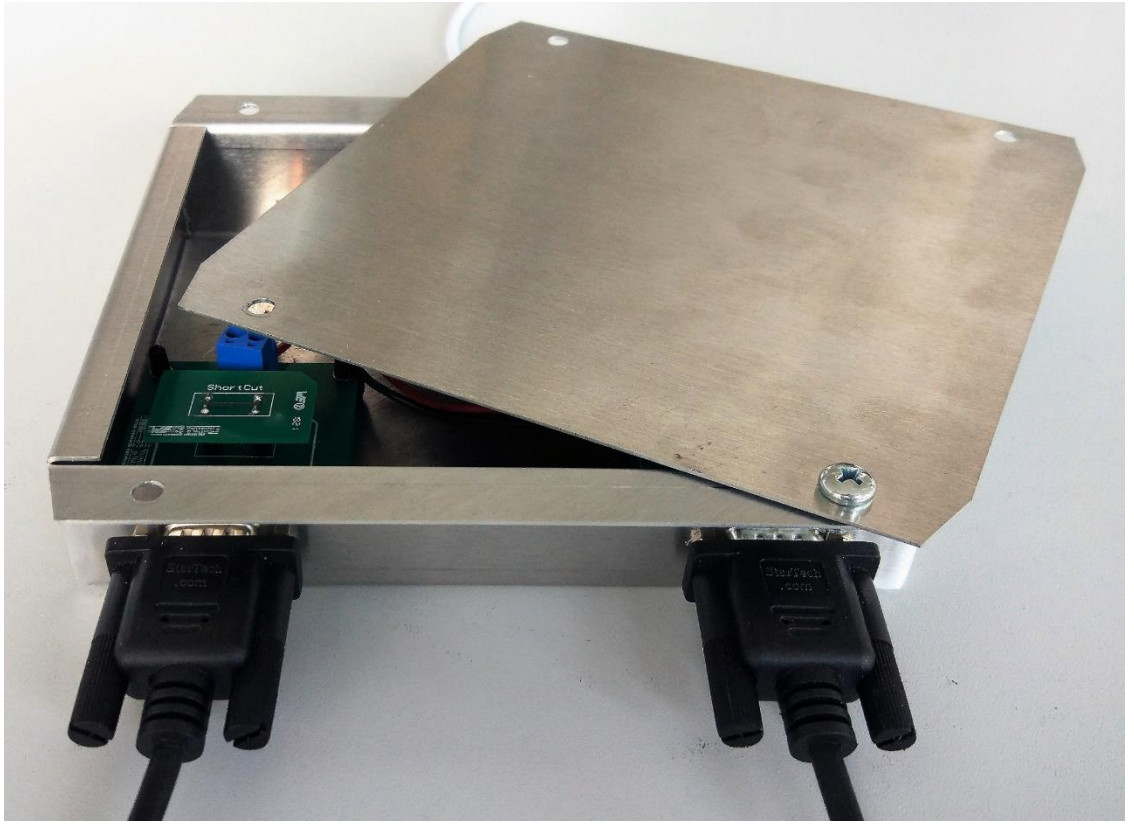


Cable „perfect“ antenna:

- 30 MHz -> λ/4 = 2,5 m
- 3 GHz -> λ/4 = 25 mm

Box characteristics

- Metal enclosure with a removable metal cover and 4 threaded fasteners distributed around the cover to pin up it to the enclosure
- Internal noise source to generate Electromagnetic Interferences.
- Shielding adapters
- Common mode chokes adapters
- 2 DB9 connectors to connect an external cable.
- Supplied by microUSB connection.
- Resistive load
- Box dimensions:
  - 16x16x3.5 cm



Box characteristics

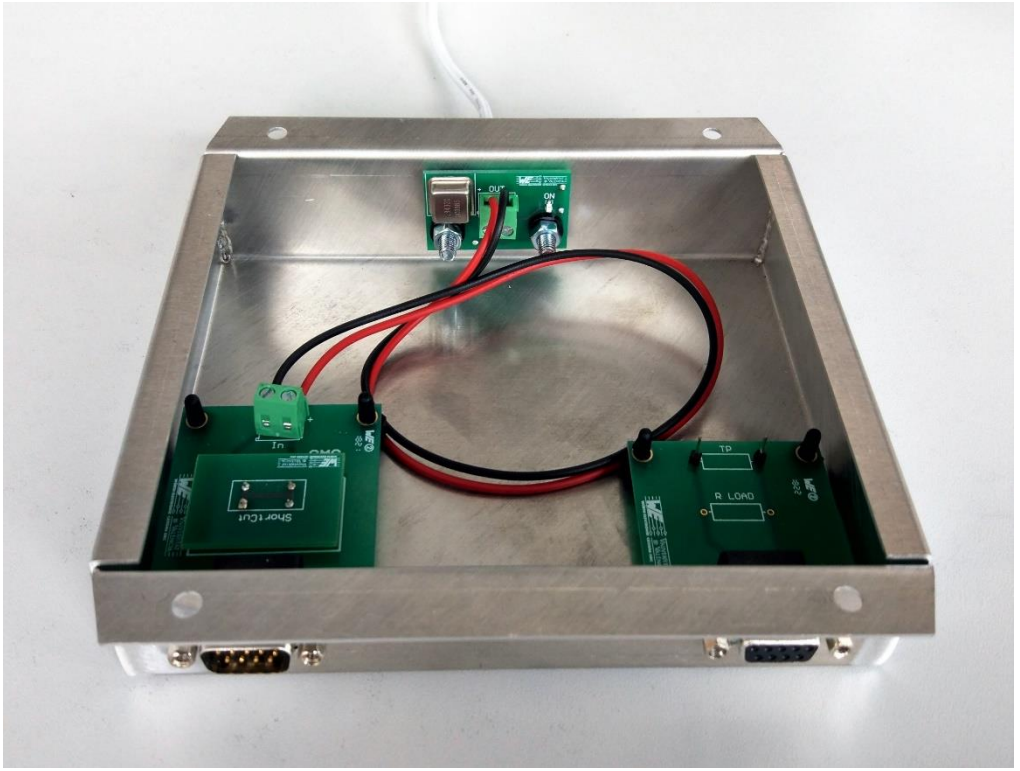
The internal noise source is composed by a high frequency oscillator circuit put inside the enclosure which is configured to generate a 1.8432 MHz square signal.

This oscillator can be replaced by other oscillators with different frequencies.

This setup could generate radiation on the cables and the box. It can also produce conducted emissions in the cable and, therefore, the DSUB connector.

EMC Problems:

- **Radiated emissions through shielded enclosure seams (Slot Antenna)**
- **Radiation in cables**
- **Radiation in DSUB Connector**
- **Radiation in traces**



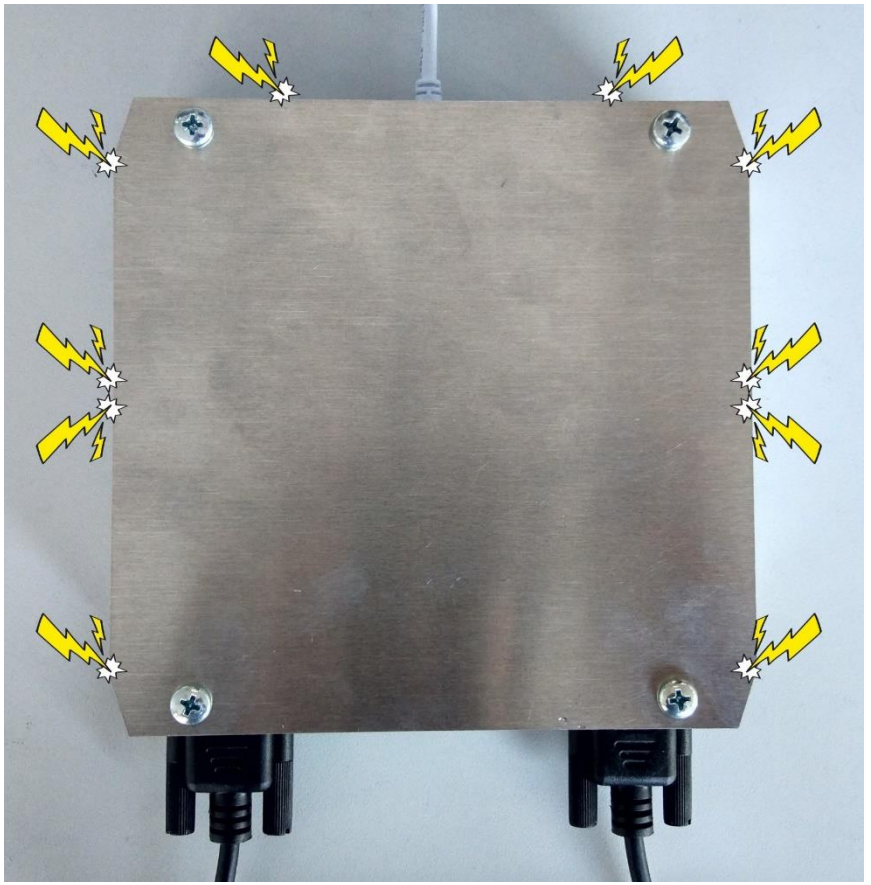
Radiated emissions through seams

When the oscillator circuit is running, radiated emissions appear in the seams through slot antenna around the cover enclosure.

The screws shown on the picture must be placed to connect and pin up the cover to the enclosure in order to directly join them and provide a direct current path in those points.

In the slots between the positions of the screws there are radiation peaks due to the poor connection in the points without screws.

The emissions around the cover have variations due to the cover is not ideal and uniform.



Radiated emissions through seams
Solution: WE Conductive Gasket

The solution is to place a WE conductive gasket between the cover and the enclosure in order to get a transfer voltage close to zero through the seams.

This product is able to distribute the current uniformly around the contacting part of the cover with the enclosure and not only through the screws.

The radiated emissions and, at the end the electromagnetic leakage, is strongly reduced and there is no slot antenna radiation when the gasket is placed.

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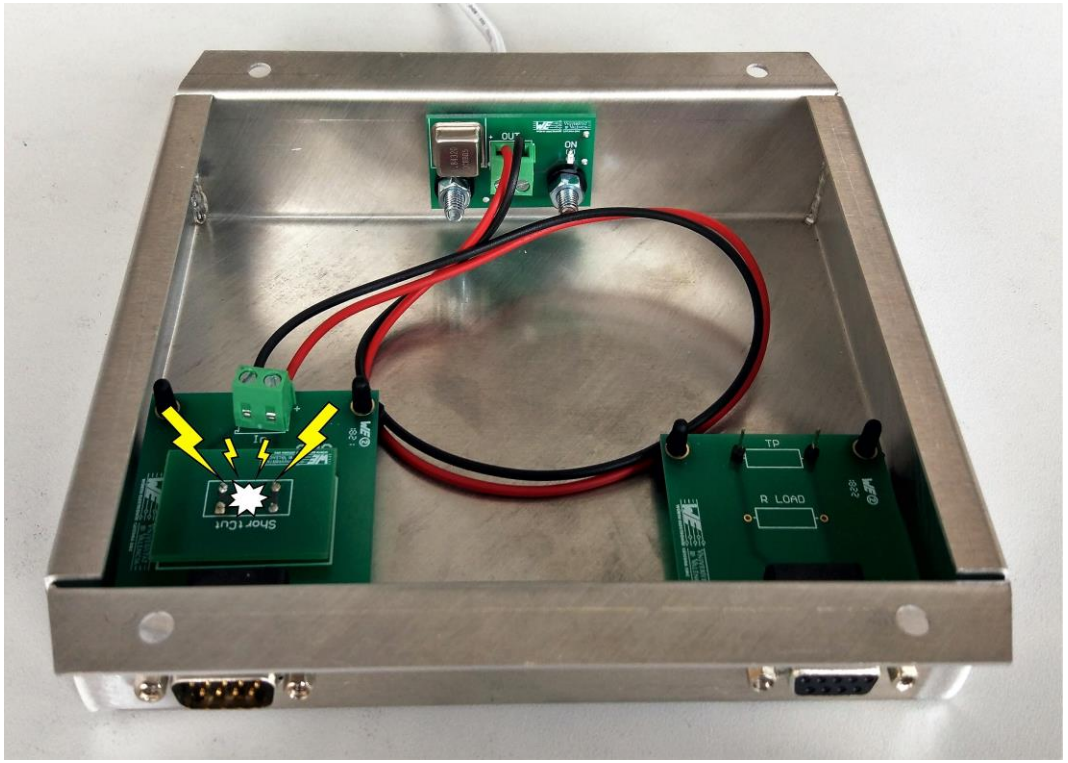
ONE SIDE WITH GASKET

Radiated emissions through Short Cut Adapter

When the oscillator circuit is running, radiated emissions appear in the Short Cut Adapter.

Radiation is generated from the traces and the pads, acting as antennas.



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Coupled noise

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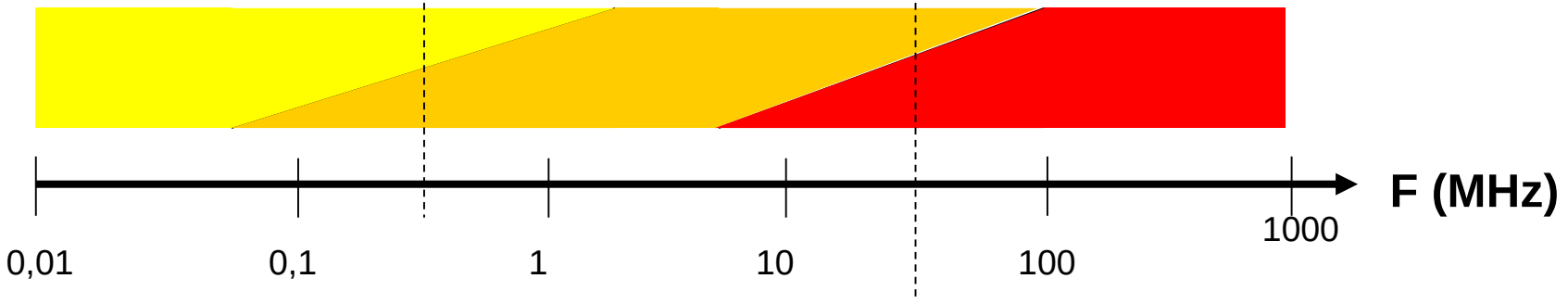
Metal or ferrite foils: *Shielding*

chip bead ferrites



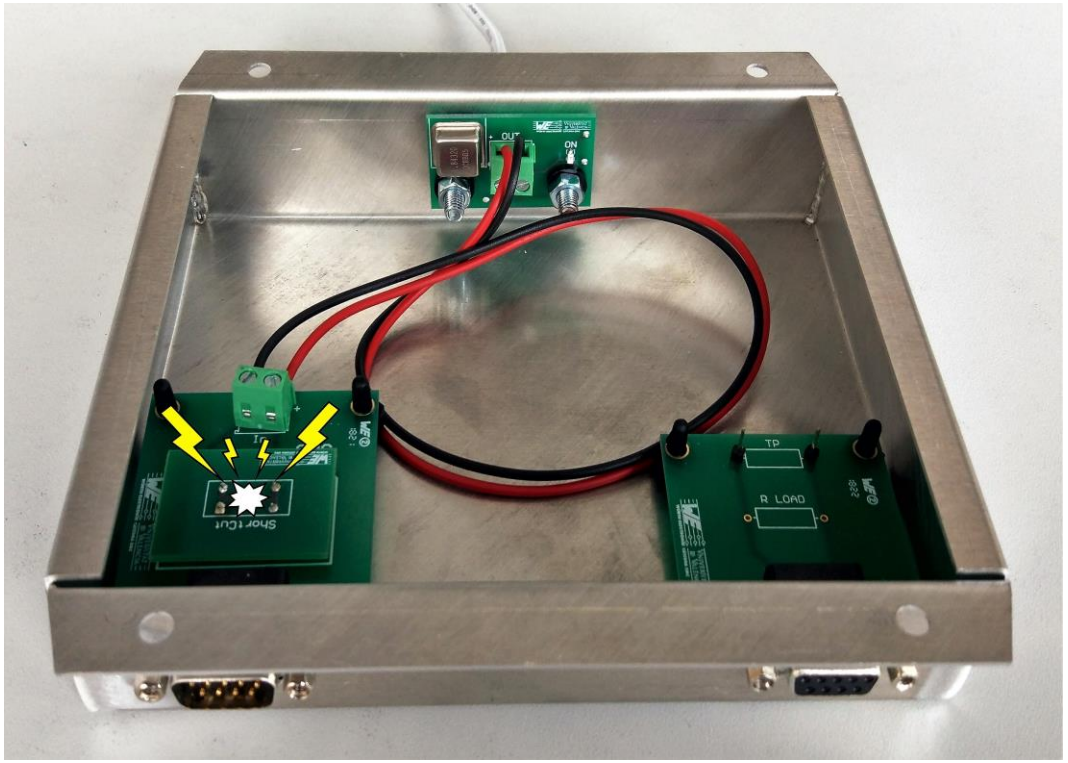
30 MHZ

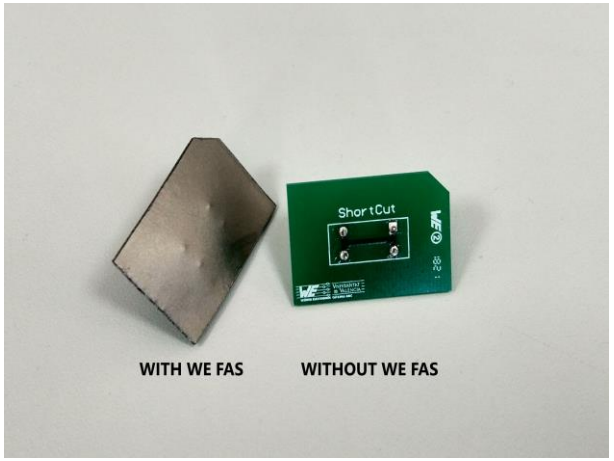
Radiated emissions through Short Cut Adapter
Solution: WE FAS

The solution is to place a WE FAS on the top of the Short Cut Adapter.

This product is able to absorb radiated emissions for near-field applications. The material of the product is flexible and has high permeability

The radiated emissions are reduced by the setting of the WE FAS.





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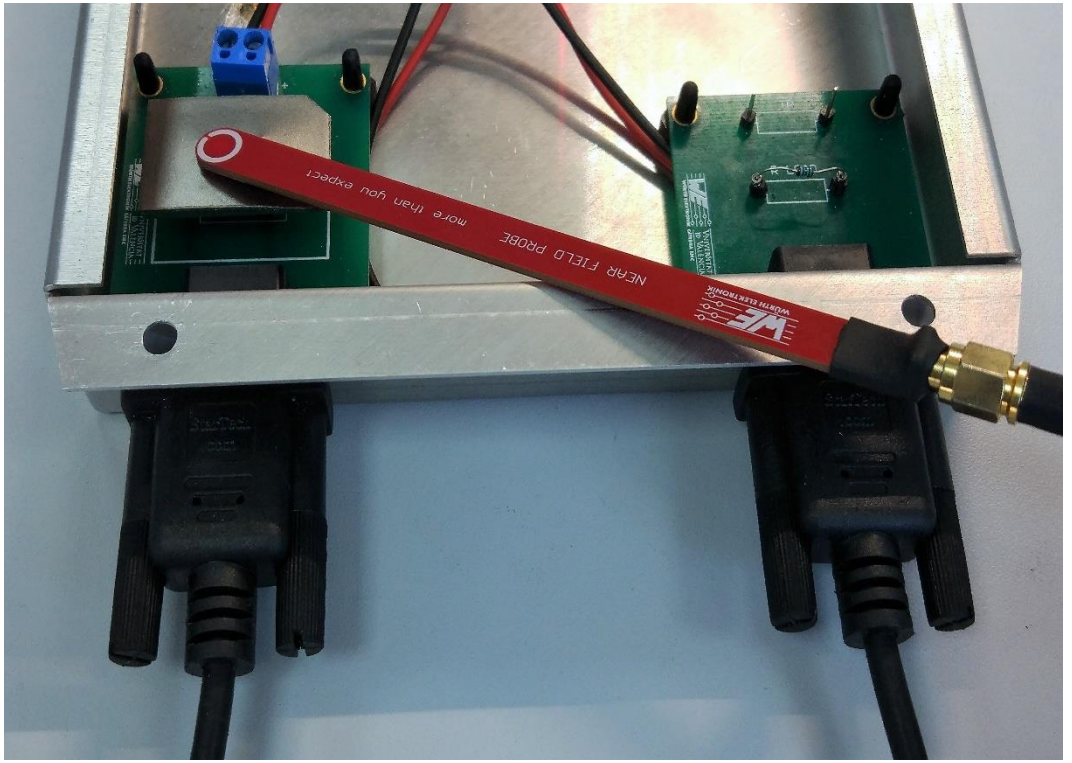
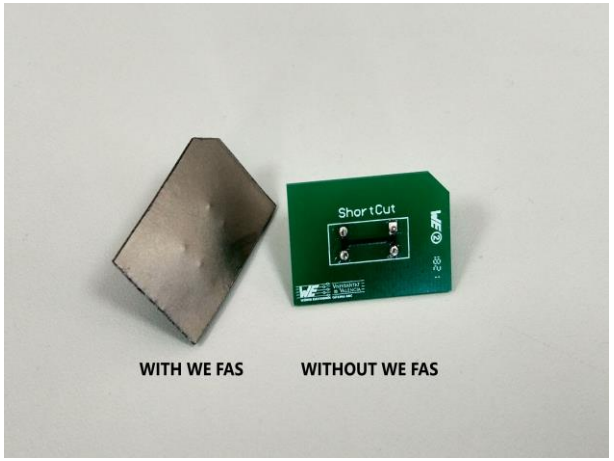




Frequency Range for Conducted and Radiated Noise

Conducted noise

Differential Filters

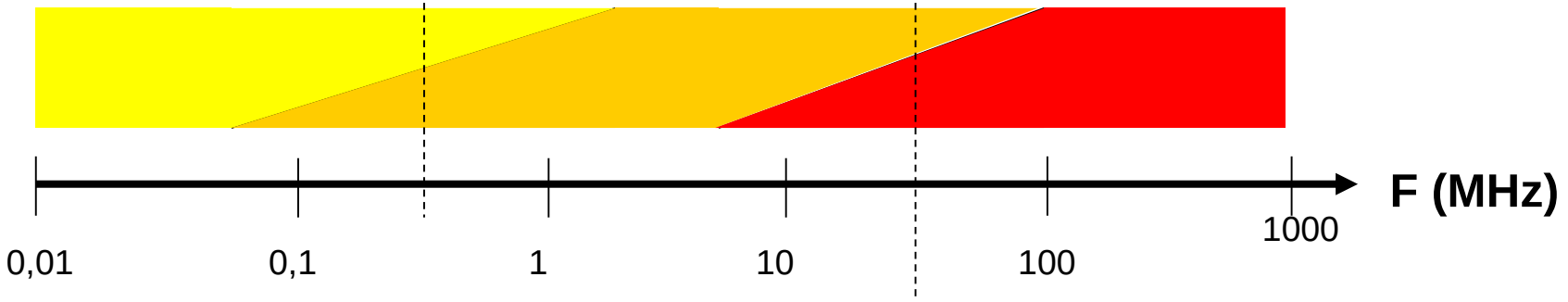
Coupled noise

Common Mode Chokes(*)

Radiated noise

Metal or ferrite foils: *Shielding*

chip bead ferrites



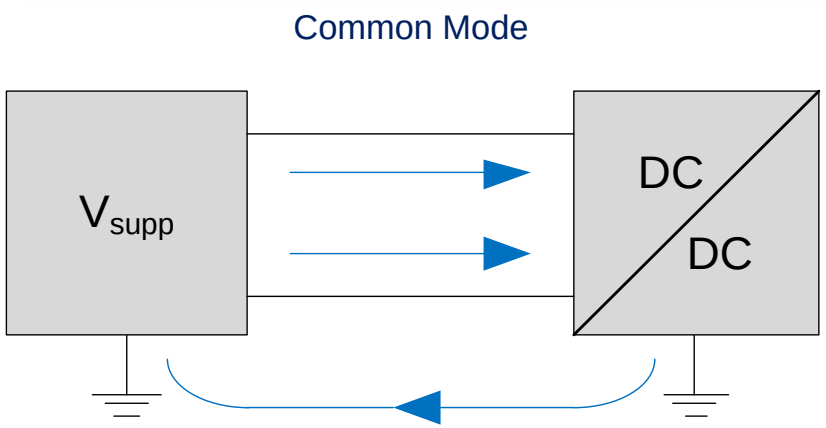
30 MHZ

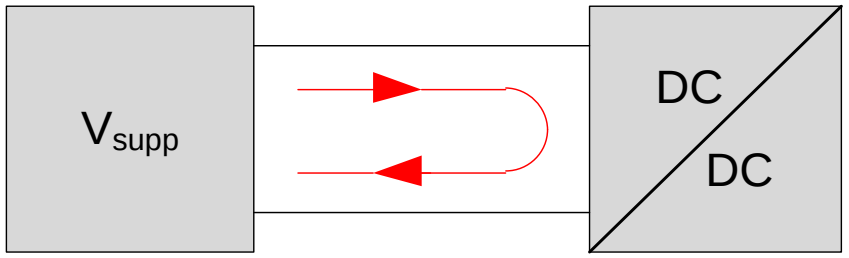
Structured noise suppression

Identification of the interference signal mode:

Common-mode noise

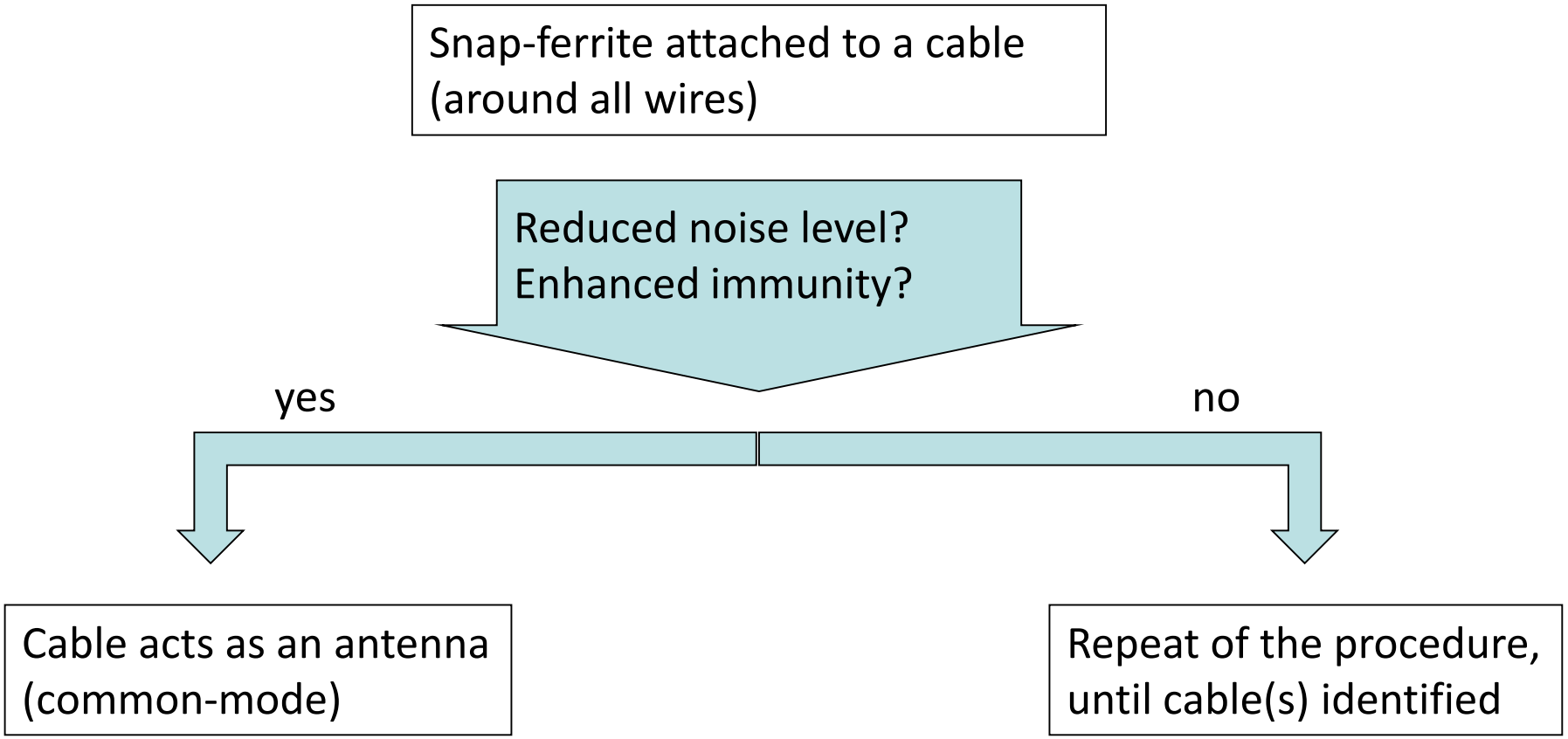
Differential-mode noise





Mode of interference – Identification

EMC laboratory approach:



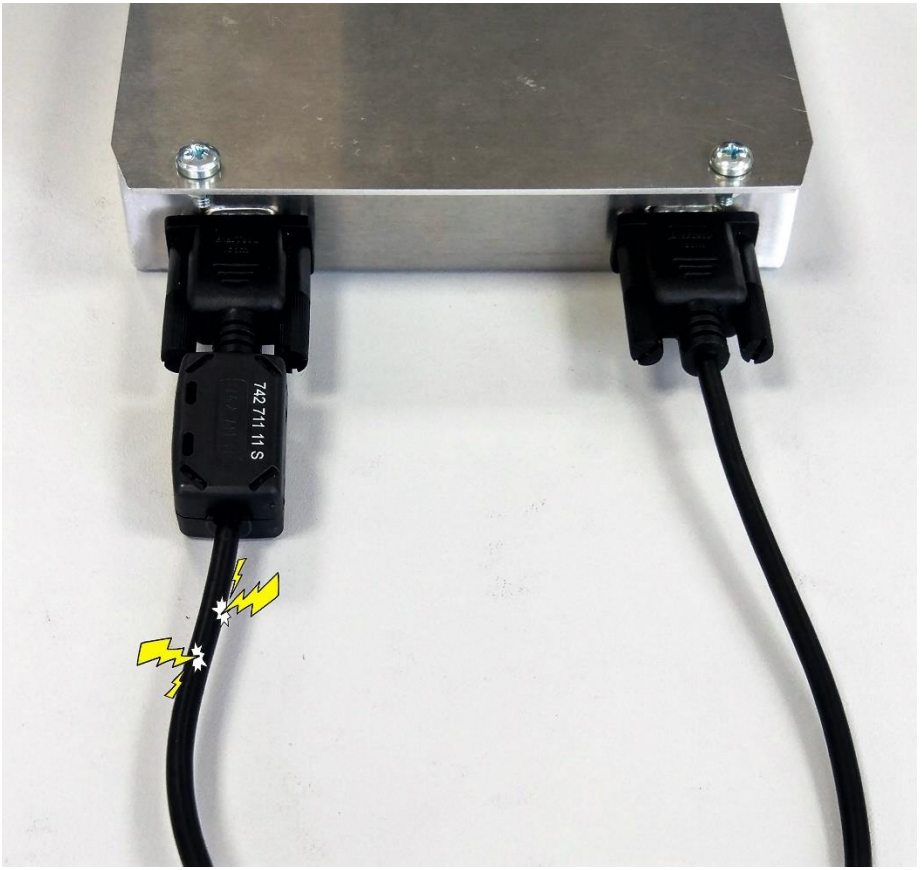
Radiation in cables Solution 2: WE Snap Ferrite

The second proposed solution is to set a WE Snap Ferrite in the external cable.

With this solution the snap ferrite placed absorbs the radiation caused by the common mode current.

In add the solution with this product achieves to reduce the radiation without changing the spectrum of the original signal.

Although it attenuates less the noise than the previous has the advantage of the signal is not changed by the ferrite material.

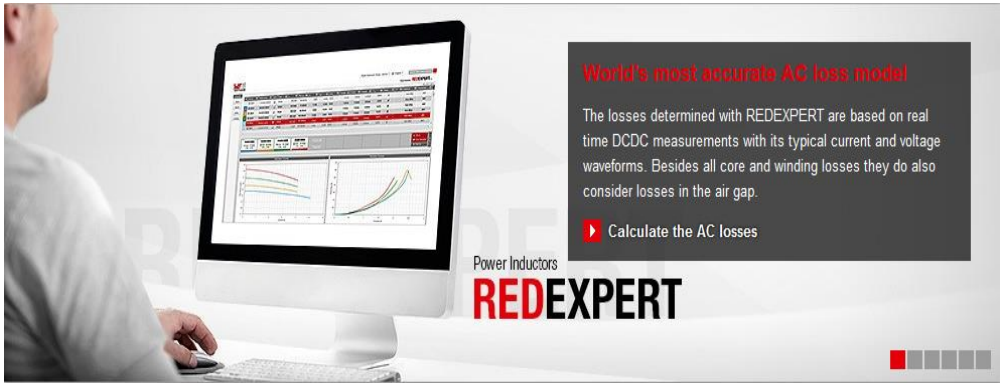


Available tools: RedExpert

REDEXPERT: What is it?

Würth Elektronik - www.we-online.com/ToolBox

- online usable
- live update
- real time calculation
- easy component comparison
- several design tools integrated



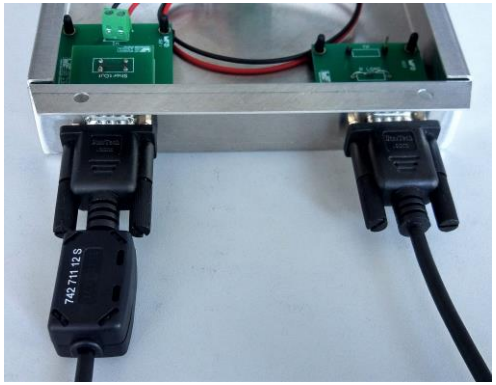
No Calculation
Smart Determination

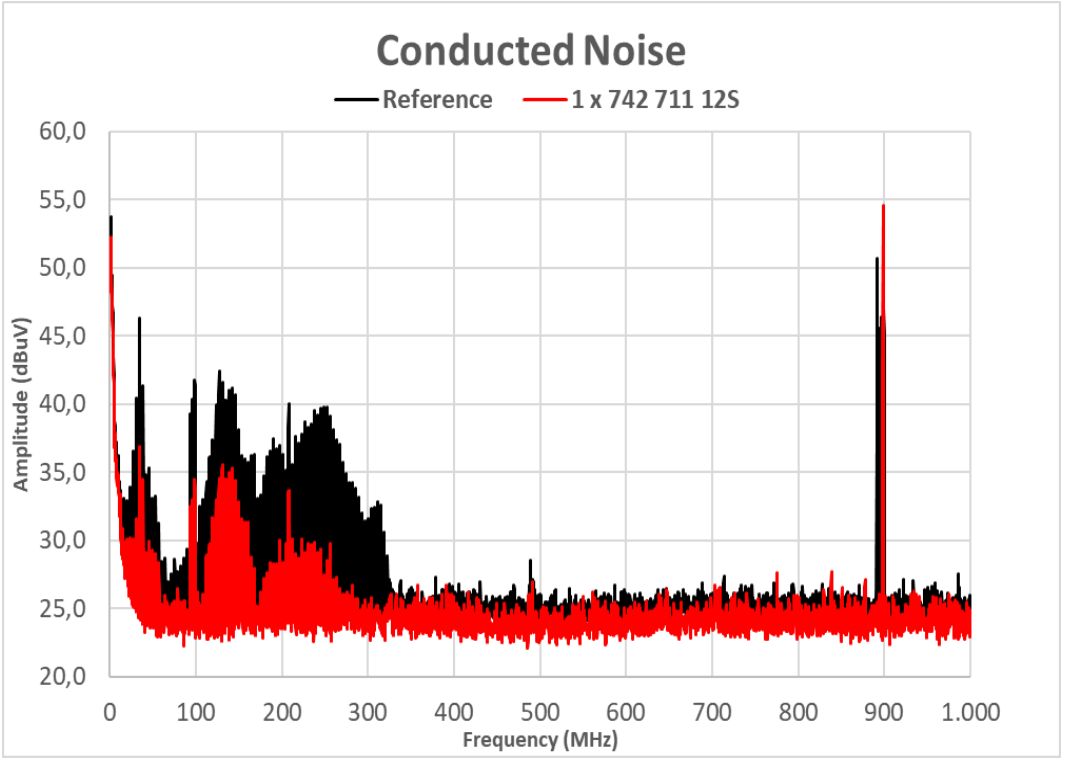
REDEXPERT

Radiation in cables Solution 2: Results

Another example:

WE Snap Ferrite, Ref nº 742 711 12S is used this time, with the resulting figure of the right.

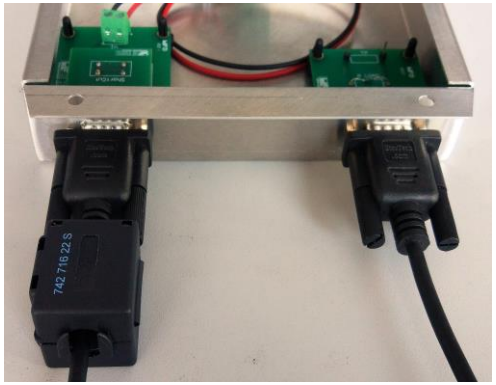


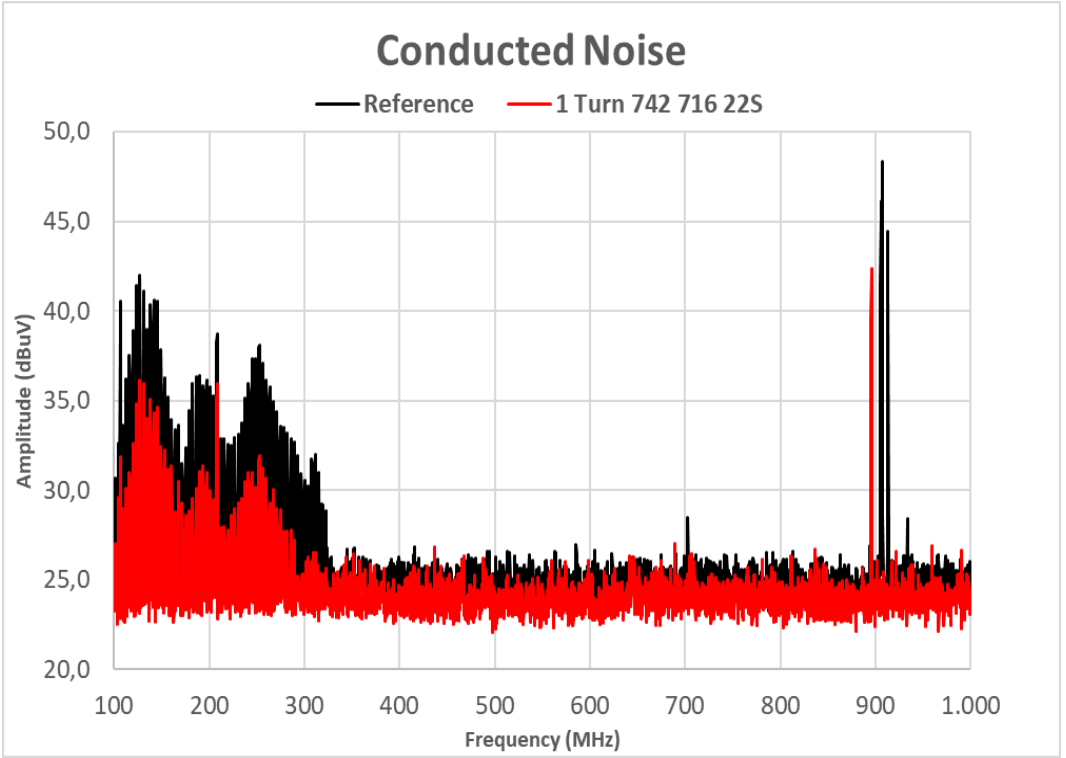


Radiation in cables Solution 2: Results

Another example:

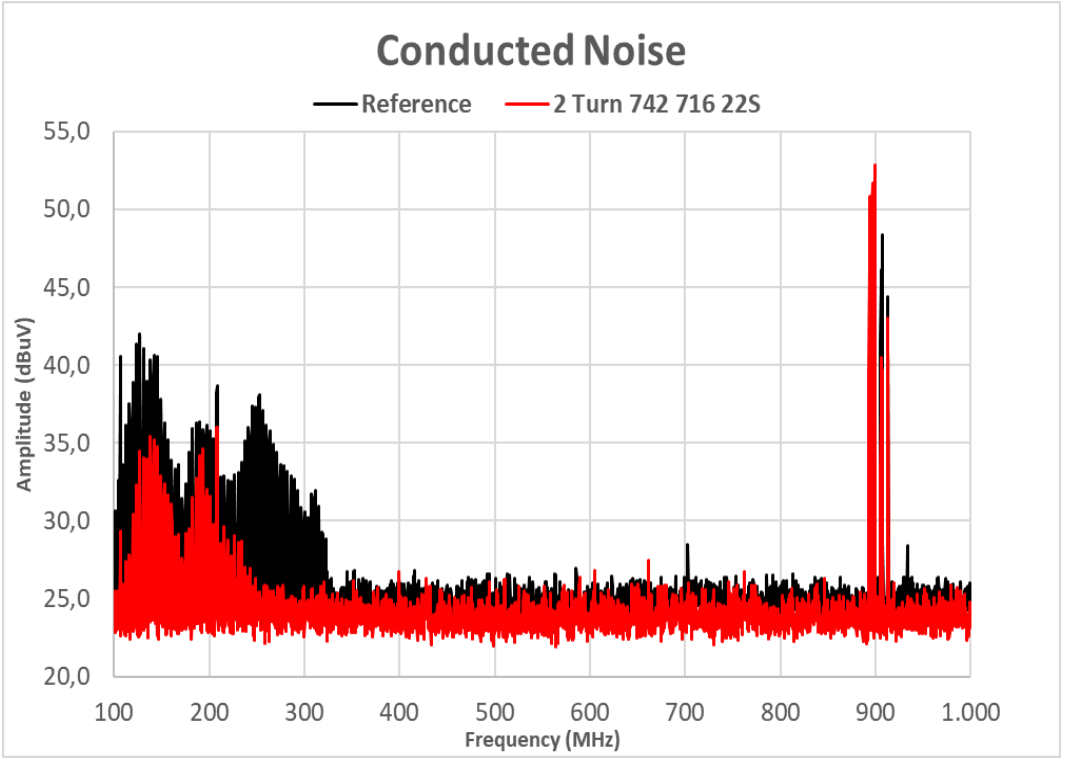
WE Snap Ferrite, Ref nº 742 716 22S is used this time, with the resulting figure of the right.





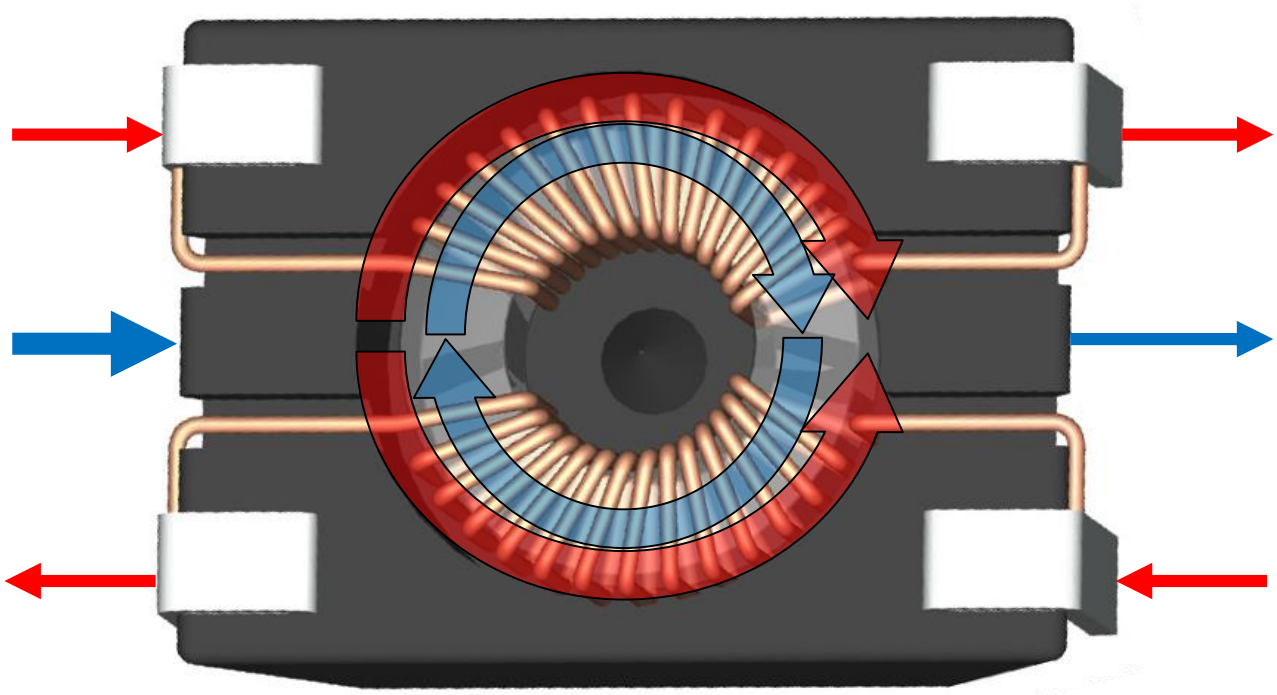
Radiation in cables Solution 2: Results

Now with two turns/two Snap Ferrites with WE Snap Ferrite, Ref nº 742 716 22S.



Common-mode choke – Signal theory

Bidirectional filter element:



- Compensation of the main magnetic flux induced by the intended DM signal
- Attenuation of an unintended CM noise signal by reflection and absorption

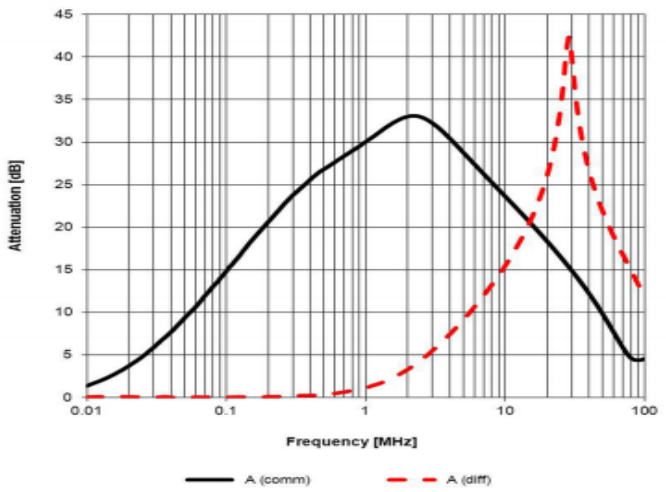
Radiation in cables Solution: WE Common Mode Choke

So next proposed solution is to include a **WE Common Mode Choke** (CMC) in the part that connects the internal circuit with the external cable (before the DB9 connector).

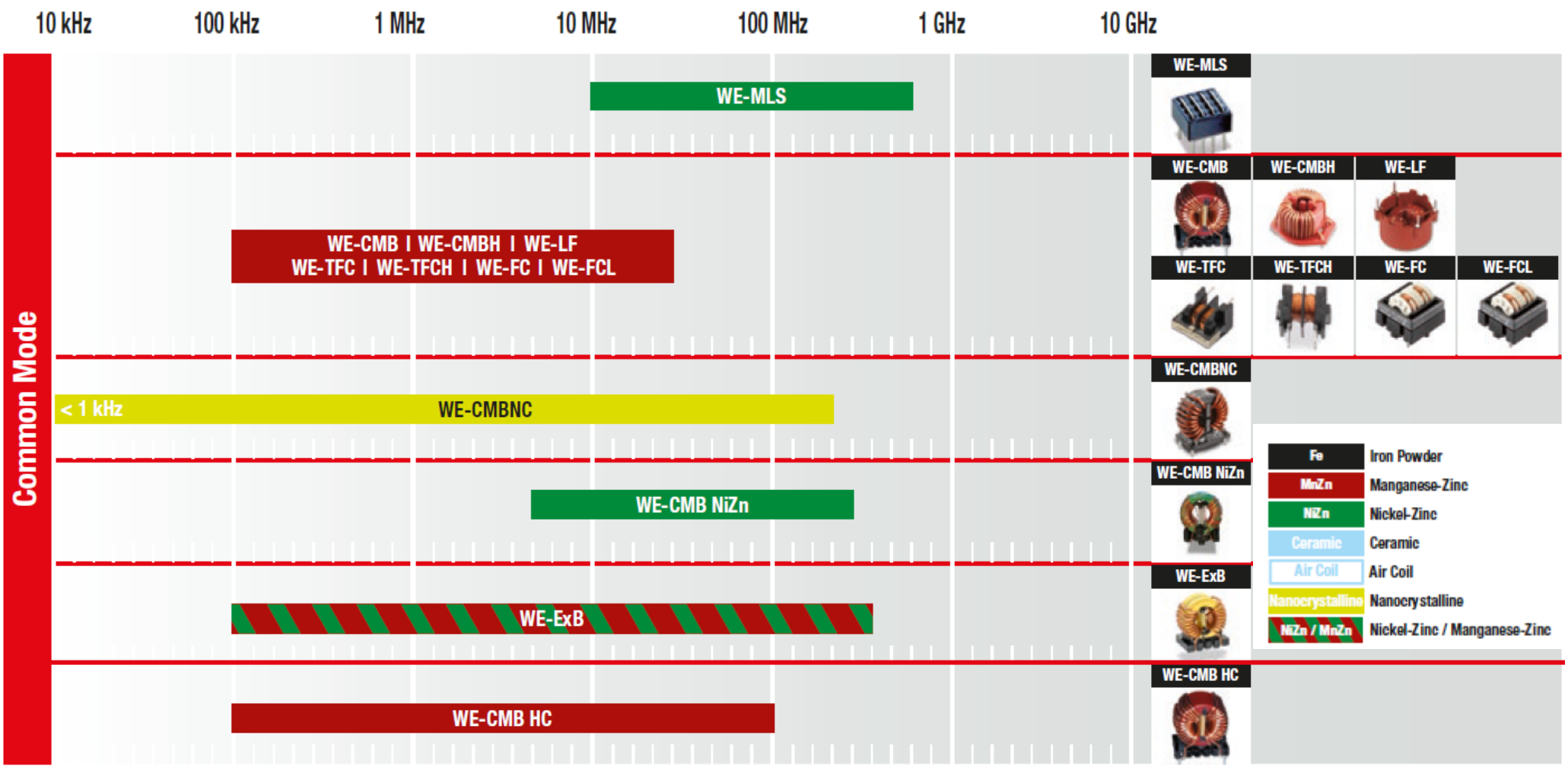
CMC works blocking through a huge impedance the noisy frequency components.

By placing it into the circuit all the high-frequency components can be reduced without modifying the original signal and decreasing considerably all the noise.

This solution is elegant because it achieves to reduce the noise without affecting the original signal. However, it has the disadvantage of that the internal circuit has to be redesigned.



Core material – Common Mode Chokes



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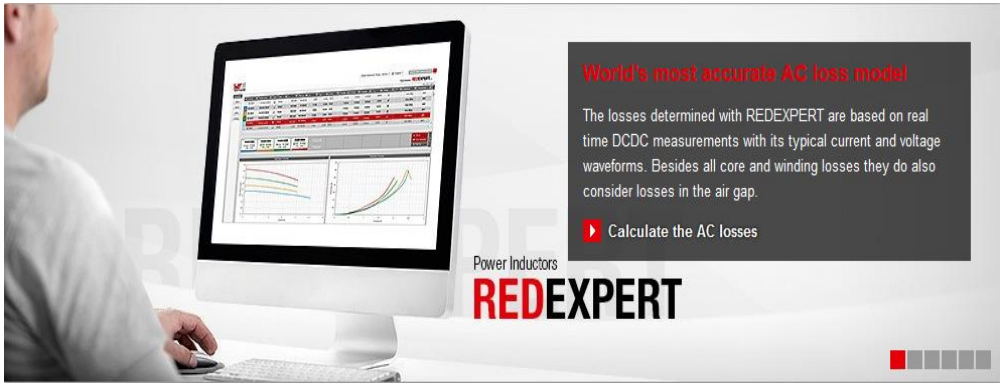


No Calculation
Smart Determination

REDEXPERT

Radiation in cables Solution CMC: Results

In order to test this solution, the desired WE Common Mode Choke has to be placed with the adapter (figures below the text) to the circuit as the figures of the right shows.

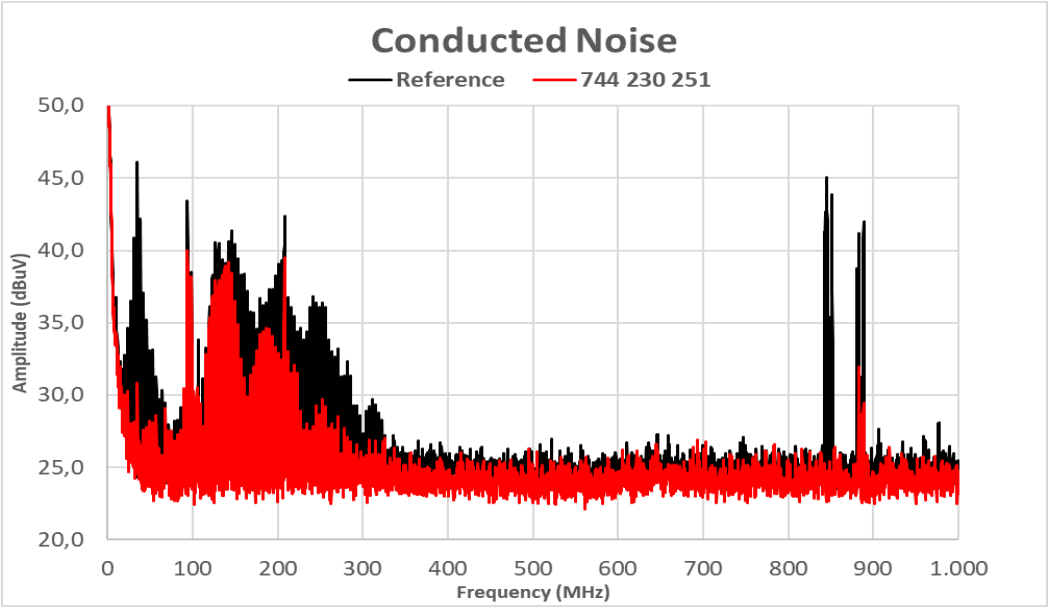
CMBNC
SIZE XS

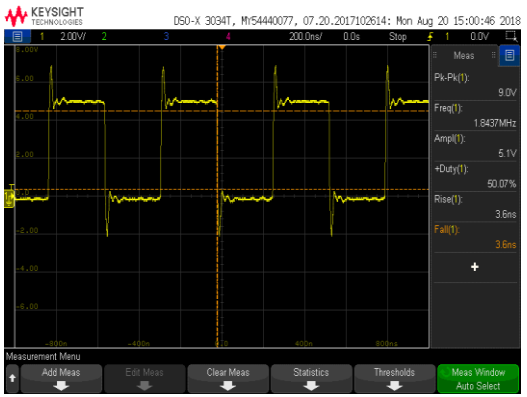
CNSW
SIZE 0603

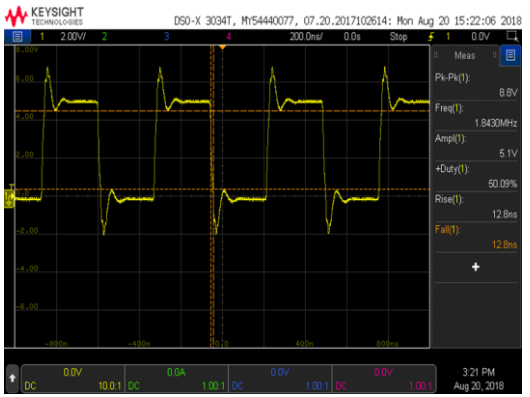
Radiation in cables Solution CMC: Results

Another example:

Now with WE Common Mode Choke CNSW Size 0603, Ref nº 744 230 251. It has a impedance of 250 Ω at 100 MHz.







Radiation in cables Solution CMC: Results

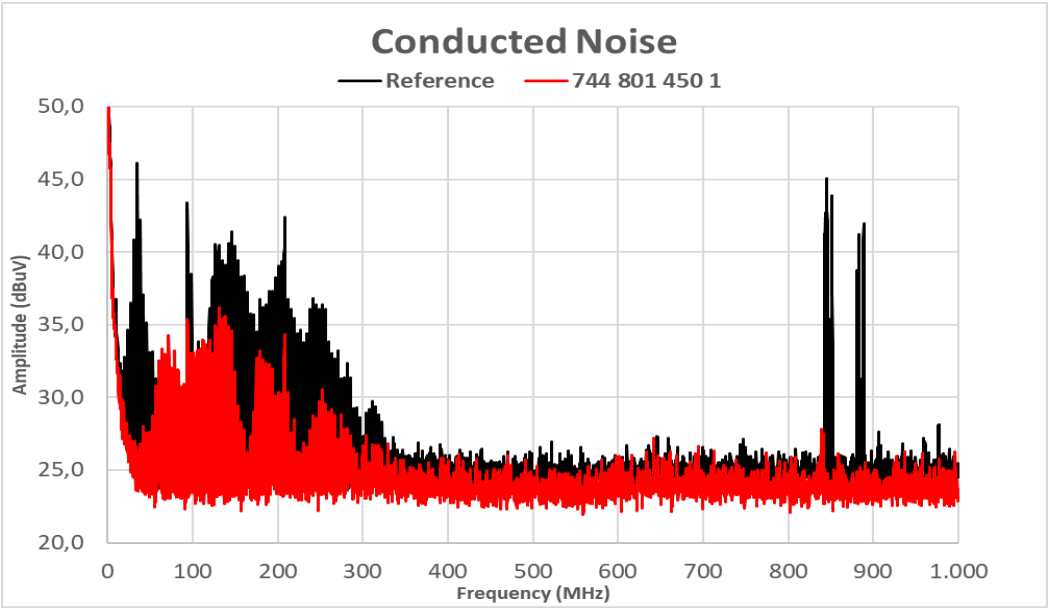
	MnZn ferrite	NC ferrite
Initial permeability μ_i	800…15000	4000…150000
Operating temperature ϑ_{op}	<120°C	<150°C
Saturation induction B_{sat}	<480mT	>1.2T
Curie temperature ϑ_C	150°C…200°C	>600°C
Coercivity H_C	5A/m…60A/m	<3A/m
Core losses p_{core} (100kHz,300mT,100°C)	140W/kg	80W/kg

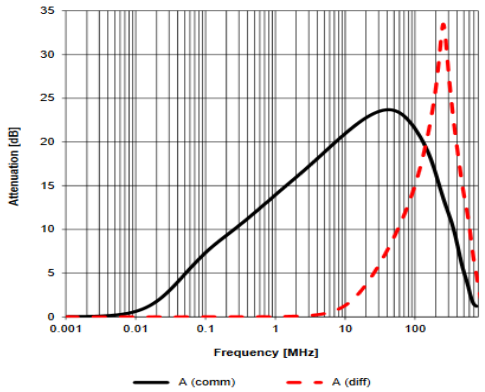
Radiation in cables Solution CMC: Results

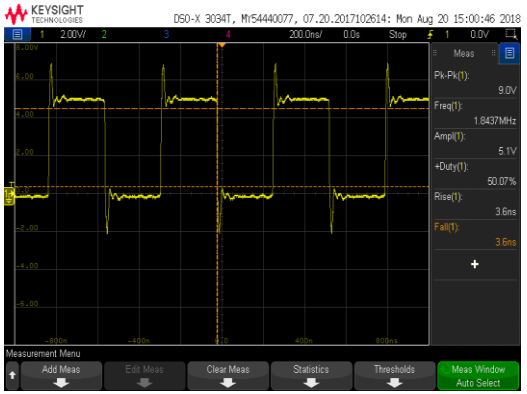
Another example:

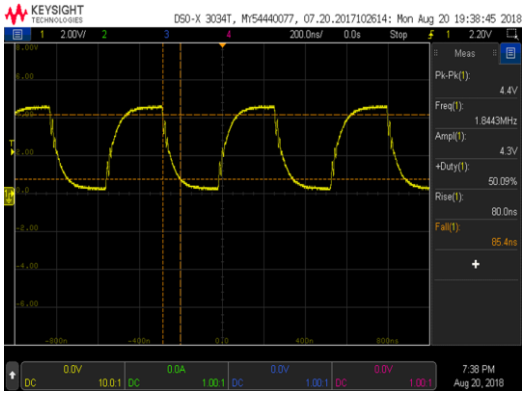
This solution attenuates the noise at the same frequency than our system, this modifies the signal how it is observable on the bottom figures of the signal.

WE Common Mode Choke CMBNC Size XS, Ref nº 744 801 450 1 (0.4mH) is used this time, with the resulting figures of the right.





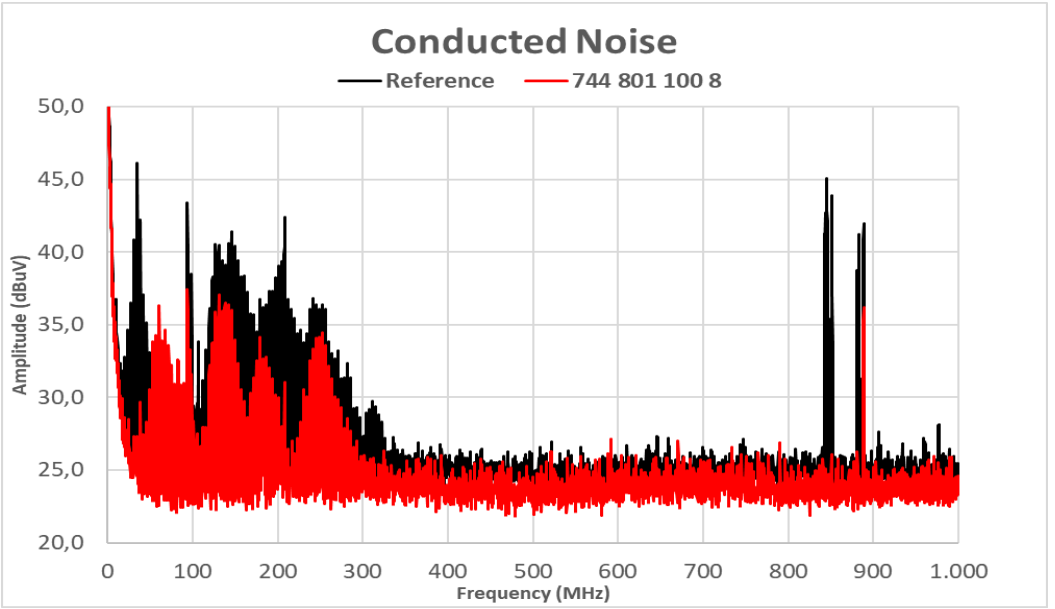


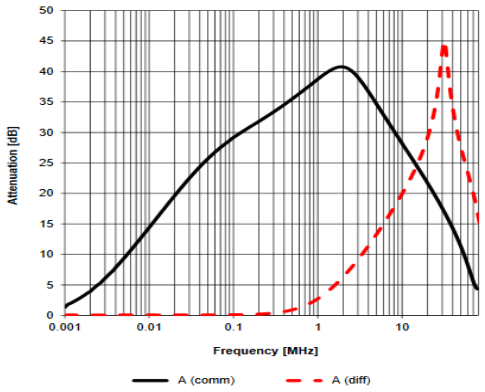


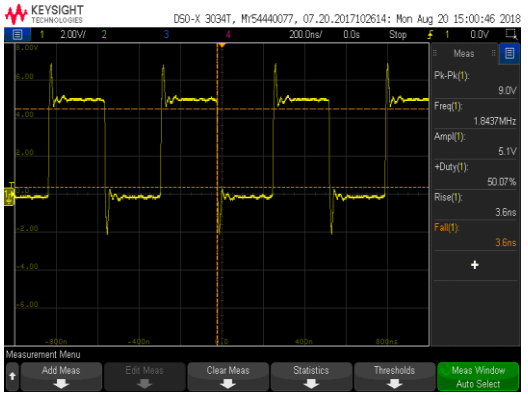
Radiation in cables Solution CMC: Results

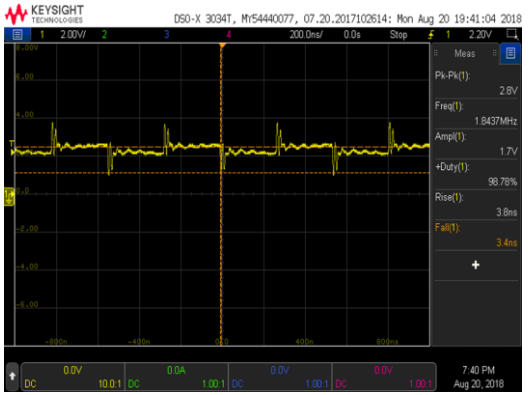
Now with WE Common Mode Choke CMBNC Size XS, Ref nº 744 801 100 8 (8mH).

As it is observable, for a higher impedance the signal get worse. (differential mode impedance!)









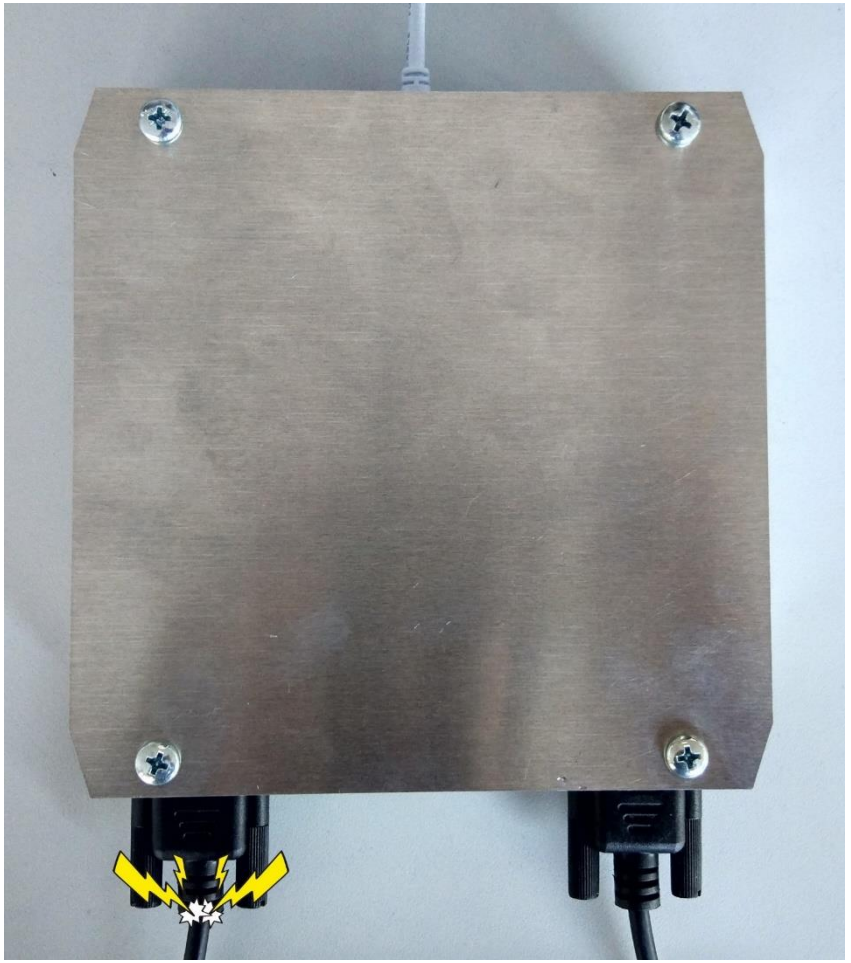
Radiation in cables

The second kind of problem is the directly dependence on edge time signal and common-mode currents with radiation in cables.

This problem can be studied by the measuring on the external cable without shielding.

The radiation spectrum of the external cable measured with a NFP shows a lot of frequency components.

These emissions are generated, mostly, by the common mode current in the cable, due to the different length of reference and signal leads.

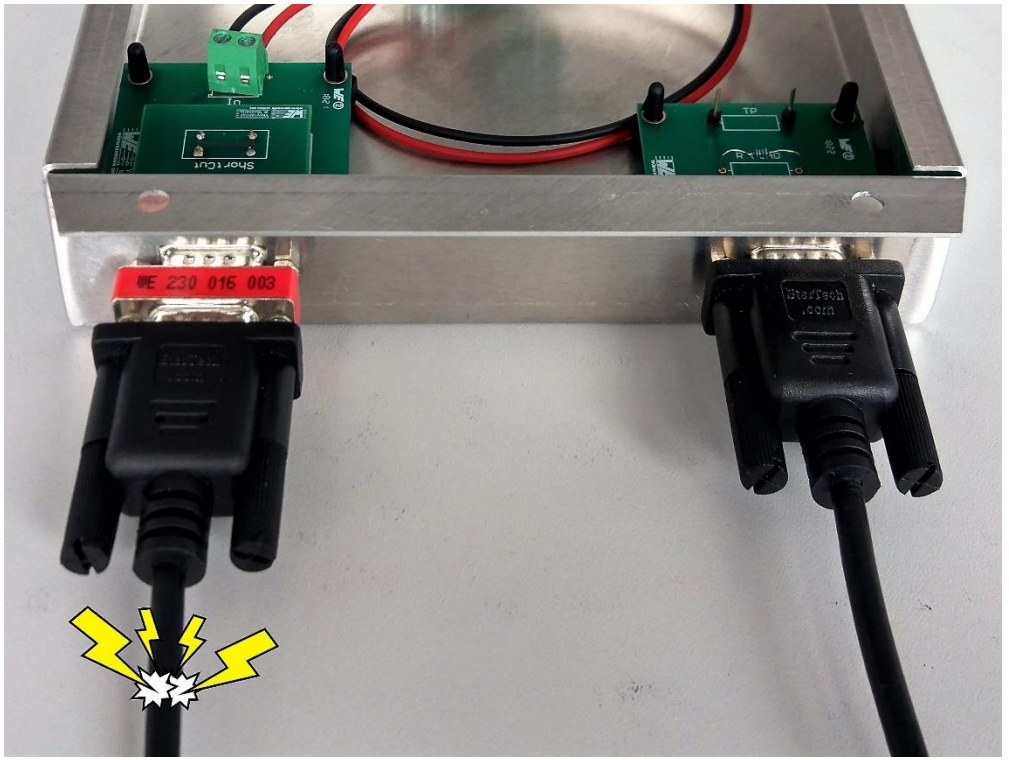


Radiation in cables Solution 1: WE DB9 Filters

The first proposed solution is to set one WE DB9 in the enclosure output connector.

These filters are designed in order to apply a low-pass filter trimming down high-frequency spectrum of the signal. It also delays the rise/fall times to reduce all the frequency components (the noise).

By the setting of the filters, the high frequencies can be filtered and the fundamental peak is reduced although the signal may be modified.



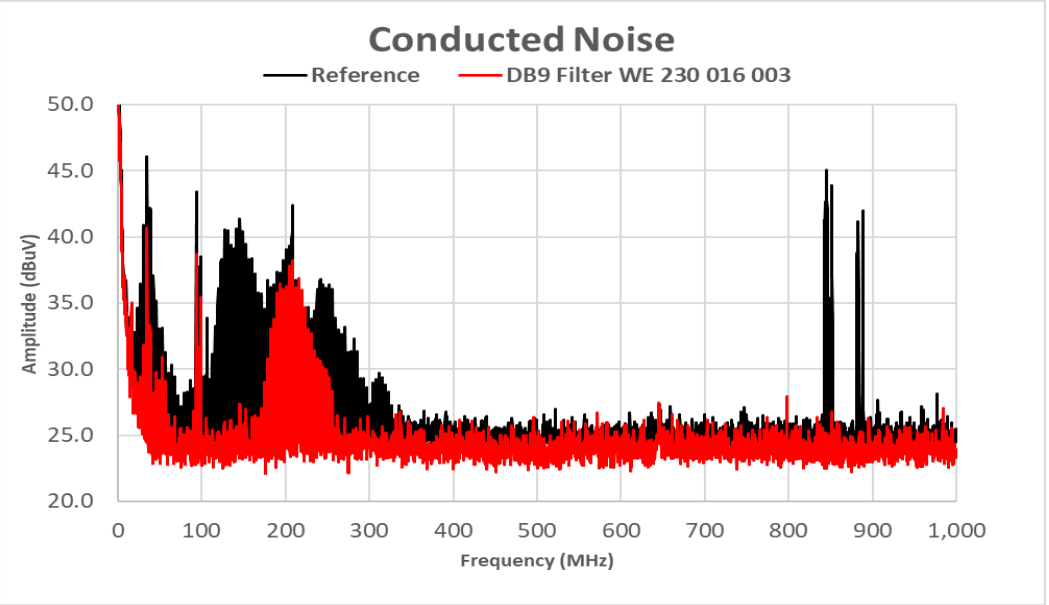
Radiation in cables Solution 1: Results

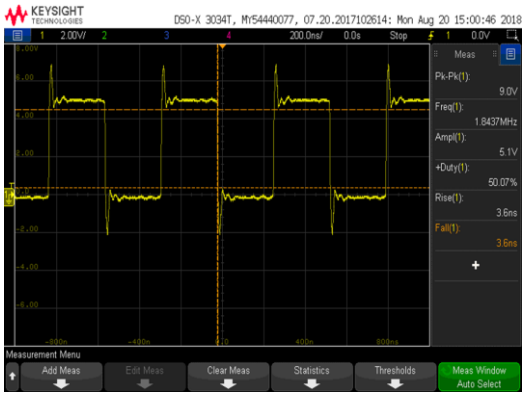
In the figure of the right, the yellow trace shows the measurement on the cable without any solution.

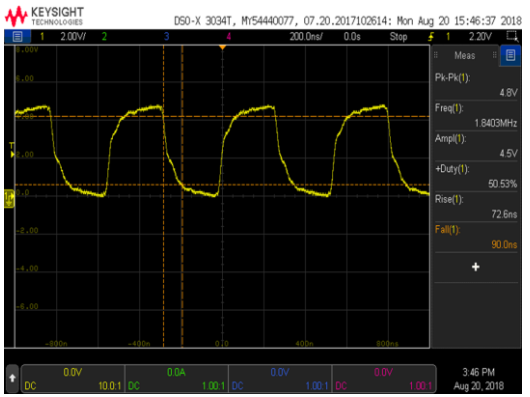
The blue trace shows the signal generated by the measurement of the first solution.

The figures of the bottom show the original signal measured on the load (left) and the figure on the right shows the degraded signal caused by the connection of the external cable to the DB9.

As can be observed, with the **WE DB9 Filter** the noise has been reduced but the signal has been modified.

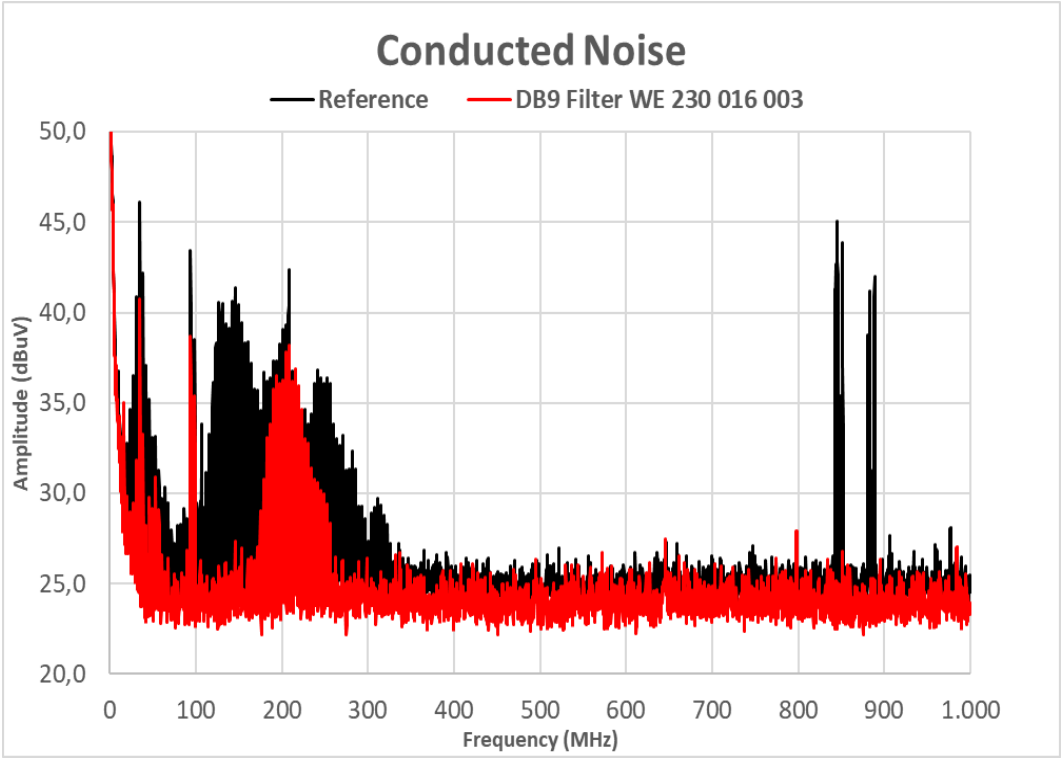






Radiation in cables Solution 2: Results

The WE DSUB-RF-Sealed Caps (black) achieves to diminish the radiated emissions through the connector as the red trace on the picture shows.



Pytania

KONFERENCJA
EMC FOR BUSINESS

Zakłócenia promieniowane ograniczanie i przeciwdziałanie

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piotr.gierwiatowski@we-online.com

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