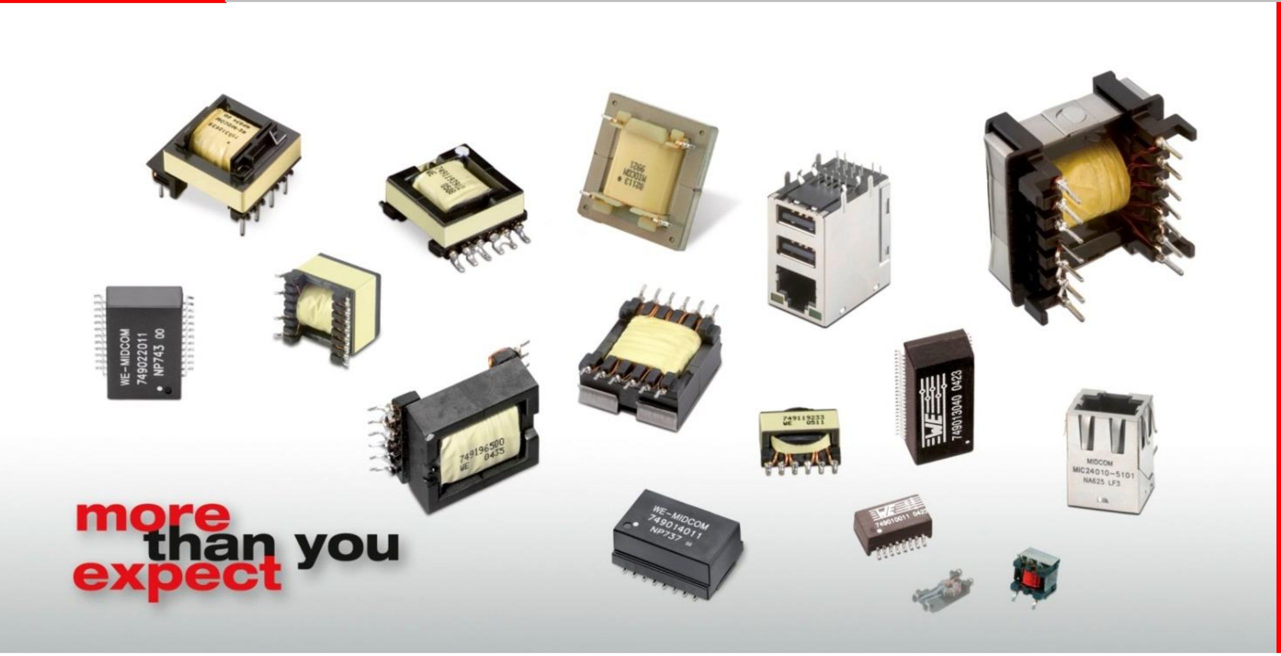
Wurth Electronics Midcom EMI

2017

WURTH ELECTRONICS MIDCOM INC.



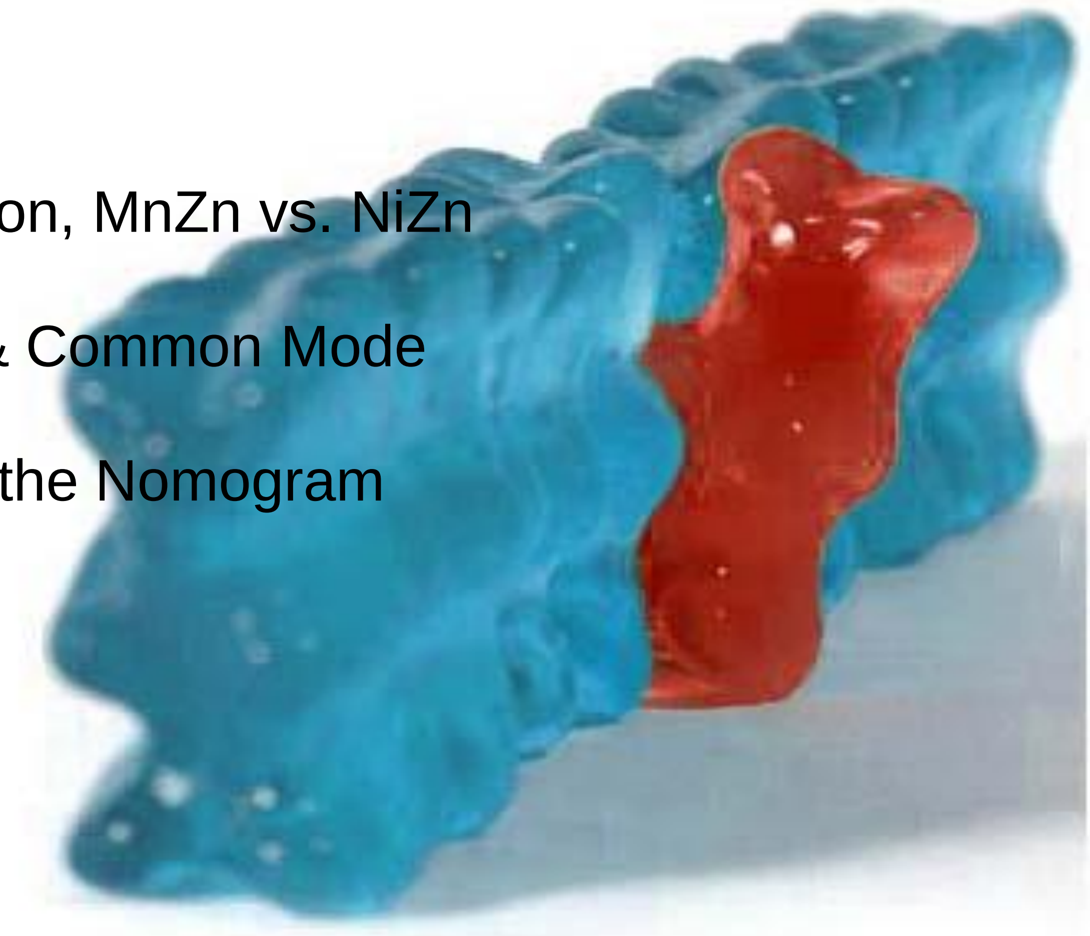
Presentation EMC, Inductors, & filtering

Speaker: Douglas A. Toth, PE

doug.toth@we-online.com

Agenda

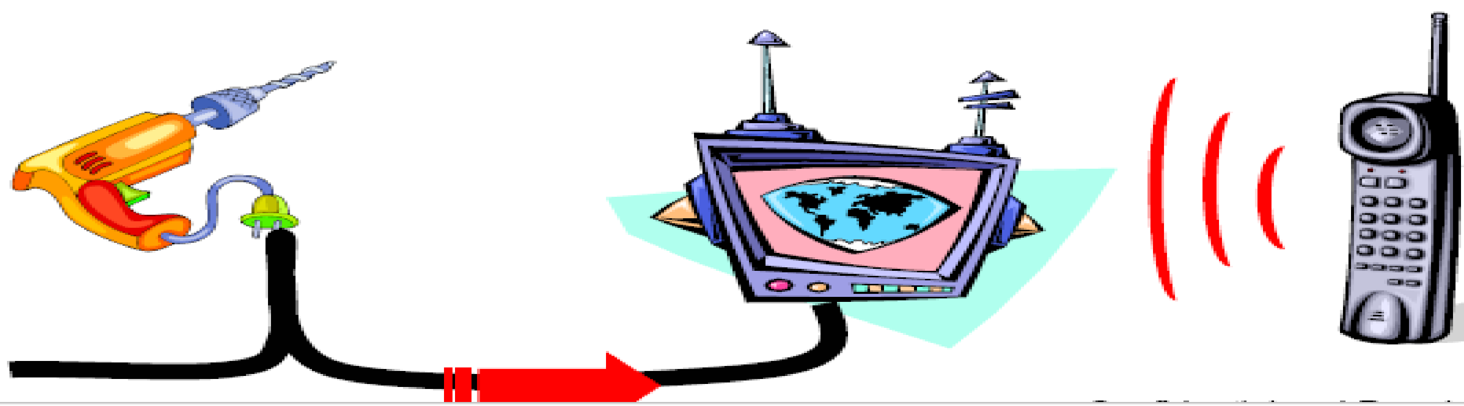
- EMC- basics
- Magnetic field basics
- Material basics Powdered Iron, MnZn vs. NiZn
- Filtering, Differential Mode & Common Mode
- Analyzing Impedance using the Nomogram



EMC - requirement

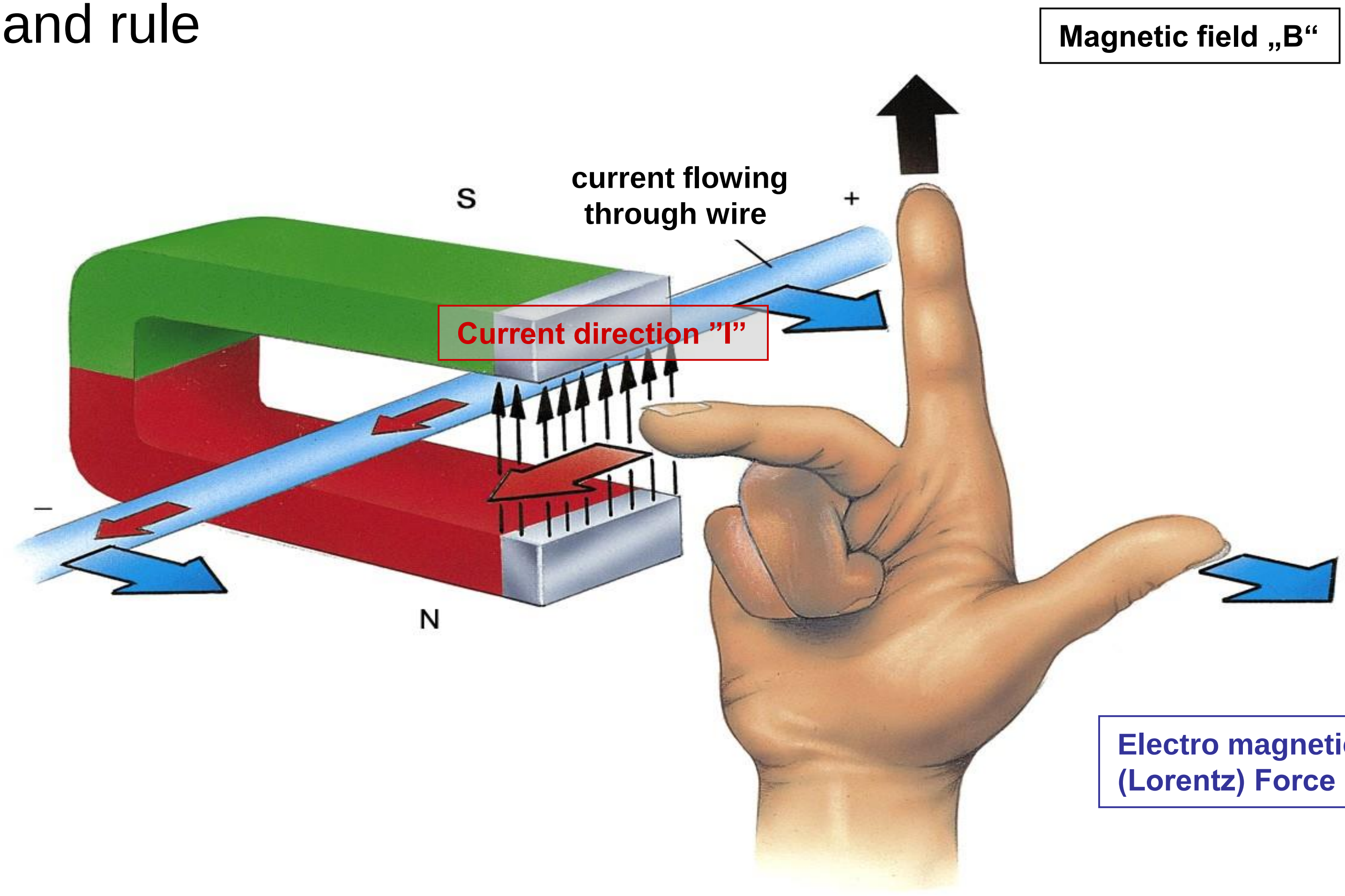
Electromagnetic Compatibility

- Emission
  - Conducted Emission
  - Radiated Emission
- Immunity
  - Conducted Suscept.
  - Radiated Suscept.



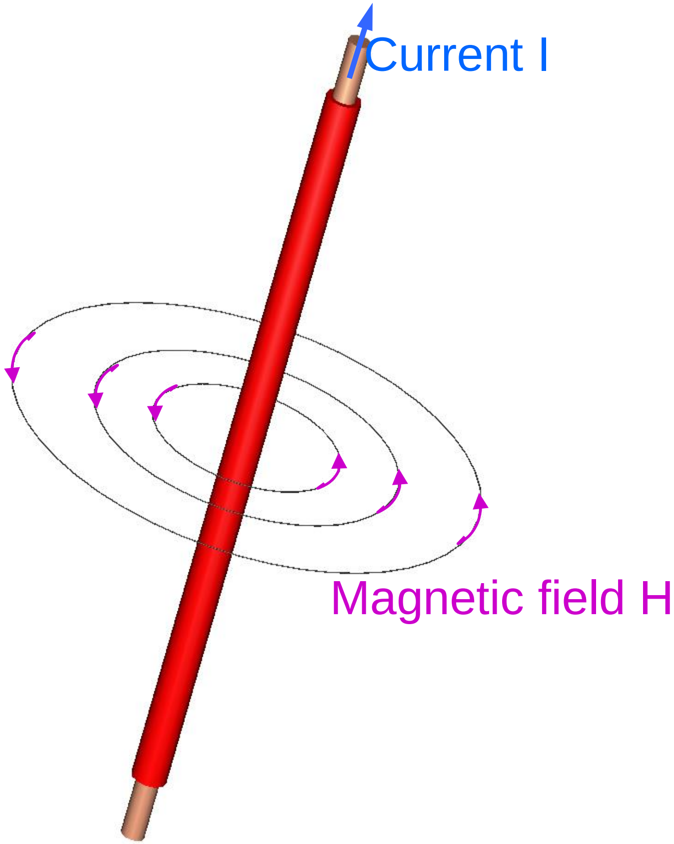
Magnetic field

- Right-hand rule



Magnetic Field

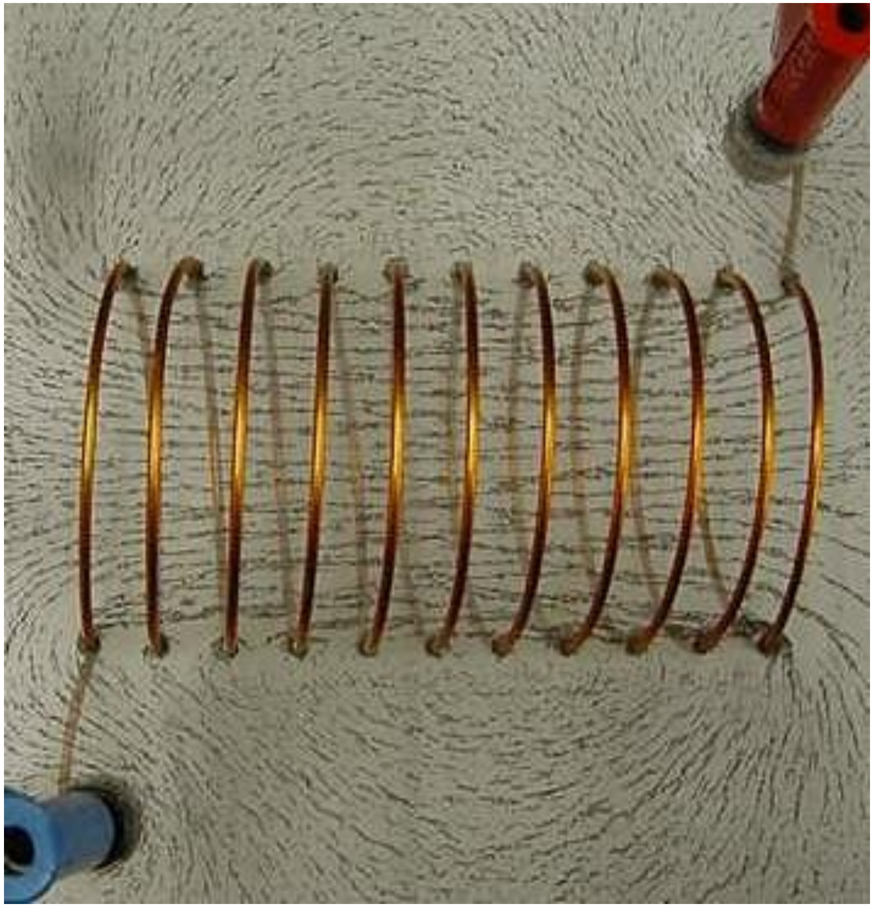
Current conducted wires are generate a magnetic field around them



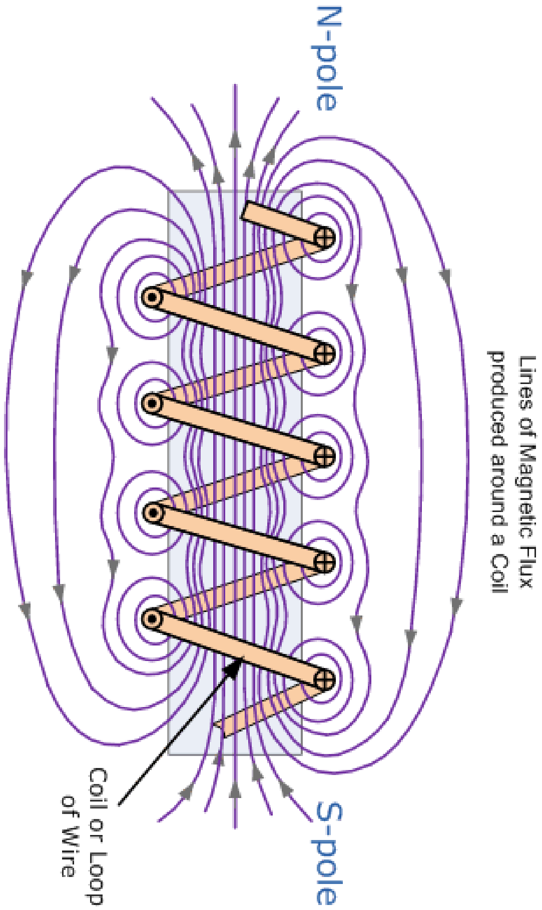
Magnetic flux lines

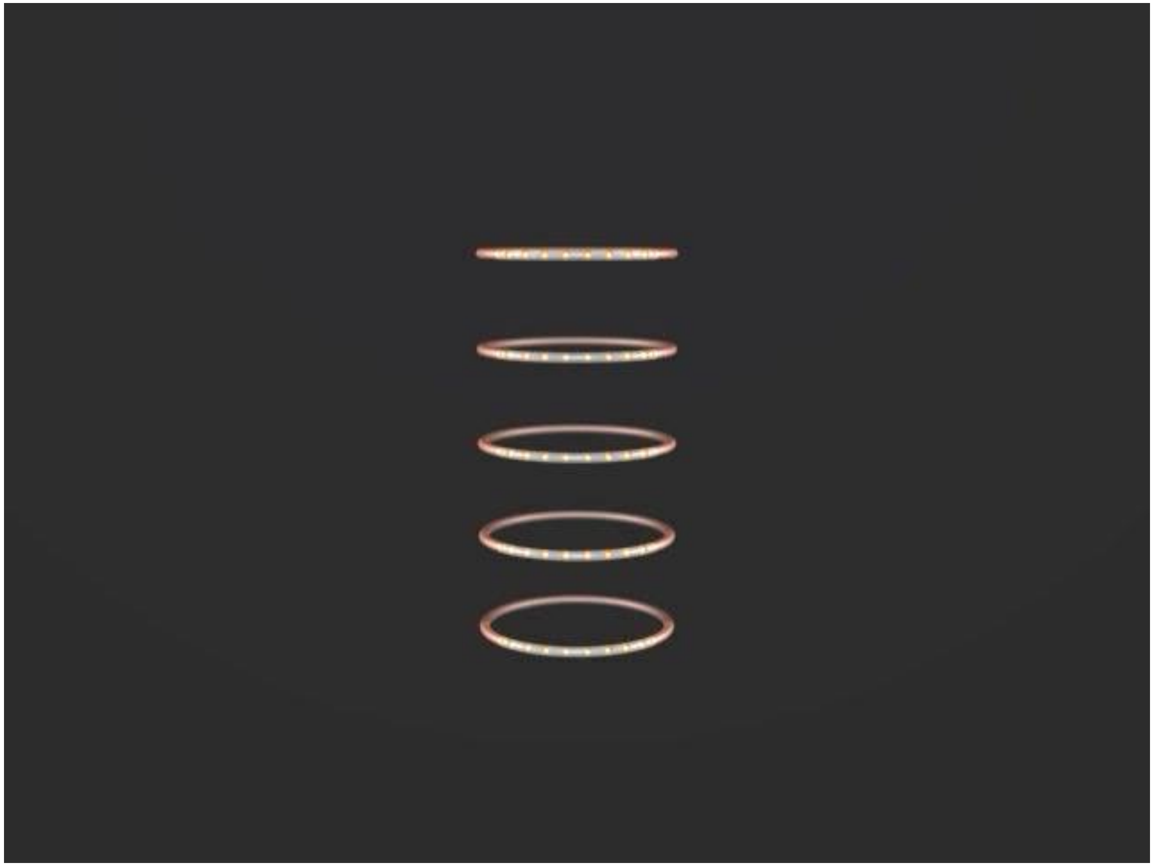
Magnetic Field

Magnetic flux lines



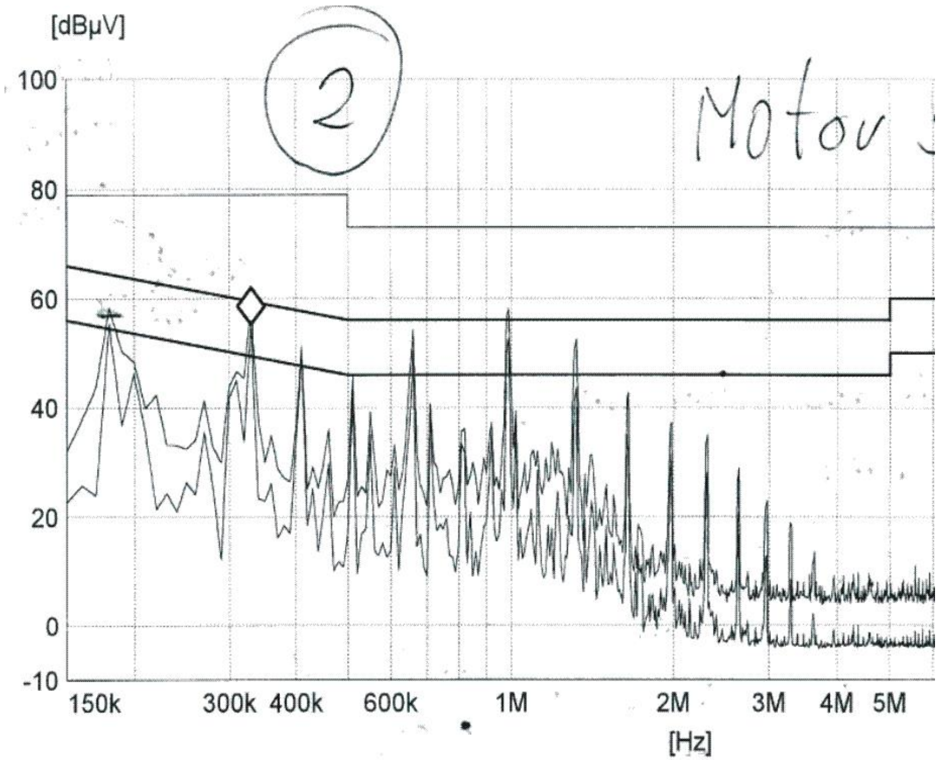
THE MAGNETIC FIELD – IN A CORE



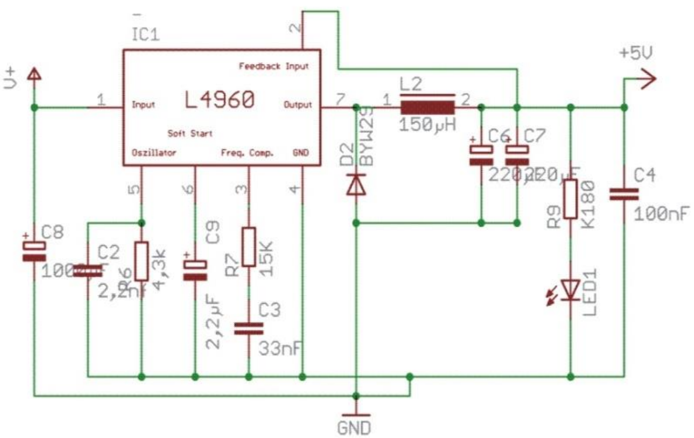


EMI: Conducted Emission Measurement

- **Power supply V 1.0**



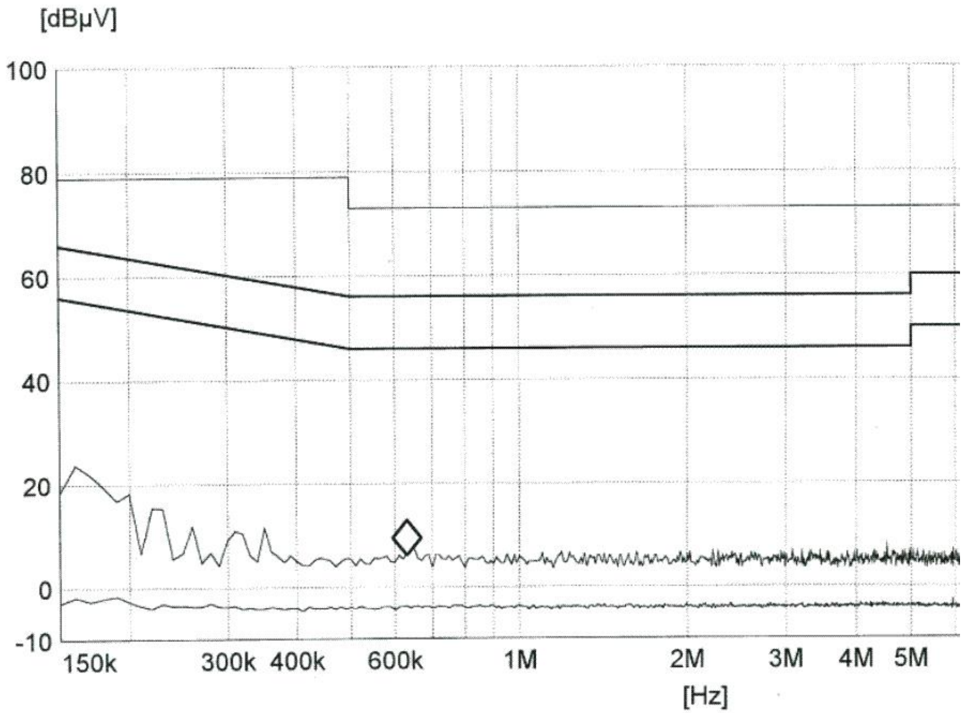
PCB

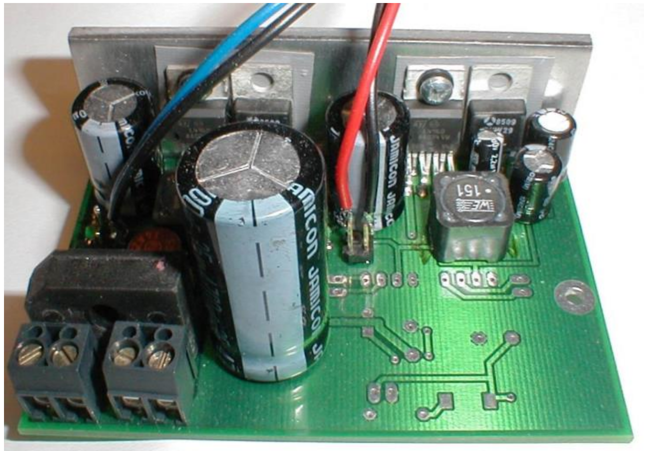


Buck Converter ST L4960/2.5A/fs 85-115KHz

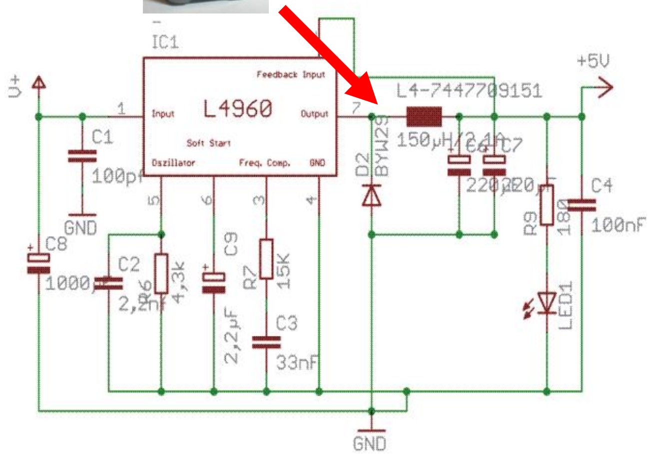
EMI: Conducted Emission Measurement

- **Power supply V 1.1**





PCB



Schematic

EMI: Be Aware:

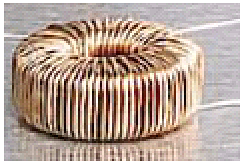
- Select the right parts for your application

- Do not always look on cost

Very easy solution with a dramatic result!!!

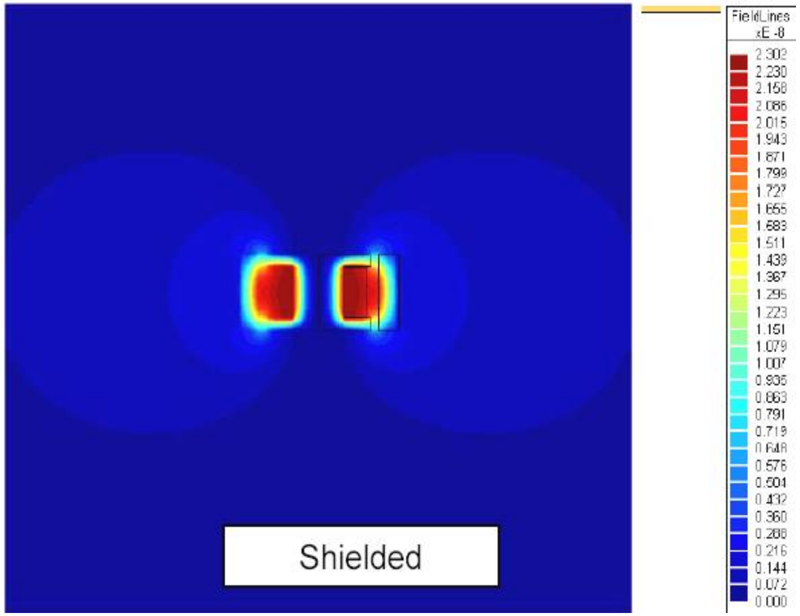
Choke before

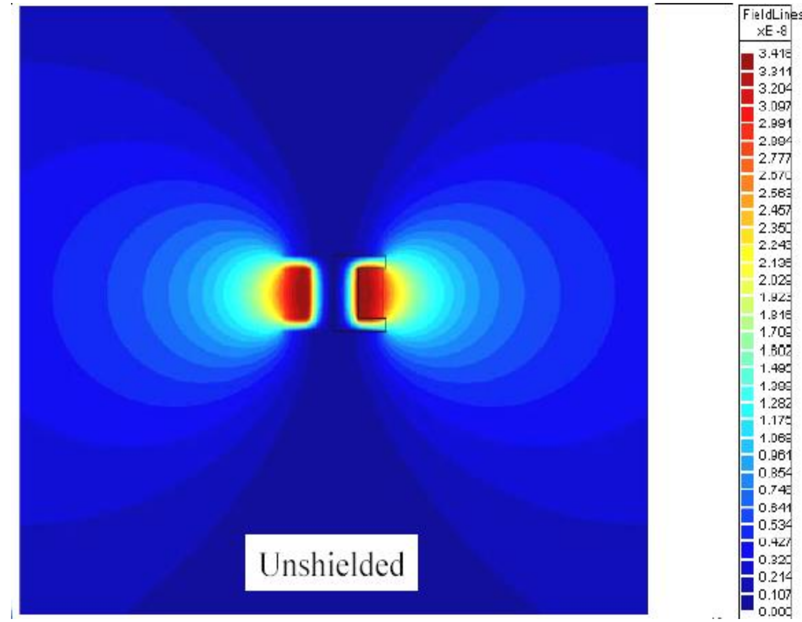
or

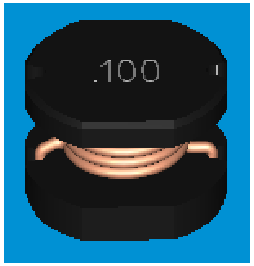


Choke after

EMI: Shielded vs. Unshielded Power Inductor





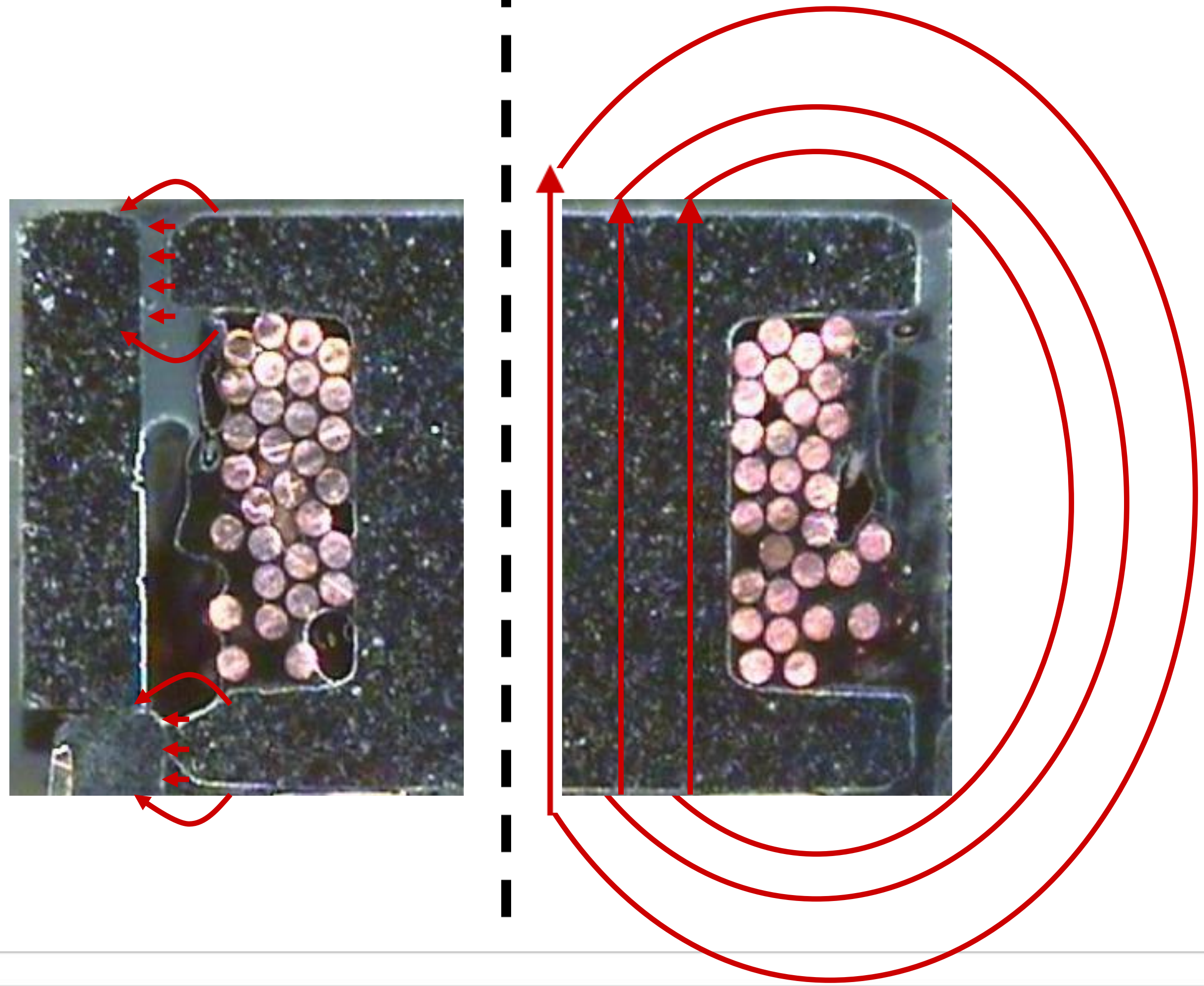


EMI: Shielded vs. Unshielded Power Inductor

- Magnetic field

shielded

unshielded



EMC - Coupling

…sometimes occurs as inter-system-influence

- a sufficient EMC-design can be done at noise source, coupling path or at coupled load

→ **Primary procedure**

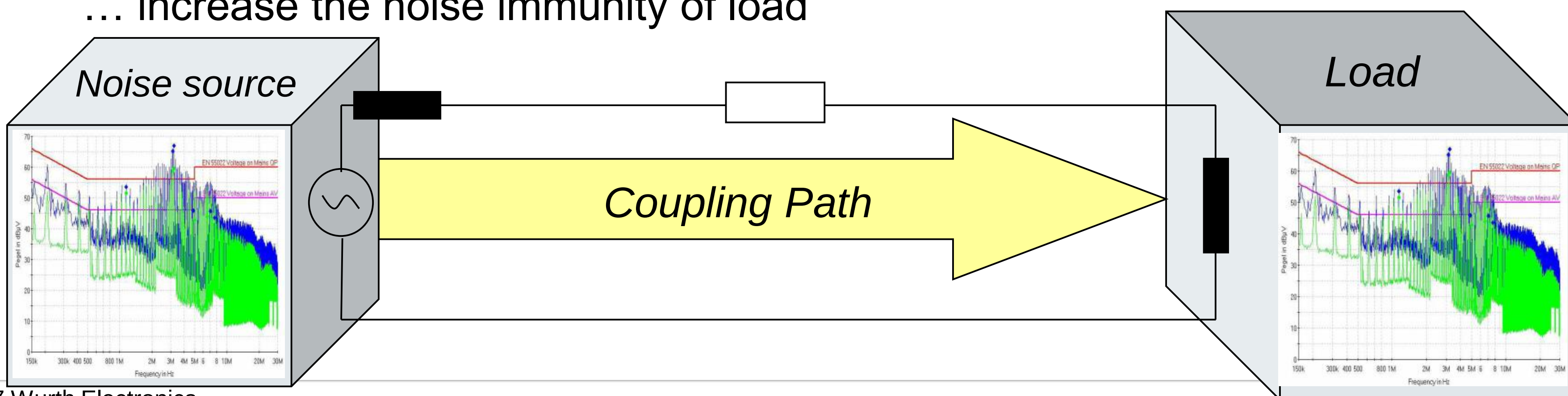
…low emission of noise at source

→ **Secondary procedure**

… eliminate the noise by interrupting it from path of the coupling

→ **Tertiary procedure**

… increase the noise immunity of load

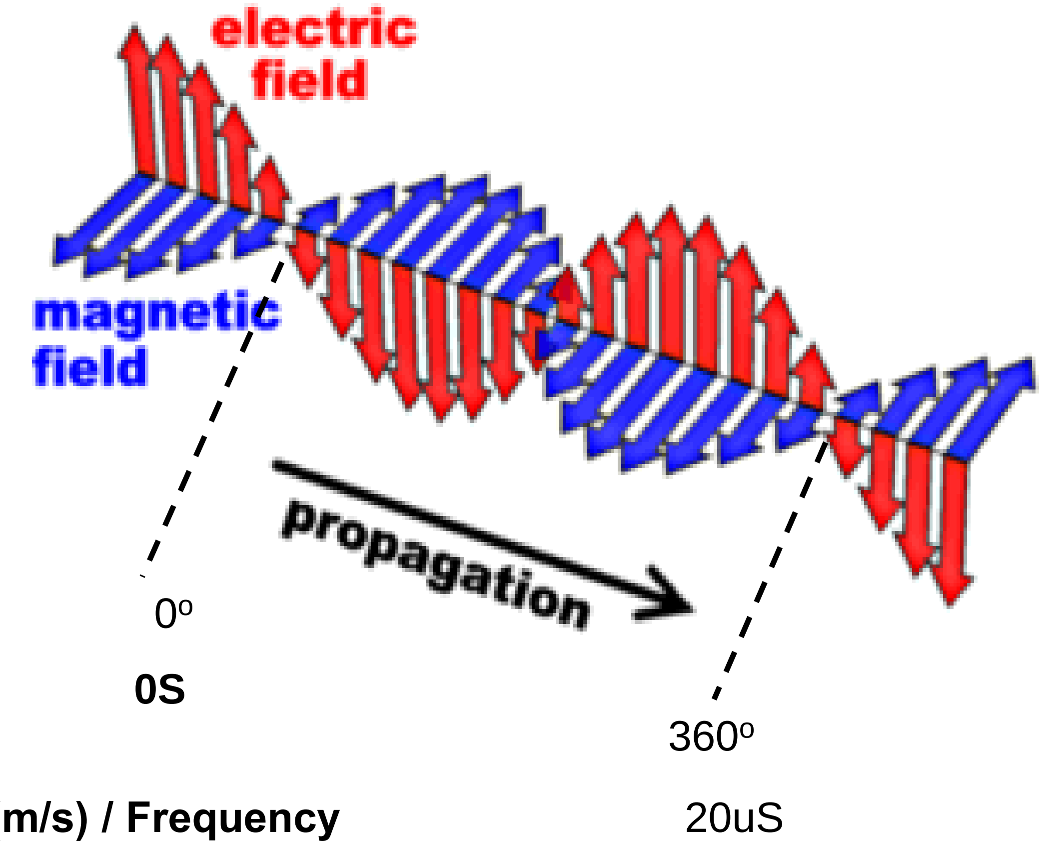


EMC – Electromagnetic Wave

1 cycle = 0º to 360º

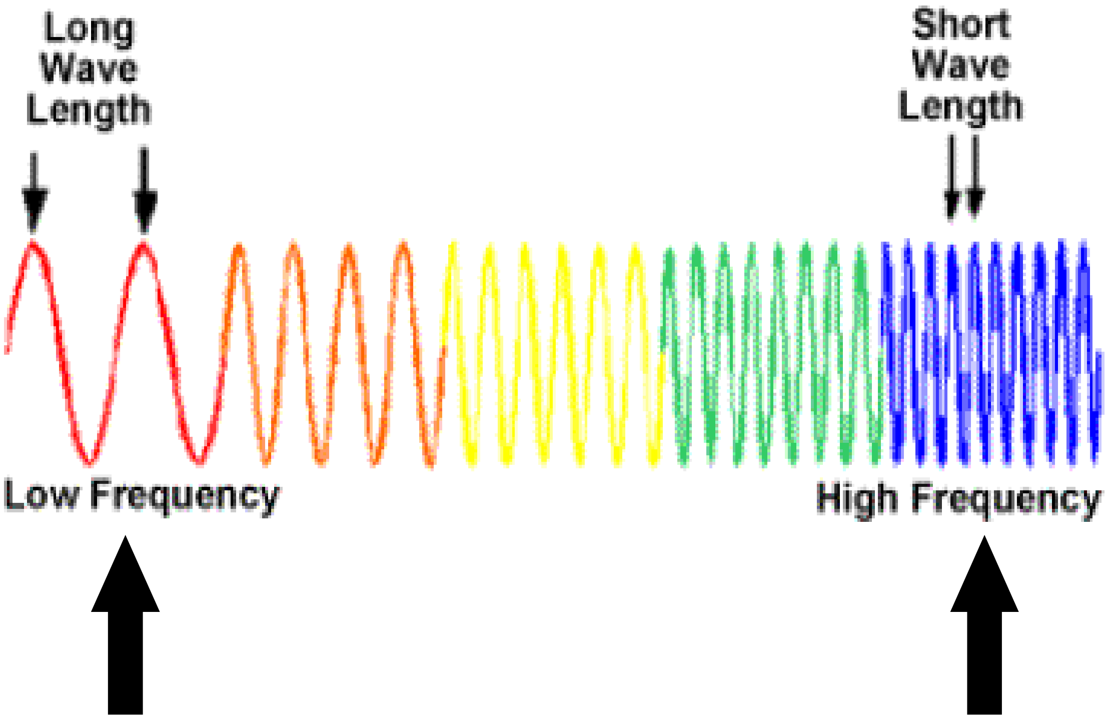
Period (S) = 0 seconds to 20uS

Frequency (F) = 1 / Period
= 1 / 20uS
= 50 kHz



Wavelength (λ) = Speed of Light (m/s) / Frequency
= $300 \times 10^6 / 50000$
= 6000 metres

EMC – Electromagnetic Wave



Frequency = 50kHz
Wavelength (λ) = 6000 metres

Frequency (F) = 500MHz
Wavelength (λ) = 0.6 metres

CISPR* 22

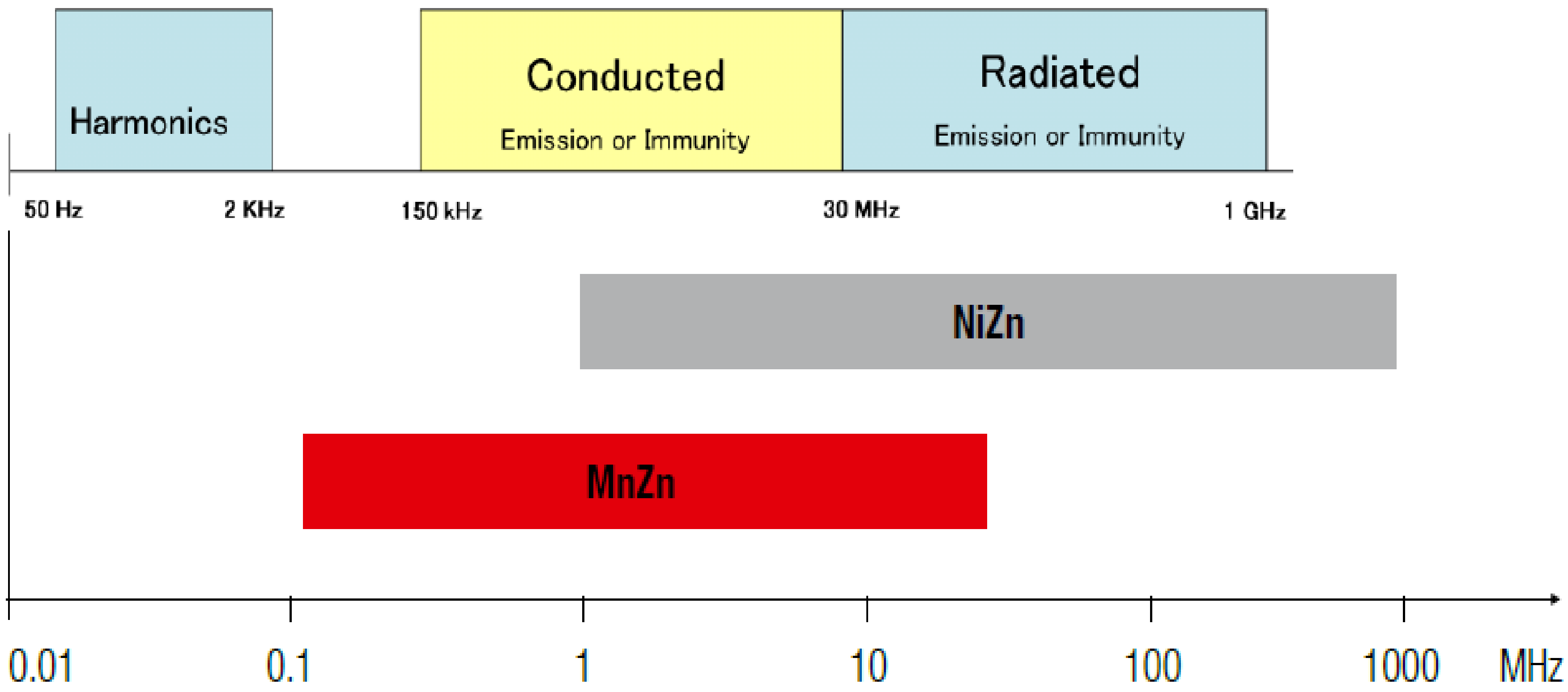
– Special International Committee on Radio Interference
– Non regulatory agency, but CISPR has adopted
  • 150kHz to 30MHz ← Conducted
  • 30MHz to 6GHz ← Radiated

FCC** 15

– Regulatory agency
  • 150kHz to 30MHz ← Conducted
  • 30MHz to 40GHz? ← Radiated

*Special International Committee on Radio Interference, Pub .22
**Federal Communications Commission, Part 15

Material characteristics

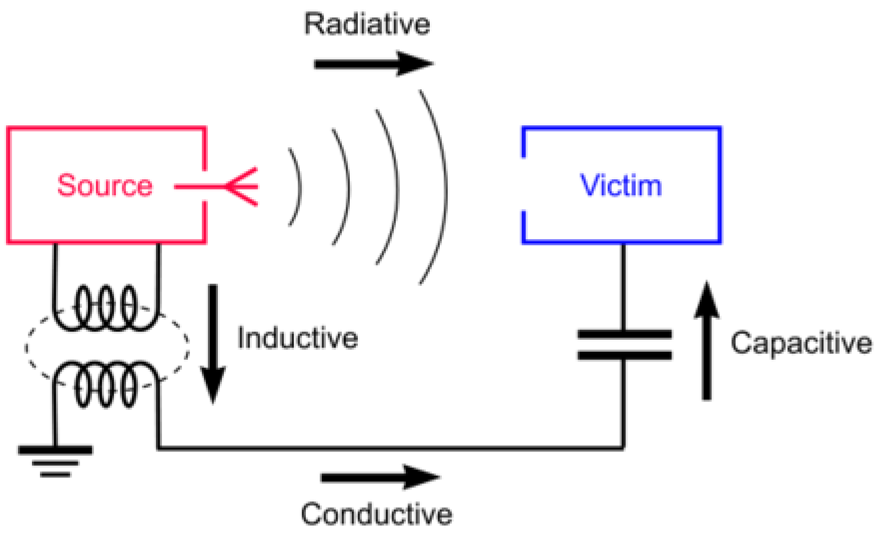


EMC – Coupling Paths

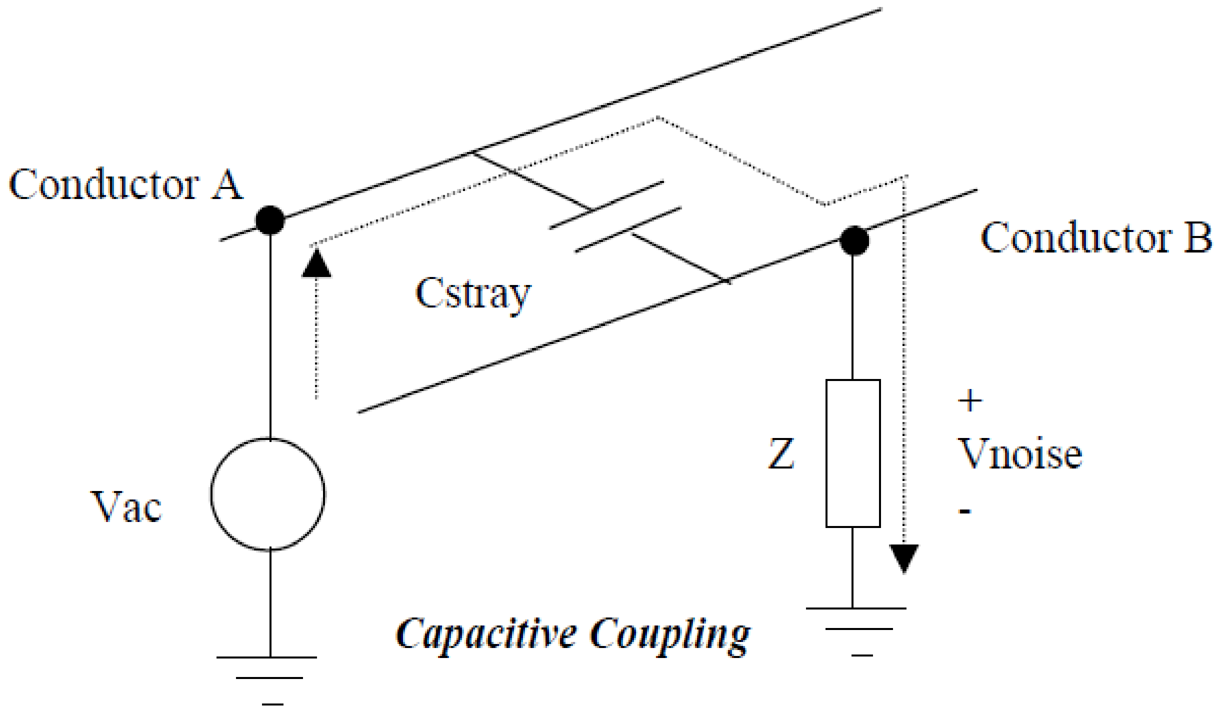
1) Conductive
   - Coupling path between source and victim is formed by direct contact.
2) Capacitive
   - Electric field coupling
3) Inductive
   - Magnetic field coupling
4) Radiative
   - Source is the “transmitter” and victim is the “receiver”

EMC and EMI

- **EMC**
  - **Electromagnetic compatibility**
    - **The electro magnetic compatibility is the ability of an electrical device, unit or system to function sufficiently well in its electromagnetic environment without generating unintentional interference to the other equipment in the system**
- **EMI**
  - **Electromagnetic Interference**
    - **Electromagnetic energy emanating from one device which degrades or obstructs the effective performance of another device.**

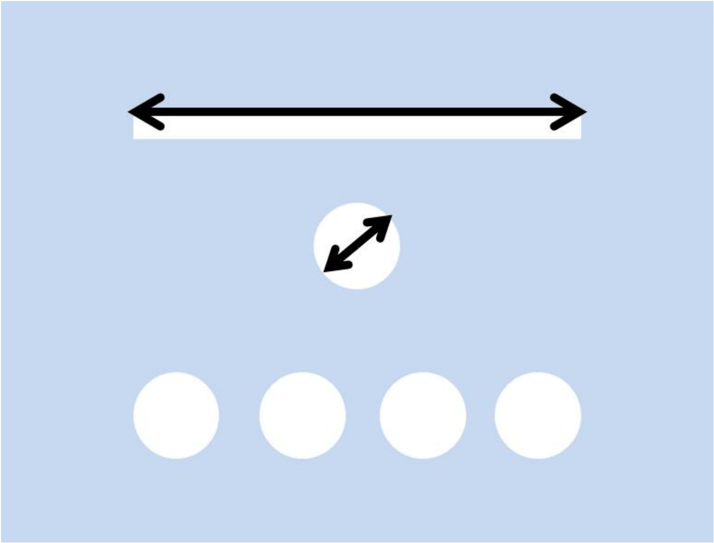


EMC – Coupling Paths (Capacitive Coupling)



- Capacitive coupling between conductors cause parasitic currents
- Noise voltage increases with frequency. Higher frequency means more high frequency harmonics flow through the capacitor.
- Two wires with 2 mm diameter and spaced by 1 cm shows about 0.1pF/cm of parasitic capacitance.

EMC Design of Electronic Devices: Ventilation

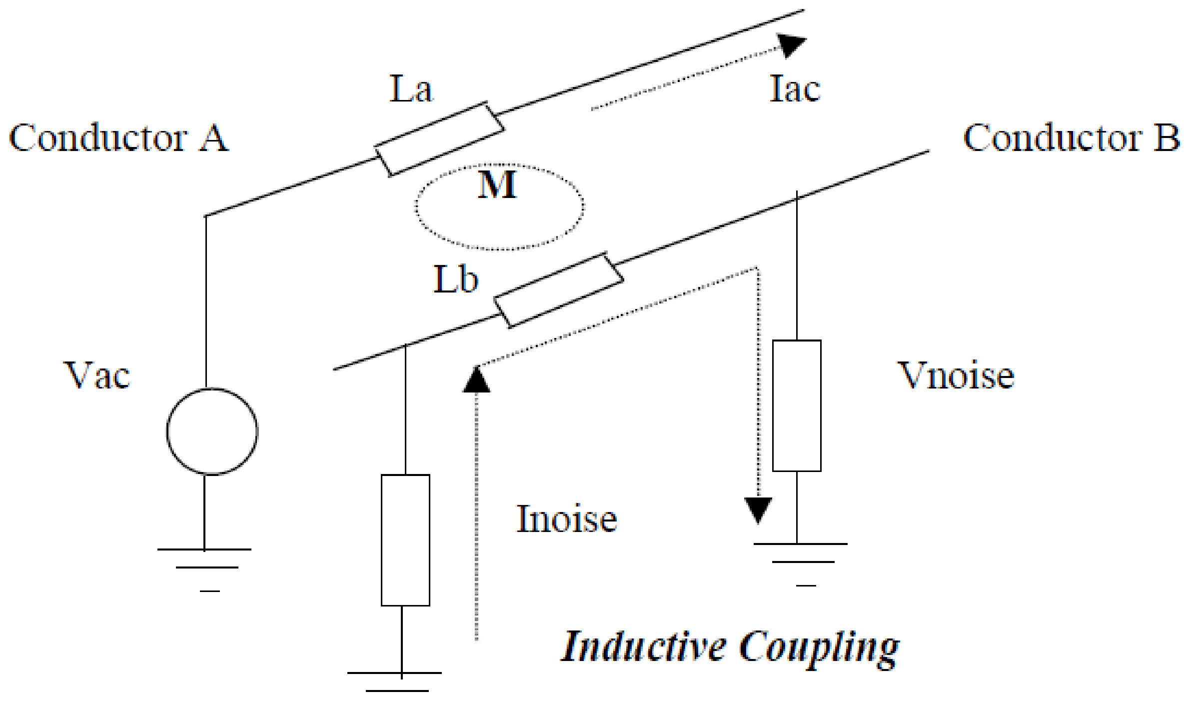


Maximum lenght for 20dB Shielding Effectiveness

Frequency (MHz)	Maximum length (cm)
30	46
50	30
100	15
300	5
500	3
1000	1.5
3000	0.2

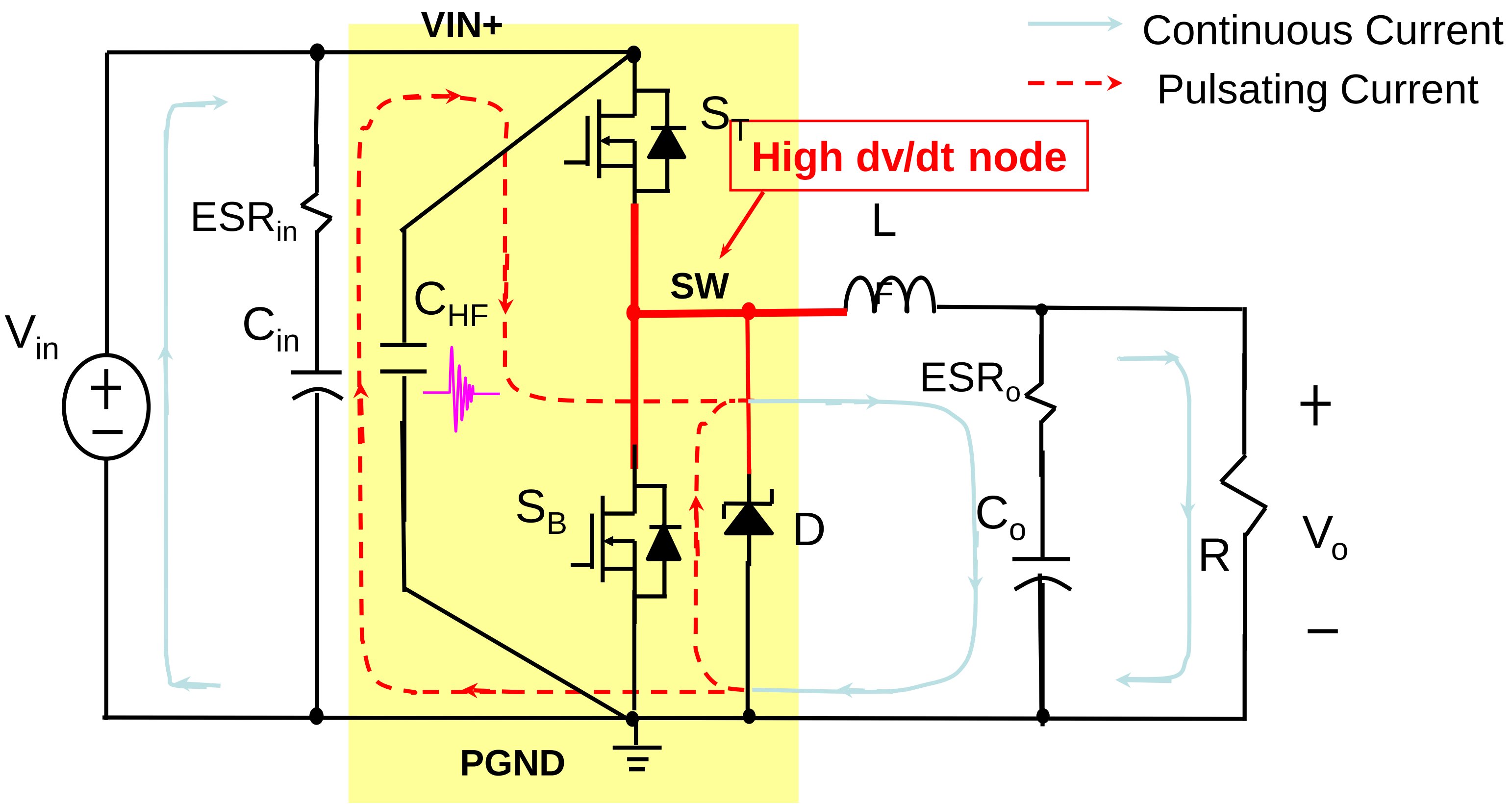
Source: Electromagnetic Compatibility Engineering. Henry W. Ott

EMC – Coupling Paths (Magnetic Coupling)



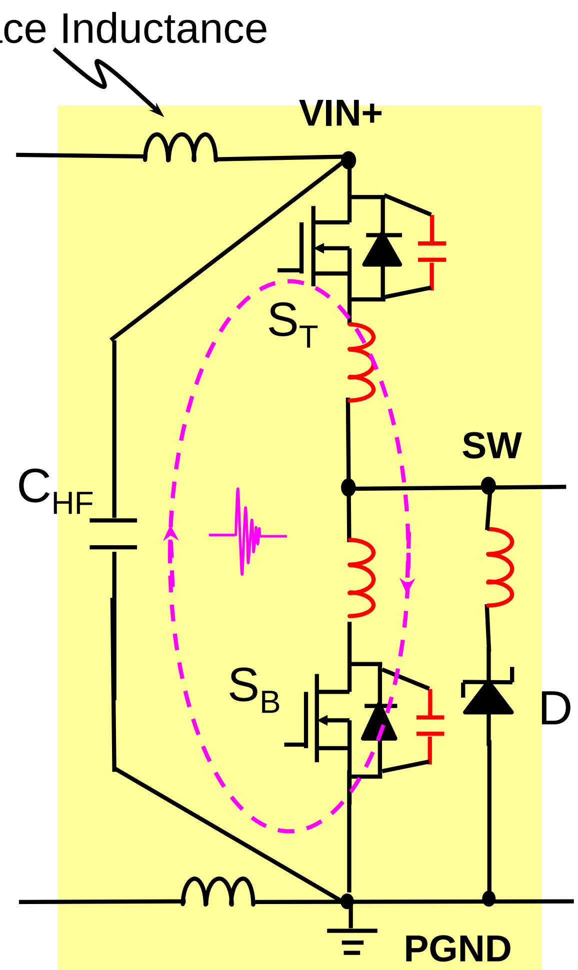
- Magnetic coupling between conductors causes parasitic induced voltages.
- Noise current increases with frequency.
- Two wires with 2mm diameter and spaced by 1cm, shows about 10nH/cm of parasitic inductance.

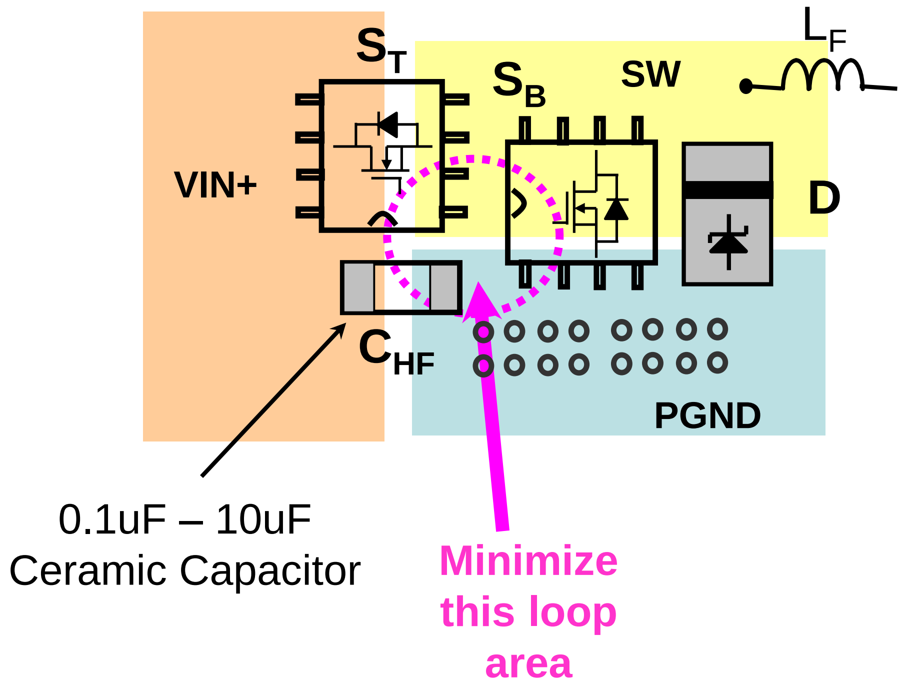
PCB Board Design Tips



- Identify the **continuous** and **pulsating current** paths
- Pay special attention to **pulsating current paths and high dv/dt switching node !**

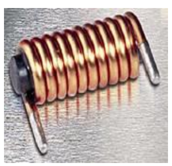
PCB Board Design Tips



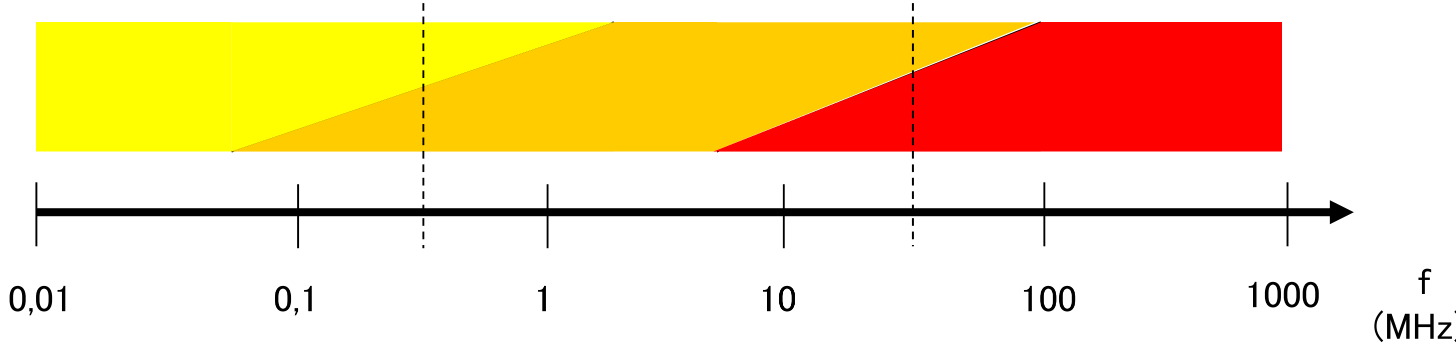


- Minimize loop between HF capacitor and MOSFETs
- It is desirable to keep C_{HF}, top FET and bottom FET on the same layer
- Use multiple vias for power connection

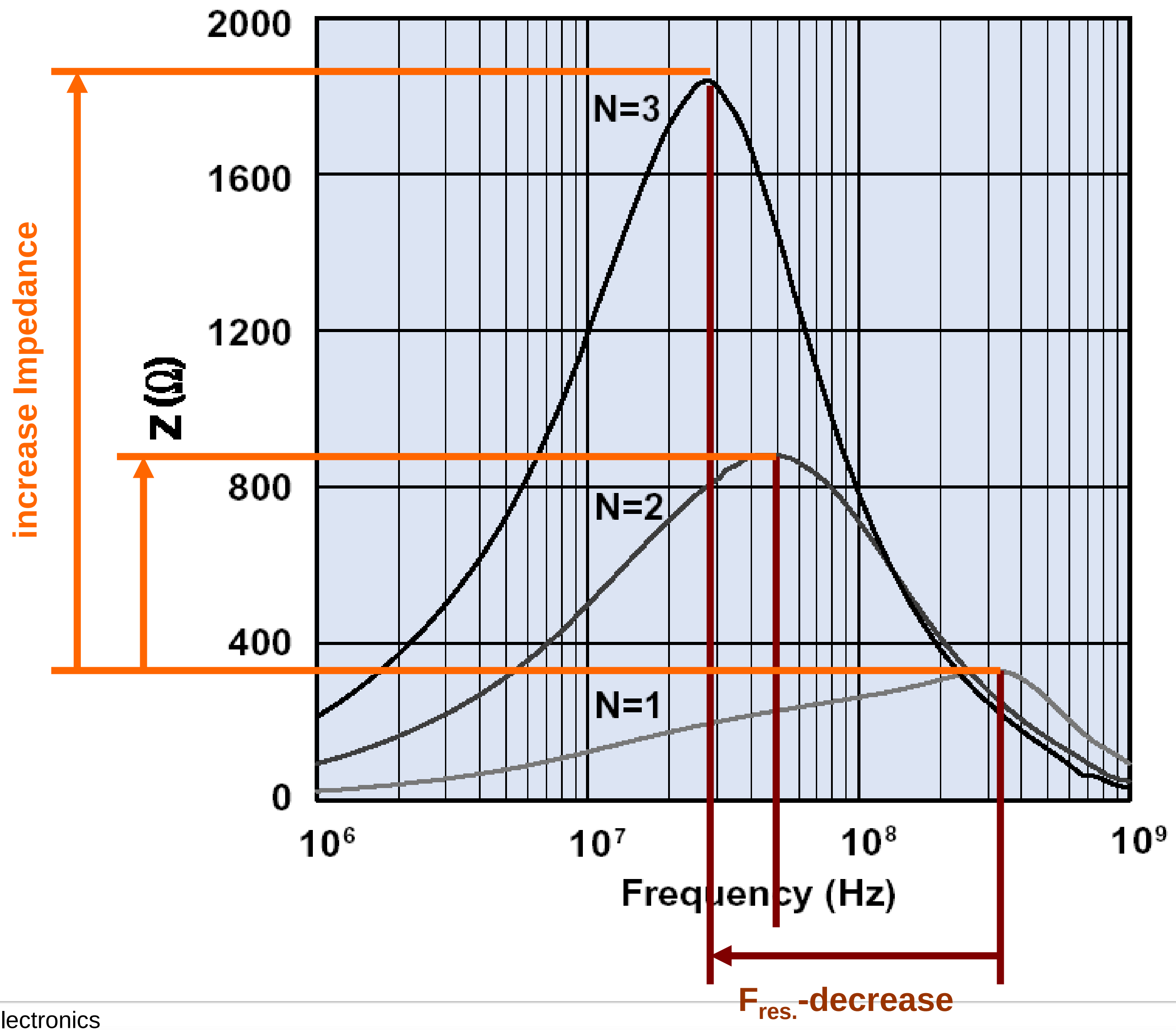
Interference Characteristics

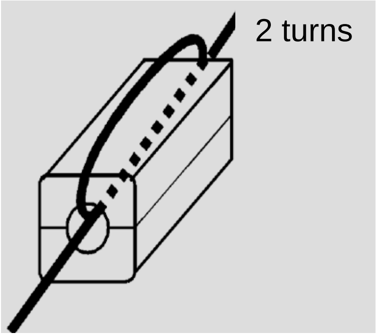


Symmetrical	Asymmetrical	Field
conducted noise	Coupled noise	radiated noise
Powder or rod core chokes	CM– chokes	EMI ferrites, shielding

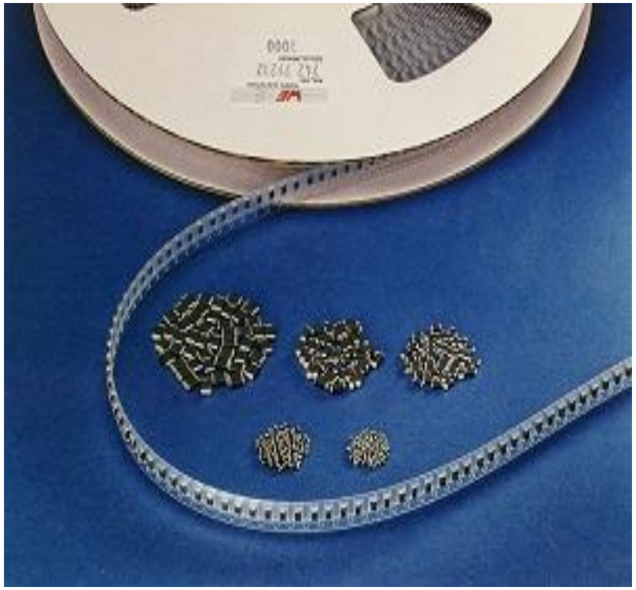


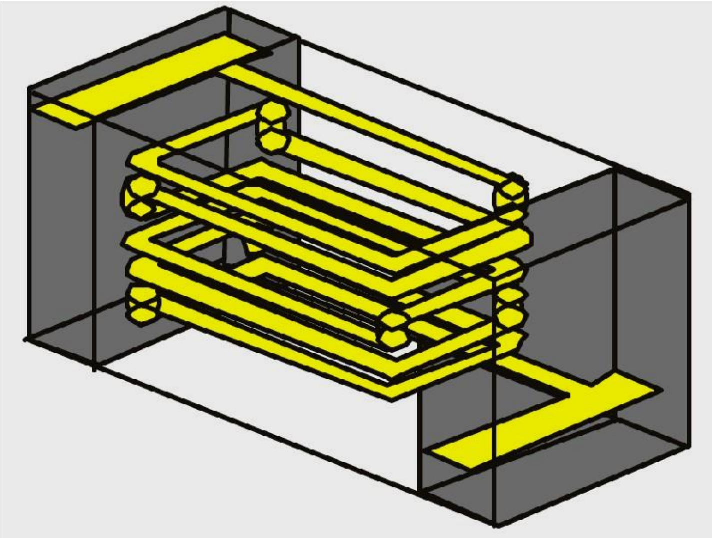
Impedance increase vs. numbers of turns

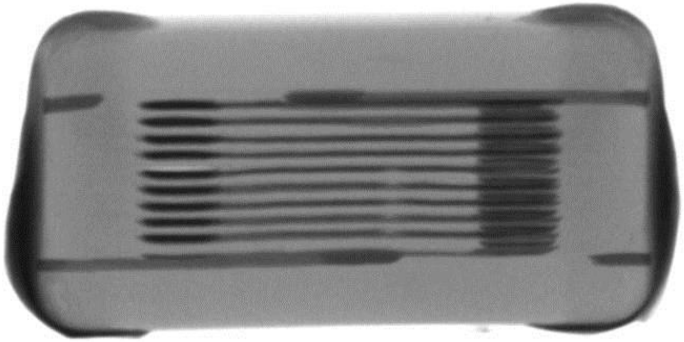


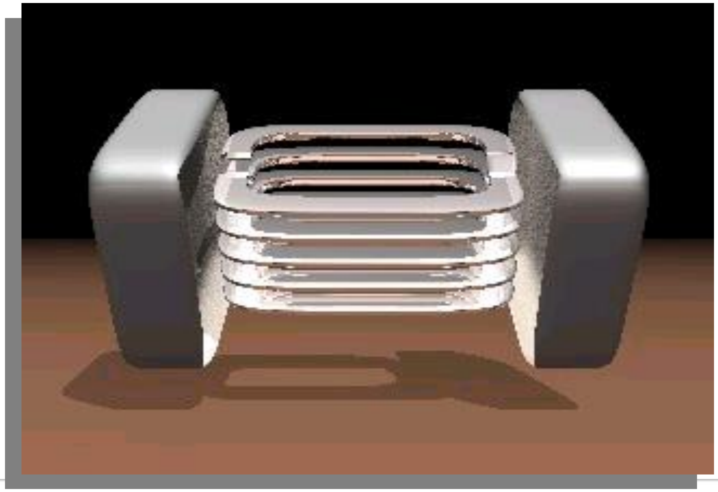


Ferrite Inductors WE-CBF



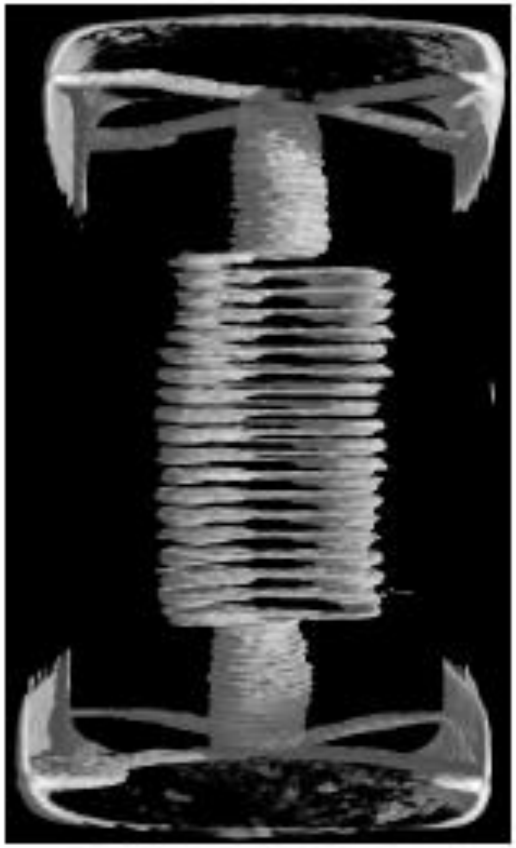






Internal structure of CBF-HF / CBF-HC

High Frequency



High Current

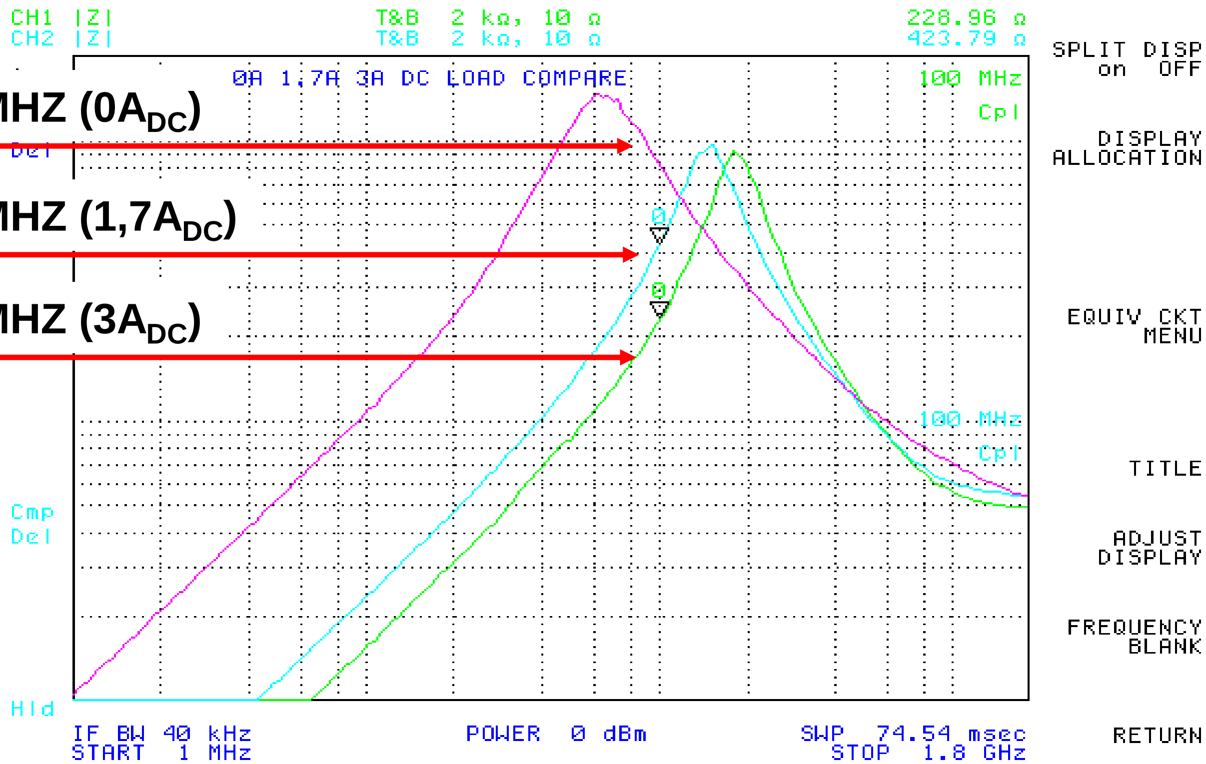
Why CMC‘s instead of Chip Beads

Impact of DC-bias (pre-magnetization (saturation)

800Ω@100MHZ (0A$_{DC}$)

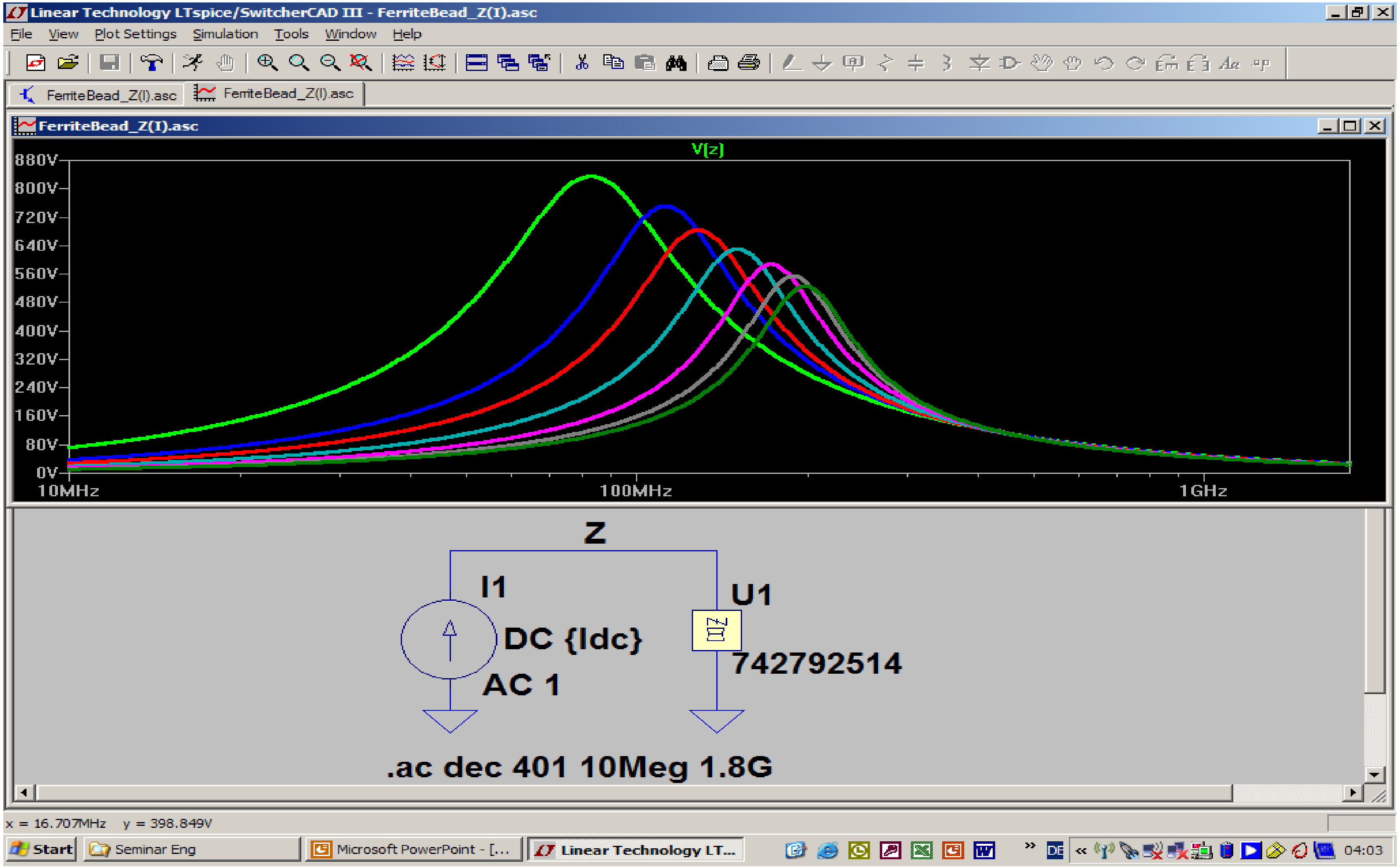
420Ω@100MHZ (1,7A$_{DC}$)

230Ω@100MHZ (3A$_{DC}$)



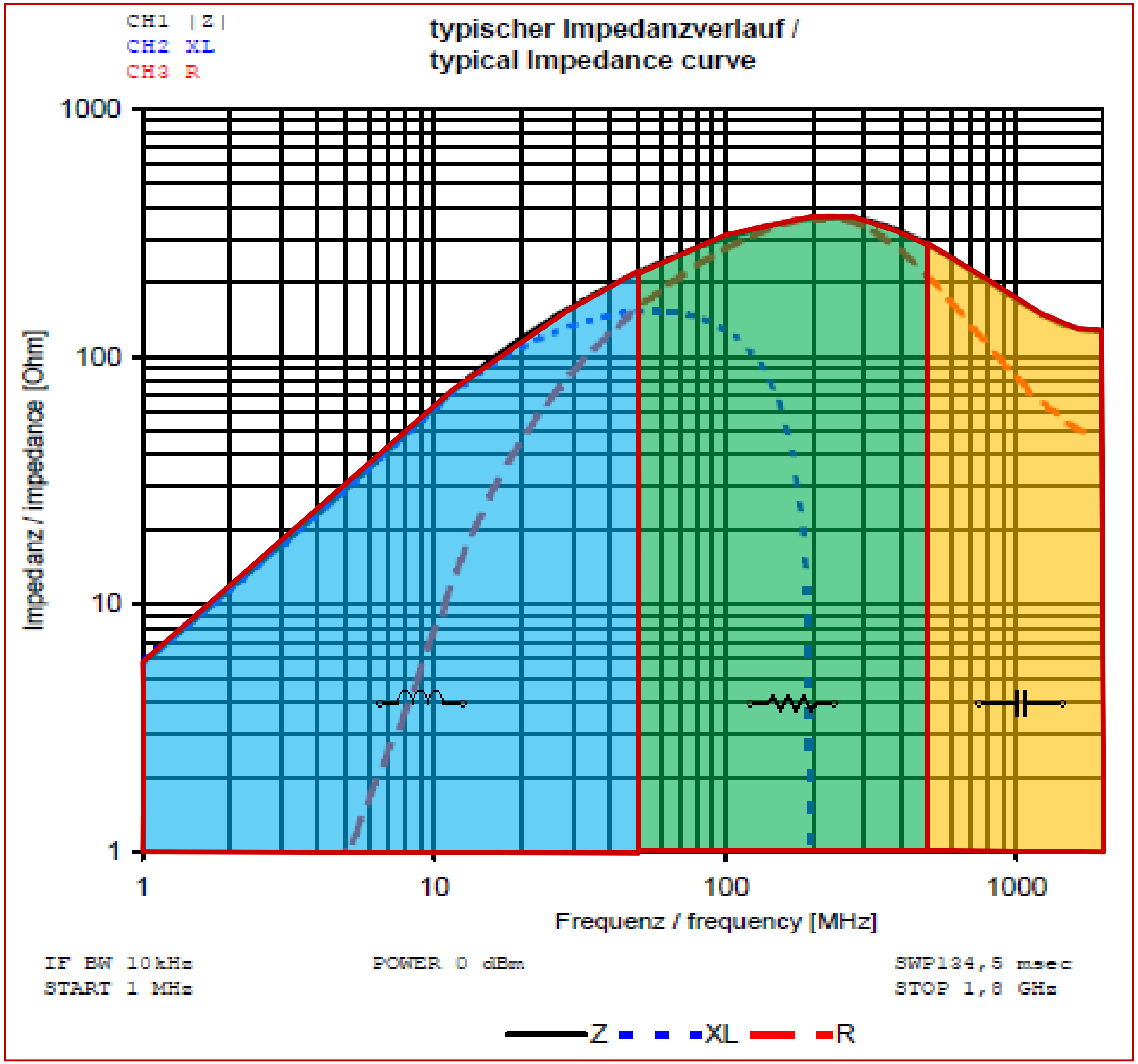
742792514 (3A typ)

Impact of DC-Bias (pre-magnetization (saturation)

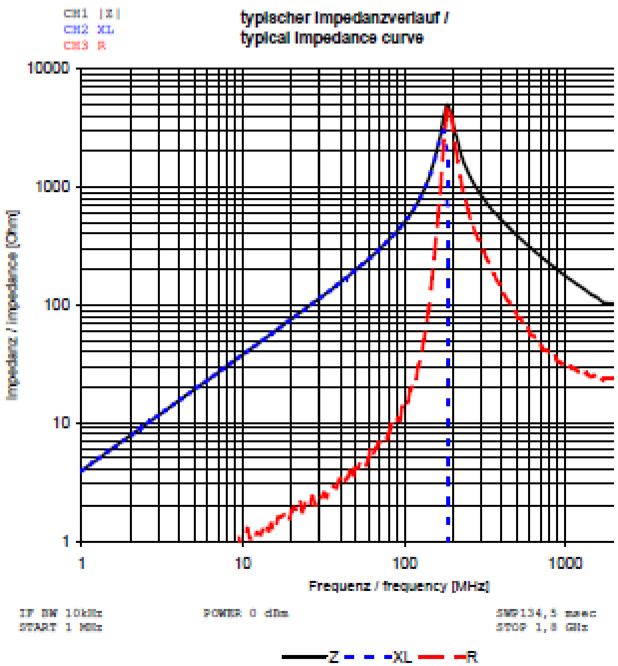


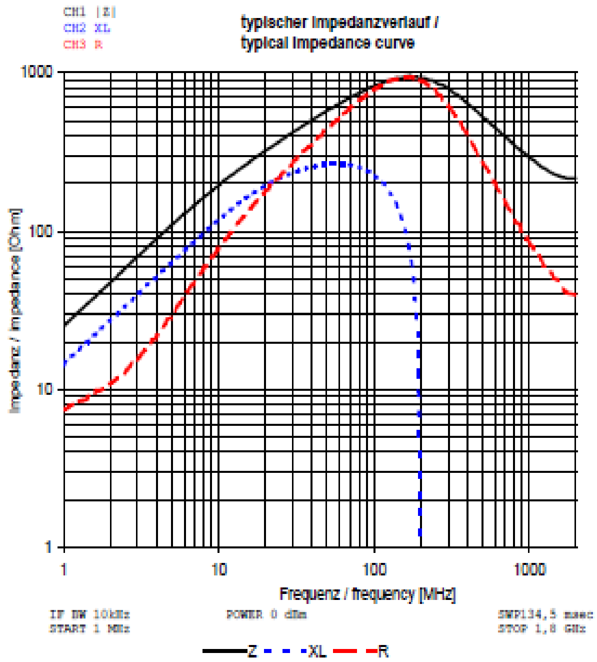
CBF Details/Reading datasheets

- Resistive
  - Impedes the noise energy and absorbs it
- Inductive
  - Energy storage
- Capacitive
  - Passes AC, blocks DC
- Cross-over Frequency
- SRF
  - XL=XC



CBF Details/Reading datasheets





High speed

- Lower impedance in lower frequency
- Low attenuation for fast signals
- Applications: USB 2.0, IEEE 1394, LVDS

Wide band

- High impedance in low frequency
- Wide band through the entire spectrum
- Applications: RS232, RS422, DC/DC converters

Main Interference we see at the board level

Common Mode Interference
(asym. Interference)

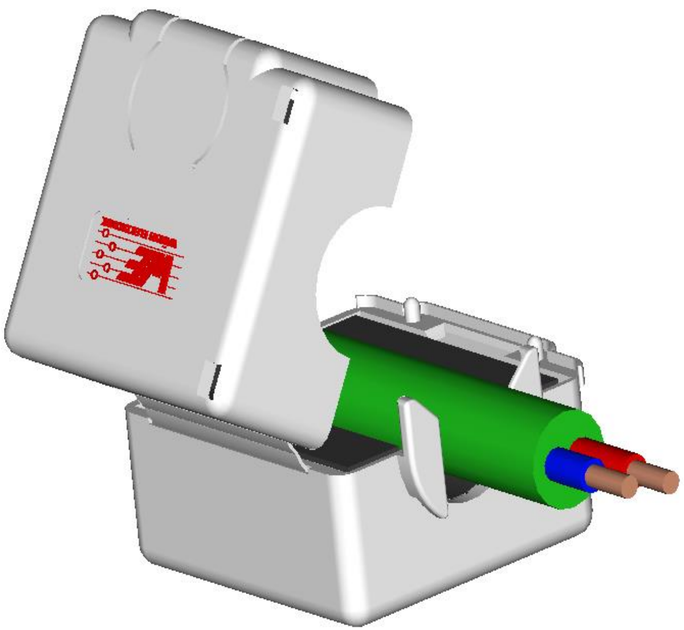
Differential Mode Interference
(sym. Interference)

Common mode choke - construction

WE-split ferrite – Is it a CMC?

- Yes, CMC with one winding

e.g. 74271712

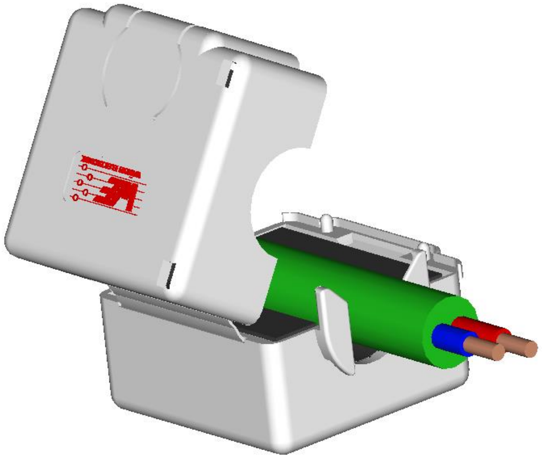


comparable with bifilar winding CMC

- both will absorb Common Mode interferences

Clamp on Ferrites – Common mode noise

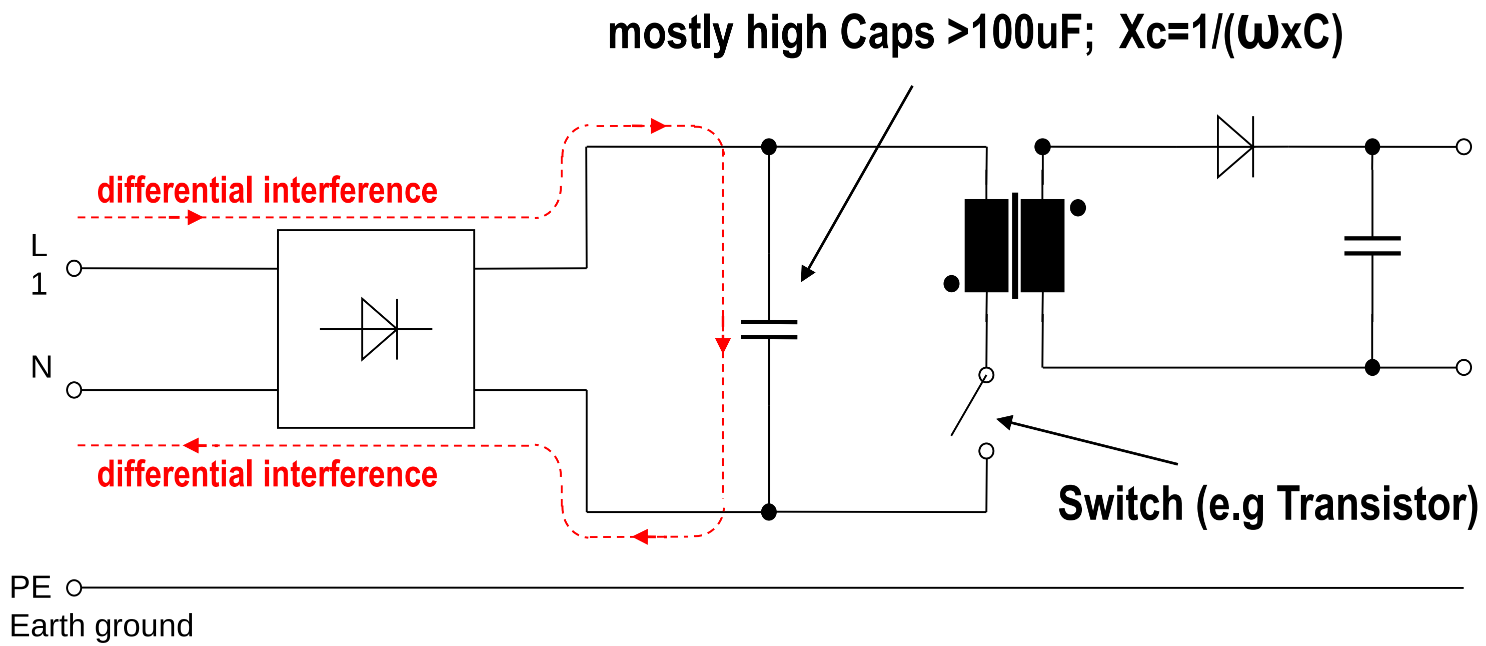
- These components are typically used as common mode choke filters.
  - In this example, it is a single cable with two wires.

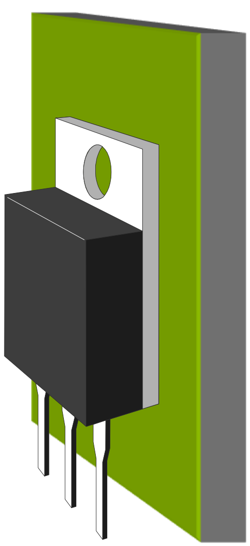


- Can also be used as a differential mode filter.
  - In this example, it is a single cable with a single wire.

Differential Noise Example: Flyback Converter

Appearance of ***differential noises*** on the input line of a Flyback Converter





differential interference occurs mainly at *lower* frequencies

Common Mode Noise Example: Flyback Converter

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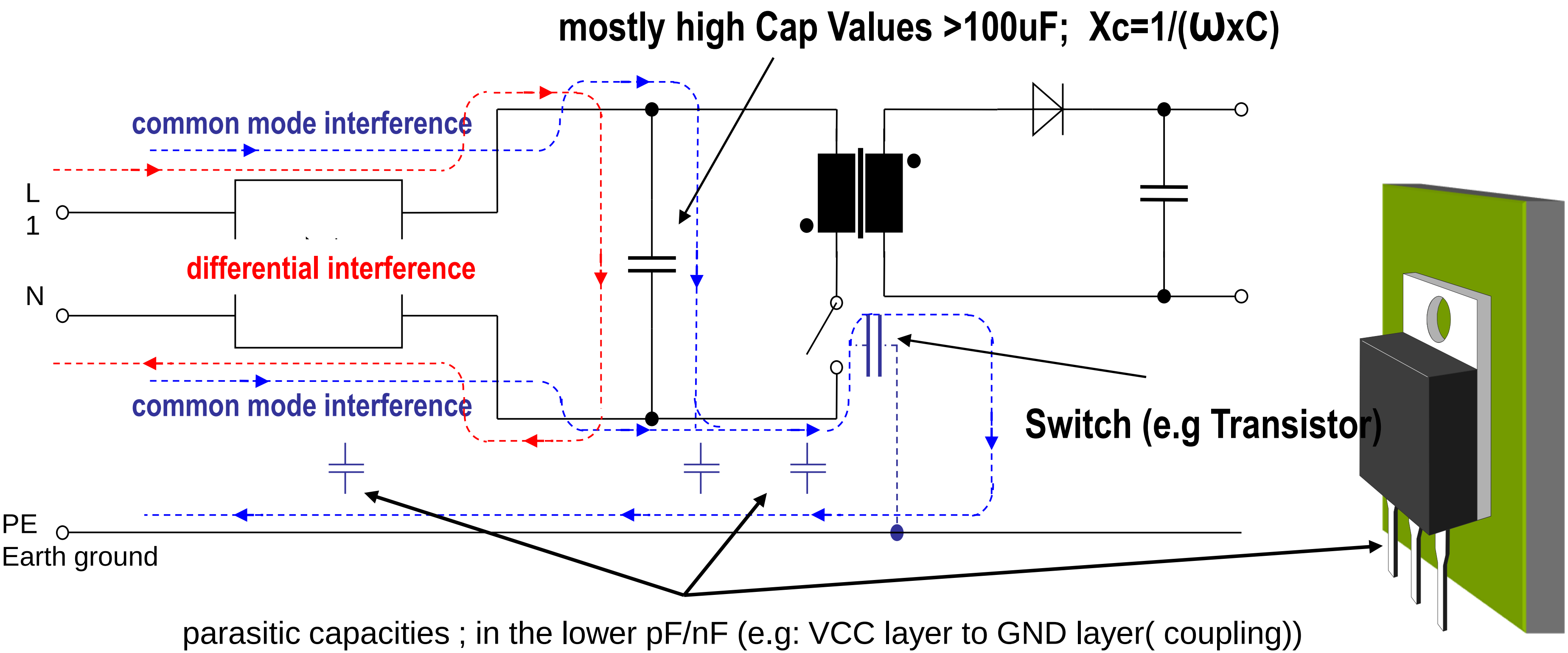
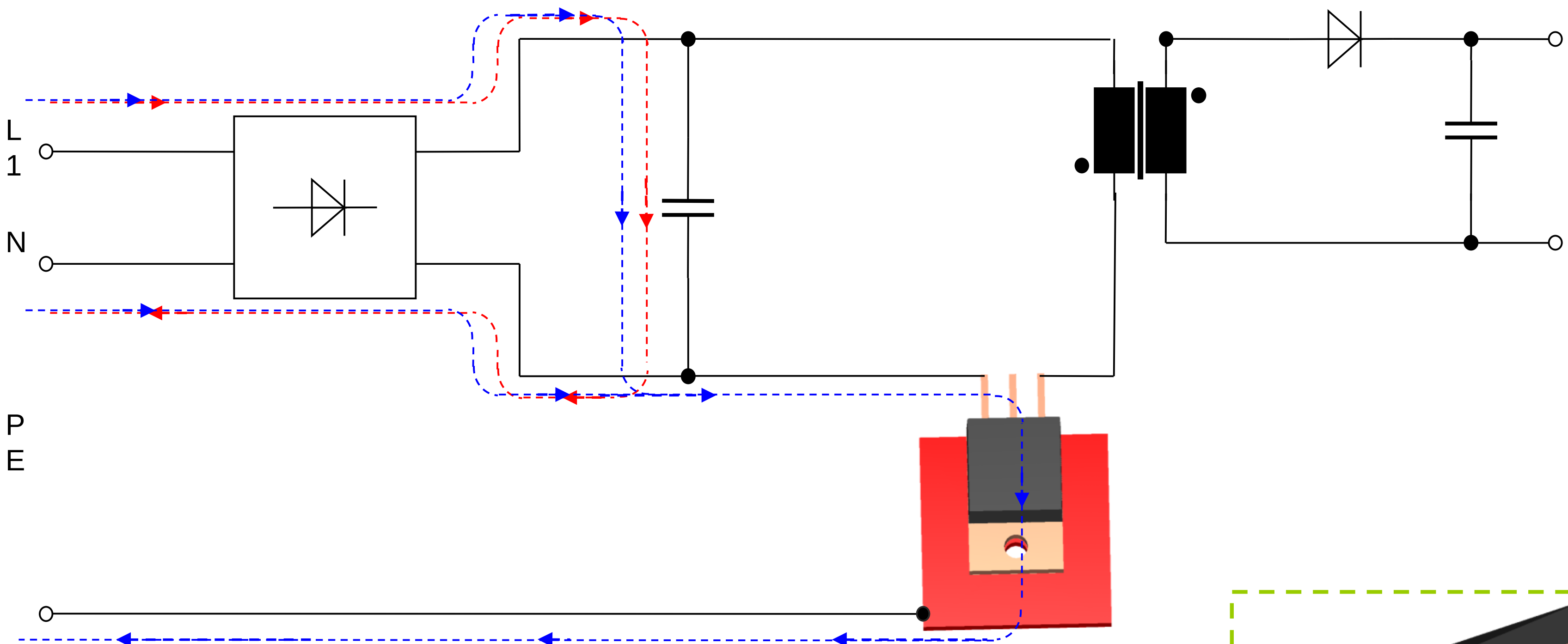
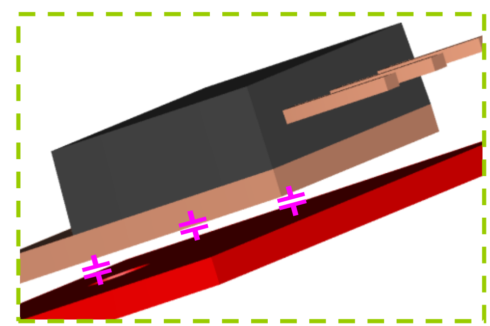


common mode interference occurs mainly at *higher* frequencies

Why Filter? – example: Fly back-Converter

Which filter do we need?



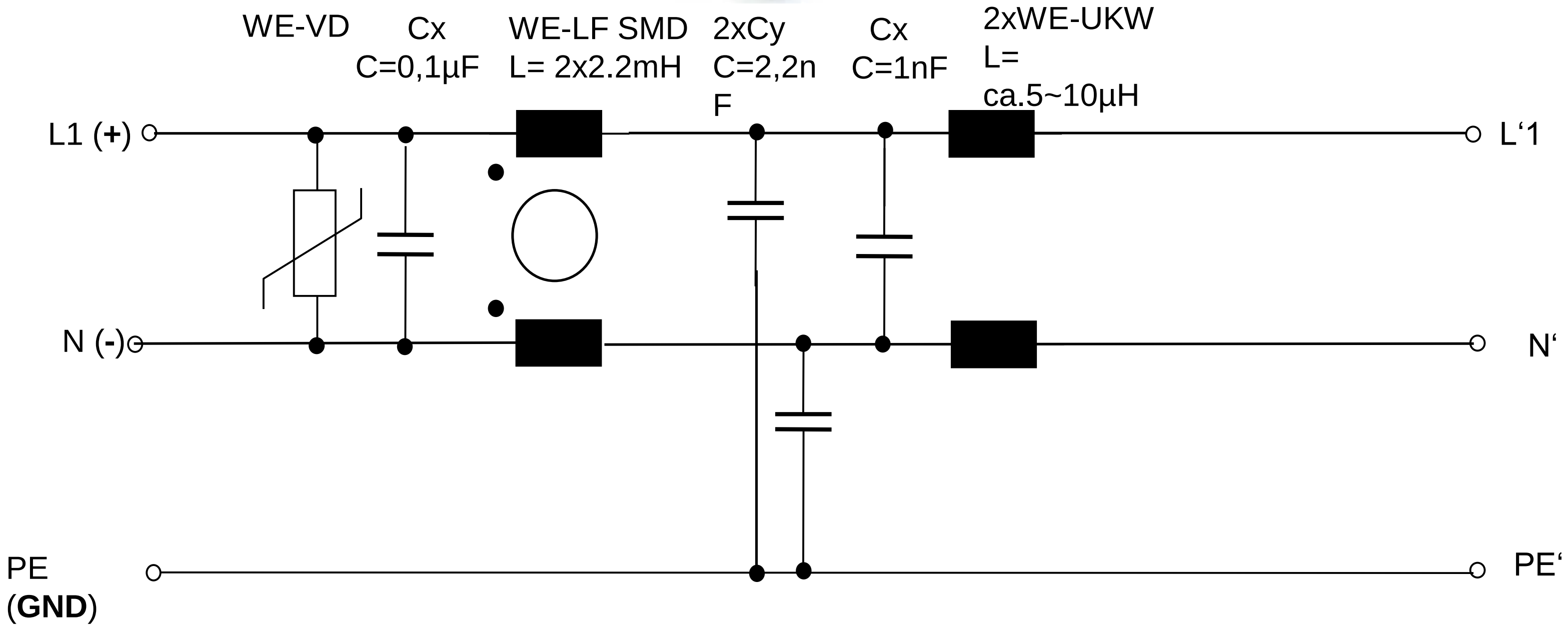


→Parasitic capacities

e.g.: collector to cooling element

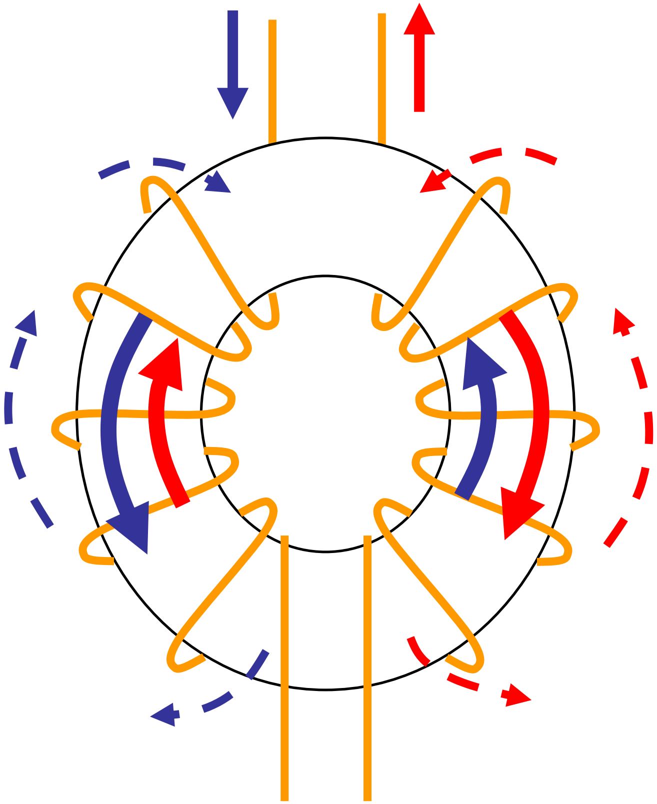
Filtering Noise Example: Flyback Converter

Filtering the mains power line for common mode and differential mode



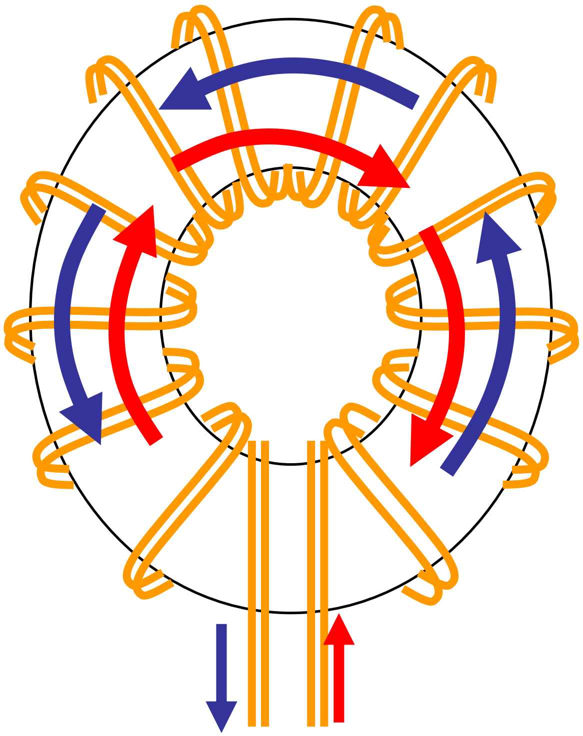
Stray inductance: Bifilar / Sectional

Sectional



$L_S \sim 0.5 \cdots 2.0\% * L_p$

Bifilar

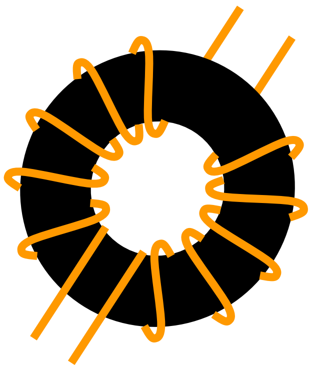


$L_S \sim 0.1 \cdots 1.0‰ * L_p$

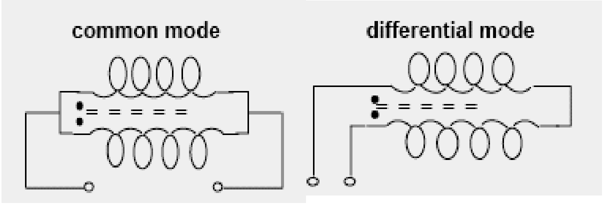
Sectional winding:

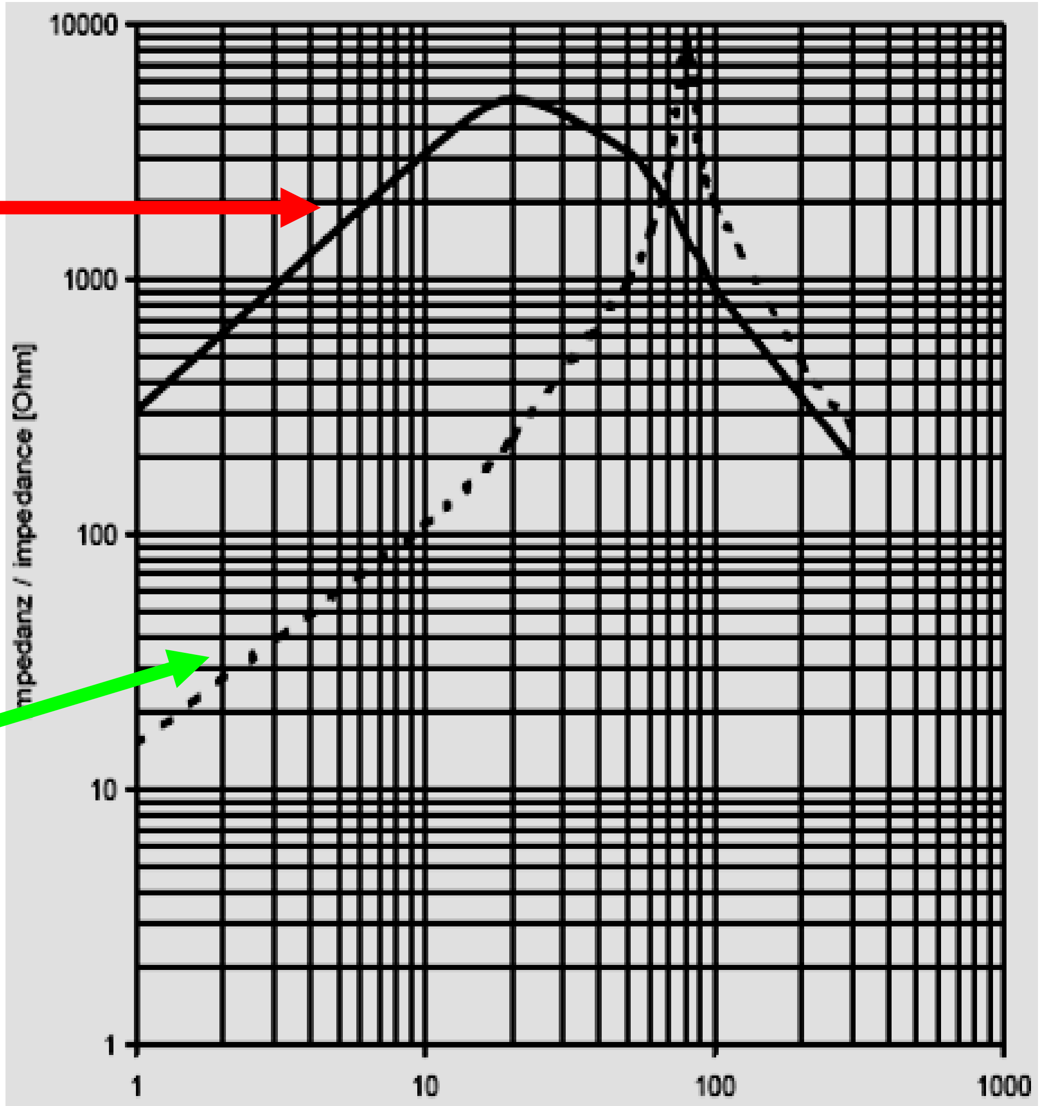
For example: WE-SL2 744227S

Common Mode suppression



Differential Mode suppression
is high!

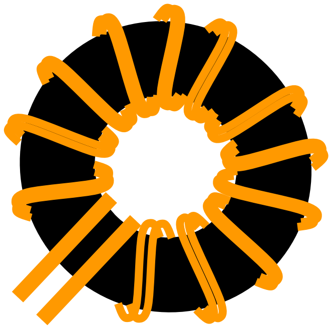




Bifilar winding vs. Sectional winding

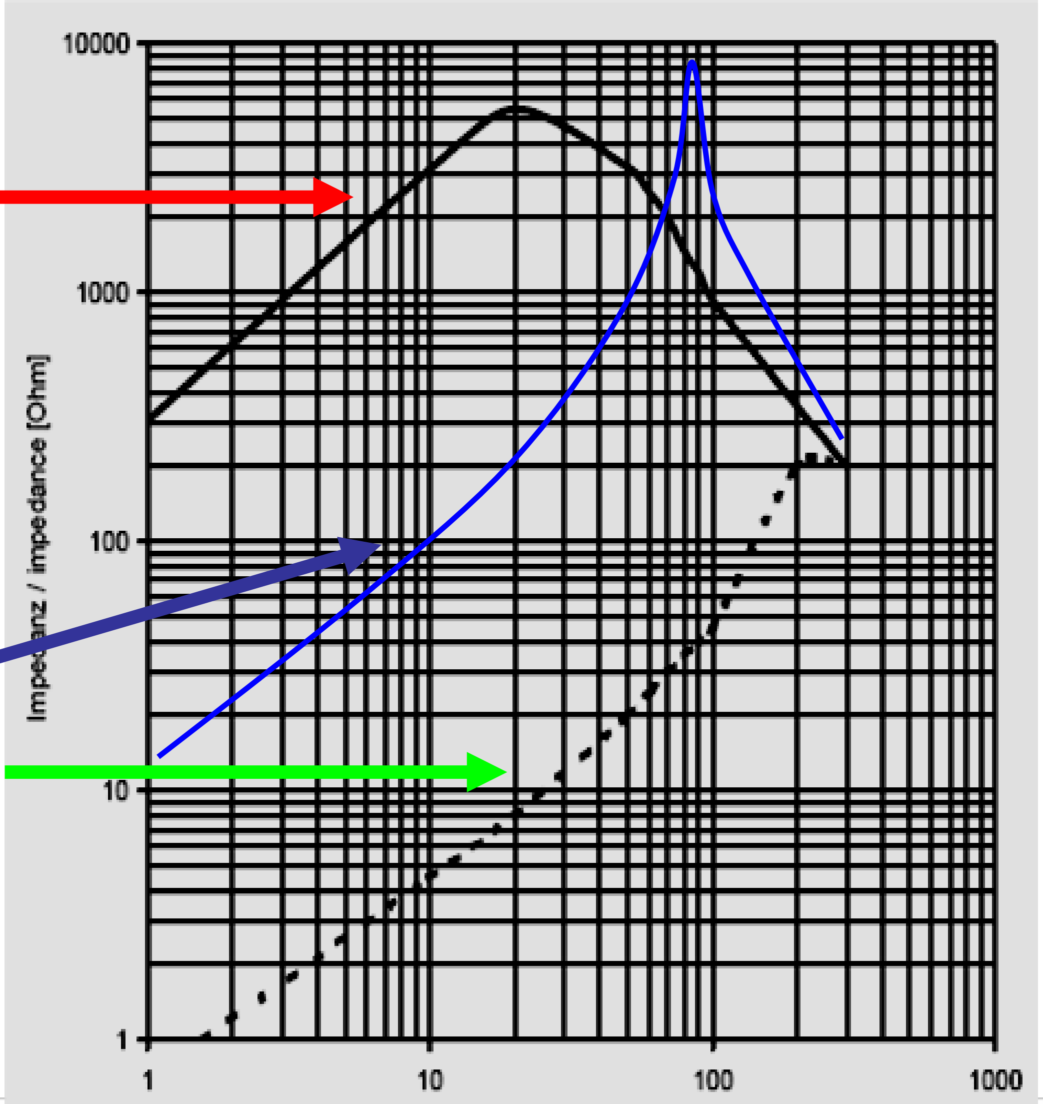
For example: WE-SL2 744227

Common Mode suppression

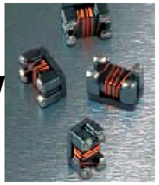
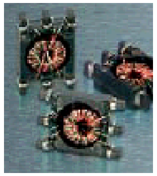
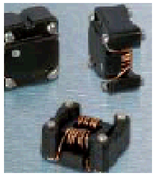


Differential Mode S-Type

Differential Mode suppression
is low!



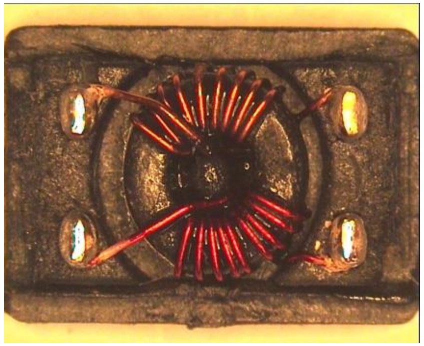
Common mode chokes for SMD:

		Size [mm]	Impedance [Ω]	Current [A]	Application
WE-CNSW		2.0 x 1.2 x 1.2 3.2 x 1.6 x 1.9	130 – 910 60 – 400	0.28 – 0.4 0.20 – 0.37	USB 2.0 Firewire/ high speed dataline
WE-SL		12.7 x 10.5 x 5,75	1100 – 14400	0.20 – 2.70	ISDN Telecom Applications
WE-SL 1 744212xxx		6.5 x 3.6 x 1.65	300 – 2000	0.30	PCMCIA cards
WE-SL 2		9.2 x 6.0 x 5.0	1000 – 20000	0.40 – 1.60	VCC Power & Datalines
WE-SL 3 744252/253xxx		9.2 x 6.6 x 2.5	1250 – 5000	0.50 – 0.70	VCC Power & Datalines higher current ratings
WE-SL 5 744272xxx		10.0 x 8.2 x 6.5	290 – 13000	0.35 – 2.50	VCC Power Lines

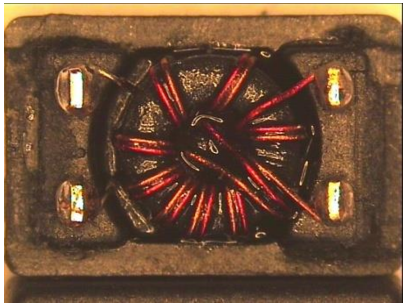
Common Mode Choke

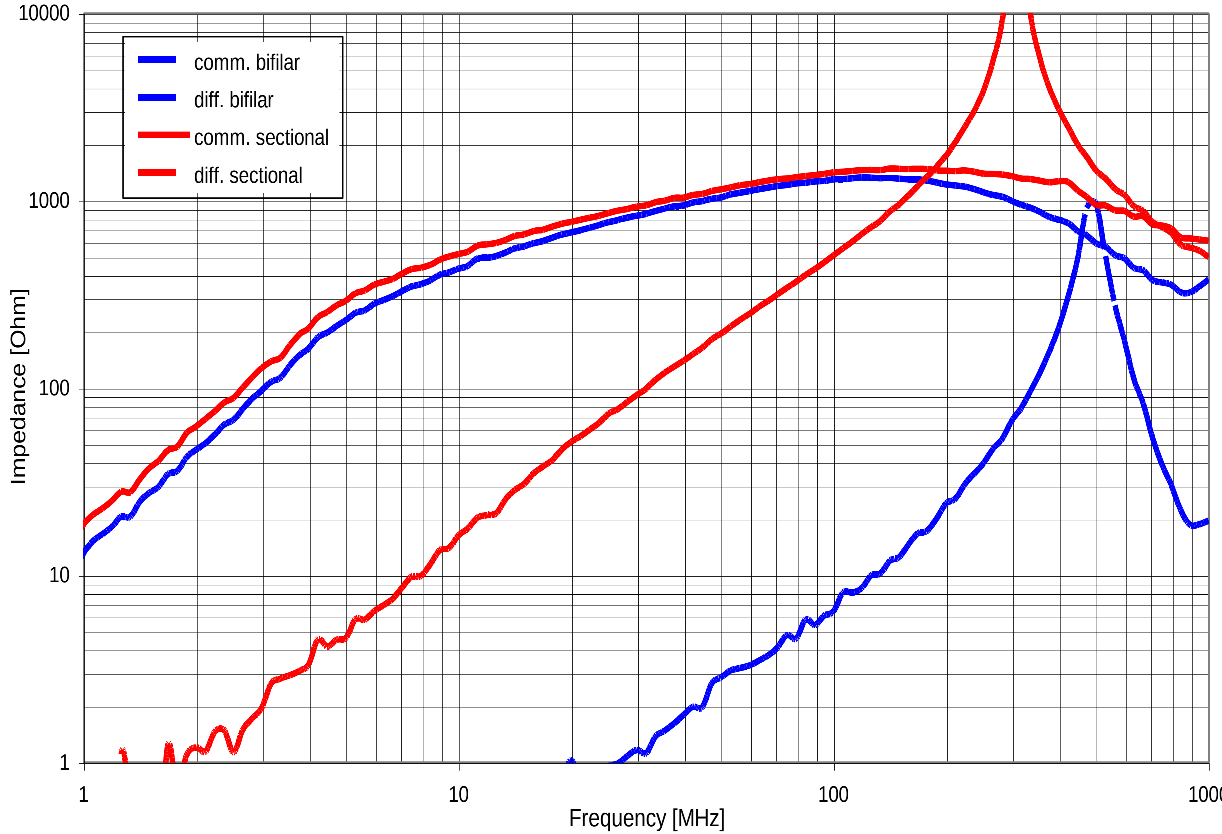
- different designs

WE-SL2 744226S
<u>sectional winding</u>

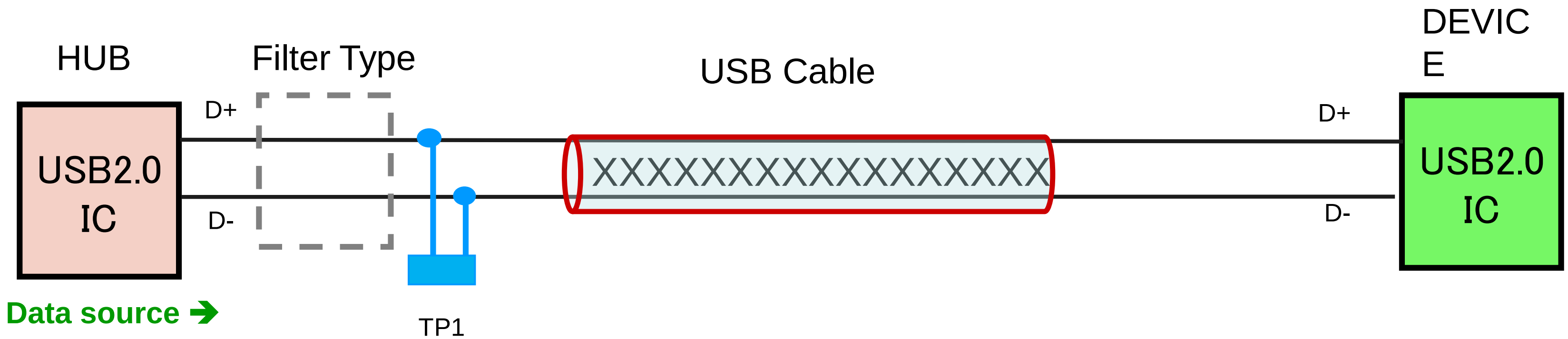


WE-SL2 7442276
<u>bifilar winding</u>



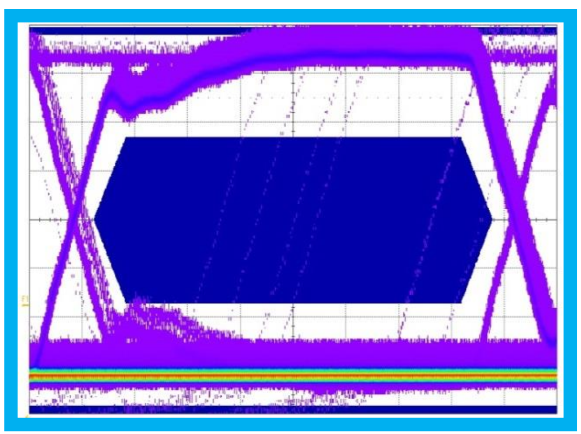


Summary→ Common mode choke – application USB2.0



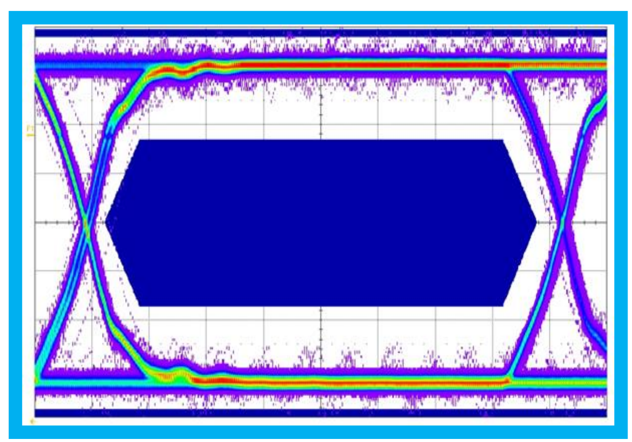
Measurement Point taken on HUB side (TP2)

Using a WE-CBF not CMC



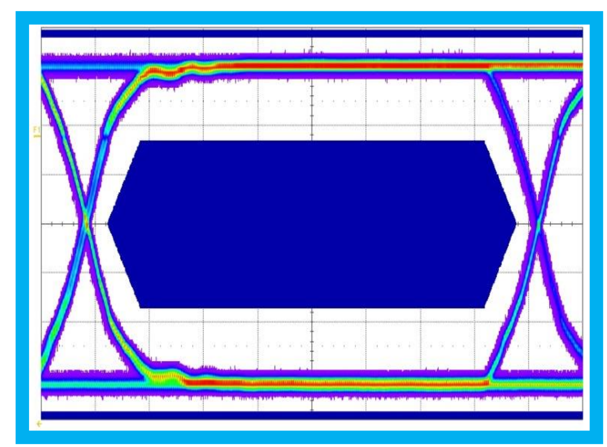
DM →110 Ohm @ 12 MHz

Using a CMC (too high Diff Mode)



CM →77 Ohm @ 12 MHz
DM →15 Ohm

Using a CMC (lower Diff Mode)

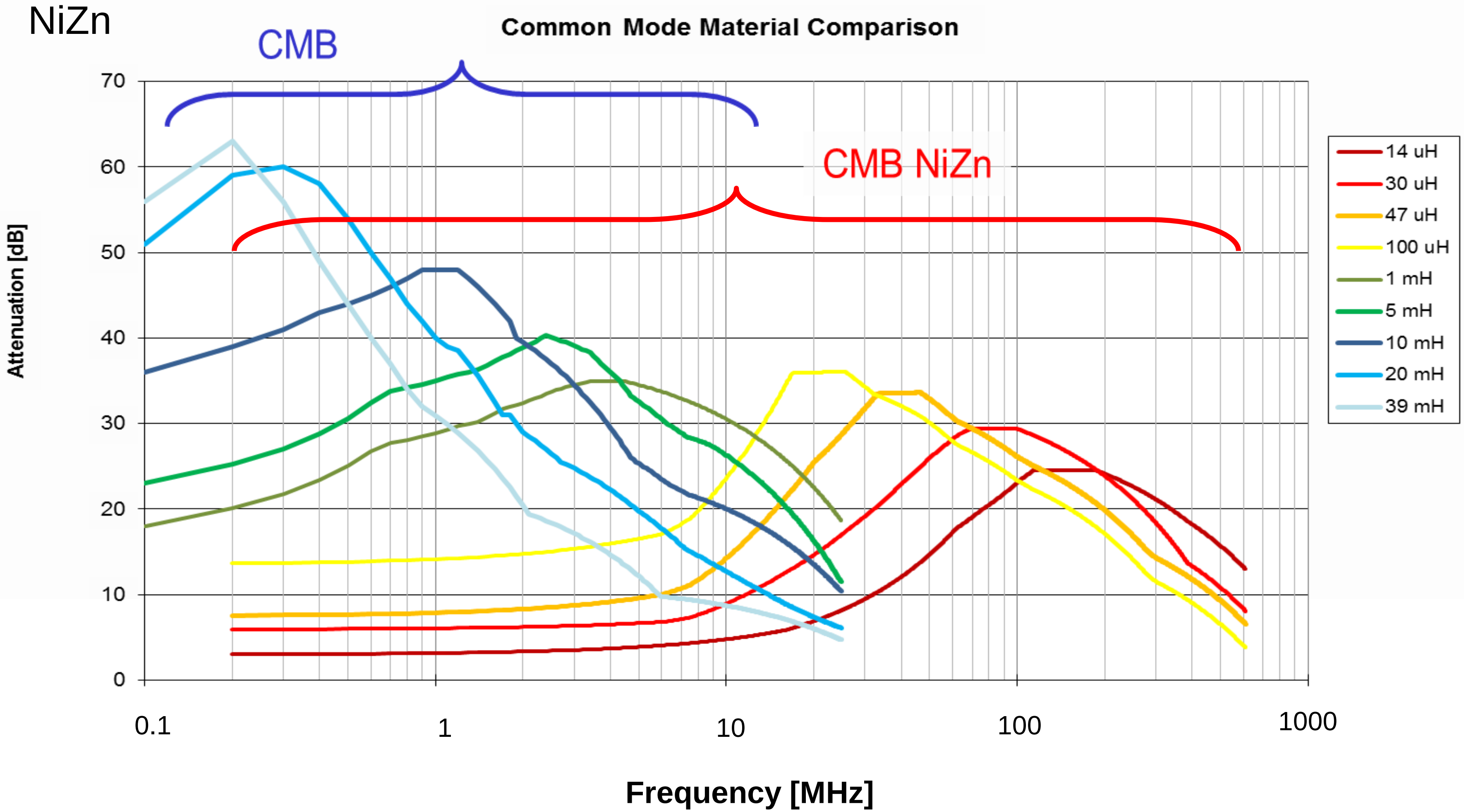


CM → 77 Ohm @ 12 MHz
DM → 1 Ohm

Too much differential mode impedance distorts the USB 2.0 eye pattern

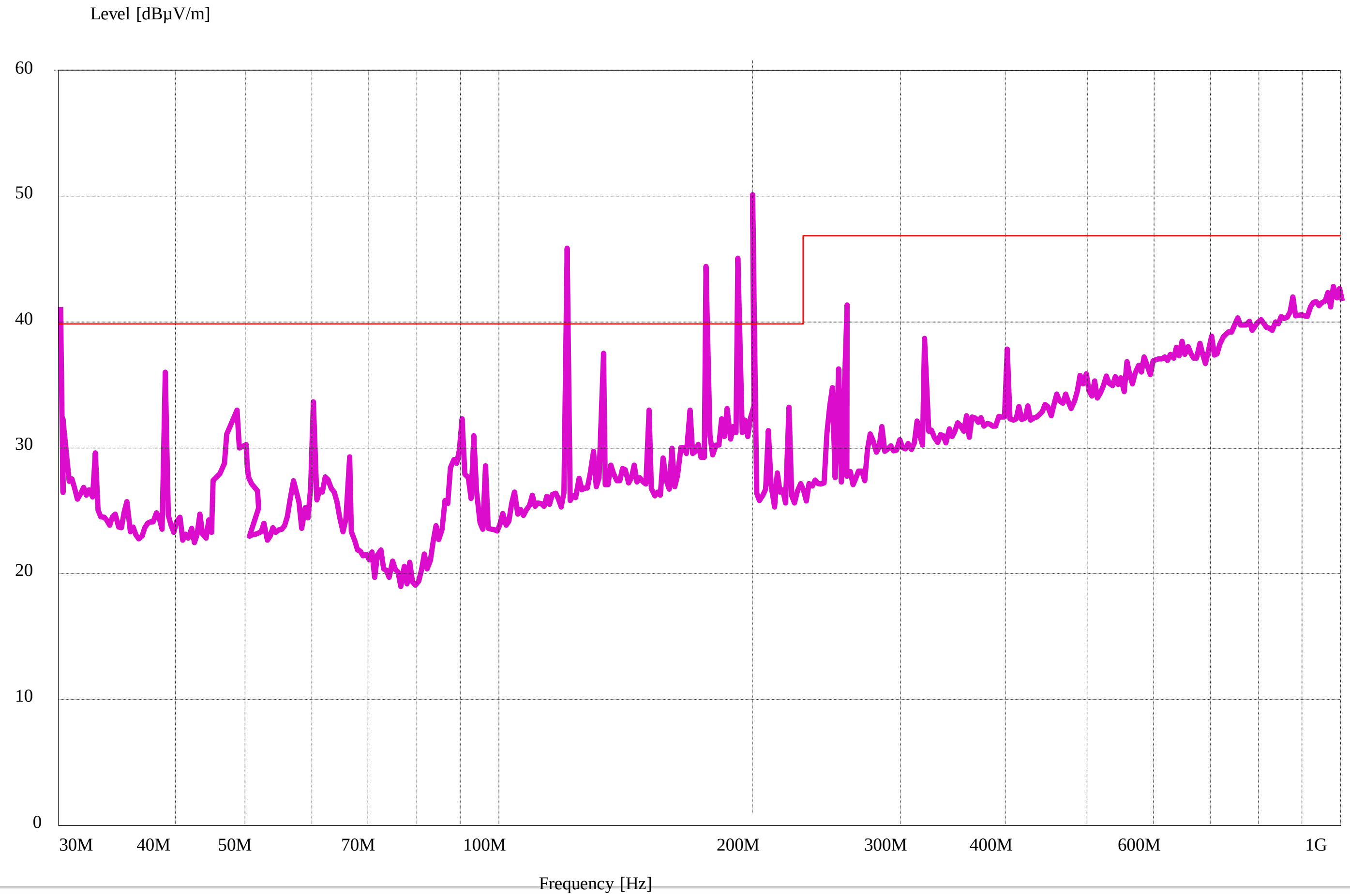
Common Mode Choke (Material Comparison)

- comparison common mode chokes CMB – CMB NiZn

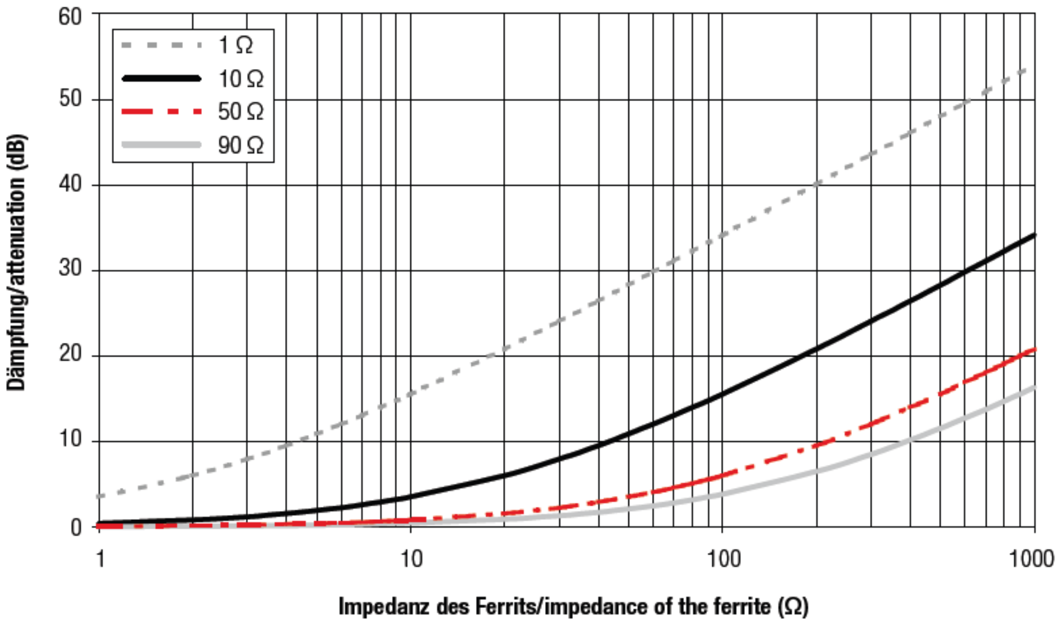


Insertion loss - Example

- Original measurement



Insertion loss calculation



Application overview	
Assumend practical system impedance	**Application**
1 Ω	GND (Ground Planes)
10 Ω	V_{CC} (Supply Voltage lines)
50 Ω – 90 Ω	Datasignal Lines/Clock/ Video Signal/USB
90 Ω – 150 Ω	Long Datasignal Lines

The mathematical approach

$$Z_F = \left[10^{\frac{A}{20}} \cdot (Z_A + Z_B)\right] - (Z_A + Z_B)$$

$$Z_F = \left[10^{\frac{20}{20}} \cdot (10_A + 10_B)\right] - (10_A + 10_B)$$

$$Z_F = 180\,\Omega$$

1. **1.Require 20dB of attenuation at 200 MHz**
2. **Know that it is a power cable**
3. **Power port has 10 Ω impedance**
4. **Result is a impedance of 180 Ω**

$$A = 20\log\frac{Z_A + Z_F + Z_B}{Z_A + Z_B}$$

$$A = 20\log\frac{10_A + 180_F + 10_B}{10_A + 10_B}$$

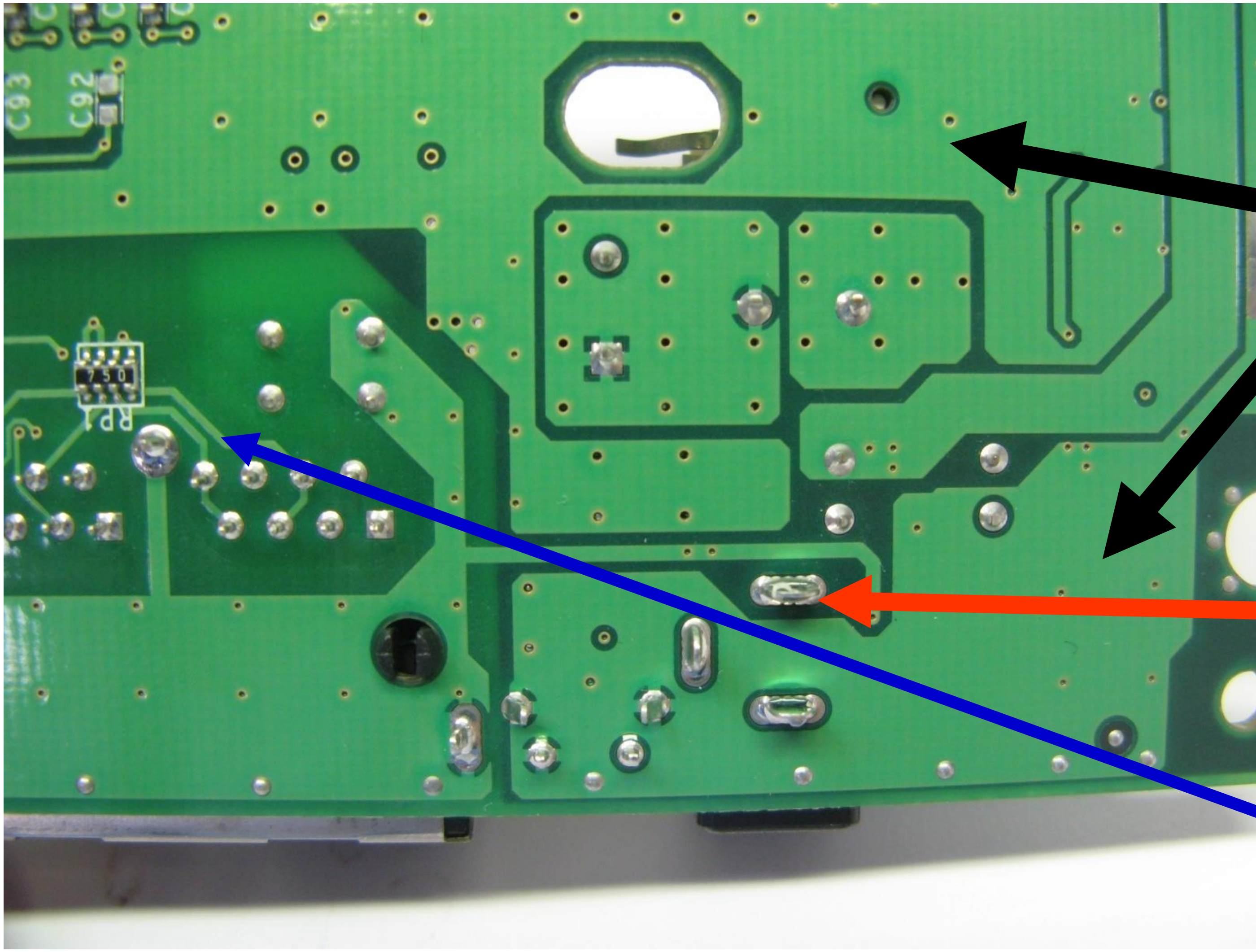
$$A = 20\log 10$$

$$A = 20.00dB$$

Application overview

Assumed practical system impedance	Application
1 Ω	GND (Ground Planes)
10 Ω	V_{cc} (Supply Voltage lines)
50 Ω – 90 Ω	Datasignal Lines/Clock/ Video Signal/USB
90 Ω – 150 Ω	Long Datasignal Lines

Insertion loss calculation



1 Ω

Ground plane

10 Ω

Supply voltage line

50 Ω - 90 Ω

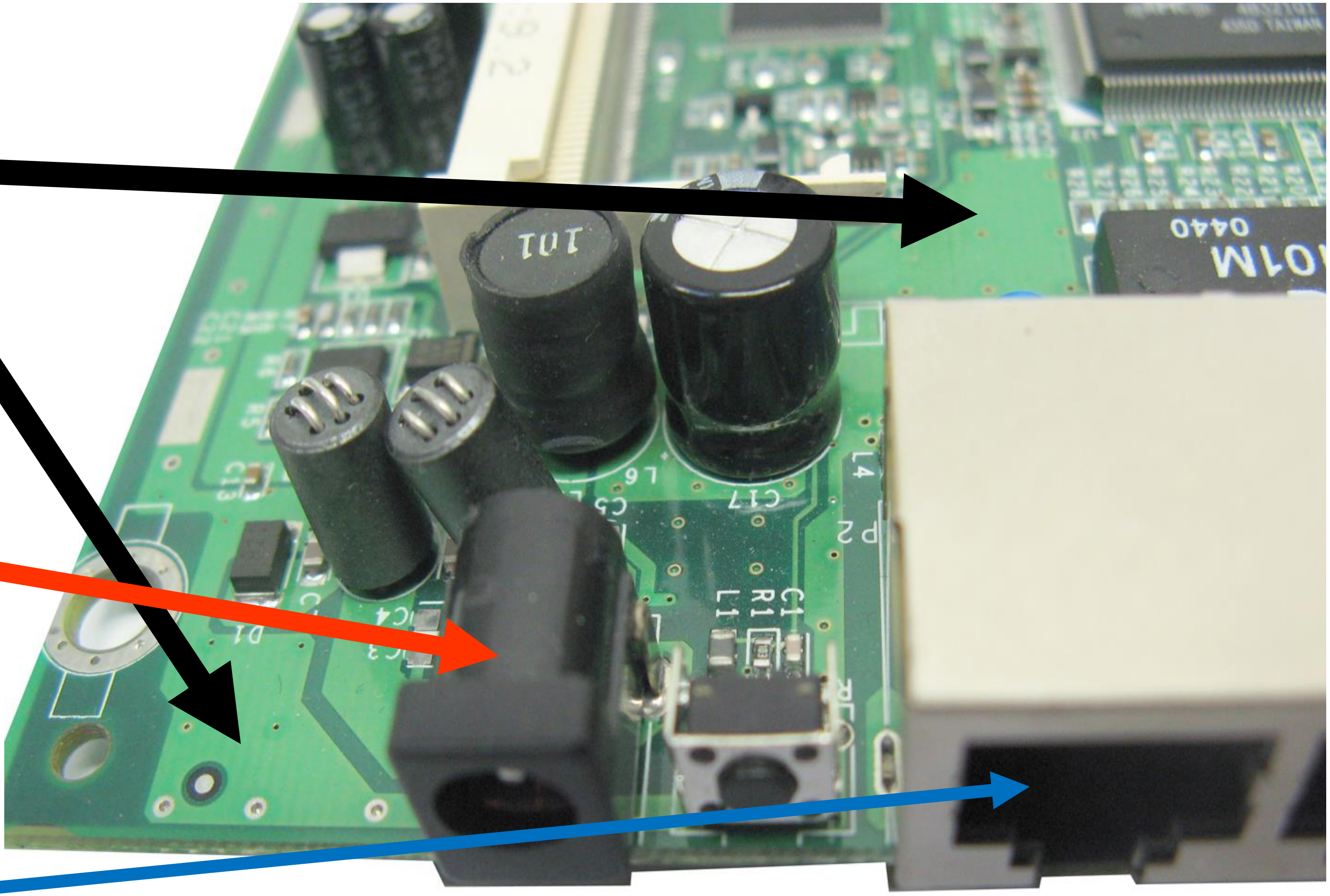
Data signal lines

System impedances

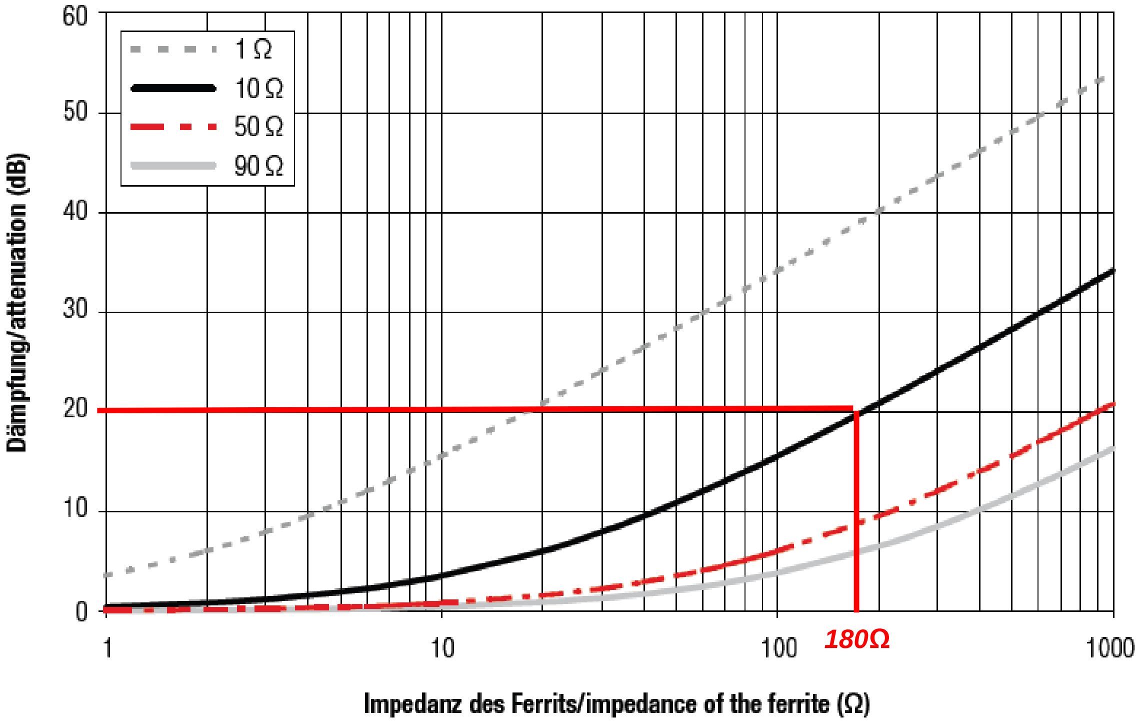
1 Ω

10 Ω

>90 Ω



The practical approach



Application overview	
Assumend practical system impedance	**Application**
1 Ω	GND (Ground Planes)
10 Ω	V_{CC} (Supply Voltage lines)
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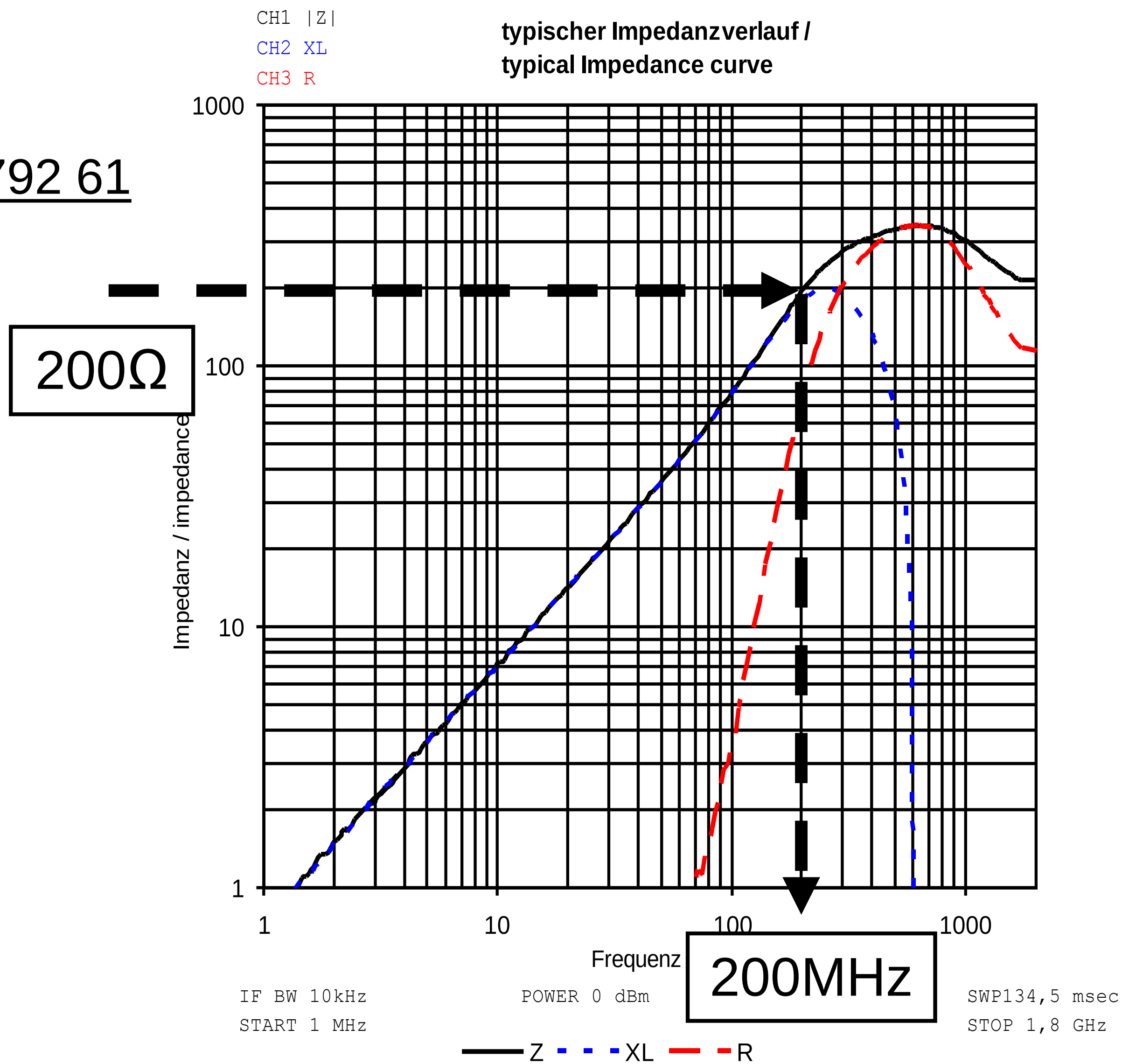
1. **Require 20dB of attenuation at 200 MHz**
2. **Know that it is a power cable**
3. **Power port has 10 Ω impedance**
4. **Result is a impedance of 180Ω**

Insertion loss - Example

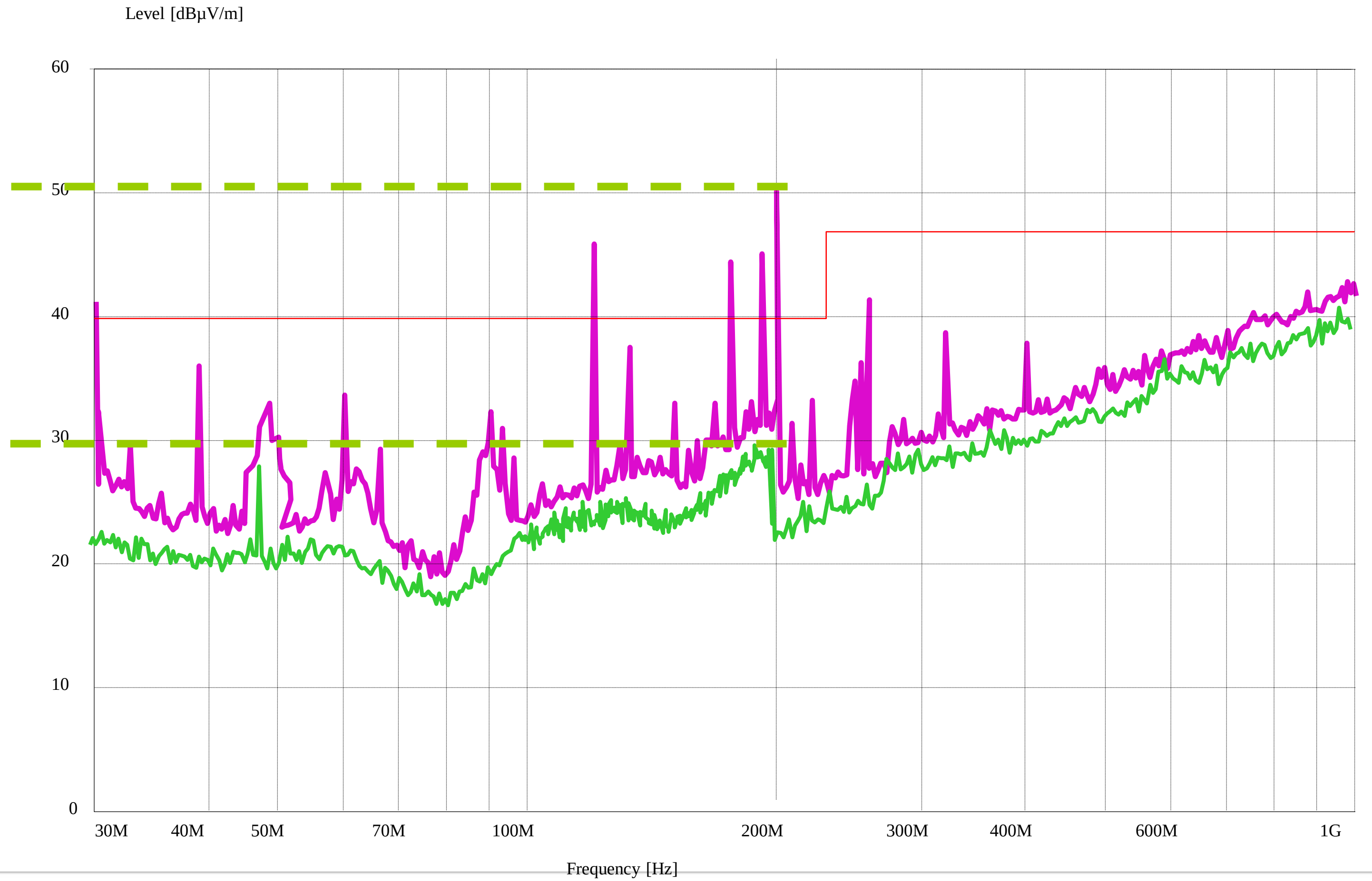
WE-CBF 742 792 61



Insertion loss - Example

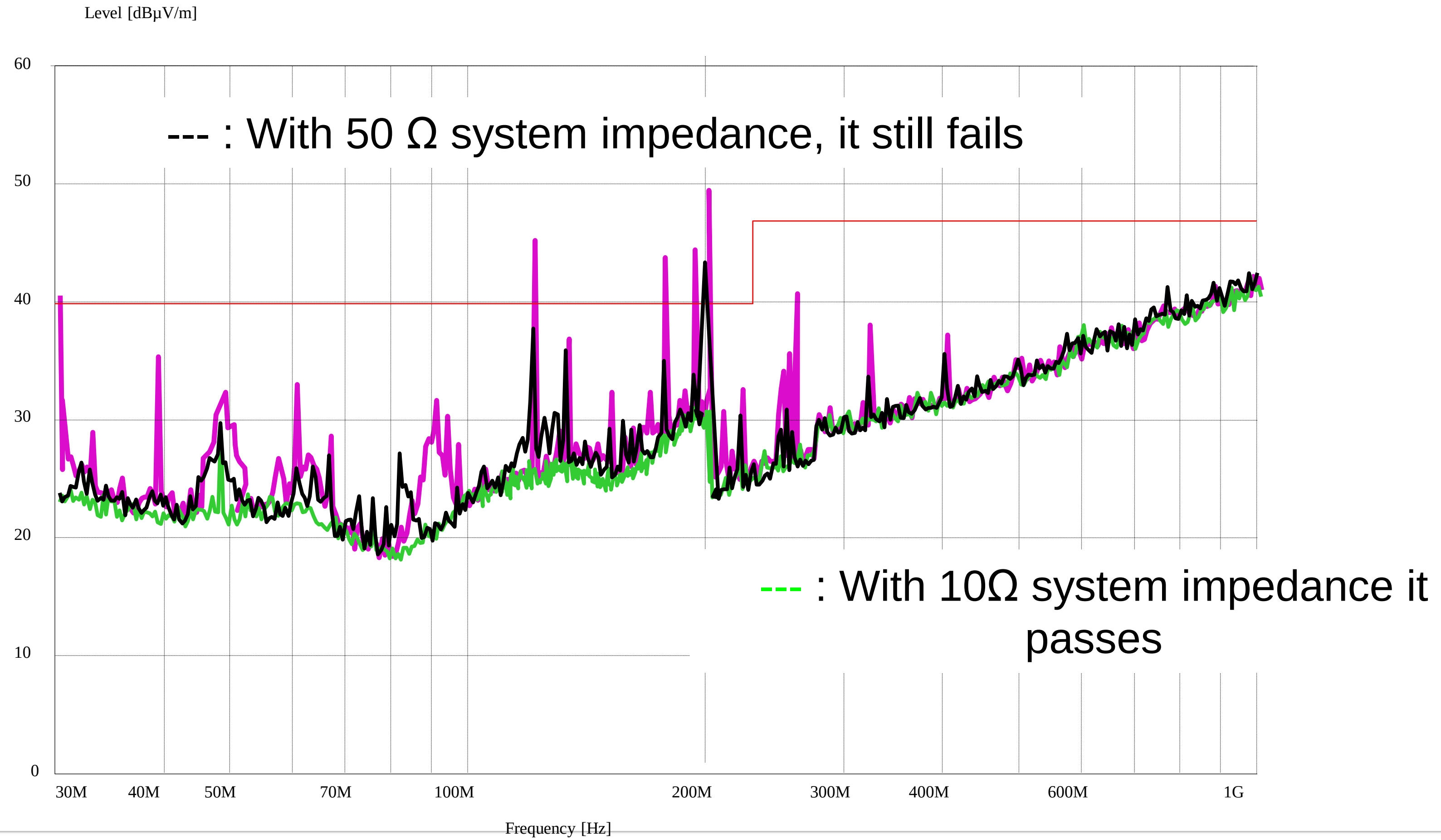
- Check the results

→ Measuring the emission and compare the attenuation



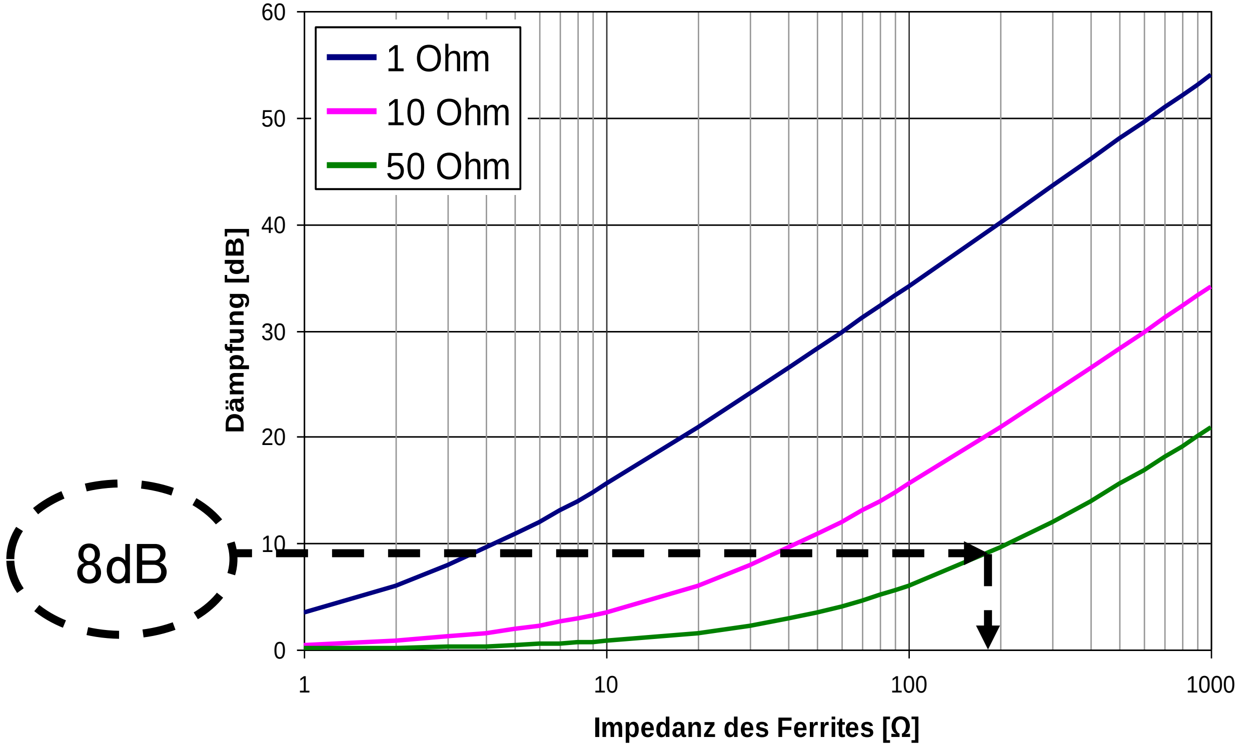
Insertion loss - Example

- Choosing different system impedance
- Effect on video/clock/dataline system impedance (50Ω)



Insertion loss - Example

- <u>Possibility:</u> Attenuation too low



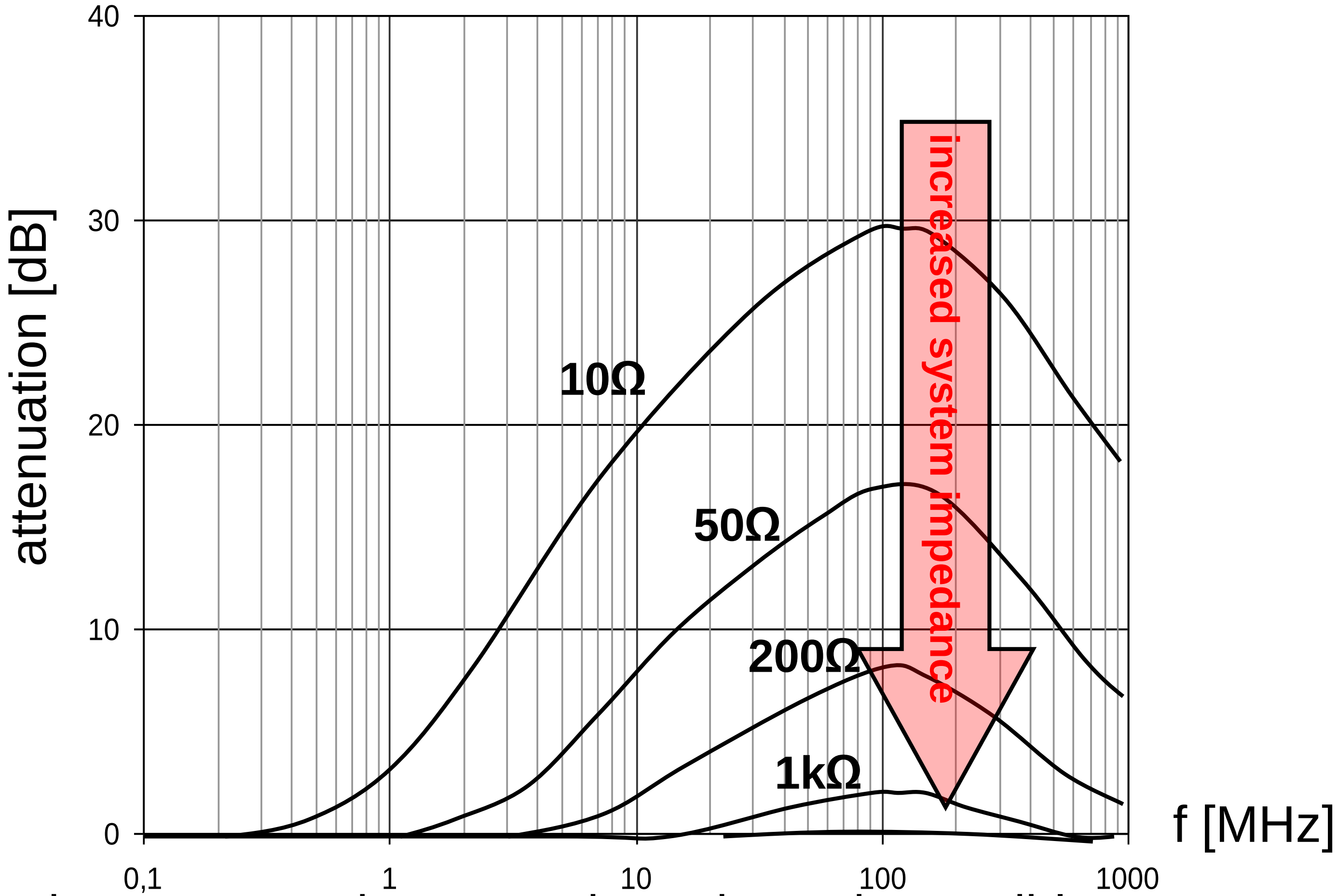
→ could be because of wrong system impedance estimation

→ increase the impedance of ferrite (Z_F~1000Ω)

Insertion loss - Example

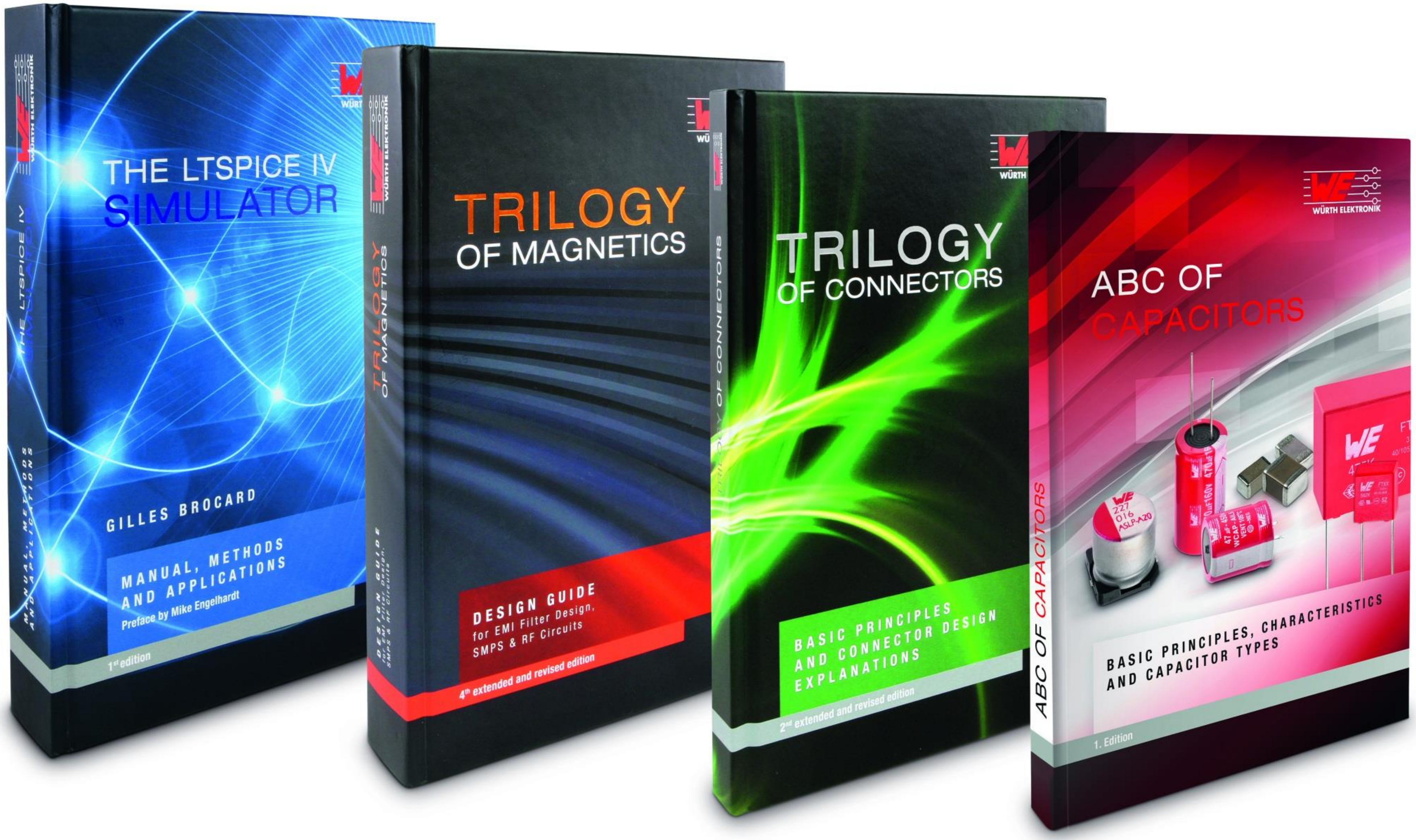
- Dependency of system impedance (Source/Load) vs. attenuation

→ high system impedances results in a low attenuation



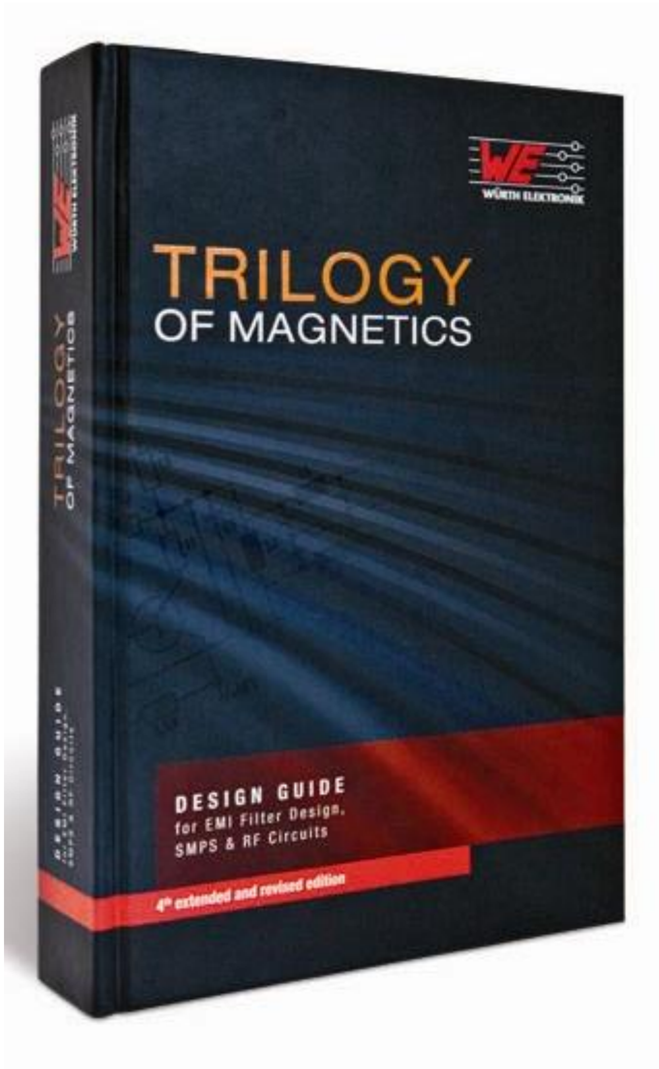
→ Filtering just to a certain system impedance is possible

More Than You Expect



WÜRTH ELEKTRONIK

What more do you need?



Look at our Book:

Chap.1: Basics

keep it simple, stupid

Chap.2: Components

Descriptions, Applications, Simulation Models and many more

Chap.3: Filter-Circuits

Design, Grounding, Layout, Tips

Chap.4: Applications

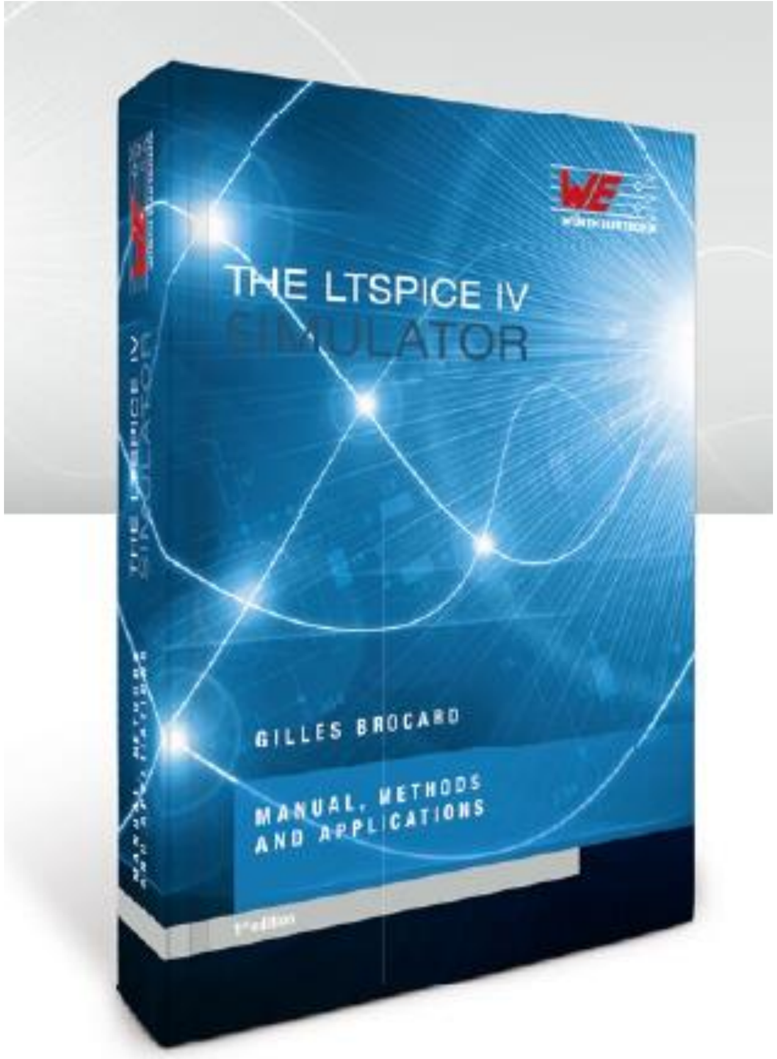
Circuit, suggested parts, Layout

Chap.5: Appendices

from A to Z

LT Spice IV Simulator Manual

- 1. Basics
  → History of the LT Spice Simulator
- 2. Electrical components
  → Libraries of existing parts
- 3. Circuit creation
  → Design recommendations
- 4. Application notes
  → Examples of syntax and simulations
- 5. Analysis
  →Temperature, Monte Carlo, operating limits, etc.



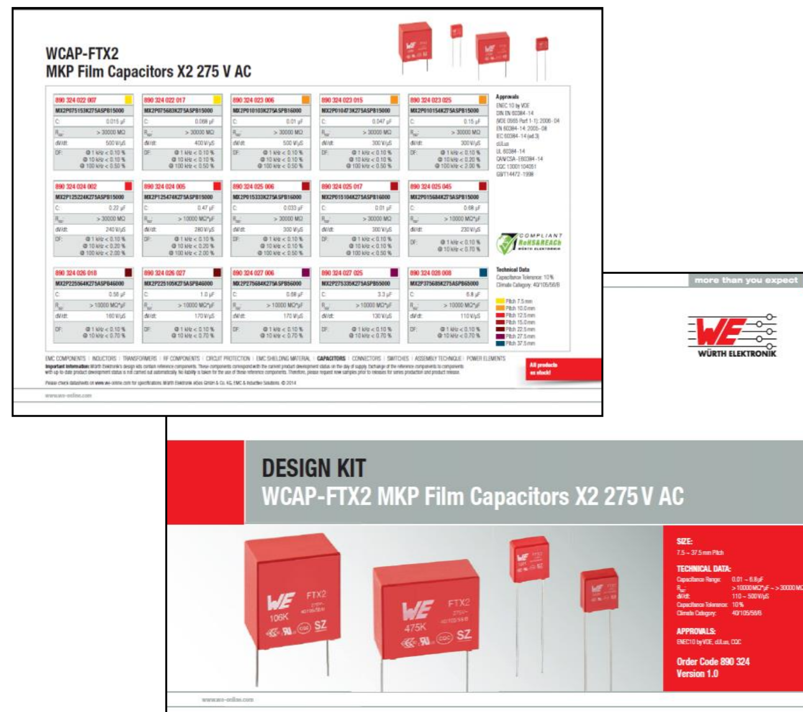
ABC of Capacitors and Design Kits

1. Technical basics
2. Characteristics
3. Types of capacitors

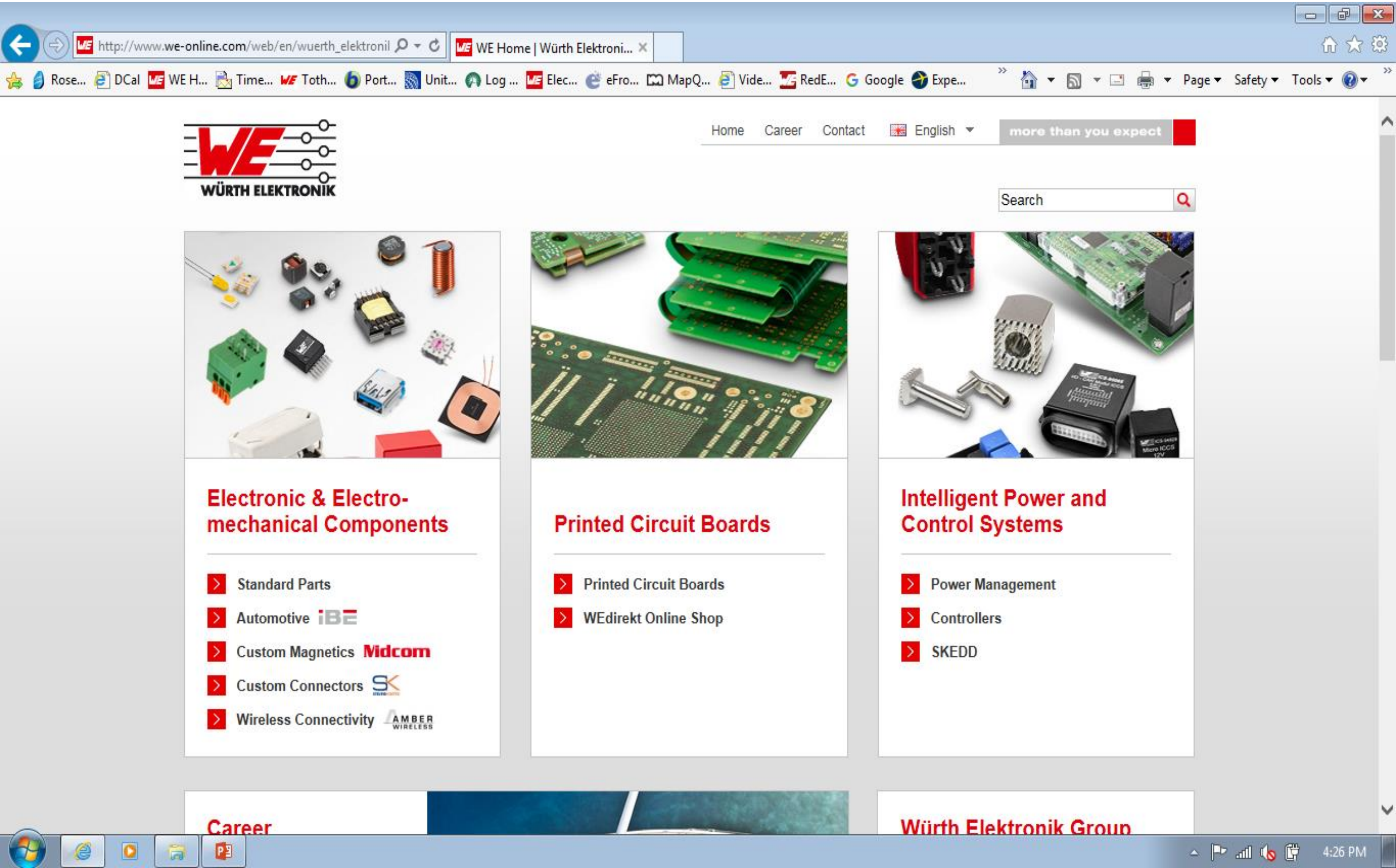
80 pages
in German

English
version
available

Design Kits WCAP-FTX2, -FTXX



Online: **www.we-online.com**



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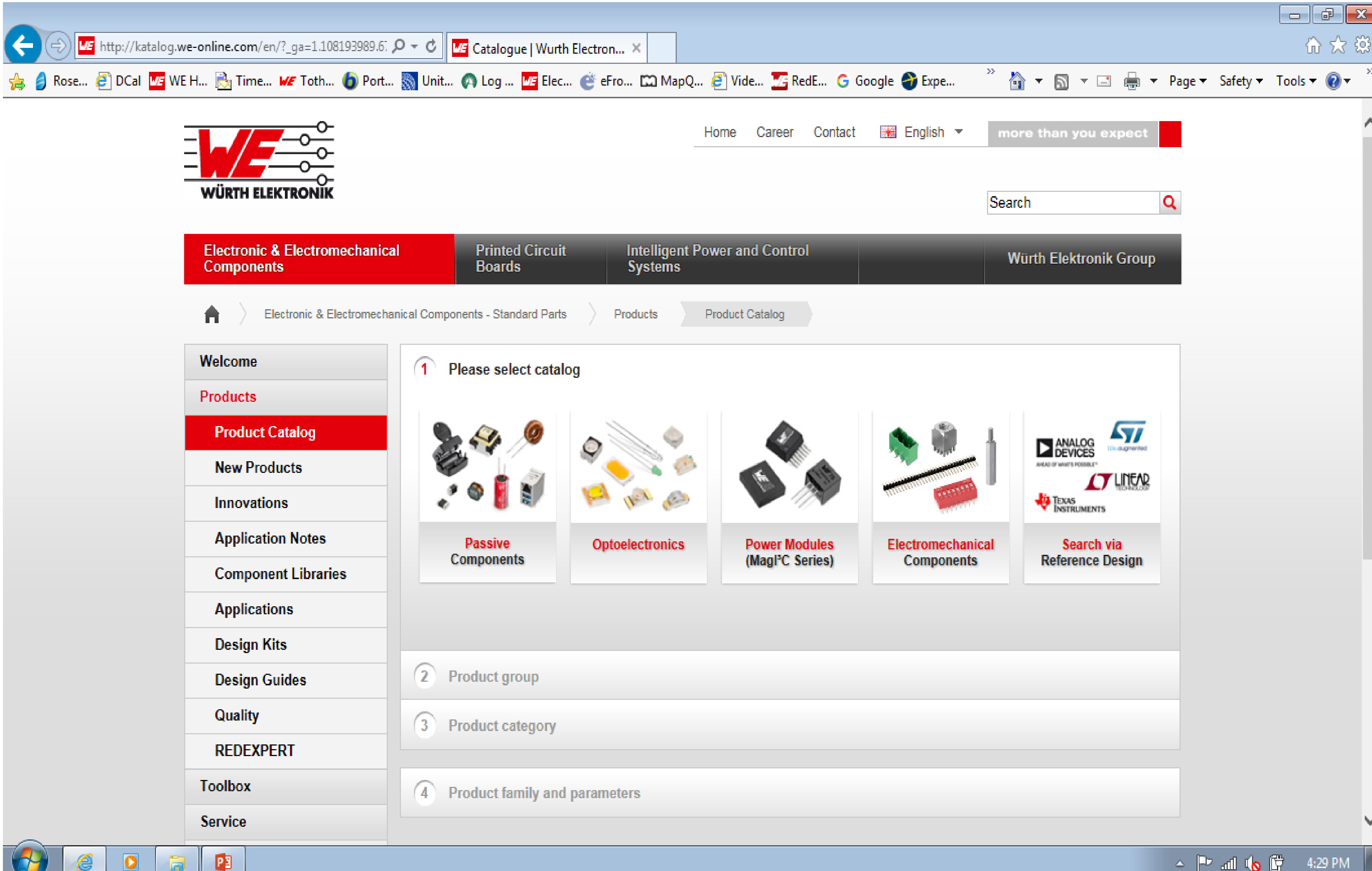
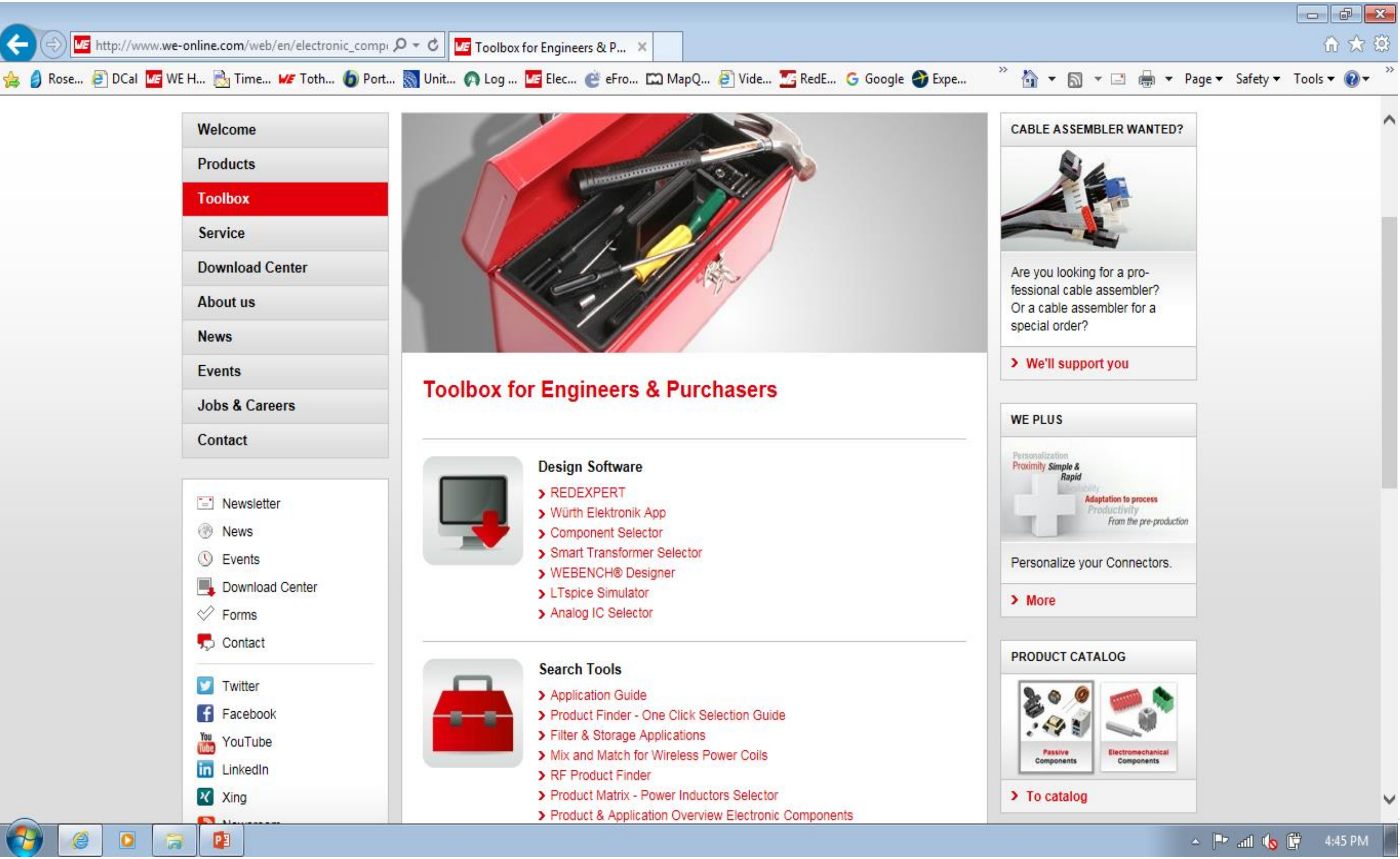


Online: www.we-online.com



Questions?


Thank you!!!
SANYO