Advanced Softmagnetic Materials for EMI Filters in future Automotive Powernet Systems

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- trends from MAGNETEC‘s point of view
- EMC basics
- EMI filters and current compensated chokes
- material comparison: NANOPERM® vs. Ferrite
- production process of nanocrystalline cores

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introduction of MAGNETEC

- MAGNETEC GmbH was founded 1984 as a private company in Langenselbold near Frankfurt
- specialized in development and production of softmagnetic tape wound cores
- production facilities in Hungary since 1989
- ~ 280 employees, ISO 9001 certified
- turnover 2001: 12 Mio € mainly in Europe
- suppling ABB, Siemens, Schneider Group etc. since many years with ~ 1 Mio products/month for earth-leakage circuit breakers and EMI filters
- NANOPERM® cores were introduced 1999

trends from MAGNETEC's point of view

New PWM-systems with IGBT technology (e.g. inverter drives) in tomorrow's cars will increase radio-frequency-noise levels at the on-board-powernet

- DC/DC converters (e.g. in 42/14V- systems)
- integrated starter/alternator (ISA)
- electrical brakes
- electrical steering (EPAS)
- electrical air conditioning systems
- engine fan control
- high intensity discharge lamps (HID) .....

In parallel, other new and highly sensitive systems, like advanced motor management and security systems (multiple Airbags, ABS, ESP...) require an even ‚cleaner' powernet in order to exclude malfunctions !

trends from MAGNETEC's point of view

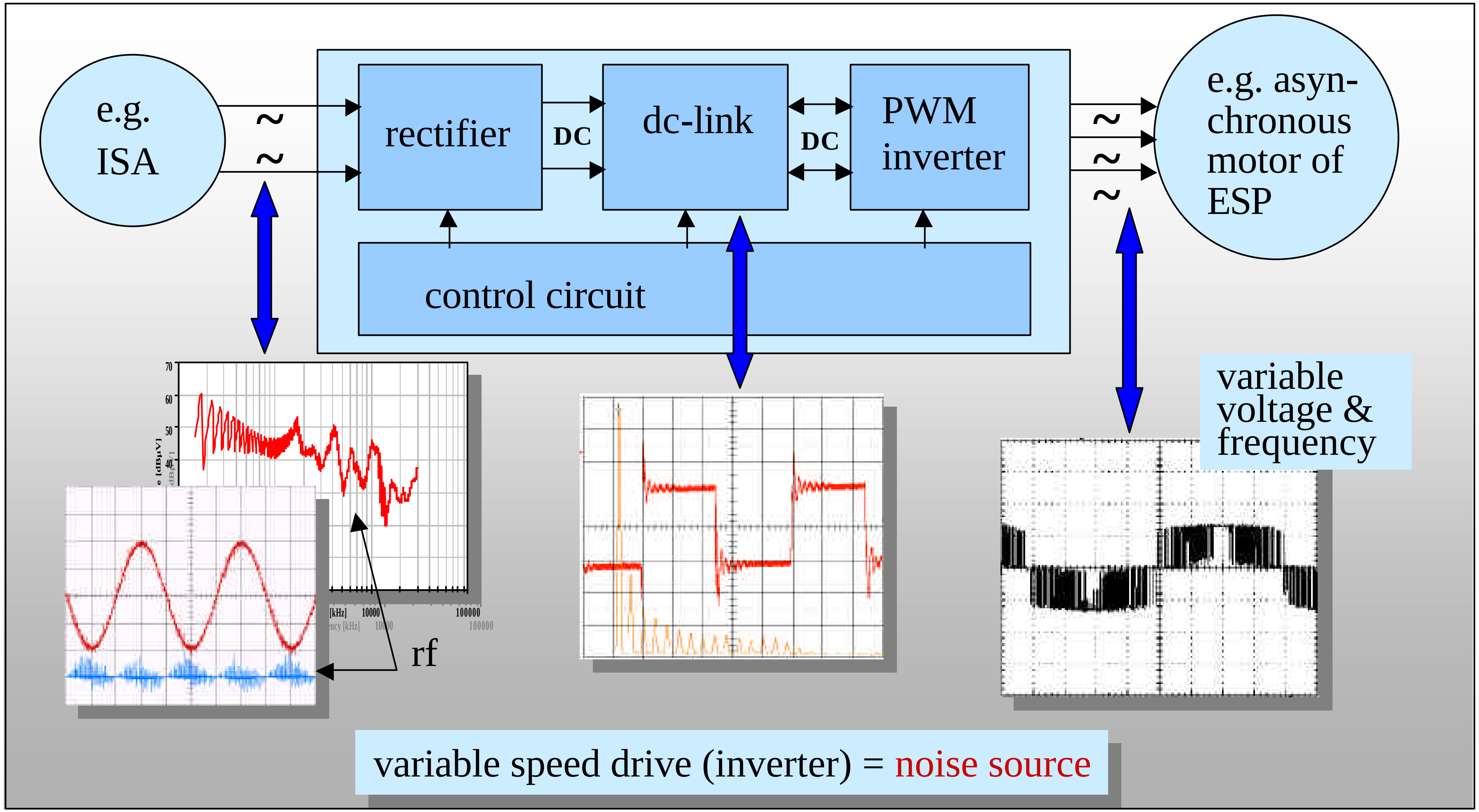
In this scenario, EMC is essential for a reliable and long term functionality of the whole vehicle system. (EMC = electromagnetic compatibility)

As a consequence, the requirements on EMI filtering will become significantly more stringent. State-of-the-art filter components may not be suitable, due to extended environmental boundary conditions like:

- operational temperature up to 180°C and higher
- increased functionality at smaller build volume
- extended shock resisitivity ...

☛ Optimized solutions can be found on the basis of new materials – critical are in particular magnetic components like chokes and coils.

EMC basics: inverter drive as rf-noise source



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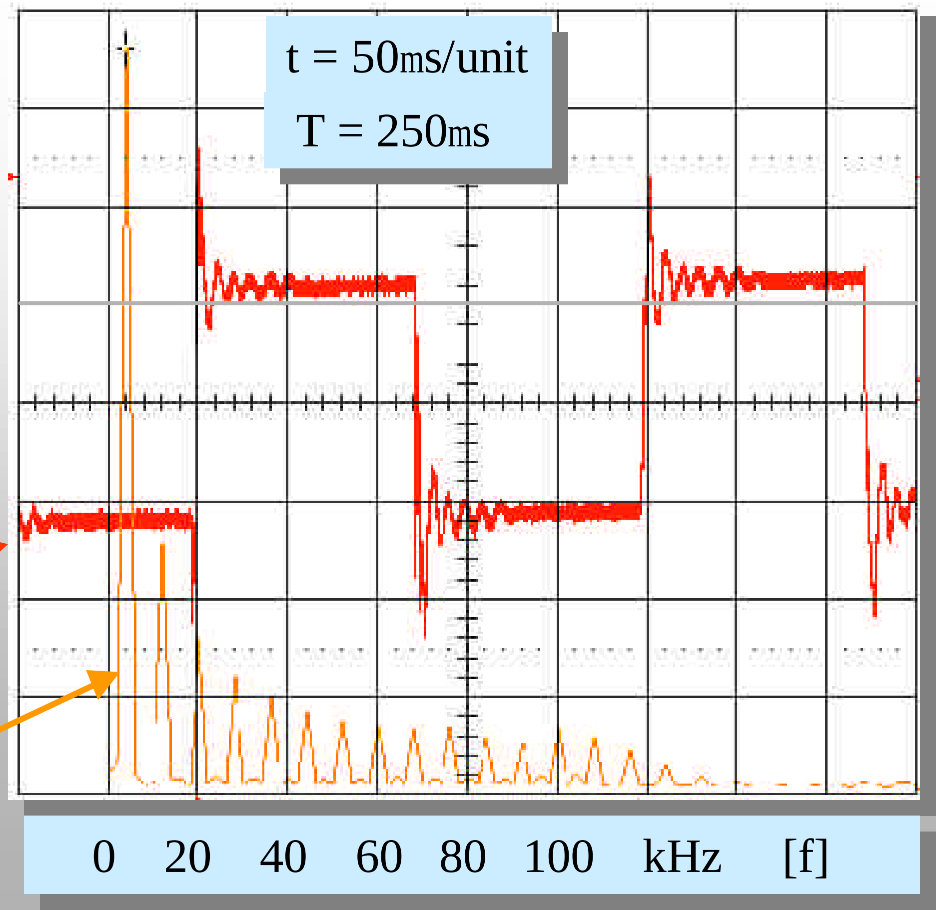
EMC basics: sources of RF noise emissions

typical voltage and harmonics in a variable speed drive (inverter) – used in future Powernet systems. Those unwanted rf-signals are distributed over all connected wiring systems

fundamental wave 4 kHz

harmonics



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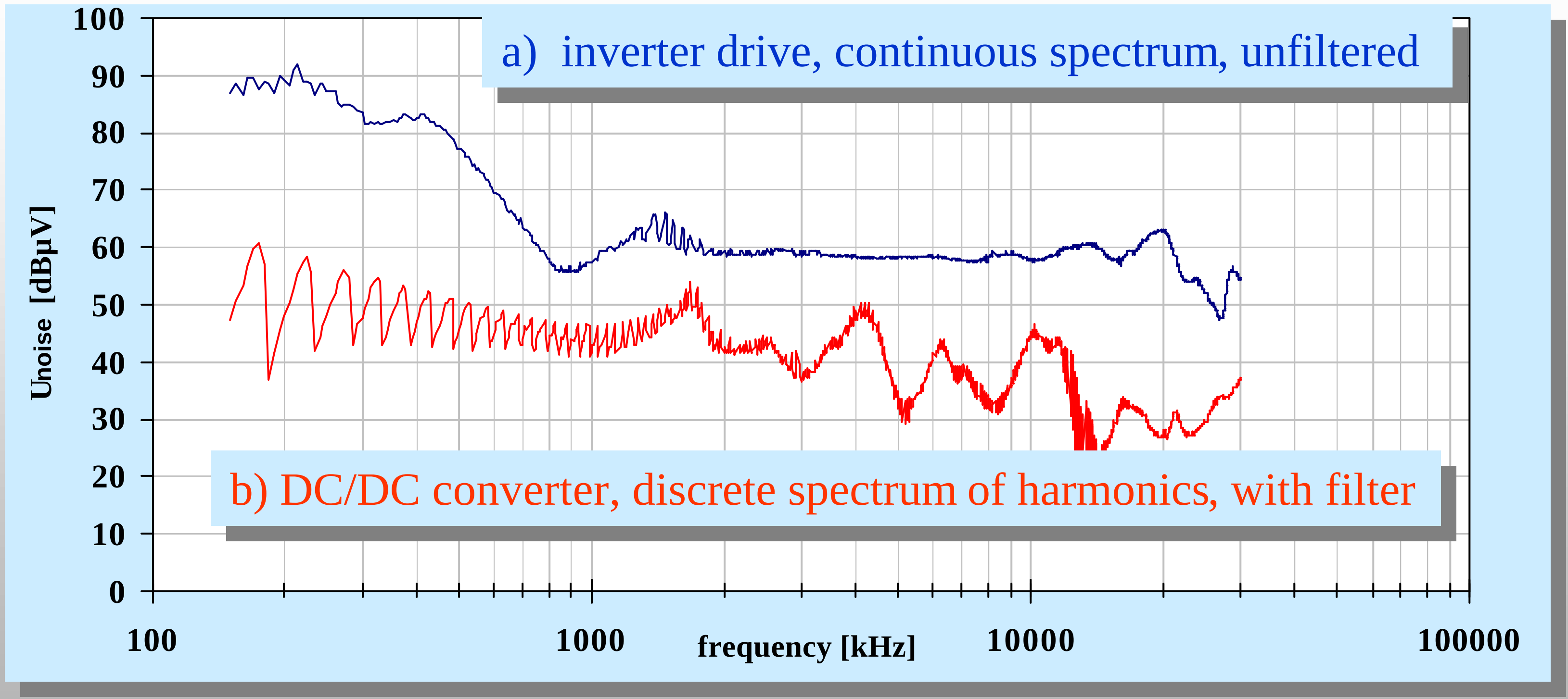
EMC basics: typical noise spectra of inverter and converter



conducted common mode noise in 50Ω-System

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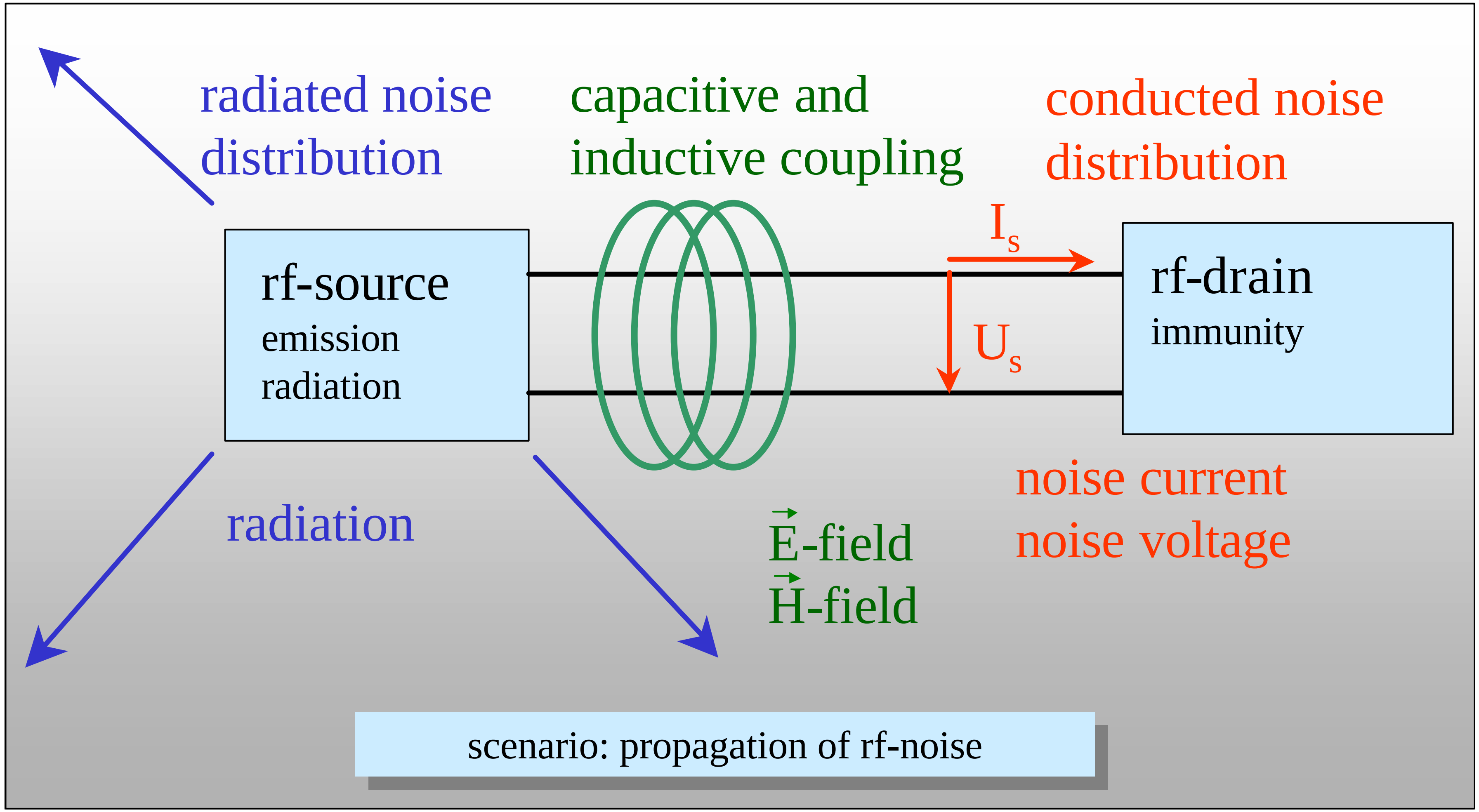
EMC basics



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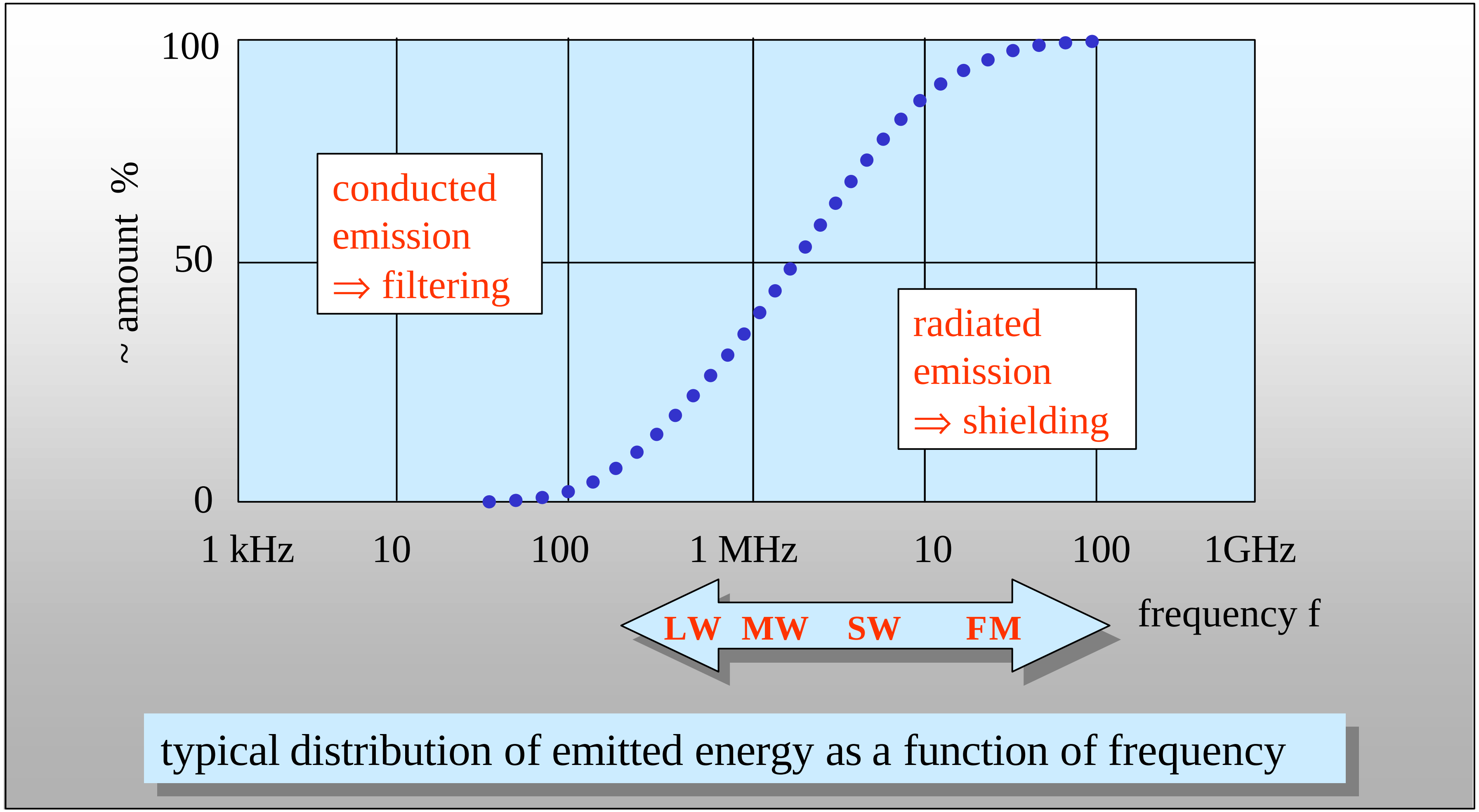
EMC basics: ways of distribution of RF noise



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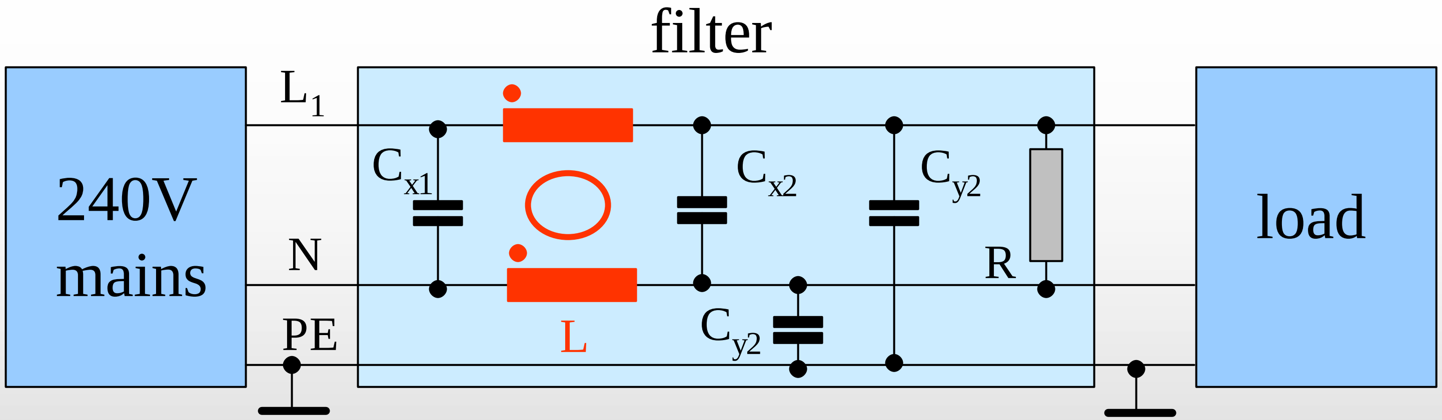
mains filter for conducted noise suppression



C_{xn}	X-capacitor
C_{yn}	Y-capacitor
L	current compensated choke
R	discharge resistor

components of EMI filters

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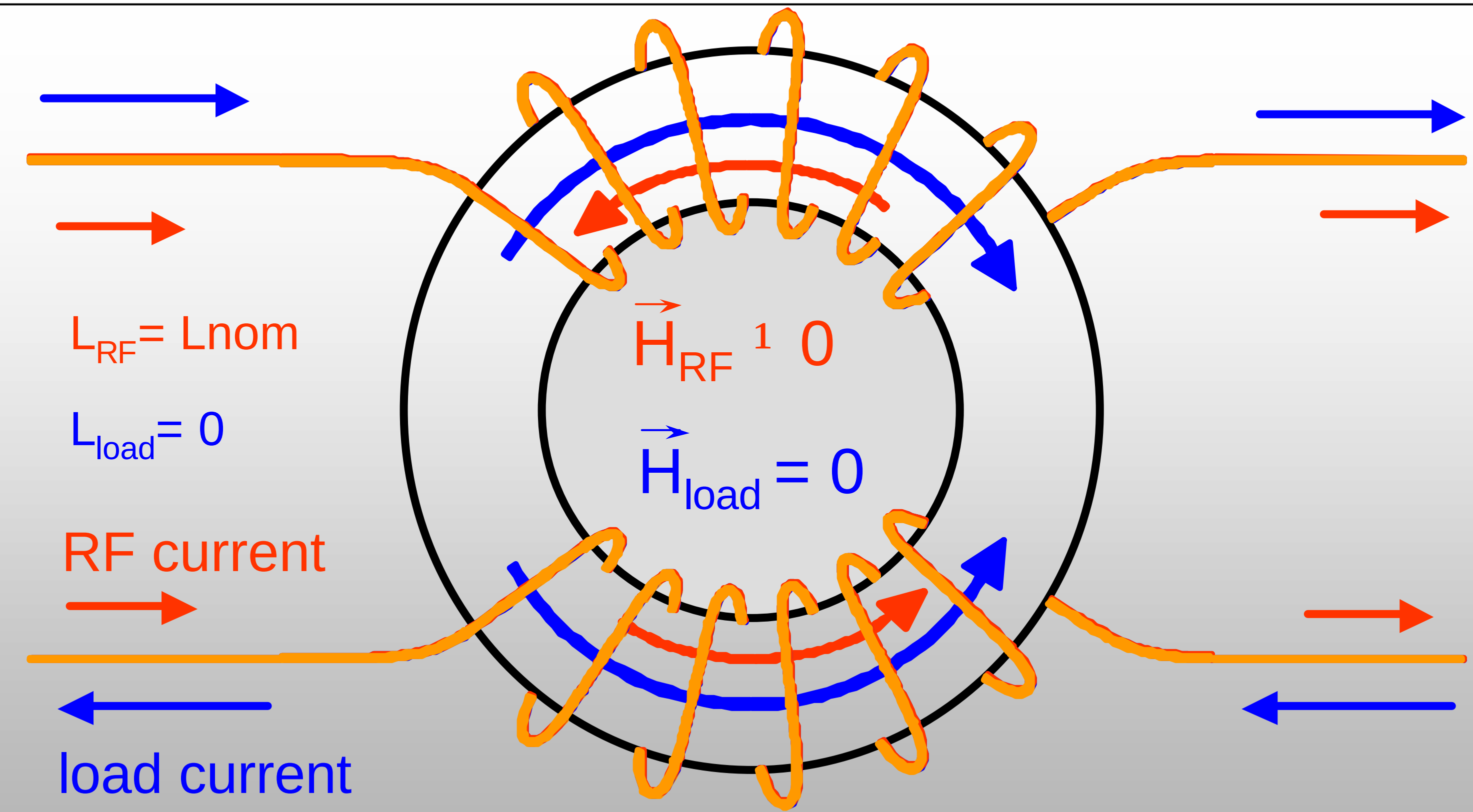
working principle of common mode chokes



the load current is not affected by a current compensated choke, but the rf-common mode noise is

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choice of softmagnetic material

main requirement on an EMC filter choke:

Þ high impedance Z *!*

$$Z(f) = \omega L(f) = 2\pi f\, L(f)$$

$$L(f) = A_L\, n^2 \quad \text{with} \quad A_L = \mu_0\, \mu_r(f)\, A_{fe}/l_f$$

number of turns

permeability *!*

iron cross section
(size of core)

comparison of materials: **NANOPERM® vs. Ferrite**

alloy	permeability μ_r (10 / 100kHz)	saturation induction B_S [T] (25 / 100°C)	Curie-temp. T_C [°C]	working temp. T_{max} [°C]
Ferrite 3E7	15.000 / 12.000	0,38 / 0,21	>130	95
Ferrite T38	10.000 / 10.000	0,38 / 0,23	>130	95
NANOPERM®	100.000 / 20.000 80.000 / 28.000 30.000 / 20.000	} 1,2 / 1,18	600	up to180

- higher permeability - up to a factor of 10 (!)
- higher saturation induction factor 3
- extended working temperature - up to 180°C

Þ advanced, smaller, lighter and cooler components Ü

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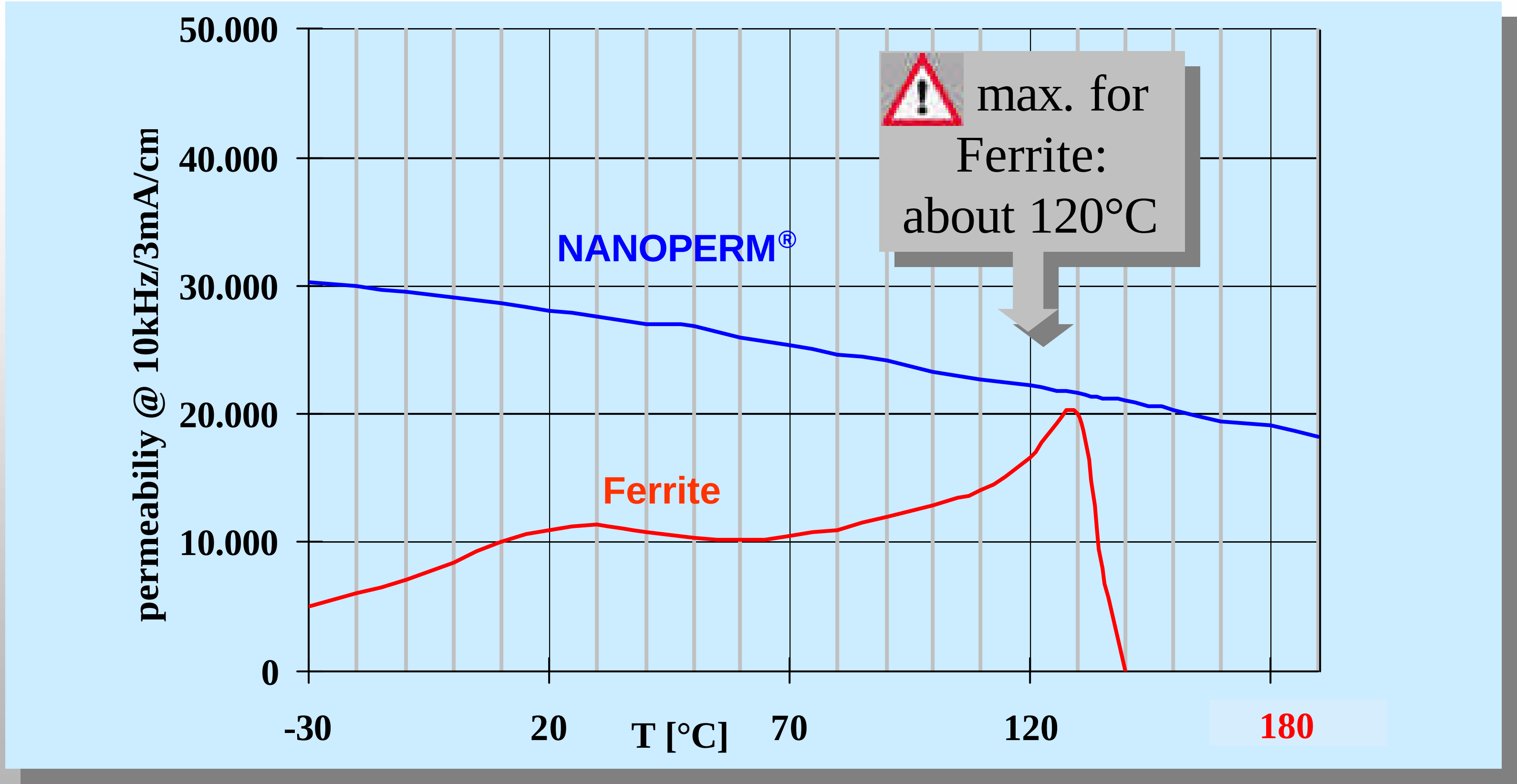

permeability as a function of temperature

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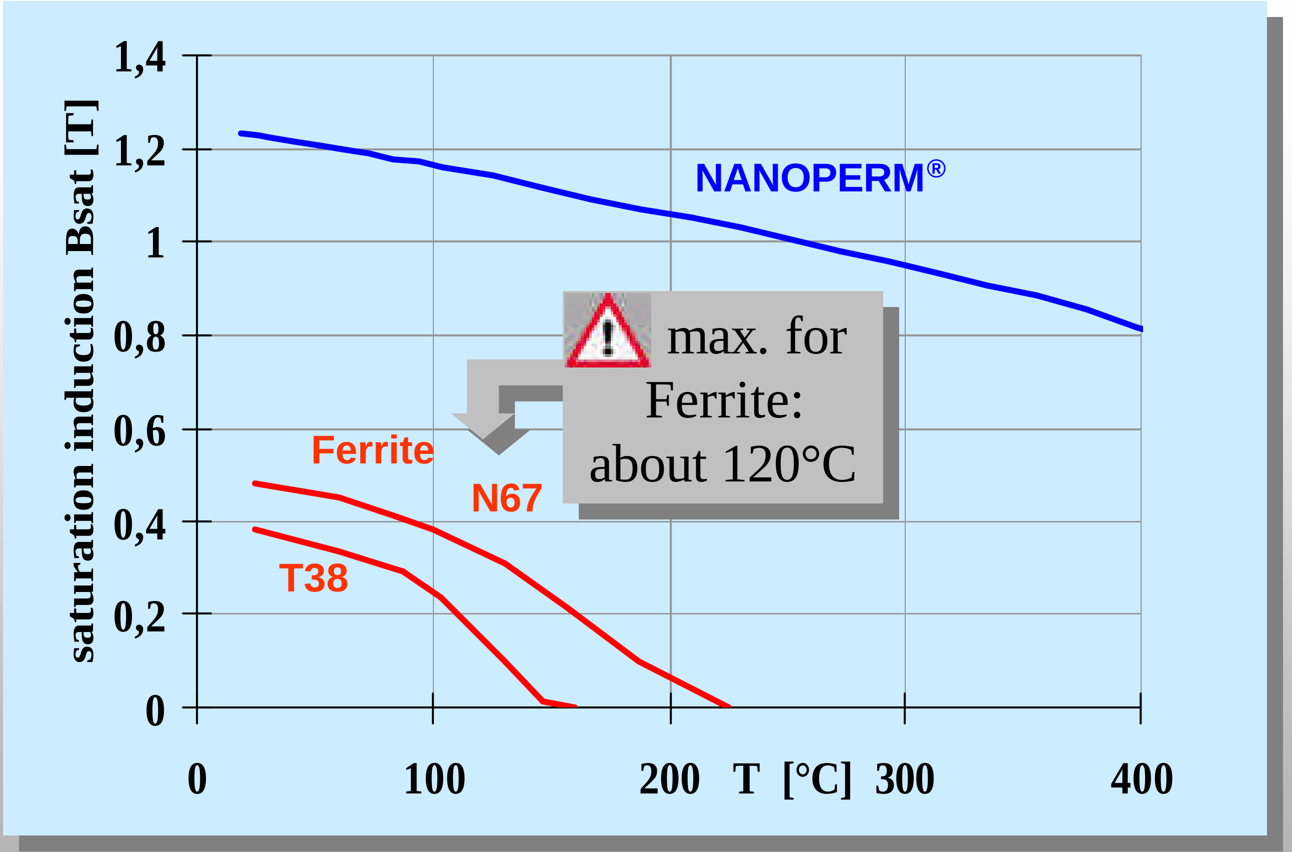
comparison of materials: **NANOPERM® vs. Ferrite**



saturation flux density as a function of temperature T

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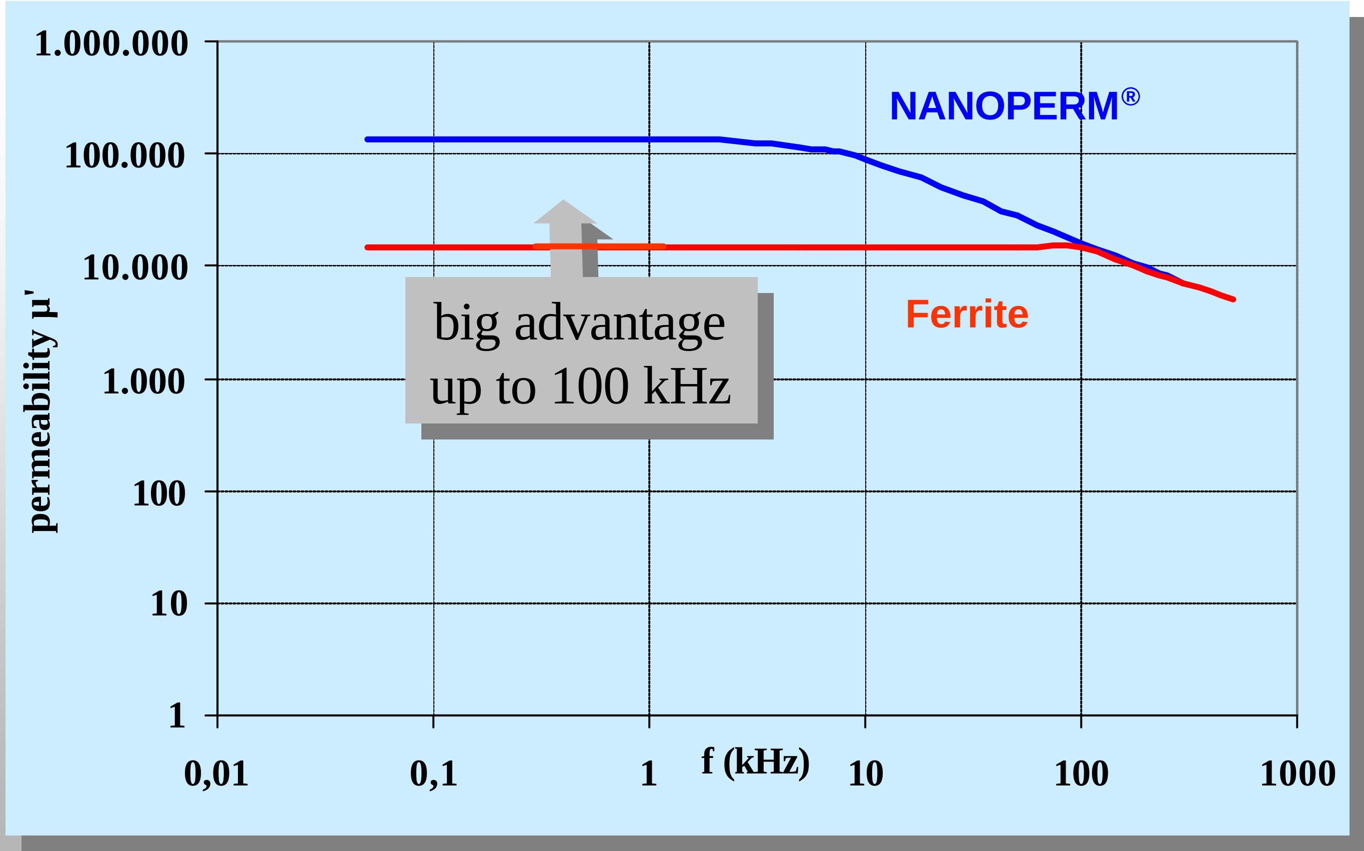

permeability as a function of frequency f

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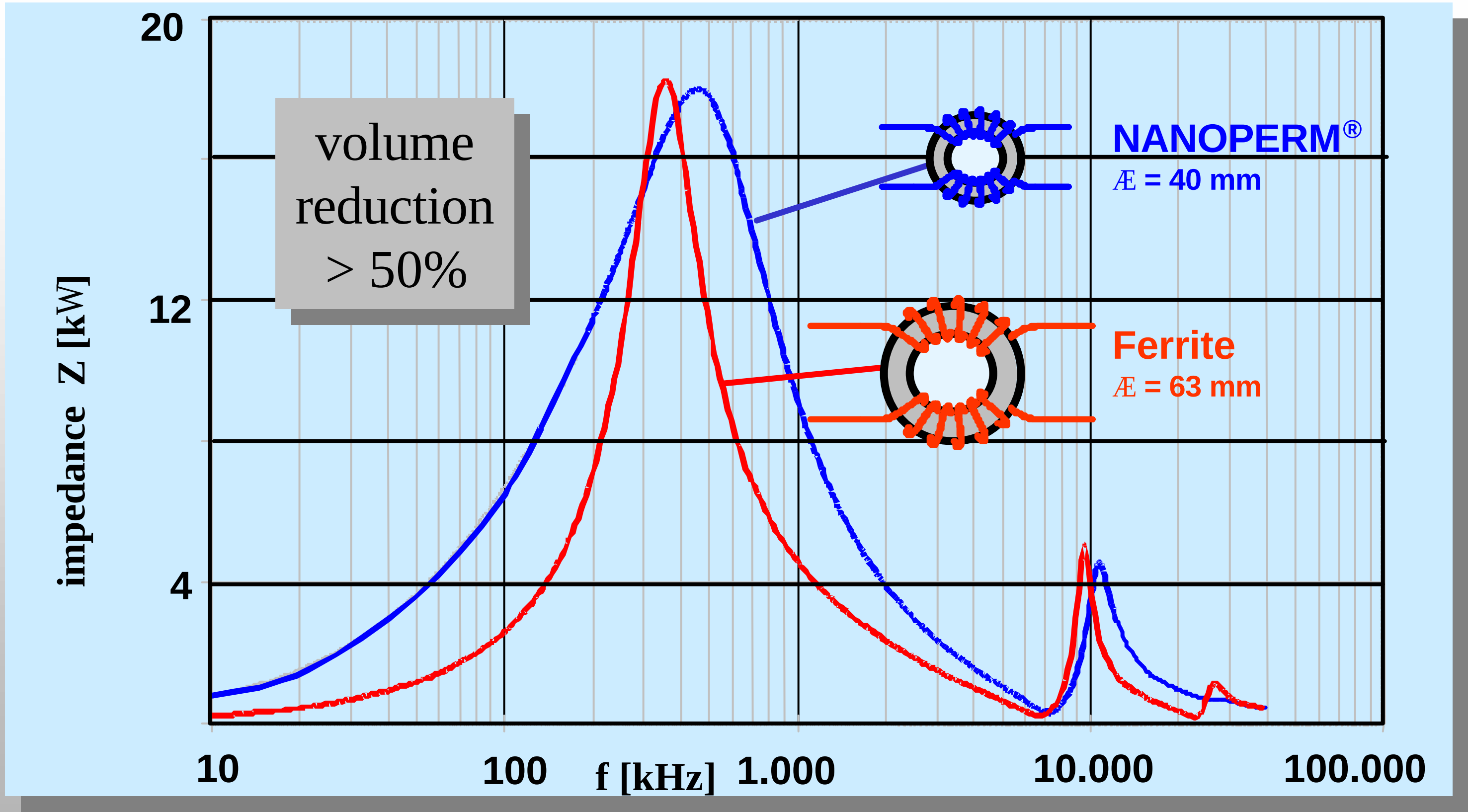
comparison of materials: **NANOPERM® vs. Ferrite**



typical impedance curve for different core geometries

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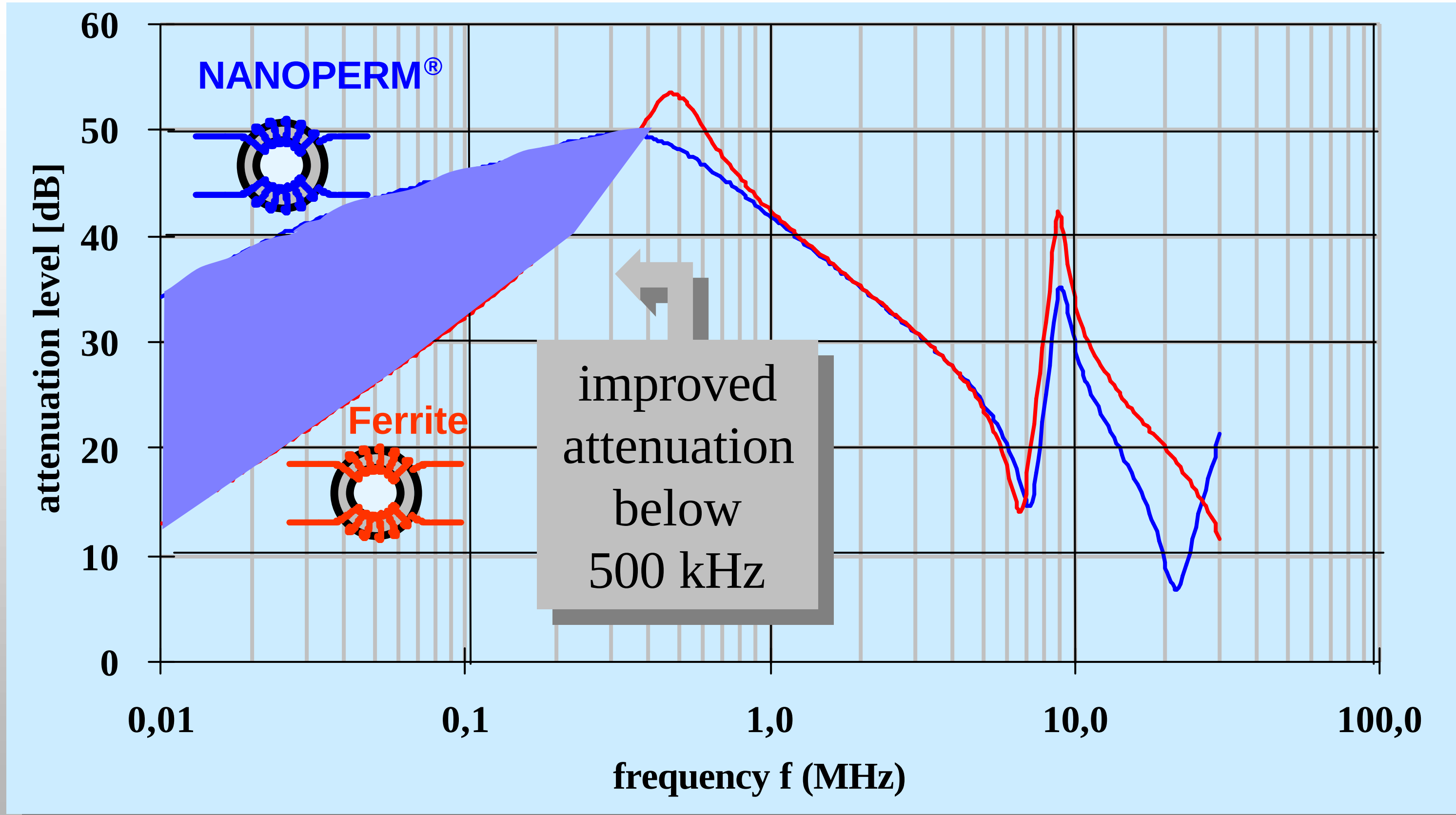
comparison of materials: **NANOPERM® vs. Ferrite**



typical impedance curve at same core geometry Ø=30mm, 22 turns

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comparison of materials: **NANOPERM® vs. Ferrite**

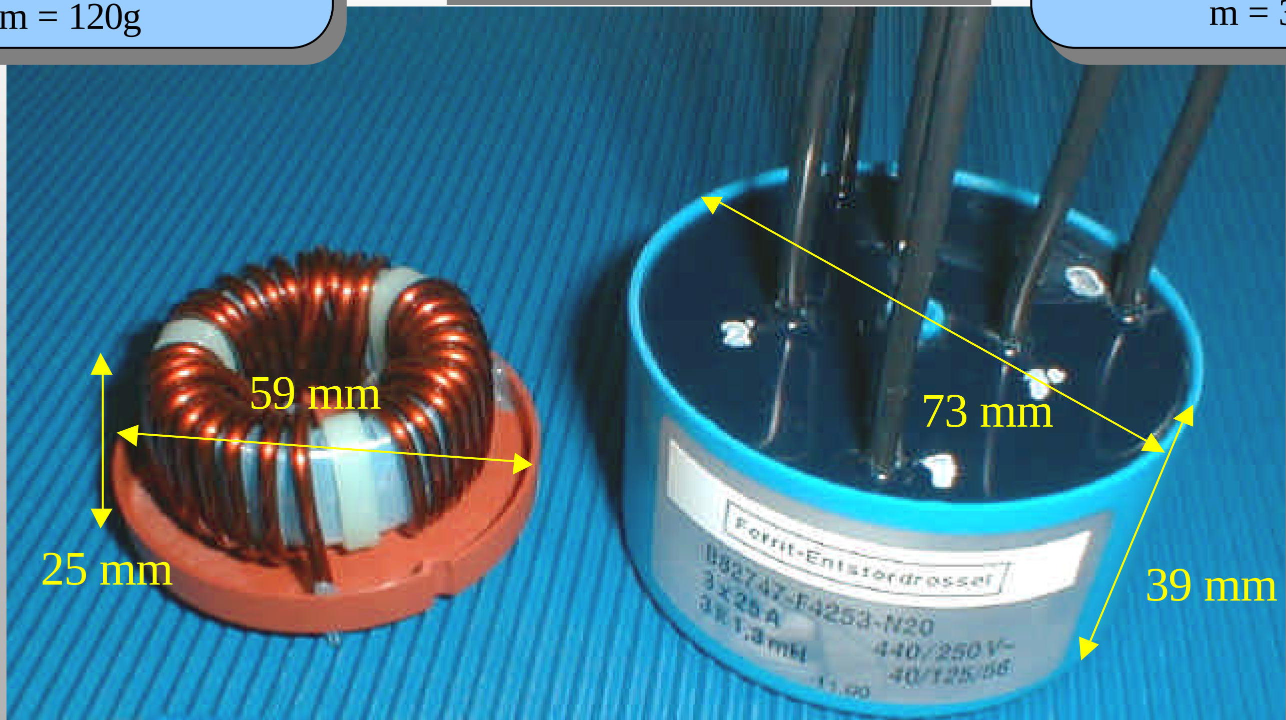
NANOPERM®-choke

I_N = 3 x 25A @ 60°C
L_N = 3 x 1,6 mH @ 10kHz
m = 120g

volume reduction 60%
weight reduction 65 %

Ferrite-choke

I_N = 3 x 25A @ 40°C
L_N = 3 x 1,3 mH @ 10kHz
m = 350g



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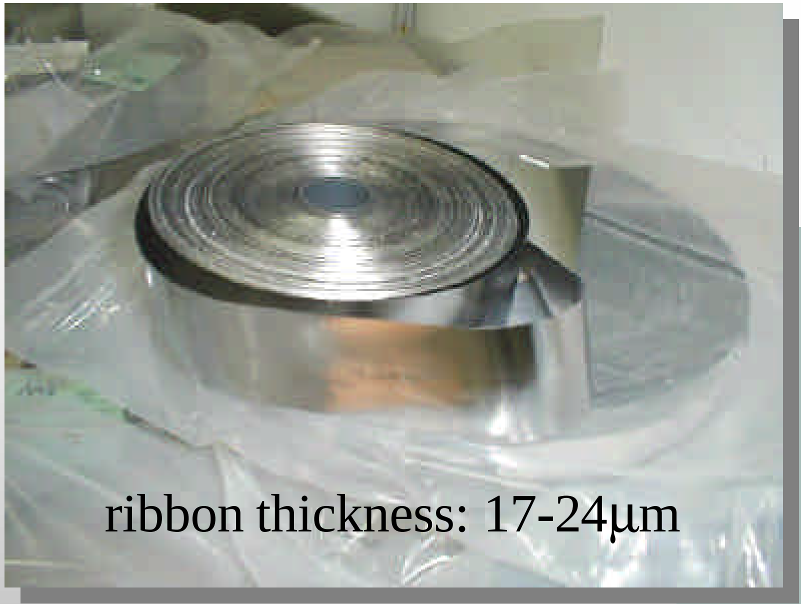
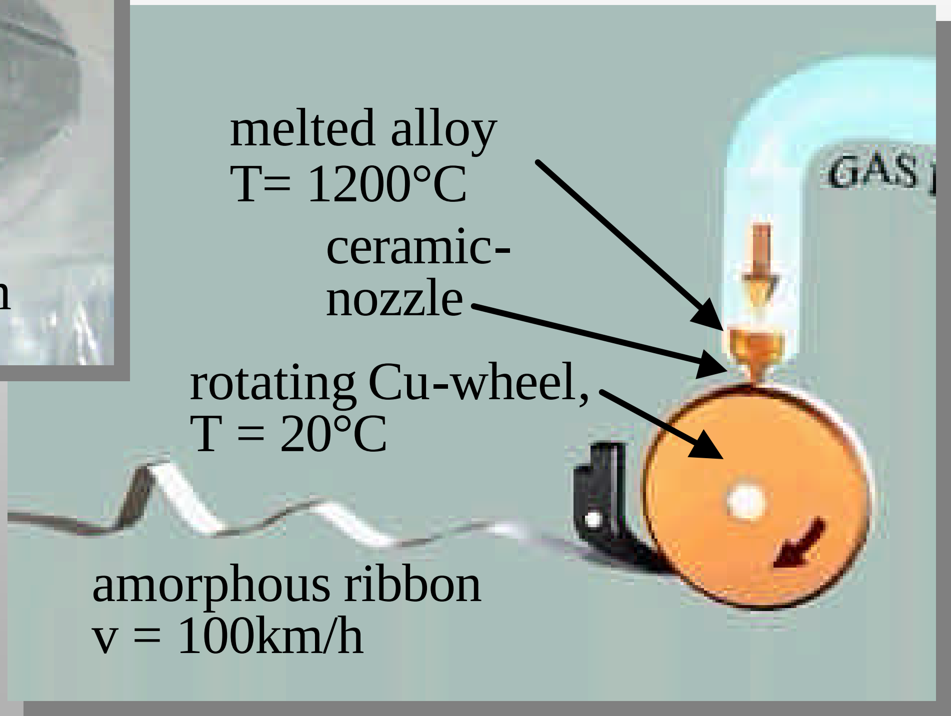
principle of production process of rapidly quenched ribbons





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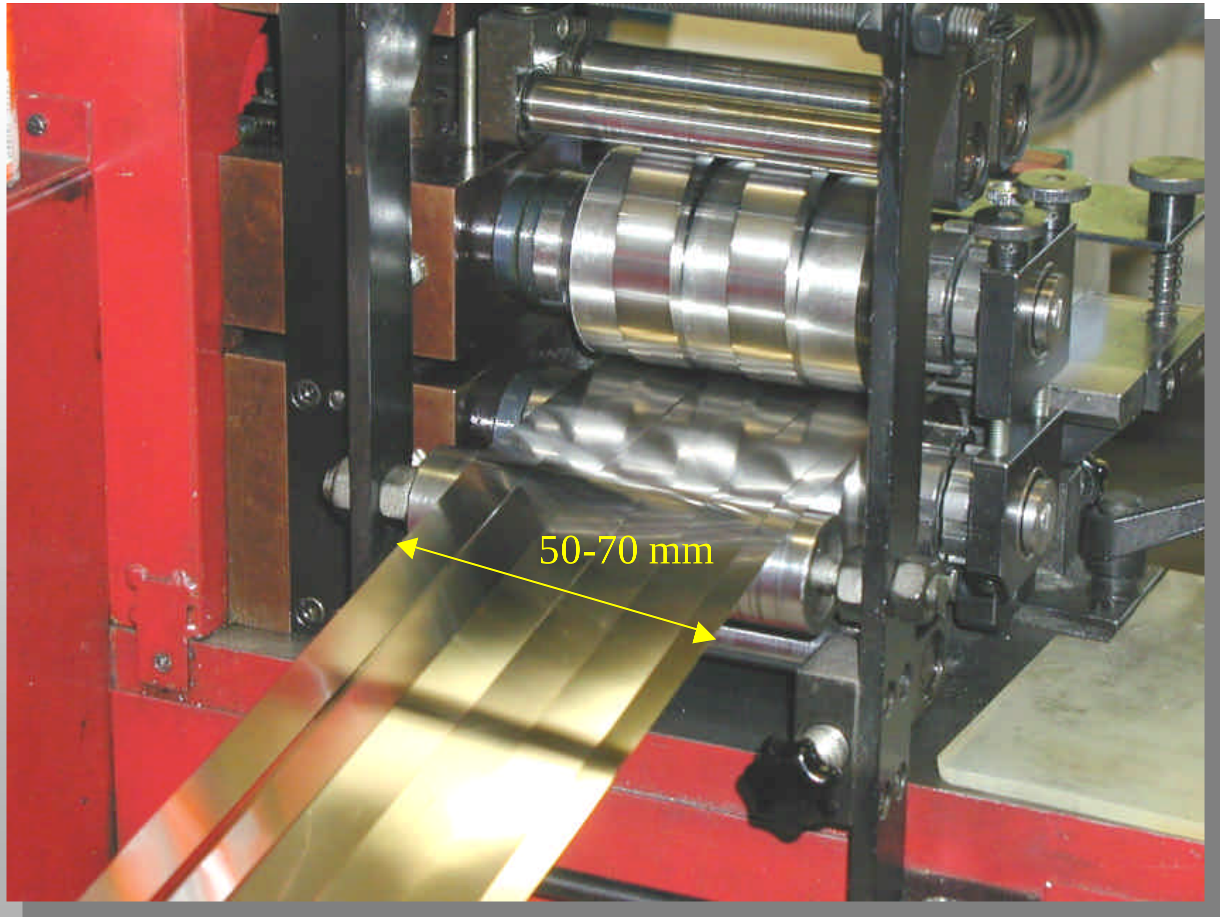
slitting of ribbons with high precision knives



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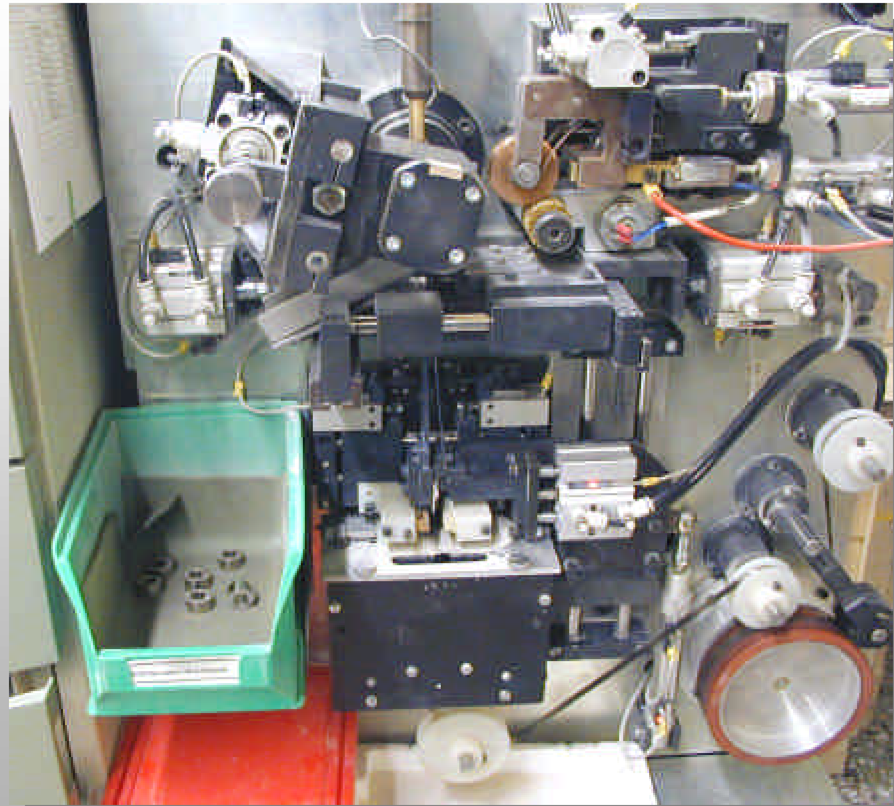
automatic winding process of tape wound cores



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furnace and batch of cores for magnetic-field treatment

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protective epoxy coating of tape wound cores

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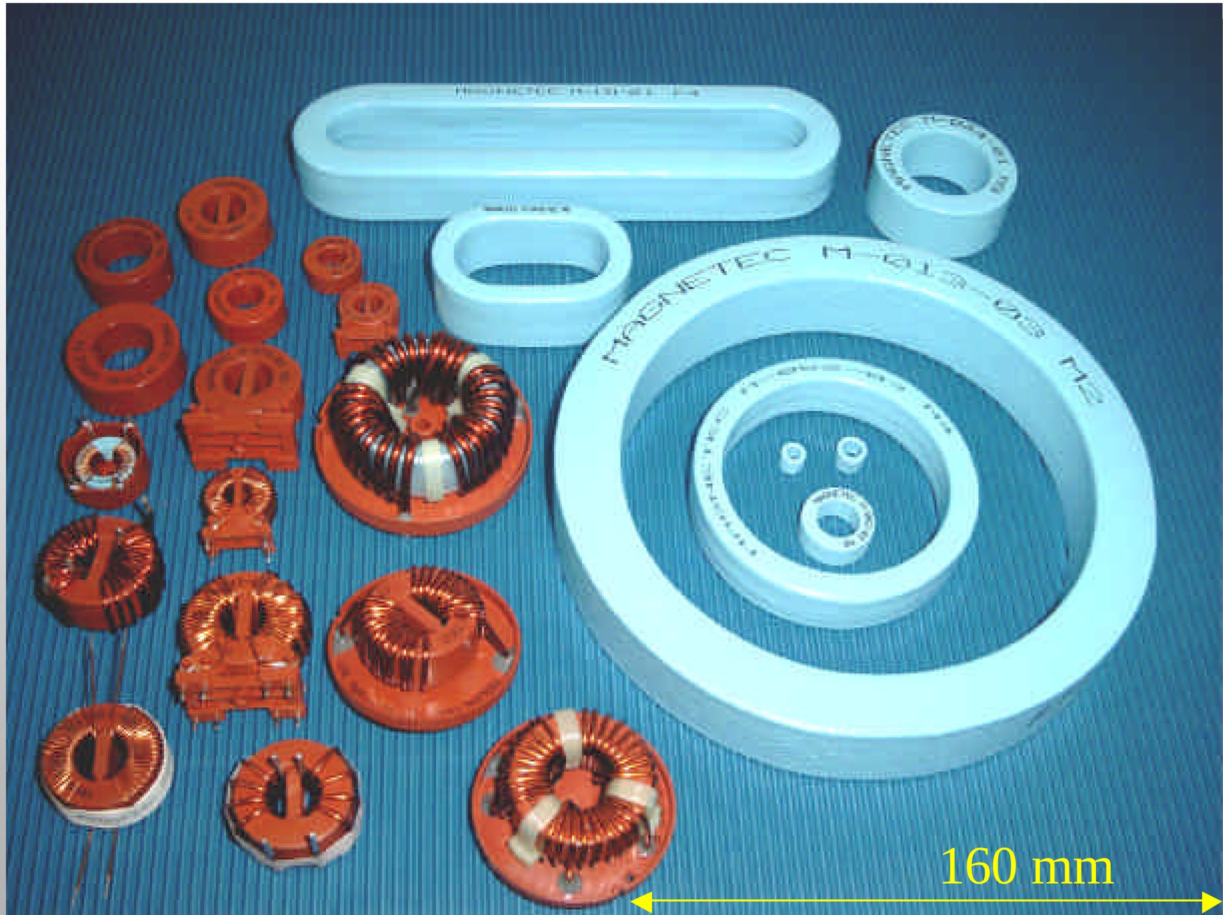
available NANOPERM® products – cores and choke types



tape wound cores from 10 ... 200 mm ∅

single phase EMC chokes up to I = 60A

three phase EMC chokes up to I = 200A

Conclusion / summary

- EMI/EMC will definitely become much more important in future vehicle powernet architectures
- EMI/EMC will become essential for the functionality of future vehicles
- Filter solutions based on state-of-the-art components may not work/not be optimal
- there are new and advanced softmagnetic materials which are able to provide solutions
- these new materials are available from several sources and their prices will come down as their market penetration actually grows rapidly

