Advanced softmagnetic materials for electromagnetic compatibility – EMC

- EMC/EMI basics
- mains filters and current compensated chokes
- comparison: nano and ferrite cores
- production process of nanocrystalline cores

Content of presentation

electromagnetical compatibility (EMC)

can be described as a - required - state:

„ the ability of a device, to work satisfactory in its electromagnetical surrounding, without generating disturbing noise, which could be unacceptable for other devices.“

(EMV-Richtlinie 89/336/EWG bzw. EMVG)

Currently, the global electromagnetical background noise level doubles every three years ! [1)]

[1)] Schaffner EMV AG

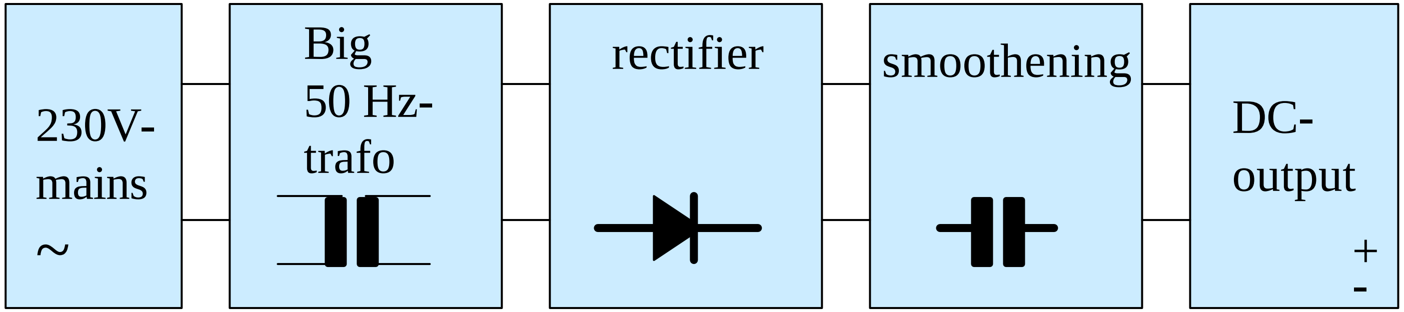
EMC basics: definition of EMC

Steep dU/dt switching edges of mircroprocessors or power transistors (IGBT) or pulsed currents drawn from the mains supply line of switched mode power supplies (SMPS) are the main reason for the unwanted emsissions of discrete or continuous RF energy.

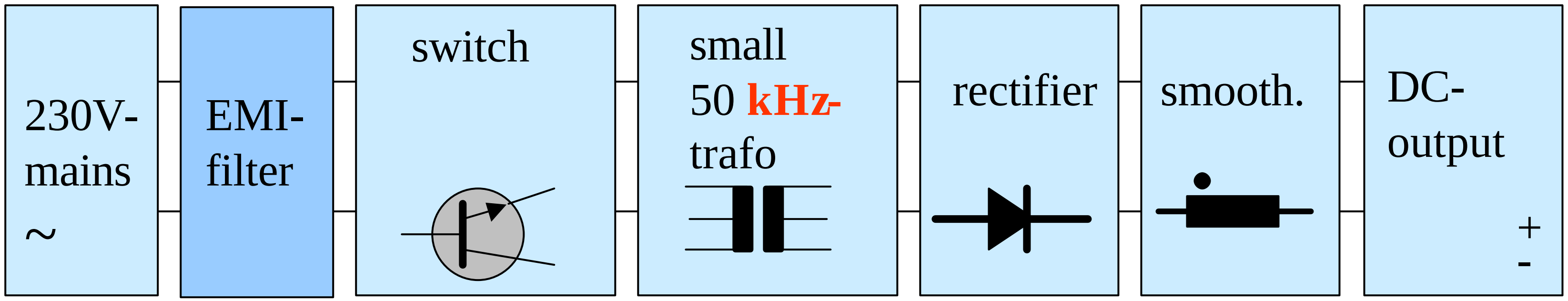
Examples:

- digital telecommunication equipment (ISDN, GSM)
- electronical power supplies for lightening applications
- any kind of voltage converter using SMPS technology
- variable speed drives
- white goods with microprocessors and variable speed drives

EMC basics: sources of RF noise emissions



50-Hz-mains adaptor - no RF- noise level but huge & heavy



SMPS - EMI filter required, compact, light weight, highly efficient

Comparison: 50Hz vs. switched mode power supply

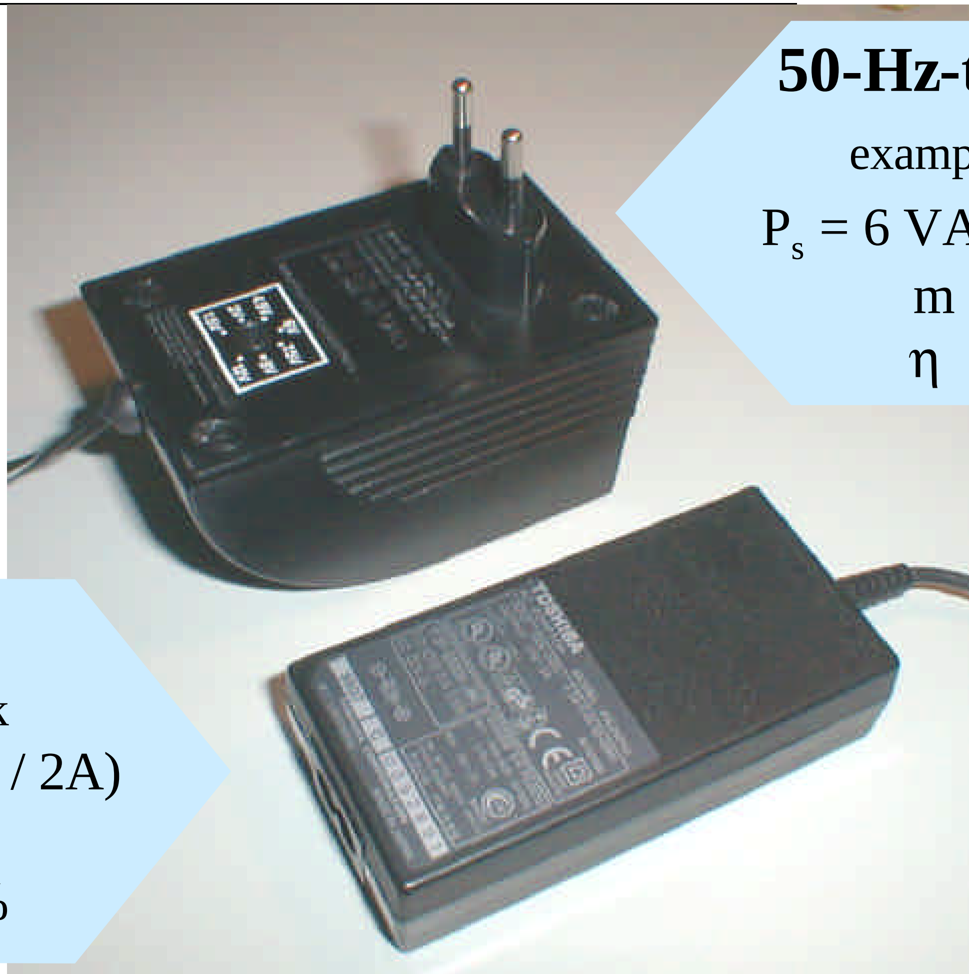
50-Hz-technology

example: adaptor

P_s = 6 VA (12V / 0,5A)

m = 440g

η = 38 %



SMPS

example: notebook

P_s = 30VA (15V / 2A)

m = 220g

η up to 95 %

SMPS technology: significant reduction of size and weight

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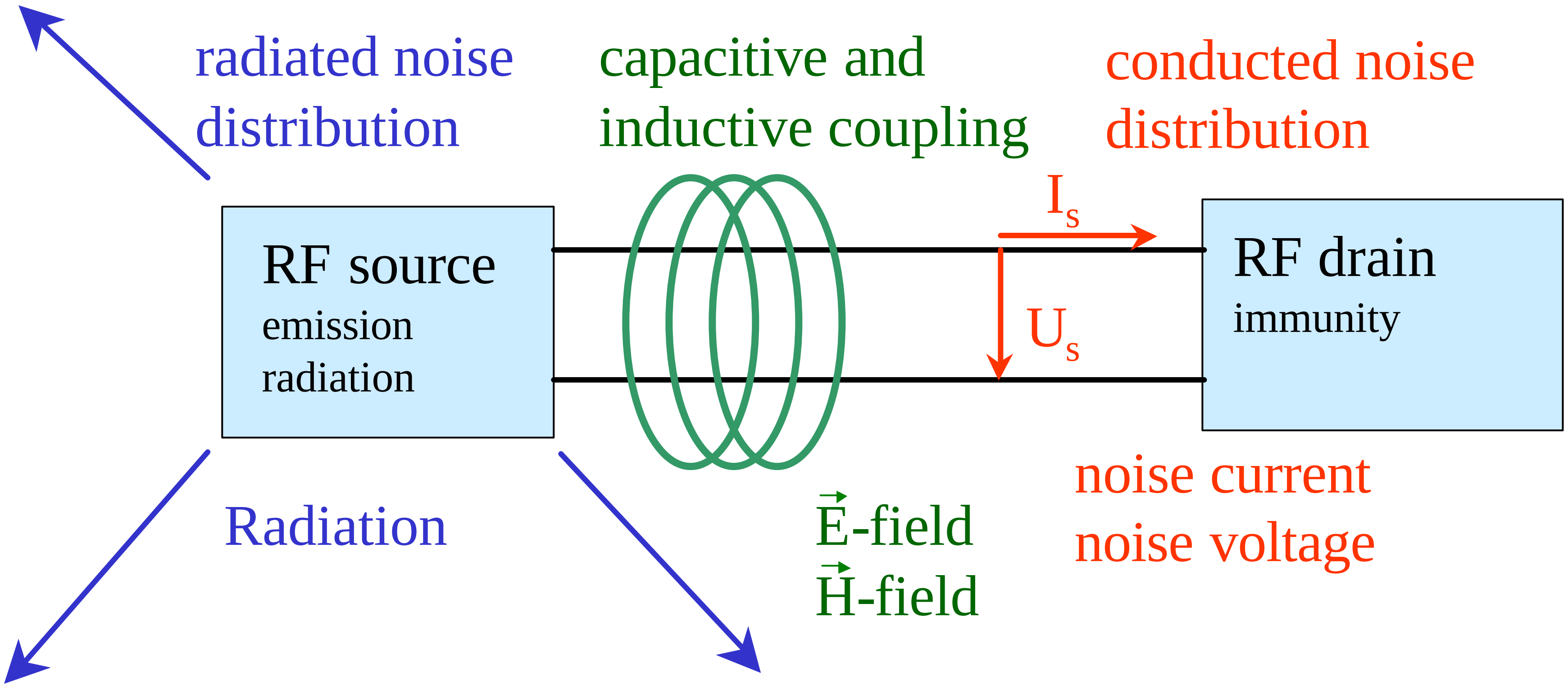

possible ways of distribution of RF noise

EMC basics: scenario

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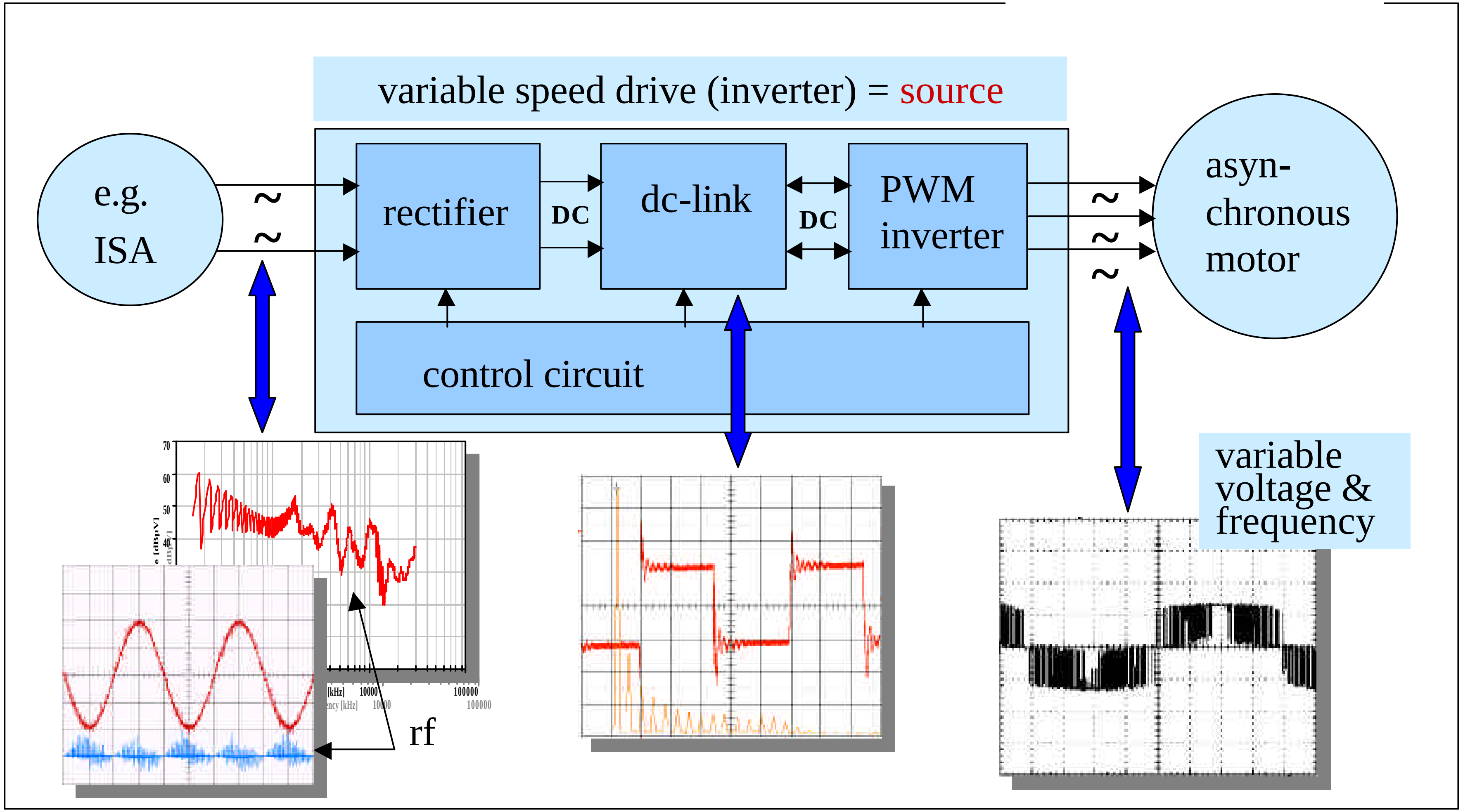

EMC basics: inverter drive as rf-noise source

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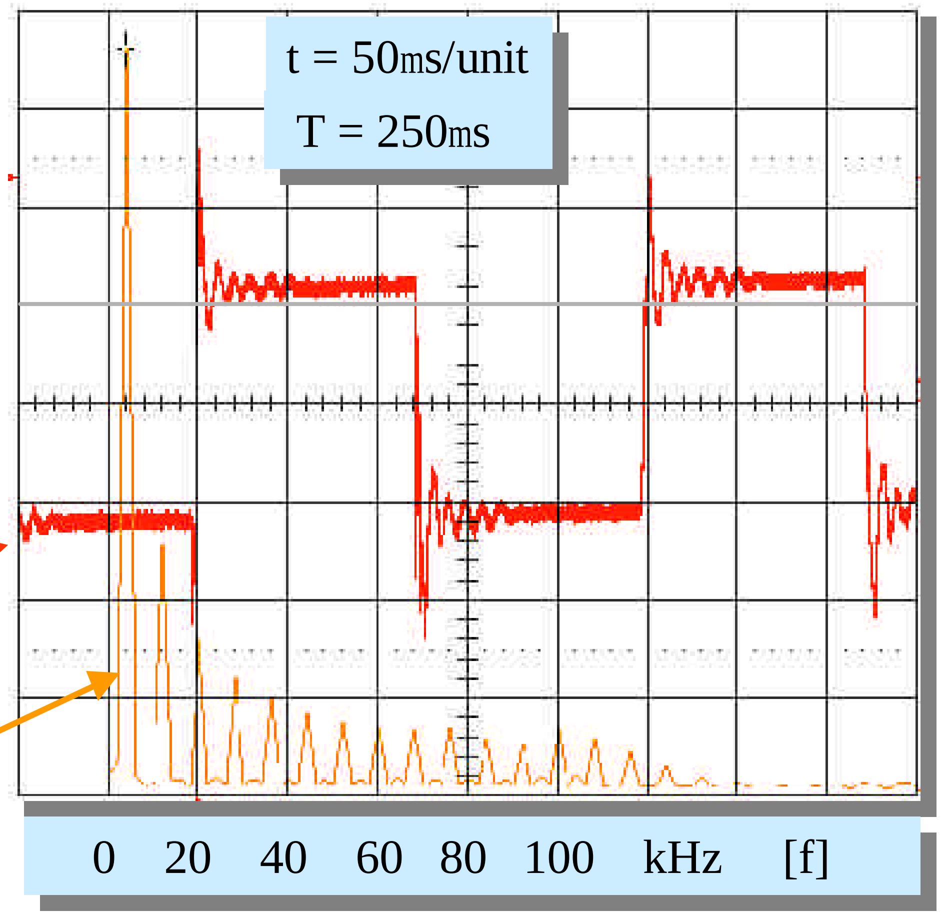
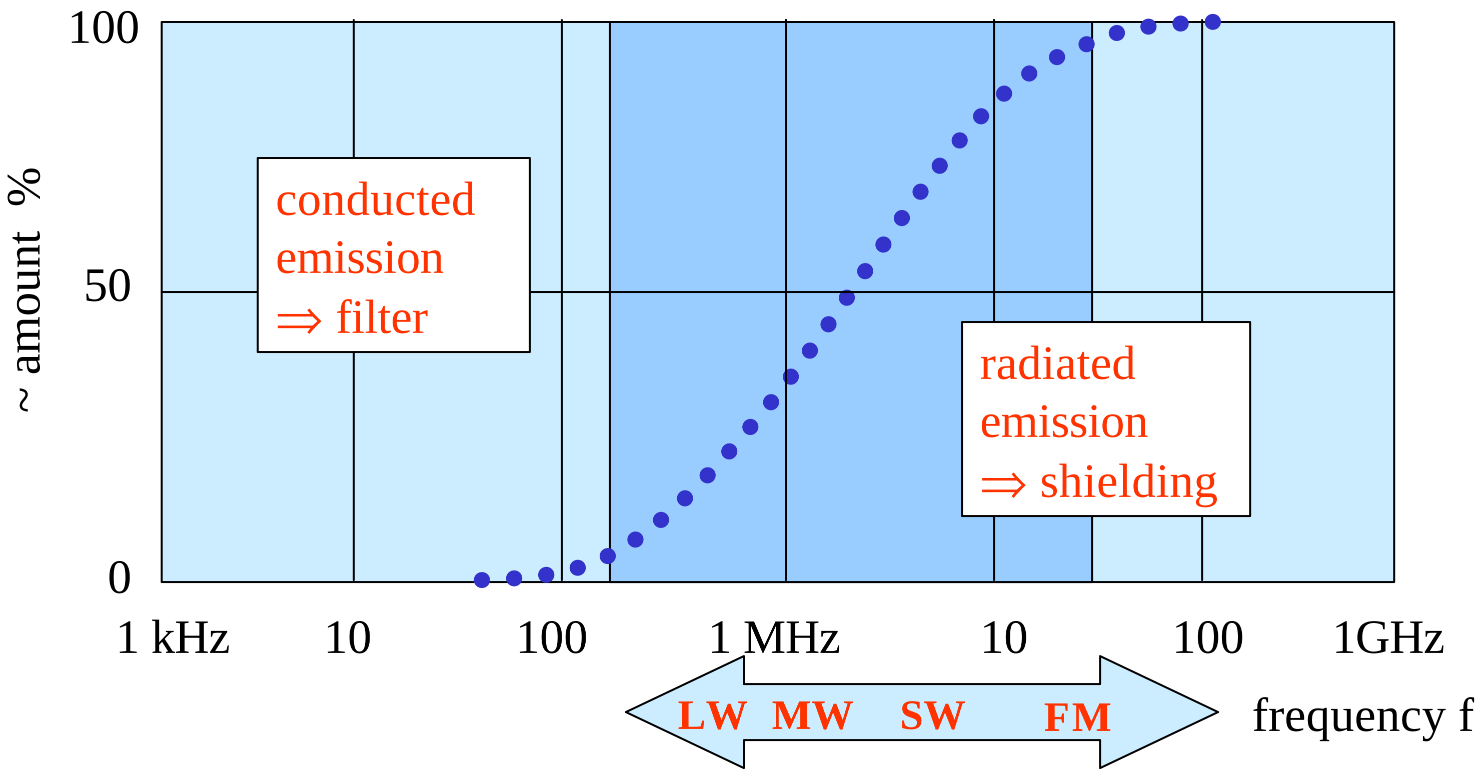
typical voltage and harmonics in a variable speed drive (inverter) – used in many future PowerNet systems. Those unwanted rf-signals are distributed over all connected wiring systems

fundamental wave 4 kHz

harmonics

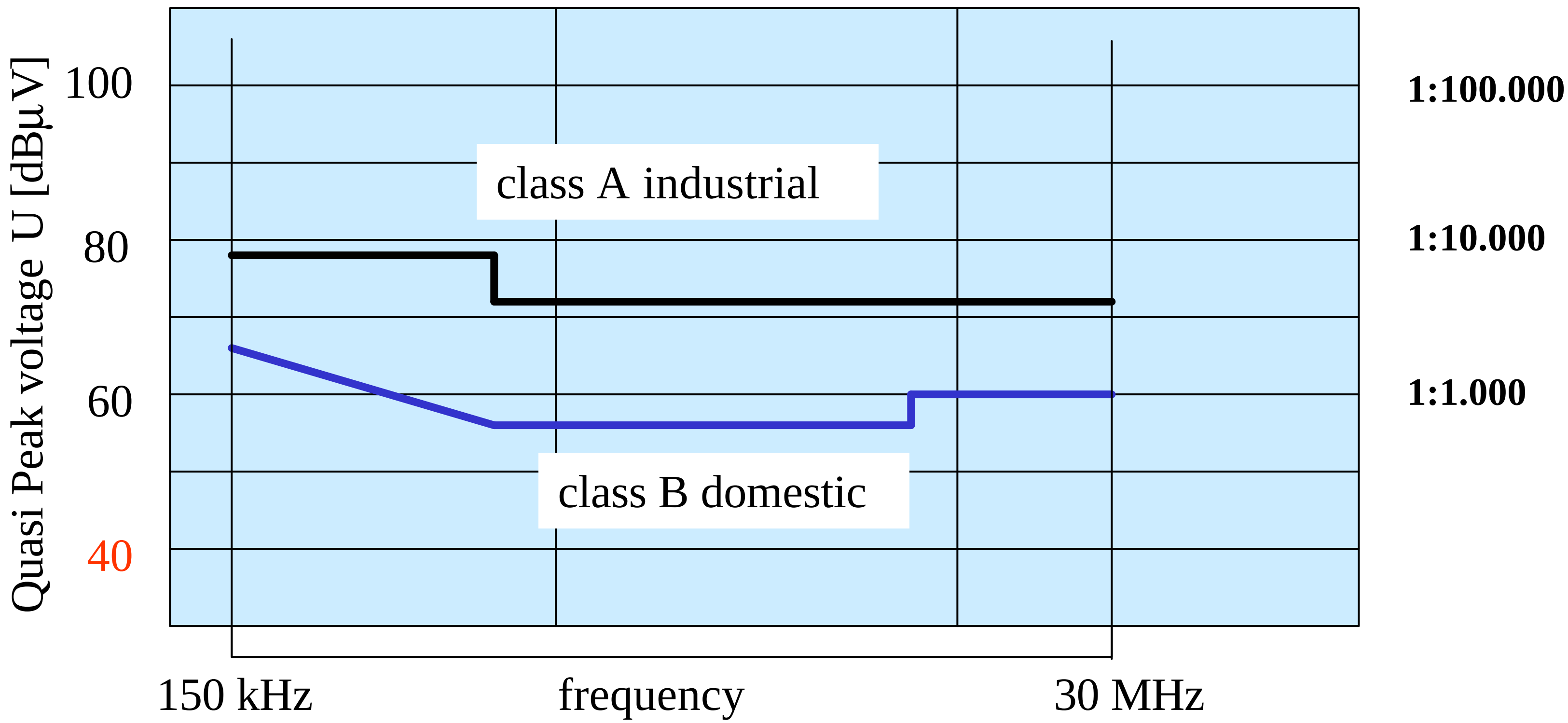


EMC basics: sources of RF noise emissions



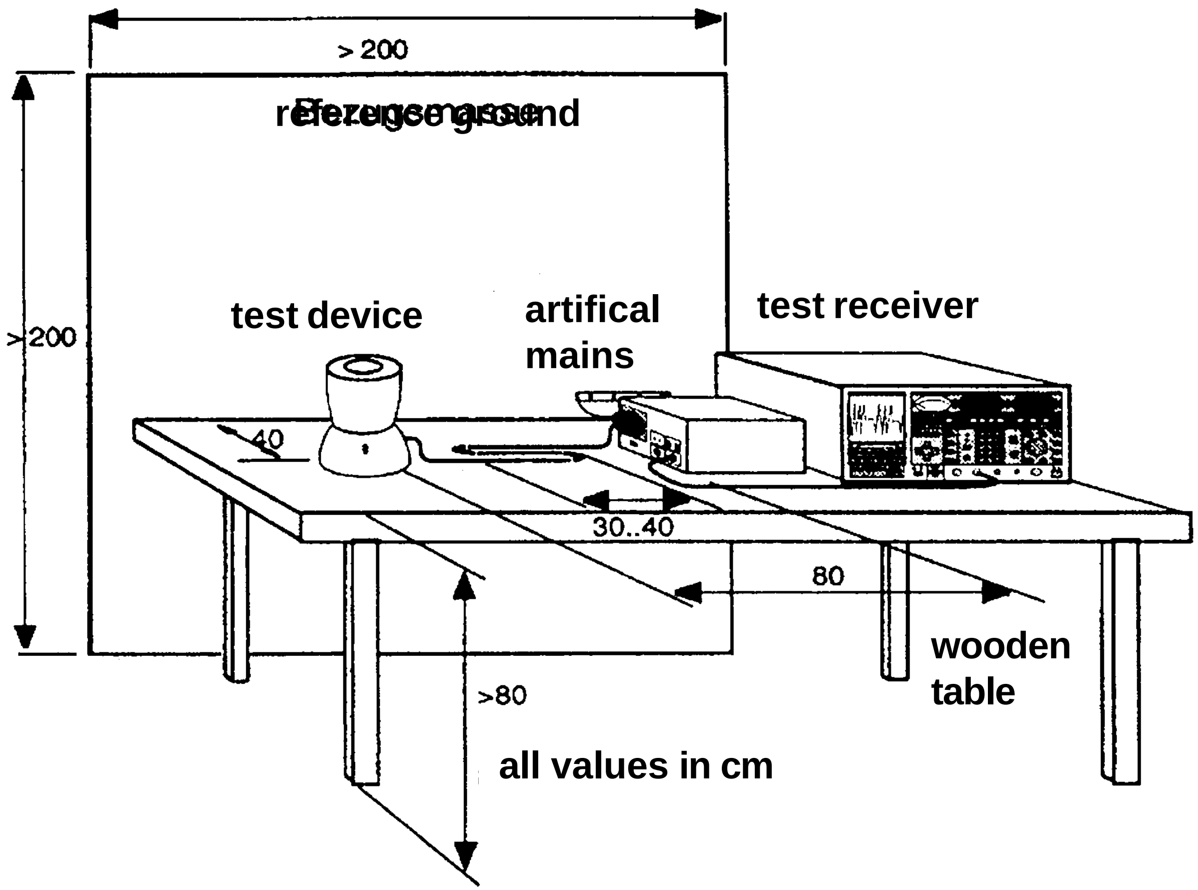
typical distribution of emitted energy as a function of frequency

EMC basics: ways of distribution of RF noise



noise level-limits of EN 55011 (common mode, conducted, 50Ω-system)

EMC basics: RF noise level limits



EMC basics: measurement setup for RF noise

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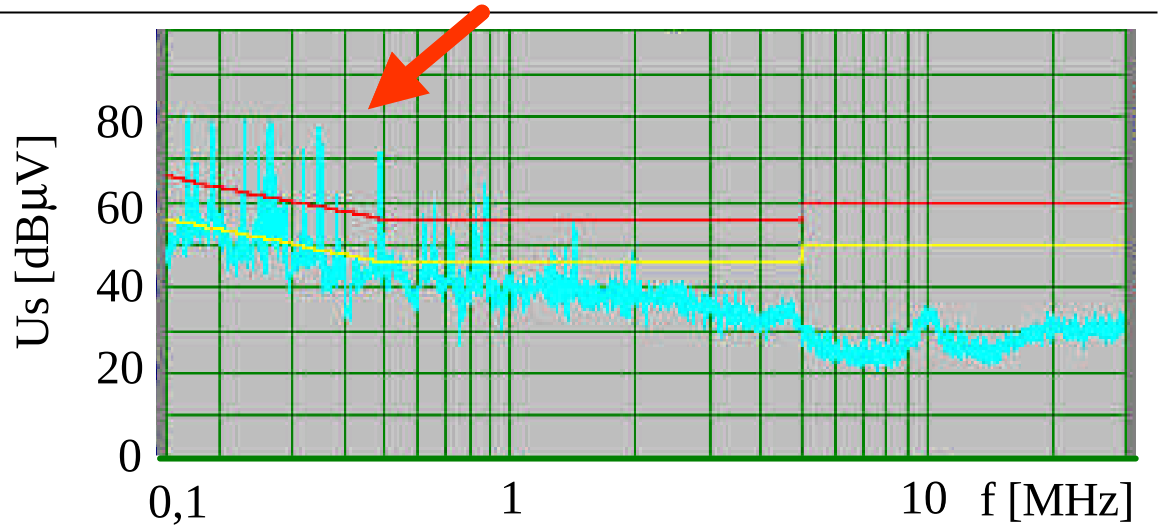
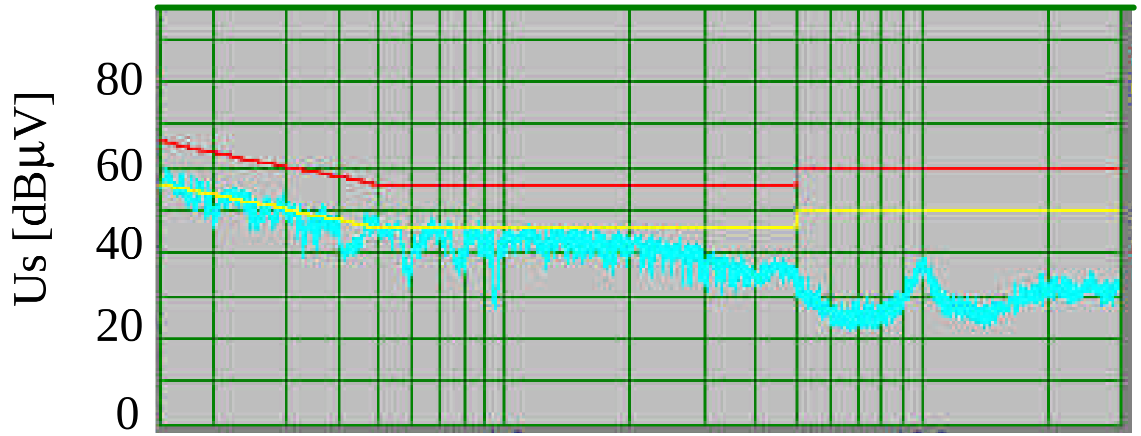


poor filtering, limits of EN55011, class B are exceeded

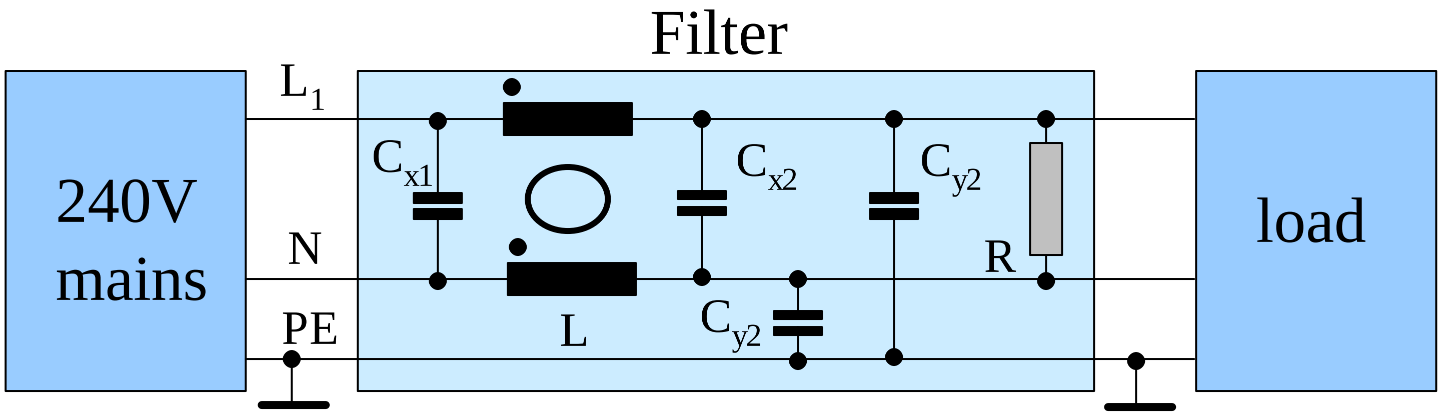


appropriate filtering, limits of EN55011, class B are met

EMC basics: real noise level spectrum (quasi-peak)

-Increasing number of unwanted RF-noise sources resulting in a continuous increase of background level
- regulations will be getting more stringent
- regulations will be defined in new
- new regulations to come
- new noise sources will come
- contious increase of costs for filtering measures
- global introduction of emc regulations

EMC basics: future trends and outlook

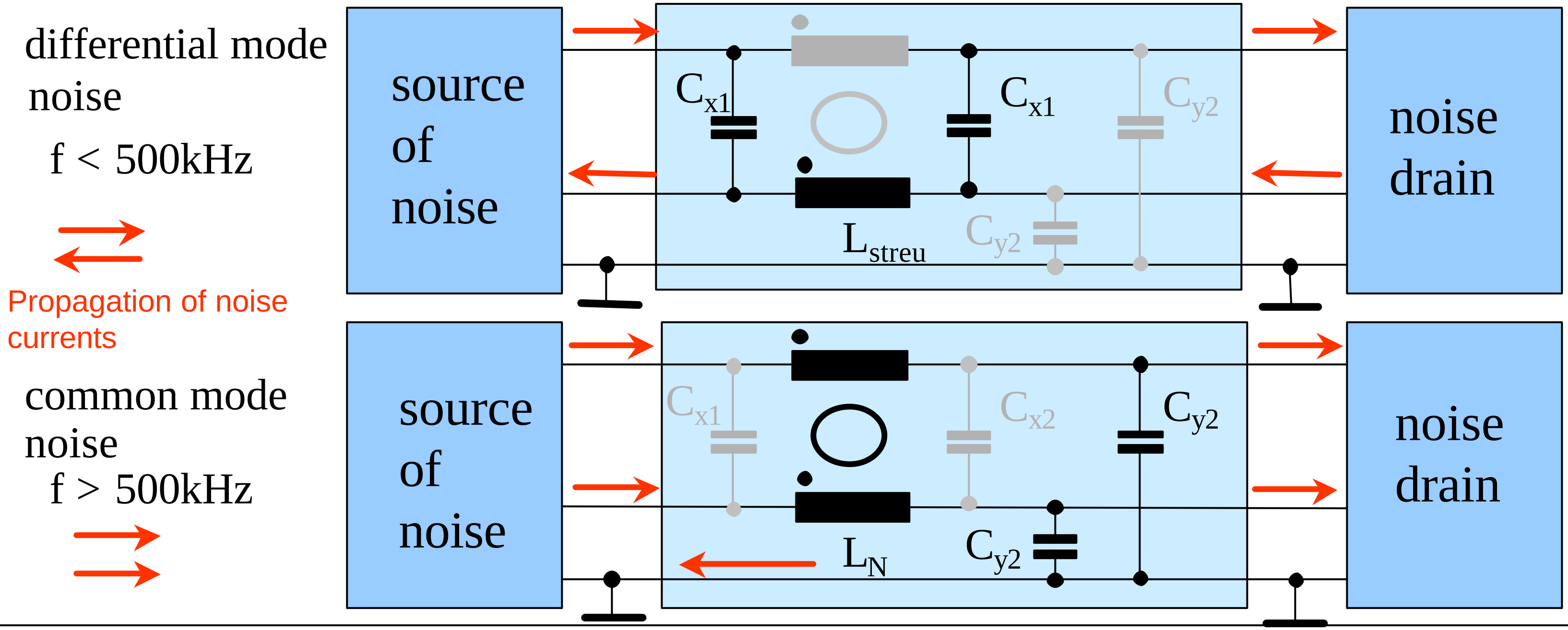


C_{xn}	X-capacitor
C_{yn}	Y-capacitor
L	current compensated choke
R	discharge resistor

basic circuitry of a EMI mains filter

EMC basics: mains filter

EMI filters are commonly desinged as **reflecting low-pass-filters** ausgelegt, this means, they work according to the principle of rf-mismatch. Thus, a part of the high-frequency currents are ‚deviated‘ – the other part will be aborped – e.g. in form of core losses and other mechanisms.



EMC basics: working principle of mains filters

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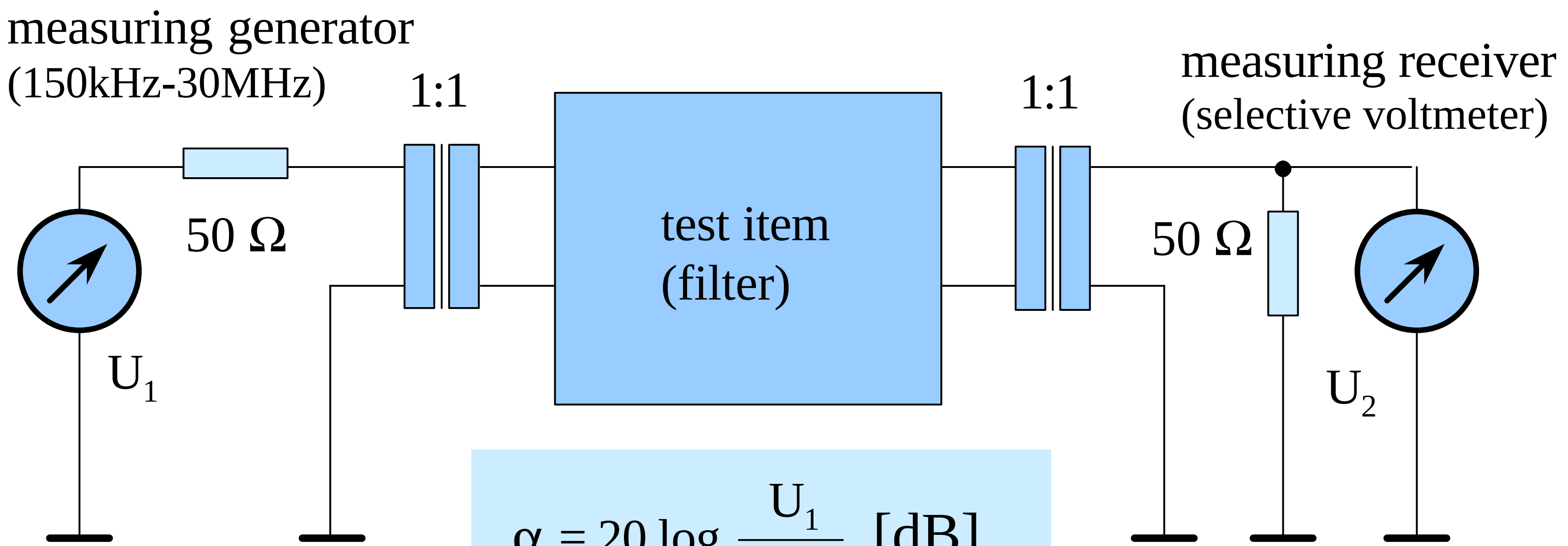
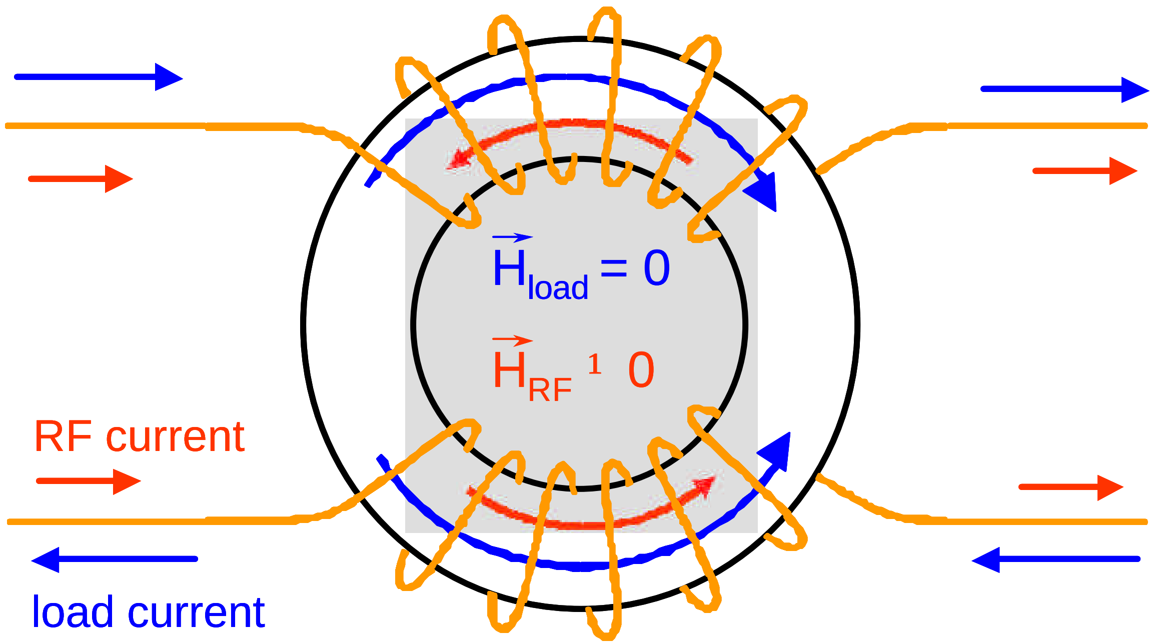


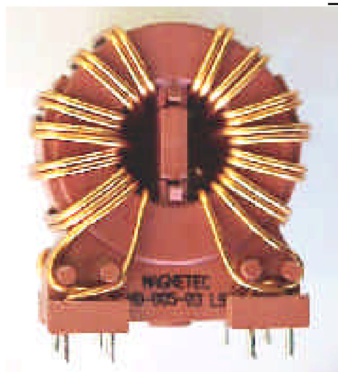
$$\alpha_e = 20 \log \frac{U_1}{2\,U_2} \quad [\text{dB}]$$

conforming test setup of attenuation level α_e

EMC basics: setup of attenuation level measurement



working principle of a current compensated choke for attenuation of common mode RF noise



single phase version

three-phase version

EMC basics: principle of common mode chokes

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main requirements on a EMC filter choke:

high impedance (f = 150 kHz to 30 MHz)

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

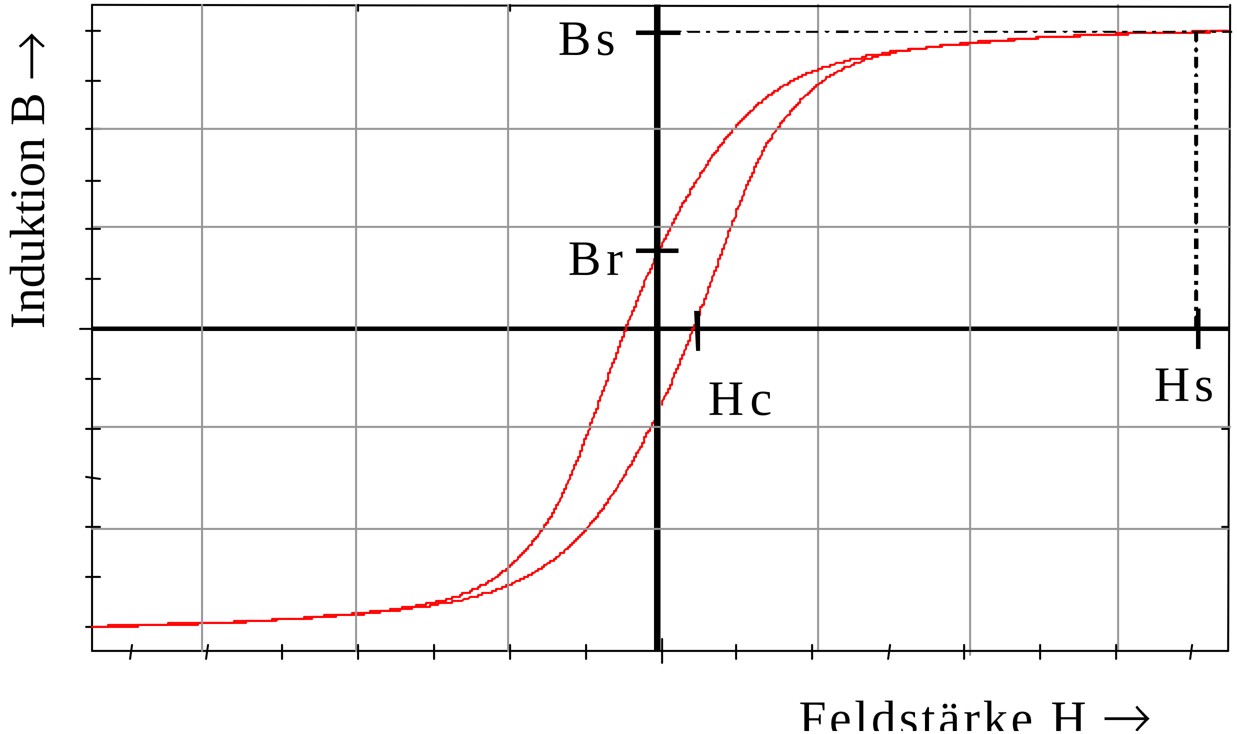
$$L(f) = A_L\, n^2 \quad \text{mit} \quad A_L = \mu_0\, \mu_r(f)\, A_{fe}/l_f$$

number of turns

iron cross section

permeability !

EMC basics: choice of softmagnetic material



Bs: saturation lux density (high!) Br: remanence (low!)
Hc: coercitivity field strength (low!) Hs: saturation field strength (high!)

Characteristics of softnagnetic alloys: Hysteresis loop

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- 1987: patent for a completely new softmagnetic material with excellent properties by Yoshizawa, Oguma and Yamauchi (Hitachi, Japan)
  alloy composition: $Fe_{73}Cu_1Nb_3Si_{16}B_7$
  production process: rapid solidification
  material structure: **nanocrystalline; i.e. grain size 15 nm**
- 1992: markt launch by VACUUMSCHMELZE (VITROPERM®) and HITACHI Metals (FINEMET®)
- since 1995: introduction into several industrial applications of power electronics and telecommunication
- 1999: 3. Source : MAGNETEC (NANOPERM®)

History of nanocrystalline alloys

Alloy	**Permeability** μ_r (10 / 100kHz)	Saturation induction B_S [T] (25 / 100°C)	Curie-temp. T_C [°C]	max. 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	120 (180)

NANOPERM vs. Ferrit:

- **permeability** - up to a factor of 10 (!)
- saturation induction - factor 3
- working temperature range - up to 180°C
- disadvantage : price ~ factor 1,5 - 2 (functional value)

Þ advanced, smaller and lighter components Ü

Comparison of materials

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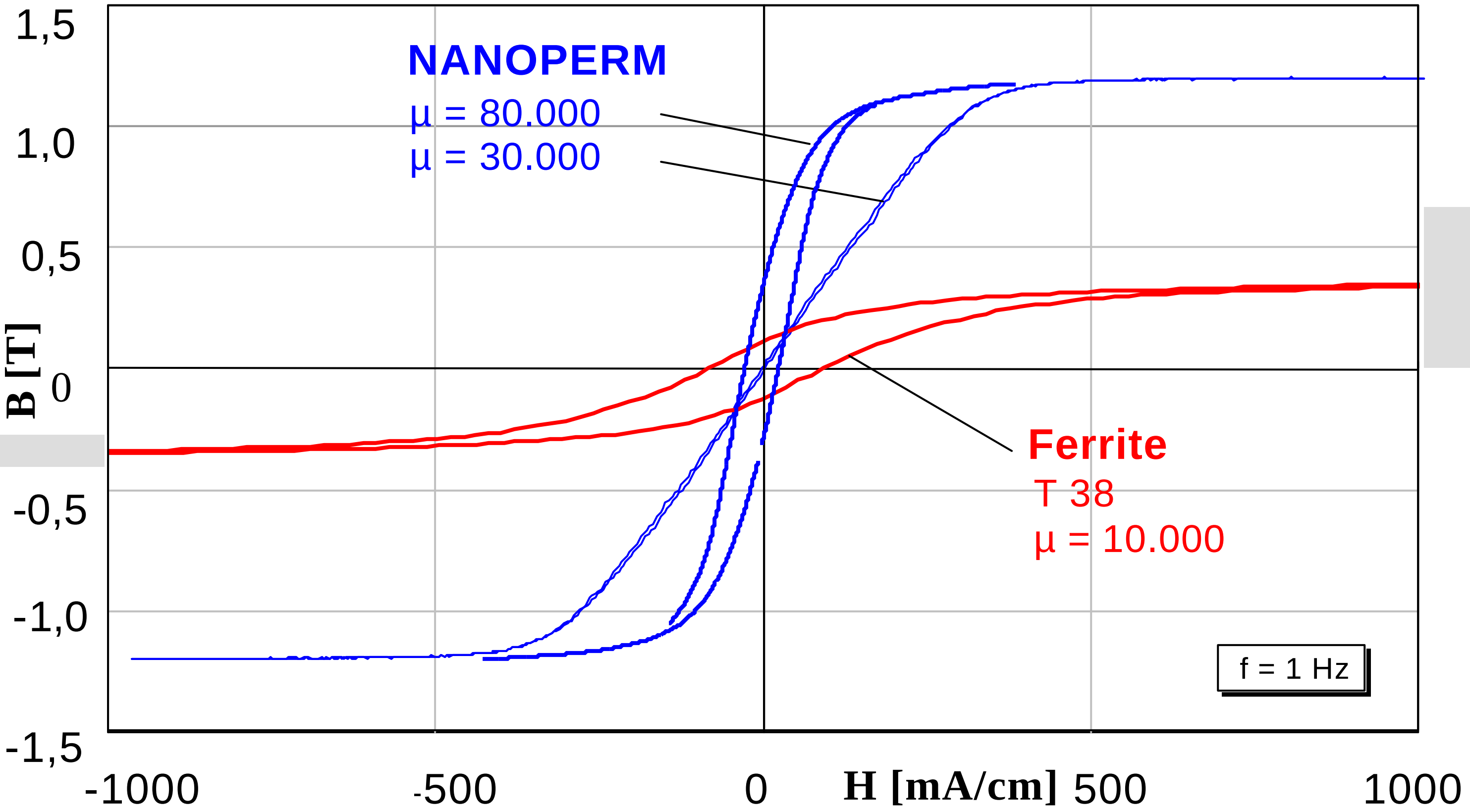
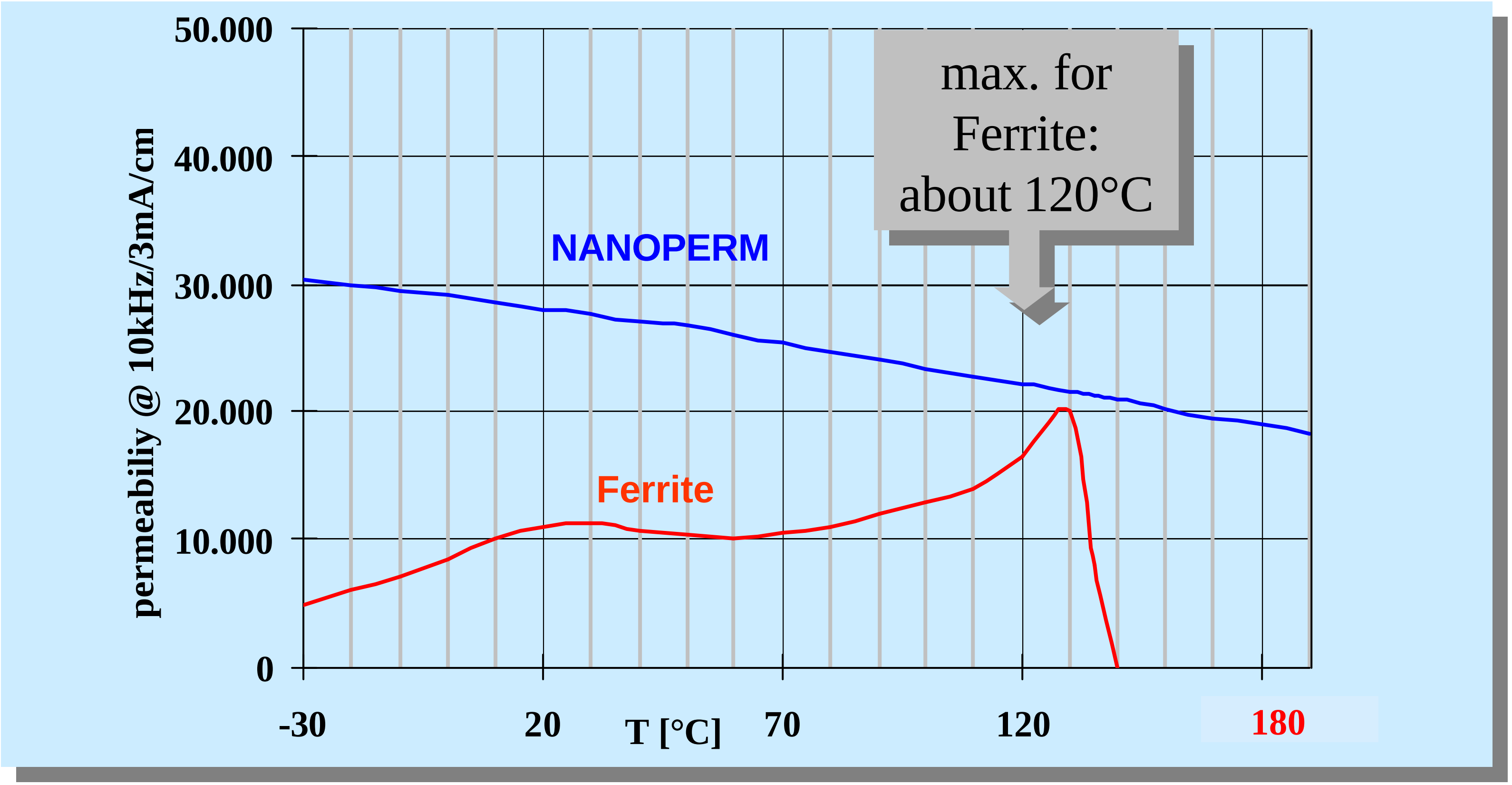


hysteresis loops, saturation field as a function of permeability level

Comparison of materials

advanced softmagnetic materials for electromagnetic compatibility - EMC



permeability as a function of temperature

Comparison of materials

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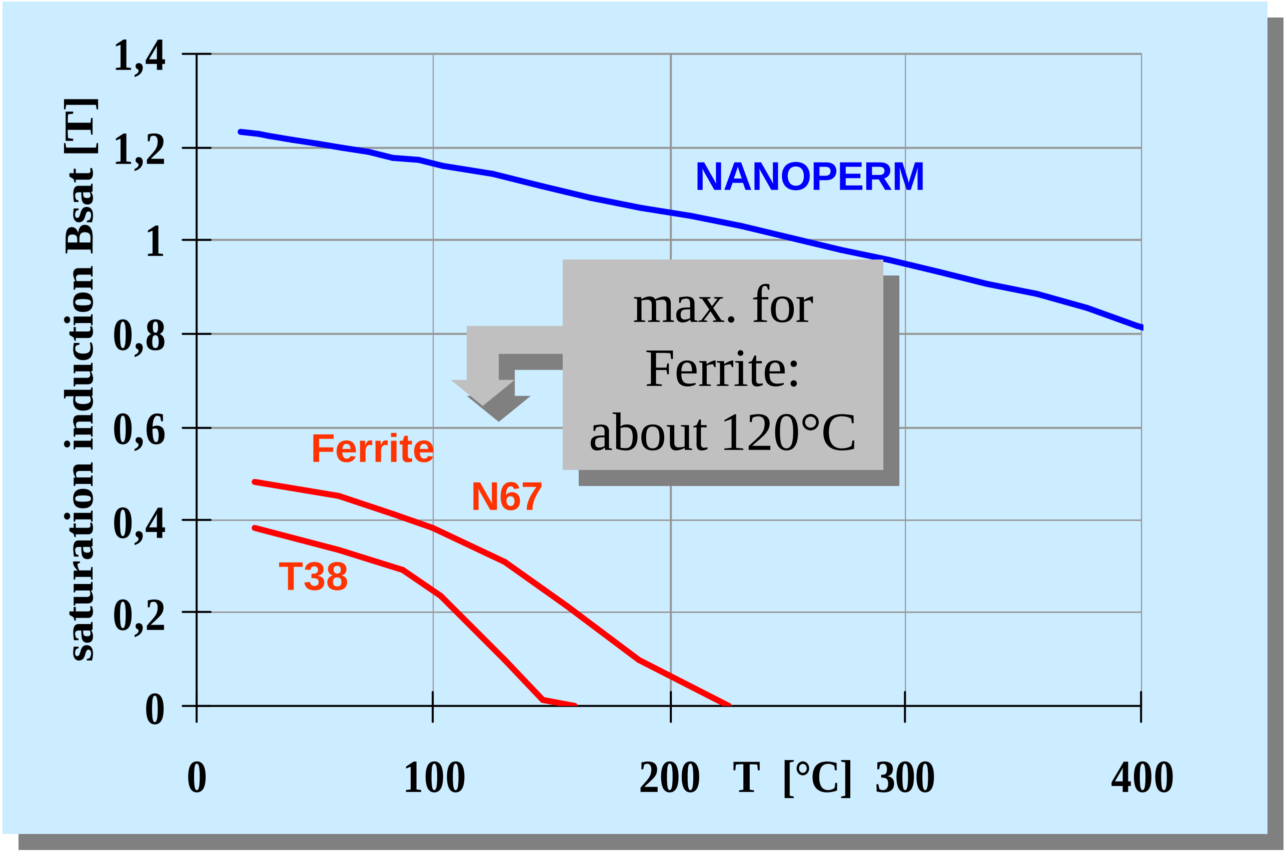

saturation flux density as a function of temperature T

Comparison of materials

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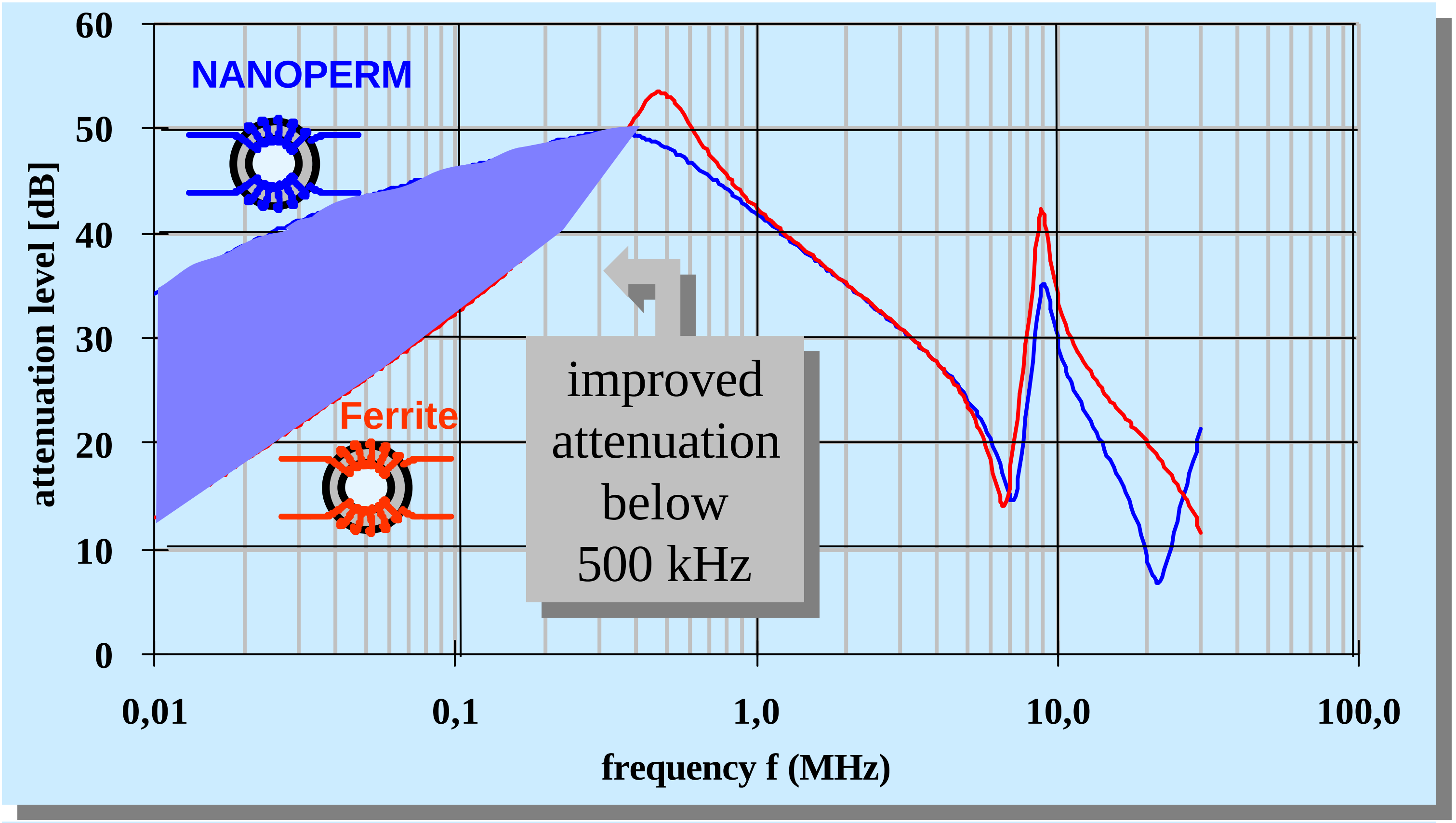

typical impedance curve at same core geometry Ø=30mm, 22 turns

Comparison of materials

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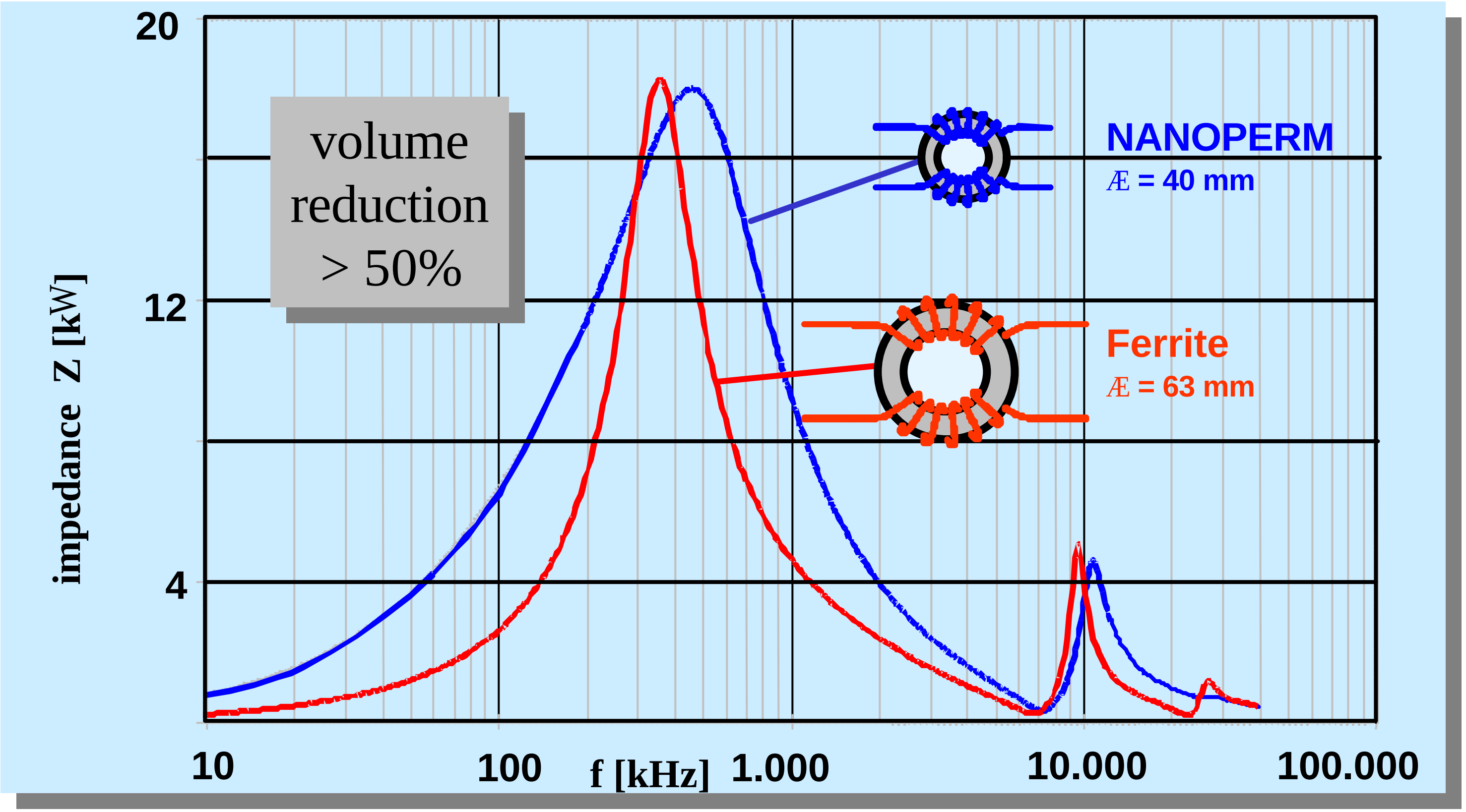

typical impedance curve for different core geometries

Comparison of materials

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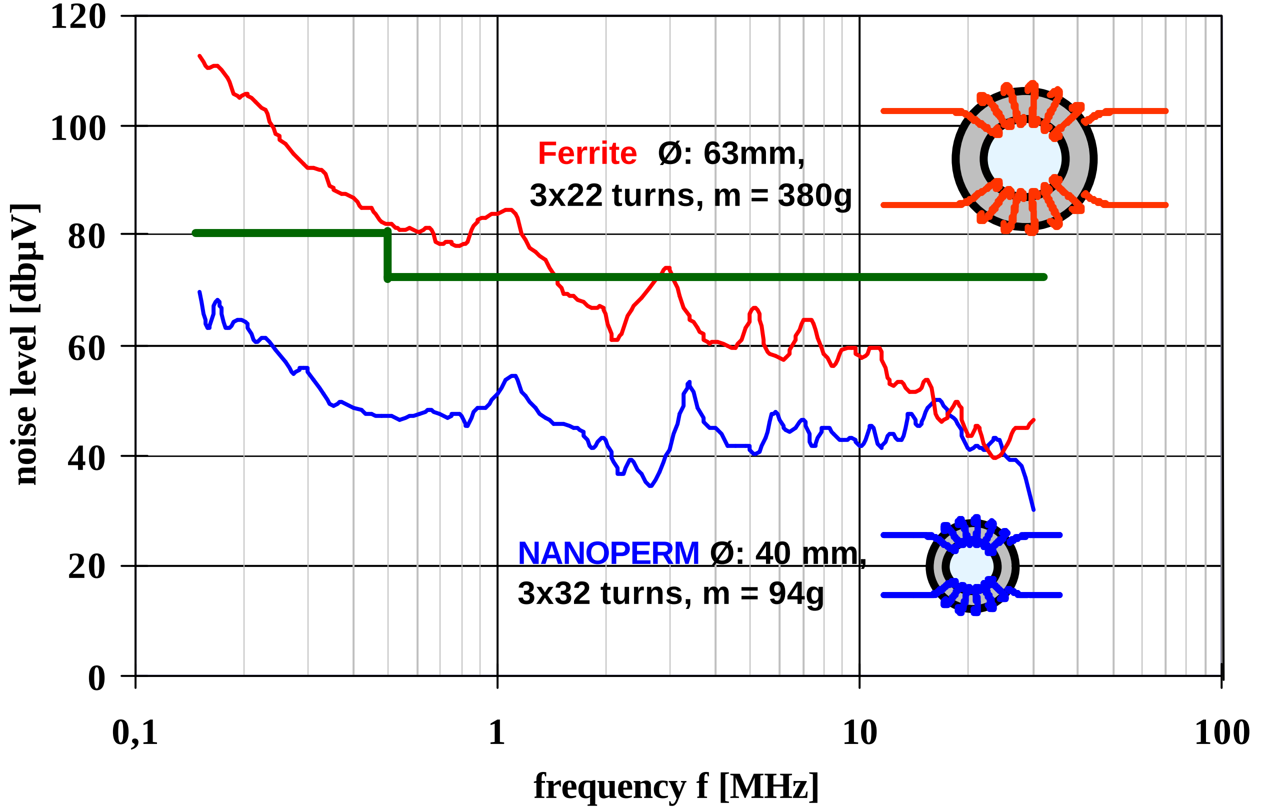

achieving more stringent noise limits even at a smaller build volume

Comparison of materials

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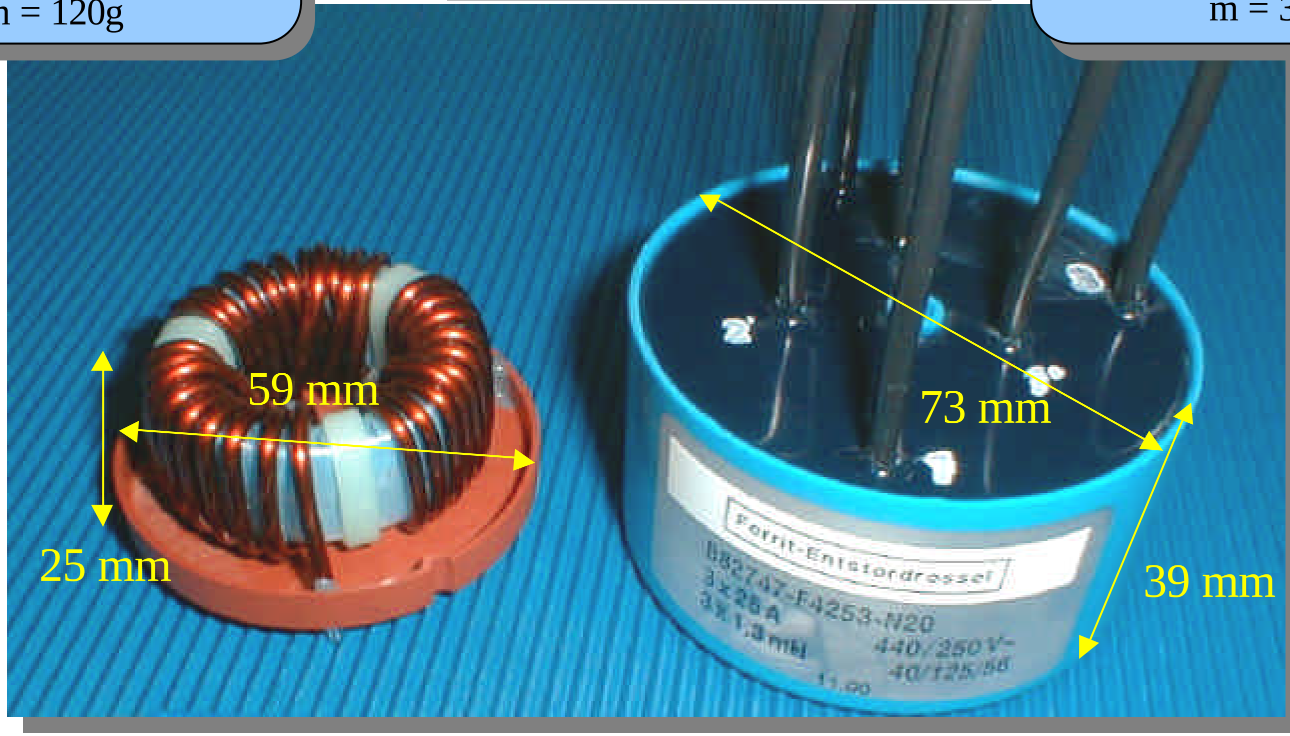
NANOPERM-choke

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



Comparison of build volume Nano/Ferrite Chokes

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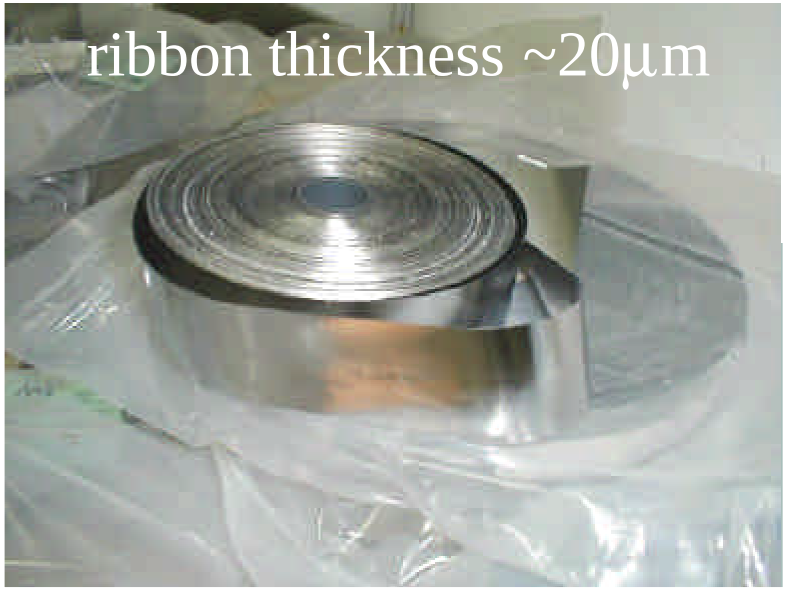
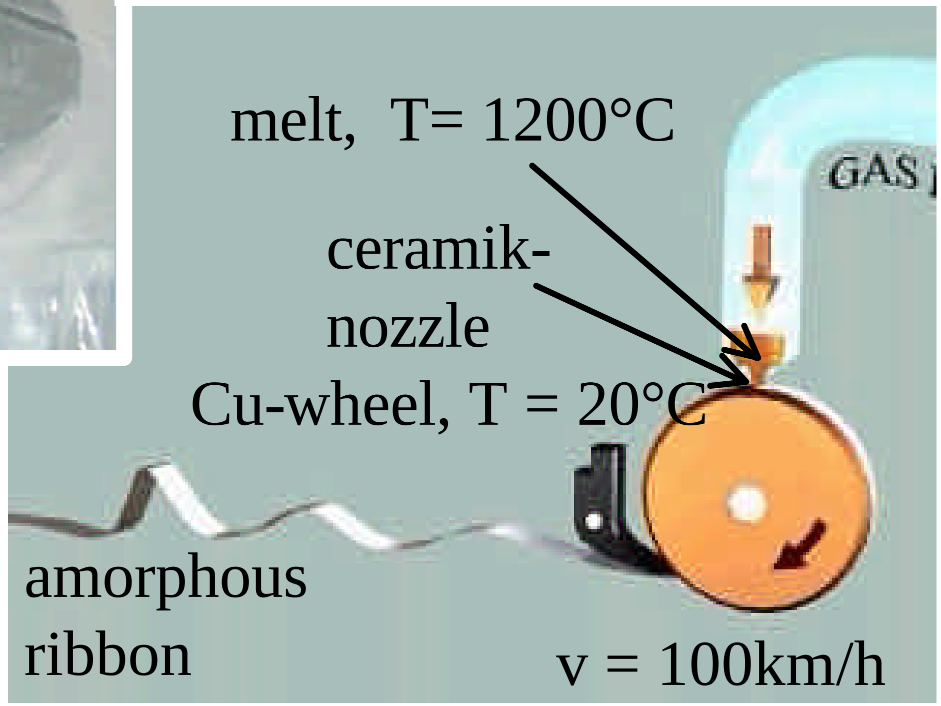
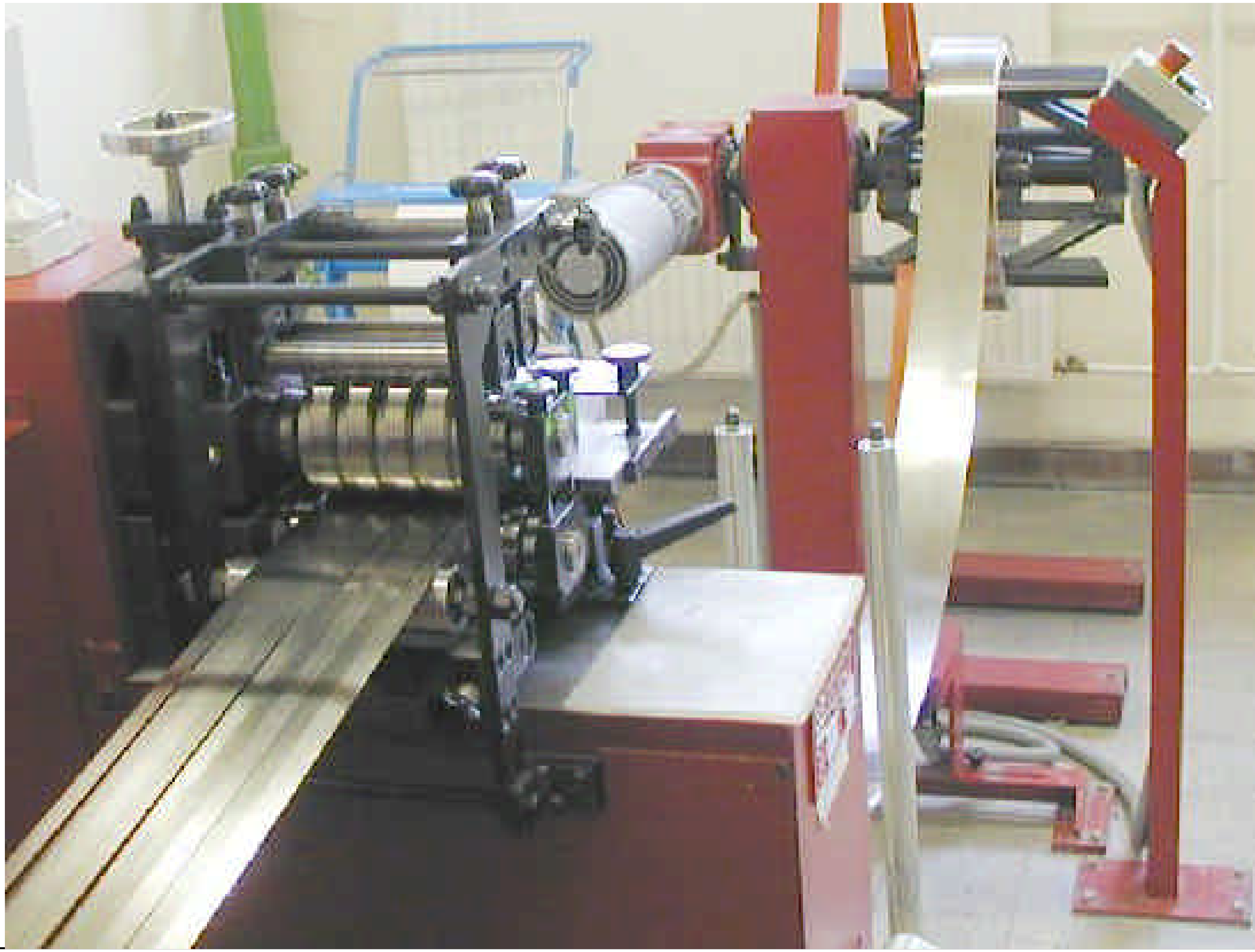
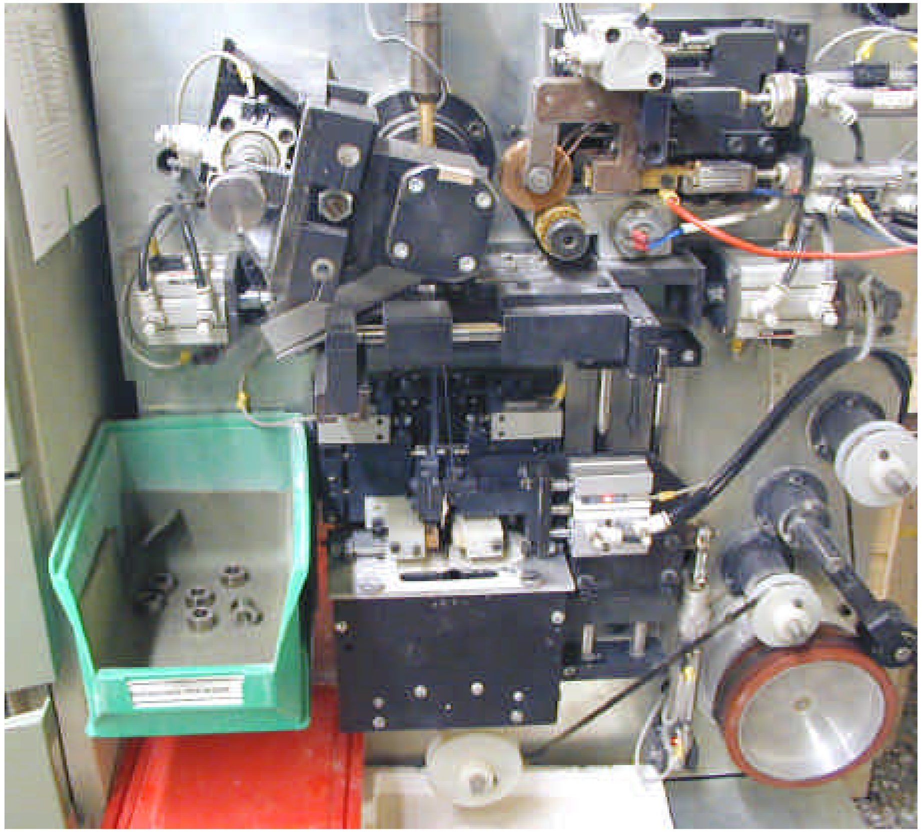




principle of production process of rapidly quenched ribbons



cutting of ribbons with high precision knives



automatic winding process of tape wound cores

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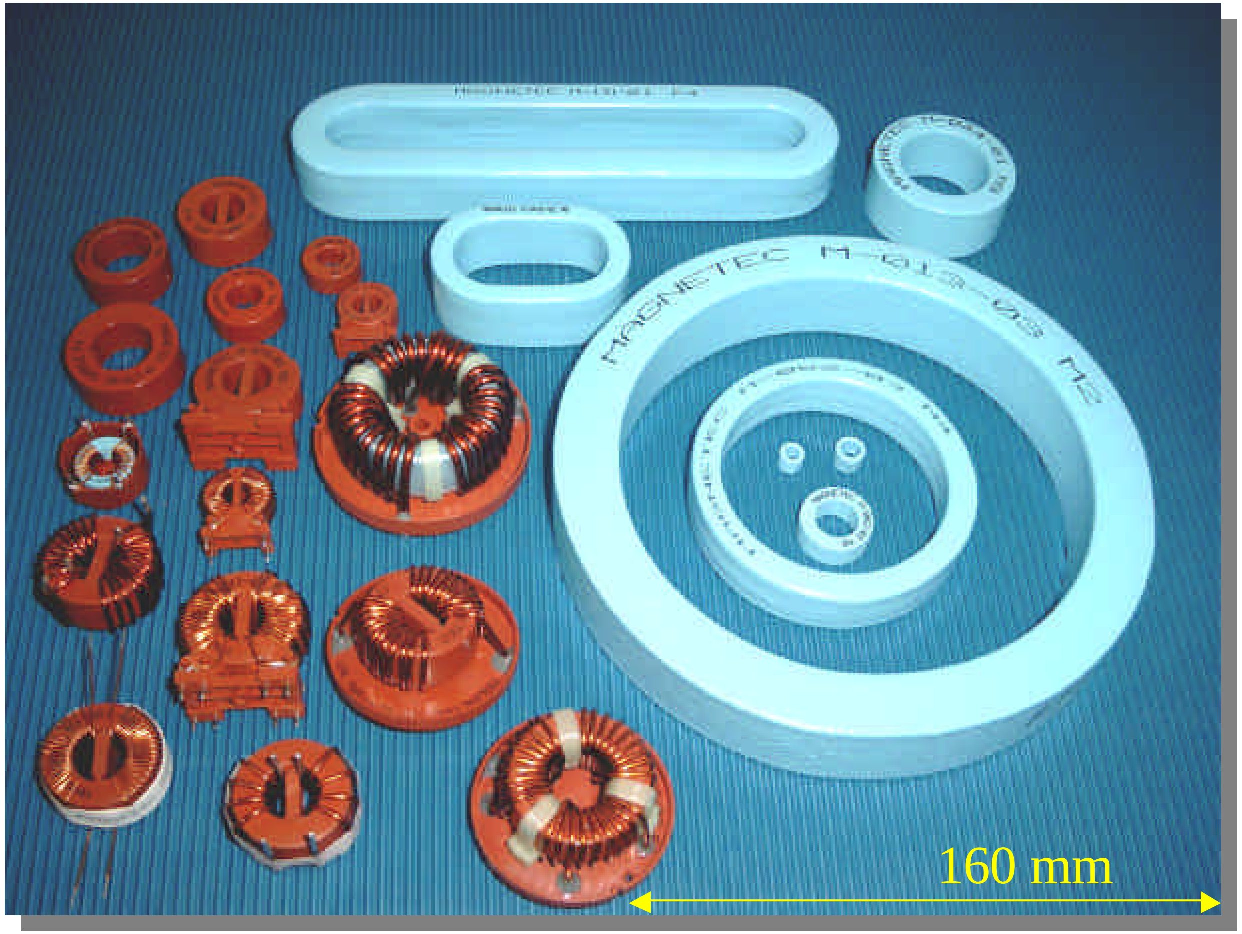
furnace and batch of cores for magnetic-field treatment

protective epoxy coating of tape wound cores



tape wound cores from 10 ... 200 mm ∅

single phase EMC chokes up to I = 60A

three phase EMC chokes up to I = 200A

available nano products – core and choke types

