TESTING & STANDARDIZATION PANEL SESSION: SPEC PROPOSAL FOR NANOCRYSTALLINE CMC

José Gató

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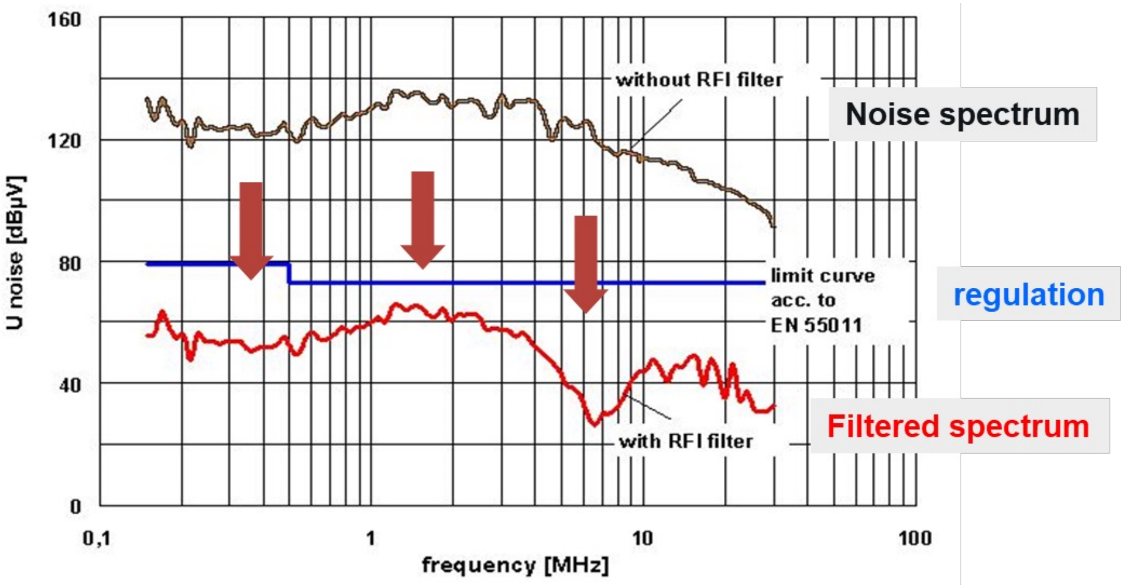
NANOCRYSTALLINE IS THE MATERIAL FOR FUTURE ELECTRIFICATION

Nanocrystalline material vs Ferrite

Material	Nanocrystalline (VITROPERM®)	Ferrite
Material base	~ 70% Fe	MnZn (NiZn)
Coercivity H_c [A/m]	<3	5....60 (....2000)
Losses $P_{Fe,ty\ p.}$ [W/kg] 100 kHz, 300mT, 100°C	60…90 (VP500) 40…50 (VP550HF)	140
Saturation flux density B_s [T]	> 1.2 (room temp.) ca. 1.1 (120°C)	< 0.48 (room temp.) ca. 0.3 (120°C)
Initial permeability μ_i	2000....200 000	10....10 000 (20000)
Saturation magnetostriction λ_s	10^{-7} …10^{-8}	10^{-6}....2×10^{-5}
Max. operating temp. T_{op}	plastic case 130°C* core 155°C, 180°C (short time)	< 100°C (120°C)
Curie temperature [°C]	> 600	150…200

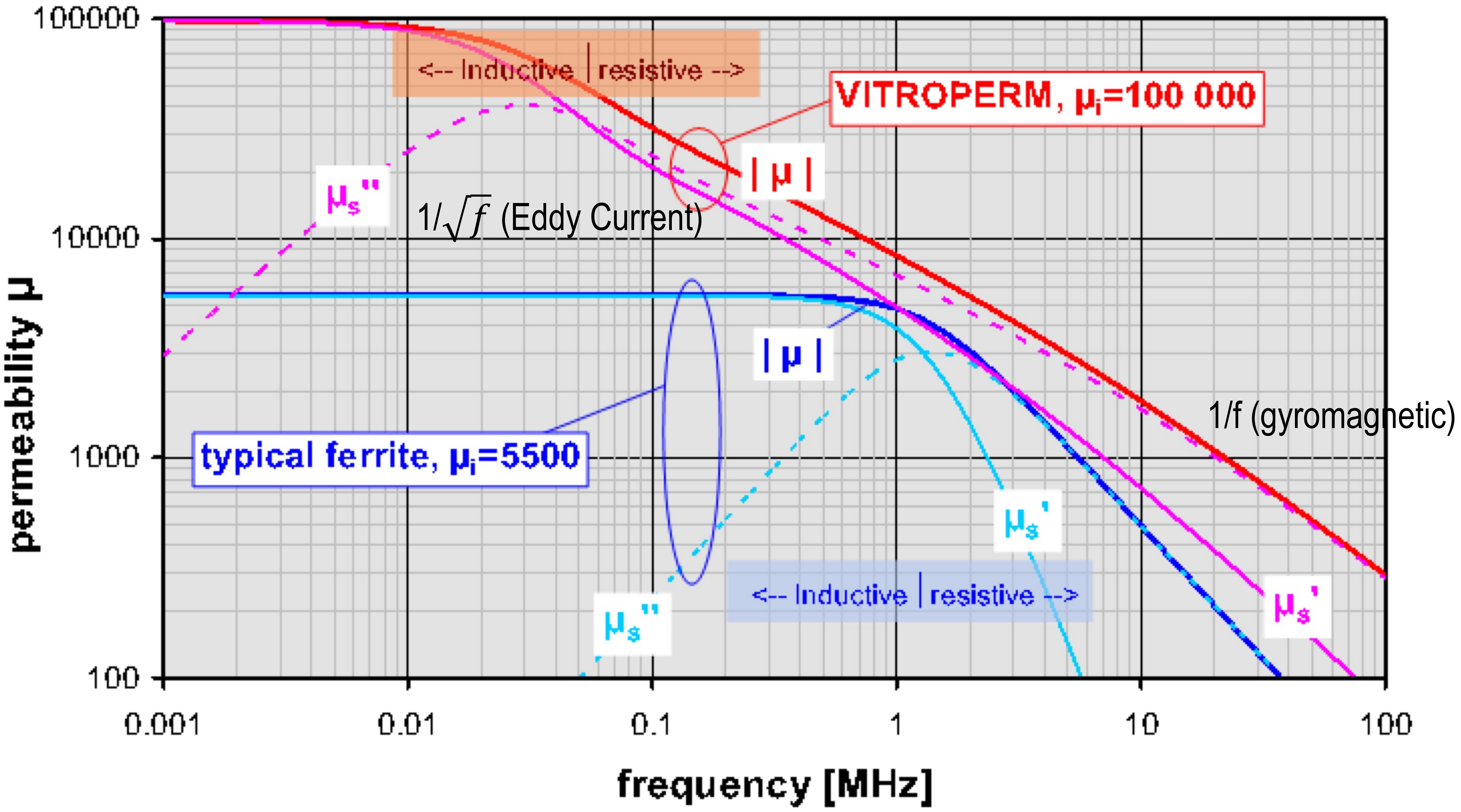
WHAT'S NECESSARY IN A CMC?

- How much attenuation of noise is needed?
  Required impedance
- Over what frequency bandwidth is the noise?
  Required frequency range
- How much current must it handle?
  Required current handling



- ❖ I Z I and L measurement in a normal Impedance Analyzer provides the basic information to calculate permeability, power losses, etc.
- ❖ Proposed range to measure is 100Hz thru 100MHz (ferrites can't effectively function as CMC above 2MHz without significant limitations in size, DC tolerance, temperature dependence, etc.).

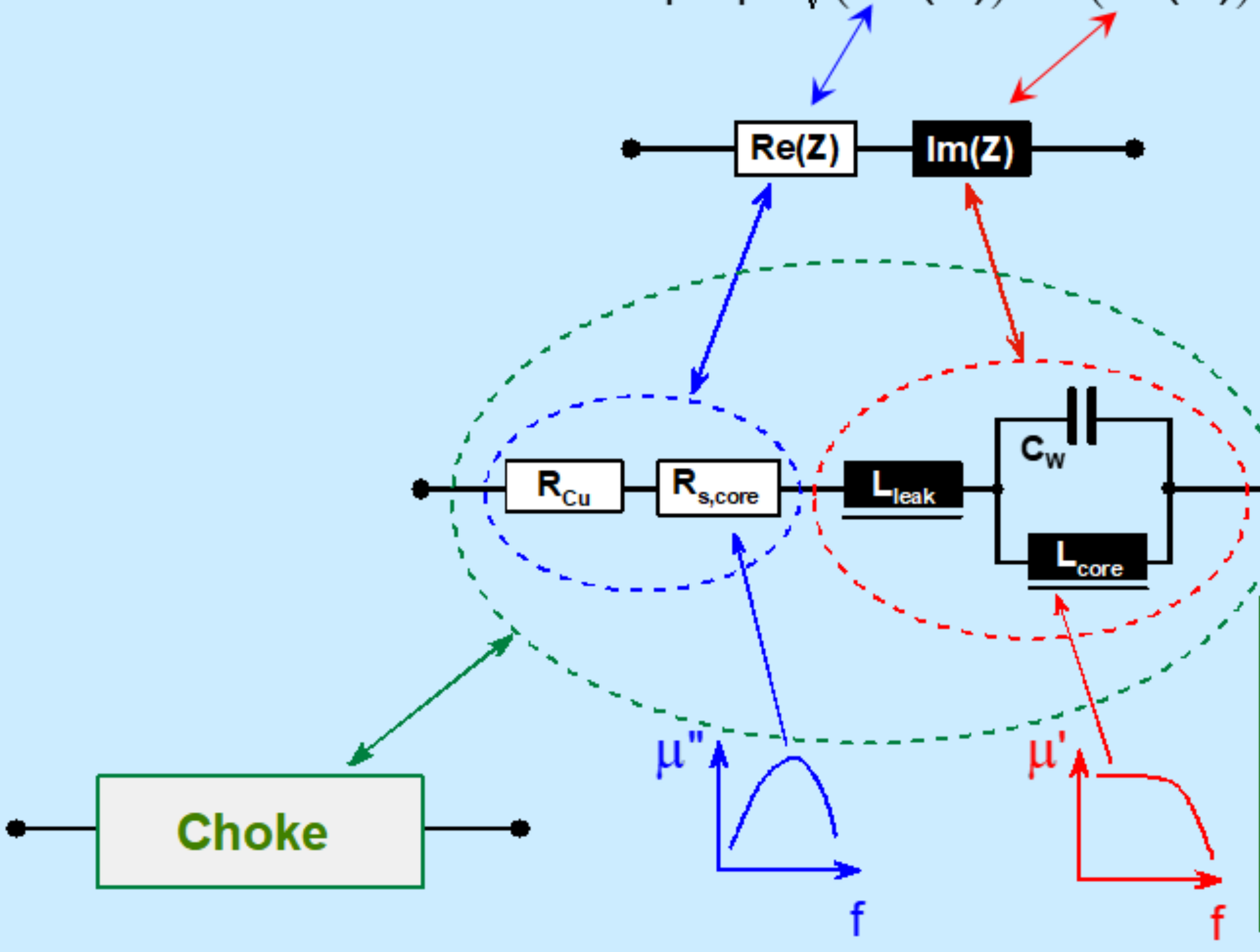
FREQUENCY DEPENDENCY OF PERMEABILITY



COMPLEX IMPEDANCE IN A CHOKE

Choke: |Z| - equivalent circuit - µ', µ''

Insertion loss a_E ⟷ $|Z| = \sqrt{(Re(Z))^2 + (Im(Z))^2} \approx \sqrt{R_{s,core}{}^2 + (\omega L_{core})^2}$



$$L_{core} = \mu_o \mu_s' \cdot N^2 \cdot \frac{A_{Fe}}{\lambda_{Fe}}$$

$$R_{s,core} = \omega \mu_o \mu_s'' \cdot N^2 \cdot \frac{A_{Fe}}{\lambda_{Fe}}$$

SPEC RECOMMENDATION (PART 1)

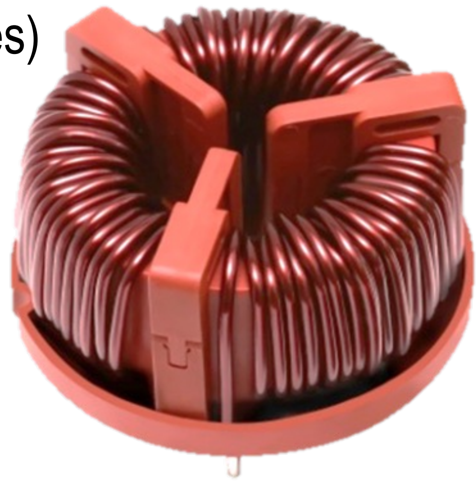
VAC recommendation is to measure IZI (complex impedance) and L (inductance) between 100Hz and 100 MHz

1. **L (10 kHz)** → comparison with ferrite
2. **L (100 kHz)** → real focus for the application
3. **IZI (f)** → insertion loss can be calculated
4. **Ls** (Leakage inductance) → interesting to understand the DM attenuation (usually better in ferrites)
5. **I_{unbal} (DC, 10kHz, 100kHz)**

Betriebsdaten/Charakteristische Daten (Typische Werte):
Operational data/characteristic data (typical values):

	f=10kHz	f=100kHz	DC
L [mH]	16,9	3,6	
|Z| [Ω]	1300	4000	
$I_{unbal.}$ [mA]	22	45	19

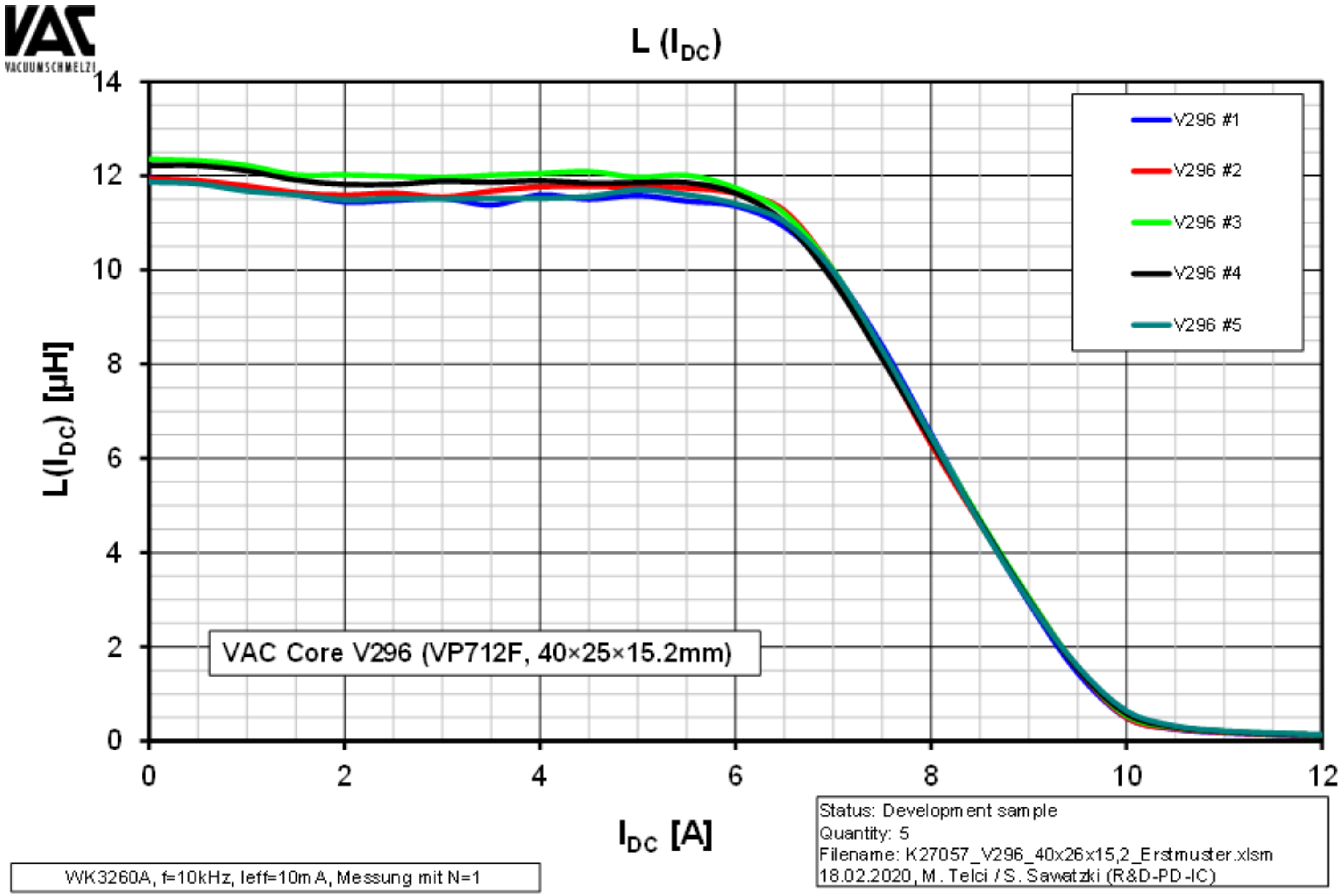
L_s / L_{leak} = 16 µH and f = 100 kHz (Eine Wicklung kurzgeschlossen / one winding shorted)
Bemessungsisolationsspannung / rated insulation voltage:
U_{is} = 600 V_{RMS} (848 V_{peak}) (Netzstromkreis / connected to the mains)
1000 V_{RMS} (1414 V_{peak}) (Nicht-Netzstromkreis / not connected to the mains)
I_N =2 x 13.5 A m = 54 g
Umgebungstemperatur / ambient temperature: T_a = -40°C...+70°C
Lagertemperatur / storage temperature: T_{st} = -40°C...+85°C



Extracted from an existing VAC datasheet

SPEC RECOMMENDATION (PART 2)

- The graph L vs DC current bias must be as rectangular as possible (optimized performance). This graph helps calculate permeability:



With

L=Inductance

N=Number of turns

l_{Fe}=Iron path length

A_{Fe}=Iron cross section

you get: $\mu' = \frac{l_{Fe}}{\mu_o \cdot A_{Fe}} \cdot \frac{L}{N^2}$

Maximum common mode current can be calculated from 70% of value at (Idc = 0)

SPEC RECOMMENDATION (PART 3)

Further recommendations to specify a superior solution…

- **Include a tighter tolerance +/- 6%:**
  - **For core weight**
  - **For A_{fe}**
  - The purpose is to reduce the scattering of the filling factor and tight the inductance range.
  - An excellent CMC should be able to reach higher DC tolerances for the same amount of material.
- The narrower the temperature dependency of the magnetic characteristics, the better performance the CMC will show across the temperature range. Interesting hint for the designer to make a good selection.