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Impact of temperature and burden on the frequency dependent transfer ratio of resin cast MV voltage instrument transformers

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Overview of influence factors

- Influence factors can be classified in three groups:

Construction

- Rated voltage
- Design
- Manufacturing tolerances
- ...

Ambient

- **Temperature**
- Distance to metallic parts
- Electric and magnetic fields
- Vibration
- ...

Operational

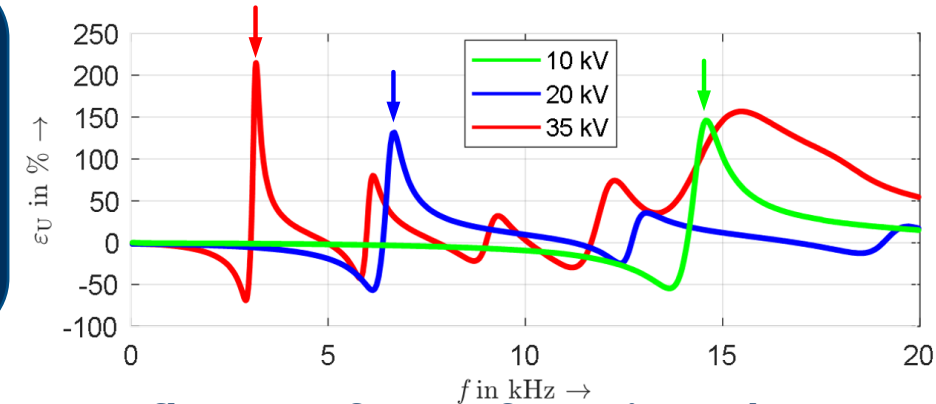
- **Burden**
- Primary voltage
 - Frequency
 - Magnitude
- ...

Internal influence factors

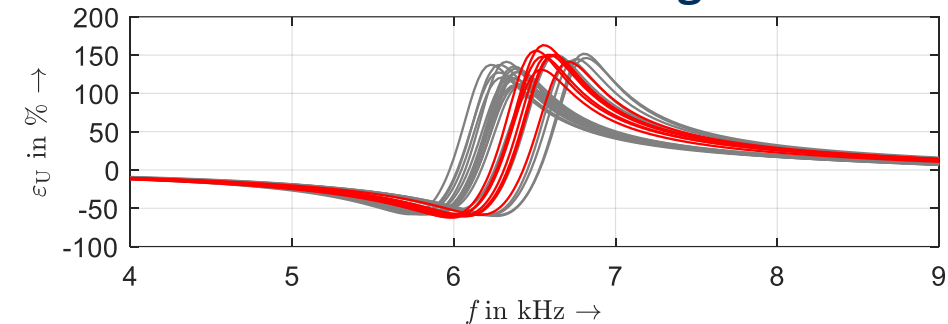
- Construction specific factors are characteristics of specific IVT
- Ambient and operational influence factors can have influence on the characterization result
- **Detailed investigation on influence of**
 - **Temperature**
 - **Burden**

External influence factors

Influence of rated voltage



Influence of manufacturing tolerances



Influence parameter range

- Definition of typical and extreme influencing quantity ranges reflecting realistic conditions
- Based on standards and experience (literature, expert responses)

Burden

- From Standards:
 - From 0% up to 100% of rated burden
 - $S_r \leq 10 \text{ VA: } \cos(\varphi) = 1$
 - $S_r \geq 10 \text{ VA: } \cos(\varphi) = 0,8_{\text{ind}}$
- Realistic Range:
 - Burden can vary in wide range
 - For simplified mass measurements of influence mainly resistive burden used
 - With modern low power measurement devices also capacitive part may dominate
 - Input capacitance of measurement device and cable capacitance sum up to 10 nF

Temperature

- Temperature classes according IEC 60721-3-3
- VT's are mostly placed in tempered places (5°C ... 40°C) but sometimes also in enclosed places without temperature control (-5°C ... 55°C)
- In extreme cases VT's are placed outside (-25°C ... 55 °C)
- Lab measurements from -25°C to 55°C

- Measurement of 4 different resin cast MV IVT's of different rated primary voltages and different manufacturers
- In preparation of the measurements in climate chamber, thermal time constant was determined

	DUT A	DUT B	DUT C	DUT D
$U_{pri\ r}$	$35/\sqrt{3}$ kV	$20/\sqrt{3}$ kV	$20/\sqrt{3}$ kV	$10/\sqrt{3}$ kV
$U_{sec\ r}$	$100/\sqrt{3}$ V			
f_r	50 Hz			
S_r	50 VA			30 VA
Class	0.5			
First resonance frequency	3.2 kHz	6.5 kHz	6.6 kHz	11 kHz
τ_{θ}	7400 s (2.1 h)	8630 s (2.4 h)	7800 s (2.2 h)	5900 s (1.6 h)

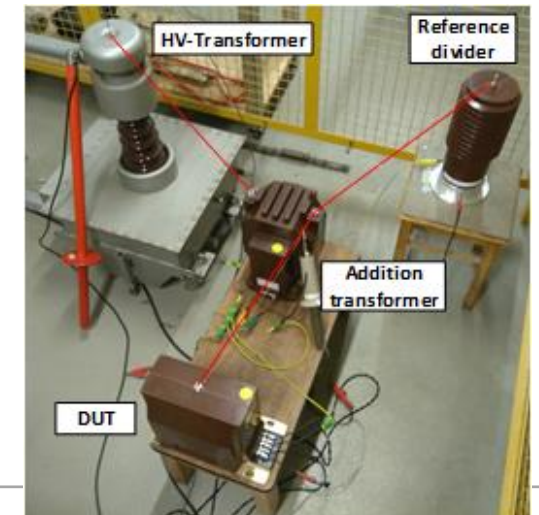
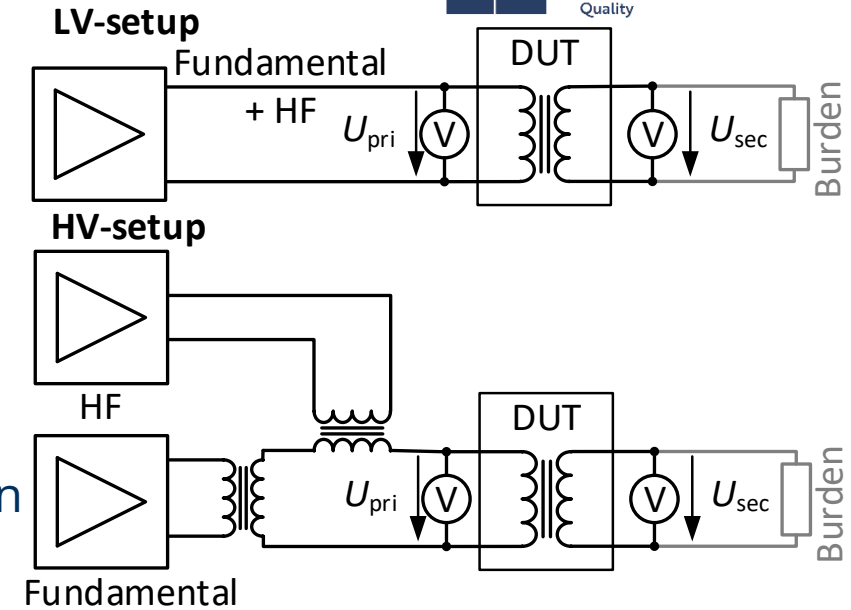


- In the following, only results of DUT A is shown, similar behaviour of other DUT's

Measurement setup

Overview

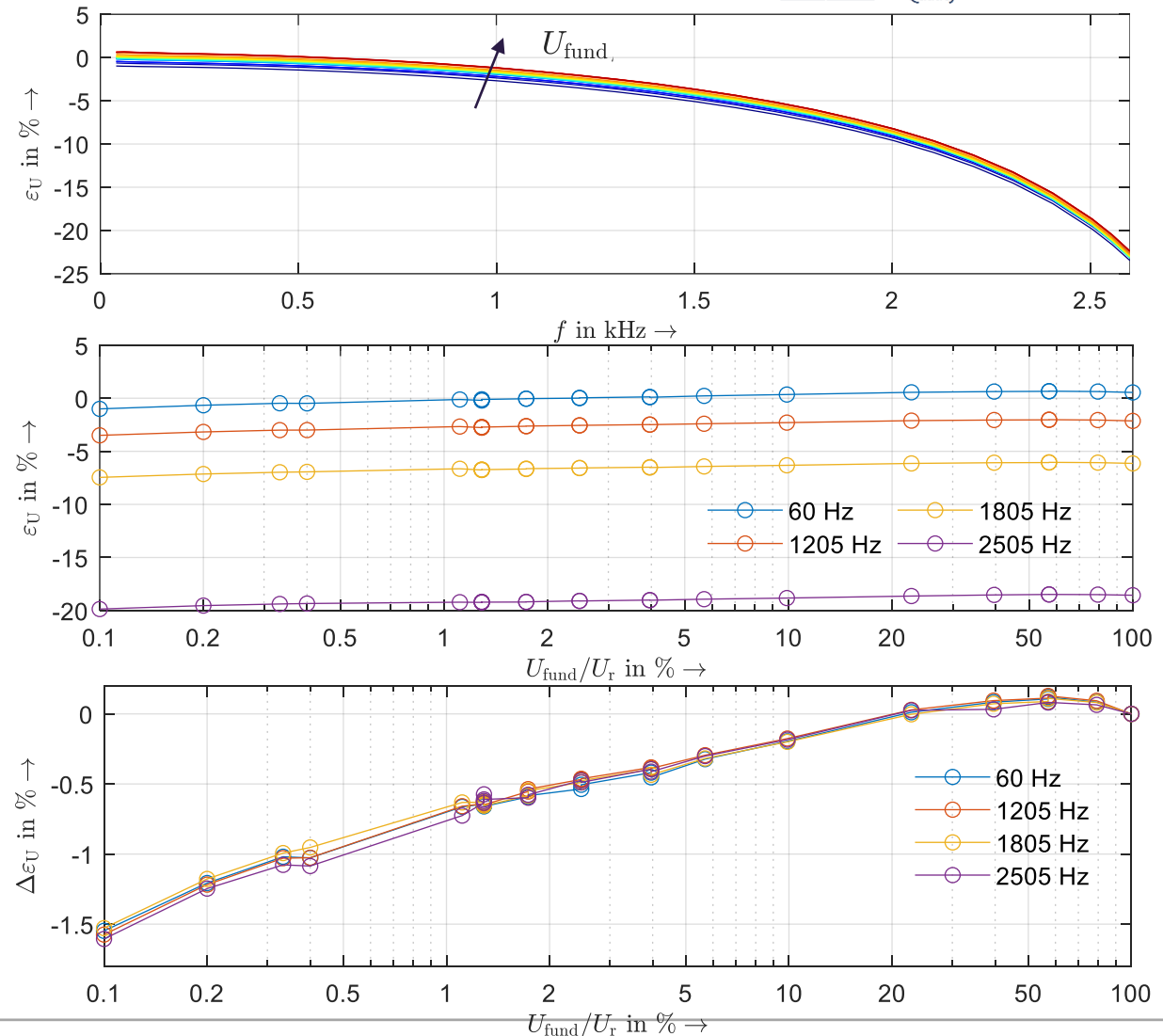
- Measurement with fundamental + 5 % frequency variable HF component
- Setup depending on required (and possible) voltage
 - LV-setup: Direct generation of voltage, up to 270 V
 - HV-setup: Separate generation and transformation, up to 24 kV
- Automated measurement for very extensive parameter variation
- Measurement of temperature influence in climatic chamber
 - After preliminary measurements: also measurements on burden dependency in climate chamber (influence of non-stable room temperature)
 - Only LV-Measurements possible
- Influence of measurement voltage?



Measurement setup

Influence of measurement voltage

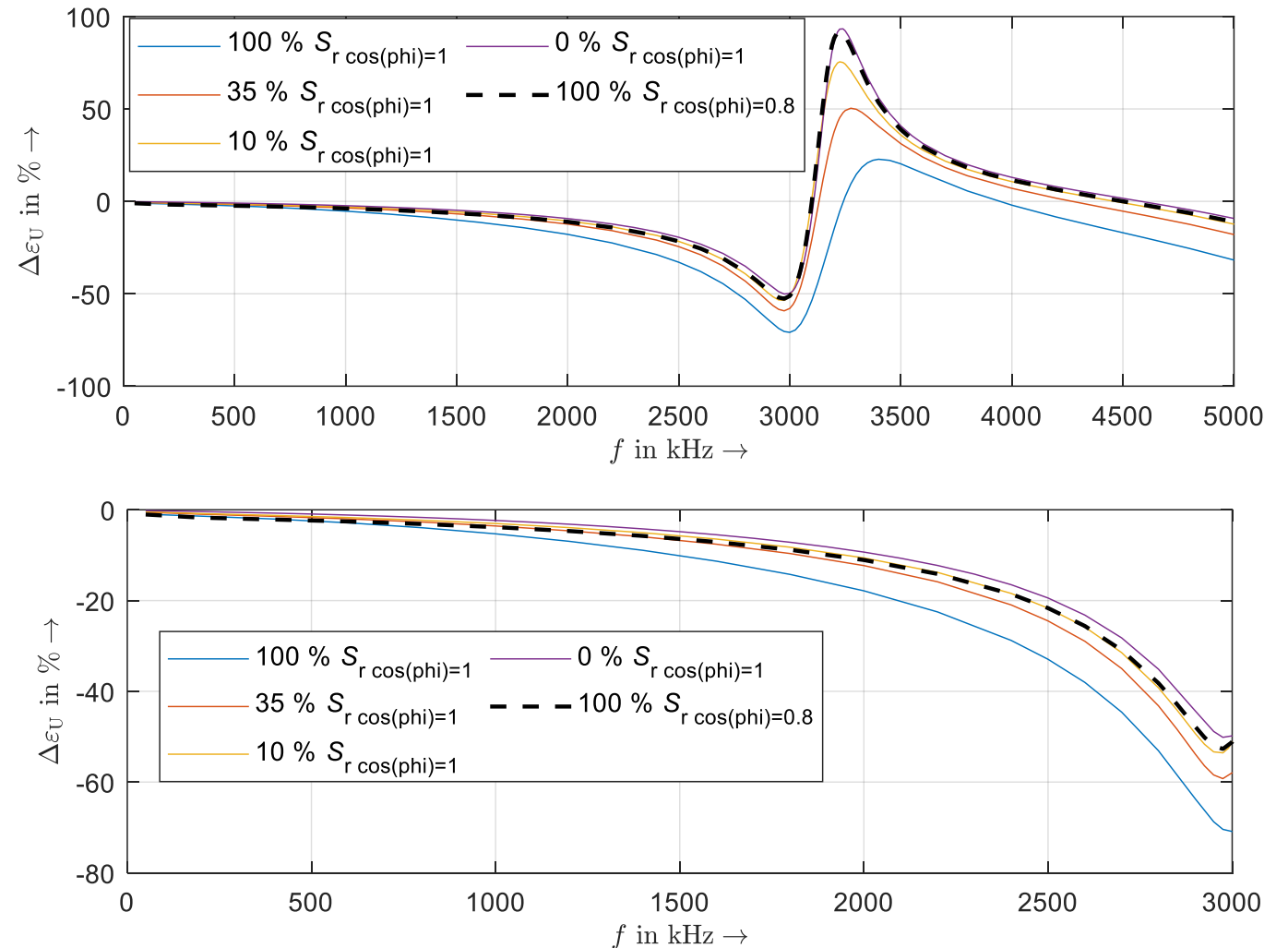
- Proposed measurement voltage for simplified LV-setup:
 - 2-frequency voltage
 - Fixed fundamental with 50 Hz, 260 V
 - Frequency variable component, 5 % of fundamental
- Measurement of the impact of measurement voltage with HV-Setup
 - Variation of fundamental from 0.1 % to 100 % of rated voltage (20 V to 20 kV)
 - Amplitude of fundamental has impact on whole frequency range
 - Change of ratio error is constant in the frequency range



Influence of burden

Resistive-inductive burden

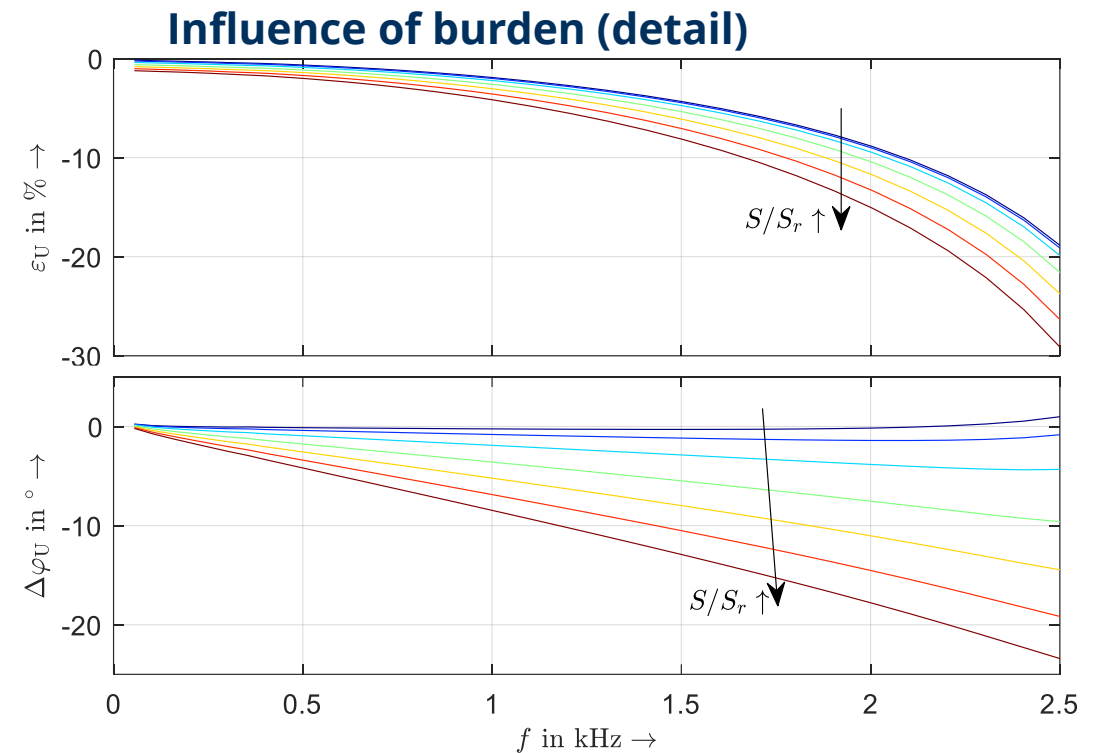
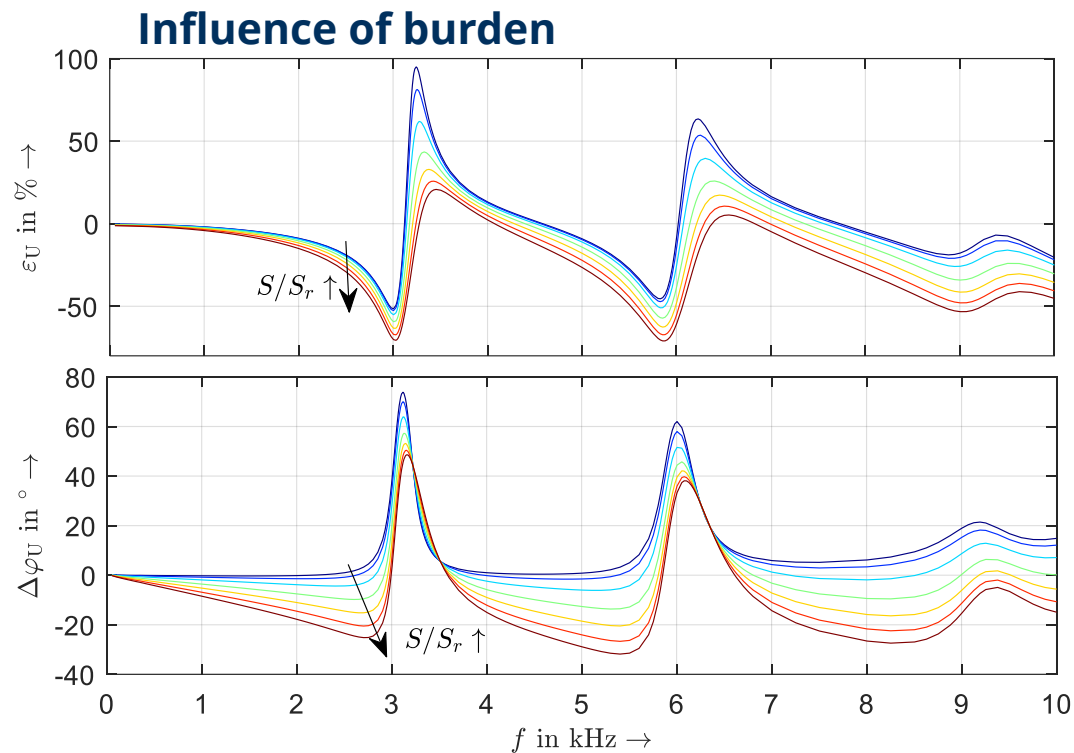
- Comparison of resistive-inductive standard burden (series burden) with resistive burden
- Impact of resistive-inductive standard burden is decreasing with frequency:
 - At low frequencies behaviour similar as resistive burden with rated power
 - At higher frequencies behaviour as with no burden



Influence of burden

Resistive burden, overview

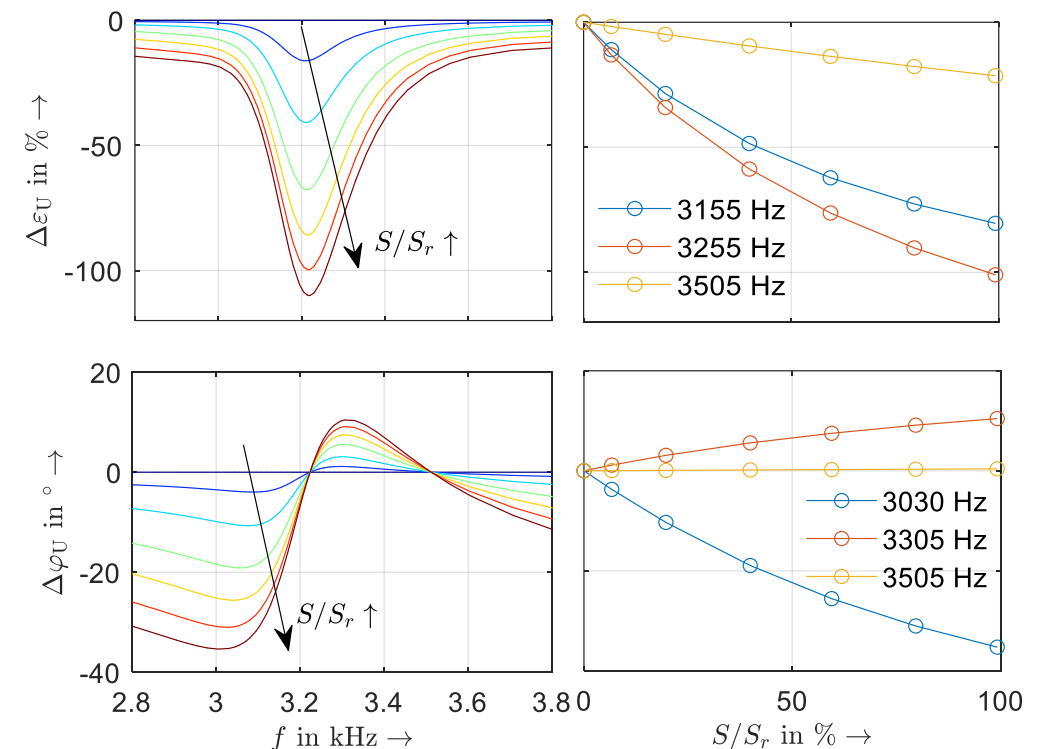
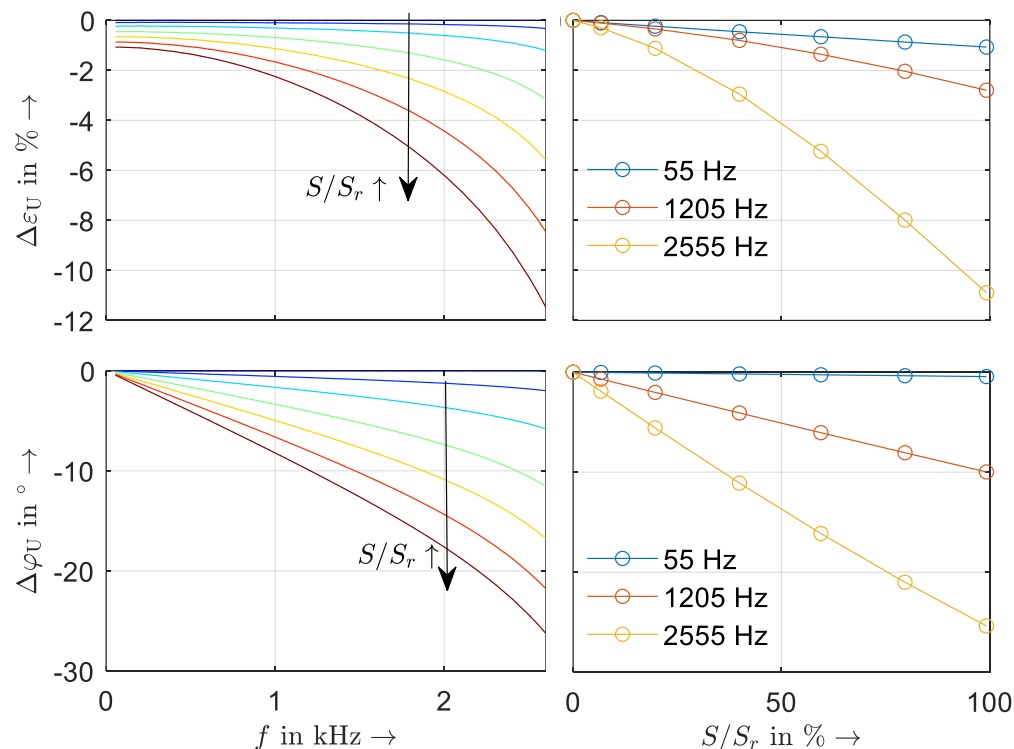
- Resistive Burden from 0% ... 100% S_r
- Influence on the whole frequency range



Influence of burden

Resistive burden, detail

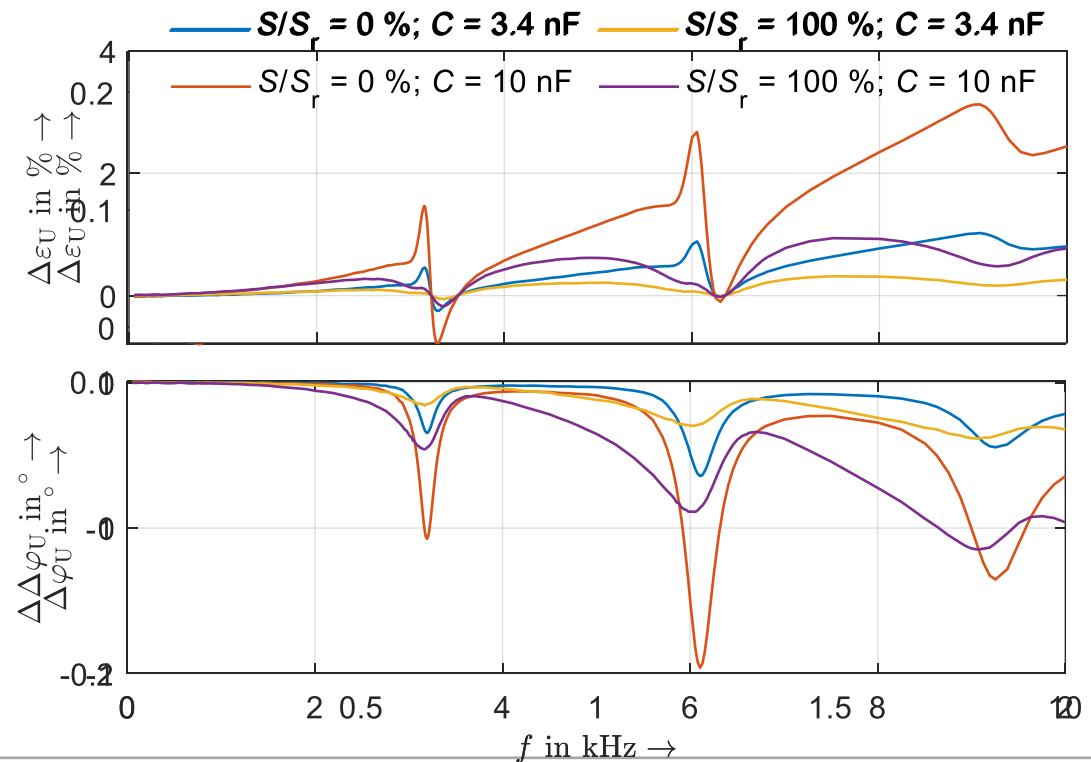
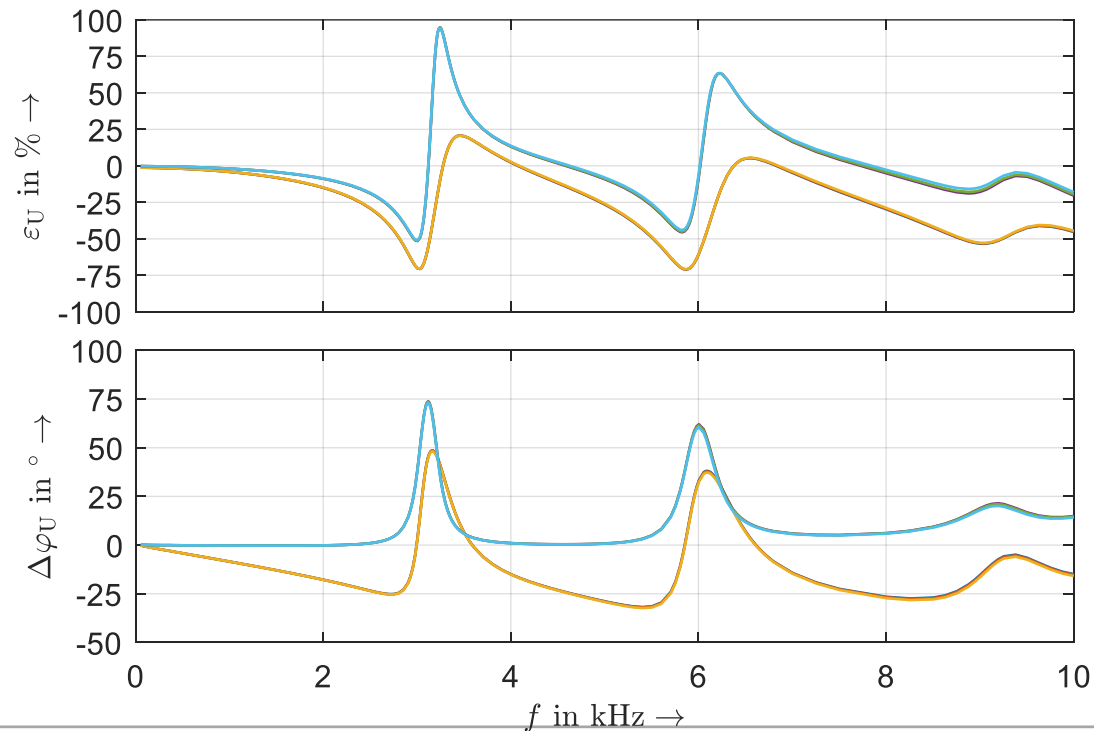
- Change of ratio error and phase displacement compared to measurement without burden
- Clear influence at fundamental (up to 2 %, 0.5°)
- Highest influence at resonance (up to 120 %, 35°)



Influence of burden

Capacitive burden

- Measurement with and without rated resistive burden
- Small but increasing influence of capacitive part with frequency
- No significant influence of capacitance at fundamental

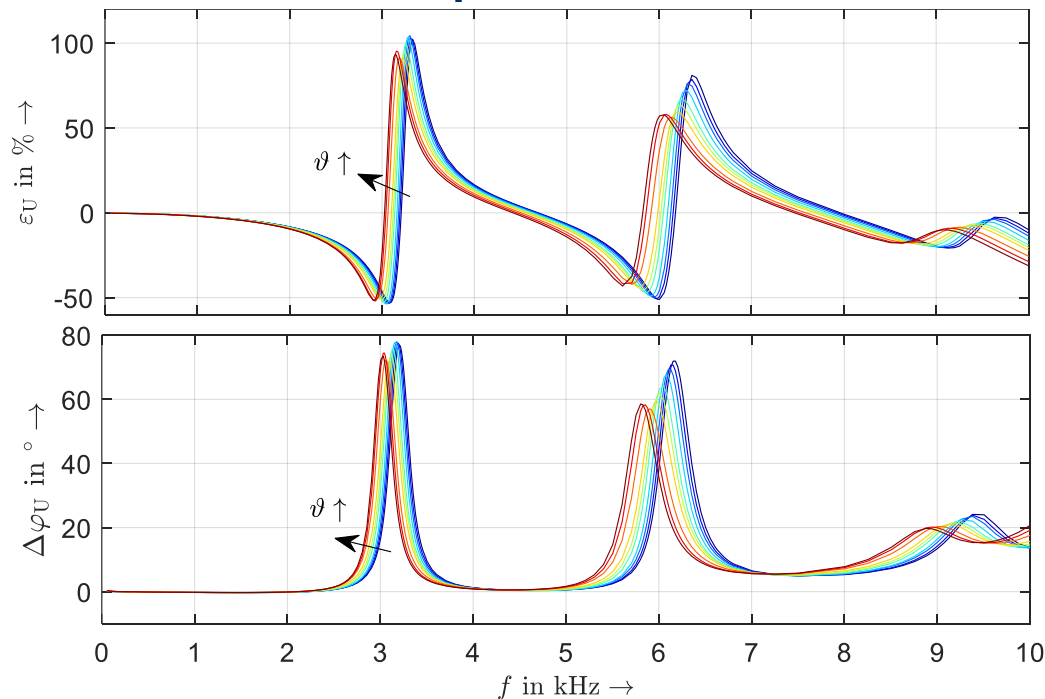


Influence of temperature

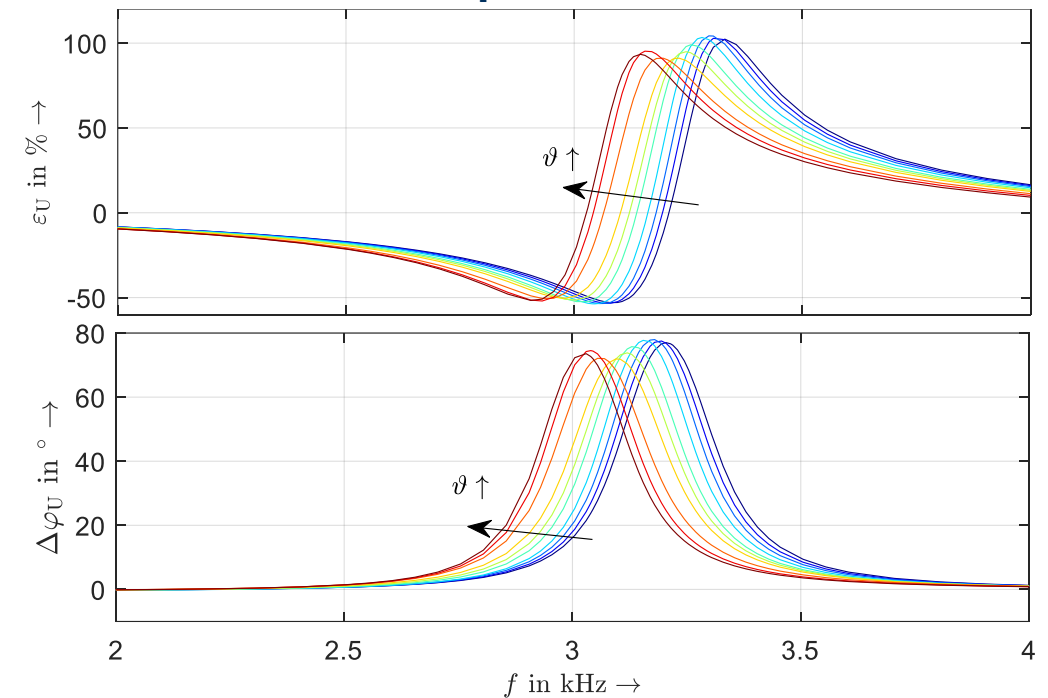
Overview

- Settling time 24 h after each temperature change ($\approx 10 \cdot \tau$)
- Measurement without burden
- Temperature shifts resonance frequencies due to changing mechanical dimensions (increasing stray capacitance with temperature rise)

Influence of temperature



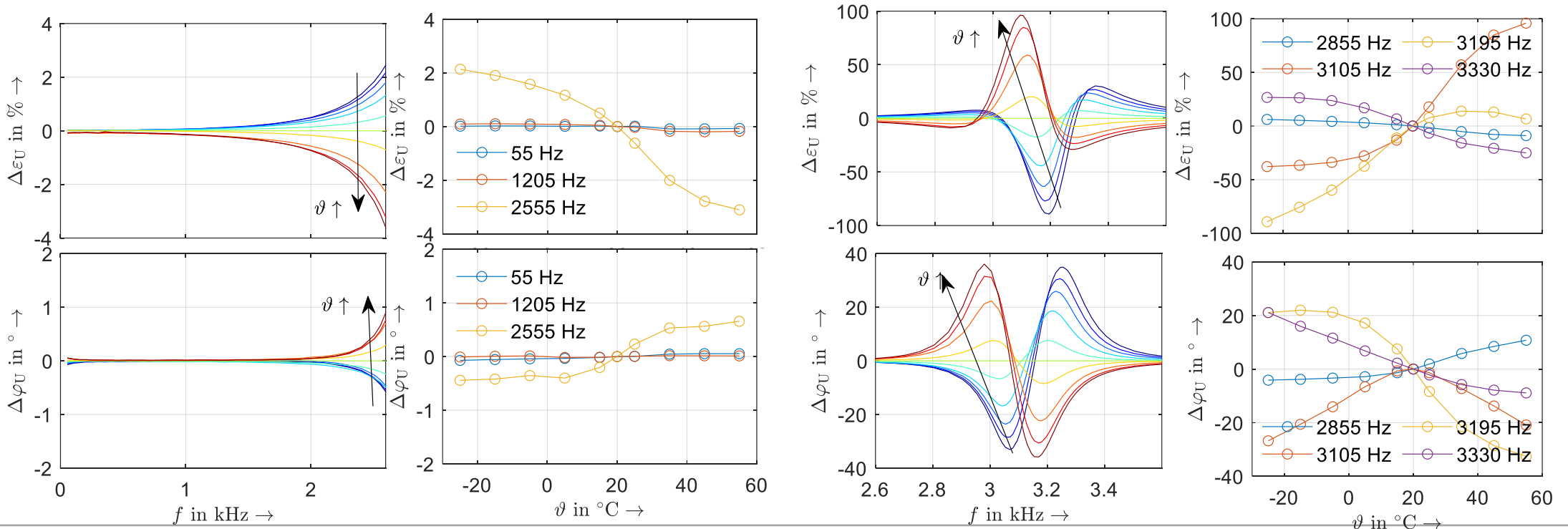
Influence of temperature (detail)



Influence of temperature

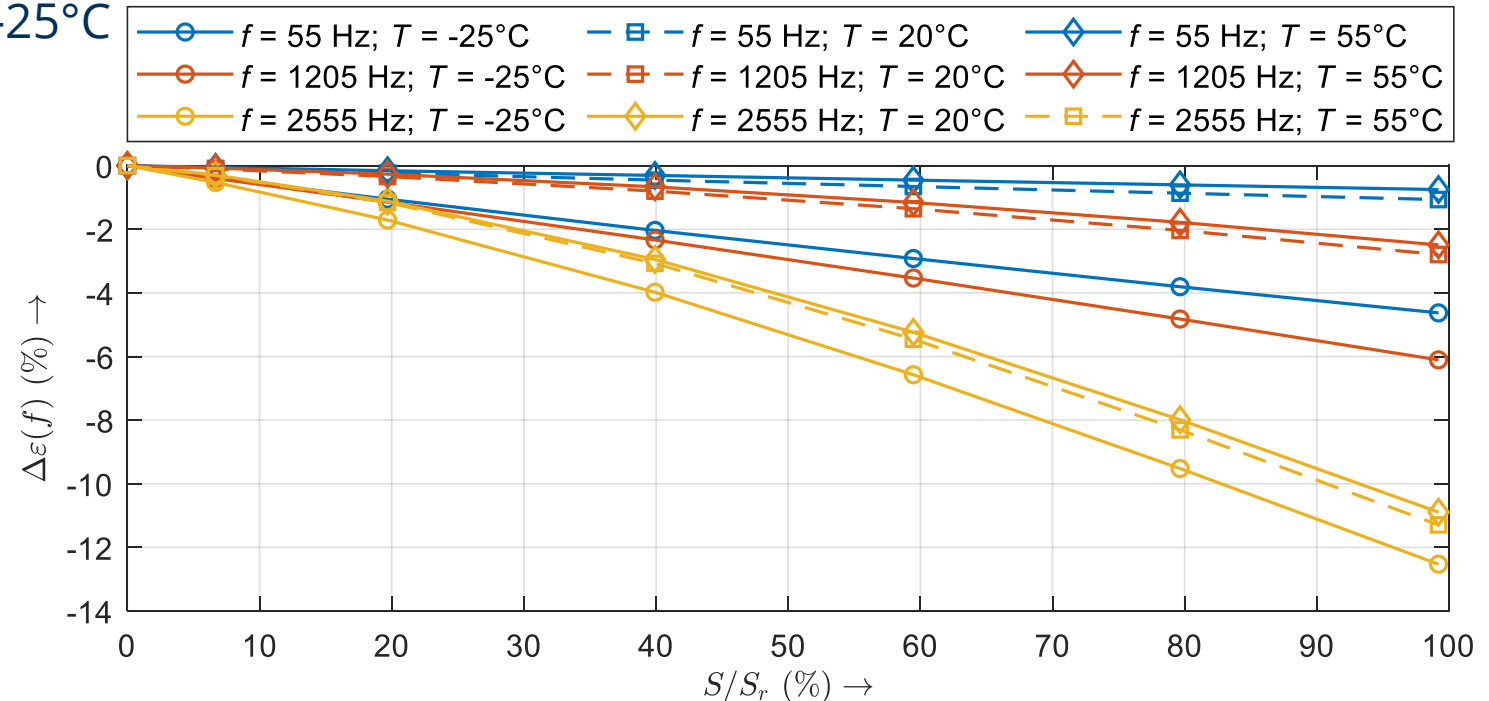
Detail

- Change of ratio error and phase displacement compared to measurement with 20°C
- No significant influence at 50 Hz
- Small influence in harmonic range (3 %, 1° @ 2.5 kHz)
- High influence in range of resonance (up to 100 %, 40°)



Combined influence: resistive burden and temperature

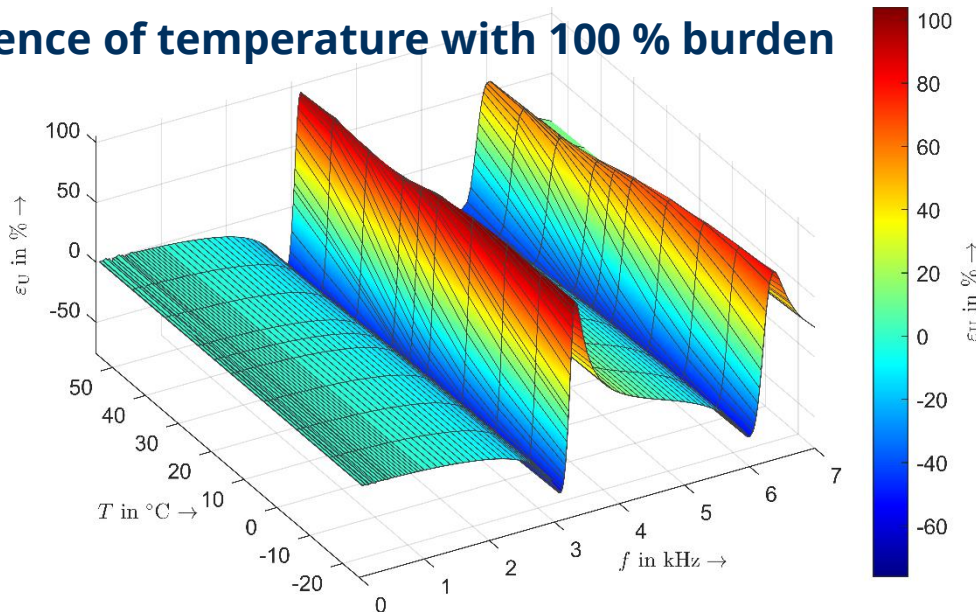
- Impact of burden on ratio error at different temperatures
- Impact is temperature dependent
- Small changes between 20°C and 55°C
- Higher changes between 20°C and -25°C
- Nonlinear influence of temperature
 - Influence of temperature on iron core?



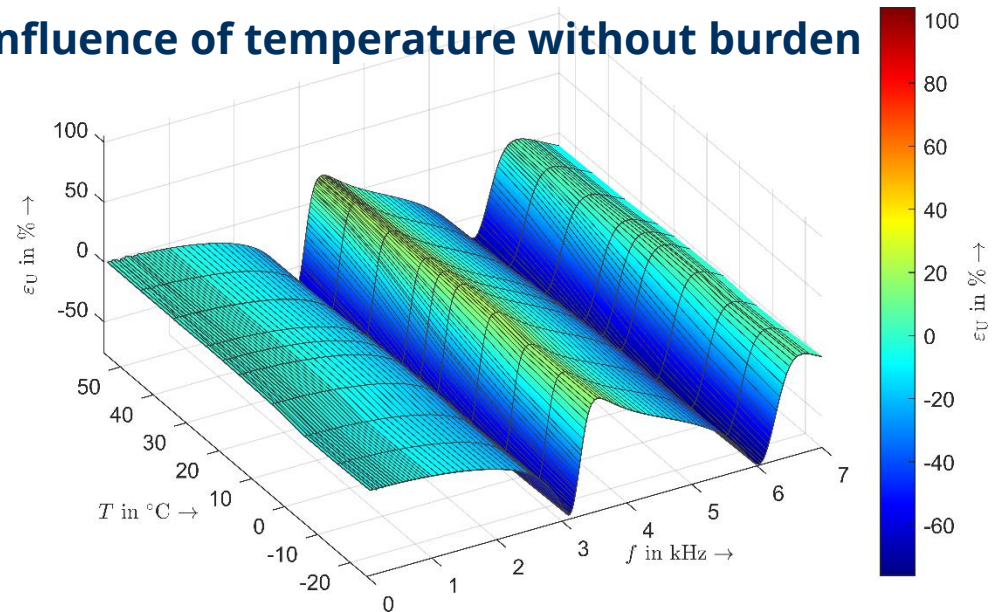
Summary

- Burden has high influence on whole frequency range
 - Realistic capacitive part in burden has small impact increasing with frequency
- Temperature has high influence mainly on resonance frequency
- Combined influence of burden and temperature is present
- Influences cannot be considered separately

Influence of temperature with 100 % burden



Influence of temperature without burden



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Thank you for your attention!
Questions?

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