Performance of inductive VTs up to 150 kHz

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ADMIT 2nd Stakeholder Workshop

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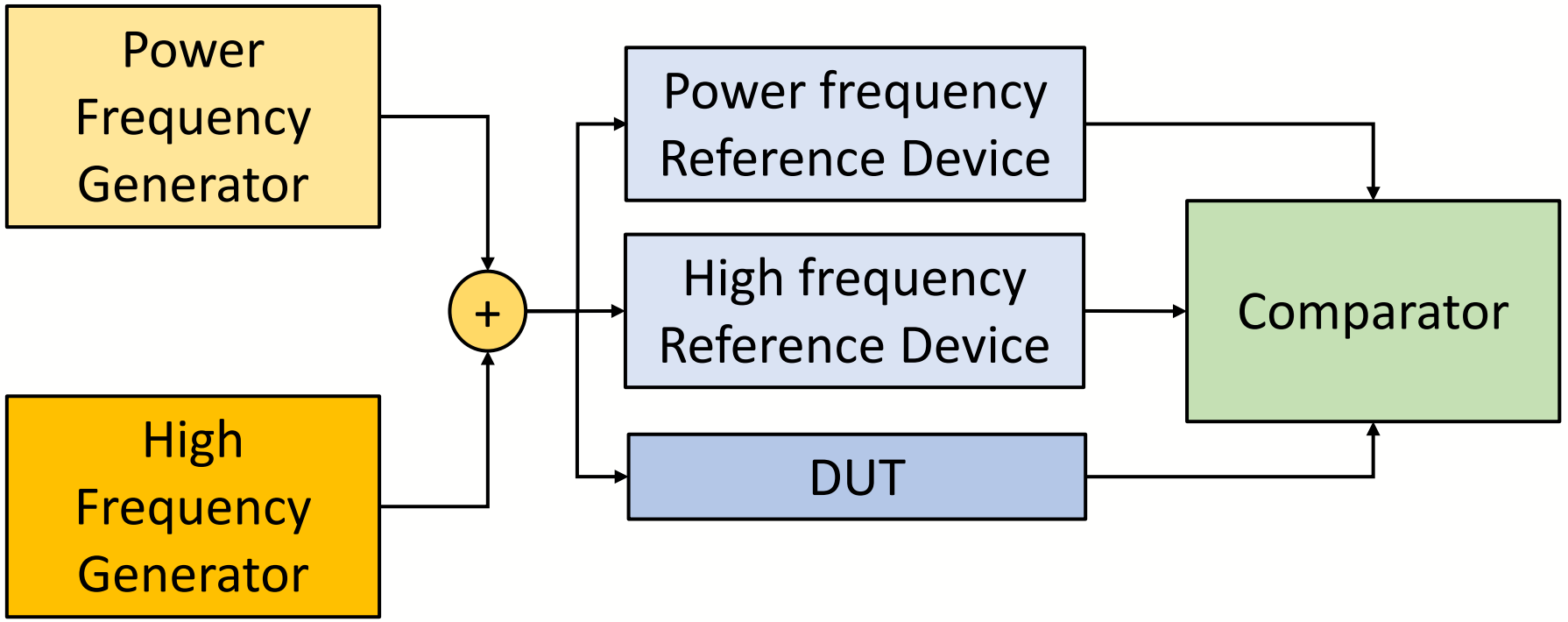
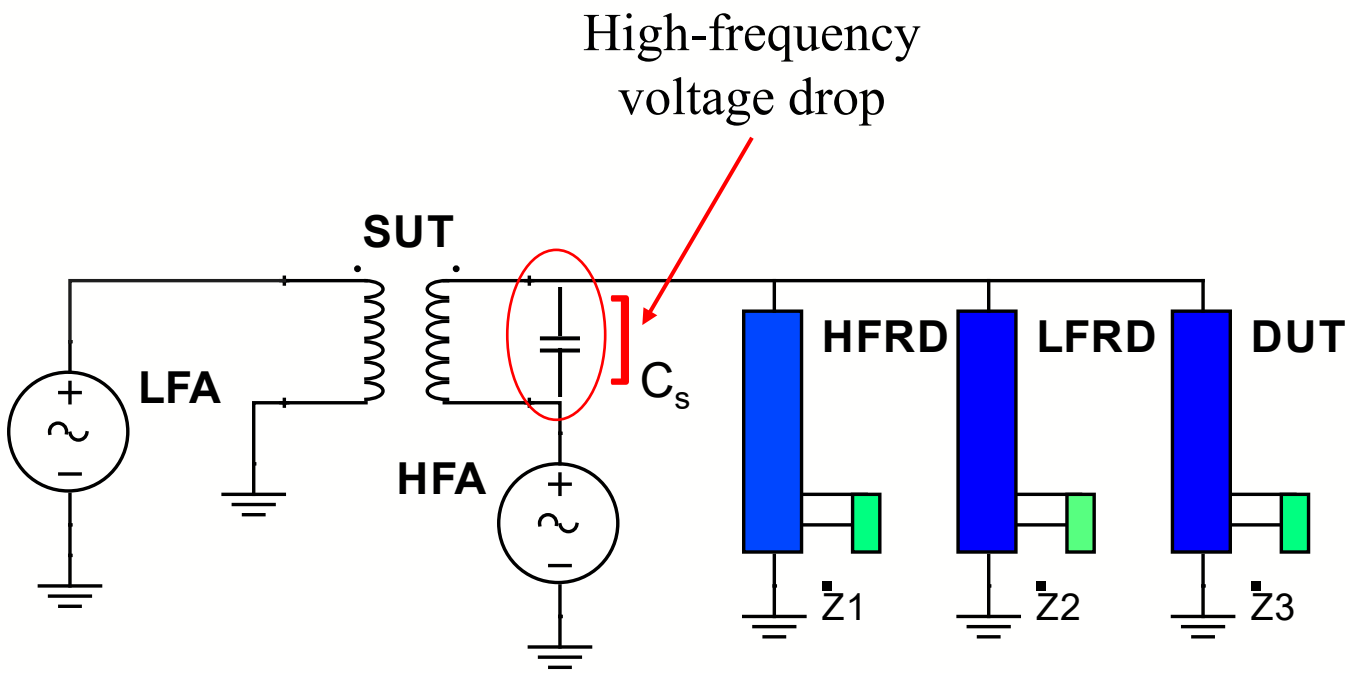
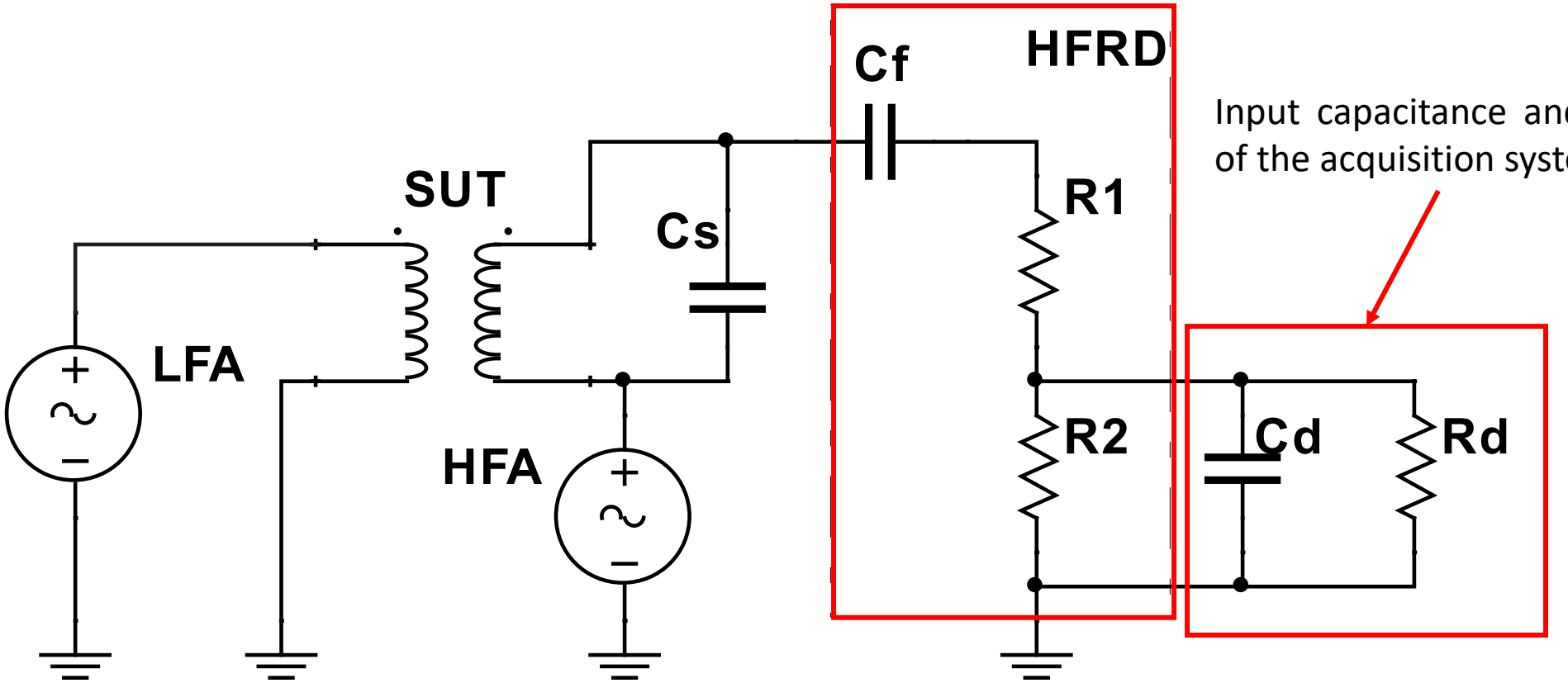
Content

- Implementation of a generation and measurement setup up to 150 kHz
- Study of non-linearities of inductive VT in the range [9, 150] kHz


Power
Frequency
Generator
High
Frequency
Generator
+
Power frequency
Reference Device
High frequency
Reference Device
DUT
Comparator



LFA	Low-Frequency Amplifier
HFA	High-Frequency Amplifier
SUT	Step-Up Transformer
LFRD	Low-Frequency Reference Device
HFRD	High-Frequency Reference Device
DUT	Device Under Test


Cf
HFRD
Input capacitance and resistance of the acquisition system
SUT
Cs
R1
LFA
HFA
R2
Cd
Rd

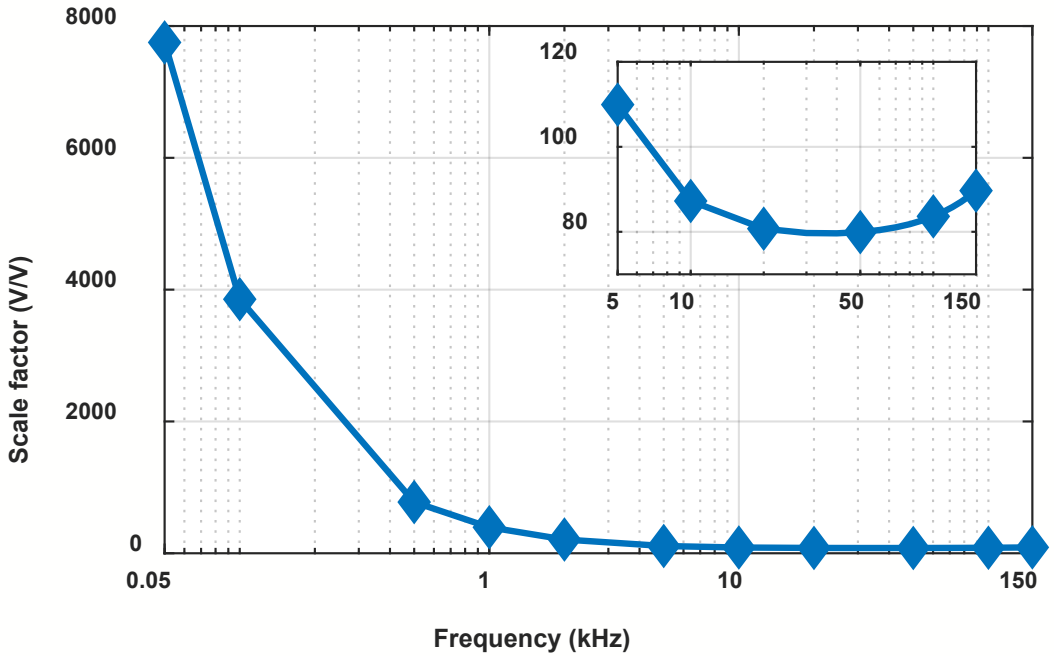
HFRD Design

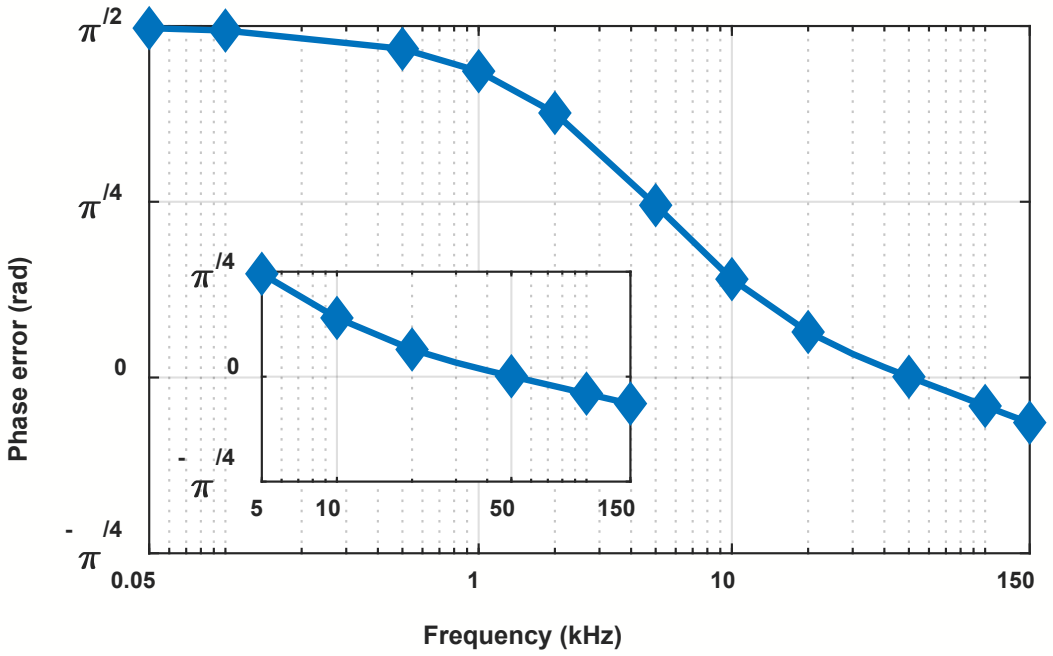
Parameter	Value
f_{cutoff}	≈ 5 kHz
C_F	275 pF
Bandpass gain	≈ 1/80
R_1	114.3 kΩ
R_2	1.5 kΩ

Two steps characterization

- Low-voltage frequency characterization
- Voltage dependance at power frequency

Low-voltage frequency characterization





$$SF(f) = V_p/V_s$$

$$\Delta\phi(f) = \phi_s - \phi_p$$

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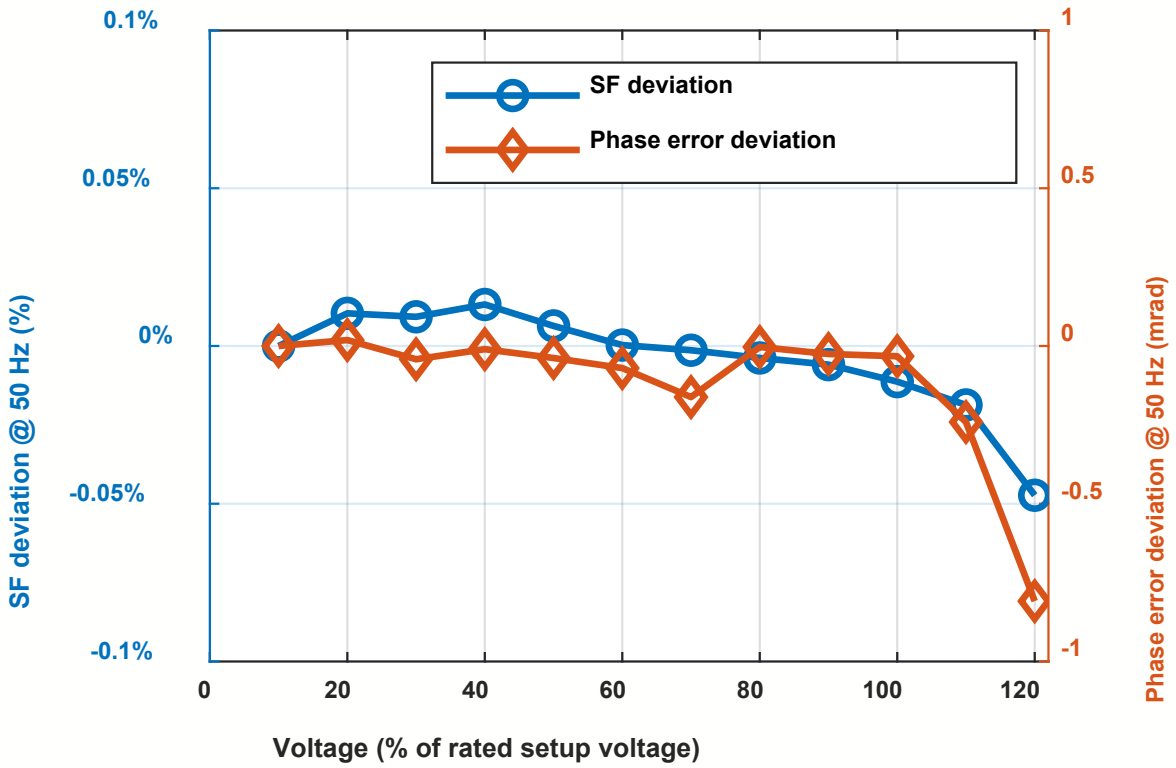
Voltage dependance at power frequency



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Study of non-linearities of inductive VT in the range [9, 150] kHz

- Fundamental component plus 1 harmonic
- Analysis of VT input and output spectra

Test waveforms

$$y(t) = \sqrt{2}A_1 \sin(2\pi f_1 t) + \sqrt{2}A_{hf} \sin(2\pi f_{hf} t)$$

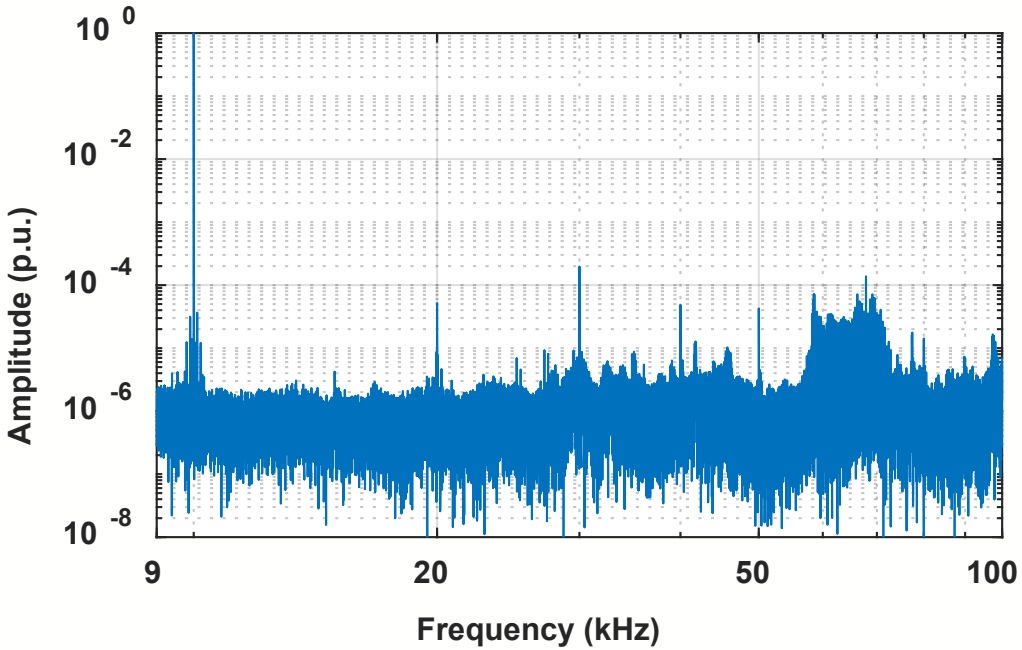
Fundamental component

1 high-frequency harmonic component

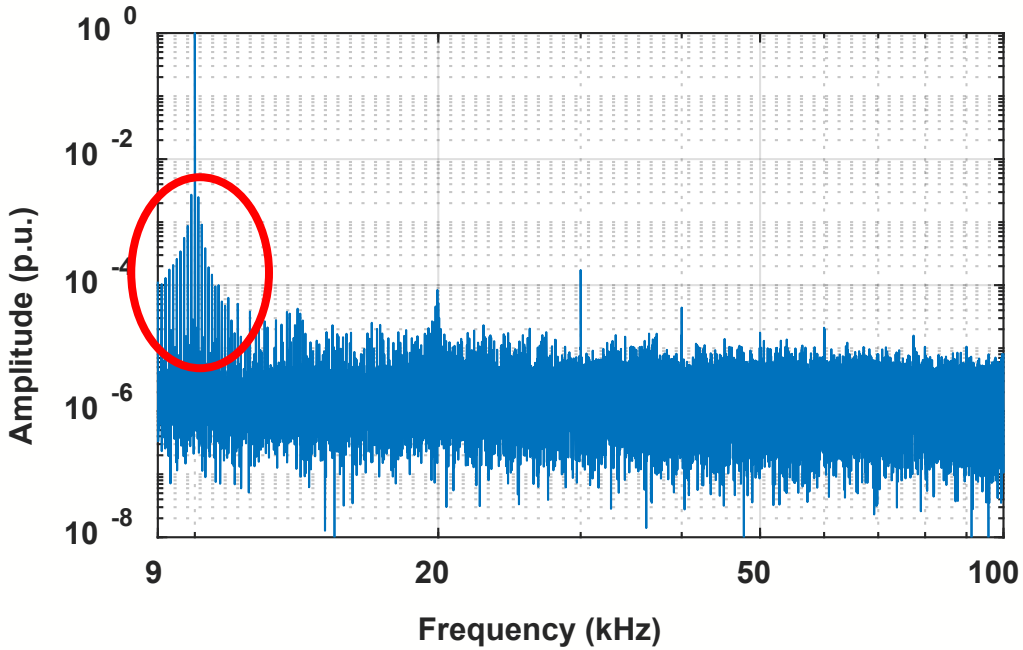
	Fundamental component	High-frequency component
Amplitude	3 kV	2% of fundamental component
Frequency	50 Hz	9-150 kHz

Analysis of VT input and output spectra

Input spectrum ($f_{hf} = 10\ kHz$)



Output spectrum ($f_{hf} = 10\ kHz$)



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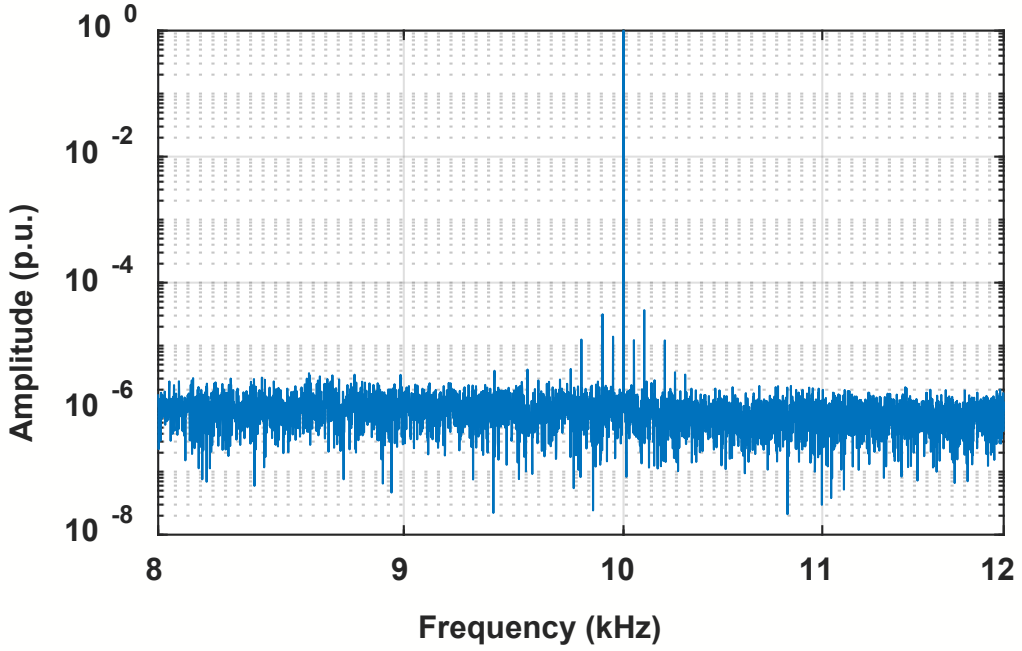
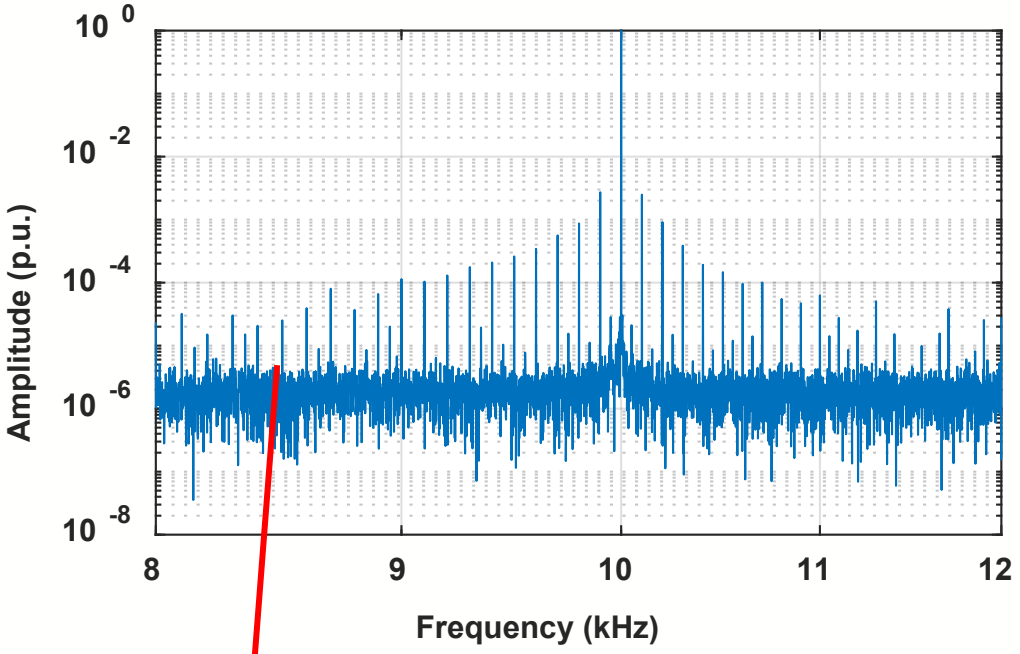
Input spectrum (zoom around 10 kHz)



Output spectrum (zoom around 10 kHz)



$$f = 10000\ Hz \pm k \cdot 50\ Hz\ (k = 1,2,3, \ldots)$$

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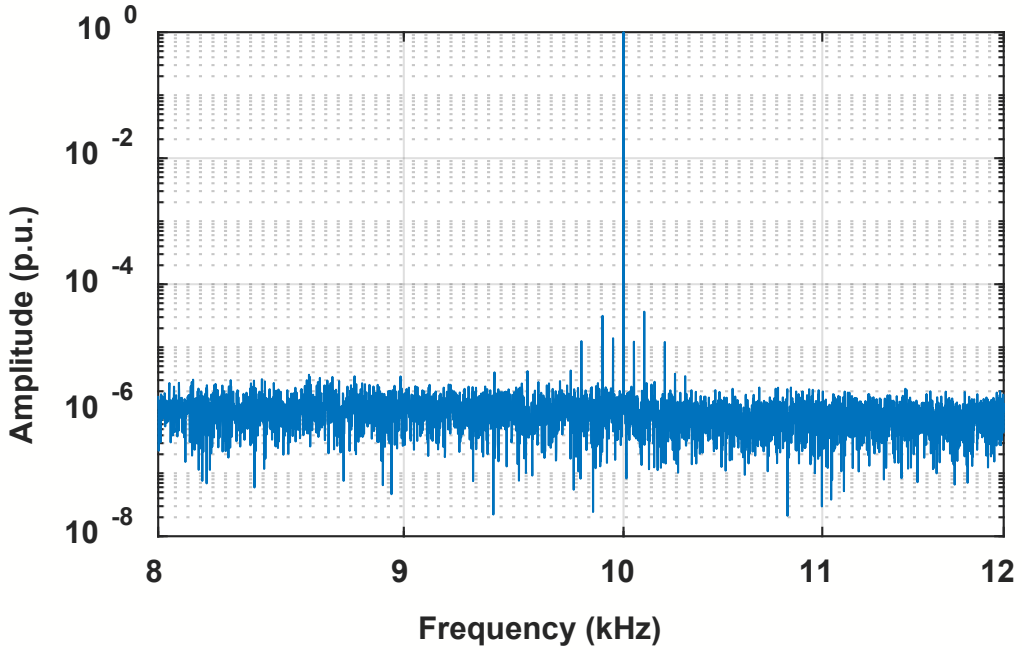
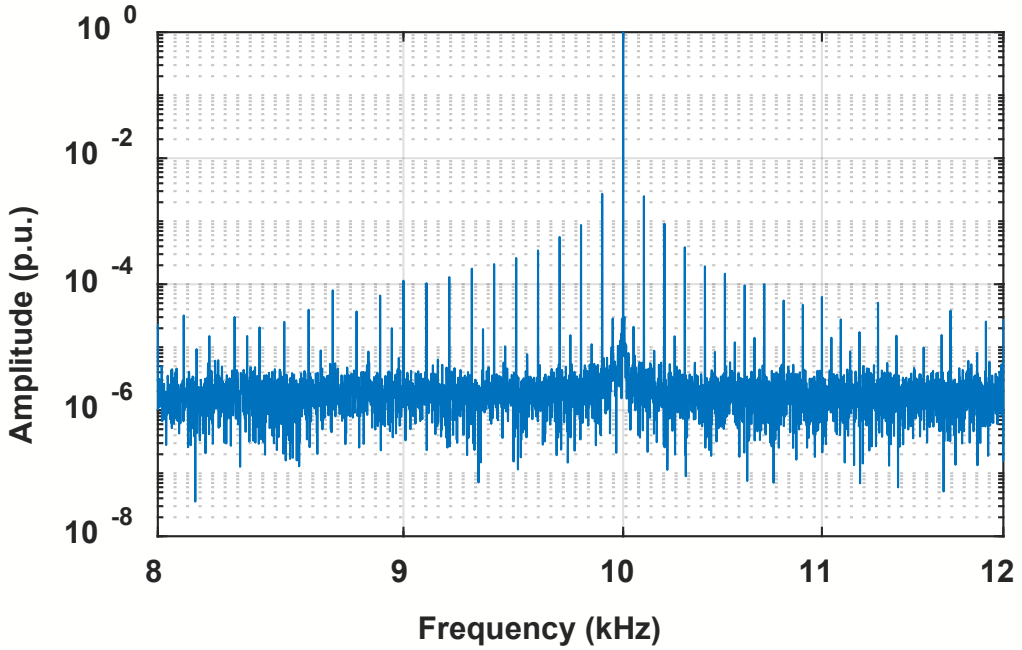
Input spectrum (zoom around 10 kHz)



% of injected tone	0.004 %
Δf	± 0.2 kHz

Output spectrum (zoom around 10 kHz)



% of injected tone	0.270 %
Δf	± 2 kHz

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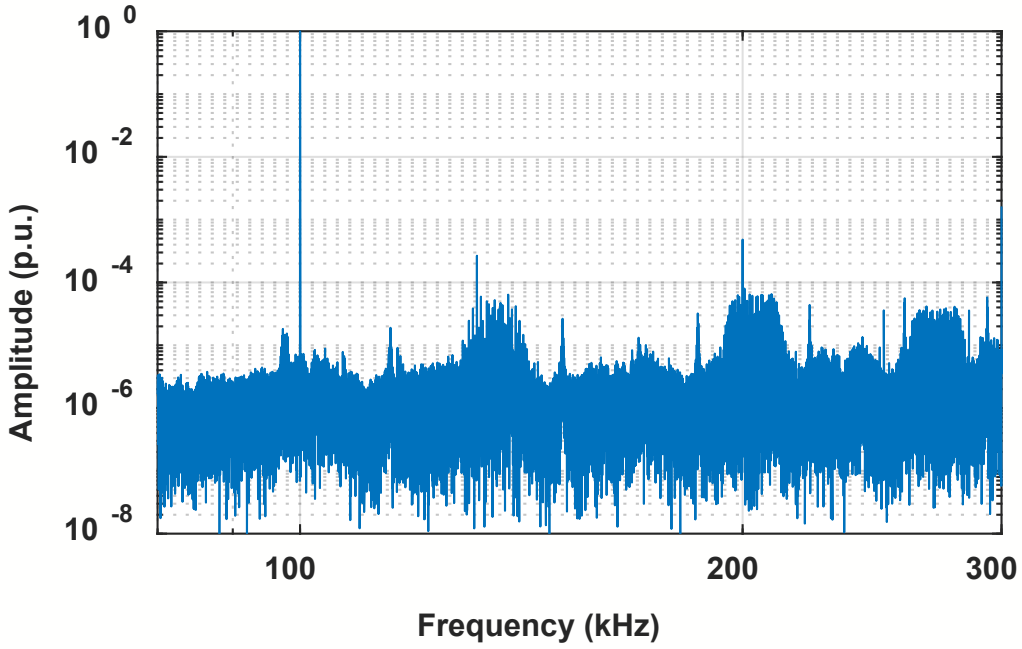
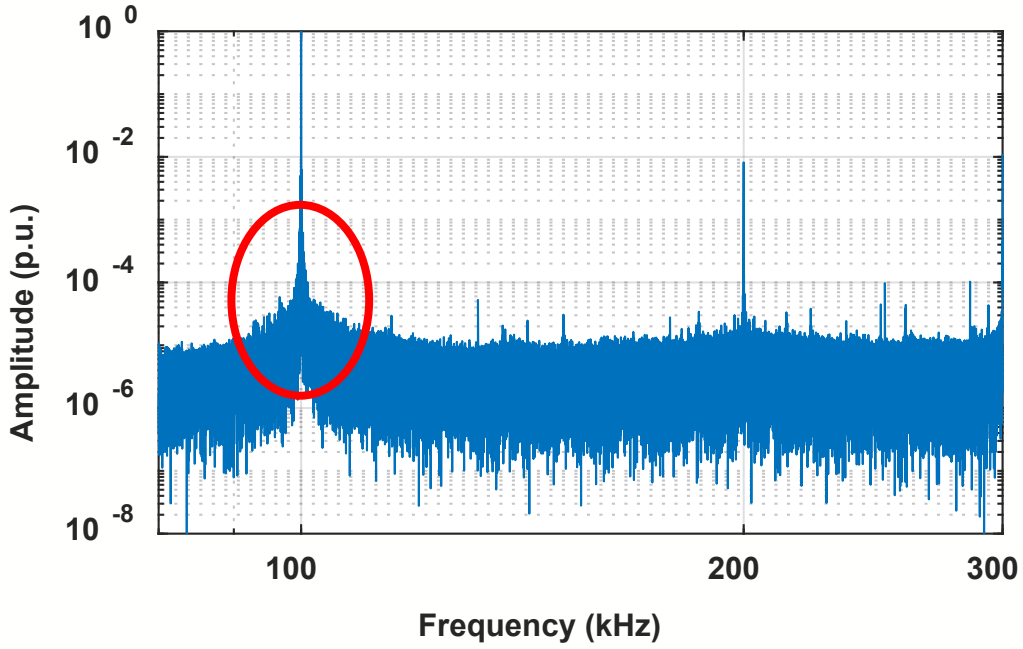
Input spectrum ($f_{hf} = 100\ kHz$)



Output spectrum ($f_{hf} = 100\ kHz$)



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Conclusions

- Implementation of a generation and measurement setup
  - Two series-connected generators
- Study of non-linear effects for inductive VTs
  - Intermodulation effect between the fundamental component and high-frequency harmonics