Purpose-build power amplifier for MIT: Evaluation using fruit

Ralf Patz, Victor Golev
Faculty of Computer Science and Electrical Engineering
Institute of Communications Technology and Embedded Systems
Kiel University of Applied Sciences

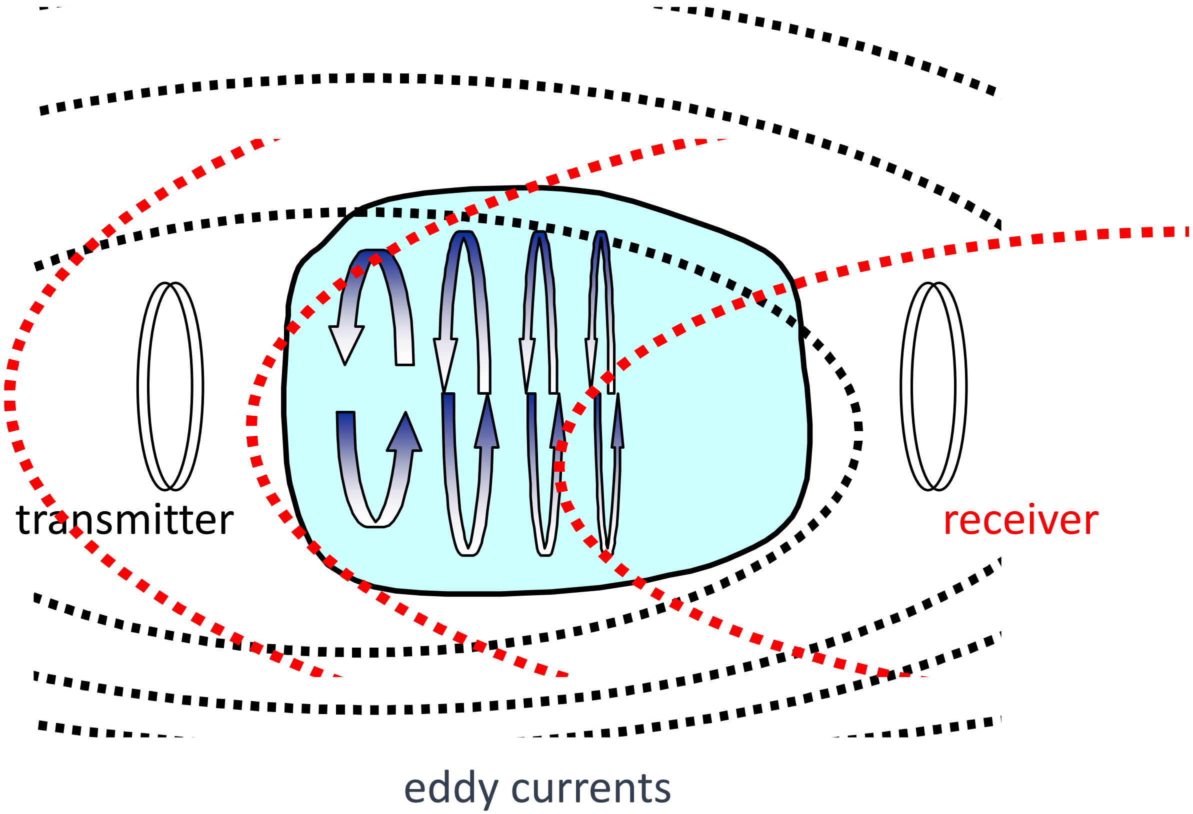
17. International Symposium on Ambient Intelligence and Embedded Systems (AmiES 2018), 12 - 15 September, 2018, Kiel, Germany

Fachhochschule Kiel
University of Applied Sciences

Introduction

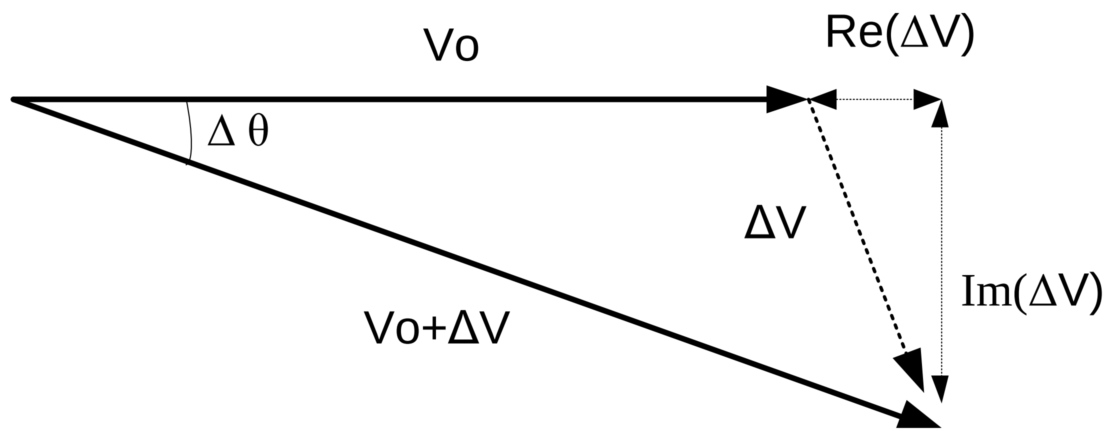
- Magnetic Induction Tomography (MIT)
- Kiel Mk II MIT/MIS System
- Problems
- New RF Power Amplifier
- Performance & Evaluation
- Limitations & Summary

Magnetic Induction Tomography



The MIT Signal

Primary and secondary magnetic fields detected – primary signal Vo, secondary signal ΔV



Phase Δθ → conductivity

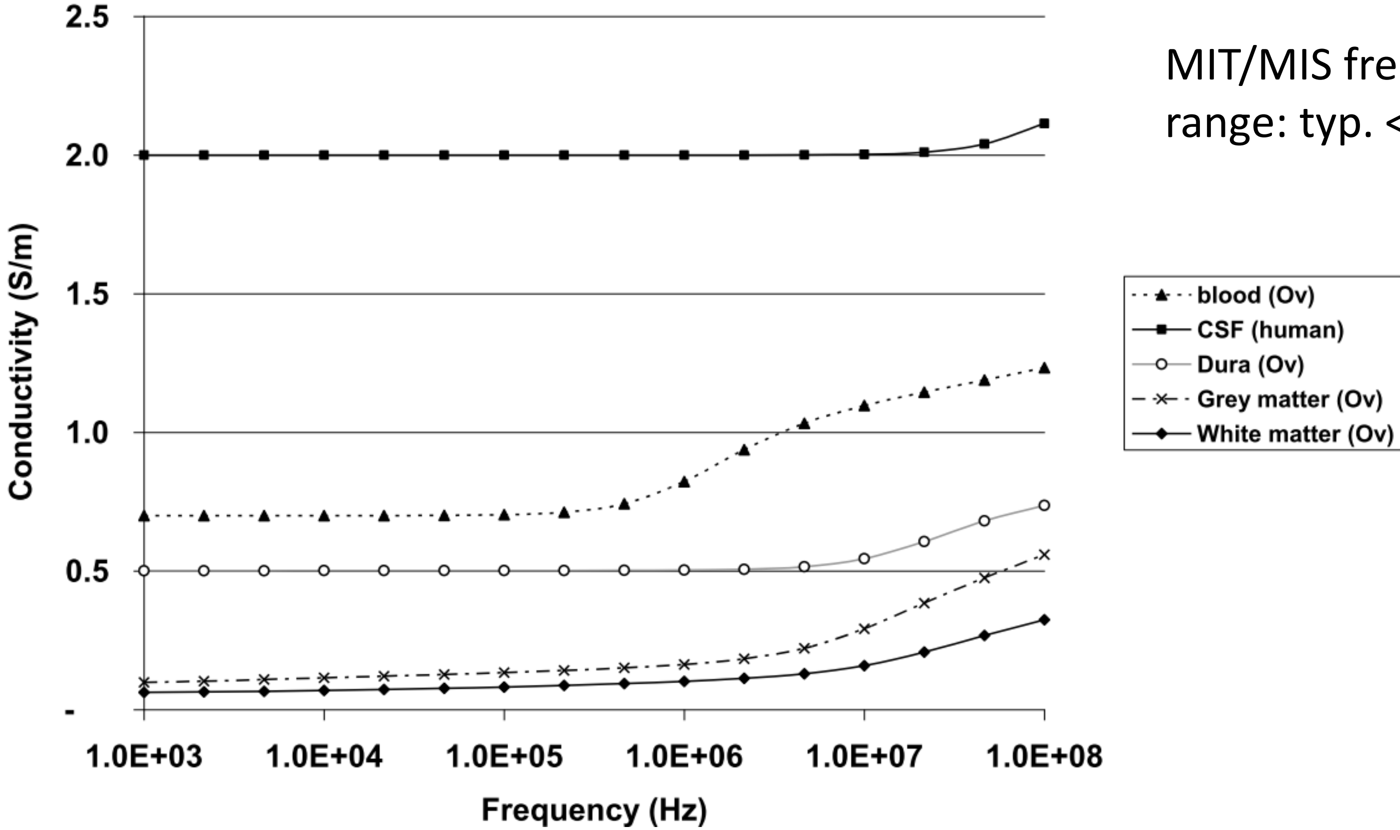
$$Im(\Delta V) \propto \omega\sigma$$

Amplitude → permittivity, permeability

$$Re(\Delta V) \propto \omega^2 \epsilon_r \epsilon_0$$

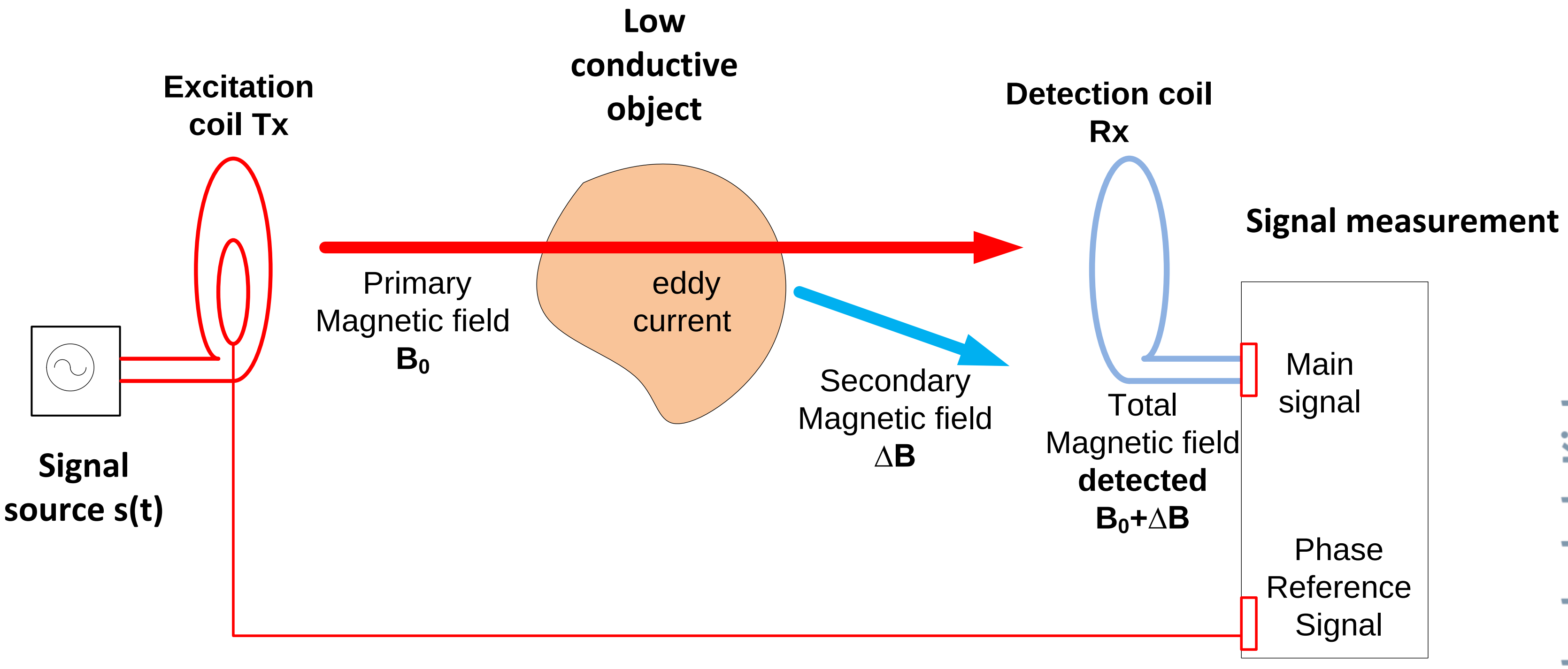
Fachhochschule Kiel
University of Applied Sciences

Conductivity of biological tissue



MIT/MIS frequency range: typ. < 20MHz

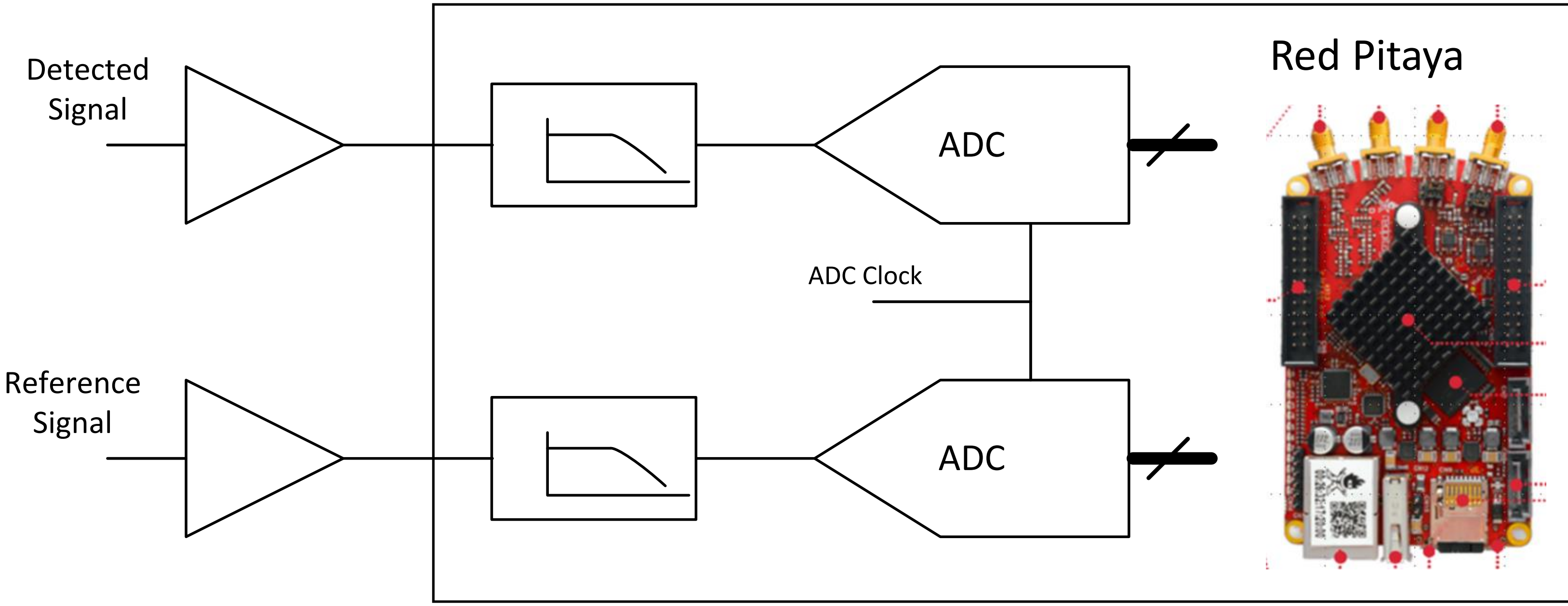
A single channel MIT system



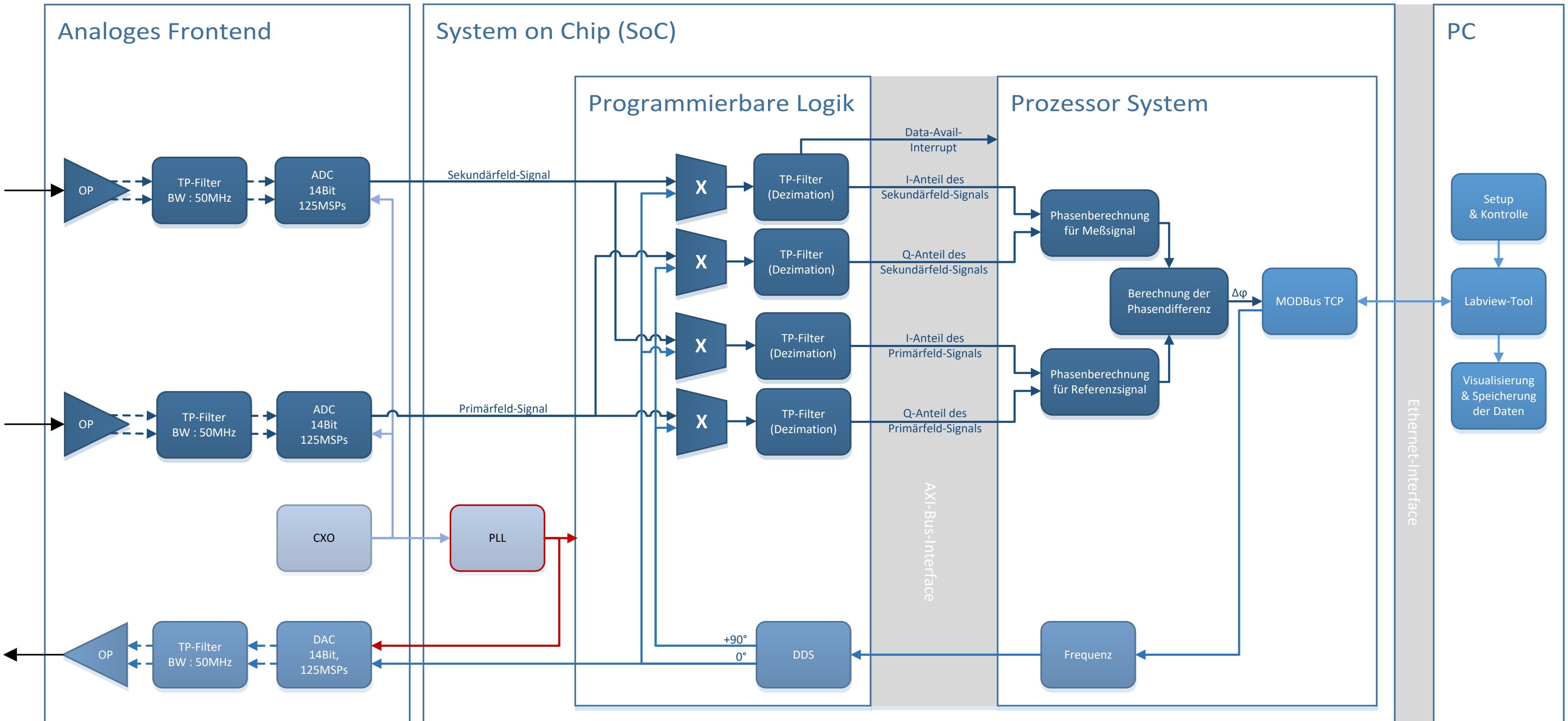
Fachhochschule Kiel
University of Applied Sciences

Phase Measurement

Direct conversion

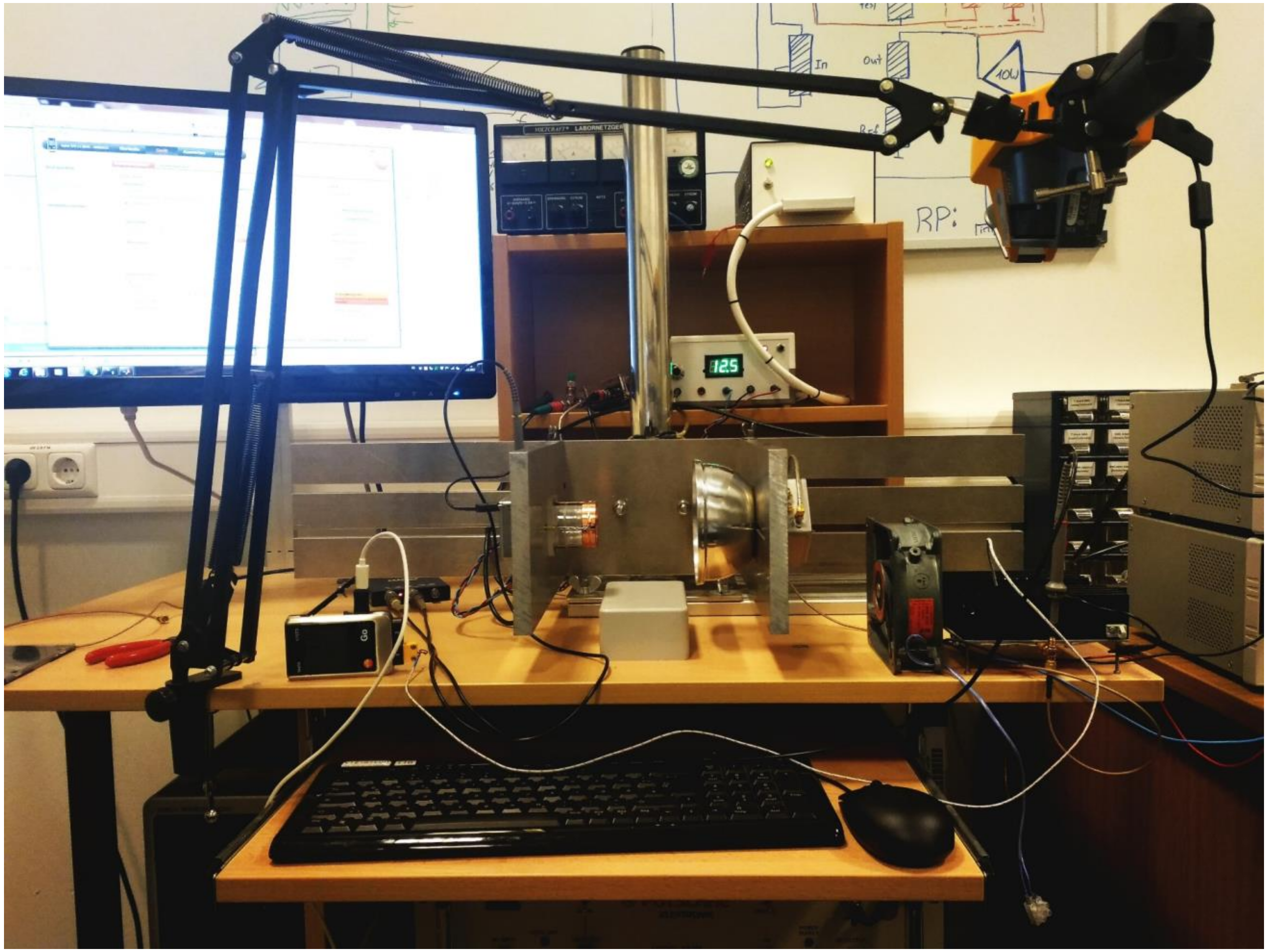


System Overview



Sample rate: 125MS/s; Full-scale input: $2V_{pp}$; Bandwidth = 50MHz

The Kiel Mk II MIT/MIS System



Problems of the Kiel Mk II

- Temperature drift
- Outside electromagnetic influence (EMC)
- Transmission power at low frequencies
  - $B \sim I$ and $B \sim f$
  - Existing RF power amplifier (Pötschke 5600)
    - 10kHz – 500MHz, P_{max}=10W
  - Transmission coil L=1,1µH

Inductance decreases with frequency → difficult to maintain current

Fachhochschule Kiel
University of Applied Sciences

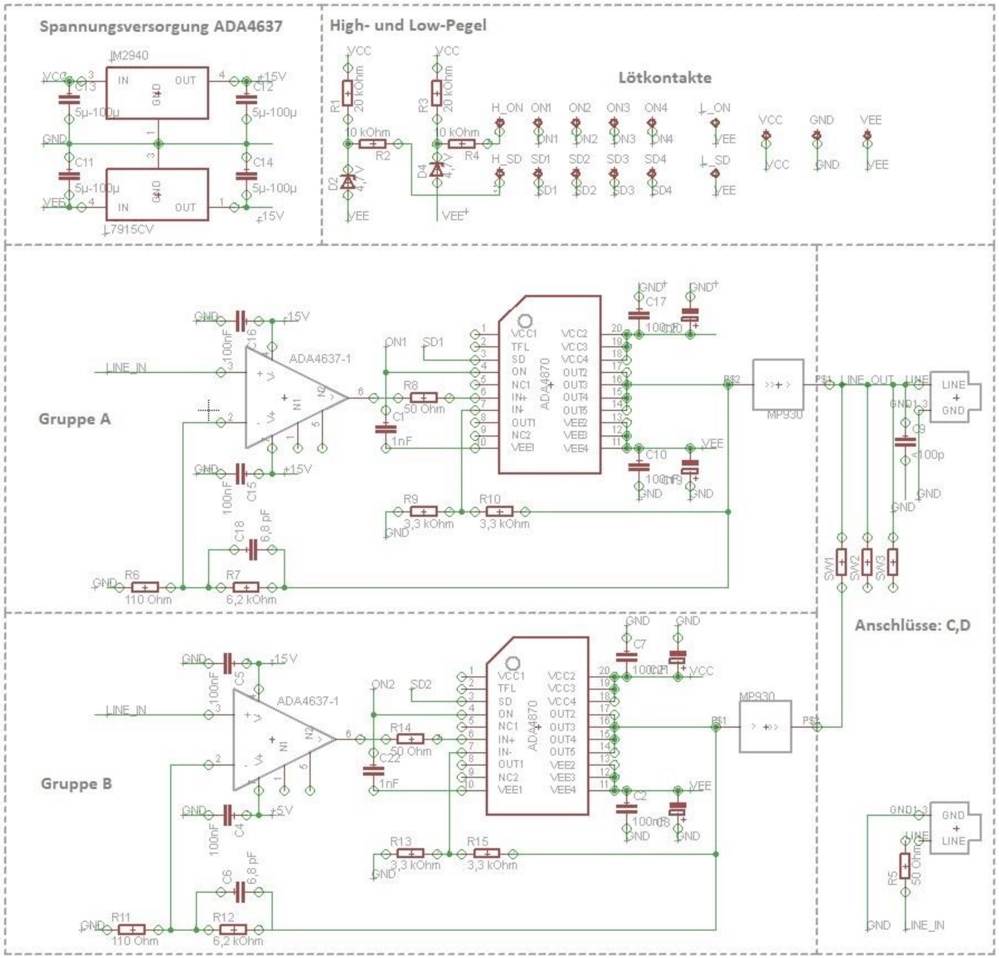
Solution

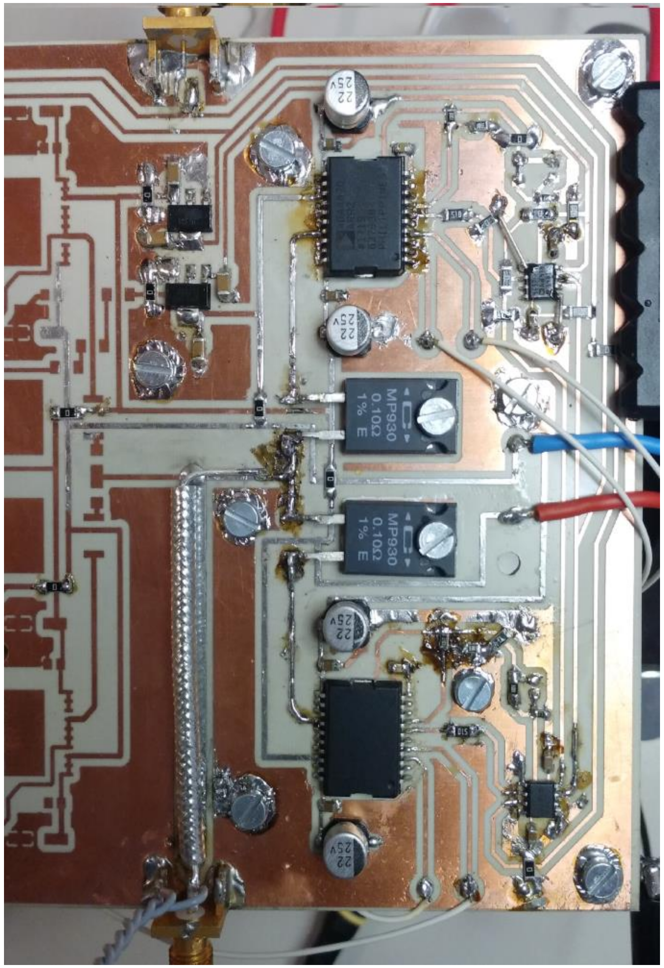
Purpose-build RF amplifier

- Bandwidth: DC – 20MHz
- Output current: 4 A
- Operational amplifier based
  - 4 x ADA4870 (1A output current, 70MHz bandwidth)

Fachhochschule Kiel
University of Applied Sciences

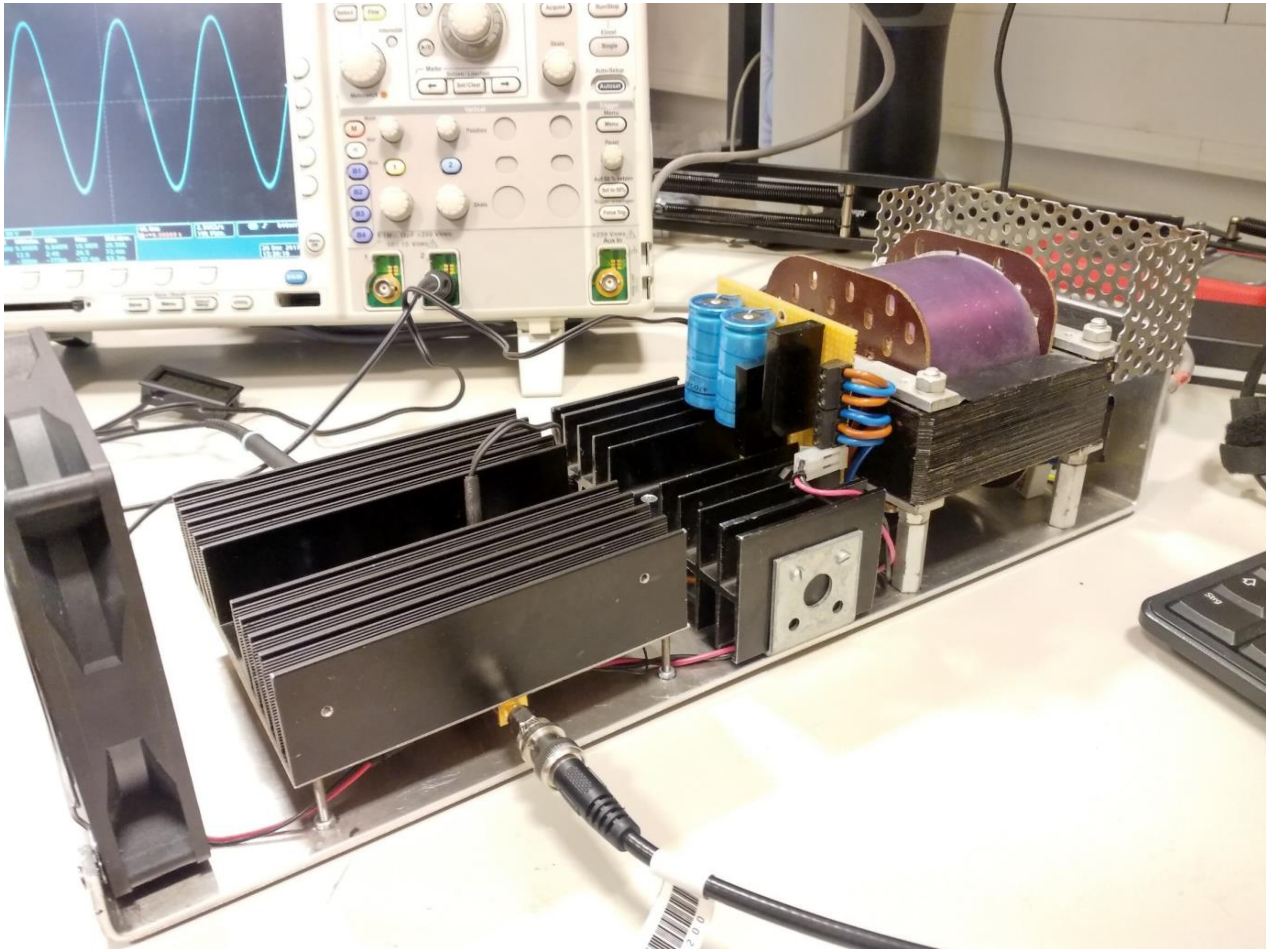
RF power amplifier: Design



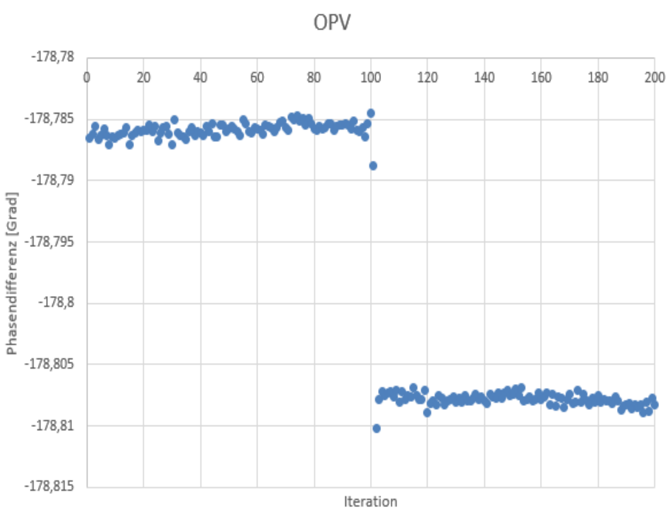


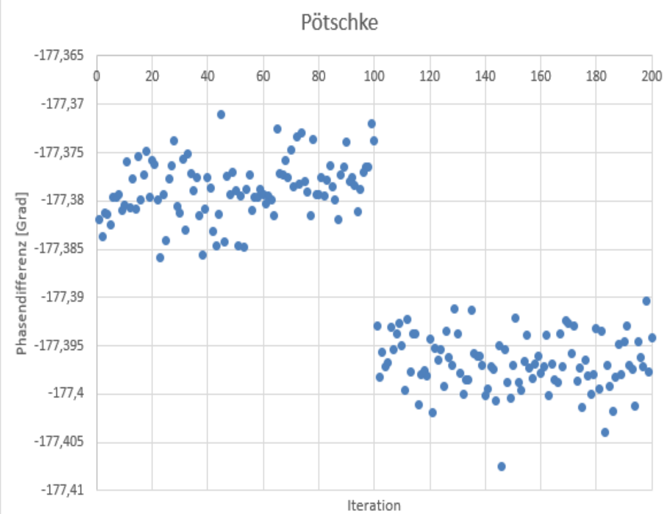
Aluminium PCB

RF power amplifier: Realisation

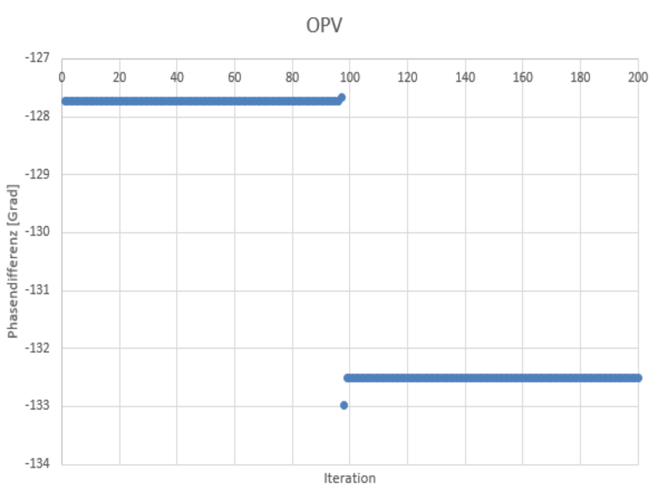


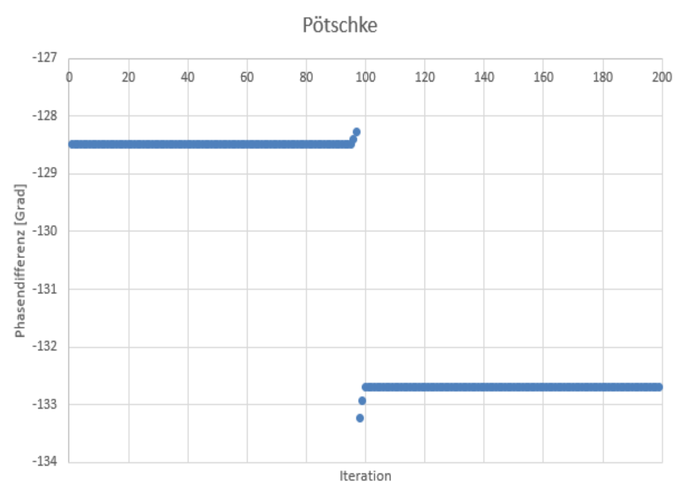
RF power amplifier: Phase Precision





Low frequency





High frequency

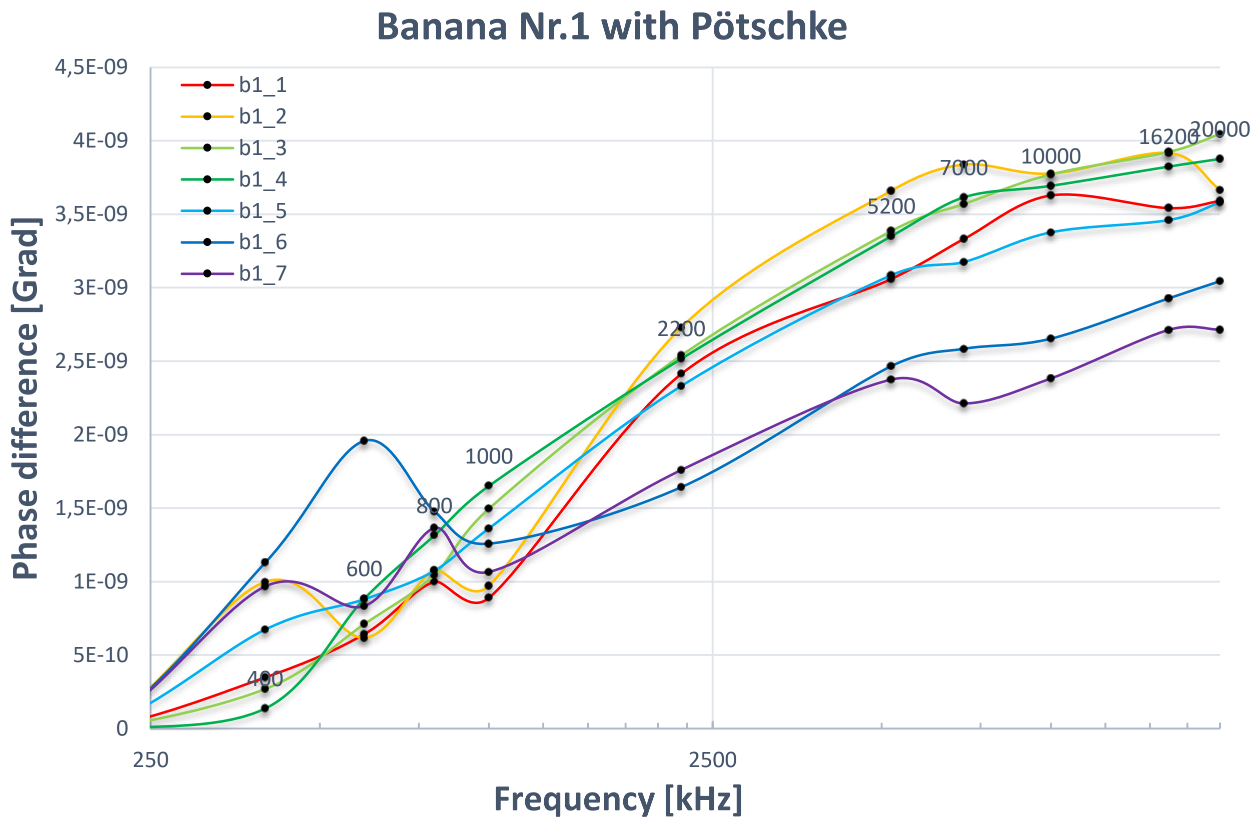
Fachhochschule Kiel
University of Applied Sciences

Evaluation: Ripening of Bananas

- Three bananas
- Seven days
- Measurement of β-dispersion
  - 250kHz – 20MHz

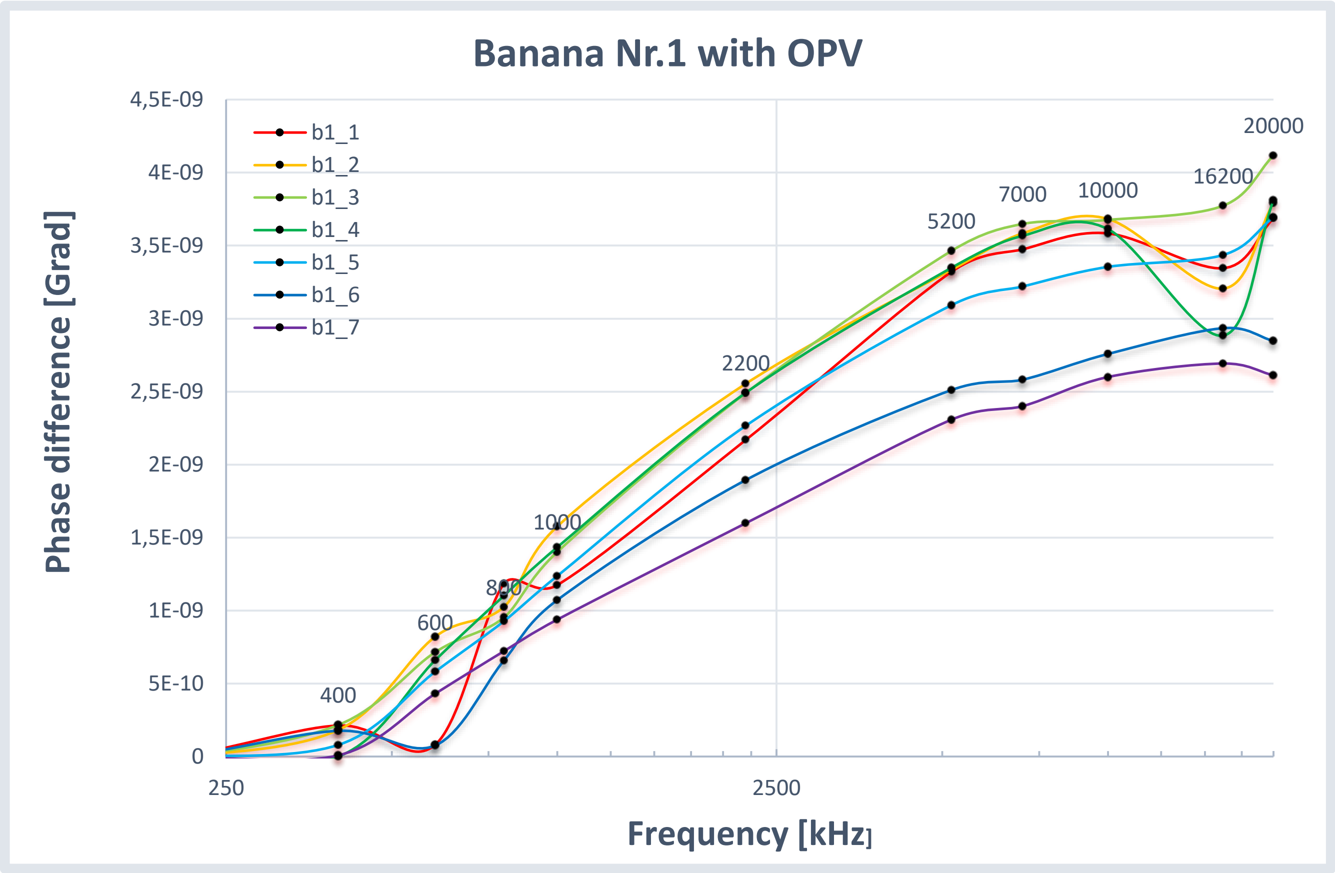
Fachhochschule Kiel
University of Applied Sciences

Ripening of Bananas
Measurement with Pötschke 5600



Fachhochschule Kiel
University of Applied Sciences

Ripening of Bananas
Measurement with new amplifier



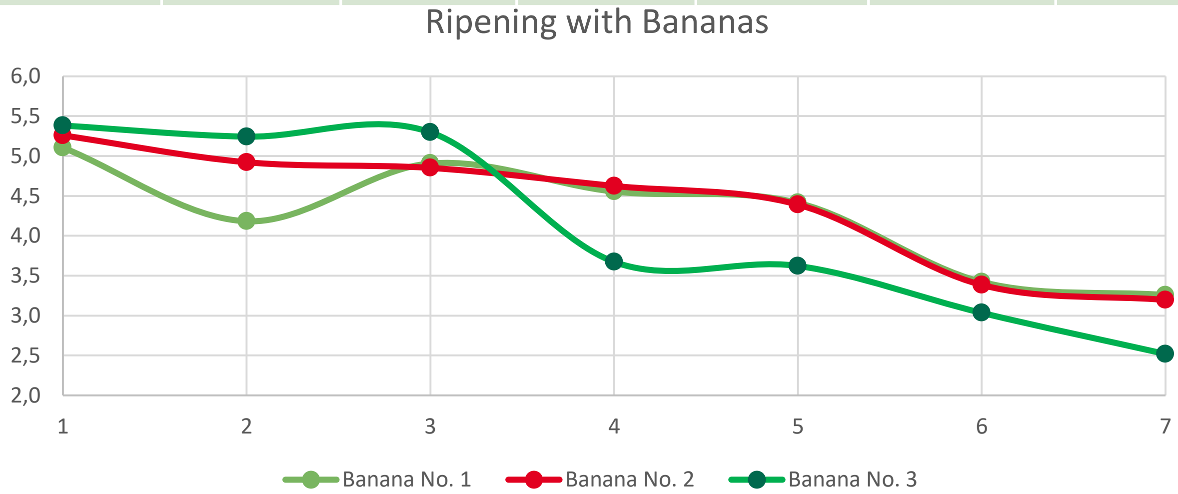
Fachhochschule Kiel
University of Applied Sciences

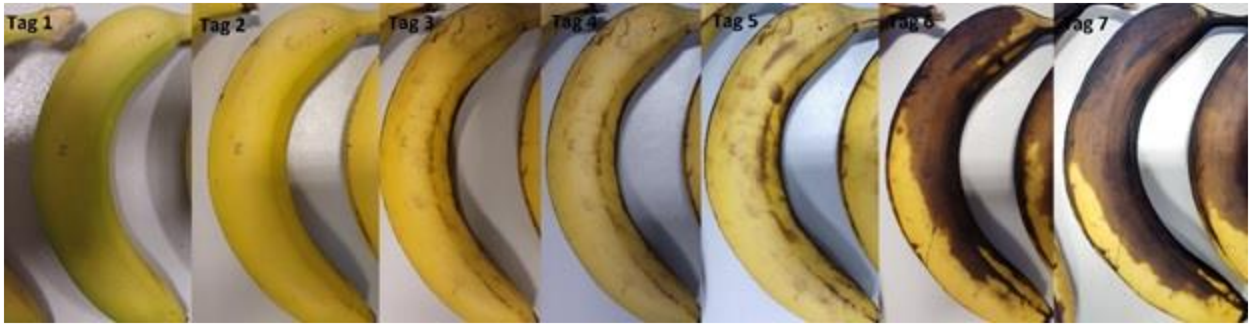
Ripening of Bananas

Gradient between 1MHz and 5,2MHz

Day	1	2	3	4	5	6	7
gradient $[10^{-13} \frac{°}{kHz}]$	5,260	4,923	4,852	4,625	4,392	3,384	3,196

Banana No. 2

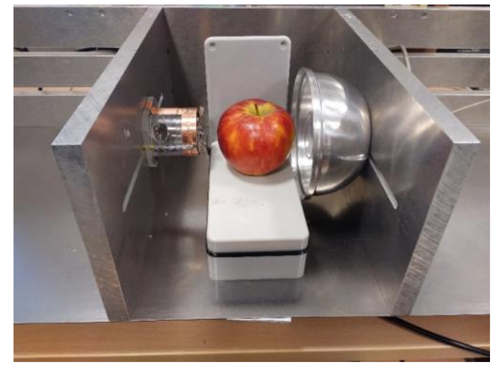




Fachhochschule Kiel
University of Applied Sciences

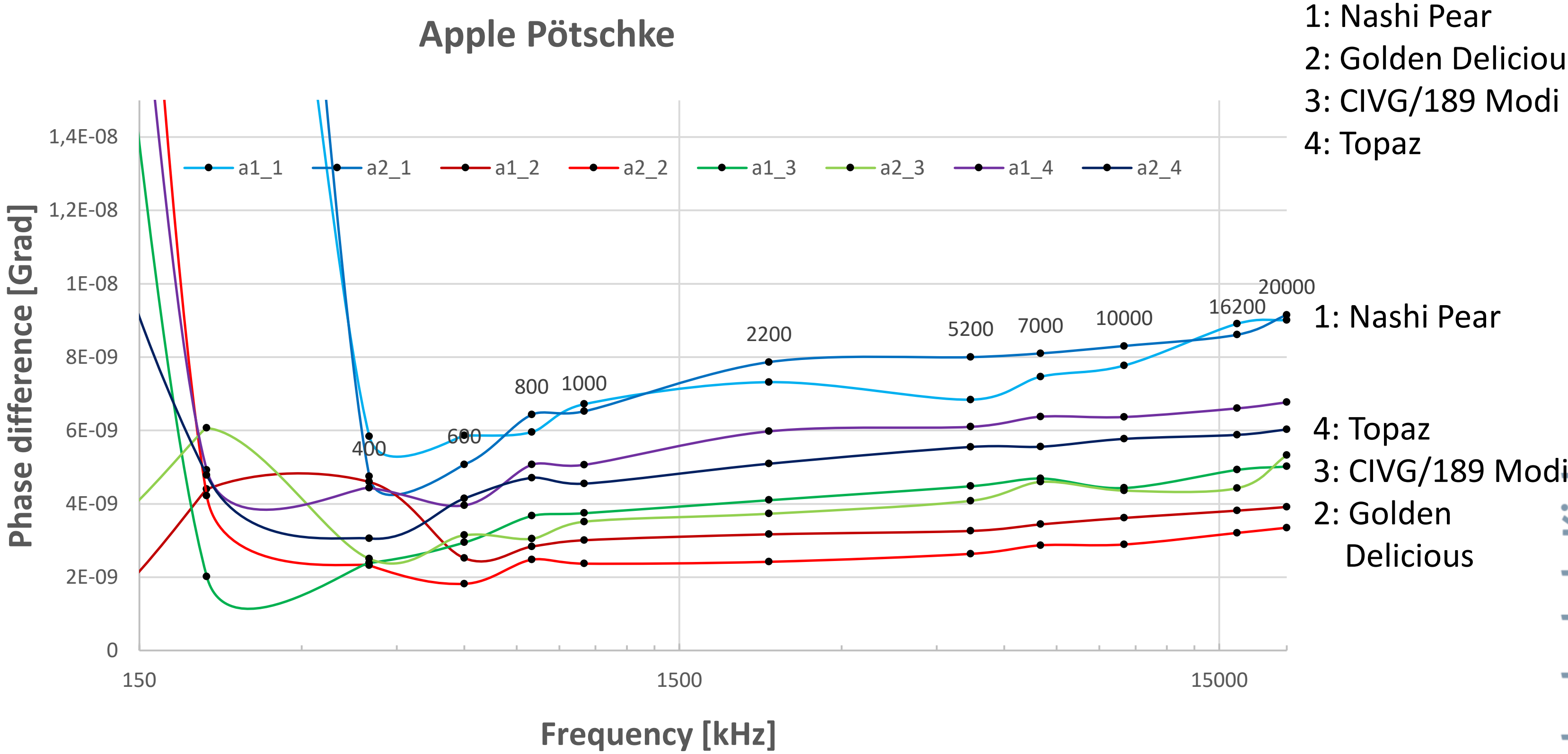
Identification of Apples

- Three types of apple & one pear
- Measurement of β-dispersion
  - 150kHz – 20MHz



Fachhochschule Kiel
University of Applied Sciences

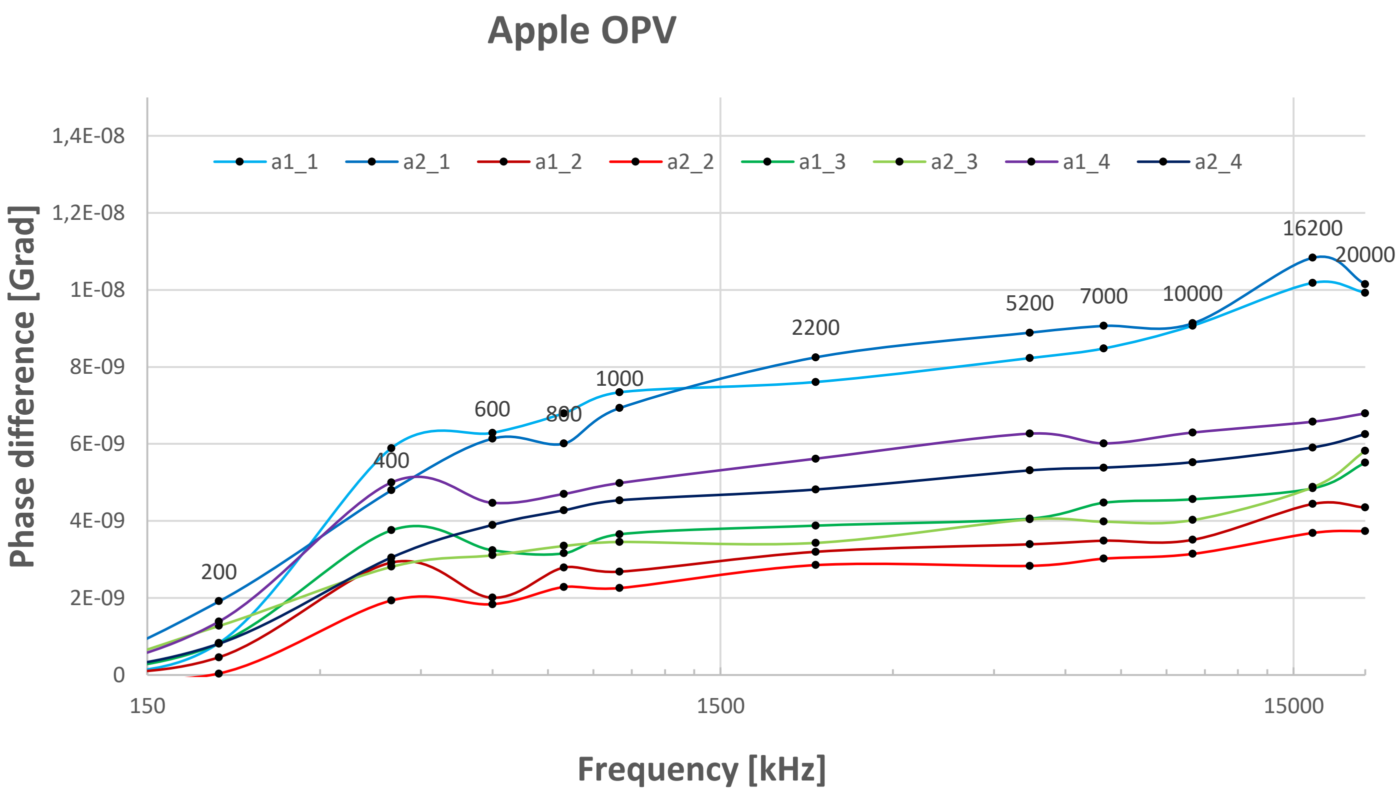
Identification of Apples Measurement with Pötschke 5600



1: Nashi Pear
2: Golden Delicious
3: CIVG/189 Modi
4: Topaz

Fachhochschule Kiel
University of Applied Sciences

Identification of Apples
Measurement with new Amplifier



1: Nashi Pear
2: Golden Delicious
3: CIVG/189 Modi
4: Topaz

1: Nashi Pear

4: Topaz
3: CIVG/189 Modi
2: Golden Delicious

Fachhochschule Kiel
University of Applied Sciences

Summary

- Magnetic Spectroscopy is able to measure the dielectric properties
- "High" currents are required to maintain the B-field
- Newly developed RF power amplifier performs well
  - Bandwith: DC – 22MHz
  - Max. output current @ low freq.: $\sim 4A$
- Detection of the state of ripening for bananas
- Differentiation of different apple types might be possible

Fachhochschule Kiel
University of Applied Sciences

Limitations

- Sized of object
- Precise location of the object
- Temperature drift over long measurement periods