Simulation and Verification of a Capacitive Proximity Sensor

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Motivation

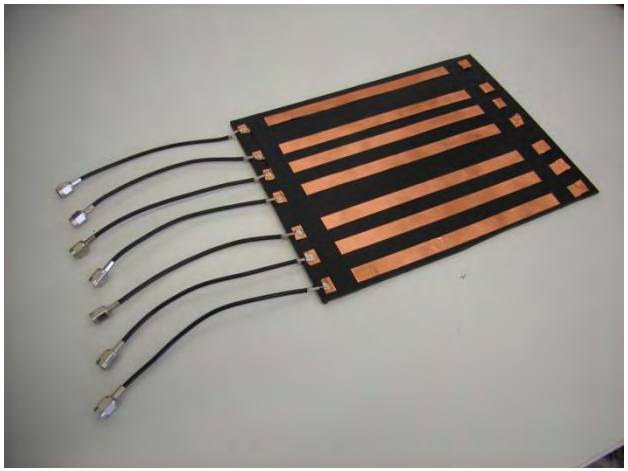
- Proximity sensing of humans in dangerous environments (clamping protection, seat occupancy detection, etc.)
- Monitoring within complex structures (no line of sight)
- Contactless
- Interesting alternative: Capacitive Measurement
- Simulate, build and verify demonstrator

Outline

- Motivation
- Introduction to Capacitive Measurement
- Computational Methods
- Optimization (2D simulation) & Results
- Verification with 3D Simulation
- Experimental Setup
- Results (Simulation & Measurement)
- Conclusion

Introduction

Capacitive Measurement

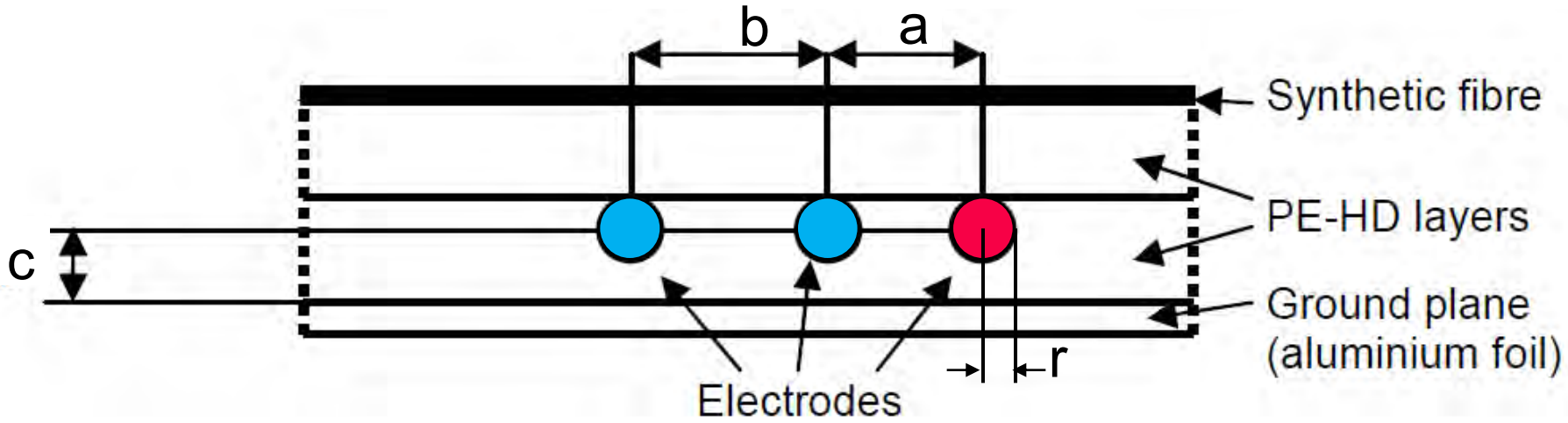


Capacitive sensors:

- Work with variety of materials
- Volumetric measurement
- Unparalleled simple sensor elements
- Well known for planar sensor geometries[1]

[1] M. Neumayer, B. George, T. Bretterklieber, H. Zangl, and G. Brasseur, "*Robust sensing of human proximity for safety applications*", I2MTC, vol. 1. IEEE, 2010

Introduction
Experimental Setup



$$C \cong \frac{\pi \varepsilon_0 \varepsilon_r L \ln(1+\frac{2c}{a})}{(\ln(\frac{2c}{r}))^2}$$

Only valid when straight and parallel!

Computational Methods

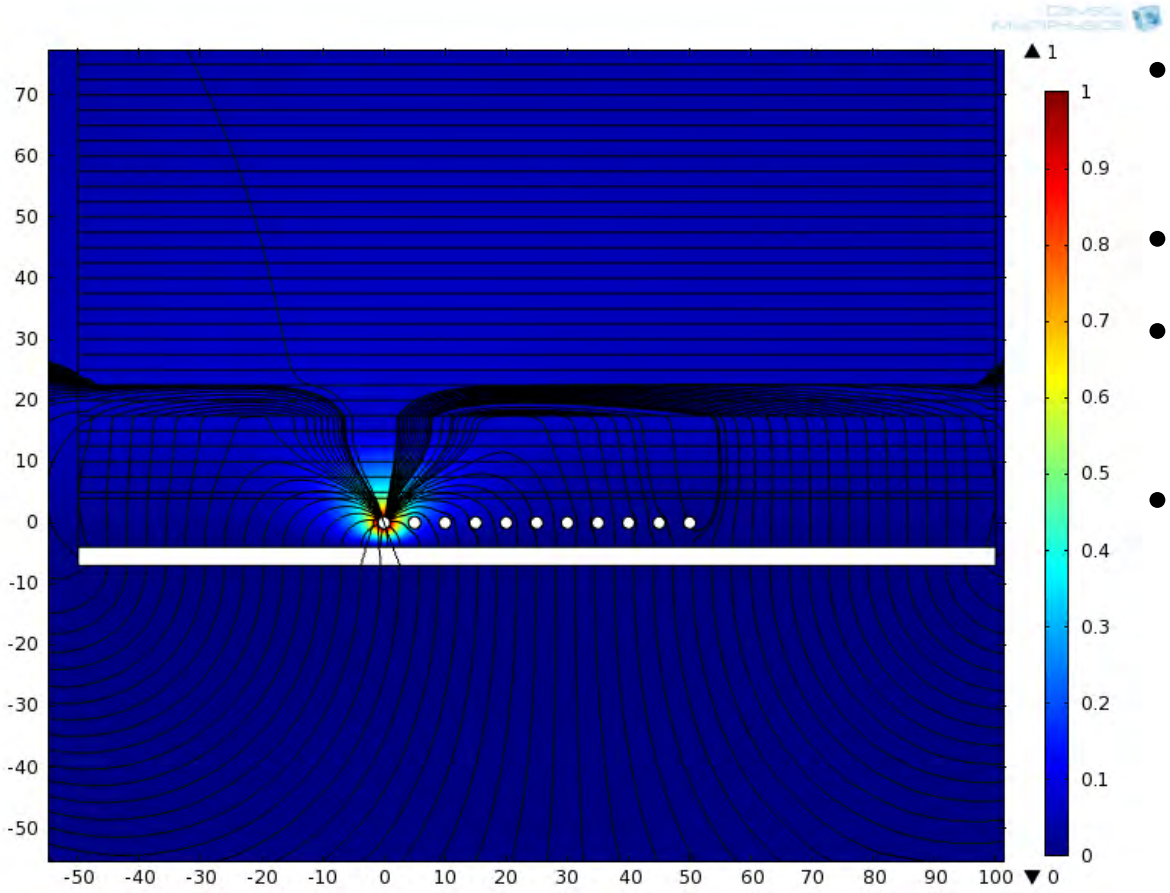
- Solving an electro static problem
- Maxwell equations lead to

$$\nabla(\varepsilon (\nabla V)) = \rho = 0$$

ε … relative permittivity
ρ … charge density
V … electric scalar potential

- Solve forward problem with COMSOL
- Optimization, post processing: LiveLink™ for MATLAB®

Optimization
2D Simulation

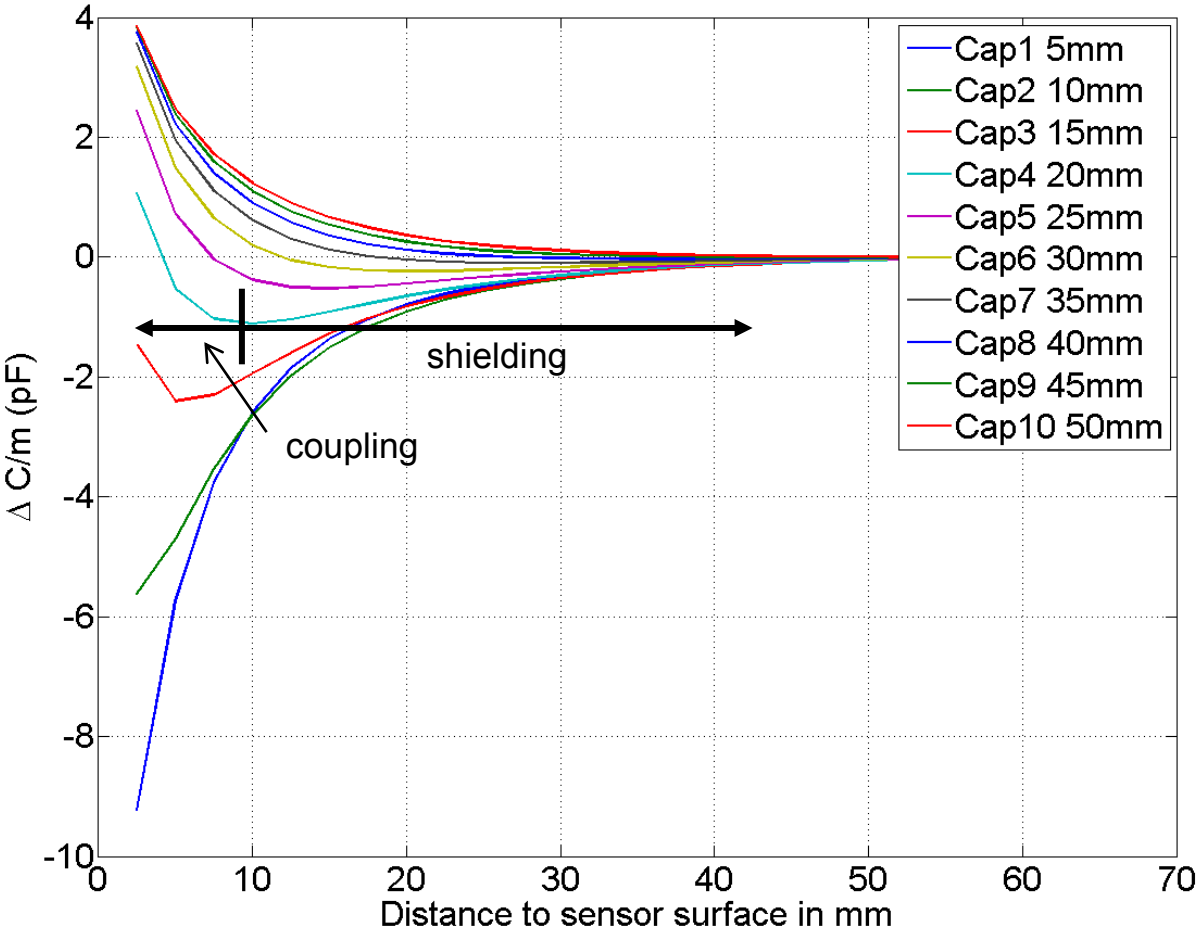


- Different pairs of electrodes
- Avoid remeshing
- Slices with different relative permittivity ε_r
- Measurement constraints:

constraint	value
capacitive range	< 4 pF
capacitance offset	< 128 pF
distance to measure	1 - 50 mm
size of approaching object	150 x 100 x 10 mm

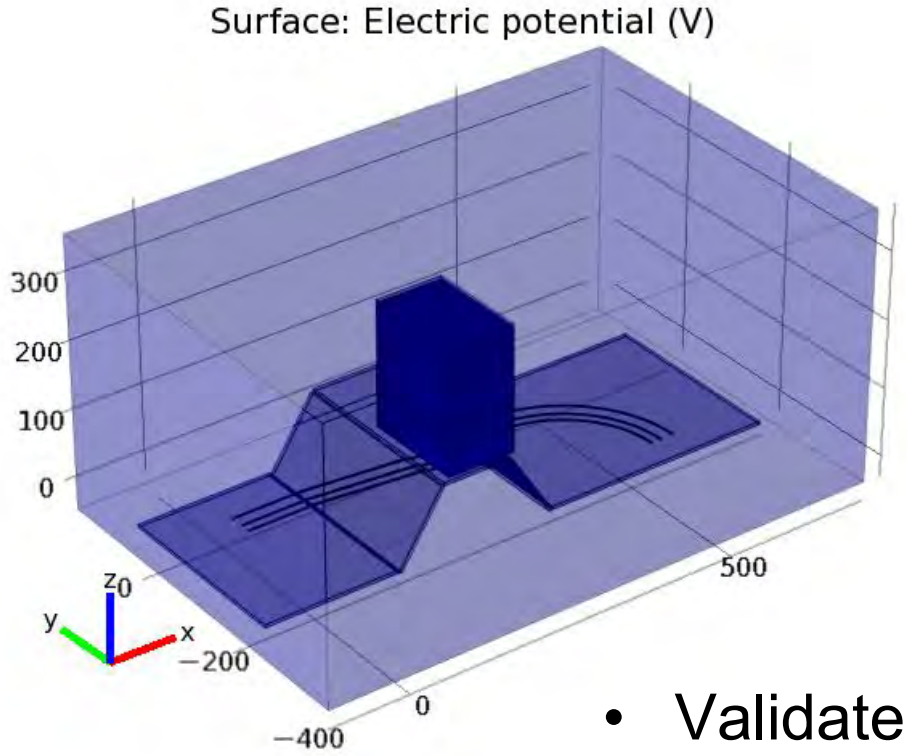
Optimization

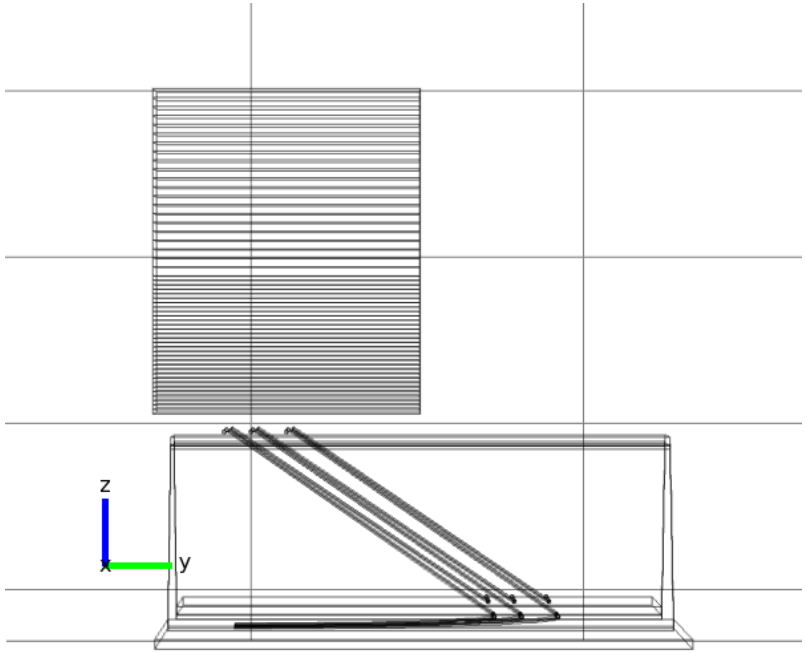
2D Results



- Effect of coupling and shielding
- Ambiguity for one pair of electrodes

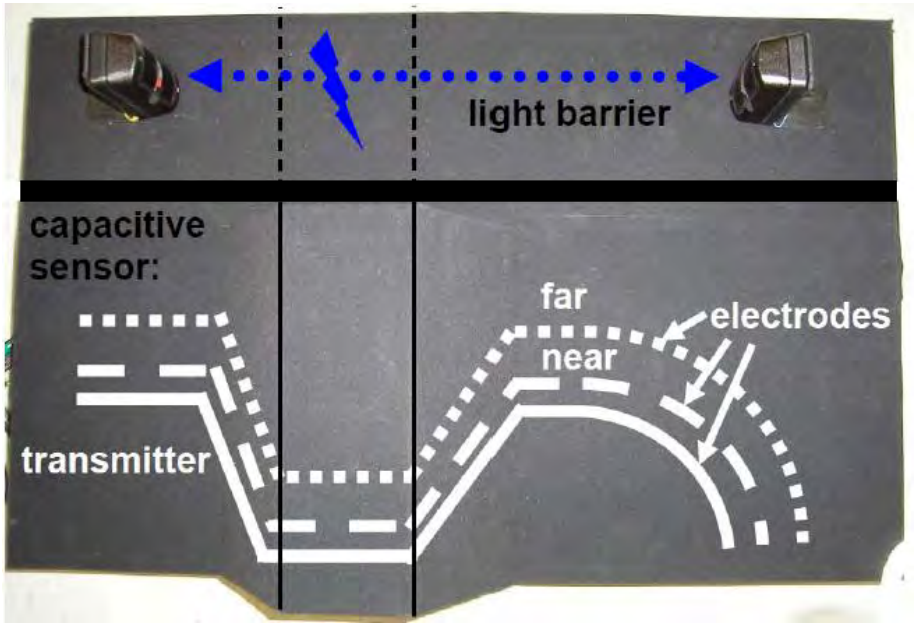
Simulation 3D





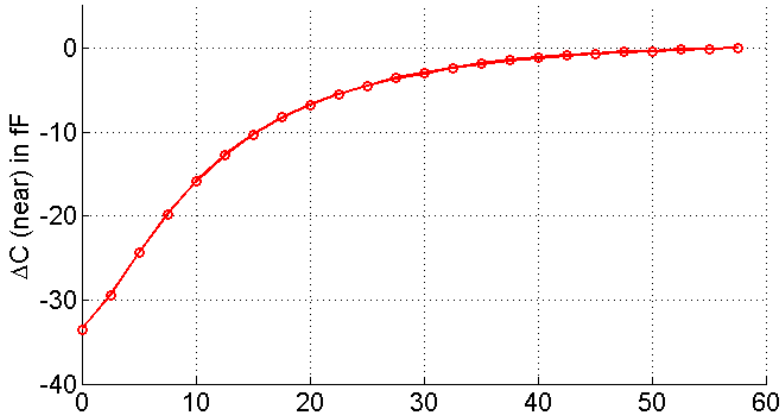
- Validate measurement results
- Slices to avoid remeshing
- 2 pairs of electrodes (15 and 30 mm)

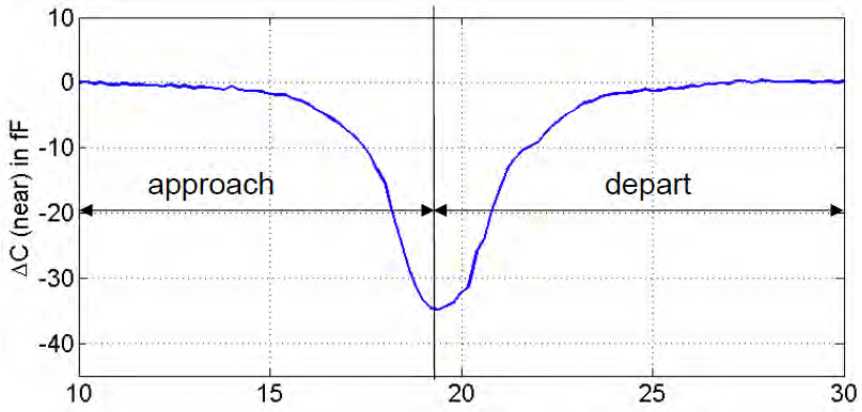
Experimental Setup

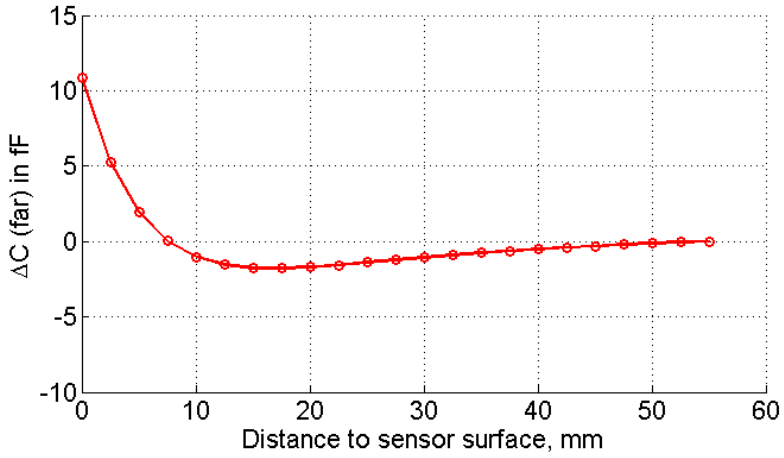


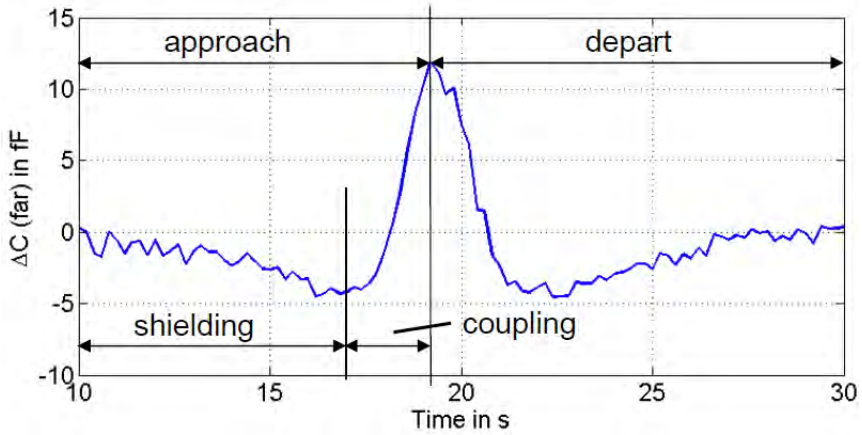
Results

Simulation and Measurement









- Introduction
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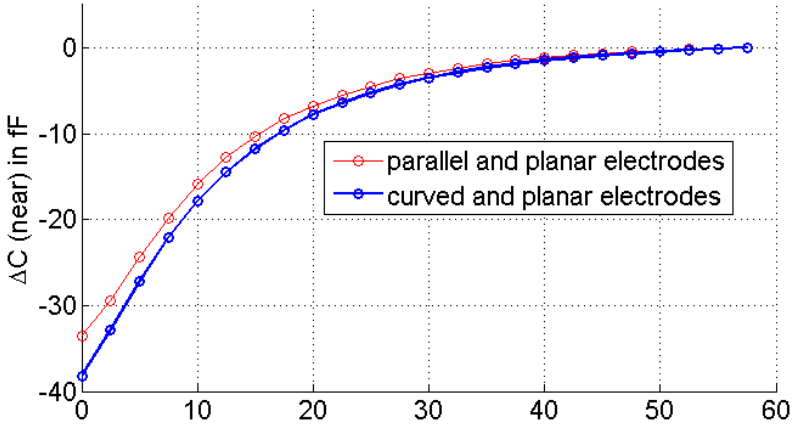
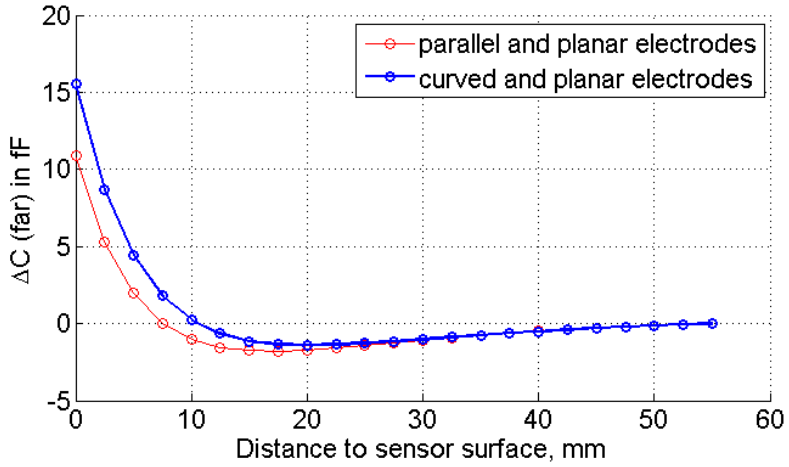
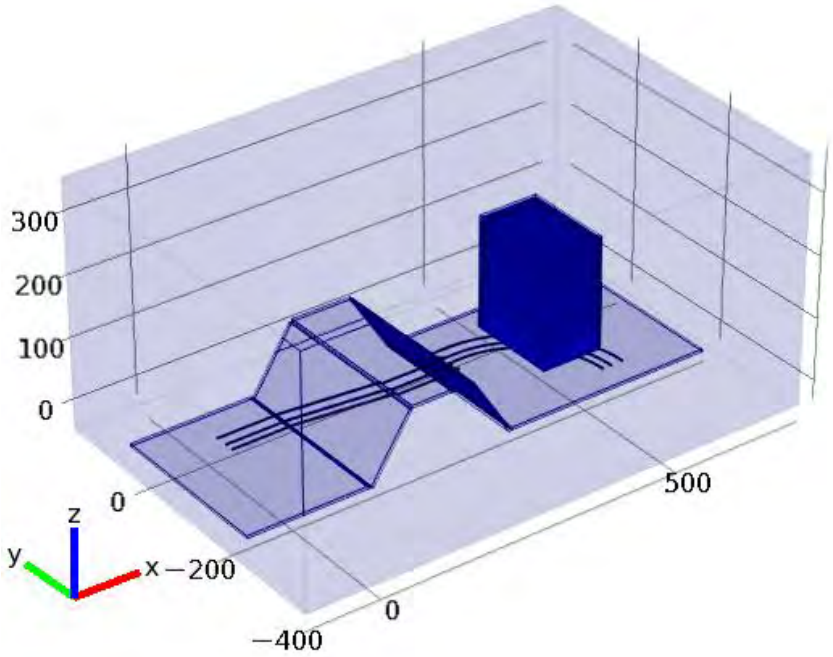
- Optimization 2D
- Verification 3D
- Experimental Setup
- **Results**
- Conclusion

Results

Simulation on different position







Conclusion

- Capacitive Measurement is feasible for proximity sensing on elongated structures
- No line of sight is necessary
- Works contactless
- Easy and very flexible to mount
- Useable on nearly every structure
- Distance measurement: > 2 sensing elements
- Simulation used for capacitive sensor design

Thank you for your attention!