J.A.M.E.S

AME

Bandpass-Filter

Design and Realization

J.A.M.E.S engineering

Motivation and UseCase

- Lumped Element filters are existing in different styles over wide frequency range to fulfill customer requirements

- Standardized Filters are available as COTs parts

- More complex system designs expect special filter behaviour → no standard requiremen
  - Individual filter designs
  - No COTs part
  - Increase of cost cause of design-, tuning- and optimization effords (sometimes in iterations for system requirement fit)
  - Filter tuning often has to be done manually by tunable capacitors or coil trimming which can be complex and time intensive
  - Negative performance effects cause of component assembly have to be optimized by verification (difficult to simulate)

Lumped Element filter as example

GOAL: To realize optimized full 3D-printed AME-Filters by simulation without additional manual tuning effords can ease engineers life significant

AME-Filter Workflow with optimization

- from Simulation to full optimized & functional electronics
  - Without tuning manually

Design,
Simulation,
Optimization

Process
Knowhow

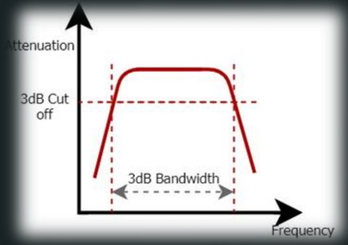
Material
Parameters

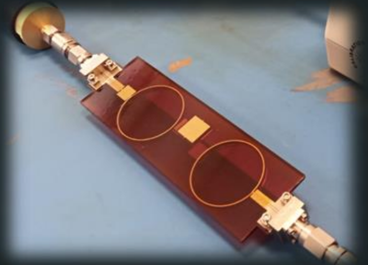
→ Slicing → PrintJob preperation, optimization → AME-Realisation →

Verification
&
Test

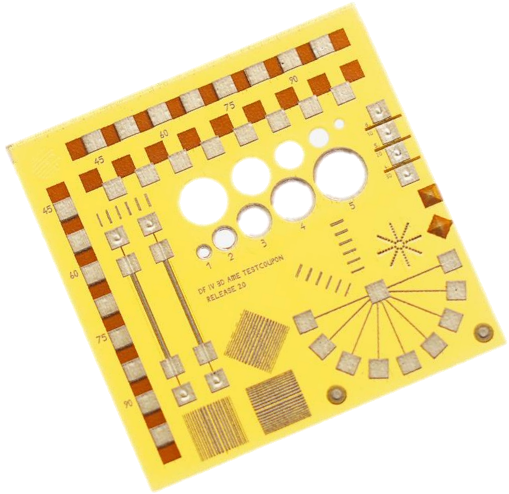
Tolerances

Electronic
performance
(RF)





Starting the Filter-Design



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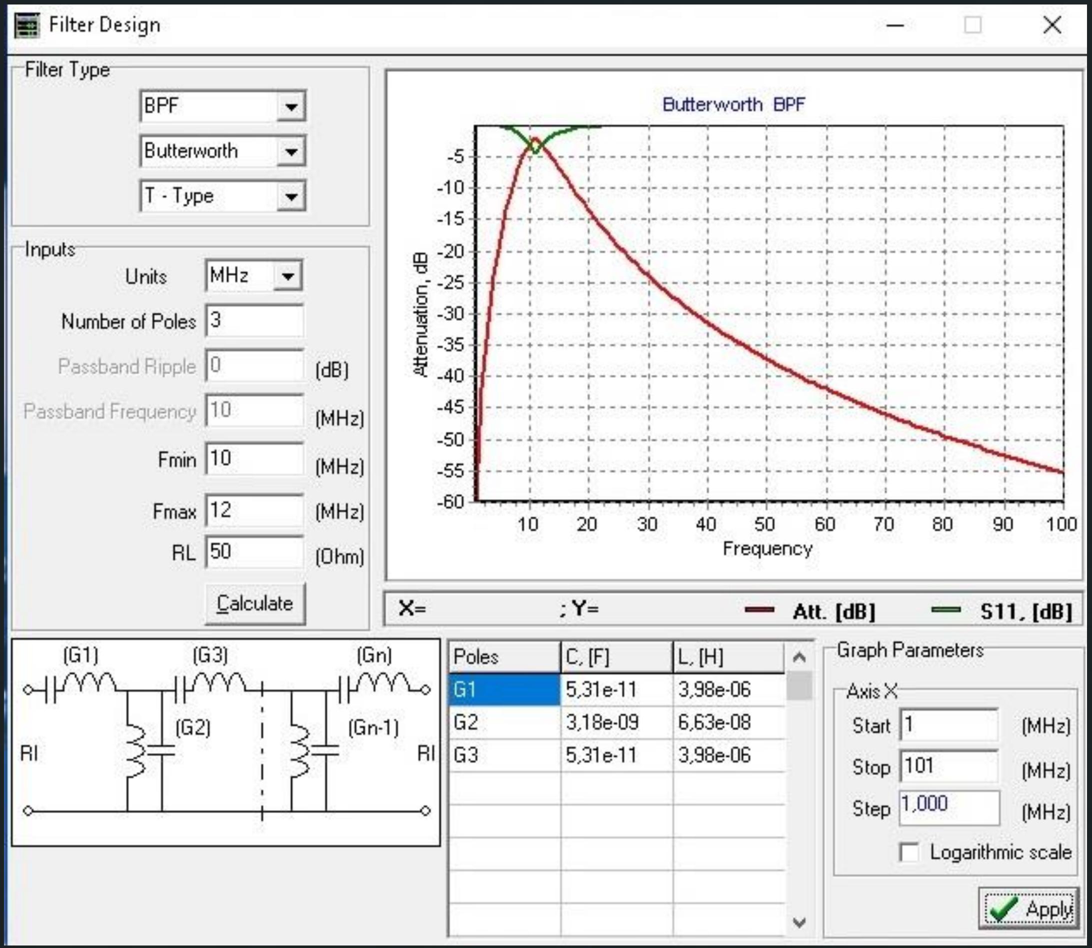
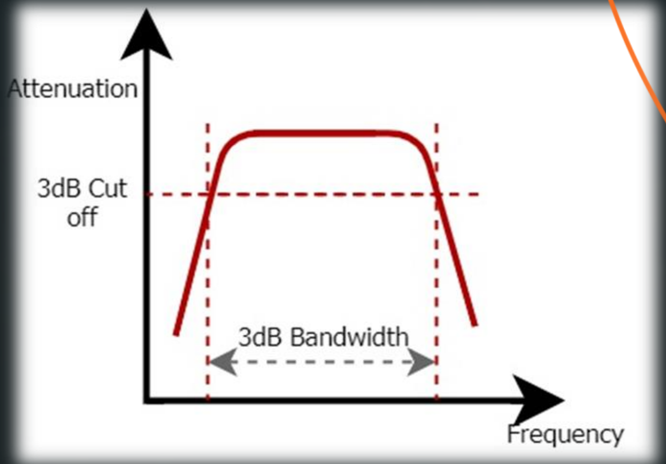
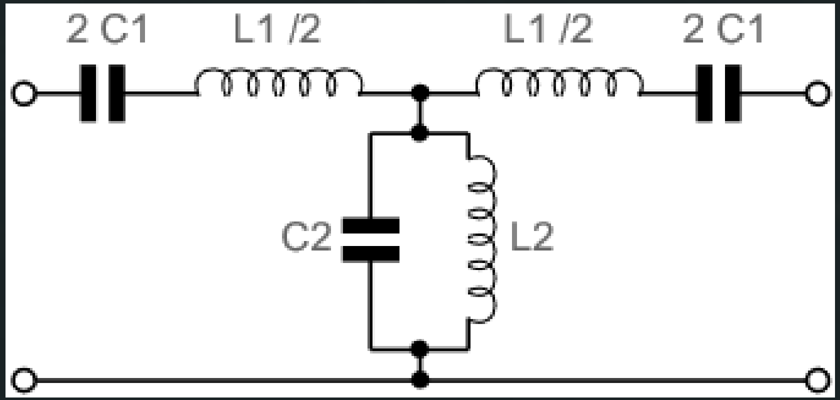
AME-Bandpass-Filter - calculator

- (3dB bandwidth cut off frequency 10 MHz and 12 MHz)
- Starting with a BPF-Butterworth Filter-Design Tool for Lumped Elements





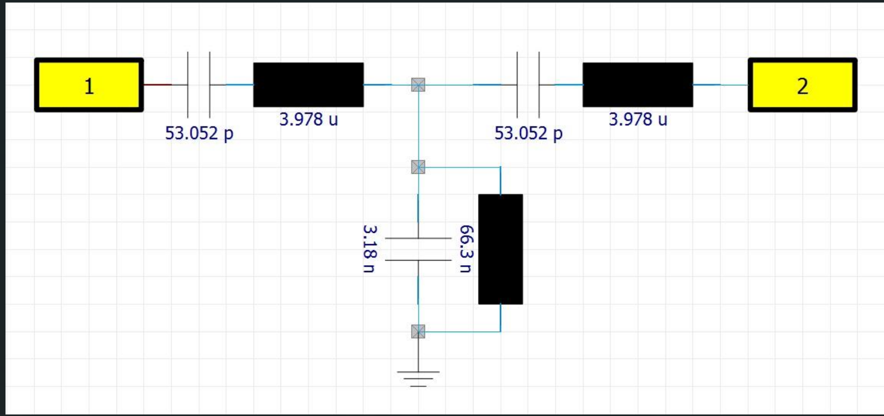


AME-Bandpass Filter – Simulation

- CST Studio Suite 2022

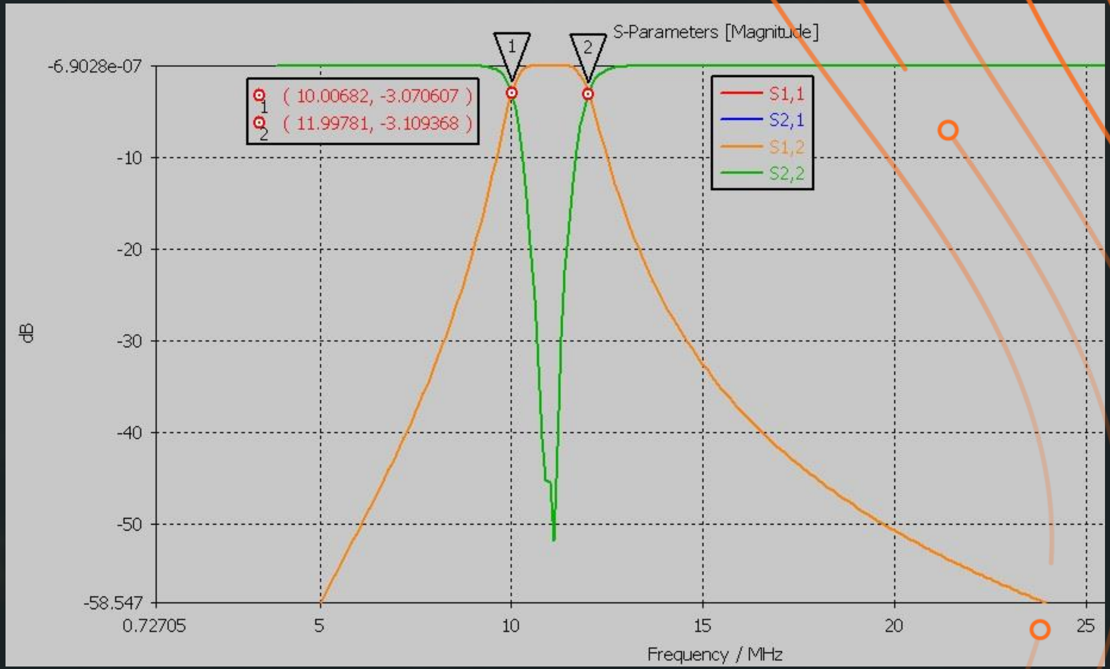
1. Simulation with discrete filter elements (Reference Simulation)

CST schematic of bandpass filter design

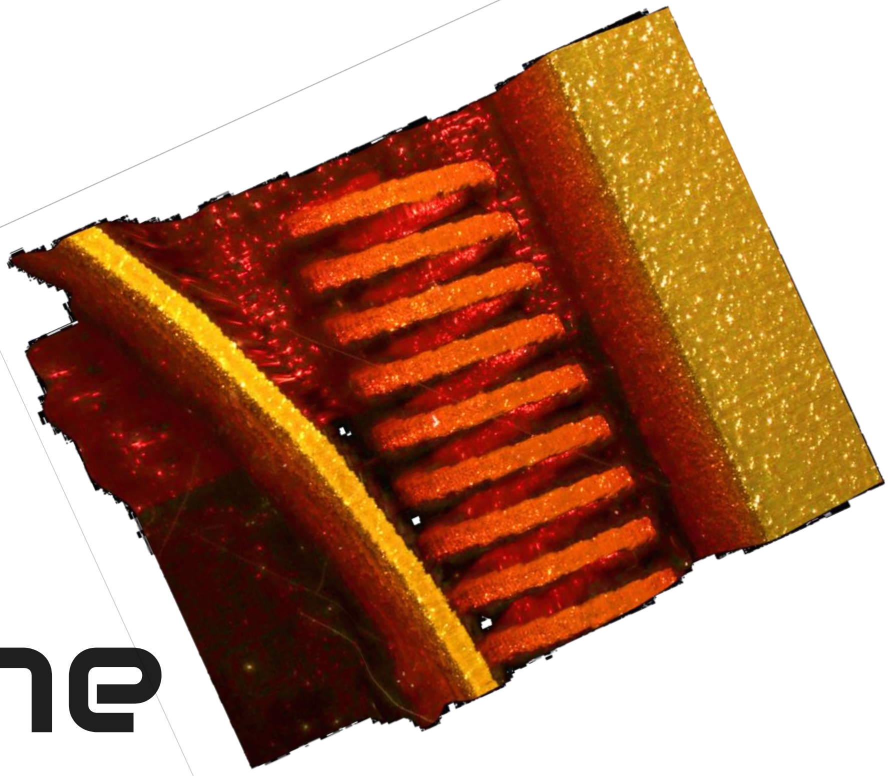


Capacity	Inductivity
C1 = 53,1 pF	L1 = 3,98 µH
C2 = 3,2 nF	L2 = 66,3 nH

Resulting bandpass filter parameters



Realization of 3D-printed elements for the Bandpass-Filter



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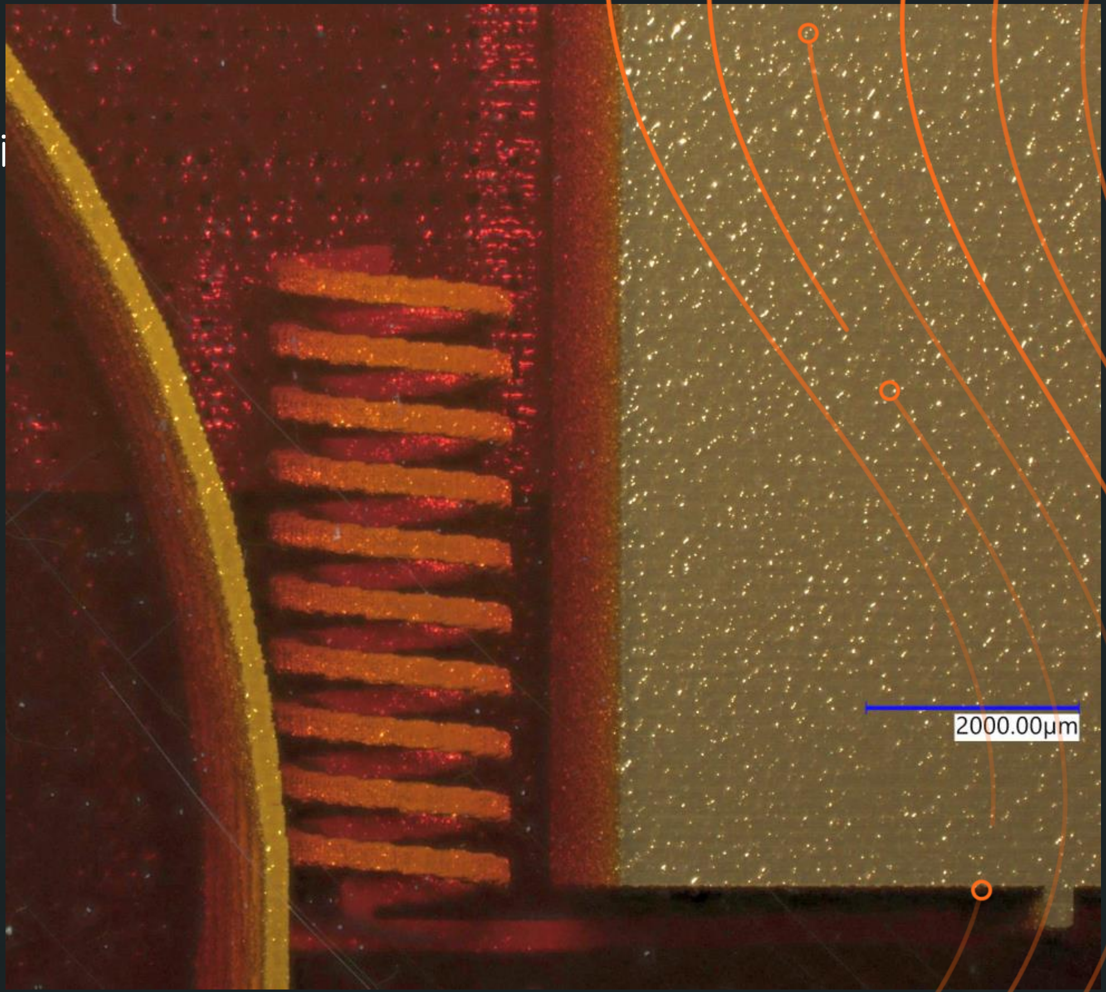
AME-Bandpass Filter – Simulation

- CST Studio Suite 2022

2. Design of 3D-printed AME filter elements
   - With needed RF-parameters of dielectric materi
     - Dielectric constant ε_r
     - loss tangens
   - Design parameters AME-filter elements

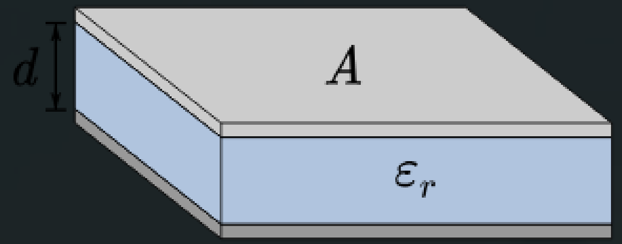
   here:
     - AME-capacitor
     - AME-coil



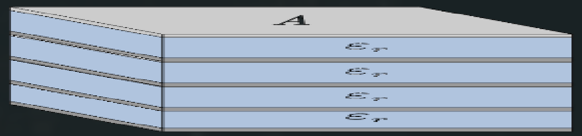
AME-Filter Elements

- AME-capacitor Design (plate capacitor)

$$C = \varepsilon_0 \, \varepsilon_r \, \frac{A}{d}$$



$$C = \varepsilon_0 \, \varepsilon_r (N-1) \frac{A}{d}$$

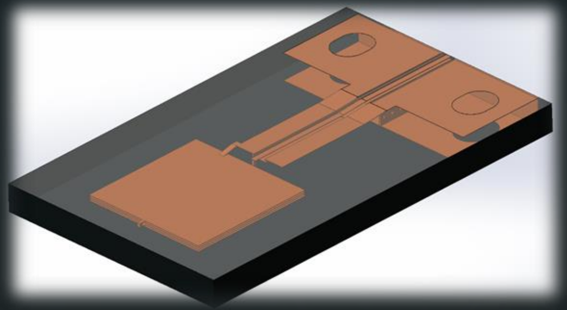


N

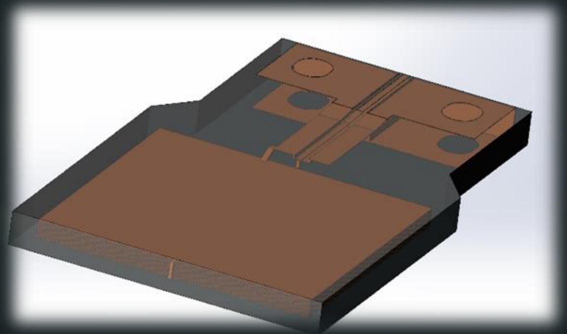
With Adaptation for VNA measurement

Design

Realization



N= 4; d= 0,1 mm

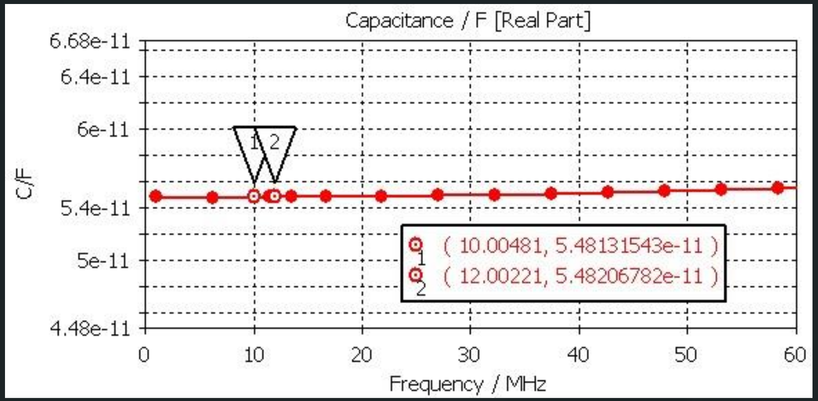


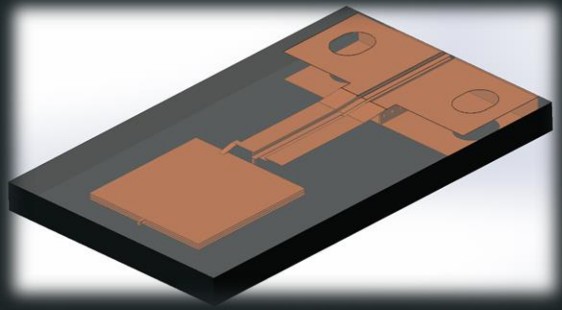
N= 16; d= 0,035 mm

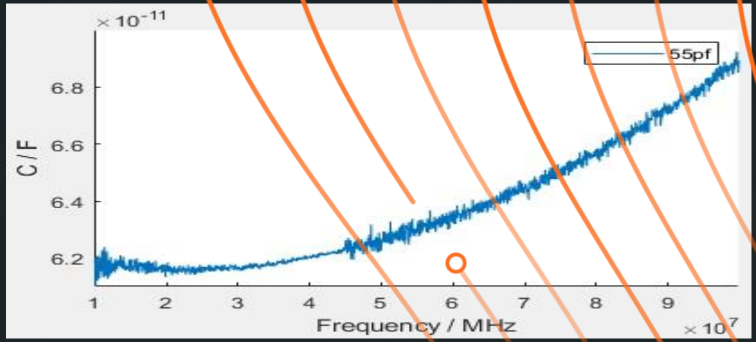
AME-Filter Elements

- AME-capacitor Design

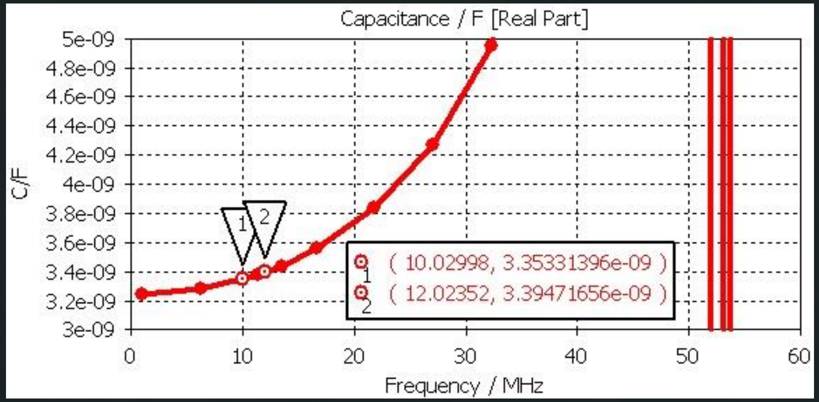
Simulation | Design | Measurement

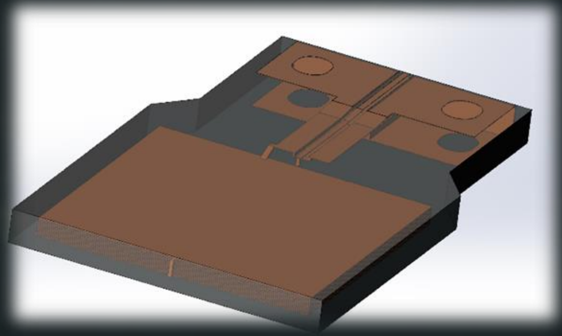


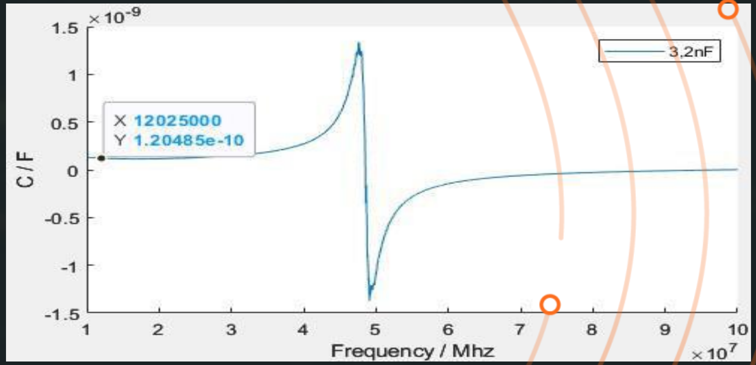




C1 = 62 pF







C2 =12 nF

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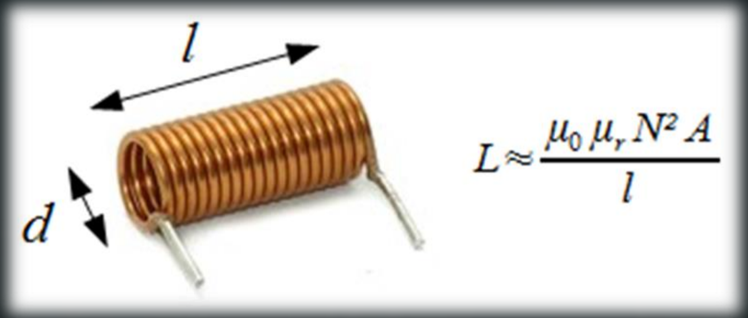
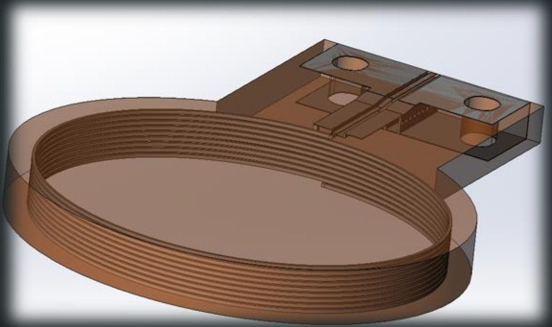
AME-Filter Elements

- AME-coil Design
(air coil)

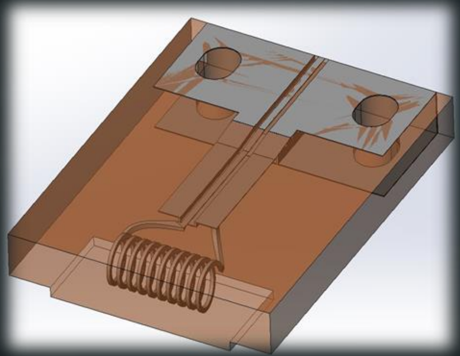


Adaptation for VNA

Design

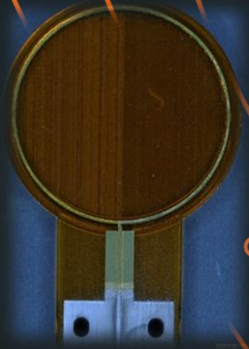


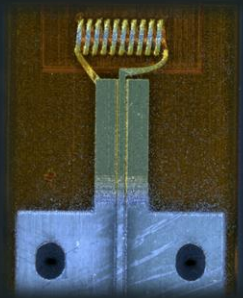
N= 9; d= 27,4 mm



N= 10; d= 2,17 mm

Realization





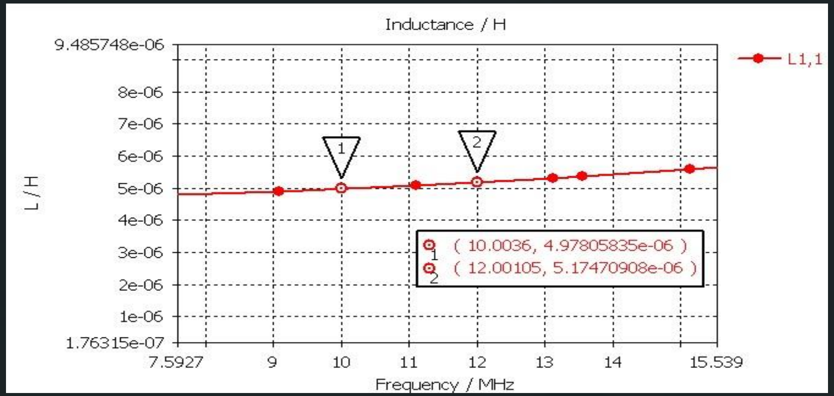
AME-Filter Elements

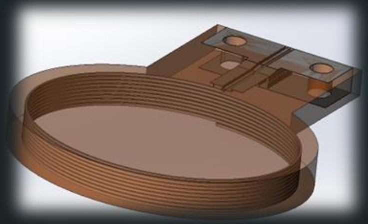
- AME-coil Design

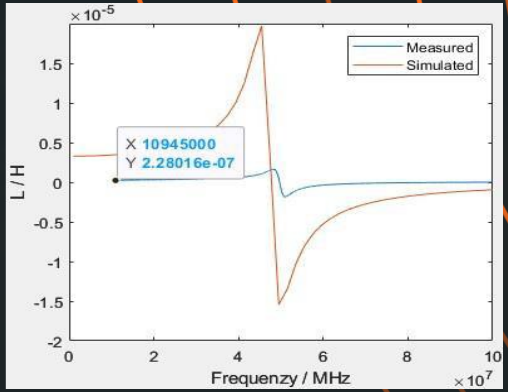
Simulation

Design

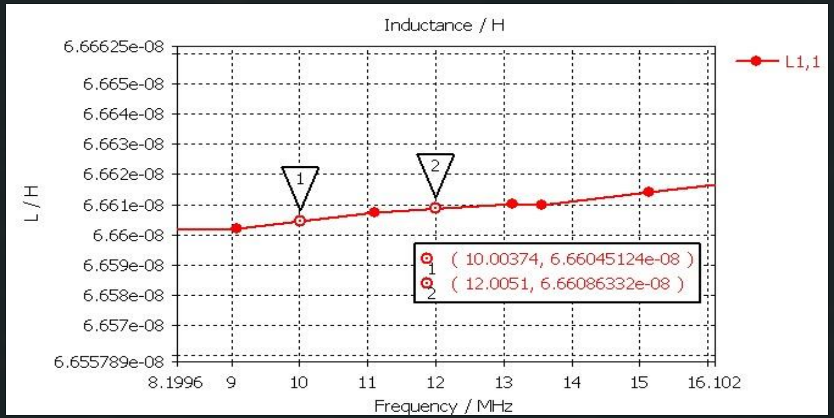
Measurement

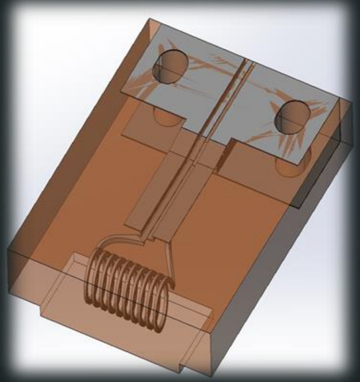


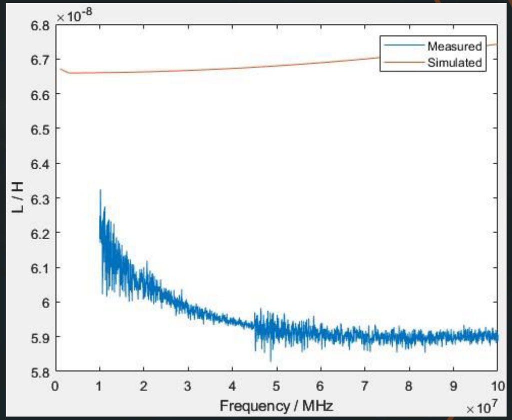




L1 = 22,8 µH



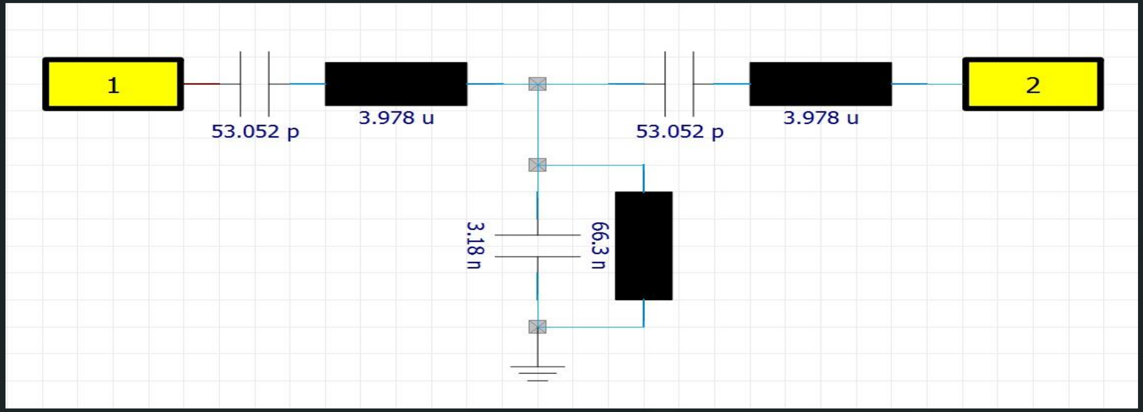




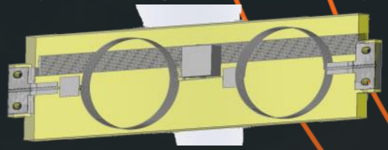
L2 = 61,5 nH

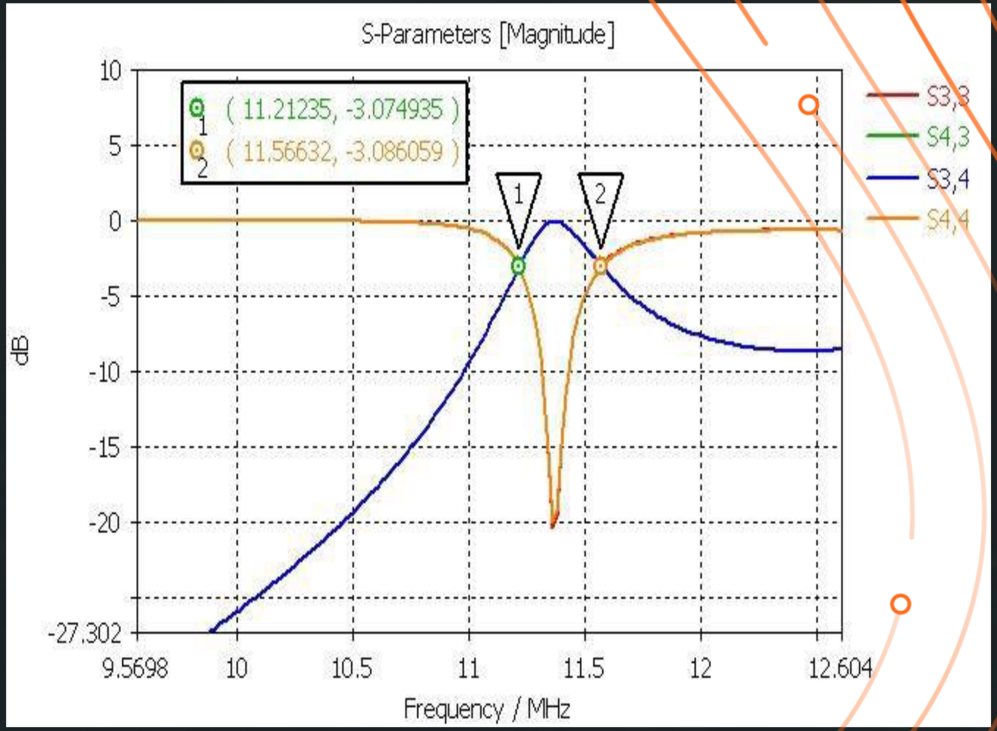
AME-Filter

- Combined lumped elements filter assembly
- CST-Simulation check with measured element values



Resulting bandpass filter parameters
With frequency shift of passband





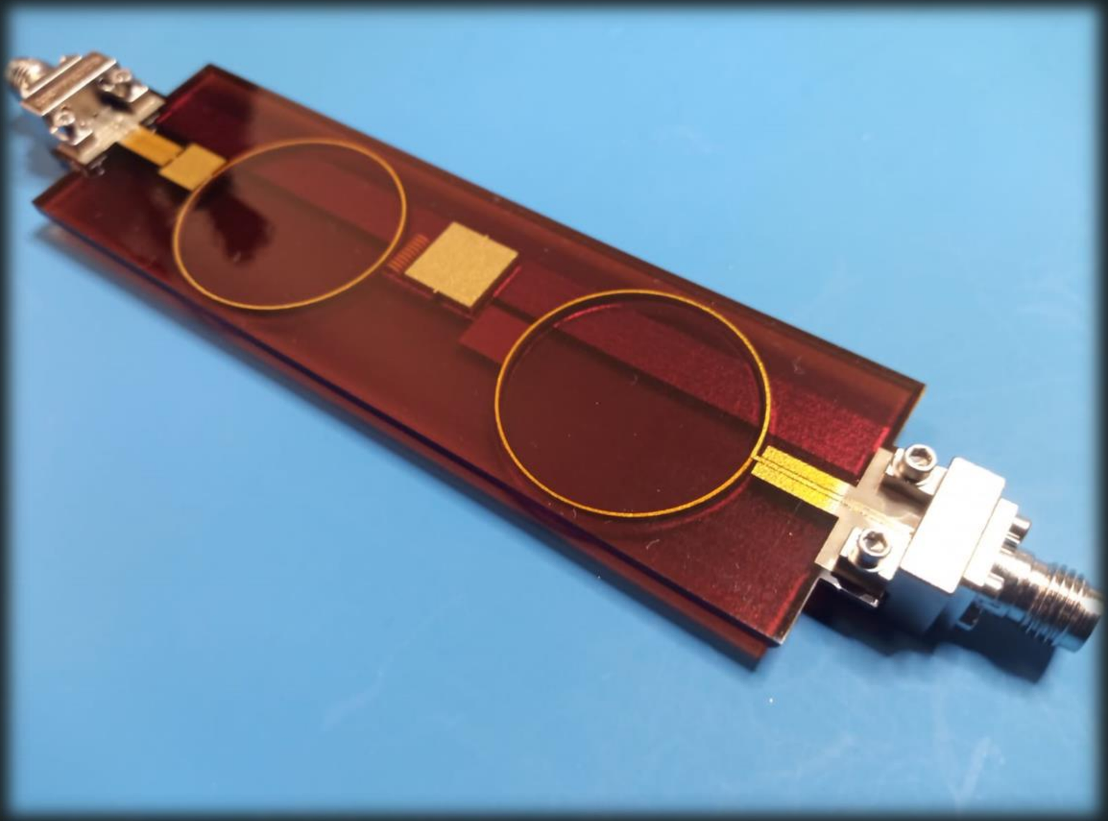
to minimize !

Reference Simulation (optimal)	
Capacity	Inductivity
C1 = 53,1 pF	L1 = 3,98 µH
C2 = 3,2 nF	L2 = 66,3 nH

Simulation with measured Elements	
Capacity	Inductivity
C1 = 62 pF	L1 = 23 µH
C2 = 12 nF	L2 = 62 nH

AME-Bandpass Filter

- Realization done



RESULT

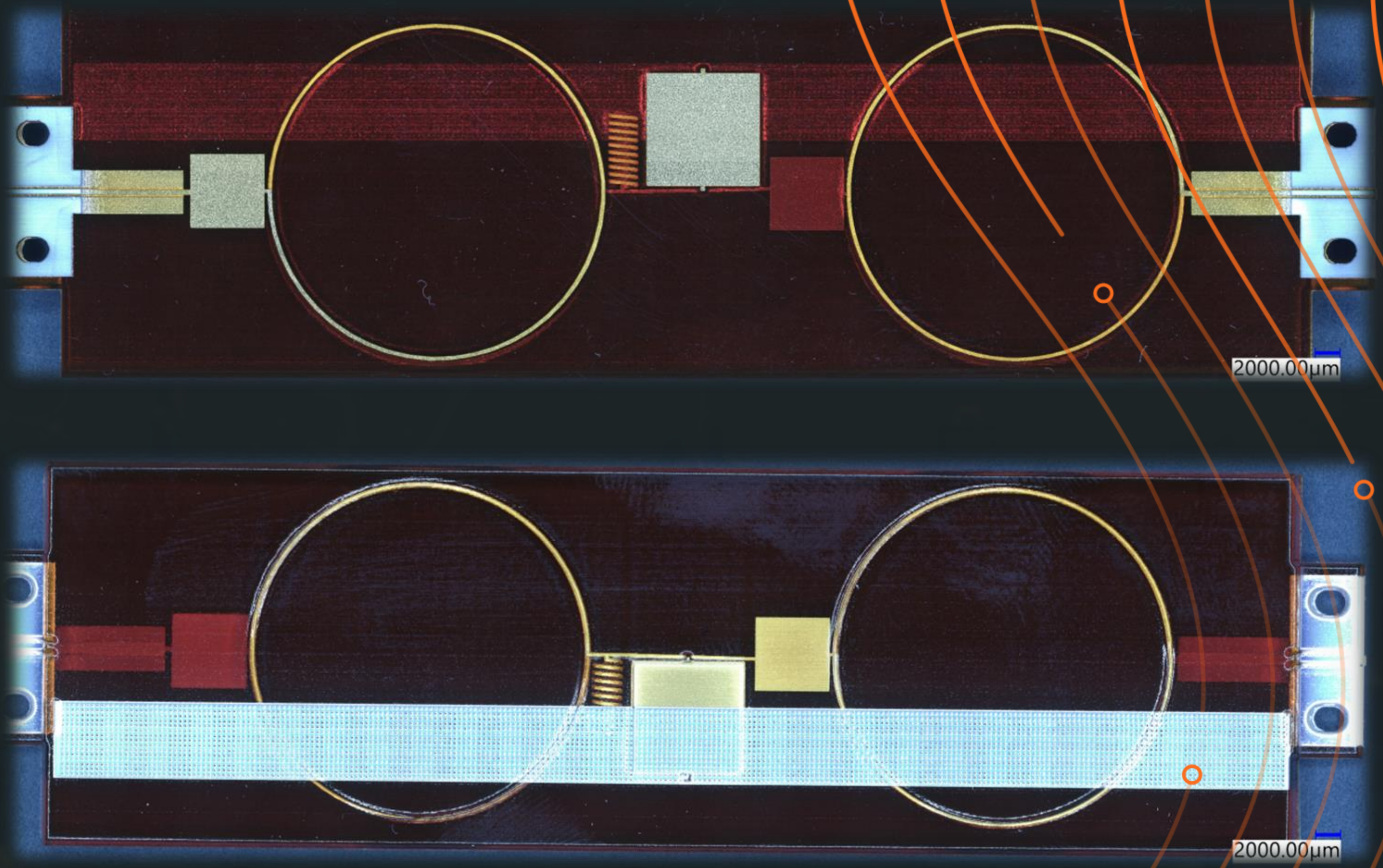
- No verification possible – short due to effects during printing process (sagging, spraying…)

AME-Bandpass Filter

SUMMARY

- J.A.M.E.S showed the potential of fully 3D-printed Filters the first time
- Fields of improvement has been identified
  - Printing process / z-axis conductivity
  - Material characteristic / RF-parameter
  - Design & Simulation workflow

➔ Further optimization will be established !



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