



Hands-on GaN Doherty amplifier design

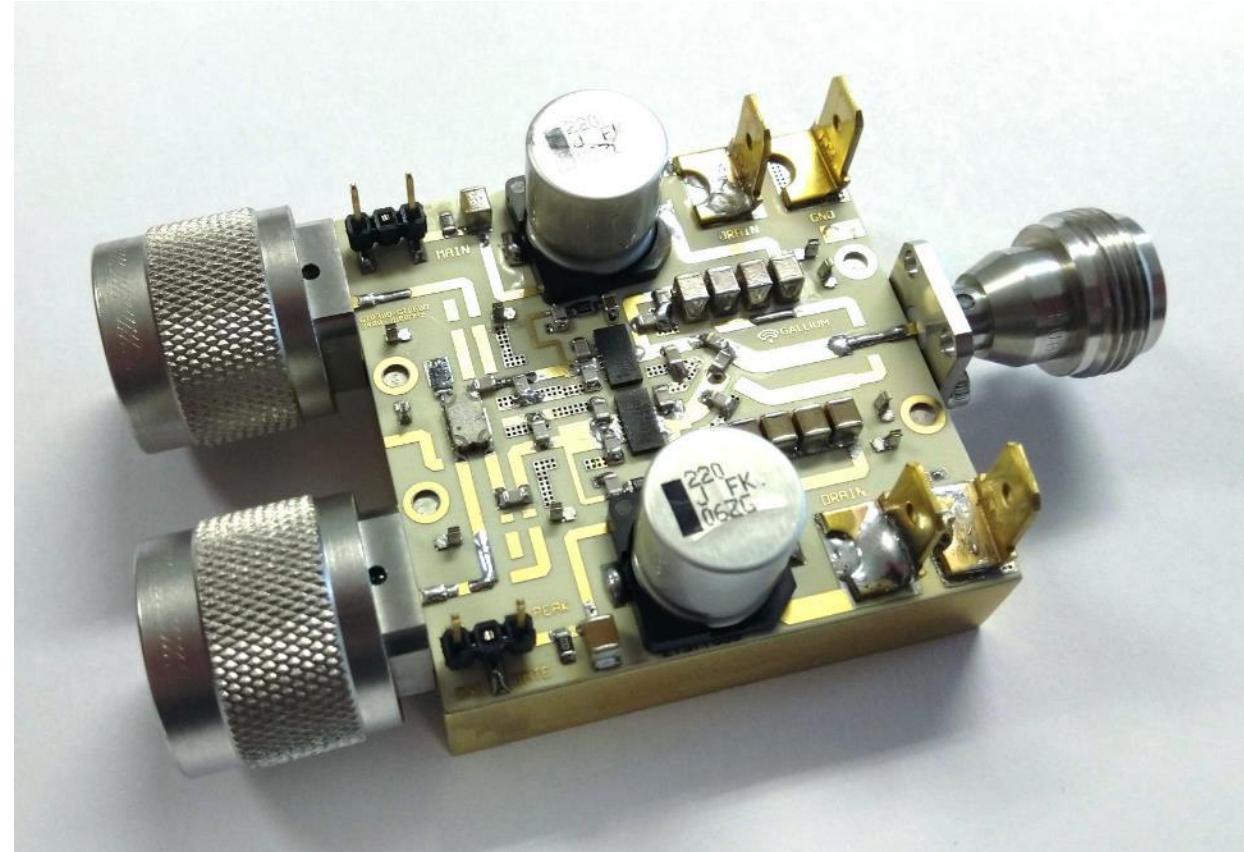
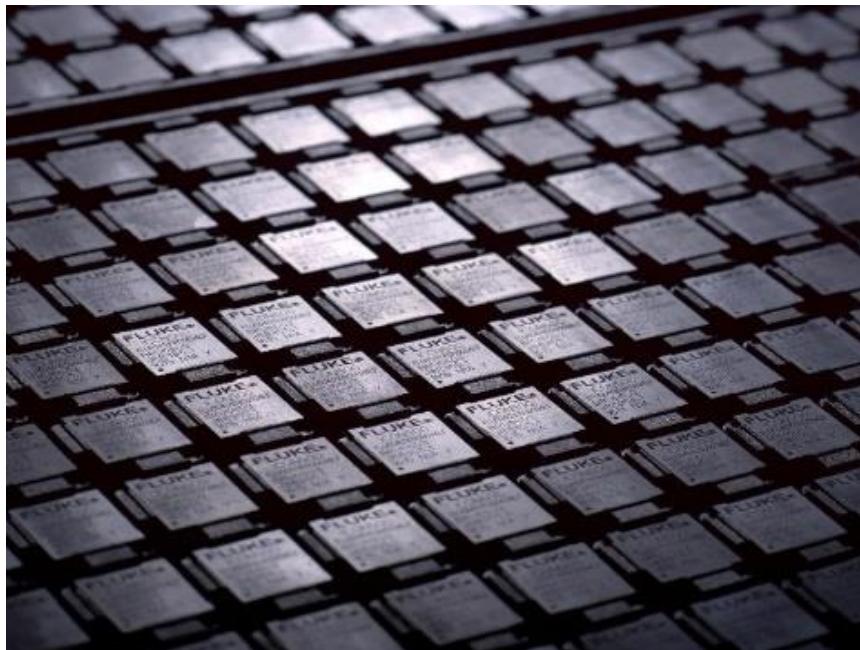
Martijn F. Brethouwer
2022-06-01





Introduction

Bruco IC

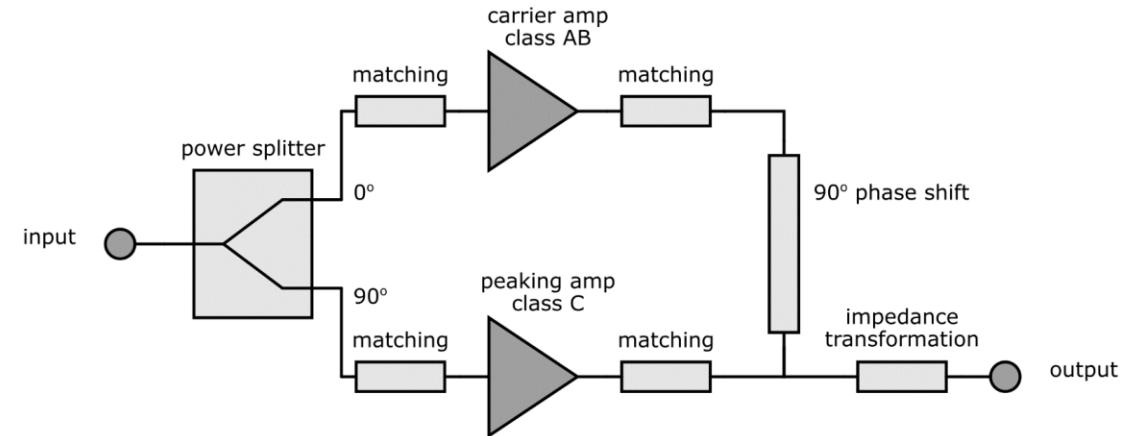
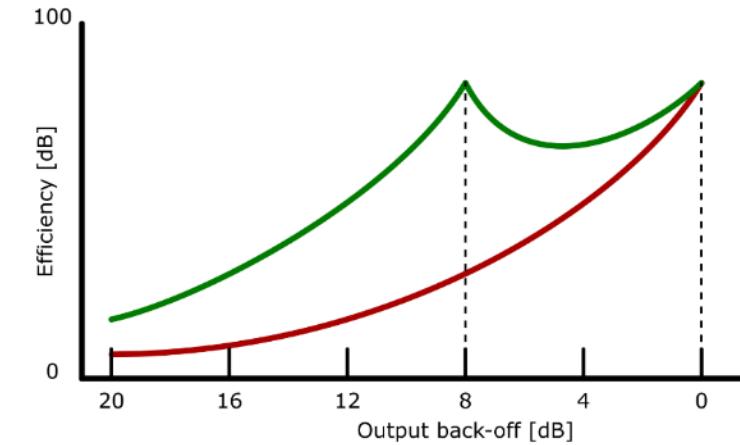




Introduction

Doherty amplifiers

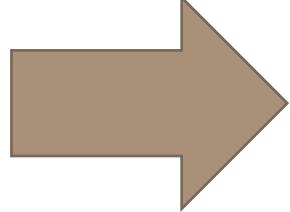
- Base-station applications
 - 1G -> 6G communication standards
 - High peak-to-average ratio signals
 - Good efficiency
- Doherty topology
 - Big improvement in efficiency
 - Many parts working together





Specifications

Doherty amplifiers

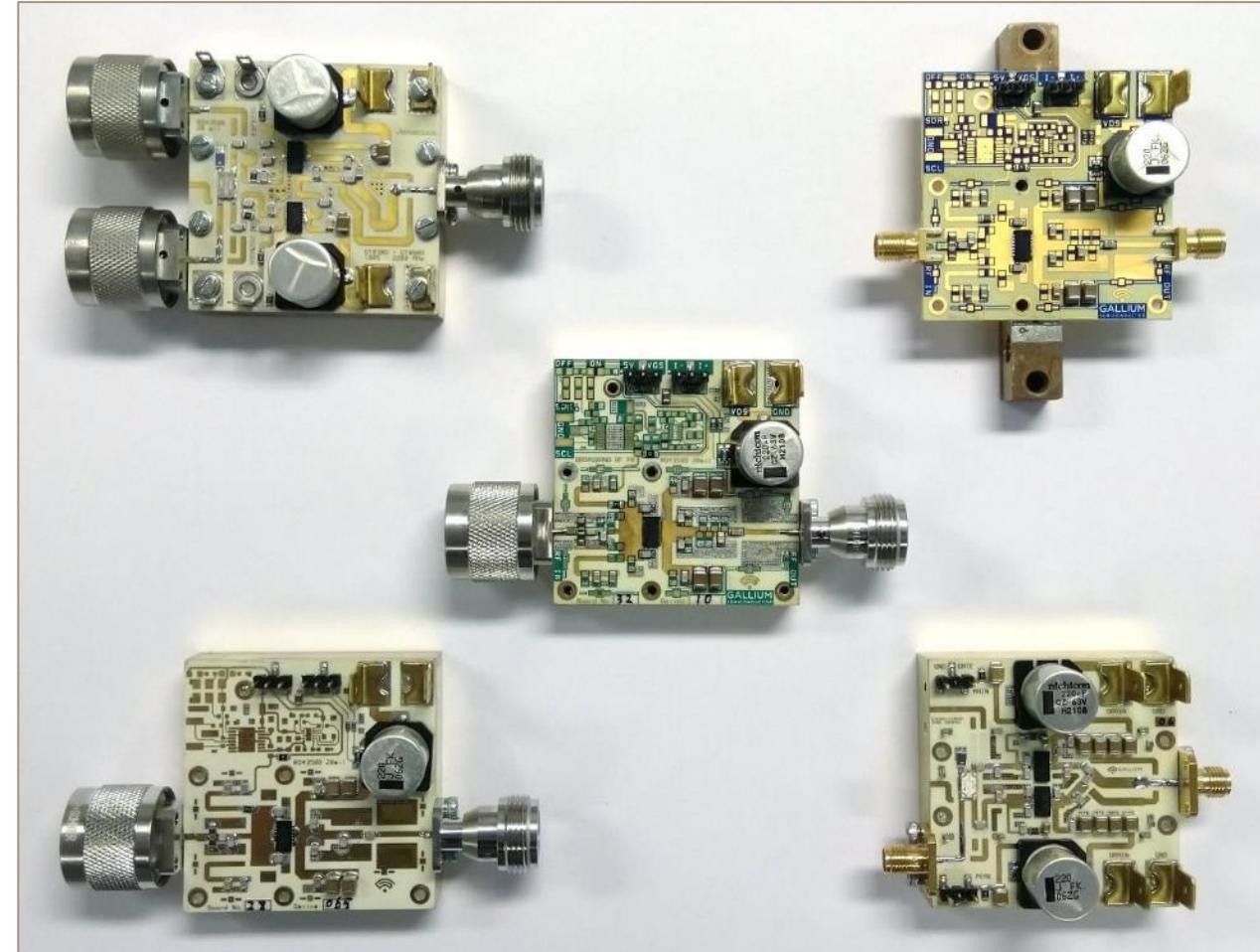
- System
 - Peak and average power
 - Frequency range
 - Efficiency
 - Gain
 - Area constraints
 - Component selection
 - Deliverables
 - Hardware
 - Measurements / Report
 - Mechanical
 - Construction
 - Soldering
 - Connectors
 - Electrical
 - Transistors selection
 - Wideband design or not
 - DC feed & baseband impedance
 - Bias control network or not
 - COTS component selection
- 



General design rules

All designs

- Manufacturing
 - Number of pieces
 - Assembly
 - Soldering
 - PCB design rules
- Testing
- Reuse
 - To save time
 - To reduce errors

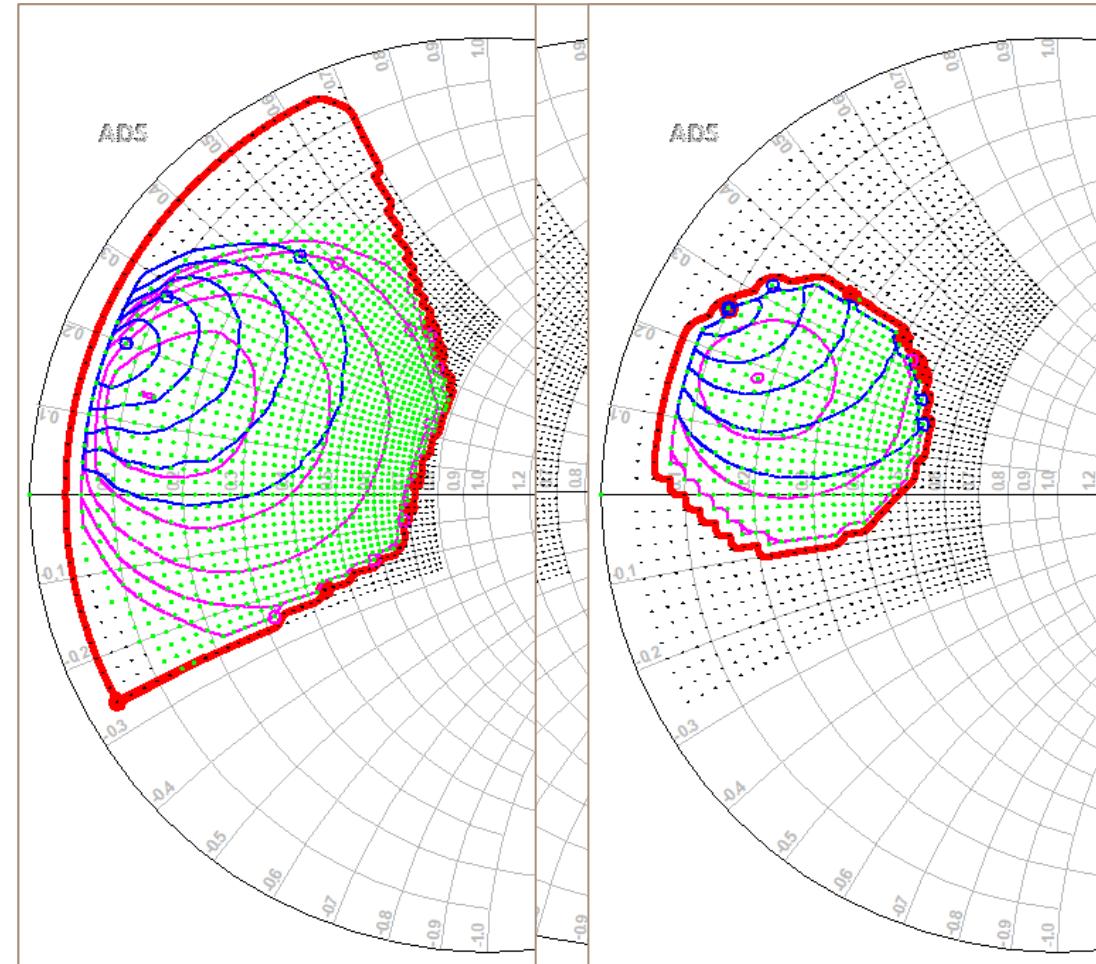
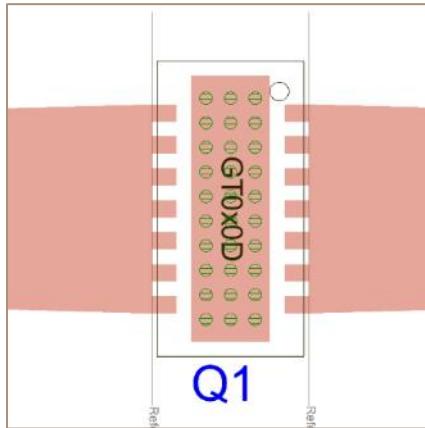
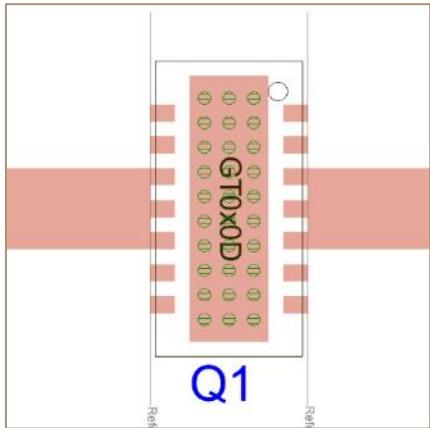




Transistor selection

Load-pull data

- GaN devices from Gallium semiconductor
- Load pull data
 - Frequency points
 - Fixtures & reference planes
 - Smith chart coverage for main transistor





Transistor selection

Load-pull system

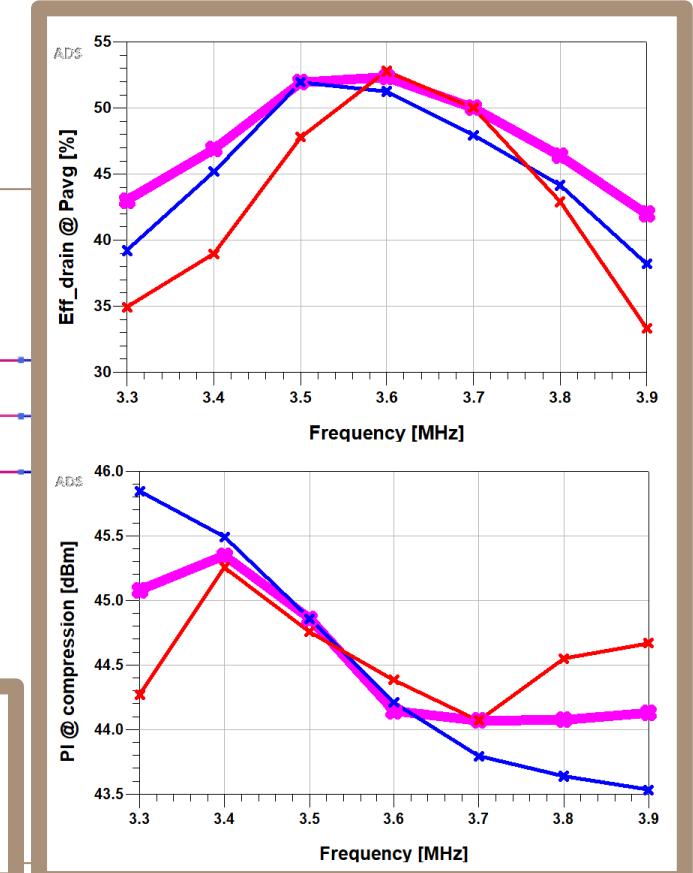
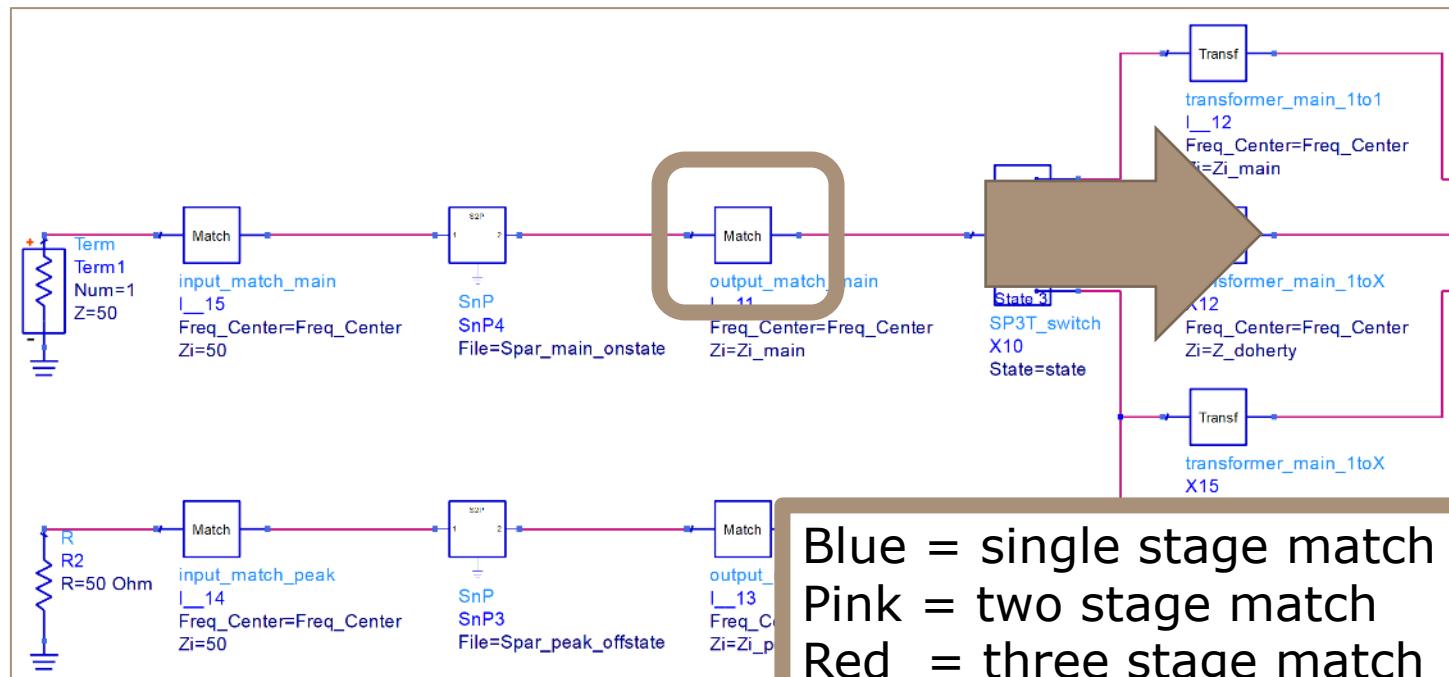




Simulation

High level

- Start with very basic design to get the design working (most hurdles are here)
- Intermediate impedances
- Check options for making wideband, what is beneficial?

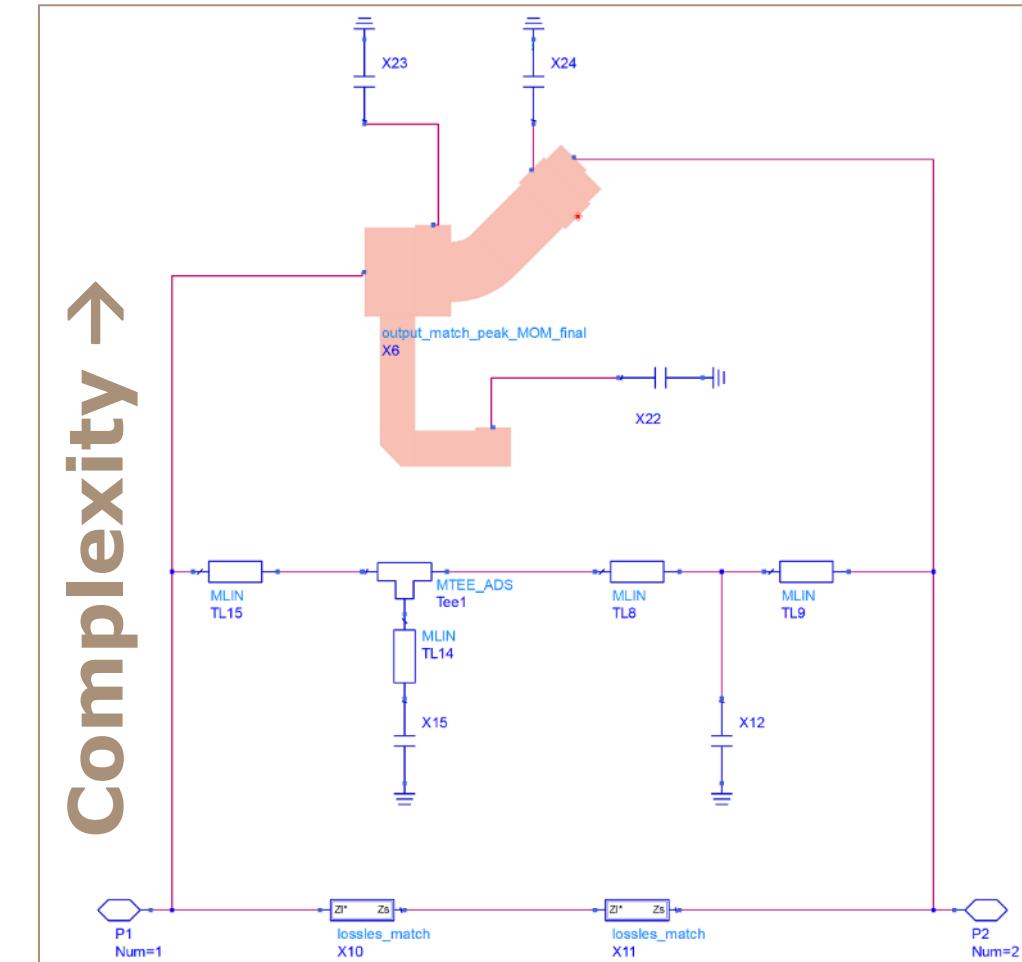




Simulation

Layout

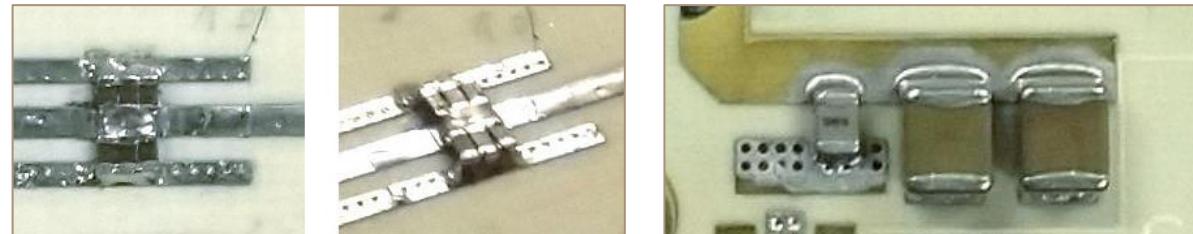
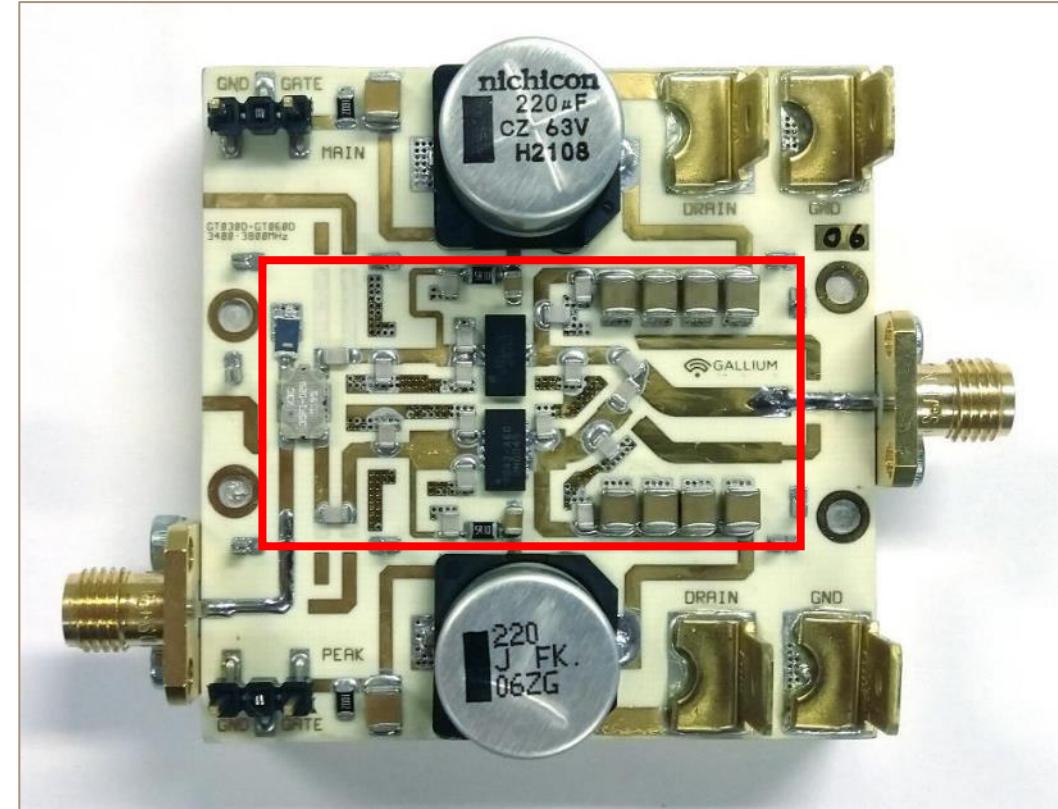
- Step-by-step increase complexity
 - Keysight / AWR webinars
 - Include DC bias
- Pitfall: Design for stability and testing early-on
 - Conditionally stable, also out-of-band
 - Test points / connectors / traces
- Pitfall: Use design for manufacturing early-on
 - Make tuning possible
 - Distance between components
 - Reproducibility





Mechanical Design

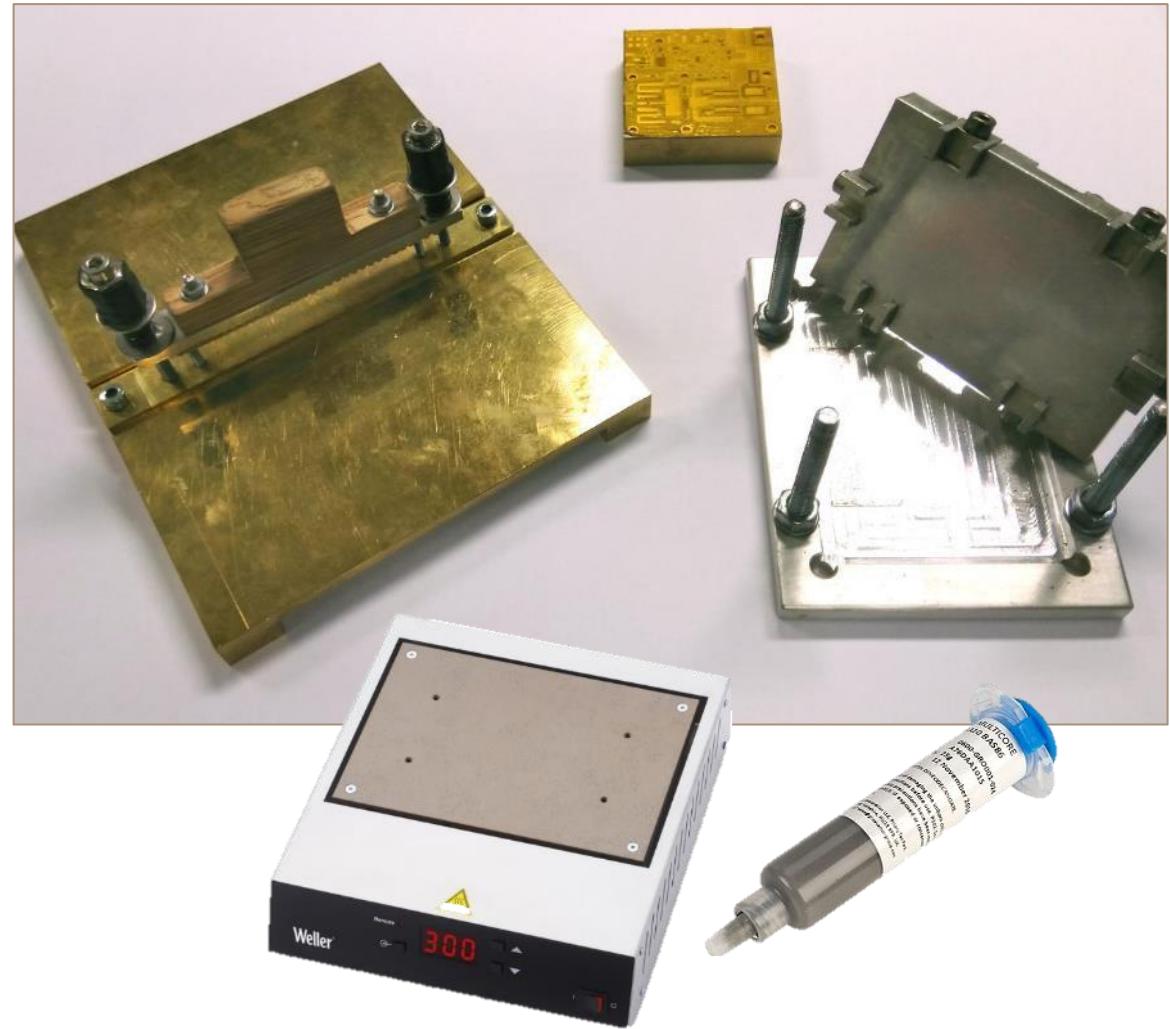
- Reserved area
 - Peripheral circuitry
 - Connectors
- Design for manufacturing
 - Distance between components
 - Component shift
 - Component footprints
 - Thermal strategy





Mechanical Construction

- **Work smart, not hard**
- If re-used a lot, design is much easier
 - Base plate dimensions (50 x 50 mm)
 - Molds and clamps
 - Templates for connectors
- All in-house incl. milling
- (reflow) soldering
- Reliable and consistent but flexible





Measurements

Testing & tuning

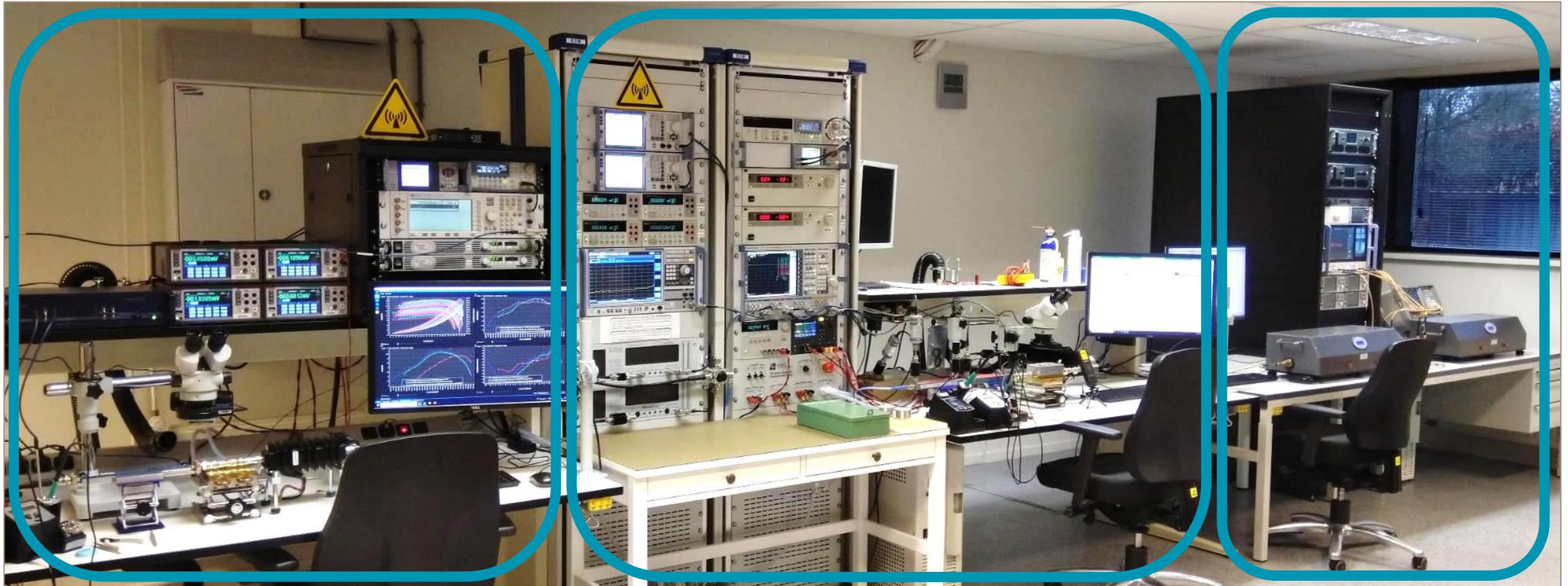
- Structured approach
 - Step-by-step to prevent finding a local optimum
 - Document results to enable comparisons
- Pitfalls:
 - Soldering without disabling PSU's
 - Damaged / degraded parts (capacitors)
 - Reproducibility





Measurements

Measurement setup

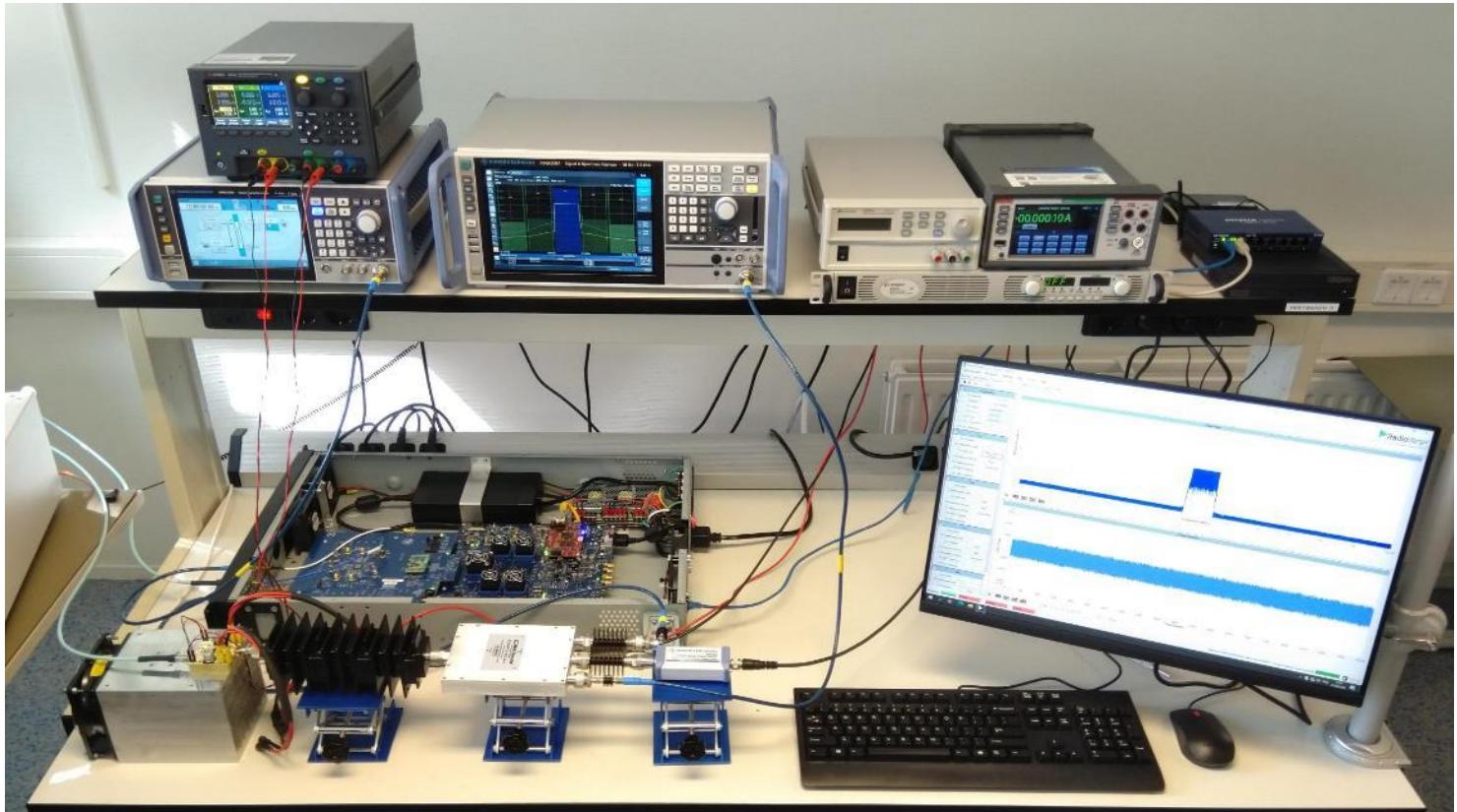
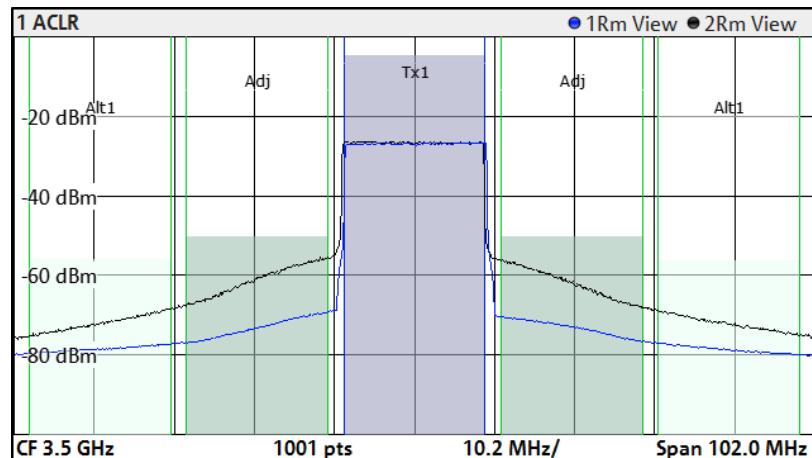




Digital Pre-Distortion

Realistic measurement

- Measurements to represent a realistic work environment
 - Specialist hardware
 - Accurate signals
 - Realistic algorithms
 - Monitoring of performance

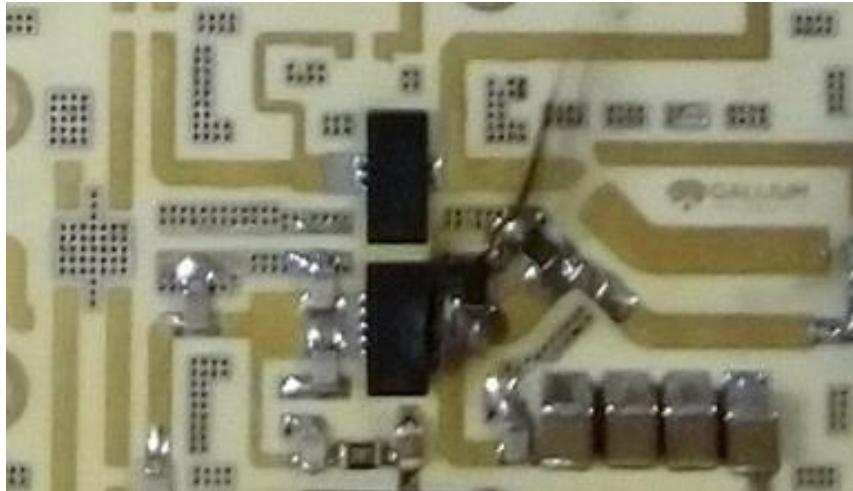




Project ending

Deliverables

- Review specifications
 - Characterization
 - Make nice report
- Learn from mistakes



bruco
INTEGRATED CIRCUITS

Measurement report
Doherty amplifier 3400-3700MHz
Board 04

Document revision history

Version	Date	Author
1.0	2022-10-20	M. F. Bröthauer

Device overview

Asymmetrical topology with a power ratio of about 3:1 is used as the main transistor. The peak power device is a GT500D device.

mm by 50 mm. The Doherty power amplifier section has multiple RF inputs and outputs which can be seen on the left side of the board. The PCB is 41.8 mm wide with a material thickness of 0.2 mm. Input amplifier for the purpose of this document, but it can be required.

RF signal at specified frequencies. The signal has a PAR of 7.6 dB with 0.01% probability of peak power. Channel bandwidths are ±10 Hz and ±10 Hz offset.

Frequency (MHz)	20 MHz	25 MHz	30 MHz	35 MHz	40 MHz
AMAR 3400	-104.0	-104.0	-104.0	-104.0	-104.0
AMAR 3500	-104.0	-104.0	-104.0	-104.0	-104.0
AMAR 3700	-104.0	-104.0	-104.0	-104.0	-104.0
EF 2500	-104.0	-104.0	-104.0	-104.0	-104.0
EF 3400	-104.0	-104.0	-104.0	-104.0	-104.0
EF 3700	-104.0	-104.0	-104.0	-104.0	-104.0

Efficiency vs. Power

Efficiency vs. Frequency

VSWR vs. Frequency

ACPR at 20 and 40 MHz vs. Input

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Contents: Company confidential

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Section: 5 Performance details
Project: BRU3151-D4
Contents: Company confidential

PCB layout

PCB dimensions: 41.8 mm x 50 mm

PCB thickness: 0.2 mm

PCB material: FR4

PCB layer stack: Top layer (Oriented towards the right), Bottom layer (Oriented towards the left)

PCB edge finish: Tin-lead (Sn-Pb)

PCB surface treatment: HASL (Hot Air Solder Leveling)

PCB assembly: Surface Mount Technology (SMT)

PCB design tools: Cadence Allegro

PCB layout software: Cadence Allegro

PCB routing style: Multilayer

PCB trace width: 0.1 mm

PCB via type: Plated through hole

PCB component placement: Manual placement

PCB solder mask: Green

PCB legend: Component symbols and reference designators

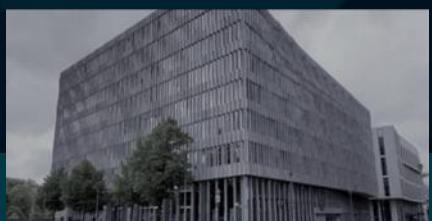
PCB notes: Design notes and manufacturing instructions



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