High Efficient Amplifier Design for Accelerator-Applications

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Broadcast Transmitter – An Overview

Customer Demands		Manufacturer Needs
High Availability	←→	Robust Design (Designed for 24/7 operation)
Redundant System Components	←→	Redundancy concepts
Wide range of output power	←→	Output Power cascadable
Efficiency	←→	Narrowband/broadband design (transistor matching!)
Low number of spare parts	←→	Broadband components
Power Density	←→	Compact design Multi-Tx solutions (within one rack)
Service and Serviceability	←→	Worldwide Service – „hot plugable modules“ Long term availability for spare parts (10+ years)
Purchasing costs (Capex)	←→	Low production costs High degree of automation High volume production Little manual work

Broadcast Transmitter – An Overview

	Band 2	Band 3	Band IV/V
Frequency range	87MHz – 108MHz (85MHz – 118MHz)	170MHz – 254MHz	470MHz – 862MHz
Channel bandwidth		6/7/8 MHz	6/7/8 MHz
AVG / CW power Peak power* Multi rack power (AVG) **per rack**	5kW – 40kW >80kW	1.7 – 20kW ~12 – 140kW >60kW	1.7 – 20kW ~12 – 140kW >100kW
Efficiency OFDM* CW***	 appr. 75%**	~50% Doherty appr. 65%	~40% Doherty appr. 55%
Max. amplifier per rack	8	12	12

* related to OFDM modulation (~10dB Crestfactor), min. 34dB MER, 37dB shoulder; **incl. Cooling**
ATSC min. 36dB MER, min. 37dB shoulder

** class C, FM

*** **incl. cooling**

Efficiency:

$$\eta = \frac{P_{AVG}(RF)}{P_{AC}}$$

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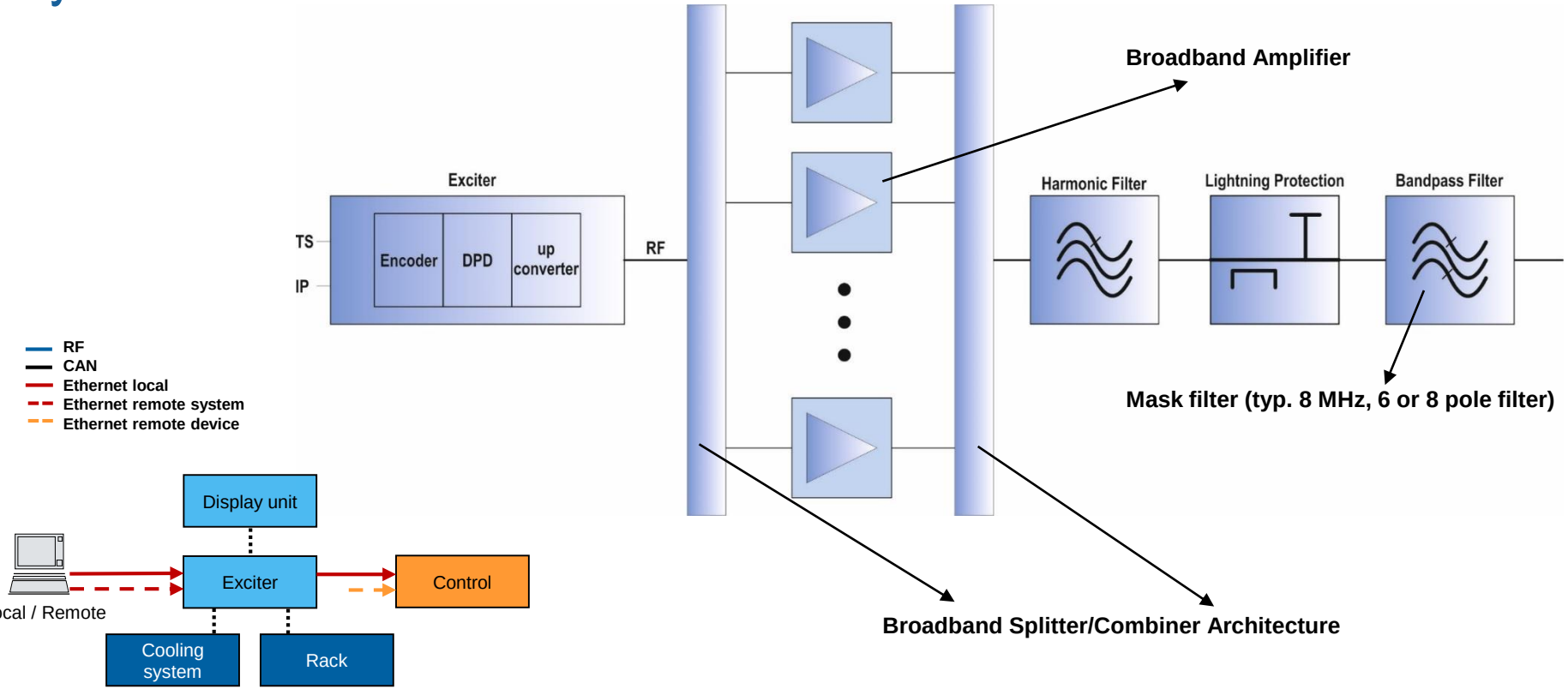
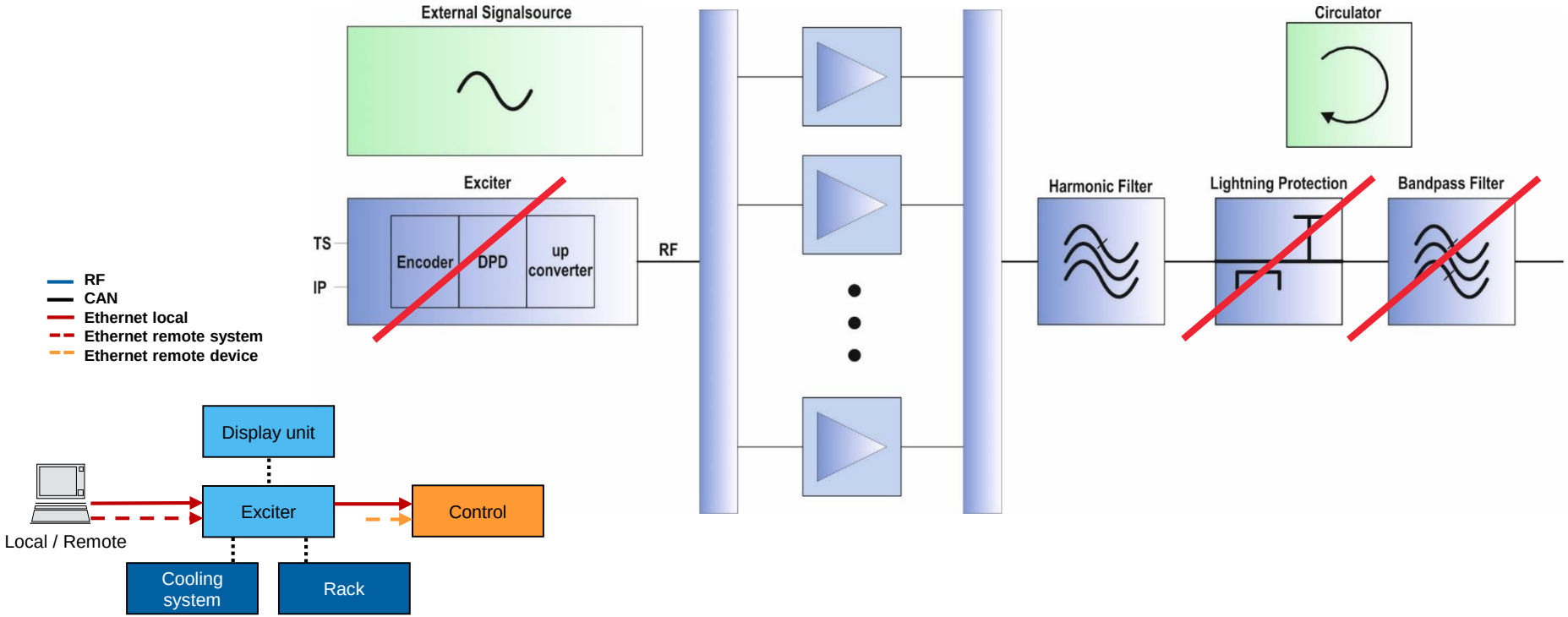
System Architecture – Broadcast Transmitters



System Architecture – Accelerator

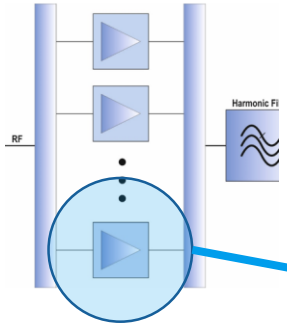


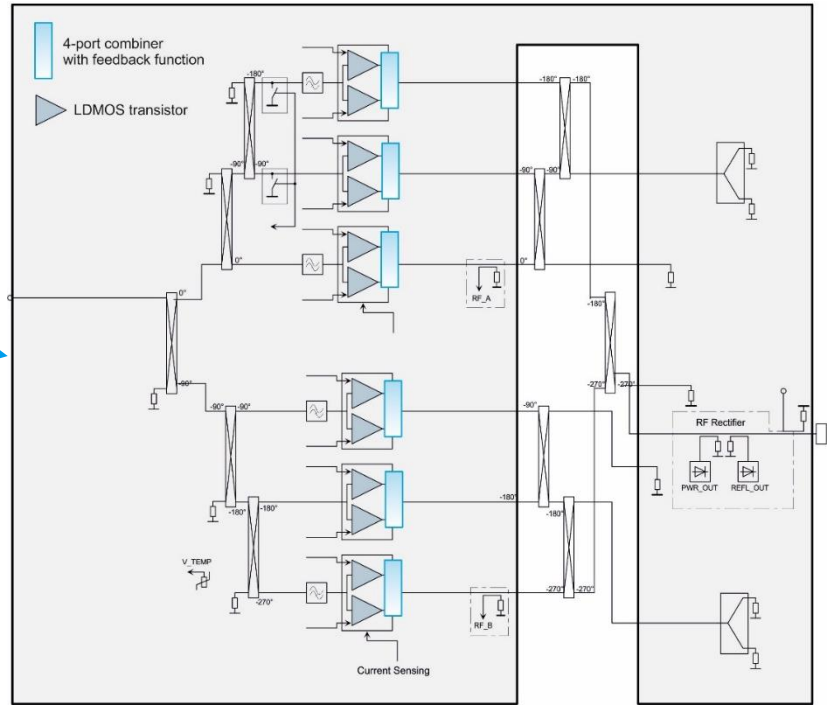
System Architecture – Amplifier Design

- LDMOS design
- Low junction temperature
- Transistors fully decoupled
- Signal quality not influenced if transistors fails
- Fully broadband design
- Power supplies integrated and redundant
- Fully liquid cooled → no fans
- Feedback combiner can be automatically set for:

  - broadband mode class A/B
  - Doherty-mode
  - CW-mode

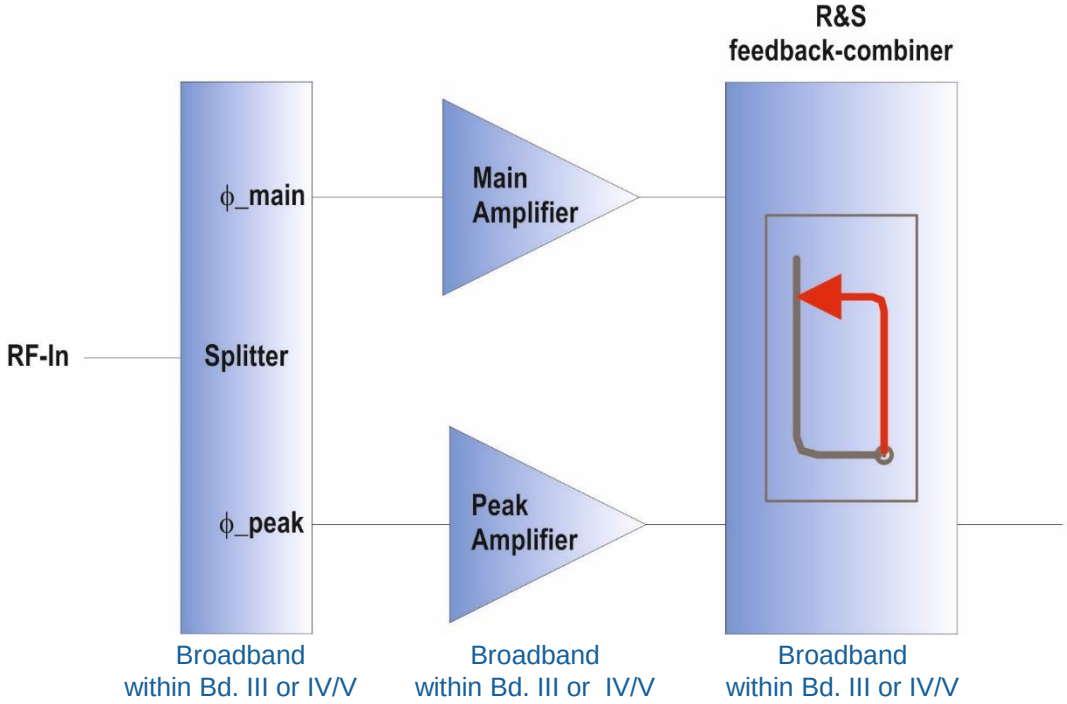
- Very high MTBF





System Architecture – Feedback Combiner

- **Doherty Amplifier – R&S-Design**
- **Useable for Broadband-/Doherty-/CW- applications (combiner with feedback function)**



Broadband operation in class A/B mode

or

Doherty-operation narrowband high efficiency

Or

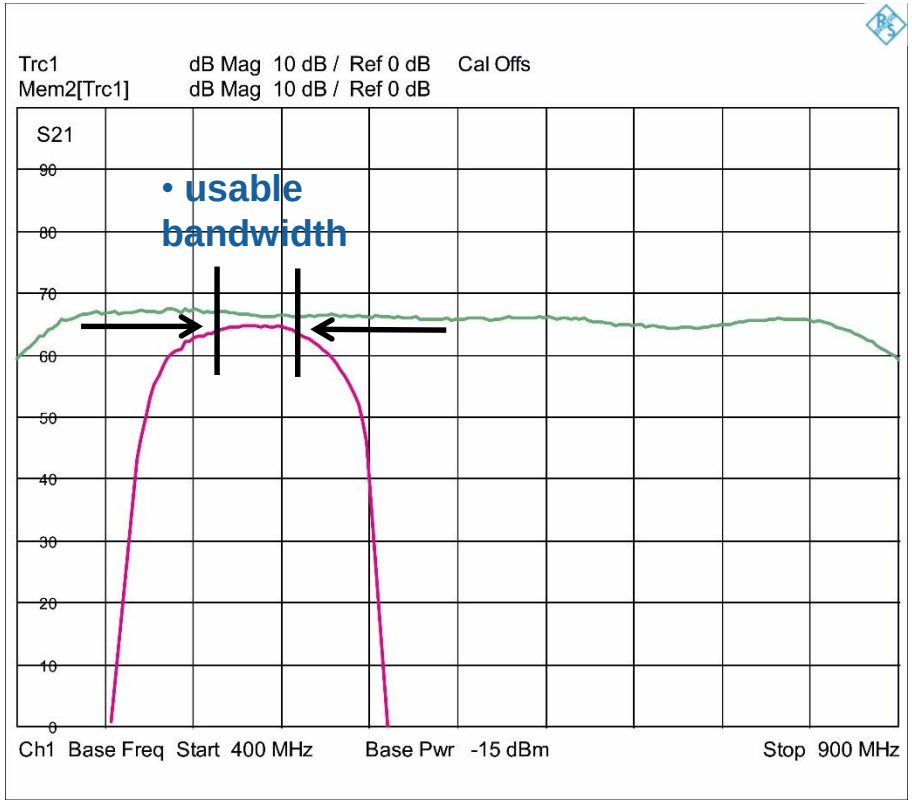
High efficient CW mode

System Architecture – „Multiband Doherty“

- **Class A/B**
- broadband from 470 MHz … 862MHz
- bandwidth ≥ 400MHz
- one amplifier-design for Band IV/V

- **small signal sweep**

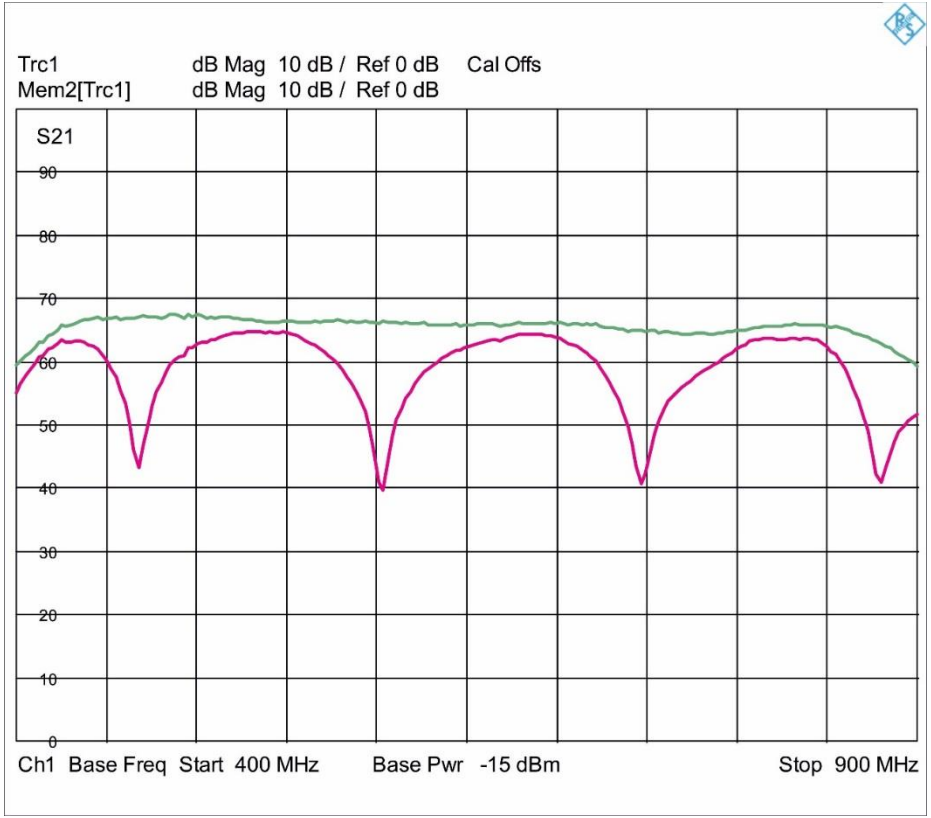
- **Doherty amplifier**
- narrowband
- bandwidth appr. 50MHz
- min. 8 … 10 different amplifiers for Band IV/V



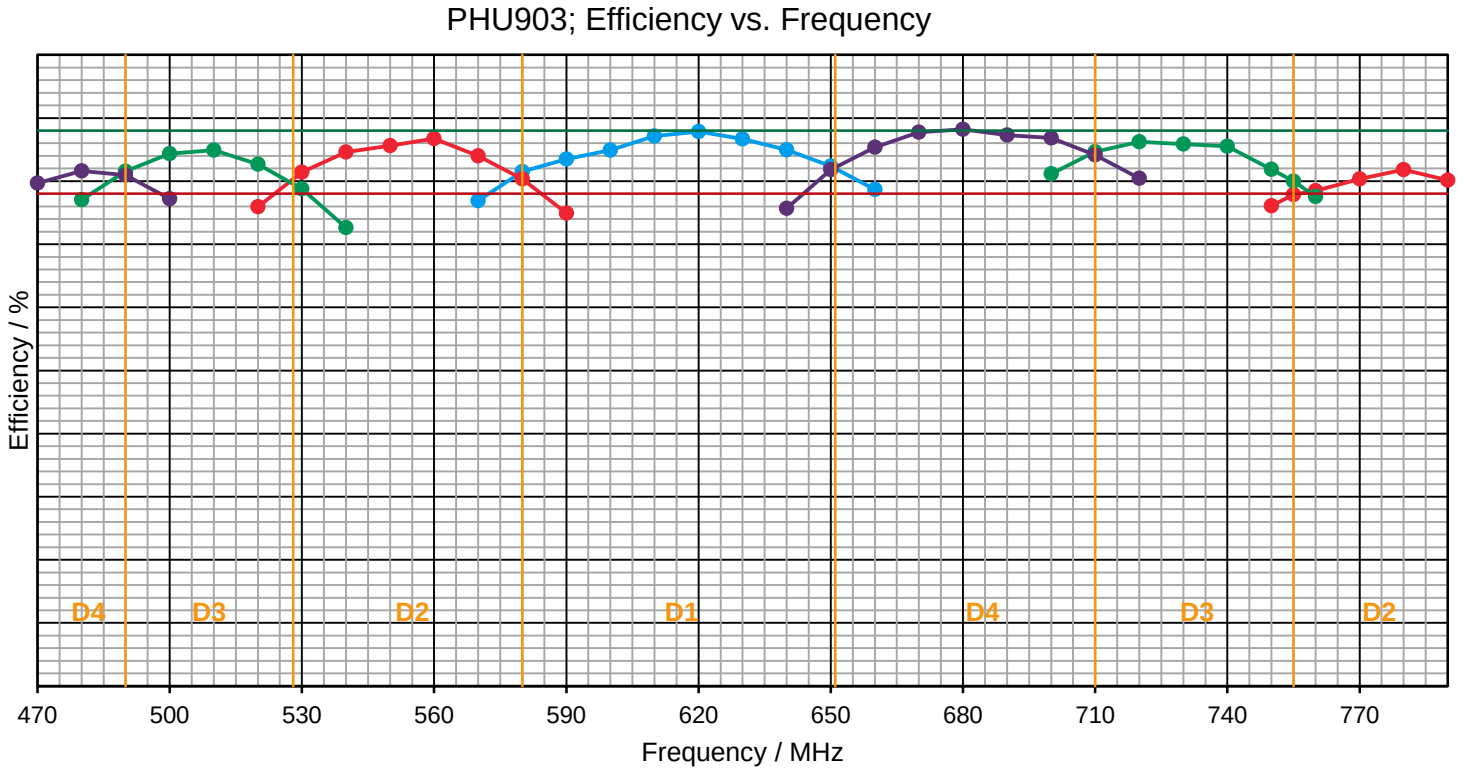
System Architecture – „Multiband Doherty“

- **Doherty Option**

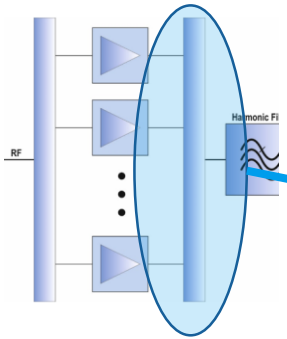
- **Periodically replication of the Doherty-region**
- **Less frequency options for broadband use**
- **Architecture gives best efficiency in CW applications**



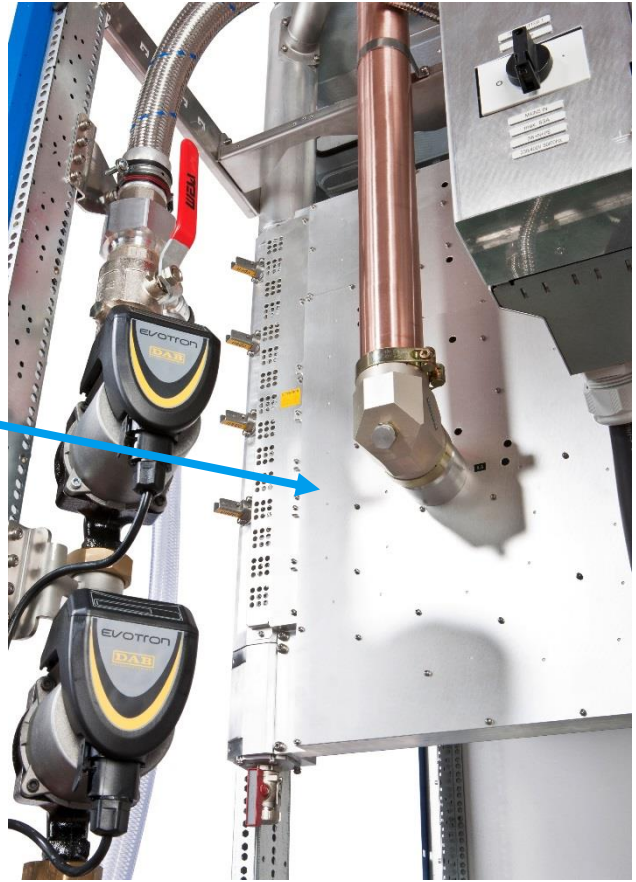
System Architecture – „Multiband Doherty“

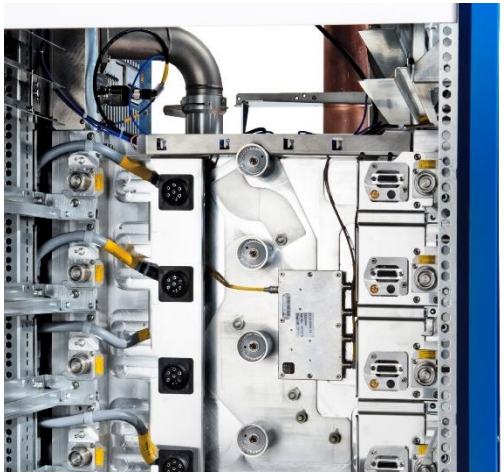


System Architecture – Combiner Design



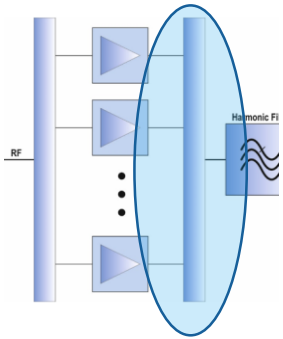
- **Example:**
  4 by 1, Band 2, 20kW





- **Amplifiers „hot pluggable“**
- **Absorbers located on the liquid hoses of the amplifiers**
- **Fully decoupled inputs**
- **Fully broadband within RF- Band**

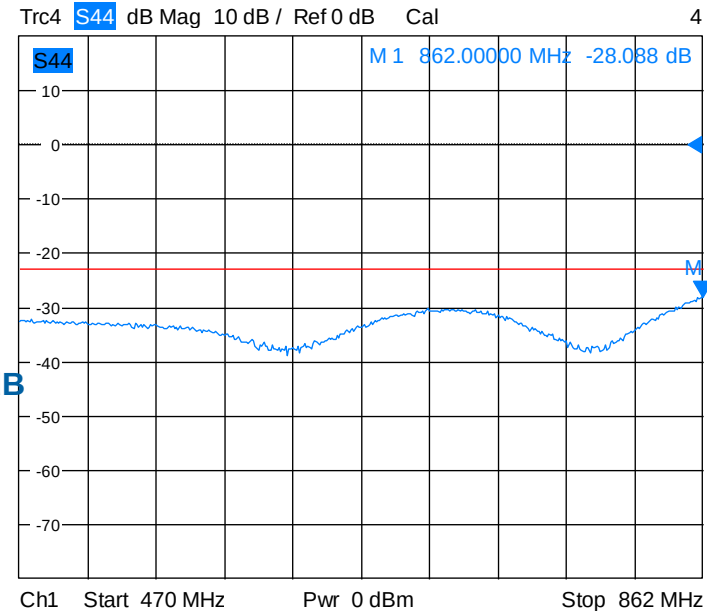
System Architecture – Combiner Design



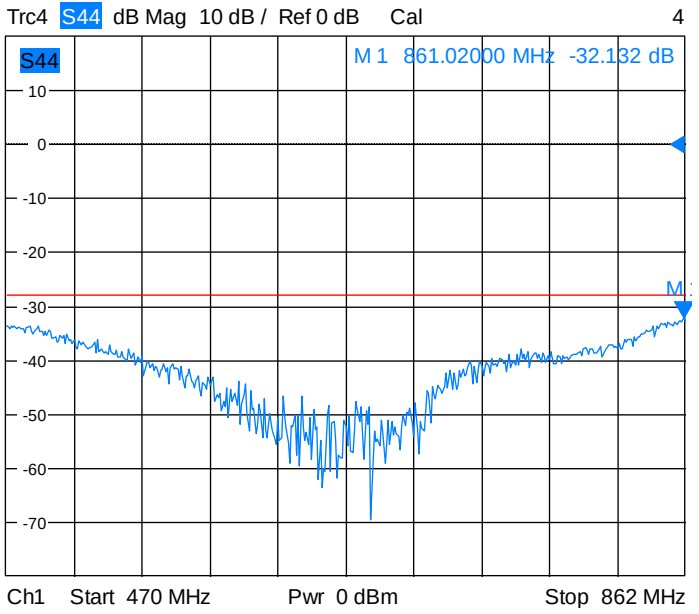
- Example:
  4 by 1, Band IV/V

- Input matching typ. <-32dB
- Decoupling typ. >28dB
- Insertion loss <0.05dB

decoupling

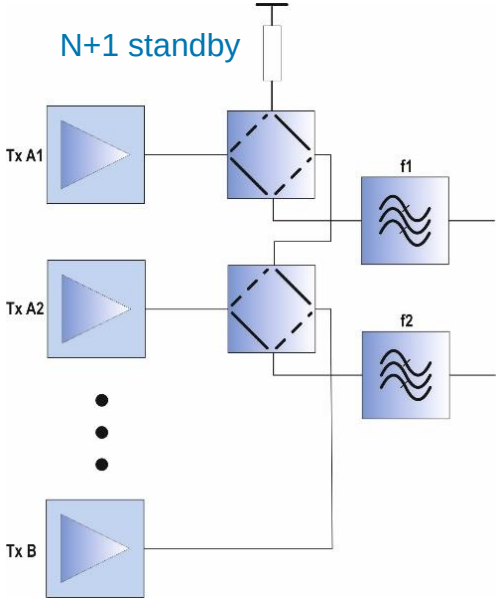


Input matching

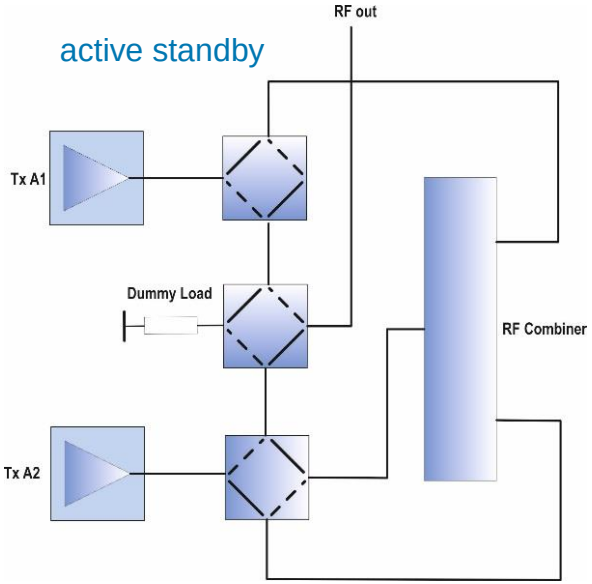


System Architecture – Reserve Systems

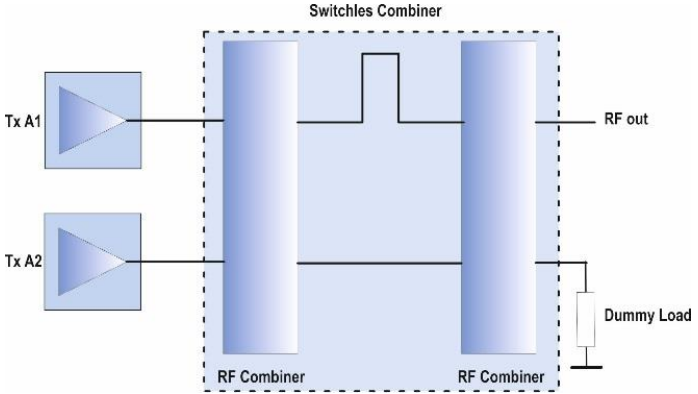
N+1 standby



active standby



dynamic reserve



→ Extremely high MTBF and availability

System Architecture – Reserve Systems

Dynamic power adaption

→ output power tracking in case of failures (transistors/modules/power supplies)

- uses the headroom of the design

Example: 70kW amplifier – 60 amplifier modules Installed power: ~80kW

Faulty device	Output power w/o. power adaption	Power reserve	No. of faulty devices with adaption (70kW)
Amplifier module	67.69kW	7.36kW	4
Power supply	69.22kW	9.11kW	12
Transistor	69.61kW	9.56kW	24

System Architecture – Common Features

- High Power liquid cooled Amplifier
- Identical mechanical design for
  Band II
  Band III
  Band IV-V

- Liquid cooled amplifier – hot pluggable
- PS included
- Fully liquid cooled – no fans

- AGC or const. Gain
- Fully decoupled RF-structures
- Self protection against:
  overpower
  reflection
  overtemperature
  mains failures
- Interlock
- Fast shutdown

System Architecture – Examples

- 100kW ATSC Broadcast Tx (=100kW CW Amplifier)
- 72 amplifiers
- 6 racks 19“ / 42 HE
- Operating frequency 470MHz … 800MHz

System Architecture – Examples

Accelerator Project:
Sweden (8 x 60kW) / Poland (2 x 60kW) :

- 60kW CW Amplifier (=60kW FM Broadcast Transmitter)
- 12 amplifier modules in 2 racks 19“ / 42 HE
- Operating frequency 100MHz

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Summary

Solid State PA‘s for Accelerator use based on Broadcast Tx have the following advantages:

- **Produced in very high numbers (well engineered and tested)**
- **Fully automated amplifier module production**
- **Efficiency comparable to tube amplifiers**
- **Very robust and high availability**
- **Different Redundancy concepts available**
- **Can be delivered with power levels >100kW CW**
- **… can replace tube amplifiers (as happens already for Broadcast transmitters)**

Thank You for

Your Attention!

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