Ericsson AAS: AIR 6449 B42
Reverse Engineering report

SE: Ivan Tsvelykh, Mikhail Shirokov
AE: Kindler Andre

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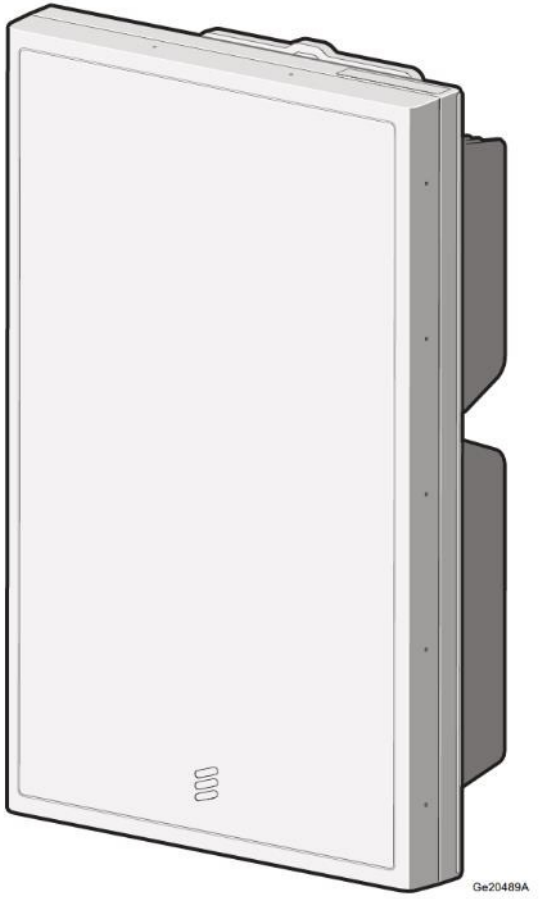
General overview, main features



AIR 6449 *

Antenna Integrated Radio Unit

AIR 6449 is a 64TR TDD AAS for LTE and NR, operating as single standard or as mixed mode.

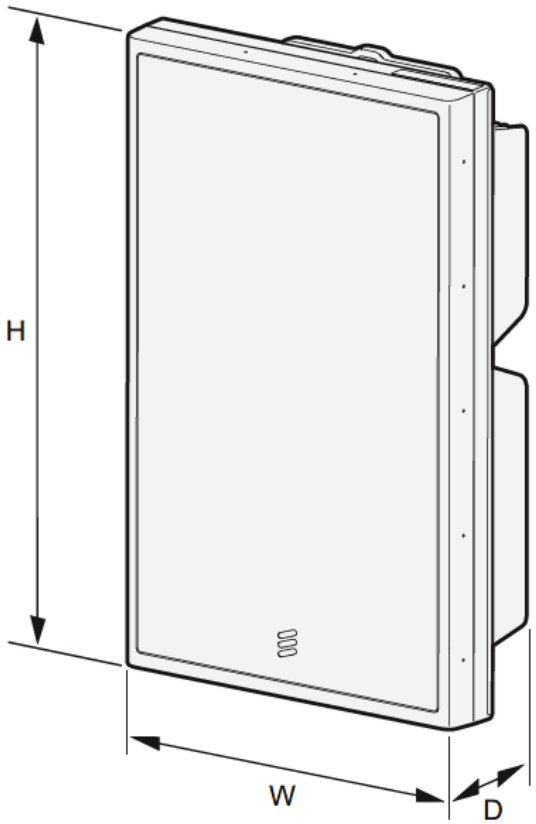
The AIR unit has beamforming and MU-MIMO technology, capable to fully utilize radio resources in both azimuth and elevation.

The main benefits compared to previous macro solutions are improvements in:

- Enhanced coverage - High gain adaptive beamforming
- Enhanced capacity - High-order spatial multiplexing and multi-user MIMO
- Advanced RAN features - Vertical and horizontal beamforming
- Improved network performance - Low inter-cell interference
- LTE TDD, NR TDD, and multistandard mixed mode LTE + NR
- 64 transmitter/receiver (64TX/64RX) branches
- eCPRI

*Hangzhou platform, released in Q1 2020

General overview, main features



Description	Value
Frequency	3400 – 3600 MHz
Number of carriers	LTE: up to three NR: up to two
Maximum nominal Pout	320 W
Unit size (H x W x D)	778 x 403 x 268 mm
Unit weight	37.5 kg
Mounting kit weight	4.4 / 5.9 kg
Ambient temperature	-40…+55 °C
Operating supply range	-36…-58.5 V DC
Nominal supply voltage	-48 V DC
Max heat dissipation	1 kW

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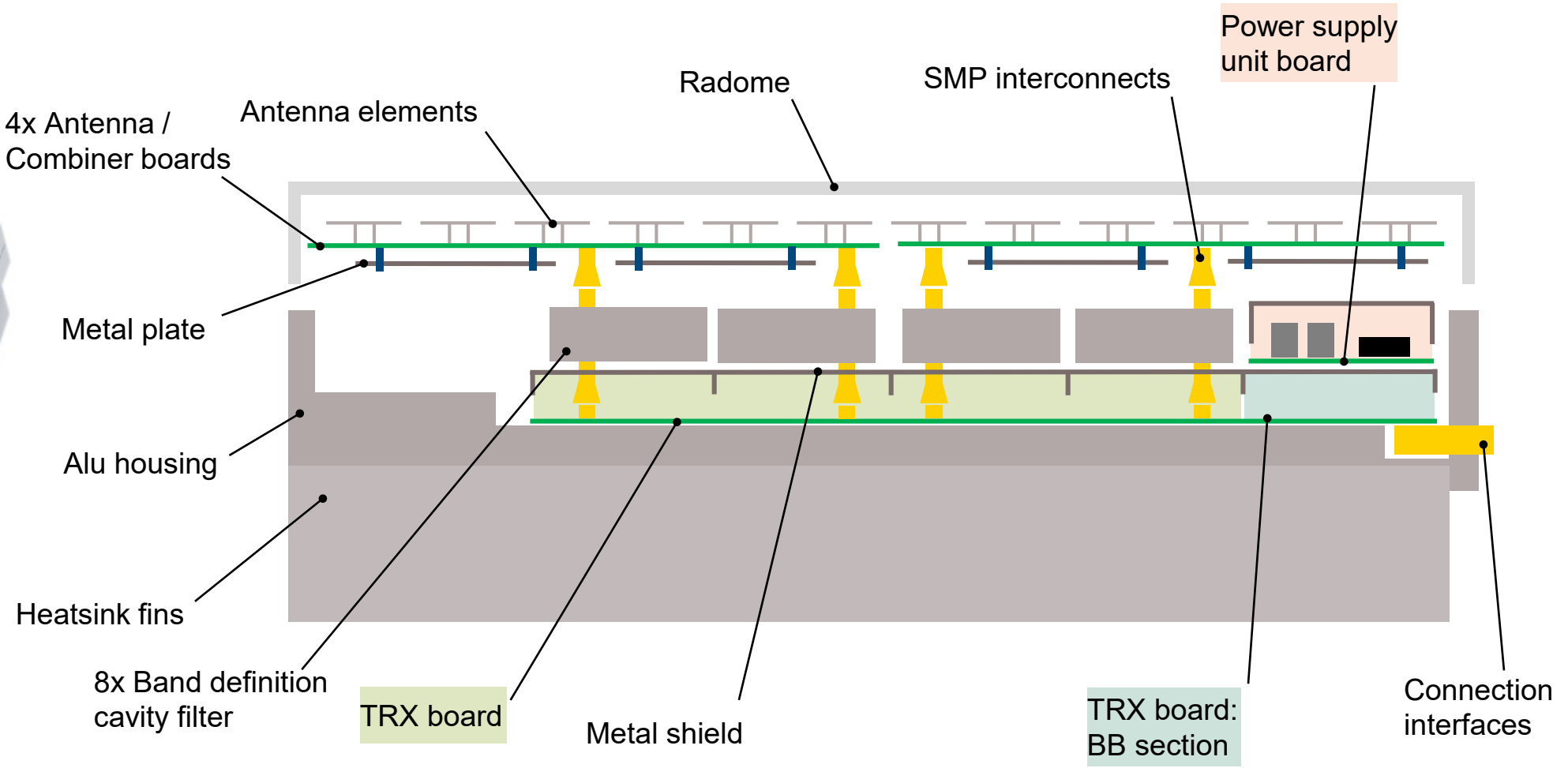
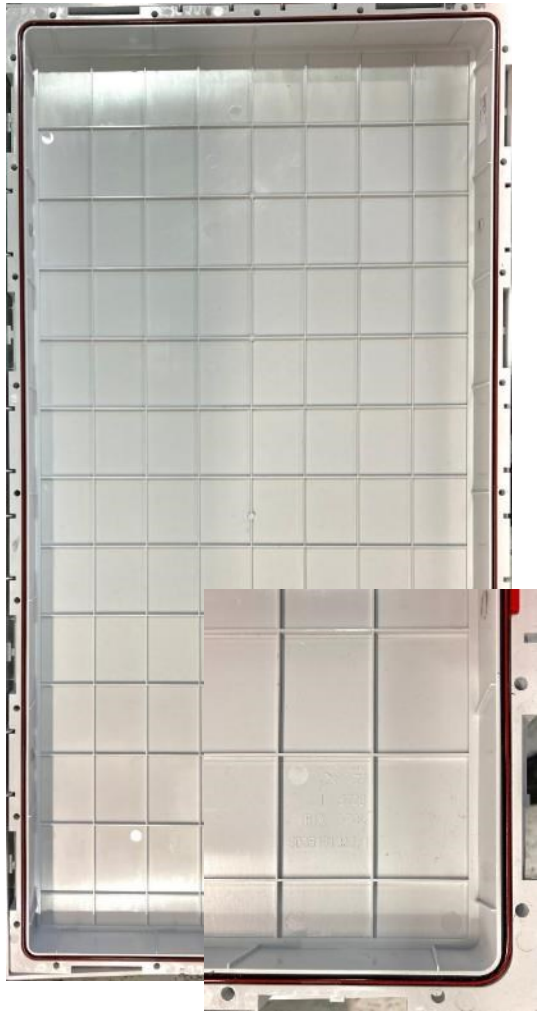
Mechanical design



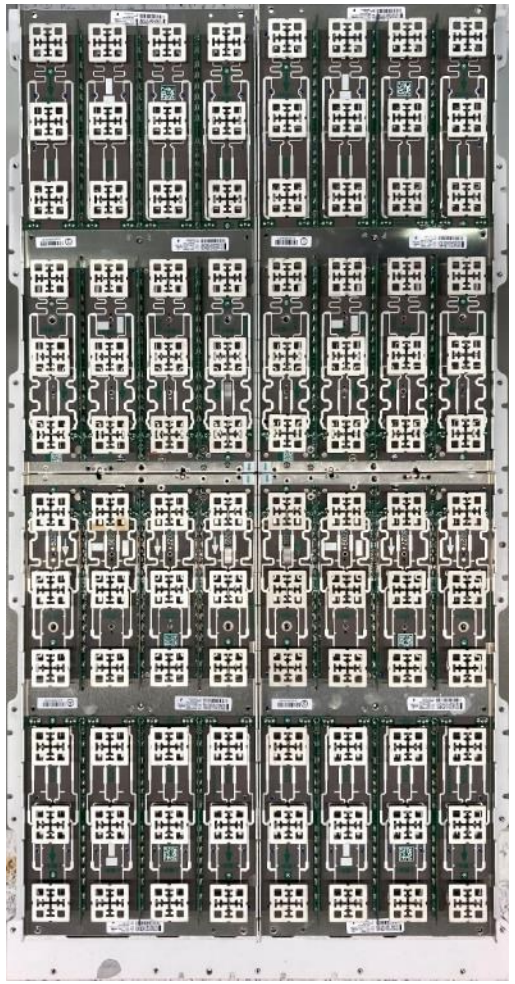
Mechanical design, disassembly steps

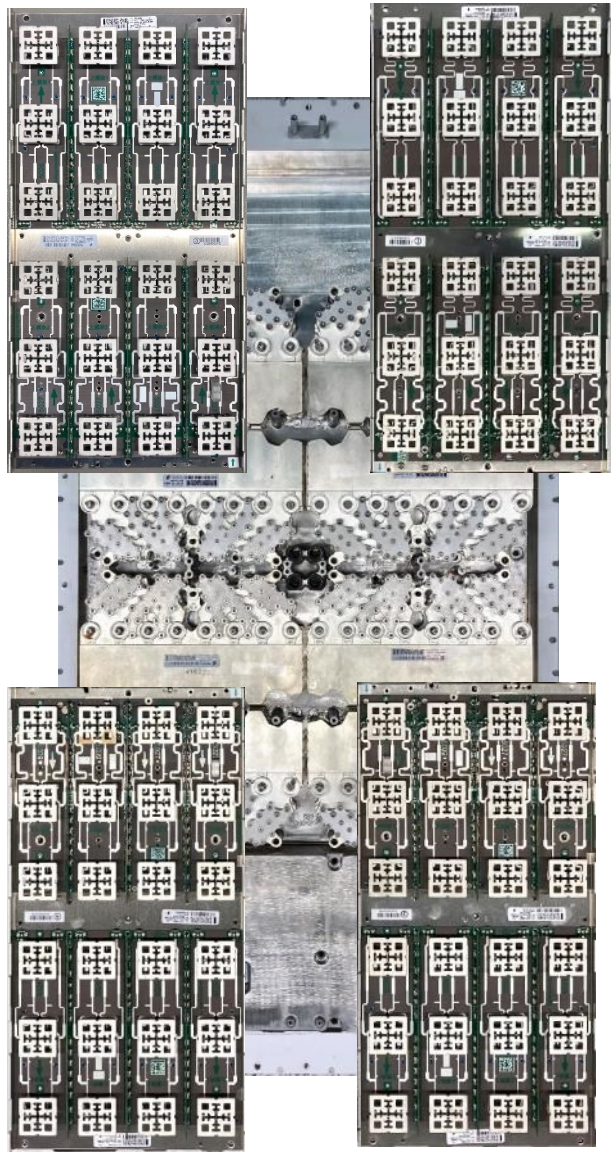
Radome (top view)

Radome (bottom view)



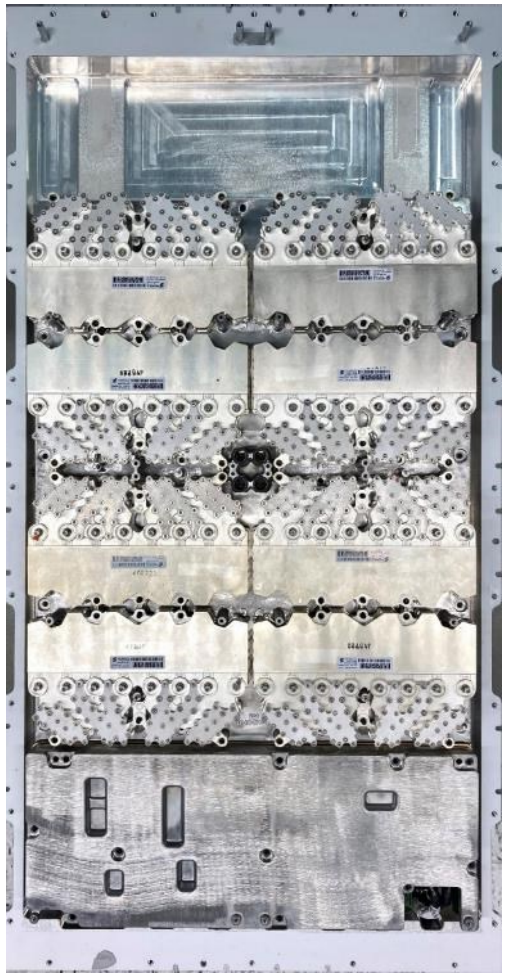
Antennas / Combiner boards





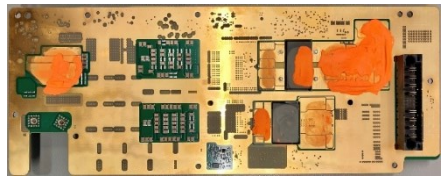
Mechanical design, disassembly steps

RF filters on a shield frame



RF filters, power supply unit shield removed

RF filters, power supply unit

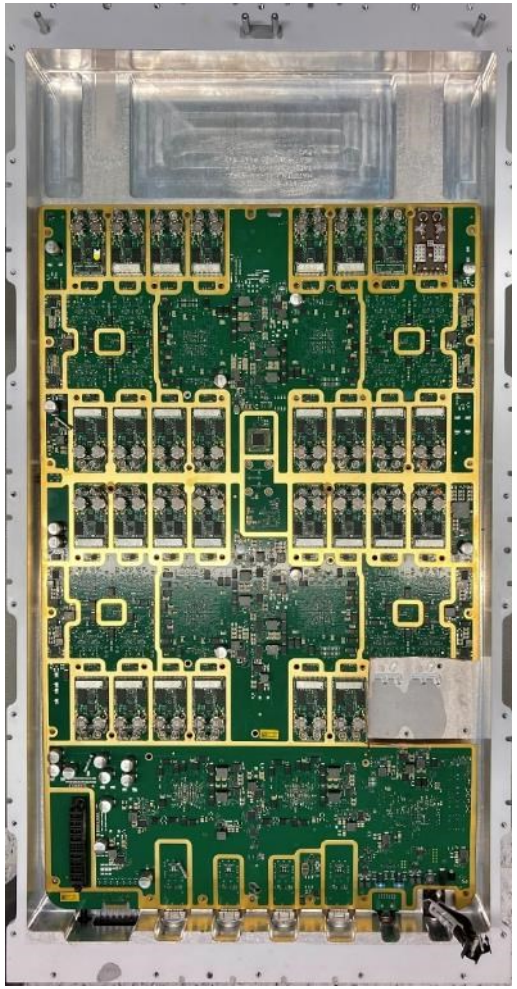


Power supply board removed, TRX board shield frame exposed

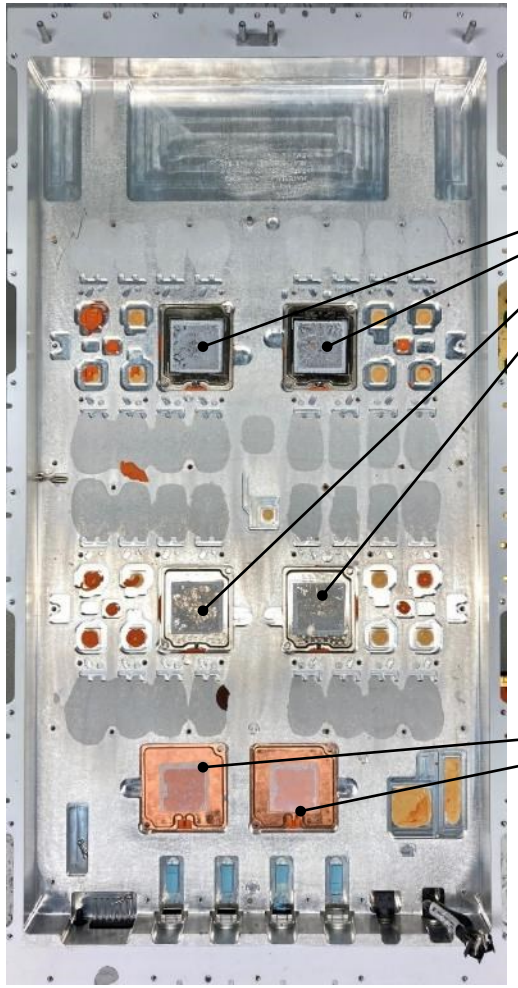
Mechanical design, disassembly steps

TRX board shield frame (bottom view)

TRX board exposed



Alu chassis (housing)



Assisted cooling for Radon ASIC

Assisted cooling for EagleOwl ASIC

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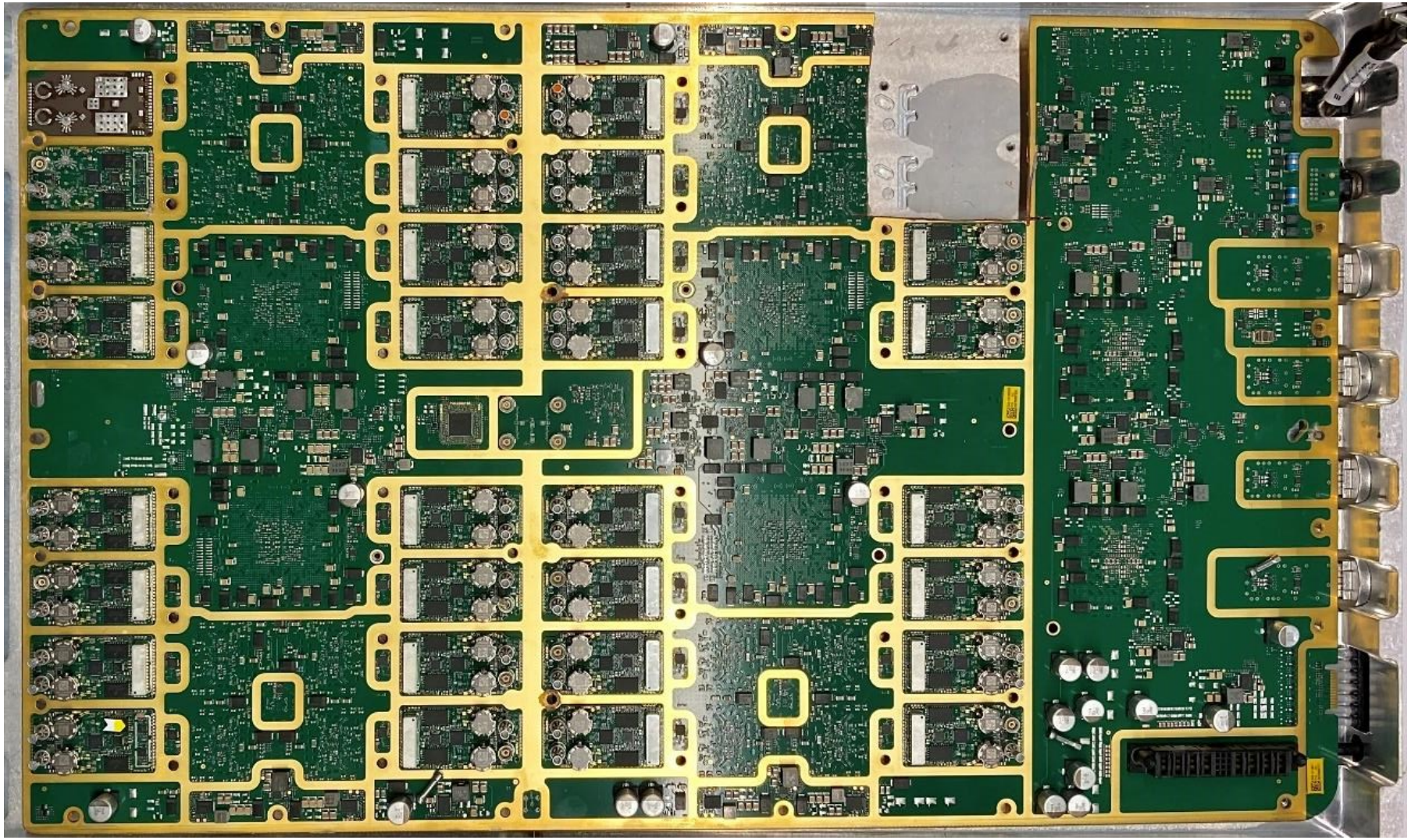
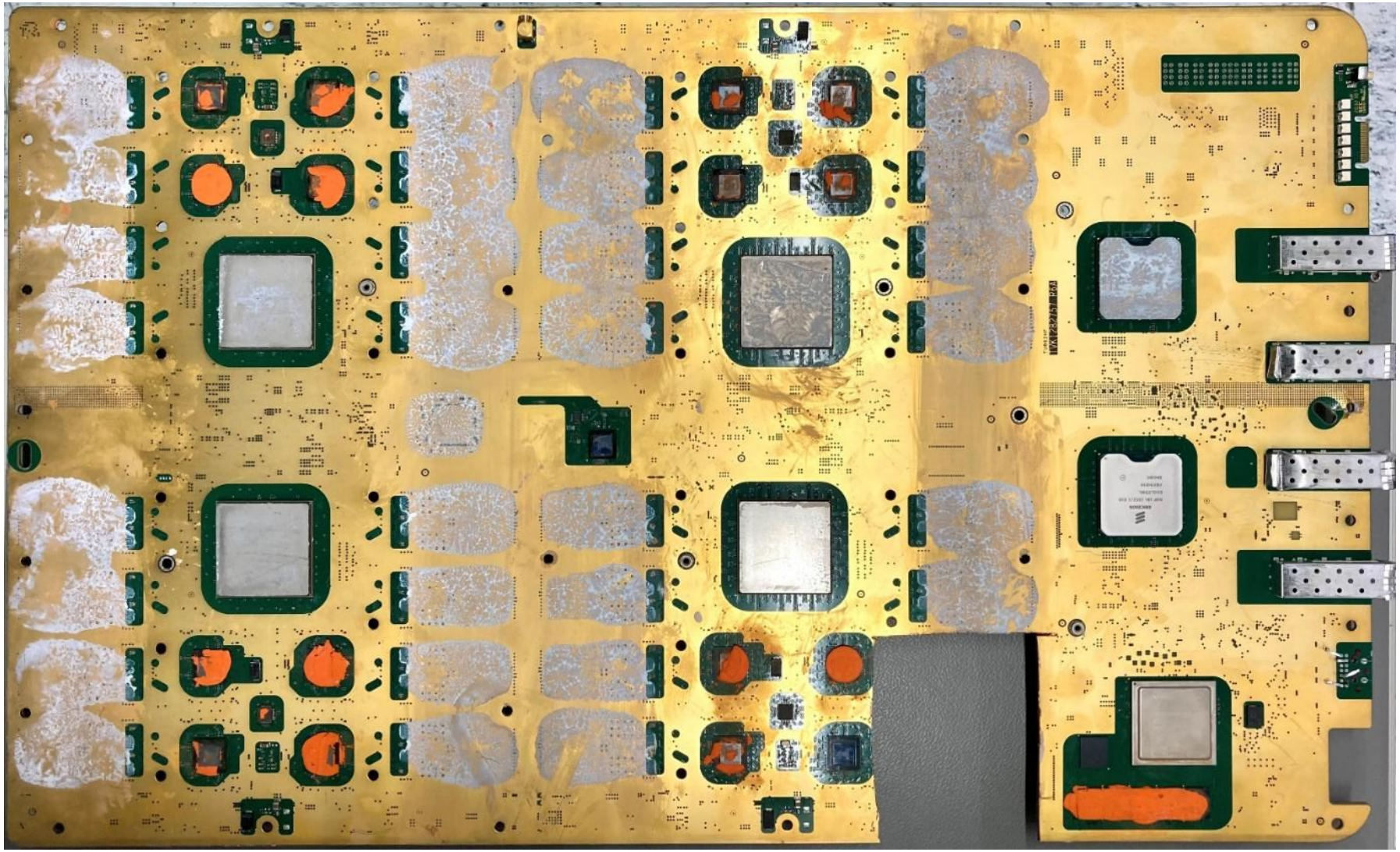
TRX board

Top view



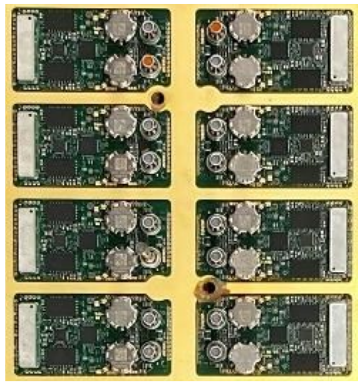
TRX board

Bottom view

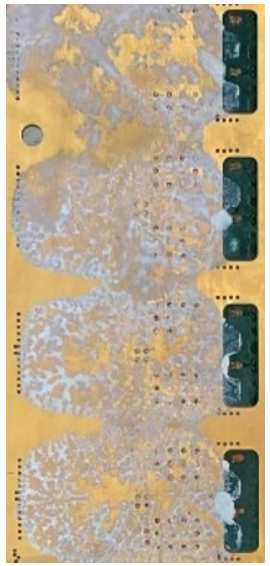


RF frontend

- 64 Transmit and Receive channels grouped in orthogonal polarization pairs



Bottom view

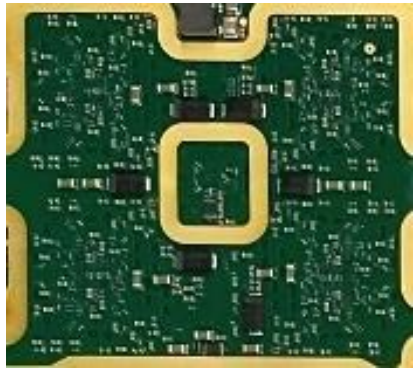


Top view

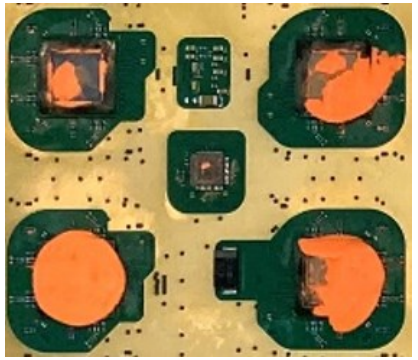
Main Transceivers

- 16 Transcevers: ADI AD80450
  - 4 T/R channels
  - 2 OR channels

Top view

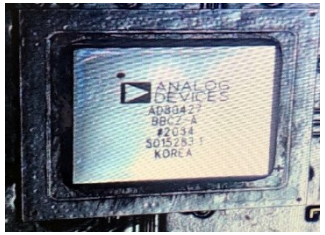


Bottom view

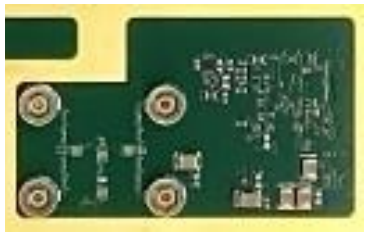


Antenna calibration/measurement transceiver

› 1 Transcever: ADI AD80427



Top view

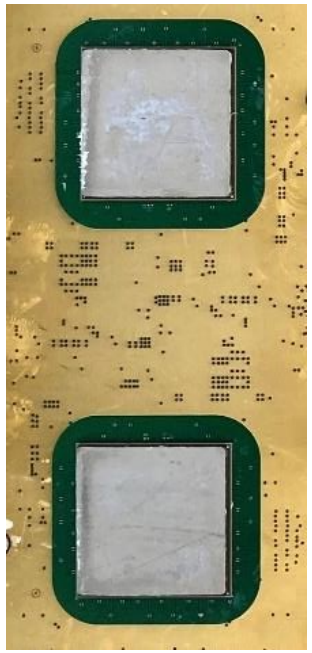


Bottom view

Radon 1.0: control ASIC

- 4 ASICs: Ericsson Radon 1.0:
  - DPD
  - centralizes control interfaces
  - support 16 pipes PA
  - SPI and I2C

Bottom view



Top view

Structure, blocks description

- 2 ASICs: Ericsson EagleOwl:
  - Baseband processing
  - Beamforming
  - eCPRI

Bottom view

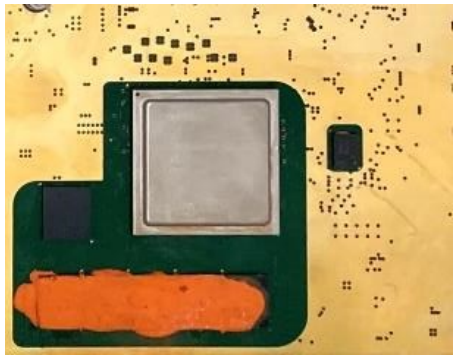
Top view

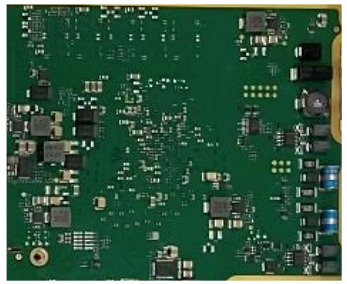
Structure, blocks description

- 1 FPGA: Xilinx Zync UltraScale+ XCZU6EG
  - Maintenance functions:
    - Remote Antenna Extension
    - Alarms
    - EC-light (optional PSU signals)

Top view

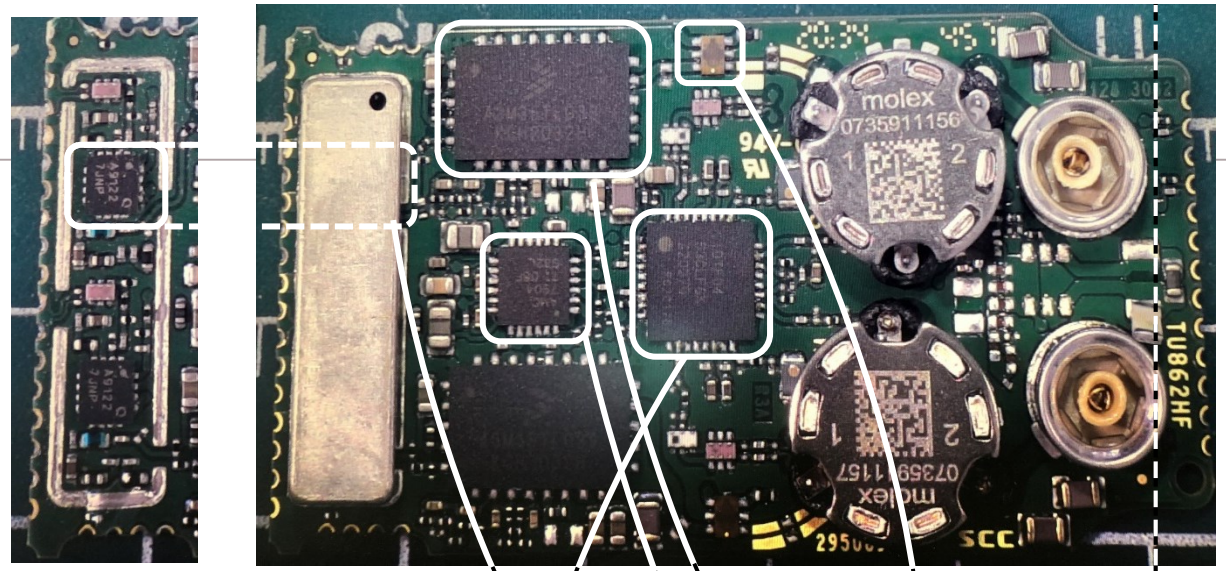
Bottom view

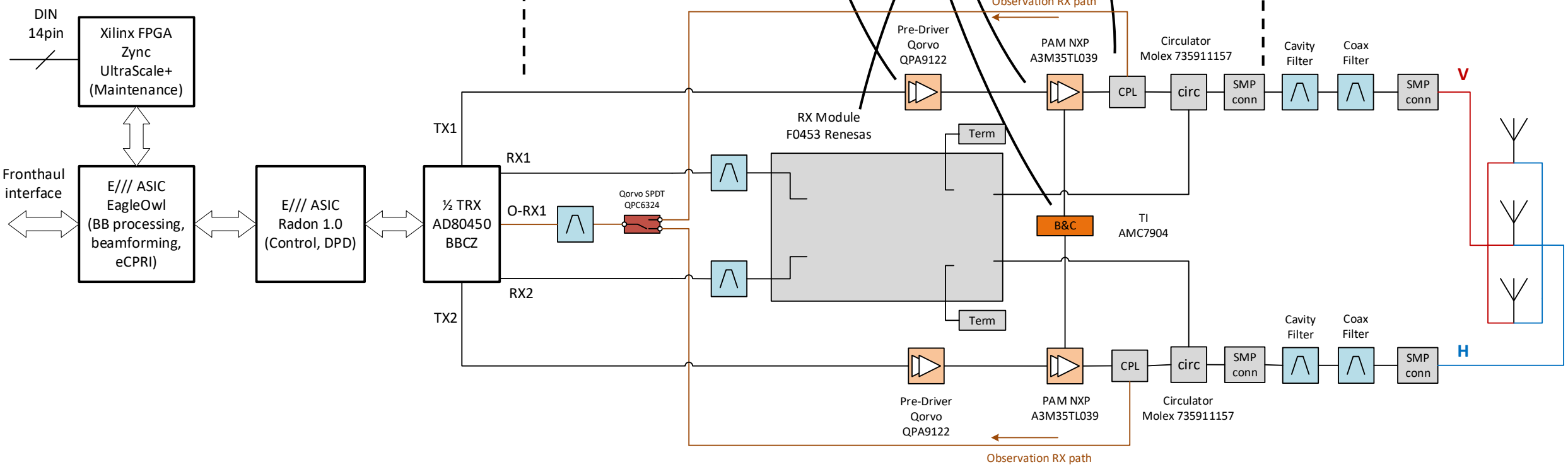




RF frontend block diagram

- Solder-in RF board for various bands
- Pre-Driver shielded with a solder-on cap
- 1 Bias & Control IC per 2 PAMs
- 4-channel Bias & Control per
  8 transistor gates with resistive dividers





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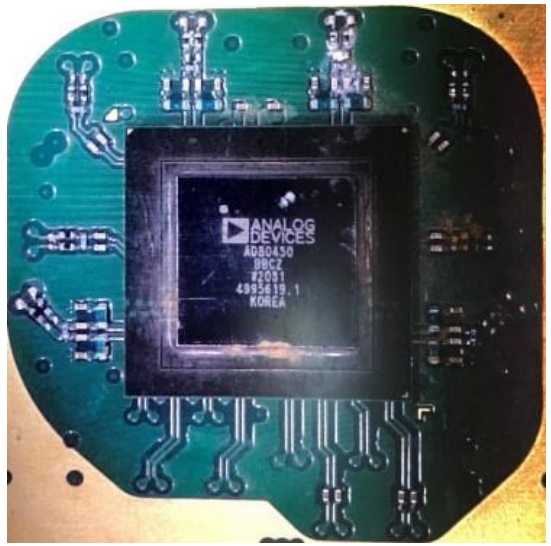
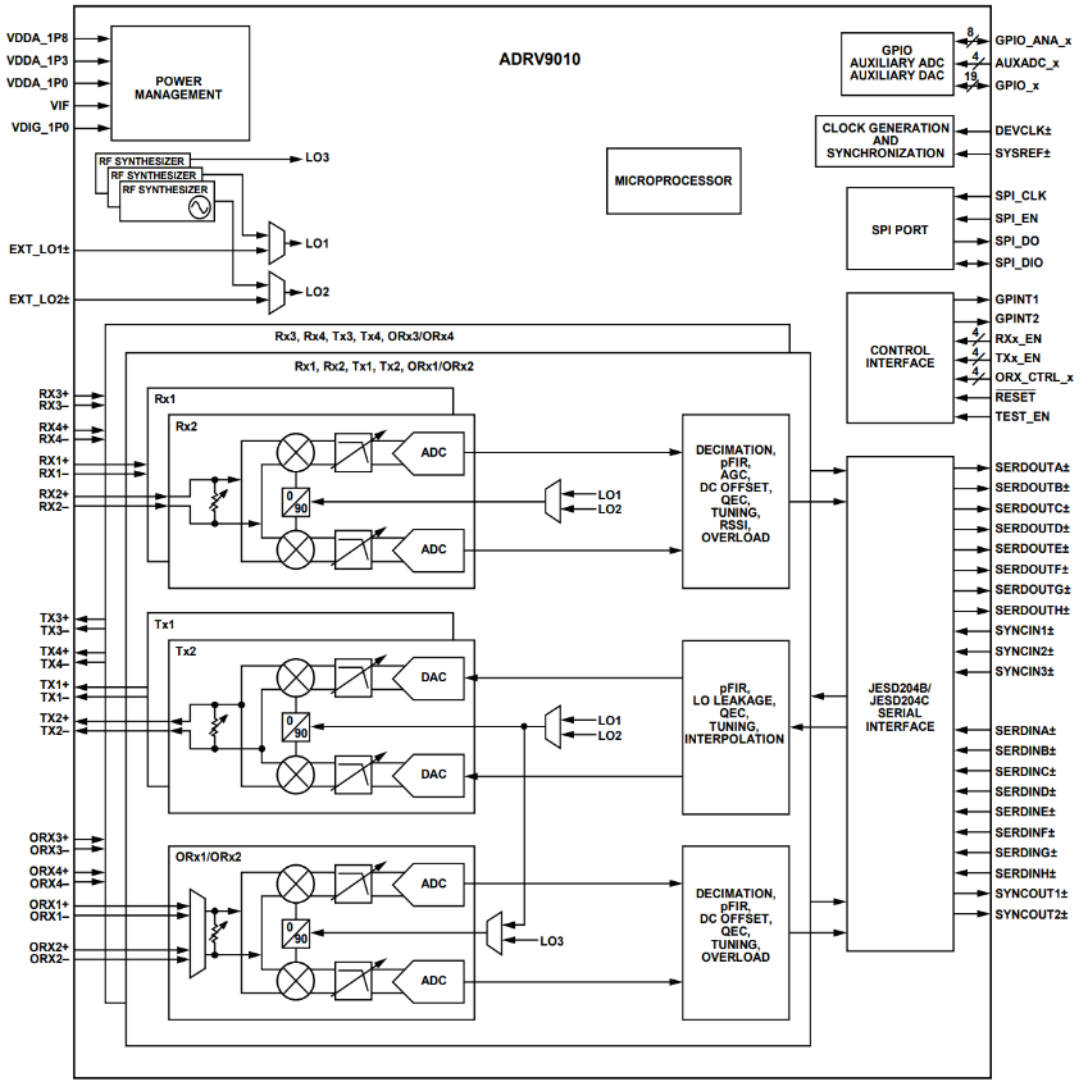
Transceiver overview: AD80450BBCZ

AD80450BBCZ – internal ADI number, Tokelau series

ADRV 9010 (closest among publicly released)

- *Direct conversion (zero-IF) architecture*
- *Frequency Range*
  - 650 - 3800 / 6000 MHz
- *TX*
  - IBW 200MHz
  - 4x differential TX outputs
- *RX*
  - IBW 200MHz
  - 4x differential RX inputs
- *ORX*
  - IBW 450MHz
  - 2x RX / 4x differential inputs
- *5 Frac-N PLLs, Clock Synth*
- *JESD204B/C up to 16.22Gbps*
- *Supply voltages:*
  - Core 1.0V, 1.3V & 1.8V
  - IF 1.8V; Digital 1.0V
- *Contrlol*
  - SPI
  - 19x GPIOs
  - 4x ADC inputs
  - 8x DAC/GPIO





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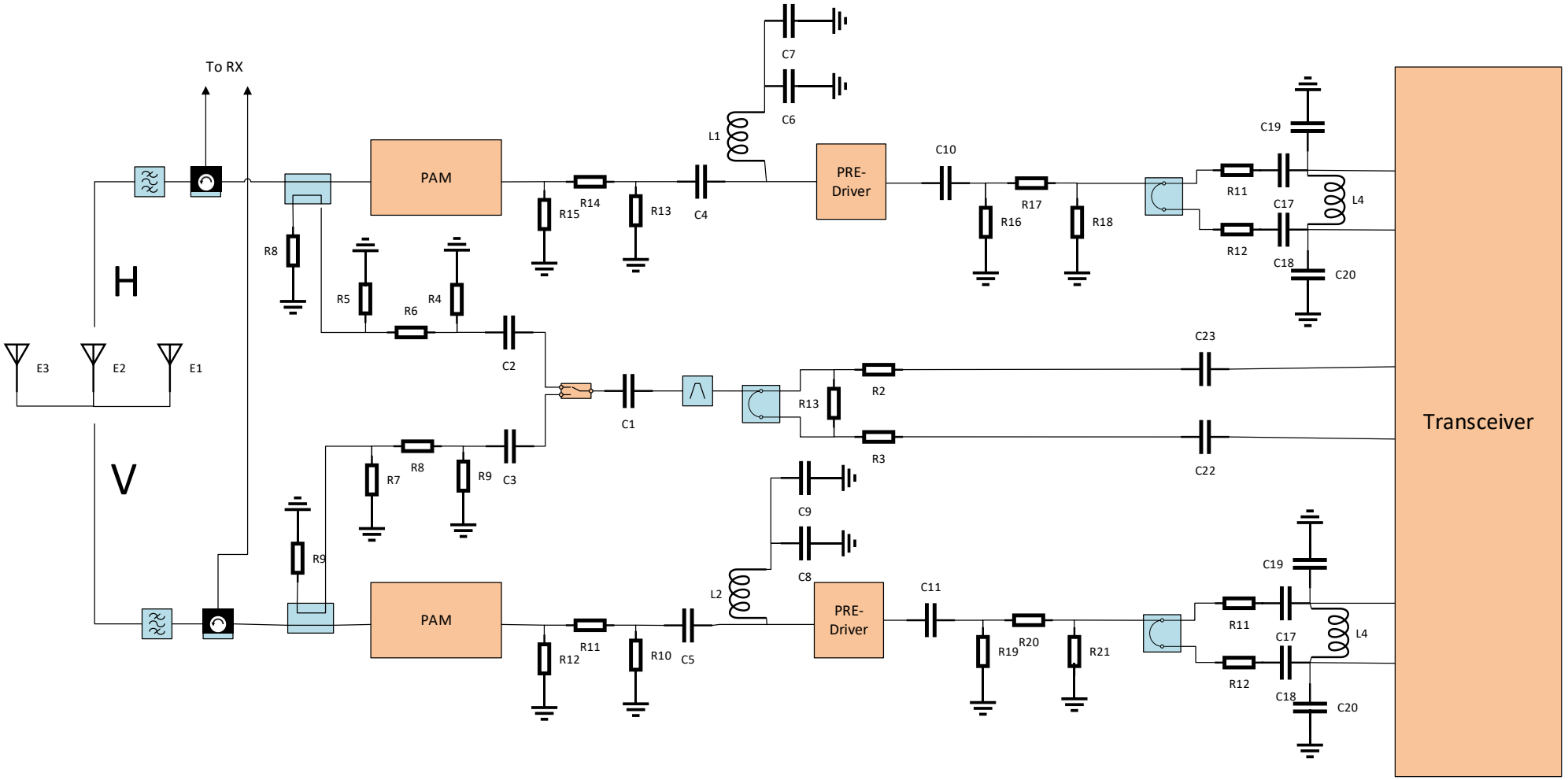
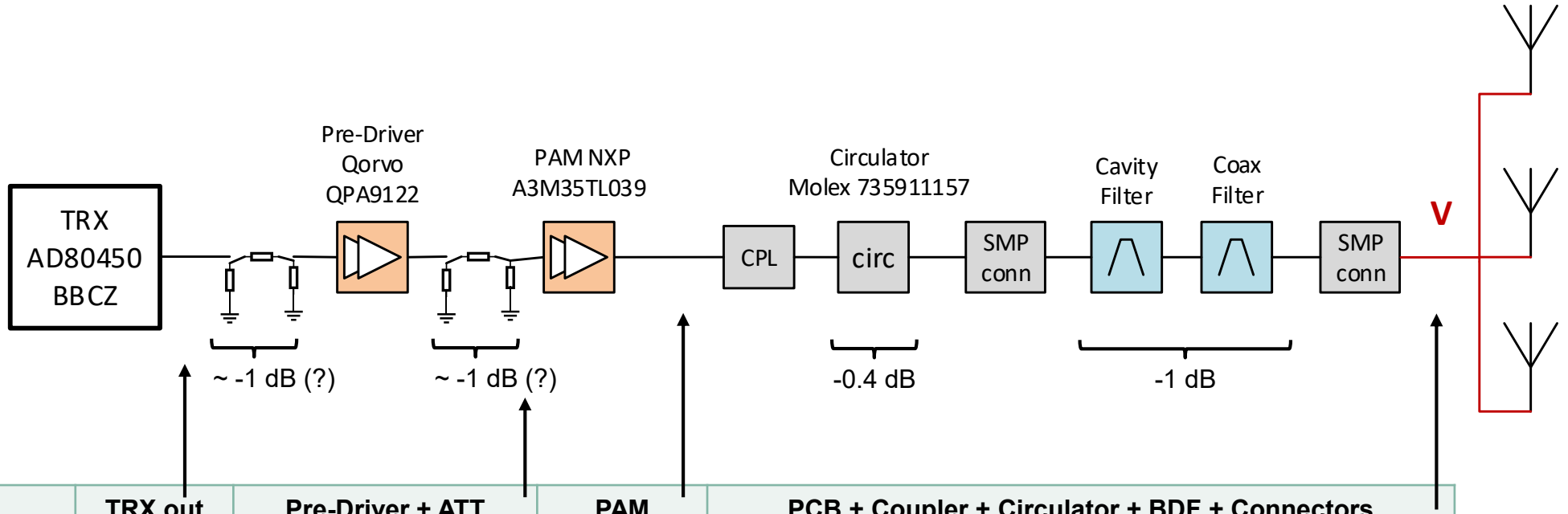
TX lineup, schematic



- Pre-Driver: Qorvo QPA9122 (Wideband GaAs 3-stage)
- PAM: NXP A3M35TL039 (39% eff. LDMOS split driver Doherty)
- O-RX switch: Qorvo QPC6324 (High isolation SOI SPDT switch)

TX lineup, nominal



	TRX out	Pre-Driver + ATT	PAM	PCB + Coupler + Circulator + BDF + Connectors
Gain	-	34 dB	27.5 dB	-1.5 dB
P_{AVG}	-23 dBm	11 dBm	38.5 dBm	37 dBm
	0.005 mW	12.6 mW	7 W	**5 W**
P_{PEAK}	-11 dBm	23 dBm	46.5 dBm	45 dBm
	0.079 mW	200 mW	44.6 W	32 W

TX lineup – Single Path Pre-Driver by Qorvo QPA9122

16 Pad 3 x 3 mm Laminate Package

Key Features

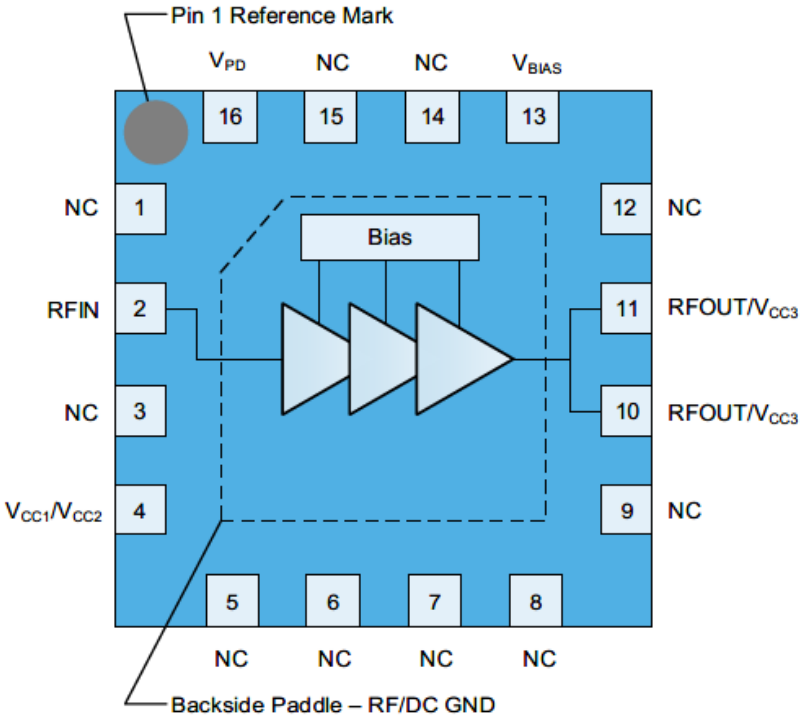
- 2.3 – 5.0 GHz Operational Frequency
- 50Ω Matched RF Input and Output
- +27 dBm P3dB
- 36.0 dB Gain at 2.6 GHz
- +5 V Single Supply, I_{CQ} 95 mA
- DC Power Shutdown Feature

Product Overview

The QPA9122 is a wideband, high gain, and high peak power driver amplifier. It provides 36dB gain at 2.6GHz and achieves a peak power of 27dBm P3dB. With a quiescent current of 95mA, the amplifier can provide good DPD linearity performance with wideband signals of up to 160 MHz IBW making it perfectly suited for m-MIMO applications.

The QPA9122 is internally match to 50Ω over the entire operating frequency band of 2.3 – 5.0 GHz and incorporates a shut-down function through the V_{PD} pin.

The QPA9122 is housed in a 16-pin 3X3mm SMT package and is footprint and pin-compatible to QPA9120 and QPA9121.

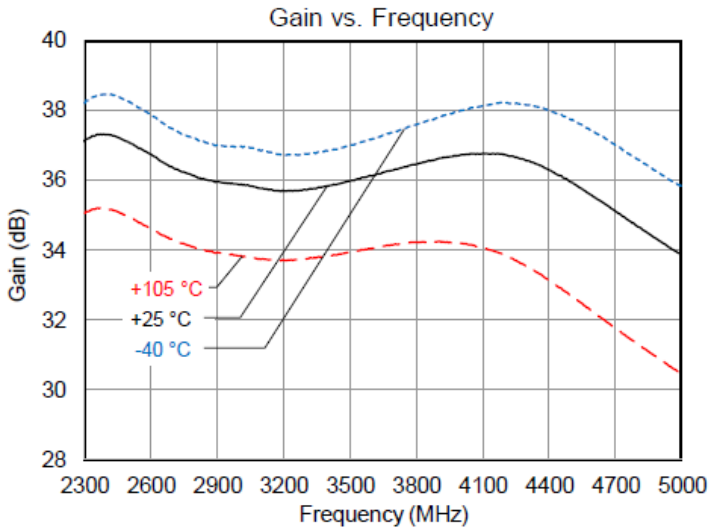


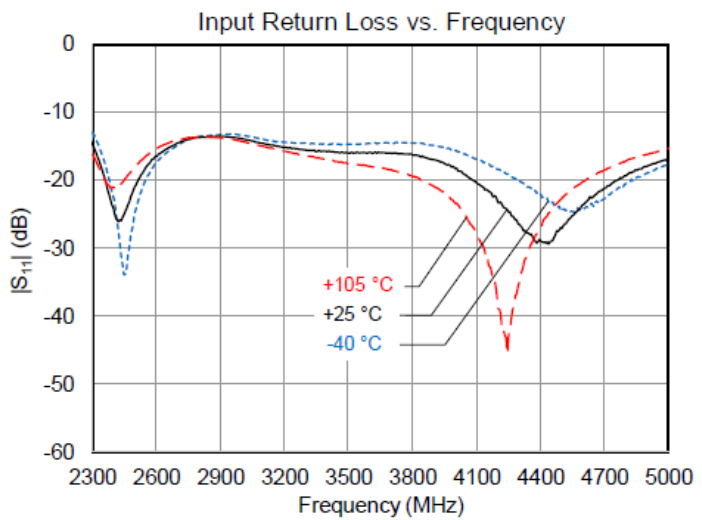
Typical Performance

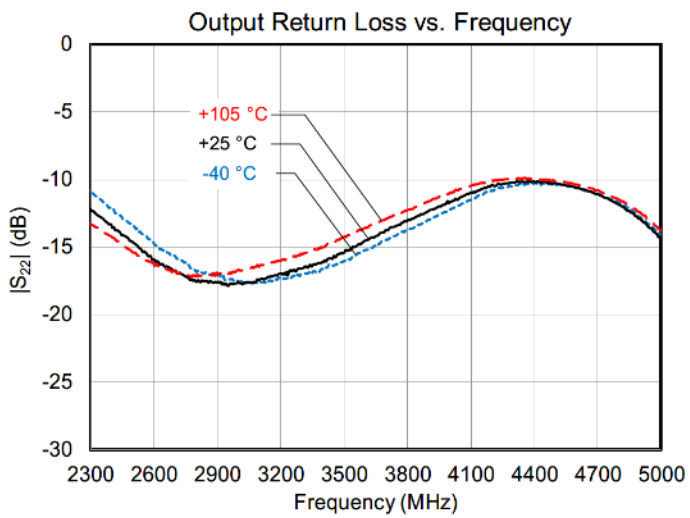
Parameter	Conditions	Typical Value			Units
Frequency		2600	3600	4900	MHz
Gain		36.8	36	34	dB
Input Return Loss		16.6	16.7	18.9	dB
Output Return Loss		17.4	18.1	13.3	dB
Output P3dB		26.9	27.2	26.8	dBm
Output IP3	Pout = +0 dBm/tone, Δf = 1 MHz	32.4	32.9	30.0	dBm
ACPR	Pout=+15 dBm, 1C LTE, 20MHz, 8.5dB PAR	-46.1	-40.7	-38.1	dBc
Device Current	V_{CC} and V_{CC1} combined		95		mA

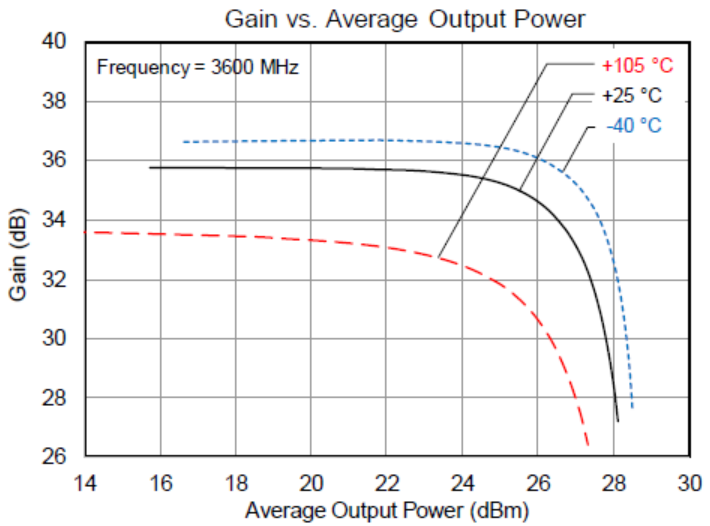
Notes:
1. Test Conditions unless otherwise noted: V_{CC} and V_{CC1} on EVB = +5.0 V, I_{CC} = 95 mA, V_{PD} = +1.8 V, Temp.=+25 °C

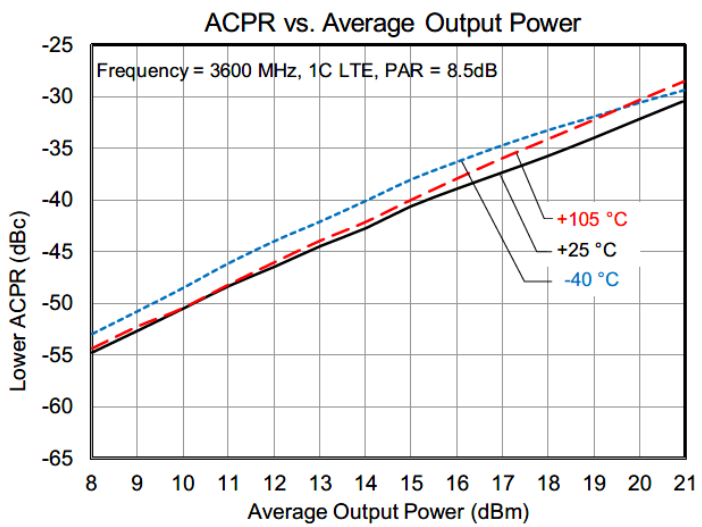
TX lineup – Single Path Pre-Driver by Qorvo QPA9122

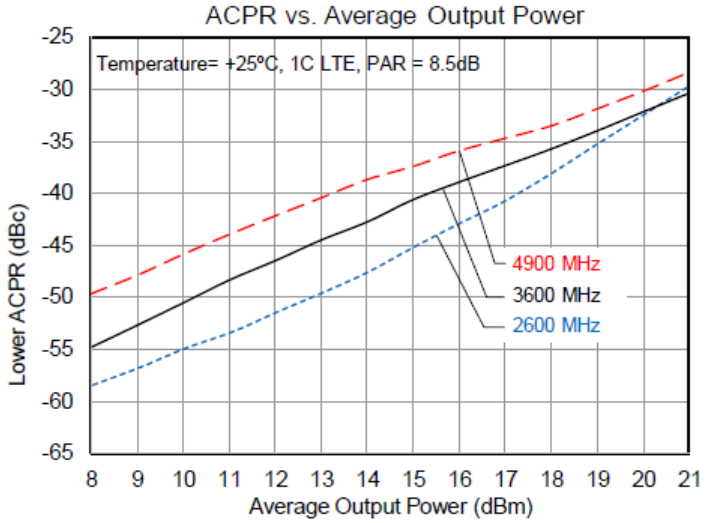








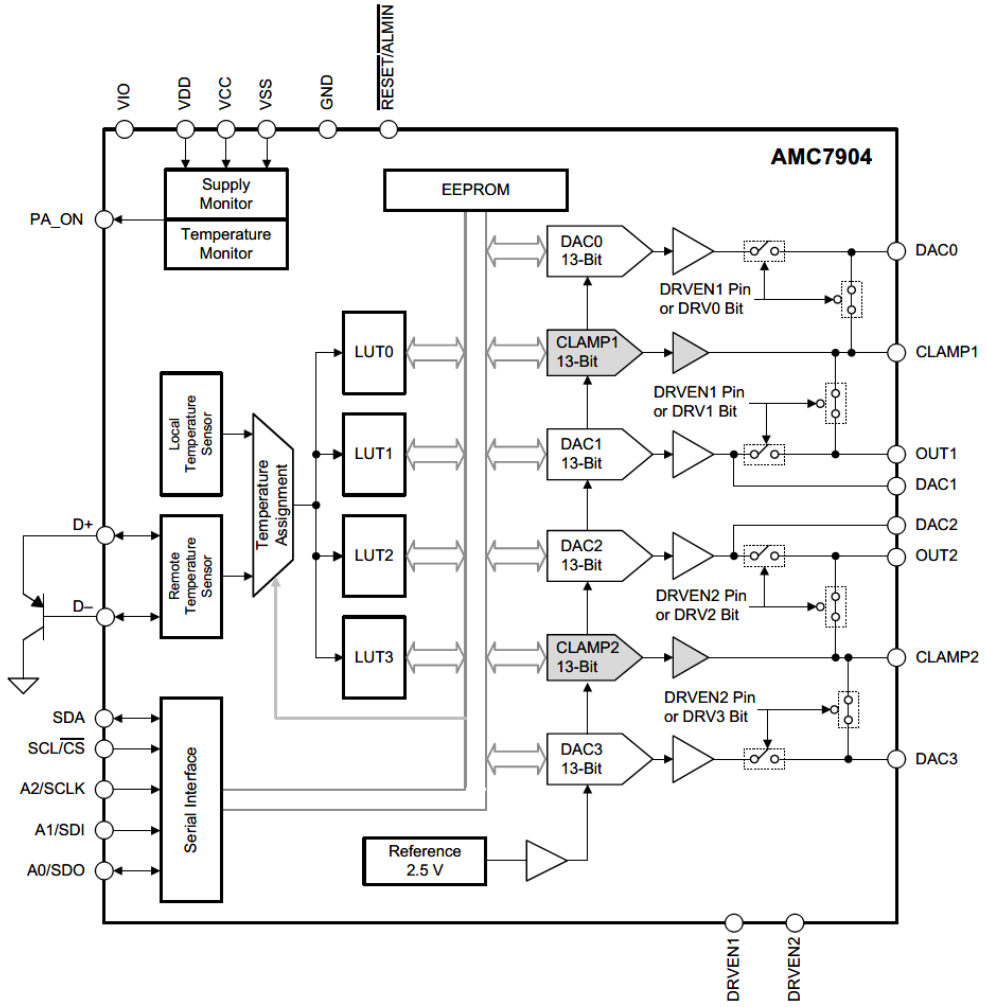




PAM Bias Controller – Quad-Channel ASIC by TI

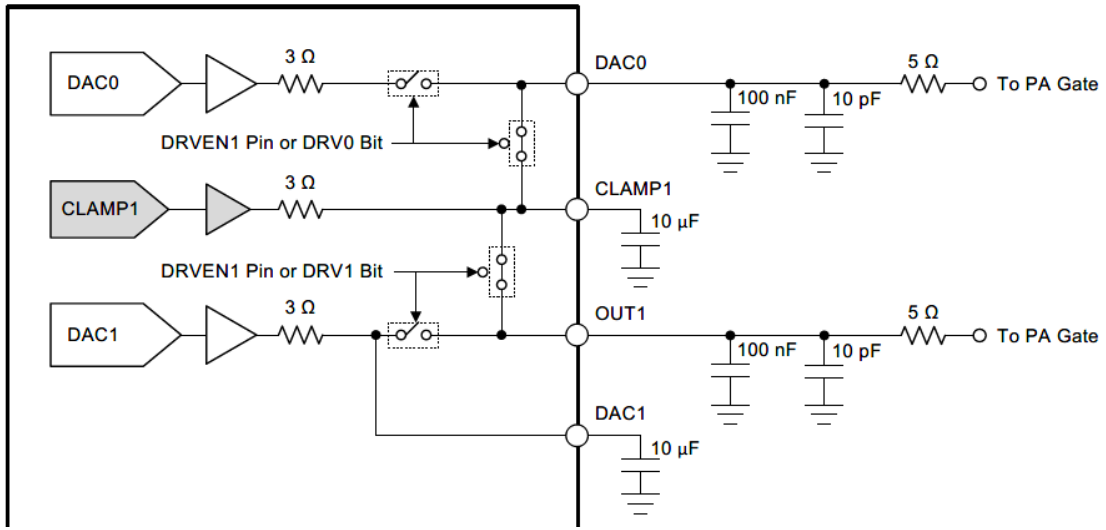
AMC7904

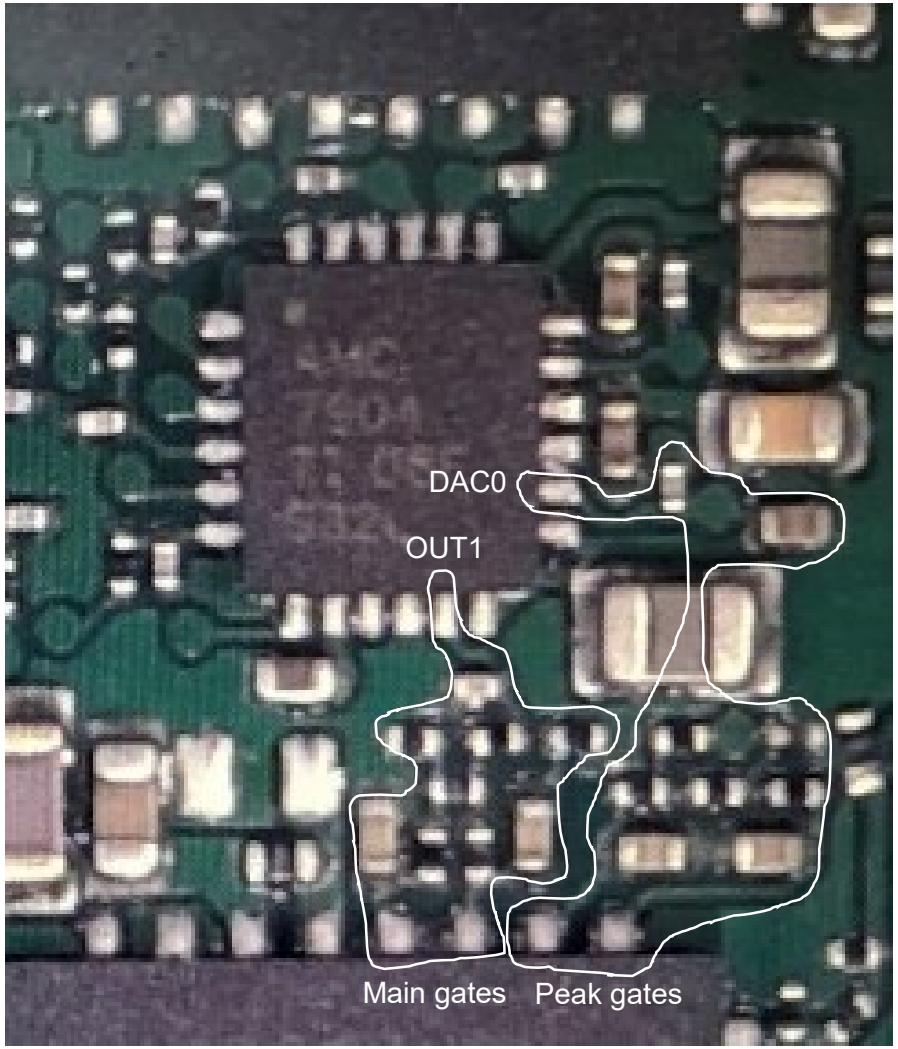
AMC7904: Key features	
DAC outputs	4
DAC resolution	13 bit resistive
Internal EEPROM	4 LUTs, configuration storage
Dual range support	4 outputs
Output range configuration	4 outputs, [-10/0]; [0/5.5] V
Switched outputs	4
Fast switching capable (<<1us)	**yes**
DAC output monitoring	no
DAC output driving capability	100 mA / 20 mA source / sink
DAC output capacitive load	0nF – 15uF
Fast switch R_{ON} DAC / Clamp	2 Ω / 10 Ω (nom)
High-side current sense ADC	no
Temperature sensing	Integrated + 1 remote diode driver
Control interface	SPI / I2C
Operational Temp range	-40 … +150 °C
Package	4x4 mm / 24 pins VQFN



PAM Bias Controller – Quad-Channel ASIC by TI

AMC7904





- AMC7904 has two OUTx pins. These pins can have fast Vgs-on to Vgs-pinchoff transitions, as well as fast Vgs-pinchoff to Vgs-on transitions. The other two channels, DAC0 and DAC3, only have fast Vgs-on to Vgs-pinchoff transitions.
- Resistive dividers used to provide bias to 8 LDMOS Gates (on 2 PAMs): one DAC output feeds two peak gates, one switched OUT feeds two main gates.

TX lineup – PAM by NXP **A3M35TL039**

Power Amplifier Module for LTE and 5G

The A3M35TL039 is a fully integrated Doherty power amplifier module designed for wireless infrastructure applications that demand high performance in the smallest footprint. Ideal for applications in massive MIMO systems, outdoor small cells and low power remote radio heads. The field-proven LDMOS power amplifiers are designed for TDD and FDD LTE systems.

3400–3650 MHz

- Typical LTE Performance: P_{out} = 7 W Avg., V_{DD} = 26 Vdc, 1 × 20 MHz LTE, Input Signal PAR = 8 dB @ 0.01% Probability on CCDF. (1)

Carrier Center Frequency	Gain (dB)	ACPR (dBc)	PAE (%)
3410 MHz	28.6	–28.8	40.8
3500 MHz	28.3	–30.7	40.5
3590 MHz	28.1	–31.6	39.4
3640 MHz	28.1	–30.8	38.9

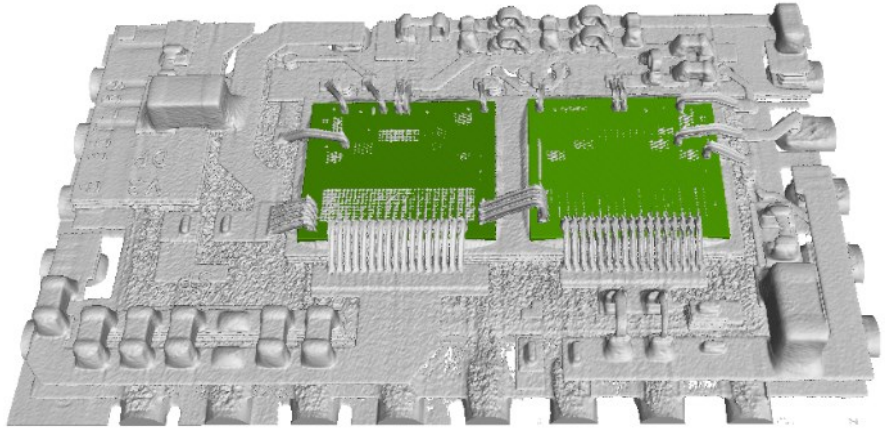
1. All data measured with device soldered in NXP reference circuit.

- Advanced high performance in-package Doherty
- Fully matched (50 ohm input/output, DC blocked)
- Designed for low complexity analog or digital linearization systems

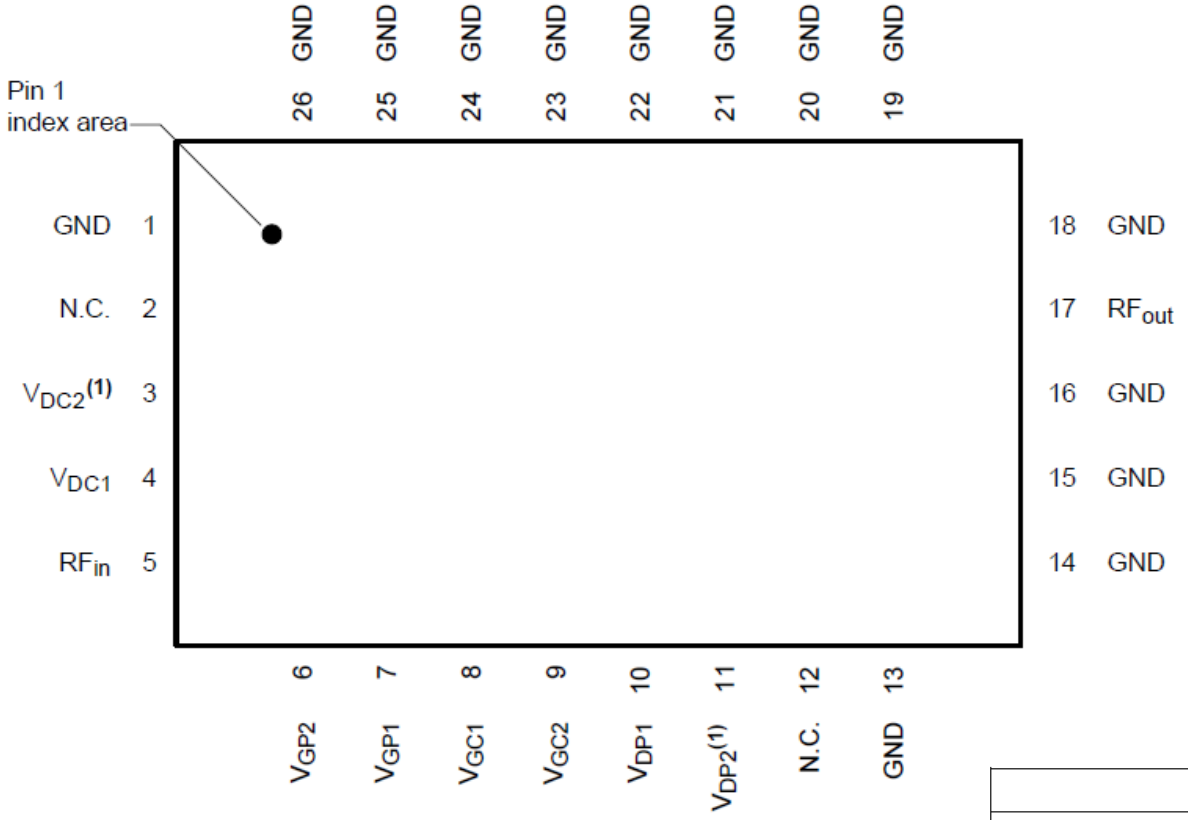
A3M35TL039

3400–3650 MHz, 28 dB, 7 W Avg. AIRFAST POWER AMPLIFIER MODULE

10 mm × 6 mm Module



TX lineup – PAM by NXP



3	V_{DC2}	Carrier Drain Supply, Stage 2
4	V_{DC1}	Carrier Drain Supply, Stage 1
5	RF_{in}	RF Input
6	V_{GP2}	Peaking Gate Supply, Stage 2
7	V_{GP1}	Peaking Gate Supply, Stage 1
8	V_{GC1}	Carrier Gate Supply, Stage 1
9	V_{GC2}	Carrier Gate Supply, Stage 2
10	V_{DP1}	Peaking Drain Supply, Stage 1
11	V_{DP2}	Peaking Drain Supply, Stage 2
17	RF_{out}	RF Output

› ***Two-stage dual driver Doherty architecture***

Characteristic	Symbol	Value	Unit
Mean Time to Failure Case Temperature 125°C, 7 W Avg., 30 Vdc	MTTF	>10	Years

Table 4. ESD Protection Characteristics

Test Methodology	Class
Human Body Model (per JS-001-2017)	1B
Charge Device Model (per JS-002-2014)	C2a

TX lineup – PAM by NXP

Functional Tests — 3400 MHz (1) (In NXP Doherty Production ATE (2) Test Fixture, 50 ohm system) V_{DD} = 26 Vdc, I_{DQ1A} = 23 mA, I_{DQ2A} = 72 mA, V_{GS1B} = (V_t – 0.2) Vdc, V_{GS2B} = (V_t – 0.25) Vdc, P_{out} = 7 W Avg., 1-tone CW, f = 3400 MHz.

Gain	G	26.8	28.8	—	dB
Drain Efficiency	η_D	36.0	42.7	—	%
P_{out} @ 3 dB Compression Point	P3dB	46.0	47.0	—	dBm

Functional Tests — 3600 MHz (1) (In NXP Doherty Production ATE (2) Test Fixture, 50 ohm system) V_{DD} = 26 Vdc, I_{DQ1A} = 23 mA, I_{DQ2A} = 72 mA, V_{GS1B} = (V_t – 0.2) Vdc, V_{GS2B} = (V_t – 0.25) Vdc, P_{out} = 7 W Avg., 1-tone CW, f = 3600 MHz.

Gain	G	26.5	27.8	—	dB
Drain Efficiency	η_D	34.5	39.4	—	%
P_{out} @ 3 dB Compression Point	P3dB	45.4	46.2	—	dBm

Wideband Ruggedness (3) (In NXP Doherty Power Amplifier Module Reference Circuit, 50 ohm system) I_{DQ1A} = 23 mA, I_{DQ2A} = 72 mA, V_{GSP1} = 1.5 Vdc, V_{GSP2} = 1.35 Vdc, f = 3500 MHz, Additive White Gaussian Noise (AWGN) with 10 dB PAR

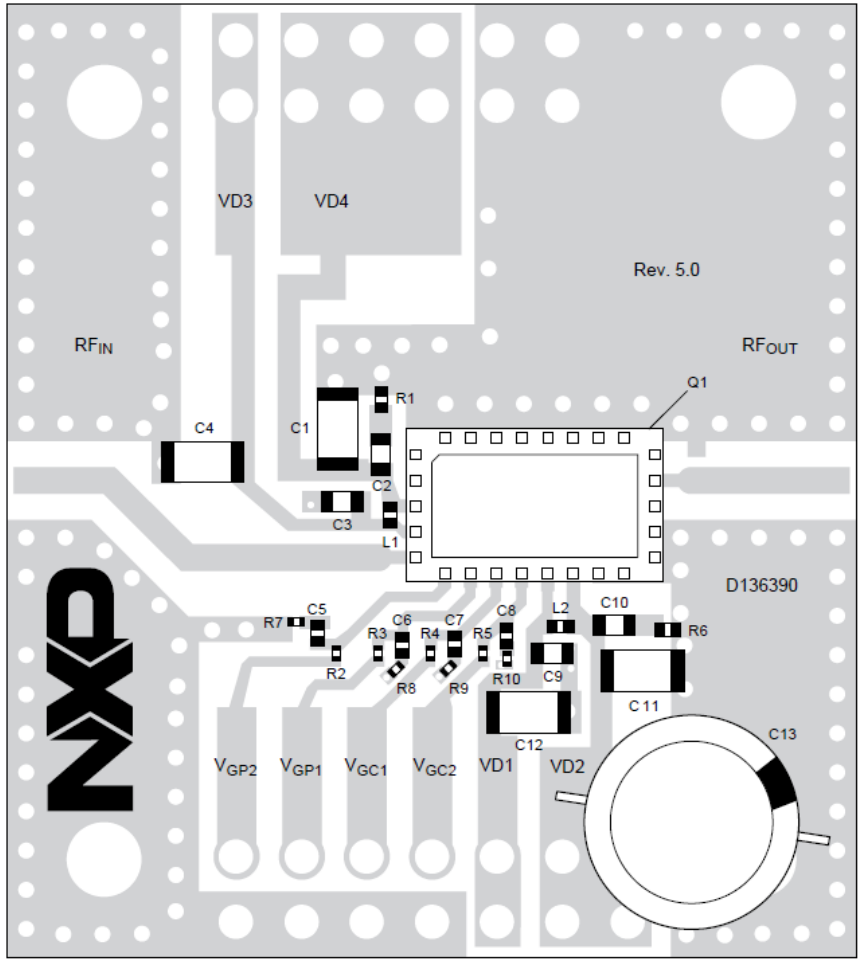
ISBW of 400 MHz at 30 Vdc, 3 dB Input Overdrive from 7 W Avg. Modulated Output Power	No Device Degradation

Typical Performance (3) (In NXP Doherty Power Amplifier Module Reference Circuit, 50 ohm system) V_{DD} = 26 Vdc, I_{DQ1A} = 23 mA, I_{DQ2A} = 72 mA, V_{GSP1} = 1.5 Vdc, V_{GSP2} = 1.35 Vdc, P_{out} = 7 W Avg., 3500 MHz

VBW Resonance Point, 2-tone, 1 MHz Tone Spacing (IMD Third Order Intermodulation Inflection Point)	VBW_{res}	—	360	—	MHz

1-carrier 20 MHz LTE, 8 dB Input Signal PAR					
Gain	G	—	28.3	—	dB
Power Added Efficiency	PAE	—	40.5	—	%
Adjacent Channel Power Ratio	ACPR	—	–30.7	—	dBc

Gain Variation @ Avg. Power over Temperature (–40°C to +105°C)	ΔG	—	0.037	—	dB/°C
P3dB Variation over Temperature (–40°C to +105°C)	P3dB	—	0.013	—	dB/°C



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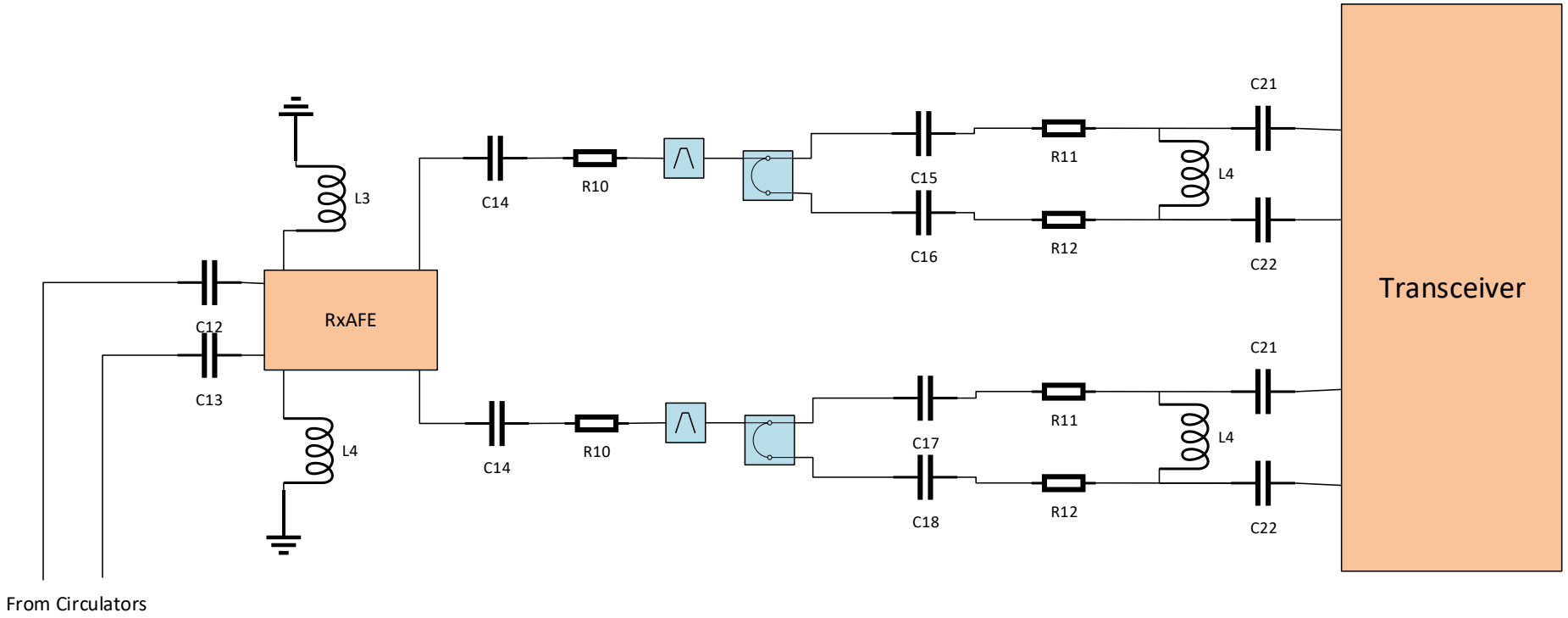
RX lineup, schematic



› Dual path RX Module: Renesas (IDT) F0453C

RX lineup – Dual Path Rx Switch with LNA by Renesas **F0453C**

Features

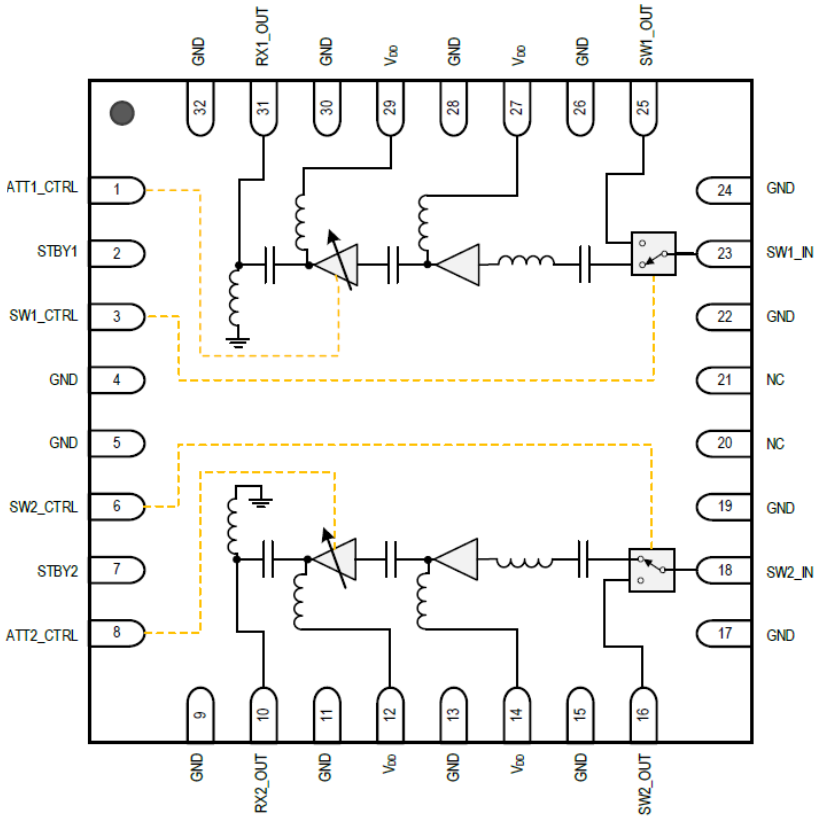
- Gain at 3500MHz
  - 35dB typical in High Gain Mode
  - 29dB typical in Low Gain Mode
- 1.35dB NF at 3500MHz
- +23dBm OIP3 at 3500MHz
- OP1dB at 3500MHz
  - +15dBm in High Gain Mode
  - +14dBm in Low Gain Mode
- 50Ω single-ended input / output amplifier impedances
- I_{DD} = 130mA
- Independent Standby Mode for power savings
- Supply voltage: +3.15V to +3.45V
- 6 × 6 mm, 32-pin LGA package
- -40°C to +105°C exposed pad operating temperature range

Description

The F0453C is an integrated dual-path RF front-end consisting of an RF switch and two gain stages with 6dB gain control used in the analog front-end receiver of an Active Antenna System (AAS). The F0453C supports frequencies from 3300MHz to 4000MHz.

The F0453C provides 35dB gain with +23dBm OIP3, +15dBm output P1dB, and 1.35dB noise figure at 3500MHz. Gain is reduced 6dB in a single step with a maximum gain settling time of 31ns. The device uses a single 3.3V supply and 130mA of I_{DD}.

The F0453C is offered in a 6 × 6 × 0.75 mm, 32-LGA package with 50Ω input and output amplifier impedances for ease of integration into the signal path.



› Maximum input power in TX mode at SW1_IN / SW2_IN: 33dBm

› NF = 1.35dB – 1.5dB, 3.3GHz – 4.0GHz; max 2.5dB at T_{EPAD}=+105°C

› Rx1_OUT to RX2_OUT isolation ^{MIN} = 55dB – 50dB, 3.3GHz – 4.0GHz

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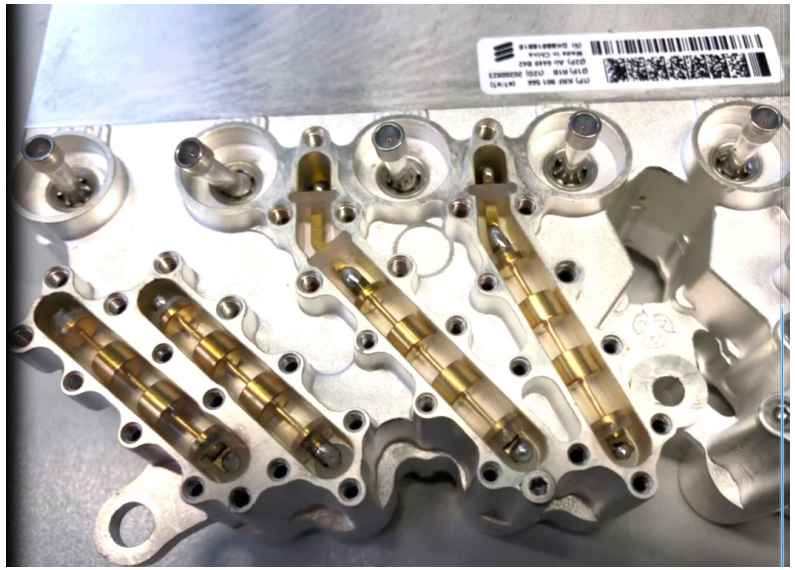
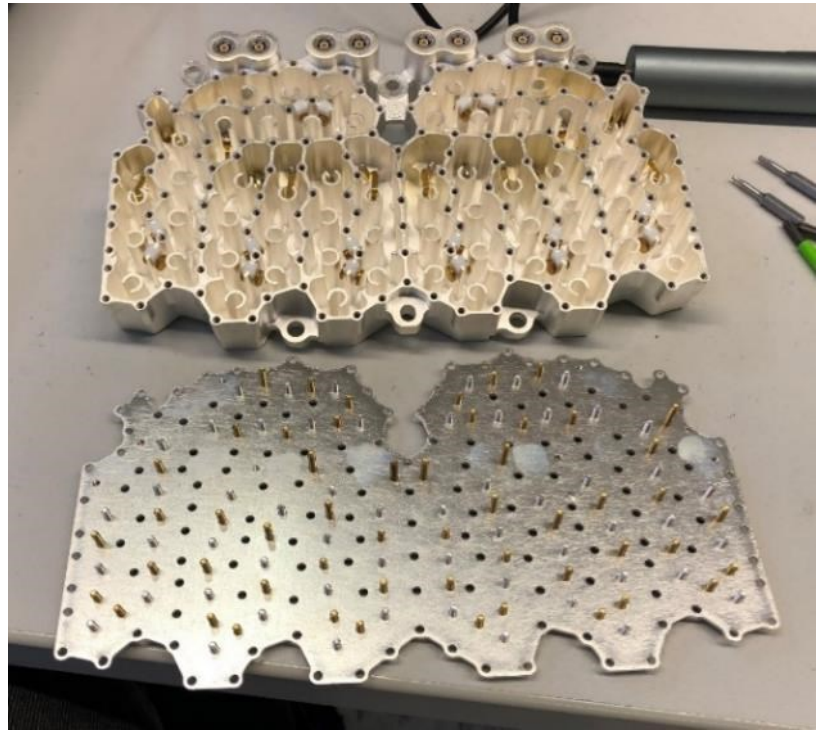
Bandpass Filter Bank with Tuned Waveguide and Cavity Resonators

Tuning screws have their heads sawn off and secured with epoxy

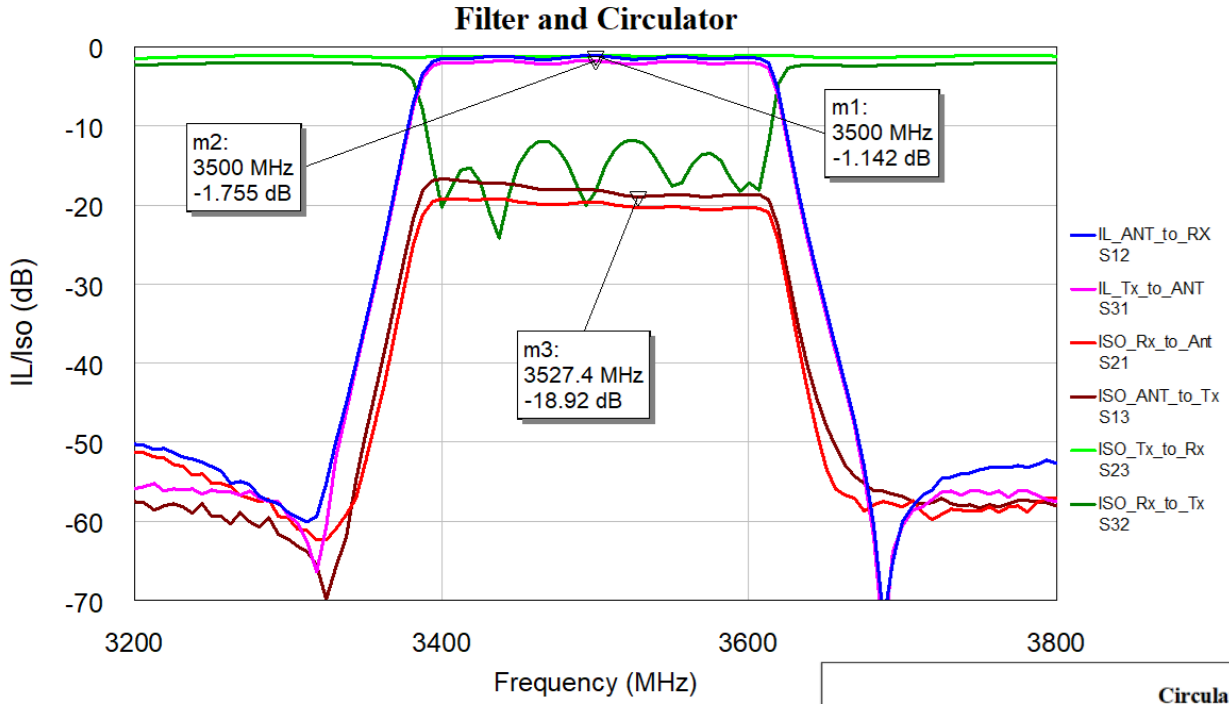


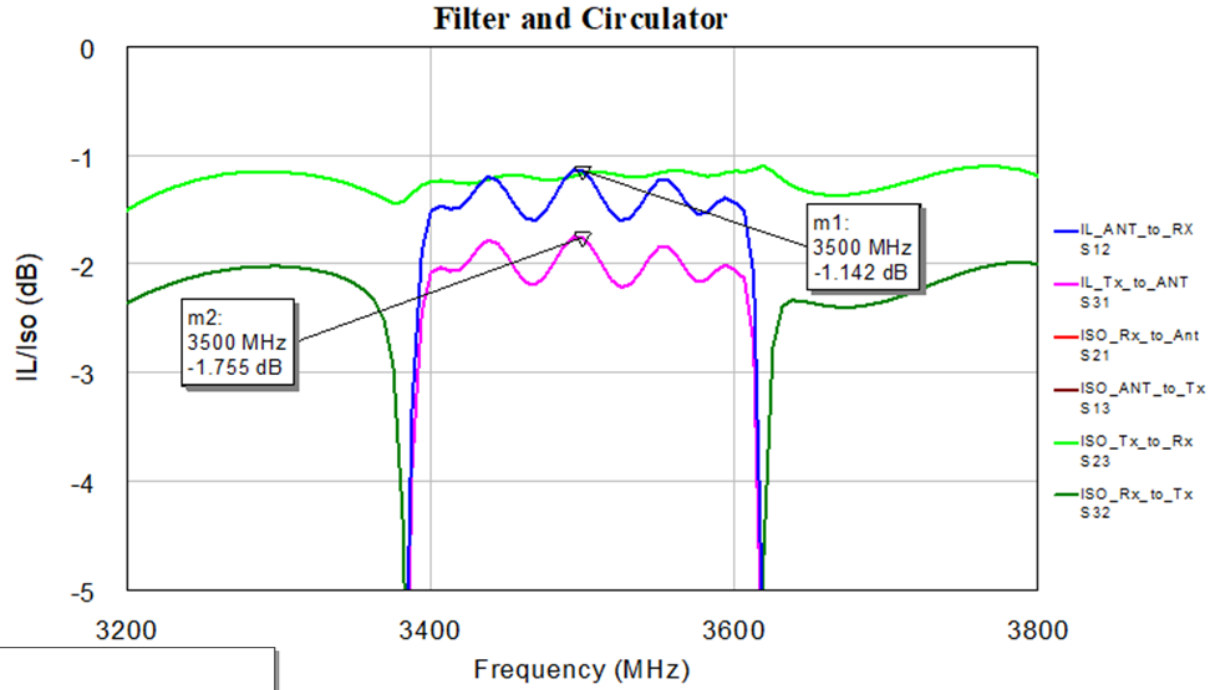
- <0.8dB loss with RF BW of 200MHz
- Expected total post PA loss <1.5dB

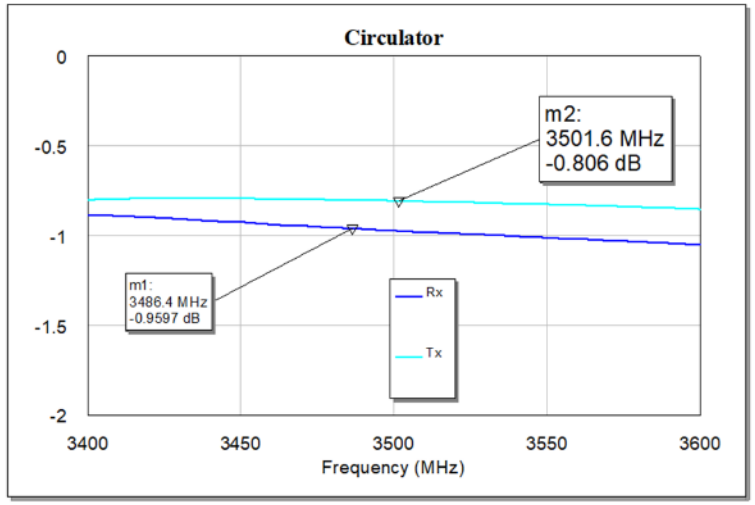
- BPF housing



Bandpass Filter Bank with Tuned Waveguide and Cavity Resonators







- <1.2dB Circulator + BPF loss with RF BW of 200MHz in Rx path
- Circulator ~0.3-0.5dB
- BPF~0.7dB
- Traces ~0.3dB
- Expected total post PA loss ~1.5-1.75dB
- Matching affects IL

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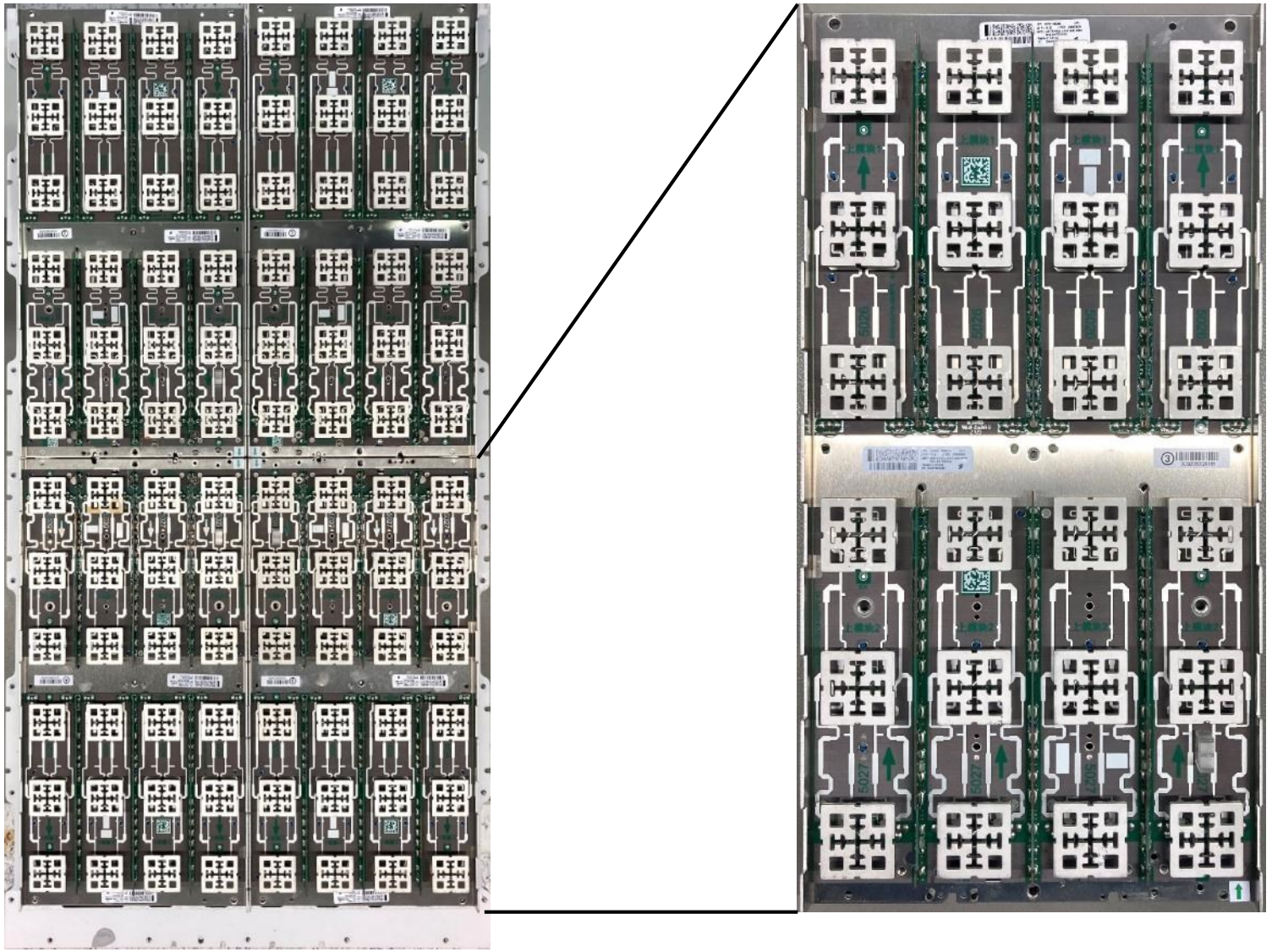
AAS Antenna Assembly

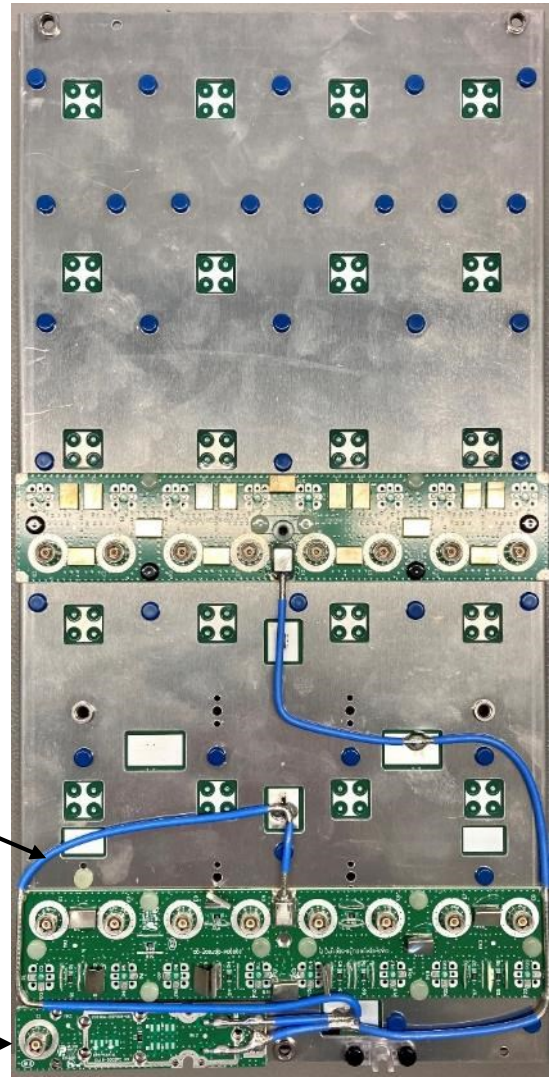
- 96 ANT element array (~19.8dBi array gain)
- Dual polarization with diagonal in-phase and alternating corner, offset, excitation per element
- 32 channels per polarization (160W RF TRP per polarization, 320W total)
- Raised flat patterned ANT elements (reduces losses, aids in heat dissipation?)
- 1 PAM exciter per 3 ANT elements
- Element separation B41: Δ_H=59mm, Δ_V=66mm

› Quad section assembly



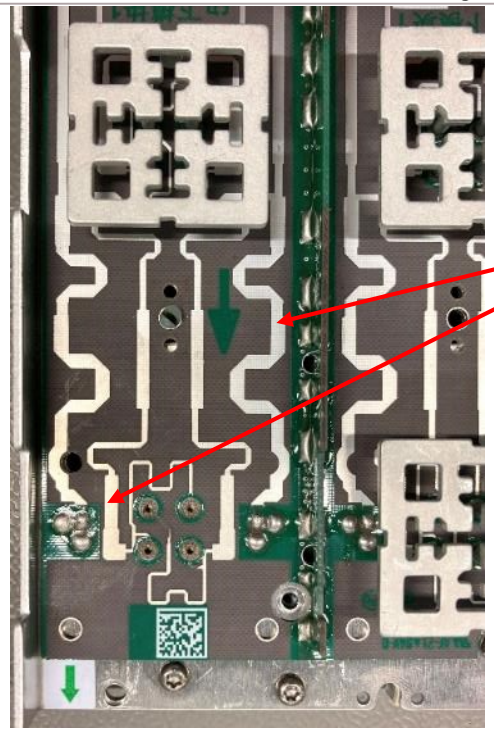
AAS Antenna Assembly – back side / Test

- Signal distribution carried out on front side
- Calibration signal is twigged on back side and terminated in final product

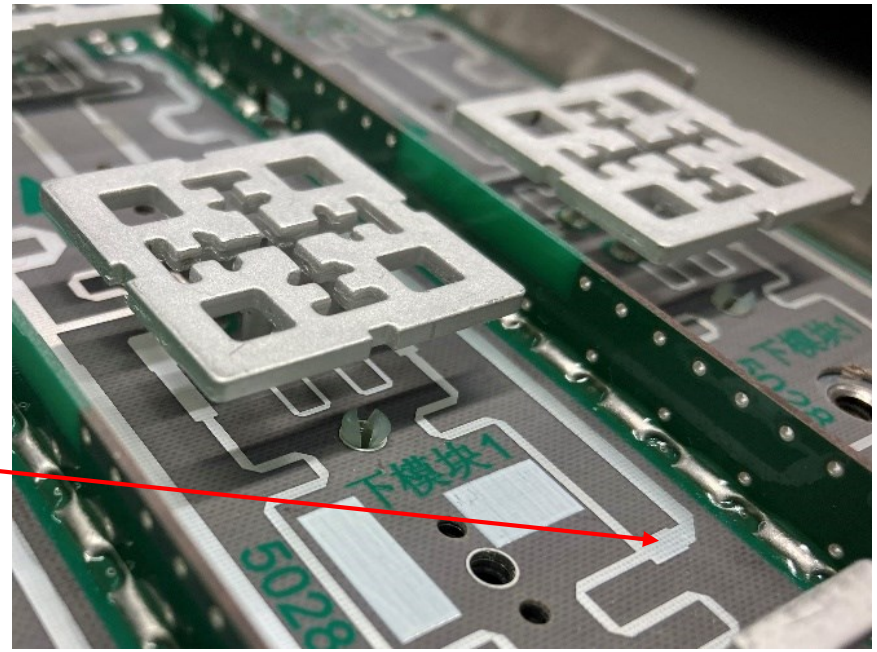


- Boresight total EiRP ~ 77.0dBm
- 32.3dBm radiated power per element
- 77.0dBm = 32.3dBm + 20log(96) + $Gain_{ELEM}$, → $Gain_{ELEM}$ =5.0dB
- HPBW (half-power beam width) for broadside beam in reference direction (θ, ϕ) = (96°, 0°):
  - 12.5° horizontal
  - 7.5° vertical
- Scan range:
  - ±60° horizontal
  - ±18° vertical
- TDD DL duty cycle = 75%

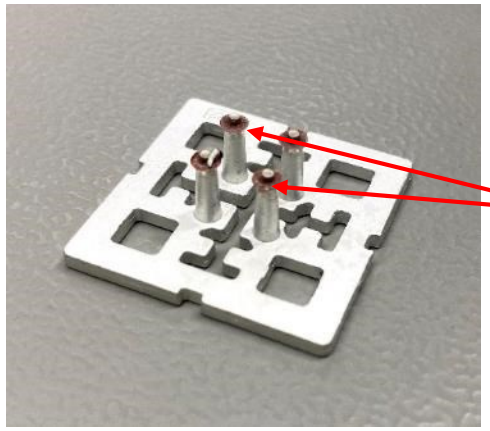
AAS Antenna Assembly – ELEM design and RF signal distribution



RF signal splitting, matching, phase rotation and equalization lines, labeled for generality.

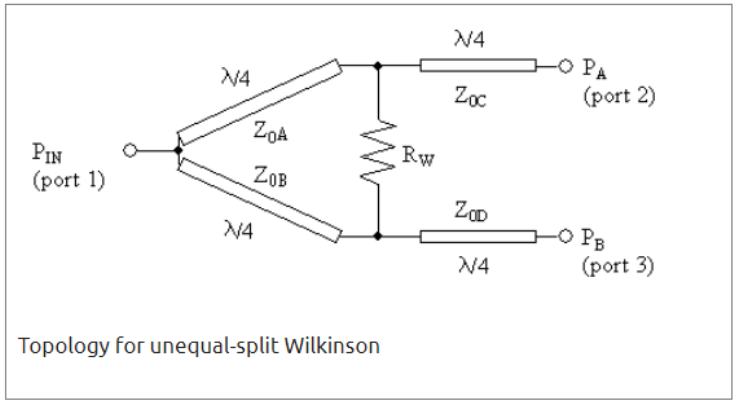


Asymmetric power split in 2 stages between 3 ELEMs

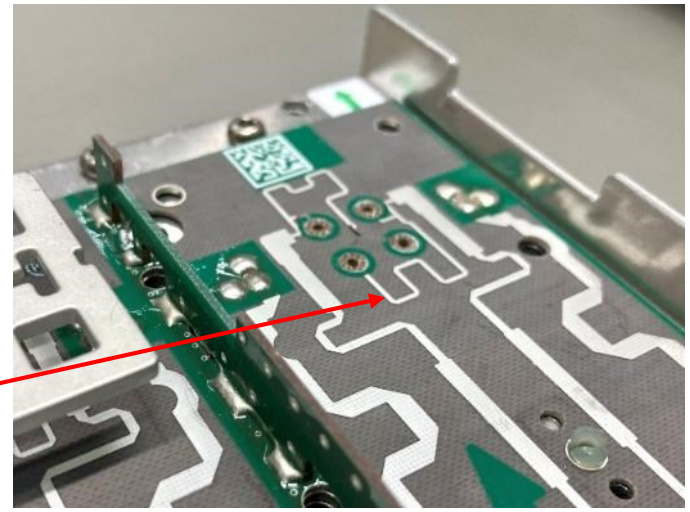


Excitation points for same polarization

Example of asymmetric power split using Wilkinson combiner



Topology for unequal-split Wilkinson



90° delay line

AAS RRU installed on roof-tops, masts, walls, poles and similar structures

Description	Value			
EIRP	Parameter	H0°V6°	H55°V6°	H0°V18°
	Vertical Beamwidth	6°	7°	6°
	Horizontal Beamwidth	12.5°	21°	13°
	Peak EIRP (Typ)	2 x 77 dBm	2 x 73 dBm	2 x 74 dBm

- Broad and thin beam (vertically squeezed)
- Variable downtilt
- Max side lobe suppression

Unit	Scenario: Macro	Beam LTE	Beam NR
	Parameter	BrM1(1), BrM2(2)	BrM1(1)
AIR 6449 B42	Vertical Beamwidth	–	6±1°
	Horizontal Beamwidth	–	65±5°
	Digital Downtilt	–	−3° to 11°
	Vertical Beam Pointing Error	–	≤ 1°
	Horizontal Beam Pointing Direction	–	0±5°
	EIRP (Typical)	–	1 × 73 dBm
	Vertical Side Lobe Suppression	–	15 dB
	Front to Back Ratio	–	25 dB
	Beam Parallelity	–	N/A

- Broad and thick beam (less squeezed)
- Fixed downtilt
- Lowest EiRP

Scenario: Hotspot	Beam LTE	Beam NR
Parameter	BrHS1(1), BrHS2(2)	BrHS1(1)
Vertical Beamwidth	–	26±3°
Horizontal Beamwidth	–	65±5°
Digital Downtilt	–	Fixed 6°
Vertical Beam Pointing Error	–	≤ 1°
Horizontal Beam Pointing Direction	–	0±5°
EIRP (Typical)	–	1 × 67 dBm
Vertical Side Lobe Suppression	–	11 dB
Front to Back Ratio	–	–
Beam Parallelity	–	N/A

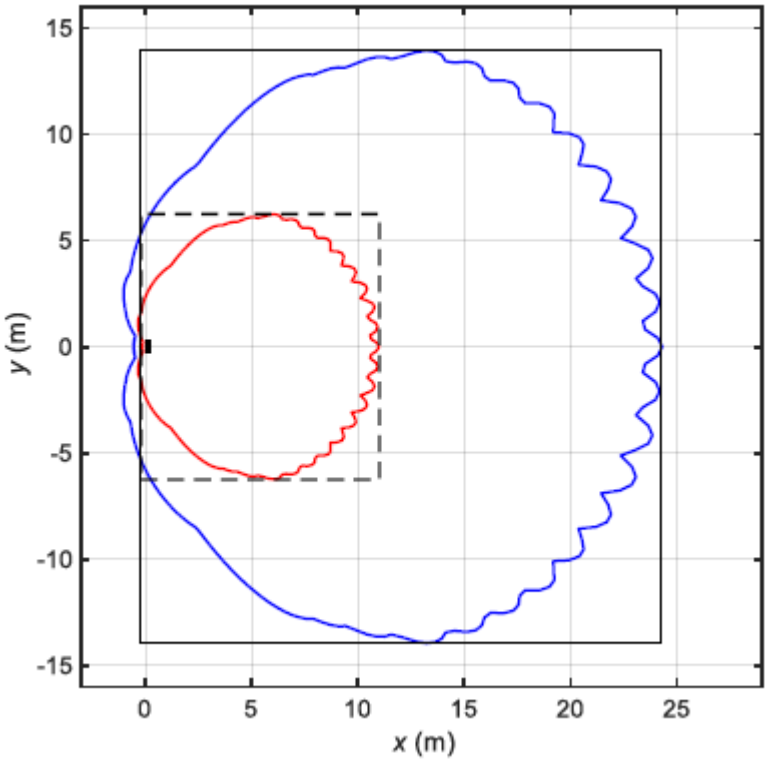
- Narrow and thick beam (symmetric)
- Fixed downtilt

Scenario: Highrise	Beam LTE	Beam NR
Parameter	BrHR1(1), BrHR2(2)	BrHR1(1)
Vertical Beamwidth	–	26±3°
Horizontal Beamwidth	–	20±2°
Digital Downtilt	–	Fixed 6°
Vertical Beam Pointing Error	–	≤ 1°
Horizontal Beam Pointing Direction	–	0±1°
EIRP (Typical)	–	1 × 72 dBm
Vertical Side Lobe Suppression	–	14 dB
Front to Back Ratio	–	–
Beam Parallelity	–	N/A

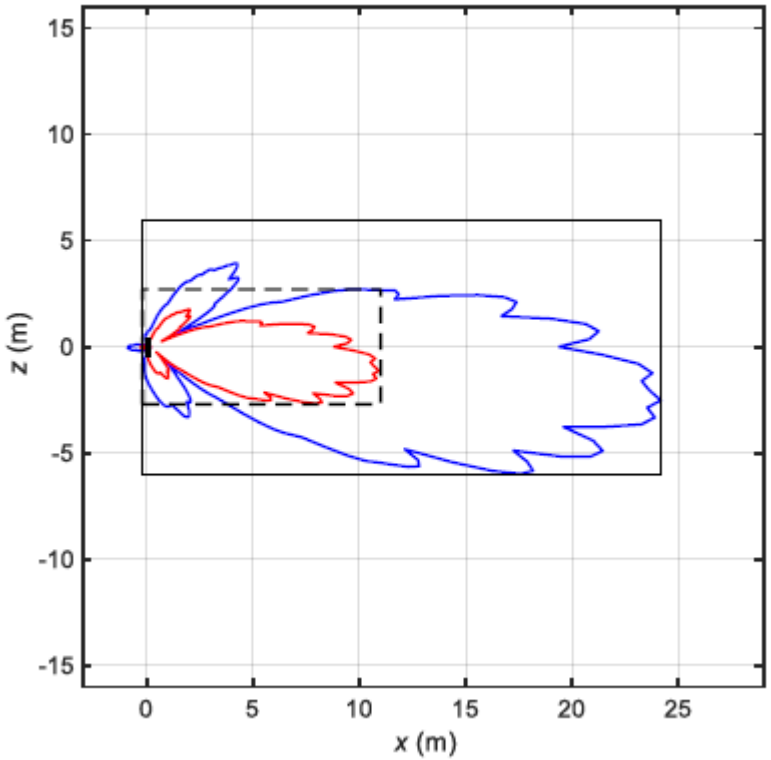
FCC EMF (Exposure) Compliance Testing

Mode and output power for AIR 6449					Dimensions of the box-shaped compliance boundary (m)							
					Distance in front of EUT		Width		Height		Distance behind EUT	
Band	Standard	Maximum nominal output power from the radio	Power tolerance	TDD DL duty cycle	GP	W	GP	W	GP	W	GP	W
B41	LTE	320 W	1.0 dB	75 %	24.0	10.8	27.9	12.5	12.0	5.4	0.2	0.2

Antenna shown from above



Antenna shown from the side



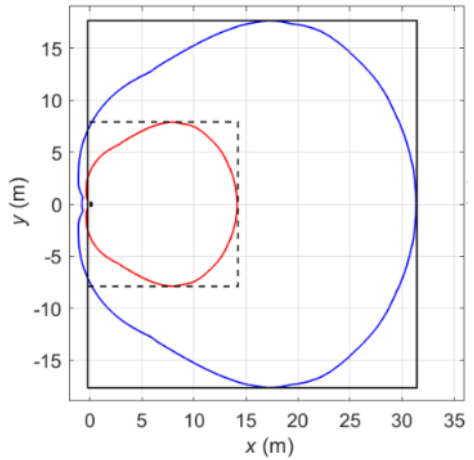
- **Compliance boundaries for general public (black solid line) and workers (black dashed line) exposure**
- **solid red lines indicate the corresponding compliance distance results for workers exposure**
- **2.5GHz case depicted**

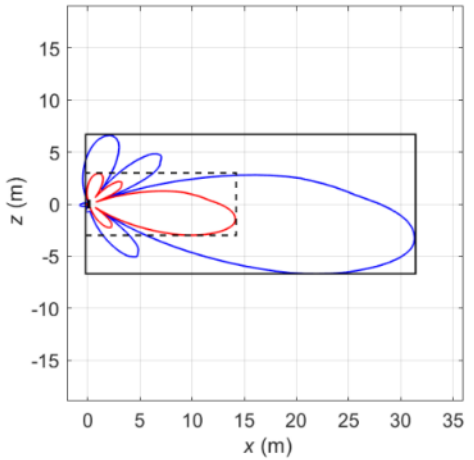
FCC EMF (Exposure) Compliance - Detailed Testing Information

Table 15 Dimensions of the Box-Shaped Compliance Boundary for General Public (GP) and Occupational (O) Exposure Applicable in the EU and Markets Employing the ICNIRP RF Exposure Limits

Mode and Output Power for AIR 6449							Dimensions of the Box-Shaped Compliance Boundary[1][2][3] (m)							
							Distance in Front of AIR		Width		Height		Distance Behind AIR	
Band	Standard	Maximum Nominal Output Power from the AIR	IEC 62232 Installation Class	Power Tolerance	TDD DL Duty Cycle	Exposure Condition	GP	O	GP	O	GP	O	GP	O
B41K	NR	320 W	E+	1.0 dB	75%	Theoretical Maximum	25.9	11.6	31.2	14.0	13.5	6.1	0	0
						Actual Maximum (PRF = 0.32)	14.7	6.6	17.7	7.9	7.6	3.4	0	0
B42	NR	320 W	E+	1.0 dB	75%	Theoretical Maximum	28.5	12.8	33.7	15.1	12.6	5.7	0	0
						Actual Maximum (PRF = 0.32)	16.1	7.2	19.1	8.6	7.2	3.2	0	0

› 3.8GHz





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