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Status of the S-band and X-band power amplifiers

Alireza Mohadeskasaei, Mykhailo Zhovner, Yasin Alekajbaf, Konrad Gajewski, Kristiaan Pelckmans, Kevin Pepitone and Dragos Dancila

2023 April 26

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Topics

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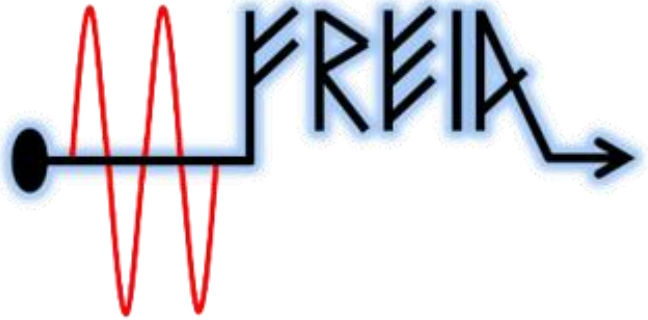

- ✓ Work progress on the 500 W solid-state power amplifier at 3 GHz
- ✓PLC control and interlocks developement
- ✓ Work progress on the 1.6 kW solid-state power amplifer at X-band – 12 GHz

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Design requirements for S band-PA

- Centre frequency 3 GHz
- Minimum output power 250 W (up to 500W is also allowed)
- Linearity is not an important factor as it could be compensated by LLRF
- Input power <10 dBm (so we need at least 45 dB signal gain-31000 times)
- Pulse Repetition Frequency (PRF) <1% with 4.5µs pulse width
- Protected against full power reflection condition

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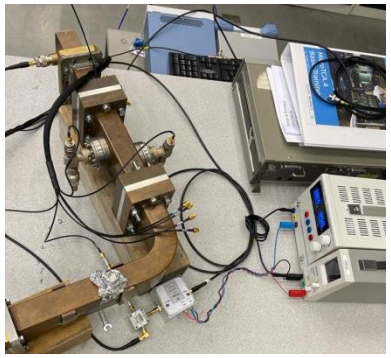

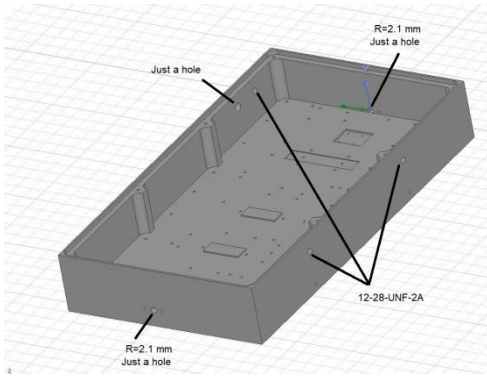

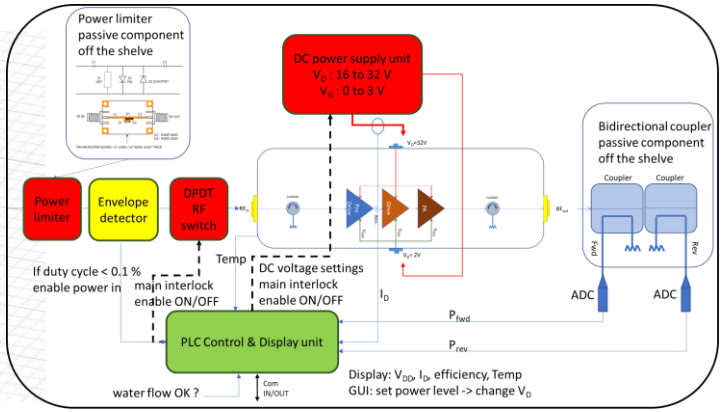

2023

Milestone 1

Milestone 3

Jan/Feb | Mar/Apr | May/Jun | July/Aug | Sep/Oct | Nov/Dec

Milestone 2

Milestone 4

M1: preamp measured and integrated with FPGA - ONGOING

M2: main amplifier measured - DONE

M3: main amplifier protection and PLC control ready - ONGOING

M4: demo main amplifier + PLC + ★ Klystron

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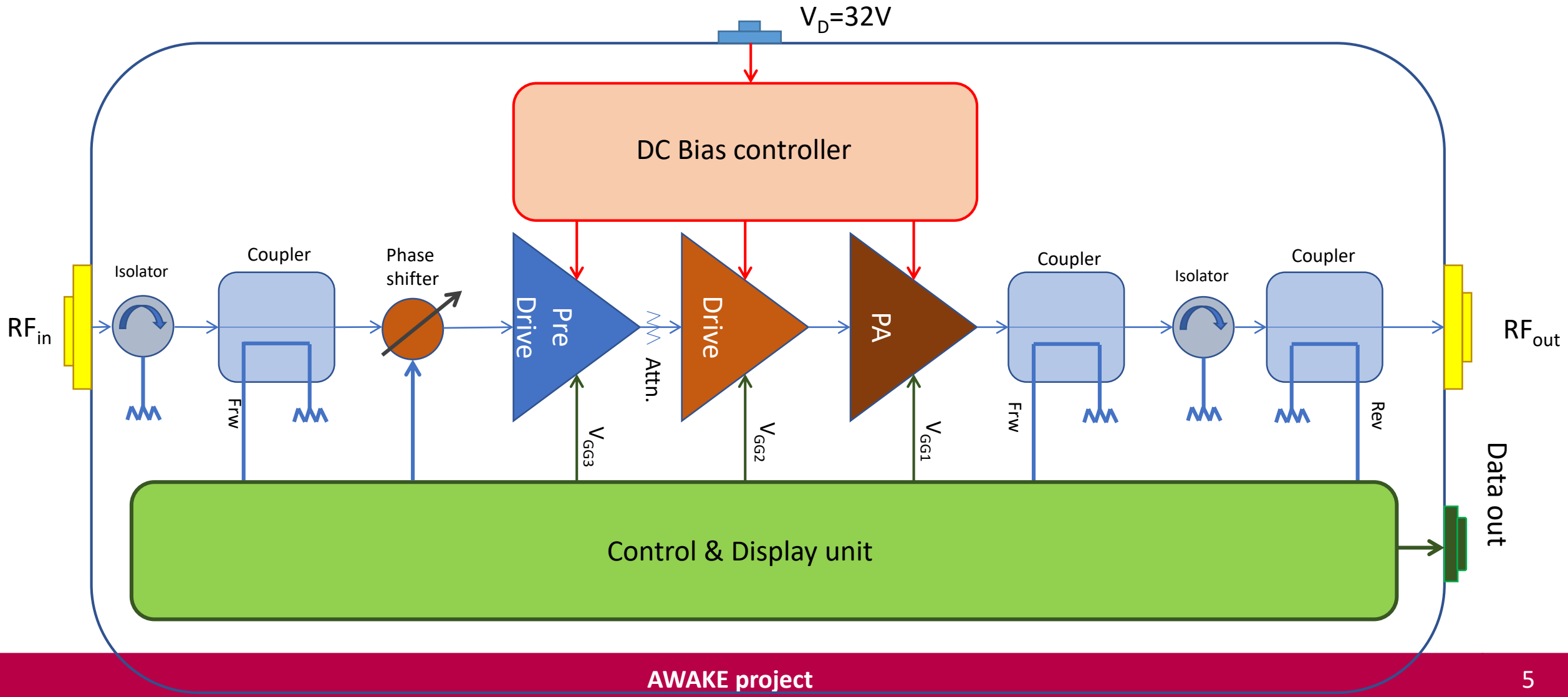
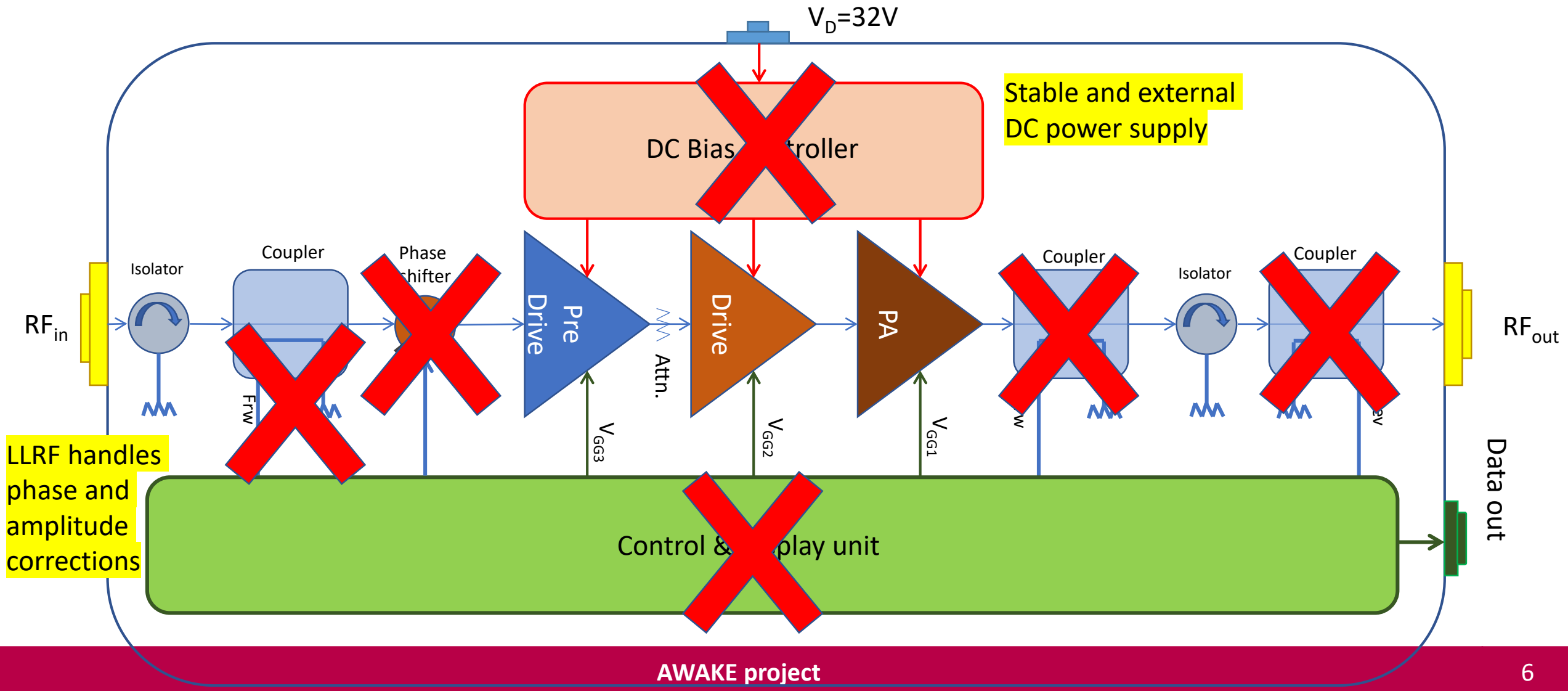
Block diagram of 500W SSPA @ 3GHz - initial



Block diagram of 500W SSPA @ 3GHz –updated



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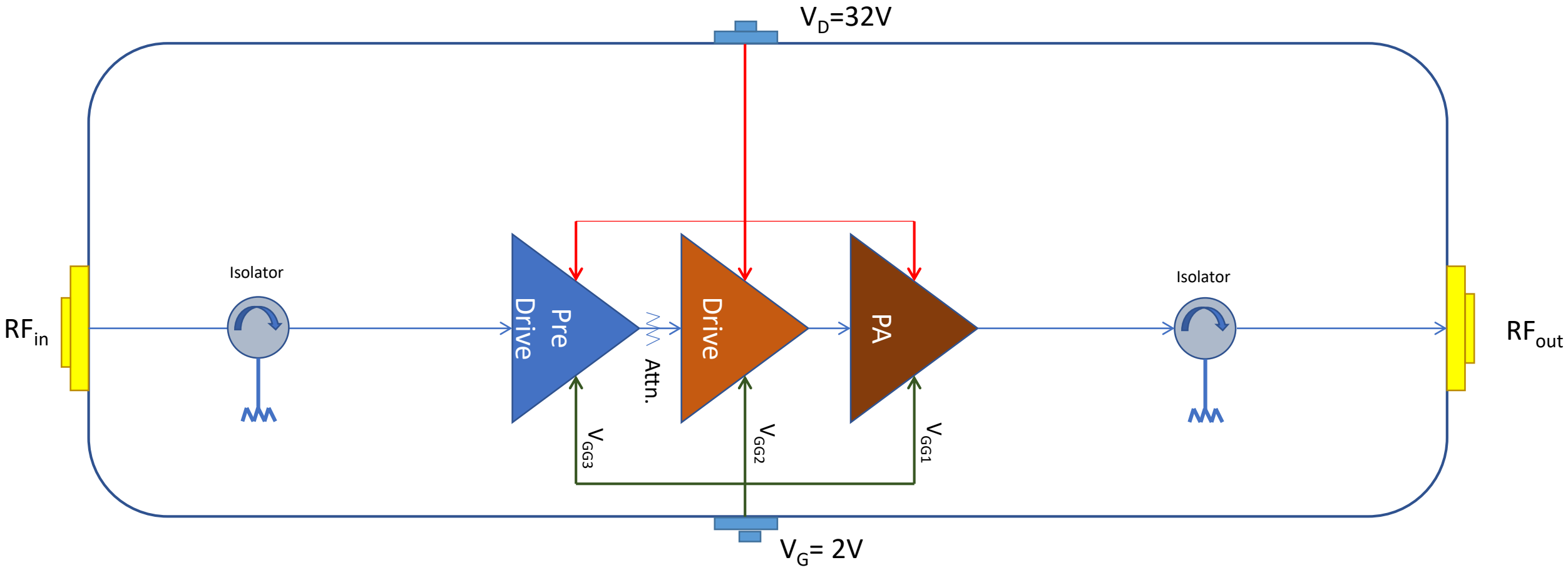
500W @ 3GHz - Development and demonstration: DONE



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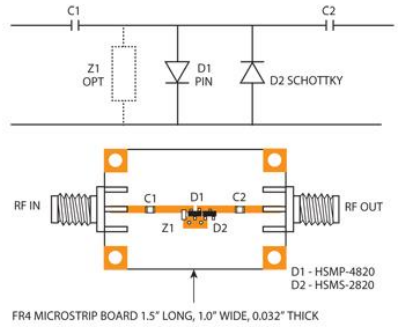
Power limiter passive component off the shelve



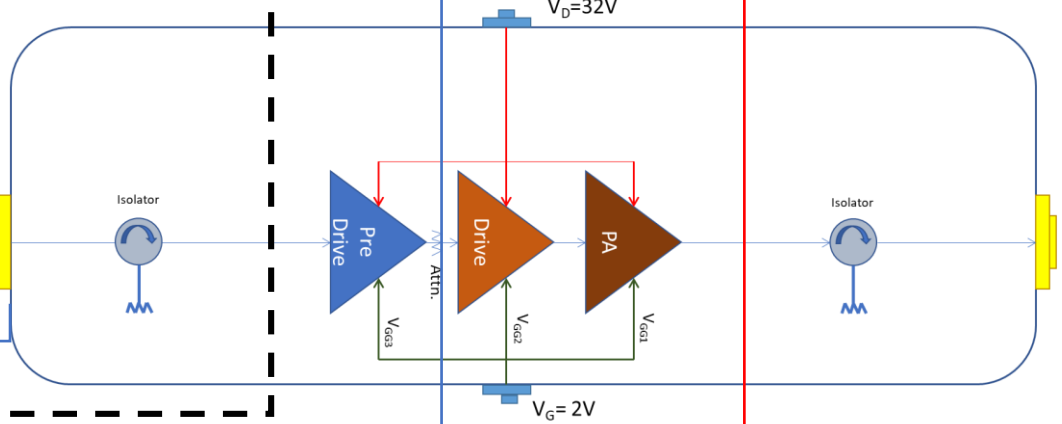
DC power supply unit
V_D : 16 to 32 V
V_G : 0 to 3 V

Power limiter

Envelope detector

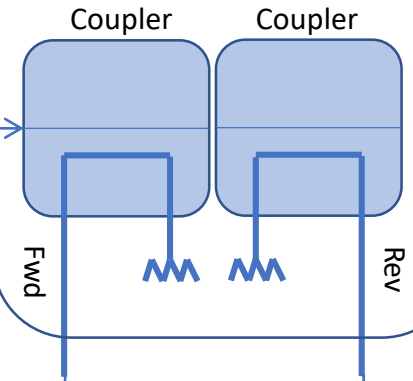
DPDT RF switch

RF_{in}



RF_{out}

Bidirectional coupler passive component off the shelve



Temp

If duty cycle < 0.1 %
enable power in

DC voltage settings
main interlock
enable ON/OFF

I_D

P_{fwd}

P_{rev}

main interlock
enable ON/OFF

PLC Control & Display unit

Display: V_{DD}, I_D, efficiency, Temp
GUI: set power level -> change V_D and V_G

water flow OK ?

Com IN/OUT

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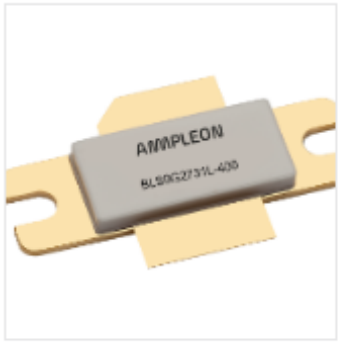

BLS9G2731L-400

Download datasheet

Overview | Product details | Recommended line-up | Quality | Ordering

LDMOS S-band radar power transistor

400 W LDMOS power transistor for S-band applications in the frequency range from 2700 MHz to 3100 MHz

Features and benefits

- High efficiency
- Excellent ruggedness
- Designed for S-band radar applications
- Excellent thermal stability
- Easy power control
- Integrated dual sided ESD protection enables excellent off-state isolation
- High flexibility with respect to pulse formats
- Internally matched for ease of use
- Compliant to Directive 2002/95/EC, regarding Restriction of Hazardous Substances (RoHS)

Driver and Pre-driver design

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BLM9D2327S-50PB;
BLM9D2327S-50PBG

LDMOS 2-stage integrated Doherty MMIC

AMPLEON

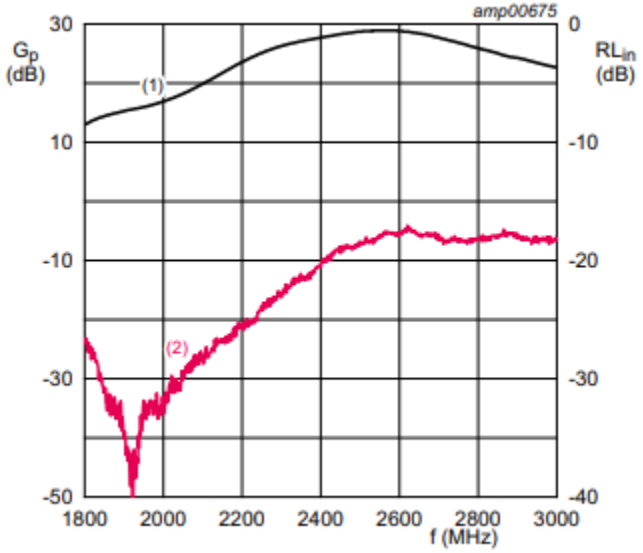
Rev. 1 — 6 April 2019 **Product data sheet**

1. Product profile

1.1 General description

The BLM9D2327S-50PB(G) is a dual section, 2-stage fully integrated Doherty MMIC solution using Ampleon's state of the art GEN9 LDMOS technology. For each section, the carrier and peaking device, input splitter and output combiner are integrated in a single package. This multiband device is perfectly suited as general purpose driver or small cell final in the frequency range from 2300 MHz to 2700 MHz. Available in gull wing or flat lead outline.

Test signal	f	V_{DS}	$P_{L(M)}$	G_p	η_D	$ACPR_{20M}$
	(MHz)	(V)	(dBm)	(dB)	(%)	(dBc)
single carrier LTE	2600	28	47.7	29.0 [1]	25.7 [1]	−39.5 [1]
				28.7 [2]	41.1 [2]	−36.2 [2]



Design and characterization - Driver

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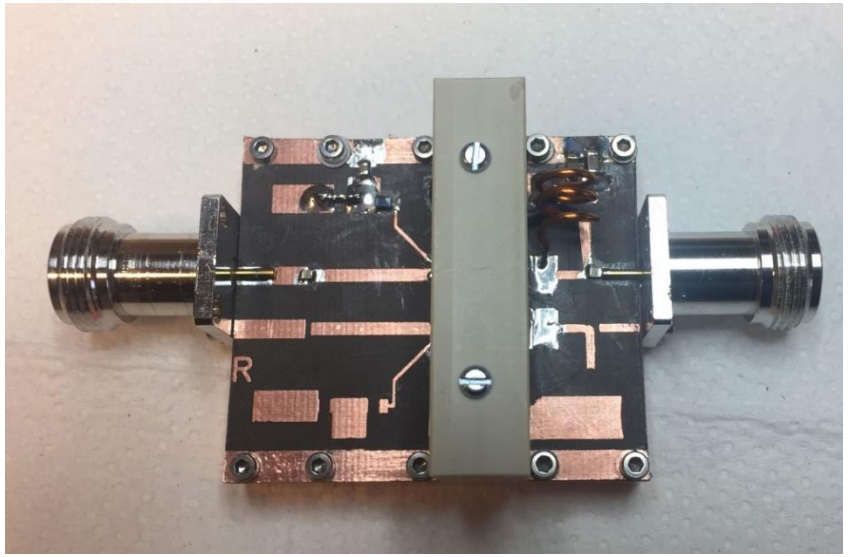
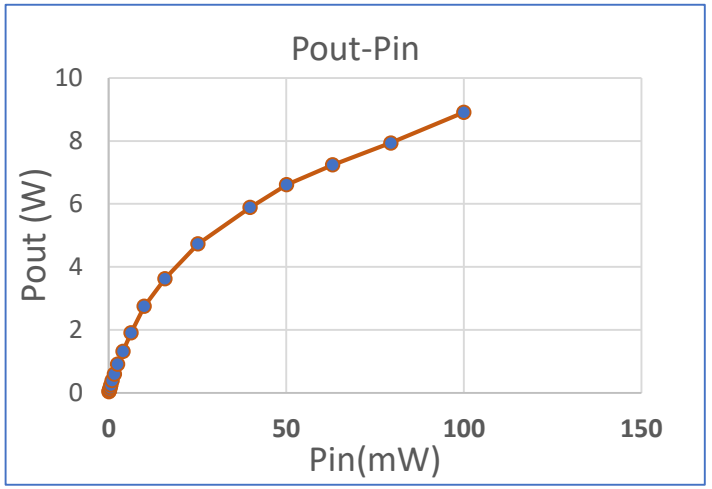
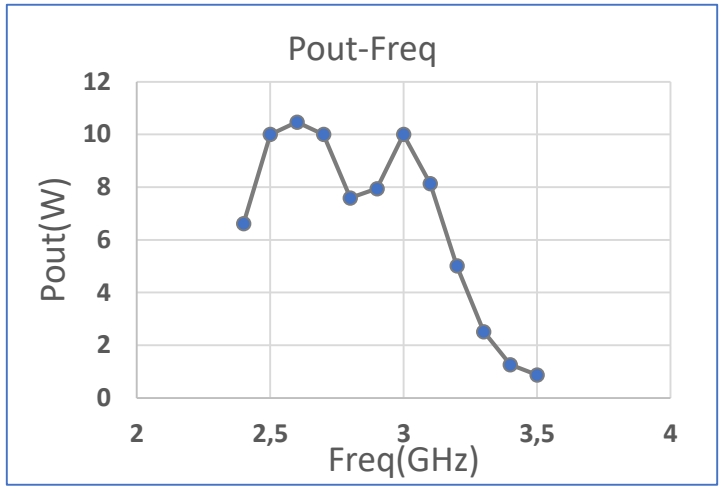
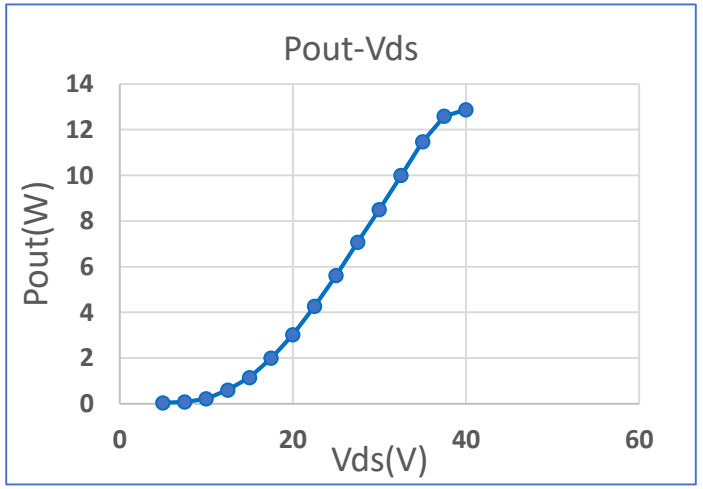
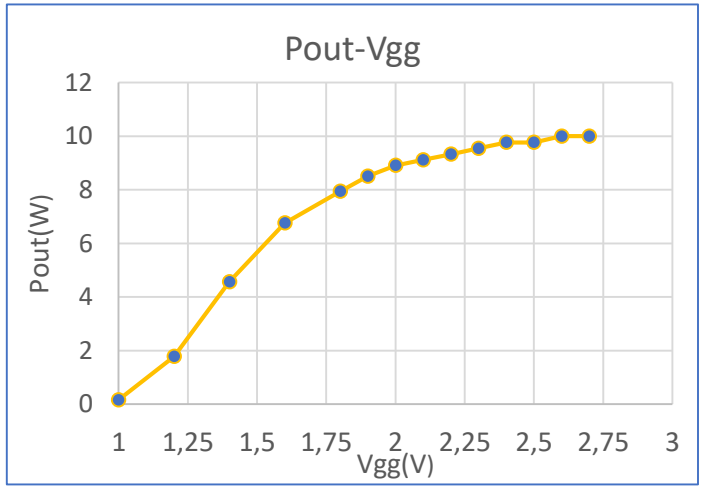


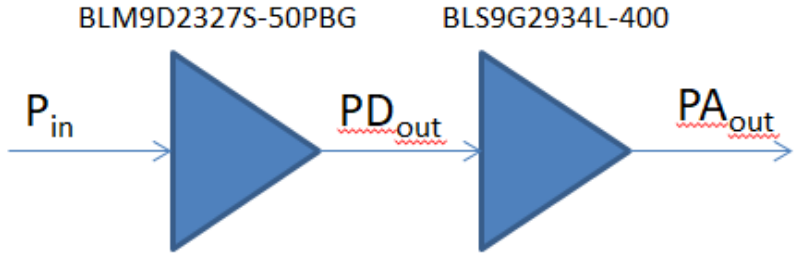


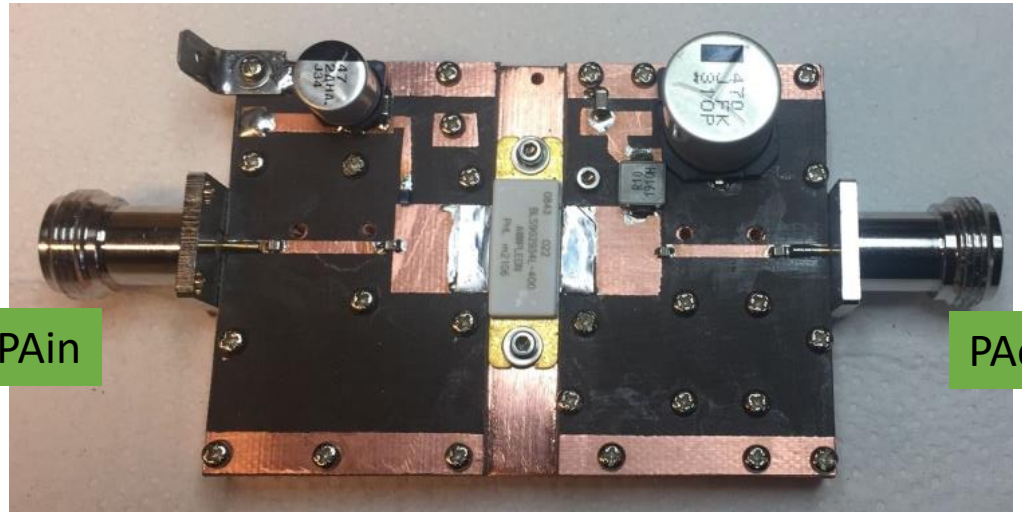


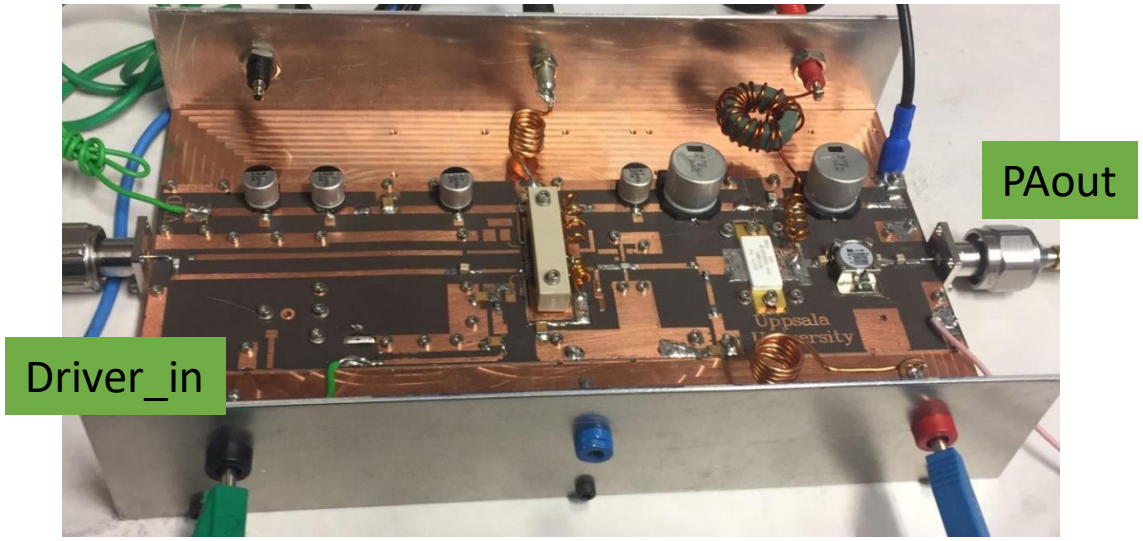


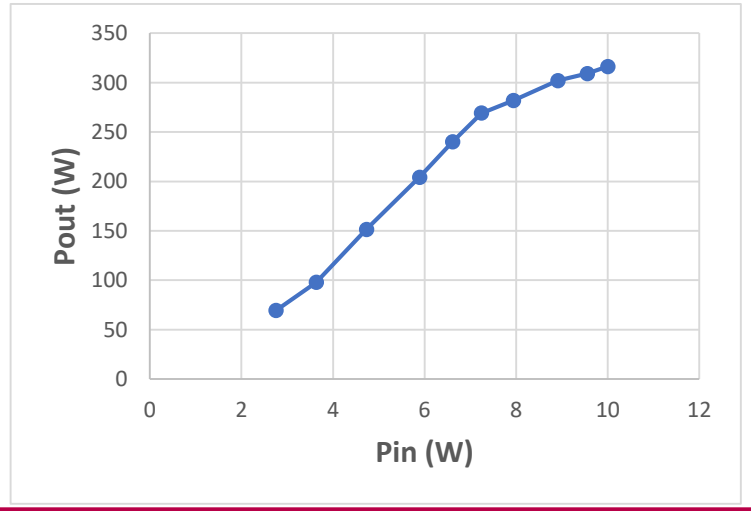


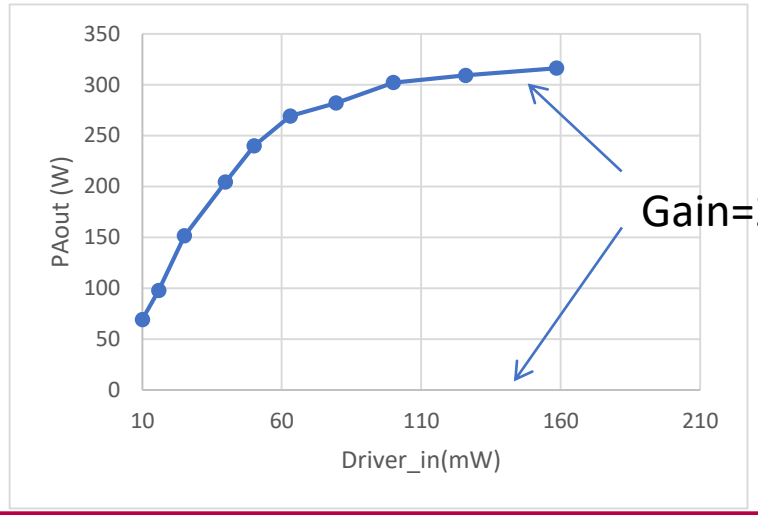
Design and meas. of the PA



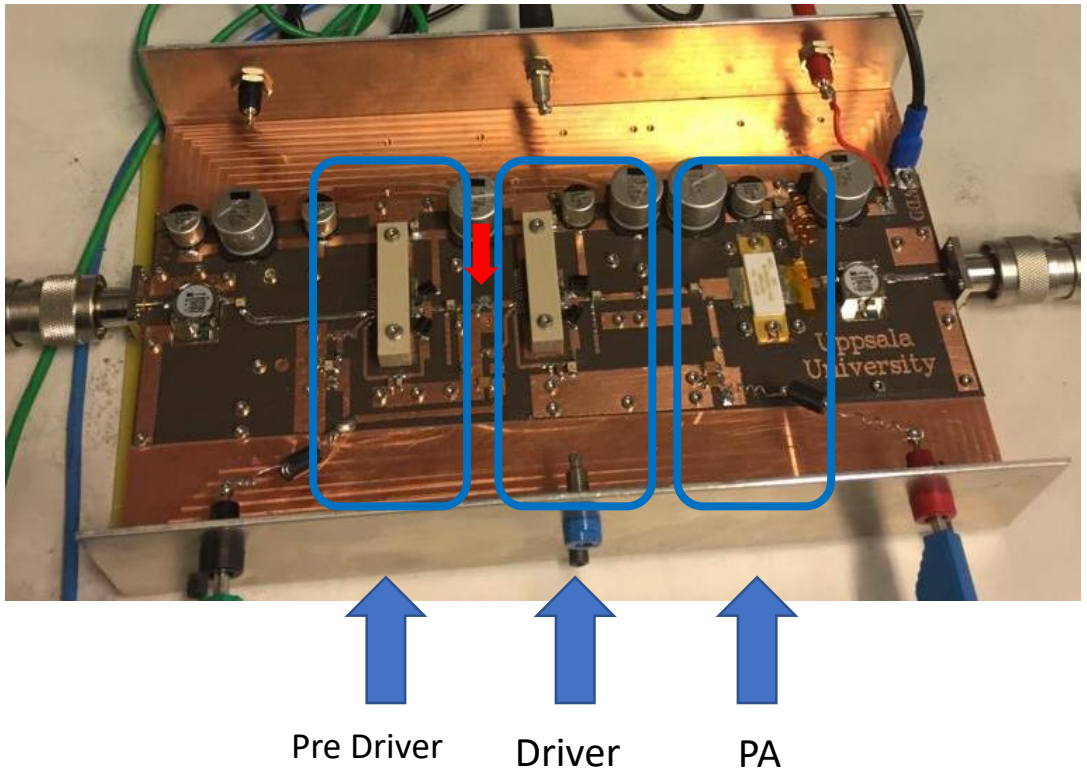


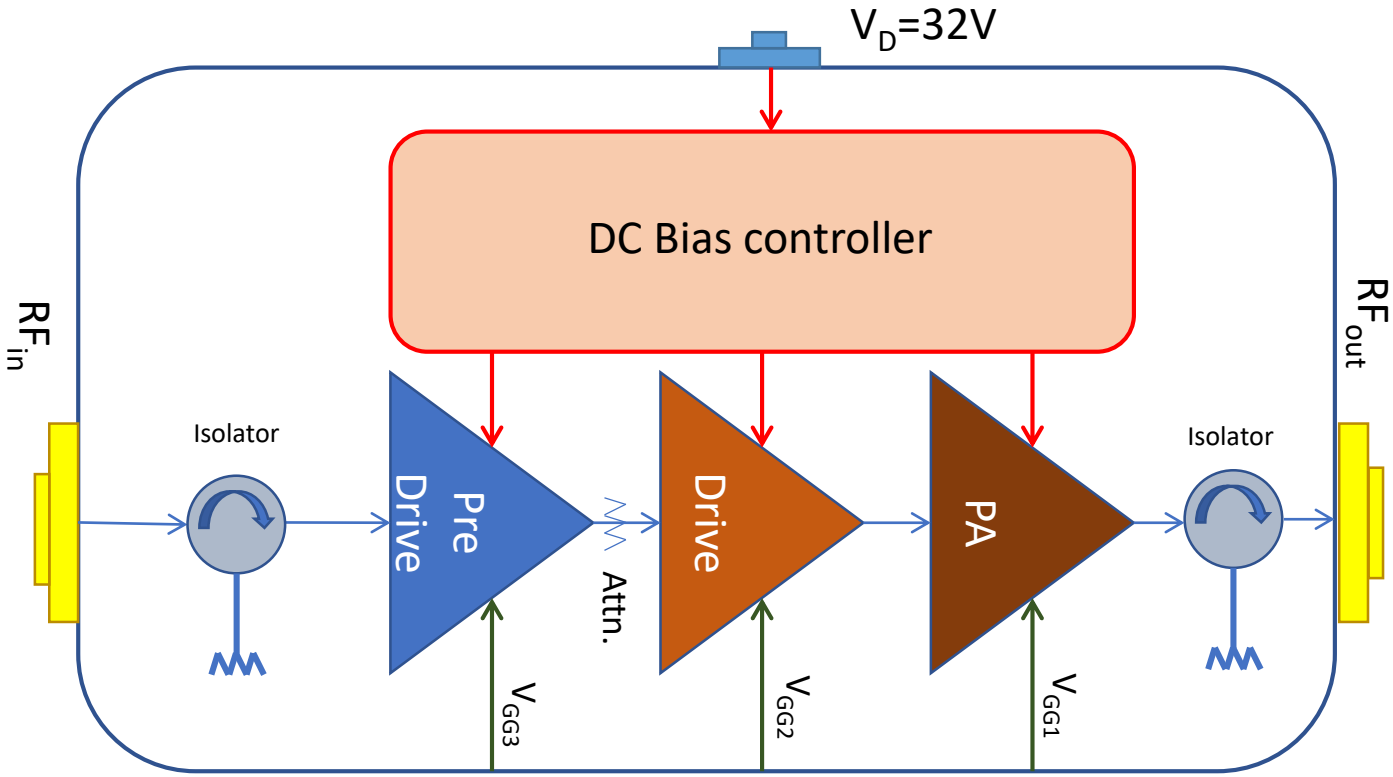






Pre-driver embeding





Test & Measurement set-up

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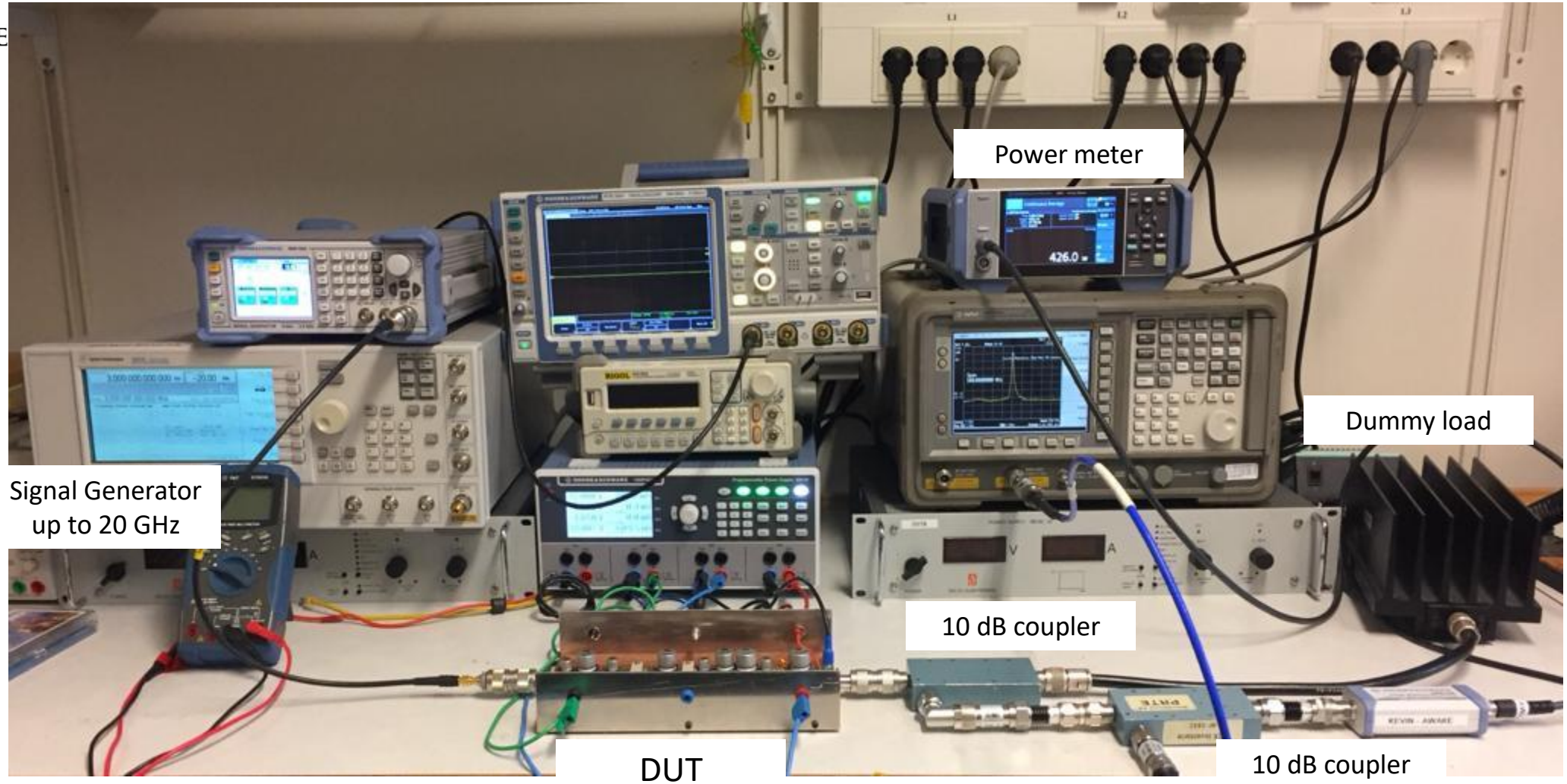

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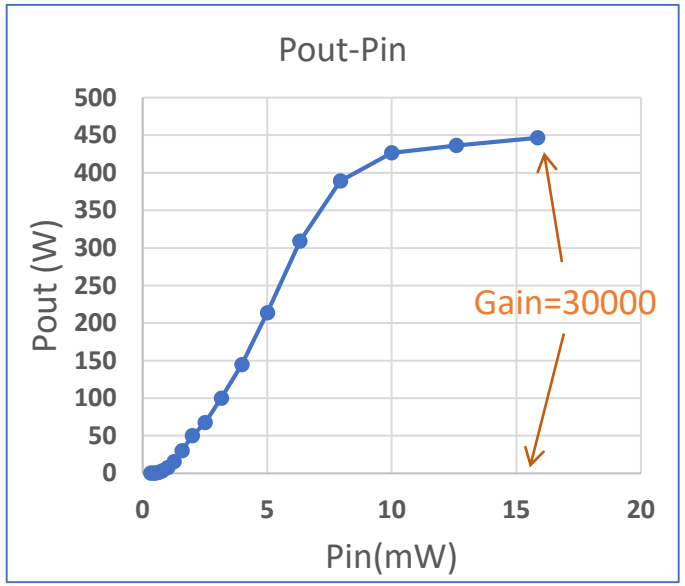
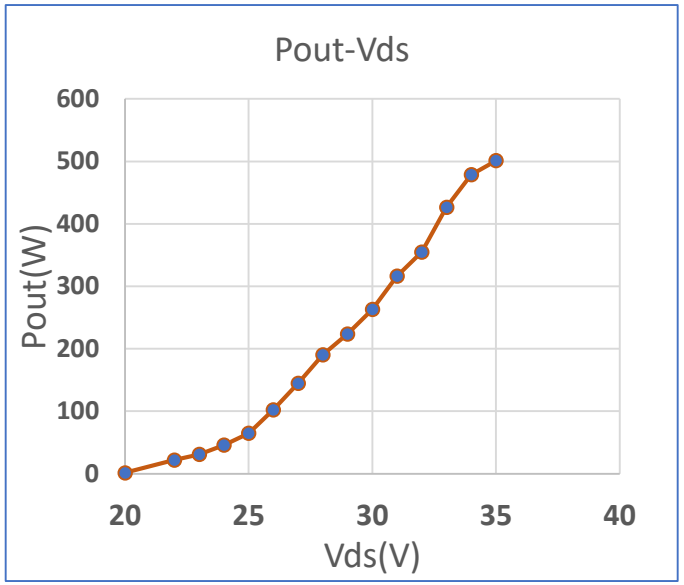
Measurement results

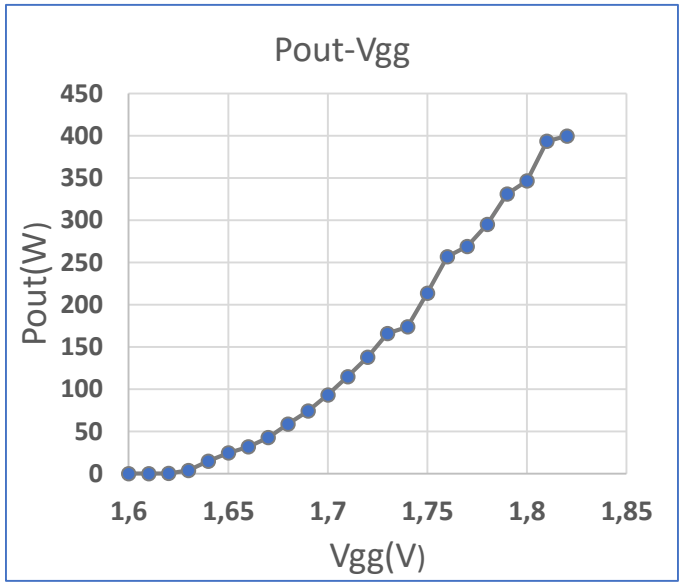
Freq 3 GHz,
Vdd=32V, Vgg=1.8V,
Pin is sweeped and Pout is measured



Freq 3 GHz,
Pin=8dBm, Vgg=1.8V,
Vds is sweeped and Pout is measured



Freq 3 GHz,
Pin=8dBm, Vdd=32V,
Vgg is sweeped and Pout is measured



- Using this data, LLRF can be further developed to tune the amplitude of the output signal
- For the phase we need a VNA.

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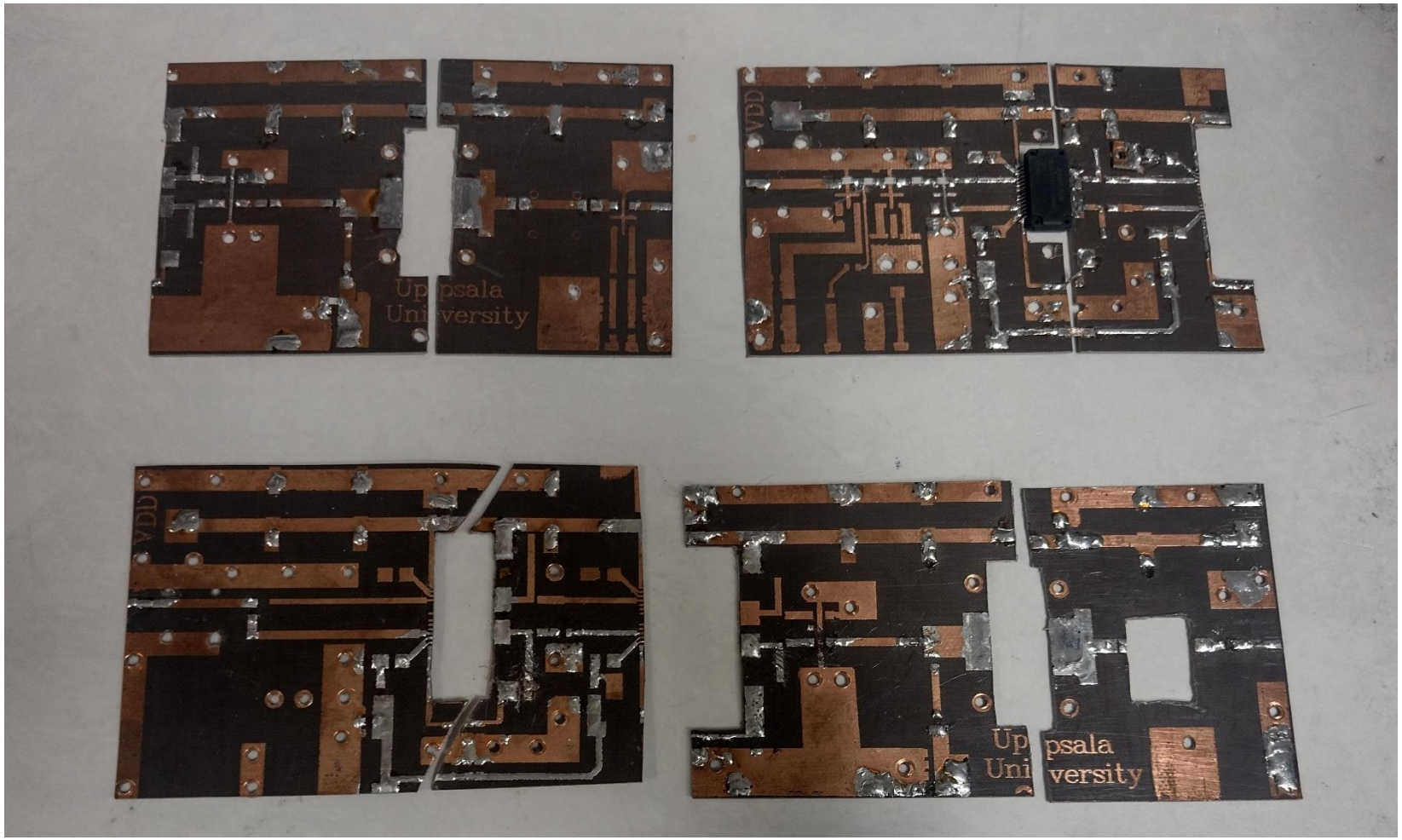
Development process - itterative



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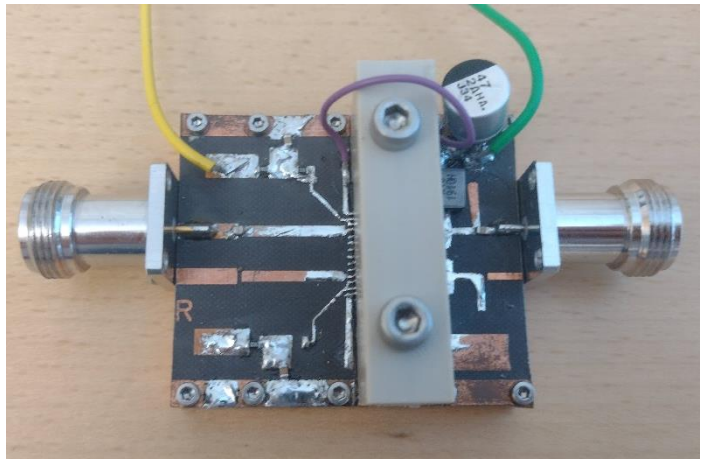
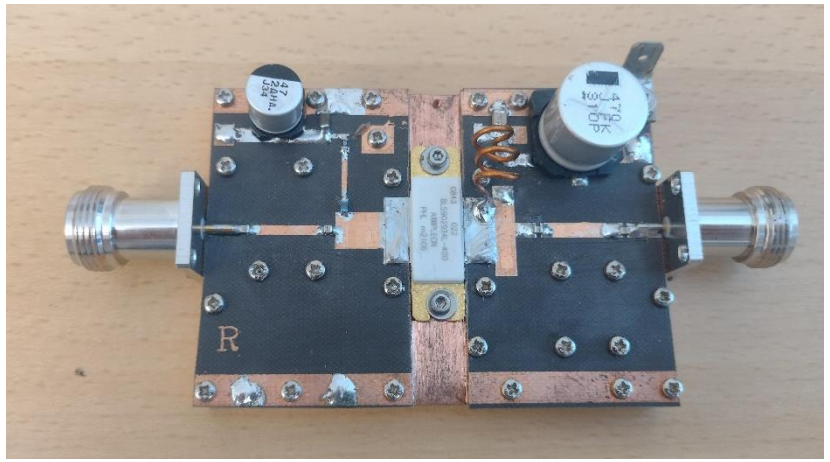
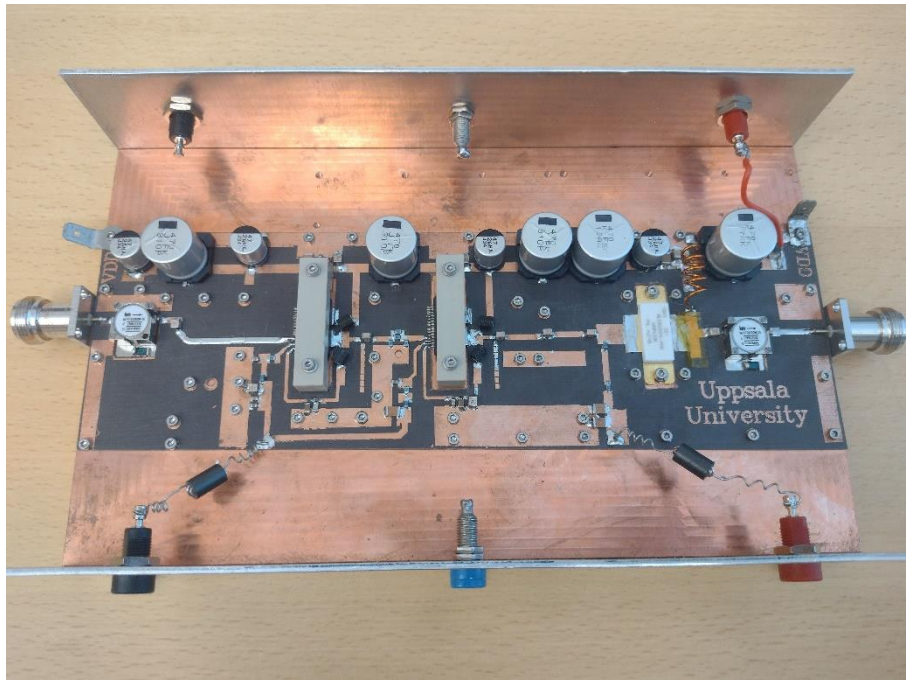
Development process - results







Remaining – next steps:

- Box design and related simulations
- Final measurement simple
- Final measurement with LLRF
- Field test at CERN

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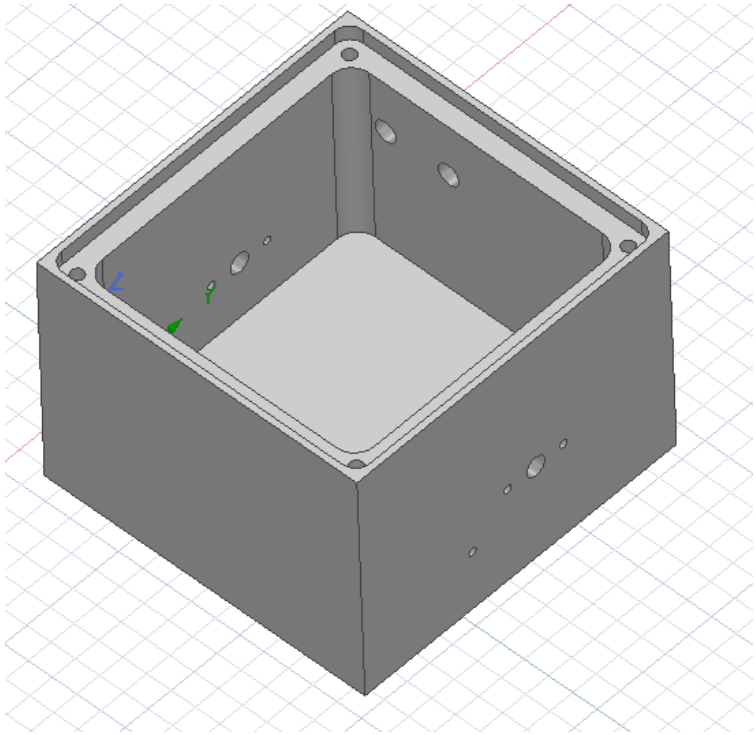
3 GHz RF power driver
Gain=26 dB, P_{out}=5W



Design of the aluminium box

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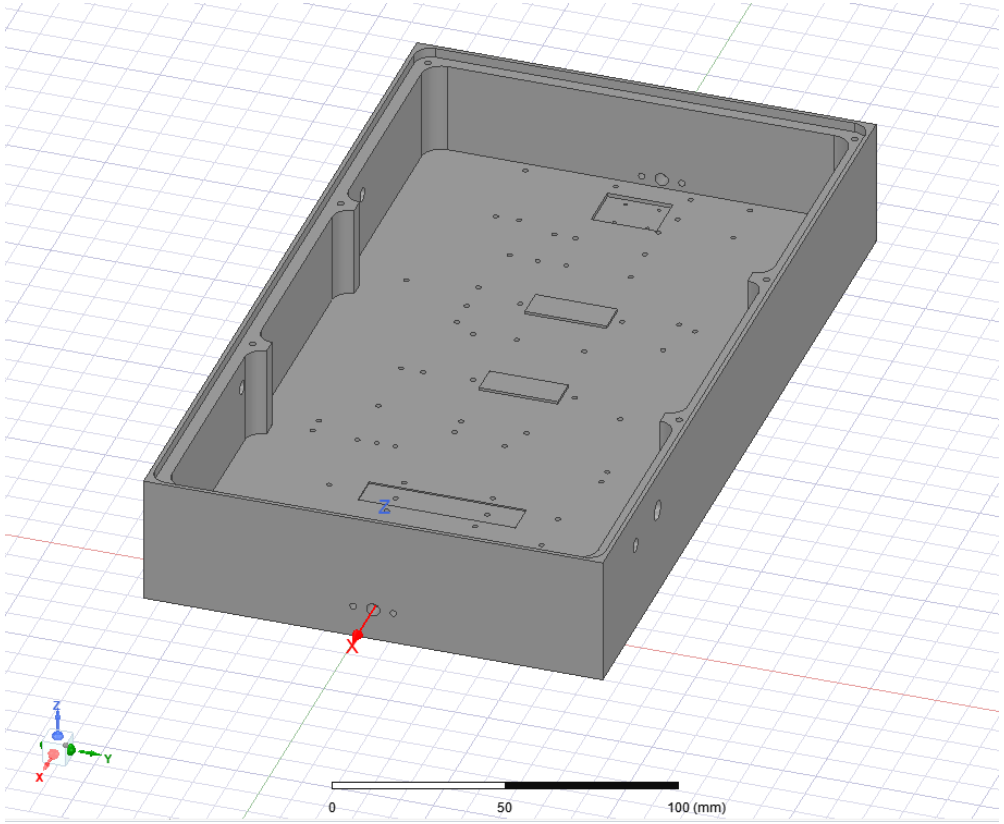
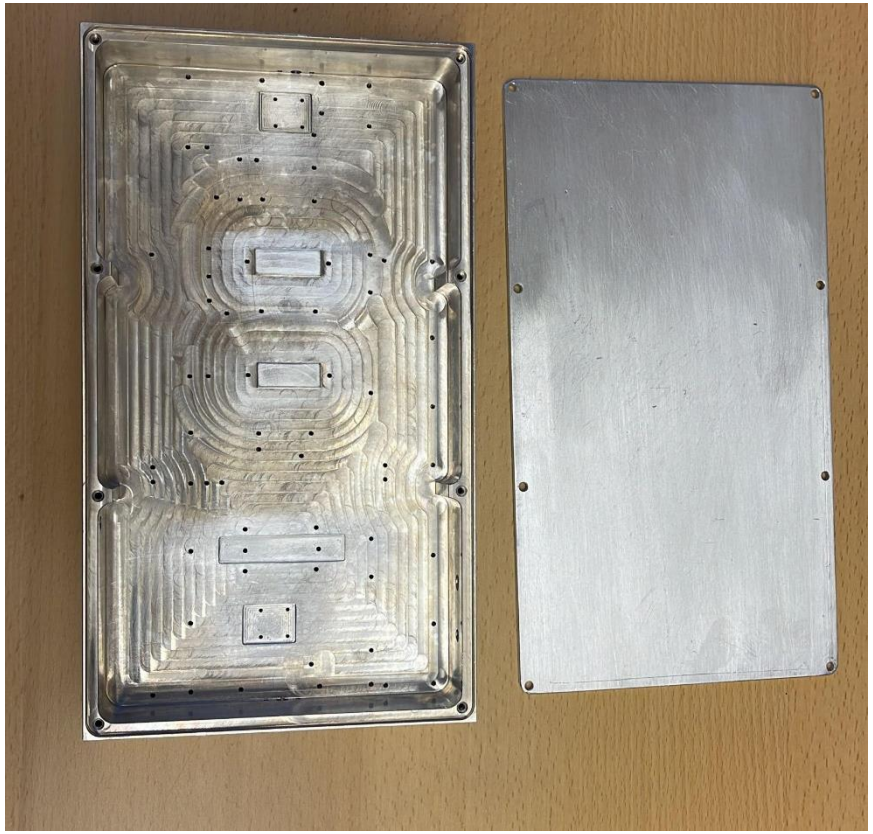
Design the aluminium box of the 500 W





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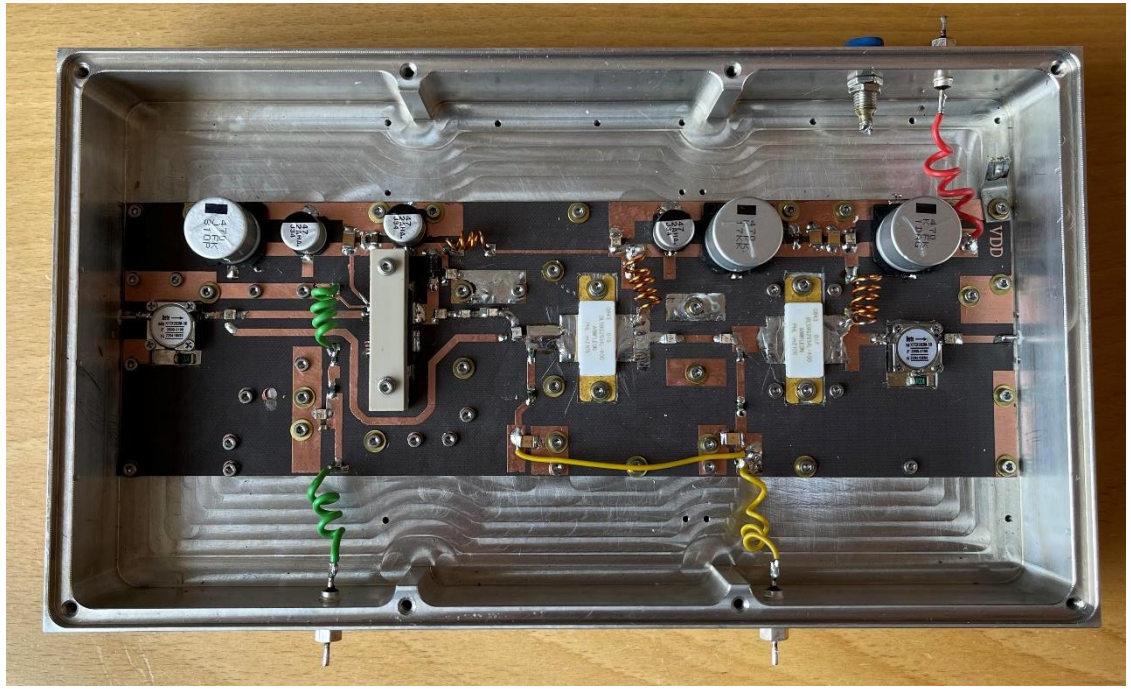
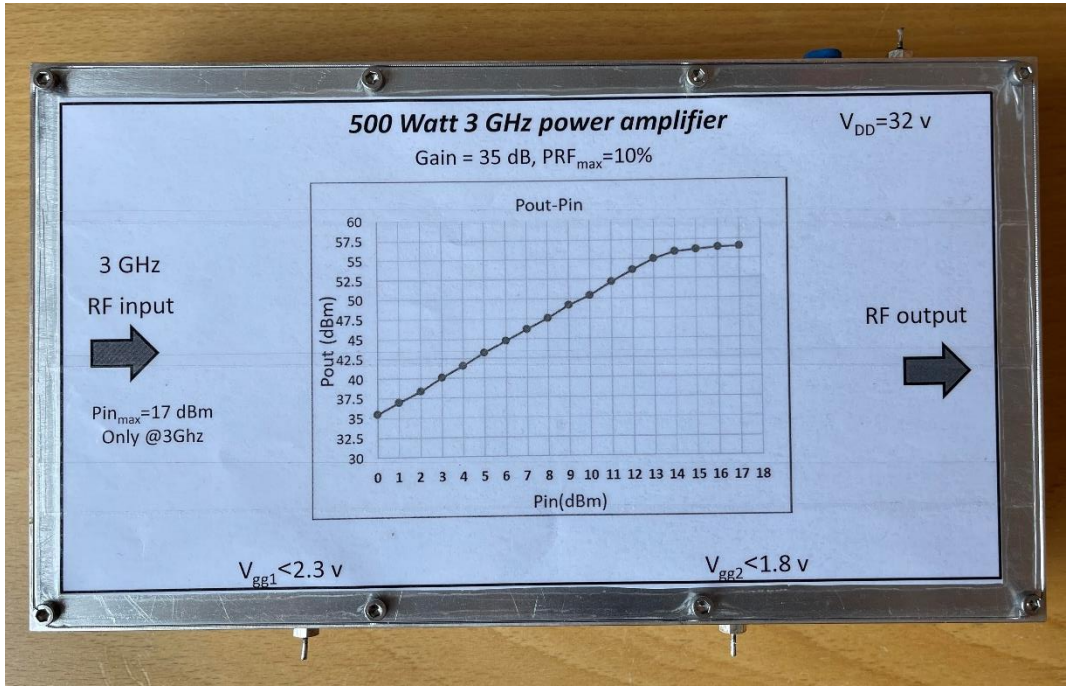
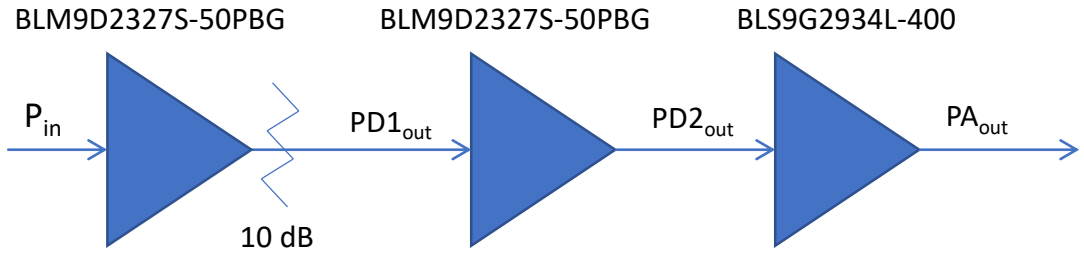
500-Watt Power amplfier – all stages







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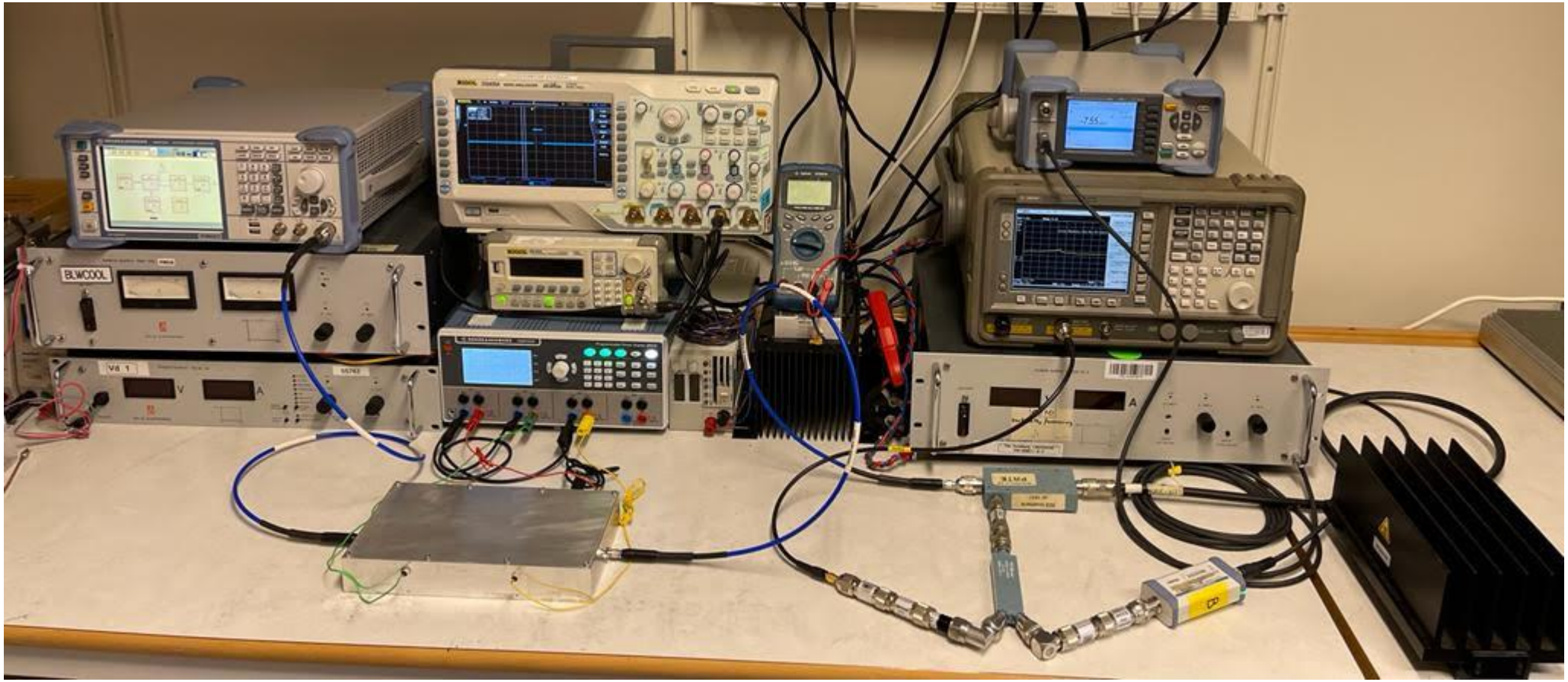
Test&measurment setup



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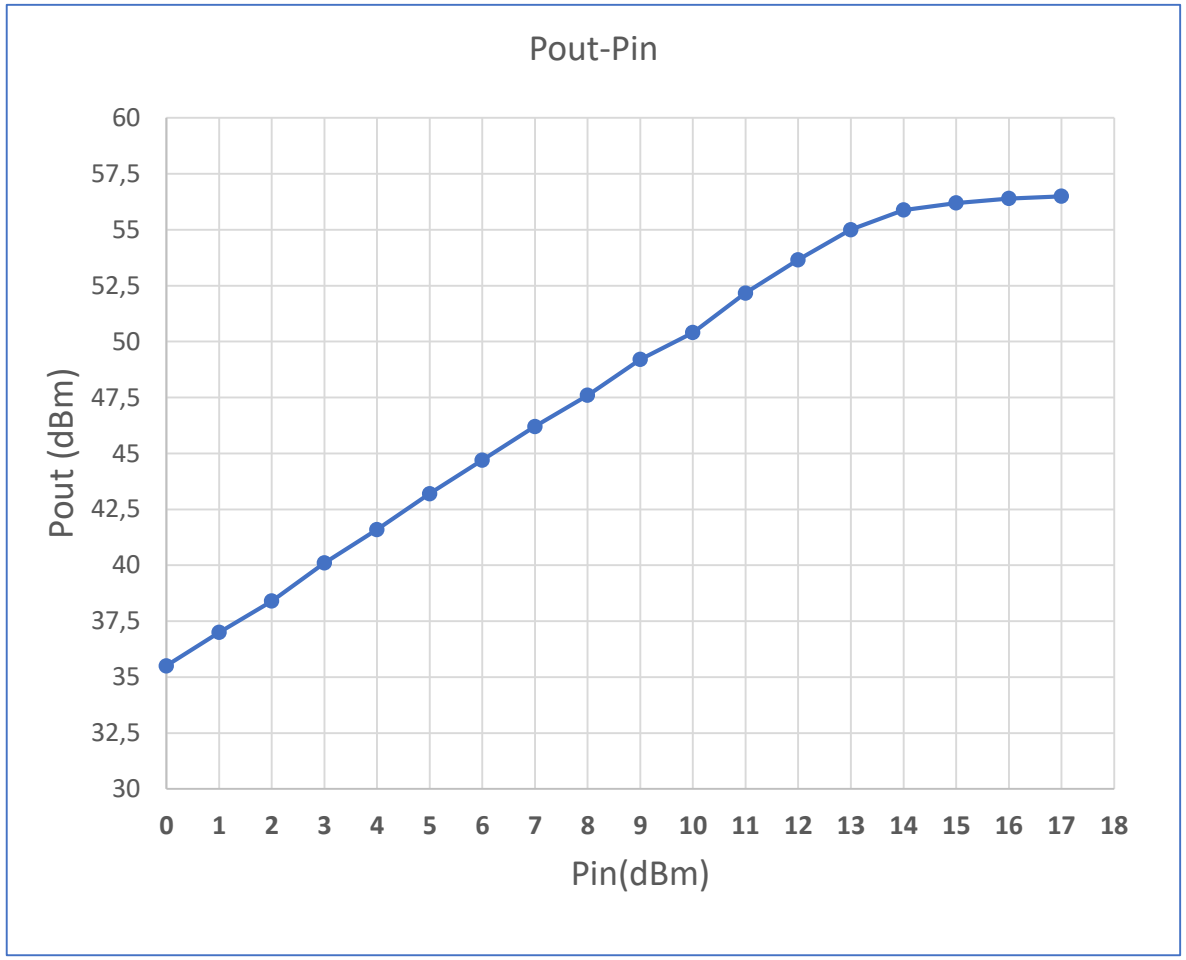
Final measurement results

Freq 3 GHz,
Vdd=32V, Vg_driver&main=1.8V, Vg_predriver=2.3V

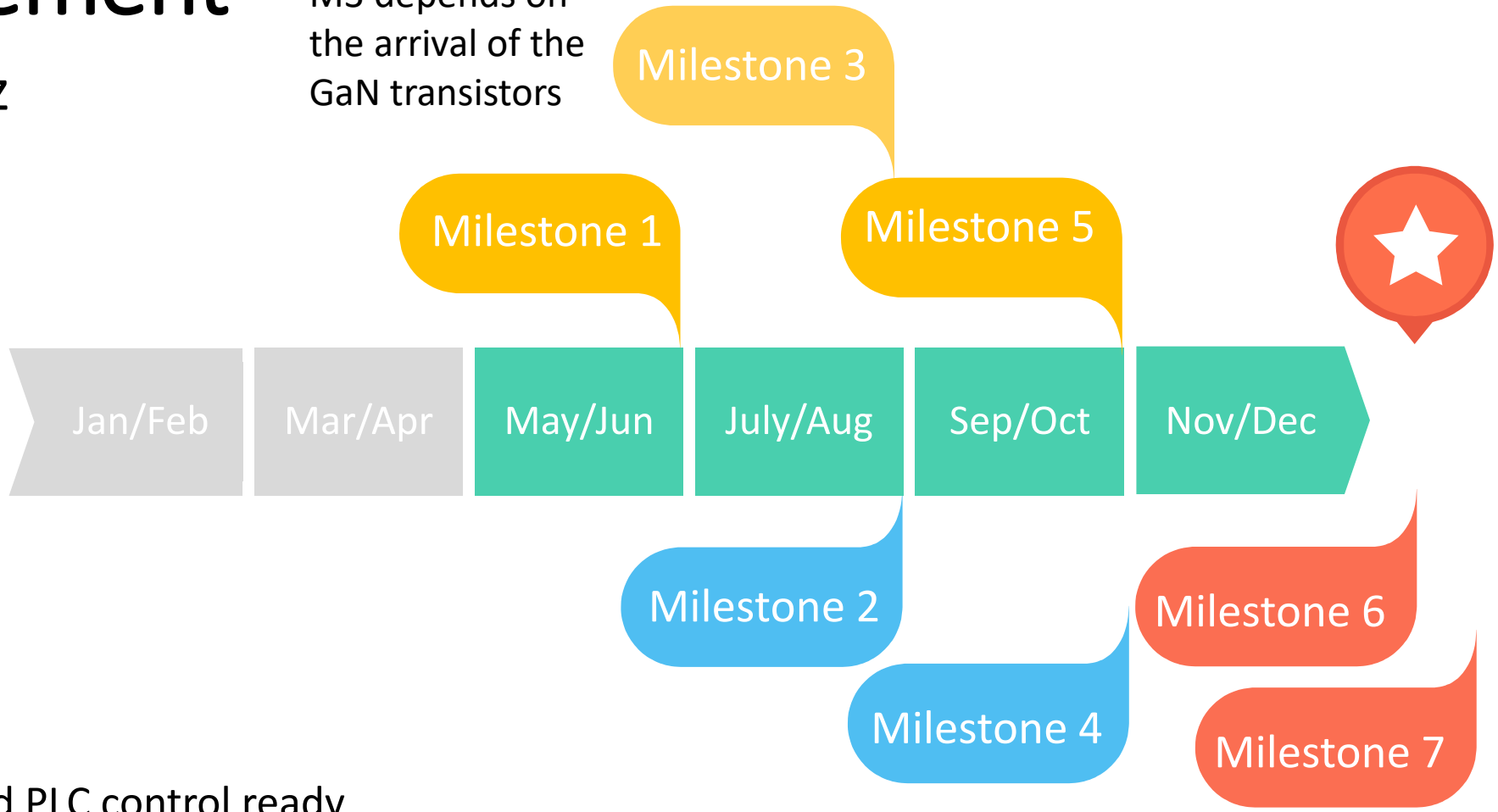
Pin (dBm)	Pout (dBm)	Pout (Watt)
0	35.5	3.55
1	37	5.01
2	38.4	6.92
3	40.1	10.23
4	41.6	14.45
5	43.2	20.89
6	44.7	29.51
7	46.2	41.69
8	47.6	57.54
9	49.2	83.18
10	50.4	109.65
11	52.17	164.82
12	53.66	232.27
13	55	316.23
14	55.88	387.26
15	56.2	416.87
16	56.4	436.52
17	56.5	446.68



X band solid state power amplifer developement

- 100 W tile @ 12GHz
- 1.6 kW @ 12GHz

M3 depends on the arrival of the GaN transistors



M0: get export control - DONE
M1: 25 W amplifier designed
M2: power combiner designed
M3: 25 W amplifier measured
M4: 100 W module measured
M5: power combiner measured
M6: main amplifier protection and PLC control ready
M7: demo main amplifier + PLC + ★ Klystron

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SSPA @ 12 GHz – available transistors

NO.	Part number	Company	F (min)-F(max)	Pout (sat)	Package	Match//Unmatch
1	TGA2590-CP	Qorvo	6-12 GHz	30 W	Flange	
2	TGA2590	Qorvo	6-12 GHz	30 W	Die	
3	FMM5061VF	Eudyna	9.5-13.3 GHz	2 W	Flange	
4	P1006-BD	Mimi Asia	8.5 – 11GHz	10 W	Die	
5	MB6.0018G434820	Elite	6-18 GHz	20 W	Connectorized	
6	TGF2979	Qorvo	DC-12 GHz	25 W	plastic package	
7	TGF2978	Qorvo	DC-12 GHz	20 W	plastic package	
8	QPD1022	Qorvo	DC-12 GHz	10 W	plastic package	
9	TGM2635-CP	Qorvo	8-11 GHz	100 W	Flange	Matched
10	QPM1021	Qorvo	10-12 GHz	100 W	Flange	Matched
11	CGHV96100	Cree	8-9.6 GHz	100W	Flange	Matched
12	**CGHV1F025**	Cree	DC-15GHz	25W	plastic package	

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Procurement of key components - DONE

- ✓ 150 x CGHV1F025S 25W RF GaN HEMT
- ✓ 100 x MACOM Power Management Modules GaN bias controller

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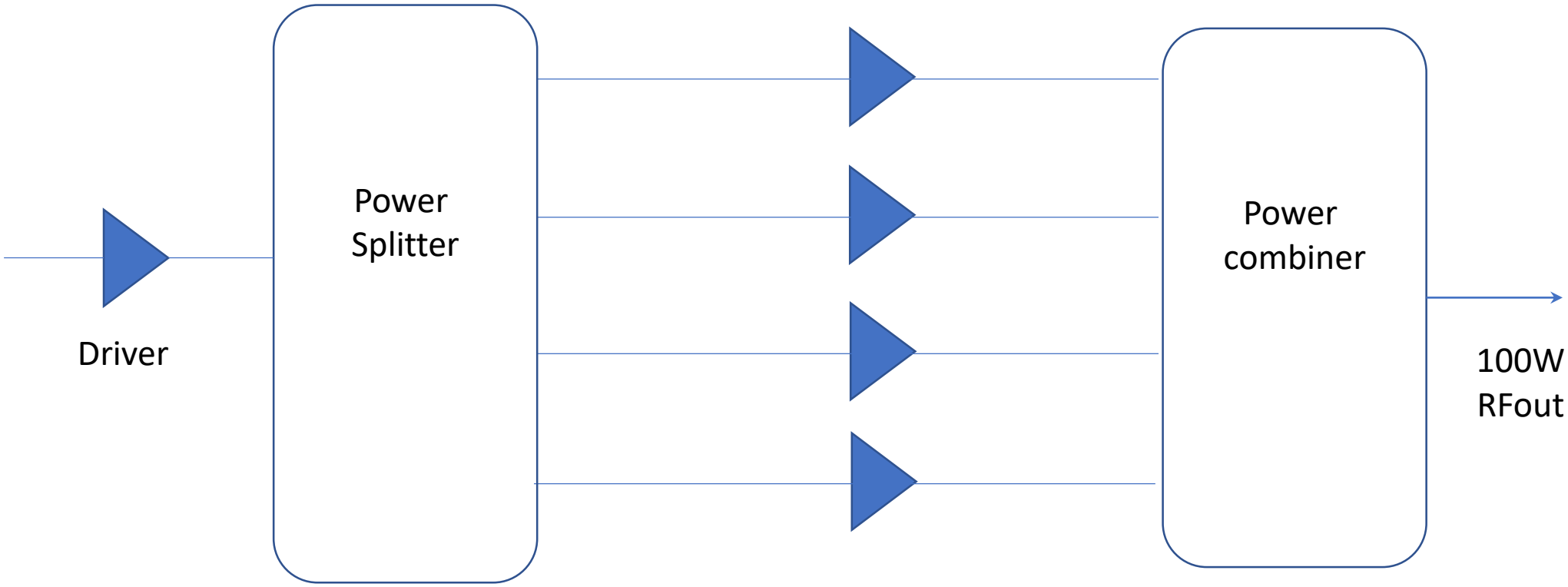
100W tile configuration



4*25W MMICs

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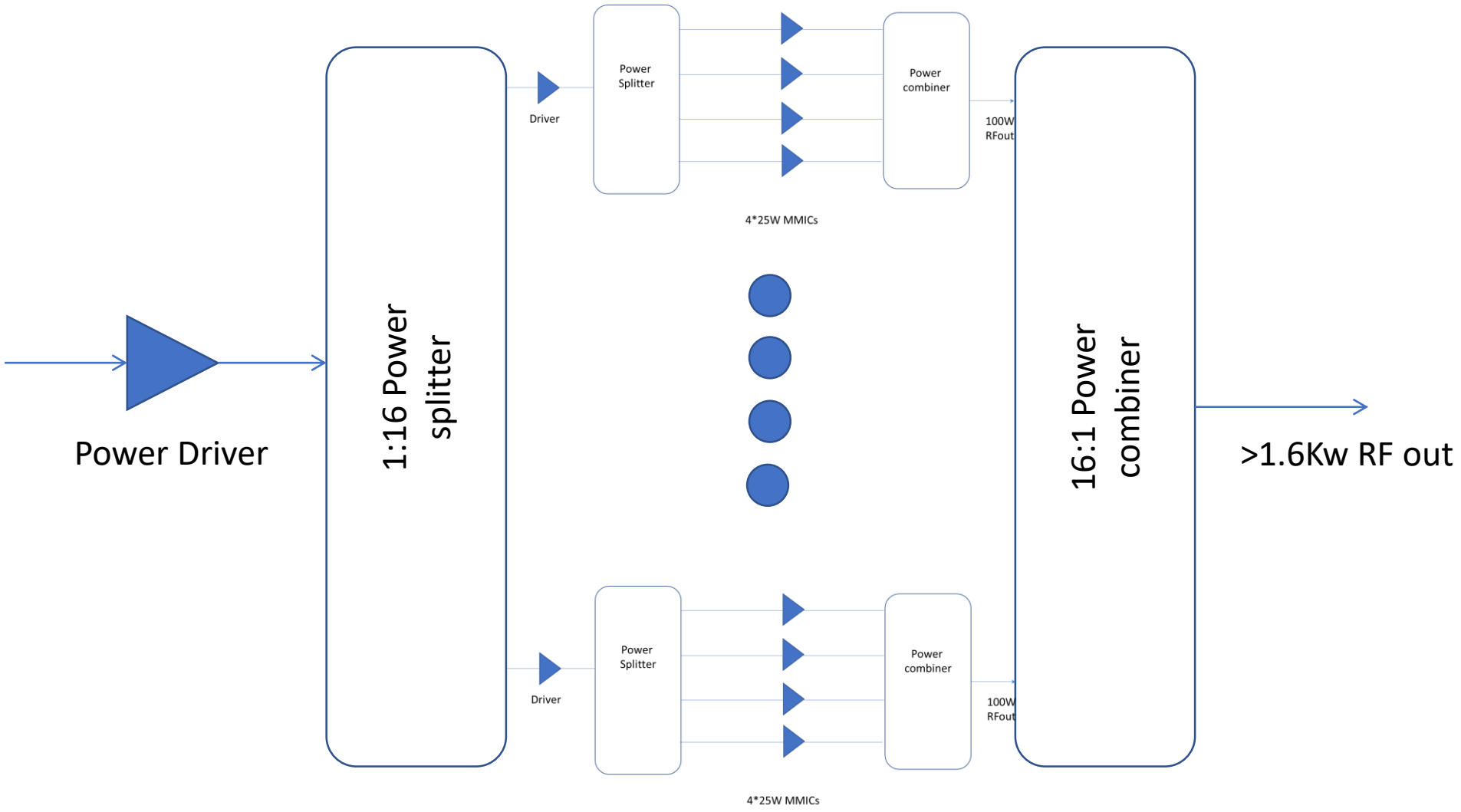
1.6 kW X-band SSPA 16:1 and 1:16



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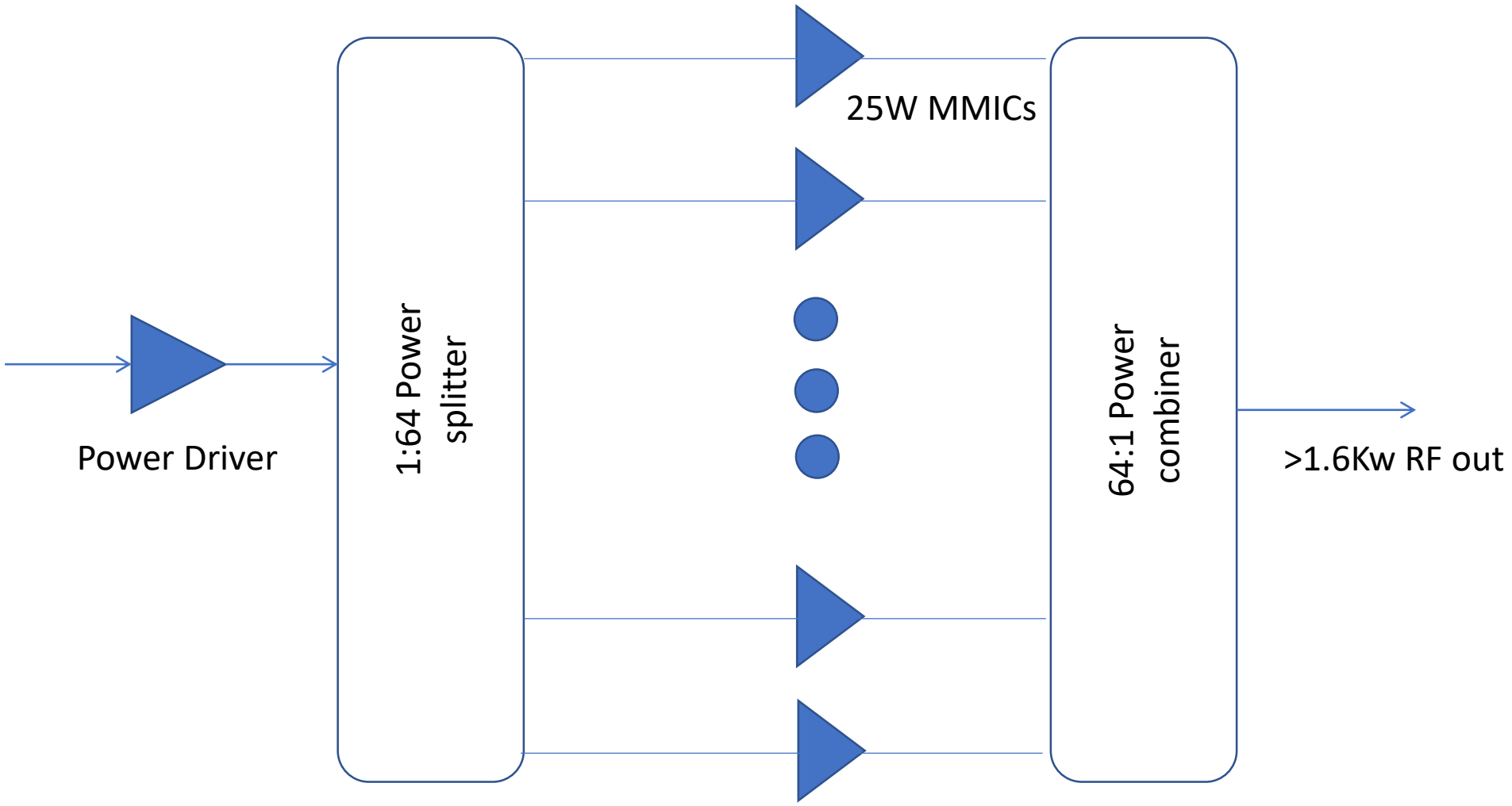
1.6 kW X-band SSPA 64:1 and 1:64



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Questions ?

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