ALBA
Synchrotron Light Facility

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

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Development of a Solid State Amplifier for the 3rd Harmonic Cavity for ALBA Synchrotron Light Source

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MOTIVATION

ALBA, a 3rd generation synchrotron light source

Required beam properties

- ✓ High brightness
- ✓ Small beam size
- ✓ large beam current

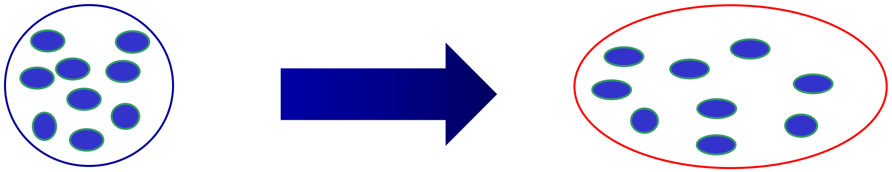
→ High electron density

↓

More electron collisions per unit time → **High beam losses**
Small beam lifetime

3^{rd} Harmonic RF System

Solution to reduce collisions



Stretch the bunch longitudinally by adding 3^{rd} Harmonic RF system

Electron bunch (Beam size) with the main RF system

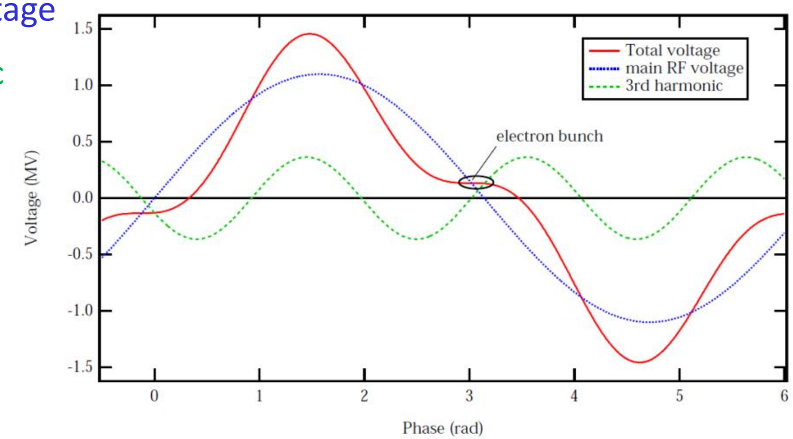
Electron bunch (Beam size) with the main and 3^{rd} Harmonic RF system

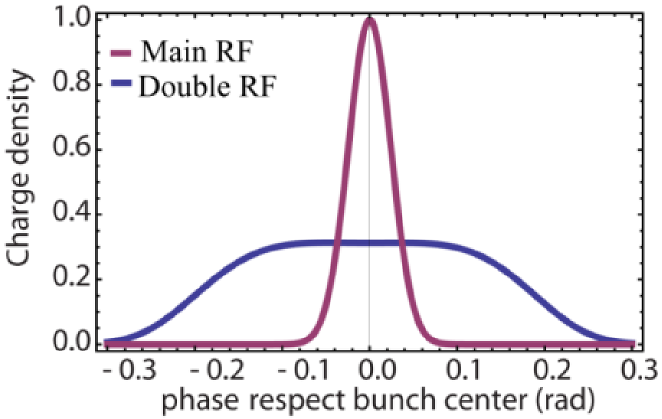
The combined voltage from the main and 3^{rd} Harmonic RF system is given by:

$$V(t) = V_{rf}\,.\sin(\varphi + \varphi_s) + V_h\,.\sin(n(\varphi + \varphi_h)) \qquad h = 3$$

V_{rf} : main RF voltage

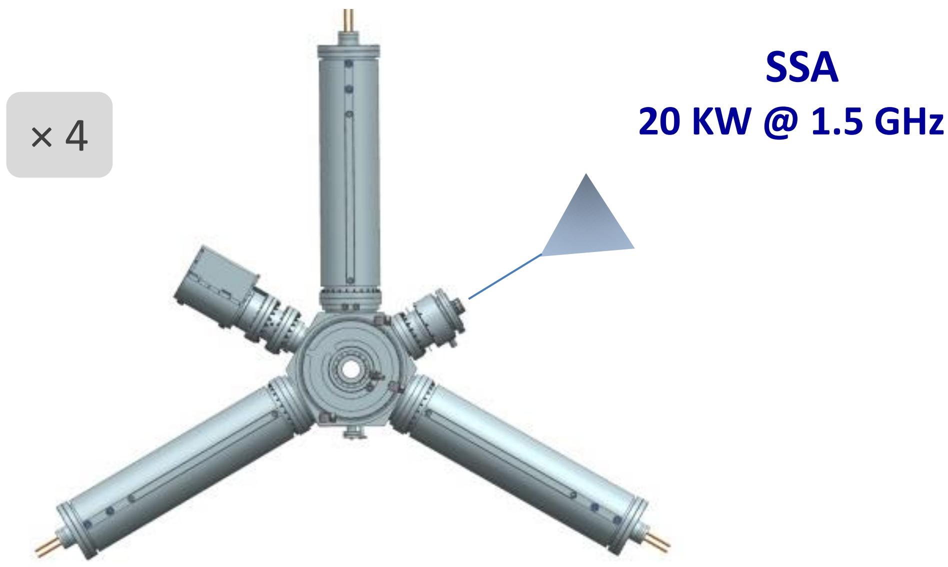
V_h : 3rd harmonic





Bunch length enlarged by a factor 2-3

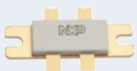
3^{rd} Harmonic RF system for ALBA Storage Ring



4 Scaled Dampy Cavities working @ **1.5 GHz**
With Vh of **1 MV** & Power/Cavity of **20 KW**

Transistor's market comparison

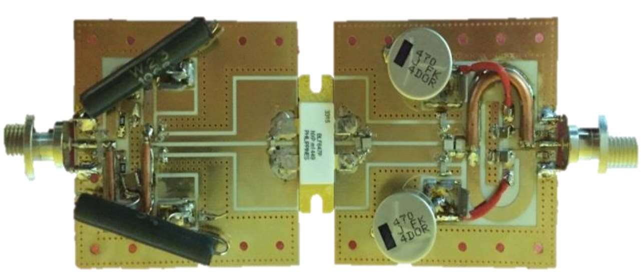
Study and comparison of technical characteristics of existing transistors

Transistor	Manufacture Part Number	Part Number	Date of production	Frequency (GHz)	Power (W)	Efficiency (%)	Gain (dB)	Price (€)
	BLF647P (NXP)	LDMOS (Si)	2013	HF-1.5	200	70	18	194.12
	CGHV14250 (CREE)	HEMT (GaN)	2014-2015	0.9-1.8	250	65	17	305.11
	CGHV14500 (CREE)	HEMT (GaN)	2014-2015	0.5-1.8	400	60	16	521.08

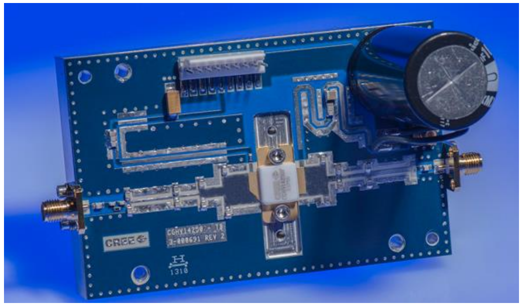
Transistor evaluation circuit (module)

Manufactured

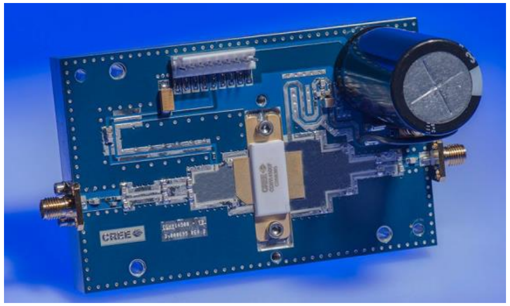
Purchased



BLF647P

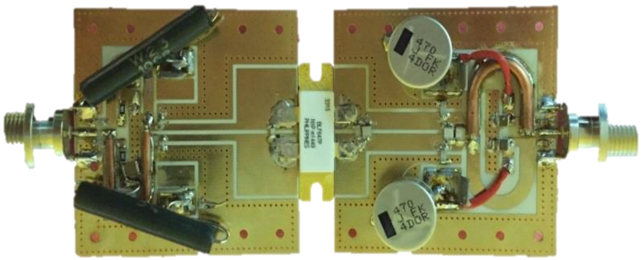


CGHV14250



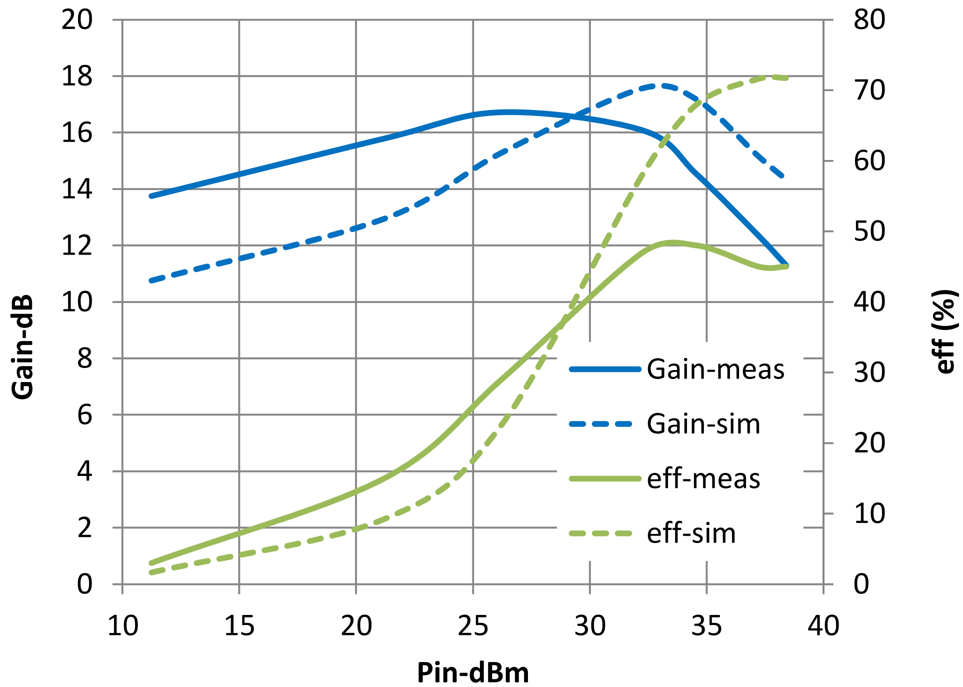
CGHV14500

BLF647P0 LDMOS (Si)- evaluation circuit



@ 1.3GHz CW , Idq: 100 mA , VDS: 32 V

Characteristics	Simulation	Measurement
Power (W)	144	104
Gain (dB)	16.6	14.7
Efficiency (%)	70	55

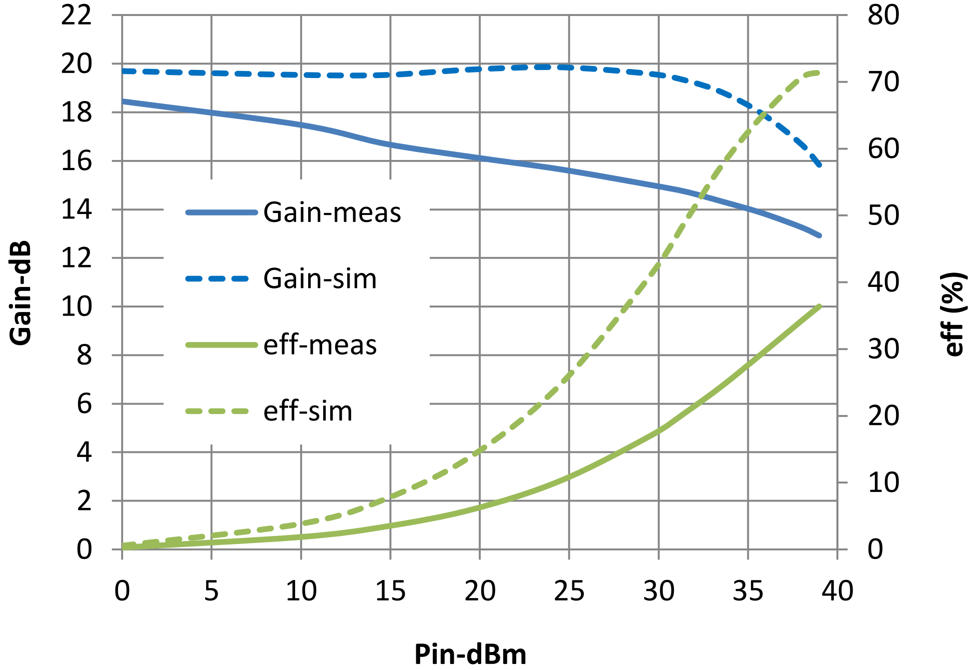


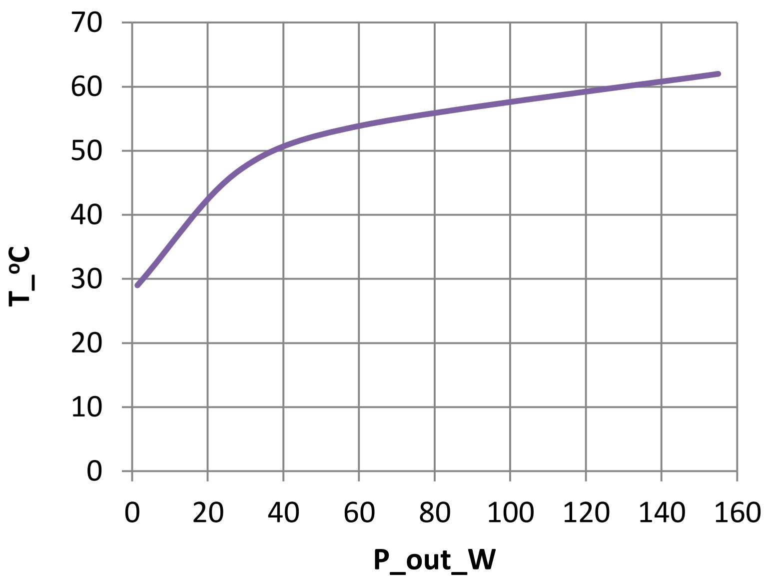
CGHV14500 - HEMT (GaN)- evaluation circuit

@ 1.2GHz CW , Idq: 500 mA , VDS: 50 V, T_{case}: 50º C

Characteristics	Simulation	Measurement
Power (W)	441	155
Gain (dB)	17.4	12.93
Efficiency (%)	58	36.38

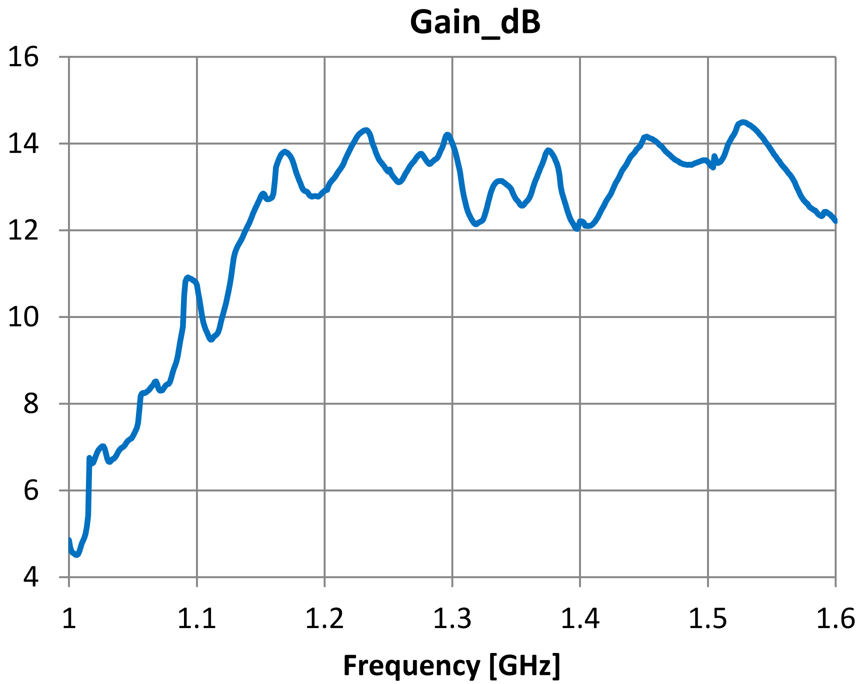
T_{case} as the measurement limitation
Tests stopped due to thermal issues
T_{case}: 64º C

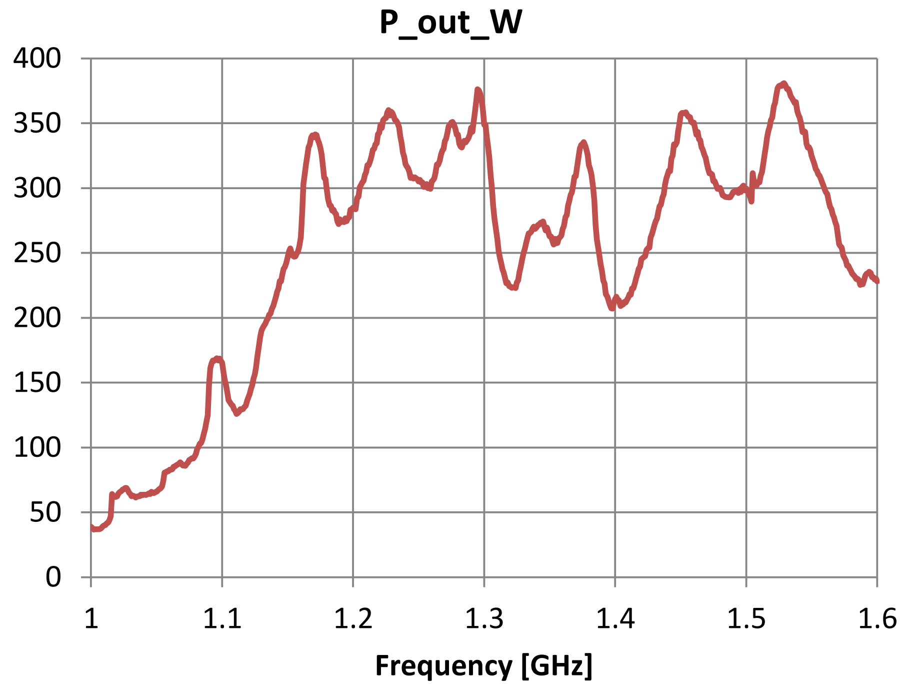




CGHV14500 - HEMT (GaN)- evaluation circuit

Fast sweep over the whole frequency range
Sweep time: 450 ms
Max output power: 375 W @ 1.3GHz
Efficiency: 83%



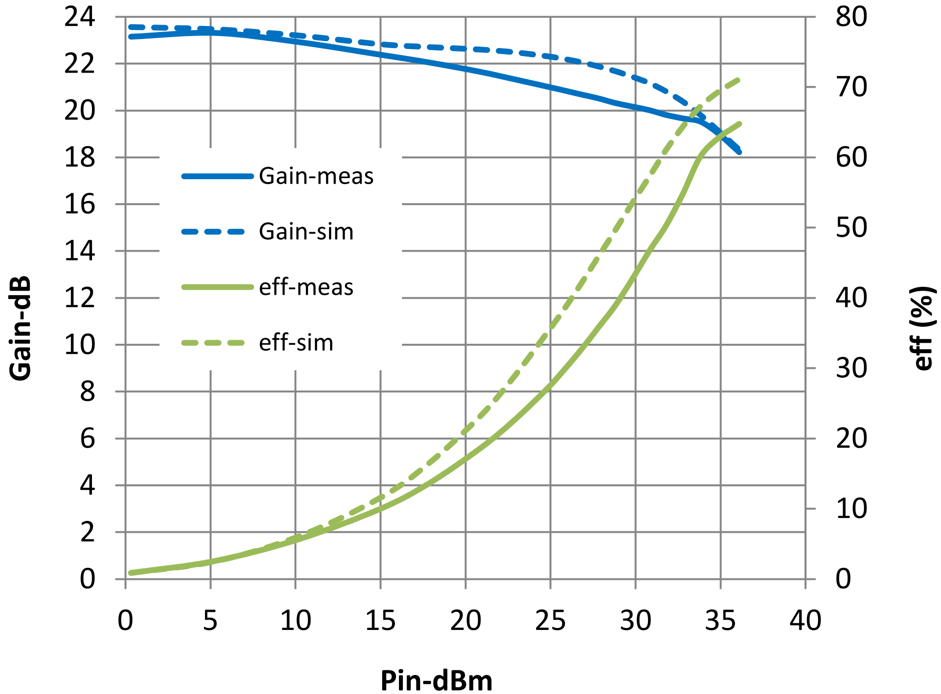


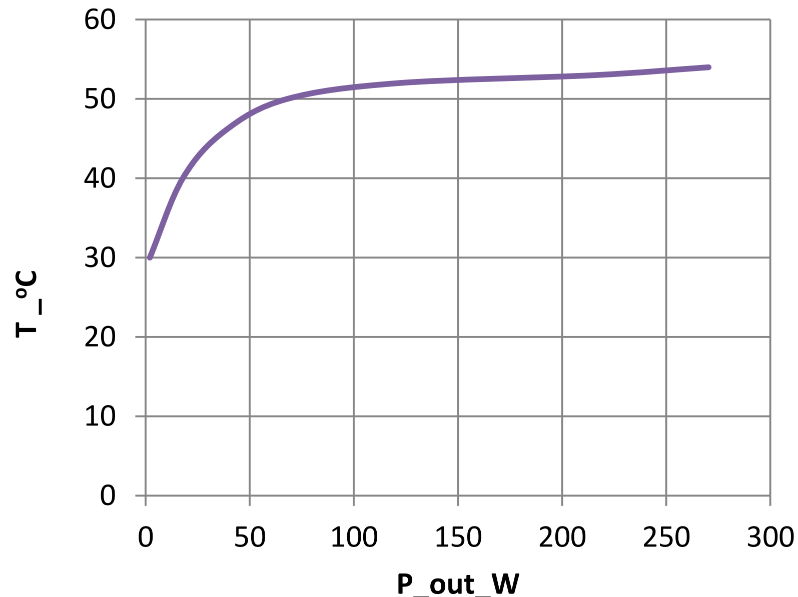
CGHV14250 - HEMT (GaN)- evaluation circuit

@ 1.2GHz CW , Idq: 500 mA , VDS: 50 V, T_{case}: 65º C

Characteristics	Simulation	Measurement
Power (W)	273	270.4
Gain (dB)	17.3	17.3
Efficiency (%)	69	64.77

Qualified enough to be selected





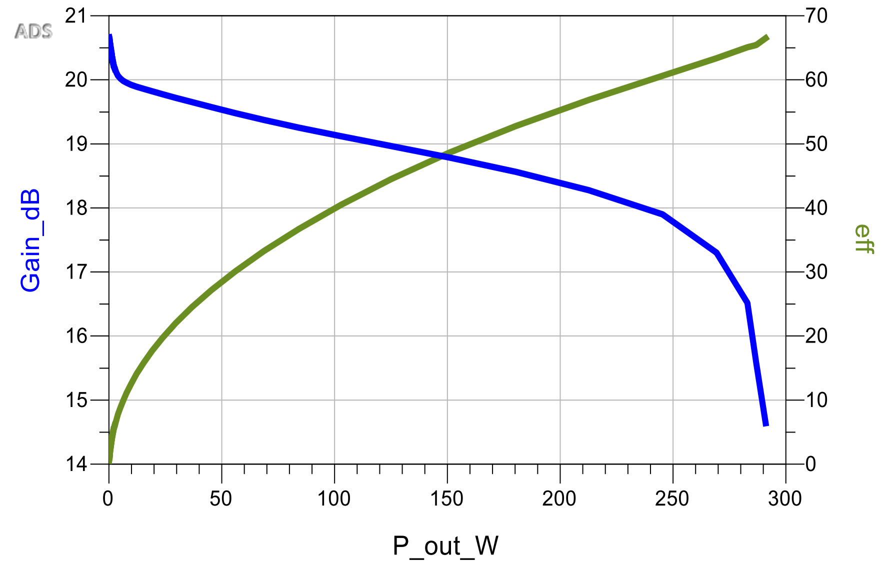
SSA development at ALBA

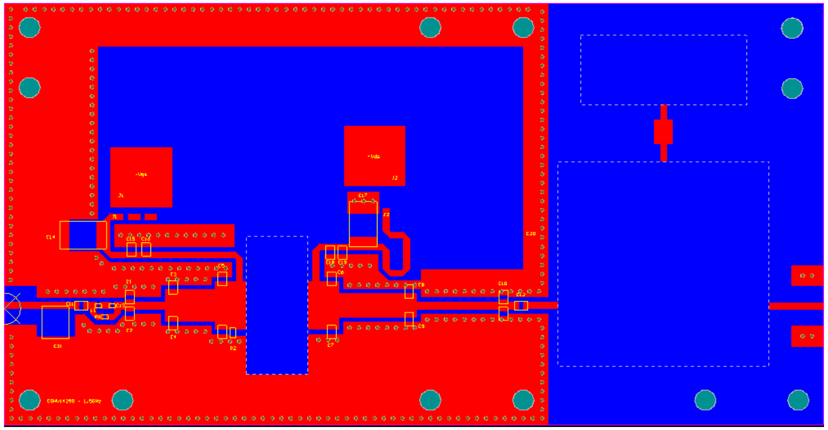
CGHV14250 HEMT(GaN)- single ended

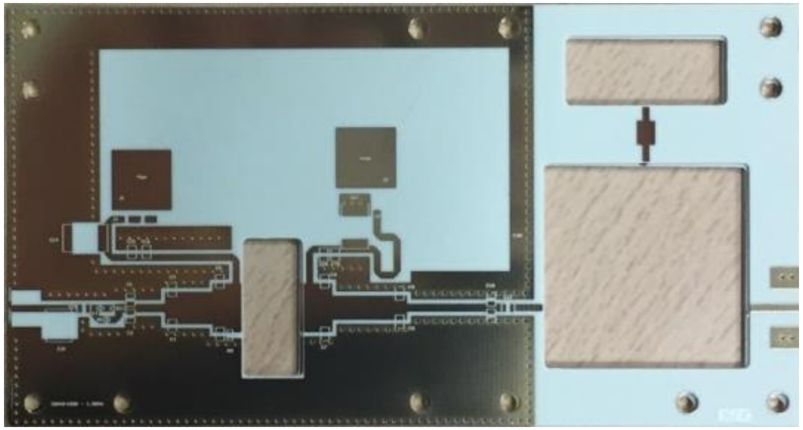
- Frequency: 1.5 GHz
- Output power: 269 W
- Efficiency: 63%
- Gain: 17dB (at 1dB compression)
- Second Harmonic at -38 dBc
- RL: -13 dB

300 W circulator

- IL< 0.2 dB
- Isolation> 25 dB
- RL > 25 dB





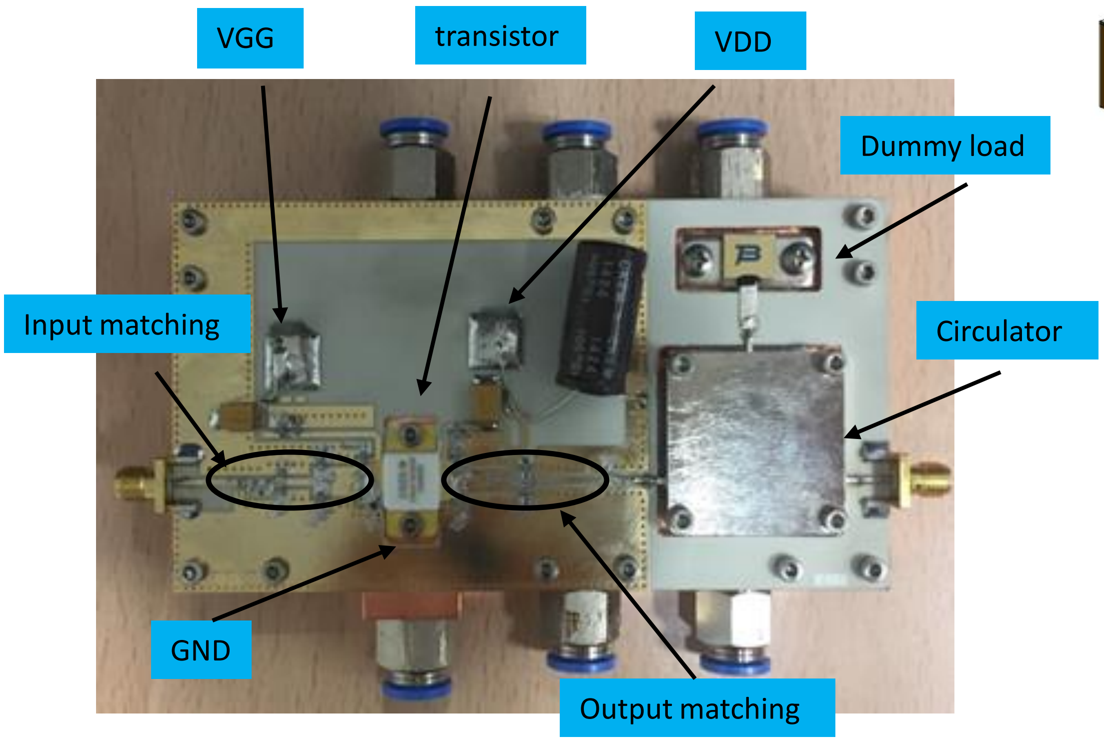


Altium Designer

250 W Solid State Power Amplifier module

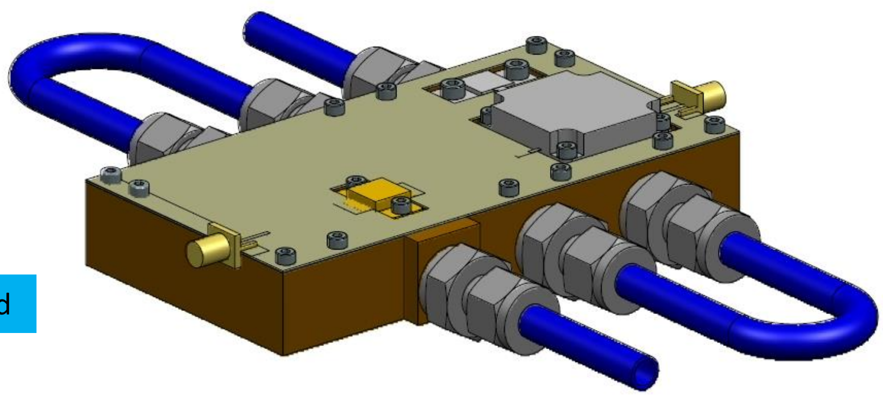
PCB
Substrate: RO4003C
Thickness: 35 um
Height: 0.5 mm

Dimension
without circulator: 89 × 70 sq. mm
with circulator: 132 × 70 sq. mm

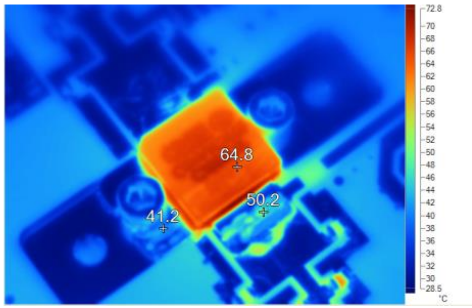


Cooling System: Water

Water flow: 3 lit/min



Copper base plate

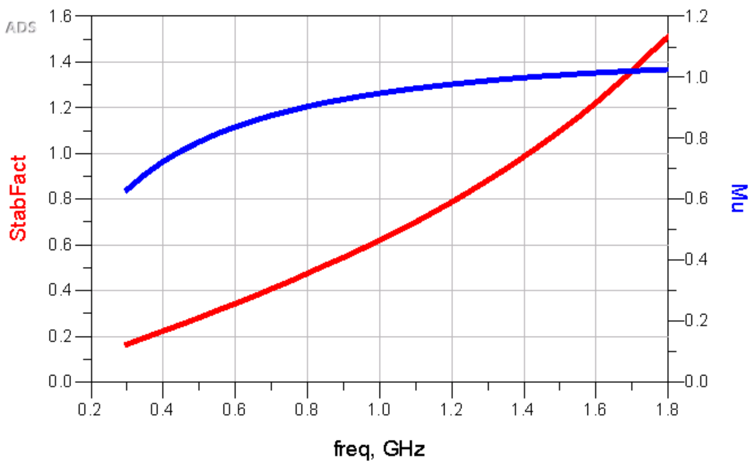


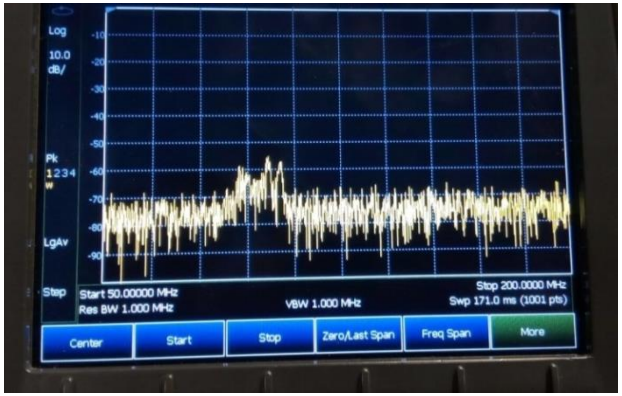
Thermal inspections

250 W Solid State Power Amplifier module

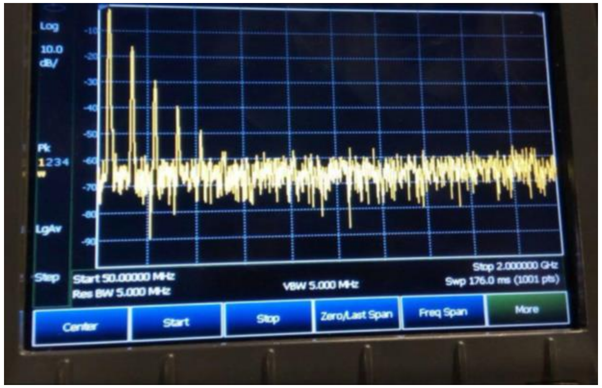
Stability test

- Transistor is unstable in almost whole range of frequency based on **S-parameter S2P file & model**
- Very sensitive to bias voltage and T_{case}

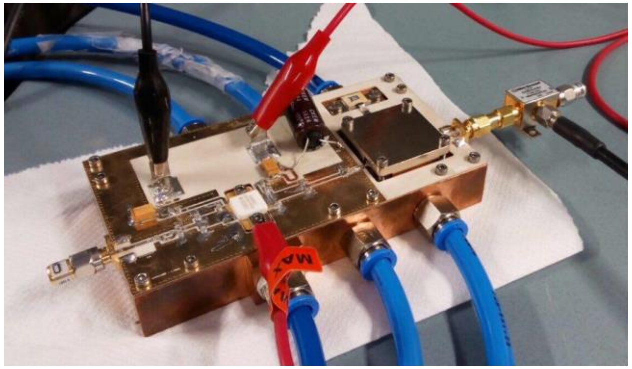




PA is unstable from 80-110 MHz without circulator at bias point

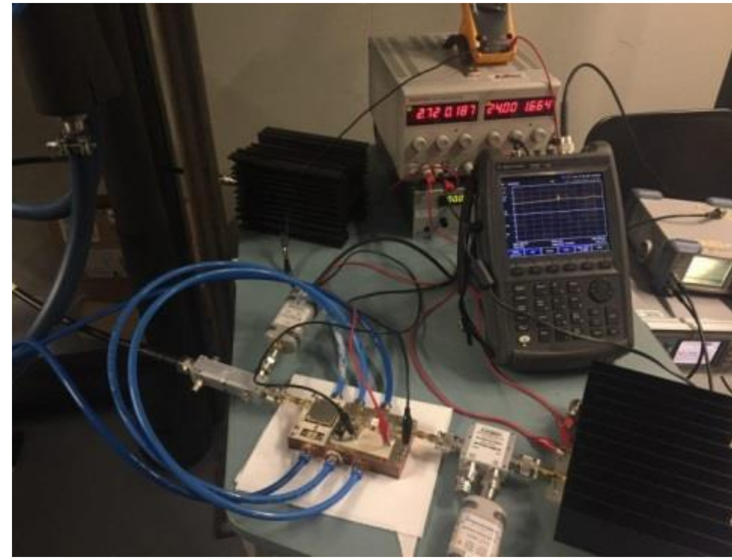


instability was seen at VDS: 35 V



PA is stable with circulator in

250 W Solid State Power Amplifier module

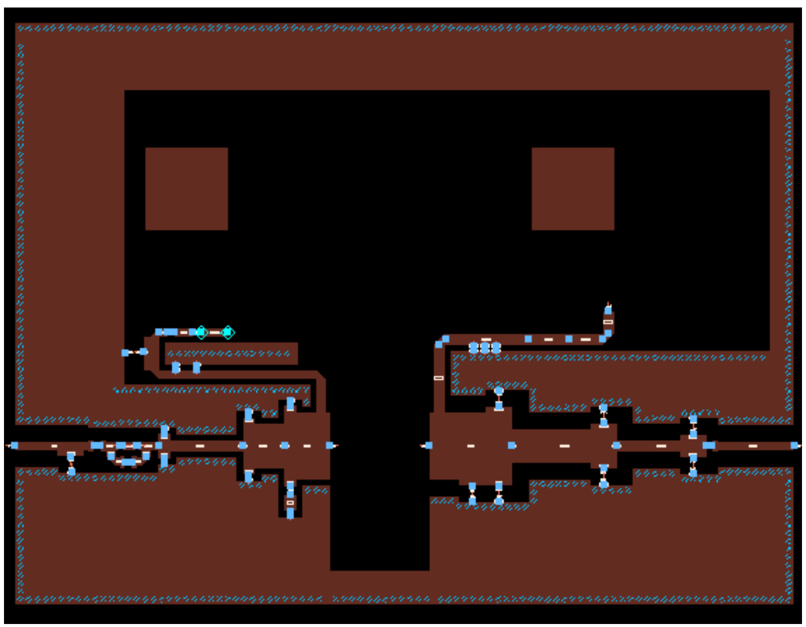


Due to Measurement obstacles as:

- Instability
- Lower gain
- Frequency shift
- Thermal issue

Modifications were done :

- output matching capacitors : ATC 600F → ATC 800B and trimmers
- output dc feed line width
- Parallel resistor for stabilization in the input matching

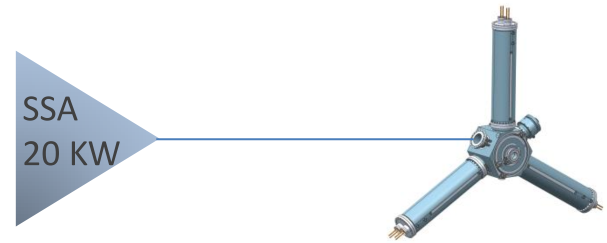


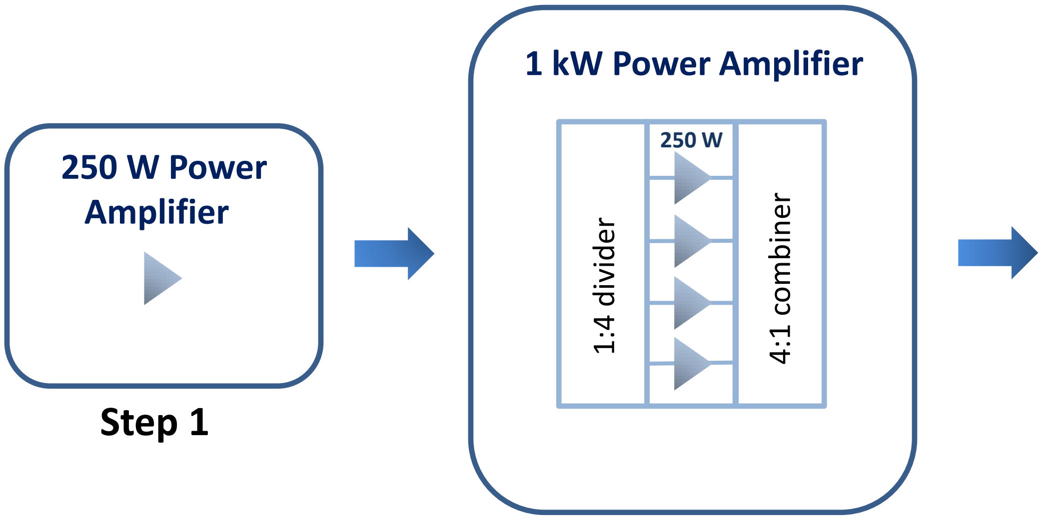
New Dimension: 94 × 70 sq. mm
Under fabrication

20 kW Solid State Power Amplifier Combining System

Parallel Combination Array

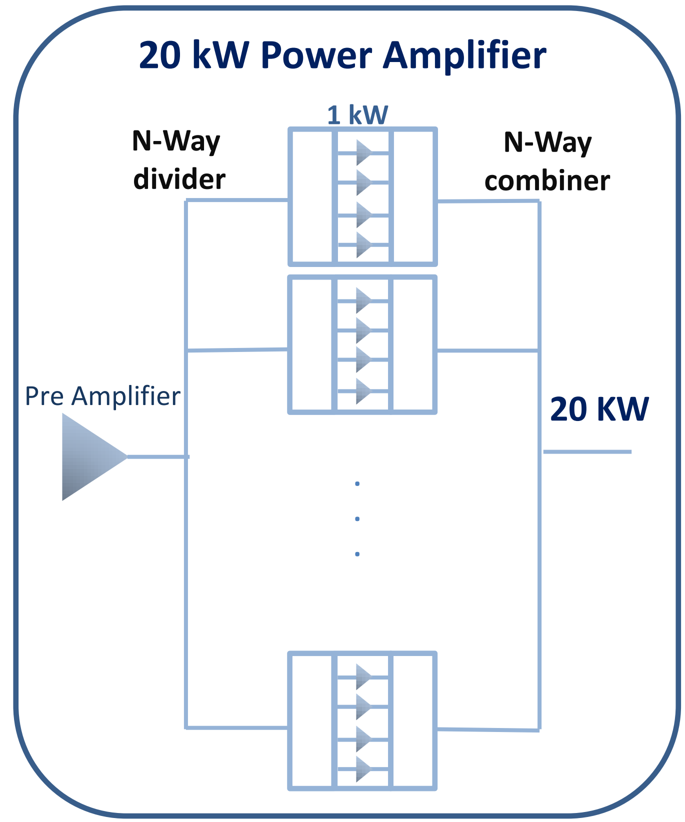
- ✓ Primary Power Amplifier module Output Power (Gain)
- ✓ Overall Output Power
- ✓ Dividers/Combiners (microstrip, coaxial & waveguide)





Step 1

Step 2



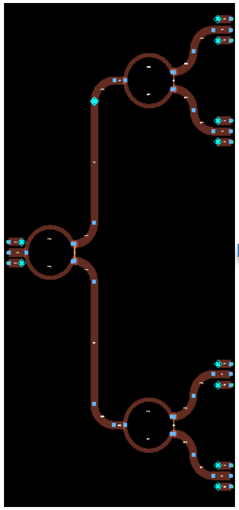
Final configuration

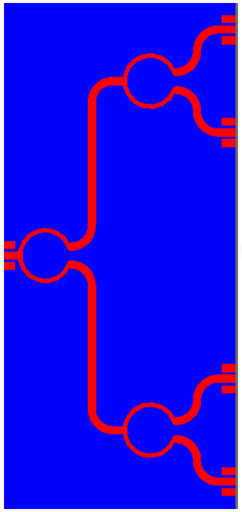
Power divider/combiner for 1 kW power Amplifier Module

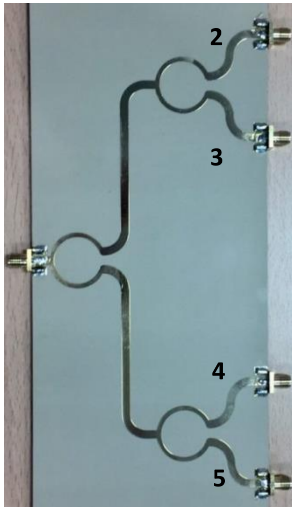
Wilkinson power divider/combiner

- Dimension: 100 × 284 sq. mm
- Substrate: RT6035HTC
- Thickness: 18 um
- Height: 1.6 mm

PORT	Freq (GHz)	Insertion loss Amplitude (IL) dB		Insertion loss (IL) Phase	
		Simulation	Measurement	Simulation	Measurement
2	1.5	-6.090	-6.374	166.148	-120.675
3	1.5	-6.136	-6.324	166.398	-119.283
4	1.5	-6.152	-6.329	165.027	-119.648
5	1.5	-6.106	-6.260	164.730	-118.496







PORT	Freq (GHz)	Return loss (RL)	
		Amp (dB)	phase
1*-2	1.5	-23.18386572	137.1471727
1*-3	1.5	-23.13089724	136.658208
1*-4	1.5	-23.42375501	139.0671877
1*-5	1.5	-23.66775796	139.4849719

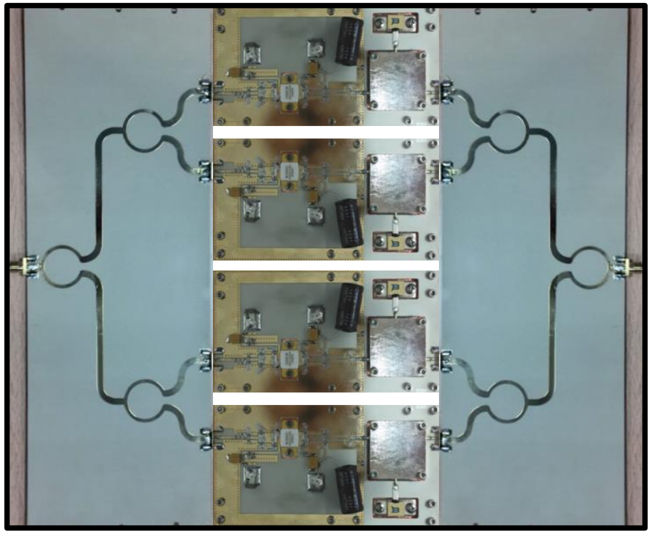
1 kW Solid State Power Amplifier module

Next Steps

- Optimization of 250 W module
- Design and build a 1 kW module out of 4 modules (cooling, casing)
- Optimization (amplitude and phase) of the 1 kW module

1 kW Power Amplifier module

~ 20 W



1 kW

THANK YOU FOR YOUR ATTENTION