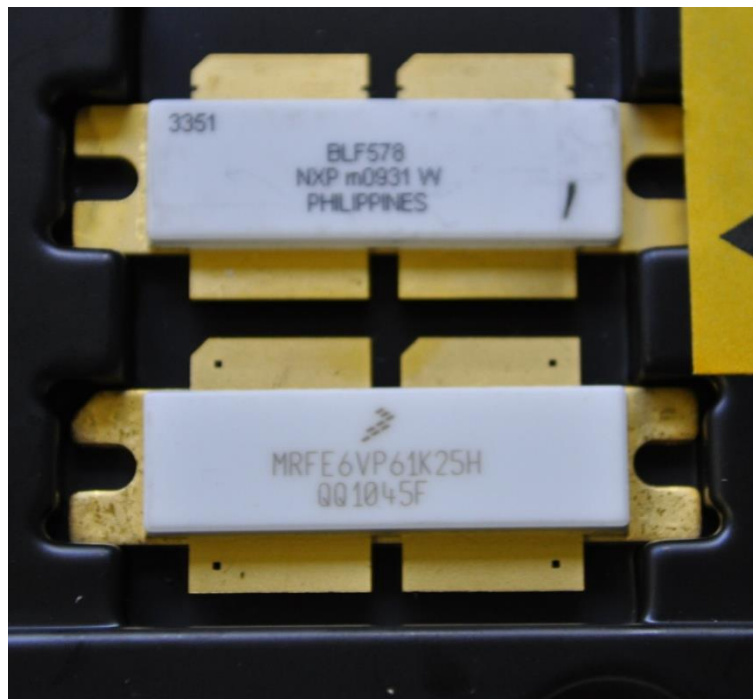




| The European Synchrotron

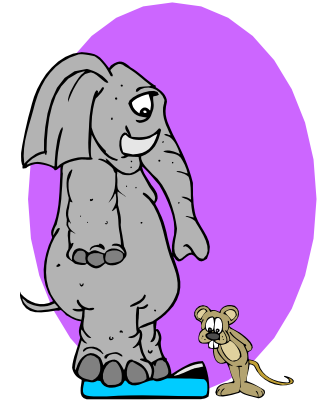


SSA using a cavity combiner

Michel Langlois, Pierre Barbier, Jörn Jacob

THE MAIN DRAWBACK OF SSA FOR SCIENCE IS THE LARGE RATIO BETWEEN SPECIFIED RF POWER AND MODEST SINGLE MODULE POWER HENCE 2 MAIN TARGETS FOR THIS DEVELOPMENT:

✓ Decrease the footprint and volume of solid state amplifiers.

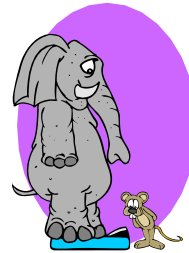


✓ Make them cheaper, i.e. decrease the €/W rating.

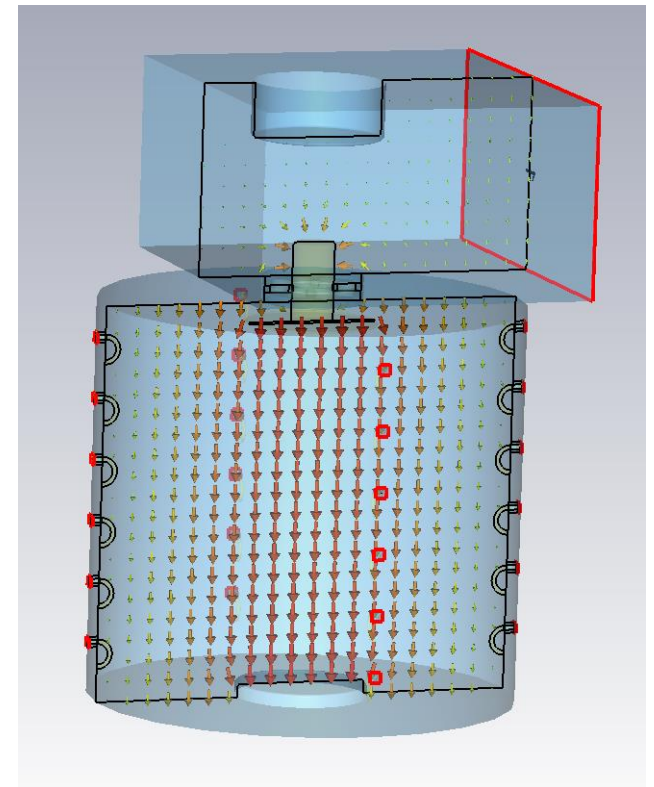


5 IDEAS COULD MAKE IT HAPPEN!

1/ Make use of a cavity combiner to provide compactedness!

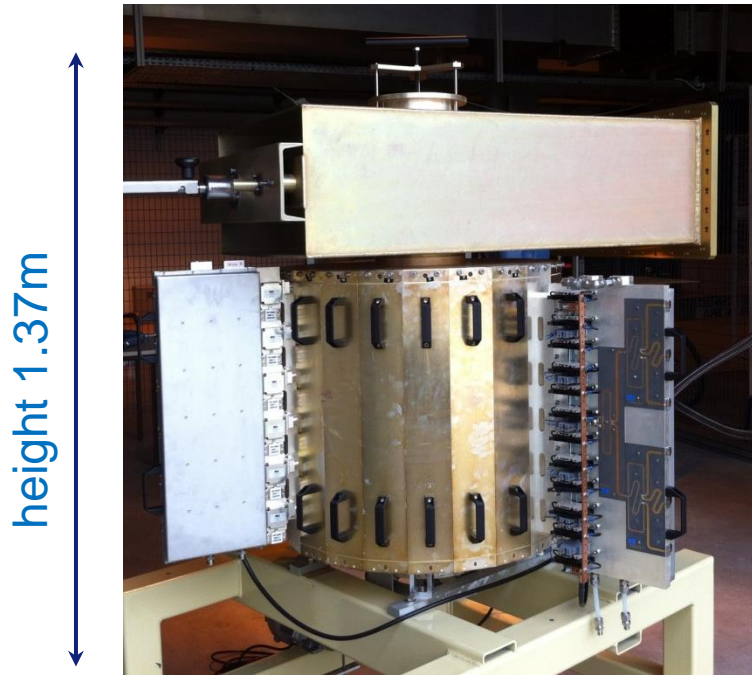


- ✓ The resonator operates in E010 mode.
- ✓ All modules are coupled to the resonator with fixed loops.
- ✓ The resonator is capacitively coupled to the waveguide. This coupling can be varied.





HOW SUCCESSFUL?

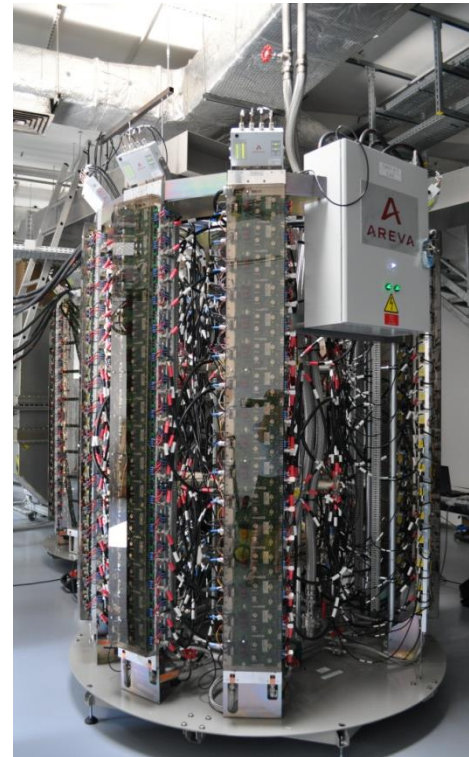
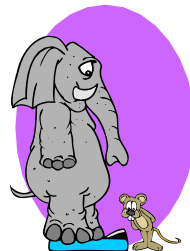


height 1.37m



diameter 1.32 m

75 kW
C.W.



height 2.7m



diameter 2.1m

Footprint efficiency=54.8 kW/m²

Volume efficiency =40 kW/m³

Footprint efficiency=21.6 kW/m²

Volume efficiency =8.02 kW/m³

2/ USE OFF-THE-SHELF POWER SUPPLIES.



A 50V/10kW supply is chosen. It is available from a European manufacturer. It feeds a wing containing 6 modules. They use the 400V/ 3 phases mains.

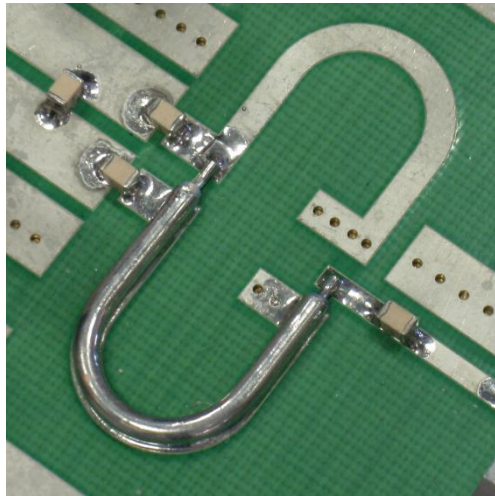
The amplifier is still in operation if one supply dies. The power derating, if any, is not known yet.



Configuration for 3 wings=18 modules of 700W each

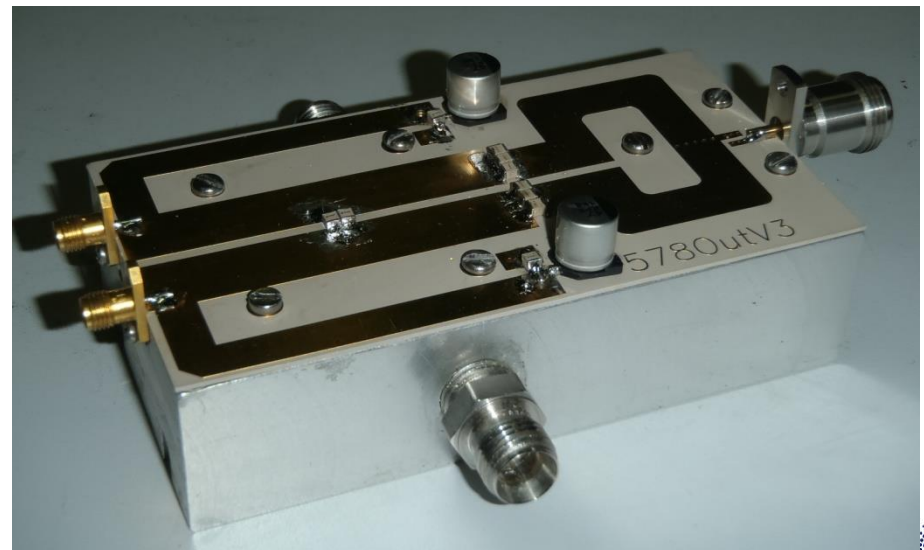
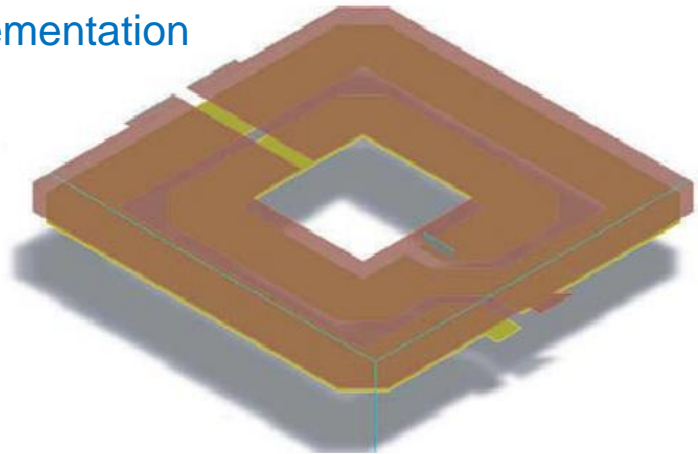
3/ RF MODULES FEATURE PLANAR BALUNS, NO CHOKES AND NO TRIMMING

Balun coaxial implementation
Involving manpower



Printed baluns, accurate capacitor
values and positions make it
possible to do away with trimming

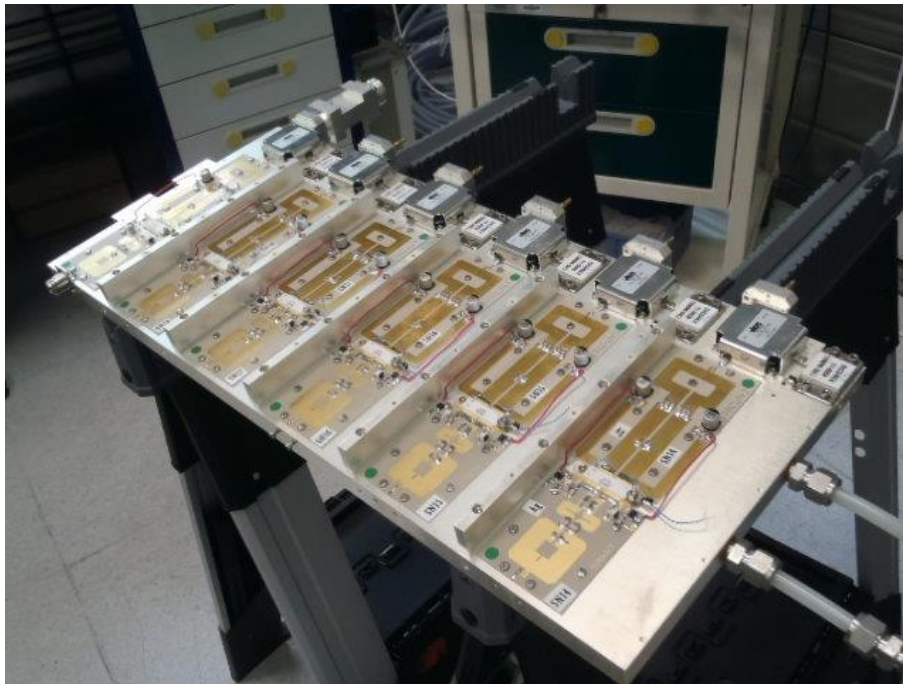
PCB implementation



4/ RF AND D.C. DISTRIBUTION USE THE SAME SUPPORT AS THE RF MODULES.

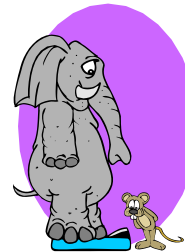
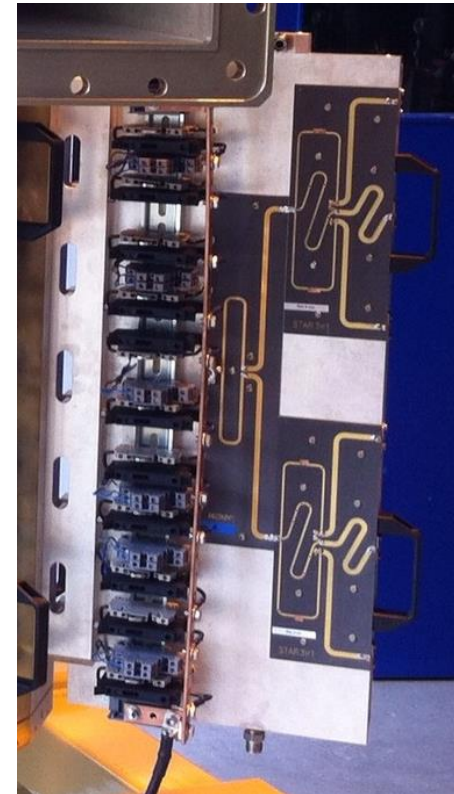
front side of a wing

Including 6 RF modules + circulators + loads



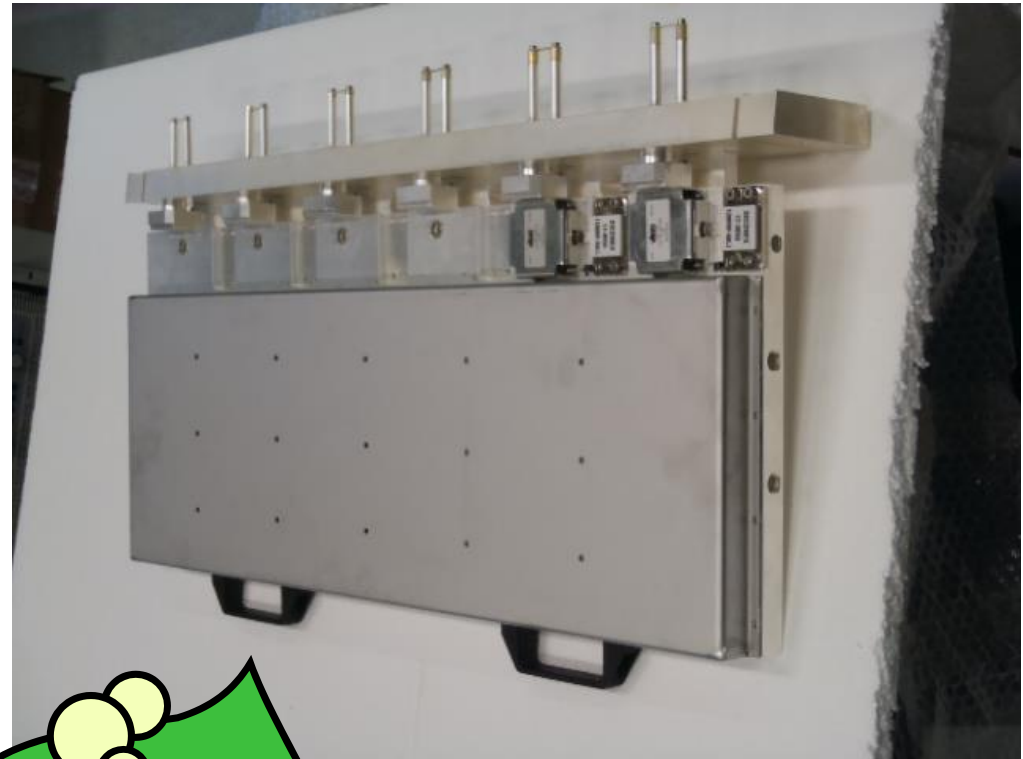
back side of a wing

Including RF drive splitting and DC distribution



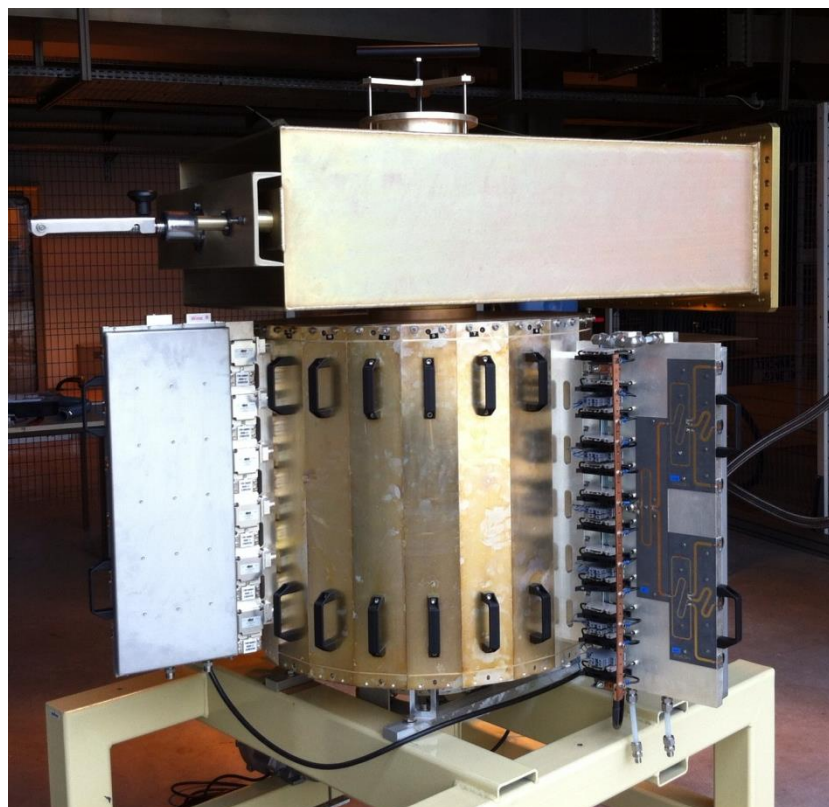
5/ THE MODULES ARE NOT INDIVIDUALLY SHIELDED

- + the sole of the transistor is very close to the cooling channel.
- + much cheaper than individual shielding.
- RF radiation originating from the circulator tabs.



ACHIEVEMENTS SO FAR

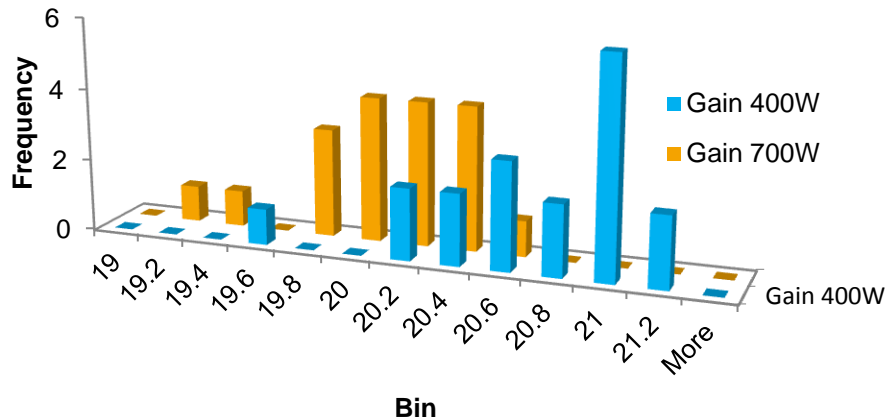
A cavity combiner equipped with 3 wings of 6 modules has been built and tested on a 50 Ω dummy load.



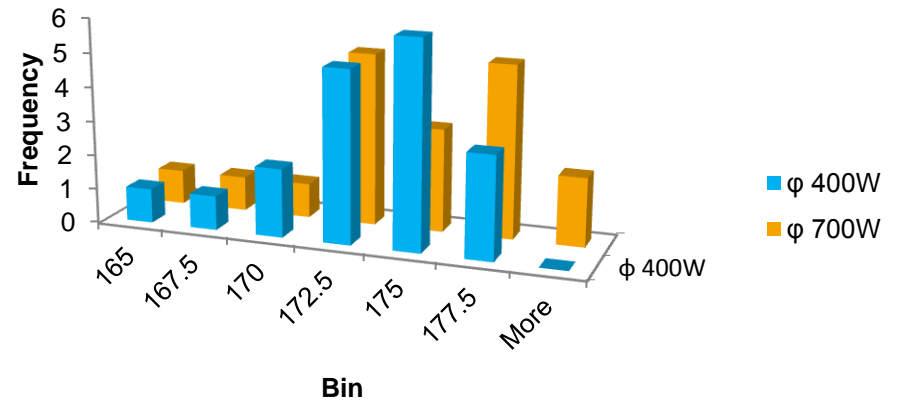
GAIN AND PHASE DISTRIBUTIONS

The modules were hand made. It caused a poor reproducibility of the matching capacitors positions. The transistors (NXP BLF578) came from different batches ordered at different times.

Gain histogram of the 18 modules



Phase histogram

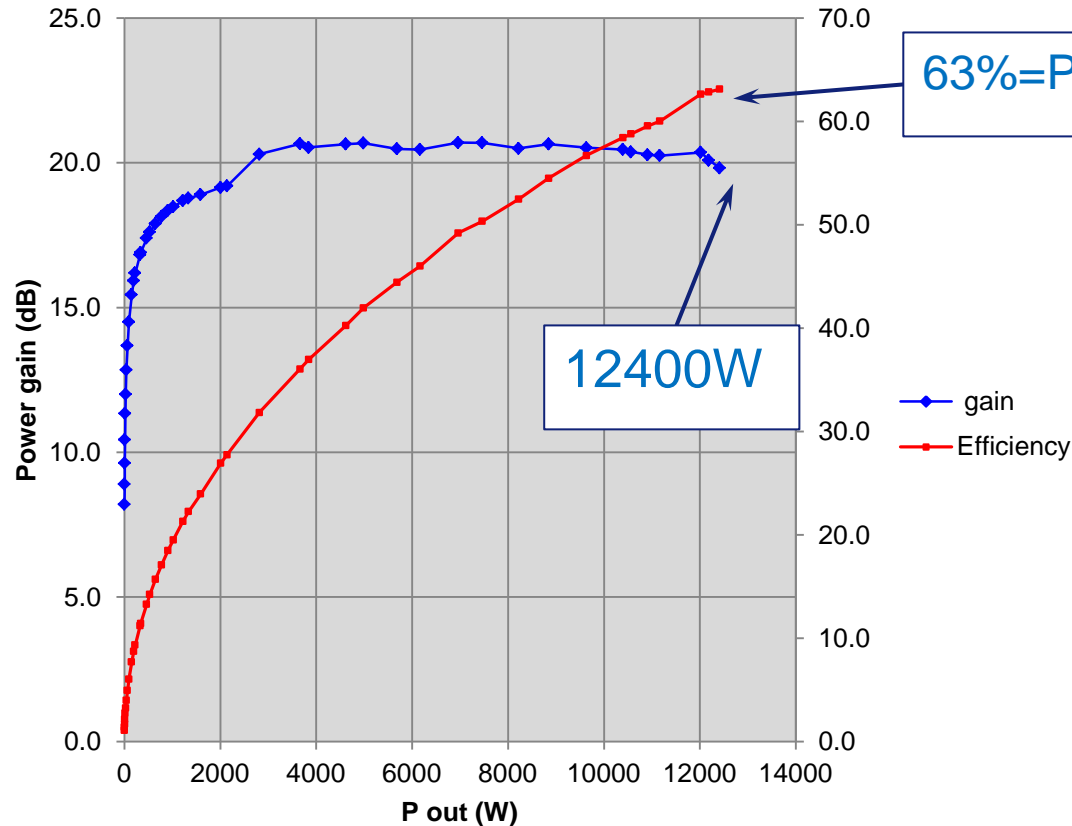


Will these modules still combine harmoniously?

AMPLIFIER PERFORMANCES

Test conditions: $I_{dq}=2 \cdot 100\text{mA}$ per module (nearly class B)
 $V_{ds}=50\text{V}$ 15l/min per wing

Amplifier performance



$63\% = P_{rf} / (V_{ds} \cdot \Sigma I_d) = \text{drain efficiency}$

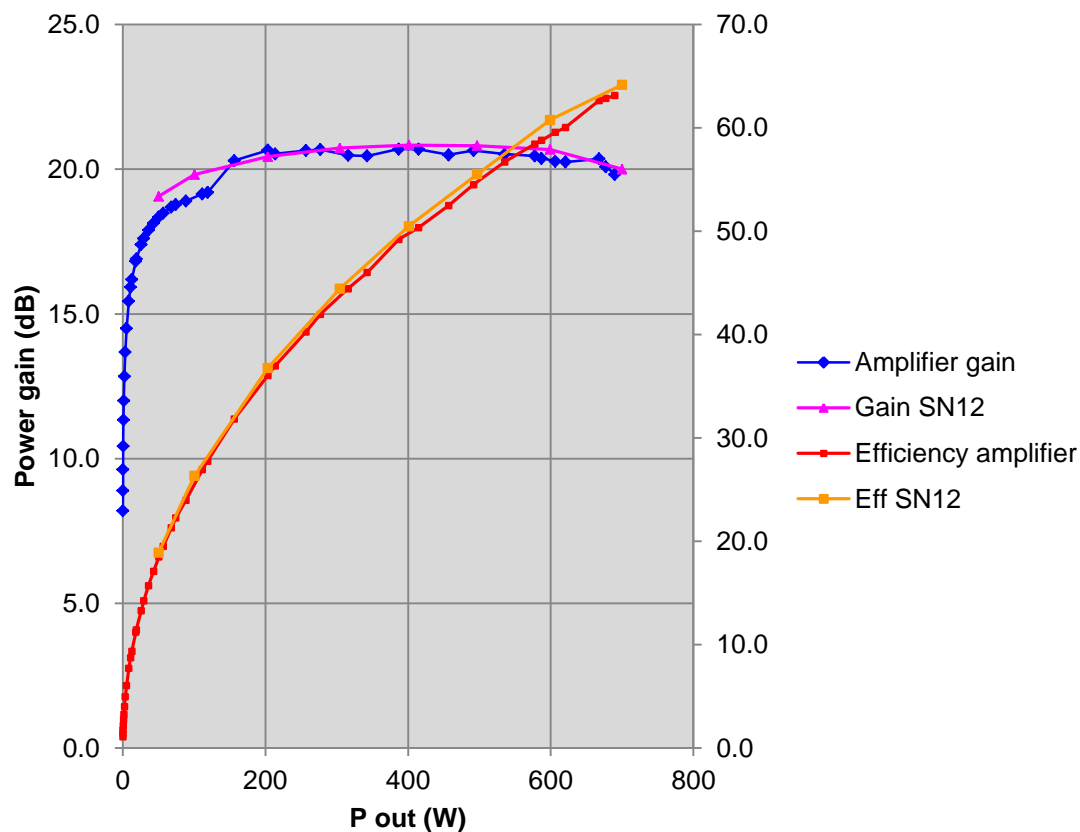
12400W

The efficiency of a class B amplifier is bad at low output level. If the RF power has been overestimated, the number of wings plugged on the cavity combiner may be decreased to run the amplifier at a decent efficiency. The output coupling has to be adjusted.

AMPLIFIER PERFORMANCES

Test conditions: $I_{dq}=2*100\text{mA}$ per module (nearly class B)
 $V_{ds}=50\text{V}$

Ampli vs. module

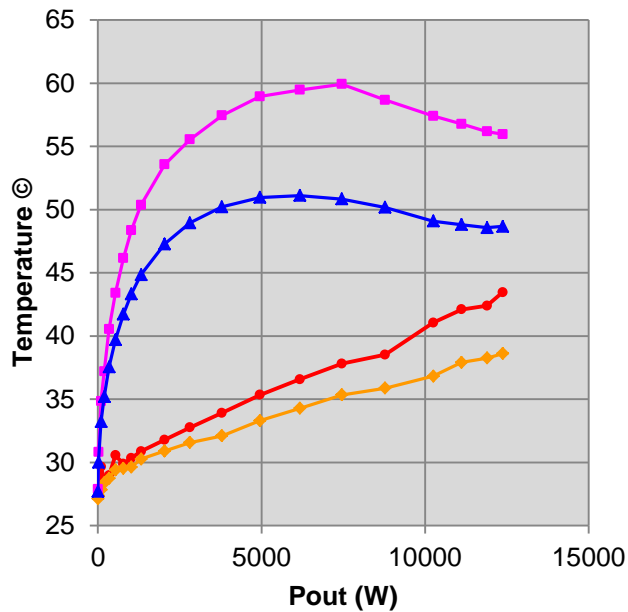


SN12 is a module chosen for its average gain and efficiency. Its performances are compared with that of the whole amplifier. The RF power and drain total current of the whole amplifier have been divided by 18. The plots are quite close.

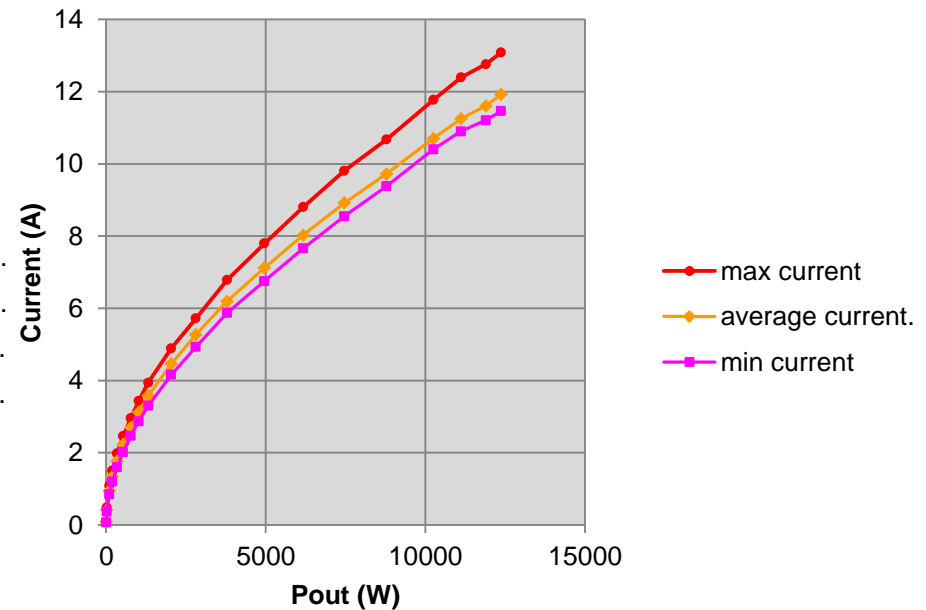
AMPLIFIER PERFORMANCES

DISCREPANCIES

Load and sole temperatures



Drain currents

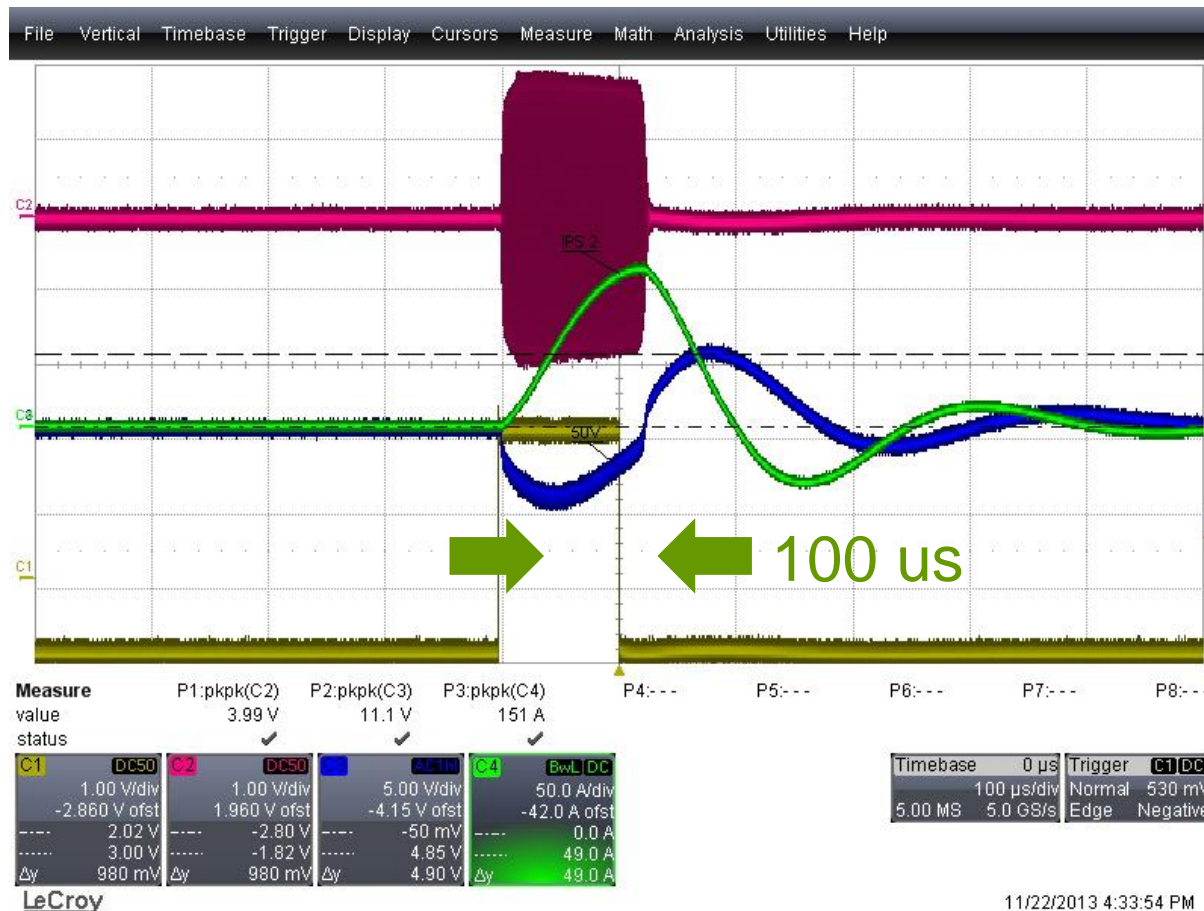


AMPLIFIER PERFORMANCES

PULSED OPERATION UP TO 10 KW

RF

Recorded at 5kW



Vds
46V min

100 us



FURTHER TESTS WITH 3 WINGS

- ✓ Check the operation with new DC distribution boards on 50Ω load and additional cooling circuit.
- ✓ Test with 3 adjacent wings on 50Ω load.
- ✓ Test with VSWR using our EH tuner.



WHAT'S NEXT?

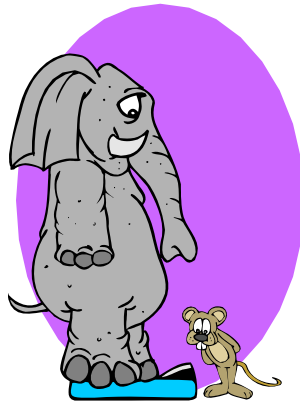
We launched the production of 19 (+2 spares) wings to complete the cavity combiner slots.

- ✓The extrusion of cooling plates has been ordered to an Italian company.
- ✓The machining and electroplating of mechanical parts has been subcontracted in France.
- ✓The manufacturing of the modules has been handed over to a French company.
- ✓The wings will be put together by ESRF people.



Thanks to my dear colleagues for their very welcomed advices

Thanks to Hans Kartman (NXP) for his help in the module design



You still here? Thank you for that too!