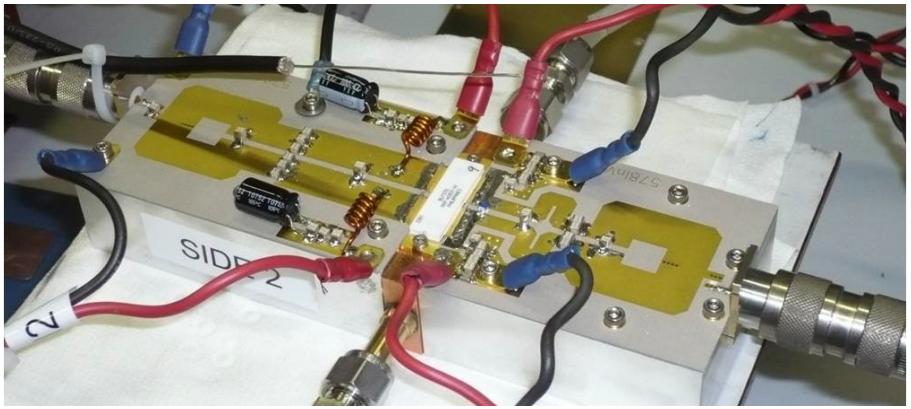
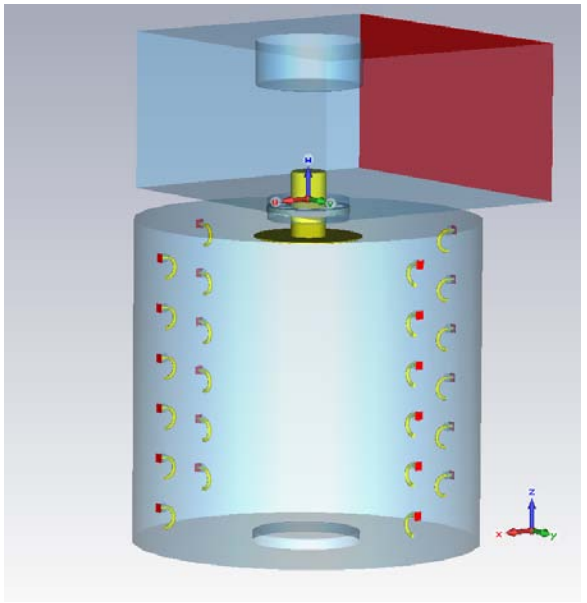
Solid state power amplifier development at ESRF





M.Langlois

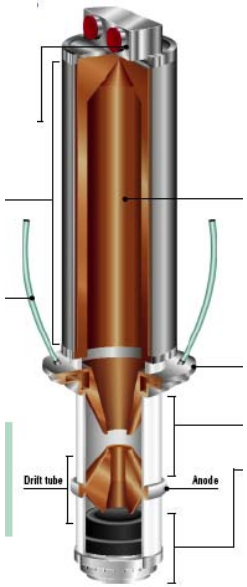
Motivation

- Get some insight of the “do and don’t” of solid state amplifiers.
- Adapt them better to synchrotron light source service.

Available RFpower components

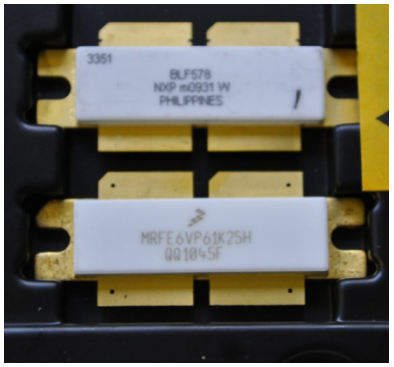

Thales TH 2089

Klystron MW range
3 acknowledged manufacturers



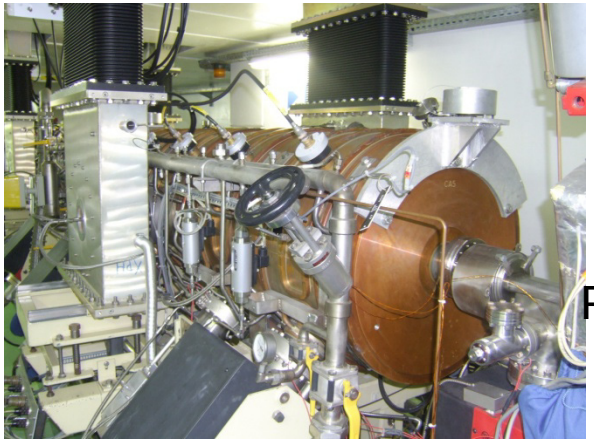
IOT a few 10 kW
3 acknowledged manufacturers

LDMOS a few 100 W
2 acknowledged manufacturers

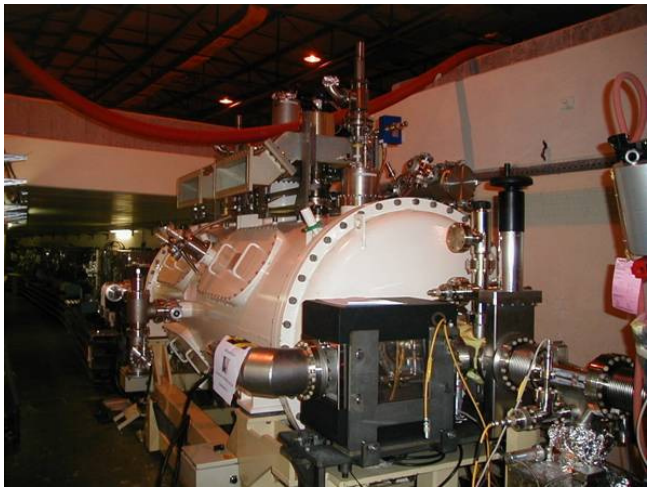


Transistors are fashionable because :
•Few people accept to deal with high voltages
•Due to the so-called graceful degradation, they fit in the operation schedule of a light source

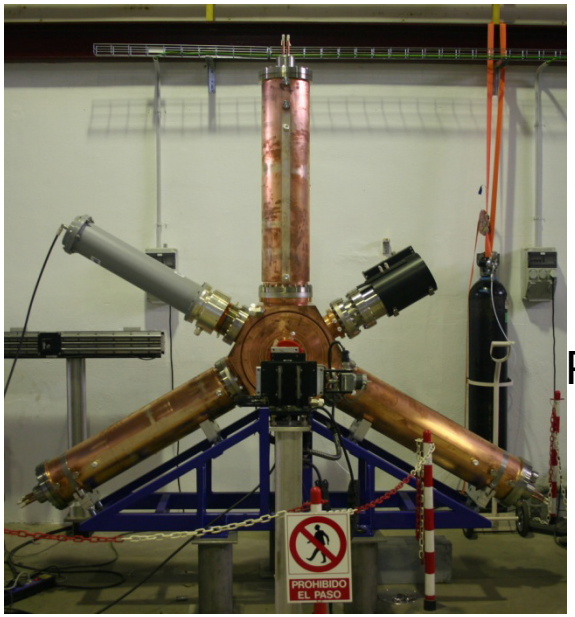
Cavities



ESRF
Voltage: 1.6 MV TTC
Power: 300 kW at 200mA

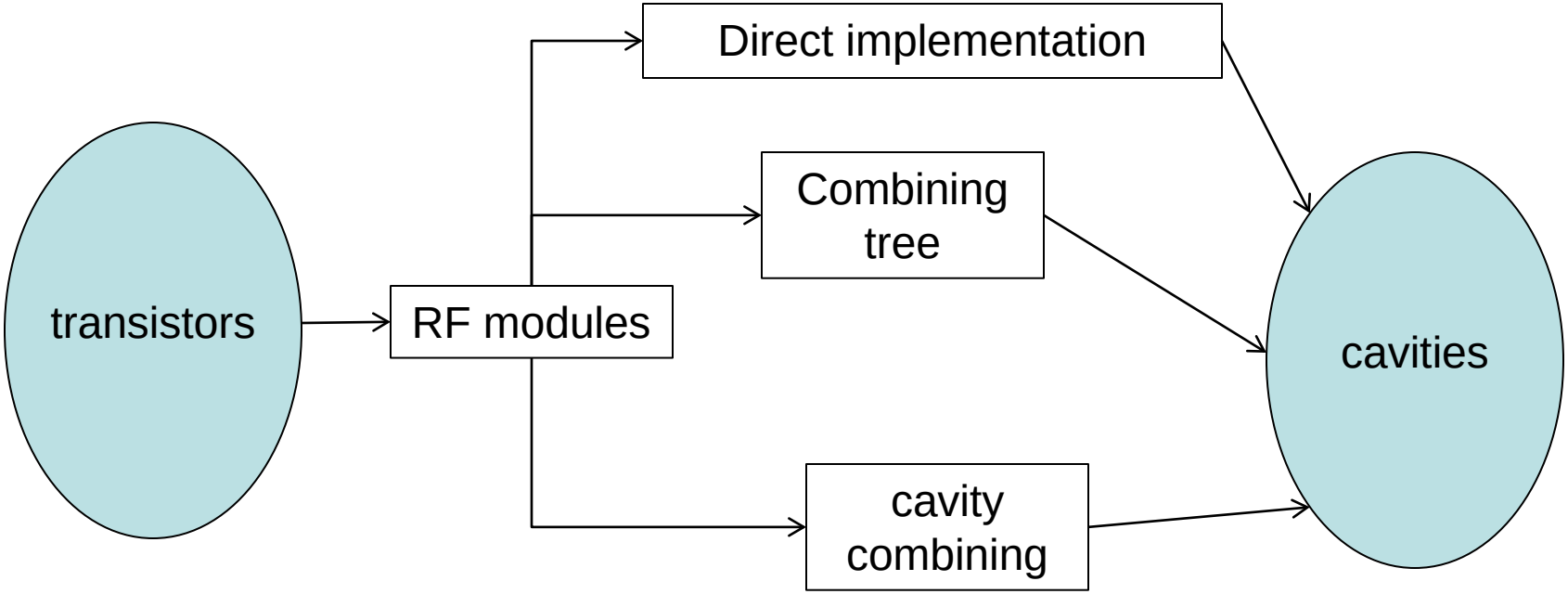


SOLEIL
Voltage: up to 5 MV TTC
Power: up to 400 kW

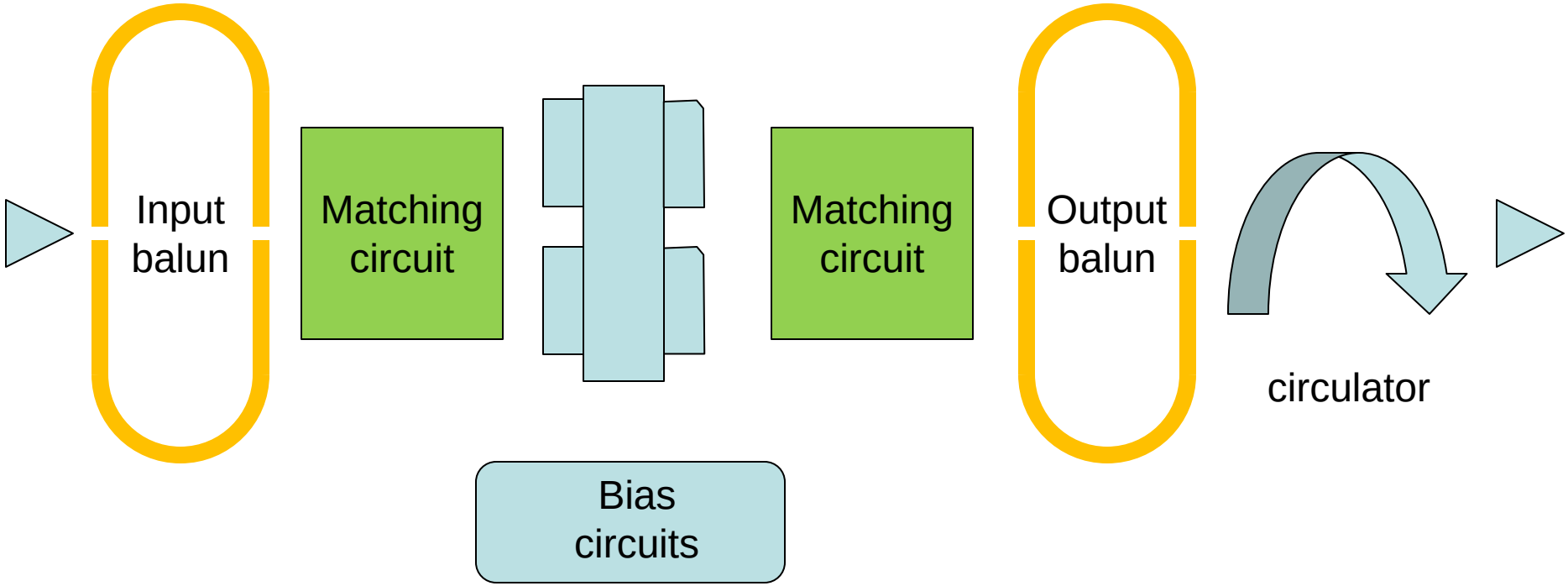


ALBA
Voltage: 600 kV TTC
Power: 140 kW at 400mA

How to bridge the gap?



RF module

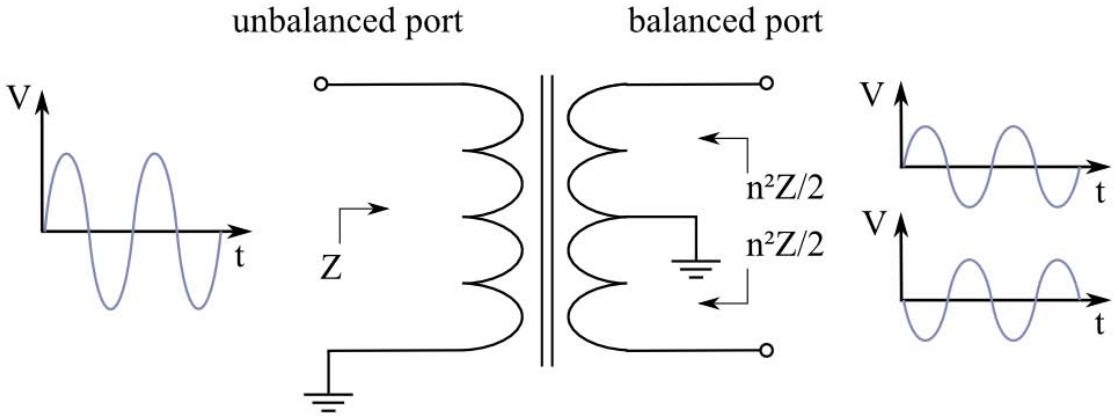

Input balun
Matching circuit
Matching circuit
Output balun
circulator
Bias circuits

Cost : expensive parts

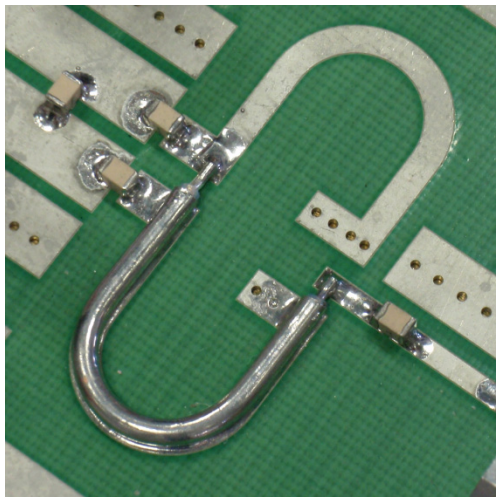
- Transistor
- Circulator
- Baluns
- Choke
- All components forbidding pick and place

Baluns

Balun transformer

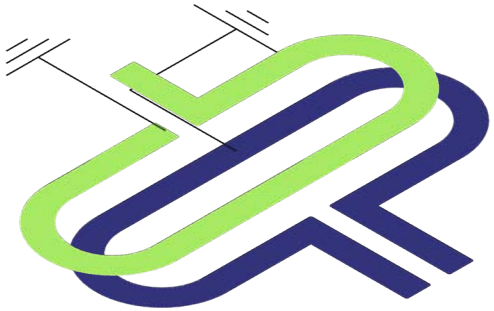


Coaxial implementation



Planar printed baluns

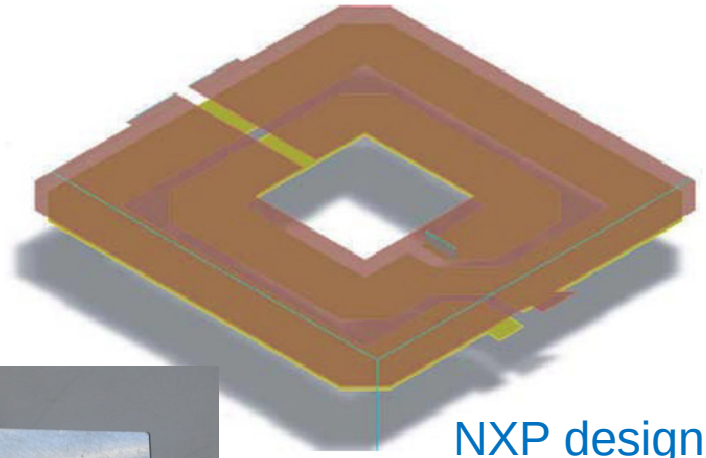
unbalanced



balanced

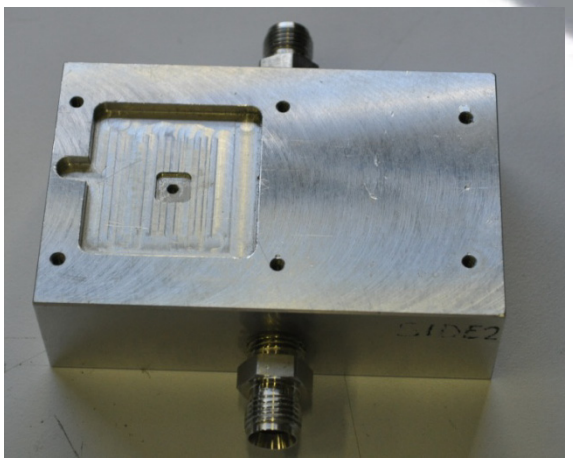
Motorola patent

Balanced on top
Unbalanced on bottom



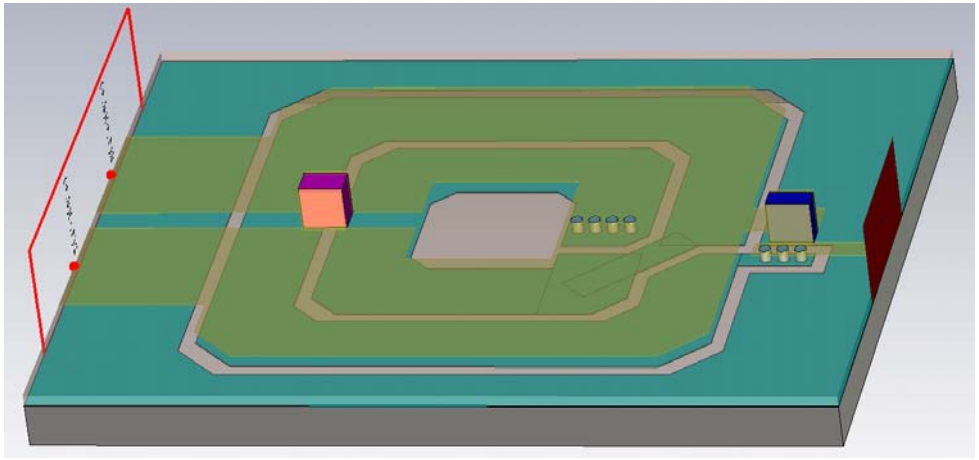
NXP design

The cooling plate has to be milled and the balun is difficult to cool

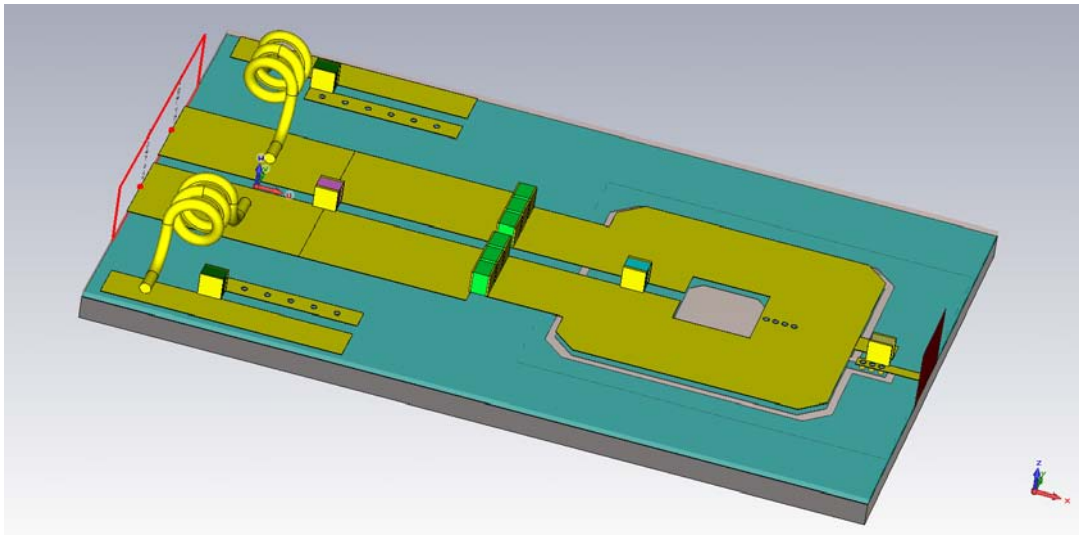


Design codes

CST Microwave

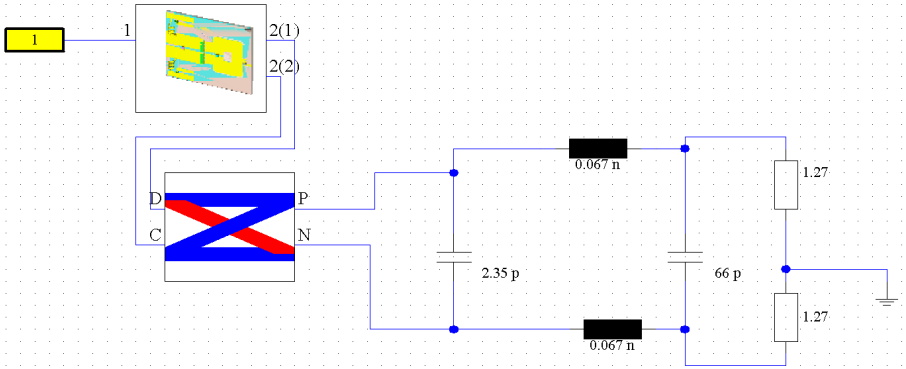


Printed balun model

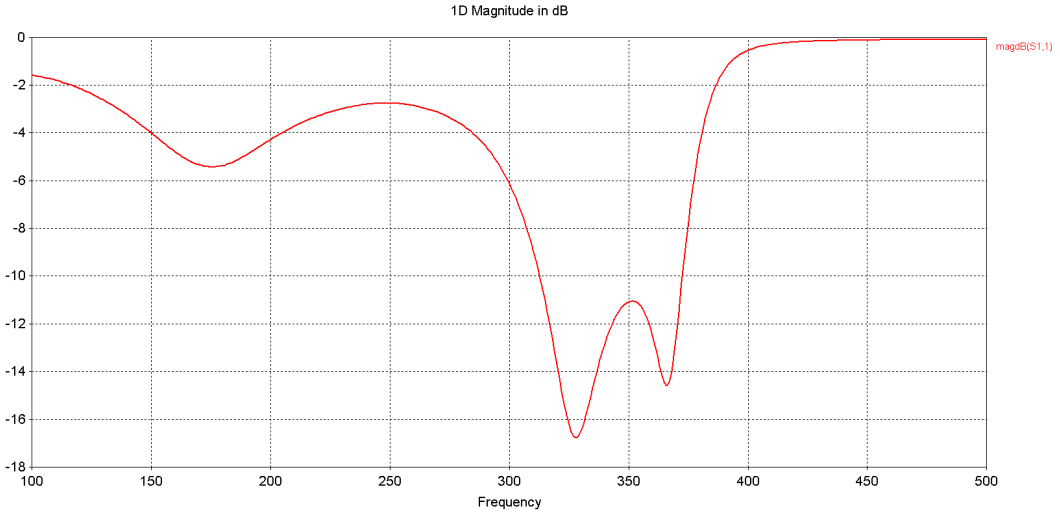


Printed balun, matching circuit and bias model

Design codes

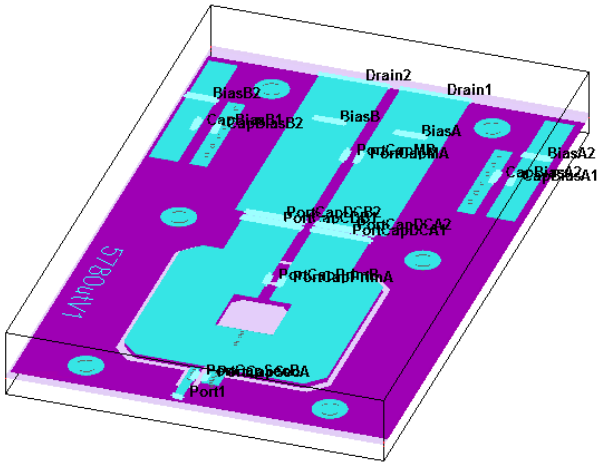


CST Microwave

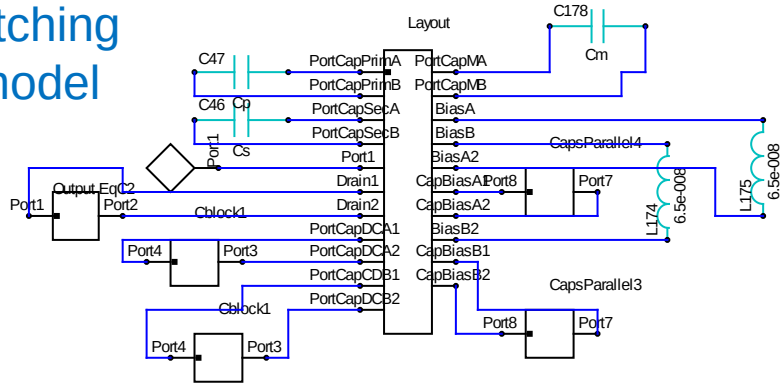


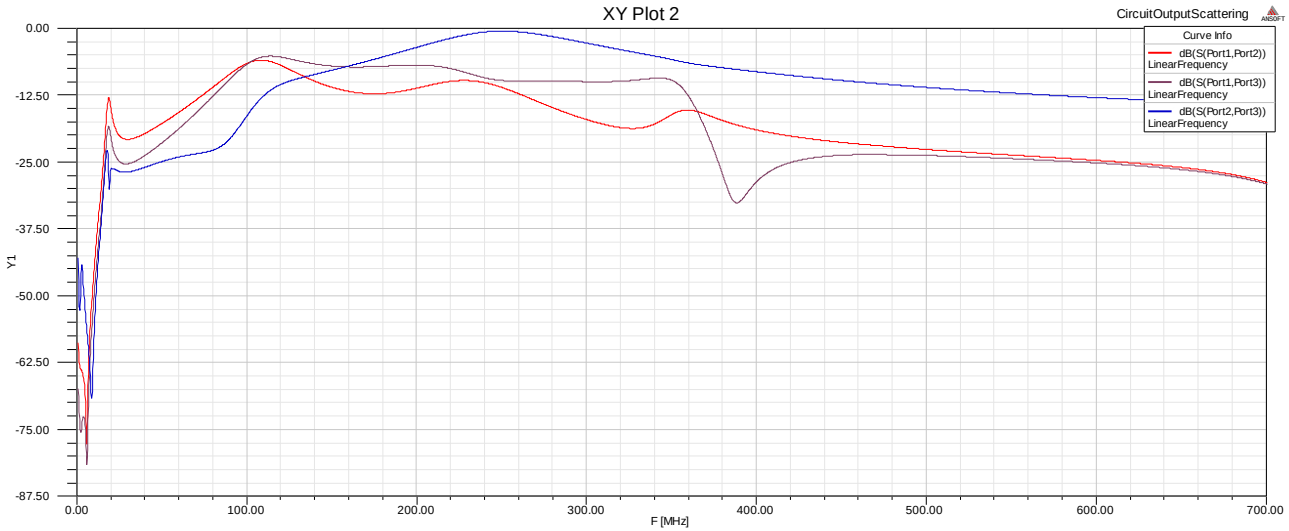
Design codes

ANSOFT Designer

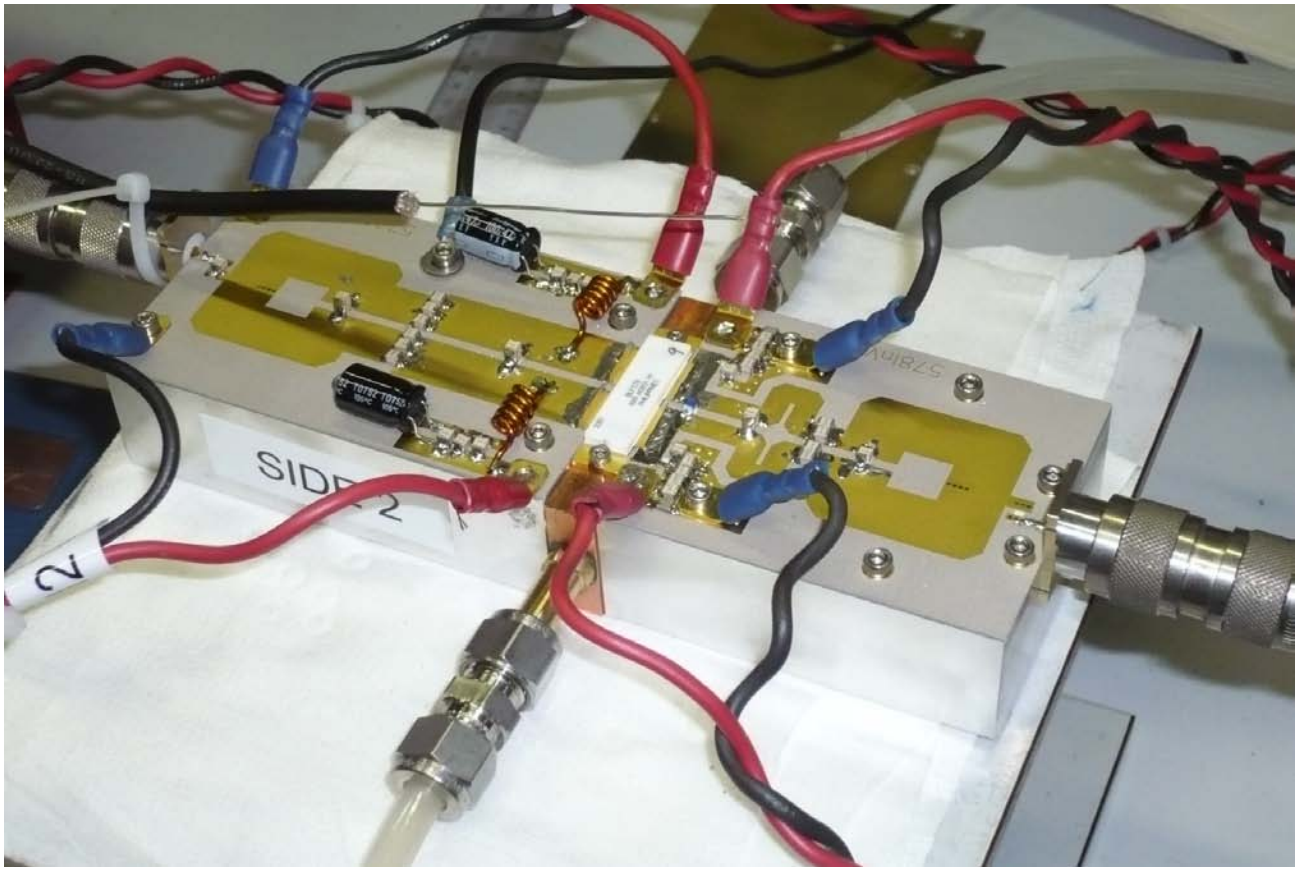


Printed balun, matching circuit and bias model



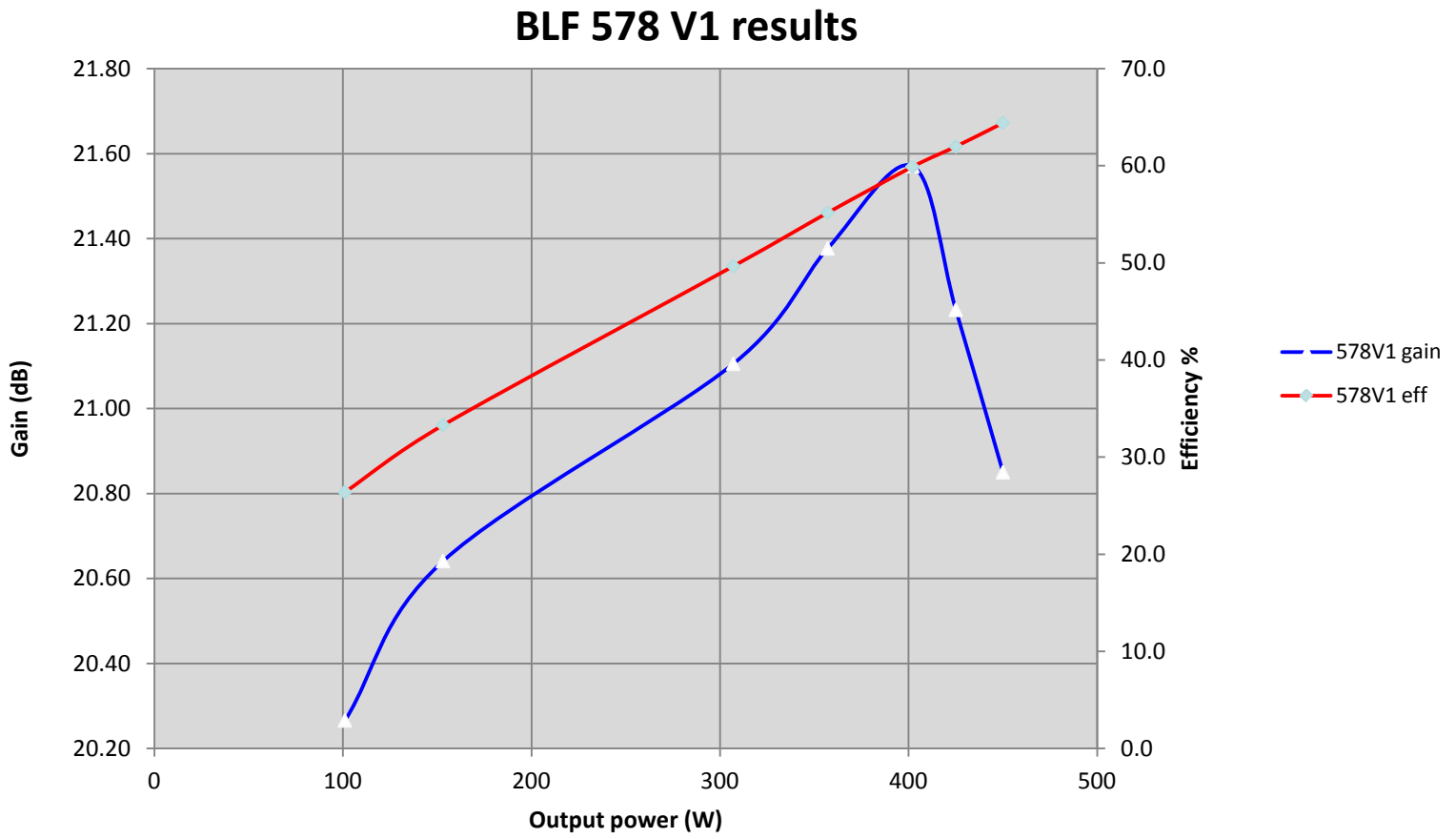


The RF module



- A RF module has been designed at ESRF.
- It is using a printed circuit balun transformer.
- It is quite narrow (65mm)
- Very few components are necessary.

Experimental results

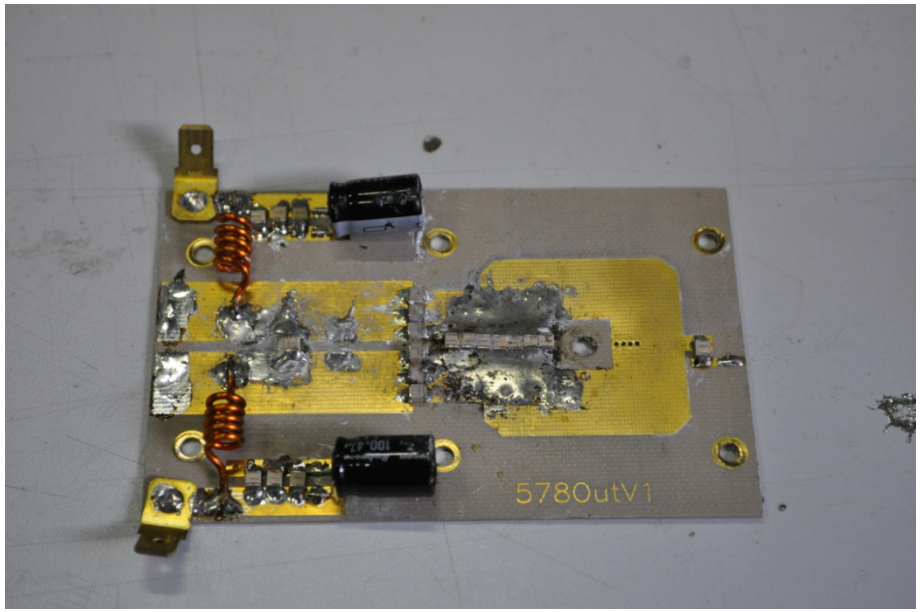


Experimental results

The matching capacitances are far too hot to ensure reliable operation. The one on the balun reached some 140°C.

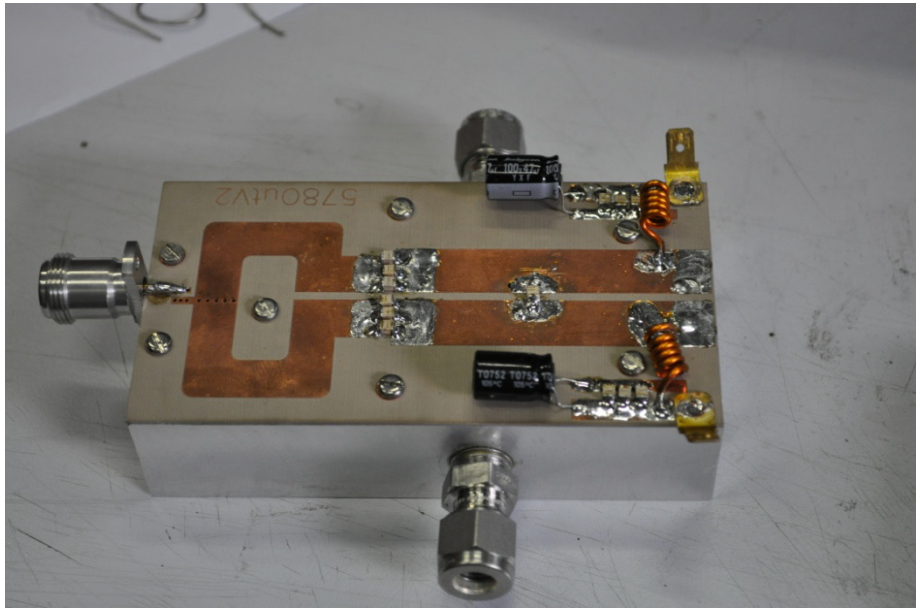
Experimental results

We tried to split the capacitances in many small ones.
We air cooled it from above.



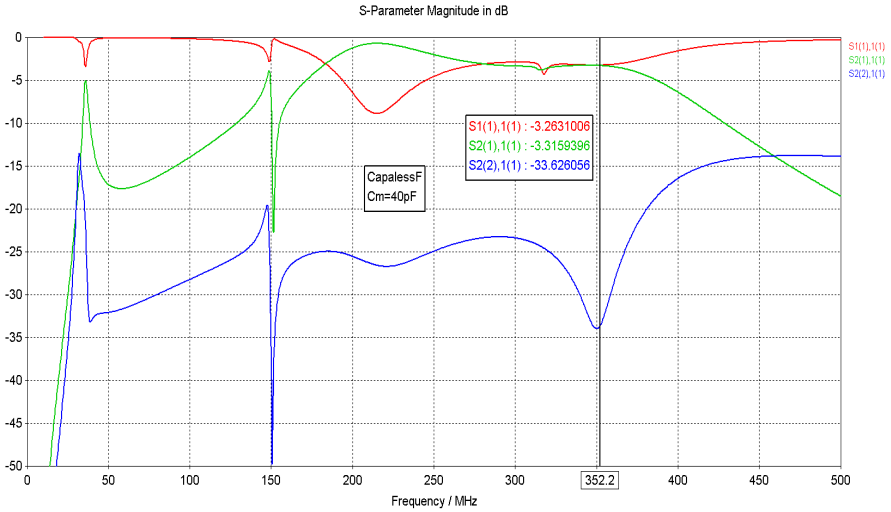
No way, another design was needed!!!

New output circuit

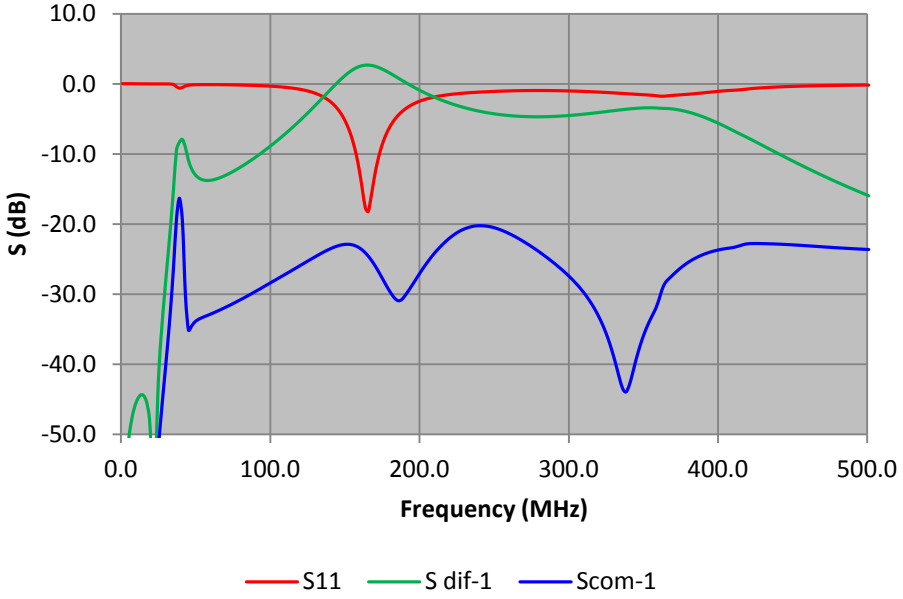


The capacitance on the balun was suppressed.
The matching circuit cap has a modest value.
The price to be paid is extra length.
It is currently in low level test.

New output circuit



Spara magnitude 578V2Out Cm=27pF at exact spot



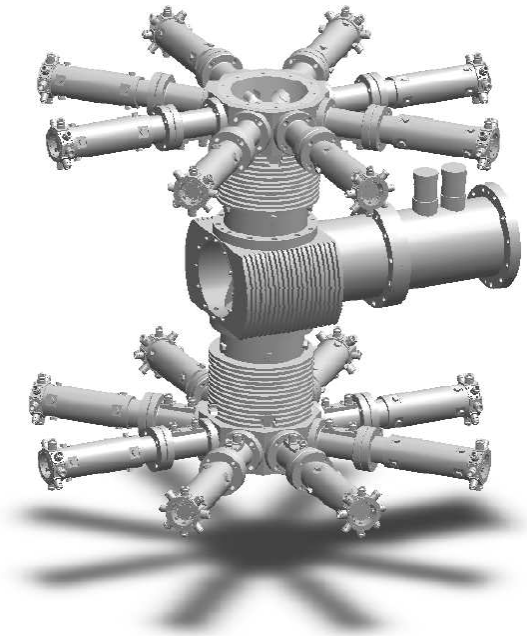
Above : S parameters computed with CST microwave
Below: S parameters measured with the R&S network analyzer
Note: the matching capacitance has been readjusted

Combining tree

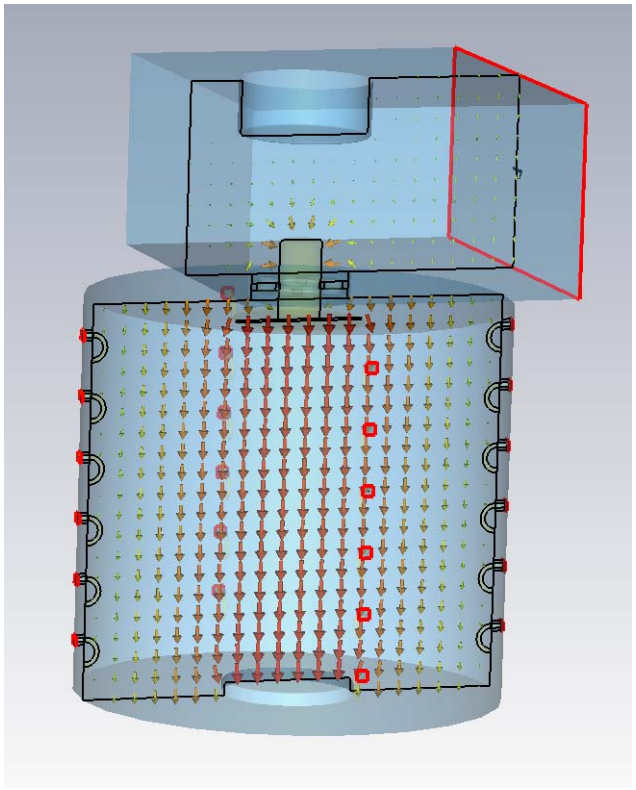
Implementation of solid state amplifiers at SOLEIL

Combining tree

Combining structure
(made in PRC)

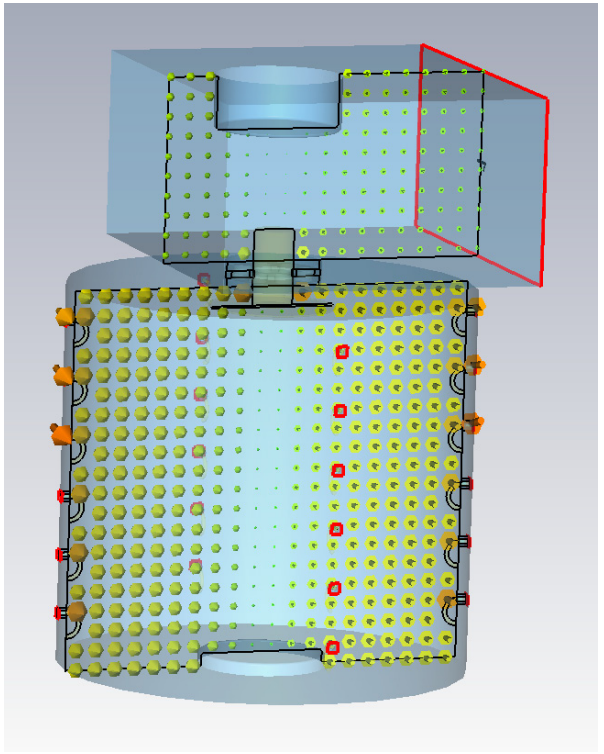


The cavity combiner



E field

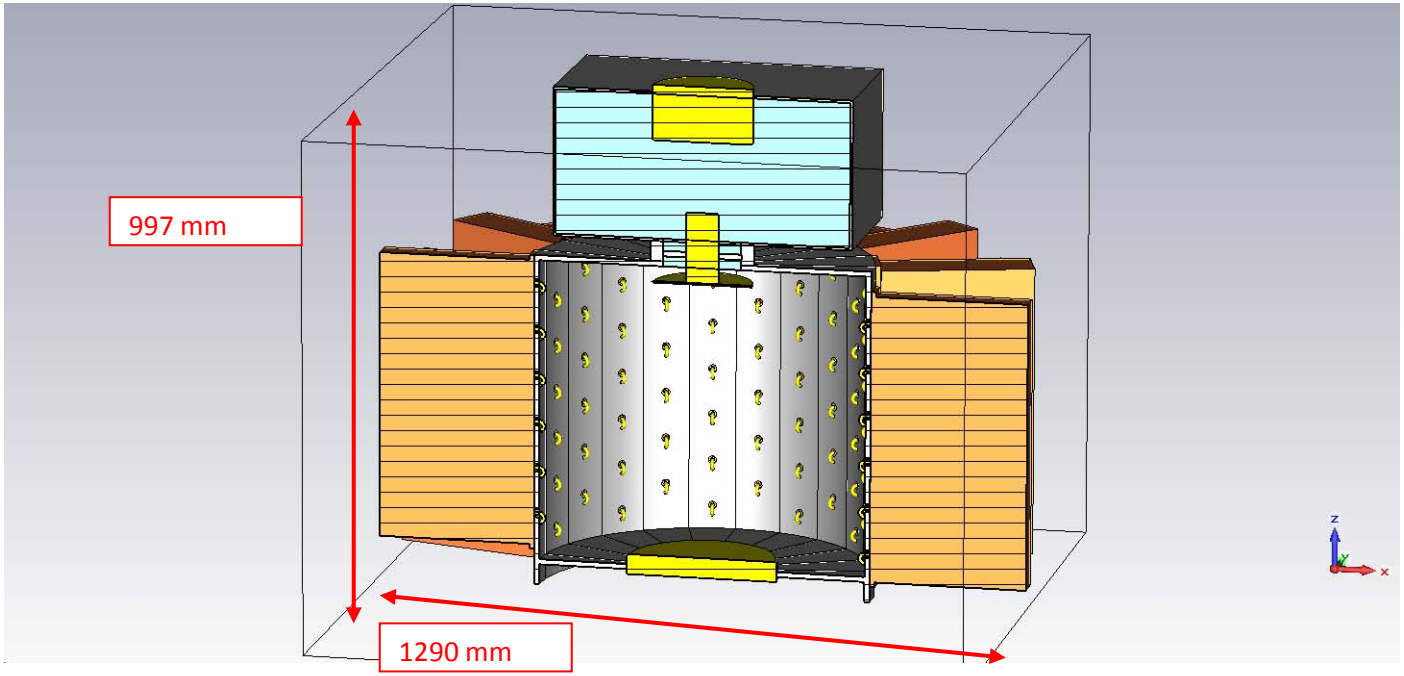
E010 mode



H field

The cavity combiner : advantages

1. Small footprint



e.g: 6*22 modules of 650 W~ 80 kW

The cavity combiner : advantages

2. Galvanic insulation

Each pallet is connected to a loop protruding inside the cavity. Live conductors from each pallet are thus insulated from each other.

3. Flexible

In the event of an overrating of the power, it is possible and easy to connect a fraction of the available openings, blinding the other ones with short-circuits. Adjusting the number of modules to the power need enhances efficiency since each module is used at nominal power and not at reduced power.

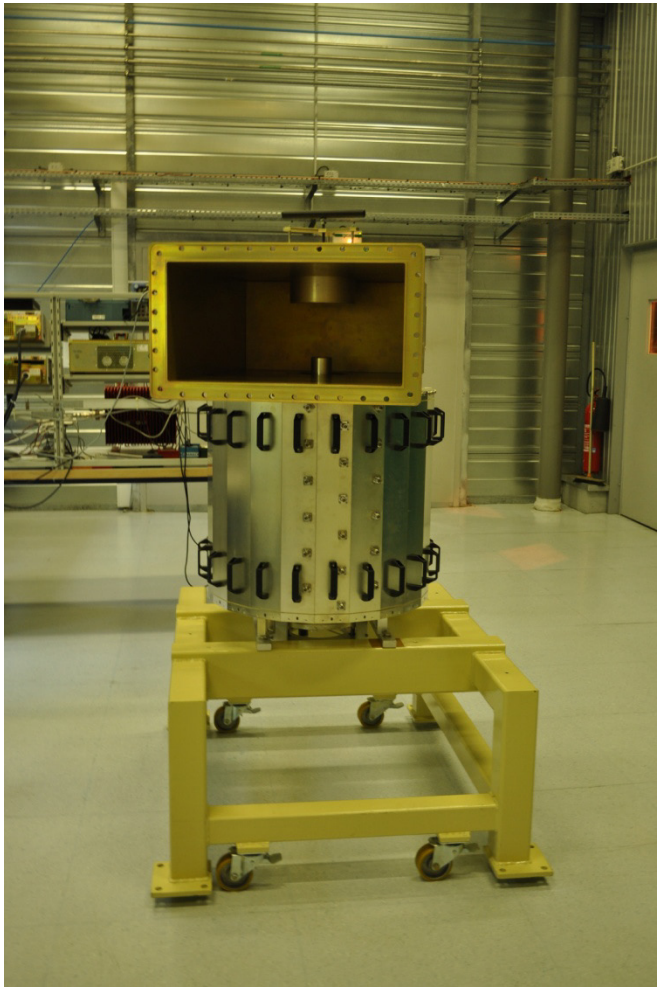
4. Efficient

One stage of coupling, moreover in waveguide mode, generate less losses than multiple stages.

5. Proven

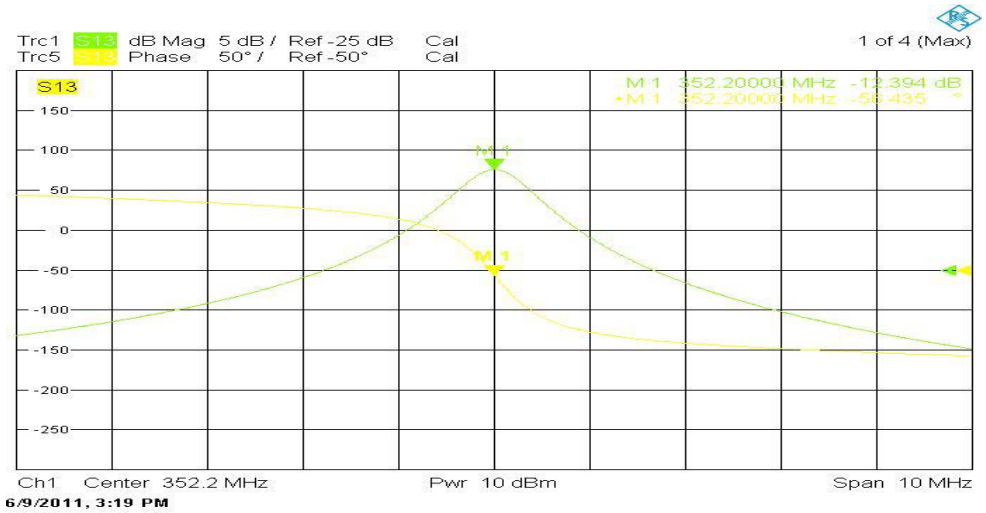
A combiner for 2 IOT's,150 kW, 500 MHz has been designed, manufactured and tested at THALES for ALBA.

The cavity combiner : status

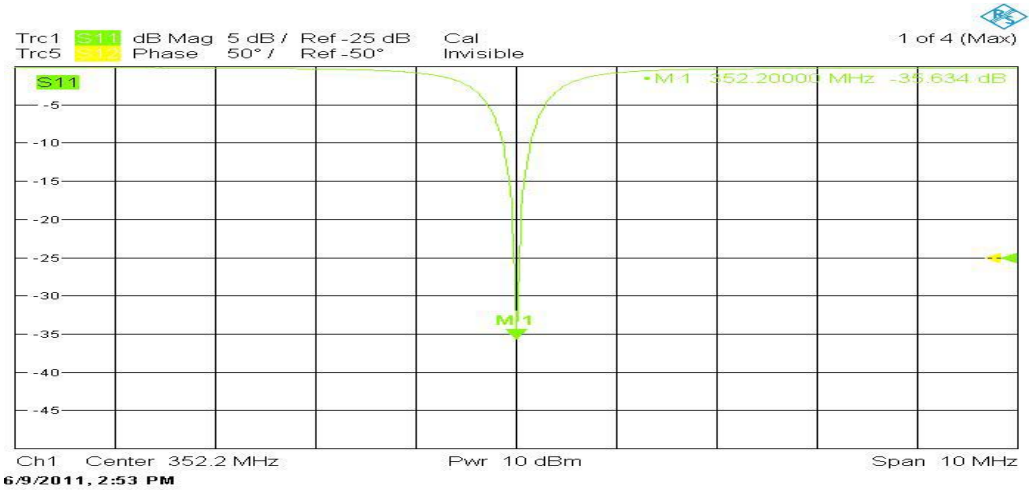


- A full size model has been designed at ESRF.
- It is meant for 3 columns of 6 rows.
- The parts were delivered in February
- The variable waveguide connection was delivered in April.
- It was tested at low level.

The cavity combiner : low level results

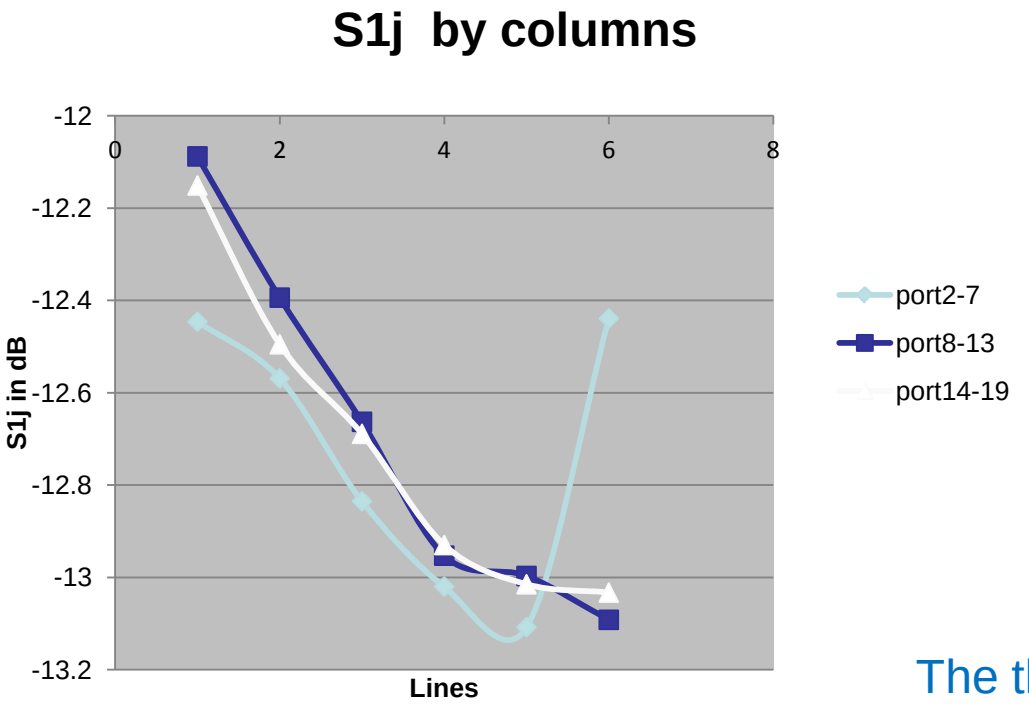


1 is the waveguide output terminated with a WR 2300 to N transition.
3 is one of the input ports.



The matching can be perfectly trimmed.

The cavity combiner : low level results

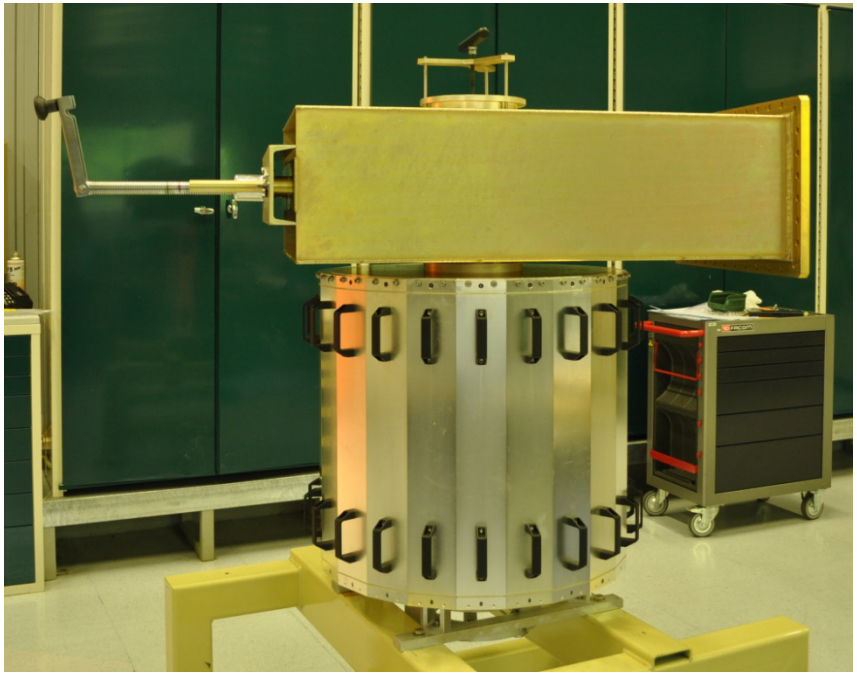


The theoretical value is -12.55 dB

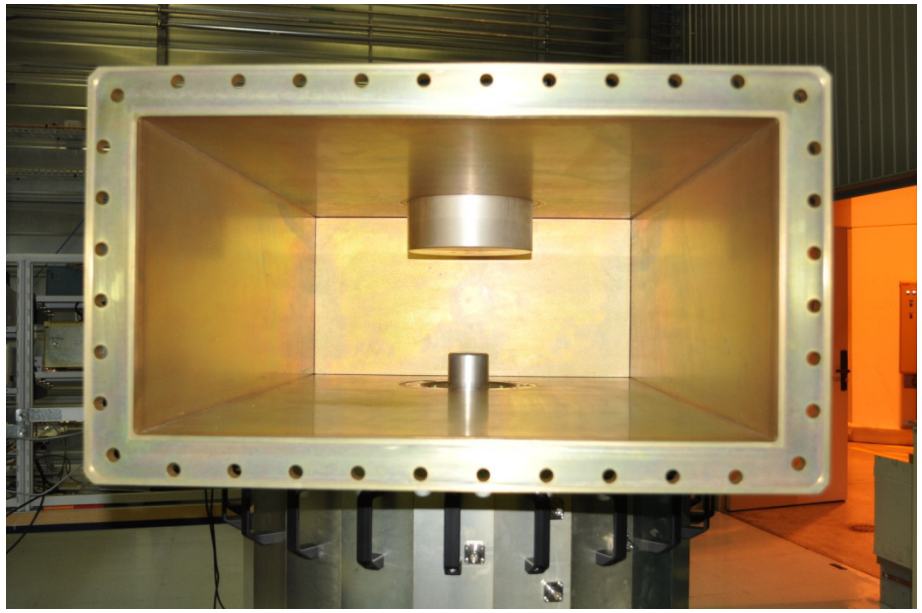
$$\left| \sum_{i=2}^{19} S_{i,1} \right| = \sqrt{17.23}$$

The theoretical value would be √18
A dubious contact was seen on the movable short circuit.

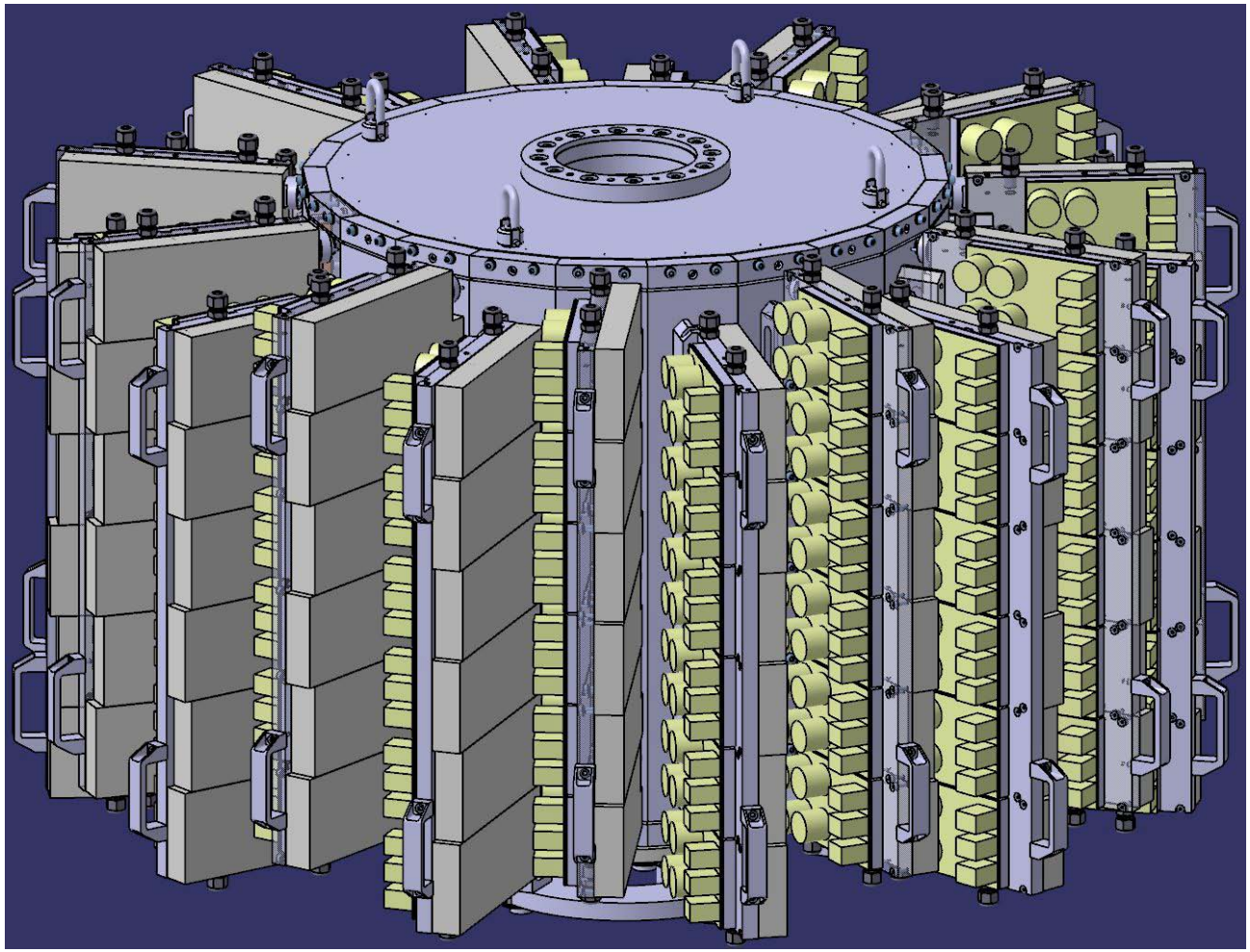
The cavity combiner : low level results



With the 2 adjustments foreseen, the output could be matched to either 1 or 2, or 3 columns of loaded ports.



The cavity combiner : the final target



Thanks!

•To my RF colleagues, for their continuous support.

•To Nora, the lovely and efficient student we had for 5 months.

•To Francois Villar who did the mechanical design of the combiner

•To the purchasing department.