

CWRf 2010

6th Workshop on CW and High Average Power RF

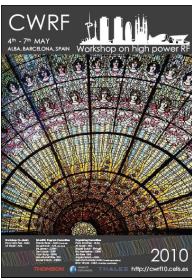
4 – 7 May 2010

CELLS - ALBA, Barcelona

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Short Presentation of ELTA - AREVA

- ▶ **ELTA is an AREVA Subsidiary specialized in Electronics for Harsh Environments, located in Toulouse (France).**

- ▶ **ELTA is a 230 employees company with 30 years Heritage in :**
 - ◆ **Radio-Frequency for Aeronautic, Space & Scientific applications**
 - ◆ **Instrumentation and Control (I&C) for Defence and Transportation markets**
 - ◆ **High Power Supplies for Defence and Aeronautic markets**
 - ◆ **Water Analysers for Nuclear market**

- ▶ **From Design to Customer Support :**
 - ◆ **Design tools : RF, Analog, Digital simulation, 3D CAD, PCB Design Software,**
 - ◆ **Test Equipments up to 40 GHz**
 - ◆ **Customer Support up to 30 years for Nuclear, Aeronautic, Defense domains**

Short Presentation of ELTA - AREVA

RF & DSP



WiFi on aircraft



Satellite Ground Station



S-Band MODEM

Power Conversion



DC-DC Converters Bay



DC-AC Converter 83 kVA

Control Command



Fault Tolerant Computer



Fail Safe Processor

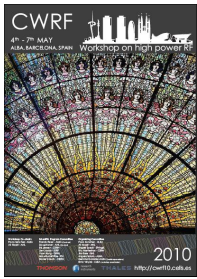
Chemistry Analysis



Oxygen Analyser



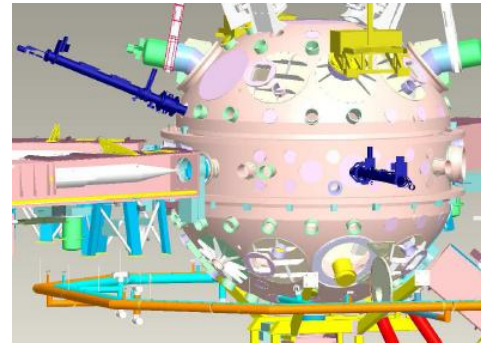
Sodium Analyser



ELTA in Scientific Programs

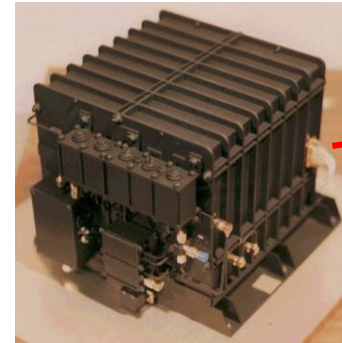
▶ LIL (Laser Integration Line) : CEA

- ◆ Featuring LMJ (Laser Mega Joule)
- ◆ Signal conditioning
- ◆ Very fast transient acquisition
- ◆ Instrumentation & Control



▶ UHF Transponders for Martian Programs : NASA

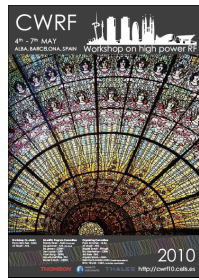
- ◆ Mars Observer, Mars Global Surveyor
- ◆ Russian mission MARS 94
- ◆ Successful Relaying of Martian Rovers in 2004



▶ Equipments for Stratospheric Ballons : CNES

- ◆ Onboard equipments
- ◆ L-Band or S-Band Transceivers
- ◆ Telemetry & Telecommand Ground Station





Partnership with SOLEIL Synchrotron

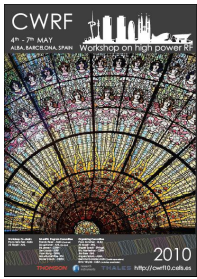
- ▶ **2009 : Agreement between ELTA and SOLEIL for transferring the « SSA » technology of high RF Power Amplifier, developed and set in operation by SOLEIL since several years**

- ▶ **Feb 2010 : Development by SOLEIL of a new Amplifier Module**
 - ◆ Doubling of the power of the elementary module up to 700 W
 - ◆ Improvement of Gain and Efficiency
 - ◆ Specification and Industrialization of the Amplifier Module driven by ELTA

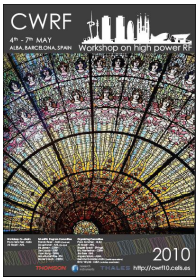
- ▶ **June 2010 : Test of the 1st assembly of 16 Amplifier Modules (10kW)**
 - ◆ Qualification & Test will be performed by ELTA and SOLEIL teams

- ▶ **Nov 2010 : Test of the first 75 kW Tower**

ESRF Project : 150 kW Power Amplifier

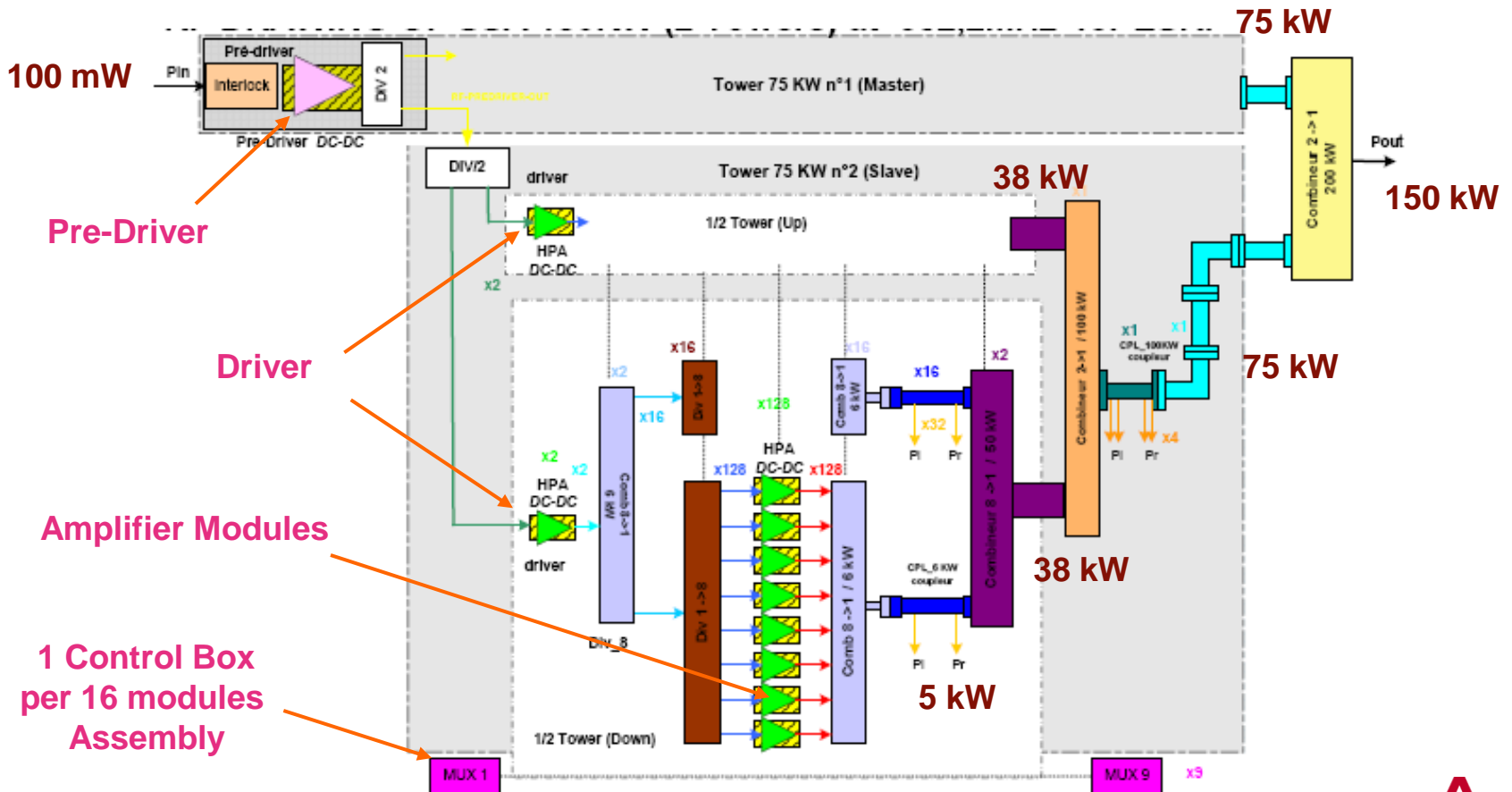


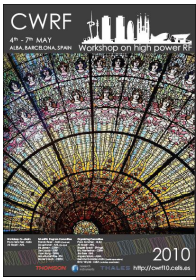
- ▶ **June 2009 : Contract with ESRF for providing seven 150 kW PA for Booster and Storage Ring**
- ▶ **Design of the overall 150kW Power Amplifier and of some specific equipments**
- ▶ **Industrialization of the Amplifier Module designed by SOLEIL**
- ▶ **Validation – Qualification Tests of the Sub-assemblies and of the overall 150 kW Power Amplifier (with SOLEIL support for High Power Tests)**



150 kW Power Amplifier for ESRF Synchrotron

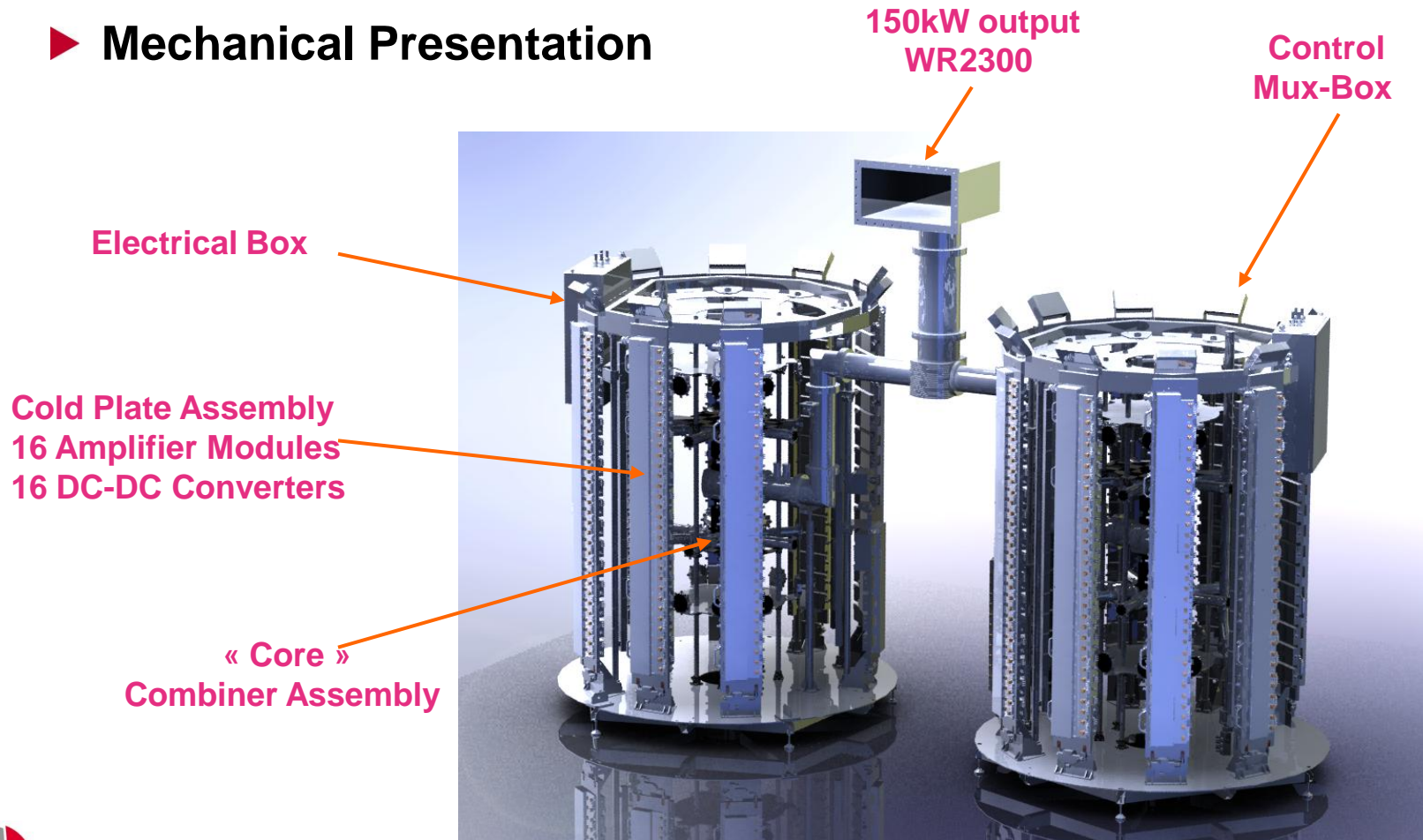
► RF Architecture of the 150 kW SSA Power Amplifier

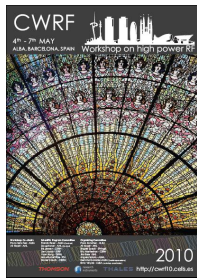




150 kW Power Amplifier for ESRF Synchrotron

► Mechanical Presentation





150 kW Power Amplifier Advantages of the Modular SSA Architecture

- ▶ High Beam Availability (full performance with up to 6 failed Amplifier modules)
- ▶ Computed MTBF of the overall 150kW Amplifier : 20 000 Hours
- ▶ Computed Failure rate of Amplifier Module : less than 0,7% per year
- ▶ Distributed Heat Dissipation
- ▶ No need for High Voltage Power Supply
- ▶ No need for High Power Circulator at RF Output
- ▶ No need for Warm-up sequence
- ▶ Very low Phase Noise ($< 0.05^\circ$ RMS up to 8 kHz)
- ▶ Easy Maintenance : MTTR < 15 min
- ▶ Flexibility to fit to different RF Output Power
- ▶ Reduced number of Spare Parts



150 kW Power Amplifier for ESRF Synchrotron

▶ Main RF Characteristics :

- ◆ 150 kW RF Power
- ◆ Bandwidth : 352,2 +/- 0,5 MHz
- ◆ Overall Efficiency better than 55% at nominal RF power (expected >60%)
- ◆ Operation on very high mismatch at all phases conditions :
 - full reverse power at 150 kW during interlocking time (typ 20 usec)
 - full reverse power at $P_{nom}/2$ during long duration,
- ◆ CW, Ramped (booster), Pulsed modes (cavity conditioning)

▶ Electrical Circuits

- ◆ 280 V dc +/- 20V
- ◆ Power Consumption less than 300 kW

▶ Water Cooling

- ◆ Less than 440 liters / mn (target 220 liters/mn)
- ◆ Inlet water temperature between around 23°C



150 kW Power Amplifier for Monitoring & Protections

▶ RF Monitorings, Protections, Interlocking :

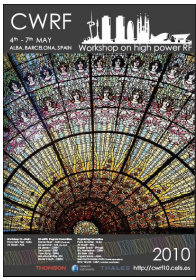
- ◆ Mismatch handling (circulator)
- ◆ P_fwd, P_rev at 5kW stage and at 75 kW Tower output
- ◆ RF over-power detection on the LLRF input (20dBm) : fast hardware detection (< 150 nsec)
- ◆ RF over-power detection on the 75 kW RF output : slow detection < 1 sec
- ◆ Reverse RF protection on the 75 kW RF output in case of severe reverse power (fast detection < 10 usec)
- ◆ Reverse RF protection on the 5 kW stage : slow detection < 1 sec

▶ Electrical Monitoring and Protections :

- ◆ Current consumption of each Amplifier Module
- ◆ ON/OFF control of each Amplifier Module

▶ Thermal and Hydraulic protections :

- ◆ Thermal Interlocking on each Cold Plate
- ◆ Water Flow Interlocking on each Cold Plate
- ◆ Internal Temperatures (2) inside each Amplifier Module

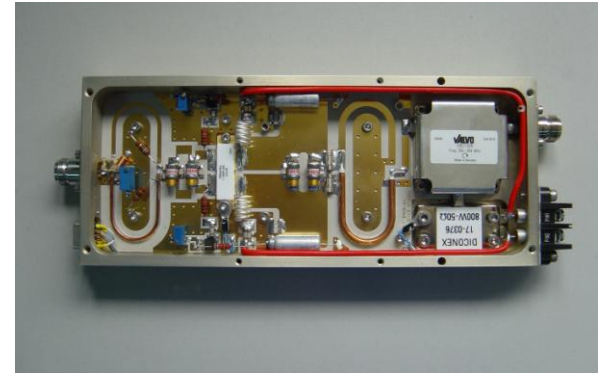


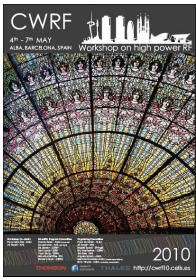
650 W Power Amplifier Module

- ▶ Developed by SOLEIL in tight coordination with ELTA for industrialization and process topics

- ▶ RF Characteristics :
 - ◆ Power Output : 650 W at P_{1dB}
 - ◆ Frequency : 352,2 MHz
 - ◆ Gain : 20, 3 dB
 - ◆ Efficiency : > 70 %
 - ◆ Gain Dispersion : +/- 0, 2 dB max
 - ◆ Phase Dispersion : +/- 5° max
 - ◆ Transistor Technology : LDMOS 6th Generation
 - ◆ Protected by internal circulator for severe mismatch conditions and for RF power stability versus cavity mismatch (any phases)

- ▶ Monitoring :
 - ◆ Drain Current
 - ◆ Temperatures of the Power Transistor Flange and of the Circulator Load





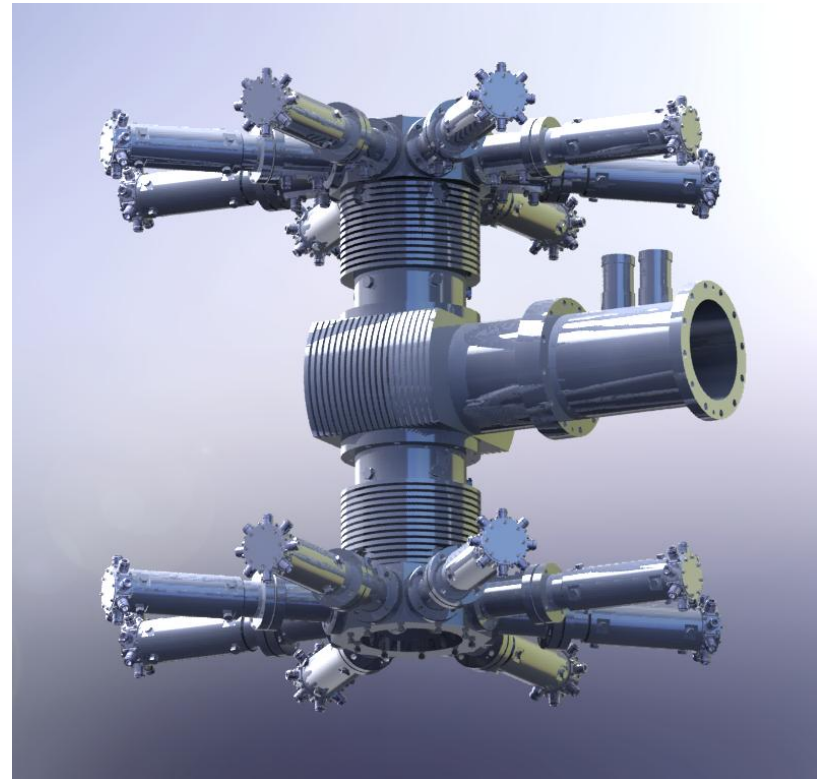
High Power Combiners

▶ Combiners :

- ◆ Low Loss Combiners developed by SOLEIL
- ◆ Severe Mismatch Handling

▶ Combining Core :

- ◆ CAD by ELTA
- ◆ Compact arrangement





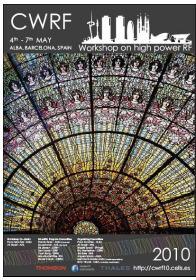
Control (Mux-Box) and Pre-Driver

► Design of a specific Control Box (ELTA) :

- ◆ Monitoring the Amplifier Modules and their associated Power Supplies
- ◆ Monitoring the Cold Plate Interlockings (Temperature and Water Flow)
- ◆ Control the ON/OFF of each Amplifier Modules (Power supply switch-off)
- ◆ Interface with Amplifier / DC-DC Modules by I2C bus
- ◆ Interface with the Supervisor : ModBus / RTU 1 Mb/sec

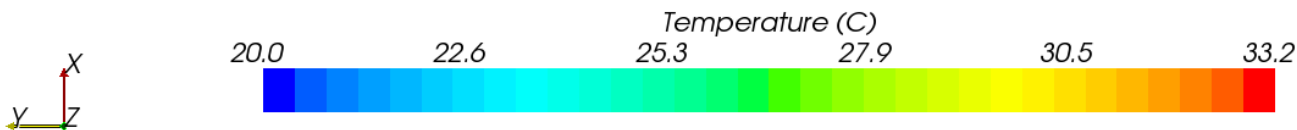
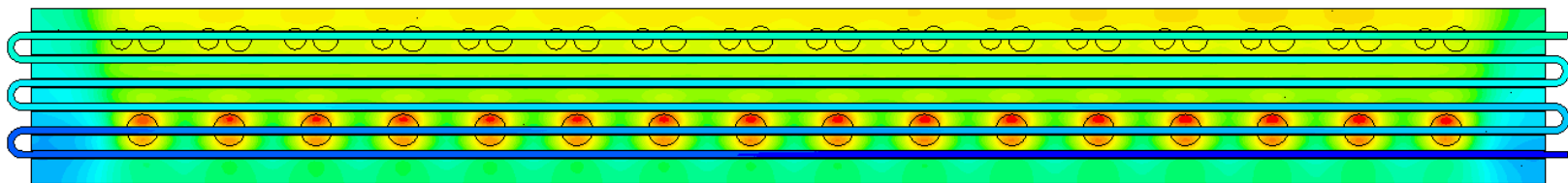
► Design of a specific Pre-Driver (ELTA) :

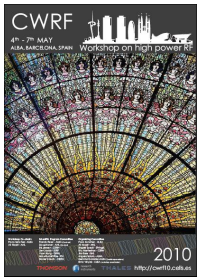
- ◆ Amplification of the input low level signal (20 dBm) up to 2 x 15W
- ◆ Internal Band Pass Filter for Time Delay purpose and RF Filtering
- ◆ Internal Interlocking on RF Input level (<150 nsec) before applying the excessive input level to the Amplifier Modules
- ◆ Internal Interlocking on Reverse Output level (< 10 usec)



Cold Plate

- ▶ **Thermal Simulation performed on the Cold Plate**
 - ◆ **Mixed simulation : Thermal & Fluidic (takes into account turbulence)**
 - ◆ **Simulation takes into account heat flux through the dissipative component flanges and through the Amplifier package**
 - ◆ **Thermal Simulation gives :**
 - **A global thermal cartography of the Cold Plate**
 - **Flange temperatures of main dissipative components (transistor, load, circulator, DC-DC converter), in order to estimate junction temperatures**





Versatility of the Modular SSA Architecture

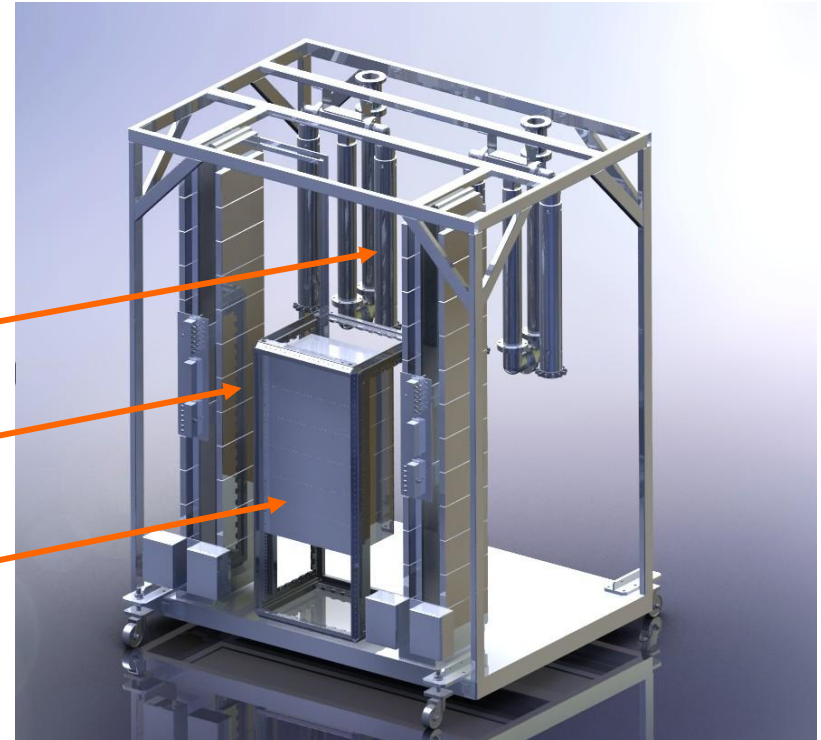
► Distributed Power Amplifiers for Linear Accelerator

- ◆ Example of 2 x 20 kW at 88 MHz based on 850 W Amplifier Module with 83 % efficiency

RF Combiners

Cold Plate Assembly

65 kW - 380V_AC / 50V DC Power Supply



► Amplifier module with integrated circulator in order :

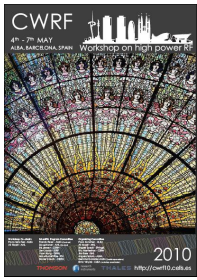
- ◆ to insure constant RF Power level for any phase conditions
- ◆ to avoid excessive stress of the transistors and associated degradation of the MTBF
- ◆ to avoid extra RF level increase (with resulting efficiency loss)



Conclusion

► Conclusion :

- ◆ This SSA architecture permits a high level of availability of the 150 kW Power Amplifier, thanks to the large number of modules in parallel
- ◆ Protections and Monitoring implemented inside the Control Box and the Pre-Driver permit safe operation and detection of failed module.
- ◆ Transferring this technology at 500 MHz is straight forward :
The 500 MHz amplifier module was recently validated at 700 W
- ◆ Other possible applications from FM to L-Band can be envisaged.



Thank you for your attention

