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RF SYSTEMS TESTING SOLUTIONS FOR SCIENTIFIC FACILITIES

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Introduction

BTESA, as a manufacturer of medium and high power air and liquid cooled SSPA, and moreover as a System integrator of RF projects, is aware of the need of having reliable testing facilities, and how difficult this can be in the mostly complex scientific installations, composed of several independent subsystems, usually manufactured by different companies, which should be tested both independent and jointly.

Having a powerful R&D department with a solid background in all areas necessary to design SSPA systems, counting not only with radiofrequency experts, but also with electrical, FPGA programming, fluid dynamics, electronic circuits, software and mechanical design engineers, several customized testing facilities have been implemented together with our System Integration department. This presentation shows some of them, trying to cover some of the main elements of the RF system: power amplifiers, combiners, cavities and power supplies

“Back to Back” Test Bench for a 200:1 200kW Power Cavity Combiner

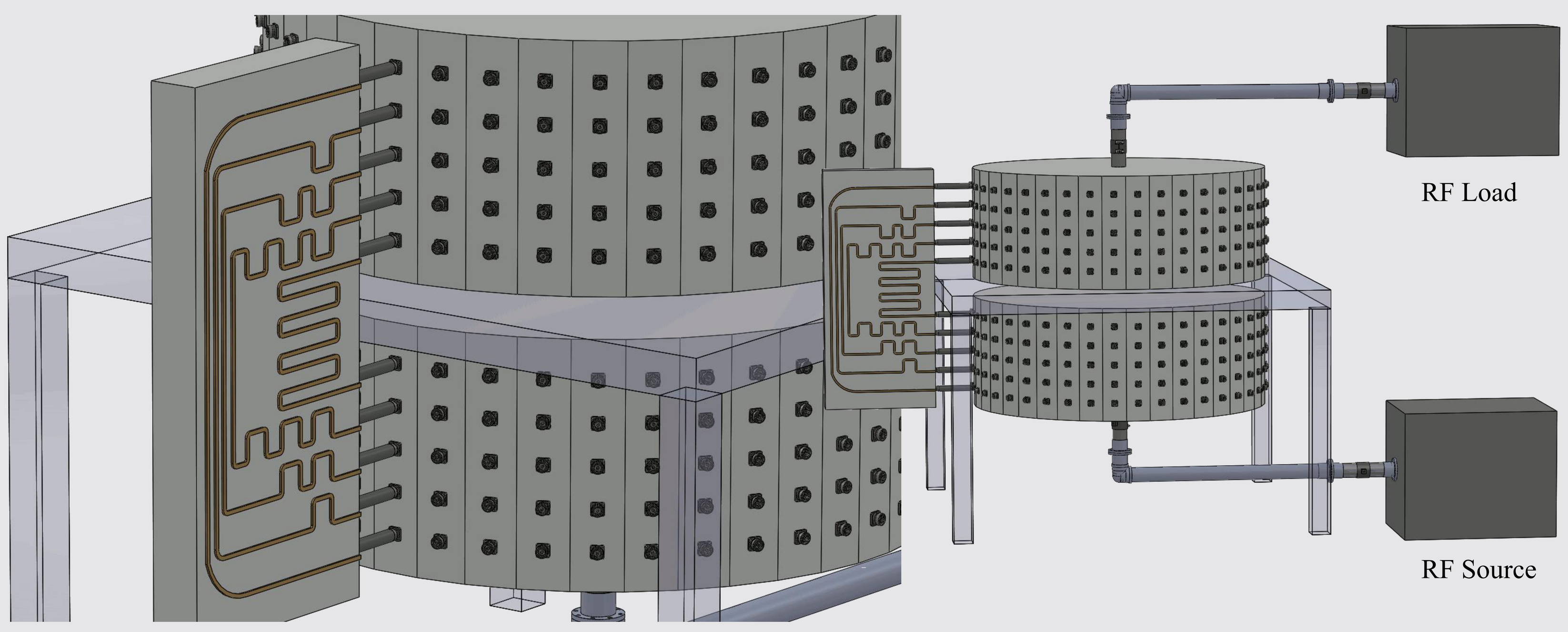
Cavity Combiners are one of the cutting-edge technologies for Solid State based Power Amplifiers to reach the required power levels with minimum losses while maintaining the excellent availability and reliability offered by this distributed architecture.

Although plenty of Electromagnetic and Thermal calculations could be simulated, it is necessary to test, characterize and optimize these combiners in a real scenario with RF power.

To test all 200 entries at the same time, it would be necessary to have 200 equal amplifiers. If only one single RF power source is available, an innovative solution proposed by CIEMAT is to test them in a “back to back” topology (like some baluns are tested), i.e., one Combiner will act as a splitter from 1 input to 200 outputs and these outputs are subsequently connected to a similar combiner to rebuild the signal from 200 inputs to 1 output.

For connecting the combiners back to back, BTESA has manufactured and tested very precise jumpers cables and printed suspended microstrip lines to maintain distances and symmetry for such a connection.

By using several RF couplers and RF Instrumentation we can determine the behavior of the Combiner. To complete the installation, an independent 500kVA energy line has been installed at BTESA together with an adiabatic liquid cooling system with heat dissipation capacity >200kW and total flow of 400l/min. Scalable manifold, input and output flow meters and dual pumps with temperature-controlled speed complete the installation.



Self contained SSPA for temporary RF applications like Cavity Conditioning

Some auxiliary RF tasks such as conditioning of cavities or couplers need temporary RF power systems.

Using tube based solutions is complicated, since they are fragile, need deionized water, have warm up times, high voltage power supplies, etc. A RF SSPA Amplifier is more cost-effective, since it can be more easily transported, easily installed and quickly started up with no warming time.

For the conditioning of a cyclotron for medical application, where no central cooling was available, BTESA manufactured a SSPA with special prototype characteristics:

- **Modular in power: delivered with 8kW but capable of easy upgrading to 12kW by adding more power amplifier modules (combiners and splitters already installed**
- **Frequency agile: capable of working in any frequency 40 to 70MHz**
- **Compact and self-contained: liquid cooling system (with redundant pumps) was designed built-in the same SSPA rack.**
- **Each power amplifier module is hot-pluggable and includes their integrated AC/DC switch mode converters**

BLAS (Beam Loading Advanced Simulator)
(Patent Pending)

It is quite important for laboratories to have a small-scale RF installation. The effects taking place while conditioning or baking some cavities with RF power, and moreover the distortion caused to the RF chain by the presence of a particle beam are difficult to model by software due to the building uncertainties. They can be studied in real installations but these are constrained by the high power and security levels involved in an accelerator.

BLAS project aimed to reproduce a RF installation at small scale. Three systems were designed and implemented:

1. **Independent SSPA drawer, extracted out of one of the two 16kW SSPA designed and manufactured by BTESA for CIEMAT for the IFMIF/EVEDA project. This drawer is liquid cooled and hot-plug.**
2. **Scaled Cavity, designed by CIEMAT.**

3. **Test bench, designed by BTESA, necessary to replace the functions of the main SSPA control, circulator, loads and installation liquid cooling, composed of:**
   - **Independent Logic Controller with color touch screen, remote access and events log**
   - **Signal Generator**
   - **RF Driver (in case the SSPA drawer is not a high-gain module).**
   - **Circulator and RF Power Load**
   - **6-port Patch Panel to send the RF signal to the Load or to the Cavity, with the possibility also to bypass the circulator to test the effects of RF distortion on the SSPA itself**
   - **Pump, heat exchanger, pipes, gauges and protections**

RF SSPA modelling for Power Supplies testing

One of the advantages of SSPA technology in Scientific Applications is their high speed response time. Therefore new conditioning modes and pulses can be used.

In short pulse modes, because of SSPA low voltage needs (40-50VDC on transistor drain), high currents are involved in a very short time and thus, Power Supplies must be designed, tested and optimized for that purpose.

By modelling the RF Amplifier in terms of DC needs, we can predict the voltages and currents transients that Power Supplies may handle.

In a distributed SSPA RF system, and moreover if intelligent regulation is applied, the Power Supplies must handle or must adapt very quickly to any change due for instance to a device failure.

Because the Power Supply architecture is also distributed, the efficiency of these units must also be measured not only in pulsed modes but also in CW mode.

Based on the SSPA modelling, several test benches have been assembled for testing the power supplies at the same conditions they will work with real RF pulsed signals.

A similar bench was used for another Scientific Installation: test the stability of high DC current power supplies for superconducting magnets without the magnet load. 250 Power supplies were designed by UPM (Universidad Politécnica de Madrid) for the European XFEL and manufactured and tested by BTESA.