Review of the Spoke RF Source for FREIA

Uppsala University

11-12 December 2012

Eric MONTESINOS (Chair)

Sebastien BOUSSON

Hans-Joerg ECKOLDT

Bert HOLMGREN

Anders SUNESSON

Table of contents :

Introduction

Lund, October 2012

To: S. Bousson , H.J. Eckhold, E. Montesinos

From: M. Lindroos
CC: R. Ruber

Subject:
Charge to the Engineering Design Review of the Spoke RF Source for FREIA

Thank you for agreeing to participate in the Design Review of the RF source for spoke cavity testing at FREIA, to take place in Uppsala on 11 and 12 December 2012.

Please review the requirements and design of the first FREIA RF source which will be used for the high power testing of spoke cavities for ESS and is also a prototype for a possible RF source for the ESS linac.

Please comment on the following:

1. System design:
   a. The specifications are properly defined and specified.
   b. The design choices made are compatible with the performance requirements.

2. Proposed hardware:
   a. The hardware is compatible with the performance requirements.
   b. Evaluate the technical risks.

3. Future benefits:
   a. The hardware is compatible with the requirements for high power testing of the ESS prototype spoke cavity.
   b. The proposed hardware is compatible with the requirements to power the spoke section of the ESS linac (as a possible fall-back solution).

Please present a close-to-final version of your report – structured into Findings, Comments and Recommendations – at the end of the review, and deliver a final written version within 10 days after the review. Feel free to include topics that you identify as important to the success of the ESS and FREIA projects, but which might be outside the scope described above.

1. High Power Amplifiers

a) Findings

Design is good for FREIA installation.

Good to see test results!

b) Comments

Overhead not harmonized with ESS: backoff for LLRF, saturation of klystron, losses,…

The ESS TDR states a total overhead of 30% with a klystron source.

FREIA with a tetrode source quantifies it to 20 %.

Design barely fits into ESS gallery, to be checked.

Full power tests, 300 kW at full length of 3.5 ms and repetition rate of 14 Hz, will be provided by the FREIA source, as it is required for the couplers conditioning and excitation of all cavity mechanical modes (full power to have the final RF ramping time as it will be on the ESS linac).

c) Recommendations

Consider development for the second unit towards a more compact source for ESS linac.

2. Power Supplies

a) Findings

There was a good overview of the power supplies.

The data for the selection of power supplies seems well understood.

The supplies for screen grid and control grid seem to be standard units that can be purchased from different vendors.

b) Comments

For the filament it should be considered that the heating should be decoupled from the 50 Hz of the mains, since ESS will operate a 14 Hz (asynchronous to mains). DC or different frequency.

Try to get a reasonable figure from the tube vendor for the maximum stored energy that they recommend for the anode filtering circuit. That will make it easier to decide the time constants for the current limiting inductance and damping circuits.

The high voltage supply seems to be the most demanding supply and needs more R&D.

There are vendors that are able to provide such power supplies.

c) Recommendations

There are different solutions for the power supply having either a crowbar system in parallel to the tetrode as used e.g. at CERN or having a series switch as proposed by Rolf Wedberg.

The finding and decision should be clearly stated.

The solution presented showed both solutions. There should be a choice for one of the solution.

Detailed specifications for the vendors are mandatory.

The first simulation model shows a large amount of ringing which should be better understood (capacitor, damping resistors, …).

The need for constant power charging of the capacitor bank was mentioned. This path should be followed.

3. RF Distribution

a) Findings

No need for transmission line cooling as operating at 15 kW average, i.e. overheating is quite low. The power levels should be rechecked. 15 kW seems the average power going through the waveguide, losses being then much lower than presented.

Aluminium oxide protection was widely used with kilometres of waveguides during LEP time, not any problem was reported.

Circulator Bandwidth (>2.5 MHz) should not be a problem.

b) Comments

WG combiner footprint is quite (too ?) large, see picture for alternative proposal.

Cost of alternative proposal should be very close; coaxial circulator 29 k€ x 2 = 58 k€, WG circulator 48 k€.

With power system S11 > 20 dB is already nice, be careful that asking for S11 > 30 dB can be very costly. In addition one need perfect adaptors to perform these measurements.

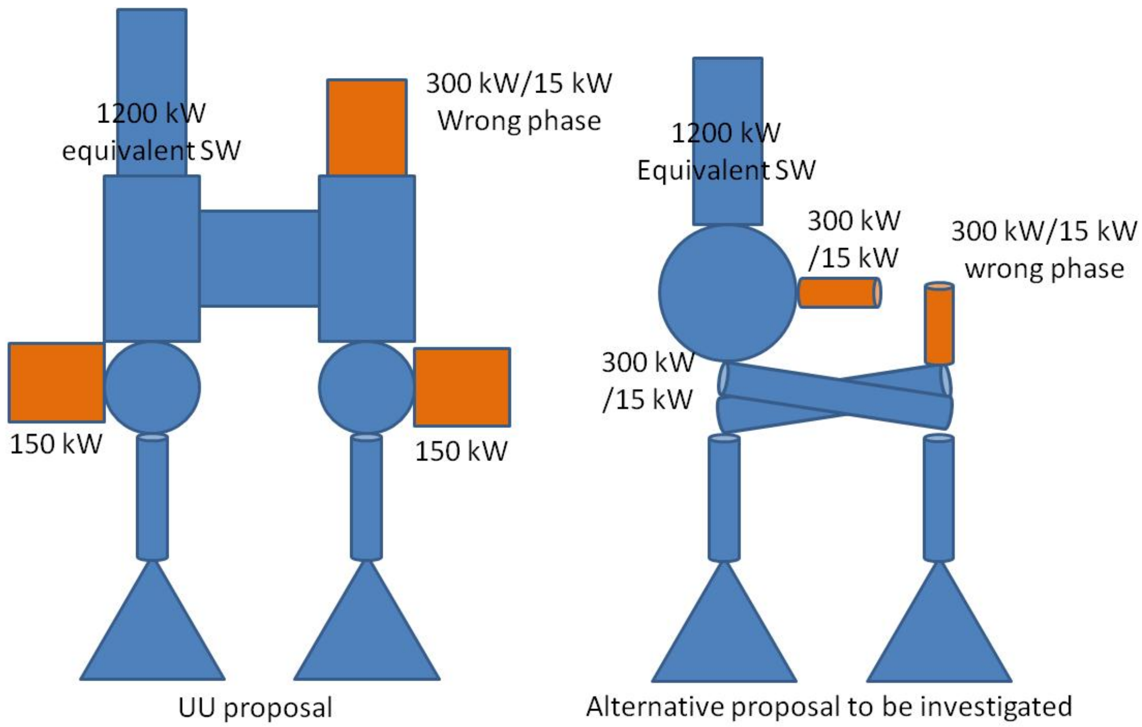
c) Recommendations

Check coaxial 3 dB combiner with coaxial 6 1/8” resistive water loads and a single output circulator with coaxial input (300kW) - WG output (4*300kW) - coaxial load (300kW).

This also saves 1 load

Compare it with the proposed solution, footprint vs cost with priority given to footprint in the perspective of an ESS amplifier.

Allow amplifier air to flow through the transmission lines, this implies non-plain spacer all along the lines, including the spacer at the amplifier output.



4. Diagnostics & Controls

a) Findings

At this stage of the design, the scheme seems reasonable.

b) Comments

A machine protection system is usually understood for machine protection with beam operation. Here we are more looking at a test area protection system. This is not implying the same level of protection.

c) Recommendations

None.

5. High Power Test Program

a) Findings

The FREIA test stand will be used to perform tests at nominal RF power for several systems: RF source alone, a fully equipped ESS spoke cavity in the future horizontal cryostat, the prototype spoke cryomodule.

Several tests will be performed to assess the cavity, coupler and tuner performances from the RF point of view.

Dedicated tests are foreseen to study the mechanical behaviour of the cavity (detuning effects), to study the impact of microphonics and Lorentz forces.

It will also be used to implement and set the parameters of the feed-forward compensation system.

b) Comments

A sliding short is envisaged for the test of the amplifier in order to check its behaviour under different phase reflection. This could be used also for the circulator test within all phases.

Study of microphonics in a dedicated test hall is always partial because there is no reasons for the test hall to be representative of the future microphonic spectrum that will exists in the linac tunnel. But still, effect of “intrinsic” microphonics will be analysed.

c) Recommendations

The test list presented is addressing issues links to RF, field and frequency in the spoke cryomodule.

The high power tests should also address the following topics:

- Cryomodule cryogenic behaviour at nominal field (cryogenic losses, cooling down time, power coupler thermal behaviour, He bath pressure variation...)
- Dedicated reliability tests (for instance operate the tuner at high rate over several days)

As the time between start of the high power tests and the launch of series production will be limited, a list of the tests to be performed, tagged with a priority level, should be established together with ESS and IPN Orsay.

6. General Comments

a) System design:

The committee found the specifications are properly specified for FREIA to test:

- Fully equipped Spoke prototype cavity (horizontal) mid-2014.
- Prototype Spoke cryomodule (ESS type) mid-2015.
- Amplifiers with respect to today ESS Linac specifications.

At least, these specifications are the best guess of ESS needs as known today.

Design choices are compatible with performance requirements and schedule:

This is the best choice to provide 300 kW @ 352 MHz - -3.5 ms pulses - 14 Hz repetition rate, being available mid-2014.

This test facility will be needed for all items tests.

b) Proposed hardware:

Hardware is compatible with requirements

The only item that would deserve a risk analysis are the Series HV switches.

Tube protection has been done.

Specify as soon as possible the water cooling system taking into account all requirements, Power supplies, Drivers, Finals, Loads, etc… AND being compatible between Uppsala & ESS:

- Materials (no aluminium, brass, only bronce)
- Material of hoses (e.g. EPDM check with other institutes)
- Test pressure, Temperature, Ph, flow rates

c) Future benefits:

Compatible with the requirements for high power testing of the ESS prototype spoke cavity

A more compact solution would be preferred for the ESS Linac.

As a possible fall-back solution, the proposed hardware is compatible with the requirements to power the spoke section of the ESS linac.

7. Conclusion

The reviewers though it was a very well organized review. They underlined the good quality of documents sent well before the date of the review.

They consider that the proposed solution match the requirements as defined today for the high power testing of the ESS spoke cavity. It is also a possible fall-back solution for RF power source for the spoke section of the ESS linac.

The reviewers are looking forward to seeing tests on-going.

They would like to thank all Uppsala University members for the very good work achieved.