THE LAYOUT OF 72 MHz 16 kW RF POWER GENERATOR

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Abstract

In this paper, we present the current design of the RF power generator for medical cyclotron Eclipse (Siemens Healthcare) based on solid-state architecture. The 16 kW machine operating at 72 MHz in continuous wave regime is being assembled into standard 19" cabinet. Brief description and technical solutions regarding 2 k W (Class-AB, Si transistor based) RF modules, power combiner and control system are shown.

INTRODUCTION

High power RF sources are important elements for most of accelerators that have found growing number of applications in physics and medicine. Current power amplifier will feed Eclipse cyclotron that is being used for PET isotopes production (^{18}F, ^{11}C, ^{13}N and ^{15}O) with H- ions at 11 MeV [1].

The main benefits of the generator under development are its smaller footprint, perspective of lower cost, better reliability and higher efficiency, achieved with class-AB operation, compared to conventional RF power sources like klystrons or other vacuum tubes generators. The solid-state microwave power amplifier modules based on Freescale LDMOS transistors arranged in parallel push-pull circuits, are designed on PCB boards.

All modules are connected to a power combiner with 50 Ohm coaxial cables.

RF POWER MODULES

We have designed and manufactured compact RF power amplifier (RFPA) modules with two pairs of Freescale™ MRF6V2010NR1 (driver stage) and MRFE6VP1K2H (main stage) transistors arranged in push-pull topology as shown on Fig. 1.

The frequency is adjustable between 72 and 73 MHz because cyclotron resonant frequency changes in this range during operation.

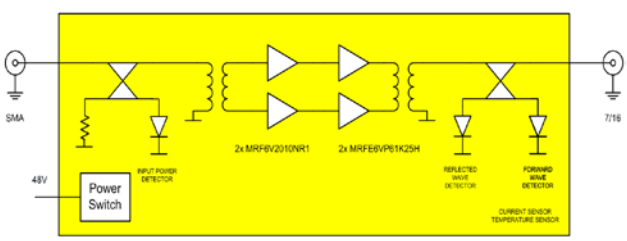

Figure 1: Parallel push-pull circuit.

The manufactured module prototype is presented on Fig. 2. Arlon AD255 with ε=2.55 is used a substrate material. The transistors are fed with 180^0 phaseshift, provided with an RF transformer. Achieved RF performance is shown in Table 1.

Table 1: RFPA Specifications

Parameter	Value
Bandwidth	72..73 MHz
Output RF power	max. 2100 W
RF efficiency	~75% (>80% planned)
Gain	52..55 dB
Input RF power	max. 30 mW
Supply voltage	48 V
Input/Output impedance	50 Ohm
Input/Output VSWR	max 1.3
Dimensions	16×25 cm^2

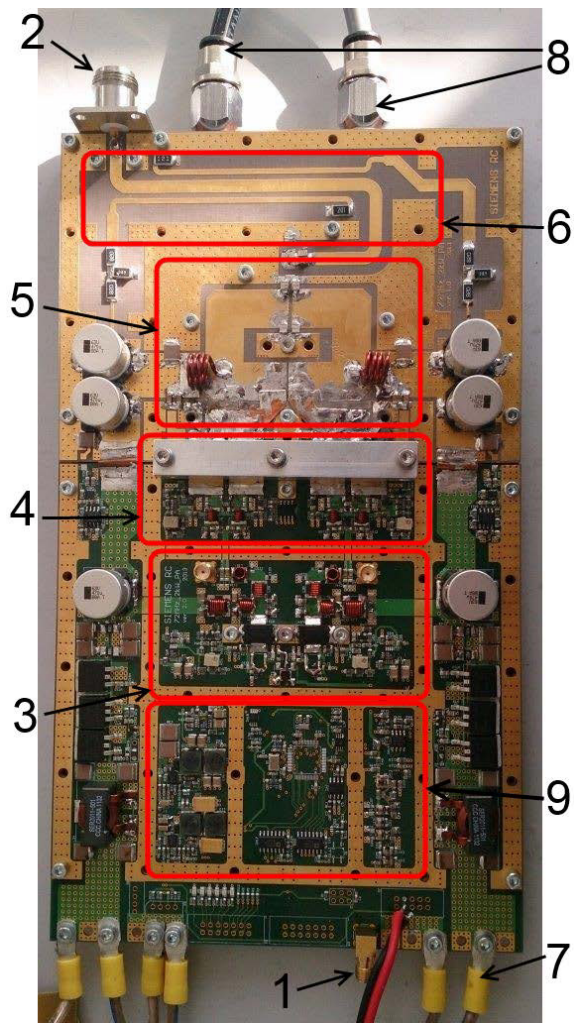

Figure 2: RFPA module: 1 – RF input; 2 – RF output; 3 – driver stage; 4 – main amp stage; 5 – output matching transformer; 6 – output directional coupler; 7 – DC supply; 8 – water cooling tubes; 9 – MCU unit.

ISBN 978-3-95450-138-0

MCU (microcontroller unit) is a logic scheme that is able to collect the following measured parameters and and communicates with the external control system:

- Supply voltage and current;
- Input LLRF power level;
- Forward/reflected power at the RFPA output.

A set of nine of these RFPAs (giving total output RF power up to 18 kW) with individual off-shelf 3kW air-cooled AC-DC converters and EMI filters are packaged inside nine 19" racks of 2 units (~90 mm) height as shown on Fig. 3.

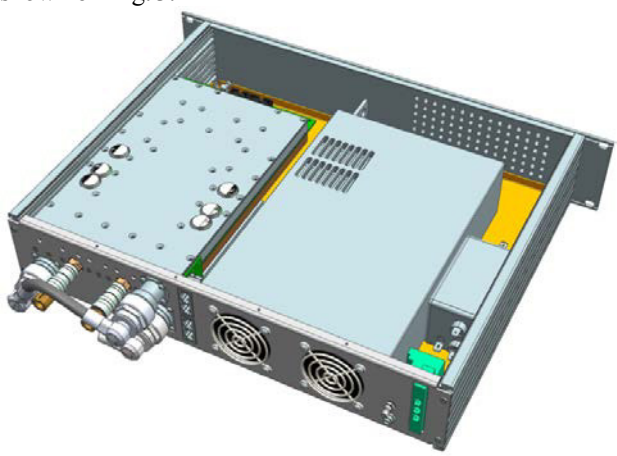

Figure 3: Single RFPA rack.

The RF efficiency dependence on output RF power is plotted on Fig. 4.

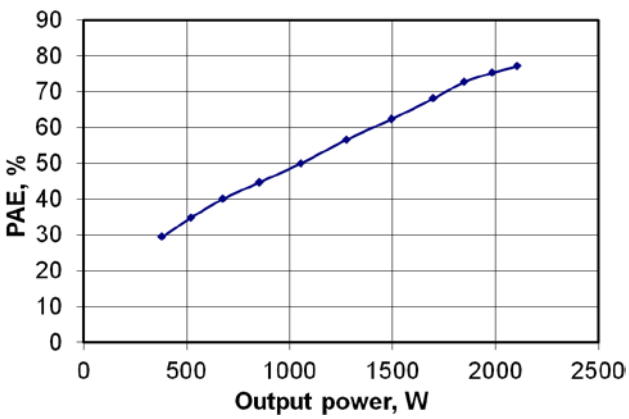

Figure 4: Measured RFPA efficiency vs. output RF power.

POWER COMBINER

Most of power combiners available on the market are based on coaxial geometry and are huge. In order to achieve the best compactness of the generator we have designed and manufactured the planar power combiner of 1 unit (~45 mm) height (see Fig. 5). It has nine 7-16 RF inputs and 1-5/8" EIA output coaxial flange.

Figure 5: 9-to-1 planar power combiner.

The inner conductor with the outer shielding aluminium case forms two sections of rectangular-coaxial serving as pre-combining and matching elements. The oval-shaped hole in the pre-combining part serves for input signals amplitude and phase balancing. The water-cooling tubes shapes have been optimized to introduce low perturbation of the EM fields.

Power combiner S-parameters measurement results referring to the common output port 1 are plotted on Fig. 6, other RF characteristics are listed in Table 2.

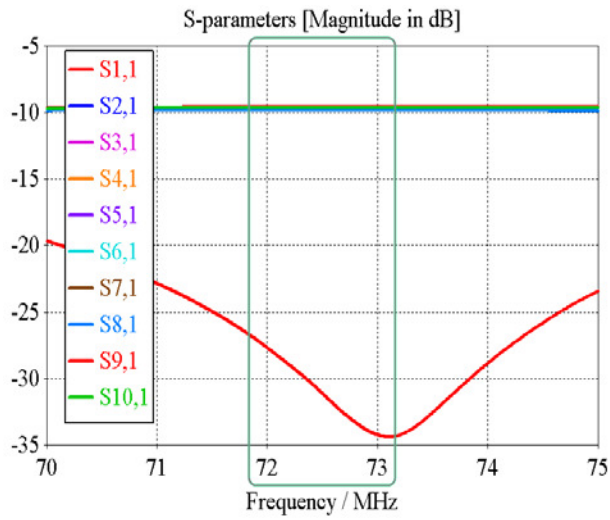

Figure 6: Measured S-parameters plot (operation frequency range is highlighted).

Table 2: Power Combiner Features

Parameter	Value
Bandwidth	72..73 MHz
Return loss	27..34 dB
Dissipated RF power ratio	0.1 %
Power splitting equality	<1 %
Dimensions	45×43×4.5 cm^3

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GENERATOR FORMFACTOR

All 12 blocks including power distribution, control, measurement and water-cooling systems will be assembled in 19" cabinet presented with components arrangement on Fig. 7.

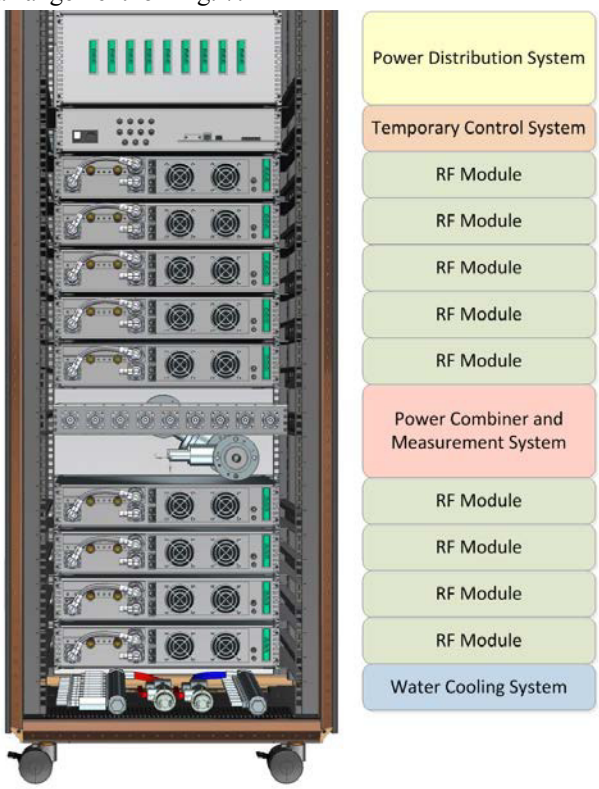

Figure 7: Generator assembly and arrangement scheme.

According to the current preliminary design the total height of the cabinet is 30 units (~1.4 m) and will be reduced down to 18 u nits (~80 cm) by arranging the components closer to each other – especially by putting all RFPAs into a single 4 units (~18 cm) high rack and uniting measurement system with the power combiner, as shown on Fig. 8.

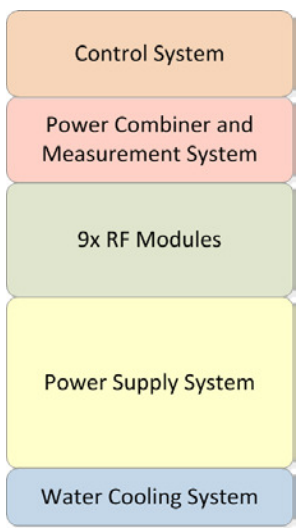

Figure 8: Goal scheme of the generator design.

The following is brief descriptions of the components.

Temporary Control System

The control system creates the reference signal, performs its splitting and amplifying. Each channel provides independent phase shift and adjustment of the transmission coefficients between master oscillator and the RFPA LLRF inputs. It is also possible to use an external reference signal.

Control system also examines the output RF signal and can adjust its phase and amplitude.

Power Distribution System

The generator can be used under 110V or 220V three-phase electrical network. The distribution system equally divides power between three phases by connecting three RFPA modules to each phase.

Cooling system located at the bottom of the cabinet provides the water flow through the RFPA modules and the power combiner.

SUMMARY

We have presented the current design of the 72 MHz 18kW (CW) power generator that is now being assembled and undergoing high power tests. The solid-state class-AB RF amplifiers show commendable efficiency of 75% at the operation output RF power level of 2 kW and will be improved to have over 80%.

As for now, the total height of the prototype device is 1.4 m and we are making efforts to shorten it down to 80 cm.

REFERENCE

[1] http://www.medical.siemens.com/siemens/en_GB/gg_nm_FBAs/files/dash/ds_09_eclipse.pdf