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Design of 71 MHz Power Amplifier in a Single-ended Architecture for IRANCYC_10 Cyclotron

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Introduction

IRANCYC-10 Accelerator is a 10 MeV AVF cyclotron accelerator for the production of radionuclides used in positron emission tomography scans.

The operating frequency of this accelerator is 71 MHz.

The radio frequency system of this accelerator consists of three parts:low level RF, intermediate power amplifier and main power amplifier. The triode vacuum tube 3CW20000A7 is used as the main power amplifier for use in the cavity and also to increase the voltage of Dee's up to 40 kV to create an electric field [1].

The use of solid-state power amplifiers results in better performance, higher reliability, lower maintenance costs, lower power consumption, longer life, and lower spare parts costs. So there is a strong motivation for this replacement.

Push-Pull configuration power amplifiers are widely used for high power amplification.

Since several modules must be used in the solid state to provide the power level of the cyclotron accelerator, the use of this type of configuration is not appropriate.Thus a single-ended configuration was recommended. The advantages of using this type of configuration include a balun-free design, suitable for mass production to create 400 kW stations, and an economical design [2].

The objective of this paper is to design an SSPA module with an output power of 1 kW with maximum efficiency in the appropriate size as well as cost-effective, for use at higher powers.

Methods and Materials

At least 11 kW of RF power is required to accelerate the negative hydrogen particles in Dee, but this power must be about 15 kW to create a beam stability factor.

A signal with a power of less than 1 watt is generated in the LLRF and feeds the preamplifier, to increase the power by 30 watts. In the middle amplifier section, by combining four 1kW amplifier modules, 2.5 kW of power is created to power the main power amplifier.

2.1. 1 kW amplifier design:

BLF188XR transistor has been used for design,. The maximum output power of this transistor is 1400 watts. This transistor has high efficiency and good thermal stability [3].

Some analysis done for design of this amplifier such as : DC analysis, stabeality, load pull analysis, large signal out put.

Figures 1 to 3 show the values of this analysis. All of analysis was performed by ADS software [4].

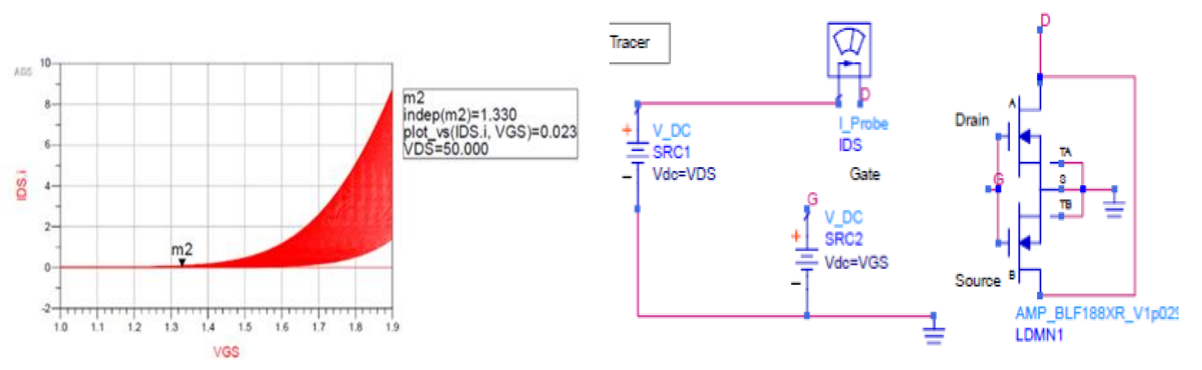

Figure 1. Schematic of DC analysis and diagram of drain current in terms of gate voltage

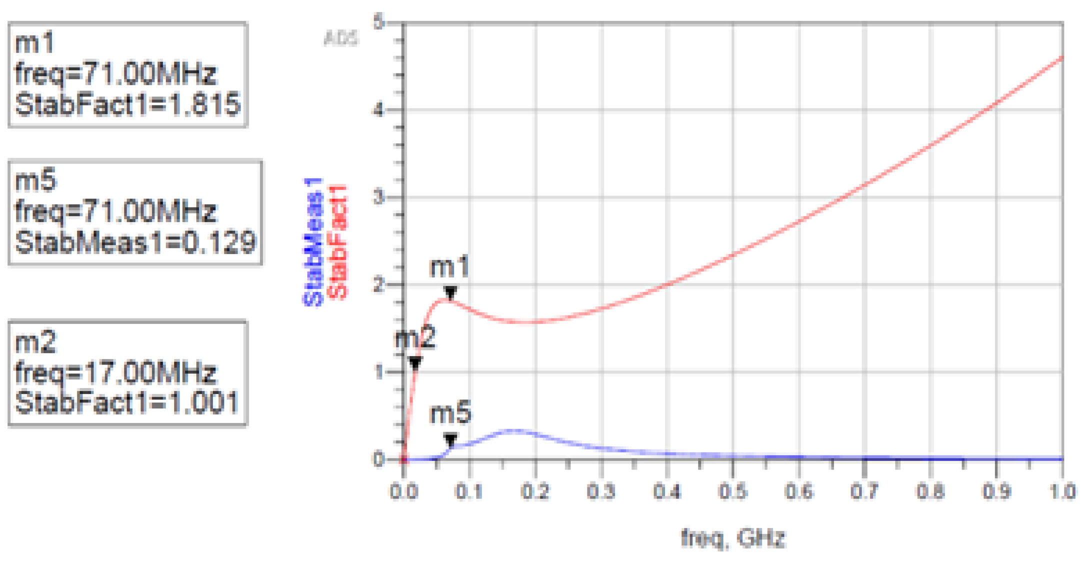

Figure 2. Diagram of transistor stability conditions

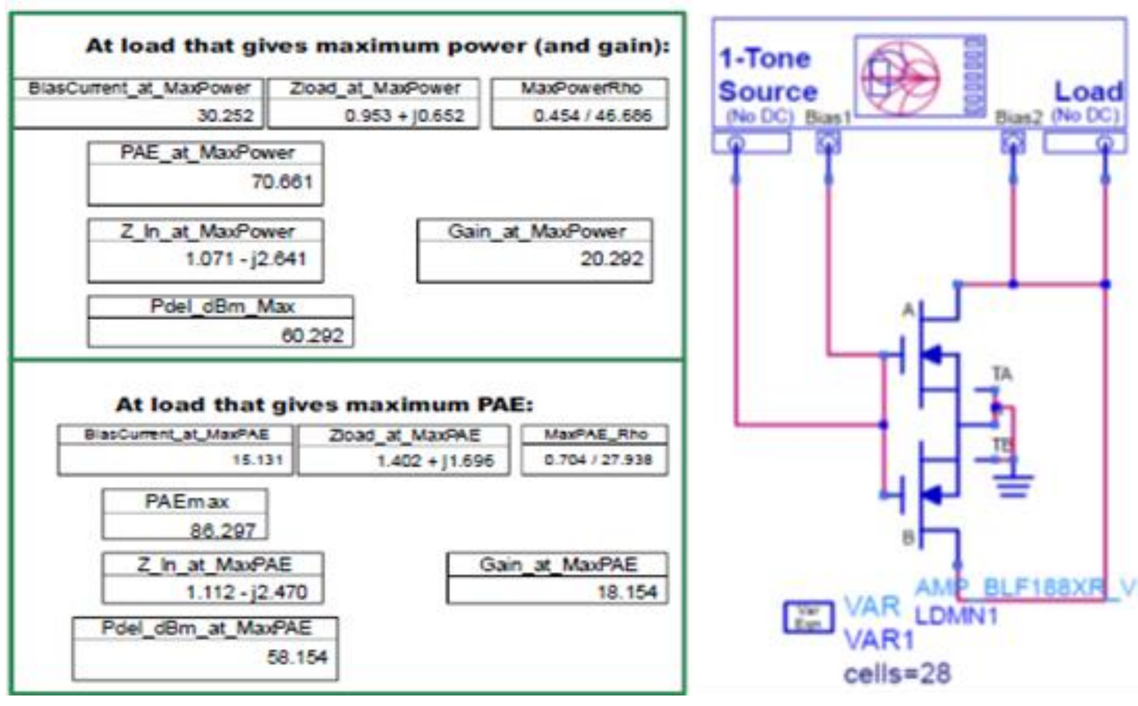

Figure 3. Load-Pull analysis of the transistor

Design of single ended amplifier:

Several solid-state modules must be used to provide the power level of the cyclotron accelerator, so a single-ended configuration has been suggested.

Figure 5 and 6 shows the final power amplifiers design for the IRANCYC-10 accelerator. One of the most important design steps of this amplifier is the design of impedance matching circuits, which increases the signal-to-noise ratio as well as maximizing power output and low loss [1]. Due to the use of this configuration and the operating frequency of the accelerator, the size of the matching circuit increased.

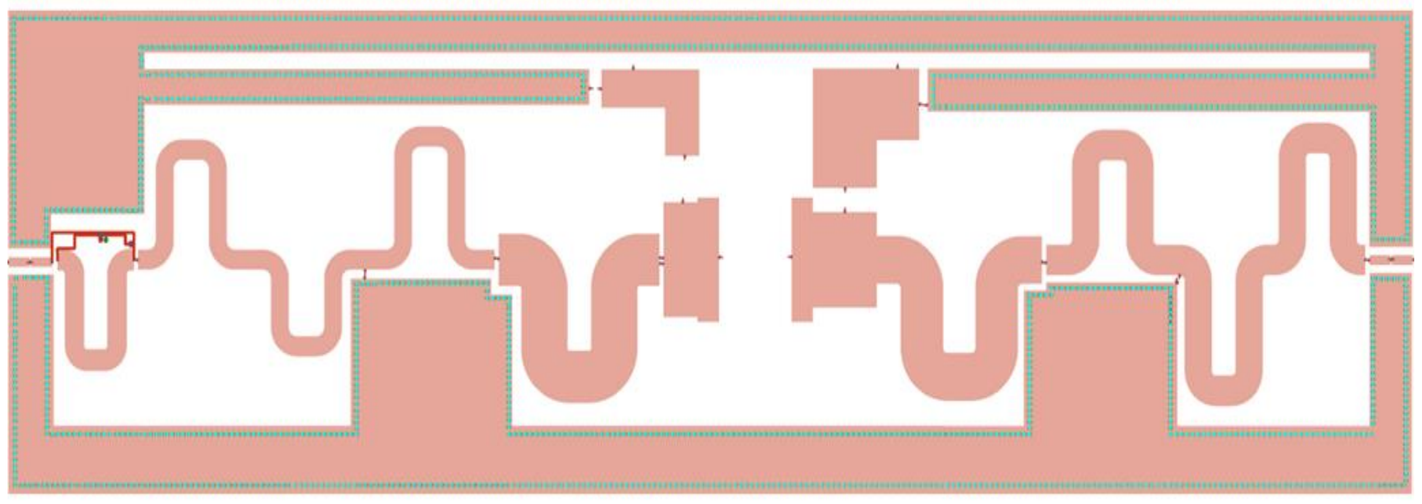

Figure 6. PCB design of 1 kW power amplifier with input transformer

For this reason, two approaches were proposed. First: the use of the FR4 substrate with a dielectric constant of 4.5 and also adding lumped elements such as inductors and capacitors. Second: the use of a transformer, which greatly reduces the size of the module.

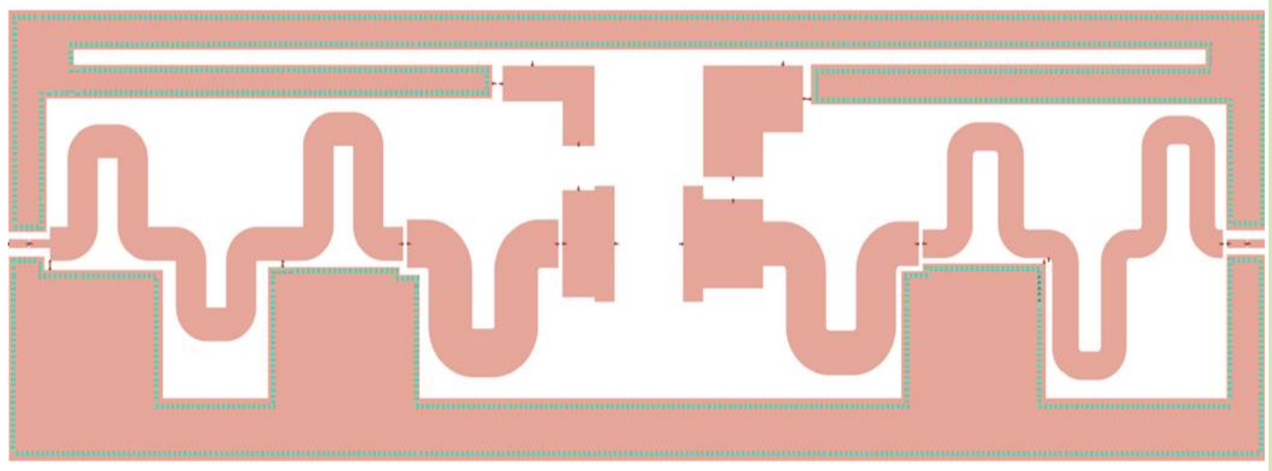

Figure 5. PCB design of the 1-kW power amplifier

Results

In the design presented in Figures 6 and 5, 1 kW output power was measured with 71% efficiency and 21.21 gain. Figures 7 and 8 show the values of this simulation.

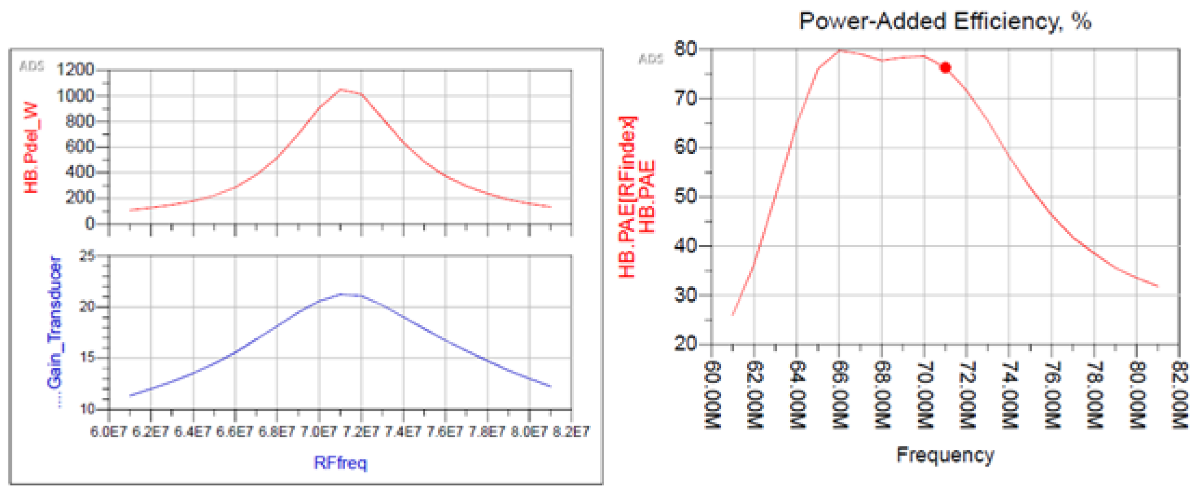

Figure 7. Final results of 1 kW power amplifier design

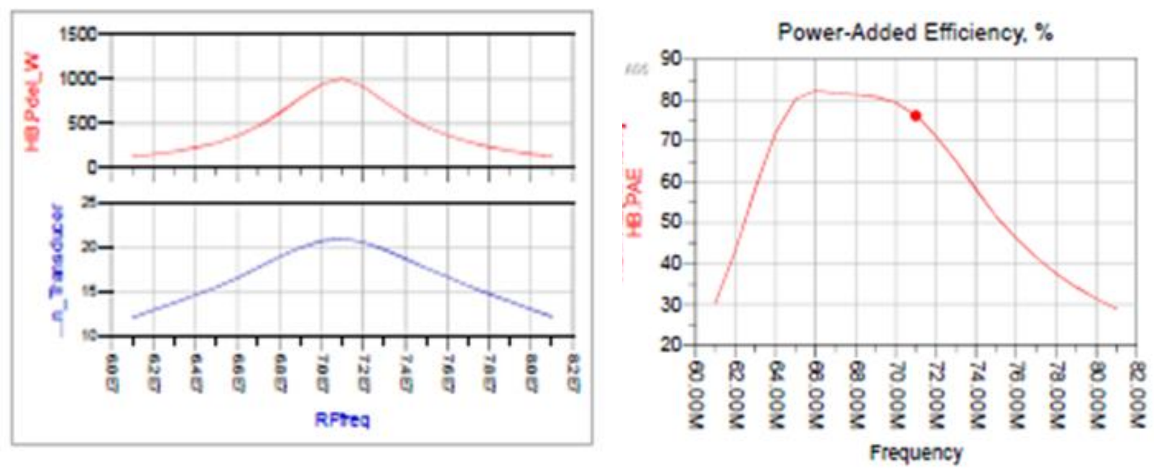

Figure 8. Final results of 1 kW power amplifier design with input transformer

Conclusions

Some of the simulations and results of the cyclotron accelerator radio frequency generator have been presented in this paper. The RF power system of this accelerator has been provided by implementing the latest technology and high power consumption strategy. Also, a solution to reduce the module size has been provided with maximum power and minimum loss. The maximum output power is 1 kW and the efficiency is 74% and the gain has been estimated at 21.21. The size of this module is 30 x 15 cm.

Also, it is possible to assemble 16 modules of this amplifier using a combiner, and use it as a main power amplifier of 15 kW and replace the triode tube.

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References

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