# DEVELOPMENT AND PERFORMACE CHARACTERIZATION OF 2 KW 505.8 MHz AND 4 KW 352 MHz SOLID STATE RF AMPLIFIERS

Akhilesh Jain, Deepak Kumar Sharma, Alok Kumar Gupta, P. R. Hannurkar
RRCAT, Indore INDIA

*Abstract*

This article reports development and measured performance of Solid State RF Power Amplifier, developed in RRCAT, operating at 352MHz and 505.8 MHz and capable of providing output power of 2 kW and 4 kW respectively. Each amplifier comprises of 270-300W amplifier modules, two numbers of radial power combiners as well dividers, high power square coaxial type directional coupler and driver amplifier stages. Measured results are in well agreement with calculated data. Presently both of these amplifiers have been put for using as high power test stand for newly developed RF components. Modular and indigenous design, low cost, complete and ease of operation are some of the notable features of this technical development.

## INTRODUCTION

Many particle accelerator laboratories around the world have harnessed the power of solid-state devices, by deploying kW level RF power source for energizing superconducting structures [1]. Along with getting clean RF power (free from phase noise and spurious) solid state device failure rate reported from Soleil is 3% per year including infant mortality. Numerous advantages [2] of SSPA, compared to vacuum tube counterpart, is the main driving force behind rapid development of kW level solid state power amplifier (SSPA).

In present work, two amplifiers with 2kW and 4kW output power were developed at 505.8 MHz and 352 MHz respectively. For these SSPAs, vector and scalar measurements were carried out for validating design procedure. Followed by this, high power continuous wave (CW) as well pulse RF testing was carried out. This exercise provided useful data for life testing, possibility of any arcing at high power, heat dissipation and graceful degradation for upcoming higher power amplifiers.

## AMPLIFIER ARCHITECTURE

Developed kW level RF amplifier consists of driver amplifier, high power (270-300W) amplifier, power divider & combiner and directional coupler, as key RF components. At 352MHz, using LR301 MOSFET, 20 numbers of 270 W water cooled amplifier modules were designed. At 505.8 MHz, similarly, 8 water cooled modules, providing 300W of RF power from MRF 9130 device, were developed. Apart from this work, driver amplifier unit at 30W was been designed for boosting signal received from RF generator to a level, required at 270-300W module input. Driver unit consists of 3 cascaded stages, each one using MRF9030 device.

Among different combining choices, radial combiners and dividers (PDC), where power combining or dividing action is achieved in a single step, was found as efficient candidate for combining n (>2) amplifiers [3]. After design optimisation using structure simulator, 8-way and 16-way combiner and dividers, operating at 352 and 505.8 MHz respectively, were designed. These structures are with 1-5/8" EIA central coaxial feed port and standard N connector, at peripheral collecting ports. For measuring output forward power, two types of wideband (300-800MHz) directional coupler were designed.

2-kW amplifier at 505.8 MHz was assembled with eight numbers of 300 W amplifier modules, two numbers of 8-way power combiner/divider and directional coupler.

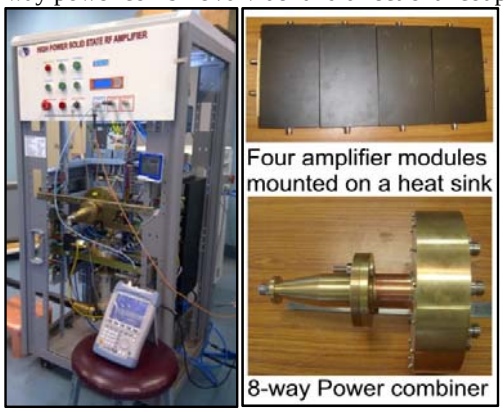


Figure 1: 2 kW amplifier rack with power combiner and amplifier modules at 505.8 MHz.

At the core of 4-kW amplifier, 16 numbers of 270W amplifier modules were power combined using 16-way radial power combiner.

Figure 2: 4-kW amplifier at 352 MHz showing amplifier, power combiner and directional couplers.

In both of these amplifiers, necessary controlling and monitoring signals like, enable signal to RF-switch, power supply OK, heat sink temperature of amplifier modules, input and output power signal from RF detector etc. were interfaced with a real time controller, for data acquisition [4] In order to extract heat dissipated by solid state devices, water cooled heat-sinks were used. Both of these systems have been tested successfully at full power.

## MEASURED PERFORMANCE

RF measurements of different RF components, described above, were performed at low and high CW and pulse RF power. Power transfer characteristics for developed amplifiers are shown in Figure 3.

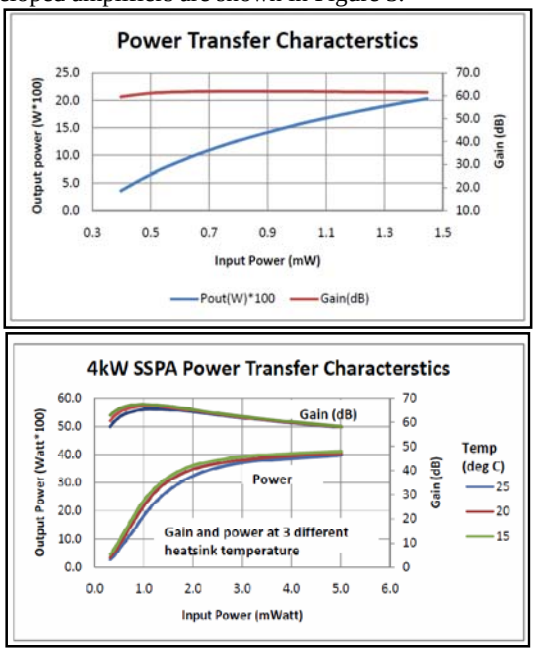


Figure 3: Measured results of 2 kW and 4 kW amplifiers at 505.8 and 352 MHz (bottom).

For developed PDC structures return loss of feed port, insertion loss, and coupling from feed port to branch port and phase imbalance were measured. Return loss for feed port was -30.8 dB and -27 dB for 8-way and 16- way PDC respectively against the calculated value of -35dB and -30 dB for respective case.

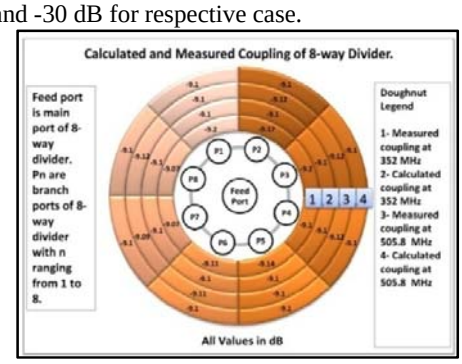


Figure 4: Measured and calculated power coupling - for 8-way PDC at 505.8 MHz

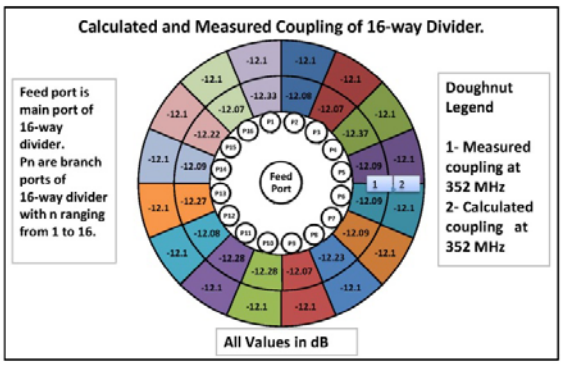


Figure 5: Measured and calculated power coupling - for 16-way PDC at 352 MHz

This work has encouraged developing high power divider and combiner [5]. For 1kW coupler, measured directivity was in excess of 27dB and 24dB at 352 and 505.8 MHz respectively. Similar figures for 4kW coupler were 22 and 21 dB.

## CONCLUSION

At 352 MHz and 505.8 MHz, modular kW level solid state RF amplifiers have been successfully tested. Successful development of, first time attempted, kW level amplifier added confidence for future development of solid state RF source for particle accelerator.

## ACKNOWLEDGEMENT

For testing and measurement work of these amplifers, we are grateful to Ms. Vasanti Sekhar and Ms Deepa Ramchandani. Mr. D. K. Verma has carefully assembled all lines and testing rack with necessary electronics.

## REFERENCES

[1] P. Marchand, et al, “High power (35 and 190 kW) solid state amplifiers at 352 MHz for synchrotron soleil”, in Proceedings of EPAC 2004, Lucerne, Switzerland

[2] Akhilesh Jain, D. K. Sharma, A. K. Gupta, and P. R. Hannurkar ", High power solid state RF amplifier for proton accelerator," Rev. of Sci. Instruments, vol. 79, 014702, Jan. 2008.

[3] Akhilesh Jain, D. K. Sharma, A. K. Gupta, and P. R. Hannurkar ", Design of high power radio frequency radial combiner for proton accelerator," Rev. of Sci. Instruments, vol. Vol. 80, no. 016106, Jan 2009.

[4] Sharma D.K, Jain A., Hannurkar P.R., " Embedded Control System for High Power RF Amplifiers", in Indian Particle Accelerator Conference INPAC 2011, New Delhi, India, 2011.

[5] A. K. Gupta, Sharma D.K, Jain A., Hannurkar P.R.," High Power, Lossless, Rigid Line 2- Way Rf Power Combiners", in Indian Particle Accelerator Conference INPAC 2011, New Delhi, India, 2011.