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Assembly and Performance Characterization of 1.4 KW 325 MHZ Solid State RF Amplifiers

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Abstract:—Development of amplifier from one frequency to another a work on SSPA has been done. Assembly and measured performance of Solid State RF Power Amplifier, which was already running at 352 MHZ, developed in RRCAT, retuned at 325MHz and capable of providing output power of 1.4 kW. Each amplifier comprises of 200W amplifier modules. The assembly of rack has eight amplifiers, 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. Retuning of amplifiers from 352 MHz to 325 MHz, modular and indigenous design, low cost, complete and ease of operation are some of the notable features of this technical development.

I. 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, RFSD Lab has one Amplifier unit which was already running at 352 MHz has been converted at 325 MHz by retuning of all amplifiers and changes in RF passive components according our required frequency (325MHz). One amplifier with 1.4kW and output power was developed at 325 MHz. For this SSPA, 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. [3]

II. TUNING AND PHASE MATCHING OF AMPLIFIER

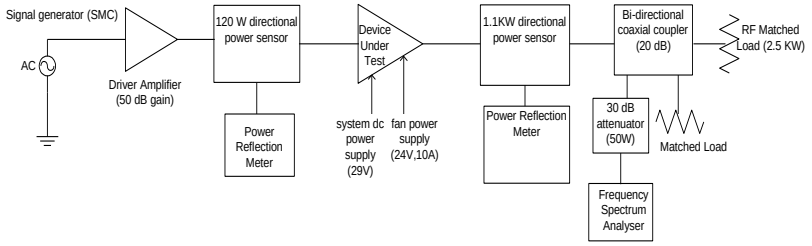

Figure 1: Experimental set-up for tuning of amplifiers modules at 325MHz

For converting frequency from 352 MHZ to 325MHz, tuning of amplifiers has been done (Fig 1). For tuning of amplifier we have some tuning capacitors. Firstly 1 more tuning capacitor has to connect at the output side. After setting generator frequency at 325MHz, tuning of capacitor will start to acquire maximum gain. After achieving max gain tuned capacitor will change by fixed capacitors. We achieved max output 200W from each amplifier. Now we have to match phase (difference of phase at input side and phase at output side of an amplifier) of each amplifier and it should be same for all amplifier.

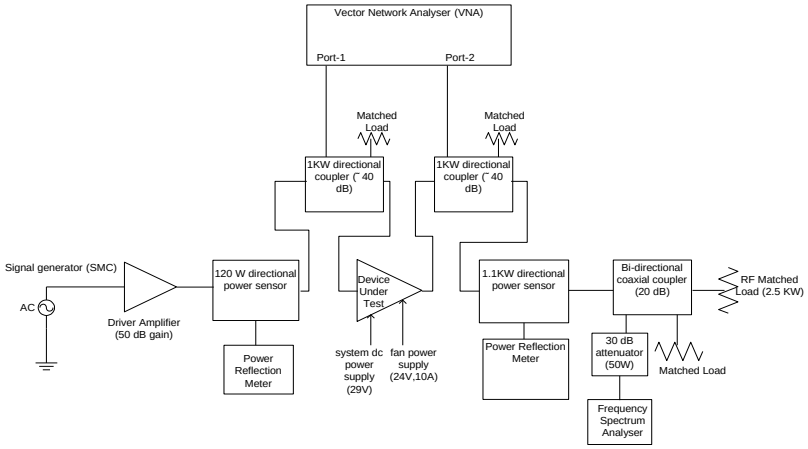

Figure 2: Experimental set-up for measuring the phase difference between input and output signals from the amplifier modules at 325 MHz

III. AMPLIFIER DESIGN

RF amplifier at 325 MHz consists of one driver amplifier, 10 high power (200W) amplifier, one power divider & one combiner and directional coupler, as key RF components. At 325MHz, using LR301 MOSFET, 10 numbers of 200 W air cooled amplifier modules were designed. Apart from this work, driver amplifier unit at 30W was been designed for boosting signal received from RF generator to a level, required at 200W module input. [3]

We used radial combiners and dividers (PDC) for efficient combining amplifiers. Combiners and dividers 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.

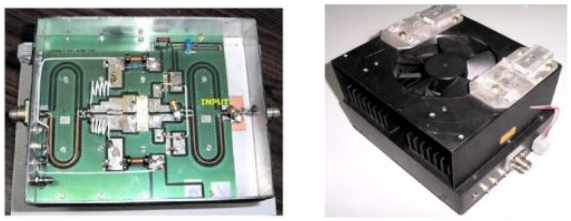

Figure 3: Amplifier module and outside view of an amplifier module with fan assembly at 325MHz

In this amplifier, 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 [5] In order to extract heat dissipated by solid state devices, air cooled heat-sinks were used. This system has been tested successfully at full power.

IV. MEASURED PERFORMANCE

RF measurements of different RF components, described above, were performed at low and high CW power. Power transfer characteristics for developed amplifiers are shown in Figure 5.

At the core of 1.4-kW amplifier, 10 numbers of 200W amplifier modules were power combined using 8-way radial power combiner.

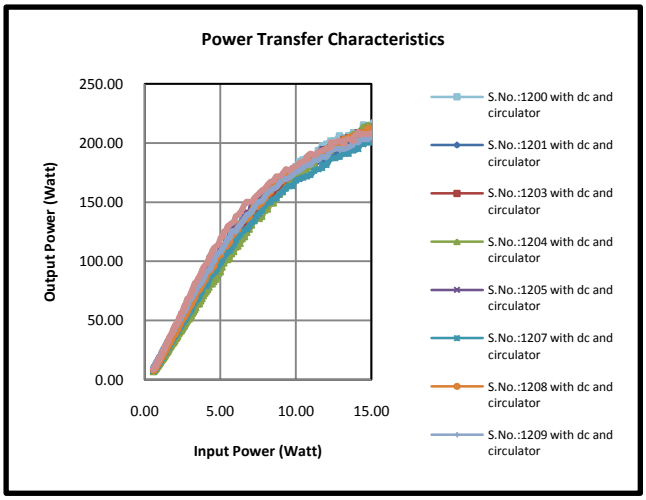

Figure 4: 1.4-kW amplifier at 325 MHz showing amplifier, power combiner and directional couple

Figure 5: Input and output characteristic of eight amplifiers at 325MHz

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. [3]

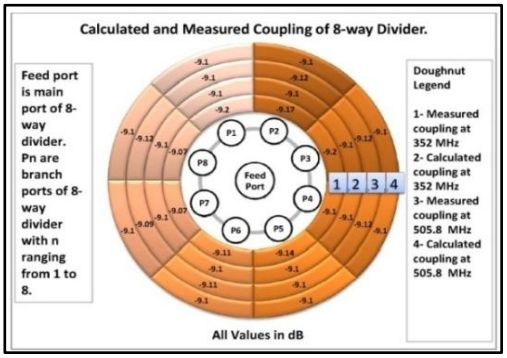

Figure 6: Measured and calculated power coupling - for 8-way PDC at 505.8 MHz

For 1kW coupler, measured directivity was in excess of 27dB and 24dB at 352 and 505.8 MHz respectively.

V. CONCLUSION

At 325MHz modular kW level solid state RF amplifier has been successfully tested. Successful development of, first time attempted, kW level amplifier added confidence for future development of solid state RF amplifiers.

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