A.8: Design and development of 150 kW pulse solid state amplifier

This article describes the design, development and testing of 150 kW pulse solid state amplifier operating at 325 MHz developed for the first time. Its output power is 150 kW, with variable pulse width from 1 ms to 5 ms, at a pulse repetition rate of 50 Hz. Its pulse amplitude droop, measured at 1 ms is 0.46 dB. The phase variation around an average value, measured within a single pulse at 1 ms is less than 2.7°. Its main features are: modular (using three 325 MHz, 50 kW amplifier units) and scalable design architecture that comprises multiple extended continuous Class-F 1.5 kW amplifiers, energy-efficient two-tier radial power dividers as well as combiners, compact dual channel power sensors, and aperture-coupled directional couplers. All these constituent radio frequency (RF) components were designed and built in-house.

For the developed 124 numbers of amplifier modules, the measured output power, was symmetric around a mean value of 1.7 kW, and nearly 95% of power amplifiers (PAs) have output power in the range of 1700 ± 12 W. The insertion-phase distribution had a mean value of 75.5°. For the power combiners, the measured insertion loss was less than 0.1 dB. Figure A.8.1 shows the complete amplifier along with the 3-way combiner, and different directional couplers. Its operation and testing were managed with the help of a distributed control and interlock hardware, designed using FPGA based real time controller along with LabVIEW™ with real-time and FPGA programming.

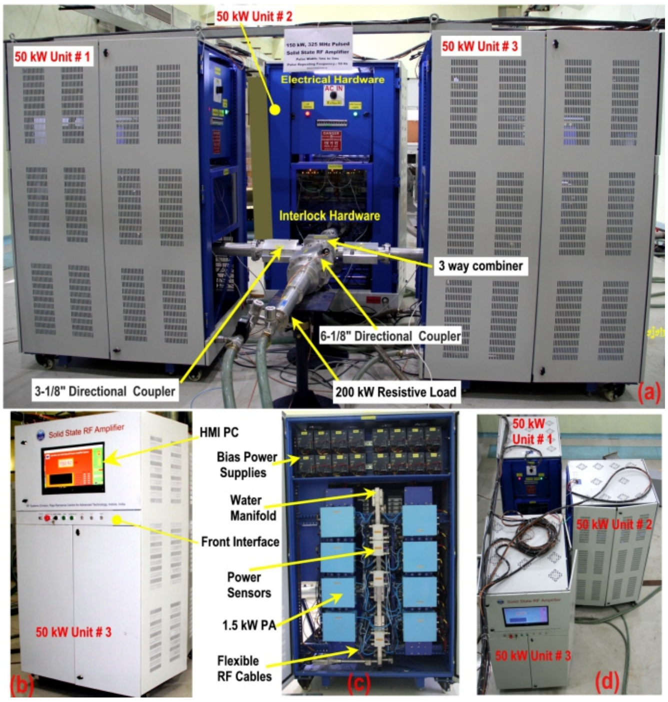

Fig. A.8.1: Photographs showing (a) the constructed 325 MHz, 150 kW amplifier connected to a 200 kW load, (b) one 50 kW unit with RFDC hardware, (c) side view of a 50 kW unit showing different components, (d) top view of 325 MHz, 150 kW amplifier.

The measured input-output power transfer characteristic at three different pulse widths, are plotted in Figure A.8.2. Here the efficiency plotted on the secondary vertical axis, is the ratio of average RF power to average AC power. All three power transfer characteristics are nearly similar and almost linear.

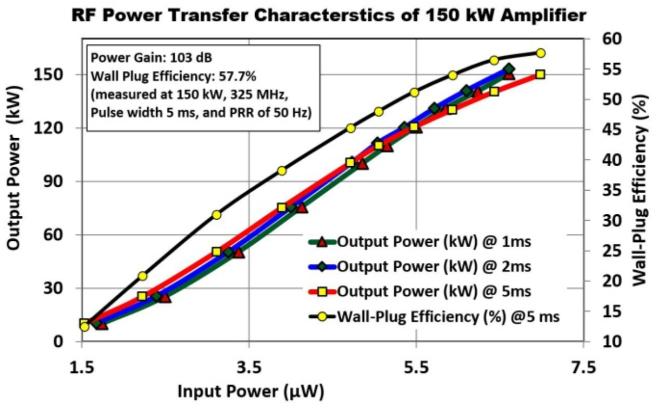

Fig. A.8.2: Measured RF power transfer characteristics, wall plug efficiency and power gain of the 150 kW amplifier.

Figure A.8.3 shows the pulse-to-pulse amplitude variation of the output RF signal over four consecutive pulses. Here, the measurement markers are placed at the same instant, relative to the rising edge for each pulse. The measured amplitude variation (the peak value of the excursion around an average value) was less than ± 0.1 dB. Also, the measured flat top pulse amplitude ripple was very low (< 0.05 dB).

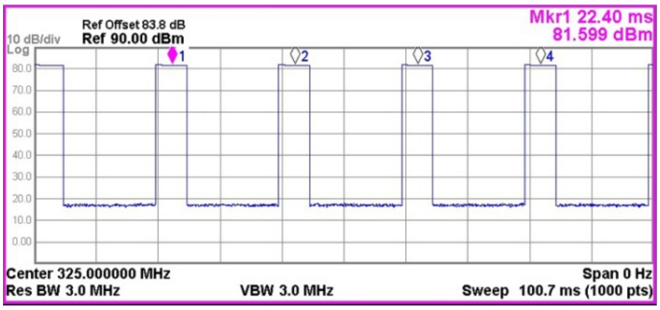

Fig. A.8.3: Measured pulse to pulse amplitude variation for 150 kW amplifier.

The measured results for the 150 kW amplifier (wall plug efficiency of 57.7%, pulse-droop of 0.52 dB, and phase stability of 3.5) and its in-house designed constituent components, extends the state of the art, at this power level. This technology development fulfills the present objective and it paves the path for next generation high-power RF source requirements. For more details, please refer to IEEE Transactions on Nuclear Science, vol. 67, no. 11, pp. 2303-2310, Nov 2020.

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