A.9: Development of 650 MHz, 30 kW solid state RF amplifier

RRCAT has developed solid-state amplifiers with total RF output of 320 kW(average), operating at 505.8 MHz, for Indus-2 Synchrotron Radiation Source. Encouraged by this success, an R&D programme has been taken upon the development of 650 MHz solid-state amplifiers to power, the elliptical superconducting cavities for high intensity proton linac. In this direction, a 30 kW (average) solid-state amplifier has been developed at 650 MHz using 500 W power amplifier modules, 2-way power combiner, 40-way power dividers, combiners, and high power directional couplers.

In this amplifier, 30 kW of RF power was achieved by combining two scalable and modular 15 kW amplifier units (Fig. A.9.1), with the help of a 2-way power combiner. The 15 kW amplifier unit employs 40 amplifier modules, each one delivering 500 W. Output RF powers from these modules were combined with the help of a 40-way radial combiner to get 15 kW of output power. For RF power sampling and monitoring, low power (1 kW) and high power (20 kW and 75 kW) directional couplers were suitably incorporated in different transmission lines of this amplifier. The 15 kW unit, housed in a single euro rack, is equipped with DC bias power supplies, electrical components, water cooling circuit and control/interlock hardware, to make it a complete stand-alone amplifier. These 15 kW units were tested successfully at full rated power with the help of a water-cooled dummy load before final combining.

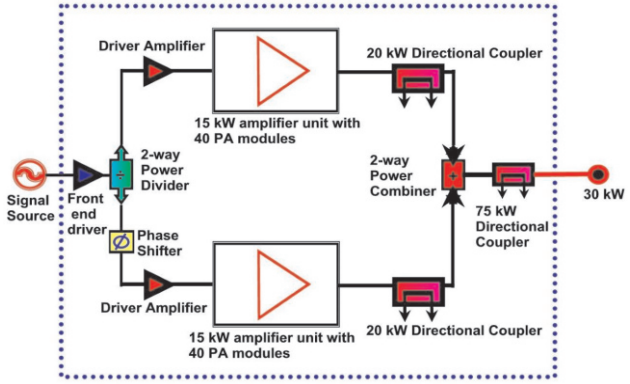

Fig. A.9.1: Simplified schematic of 650 MHz, 30 kW solid state RF amplifier

The enhancement in the output power of the15 kW unit (compared to the 13 kW solid-state amplifier unit of Indus-2 RF system) was achieved with the help of newly designed RF components, including a compact 650 MHz 500 W amplifier module, a 40-port 20 kW power combiner and a 40-port power divider. This amplifier module operates in extended continuous class F operating mode with power gain of 19 dB and drain-conversion efficiency in excess of 62%. Its input and output impedance matching networks are very compact. Compared to the Indus-2 RF system's power modules, its physical dimensions are nearly half, whereas its RF performance is better. This 30 kW, 650 MHz amplifier make use of 80 such modules. New 40-way power combiner saves the space and fabrication cost, as compared with earlier designed 16-port combiner at 505.8 MHz. It also minimize the RF energy loss by incorporating more than twice of the peripheral combining ports in a single structure. An inductive shorted stub, provided in this combiner, balances the capacitive reactance at the junction of the radial line. This balancing helps maintaining a stable return loss over a wider bandwidth. This stub additionally serves as a heat transfer path from the central conductor to the outer one. The 40-way divider is nearly similar to the combiner, except that its input port is different in order to handle lower RF power.

Fig.A.9.2: Fabricated 650 MHz, 30 kW solid state RF amplifier

The sampled forward and reflected RF signals from each 500 W module were rectified using the respective logarithmic RF power detector. The output of the detector is communicated to a FPGA control and interlock unit. An application-specific circuit board provides the interface with front-panel switches-indicators and enables the remote control of the complete amplifier. A graphical code, developed in-house using LabVIEW-RT software, is used for data acquisition and control/interlock. This 30 kW amplifier (Fig.A.9.2) was rigorously tested with a water-cooled load at its output. Its high power measurement results, including swept power characteristics, 1-dB bandwidth and power gain were satisfactory.

Reported by:
Akhilesh Jain (ajain@rrcat.gov.in) and M. R. Lad