A.2: Development of 15 kW Solid State RF Amplifiers for Indus-2 SRS

Indus-2 RF power system was designed and built using four 64 kW Klystron based RF stations, making up total installed capacity of 240 kW of RF power at 505.8 MHz. As the availability of the klystrons from foreign sources was uncertain due to export control conditions, the development of solid state high power amplifier was taken up to replace the Klystron . In this direction a 15 kW solid state RF amplifier was designed and integrated with RF station No.1. With the support of the Solid State RF amplifier, beam energy could be increased up to 2.2 GeV at 100 mA stored current. With the practical experience gained with the deployment of solid state amplifiers for Indus-2, work is in progress to replace all Klystron based RF amplifiers with solid state amplifiers.

In this amplifier, the 15 kW CW RF power was generated using scalable and modular combination of two 8 kW amplifier units operating at 505.8 MHz. 8 kW of RF power was obtained by paralleling 320 W amplifier modules, with the help of 16-way power combiner and 2-way combiners in two stages (Fig. A.2.1). In view of this work, necessary efforts were carried out for amplifier design studies, amplifier architecture selection, component selection and RF characterization. The 8 kW amplifier unit is housed in a standard euro cabinet and employs 32 numbers of 320 W RF amplifier modules , 2 power dividers, 2 power combiners and high power directional coupler. Based on the results of circuit simulation studies and engineering prototyping, RF transistor BLF 573 was selected to serve as solid state active device in amplifier module. Impedance matching and amplifier circuit in this module is based on transmission line transformer topology. Wilkinson circuit divider/combiner was used to get 320 W of RF power from two RF transistors. 350 W circulator was used to protect the RF devices from reflected power. The power reflected at third port of the circulator was monitored using suitable RF detector. Group of five such modules was mounted on a water cooled copper heat-sink. For power combining and power measurement, 16-way power combiners with 1-5/8" flange and two high power directional couplers were designed. Apart from this 8 kW 3-1/8" directional couplers used for power measurement were designed using square coaxial line for final power measurement.

All these components, developed indigenously, were tested and integrated with safety interlocks, FPGA based data acquisition system and water cooling circuit to make a complete 15 kW amplifier as shown in Fig. A.2.2.

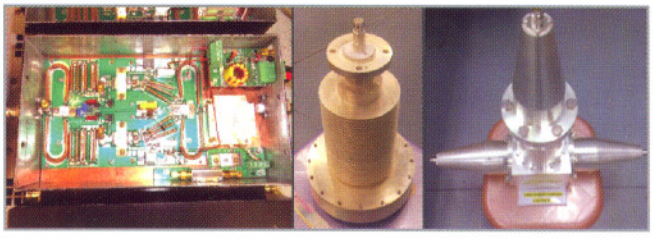

Fig. A.2.1: 320 W amplifier module with 16-way power combiner/divider and 2-way 20 kW combiner

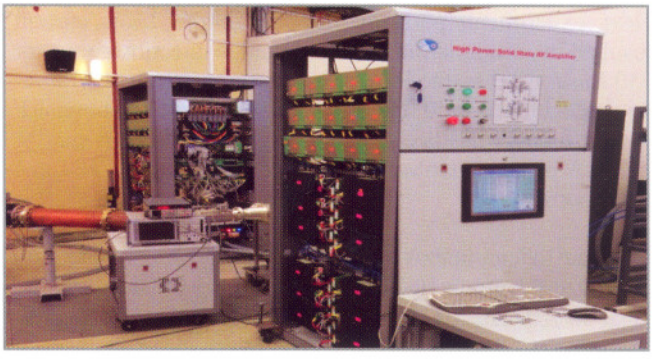

Fig. A.2.2: 15 kW amplifier installed in Indus-2

Measured RF power transfer characteristics and gain of the amplifier are shown in Fig. A.2.3. This characteristic is linear in common operation region (5 kW onwards). One dB compression point is beyond 15 kW. With more than 87 dB RF power gain (with driver amplifier), this amplifier was tested at full power and commissioned in Indus-2. Successful experimental verification of these amplifiers put confidence in proposed design methodology and 60-80 kW development. Such a new technology has reached a competitive price/performance ratio and expected lifetime in comparison with klystron and IOT amplifiers.

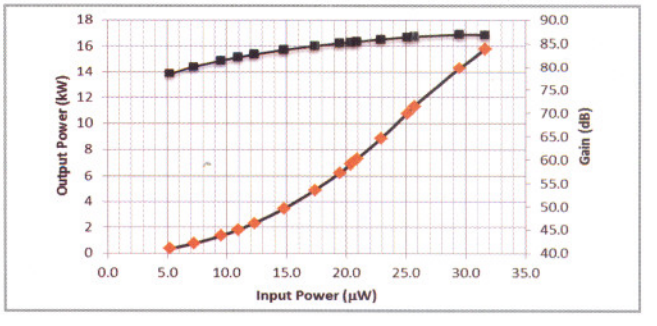

Fig. A.2.3: Measured performance of the 15 kW amplifier at 505.8 MHz

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