INHOUSE DEVELOPMENT OF WIDEBAND 10 KW SOLID STATE POWER AMPLIFIER FOR ICH & CD RF SOURCE

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1. ABSTRACT

ITER-India is developing Ion Cyclotron Heating & Current Drive (ICH&CD) 3 MW RF source in the frequency of 40 MHz to 55 MHz [1], [2]. Single RF source has identical 2 chain of 3 stage cascaded amplifiers, along with 3 MW hybrid combiner, low power RF components, AC/DC power supplies and interlocks perform MW level RF operation. Single chain configured with 10 kW Pre-driver amplifier, 120 kW Driver amplifier and 1.7 MW End stage amplifier using solid state technology which has certain advantages over tube-based amplifier at power level of ~ 10 kW. This development is aiming for achieving compact modular design, wideband application without tuning element, usage of low voltage power supplies and better MTBF value compared with tube-based amplifier of similar specification. Development of such Solid Stare Power Amplifier (SSPA) in the above frequency range is very challenging, due to unique design of combiner and matching circuit. In this development, 16 number of 1 kW amplifier modules are used. Multi stage amplitude and phase balanced power splitters & power combiners are used. Current monitoring circuit, interlock card, low power components and power detectors are developed inhouse to meet ICH operational specifications. Since 7 kW input power is needed from SSPA to get max power of RF source, the design goal for SSPA is to achieve power level of around 10kW.

2. DEVELOPMENTAL ACTIVITIES AND PROGRESS

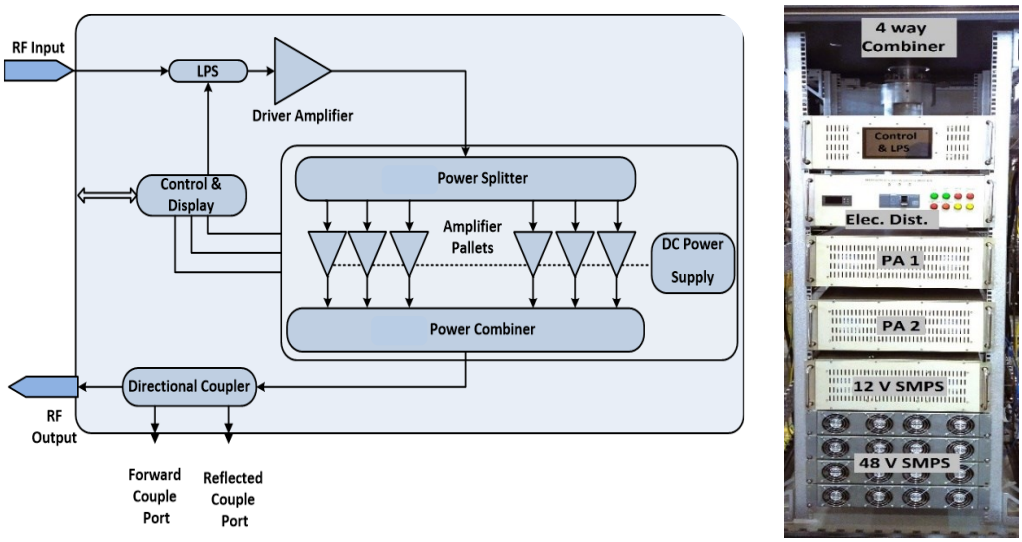
RF amplifier module is a key component of SSPA and the NXP make MRFX1K80H LDMOS RF transistor [3] is chosen based on technical compatibility for our application. This is highly rugged device with supporting frequency of 1.8 MHz to 400 MHz. It is qualified for 65 V Drain bias operation. We have characterised the device from 48 to 65 V drain bias range for individual amplifier module. Input matching circuit for RF transistor is designed to provide matching from unbalanced 50 Ohm input to balanced device input, using 9:1 coaxial transformer. Output matching is performed from balanced drain ports to unbalanced 50 Ohm output using two stages coaxial transformers for achieving wideband performance. Proper drain bias and gate bias filters are used in the amplifier circuit. Amplifier module was configured for class AB push pull operation. For thermally stable CW operation, water cooling is used.

Amplifier module testing was done successfully. Each module is able to deliver 1kW CW power in frequency range of 35 to 60 MHz band. Achieved ± 2 dB bandwidth for entire operating band. Such 16 identical modules are developed & integrated with power splitters and combiners as shown in Fig.1. It also contains DC power supply, Low Power System (LPS), driver amplifier, directional coupler, control and display modules.

LPS in Fig. 1 which includes RF switch, voltage variable attenuator, pre-driver amplifier and RF power detectors. These components are designed and developed as per ICH requirement. Each amplifier module requires to drive input with balanced phase and amplitude. Wilkinson type 16-way power splitter developed with coaxial cable. 3 stages of cascaded combiner are designed for 16-way combiner scheme [4]. 1st stage is lumped type (quantity 08 Nos), 2nd stage is coaxial type (Quantity 04 Nos) and 3rd stage is 4-way end stage combiner. Dual directional coupler is integrated at output side for forward and reflected power measurement. Each Power Amplifier (PA 1 and PA 2) enclosure shown in fig. 1(b) includes 08 Nos of 1 kW amplifier modules, 1 set of 8-way power splitter, 04 Nos of 1st stage lumped type combiners and 02 Nos of 2nd stage coaxial type combiner.

Amplifier system has an interlock and protection module for safe and reliable operation. Over current interlock is implemented for each 16 amplifier modules. Dedicated current detection modules are also developed for same purpose. Other protection like over VSWR, water flow error, over temperature, door open, AC phase fault, SMPS

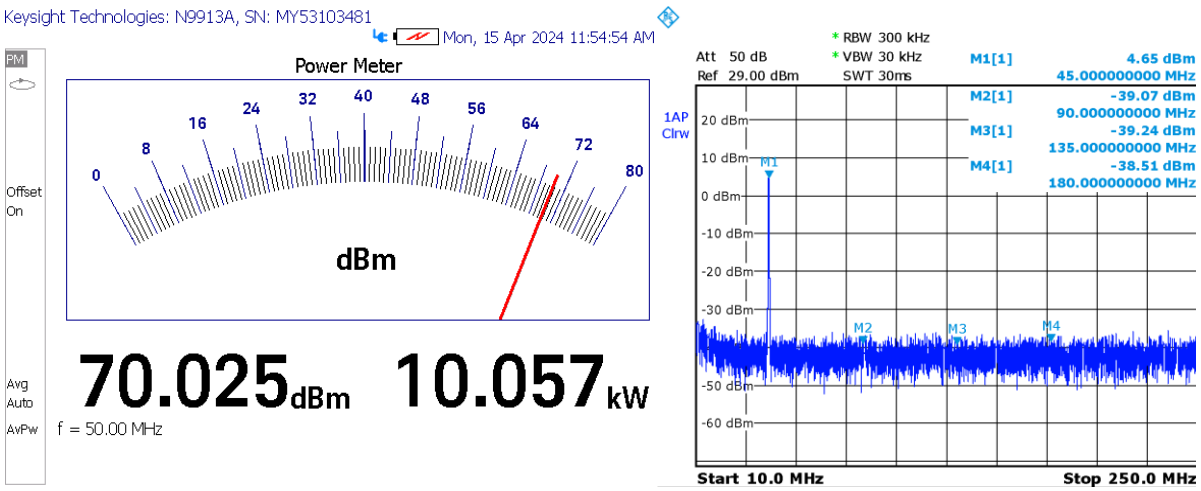
faults etc. are implemented in present SSPA. All system integrated and test performed. Fig. 2 shows RF forward power of 10 kW and spectrum at 45 MHz.



(a) *(b)*

Fig. 1. (a) 16 amplifier modules interface scheme and (b) actual image of 10kW SSPA at ICH lab

The class AB push-pull architecture used in the design of 1 kW amplifier modules is likely to accommodate larger levels of harmonic distortion. Stable RF operation requires minimizing harmonic distortion. The innovative design of power combiners allows for a significant reduction in harmonic level. Fig. 2(b) shows Harmonics and spurious level, which is better than 40 dBc at 45 MHz operation.



(a) *(b)*

Fig. 2 (a) RF power measurement and (b) Spectrum measurement

This paper includes detailed test results of standalone low power components, combiners, splitters, interlock cards etc. and high-power test of integrated SSPA.

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