# THERMAL MANAGEMENT STUDY ON INDIGINEOUSLY DEVELOPED HIGH POWER RF COMBINER FOR RF SOURCE OF ITER ION CYCLOTRON RESONANCE HEATING SYSTEM

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## 1. ABSTRACT

This work describes the development and qualification of a high-power Radio Frequency (RF) combiner for the ITER Ion Cyclotron Resonance Heating (ICRH) system. The RF source of ICRH has two parallel amplifier chains, combined at the end stage by the RF combiner, to deliver 3 MW output power in the 40 to 55 MHz frequency range. This RF combiner features a wideband fixed-type broadside coupled strip line design with dimensions of 2400mm x 950mm x 600mm. The outer conductor is a rectangular aluminum box with leakproof Viton O-rings, and the inner conductor strip lines are supported by PTFE components. The inner conductor strip lines are parallel throughout the coupling region but diverge near the ends to connect with the coaxial section via an inclined joint. A prototype RF combiner which is completely air cooled has been manufactured and design modifications were made after conducting high-power experiments in order to optimize the performance. Prototype's high-power test setup showed effective cooling in the second air cooling configuration, with thermal simulations indicating maximum surface temperatures of 53°C for the inner conductor and 27°C for the outer conductor. Details are presented in the poster.

## 2. SYNOPSIS

The Radio frequency (RF) source as shown in Figure 1, for ITER Ion Cyclotron Resonance Heating (ICRH) system including two parallel RF amplifier chains combined at the end stage by the RF combiner to deliver output power of 3 MW at VSWR 1.5 in frequency range of 40 to 55 MHz [1]. The end stage high power combiner has been developed indigenously and rigorous qualification tests have been performed on this RF combiner [1]. The measured combiner characteristics have been validated with simulation, performance in power combiner mode at low power (~ 5kW) and in splitter mode at high power (~ 1.5 MW) has been validated [2].

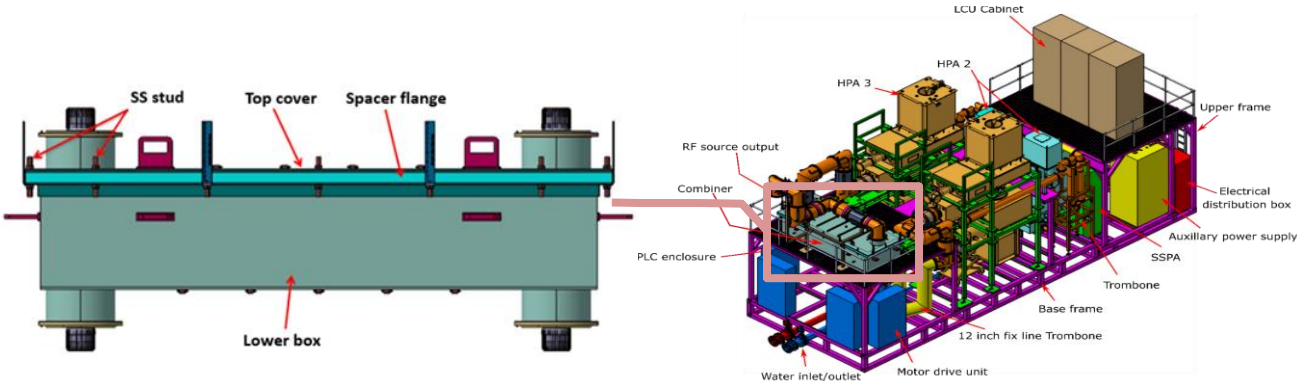
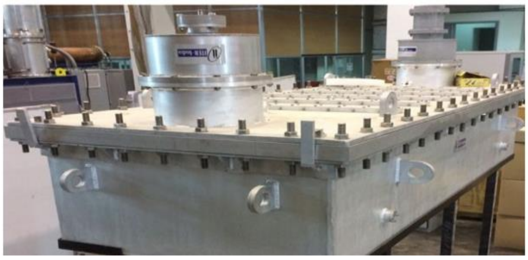



Figure 1: 3D view of RF source layout showing position of RF combiner

To meet these stringent requirements, the design of a wideband fixed-type broadside coupled strip line combiner was chosen. This combiner was developed by ITER-India as part of their high-power transmission line component development program, as illustrated in Figure 2. The combiner's overall dimensions are approximately 2400mm in length, 950mm in width, and 600mm in height. The outer conductor (OC) assembly comprises a rectangular aluminum box, split into two parts: the lower box and the top cover. These parts are bolted together with stainless steel (SS) studs, using an aluminum spacer flange in between. Viton O-rings are placed on both sides of the aluminum spacer to ensure the outer conductor assembly remains leakproof. The lower box and the top cover are electrically connected using multiple flexible Be Cu finger contacts. The main novelty of this design is that throughout the coupling region, the inner conductor (IC) strip lines are parallel, maintaining a uniform gap and near the ends, the IC strip lines diverge at a constant angle to connect with the coaxial IC section via an inclined joint. This novel configuration facilitates a smooth transition from the strip line to the coaxial transmission path. Another new aspect is design of PTFE supports. The PTFE supports are manufactured with holes designed in such a way that forced air flows throughout the combiner for efficient air cooling. PTFE supports are used to hold the inner conductor in place with respect to the outer conductors, while IC joints are employed at the coaxial section. The PTFE spacer block and PTFE locking block are connected to the PTFE main body using Delrin screws. Following the high-power experiment, the mechanical design is further upgraded, such as adding a bulge to the strip line end, which was also supported by PTFE supports (Fig. 2.). Additionally, the screws were changed from Delrin to Ultem to enhance strength.

The various cooling configurations were simulated and is depicted in Figure 3. In the first configuration, air entered through opposite ports 1 and 4. In the second configuration, air entered through ports 1 and 3. Initial thermal simulation of the model with the second cooling configuration indicated a maximum surface temperature of 53°C for the IC and 27°C for the OC whereas maximum surface temperature of 65°C for the IC and 34°C for the OC with the first configuration. The temperature was observed to be lower in the second configuration. This was primarily because, in the first configuration, the airflow from port 4 obstructed the airflow from port 1. In contrast, in the second configuration, the air entering from ports 1 and 3 mixed well and flowed towards the other end of the combiner, providing better cooling across the entire combiner length. All the technical details about the mechanical design and thermal management of RF combiner will be presented in the poster.



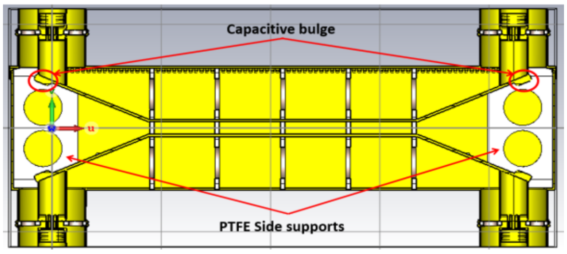
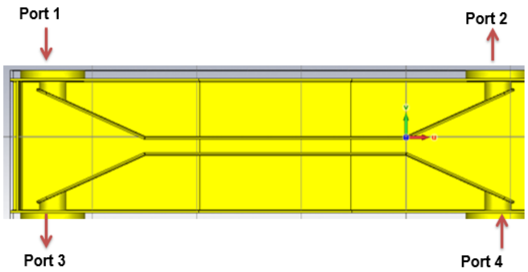
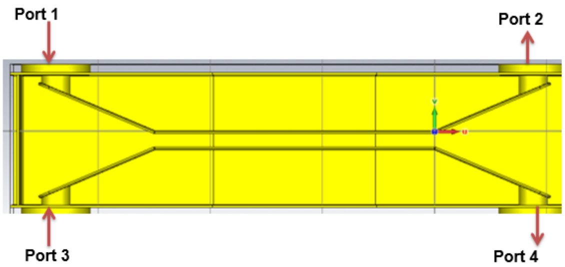



Figure 2: Developed RF combiner by ITER India




Figures 3 (a): Air Cooling configuration 1 3 (b): Air Cooling configuration 2

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Track Classification**:** Fusion Energy Technology

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