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Two-Strap Feeding Test of KSTAR ICRF Antenna

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1. Introduction

KSTAR ICRF (Ion Cyclotron Range of Frequency) system is being developed for the high-power and long-pulse operation. Through several RF test campaigns, the ICRF antenna was verified to be applicable to the high-voltage and long-pulse operation. In previous campaigns, the antenna was tested by applying RF power to only a half of one current strap. Because four current straps have a similar geometry with each other, we can estimate high-voltage and long-pulse performances of whole antenna by performing RF test for only one current strap. During the initial phase of the KSTAR operation, the ICRF system will be operated with only one RF source. A RF feeding configuration in which two straps of the antenna are fed by one source is a major candidate for initial operation scheme of the ICRF system. Therefore it is necessary to test the antenna with the similar configuration in the test stand. Major objectives of this test are to develop the operation skill of two-strap feeding and to study how the RF power is distributed to two straps.

2. Two-Strap Feeding System

A test stand for the test of two-strap feeding was designed and constructed at RF test facility in KAERI. Schematic diagram of the test stand is shown in Figure 1. The current strap-1 and the strap-4 are chosen to be tested because its mutual coupling is so low, and the enough space for the construction of the test stand is needed. The bottom half of each strap is connected to a long transmission line in which a standing wave is generated. RF power is fed to the each line through a 3 dB power divider which is connected to the RF source. Each test line consists of a current strap, a vacuum transmission line (VTL), a vacuum feedthrough (VF), a transmission line section, and short stub tuner which has a tee part for RF feeding. Two VFs for the current strap-1 were domestically fabricated, and that of the current strap-4 was provided by NIFS (National Institute for Fusion Science) as Korea-Japan fusion collaboration program, which is identical with the VF used in LHD (Large Helical Device) of NIFS. Each transmission line section from VF to stub tuner was pressurized with N_2 gas up to 3 kgf/cm^2 to increase standoff voltage. Several voltage probes were installed on each transmission line section to measure voltage profile along the line. Center conductors of the VF, transmission line section, and stub tuner have cooling channel inside themselves and they are connected in series. Cooling water is supplied from the end of the stub tuber and U-turned at the end of VF center conductor. Outer conductors of VFs and some parts of transmission line section on which a standing wave was gernerated were also water-cooled by attaching Al blocks which have a concave surface and a cooling channel. The 3 dB power divider has four ports; one input port connected to RF source, two output ports connected to the feeding lines for two current straps, and one isolated output connected to a dummy load. Two output ports have phase differences of 0° and 90° respectively. The operating frequency range of the power divider is 27-55 MHz, and the power rating is 50 kW CW. Several bi-directional couplers were installed at the input port of the power divider, input ports of two test lines, and mid point of top and bottom test lines connected to the current strap-1 in order to measure the forwarding and reflected powers on each line. The current strap-2 and 3 were shorted at the input ports. A 3-D drawing of the constructed test stand is shown in Figure 2.

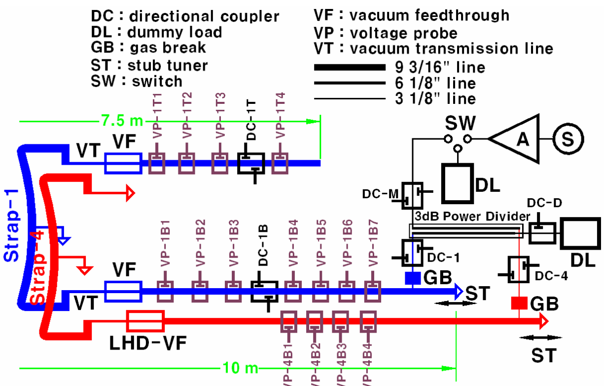

Figure 1. Schematic diagram of the two-strap feeding test circuit for the RF test campaign-9.

In order to make two test lines have the same matching condition, we had several tries to equalize the electrical lengths of two test lines. But it was extremely difficult to make two lengths be exactly same without changeable phase shifter. Finally a little difference remained. It means that there is no exact operating condition which satisfies two test lines to have a matching condition at same time for a given frequency. However through careful control of the stub tuners, we found out an optimum condition with which input port of the power divider has matching impedance. The measured input impedance is shown in Figure 3. The input port of the test circuit was well matched at a frequency of 29.794 MHz. The transmission coefficient from the input port to the dummy load was also measured to be as low as -12 dB at 29.794 MHz, which means that only 6% of input power is transferred to the dummy load.

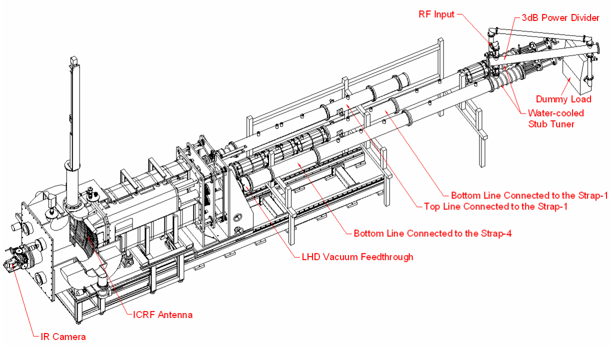

Figure 2. 3-D drawing of the test stand for RF test campaign-9

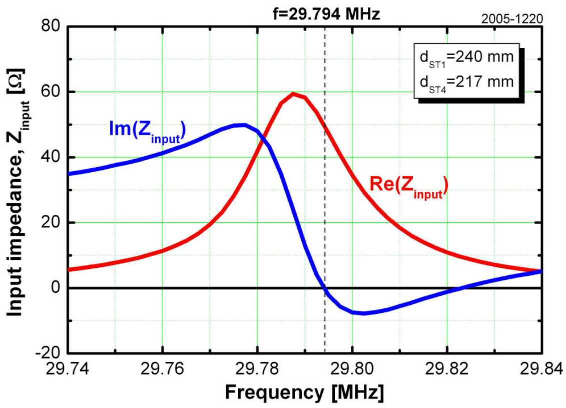

Figure 3. Measured input impedance of the test circuit.

3. RF Test of Two-Strap Feeding System

During the RF test campaign-9, several RF tests were performed at a fixed frequency of 29.794 MHz. When RF power was applied to the test circuit, voltage profiles along the transmission lines, forward and reflected powers at each input port, RFTC pressure, and antenna temperature were measured. For the conditioning of the antenna and the VTL, the power level was gradually increased shot by shot. After the conditioning, the main test pulse was applied to the antenna. As a test result, the time evolutions of the forward and reflected powers, the maximum peak voltage, the maximum temperature of the antenna, and the vacuum pressure of the test camber for 300-s pulse are shown in Figure 4. RF power was not equally distributed to the strap-1 and 2, which was caused by different matching condition of two test lines as described before. The maximum voltages along the strap-1 line and strap-4 line were 12.87 and 22.30 kVp respectively, which are equivalent to heating powers of 0.72 and 2.16 MW in the case of plasma loading of 6 Ω/m. The temperature on the left cavity wall near the strap-1 increased up to 73.8 °C, which was higher than that of right wall near the strap-4. The vacuum pressure of the RFTC was maintained at lower than 3.6×10^{-7} mbar. The limitation of a higher voltage testing was mainly caused by overheating of some non-cooled components such as the LHD vacuum feedthrough, outer conductor of the test line connected to the strap-4.

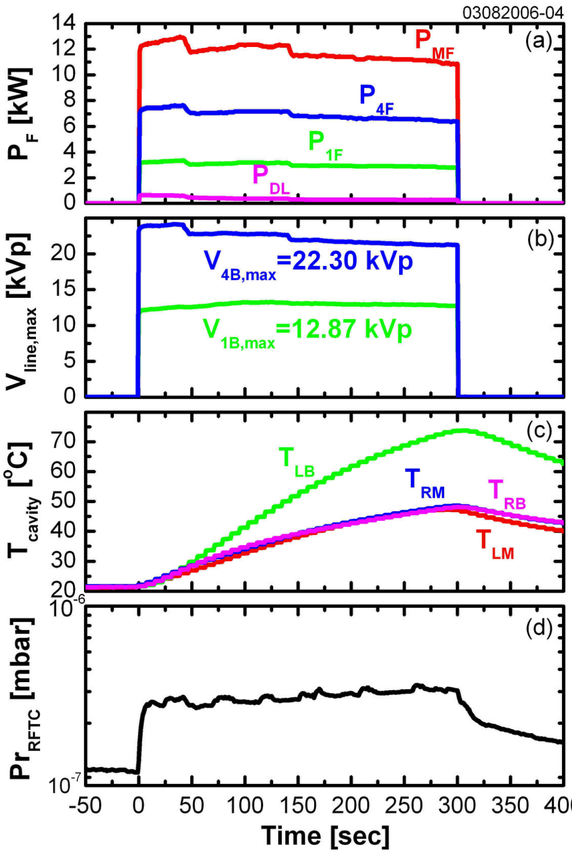

Figure 4. Time evolutions of the RF powers (a), line voltages (b), temperatures of the antenna cavity (c), and vacuum pressure of the RFTC (d) measured during 300-s long-pulse duration.

4. Conclusion

Preliminary RF tests were performed with the two-strap feeding configuration. The test result show the maximum voltages of 12.87 and 22.30 kVp for the strap-1 line and strap-4 line respectively. As future works, similar RF test will be going on at a higher RF voltage.