The Balanced RF Feeding of Resonant Loops for the KSTAR ICRF

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1. Introduction

An ICRF system for the KSTAR [1,2] tokamak is planned for the next campaign to deliver nominally 2 MW of RF power to the plasma to heat the ions through minority fundamental or second harmonic ion cyclotron resonance heating. [3] The maximum RF power deliverable to the plasma is limited by the maximum RF voltages on the transmission line or antenna system. The higher RF voltage or current than the limited values may destroy the transmission lines, tuners or antenna by arcing or burning. The convenient method to reduce the RF voltage with the same power is dividing the power to the many branches. It is one of the reasons of installing four current straps within an KSTAR ICRF antenna as shown in Fig. 1. To archive this goal, eight power branches connecting to each upper and bottom current straps were designed and among them, four branches of two resonant loops were installed.

Balanced power dividing in the ion cyclotron frequency range can be archived by using hybrid divider if the phase difference between the outputs of the divider is +/-90 degrees. For the ion heating schemes, these phase differences should be avoided because the antenna currents having these phase relation could heat the electrons through resonant heating. Therefore, the ICRF circuit for the early experiment of the KSTAR has been prepared by using simple Tee. Using simple Tee cannot guarantee balanced power dividing to the outputs of unequal impedances.

This presentation will give the analysis of the unbalanced voltages measured during the last campaign and the technical methods to archive balanced voltages for high power feeding.

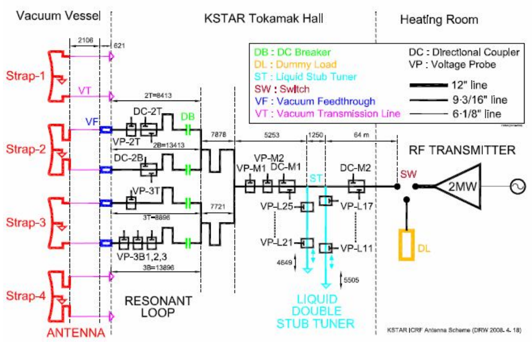

Fig. 1. ICRF circuit having two resonant loops connected by simple Tee.

2. Circuit Analysis

The frequency of the last campaign was chosen to have good matching condition for ICRF discharge cleaning regardless of heating efficiency. But the voltage amplitude ratio between second and third resonant loops was severely deviated from unity. Fig. 2 shows the results of the idealized calculation of the current amplitude ratio and phase difference at the operating frequency range. Because the exact length of the transmission line cannot be applied to the calculation, the abscissa is not accurate. The trend of the curves gives that the initial configuration has intrinsic problem for archiving balanced feeding. This imbalance was caused by the unequal impedances of each resonant loop due to the unequal transmission line length inserted between tee and input ports of the resonant loops.

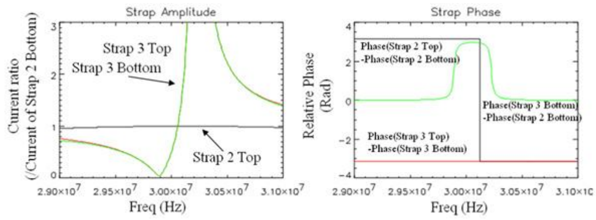

Fig. 2. Poor amplitude ratio and phase difference between four current straps.

We measured the impedances of each resonant loop separately and found the impedances agree well with the calculated expectation except a few resonant peaks which can be explained by the stray resonances at the antenna. But the connected impedance is not matched with the expectation. These results imply that there should be other couplings except connecting Tee because the calculated model does contain any coupling between branches except connecting Tees.

One evident cross talk between loops is coupling at the antenna straps. The couplings between each strap were significantly reduced by installing septum plates between each strap. The geometry of septum plate was experimentally optimized to minimize the couplings. Despite these efforts, a measured amplitude of coupling between second and third straps is almost 0.2. But this coupling was ignored because the coupling would not affect the circuit of the same phase operation. We need to include this coupling into the calculation because the circuit seems not identical with the idealized transmission line circuit.

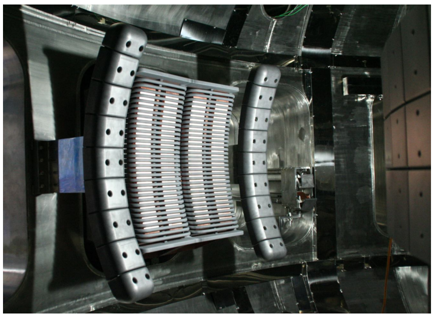

Fig. 3. Face of the antenna installed at the KSTAR port.

The amplitude of coupling between second and third loops are almost 0.2.

3. Summary

The ICRF circuit was analyzed to find the reason of power feeding imbalance between resonant loops. The length difference between resonant loops and connecting Tee is the main reason of this imbalance. Furthermore, cross talk at the antenna strap cannot be ignored in our circuit. Technical method to decouple the cross talk is needed to have high deliverable power with limited maximum voltage on the RF components.

REFERENCES

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