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TWO FREQUENCY ICRF OPERATION ON TFTR

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ABSTRACT

Modifications have been made recently to allow two of the ICRF antennas (bays L and M) on TFTR to operate at either of two frequencies, 43 MHz or 64 MHz. This was accomplished by lengthening the resonant loops (2λ at 43 MHz, 3λ at 64 MHz) and replacing the conventional quarter wave impedance transformers with a tapered impedance design. The other two antennas (bays K and N) will operate at a fixed frequency, 43 MHz. The two frequency operation will allow a combination of ^{3}He-minority and H-minority heating at near full field on TFTR. The higher frequency, 64 MHz, may also be useful in direct electron heating and current drive experiments at lower toroidal fields. Models of the antenna, resonant loops and impedance matching system are presented.

INTRODUCTION

The motivation for two frequency ICRF operation on TFTR are the potential benefits from both an operational and a physics perspective. Previous experience has shown that significant reflected power signals are difficult to avoid during injection of ICRF power into low absorption plasmas, such as experienced during direct electron heating or current drive experiments. The reflected signal is modulated in time, presumably due to toroidal eigenmodes. This is a significant operational difficulty because the RF transmitters can be damaged by the large reflected signals. On TFTR, a large component of this signal is comprised of cross talk from other antennas. By having the impedence matching elements of an antennas set for one frequency any received signal at another frequency will be reflected at the mismatch at the resonant loop (in the case of bay K or N) or at the impedence matching elements, thus protecting the transmitter.

The combination of frequencies chosen will provide an oppertunity for a number of interesting experiments. For maximum toroidal magnetic field, 43MHz can be used for on axis He^3 minority heating (or tritium second harmonic heating), and 64MHz can be used for on axis H minority heating (and deuterium second harmonic heating). Splitting up a given injected power between different ion species, the heated ions will have lower energy, enhancing the confinement, and during the upcoming D-T operations on TFTR, will give an additional control with which to optimize the nuclear reaction rate. Also, the two frequency capability may have a significant impact on direct electron heating and current drive experiments. The coupling to the electrons has a strong temperature dependance. One frequency can be used for H minority heating (which couples energy to the electrons well) to heat the electrons, while the other frequency directly heats the electrons.

RF DESIGN

The modifications which will allow two frequency operation are simple. First, the resonant loops which feed the antenna were lengthened so that they are two wavelengths long at 43 MHz and three wavelengths long at 64 MHz (see fig. 1). Second, instead of using quarter wave transformers to bring the input impedance closer to 50Ω, a tapered transformer design was used. Only bays M and L are fed on each strap by FMIT transmitters which are tunable from 40-80 MHz. Thus, bays K and N are configured as before to operate at a single frequency, 43 MHz.

A broadband impedance transformer was designed which is optimized for the two operating frequencies.[1] The input impedance of the resonant loop is ~ 3kΩ for vacuum conditioning and ~ 240Ω for plasma operation. The transformer is optimized for coupling to a 240Ω load. The transformer is composed of two sections of length $\lambda/4$ at 53.5 MHz. The first section has impedance 74.5Ω, the second 149.1Ω. Ideally, the 149.1Ω section would be attatched directly to the resonant loop, however this proved difficult due to physical constraints, so a 6.98 m long (λ at 43 MHz, ~ 1.5λ at 64 MHz), 50Ω line connects the loop to the high impedance side of the transformer.

In order to aid modeling of the RF design, a lumped element model of the antenna was developed (figure 2). The model incorporates a three component transmission line approximation for the vacuum feedthrough.[2] The current strap is approximated as a transmission line along the distance which it runs along the antenna box wall (seperation is 11mm). The radiating part of the current strap is modeled by two transformers (coupling the two adjacent straps) with resistors tied to an inductive ground in the center. In addition, stray capacitance to ground is represented by a single capacitor for each strap at the end of the radiating element. The S-parameters of the actual antenna were measured, and the component values of the model were determined by optimizing the match between the model S-parameters and the measured S-parameters. When the appropriate length resonant loop is included in the model to give a resonant frequency of 43MHz, the second resonant frequency, 63.85 MHz agrees with that measured on bay L.

The PSpice circuit simulation software was used estimate the input imedance of the resonant loops with 0-π phasing, including the 6.98m length of 50Ω transmission line and tapered transition. The VSWR of this system is shown in figure 3 as a function of resistance, R. Note that this resistance is not the same as the integrated radiation resistance, since the later is distributed over a finite length, however the two are proportional.

REFERENCES

[1]G. Matthaei, L. Young, and E. M. T. Jones, Microwave Filters, Impedance Matching Networks, and Coupling Structures, (Artech House Books, Dedham, 1980).
[2]G. Greene, RF conference

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