Development of Impedance Matching, Phase, and Amplitude Control Technologies for ICRF Antenna Arrays*

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All of the large tokamaks in the world now are equipped with multi-MW ICRF heating and current drive systems, and in each installation the antennas used to couple the rf power to the plasma are deployed as phased arrays of two or four elements. The spectrum of waves excited in the plasma (and thereby the input impedance of the antennas) is strongly influenced by the relative phasing and amplitude of the antenna currents, and even more so by the parameters of the plasma adjacent to the antenna arrays. While these edge plasma parameters are generally strongly time-dependent on timescales as rapid as 10^{-4} s, the rf generators used are capable of producing full power only into a stationary load impedance. Hence, to maximize the power coupled to the plasma with a given rf source, various technologies have been developed to present an approximately fixed load impedance to the rf source and to control the spectrum of the coupled waves despite rapidly changing edge plasma conditions. In this paper, world-wide developments in this field over the past decade are reviewed. These techniques may be divided into several classes. First, the edge plasma parameters themselves may be controlled to maintain a fixed antenna loading, with an accompanying undesirable loss in experimental flexibility. The parameters of the rf source (frequency, relative phasing) can be feedback controlled to compensate for changes in the edge plasma conditions, or fast variable tuning elements in the transmission line between the generator output and the antenna input connections can provide the necessary time-varying impedance transformation. In lossy passive schemes, which require the application of a hybrid junction or a non-reciprocal circuit element (such as a circulator), reflected power due to the time-varying impedance of the antennas is diverted to a dummy load. Each of these techniques can be applied to a pre-existing antenna system. If, however, a new antenna is to be designed, recent advances ("combline antenna") allow the antenna array to have the intrinsic property of presenting a constant load to the feeding transmission lines despite the varying load seen by each antenna in the array. The transmission line system can therefore be quite simple. Examples of each of these technologies will be discussed in this paper.

*Work supported by U.S. Department of Energy under Contract No. DE-AC03-89ER51114.