ICRF ANTENNA DESIGN FOR THE HL-3 TOKAMAK

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A 6MW ICRF system is currently under construction for the HL-3 tokamak (previously known as HL-2M) at SWIP, aiming at providing central ion heating and producing energetic particles whose energy is equivalent to the fusion products. Two 2-strap antennas operating at a pulse length of 5s are designed under a frequency range of 25-50MHz and $k_{//}$~$7m^{-1}$. The goal is to couple 2MW power for each antenna. In a Deuterium (D) plasma, the 2^{nd} harmonic D heating and fundamental resonant frequency of Hydrogen are 33MHz under B_0=2.2T, while in Deuterium-Tritium (D-T) plasmas, the 2^{nd} harmonic T heating and fundamental resonant frequency of Helium-3 are 25MHz under B_0=2.5T. These are two main frequencies that will be used [1]. The size of the antenna is 1.4m poloidally and 1.2m toroidally. Because of the limit of the port size, it can only be installed inside the vacuum vessel. The radial space to allocate an antenna is constrained by the large plasma size needed for the high current operation in the front and the existed resonant magnetic perturbation coils at the back, only 9cm at the middle plane and 15cm at the poloidal position of Z=700mm. Several types of antenna configurations are considered, which have different feeder connections and ground positions, as shown in Figure 1. Their corresponding electrical circuit models are also shown in Figure 1, where L_A is the electrical length of the strap, λ_0 the vacuum wave length, Z_L the antenna load impedance, Z_0 the character impedance of the antenna, Z_T the character impedance of the transmission line, V_{max} the maximum voltage at the transmission line, P_{in} the input RF power and Z_{in} the antenna input impedance. A quick analysis based on the electrical circuit model suggests that compared to the antenna configurations with 2 feeder lines, either with central grounded or end grounded, the antenna fed by four feeder lines with end grounded has the minimum V_{max} at the feeder, as shown in Figure 2.

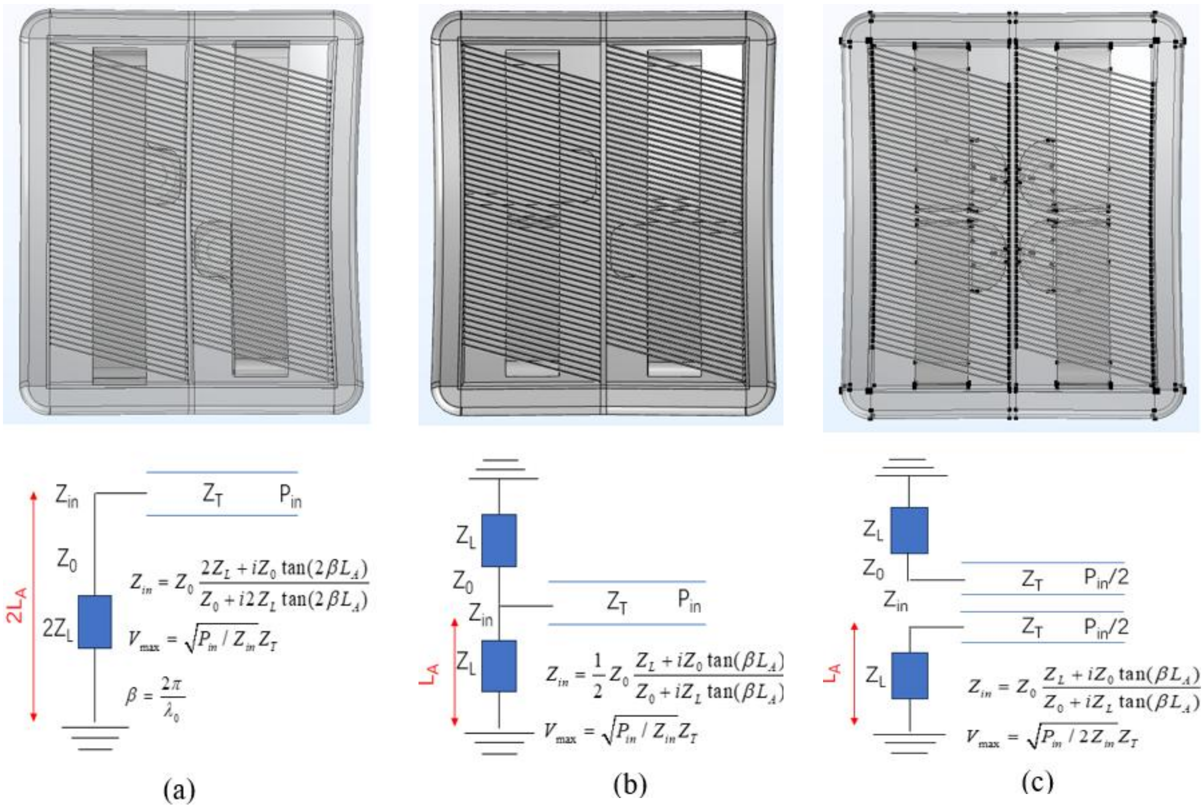

Figure 1. Three types of antenna configurations and their corresponding electrical circuit models. (a) Double feeder lines, each strap forms a single loop, grounded at two poloidal ends; (b) Double feeder lines, each strap

forms double loops, grounded at center; (c) Four feeder lines, each strap forms double loops, grounded at two poloidal ends.

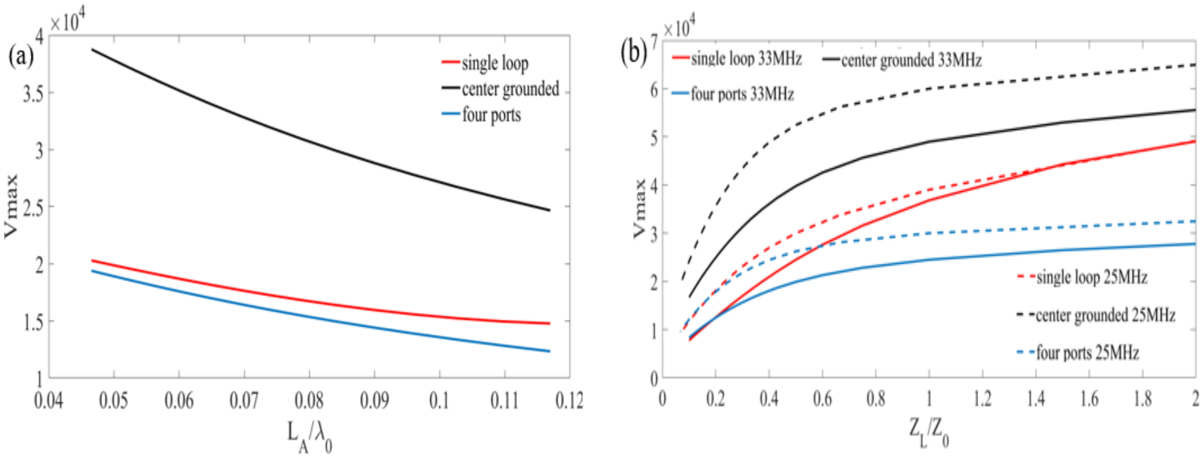

Figure 2. Comparison of V_{max} among three antenna configurations. (a) V_{max} VS the normalized electrical length; (b) V_{max} VS the normalized antenna load impedance.

The antenna configuration (c) in Figure 1 is thus chosen. In order to constrain the antenna within the permitted radial space, i.e., 9cm at the middle plane and 15cm at poloidal extremities, the detour structure of the strap near the feeder has to be removed which further reduces the strap length and decreases the capacitance of the strap. To further optimize the antenna geometry, i.e., to get larger coupling resistance, lower the feeder voltage and more symmetric S parameters between the two straps under a realistic HL-3 density profile, a 3D full wave model is developed based on the COMSOL software. It further integrates the 3D realistic antenna with the transmission lines so as to determine the positions to put dual vacuum windows, after a 50ohm to 25ohm impedance transformer which can provide smooth transition from 9-inch to 6-inch transmission line before the feeder lines entering into the vacuum vessel. The rectified DC plasma potential is also calculated by implementing the RF sheath boundary conditions at the antenna surface [2], although the impurity sputtering is not expected to be serious under a carbon wall and short pulse operation.

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