Numerical simulations for ICRF wave fields in a linear plasma device


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Linear plasma device

No plasma yet! Only vacuum.

Example of magnetic field distribution (logarithmic scale)
ICRH

ASDEX Upgrade tokamak at Max Planck Institute of Plasma Physics

ICRH – Ion Cyclotron Resonance Heating

ICRH – Ion Cyclotron Range of Frequency (30-120 MHz)
Ion cyclotron Sheath Test ARrangement

RF Sheath
Wave propagation
ICRF power – edge interaction

Typical measured parameters:

- Density: $10^{16}-10^{18}$ m$^{-3}$
- Electron temperature: 1-10 eV
- RF B-fields power: 100 mW
Motivation

Tasks addressed:

- power losses through the use of a perfectly matched layer (PML)
- disturbance caused by a metallic probe presence
- probe calibration
- fields distribution in realistic IShTAR geometry
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Power losses

Main components of IShTAR:

- vacuum chamber
- ICRF antenna
- coaxial transmission line
- quartz windows causing power losses

Simplified geometry (sizes in m) with realistic characteristic dimensions:
E-field distribution **without** PML (log scale)

E-field distribution **with** PML (log scale)

Power flow through the PML edge surface, time average, x-component \((f_0 = 5 \text{ MHz})\):

- **without** PML: \(2.6 \times 10^{-13} \text{ W}\)
- **with** PML: \(3 \times 10^{-3} \text{ W}\)
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Fields disturbance by probe

2 m

22 mm

35 mm

22 mm
Fields disturbance by probe

M. Usoltceva
COMSOL Conference Munich 12-14 October 2016
Fields disturbance by probe

Distance of disturbance:
5 cm for electric field and
3 cm for magnetic field
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Probe calibration

2 m

22 mm
Probe calibration

Magnetic field, z-component

- Radial profile from simulation
- Analytical radial profile
- Volume average far from probe
- Inductor volume average

\[ H(r) = \frac{U}{2\pi r R} \]
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Main chamber with ports

Quartz tube with helicon antenna

IShTAR model
ISHTAR model
H-field in IShTAR model

Log of the H norm (in A/m)
Fields profiles along manipulator

Input power: 1 W from the ICRF antenna and 1 V from the helicon antenna (50 Ω impedance)
COMSOL simulations provide necessary support for RF sheath studies on IShTAR and complement experimental results from diagnostics.

Several tasks are completed in an attempt to approach the realistic IShTAR conditions.

Modeling results are ahead of the experiments at the moment.

Future steps:

• Experimental data processing by using results from simulations.
• New antenna geometry implementation.
• Simulations in plasma instead of vacuum.
Middle coaxial cable 2 performs impedance matching for cables 1 and 3.

**Conditions:**
- \( l_{in2} = \frac{c}{4f_0} \)
- \( \frac{Z_1}{Z_2} = \frac{Z_2}{Z_3} \)

**Parameters:**
- \( f_0 = 200 \text{ MHz} \rightarrow l_{in2} = 0.38 \text{ m} \)
- \( Z_1 = 50 \Omega, \ Z_3 = 25 \Omega \)
- \( r_{in2} = \text{range}(r_{out} \times 0.025, r_{out}/40, r_{out} \times 0.975) \)
- \( Z_2 = \text{range}(221.18 \Omega, 1.518 \Omega) \)

\( S_{11} \) should reach minimum at \( Z_2 = 35.3 \Omega \), i.e. \( r_{in2} = 0.128 \text{ m} \)
Impedance matching to vacuum

freq(11)=3E8  Multislice: log(emw.normE)
ICRH

Ion Cyclotron Resonance Heating (30-120 MHz)

Hot spots on antenna structures:

- Increased impurity concentration in plasma
- Power losses, reduced heating
- Can damage the antenna

IR image - front face of the Tore Supra ICRH antenna
[J. Jacquot et al, PoP 21, 061509 (2014)]