

SELFCONSISTENT DETERMINATION OF CURRENTS ON ICRH ANTENNAE TAKING INTO ACCOUNT MAGNETIC SHIELDING

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1. The Slab Coupling Model and Implementation of the ICANT code

The ICANT code allows to compute self-consistently the currents on different parts of the central conductor and screen of ICRH antennae in vacuum [1] and in the presence of plasma [2]. The ICANT code solves the antenna radiation problem using a finite boundary element technique combined with a spectral solution of the interior problem [1-3]. The slab approximation is used and periodicity in y and z directions is introduced to account for toroidal geometry. The boundary conditions between the plasma and the vacuum can be easily related [1-2] to the spectral surface impedance matrix ξ . The Fourier components of the fields at $x=-v$ are related by the expression $(E_y, E_z) = \omega \xi \cdot (B_z, B_y)$. For simplicity, we assume that the plasma is modelled by a density step with a surface impedance matrix resulting from the magnetosonic wave dispersion relation $k_{\perp}^2 = u(1 - \mu^2)$, $u = \varepsilon_1 - n_z^2$, $\mu = \varepsilon_2/u$ where ε_1 and ε_2 are the xx and xy components of the dielectric tensor. It is also possible to treat the case of an inhomogeneous plasma with different profiles but, in this case, the computation of the impedance matrix ξ for each (k_y, k_z) is time consuming. A proper choice of the finite element representation of the current $\mathbf{J} = \sum c_i \mathbf{T}_i$ is important. To avoid numerical instability due to residual space charges, we choose rooftops in the y direction and step function in the z direction (see Fig. 1). For any given excitation condition (the *active* elements), the current profile is built self consistently by imposing the vanishing of the tangential electric field on the antenna surface (the *passive* elements) as the conditions

$$\int_{-v}^d \mathbf{E} \cdot \mathbf{T}_i dx = 0 \quad (1)$$

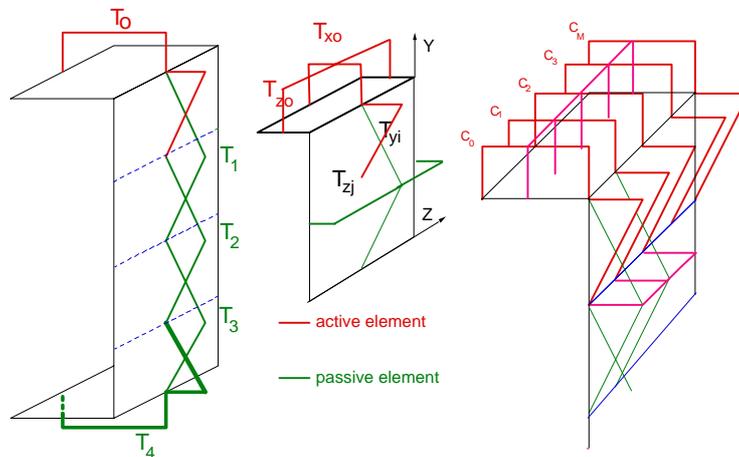


Fig. 1. Some finite element representations of the current.

From the set of c_j which determines the current on the antenna we can obtain the parameters which characterise the antenna (radiated power, impedance, electric field components, ...).

An interesting point of the selfconsistent calculation is that the unrealistic features found when using the idealised infinite screen model are removed by the consideration of discrete screen blades. It was found that both when the screen is between the central conductor and the plasma and when it is located between the central conductor and the back wall, the self-consistent β values agree well with the classical formulae in the plane capacitor limit [3].

2. Magnetic shielding effects: hollow profiles and current loops

Due to the current selfconsistency, magnetic shielding occurs automatically provided a bidimensional variation of the currents is allowed. The magnetic shielding modifies the current distribution in two ways: hollow transverse current profiles on the antenna strap (see Fig. 2) and current loop formation on the screen blades (see Fig. 3).

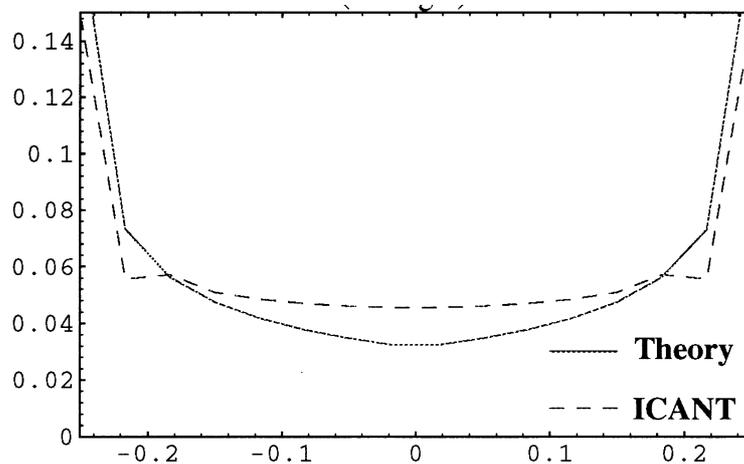


Fig. 2. Comparison between the theoretical and computed current density $J_y(z)$ on the strap.

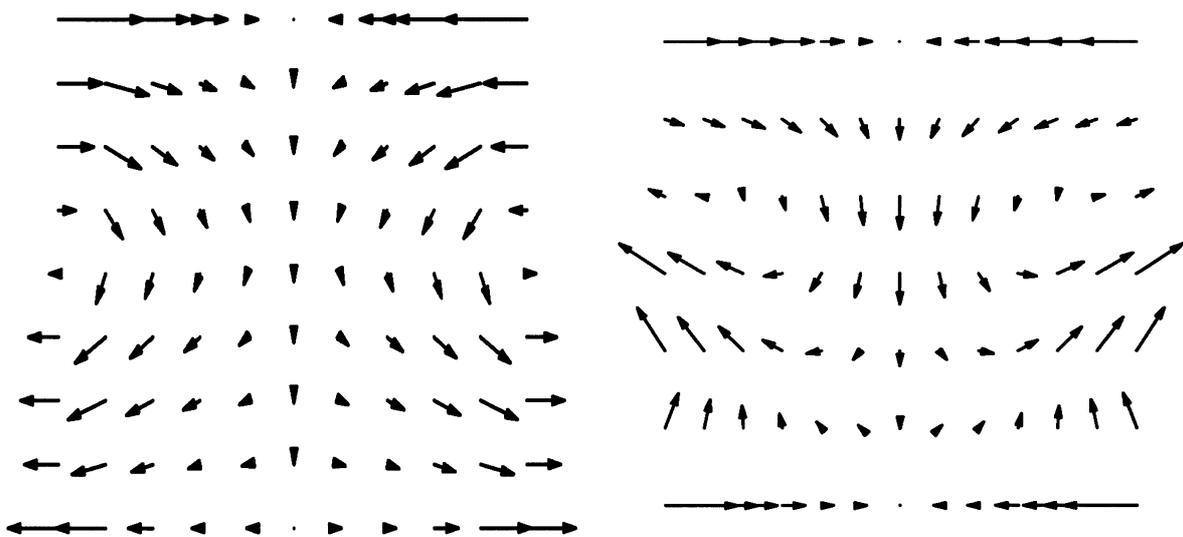


Fig. 3. a) The magnetic shielding effects on a single large screen blade for $k_0 = 0,2 \text{ m}^{-1}$

b) The magnetic shielding effects on a single large screen blade for $k_0 = 0,875 \text{ m}^{-1}$

Conversely, the occurrence of hollow transverse current profiles on a single strap (no screen) when the antenna is moved away from the wall has been found in agreement with the transmission line theory [4].

Preliminary results on these two effects have been obtained for an antenna in vacuum. Current loops on a single large screen blade have been observed (see Fig. 3) [5], or a flat transverse profile of the current flowing on the strap.

3. Influence of the antenna-plasma distance

When the antenna-plasma or the wall-strap distances (v or d) are varied, the radiated power has different behaviours according to whether these distances are large or not. For large v and small d the results are qualitatively similar to those obtained with no magnetic shielding. Once the plasma comes close to the antenna, or the strap is moved away from the wall, the propagation constant β and the radiated power have large variations. The reason is probably the influence of coaxial modes due to the conjunction of the current loop formation on the screen and the surface impedance matrix that we use: only the fast wave is allowed, which is equivalent to having an ideal Faraday screen at the boundary. The presence of spurious coaxial modes is seen on the spectral power as two highly localized peaks in k_y , k_z . Therefore, as long as the total surface impedance matrix is not used, the evolution of the radiated power with the distance is best understood if only one-dimensional (j_z) currents are allowed on the screen blades, with a small strap-wall distance.

Figure 4 shows the evolution of the radiated power versus the antenna-plasma distance for different frequencies. The strap is 1 m long and 0.16 m wide, the wall-strap distance is 0.36 m and the screen-strap distance is 0.05 m. As expected, the power increases as the plasma comes closer to the antenna. When the frequency grows, magnetic shielding effects slightly reduce the power. As mentioned above, at small antenna-plasma distance and high frequency, the occurrence of coaxial modes causes a significant increase of the power.

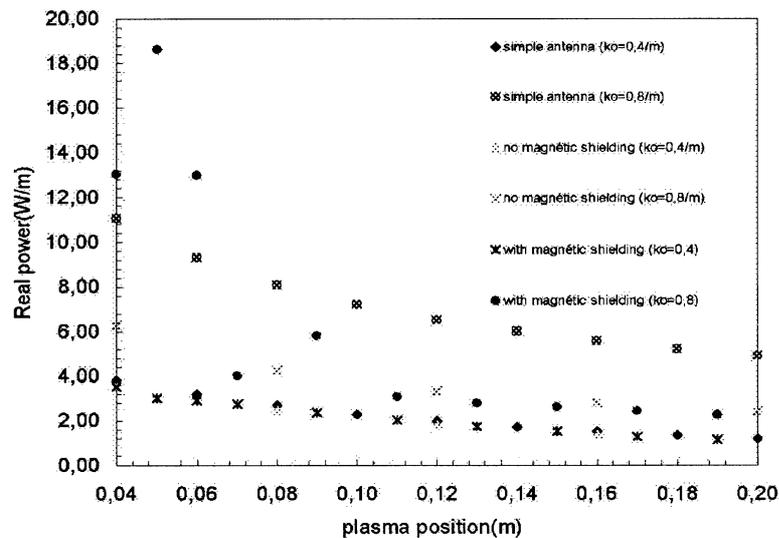


Fig. 4. Radiated power as a function of the antenna- plasma distance for different frequencies.

The propagation constant β is also significantly changed by the magnetic shielding; depending on the frequency and the antenna-plasma distance, the change can amount to 20%.

4. Influence of the plasma density

Figure 5 shows the radiated power as a function of the plasma density, for a homogeneous plasma model. The antenna parameters are as above, but for the wall-strap distance which is set to 0.06 m in order to minimize the effect of coaxial modes. The magnetic shielding reduces generally the radiated power. The reduction increases with the frequency.

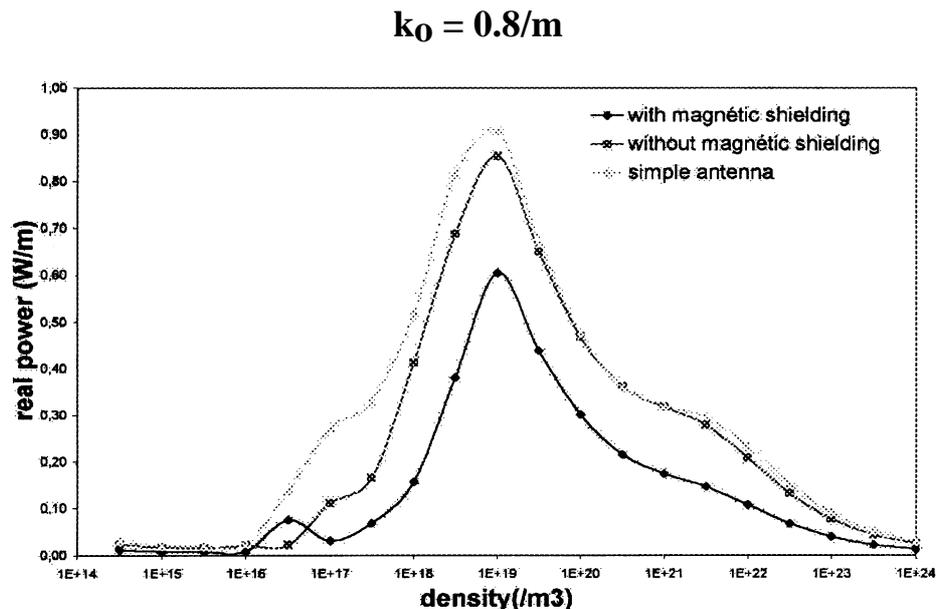


Fig. 5. Radiated power as a function of the plasma density.

5. Conclusions

Magnetic shielding effects (bi-directional currents on the strap or the screen) can lead to significant modifications of the selfconsistent propagation constant. Similarly, the radiated power is found to be less than in the case with no magnetic shielding, especially at high frequency. When a simplified surface impedance matrix is used, these effects allow anew the occurrence of coaxial modes, which have a strong influence at large wall-strap distances and/or small antenna-plasma distances.

References

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