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Self-consistent computations of currents on ICRH antennas with the ICANT code

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1. Antenna Modelling and Implementation of the ICANT code.

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 code has been tested by computing the current distribution on the central conductor and screen of simplified ICRH antennas in different cases: in vacuum [1] and in the presence of plasma [2], without or with magnetic shielding effects [3-5]. The unrealistic features (spurious modes such as screen modes), found when using the idealised infinite screen model, are removed by the consideration of a more realistic array of finite blade elements to describe the screen. The Q1 antenna used in the Tore Supra tokamak has shown hot spots [6] and to better understand their origin, it is necessary to know the electric field structure in front of it. To achieve this goal, specific current elements have been constructed which either describe the tilted screen blades or allow to model a tuned antenna [7]. In the following, the computation parameters correspond to the Q1 antenna of the Tore Supra tokamak (R_o= 2.3 m, a= 0.74 m, B_t= 3 T, n_e= 10^{19} m^{-3}, l_y =0.7 m, l_z= 0.23 m and ν= 48 MHz).

2. Magnetic shielding effects on realistic antennas.

Due to the current self-consistency, magnetic shielding effects occur and modify the current distribution in two ways as compared to the idealised case where the current on conductors is assumed to flow only in one direction. (i) The transverse (⊥ to current flow) current profiles on the antenna strap are hollow rather than flat and (ii) Current loops appear on the screen blades. Flat and hollow profiles on the strap give nearly the same radiated power. In the case of wide screen blades (same width =0.10 m as the central conductor), the magnetic shielding reduces the radiated power. This reduction increases with the wave frequency. It is of the order of 20% for k_o= 0.8 m^{-1}. Without magnetic shielding, a reduction of the blade widths keeping the screen opacity unchanged leaves the radiated power nearly unchanged. On the contrary, with magnetic shielding, the narrowing of the blades causes a significant increase in radiated power. This fact can be explained by a reduction of the magnetic shielding effects, due to a reduction of the space available to the current distribution on the screen blades. It is noticeable that taking magnetic shielding into account can cause an increased excitation of the coaxial modes or screen modes. In this case, the structure of the electric field exhibits a large x-component electric field as shown on figure 1.

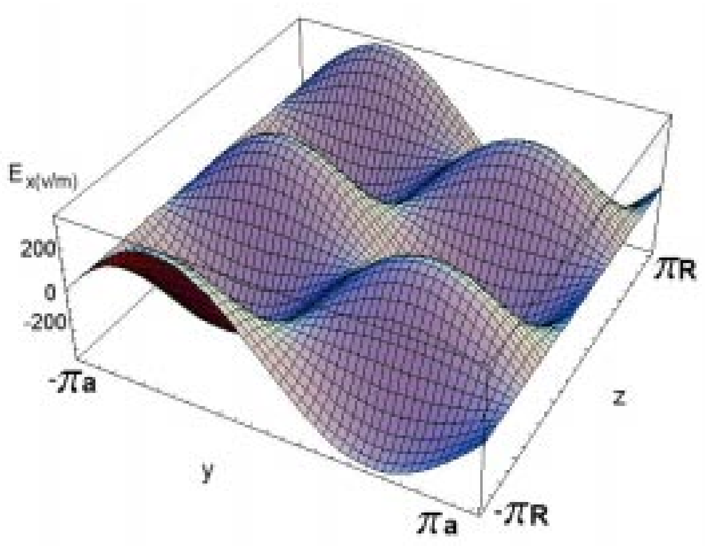

Figure 1: E_x (V/m) component of the electric field on a torus when a coaxial mode is excited.

3. Existence of an optimal density for the antenna-plasma coupling.

In the case of the a step plasma model with only the Fast Wave (FW), the mapping of the radiated power, viewed as a function of the plasma density and the frequency, shows that the optimum density, corresponding to a maximum in the radiated power, decreases with the frequency.

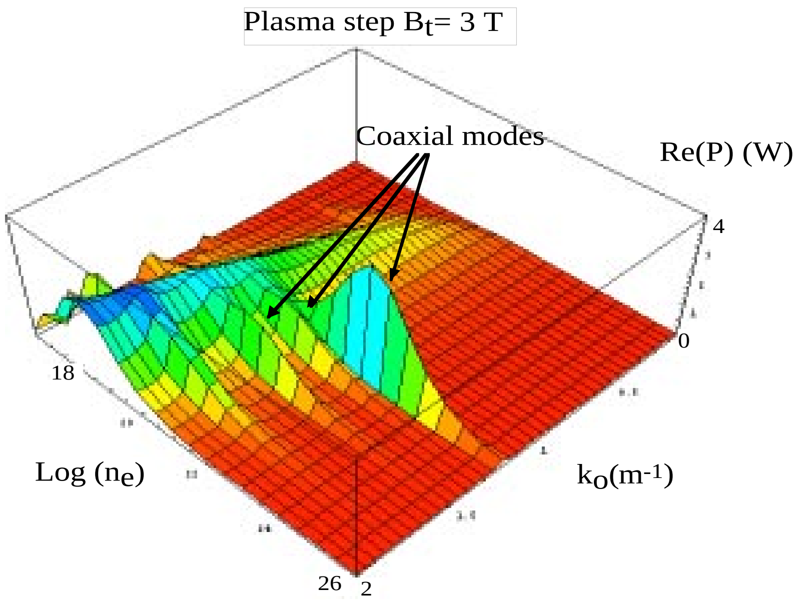

Figure 2: *Radiated power mapping versus density and frequency on the fast wave in the case of a plasma step mode and a finite screen (transparency = 0.5)*

This function has also peaks associated with coaxial modes and screen modes. The former appear at high density, where the plasma nearly behaves like a metal, the latter at low density, where the FW-only boundary condition $E_z=0$ is kept while wave propagation in the plasma goes to the vacuum limit. Both are excited by radial currents. Without a finite screen around the strap, the screen and coaxial modes have similar amplitudes. With a finite screen, the screen modes are slightly excited only for low density and the coaxial modes have lower amplitudes. The screen modes are always unphysical and can be removed from the computation numerically. Coaxial modes on the other hand can have a physical meaning and it might be envisaged to use them to couple more power to the plasma. The adjunction of appropriate current elements can suppress or enhance the coaxial modes.

For an inhomogeneous plasma, there is still an optimal density but it is shifted toward higher values. At low central density, the radiated power is smaller than in the homogeneous plasma case because the propagation region of the plasma is pushed farther away. On the contrary, at higher density, coupling is improved by the smoother density gradient. However, at high enough central density, the inhomogeneous plasma looks again like a metallic wall. These facts explain why an optimal density can be found for each frequency. For inhomogeneous plasmas, the contribution of the coaxial modes is usually lower, although in some cases the contrary may happen. In the case of a single antenna radiating in inhomogeneous plasma, the electric field is less localised and spreads out more in the z direction, as compared to the step density case.

4. A realistic modelling of a two strap antenna.

The geometrical features of the antenna must be properly included in the modelling (slanted Faraday screen, trombone shaped elements, …). Trapezoidal elements have been implemented to take into account the tilted screen blades connected to a vertical boundary, thus allowing to describe more realistic antennas (e.g. the Tore Supra antenna). A good description of the electric properties of each antenna part is needed (anisotropy of the bumper conductivity, tuned antenna and so on). The computation of the impedance matrix should include a misalignment of the external magnetic field with the screen blades. As a result of this misalignment the parallel component $E_{//}$ is greatly enhanced although the radiated power is only slightly modified for realistic values of the tilt angle (≈ 7°).

As an example, let us consider a two-strap antenna with an unslanted screen, without and with bumper limiters [7]. Figure 3 shows the 3D vector representation of the electric field at a given radial position between the screen and the plasma. In the presence of the bumpers, the $E_{//}=E_Z$ component of the electric field is enhanced at each corner of the screen. Another example with a similar 2D vector representation is shown on Figure 4 for the electric field at a given radial position in the mid-plane z = 0 of a single strap antenna with the magnetic shielding on the screen blades. The interest of these maps is that a quick look allows to see the qualitative changes of the field due for instance to the magnetic shielding effects or the screen tilting. These computations of the three components of the electric field can be used as an input to a HF sheath code.

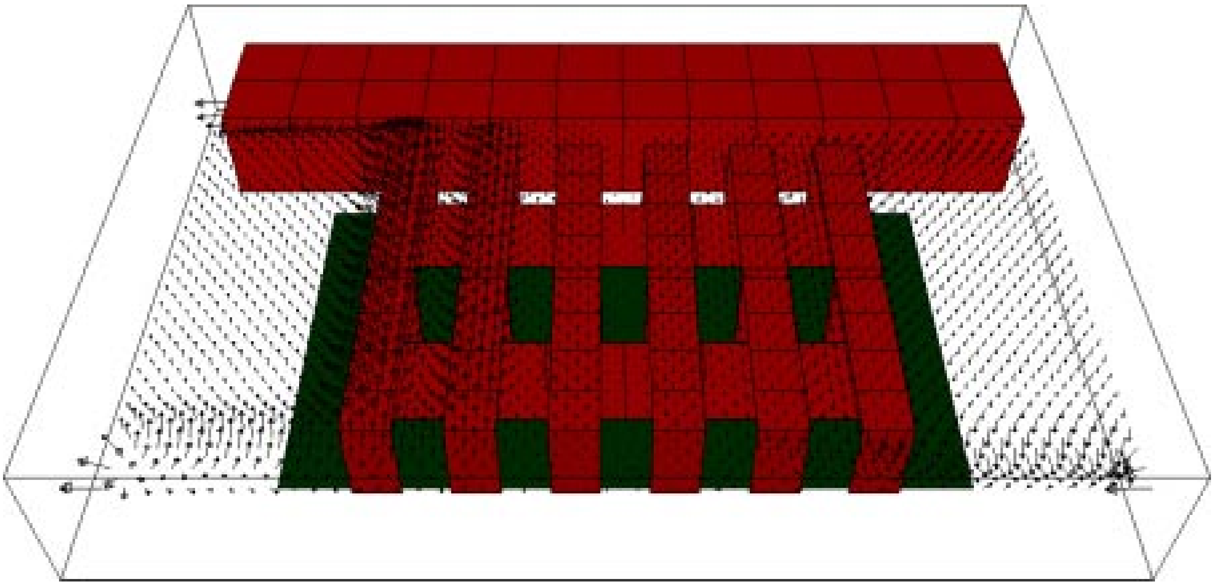

Figure 3: *3D vector map of the electric field at a fixed radial position. Case of a simplified two-strap antenna with finite screen; no magnetic shielding. Front bumper not shown.*

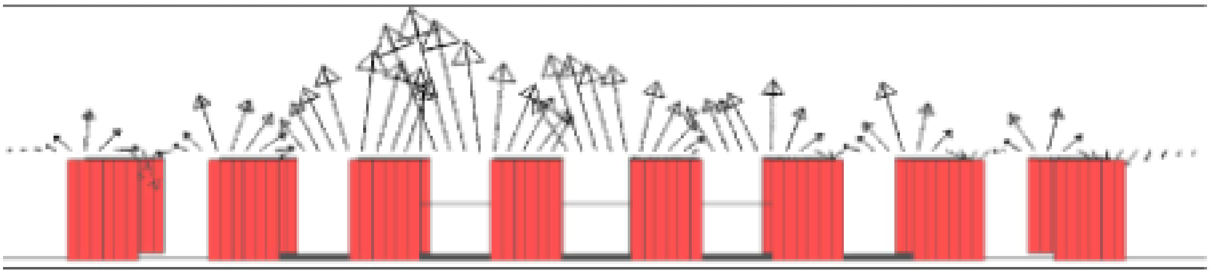

Figure 4: *E (V/m) vector at a given (x, z) position in the case of a step plasma model, with magnetic shielding on the screen blades.*

References

[1] Pecoul S, Heuraux S, Koch R and Leclert G, in *11th Radio frequency Power in plasmas,* Palm Springs, AIP Conf Proc.**355**, 409 (1995) .

[2] Pecoul S, Heuraux S, Koch R and Leclert G, *22nd EPS Conf. on Controlled Fusion and plasma physics* Bournemouth **19C,** II-337, (1995).

[3] Koch R., Bhatanagar V., Messiaen A., VanEeester D., *Comp.Phys.Com*. **40** 1 (1986).

[4] Pecoul S, Heuraux S, Koch R and Leclert G, *2nd Europhysics Topical Conf. on Radio frequency heating and current drive of fusion devices* Brussel (1998) .

[5] Pecoul S, Heuraux S, Koch R and Leclert G, *25rd EPS Conf. on Controlled Fusion and plasma physics* Praha **23C,** II-965, (1998).

[6] Colas L. *et al, 13th Topical Conference on applications of Radio frequency Power to plasmas,* Annapolis, AIP Conf Proc. (1999) to be published.

[7] Pecoul S, Heuraux S, Koch R Leclert G, A Bécoulet and L. Colas *13th Topical Conference on applications of Radio frequency Power to plasmas,* Annapolis, AIP Conf.Proc.(1999) to be published.