Optimization Of The JET-EP ICRH Antenna With The ICANT Code

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Introduction

The ICANT[1] code computes self-consistently the current on a 3D model of an ICRH antenna. It does so by solving Maxwell's equations in the vacuum layer between plasma and metallic wall, taking the plasma into account in boundary conditions calculated by a 1D full-wave code.

This code has been used to model the next JET[3] antenna and assess its coupling capabilities. Some enhancements have been made in the code, specially the ability of working with thick main conductors (straps). Comparisons are made with Transmission-Line theory (TL) and BRACC[2] and the case of JET A2 antennas is considered.

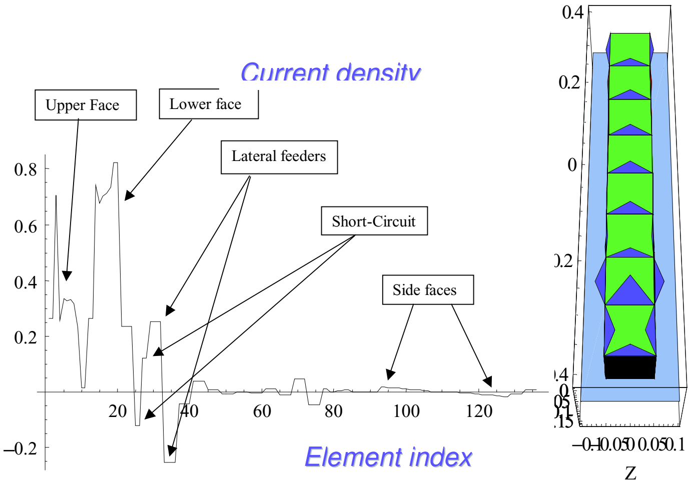


Figure 1 – Current density for each element of a thick strap model.

Thick Straps

The possibility to model thick antenna straps has been recently implemented in the code. This possibility allows to assess more realistically the flow pattern of the current on the main conductors of the antenna. The main effect, as shown in a simple strap model in Figure 1, is that a significant fraction of the current "prefers" to flow to the back of the strap, thereby reducing the current flowing on the upper face, close to the plasma.This affects the coupling. As one can see on Fig. 2, for the single thick strap

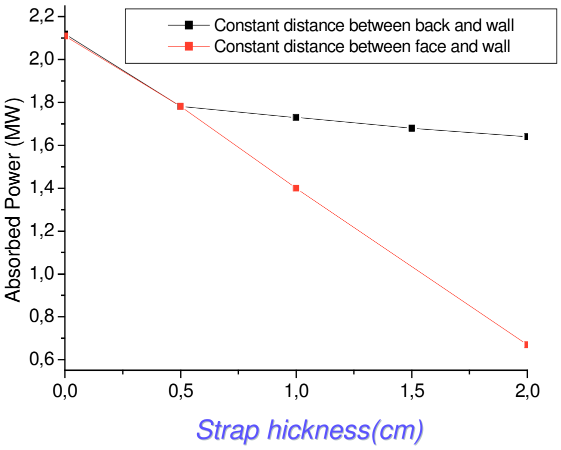
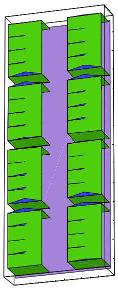


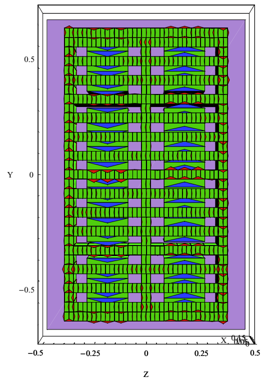
Figure 2 – Power coupled for different thickness of a main conductor. The red curve shows the case with distance of the upper face to the wall constant . The black one shows the distance from the back face to the wall constant.

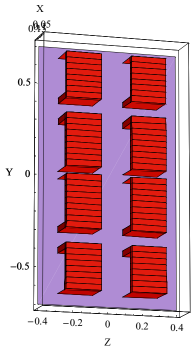
depicted above, the coupling varies significantly with the thickness of the strap. The difference with the thin-strap model used in previous simulations [3] is even more striking. Taking into account strap thickness is also very important for the computation of the antenna reactive properties (imaginary part of the input impedance).

Input Impedance Matrix

The power delivered by an array of conductors as function of the input current at their feeding point can be expressed as $P=(1/2)I^{*}\cdot\mathbf{M}\cdot I$, where I is the vector of input currents (accounting for respective phasings) and **M** is called Input Impedance Matrix (IIM)[2]. This matrix is crucial to describe the various operational scenarios as well as to program the antenna matching system. We have performed a series of calculation of the IIM for different configurations of the JET-EP antenna. Examples of coupling versus phasing obtained using these IIM's for three different models (simple array of thin straps, complete model with box and septa, but thin straps and a model with thick straps only) are shown in Table 1. One can see there, among other things, the effect of the thickness of the main conductors on coupling (columns 1 and 3) and the reduction of the effect of toroidal phasing by addition of the surrounding structure. Parameters used here are: Current on each strap 1kA, distance strap-wall 0.145m, distance strap-last closed flux surface (LCFS) 0.1m, density decay length λ_n=0.005m, distance strap-plasma edge 0.049m, strap width $2w_z$=0.2m, density profile parabolic to the power α_n=0.2, central density $n_{e0}=3\times10^{19}\text{m}^{-3}$, LCFS density $n_{e1}=0.25\times10^{19}\text{m}^{-3}$, f=45.5MHz, B_0=3T, R_0=2.301m, a_p=0.741m.







phase \ model	Thin straps	Complete	Thick straps
0, 0, 0 0	7.64	9.90	5.72
0,0,180,180	3.93	8.64	2.56
0, 180, 0, 180	1.64	5.08	0.94
0, 15, 0, 15	8.19	9.41	5.64
45, 0, 45, 0	7.53	8.84	5.02
90, 0, 90, 0	4.64	7.28	3.33
0-toroidal phas	12.0	10.51	10.63

Table 1 - Power in MW for 1kA at the feeders, f=45,5MHz, B=3T, Toroidal phase π (except last line) for different models of the JET-EP antenna.

JET-A2 antenna

A model of the present JET antennas has been constructed (Figure 3, half of the antenna, without screen) and a frequency scan was made with the “standard” plasma used in the JET-EP computations (see above), which is rather far away. Figure 4 shows the real part of the power for each strap considered in isolation. The inner and the outer straps (left and right, respectively, in Figure 3) are resonant at different frequencies. Further computations are planned to compare the results of this model with experimental values.

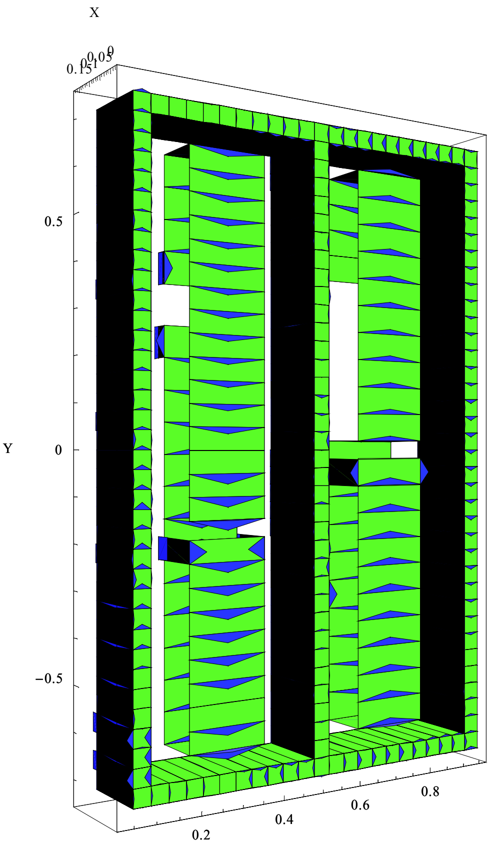


Figure 3 - JETA2 half of the antenna screenless model – Current distribution for π phase.

Near Fields

Figure 5 shows how the near-fields can be affected by changes in the geometric properties of the antenna. In this example one can see the imaginary part of the toroidal component of the RF electric field with and without screen bars. The screen diminishes overall the amplitude of this field component while imposing its structure to it. The model for the screen bars allows conductivity only in the toroidal direction. A separate study has shown that the bi-directional conductivity on thin screen elements leads to an underestimation of the coupling, as compared to the more realistic thick screen case. As a three-dimensional screen is very time- (and memory) consuming, the bars with unidirectional conductivity are a good approximation.

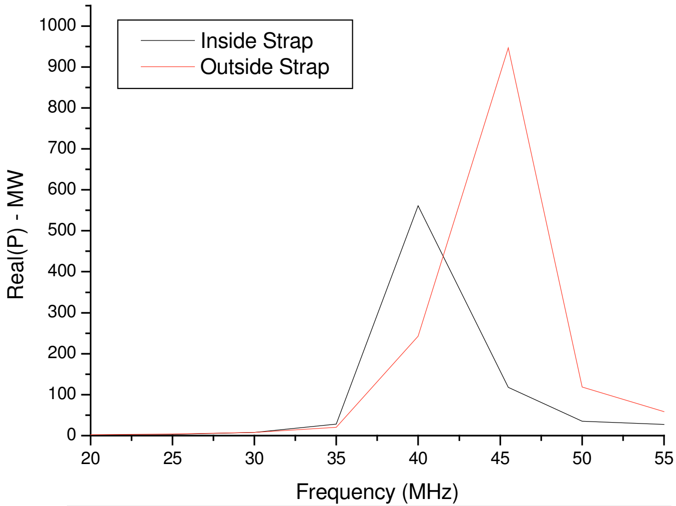


Figure 4 – Power versus frequency for 1kA at the feeder for the two resonant straps of JETA2

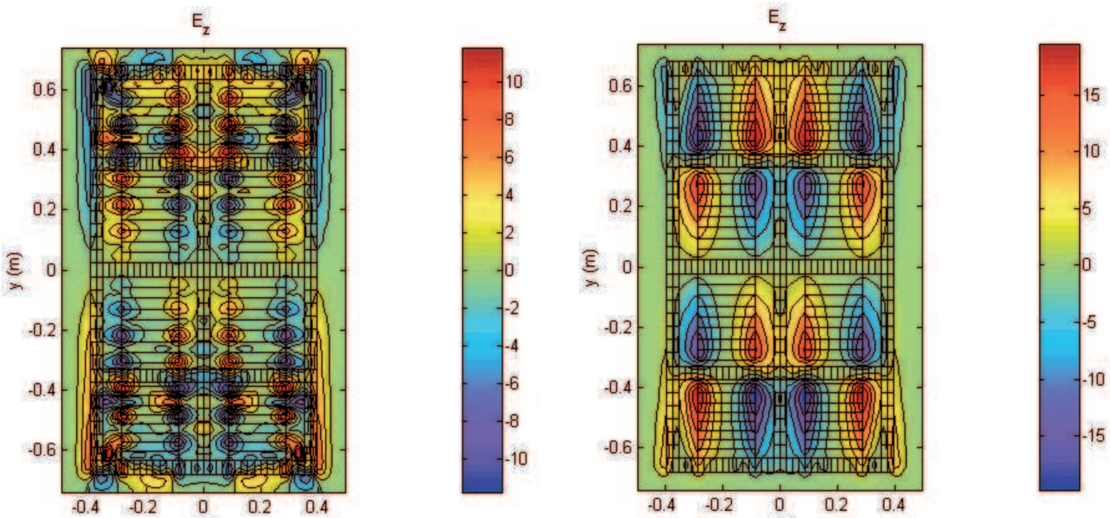


Figure 5 – Imaginary part of E_z for the JET-EP antenna with or without Faraday screen.

Spectrum

ICANT can also calculate the spectrum of the wave absorption, as shown in Fig. 6. It helps to perceive necessary corrections in the modeling of the antenna structures and also to understand the mechanisms of absorption expected for the future experimental exploitation of the antenna.

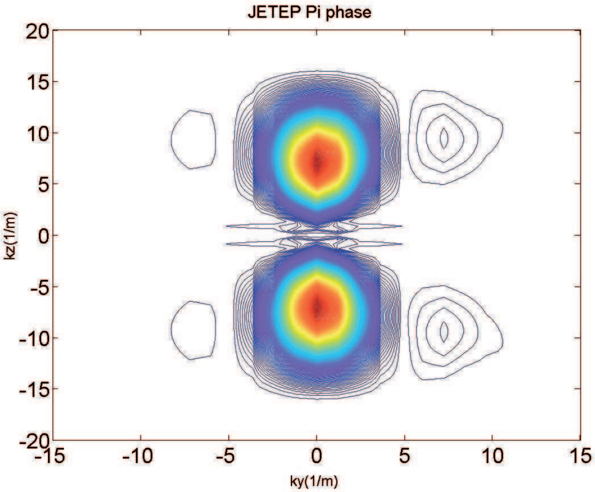


Figure 6 – Spectrum of the radiated power by the JET-EP antenna with toroidal phase π.

BRACC and TL Benchmarking.

The input impedance of a single strap in vacuum (45.5MHz, lengths 0.2-2.5m) was computed with both BRACC and ICANT. The latter gives an effective electrical length about 10cm longer than the geometric length (not counting the feeders). The ICANT results are in good agreement with those of BRACC. Figs. 2 and 3 of Ref.3 were also re-computed with BRACC. ICANT gives slightly (5-10%) larger radiated power due to the excitation of surface waves by the short y-structure of the antenna currents. Presence of these modes is easily detected in the spectrum (they appear at $k_{//}=\pm k_0$ with strong asymmetry in k_y) and are not excited when the antenna is in a box.

References

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