

TOPICA/TORIC integration for self-consistent antenna and plasma analysis

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**POLITECNICO
DI TORINO**

APS-DPP meeting, Philadelphia, 2 November 2006



TOPICA/TORIC integration for self-consistent antenna and plasma analysis

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48th Annual Meeting of the Division of Plasma Physics of
The American Physical Society

October 30-November 3, 2006 - Philadelphia, Pennsylvania, USA



TOPICA/TORIC Integration

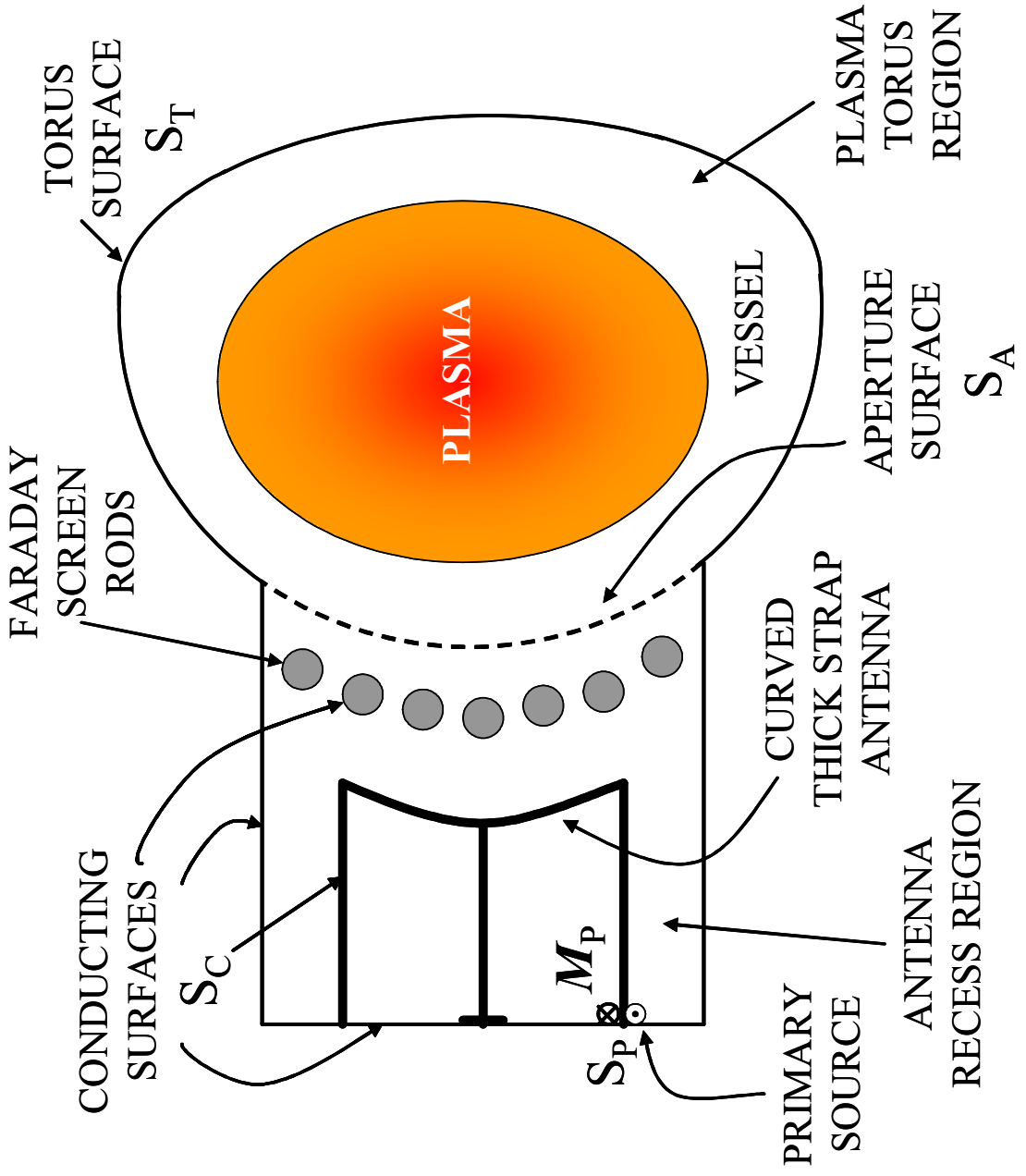
- **TOPICA** is a numerical suite for prediction and analysis of real-life plasma facing antennas also during operation
 - It can account for **any plasma** model, provided the relevant Green's function is given
- **TORIC** solves the FLR wave equations in the ICRF regime in arbitrary axisymmetric toroidal plasmas
 - It can compute and export the relationship (in TORIC “spectral domain”) between **H** and **E** transverse fields (the Green's function) at the tokamak outer wall



Present TOPICA Capabilities

- Fully **3D solid antenna** structure model
- CAD input GUI interface; import/export standard file formats (IGES, DXF, ...)
- **Realistic plasma**, non-homogeneous, FLR effects, absorption (FELICE plasma model); fitted to curved boundary (1.5D)
- Multi-port circuit parameters ($[Y]$, $[Z]$, $[S]$ matrices)
- Coax and voltage excitation of strap ports
- Computes **currents, fields**, and voltages everywhere around antenna and housing
- Computes **power density spectra**
- **Parallelized** versions now run on:
 - Marshall cluster @ PSFC/MIT
 - 160-node cluster @ Max Planck IPP

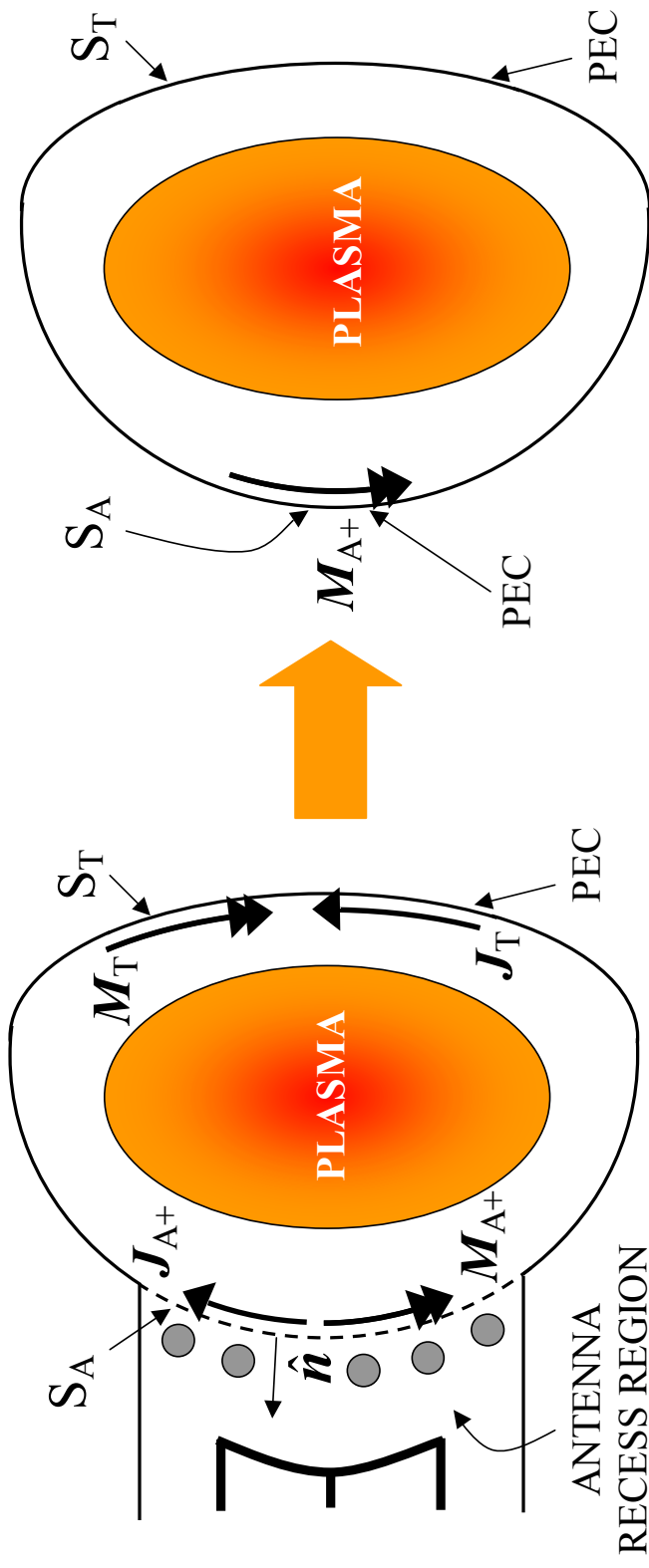
ICRH Antenna Geometry



Plasma/Antenna Separation via Equivalence Theorem (1)

Original problem plus
equivalent current densities

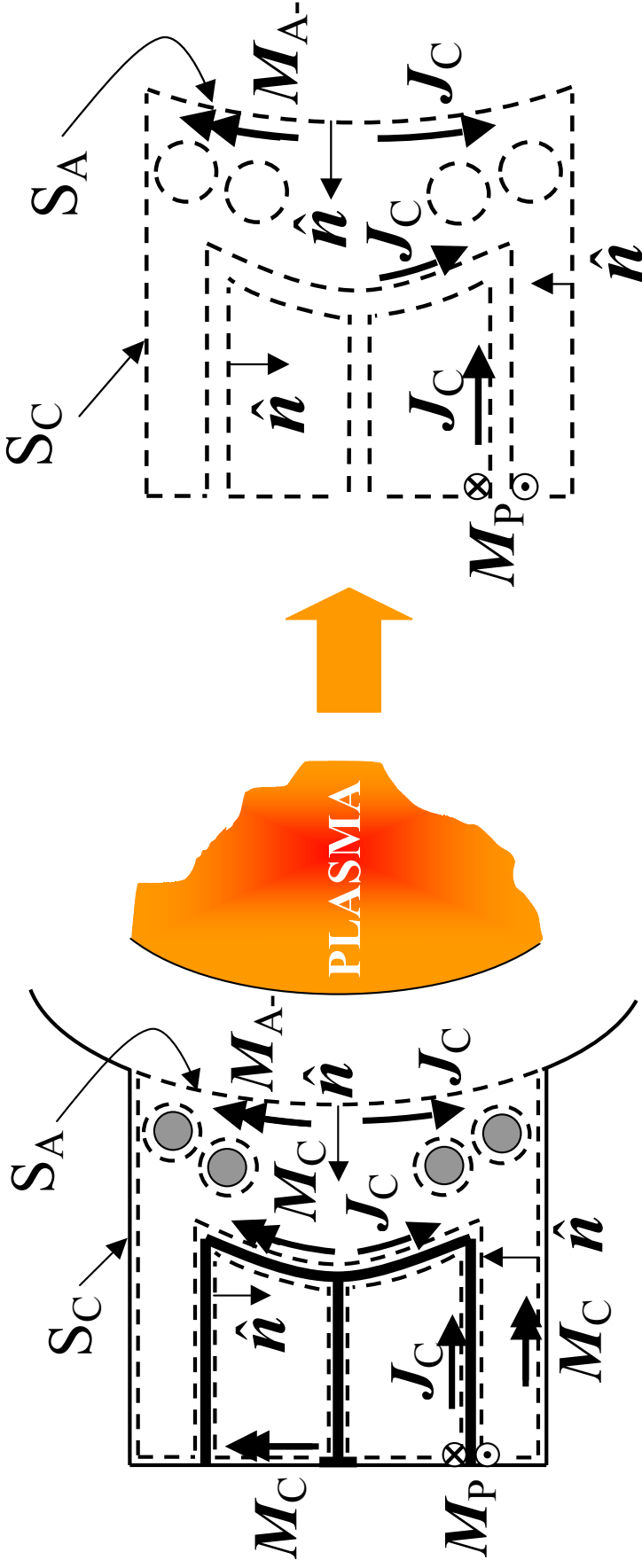
Final (exactly)
equivalent problem



Plasma/Antenna Separation via Equivalence Theorem (2)

Original problem plus
equivalent current densities

Final (exactly)
equivalent problem



Formulation and Coupling to TORIC

Source term (coax)

$$\left\{ \begin{array}{l} (\underline{E}_1^p + \underline{E}_1^s) \chi_C \Big|_{\tan} = \hat{n} \times \underline{M}_P \chi_P + \hat{u}_\psi \times \underline{M}_{A-} \chi_A \\ (\underline{H}_1^p + \underline{H}_1^s) \chi_A \Big|_{\tan} = \underline{H}_2^s \chi_A \Big|_{\tan} \\ \underline{M}_{A-} = -\underline{M}_{A+} \end{array} \right. \quad \chi_\beta = \begin{cases} 1 & r \in S_\beta \\ 0 & r \notin S_\beta \end{cases} \quad \beta = A, C, P$$

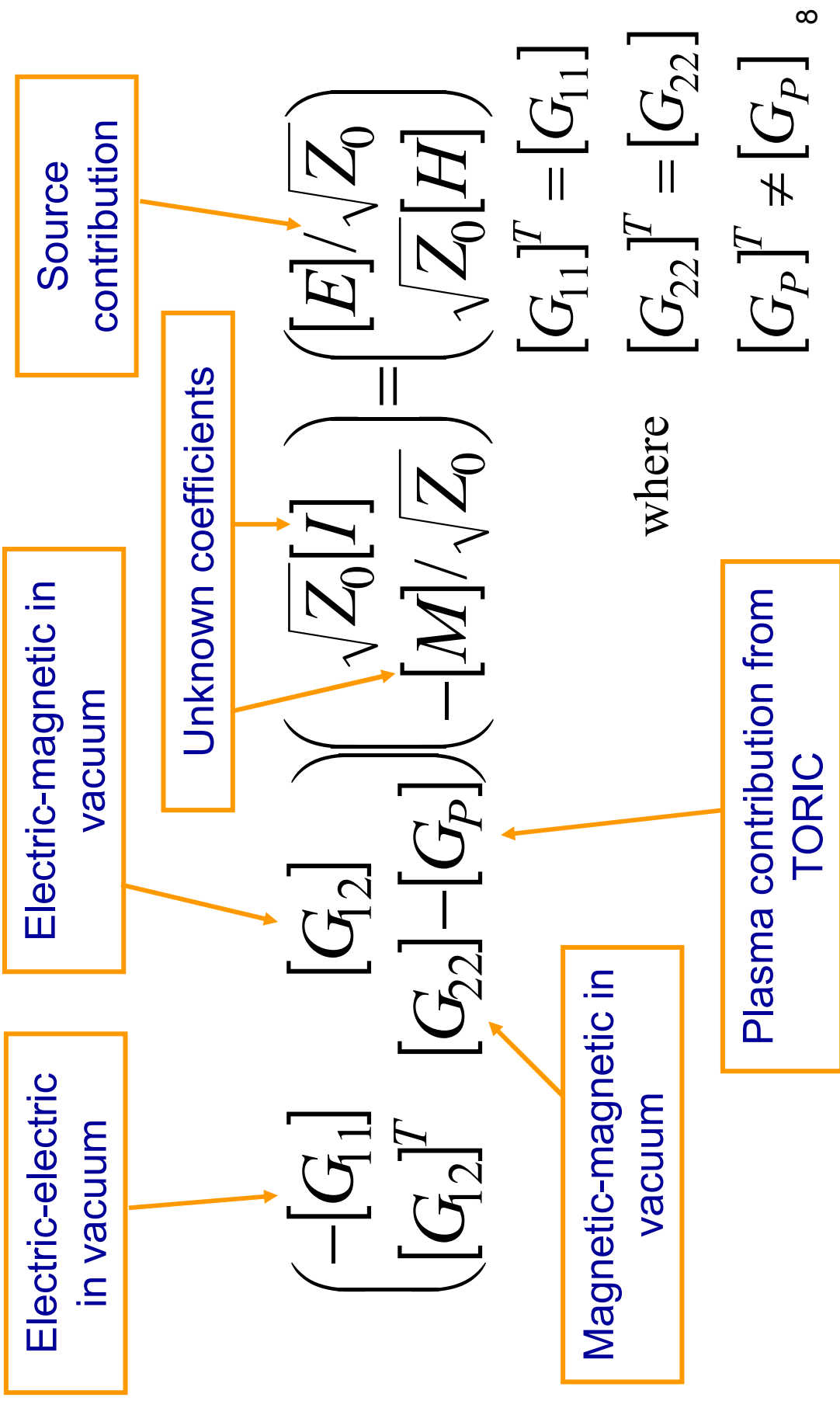
TORIC
contribution:
plasma Green's
function

Magnetic field
on S_A in TORIC
spectral domain

Electric field on
 S_A in TORIC
spectral domain

$$\tilde{\underline{H}}_{-t}(m, n) \times \hat{u}_\psi = \sum_{m'} \tilde{\underline{Y}}(m, m', n) \cdot \tilde{\underline{E}}_{-t}(m', n)$$

Matrix Form of the Formulation





TOPICA usage

- Draw or **import** the antenna with input CAD graphic tool and specify ports/feeding
- Input **plasma parameters**: point-wise (e.g. if measured or out of transport codes) or in parametric form (to ease parametric loading studies)
- Run the **plasma module** of code (modified FELICE or TORIC)
- Run the **TOPICA “core”** modules
- Default output: **antenna parameters**
- Optional output (direct): **currents** on all metal parts, **electric field distribution** on apertures, **spectra**
- Optional output (post-processing): **electric field/voltages** everywhere in vacuum region (at points specified by user)



Conclusions

- Plasma/Vacuum region separation allows analysing **very detailed antenna geometry** with **very accurate plasma parameters**
- **Accurate model of coax** leads to an excellent agreement (magnitude and phase) achieved both in vacuum and with realistic plasmas
- TOPICA is capable of **reliably predicting behavior of plasma facing antennas**
- **TORIC** has been modified to provide the plasma Green's function at the torus wall, which is input to TOPICA and it is currently being tested by PSFC/MIT