Modeling the ICH Antenna on Alcator C-Mod

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Computer modeling of the ICH antennas on Alcator C-Mod has been initiated with the goal of providing more detailed understanding of the rf operation. The RANT3D code is being used to calculate the plasma loading for both the two-strap (D, E-port) antennas[1] and the four-strap (J-port) antenna[2]. These antennas have provided up to 5 MW of power to the plasma at a frequency of 80 MHz[3]. Sensitivity of the calculated plasma loading with respect to plasma parameters and strap phasing will be presented. A circuit model for coupled transmission line analysis is also being constructed; calculated electrical characteristics will be adjusted, if necessary, to match measured S-parameter scans. The model will be used to study current and voltage distributions throughout the antennas' power distribution system and also to anticipate future operation of the J-port antenna at selected frequencies over its 40-80 MHz operating range.

[1] Takase, Y., et al, Proc. 14th IEEE/NPSS Symp. Fusion Eng., 118, San Diego, CA (1992)
[2] Schilling, G., et al, AIP Conf. Proc. 485, Annapolis, MD (1999)
[3] Schilling, G. et al, Bull Amer Phys Soc 45 (Quebec City, 2000)

MOTIVATION FOR MODELING THE J-PORT ANTENNA

- **Understand the electrical load that the powered antennas present to the transmitters.**
- **Calculate voltages in the structure, particularly in the strip lines behind the antenna back plane.**
- **Predict operation (strap phasing, current distributions) as a function of frequency.**
- **Compare expected plasma loading with measurements; look for agreement for both the J-port and D,E-port antennas for the same plasma conditions.**
- **Calculate electric fields on antenna frame as a function of plasma parameters, antenna power, and strap phasing.**
- **Study the plasma influence on the internal coupling between antenna elements.**

MODELING APPROACH

- **Use a coupled-transmission line (CTL) model to calculate the currents and voltages in the antenna and in the power distribution system.**
  - Use 2D static codes to calculate the inductive and capacitive coupling between antenna sections.
  - Tweak calculated parameters to match vacuum measurements.

- **Use 1D/3D codes with warm plasmas to calculate loading, field distributions.**
  - Warm plasma slab code (GLOSI) used to calculate a plasma surface impedance in Fourier space for wave boundary condition.
  - Use 3D Fourier mode code (RANT3D) with plasma surface impedance to calculate **E**, **B**, *V*, *I* and Power.

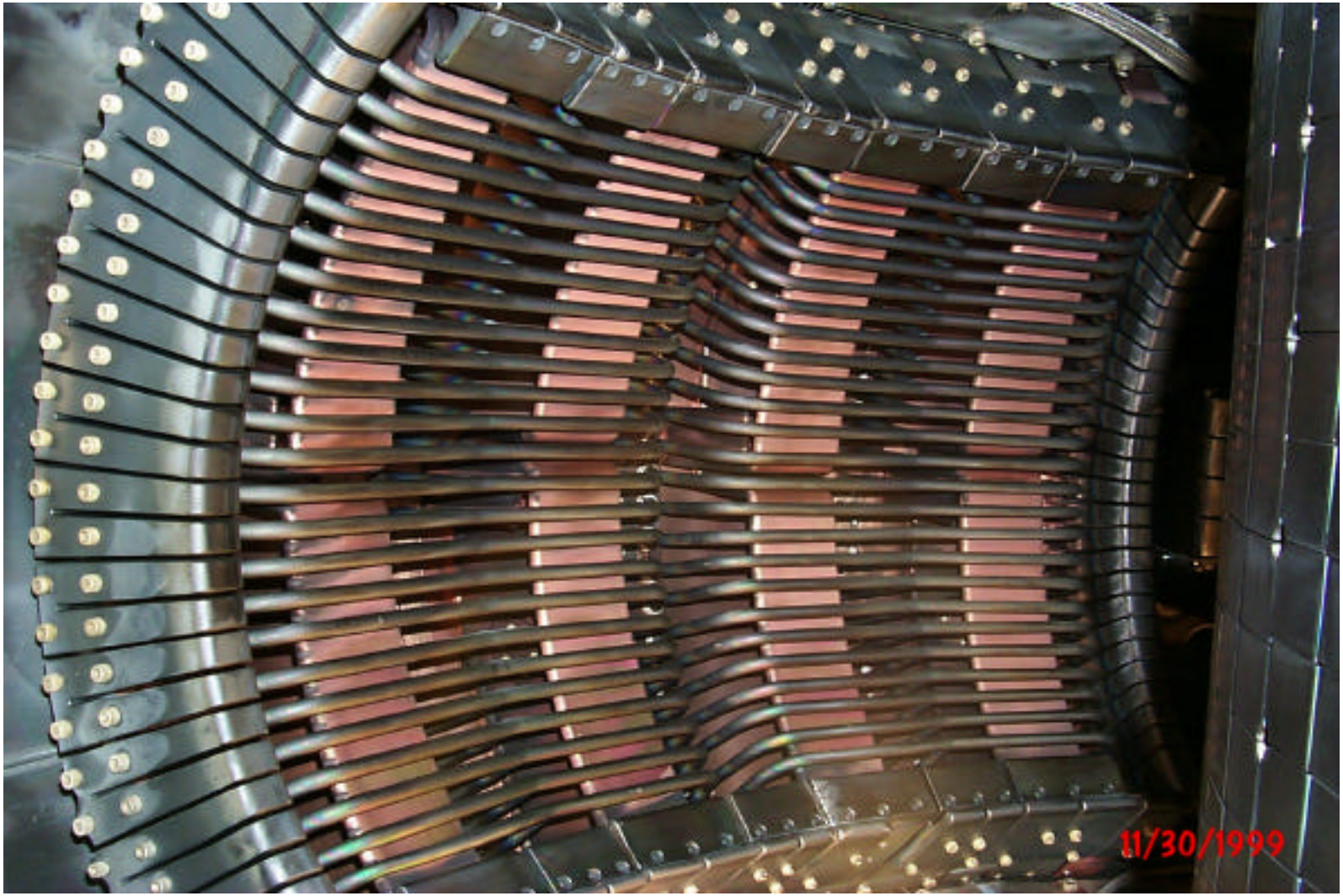
STATUS OF MODELING EFFORT

- **Coupled-transmission line model**
  - CTL model has been constructed and the inductive and capacitive coupling parameters for it have been calculated.
  - Complex geometry of the J-port antenna precluded using our CTL code of choice (FDAC). The ANTMOD code, originally developed by Goulding for JET antenna analysis, has been resurrected.
  - The CTL model agrees well with vacuum measurements for the frequencies of immediate interest (70 & 80 MHz).
  - Some parameter tweaking will be needed for low frequency study.

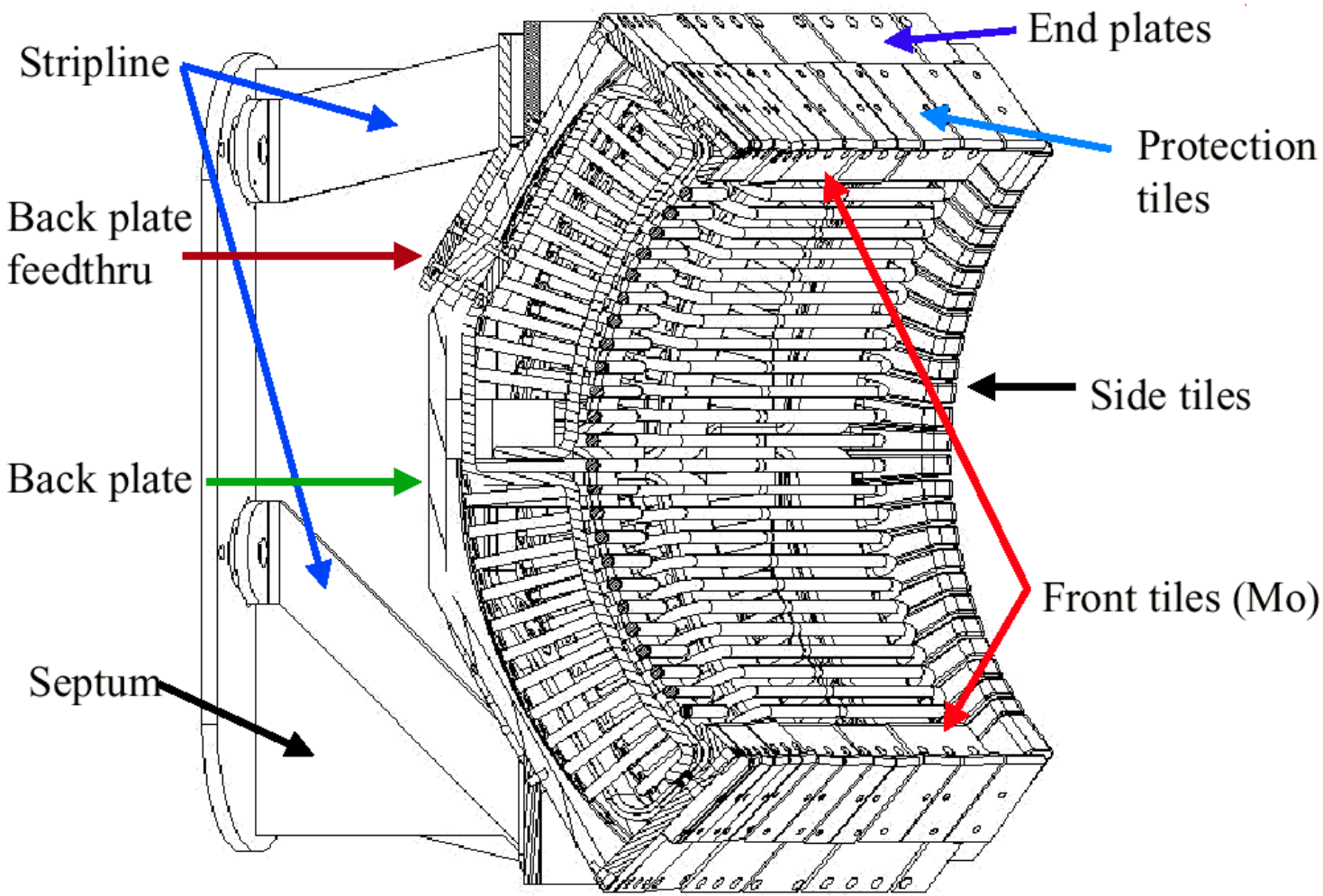
- **GLOSI/RANT3D Model**
  - Geometry for both the J-port and D,E-port antennas has been incorporated into RANT3D data sets.
  - Presently in the process of determining number of modes needed to resolve items of interest with GLOSI and RANT3D. Long run times are a problem.
  - Basic plasma loading has been calculated; surface fields are still untrustworthy.

The J-port Antenna has high directionality

➡ high internal coupling between elements

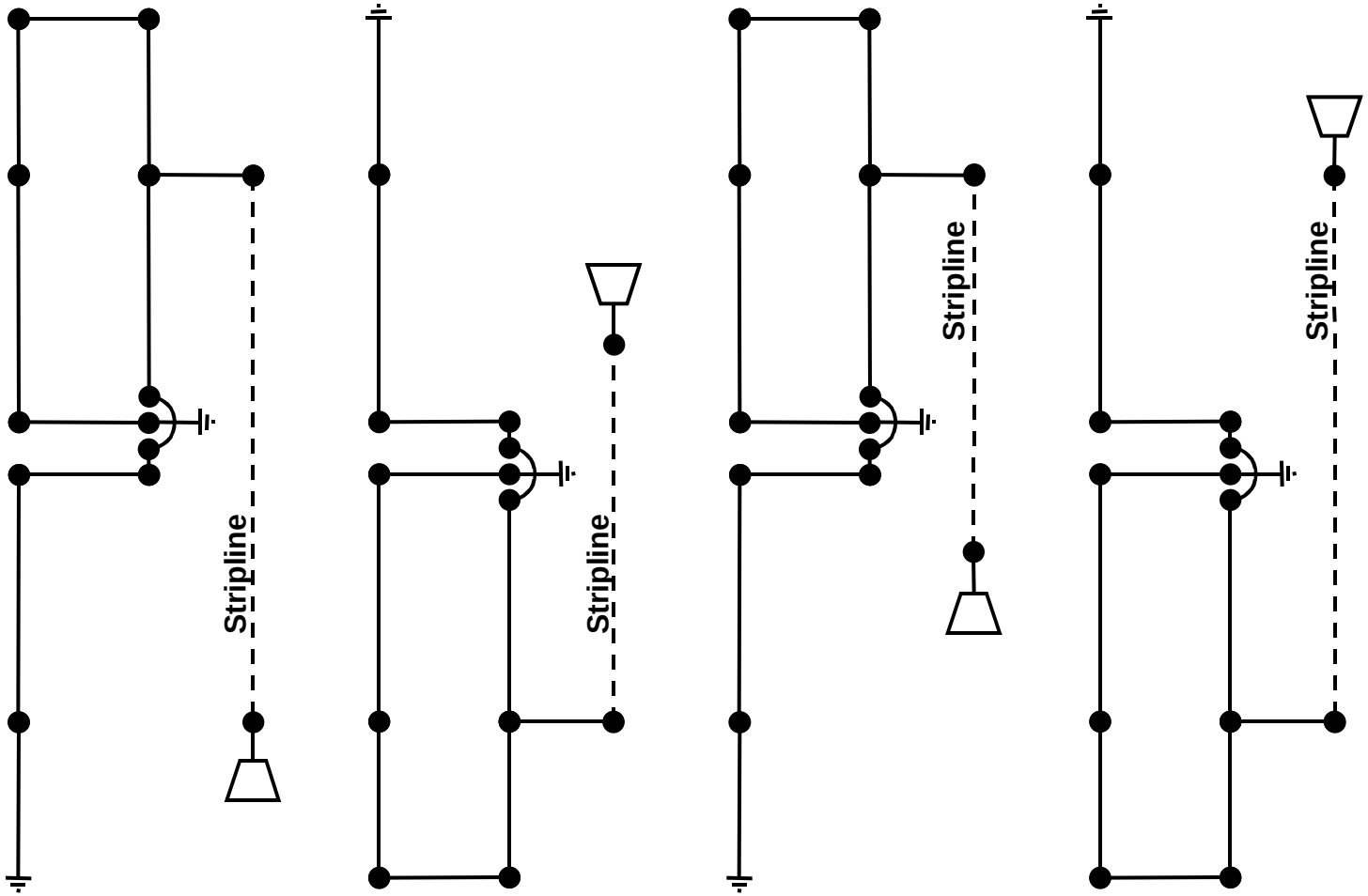


ORIGINAL J-PORT ANTENNA
(BEFORE MODIFICATIONS)



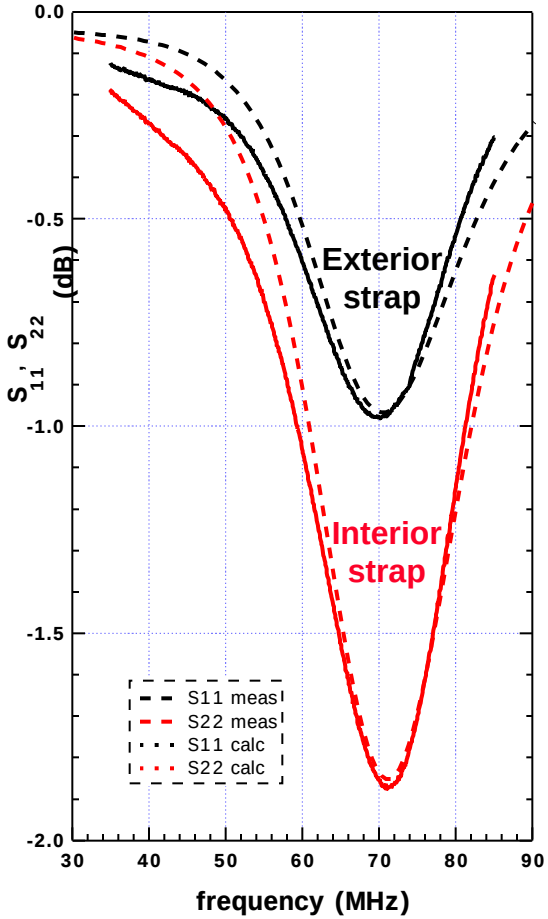
The CTL model for the J-port Antenna consists of 60 sections

ANTMOD model for J-port antenna (up to vacuum feedthroughs)
Coupling coefficients calculated with 2D static codes.

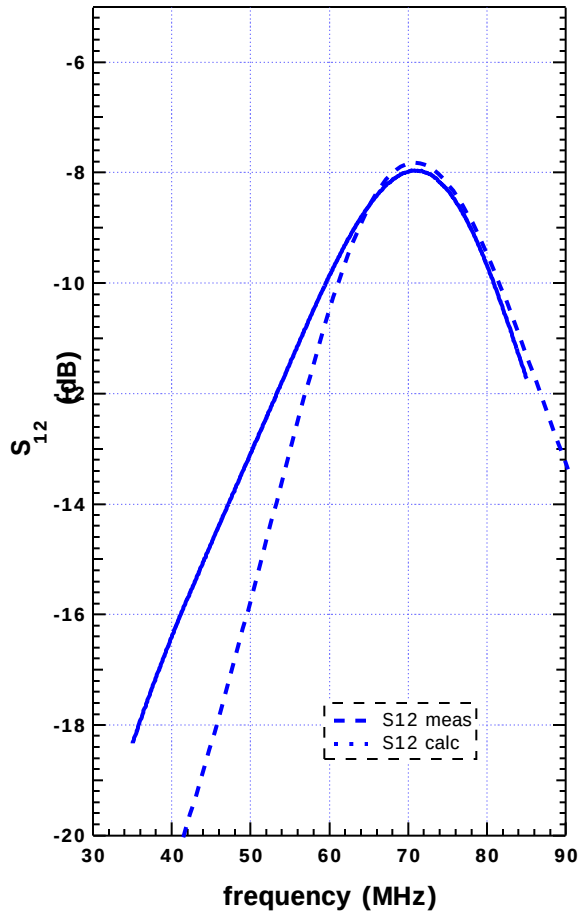


Calculated parameters for CTL model agree with 70-80 MHz S-parameter measurements. Tweaking will be needed for f < 60 MHz

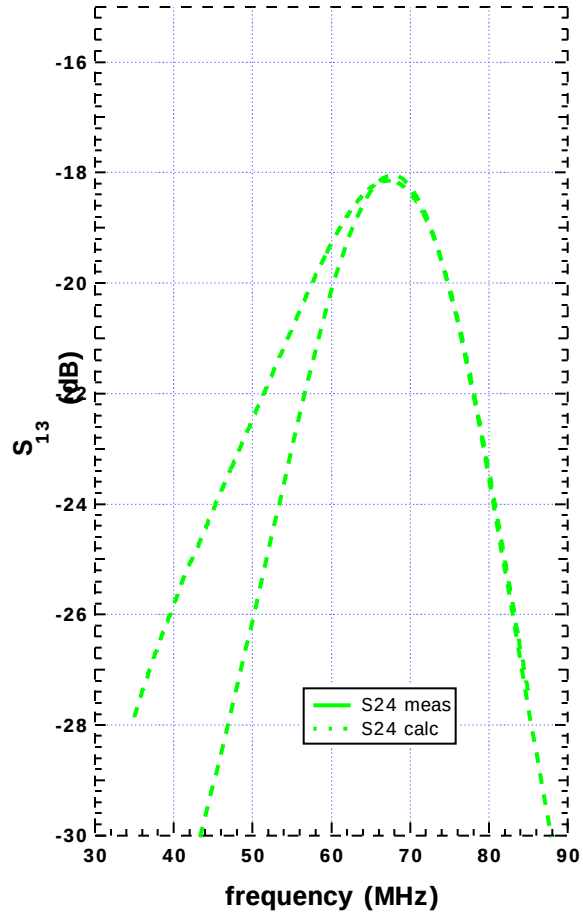
Reflection Coefficients



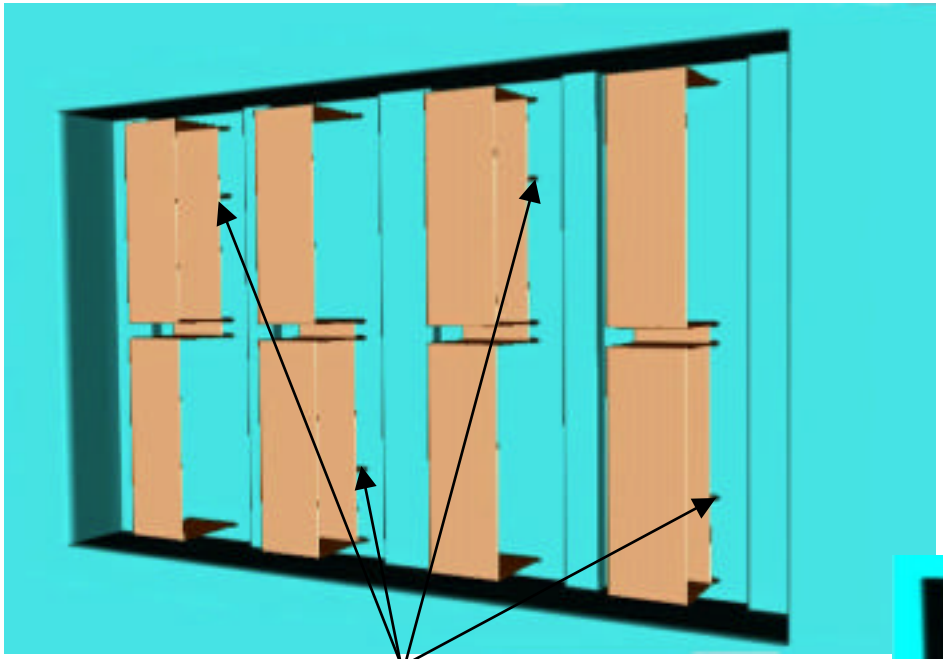
Nearest Neighbor Coupling

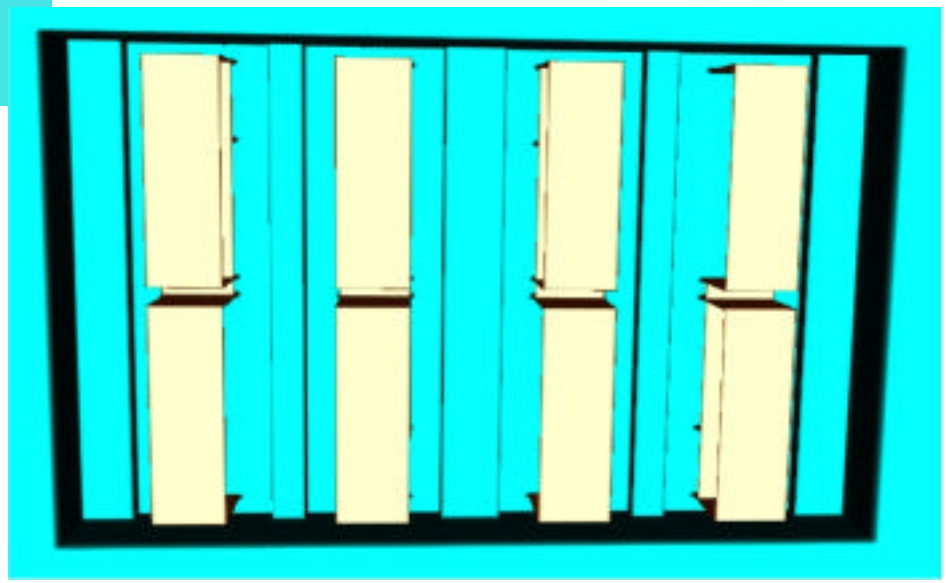


Next to Nearest Neighbor Coupling



J-PORT GEOMETRY FOR RANT3D CODE





Plasma Loading Calculations

PLASMA PARAMETERS

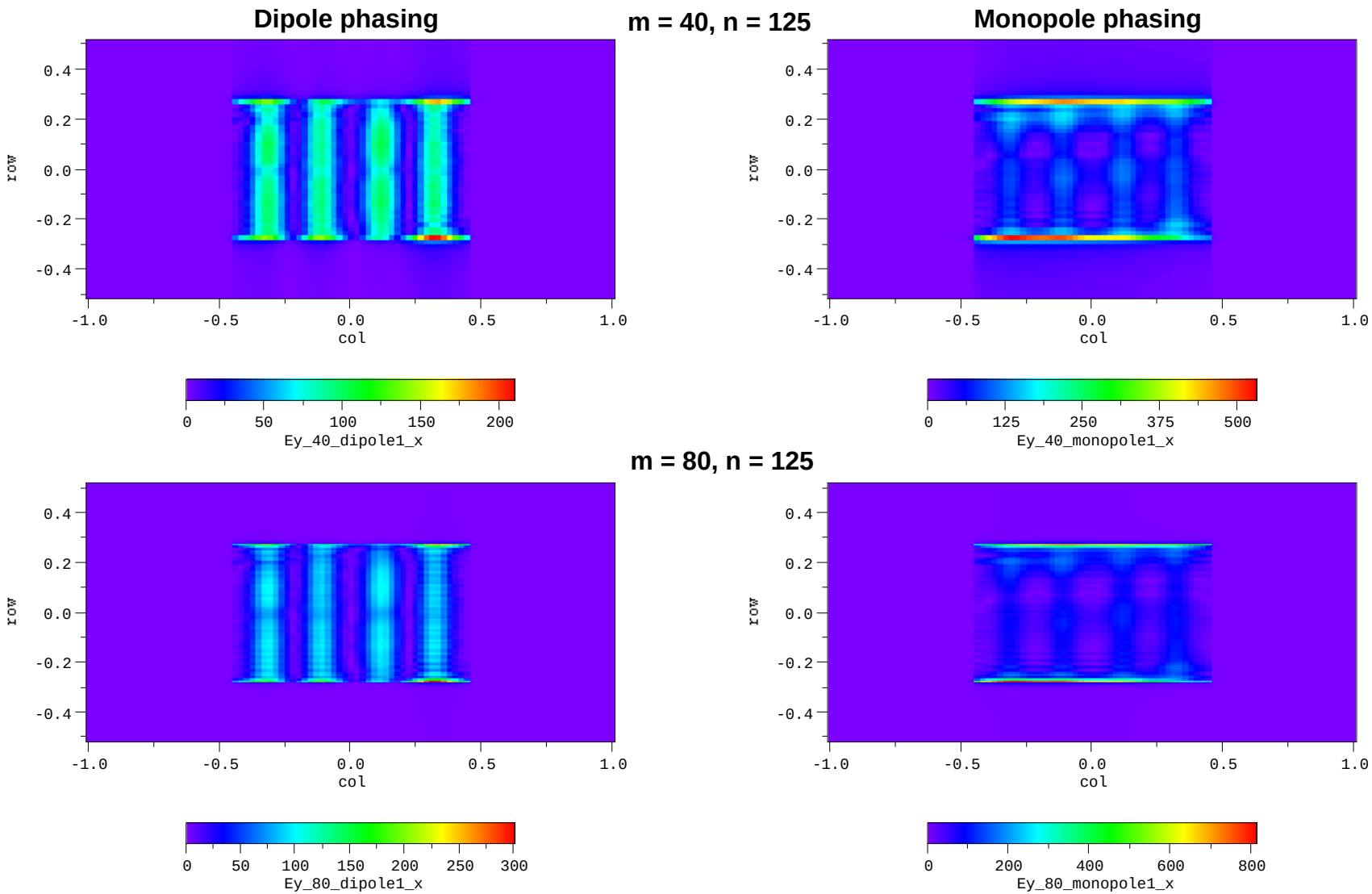
B_{T0}	5.2 T
$B_{p(sep)}$	0.36 T
H:D	0.05:0.95
T_{e0}	2.2 keV
$T_{e(sep)}$	75 eV
n_{e0}	1.2e20 m^{-3}
$n_{e(sep)}$	0.6e20 m^{-3}
λ	0.003 m
Gap (sep to FS)	0.023 m
Freq	80 MHz

CALCULATED LOADING

Dipole phasing	15 Ω/m
Monopole phasing	23 Ω/m

- **There exists some uncertainty in the plasma edge conditions.**
- **Calculated loading will be transformed to transmitter loading through circuit models for D, E, and J port antennas.**
- **Plasma conditions will be varied and compared to measured loading.**
- **Loading calculations do not change with increasing mode numbers (m from 40 to 80, n from 125 to 200).**
- **Fields calculated at antenna surface <u>are</u> changing with mode numbers. More work is needed on refining the antenna geometry and increasing spatial resolution.**

Poloidal electric fields are still not well-resolved at antenna surface



Next steps

- **Tweak CTL parameters for better low frequency agreement.**
- **Add resonant loops, tuning/matching to CTL model.**
- **Study antenna phasing vs frequency with CTL model.**
- **Calculate voltages along the strip line feeders and at vacuum feedthroughs.**
- **Compare D, E port loading calculations with J-port calculations; compare with measurements.**
- **Add recesses to antenna geometry to isolate antenna frame; add finite phase velocity to strap current distributions.**