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NEW ALCATOR C-MOD ROTATED 10° 4-STRAP ICRF ANTENNA

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Abstract—We have developed a design for a new rotated 4-strap ICRF antenna. The design is based on a modification of the existing C-Mod antennas with the antenna rotated 10° such that the entire structure is perpendicular to total magnetic field. This rotation is implemented in an attempt to reduce ICRF impurity production. The rotation results in an antenna with less surface area than the previous antennas and therefore a higher power density will be obtained for a given input power of 3 MW. The power density would reach 15MW/m², near the world record power density obtained in Tore Supra. We will describe the RF of this new design. The RF analysis was accomplished using the CST computer code. The fields were studied to minimize E field breakdown in the feed system and to accomplish the symmetry required for reduced impurity production in the four straps.

I. INTRODUCTION

The ICRF system operating on Alcator C-Mod is a key component of the operation in advance tokamak regimes. A number of physics and technological issues can be addressed at C-Mod relevant to ITER and future devices: coupling physics; compatibility with high performance discharges and metallic plasma facing components; reliably maintain coupled power despite load variations; and availability to deliver ICRF power on demand without burdensome antenna conditioning. At C-Mod, antenna operation of the two 2-strap (D and E antennas) and a 4-strap (J antenna) antenna at high power density (>10MW/m²) has become routine. We plan to install a new four strap antenna in fiscal year (F9) 2010 to replace the J antenna and if successful a second in (F9) 2011 to replace the D and E antennas. A picture of the J antenna is shown in Fig. 1. One of the primary design goals is to reduce the RF sheaths by antenna design. [1]



Fig. 1 J antenna

The proposed antenna will be a modified J antenna with the antenna rotated 10° such that the entire antenna structure is perpendicular to the total magnetic field. This rotation is attempted to reduce impurity production is shown in Fig. 2. In addition to the rotation many parts of the antenna system in which experimental evidence and simulation have shown where breakdown has or is likely to occur will be modified. This includes the coaxial feed through and the strip lines linking up the antenna straps with the coaxial feed.

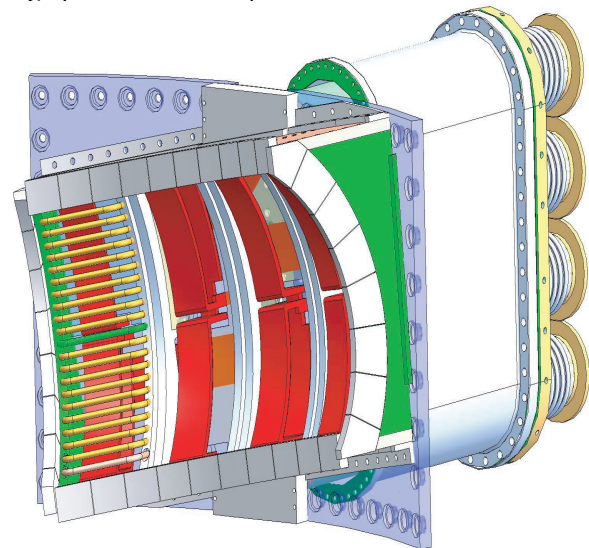


Fig. 2 Proposed ICRF 4-Strap Antenna

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In this paper we will show the results of simulations of the J antenna using the CST code (microwave studio) for electrical and RF results. The critical areas for breakdown along with experimental evidence and the reduction of the E field parallel to the B field.

II RF ANALYSIS

A. Electric Fields and Tilting

The simulation was done by having the proposed J antenna radiated into a lossy dielectric approximating the plasma loading of the antenna. The simulation setup is shown in Fig 3. The lines shown in Fig. 3 are monitor lines to display the values of the fields. The horizontal lines along the x axis are perpendicular to the straps. Fig. 4 shows the fields from along the horizontal line in the center of the antenna and 1.0 inch in front of the straps. The lossy dielectric load is a 0.5 inch in front of the straps. The values of the electric field are for 4 megawatts of input power. In this position the field is close to those desired with the vertical field Ez being the dominant field. However this degenerates at other locations as seen by the fields in Fig. 5 for the line along the middle of the upper half of the antenna. Fig 5 show the undesirable field Ex which is close to being parallel to the magnetic field increasing.

The reason to tilt the antenna 10° is to reduce the E field parallel to the magnetic field. Fig. 6 shows the difference between the real and imaginary components of the E_x field along horizontal and tilted 10° lines which intersect at the center of the antenna and are 1.0 inch out from the straps for 4 watts. If these plots were exchanged by tilting the antenna, tilting would be beneficial. The ratio of integrated voltages (12) is an indicator of the reduction in the unwanted force along the magnetic field. Fig. 7 and 8 show the fields of horizontal to tilt at middle upper and upper antenna. Here the ratios are 11 and 36.

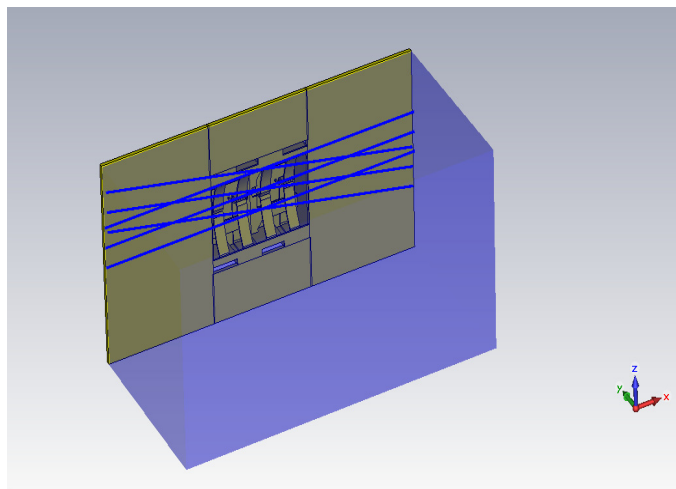


Fig. 3 Simulation setup performed with CST

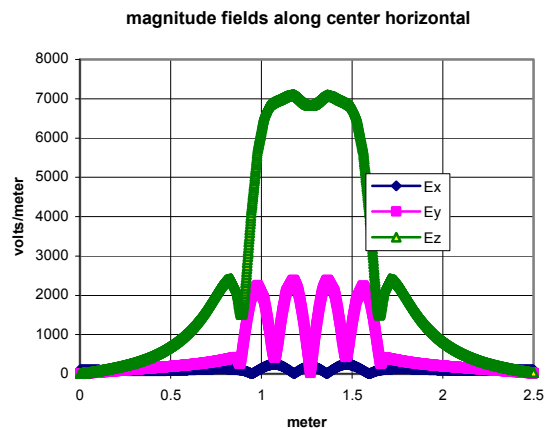


Fig. 4 Fields along center horizontal, Ez parallel to strap, Ey radial field perpendicular to strap, Ex along horizontal line.

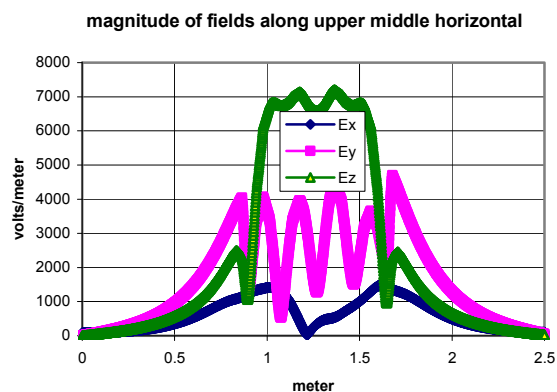


Fig. 5 Fields along upper middle horizontal, Ez parallel to strap, Ey radial field perpendicular to strap, Ex horizontal

**Perpendicular E field and tilted 10 degrees 4 watts
integrated field equals 143volts for Ex and 1725volts for
Ex tilted for 4 megawatts Ratio=12**

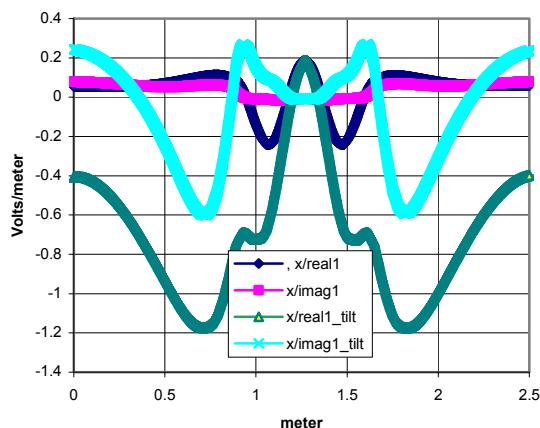


Fig. 6 Comparison of Ex for horizontal and tilted lines through the center of J antenna.

Perpendicular E field and tilted 10 degrees for 4 watt integrated field equals 182volts for Ex and 1995volts for Ex tilted for 4 megawatt Ratio=11

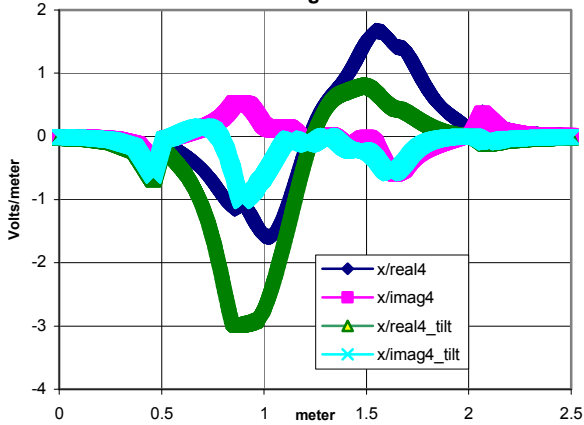


Fig. 7 Comparison of Ex for horizontal and tilted lines along the middle of upper half of J antenna

Perpendicular E field and tilted 10 degrees 4 watts integrated field equals 11volts for Ex and 396volts for Ex tilted for 4 megawatts Ratio=36

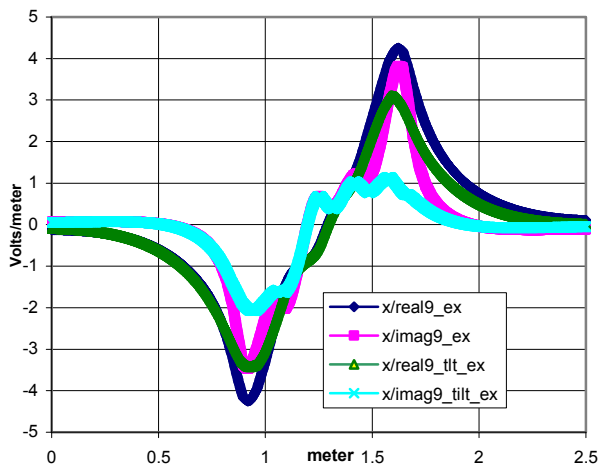


Fig. 8 Comparison of Ex for horizontal and tilted lines through the center of J antenna

B. Electric Fields and Breakdown

For the J antenna the breakdown occurs in the feed system. Experimental evidence has shown that breakdown levels are substantially reduced if the electric field is parallel to the magnetic field. For above simulation coordinates this would be Ex. Fig. 9. shows a picture of the breakdown evidence on the J antenna and Fig. 10 shows the Ex field in this section. This good agreement between breakdown evidence and simulation indicates that this transition from strip line to strap will have to be modified.



Fig. 9 Evidence of breakdown in feed system

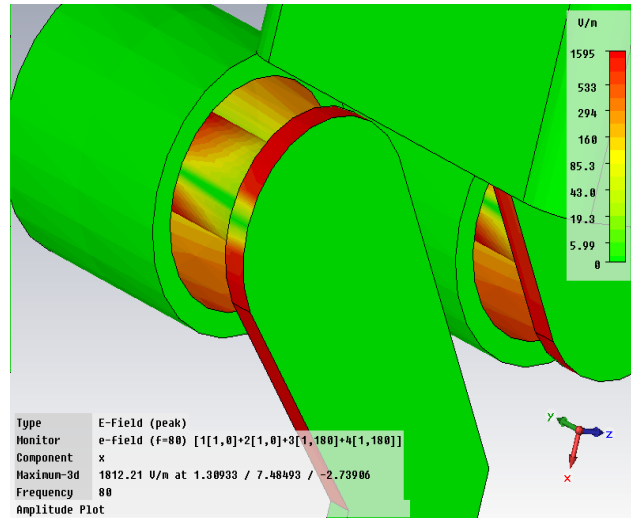


Fig. 10 Simulated Ex field in the feed system

III CONCLUSIONS

The simulation shows that the voltage obtain from integrating the fields approximately parallel to the total B field is substantially different between the horizontal and 10° tilt. The indicator of this difference “The Ratio” indicates that difference is over an order. This implies that the forces along the B field lines can be reduced and order by tilting the antenna 10°. Also the simulations show a good agreement between evidence of breakdown in the feed system and high E fields parallel to the total B field.

IV REFERENCES

- [1] S. J. Wukitch et al., J. Nucl. Mat. “363-365”, 419 (2007)