# SIMULATIONS VS. MEASUREMENTS ON IPHI RFQ COLD MODEL

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*Abstract*

The IPHI RFQ cold model is a good bench to test the validity of MAFIA simulations, since the design of the real RFQ is based on such simulations. Though absolute frequencies are not significant because of MAFIA staircase approximations, vane-end matching is pretty well predicted: accurate field measurements on a 1-m long configuration showed excellent agreement vs. simulation with or without dipolar stabilizer rods. Simulations also confirmed the small discrepancy between electric and magnetic field bead-pull measurements. Also, monopolar local modes in vane-end regions were measured at frequencies close to calculated ones. Finally, measurements, MAFIA simulations, and recent SOPRANO ones, confirm the high increase of RF losses in vane end regions.

## 1 INTRODUCTION

As the IPHI RFQ was preliminary designed from 2D Superfish calculations, many 3D adjustments had to be made. This was done with MAFIA, by difference between 2D and 3D structures with the same mesh grid [1]. Thus, inherent frequency bias caused by the mesh approximation is almost cancelled. Our RFQ cold model in its 1-m configuration with flush plungers is a good tool to test the validity of the design method, associated with the vane voltage measurement bench based on bead-pull perturbations [2].

## 2 ELECTRIC VS MAGNETIC PERTURBATION MEASUREMENTS

Bead-pull field measurements in the RFQ cold model can be made either by perturbing the electric field in the central region, or the magnetic field in the outer quadrant (fig. 1). In a 1-m long RFQ, the tuning of a flat quadrupolar voltage profile has been made from E-field perturbation measurements [3]. We established that, after this tuning, the measured magnetic field was not totally flat and presented a slight curvature (fig. 3).

To study this phenomenon, a complete 4-quadrant 1-m RFQ with undercut-matched vane ends was simulated (without any symmetry) (fig. 2). In that structure, a bead has been introduced at different positions on a line parallel to the z-axis. Three beads were considered: a dielectric bead leaning on the vane tips, and two sizes of metallic beads in the magnetic region.

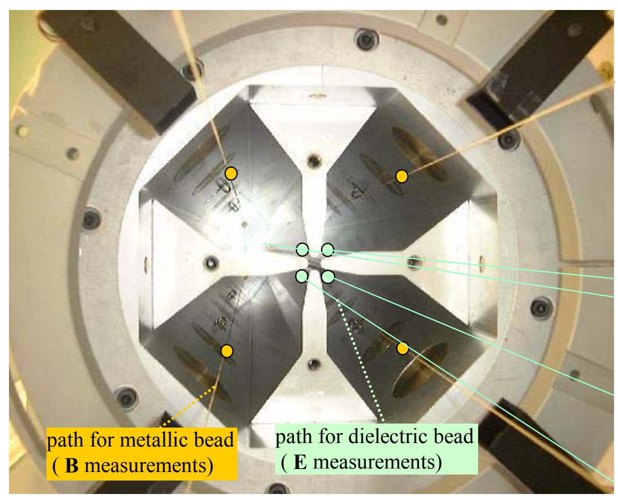


Figure 1. Electric and magnetic bead-pull measurements.

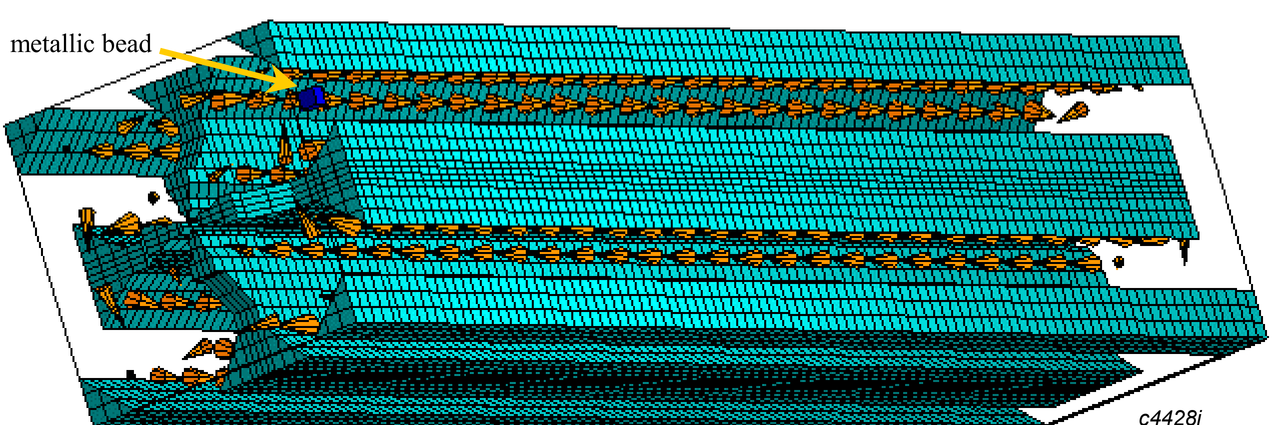


Figure 2. Simulation of magnetic field bead-pull measurement in a 1-m RFQ.

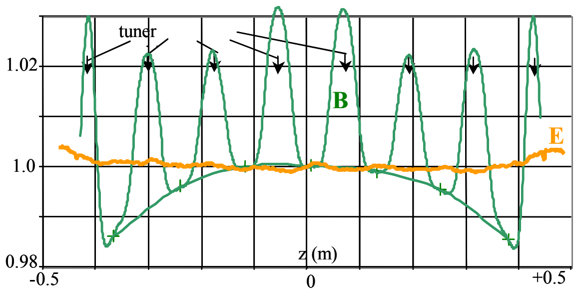


Figure 3. Field measurements in the tuned cold model from E-field perturbation. B exhibits a slight curvature.

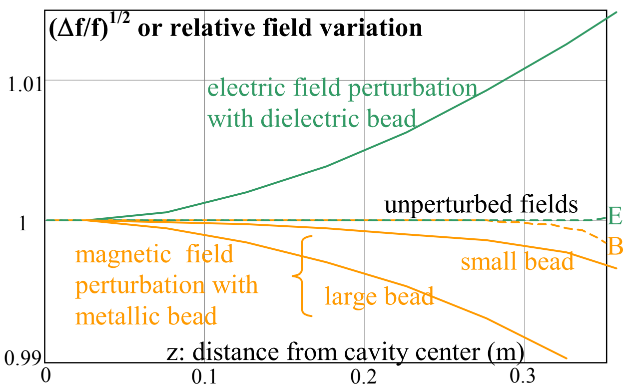


Figure 4. Simulation of bead-pull measurements.

MAFIA calculated frequency shifts caused by the bead, and the field was deduced from Slater's perturbation formula. It came out a slight error in the field curve, whose sign depends on the perturbed field (E or B) (fig. 4). The assumption that the error is proportional to Δf in the cavity center is fully compatible with our simulations and explains exactly the discrepancy in the measurements (fig. 3).

We conclude that too big beads should be avoided for our measurements. The 16-mm-long ∅-8-mm metallic bead for magnetic measurement that will be used in the real RFQ causes a small enough frequency shift (typically, Δf=-39 kHz in a 1-m RFQ) to keep the error much below our goal (less than 1 %).

## 3 VANE END MATCHING

We measured the magnetic field in the 1-m RFQ with flush plungers without and with dipolar stabilizer rods. Vane ends were supposed to be matched by appropriate undercuts, according to MAFIA simulations: no frequency shift and flat voltage. Indeed, we obtained a very flat B(z) curve (fig. 5). Measurements were sensitive enough to see the residual effect (about 0.1%) of the plungers in spite of their flush position. After correction of the effect mentioned in previous section, the residual curvature gives the frequency shift between the 2D proper frequency of the structure and the actual 3D cavity frequency: $\Delta f=(f/2)\,(\lambda/2\pi)^2\,V''/V=$ -20 kHz. We conclude that vane end mismatch is -0.01 m.MHz. It is much lower than the tuning range planed for the real RFQ (±0.55 m.MHz).

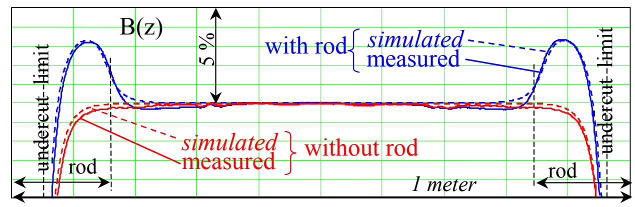


Figure 5. B field simulation/measurement in the cavity with flush tuners, with/without dipolar rod stabilizers.

## 4 MONOPOLAR LOCAL MODES

In such a resonant mode, magnetic field lines circle around the four vane ends through undercuts, and the four vanes keep the same potential; energy is localized in the vane end region (fig. 6). Rods dramatically influence the resonant frequencies. Such modes have been observed on our mock-up, in a 2-section configuration without dipolar stabilizer rods in coupling region, in good agreement with simulations (table 1). In the real RFQ, we will have to make sure that the presence of rods does not shift the monopolar local mode frequencies too close to the operating frequency (352.2 MHz).

Table. 1. Frequency of monopolar local modes.

| mode | coupling-gap | plate |
|---|---|---|
| MAFIA | 488 MHz | 1023 MHz |
| measurements | 469 MHz | 1014 MHz |

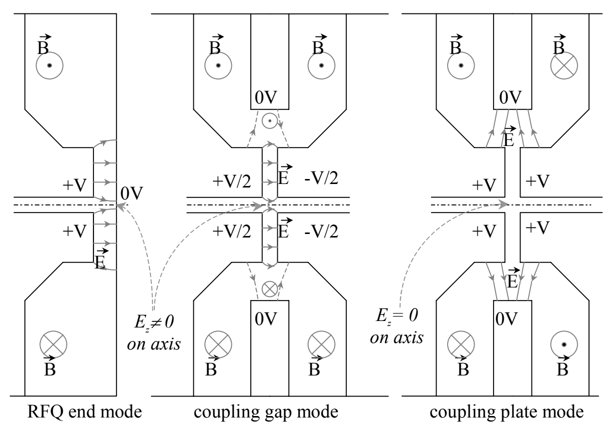


Figure 6. Different types of monopolar local modes.

## 5 LOSSES IN VANE UNDERCUTS

As MAFIA predicted very high RF losses in undercut regions, we wanted to check the reality of this phenomenon. We used the cold model equipped with vanes that have exactly the same profile as the ones of the first meter of the real RFQ. Using the bead-pull bench with a small metallic sphere (∅2.5 mm) on a wire tightened between two adjacent quadrants (fig. 7), we were able to measure the $B^2$ enhancement around the undercut, at a 75-mm distance from axis.

A geometrical model was imported from I-DEAS for MAFIA calculations. Loss data (fig. 8) were sent back to I-DEAS with our transfer software MAPFLUX in order to use the same method than during the RFQ thermal studies [3]. As some noise (due to the staircase approximation in the MAFIA model) corrupted the data, they were smoothed though a 4-mm wide window.

Recently, progress on SOPRANO permitted to do the same simulation, with the advantage of the triangular mesh of this software (fig. 9).

After evaluating the squared magnetic field along the bead trajectory, we plotted the result for the three methods normalized to its value far from undercuts (fig. 10). We observe that measurements qualitatively confirm the power density enhancement in undercuts. The lower peak value in measurements is easily explained by the non-negligible bead size (measurement path is 1.25 mm away from the surface), and by the fact that electric field contribution was neglected. Comparing the two simulations, MAFIA and SOPRANO agree about the amplitude of loss enhancements, though the position of the maximum slightly differs. As they also agree about global losses, our conclusions about thermal effect computed from MAFIA estimations [4], remain valid.

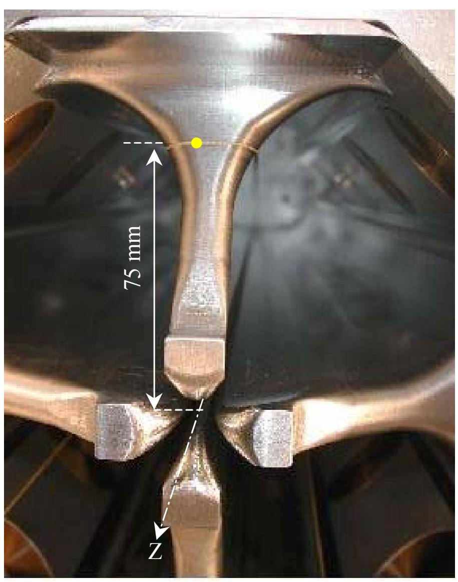


Figure 7. Bead-pull $B^2$ measurement in undercut region.

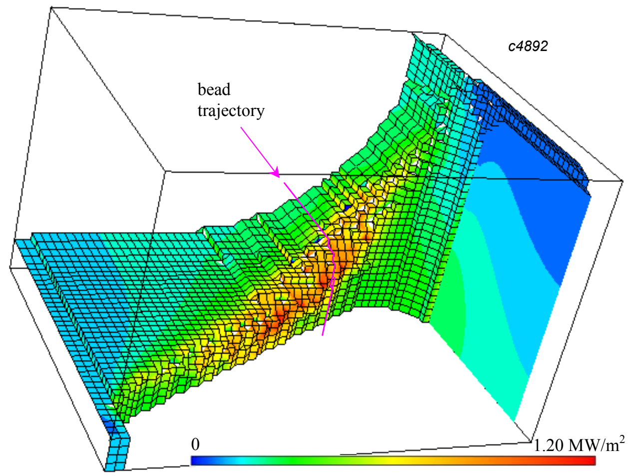


Figure 8. RF losses in undercut computed by MAFIA.

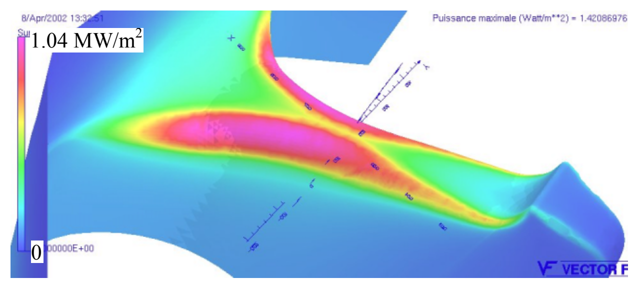


Figure 9. RF losses computed by SOPRANO.

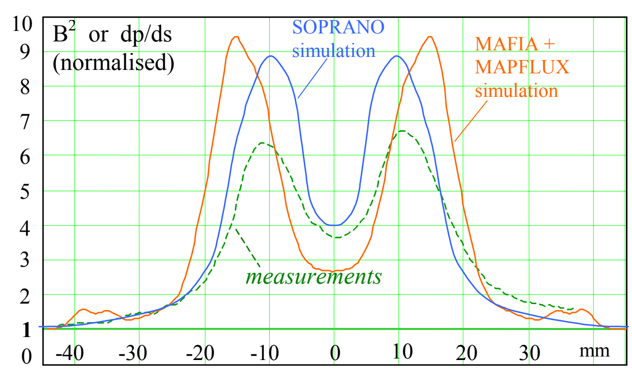


Figure 10. Losses enhancement along bead trajectory.

## 6 CONCLUSIONS

The RFQ cold model is a very useful bench to get confidence in our simulations. Bead pull measurements are very sensitive and accurate. MAFIA simulations of on-axis (or parallel to axis) fields are excellent. Power densities computed by MAFIA are correct if interpreted with care: data smoothing is necessary because of discontinuities due to staircase approximation in the model. The new SOPRANO version is now a good alternative to MAFIA for estimation of RF losses.

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## REFERENCES

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