NEW METHOD FOR OVERCOMING DIPOLE EFFECTS OF 4-ROD RFQs

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Introduction

The asymmetrical structure of 4-rod RFQs will cause dipole modes. Which can have a negative impact on the design beam performance. A 4-rod RFQ can be described by a chain of capacitively shortened $\lambda/4$ resonators. Like for any quarter wave structure, there is a voltage gradient along the height of the stem structure, which leads to higher potential on the upper electrodes [1]. This is the origin of the dipole effect for 4-rod RFQs (see Fig. 2).

To compensate this effect the current path lengths of the two stems must be balanced. The classical way to compensate the dipole field is to make an inner cutting on the stem [3]. Various new methods to compensate dipole field components have been proposed, which use path deviations or alternating stem displacements perpendicular to the beam axis [2].

In this paper, a new idea to modify the electrode holder of the arm to the lower electrodes based on the classic method is being proposed. It prolongs the current path to the lower electrodes by shifting the electrode holder in longitudinal direction by Δz (see Fig. 1).

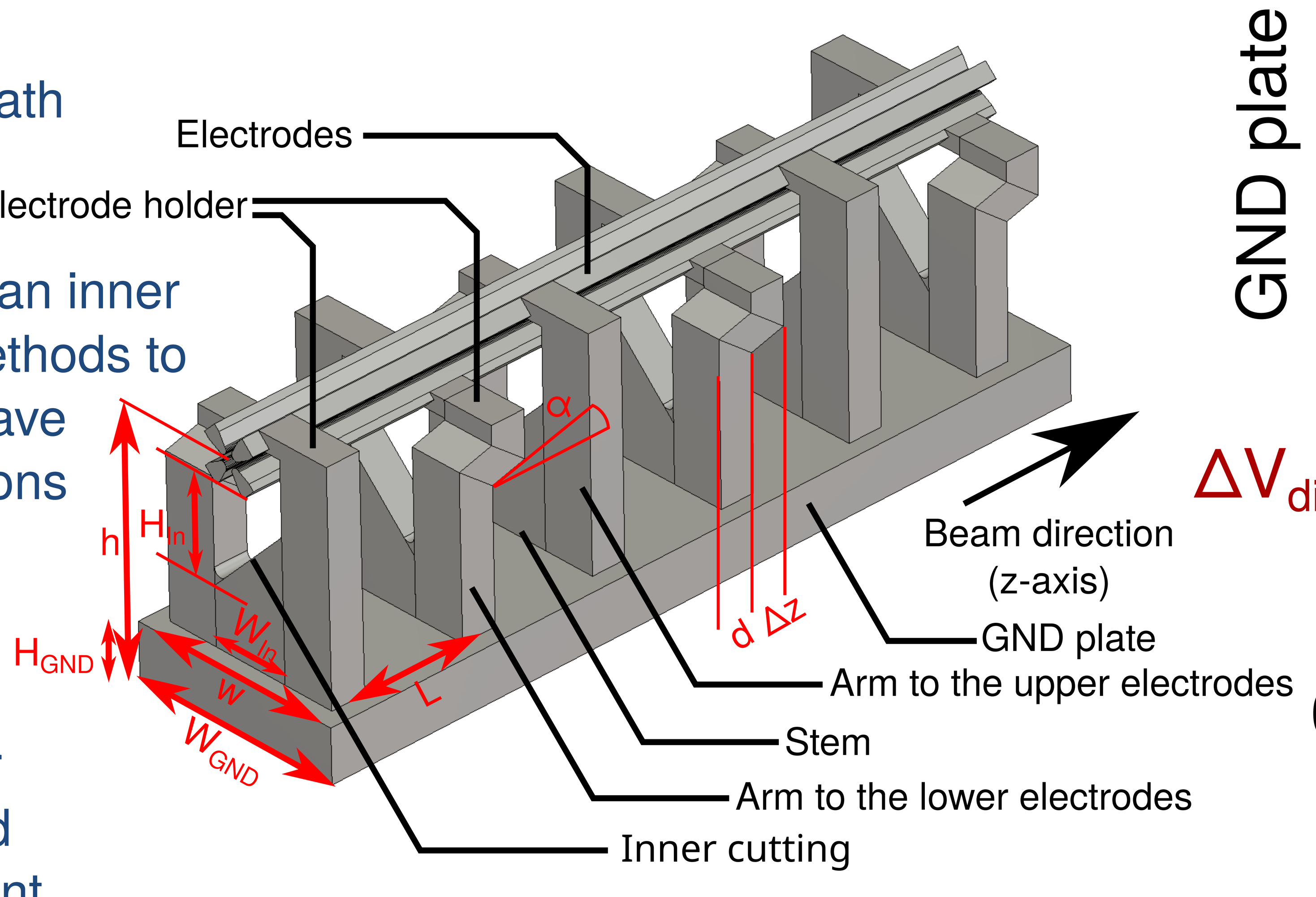

Figure 1: New type 4-rod RFQ model. This particular model uses an electrode holder shift Δz = 20 mm with a rotating angle α = 15°.

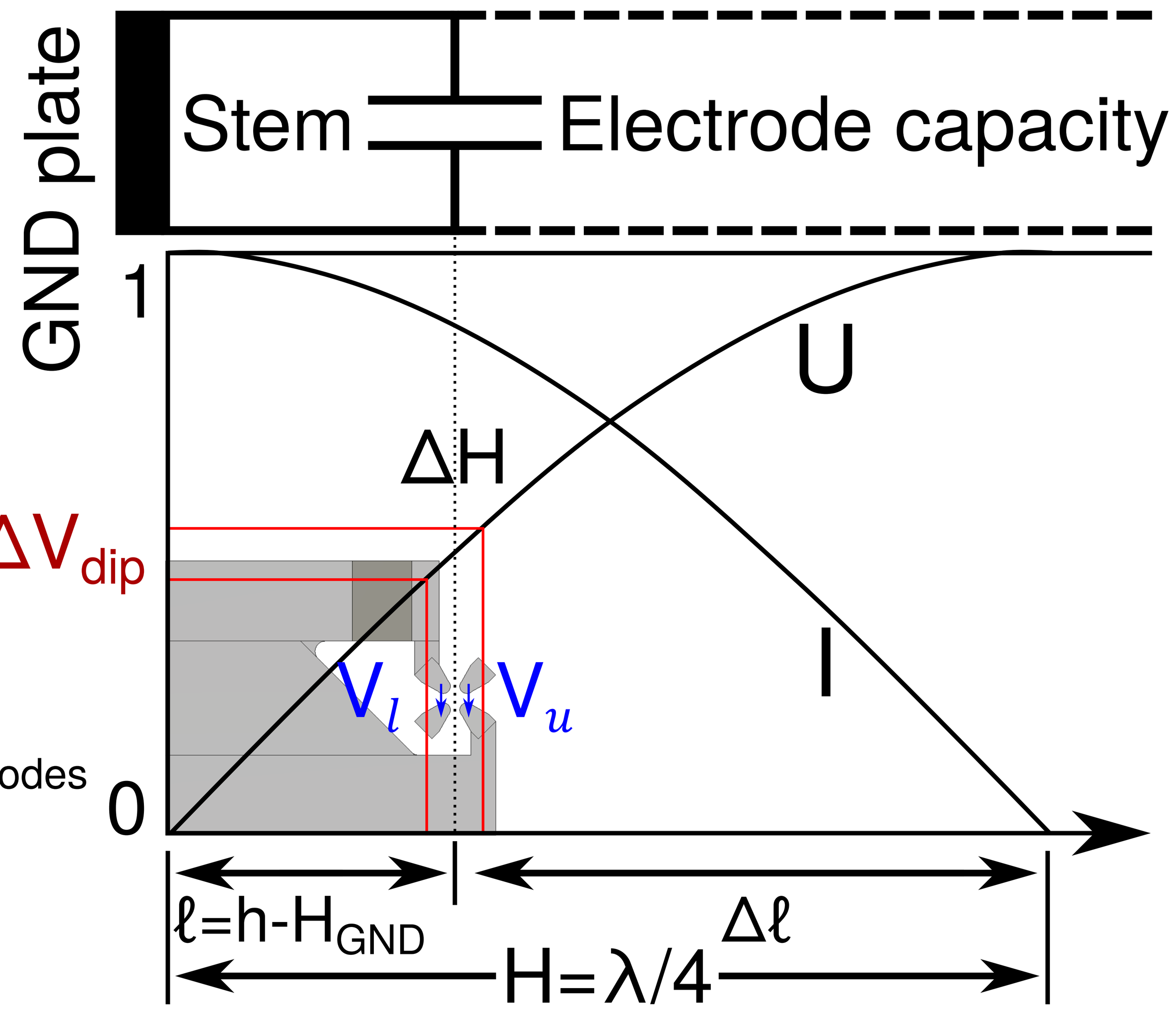

Figure 2: Potential distribution along the height ℓ of the stem. Showing the voltage difference between the upper and lower electrode pair ΔV_{dip}. V_u and V_l are the absolute voltages used for the dipole factor calculation [1].

Simulation: Analysis

In the ideal case, the voltage between the upper electrode pair V_u and the lower electrode pair V_l is the same, but with inverted polarity (see Fig. 2). The dipole mode perturbs this equality, increasing one of the voltages and decreasing the other by means of superposition. This effect can be expressed by the dipole factor DF:

$$DF = 1 + \frac{V_u - V_l}{V_l}$$

$DF > 1$ means that the current path of the arm to the lower electrodes is shorter than the current path of the arm to the upper electrodes—the system is undercompensated. Accordingly, $DF < 1$ means overcompensation and $DF = 1$ means that the system is balanced with equal current paths.

References

[1] B. Hofmann, "Untersuchungen an einem RFQ-Beschleuniger für hohe Betriebsfrequenzen," Diplomarbeit, Goethe University Frankfurt, 2004.

[2] B. Koubek, H. Podlech, and A. Schempp, "Design of the 325 MHz 4-rod RFQ for the FAIR Proton Linac,"en, Proceedings of the 6th Int. Particle Accelerator Conf.,vol. IPAC2015, USA, 2015. DOI: 10 . 18429 / JACOW -IPAC2015-THPF022.

[3] K. Kümpel, A. Bechtold, H. Lenz, N. Petry, H. Podlech, and C.Zhang, "Dipole compensation of the 176 MHz MYRRHA RFQ,"en, Proceedings of the 8th Int. Particle Accelerator Conf.,vol. IPAC2017, Denmark, 2017. DOI: 10 . 18429 / JACOW -IPAC2017-TUPVA070.

[4] CST Studio Suite, www.cst.com

Simulation: Results

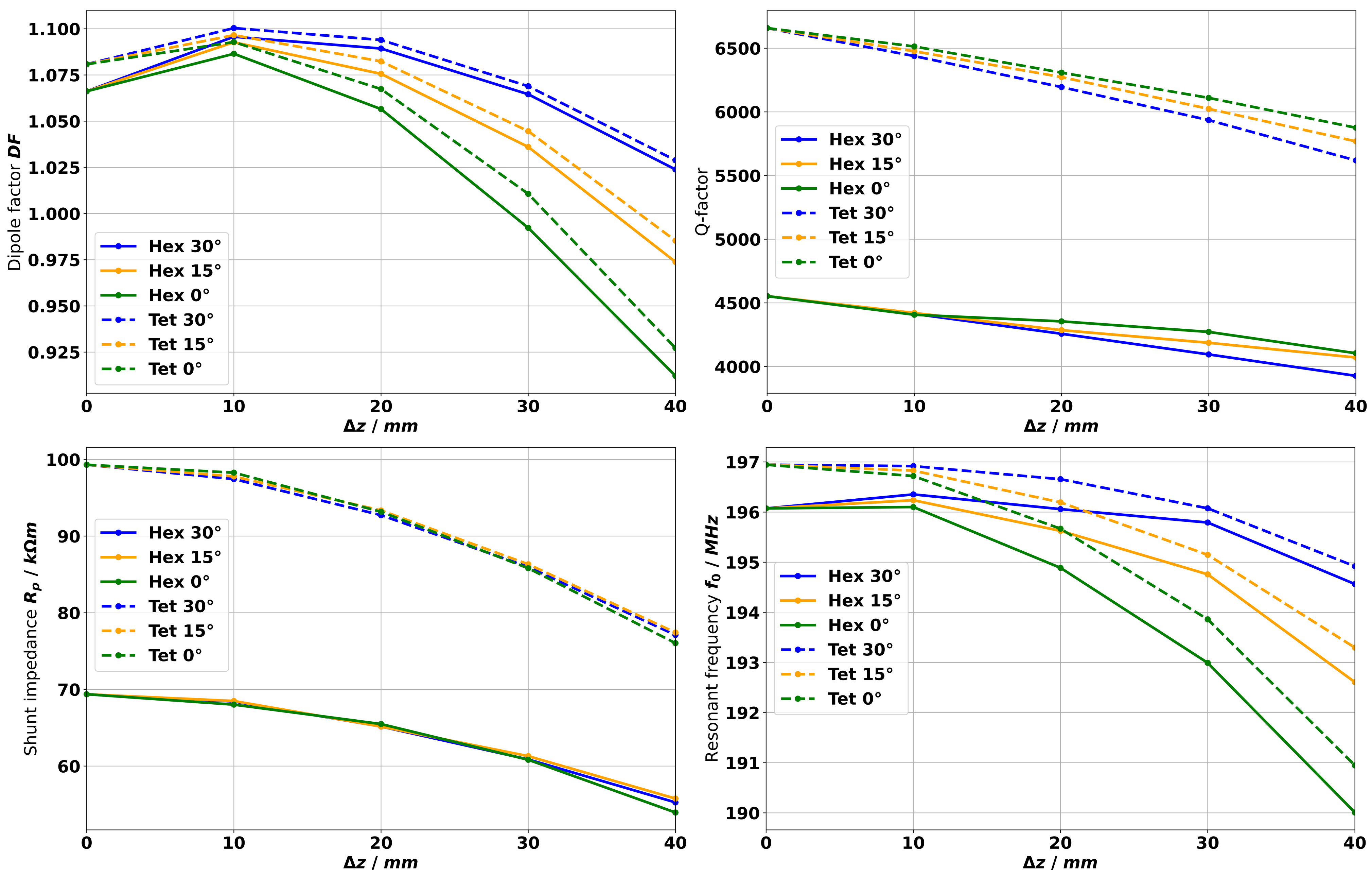

Figure 3: Dipole factor DF, Q-factor, specific shunt impedance R_p, and resonant frequency f_0 vs. Δz for tetrahedral and hexahedral meshes at different α.

Simulations with CST Studio Suite [4] have been performed on the new model with different settings for the electrode holder shift Δz as well as the rotating angle α (see Fig. 1).

Simulation results show a decreasing dipole factor DF with an increasing Δz. Depending on α the dipole factor decreases with different gradients. The current path balance point was found around Δz = 29 mm for α = 0° and Δz = 35 mm for α = 15°. The model with α = 30° did not reach DF = 1 even at the maximum Δz = 40 mm—it stays undercompensated (see Fig. 3).

The simulation results show that the new method can compensate the dipole field components successfully. This is a preliminary study to prove the principle of the method.

More detailed studies will be performed in the future, especially focusing on the open questions:

- To improve shunt impedances and Q-factors, which suffered from the new style dipole compensation.
- To understand the difference of the simulation results using hexahedral and tetrahedral meshes.