Effects of RFQ machining errors.

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Assumptions:

- The modulation *shape* in section 1 is correct but offset from the correct position.
- The offset is ~1.4mm longitudinally and ~0.2mm transversely, equal for all vanes.
- The transverse offset is away from the beam axis.
- The longitudinal offset is ‘trivially’ corrected and not considered further.
- The final 3 sections are made correctly.

Beam dynamics.

The effect of increasing the vane separation is to reduce the transverse field strength in section 1 by ~10%.
The longitudinal field strength at the end of section 1 is reduced by ~14%.

Three cases simulated:
(a) Nominal case
(b) Section 1 as built, 2-4 nominal
(c) Section 1 as built with +12% field level, 2-4 nominal

	(a)	(b)	(c)
Transmission (%)	96	93	96
W_{final} (MeV)	3.014	3.017	3.016
$\varepsilon_{x/y}$ (πmmmrad)	0.36/0.35	0.38/0.36	0.36/0.35
ε_z (π°MeV)	0.21	0.21	0.22
$\Delta\phi_{rms}$ (°)	11.2	11.1	11.3
ΔW_{rms} (keV)	18.8	18.7	19.4

RF properties.

Increasing the vane separation will increase the resonant frequency.
Checked in CST:

- 1m long model of a single sector with symmetries.
- No end regions.
- No ports.

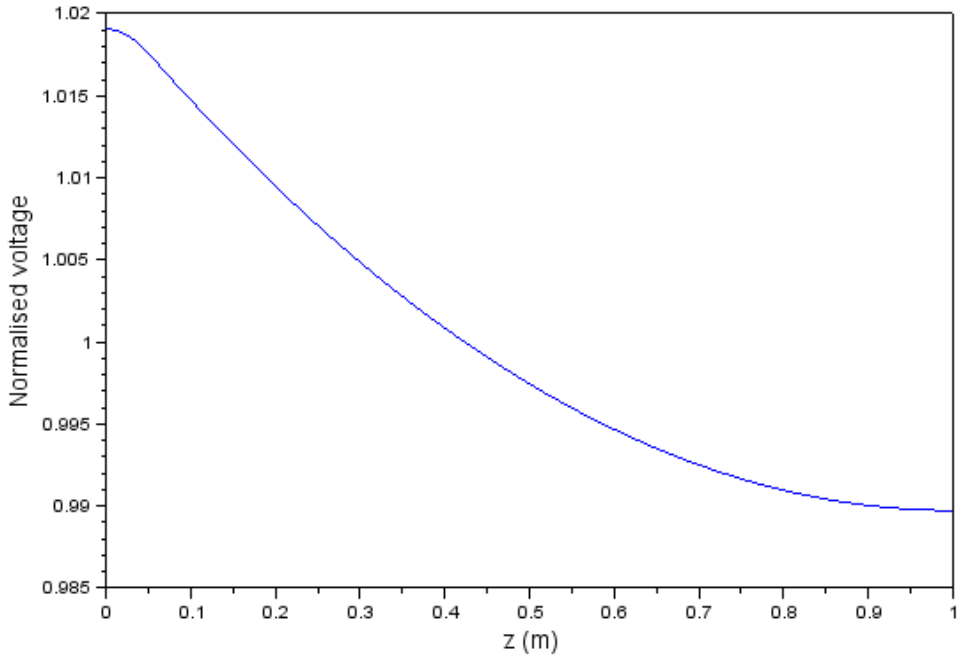
Resonant frequency of the quadrupole model increases:

323.2 MHz → 329.3 MHz

+6.1 MHz is well outside the tuneable range of the section.

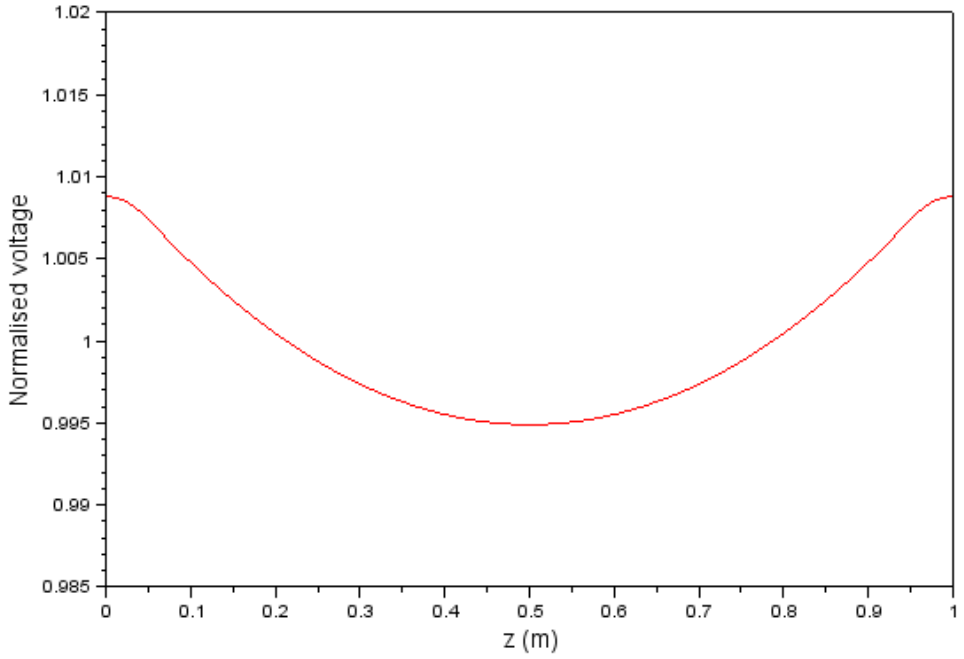
RF properties.

Actually it's more complicated due to the input end region which is probably still tuned correctly to 323.2 MHz.
With the output end region tuned to the bulk frequency of the section (329.3 MHz) the overall frequency is 329.0 MHz.
The field shape will be:



RF properties.

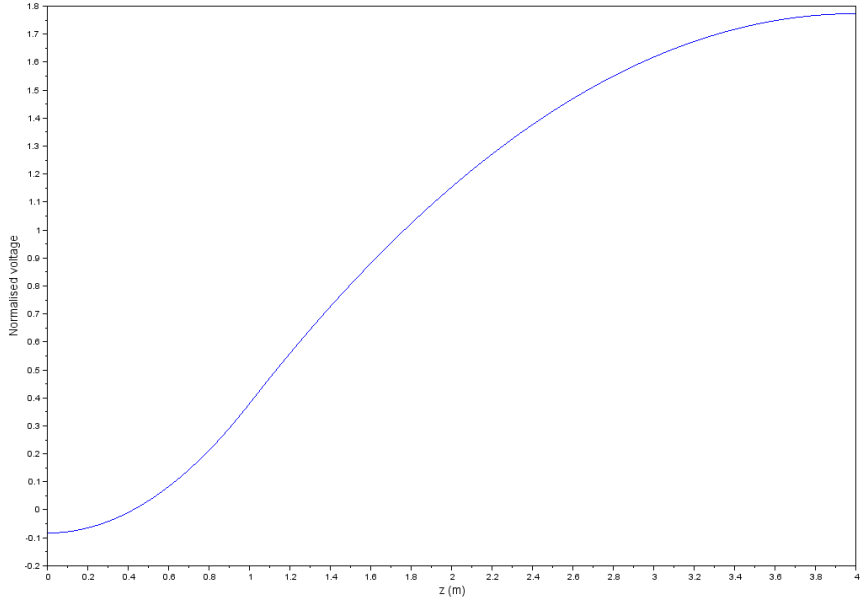
With the output end region tuned to the same frequency as the input section (323.2 MHz) the overall frequency is 328.7 MHz.
The field shape will be:



Options.

(1) Do nothing. What happens if we simply bolt section 1 as-is to the rest of the RFQ?
Overall resonant frequency increases:
323.2 MHz → 324.7 MHz

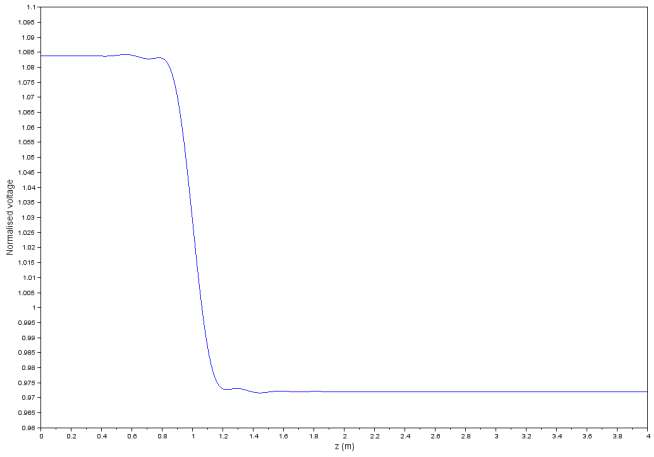
Could probably live with this but as expected the effect on the field flatness is disastrous.

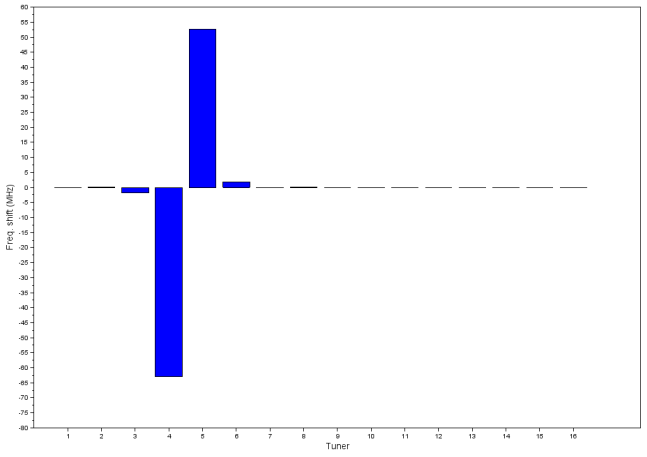


Doing nothing is not an option. Sec. 1 must be retuned to 323 MHz.

Options.

(2) Increasing the field level. What is required to produce a step function field increase in section 1 (assuming the frequency is corrected)?

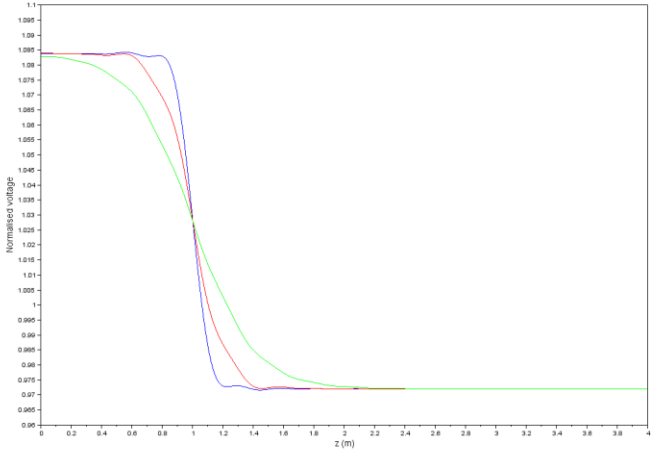


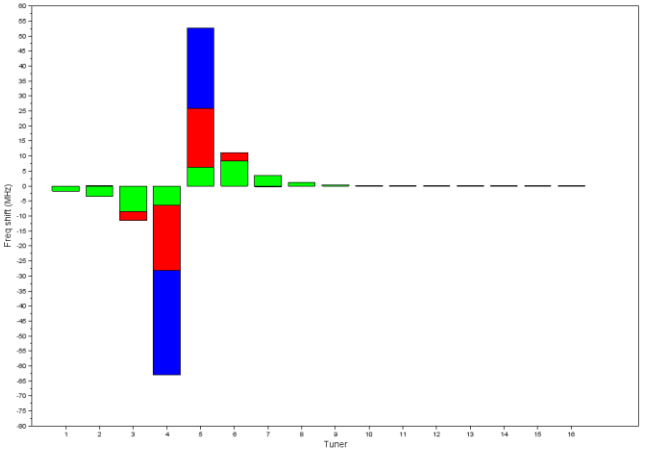


An almost arbitrarily sharp step in the field can be produced but at the expense of large (and unachievable?) tuner offsets.

Options.

(2) Reducing the slope of the field step reduces the required tuner offsets.





A sub-optimal but achievable solution looks possible.

Conclusions.

The resonant frequency shift due to the vane offsets is not tolerable. Corrective action – probably involving removing material at the outer edge of the sector – is necessary.

The effect on the beam dynamics is negative but if the errors are restricted to section 1 we may be able to live with it.

The reduction in transmission can be mostly recovered by increasing the voltage in section 1 by ~12%.

Some tuning solutions to produce the required voltage profile look possible.