Effect of RFQ machining errors II.

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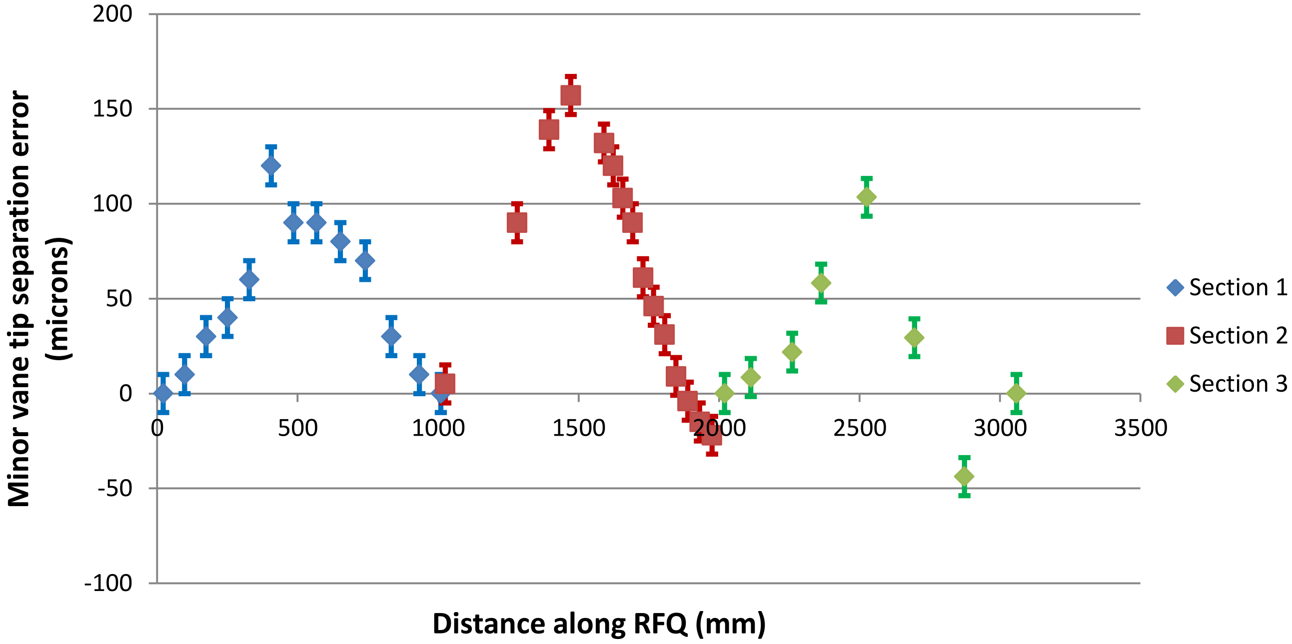
FETS meeting, 5th Aug 2015, Imperial

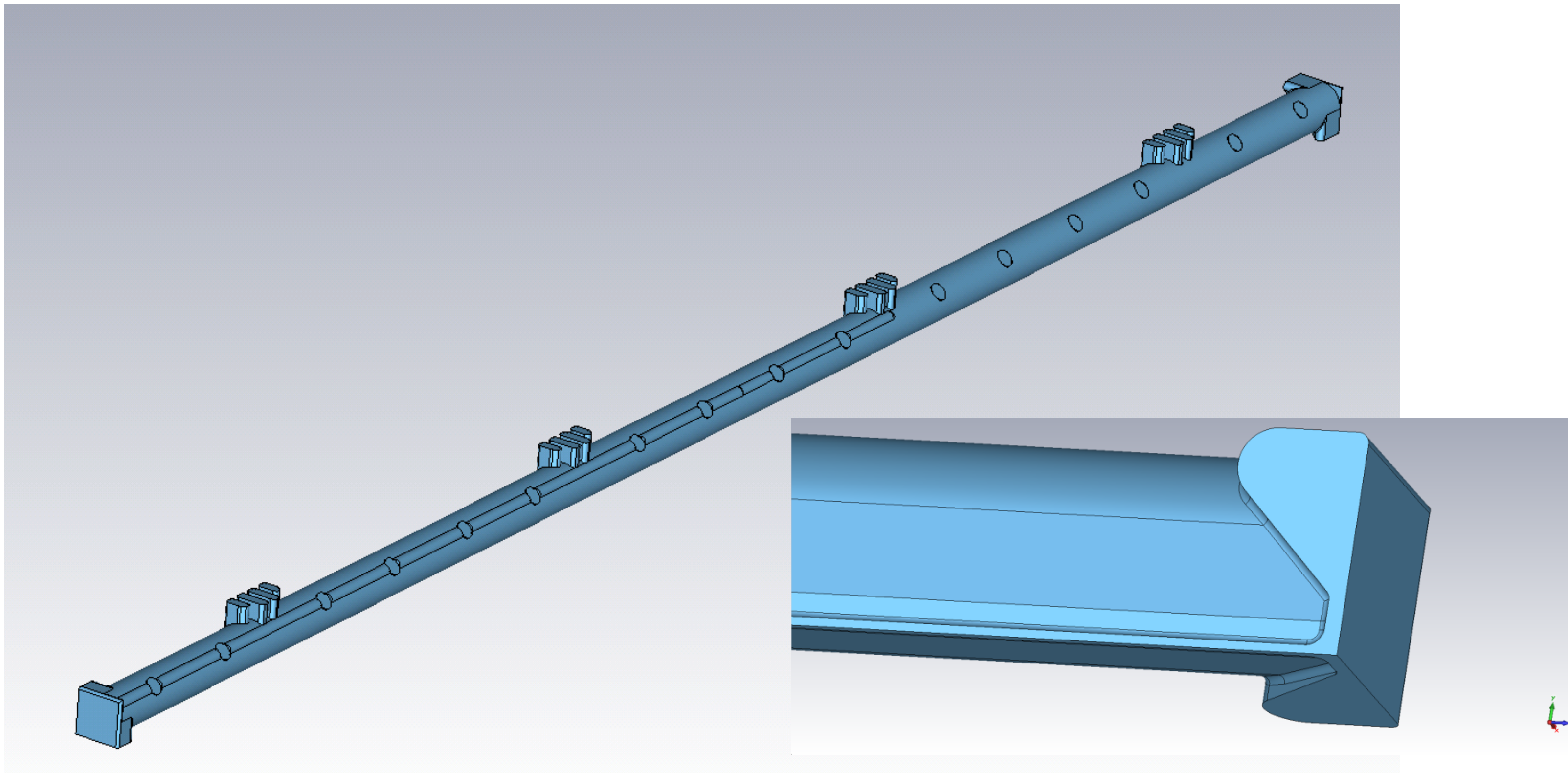
The problem:

An error has been found which results in a bow of the minor vane tip away from the beam axis. The error has been found in sections 1, 2 & 3 and is fairly consistent.



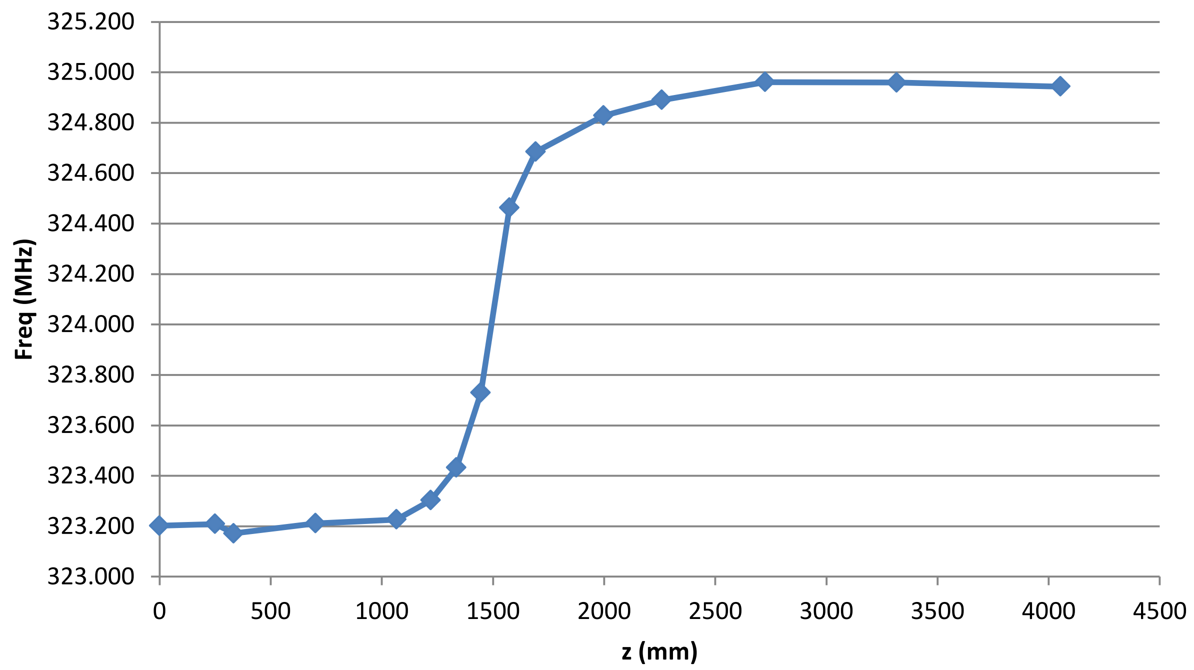
Do we have to re-machine these sections and find a solution for section 4?

In order to answer this question a complete model of the RFQ with all the important features including the errors has been generated in CST.



Due to memory limitations only one quadrant has been modelled.

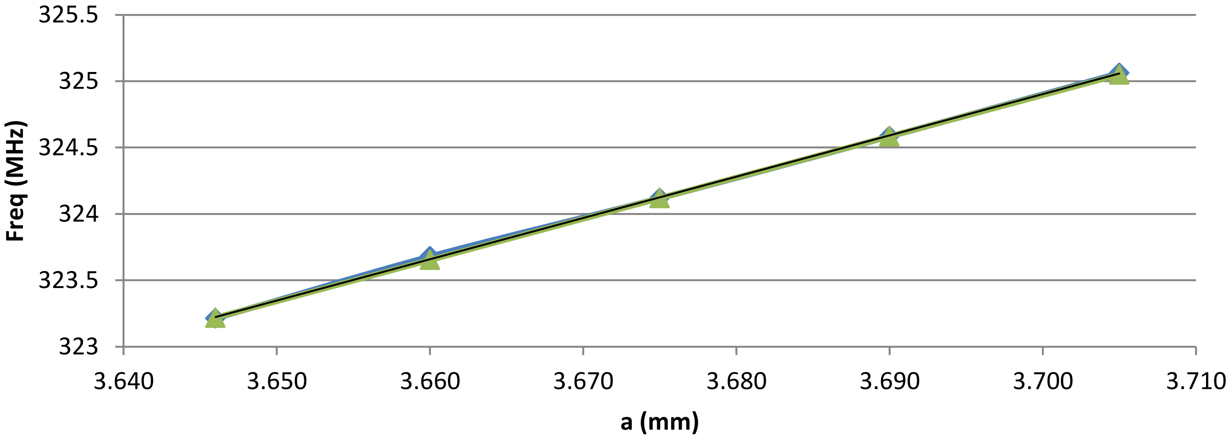
Modelling the complete RFQ is complicated by the frequency shift introduced by the vane modulation.



The frequency shift is compensated by tuning grooves in sections 2, 3 & 4 but if the grooves are to be included in the model the effect of the modulation has to be included too. Meshing limitations mean it is unfeasible to actually include the modulation in the model.

To overcome this limitation, equivalent unmodulated cell parameters have been calculated to give the same local resonant frequency.

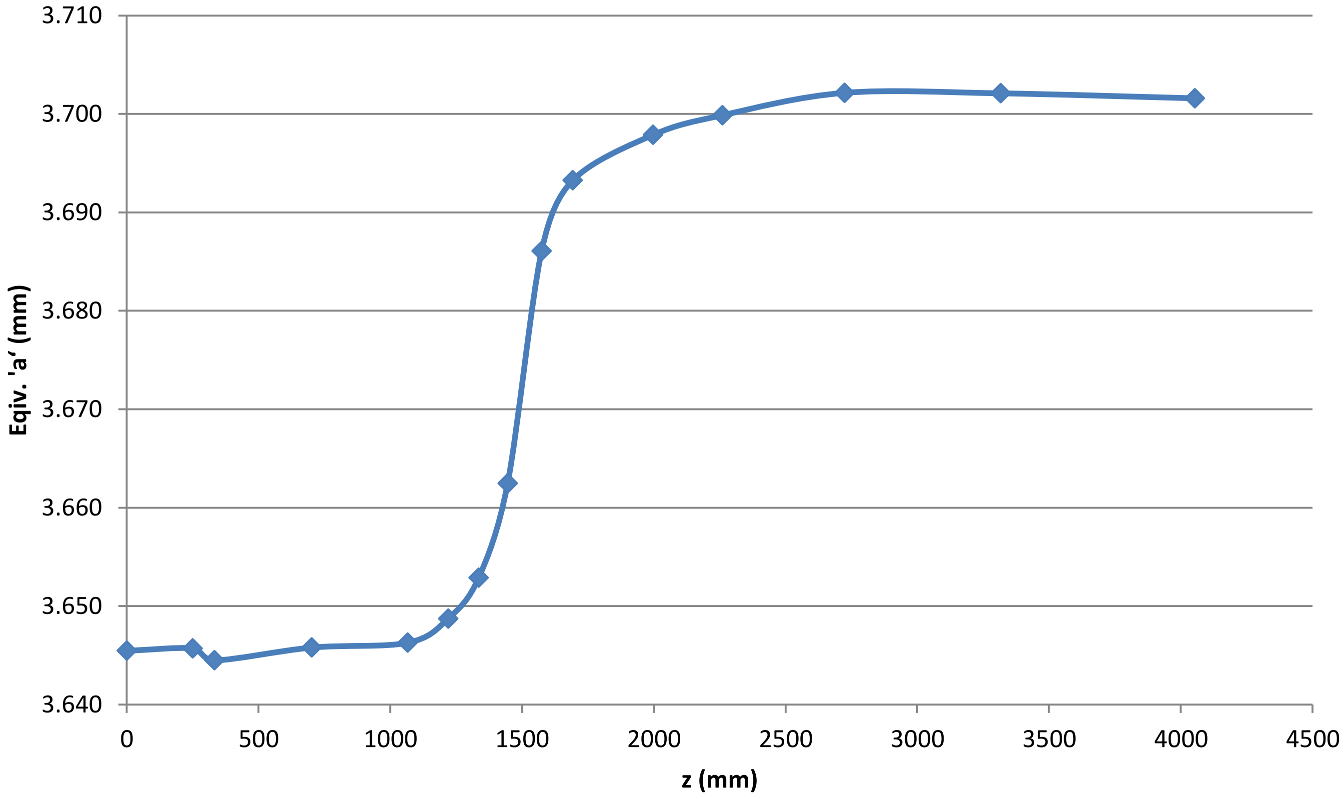
For the range of cell parameters in the RFQ the local resonant frequency is very linear in ‘a’ for unmodulated cells (m = 1.0)



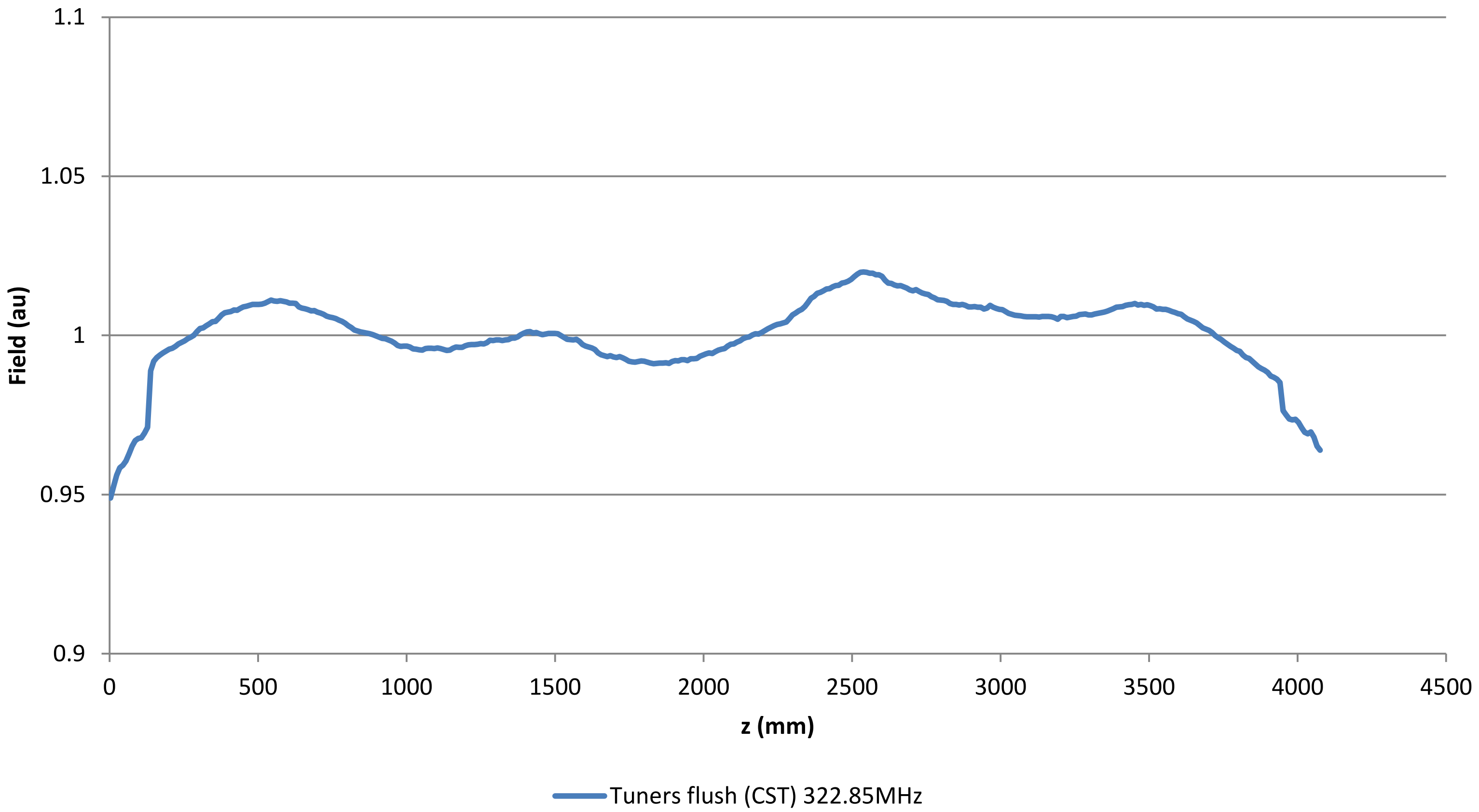
Frequency in MHz = 210.0575 + 31.037a

Where ‘a’ is the unmodulated aperture in mm

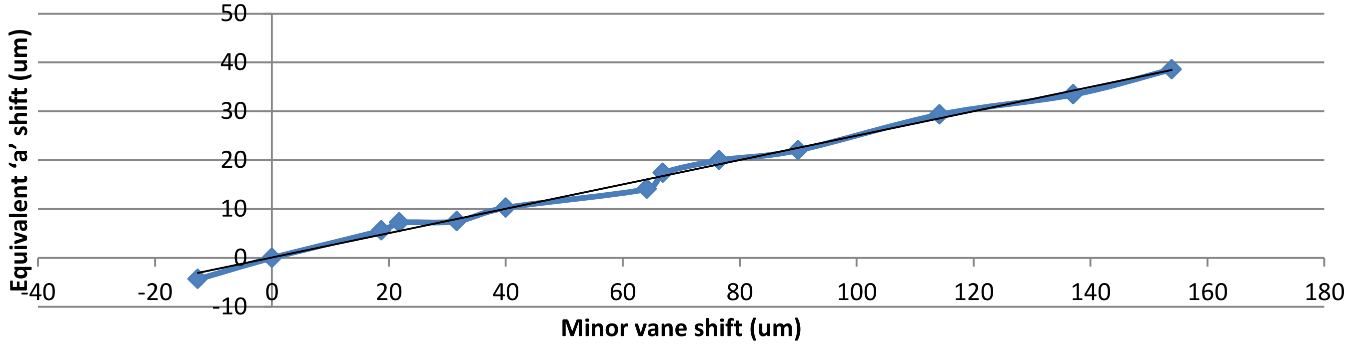
The effect of the modulation can therefore easily be included by having a smoothly varying vane aperture along the RFQ.



Including all the known effects such as modulation, tuning grooves, vacuum ports, fixed tuners etc the RFQ field from CST is reasonably flat (+/- 2%) with all the tuners in the ‘flush’ position.

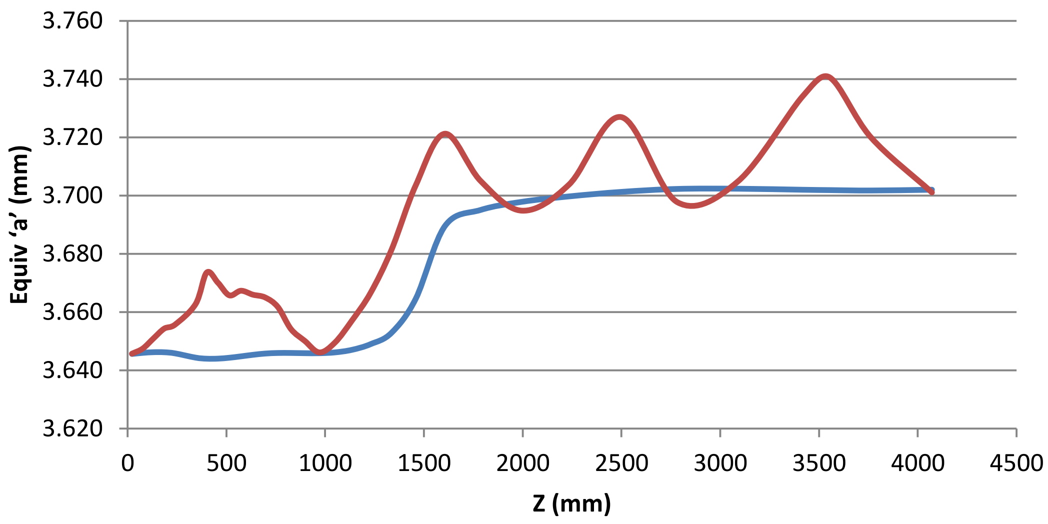


To include the effect of the minor vane errors the corresponding shift in the equivalent unmodulated 'a' was calculated by CST for a range of cell parameters and errors.



$$\Delta a = 0.09 + 0.2491\varepsilon$$

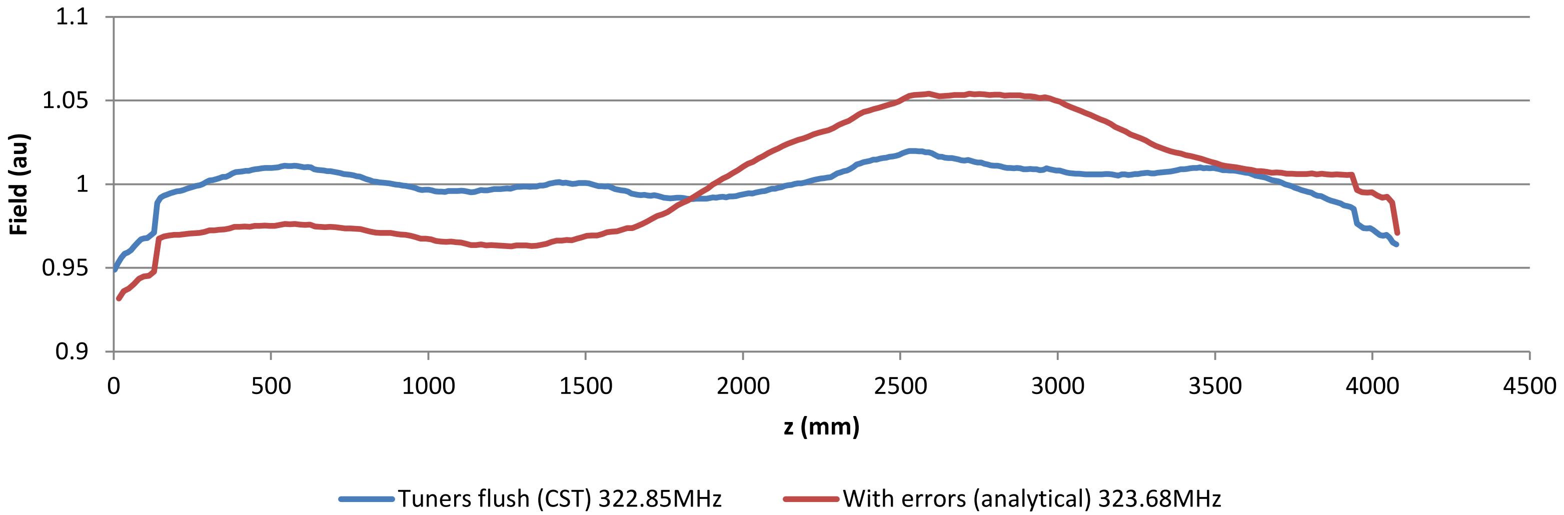
Δa and ε in μm

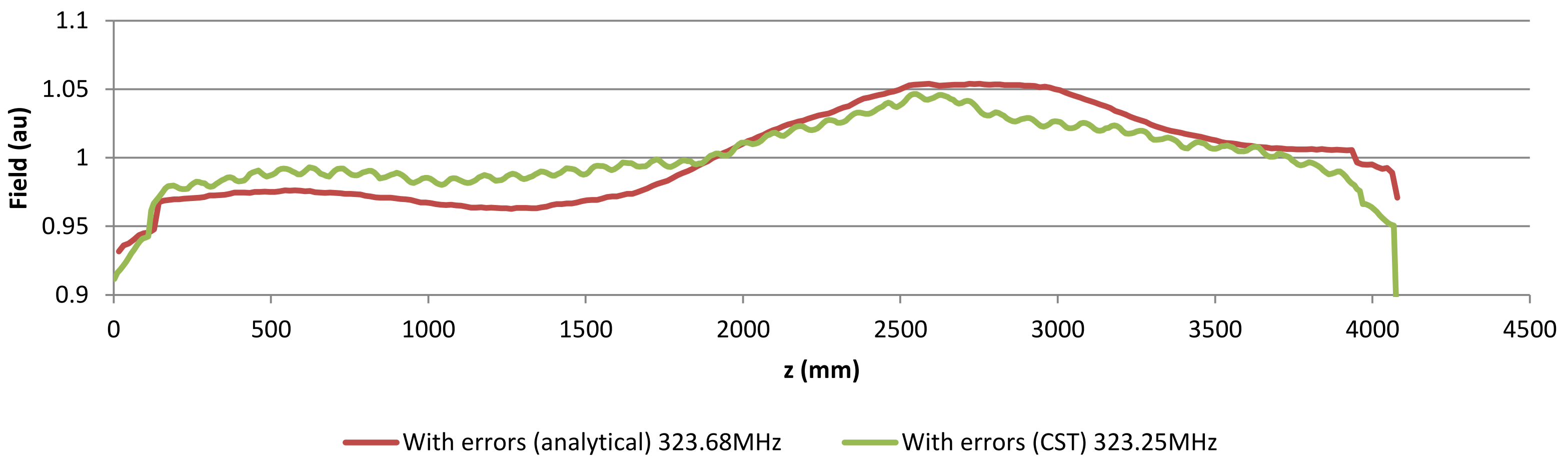


Equivalent smooth unmodulated vane aperture including the effect of modulation and errors.

Errors in section 4 are duplicated from section 2 (because section 4 isn't machined yet).

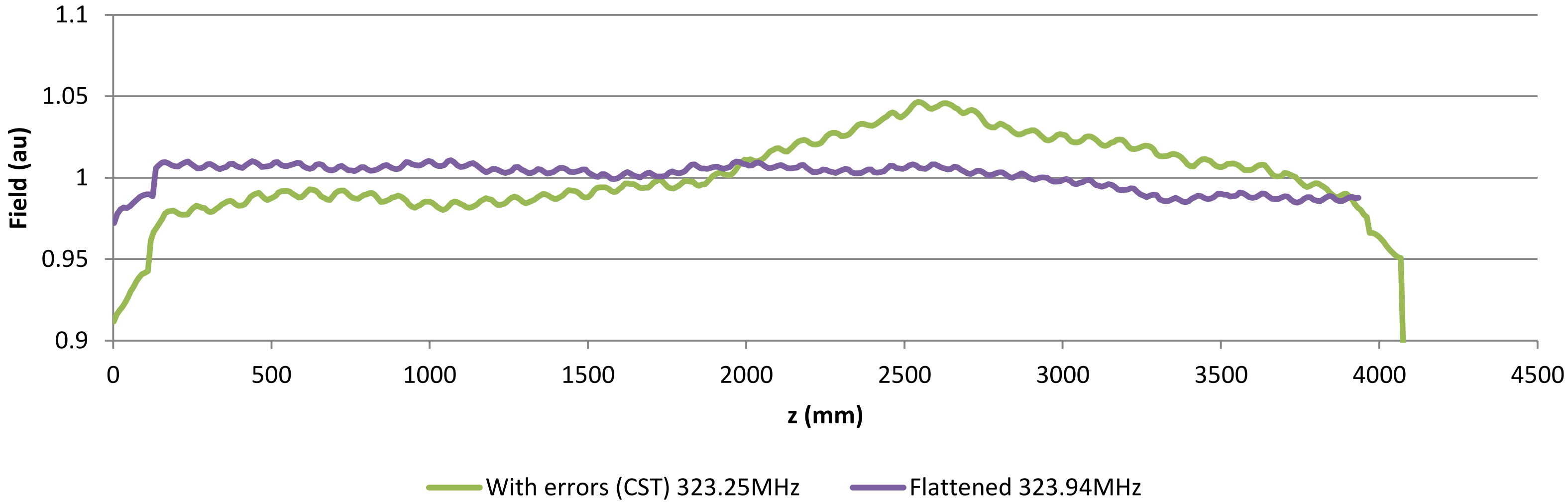
Before modelling the RFQ with errors in CST an attempt was made to calculate the effect of the errors analytically.

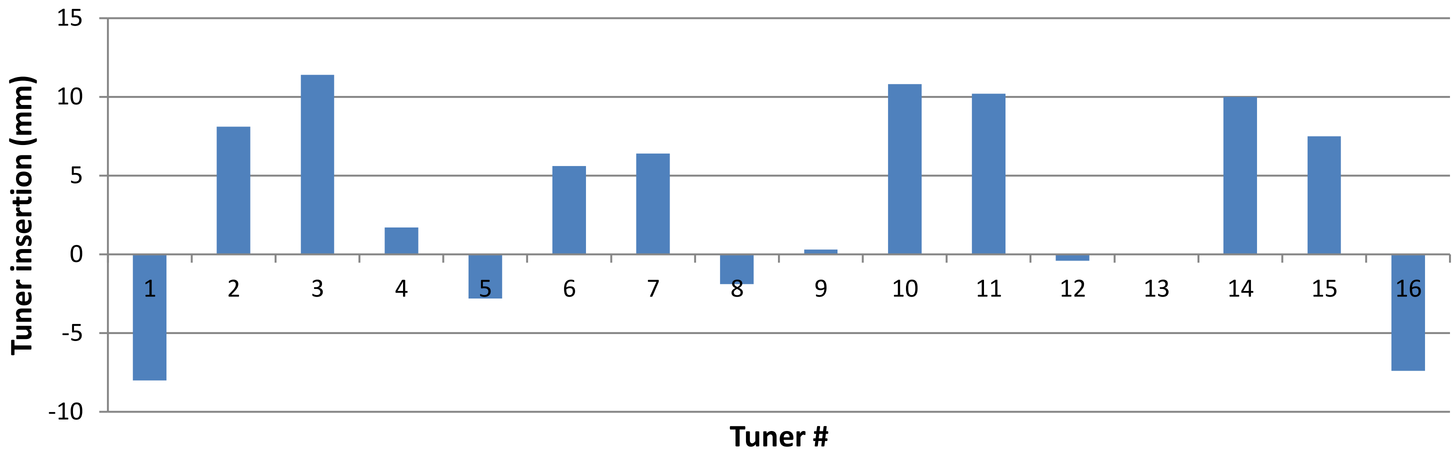




The agreement between theory and model is encouraging.

Finally tuner positions were calculated to bring the frequency to 324.000 MHz and flatten the field.





All the tuner positions are within their allowable range.

As well as the effect on frequency and field flatness, the effect of the errors on the beam dynamics must be considered.

Previously written code to generate a field map based on a tetrahedral meshing of RFQ cells was modified to include arbitrary offsets of the major and minor vanes.

Using the same errors as included in the CST model (duplicating section 2 for section 4) a field map was generated and particles tracked through the RFQ with errors in GPT.

Assuming a flat field, the change in transmission by introducing the minor vane errors was <1%.

Conclusion

Based on the modelling carried out so far it appears that the effect of the minor vane errors is negligible on the RFQ transmission and can be compensated for with the fixed tuners assuming there are no other significant machining errors and the RFQ is well aligned.