HOM cavities

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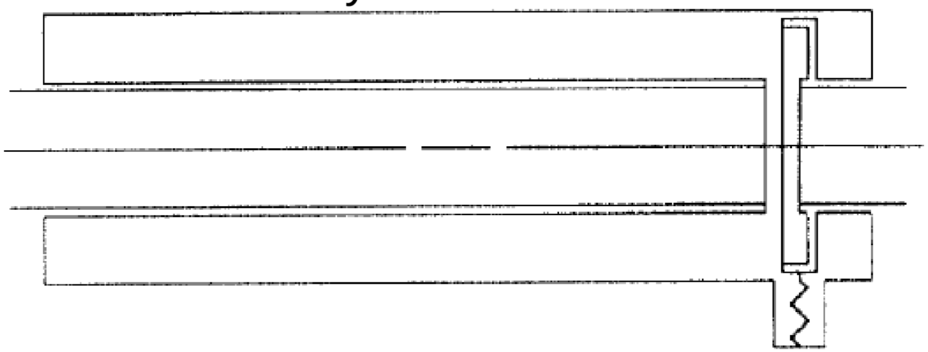
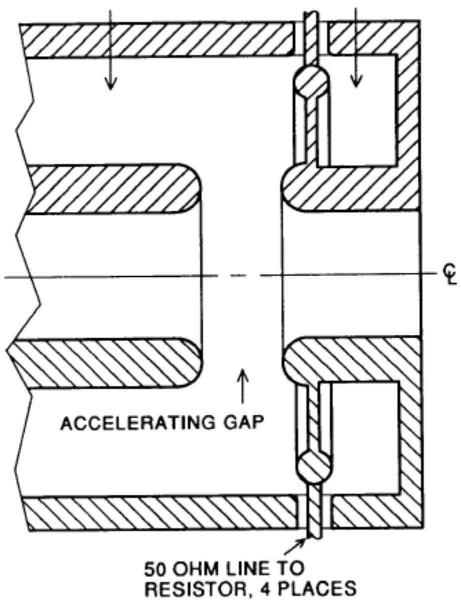
Goals

- Need HOM cavity to reduce the size of the higher order modes
  - Mainly to reduce wakefield effects from these modes.
    - Also limits depend on the shape of the beam – form factors are required.
  - What's small enough? Need to do a coupled bunch mode calculation.
    - MI Recycler cavities HOM < 0.5% of fundamental? Seems to be too stringent!
- SSC and TRIUMF use a Smythe style HOM cavity.
- If necessary, we have to consider using a Mitra style HOM cavity – more complicated.

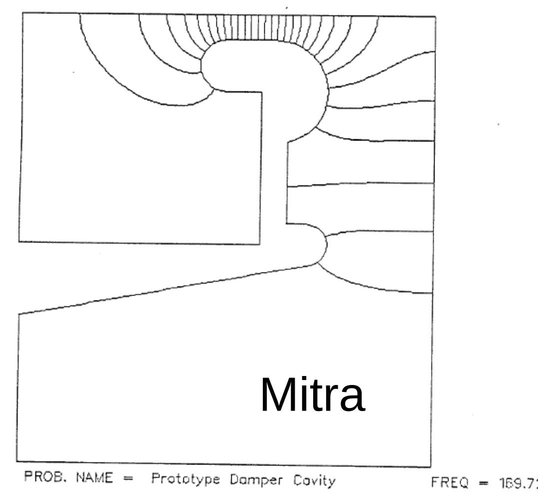
Smythe style HOM cavities and its derivatives

Smythe v1

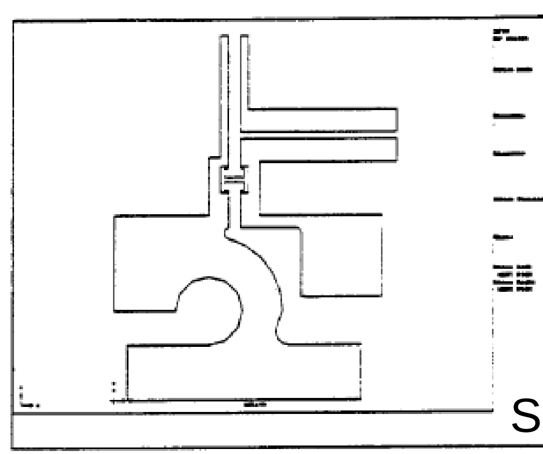




Smythe v2

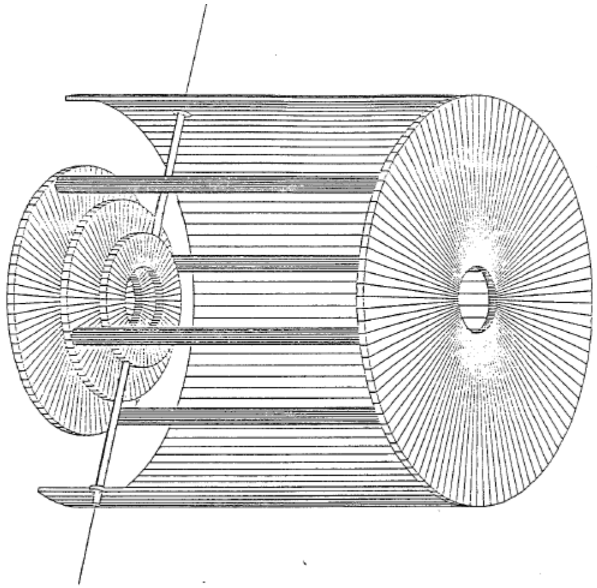


Mitra



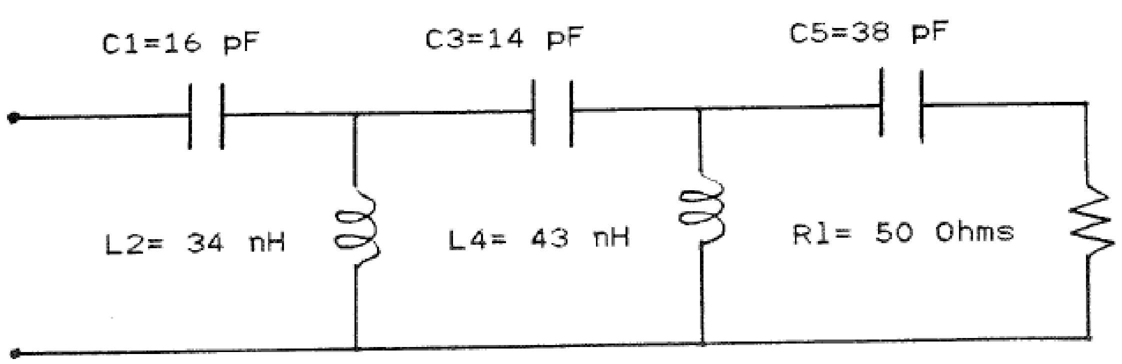
SSC

Mitra Chebyshev HOM cavity



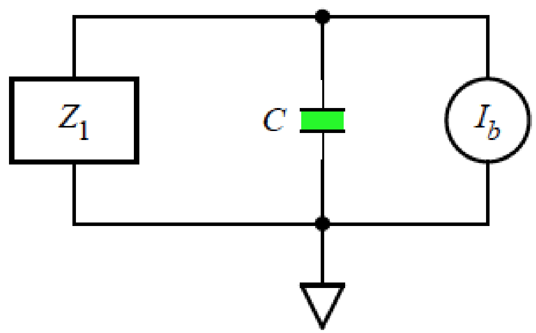
Advantage is that we can have very good suppression of higher order modes. But definitely a lot more complicated.

Does this really work with beam? No published results at this time.



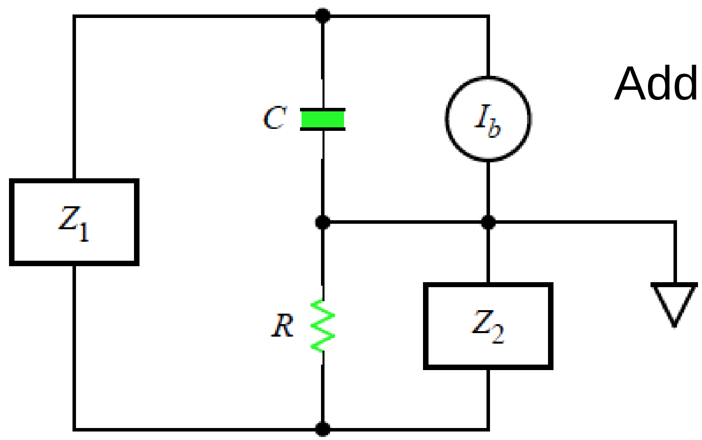
Can do analytic calculation to understand effect of HOM cavity

(a)



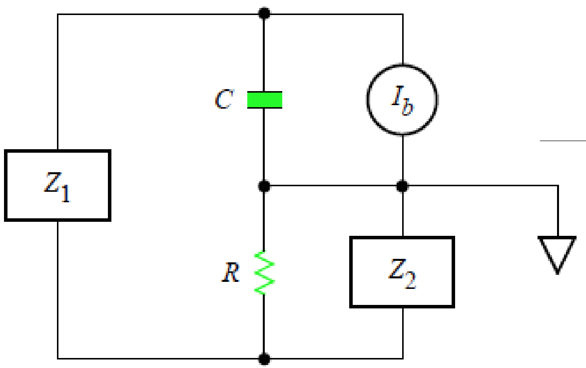
Z_1 is shorted transmission line. No HOM cavity

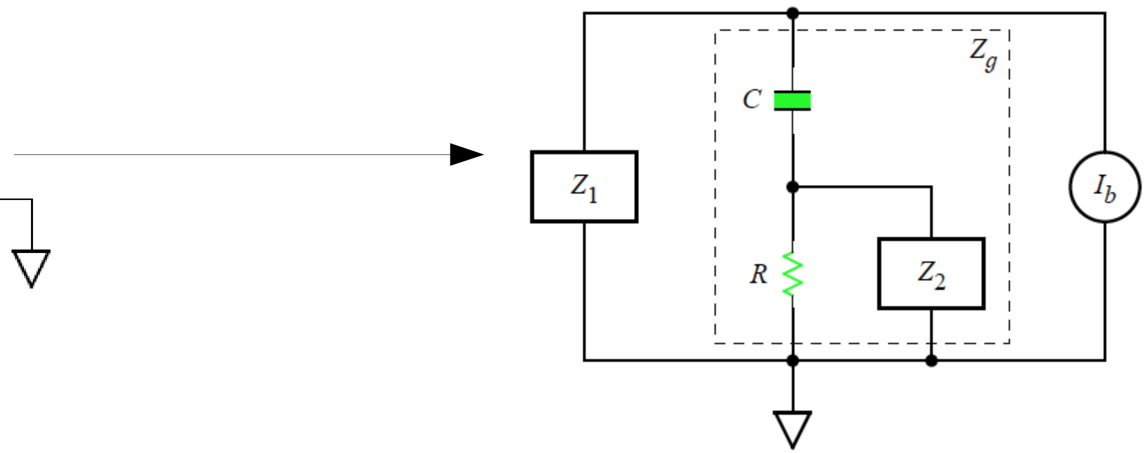
(b)

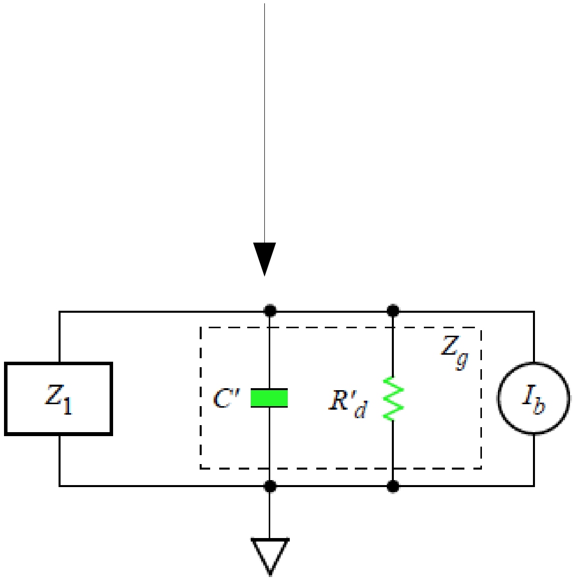


Add in HOM cavity Z_2 and load resistor R.

Make approximations to calculate a damping resistance R'_d







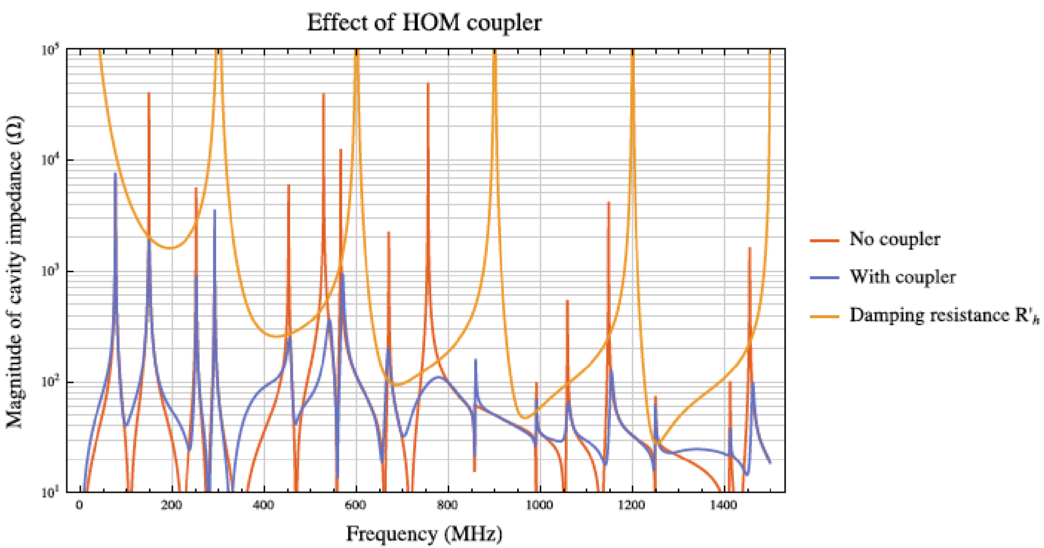
Approximation comes from Smythe.
See

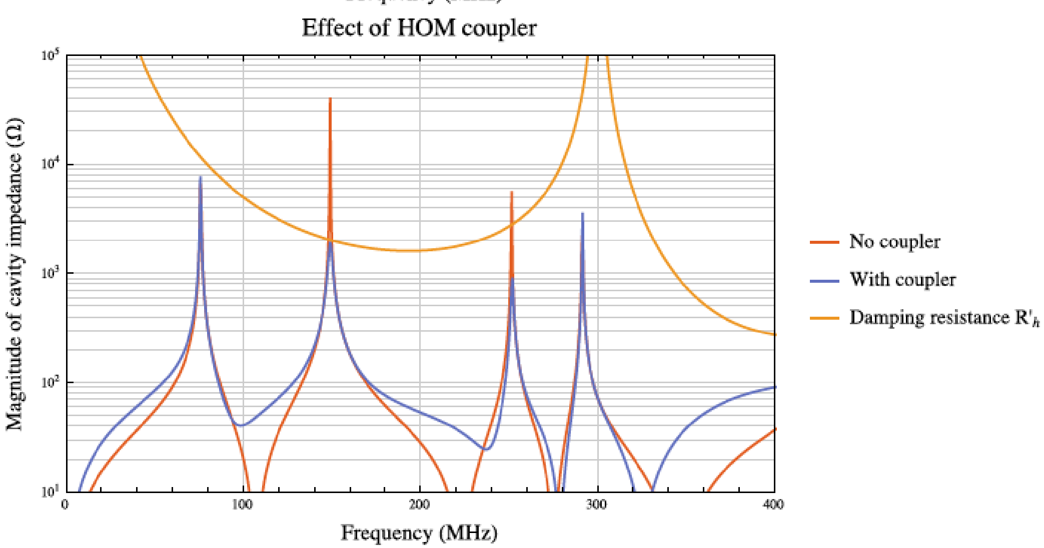
W.R. Smythe, T.A. Enegren, and R.L. Poirier. A versatile RF cavity mode damper. In *EPAC'90, Nice, France, 12–16 June 1990*, pages 976–978, 1990.

Can show that R'_d is

$$R'_d = \frac{1}{\mathrm{Re}[1/Z_g]}$$

Z_1 our cavity model with coupler+λ/4 HOM cavity (150 MHz)





HOM cavity is a shorted transmission line that resonates at 150 MHz. This means it will reduce the mode at 150 MHz ($1/Z_g$ effect).

However, notice 2*n**150 MHz resonances, i.e. there's not damping at these frequencies.

Therefore, Smythe reshaped cavity to push 2*150 MHz to much higher frequency.

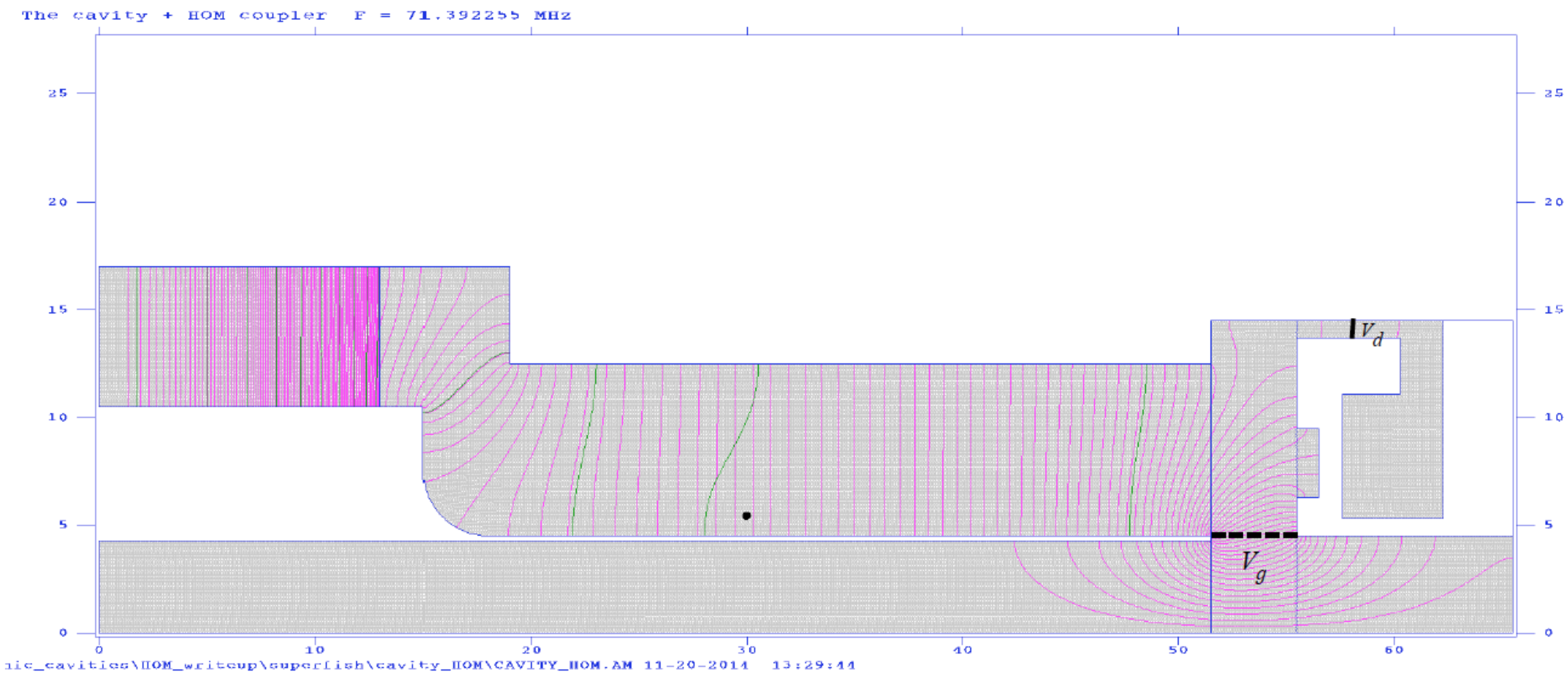
Note that our resonances are **not** at (2*n*+1)*fres!!!!

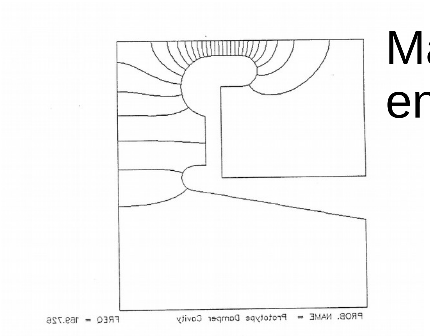
This is because our cavity is not π/2. This has nothing to do with power coupler breaking transverse symmetry.

Using Superfish

- Superfish problems must be cylindrically symmetric.
- Can handle complex μ using cfish.exe
- Does not handle load resistors, so must use formula: $R'_g = (V_{\mathrm{gap}}/V_{\mathrm{load}})^2\, R_{\mathrm{load}}$.
  - Formula comes from Smythe (and easily derived), and it is obviously an approximation.
  - Use sf7.exe and tablplot.exe to calculate fields and do integration
- Compare with analytic results.

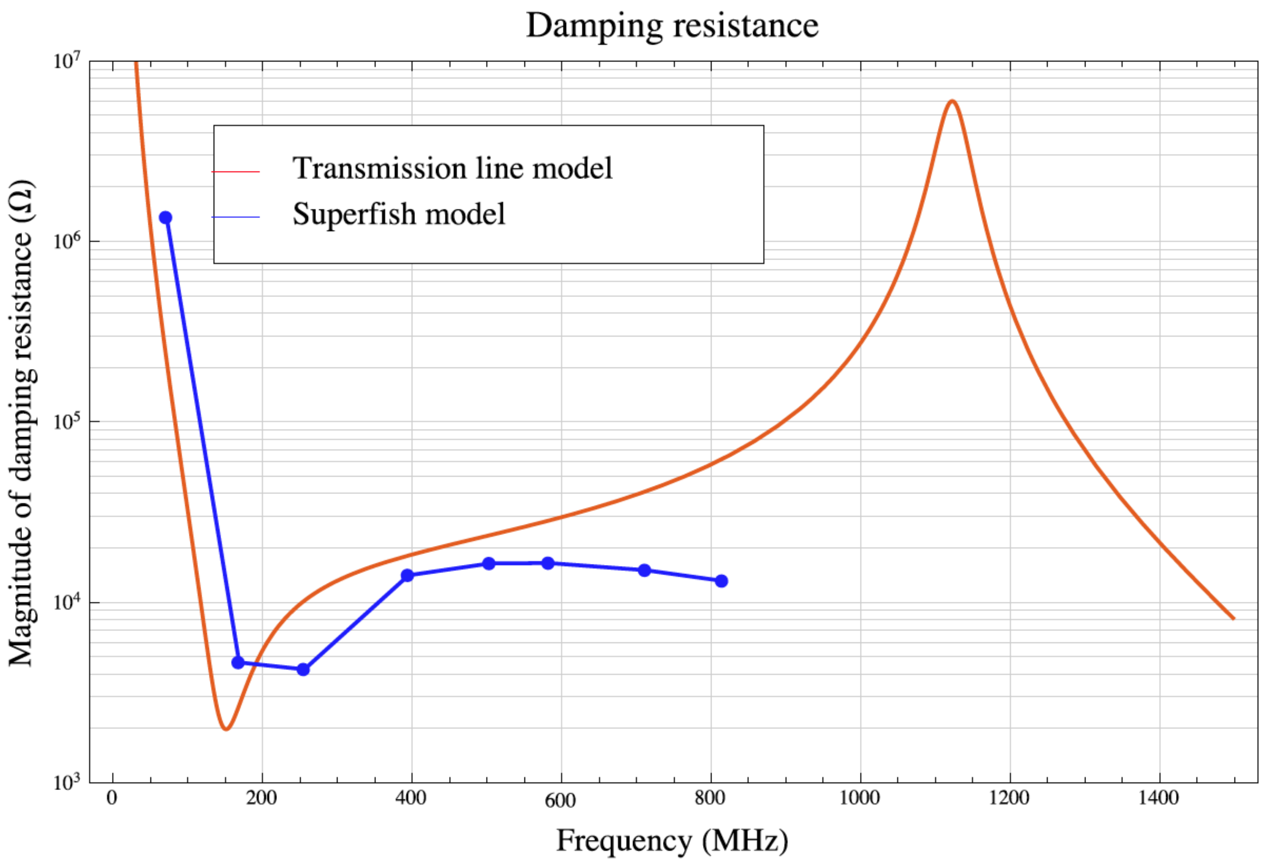
Superfish model with HOM Mitra HOM cavity





Make a really simply model of Mitra's HOM cavity and add it to the end of our cavity.

Damping resistance with Mitra HOM cavity

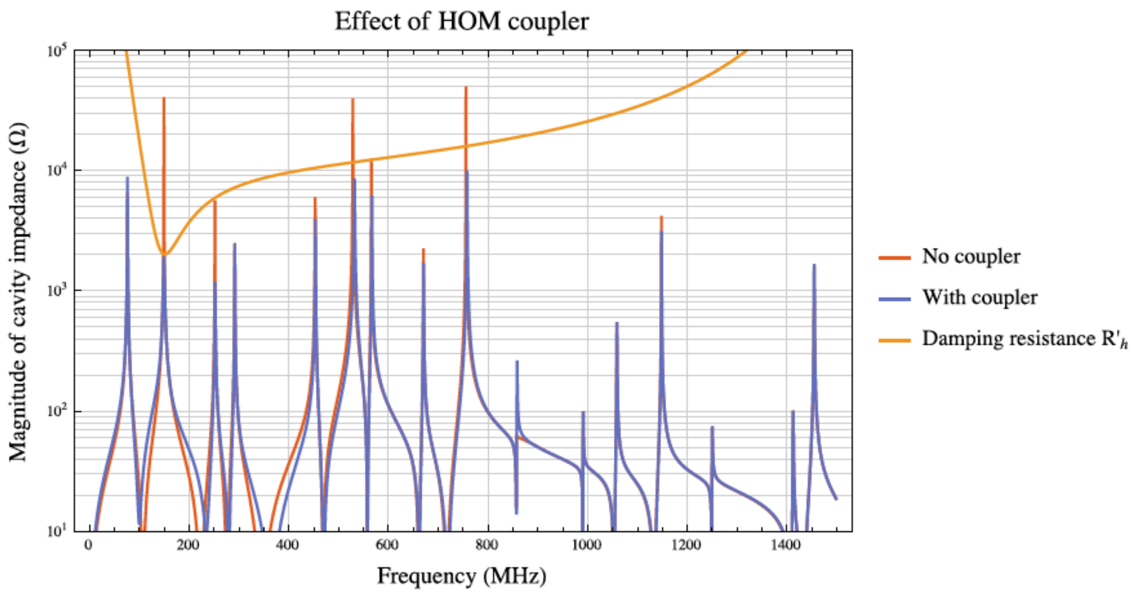


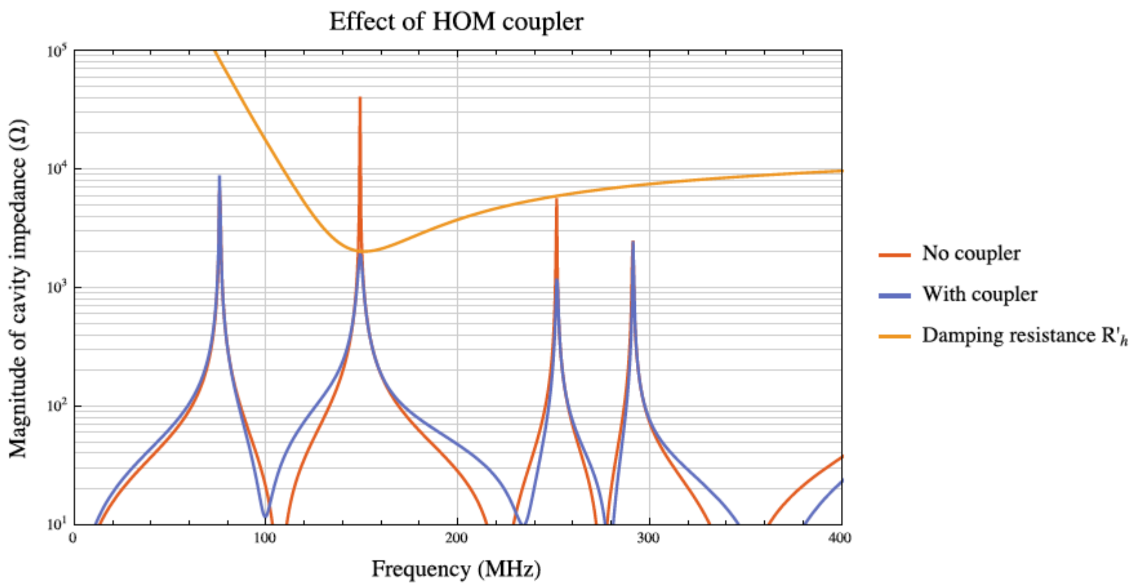
Mitra cavity modelled as 2 transmission lines, one is shorted. Personally, I don't think this is very trustworthy …

However results are very similar to Superfish! Note horizontal frequency displacement is because the Superfish model resonant frequencies do not completely match transmission line mode.

Note: R_{load} = 50Ω.

Results with Mitra Cavity

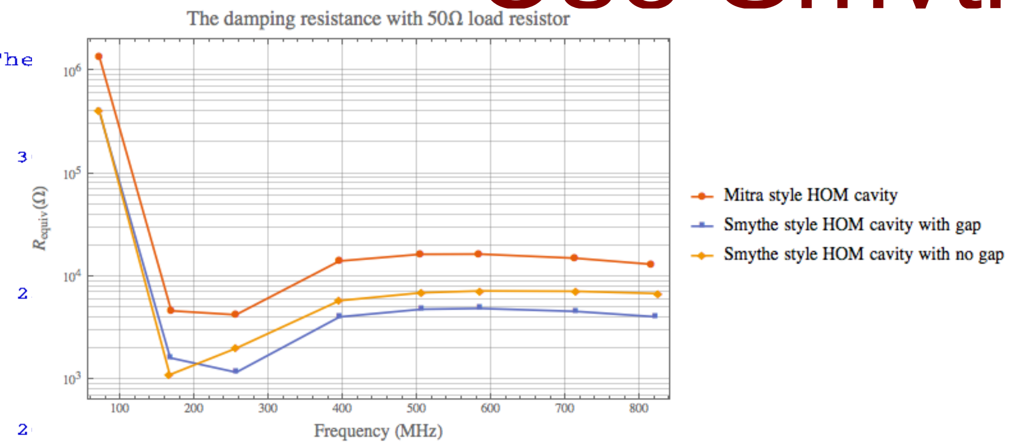


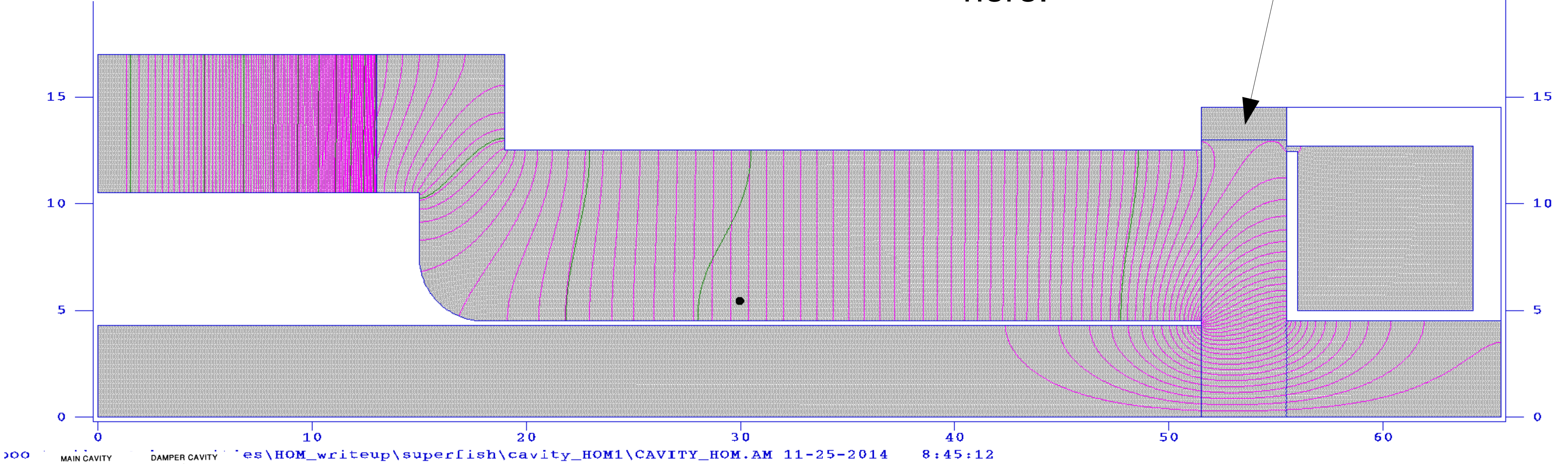


Doesn't look very good.

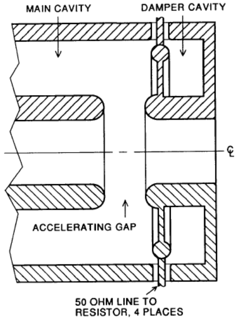
Damping of next higher order mode is quite poor! And doesn't seem to have an effect on modes above 200 MHz.

Use Smvthe cavity



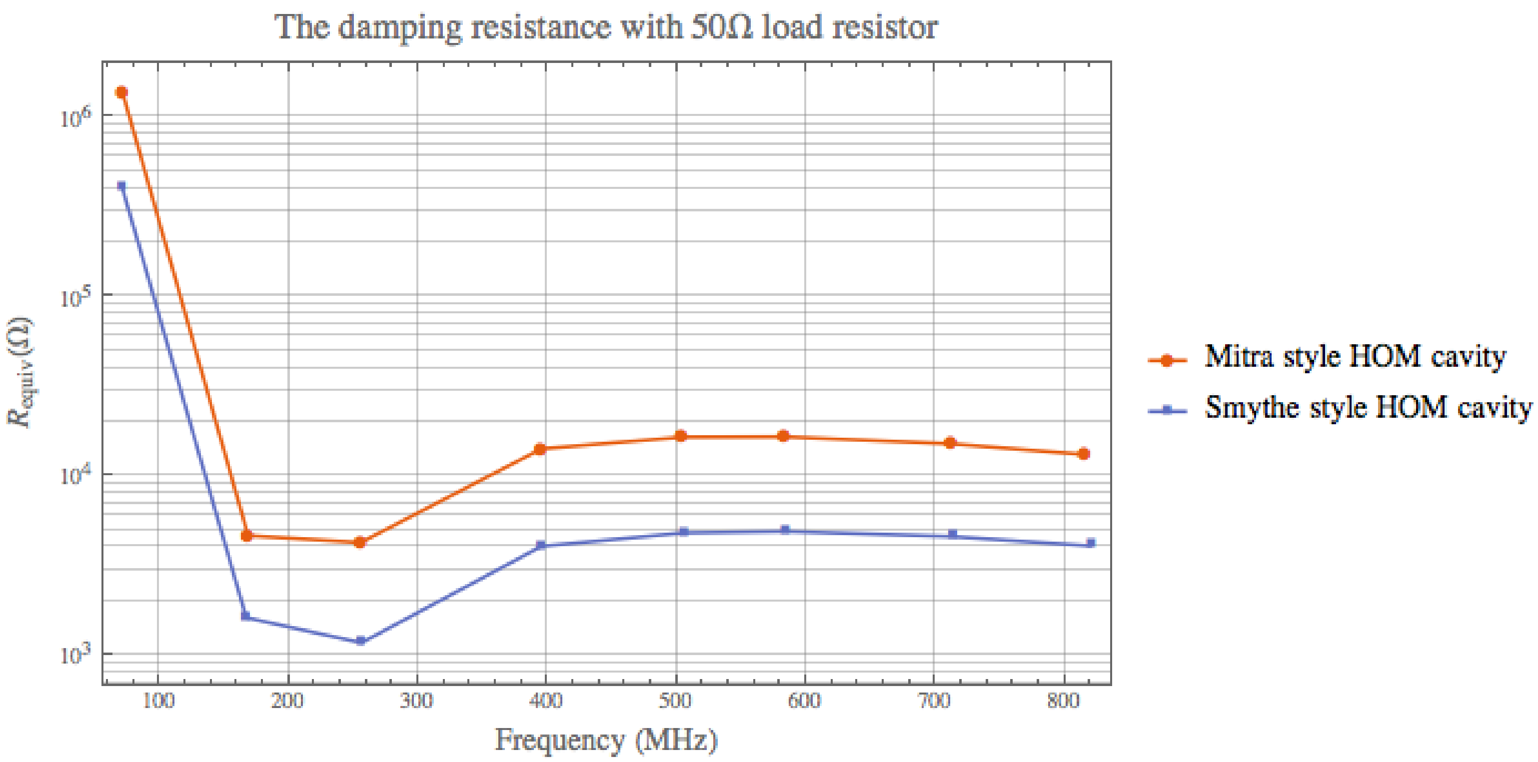


Note gap here. Seems to give a larger Requiv. c.f. Smythe's original design had a “cap” here.



For comparison purposes, always use R_{load} = 50Ω.

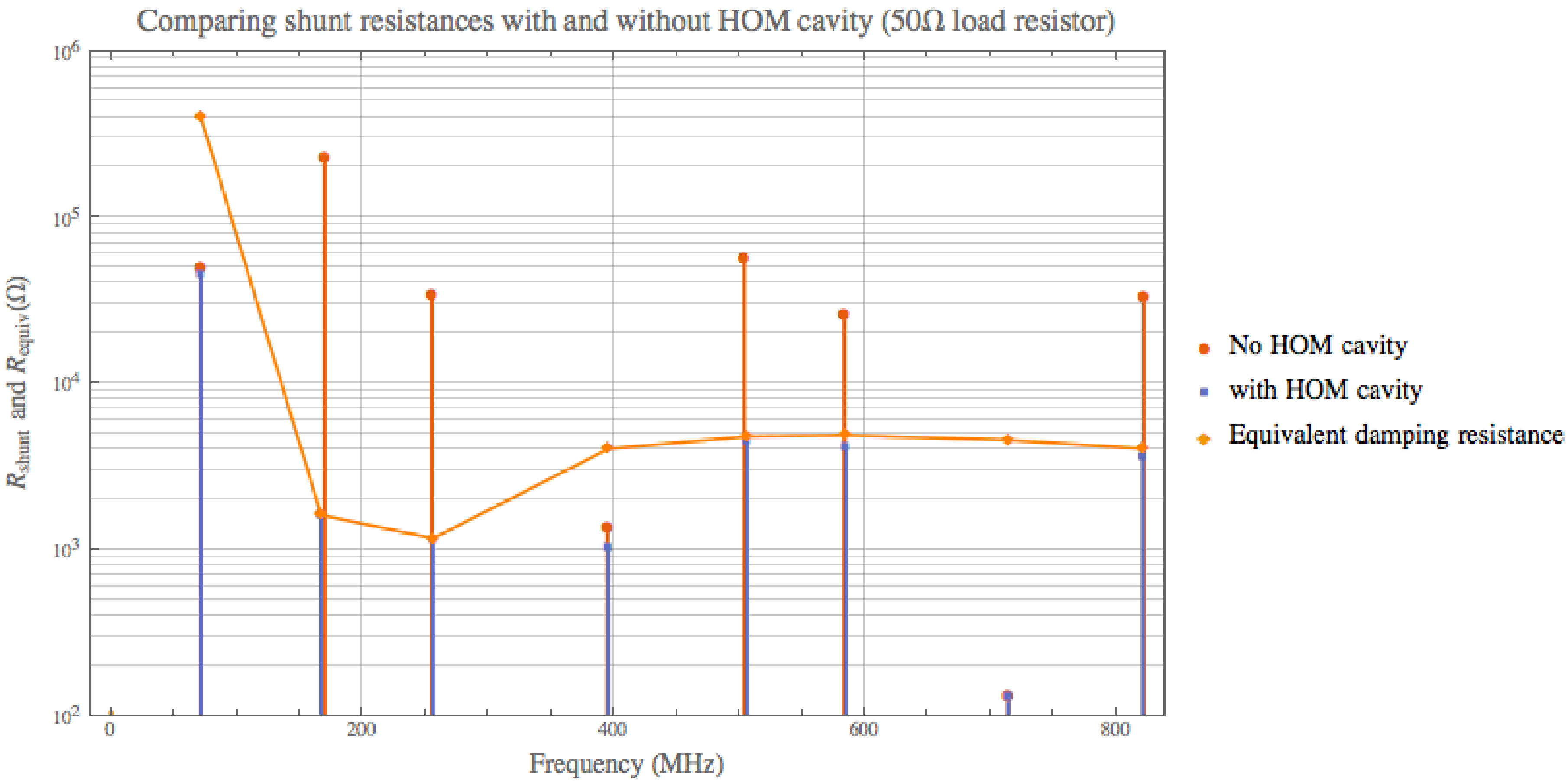
Comparing Smythe to Mitra damping resistance



Calculated with Superfish.

R_{load} is about factor of 3 smaller. Affects fundamental!

Comparing impedances with and without HOM cavity



Shunt impedance of fundamental reduced by 11%.
Next higher order mode reduced by 99.3%.
Everybody else between 84% to 96%. (except for 713 MHz which is small to begin with)

Next steps

- Build a mock up of our cavity
  - Add in HOM to make sure that it damps the modes
  - Used to check impedances.
- Calculate the required HOM impedances so as not to cause longitudinal instabilities.
  - We are probably ok under 5 kΩ, but this really needs to be checked …
  - High frequency modes are not important because of frequency content of the beam. Form factors!
    - Probably only need to consider modes < 500 MHz.