Studies of the TRIUMF KAON Factory Booster Cavity HOM Damper

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Abstract

A new concept was proposed at TRIUMF to damp the higher order modes in Booster cavity by employing a semi-lumped high-pass filter connected across the accelerating gap. The HOM investigation was conducted on the existing prototype ferrite loaded Booster cavity.

This paper reports numerical studies of the various HOM dampers using the electromagnetic simulation code MAFIA. During numerical modelling, some modifications of the original design were proposed; coupling reduction to the fundamental and the second HOM damping increase were predicted theoretically.

1 INTRODUCTION

In the Los Alamos-TRIUMF cavity[1], intended as an accelerating structure for the Booster ring of the TRIUMF KAON project, the shunt resistance of the cavity second harmonic (in some part of the frequency range) is approximately as high as that of the fundamental mode. Consequently, it is necessary to provide means to suppress higher order modes so as to avoid beam instabilities.

The first type of HOM damper proposed for the Los Alamos- TRIUMF cavity was the so called 'Smythe-type' damper[2]. However, this damper has the disadvantage that the influence on the fundamental mode is relatively strong. In order to reduce the coupling to the fundamental, a new concept of damping higher order modes by employing a high-pass filter was proposed at TRIUMF[3].

2 CAVITY SIMULATION

Formerly the filter-type damper consisted of three plane copper disks terminated by an arrangement of rods (Fig. 1) and the rods for the third disk are terminated by 50-Ohm resistors. But, in this case, the gap between the first and second plates presents a decelerating gap for charged particles. Because of this fact, an additional structure, the so called 'horn', was installed between the main gap and the first filter disk (Fig. 2).

The horn is comprised of a tube, concentric with the beam axis, and a large diameter disc with iris for the beam. The tube, which is situated close to the beam pipe, is intended to screen the beam from the unwanted decelerating field. The influence of the 'horn' on the filter parameters and damping effectiveness was studied.

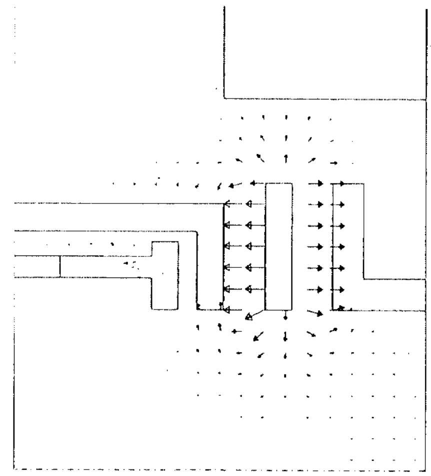

Figure 1: *Electric field distribution in filter*

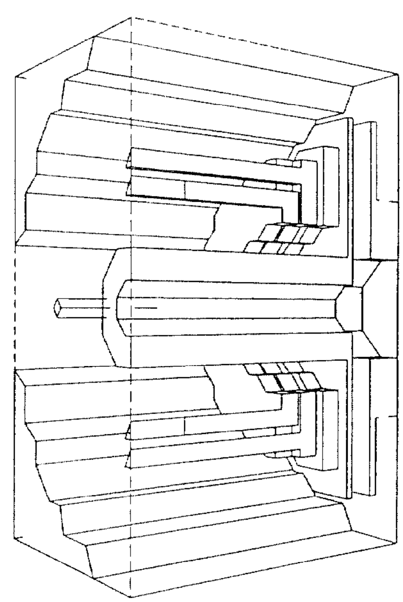

Figure 2: *Modified filter geometry with 'horn'*

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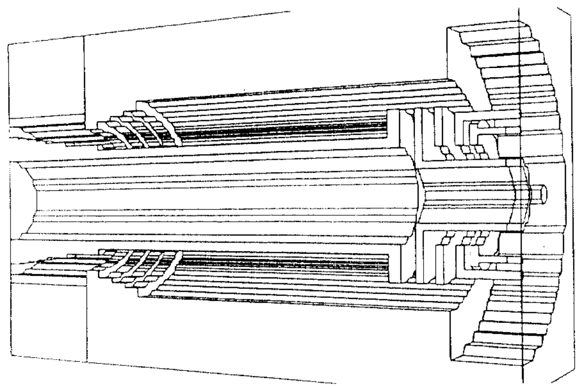

Figure 3: *TKF booster cavity with HOM damping filter*

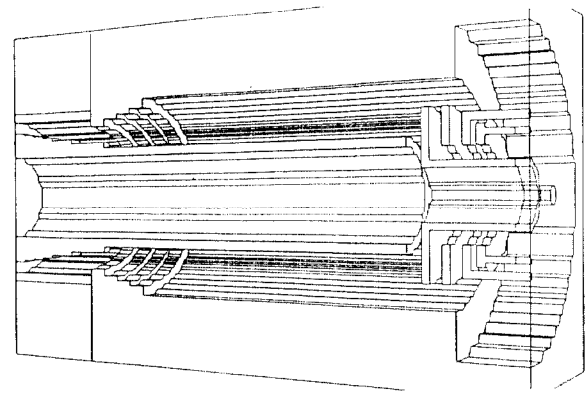

Figure 4: *Cavity with reduced gap capacitance*

To simulate the damping resistors, the conductivity of the part of the terminating rods for the third disk (approx. 1/3 part) was changed. Simulations were made of the HOM damper cavity alone.

The measured electrical characteristic of the filter shows that for frequencies above 150 MHz the resistance should be 50 Ohm, whereas for the fundamental mode it is around 10 kOhm. Keeping these parameters constant, values for the conductivity of the changeable part of the rods were found for the computer model. Throughout this paper, the terms 'loaded' and 'unloaded' refer respectively to the cases of: (i) conductivity of the termination parts of the damper (in isolation) adjusted to give a shunt resistance of 50 ohm at the fundamental of the damper, (ii) conductivity of termination parts of the damper as for copper.

Using the same value of conductivity found in the previous simulation, a calculation of the full cavity structure was performed (Fig. 3, only a quarter of the structure is shown). The calculations were done for the following particular value of the (non-isotropic) ferrite permeability: $\mu_x = \mu_y = 2.9$, $\mu_z = 1.0$.

The 'horn' installation results in lower Q factor and shunt resistance R of the second mode in the unloaded case, and provides better damping of the second mode when loaded by the damping filter. Moreover, there is no affect on the fundamental[4]-[5].

The HOM results for the structure with the 'horn' are presented in Table 1–2 (only modes which are related to the accelerating gap are presented).

The main result of this calculation is the identification of a relatively strong damping of the fundamental mode as a result of coupling to the filter via the accelerating gap. It was suspected that the coupling could be decreased by reducing the gap capacitance; see Fig. 4. Table 3 summarizes the results of a cavity simulation using a reduced gap capacitance.

Because the horn is the additional capacitance and inductance in the filter structure, and the inductance of the horn is smaller than the rod inductances, so it follows that the predominant part of the rf current flows along the tube of the horn. This results in a reduction of the HOM damping because the rf current by-passes the rods. (This can be another possibility for the filter – to terminate the horn

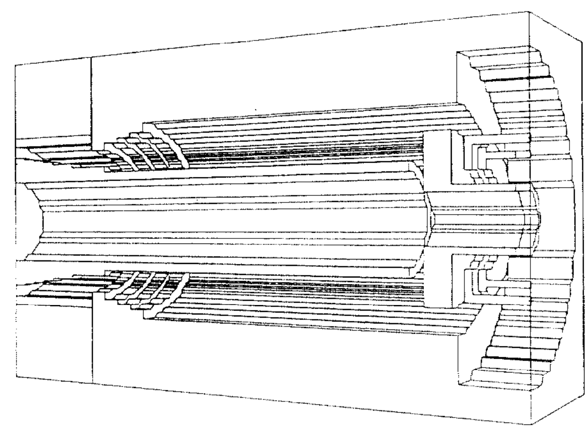

Figure 5: *Filter with terminated first gap*

by 50-Ohm resistors). To avoid this, the first gap between the 'horn' and the first plate was eliminated (Fig. 5). The HOM results of simulating this structure are shown in Tables 4–5. The damping effect on the second mode was increased. The structure with reduced gap capacitance is still preferable in terms of the fundamental mode coupling.

Thus, provisionally, the 'best' structure is that with reduced accelerating gap capacitance and with the first filter gap eliminated; the characteristics of this cavity in the required frequency span are given in Figs. 6–7.

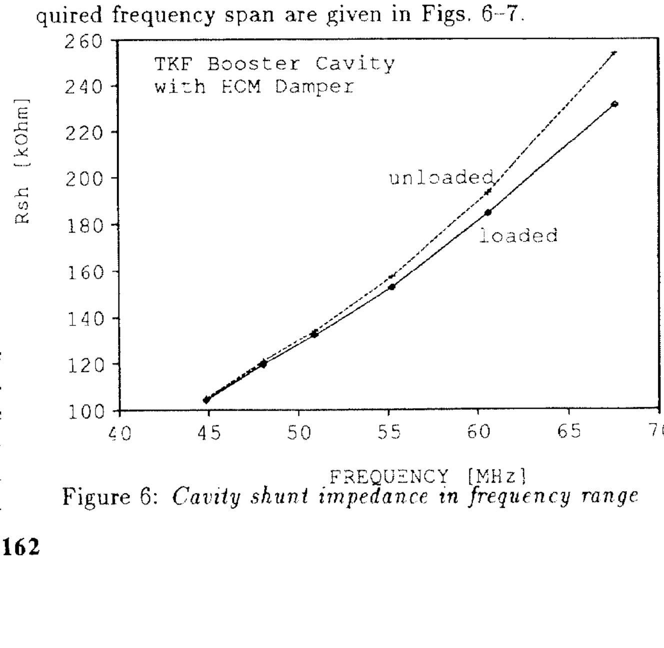

Figure 6: *Cavity shunt impedance in frequency range*

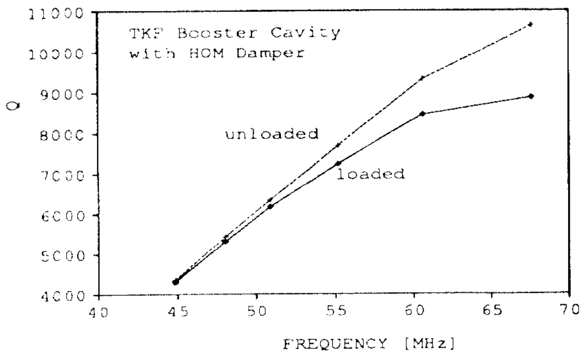

Figure 7: *Cavity Q-factor in frequency range*

3 CONCLUSIONS

HOM dampers for TRIUMF KAON Booster cavity were investigated using the MAFIA simulation code. A design solution better than the existing one was proposed and verified numerically. However, some model assumptions had to be made, and these should be taken into consideration while comparing the filter options. It was supposed that in all cases the shunt resistance of the HOM damper itself is 10 kOhm at the cavity fundamental mode and 50 Ohm at the higher order mode frequencies. But in the case of a filter with three disks and horn (first filter gap not eliminated), the filter characteristic in the frequency span of the cavity fundamental behaves differently than in the other cases. The absence of measured impedance data (at the cavity fundamental) for some of the filter designs implies that exact comparative simulations could not be performed. This fact could be another reason for the strong damping of the fundamental mode reported in Table 1.

4 REFERENCES

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[2] W.R.Smythe, T.A.Enegren and R.L.Poirier, "A Versatile RF Cavity Mode Damper", Proc. of the 2nd EPAC, Vol.1, pp.976- 978 (1990).

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Table 1: TKF Booster Cavity With HOM Filter Damper (no 'horn', all disks, large gap capacitance)

mode	f/MHz	Q	R/Ohm	Q_l	R_l/Ohm
1	41.74	5299	120384	4190	106211
2	102.08	7379	46892	177	1633
3	128.34	5389	18579	20	79
6	171.96	5385	4051	6	6
8	183.35	5972	23350	3	19
10	224.75	11474	16381	39	84

Table 2: TKF Booster Cavity With HOM Filter Damper ('horn', all disks, large gap capacitance)

mode	f/MHz	Q	R/Ohm	Q_l	R_l/Ohm
1	43.47	5303	126605	4149	109443
2	104.98	7133	121904	30	712
3	118.45	4887	3161	0	0
4	147.28	5453	17210	0	1
5	147.93	4877	33	52	0
7	177.59	4865	9535	0	0

Table 3: TKF Booster Cavity With HOM Filter Damper ('horn', all disks, redused gap capacitance)

mode	f/MHz	Q	R/Ohm	Q_l	R_l/Ohm
1	48.03	5430	122113	5284	120336
2	112.89	5756	117757	35	819
3	121.21	5895	68611	2	36
4	147.96	4952	283	31	3
5	148.47	5429	12584	1	3
7	179.37	4753	17854	0	1

Table 4: TKF Booster Cavity With HOM Filter Damper (filter with terminated first gap, large gap capacitance)

mode	f/MHz	Q	R/Ohm	Q_l	R_l/Ohm
1	43.51	5310	124754	5014	120749
2	106.36	7805	124692	11	276
3	137.90	4826	4778	1	1
6	169.31	5250	20164	0	4
10	221.93	8150	3477	0	0

Table 5: TKF Booster Cavity With HOM Filter Damper (filter with terminated first gap, reduced gap capacitance)

mode	f/MHz	Q	R/Ohm	Q_l	R_l/Ohm
1	48.05	5435	120745	5316	119310
2	116.29	7512	197265	8	298
3	139.38	5000	338	1	0
6	170.91	5200	32620	1	9
9	203.57	8978	3982	2	1
10	222.36	8387	2924	0	0