HOM Damping with Coaxial Dampers in a Pillbox Cavity without the Fundamental Mode Frequency Rejection Filter *

Y. W. Kang, R. L. Kustom, and J. F. Bridges
Accelerator Systems Division
Argonne National Laboratory
9700 S. Cass Ave., Argonne, IL 60439

Abstract

Coaxial dampers with E-probe and H-loop couplers are used to damp higher-order mode (HOM) in an 840-MHz cylindrical prototype cavity. The dampers are positioned to have minimum coupling at the fundamental frequency, f_o, without using any blocking circuit. The E-probe dampers are used at the equatorial plane of the cavity. The H-loop dampers are used in the end wall of the cavity. The fundamental mode decoupling can be done by positioning the loop plane in the direction of the H-field of the mode. For both dampers, the fundamental mode coupling can be better than -50 dB. The damper load resistance is varied to find the optimum loading. Measurement is made for three cases with 1) three E-probe dampers, 2) three H-loop dampers, and 3) three E-probe and three H-loop dampers.

I. Introduction

There has been much work on development of HOM dampers in accelerating RF cavities. The most important tasks in designing a HOM damping system are broadbanding and suppression of fundamental mode power coupling. Coaxial dampers are used in both superconducting and normal conducting cavities for particle accelerators [1-5]. Aperture-coupled hollow waveguide type dampers have been recently investigated [6, 7]. These hollow waveguide dampers are used in multiples (usually three to damp the degenerate modes). The fundamental frequency rejection is achieved by the cutoff characteristic of the waveguide. However, degradation of the Q-factor at f_o is appreciable in this approach.

In coaxial HOM damper designs, the f_o decoupling is a difficult task. However, the coaxial dampers can be used anywhere in the cavity if a proper f_o rejection method is used. The coaxial dampers can have the following advantages:

- The fundamental frequency power loss can be minimized with a proper f_o rejection scheme.
- Dampers are compact, lightweight, and inexpensive.
- Cooling is easy and does not disturb the cavity heat distribution.

E-probe dampers can be used in the cavity equatorial plane without any f_o rejection filter, since the radial component of the TM_{01} electric field is zero in the midplane.

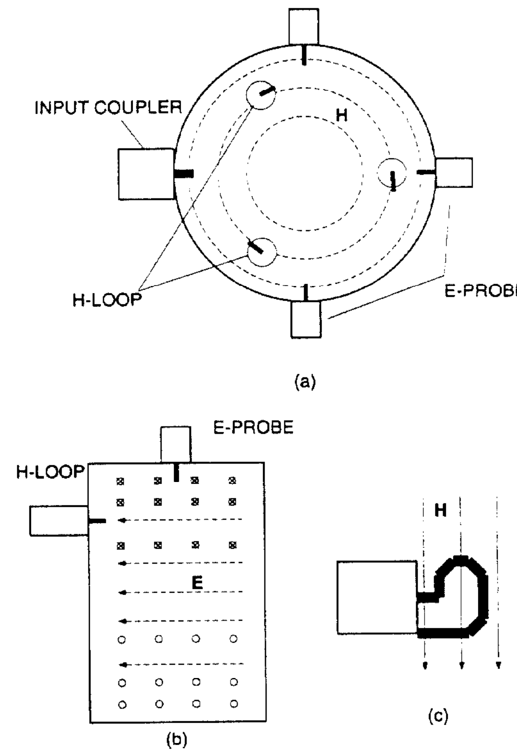

Figure 1
a) E-probe and H-loop coaxial dampers in a cylindrical pillbox cavity. b) Probes and the loops are positioned for least coupling to the TM_{01} accelerating mode. c) The loop plane is parallel to the H-field.

If H-loop dampers are used in the equatorial plane of the cavity, the loop plane must be positioned perpendicular to the fundamental mode H-field to couple to the higher order TM modes. Then, a fundamental frequency rejection filter must be used. H-loop dampers use a half-wavelength short stub in parallel [1] or a quarter wavelength short stub in series [2]. These short stub fundamental frequency rejection circuits also block the signal frequencies at around the even and odd multiples of f_o, respectively, and also increase the fundamental mode power loss due to the increased current path.

Figure 1 shows the coaxial dampers used with a cylindrical pillbox cavity without a f_o rejection circuit. A pillbox cavity with f_o=840 MHz is used in the measurement. The HOM frequencies are found using the URMEL-T code.

The E-probes are used in the cavity equatorial plane. The H-loops are used in the cavity side-wall. The loop plane is parallel to the TM_{01} mode H-field. Three dampers

*Work supported by U.S. Department of Energy, Office of Basic Energy Sciences under Contract No. W-31-109-ENG-38.

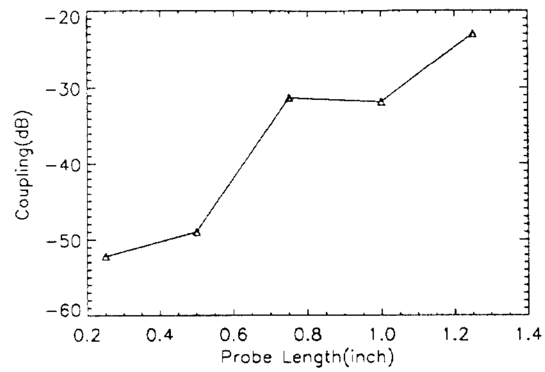

Figure 2
Isolation between power input loop and an E-probe damper at f_o. $R_L = 50\Omega$

are used to increase the coupling to the degenerate modes.

The size of the loop or the probe as well as the location in the cavity determine the coupling to specific HOM fields and thus the damping ratio. The fundamental mode coupling to the dampers is also dependent on the position and size. The coupling between the input coupler and a damper at f_o with respect to the size of the probe or the loop is measured and shown in the next sections.

II. E-probe Dampers

The fundamental mode coupling as a function of the probe length is shown in Figure 2. A probe diameter of $d = 0.25$" is used. The probe in this position should not couple to the fundamental TM_{01} mode field. But, due to imperfect probe alignment and mutual coupling between the two coupling devices, a small amount of coupling exists.

Three E-probe dampers are used in the cavity equatorial plane with an angular separation of 90^o. The load resistance is varied to see how the damping ratios change. A probe with diameter $d = 0.25$" and length $\ell = 0.50$" is used. Measurement of the damping ratio of thirteen HOMs is shown in Table 1. These modes are the cylindrical equivalent of the higher-order TM modes of the storage ring single cell cavity to be used in the APS and can cause beam instability [8, 9]. Measurements are taken in dB scale which is related as $10 \log |S_{21}|^2$. The Q-factor for a mode is proportional to $|S_{21}|$. TM0 denotes the monopole modes and TM1 denotes the dipole modes. ME and EE denote the boundary conditions with magnetic and electric conductors in the cavity equatorial plane, respectively. The results show that the modes with E-field at the cavity midplane (ME boundary condition) are damped effectively and the modes with no E-field in the midplane (EE boundary) are not.

III. H-loop Dampers

The power input loop to the damper coupling was measured and is shown in Figure 3. The plane of the H-loop

Table 1
HOM damping with E-probe dampers. $R_L = 30, 50, 100\Omega$

Mode type	f(MHz)	Damping (dB)		
		30Ω	50Ω	100Ω
TM0-EE-1	840.412	0	0	0
TM0-ME-1	1293.773	20.0	28.5	25.0
TM1-EE-1	1340.911	0	0	0
TM1-ME-2	1663.036	21.5	28.0	21.0
TM0-EE-2	1928.998	4.5	0.5	3.5
TM0-EE-3	2141.433	2.5	0.2	3.0
TM0-ME-2	2165.287	18.5	4.0	14.0
TM1-EE-3	2379.244	4.5		
TM1-ME-4	2643.410	15.5	>30	18.0
TM1-EE-5	2708.200	0		3.0
TM0-EE-4	2758.015	2.7	4.5	1.5
TM0-ME-3	3067.968	6.5	>20	1.5
TM1-EE-6	3147.284	9.5	5.0	
TM0-EE-6	3611.091	>30	> 30	>30

is turned carefully to the minimum coupling position. The coupling increases drastically as the loop area increases over ~ 0.15 $inch^2$. This indicates that the input loop and the damper loop couple directly, not through TM_{01} mode. The coupling can be < -50 dB which is less than 1 W of power dissipation for a 100 kW cavity input power.

Three H-loop-coupled coaxial dampers are used in an uniformly spaced circular array at r=$0.6r_o$ as shown in Figure 1(a). Each damper has a loop area of 0.04 $inch^2$. The load resistance is varied as in the E-probe damper measurement. Table 2 shows the measured damping ratios. Most ME boundary modes and EE boundary modes are damped effectively with the exception of some EE boundary monopole modes.

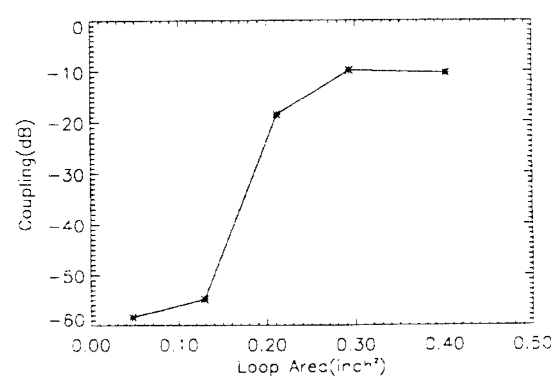

Figure 3
Isolation between power input loop and an H-loop damper at f_o. $R_L = 50\Omega$

Table 2
HOM damping with H-loops. $R_L = 30, 50, 100\Omega$

Mode type	f(MHz)	Damping (dB)		
		30Ω	50Ω	100Ω
TM0-EE-1	840.412	0	0	0
TM0-ME-1	1293.773	0	0	0
TM1-EE-1	1340.911	4.0	7.0	7.0
TM1-ME-2	1663.036	12.0	21.0	14.0
TM0-EE-2	1928.998	19.0	19.5	17.5
TM0-EE-3	2141.433	1.5	3.5	5.3
TM0-ME-2	2165.287	28.0	24.5	30.5
TM1-EE-3	2379.244	20.0	17.5	23.5
TM1-ME-4	2643.410	20.0	>30	>30
TM1-EE-5	2708.200	10.0	13.5	10.0
TM0-EE-4	2758.015	16.5	22.5	17.4
TM0-ME-3	3067.968	6.0	4.5	3.0
TM1-EE-6	3147.284	4.5	11.0	7.0
TM0-EE-6	3611.091	11.5	22.0	14.5

Table 3
HOM damping with E- and H-dampers. $R_L = 50\Omega$

Mode type	f(MHz)	Damping (dB)	
		50,50	50,100
TM0-EE-1	840.412	0	0
TM0-ME-1	1293.773	26.0	22.5
TM1-EE-1	1340.911	18.0	18.5
TM1-ME-2	1663.036	28.0	28.0
TM0-EE-2	1928.998	24.0	23.0
TM0-EE-3	2141.433	4.5	5.0
TM0-ME-2	2165.287	28.5	29.0
TM1-EE-3	2379.244	19.0	20.0
TM1-ME-4	2643.410	25.0	23.5
TM1-EE-5	2708.200	13.5	10.0
TM0-EE-4	2758.015	23.0	22.5
TM0-ME-3	3067.968	6.0	7.0
TM1-EE-6	3147.284	7.5	10.0
TM0-EE-6	3611.091	>30	>30

IV. Combined E- and H-Dampers

Three E-probe dampers and three H-loop dampers were used together in a measurement. The measured damping ratios are shown in Table 3. The result shows that most modes (both ME and EE boundary) are damped effectively. 50 Ω loads are used in E-probe dampers while 50 Ω and 100 Ω are used for two separate measurements in H-loop dampers. The results from the two cases are about the same except for the TM1-EE-5 mode.

V. Conclusion

The above measurements show that the HOM can be damped with E-probe and H-loop dampers with negligible fundamental frequency power loss. They can therefore be compact in size, inexpensive, and easy to maintain. The E-dampers in the equatorial plane and the H-dampers in the endwall can achieve very weak coupling at the fundamental frequency without using decoupling circuits. The mode selectiveness of the two damper designs are nearly complimentary to each other.

Since each damper port input impedance is a function of frequency, a fixed resistance loading cannot damp each mode completely but can be the optimum for all modes. Although the sizes of the E-probe and the H-loop are not optimized, the damping is enough for use in actual APS storage ring cavities.

The next activity is to apply this design in the actual 352 MHz APS single cell cavity and find the optimum probe and loop sizes.

VI. References

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