PBAR NOTE 591
THE EFFECT OF SIDEBAR ABSORBERS ON THE FREQUENCY RESPONSE OF SLOW WAVE KICKERS

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INTRODUCTION

The slow wave pickups and kicker used in the 4-8 GHz Debuncher Upgrade are based on the principle of slowing the phase velocity of the waveguide modes in the beam-pipe and input/output waveguides to match the velocity of the beam. The pickups and kickers will be used for transverse and longitudinal cooling simultaneously.

In the transverse mode, the phase between opposing input/output waveguides is 180 degrees. This results in the tangential electric field at the mid-plane of the beam-pipe aperture to vanish. This mid-plane can then be replaced with a virtual perfect electric conductor and only half the problem needs to be analyzed. (The dotted line in Figure 1 can be replaced with a perfect electric conductor.) In this case, the field patterns of the fundamental mode in both the half beam-pipe and input/output waveguide are the same. If the transverse size (the x direction of Figure 1) of the beam-pipe and the waveguide is not too different, the phase velocities of the fundamental modes will be similar.

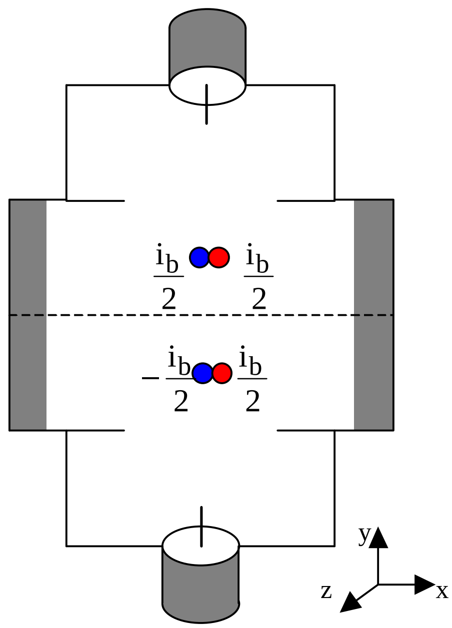

Figure 1. Transverse view of slow wave pickup.

In the longitudinal mode, the phase between opposing input/output waveguides is 0 degrees. This results in the tangential magnetic field at the mid-plane of the beam-pipe aperture to vanish. This mid-plane can then be replaced with a virtual perfect magnetic conductor and only half the problem needs to be analyzed. (The dotted line in Figure 1 can be replaced with a perfect magnetic conductor.) In this case, the field patterns of the fundamental mode in both the half beam-pipe and input/output waveguide are much different. For example, in Figure 1, the magnetic field in the x direction for the input/output waveguide is uniform along the y direction. For the beam-pipe, the magnetic field in the x direction must vanish at the mid-plane (the dotted line) but become a maximum at the slot aperture (where the beam-pipe and waveguide meet). The cutoff frequency for this sum mode in the beam pipe occurs when the transverse aperture of the beam-pipe (in the y direction of Figure 1) is much larger than a half wavelength. Because the height of the beam-pipe (which is chosen for beam aperture reasons) is usually much different than the width of the beam-pipe and input/output waveguides, the phase velocity in the beam-pipe can be substantially different than the phase velocity of the input/output waveguides. The result of this mismatch in velocities is large gain notches in the pass-band of the pickup/kicker. Figure 2 shows the transverse response for the Horizontal Band 1 of the kicker (C201_QC2_HKR_B1C). Figure 3 shows the longitudinal response of the same structure. Table 1 gives the input file used for generating the plots in Figures 2 and 3.

0	Absorber Thickness (mm)
1.75	Absorber Mu Mag
0.18	Absorber Mu tan
9.85	Absorber Ep Mag
0.06	Absorber Ep tan
2.032	Slot Width (mm)
2.032	Slot Spacing (mm)
20	Width Waveguide modes
100	Height Waveguide modes
2	Slot modes
101	Number of frequency points
D	Difference or Sum mode
KR	Kicker (KR) or Pickup (PU)
58.166	Waveguide width (mm)
16.764	Waveguide height (mm)
48.387	Beam pipe width (mm)
39.624	Beam pipe center height (mm)
436.88	Array length (mm)
21.573	Slot length (mm)
4.35	Center Frequency (GHz)
2	Frequency Span (GHz)
2.85E-07	c1 Beta W (m/mm**2)
-2.96E-03	c2 Beta W (m/mm)
1.12E+01	c3 Beta W (m)
3.61E-07	c1 Beta H (m/mm**2)
2.93E-03	c2 Beta H (m/mm)
8.72E+00	c3 Beta H (m)
40	emittance (pi-mm-mrad)

Table 1. Input file for C201_QC2_HKR_B1C

LOSSY MAGNETIC SIDEBARS

One solution that was used to remove the large gain variations in the longitudinal response was to place magnetic absorbing sidebars in the beam-pipe as shown in Figure 1. These sidebars reduce the strength of the waveguide modes in the beam-pipe which in turn reduces the interference between the waveguide modes of the beam-pipe and the input/output waveguides. One disadvantage to this solution is that the sensitivity of the transverse (difference) mode is also reduced. Figures 2 and 3 show the response of the HB1 kicker with magnetic absorbing sidebars made of Emerson & Cuming MF114.

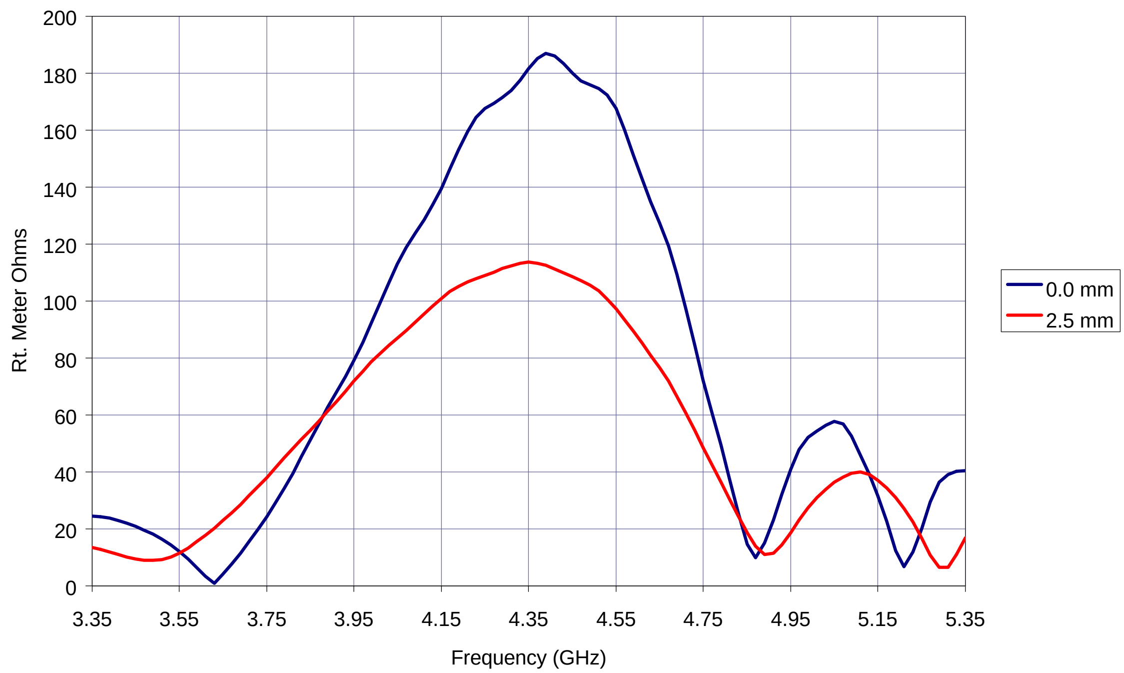

Figure 2. The difference mode kicker response of HB1 with MF114 absorbing sidebars.

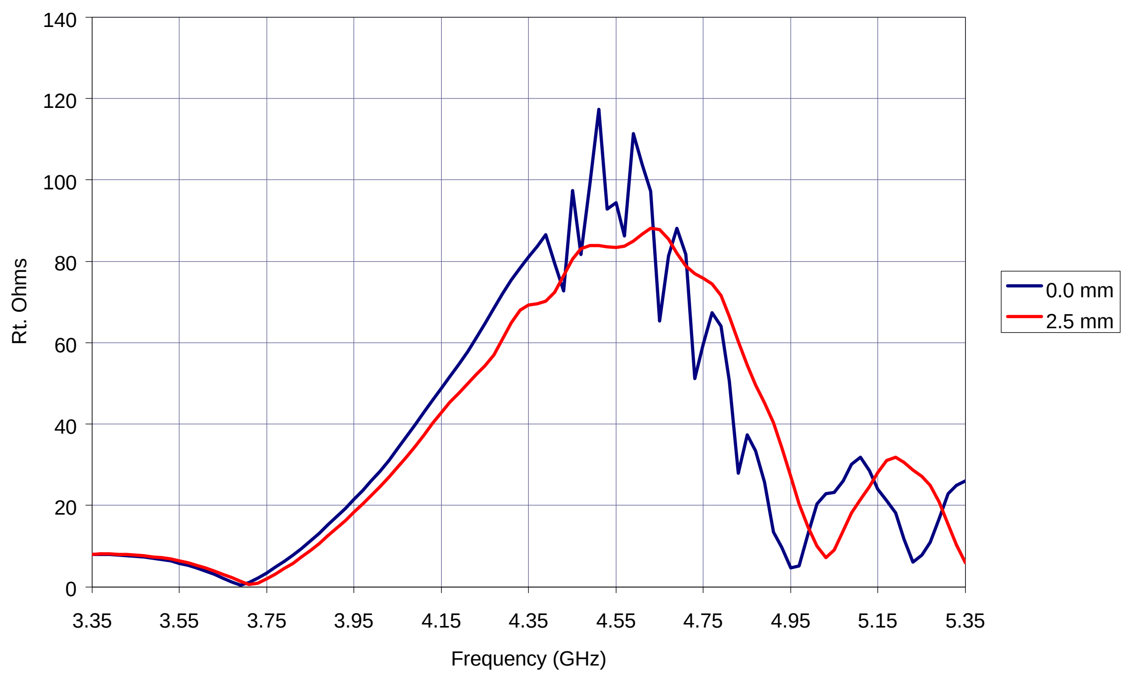

Figure 3. The sum mode kicker response of HB1 with MF114 absorbing sidebars.

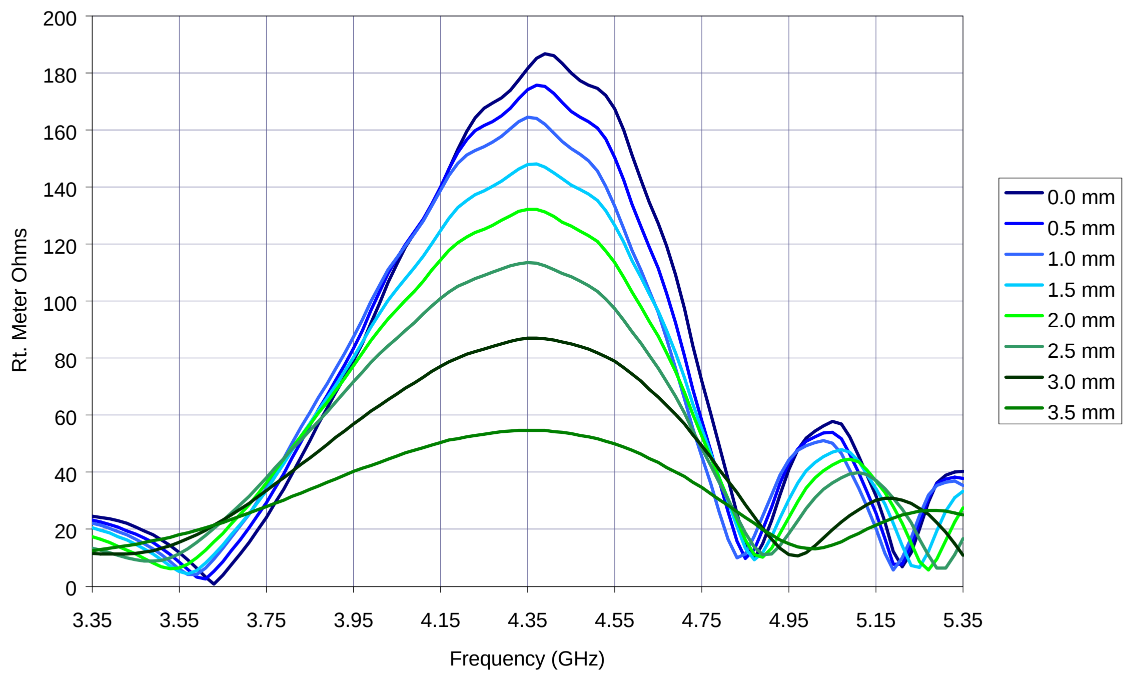

Figure 4. The difference mode kicker response of HB1 with MF114 absorbing sidebars.

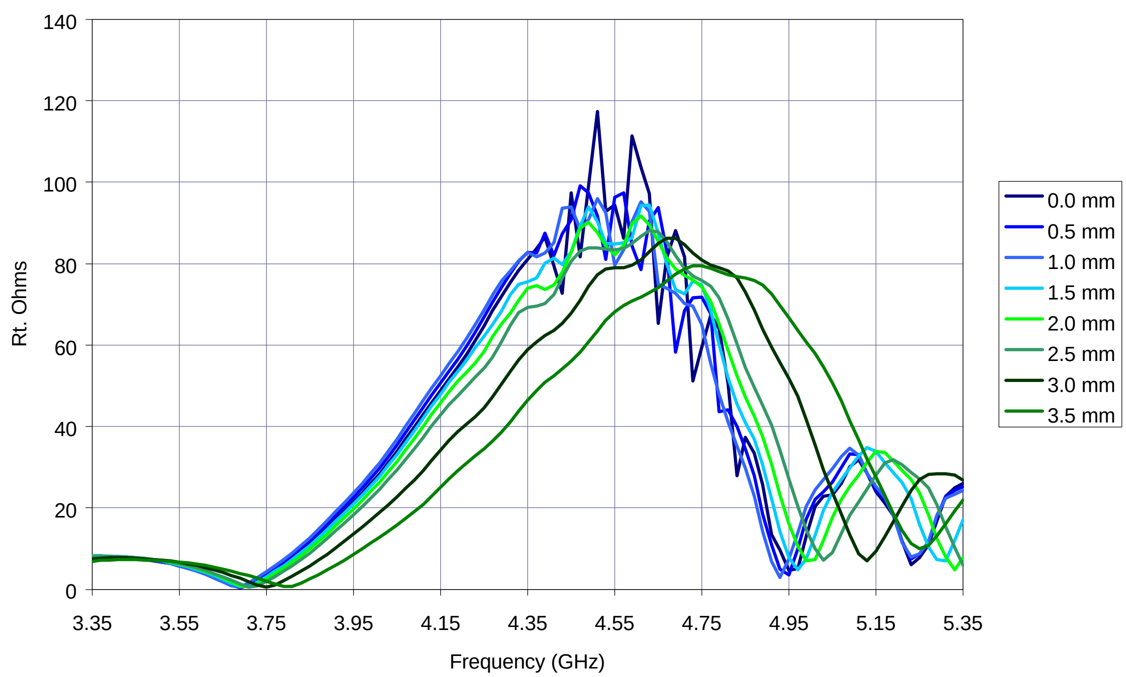

Figure 5. The sum mode kicker response of HB1 with MF114 absorbing sidebars.

The absorber needs to placed on the walls of the beam pipe so that it does not present an aperture obstruction. Since electric fields vanish at the sides of the beam-pipe, it was thought that a lossy magnetic absorber would have the best performance. As the absorber thickness increases, the variations in the sum mode gain are reduced but the sensitivity of the difference mode is also reduced. Figures 4 and 5 show the difference and sum mode sensitivity as a function of absorber thickness. Figure 6 is a summary of the multiple traces of Figures 4 and 5. For an absorber thickness between 2.0 – 2.5 mm, the gain variations in the sum mode are reduced to a reasonable level. However, at this thickness, the gain of the difference mode has been reduced by about 30%. One should note that as the absorber thickness is increased, the center frequency of the sum mode response increases.

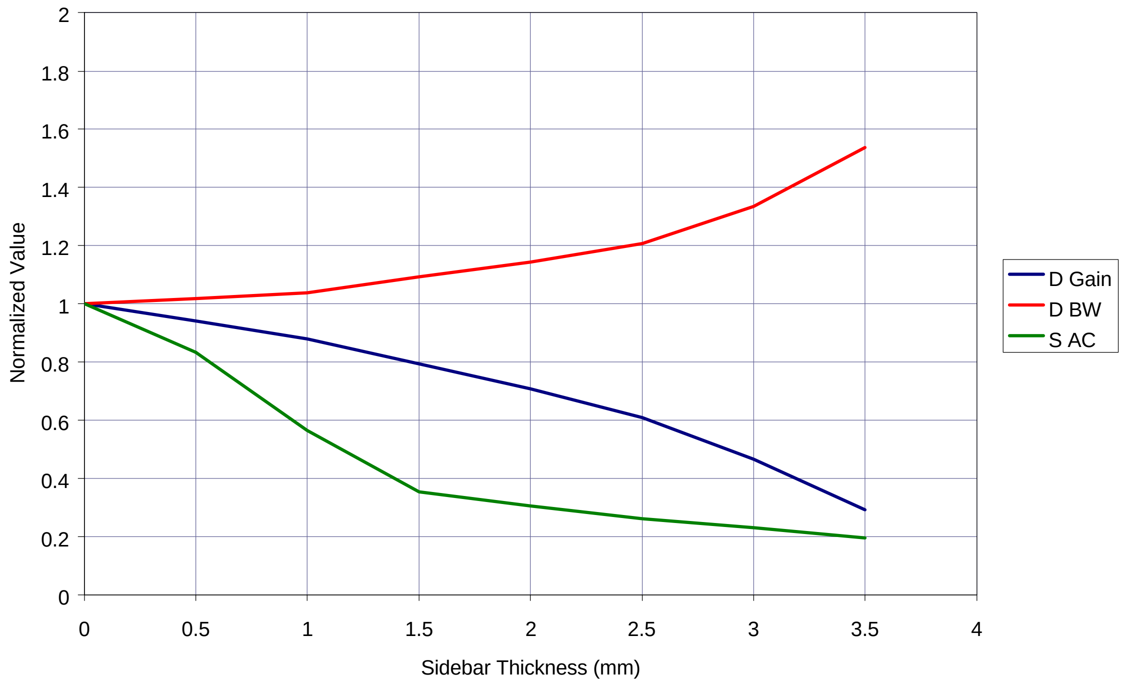

Figure 6. Summary plot of MF114 sidebars. The blue trace is the maximum difference mode gain. The red trace is the difference mode bandwidth. The green trace is the amplitude of the sum mode gain variations.

Lossy Electric Sidebars

While the lossy magnetic absorber reduces the gain variations in the sum mode response, the vacuum properties of this absorber (Emerson Cuming MF series) are poor. It has been shown that lossy electric materials can be used for sidebar absorbers.[1] This section will look at the reduction of sum mode gain variations with a lossy dielectric absorber such as Silicon Carbon (SiC). Figures 7-9 show the results of the HB1 kicker with a permittivity magnitude of 30.0 and an electric loss tangent of 0.3. The permeability magnitude is 1.0 and the magnetic loss tangent is 0.0. The optimum sidewall thickness for reducing sum mode gain variations is around 2.5 mm. The reduction of difference mode sensitivity is about 35%. However, increases in absorber thickness above 2.5 mm show a dramatic drop in difference mode sensitivity. For absorber thicknesses greater than 3.5 mm the difference mode gain actually increases. This is characteristic of the resonant behavior of lossy dielectric absorbers.

[1] PBAR Note 584 Comparison Between a Lossy Magnetic Absorber and a Lossy Electric Absorber

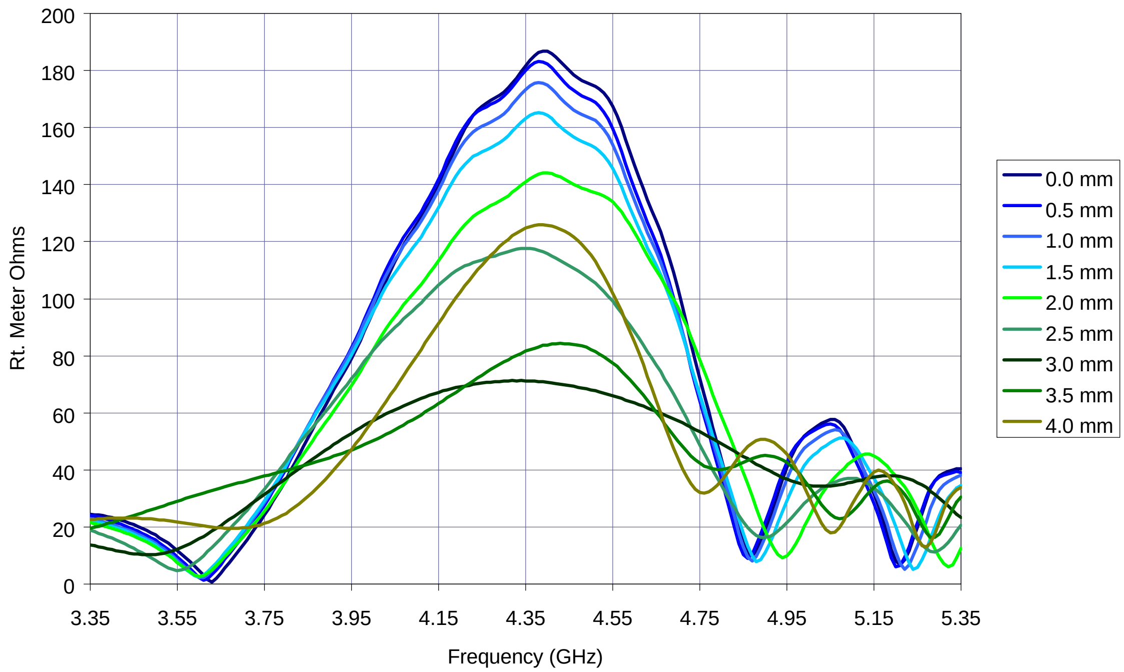

Figure 7. The difference mode kicker response of HB1 with SiC absorbing sidebars.

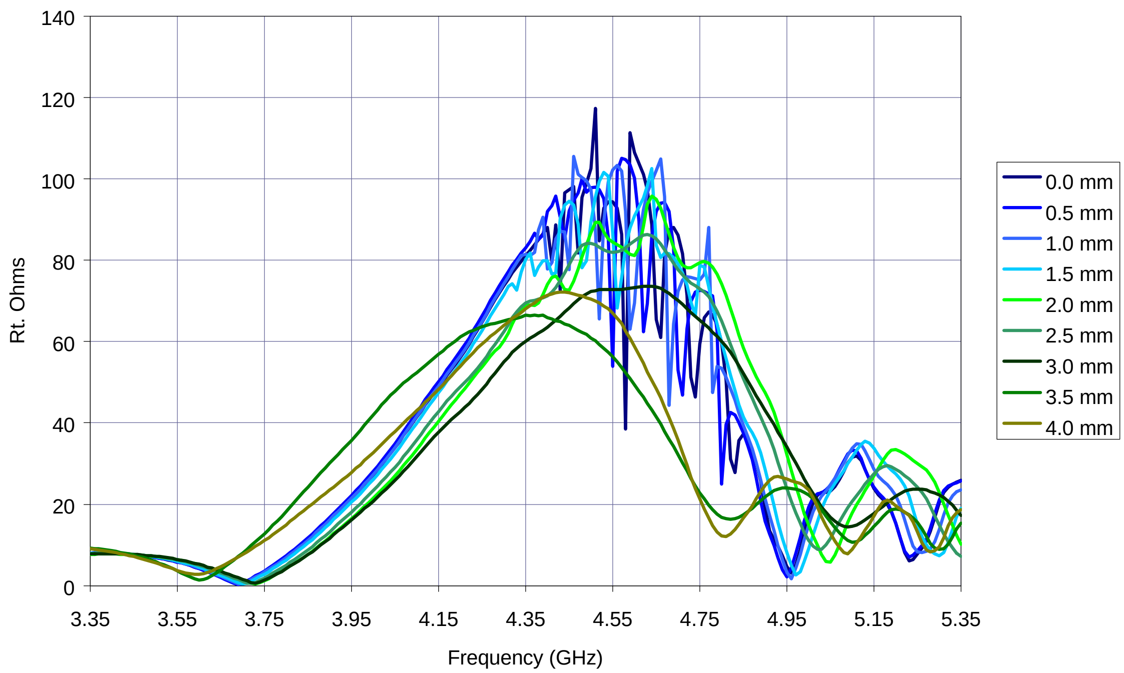

Figure 8. The sum mode kicker response of HB1 with SiC absorbing sidebars.

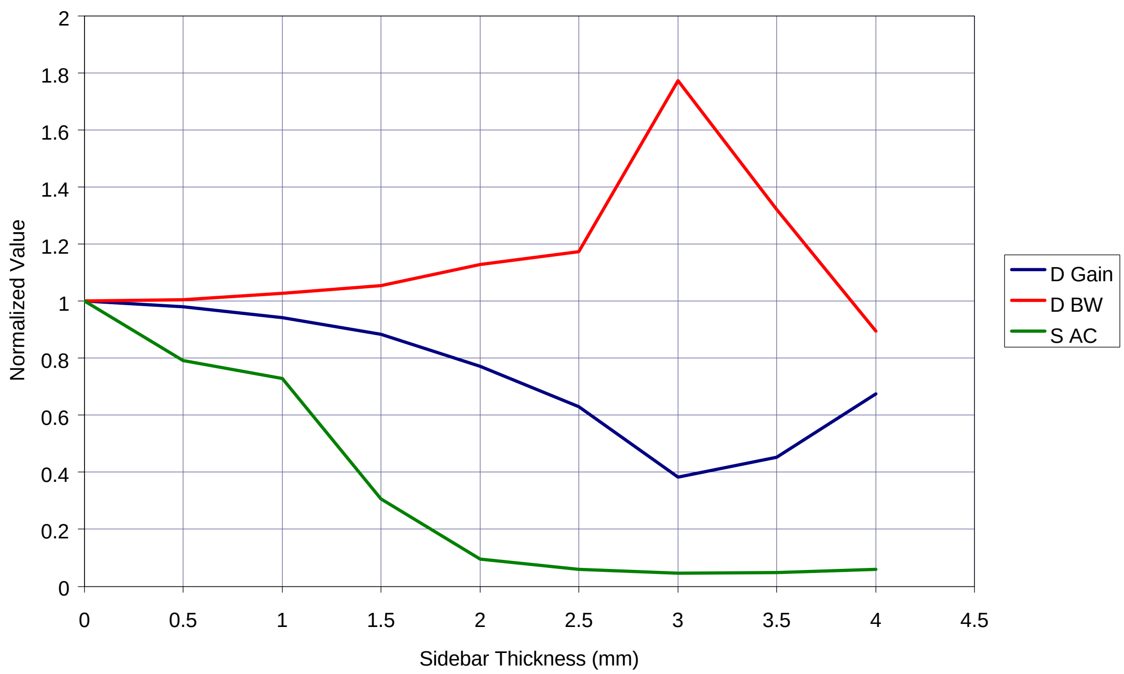

Figure 9. Summary plot of SiC sidebars. The blue trace is the maximum difference mode gain. The red trace is the difference mode bandwidth. The green trace is the amplitude of the sum mode gain variations.

NO ABSORBING SIDEBARS

Another way to remove the sum mode gain variations is to increase the transverse aperture of the beam-pipe (the y direction of Figure 1) until the magnetic mode in the beam pipe is well above cutoff. At this point the phase velocity between the beam-pipe magnetic mode and the input/output waveguide mode are similar and the sum mode gain variations decrease. As the transverse aperture increases, the difference mode sensitivity will decrease. However, since the difference mode sensitivity decreases with the introduction of absorbing sidebars, the results between absorbing sidebars and increased transverse aperture are similar. Figures 10 through 12 show the response of the HB1 kicker as a function of beam pipe height. The starting point of 40mm would accommodate a 40 π-mm-mrad beam. The sum mode gain variations are reduced to an acceptable level for a beam-pipe height somewhere between 55-60mm. The difference mode sensitivity is reduced by 35-40% which is comparable to the MF114 or SiC absorbing sidebars. However, the sum mode sensitivity with acceptable gain variations for the increased aperture case is about 35% lower than the sum mode sensitivity for absorbing sidebars. But this drawback is partially redeemed with the fact that the sum mode response for the case of the increased aperture is more centered at the design frequency than for the solutions with the absorbing sidebars.

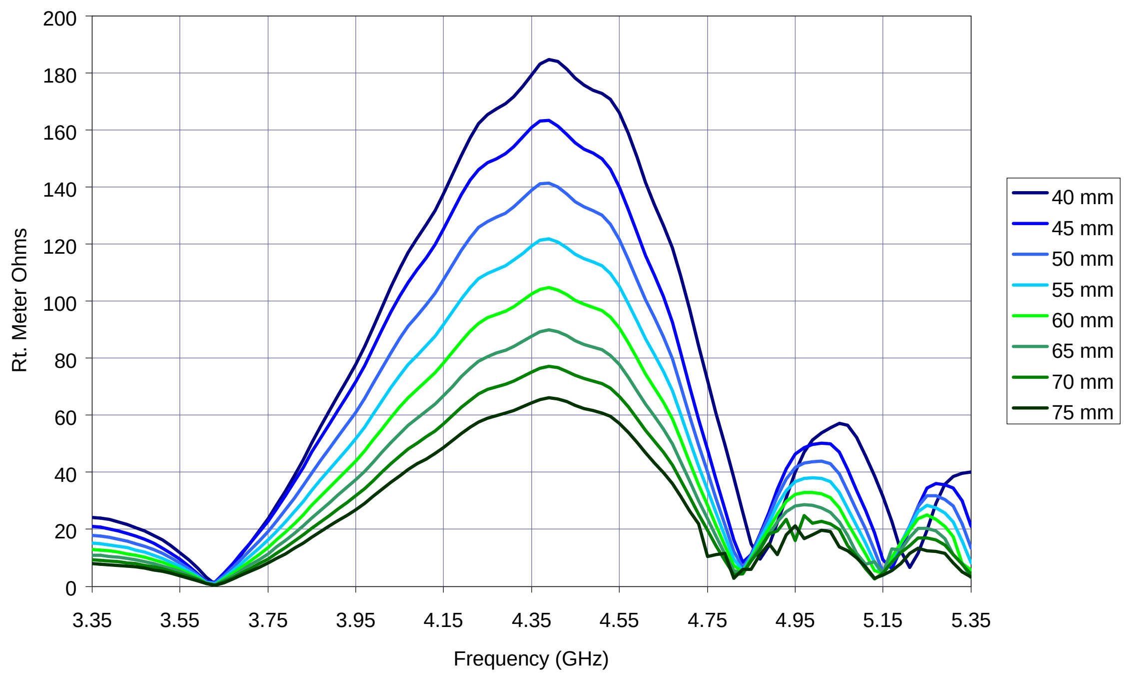

Figure 10. The difference mode kicker response of HB1 as a function of beam-pipe aperture with no absorbing sidebars.

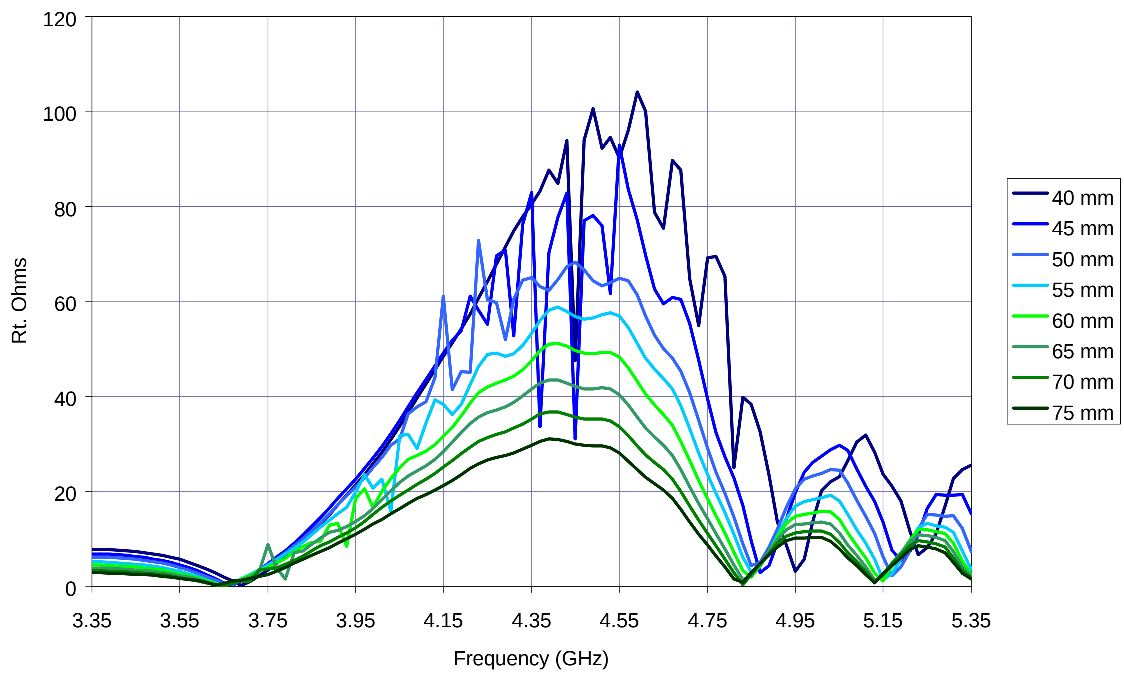

Figure 11. The sum mode kicker response of HB1 as a function of beam-pipe aperture with no absorbing sidebars.

Conclusions

Using electric or magnetic lossy sidebars in the beam-pipe can reduce variations in the sum mode gain. Increasing the transverse aperture of the beam-pipe can also reduce the variations. The most satisfactory results occur with a lossy magnetic absorber. However, the vacuum properties of this type of material are poor. The lossy electric absorber has the next best characteristics. However, the electrical properties and the thickness of this material must be carefully controlled to avoid reducing the difference mode sensitivity by too large a factor. These types of materials (especially SiC) are difficult to machine. Increasing the transverse aperture yields similar results to absorbing sidebars with a little more reduction in difference mode gain and a fairly large reduction in sum mode sensitivity. But the advantages of the increased aperture solution are:

1. There is no vacuum problem.
2. The are no tight material properties specifications.
3. The sum mode response is more centered at the design frequency.

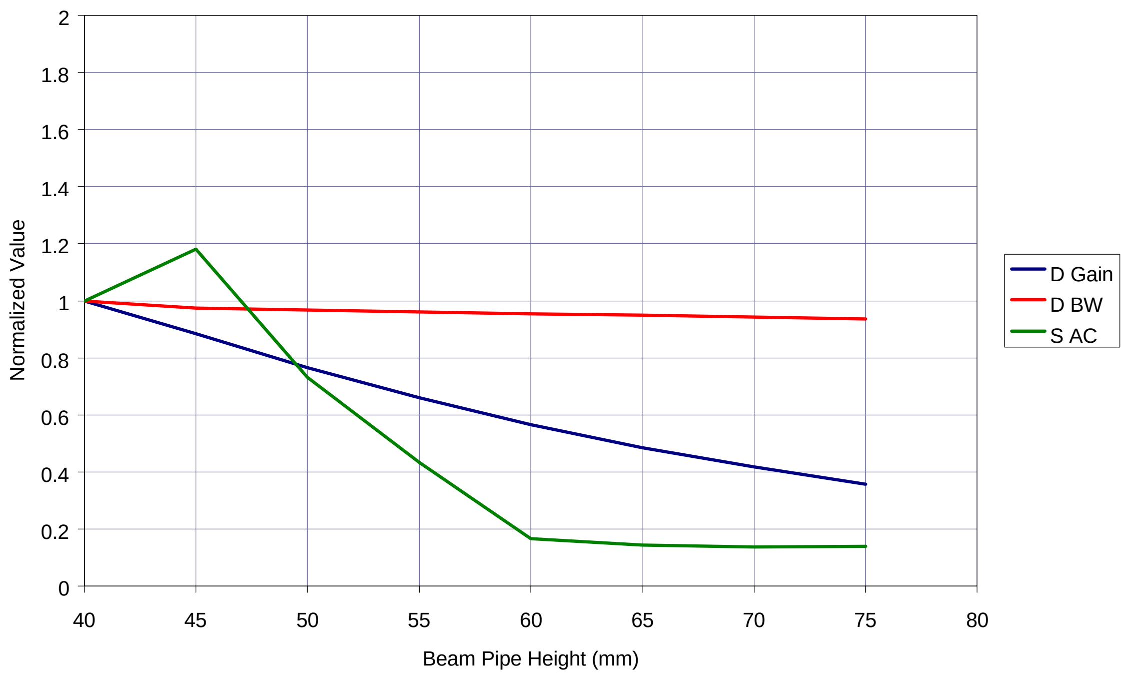

Figure 12. Summary plot as a function of beam-pipe aperture with no absorbing sidebars. The blue trace is the maximum difference mode gain. The red trace is the difference mode bandwidth. The green trace is the amplitude of the sum mode gain variations.