Note on Beam Position Monitor Sensitivity Scale Factors to Use for NuMI BPM System

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Introduction

All BPM pick-ups to be installed in the NuMI beam line were measured in a BPM test stand using 53MHz signals in a stretched wire configuration to determine individual position sensitivity scale factors and electrical/mechanical center offsets. This included both the standard 3.87 inch (98.3 mm) diameter MI-8 style BPMs used in most of the transport line and the 1.995 inch (50.6 mm) "Target" BPMs used near the neutrino production target. A description of this work and summary of results are contained in Numi BPM Measurement Data, Beams-doc-1412, by Jim Fitzgerald.

The summary measurement results reported in that document were obtained using an analysis spreadsheet created by Fitzgerald and Jim Crisp. That analysis results in a single sensitivity scale factor (decibels per millimeter) that is a best fit to all the measurement data over the area of the BPM aperture scanned in the test stand. Most of the BPMs (both sizes) were measured only within a ±15 mm grid. About five of the BPMs were scanned to ±20 mm and one to ±30 mm.

The software that will compute and report beam position from the measured BPM signal magnitudes is programmed to process the data in a linear difference-over-sum, rather than dB ratio, formulation. This note discusses the suitability of that formulation and the scale factors that might be used.

Analysis

Figure 1 shows measurement grids for BPM test stand measurements. The average sensitivity scale factors reported from those measurements are 0.245 dB/mm and 0.558 dB/mm for the MI-8 style and the Target BPMs respectively.

Beams-doc-1415, Relationship Between Beam Position Monitor Log Ratio and Difference-Over-Sum Formulations by Bob Webber, suggests how these scale factors might be translated into values compatible with a difference-over-sum computation. However, the NuMI BPM software is presently configured for a linear term only and errors associated with that approximation, assuming a linear log ratio BPM model, are described in doc-1415.

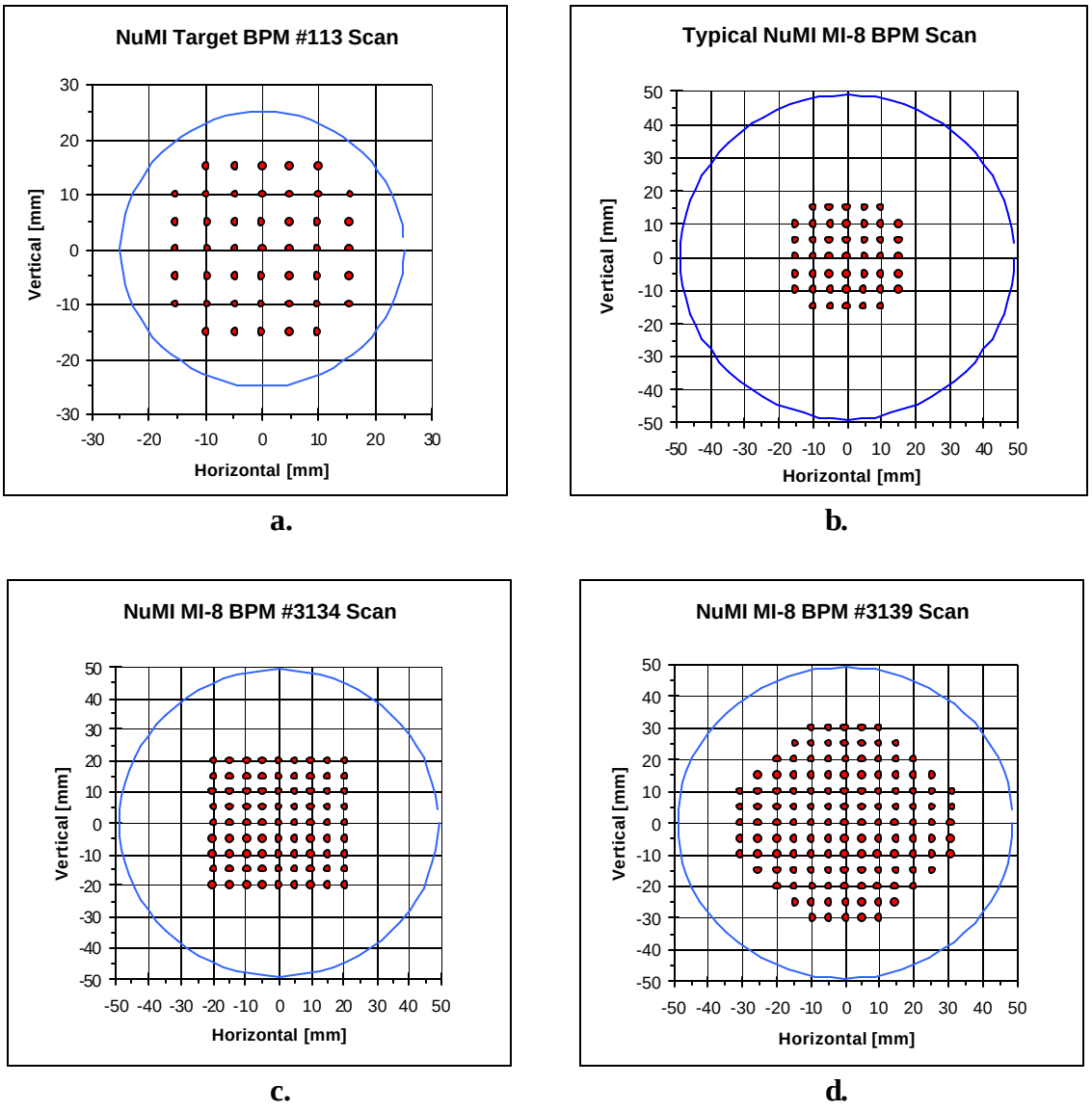


Figure 1. Measurement grids for NuMI BPMs -- **a.** ±15 mm scan for 50mm Target BPMs, **b.** ±15 mm scan for most 100mm MI-8 style BPMs, **c.** ±20 mm scan for five MI-8 style BPMs, **d.** ±30 mm scan for one MI-8 style BPM.

A second look at the original measurement data was taken to determine whether a linear difference-over-sum model, with suitable "effective radius", might be as accurate as the linear dB ratio assumed in the initial analysis.

Assuming that non-linearity errors would be most apparent in data for scans covering the greatest fractional BPM areas, the original data for the ±15 mm scan of Target BPM #113, the ±20 mm scan of MI-8 BPM #3134, and the ±30 mm scan of MI-8 BPM were processed to obtain difference-over-sum values for all measurement points. A linear fit to

the difference-over-sum values for each BPM was obtained in the same manner as was the dB/mm scale factor fit in the original analysis. The results yield an effective radius of 72.5-72.7 mm for the MI-8 BPMs and 33.0 mm for the Target BPMs.

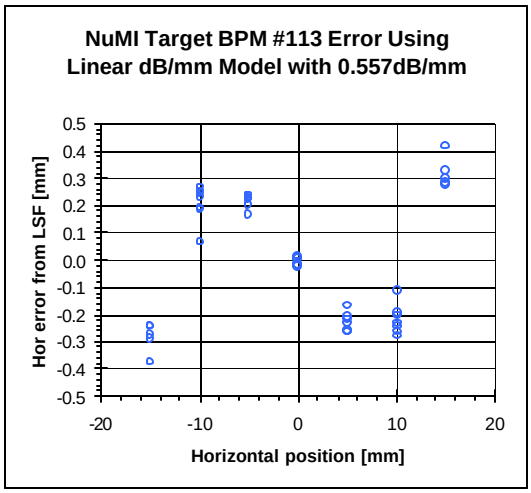
The errors between known wire position and the position computed from measured signal amplitudes are shown in Figures 2-4 for each model. The plots were obtained in the same manner as in the original analysis spreadsheet.

These data indicate that an assumed linear difference-over-sum model can fit the response of these BPMs at least as well as an assumed linear log ratio response. The errors, with correct choice of model parameters, are less than one millimeter for either model. Advantage of the difference-over-sum model, suggested by the figures, may or may not be realized in actual system implementation due to other contributing error sources.

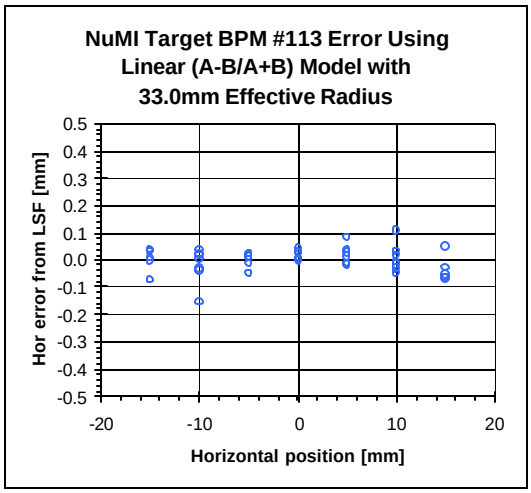
It might be noted that the ratio of effective radius to mm/dB obtained in these analyses is not exactly 40/ln(10) as would be suggested assuming a linear relation between the two models. This should be no surprise since these scale factors are obtained from data over fraction of the BPM aperture and on a scale of accuracy that are beyond the range where the linear approximation between the models makes sense.

Conclusion

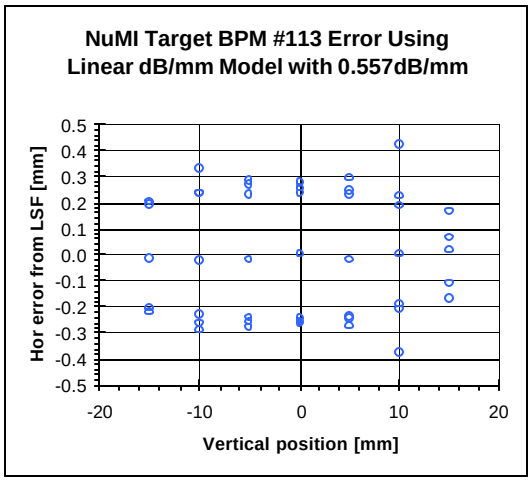
Data indicate that a linear difference-over-sum model for the NuMI BPMs is at least as good as, even somewhat better than, a linear log ratio model. This suggests that it is perfectly acceptable to use the existing linear difference-over-sum position computation with effective radii of 72.6 mm for the MI-8 style BPMs and 33.0 mm for the Target BPMs.



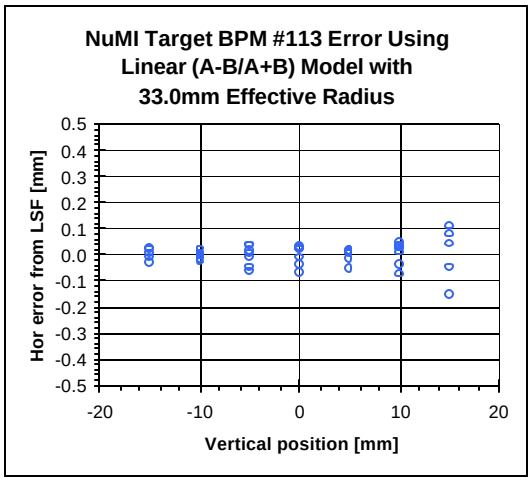
a.



b.



c.



d.

Figure 2. Errors between actual wire position and computed position over ±15 mm range for 50mm aperture Target BPM #113 using linear log ratio model in **a.** and **c.** and using linear difference-over-sum model in **b.** and **d.**

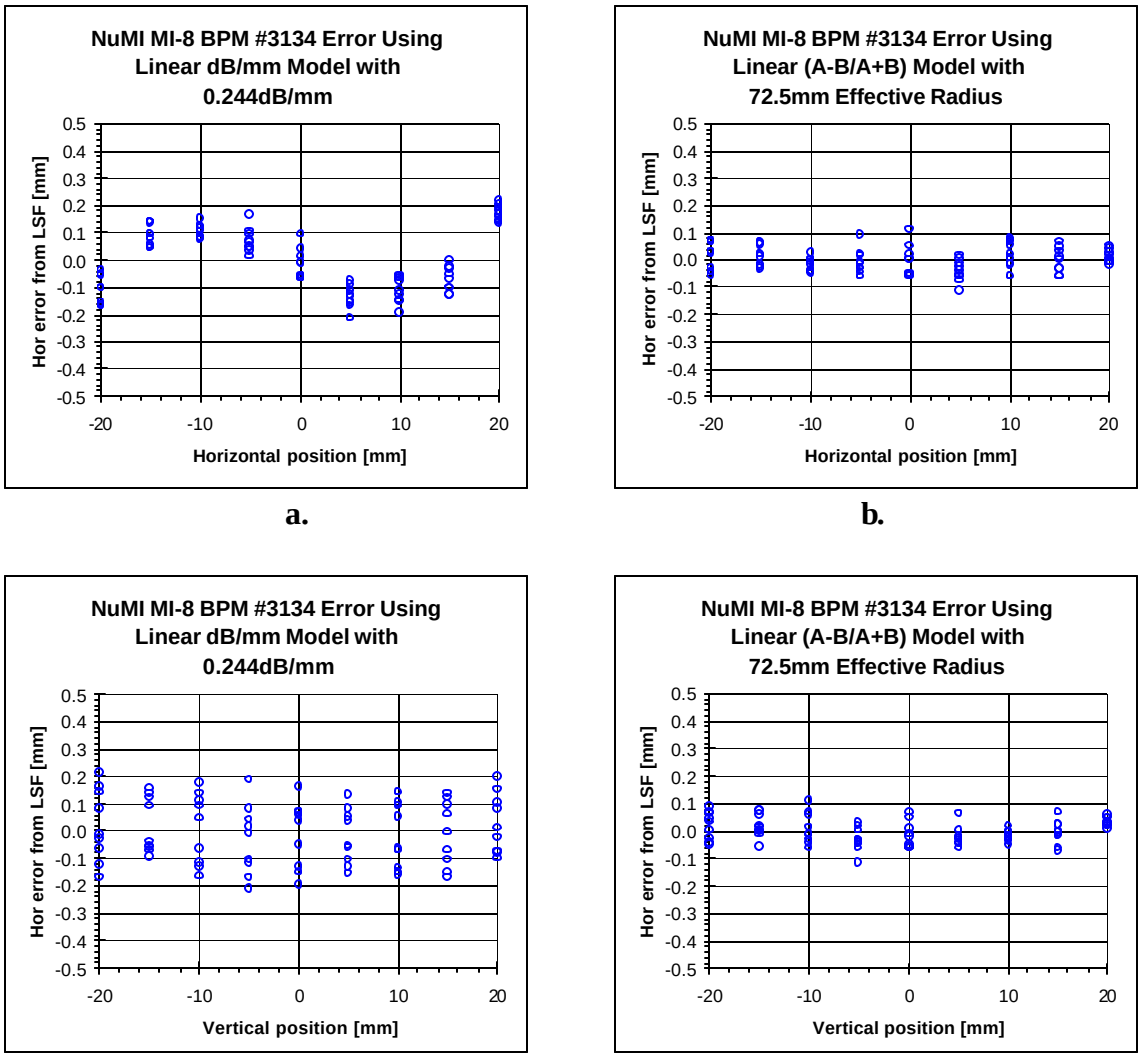
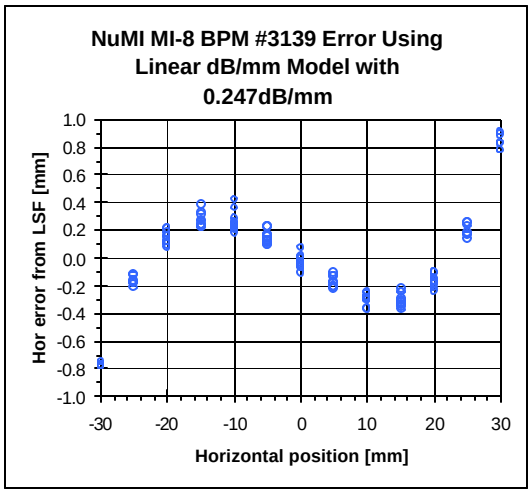
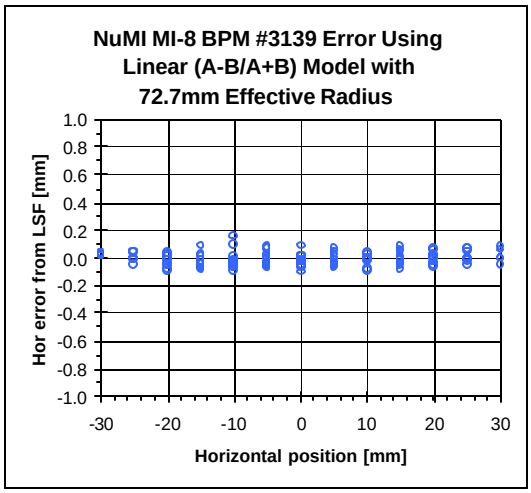


Figure 3. Errors between actual wire position and computed position over ±20 mm range for 100mm aperture MI-8 BPM #3134 using linear log ratio model in **a.** and **c.** and using linear difference-over-sum model in **b.** and **d.**



a.



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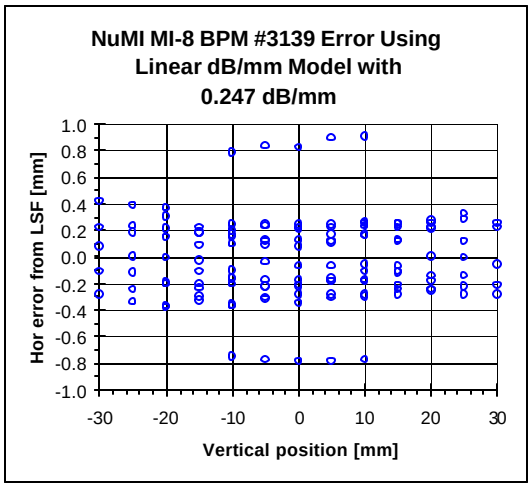
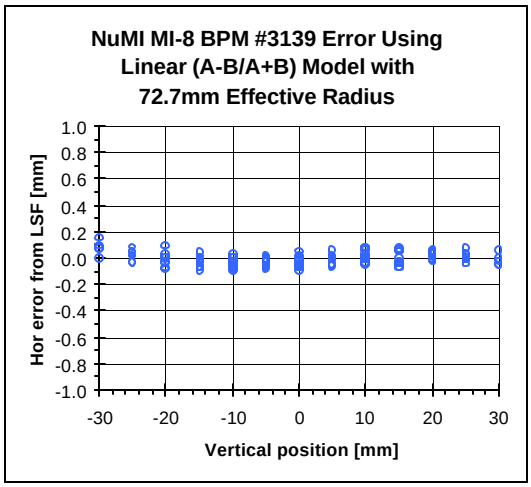


c.



d.

Figure 4. Errors between actual wire position and computed position over ±30 mm range for 100mm aperture MI-8 BPM #3139 using linear log ratio model in **a.** and **c.** and using linear difference-over-sum model in **b.** and **d.**