# Accumulator BPMs: Reported Position Not Independent of Signal Intensity

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P-Bar Note #616

The position reported by the Accumulator Beam Position Monitor (BPM) system is not independent of the signal intensity. Studies of the Closed Orbit mode have been done using the in-situ calibration system as well as a function generator The BPM signals are combined to calculate the position within the DSP. The results are independent of which DSP algorithm is used (see the histogram means reported in figures 7 and 8 of P-Bar Note #615).

The calibration signal is split evenly within the preamp; the signals are added to the BPM plates' signals. Each signal is then sent up stairs to an analog VXI module (also know as the down converter, DC). For the closed orbit electronics path in the DC card, a signal goes through a low pass filter before an amplifier ($-10$ to 30 dB) followed by a second low pass filter. The signal is then sent to a digital VXI module (also known as the ADC card) where the signal is digitized (12-bit at 25.6 MHz) and written to memory (128K samples). A DSP on the digital card then processes the ADC memory data to determine the intensity of a signal. The intensities of the two channels which make up a BPM are then used to calculate the position and an overall intensity.

The closed orbit mode calibration signal is a pulse repeated at a rate of 2.5 MHz (results are the same for 1.27 MHz). The pulse is designed to have a duration of 100 ns with rise and fall times of 10 ns. The amplitude of the pulse can be as little as 50 mV and as large as 5 V.

Studies have been done varying the DC card amplifier gain or changing the amplitude of the calibration signal. For all studies the calibration coefficients have been set to 1. Since the calibration signal is split evenly, the resulting positions should be 0 mm with the exceptions of four BPMs which are mechanically offset.

Figure 1 shows the response (position and intensity) of a single BPM (effective radius, $R_e = 69.8$ mm) to a calibration signal of 50 mV. Ten measurements were made for different gain settings which ranged $-10$ to 30 dB. The heterodyne algorithm in the DSP determines the intensity of the signal that the ADC has seen for each channel. The two channels intensities corresponding to a single

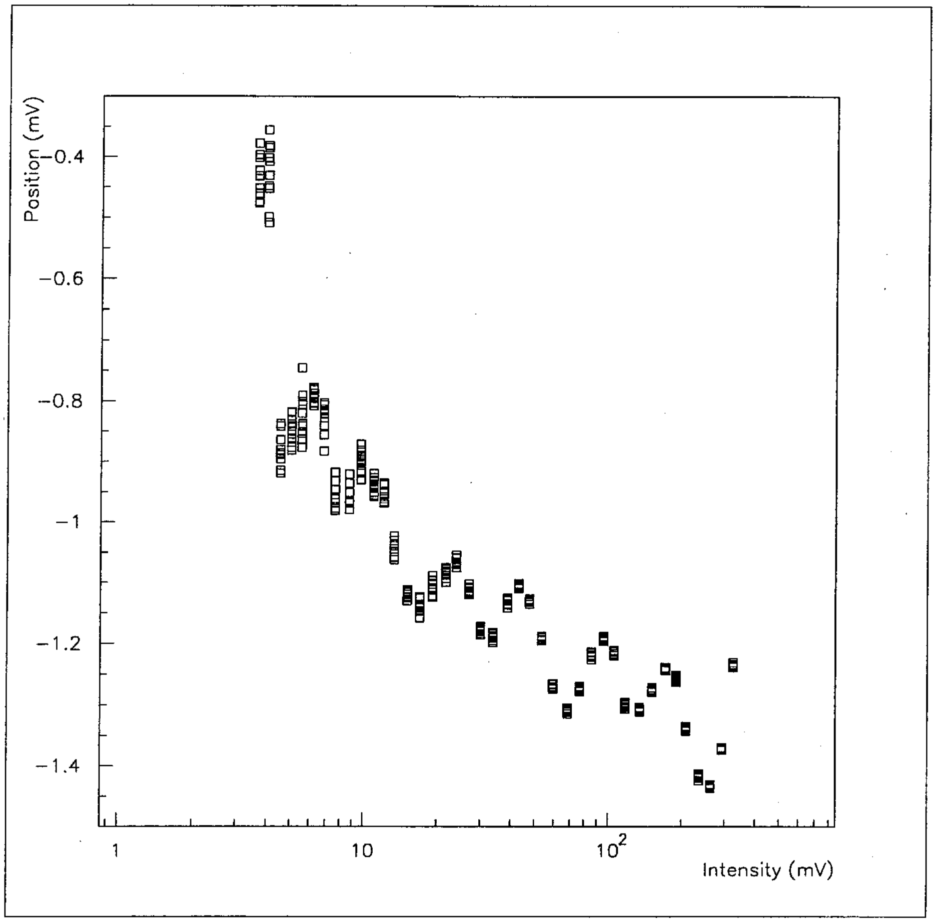


Figure 1: The reported positions and intensities for BP101H ($R_e$ = 69.8 mm) to a calibration pulse of 50 mV for different gain settings.

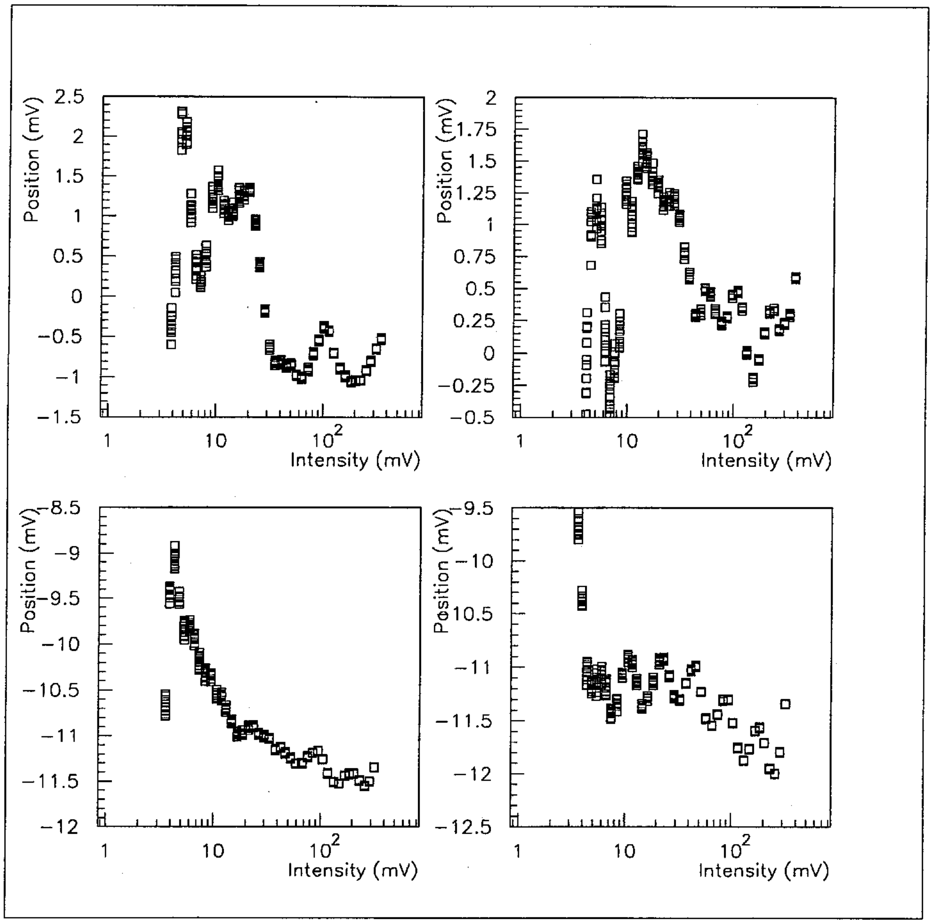


Figure 2: The reported positions and intensities for several BPMs to a calibration pulse of 50 mV for different gain settings. The upper two are the largest type, $R_e = 252.5$ mm; the lower two are $R_e = 100.5$ mm and offset 10 mm.

BPM are then used to calculate the position:

$$X = R_e \frac{A-B}{A+B} - X_0.$$

The intensity reported is the denominator of the *difference by sum ratio*. Figure 2 shows that the there is no consistent dependency of the position upon the intensity. The spread of the 10 measurements becomes less than 0.2 mm when the reported intensity is greater than 20 mV. Excursions up to 3 mm can be seen while changing the gain. Calibration can be done at each gain setting so that all reported positions are 0 mm for a **constant** amplitude signal.

Figure 3 shows the response to different gain settings while the calibration signal is varied (50 mV to 5 V); this is the same BPM as shown in figure 1. The gain settings ($-10$, 0, 10, 20, and 30 dB) include the minimum and maximum gains allowed. The ADC saturates around the reported intensity of 850 mV (the BPM saturation bit is set). Each gain setting has its own position versus intensity curve; this can definitely be seen in figure 4. Unfortunately, the 30 dB reaches saturation quickly but for the limited range there is definitely a change of position. For the larger BPMs the change on the 30 dB curve is 0.1 mm, see figure 5.

The position can be divided by $R_e$ to perform a normalization and set the scale of change between the two signals that comprise the BPM results. Figures 6, 7 and 8 show the *difference by sum ratio* for the same BPMs shown in figures 3, 4 and 5, respectively, as a function of the *sum* (reported intensity). The ratio changes on the order of 0.1% for reported intensities greater than 100 mV. This corresponds to roughly the difference in signal intensities changing less than 1 mV.

A study using a function generator (sine wave setting) was done for one BPM (BP501H) set of electronics. The sine wave was split and sent into the electronics as the $A$ and $B$ signals. The FFT DSP algorithm was used since the heterodyne algorithm needs to know the frequency on the order of $\approx$ 10 Hz. The upper left plot of figure 9 shows the response when the sine wave is directly into the ADC and hence no gain amplifier. The other plots of figure 9 are when the sine wave is directly into the DC card for gain settings of $-10$, 0 and 30 dB. The DC card has a larger effect as can be seen in figure 10 where a comparison of the two plots with no gain are shown.

From the calibration study the larger effect is caused by changing the gain setting of the DC card. However, this can be *calibrated out*. The smaller effect, input signal amplitude, cannot be *calibrated out*. It appears that if the gain is set so that the reported intensity is greater than 50 mV (preferably more than 200 mV) and a calibration is done, then small changes of the signal amplitude will not affect the reported position. The DC card appears to be the element of the BPM system electronics which causes the position to be sensitive to the signal intensity.

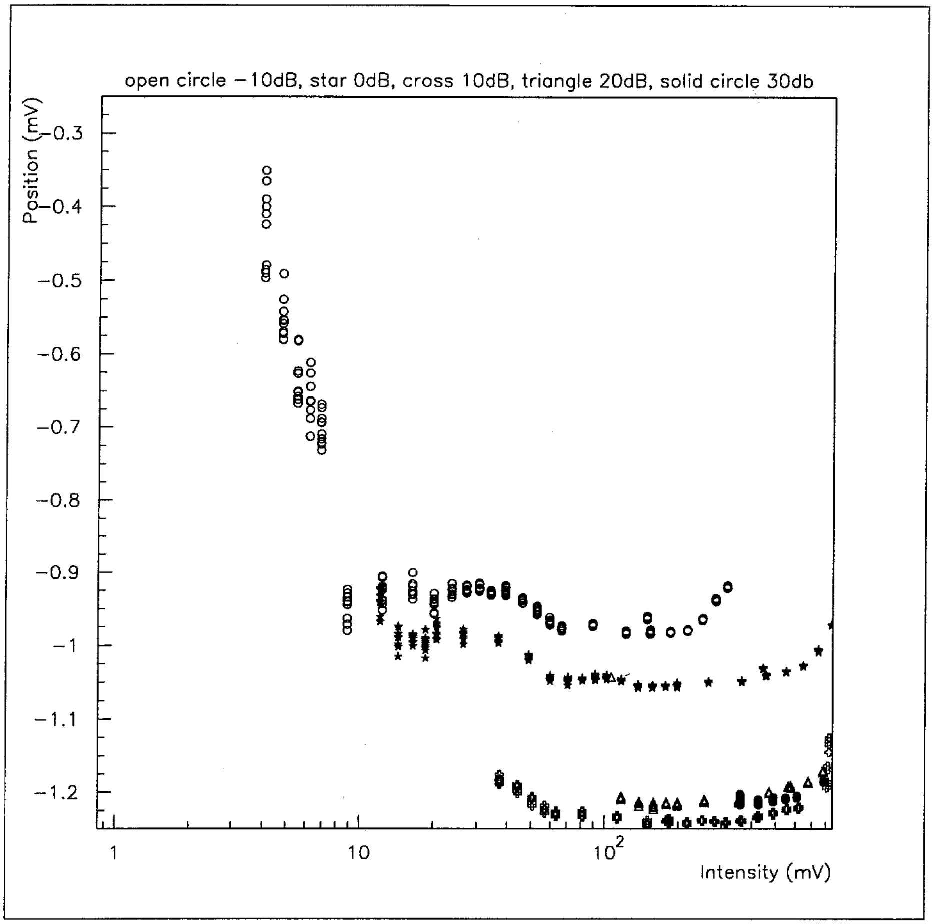


Figure 3: The reported positions and intensities for BP101H ($R_e = 69.8$ mm) to five different gain settings while the calibration amplitude was varied between 50 mV and 5 V.

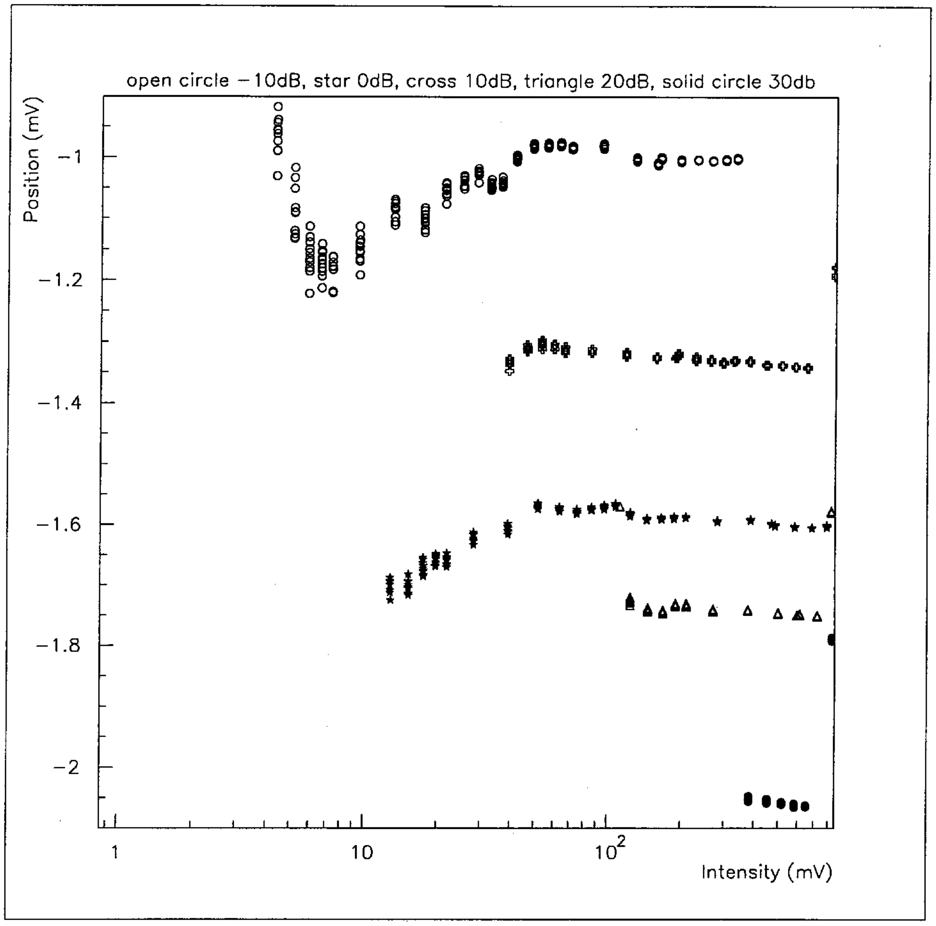


Figure 4: The reported positions and intensities BP105V ($R_e$ = 69.8 mm) to five different gain settings while the calibration amplitude was varied between 50 mV and 5 V. The five curves from top to bottom are −10, 10, 0, 20 and 30 dB.

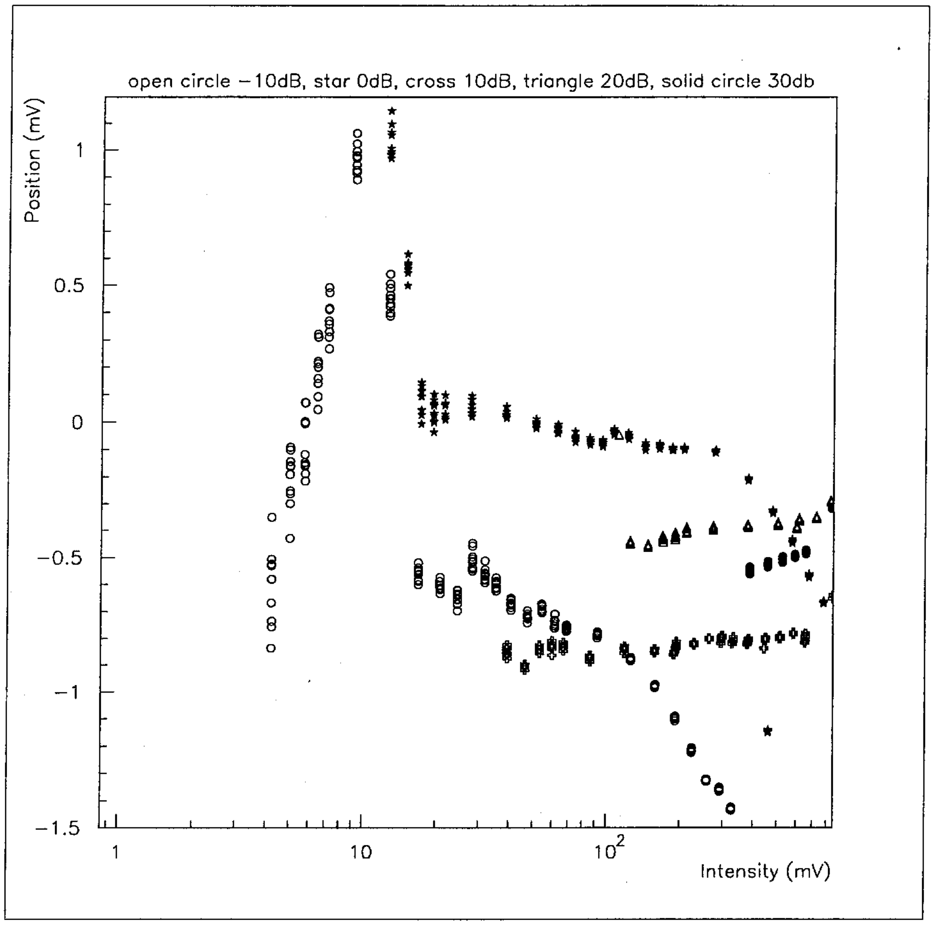


Figure 5: The reported positions and intensities for BP114H ($R_e = 252.5$ mm) to five different gain settings while the calibration amplitude was varied between 50 mV and 5 V.

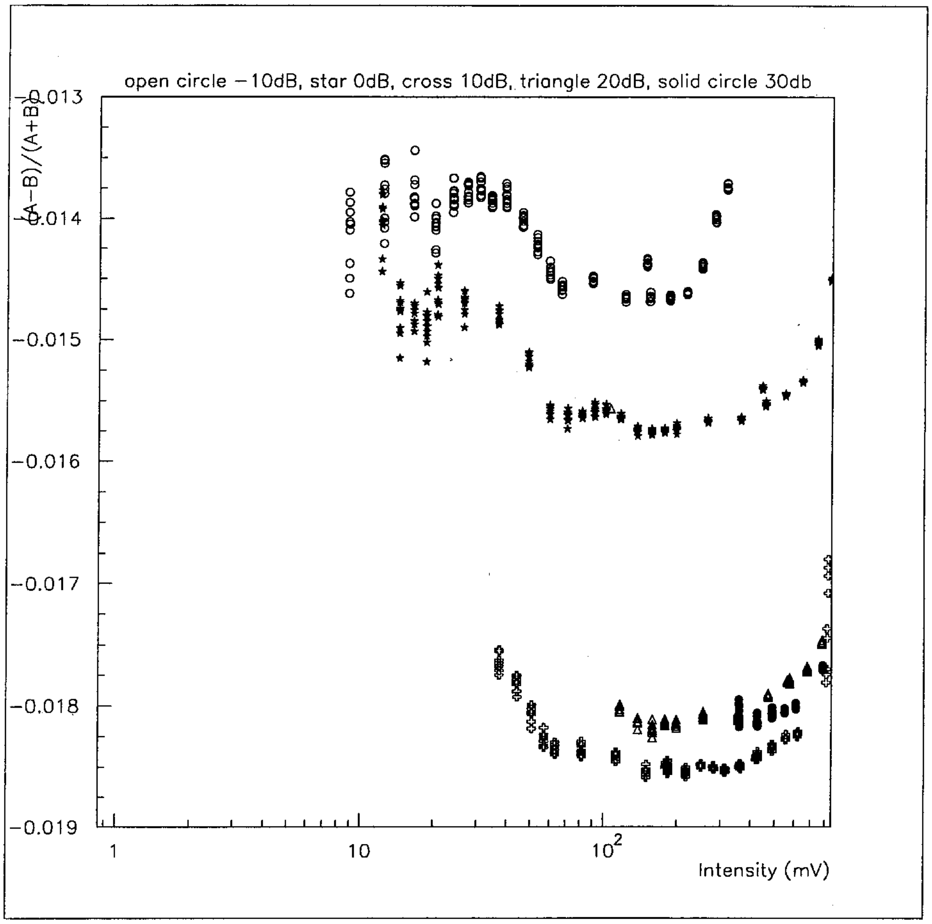


Figure 6: The difference by sum ratio for BP101H ($R_e$ = 69.8 mm) to five different gain settings while the calibration amplitude was varied between 50 mV and 5 V. The scale has been expanded; the lower intensity data associated with −10 dB are offscale.

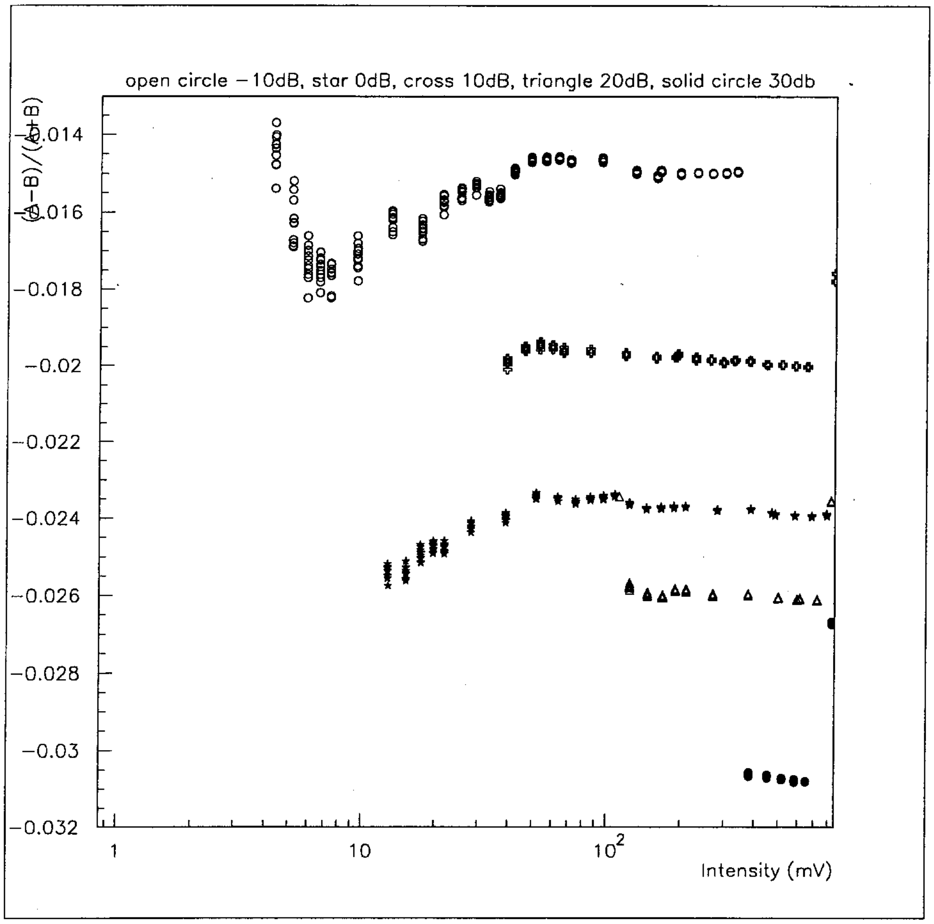


Figure 7: The difference by sum ratio for BP105V ($R_e$ = 69.8 mm) to five different gain settings while the calibration amplitude was varied between 50 mV and 5 V.

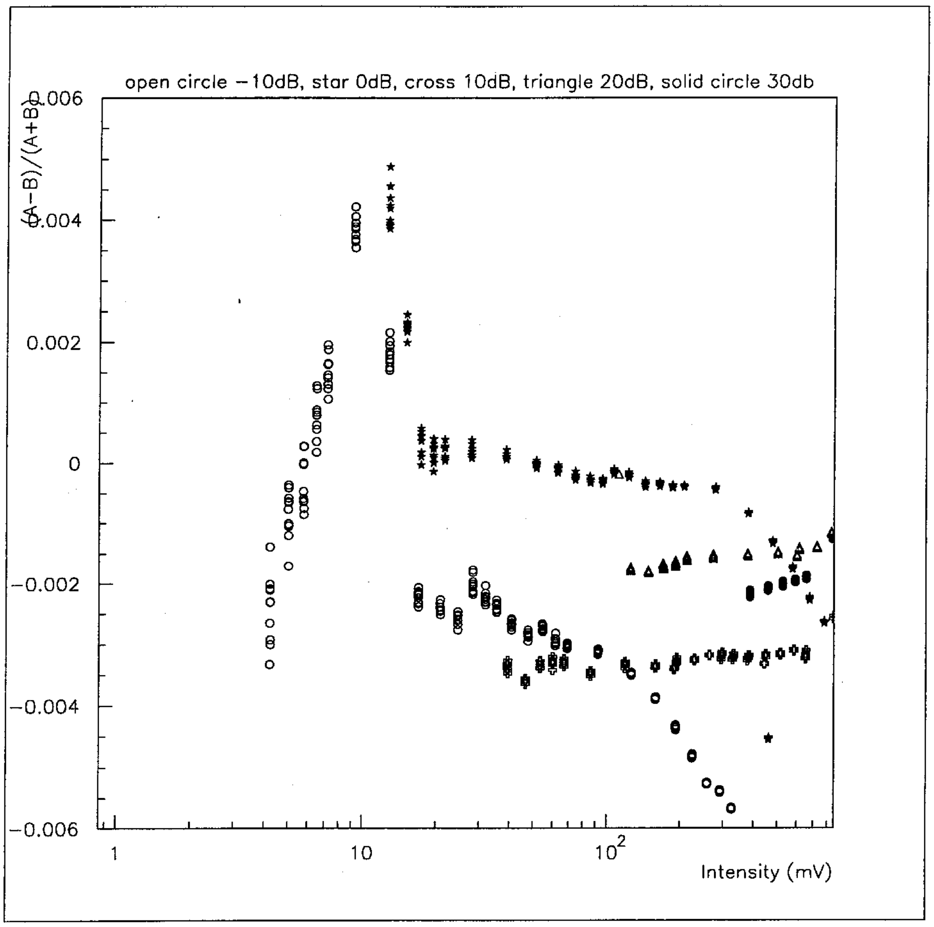


Figure 8: The difference by sum ratio for BP114H ($R_e$ = 252.5 mm) to five different gain settings while the calibration amplitude was varied between 50 mV and 5 V.

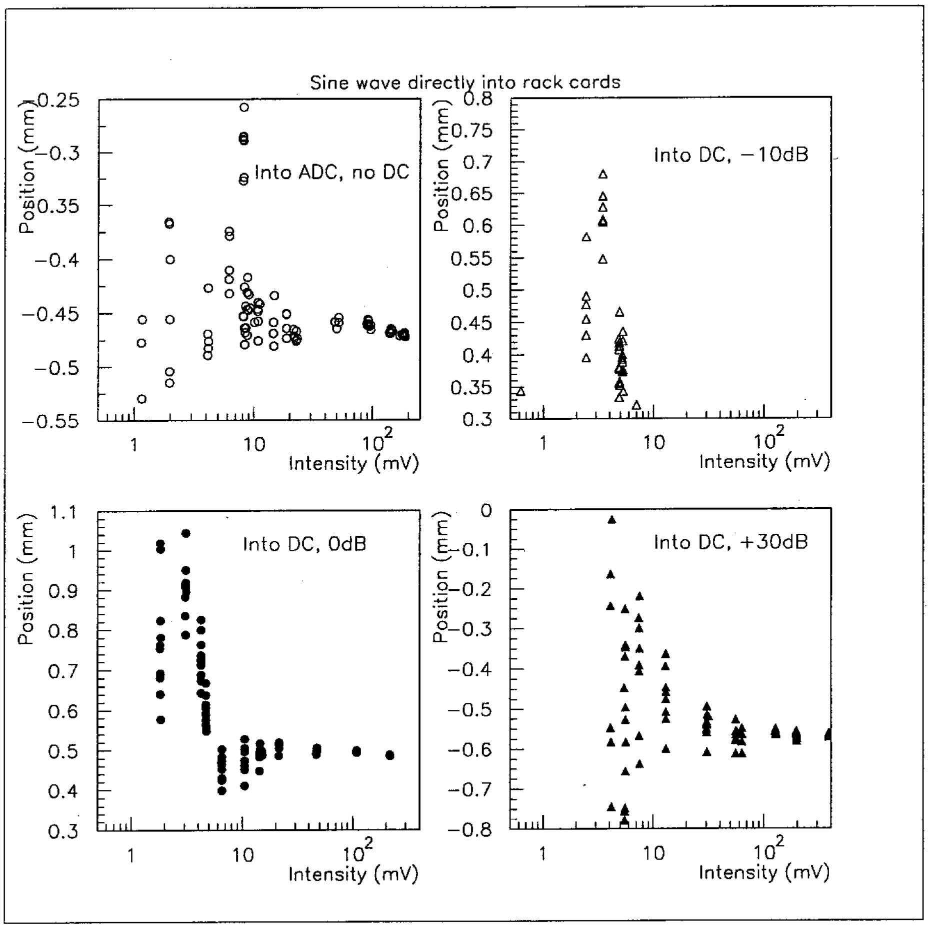


Figure 9: The reported positions and intensities for BP501H ($R_e$ = 69.8 mm) to a sine wave. The upper left plot is when directly put into the ADC; the rest are directly into the DC card with gains of −10, 0 and 30 dB.

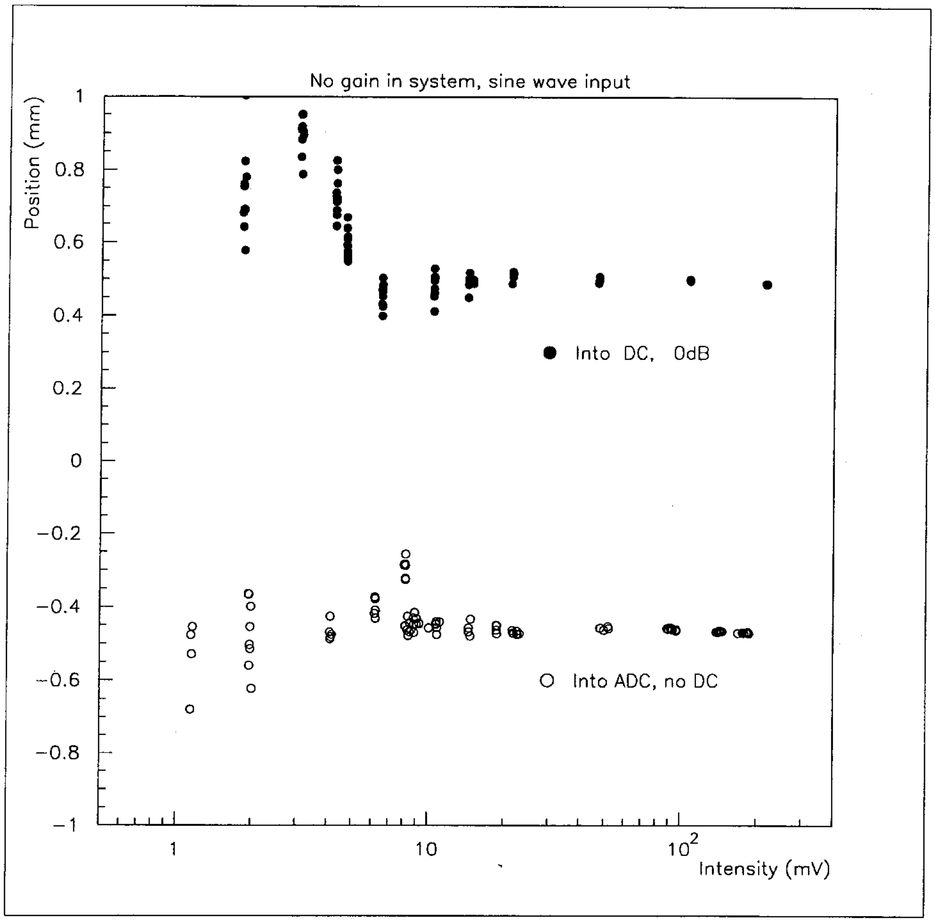


Figure 10: Comparison of the reported positions and intensities for BP501H ($R_e = 69.8$ mm) to a sine wave for two no gain configurations (with and without the DC card/amplifier).