Program to read MI Extra-wide Aperture BPM test stand measurement data files, compute BPM transfer function in difference-over-sum formulation, and generate polynomial coefficients to compute position from difference-over-sum

Set working directory

CWD := "Z:\Instrumentation\MI_BPMs\ExtraWideApertureMIBPMs\EXWABPM_Raw_Data"

Import data:
Use data from Vertical measurements of all BPMs #1-8 and Horizontal measurements of all BPMs #1-7 (#8 contains no horizontal scan data).
Note: In the case of single-digit file numbers, those are the BPM serial number. In the case of two-digit file numbers, the "tens place" digit is the BPM serial number. (The 2 in the "ones place" simply represents that this is data from a second test stand measurement.

$$\text{hfilenum} := \begin{pmatrix} 12 \\ 22 \\ 32 \\ 42 \\ 5 \\ 6 \\ 7 \end{pmatrix} \qquad \text{vfilenum} := \begin{pmatrix} 12 \\ 22 \\ 32 \\ 42 \\ 5 \\ 6 \\ 7 \\ 8 \end{pmatrix}$$

Get horizontal and vertical scan data at orthogonally centered positions

```
hdatav0 := | a ← READPRN(concat("EXWA0", num2str(hfilenum_0), "Horiz.txt"))
           | mat ← submatrix(a, 169, 189, 0, 3)
           | for i ∈ 1 .. length(hfilenum) − 1
           |    | a ← READPRN(concat("EXWA0", num2str(hfilenum_i), "Horiz.txt"))
           |    | mat ← stack(mat, submatrix(a, 169, 189, 0, 3))
           | mat
```

$\text{length}\left(\text{hdatav0}^{\langle 0 \rangle}\right) = 147$

```
vdatah0 := | mrow ← 0
           | for i ∈ 0.. length(vfilenum) − 1
           |   | a ← READPRN(concat("EXWA0", num2str(vfilenum_i), "Vert.txt"))
           |   | for m ∈ 0.. length(a^⟨0⟩) − 1
           |   |   if |a_{m,0}| ≤ 0.5
           |   |     | for c ∈ 0.. 3
           |   |     |   mat_{mrow,c} ← a_{m,c}
           |   |     | mrow ← mrow + 1
           | mat
```

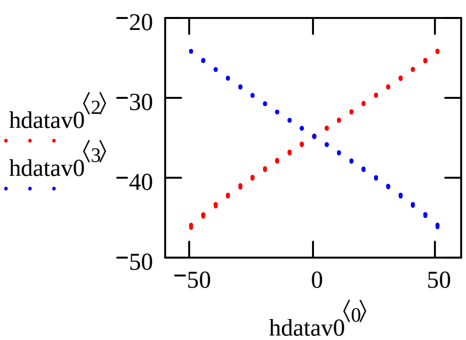
$$hdatav0bpm(k) := submatrix\left(hdatav0, match(k, hfilenum)_0 \cdot 21, match(k, hfilenum)_0 \cdot 21 + 20, 0, 3\right)$$

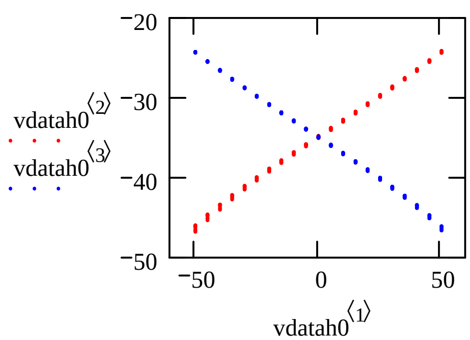
$$hbpm(k) := hdatav0bpm(k)$$

$$vdatah0bpm(k) := submatrix\left(vdatah0, match(k, vfilenum)_0 \cdot 21, match(k, vfilenum)_0 \cdot 21 + 20, 0, 3\right)$$

$$vbpm(k) := vdatah0bpm(k)$$

$$length\left(vdatah0^{\langle 0 \rangle}\right) = 168$$





Plots of electrode signal amplitudes in dB vs. wire position in millimeters.
Horizontal BPM scans in left plot and vertical scans in right.

Sign convention is such that in horizontal array first electrode signal column is electrode labeled "A" and in vertical the first signal column is electrode labeled "C". "A" and "C" signals get larger for increasingly positive wire positions in test stand convention.

Now create two-column arrays for Horizontal and Vertical, first column 'in-plane' position and second column difference-over-sum (with convention that positive difference corresponds to positive position in test stand convention, i.e. larger "A" or "C" signal than "B" or "D" signal. NOTE: this is opposite the convention in the actual MI BPM system, so be alert for sign changes! Also create "combo" array that combines both the horizontal and vertical.

$$
\text{hdosv0} := \left|\begin{array}{l} \text{result}^{\langle 0\rangle} \leftarrow \text{hdatav0}^{\langle 0\rangle} \\ \text{for } m \in 0..\text{rows(hdatav0)} - 1 \\ \quad \left|\begin{array}{l} S1 \leftarrow 10^{\frac{\text{hdatav0}_{m,2}}{20}} \\ S2 \leftarrow 10^{\frac{\text{hdatav0}_{m,3}}{20}} \\ \text{result}_{m,1} \leftarrow \dfrac{S1 - S2}{S1 + S2} \end{array}\right. \\ \text{result} \end{array}\right.
$$

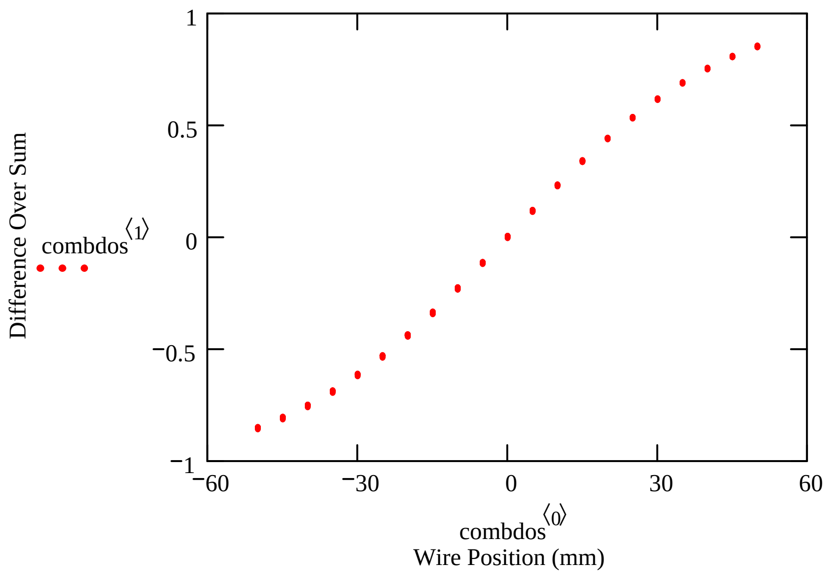
$$\text{length}\left(\text{hdosv0}^{\langle 0\rangle}\right) = 147$$

$$
\text{vdosh0} := \left|\begin{array}{l} \text{result}^{\langle 0\rangle} \leftarrow \text{vdatah0}^{\langle 1\rangle} \\ \text{for } m \in 0..\text{rows(vdatah0)} - 1 \\ \quad \left|\begin{array}{l} S1 \leftarrow 10^{\frac{\text{vdatah0}_{m,2}}{20}} \\ S2 \leftarrow 10^{\frac{\text{vdatah0}_{m,3}}{20}} \\ \text{result}_{m,1} \leftarrow \dfrac{S1 - S2}{S1 + S2} \end{array}\right. \\ \text{result} \end{array}\right.
$$

$$\text{length}\left(\text{vdosh0}^{\langle 0\rangle}\right) = 168$$

$$\text{combdos} := \text{stack(hdosv0, vdosh0)}$$

$$\text{length}\left(\text{combdos}^{\langle 0\rangle}\right) = 315$$



Now generate 5th order polynomial fits to this data

$$oncenterfith := regress\left(hdosv0^{\langle 0 \rangle}, hdosv0^{\langle 1 \rangle}, 5\right)$$

$$oncenterfitv := regress\left(vdosh0^{\langle 0 \rangle}, vdosh0^{\langle 1 \rangle}, 5\right)$$

$$inversefith := regress\left(hdosv0^{\langle 1 \rangle}, hdosv0^{\langle 0 \rangle}, 5\right)$$

$$inversefitv := regress\left(vdosh0^{\langle 1 \rangle}, vdosh0^{\langle 0 \rangle}, 5\right)$$

$$combofith := regress\left(combdos^{\langle 0 \rangle}, combdos^{\langle 1 \rangle}, 5\right)$$

$$inversecombofith := regress\left(combdos^{\langle 1 \rangle}, combdos^{\langle 0 \rangle}, 5\right)$$

Coefficients for diffoversum = poly(mm) follow.
Ignore first 3 values in column!

$$oncenterfith = \begin{pmatrix} 3 \\ 3 \\ 5 \\ 1.554 \times 10^{-3} \\ 0.023 \\ -1.49 \times 10^{-6} \\ -3.343 \times 10^{-6} \\ 2.528 \times 10^{-10} \\ 3.402 \times 10^{-10} \end{pmatrix} \quad oncenterfitv = \begin{pmatrix} 3 \\ 3 \\ 5 \\ 2.027 \times 10^{-3} \\ 0.023 \\ -1.446 \times 10^{-6} \\ -3.342 \times 10^{-6} \\ 3.479 \times 10^{-10} \\ 3.38 \times 10^{-10} \end{pmatrix} \quad combofith = \begin{pmatrix} 3 \\ 3 \\ 5 \\ 1.806 \times 10^{-3} \\ 0.023 \\ -1.467 \times 10^{-6} \\ -3.342 \times 10^{-6} \\ 3.036 \times 10^{-10} \\ 3.39 \times 10^{-10} \end{pmatrix}$$

Coefficients for mm = poly(diffoversum) are:

$$inversefith = \begin{pmatrix} 3 \\ 3 \\ 5 \\ -0.065 \\ 43.602 \\ 0.018 \\ 5.311 \\ 0.226 \\ 21.492 \end{pmatrix} \quad inversefitv = \begin{pmatrix} 3 \\ 3 \\ 5 \\ -0.088 \\ 43.454 \\ 0.05 \\ 5.408 \\ 0.011 \\ 20.871 \end{pmatrix} \quad inversecombofith = \begin{pmatrix} 3 \\ 3 \\ 5 \\ -0.078 \\ 43.513 \\ 0.047 \\ 5.432 \\ 0.092 \\ 21.071 \end{pmatrix}$$

Extract first through fifth order coefficients and set all even coefficients (including offset) to zero.

$mm2dos := submatrix(combofith, 3, 8, 0, 0)$

$mm2dos_0 := 0 \qquad mm2dos_2 := 0 \qquad mm2dos_4 := 0$

$dos2mm := submatrix(inversecombofith, 3, 8, 0, 0)$

$dos2mm_0 := 0 \qquad dos2mm_2 := 0 \qquad dos2mm_4 := 0$

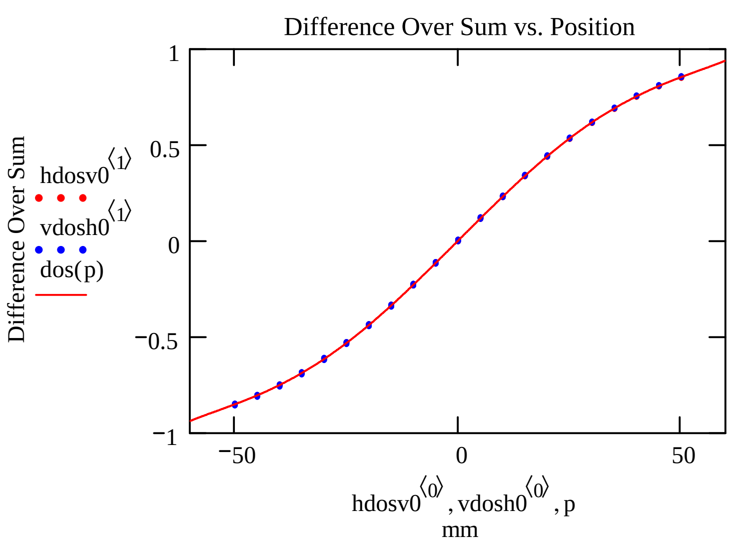
Use these for futher transfer function computations.

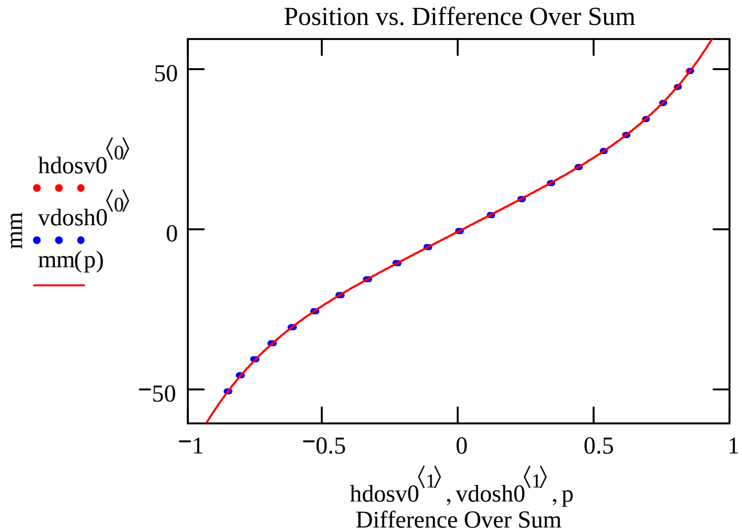
$$mm2dos = \begin{pmatrix} 0 \\ 0.023 \\ 0 \\ -3.342 \times 10^{-6} \\ 0 \\ 3.39 \times 10^{-10} \end{pmatrix} \qquad dos(mm) := \sum_{i=0}^{5} \left[\left(mm2dos_i \right) \cdot mm^i \right]$$

And

$$dos2mm = \begin{pmatrix} 0 \\ 43.513 \\ 0 \\ 5.432 \\ 0 \\ 21.071 \end{pmatrix} \qquad mm(db) := \sum_{i=0}^{5} \left[\left(dos2mm_i \right) \cdot db^i \right]$$

And check polynomial functions against data





Summary and Conclusion

A polynomial to compute beam position in millimeters from difference-over-sum values for the MI ExtraWide Aperture BPMs has been obtained from test stand data for scans centered on the orthogonal axis.

The polynomial for computing position in mm from Difference-Over-Sum for the EWA BPMs is:

mm = 43.513 * dos + 5.432 * dos**3 + 21.071 * dos**5 hdosv0 =

	0	1
0	50.002	0.849
1	44.998	0.803
2	40	0.749
3	34.998	0.687
4	30	0.615
5	24.998	0.531
6	20	0.44
7	14.998	0.338
8	10	0.231
9	5	0.118
10	0	$1.616 \cdot 10^{-3}$
11	-5	-0.115
12	-10	-0.228
13	-15.002	-0.336
14	-20.002	-0.438
15	-25.002	-0.53