MPMS Application Note 1014-204

Variation of Magnetic Field over the Scan Length

Since the magnetic field in the MPMS is a function of position due to the solenoid-type winding in the magnet, the sample is exposed to variations in magnetic field as it moves through the SQUID coils. The percent variation in the field seen by the sample depends on the scan length used. It is approximately .005% for a 2 cm scan length. It increases to nearly 6% for an 8 cm scan.

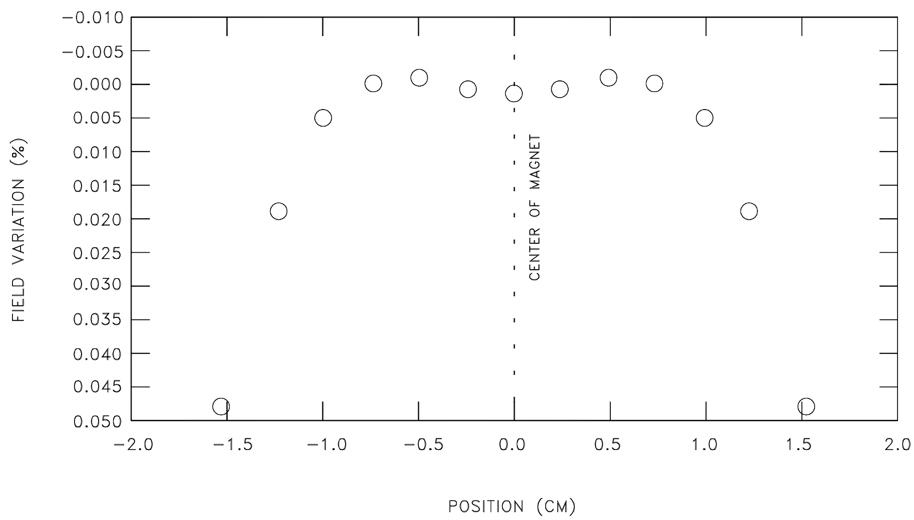
The data shown are taken from our magnet design calculations. Table 1 shows the percent variation in magnetic field experienced by a sample when using various scan lengths. The field variation in the MPMS as a function of position along the axis of the solenoid is shown in Figure 1.

Table 1. Variation of Magnetic Field

Scan Length	Field Variation
1 cm	.001 %
2 cm	.005 %
3 cm	.048 %
4 cm	.19 %
6 cm	1.4 %
8 cm	5.8 %

Each instrument is originally calibrated using a 6 cm scan and a palladium or platinum sample, neither of which displays any hysteretic effects. Our original calibration error due to this effect is estimated to be less than 0.1% because the response of the SQUID detection coils is also falling off rapidly. For example, at the end of a 6 cm scan (3 cm from the center of the magnet and detection coils) where the field is reduced by 1.43%, the signal from the sample is only about 7.5% of its maximum value.

Therefore, when measuring samples that are not hysteretic, the total estimated error introduced by the field variation is well within the 0.5% specification for the accuracy of the system. However, measurements on samples that display magnetic hysteresis effects can be substantially affected by the variations in field over the scan length since the sample is being cycled through a minor hysteresis loop with each scan.



POSITION (INCHES)	POSITION (cm)	FIELD GAUSS	FIELD VARIATION $\{\beta(n)/\beta(o)\}-1$
0.00	0.000	1550.4	0.000000
0.10	0.254	1550.4	0.000004
0.20	0.508	1550.4	0.000010
0.30	0.762	1550.4	0.000004
0.40	1.016	1550.3	−0.000046
0.50	1.270	1550.1	−0.000186
0.60	1.524	1549.6	−0.000484
0.80	2.032	1547.3	−0.001990
1.00	2.540	1541.3	−0.005861
1.20	3.048	1528.3	−0.014266
1.40	3.556	1503.2	−0.030412
1.60	4.064	1459.6	−0.058525
1.80	4.572	1389.7	−0.103601
2.00	5.080	1285.7	−0.170734
2.50	6.350	870.0	−0.438845
3.00	7.620	464.3	−0.700517
4.00	10.160	140.9	−0.909120
5.00	12.700	57.7	−0.962754
6.00	15.240	29.2	−0.981144
7.00	17.780	16.9	−0.989081

Figure 1. Field Variation versus Position (5.5 Tesla MPMS Magnet)

Short Scan Length Measurement Technique

If your measurements are likely to be affected by magnetic field variations at the levels indicated in Table 1, you may use a shorter scan length to minimize field variation on the sample. If you do, we recommend either the linear regression or iterative regression methods for computing the sample moment.

Perform measurements using very short scan lengths by setting up the system as follows:

1. Set the scan length to the desired value. We recommend a scan length of 3 cm because it gives a total field variation of about .05% over the length of the scan.
2. Adjust the position of the sample so that the center peak of the response curve is at the center of the scan. Note the iterative regression calculation can correct for small errors in position while the linear regression calibration assumes that the sample is perfectly centered.

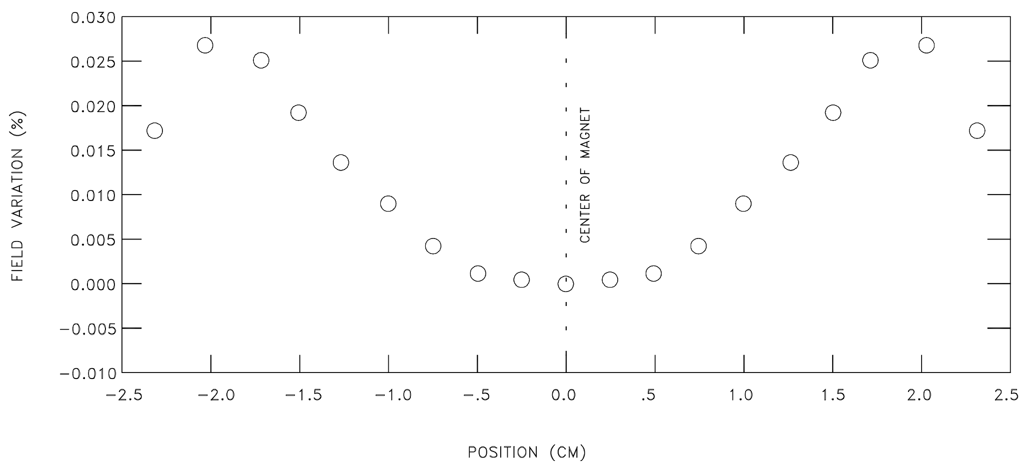
Correcting the Calibration Error

The moment computed with the regression calculation is a function of the scan length. The estimated percentage error in the absolute calibration of the instrument increases dramatically at very short scan lengths. Three methods that correct the scan length calibration error are:

- Measurement correction, which is based on the calculated response curves for the detection loops.
- Using a non-hysteretic sample of known susceptibility to measure the scan length dependence and correct your data.
- Normalizing all of your data to measurements of a non-hysteretic sample of similar shape, size, and known susceptibility. This method offers a powerful and useful technique when using any instrument of this type since calibration factors and normalizing the data to a well-defined and known sample can eliminate many low-level systematic errors.

$MPMS_2$ - 1.0 Tesla Magnet

The field variation in the $MPMS_2$ as a function of position along the axis of the solenoid is shown in Figure 2. The $MPMS_2$ is calibrated in the same manner as the MPMS. Due to the increased uniformity in the $MPMS_2$ magnet, you may use longer scan lengths for samples that display magnetic hysteresis effects. This will decrease the percent error in the calculation of the moment when using the regression algorithms. You may correct the scan length calibration error by using the same methods as those described in the previous section, Correcting the Calibration Error.



POSITION		FIELD	FIELD VARIATION
(INCHES)	(cm)	GAUSS	$\lvert \beta(n)/\beta(o) \rvert - 1$
0.00	0.000	526.3	0.0000
0.10	0.254	526.3	0.0004
0.20	0.508	526.3	0.0016
0.30	0.762	526.3	0.0040
0.40	1.016	526.3	0.0077
0.50	1.270	526.4	0.0130
0.60	1.524	526.4	0.0194
0.70	1.780	526.4	0.0252
0.80	2.032	526.4	0.0269
0.90	2.290	526.4	0.0171
1.00	2.540	526.2	−0.0162
1.10	2.790	525.8	−0.0929
1.20	3.050	525.0	−0.2429
1.30	3.300	523.6	−0.5087
2.00	5.080	464.6	−11.7206
3.00	7.620	191.3	−63.6498
4.00	10.160	57.9	−88.9995
5.00	12.700	23.2	−95.5957
6.00	15.240	11.3	−97.7985
7.00	17.780	6.7	−98.7339
8.00	20.320	4.2	−99.2009
10.00	25.400	2.0	−99.3186

Figure 2. Field Variation versus Position (1.0 Tesla $MPMS_2$ Magnet)