Q u a n t u m   D e s i g n

MPMS Application Note 1014-202

# Transverse Detection System

The transverse measurement system of the Magnetic Property Measurement System (MPMS) has a different pickup coil configuration than the longitudinal system. As a result, proper transverse measurements require centering the sample radially as well as longitudinally. It is also necessary to account for the longitudinal component of a transverse measurement when analyzing data.

The transverse system is similar to the longitudinal system in that both longitudinal and transverse pickup coils are second derivative coils designed to reject signals from uniform and linearly varying fields along the longitudinal axis. In addition, both systems use a regression calculation to fit the sample response to that of an ideal magnetic dipole. However, it is important to understand the differences between the longitudinal and transverse pickup coils to properly use these two detection systems.

The longitudinal coils consist of four circular coaxial loops that lie in planes perpendicular to the field as shown in **Figure la**. All four loops have equal areas. The two center coils are wound in the opposite direction from the end coils. Hence, the complete coil system is ideally insensitive to uniform and linearly varying longitudinal fields.

In contrast, the transverse coils are comprised of three pairs of symmetrically arranged saddle coils. As shown in **Figure lb**, these rectangular loops are wound so that they detect only transverse fields. Note that the center and end coils do not have equal areas. The transverse coils reject transverse fields that are uniform or that vary linearly in the longitudinal direction by doubling the area of the center loops.

The difference between the two configurations is shown in the graphs of their respective SQUID responses in **Figure 2a** and **Figure 2b**. The relative amplitude and shape of the transverse maxima/minima for a transverse moment are different than those obtained with the longitudinal coils when measuring a longitudinal moment.
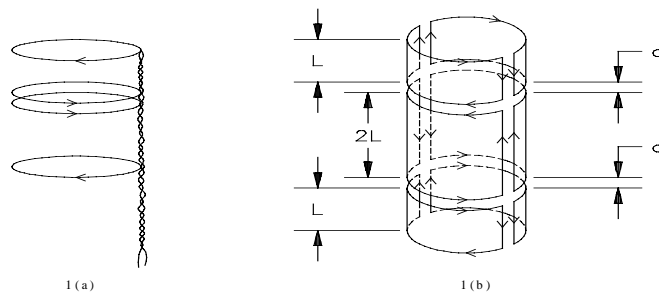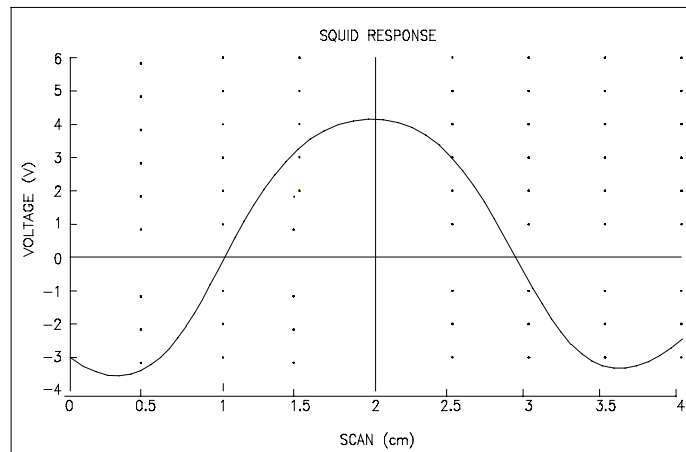

Figure 1. (a) Longitudinal Pickup Coils (b) Transverse Pick Up Coils

a) LONGITUDINAL SQUID RESPONSE
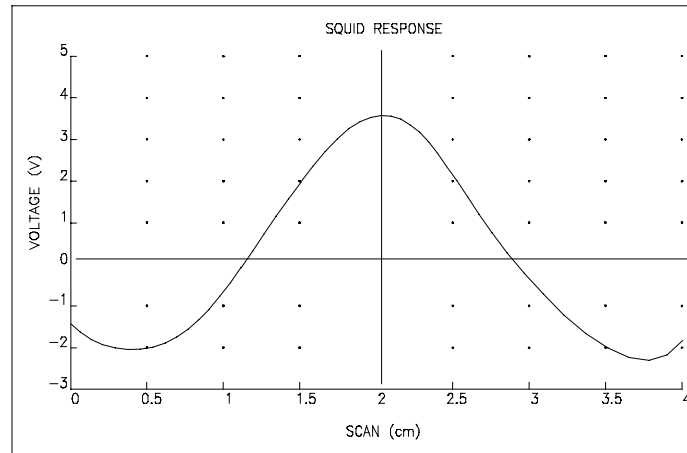

b)

TRANSVERSE SQUID RESPONSE

Figure 2. SQUID Response for (a) Longitudinal Moment in Longitudinal Pickup Coils (b) Transverse Moment in Transverse Pickup Coils

Assuming ideal coil geometry, the two systems are orthogonal. That is, a longitudinal moment produces no signal in the transverse coils, and a transverse moment produces no signal in the longitudinal coils. But in actual use there are discrepancies that must be understood when using a system with both longitudinal and transverse detection systems installed. This is particularly true when trying to evaluate the absolute magnitude of a transverse moment.

The primary effect that breaks the symmetry of the longitudinal system is the presence of the twisted leads. Twisted leads connect the pickup loops together and also connect to the SQUID sensor. If you mount a sample off center in the sample chamber, the asymmetry in the loops, due to the twisted pair, gives rise to a small variation in the measured

moment as you rotate the sample about a longitudinal axis. However, the effect should be small when the sample is located precisely in the center of the sample chamber. Since the calibration assumes the sample is at the center of the sample chamber, it is important that the sample be centered not only along the z-axis but radially in the sample chamber also.

The twisted leads also break the symmetry of the transverse coils, but the transverse coils do not have the inherent rotational symmetry of the longitudinal coils. When a sample with a transverse moment is positioned in the center of one of the coil pairs and rotated, the transverse SQUID output appears roughly sinusoidal. The maxima and minima occur when the transverse moment is pointed toward one of the detection coils. The zeros of the sinusoidal output occur when the moment is pointed toward the gap between the coils. See **Figure 3**. Because of this effect, it is important to rotate the sample in the x−y plane to get a maximum moment. This can be done by first centering the sample vertically in the transverse coil set, then rotating the sample while monitoring the voltage output of the transverse SQUID. To do this, place the sample in the center of the pickup coils and either monitor the output voltage from channel 7 or connect a voltmeter to the analog output located on the back of the Model 1822 controller, JC-14.
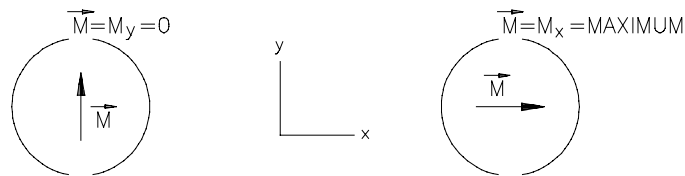
Figure 3. Zero SQUID output for transverse moment in transverse coils occurs when moment is pointed at gap between coils. Maximum and minimum outputs occur when moment is pointed directly at one of the coils.

After the sample is properly centered and aligned with the transverse coils, there can still be effects from the radial positioning. In theory, a perfectly centered sample with a longitudinal moment produces no signal in the transverse coils, as indicated in **Figure 4**. However, perfect centering is difficult to achieve. The coils can only be made geometrically orthogonal to a precision of order one percent. So, you nearly always observe a signal in the transverse detection system from a longitudinal moment. The size of this contribution varies non-linearly as the sample is moved off center. Also, a longitudinal magnetic field is applied to the sample. The longitudinal moment is normally many times larger than the transverse moment. Therefore, even a small misalignment can result in a significant signal being induced in the transverse coils by an off-center longitudinal moment.
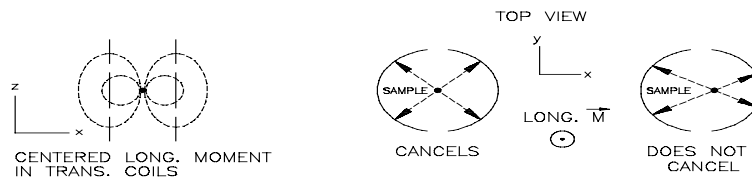

Figure 4. Perfectly centered sample with a longitudinal moment in transverse coils produces no signal.

One technique for eliminating this effect relies on the observation that the signal from the longitudinal component of the magnetic moment has the wrong symmetry. As seen in **Figure 5**, the transverse response to a longitudinal moment is an odd function about the center point of the scan.

The response of the transverse coils to a transverse moment has even geometry. See **Figure 6**. It is easy to understand this by drawing the transverse pickup coils with one side removed, corresponding to an extreme case of off-centering in the x, y plane. Then, graph the longitudinal field lines that pass through the remaining transverse pickup coils as the sample moves from one end of the coils to the other. The difference in symmetry can be exploited to eliminate the effects of the longitudinal moment in the transverse coils by computing the Fourier components of the response curve, then using only the even components to reconstruct the signal due to the transverse moment.

Another technique for subtracting the longitudinal component is to recognize that when a transverse moment is rotated 180°, its measured signal reverses polarity, as shown in **Figure 6**, but the interfering signal from the longitudinal moment does not. Consequently, you can subtract two measurements where the sample has been rotated 180° to determine a transverse moment. Note, however, that a change in the measured longitudinal moment may also occur because of the 180° rotation. This limits the precision of the subtraction technique due to the rotational effect described above so that it may be somewhat less accurate than a full Fourier analysis, but it may be adequate for some applications.
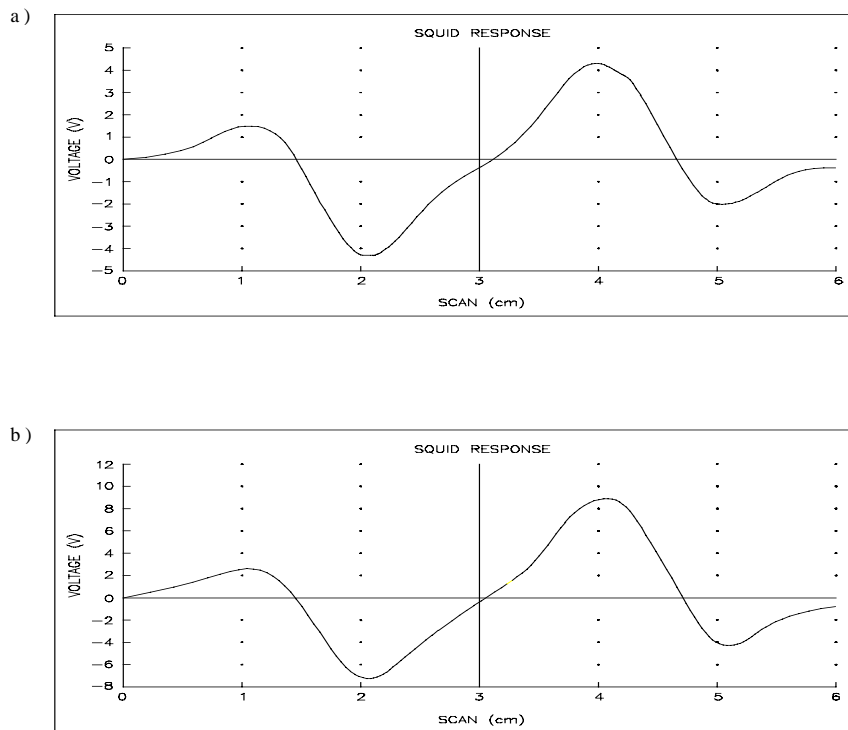
Figure 5. Transverse SQUID Response to Longitudinal Moment for Ni Sphere at (a) 0° and (b) 180°.

a)

b)
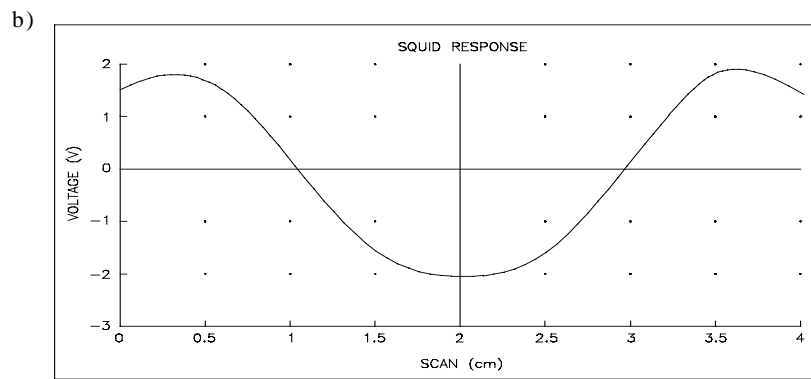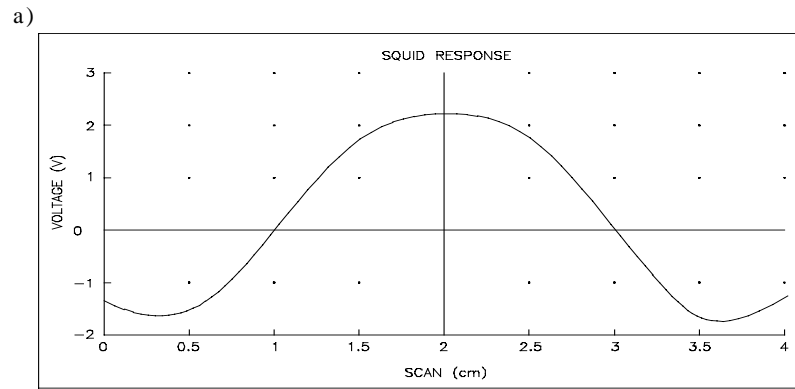
Figure 6. Transverse SQUID Response to Transverse Moment for Cu Coil at (a) 0° and (b) 180°.