Quantum Design

VSM Application Note 1096-301

Performing VSM Measurements in PPMS High-Field (14 T or Higher) Magnets

The VSM option for the PPMS offers rapid measurements—data can be collected fast (greater than 1 Hz data rate) and it can be collected while the magnetic field is being ramped. However, when a 14 T (or higher) magnet is used to measure between –2 T and +2 T, Quantum Design advises users to measure at stable magnetic fields. The reason for this advice is that there is significant magnetic noise emanating from the superconducting magnet at these fields, and this is picked up by the VSM detection coilset, which lies in the center of the magnet.

The noise originates from *magnetic flux jumps* in the windings of the high-field superconductor insert, which is composed of Nb_3Sn wire. Magnetic field penetrates a superconductor in the form of miniscule discrete flux lines. The magnet windings immobilize (or pin) the magnetic flux lines, and Nb_3Sn wire is especially good at this. A trade-off of such strong pinning is that, when the field density in the magnet bore is sufficiently different than the pinned flux in the windings, the flux lines in the superconductor tend to be released and trapped rapidly. The field equilibrates during such flux-jump events as magnetic field enters or leaves the windings in small avalanches of flux lines. This equilibration tends to occur when the field-charging direction is reversed at low field magnitudes (less than 2 T) or when the sign of the field changes. Flux jumping subsides at higher fields because the magnet is "saturated" with flux lines.

Another aspect of high flux pinning in the magnet is large remanent magnetic fields in the sample space (about 100 Oe for the 14-T magnets used currently at Quantum Design, which are fabricated using the "internal tin process" Nb_3Sn magnets). Remanence is the field that remains in the magnet after it has been brought back to zero current from full field.

Flux jumping is not a problem in the low-field magnets (up to 9 T), because the windings are made of NbTi superconducting wire, which does not pin flux as strongly as the Nb_3Sn wire and which has not been found to present a problem for VSM measurements while ramping the field. Additionally, the remanence in these magnets is generally less than about 10 Oe at the sample location.

Figure 1 illustrates flux jumps and their effects on moment versus field data collected with a 14-T magnet during ramping and stable fields. The data show flux-jump noise in the magnetic moment while the field is ramping, but the noise has settled by the beginning of the field-iteration phase. Thus, by the time that field stability has been declared (labeled “Holding” in Figure 1), the flux jumps have clearly subsided. Note that the driven mode was used for the measurements presented in Figure 1.

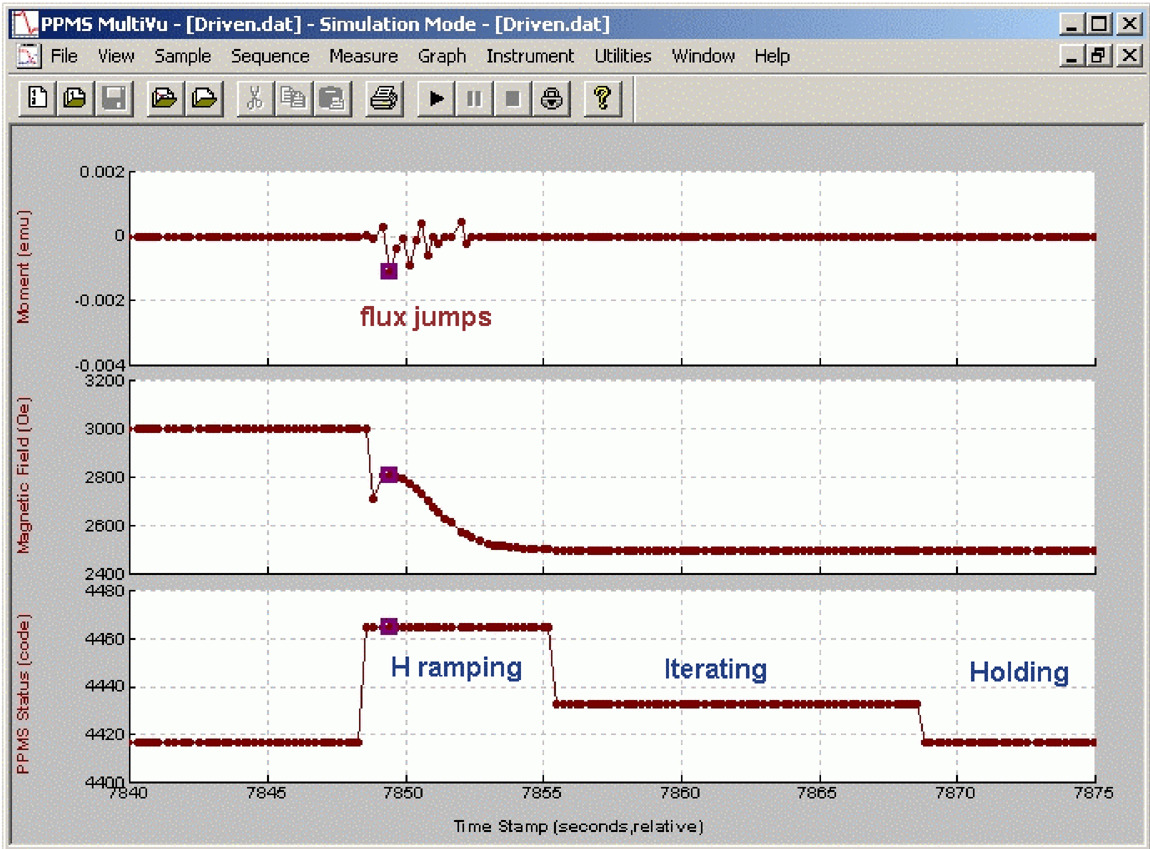

Figure 1. The effect of flux jumps on VSM moment versus field data during ramping and stable fields when using a 14-T magnet at fields between –2 T to +2 T.

Thus, Quantum Design strongly advises users to measure moment versus field in a stepwise manner and perform measurements only at stable fields when measuring between –2 T to +2 T. In the event that a user would like to sweep the field over the full range in a 14-T magnet, below is a model for constructing a sequence file that helps minimize flux jumps.

SEQUENCE MODEL: M(H) FROM +14 TESLA TO –14 TESLA

(Initial field = +14 T)
Start VSM continuous measure
Set Field 2 T at 100 Oe/sec, end in driven mode
Wait for Field, 0 sec
Stop VSM continuous measure
Scan Field from +2 T to –2 T in 500 Oe steps, driven mode
    VSM single measure
End Scan
Start VSM continuous measure
Set Field –14 T at 100 Oe/sec, end in persistent mode
Wait for Field
Stop VSM continuous measure