Quantum Design

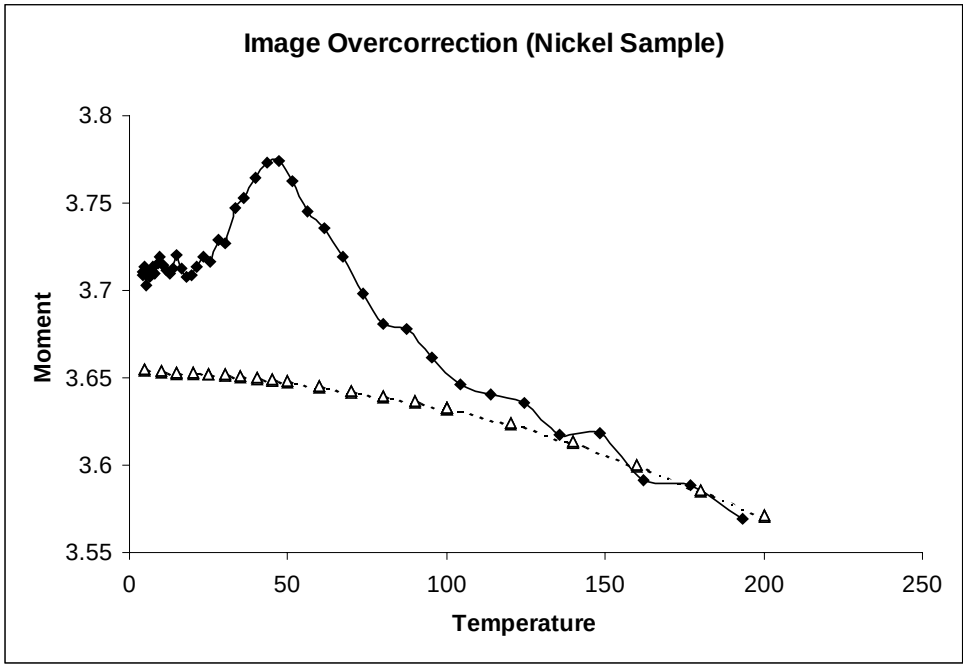
PPMS Application Note 1084-305

The ACMS Image Effect

Symptoms

The ACMS Image Effect is a false peak in DC ACMS measurements (sample moment vs. temperature) in temperature range 5-100 K due to eddy currents in the isothermal region of the PPMS sample chamber.

Several PPMS users have noticed a false peak or bump in their ACMS data when performing DC measurements vs. temperature. The moment of the sample is artificially increased in the temperature range from approximately 100 K down to 5 K, with a peak occurring at about 45 K (see Graph 1). The effect in the graph below was produced by measuring a nickel sample versus temperature at a field of 1 Tesla. Note the MPMS data, also taken with a nickel sample, does not show the peak. The size of the peak can vary from 1 percent to 4 percent of the sample moment, and the width and shape of the peak may change slightly on different PPMS systems.

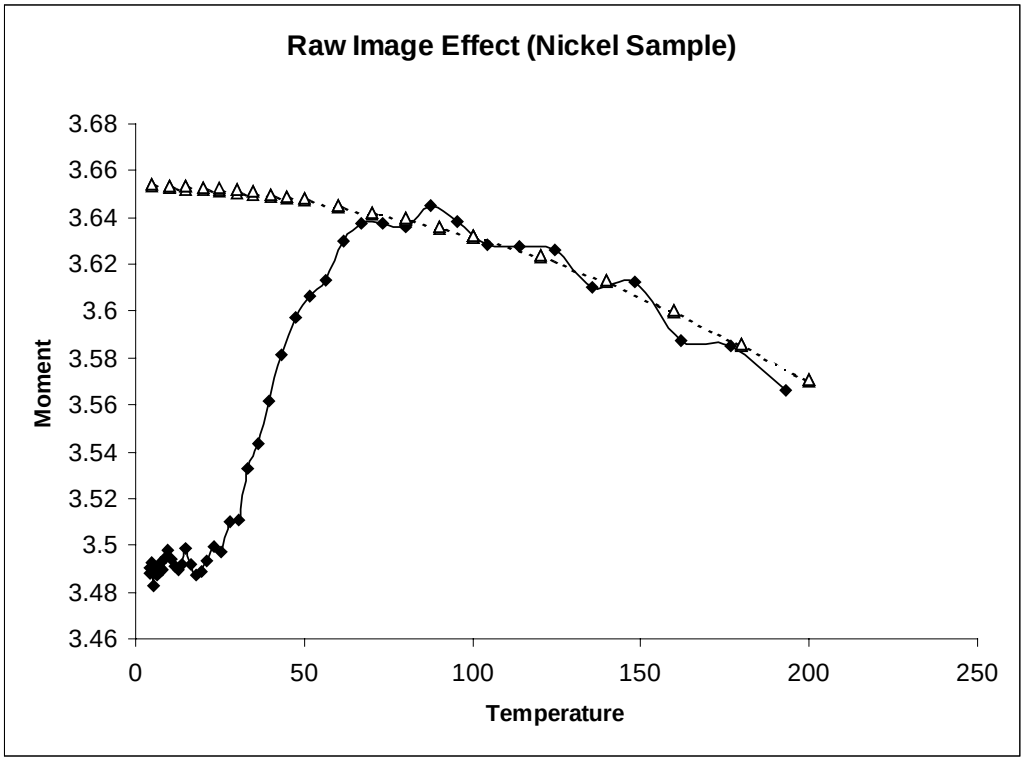


Graph 1. Data taken with a Nickel sample at 1 Tesla. Note the dashed lines, which represent the shape of the data curve taken with an MPMS system, do not exhibit the image effect.

Cause

The effect shown in Graph 1 is actually an irregularity caused by overcorrection for eddy currents in the isothermal region of the PPMS sample chamber. To detect the sample moment, the ACMS jerks the sample with high velocity through the detection coils built into the ACMS coil set. The moving magnetic moment of the sample induces a time-decaying current in the detection coils, which can be mathematically analyzed to determine the sample moment.

However, for thermal stability purposes, the bottom portion of the PPMS sample chamber (the isothermal region) is made of OFHC copper. At low temperatures the resistance of the copper becomes low enough to permit eddy currents. The moving magnetic moment of the sample (as it is jerked through the detection coils) induces a current in the sample chamber walls. This current (according to Lenz's law) creates a magnetic flux, which opposes the magnetic flux produced by the sample, affecting the measurement. This opposing magnetic field is known as the image effect. At low temperatures the effect can be seen as a reduction of the sample's moment. The ACMS software attempts to correct for this temperature-dependent effect. **Graph 2** below shows what the same nickel sample looks like with *no correction* applied to the data, the raw image effect.



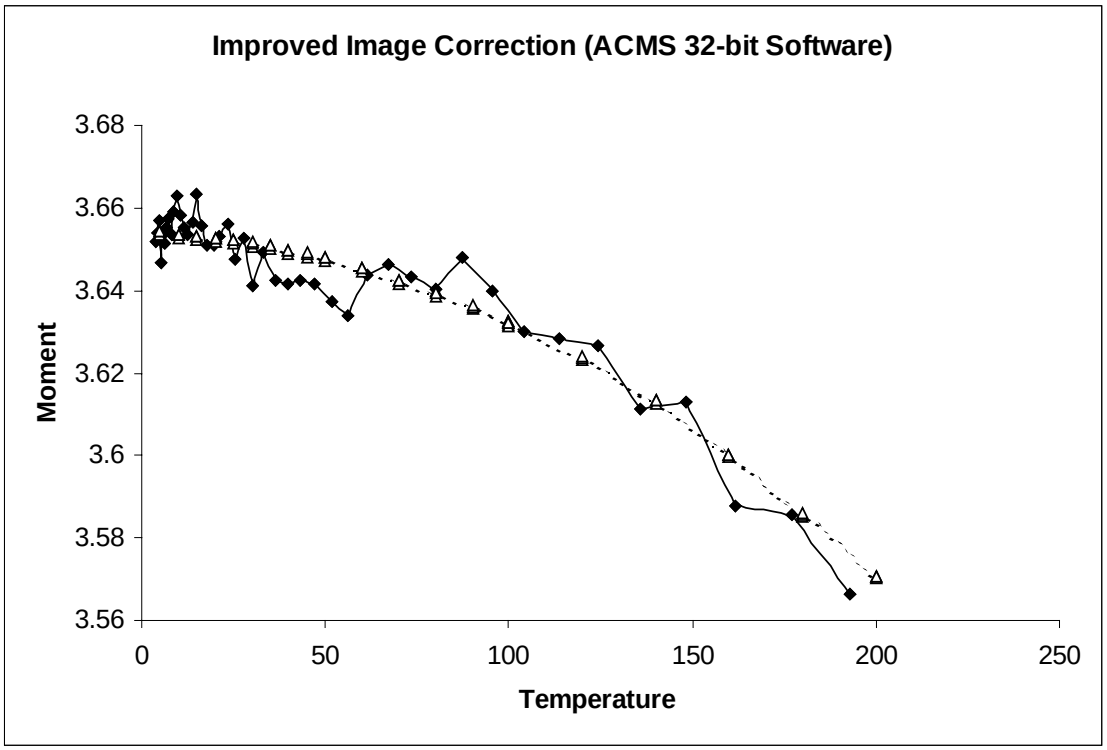
Graph 2. Data taken with the same Nickel sample as in Graph 1. Here, no correction is applied for the image effect. The raw image effect causes reduced sample moment at low temperatures.

The 16-bit ACMS software attempts to model the effect as if it were caused by an AC magnetic field. This is not a precise model because the effects produced by the rapid jerk of the DC measurement are transient and not necessarily the same as applying an alternating magnetic field. The software assumes a frequency of 40 Hz for the measurement and applies a correction factor based on this assumption. As it turns out, the

40 Hz assumption is flawed. The result is an overcorrection for the image effect that causes an artificially high sample moment to be reported, as evident in Graph 1. The percent error depends on temperature because the resistivity of the sample chamber, and therefore the size of image effect produced, varies with temperature.

Solution

Through experimentation, Quantum Design has determined that changing the assumed frequency for the correction algorithm drastically reduces the overcorrection for the image effect. The MultiVu ACMS software version 1.08 or later assumes a frequency of 11 Hz for the DC jerk measurements. We have taken data showing that this 11 Hz change reduces the image effect overcorrection peak to less than 0.5% of the sample moment. The measurements below in Graph 3 were taken with the same nickel sample as Graph 1.



Graph 3. Data taken with the same Nickel sample as in Graphs 1 and 2. Here, the 11Hz image correction is applied. Note that the shape of the curve now matches that of the MPMS data.

Conclusions

The image effect overcorrection is evident in ACMS 16-bit software and in very early versions of the MultiVu ACMS software. ACMS MultiVu version 1.0.8 or later has the improved correction algorithm and is available for download on the Quantum Design website at the following address: http://www.qdusa.com/user/downloads.htm.

We have determined that the new correction reduces the false moment variation to within approximately 0.5% or less of the magnitude of the sample moment. Due to variations among systems, more specifically among PPMS sampler chambers, it would require

major effort to further reduce the image effect. Each sample chamber would have to undergo a lengthy calibration process, which would increase cost and production time for the systems. Currently Quantum Design does not plan to initiate further work on the ACMS image effect project, since the MPMS system is available for much more accurate measurements with no image effect.