An AC susceptibility measurement system for detecting the frequency dependence over a wide range of frequencies

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The frequency dependence of low-field AC susceptibility has frequently been used in environmental magnetism for identifying fine grains near the SP-SD boundary. It has often been referred as k_{fd}(=k_{lf}-k_{hf}), where k_{lf} and k_{hf} are the AC suceptibilities at low (470 Hz) and high (4.7 kHz), respectively. The two different frequencies are based primarily on a commercial susceptibility meter, or the Bartington device, which has been widely used in environmental research. However, the conventional frequency dependence index, k_{fd}, is insufficient to evaluate the spectrum of grain size distribution below the SP-SD threshold. Attempts have been made to measure AC suceptibilites over a wide range of frequencies, though they appear to be not enough to detect a continuous change in susceptibility over a broader range of frequencies.

The aim of this study is to devise a unique equipment that enables susceptibility measurements over a broader frequency spectrum ranging from 10 to 10^5 Hz, which could allow to provide new experimental data for better understanding rock magnetic characteristics, including grain size distributions near the SP-SD boundary, the effect of grain interactions and any other rock magnetic information applicable to environmental magnetism. The new measurement system consists of a primary coil for applying an excitation field to a small, millimeter-size, sample, and a set of pickup coils linked in series and wound oppositely for compensation. The number of turns for the primary coil is 5,000 and that for the respective pickup coil is 2,000. All of them are made of a copper wire, 800 micrometer in diameter, and wound around a quartz-glass tube of 8 mm in diameter. The excitation field is produced by a commercial function generator with two independent outputs, capable of generating sinusoidal current with frequencies of 0 to 10 MHz. To achieve null compensation of the pickup coil output, a mutual inductor coil is connected in series with the pickup coil system, to which the function generator supplies, through the second output, a small current that can be adjusted in phase and magnitude to compensate an unbalanced output prior to loading a sample. The resulting signal output voltage is fed, through a differential amplifier, to a digital rock-in amplifier that is connected to the primary coil as a reference signal input. The AC frequency spans from 10 Hz to 200 kHz due to the limitation of the lock-in amplifier, but can be changed continuously over the entire range. The outputs from the lock-in amplifier, in both magnitude and phase, are fed to a PC to draw the frequency dependence spectrum of both real and imaginary parts of AC susceptibility. System calibration has been made using a synthetic, paramagnetic Gd_2O_3 powder, and several natural paramagnetic samples as Yucca Mountain tuff that has ever been used for inter-laboratory calibrations.