SYNOPSIS

In material science, the measurement of ac susceptibility is an important experimental tool to study the magnetic and electronic properties of materials. This technique can be used for studying magnetic transitions, spin-glass transitions, superconducting transitions, re-entrant spin glass behaviour and dissipative processes. The information regarding the dissipative nature can be calculated from the complex part of the magnetic susceptibility \( \chi = \chi' + i\chi'' \). Study of the frequency and field dependence of real and imaginary parts of ac susceptibility has become an established tool for investigating magnetic and superconducting materials. Through a measurement of higher harmonics, this technique has become even more versatile as it provides a quicker and easier way to acquire a wealth of information that is contained in the nonlinear part of the ac susceptibility.

The present work aims to develop some necessary instruments in-house for the study of response (transport and susceptibility) of different materials (like ferromagnetic materials, composites, etc.) by using AC probes. The probes which were developed are useful for AC susceptometry and AC resistivity. These are particularly suitable for the study of bulk materials because of the multiple parameters (temperature, amplitude, frequency, etc.) that may be varied during experimentation. We have fabricated the necessary sub-systems and developed a simple, low-cost ac susceptometer working in the room temperature range. One of the main thrusts of the work was to avoid purchase of complicated and expensive equipment to the extent possible by the in-house development of subsystems. It may be noted that one of the major advantages of in-house development is the ease of maintenance, and customized configuration in accordance with the particular requirements of an experiment, apart from the huge saving in costs. This type of developmental work may be very effective for low budget laboratories.

In chapter 1, we present an introduction and brief review of AC techniques, magnetic susceptibility, different techniques for measuring magnetic susceptibility, AC susceptometer and objective of the thesis.

In chapter 2, consists of three sections each of which describes a lock-in-amplifier (LIA). In section 1, we have described a simple and extremely cheap analog phase-sensitive detector using commonly available components. Instead of multiplication by a square wave as found in many standard lock-in-amplifiers, we have used multiplication by a sine wave to eliminate higher harmonic contributions. One of the main features of the system is the incorporation of an auto-balancing circuitry to minimize distortions due to transistor mismatch in the multiplier. A pair of sample-and-hold circuits arranged in a master-slave configuration is used to hold the final integrated value, ensuring a constant and
easily controllable integration time with the limits located almost exactly at the zero crossings. In section 2, we have described PHOENIX-kit based computer-controlled lock-in-amplifier for fast processing. In section 3, we have described another LIA, the principle of which is often used by commercially available analog LIAs. The basic principle is to multiply the input signal with a square wave of the same phase and frequency as the reference. This particular instrument has been used to detect the errors produced due the enhancement signal used in the enhancement type susceptometer.

In chapter 3, we have described a 16-channel voltmeter implemented with a microprocessor and some supporting circuitry. We have used the free LAM (Local Area Multicomputer) software, which implements the MPI (Message Passing Interface) standard, allowing parallel programmes to run on clusters. The voltmeter uses daemon programmes written in C++ language. The meter has a browser-based version which enables one to access the instrument from anywhere in the world.

In chapter 4, we have described the details of an automated AC susceptometer with bridge balancing circuitry. We have developed this setup including the software and hardware like coil system, sample movement, temperature controller and bridge balancing circuit. This apparatus is calibrated with nickel in room temperature.

In chapter 5, we have described the necessary modification of our existing AC susceptometer for measuring magnetic enhancement susceptibility. In this technique, an extra field of often large amplitude, having a frequency different from the basic exciting field is added to the signal in the primary. The idea is to study only the response to the system under the influence of the original exciting field, without directly measuring the response of the system to the enhancing field. Here we have used an adder circuit to mix the original signal with the ‘enhancing’ signal and a voltage-to-current converter, based on high gain and high current operational amplifier, to drive the current to the primary coil of the coil assembly. An LED-LDR pair, driven by another voltage-to-current converter controlled by the output of an LIA locked at same phase and frequency of the enhancing signal, has been also introduced.

In chapter 6, we have briefly discussed the use and necessity of daemon programmes in our measuring system.

In chapter 7, we have discussed the experimental results of of Nickel ferrites and $Ba_2FeMoO_6$ (BFMO) around room temperature range.

Finally in chapter 8, we conclude the thesis and have discussed the future plans.