Preface

We hope that this two-volume Handbook will provide an in-depth, systematic treatment of Superconducting QUantum Interference Devices (SQUIDs) and their many applications. Our intent is to offer the reader a reasonably complete, balanced and up-to-date presentation of the entire field, with as few omissions and duplications as possible. Although our publisher initially suggested that one or two of us write the Handbook, we pointed out that the field had become so large and diverse that this would be an almost impossible undertaking. Many aspects of SQUIDs, especially applications, have become so specialized that no single person can realistically provide adequate coverage. Consequently, we invited various colleagues collectively to write a comprehensive treatise. Fortunately, virtually everyone we asked graciously agreed to participate.

The first volume of the Handbook, published in 2004, contained seven chapters devoted to the fundamental science, fabrication and operation of low-$T_c$ and high-$T_c$, dc and rf SQUIDs. After an introductory overview, subsequent chapters were entitled SQUID Theory, SQUID Fabrication Technology, SQUID Electronics, Practical DC SQUIDs: Configuration and Performance, Practical RF SQUIDs: Configuration and Performance, and SQUID System Issues. Appendix 1 briefly described the Basic Properties of Superconductivity and Appendix 2 listed the acronyms and symbols used in the Handbook.

Volume II contains eight chapters concerned with applications using SQUIDs as sensors and readout devices.

In Chapter 8, Clarke, Lee, Mück and Richards describe the theory and implementation of SQUID voltmeters and amplifiers. The first sections describe measurements of quasistatic voltages, the use of the dc SQUID as a radiofrequency amplifier, and the extension of the frequency range into the microwave regime by means of a microstrip input circuit. Subsequently, the application of SQUIDs to read out thermal detectors and their multiplexing in the time- and frequency-domains are discussed. SQUID amplifiers for nuclear magnetic resonance and magnetic resonance imaging are reviewed, and various examples are presented. The chapter concludes with a brief discussion of the implementation of a near-quantum-limited SQUID amplifier on a detector to search for the axion, a candidate for cold dark matter.
In Chapter 9, Gallop and Piquemal describe the role of SQUIDs in standards and metrology. After a brief discussion of highly accurate voltage measurement, the authors focus on the principles and accuracy limits of the cryogenic current comparator (CCC). Among its applications are measurements of resistance ratios, very low currents from superconducting electron transistors, and currents in beams of charged particles. Other metrology applications include secondary thermometers based on magnetic susceptibility and resistance, and a primary thermometer based on Nyquist noise.

In Chapter 10, Lima, Irimia and Wikswo tackle the magnetic inverse problem that is central to interpreting measurements in biomagnetism, geophysics and nondestructive evaluation. They first describe the forward problem – the determination of magnetic fields produced by distributions of magnetization and current and by multipoles. They begin their discussion of the inverse problem with the law of Biot and Savart, and go on to discuss the imaging of distributions of magnetization. An important aspect of the inverse problem is “silent sources” – for example, source configurations that produce either an electric or a magnetic field but not both. They conclude with a treatment of the three-dimensional inverse problem – which, in general, has no unique solution – that highlights some of the most widely used algorithms.

In Chapter 11, Vrba, Nenonen and Trahms address biomagnetism, unquestionably the largest single consumer of SQUIDs. They begin with magnetoencephalography (MEG) – magnetic signals from the brain – and describe whole cortex systems, types of sensors, fetal MEG, and data analysis with clinical examples. They continue with magnetocardiography, describing the kinds of instrumentation, types of sensors, and clinical applications. There follows a miscellany of topics in biomagnetism, including the measurement of static fields from the body, detecting signals propagating along nerves, the susceptibility of the liver as a diagnostic tool, gastro-magnetometry, and immunoassay using magnetic labeling of cells.

In Chapter 12, Black and Wellstood describe measurements of magnetism and magnetic properties of matter. The first part describes the history, development and operation of the most widely used SQUID system, namely a commercially available magnetometer and susceptometer. Issues of accuracy and sensitivity are discussed. The second part of the chapter is concerned with the scanning SQUID microscope. The authors outline the special requirements for the SQUIDs and cryogenics, describe the techniques for scanning and image processing, and discuss issues of spatial resolution. They conclude with a review of current and potential applications.

In Chapter 13, Krause and Donaldson give an overview of methods for nondestructive evaluation. These include the detection of static magnetic moments, the magnetic flux leakage technique, static current distribution mapping, and the eddy current technique. A number of examples is presented. The chapter concludes with a brief discussion of alternative ways of exciting a magnetic response.

In Chapter 14, Clem, Foley and Keene describe the application of SQUIDs to geophysical survey and magnetic anomaly detection. They begin with issues of magnetic measurements in the presence of the Earth’s field and operating
SQUIDs in harsh environments, and continue with data acquisition and signal processing. A major portion of the chapter is concerned with geophysical applications, ranging from rock magnetometry to a variety of prospecting and surveying methods. They conclude with an overview of the detection of magnetic anomalies, for example, buried ordnance.

Finally, in Chapter 15, Paik addresses gravity and motion sensors. He describes in turn a superconducting accelerometer, a superconducting transducer for gravitational-wave detectors, and the superconducting gravity gradiometer (SGG). Applications of the SGG include precision tests of the laws of gravity, searching for new weak forces, gravity mapping and mass detection, and inertial navigation and survey.

In the Appendix, we duplicate Appendix 2 of Volume I and provide a list of additional acronyms and symbols for each chapter of Volume II.

This very brief survey illustrates the remarkable diversity of the SQUID, which finds applications to physics, astrophysics, cosmology, chemistry, materials science, standards, biology and medicine. We would like to believe that the Handbook will be of use not only to practitioners of the art of SQUIDs but also to students and professionals working in these fields.

In conclusion, we express our heartfelt thanks to the authors of both volumes of the Handbook for their hard work, their attention to quality and accuracy and not least for their patience and perseverance during our editing of their manuscripts. One of us (JC) expresses his grateful thanks to his assistant, Barbara Salisbury, for her unflagging help with all the manuscripts for both volumes. We owe an enormous debt of gratitude to the staff at Wiley-VCH, particularly to Dr. Michael Bär, who first asked us to co-write the Handbook, and to Mrs. Vera Palmer and Mrs. Ulrike Werner without whose expert guidance and extraordinary patience the Handbook would never have seen the light of day. Finally, we thank our wives Maria Teresa and Grethe for their patience and understanding during our editing of both volumes of the Handbook, which took much of our time away from them.

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