# PREFACE TO THE SECOND EDITION

Half a century of remarkable scientific progress has resulted from the application of radio interferometry to astronomy. Advances in technology over the fourteen years since the first publication of this book have resulted in the first array fully dedicated to very long baseline interferometry (the VLBA), the use of antennas in orbit in VLBI, increasing importance of spectral line observations, and planning and design of a major international project at millimeter and submillimeter wavelengths (ALMA). Such progress has led to this revised edition, the intent of which is not only to bring the material up to date but to improve the intelligibility and general usefulness. In a few cases, symbols used in the first edition have been changed to follow the general usage that is becoming established in radio astronomy. Every chapter contains new material, and there are new figures and many new references. Material in the original Chapter 3 that was not essential to the basic discussion has been removed, and this chapter now contains the essential analysis of the response of an interferometer. The section on polarization in Chapter 4 has been substantially expanded and a brief introduction to antenna theory has been added to Chapter 5. A discussion of spectral line observations is included in Chapter 10. Chapter 14 has been added, and contains an examination of the Van Cittert-Zernike theorem, and discussions of spatial coherence and scattering, some of which is derived from the original Chapter 3.

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# PREFACE TO THE FIRST EDITION

The techniques of radio interferometry as applied to astronomy and astrometry have developed enormously in the past four decades, and the attainable angular resolution has advanced from degrees to milliarcseconds, a range of over six orders of magnitude. As arrays for synthesis mapping [†] have developed, techniques in the radio domain have overtaken those in optics in providing the finest angular detail in astronomical images. The same general developments have introduced new capabilities in astrometry and in the measurement of the earths polar and crustal motions. The theories and techniques that underlie these advances continue to evolve, but have reached by now a sufficient state of maturity that it is appropriate to offer a detailed exposition.

The book is intended primarily for graduate students and professionals in astronomy, electrical engineering, physics, or related fields who wish to use interferometric or synthesis-mapping techniques in astronomy, astrometry, or geodesy. It is also written with radio systems engineers in mind and includes discussions of important parameters and tolerances for the types of instruments involved. Our aim is to explain the underlying principles of the relevant interferometric techniques but to limit the discussion of details of implementation. Such details of the hardware and the software are largely specific to particular instruments and are subject to change with developments in electronic engineering and computing techniques. With an understanding of the principles involved, the reader should be able to comprehend the

[†] We define synthesis mapping as the reconstruction of images from measurements of the Fourier transforms of their brightness distributions. In this book the terms map, image, and brightness (intensity) distribution are largely interchangeable.

instructions and instrumental details that are encountered in the user-oriented literature of most observatories.

The book does not stem from any course of lectures, but the material included is suitable for a graduate level course. A teacher with experience in the techniques described should be able to interject easily any necessary guidance to emphasize astronomy, engineering, or other aspects as required.

The first two chapters contain a brief review of radio astronomy basics, a short history of the development of radio interferometry, and a basic discussion of the operation of an interferometer. Chapter 3 discusses the underlying relationships of interferometry from the viewpoint of the theory of partial coherence and may be omitted from a first reading. Chapter 4 introduces coordinate systems and parameters that are required to describe synthesis mapping. It is appropriate then to examine configurations of antennas for multielement synthesis arrays in Chapter 5. Chapters 6–8 deal with various aspects of the design and response of receiving systems, including the effects of quantization in digital correlators. The special requirements of very-long-baseline interferometry (VLBI) are discussed in Chapter 9. The foregoing material covers in detail the measurement of complex visibility and leads to the derivation of radio maps discussed in Chapters 10 and 11. The former presents the basic Fourier transformation method, and the latter the more powerful algorithms that incorporate both calibration and transformation. Precision observations in astrometry and geodesy are the subject of Chapter 12. There follow discussions of factors that can degrade the overall performance, namely, effects of propagation in the atmosphere, the interplanetary medium and the interstellar medium in Chapter 13, and radio interference in Chapter 14. Propagation effects are discussed at some length since they involve a wide range of complicated phenomena that place fundamental limits on the measurement accuracy. The final chapter describes related techniques including intensity interferometry, speckle interferometry, and lunar occultation observations.

References are included to seminal papers and to many other publications and reviews that are relevant to the topics of the book. Numerous descriptions of instruments and observations are also referenced for purposes of illustration. Details of early procedures are given wherever they are of help in elucidating the principles or origin of current techniques, or because they are of interest in their own right. Because of the diversity of the phenomena described, it has been necessary, in some cases, to use the same mathematical symbol for different quantities. A glossary of principal symbols and usage follows the final chapter.

The material in this book comes only in part from the published literature, and much of it has been accumulated over many years from discussions, seminars, and the unpublished reports and memoranda of various observatories. Thus we acknowledge our debt to colleagues too numerous to mention individually. Our special thanks are due to a number of people for

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