The selection of books for review is entirely the purview of the editorial board. The opinions reflected in any review are solely those of the reviewer. Authors may send books for consideration of possible review to the IEEE Signal Processing Society's office: 445 Hoes Lane, Piscataway, NJ 08854; no submitted books will be returned.

Tools of Radio Astronomy by Thomas L. Wilson, Kristen Rohlfs, and Susanne Hüttemeister, Springer-Verlag, ISBN 978-3-540-85121-9, hardcover, 515 pages, 2009. *Reviewed by Gregory Wright (gwright@antiope.com), Antiope Associates LLC., Fair Haven, New Jersey*.

In our day-to-day work, most of us apply signal processing on a small scale, yet most of us are fascinated by its applications larger scales. During the Cold War, these were the efforts in submarine detection, airborne radar, and electronic signals intelligence. In recent years, these applications have become less urgent and one might despair that the future for signal processing will only involve cell phones and digital music players. Fortunately, a cottage industry of signal processing in radio astronomy has sprung up and is beginning to do work on a grand scale.

Radio astronomy is off the beaten path for most of us and finding a starting point to learn about it is not obvious. There are a handful of semipopular introductions, and most general astronomy texts touch briefly on it. For the reader who wants to get to the meat of the subject quickly, the latest edition of *Tools of Radio Astronomy* by Thomas L. Wilson, Kristen Rohlfs, and Susanne Hüttemeister is a good place to start.

The book is organized in two halves. The first half covers electromagnetic wave fundamentals and instrumentation. After a fairly standard introduction to propagation and wave polarization, subsequent chapters address receiver theory and signal processing, practical receiver systems, antenna theory, single dish antennas, single dish observational techniques, and interferometers and aperture synthesis. The second half deals with the physical processes that produce radio waves in celestial sources. The first half of the book should be accessible to readers with some familiarity with engineering electromagnetics while, on the other hand, the second half requires some knowledge of thermodynamics and quantum mechanics at the introductory undergraduate level. Interestingly, radio methods used in the search for extraterrestrial intelligence (SETI) are not covered in this book, and this reviewer believes that this is because SETI is considered beyond the pale by most professional radio astronomers. However, if one is interested, the material in this book will prepare one to read specialized literature on receivers and telescopes built for SETI.

Readers from a signal processing background will find that *Tools of Radio Astronomy* has perhaps the most accessible introduction to aperture synthesis: using multiple antennas to achieve the spatial resolution (but not the sensitivity) of a much larger antenna. The underlying idea is that each pair of antennas is coherently compared, giving an estimate of one point in the Fourier transform source intensity—the radio brightness of part of the sky. From the collection of these Fourier components it is possible to make a picture of radio source. Most of us would recognize pictures of the very large array, the 27 antenna synthesis array in the New Mexico desert. The next generation of synthesis arrays, the Atacama large millimeter array (ALMA) and the square kilometer array (SKA) will be much larger. ALMA will have as many as 64 antennas with a 16-GHz receiver passband. The signal processor that constructs the images for ALMA (called a "correlator" in the trade) will be one of the largest computing devices ever built, capable of up to 10^{16} operations/s. If constructed from field programmable gate arrays, it will be the largest reconfigurable processor yet. In many ways, the SKA, operating at a lower frequency, is even more challenging. A key project for the SKA is imaging the epoch of reionization, when ultraviolet light from the first stars ionized much of the hydrogen gas that filled the universe. A spectral line from neutral hydrogen gas is easy to detect, so our picture of reionization will be like a photographic negative, the still neutral regions will emit radiation, with empty areas around the new stars. There is one difficulty with this simple picture. Reionization occurred about a billion years after the big bang, and the expansion of the universe has shifted the frequency of the radio signal of hydrogen from 1.4 GHz into the crowded VHF band. For the first time, radio astronomers will have to worry about the dynamic range of the receivers and signal processing back ends so that strong interference can be measured and removed. Beamforming to actively null interference might also be needed for the first time in astronomy. Clearly, there is a significant role for signal processing in the next generation of synthesis arrays and thus *Tools of Radio Astronomy* is quite timely in that it will help signal processors

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meet the needs of these emerging radio astronomy tools.

For someone looking for an introduction to the field, there are not many other choices. B. Burke and F. Graham-Smith's *Introduction to Radio Astronomy* (second edition) covers much of the same ground but in less detail. It is suited for the technically knowledgeable reader who wants an overview of the field. *Radio Astronomy* (second edition) by J.D. Kraus is out of print, but it is worth a trip to library for its coverage of antennas and basic receiver theory. However, it predates current receiver technology and signal processing methods. Neither has the balance of engineering and astronomical depth that should keep *Tools of Radio Astronomy* the standard introduction. For the teacher, this book can serve as a text for a course on instrumentation and observational techniques in radio astronomy. Luckily, for the teacher (or self-taught student) there is a good selection of problems at the end of each chapter.

TOOLS OF RADIO ASTRONOMY IS QUITE TIMELY IN THAT IT WILL HELP SIGNAL PROCESSORS MEET THE NEEDS OF THESE EMERGING RADIO ASTRONOMY TOOLS.

The problems are at a consistent level and complement the discussion in the text. For the engineer with some background in electromagnetics, the first half of the book can be used as an introduction and reference for radio astronomical instrumentation.

The only significant shortcoming of this book is that the references devoted to instrumentation are not as well organized as those on astronomical sources. For some chapters, the references are divided into the categories "general," giving the basic references for the material covered in the text, and "specialized," which are pointers into the detailed literature. In other chapters, historically interesting papers and general references are mixed in with accounts of more recent work. Beginners in the field would have an easier time getting started with the literature if the scheme of the general and specialized categories were used consistently. This quibble aside, *Tools of Radio Astronomy* does a very good job of covering the basics of the field for the beginning user of the radio telescopes as well as for their builder. Furthermore, the production standard is high. The text is well laid out and equations are easy to read.

The fifth edition of *Tools of Radio Astronomy* is a conservative update of the basic material in the earlier editions, but it describes how the principles are being applied to the most recent telescopes. Although the book is aimed at astronomy students and professionals, it can also serve as an introduction for engineers working in millimeter wave remote sensing and terahertz imaging. And some may be inspired to take a hand in building the next generation of machines that take pictures of the radio universe.

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standards in a **NUTSHELL** continued from page 164

guarantees that it is appropriate for any specific platform. In fact, sequential descriptions hide the essential structure of the program among the code required to handle threads and platform specifics. Conversely, parallelism is implicit in the dataflow nature of RVC-CAL.

FURTHER TECHNICAL DEVELOPMENTS

Although encoders are typically not covered in MPEG video coding standards, it has been seen that the nature of the RVC framework actually embraces reconfigurable video encoders and even more complex multimedia computing systems. A core experiment that investigates the feasibility of having informative encoding tools within the RVC tool libraries is currently ongoing. Other interesting discussions are currently taking place in the RVC community, aiming at extending the approach and the specification languages of the RVC standard to cover other fields and applications that share common features with video coding or that could benefit of being included and embedded as part of the standard, such as computer graphics, cryptography, and video coding for wireless multimedia sensor networks.

RESOURCES

Several RVC Resources are listed in "RVC Resources."

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