The ARRL Handbook for Radio Communications

Eighty-Seventh Edition

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Cover Info: Software, hardware, projects, theory, antennas, construction techniques — The ARRL Handbook presents a wide variety of technical information for today’s radio amateur.

Cover Photography: Clockwise from lower right corner: Antennas at W2RE by Ray Higgins, W2RE; ARRL Laboratory repair bench by Dave Pingree, N1NAS; Windows software screen capture by Grant Connell, WD6CNF; electromyogram unit for station control by Grant Connell, WD6CNF.

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Technical resources used by radio amateurs have varied widely over the past century – magazine articles, textbooks, application notes, CD-ROMs, and Web pages have all provided training and tutoring. Yet one reference has been a constant companion to the Amateur Radio service since 1926 – The ARRL Handbook, known as simply, “the Handbook” to hams and radio professionals alike. From its position on a workbench, in a technical library, or at the operating desk, there is nothing like the Handbook’s immediacy and accessibility, providing instant consultation and guidance.

Mirroring the processes by which technology is applied to and integrated into Amateur Radio, each chapter takes one of two approaches to its subject: encyclopedic chapters present a broad view of technology, and practical chapters contain more specific techniques, designs, and projects. While the Handbook contains and preserves a wealth of time-tested material, it must be continually renewed and updated. This is especially necessary today due to the accelerating evolution of technology and the expanding scope of Amateur Radio.

Responding to the needs of today’s amateurs, there is much that is new in this edition. Following the Introduction, the chapters have been organized into five major sections: Fundamental Theory, Practical Design and Principles, Antenna Systems and Radio Propagation, Equipment Construction and Maintenance, and Station Assembly and Management. Within each section, there is plenty of new and updated material. There are too many new items to list separately, but here are several examples representative of the changes throughout this edition:

- A full suite of new or revised chapters address the burgeoning digital modes: Modulation (by Alan Bloom, N1AL); DSP and Software Radio Design (also by N1AL), Digital Modes (by Scott Honaker, N7SS, and Kok Chen, W7AY), and Digital Communications (by Steve Ford, WB8IMY). There’s also a new section on D-STAR digital repeaters by Pete Loveall, AE5PL and Jim McClellan, N5MIJ.
- The ever-popular chapter on RF Power Amplifiers has gotten a thorough refreshing by experts John Stanley, K4ERO (vacuum tube technology) and Dick Frey, K4XU (solid-state amplifiers). You’ll find new software, expanded design examples, and a new 250-W solid state amplifier project to get you started toward that bigger signal.
- Power Supplies, a chapter that every ham turns to occasionally, received the attention of world-class authority Rudy Severns, N6LF. As a result, there is a detailed introduction to switch-mode power conversion — arguably the most common power supply technology in the world and whose coverage was long overdue in the Handbook.
- If you’re learning electronics from the Handbook, as many do, the Fundamental Theory section sports reworked and expanded chapters on basic electronics and analog design (both by N0AX), and digital design (by Dale Botkin, N0XAS), including analog-digital conversion and microprocessor interfacing.
- New resources for experimenters include a chapter on Computer-Aided Circuit design by Dave Newkirk, W9VES. The Component Data and References chapter received needed updates to the information on component characteristics and surface mount devices by Paul Harden, NASN.
- In recognition of the growing range of operating modes and activities, we’ve updated and expanded chapters on Space Communications (satellites by Steve Ford, WB8IMY and EME by Joe Taylor, K1JT) and Image Communications (ATV by Tom O’Hara, W6ORG and SSTV by Dave Jones, KB4YZ).

Nearly every chapter has been rewritten or reworked, with many projects making their first appearance in the Handbook. The book’s accompanying CD-ROM inside the back cover once again includes a searchable PDF version of the entire book, including graphics. Construction information and PC board templates for all projects are included as are the original QST articles, if that was the project’s source. Once again, Jim Tonne, W4ENE, has generously provided his powerful filter design and analysis software, Elsie, as well as other useful applications. Recognizing that the printed Handbook and CD-ROM support a dynamic activity, a Web page (www.arrl.org/tis/handbook) has been created to provide links and supplemental information that may change with time.

For more than eight decades, hams, hobbyists, engineers, and scientists have used the Handbook for both practical solutions and as a teacher to open doors of understanding. The many authors, editors, reviewers, and the production team have all worked together in hopes of making this edition your favorite.

David Sumner, K1ZZ
Chief Executive Officer
Newington, Connecticut
September 2009
The Amateur’s Code

The Radio Amateur is:

CONSIDERATE…never knowingly operates in such a way as to lessen the pleasure of others.

LOYAL…offers loyalty, encouragement and support to other amateurs, local clubs, and the American Radio Relay League, through which Amateur Radio in the United States is represented nationally and internationally.

PROGRESSIVE…with knowledge abreast of science, a well-built and efficient station and operation above reproach.

FRIENDLY…slow and patient operating when requested; friendly advice and counsel to the beginner; kindly assistance, cooperation and consideration for the interests of others. These are the hallmarks of the amateur spirit.

BALANCED…radio is an avocation, never interfering with duties owed to family, job, school or community.

PATRIOTIC…station and skill always ready for service to country and community.

—The original Amateur’s Code was written by Paul M. Segal, W9EEA, in 1928.
Guide to ARRL Member Services

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About the ARRL

The seed for Amateur Radio was planted in the 1890s, when Guglielmo Marconi began his experiments in wireless telegraphy. Soon he was joined by dozens, then hundreds, of others who were enthusiastic about sending and receiving messages through the air—some with a commercial interest, but others solely out of a love for this new communications medium. The United States government began licensing Amateur Radio operators in 1912.

By 1914, there were thousands of Amateur Radio operators—hams—in the United States. Hiram Percy Maxim, a leading Hartford, Connecticut inventor and industrialist, saw the need for an organization to band together this fledgling group of radio experimenters. In May 1914 he founded the American Radio Relay League (ARRL) to meet that need.

Today ARRL, with approximately 155,000 members, is the largest organization of radio amateurs in the United States. The ARRL is a not-for-profit organization that:

• promotes interest in Amateur Radio communications and experimentation
• represents US radio amateurs in legislative matters, and
• maintains fraternalism and a high standard of conduct among Amateur Radio operators.

At ARRL headquarters in the Hartford suburb of Newington, the staff helps serve the needs of members. ARRL is also International Secretariat for the International Amateur Radio Union, which is made up of similar societies in 150 countries around the world.

ARRL publishes the monthly journal QST, as well as newsletters and many publications covering all aspects of Amateur Radio. Its headquarters station, W1AW, transmits bulletins of interest to radio amateurs and Morse code practice sessions. The ARRL also coordinates an extensive field organization, which includes volunteers who provide technical information and other support services for radio amateurs as well as communications for public-service activities. In addition, ARRL represents US amateurs with the Federal Communications Commission and other government agencies in the US and abroad.

Membership in ARRL means much more than receiving QST each month. In addition to the services already described, ARRL offers membership services on a personal level, such as the Technical Information Service—where members can get answers by phone, email or the ARRL website, to all their technical and operating questions.

Full ARRL membership (available only to licensed radio amateurs) gives you a voice in how the affairs of the organization are governed. ARRL policy is set by a Board of Directors (one from each of 15 Divisions). Each year, one-third of the ARRL Board of Directors stands for election by the full members they represent. The day-to-day operation of ARRL HQ is managed by an Executive Vice President and his staff.

No matter what aspect of Amateur Radio attracts you, ARRL membership is relevant and important. There would be no Amateur Radio as we know it today were it not for the ARRL. We would be happy to welcome you as a member! (An Amateur Radio license is not required for Associate Membership.) For more information about ARRL and answers to any questions you may have about Amateur Radio, write or call:

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Internet: www.arrl.org/

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800-32-NEW HAM (800-326-3942)
You can also contact us via e-mail at newham@arrl.org
or check out ARRLWeb at www.arrl.org/