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Chapter 1

What is Amateur (Ham) Radio?

Amateur radio enthusiasts — hams — often have been at the forefront of the sweeping blaze of progress over the past century in wireless and electronics, leading to technology that has broadened our horizons and touched virtually all of our lives. In the days before the telephone and household electricity were commonplace and the internet not yet conceived, hams pioneered personal communication. Amateur radio was the first wireless social medium.

From sophisticated smartphones, tablets, and devices worn on your wrist to diminutive laptop PCs that go anywhere, wireless technology is changing so rapidly that it can be difficult to keep current. People-to-people communication is the goal, whether by voice, text, or image, but amateur radio remains vital and active today. In this chapter, we present an overview of what to expect from *The ARRL Handbook*, as well as a brief look at amateur radio activities and licensing requirements.

Amateur radio, better known as "ham radio," is many things to many people — more than 750,000 of them in the US alone. Ham radio hobbyists have at their fingertips the ability to directly contact diverse and fascinating people they may never meet who live in distant places they'll never visit. They do this without any external infrastructure, such as a cellular network or the internet, using their own equipment and antennas. They contact one another directly, and do it because it's fun and offers a sense of accomplishment — "*I* made this happen!" As a radio amateur, you can meet new friends, win awards, experiment with and learn about radio science and technology, challenge yourself in on-the-air competitions (radiosport), contribute to your community, travel, promote international goodwill, and continue a more than century-old wireless communication tradition.

A NEW WINDOW ON THE WORLD

Amateur radio is almost unique in allowing hams to experience the world in ways of which many people are unaware by using the atmosphere to send signals around the Earth. Reaching to the edge of outer space, the ionosphere bends and reflects radio signals. This upper region of the atmosphere changes with solar activity, terrestrial seasons, and the hours of light and darkness, so radio conditions are continually changing, too. In fact, hams can literally "hear the world turning" as different areas become illuminated by the Sun at sunrise, pass through the day, and then enter the nighttime hours after sunset.

Lower down where the air is denser, there are clouds and precipitation — this is the troposphere — and hams interact with that part of the atmosphere, too. By using their knowledge of how radio waves travel, hams can communicate far beyond the "line of sight," extending their radio horizon to hundreds of miles. Hams even bounce signals off mountains and buildings!

Space weather also gets into the act. If you are interested in what's happening on the Sun or in the magnetic fields around Earth, radio signals are a great way to measure or observe these effects in real time. A beautiful aurora can reflect radio signals. When a new sunspot, crackling with energy, makes its appearance on the Sun's surface, hams can sense its presence as it enables communication at higher and higher frequencies. The HamSCI community of researchers and amateurs (**hamsci.org**) constantly collaborates in group experiments and measurements.

THE ORIGINAL SOCIAL MEDIUM

In this age of multiple sophisticated communication platforms, it's not uncommon for people to ask, "Ham radio? Do they still *do* that?" Yes, "they" do. But, given the proliferation of communication alternatives, the larger question may be, *Why*?

Ham radio is a hands-on technological and social medium — *personal* communication with no bills, minutes, or data plans. It's personal communication that's "off the grid," a wireless service you can rely on when other services become unavailable.

It doesn't cost a lot to get into amateur radio, and participation is open and accessible to everyone. Hams are mothers, fathers, and children of all ages, ethnic backgrounds, physi-

Figure 1.1 — Tom Gaines, KB5FHK, and Sloan Davis, N3UPS (not shown) demonstrated how to make contacts through amateur radio satellites from the parking lot at the Orlando HamCation ham convention.

Figure 1.3 — Audrey Hance, KN4TMU, enjoys operating from a state park in Tennessee. Parks On the Air (POTA) is a program that encourages hams to enjoy the outdoors while using temporary ham radio setups.

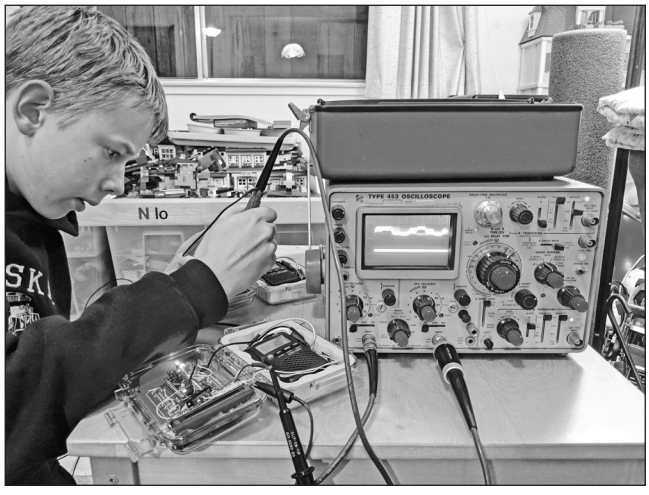


Figure 1.2 — Roy Gross, KM6EOO, got interested in ham radio in the second grade. He enjoys building and experimenting with antennas and radios. Here, he debugs a science fair project using an oscilloscope.

Figure 1.4 — Elixander Valladares, Jr., N4EVJ, took part in the ARRL Rookie Roundup, an operating event for newcomers. [Elixander Valladares, Sr., W7HU, photo]

ARRL The National Association for Amateur Radio®

ARRL is the internationally recognized society representing amateur radio in the US. Since its founding in 1914, ARRL has grown and evolved along with amateur radio. ARRL Headquarters and the Maxim Memorial Station W1AW are in Newington, Connecticut, near Hartford. Through its dedicated volunteers and a professional staff, ARRL promotes the advancement of the amateur service in the US and around the world.

ARRL is a nonprofit, educational, and scientific organization dedicated to the promotion and protection of the many privileges that ham radio operators enjoy. Of, by, and for the radio amateur, ARRL numbers some 150,000 members — the vast majority of active amateurs in North America. Licensees can become Full Members, while unlicensed persons are eligible to become Associate Members with all membership privileges except for voting in ARRL elections. Anyone with a genuine interest in amateur radio belongs in the ARRL.

The ARRL volunteer corps is called the Field Organization. Working at the state and local level, these individuals tackle ARRL's goals to further amateur radio. They organize emergency communication in times of disaster and work with agencies such as American Red Cross and Citizen Corps. Other volunteers keep state and local government officials abreast of the good that hams do at the state and local level.

When you join ARRL, you add your voice to those who are most involved with ham radio. The most prominent membership benefits are its membership journal *QST*, published monthly in print and digital form, and *On the Air*, a bi-monthly magazine aimed at amateur radio newcomers and hams gaining experience. *QST* includes stories you'll want to read; articles on projects to undertake; announcements of upcoming hamfests, conventions, contests, and other on-air activities; reviews of new equipment; reports on the role hams play in emergencies; and much more.

On the Air helps you make the most of your amateur radio license with helpful articles and infographics explaining the fundamentals of ham radio, including popular antenna setups and projects, best practices for operating your handheld transceiver, tips for participating in field day events, and many other topics — all written without a lot of math or jargon. The accompanying *On the Air* podcast dives deep into a single subject drawn from the magazine.

Members may elect to receive the print edition of either *QST* or *On the Air*. In addition, ARRL publishes a couple of bimonthly specialty magazines aimed at particular segments of amateur radio: *QEX — The Forum for Communications Experimenters* and *NCJ — National Contest Journal*, which caters to those interested in amateur radio contesting, or "radiosport." All of these magazines are available to all ARRL members in online digital format, as a member service.

Being an ARRL member is far more than a magazine subscription. ARRL represents your interests before the FCC and Congress, sponsors operating events throughout the year, and offers membership services at a personal level. These include:

- low-cost ham radio equipment insurance
- the Volunteer Examiner program
- the Technical Information Service, which answers your questions about amateur radio technical topics
- the ARRL Learning Center, with online courses for getting on the air, emergency communications, and electronics and technology
- Logbook of The World (LoTW), an online database for recording your contacts and cross-checking them with other amateurs around the world for award programs
- the QSL Service, which helps you exchange paper QSL cards in bulk with hams in other countries to confirm your contacts with them

For answers to any questions about amateur radio, contact ARRL Headquarters. See the Resources section at the end of this chapter for more information.

ARRL The National Association for Amateur Radio®

Figure 1.5 — NASA Astronaut Tim Kopra, KE5UDN, makes the 1000th ARISS school contact from NA1SS aboard the International Space Station, where he spent one year in 2016. [NASA Photo]

cal abilities, and walks of life who belong to a unique worldwide community of licensed radio hobbyists. Some are even well-known celebrities. All find joy and excitement by experiencing radio communication and electronics on a very personal level across a spectrum of activities.

HAMS ARE EVERYWHERE

The driver of that car sporting an odd-looking antenna may be a radio amateur equipped to enjoy his or her hobby while on the road — called mobile operation. Your neighbor on the next block with the wires strung between trees or, perhaps, a tower supporting what looks like a very large television antenna probably is one too.

Modern technology continues to make ham radio more accessible to all, including those living on tight budgets or facing physical challenges. People lacking mobility may find the world of amateur radio a rewarding place to find lasting friendships — on the next block, in the next state, or around the world.

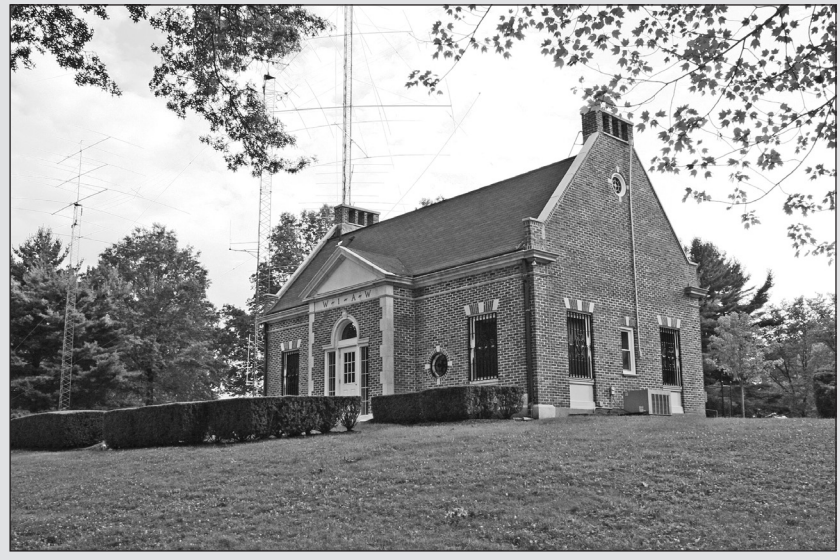
Hams are ambassadors, contacting and making friends with other enthusiasts in other countries and sometimes traveling to far-flung locations to get on the air and meet the people who live there. Amateur radio recognizes no international or political boundaries, and it brings the world together in friendship.

The Second Century of Ham Radio

We may think of "wireless" as a relatively modern term that applies to a wide variety of electronic devices, but it's been around since the late 19th century. At some point along the way, "radio" (and later "television") took over as the preferred term. Being able to communicate from one place to another without connecting wires was a goal of late 19th and early 20th century experimenters. Equipment and methods for early wireless were rudimentary — a simple "crystal" radio to listen, and a "spark gap" transmitter (it *actually* generated sparks) to send Morse code, coupled with what was then called an "aerial" — we'd call it an antenna today. Little to no ready-made equipment was available, and parts for these early radio do-it-yourselfers were expensive and hard to obtain. On a good night, their transmissions might even span 50 miles. In the early 20th century, when few households had telephones and calling long-distance was pricey, ham radio was, in more contemporary terms, "really cool technology."

In 1914, just two years after the federal government required hams to hold licenses, inventor and industrialist Hiram Percy Maxim, 1AW, and radio enthusiast Clarence Tuska, 1WD, established the American Radio Relay League (ARRL) to bring US radio hobbyists under one tent to serve their common interests. These two founding fathers of ham radio and their peers would be awestruck to see how the world of amateur radio and wireless technology has expanded and evolved in the intervening years.

While Maxim and Tuska were not the first hams, the organization they founded, now known as ARRL® The National Association for Amateur Radio®, has championed and sustained these radio pioneers and their successors. Now more than 100 years down the road — light years in terms of radio science and technology — amateur radio continues to adapt to the times. While many traditions continue, today's ham radio is *not* the ham radio of yesteryear.



This iconic brick building houses W1AW, the station operated by the ARRL in Newington, Connecticut, and known around the world. W1AW memorializes Hiram Percy Maxim, one of the founders of the ARRL. Visitors are welcome and often operate the station. [Rick Lindquist, WW1ME, photo]

1.1 About this Book

For nearly a century, *The ARRL Handbook* has helped amateurs explore and learn about our great hobby. Of course amateur radio covers a very wide spectrum of interests, and the *Handbook* is a great resource for theoretical and practical information no matter what areas catch your interest. Here's a sampling:

• If you're putting together a home, portable, or mobile station, the **Power Sources**, **Transmission Lines**, **Antennas**, **Safe Practices**, **Assembling a Station**, and **RFI and EMC** chapters will be of special interest.

• Emergency communications (EmComm)/public service operators will find useful material in the **Power Sources**, **Repeater Systems, Antennas**, **Safe Practices**, and **Assembling a Station** chapters

• If your interests lie in equipment and circuit design and building, there is a wealth of material in the **Circuits and Components**, **RF Techniques**, **Electronic Design Automation (EDA)**, **DSP and SDR Fundamentals**, **Oscillators and Synthesizers**, **Analog and Digital Filtering**, **Modulation**, **Receiving**, **Transmitting**, **Transceiver Design Topics**, and **Power Amplifiers** chapters, among others.

• If you're more involved with repairing equipment or restoring vintage gear, the **Test Equipment and Measurements** and **Troubleshooting and Maintenance** chapters will be valuable.

• For antenna design and building, the **Antennas** chapter is filled with theoretical and practical information. Also check out the antenna-related sections of the **Test Equipment and Measurements** and **Troubleshooting and Maintenance** chapters.

• Amateur satellite theory, station design, and antennas are covered in detail in the online **Space Communications** chapter.

• Digital mode operators can take a deep dive into the theory behind many digital modes in the **Digital Protocols and Modes** chapter, or turn to the online **Digital Communications** chapter for practical advice on putting these modes to use.

• For insight into amateur radio applications for balloons, buoys, autonomous craft, UAV (drones), radio controlled (R/C) craft, and robotics, try the **Amateur Radio Data Platforms** chapter. There's some useful material in the online **Image Communications** chapter as well.

• Those interested in STEM education topics and learning about how electronics and radio work will find a wealth of useful theoretical and practical material throughout this book. In particular, the **Electrical Fundamentals**, **Radio Fundamentals**, **Circuits and Components**, and **RF Techniques** chapters, along with the online **Digital Basics** chapter, offer a well-rounded look at fundamental electronic and radio theory. The **Propagation of Radio Signals** and **Amateur Radio Data Platforms** chapters offer background for those interested in scientific experimentation, research, and geophysics.

And the list goes on and on.

In addition to amateur radio operators, electronics hobbyists, engineers, and technicians turn to *The ARRL Handbook* for practical information about electronics and radio communication topics.

1.1.1 A Brief Handbook Tour

This *Handbook* presents a mix of theory and practical applications presented in the following chapters, which are divided into four broad sections:

• Fundamentals
• Practical Design and Principles
• Antenna Systems and Radio Propagation
• Station Construction, Maintenance, and Management

In addition to the material in the printed book, companion online resources include a fully searchable version of the *Handbook* and a wealth of additional chapters, articles, tools, and other useful information.

The next sections are a brief overview of the *Handbook's* contents. For a more in-depth look, check out the detailed **Contents** page at the beginning of each chapter.

FUNDAMENTALS

The three chapters in the Fundamentals section cover basic electronic and radio concepts and components that are common throughout our station equipment and accessories.

Chapter 2, Electrical Fundamentals is an overview of fundamental electrical and electronic concepts, including voltage and current, units of measurement, series and parallel circuits, direct and alternating current, and basic circuit components.

Chapter 3, Radio Fundamentals moves into the realm of ac waveforms and signals and radio frequency (RF). The chapter discusses ac in capacitors and inductors, along with reactance, impedance, Q, and resonant circuits. It wraps up with a discussion of analog signal processing and electromagnetic waves.

Chapter 4 — Circuits and Components gets into the practical devices used throughout electronic equipment. The chapter covers passive components such as resistors, capacitors, inductors, and transformers, as well as semiconductors and basic amplifier circuits.

PRACTICAL DESIGN AND PRINCIPLES

The 14 chapters in this section discuss analog and digital techniques, circuits, building blocks, and systems essential to understanding how radios work.

Chapter 5 — RF Techniques covers a wide range of topics relating to how components behave when used in radio frequency (RF) circuits. Other popular topics include ferrite materials, impedance matching networks, and RF transformers.

Chapter 6 — Electronic Design Automation (EDA) is an overview of computer-aided tools and techniques for electronic design and circuit simulation. Later sections discuss

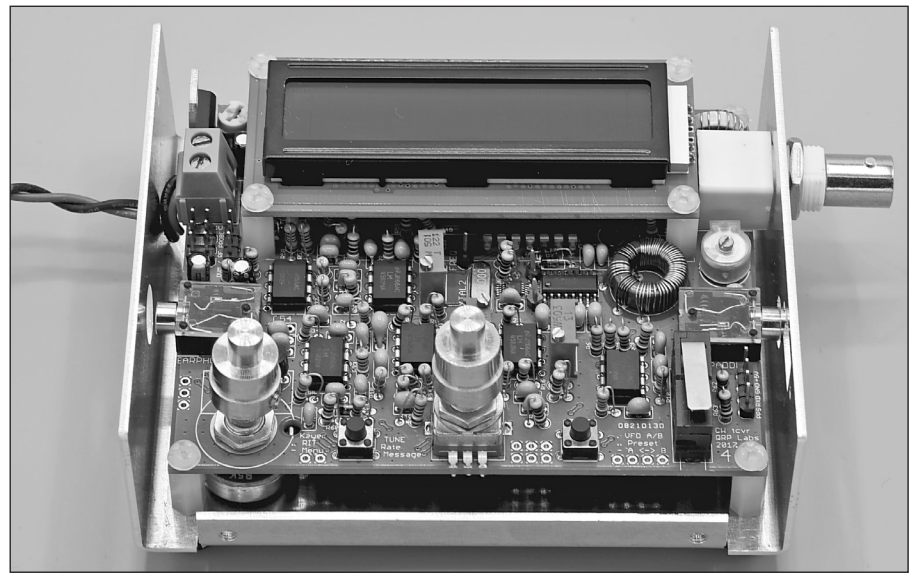


Figure 1.6 — Hams enjoy learning how their equipment works, as well as the satisfaction that comes from building their own equipment. This CW transceiver was assembled from a kit that included all of the parts, a circuit board, and detailed instructions.

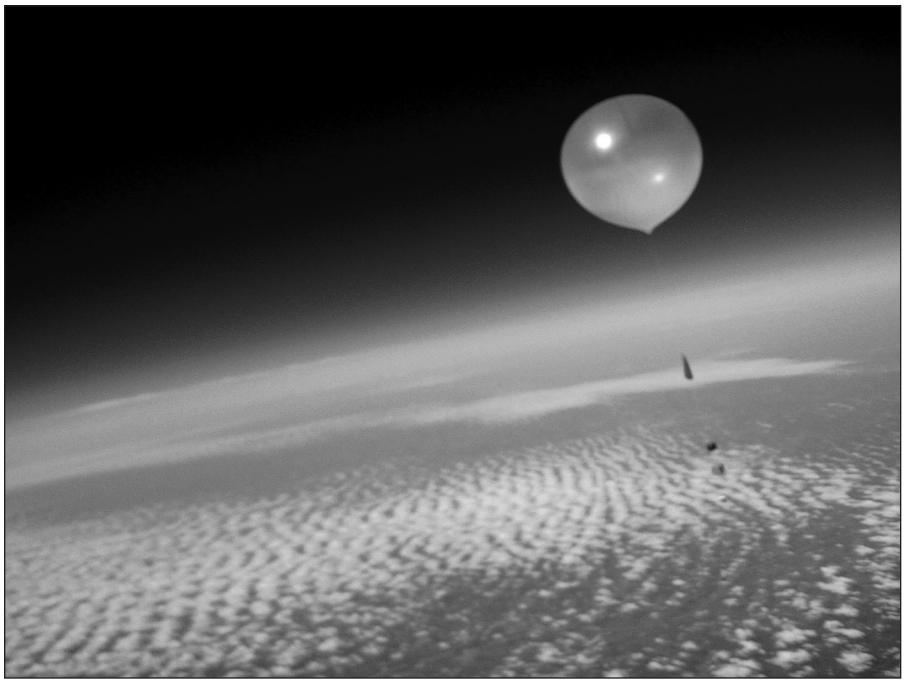


Figure 1.7 — An amateur radio balloon project by Bill Brown, WB8ELK; Paul Verhage, KD4STH; and Ann Boes, KDØQCA; carries a 4-H Lab Revolution student experiment at 53,000 feet. [Jeff Ducklow, NØNQN, photo]

Figure 1.8 — Antennas are always a popular topic among hams. The Lake Area Radio Klub (LARK) in South Dakota embarked on a club project to design and build baluns for use with wire dipole antennas. It offered club members a chance to learn more about antennas and build a useful project for their station. Rich Grant, KEØEPY, helped club members with assembly.

special considerations for simulation of RF circuits, as well as electromagnetic analysis of RF circuits.

Chapter 7 — Power Sources covers the wide range of options for powering electronic circuits. The chapter covers analog power supply concepts as well as switchmode dc-dc power conversion and high voltage techniques. Extensive coverage of batteries is essential for portable, mobile, and emcomm operators. Practical construction projects round out the chapter.

Chapter 8 — DSP and SDR Fundamentals explores the fundamentals of digital signal processing (DSP) and software defined radio (SDR), which are at the heart of new radio designs.

Chapter 9 — Oscillators and Synthesizers is an overview of the many ways RF signals can be generated. The chapter covers analog LC oscillators, crystal oscillators, and UHF techniques, as well as digital frequency synthesizers. The chapter wraps up with an in-depth look at phase noise and its effects on receiver and transmitter performance.

Chapter 10 — Analog and Digital Filtering starts with a discussion of basic filter concepts and characteristics, followed by sections on many types of analog and digital filters. The chapter includes several practical filter projects you can build.

Chapter 11 — Modulation covers the wide range of modulation types used in amateur radio. Topics include CW and analog voice modulation, as well as digital modulation techniques, image modulation, and spread spectrum.

Chapter 12 — Receiving discusses characteristics common to all receivers, such as sensitivity and dynamic range, and then explores heterodyne and SDR receiver architecture. The chapter also examines various building blocks such as mixers, demodulators, automatic gain control circuits, and noise reduction techniques.

Chapter 13 — Transmitting is the counterpart to Chapter 12. Topics include FCC rules for transmitter signal purity, performance measurements, heterodyne and SDR transmitter architecture, and basic building blocks.

Chapter 14 — Transceiver Design Topics includes a mix of some system level topics that deal with integrating receiving and transmitting functions into an effective transceiver. SDR technology is covered in more depth, along with user interface, panadapters, computer control interfaces, and transverters.

Chapter 15 — Digital Protocols and Modes takes a detailed look at the many different digital protocols and modes used by amateurs for transferring data. These are grouped into several categories: unstructured

Figure 1.9 — Hams operate using a wide variety of digital modes. Rosemarie Lones, K1AQT, operated radioteletype (RTTY) as part of the Nashua (New Hampshire) Area Radio Society team during an on-air radiosport competition. [Nashua Area Radio Society photo]

Figure 1.10 — Amateur radio frequency allocations extend well into the microwaves. Here, Chip Taylor, W1AIM, hunts contacts on the 10 GHz band from Mount Washington in New Hampshire, some 6,200 feet above sea level. [Chris Craig, K1MHZ, photo]

modes, fuzzy modes, structured modes, and networking modes.

Chapter 16 — Amateur Radio Data Platforms addresses the increasing use of amateur communication as a key element of scientific experimentation. Topics include different types of sensors, data, telemetry, and payloads. Then the chapter looks at vehicles to carry the payloads — high altitude balloons, UAVs, rockets, and robotics platforms.

Chapter 17 — RF Power Amplifiers covers RF power amplifiers beyond the typical 100 to 150 W transceiver and up to the legal power limit of 1.5 kW. Coverage includes the theory, characteristics, construction, and operation of both vacuum tube and solid-state amplifiers.

Chapter 18 — Repeater Systems is an overview of analog and digital VHF/UHF repeater technologies used by amateurs today. FM voice, D-STAR, DMR, and System Fusion systems are covered.

ANTENNA SYSTEMS AND RADIO PROPAGATION

The three chapters in this section discuss how signals generated by our transmitters leave our stations and travel to distant receivers.

Chapter 19 — Propagation of Radio Signals explores the principles of electromagnetic waves, the structure of the Earth's atmosphere, and solar-terrestrial interactions necessary for a working knowledge of radio propagation at MF, HF, VHF, UHF, and microwaves.

Chapter 20 — Transmission Lines starts with fundamental transmission line concepts and practical considerations for their selection, installation, and use. Related topics include impedance transformation, transmission line stub filters, antenna system impedance matching, antenna tuners, baluns, chokes, transmission line transformers, and waveguides.

Chapter 21 — Antennas is a perennial favorite. This chapter covers basic antenna theory, and then goes into a broad assortment of HF antennas, including dipoles, verticals, Yagis, and loops of various types. Antennas for HF mobile and portable operation are covered in detail, as are VHF/UHF home station and mobile antennas. A final section covers rotators. Throughout the chapter you'll find antenna projects that you can build or modify.

STATION CONSTRUCTION, MAINTENANCE, AND MANAGEMENT

The six chapters in the final section are devoted to combining the concepts in the earlier sections into a working amateur station that you can use on the air for years to come.

Chapter 22 — Safe Practices discusses electrical safety inside your station, along with best practices for grounding, bonding, and lightning protection. Antenna and tower safety includes some information on trees and masts, but focuses primarily on safely installing and working on towers. In the RF Safety section, you'll find coverage of RF exposure concerns and regulations, along with guidelines for safe operation of your station.

Chapter 23 — Construction Techniques is a great resource for anyone who likes to build their own equipment. Topics include soldering tools and techniques, working with surface mount devices (SMD), and computer-aided design (CAD) using free or low-cost schematic capture and PC board design software. Microwave construction techniques and mechanical fabrication (chassis, panels) are covered, along with a comprehensive section on 3D printing.

Chapter 24 — Assembling a Station is all about station installation and integration for fixed, mobile, portable, and remote stations.

Figure 1.11 — Learning to use basic test equipment such as an antenna analyzer will help you keep your amateur station running at peak efficiency,

The chapter covers power sources, antennas, and setup techniques for portable and temporary stations. The section on remote control covers network configuration and important performance issues like latency.

Chapter 25 — Test Equipment and Measurements explains the fundamentals of dc and ac measurements, including the use of multimeters, oscilloscopes, frequency counters, and function generators. RF measurements and equipment including spectrum analyzers, network analyzers, and signal generators are covered, as well as details of receiver and transmitter measurements in the ARRL Lab. Antenna system measurements and instruments are included, along with some practical projects.

Chapter 26 — Troubleshooting and Maintenance offers techniques for troubleshooting equipment problems at the compo-

nent, circuit, and system levels. The chapter offers insight on typical problems with different types of equipment, troubleshooting antenna systems, and working on vintage gear.

Chapter 27 — RFI and EMC is an in-depth look at common types of interference both from and to amateur radio equipment. Basic concepts of electromagnetic compatibility and associated components are presented.

ONLINE CONTENT, TOOLS, AND RESOURCES

In addition to the printed *ARRL Handbook*, a number of additional chapters, articles, and tools are available online, along with a fully searchable copy of the book. See the page at the front of this book for details on how to access this information.

Additional chapters included with the fully searchable online version of the *ARRL Handbook* include:

• **Space Communications** with details of amateur satellite and EME (earth-moon-earth, or moonbounce) stations.

• **Digital Communications** discusses station setup, technical details, and operating tips for many popular digital data and voice modes.

• **Image Communications** is all about analog and digital flavors of fast scan amateur television (ATV) and slow scan television (SSTV).

• **Digital Basics** covers digital theory fundamentals and some applications of that theory in amateur radio.

• **Station Accessories and Projects** is a collection of useful projects that you can undertake.

• **Radio Mathematics** is a collection of tutorial information on a variety of mathematics used in amateur radio.

In addition to these chapters, there is a collection of useful design software and a wide variety of supplemental articles and files for each chapter. A list of relevant online information and software is included at the beginning of each *Handbook* chapter.

Figure 1.12 — Nathan Charles, N3QKA, installed and maintained the solar power system at the Signal Hill Amateur Radio Club's ARRL Field Day site atop a mountain ridge on the Virginia/West Virginia border. Batteries were sheltered in tents to keep them out of the rain. [Jonathan Charles, NB3I, photo]

1.2 Structure of Amateur Radio

International and national radio regulations govern the operational and technical standards of all radio stations. The International Telecommunication Union (ITU) governs telecommunication on the international level. In the US, the Federal Communication Commission (FCC) is the agency that administers and oversees the operation of nongovernmental and nonmilitary stations — including amateur radio. Title 47 of the *US Code of Federal Regulations* governs telecommunication, and Part 97 of the Code spells out the Amateur Service rules. (See **www.arrl.org/part-97-amateur-radio**.)

Part 97 includes a definition of the Amateur Service: "A radiocommunication service for the purpose of self-training, intercommunication, and technical investigations carried out by licensed individuals interested in radio technique solely with a personal aim and without pecuniary interest." (*Pecuniary* means payment of any type, whether money or goods.) Amateur radio is a recognized national asset, a noncommercial service providing trained operators, technical specialists, and disaster response communications in time of need. It was created for people who have an interest in radio communications (see the sidebar, "Basis and Purpose of Amateur Radio").

Amateur radio will surprise you with all its different activities. If you've encountered amateur radio in a public service role or if someone you know has a ham radio in their home or car, then you already have some ideas.

Some hams prefer to focus on the technology and science of radio. Competitive events and award programs hold the interest of others. Some train to use radio in support of emergency response efforts, to provide public service, or to keep in touch with family. There are many hams who simply like to talk with other hams. The ARRL website (**www.arrl.org**) has much more information on these activities in the On the Air, Public Service, Technology, and Get Involved sections.

Figure 1.13 — Providing communication during emergencies is part of the Basis and Purpose of amateur radio as spelled out in the FCC rules. James Plumlee, KI5DAZ, serves as net control operator for the Hospital Net during the annual Simulated Emergency Test (SET) training exercise. [Paul Teel, WB5ANX, photo]

1.2.1 Bands and Modes

Anyone can listen to amateur radio signals, but an FCC license is required to transmit. There are currently three levels of license available — Technician, General, and Amateur Extra — each requiring an exam and conveying a set of privileges. We'll explain more about licensing and testing later in this chapter. Licensed hams have access to small frequency bands (segments) throughout the radio spectrum (see **Figure 1.14**), with some limitations depending on license class.

Each band has different characteristics, opportunities, and challenges to learn about— part of what makes ham radio so interesting. Depending upon license class, hams have access to up to 10 distinct "high frequency" (HF or shortwave) bands in the range from 1.8 to 29.7 MHz, where most direct international communication happens. All licensees have all amateur privileges in the VHF-UHF and microwave spectrum (50 MHz and higher), which allow more local and regional operation on widely available FM voice repeaters and digital voice networks. Frequency and wavelength terms are explained in the **Electrical Fundamentals** chapter.

Amateurs also use a wide variety of "modes" for making contacts. Some have been around since amateur radio began, while others are very recent creations. Much more information about various modes may be found in the **Modulation**, **Digital Protocols and Modes**, and **Repeater Systems** chapters.

VOICE MODES

Hams use a number of analog and digital voice modes (methods of adding voice to a radio signal). Analog voice modes are amplitude modulation (AM), which includes the narrower-bandwidth single sideband (SSB), and frequency modulation (FM). For the most part, SSB is heard on HF, while FM is the typical voice mode employed on VHF, UHF, and microwave bands.

Amateurs also use digital voice modes that convert speech into a bit stream for transmission. Systems such as D-STAR, System Fu-

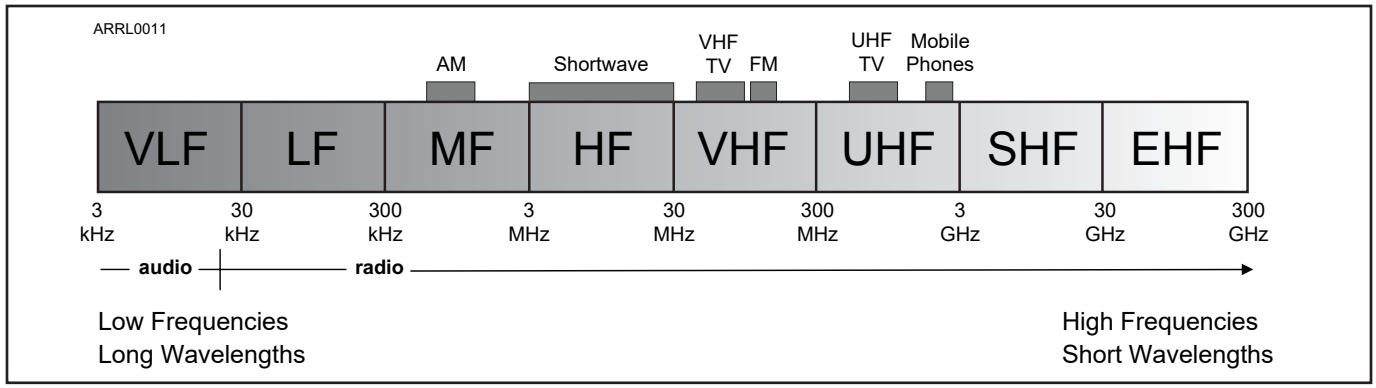


Figure 1.14 — The radio spectrum extends over a very wide range of frequencies. The drawing shows the frequency ranges used by broadcast stations and mobile phones. Amateurs can use small frequency bands in the LF and higher frequency regions of the spectrum.

sion, and DMR are being rapidly adopted for repeater use. The FreeDV system is designed for use on the HF bands along with SSB.

The great majority of ham radio HF phone operators use SSB (subdivided further into upper sideband and lower sideband), but a few still enjoy and experiment with heritage "full-carrier AM" with its warm, rich audio quality. See **www.arrl.org/am-phone-operating-and-activities**.

REPEATERS

Hams often make their first contacts on local voice repeaters, using analog FM or one of the digital voice modes. Repeaters can greatly extend the useful range of a typical handheld or mobile transceiver much in the same way a cell tower retransmits voice or text messages. Repeaters carry the vast majority of VHF/UHF traffic, making local and even regional mobile communication possible for many hams. Located in high spots, repeaters strengthen signals and retransmit them to provide communication over much greater distances than would be possible when operating point-to-point or "simplex." The wider coverage can be especially important if the repeater is ever pressed into service during an emergency.

Most repeaters are maintained by clubs or groups of hams. If you use a particular repeater frequently, you should join and support the repeater organization. Some hams set up their own repeaters as a service to the community. The best way to learn the customs of a particular repeater is to listen for a while before transmitting.

Most repeaters are *open*, meaning that any amateur may use the repeater, although FM repeaters typically require users to transmit an access tone (which any modern FM transceiver can transmit). Some repeaters are *closed*, meaning that usage is restricted to members of the club or group that owns and operates the repeater. The *ARRL Repeater Directory* shows repeater locations, frequencies, and other details. See the **Repeater Systems** chapter for more information.

MORSE CODE

Morse code was the very first radio transmission mode, although it wasn't long before early experimenters figured out how to transmit the human voice and even music over the airwaves. Morse is also the original digital mode; the message is transmitted by turning a radio signal on and off ("1" and "0" in digital terms) in a prescribed pattern to represent individual letters, numerals, and characters. This pattern is the International Morse Code. Hams often refer to Morse transmissions as "CW," after an archaic definition for "continuous wave," which described the type of radio wave transmitted.

Although proficiency in Morse code is no longer required for any class of amateur radio license in the US, many hams still embrace CW as a favorite mode and use it routinely. Hams typically send Morse code signals by manipulating a manual telegraph key, a "semi-automatic" key (called a "bug"), or a CW "paddle" and an electronic keyer to form the dots and dashes. Experienced hams decipher Morse code "by ear," either writing down the letters, numerals, and characters as they come through the receiver's headphones or speaker or simply reading it in their heads. Some use one of the available computer-based or stand-alone accessories that can translate CW into plain text without the need to learn the code.

Hams who enjoy CW cite its narrow bandwidth — a CW signal takes up very little of the radio spectrum — simpler equipment, and the ability of a CW signal to "get through" noise and interference with minimal transmitting power. CW is a common low-power (QRP) mode.

DIGITAL MODES

Digital modes are used to exchange information between computers as individual characters — either in complete files or one character at a time in "keyboard-to-keyboard" contacts. Amateurs use modes originally invented for commercial or military applications and have invented several of their own! Innovation in digital communications is one of amateur radio's most important and active contributions. Digital modes are described in detail in the **Digital Protocols and Modes** chapter and also in the **Digital Communications** supplement available online. Note that the FCC rules spell out limitations to the bandwidth digital modes may occupy, as shown in **Table 1.1**.

Two popular digital modes today are FT8, one of several modes in the *WSJT-X* software package (**physics.princeton.edu/pulsar/k1jt/wsjtx.html**), and either PACTOR or ARDOP and VARA, which are used to ex-change email and other types of information as part of the Winlink system (**winlink.org**). FT8, PACTOR, and VARA use your PC with its sound card interfaced to a transceiver. The later versions of PACTOR that are most widely used require a special modem between the PC and radio.

The free package of *WSJT-X* software includes a number of specialized digital modes optimized for different uses: JT65 for EME, MSK144 for meteor scatter, FT8 for HF operation (a similar FT4 protocol is customized for radio contesting), WSPR for very low-power beacons, and more. FT8 is extremely popular due to its ability to exchange data with signals many times weaker than the noise. FT8 is a great mode for hams in noisy neighborhoods or who can't put up big antennas. Hams have also developed a number of versions of FT8 that add features or variations of messages.

Hams interested in public service, especially emergency communications, make use of the Winlink system to maintain contact while camping, boating, or just traveling. Many public service teams include Winlink as part of their training and operation programs. The system acts as a worldwide gateway between amateur radio and the internet, although the restrictions on commercial content must be strictly followed.

Two other keyboard-to-keyboard modes used by hams to "talk by typing" include radioteletype (RTTY) and PSK31. Often

Basis and Purpose of Amateur Radio

Experimentation has always been the backbone of amateur radio, and the Amateur Service rules provide a framework within which hams enjoy wide latitude to operate and experiment. The FCC's rules governing amateur radio recognize five aspects, paraphrased below, in the Basis and Purpose of the Amateur Service.

- Amateur radio's value to the public, particularly with respect to providing emergency communication support
- Amateur radio's proven ability to contribute to the advancement of the radio art
- Encouraging and improving the Amateur Service through rules that help advance communication and technical skills
- Maintaining and expanding the Amateur Service as a source of trained operators, technicians, and electronics experts
- Continuing and extending the radio amateur's unique ability to enhance international goodwill

The Amateur Service rules, Part 97, are in six sections: General Provisions, Station Operation Standards, Special Operations, Technical Standards, Providing Emergency Communication, and Qualifying Examination Systems. Part 97 is available in its entirety online (see the Resources section at the end of this chapter for further information).

Table 1.1

Maximum Symbol Rates and Bandwidth

Band (meters)	*Symbol Rate (baud)*	*Bandwidth (kHz)*
160 through 12 m	300	1
10 m	1200	1
6 m, 2 m	19.6k	20
1.25 m, 70 cm	56k	100
33 cm and above	no limit	no limit

Figure 1.15 — Hams use repeaters to relay signals from low-power radios over a wide area. Repeaters are a popular on-the-air meeting place for hams.

Figure 1.16 — ARRL Field Day is an annual event that combines emergency preparedness training and radiosport as individuals and clubs set up stations off the grid with temporary antennas and try to make as many contacts as possible. The Huntsville Amateur Radio Club's K4BFT setup in Alabama attracted a group of teachers from the nearby US Space and Rocket Center Space Camp. Todd Cline, K7KDT, demonstrates a digital "waterfall" as club members John Boyette, KK5KKT (leaning at left), and Geoff Suiter, KK4IV (at keyboard), operate the station. [William Martin, KK4FDF, photo]

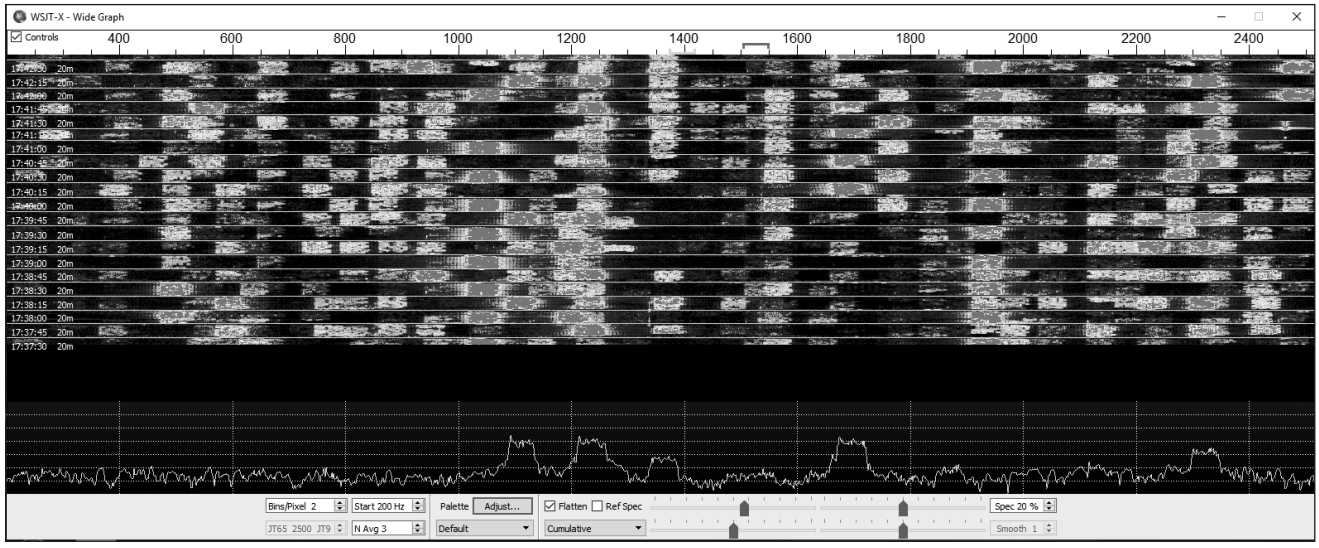


Figure 1.17 — Waterfall display of stations using the FT8 digital mode on a busy 20 meter band. Each small rectangle represents a transmission from a different station. Using state-of-the-art signal processing technology, it allows an astonishing number of stations to squeeze into a 2.5 kHz passband that would accommodate just one SSB voice signal. It also allows decoding of weak signals inaudible to the human ear, making it ideal for stations with low power and compromise antennas that would have difficulty making contacts using other modes.

pronounced "ritty," radioteletype was originally developed for point-to-point communications. Software such as *fldigi* supports many different modes including PSK31 and RTTY (see **www.w1hkj.com**).

Another amateur innovation is the Automatic Packet Reporting System or APRS, which combines position information (such as from GPS) with text messages and packet radio. This worldwide system (**www.aprs.org**) uses continuously monitoring "gateway" receivers to listen for the low-power APRS signals, relaying the information to internet servers where the information is viewed. Hams use APRS in their vehicles, while biking or boating, for weather reporting, and even to track high-altitude balloons during experiments.

The digital modes mentioned here are just a fraction of the many different digital modes used in amateur radio. New variations and innovations are being released all the time as experimenters try a new modulation or encoding scheme. This is a great example of the Amateur Service fulfilling its Basis and Purpose by "contribut(ing) to the advancement of the radio art."

IMAGE COMMUNICATION

Users of current cell phone and internet technology often enjoy sharing photos or talking face-to-face. While not as sophisticated, several ham radio communication modes allow the exchange of still or moving images over the air. Amateur radio communication takes on an exciting, new dimension when you can actually *see* the person you're communicating with.

Amateur TV (ATV) is full-motion video over the air, sometimes called "fast-scan TV." It's newer form is digital amateur radio TV (DATV), which is used to transmit distinctly sharper images and voice. Amateur groups in some areas have set up ATV repeaters, allowing lower-power stations to communicate over a fairly wide area. Since this is a wide-bandwidth mode, operation is limited to the UHF bands (70 centimeters and higher).

DATV folds nicely into an amateur radio technological initiative called high-speed multimedia (HSMM), which supports networks such as Broadband-Hamnet and Amateur Radio Emergency Data Network (AREDN). The ham bands above 50 MHz can support computer-to-computer communication at speeds high enough to sustain multimedia applications — voice, data, and image. One approach adapts IEEE 802 technologies, particularly 802.11b, to operating on specific amateur radio frequencies in the 2.4, 3.4, and 5.6 GHz microwave bands.

SSTV or "slow-scan TV" is an older, narrow-bandwidth image mode similar to fax. Instead of full-motion video, SSTV enthusiasts exchange photographs and other static images. Individual SSTV pictures take anywhere from 8 seconds to about 2 minutes to send, depending on the transmission method. Most SSTV operation is done in color, using computers and soundcards in conjunction with special software that converts images into a series of audio tones representing brightness level and colors that are "painted" on the receiver's screen line by line. Since SSTV is a narrow-band mode, it is popular on HF on the same frequencies used for voice operation.

For more information, see the online **Image Communications** chapter for details on these modes.

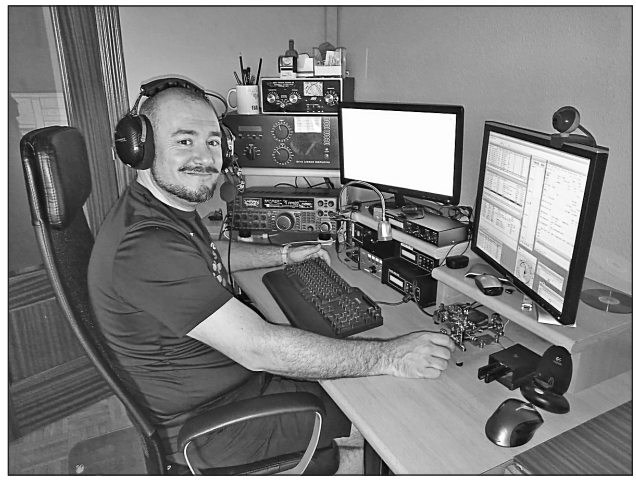


Figure 1.18 — Ricardo "Rick" Navarrete Lopez, EA4M, used this nicely appointed station during the CW weekend of ARRL International DX Contest.

1.2.2 A Sampling of FCC On-Air Operating Rules

There are quite a few FCC rules and regulations covering behavior on the air, but much of it boils down to polite behavior and common sense. In the FCC rules, you'll see references to the *control operator*. That's simply the licensed amateur designated to be responsible for making sure that transmissions comply with FCC rules. Any licensed amateur can be a control operator, and that doesn't have to be the same person as the station owner. The station licensee is responsible for designating the control operator.

Proper identification of your station while on the air is important so the FCC knows who's transmitting and for any other station that wants to contact you or to know where your signal is coming from. The identification rules are simple — give your call sign at least once every 10 minutes during a contact and when the communication is finished. Unidentified transmissions are not allowed.

As noted earlier, amateur radio is a non-commercial service. Transmissions related to conducting your business or employer's activities are not permitted, and you can't be paid for using your amateur station. There are plenty of other radio services available for commercial activities. (Note that your personal activities don't count as "business" communications. For example, it's perfectly

Figure 1.19 — Sean Kutzko, KX9X, uses a handheld antenna to make contacts through an amateur radio satellite.

okay for you to use ham radio to talk to your spouse about doing some shopping or to confer about what to pick up at the store.)

Prohibited transmissions include false distress or emergency signals, obscene or indecent speech, or encrypted transmissions intended to hide the meaning. You're also not allowed to engage in one-way broadcasting for the general public or transmit music. And it's not okay to intentionally interfere with other hams using the band.

1.2.3 Station Considerations

The FCC rules include some station requirements as well. For example, the maximum allowed transmitter power is 1500 W PEP output on most bands. There are lower power limits for 2200, 630, 60, and 30 meter bands, and for Novice and Technician licensees in their HF allocations. Full details are available from the US Amateur Bands chart at the front of this book or online from **www.arrl.org/band-plan**.

There are also some rules about signal quality because a poor quality signal may interfere with other hams or even other radio services. Signal quality for various modes is covered in the **Modulation**, **Transmitters**, and **Test Equipment and Measurements** chapters. Fortunately most commercially produced transceivers produce good quality voice, CW, and digital signals when properly adjusted, and you should take the time to read the instructions for your gear. ARRL Lab tests and *QST* Product Reviews are also a good resource for learning about how well equipment complies with FCC rules and good engineering practice for signal quality. See **www.arrl.org/arrl-lab**.

Amateur radio is basically a safe activity. In recent years, however, there has been considerable discussion and concern about the possible hazards of electromagnetic radiation, including both RF energy and power-frequency (50 to 60 Hz) electromagnetic fields. To allay such concerns, the FCC set limits on the amount of RF energy to which people can be exposed. Some amateur radio stations need to be evaluated to see if they are in compliance with the rules. Detailed information on RF safety may be found in the **Safe Practices** chapter of this book and online at **www.arrl.org/rf-exposure**.

STATION EQUIPMENT AND ANTENNAS

Amateur radio costs as much or as little as your budget and enthusiasm dictate. Today's radio amateurs most often start out using off-the-shelf, commercially made transceivers purchased new or on the used market, perhaps at a ham radio flea market ("hamfest") or through an internet auction or classified ad site. An abundance of ham gear is readily available, and it's not hard to find something that meets your needs and suits your budget. Used higher-end VHF or VHF-UHF (or "dual-band") handheld transceivers often are available for $100 to $200 or so. The entrance of Chinese manufacturers into the ham radio market has dramatically driven down the cost of a basic VHF-UHF handheld to well under $100. To find hamfests in your area, try **www.arrl.org/hamfests-and-conventions-calendar**.

Those interested in HF work can get in on the ground floor with a used, but serviceable, transceiver in the $200 to $500 range, and an excellent selection of new transceivers is available in the $500 to $1,500 range. Low-power CW (Morse code) transceivers covering single bands sell new for less than $100 in kit form. An HF antenna such as a simple backyard dipole suspended from available trees is both inexpensive and effective. You'll find a wide variety of equipment advertised in ARRL's monthly journal, *QST*, which also includes comprehensive equipment reviews (**www.arrl.org/product-review**). Some helpful tips and resources may be found at **www.arrl.org/what-rig-should-i-buy**.

More elaborate antennas and various accessories can add appreciably to the cost of your station, but less-expensive alternatives are available, including building your own. The **Antennas** chapter features a number of simple and effective antennas that you can build from wire and readily available parts.

Early radio amateurs generally built their own gear, mainly out of necessity, and constructing ham radio equipment from kits became popular in the mid-20th century. Several manufacturers still provide parts kits and circuit boards to make it easier to build equipment yourself. Some hams still like to design and build their own equipment (called "homebrewing"), saving money in the bargain and enjoying the challenge. Check out the **Construction Techniques** chapter for a look at how you can get involved in building equipment or kits, even using 3D printing.

COMPUTERS AND HAM RADIO

Amateurs discovered decades ago that interconnecting their PCs with their ham stations not only makes operating more convenient but can open the door to additional activities on the ham bands. Most ham radio stations include a computer with software for many ham radio applications, from record keeping to antenna and circuit design.

Probably the most common use for a computer in the ham station is logging your contacts — keeping a record of the stations you have communicated with on the air. Some computer logging applications also let you control many or most of your radio's functions, such as frequency or band selection, without having to leave your logging program. It's also possible to control various accessories, such as antenna rotators or selection switches, by software.

You can enjoy digital modes with nothing more than a couple of simple connections, operating software (typically free), and an interface. Most current generation transceivers have a built-in sound card device, and all that's needed is a USB cable and appropriate software. Everything you need to know to get started with FT8 and other digital modes may

Figure 1.20 — Johannes Hafkenscheid, PA5X, operated from Mauritania as 5T5PA, while working there for several months.

be found in the online **Digital Communications** chapter.

Computers also can alert you to DX activity on the bands, help you practice taking amateur radio license examinations, or improve your Morse code skill. Many ham radio organizations and interest groups maintain online discussion groups with valuable information about a wide variety of topics, and, of course, equipment vendors maintain websites too.

STATION LOCATION

Many hams set up home-based stations. By tradition the room or place where a station is located is your "ham shack," but many lower-profile hams carry their stations with them in the form of relatively inexpensive handheld VHF/UHF transceivers. Without requiring any antenna beyond the one attached to the radio itself, such radios can accompany you when you're out and about or traveling.

On the other end of the scale, radio amateurs serious about radiosport competitions or DXing (contacting distant stations in other countries) often invest in top-tier equipment and extensive antenna systems. Most hams fall somewhere between these extremes. They have a modest equipment complement, simple wire antennas suspended from trees, and maybe a small "beam" (directional antenna) on a backyard tower or mast. Whatever your investment level, you'll be able to talk around the world.

ANTENNA RESTRICTIONS

In today's world, it's common for hams to face limitations on installing antennas if they live in an apartment or condo, or in a development governed by a homeowner's association (HOA) with restrictions on how they can use their property. Some areas have zoning requirements such as height limits or setback from adjacent properties. In most cases a building permit from the local town offices is needed for a larger installation such as a permanent mast or tower. This is something to explore when buying a property or planning to install an antenna. It's worth some time to review the ARRL web pages on this topic at **www.arrl.org/antenna-regulation-and-zoning**.

In some cases hams are able to install "low profile" indoor or outdoor antennas. In recent years there has been increased interest in portable operation from outdoor locations such as local or state parks. This allows temporary installation of a more effective antenna on a mast or in a tree (if allowed) but usually requires a portable power source such as a battery.

Other hams install VHF/UHF and/or HF equipment and antennas in their vehicles for mobile operation. Some installations are for a single band (say, 2 meters), while others use complex antenna systems to cover a number of HF bands. It's not unusual for hams to use their mobile stations to chat with friends during commuting hours, to stay in touch with friends while traveling, or to travel to rare locations to contact hams chasing various awards. An effective mobile station has a more serious side — use during disasters or other interruptions in normal communication channels.

Portable and mobile stations, antennas, and batteries are discussed in the **Power Sources**, **Antennas**, and **Assembling a Station** chapters. Another good resource is *Portable Operating for Amateur Radio* by Stuart Thomas, KB1HQS, available from the ARRL Store.

Figure 1.21 — Dennis Lazar, W4DNN, using his vintage station on CW. Some hams enjoy restoring and using classic tube-type equipment, often called "boat anchors" because of their weight.

Figure 1.22 — Amateur Radio Direction Finding (ARDF) equipment need not be expensive. Yagis made from measuring tapes and PVC pipe are very popular for direction finding on 2 meters with a handheld transceiver. Here, Dan Slater, AG6HF (left), tests an antenna he built. [Joe Moell, KØOV, photo]

REMOTE AND AUTOMATIC OPERATION

It is becoming common to operate a remote HF station via a link over the internet. You may have your own remote station, belong to a group with a shared club station with remote access, or you may use one of the stations available for rent. Availability of remote hardware and widespread access to reliable, high-speed internet service has been a huge benefit to hams living in locations where outdoor antennas are limited or prohibited. Remote operation is discussed in detail in the **Assembling a Station** chapter.

Many stations, such as repeaters and beacons, operate without a human control operator present to perform control functions. This is called automatic operation.

Remote and automatic operation are defined in the FCC rules, but the requirement remains the same — the station must be operated in compliance with FCC rules, no matter where the control point is located. See the sidebar, "Local, Remote, and Automatic Control" for more information.

1.3 Amateur Radio Licensing in the US

As noted earlier, the Federal Communications Commission (FCC) is charged with administering all of the radio signals transmitted by US radio stations. The vast majority of radio users must have a license or be employed by a company that has a license. This section explains how licensing works for amateur radio.

1.3.1 Licensing Overview

The FCC has a different set of rules for each type of radio use. These uses are called *services*. Each service was created for a specific purpose — Land Mobile, Aviation, and Broadcasting, for example. Nearly all services require that a license be obtained before transmissions are made. These are called licensed services, and the Amateur service is one of them.

Most services do not require an examination to be licensed. This is because the FCC sets strict technical standards for the radio equipment used in these services and restricts how those radios may be used. This tradeoff reduces the training required for those radio users. Licensing in these services is primarily a method to control access to the airwaves.

Why Get A License?

Amateurs are free to choose from many types of radios and activities — that's what you get in return for passing the license exam. If you can learn the basics of radio and the rules of amateur radio, then the opportunities of ham radio are all yours! Just remember that the license is there to ensure that you understand the basics before transmitting. This helps keep amateur radio useful and enjoyable to everyone.

Why don't people just buy radios and transmit anyway? (This is called "bootlegging" or "pirating.") First of all, it's quite apparent to hams who has and who hasn't passed a license exam. You'll find yourself attracting the attention of the FCC, but more importantly, you won't fit in and you won't have fun.

One of the most important benefits to being licensed is that you have the right to be protected from interference by signals from unlicensed devices, such as consumer electronics. Your right to use the amateur bands is similarly protected. The protection doesn't work perfectly all the time, but nevertheless, as a licensed amateur operator your license is recognized by law. This is a big improvement over unlicensed radio users. It's definitely worth the effort to get that license!

Local, Remote, and Automatic Control

Local control — a control operator is physically present at the control point, the physical location from which the station controls are operated. This is the situation for nearly all amateur stations, including mobile operation. Any type of station can be locally controlled.

Remote operation — the control point is located away from the transmitter and the control operator adjusts or operates the transmitter indirectly via some kind of *control link*. The control operator must be present at the control point during all transmission. Many stations operate under remote control over an internet link. Any station can be remotely controlled.

Automatic operation — the station operates completely under the control of devices and procedures that ensure compliance with FCC rules. A control operator is still required, but need not be at the control point when the station is transmitting. Repeaters, beacons and space stations are allowed to be automatically controlled. Digipeaters that relay messages, such as for the APRS network, are also automatically controlled.

UNLICENSED PERSONAL RADIOS

The most popular personal radios are the FRS/GMRS handheld radios that are seemingly sold everywhere. FRS stands for Family Radio Service and GMRS stands for General Mobile Radio Service. These radios use a set of 22 channels in a narrow frequency band best suited for short-range, line-of-sight communications.

Citizens Band remains popular in the applications for which it was originally intended. Mobile radios in vehicles, boats, and farm equipment provide useful, medium-range radio communications to other vehicles or with radios at home or at work. Communication is fairly reliable over a range of several miles.

Boaters will be familiar with marine VHF radios used for boats to communicate with each other and with stations on shore. These radios can use up to 50 channels for communicating around harbors and for short-range needs during both fresh and salt-water travel.

All three of these radios are designed to use a set of channels selected for a single type of communication as shown in **Table 1.2**. They do their designated job well. If you find your personal radio interesting, but limited, then amateur radio is definitely the place for you.

Amateurs have access to a much broader range of communications options and create new ways of communicating that are more powerful and flexible than those of the unlicensed radio services. We can build and repair our own radios. The procedures we use to communicate are completely up to us. We can operate however we want, with few restrictions. This flexibility, in order to not cause interference to other radio services, requires that amateurs be more knowledgeable than the typical user in other services. That is why amateurs have to pass a licensing examination.

AMATEUR LICENSES

Amateurs give and grade the exams themselves under the guidance of a Volunteer Examiner Coordinator (VEC). There are currently 14 different clubs or organizations recognized as VECs by the FCC. Each VEC also certifies Volunteer Examiners (VEs), who actually administer the exam sessions. The VEC then handles the paperwork for each license exam and application. The examination process is not as imposing as it may seem.

The result of passing the exam is an *operator license* (or "ticket") granted by the FCC after it receives the necessary paperwork from the VEC that administered your exam session. The license also specifies a call sign that becomes your radio identity.

There are three classes of license being granted today: the Technician, General, and Amateur Extra. The exam for each of the three license classes is called an *element*. Passing each of the elements grants the licensee more and more *privileges* allowed by the FCC's Amateur service rules. **Table 1.3** shows the elements and privileges for each of the Amateur license classes, and the US Amateur

Table 1.2
Types of Personal Radio

Service	*Channels*	*Intended Use*	*Range*
Citizens Band (CB)	40	Private/Business	10 miles +
Marine VHF	50	Maritime	20 miles +
Family Radio Service (FRS)	22	Personal	2 miles
Multi-Use Radio Service (MURS)	5	Personal	5 miles +

Table 1.3

Amateur License Class Examinations

License Class	*Exam Element*	*Number of Questions*	*Privileges*
Technician	2	35 (passing grade is 26 correct)	All VHF and UHF privileges, with some HF privileges
General	3	35 (passing grade is 26 correct)	All VHF, UHF and most HF privileges
Amateur Extra	4	50 (passing grade is 37 correct)	All amateur privileges

Table 1.4

ARRL License Study Guides

Technician	*The ARRL Ham Radio License Manual ARRL's Tech Q&A*
General	*The ARRL General Class License Manual ARRL's General Q&A*
Amateur Extra	*The ARRL Extra Class License Manual ARRL's Extra Q&A*

Question pools are revised every four years. When new question pools are released, ARRL will produce new study materials before the effective date. Be sure to check the book cover or copyright page to ensure that you're using a study guide for the question pool currently in use.

Figure 1.23 — ARRL *License Manuals* are a great way to prepare for the Technician, General, or Extra class exams. Each book thoroughly covers the exam questions and topics.

The FCC Universal Licensing System (ULS)

The Universal Licensing System (ULS) and FCC registration and filing systems were deployed in the Amateur Service on August 16, 1999. To conduct business with the FCC, you must register through the FCC Commission Registration System (CORES) and be assigned an FCC Registration Number (FRN). This number will be used to uniquely identify you in all transactions with the FCC. You must do this before you can use ULS to renew your license, change your address, obtain a duplicate license, or use any of the other services that the FCC offers. Not sure if you have an FRN? Check your license to determine if it's been assigned an FRN.

The FCC has taken great strides to make the ULS and the CORES easy to use and has devoted a section of their website to the Amateur Service. Helpful web pages include:

- New Users Guide To Getting Started With Universal Licensing System (ULS)
- Common Amateur Filing Tasks
- Commission Registration System Video Tutorials

These web pages offer instruction on setting up a user account, registering for a FRN, and filing electronically via the ULS. For more information on the ULS and links to these FCC online resources, visit **www.arrl.org/universal-licensing-system**.

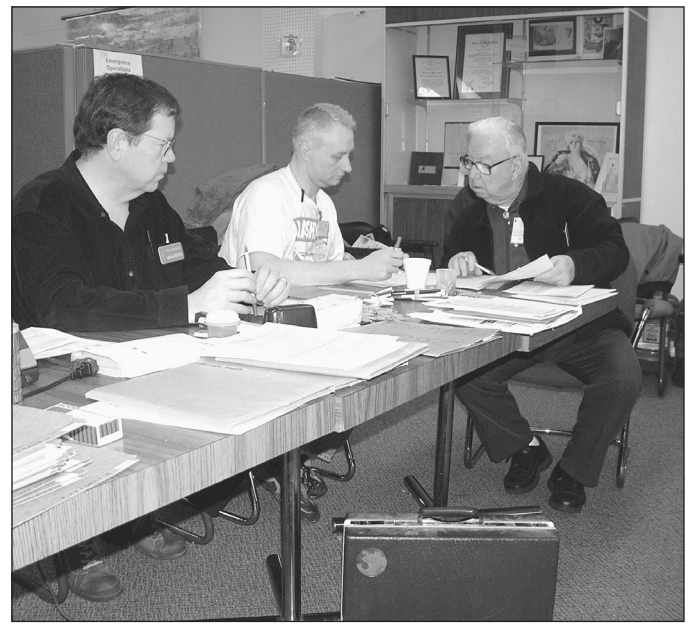


Figure 1.24 — Amateur radio licensing test sessions are administered by volunteer examiners — hams just like you will be. They grade the exams, help you fill out the necessary forms, and take care of all the paperwork for your ham radio license.

Bands chart at the front of this book shows the privileges by license class on the various frequency bands. (You may see references to Novice and Advanced amateur licenses. These have not been issued in many years, but some amateurs still hold them.)

1.3.2 Getting Your Ham Radio License

A comprehensive overview and many helpful resources for newcomers to ham radio may be found at **www.arrl.org/getting-licensed**. The Technician license is the first one for most people, and it requires passing a 35-question, multiple-choice exam on the rules of ham radio, simple operating procedures, and basic electronics.

The next step is the General license, which grants many more privileges, including access to large portions of the HF amateur bands and operation using all legal modes. The General exam is 35 questions about rules applicable to the expanded General privileges, more advanced electronics and radio theory, and operating procedures with a focus on modes and activities used on the HF bands.

The Amateur Extra license is the "all access pass" to amateur privileges. The exam is 50 questions, and it takes some dedication to learn about all of the advanced topics covered. Once you've passed the Extra exam, you're done with exams as long as you keep your license renewal up to date.

You can study on your own or you can enroll in a licensing class. Log on to the ARRL website where you can search for classes being held near you (**www.arrl.org/find-an-amateur-radio-license-class**). **Table 1.4** shows the appropriate ARRL study materials for the various exams. A note of caution: No matter what study guide you use, be sure that the questions used are current — the Technician, General, and Extra question pools are revised and updated every four years on a rotating schedule.

TESTING PROCESS

When you are comfortable with the study material, it's time to locate an exam session. If you're part of a study class, the instructor will make the necessary arrangements. For solo students, you can find a nearby exam session by visiting the ARRL website (**www.arrl.org/find-an-amateur-radio-license-exam-session**). Some organizations such as the Greater Los Angeles Area Repeater Group (GLAARG, **glaarg.org**) are offering online exam sessions to anyone.

Whether the exam is in-person or online, be sure to come prepared (see **www.arrl.org/what-to-bring-to-an-exam-session**) and contact the exam sponsors if you have any questions. Note that before the exam session, you *must* create an online account through the FCC Commission Registration System (CORES) and be assigned an FCC Registration Number (FRN). You will need to bring your FRN to the exam session, whether it's for your first license or an upgrade. See the sidebar, "The FCC Universal Licensing System (ULS)," for more information.

Once you're signed in at (or logged on to) the exam session, you pay the test fee (check with the test session administrator) and get ready. Amateur radio tests usually take less than an hour. You will be given a question sheet and an answer sheet or presented with an online screen. As you answer each question, mark a box on the answer sheet or select your desired answer. Once you've answered all of the questions, the volunteer examiners will grade and verify your test results.

Assuming you've passed (congratulations!) you'll fill out a Certificate of Successful Completion of Examination (CSCE) and a NCVEC Form 605. The exam organizers will submit your results to the FCC while you keep the CSCE as evidence that you've passed your latest test. Licensed hams who already have a call sign and are upgrading may use their new privileges right away. If this is your first amateur exam, in a week to 10

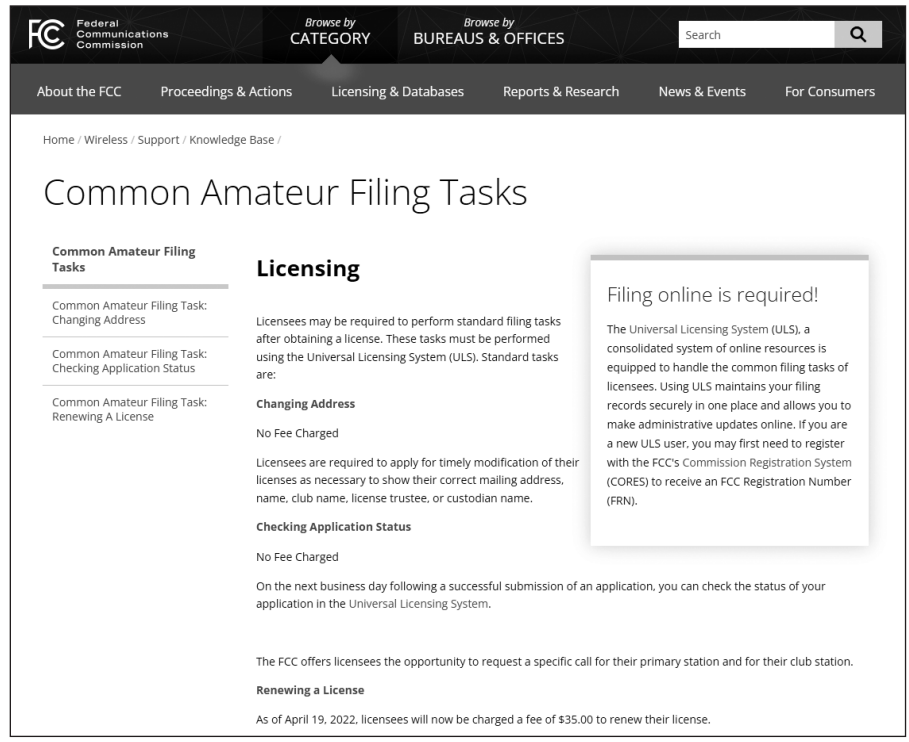


Figure 1.25 — The FCC website includes a Common Amateur Filing Tasks page to help licensees navigate the Universal Licensing System.

Operating from Other Countries

There are three basic types of agreements that allow amateurs licensed in one country to operate from the territory of another country.

• **European Conference of Postal and Telecommunications Administrations (CEPT) radio-amateur license** — allows US amateurs to travel to and operate from most European countries and their overseas territories without obtaining an additional license or permit. (This does not automatically confer permission to enter restricted areas. You must also carry with you a copy of FCC Public Notice DA 11-221.) Amateurs from countries that participate in CEPT may also operate in the US. The CEPT treaty does not automatically allow remote-control operation across international borders. Be sure you know the rules for transmitting in the host country!

• **International Amateur Radio Permit (IARP)** — For operation in certain countries of Central and South America, the IARP allows US amateurs to operate without seeking a special license or permit to enter and operate from that country.

• **ITU Reciprocal Permit** — a reciprocal agreement between the US and a country that does not participate in either CEPT or IARP agreements.

More information about obtaining permission to use your license elsewhere in the world is available online from **www.arrl.org/international-operating** or **www.arrl.org/us-amateurs-operating-overseas**.

days your name and new call sign will appear in the FCC's database of licensees and you can start transmitting. Although the FCC no longer routinely prints or mails license documents, you can print your own "official copy" from the FCC Universal Licensing System (ULS) site.

In 2022, the FCC introduced a $35 application fee that applies to new, renewal, rule waiver, and modification applications that request a new vanity call sign. The fee is per application and must be paid online directly to the FCC and not at your exam session. For details, see **www.arrl.org/fcc-application-fee**.

Once you have your license, you can operate from all 50 states, the District of Columbia, and all US territories. Your US amateur license is also recognized in many countries outside the US, although the specific requirements vary widely. See the sidebar "Operating from Other Countries."

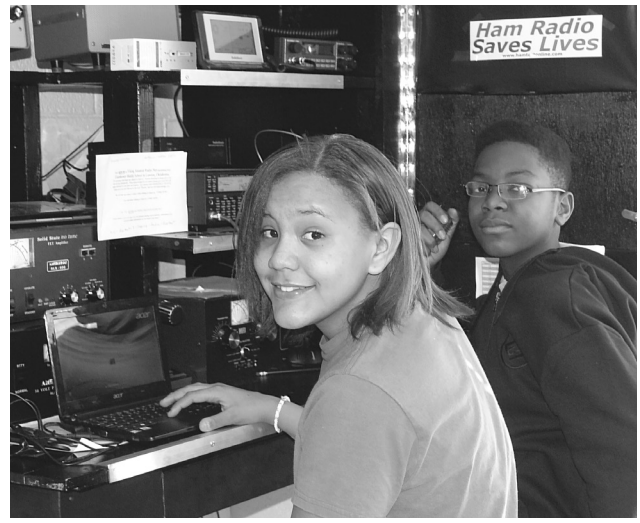


Figure 1.26 — At Eisenhower Middle School in Lawton, Oklahoma, Jada, KF5TAT (left) and Kerson, KF5TAQ sit at the Viking Radio Club station in the classroom of teacher Clifton Harper, KE5YZB. The school received a ham radio equipment grant through the ARRL Foundation. Harper also attended an ARRL Education & Technology Program Teacher's Institute on Wireless Technology at ARRL Headquarters. [Pamely Harper, KF5JXO, photo]

Figure 1.27 — Then-13-year-old Aidan helped his grandfather, Chuck Schneebeli, KI9A, during the 2018 ARRL November Sweepstakes, which attracts thousands of hams to the airwaves each fall.

1.3.3 Your Ham Radio Identity

A ham radio operator is known and recognized by a unique call sign (some hams shorten this to simply "call") that the FCC issues when granting your license. Your call sign not only identifies your station on the air, it's an individual ham radio identity, and many hams become better known by their call signs than by their names!

A call sign also identifies the issuing country. US call signs, for example, begin with W, K, N, or A. Canadian call signs usually start with VE or VA. See **www.arrl.org/international-call-sign-series** for a list of worldwide call sign allocations.

US call signs start with one or two letters, a numeral from 0 to 9, and up to three more letters. The first part of a call sign is called the *prefix*. The part following the numeral is called the *suffix* and is unique to a specific licensee. For example, one well-known ham radio call sign is W1AW, assigned to the Hiram Percy Maxim Memorial Station at ARRL Headquarters in Newington, Connecticut. "W1" is the prefix and "AW" is the suffix. At one time, the numeral indicated a US station's geographical region — 9 or Ø (zero) for the Midwest, for example — but that's no longer the case. So, a call sign with "9" may belong to a ham located in Florida.

The shortest call signs — known as 1×2 or 2×1— are reserved for Extra class hams, such as NØAX, or NN1N. Technician call signs are the longest — 2×3, such as KA1JPA. Details of how amateur call signs are allocated for the various license classes may be found online at **www.fcc.gov/wireless/bureau-divisions/mobility-division/amateur-radio-service/amateur-call-sign-systems**.

You don't have to keep the call sign the FCC assigns. The FCC's *vanity call sign* program permits a ham to select a new call sign from among the database of certain unassigned call signs, based on the applicant's license class, and to file an application for it along with the application fee. See **www.arrl.org/vanity-call-signs** for details.

1.4 Resources

1.4.1 ARRL Resources

ARRL—the National Association for Amateur Radio
225 Main St.
Newington, CT 06111-1494
860-594-0200
Fax: 860-594-0259
email: **hq@arrl.org**
www.arrl.org

Prospective hams call
1-800-32 NEW HAM (1-800-326-3942)

ARRL is the membership organization for US ham radio operators and those interested in ham radio. ARRL publishes study guides for all amateur radio license classes, a monthly journal (*QST*), and many books on amateur radio and electronics. ARRL also sponsors a variety of activities to encourage amateurs to get on the air and use their radios.

Amateur Radio Service Rules & Regulations — FCC Part 97
Available on the ARRL website:
www.arrl.org/part-97-amateur-radio

ARRL Technical Information Service
Member resource for technical problems:
www.arrl.org/technical-information-service
Technical pages on various topics:
www.arrl.org/radio-technology-topics

Interference and RF Safety
All about interference to and from amateur stations: **www.arrl.org/radio-frequency-interference-rfi**
All about RF safety:
www.arrl.org/rf-exposure

Licensing and Training
For those new to ham radio:
www.arrl.org/new-ham-resources
All about training opportunities:
www.arrl.org/licensing-education-training
All about license exams:
www.arrl.org/getting-licensed
ARRL Learning Center for skill development: **learn.arrl.org**

Local Contacts, Clubs, and Events
ARRL Field Organization:
www.arrl.org/sections
Find a club nearby:
www.arrl.org/find-a-club
Find a hamfest or convention:
www.arrl.org/hamfests-and-conventions-calendar

Publications
ARRL offers a wide variety of books, periodicals, electronic publications, maps, kits, and other products of interest to radio amateurs at all levels.
www.arrl.org/shop

Station Construction
Overview:
www.arrl.org/setting-up-a-station
Grounding, bonding, lightning protection, electrical safety: **www.arrl.org/safety**
Buying equipment:
www.arrl.org/buying-your-first-radio
New equipment reviews:
www.arrl.org/product-review
Antenna ideas:
www.arrl.org/building-simple-antennas

1.4.2 Other Organizations

AMSAT NA (The Radio Amateur Satellite Corporation)
Membership organization for those interested in amateur radio satellites.
www.amsat.org

Amateur Radio on the International Space Station, Inc (ARISS-USA)
Promotes amateur radio and science, technology, engineering, arts, and math within educational organizations; arranges ham radio contacts with ISS crew members for schools and educational organizations.
www.ariss-usa.org

Courage Kenny Handiham Program
Provides assistance to persons with disabilities who want to earn a ham radio license or set up a station.
handiham.org