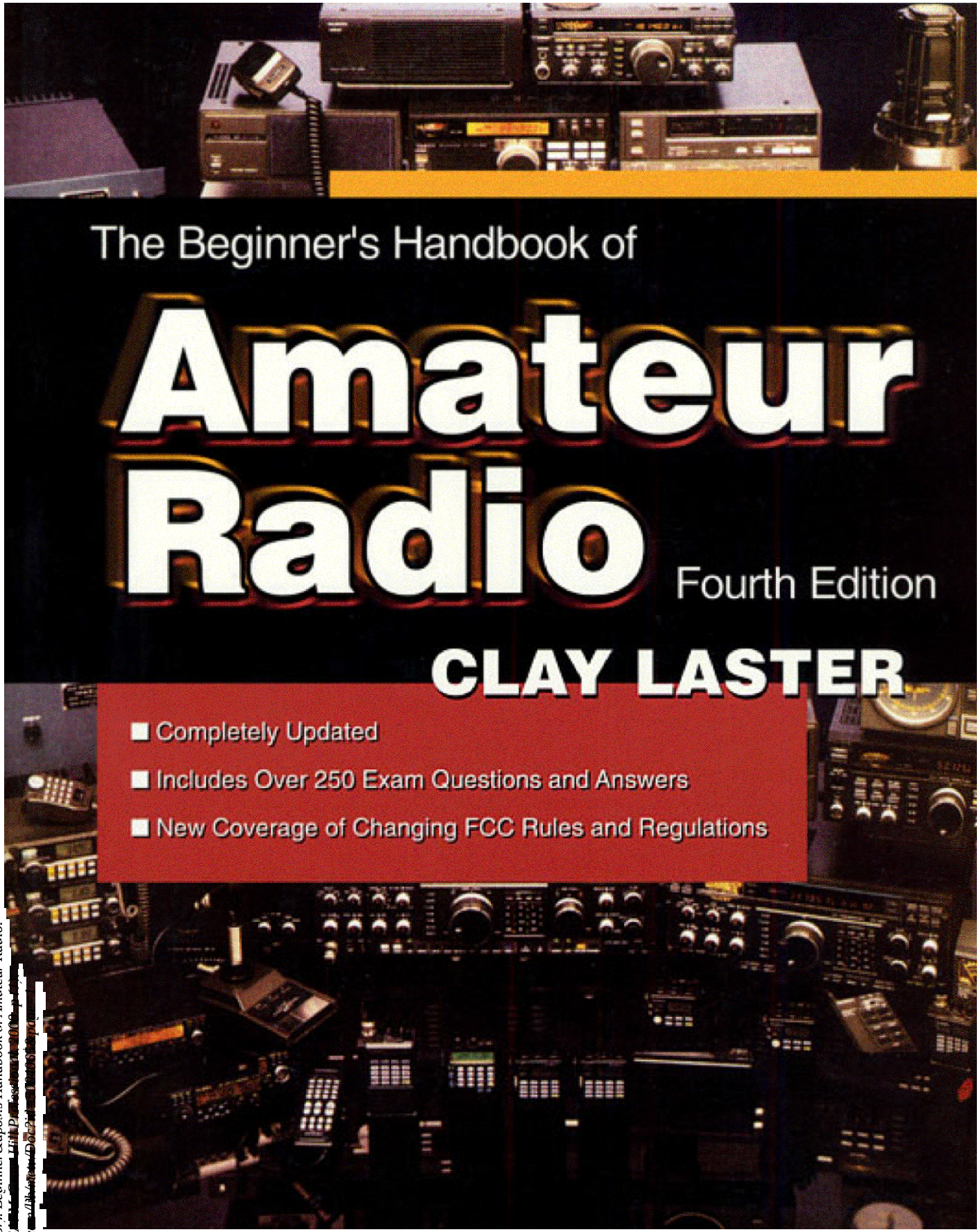


# THE BEGINNER'S HANDBOOK OF AMATEUR RADIO

*This page intentionally left blank.*

# THE BEGINNER'S HANDBOOK OF AMATEUR RADIO

**Clay Laster, W5ZPV**

**FOURTH EDITION**

**McGraw-Hill**

New York San Francisco Washington, D.C. Auckland Bogotá
Caracas Lisbon London Madrid Mexico City Milan
Montreal New Delhi San Juan Singapore
Sydney Tokyo Toronto

*McGraw-Hill*

*A Division of The McGraw-Hill Companies*



0-07-139550-4

The material in this eBook also appears in the print version of this title: 0-07-136187-1.



## TERMS OF USE



DOI: 10.1036/0071395504

# CONTENTS

*This page intentionally left blank.*

# PREFACE

Welcome to the world of amateur radio! We (the term "we" applies not only to myself, but to all the pioneering hams who helped to make amateur radio available to everyone) prepared this book with two major objectives in mind. First, we want to introduce you to the exciting world of amateur radio, one of the most interesting and challenging hobbies available today. Once you're hooked, our second objective is help prepare you for the FCC Technician Class license examinations, including both theory and Morse code. There is also another important objective: enticing the many dedicated electronics and computer experimenters, technicians, engineers, and serious CB enthusiasts throughout the country to join the ranks of amateur radio operators.

In no other hobby can one find such a diversity of individual and group endeavors involving scientific study and experimentation. The fields of amateur radio range from basic electronics, voice and data communications on a local and world-wide basis, and space and satellite communications to public service (especially during emergencies) and close camaraderie or friendships that last a lifetime. Truly, amateur radio is one of the largest fraternities in the world, open to persons of all ages and nationalities. The No-Code Technician Class license—yes, at last an amateur radio license with no Morse code examination—makes it easy for you to become a ham operator in a minimum of time. Then to earn hf Morse code and single-sideband voice privileges in selected hf bands, you need only to pass a 5 words-per-minute Morse code test. We'll show you how to study for and pass both the Technician written examination and the Morse code test.

This book is designed for either self-study or group use in Technician Class code and theory classes. The only additional material needed is a source of Morse code practice signals (cassettes or CDs) and a telegraph key/code oscillator for generating Morse code signals. Also, excellent PC

and other home computer educational programs for both Morse code and theory instruction are available.

Chapters 1 and 2 provide an introduction to amateur radio, the FCC Part 97 Rules and Regulations for amateur radio, and how to prepare for and take the Technician Class license code and theory examinations. Chapters 3 through 10 form the basis for a "mini-course" in electronics technology, with emphasis on radio communications. Chapter 11 provides specific and technical information on amateur radio operating procedures, rf radiation safety requirements, and advanced amateur radio communications systems involving single sideband, frequency modulation, repeaters, digital and packet communications, and space and satellite communications. The appendices contain the FCC Technician question pool, as well as answers for each question. Sounds easy, doesn't it? All it takes on your part is a concentrated study effort to prepare for and pass the FCC license examinations.

We suggest that you review this book, chapter by chapter, before starting a detailed study of the course material. This will give you an overall perspective on amateur radio and help you develop a study schedule. Finally, review the question pool in Appendix A. One proven study technique is to write each FCC question on a 3-inch reference card, and your answer on the back. Check your answer against the correct answer given in the appendix. The writing of the questions and digging out the correct answers is part of the learning process. As you write each question on the card, you also help to write the question in your memory. To complete this process, review the set of cards until you learn the correct answers to all questions for each required license class examination. Remember, passing the Morse code examination requires a code speed proficiency of at least five words per minute. Build up this code speed before the end of your studies. With these factors in mind, you can develop a realistic schedule for preparing for the FCC Technician code and theory examinations.

One final recommendation: contact the local amateur radio club or a neighborhood ham and make arrangements for a volunteer examiner (VE) to administer the FCC Technician Class license examinations. Finding a ham in the neighborhood is easy—just check with the local radio club or the volunteer examiner before taking the examinations. Good luck!

*Clay Laster*

# INTRODUCTION

Do you want to learn all about amateur radio? How to prepare for the FCC license examinations, all about radio communications and electronics principles, how personal computers can be used to enhance the learning, as well as the operation, of amateur radio comunications, how to assemble and operate an amateur radio "ham" station? This is one of the most comprehensive books for the beginner in amateur radio. It combines theory and practice in a clear and easy-to-understand manner. The many illustrations and photographs make learning all about amateur radio easy and exciting. The book contains complete information on how to study for the Technician Class license examinations and includes *all* of the FCC test questions and answers.

A variety of construction projects, transmitters, receivers, and other electronic equipment are examined to give the beginner practical experience in designing and building amateur radio projects. The book also provides parts and source information for radio components, equipment, and antennas, all typical of current-day technology. This book is unique in that technical information concerning vacuum tubes and associated circuits are covered. Why are these obsolete devices covered in a modern book? Many excellent vacuum-tube amateur receivers, transmitters, and transceivers are to be found at ham swapfests and conventions. Also, many kilowatt final power amplifiers for amateur hf service are marketed by amateur suppliers today.

Anyone interested in amateur radio—student, electronics or CB enthusiast, personal computer buff, doctor, lawyer, or engineer—will want to explore this worldwide hobby. This book offers you the opportunity to get in on the ground floor of amateur radio.

*This page intentionally left blank.*

# ACKNOWLEDGMENTS

The author is grateful for the cooperation and assistance extended by individuals, companies, and amateur organizations during the preparation of this book. Space does not permit listing these entities here. However, an attempt is made to acknowledge these many contributions as each particular item—circuit, device, or equipment—is covered. This approach also provides the beginner in amateur radio with specific information and source(s) concerning amateur parts and equipment.

Many thanks are due the author's wife, Irma, who provided invaluable assistance and encouragement during the preparation of the manuscript. Finally, the publisher's cooperation and patience for extending the deadline, as well as superb technical expertise in publishing this book, is greatly appreciated.

*This page intentionally left blank.*

CHAPTER 1

# Introduction to Amateur Radio

Have you ever listened to an AM or FM radio receiver and wondered how radio waves travel through space? Have you gazed at a television set and asked how pictures generated on the other side of the earth can be transmitted to your TV receiver? Have you operated a citizens band radio and wanted to extend your range of communications worldwide? If you answered yes to any of these questions, you may be on the road to amateur radio, an exciting and rewarding hobby extending into almost every phase of electronics. Just pass the required Federal Communications Commission (FCC) exams given by authorized amateur radio operators in your neighborhood and you're ready to become an amateur operator (or "ham") yourself.

## Who Can Become a Ham Radio Operator?

Anyone, regardless of age, is eligible to become a ham radio operator in the United States. Persons from less than 10 years to over 80 years of age have become hams.

Many disabled individuals have entered the ranks of amateur radio. Operators can apply for special testing provisions if they have physical disabilities. Learning materials are available on video or audio tape or in books to assist in the learning processes. After becoming an amateur radio operator, the ham has many radio equipment

options. Many modern amateur radios (receivers, transmitters, etc.) provide voice outputs and can be controlled by computers using voice commands. Organizations such as the Courage HANDIHAM System (see Chap. 2) provide a wide variety of services to aid those with disabilities.

Aliens, except representatives of foreign governments, are encouraged to apply for a U.S. ham license if they plan to be in the country for an extended period of time. We'll tell you how to prepare and apply for your ham license in Chap. 2.

## New Avenues into Amateur Radio

The FCC No-Code Technician License will allow you to enter the ranks of amateur radio and get on the air with a minimum of effort. Yes, that's right—you can skip the Morse code tests and pass a written test for the new No-Code Tech class license. This license allows you to operate on all amateur bands above 50 megahertz (MHz), including the popular 6-meter and 2-meter bands with exciting local repeater and packet radio operation, 440 MHz for amateur television, satellite and long-range "radio link" operation, and advanced microwave systems.

In case the megahertz and meter terms confuse you, just remember that they refer to the bands of frequency for amateur operation. You probably already know that the AM broadcast band covers 540 to 1650 kilohertz (kHz) and the FM broadcast band covers 88 to 108 MHz. However, we'll explain the meaning of these and other terms later. The important thing is that you can talk to other hams, using single sideband (SSB), frequency modulation (FM), or packet radio modes of operation. Then later, if you want to get on some of the amateur radio high-frequency bands (i.e., below 50 MHz) for direct long-distance voice or Morse code contacts, you can pass an easy five words per minute (WPM) Morse code test to qualify for the Technician Class license. Finally, you can earn even more amateur operating privileges by passing General and Extra Class license tests. Remember, you can take any of these tests from qualified hams in your area at a time convenient to you and the ham volunteer examiner.

## About Amateur Radio

We live in a world of fantastic technological developments that affect almost every phase of our daily lives. Space exploration, high-speed

jet aircraft, and advanced developments in medicine, digital computers, and worldwide electronic communications are but a few of these achievements. Amateur radio offers a challenging entry into exploring much of the technology involved in many of these fields. Amateur radio operators have made many significant contributions to radio communications and electronics technology. In fact, many scientists, engineers, and even astronauts pursue amateur radio as a rewarding hobby. Many of NASA's space shuttle craft flights include Shuttle Amateur Radio Experiment (SAREX) contacts with amateur radio operators.

There are many fascinating aspects to amateur radio—talking to fellow hams, participating in emergency communications during disasters, studying electronics technology, or building ham gear and antennas using state-of-the-art electronic components. Many hams use amateur radio as a steppingstone to a rewarding career in electronics.

But wait—this marvelous technology is only about 100 years old. Before we get into the details of amateur radio and how to pass the FCC exam for an amateur radio license, let's look into the fascinating history of amateur radio.

## A History of Amateur Radio

A history of amateur radio would not be complete without acknowledging some of the early discoveries in the field of electricity and magnetism. From the dawn of history, man has been fascinated by the effects of electricity and magnetism produced by nature such as lightning, static electricity, and magnets.

### Early pioneers

One of the first major scientific breakthroughs was made by Michael Faraday, an English physicist and the son of a blacksmith, in the early nineteenth century. Although he made many discoveries in several scientific fields, Faraday's major achievement was the discovery of electromagnetic induction and the formulation of the laws of induction. Today we know this as the process where electrons move in a conductor when the conductor is moved through a magnetic field. This discovery led to the development of the electric generator and motor.

In 1873 James Clerk Maxwell, a Scottish physicist-astronomer, mathematically proved the existence of electromagnetic (or radio) waves traveling at the speed of light. Now the stage was set to prove the existence of radio waves in the laboratory.

About 15 years after Maxwell's investigation (and 5 years after his death), Heinrich Hertz, a German physicist, demonstrated that radio waves could be generated and transmitted over short distances of up to about 60 feet (or about 20 meters). With his crude laboratory apparatus, Hertz was able to measure the wavelength of the waves he generated and show that these waves could be reflected, refracted, and polarized just as light waves are. Working in the 150-MHz-and-above radio spectrum, he designed and built spark-gap transmitters, resonator circuits for receiving radio waves, and directional antennas. As you will see later, 1 MHz is the expression of radio frequency for 1 million Hertz, or 1 million cycles per second. This frequency of 150 MHz is just above the amateur 2-meter band at 144–148 MHz.

In the early 1890s Guglielmo Marconi, an Italian inventor, began to experiment with radio waves using equipment similar to that developed by Hertz and other scientists of the era (Fig. 1.1). Marconi made many improvements and inventions that resulted in extending the range of radio transmissions. He conceived the concept of a vertical radiating antenna, and the Marconi (or vertical) antenna is one of his major accomplishments.

Marconi's first crude equipment was capable of a range of about one-half mile (about 800 meters). In 1896 he moved from Bologna, Italy, to England, where he made substantial improvements that increased the operating range of his equipment to about 4 miles (about 6.5 kilometers). By 1898, he succeeded in transmitting "wireless" signals across the English Channel. A major milestone was reached in 1901 when Marconi and his English associates transmitted radio waves across the Atlantic Ocean from Poldu, England, to Halifax, Newfoundland. Thus born, long-range radio communications would have an impact upon the lives of all people regardless of nationality or position in life.

The first major use of the new wireless telegraph sets was to provide for maritime communications. By 1905, spark-gap transmitters and coherer detector receivers were installed on many of the merchant ships and naval vessels on the high seas. For the first time, instant

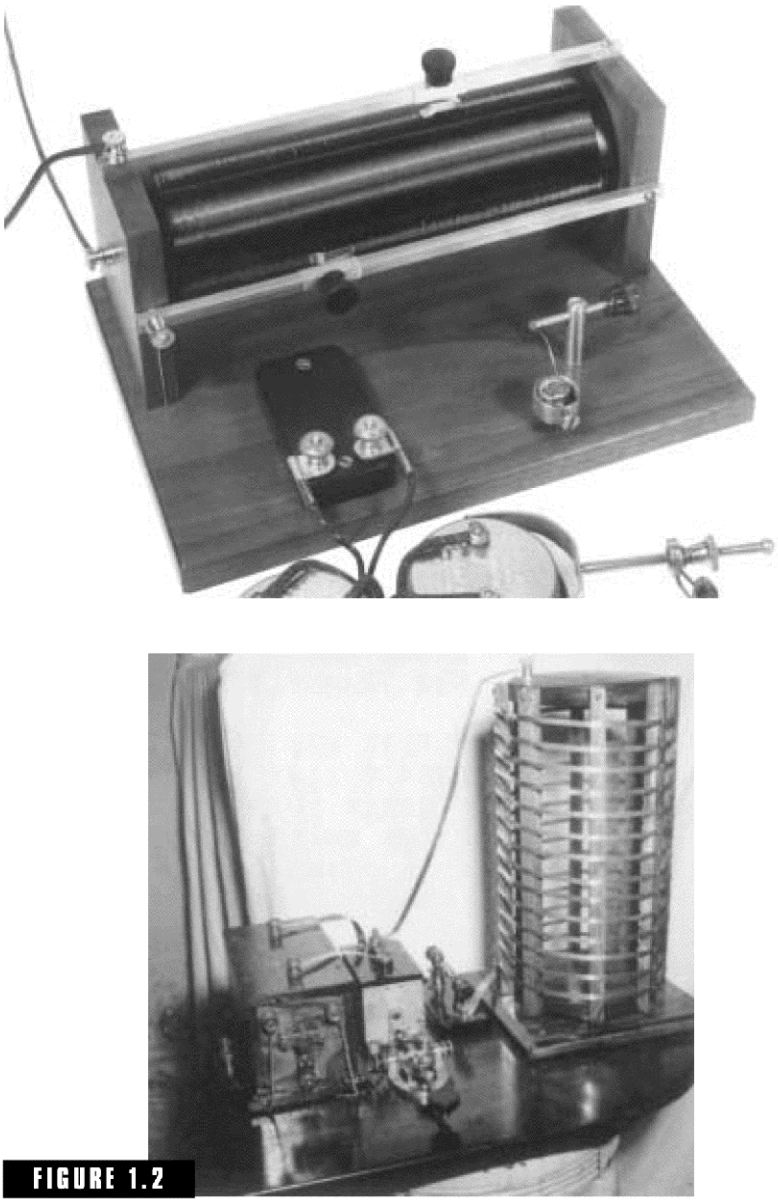
FIGURE 1.1

**Guglielmo Marconi with one of his early wireless sets. This photograph, taken in 1902, illustrates the induction spark coil transmitter (*right*), the "grasshopper" handkey (*center*), and the receiving apparatus (*left*).**

communications between remote ships and land-based communications centers were feasible. All of this was accomplished without the use of vacuum tubes or transistors—they would be invented later to provide for amplification of the weak radio signals intercepted by the antennas.

## Beginning of amateur radio

The introduction of commercial wireless telegraph equipment after the turn of the century aroused the imagination and interest of people around the world. Some experimenters were content to build simple crystal detector receivers and monitor the raspy code signals transmitted from fixed or rotary spark transmitters at marine or government communications stations. Other experimenters, particularly the restless and aggressive youngsters, assembled spark-gap transmitters, as well as crystal detector receivers, and began sending "dots and dashes" between home separated by a few miles (Fig. 1.2). The range of these early "amateur" stations was increased by continual improvements in equipment and higher power output. Amateur wireless organizations



A

B

**FIGURE 1.2**

**Early amateur radio wireless equipment. (*a*) Early crystal receiver using a 2-side antenna tuning inductor, "Cat Whisper" detector, phone blocking capacitor, and headphones. (*b*) 1914 spark-gap transmitter, employing a vibrator-type spark coil, Dubilier fixed capacitor, Bunnel telegraph key (*in front*), Murdock straight spark gap, and homemade helix coil. These are representative of amateur radios used around 1914. Under favorable conditions, the transmitter could be heard for distances up to about 30 miles.**

were formed across the country, beginning with the Junior Wireless Club of New York in January 1909. Amateur radio had come of age!

During radio's infancy, no government rules or regulations were in effect to govern the use of wireless operations. Wavelengths, or operating frequencies, in the vicinity of 300 to 1000 meters were selected by the users on the basis of available equipment. The inevitable conflict between commercial and amateur users abruptly surfaced when interference from amateur transmissions threatened the reliability of commercial radio communications. The U.S. Navy, which was quickly developing radio communications facilities, addressed some of the administrative problems and began issuing "certificates of skill in radio communications" in lieu of licenses. By late 1910, the Navy had issued some 500 of these certificates, many to amateur operators.

By this time, the number of individuals interested in or participating in amateur radio had grown to an estimated 10,000 or more. Amateur transmitters with power outputs of several kilowatts could be heard up to 400 miles (about 650 kilometers) away. However, most amateurs could not afford such luxury and had to be content with ranges of about 5 miles (8 kilometers), with occasional contacts up to 100 miles (160 kilometers). Many wireless equipment stores had appeared by this time, selling crystal detectors, spark-gaps, induction coils, and tuners—the basic ingredients of wireless stations.

## First licenses for amateur radio operators

Beginning in 1902, the U.S. Congress recognized the need for regulating the use of wireless operation. However, it was not until 1910 that the first bill (the Act of June 24, 1910) was passed. This bill required the mandatory use of wireless equipment on certain ocean steamers and did not apply to amateur radio. Some bills were introduced in the Congress that would have given all authority for radio communications to the government. If passed, any of these bills would have abolished amateur radio. Fortunately, these bills were defeated and amateur experimentation increased at a rapid rate.

Finally in 1912, Congress passed an all-encompassing bill covering all phases of radio communications in the United States. Amateur operation was restricted to wavelengths below 200 meters and maximum power levels of 1 kilowatt. The lawmakers believed that

wavelengths below 200 meters were useless and that this restriction would eventually eliminate the troublesome amateur radio society.

This action by the government proved to be a gold mine for the amateur operators. Refinements in electronics technology and the introduction of the new deForest vacuum tube allowed the amateurs to build short-wave equipment capable of spanning distances of hundreds of miles with low power. Radio clubs were established in all parts of the country. Amateurs began to send personal messages for other individuals to distant cities and remote locations. Emergency communications during periods of disasters were now emerging as a major contribution by the amateurs.

By 1914, the American Radio Relay League (ARRL) was formed to promote the concept of national relaying of amateur traffic across the country. Through the dynamic leadership of Hiram Percy Maxim, the ARRL grew to become the largest amateur radio organization in the United States. By late 1914, efficient relay networks were organized over most of the eastern United States and many stations were dedicated to handling traffic as a public service. By 1915, the ARRL introduced *QST,* a radio amateur journal devoted solely to the pursuits of amateur radio. Today, the ARRL membership includes over 120,000 in North America and some 12,000 foreign and unlicensed associate members. You'll want to consider joining the ARRL to support amateur radio and to receive the monthly *QST.* This magazine features construction articles, technical information, news concerning amateurs and amateur meetings, etc. For more information, you can contact the American Radio Relay League at ARRL, 225 Main Street, Newington, CT 06111-1494; telephone: (860) 594-0200; or on the World Wide Web at: *http://www.arrl.org/.*

## The death knell for amateur radio

All amateur radio operations were suspended when the United States entered World War I in 1917. The government order suspending all forms of amateur radio required that the aerial wires be lowered to the ground and all radio apparatus for transmitting and receiving be disconnected from the antennas and rendered inoperative.

The U.S. military forces were faced, at the beginning of the war, with virtually no radio operators, instructors, or technical specialists. The ARRL assisted the government in locating volunteers

among the amateur ranks to meet immediate needs in the military. In addition, some of the equipment from the more elaborate amateur stations was released to the government for use by the military. Altogether, an estimated 3500 to 4000 amateur radio operators served in the U.S. Armed Forces, contributing their knowledge and expertise in radio communications to the war effort. When the armistice ending World War I was signed in November 1918, the amateurs were impatient to resume operation. However, the U.S. Congress was considering legislation that would eliminate all forms of amateur radio activity. This legislation would have granted control of all forms of radio communications to the Navy Department. Fortunately, amateur operators, led by ARRL President Maxim, descended upon Congress and mounted sufficient opposition to defeat the proposed bill. Control and regulation of radio communications was left to the Commerce Department. The wartime ban on amateur radio activity was finally lifted on November 1, 1919.

After 2 1/2 years of silence, the amateurs were finally permitted to resume operation. There was a rush to obtain licenses and get back on the air. Some of the amateurs dusted off their old spark-gap transmitters and crystal-detector receivers for immediate operation. Others began to adapt to the new vacuum tubes for both transmitter and receiver use. Radio parts houses sprang up in all major urban areas and mail-order firms began to advertise regularly in the few available radio publications, such as *QST.*

## The golden age of amateur radio

Beginning in the late 1920s, amateur radio experienced phenomenal growth in the numbers of operators and in radio communications technology. This growth continued until the United States entered World War II in 1941 and the amateurs were forced to cease operation for the duration of the war. During this period, the number of amateurs had increased from almost 17,000 in 1929 to over 54,000 in 1941.

The typical ham of the 1930s was a young high-school or trade-school graduate with little or no extra money with which to buy radio equipment. Fortunately, the coming of age of the commercial radio broadcasting field brought a bonanza of radio parts that could be adapted to amateur radio uses. Used AM broadcast receiving tubes were readily available at little cost for the amateur-built receivers and

transmitters. The typical amateur transmitter consisted of a single-tube oscillator circuit. The power output of this simple rig varied from about 1 to 2 watts, depending on the power supply and the type of tube. A two-tube receiver with a regenerative detector and audio amplifier was used by most amateurs in the early 1930s. Dry-cell batteries or a junk-box "battery-eliminator" power supply normally served to power the transmitter and receiver. Today, you can build and use simple short-wave receivers and QRP (low-power) transmitters for contacts with other hams over distances of thousands of miles (Fig. 1.3). These easy-to-build radios are described in Chaps. 8 and 9.

This period of amateur radio saw many important technological advances. In fact, most of the techniques and tools used by the modern amateur were developed and tested during this time period. These developments included the superheterodyne receiver, single-sideband

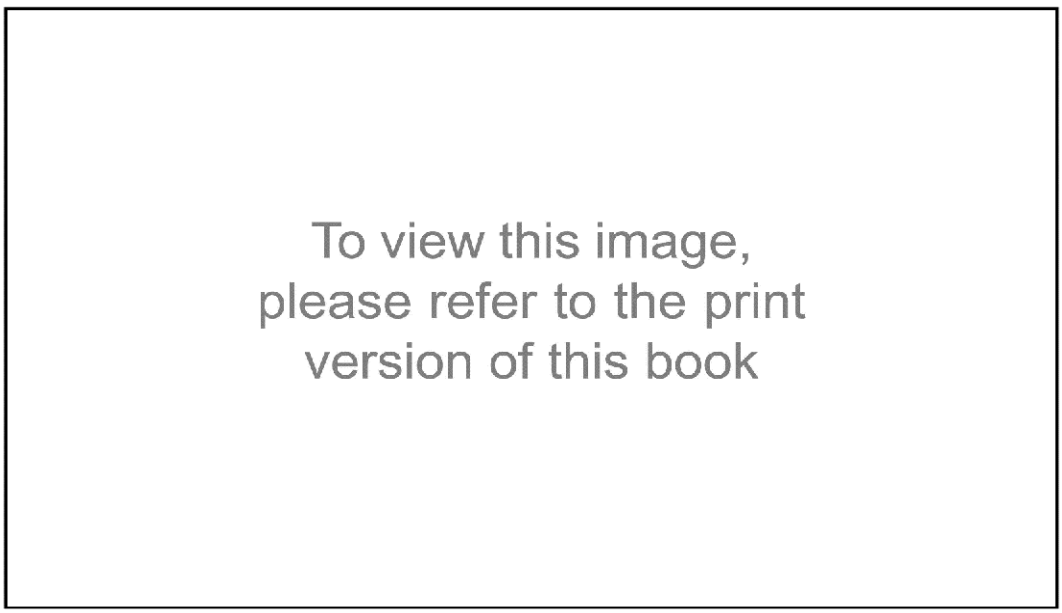



**FIGURE 1.3**

**The MFJ enterprised low-power CW "QRP" 20-meter amateur radio station. (*a*) The MFJ-0120 20-meter transceiver, MFJ-971 antenna tuner and MFJ-4114 power pack. (*b*) The MFJ-1772-20 meter folded dipole antenna for fixed or portable operation. This compact ham station is capable of 4 watts output for virtually worldwide contacts. Other similar MFJ transceivers and antennas are available for 40-, 30-, and 17-, and 15-meter operations.** [*MFJ Enterprises, Inc., Box 494, Mississippi State, MS 39762, Telephone (601) 323-5869*]

modulation, frequency modulation, high-gain beam antennas, and vhf communications techniques. Amateur experimentation ranged from improving simple transmitters and receivers to pioneering developments in radio astronomy.

The old raspy sounds of the spark-gap transmitters had been replaced by the clear, crisp signals of continuous-wave (cw) transmitters and voice-modulated rigs. Amateur radio had become a permanent part of the American way of life.

## Amateur Radio—A Scientific Hobby

Amateur radio today is a highly specialized hobby involving almost all phases of electronics. There are about 500,000 ham radio operators in the United States. Worldwide, there are some 700,000 amateurs, and almost all countries authorize some form of amateur radio. Hams come from all walks of life: for example, students, salesmen, plumbers, doctors, lawyers, engineers, seamen, and the handicapped.

The FCC, which administers and regulates all radio activity in the United States, defines the Amateur Radio Service as one of self-training, intercommunication, and technical investigation carried on by amateur radio operators.

The great appeal of amateur radio is centered on the incredible ability to communicate person-to-person worldwide and a fascination with the marvels of electronics. Hams constantly keep abreast of technical advances in electronics, and in some cases it is the ham who pioneers the development of some phase of radio or electronics.

Amateur radio activity today ranges from high-frequency (80 to 100 meters) communications [involving cw, single-sideband voice, data (computer-to-computer and teletypewriter), and slow-scan television] to amateur communications satellites operating on frequencies from 28 MHz to 435 MHz and microwave frequencies (Figs. 1.4 and 1.5). Another space-age development is that of moon-bounce communications using the moon as a passive reflector for communications signals in the 144-MHz to 2450-MHz frequency bands. A recent development in the electronics field—digital microelectronics—is being adapted to amateur radio with increasing applications. The integrated-circuit (IC) chips containing logic gates, flip-flops, and even a complete "computer-on-a-chip" or digital processor, are

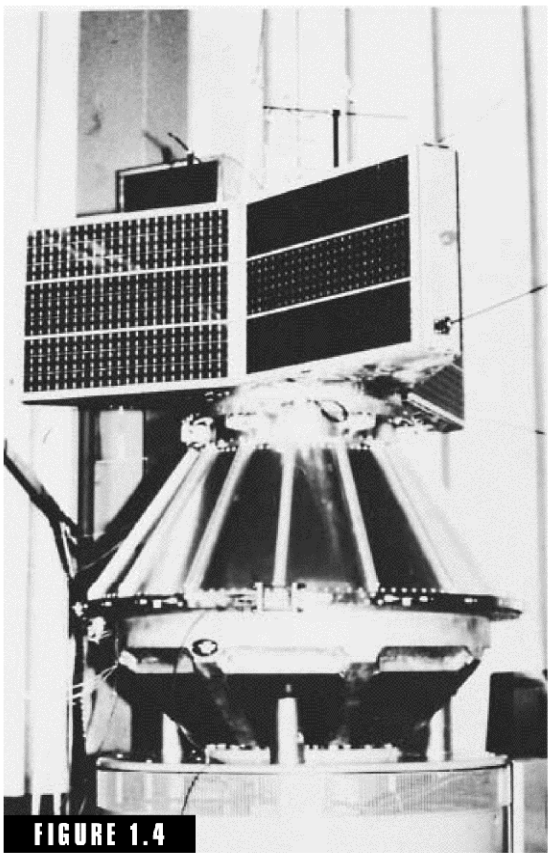


FIGURE 1.4

**The OSCAR 10 radio communications satellite. One of a series of amateur satellites, OSCAR 10 was launched in June 1983. Amateurs on a worldwide basis are able to extend their communications using these satellites. Additional information can be obtained from AMSAT-NA, 850 Sligo Avenue, Silver Spring, MD 20910-4703; telephone: (301) 589-6062.**

available to hams at bargain-basement prices. A typical IC chip—containing up to a hundred or more transistors, diodes, and resistors and forming many digital circuits—will cost the ham a mere $0.50 to several dollars each. Hams have adapted these chips to digital circuits ranging from electronic keyers to Morse code translators. Many ham "shacks" include a personal computer (PC) for maintaining station log records, propagation analysis, packet radio, locations of amateur satellites, and even automatic tracking of the station antennas for satellite communications. By the way, don't be alarmed by the subjects mentioned above—we'll cover all of them in this book.

Another exciting aspect of microelectronic circuits is the operational amplifier (op-amp) and related types of "analog" IC chips. The availability of the op-amp has allowed the amateur to design and build active filters for cw (Morse code) applications with bandwidths of less than 100 Hz. Other linear-circuit ICs containing many transistors are used as basic building blocks for receivers, modulators, and low-power transmitters. We will examine some of these devices in subsequent chapters and show you how you can build a complete ham station with a minimum of cost and effort.

## Amateur Radio Public Service

One of the most important aspects of amateur radio is that of public service. The FCC states that one justification for the Amateur Radio Service is the recognition and enhancement of the value of the amateur service to the public as a voluntary noncommercial communi-

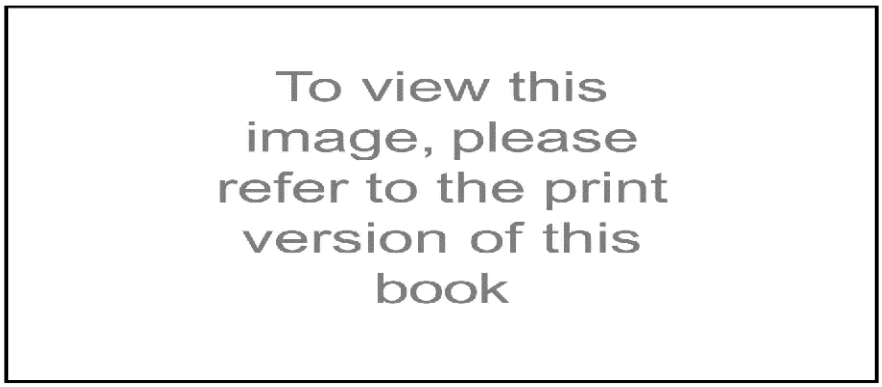



**FIGURE 1.5**

**The Kenwood TS-50S/60S hf transceiver with 6-meter capability. The TS-50S/60 is one of the smallest and hottest hf mobile radios available today. Featuring most of the capabilities of the "big brother" hf radios, this compact mobile rig provides 100 watts power output, 100 memory channels, dual VFOs, split operation and a power menu system.** [*Kenwood Communications Corporation, Amateur Radio Products, P.O. Box 22745, 2201 E. Dominguez St., Long Beach, CA 90801-5745; telephone: (310) 639-5300; Internet address: http://www.kenwood.net/.*]

cations service, particularly with respect to providing emergency communications.

One of the first disasters for which amateurs provided emergency communications was the heavy sleet storm that hit western and northern New York State in December 1929. The storm tore down telephone and power lines and isolated many cities in the area. Hams assisted telephone and power companies and the railroads in establishing emergency communications.

Since that time, hams have been instrumental in establishing emergency communications during natural disasters such as floods, earthquakes, fires, storms, explosions, train wrecks, and plane crashes. Although space does not permit a complete summary of these activities, some of the major disasters during which hams provided emergency communications were Hurricane Carla in Texas (September 1961), Hurricane Hugo in the Caribbean and Puerto Rico (September 1989), and the Loma Prieta earthquake (October 1989).

In addition to major disasters, hams have continually been in the forefront in providing communications in the event of personal

emergencies such as a lost child, an automobile accident, or participation in an eye transplant bank.

Hams are organized in almost all communities to provide communications service to the public. Each year, hams participate in Field Day exercises during which they set up simulated emergency field communications centers powered by portable gasoline or diesel generators (Fig. 1.6). In addition to Field Day, hams across the country practice sending emergency traffic on Simulated Emergency Traffic (SET) Day.

The radio amateur's contribution to the country during war has been outstanding. In World War I, some 4000 hams served in the Armed Forces. Again in World War II, more than 24,000 hams served in the Army, Air Force, Navy, Coast Guard, and Marine Corps, contributing their skills and talent to the war effort. Countless numbers of other hams were engaged in electronics research and manufacturing activities supporting the war effort. During the Korean and Vietnam

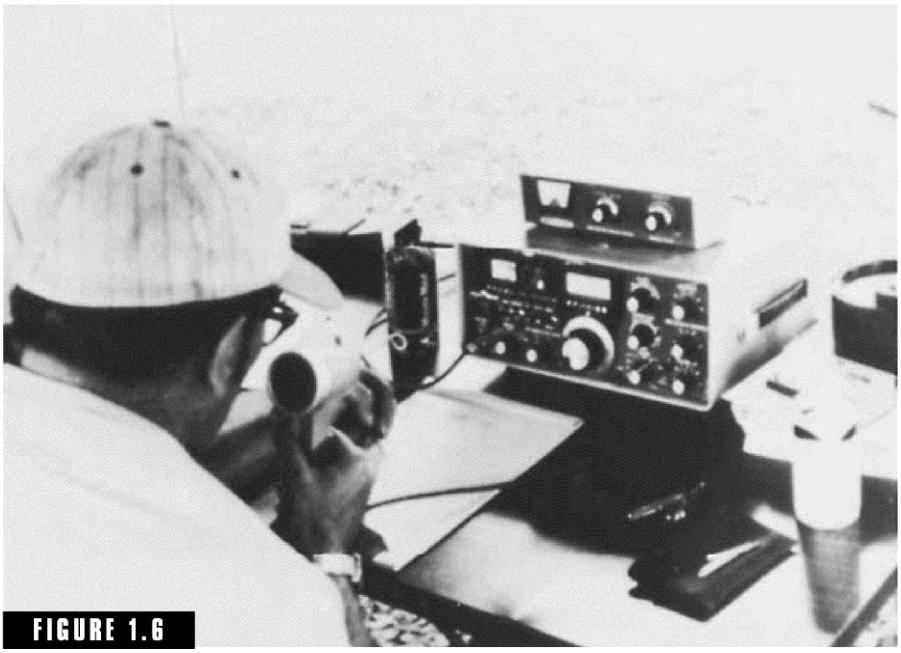


**FIGURE 1.6**

**Typical amateur Field Day activity. Hams across the country participate in Field Day, held each year during the summer. The purpose is to develop and test emergency communications techniques for disasters such as floods, storms, or power blackouts.**

conflicts, amateurs relayed many messages from service personnel overseas to their families and friends in the States. These traffic nets handled personal messages via relay stations located mostly on the West Coast. In many cases, the service personnel were able to talk directly to their loved ones in the United States using telephone patches established by the amateurs.

Another important area of public service by the amateur is in providing communications for expeditions to remote areas such as the Arctic and Antarctic. In 1923, Con Mix, 1TS (early call signs did not have a W, K, A, or N prefix) accompanied MacMillan to the Arctic aboard the schooner *Bowdoin.* Hams in Canada and the United States provided home contacts for the explorers. Since that time, amateurs have assisted some 200 expeditions. At present, amateurs provide much of the personal communications for the personnel at the Antarctic research stations.

## The Path into Amateur Radio—The Technician Class License

Prior to April 15, 2000, the beginner in amateur radio could select the Novice Class, Technician (Tech-Plus) Class, or the No-Code Technician Class License. Today, the entry-level license is the Technician Class, which requires only a 35-question written examination. The operating privileges for the Technician cover all amateur bands above 50 MHz. This includes the 6-meter band (50–54 MHz), the 2-meter band (144–148 MHz), and the 70-cm band (420–450 MHz). Additional hf operating frequencies are available when the Technician Class amateur operator passes the 5-WPM Morse code test. Tables 1.1 and 1.2 present the key information on these Technician operating bands.

With this preliminary background, let's get started on the basics of amateur radio. We want you to learn the theory of ham radio as well as a good proficiency in Morse code as soon as possible. In this way, you can schedule and pass the Technician examination in a minimum of time. Good luck and good contacts!

**TABLE 1.1** Technician Operating Bands, Privileges, and Normal Communications Capability

| Operating Band | Frequencies and Operating Privileges | Communications Capability |
|---|---|---|
| 6 meters | 50–54 MHz: Morse code (cw), single sideband voice (SSB), frequency modulation voice (SSB), radio printer (RTTY), FM repeaters, radio control (RC), experimental modes and signal beacons | This band features almost all modes of propagation as it is situated between the hf and vhf frequency bands. During times of high sunspot activity, daytime contacts of up to 3200 km (2000 miles) are possible via skywave propagation. Routine contacts of up to 500 km (300 miles) are possible with high-power transmitters and high-gain antennas. Sporadic E-layer propagation is a favorite of 6-meter hams, providing short band openings at distances of up to about 3000 km (1200 miles). |
| 2 meters | 144–148 MHz: Most of the above privileges plus: amateur satellite operation, earth-moon-earth (EME or "moon bounce"), packet (digital) radio | Most hams use the 2-meter band for local repeater operation. Most metropolitan areas will have literally dozens of 2-meter repeaters. The higher frequencies permit smaller antennas and inexpensive repeater equipment. The 2-meter mobile for automobiles (and even airplanes and boats) and hand-held (HT, or walkie-talkies) permit new hams to get on the air with a minimum of equipment and small, inexpensive antennas. Some hams do build elaborate 2-meter stations that can provide long-range contacts of up to about 2000 km (1200 miles) via sporadic E-layer propagation and tropospheric ducting. Finally, the "line of sight" propagation mode of 2-meter frequency signals is used extensively in amateur ratio satellite and earth-moon-earth (EME) operations. |

| | | |
|---|---|---|
| 135 centimeters | 222–225 MHz: Same privileges as 2-meter band above | Propagation modes via the 135-centimeter band are simi lar to those via the above 2-meter band. |
| 70 centimeters | 420–450 MHz: Most of the above privileges plus: amateur television (ATV) | As with 2 meters, the 70-centimeter band is very popular for amateur radio repeater, satellite, and EME operation. The small size of 70-centimeter radios and antennas permits installation of 70-centimeter radios almost anywhere. More elaborate 70-centimeter stations can also permit long-range contacts between "earth-bound" hams over distance of up to about 2000 km (1200 miles). Propagation in these cases includes ionospheric modes and meteor scatter. |
| 35 centimeters | 902–928 MHz: Most of above privileges plus: digital communications and wideband ATV | The 35-centimeter and 23-centimeter bands represent the amateur's entry into the microwave frequencies. Here, the assembly and construction of ham microwave equipment are much different than those in the lower frequency bands. A short length of wire—say 2.5 to 7 cm (1 to 3 inches)—may act as an inductor or a filter, or even as an antenna! Small and compact is the name of the game. Also, propagation of microwave signals is very similar to that of optical or light signals. Much amateur operation in these bands is accomplished in the "line of sight" mode. However, more elaborate amateur stations can accomplish long-range contacts from 50 to 500 miles or more. |
| Amateur bands above the 902- to 928-MHz band extend up to 300 GHz. Much of this part of the radio frequency spectrum is still undeveloped, with little equipment available for amateur use. Considerable research and development, some by amateur radio specialists, is being accomplished to develop new equipment and investigate propagation techniques in these higher frequency bands. | | |

**TABLE 1.2** Technician HF Operating Bands, Privileges and Normal Communications Capability.

| Operating Band | Frequencies and Operating Privileges | Communications Capability |
|---|---|---|
| 80 meters | 3.675–3.725 MHz: Morse code (cw) | *Day:* Reliable communications up to 250 km (150 miles) to about 400 km (250 miles). Range will increase during early morning and evening hours. *Night:* Reliable communications up to about 800 km (500 miles) to about 2400 km (1500 miles). Possible contacts to 4000 km (2500 miles) and beyond. |
| 40 meters | 7.100–7.150 MHz: Morse code (cw) | *Day:* Reliable communications to about 1100 km (700 miles) and beyond. Range will decrease at midday and early afternoon hours. *Night:* Reliable communications up to about 16,000 km (10,000 miles). |
| 15 meters | 21.100–21.150 MHz: Morse code (cw) | *Day:* Communication distances vary with sunspot activity. During maximum sunspot activity, worldwide communication is possible. During minimum sunspot activity, limited daytime contacts during "band openings" are possible. *Night:* Virtually no nighttime contacts are possible during minimal sunspot activity, except for ground-wave communications up to about 30 km (20 miles). |
| 10 meters | 28.100—28.300 MHz: Morse code (cw), RTTY, and data; 28.300–28.500 MHz: SSB voice and cw | Similar to 15 meters, above. |

NOTE: Technician Class Operator must have passed the 5 WPM Morse code test to qualify for these privileges.

CHAPTER 2

# How to Prepare for the FCC Technician Class Examination

## The Entrance to the World of Amateur Radio Is Easy

The FCC has established the Technician license for the beginner in amateur radio. Furthermore, the FCC authorizes local volunteer examiners to administer the examinations for the Technician Class license and higher class licenses such as the General Class and Extra Class licenses. As stated in Chap. 1, the Technician Class license provides for all amateur radio operating privileges above 50 MHz. To qualify for selected operating privileges in the amateur HF bands, you must pass a 5 words per minute (WPM) Morse code test.

The Technician Class license examination has 35 questions, and passing requires a minimum of 75 percent (or a total of 27) correct answers. This written examination covers radio theory, FCC rules and regulations, and operating procedures—all the knowledge you will need to set up and operate your ham station. As a general rule, you can master the requirements for the Technician Class license with two or three months of dedicated study. Considerable less time (six to eight weeks) will be sufficient if you are fortunate to enroll in local "Code and Theory" classes handled by amateur radio clubs or civic organizations.

To prepare for the Technician examination, the beginner in amateur radio can obtain any necessary help from a variety of sources. One of the more successful approaches is to enroll in a Technician class sponsored by a local ham club or other organizations, such as the YMCA or a church group. These courses give you the advantage of studying with

your peers in an educational environment. Most of these courses will run for about 7 to 10 weeks with one or two class periods per week. Each period may last for about 2 to 4 hours. The final class period is usually a test session whereby the volunteer examiner (VE) team is scheduled to hold an open test session. Classes sponsored by the local ham club are usually very inexpensive, sometimes only the cost of the course text and a year's club membership dues. If no local ham course is available, the neighborhood ham (or "Elmer" as they are affectionately called) will be pleased to help you prepare for your Technician exam.

Self-study is another approach for learning the material required for the Technician examination. This book covers all of the material contained in the Technician examination—namely, FCC rules and regulations, electronics theory, ham receivers and transmitters, antennas and propagation, and radio communications practices and operating procedures. Furthermore, this book contains the actual FCC question pool from which the 35 Technician examination questions are taken. Yes, you actually have access to the Technician question pool, and answers to each question are available at the end of this book (see Appendix A).

Additional study guides for amateur radio examinations are available from various sources. For example, the amateur radio organizations listed below offer study texts, videotapes, and computer software packages designed to make learning the required material more efficient (Fig. 2.1).

*QST.* A monthly magazine published as the official journal of the American Radio Relay League, 225 Main Street, Newington, CT 06111-1494. For more information call (800) 326-3942, or e-mail: newham@arrl.org. Web page: *http://www.arrl.org*

*73 Amateur Radio Today.* A monthly magazine published by 73 Magazine, 70 N202, Peterborough, NH 03458-1107. For more information call (603) 924-0058. Web page: *www.waynegreen.com*

*The W5YI Group, Inc.* Offers ham test prep tapes, books, software, and videos. Contact the W5YI Group at P.O. Box 565101, Dallas, TX 75356, or call toll-free 1-800-669-9594. Web page: *www.w5yI.org*

*The HANDIHAM World.* Published three times annually by the Courage HANDIHAM System, an organization devoted since 1967 to amateur radio for persons with physical disabilities and sensory impairments. 3915 Golden Valley Road, Golden Valley, MN 55422. Telephone:

(763) 520-0511 (voice), (763) 520-0577 (fax), or e-mail: handiham@mtn.org. Additional information may be obtained from the HANDIHAM Web site: *http://www.handiham.org*

When you are ready to take the Technician (or higher) Class license examination, a local VE team consisting primarily of EXTRA Class hams, will be available to schedule the examination. Most VE teams regularly schedule VE examinations on a monthly or semimonthly basis. For further information on the VE test teams, contact the local amateur radio club or ARRL at the above address. Practically everyone in the United States, regardless of age, is eligible to take the FCC amateur radio examinations. This includes aliens who have a valid U.S. address and are not representatives of a foreign government.

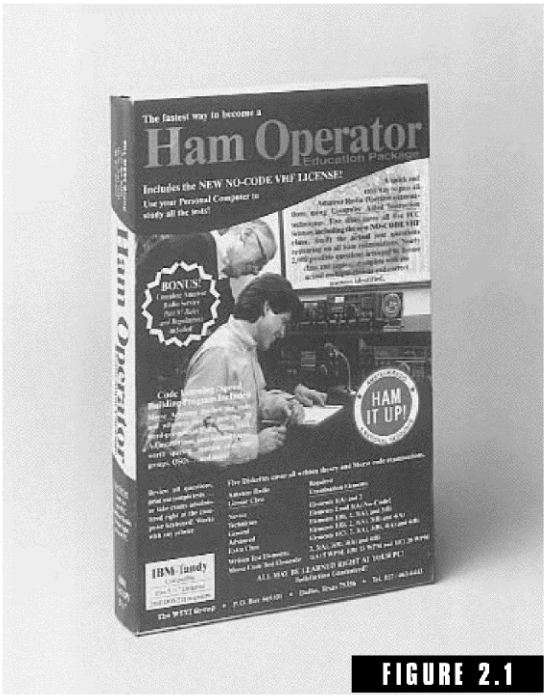



**FIGURE 2.1**

**The W5YI Computer Aided Instruction Software Package for all Amateur Radio Morse code and written elements, including Technician and up to Extra Class. Probably the fastest way to learn Morse code, and study all of the questions that appear on the various ham radio written tests, is with a personal computer. This Ham Operator software package contains material that covers everything, including teaching code and all questions in every question pool.**

## The Federal Communications Commission

The FCC, established by the Communications Act of 1934, regulates and licenses all radio transmitters in the United States and aboard all U.S.-registered ships and aircraft. Unlike many other countries, the U.S. does not license the possession of radio receivers. The "bible" of radio laws that governs all FCC activity contains some 40 parts. The Amateur Radio Service is covered in Part 97, Rules and Regulations. A copy of Part 97 can be obtained from the ARRL, local ham radio and book stores, or the FCC. Also, Part 97 can be downloaded from the Government Printing Office at www.gpo.gov.

The structure of the FCC includes a headquarters located in Washington, DC, a license and call-sign processing facility in Gettysburg, Pennsylvania, some 16 radio districts or field offices, and some 13 FCC monitoring stations. For more information concerning any FCC radio

district or monitoring station, contact the Public Service Division, Federal Communications Commission, 445 12th Street SW, Washington, DC 20554 [telephone: (202) 418-0200, fax: (202) 418-2555].

## The FCC Volunteer Examiner Program

The FCC has "deregulated" the amateur radio service in terms of amateur radio license examinations. In effect, the responsibility for administering all examinations for amateur radio licenses has been transferred to the amateur radio community. The chances are good that any local ham club will be affiliated with the ARRL and will be authorized by the ARRL to administer all amateur radio license examinations, including the Technician Class exam.

Examinations for the Technician and higher-class (General and Extra) amateur radio licenses are administered by amateur radio VE teams. Each VE team consist of a minimum of three qualified volunteer examiners, certified by a volunteer examiner coordinator (VEC) authorized by the FCC. The ARRL and the W5YI Group are representative of the VECs. Each VEC must maintain a question pool (available to the public), prepare and administer license examinations, make public announcements for examination schedules, and qualify VE personnel.

The VEC entity must be organized, at least partially, for the purpose of furthering amateur radio, and agree not to accept any compensation from any source for its services. However, in order to defray the expense of preparing and administering tests, the VEC is authorized to charge a maximum fee (on the order of $6) for each applicant.

## FCC Amateur Radio Operating Classes

There are currently five classes of amateur radio licenses, which provide increasing privileges at each step forward. However, the recent FCC changes to the amateur license structure call for the eventual elimination of the Novice and Advanced Class Licenses. Current licensed Novice and Advanced amateur operators may continue to operate on the authorized amateur frequency bands or elect to upgrade to higher-class licenses. No new FCC examinations for the Novice and Advanced class licenses will be permitted. The Technician Class license is now the entry level into amateur radio. As a Technician

Class amateur operator, you will enjoy all amateur privileges above 50 MHz. No Morse code test is required for the Technician Class license. However, you must pass a 35-question written examination (Element 2) to receive this license. Technician Class privileges can be expanded to selected portions of the HF bands by passing the Element 1, a 5-WPM Morse code test.

The second step in amateur radio is the General Class license. This license requires that you pass a second 35-question written exam (Element 3) and have credit for the 5-WPM Morse code test (Element 1). In return, you will receive operating privileges for all or portions of all amateur bands. This includes the exciting hf bands between 3 and 30 MHz.

The top amateur license, the Amateur Extra Class, requires passing a 50-question written exam (Element 4) on advanced topics. This "top prize" in amateur radio gives you all the operating privileges in all amateur bands. Keep this goal in mind as you progress through the ranks of amateur radio.

A summary of the amateur radio license requirements and privileges is given in Table 2.1. Note that the Technician Class license permits the beginner to obtain valuable experience in virtually all types of amateur radio communications.

## The Amateur Radio Frequency Spectrum

The amateur radio frequency begins just above the AM broadcast band (540–1650 kHz) at 1800 kHz and contains small "chunks" of bandwidth or bands of frequencies up to 300 GHz and beyond. At this time, the amateur portion of the radio frequency spectrum is probably the largest of any single user organization. However, as electronic techniques and development of communications equipment for the higher frequency bands advance, commercial and government organizations will find ways to use these bands.

One of the strengths of amateur radio that attracts so many people is the abundance and diverse nature of the frequency spectrum allocated to amateur radio operators. Amateurs can build and/or experiment with a wide variety of antennas, radio receivers, radio transmitters, computers, and other communications systems that operate from the 1800–2000 kHz band to the microwave frequency bands (tens of thousands of megahertz near the optical frequencies of light).

**TABLE 2.1** FCC Amateur Radio Licenses, Examination Requirements, and Operating Privileges

| Operator license class | Morse code examination | Written examination | Operating privileges |
|---|---|---|---|
| Technician (entry level) | None | Element 2 (35 questions) | All amateur privileges above 50 MHz. This includes specific frequency bands up to 300 GHz and beyond |
| Technician with Morse code | Element 1 5-WPM test | Element 2 (35 questions) | All privileges above 50 MHz and privileges on portions of selected amateur HF bands below 30 MHz. |
| General | Element 1 5-WPM test | Element 3 (35 questions) | All privileges above 50 MHz and privileges on portions of all amateur HF bands below 30 MHz. |
| Amateur Extra | Note 1 | Element 4 (50 questions) | All privileges on all amateur bands. |

Each amateur radio band exhibits a unique set of characteristics, requiring special techniques for designing and building antennas, transmission lines, transmitters, and receivers. Some amateur radio bands permit reliable communications on a worldwide basis, while others are limited primarily to "line-of-sight" propagation. Some amateurs specialize in the HF bands (3–30 MHz) for long-range DX contacts involving single sideband (SSB) voice, Morse code (CW) communications, or amateur slow-scan television. Some of these amateurs use low-power "QRP rigs" of only a few watts to work with other amateurs over long distances. Many of these QRP rigs are easily built and tested. Other amateurs experiment with digital data transmissions involving computer-to-computer operation and slow-scan television systems in the VHF and UHF frequency bands. You will probably want to investigate many of these exciting aspects of ham radio.

Figure 2.2 shows the total amateur radio frequency spectrum, including the Technician Class license operating privileges. Many of the amateur bands are assigned on approximate octave intervals throughout the spectrum. For example, the 40-meter band is approxi-

mately twice the frequency of the 80-meter band. In many instances, this octave relationship aids in the design and construction of multiband radio transmitters, receivers, and even antennas. Additional information concerning the methods of modulation and propagation characteristics is discussed in Chap. 3. For a more detailed and up-to-date listing of amateur frequencies and operating privileges, refer to the current edition of the *ARRL Handbook for the Radio Amateur.*

## FCC Rules and Regulations

### Part 97: Amateur Radio Service

Basic law comprising rules and regulations essential to the operation of amateur radio stations is contained in the Rules and Regulations of the FCC, Part 97: Amateur Radio Service. As stated earlier, a copy of Part 97 may be obtained from the U.S. Printing Office or directly from the FCC. You are encouraged to obtain a copy of this document.

We will review Part 97 in terms of the Technician Class license examination and subsequent Technician station operation, and provide selected portions of Part 97. You should become completely familiar with these rules and regulations prior to taking the written examination. Virtually all the FCC rules presented here relate to questions that will appear on the Element 2 exam.

**BASIS AND PURPOSE.**

This section expresses the justification for the existence of the Amateur Radio Service. You may have wondered why the Amateur Radio Service controls so much of the valuable radio frequency spectrum. This justification is based on the following five functions of amateur radio.

**97.1 Basis and purpose.** The rules and regulations in this part are designed to provide an amateur radio service having a fundamental purpose as expressed in the following principles:

(a) Recognition and enhancement of the value of the amateur radio service to the public as a voluntary noncommercial service particularly with respect to providing emergency communications.

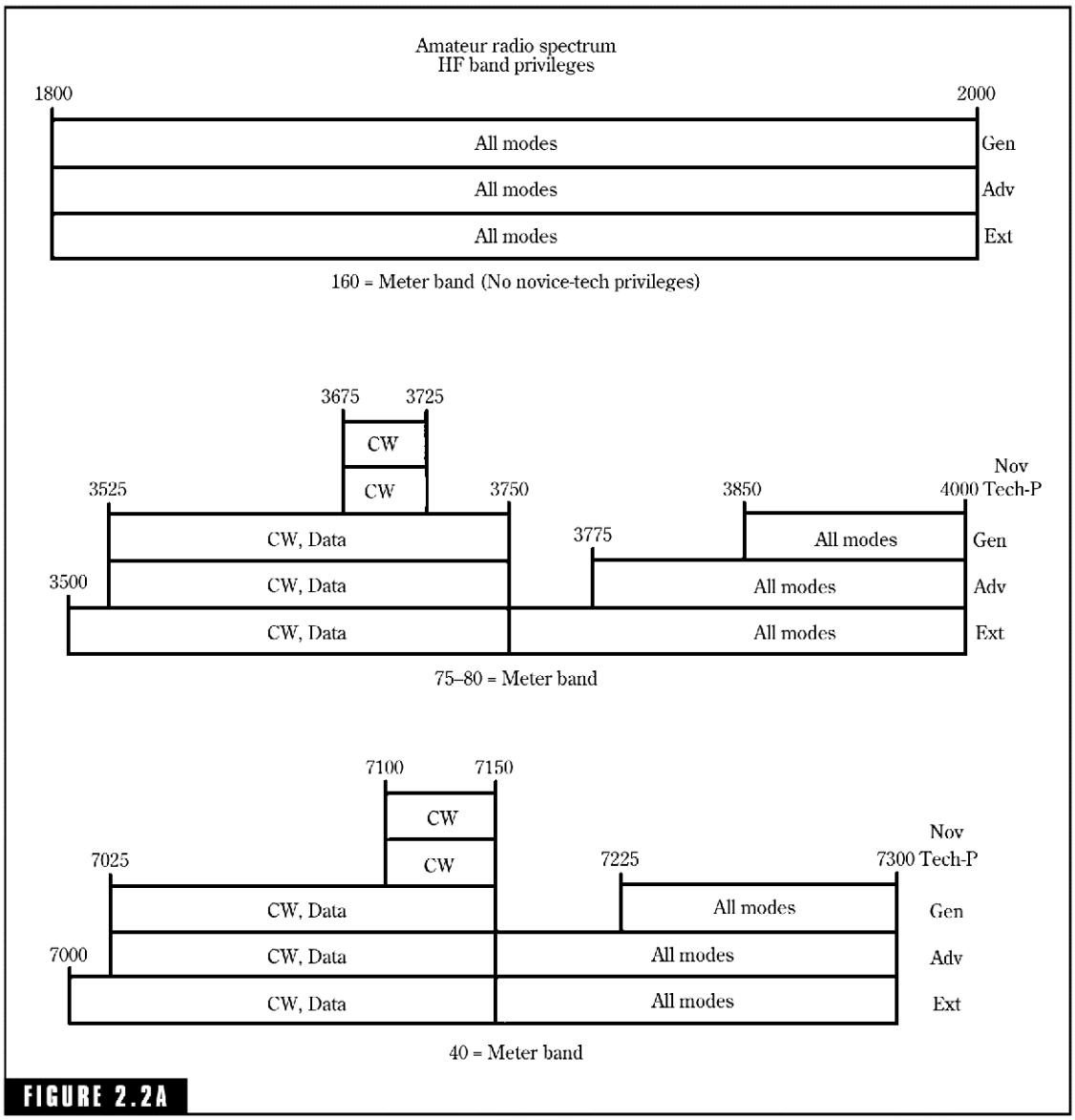



**FIGURE 2.2A**

**Amateur radio frequency spectrum and operating privileges.**

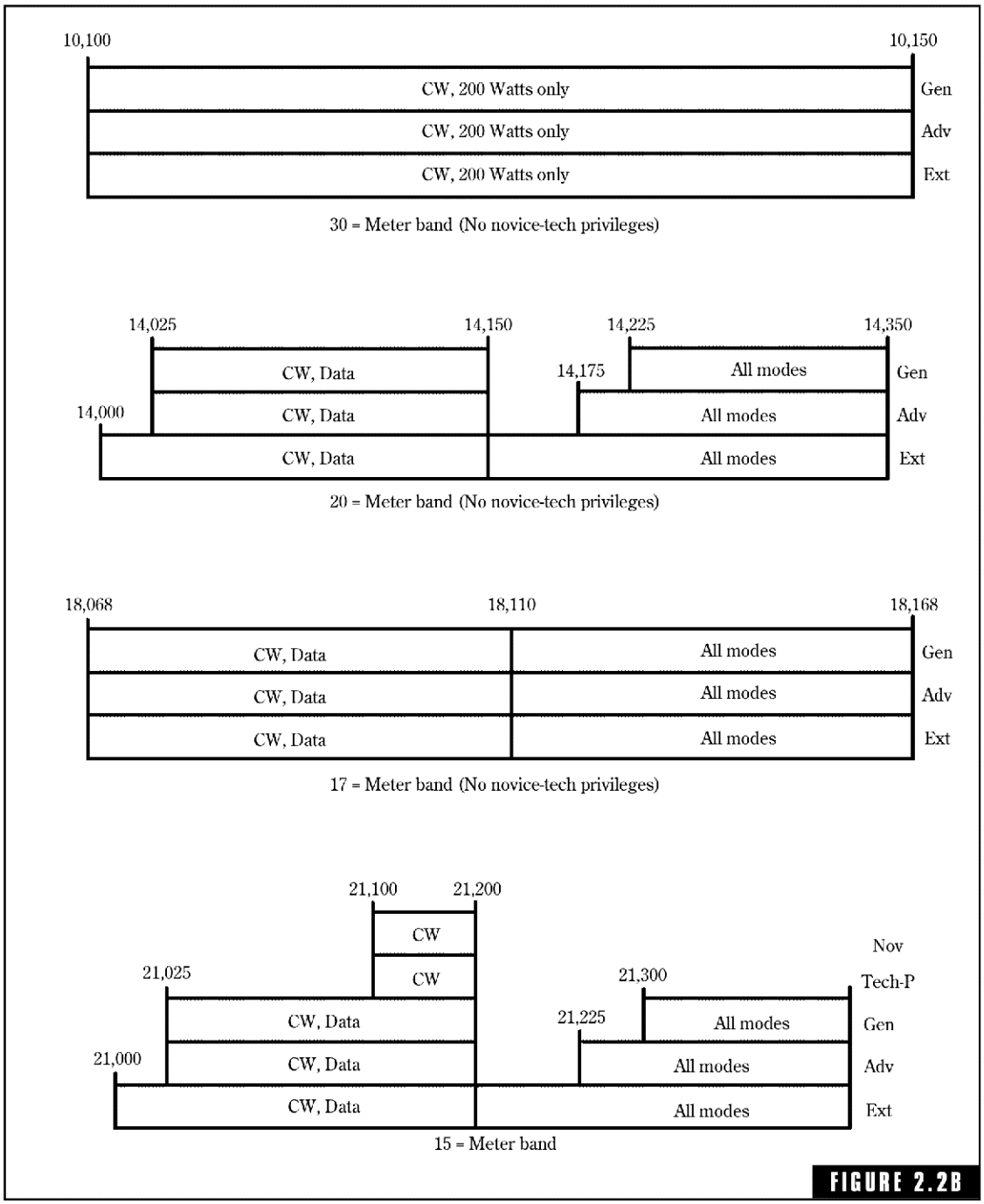



**FIGURE 2.2B**

**Amateur radio frequency spectrum and operating privileges.**

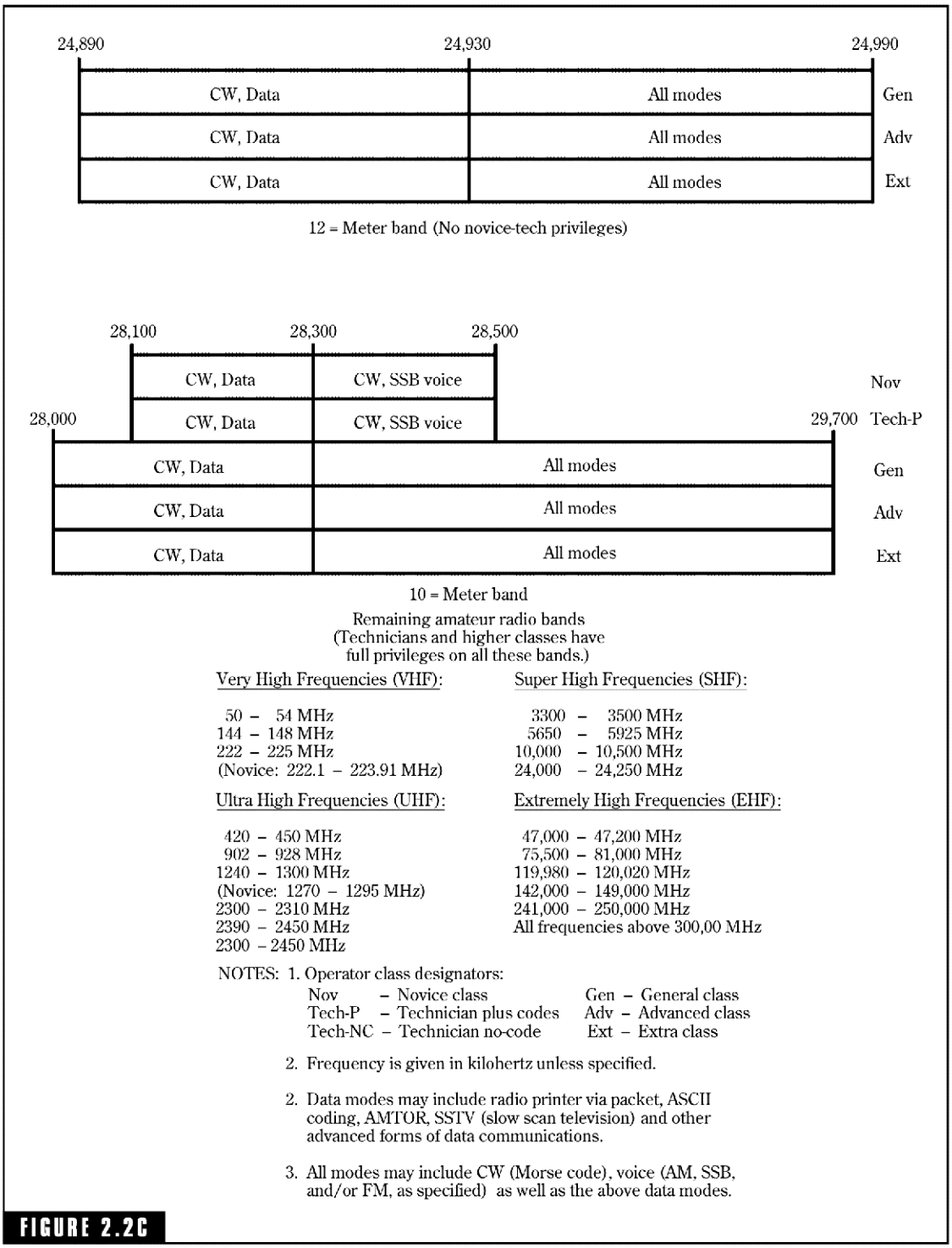



**FIGURE 2.2C**

**Amateur radio frequency spectrum and operating privileges.**

(b) Continuation and extension of the amateur's proven ability to contribute to the advancement of the radio art.

(c) Encouragement and improvement of the amateur radio service through rules which provide for advancing skills in both the communication and technical phases of the art.

(d) Expansion of the existing reservoir within the amateur radio service of trained operators, technicians, and electronics experts.

(e) Continuation and extension of the amateur's unique ability to enhance international good will.

**DEFINITIONS**

The definitions of terms essential to the operation of amateur radio stations are contained in Part 97.3. Almost all Technician examinations will include one or more of these definitions.

**97.3 Definitions.**

(a) The definitions of terms used in Part 97 are:

(1) Amateur operator. A person holding a written authorization to be the control operator of an amateur station.

(2) Amateur radio service. The amateur service, the amateur-satellite service and the radio amateur civil emergency service (RACES).

(3) Amateur-satellite service. A radiocommunications service using stations on Earth satellites for the same purpose as those of the amateur service.

(4) Amateur service. A radiocommunications service for the purpose of self training, intercommunication and technical investigations carried out by amateurs, that is, duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest.

(5) Amateur station. A station in an amateur radio service consisting of the apparatus necessary for carrying on radio communications.

(6) Automatic control. The use of devices and procedures for control of a station when it is transmitting so that compliance with the FCC Rules is achieved without the control operator being present at a control point.