An Amateur Radio Technician and General Class License Study Guide

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Based on the Element 2 Technician Exam Question Pool valid until 6/30/2018 and the Element 3 General Exam Question Pool valid until 6/30/2019

How to use this study guide

Contained within these pages is text derived from the official exam question pools for Element 2 Technician and Element 3 General class exams. Studying the full question pool text is counterproductive in attempting to obtain your Amateur Radio License. Therefore, it is not recommend downloading the actual exam question pool texts.

This study guide is divided into sections of related information. Each section deals with a set of facts representing a block of the exam pool questions. The explanatory text is based on answering questions about the subjects contained in each block that have commonly been asked in classes over the years.

In each section, the actual exam question text along with the answer in **bold** is used. At the end of each is the exam question number in parenthesis. **T** is from the Tech question pool and **G** is from the General question pool. In some there is a reference in **[square brackets]** that is a citation of the relevant info in Part 97 of the FCC rules and Regulations. All the distractor answers have been removed to avoid placing the incorrect information in your mind while studying. During the exams you should generally go with the first impression you have about the correct answer as your selected answer.

This study guide does not represent the total of knowledge you should have as a radio operator, but only represents the beginning step required to pass the Technician class license exam and the General class license exam.

Since amateur radio is an on the job training program, you should continue to develop skills and knowledge about radio communications. When you have developed your skills and knowledge a bit, you can share it by teaching others about amateur radio.

If you have questions and need an answer, ask on the **Tech-General-Ham-Class** mailing list.

Be sure to put the subject matter in question in the subject line.

If you love the hobby, you have a duty to pass it along to the next generation.

We hope your study experience is a pleasant and successful one.

73 and good luck – N2NOV, Charles

Have fun!

Let's get started.

FCC Rules, descriptions and definitions for the Amateur Radio Service, operator and station license responsibilities

Amateur Radio Service: purpose and permissible use of the Amateur Radio Service, operator/primary station license grant, where FCC rules are codified, basis and purpose of FCC rules, meanings of basic terms used in FCC rules, interference, spectrum management

The Amateur Radio Service is a service administered by the Federal Communications Commission (FCC). **The FCC** is the agency that regulates and enforces the rules for the Amateur Radio Service in the United States. (T1A02) **Part 97** is the part of the FCC regulations that contains the rules governing the Amateur Radio Service. (T1A03)

Part 97.1 lists five “purposes” for the existence of amateur radio. The first is recognition of its usefulness in providing emergency and public service communications. **Enhancing international goodwill** is another purpose of the Amateur Radio Service rules and regulations as defined by the FCC. (T1A05)

The rules also cite the use of amateur radio as a way to help people become better technicians and operators. **Advancing skills in the technical and communication phases of the radio art** is a purpose of the Amateur Radio Service as stated in the FCC rules and regulations. (T1A01) Accordingly, **allowing a person to conduct radio experiments and to communicate with other licensed hams around the world** is a permissible use of the Amateur Radio Service. (T1A12)

Part 97 also defines terms and concepts that every amateur radio operator needs to know. For example, the FCC Part 97 definition of an amateur station is **a station in the Amateur Radio Service consisting of the apparatus necessary for carrying on radio communications**. (T1A10)

One of the most important concepts in amateur radio is that of harmful interference. The FCC definition of harmful interference is **that which seriously degrades, obstructs, or repeatedly interrupts a radio communication service operating in accordance with the Radio Regulations**. (T1A04) **At no time** is willful interference to other amateur radio stations permitted. (T1A11)

The **Radionavigation Service** is one of the services that are protected from interference by amateur signals under all circumstances. (T1A06) If you are operating on the 23 cm band and learn that you are interfering with a radiolocation station outside the United States, you must **stop operating or take steps to eliminate the harmful interference.** (T1A14)

The FCC Part 97 definition of telemetry is **a one-way transmission of measurements at a distance from the measuring instrument.** (T1A07) Transmitting telemetry is one of the very few examples of a one-way amateur communication. Another is sending telecommands, usually to a satellite or radio-control model. The FCC Part 97 definition of telecommand is **a one-way transmission to initiate, modify or terminate functions of a device at a distance**. (T1A13)

The **Frequency Coordinator** is the entity that recommends transmit/receive channels and other parameters for auxiliary and repeater stations. (T1A08) **Amateur operators in a local or regional area whose stations are eligible to be auxiliary or repeater stations** select a Frequency Coordinator. (T1A09)

Authorized frequencies: frequency allocations, ITU regions, emission modes, restricted sub-bands, spectrum sharing, transmissions near band edges

The ITU is **a United Nations agency for information and communication technology issues**. (T1B01) There are three ITU regions. North American amateur stations are located in ITU region 2.

One of the reasons that it is important to know about the ITU zones is that different zones often have different frequency assignments. For example, the frequency assignments for some

U.S. Territories are different from those in the 50 U.S. States because **some U. S. Territories are located in ITU regions other than region 2**. (T1B02) Similarly, frequency assignments for U.S. stations operating maritime mobile are not the same everywhere in the world because **amateur frequency assignments can vary among the three ITU regions**. (T1B12)

Refer to the US Amateur Radio Bands colored band plan chart for the questions in this section. You will need to memorize a number of the band plan edges for the questions in this section.

Because operation outside of the amateur radio bands is a serious offense, it is important to know about the frequencies and bands that amateur radio operators can use:

52.525 MHz is a frequency within the 6 meter band. (T1B03)

The **2 meter band** is the amateur band you are using when your station is transmitting on 146.52 MHz. (T1B04)

443.350 MHz is a 70 cm frequency authorized to a Technician Class license holder operating in ITU Region 2. (T1B05)

1296 MHz is a 23 cm frequency authorized to a Technician Class licensee. (T1B06)

1.25 meter band is the amateur band you are using if you are transmitting on 223.50MHz. (T1B07)

All of these choices are correct when thinking about why you should not set your transmit frequency to be exactly at the edge of an amateur band or sub-band (T1B09):

To allow for calibration error in the transmitter frequency display

So that modulation sidebands do not extend beyond the band edge

To allow for transmitter frequency drift

In addition to defining which frequencies are available to amateur radio operators, the FCC also defines sub-bands for various modes. For example, **CW only** is the emission mode permitted in the mode-restricted sub-bands at 50.0 to 50.1 MHz and 144.0 to 144.1 MHz (T1B11). **The 6 meter, 2 meter, and 1.25 meter bands** are the bands available to Technician Class operators that have mode-restricted sub-bands (T1B10). The use of SSB phone in amateur bands above 50 MHz **is permitted in at least some portion of all the amateur bands above 50 MHz**. (T2B13) **Data** is the type of emission that may be used between 219 and 220 MHz. (T1B13)

Amateur radio operators share some bands with users from other services. Sometimes, amateurs are the primary users, such as the 2 meter band, but sometimes amateur radio operators are secondary users. One result of the fact that the amateur service is secondary in some portions of the 70 cm band is that **U.S. amateurs may find non-amateur stations in the bands, and must avoid interfering with them**. (T1B08) [97.303]

A General Class license holder is granted all amateur frequency privileges on the **160, 60, 30, 17, 12, and 10 meter bands**. (G1A01) Many of the bands, such as 80/75, 40, 20, and 15 meters, have segments (primarily in the voice segment) that are reserved for extra class license holders. When General Class licensees are not permitted to use the entire voice portion of a particular band, **the upper frequency end** of the voice segment is generally available to them. (G1A11)

3,560 kHz is within the General Class portion of the 80-meter band (G1A08)
3,900 kHz is within the General Class portion of the 75-meter phone band (G1A06)
7.250 MHz is in the General Class portion of the 40-meter band (G1A05).
14305 kHz is within the General Class portion of the 20-meter phone band (G1A07)
21,300 kHz is within the General Class portion of the 15-meter band (G1A09)

28.020, 28.350, and 28.550 MHz are all frequencies available to a control operator holding a General Class license (G1A10).

The 30 and 60 meter bands have restrictions that are different from other amateur bands. On **30 meters**, only narrow data modes are used while phone (SSB voice) operation is prohibited (G1A02) and image transmission is also prohibited (G1A03). **60 meters** is the only amateur radio band where communication is restricted to only specific channels (G1A04) instead of a range of frequencies.

Amateur radio is designated as a secondary user on some bands, namely 30 and 60 meters. **Amateur stations are allowed to use the band only if they do not cause harmful interference to primary users**. (G1A12) When operating on either the 30-meter or 60-meter bands, if a station in the primary service interferes with your contact, the appropriate action is to **move to a clear frequency or stop transmitting**. (G1A13)

The frequencies allocated to amateur radio can be different around the world in different ITU regions. Notably the voice segment on 40 meters is different. 7.175 to 7.300 MHz is permitted for a control operator holding an FCC issued General Class license in ITU **Region 2**. (G1A14)

In general, amateurs are allowed a maximum, legal power output of 1,500 Watts Peak Envelope Power (PEP) on most bands. This is way more than you need for almost all situations. Good amateur practice requires you to use **only the minimum amount of power necessary to carry out the desired communications**. (G1C04) This reduces interference and enables more amateurs to share the available bandwidth.

On some bands, particularly those where amateur radio is a secondary user of the band, such as 30 and 60 meters, power levels are restricted far below 1,500 Watts PEP.

200 watts PEP is the maximum transmitting power an amateur station may use on 10.140 MHz (30 meters). (G1C01)

1500 watts PEP is the maximum transmitting power a general class amateur station may use:
on the 12-meter band (G1C02)
on 28 Mhz (G1C05)
on 1.8 Mhz (G1C06)

2.8 kHz is the maximum bandwidth permitted by FCC rules for Amateur Radio stations transmitting on USB frequencies in the 60-meter band. (G1C03) You are also limited to 50 watts ERP (Effective Radiated Power).

On HF, below 28 Mhz, to preserve the limited bandwidth, the maximum symbol rate (or baud rate) for RTTY or data emission is limited to **300 baud**. As the frequency increases the available bandwidth for modulation increases.

HF up to 28 Mhz, **300 baud** (G1C07) (G1C08)
10 meters (28 Mhz) **1,200 baud** (G1C10)
6/2 meters (50 Mhz/144 Mhz) **19.6 Kilobaud** (G1C11)
1.25 meter/70cm (222 Mhz/440 Mhz) **56 Kilobaud** (G1C09)

Operator licensing: operator classes; sequential, special event, and vanity call sign systems; international communications; reciprocal operation; station license and licensee; places where the amateur service is regulated by the FCC; name and address on FCC license database; license term; renewal; grace period

Technician, General, Amateur Extra are the license classes for which new licenses are currently available from the FCC. (T1C13) You may operate a transmitter on an amateur service frequency after you pass the examination required for your first amateur radio license **as soon as your name and call sign appear in the FCC's ULS database** (T1C10). **Ten years** is the normal term for an FCC-issued primary station/operator amateur radio license grant (T1C08).

When the FCC issues an amateur radio operator license, it also issues a station license. The call sign of that station consists of one or two letters, followed by a number and then one, two, or three letters. **W3ABC** is an example of a valid US amateur radio station call sign (T1C02). After you pass the test, the FCC will assign you a call sign sequentially from the pool of available call signs. If you do not like this call sign, you can apply for a vanity call sign. **Any licensed amateur** may select a desired call sign under the vanity call sign rules. (T1C12)

The call sign you select must not only be available, it must have an appropriate format for the class of license you hold. Extra class licensees are the only ones who may hold 1x2 or 2x1call signs. **K1XXX** is, therefore, a vanity call sign which a Technician class amateur operator might select if available. (T1C05) A Technician class amateur radio operator may not choose the call signs KA1X or W1XX.

Two years is the grace period following the expiration of an amateur license within which the license may be renewed. (T1C09) If you don't renew your license before it expires, or within the two-year grace period, you will have to take the test again to get a new amateur radio license. If your license has expired and is still within the allowable grace period, **transmitting is not allowed until the ULS database shows that the license has been renewed** (T1C11).

Amateurs that set up stations at special events, such as a community fair or fundraising event, can request a special call sign specifically for that event. A **special event** call sign is the type of call sign that has a single letter in both the prefix and suffix (T1C01). An example of a special event call sign is W1K.

Clubs may apply for a station license for their club station. The club may even apply for a vanity call sign. **At least 4** persons are required to be members of a club for a club station license to be issued by the FCC. (T1F12) **Only the person named as trustee on the club station license grant** may select a vanity call sign for a club station. (T1C14)

When you get your first license, you must give the examiners a mailing address. Should you move, you must inform the FCC of our new mailing address. **Revocation of the station license or suspension of the operator license** may result when correspondence from the FCC is returned as undeliverable because the grantee failed to provide the correct mailing address (T1C07).

You are allowed to operate your amateur station in a foreign country **when the foreign country authorizes it** (T1C04). Sometimes countries have reciprocal licensing agreements, and you can operate from that country without any specific authorization. For example, I could operate my station in Ireland by simply using the callsign **EI** / **N2NOV**. There are restrictions on your operating privileges, depending on the country from which you plan to operate, and you should investigate these before you get on the air.

You can also operate your station while aboard a ship in international waters. An FCC-licensed amateur station may transmit **from any vessel or craft located in international waters and documented or registered in the United States**, in addition to places where the FCC regulates communications (T1C06).

A Certificate of Successful Completion of Examination (CSCE) is valid for exam element credit for **365 days**. (G1D09)

If you are a Technician Class operator and have a CSCE for General Class privileges, you may operate **on any General or Technician Class band segment**. (G1D03) If you are a Technician Class licensee and have a CSCE for General Class operator privileges, but, the FCC has not yet posted your upgrade on its website, you must add the special identifier "AG" after your call sign **whenever you operate using General Class frequency privileges**. (G1D06)

Any person who can demonstrate that they once held an FCC issued General, Advanced, or Amateur Extra class license that was not revoked by the FCC, may receive credit for the elements represented by an expired amateur radio license. (G1D01) If a person has an expired FCC issued amateur radio license of General Class or higher, **the applicant must pass the current element 2 exam**. (G1D11)

Volunteer Examiners (VEs) are accredited by **a Volunteer Examiner Coordinator** (VEC). (G1D07) **An FCC General Class or higher license and VEC accreditation** is required before you can be an administering VE for a Technician Class license examination. (G1D05) To qualify as an accredited Volunteer Examiner the minimum age is **18 years**. (G1D10) A non-U.S. citizen **must hold an FCC granted Amateur Radio license of General Class or above** to be an accredited Volunteer Examiner. (G1D08) An accredited VE holding a General Class operator license may only administer **the technician exam**. (G1D02) **At least three General Class or higher VEs are required to observe** a Technician Class license examination. (G1D04)

Authorized and prohibited transmission: communications with other countries, music, exchange of information with other services, indecent language, compensation for use of station, retransmission of other amateur signals, codes and ciphers, sale of equipment, unidentified transmissions, broadcasting

As a licensed radio amateur, it's important to know what you can and can't do on the air. For example, **any language** that is considered obscene or indecent **is prohibited.** (T1D06). For the most part, transmitting music is also prohibited. The only time an amateur station is authorized to transmit music is **when incidental to an authorized retransmission of manned spacecraft communications** (T1D04).

Transmitting any codes whose specifications are not published or well known is prohibited. The transmission of codes or ciphers that hide the meaning of a message transmitted by an amateur station is allowed **only when transmitting control commands to space stations or radio control craft** (T1D03). An amateur station is only permitted to transmit secret codes **to control a space station** (G1B06). Abbreviations or procedural signals may not be used to **obscure the meaning of a message** in the Amateur Service (G1B07).

Amateur radio operators are only allowed to communicate with other amateur radio stations, except in specific instances. For example, in an emergency, you are allowed to communicate with stations in other radio services. Another example is during the special event called Armed Forces Day Communications Test. An FCC-licensed amateur station may exchange messages with a U.S. military station **during an Armed Forces Day Communications Test** (T1D02).

FCC-licensed amateur stations are prohibited from exchanging communications with **any country whose administration has notified the ITU that it objects to such communications**. (T1D01) Currently, there are no countries that U.S. amateurs are prohibited from contacting.

Amateur radio operators may not use their stations to make money, except in some very special circumstances. For example, the control operator of an amateur station may receive compensation for operating the station only **when the communication is incidental to classroom instruction at an educational institution** (T1D08). Amateur radio operators may use their stations to notify other amateurs of the availability of equipment for sale or trade, but only **when the equipment is normally used in an amateur station and such activity is not conducted on a regular basis** (T1D05).

All amateur communications must be station to station. That is to say, amateur radio operators may not broadcast. The term broadcasting in the FCC rules for the amateur services means **transmissions intended for reception by the general public** (T1D10). Only **when transmitting code practice, information bulletins, or transmissions necessary to provide emergency communications** may an amateur radio station engage in broadcasting. (T1D12)

Amateur stations are authorized to transmit signals related to broadcasting, program production, or news gathering, assuming no other means is available, **only where such communications directly relate to the immediate safety of human life or protection of property.** (T1D09). When an amateur station provides communication to broadcasters for dissemination to the public, **the communications must directly relate to the immediate safety of human life or protection of property and there must be no other means of communication reasonably available before or at the time of the event** (G1B04).

So, what is allowed? **Communications incidental to the purposes of the amateur service and remarks of a personal character** are the types of international communications that are permitted to an FCC-licensed amateur station (T1C03).

The only time music may be transmitted by an amateur station is **when it is an incidental part of a manned spacecraft retransmission** (G1B05).

All of these choices are correct when choosing a transmitting frequency, to comply with good amateur practice you should: (G1B08)

Insure that the frequency and mode selected are within your license class privileges
Follow generally accepted band plans agreed to by the Amateur Radio community
Monitor the frequency before transmitting

An exception when an amateur station may transmit communications in which the licensee or control operator has a pecuniary (monetary) interest is **when other amateurs are being notified of the sale of apparatus normally used in an amateur station and such activity is not done on a regular basis** (G1B09).

When an not specifically covered by Part 97 rules, the FCC requires an amateur station be operated **in conformance with good engineering and good amateur practice** (G1B11).

The FCC determines what is considered "good engineering and good amateur practice" as applied to the operation of an amateur station in all respects not covered by the Part 97 rules (G1B12).

Control operator and control types: control operator required, eligibility, designation of control operator, privileges and duties, control point, local, automatic and remote control, location of control operator

An important concept in amateur radio is the control operator. **Only a person for whom an amateur operator/primary station license grant appears in the FCC database or who is authorized for alien reciprocal operation** is eligible to be the control operator of an amateur station. (T1E02) The FCC presumes **the station licensee** to be the control operator of an amateur station, unless documentation to the contrary is in the station records. (T1E11)

An amateur station is **never** permitted to transmit without a control operator. (T1E01) **The station licensee** must designate the station control operator. (T1E03) When the control operator is not the station licensee, **the control operator and the station licensee are equally responsible** for the proper operation of the station. (T1E07) **The control operator of the originating station** is accountable should a repeater inadvertently retransmit communications that violate the FCC rules. (T1F10)

The class of operator license held by the control operator determines the transmitting privileges of an amateur station. (T1E04) **At no time**, under normal circumstances, may a Technician Class licensee be the control operator of a station operating in an exclusive Extra Class operator segment of the amateur bands. (T1E12)

Two related concepts are the control type and control point. An amateur station control point is **the location at which the control operator function is performed**. (T1E05)

Local control is the type of control being used when transmitting using a handheld radio. (T1E09) **Operating the station over the Internet** is an example of remote control as defined in Part 97. (T1E10) **Repeater operation** is an example of automatic control. (T1E08) APRS network digipeaters operate under **automatic** control. (T1E06)

A 10-meter repeater may retransmit the 2-meter signal from a station having a Technician Class control operator **only if the 10-meter repeater control operator holds at least a General Class license.** (G1E02)

When conducting communications with a digital station operating under automatic control outside the automatic control band segments, **the station initiating the contact must be under local or remote control.** (G1E03)

All of these choices are correct as conditions that require a licensed Amateur Radio operator to take specific steps to avoid harmful interference to other users or facilities: (G1E04)

When operating within one mile of an FCC Monitoring Station
When using a band where the Amateur Service is secondary
When a station is transmitting spread spectrum emissions

English only must be used when identifying your station if you are using a language other than English in making a contact using phone emission. (G1E09)

In the event of interference between a coordinated repeater and an uncoordinated repeater **the licensee of the uncoordinated repeater has primary responsibility to resolve the interference**. (G1E06)

The FCC term for an unattended digital station that transfers messages to and from the Internet is an **automatically controlled digital station.** (G1E11) Automatically controlled stations transmitting RTTY or data emissions may communicate with other automatically controlled digital stations **anywhere in the 1.25-meter or shorter wavelength bands and in specified segments of the 80-meter through 2-meter bands**. (G1E13)

Station identification, repeaters, third party communications, club stations, FCC inspection

Proper station identification is also very important. The basic rule is that an amateur station is required to transmit its assigned call sign **at least every 10 minutes during and at the end of a communication.** (T1F03) The only time an amateur station may transmit without identifying is **when transmitting signals to control a model craft**. (T1D11)

The English language is the only acceptable language for use for station identification when operating in a phone sub-band. (T1F04) **Sending the call sign using CW or phone emission** is the required method of call sign identification for a station transmitting phone signals. (T1F05)

For some types of operations, using a tactical call is allowed. A tactical call describes the function of the station or the location of a station. For example, a **tactical call** is the type of identification being used when identifying a station on the air as “Race Headquarters.” (T1F01) When using tactical identifiers such as “Race Headquarters” during a community service net operation, your station must transmit the station’s FCC-assigned callsign **at the end of each communication and every ten minutes during a communication**. (T1F02)

When operating mobile or portable, or when you wish to note something about your station, you may use a self-assigned call sign indicator, such as “/3,” “mobile,” or “QRP.” **All of these choices are correct** when choosing formats for self-assigned indicators that are acceptable when identifying using a phone transmission. (T1F06)

KL7CC stroke W3

KL7CC slant W3

KL7CC slash W3

Indicators required by the FCC to be transmitted after a station call sign include **/KT, /AE or /AG when using new license privileges earned by CSCE while waiting for an upgrade to a previously issued license to appear in the FCC license database.** (T1F08)

Third-party communications are communications on behalf of someone who is not the station licensee. For example, if you have a friend over to your house and let him or her talk on your radio, that is a third-party communication.

These are entirely legal within the United States, but there are some restrictions when you are in contact with an amateur station in a foreign country. The FCC rules authorize the transmission of non-emergency, third party communications to **any station whose government permits such communications**. (T1F11) A non-licensed person is allowed to speak to a foreign station using a station under the control of a Technician Class control operator only if **the foreign station is one with which the U.S. has a third party agreement**. (T1F07)

A **third party whose amateur license has been revoked and not reinstated** is disqualified from being a valid third party participant in stating a message over an amateur station. (G1E01)

Third party traffic to foreign countries is prohibited, **unless there is a third party agreement in effect with that country**. The exception to this is messages directly involving emergencies or disaster relief communications. (G1E07) **Only messages relating to Amateur Radio or remarks of a personal character, or messages relating to emergencies or disaster relief** may be transmitted by an amateur station for a third party in another country. (G1E05) The requirement to communicate with a non-licensed person in a foreign country, from a station with an FCC-granted license at which an FCC licensed control operator is present, t**he foreign amateur station must be in a country with which the United States has a third party agreement**. (G1E08)

Under no circumstances are messages that are sent via digital modes exempt from Part 97 third party rules that apply to other modes of communication. (G1E12)

The station licensee must make the station and its records available for FCC inspection **any time upon request by an FCC representative**. (T1F13) One of your obligations as a licensee is to make your station and your records available when requested to do so.

Radio wave characteristics: properties of radio waves, propagation modes

Frequency, wavelength, the electromagnetic spectrum

Electromagnetic is the type of wave that carries radio signals between transmitting and receiving stations. (T3A07) The usual name for electromagnetic waves that travel through space is **radio waves**. (T5C07) As the name would imply, the two components of a radio wave are **electric and magnetic fields**. (T3B03)

One important parameter of a radio wave is its frequency, or the number of cycles that it goes through per second. The unit of frequency is the **Hertz** (Hz). (T5C05) One Hz is one cycle per second.

A radio wave travels **at the speed of light** through free space. (T3B04) Because the speed of light is about 300,000,000 meters per second, the approximate velocity of a radio wave as it travels through free space is **300,000,000 meters per second**. (T3B11)

Another important parameter of a radio wave is its wavelength. **Wavelength** is the name for the distance a radio wave travels during one complete cycle. (T3B01)

Because radio waves travel at the speed of light, no matter what their frequency happens to be, **the wavelength gets shorter as the frequency increases**. (T3B05) The formula for converting frequency to wavelength in meters is **wavelength in meters equals 300 divided by frequency in megahertz**. (T3B06)

The approximate wavelength of radio waves is often used to identify the different frequency bands. (T3B07) For example, when we refer to the 2 meter band, we are referring to the amateur radio band that spans 144 MHz to 148 MHz. A radio wave with a frequency of 148 MHz would have a wavelength of 2.03 meters.

The abbreviation "RF" refers to **radio frequency signals of all types**. (T5C06) For convenience, we split the entire range of radio frequencies into sub-ranges, including high frequency (HF), very high frequency (VHF), and ultra-high frequency (UHF). The frequency range **3 to 30 MHz** is referred to as HF. (T3B10) The frequency limits of the VHF spectrum are **30 to 300 MHz**. (T3B08) The frequency limits of the UHF spectrum are **300 to 3000 MHz**. (T3B09)

Radio wave characteristics, how a radio signal travels, propagation mode

As amateur radio operators, we should always try to use the right frequency and the right mode when communicating. To do this, we need to know how radio signals travel from one point to another and what affect frequency, our antennas, and even our location have on signal propagation.

Communications at VHF and UHF frequencies are generally "line of sight" communications. That is to say that normally they travel in a straight line from the transmitter to the receiver. For this reason, they are normally used for local communications. The reason "direct" (not via a repeater) UHF signals are rarely heard from stations outside your local coverage area is that **UHF signals are usually not reflected by the ionosphere**. (T3C01) We'll talk more about the ionosphere below.

The maximum distance for line-of-sight communications is called the radio horizon. The radio horizon is **the distance at which radio signals between two points are effectively blocked by the curvature of the Earth**. (T3C10) Because **the Earth seems less curved to radio waves than to light,** VHF and UHF radio signals usually travel somewhat farther than the visual line of sight distance between two stations, meaning that the radio horizon is somewhat farther than the visual horizon. (T3C11)

One problem often encountered when using VHF and UHF frequencies is multi-path distortion. Multi-path distortion occurs when your signals arrive at a receiving station via two or more paths. Since the signal paths may be different lengths, they may arrive out of phase and cancel one another. For example, if another operator reports that your station's 2 meter signals were strong just a moment ago, but now they are weak or distorted, **try moving a few feet, as random reflections may be causing multi-path distortion**. (T3A01)

Multi-path distortion affects both voice and digital transmissions. **Error rates are likely to increase** if VHF or UHF data signals propagate over multiple paths. (T3A10)

When using a repeater, you may find yourself in a place where a direct path to the repeater is not possible. If you find yourself in this situation, you could try using a directional antenna. When using a directional antenna, **try to find a path that reflects signals to the repeater** if buildings or obstructions are blocking the direct line of sight path to a distant repeater. (T3A05)

If you try to use a hand-held transceiver inside a building to communicate with someone, you might want to choose to operate in a UHF band. The reason for this is that UHF signals are often more effective from inside buildings than VHF signals because **the shorter wavelength allows them to more easily penetrate the structure of buildings**. (T3A02)

Another interesting phenomenon is "knife-edge" propagation. Knife-edge propagation is the term used to describe when **signals are partially refracted around solid objects exhibiting sharp edges**. (T3C05) You might be able to use this phenomenon to get your signal around a building in an urban setting.

Antenna polarization is also important at VHF and UHF frequencies. **The orientation of the electric field** is the property of a radio wave that is used to describe its polarization. (T3B02) **Signals could be significantly weaker** if the antennas at opposite ends of a VHF or UHF line of sight radio link are not using the same polarization. (T3A04)

When using a repeater, vertical polarization is most often used. So, when using a hand-held transceiver, make sure to hold it so that your antenna is vertically oriented. On the other hand, **horizontal** antenna polarization is normally used for long-distance weak-signal CW and SSB contacts using the VHF and UHF bands. (T3A03)

Mobile operation has its own unique challenges as your transmitter location is constantly changing. This means that the signal at the receiving station constantly changes as well. **Picket fencing** is the term commonly used to describe the rapid fluttering sound sometimes heard from mobile stations that are moving while transmitting. (T3A06)

Even though VHF communications are most often line-of-sight, there are times when it's possible to communicate over long distances. Sometimes, VHF signals will bounce off the E layer of the ionosphere. When VHF signals are being received from long distances, what might be happening is that **signals are being refracted from a sporadic E layer**. (T3C02) **Sporadic E** propagation is most commonly associated with occasional strong over-the-horizon signals on the 10, 6, and 2 meter bands. (T3C04)

Other interesting propagation phenomena at VHF frequencies include auroral reflection, meteor scatter, tropospheric scatter, and tropospheric ducting. Bouncing signals off the earth's aurora is very interesting. A characteristic of VHF signals received via auroral reflection is that **the signals exhibit rapid fluctuations of strength and often sound distorted**. (T3C03)Some hams also bounce signals off meteor showers. This propagation mode is called meteor scatter. **6 meters** is the band best suited to communicating via meteor scatter. (T3C07)

The troposphere is the lowest region of the atmosphere, extending from the earth's surface to a height of about 6–10 km. **Tropospheric scatter** is the mode responsible for allowing over-the-horizon VHF and UHF communications to ranges of approximately 300 miles on a regular basis. (T3C06) **A temperature inversion in the atmosphere causes** "tropospheric ducting." (T3C08) Tropospheric ducting can also propagate VHF signals for many hundreds of miles.

HF Propagation

For more reliable long-distance communications, amateurs use the HF frequencies. The reason for this is that HF signals bounce off the ionosphere. **The ionosphere** is the part of the atmosphere that enables the propagation of radio signals around the world. (T3A11) It contains a high concentration of ions and free electrons and is able to reflect radio waves. It extends from about 50 to 600 miles above the earth's surface. The layers of the ionosphere are called the D, E, F1 and F2 layers. The layer closest to the surface of the Earth is **the D layer**. (G3C01) The **D-layer** is the most absorbent of HF signals below 10 Mhz during the daylight hours. (G3C12). Any long distance communications on the 40-meter, 60-meter, 80-meter and 160-meter bands are more difficult because **the D-layer absorbs signals at these frequencies during daylight hours**. (G3C05) The E, F1 and F2 layers reflect signals back depending on time of day, with the F2 being the highest and more usable in the overnight hours (see MUF below). The ionospheric layers reach their maximum height **where the Sun is overhead.** (G3C02) The approximate maximum distance along the Earth's surface covered in one hop using the E-layer is **1,200 miles**. (G3B10) The maximum distance covered in one hop for the F2 layer is **2,500 miles.** (G3B09) The F2 region is mainly responsible for the longest distance radio propagation and **all of these choices are correct** (G3C03):

Because it is the densest ionospheric layer

Because it does not absorb radio waves as much as other ionospheric regions

Because it is the highest ionospheric region

One interesting phenomenon that is related to HF propagation is the sunspot cycle. Generally, the number of sunspots increases and decrease over an **11-year cycle** (G3A11), and HF propagation is best at times when there are many sunspots. Because of this, **six or ten meters** may provide long distance communications during the peak of the sunspot cycle. (T3C12) HF propagation conditions vary in a 28 day cycle because of **the Sun's rotation on its axis**. (G3A10) **Higher sunspot numbers generally indicate a greater probability of good propagation at higher frequencies** in the HF and lower VHF bands. (G3A01) & (G3A09) The 20 meter band usually supports worldwide propagation **at any point in the solar cycle**. (G3A07) During periods of low solar activity, the bands that are least reliable for long distance contacts are **15 meters, 12 meters and 10 meters**. (G3A04)

The solar flux index is **a measure of solar radiation at 10.7 centimeters wavelength**. (G3A05) It takes approximately **8 minutes** for the increased ultraviolet and X-ray radiation from solar flares to affect radio propagation on the Earth. (G3A03) A Sudden Ionospheric Disturbance affects daytime propagation on HF because **it disrupts signals on lower frequencies more than those on higher frequencies**. (G3A02)

A geomagnetic storm is **a temporary disturbance in the Earth's magnetosphere**. (G3A06) A geomagnetic storm results in **degraded high-latitude HF propagation**. (G3A08) When charged particles from solar coronal holes reach the Earth, **HF communications are disturbed**. (G3A14) The charged particles from coronal mass ejections (CMEs), takes **20 to 40 hours** to affect radio propagation on Earth. (G3A15) One benefit to radio communications during periods of high geomagnetic activity is that **auroras can reflect VHF signals**. (G3A16) Two important indicators of geomagnetic activity are the K-index and the A-index. The K-index measures **the short term stability of the Earth's magnetic field**. (G3A12) The A-index measures **the long term stability of the Earth's geomagnetic activity**. (G3A13)

Because of the way that the ionosphere changes throughout the day, propagation is best on the higher frequency bands, such as 10m, 15m and 20m, during the day while propagation is best on the lower frequency bands (160m, 80m, and 40m) at night. Consequently, the best time for long-distance 10 meter band propagation via the F layer is **from dawn to shortly after sunset during periods of high sunspot activity**. (T3C09) A good indicator of the possibility of sky-wave propagation on the 6-meter band would be **short skip sky-wave propagation on the 10-meter band**. (G2B02)

A common phenomenon of HF signal propagation is fading. The cause of irregular fading of signals from distant stations during times of generally good reception is **random combining of signals arriving via different path lengths**. (T3A08) If you had a sky-wave signal arriving at your receiver that traveled by both long and short paths, **a well-defined echo might be heard**. (G3B01) Unlike VHF/UHF communications, antenna polarization is not quite so important. This is because signals "skip" off the ionosphere and become elliptically polarized. Because skip signals refracted from the ionosphere are elliptically polarized, **either vertically or horizontally polarized antennas may be used for transmission or reception**. (T3A09)

By looking at the previous information in more practical terms, we can see the effects of how the radio waves behave. Two common terms for the upper and lower frequency limits during changing propagation conditions are MUF and LUF. MUF stands for **the Maximum Usable Frequency for communications between two points**. (G3B08). LUF stands for **the Lowest Usable Frequency for communications between two points**. (G3B07) When choosing a frequency that is attenuated the least on HF, **select a frequency just below the MUF**. (G3B03) Radio waves on frequencies between the MUF and LUF **are bent back to Earth**. (G3B05) Frequencies above the MUF penetrate the ionosphere and escape into outer space. Radio waves below the LUF **are completely absorbed by the ionosphere** and limit your coverage area. (G3B06) When the LUF reaches above the MUF during certain solar conditions, **no HF frequency will support ordinary sky-wave communications over the path**. (G3B11)

A reliable way to determine if the MUF is high enough to support skip propagation on frequencies between 14 and 30 Mhz is to **listen for signals from an international beacon in the frequency range you plan to use**. (G3B04) **All of these choices are correct** for factors affecting MUF (G3B12):

Path distance and location

Time of day and season

Solar radiation and ionospheric disturbances

The purpose of a beacon station as identified in the FCC rules is the observation of propagation and reception (G1B03). Beacon stations are limited to **100 watts PEP output**. (G1B10) **There must be no more than one beacon signal transmitting in the same band from the same station location**. (G1B02)

The term “critical angle” is **the highest takeoff angle that will return a radio wave to the Earth under specific ionospheric conditions**. (G3C04) Anything higher will probably not be reflected and pass on out of the ionosphere. A special technique for covering a regional area, up to 400 miles, in an umbrella-like fashion is called NVIS or Near Vertical Incident Sky-wave and has been described as a poor man’s satellite. NVIS covers **short distance MF and HF propagation using high elevation angles**. (G3C13)

Another way that HF signals cover varied distances is called **scatter** and allows a signal to be detected at a distance too far for ground wave but too near for normal sky-wave propagation. (G2C09) HF scatter signals heard are usually weaker because **only a small part of the signal energy is scattered into the skip zone**. (G3C08) The signal often sounds distorted because **energy is scattered into the skip zone through several different radio wave paths**. (G3C07) An indication that signals heard on the HF bands are via scatter propagation is that **the signal is heard on a frequency above the Maximum Usable Frequency**. (G3C10) **All of these choices are correct** in determining the characteristic of HF scatter signals (G3C06):

The have high intelligibility

They have a wavering sound

They have very large swings in signal strength

The best antenna type for skip communications on 40-meters during the day is **a horizontal dipole placed between 1/8 and 1/4 wavelength above the ground**. (G3C11) This works out to be 16 to 33 feet high.

Operating Procedures

FM Operation

A **repeater station** is the type of amateur station that simultaneously retransmits the signal of another amateur station on a different channel or channels. (T1F09) **Auxiliary, repeater, or space stations** amateur stations can automatically retransmit the signals of other amateur stations. (T1D07)

To use repeaters, you need to know how to set up your radio. Repeaters receive on one frequency and transmit on another. You program your radio so that it receives on the repeater's transmit frequency and transmits on the repeater's receive frequency.

The difference between the transmit frequency and receive frequency is called the repeater frequency offset. **Plus or minus 600 kHz** is the most common repeater frequency offset in the2 meter band. (T2A01) **Plus or minus 5 MHz** is a common repeater frequency offset in the 70cm band. (T2A03)

Repeater operation is called duplex operation because you're transmitting and receiving on two different frequencies. **When the stations can communicate directly without using a repeater**, you should consider communicating via simplex rather than a repeater. (T2B12) **Simplex communication** is the term used to describe an amateur station that is transmitting and receiving on the same frequency. (T2B01)

To help amateurs operating simplex find one another, frequencies on each band have been set aside as "national calling frequencies." **446.000 MHz** is the national calling frequency for FM simplex operations in the 70 cm band. (T2A02) 146.52 MHz is the national calling frequency for FM simplex operation in the 2 m band.

Because repeaters often operate in environments where there is a lot of interference they are programmed not to operate unless the station they are receiving is also transmitting a subaudible tone of a specific frequency. These tones are sometimes called PL (short for "private line") tones or CTCSS (short for "continuous tone-coded squelch system") tones. **CTCSS** is the term used to describe the use of a sub-audible tone transmitted with normal voice audio to open the squelch of a receiver. (T2B02) If your radio has not been programmed to transmit the proper sub-audible tone when you transmit, the repeater will not repeat your transmission.

All of these choices are correct when talking about common problems that might cause you to be able to hear but not access a repeater even when transmitting with the proper offset: (T2B04)

The repeater receiver requires audio tone burst for access

The repeater receiver requires a CTCSS tone for access

The repeater receiver may require a DCS tone sequence for access

One of the controls on a VHF/UHF transceiver is the squelch control. **Carrier squelch** is the term that describes the muting of receiver audio controlled solely by the presence or absence of an RF signal. (T2B03) You can set this control so that you only get an audio output when receiving a signal over a set threshold level.

Microphone gain is also an important control. The reason for this is that **the amplitude of the modulating signal** determines the amount of deviation of an FM signal. (T2B05) When the deviation of an FM transmitter is increased, **its signal occupies more bandwidth**. (T2B06) One thing that could cause your FM signal to interfere with stations on nearby frequencies is that you have set your **microphone gain too high, causing over-deviation**. (T2B07)

In addition to knowing how to set the controls of your radio, you need to know the protocol for making contacts. First, when using a repeater, it is rare to hear stations calling CQ. In place of "CQ," **say your call sign** to indicate that you are listening on a repeater. (T2A09) An appropriate way to call another station on a repeater if you know the other station's call sign is to **say the station's call sign then identify with your call sign**. (T2A04)

HF Operation

On the HF bands, when you want to contact another station, you “call CQ.” That is to say, you would say something like, “CQ CQ CQ. This is N2NOV.” The meaning of the procedural signal “CQ” is **calling any station**. (T2A08) **All of these choices are correct** when choosing an operating frequency for calling CQ (T2A12):

Listen first to be sure that no one else is using the frequency

Ask if the frequency is in use

Make sure you are in your assigned band

When responding to a call of CQ, you should transmit **the other station’s call sign followed by your call sign.** (T2A05) If W4ABC heard my call and wanted to talk to me, he would reply, “N2NOV this is W4ABC. Over.” Then, I would return the call, and our contact would begin.

It’s important to always identify your station, even when only performing tests. An amateur operator must **properly identify the transmitting station** when making on-air transmissions to test equipment or antennas. (T2A06) When making a test transmission, **station identification is required at least every ten minutes during the test and at the end**. (T2A07)

The expression "CQ DX" usually indicates **the caller is looking for any station outside their own country**. (G2A11)

A practical way to avoid harmful interference on an apparently clear frequency before calling CQ on CW or phone is to **send "QRL?" on CW, followed by your call sign; or, if using phone, ask if the frequency is in use, followed by your call sign**. (G2B06) The customary minimum frequency separation between SSB signals under normal conditions is approximately **3 kHz**. (G2B05) When selecting a CW transmitting frequency, the minimum separation should be **150 to 500 Hz** to minimize interference to stations on adjacent frequencies. (G2B04)

The "DX window" in a voluntary band plan **is a portion of the band that should not be used for contacts between stations within the 48 contiguous United States**. (G2B08) **Following the voluntary band plan for the operating mode you intend to use** complies with good amateur practice when choosing a frequency on which to initiate a call. (G2B07)

If propagation changes during your contact and you notice increasing interference from other activity on the same frequency, **as a common courtesy, move your contact to another frequency**. (G2B03)

Matching your transmit frequency in CW operation to the frequency of a received signal is called "zero beat". (G2C06)

The advantage of using full break-in telegraphy (QSK) allows **transmitting stations to receive between code characters and elements**. (G2C01)

The best speed to use when answering a CQ in Morse code is **the speed at which the CQ was sent**. (G2C05) If a CW station sends "QRS", you should **send slower**. (G2C02)

When a CW operator sends "KN" at the end of a transmission it means he or she is **listening only for a specific station or stations**. (G2C03) The prosign **“AR”** is sent to indicate the end of a formal message when using CW. (G2C08)

The Q signal "QSL" means, **I acknowledge receipt**. (G2C09)
The Q signal "QRL?" means, **"Are you busy?" or "Is this frequency in use?"** (G2C04)
The Q signal "QRV" means, **I am ready to receive messages**. (G2C11)
The Q signal "QRN" means **I am troubled by static**. (G2C10)

When sending CW, a "C" mean added to the RST report indicates a **chirpy or unstable signal**. (G2C07)

To shorten the number of characters sent during a CW contact, amateurs often use three-letter combinations called Q-signals. **QRM** is the “Q” signal used to indicate that you are receiving interference from other stations. (T2B10) The “Q” signal used to indicate that you are changing frequency is **QSY**. (T2B11)

Single sideband is the mode of voice communication is most commonly used on the HF amateur bands. (G2A05) On single sideband voice mode, **only one sideband is transmitted; the other sideband and carrier are suppressed**. (G2A07) The advantage of using single sideband as compared to other analog voice modes on the HF amateur bands is that **less bandwidth is used with greater power efficiency**. (G2A06)

Current amateur practice is to use lower sideband on lower frequencies. (G2A09) **Lower sideband** is most commonly used for voice communications on the 160-meter, 75-meter, and 40-meter bands. (G2A02) **Upper sideband** is most commonly used for voice communications on frequencies of 14 MHz (20 meters) or higher, such as 17 and 12 meters. (G2A01) (G2A04) **Upper sideband** is most commonly used for SSB voice communications in the VHF and UHF bands. (G2A03)

To break into a contact when using phone, **say your call sign during a break between transmissions by the other stations**. (G2A08)

VOX operation **allows "hands free" operation** versus PTT operation. (G2A10)

The Amateur Auxiliary are **amateur volunteers who are formally enlisted to help the FCC monitor the airwaves for rules violations**. (G2D01) The objective of the Amateur Auxiliary is **to encourage self-regulation and compliance with the rules by radio amateur operators**. (G2D02).

Direction finding used to locate stations during hidden transmitter hunts is a skill that is helpful to the Amateur Auxiliary for locating stations **violating FCC Rules**. (G2D03)

An azimuthal projection map **shows true bearings and distances from a particular location**. (G2D04)

It permissible to communicate with amateur stations in countries outside the areas administered by the Federal Communications Commission **when the contact is with amateurs in any country except those whose administrations have notified the ITU that they object to such communications**. (G2D05)

When making a "long-path" contact with another station, a directional antenna pointed **180 degrees from its short-path heading**. (G2D06)

A station log is kept by many amateurs **to help with replying if the FCC requests information**. (G2D08)

The details traditionally contained in a station log include (**all of these choices are correct**): (G2D09)

- Date and time of contact
- Band and/or frequency of the contact
- Call sign of station contacted and the signal report given

QRP is a **low power transmit operation**. (G2D10) It is typically 5 watts or less.

A directional antenna is best to use for minimizing interference during HF operation. (G2D11)

When operating in the 60-meter band, **if you are using other than a dipole antenna, the FCC rules require you to keep a record of the gain of your antenna**. (G2D07)

General Guidelines

FCC rules specify broadly where amateur radio operators have operating privileges, but are not very detailed. Band plans take this one step further, suggesting where amateurs should use certain modes. While consulting a band plan before operating is a good idea, realize that a band plan is **a voluntary guideline for using different modes or activities within an amateur band**. (T2A10)

Regarding power levels used in the amateur bands under normal, non-distress circumstances, the FCC rules state that, **while not exceeding the maximum power permitted on a given band, use the minimum power necessary to carry out the desired communication**. (T2A11) So, while you are authorized to use up to 1,500 W output power on HF and above (200W on HF for Techs), you should only use that much power when you really need it.

The basics of good operation include keeping your signals clean and avoid interference to other stations. When two stations transmitting on the same frequency interfere with each other, **common courtesy should prevail, but no one has absolute right to an amateur frequency**. (T2B08) **Except during FCC declared emergencies, no one has priority access to frequencies**. (G2B01)

When identifying your station when using phone, **use of a phonetic alphabet** is encouraged by the FCC. (T2B09) Most hams around the world understand and use the NATO, or ITU phonetic alphabet. Learn it and use it.

Public service: emergency and non-emergency operations, applicability of FCC rules, net and traffic procedures, emergency restrictions

One of the reasons amateur radio exists at all is that ham radio operators are uniquely set up to provide emergency and public-service communications. As a result, many hams consider it an obligation to be prepared to help out when called upon to do so. This includes having the proper equipment and knowing the proper operating procedures.

Two organizations that provide emergency communications: the Radio Amateur Civil Emergency Service (RACES) and the Amateur Radio Emergency Service (ARES). There are other independent groups like **NYC-ARECS**, SATERN, statewide ACS organizations as in Pennsylvania or California, etc. The thing that both RACES and ARES have in common is that **both organizations may provide communications during emergencies**. (T2C04) The Amateur Radio Emergency Service (ARES) is a **group of licensed amateurs who have voluntarily registered their qualifications and equipment for communications duty in the public service**. (T2C12) **All of these choices are correct** when describing the Radio Amateur Civil Emergency Service (RACES) (T2C05):

A radio service using amateur frequencies for emergency management or civil defense communications

A radio service using amateur stations for emergency management or civil defense communications

An emergency service using amateur operators certified by a civil defense organization as being enrolled in that organization

When the President's War Emergency Powers have been invoked, the FCC may restrict normal frequency operations of amateur stations participating in RACES. (G2B10) **Only a person holding an FCC issued amateur operator license** may be the control operator of an amateur station transmitting in RACES to assist relief operations during a disaster. (G2B09)

When an emergency occurs, it's common for amateur radio operators to form a network or "net" to facilitate emergency communications. The net is led by the net control station, whose job it is to make sure that messages are passed in an efficient and timely manner. Stations other than the net control station are said to "check into" the net. An accepted practice for an amateur operator who has checked into an emergency traffic net is to **remain on frequency without transmitting until asked to do so by the net control station**. (T2C07) There are, however, times when a station may need to get the immediate attention of the net control station. If this is the case, an accepted practice to get the immediate attention of a net control station when reporting an emergency is to **begin your transmission by saying "Priority" or "Emergency" followed by your call sign**. (T2C06) The first thing you should do if you are communicating with another amateur station and hear a station in distress break in is to **acknowledge the station in distress and determine what assistance may be needed** (G2B02). When sending a distress call, **whichever frequency has the best chance of communicating the distress message should be used**. (G2B11) **At any time during an actual emergency**, an amateur station allowed to use any means at its disposal to assist another station in distress. (G2B12)

The term for messages passed between stations in an emergency net is "traffic," and the process of passing messages to and from amateur radio stations is called "handling traffic." Message traffic may be formal or informal. A characteristic of good emergency traffic handling is **passing messages exactly as received**. (T2C08) To insure that voice message traffic containing proper names and unusual words are copied correctly by the receiving station, **such words and terms should be spelled out using a standard phonetic alphabet**. (T2C03)

Formal traffic messages consist of four parts: preamble, address, text, and signature. The preamble in a formal traffic message is **the information needed to track the message as it passes through the amateur radio traffic handling system**. (T2C10) Part of the preamble is the check. **The check is a count of the number of words or word equivalents in the text portion of the message**. (T2C11) The address is the name and address of the intended recipient, the text is the message itself, and the signature is the part of the message that identifies the originator of the message.

An important thing to remember is that **FCC rules always apply** to the operation of an amateur station. (T2C01) Amateur station control operators are permitted to operate outside the frequency privileges of their license class **only if necessary in situations involving the immediate safety of human life or protection of property**. (T2C09)

In an emergency situation, amateur radio operators often find themselves using battery power. It is, therefore, important to keep batteries charged and ready to go. One way to recharge a 12-volt lead-acid station battery if the commercial power is out is to **connect the battery in parallel with a vehicle's battery and run the engine**. (T2C02)

Amateur satellite operation, Doppler shift, basic orbits, operating protocols, control operator, transmitter power considerations, satellite tracking, digital modes

As a Technician Class licensee, you can make contacts via amateur radio satellites. **Any amateur whose license privileges allow them to transmit on the satellite uplink frequency** may be the control operator of a station communicating through an amateur satellite or space station. (T8B01)

Amateur satellites are basically repeaters in space. As such they have an uplink frequency, which is the frequency on which you transmit and the satellite receives, and a downlink frequency, on which the satellite transmits and you receive. As with other transmissions, **the minimum amount of power needed to complete the contact** should be used on the uplink frequency of an amateur satellite or space station. (T8B02)

Often, the uplink frequency and downlink frequency are in different amateur bands. For example, when a satellite is operating in "mode U/V," **the satellite uplink is in the 70 cm band and the downlink is in the 2 meter band**. (T8B08) The 70 cm band is in the UHF portion of the spectrum, while the 2 meter band is in the VHF portion of the spectrum.

The International Space Station often has amateur radio operators on board. **Any amateur holding a Technician or higher class license** may make contact with an amateur station on the International Space Station using 2 meter and 70 cm band amateur radio frequencies. (T8B04) Like most amateur satellites, the Space Station is in low earth orbit. When used to describe an amateur satellite, the initials LEO mean that **the satellite is in a Low Earth Orbit**. (T8B10)

Amateur satellites are often equipped with beacons. A satellite beacon is **a transmission from a space station that contains information about a satellite**. (T8B05) **FM Packet** is a commonly used method of sending signals to and from a digital satellite. (T8B11)

How do you know when you are able to communicate via an amateur satellite? **A satellite tracking program** can be used to determine the time period during which an amateur satellite or space station can be accessed. (T8B03) **The Keplerian elements** are inputs to a satellite tracking program. (T8B06)

Two problems that you must deal with when communicating via satellite is Doppler shift and spin fading. Doppler shift is **an observed change in signal frequency caused by relative motion between the satellite and the earth station**. (T8B07) **Rotation of the satellite and its antennas** causes “spin fading” of satellite signals. (T8B09)

LSB is normally used when sending an RTTY signal via AFSK with an SSB transmitter. (G2E01)

USB is the standard sideband used to generate a JT65 or JT9 digital signal when using AFSK in any amateur band. (G2E05)

The **14.070 - 14.100 MHz** segment of the 20-meter band is most often used for digital transmissions. (G2E04) On the 20-meter band are most PSK31 operations are commonly found **below the RTTY segment, near 14.070 MHz**. (G2E08) The **3570 - 3600 kHz** segment of the 80-meter band is most commonly used for digital transmissions. (G2E07)

The most common frequency shift for RTTY emissions in the amateur HF bands is **170 Hz**. (G2E06)

All of these choices are correct if you cannot decode an RTTY or other FSK signal even though it is apparently tuned in properly (G2E14):

- The mark and space frequencies may be reversed
- You may have selected the wrong baud rate
- You may be listening on the wrong sideband

A waterfall display shows **frequency in the horizontal direction, signal strength is intensity, time is vertical**. (G2E12)

On a waterfall display, one or more vertical lines adjacent to a PSK31 signal indicates **overmodulation**. (G2E11)

To establish contact with a digital messaging system gateway station, **transmit a connect message on the station’s published frequency**. (G2E10)

Winlink is a communication system that sometimes uses the Internet to transfer messages. (G2E13)

A PACTOR modem or controller be used to determine if the channel is in use by other PACTOR stations by **putting the modem or controller in a mode which allows monitoring communications without a connection**. (G2E02) **Joining an existing contact between two stations using the PACTOR protocol is not possible, PACTOR connections are limited to two stations**. (G2E09)

All of these choices are correct for symptoms that may result from other signals interfering with a PACTOR or WINMOR transmission (G2E03):

- Frequent retries or timeouts
- Long pauses in message transmissions
- Failure to establish a connection between stations

Operating activities: radio direction finding, radio control, contests, linking over the Internet, grid locators

There are many different ways to have fun with amateur radio. **Contesting**, for example, is a popular operating activity that involves contacting as many stations as possible during a specified period of time. (T8C03) When contacting another station in a radio contest, a good procedure is to **send only the minimum information needed for proper identification and the contest exchange**. (T8C04)

In VHF/UHF contests, stations often send each other their grid locators. A grid locator is **a letter-number designator assigned to a geographic location**. (T8C05)

One fun activity that is very practical is radio direction finding. You would use radio direction finding equipment and skills to participate in a hidden transmitter hunt, sometimes called a “fox hunt.” In addition to participating in this kind of contest, **radio direction finding** is one of the methods used to locate sources of noise interference or jamming. (T8C01) **A directional antenna** would be useful for a hidden transmitter hunt. (T8C02)

Some amateurs get licensed because they like to build and operate radio-controlled models, including boats, planes, and automobiles. The maximum power allowed when transmitting telecommand signals to radio controlled models is **1 watt**. (T8C07) In place of on-air station identification when sending signals to a radio control model using amateur frequencies, **a label indicating the licensee’s name, call sign and address must be affixed to the transmitter**. (T8C08)

If the only radios that you have are VHF or UHF radios, you might want to look into EchoLink and the Internet Radio Linking Project (IRLP). Both systems provide a way to communicate with amateurs far away with a VHF or UHF transceiver.

The Internet Radio Linking Project (IRLP) is **a technique to connect amateur radio systems, such as repeaters, via the Internet using Voice Over Internet Protocol**. (T8C13) Voice Over Internet Protocol (VoIP), as used in amateur radio, is **a method of delivering voice communications over the Internet using digital techniques**. (T8C12)

Stations that connect to EchoLink or IRLP are called nodes. One way to obtain a list of active nodes that use VoIP is **from a repeater directory**. (T8C09) You access an IRLP node **by using DTMF signals**. (T8C06) To select a specific IRLP node when using a portable transceiver, **use the keypad to transmit the IRLP node ID**. (T8C10)

Sometimes nodes are also called gateways. **A gateway** is the name given to an amateur radio station that is used to connect other amateur stations to the Internet. (T8C11)

Amateur radio practices and station setup

Station setup: connecting microphones, reducing unwanted emissions, power source, connecting a computer, RF grounding, connecting digital equipment

When setting up an amateur radio station, choosing the radio itself is the most important consideration, but you must also choose a wide range of accessories, such as power supplies and microphones. In addition, how you set up the station is important for it to operate efficiently.

One accessory that you'll definitely need is a power supply to provide the DC voltage and current that your radio needs. A good reason to use a regulated power supply for communications equipment is that **it prevents voltage fluctuations from reaching sensitive circuits**. (T4A03) When choosing a supply, check the voltage and current ratings of the supply and be sure to choose one capable of supplying a high enough voltage and enough current to power your radio.

If you are going to operate with one of the voice modes, you'll need a microphone. When considering the micro hone connectors on amateur transceivers, note that **some connectors include push-to-talk and voltages for powering the microphone**. (T4A01)

A computer has become a very common accessory in an amateur radio "shack." **All of these choices are correct** when talking about how a computer is used as part of an amateur radio station (T4A02):

For logging contacts and contact information

For sending and/or receiving CW

For generating and decoding digital signals

If you plan to operate packet radio, you will need a computer and a terminal node controller, or TNC, in addition to the radio. A **terminal node controller** would be connected between a transceiver and computer in a packet radio station. (T4A06) The TNC converts the ones and zeroes sent by the computer into tones sent over the air.

A more modern way to operate digital modes, such as RTTY or PSK-31, is to use a computer equipped with a sound card. When conducting digital communications using a computer, **the sound card provides audio to the microphone input and converts received audio to digital form**. (T4A07) The sound card may be connected directly to the radio, but it's usually better to connect it through a device that isolates the radio from the computer. This prevents ground loops from causing the signal to be noisy.

Audio and power supply cables in an amateur radio station sometimes pick up stray RF. At minimum, this RF can cause the audio to be noisy. At worst, it can cause a radio or accessory to malfunction. To reduce RF current flowing on the shield of an audio cable (or in a power supply cable), you would use a **ferrite choke**. (T4A09)

Modern radio equipment is very well designed, and harmonic radiation is rarely a problem these days. Even so, there may be times when it does become a problem, and you'll have to take steps to attenuate the harmonics. To reduce harmonic emissions, a filter must be installed **between the transmitter and the antenna**. (T4A04)

Good grounding techniques can help you avoid interference problems. When grounding your equipment, you should connect the various pieces of equipment to a single point, keep leads short, and use a heavy conductor to connect to ground. **Flat strap** is the type of conductor that is best to use for RF grounding. (T4A08)

If you plan to install a radio in your car and operate mobile, you have a different set of challenges. One is connecting the radio to the car's power system. Some amateurs connect their radio with a cigarette lighter plug, but this plug is not designed for high currents. Instead, a mobile transceiver's power negative connection should be made **at the battery or engine block ground strap**. (T4A11) The positive connection can also be made at the battery or through an unused position of the vehicle's fuse block.

Another challenge is noise generated by the car itself. One thing that could be happening if another operator reports a variable high-pitched whine on the audio from your mobile transmitter is that **noise on the vehicle's electrical system is being transmitted along with your speech audio**. (T4A12)

The alternator is often the culprit. **The alternator** is the source of a high-pitched whine that varies with engine speed in a mobile transceiver's receive audio. (T4A10) Should this be a problem, there are filters that you can install to mitigate the alternator whine. One thing that would reduce ignition interference to a receiver is to **turn on the noise blanker**. (T4B05)

Operating controls: tuning, use of filters, squelch function, AGC, repeater offset, memory channel

To properly operate a transceiver, you need to know how to use the controls. Perhaps the most important transmitter control is microphone gain. If a transmitter is operated with the microphone gain set too high, **the output signal might become distorted**. (T4B01) On an HF transceiver it is called the Automatic Level Control (ALC) and it is used **to reduce distortion due to excessive drive**. (G4A05) **Excessive drive power** can lead to permanent damage to a solid-state RF power amplifier. (G4A07) What is likely to happen if the ALC is not set properly when transmitting AFSK signals is the **improper action of ALC distorts the signal and can cause spurious emissions**. (G4A14)

You also need to know how to set the operating frequency of your transceiver. **The keypad or VFO knob** can be used to enter the operating frequency on a modern transceiver. (T4B02) A way to enable quick access to a favorite frequency on your transceiver is to **store the frequency in a memory channel**. (T4B04) On an HF transceiver, the dual VFO feature is **to permit monitoring of two different frequencies**. (G4A12)

A common receiver control on VHF/UHF transceivers is the squelch control. The purpose of the squelch control on a transceiver is **to mute receiver output noise when no signal is being received**. (T4B03) If set too high then you will not be able to hear low-level signals.

Another common setting on VHF/UHF transceivers is the offset frequency. This is especially important when operating repeaters. The common meaning of the term “repeater offset” is **the difference between the repeater's transmit and receive frequencies**. (T4B11) This is similar to operating an HF transceiver in “split” mode, where **the transceiver is set to different transmit and receive frequencies**. (G4A03)

A common receiver control on HF transceivers is the RIT control. The term “RIT” means **Receiver Incremental Tuning**. (T4B07) **The receiver RIT or clarifier** are controls that could be used if the voice pitch of a single-sideband signal seems too high or low. (T4B06) The IF shift control on a receiver is **to avoid interference from stations very close to the receive frequency**. (G4A11) The attenuator function is **to reduce signal overload due to strong incoming signals**. (G4A13)

Another common control on a receiver is the automatic gain control, or AGC. Its function is **to keep received audio relatively constant**. (T4B12) This is important because HF signal strengths can vary widely and that can cause audio levels to vary widely as well.

HF transceivers are often equipped with a variety of different filters. The advantage of having multiple receive bandwidth choices on a multimode transceiver is that it **permits noise or interference reduction by selecting a bandwidth matching the mode**. (T4B08) For example, **2400 Hz** is an appropriate receive filter to select in order to minimize noise and interference for SSB reception. (T4B09) **500 Hz** is an appropriate receive filter to select in order to minimize noise and interference for CW reception. (T4B10) The notch filter is **to reduce interference from carriers in the receive passband**. (G4A01) One advantage to selecting the opposite or "reverse" sideband when receiving CW is that **it may be possible to reduce or eliminate interference from other signals**. (G4A02)

A common transmitter control is push-to-talk, or PTT. **The push to talk function is the function which switches between receive and transmit**. (T7A07) Most of the time PTT refers to an actual switch on the microphone that an operator must push to begin transmitting, but it also refers to the name of a signal line on a transceiver's accessory socket that can be used to automatically switch a transceiver into transmit mode.

All of these choices are correct when transmitted RF is picked up in the audio cables carrying AFSK signals between a computer and a transceiver (G4A15):

The VOX circuit does not un-key the transmitter

The transmitter signal is distorted

Frequent connection timeouts

Electrical principles: math for electronics, electronic principles, Ohm’s Law, Power Law

Electrical principles, units, and terms: current and voltage, conductors and insulators, alternating and direct current, resistance, power, inductance, capacitance, reactance, impedance

You don't have to be an electronics engineer to get a Technician Class license, but it does help to know the basics of electricity and some of the units we use in electronics. The most important concepts are current, voltage, resistance, power, and frequency.

Voltage is the force that causes electrons to flow in a circuit. Voltage is sometimes called electromotive force, or EMF. **Voltage** is the electrical term for the electromotive force (EMF) that causes electron flow. (T5A05) **The volt** is the basic unit of electromotive force. (T5A11) The letter V is the symbol we use for volts. **About 12 volts** is the amount of voltage that a mobile transceiver usually requires. (T5A06)

Current is the name for the flow of electrons in an electric circuit. (T5A03) Electrical current is measured in **amperes**. (T5A01) **Direct current** is the name for a current that flows only in one direction. (T5A04) Batteries supply direct current, or simply DC.

Alternating current is the name for a current that reverses direction on a regular basis. (T5A09) **Frequency** is the term that describes the number of times per second that an alternating current reverses direction. (T5A12) Alternating current, or AC, is what is available from your home’s wall sockets. Power supplies convert the AC into DC, which is required for most modern amateur radio equipment.

Resistance is the term used to describe opposition to current flow in a circuit. The basic unit of resistance is the ohm. The Greek letter omega (Ω) is shorthand for ohms.

Conductors are materials that conduct electrical current well, or, in other words, have a low resistance. The copper wires that we use to connect a power supply to a radio are good conductors because **copper** is a good electrical conductor. (T5A07)

Insulators are materials that that have a high resistance. They do not conduct electrical current very well. Plastics and **glass**, for example, are good electrical insulators. (T5A08)

The term that describes the rate at which electrical energy is used (or generated) is **power**. (T5A10) Electrical power is measured in **watts**. (T5A02) The letter W is the symbol we use for watts.

Ohm's Law: formulas and usage

Ohm's Law is the relationship between voltage, current, and the resistance in a DC circuit. When you know any two of these values, you can calculate the third.

The most basic equation for Ohm's Law is:

$$E = I \times R$$

In other words, when you know the current going into a circuit and the resistance of the circuit, the formula used to calculate voltage across the circuit is **voltage (E) equals current (I) multiplied by resistance (R).** (T5D02)When you know the voltage across a circuit and the current in a circuit, the formula used to calculate resistance in a circuit is **resistance (R) equals voltage (E) divided by current (I).** (T5D03) We can also write this formula as

$$R = E \div I$$

When you know the voltage across a circuit and the resistance of a circuit, the formula used to calculate current in the circuit is **current (I) equals voltage (E) divided by resistance (R)**. (T5D01) This formula is written

$$I = E \div R$$

Examples:

The resistance of a circuit in which a current of 3 amperes flows through a resistor connected to 90 volts is **30 ohms**. (T5D04)

$$R = E \div I = 90\ V \div 3\ A = 30\ \Omega$$

The resistance in a circuit for which the applied voltage is 12 volts and the current flow is 1.5amperes is **8 ohms**. (T5D05)

$$R = E \div I = 12\ V \div 1.5\ A = 8\ \Omega$$

The resistance of a circuit that draws 4 amperes from a 12-volt source is **3 ohms**. (T5D06)

$$R = E \div I = 12\ V \div 4\ A = 3\ \Omega$$

The current flow in a circuit with an applied voltage of 120 volts and a resistance of 80 ohms is **1.5 amperes**. (T5D07)

$$I = E \div R = 120\ V \div 80\ \Omega = 1.5\ A$$

The current flowing through a 100-ohm resistor connected across 200 volts is **2 amperes**. (T5D08)

$$I = E \div R = 200\ V \div 100\ \Omega = 2\ A$$

The current flowing through a 24-ohm resistor connected across 240 volts is **10 amperes**. (T5D09)

$$I = E \div R = 240\ V \div 24\ \Omega = 10\ A$$

The voltage across a 2-ohm resistor if a current of 0.5 amperes flows through it is **1 volt**. (T5D10)

$$E = I \times R = 0.5\ A \times 2\ \Omega = 1\ V$$

The voltage across a 10-ohm resistor if a current of 1 ampere flows through it is **10 volts**. (T5D11)

$$E = I \times R = 1\ A \times 10\ \Omega = 10\ V$$

The voltage across a 10-ohm resistor if a current of 2 amperes flows through it is **20 volts**. (T5D12)

$$E = I \times R = 2\ A \times 10\ \Omega = 20\ V$$

The total current of a parallel resistive circuit is equal to **the sum of the current through each branch**. (G5B02)

Resistors

A **resistor** is the electrical component used to oppose the flow of current in a DC circuit. (T6A01) Most resistors have a fixed value, which is specified in ohms. Some resistors are variable, which is you can change the resistance of the resistor by turning a shaft or sliding a control back and forth. These variable resistors are called potentiometers. A **potentiometer** is the type of component that is often used as an adjustable volume control. (T6A02) **Resistance** is the electrical parameter that is controlled by a potentiometer. (T6A03)

Resistors come in different formats. There are the common carbon resistors, metal film resistors and wire-wound resistors. A reason to not use wire-wound resistors in an RF circuit is that **the resistor's inductance could make circuit performance unpredictable**. (G6A17) The wire-wound resistor can be found in power supplies. More about inductance later

Adding **a resistor in series** to an existing resistor increases the total resistance. (G5C03)

Rtotal = R1 + R2 + R3 etc

If three equal resistors in series produces 450 ohms, the value of each resistor is **150 ohms**. (G5C05)

However, if resistors are added in parallel to each other, the total resistance decreases since there is now more than one path for the electrons to travel. The total resistance of three 100 ohms resistors in parallel is **33.3 ohms**. (G5C04) Total resistance of **a 10 ohm, a 20 ohm and a 50 ohm resistor connected in parallel is 5.9 ohms**. (G5C15)

Rtotal = 1/ (1/R1+1/R2+1/R3 etc)

If the temperature is increased, **the resistance will change depending on the resistor's coefficient**. (G6A16)

Capacitors

The type of electrical component that consists of two or more conductive surfaces separated by an insulator is a **capacitor**. (T6A05) A **capacitor** is the electrical component that stores energy in an electric field. (T6A04) **Capacitance** is the ability to store energy in an electric field. (T5C01) **The farad** is the basic unit of capacitance. (T5C02)

The larger the surface area of the plates, the more charge they can store. To increase capacitance, we would add **a capacitor in parallel**. (G5C13) If we have two 5 nanofarad capacitors in parallel and add a 750 picofarad capacitor in parallel, we will have a total capacitance of **10.750 nanofarads**. (G5C08)

However, if capacitors are added in series, this effectively increases the distance of the two parallel plates holding a charge and makes the total capacitance weaker. The total capacitance of **three 100 microfarad capacitors connected in series is 33.3 microfarads**. (G5C09) If we add a 20 microfarad capacitor in series with a 50 microfarad capacitor we get a total of **14.3 microfarads**. (G5C12)

Small ceramic capacitors are an advantage because of their **comparatively low cost**. (G6A14)

There are capacitors that only allow positive or negative charges on a certain side. These are called polarized or electrolytic capacitors. An advantage of an electrolytic capacitor is that they can handle a **high capacitance for a given volume**. (G6A15) **All of these choices are correct** for polarized capacitors: (G6A13)

Incorrect polarity can cause the capacitor to short-circuit

Reverse voltages can destroy the dielectric layer of an electrolytic capacitor

The capacitor could overheat and explode

Inductors

The type of electrical component that stores energy in a magnetic field is an **inductor**. T6A06 The electrical component that is usually composed of a coil of wire is an **inductor**.(T6A07) The ability to store energy in a magnetic field is called **inductance**. (T5C03) **The henry** is the basic unit of inductance. (T5C04) Inductors are coils of wire that can either create a magnetic field when electricity passes through it or create an electric current when it is in the presence of a magnetic field. Inductance increases when we connect **inductors in series**. (G5C14) and decreases when they are connected in parallel. When we add a 20 millihenry inductor in series with a 50 millihenry inductor, we get a total of **70 millihenrys**. (G5C11) Instead, when we add three 100 millihenry inductors in parallel, we get a total of **33.3 millihenrys**. (G5C10)

Inductors can be placed near each other so that when one creates a magnetic field from having an AC voltage source passing through it, it will cause the magnetic field passing the second inductor to create an AC voltage in the second inductor. This is how transformers are made. The ratio of the number of turns in each winding will determine the voltages induced. This is called **mutual inductance.** (G5C01) To minimize mutual inductance, as in two solenoid inductors near each other, turn them to **right angles to each other**. (G6A19)

The turns ratio of a transformer used to match an audio amplifier having 600 ohms output impedance to a speaker having a 4 ohm impedance is 12.2 to 1. (G5C07) **If you reverse the primary and secondary windings of a 4:1 voltage step down transformer, the secondary voltage becomes 4 times the primary voltage.** (G5C02)

The RMS voltage across a 500-turn secondary winding in a transformer with a 2250-turn primary connected to 120 volts AC which equals **26.7 volts**. (G5C06)

(500 secondary/2250 primary) * 120 Volts = 26.7 Volts

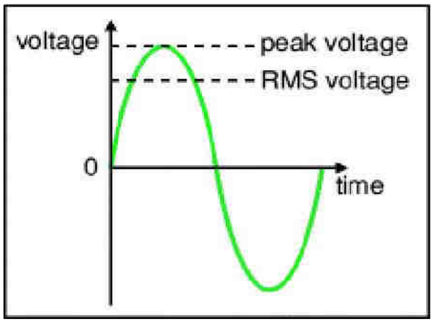
Inductors can be wound with nothing in the center (air-wound) or around a dampening material like a ferrite and clay compound. The advantage to using a ferrite core toroidal inductor, **all of these choices are correct**: (G6A18)

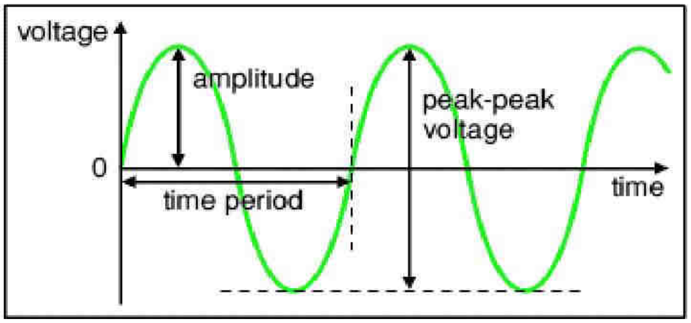
Large values of inductance may be obtained

The magnetic properties of the core may be optimized for a specific range of frequencies

Most of the magnetic field is contained in the core

To accommodate the higher current of the primary, the conductor in the primary winding of a transformer has a larger diameter than the secondary winding. (G5C16)





The RMS value of an AC signal produces the same power dissipation in a resistor as a DC voltage of the same value. (G5B07) RMS is equal to 70.7% of the positive peak voltage. The RMS voltage of a sine wave with a value of 17 volts peak is **12 volts**. (G5B09) The RMS voltage across a 50 ohm dummy load dissipating 1200 watts is **245 volts**. (G5B12)

SQRT (1200 Watts * 50 Ohms) = 245 Volts RMS

Electronic principles: DC power calculation

Power is the rate at which electrical energy is generated or consumed. The formula used to calculate electrical power in a DC circuit is **power (P) equals voltage (E) multiplied by current (I),** or P = E × I. (T5C08)

138 watts is the power being used in a circuit when the applied voltage is 13.8 volts DC and the current is 10 amperes. (T5C09)

P = E × I = 13.8 V × 10 A = 138 W

When the applied voltage in a circuit is 12 volts DC and the current is 2.5 amperes, the power being used is **30 watts**. (T5C10)

P = E × I = 12 V × 2.5A = 30 W

Just as with Ohm's Law, you can use algebra to come up with other forms of this equation to calculate the voltage if you know the power and the current, or to calculate the current if you know the power and the voltage. The formula to calculate the current, if you know the power and the voltage is I =P÷E.

For example, **10 amperes** are flowing in a circuit when the applied voltage is 12 volts DC and the load is 120 watts. (T5C11)

I = P ÷ E = 120 W ÷ 12 V = 10A

200 watts of electrical power is used through an 800 ohm load with 400 volts DC applied to it. (G5B03)

A 12 volt DC light bulb uses **2.4 watts** when it draws 0.2 amperes. (G5B04)

61 milliwatts is dissipated through a 1.25 kilohm resistor when 7 milliamperes goes through it. (G5B05)

Here are some examples of power calculations based on the output of a transmitter:

100 watts is the output PEP (Peak Envelope Power) from a transmitter if an oscilloscope measures 200 volts peak-to-peak across a 50 ohm dummy load. (G5B06)

(P-to-P Volts/2) * .707 = RMS Volts

(RMS Volts)^2 / Ohms = Watts

(70.7 Volts RMS * 70.7 Volts RMS) / 50 Ohms = 100 Watts

The ratio of peak envelope power to average power for an unmodulated carrier is **1.00**. (G5B11) **1060 watts** is the output PEP of an unmodulated carrier with an average reading on a wattmeter indicating 1060 watts. (G5B13) This is because a carrier is steady with no sidebands to bounce up and down with audio.

If an oscilloscope measures 500 volts peak-to-peak across a 50 ohm resistive load, the transmitter output PEP is **625 watts**. (G5B14)

(176.75 Volts RMS * 176.75 Volts RMS) / 50 Ohms = 625 Watts

Impedance

Impedance is **the opposition to the flow of current in an AC circuit**. (G5A01) It is measured in Ohms. This is not the same as resistance. Think of resistance for DC circuits and Impedance for AC circuits. This is because of the magnetic fields created by an increasing AC voltage that in turn creates an opposing current when the magnetic field collapses as the AC voltage drops in the next part of the sine wave.

When the impedance of an electrical load is equal to the output impedance of a power source, **the source can deliver maximum power to the load.** (G5A07)

One method to match impedance between two AC circuits is to **insert an LC network between the two circuits.** (G5A11)

For various devices to be used for impedance matching, **all of these choices are correct** (G5A13):

A transformer

A Pi-network

A length of transmission line

Reactance

Reactance is the **opposition to the flow of alternating current caused by <u>capacitance</u> or <u>inductance</u>**. (G5A02) It is also measured in Ohms.

With a capacitor, **as the frequency of the applied AC increases, the reactance decreases**. (G5A06)

With an inductor, **as the frequency of the applied AC increases, the reactance increases**. (G5A05)

Math for electronics: conversion of electrical units, decibels, the metric system

When dealing with electrical parameters, such as voltage, resistance, current, and power, we use a set of prefixes to denote various orders of magnitude:

milli - is the prefix we use to denote 1 one-thousandth of a quantity. A milliampere, for example, is 1 one-thousandth of an ampere, or 0.001 A. Often, the letter m is used instead of the prefix milli -. 1 milliampere is, therefore, 1 mA.

micro - is the prefix we use to denote 1 millionth of a quantity. A microvolt, for example, is 1 millionth of a volt, or 0.000001 V. Often you will see the Greek letter mu, or μ, to denote the prefix micro -. 1 microvolt is, therefore, 1 μV.

pico - is the prefix we use to denote 1 trillionth of a quantity. A picovolt is 1 trillionth of a volt, or 0.000001 μV.

kilo - is the prefix we use to denote 1 thousand of a quantity. A kilovolt, for example, is 1000 volts. Often, the letter k is used instead of the prefix kilo-. 1 kilovolt is, therefore, 1kV.

mega - is the prefix we use to denote 1 million of a quantity. A megahertz, for example, is 1 million Hertz. The unit of frequency is the **Hertz.** (T5C05) It is equal to one cycle per second. Often, the letter M is used instead of the prefix mega-. 1 megahertz is, therefore, 1 MHz.

giga - is the prefix we use to denote 1 billion of a quantity. A gigahertz, or GHz, for example is 1 billion Hertz.

Here are some examples:

1,500 milliamperes is 1.5 amperes. (T5B01)

Another way to specify a radio signal frequency of 1,500,000 hertz is **1500 kHz**. (T5B02)

One thousand volts are equal to one kilovolt. (T5B03)

One one-millionth of a volt is equal to one microvolt. (T5B04)

0.5 watts is equivalent to 500 milliwatts. (T5B05)

If an ammeter (a meter that measures current) calibrated in amperes is used to measure a 3000-milliampere current, the reading it would show would be **3 amperes**. (T5B06)

If a frequency readout calibrated in megahertz shows a reading of 3.525 MHz, it would show **3525 kHz** if it were calibrated in kilohertz. (T5B07)

1 microfarad is 1,000,000 picofarads. (T5B08) (Farad is the unit for capacitance.)

28.400 MHz is equal to 28,400 kHz. (T5B12)

If a frequency readout shows a reading of 2425 MHz, the frequency in GHz is **2.425 GHz**. (T5B13)

22 nF is the value in nanofarads of a 22,000 pF capacitor (G5C17)

4.7 uF is the value in microfarads of a 4700 nanofarad capacitor (G5C18)

When dealing with ratios—especially power ratios—we often use decibels (dB). The reason for this is that the decibel scale is a logarithmic scale, meaning that we can talk about large ratios with relatively small numbers. When the value is positive, it means that there is a power increase. When the value is negative, it means that there is a power decrease.

At this point, you don't need to know the formula used to calculate the ratio in dB, but keep in mind the following values:

3 dB is the approximate amount of change, measured in decibels (dB), of a power increase from 5 watts to 10 watts. (T5B09) This is a ratio of 2 to 1.

–**6 dB** is the approximate amount of change, measured in decibels (dB), of a power decrease from 12 watts to 3 watts. (T5B10) This is a ratio of 4 to 1.

10 dB is the approximate amount of change, measured in decibels (dB), of a power increase from 20 watts to 200 watts. (T5B11) This is a ratio of 10 to 1.

A 1dB loss in a transmission line would be equal to **20.5 percent**. (G5B10)

Other components: switches, fuses, batteries, solar panels

A **switch** is the electrical component used to connect or disconnect electrical circuits. (T6A08)

A **fuse** is the electrical component used to protect other circuit components from current overloads. (T6A09)

As amateur radio operators, we often use batteries to power our radio equipment. Some types of batteries are rechargeable, while others are not. The battery type that is not rechargeable is the **carbon-zinc** battery. (T6A11) **All of these choices are correct** when talking about battery types that are rechargeable (T6A10):

Nickel-metal hydride

Lithium-ion

Lead-acid gel-cell

Low internal resistance of a nickel-cadmium battery results in a **high discharge current**. (G6A02)

The minimum allowable discharge voltage for maximum life of a standard 12 volt lead acid battery is **10.5 volts** (G6A01)

Photovoltaic conversion is the name of the process where sunlight is changed into electricity. (G4E08) The approximate open-circuit voltage from a fully illuminated photovoltaic cell is **0.5 VDC**. (G4E09) You need to place a diode between a solar panel and a storage battery because **the diode prevents self-discharge of the battery through the panel during times if low or no illumination**. (G4E10)

A disadvantage to using wind as the primary source of power for an emergency station is that **a large storage system is needed to supply power when the wind is not blowing**. (G4E11)

Semiconductors: basic principles and applications of solid state devices, diodes and transistors

A **diode** is an electronic component that allows current to flow in only one direction. (T6B02)Diodes have only two electrodes. **Anode and cathode** are the names of the two electrodes of a diode. (T6B09) A semiconductor diode's cathode lead is usually identified **with a stripe**. (T6B06) The junction threshold voltage of a germanium diode is **0.3 volts**. (G6A03) The junction threshold voltage of a conventional silicone diode is **0.7 volts**. (G6A05) In an RF switching circuit, a Shottky diode has a **lower capacitance** than a standard silicone diode. (G6A06)

Light-emitting diodes are a particular type of diode. When current flows through them, they emit visible light, making them useful as indicators and as part of digital readouts. The abbreviation "LED" stands for **Light Emitting Diode**. (T6B07)

Transistors are electronic components capable of using a voltage or current signal to control current flow. (T6B01) The **transistor** is a component that can be used as either an electronic switch or amplifier. (T6B03) **Gain** is the term that describes a transistor's ability to amplify a signal. (T6B12) The **transistor** is an electronic component that can amplify signals. (T6B05)

A **transistor** is a component made of three layers of semiconductor material. (T6B04)Bipolar junction transistors have layers that are either P-type, which means that it has a positive net charge, or N-type, which means it has a net negative charge. Each layer has an electrode, making the transistor a device with three leads.

There are two types of bipolar junction transistors: PNP or NPN. A PNP transistor has two Players, with an N layer sandwiched between them. An NPN transistor has two N layers, with a P layer sandwiched between them. The three electrodes of a PNP or NPN transistor are the **emitter, base, and collector**. (T6B10)

Another type of transistor often found in amateur radio equipment is the field-effect transistor. The abbreviation "FET" stands for **Field Effect Transistor**. (T6B08) FETs, like NPN and PNP transistors have three leads. **Source, gate, and drain** are the three electrodes of a field effect transistor. (T6B11) In a MOSFET, **the gate is separated from the channel with a thin insulating layer**. (G6A09)

The stable operating points for a bipolar transistor when used as a switch in a logic circuit are **its saturation and cutoff regions**. (G6A07)

Large power transistors must be insulated from ground **to avoid shorting the collector or drain voltage to ground**. (G6A08)

A microprocessor is **a computer on a singled integrated circuit**. (G6B11)

Vacuum tube basics

The precursor to transistors was the vacuum tube. They can handle higher power and higher loads. Unfortunately, they require higher voltages, generate more heat than a transistor and are made of glass. Tubes have elements like cathode, plate, heater and various grids. A tube similar to a transistor is the triode. The element of a triode that regulates the flow of electrons between the cathode and plate is the **control grid**. (G6A10) The screen grid in a vacuum tube is used **to reduce grid-to-plate capacitance**. (G6A12) The tube is most like **a field effect transistor** in its general operating characteristics. (G6A11)

Circuit diagrams, schematic symbols, component functions

Schematic symbols are the name for standardized representations of components in an electrical wiring diagram. (T6C01) The symbols on an electrical circuit schematic diagram represent **electrical components**. (T6C12) **The way components are interconnected** is accurately represented in electrical circuit schematic diagrams. (T6C13)

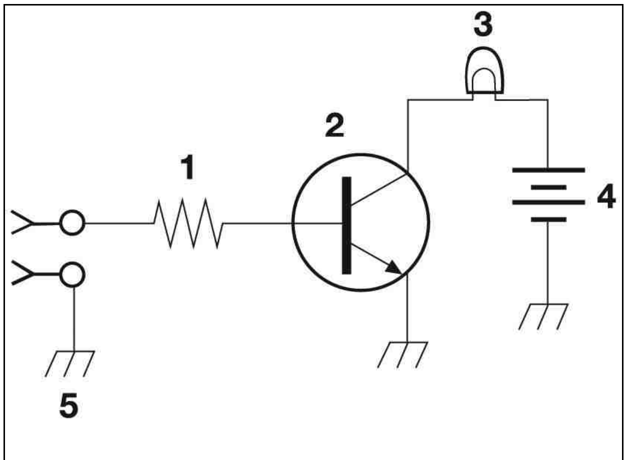


Figure T-1

Figure T1 is a schematic diagram of a simple circuit that turns on a lamp when a positive voltage is applied to the input.

Component 1 in figure T1 is a **resistor**. (T6C02) Its function is to limit the input current.

Component 2 in figureT1 is a **transistor**. (T6C03) Its function is to switch the current through the lamp on and off. The function of component 2 in Figure T1 is to **control the flow of current**. (T6D10)

Component 3 in figure T1 is the **lamp**. (T6C04)

Component 4 in figureT1 is a **battery**. (T6C05) This battery supplies the current that lights the lamp.

The circuit shown in Figure T2 is a simple power supply. Component 2 is a fuse.

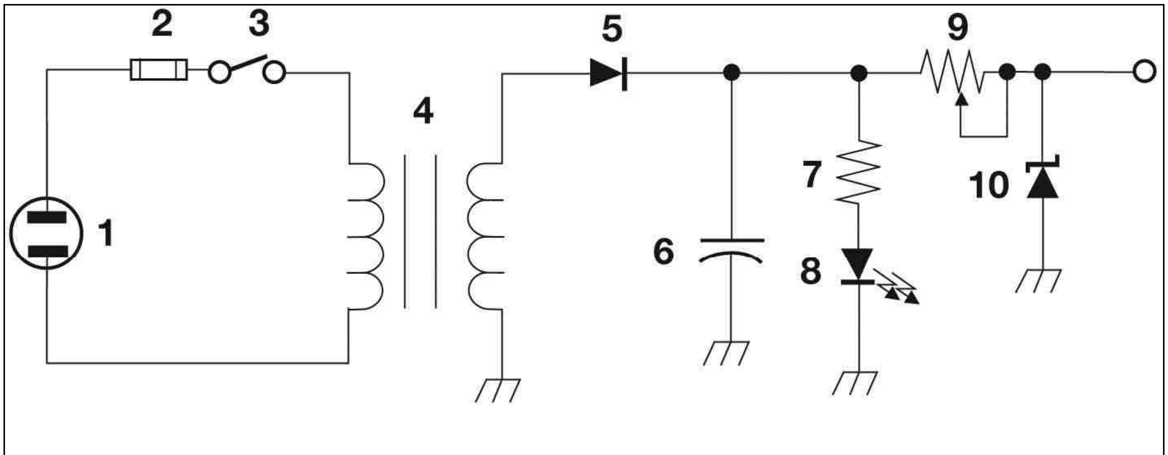


Figure T-2

Component 3 in figure T2 represents a **single-pole single-throw** switch. (T6D03) It turns the power supply on and off.

Component 4 in figure T2 is a **transformer**. (T6C09) A **transformer** is commonly used to change 120V AC house current to a lower AC voltage for other uses. (T6D06)

A **rectifier** changes an alternating current into a varying direct current signal. (T6D01) Component 5 in Figure T2 is a rectifier diode.

Component 6 in figure T2 is a **capacitor**. (T6C06) It is a filter capacitor, whose function is to help filter out the 60 Hz component of the rectified AC.

Component 8 in figure T2 is a **light emitting diode**. (T6C07). It is a pilot light, serving to alert a user when the power supply is on.

Component 9 in figure T2 is a **variable resistor**, or potentiometer. (T6C08) Its purpose is to limit the output current of the supply.

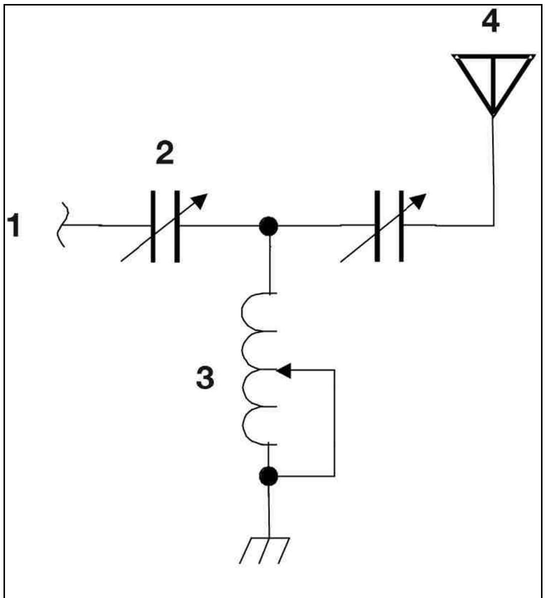


Figure T-3

The circuit shown in Figure T3 is the output circuit of a transmitter. Component 3 in figure T3 is a **variable inductor**. (T6C10)

There are two variable capacitors in this circuit - component 2 and the unlabeled component. A **capacitor** is used together with an inductor to make a tuned circuit. (T6D08)

Component 4 in figure T3 is an **antenna**. (T6C11)

An inductor and a capacitor connected in series or parallel to form a filter is a simple resonant or tuned circuit. (T6D11) When the capacitor and inductor are connected in series, the circuit has very low impedance at the resonant frequency. When the capacitor and inductor are connected in parallel, the circuit has very high impedance at the resonant frequency.

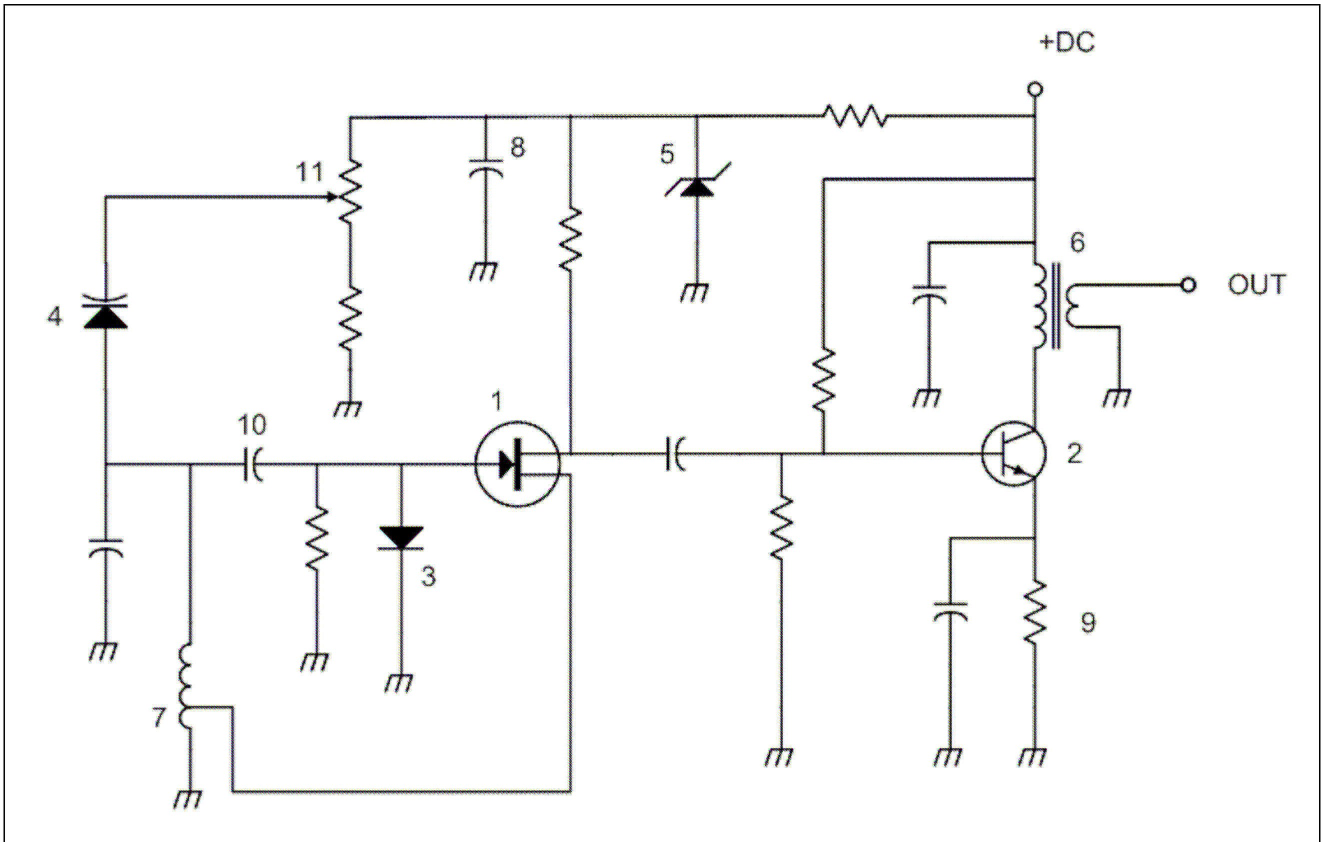


Figure G7-1

In figure G7-1 above, **Symbol 1 if a field effect transistor**. (G7A09) Notice how it is different than in **Symbol 2, which is an NPN junction transistor**. (G7A11)

Symbol 5 is a Zener diode, with the zigzag type line across it. (G7A10)

Symbol 7 is a tapped inductor (G7A13) and **Symbol 6 is a multiple-winding transformer** (G7A12)

Other components

There are many different types of components in modern radio equipment.

A relay is **a switch controlled by an electromagnet**. (T6D02)

Meters are devices used to indicate many different values. For example, a **meter** can be used to display signal strength on a numeric scale. (T6D04) Meters are also used to indicate the output voltage of a power supply, the output power of a transmitter, and many other parameters.

Integrated circuit is the name of a device that combines several semiconductors and other components into one package. (T6D09) Integrated circuits may perform either analog or digital functions. One type of analog integrated circuit that is very common is the voltage regulator. A **regulator** is the type of circuit that controls the amount of voltage from a power supply. (T6D05)

Other devices are:

The CMOS has **low power consumption** compared to TTL integrated circuits. (G6B03)

An integrated circuit operational amplifier (op-amp) is an **analog** device. (G6B06)

The term MMIC stands for **Monolithic Microwave Integrated Circuit**. (G6B02)

Computers use ROM - **Read Only Memory** (G6B04) as well as RAM - Random Access Memory

Non-volatile memory: **stored information is maintained even if power is removed**. (G6B05)

An **LED** is commonly used as a visual indicator. (T6D07) LED is short for light-emitting diode. They come in a variety of colors. An LED is **forward biased** when emitting light. (G6B08) The LED differs from a liquid crystal display (LCD) in that the LCD **requires ambient or back lighting** to be seen. (G6B09) Advantages for using an LED indicator compared to an incandescent indicator is because **all of these choices are correct** (G6B07):

Lower power consumption

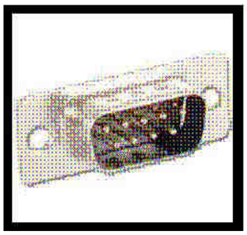
Faster response time

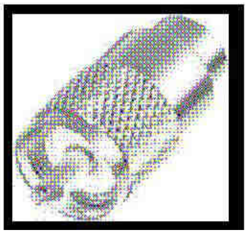
Longer life

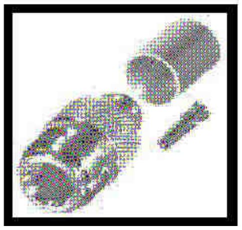
When connecting electronic assemblies together, we often use cables with one or more conductors. Some of those conductors may have a shield around them that is connected to ground. A common reason to use shielded wire is **to prevent coupling of unwanted signals to or from the wire**. (T6D12) A USB interface cable can be used between a **computer and transceiver**. (G6B10)

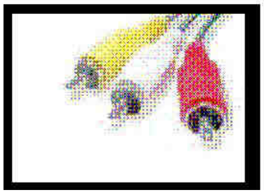
A good connector for a serial data port would be a **DE-9**. (G6B12)

Audio signals can be found on cables with **RCA Phono** connectors. (G6B14)


A DB-9 Connector


PL-259 Connector


Type N Connector


RCA Phono Plugs


Anderson Power Poles (a high quality keyed power connector)

On the RF side, we have a **PL-259** connector on mobile radios for frequencies up to 150 Mhz. (G6B13) A **small threaded connector suitable for signals up to several GHz** called an SMA connector is found on HTs. (G6B18) UHF antennas use a type N connector, which is **a moisture-resistant RF connector useful to 10 Ghz**. (G6B16)

A main reason we would use a keyed connector is the **reduced chance of incorrect mating**. (G6B15)

A DIN connector is **a family of multiple circuit connectors suitable for audio and control signals**. (G6B17)

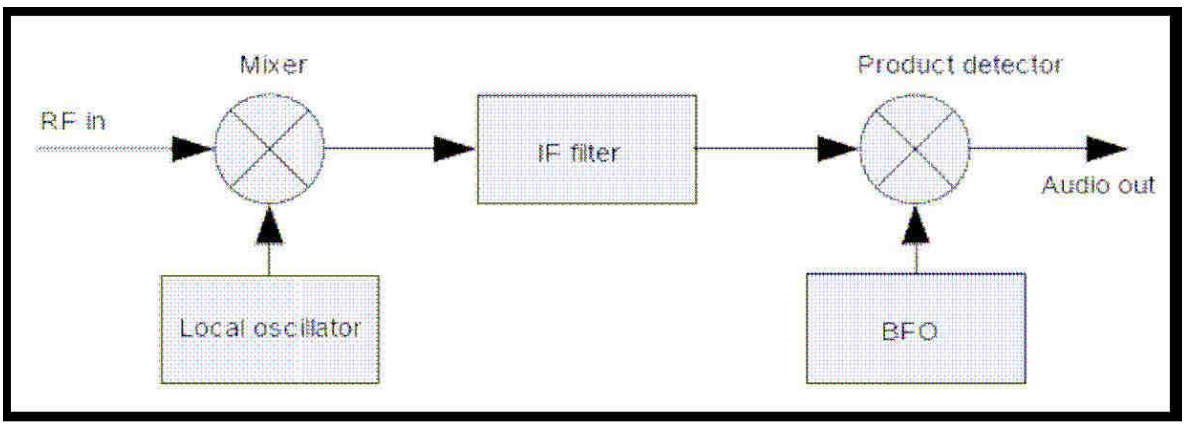
Practical Circuits: Oscillators, Receiver & Transmitter Stages, Amplifiers

Oscillators

Oscillators are circuits that create an AC waveform for various purposes. These can be used in receivers, transmitters, amplifiers or filters. The basic components of virtually all sine wave oscillators are **a filter and an amplifier operating in a feedback loop**. (G7B07) **The inductance and capacitance in the tank circuit** determines the frequency of an LC oscillator. (G7B09)

Receiver & Transmitter Stages

When we have a signal from an oscillator, we need to do something with it. To get the signal to a higher frequency, we can mix it with another to add them together or we can multiply our original signal. The circuit that is used to process signals from the RF amplifier and local oscillator then send the result to the IF filter in a superheterodyne receiver is a **mixer**. (G7C03) The circuit that is used to combine signals from the IF amplifier and BFO and then send the result to the AF amplifier in some single sideband receivers is the **product detector**. (G7C04) The simplest combination of stages that implement a superheterodyne receiver are the **HF oscillator, mixer and detector**. (G7C07) The circuit used in many FM receivers to convert signals coming in from the IF amplifier to audio is the **discriminator**. (G7C08)



On the transmitter side, we have some other types of circuits. The circuit that is used to combine signals from the carrier oscillator and speech amplifier, then send the result to the filter in some single sideband phone transmitters is the **balanced modulator**. (G7C02) A single sideband (USB or LSB) **filter** is used to process signals from the balanced modulator then send them to the mixer in some single sideband phone transmitters. (G7C01) The advantage of a transceiver controlled by a direct digital synthesizer (DDS) is that it can provide a **variable frequency with the stability of a crystal oscillator**. (G7C05)

Amplifiers

An amplifier is a circuit that can take a waveform and boost the output wattage to produce a stronger signal. A linear amplifier is **an amplifier in which the output preserves the input waveform**. (G7B14) The reason for neutralizing the final amplifier stage of a transmitter is **to eliminate self-oscillations**. (G7B13)

Efficiency of an RF power amplifier is determined by **dividing the RF output power by the DC input power**. (G7B08) A **Class C** amplifier has the highest efficiency. (G7B12) A Class C power stage amplifier is appropriate for amplifying a **CW** signal. (G7B11) A Class A amplifier is known for it's **low distortion** of a signal. (G7B10)

Last but not least, putting a low pass filter between your transmitter and antenna will prevent harmonics from interfering with services in the higher frequencies. To make sure that you have maximum power transfer from the transmitter to the filter, to the antenna, the impedance of a low pass filter as compared to the transmission line should be **about the same**. (G7C06)

Station equipment

Receivers, transmitters, transceivers, modulation, transverters, low power and weak signal operation, transmit and receive amplifier, power supplies

In the early days of radio, amateur radio operators used separate receivers and transmitter units. Nowadays, however, most use radios called transceivers. A transceiver is **a unit combining the functions of a transmitter and a receiver**. (T7A02)

There are many different types of transceivers. **A multi-mode VHF transceiver** is the type of device that is most useful for VHF weak-signal communication. (T7A09) Instead of purchasing a multi-mode VHF transceiver, many amateurs use a transverter to convert the signals from their HF transceiver to the VHF, UHF, and even microwave bands. For example, a device that would take the output of a low-powered 28 MHz SSB exciter and produces a 222MHz output signal is a **transverter**. (T7A06)

Many, if not most, new amateurs buy a hand-held transceiver, usually called an "HT," as their first transceiver. One disadvantage of using a hand-held transceiver is that the maximum output power is generally only 5 W, and because of this, they have limited range. To increase the low-power output of a handheld transceiver, and therefore it's, range, you can use **an RF power amplifier**. (T7A10)

When talking about a transceiver's specifications, we still refer to its receiver and transmitter. The two most important specifications for a receiver are sensitivity and selectivity. **Sensitivity** is the term that describes the ability of a receiver to detect the presence of a signal. (T7A01) The term that describes the ability of a receiver to discriminate between multiple signals is **selectivity**. (T7A04)

To improve the sensitivity of a receiver, you can use an RF preamplifier. An RF preamplifier is installed **between the antenna and receiver**. (T7A11)

Most HF transceivers have some version of a superheterodyne receiver. In a superheterodyne receiver, we first convert an incoming radio signal from its frequency to an intermediate frequency, or IF. The circuit that does this is the mixer. A **mixer** is used to convert a radio signal from one frequency to another. (T7A03)

When transmitting, we want to generate an RF signal with a specific frequency. To do that, we use an oscillator. **Oscillator** is the name of a circuit that generates a signal of a desired frequency. (T7A05)

To transmit a voice or data signal, we have to combine an audio frequency signal from the microphone with the RF carrier signal generated by the transmitter. **Modulation** is the term that describes combining speech with an RF carrier signal. (T7A08) Modulators use a type of mixer circuit to accomplish this process.

Operating an HF rig, especially one with tubes instead of transistors, takes a different approach in operation. Vacuum tubes require adjusting the current in certain circuits to provide enough drive without overdriving. For example, the plate tuning control needs to be adjusted so that there is **a pronounced dip** on the plate current meter. (G4A04) The correct adjustment for the load or coupling control of a vacuum tube RF power amplifier is for **maximum power output without exceeding maximum allowable plate current**. (G4A08) You might also need to use a time delay in the transmitter keying circuit **to allow time for transmit-receive changeover operations to complete properly before RF output is allowed**. (G4A09) Don't forget **an antenna coupler or antenna tuner** to match the transmitter output impedance to an impedance not equal to 50 ohms. (G4A06)

If you are so inclined, you could use an electronic keyer for **automatic generation of strings of dots and dashes for CW operation**. (G4A10)

For voice operations, you might use a speech processor to **increase the intelligibility of transmitted phone signals during poor conditions**. (G4D01) The speech processor can affect a single sideband phone signal when it increases average power. (G4D02) **All of these choices are correct** when the speech processor is incorrectly adjusted (G4D03):

Distorted speech

Splatter

Excessive background pickup

In a receiver an S meter can be found. (G4D06) The S meter measures the **received signal strength**. (G4D04) For a received signal on the S meter to go from S8 to S9, the transmitted signal power output must be raised **approximately 4 times**. (G4D07) Assuming a properly calibrated S meter, a signal reading 20 dB over S9 compared to one reading S9 **is 100 times more powerful**. (G4D05)

An S-Meter

And a very good signal!

Proper use of the dial for setting the displayed frequency is important so that you don't go over a band or sub-band edge. You need to understand exactly where your transmitted signal is. When using a 3 kHz LSB signal in the lower edge of the 40-meter General phone segment, the displayed carrier frequency needs to be **at least 3 kHz above the edge of the segment**. (G4D10) When the displayed carrier frequency is set to 7.178 Mhz, a 3 kHz LSB signal occupies **7.175 to 7.178 Mhz**. (G4D08) When using a 3 kHz USB signal in the upper edge of the 20-meter General Class band, the displayed carrier frequency needs to be **at least 3 kHz below the edge of the band**. (G4D11) When the displayed carrier frequency is set to 14.347 Mhz, a 3 kHz USB signal occupies **14.347 to 14.350 Mhz**. (G4D09)

One of the neat things some hams do is to take their HF rig out on the open road. There are some unique challenges to doing this, like you can't bring your tower and beam antenna with you! Let's look at some of these challenges.

<u>Power</u>: It is best not to draw DC power for a 100 watt HF transceiver from a vehicle's auxiliary power socket because **the socket's wiring may be inadequate for the current drawn by the transceiver**. (G4E04) Connecting directly **to the battery using heavy gauge wire** would be best for a 100 watt HF mobile installation. (G4E03)

<u>Antenna</u>: The antenna system limits the effectiveness of an HF mobile transceiver operating in the 75-meter band. (G4E05) One disadvantage of using a shortened mobile antenna as opposed to a full size antenna is the **operating bandwidth may be very limited**. (G4E06) Mobile antennas may have unique features that are not found on your home antenna. A capacitance hat on a mobile antenna is used **to electrically lengthen a physically short antenna**. (G4E01) The purpose of a corona ball on a HF mobile antenna is **to reduce high voltage discharge from the tip of the antenna**. (G4E02)

All of these choices are correct as a possible cause when experiencing interference heard in the receiver of an HF radio installed in a recent model vehicle (G4E07):

The battery charging system

The fuel delivery system

The vehicle control computer

Base Station Power Supplies

A power supply for your amateur station needs to convert the household 120 Volts AC to a usable 12 Volts DC. We can do this by first using a step-down transformer with a 10:1 ratio of primary to secondary windings. Then we need to rectify for only the positive side of the AC waveform. The portion of the AC cycle that is converted to DC by a half-wave rectifier is **180 degrees**. (G7A05) The peak-inverse-voltage (PIV) across the rectifier in a half-wave power supply is **two times the normal peak output voltage of the power supply**. (G7A04) If we use a full-wave bridge rectifier, the portion of the AC cycle that is converted to DC is **360 degrees**. (G7A06) The peak-inverse-voltage across the full-wave rectifier is **equal to the normal peak output voltage of the power supply**. (G7A03) The output waveform of an unfiltered full-wave rectifier connected to a resistive load is **a series of DC pulses at twice the frequency of the AC input**. (G7A07) To smooth out the secondary winding rectified voltage to create DC volts, a power supply filter network uses **capacitors and inductors**. (G7A02) A useful feature that a power supply bleeder resistor provides is that **it ensures that the filter capacitors are discharged when power is removed**. (G7A01)

While the above is the basic layout for a linear power supply, we can do a lot of this with semiconductors in what is called a switchmode power supply. Switchmode power supplies do not use a step-down transformer. By using semiconductors, the AC waveform can be sliced up into tiny segments in rapid speed and make the desired conversion into DC. An advantage to using a switchmode power supply as compared to a linear power supply is that the **high frequency operation allows the use of smaller components**. (G7A08) This helps to make the switchmode power supply much lighter in weight than a linear power supply.

Common transmitter and receiver problems: symptoms of overload and overdrive, distortion, causes of interference, interference and consumer electronics, part 15 devices, over and under modulation, RF feedback, off frequency signals, fading and noise, problems with digital communications interface

Since Murphy's Law ("if anything can go wrong, it will") applies to amateur radio as much as it does to any other pursuit, at some point you will have to deal with problems. These may include overload, distortion, feedback, and interference.

Let's first consider interference. **All of these choices are correct** when talking about causes of radio frequency interference (T7B03):

- fundamental overload
- harmonics
- spurious emissions.

Any of these could cause interference to a TV set or radio, and you will want to take steps to find and eliminate that interference. If someone tells you that your station's transmissions are interfering with their radio or TV reception, you should first **make sure that your station is functioning properly and that it does not cause interference to your own radio or television when it is tuned to the same channel** or frequency. (T7B06)

While it's not very likely that your amateur radio station will interfere with a neighbor's cable TV service, it can sometimes occur. The first step to resolve cable TV interference from your ham radio transmission is to **be sure all TV coaxial connectors are installed properly**. (T7B12)

Your amateur radio station may interfere with a nearby radio receiver if your signal is so strong that the receiver cannot reject the signal even though your signal is not on the frequency to which the receiver is tuned. When a **receiver is unable to reject strong signals outside the AM or FM band,** it can cause a broadcast AM or FM radio to receive an amateur radio transmission unintentionally. (T7B02) One way to reduce or eliminate the overloading of a non-amateur radio or TV receiver by an amateur signal is to **block the amateur signal with a filter at the antenna input of the affected receiver**. (T7B05)

Another device that often experiences interference from amateur radio stations is the telephone. The telephone wires act as antenna and the telephone itself demodulates the signal. One way to reduce or eliminate interference by an amateur transmitter to a nearby telephone is to **install an RF filter at the telephone**. (T7B04)

All of these choices are correct when considering what may be useful in correcting a radio frequency interference problem (T7B07):

Snap-on ferrite chokes

Low-pass and high-pass filters

Band-reject and band-pass filters

Interference works both ways. Your neighbors may have wireless devices, sometimes called “Part 15 devices,” that can interfere with your station. A Part 15 device is **an unlicensed device that may emit low powered radio signals on frequencies used by a licensed service**. (T7B09) **All of these choices are correct** when considering what you should do if something in a neighbor’s home is causing harmful interference to your amateur station (T7B08):

Work with your neighbor to identify the offending device

Politely inform your neighbor about the rules that require him to stop using the device if it causes interference

Check your station and make sure it meets the standards of good amateur practice

Perhaps the most common problem that amateur radio operators have is distorted or noisy audio when transmitting. There are many reasons for poor audio. **All of these choices are correct** if you receive a report that your audio signal through the repeater is distorted or unintelligible (T7B10):

Your transmitter may be slightly off frequency

Your batteries may be running low

You could be in a bad location

Reports of garbled, distorted, or unintelligible transmissions are a symptom of RF feedback in a transmitter or transceiver. (T7B11) Sometimes, garbled or distorted audio when operating FM is the result of over-deviation. **Talk farther away from the microphone** is one thing you can do if you are told your FM handheld or mobile transceiver is over-deviating. (T7B01)

A **bypass capacitor** might be useful in reducing RF interference to audio frequency devices. (G4C01) One method to tell if the sound heard in an audio device or telephone is interference from a nearby single sideband transmitter is hearing **distorted speech**. (G4C03) Hearing **on-and-off humming or clicking** is an effect of interference from a nearby CW transmitter. (G4C04) If there is interference covering a wide range of frequencies, you could have a nearby **arcing at a poor electrical connection**. (G4C02) **Placing a ferrite choke around the cable** would reduce RF interference caused by common-mode current on an audio cable. (G4C08)

A handy device to have when receiving an HF signal is a DSP (digital signal processor). Some modern radios come with the DSP circuitry built into it. The function of a digital signal processor is **to remove noise from received signals**. (G4C11) An advantage to having a DSP filter in the receiver’s IF filter as compared to the analog filter is **a wide range of filter bandwidths and shapes can be created**. (G4C12) **A digital signal processor (DSP) filter** can also perform automatic notching of interfering carriers. (G4C13) Digital Signal Processor filtering is accomplished **by converting the signal from analog to digital and using digital processing**. (G7C10) This is similar to a “software defined radio” (SDR), which is **a radio in which most major signal processing functions are performed by software**. (G7C11)

All of these choice are correct for what is needed for a Digital Signal Processor IF filter (G7C09):

An analog to digital converter

A digital to analog converter

A digital processor chip

Properly grounded equipment is an important part of your station, especially on HF. One good way to avoid unwanted effects of stray RF energy in an amateur station is to **connect all equipment grounds together**. (G4C07) A ground loop can be avoided when you **connect all ground conductors to a single point**. (G4C09) A symptom of a ground loop is that **you receive reports of "hum" on your station's transmitted signal**. (G4C10) An effect of the ground connection being resonant on a particular frequency, is that you will get **high RF voltages on the enclosures of station equipment**. (G4C06) If you get an RF burn when touching equipment while transmitting on HF, assuming it is connected to a ground rod, then **the ground wire has high impedance on that frequency**. (G4C05)

Basic repair and testing: soldering; using basic test instruments; connecting a voltmeter, ammeter, or ohmmeter; using an oscilloscope

The most common test instrument in an amateur radio shack is the multimeter. Multimeters combine into a single instrument the functions of a voltmeter, ohmmeter, and ammeter. **Voltage and resistance** are two measurements commonly made using a multimeter. (T7D07) You use **a voltmeter** to measure electric potential or electromotive force. (T7D01) The correct way to connect a voltmeter to a circuit is **in parallel with the circuit**. (T7D02) When measuring high voltages with a voltmeter, one precaution you should take is to **ensure that the voltmeter and leads are rated for use at the voltages to be measured**. (T7D12)

An ohmmeter is the instrument used to measure resistance. (T7D05) When measuring circuit resistance with an ohmmeter **ensure that the circuit is not powered**. (T7D11) **Attempting to measure voltage when using the resistance setting** might damage a multimeter. (T7D06) What is probably happening when an ohmmeter, connected across a circuit, initially indicates a low resistance and then shows increasing resistance with time is that **the circuit contains a large capacitor**. (T7D10)

An ammeter is the instrument used to measure electric current. (T7D04) An ammeter is usually connected to a circuit **in series with the circuit**. (T7D03)

In addition to knowing how to make electrical measurements, knowing how to solder is an essential skill for amateur radio operators. **Rosin-core solder** is best for radio and electronic use. (T7D08) **A grainy or dull surface** is the characteristic appearance of a "cold" solder joint. (T7D09)

An oscilloscope is a very useful piece of test gear to own. An advantage to having an oscilloscope is that **complex waveforms can be measured**. (G4B02) To display these waveforms live on the screen, **an oscilloscope** contains horizontal and vertical channel amplifiers. (G4B01) To check the keying waveform of a CW transmitter, you will need to use **an oscilloscope** to see if you have badly formed on/off shapes. (G4B03 **The attenuated RF output of the transmitter** is the signal source you would connect to the vertical input of an oscilloscope to view the RF envelope pattern of a transmitted signal. (G4B04) To look for a clean waveform for AM or SSB on the oscilloscope, **choose two non-harmonically related audio signals** to conduct a two-tone test. (G4B07) The two-tone test analyzes a transmitter's **linearity** in the audio section. (G4B15)

When using a voltmeter, the high input impedance is desirable because **it decreases the loading on circuits being measured**. (G4B05) A digital voltmeter gives **better precision for most uses** as compared to an analog voltmeter. (G4B06) One instance where the analog readout would be better than digital would be **when adjusting tuned circuits**. (G4B14)

For measuring the RF being transmitted, we have several test instruments that are crucial to have. **A field strength meter** is used to monitor relative RF output whenever making antenna or transmitter adjustments. (G4B08) You can determine **the radiation pattern of an antenna** when you use a field strength meter. (G4B09) In addition to an SWR meter, a directional wattmeter can measure the **standing wave ratio**. (G4B10) Lastly, the **antenna and feedline** must be connected to an antenna analyzer when making SWR measurements. (G4B11) Other than measuring SWR, an antenna analyzer is used in **determining the impedance of an unknown or unmarked coaxial cable**. (G4B13) **Strong signals from nearby transmitters can affect the accuracy of measurements** when using an antenna analyzer to check your antenna setup. (G4B12)

Digital Circuits

Digital circuits use a simple on/off, high/low or true/false method of determining the current state of the circuit. **Binary “ones” and “zeroes” are easy to represent by an “on” or “off” state** when processing a digital signal. (G7B02)

With this binary logic, we can make decisions based on either/or/both of two or more inputs being on or off. A two input AND gate **output is high only when both inputs are high**. (G7B03) A two input NOR gate **output is low when either or both inputs are high**. (G7B04)

We can count in binary. A 3-bit binary counter has **8** different states. (G7B05) They can go from 000 to 111. These numbers increment from the right and go to the left (000, 001, 010, 011, 100, 101, 110, 111).

A shift register is **a clocked array of circuits that passes data in steps along the array**. (G7B06)

Complex digital circuitry can often be replaced by a **microcontroller**. (G7B01)

Amateur radio signals

Modulation modes, signal bandwidth

Frequency modulation, or **FM,** is the type of modulation most commonly used for VHF and UHF voice repeaters. (T8A04) **FM** is also the type of modulation most commonly used for VHF packet radio transmissions. (T8A02) The process that changes the instantaneous frequency of an RF wave to convey information is called **frequency modulation**. (G8A03) Frequency Modulation (FM) is commonly used for local broadcasting in the VHF bands from 88 to 108 Mhz. Frequency Modulation is also used for voice communications for business and government communications. A close relative to FM is **Phase Modulation** (PM), where the changing of the phase angle of a RF wave is used to convey information. (G8A02) **Phase Modulation** is produced by a reactance modulator connected to a transmitter RF amplifier stage. (G8A04)

The type of modulation that varies the instantaneous power level of the RF signal is called **amplitude modulation**. (G8A05) Amplitude Modulation (AM) is commonly used for broadcasting in the shortwave bands from 2 to 30 Mhz, in the local mediumwave frequency band from 540 kHz to 1700 kHz and on the Citizens Band (CB) at 27 Mhz. The signal is made up of a carrier signal with two sidebands of audio, which are mirror images of each other. The modulation envelope of an AM signal is **the waveform created by connecting the peak values of the modulated signal**. (G8A11)

Single sideband, or **SSB,** is the type of voice modulation most often used for long-distance or weak signal contacts on the VHF and UHF bands. (T8A03) **Single sideband** is a form of amplitude modulation. (T8A01) A single-sideband signal may be upper-or lower-sideband. **Upper sideband** is normally used for 10 meter HF, VHF and UHF single-sideband communications. (T8A06) **Single sideband** is one of the narrowest voice bandwidths. (G8A07) An advantage to the carrier suppression of SSB and only using one sideband is that the **available transmitter power can be used more effectively**. (G8A06) The primary advantage of single sideband over FM for voice transmissions is that **SSB signals have narrower bandwidth**. (T8A07) The approximate bandwidth of a single sideband voice signal is **3 kHz**. (T8A08) The approximate bandwidth of a VHF repeater FM phone signal is **between 10 and 15 kHz**. (T8A09)

An effect of overmodulation is the **excessive bandwidth** of the signal. (G8A08) **Signal distortion caused by excessive drive** in an SSB signal is called flat-topping of the signal. (G8A10) The control for proper ALC on an SSB transceiver is the **transmit audio or microphone gain** knob. (G8A09)

Morse Code, or **CW,** is the type of emission that has the narrowest bandwidth. (T8A05) The approximate maximum bandwidth required to transmit a CW signal is **150 Hz**. (T8A11) **International Morse** is the code used when sending CW in the amateur bands. (T8D09) **All of these choices are correct** when talking about instruments used to transmit CW in the amateur bands (T8D10):

Straight Key

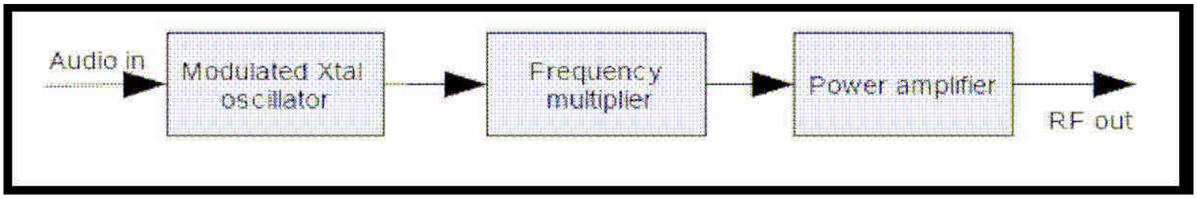
Electronic Keyer

Computer Keyboard

Some modes have very wide bandwidths. The typical bandwidth of analog fast-scan TV transmissions on the 70 cm band, for example, is **about 6 MHz**. (T8A10) The type of transmission indicated by the term NTSC is **an analog fast scan color TV signal**. (T8D04)

Frequency Mixing, Multiplication, Deviation, Duty Cycle

Frequencies in a radio transmitter or receiver are created by multiplying a lower frequency to get a higher frequency, mixing two signals together or a combination of these two techniques. The stage in a VHF FM transmitter that generates a harmonic of a lower frequency to reach the desired frequency is called a **multiplier**. (G8B04)



The receiver stage that combines a 14.250 Mhz input signal with a 13.795 Mhz oscillator signal to produce a 455 kHz intermediate frequency (IF) signal is called a **mixer**. (G8B01) Another term for the mixing of two RF signals is called **heterodyning**. (G8B03) If a receiver mixes a 13.800 MHz VFO with a 14.255 Mhz received signal to produce a 455 kHz IF, the type of interference caused by a 13.345 Mhz signal is called an **image response**. (G8B02)

When you modulate an FM signal of 5 kHz deviation with a 3 kHz audio, the total bandwidth of **16 kHz** is produced. (G8B06) To create a VHF FM signal at 146.520 Mhz with a 5 kHz deviation, you can multiply a 12.21 Mhz reactance modulated oscillator with **416.7 hz** deviation by a factor of 9. (G8B07)

It is best to match the receiver bandwidth to the bandwidth of the operating mode because **it results in the best signal to noise ratio**. (G8B09)

Duty cycle is the comparison to transmitter maximum level to transmitter minimum level while transmitting. It is important to know the duty cycle of the mode that you are transmitting because **some modes have high duty cycles which could exceed the transmitter's average power rating**. (G8B08) That would be a sure way to cause your transmitter to overheat. Too long before unkeying could also cause overheating. Of course, the SWR should be low or that will contribute to overheating as well. Imagine if all three contributed! Time to buy a new radio.

Digital modes: packet, PSK31

When hams talk about "digital modes," we are talking about modes that send digital data rather than voice or other types of analog signals, such as television. Usually, we connect our transceivers to a computer to modulate and demodulate the digital signals, but some newer transceivers can do this internally. **All of these choices are correct** examples of digital communications methods (T8D01):

Packet

PSK31

MFSK

Packet radio was one of the first digital modes. It is called packet radio because the data to be sent from station to station is separated into a number of packets, which are then sent separately by the transmitting station and received and re-assembled by the receiving station. The part of the packet which contains the routing and handling information is called the **header**. (G8C03) **All of these choices are correct** when talking about what may be included in a packet transmission (T8D08):

A check sum which permits error detection

A header which contains the call sign of the station to which the information is being sent

Automatic repeat request in case of error

Some amateur radio digital communications systems use protocols that ensure error-free communications. One such system is called **A**utomatic **R**epeat re**Q**uest (ARQ). An ARQ transmission is **a digital scheme whereby the receiving station detects errors and sends a request to the sending station to retransmit the information**. (T8D11) (G8C07) Another method is called **F**orward **E**rror **C**orrection (FEC). FEC allows the receiver to correct errors in received packets **by transmitting redundant information with the data**. (G8C10)

APRS is one service that uses packet radio. The term APRS means **Automatic Packet Reporting System**. (T8D02) **A Global Positioning System receiver** is normally used when sending automatic location reports via amateur radio. (T8D03) **Providing real time tactical digital communications in conjunction with a map showing the locations of stations** is an application of APRS (Automatic Packet Reporting System). (T8D05)

A popular digital mode on the HF bands is PSK31. The abbreviation PSK means **Phase Shift Keying**. (T8D06) PSK31 is **a low-rate data transmission mode**. (T8D07) The “31” in PSK31 is the **approximate transmitted symbol rate**. (G8C09) When it comes to the number of data bits sent in a single PSK31 character, **the number varies**. (G8C02) The type of code used for PSK31 is called **Varicode**. (G8C12) **Uppercase letters use longer Varicode signals and thus slow down transmission**. (G8C08) That’s why most people use lowercase letters to shorten the length of the transmission.

Another digital mode is called Radio Teletype (RTTY). RTTY uses Baudot code which is **a 5-bit code with additional start and stop bits**. (G8C04) The RTTY signal is Frequency Shift Keyed (FSK) which uses two separate frequencies for **mark and space**. (G8C11) The FSK signal is generated **by changing an oscillator’s frequently directly with a digital control signal**. (G8A01)

A combination between Packet and an ARQ version of RTTY is called Pactor. There are three versions available: Pactor, Pactor2 and Pactor3. Pactor4 is currently not allowed on the amateur HF bands because of a very high symbol rate. In the Pactor protocol, a NAK response (negative acknowledgement) to a transmitted packet is given when **the receiver is requesting the packet be retransmitted**. (G8C05) When there is a failure to exchange information due to excessive transmission attempts when using Pactor or Winmor, **the connection is dropped**. (G8C06) The approximate bandwidth of a Pactor3 signal at maximum data rate is **2300 hz**. (G8B05) The relationship between transmitted symbol rate and bandwidth is that **higher symbol rates require wider bandwidth**. (G8B10)

Two very narrow modes of digital communications are called JT9 (9 hz wide) and JT65 (65 hz wide). **JT9 and JT65** are designed to operate at extremely low signal strength on the HF bands. (G8C01)

Antennas and feedlines

Antenna types, antenna polarization

The most common, and perhaps the simplest, antenna is the half-wave dipole antenna. As the name suggests, it measures close to one half wavelength from one end of the antenna to the other. A simple dipole mounted so the conductor is parallel to the Earth's surface is **a horizontally polarized antenna**. (T9A03) The direction that radiation is strongest from a half-wave dipole antenna in free space is **broadside to the antenna**. (T9A10) The radiation pattern of a dipole in free space **is a figure-eight at right angles to the antenna**. (G9B04) You can make an HF antenna out of a random length of long wire that is fed directly by the radio. One disadvantage to this is **you may experience RF burns when touching metal objects in your station**. (G9B01)

The length of a dipole antenna is actually about 5% shorter than the value that you would calculate using the formula **wavelength in meters equals 300 divided by frequency in megahertz**. The reason for this is that there will be some stray capacitance between the wire and the ground and other objects near the antenna. Using this formula, the approximate length of a 6 meter 1/2-wavelength wire dipole antenna is **112** inches. (T9A09) To make a dipole antenna resonant on a higher frequency, you would **shorten it**. (T9A05) The approximate length for a 1/2 wave dipole antenna cut for 14.250 Mhz is **32 feet**. (G9B10) The approximate length for a 1/2 wave dipole antenna cut for 3.550 Mhz is **131 feet**. (G9B11) **If the antenna is less than 1/2 wavelength high, the azimuthal pattern is almost omnidirectional**. (G9B05) As a 1/2 wave dipole is lowered below 1/4 wave above ground, the feed point impedance **steadily decreases**. (G9B07) As the feed point is moved from the center toward the ends of a 1/2 wave dipole, the feed point impedance **steadily increases**. (G9B08) An advantage of a horizontally polarized antenna compared to a vertically polarized HF antenna is the **lower ground reflection losses**. (G9B09)

The second-most popular type of amateur radio antenna is the quarter-wave vertical antenna. For vertical antennas, **the electric field is perpendicular to the Earth**. (T9A02) This makes them vertically polarized antennas. The approximate length of a quarter-wavelength vertical antenna for 146 MHz is **19** inches. (T9A08) A common way to adjust the feed point impedance of a quarter wavelength vertical antenna to be approximately 50 ohms is to **slope the radials downward**. (G9B02) When you change the radials from horizontal to sloping downward, **it increases** the impedance. (G9B03) The radial wires of a ground-mounted vertical antenna should be placed **on the surface of the Earth or buried a few inches below the ground**. (G9B06) The approximate length for a 1/4 wave vertical antenna cut for 28.5 Mhz is **8 feet**. (G9B12)

Because HF antennas can be very long, many amateurs use a technique called “loading” to shorten them. Antenna loading means **inserting an inductor in the radiating portion of the antenna to make it electrically longer**. (T9A14) Combining this inductor with a capacitor soldered in parallel across it is called a trap. The primary purpose of these antenna traps is **to permit multiband operation**. (G9D04) A disadvantage to multiband antennas is that **they have poor harmonic rejection**. (G9D11)

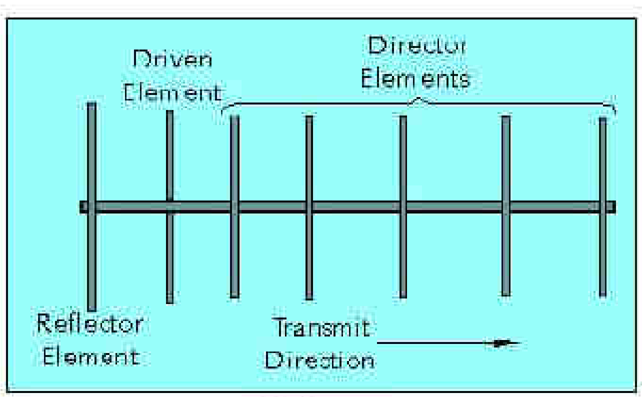
Another popular type of antenna is the beam antenna. A beam antenna is **an antenna that concentrates signals in one direction**. (T9A01) The quad, Yagi, and dish antennas are **directional antennas**. (T9A06) The gain of an antenna is **the increase in signal strength in a specified direction when compared to a reference antenna**. (T9A11) The approximate length of the driven element of a Yagi antenna is **1/2 wavelength**. (G9C02) **The director is normally the shortest element**. (G9C03) **The reflector is normally the longest element**. (G9C04) To increase the bandwidth of a Yagi, you would use **larger diameter elements**. (G9C01) When you increase the boom length and add directors, the **gain increases**. (G9C05) The front to back ratio is **the power radiated in the major radiation lobe compared to the power radiated in exactly the opposite direction**. (G9C07) The main lobe of a directive antenna is **the direction of maximum radiated field strength from the antenna**. (G9C08) The purpose of a gamma match is **to match the relatively low feed point impedance to 50 ohms**. (G9C11) Using a gamma match **does not require that the elements be insulated from the boom**. (G9C12) Two 3-element horizontally polarized Yagi antennas spaced vertically 1/2 wavelength apart will have **approximately 3 dB higher** gain compared to a single 3-element Yagi. (G9C09) An advantage of vertical stacking horizontally polarized Yagi antennas is that **it narrows the main lobe in elevation**. (G9D05)

All of these choices are correct when trying to adjust for optimizing forward gain, front-to-back ratio or SWR bandwidth (G9C10):

The physical length of the boom

The number of elements on the boom

The spacing of each element along the boom



Yagi antenna

For the reference given after a gain figure **dBi refers to an isotropic antenna, dBd refers to a dipole antenna**. (G9C20) In comparing the two, **dBi gain figures are 2.15 dB higher than dBd gain figures**. (G9C19)

Variations on Yagi antennas are loop antennas called Quads (4 sides) or Delta Loops (3 sides). The approximate length of each side of the driven element of a quad antenna is **1/4 wavelength**. (G9C13) The approximate length of each leg of a symmetrical delta-loop antenna is **1/3 wavelength**. (G9C17) The approximate length of a reflector element of a quad antenna configured as a beam would be **slightly more than 1/4 wavelength**. (G9C15) **The reflector element must be approximately 5 percent longer than the driven element**. (G9C06) The forward gain of a two-element quad, compared to a 3-element Yagi, is **about the same**. (G9C14) The gain of a two-element delta-loop is **about the same** as a two-element quad antenna. (G9C16) **The polarization of the radiated signal changes from horizontal to vertical** when the feed point of the quad antenna is moved from the midpoint of the top or bottom to the midpoint of either side. (G9C18)

Another variation on a Yagi antenna is called a Log Periodic Antenna. A description of a Log Periodic Antenna would be that the **length and spacing of the elements increase logarithmically from one end of the boom to the other**. (G9D07) An advantage to using a Log Periodic Antenna is that it has a **wide bandwidth** spanning multiple bands. (G9D06)

A specialty antenna mentioned in the section on propagation is the NVIS or **Near Vertical Incidence Sky-wave** antenna. (G9D01) An advantage of an NVIS antenna is the **high vertical angle radiation for working stations within a radius of a few hundred kilometers**. G9D02) The typically mounted height for an NVIS antenna is **between 1/10 and 1/4 wavelength**. (G9D03)

Another antenna is called a Beverage antenna. A Beverage is **a very long and low directional receiving antenna**. (G9D10) A Beverage is used for **directional receiving for low HF bands** like 80 and 160 meters. (G9D09) A Beverage is not used for transmitting because **it has high losses compared to other types of antennas**. (G9D08)

Most hand-held VHF and UHF transceivers come with what's called a "rubber duck" antenna. Rubber duck antennas use inductive loading to make them shorter than a full-sized antenna. A disadvantage of the "rubber duck" antenna supplied with most handheld radio transceivers is that **it does not transmit or receive as effectively as a full-sized antenna**. (T9A04) A good reason not to use a "rubber duck" antenna inside your car is that **signals can be significantly weaker than when it is outside of the vehicle**. (T9A07)

A better option is to use an externally mounted antenna. VHF or UHF mobile antennas are often mounted in the center of the vehicle roof because **a roof mounted antenna normally provides the most uniform radiation pattern.** (T9A13) Many mobile installations use a 5/8-wavelength vertical antenna. One reason to use a properly mounted 5/8 wavelength antenna for VHF or UHF mobile service is that **it offers a lower angle of radiation and more gain than a 1/4 wavelength antenna and usually provides improved coverage**. (T9A12)

Feedlines: types of feedline, connectors

Feedlines connect radios to antennas. There are many different types of feedlines, but coaxial cable is used more often than any other feedline for amateur radio antenna systems because **it is easy to use and requires few special installation considerations.** (T9B03) A common use of coaxial cable is **carrying RF signals between a radio and antenna**. (T7C12) Note, however, that **the loss increases** as the frequency of a signal passing through coaxial cable is increased. (T9B05)

When choosing a feedline, it is important to match the impedance of the feedline to the output impedance of the transmitter and the input impedance of the antenna. Impedance **is a measure of the opposition to AC current flow in a circuit**. (T5C12) **Ohms** are the units of impedance. (T5C13)

Most amateur radio transmitters are designed to have an output impedance of 50 ohms. Because that is the case, the impedance of the most commonly used coaxial cable in amateur radio installations is **50 ohms**. (T9B02) There are two different types of coaxial cables used in amateur stations - **50 and 75 ohms**. (G9A02) The 75 ohm coaxial cable is typically used in video connections like cable TV or satellite TV installations.

RG-58 and RG-8 are two types of coaxial cable often used in amateur radio stations. Both have an impedance of 50 ohms, but there are important differences between the two. One electrical difference between the smaller RG-58 and larger RG-8 coaxial cables is that **RG-8 cable has less loss at a given frequency**. (T9B10) The type of coax that has the lowest loss at VHF and UHF is **air-insulated hard line**. (T9B11) As the frequency of a signal carried in a coaxial cable increases, the **attenuation increases**. (G9A05) RF feedline loss is usually expressed as **decibels per 100 feet**. (G9A06)

Moisture contamination is the most common cause for failure of coaxial cables. (T7C09)One way that moisture enters a cable is via cracks in the cable's outer jacket. The reason that the outer jacket of coaxial cable should be resistant to ultraviolet light is that **ultraviolet light can damage the jacket and allow water to enter the cable**. (T7C10) A disadvantage of "air core" coaxial cable when compared to foam or solid dielectric types is that **it requires special techniques to prevent water absorption**. (T7C11)

PL-259 connectors are the most common type of connectors used on coaxial cables in amateur radio stations. One thing that is true of PL-259 type coax connectors is that **they are commonly used at HF frequencies**. (T9B07)

One problem with PL-259 connectors is that they are not the most suitable connector when operating at higher frequencies. Instead, **a Type N connector** is most suitable for frequencies above 400 MHz. (T9B06)

No matter what type of connector you use, coax connectors exposed to the weather should be sealed against water intrusion **to prevent an increase in feedline loss**. (T9B08) Also make sure that your antenna connections are tight and the connectors are soldered properly. **A loose connection in an antenna or a feedline** might cause erratic changes in SWR readings. (T9B09)

A characteristic of parallel conductor antenna feed lines that determine the impedance is **the distance between the centers of the conductors and the radius of the conductors**. (G9A01) The impedance of flat ribbon TV type twinlead is **300 ohms**. (G9A03)

Standing wave ratio and antenna measurements

Standing wave ratio is a term you'll often hear when talking about antennas and feedlines. In general terms, standing wave ratio (SWR) is **a measure of how well a load is matched to a transmission line**. (T7C03) In this context, the "load" is the antenna. When we say that an antenna is matched to a transmission line, we mean that the impedance of the transmission line is equal to the impedance of the antenna. The cause of reflected power at the point where the feed line connects to the antenna is **a difference between the feed line impedance and antenna feed point impedance**. (G9A04) So, to prevent standing waves on the antenna feed line, **the antenna feed point impedance must be matched to the characteristic impedance of the feed line**. (G9A07)

The reason it is important to have a low SWR in an antenna system that uses coaxial cable feedline is **to allow the efficient transfer of power and reduce losses**. (T9B01) The bigger the mismatch is between the feedline and the load, the higher the SWR will be, and the more power you will lose in the feedline. Power lost in a feedline **is converted into heat**. (T7C07)Power converted into heat is not radiated by the antenna, meaning your radiated signal will be weaker. **If a transmission line is lossy, high SWR will increase the loss**. (G9A14) **The higher the transmission line loss, the more the SWR will read artificially low**. (G9A15) So, to increase the accuracy of your SWR reading, start with the lowest possible loss coaxial cable for the frequency that you are using. You can measure the SWR of your antenna system with an SWR meter. An in-line SWR meter should be connected **in series with the feed line, between the transmitter and antenna** to monitor the standing wave ratio of the station antenna system. (T4A05) You usually connect the SWR meter near the output of your transmitter because it is important to have a low SWR at that point.

An SWR meter is not the only way to measure SWR. A **directional wattmeter** is an instrument other than an SWR meter that you could use to determine if a feedline and antenna are properly matched. (T7C08) When using a directional wattmeter, you first measure the forward power, then the reflected power, and from those two values, calculate the SWR. **1 to 1** is the reading on an SWR meter indicates a perfect impedance match between the antenna and the feedline. (T7C04) **2 to 1** is the approximate SWR value above which the protection circuits in most solid-state transmitters begin to reduce transmitter power. (T7C05) An SWR reading of 4:1 means that there is **an impedance mismatch**. (T7C06)

Some typical SWR calculations are:

4:1 SWR ratio for a 50 ohm feed line to a non-reactive load having 200 ohm impedance (G9A09)

5:1 SWR ratio for a 50 ohm feed line to a non-reactive load having 10 ohm impedance (G9A10)

1:1 SWR ratio for a 50 ohm feed line to a non-reactive load having 50 ohm impedance (G9A11)

2:1 SWR ratio for a 50 ohm feed line to a non-reactive load having 25 ohm impedance (G9A12)

6:1 SWR ratio for a 50 ohm feed line to a purely resistive 300 ohm feed point impedance (G9A13)

One way to ensure that the impedance of the antenna system matches the output impedance of transmitter is to use an antenna tuner. An antenna tuner **matches the antenna system impedance to the transceiver's output impedance**. (T9B04) If the SWR on an antenna feed line is 5 to 1, and a matching network at the transmitter end of the feed line is adjusted to 1 to 1 SWR, the resulting SWR on the feed line is still **5 to 1**. (G9A08) The radio is seeing the 50 ohms that it wants to efficiently output the power, but the losses in the feed line will result in signal loss and heat generation in the coaxial cable. More work still needs to be done at the antenna feed point to match the impedances.

In addition to the SWR meter and the directional wattmeter, there are a couple of other types of test instruments commonly found in an amateur's "shack." One instrument that every shack should have is the dummy load. A dummy load consists of **a non-inductive resistor and a heat sink**. (T7C13) The primary purpose of a dummy load is **to prevent the radiation of signals when making tests**. (T7C01) Another common test instrument is the antenna analyzer. **An antenna analyzer** is an instrument that can be used to determine if an antenna is resonant at the desired operating frequency. (T7C02) You can also make a number of other measurements that will help you setup an antenna system, such as SWR, capacitive reactance, and inductive reactance.

Electrical safety: AC and DC power circuits, antenna installation, RF hazards

Power circuits and hazards: hazardous voltages, fuses and circuit breakers, grounding, lightning protection, battery safety, electrical code compliance

When operating or working on amateur radio equipment, it's possible to come into contact with dangerous voltages and currents. People have died working on high-voltage circuits or putting up antennas. It's important to know how to be safe when working with electricity. Having said that, 30 volts is the commonly accepted value for the lowest voltage that can cause a dangerous electric shock and 100 mA is the lowest amount of electrical current flowing through the body that is likely to cause death. These are not very large values.

All of these choices are correct when considering how current flowing through the body can cause a health hazard (T0A02):

By heating tissue

It disrupts the electrical functions of cells

It causes involuntary muscle contractions

When properly wired, three-wire electrical outlets and plugs are safer than two-wire outlets and plugs, and you should use three-wire plugs for all of your amateur radio equipment. The third wire provides an independent, or safety ground. **Safety ground** is connected to the green wire in a three-wire electrical AC plug. (T0A03) **Current flowing from one or more of the voltage-carrying wires directly to ground** will cause a Ground Fault Circuit Interrupter (GFCI) to disconnect the power to a device. (G0B05)

All of these choices are correct when choosing a good way to guard against electrical shock at your station (T0A06):

Use three-wire cords and plugs for all AC powered equipment

Connect all AC powered station equipment to a common safety ground

Use a circuit protected by a ground-fault interrupter

Individual pieces of equipment may have their own fuses to protect that piece of equipment should something happen that causes that equipment to draw excessive current. The purpose of a fuse in an electrical circuit is **to interrupt power in case of overload**. (T0A04) When replacing a fuse, always replace the blown fuse with a fuse of the same type and value. It is, for example, unwise to install a 20-ampere fuse in the place of a 5-ampere fuse because **excessive current could cause a fire**. (T0A05)

Only the two wires carrying voltage in a four-conductor connection should be attached to a fuse or circuit breaker when the device is connected to a 240 VAC single phase source. (G0B01) **AWG number 12** is the minimum wire size for a circuit that draws up to 20 amperes. (G0B02) AWG number 14 is the minimum wire size for a circuit that draws up to **15 amperes**. (G0B03)

If you plan to build your own equipment, be sure to include fuses in your designs. **A fuse or circuit breaker in series with the AC "hot" conductor** should always be included in home-built equipment that is powered from 120V AC power circuits. (T0A08) Keep all metal enclosures of your equipment grounded because **it ensures that hazardous voltages cannot appear on the chassis**. (G0B06) The purpose of a power supply interlock is **to ensure that dangerous voltages are removed if the cabinet is opened**. (G0B12) **Electrical safety inside the ham shack** is covered by the National Electric Code. (G0B14)

Whenever you're working on equipment, be sure to disconnect it from the power lines, and even then be careful working around a power supply's capacitors. If a power supply is turned off and disconnected, **you might receive an electric shock from stored charge in large capacitors**. (T0A11)

Be sure to also take precautions when using batteries to power your amateur radio station. Conventional 12-volt storage batteries present several safety hazards. **Shorting the terminals can cause burns, fire, or an explosion** (T0A01)**, explosive gas can collect if not properly vented** (T0A09), and, if a lead-acid storage battery is charged or discharged too quickly, **the battery could overheat and give off flammable gas or explode**. (T0A10)

A primary reason for not placing a gasoline-fueled generator inside an occupied area is the **danger of carbon monoxide poisoning**. (G0B04) **The generator should be located in a well-ventilated area** (G0B15) If powering your house from an emergency generator, **disconnect the incoming utility power feed**. (G0B13)

Lastly, a danger from lead-tin solder is that l**ead can contaminate food if hands are not washed carefully after handling the solder**. (G0B10)

Antenna safety: tower safety, erecting an antenna support, overhead power lines, installing an antenna

Antenna safety is also of primary concern. There are two aspects of antenna safety—being safe when installing an antenna and safely operating an antenna.

When putting up an antenna tower, an important safety precaution is to **look for and stay clear of any overhead electrical wires**. (T0B04) When installing an antenna, make sure that it is far enough from power lines, **so that if the antenna falls unexpectedly, no part of it can come closer than 10 feet to the power wires**. (T0B06) This is the reason you should avoid attaching an antenna to a utility pole. **The antenna could contact high-voltage power wires**. (T0B09)

200 feet is the maximum height above ground to which an antenna structure may be erected without requiring notification to the FAA and registration with the FCC, provided it is not at or near a public use airport. (G1B01)

You also should position the antenna so that no one can touch it while you are transmitting. If a person accidentally touched your antenna while you were transmitting, **they might receive a painful RF burn**. (T0C07)

Another safety tip is to use a gin pole designed for use with the tower that you're installing. The purpose of a gin pole is **to lift tower sections or antennas**. (T0B05)

At all times when any work is being done on the tower, members of a tower work team should wear a hard hat and safety glasses. (T0B01) Before climbing an antenna tower, it is a good precaution to **put on a climbing harness and safety glasses**. (T0B02) When climbing a tower using a safety belt or harness, **confirm that the belt is rated for the weight of the climber and that it is within its allowable service life**. (G0B07) It is **never** safe to climb a tower without a helper or observer. (T0B03) When using a crank-up tower, an important safety rule to remember is that **this type of tower must never be climbed unless it is in the fully retracted position**. (T0B07) When preparing to climb a tower that supports electrically powered devices, **make sure all circuits that supply power to the tower are locked out and tagged**. (G0B08)

Grounding is very important when installing a tower because the tower is basically a big lightning rod. **Local electrical codes** establish grounding requirements for an amateur radio tower or antenna. (T0B11)

Separate eight-foot long ground rods for each tower leg, bonded to the tower and each other is considered to be a proper grounding method for a tower. (T0B08) When installing ground wires on a tower for lightning protection, it is good practice to **ensure that connections are short and direct**. (T0B12) **Sharp bends must be avoided** when installing grounding conductors used for lightning protection. (T0B10) You should never solder the wires that connect the base of a tower to a system of ground rods because **a soldered joint will likely be destroyed by the heat of a lightning strike**. (G0B09)

Lightning can also be conducted down a feedline and into your shack. To prevent this, several manufacturers make devices designed to shunt this current to ground before it gets into the shack. When installing devices for lightning protection in a coaxial cable feedline, **ground all of the protectors to a common plate which is in turn connected to an external ground**. (T0A07) Good practice for lightning protection grounds is that **they must be bonded together with all other grounds**. (G0B11)

RF hazards: radiation exposure, proximity to antennas, recognized safe power levels, exposure to others, radiation types, duty cycle

Finally, let's consider the safety hazards of being exposed to radio waves. When using high power, you are required to perform an RF exposure evaluation, even though VHF and UHF radio signals are **non-ionizing radiation**. (T0C01) RF radiation differs from ionizing radiation (radioactivity) in that **RF radiation does not have sufficient energy to cause genetic damage**. (T0C12) Even so small levels of RF energy can be unsafe. RF energy can affect you because **it heats body tissue**. (G0A01) The maximum power level that an amateur radio station may use at VHF frequencies before an RF exposure evaluation is required is **50 watts PEP at the antenna.** (T0C03)

When installing a ground-mounted antenna, **it should be installed such that it is protected against unauthorized access**. (G0A06) If you install an indoor transmitting antenna, **make sure that MPE limits are not exceeded in occupied areas**. (G0A11)

A calibrated field strength meter with a calibrated antenna is one type of instrument to accurately measure an RF field. (G0A09)

How do you perform an RF exposure evaluation? **All of these choices are correct** as acceptable methods to determine if your station complies with FCC RF exposure regulations (T0C06):

- By calculation based on FCC OET Bulletin 65
- By calculation based on computer modeling
- By measurement of field strength using calibrated equipment

All of these choices are correct in importance for estimating whether an RF signal exceeds the maximum permissible exposure (MPE) (G0A02):

- Its duty cycle
- Its frequency
- Its power density

One of the steps to take to ensure compliance with RF safety regulations should transmitter power exceed levels specified in FCC Part 97.13 is to **perform a routine RF exposure evaluation**. (G0A08) A precaution to take when making adjustments or repairs to an antenna is to **turn off the transmitter and disconnect the feedline**. (G0A12)

If evaluation shows that a neighbor might receive more than the allowable limit of RF exposure from the main lobe of the antenna, **take precautions to ensure that the antenna cannot be pointed in their direction**. (G0A10)

How can you determine that your station complies with FCC RF exposure regulations? **All of these choices are correct** (G0A03):

- By calculation based on FCC OET Bulletin 65
- By calculation based on computer modeling
- By measurement of field strength using calibrated equipment

One of the factors to consider when performing an RF exposure evaluation is the duty cycle of your transmissions. The term “duty cycle” when referring to RF exposure is **the percentage of time that a transmitter is transmitting**. (T0C11) Duty cycle is one of the factors used to determine safe RF radiation exposure levels because **it affects the average exposure of people to radiation**. (T0C10) A transmission with a lower duty cycle would be less hazardous than a high duty cycle transmission. **A lower transmitter duty cycle permits greater short-term exposure levels**. (G0A07)

If the averaging time for exposure is 6 minutes, **2 times as much** power density is permitted if the signal is present for 3 minutes and absent for 3 minutes rather than being present for the entire 6 minutes. (T0C13) Time averaging is **the total RF exposure averaged over a certain time**. (G0A04)

Because of the way radio waves interact with the body, the exposure limits are different for each amateur radio band. Exposure limits vary with frequency because **the human body absorbs more RF energy at some frequencies than at others**. (T0C05) The **50 MHz** band has the lowest Maximum Permissible Exposure limit. (T0C02) **All of these choices are correct** when talking about factors that affect the RF exposure of people near an amateur station antenna (T0C04):

- Frequency and power level of the RF field
- Distance from the antenna to a person
- Radiation pattern of the antenna

So, what should you do if your RF exposure evaluation shows that people are being exposed to excessive RF? One action amateur operators might take to prevent exposure to RF radiation in excess of FCC-supplied limits is to **relocate antennas**. (T0C08) You could also lower the power or simply transmit less. If the evaluation of your station shows RF energy exceeds permissible levels, **take action to prevent human exposure to the excessive RF fields**. (G0A05)

After the initial RF exposure evaluation, you make sure your station stays in compliance with RF safety regulations **by re-evaluating the station whenever an item of equipment is changed**. (T0C09)

Glossary

AC: alternating current. Alternating current is the name for current that reverses direction on a regular basis. (T5A09). The power outlets in your home provide alternating current.

APRS: Automatic Packet Reporting System. APRS is digital communications system used by amateur radio operators. While it is normally used for tracking the location of mobile stations, it can be used for other purposes as well. For more information, go to http://www.aprs.org.

AM: amplitude modulation. The type of modulation that varies the amplitude of a radio signal in accordance with the amplitude of a modulating signal. For more information, go to http://www.pa2old.nl/files/am_fundamentals.pdf.

CTCSS: Continuous Tone Coded Squelch System. A system that uses sub-audible tones, transmitted along with the audio portion of a transmission to control whether or not a repeater will re-transmit a signal. It is known by a number of different trade names, including Private Line® (PL) by Motorola. In practice, it's used to prevent nearby transmitters from inadvertently turning on repeaters.

CW: continuous wave. This is the operating mode amateur radio operators use when sending Morse Code.

DC: direct current. Direct current is the name for current that never reverses direction.

DTMF: dual-tone, multi-frequency. DTMF is a type of signaling used to send data over voice channels. Its most common use in amateur radio is to allow users of hand-held transceivers to send commands to repeater systems. It is called DTMF because every time a user presses a keypad button a unique tone consisting of two frequencies is transmitted. For more information, see http://www.genave.com/dtmf.htm.

FCC: Federal Communications Commission. This is the government body that sets the rules for amateur radio in the U.S.

FM: frequency modulation. The type of modulation normally used when operating on VHF and UHF repeaters.

HF: high frequency. The range of frequencies between 3 MHz and 30 MHz.

HT: handy-talky or handheld transceiver. "Handy Talky" is a Motorola trademark.

ITU: International Telecommunications Union. This is the international body that governs amateur radio worldwide.

LSB: lower sideband. See **SSB**.

MFSK: multi-frequency shift keying. A type of modulation used to send digital information over a radio channel.

PL: Private Line. See **CTCSS**.

PSK: phase shift keying. A method for sending digital information over a radio channel. A popular amateur radio "digital mode" is PSK31, which uses PSK modulation and occupies only 31 Hz of bandwidth.

PTT: push-to-talk

RACES: Radio Amateur Civil Emergency Service. RACES is an amateur radio emergency communications service created by the Federal Emergency Management Agency (FEMA) and the FCC. RACES volunteers serve their respective jurisdictions pursuant to guidelines and mandates established by local emergency management officials. See http://www.usraces.org/ for more information.

RIT: receiver incremental tuning. A control which allows a user to set the receive frequency of a transceiver either slightly higher or slightly lower than the transmit frequency.

RF: radio frequency

SSB: single sideband. When a carrier is amplitude modulated, both upper and lower sidebands are produced. This results in a signal that is 6 kHz wide. Since both sidebands carry the same information, and the carrier carries no information, someone figured out that if they could filter out the carrier and one of the sidebands, and put all the power into a single sideband, the efficiency of voice communications would be much greater. Nearly all voice communications on the shortwave bands now use SSB.

SWR: standing-wave ratio. The SWR of an antenna system is a measure of how closely the impedances of the antenna and feedline match the output impedance of the transmitter.

VHF: very high frequency. The range of frequencies between 30 MHz and 300 MHz.

ULS: Universal Licensing System. The FCC's Universal Licensing system contains information on all FCC licensees, including amateur radio operators. For more information, go to http://www.fcc.gov/uls.

UHF: ultra high frequency. The range of frequencies between 300 MHz and 3000 MHz.

USB: upper sideband. See **SSB**.

VFO: variable frequency oscillator. VFOs are used to control the receiving and transmitting frequencies of amateur radio equipment.

About the Exam

Now you are ready for the fun part. First, relax! Be sure to take a rest break. Once you begin the exam you may not leave the room. Be sure to turn off cell phones, pagers, watches that make noise, and any two-way radio equipment you may have with you. Place books and study materials on the floor or out of sight. Each exam is a simple 35 question multiple choice test, and you have been studying all the correct answers. You know this stuff. You are ready! Please follow the instructions of the Volunteer examiners carefully! First there is a little paperwork that needs to be done. The Volunteer Examiners will assist you in filling out the necessary application form NVEC-610. When this form is completed, they will ask to see your photo ID. This is required to verify that you are in fact the person you claim to be on the application form. If you have copies of CSCE documents or licenses to be counted as credit for exam elements, be sure to inform the VE that checks your ID. They will now take your money. The exam processing fee on July 1 of 2016 is $15.00. This payment is to defray the actual costs of processing your application from the exam all the way to the FCC ULS Database.

Now you will receive the actual exam materials, and you may begin taking your exam. When you are finished, return your exam materials including scratch pages you used for calculations to the examiners. They will grade your exam while you wait. **IMPORTANT!!!** Do not leave the session until your exam has been graded. Before you leave you should receive a CSCE document for any exam elements you have passed in this session. This is your only proof of passing this exam should the paperwork be lost in handling. Keep this CSCE in a safe place. If you pass the Element 2 exam, you will be given an opportunity to take the Element 3 exam for the General class license. There is no additional charge for taking another exam element so long as you pass each previous element. If you pass the Element 3 exam, you will be given an opportunity to take the Element 4 exam for the Extra class license. **DO IT!** You might end this exam session as an amateur Extra class operator.

If you need to re-take an exam element, there will be a new $15.00 fee required. If you have passed elements that qualify for a license, you will be able to see your call sign in the ULS system typically in 5-7 days. A hardcopy document from the FCC will follow via US Mail to the address given on your application. If you are upgrading from Technician to General class, you may use your new privileges as soon as you have received your CSCE document, because you already have a callsign. Be sure to add the “temporary AG” to your identification if you are on a General class frequency.

To search in the ULS if your are getting a new call sign, visit: **http://callsign.ualr.edu/callsign.shtml**
and enter your name in the name-search box just as you entered it onto the application form.