FLASHFEED STUDY GUIDE

Ham Radio Technician License

Study guide by FlashFeed

November 2026 edition · pack version 1.0.11

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Ham Radio Technician License: study guide

Prepares adults for the Technician license exam, in the question pool's own order.

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Contents	15 lessons · 1179 cards in the app · 409 self-test questions · 239 pictures
In the app	flashfeedlearningapp.com/packs/ham-radio-technician

How to use this guide

Take one lesson at a time: read the study guide, then go over any key facts. Where a lesson has a self-test, try it from memory before you check the answer key at the back. Follow the Go deeper links when you want more.

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LESSON 1 OF 15

The Rules: Licenses, Bands and Call Signs

Purpose, license grants and key terms · Frequency allocations, modes and power · License classes, call signs and terms

WHAT YOU'LL BE ABLE TO DO

- Explain the purpose of the Amateur Radio Service, who regulates it, what it prohibits or encourages, and what counts as a space station
- Describe how a license grant is issued and proven, and how beacons, frequency coordinators and RACES operation work
- Identify the bands and band segments where a Technician may operate, including phone, digital and ISS contacts
- Explain CW-only segments, secondary allocations, band-edge practice, SSB use and the power limits for Technicians
- Identify the license classes the FCC issues, vanity and valid call signs, and the rules for international contacts and operating on vessels
- Explain when a new licensee may transmit, the license term, renewal and its grace period, and what follows if the FCC can't reach a licensee by email

This lesson covers the rules that decide who may operate an amateur station, where on the radio spectrum, and under what call sign. It has three parts. The first covers the purpose of the service, license grants and the terms the rules use. The second covers bands, modes and power. The third covers license classes, call signs and keeping a license current. A new licensee works under these rules from the first transmission.

Purpose, license grants and key terms

The Amateur Radio Service in the United States is regulated and enforced by the Federal Communications Commission (FCC). The FCC writes its amateur rules in Part 97 of its regulations.

Purpose of the service

The rules give the service a fundamental purpose, expressed in five principles:

- Recognition of the service's value to the public as a voluntary noncommercial communication service, particularly for emergency communications.
- Continuation and extension of the amateur's proven ability to contribute to the advancement of the radio art.

- Encouragement and improvement of the service through rules that advance skills in both the communication and technical phases of the art.
- Expansion of the existing reservoir of trained operators, technicians and electronics experts.
- Continuation and extension of the amateur's unique ability to enhance international goodwill.

So advancing skills in the technical and communication phases of the radio art is part of the service's basis and purpose.

Operators, stations and control operators

An **amateur station** is a station in an amateur radio service consisting of the apparatus necessary for carrying on radiocommunications. An amateur operator is a person named in an amateur operator/primary station license grant on the consolidated licensee database to be the control operator of an amateur station. That database is the **Universal Licensing System (ULS)**. The ULS is the consolidated database, application filing system and processing system for all Wireless Telecommunications Services.

A **control operator** is an amateur operator designated by the licensee of a station to be responsible for the transmissions from that station. The control operator assures compliance with the FCC rules. When transmitting, each amateur station must have a control operator. That person must have an operator/primary station license grant on the ULS database. The other way to qualify is to be authorized for alien reciprocal operation under a separate rule.

Notice and proof of a license grant

After a candidate passes the exam, the official notice of the new license and call sign is an email from the FCC. The email has a link to download the license grant.

What proves that the FCC has issued an operator/primary license grant is that the license appears in the ULS database.

Phonetics and station identification

A station may identify itself by a phone emission in the English language. **Phone** means speech and other sound emissions, and it also covers incidental tones used for selective calling or alerting. The rules encourage a phonetic alphabet as an aid for correct station identification when using phone emissions.

Beacons

The rules allow a beacon to be automatically controlled while it transmits on certain segments. These segments are 28.20-28.30 megahertz (MHz), 50.06-50.08 MHz, 144.275-144.300 MHz, 222.05-222.06 MHz and 432.300-432.400 MHz. Beacons may also be automatically controlled on the 33 cm and shorter wavelength bands. Among the high frequency (HF) bands, the range of 3-30 MHz, the segment is on ten meters. Automatically controlled amateur propagation beacons are found there, between 28.200 MHz and 28.300 MHz.

Space stations

A **space station** is an amateur station located more than 50 kilometers (km) above the Earth's surface. Height above the Earth's surface decides it.

Frequency coordinators and repeaters

A **repeater** is an amateur station that simultaneously retransmits the transmission of another amateur station on a different channel or channels. A **frequency coordinator** recommends transmit/receive channels and associated operating and technical parameters for repeater and auxiliary stations. The purpose is to avoid or minimize potential interference. A Volunteer Frequency Coordinator recognized by local amateurs does this. Amateur operators in a local or regional area whose stations are eligible to be repeater or auxiliary stations select the coordinator.

Emergency service and prohibited acts

The **Radio Amateur Civil Emergency Service (RACES)** is a radio service using amateur stations for civil defense communications during periods of local, regional or national civil emergencies. To be a control operator in RACES, a person needs an FCC-issued amateur operator license. The person also needs certification by a civil defense organization of current enrollment in that organization.

Willful or malicious interference with any radio communication or signal is prohibited. No amateur operator shall willfully or maliciously interfere with or cause interference to any radio communication or signal.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)
- 47 CFR § 97.1 Basis and purpose
- 47 CFR § 97.101 General standards
- 47 CFR § 97.119 Station identification
- 47 CFR § 97.203 Beacon station
- 47 CFR § 97.23 Mailing and email addresses
- 47 CFR § 97.3 Definitions
- 47 CFR § 97.407 Radio amateur civil emergency service
- 47 CFR § 97.7 Control operator required

Frequency allocations, modes and power

Technician licensees may use certain slices of the spectrum, with limits on how those slices are used and on power. The ranges below are those the rules give for each band.

Bands and frequencies to recognize

The 6-meter band spans 50-54 MHz, so 52.525 MHz is in it. The 2-meter band spans 144-148 MHz, and it includes 146.52 MHz.

HF privileges for Technicians

Technician licensees have only a few HF segments. They are:

- 80 meters: 3.525-3.600 MHz
- 40 meters: 7.025-7.125 MHz
- 15 meters: 21.025-21.200 MHz
- 10 meters: 28.0-28.5 MHz

Phone privileges on HF are on the 10-meter band only. The phone range available to Technician licensees is 28.300 MHz to 28.500 MHz.

Digital modes

Technicians may use digital modes such as FT8 on frequencies in the 10-meter band. They may also use them on the 6-meter band and the 2-meter band. All three of those bands include such frequencies.

Contacting the International Space Station

The International Space Station (ISS) is a space station. Space stations are authorized in the 144-146 MHz segment, which lies in the 2-meter band. Any amateur with a Technician class or higher license may contact the ISS on very high frequency (VHF) bands. VHF is the range 30-300 MHz.

CW-only segments and single sideband

CW means International Morse code telegraphy emissions, together with certain defined designators. An amateur station may transmit CW on any frequency authorized to its control operator. Two segments in the VHF and ultra high frequency (UHF) ranges are limited to CW only: 50.0 MHz to 50.1 MHz and 144.0 MHz to 144.1 MHz. UHF is the range 300-3000 MHz. Other emissions begin above those points. On 6 meters, other emissions begin at 50.1 MHz, and on 2 meters, at 144.1 MHz.

Single sideband (SSB) phone may be used in at least some segment of every amateur band above 50 MHz.

Secondary segments

In each band segment, the Amateur Radio Service is designated either a secondary service or a primary service. A station in a secondary service must not cause harmful interference to stations in a primary service. It must also accept interference from them. So in segments where the Amateur Radio Service is secondary, U.S. amateurs may find non-amateur stations. They must avoid interfering with them.

Staying off the band edge

A station should not set its transmit frequency exactly at the edge of an amateur band or sub-band, for three reasons:

- The transmitter's frequency display may have calibration error.
- Modulation sidebands could extend beyond the band edge.
- The transmitter frequency may drift.

These reasons follow the rule that each station must be operated in accordance with good engineering and good amateur practice.

Power limits

An amateur station must use the minimum transmitter power necessary to carry out the desired communications. **Peak envelope power (PEP)** is the average power supplied to the antenna transmission line by a transmitter during one radio frequency (RF) cycle at the crest of the modulation envelope, under normal operating conditions.

In their HF segments, Technician class operators may not exceed 200 watts PEP. The rule applies on 3.525-3.60 MHz, 7.025-7.125 MHz, 21.025-21.20 MHz and 28.0-28.5 MHz.

Above 30 MHz, Technicians may use up to 1500 watts PEP (1.5 kilowatts), except for some specific restrictions. This limit covers UHF as well as VHF. One example of a restriction is the 219-220 MHz segment of the 1.25 m band. No station may exceed 50 watts PEP there.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)
- 47 CFR § 97.101 General standards
- 47 CFR § 97.207 Space station
- 47 CFR § 97.3 Definitions
- 47 CFR § 97.301 Authorized frequency bands
- 47 CFR § 97.303 Frequency sharing requirements
- 47 CFR § 97.305 Authorized emission types
- 47 CFR § 97.313 Transmitter power standards

License classes, call signs and terms

A license ties a person to a class, a call sign and a term. This part covers which classes the FCC issues, how call signs are chosen, and how a license is started, kept current and renewed.

License classes

The operator license classes in the rules are Novice, Technician, General, Advanced and Amateur Extra. As of 2026, the FCC issues new licenses only for Technician, General and Amateur Extra. No new license grant is issued for a Novice or Advanced Class operator/primary station. An application to renew a Technician Plus Class license is processed as a renewal of a Technician Class license. The person named in the grant may be the control operator of an amateur station with the privileges of the class on the license.

Call signs

A **vanity call sign** is a call sign the licensee requests through the vanity call sign system. The licensee lists up to 25 call signs in order of preference, and the FCC assigns the first one that can be assigned. Any licensed amateur may use the vanity rules to request a desired call sign.

A valid Group D call sign format for a Technician class is KF1XXX. That is two letters, a digit and three letters.

International communications

Transmissions to a different country, where permitted, are limited to communications incidental to the purposes of the amateur service and to remarks of a personal character.

Operating aboard a vessel

A station may transmit from any place within 50 km of the Earth's surface aboard a vessel or craft documented or registered in the United States. The station apparatus must be under the physical control of a person named in an amateur station license grant. Operation on a ship or aircraft must be approved by the ship's master or the aircraft's pilot in command. So a licensee may operate from a US-documented vessel with the master's permission.

Starting to transmit

A new licensee may transmit as soon as the operator/station license grant appears in the FCC's license database. A **certificate of successful completion of an examination (CSCE)** shows that a candidate passed the exam.

Keeping contact details current

Each license grant must show the grantee's correct name, mailing address and email address. The email address must be one where the grantee can receive electronic correspondence. A licensee must apply to the FCC to modify the grant as necessary to show correct addresses. If correspondence from the FCC is returned as undeliverable because the grantee did not provide the correct email address, revocation of the station license or suspension of the operator license may result.

Term, renewal and grace period

An amateur service license is normally granted for a 10-year term. A renewal application must be filed no later than the expiration date and no sooner than 90 days before it. A renewal request therefore may be made 90 days before expiration. For a primary station license, when the FCC receives the application on or before the expiration date, the license operating authority continues until the application is finally decided.

A license that has expired can still be renewed during a **grace period** of 2 years. The renewal application must be received before that period ends. Unless and until the license grant is renewed, no privileges are conferred. A licensee whose license has expired may not transmit during the grace period.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)
- 47 CFR § 1.949 Application for renewal of authorization
- 47 CFR § 97.11 Stations aboard ships or aircraft
- 47 CFR § 97.117 International communications
- 47 CFR § 97.17 Application for new license grant
- 47 CFR § 97.19 Application for a vanity call sign
- 47 CFR § 97.21 Application for a modified or renewed license grant
- 47 CFR § 97.23 Mailing and email addresses
- 47 CFR § 97.25 License term
- 47 CFR § 97.3 Definitions
- 47 CFR § 97.5 Station license required
- 47 CFR § 97.9 Operator license grant

Key terms

Control operator
An amateur operator the station's licensee designates to be responsible for its transmissions and rule compliance

Repeater
A station that simultaneously retransmits another amateur station's signal on a different channel or channels

PEP
Peak envelope power: average power fed to the antenna line during one radio frequency (RF) cycle at the modulation crest

CW
International Morse code telegraphy emissions, together with certain defined designators

CSCE

Certificate of successful completion of an examination; it shows that a candidate passed the exam

Vanity call sign

A station identifier the licensee requests by listing up to 25 in order of preference; the Federal Communications Commission assigns the first assignable one, and any licensed amateur may apply

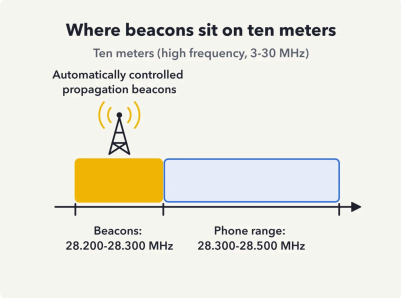
Key facts

Proof of a License Grant

After a candidate passes the exam, the official notice is an email from the Federal Communications Commission (FCC) with a link to download the license grant. What proves the grant exists is the license appearing in the **Universal Licensing System (ULS)** database.

Phonetic Alphabet Is Encouraged

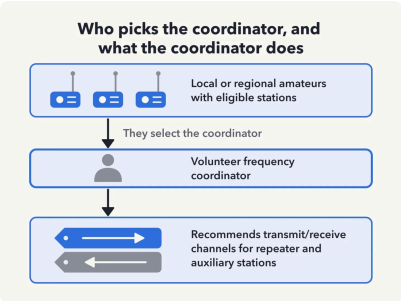
A station may identify itself by a **phone** emission in the English language. The rules encourage a phonetic alphabet as an aid for correct station identification when using phone emissions.



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Beacons on Ten Meters

The rules allow a **beacon** to be automatically controlled on certain segments. Among the high frequency (HF) bands, the range of 3-30 megahertz (MHz), automatically controlled amateur propagation beacons are found on ten meters, from 28.200 MHz to 28.300 MHz.



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Who Picks Repeater Channels

A **frequency coordinator** recommends transmit/receive channels for repeater and auxiliary stations, to avoid or minimize potential interference. Amateur operators in the local or regional area whose stations are eligible select the coordinator.

The FCC Regulates Amateur Radio

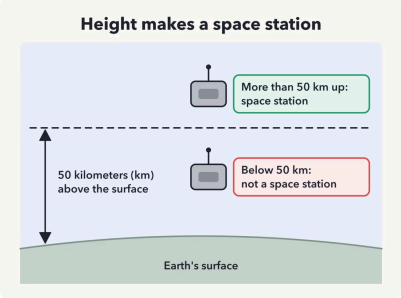
The Amateur Radio Service in the United States is regulated and enforced by the **Federal Communications Commission (FCC)**.

Who Controls a RACES Station

A control operator in the **radio amateur civil emergency service (RACES)** needs a Federal Communications Commission (FCC) amateur operator license. The person also needs certification by a civil defense organization of current enrollment in that organization.

Purpose of the Service

Advancing skills in the technical and communication phases of the radio art is part of the **basis and purpose** of the Amateur Radio Service. Other principles include recognizing the service's value to the public as a voluntary noncommercial communication service, particularly for emergency communications.



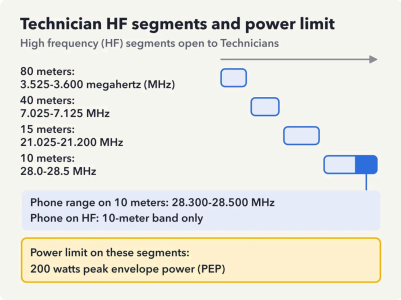
FlashFeed original diagram · CC-BY-4.0

What Is a Space Station

A **space station** is an amateur station located more than 50 kilometers (km) above the Earth's surface. Height decides it.

Interference Is Prohibited

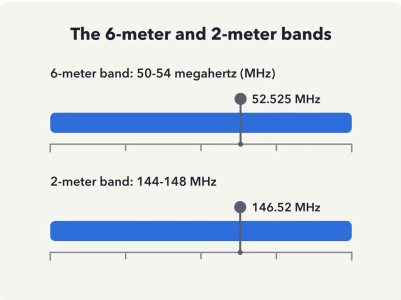
Willful or malicious **interference** with any radio communication or signal is prohibited. No amateur operator shall willfully or maliciously interfere with or cause interference to any radio communication or signal.



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HF Phone Only on 10 Meters

Technician licensees have phone privileges on high frequency (HF) only on the **10-meter band**. The phone range available to them is 28.300 megahertz (MHz) to 28.500 MHz.



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The 6-Meter and 2-Meter Bands

The **6-meter band** spans 50-54 megahertz (MHz), so 52.525 MHz is in it. The 2-meter band spans 144-148 MHz, and it includes 146.52 MHz.

200 Watts PEP on HF

In their high frequency (HF) segments, Technician class operators may not exceed 200 watts of **peak envelope power (PEP)**. The limit applies on 3.525-3.60, 7.025-7.125, 21.025-21.20 and 28.0-28.5 megahertz (MHz).



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Contacting the Space Station

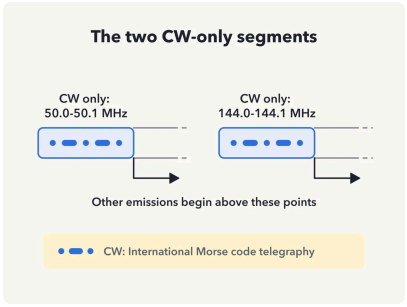
Any amateur with a Technician class or higher license may contact the International Space Station (ISS) on very high frequency (VHF) bands. VHF is the range 30-300 megahertz (MHz). The **ISS** is a space station.

Secondary Segments

In each band segment, the Amateur Radio Service is designated a **secondary service** or a primary service. A station in a secondary service must not cause harmful interference to stations in a primary service, and it must accept interference from them.

Digital Modes for Technicians

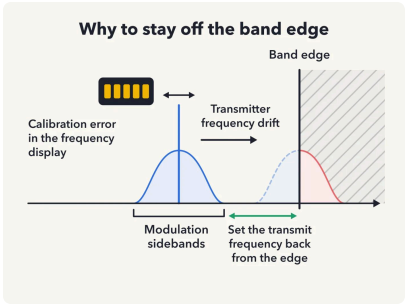
Technicians may use **digital modes** such as FT8 on frequencies in the 10-meter band. They may also use them on the 6-meter band and the 2-meter band. All three bands include such frequencies.



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CW-Only Segments

Two segments in the very high frequency (VHF) and ultra high frequency (UHF) ranges are limited to **CW** (International Morse code telegraphy emissions) only: 50.0 megahertz (MHz) to 50.1 MHz and 144.0 MHz to 144.1 MHz. Other emissions begin above those points.



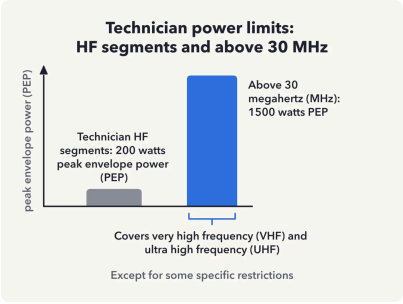
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Stay Off the Band Edge

A station should not transmit exactly at a band or sub-band edge. The transmitter's frequency display may have **calibration error**, modulation sidebands could extend beyond the edge, and the transmitter frequency may drift.

SSB Above 50 MHz

Single sideband (SSB) phone may be used in at least some segment of every amateur band above 50 megahertz (MHz).

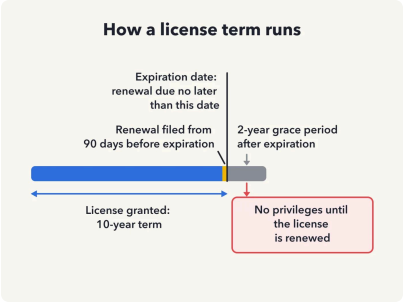


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1500 Watts Above 30 MHz

Above 30 megahertz (MHz), Technicians may use up to **1500 watts** of peak envelope power (PEP), except for some specific restrictions. This limit covers ultra high frequency (UHF) as well as very high frequency (VHF).

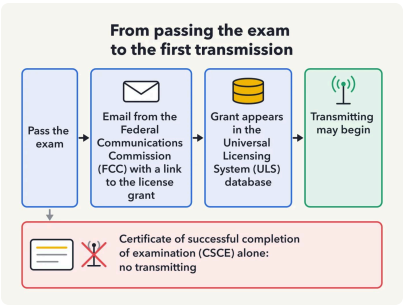
> ### Classes Issued as of 2026
>
> As of 2026, the Federal Communications Commission (FCC) issues new licenses only for **Technician**, General and Amateur Extra. No new license grant is issued for a Novice or Advanced Class operator/primary station.



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Ten-Year Term, 90-Day Window

An amateur service license is normally granted for a **10-year term**. A renewal application must be filed no later than the expiration date and no sooner than 90 days before it.



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When Transmitting May Begin

A new licensee may transmit as soon as the **license grant** appears in the license database of the Federal Communications Commission (FCC).

> ### No Operating in the Grace Period
>
> An expired license can still be renewed during a 2-year **grace period**. No privileges are conferred until the grant is renewed, so a licensee whose license has expired may not transmit during the grace period.

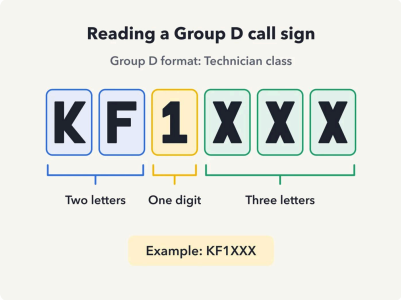
> ### Operating Aboard a Vessel
>
> A licensee may operate from a **US-documented vessel** with the master's permission. Operation of an amateur station on a ship or aircraft must be approved by the ship's master or the aircraft's pilot in command.

Keep a Valid Email Address

Each license grant must show the grantee's correct name, mailing address and email address. If correspondence from the Federal Communications Commission (FCC) is returned undeliverable because of an incorrect email address, **revocation** of the station license or suspension of the operator license may result.

International Communications

Transmissions to a different country, where permitted, are limited to communications incidental to the purposes of the amateur service and to **remarks of a personal character**.



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A Valid Group D Format

A valid **Group D** call sign format for a Technician class is KF1XXX: two letters, a digit and three letters.

Matched pairs

Each item on the left goes with the one on the right.

Space station → Station over 50 kilometers up

6 m segment limited to Morse code (CW) → 50.0 to 50.1 megahertz

Valid Group D format → KF1XXX

Self-test

Answer each question from memory, then check your work against the answer key.

1. Which of the following is part of the Basis and Purpose of the Amateur Radio Service?

- A Providing communications for international contesting
- B Advancing skills in the technical and communication phases of the radio art
- C All these choices are correct
- D Providing personal radio communications for as many citizens as possible

2. Which agency regulates and enforces the rules for the Amateur Radio Service in the United States?

- A Homeland Security
- B All these choices are correct
- C ARRL
- D The FCC

3. Which of the following is prohibited?

A. International communications on VHF bands and higher frequencies
B. Third-party traffic using digital modes
C. Willful or malicious interference
D. All these choices are correct

4. What do the FCC rules state regarding the use of a phonetic alphabet for station identification in the Amateur Radio Service?

A. It is encouraged when using phone emissions
B. It is required when in contact with foreign stations
C. All these choices are correct
D. It is required when transmitting emergency messages

5. What is the FCC Part 97 definition of a space station?

A. An amateur station using amateur radio satellites for relay of signals
B. Any satellite orbiting Earth
C. An amateur station located more than 50 km above Earth's surface
D. A manned satellite orbiting Earth

6. How do you receive official notification of your new license and call sign after passing the exam?

A. USPS First-Class Mail from the lead volunteer examiner
B. Email from the FCC with a link to download the license grant
C. Email from the lead volunteer examiner
D. USPS First-Class Mail from the FCC

7. What proves that the FCC has issued an operator/primary license grant?

A. All these choices are correct
B. A printed copy of the certificate of successful completion of examination
C. An email notification from the NCVEC granting the license
D. The license appears in the FCC ULS database

8. On which of the following HF frequencies can automatically controlled amateur propagation beacons be found?

A. On ten meters, between 28.200 MHz and 28.300 MHz
B. In a specific portion of each of the HF Technician bands
C. Anywhere, if they are registered with the FCC
D. Anywhere in the Technician portion of 10 meters

9. Who recommends transmit/receive channels for repeater and auxiliary stations?

A. A Frequency Spectrum Manager appointed by the FCC
B. An FCC Regional Field Office
C. The International Telecommunication Union
D. A Volunteer Frequency Coordinator recognized by local amateurs

10. Who selects a Frequency Coordinator?

A. Local or regional amateurs whose stations are eligible as repeater or auxiliary stations
B. The FCC Office of Spectrum Management and Coordination Policy
C. The FCC Regional Field Office
D. The local chapter of the Office of National Council of Independent Frequency Coordinators

11. Besides an FCC-issued amateur operator license, what is required to be the control operator of a Radio Amateur Civil Emergency Service (RACES) Station?

A. Membership in the Amateur Radio Emergency Service (ARES)
B. Certification of current enrollment by a civil defense organization
C. Nothing
D. A written recommendation by the local ARRL Emergency Coordinator

12. Which frequency is in the 6-meter amateur band?

A. 28.50 MHz
B. 222.15 MHz
C. 52.525 MHz
D. 49.00 MHz

13. Which amateur band includes 146.52 MHz?

A. 20 meters
B. 2 meters
C. 70 centimeters
D. 6 meters

14. Which of the following frequency ranges are available for phone operation by Technician licensees?

A. 28.300 MHz to 28.500 MHz
B. 28.050 MHz to 28.150 MHz
C. 28.100 MHz to 28.300 MHz
D. 28.500 MHz to 28.600 MHz

15. On which HF bands does a Technician class operator have phone privileges?

A. 30-meter band only
B. 80-meter, 40-meter, 15-meter, and 10-meter bands
C. None
D. 10-meter band only

16. Which of the following bands include frequencies where Technicians are authorized to use digital modes such as FT8?

A. 10 meters
B. 2 meters
C. All these choices are correct
D. 6 meters

17. Which of the following U.S. amateur radio operators are allowed to contact the International Space Station (ISS) on VHF bands?

A. Any amateur with a Technician class or higher license
B. Only amateurs with a General class or higher license
C. Any amateurs with a Technician class or higher license, and NASA approval
D. Only amateurs with a General class or higher license, and NASA approval

18. Which of the following VHF/UHF band segments are limited to CW only?

A 902.0 MHz to 902.1 MHz
B All these choices are correct
C 219 MHz to 220 MHz and 420.0 MHz to 420.1 MHz
D 50.0 MHz to 50.1 MHz and 144.0 MHz to 144.1 MHz

19. Where may SSB phone be used in amateur bands above 50 MHz?

A On any band if the power is limited to 25 watts
B In at least some segment of all these bands
C Only on repeaters
D Only in sub-bands allocated to General class or higher licensees

20. How are US amateurs restricted in segments of bands where the Amateur Radio Service is secondary?

A Digital transmissions are not permitted in those segments
B International communications are not permitted in those segments
C U.S. amateurs may find non-amateur stations there and must avoid interfering with them
D U.S. amateurs must give foreign amateur stations priority in those segments

21. Why should you not set your transmit frequency to be exactly at the edge of an amateur band or sub-band?

A To allow for transmitter frequency drift
B So that modulation sidebands do not extend beyond the band edge
C All these choices are correct
D To allow for calibration error in the transmitter frequency display

22. What is the maximum peak envelope power output for Technician class operators in their HF band segments?

A 50 watts
B 100 watts
C 10 watts
D 200 watts

23. Except for some specific restrictions, what is the maximum peak envelope power output for Technician class operators using frequencies above 30 MHz?

A 1500 watts
B 50 watts
C 100 watts
D 500 watts

24. For which classes of amateur radio licenses does the FCC currently issue new licenses?

A Novice, Technician, General, Amateur Extra
B Technician, General, Amateur Extra
C Novice, Technician Plus, General, Advanced
D Technician, Technician Plus, General, Amateur Extra

25. Who may select a desired call sign under the vanity call sign rules?

A. Only a licensed amateur with an Amateur Extra Class license
B. Only a licensed amateur who has been licensed continuously for more than 10 years
C. Any licensed amateur
D. Only a licensed amateur with a General or Amateur Extra Class license

26. Which of the following is a valid Group D call sign format for Technician class?

A. KF1XXX
B. KA1X
C. All these choices are correct
D. W1XX

27. What types of international communications are FCC-licensed amateur radio stations permitted to make?

A. Any communications that would be permitted by an international broadcast station
B. Communications incidental to amateur radio purposes and remarks of a personal character
C. Communications incidental to conducting business or remarks of a personal nature
D. Only communications incidental to contest exchanges; all others are prohibited

28. Which of the following statements is true about using your amateur radio license when operating aboard a vessel or craft in international waters?

A. You need special FCC authorization for maritime mobile operation
B. You may only operate during maritime emergencies
C. Amateur operation is prohibited in international waters
D. You may operate from a US-documented vessel with the master's permission

29. How soon after passing the examination for your first amateur radio license may you transmit on the amateur radio bands?

A. Immediately on receiving your Certificate of Successful Completion of Examination (CSCE)
B. As soon as your operator/station license grant appears in the FCC's license database
C. As soon as you receive your license in the mail from the FCC
D. As soon as your operator/station license grant appears on the ARRL website

30. What is the normal term for an FCC-issued amateur radio license?

A. Five years
B. Eight years
C. Life
D. Ten years

31. How long before the expiration date may an amateur radio license renewal be requested?

A. 30 days
B. 1 year
C. 90 days
D. 6 months

32. What is the grace period for renewal if an amateur license expires?

A. Two years
B. Ten years
C. Five years
D. Three years

33. If your license has expired and is still within the allowable grace period, may you continue to transmit on the amateur radio bands?

- A Yes, for up to two years
- B Yes, as soon as you apply for renewal
- C No, you must wait until the license has been renewed
- D Yes, for up to one year

34. What may happen if the FCC is unable to reach you by email?

- A Revocation of the station license or suspension of the operator license
- B Revocation of access to the license record in the FCC system
- C Fine and suspension of operator license
- D Nothing; there is no such requirement

Go deeper

LISTEN Lesson 1 episode 7:57 · FlashFeed Study Notes podcast

WATCH Technician Phone on High Frequency 0:28 · YouTube
A Technician can use high frequency (HF) radio on a few segments. But how many of those bands allow phone?

WATCH Expired License and the Grace Period 0:29 · YouTube
Your amateur radio license expired yesterday. Can you still transmit while you renew it?

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/the-rules-licenses-bands-and-call-signs

STUDY Ham Radio Technician License in the FlashFeed app flashfeedlearningapp.com/packs/ham-radio-technician

LESSON 2 OF 15

The Rules: Operating a Station

Authorized and prohibited transmissions · The control operator and control types · Identification, repeaters and third parties

WHAT YOU'LL BE ABLE TO DO

- Identify which communications an amateur station may not transmit, including broadcasting, coded messages, music and indecent language
- Explain when a station may be used for sale of equipment, paid operation or news support, what an auxiliary station does, and when it must identify
- Explain who must be the control operator of a station, who designates one, and who is responsible for its operation
- Describe how license class sets privileges, what a control point is, and how automatic and remote control differ
- Explain when, how and in what language a station must identify, and when it must be open for FCC inspection
- Describe third-party communications, repeater responsibility and the requirement for a club station license

This lesson covers what an amateur station may and may not transmit, who must be in charge of a station, and how a station identifies itself. It also covers who answers for a repeater, how third-party messages work, and what a club needs for a station license. Rules like these apply from the first time a new licensee keys a microphone. The Federal Communications Commission (FCC) makes them, and they are set out in Part 97 of Title 47 of the Code of Federal Regulations (CFR). Every operator is expected to follow them. They are stated here as of 2026, for the 2026–2030 Technician exam.

Authorized and prohibited transmissions

Countries and international contacts

An amateur station may transmit what is needed to exchange messages with other stations in the amateur service. One exception covers other countries. FCC-licensed stations may not exchange communications with any country whose administration has notified the International Telecommunication Union (ITU) that it objects to such communications. The FCC issues public notices of current arrangements for international communications.

Only an objection notified to the ITU creates this ban.

Broadcasting and one-way transmissions

Broadcasting means transmissions intended for reception by the general public, either direct or relayed. An amateur station may not engage in any form of broadcasting. It also may not send one-way

communications except where the rules specifically provide.

The rules do provide for several kinds of one-way transmission:

- brief transmissions needed to make adjustments to the station;
- brief transmissions needed to establish two-way communications with other stations;
- **telecommand**, a one-way transmission to initiate, modify, or terminate functions of a device at a distance;
- transmissions needed to provide emergency communications;
- transmissions that help people learn, or improve their skill in, international Morse code;
- transmissions needed to disseminate information bulletins;
- **telemetry**, a one-way transmission of measurements at a distance from the measuring instrument.

International Morse code is a dot-dash code that the rules define by reference to an ITU recommendation. Broadcasting stays prohibited even though these other one-way uses are allowed.

Codes, music and indecent language

An amateur station may not send messages encoded to obscure their meaning, except as the rules provide. The exception covers control commands to space stations or model craft. A telecommand station may send special codes meant to obscure its commands to a station in space. Signals that control a model craft are not considered codes or ciphers.

A phone emission may not carry music, except as the rules provide elsewhere. The exception is music incidental to an authorized retransmission of manned spacecraft communications. In general, no station may retransmit programs or signals from any radio station other than an amateur station. The exceptions are:

- propagation and weather forecast information meant for the general public and originating from United States Government stations;
- communications, including incidental music, between a manned spacecraft and its Earth stations on United States Government frequencies.

Manned spacecraft retransmissions need prior approval from the National Aeronautics and Space Administration. They must be for the exclusive use of amateur radio operators. They may happen only occasionally, as an incident of normal amateur communications, and never on a regular basis.

Obscene or indecent words or language are prohibited, with no exception. The rule is a flat ban on any such language. Communications meant to help commit a crime are prohibited too, as are false or deceptive messages, signals or identification.

Selling, pay and news gathering

An amateur may use the station to tell others that apparatus normally used in an amateur station is for sale or trade. This is allowed only when it is not done on a regular basis.

A control operator generally may not accept pay for operating. One exception is a teaching position. A control operator may accept compensation as an incident of teaching when the teacher uses the station as part of classroom instruction at an educational institution.

Amateur stations may not do program production or news gathering for broadcasting. The one exception is communications directly related to the immediate safety of human life or the protection of property. An amateur station may provide these to broadcasters for dissemination to the public. This applies only where no other means of communication is reasonably available before or at the time of the event.

Auxiliary stations

An **auxiliary station** is an amateur station, other than in a message forwarding system, that transmits communications point-to-point within a system of cooperating amateur stations. One example is a station sending one-way transmissions between a remote repeater receiver and the main repeater transmitter. An auxiliary station may transmit one-way communications.

Automatic retransmission of other amateur stations' signals is limited to auxiliary and repeater stations, and to space stations, which the next section describes.

Identification during tests

Test transmissions on the air must identify the transmitting station. One exception covers signals that control a model craft. Identification is not required for transmissions directed only to the model craft. A label with the station call sign and the licensee's name and address must be affixed to the transmitter, and the transmitter power must not exceed 1 watt (W).

Sources

- NCVEC Question Pool Committee — 2026–2030 Technician question pool
- FCC — 47 CFR § 97.111 Authorized transmissions
- FCC — 47 CFR § 97.113 Prohibited transmissions
- FCC — 47 CFR § 97.119 Station identification
- FCC — 47 CFR § 97.201 Auxiliary station
- FCC — 47 CFR § 97.211 Space telecommand station
- FCC — 47 CFR § 97.215 Telecommand of model craft
- FCC — 47 CFR § 97.3 Definitions

The control operator and control types

What a control operator is

A control operator is an amateur operator designated by the licensee of a station to be responsible for the transmissions from that station and for compliance with the FCC rules. The licensee's designation is what makes someone the control operator.

An amateur station may never transmit without a control operator. None of these removes the requirement:

- automatic control, as with a repeater;
- the licensee being away while another licensed amateur uses the station;
- the station being an auxiliary station.

Who designates and who is responsible

The station licensee must designate the station control operator. A **frequency coordinator** is an entity, recognized in a local or regional area by amateur operators whose stations are eligible to be auxiliary or repeater stations. It recommends transmit and receive channels and related operating and technical parameters for such stations, to avoid or minimize interference.

The FCC presumes the licensee is also the control operator, unless documentation to the contrary is in the station records.

The licensee is responsible for the proper operation of the station under the FCC rules. When the control operator is a different amateur from the licensee, both are equally responsible for proper operation.

Privileges follow the control operator

The control operator's license class determines the transmitting frequency privileges of the station.

The same principle bars a Technician from an Amateur Extra Class band segment. Apart from an emergency, a Technician class licensee may never be the control operator of a station operating in such a segment. The rule holds even if an Amateur Extra Class licensee designates the Technician.

Satellites and space stations

A **space station** is an amateur station located more than 50 km above the Earth's surface. Any amateur allowed to transmit on the satellite uplink frequency may be the control operator of a station communicating through an amateur satellite or space station.

The control point

A **control point** is the location at which the control operator function is performed.

Automatic and remote control

Under **automatic control**, devices and procedures control a station while it transmits. Compliance with the FCC rules is achieved without the control operator being present at a control point. Repeater operation is the standard example, and a repeater may be automatically controlled.

Under **remote control**, a control operator indirectly manipulates the station's operating adjustments through a control link, to achieve compliance with the FCC rules. Operating a station over the internet is an example.

The two types differ in where the control operator is. Under automatic control, no control operator needs to be at a control point. When a station is remotely controlled, the control operator must be at the control point. Any station may be remotely controlled.

Sources

- NCVEC Question Pool Committee — 2026–2030 Technician question pool
- FCC — 47 CFR § 97.7 Control operator required
- FCC — 47 CFR § 97.103 Station licensee responsibilities
- FCC — 47 CFR § 97.109 Station control
- FCC — 47 CFR § 97.205 Repeater station
- FCC — 47 CFR § 97.207 Space station
- FCC — 47 CFR § 97.301 Authorized frequency bands
- FCC — 47 CFR § 97.3 Definitions

Identification, repeaters and third parties

Inspection

The station licensee must make the station and the station records available for inspection upon request by an FCC representative. That means at any time upon request.

When to identify

Each amateur station must transmit its assigned call sign at the end of each communication and at least every 10 minutes during a communication. The purpose is to make clear to listeners where the transmissions come from. Space stations and telecommand stations are exempt from this rule.

A station may not transmit unidentified communications or signals. It also may not transmit as its call sign any call sign not authorized to the station.

A tactical call such as "Race Headquarters" does not change this. The station must still give its FCC-assigned call sign at least every 10 minutes during the communication and at its end. The tactical call is not sufficient alone.

How and in what language

A station transmitting phone signals may send its call sign using a CW or phone emission. CW means international Morse code telegraphy emissions. A phone identification must be in the English language. The rules encourage using a phonetic alphabet as an aid to correct identification.

Indicators

An **indicator** is words, letters or numerals appended to and separated from the call sign during identification. An indicator must be separated from the call sign by the slant mark (/) or by any suitable word that denotes it. On a phone transmission, "KL7CC stroke W3", "KL7CC slant W3" and "KL7CC slash W3" are all acceptable.

A self-assigned indicator must be included before the call sign, after it, or on both sides. It may not conflict with any other indicator specified by the FCC rules or with any prefix assigned to another country.

Third-party communications

Third-party communications are messages from the control operator (the first party) of an amateur station to another amateur station's control operator (the second party) on behalf of another person (the third party).

An unlicensed person may speak to a foreign amateur station through a station under an FCC-licensed control operator. The foreign station must then be in a country with which the United States has a third-party agreement. The rules put it this way: the foreign country's administration has made arrangements with the United States for such international communications. Emergency or disaster relief communications are also permitted. The prohibition does not apply to a message for a third party who is eligible to be a control operator of the station.

Repeaters and accountability

A **repeater** is an amateur station that simultaneously retransmits the transmission of another amateur station on a different channel or channels. It is a different thing from a **beacon**. A beacon is an amateur station transmitting communications to observe propagation and reception, or for other related experimental activities.

Suppose a repeater inadvertently retransmits communications that violate the FCC rules. The control operator of the originating station is accountable.

Club stations

A club station license grant may be held only by the license trustee, a person designated by an officer of the club. The trustee must hold an operator/primary station license grant. The club must be composed of at least four persons, and it must have:

- a name;
- a document of organization;
- management;
- a primary purpose devoted to amateur service activities consistent with the rules.

Sources

- NCVEC Question Pool Committee — 2026–2030 Technician question pool
- FCC — 47 CFR § 97.103 Station licensee responsibilities
- FCC — 47 CFR § 97.115 Third party communications
- FCC — 47 CFR § 97.119 Station identification
- FCC — 47 CFR § 97.205 Repeater station
- FCC — 47 CFR § 97.5 Station license required

- FCC — 47 CFR § 97.3 Definitions

Key terms

Telecommand
A one-way transmission to initiate, modify, or terminate functions of a device at a distance

Telemetry
A one-way transmission of measurements at a distance from the measuring instrument

Frequency coordinator
A locally recognized entity that recommends channels and parameters for repeater and auxiliary stations to minimize interference

Space station
An amateur station located more than 50 km above the Earth's surface

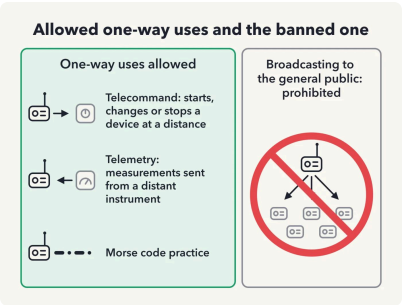
Beacon
An amateur station transmitting to observe propagation and reception, or for related experimental activities

Indicator
Words, letters or numerals appended to and separated from the call sign during identification

Key facts

Countries That Object to Contact

Stations licensed by the Federal Communications Commission (FCC) may not exchange communications with any country whose administration has notified the **International Telecommunication Union (ITU)** that it objects to such communications.



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Broadcasting Is the Banned One-Way Use

An amateur station may not send one-way communications except where the rules provide. Allowed one-way uses include brief adjustment transmissions, Morse code practice, **telecommand** and telemetry. Broadcasting stays prohibited even though these other one-way uses are allowed.

Coded Messages and Their Exception

An amateur station may not send messages encoded to obscure their meaning. The exception covers control commands to space stations or model craft. A telecommand station may send special **codes** meant to obscure its commands to a station in space. Signals controlling a model craft are not considered codes or ciphers.

Music on a Phone Emission

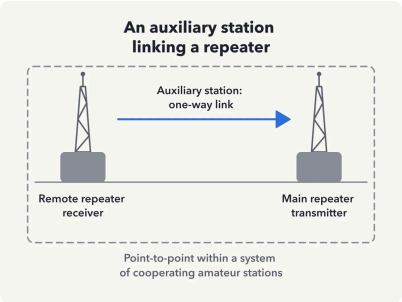
A phone emission may not carry music, except as the rules provide. The exception is music incidental to an authorized retransmission of manned spacecraft communications. These retransmissions need prior approval from the National Aeronautics and Space Administration (NASA). They may happen only occasionally, never on a regular basis.

Selling Equipment on the Air

An amateur may use the station to tell others that apparatus normally used in an amateur station is for **sale or trade**. This is allowed only when it is not done on a regular basis.

Indecent Language Is Banned

Obscene or indecent words or language are prohibited, with no exception. The rule is a flat ban on any such language.



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An Example of an Auxiliary Station

An **auxiliary station** transmits point-to-point within a system of cooperating amateur stations. One example is a station sending one-way transmissions between a remote repeater receiver and the main repeater transmitter.

When a Control Operator Gets Paid

A control operator generally may not accept pay for operating. One exception is a teaching position. **Compensation** is allowed when the teacher uses the station as part of classroom instruction at an educational institution.

News Gathering and Its One Exception

Amateur stations may not do program production or **news gathering** for broadcasting. The one exception is communications directly related to the immediate safety of human life or the protection of property. This applies only where no other means of communication is reasonably available before or at the time of the event.

What Broadcasting Means

In the Amateur Radio Service, **broadcasting** means transmissions intended for reception by the general public, either direct or relayed. An amateur station may not engage in any form of it.

Transmitting Without Identifying

Identification is not required for transmissions directed only to a **model craft**. A label with the station call sign and the licensee's name and address must be affixed to the transmitter. The transmitter power must not exceed 1 watt (W).

Identifying During On-Air Tests

Test transmissions on the air must identify the transmitting station.

A Control Operator Is Always Required

An amateur station may never transmit without a **control operator**. Automatic control, as with a repeater, does not remove the requirement.

Control Operators for Satellite Stations

Any amateur allowed to transmit on the satellite **uplink** frequency may be the control operator of a station communicating through an amateur satellite or space station.

The Licensee Designates the Operator

The **station licensee** must designate the station control operator. The Federal Communications Commission (FCC) presumes the licensee is also the control operator, unless documentation to the contrary is in the station records.

Privileges Follow the Control Operator

The control operator's **license class** determines the transmitting frequency privileges of the station.

The Control Point

A **control point** is the location at which the control operator function is performed.

Technicians and Extra Class Segments

Apart from an emergency, a Technician class licensee may never be the control operator of a station in an **Amateur Extra Class** band segment. The rule holds even if an Amateur Extra Class licensee designates the Technician.

Who Is Responsible for the Station

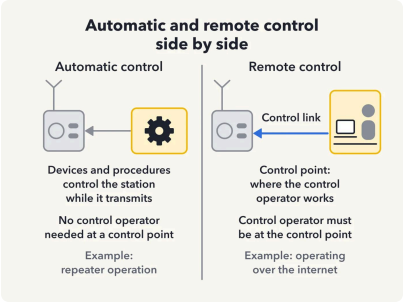
The licensee is responsible for the proper operation of the station. When the control operator is a different amateur, both are **equally responsible**.

Automatic Control and Repeaters

Under **automatic control**, devices and procedures control a station while it transmits. Compliance is achieved without the control operator being present at a control point. Repeater operation is the standard example.

Any Station May Be Remote

Any station may be remotely controlled. When a station is remotely controlled, the control operator must be at the control point.



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What Counts as Remote Control

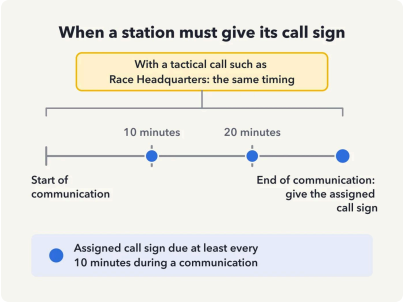
Under **remote control**, a control operator indirectly adjusts the station through a control link. Operating a station over the internet is an example.

What a Control Operator Is

A **control operator** is the amateur designated by the licensee to be responsible for transmissions and for compliance with the Federal Communications Commission (FCC) rules.

Inspection on Request

The station licensee must make the station and the station records available for **inspection** upon request by a Federal Communications Commission (FCC) representative. That means at any time.



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Identify at Least Every 10 Minutes

A station must give its assigned **call sign** at the end of each communication and at least every 10 minutes during it. A tactical call such as "Race Headquarters" does not change this, because the tactical call is not sufficient alone.

English for Phone Identification

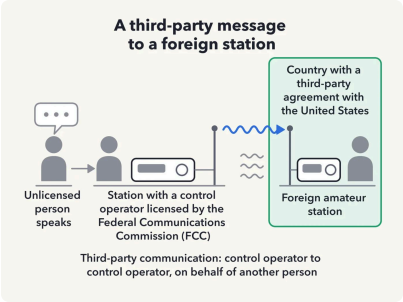
A phone identification must be in the **English language**. The rules encourage a phonetic alphabet as an aid to correct identification.

How a Phone Station Identifies

A station transmitting phone signals may send its call sign using a **CW** or phone emission. CW means international Morse code telegraphy emissions.

Acceptable Phone Indicators

An indicator must be separated from the call sign by the **slant mark** (/) or by a suitable word that denotes it. On a phone transmission, "KL7CC stroke W3", "KL7CC slant W3" and "KL7CC slash W3" are all acceptable.



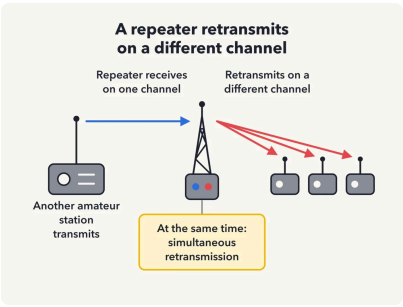
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Unlicensed Speakers and Foreign Stations

An unlicensed person may speak to a foreign amateur station through a station whose control operator is licensed by the Federal Communications Commission (FCC). The foreign station must be in a country with which the United States has a **third-party agreement**.

What Third-Party Communications Are

Third-party communications are messages from one control operator to another station's control operator on behalf of another person.



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Repeaters Retransmit on Another Channel

A **repeater** simultaneously retransmits the transmission of another amateur station on a different channel or channels. That is what sets it apart from stations with other jobs.

Who Answers for Repeater Violations

If a repeater inadvertently retransmits communications that violate the rules, the control operator of the **originating station** is accountable.

Requirements for a Club License

A **club station** license grant may be held only by the license trustee. The club must be composed of at least four persons.

Matched pairs

Each item on the left goes with the one on the right.

Music on phone → Only incidental to manned spacecraft relay

Control point → Where the control operator function is done

Repeater violation → Originating station's control operator

Self-test

Answer each question from memory, then check your work against the answer key.

1. With which countries are FCC-licensed amateur radio stations prohibited from exchanging communications?

- A Any country banned from such communications by the IARU
- B Any country that has notified the ARRL that it objects to such communications
- C Any country that has notified the ITU that it objects to such communications
- D Any country banned from such communications by the ARRL

2. Under which of the following circumstances are one-way transmissions by an amateur station prohibited?

- A Broadcasting
- B Telecommand or transmissions of telemetry
- C Announcements of upcoming ham radio operating events
- D International Morse Code Practice

3. How does the FCC define broadcasting for the Amateur Radio Service?

- A Transmission of messages directed only to amateur operators
- B Any transmission made by the licensed station
- C Two-way transmissions by amateur stations
- D Transmissions intended for reception by the general public

4. When is it permissible to transmit messages encoded to obscure their meaning?

- A Never
- B Only when transmitting control commands to space stations or model craft
- C Only when transmitting certain approved digital codes
- D Only when using a remote station during a contest

5. Under what conditions is an amateur station authorized to transmit music using a phone emission?

- A When incidental to an authorized retransmission of manned spacecraft communications
- B When the music is transmitted above 1280 MHz
- C When transmissions are limited to less than three minutes per hour
- D When the music produces no spurious emissions

6. What, if any, are the restrictions concerning transmission of language that may be considered indecent or obscene?

A. The FCC maintains a list of words that are not permitted to be used on amateur frequencies
B. There is no such prohibition
C. Any such language is prohibited
D. The International Telecommunications Union lists words not allowed on amateur frequencies

7. When may amateur radio operators use their stations to notify other amateurs of the availability of equipment for sale or trade?

A. When no profit is made on the sale
B. When selling amateur radio equipment and not on a regular basis
C. When not the personal property of the licensee, control operator, or close relatives
D. Never

8. In which of the following circumstances may the control operator of an amateur station receive compensation for operating that station?

A. When made to obtain emergency information for a local broadcast station
B. When related to the sale of amateur equipment by the control operator's employer
C. All these choices are correct
D. When the communication is a part of classroom instruction at an educational institution

9. When may amateur stations transmit information in support of broadcasting, program production, or news gathering, assuming no other means is available?

A. Where non-commercial programming is supplied only to the National Public Radio network
B. When broadcasting communications to or from the space shuttle
C. Never
D. When directly related to the immediate safety of human life or protection of property

10. Which of the following is an example of an auxiliary station?

A. A backup radio for emergency use in case the main station radio fails
B. A station sending one-way signals between remote repeater receiver and main transmitter
C. A Military Auxiliary Radio System station linking government and amateur stations
D. A second station utilized in multi-operator contest stations

11. When may an amateur station transmit without identifying on the air?

A. When the transmitted power level is below 0.1 watt
B. When the transmissions are of a brief nature to make station adjustments
C. When transmitting signals to control model craft
D. When the transmissions are unmodulated

12. Which of the following is required when making on-the-air test transmissions?

A Identify the transmitting station
B Conduct tests only between 10 p.m. and 6 a.m. local time
C All these choices are correct
D Notify the FCC of the transmissions

13. When may an amateur station transmit without a control operator?

A Never
B When the station licensee is away and another licensed amateur is using the station
C When using automatic control, such as in the case of a repeater
D When the transmitting station is an auxiliary station

14. What is a control operator as defined in Part 97?

A The person speaking or otherwise communicating messages over an amateur station
B The person who is the licensee of an amateur station
C Amateur designated by licensee responsible for transmissions and FCC rules at station
D Amateur in FCC database responsible for transmissions and FCC rules at license location

15. Who must designate the station control operator?

A The FCC
B The station licensee
C The frequency coordinator
D Any licensed operator

16. When the control operator is not the station licensee, who is responsible for the proper operation of the station?

A All licensed amateurs who are present at the operation
B Only the station licensee
C Only the control operator
D The control operator and the station licensee

17. Who may be the control operator of a station communicating through an amateur satellite or space station?

A A General class or higher licensee with a satellite operator certification
B Only an Amateur Extra Class operator who is also an AMSAT member
C Only an Amateur Extra Class operator
D Any amateur allowed to transmit on the satellite uplink frequency

18. What determines the transmitting frequency privileges of an amateur station?

A The frequency authorized by the frequency coordinator
B The frequencies printed on the license grant
C The class of operator license held by the control operator
D The highest class of operator license held by anyone on the premises

19. When, other than during an emergency, may a Technician class licensee be the control operator of a station operating in an Amateur Extra Class band segment?

A At no time
B When using a club station whose trustee holds an Amateur Extra Class license
C As part of a multi-operator contest team
D When designated as the control operator by an Amateur Extra Class licensee

20. What is an amateur station's control point?

A The mailing address of the station licensee
B The location at which the control operator function is performed
C The location of the station's transmitting antenna
D The location of the station's transmitting apparatus

21. Which of the following is an example of automatic control?

A Repeater operation
B Using a computer or other device to send CW automatically
C Controlling a station over the internet
D Using a computer or other device to identify automatically

22. Which amateur stations may be remotely controlled?

A Only digital stations
B Any station
C Only repeater stations
D Only automatically controlled stations

23. Which of the following is an example of remote control as defined in Part 97?

A Earth-Moon-Earth (EME) communication
B Controlling a model aircraft, boat, or car by amateur radio
C A software defined radio (SDR)
D Operating the station over the internet

24. When must the station licensee make the station and the station records available for inspection?

A Only when presented with a valid warrant by an FCC official or government agent
B At any time ten days after notification by the FCC of such an inspection
C At any time upon request by an FCC representative
D At any time after a written notification by the FCC of such inspection

25. How often must you identify with your FCC-assigned call sign when using tactical call signs such as "Race Headquarters"?

A Once every hour
B Never, the tactical call is sufficient
C At least every 10 minutes during and at the end of a communication
D At the end of every transmission

26. When are you required to transmit your assigned call sign?

A. At least every 10 minutes during and at the end of a communication
B. At the beginning of each contact, and every 10 minutes thereafter
C. At least once during each transmission
D. At least every 15 minutes during and at the end of a communication

27. What language must you use for identification when using a phone emission?

A. Any language recognized by the ITU
B. Any language recognized by the United Nations
C. English, French, or Spanish
D. English

28. What method of call sign identification is required for a station transmitting phone signals?

A. Send the call sign using only a phone emission
B. Send the call sign using a CW or phone emission
C. Send the call sign followed by the indicator RPT
D. Send the call sign followed by the indicator R

29. Which of the following self-assigned indicators are acceptable when using a phone transmission?

A. KL7CC stroke W3
B. KL7CC slant W3
C. KL7CC slash W3
D. All these choices are correct

30. Which of the following restrictions apply when a non-licensed person speaks to a foreign amateur radio station via a station under the control of an FCC-licensed amateur radio operator?

A. The licensed control operator must do the station identification
B. The person must be a U.S. citizen
C. The foreign station must be in a country with which the U.S. has a third-party agreement
D. All these choices are correct

31. What is the definition of third-party communications?

A. Amateur radio communications where three stations are in communications with one another
B. A message from a control operator to another control operator on behalf of another person
C. Operation when equipment is licensed to a person other than the control operator
D. Temporary authorization for an unlicensed person to transmit for technical experiments

32. What type of amateur station simultaneously retransmits the signal of another amateur station on a different channel or channels?

A. Repeater station
B. Remote control station
C. Message forwarding station
D. Beacon station

33. Who is accountable if a repeater inadvertently retransmits communications that violate the FCC rules?

A. Both the originating station and the repeater owner
B. The control operator of the originating station
C. The control operator of the repeater
D. The owner of the repeater

34. Which of the following is a requirement for the issuance of a club station license grant?

A. All these choices are correct
B. The trustee must have an Amateur Extra Class operator license grant
C. The club must have at least four members
D. The club must be registered with the American Radio Relay League (ARRL)

Go deeper

LISTEN Lesson 2 episode 7:06 · FlashFeed Study Notes podcast

WATCH When a Ham Station Can Skip Identifying 0:28 · YouTube
Ham stations must give their call sign on the air. So when can a station skip it?

WATCH Tactical Calls and the Call Sign 0:29
A station signs on as Race Headquarters and never gives its own call sign. Is that enough?

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/the-rules-operating-a-station

STUDY Ham Radio Technician License in the FlashFeed app flashfeedlearningapp.com/packs/ham-radio-technician

LESSON 3 OF 15

Operating Procedures

Choosing frequencies and making calls · Repeater operating and access tones · Public service and emergency operation

WHAT YOU'LL BE ABLE TO DO

- Identify common repeater offsets, the 2-meter FM simplex calling frequency, and what simplex, repeater offset and band plans mean
- Explain what CQ means and how an operator answers one, calls a known station, or announces listening, on a repeater or without one
- Explain how repeater access works, including tones, squelch, reverse and offset, and how to fix common access and audio problems
- Describe DMR talkgroups and color codes, how to share frequencies and simplex channels, and what common Q signals mean
- Describe net operation and formal message handling: net control duties, net practice, traffic, preambles, check and phonetics
- Explain emergency operation: how FCC rules apply, what RACES and ARES are, and how Winlink relays messages by email

This lesson covers how a licensee operates on the air day to day: where to transmit, how to call and answer other stations, how repeaters are reached, and how organized groups handle messages and emergencies. A new licensee who knows these habits can make a first contact without confusion or interference. The Federal Communications Commission (FCC) rules still apply the whole time, so the lesson ends with how emergency work fits under them.

Choosing frequencies and making calls

Repeater offsets

A **repeater offset** is the difference between a repeater's transmit and receive frequencies. A repeater listens on one frequency and retransmits on another, and the gap between the two is the offset. Each band has a common offset.

- In the 2-meter band, a common repeater offset is plus or minus 600 kilohertz (kHz).
- In the 70-centimeter band, a common repeater offset is plus or minus 5 megahertz (MHz).

The two bands differ here. Plus or minus 600 kHz belongs to 2 meters, and plus or minus 5 MHz belongs to 70 centimeters.

Simplex and the calling frequency

An amateur station that transmits and receives on the same frequency is operating **simplex**. Nothing is retransmitted, so only stations within range of each other can talk. This is the opposite of repeater operation, where the transmit and receive frequencies differ by the offset.

The national calling frequency for frequency modulated (FM) simplex operation in the 2-meter band is 146.520 MHz. A new licensee who wants a first simplex contact can start there.

Band plans

A **band plan** is a voluntary guideline for using different modes or activities within an amateur band. It goes beyond the privileges the FCC establishes. The FCC sets which frequencies a license class may use. A band plan is a courtesy agreement about how operators share those frequencies.

Calling another station

How an operator calls depends on whom the operator wants to reach. The procedural signal CQ means calling any station. An operator who sends it invites anyone who hears it to answer.

Four situations come up.

- **Answering a CQ.** The responding operator transmits the other station's call sign followed by his or her own call sign.
- **Calling a known station on a repeater.** The operator says that station's call sign, then identifies with his or her own call sign.
- **Announcing availability on a repeater.** A customary way to show that a station is listening and looking for a contact is to say the station's own call sign followed by the word listening. Anyone hearing it may then call.
- **Seeking any phone contact without a repeater.** An effective way is to repeat CQ a few times, followed by the words this is and the operator's call sign. The operator then pauses to listen and repeats as necessary.

Taken together, a CQ is an open invitation and the answer to it is a direct reply. A call to a known station goes straight to that station's call sign. In both cases the call sign of the station being addressed comes first, and the caller's own call sign follows it.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)

Repeater operating and access tones

Getting into a repeater

On the very high frequency (VHF) and ultra high frequency (UHF) bands, reaching a repeater means getting the radio frequency (RF) offset right, and often a tone or code as well. When an operator can

hear a repeater's output but cannot get into it, any of three things could be the cause:

- an improper transceiver offset;
- the wrong Continuous Tone-Coded Squelch System (CTCSS) tone;
- the wrong Digital Coded Squelch (DCS) code.

CTCSS is a sub-audible tone. It is transmitted along with normal voice audio to open the squelch of a receiver. DCS is a related code that serves a similar access purpose.

Dual-Tone Multi-Frequency (DTMF) is a different kind of signaling to a repeater. It uses two simultaneous audio tones. CTCSS is a single sub-audible tone sent with voice. DTMF is two tones sent together.

The reverse function

Many VHF/UHF transceivers have a reverse function. It lets the operator listen on a repeater's input frequency. The input frequency is the one on which the repeater receives.

Squelch and audio problems

The purpose of **squelch** is to mute the receiver audio when a signal is not present. A CTCSS tone can open the squelch so that the receiver speaks only for the right signals.

An operator whose FM transmission audio drops out on voice peaks is talking too loudly. The fix is to speak at a lower level.

Linked repeaters

A linked repeater network is a network of repeaters in which signals received by one repeater are transmitted by all the repeaters in the network. A call made into one reaches users of every other.

Digital Mobile Radio talkgroups and color codes

Digital Mobile Radio (DMR) is a digital system with its own access terms.

- A **talkgroup** is an identifier used by DMR to organize radio traffic, so that those who want to hear the group are not bothered by other radio traffic. An operator joins a digital repeater's talkgroup by programming the radio with the group's ID or code.
- The digital **color code** is an access code that must be programmed into a DMR transmitter to access a specific repeater.

Sharing frequencies and simplex channels

Simplex channels are designated in the VHF/UHF band plans so that stations within range of each other can communicate without tying up a repeater.

When two stations transmitting on the same frequency interfere with each other, the stations should negotiate continued use of the frequency.

Q signals

Two Q signals matter here: QRM (interference from other stations) and QSY (changing frequency).

- QRM indicates that an operator is receiving interference from other stations.
- QSY indicates that an operator is changing frequency.

A station that finds a repeater busy, for instance, might use QSY to tell a friend to move to a simplex channel.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)
- 47 CFR § 97.3 Definitions

Public service and emergency operation

FCC rules always apply

The FCC's Part 97 rules for the Amateur Radio Service always apply to the operation of an amateur station. They keep applying when a station operates under Radio Amateur Civil Emergency Service rules, Amateur Radio Emergency Service rules, or the rules of the Federal Emergency Management Agency (FEMA). The station licensee is responsible for the proper operation of the station under the FCC Rules. When the control operator is a different amateur operator than the licensee, both persons are equally responsible for proper operation.

One narrow exception concerns frequency privileges. A control operator may operate outside the frequency privileges of his or her license class, but only in situations involving the immediate safety of human life or protection of property.

Emergency organizations

Two groups serve in emergencies, and they are different.

- The **radio amateur civil emergency service (RACES)** is an FCC Part 97 amateur radio service for civil defense communications during national emergencies. The definition in § 97.3 reaches further, to periods of local, regional or national civil emergencies. RACES requires certification by a civil defense agency.
- 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.

Nets and traffic

The **net control station** calls the net to order and directs communications between stations checking in.

A participant follows standard practice. Unless reporting an emergency, a participant transmits only when directed by the net control station.

In net operation, **traffic** means formal messages exchanged by net stations.

The preamble of a formal traffic message contains information needed to track the message. The word **check** in a radiogram header means the number of words or word equivalents in the text portion of the message.

Phonetics and Winlink

To make sure voice messages containing unusual words are received correctly, the operator spells the words using a standard phonetic alphabet.

Winlink relays messages using email addresses based on amateur callsigns.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)
- 47 CFR § 97.3 Definitions
- 47 CFR § 97.103 Station licensee responsibilities

Key terms

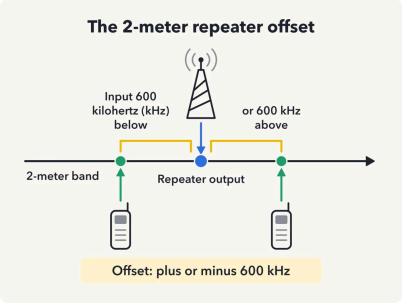
CQ
Procedural signal meaning an operator is calling any station

RF
Short for radio frequency, as defined in the Federal Communications Commission (FCC) rules

QRM
Q signal meaning an operator is receiving interference from other stations

QSY
Q signal meaning an operator is changing frequency

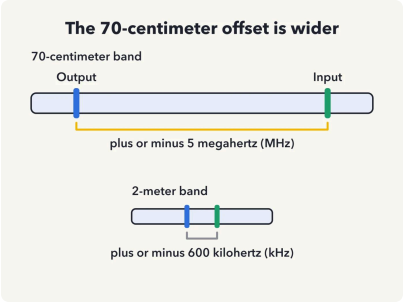
Key facts



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2-Meter Repeater Offset

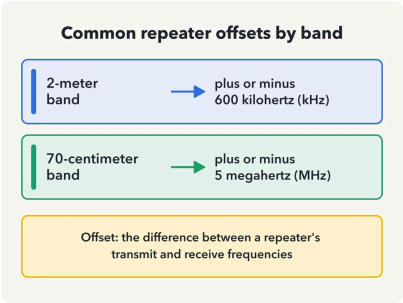
A common repeater offset in the 2-meter band is **plus or minus 600 kilohertz (kHz)**.



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70-Centimeter Repeater Offset

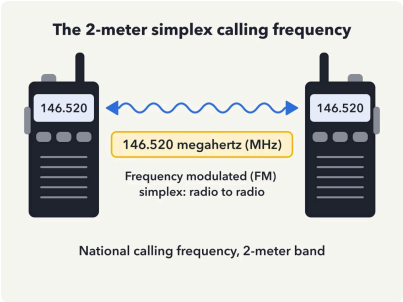
A common repeater offset in the 70-centimeter band is **plus or minus 5 megahertz (MHz)**. The plus or minus 600 kilohertz (kHz) offset belongs to the 2-meter band instead.



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What a Repeater Offset Is

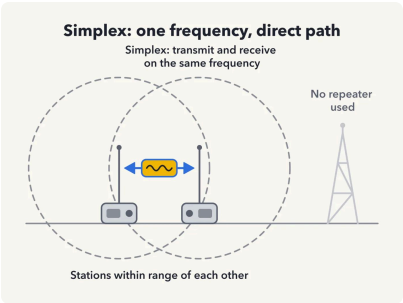
A **repeater offset** is the difference between a repeater's transmit and receive frequencies. A repeater listens on one frequency and retransmits on another, and the gap between the two is the offset.



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2-Meter Simplex Calling Frequency

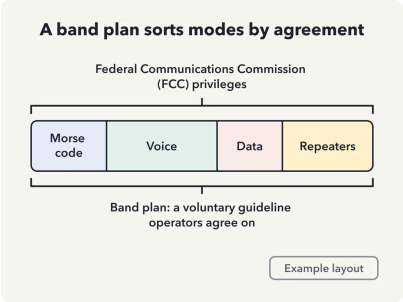
The national calling frequency for frequency modulated (FM) simplex operation in the 2-meter band is **146.520 megahertz (MHz)**. A new licensee who wants a first simplex contact can start there.



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Simplex Operation

A station that transmits and receives on the same frequency is operating **simplex**. Nothing is retransmitted, so only stations within range of each other can talk.



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What a Band Plan Is

A **band plan** is a voluntary guideline for using different modes or activities within an amateur band. It goes beyond the privileges the Federal Communications Commission (FCC) establishes, and it is a courtesy agreement among operators.

What CQ Means

The signal **CQ** means calling any station. An operator who sends it invites anyone who hears it to answer.

Answering a CQ

The responding operator transmits the other station's **call sign** followed by his or her own call sign.

Calling a Known Station

To call a known station on a repeater, the operator says that station's **call sign**, then identifies with his or her own call sign.

Announcing You Are Listening

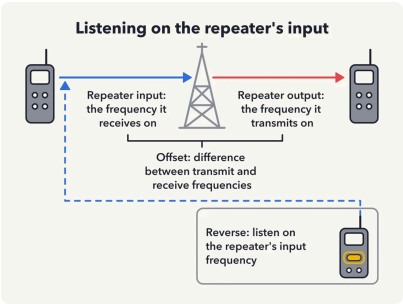
On a repeater, a customary way to show that a station is looking for a contact is to say its own call sign followed by the word **listening**. Anyone hearing it may then call.



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Seeking a Contact Without a Repeater

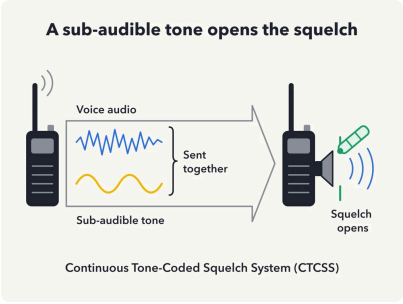
To seek any phone contact without a repeater, an effective way is to repeat **CQ** a few times, followed by the words this is and the operator's call sign. The operator then pauses to listen and repeats as necessary.



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The Reverse Function

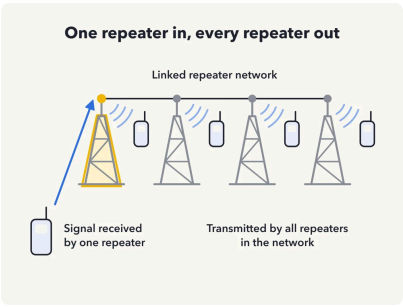
Many very high frequency (VHF) and ultra high frequency (UHF) transceivers have a **reverse** function. It lets the operator listen on a repeater's input frequency, the one on which the repeater receives.



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CTCSS Sub-Audible Tone

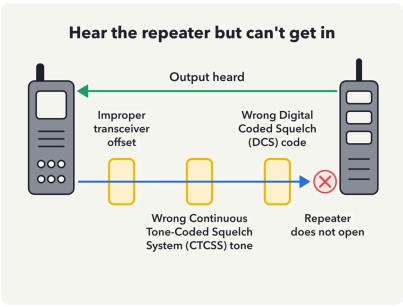
The **Continuous Tone-Coded Squelch System (CTCSS)** is a sub-audible tone. It is transmitted along with normal voice audio to open the squelch of a receiver.



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Linked Repeater Networks

A **linked repeater network** is a network of repeaters in which signals received by one repeater are transmitted by all the repeaters in the network. A call into one reaches the users of every other.



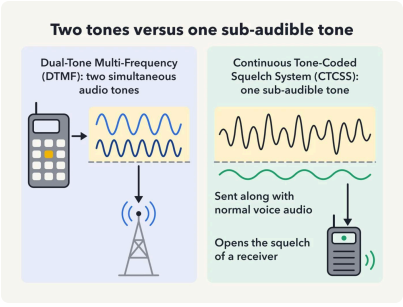
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Why a Repeater Won't Open

An operator who can hear a repeater's output but cannot get in may have an improper transceiver **offset**. The wrong Continuous Tone-Coded Squelch System (CTCSS) tone or the wrong Digital Coded Squelch (DCS) code can cause the same problem.

Audio Dropping Out on Peaks

When frequency modulated (FM) transmission audio drops out on voice peaks, the operator is **talking too loudly**. The fix is to speak at a lower level.



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Two-Tone Signaling to Repeaters

Dual-Tone Multi-Frequency (DTMF) signaling to a repeater uses two simultaneous audio tones. A Continuous Tone-Coded Squelch System (CTCSS) tone is one sub-audible tone sent with voice.

Joining a Talkgroup

An operator joins a digital repeater's **talkgroup** by programming the radio with the group's ID or code.

Sharing a Contested Frequency

When two stations transmitting on the same frequency interfere with each other, the stations should **negotiate** continued use of the frequency.

Why Simplex Channels Exist

Simplex channels are designated in the very high frequency and ultra high frequency band plans so that stations within range of each other can communicate **without tying up a repeater**.

The Q Signal QRM

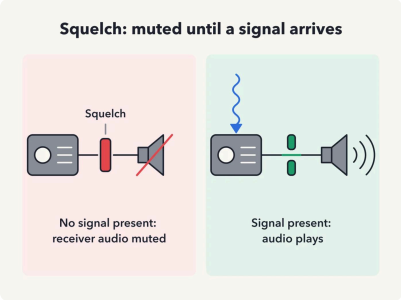
QRM is a Q signal. It indicates that an operator is receiving interference from other stations.

The Q Signal QSY

QSY is a Q signal. It indicates that an operator is changing frequency. A station might use it to tell a friend to move to a simplex channel.

The DMR Color Code

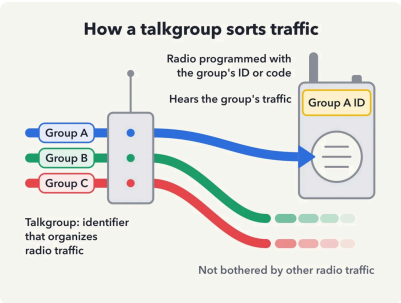
On Digital Mobile Radio (DMR) systems, the digital **color code** is an access code that must be programmed into a DMR transmitter to access a specific repeater.



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What Squelch Does

The purpose of **squelch** is to mute the receiver audio when a signal is not present.



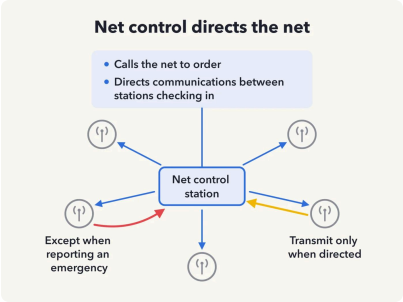
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What a Talkgroup Is

A **talkgroup** is an identifier used by Digital Mobile Radio (DMR) to organize radio traffic, so that those who want to hear the group are not bothered by other radio traffic.

FCC Rules Always Apply

The Federal Communications Commission (FCC) Part 97 rules **always apply** to an amateur station. They do not stop applying under Radio Amateur Civil Emergency Service, Amateur Radio Emergency Service, or Federal Emergency Management Agency rules.



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Net Control Duties

The **net control station** calls the net to order and directs communications between stations checking in.

Phonetics for Unusual Words

To make sure a voice message with unusual words is received correctly, the operator spells the words using a **standard phonetic alphabet**.

What RACES Is

The **radio amateur civil emergency service (RACES)** is a Federal Communications Commission (FCC) Part 97 amateur radio service for civil defense communications during national emergencies. It requires certification by a civil defense agency.

What Traffic Means

In net operation, **traffic** means formal messages exchanged by net stations.

What ARES Is

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.

Standard Net Practice

Unless reporting an emergency, a net participant transmits **only when directed** by the net control station.

Winlink Email Relay

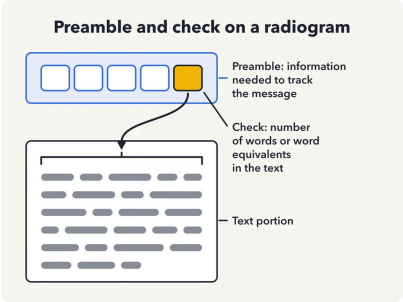
Winlink relays messages using email addresses based on amateur callsigns.

Operating Outside Privileges

A control operator may operate outside the frequency privileges of his or her license class, **but only** in situations involving the immediate safety of human life or protection of property.

The Message Preamble

The **preamble** of a formal traffic message contains information needed to track the message.



FlashFeed original diagram · CC-BY-4.0

What Check Means

The word **check** in a radiogram header means the number of words or word equivalents in the text portion of the message.

> **Certification by Civil Defense**
>
> The **radio amateur civil emergency service (RACES)** requires certification by a civil defense agency. The Amateur Radio Emergency Service (ARES) is a voluntary registration instead.

Matched pairs

Each item on the left goes with the one on the right.

Signal CQ → Calling any station

Q signal QRM → Interference from other stations

Winlink → Relays email via amateur callsigns

Self-test

Answer each question from memory, then check your work against the answer key.

1. What is a common repeater frequency offset in the 2-meter band?

- A Plus or minus 500 kHz
- B Plus or minus 1 MHz
- C Plus or minus 600 kHz
- D Plus or minus 5 MHz

2. What is a common repeater frequency offset in the 70-centimeter band?

- A Plus or minus 5 MHz
- B Plus or minus 1 MHz
- C Plus or minus 500 kHz
- D Plus or minus 600 kHz

3. What does the term "repeater offset" mean?

- A The repeater has a time delay to prevent interference
- B The fee charged by the repeater owner or club to provide for maintenance
- C The approximately half-second delay to allow for the “squelch tail” to be removed
- D The difference between a repeater’s transmit and receive frequencies

4. What is the national calling frequency for FM simplex operations in the 2-meter band?

- A 145.000 MHz
- B 146.520 MHz
- C 446.000 MHz
- D 432.100 MHz

5. What term describes an amateur station that is transmitting and receiving on the same frequency?

A) Multiplex
B) Simplex
C) Full duplex
D) Diplex

6. What is a band plan, beyond the privileges established by the FCC?

A) A plan devised by a club to indicate frequency band usage
B) A list of operating schedules
C) A list of available net frequencies
D) A voluntary guideline for using different modes or activities within an amateur band

7. How should you respond to a station calling CQ?

A) Transmit the other station's call sign followed by your call sign
B) Transmit a signal report followed by your call sign
C) Transmit your call sign followed by the other station's call sign
D) Transmit "CQ" followed by the other station's call sign

8. What is the meaning of the procedural signal "CQ"?

A) Only the called station should transmit
B) "Communication Quality," used to indicate transmitted audio clarity
C) Calling any station
D) A shortened form of the term "Contest QSO"

9. What is an appropriate way to call another station on a repeater if you know the other station's call sign?

A) Say "CQ" three times, then the other station's call sign, followed by your call sign
B) Say the station's call sign, then identify with your call sign
C) Wait for the station to call CQ, then answer with your call sign
D) Say "break, break," then the other station's call sign, followed by your call sign

10. Which of the following is a customary way to indicate a station is listening on a repeater and looking for a contact?

A) The station's call sign followed by the word "listening"
B) "CQ CQ" followed by the repeater's call sign
C) "QSY" followed by your call sign
D) The repeater's call sign followed by the station's call sign

11. What is an effective way to seek a call from any phone station when not using a repeater?

A) Send unmodulated carrier ~10 seconds, then "this is" and call sign; listen; repeat
B) Sign call once, then "listening for a call;" if no answer, change frequency and repeat
C) Say "QTC," then "this is" and your call sign; if no answer, change frequency and repeat
D) Repeat "CQ" a few times, "this is" and your call sign, then listen; repeat as needed

12. What is the purpose of the reverse function on a VHF/UHF transceiver?

A To listen on a repeater's output frequency
B To reduce power output
C To listen on a repeater's input frequency
D To increase power output

13. Which of the following describes a linked repeater network?

A Repeaters in a network all transmit the signals received by any one repeater
B A single repeater with more than one receiver
C A system of repeaters linked by APRS
D Multiple repeaters with the same control operator

14. Which of the following could be the reason you are unable to access a repeater whose output you can hear?

A You are using the wrong CTCSS tone
B You are using the wrong DCS code
C Improper transceiver offset
D All these choices are correct

15. What term describes the use of a sub-audible tone transmitted along with normal voice audio to open the squelch of a receiver?

A DTMF
B Carrier squelch
C CTCSS
D Tone burst

16. What type of signaling to a repeater uses two simultaneous audio tones?

A CTCSS
B DTMF
C D-STAR
D GMRS

17. Which of the following would cause your FM transmission audio to drop out on voice peaks?

A You are talking too loudly
B Your repeater offset is inverted
C Your FM deviation is too low
D Your transmit power is too high

18. What is the purpose of a squelch function?

A Reduce interference from impulse noise
B Reduce a CW transmitter's key clicks
C Mute the receiver audio when a signal is not present
D Eliminate parasitic oscillations in an RF amplifier

19. How can you join a digital repeater's "talkgroup"?

A Program your radio with the DTMF tone used by the talkgroup
B Register with the local Frequency Coordinator
C Register with the digital repeater control operator
D Program your radio with the group's ID or code

20. What is the digital color code used on DMR repeater systems?

A. A code which automatically programs the repeater offset to a frequency chosen by the user
B. An access code programmed into a DMR transmitter to access a specific repeater
C. A code transmitted by the repeater to indicate health and status of the equipment
D. A code identifying the CODEC used so the repeater can properly decode the audio

21. Which of the following is a “talkgroup”?

A. The members of a net organized for amateur radio operators with a specific common interest
B. A DMR identifier that organizes traffic so listeners aren't bothered by other traffic
C. A group of amateur radio operators who share email on a specific amateur radio topic
D. Automatically alerts all members to the frequency where any member is transmitting

22. Which of the following applies when two stations transmitting on the same frequency interfere with each other?

A. The stations should negotiate continued use of the frequency
B. Whichever station was on the frequency first has preemptive rights to the frequency
C. Both stations should choose another frequency to avoid conflict
D. Use subaudible tones so both stations can share the frequency

23. Why are simplex channels designated in the VHF/UHF band plans?

A. So stations with simple transmitters can access the repeater without automated offset
B. For working DX only
C. So stations within range of each other can communicate without tying up a repeater
D. For contest operation

24. Which Q signal indicates that you are receiving interference from other stations?

A. QSB
B. QTH
C. QRN
D. QRM

25. Which Q signal indicates that you are changing frequency?

A. QSY
B. QSL
C. QRU
D. QRZ

26. Which of the following are typical duties of a Net Control Station?

A. Choose the regular net meeting time and frequency
B. All these choices are correct
C. Call the net to order and direct communications between stations checking in
D. Ensure all stations checking in are properly licensed for the net frequency

27. Which of the following is standard practice when you participate in a net?

A. On first response, give call sign, name, and address as in the FCC database
B. Record the time of each of your transmissions
C. All these choices are correct
D. Unless reporting an emergency, transmit only when directed by the net control station

28. What does the term "traffic" refer to in net operation?

A. A count of the number of activations of the net each month
B. Formal messages exchanged by net stations
C. Operation by mobile or portable stations
D. The number of stations checking in and out of a net

29. What information is contained in the preamble of a formal traffic message?

A. The address of the intended recipient
B. Information needed to track the message
C. The telephone number of the addressee
D. The email address of the originating station

30. What is meant by "check" in a radiogram header?

A. A box on the message form that indicates that the message was received and/or relayed
B. The call sign of the originating station
C. A list of stations that have relayed the message
D. The number of words or word equivalents in the text portion of the message

31. What technique is used to ensure that voice messages containing unusual words are received correctly?

A. All these choices are correct
B. Use the Q-code "QSR" to ask the receiving station to repeat the words back
C. Spell the words using a standard phonetic alphabet
D. Send the words by voice and Morse code

32. When do the FCC Part 97 Amateur Radio Service rules NOT apply to the operation of an amateur station?

A. FCC rules always apply
B. When operating under ARES rules
C. When operating under FEMA rules
D. When operating under RACES rules

33. Are amateur station control operators ever permitted to operate outside the frequency privileges of their license class?

A. Yes, but only when part of a RACES emergency plan
B. No
C. Yes, but only when part of a FEMA emergency plan
D. Yes, but only for the immediate safety of human life or protection of property

34. What is RACES?

A. An emergency organization combining amateur and citizens band operators and frequencies
B. An international radio experimentation society
C. An FCC Part 97 amateur service for civil defense communications in national emergencies
D. A radio contest held in a short period, sometimes called a “sprint”

35. What is the Amateur Radio Emergency Service (ARES)?

A. Licensed amateurs who registered qualifications and equipment for public service duty
B. Licensed military amateurs who volunteered message handling service in an emergency
C. A training program offering license courses for those wanting a license for emergencies
D. A training program certifying operators to join the Radio Amateur Civil Emergency Service

36. Which of the following requires certification by a civil defense agency?

A. ARES
B. RACES
C. SKYWARN
D. MARS

37. Which of the following relays messages using email addresses based on amateur callsigns?

A. FT8
B. Winlink
C. AMTOR
D. PSK31

Go deeper

LISTEN Lesson 3 episode 7:00 · FlashFeed Study Notes podcast

WATCH Repeater Offsets on Two Bands 0:28
A repeater listens on one frequency and retransmits on another. How far apart are the two?

WATCH Emergencies Don't Switch Off the Rules 0:30
In an emergency, do the amateur radio rules switch off at all?

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/operating-procedures

STUDY Ham Radio Technician License in the FlashFeed app flashfeedlearningapp.com/packs/ham-radio-technician

LESSON 4 OF 15

How Radio Waves Travel

How radio signals travel · Wavelength, frequency and radio waves · Propagation modes and the radio horizon

WHAT YOU'LL BE ABLE TO DO

- Explain how multipath, vegetation and weather change signals on very high, ultra high and microwave frequencies along a path
- Describe how polarization, the ionosphere and multipath affect signal strength, fading and data errors
- Describe the nature of a radio wave: its electric and magnetic fields, polarization and speed in free space
- Relate wavelength to frequency and identify the HF, VHF and UHF ranges
- Explain the radio horizon, why long-distance ionospheric paths are common on HF, and when the F region carries 10-meter and 6-meter signals
- Identify the scatter, diffraction and tropospheric ducting modes that carry VHF and UHF signals past obstructions or the horizon, and ionospheric sporadic E

This lesson explains how a radio signal gets from one antenna to another. It covers what a radio wave is made of and how its wavelength relates to its frequency. It also covers the paths a signal can take: straight across, bounced off obstacles, reflected by the upper atmosphere or bent past the horizon. A new licensee who knows these paths can choose a band, an antenna and a time of day that suit the contact.

How radio signals travel

Radio signals rarely take one clean path. Buildings, trees, weather and the upper atmosphere all change what a receiver hears. The facts below are grouped by cause.

Multipath and fading

Multipath propagation means a signal reaches the receiver by more than one path. The signals from the different paths combine at the antenna, and multipath propagation cancels or reinforces signals. For this reason, very high frequency (VHF) signal strength can vary greatly when an antenna is moved only a few feet.

Picket fencing is the rapid flutter heard on mobile signals due to multipath propagation.

A reflected path can also be useful. A station with a directional antenna may be blocked from a distant repeater by buildings or other obstructions. That station can try to find a path that reflects signals to the repeater.

Multipath also explains fading on longer paths. A likely cause of irregular fading of signals propagated by the ionosphere is random combining of signals arriving via different paths.

Multipath matters for data as well. Multipath propagation makes error rates likely to increase on data transmissions.

The ionosphere

The ionosphere is the region of the atmosphere that can reflect high frequency (HF) radio waves.

Absorption by vegetation and weather

Vegetation absorbs ultra high frequency (UHF) and microwave signals, which leads to poor reception of weak signals.

Weather matters as well. Precipitation might decrease range at microwave frequencies.

The 10-meter and 6-meter bands differ. Fog or rain has little effect on 10-meter and 6-meter band signals.

Antenna polarization

The polarization of a radio wave is the way its electric field is oriented. The next section looks at this more closely. Antenna polarization is a choice, and it matters on some paths more than others. The two modes named below are CW (international Morse code telegraphy) and single sideband (SSB).

For long-distance CW and SSB contacts on the VHF and UHF bands, horizontal polarization is normally used.

Mismatched polarization costs signal. **Cross-polarization** of the antennas over a line-of-sight VHF or UHF path reduces received signal strength.

Ionospheric paths are more forgiving. Signals propagated by the ionosphere are elliptically polarized. As a result, either vertically or horizontally polarized antennas may be used for transmission or reception.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)

Wavelength, frequency and radio waves

A radio wave is an electromagnetic wave. Its parts, its speed and the link between its frequency and its length are the foundation for the band names a licensee uses every day.

What a radio wave is made of

A radio wave has two components: electric and magnetic fields. The two fields are at right angles to each other.

Polarization is defined by the orientation of the electric field. Over a line-of-sight VHF or UHF path, antennas of crossed polarization reduce received signal strength.

How fast radio waves travel

In free space, a radio wave travels at the speed of light. That is approximately 300,000,000 meters per second. Every radio frequency travels at the same velocity in free space.

Wavelength and frequency

The **wavelength** of a wave is related to its **frequency**. Wavelength gets shorter as frequency increases.

To convert a frequency to an approximate wavelength, divide 300 by the frequency in megahertz (MHz). The result is the wavelength in meters. A signal at 30 MHz therefore has a wavelength of about 10 meters. A signal at 300 MHz has a wavelength of about 1 meter. The higher frequency gives the shorter wavelength.

This link explains how amateur bands are named. In addition to frequency, the approximate wavelength in meters identifies a band. That is why a licensee speaks of "the 2-meter band" or "10 meters".

HF, VHF and UHF

Three frequency ranges come up constantly. Each runs from one figure to ten times that figure:

- **HF** (high frequency): 3 to 30 MHz.
- **VHF** (very high frequency): 30 MHz to 300 MHz.
- **UHF** (ultra high frequency): 300 to 3000 MHz.

All three ranges are measured in megahertz. The ranges also line up with the formula above. As frequency rises from HF through VHF to UHF, wavelength shortens.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)

Propagation modes and the radio horizon

Beyond the direct path, signals can reach farther by several modes. Which one applies depends on the band, the time of day and conditions in the atmosphere. Each mode has its own signature.

The radio horizon

The radio horizon for VHF and UHF signals is more distant than the visual horizon. The reason is that the atmosphere refracts radio waves slightly.

UHF signals are usually not propagated by the ionosphere, so simplex UHF signals are rarely heard beyond their radio horizon.

HF and the F region

Long-distance ionospheric propagation is far more common on HF than on VHF and higher frequencies.

A term defined in the Federal Communications Commission (FCC) rules (47 CFR § 97.3, as of 2026) is **bandwidth**, which is the width of a frequency band outside of which the mean power of the transmitted signal is attenuated at least 26 dB below the mean power of the transmitted signal within the band.

The best time for long-distance 10-meter band propagation via the F region of the ionosphere is from dawn to shortly after sunset during periods of high sunspot activity.

At the peak of the sunspot cycle, the 6-meter and 10-meter bands may provide long-distance communications via the F region.

Scatter modes and sporadic E

In auroral backscatter, VHF signals are distorted, with a characteristic raspy sound.

Meteor scatter is best suited to the 6-meter band.

Sporadic E is the type of propagation most commonly associated with occasional strong signals on the 10-, 6- and 2-meter bands from beyond the radio horizon.

Diffraction and ducting

Knife-edge diffraction may allow radio signals to travel beyond obstructions between the transmitting and receiving stations.

Tropospheric ducting is responsible for over-the-horizon VHF and UHF communications to ranges of approximately 300 miles on a regular basis.

Tropospheric ducting is caused by temperature inversions in the atmosphere.

Sources

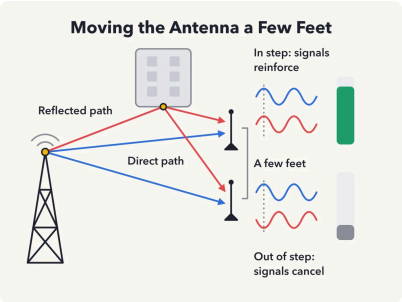
- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)
- 47 CFR § 97.3 Definitions

Key terms

Bandwidth

Span of frequencies outside which a transmitted signal's mean power is attenuated at least 26 dB below its mean power inside that span

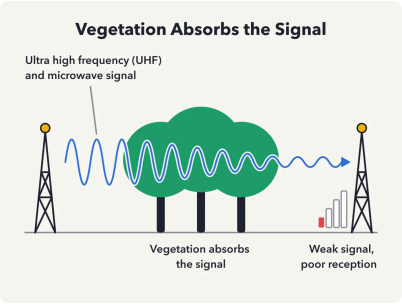
Key facts



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Why Signals Change Over Feet

Multipath propagation means a signal reaches the receiver by more than one path. The signals from the different paths combine at the antenna, and they cancel or reinforce each other. That is why very high frequency (VHF) signal strength can vary greatly when an antenna is moved only a few feet.



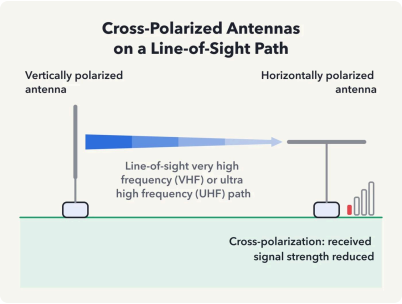
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Vegetation and Microwave Signals

Vegetation **absorbs** ultra high frequency (UHF) and microwave signals. The result is poor reception of weak signals.

Polarization for Long-Distance Contacts

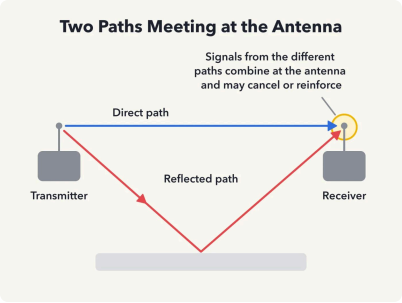
Long-distance contacts by CW (international Morse code telegraphy) and single sideband (SSB) on the very high frequency (VHF) and ultra high frequency (UHF) bands normally use **horizontal polarization**.



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Cost of Cross-Polarization

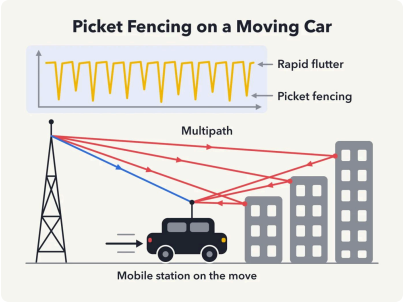
Cross-polarization of the antennas over a line-of-sight very high frequency (VHF) or ultra high frequency (UHF) path reduces received signal strength.



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Reaching a Repeater Around Obstacles

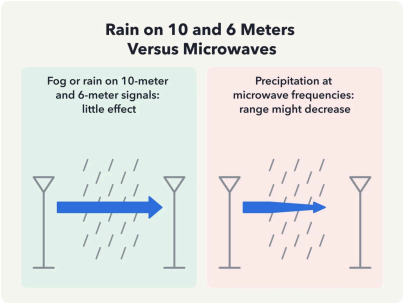
A station with a directional antenna may be blocked from a distant repeater by buildings or other obstructions. That station can try to find a **reflected path** that carries signals to the repeater.



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Picket Fencing on Mobile Signals

Picket fencing is the rapid flutter heard on mobile signals due to multipath propagation.



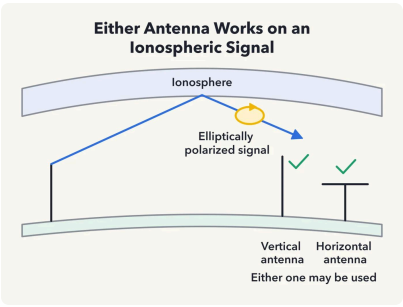
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Weather That Shortens Microwave Range

Precipitation might decrease range at microwave frequencies.

Irregular Fading on Ionospheric Paths

A likely cause of irregular **fading** of signals propagated by the ionosphere is random combining of signals arriving via different paths.



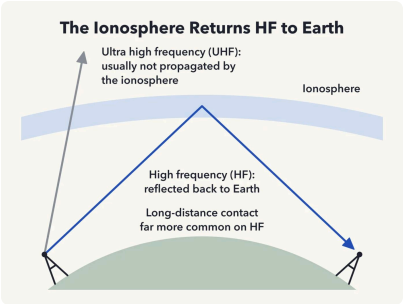
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Ionospheric Signals Are Elliptically Polarized

Signals propagated by the ionosphere are **elliptically polarized**. As a result, either vertically or horizontally polarized antennas may be used for transmission or reception.

Multipath and Data Errors

Multipath propagation makes **error rates** likely to increase on data transmissions.



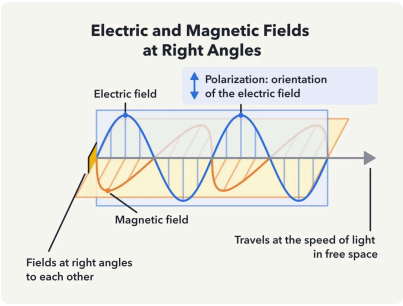
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The Region That Reflects HF

The **ionosphere** is the region of the atmosphere that can reflect high frequency (HF) radio waves.

Fog and Rain on 10 and 6 Meters

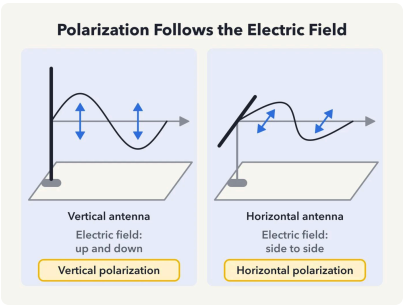
Fog or rain has **little effect** on 10-meter and 6-meter band signals.



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Fields at Right Angles

The electric and magnetic fields of a radio wave are **at right angles** to each other.



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What Defines Polarization

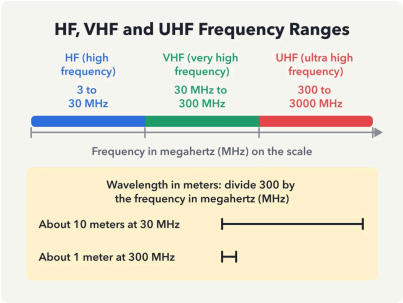
Polarization is defined by the orientation of the electric field.

Two Parts of a Radio Wave

A radio wave has two components: **electric and magnetic fields**.

Radio Waves Move at Light Speed

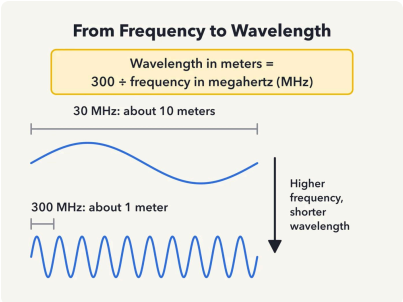
In free space, a radio wave travels at the **speed of light**.



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Higher Frequency, Shorter Wavelength

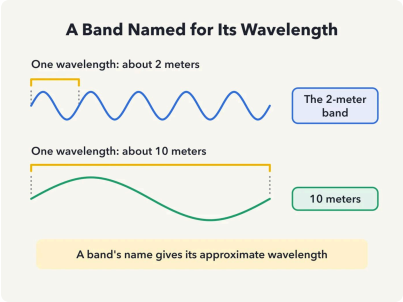
The **wavelength** of a wave is related to its frequency. Wavelength gets shorter as frequency increases.



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Converting Frequency to Wavelength

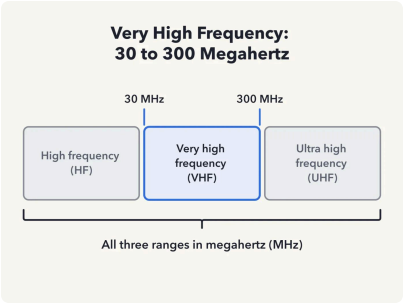
To convert a frequency to an approximate wavelength, divide 300 by the frequency in megahertz (MHz). The result is the **wavelength** in meters. A signal at 30 MHz has a wavelength of about 10 meters, and one at 300 MHz about 1 meter.



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Naming Bands by Wavelength

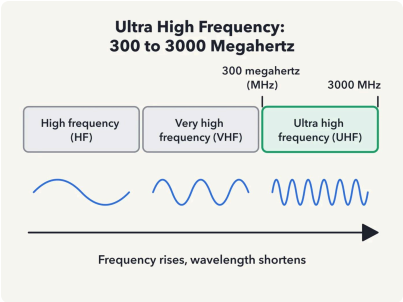
In addition to frequency, the approximate **wavelength** in meters identifies an amateur radio band. That is why a licensee speaks of the "2-meter band" or "10 meters".



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The Very High Frequency Range

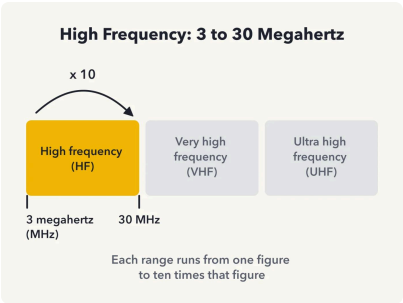
Very high frequency (VHF) covers 30 megahertz (MHz) to 300 MHz. All three ranges, high frequency (HF), VHF and ultra high frequency (UHF), are measured in megahertz.



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The Ultra High Frequency Range

Ultra high frequency (UHF) covers 300 to 3000 megahertz (MHz). As frequency rises from high frequency (HF) through very high frequency (VHF) to UHF, wavelength shortens.

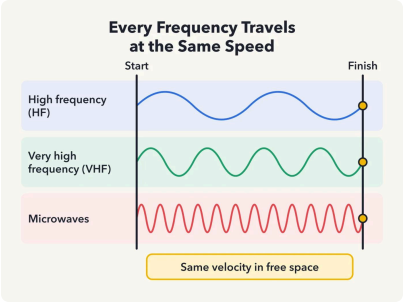


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The High Frequency Range

High frequency (HF) covers 3 to 30 megahertz (MHz). Each of the three ranges, HF, very high frequency (VHF) and ultra high frequency (UHF), runs from one figure to ten times that figure.

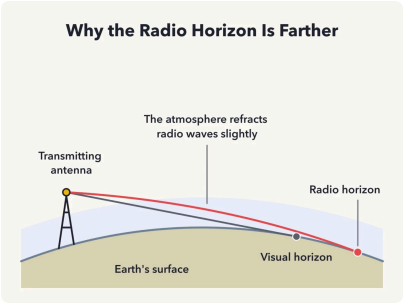
> ### Free-Space Speed in Meters
>
> The speed of light, and so of a radio wave in free space, is approximately **300,000,000 meters per second**.



FlashFeed original diagram · CC-BY-4.0

Every Frequency, Same Speed

Every radio frequency travels at the **same velocity** in free space.



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Why UHF Stays Near the Horizon

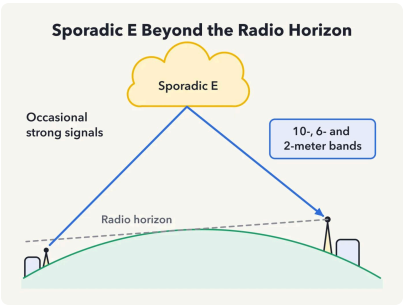
Ultra high frequency (UHF) signals are usually not propagated by the ionosphere, so simplex UHF signals are rarely heard beyond their **radio horizon**.

HF Carries Farthest

Long-distance ionospheric propagation is far more common on high frequency (HF) than on very high frequency (VHF) and higher frequencies.

The Sound of Auroral Backscatter

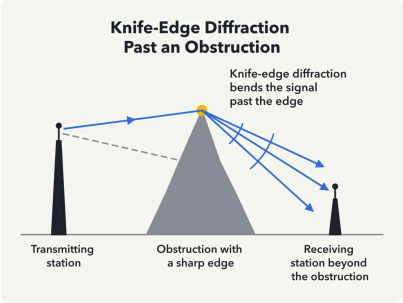
In **auroral backscatter**, very high frequency (VHF) signals are distorted, with a characteristic raspy sound.



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Sporadic E Surprises

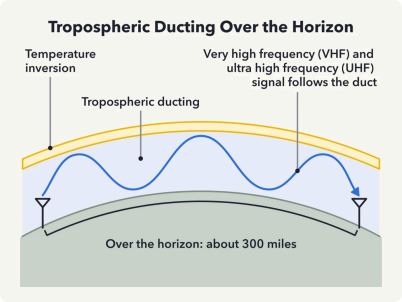
Sporadic E is the type of propagation most commonly associated with occasional strong signals on the 10-, 6- and 2-meter bands from beyond the radio horizon.



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Knife-Edge Diffraction Past Obstructions

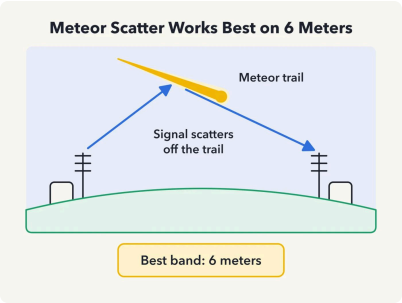
Knife-edge diffraction may allow radio signals to travel beyond obstructions between the transmitting and receiving stations.



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Tropospheric Ducting Range

Tropospheric ducting is responsible for over-the-horizon very high frequency (VHF) and ultra high frequency (UHF) communications to ranges of approximately 300 miles on a regular basis.



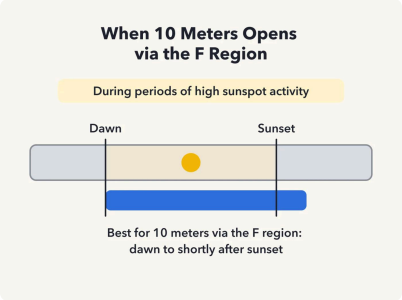
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Best Band for Meteor Scatter

Meteor scatter is best suited to the 6-meter band.

What Causes Ducting

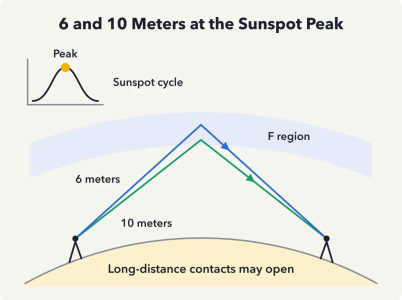
Tropospheric ducting is caused by **temperature inversions** in the atmosphere.



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Best Time for 10 Meters

The best time for long-distance 10-meter band propagation via the **F region** of the ionosphere is from dawn to shortly after sunset during periods of high sunspot activity.



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Bands That Use the F Region

At the peak of the sunspot cycle, the 6-meter and 10-meter bands may provide long-distance communications via the **F region**.

Why the Radio Horizon Is Farther

The **radio horizon** for very high frequency (VHF) and ultra high frequency (UHF) signals is more distant than the visual horizon. The reason is that the atmosphere refracts radio waves slightly.

Matched pairs

Each item on the left goes with the one on the right.

Picket fencing → Rapid flutter on mobile signals from multipath

HF (high frequency) → 3 to 30 megahertz (MHz)

Radio horizon → Farther than the visual horizon

Self-test

Answer each question from memory, then check your work against the answer key.

1. Why do VHF signal strengths sometimes vary greatly when the antenna is moved only a few feet?

- A Multipath propagation cancels or reinforces signals
- B The signal path encounters different concentrations of water vapor
- C The Doppler effect causes slight frequency shifts that change signal strength
- D VHF ionospheric propagation is very sensitive to path length

2. When using a directional antenna, how might your station be able to communicate with a distant repeater if buildings or obstructions are blocking the direct line of sight path?

- A Increase the antenna SWR
- B Try to find a path that reflects signals to the repeater
- C Change from vertical to horizontal polarization
- D Try the long path

3. What is the meaning of the term "picket fencing"?

- A A type of ground system used with vertical antennas
- B Alternating transmissions during a net operation
- C Interference from cable TV in the form of carriers at fixed intervals across the band
- D Rapid flutter on mobile signals due to multipath propagation

4. How does vegetation affect UHF and microwave signals?

- A Amplifies signals, improving reception of weak signals
- B Causes knife-edge diffraction, distorting voice peaks
- C Absorbs signals, leading to poor reception of weak signals
- D Has no effect

5. What weather condition might decrease range at microwave frequencies?

- A High winds
- B Precipitation
- C Colder temperatures
- D Low barometric pressure

6. What effect does fog or rain have on 10-meter and 6-meter band signals?

A Little effect
B Absorption
C Deflection
D Increased range

7. What antenna polarization is normally used for long-distance CW and SSB contacts on the VHF and UHF bands?

A Right-hand circular
B Left-hand circular
C Horizontal
D Vertical

8. What is the effect of antenna cross-polarization over a line-of-sight VHF or UHF path?

A Modulation sidebands might become inverted
B Nothing significant will happen
C Signals have an echo effect
D Received signal strength is reduced

9. Which of the following results from the fact that signals propagated by the ionosphere are elliptically polarized?

A FM voice is unusable
B Either vertical or horizontal antennas may be used to transmit or receive
C Digital modes are unusable
D Both the transmitting and receiving antennas must be of the same polarization

10. What is a likely cause of irregular fading of signals propagated by the ionosphere?

A Frequency shift due to Faraday rotation
B Interference from thunderstorms
C Random combining of signals arriving via different paths
D Intermodulation distortion

11. What effect does multi-path propagation have on data transmissions?

A No significant changes will occur if the signals are transmitted using FM
B Transmission rates must be increased by a factor equal to the number of paths observed
C Transmission rates must be decreased by a factor equal to the number of paths observed
D Error rates are likely to increase

12. Which region of the atmosphere can reflect HF radio waves?

A The ionosphere
B The troposphere
C The stratosphere
D The electrosphere

13. What is the relationship between the electric and magnetic fields of an electromagnetic wave?

A They travel at different speeds
B They are in parallel
C They revolve in opposite directions
D They are at right angles

14. What property of a radio wave defines its polarization?

A. The orientation of the magnetic field
B. The orientation of the electric field
C. The ratio of the velocity to the wavelength
D. The ratio of the energy in the magnetic field to the energy in the electric field

15. What are the two components of a radio wave?

A. Voltage and current
B. Impedance and reactance
C. Electric and magnetic fields
D. Ionizing and non-ionizing radiation

16. What is the velocity of a radio wave traveling through free space?

A. Speed of light
B. 1.86 times the speed of sound
C. Speed of sound
D. 0.86 times the speed of light

17. What is the approximate velocity of a radio wave in free space?

A. 300,000,000 meters per second
B. 150,000,000 meters per second
C. 300,000,000 miles per hour
D. 150,000,000 miles per hour

18. Which of these frequencies travels at the highest velocity in free space?

A. Microwaves
B. UHF
C. All radio frequencies travel at the same velocity
D. VHF

19. What is the relationship between wavelength and frequency?

A. Wavelength gets longer as frequency increases
B. Wavelength is constant at all frequencies
C. Wavelength and frequency increase as path length increases
D. Wavelength gets shorter as frequency increases

20. What is the formula for converting frequency to approximate wavelength in meters?

A. Wavelength in meters equals frequency in megahertz divided by 300
B. Wavelength in meters equals 300 divided by frequency in megahertz
C. Wavelength in meters equals frequency in hertz multiplied by 300
D. Wavelength in meters equals frequency in hertz divided by 300

21. In addition to frequency, which of the following is used to identify amateur radio bands?

A. All these choices are correct
B. Traditional letter/number designators
C. The approximate wavelength in meters
D. Channel numbers

22. What frequency range is referred to as VHF?

A. 300 MHz to 3000 MHz
B. 300 kHz to 3000 kHz
C. 30 kHz to 300 kHz
D. 30 MHz to 300 MHz

23. What frequency range is referred to as UHF?

A 300 to 3000 kHz
B 300 to 3000 MHz
C 30 to 300 MHz
D 30 to 300 kHz

24. What frequency range is referred to as HF?

A 3 to 30 MHz
B 30 to 300 MHz
C 300 to 3000 MHz
D 300 to 3000 kHz

25. Why are simplex UHF signals rarely heard beyond their radio horizon?

A UHF signals are absorbed by the ionospheric D region
B FCC regulations prohibit them from going more than 50 miles
C UHF signals are usually not propagated by the ionosphere
D They are too weak to go very far

26. Why is the radio horizon for VHF and UHF signals more distant than the visual horizon?

A Radio signals move somewhat faster than the speed of light
B Radio waves are blocked by dust particles
C Radio waves are not blocked by dust particles
D The atmosphere refracts radio waves slightly

27. What is a characteristic of HF communication compared with communications on VHF and higher frequencies?

A Long-distance ionospheric propagation is far more common on HF
B HF accommodates wider bandwidth signals
C HF antennas are generally smaller
D There is less atmospheric interference (static) on HF

28. What is generally the best time for long-distance 10-meter band propagation via the F region?

A From shortly after sunset to dawn during periods of low sunspot activity
B From dawn to shortly after sunset during periods of high sunspot activity
C From dawn to shortly after sunset during periods of low sunspot activity
D From shortly after sunset to dawn during periods of high sunspot activity

29. Which of the following bands may provide long-distance communications via the ionosphere's F region during the peak of the sunspot cycle?

A 23 centimeters
B 70 centimeters and 1.25 meters
C All these choices are correct
D 6 and 10 meters

30. What is one characteristic of VHF signals received via auroral backscatter?

A They are often received from 10,000 miles or more
B They are distorted, with a characteristic raspy sound
C They occur only during winter nighttime hours
D They are generally strongest when your antenna is aimed west

31. Which of the following types of propagation is most commonly associated with occasional strong signals on the 10-, 6-, and 2-meter bands from beyond the radio horizon?

- A Backscatter
- B D region absorption
- C Sporadic E
- D Gray-line propagation

32. What band is best suited for communicating via meteor scatter?

- A 6 meters
- B 33 centimeters
- C 2 meters
- D 70 centimeters

33. Which of the following effects may allow radio signals to travel beyond obstructions between the transmitting and receiving stations?

- A Quantum tunneling
- B Doppler shift
- C Knife-edge diffraction
- D Faraday rotation

34. What type of propagation is responsible for allowing over-the-horizon VHF and UHF communications to ranges of approximately 300 miles on a regular basis?

- A D region refraction
- B F2 region refraction
- C Faraday rotation
- D Tropospheric ducting

35. What causes tropospheric ducting?

- A Temperature inversions in the atmosphere
- B Updrafts from hurricanes and tornadoes
- C Discharges of lightning during electrical storms
- D Sunspots and solar flares

Go deeper

LISTEN Lesson 4 episode 7:11 · FlashFeed Study Notes podcast

WATCH Move the Antenna, Change the Signal 0:25
Move an antenna just a few feet, and a very high frequency signal can vary greatly.

WATCH The Mode That Reaches Past the Horizon 0:28
300 miles, over the horizon: how can a radio signal get that far?

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/how-radio-waves-travel

STUDY Ham Radio Technician License in the FlashFeed app flashfeedlearningapp.com/packs/ham-radio-technician

LESSON 5 OF 15

Setting Up and Running a Station

Setting up a station · Operating controls on a radio

WHAT YOU'LL BE ABLE TO DO

- Explain how to power a mobile transceiver and place meters and grounds correctly in a station
- Describe how to connect a computer to a transceiver, how to choose a standing wave ratio (SWR) meter, and what hotspots and electronic keyers do
- Use frequency entry, scanning, squelch, the RIT or clarifier and SSB filter width to find and tune in stations clearly
- Explain microphone gain, filter bandwidth and the setup of DMR and D-STAR digital radios

A working station needs more than a radio. It needs a suitable power source, correct wiring and grounds, meters in the right places, and often a computer. This lesson covers how a Technician licensee connects those parts. It then covers the controls on a transceiver used to enter frequencies, hear weak signals and keep audio clean. It ends with the setup needed before a digital voice radio such as a Digital Mobile Radio (DMR) or Digital Smart Technologies for Amateur Radio (D-STAR) unit can be used.

Setting up a station

Power and wiring

A typical 50-watt output mobile frequency modulated (FM) transceiver is powered from a supply rated **13.8 volts at 12 amperes**.

A transceiver's direct current (DC) power connection uses short, heavy-gauge wires. They are used to minimize voltage drop when transmitting.

A battery can run equipment only for a limited time. To find how long, divide the battery's **ampere-hour** rating by the average current draw of the equipment.

Grounding and bonding

In a vehicle, the negative power return of a mobile transceiver is connected at the 12-volt battery chassis ground.

A separate point concerns **bonding** at radio frequency (RF). The preferred conductor for bonding at RF is flat copper strap.

Meters in the feed line

An **RF power meter** is installed in the feed line, between the transmitter and the antenna.

An accessory **standing wave ratio (SWR) meter** is chosen by considering the frequency and power level at which the measurements will be made.

Computer and digital connections

To operate FT8, the audio input and output of the transceiver connect to the audio output and input of a computer running FT8 software.

A computer-radio interface for digital modes carries three signals: receive audio, transmit audio and transmitter keying.

One required connection between a computer and a transceiver is the computer's "line in" to the transceiver's speaker connector.

The Federal Communications Commission (FCC) defines **radioteletype (RTTY)** as narrow-band direct-printing telegraphy emissions with certain emission designators, including J2B. Only a digital code of a type specifically authorized in the amateur rules may be transmitted.

Hotspots and keyers

A digital mode **hotspot** gives nearby transceivers communication with a digital voice or data network.

An **electronic keyer** is a device that assists in manual sending of Morse code.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)
- 47 CFR § 97.3 Definitions

Operating controls on a radio

Entering and scanning frequencies

A transceiver's operating frequency is entered with the keypad or the variable frequency oscillator (VFO) knob.

The **scanning** function of an FM transceiver tunes through a range of frequencies to check for activity.

Squelch and off-frequency FM

To hear a weak FM signal, the **squelch** threshold is set so that receiver output audio is on all the time.

An FM signal received slightly off frequency sounds distorted.

Pitch, filters and gain

The **receiver incremental tuning (RIT)** control, also called the **clarifier**, is the one to use when the voice pitch of a single sideband (SSB) signal answering a CQ (calling any station) call seems too high or low.

A multimode transceiver offers a choice of receiver filter bandwidths. The advantage is that noise or interference can be reduced by selecting a bandwidth matching the mode.

For SSB reception, a receiver filter bandwidth of 2400 hertz (Hz) provides the best signal-to-noise ratio.

Excessive microphone gain on SSB transmissions distorts the transmitted audio.

DMR and D-STAR radios

On a Digital Mobile Radio (DMR) transceiver, a **code plug** is configuration data loaded onto the radio to access repeaters and talkgroups.

A specific group of stations is selected on a DMR transceiver by entering the group's identification code.

A D-STAR digital transceiver must have the operator's call sign programmed into it before transmitting.

Sources

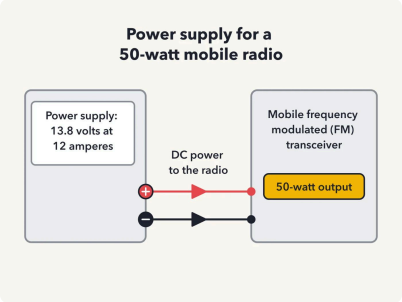
- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)

Key terms

Radioteletype (RTTY)

Narrow-band direct-printing telegraphy; only an authorized digital code may be sent

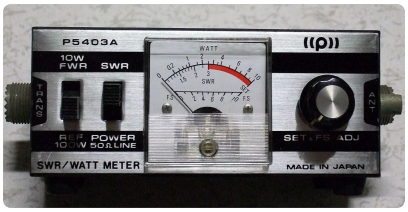
Key facts



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Mobile Radio Power Supply Rating

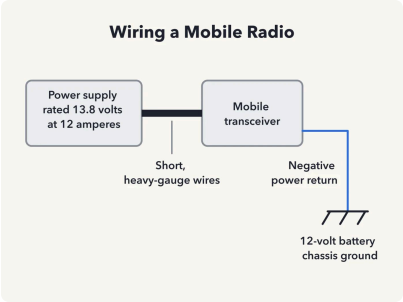
A typical 50-watt output mobile frequency modulated (FM) transceiver is powered from a supply rated **13.8 volts at 12 amperes**.



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Choosing an SWR Meter

An accessory **standing wave ratio (SWR) meter** is chosen by considering the frequency and power level at which the measurements will be made.



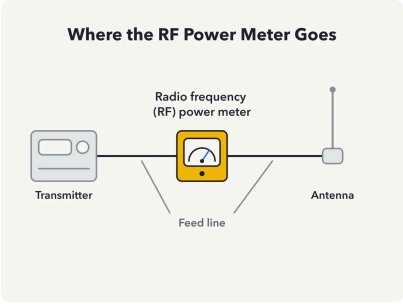
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Why Short, Heavy Power Wires

A transceiver's direct current (DC) power connection uses short, heavy-gauge wires. They are used to minimize **voltage drop** when transmitting.

Connecting a Radio for FT8

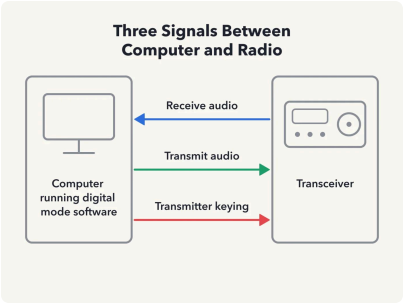
To operate FT8, the transceiver's audio input and output connect to the audio output and input of a computer running FT8 software.



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Where the Power Meter Goes

A **radio frequency (RF) power meter** is installed in the feed line, between the transmitter and the antenna.



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Three Signals in a Digital Interface

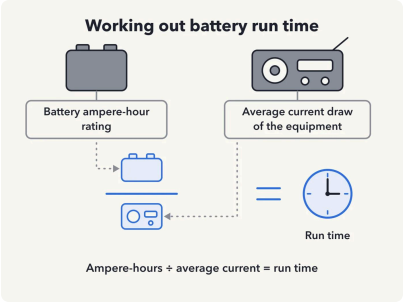
A computer-radio interface for digital modes carries three signals: receive audio, transmit audio and transmitter keying.

Computer Line In to Speaker Jack

One required connection between a computer and a transceiver for digital modes is the computer's "line in" to the transceiver's speaker connector.

Best Conductor for RF Bonding

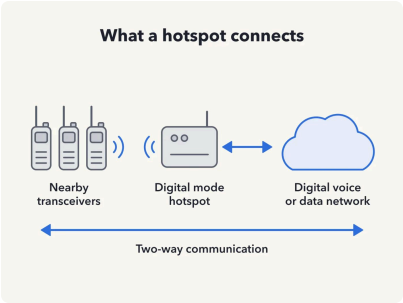
The preferred conductor for **bonding** at radio frequency (RF) is flat copper strap.



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Battery Run Time

To find how long a battery can power equipment, divide the battery's **ampere-hour** rating by the average current draw of the equipment.



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What a Hotspot Does

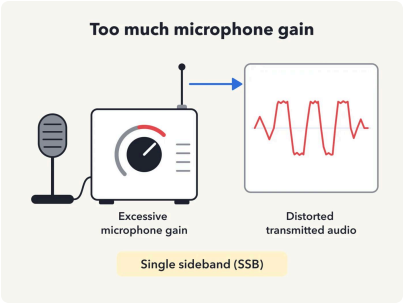
A digital mode **hotspot** gives nearby transceivers communication with a digital voice or data network.

Negative Return in a Vehicle

In a vehicle, the negative power return of a mobile transceiver is connected at the 12-volt battery chassis ground.

What an Electronic Keyer Is

An **electronic keyer** is a device that assists in manual sending of Morse code.



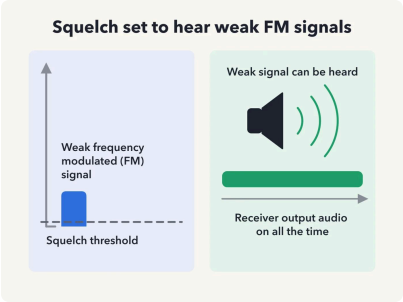
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Too Much Microphone Gain

Excessive **microphone gain** on single sideband (SSB) transmissions distorts the transmitted audio.

Entering an Operating Frequency

A transceiver's operating frequency is entered with the keypad or the variable frequency oscillator (VFO) knob.



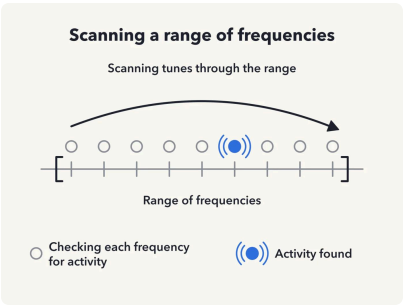
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Squelch for Weak FM Signals

To hear a weak frequency modulated (FM) signal, the **squelch** threshold is set so that receiver output audio is on all the time.

FM Received Off Frequency

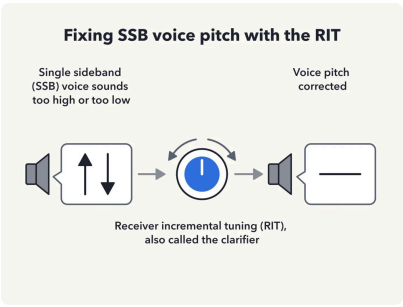
A frequency modulated (FM) signal received slightly off frequency sounds distorted.



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What Scanning Does

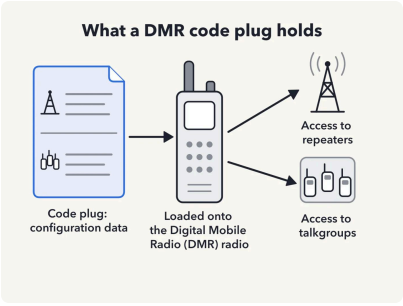
The **scanning** function of a frequency modulated (FM) transceiver tunes through a range of frequencies to check for activity.



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Fixing Pitch with the RIT

The **receiver incremental tuning (RIT)** control, also called the **clarifier**, fixes a single sideband (SSB) voice that sounds too high or low.



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What a DMR Code Plug Is

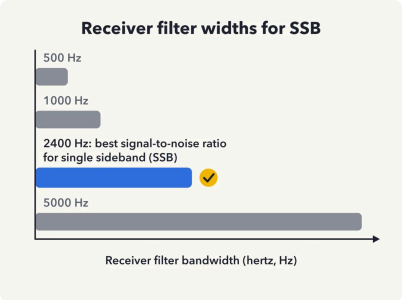
On a Digital Mobile Radio (DMR) transceiver, a **code plug** is configuration data loaded onto the radio to access repeaters and talkgroups.

Why Choose a Filter Bandwidth

A multimode transceiver offers a choice of receiver **filter bandwidths**. Noise or interference can be reduced by selecting a bandwidth matching the mode.

Selecting a DMR Group

A specific group of stations is selected on a Digital Mobile Radio (DMR) transceiver by entering the group's identification code.



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Best SSB Filter Width

For single sideband (SSB) reception, a receiver filter bandwidth of 2400 hertz (Hz) provides the best signal-to-noise ratio.

A Call Sign for Digital Radio

A Digital Smart Technologies for Amateur Radio (D-STAR) digital transceiver must have the operator's **call sign** programmed into it before transmitting.

Matched pairs

Each item on the left goes with the one on the right.

Electronic keyer → Aids manual Morse code sending

Scanning → Tunes through frequencies to check activity

Self-test

Answer each question from memory, then check your work against the answer key.

1. Which of the following is an appropriate power supply rating for a typical 50-watt output mobile FM transceiver?

- (A) 13.8 volts at 4 amperes
- (B) 24.0 volts at 12 amperes
- (C) 24.0 volts at 4 amperes
- (D) 13.8 volts at 12 amperes

2. Why are short, heavy-gauge wires used for a transceiver's DC power connection?

- (A) To provide a close match to the power supply output impedance
- (B) To minimize radiative losses in the power cable
- (C) To minimize voltage drop when transmitting
- (D) To avoid RF interference

3. How can you determine the length of time that equipment can be powered from a battery?

A. Divide the battery ampere-hour rating by the average current draw of the equipment
B. Multiply the square of the battery's current rating by the equipment's input resistance
C. Divide the watt-hour rating of the battery by the peak power consumption of the equipment
D. Multiply the watts per hour consumed by the equipment by the battery power rating

4. Which of the following conductors is preferred for bonding at RF?

A. Twisted-pair cable
B. Flat copper strap
C. Copper braid removed from coaxial cable
D. Copper-clad steel wire

5. Where should the negative power return of a mobile transceiver be connected in a vehicle?

A. At the 12-volt battery chassis ground
B. To any metal part of the vehicle
C. Through the transceiver's mounting bracket
D. To the shell of the power connector

6. Where should an RF power meter be installed?

A. At the power supply output
B. In parallel with the push-to-talk line and the antenna
C. In the power supply cable, as close as possible to the radio
D. In the feed line, between the transmitter and antenna

7. Which of the following should be considered when selecting an accessory SWR meter?

A. The distance that the meter will be located from the antenna
B. The ability of the meter to compensate for a poor transmission line match to the antenna
C. The frequency and power level at which the measurements will be made
D. The maximum SWR anticipated on the transmission line

8. How are the audio input and output of a transceiver connected in a station configured to operate using FT8?

A. To a computer connected to the FT8converter.com website
B. To the audio output and input of a computer running FT8 software
C. To an FT8 conversion unit, a keyboard, and a computer monitor
D. To a computer running a terminal program and connected to a terminal node controller unit

9. What signals are used in a computer-radio interface for digital mode operation?

A. NMEA GPS location and DC power
B. Antenna and RF power
C. Receive audio, transmit audio, and transmitter keying
D. Receive and transmit mode, status, and location

10. Which of the following is one of the connections required between a computer and a transceiver to operate digital modes?

- A Computer “line out” to transceiver push-to-talk
- B Computer “line in” to transceiver push-to-talk
- C Computer “line out” to transceiver speaker connector
- D Computer “line in” to transceiver speaker connector

11. What function does a digital mode hotspot perform for nearby transceivers?

- A FT8 digital communications via AFSK using a smartphone connected to the internet
- B Communication with a digital voice or data network
- C High-speed digital communications for meteor scatter
- D RTTY encoding and decoding without a computer

12. What is an electronic keyer?

- A A device that assists in manual sending of Morse code
- B An interlock to prevent unauthorized use of a radio
- C A device for switching antennas from transmit to receive
- D A device for voice activated switching from receive to transmit

13. Which of the following can be used to enter a transceiver’s operating frequency?

- A The Automatic Frequency Control
- B All these choices are correct
- C The CTCSS or DTMF encoder
- D The keypad or VFO knob

14. What does the scanning function of an FM transceiver do?

- A Tunes through a range of frequencies to check for activity
- B Tunes through a range of frequencies to determine the antenna’s resonant frequency
- C Checks incoming signal deviation
- D Prevents interference to nearby repeaters

15. How is squelch adjusted so that a weak FM signal can be heard?

- A Turn on the anti-squelch function
- B Turn up the audio level until it overcomes the squelch threshold
- C Set the squelch threshold so that receiver output audio is on all the time
- D Enable squelch enhancement

16. What does an FM signal sound like when received slightly off frequency?

- A There is no effect except for reduction in amplitude
- B The audio becomes distorted
- C The audio increases in pitch
- D The audio decrease in pitch

17. Which of the following controls could be used if the voice pitch of a single-sideband signal returning to your CQ call seems too high or low?

A The RIT or Clarifier
B The AGC or limiter
C The bandwidth selection
D The tone squelch

18. Which of the following receiver filter bandwidths provides the best signal-to-noise ratio for SSB reception?

A 5000 Hz
B 2400 Hz
C 500 Hz
D 1000 Hz

19. What is the effect of excessive microphone gain on SSB transmissions?

A Frequency instability
B Sideband inversion
C Distorted transmitted audio
D Increased SWR

20. What is the advantage of having a choice of receiver filter bandwidths in a multimode transceiver?

A Increases the number of frequencies that can be stored in memory
B Increases the amount of offset between receive and transmit frequencies
C Permits monitoring several modes at once by selecting a separate filter for each mode
D Permits noise or interference reduction by selecting a bandwidth matching the mode

21. What is a DMR “code plug”?

A A manufacturer's DMR programming software upgrade to support new radio models
B An adapter cable used to connect a DMR radio to a computer for internet access
C A Coder-Decoder (CODEC) that converts analog voice data to DMR digital data and vice versa
D Configuration data loaded onto your radio to access repeaters and talkgroups

22. How is a specific group of stations selected on a DMR digital voice transceiver?

A By enabling the group’s CTCSS tone
B By entering the group’s identification code
C By retrieving the frequencies from transceiver memory
D By inserting a five-pin, pre-programmed code plug

23. Which of the following must be programmed into a D-STAR digital transceiver before transmitting?

A Your call sign
B All these choices are correct
C Your output power
D The codec type being used

Go deeper

LISTEN Lesson 5 episode 6:51 · FlashFeed Study Notes podcast

WATCH Powering a Mobile Radio 0:28
A typical fifty-watt mobile radio needs a power supply. What should that supply be rated?

WATCH Hearing a Weak Signal 0:26
A weak frequency modulated (FM) signal is on the air. The radio stays quiet, and nothing can be heard.

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/setting-up-and-running-a-station

STUDY Ham Radio Technician License in the FlashFeed app flashfeedlearningapp.com/packs/ham-radio-technician

LESSON 6 OF 15

Electrical Principles: Current, Voltage and Units

Current, voltage and conductors · Unit conversions and decibels

WHAT YOU'LL BE ABLE TO DO

- Identify the units and terms for current, power, voltage and frequency, and what causes electron flow
- Explain why metals conduct and glass insulates, and describe alternating current, its frequency and resistance
- Convert between metric prefixes for amperes, volts, watts and farads using milli, micro, kilo and pico
- Convert between hertz, kilohertz, megahertz and gigahertz and estimate decibel changes in power

Every radio circuit rests on a few basic electrical ideas. This lesson names those ideas, gives the unit for each, and shows how the units scale up and down. A new licensee needs both skills to read meter scales and equipment labels, and to follow the numbers in later lessons on components, circuits and antennas.

Current, voltage and conductors

Current is the flow of electrons in an electric circuit. It is measured in **amperes**.

Voltage is what makes electrons move. A difference in voltage causes electron flow. Voltage is counted in volts.

Power is the rate at which electrical energy is used. Its unit is the **watt**.

These three quantities fit together as a set:

- Current is the flow of electrons, measured in amperes.
- Voltage is the difference that causes the flow, measured in volts.
- Power is the rate of energy use, measured in watts.

A power supply label can list all three. The ampere rating gives the current, the volt rating gives the voltage, and the watt rating gives the power. Each unit goes with its own quantity.

Frequency applies to alternating current. In **alternating current (AC)**, the current alternates between positive and negative directions. Each time the current completes a full back-and-forth swing, that is one cycle. Frequency is the number of times per second that an alternating current makes a complete cycle. The unit of frequency is the **hertz**.

Some materials carry current easily and some resist it. Metals are generally good conductors of electricity because they have many free electrons. Glass, on the other hand, is a good electrical insulator. The pairing is easy to remember. A metal wire suits the job of carrying current, and a piece of glass suits the job of keeping current out.

Resistance is the opposition to current flow. Resistance opposes direct current, alternating current and radio frequency (RF) current alike:

- direct current;
- alternating current;
- radio frequency (RF) current.

Resistance is the opposition that current meets while it flows, whatever form the current takes.

Sources

- 2026–2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)

Unit conversions and decibels

Electrical values often come with a prefix that scales the unit. Worked examples show what each prefix means.

Milli means one-thousandth. These pairs are equal:

- 1.5 amperes is 1500 milliamperes.
- 3000 milliamperes is 3 amperes.
- 500 milliwatts is 0.5 watts.

Going from amperes or watts to the milli form multiplies the number by 1000. Going back divides it by 1000.

Kilo means one thousand. One **kilovolt** is one thousand volts.

Micro means one-millionth. One **microvolt** is one one-millionth of a volt.

Pico is smaller still. 1,000,000 picofarads equals 1 microfarad, so a picofarad is one-millionth of a microfarad.

Frequency units step up by thousands. A hertz is the base unit, and the larger units are kilohertz (kHz), megahertz (MHz) and gigahertz (GHz). The examples show the steps:

- 1,500,000 hertz is 1500 kHz, so a kilohertz is 1000 hertz.
- 3.525 MHz is 3525 kHz, so a megahertz is 1000 kilohertz.
- 28400 kHz is 28.400 MHz.
- 2425 MHz is 2.425 GHz, so a gigahertz is 1000 megahertz.

Moving to a larger unit makes the number smaller, because each step holds a thousand of the smaller one. A licensee can use this to restate a band edge in whichever unit a radio or a chart uses.

The **decibel** value (dB) describes a change in power. An increase gives a positive value and a decrease gives a negative one. Three examples show typical changes:

- A power increase from 5 watts to 10 watts, a doubling, is most closely 3 dB.
- A power decrease from 12 watts to 3 watts, a drop to one quarter, is most closely -6 dB.
- A power increase from 20 watts to 200 watts, ten times as much, is 10 dB.

A rise in power therefore shows as a positive number of decibels, and a fall shows as a negative number. An amplifier that doubles power adds about 3 dB. Using only these values, a licensee can estimate a decibel change by comparing the starting and ending power.

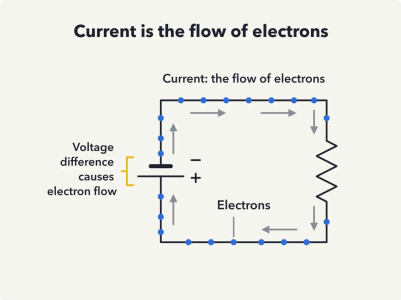
Sources

- 2026–2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)

Key facts

> **Current is measured in amperes**
>
> Electrical **current** is measured in amperes. The ampere goes with current, the volt with voltage and the watt with power.

> **Power is measured in watts**
>
> Electrical power is measured in **watts**.

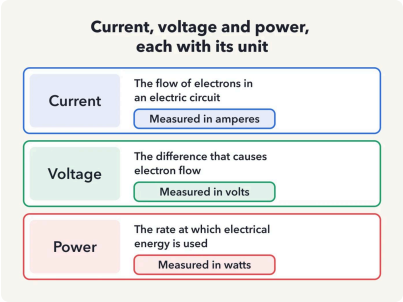


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Current: the flow of electrons

The flow of electrons in an electric circuit is called **current**.

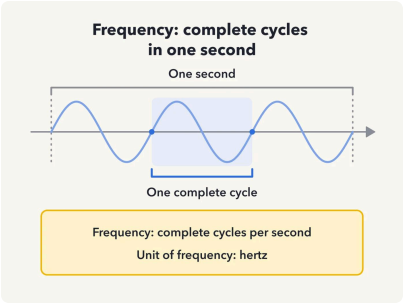
> **Frequency counts cycles per second**
>
> **Frequency** is the number of times per second that an alternating current makes a complete cycle. Each full back-and-forth swing of the current is one cycle.



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Voltage difference moves electrons

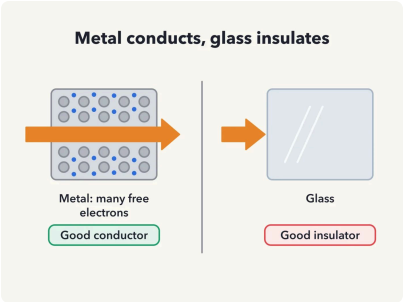
A difference in **voltage** causes electron flow. Voltage is counted in volts.



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Hertz is the unit of frequency

The **hertz** is the unit of frequency. Frequency is the number of times per second that an alternating current makes a complete cycle.



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Why metals conduct well

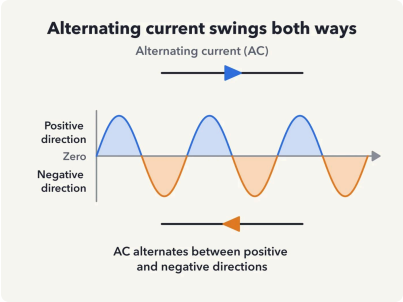
Metals are generally good **conductors** of electricity because they have many free electrons.



Wikimedia Commons · Bill "Hemingray" Meier at English Wikipedia · Public domain

Glass is a good insulator

Glass is a good electrical **insulator**. A piece of glass suits the job of keeping current out.



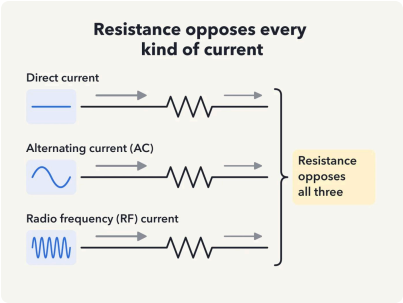
FlashFeed original diagram · CC-BY-4.0

What alternating current does

In **alternating current (AC)**, the current alternates between positive and negative directions.

Power: the rate of energy use

Power is the rate at which electrical energy is used. Its unit is the watt.



FlashFeed original diagram · CC-BY-4.0

Resistance opposes every current

Resistance opposes direct current, alternating current (AC) and radio frequency (RF) current alike. It is the opposition that current meets while it flows, whatever form the current takes.

Amperes to milliamperes

1.5 amperes is 1500 milliamperes. Going from amperes to the **milli** form multiplies the number by 1000.

Hertz to kilohertz

1,500,000 hertz is 1500 kilohertz (kHz). A **kilohertz** is 1000 hertz.

What a kilovolt equals

Kilo means one thousand, so one **kilovolt** is one thousand volts.

What a microvolt equals

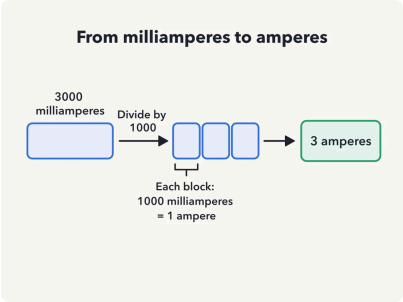
Micro means one-millionth, so one **microvolt** is one one-millionth of a volt.



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Milliwatts to watts

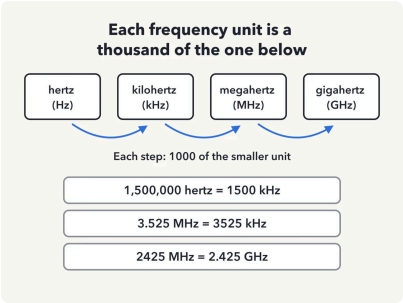
Milli means one-thousandth. So 500 **milliwatts** is 0.5 watts, and going back from the milli form to watts divides the number by 1000.



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Milliamperes to amperes

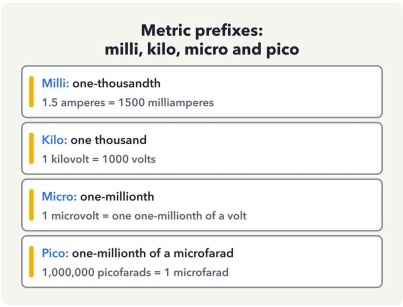
3000 milliamperes is 3 amperes. Dividing by 1000 gives the **amperes** value.



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Megahertz to kilohertz

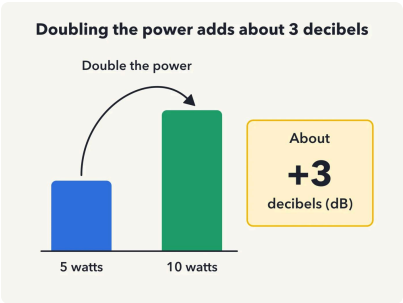
3.525 megahertz (MHz) is 3525 kilohertz (kHz). A **megahertz** is 1000 kilohertz.



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Picofarads to microfarads

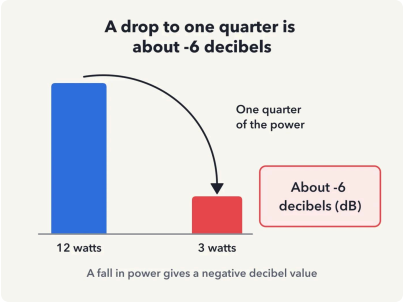
1,000,000 picofarads equals 1 microfarad. So a **picofarad** is one-millionth of a microfarad.



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Doubling power is about 3 dB

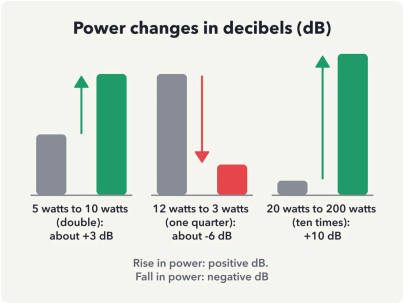
A power increase from 5 watts to 10 watts, a doubling, is most closely 3 dB. The **decibel** (dB) describes a change in power.



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A drop to one quarter is -6 dB

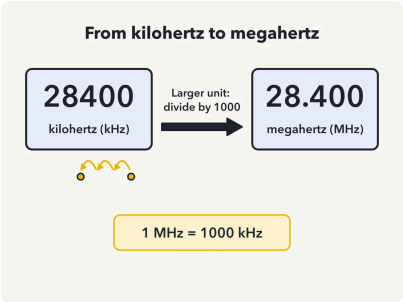
A power decrease from 12 watts to 3 watts, a drop to one quarter, is most closely -6 decibels (dB). A fall in power shows as a **negative** decibel value.



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Ten times the power is 10 dB

A power increase from 20 watts to 200 watts, ten times as much, is 10 decibels (dB). A rise in power shows as a **positive** decibel value.



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28400 kilohertz in megahertz

28400 kilohertz (kHz) is 28.400 megahertz (MHz). A **megahertz** is 1000 kilohertz, so moving to the larger unit divides the number by 1000.

> ### Megahertz to gigahertz
>
> 2425 megahertz (MHz) is 2.425 gigahertz (GHz). A **gigahertz** is 1000 megahertz.

Matched pairs

Each item on the left goes with the one on the right.

Unit of frequency → Hertz

One microvolt → One one-millionth of a volt

Self-test

Answer each question from memory, then check your work against the answer key.

1. Electrical current is measured in which of the following units?

A Volts
B Watts
C Amperes
D Ohms

2. Electrical power is measured in which of the following units?

A Watts
B Watt-hours
C Volts
D Amperes

3. What is the unit of frequency?

A Epicycles per second
B Hertz
C Farad
D Henry

4. What is the term for the flow of electrons in an electric circuit?

A Volts per second
B Amperes per second
C Voltage
D Current

5. A difference in which of the following causes electron flow?

A Voltage
B Ampere-hours
C Capacitance
D Inductance

6. Which term describes the rate at which electrical energy is used?

A Voltage
B Power
C Resistance
D Current

7. Why are metals generally good conductors of electricity?

A They have relatively high density
B They have many free protons
C They have relatively high Young's modulus values
D They have many free electrons

8. Which of the following is a good electrical insulator?

A Sea water
B Stainless steel
C Glass
D Graphite

9. What term describes the number of times per second that an alternating current makes a complete cycle?

A Wavelength
B Wave number
C Frequency
D Pulse rate

10. Which of the following describes alternating current?

A All these answers are correct
B Current that alternates between a negative direction and zero
C Current that alternates between a positive direction and zero
D Current that alternates between positive and negative directions

11. What type of current flow is opposed by resistance?

A All these choices are correct
B Direct current
C Alternating current
D RF current

12. How many milliamperes is 1.5 amperes?

A 0.0000015 milliamperes
B 1500 milliamperes
C 0.0015 milliamperes
D 1,500,000 milliamperes

13. Which is equal to 500 milliwatts?

A 5 watts
B 500,000 watts
C 500,000,000 watts
D 0.5 watts

14. Which is equal to 3000 milliamperes?

A 3,000,000 amperes
B 3 amperes
C 0.003 amperes
D 0.3 amperes

15. Which is equal to one kilovolt?

A One one-thousandth of a volt
B One million volts
C One thousand volts
D One hundred volts

16. Which is equal to one microvolt?

A One one-millionth of a volt
B One one-thousandth of a volt
C One thousand kilovolts
D One million volts

17. Which is equal to 1,000,000 picofarads?

A 1000 microfarads
B 0.001 microfarads
C 1 microfarad
D 1,000,000,000 microfarads

18. Which is equal to 1,500,000 hertz?

A 150 kHz
B 1500 kHz
C 1500 MHz
D 15 GHz

19. Which is equal to 3.525 MHz?

A 3525 kHz
B 35.25 kHz
C 0.003525 kHz
D 3,525,000 kHz

20. Which is equal to 28400 kHz?

(A) 284.00 MHz
(B) 28.400 kHz
(C) 2.800 MHz
(D) 28.400 MHz

21. Which is equal to 2425 MHz?

(A) 242.5 GHz
(B) 2.425 GHz
(C) 24.25 GHz
(D) 0.002425 GHz

22. Which decibel value most closely represents a power increase from 5 watts to 10 watts?

(A) 2 dB
(B) 10 dB
(C) 5 dB
(D) 3 dB

23. Which decibel value most closely represents a power decrease from 12 watts to 3 watts?

(A) -3 dB
(B) -1 dB
(C) -6 dB
(D) -9 dB

24. Which decibel value represents a power increase from 20 watts to 200 watts?

(A) 10 dB
(B) 28 dB
(C) 18 dB
(D) 12 dB

Go deeper

LISTEN Lesson 6 episode 6:38 · FlashFeed Study Notes podcast

WATCH What Resistance Opposes 0:27
3 kinds of current all meet the same opponent.

WATCH Doubling Power in Decibels 0:26
Imagine a radio's power doubles, from 5 watts to 10 watts. How many decibels does that add?

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/electrical-principles-current-voltage-and-units

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LESSON 7 OF 15

Electrical Principles: Impedance, Power and Ohm's Law

Capacitance, inductance, impedance and power · Ohm's law, series and parallel

WHAT YOU'LL BE ABLE TO DO

- Identify the terms and units for capacitance, inductance and impedance, and define impedance
- Write frequency unit abbreviations and calculate DC power from voltage and current
- Choose the Ohm's law formula for current, voltage or resistance and calculate resistance
- Calculate current and voltage with Ohm's law and tell series from parallel circuits

This lesson turns the electrical vocabulary of the previous lesson into working tools. It names the properties that store energy in a circuit, gives their units, and shows how to write frequency units correctly. It then adds the formulas for power and for Ohm's law, which let a new licensee work out current, voltage, resistance and power from numbers a meter or a label provides. These calculations are short, and they come up whenever a radio's power supply or wiring is discussed.

Capacitance, inductance, impedance and power

Capacitance and inductance

Electrical parts can store energy in two different ways. **Capacitance** describes the ability to store energy in an electric field. **Inductance** describes the ability to store energy in a magnetic field. The two are easy to swap, so it helps to pair each with its field: electric field with capacitance, magnetic field with inductance.

Each property has its own unit. The unit of capacitance is the **farad**. The unit of inductance is the **henry**. Neither is interchangeable with the other.

Impedance

Impedance is the opposition to alternating current (AC) flow. Its unit is the **ohm**.

Writing frequency units

Frequency units have exact capitalization when written as abbreviations.

- Kilohertz is written **kHz**: a lowercase k, a capital H and a lowercase z.
- Megahertz is written **MHz**: a capital M, a capital H and a lowercase z.

The two abbreviations differ in their first letter: a lowercase k in kHz and a capital M in MHz. Both end in a capital H and a lowercase z, and the case of every letter counts.

Power in a direct current circuit

Electrical power (P) in a direct current (DC) circuit is found by multiplying current (I) by voltage (E): P = I x E. Power is measured in watts, current in amperes and voltage in volts.

Three worked examples show the formula in use.

- A voltage of 13.8 volts DC and a current of 10 amperes deliver 138 watts, because 13.8 x 10 is 138.
- A voltage of 12 volts DC and a current of 2.5 amperes deliver 30 watts, because 12 x 2.5 is 30.
- Delivering 120 watts at 12 volts DC takes 10 amperes. Since power equals current times voltage, dividing the power by the voltage gives the current: 120 divided by 12 is 10.

The third example runs the formula backward. When power and voltage are known, the current is the power divided by the voltage.

A 13.8 volt supply feeding a radio that draws 10 amperes is a realistic case of the first example. The result is 138 watts of power delivered to the radio.

With different numbers, 6 volts DC and a current of 4 amperes deliver 24 watts, because 6 x 4 is 24. Run backward, 48 watts at 12 volts DC takes 4 amperes, because 48 / 12 is 4.

Checking an answer

A quick sense check catches most mistakes. In the first example, 13.8 volts is a little under 14, and 14 x 10 is 140, so an answer near 138 makes sense. In the second example, 12 x 2.5 is half of 12 x 5, which is 60, so 30 watts fits.

Sources

- NCVEC Question Pool Committee — 2026–2030 Technician question pool

Ohm's law, series and parallel

The three forms of Ohm's law

Ohm's law ties together three quantities of a circuit: current (I), voltage (E) and resistance (R). Knowing any two lets a licensee find the third. The formula depends on which one is unknown.

- Current: I = E / R. Current is voltage divided by resistance.
- Voltage: E = I x R. Voltage is current times resistance.
- Resistance: R = E / I. Resistance is voltage divided by current.

A good habit is to say the three formulas as a set. Each is the same relationship rearranged, so one of them can be rebuilt from another.

Calculating resistance

To find resistance, divide the voltage by the current.

- A circuit in which 3 amperes flows when connected to 90 volts has a resistance of 30 ohms, because 90 / 3 is 30.
- A circuit with 12 volts applied and 1.5 amperes flowing has a resistance of 8 ohms, because 12 / 1.5 is 8.
- A circuit that draws 4 amperes from a 12-volt source has a resistance of 3 ohms, because 12 / 4 is 3.

The ohm is the unit of resistance in all three answers. With different numbers, 20 volts applied to a circuit carrying 5 amperes gives a resistance of 4 ohms, because 20 / 5 is 4.

Calculating current

To find current, divide the voltage by the resistance.

- A circuit with an applied voltage of 120 volts and a resistance of 80 ohms carries 1.5 amperes, because 120 / 80 is 1.5.
- A 100-ohm resistor connected across 200 volts carries 2 amperes, because 200 / 100 is 2.
- A 24-ohm resistor connected across 240 volts carries 10 amperes, because 240 / 24 is 10.

Multiplying the voltage by the resistance is the usual slip when finding current. A current of several thousand amperes is a clear sign that the voltage was multiplied by the resistance instead of divided by it. With different numbers, a 15-ohm resistor connected across 60 volts carries 4 amperes, because 60 / 15 is 4.

Calculating voltage

To find voltage, multiply the current by the resistance.

- A current of 0.5 amperes through a 2-ohm resistor gives a voltage of 1 volt, because 0.5 x 2 is 1.
- A current of 1 ampere through a 10-ohm resistor gives 10 volts, because 1 x 10 is 10.
- A current of 2 amperes through a 10-ohm resistor gives 20 volts, because 2 x 10 is 20.

Doubling the current through the same 10-ohm resistor doubles the voltage, from 10 volts to 20 volts. That is a handy check on the result.

Series and parallel circuits

Components can be connected in two basic ways, and each way keeps one quantity the same.

- In a **series circuit**, the current is always the same through all components.
- In a **parallel circuit**, the voltage is always the same across all components.

Series goes with current, and parallel goes with voltage.

Sources

- NCVEC Question Pool Committee — 2026–2030 Technician question pool

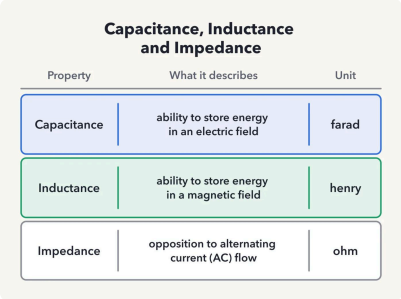
Key facts

Capacitance Stores Electric-Field Energy

Capacitance describes the ability to store energy in an electric field. Pairing each property with its field helps: electric field goes with capacitance.

The Farad Measures Capacitance

The unit of capacitance is the **farad**.



FlashFeed original diagram · CC-BY-4.0

Inductance Stores Magnetic-Field Energy

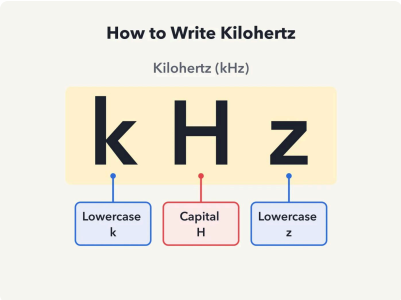
Inductance describes the ability to store energy in a magnetic field. Magnetic field goes with inductance, and electric field goes with capacitance.

The Henry Measures Inductance

The unit of inductance is the **henry**. The farad belongs to capacitance.

The Ohm Measures Impedance

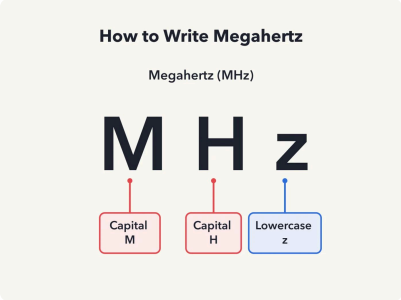
The unit of **impedance** is the ohm. Impedance is the opposition to alternating current (AC) flow.



FlashFeed original diagram · CC-BY-4.0

Writing Kilohertz Correctly

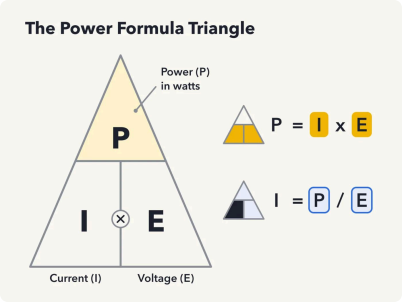
Kilohertz is written **kHz**: a lowercase k, a capital H and a lowercase z.



FlashFeed original diagram · CC-BY-4.0

Writing Megahertz Correctly

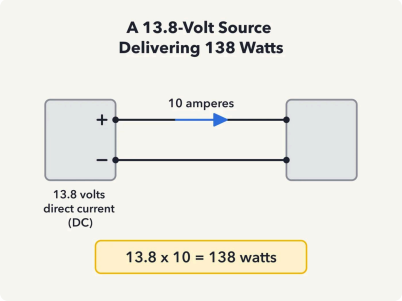
Megahertz is written **MHz**: a capital M, a capital H and a lowercase z.



FlashFeed original diagram · CC-BY-4.0

The Power Formula

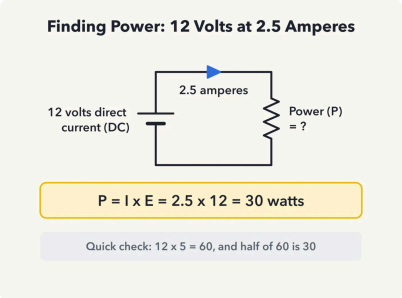
In a direct current (DC) circuit, electrical **power** (P) is current (I) multiplied by voltage (E): P = I x E. Power is measured in watts.



FlashFeed original diagram · CC-BY-4.0

13.8 Volts at 10 Amperes

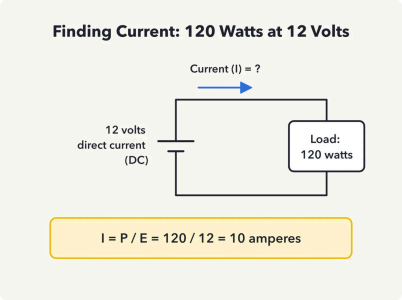
A voltage of 13.8 volts of direct current (DC) and a current of 10 amperes deliver **138 watts**, because 13.8 x 10 is 138. A 13.8 volt supply feeding a radio that draws 10 amperes is a realistic case of this formula.



FlashFeed original diagram · CC-BY-4.0

12 Volts at 2.5 Amperes

A voltage of 12 volts of direct current (DC) and a current of 2.5 amperes deliver **30 watts**, because 12 x 2.5 is 30. A quick check: 12 x 5 is 60, so half of that, 30, fits.



FlashFeed original diagram · CC-BY-4.0

Finding Current from Power

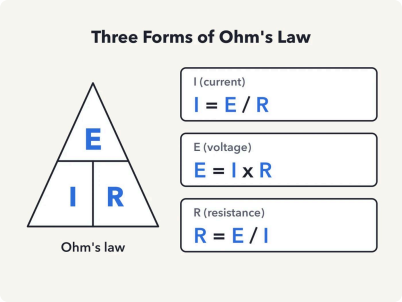
Delivering 120 watts at 12 volts of direct current (DC) takes **10 amperes**. Since power equals current times voltage, the current is the power divided by the voltage: 120 divided by 12 is 10.

What Impedance Means

Impedance is the opposition to alternating current (AC) flow.

Ohm's Law for Current

Ohm's law ties together current (I), voltage (E) and resistance (R). Current is voltage divided by resistance: I = E / R.

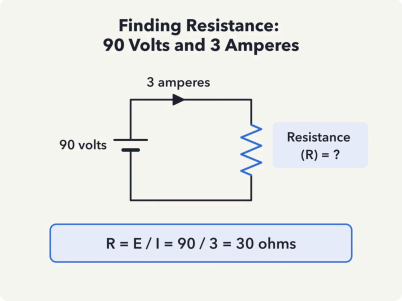


FlashFeed original diagram · CC-BY-4.0

Ohm's Law for Voltage

Voltage is current times resistance: E = I x R. This is one form of **Ohm's law**.

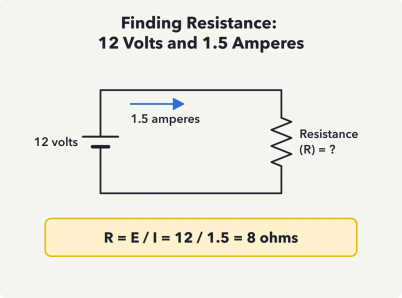
> ## Ohm's Law for Resistance
>
> **Resistance** is voltage divided by current: R = E / I. To find resistance, divide the voltage by the current.



FlashFeed original diagram · CC-BY-4.0

90 Volts and 3 Amperes

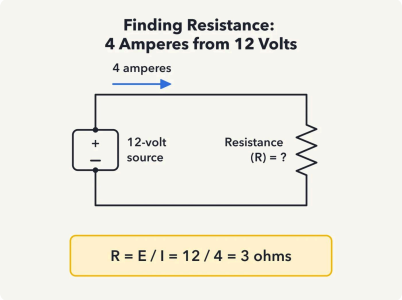
A circuit in which 3 amperes flows when connected to 90 volts has a resistance of **30 ohms**, because 90 / 3 is 30.



FlashFeed original diagram · CC-BY-4.0

12 Volts and 1.5 Amperes

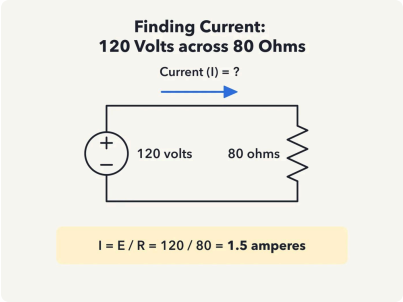
A circuit with 12 volts applied and 1.5 amperes flowing has a resistance of **8 ohms**, because 12 / 1.5 is 8.



FlashFeed original diagram · CC-BY-4.0

4 Amperes from 12 Volts

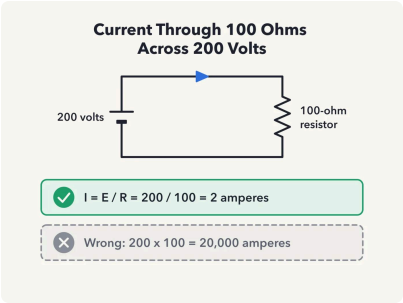
A circuit that draws 4 amperes from a 12-volt source has a resistance of **3 ohms**, because 12 / 4 is 3.



FlashFeed original diagram · CC-BY-4.0

120 Volts across 80 Ohms

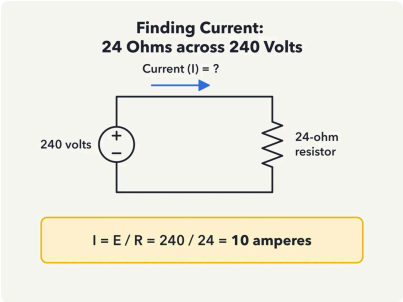
A circuit with an applied voltage of 120 volts and a resistance of 80 ohms carries **1.5 amperes**, because 120 / 80 is 1.5.



FlashFeed original diagram · CC-BY-4.0

100 Ohms across 200 Volts

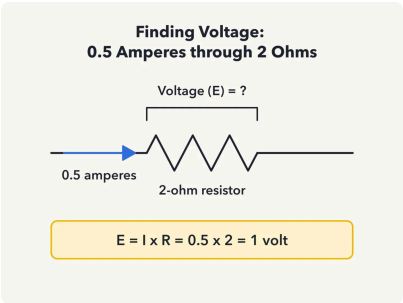
A 100-ohm resistor connected across 200 volts carries **2 amperes**, because 200 / 100 is 2. A current of several thousand amperes is a clear sign that the voltage was multiplied by the resistance instead of divided by it.



FlashFeed original diagram · CC-BY-4.0

24 Ohms across 240 Volts

A 24-ohm resistor connected across 240 volts carries **10 amperes**, because 240 / 24 is 10.



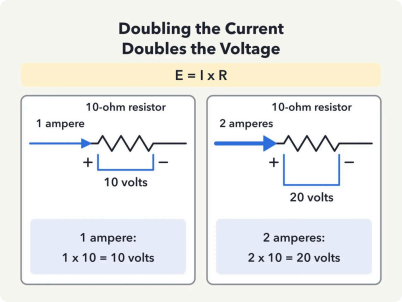
FlashFeed original diagram · CC-BY-4.0

0.5 Amperes through 2 Ohms

A current of 0.5 amperes through a 2-ohm resistor gives a voltage of **1 volt**, because 0.5 x 2 is 1.

1 Ampere through 10 Ohms

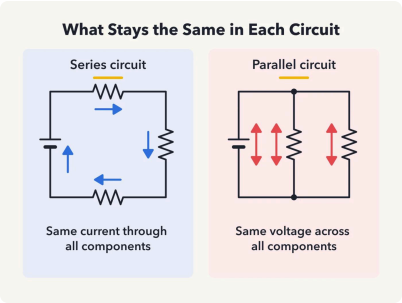
A current of 1 ampere through a 10-ohm resistor gives **10 volts**, because 1 x 10 is 10.



FlashFeed original diagram · CC-BY-4.0

2 Amperes through 10 Ohms

A current of 2 amperes through a 10-ohm resistor gives **20 volts**, because 2 x 10 is 20. Doubling the current through the same resistor doubles the voltage.



FlashFeed original diagram · CC-BY-4.0

Series Circuits Share Current

In a **series circuit**, the current is always the same through all components. A parallel circuit keeps the voltage the same instead.

> ### Parallel Circuits Share Voltage
>
> In a **parallel circuit**, the voltage is always the same across all components. Series goes with current, and parallel goes with voltage.

Matched pairs

Each item on the left goes with the one on the right.

Magnetic-field storage → Inductance

Series circuit → Same current through all parts

Self-test

Answer each question from memory, then check your work against the answer key.

1. What describes the ability to store energy in an electric field?

- A Capacitance
- B Frequency
- C Inductance
- D Resistance

2. What is the unit of capacitance?

- A Ohm
- B Henry
- C Volt
- D Farad

3. What describes the ability to store energy in a magnetic field?

A Resistance
B Admittance
C Inductance
D Capacitance

4. What is the unit of inductance?

A Coulomb
B Henry
C Ohm
D Farad

5. What is the unit of impedance?

A Ohm
B Ampere
C Volt
D Coulomb

6. What is impedance?

A The inverse of resistance
B The inverse of reactance
C The power handling capability of a component
D The opposition to AC current flow

7. What is the abbreviation for kilohertz?

A KHz
B khz
C kHz
D KHZ

8. What is the abbreviation for megahertz?

A Mhz
B MHz
C mHz
D mHZ

9. What formula is used to calculate electrical power (P) in a DC circuit?

A P = I / E
B P = E / I
C P = I x E
D P = I2 x E

10. How much power is delivered by a voltage of 13.8 volts DC and a current of 10 amperes?

A 23.8 watts
B 138 watts
C 3.8 watts
D 0.7 watts

11. How much power is delivered by a voltage of 12 volts DC and a current of 2.5 amperes?

A 14.5 watts
B 0.208 watts
C 4.8 watts
D 30 watts

12. How much current is required to deliver 120 watts at a voltage of 12 volts DC?

A 10 amperes
B 0.1 amperes
C 132 amperes
D 12 amperes

13. What formula is used to calculate current in a circuit?

A) I = E2 x R
B) I = E2 / R
C) I = E x R
D) I = E / R

14. What formula is used to calculate voltage in a circuit?

A) E = I x R
B) E = I / R
C) E = I2 / R
D) E = I2 x R

15. What formula is used to calculate resistance in a circuit?

A) R = E + I
B) R = E / I
C) R = E x I
D) R = E - I

16. What is the resistance of a circuit in which a current of 3 amperes flows when connected to 90 volts?

A) 270 ohms
B) 1/30 ohm
C) 30 ohms
D) 3 ohms

17. What is the resistance of a circuit for which the applied voltage is 12 volts and the current flow is 1.5 amperes?

A) 13.5 ohms
B) 0.125 ohms
C) 8 ohms
D) 18 ohms

18. What is the resistance of a circuit that draws 4 amperes from a 12-volt source?

A) 48 ohms
B) 8 ohms
C) 16 ohms
D) 3 ohms

19. What is the current in a circuit with an applied voltage of 120 volts and a resistance of 80 ohms?

A) 0.667 amperes
B) 1.5 amperes
C) 200 amperes
D) 9600 amperes

20. What is the current through a 100-ohm resistor connected across 200 volts?

A) 2 amperes
B) 0.5 amperes
C) 20,000 amperes
D) 100 amperes

21. What is the current through a 24-ohm resistor connected across 240 volts?

A) 2400 amperes
B) 5760 amperes
C) 0.1 amperes
D) 10 amperes

22. What is the voltage across a 2-ohm resistor if a current of 0.5 amperes flows through it?

A) 1 volt
B) 1.5 volts
C) 2.5 volts
D) 0.25 volts

23. What is the voltage across a 10-ohm resistor if a current of 1 ampere flows through it?

- A 1 volt
- B 10 volts
- C 9 volts
- D 11 volts

24. What is the voltage across a 10-ohm resistor if a current of 2 amperes flows through it?

- A 12 volts
- B 0.2 volts
- C 20 volts
- D 8 volts

25. In which type of circuit is the current always the same through all components?

- A Branch
- B Series
- C Resonant
- D Parallel

26. In which type of circuit is the voltage always the same across all components?

- A Series
- B Resonant
- C Parallel
- D Branch

Go deeper

LISTEN Lesson 7 episode 7:45 · FlashFeed Study Notes podcast

WATCH Power From a 13.8 Volt Radio 0:29
A radio on a 13.8 volt supply draws 10 amperes. How much power does it use?

WATCH Finding Current With Ohm's Law 0:31
Put 200 volts across a resistor of 100 ohms. How many amperes flow through it?

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/electrical-principles-impedance-power-and-ohm-s-law

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LESSON 8 OF 15

Electronic Components: Parts and Semiconductors

Resistors, capacitors, inductors and batteries · Semiconductors: diodes and transistors

WHAT YOU'LL BE ABLE TO DO

- Identify resistors, potentiometers, capacitors and inductors by function, construction and the energy they store
- Describe inductor construction, SPDT and other switch types, and which battery chemistries can be recharged
- Explain how diodes work, how their leads are marked and named, and how LEDs light, and name a component that can act as an electronic switch
- Identify transistor types and electrodes, the FET abbreviation, and what gain means in amplifiers

Every circuit in a station is built from a small set of parts, and each part has a recognizable job. This lesson covers the parts that oppose current, store energy, switch between circuits and supply power. It then covers the semiconductor parts: diodes, light-emitting diodes and transistors. A new licensee who can tell these parts apart can read a schematic and understand what each part does in a radio.

Resistors, capacitors, inductors and batteries

Resistors and potentiometers

A **resistor** is the component that opposes the flow of current in a direct current (DC) circuit.

A **potentiometer** is the component often used as an adjustable volume control. What a potentiometer controls is resistance. Together these facts show the link: an adjustable volume control is a part whose resistance can be changed, and the potentiometer is that part.

Capacitors and inductors

Two common parts store energy, and the kind of field tells them apart.

A **capacitor** stores energy in an electric field. A capacitor consists of conductive surfaces separated by an insulator.

An **inductor** stores energy in a magnetic field. An inductor is typically constructed as a coil of wire.

To keep the two apart, pair each with its field and its shape:

- Capacitor: electric field, conductive surfaces separated by an insulator.
- Inductor: magnetic field, coil of wire.

Switches

A **single-pole double-throw (SPDT) switch** switches a single circuit between one of two other circuits.

Switch types carry names such as single-pole single-throw and double-pole double-throw, and a schematic shows which type is used. In the reference schematic labeled figure T-2, component 3 is a single-pole single-throw switch.

Batteries

Some battery chemistries can be recharged and some cannot. Nickel-metal hydride, lithium-ion and lead-acid are all rechargeable.

Carbon-zinc is a chemistry that cannot be recharged. Nickel-cadmium is rechargeable as well.

A builder choosing a power source for a portable station can sort chemistries by this one fact: carbon-zinc cannot be recharged, and the other chemistries named here can.

Sources

- 2026–2030 Technician Class (Element 2) Question Pool and Syllabus

Semiconductors: diodes and transistors

Diodes

A **diode** is the electronic component that allows current to flow in only one direction.

The electrodes of a diode are named the **anode and cathode**.

The cathode lead of a semiconductor diode is often marked on the package with a stripe. The stripe on a diode's package points out the cathode end.

A diode's **forward voltage drop** is lower in some diode types than in others.

Light-emitting diodes

A **light-emitting diode (LED)** is a diode that gives off light. Forward current is what causes an LED to emit light. Because an LED is a diode, the one-way idea applies to it too: it lights with forward current.

Transistors

A **transistor** is a component that can consist of three regions of semiconductor material.

A transistor can be used as an electronic switch.

Transistors come in more than one type, and the names of their electrodes differ:

- A **Field Effect Transistor (FET)** is the type that has a gate, a drain and a source.
- A **bipolar junction transistor** has the electrodes emitter, base and collector.

The abbreviation FET stands for Field Effect Transistor.

Gain in amplifiers

Gain describes what an amplifier does to a signal: it compares the output signal with the input signal. The comparison can be made in three ways, and each is a meaning of gain:

- the output signal voltage relative to the input signal voltage;
- the output signal current relative to the input signal current;
- the output signal power relative to the input signal power.

A transistor is a component that can provide power gain.

The transistor shows up in three jobs in this section: a three-region semiconductor part, an electronic switch, and a source of power gain. A diode, by contrast, is the part for one-way current, and an LED is a diode that lights with forward current.

Sources

- 2026–2030 Technician Class (Element 2) Question Pool and Syllabus

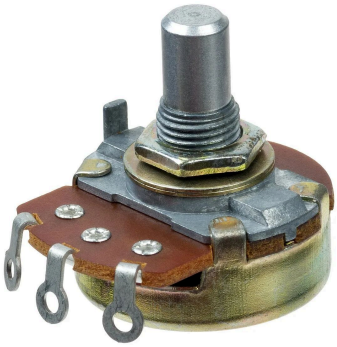
Key facts



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The Resistor Opposes Current

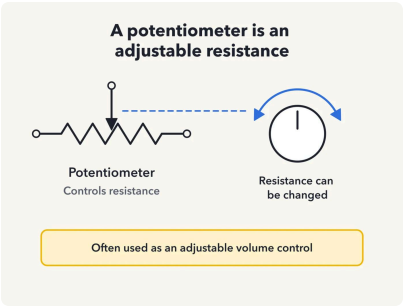
A **resistor** is the component that opposes the flow of current in a direct current (DC) circuit.



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Potentiometer as Volume Control

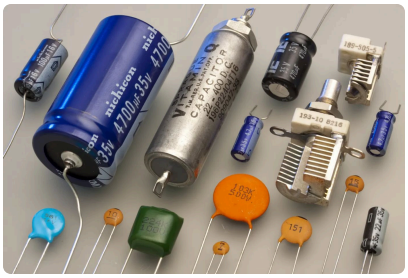
A **potentiometer** is the part often used as an adjustable volume control.



FlashFeed original diagram · CC-BY-4.0

What a Potentiometer Controls

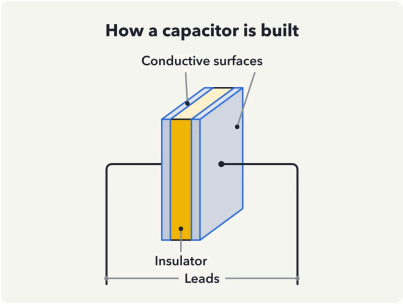
A potentiometer controls **resistance**. An adjustable volume control is a part whose resistance can be changed.



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Capacitors Store Electric-Field Energy

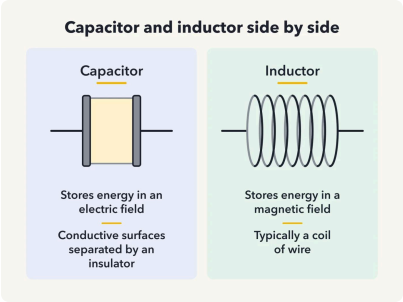
A **capacitor** stores energy in an electric field.



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How a Capacitor Is Built

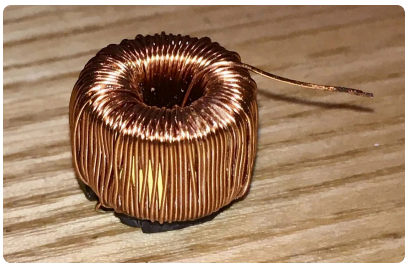
A capacitor consists of **conductive surfaces separated by an insulator**.



FlashFeed original diagram · CC-BY-4.0

Inductors Store Magnetic-Field Energy

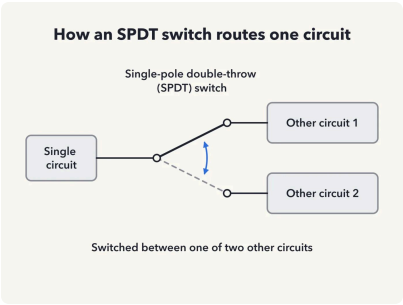
An **inductor** stores energy in a magnetic field.



Wikimedia Commons · Pittigrilli · CC BY-SA 4.0

An Inductor Is a Coil

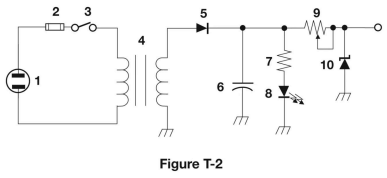
An inductor is typically constructed as a **coil of wire**.



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What an SPDT Switch Does

A **single-pole double-throw (SPDT) switch** switches a single circuit between one of two other circuits.



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Reading Switch Type on Figure T-2

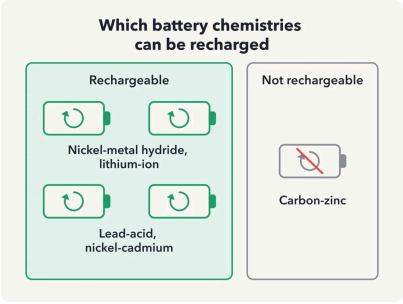
In the reference schematic labeled figure T-2, component 3 is a **single-pole single-throw** switch.



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Rechargeable Battery Chemistries

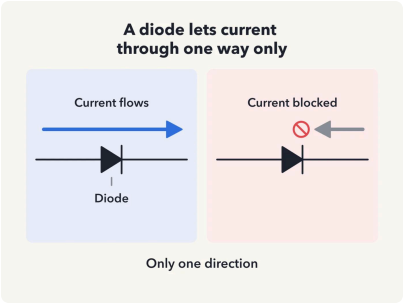
Nickel-metal hydride, **lithium-ion** and **lead-acid** batteries can all be recharged. Nickel-cadmium can be recharged as well.



FlashFeed original diagram · CC-BY-4.0

Carbon-Zinc Is Not Rechargeable

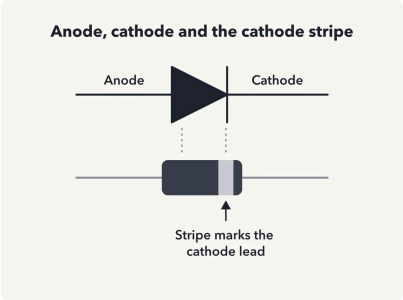
Carbon-zinc batteries cannot be recharged. Nickel-metal hydride, lithium-ion, lead-acid and nickel-cadmium batteries can all be recharged.



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The Diode Passes Current One Way

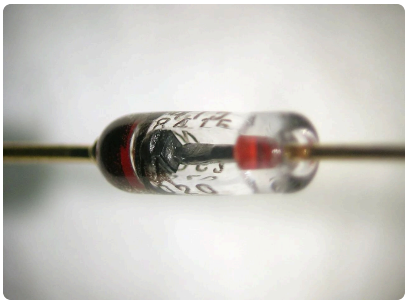
A **diode** is the electronic component that allows current to flow in only one direction.



FlashFeed original diagram · CC-BY-4.0

Diode Electrode Names

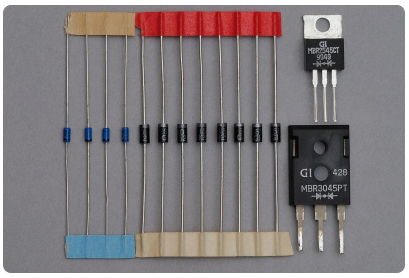
The two electrodes of a diode are the **anode and cathode**.



Wikimedia Commons · John Maushammer · CC BY-SA 2.5

Stripe Marks the Cathode

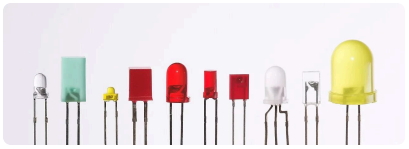
The cathode lead of a semiconductor diode is often marked on the package with a **stripe**.



Wikimedia Commons · Steffen Maisch · Public domain

Diode Forward Voltage Drop

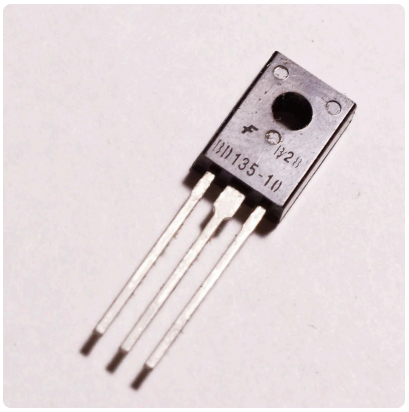
A diode's **forward voltage drop** is lower in some diode types than in others.



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What Lights an LED

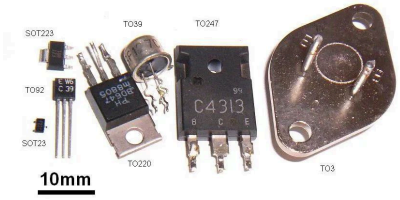
Forward current is what causes a **light-emitting diode (LED)** to emit light.



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Three Regions of Semiconductor

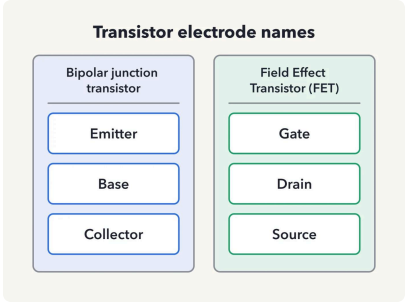
A **transistor** is a component that can consist of three regions of semiconductor material.



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Transistor as Electronic Switch

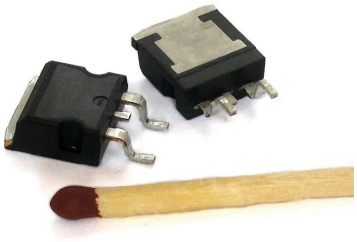
A transistor can be used as an **electronic switch**.



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Gate, Drain and Source

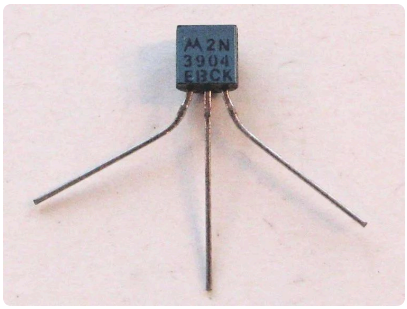
A **Field Effect Transistor (FET)** is the type that has a gate, a drain and a source.



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What FET Stands For

The abbreviation **FET** stands for Field Effect Transistor.

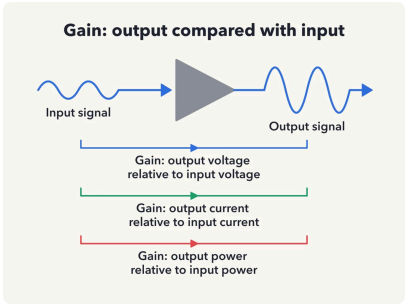


Wikimedia Commons · Windell Oskay · CC BY 2.0

Bipolar Transistor Electrodes

A **bipolar junction transistor** has the electrodes emitter, base and collector.

> ### Transistors Provide Power Gain
>
> A transistor is a component that can provide **power gain**.



FlashFeed original diagram · CC-BY-4.0

Three Meanings of Gain

Gain compares an amplifier's output signal with its input signal. It can mean output voltage relative to input voltage, output current relative to input current, or output power relative to input power. Each is a meaning of gain.

Matched pairs

Each item on the left goes with the one on the right.

Inductor → Stores energy in a magnetic field

Diode electrodes → Anode and cathode

Self-test

Answer each question from memory, then check your work against the answer key.

1. What electrical component opposes the flow of current in a DC circuit?

- A Transformer
- B Resistor
- C Inverter
- D Inductor

2. What type of component is often used as an adjustable volume control?

- A Transformer
- B Power resistor
- C Potentiometer
- D Fixed resistor

3. What electrical parameter is controlled by a potentiometer?

- A Resistance
- B Inductance
- C Capacitance
- D Field strength

4. What electrical component stores energy in an electric field?

- A Resistor
- B Diode
- C Inductor
- D Capacitor

5. What type of electrical component consists of conductive surfaces separated by an insulator?

- A Potentiometer
- B Oscillator
- C Resistor
- D Capacitor

6. What type of electrical component stores energy in a magnetic field?

- A Resistor
- B Diode
- C Inductor
- D Capacitor

7. What electrical component is typically constructed as a coil of wire?

- A Capacitor
- B Inductor
- C Diode
- D Transistor

8. What is the function of an SPDT switch?

- A A single circuit is switched between one of two other circuits
- B A single circuit is opened or closed
- C Two circuits are opened or closed
- D Two circuits are each switched between one of two other circuits

9. What type of switch is represented by component 3 in figure T-2?

- A Single-pole double-throw
- B Double-pole double-throw
- C Double-pole single-throw
- D Single-pole single-throw

10. Which of the following battery chemistries is rechargeable?

A All these choices are correct
B Lead-acid
C Lithium-ion
D Nickel-metal hydride

11. Which of the following battery chemistries is not rechargeable?

A Lithium-ion
B Carbon-zinc
C Lead-acid
D Nickel-cadmium

12. Which is true about forward voltage drop in a diode?

A It is proportional to peak inverse voltage
B It indicates that the diode is defective
C It is lower in some diode types than in others
D It has no impact on the voltage delivered to the load

13. What electronic component allows current to flow in only one direction?

A Diode
B Fuse
C Resistor
D Driven element

14. How is the cathode lead of a semiconductor diode often marked on the package?

A With the letter K
B With the word "cathode"
C With the letter C
D With a stripe

15. What are the names for the electrodes of a diode?

A Gate and base
B Anode and cathode
C Source and drain
D Plus and minus

16. What causes a light-emitting diode (LED) to emit light?

A Reverse current
B Inductively-coupled RF signal
C Forward current
D Capacitively-coupled RF signal

17. Which of these components can be used as an electronic switch?

A Thermistor
B Transistor
C Varistor
D Potentiometer

18. Which of the following components can consist of three regions of semiconductor material?

A Transistor
B Alternator
C Pentode
D Triode

19. What type of transistor has a gate, drain, and source?

A Bipolar junction
B Hall-effect
C Varistor
D Field-effect

20. What does the abbreviation FET stand for?

- A Free Electron Transmitter
- B Frequency Emission Transmitter
- C Field Effect Transistor
- D Fast Electron Transistor

21. What are the names of the electrodes of a bipolar junction transistor?

- A Pole one, pole two, output
- B Emitter, base, collector
- C Input, output, supply
- D Signal, bias, power

22. Which of the following can provide power gain?

- A Resistor
- B Transformer
- C Transistor
- D Reactor

23. What does the term gain mean in amplifiers?

- A All these choices are correct
- B The output signal power relative to the input signal power
- C The output signal current relative to the input signal current
- D The output signal voltage relative to the input signal voltage

Go deeper

LISTEN Lesson 8 episode 6:48 · FlashFeed Study Notes podcast

WATCH Rechargeable or Not 0:29
Which common battery chemistry can never be recharged? Some can be recharged, and some cannot.

WATCH Which Way Current Flows 0:25
Which way does current have to flow for a light-emitting diode (LED) to light up?

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/electronic-components-parts-and-semiconductors

STUDY Ham Radio Technician License in the FlashFeed app flashfeedlearningapp.com/packs/ham-radio-technician

LESSON 9 OF 15

Electronic Components: Schematics and Circuits

Schematic diagrams and symbols · Component functions and resonant circuits

WHAT YOU'LL BE ABLE TO DO

- Identify a schematic and the basic parts shown in a simple circuit diagram, such as resistors, transistors, lamps and batteries
- Identify the symbols for capacitors, inductors, LEDs, transformers, variable parts and antennas on a schematic
- Explain what rectifiers, relays, regulators, transformers, transistors and meters do in a circuit
- Describe resonant circuits, shielded wire, LED indicators and integrated circuits and what each is used for

Radio circuits are drawn as diagrams, and a new licensee needs to read them. This lesson covers what a schematic is, how the common parts are labeled in the sample diagrams, and what several key parts do. It also covers resonant circuits and shielded wire. Knowing the parts by name and by job makes any radio diagram easier to follow.

Schematic diagrams and symbols

An electrical diagram that uses standard component symbols is called a **schematic**. Each part in a schematic is drawn with its own agreed **symbol**, so a reader who knows the symbols can tell the parts apart on the page.

What a schematic shows

A schematic accurately represents the **component connections**. It shows which part is joined to which, and that is the information a circuit diagram exists to give.

In practice, a part that looks big and bulky in real life may be a small symbol on the page. A long wire may be a short line. Only the connections between the symbols can be trusted.

The first sample diagram

Figure T-1 is a simple circuit whose parts are numbered. Each number points to one symbol.

- Component 1 is a **resistor**.
- Component 2 is a **transistor**.
- Component 3 is a **lamp**.
- Component 4 is a **battery**.

In this figure, the resistor and the transistor are separate symbols with separate jobs, and the lamp and the battery are distinct as well.

The second sample diagram

Figure T-2 is a second circuit diagram. Its numbers are separate from those in figure T-1, so the same number means a different part here.

- Component 4 is a **transformer**.
- Component 6 is a **capacitor**.
- Component 8 is a **light emitting diode (LED)**.
- Component 9 is a **variable resistor**.

The third sample diagram

Figure T-3 adds two more symbols. Component 3 is a **variable inductor**. Component 4 is an **antenna**.

Component 4 appears in all three figures, and it is a different part each time. In figure T-1 it is the battery, in figure T-2 the transformer, and in figure T-3 the antenna. Numbers only have meaning inside their own diagram.

Sources

- NCVEC Question Pool Committee — 2026–2030 Technician question pool

Component functions and resonant circuits

Knowing a symbol is half the job. The other half is knowing what the part does in a circuit. These are the functions a Technician licensee should connect to each part.

Changing power

A **rectifier** is the device or circuit that changes an alternating current (AC) into a varying direct current (DC) signal.

A **transformer** is the component that changes 120 V AC power to a lower AC voltage for other uses. Both of these parts work on alternating current, but they do different jobs. The transformer changes the AC voltage and the output is still AC. The rectifier changes AC into varying DC.

A **regulator** is the type of circuit that controls the amount of voltage from a power supply. A small power supply can draw on all three parts: a transformer to lower the AC voltage, a rectifier to change AC to varying DC, and a regulator to control the voltage the supply delivers.

Switching, controlling and measuring

A **relay** is an electrically-controlled switch.

A **transistor** controls the flow of current. This is the function of component 2 in figure T-1.

A **meter** displays an electrical quantity as a numeric value.

Indicators and integrated circuits

An LED is the part commonly used as a visual indicator.

An **integrated circuit** is a device that combines several semiconductors and other components into one package.

Tuned circuits and shielded wire

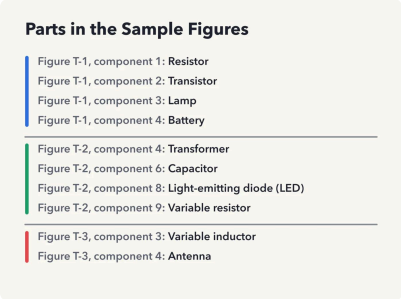
A **resonant circuit**, also called a tuned circuit, is made from an inductor and a capacitor in series or parallel. A capacitor is therefore the part combined with an inductor to make a resonant circuit.

Shielded wire is used to prevent coupling of unwanted signals to or from the wire. That is its reason for use. Shielding works in both directions: it keeps unwanted signals from getting into the wire and from getting out of it.

Sources

- NCVEC Question Pool Committee — 2026–2030 Technician question pool

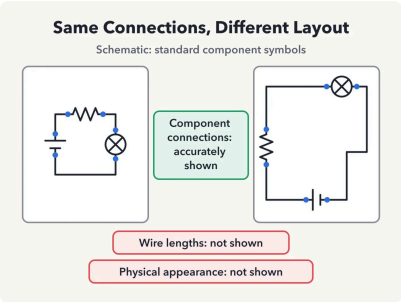
Key facts



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What a Schematic Is

An electrical diagram that uses standard component symbols is called a **schematic**. Each part is drawn with its own agreed symbol.



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What a Schematic Shows

A schematic accurately represents the **component connections**. Only the connections between the symbols can be trusted.

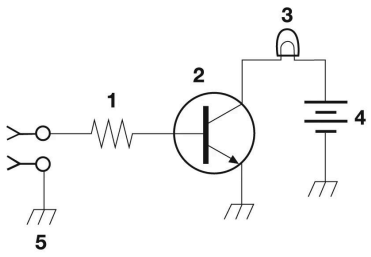


Figure T-1

NCVEC Question Pool Committee · Public domain

Component 1 in Figure T-1

Figure T-1 is a simple circuit whose parts are numbered. Component 1 is a **resistor**.

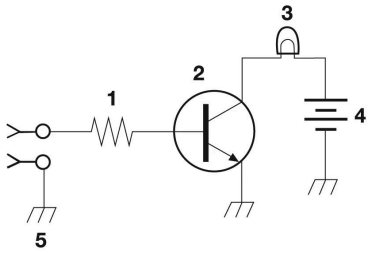


Figure T-1

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Component 2 in Figure T-1

In figure T-1, component 2 is a **transistor**. The resistor and the transistor are separate symbols with separate jobs.

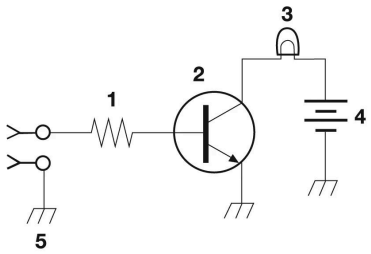


Figure T-1

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Component 3 in Figure T-1

In figure T-1, component 3 is a **lamp**.

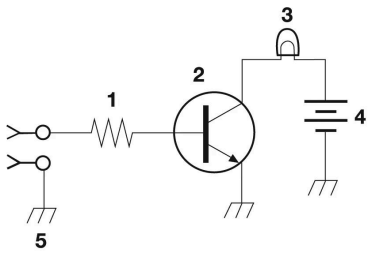


Figure T-1

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Component 4 in Figure T-1

In figure T-1, component 4 is a **battery**.

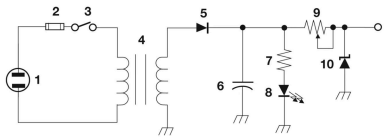


Figure T-2

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Component 6 in Figure T-2

Figure T-2 numbers its parts separately from figure T-1. In figure T-2, component 6 is a **capacitor**.

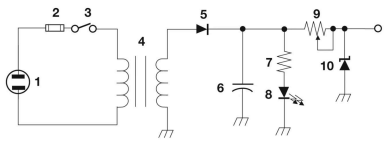


Figure T-2

NCVEC Question Pool Committee · Public domain

Component 8 in Figure T-2

In figure T-2, component 8 is a **light emitting diode** (LED).

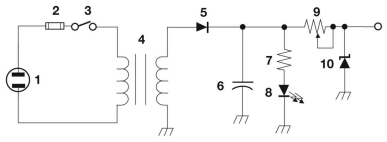


Figure T-2

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Component 9 in Figure T-2

In figure T-2, component 9 is a **variable resistor**.

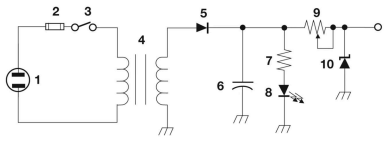


Figure T-2

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Component 4 in Figure T-2

In figure T-2, component 4 is a **transformer**.

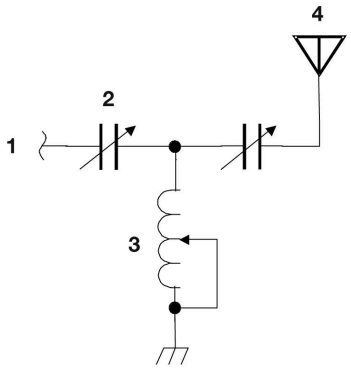


Figure T-3

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Component 3 in Figure T-3

In figure T-3, component 3 is a **variable inductor**.

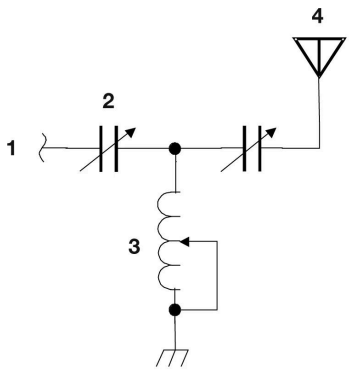
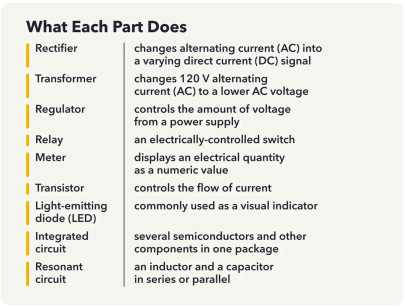


Figure T-3

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Component 4 in Figure T-3

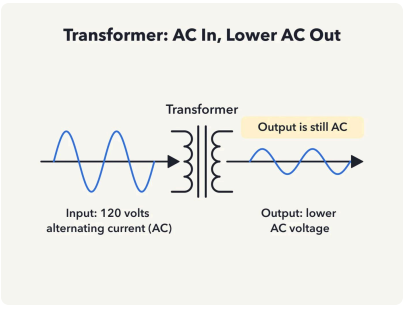
In figure T-3, component 4 is an **antenna**. Component 4 is a different part in each of the three figures, so numbers only have meaning inside their own diagram.



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Rectifier Changes AC to DC

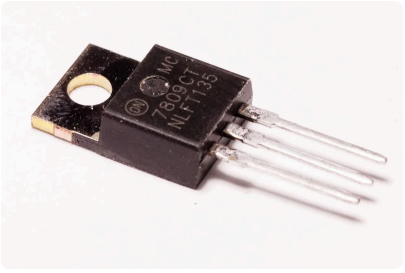
A **rectifier** changes alternating current (AC) into a varying direct current (DC) signal.



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Transformer Lowers AC Voltage

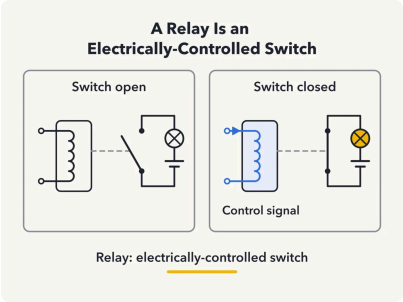
A **transformer** changes 120 V alternating current (AC) to a lower AC voltage for other uses. The output is still AC.



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Regulator Controls Voltage

A **regulator** is the type of circuit that controls the amount of voltage from a power supply.



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A Relay Is a Switch

A **relay** is an electrically-controlled switch.

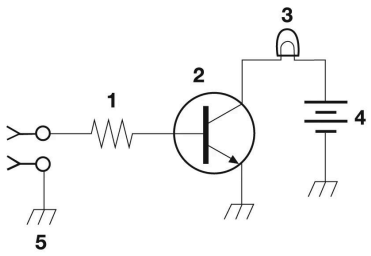


Figure T-1

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Function of a Transistor

A **transistor** controls the flow of current. That is the function of component 2 in figure T-1.

A Meter Shows a Number

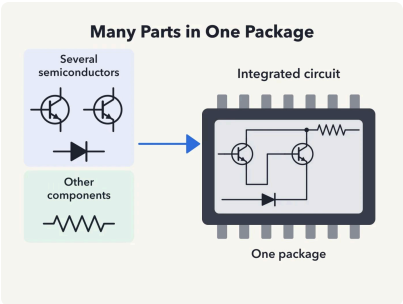
A **meter** displays an electrical quantity as a numeric value.



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LED as Visual Indicator

A light-emitting diode (LED) is the part commonly used as a visual indicator.



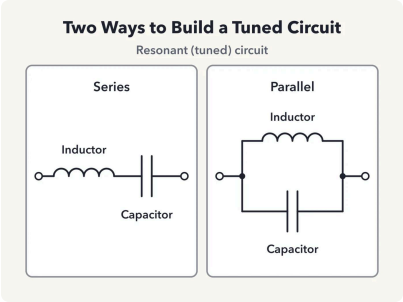
FlashFeed original diagram · CC-BY-4.0

Integrated Circuit Defined

An **integrated circuit** is a device that combines several semiconductors and other components into one package.

Capacitor Pairs With Inductor

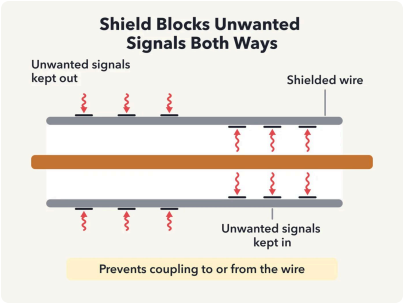
A **capacitor** is the part combined with an inductor to make a resonant circuit.



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What a Resonant Circuit Is

A **resonant circuit**, also called a tuned circuit, is made from an inductor and a capacitor in series or parallel.



FlashFeed original diagram · CC-BY-4.0

Why Use Shielded Wire

Shielded wire is used to prevent coupling of unwanted signals to or from the wire.

Matched pairs

Each item on the left goes with the one on the right.

Integrated circuit → Many parts in one package

Self-test

Answer each question from memory, then check your work against the answer key.

1. What is an electrical diagram using standard component symbols called?

A. Instrumentation system
B. Flow chart
C. Connection chart
D. Schematic

2. Which of the following is accurately represented in electrical schematics?

A. Component connections
B. All these choices are correct
C. Physical appearance of components
D. Wire lengths

3. What is component 1 in figure T-1?

A. Transistor
B. Resistor
C. Battery
D. Connector

4. What is component 2 in figure T-1?

A. Resistor
B. Indicator lamp
C. Transistor
D. Connector

5. What is component 3 in figure T-1?

A Resistor
B Lamp
C Ground symbol
D Transistor

6. What is component 4 in figure T-1?

A Resistor
B Transistor
C Battery
D Ground symbol

7. What is component 6 in figure T-2?

A Capacitor
B Regulator IC
C Transistor
D Resistor

8. What is component 8 in figure T-2?

A Inductor
B Resistor
C Regulator IC
D Light emitting diode

9. What is component 9 in figure T-2?

A Variable resistor
B Variable inductor
C Variable capacitor
D Variable transformer

10. What is component 4 in figure T-2?

A Variable inductor
B Double-pole switch
C Transformer
D Potentiometer

11. What is component 3 in figure T-3?

A Variable capacitor
B Connector
C Meter
D Variable inductor

12. What is component 4 in figure T-3?

A Ground
B Antenna
C Dummy load
D Transmitter

13. Which of the following devices or circuits changes an alternating current into a varying direct current signal?

A Reflector
B Transformer
C Amplifier
D Rectifier

14. What component changes 120 V AC power to a lower AC voltage for other uses?

A Transformer
B Variable capacitor
C Transistor
D Diode

15. What is a relay?

A. A current-controlled amplifier
B. An electrically-controlled switch
C. An inverting amplifier
D. A pass transistor

16. What type of circuit controls the amount of voltage from a power supply?

A. Oscillator
B. Phase inverter
C. Regulator
D. Filter

17. Which of the following displays an electrical quantity as a numeric value?

A. Potentiometer
B. Meter
C. Relay
D. Transistor

18. What is the function of component 2 in figure T-1?

A. Control the flow of current
B. Convert electrical energy into radio waves
C. Supply electrical energy
D. Give off light when current flows through it

19. Which of the following is combined with an inductor to make a resonant circuit?

A. Zener diode
B. Resistor
C. Potentiometer
D. Capacitor

20. Which of the following is a resonant or tuned circuit?

A. A circuit designed to provide high-fidelity audio
B. A resistor circuit used for reducing standing wave ratio
C. An inductor and a capacitor in series or parallel
D. A linear voltage regulator

21. Which of the following is a reason to use shielded wire?

A. To increase the current carrying capability of the wire
B. To decrease the resistance of DC power connections
C. To prevent coupling of unwanted signals to or from the wire
D. To reduce receiver overload

22. Which of the following is commonly used as a visual indicator?

A. LED
B. FET
C. All these choices are correct
D. Zener diode

23. What is the name of a device that combines several semiconductors and other components into one package?

A. Transformer
B. Multi-pole relay
C. Transducer
D. Integrated circuit

Go deeper

LISTEN Lesson 9 episode 6:39 · FlashFeed Study Notes podcast

WATCH What a Schematic Leaves Out 0:25
A circuit diagram can draw a big part as a small symbol, and a long wire as a short line.

WATCH Lowering 120 Volts in a Power Supply 0:29
Which part takes 120 volts of alternating current and lowers its voltage?

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/electronic-components-schematics-and-circuits

STUDY Ham Radio Technician License in the FlashFeed app flashfeedlearningapp.com/packs/ham-radio-technician

LESSON 10 OF 15

Practical Circuits: Radios and Their Common Problems

Station equipment and receiver concepts · Transmitter and receiver problems

WHAT YOU'LL BE ABLE TO DO

- Explain basic receiver and circuit terms: sensitivity, selectivity, mixers, oscillators, VFOs and modulation
- Identify station equipment (transceivers, transverters, amplifiers) and describe what each does and how PTT and mode switches work
- Explain why a station causes interference to broadcast, TV and other receivers and how to reduce it
- Identify causes and cures of over-deviation, distorted audio, RF feedback on a microphone cable, low power from high SWR and interference

This lesson covers the building blocks inside a radio and the equipment around it, such as transceivers, transverters and power amplifiers. It also covers the common ways a station goes wrong. A new licensee needs both: the vocabulary to read a radio's controls and specifications, and a sense of what to check when a signal sounds bad or a neighbor's TV acts up.

Station equipment and receiver concepts

Judging a receiver

Two terms rate how well a receiver performs. **Sensitivity** is the ability of a receiver to detect the presence of a signal. **Selectivity** is the ability of a receiver to discriminate between multiple signals, which means picking out one signal from among several. The two are easy to confuse: sensitivity is about detecting a signal at all, while selectivity is about telling signals apart.

Circuit building blocks

A **mixer** converts a signal from one frequency to another.

An **oscillator** is a circuit that generates a signal at a specific frequency.

Modulation is combining speech with a radio frequency (RF) carrier signal.

The variable frequency oscillator (VFO) in a transceiver sets the receive and transmit frequency.

Transceivers and add-on equipment

A **transceiver** is a device that combines a receiver and a transmitter.

A **transverter** is the device that converts the RF input and output of a transceiver to another band. This is how a transceiver can work on a band it does not cover itself.

Push to talk

A transceiver's push to talk (PTT) input switches the transceiver from receive to transmit when it is grounded.

Raising output power

An **RF power amplifier** added to the output of a transceiver increases the transmitted output power.

Some very high frequency (VHF) power amplifiers have a switch that selects either single sideband (SSB) or CW-FM, where CW means International Morse code telegraphy and FM stands for frequency modulated. That switch sets the amplifier for proper operation in the selected mode.

How the pieces fit together

Read along a transceiver's signal path and these terms line up. The VFO sets the frequency. Oscillators make signals at specific frequencies, and mixers move signals from one frequency to another. In transmitting, modulation puts speech onto the RF carrier. The PTT input decides whether the radio is receiving or transmitting. An RF power amplifier on the output raises the transmitted power, and a transverter carries the transceiver's input and output to a different band. Sensitivity and selectivity then describe how well the receiving side hears the signal it wants.

Sources

- NCVEC Question Pool Committee — 2026–2030 Technician question pool

Transmitter and receiver problems

Why other receivers hear a station

A broadcast amplitude modulated (AM) or FM radio can pick up an amateur transmission unintentionally because the receiver is unable to reject strong signals outside the AM or FM band.

Radio frequency interference can come from several sources. Fundamental overload, harmonics and spurious emissions can each cause it.

Reducing interference at the affected receiver

To reduce interference by an amateur station to a non-amateur over-the-air radio receiver, block the amateur signal with a filter at the antenna input of the affected receiver.

A **band-reject filter** can reduce interference to a 2-meter band transceiver from a nearby commercial FM station.

For interference to non-fiber optic cable TV, the first step is to be sure all TV feed line coaxial connectors are installed properly.

When a neighbor reports interference

If a neighbor says a station's transmissions are interfering with their radio or TV reception, the operator should first make sure the station is functioning properly. It should not cause interference to the operator's own radio or television when tuned to the same channel.

The problem can also run the other way. **Harmful interference** is interference that endangers radionavigation or other safety services, or one that "seriously degrades, obstructs or repeatedly interrupts a radiocommunication service operating in accordance with the Radio Regulations." When something in a neighbor's home causes harmful interference to an amateur station, all three of these responses are correct:

- Work with the neighbor to identify the offending device.
- Politely inform the neighbor that Federal Communications Commission (FCC) rules prohibit the use of devices that cause interference.
- Make sure the station meets the standards of good amateur practice.

Distorted audio and low power

A report that an FM handheld or mobile transceiver is over-deviating is answered by talking farther away from the microphone.

A report that audio through an FM repeater is distorted or unintelligible can have several causes. The transmitter may be slightly off frequency. The operator may be speaking too loudly or too close to the microphone. The operator may also be in a bad location. All three are correct.

A clip-on ferrite "choke" on the microphone cable can eliminate distorted voice transmissions. It prevents the transmitted signal from feeding back into the transmitter.

Finally, a high standing wave ratio (SWR) might be the cause of low RF power output from a solid-state transceiver.

Sources

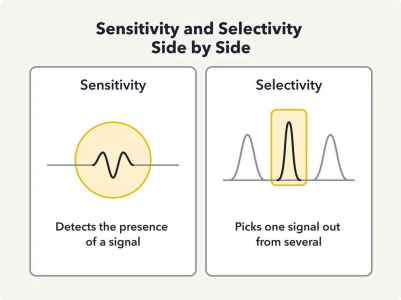
- NCVEC Question Pool Committee — 2026–2030 Technician question pool
- FCC — 47 CFR § 97.3 Definitions

Key terms

Harmful interference

Interference that endangers radionavigation or other safety services, or seriously degrades, obstructs or repeatedly interrupts a radiocommunication service operating under the Radio Regulations

Key facts



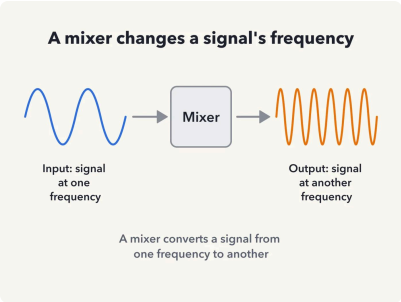
FlashFeed original diagram · CC-BY-4.0

Sensitivity: Detecting a Signal

Sensitivity is the ability of a receiver to detect the presence of a signal.

Selectivity: Telling Signals Apart

Selectivity is the ability of a receiver to discriminate between multiple signals. It means picking out one signal from among several. It is a different property from sensitivity.



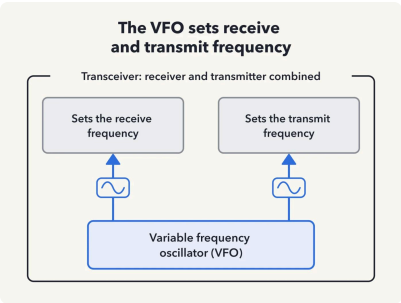
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The Mixer Changes Frequency

A **mixer** converts a signal from one frequency to another.

The Oscillator Makes a Frequency

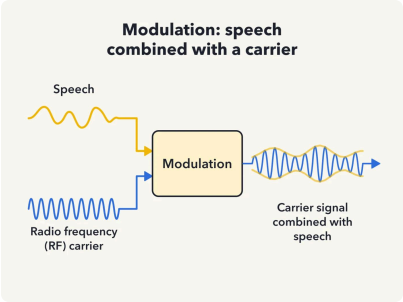
An **oscillator** is a circuit that generates a signal at a specific frequency.



FlashFeed original diagram · CC-BY-4.0

What the VFO Does

The **variable frequency oscillator (VFO)** in a transceiver sets the receive and transmit frequency.



FlashFeed original diagram · CC-BY-4.0

Modulation Puts Speech on a Carrier

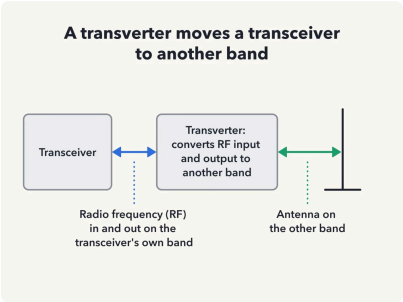
Modulation is combining speech with a radio frequency (RF) carrier signal.



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A Transceiver Is Two Radios in One

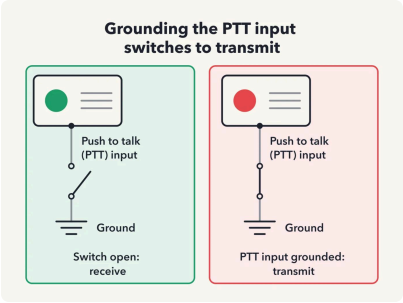
A **transceiver** is a device that combines a receiver and a transmitter.



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A Transverter Shifts Bands

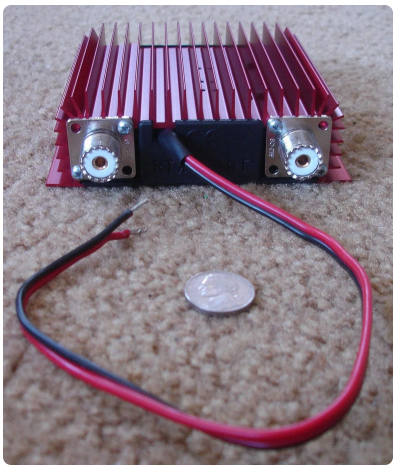
A **transverter** is the device that converts the radio frequency (RF) input and output of a transceiver to another band. That is how a transceiver can work on a band it does not cover itself.



FlashFeed original diagram · CC-BY-4.0

The PTT Input Switches to Transmit

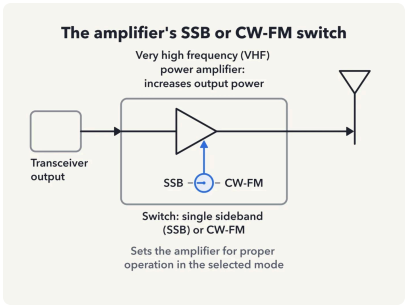
A transceiver's **push to talk (PTT)** input switches the transceiver from receive to transmit when it is grounded.



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Adding a Power Amplifier

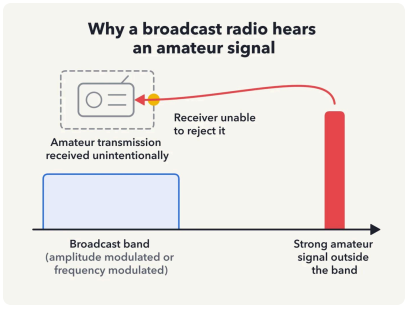
A **radio frequency (RF) power amplifier** added to the output of a transceiver increases the transmitted output power.



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Amplifier Mode Switch

Some very high frequency (VHF) power amplifiers have a switch that selects either single sideband (SSB) or CW-FM, where CW means International Morse code telegraphy emissions and FM stands for frequency modulated. That switch sets the **amplifier** for proper operation in the selected mode.



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Why Broadcast Radios Hear Hams

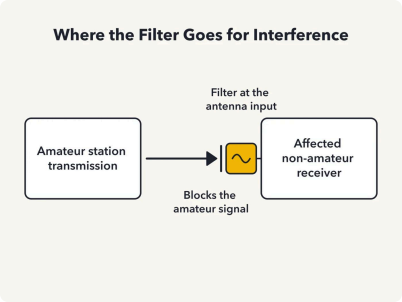
A broadcast amplitude modulated (AM) or frequency modulated (FM) radio can pick up an amateur transmission unintentionally. The cause is that the receiver is **unable to reject** strong signals outside the AM or FM band.

Three Causes of Interference

Radio frequency (RF) interference can come from several sources. **Fundamental overload**, harmonics and spurious emissions can each cause it. All three are correct causes.

High SWR and Low Power

High standing wave ratio (SWR) might be the cause of low radio frequency (RF) power output from a solid-state transceiver.



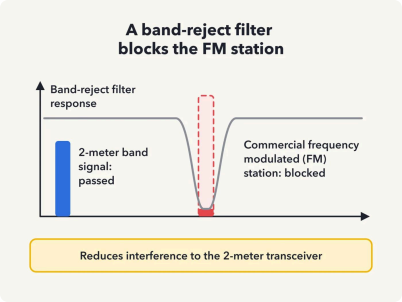
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Filter at the Affected Receiver

To reduce interference from an amateur station to a non-amateur over-the-air receiver, put a **filter** at the antenna input of the affected receiver. It blocks the amateur signal.

First Response to a Neighbor's Complaint

When a neighbor reports interference to radio or TV, the operator should first make sure the station is functioning properly. It should not interfere with the operator's own radio or television on the same channel.



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Band-Reject Filter Against FM Stations

A **band-reject filter** can reduce interference to a 2-meter band transceiver from a nearby commercial frequency modulated (FM) station.

A Neighbor's Device Interferes

If something in a neighbor's home causes harmful interference to an amateur station, three responses are correct. Work with the neighbor to identify the offending device. Politely inform the neighbor that Federal Communications Commission (FCC) rules prohibit the use of devices that cause interference. Make sure the station meets the standards of good amateur practice.



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First Step for Cable TV Interference

For interference to non-fiber optic cable TV, the first step is to be sure all TV feed line **coaxial connectors** are installed properly.

Curing Over-Deviation

A report that a frequency modulated (FM) handheld or mobile transceiver is **over-deviating** is answered by talking farther away from the microphone.

> **Distorted Audio Through a Repeater**
> If a report says audio through a frequency modulated (FM) repeater is distorted or unintelligible, three causes are all correct. The transmitter may be slightly off frequency. The operator may be speaking too loudly or too close to the microphone. The operator may also be in a bad location.



Wikimedia Commons · Karl-Martin Skontorp · CC BY 2.0

Ferrite Choke on the Mic Cable

A clip-on **ferrite choke** on the microphone cable can eliminate distorted voice transmissions. It prevents the transmitted signal from feeding back into the transmitter.

Matched pairs

Each item on the left goes with the one on the right.

Transverter → Converts a transceiver to another band

Transceiver → Combines a receiver and a transmitter

Over-deviation → Talk farther from the microphone

Self-test

Answer each question from memory, then check your work against the answer key.

1. Which term describes the ability of a receiver to detect the presence of a signal?

- A Sensitivity
- B Selectivity
- C Total Harmonic Distortion
- D RF gain

2. Which term describes the ability of a receiver to discriminate between multiple signals?

- A Harmonic distortion
- B Selectivity
- C Discrimination ratio
- D Sensitivity

3. Which of the following is used to convert a signal from one frequency to another?

- A Phase splitter
- B Inverter
- C Mixer
- D Amplifier

4. What is the name of a circuit that generates a signal at a specific frequency?

- A Low-pass filter
- B Reactance modulator
- C Phase modulator
- D Oscillator

5. What is the function of the Variable Frequency Oscillator (VFO) circuit in a transceiver?

A. Set the receive and transmit frequency
B. Inject a variable frequency to allow CW reception
C. Generate and demodulate single sideband signals
D. Provide automatic frequency control

6. Which of the following describes combining speech with an RF carrier signal?

A. Oscillation
B. Impedance matching
C. Modulation
D. Low-pass filtering

7. What is a transceiver?

A. A device for matching feed line impedance to 50 ohms
B. A device that combines a receiver and transmitter
C. A device for automatically sending and decoding Morse code
D. A device for converting receiver and transmitter frequencies to another band

8. What device converts the RF input and output of a transceiver to another band?

A. Low-pass filter
B. Phase converter
C. High-pass filter
D. Transverter

9. What is the function of a transceiver's PTT input?

A. Input for a preamplifier tuning tone
B. Switches transceiver from receive to transmit when grounded
C. Provides a transmit tuning tone when grounded
D. Input for a key used to send CW

10. What is the function of the switch which selects either SSB or CW-FM on some VHF power amplifiers?

A. Set the amplifier for proper operation in the selected mode
B. Change the frequency range of the amplifier to operate in the proper segment of the band
C. Change the mode of the transmitted signal
D. Reduce the received signal noise

11. What can be added to the output of a transceiver to increase the transmitted output power?

A. An impedance multiplier
B. A potentiometer
C. All these choices are correct
D. An RF power amplifier

12. What would cause a broadcast AM or FM radio to receive an amateur radio transmission unintentionally?

A. The deviation of an FM transmitter is set too low
B. The microphone gain of the transmitter is turned up too high
C. The receiver is unable to reject strong signals outside the AM or FM band
D. The audio amplifier of the transmitter is overloaded

13. Which of the following can cause radio frequency interference?

A. All these choices are correct
B. Harmonics
C. Spurious emissions
D. Fundamental overload

14. Which of the following might reduce interference by an amateur station to a non-amateur over-the-air radio receiver?

A. Switch the transmitter to a narrow-band mode
B. Block the amateur signal with a filter at the antenna input of the affected receiver
C. Block the interfering signal with a filter on the amateur transmitter
D. Switch the transmitter from FM to SSB

15. Which of the following can reduce interference to a 2-meter band transceiver from a nearby commercial FM station?

A. Installing bypass capacitors on the microphone cable
B. Using double-shielded coaxial cable
C. Installing a band-reject filter
D. Installing an RF preamplifier

16. Which of the following actions should you take if a neighbor tells you that your station's transmissions are interfering with their radio or TV reception?

A. Immediately turn off your transmitter and contact the nearest FCC office for assistance
B. All these choices are correct
C. Install a harmonic doubler on the transmitter output and tune until interference stops
D. Make sure station works properly, doesn't interfere with own radio or TV on same channel

17. What should be the first step to resolve non-fiber optic cable TV interference caused by your amateur radio transmission?

A. Add a low-pass filter to the TV antenna input
B. Be sure all TV feed line coaxial connectors are installed properly
C. Add a high-pass filter to the TV antenna input
D. Add a preamplifier to the TV antenna input

18. What can you do if you are told your FM handheld or mobile transceiver is over-deviating?

A. Talk farther away from the microphone
B. Let the transceiver cool off
C. Talk louder into the microphone
D. Change to a higher power level

19. What might be a problem if you receive a report that your audio signal through an FM repeater is distorted or unintelligible?

A. You are speaking too loudly or too close to the microphone
B. Your transmitter is slightly off frequency
C. You are in a bad location
D. All these choices are correct

20. Which of the following might be the cause of low RF power output from a solid-state transceiver?

- A Poor amplifier noise figure
- B Low SWR
- C High SWR
- D Poor amplifier linearity

21. What should you do if something in a neighbor's home is causing harmful interference to your amateur station?

- A Make sure your station meets the standards of good amateur practice
- B Politely tell your neighbor FCC rules prohibit devices that cause interference
- C Work with your neighbor to identify the offending device
- D All these choices are correct

22. Which of the following can eliminate distorted voice transmissions?

- A Adding extra feedline to the antenna to lower SWR
- B Turning squelch fully clockwise to stop the transmitted signal triggering squelch
- C Adding a clip-on ferrite "choke" on mic cable to stop transmitted signal feeding back
- D Turning the radio on and off to reset the computer-controlled circuitry

Go deeper

LISTEN Lesson 10 episode 6:46 · FlashFeed Study Notes podcast

WATCH Why a Broadcast Radio Picks Up a Ham 0:29
Imagine an amateur station is on the air, and a broadcast radio picks up its signal. Nobody meant it to happen.

WATCH How a Transceiver Reaches Another Band 0:26
A transceiver covers certain bands on its own. Could it work a band it does not cover?

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/practical-circuits-radios-and-their-common-problems

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LESSON 11 OF 15

Practical Circuits: Measuring and Testing

Measuring and troubleshooting antennas and lines · Test meters and soldering

WHAT YOU'LL BE ABLE TO DO

- Explain how dummy loads, antenna analyzers and directional wattmeters are used, and what SWR readings such as 1:1 and 4:1 mean
- Describe the effects of high SWR, where feed line loss goes, why coaxial cable fails, and the advantage of foam-dielectric coax
- Identify the meters for voltage, current and resistance, how each connects to a circuit, and how an ohmmeter measures resistance
- Explain safe multimeter and ohmmeter use, what an ohmmeter shows across a capacitor, and how to choose solder and judge joints

This lesson covers the instruments and habits used to check a station. The first half deals with antennas and feed lines: dummy loads, standing wave ratio (SWR) readings, coaxial cable and why it fails. The second half deals with test meters and solder: what each meter measures, how it connects, and what a good solder joint looks like. A new licensee who knows these points can test equipment without damaging it and can tell a sound connection from a poor one.

Measuring and troubleshooting antennas and lines

Dummy loads

A **dummy load** lets a transmitter be tested without putting a signal on the air. Its primary purpose is to prevent transmitting signals over the air when making tests.

A typical radio frequency (RF) dummy load consists of a 50-ohm non-inductive resistor mounted on a heat sink. A new licensee who connects a dummy load is, in effect, giving the transmitter a resistor to work into instead of an antenna.

Resonance and SWR readings

An **antenna analyzer** is the instrument used to determine whether an antenna is resonant at the desired operating frequency.

The **standing wave ratio (SWR)** is read on an SWR meter as a ratio. A reading of 1:1 indicates a perfect impedance match between the antenna and the feed line. A reading of 4:1 indicates an impedance mismatch.

A **directional wattmeter** can be used to determine SWR.

What high SWR does

Most solid-state transmitters reduce output power as SWR increases beyond a certain level. The reduction protects the RF output amplifier transistors.

Feed line loss and coax failure

Power lost in a feed line is converted into heat.

Moisture contamination causes failure of coaxial cables.

This is also why the outer jacket of coaxial cable should be resistant to ultraviolet light. Ultraviolet light can damage the jacket and allow water to enter the cable. A cable with a sound jacket keeps water out, and water getting in is the failure to avoid.

When choosing between cables, a foam-dielectric coaxial cable has an advantage over a solid-dielectric one: it has less loss per foot.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)

Test meters and soldering

What each meter measures

A **voltmeter** measures electric potential, which is the voltage across a part. An **ammeter** measures electric current. An **ohmmeter** measures resistance.

A **multimeter** combines these functions in one instrument. Voltage and resistance are among the measurements made using a multimeter. When it is configured to measure current, a multimeter works as an ammeter.

How meters connect

A voltmeter is connected to a component in parallel to measure applied voltage. A multimeter configured to measure current is connected to the component in series. A new licensee reading a voltage connects the meter in parallel, then switches to the current setting and connects it in series to read a current.

How an ohmmeter works

An ohmmeter measures the resistance of a circuit or component by applying a small current and measuring the resulting voltage.

Two precautions follow from careful use. Attempting to measure voltage when using the resistance setting can damage a multimeter. When measuring in-circuit resistance with an ohmmeter, the circuit must not be powered.

An ohmmeter connected across a large, discharged capacitor shows increasing resistance with time.

Solder and joints

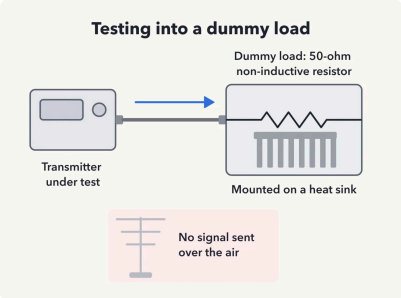
Acid-core solder should not be used for radio and electronic applications. A licensee soldering a connection therefore chooses rosin-core solder rather than acid-core.

A **cold solder joint** made with tin-lead solder has a rough or lumpy surface. A joint that comes out rough or lumpy is the one to suspect.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)

Key facts



FlashFeed original diagram · CC-BY-4.0

Why Use a Dummy Load

A **dummy load** lets a transmitter be tested without putting a signal on the air. Its primary purpose is to prevent transmitting signals over the air when making tests.



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Checking Antenna Resonance

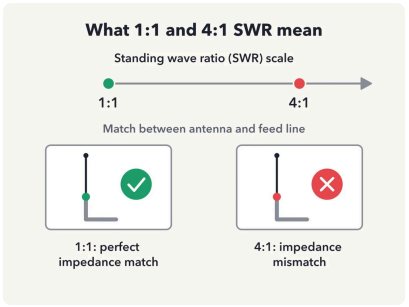
An **antenna analyzer** is the instrument used to determine whether an antenna is resonant at the desired operating frequency.



Wikimedia Commons · Karl-Martin Skontorp from Norway · CC BY 2.0

What a Dummy Load Is Made Of

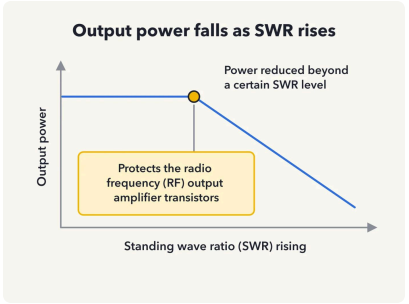
A typical radio frequency (RF) dummy load consists of a 50-ohm non-inductive resistor mounted on a **heat sink**.



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SWR of 1:1 Means a Match

The **standing wave ratio (SWR)** is read on an SWR meter as a ratio. A reading of 1:1 indicates a perfect impedance match between the antenna and the feed line.



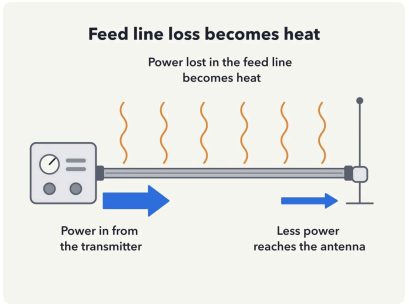
FlashFeed original diagram · CC-BY-4.0

Why Transmitters Cut Power

Most solid-state transmitters reduce output power as standing wave ratio (SWR) increases beyond a certain level. The reduction protects the radio frequency (RF) output amplifier **transistors**.

SWR of 4:1 Means Mismatch

A standing wave ratio (SWR) reading of 4:1 indicates an **impedance mismatch**.



FlashFeed original diagram · CC-BY-4.0

Where Lost Power Goes

Power lost in a feed line is converted into **heat**.



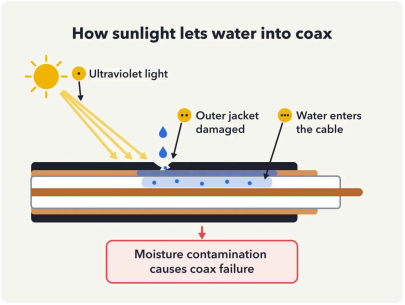
Wikimedia Commons · Theonlysilentbob at English Wikipedia · CC BY-SA 3.0

Instrument That Finds SWR

A **directional wattmeter** can be used to determine standing wave ratio (SWR).

What Makes Coax Fail

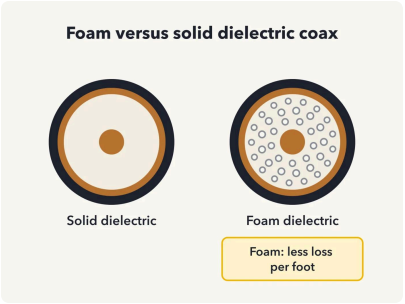
Moisture contamination causes failure of coaxial cables.



FlashFeed original diagram · CC-BY-4.0

Why Coax Jackets Resist Sunlight

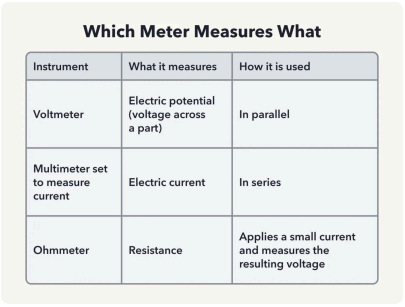
The outer jacket of coaxial cable should be resistant to ultraviolet light. Ultraviolet light can damage the **jacket** and allow water to enter the cable.



FlashFeed original diagram · CC-BY-4.0

Foam Versus Solid Dielectric

A **foam-dielectric** coaxial cable has less loss per foot than a solid-dielectric one.



Which Meter Measures What

Instrument	What it measures	How it is used
Voltmeter	Electric potential (voltage across a part)	In parallel
Multimeter set to measure current	Electric current	In series
Ohmmeter	Resistance	Applies a small current and measures the resulting voltage

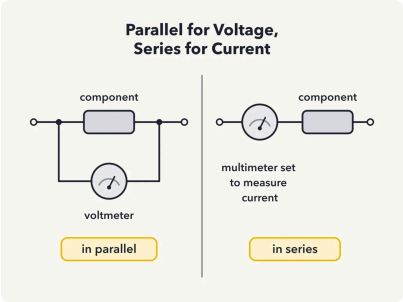
FlashFeed original diagram · CC-BY-4.0

Voltmeter Measures Potential

A **voltmeter** measures electric potential, which is the voltage across a part.

Voltmeters Connect in Parallel

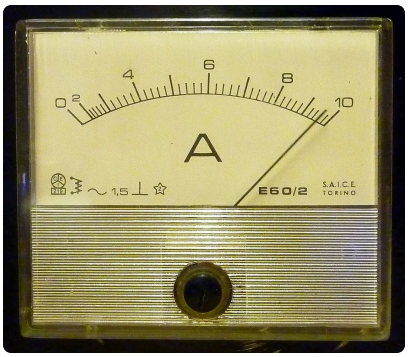
A voltmeter is connected to a component **in parallel** to measure applied voltage.



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Current Readings Use Series

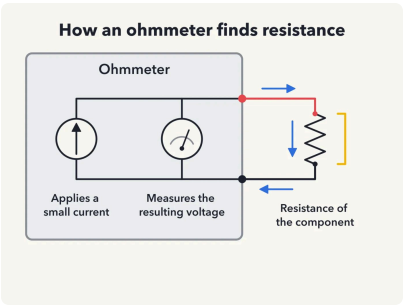
A multimeter configured to measure current is connected to the component **in series**.



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Ammeter Measures Current

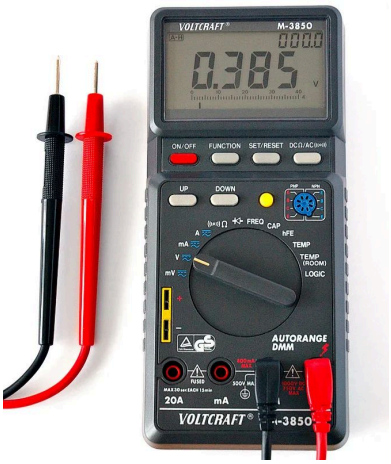
An **ammeter** measures electric current.



FlashFeed original diagram · CC-BY-4.0

How an Ohmmeter Works

An **ohmmeter** measures the resistance of a circuit or component by applying a small current and measuring the resulting voltage.



Wikimedia Commons · André Karwath aka Aka · CC BY-SA 2.5

What Damages a Multimeter

Attempting to measure voltage when using the **resistance setting** can damage a multimeter.



Wikimedia Commons · Jacek Halicki · CC BY-SA 4.0

What a Multimeter Measures

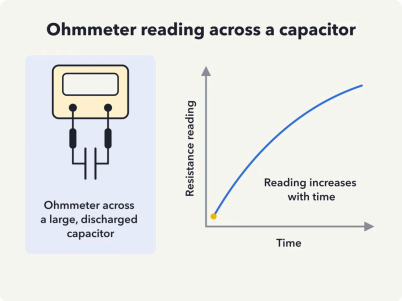
A **multimeter** combines meter functions in one instrument. Voltage and resistance are among the measurements made using a multimeter, and it can also be configured to measure current.

Solder to Avoid

Acid-core solder should not be used for radio and electronic applications.

Spotting a Cold Solder Joint

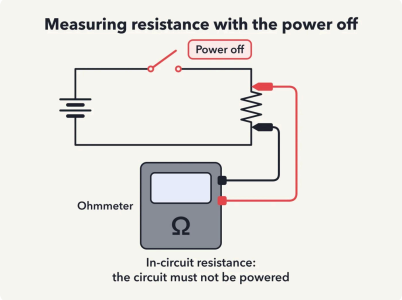
A **cold solder joint** made with tin-lead solder has a rough or lumpy surface.



FlashFeed original diagram · CC-BY-4.0

Ohmmeter Across a Capacitor

An ohmmeter connected across a large, discharged capacitor shows **increasing resistance** with time.



FlashFeed original diagram · CC-BY-4.0

Unpowered for Resistance Checks

When measuring in-circuit resistance with an ohmmeter, the circuit must **not be powered**.

Matched pairs

Each item on the left goes with the one on the right.

Dummy load → 50-ohm non-inductive resistor on a heat sink

Voltmeter → Measures electric potential

Self-test

Answer each question from memory, then check your work against the answer key.

1. What is the primary purpose of a dummy load?

- A To improve the efficiency of an antenna
- B To prevent transmitting signals over the air when making tests
- C To prevent over-modulation of a transmitter
- D To improve the signal-to-noise ratio of a receiver

2. What does a typical RF dummy load consist of?

- A A 50-ohm inductive reactance mounted in a shielded enclosure
- B A low-voltage power supply and a DC relay
- C A 50-ohm non-inductive resistor mounted on a heat sink
- D A low-voltage power supply and an AC relay

3. Which of the following is used to determine if an antenna is resonant at the desired operating frequency?

- A An antenna analyzer
- B A VTVM
- C A frequency counter
- D A Q meter

4. Which instrument can be used to determine SWR?

- A Voltmeter
- B Iambic pentameter
- C Ohmmeter
- D Directional wattmeter

5. What reading on an SWR meter indicates a perfect impedance match between the antenna and the feed line?

- A Zero
- B Full Scale
- C 50:50
- D 1:1

6. What does an SWR reading of 4:1 indicate?

- A Impedance mismatch
- B Good impedance match
- C Loss of -4 dB
- D Gain of +4 dB

7. Why do most solid-state transmitters reduce output power as SWR increases beyond a certain level?

- A Because power supplies cannot supply enough current at high SWR
- B To protect the RF output amplifier transistors
- C To comply with FCC rules on spectral purity
- D To lower the SWR on the transmission line

8. What happens to power lost in a feed line?

A) It increases the SWR
B) It is radiated as harmonics
C) It is converted into heat
D) It distorts the signal

9. Which of the following causes failure of coaxial cables?

A) Operation at 100% duty cycle for an extended period
B) Solder flux contamination
C) Moisture contamination
D) Rapid fluctuation in transmitter output power

10. Why should the outer jacket of coaxial cable be resistant to ultraviolet light?

A) Ultraviolet light can damage the jacket and allow water to enter the cable
B) Ultraviolet light can increase the resistance of the conductors
C) Ultraviolet light can increase losses in the cable's jacket
D) Ultraviolet and RF signals can mix, causing interference

11. What is an advantage of foam-dielectric versus solid-dielectric coaxial cable?

A) It is more resistant to moisture contamination
B) It has less loss per foot
C) It has a better impedance match to 50 ohms
D) It has higher voltage breakdown

12. Which instrument would you use to measure electric potential?

A) An ammeter
B) An ohmmeter
C) A potentiometer
D) A voltmeter

13. Which instrument is used to measure electric current?

A) An ohmmeter
B) An ammeter
C) An electrometer
D) A voltmeter

14. Which of the following measurements are made using a multimeter?

A) Voltage and resistance
B) All these choices are correct
C) Impedance and reactance
D) Signal strength and noise

15. How is a voltmeter connected to a component to measure applied voltage?

A) In phase
B) In quadrature
C) In series
D) In parallel

16. When configured to measure current, how is a multimeter connected to a component?

A) In parallel
B) In phase
C) In series
D) In quadrature

17. How does an ohmmeter measure the resistance of a circuit or component?

- A) By applying a small current and measuring the resulting voltage
- B) By placing a variable resistor in parallel with the circuit
- C) By placing a variable resistor in series with the circuit
- D) By applying a variable voltage and measuring the resulting current change

18. Which of the following can damage a multimeter?

- A) Failing to connect one of the probes to ground
- B) Not allowing it to warm up properly
- C) Attempting to measure resistance using the voltage setting
- D) Attempting to measure voltage when using the resistance setting

19. What reading indicates that an ohmmeter is connected across a large, discharged capacitor?

- A) Steady full-scale reading
- B) Increasing resistance with time
- C) Decreasing resistance with time
- D) Alternating between open and short circuit

20. Which of the following precautions should be taken when measuring in-circuit resistance with an ohmmeter?

- A) Ensure that the applied voltages are correct
- B) Ensure that the circuit is grounded
- C) Ensure that the circuit is not powered
- D) Ensure that the circuit is operating at the correct frequency

21. Which of the following types of solder should not be used for radio and electronic applications?

- A) Tin-copper solder
- B) Lead-tin solder
- C) Rosin-core solder
- D) Acid-core solder

22. What is the characteristic appearance of a cold tin-lead solder joint?

- A) A bright or shiny surface
- B) A greenish tinge
- C) A rough or lumpy surface
- D) Dark black spots

Go deeper

LISTEN Lesson 11 episode 6:18 · FlashFeed Study Notes podcast

WATCH Why Transmitters Cut Their Own Power 0:27
Why would a transmitter turn its own power down, even while it is still on the air?

WATCH Which Setting Can Damage a Multimeter 0:26
Which simple mistake can damage a multimeter when it is being used?

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/practical-circuits-measuring-and-testing

STUDY Ham Radio Technician License in the FlashFeed app flashfeedlearningapp.com/packs/ham-radio-technician

LESSON 12 OF 15

Signals and Emissions: Modes and Satellites

Modulation modes and bandwidth · Amateur satellite operation

WHAT YOU'LL BE ABLE TO DO

- Identify the modulation used for SSB, FM, packet and repeaters, the sideband for weak-signal VHF and UHF work, and how SSB compares with FM
- Compare the bandwidths of CW, SSB, FM voice and fast-scan TV, and name a disadvantage of FM versus SSB
- Explain what satellite beacons, telemetry and tracking programs provide, and how to set uplink power properly
- Describe satellite modes, bands, orbits, Doppler shift and spin fading, and who may receive telemetry

A new licensee has several ways to put a voice or data signal on the air, and each suits a different job. This lesson covers which type of signal fits repeaters, packet radio and long-distance work. It also covers how much room each signal takes on a band. The second half turns to amateur satellites: what they send, how operators track them, and how to use them without crowding out other stations.

Modulation modes and bandwidth

Single sideband (SSB) is a form of amplitude modulated (AM) signal.

Frequency modulated (FM) is paired here with phase modulated (PM). **FM or PM** is the type of modulation commonly used for two jobs. One is very high frequency (VHF) packet radio. The other is VHF and ultra high frequency (UHF) voice repeaters.

SSB is the voice mode often used for long-distance, weak-signal contacts on the VHF and UHF bands. A licensee chasing a distant station on VHF or UHF therefore turns to SSB. The same licensee uses FM or PM for a local repeater.

Upper sideband is the one normally used for SSB communications on 10-meter high frequency (HF), VHF and UHF.

Why SSB differs from FM

One characteristic of SSB compared to FM is that SSB signals have narrower bandwidth. Bandwidth, taught in an earlier lesson, is the measure compared here. FM has a matching disadvantage compared with single sideband: only one signal can be received at a time.

Comparing bandwidths

The approximate bandwidths below run from the narrowest signal to the widest.

- **International Morse code telegraphy (CW)** needs about 150 hertz (Hz). CW is international Morse code telegraphy, and it has the narrowest bandwidth of the signal types compared.
- A typical SSB voice signal is about 3 kilohertz (kHz) wide.
- An FM voice signal on VHF repeaters is between 10 and 15 kHz wide.
- AM fast-scan TV transmissions are about 6 megahertz (MHz) wide.

These figures show why SSB is called narrower than FM: a typical SSB voice signal is about 3 kHz wide, while FM voice on repeaters is 10 to 15 kHz.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)

Amateur satellite operation

Amateur radio satellites carry their own transmitters, and many operators work them from the ground. The Federal Communications Commission (FCC) defines an **Earth station** as an amateur station located on, or within 50 km of, the Earth's surface. It is intended for communications with space stations, or with other Earth stations by means of one or more other objects in space.

Beacons and telemetry

A **satellite beacon** is a transmission from a satellite that contains status information. The telemetry that beacons typically send is the health and status of the satellite. Anyone is permitted to receive telemetry from an amateur radio satellite.

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.

Spin fading of satellite signals is caused by rotation of the satellite and its antennas. It is a separate effect from Doppler shift, which comes from relative motion.

Tracking programs

Satellite tracking programs take the Keplerian elements as their input. In return, a tracking program provides all of the following:

- maps showing the real-time position of the satellite track over Earth;
- the time, azimuth and elevation of the start, maximum altitude and end of a pass;
- the apparent frequency of the satellite transmission, including the effects of Doppler shift.

This is why a tracking program shows an apparent frequency rather than a fixed one.

Modes, bands and orbits

Amateur radio satellites commonly use SSB, FM and CW/data.

A satellite operating in **U/V mode** has its uplink in the 70-centimeter band and its downlink in the 2-meter band.

A **Low Earth Orbit (LEO)** has a period of around 100 minutes.

Setting uplink power

A satellite uplink can be overdriven. Using excessive effective radiated power (ERP) on a satellite uplink blocks access by other users.

ERP is the product of the power supplied to the antenna and its gain relative to a half-wave dipole in a given direction. Multiplying ERP by 1.64 converts it to equivalent isotropically radiated power (EIRP). A stronger antenna gain raises ERP just as more transmitter power does.

For a linear transponder satellite, the uplink power is neither too low nor too high when the operator's signal strength on the downlink is about the same as the beacon. Together these points give the order of a pass. The operator loads the Keplerian elements into a tracking program and reads the pass times. During the pass the operator expects Doppler shift and spin fading. The operator sets uplink power by matching the downlink signal to the beacon, so other users keep their access.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)
- 47 CFR § 97.3 Definitions

Key terms

Earth station

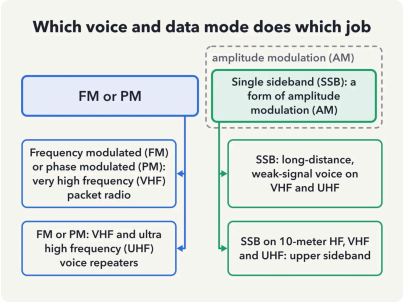
An amateur station on, or within 50 km of, Earth's surface, intended for communications with space stations or with other such stations via objects in space

ERP

Effective radiated power: the power supplied to the antenna times its gain relative to a half-wave dipole in a given direction

Key facts

> **SSB Is Amplitude Modulation**
>
> **Single sideband (SSB)** is a form of amplitude modulation (AM).



FlashFeed original diagram · CC-BY-4.0

FM or PM for Packet and Repeaters

FM or PM is the modulation commonly used for two jobs: very high frequency (VHF) packet radio, and VHF and ultra high frequency (UHF) voice repeaters. Here FM means frequency modulated and PM means phase modulated.

SSB for Weak-Signal Contacts

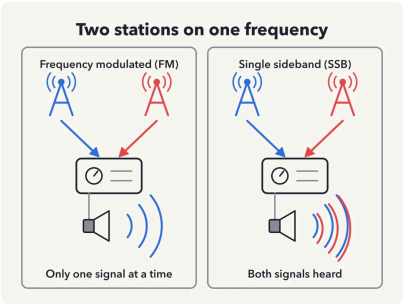
Single sideband (SSB) is the voice mode often used for long-distance, **weak-signal** contacts on the very high frequency (VHF) and ultra high frequency (UHF) bands.

Upper Sideband Is the Norm

Upper sideband is normally used for single sideband (SSB) communications on 10-meter high frequency (HF), very high frequency (VHF) and ultra high frequency (UHF).

SSB Is Narrower Than FM

Compared with frequency modulated (FM) signals, single sideband (SSB) signals have **narrower bandwidth**.



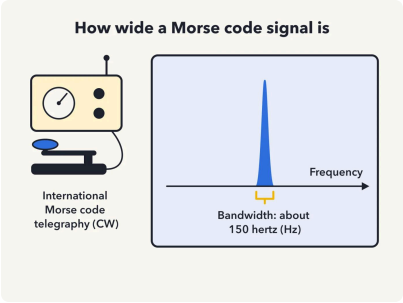
FlashFeed original diagram · CC-BY-4.0

The Drawback of FM

A disadvantage of frequency modulated (FM) compared with single sideband is that **only one signal can be received at a time**.

CW Is the Narrowest Signal

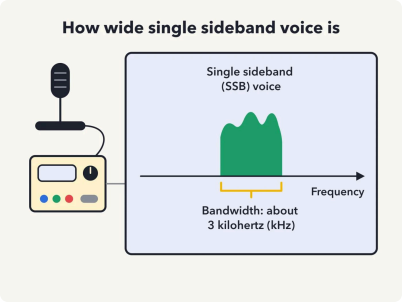
International Morse code telegraphy (CW) has the narrowest bandwidth of the signal types compared.



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CW Bandwidth: About 150 Hz

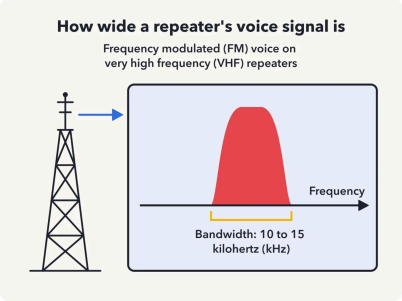
An international Morse code telegraphy (CW) signal needs about **150 hertz (Hz)** of bandwidth.



FlashFeed original diagram · CC-BY-4.0

SSB Voice Is About 3 kHz

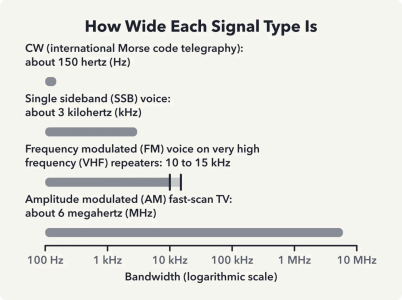
A typical single sideband (SSB) voice signal is about **3 kilohertz (kHz)** wide.



FlashFeed original diagram · CC-BY-4.0

FM Repeater Voice Is 10–15 kHz

A frequency modulated (FM) voice signal on very high frequency (VHF) repeaters is **between 10 and 15 kilohertz (kHz)** wide.



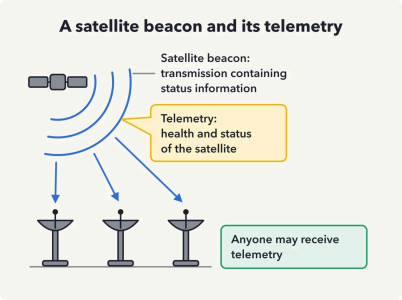
FlashFeed original diagram · CC-BY-4.0

Fast-Scan TV Is About 6 MHz

Amplitude modulated (AM) **fast-scan TV** transmissions are about 6 megahertz (MHz) wide.

What Beacons Send

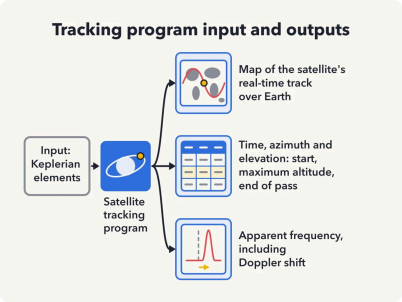
The **telemetry** that satellite beacons typically send is the health and status of the satellite.



FlashFeed original diagram · CC-BY-4.0

A Satellite Beacon Defined

A **satellite beacon** is a transmission from a satellite that contains status information.



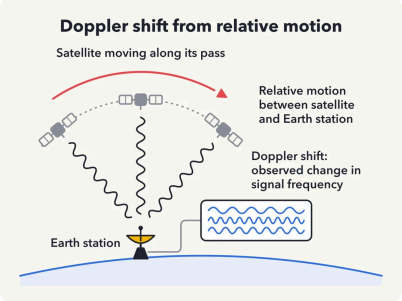
FlashFeed original diagram · CC-BY-4.0

What Tracking Programs Provide

A satellite **tracking program** provides all of these: maps showing the real-time position of the satellite track over Earth; the time, azimuth and elevation of the start, maximum altitude and end of a pass; and the apparent frequency of the transmission, including Doppler shift effects.

Keplerian Elements Feed Trackers

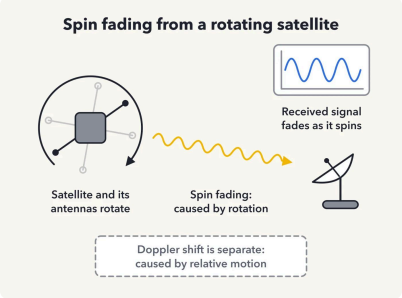
Satellite tracking programs take the **Keplerian elements** as their input.



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Doppler Shift Explained

Doppler shift is an observed change in signal frequency caused by relative motion between the satellite and the Earth station.



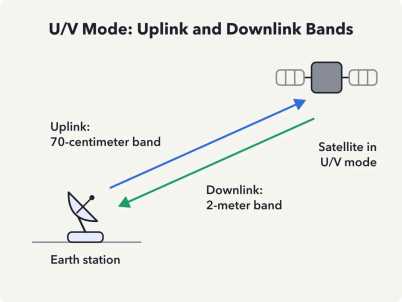
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What Causes Spin Fading

Spin fading of satellite signals is caused by rotation of the satellite and its antennas. It is a separate effect from Doppler shift, which comes from relative motion.

Modes Satellites Commonly Use

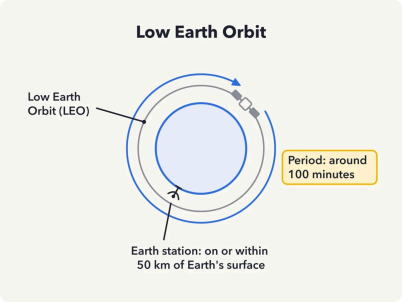
Amateur radio satellites commonly use **single sideband (SSB)**, frequency modulated (FM) and international Morse code telegraphy (CW)/data.



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U/V Mode Bands

A satellite operating in **U/V mode** has its uplink in the 70-centimeter band and its downlink in the 2-meter band.



FlashFeed original diagram · CC-BY-4.0

LEO: Low Earth Orbit

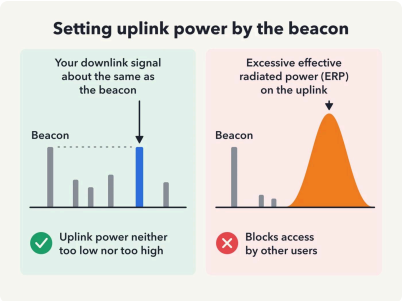
Low Earth Orbit (LEO) has a period of around 100 minutes.

Anyone May Receive Telemetry

Anyone is permitted to receive telemetry from an amateur radio satellite.

Excess Uplink Power Blocks Others

Using excessive effective radiated power (ERP) on a satellite uplink **blocks access by other users**.



FlashFeed original diagram · CC-BY-4.0

Matching the Beacon

On a linear transponder satellite, uplink power is neither too low nor too high when the operator's signal strength on the **downlink** is about the same as the beacon.

Matched pairs

Each item on the left goes with the one on the right.

Frequency modulated (FM) voice signal on very high frequency (VHF) repeaters → Between 10 and 15 kilohertz (kHz) wide

Spin fading → Rotation of satellite and its antennas

Self-test

Answer each question from memory, then check your work against the answer key.

1. Which of the following is a form of amplitude modulation?

(A) Phase shift keying (PSK)
(B) Single sideband
(C) Spread spectrum
(D) Packet radio

2. What type of modulation is commonly used for VHF packet radio transmissions?

(A) AM
(B) SSB
(C) PSK
(D) FM or PM

3. Which type of modulation is commonly used for VHF and UHF voice repeaters?

A FM or PM
B SSB
C AM
D PSK

4. Which type of voice mode is often used for long-distance (weak signal) contacts on the VHF and UHF bands?

A DRM
B FM
C SSB
D PM

5. Which sideband is normally used for 10-meter HF, VHF, and UHF single-sideband communications?

A Lower sideband
B Upper sideband
C Suppressed sideband
D Inverted sideband

6. What is one characteristic of single sideband (SSB) compared to FM?

A SSB signals are less susceptible to interference
B SSB signals are less susceptible to high SWR
C SSB signals are easier to tune in correctly
D SSB signals have narrower bandwidth

7. Which of the following signal types has the narrowest bandwidth?

A FM voice
B SSB voice
C CW
D Slow-scan TV

8. What is the approximate bandwidth of a typical single sideband (SSB) voice signal?

A 3 kHz
B 15 kHz
C 1 kHz
D 6 kHz

9. What is the approximate bandwidth required to transmit a CW signal?

A 1000 Hz
B 15 kHz
C 2.4 kHz
D 150 Hz

10. What is the approximate bandwidth of an FM voice signal on VHF repeaters?

A Less than 500 Hz
B About 150 kHz
C Between 10 and 15 kHz
D Between 50 and 125 kHz

11. What is the approximate bandwidth of AM fast-scan TV transmissions?

A About 1 MHz
B About 6 MHz
C More than 10 MHz
D About 3 MHz

12. Which of the following is a disadvantage of FM compared with single sideband?

A Only one signal can be received at a time
B FM signals are more susceptible to high SWR
C FM signals are harder to tune
D Voice quality is poorer

13. What telemetry information is typically transmitted by satellite beacons?

A. Time of day accurate to plus or minus 1/10 second
B. All these choices are correct
C. Health and status of the satellite
D. The signal strength of received signals

14. What is a satellite beacon?

A. An indicator light that shows where to point your antenna
B. The primary transmit antenna on the satellite
C. A reflective surface on the satellite
D. A transmission from a satellite that contains status information

15. Which of the following are provided by satellite tracking programs?

A. All these choices are correct
B. The apparent frequency of the satellite transmission, including effects of Doppler shift
C. Maps showing the real-time position of the satellite track over Earth
D. The time, azimuth, and elevation of the start, maximum altitude, and end of a pass

16. Which of the following are inputs to a satellite tracking program?

A. The satellite transmitted power
B. The Keplerian elements
C. The last observed time of zero Doppler shift
D. All these choices are correct

17. What is the impact of using excessive effective radiated power on a satellite uplink?

A. Blocking access by other users
B. Possibility of rebooting the satellite control computer
C. Overloading the satellite batteries
D. Possibility of commanding the satellite to an improper mode

18. Which of the following is a way to determine whether your satellite uplink power into a linear transponder satellite is neither too low nor too high?

A. Listen for distortion on your downlink signal
B. Compare your signal to others on the downlink using an internet SDR receiver
C. Check your signal strength report in the telemetry data
D. Your signal strength on the downlink should be about the same as the beacon

19. What mode of transmission is commonly used by amateur radio satellites?

A. SSB
B. All these choices are correct
C. CW/data
D. FM

20. What does it mean if a satellite is operating in U/V mode?

- A The satellite operates using ultraviolet frequencies
- B The satellite uplink is in the 15-meter band and the downlink is in the 10-meter band
- C The satellite uplink is in the 70-centimeter band and the downlink is in the 2-meter band
- D The satellite frequencies are usually variable

21. What does the term LEO mean in reference to communication satellites?

- A Low Energy Orbit, which conserves battery power
- B Low Earth Orbit, which has a period of around 100 minutes
- C Low Elevation Orbit, which appears close to the horizon from the earth station
- D Low Equilibrium Orbit, which has a slightly unstable period

22. What is Doppler shift in reference to satellite communications?

- A A special digital communications mode for some satellites
- B A mode where the satellite receives signals on one band and transmits on another
- C An observed change in signal frequency from relative motion of satellite and Earth station
- D A change in the satellite orbit

23. What causes spin fading of satellite signals?

- A Rotation of the satellite and its antennas
- B Interfering signals within the satellite uplink band
- C Circular polarized noise interference radiated from the sun
- D Doppler shift of the received signal

24. Who is permitted to receive telemetry from an amateur radio satellite?

- A Only control operator or a licensed amateur given the encryption key by that operator
- B Only a licensed radio amateur who has received the encryption key from AMSAT
- C Only the satellite control operator
- D Anyone

Go deeper

LISTEN Lesson 12 episode 7:23 · FlashFeed Study Notes podcast

WATCH Morse Code or Fast-Scan TV: Which Takes More Room? 0:29
Which takes more room on a band: a Morse code signal, or a fast-scan TV signal?

WATCH Why Too Much Satellite Power Hurts Others 0:28
More power is not always better on a satellite uplink.

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/signals-and-emissions-modes-and-satellites

STUDY Ham Radio Technician License in the FlashFeed app flashfeedlearningapp.com/packs/ham-radio-technician

LESSON 13 OF 15

Signals and Emissions: Contests, Linking and Digital Modes

Direction finding, contests and internet linking · Digital and non-voice modes

WHAT YOU'LL BE ABLE TO DO

- Explain how direction finding, contests and grid locators are used in operating activities, including good contest practice
- Describe how IRLP, EchoLink, VoIP and gateways link amateur stations over the internet, and how to access them
- Identify common digital and non-voice modes and terms, including FT8, WSJT-X, PSK, CW and NTSC
- Describe how APRS, packet radio, ARQ, DMR and mesh networks send and protect data

This lesson covers the activities that go beyond ordinary conversation on the air. It starts with finding the source of a signal, then covers contests, grid locators and the systems that link stations over the internet. It then turns to digital and non-voice modes, including packet radio, position reporting, digital voice and mesh networks. A new licensee meets all of these terms in club talk and on the air, so each needs a plain meaning.

Direction finding, contests and internet linking

Finding a signal's source

Radio direction finding is the method used to locate sources of noise interference or jamming.

The same skill is the point of a hidden transmitter hunt, where operators search for a transmitter that has been concealed. The useful item for such a hunt is a directional antenna.

Contests and grid locators

Contesting is the operating activity of contacting as many stations as possible during a specified period.

Good practice in a contest contact is to send only the minimum information needed for proper identification and the contest exchange. A **grid locator** is a letter-number designator assigned to a geographic location.

Linking stations through the internet

The **Internet Radio Linking Project (IRLP)** is a technique to connect amateur radio systems, such as repeaters, via the internet.

Over-the-air access to IRLP nodes is accomplished by using Dual-Tone Multi-Frequency (DTMF) signals.

Voice Over Internet Protocol (VoIP) is a method of delivering voice communications over the internet using digital techniques.

EchoLink is the protocol that enables an amateur station to transmit through a repeater without using a radio to initiate the transmission.

Before using the EchoLink system, a person must register a call sign and provide proof of license.

An amateur radio station that connects other amateur stations to the internet is a **gateway**.

Sources

- NCVEC Question Pool Committee — 2026–2030 Technician question pool

Digital and non-voice modes

Digital modes

Several modes count as digital communications modes. Packet radio is one. IEEE 802.11 is another, where IEEE stands for Institute of Electrical and Electronics Engineers. FT8 is a third. Each of the three is a digital communications mode.

FT8 is a digital mode capable of low signal-to-noise operation. That means it can work with weak signals.

WSJT-X is a software suite for weak-signal work; the name begins with Weak Signal communication by K1JT (WSJT). Its digital mode software supports all three of these operating activities:

- Earth-Moon-Earth (EME);
- weak signal propagation beacons;
- meteor scatter.

Keying and Morse code

Phase Shift Keying is what the abbreviation PSK means.

CW, short for continuous wave, is another name for a Morse code transmission.

Television signals

National Television System Committee (NTSC) is the full name. As a term, it means an analog fast-scan color TV signal.

Packet radio and error control

Packet radio transmissions include all three of the following:

- a checksum that permits error detection;
- a header that contains the call sign of the station to which the information is being sent;
- automatic repeat request (ARQ) in case of error.

ARQ is an error correction method in which the receiving station detects errors and sends a request for retransmission.

Position reporting

The Automatic Packet Reporting System (APRS) can transmit all three of these kinds of data: Global Positioning System (GPS) position data, text messages and weather data.

An application of APRS is real-time tactical digital communications in conjunction with a map showing the locations of stations.

Digital voice and mesh networks

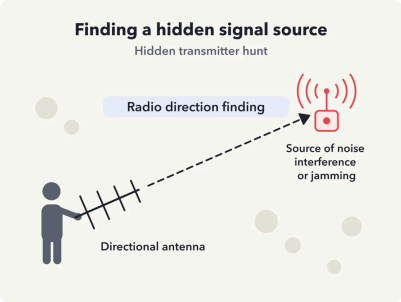
Digital Mobile Radio (DMR) is a technique for time-multiplexing two digital voice signals on a single 12.5 kilohertz (kHz) repeater channel.

An amateur radio **mesh network** is an amateur-radio data network using commercial Wi-Fi equipment with modified firmware.

Sources

- NCVEC Question Pool Committee — 2026–2030 Technician question pool

Key facts



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Radio Direction Finding

Radio direction finding is the method used to locate sources of noise interference or jamming.



Wikimedia Commons · Lz1adf · CC BY-SA 3.0

Gear for a Transmitter Hunt

In a hidden transmitter hunt, operators search for a transmitter that has been concealed. The useful item for the hunt is a **directional antenna**.

What Contesting Is

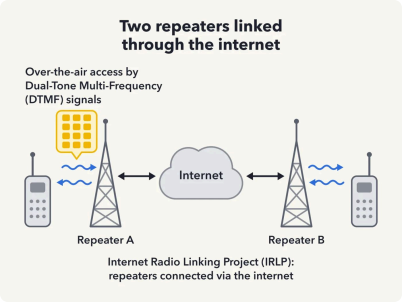
Contesting is the operating activity of contacting as many stations as possible during a specified period.

Good Contest Practice

Good practice in a contest contact is to send only the minimum information needed for proper identification and the **contest exchange**.

Grid Locator Meaning

A **grid locator** is a letter-number designator assigned to a geographic location.



FlashFeed original diagram · CC-BY-4.0

Reaching IRLP Nodes

Over-the-air access to Internet Radio Linking Project (IRLP) nodes is accomplished by using **Dual-Tone Multi-Frequency (DTMF)** signals.

Voice Over the Internet

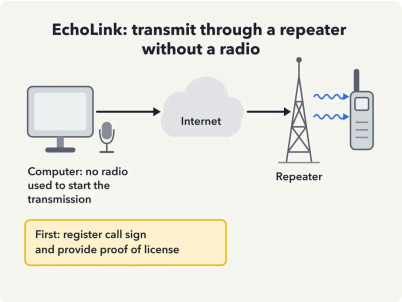
Voice Over Internet Protocol (VoIP) is a method of delivering voice communications over the internet using digital techniques.

What IRLP Does

The **Internet Radio Linking Project (IRLP)** is a technique to connect amateur radio systems, such as repeaters, via the internet.

EchoLink Without a Radio

EchoLink is the protocol that enables an amateur station to transmit through a repeater without using a radio to initiate the transmission.



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Starting With EchoLink

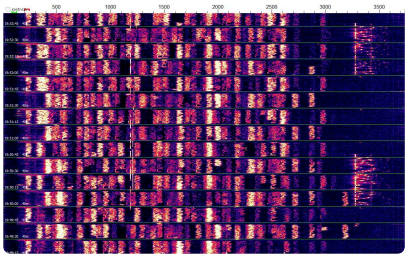
Before using **EchoLink**, a person must register a call sign and provide proof of license.

Gateway Stations

An amateur radio station that connects other amateur stations to the internet is a **gateway**.

Digital Communications Modes

Packet radio, IEEE 802.11 and FT8 all count as **digital communications modes**. IEEE stands for Institute of Electrical and Electronics Engineers.



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FT8 Weak-Signal Mode

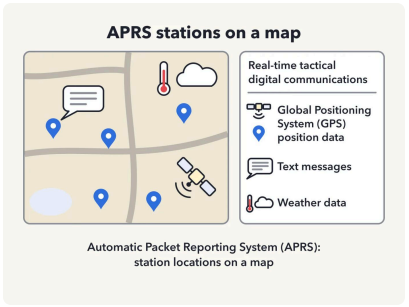
FT8 is a digital mode capable of low signal-to-noise operation, so it can work with weak signals.

Data Sent by APRS

The **Automatic Packet Reporting System (APRS)** can transmit three kinds of data. They are Global Positioning System (GPS) position data, text messages and weather data.

What NTSC Means

National Television System Committee (NTSC) is the full name. As a term, it means an analog fast-scan color TV signal.



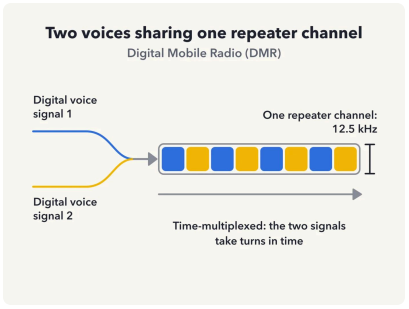
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APRS Maps and Messages

An application of the **Automatic Packet Reporting System (APRS)** is real-time tactical digital communications in conjunction with a map showing the locations of stations.

PSK Spelled Out

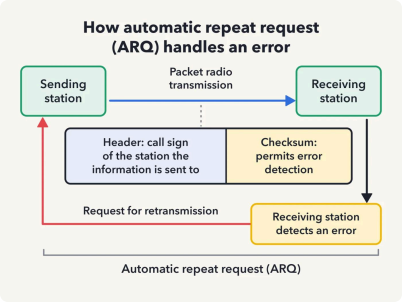
Phase Shift Keying is what the abbreviation PSK means.



FlashFeed original diagram · CC-BY-4.0

What DMR Does

Digital Mobile Radio (DMR) is a technique for time-multiplexing two digital voice signals on a single 12.5 kilohertz (kHz) repeater channel.



FlashFeed original diagram · CC-BY-4.0

Inside Packet Transmissions

Packet radio transmissions include a checksum that permits error detection. They include a header containing the call sign of the station receiving the information. They also include automatic repeat request (ARQ) in case of error.

What CW Means

CW, short for continuous wave, is another name for a Morse code transmission.

Digital and non-voice mode names side by side

FT8	a digital mode capable of low signal-to-noise operation
Phase Shift Keying (PSK)	what the abbreviation PSK stands for
International Morse code telegraphy (CW)	another name for a Morse code transmission
National Television System Committee (NTSC)	an analog fast-scan color TV signal
Automatic Packet Reporting System (APRS)	real-time tactical digital communications with a map of station locations
Digital Mobile Radio (DMR)	two digital voice signals on a single 12.5 kilohertz (kHz) repeater channel
Weak Signal communication by K1JT (WSJT) suite, WSJT-X	a software suite for weak-signal work

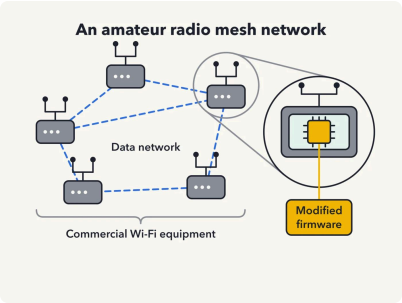
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What WSJT-X Supports

WSJT-X is a software suite for weak-signal work; the name begins with Weak Signal communication by K1JT (WSJT). Its digital mode software supports Earth-Moon-Earth (EME), weak signal propagation beacons and meteor scatter.

How ARQ Fixes Errors

Automatic repeat request (ARQ) is an error correction method in which the receiving station detects errors and sends a request for retransmission.



FlashFeed original diagram · CC-BY-4.0

Amateur Radio Mesh Networks

An amateur radio **mesh network** is an amateur-radio data network using commercial Wi-Fi equipment with modified firmware.

Matched pairs

Each item on the left goes with the one on the right.

Gateway → Links amateur stations to the internet

CW → Another name for a Morse code transmission

Self-test

Answer each question from memory, then check your work against the answer key.

1. Which of the following methods is used to locate sources of noise interference or jamming?

- A Phase locking
- B Radio direction finding
- C Echolocation
- D Doppler radar

2. Which of these items would be useful for a hidden transmitter hunt?

- A Calibrated SWR meter
- B A directional wattmeter
- C A directional antenna
- D All these choices are correct

3. What operating activity involves contacting as many stations as possible during a specified period?

- A Simulated emergency exercises
- B Hidden transmitter hunts
- C Net operations
- D Contesting

4. Which of the following is good practice when contacting another station in a contest?

- A Sending only the minimum information for proper identification and the contest exchange
- B Adding “Please copy” before your exchange
- C Contacting the station twice to be sure that you are in his log
- D Signing only the last two letters of your call if there are many other stations calling

5. What is a grid locator?

- A An instrument for radio direction finding
- B A letter-number designator assigned to a geographic location
- C An instrument for locating faults in power amplifiers
- D A letter-number designator assigned to an azimuth and elevation

6. How is over the air access to Internet Radio Linking Project (IRLP) nodes accomplished?

- A By using Continuous Tone-Coded Squelch System (CTCSS) tone codes
- B By entering the proper internet password
- C By using Dual-Tone Multi-Frequency (DTMF) signals
- D By obtaining a password that is sent via voice to the node

7. What is the Internet Radio Linking Project (IRLP)?

- A A system for informing amateurs in real time of the frequency of active DX stations
- B A system for providing access to websites via amateur radio
- C A technique for measuring signal strength of an amateur transmitter via the internet
- D A technique to connect amateur radio systems, such as repeaters, via the internet

8. What is Voice Over Internet Protocol (VoIP)?

A. A method of delivering voice communications over the internet using digital techniques
B. Measuring transmitter modulation quality using remote sites monitored via the internet
C. Rules for identifying your station when linked over the internet to another station
D. A technique employed to “spot” DX stations via the internet

9. Which of the following protocols enables an amateur station to transmit through a repeater without using a radio to initiate the transmission?

A. D-STAR
B. IRLP
C. EchoLink
D. DMR

10. What is required before using the EchoLink system?

A. Register your call sign and provide proof of license
B. Purchase a license to use the EchoLink software
C. Complete the required EchoLink training
D. At least a General Class license

11. What is an amateur radio station that connects other amateur stations to the internet?

A. A digipeater
B. A beacon
C. A repeater
D. A gateway

12. Which of the following is a digital communications mode?

A. IEEE 802.11
B. All these choices are correct
C. Packet radio
D. FT8

13. What is FT8?

A. A wideband FM voice mode
B. A digital slow-scan TV mode with forward error correction and automatic color compensation
C. An eight-channel multiplex mode for FM repeaters
D. A digital mode capable of low signal-to-noise operation

14. Which of the following operating activities is supported by digital mode software in the WSJT-X software suite?

A. All these choices are correct
B. Weak signal propagation beacons
C. Earth-Moon-Earth
D. Meteor scatter

15. What does the abbreviation "PSK" mean?

A. Pulse Shift Keying
B. Packet Sampled Keying
C. Phase Shift Keying
D. Power Sampled Keying

16. What is CW?

- A Error correction for digital transmission using code words
- B Another name for a Morse code transmission
- C A digital mode used primarily on 2-meter FM
- D A type of electromagnetic propagation

17. What is meant by the term "NTSC?"

- A A special mode for satellite uplink
- B A digital transmission standard for encrypting data
- C An analog fast-scan color TV signal
- D A frame compression scheme for TV signals

18. What kind of data can be transmitted by APRS?

- A Text messages
- B GPS position data
- C Weather data
- D All these choices are correct

19. Which of the following is an application of APRS?

- A Providing real-time tactical digital communications with a map showing station locations
- B Providing information on the number of stations signed into a repeater
- C Automatically showing the number of PACTOR packets sent during a specific time interval
- D Providing voice over internet connection between repeaters

20. Which of the following is included in packet radio transmissions?

- A A checksum that permits error detection
- B All these choices are correct
- C A header that contains the call sign of the station to which the information is being sent
- D Automatic repeat request in case of error

21. What is the role of ARQ in a transmission system?

- A An error correction method where the receiver detects errors and requests retransmission
- B A special transmission format limited to video signals
- C A method of compressing data using autonomous reiterative Q codes prior to final encoding
- D A system used to encrypt command signals to an amateur radio satellite

22. Which of the following describes DMR?

- A An automatic position tracking mode for FM mobiles communicating through repeaters
- B Transmitting on two repeater inputs simultaneously for automatic error correction
- C Automatic computer logging for hands-off logging while operating a vehicle
- D Time-multiplexing two digital voice signals on a single 12.5 kHz repeater channel

23. Which of the following best describes an amateur radio mesh network?

(A) A wide-bandwidth digital voice mode employing DMR protocols

(B) An amateur-radio satellite network using modified commercial satellite TV hardware

(C) An amateur-radio data network using commercial Wi-Fi equipment with modified firmware

(D) An internet linking protocol allowing communication through repeaters around the world

Go deeper

LISTEN Lesson 13 episode 7:04 · FlashFeed Study Notes podcast

WATCH Why Contest Stations Send Less 0:30
In a radio contest, sending less can be the smarter move.

WATCH How Radio Packets Fix Errors 0:26
How does a digital radio message deal with an error on the way?

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/signals-and-emissions-contests-linking-and-digital-modes

STUDY Ham Radio Technician License in the FlashFeed app flashfeedlearningapp.com/packs/ham-radio-technician

LESSON 14 OF 15

Antennas and Feed Lines

Antenna types, polarization and gain · Feed lines, standing waves and connectors

WHAT YOU'LL BE ABLE TO DO

- Explain antenna polarization, gain and loading, and identify which antenna types give the most gain
- Describe how length sets resonant frequency and how common portable, mobile and dipole antennas perform
- Identify the usual impedance of coax and why it is the most common feed line, the main connectors and their weatherproofing, and how feed lines compare
- Explain SWR, feed line loss and the role of an antenna tuner, and name causes of loss and SWR changes

Every station depends on its antenna and on the feed line that carries the signal to it. This lesson covers what makes an antenna concentrate a signal, how antenna length relates to frequency, and how handheld and mobile antennas behave. It then covers the cable and connectors that join the radio to the antenna, and the measure of how well the two are matched. A new licensee needs these ideas to choose equipment sensibly and to spot why a station is performing poorly.

Antenna types, polarization and gain

Beam antennas and gain

A **beam antenna** is an antenna that concentrates signals in one direction. It simply favors one direction over the others.

Antenna gain is the increase in signal strength in a specified direction compared to a reference antenna. It describes how much stronger the signal is in a chosen direction than it would be from the reference antenna.

Among a 5/8 wave vertical, an isotropic antenna (a theoretical reference that radiates equally in all directions), a J pole and a Yagi, the Yagi offers the greatest gain. A new licensee who wants the most signal toward a distant station would therefore pick the Yagi.

Polarization and loading

The **polarization** of an antenna is described by the orientation of its electric field.

Antenna loading is a way of electrically lengthening an antenna by inserting inductors in its radiating elements. The antenna behaves as though it were longer than its physical size.

Length and resonant frequency

Length and resonant frequency are tied together. Shortening a dipole antenna increases its resonant frequency.

A familiar case is the 19-inch-long vertical antenna often used on 2 meters. It works there because it is a resonant quarter-wave.

Handheld and mobile antennas

A handheld radio transceiver usually carries a short flexible antenna. Compared with a full-sized quarter-wave antenna, its disadvantage is low efficiency.

Using a handheld very high frequency (VHF) transceiver inside a vehicle with no externally mounted antenna has its own drawback. Signal strength is reduced by the shielding effect of the vehicle.

For VHF or ultra high frequency (UHF) mobile service, a 5/8-wavelength whip has an advantage over a 1/4-wave antenna: it has more gain.

The dipole pattern

A half-wave dipole antenna radiates its strongest signal broadside to the antenna. A station placed broadside to a dipole gets the strongest signal, and a station off the ends gets less.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)

Feed lines, standing waves and connectors

Coaxial cable

The most common impedance of coaxial cable (coax) used in amateur radio is 50 ohms.

Coax is the most common feed line for amateur antenna systems because it is easy to use and requires few special installation considerations.

Loss in coax

As the frequency of a signal in coaxial cable increases, the loss increases.

Loss in a coaxial feed line comes from each of these sources:

- water intrusion into coaxial connectors;
- high standing wave ratio (SWR);
- multiple connectors in the line.

Comparing feed lines

Two common coaxial cables differ electrically in their loss. RG-213 cable has less loss at a given frequency than RG-58.

Among the feed lines listed (50-ohm flexible coax, multi-conductor unbalanced cable, 75-ohm flexible coax and air-insulated hardline), air-insulated hardline has the lowest loss.

Connectors

Three connector types should be carefully taped for weather protection when used outdoors:

- PL259;
- Bayonet Neill-Concelman (BNC);
- Type N.

The PL-259 is commonly used at HF (high frequency) and VHF frequencies. Because it is not watertight, a PL-259 outdoors needs its tape.

For frequencies above 400 megahertz (MHz), the Type N is the most suitable radio frequency (RF) connector.

SWR and antenna tuners

Standing wave ratio (SWR) is a measure of how well a load is matched to a transmission line.

An **antenna tuner**, also called an antenna coupler, has one major function. It matches the antenna system impedance to the transceiver's output impedance.

Erratic SWR

A loose connection in the antenna or feed line can cause erratic changes in SWR. When the reading jumps around, the connections in the antenna and feed line are the place to look.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus, public release of February 19, 2026 (errata applied)

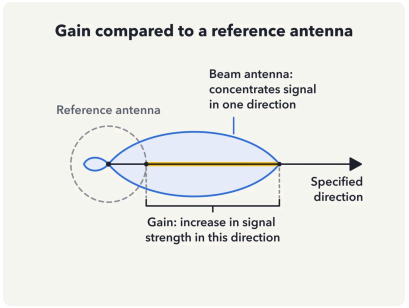
Key facts



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What a beam antenna does

A **beam antenna** concentrates signals in one direction. It favors one direction over the others.



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Antenna gain defined

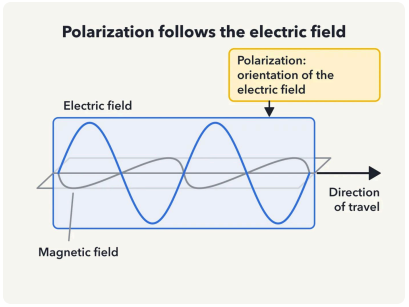
Antenna gain is the increase in signal strength in a specified direction compared to a reference antenna. It describes how much stronger the signal is in a chosen direction.



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The Yagi has the most gain

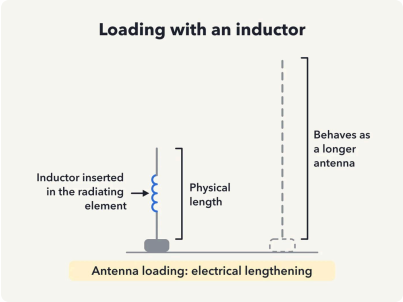
Among a 5/8 wave vertical, an isotropic antenna, a J pole and a **Yagi**, the Yagi offers the greatest gain. It is the pick for the most signal toward a distant station.



FlashFeed original diagram · CC-BY-4.0

How polarization is described

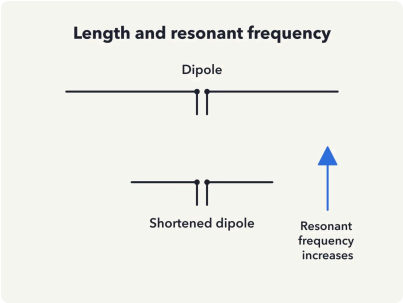
The **polarization** of an antenna is described by the orientation of its electric field.



FlashFeed original diagram · CC-BY-4.0

Antenna loading explained

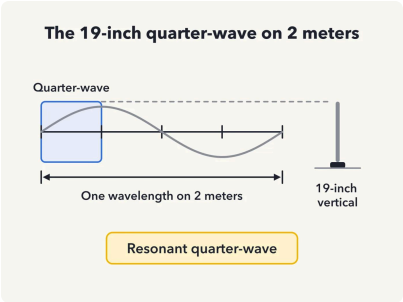
Antenna loading is a way of electrically lengthening an antenna by inserting inductors in its radiating elements. The antenna then behaves as though it were longer than its physical size.



FlashFeed original diagram · CC-BY-4.0

Shorter dipole, higher frequency

Shortening a dipole antenna increases its **resonant frequency**.



FlashFeed original diagram · CC-BY-4.0

The 19-inch 2-meter vertical

A 19-inch-long vertical antenna is often used on 2 meters because it is a resonant **quarter-wave**.



Wikimedia Commons · Jakez · CC BY-SA 3.0

The handheld's short antenna

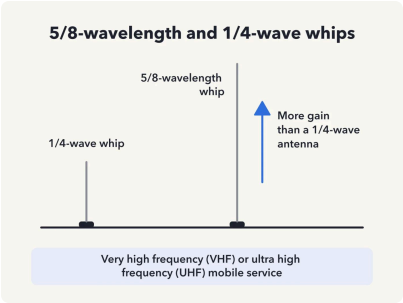
A handheld transceiver's short flexible antenna has **low efficiency** compared with a full-sized quarter-wave antenna.



FlashFeed original diagram · CC-BY-4.0

Handheld inside a vehicle

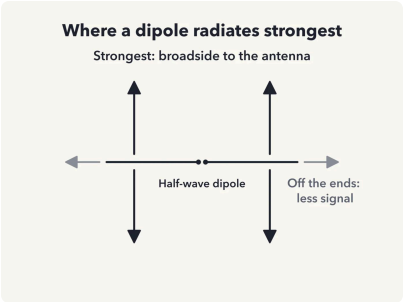
Using a handheld very high frequency (VHF) transceiver inside a vehicle with no externally mounted antenna has a drawback. Signal strength is reduced by the **shielding effect** of the vehicle.



FlashFeed original diagram · CC-BY-4.0

Why a 5/8-wavelength whip

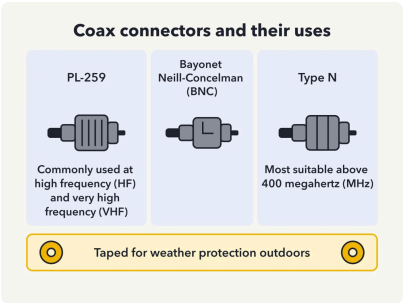
For very high frequency (VHF) or ultra high frequency (UHF) mobile service, a **5/8-wavelength whip** has more gain than a 1/4-wave antenna.



FlashFeed original diagram · CC-BY-4.0

Where a dipole radiates most

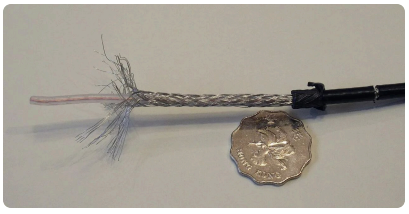
A half-wave **dipole** radiates its strongest signal broadside to the antenna.



FlashFeed original diagram · CC-BY-4.0

Taping connectors outdoors

PL259, Bayonet Neill-Concelman (BNC) and Type N connectors should all be carefully taped for **weather protection** when used outdoors.



Wikimedia Commons · Wtshymanski · CC BY-SA 4.0

Common coax impedance

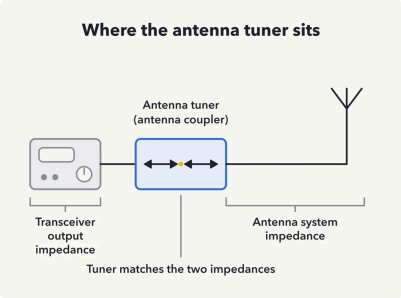
The most common impedance of **coaxial cable** (coax) used in amateur radio is 50 ohms.

Why coax is so common

Coax is the most common **feed line** for amateur antenna systems because it is easy to use and needs few special installation considerations.

What standing wave ratio means

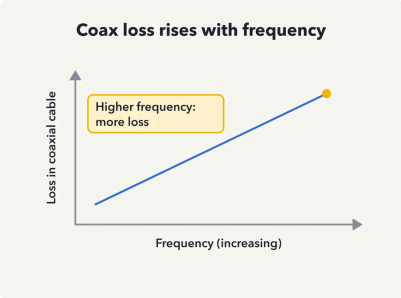
Standing wave ratio (SWR) is a measure of how well a load is matched to a transmission line.



FlashFeed original diagram · CC-BY-4.0

What an antenna tuner does

An **antenna tuner**, or antenna coupler, matches the antenna system impedance to the transceiver's output impedance.



FlashFeed original diagram · CC-BY-4.0

Type N above 400 megahertz

For frequencies above 400 megahertz (MHz), the **Type N** is the most suitable radio frequency (RF) connector.



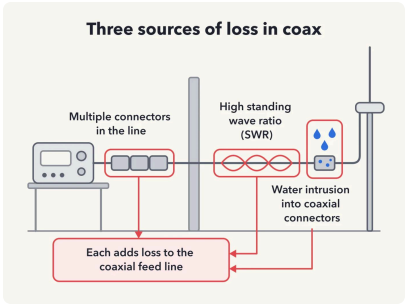
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Where the PL-259 is used

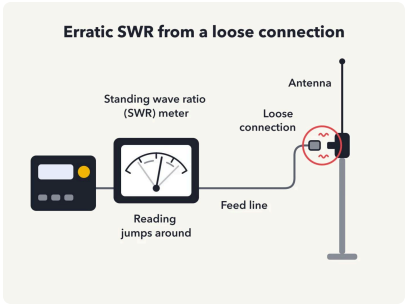
The **PL-259** is commonly used at high frequency (HF) and very high frequency (VHF) frequencies. Because it is not watertight, it needs tape outdoors.



FlashFeed original diagram · CC-BY-4.0

Sources of loss in coax

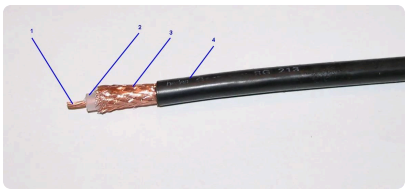
Three things add **loss** to a coaxial feed line: water intrusion into coaxial connectors, high standing wave ratio (SWR), and multiple connectors in the line.



FlashFeed original diagram · CC-BY-4.0

What makes SWR erratic

A **loose connection** in the antenna or feed line can cause erratic changes in standing wave ratio (SWR).



Wikimedia Commons · User Appaloosa on de.wikipedia · CC BY-SA 3.0

RG-213 versus RG-58

RG-213 cable has less loss at a given frequency than RG-58.

Hardline has the lowest loss

Among 50-ohm flexible coax, multi-conductor unbalanced cable, 75-ohm flexible coax and **air-insulated hardline**, the hardline has the lowest loss.

Matched pairs

Each item on the left goes with the one on the right.

Antenna gain → Signal increase vs a reference antenna

Type N connector → Suits frequencies above 400 megahertz

Self-test

Answer each question from memory, then check your work against the answer key.

1. What is a beam antenna?

- A An antenna built from square aluminum beams
- B An omnidirectional antenna invented by Clarence Beam
- C An antenna that focuses the signal into two intense rays
- D An antenna that concentrates signals in one direction

2. Which of the following types of antennas offers the greatest gain?

- A 5/8 wave vertical
- B Isotropic
- C Yagi
- D J pole

3. What is antenna gain?

- A The additional power that is added to the transmitter power
- B The increase in signal strength in a specified direction compared to a reference antenna
- C The increase in impedance on receive or transmit compared to a reference antenna
- D The additional power the antenna needs on a higher frequency

4. Which of the following describes a type of antenna loading?

- A Electrically lengthening by inserting inductors in radiating elements
- B Strengthening the radiating elements of a beam antenna to better resist wind damage
- C Installing a spring in the base of a mobile vertical antenna to make it more flexible
- D Inserting a resistor in the radiating portion of the antenna to make it resonant

5. How is the polarization of an antenna described?

- A By the direction of radiation
- B By the orientation of the electric field
- C By the shape of the driven element
- D By the orientation of the magnetic field

6. Which of the following increases the resonant frequency of a dipole antenna?

- A Shortening it
- B Inserting coils in series with radiating wires
- C Adding capacitive loading to the ends of the radiating wires
- D Lengthening it

7. Why is a 19-inch-long vertical antenna often used on 2 meters?

A It has low RF radiation exposure
B It has high gain
C It is a resonant quarter-wave
D It is a resonant half-wave

8. What is a disadvantage of a handheld radio transceiver's short flexible antenna compared to a full-sized quarter-wave antenna?

A It only works on analog signals, not digital ones
B It transmits only circularly polarized signals
C It is more susceptible to receiver desensitization
D It has low efficiency

9. What is a potential drawback of using a handheld VHF transceiver inside a vehicle that lacks an externally mounted antenna?

A The SWR might decrease, decreasing the signal strength
B Signal strength is reduced due to the shielding effect of the vehicle
C The bandwidth of the antenna will decrease, increasing SWR
D The handheld will overheat due to reflected power in the vehicle

10. What is an advantage of a 5/8-wavelength whip antenna for VHF or UHF mobile service compared to a 1/4-wave antenna?

A It has lower SWR
B It radiates at a higher angle
C It has lower impedance
D It has more gain

11. In which direction does a half-wave dipole antenna radiate the strongest signal?

A Broadside to the antenna
B Equally in all directions
C In the direction of the feed line
D Off the ends of the antenna

12. What is the most common impedance of coaxial cables used in amateur radio?

A 8 ohms
B 600 ohms
C 50 ohms
D 12 ohms

13. Why is coaxial cable the most common feed line for amateur radio antenna systems?

A It can handle more power than any other type of feed line
B It is less expensive than any other type of feed line
C It is easy to use and requires few special installation considerations
D It has less loss than any other type of feed line

14. Which of the following connectors should be carefully taped for weather protection when used outdoors?

A All these choices are correct
B BNC
C PL259
D Type N

15. Which of the following connector types is most suitable as an RF connector for frequencies above 400 MHz?

A PL-259
B DB-25
C RS-213
D Type N

16. Which of the following is true of PL-259 type coax connectors?

A They are watertight
B They are commonly used at HF and VHF frequencies
C They are preferred for microwave operation
D They are a bayonet-type connector

17. What is the electrical difference between RG-58 and RG-213 coaxial cable?

A RG-213 cable has less loss at a given frequency
B RG-58 cable can handle higher power levels
C There is no significant difference between the two types
D RG-58 cable has two shields

18. Which of the following types of feed line has the lowest loss?

A 50-ohm flexible coax
B Air-insulated hardline
C 75-ohm flexible coax
D Multi-conductor unbalanced cable

19. What is the major function of an antenna tuner (antenna coupler)?

A It automatically selects the proper antenna for the frequency band being used
B It allows an antenna to be used on both transmit and receive
C It matches the antenna system impedance to the transceiver's output impedance
D It helps a receiver automatically tune in weak stations

20. What is standing wave ratio (SWR)?

A The transmitter efficiency ratio
B An indication of the quality of your station's ground connection
C The ratio of amplifier power output to input
D A measure of how well a load is matched to a transmission line

21. What happens as the frequency of a signal in coaxial cable is increased?

A The characteristic impedance decreases
B The characteristic impedance increases
C The loss increases
D The loss decreases

22. Which of the following is a source of loss in coaxial feed line?

A Water intrusion into coaxial connectors
B All these choices are correct
C High SWR
D Multiple connectors in the line

23. What can cause erratic changes in SWR?

A Loose connection in the antenna or feed line
B Local thunderstorm
C Overload from a strong local station
D Over-modulation

Go deeper

LISTEN Lesson 14 episode 6:49 · FlashFeed Study Notes podcast

WATCH A 19-Inch Antenna on 2 Meters 0:29
A 19-inch vertical antenna is often used on 2 meters. Why does such a short antenna work?

WATCH When Your Standing Wave Ratio Jumps Around 0:28
Your standing wave ratio, usually called S-W-R, keeps jumping around.

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/antennas-and-feed-lines

STUDY Ham Radio Technician License in the FlashFeed app flashfeedlearningapp.com/packs/ham-radio-technician

LESSON 15 OF 15

Safety

Electrical hazards and battery safety · Antenna and tower safety · Radio frequency exposure

WHAT YOU'LL BE ABLE TO DO

- Identify battery hazards, how current through the body harms it, and how to guard against shock and stored charge in station equipment
- Explain what fuses do and how they are sized, how AC wiring is fused and colored, and how grounds and lightning arresters protect a station
- Describe safe practices for climbing towers, and for keeping antennas clear of power lines and off utility poles
- Explain how to ground a tower for lightning protection, and why guy-line turnbuckles are secured with safety wire
- Explain why RF radiation is non-ionizing, what affects exposure and can cause RF burns, and why exposure limits vary with frequency
- Describe how duty cycle affects RF exposure and how a licensee shows and keeps RF safety compliance

A ham station mixes household-voltage wiring, batteries, power supplies, towers, and radio energy. Each brings its own hazards, and each has well-known precautions. This lesson covers electrical and battery hazards, antenna and tower work, and exposure to radio frequency (RF) energy. A new licensee should know all three, because the station licensee is responsible for ensuring that no person is exposed to RF energy above the Federal Communications Commission (FCC) exposure limits.

Electrical hazards and battery safety

Batteries. A 12-volt storage battery that lacks internal protection circuitry is a hazard because shorting its terminals can cause burns, fire, or an explosion. Rapidly charging or discharging an unprotected battery carries a related hazard: overheating or out-gassing.

Current through the body. Electrical current flowing through the body is a health hazard in three ways, and all three are real:

- It may cause injury by heating body tissue.
- It may disrupt the electrical functions of cells.
- It may cause involuntary muscle contractions.

Guarding against shock. Three habits are good ways to guard against electrical shock at a station, and all three are correct:

- Use three-wire cords and plugs for all alternating current (AC) powered equipment.

- Connect all AC powered station equipment to a common safety ground.
- Ensure that all capacitors used for high-voltage direct current (DC) are fully discharged before working inside equipment.

Stored charge. The capacitor habit matters because a power supply is not safe the instant it is turned off. The hazard that remains is charge stored in its filter capacitors. Turning the supply off does not remove it, so capacitors must be fully discharged before anyone works inside the equipment.

Measuring high voltage. When measuring high voltages with a voltmeter, the key precaution is to ensure that the voltmeter and its leads are rated for use at the voltages being measured.

Fuses. A **fuse** exists to remove power in case of an overload.

A fuse must also be the right size. A 5-ampere fuse should never be replaced with a 20-ampere fuse, because excessive current could cause a fire. The danger is that it allows more current than the circuit was protected for.

Wiring and where to fuse. In the United States, black wire insulation in a three-wire 120-volt AC cable indicates the **hot** circuit.

A fuse or circuit breaker in a 120-volt AC power circuit goes in series with the hot conductor only.

Lightning protection and grounds. A **lightning arrester** in a coaxial feed line is installed on a grounded panel near where the feed lines enter the building.

All external ground rods and earth connections should be bonded together with heavy wire or conductive strap.

Taken together, these points describe a protected station. The wiring is fused on the hot lead and grounded through three-wire cords. The supply is discharged before anyone works inside it. The feed lines are protected by an arrester at the building entrance, and the ground connections are bonded into one system.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus

Antenna and tower safety

Climbing. Three things are required when climbing an antenna tower, and all three are correct:

- Sufficient training on safe tower climbing techniques.
- Appropriate tie-off to the tower at all times.
- An approved climbing harness, always worn.

No circumstance makes it safe to climb a tower without a helper or observer. The rule holds even when no electrical work or no mechanical work is being performed, or when the work is not more than 20 feet above the ground.

Crank-up towers. A crank-up tower must not be climbed unless it is retracted, or mechanical safety locking devices have been installed.

Overhead wires. An important precaution when putting up an antenna tower is to look for and stay clear of any overhead electrical wires.

The minimum safe distance from a power line is stated as a condition on a falling antenna. Enough distance must be allowed so that if the antenna falls, no part of it can come within 10 feet of the power wires.

Utility poles. An antenna should never be attached to a utility pole, because it could contact high-voltage power lines.

Guy-line turnbuckles. A turnbuckle is used to tension a guy line. A safety wire through it has one purpose: to prevent loosening of the turnbuckle from vibration.

Grounding conductors. For lightning protection, ground wires on a tower should have connections that are short and direct. Sharp bends must be avoided in grounding conductors.

Tower grounds. A proper grounding method for a tower is a set of separate eight-foot ground rods for each tower leg, bonded to the tower and to each other.

Who sets grounding requirements. Local electrical codes establish grounding requirements for an amateur radio tower or antenna. Federal Aviation Administration (FAA) tower lighting regulations do not set them, and neither do FCC Part 97 rules. The amateur rules define FAA as the Federal Aviation Administration (§ 97.3).

A safe tower job therefore starts before the climb. The worker checks for overhead wires and arranges a helper or observer. Training, a harness, and constant tie-off are in place, and a crank-up tower is either retracted or locked mechanically. The installation itself uses safety-wired turnbuckles and short, direct ground wires. It also uses bonded ground rods at each leg, built to local electrical codes.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus
- 47 CFR § 97.3 Definitions

Radio frequency exposure

What kind of radiation. Radio signals are **non-ionizing radiation**. RF radiation does not have sufficient energy to cause chemical changes in cells and damage DNA, which separates it from ionizing radiation (radioactivity). That does not make it harmless: exposure is still limited by FCC rules.

What affects exposure. The RF exposure of people near an amateur station antenna depends on three factors, and all three are correct:

- The frequency and power level of the RF field.
- The distance from the antenna to a person.

- The radiation pattern of the antenna.

Frequency and limits. Exposure limits vary with frequency because the human body absorbs more RF energy at some frequencies than at others.

Among the bands 3.5 megahertz (MHz), 50 MHz, 440 MHz, and 1296 MHz, the 50 MHz band has the lowest maximum permissible exposure for RF safety.

Duty cycle. Duty cycle during the averaging time for RF exposure is the percentage of time that a transmitter is transmitting. It is one of the factors used to determine safe exposure levels because it affects the average exposure to radiation.

A lower duty cycle means less average exposure. When duty cycle changes from 100 percent to 50 percent, the allowable power density for RF safety increases by a factor of 2. Adjustment for a lower duty cycle is allowed.

RF burns. Touching an antenna during a transmission creates the hazard of an **RF burn** to skin.

Showing compliance. Any of three methods is acceptable to determine whether a station complies with FCC RF exposure regulations, and all three are correct:

- Calculation based on FCC Office of Engineering and Technology (OET) Bulletin 65.
- Calculation based on computer modeling.
- Measurement of field strength using calibrated equipment.

Staying in compliance. A station stays in compliance by re-evaluating it whenever an item in the transmitter or antenna system is changed.

Reducing exposure. Relocating antennas can reduce exposure to RF radiation.

Responsibility. The station licensee is responsible for ensuring that no person is exposed to RF energy above the FCC exposure limits.

In practice, a licensee considers the frequency, power, distance, and antenna pattern, and accounts for duty cycle when averaging. The licensee then checks compliance by calculation, modeling, or measurement. A change to the transmitter or antenna calls for a fresh evaluation, and if exposure is too high, relocating an antenna is one way to lower it.

Sources

- 2026-2030 Technician Class (Element 2) Question Pool and Syllabus

Key terms

FAA

Federal Aviation Administration

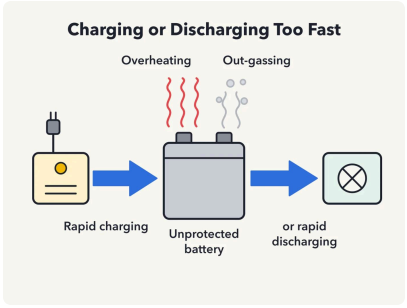
Key facts



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Shorted Battery Terminals

A 12-volt storage battery that lacks internal protection circuitry is a hazard. **Shorting the terminals** can cause burns, fire, or an explosion.



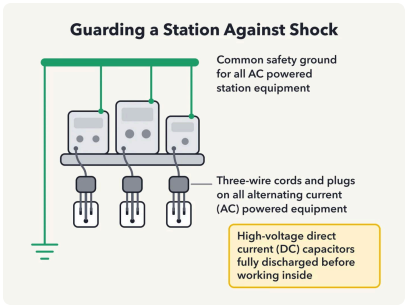
FlashFeed original diagram · CC-BY-4.0

Fast Charging Hazard

Rapidly charging or discharging an unprotected battery carries a hazard of **overheating or out-gassing**. It is a related risk to shorting the terminals.

Current Through the Body

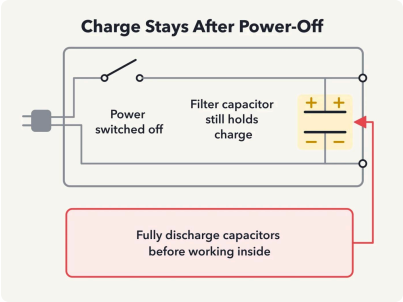
Electrical current flowing through the body is a health hazard in three ways. It may cause injury by heating body tissue. It may disrupt the electrical functions of cells. It may also cause involuntary muscle contractions.



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Three Ways to Guard Against Shock

Use three-wire cords and plugs for all alternating current (AC) powered equipment. Connect all AC powered station equipment to a common **safety ground**. Ensure that capacitors used for high-voltage direct current (DC) are fully discharged before working inside equipment.



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Danger After Power-Off

A power supply is not safe the instant it is turned off. The hazard that remains is **charge stored** in its filter capacitors. Capacitors must be fully discharged before anyone works inside the equipment.

> ### Measuring High Voltage
>
> When measuring high voltages, the key precaution is to ensure that the voltmeter and its leads are **rated** for the voltages being measured.



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What a Fuse Does

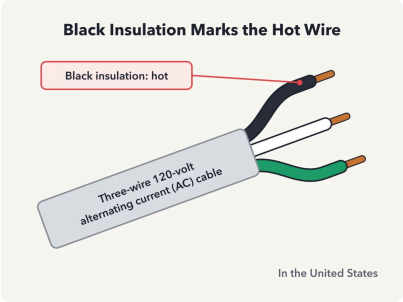
A **fuse** exists to remove power in case of an overload.



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Never Upsize a Fuse

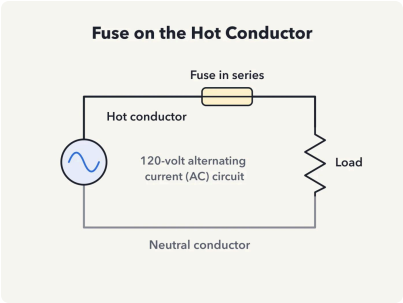
A 5-ampere fuse should never be replaced with a 20-ampere fuse, because **excessive current** could cause a fire. The larger fuse allows more current than the circuit was protected for.



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Black Wire Is Hot

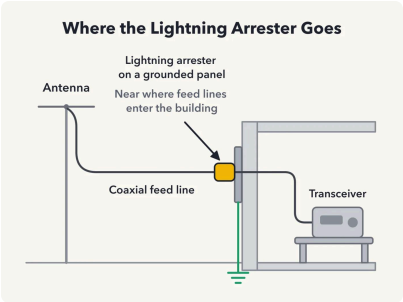
In the United States, black wire insulation in a three-wire 120-volt alternating current (AC) cable indicates the **hot** circuit.



FlashFeed original diagram · CC-BY-4.0

Where to Fuse 120-Volt AC

A fuse or circuit breaker in a 120-volt alternating current (AC) power circuit goes **in series** with the hot conductor only.



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Lightning Arrester Location

A **lightning arrester** in a coaxial feed line is installed on a grounded panel near where the feed lines enter the building.

Bond All Ground Rods

All external ground rods and earth connections should be **bonded** together with heavy wire or conductive strap.

Short, Direct Ground Wires

For lightning protection, ground wires on a tower should have connections that are **short and direct**. Sharp bends must be avoided.

Requirements for Climbing

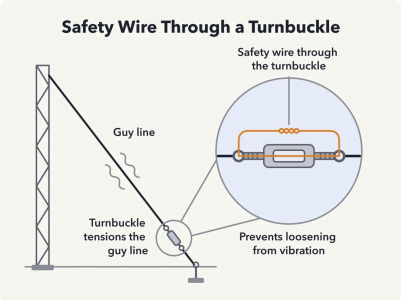
Three things are required when climbing an antenna tower. The climber needs sufficient training on safe climbing techniques. Appropriate **tie-off** to the tower is needed at all times. An approved climbing harness must always be worn.

Never Climb Without a Helper

No circumstance makes it safe to climb a tower without a **helper or observer**. Doing no electrical work, doing no mechanical work, or working no more than 20 feet up does not change this.

Watch for Overhead Wires

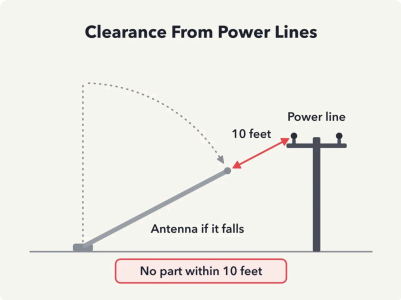
An important precaution when putting up an antenna tower is to look for and stay clear of any **overhead electrical wires**.



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Turnbuckle Safety Wire

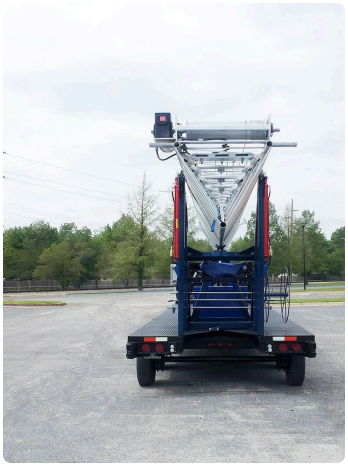
A **turnbuckle** is used to tension a guy line. A safety wire through it has one purpose: to prevent loosening of the turnbuckle from vibration.



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Distance From Power Lines

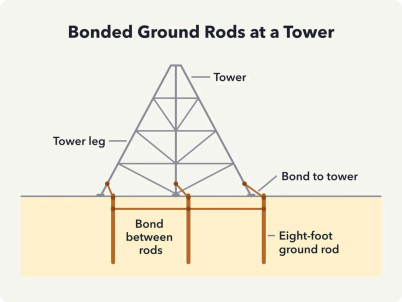
The minimum safe distance from a power line is a condition on a falling antenna. Enough distance must be allowed so that if the antenna falls, no part of it can come within **10 feet** of the power wires.



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Crank-Up Tower Rule

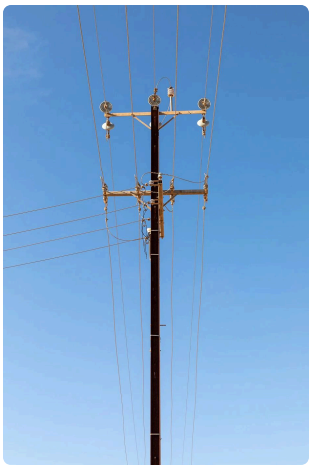
A **crank-up tower** must not be climbed unless it is retracted, or mechanical safety locking devices have been installed.



FlashFeed original diagram · CC-BY-4.0

Grounding a Tower

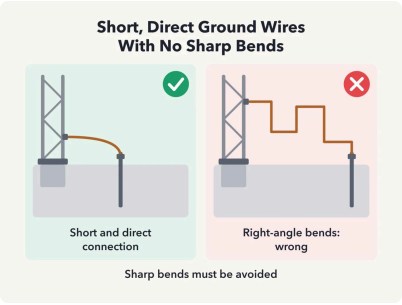
A proper grounding method for a tower is a set of separate **eight-foot ground rods** for each tower leg, bonded to the tower and to each other.



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No Antennas on Utility Poles

An antenna should never be attached to a **utility pole**, because it could contact high-voltage power lines.



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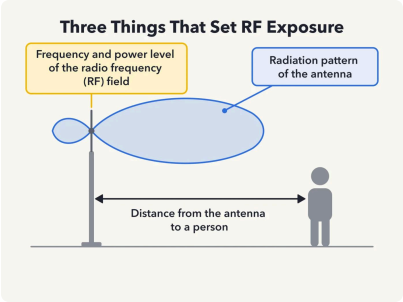
Avoid Sharp Bends

Sharp bends must be avoided in grounding conductors used for lightning protection.

> ### Who Sets Grounding Rules
>
> **Local electrical codes** establish grounding requirements for an amateur radio tower or antenna.

> ### Radio Signals Are Non-Ionizing
>
> As **non-ionizing radiation**, radio signals lack the energy to cause chemical changes in cells and damage DNA, unlike ionizing radiation (radioactivity). That does not make them harmless: Federal Communications Commission rules still limit exposure.

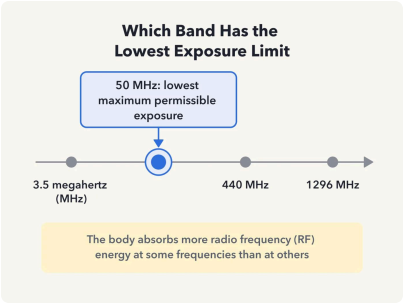
> ### Radio Frequency vs. Ionizing Radiation
>
> Radio frequency (RF) radiation differs from ionizing radiation (radioactivity). It does not have sufficient energy to cause chemical changes in cells and damage DNA. That does not make it harmless, because RF exposure is still limited.



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What Affects Exposure

The radio frequency (RF) exposure of people near an amateur antenna depends on three factors. These are the frequency and power level of the field, the distance from the antenna to a person, and the **radiation pattern** of the antenna.



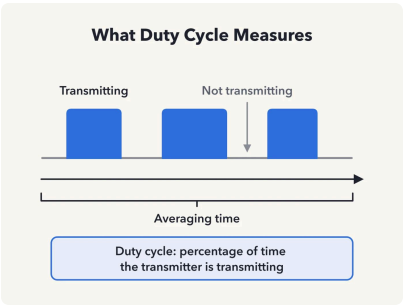
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Why Limits Vary With Frequency

Exposure limits vary with frequency because the human body **absorbs** more radio frequency (RF) energy at some frequencies than at others.

Lowest Permissible Exposure Band

Among 3.5 megahertz (MHz), 50 MHz, 440 MHz, and 1296 MHz, the **50 MHz** band has the lowest maximum permissible exposure for radio frequency (RF) safety.



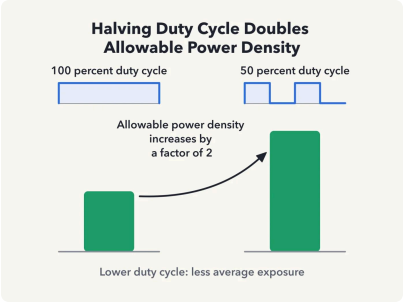
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What Duty Cycle Means

Duty cycle during the averaging time for radio frequency (RF) exposure is the percentage of time that a transmitter is transmitting.

Why Duty Cycle Matters

Duty cycle is one of the factors used to determine safe radio frequency (RF) exposure levels. It matters because it affects the **average exposure** to radiation. A lower duty cycle means less average exposure.



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Duty Cycle and Power Density

When duty cycle changes from 100 percent to 50 percent, the **allowable power density** for radio frequency (RF) safety increases by a factor of 2. An adjustment for a lower duty cycle is allowed.

Touching a Transmitting Antenna

Touching an antenna during a transmission creates the hazard of a radio frequency (RF) **burn to skin**.

Ways to Show Compliance

Any of three methods is acceptable to show a station complies with Federal Communications Commission (FCC) radio frequency (RF) exposure regulations. These are calculation based on FCC Office of Engineering and Technology (OET) Bulletin 65, **computer modeling**, and measurement of field strength with calibrated equipment.

Staying in Compliance

A station stays in compliance by **re-evaluating** it whenever an item in the transmitter or antenna system is changed.

Reducing RF Exposure

Relocating antennas can reduce exposure to radio frequency (RF) radiation.

Who Is Responsible

The **station licensee** is responsible for ensuring that no person is exposed to radio frequency (RF) energy above the Federal Communications Commission (FCC) exposure limits.

Matched pairs

Each item on the left goes with the one on the right.

Black 120-volt wire → Hot, in a 120-volt alternating current (AC) cable

Tower ground rods → Eight feet, one per leg, bonded

Duty cycle → Percent of time a radio frequency (RF) transmitter transmits

Self-test

Answer each question from memory, then check your work against the answer key.

1. Which of the following is a safety hazard of a 12-volt storage battery that lacks internal protection circuitry?

- A RF emissions from a nearby transmitter can cause the electrolyte to emit poison gas
- B All these choices are correct
- C Shorting the terminals can cause burns, fire, or an explosion
- D Touching both terminals with your hands can cause electrical shock

2. What hazard exists when rapidly charging or discharging an unprotected battery?

- A Excess output ripple
- B Electric shock
- C Overvoltage
- D Overheating or out-gassing

3. What health hazard is posed by electrical current flowing through the body?

- A All these choices are correct
- B It may cause involuntary muscle contractions
- C It may disrupt the electrical functions of cells
- D It may cause injury by heating body tissue

4. What is a good way to guard against electrical shock at your station?

- A Connect all AC powered station equipment to a common safety ground
- B All these choices are correct
- C Use three-wire cords and plugs for all AC powered equipment
- D Fully discharge all high-voltage DC capacitors before working inside equipment

5. What hazard exists in a power supply immediately after turning it off?

- A Voltage transients from kickback diodes
- B Charge stored in filter capacitors
- C Leakage flux in the power transformer
- D Circulating currents in the dc filter

6. Which of the following precautions should be taken when measuring high voltages with a voltmeter?

- A Ensure that the voltmeter is set to the correct frequency
- B Ensure that the voltmeter has very low impedance
- C Ensure that the circuit is grounded through the voltmeter
- D Ensure that the voltmeter and its leads are rated for use at the voltages being measured

7. What is the purpose of a fuse in an electrical circuit?

- A All these choices are correct
- B To limit current and prevent shocks
- C To remove power in case of an overload
- D To prevent power supply ripple from damaging a component

8. Why should a 5-ampere fuse never be replaced with a 20-ampere fuse?

A. Excessive current could cause a fire
B. The power supply ripple would greatly increase
C. Higher current fuse voltage drop could result in excessively low voltage to the device
D. The larger fuse would be likely to blow because it is rated for higher current

9. In the United States, what circuit does black wire insulation indicate in a three-wire 120 V AC cable?

A. Equipment ground
B. Neutral
C. Hot
D. Negative

10. Where should a fuse or circuit breaker be installed in a 120V AC power circuit?

A. In parallel with the hot conductor only
B. In series with the hot and neutral conductors
C. In parallel with the hot and neutral conductors
D. In series with the hot conductor only

11. Where should a lightning arrester be installed in a coaxial feed line?

A. At the output connector of a transceiver
B. On a grounded panel near where feed lines enter the building
C. At the AC power service panel
D. At the antenna feed point

12. What should be done to all external ground rods or earth connections?

A. Bond them together with heavy wire or conductive strap
B. Waterproof them with silicone caulk or electrical tape
C. Keep them as far apart as possible
D. Tune them for resonance on the lowest frequency of operation

13. What is required when climbing an antenna tower?

A. All these choices are correct
B. Use appropriate tie-off to the tower at all times
C. Always wear an approved climbing harness
D. Have sufficient training on safe tower climbing techniques

14. Under what circumstances is it safe to climb a tower without a helper or observer?

A. When no electrical work is being performed
B. When the work being done is not more than 20 feet above the ground
C. When no mechanical work is being performed
D. Never

15. Which of the following is an important safety rule to remember when using a crank-up tower?

A. This type of tower must never be painted
B. All these choices are correct
C. This type of tower can't be climbed unless retracted or mechanical safety locks are used
D. This type of tower must never be grounded

16. Which of the following is an important safety precaution to observe when putting up an antenna tower?

A. Wear a ground strap connected to your wrist at all times
B. Look for and stay clear of any overhead electrical wires
C. Insulate the base of the tower to avoid lightning strikes
D. All these choices are correct

17. What is the minimum safe distance from a power line to allow when installing an antenna?

A. 1/2 wavelength at the operating frequency
B. Add antenna height to power line height and multiply by 1.5
C. The height of the power line above ground
D. Enough that a falling antenna cannot come within 10 feet of the power wires

18. Why should you avoid attaching an antenna to a utility pole?

A. All these choices are correct
B. The antenna will not work properly because of induced voltages
C. The antenna could contact high-voltage power lines
D. The antenna may unbalance the power transformer, causing power fluctuations

19. Which of the following is good practice when installing ground wires on a tower for lightning protection?

A. Ensure that connections are short and direct
B. Put a drip loop in the ground connection to prevent water damage to the ground system
C. Make sure all ground wire bends are right angles
D. All these choices are correct

20. Which of the following is true when installing grounding conductors used for lightning protection?

A. Wires must be carefully routed with precise right-angle bends
B. Sharp bends must be avoided
C. Use only non-insulated wire
D. Common grounds must be avoided

21. Which is a proper grounding method for a tower?

A. A ferrite-core RF choke connected between the tower and ground
B. A connection between the tower base and a cold-water pipe
C. A single four-foot ground rod, driven into the ground no more than 12 inches from the base
D. Separate eight-foot ground rods for each tower leg, bonded to the tower and each other

22. Which of the following establishes grounding requirements for an amateur radio tower or antenna?

A. Local electrical codes
B. FCC Part 97 rules
C. UL recommended practices
D. FAA tower lighting regulations

23. What is the purpose of a safety wire through a turnbuckle used to tension guy lines?

A Secure the guy line if the turnbuckle breaks
B Prevent loosening of the turnbuckle from vibration
C Provide a ground path for lightning strikes
D Provide an ability to measure for proper tensioning

24. What type of radiation are radio signals?

A Ionizing radiation
B Gamma radiation
C Non-ionizing radiation
D Alpha radiation

25. How does RF radiation differ from ionizing radiation (radioactivity)?

A RF radiation is limited in range to a few feet
B RF radiation lacks enough energy to cause chemical changes in cells and damage DNA
C RF radiation can only be detected with an RF dosimeter
D RF radiation is perfectly safe

26. Which of the following bands has the lowest maximum permissible exposure for RF safety?

A 3.5 MHz
B 440 MHz
C 1296 MHz
D 50 MHz

27. Why do exposure limits vary with frequency?

A The human body absorbs more RF energy at some frequencies than at others
B Higher frequency RF fields are transient in nature
C Lower frequency RF fields do not penetrate the human body
D Lower frequency RF fields have more energy than higher frequency fields

28. What factors affect the RF exposure of people near an amateur station antenna?

A Distance from the antenna to a person
B Frequency and power level of the RF field
C All these choices are correct
D Radiation pattern of the antenna

29. What hazard is created by touching an antenna during a transmission?

A RF burn to skin
B All these choices are correct
C Exposure to ionizing radiation
D Electrocution

30. How does the allowable power density for RF safety change if duty cycle changes from 100 percent to 50 percent?

A There is no adjustment allowed for lower duty cycle
B It increases by a factor of 3
C It decreases by 50 percent
D It increases by a factor of 2

31. Why is duty cycle one of the factors used to determine safe RF radiation exposure levels?

A It affects the peak exposure to radiation
B It affects the average exposure to radiation
C It takes into account the antenna feed line loss
D It takes into account the thermal effects of the final amplifier

32. What is the definition of duty cycle during the averaging time for RF exposure?

A The difference between the lowest and highest power output of a transmitter
B The percentage of time that a transmitter is not transmitting
C The percentage of time that a transmitter is transmitting
D The difference between the PEP and the average power output of a transmitter

33. Which of the following is an acceptable method to determine whether your station complies with FCC RF exposure regulations?

A All these choices are correct
B By measurement of field strength using calibrated equipment
C By calculation based on FCC OET Bulletin 65
D By calculation based on computer modeling

34. How can you make sure your station stays in compliance with RF safety regulations?

A By informing the FCC of any changes made in your station
B By making sure your antennas have low SWR
C By using only Underwriter Laboratories approved transmitting equipment
D By re-evaluating the station whenever an item in the transmitter or antenna system changes

35. Which of the following actions can reduce exposure to RF radiation?

A Increase the duty cycle
B All these choices are correct
C Relocate antennas
D Relocate the transmitter

36. Who is responsible for ensuring that no person is exposed to RF energy above the FCC exposure limits?

A The FCC
B The station licensee
C Anyone who is near an antenna
D The local zoning board

Go deeper

LISTEN Lesson 15 episode 7:06 · FlashFeed Study Notes podcast

WATCH Stored Charge After Switch-Off 0:29
You switch off a power supply and assume it is safe to open. It isn't, not yet.

WATCH The Helper Rule for Tower Climbs 0:26
Could you climb a tower alone, if the job is small? Never. Not without a helper.

ONLINE This lesson on the web flashfeedlearningapp.com/study-guides/ham-radio-technician/safety

STUDY Ham Radio Technician License in the FlashFeed app flashfeedlearningapp.com/packs/ham-radio-technician

Answer key

Lesson 1: The Rules: Licenses, Bands and Call Signs

1. B Advancing skills in the technical and communication phases of the radio art

Advancing skills in the technical and communication phases of the radio art is one of the service's stated principles. The other options are not among them.

2. D The FCC

The Federal Communications Commission (FCC) regulates and enforces the amateur rules. Homeland Security does not. ARRL stands for American Radio Relay League.

3. C Willful or malicious interference

Willful or malicious interference with any radio communication or signal is prohibited. VHF stands for very high frequency.

4. A It is encouraged when using phone emissions

A phonetic alphabet is encouraged on phone to aid correct identification. It is not required for emergency messages or foreign contacts. FCC stands for Federal Communications Commission.

5. C An amateur station located more than 50 km above Earth's surface

Height decides it: a space station is an amateur station more than 50 km above Earth's surface. FCC stands for Federal Communications Commission.

6. B Email from the FCC with a link to download the license grant

The official notice is a Federal Communications Commission (FCC) email with a link to download the license grant. USPS stands for United States Postal Service.

7. D The license appears in the FCC ULS database

The license appearing in the Universal Licensing System (ULS) database proves the grant. A printed examination certificate does not. FCC stands for Federal Communications Commission and NCVEC stands for National Conference of Volunteer Examiner Coordinators.

8. A On ten meters, between 28.200 MHz and 28.300 MHz

Automatically controlled propagation beacons are on ten meters, 28.200 to 28.300 MHz. HF stands for high frequency and FCC stands for Federal Communications Commission.

9. D A Volunteer Frequency Coordinator recognized by local amateurs

A Volunteer Frequency Coordinator recognized by local amateurs recommends repeater and auxiliary channels, not the Federal Communications Commission (FCC).

10. A Local or regional amateurs whose stations are eligible as repeater or auxiliary stations

Amateur operators in the local or regional area whose stations are eligible to be repeater or auxiliary stations select the coordinator. FCC stands for Federal Communications Commission.

11. B Certification of current enrollment by a civil defense organization

A RACES control operator needs a Federal Communications Commission (FCC) amateur license plus civil defense certification of current enrollment. ARRL stands for American Radio Relay League.

12. C 52.525 MHz

The 6-meter band spans 50-54 MHz, so 52.525 MHz is in it.

13. B 2 meters

The 2-meter band spans 144-148 MHz and includes 146.52 MHz.

14. A 28.300 MHz to 28.500 MHz

The Technician phone range on 10 meters is 28.300 to 28.500 MHz. Ranges starting lower or ending higher are not it.

15. D 10-meter band only

Technician high frequency (HF) phone privileges are on the 10-meter band only, not on 80, 40 or 15 meters.

16. C All these choices are correct

Technicians may use digital modes such as FT8 on 10 meters, 6 meters and 2 meters, so all three are correct.

17. A Any amateur with a Technician class or higher license

Any Technician or higher licensee may contact the ISS on very high frequency (VHF) bands. No General license or NASA approval is needed.

18. D 50.0 MHz to 50.1 MHz and 144.0 MHz to 144.1 MHz

50.0 to 50.1 MHz and 144.0 to 144.1 MHz are the segments for continuous wave (CW) only. The other ranges listed are not.

19. B In at least some segment of all these bands

Single sideband (SSB) phone may be used in at least some segment of every amateur band above 50 MHz.

20. C U.S. amateurs may find non-amateur stations there and must avoid interfering with them

Where amateur service is secondary, amateurs may find non-amateur stations and must avoid interfering with them.

21. C All these choices are correct

Display calibration error, sidebands past the edge and frequency drift are all reasons to stay off the band edge.

22. D 200 watts

In their high frequency (HF) segments, Technician operators may not exceed 200 watts peak envelope power (PEP).

23. A 1500 watts

Above 30 MHz, Technicians may use up to 1500 watts peak envelope power (PEP), except for specific restrictions.

24. B Technician, General, Amateur Extra

As of 2026, the Federal Communications Commission (FCC) issues new licenses only for Technician, General and Amateur Extra; no new Novice or Advanced grants are issued.

25. C Any licensed amateur

Any licensed amateur may select a call sign under the vanity rules, whatever the class.

26. A KF1XXX

KF1XXX, two letters, a digit and three letters, is a valid Group D format for a Technician. KA1X and W1XX are not.

27. B Communications incidental to amateur radio purposes and remarks of a personal character

International transmissions are limited to communications incidental to the purposes of the service and personal remarks. FCC stands for Federal Communications Commission.

28. D You may operate from a US-documented vessel with the master's permission

A licensee may operate from a US-documented vessel with the master's permission. No special Federal Communications Commission (FCC) authorization is needed.

29. B As soon as your operator/station license grant appears in the FCC's license database
A new licensee may transmit once the grant appears in the license database of the Federal Communications Commission (FCC), not on holding a CSCE or receiving mail. ARRL stands for American Radio Relay League.

30. D Ten years
An amateur license is normally granted for a 10-year term. FCC stands for Federal Communications Commission.

31. C 90 days
Renewal may be requested no sooner than 90 days before the expiration date.

32. A Two years
An expired license can be renewed during a 2-year grace period, provided the application is received before it ends.

33. C No, you must wait until the license has been renewed
No privileges are conferred until the license is renewed, so transmitting is not allowed during the grace period.

34. A Revocation of the station license or suspension of the operator license
If Federal Communications Commission (FCC) mail is returned undeliverable because of a wrong email address, the station license may be revoked or the operator license suspended.

Lesson 2: The Rules: Operating a Station

1. C Any country that has notified the ITU that it objects to such communications
Only an objection notified to the International Telecommunication Union (ITU) bans contact with a country. A notice to the American Radio Relay League (ARRL), or a ban by the ARRL or International Amateur Radio Union (IARU), does not. FCC stands for Federal Communications Commission.

2. A Broadcasting
Broadcasting stays prohibited even though other one-way uses, like telecommand and telemetry, are allowed.

3. D Transmissions intended for reception by the general public
Broadcasting is defined by its audience: transmissions intended for reception by the general public. FCC stands for Federal Communications Commission.

4. B Only when transmitting control commands to space stations or model craft
Coded messages are barred except control commands to space stations or model craft.

5. A When incidental to an authorized retransmission of manned spacecraft communications
Music on phone is allowed only when incidental to an authorized retransmission of manned spacecraft communications.

6. C Any such language is prohibited
Any obscene or indecent language is prohibited. No word list is involved. FCC stands for Federal Communications Commission.

7. B When selling amateur radio equipment and not on a regular basis
Sale or trade notices are allowed when not done on a regular basis. It is not a flat ban, and profit does not decide it.

8. D When the communication is a part of classroom instruction at an educational institution
Pay is allowed as an incident of teaching with the station in classroom instruction. Employer sales and broadcaster news gathering are not exceptions.

9. D When directly related to the immediate safety of human life or protection of property

The only news-support exception is communications directly related to immediate safety of life or protection of property.

10. B A station sending one-way signals between remote repeater receiver and main transmitter

An auxiliary station sends point-to-point one-way links within a system, such as between a remote repeater receiver and the main transmitter.

11. C When transmitting signals to control model craft

Transmissions directed only to a model craft need no identification, if the transmitter is labeled and power is within 1 watt.

12. A Identify the transmitting station

On-air tests must identify the transmitting station. No Federal Communications Commission (FCC) notice or set hours are required.

13. A Never

A control operator is always required. Automatic control, an absent licensee or auxiliary status does not remove that.

14. C Amateur designated by licensee responsible for transmissions and FCC rules at station

A control operator is designated by the licensee and is responsible for transmissions and rules compliance. It is not simply the speaker or licensee. FCC stands for Federal Communications Commission.

15. B The station licensee

The station licensee designates the control operator. The Federal Communications Commission (FCC), a frequency coordinator or any licensed operator does not.

16. D The control operator and the station licensee

When the control operator differs from the licensee, both are equally responsible. Bystanders are not.

17. D Any amateur allowed to transmit on the satellite uplink frequency

Any amateur allowed to transmit on the uplink frequency may be control operator. No Extra Class license, certification or membership is needed. AMSAT stands for Radio Amateur Satellite Corporation.

18. C The class of operator license held by the control operator

The control operator's license class sets the station's privileges, not the license grant, a coordinator or others present.

19. A At no time

Apart from an emergency, a Technician may never be control operator in an Extra Class segment, even if designated by an Extra Class licensee.

20. B The location at which the control operator function is performed

The control point is where the control operator function is performed, not the antenna, apparatus or mailing address.

21. A Repeater operation

Repeater operation is the standard example of automatic control. Internet control is remote control. CW stands for continuous wave.

22. B Any station

Any station may be remotely controlled, not only repeaters, automatic or digital stations.

23. D Operating the station over the internet

Operating a station over the internet is remote control. Model craft control, an SDR and EME are not.

24. C At any time upon request by an FCC representative

The station and records must be available at any time on a Federal Communications Commission (FCC) representative's request. No notice period or warrant applies.

25. C At least every 10 minutes during and at the end of a communication

A tactical call does not replace the call sign assigned by the Federal Communications Commission (FCC). That call sign is due at least every 10 minutes and at the end.

26. A At least every 10 minutes during and at the end of a communication

The call sign is due at the end of each communication and at least every 10 minutes during it, not every 15 minutes or each transmission.

27. D English

A phone identification must be in English, not another language recognized by the UN or International Telecommunication Union (ITU).

28. B Send the call sign using a CW or phone emission

A phone station may send its call sign by continuous wave (CW) or phone emission. RPT or R indicators are not the required method.

29. D All these choices are correct

An indicator may be set off by the slant mark or a word denoting it, so stroke, slant and slash are all acceptable.

30. C The foreign station must be in a country with which the U.S. has a third-party agreement

The foreign station must be in a country with a third-party agreement with the United States. Citizenship is not a restriction. FCC stands for Federal Communications Commission.

31. B A message from a control operator to another control operator on behalf of another person

Third-party communication is a message between control operators on behalf of another person, not three stations talking.

32. A Repeater station

A repeater simultaneously retransmits another station's transmission on a different channel or channels.

33. B The control operator of the originating station

The originating station's control operator is accountable. The repeater's control operator and owner are not for an inadvertent retransmission. FCC stands for Federal Communications Commission.

34. C The club must have at least four members

A club must be composed of at least four persons. The trustee need not be Extra Class, and ARRL registration is not required.

Lesson 3: Operating Procedures

1. C Plus or minus 600 kHz

Plus or minus 600 kHz is the common repeater offset on 2 meters. Plus or minus 5 MHz belongs to 70 centimeters.

2. A Plus or minus 5 MHz

Plus or minus 5 MHz is the common repeater offset on 70 centimeters. The 600 kHz figure is the 2-meter offset.

3. D The difference between a repeater's transmit and receive frequencies

A repeater listens on one frequency and retransmits on another. The gap between them is the offset.

4. B 146.520 MHz

146.520 MHz is the national calling frequency for frequency modulated (FM) simplex operation on the 2-meter band.

5. B Simplex

A station that sends and receives on the same frequency is operating simplex.

6. D A voluntary guideline for using different modes or activities within an amateur band

A band plan is a voluntary guideline for modes and activities within a band. It goes beyond the privileges the Federal Communications Commission (FCC) grants.

7. A Transmit the other station's call sign followed by your call sign

The responder sends the other station's call sign first, then their own. They do not repeat CQ (calling any station) or start with a report.

8. C Calling any station

CQ means calling any station. It invites anyone who hears it to answer. QSO means communicating directly with a station.

9. B Say the station's call sign, then identify with your call sign

To call a known station on a repeater, say its call sign and then identify with your own. No CQ (calling any station) or break is needed.

10. A The station's call sign followed by the word "listening"

Saying your own call sign followed by the word listening is the customary way to show you are available on a repeater. QSY means changing frequency.

11. D Repeat "CQ" a few times, "this is" and your call sign, then listen; repeat as needed

Repeat CQ (calling any station) a few times, say this is and your call sign, then pause to listen. Repeat as necessary. QTC means messages to send.

12. C To listen on a repeater's input frequency

Reverse lets the operator listen on the repeater's input frequency. It does not change power output.

13. A Repeaters in a network all transmit the signals received by any one repeater

In a linked network, signals received by one repeater are transmitted by all the repeaters in it. APRS stands for Automatic Packet Reporting System.

14. D All these choices are correct

An improper offset, the wrong Continuous Tone-Coded Squelch System (CTCSS) tone and the wrong Digital Coded Squelch (DCS) code are each real causes of being unable to access a repeater you can hear, so all choices are correct.

15. C CTCSS

Continuous Tone-Coded Squelch System (CTCSS) is a sub-audible tone sent with normal voice audio to open a receiver's squelch. DTMF stands for Dual-Tone Multi-Frequency.

16. B DTMF

Dual-Tone Multi-Frequency (DTMF) uses two simultaneous audio tones. Continuous Tone-Coded Squelch System (CTCSS) is a single sub-audible tone. GMRS stands for General Mobile Radio Service and D-STAR stands for Digital Smart Technologies for Amateur Radio.

17. A You are talking too loudly

Audio that drops out on voice peaks means the operator is talking too loudly. A wrong offset does not cause it. FM stands for frequency modulated.

18. C Mute the receiver audio when a signal is not present

Squelch mutes the receiver audio when no signal is present. CW stands for continuous wave and RF stands for radio frequency.

19. D Program your radio with the group's ID or code

A talkgroup is joined by programming the radio with the group's ID or code. No registration is needed. DTMF stands for Dual-Tone Multi-Frequency.

20. B An access code programmed into a DMR transmitter to access a specific repeater

The color code is an access code programmed into a Digital Mobile Radio (DMR) transmitter to reach a specific repeater. It does not set the offset. CODEC stands for coder-decoder.

21. B A DMR identifier that organizes traffic so listeners aren't bothered by other traffic

A talkgroup is an identifier Digital Mobile Radio (DMR) uses to organize traffic, so listeners are not bothered by other traffic.

22. A The stations should negotiate continued use of the frequency

Interfering stations on one frequency should negotiate continued use. Arriving first gives no preemptive rights.

23. C So stations within range of each other can communicate without tying up a repeater

Simplex channels let stations within range talk without tying up a repeater. DX means long distance.

24. D QRM

QRM means receiving interference from other stations. The other choices are QRN (troubled by static), QTH (location) and QSB (fading signals).

25. A QSY

QSY means changing frequency. The other choices are QRU (have you anything for me?), QSL (acknowledging receipt) and QRZ (who is calling me?).

26. C Call the net to order and direct communications between stations checking in

The net control station calls the net to order and directs communications between stations checking in.

27. D Unless reporting an emergency, transmit only when directed by the net control station

Unless reporting an emergency, a participant transmits only when directed by net control. FCC stands for Federal Communications Commission.

28. B Formal messages exchanged by net stations

In net operation, traffic means formal messages exchanged by net stations, not a count of check-ins.

29. B Information needed to track the message

The preamble holds the information needed to track the message.

30. D The number of words or word equivalents in the text portion of the message

Check is the number of words or word equivalents in the text portion of the message.

31. C Spell the words using a standard phonetic alphabet

Spelling unusual words with a standard phonetic alphabet is the technique. Adding Morse code is not.

32. A FCC rules always apply

Federal Communications Commission (FCC) Part 97 rules always apply to an amateur station, including under radio amateur civil emergency service (RACES), Amateur Radio Emergency Service (ARES) or Federal Emergency Management Agency (FEMA) rules.

33. D Yes, but only for the immediate safety of human life or protection of property

Operating outside license frequency privileges is allowed only for the immediate safety of human life or protection of property. FEMA stands for Federal Emergency Management Agency and RACES stands for radio amateur civil emergency service.

34. C An FCC Part 97 amateur service for civil defense communications in national emergencies

RACES is a Federal Communications Commission (FCC) Part 97 amateur radio service for civil defense communications during national emergencies.

35. A Licensed amateurs who registered qualifications and equipment for public service duty

ARES is a group of licensed amateurs who voluntarily registered their qualifications and equipment for public service communications duty.

36. B RACES

Radio amateur civil emergency service (RACES) requires certification by a civil defense agency. Amateur Radio Emergency Service (ARES) is voluntary registration. MARS is the Military Auxiliary Radio System; SKYWARN is the National Weather Service's volunteer severe weather spotter program.

37. B Winlink

Winlink relays messages using email addresses based on amateur callsigns. AMTOR stands for Amateur Teleprinting Over Radio.

Lesson 4: How Radio Waves Travel

1. A Multipath propagation cancels or reinforces signals

Signals arriving by several paths combine at the antenna and cancel or reinforce each other, so moving a few feet changes strength. VHF stands for very high frequency.

2. B Try to find a path that reflects signals to the repeater

When buildings block the direct path, the station can try to find a path that reflects signals to the repeater. SWR stands for standing wave ratio.

3. D Rapid flutter on mobile signals due to multipath propagation

Picket fencing is the rapid flutter on mobile signals caused by multipath propagation.

4. C Absorbs signals, leading to poor reception of weak signals

Vegetation absorbs ultra high frequency (UHF) and microwave signals, so weak signals are received poorly. It does not amplify them.

5. B Precipitation

Precipitation might decrease range at microwave frequencies. Wind, low pressure and cold are not the conditions that do this.

6. A Little effect

Fog or rain has little effect on 10-meter and 6-meter signals: no significant absorption or deflection, and no added range.

7. C Horizontal

Horizontal polarization is normally used for long-distance continuous wave (CW) and single sideband (SSB) contacts on very high frequency (VHF) and ultra high frequency (UHF).

8. D Received signal strength is reduced

Cross-polarized antennas over a line-of-sight path reduce received signal strength. They do not invert sidebands or cause an echo. VHF stands for very high frequency and UHF stands for ultra high frequency.

9. B Either vertical or horizontal antennas may be used to transmit or receive

Ionospheric signals are elliptically polarized, so either vertical or horizontal antennas may be used. FM stands for frequency modulated.

10. C Random combining of signals arriving via different paths

Irregular fading of ionospheric signals is likely caused by random combining of signals arriving via different paths.

11. D Error rates are likely to increase

Multipath makes error rates likely to increase on data transmissions. No fixed rate change is required, and frequency modulated (FM) operation does not cure it.

12. A The ionosphere

The ionosphere is the atmospheric region that can reflect high frequency (HF) radio waves. The stratosphere and troposphere are not.

13. D They are at right angles

The electric and magnetic fields of a radio wave are at right angles to each other.

14. B The orientation of the electric field

Polarization is defined by the orientation of the electric field, not the magnetic field or any ratio.

15. C Electric and magnetic fields

A radio wave has two components: electric and magnetic fields.

16. A Speed of light

In free space a radio wave travels at the speed of light, not the speed of sound.

17. A 300,000,000 meters per second

The speed of light is approximately 300,000,000 meters per second. The 150,000,000 figure and miles per hour figures are wrong.

18. C All radio frequencies travel at the same velocity

Every radio frequency travels at the same velocity in free space, so none is faster than another. UHF stands for ultra high frequency and VHF stands for very high frequency.

19. D Wavelength gets shorter as frequency increases

Wavelength gets shorter as frequency increases.

20. B Wavelength in meters equals 300 divided by frequency in megahertz

Wavelength in meters equals 300 divided by the frequency in megahertz.

21. C The approximate wavelength in meters

Besides frequency, the approximate wavelength in meters identifies a band, as in the 2-meter band.

22. D 30 MHz to 300 MHz

Very high frequency (VHF) runs from 30 MHz to 300 MHz. Kilohertz ranges are wrong.

23. B 300 to 3000 MHz

Ultra high frequency (UHF) runs from 300 to 3000 MHz. A range in kilohertz is not UHF.

24. A 3 to 30 MHz

High frequency (HF) runs from 3 to 30 MHz.

25. C UHF signals are usually not propagated by the ionosphere

Simplex ultra high frequency (UHF) signals are rarely heard beyond the radio horizon because UHF signals are usually not propagated by the ionosphere. FCC stands for Federal Communications Commission.

26. D The atmosphere refracts radio waves slightly

The radio horizon is farther than the visual horizon because the atmosphere refracts radio waves slightly. VHF stands for very high frequency and UHF stands for ultra high frequency.

27. A Long-distance ionospheric propagation is far more common on HF

Long-distance ionospheric propagation is far more common on high frequency (HF) than on very high frequency (VHF) and higher frequencies.

28. B From dawn to shortly after sunset during periods of high sunspot activity

The best time for long-distance 10-meter F region paths is from dawn to shortly after sunset during high sunspot activity.

29. D 6 and 10 meters

At the sunspot peak the 6-meter and 10-meter bands may provide long-distance F region communications. The other bands listed do not.

30. B They are distorted, with a characteristic raspy sound

Very high frequency (VHF) signals received by auroral backscatter are distorted, with a characteristic raspy sound.

31. C Sporadic E

Sporadic E is most commonly associated with occasional strong signals on 10, 6 and 2 meters from beyond the radio horizon.

32. A 6 meters

Meteor scatter is best suited to the 6-meter band.

33. C Knife-edge diffraction

Knife-edge diffraction may let signals travel beyond obstructions between stations. Faraday rotation, quantum tunneling and Doppler shift do not.

34. D Tropospheric ducting

Tropospheric ducting regularly carries very high frequency (VHF) and ultra high frequency (UHF) signals over the horizon to about 300 miles.

35. A Temperature inversions in the atmosphere

Tropospheric ducting is caused by temperature inversions in the atmosphere, not lightning, sunspots or storm updrafts.

Lesson 5: Setting Up and Running a Station

1. D 13.8 volts at 12 amperes

A typical 50-watt output mobile frequency modulated (FM) transceiver runs from a supply rated 13.8 volts at 12 amperes. The 24.0-volt ratings and the 4-ampere rating are wrong for that radio.

2. C To minimize voltage drop when transmitting

Short, heavy-gauge wires minimize voltage drop when transmitting. They are not used for impedance matching, radio frequency (RF) interference or radiative losses. DC stands for direct current.

3. A Divide the battery ampere-hour rating by the average current draw of the equipment

Run time is the battery's ampere-hour rating divided by the equipment's average current draw. Peak power consumption is not used.

4. B Flat copper strap

Flat copper strap is the preferred conductor for bonding at radio frequency (RF). Coax braid, copper-clad steel wire and twisted-pair cable are not preferred.

5. A At the 12-volt battery chassis ground

The negative power return of a mobile transceiver goes at the 12-volt battery chassis ground, not the connector shell, any metal part or the bracket.

6. D In the feed line, between the transmitter and antenna

A radio frequency (RF) power meter goes in the feed line between the transmitter and the antenna, not at the power supply output or in the power cable.

7. C The frequency and power level at which the measurements will be made

An accessory standing wave ratio (SWR) meter is chosen by the frequency and power level of the measurements. Distance, expected SWR and match compensation are not the considerations.

8. B To the audio output and input of a computer running FT8 software

For FT8, the transceiver's audio input and output connect to the audio output and input of a computer running FT8 software.

9. C Receive audio, transmit audio, and transmitter keying

A computer-radio interface for digital modes carries receive audio, transmit audio and transmitter keying. Location data, antenna and direct current (DC) power are not among them. RF stands for radio frequency.

10. D Computer “line in” to transceiver speaker connector

One required connection is the computer's "line in" to the transceiver's speaker connector. "Line out" to the speaker connector is wrong.

11. B Communication with a digital voice or data network

A hotspot gives nearby transceivers communication with a digital voice or data network. It is not an FT8 smartphone setup or a radioteletype (RTTY) device. AFSK stands for audio frequency-shift keying.

12. A A device that assists in manual sending of Morse code

An electronic keyer assists in manual sending of Morse code. It is not an antenna switch, voice-activated switch or interlock.

13. D The keypad or VFO knob

The keypad or the variable frequency oscillator (VFO) knob enters a frequency. The Continuous Tone-Coded Squelch System (CTCSS) or Dual-Tone Multi-Frequency (DTMF) encoder and Automatic Frequency Control do not.

14. A Tunes through a range of frequencies to check for activity

Scanning tunes through a range of frequencies to check for activity. It does not find the antenna's resonant frequency. FM stands for frequency modulated.

15. C Set the squelch threshold so that receiver output audio is on all the time

For a weak frequency modulated (FM) signal, the squelch threshold is set so receiver audio is on all the time. Raising the audio level is not the method.

16. B The audio becomes distorted

A frequency modulated (FM) signal received slightly off frequency sounds distorted, not simply higher or lower in pitch.

17. A The RIT or Clarifier

The receiver incremental tuning (RIT) or clarifier corrects the pitch of a single sideband (SSB) voice that seems too high or low. Automatic gain control (AGC), bandwidth selection and tone squelch do not. CQ means calling any station.

18. B 2400 Hz

For single sideband (SSB), a 2400 Hz receiver filter bandwidth gives the best signal-to-noise ratio. 500, 1000 and 5000 Hz are not the best.

19. C Distorted transmitted audio

Excessive microphone gain distorts the transmitted audio. It does not cause frequency instability, increased standing wave ratio (SWR) or sideband inversion. SSB stands for single sideband.

20. D Permits noise or interference reduction by selecting a bandwidth matching the mode

Choosing a receiver filter bandwidth matching the mode reduces noise or interference. It does not store more frequencies or monitor several modes at once.

21. D Configuration data loaded onto your radio to access repeaters and talkgroups

A Digital Mobile Radio (DMR) code plug is configuration data loaded onto the radio to access repeaters and talkgroups. It is not a cable, upgrade or CODEC.

22. B By entering the group's identification code

A group of stations is selected on a Digital Mobile Radio (DMR) transceiver by entering the group's identification code, not by memory frequencies or a Continuous Tone-Coded Squelch System (CTCSS) tone.

23. A Your call sign

A Digital Smart Technologies for Amateur Radio (D-STAR) transceiver needs the operator's call sign programmed before transmitting. Output power and codec type are not what must be programmed.

Lesson 6: Electrical Principles: Current, Voltage and Units

1. C Amperes

Current is the flow of electrons and is measured in amperes. Volts, watts and ohms are units of other quantities.

2. A Watts

Power is measured in watts. Watt-hours, volts and amperes are not the unit of power.

3. B Hertz

Frequency is measured in hertz. Henry, farad and epicycles per second are not units of frequency.

4. D Current

The flow of electrons in a circuit is called current. Voltage is the difference that causes the flow.

5. A Voltage

A difference in voltage makes electrons move. Ampere-hours, capacitance and inductance do not cause the flow.

6. B Power

Power is the rate at which electrical energy is used. Resistance, current and voltage are different quantities.

7. D They have many free electrons

Metals have many free electrons, which carry current easily. Density, Young's modulus and free protons are not the reason.

8. C Glass

Glass is a good electrical insulator. Sea water, stainless steel and graphite are not good insulators.

9. C Frequency

Frequency is the number of complete cycles per second of an alternating current. Wavelength and the others are not that term.

10. D Current that alternates between positive and negative directions

Alternating current swings between positive and negative directions. Swinging between one direction and zero is not alternating current.

11. A All these choices are correct

Resistance opposes direct current, alternating current and radio frequency (RF) current alike, so each choice is correct.

12. B 1500 milliamperes

Going from amperes to milliamperes multiplies by 1000, so 1.5 amperes is 1500 milliamperes.

13. D 0.5 watts

Milli means one-thousandth, so 500 milliwatts divided by 1000 is 0.5 watts.

14. B 3 amperes

Dividing milliamperes by 1000 gives amperes, so 3000 milliamperes is 3 amperes.

15. C One thousand volts

Kilo means one thousand, so a kilovolt is one thousand volts, not one hundred or one million.

16. A One one-millionth of a volt

Micro means one-millionth, so a microvolt is one one-millionth of a volt.

17. C 1 microfarad

A picofarad is one-millionth of a microfarad, so 1,000,000 picofarads make 1 microfarad.

18. B 1500 kHz

A kilohertz is 1000 hertz, so 1,500,000 hertz is 1500 kHz.

19. A 3525 kHz

A megahertz is 1000 kilohertz, so 3.525 MHz is 3525 kHz.

20. D 28.400 MHz

Moving to the larger unit divides by 1000, so 28400 kHz is 28.400 MHz.

21. B 2.425 GHz

A gigahertz is 1000 megahertz, so 2425 MHz is 2.425 GHz.

22. D 3 dB

Doubling power from 5 watts to 10 watts is a rise of about 3 dB.

23. C -6 dB

Power falling to one quarter, from 12 watts to 3 watts, is a negative value, most closely -6 dB.

24. A 10 dB

Ten times the power, from 20 watts to 200 watts, is 10 dB.

Lesson 7: Electrical Principles: Impedance, Power and Ohm's Law

1. A Capacitance

Capacitance stores energy in an electric field. Inductance is the magnetic-field property, and resistance and frequency are not storage abilities.

2. D Farad

The farad is the unit of capacitance. The henry is for inductance, and the ohm and volt are not capacitance units.

3. C Inductance

Inductance stores energy in a magnetic field. Capacitance is its electric-field counterpart.

4. B Henry

The henry is the unit of inductance. The farad measures capacitance and the ohm is not an inductance unit.

5. A Ohm

Impedance is opposition to alternating current (AC) flow and is measured in ohms. Volt, ampere and coulomb are not impedance units.

6. D The opposition to AC current flow

Impedance is the opposition to alternating current (AC) flow. It is not an inverse of resistance or reactance, nor a power rating.

7. C kHz

Kilohertz is kHz: lowercase k, capital H, lowercase z. The other capitalizations are wrong.

8. B MHz

Megahertz is MHz: capital M, capital H, lowercase z. The lowercase m forms and Mhz are wrong.

9. C P = I x E

In a direct current (DC) circuit, power is current times voltage, P = I x E. Dividing them or squaring the current does not give power.

10. B 138 watts

Power is voltage times current: 13.8 x 10 = 138 watts. 0.7 comes from dividing, 23.8 from adding and 3.8 from subtracting. DC stands for direct current.

11. D 30 watts

Multiply voltage by current: 12 x 2.5 = 30 watts. DC stands for direct current.

12. A 10 amperes

Current is power divided by voltage: 120 / 12 = 10 amperes. DC stands for direct current.

13. D I = E / R

Current is voltage divided by resistance, I = E / R. Multiplying them gives wrong, very large values.

14. A E = I x R

Voltage is current times resistance, E = I x R. Dividing current by resistance is not Ohm's law for voltage.

15. B R = E / I

Resistance is voltage divided by current, R = E / I. Multiplying, adding or subtracting them is wrong.

16. C 30 ohms

Divide voltage by current: 90 / 3 = 30 ohms.

17. C 8 ohms

Divide voltage by current: 12 / 1.5 = 8 ohms.

18. D 3 ohms

Divide voltage by current: 12 / 4 = 3 ohms. Multiplying gives 48, which is not the resistance.

19. B 1.5 amperes

Divide voltage by resistance: 120 / 80 = 1.5 amperes. 9600 comes from multiplying.

20. A 2 amperes

Divide voltage by resistance: 200 / 100 = 2 amperes. 20,000 comes from multiplying.

21. D 10 amperes

Divide voltage by resistance: 240 / 24 = 10 amperes.

22. A 1 volt

Voltage is current times resistance: 0.5 x 2 = 1 volt.

23. B 10 volts

Voltage is current times resistance: 1 x 10 = 10 volts.

24. C 20 volts

Voltage is current times resistance: 2 x 10 = 20 volts.

25. B Series

In a series circuit the current is the same through all components. Parallel circuits share voltage instead.

26. C Parallel

In a parallel circuit the voltage is the same across all components. Series circuits share current instead.

Lesson 8: Electronic Components: Parts and Semiconductors

1. B Resistor

A resistor opposes current flow in a direct current (DC) circuit. An inductor, an inverter and a transformer do not do this job.

2. C Potentiometer

A potentiometer is the part often used as an adjustable volume control, because its resistance can be changed.

3. A Resistance

A potentiometer controls resistance, not inductance, capacitance or field strength.

4. D Capacitor

A capacitor stores energy in an electric field. Resistors, inductors and diodes do not.

5. D Capacitor

A capacitor is built from conductive surfaces separated by an insulator.

6. C Inductor

An inductor stores energy in a magnetic field. Resistors, capacitors and diodes do not.

7. B Inductor

An inductor is typically constructed as a coil of wire. Transistors, capacitors and diodes are not typically coils.

8. A A single circuit is switched between one of two other circuits

A single-pole double-throw (SPDT) switch moves a single circuit between one of two other circuits. Simply opening or closing a circuit is a different switch type.

9. D Single-pole single-throw

In figure T-2, component 3 is a single-pole single-throw switch, not a double-pole or double-throw type.

10. A All these choices are correct

Nickel-metal hydride, lithium-ion and lead-acid are all rechargeable, so all three choices are correct.

11. B Carbon-zinc

Of these four, carbon-zinc is the chemistry that cannot be recharged. Nickel-cadmium, lead-acid and lithium-ion are rechargeable.

12. C It is lower in some diode types than in others

Forward voltage drop is lower in some diode types than in others. It does not mean the diode is defective.

13. A Diode

A diode allows current to flow in only one direction. Resistors, fuses and driven elements do not.

14. D With a stripe

The cathode lead is often marked with a stripe, not the word cathode or the letter C or K.

15. B Anode and cathode

A diode's electrodes are the anode and cathode. Plus and minus, source and drain, and gate and base are not diode electrode names.

16. C Forward current

An LED is a diode that lights with forward current. Reverse current and radio frequency (RF) signals do not make it emit light.

17. B Transistor

A transistor can act as an electronic switch. Varistors, potentiometers and thermistors are not named for that job.

18. A Transistor

A transistor can consist of three regions of semiconductor material. An alternator, triode and pentode are not described that way.

19. D Field-effect

The Field Effect Transistor has a gate, a drain and a source. A bipolar junction transistor has other electrode names.

20. C Field Effect Transistor

FET stands for Field Effect Transistor, not any of the transmitter or electron-based names.

21. B Emitter, base, collector

A bipolar junction transistor has an emitter, base and collector. Signal, bias and power are not its electrode names.

22. C Transistor

A transistor can provide power gain. A transformer, a reactor and a resistor are not named for that job.

23. A All these choices are correct

Gain can compare output to input voltage, current or power, so all three choices are correct meanings.

Lesson 9: Electronic Components: Schematics and Circuits

1. D Schematic

A diagram using standard component symbols is a schematic, not a connection chart, instrumentation system or flow chart.

2. A Component connections

A schematic accurately represents component connections, not wire lengths or physical appearance.

3. B Resistor

Component 1 in figure T-1 is a resistor.

4. C Transistor

Component 2 in figure T-1 is a transistor.

5. B Lamp

Component 3 in figure T-1 is a lamp.

6. C Battery

Component 4 in figure T-1 is a battery.

7. A Capacitor

Component 6 in figure T-2 is a capacitor. IC stands for integrated circuit.

8. D Light emitting diode

Component 8 in figure T-2 is a light emitting diode. IC stands for integrated circuit.

9. A Variable resistor

Component 9 in figure T-2 is a variable resistor.

10. C Transformer

Component 4 in figure T-2 is a transformer.

11. D Variable inductor

Component 3 in figure T-3 is a variable inductor.

12. B Antenna

Component 4 in figure T-3 is an antenna.

13. D Rectifier

A rectifier changes alternating current (AC) into varying direct current (DC); a transformer only changes the AC voltage.

14. A Transformer

A transformer changes 120 V alternating current (AC) to a lower AC voltage.

15. B An electrically-controlled switch

A relay is an electrically-controlled switch, not an amplifier or pass transistor.

16. C Regulator

A regulator controls the amount of voltage from a power supply.

17. B Meter

A meter displays an electrical quantity as a numeric value.

18. A Control the flow of current

A transistor controls the flow of current; it does not light up, supply energy or make radio waves.

19. D Capacitor

A capacitor is combined with an inductor to make a resonant circuit.

20. C An inductor and a capacitor in series or parallel

A tuned circuit is an inductor and a capacitor in series or parallel.

21. C To prevent coupling of unwanted signals to or from the wire

Shielded wire prevents coupling of unwanted signals to or from the wire. DC stands for direct current.

22. A LED

A light-emitting diode (LED) is commonly used as a visual indicator; a field effect transistor (FET) and a Zener diode are not, so "all correct" is wrong.

23. D Integrated circuit

An integrated circuit combines several semiconductors and other components into one package.

Lesson 10: Practical Circuits: Radios and Their Common Problems

1. A Sensitivity

Sensitivity is the ability of a receiver to detect the presence of a signal. Selectivity is a different property: telling signals apart. RF stands for radio frequency.

2. B Selectivity

Selectivity is the ability of a receiver to discriminate between multiple signals, picking one out from several.

3. C Mixer

A mixer converts a signal from one frequency to another. A phase splitter, inverter and amplifier do not.

4. D Oscillator

An oscillator is a circuit that generates a signal at a specific frequency.

5. A Set the receive and transmit frequency

The VFO in a transceiver sets the receive and transmit frequency. CW stands for continuous wave.

6. C Modulation

Modulation is combining speech with a radio frequency (RF) carrier signal.

7. B A device that combines a receiver and transmitter

A transceiver is a device that combines a receiver and a transmitter.

8. D Transverter

A transverter converts the radio frequency (RF) input and output of a transceiver to another band. Filters do not convert frequencies.

9. B Switches transceiver from receive to transmit when grounded

The push to talk (PTT) input switches the transceiver from receive to transmit when grounded. CW stands for continuous wave.

10. A Set the amplifier for proper operation in the selected mode

The switch sets the amplifier for proper operation in the selected mode. It does not change the transmitted signal's mode. SSB stands for single sideband and VHF stands for very high frequency.

11. D An RF power amplifier

A radio frequency (RF) power amplifier added to the output increases transmitted power. A potentiometer and impedance multiplier do not, so all-correct is wrong.

12. C The receiver is unable to reject strong signals outside the AM or FM band

A broadcast receiver hears a ham because it cannot reject strong signals outside the amplitude modulated (AM) or frequency modulated (FM) band. High microphone gain is not the cause.

13. A All these choices are correct

Fundamental overload, harmonics and spurious emissions can each cause radio frequency interference, so all are correct.

14. B Block the amateur signal with a filter at the antenna input of the affected receiver

A filter at the antenna input of the affected receiver blocks the amateur signal. Mode changes are not the answer. FM stands for frequency modulated and SSB stands for single sideband.

15. C Installing a band-reject filter

A band-reject filter can reduce interference from a nearby commercial frequency modulated (FM) station. A preamplifier or shielded cable is not the remedy. RF stands for radio frequency.

16. D Make sure station works properly, doesn't interfere with own radio or TV on same channel

First make sure the station works properly and does not interfere with the operator's own radio or TV on the same channel. FCC stands for Federal Communications Commission.

17. B Be sure all TV feed line coaxial connectors are installed properly

For non-fiber optic cable TV, first be sure all TV feed line coaxial connectors are installed properly.

18. A Talk farther away from the microphone

Over-deviation is cured by talking farther away from the microphone. Talking louder is not the cure. FM stands for frequency modulated.

19. D All these choices are correct

Being off frequency, speaking too loudly or too close to the microphone, and a bad location can each distort repeater audio. All are correct. FM stands for frequency modulated.

20. C High SWR

High standing wave ratio (SWR) might cause low radio frequency (RF) power output from a solid-state transceiver. Low SWR is not a cause.

21. D All these choices are correct

Work with the neighbor to find the device, politely note Federal Communications Commission (FCC) rules, and ensure good amateur practice. All three are correct.

22. C Adding a clip-on ferrite “choke” on mic cable to stop transmitted signal feeding back

A clip-on ferrite choke on the microphone cable keeps the transmitted signal from feeding back into the transmitter. SWR stands for standing wave ratio.

Lesson 11: Practical Circuits: Measuring and Testing

1. B To prevent transmitting signals over the air when making tests

A dummy load lets a transmitter be tested without putting a signal on the air. It does not prevent over-modulation or improve antennas or receivers.

2. C A 50-ohm non-inductive resistor mounted on a heat sink

A typical radio frequency (RF) dummy load is a 50-ohm non-inductive resistor on a heat sink, not a power supply with a relay or an inductive reactance. AC stands for alternating current and DC stands for direct current.

3. A An antenna analyzer

An antenna analyzer shows whether an antenna is resonant at the desired operating frequency. A Q meter and frequency counter are not the right tools. VTVM stands for vacuum-tube voltmeter.

4. D Directional wattmeter

A directional wattmeter can determine standing wave ratio (SWR). A voltmeter and an ohmmeter are not the instruments for that purpose.

5. D 1:1

A standing wave ratio (SWR) of 1:1 means a perfect impedance match between antenna and feed line. 50:50, zero and full scale do not.

6. A Impedance mismatch

A 4:1 standing wave ratio (SWR) reading indicates an impedance mismatch. It is not a good match and not a gain or loss in dB.

7. B To protect the RF output amplifier transistors

Solid-state transmitters cut power at high standing wave ratio (SWR) to protect the radio frequency (RF) output amplifier transistors. Doing so does not lower the SWR. FCC stands for Federal Communications Commission.

8. C It is converted into heat

Power lost in a feed line becomes heat. It does not raise standing wave ratio (SWR), radiate as harmonics or distort the signal.

9. C Moisture contamination

Moisture contamination causes coax failure. Flux, power fluctuation and long duty cycles are not the cause.

10. A Ultraviolet light can damage the jacket and allow water to enter the cable

Ultraviolet light can damage the jacket and let water in, and water is what fails coax. It does not change conductor resistance or mix with radio frequency (RF).

11. B It has less loss per foot

Foam-dielectric coax has less loss per foot than solid-dielectric. It is not better at moisture, voltage breakdown or 50-ohm match.

12. D A voltmeter

A voltmeter measures electric potential, the voltage across a part. An ammeter measures current, an ohmmeter measures resistance, and in radio work a potentiometer is a variable resistor rather than a meter.

13. B An ammeter

An ammeter measures electric current. An ohmmeter, electrometer and voltmeter are not the instrument for it.

14. A Voltage and resistance

A multimeter measures voltage and resistance. Signal strength, noise, impedance and reactance are not its measurements.

15. D In parallel

A voltmeter connects in parallel with the component to measure applied voltage, not in series, quadrature or phase.

16. C In series

A multimeter set to measure current connects in series with the component, not in parallel.

17. A By applying a small current and measuring the resulting voltage

An ohmmeter applies a small current and measures the resulting voltage. It does not use a variable resistor or a variable voltage.

18. D Attempting to measure voltage when using the resistance setting

Trying to measure voltage on the resistance setting can damage a multimeter. The other listed actions do not.

19. B Increasing resistance with time

Across a large, discharged capacitor an ohmmeter shows increasing resistance with time, not decreasing, steady or alternating readings.

20. C Ensure that the circuit is not powered

For in-circuit resistance, the circuit must not be powered. Checking voltages, grounding or frequency are not the precautions.

21. D Acid-core solder

Acid-core solder should not be used for radio and electronic work. Lead-tin, rosin-core and tin-copper are not the types to avoid.

22. C A rough or lumpy surface

A cold tin-lead joint has a rough or lumpy surface. A bright or shiny surface is not its mark.

Lesson 12: Signals and Emissions: Modes and Satellites

1. B Single sideband

Single sideband is a form of amplitude modulation. Spread spectrum, packet radio and PSK are not.

2. D FM or PM

Frequency modulation (FM) or phase modulation (PM) is commonly used for very high frequency (VHF) packet radio. Single sideband (SSB), amplitude modulation (AM) and Phase Shift Keying (PSK) are not the common choice.

3. A FM or PM

Very high frequency (VHF) and ultra high frequency (UHF) voice repeaters commonly use frequency modulation (FM) or phase modulation (PM), not amplitude modulation (AM), single sideband (SSB) or Phase Shift Keying (PSK).

4. C SSB

Single sideband (SSB) is the voice mode often used for long-distance weak-signal contacts on very high frequency (VHF) and ultra high frequency (UHF). FM stands for frequency modulated, DRM stands for Digital Radio Mondiale, and PM stands for phase modulated.

5. B Upper sideband

Upper sideband is the one normally used for single sideband (SSB) on 10 meters, very high frequency (VHF) and ultra high frequency (UHF). HF stands for high frequency.

6. D SSB signals have narrower bandwidth

SSB signals have narrower bandwidth than frequency modulated (FM) signals. The other claims about SSB are wrong. SWR stands for standing wave ratio.

7. C CW

Continuous wave (CW) has the narrowest bandwidth; frequency modulated (FM) voice, single sideband (SSB) voice and slow-scan TV are all wider.

8. A 3 kHz

A typical SSB voice signal is about 3 kHz wide.

9. D 150 Hz

A continuous wave (CW) signal needs about 150 Hz, the narrowest of the signal types.

10. C Between 10 and 15 kHz

Frequency modulated (FM) voice on very high frequency (VHF) repeaters is between 10 and 15 kHz wide.

11. B About 6 MHz

Amplitude modulated (AM) fast-scan TV is about 6 MHz wide.

12. A Only one signal can be received at a time

With frequency modulated (FM) operation, only one signal can be received at a time. Voice quality, tuning and standing wave ratio (SWR) are not the drawbacks.

13. C Health and status of the satellite

Beacons typically send the health and status of the satellite as telemetry.

14. D A transmission from a satellite that contains status information

A beacon is a satellite transmission containing status information, not an antenna, light or reflector.

15. A All these choices are correct

Tracking programs provide maps of the track, pass times with azimuth and elevation, and apparent frequency with Doppler shift. All are correct.

16. B The Keplerian elements

Tracking programs take the Keplerian elements as input; transmitted power and zero-Doppler time are not inputs.

17. A Blocking access by other users

Excessive effective radiated power (ERP) on an uplink blocks access by other users.

18. D Your signal strength on the downlink should be about the same as the beacon

Uplink power is about right when the downlink signal strength is about the same as the beacon. SDR stands for software defined radio.

19. B All these choices are correct

Satellites commonly use single sideband (SSB), frequency modulated (FM) and continuous wave (CW) or data, so all three choices are correct.

20. C The satellite uplink is in the 70-centimeter band and the downlink is in the 2-meter band

U/V mode means uplink in the 70-centimeter band and downlink in the 2-meter band.

21. B Low Earth Orbit, which has a period of around 100 minutes

LEO means Low Earth Orbit, with a period of around 100 minutes.

22. C An observed change in signal frequency from relative motion of satellite and Earth station

Doppler shift is an observed frequency change caused by relative motion between satellite and Earth station.

23. A Rotation of the satellite and its antennas

Spin fading is caused by rotation of the satellite and its antennas.

24. D Anyone

Anyone may receive amateur satellite telemetry; no control operator role or encryption key is needed. AMSAT stands for Radio Amateur Satellite Corporation.

Lesson 13: Signals and Emissions: Contests, Linking and Digital Modes

1. B Radio direction finding

Radio direction finding is the method used to locate sources of noise interference or jamming. Echolocation, Doppler radar and phase locking are not methods for this job.

2. C A directional antenna

A hidden transmitter hunt calls for a directional antenna. A calibrated standing wave ratio (SWR) meter and a directional wattmeter are not the right tools, so "all of these" is wrong.

3. D Contesting

Contesting is contacting as many stations as possible during a specified period. Emergency exercises, nets and transmitter hunts are different activities.

4. A Sending only the minimum information for proper identification and the contest exchange

Good contest practice is sending only the minimum information needed for identification and the exchange. Partial call signs, repeat contacts and "Please copy" are poor practice.

5. B A letter-number designator assigned to a geographic location

A grid locator is a letter-number designator for a geographic location. It is not tied to an azimuth and elevation, and it is not an instrument.

6. C By using Dual-Tone Multi-Frequency (DTMF) signals

IRLP nodes are reached over the air with DTMF signals, not a voice-sent password, an internet password or CTCSS tone codes.

7. D A technique to connect amateur radio systems, such as repeaters, via the internet

IRLP connects amateur radio systems, such as repeaters, via the internet. It does not give website access, report DX (long distance) stations or measure signal strength.

8. A A method of delivering voice communications over the internet using digital techniques

VoIP delivers voice communications over the internet using digital techniques. It is not station identification rules, DX (long distance) spotting or modulation measurement.

9. C EchoLink

EchoLink lets a station transmit through a repeater without using a radio to start the transmission. Internet Radio Linking Project (IRLP), Digital Smart Technologies for Amateur Radio (D-STAR) and Digital Mobile Radio (DMR) are not the answer.

10. A Register your call sign and provide proof of license

EchoLink requires registering a call sign and providing proof of license. Training, a purchased software license and a General Class license are not required.

11. D A gateway

A gateway is a station that connects other amateur stations to the internet. It is not the same thing as a repeater, digipeater or beacon.

12. B All these choices are correct

Packet radio, Institute of Electrical and Electronics Engineers (IEEE) 802.11 and FT8 are all digital communications modes, so all three choices are correct.

13. D A digital mode capable of low signal-to-noise operation

FT8 is a digital mode capable of low signal-to-noise operation, meaning it works with weak signals. It is not a voice, repeater multiplex or slow-scan TV mode. FM stands for frequency modulated.

14. A All these choices are correct

WSJT-X, whose name begins with Weak Signal communication by K1JT (WSJT), supports Earth-Moon-Earth, weak signal propagation beacons and meteor scatter, so each choice is correct.

15. C Phase Shift Keying

PSK stands for Phase Shift Keying. Pulse Shift, Packet Sampled and Power Sampled Keying are wrong.

16. B Another name for a Morse code transmission

Continuous wave (CW) is another name for a Morse code transmission. It is not propagation, a 2-meter frequency modulated (FM) digital mode or code-word error correction.

17. C An analog fast-scan color TV signal

NTSC means an analog fast-scan color TV signal. It is not an encryption standard, a satellite uplink mode or a frame compression scheme.

18. D All these choices are correct

Automatic Packet Reporting System (APRS) can send GPS position data, text messages and weather data, so all three choices are correct.

19. A Providing real-time tactical digital communications with a map showing station locations

Automatic Packet Reporting System (APRS) provides real-time tactical digital communications with a map showing station locations. It does not link repeaters by voice or count stations. PACTOR means a digital mode combining packet and Amateur Teleprinting Over Radio (AMTOR).

20. B All these choices are correct

Packet radio transmissions include a checksum for error detection, a header with the destination call sign and automatic repeat request, so all three are correct.

21. A An error correction method where the receiver detects errors and requests retransmission

Automatic repeat request (ARQ) is error correction in which the receiver detects errors and requests retransmission. It is not a video format, satellite encryption or compression.

22. D Time-multiplexing two digital voice signals on a single 12.5 kHz repeater channel

Digital Mobile Radio (DMR) time-multiplexes two digital voice signals on a single 12.5 kHz repeater channel. It is not position tracking, logging or dual-input error correction. FM stands for frequency modulated.

23. C An amateur-radio data network using commercial Wi-Fi equipment with modified firmware

A mesh network is a data network using commercial Wi-Fi equipment with modified firmware. It is not a Digital Mobile Radio (DMR) voice mode, a satellite network or a linking protocol.

Lesson 14: Antennas and Feed Lines

1. D An antenna that concentrates signals in one direction

A beam antenna concentrates signals in one direction. It is not omnidirectional and does not make two intense rays.

2. C Yagi

Of a 5/8 wave vertical, isotropic, J pole and Yagi, the Yagi offers the greatest gain.

3. B The increase in signal strength in a specified direction compared to a reference antenna

Gain is the increase in signal strength in a specified direction compared to a reference antenna. It adds no transmitter power.

4. A Electrically lengthening by inserting inductors in radiating elements

Loading electrically lengthens an antenna by inserting inductors in its radiating elements. Resistors, springs and stronger elements are not loading.

5. B By the orientation of the electric field

Polarization is described by the orientation of the electric field, not the magnetic field or direction of radiation.

6. A Shortening it

Shortening a dipole raises its resonant frequency. Lengthening, coils and end capacitive loading do not raise it.

7. C It is a resonant quarter-wave

A 19-inch vertical is a resonant quarter-wave on 2 meters, not a half-wave or a high-gain antenna. RF stands for radio frequency.

8. D It has low efficiency

A short flexible handheld antenna has low efficiency compared with a full-sized quarter-wave antenna.

9. B Signal strength is reduced due to the shielding effect of the vehicle

Inside a vehicle without an outside antenna, signal strength is reduced by the vehicle's shielding effect. VHF stands for very high frequency and SWR stands for standing wave ratio.

10. D It has more gain

A 5/8-wavelength whip has more gain than a 1/4-wave antenna, not lower standing wave ratio (SWR) or impedance. VHF stands for very high frequency and UHF stands for ultra high frequency.

11. A Broadside to the antenna

A half-wave dipole radiates its strongest signal broadside, not off the ends or along the feed line.

12. C 50 ohms

The most common impedance of amateur coax is 50 ohms, not 8, 12 or 600.

13. C It is easy to use and requires few special installation considerations

Coax is common because it is easy to use and needs few special installation considerations, not because it beats all others in loss, power or cost.

14. A All these choices are correct

PL259, BNC (usually expanded as Bayonet Neill-Concelman) and Type N connectors should all be carefully taped for weather protection outdoors, so each choice is right.

15. D Type N

Above 400 MHz, the most suitable listed connector is the Type N. RF stands for radio frequency.

16. B They are commonly used at HF and VHF frequencies

The PL-259 is commonly used at high frequency (HF) and very high frequency (VHF). It is not for microwave, not watertight and not bayonet-type.

17. A RG-213 cable has less loss at a given frequency

RG-213 has less loss at a given frequency than RG-58. RG-58 has no second shield and does not handle more power.

18. B Air-insulated hardline

Air-insulated hardline has the lowest loss of the listed feed lines.

19. C It matches the antenna system impedance to the transceiver's output impedance

An antenna tuner matches the antenna system impedance to the transceiver's output impedance.

20. D A measure of how well a load is matched to a transmission line

SWR measures how well a load is matched to a transmission line, not power ratio, efficiency or ground quality.

21. C The loss increases

Coax loss increases as signal frequency increases.

22. B All these choices are correct

Water in connectors, high standing wave ratio (SWR) and multiple connectors are each sources of loss, so all choices are correct.

23. A Loose connection in the antenna or feed line

A loose connection in the antenna or feed line can cause erratic standing wave ratio (SWR). Storms, over-modulation and overload do not.

Lesson 15: Safety

1. C Shorting the terminals can cause burns, fire, or an explosion

Shorting the terminals of an unprotected 12-volt battery can cause burns, fire, or an explosion. Touching both terminals is not the hazard named. RF stands for radio frequency.

2. D Overheating or out-gassing

Rapid charging or discharging of an unprotected battery risks overheating or out-gassing.

3. A All these choices are correct

Current can heat tissue, disrupt the electrical functions of cells, and cause involuntary muscle contractions. All three are real.

4. B All these choices are correct

Three-wire cords, a common safety ground, and fully discharged high-voltage capacitors are all good shock precautions. AC stands for alternating current and DC stands for direct current.

5. B Charge stored in filter capacitors

Turning a supply off does not remove charge stored in its filter capacitors.

6. D Ensure that the voltmeter and its leads are rated for use at the voltages being measured

The meter and its leads must be rated for the voltages measured. Low impedance, grounding through the meter, or a frequency setting are not the precautions.

7. C To remove power in case of an overload

A fuse removes power in case of an overload. It does not limit current to prevent shocks or stop ripple.

8. A Excessive current could cause a fire

A 20-ampere fuse allows more current than the circuit was protected for, so excessive current could cause a fire.

9. C Hot

In the United States, black insulation in a three-wire 120-volt alternating current (AC) cable marks the hot circuit.

10. D In series with the hot conductor only

The fuse or breaker goes in series with the hot conductor only, not both conductors and not in parallel. AC stands for alternating current.

11. B On a grounded panel near where feed lines enter the building

The arrester sits on a grounded panel near where the feed lines enter the building, not at the transceiver, feed point, or alternating current (AC) panel.

12. A Bond them together with heavy wire or conductive strap

External ground rods and earth connections are bonded together with heavy wire or conductive strap.

13. A All these choices are correct

Training, constant tie-off, and an approved harness are all required when climbing a tower.

14. D Never

No circumstance makes solo climbing safe. Doing no electrical or mechanical work, or working no more than 20 feet up, does not change that.

15. C This type of tower can't be climbed unless retracted or mechanical safety locks are used

A crank-up tower may be climbed only when retracted or when mechanical safety locking devices are installed.

16. B Look for and stay clear of any overhead electrical wires

Looking for and staying clear of overhead electrical wires is the precaution. A wrist strap and insulated base are not.

17. D Enough that a falling antenna cannot come within 10 feet of the power wires

The distance must keep every part of a fallen antenna at least 10 feet from the power wires.

18. C The antenna could contact high-voltage power lines

An antenna on a utility pole could contact high-voltage power lines.

19. A Ensure that connections are short and direct

Lightning ground wires should have short, direct connections, and right-angle bends are not good practice.

20. B Sharp bends must be avoided

Sharp bends must be avoided in grounding conductors for lightning protection.

21. D Separate eight-foot ground rods for each tower leg, bonded to the tower and each other

Separate eight-foot rods at each tower leg, bonded to the tower and each other, are a proper method. RF stands for radio frequency.

22. A Local electrical codes

Local electrical codes set tower grounding requirements, not Part 97, Federal Aviation Administration (FAA) lighting rules, or Underwriters Laboratories (UL) practices. FCC stands for Federal Communications Commission.

23. B Prevent loosening of the turnbuckle from vibration

The safety wire prevents loosening of the turnbuckle from vibration. It is not a backup, ground path, or tension gauge.

24. C Non-ionizing radiation

Radio signals are non-ionizing radiation, unlike gamma or alpha radiation.

25. B RF radiation lacks enough energy to cause chemical changes in cells and damage DNA
Radio frequency (RF) lacks the energy to cause chemical changes in cells and damage DNA, though it is not called perfectly safe.

26. D 50 MHz
Of the listed bands, 50 MHz has the lowest maximum permissible exposure. RF stands for radio frequency.

27. A The human body absorbs more RF energy at some frequencies than at others
Limits vary because the body absorbs more radio frequency (RF) energy at some frequencies than others.

28. C All these choices are correct
Frequency and power, distance from the antenna, and antenna radiation pattern all affect exposure. RF stands for radio frequency.

29. A RF burn to skin
Touching an antenna during transmission causes a radio frequency (RF) burn to skin, not electrocution or ionizing exposure.

30. D It increases by a factor of 2
Going from 100 percent to 50 percent duty cycle raises allowable power density by a factor of 2. RF stands for radio frequency.

31. B It affects the average exposure to radiation
Duty cycle matters because it affects the average exposure to radiation. RF stands for radio frequency.

32. C The percentage of time that a transmitter is transmitting
Duty cycle is the percentage of time a transmitter is transmitting, not the time it is idle. RF stands for radio frequency and PEP stands for peak envelope power.

33. A All these choices are correct
Office of Engineering and Technology (OET) Bulletin 65 calculation, computer modeling, and calibrated field-strength measurement are all acceptable.

34. D By re-evaluating the station whenever an item in the transmitter or antenna system changes
Re-evaluating whenever an item in the transmitter or antenna system is changed keeps a station compliant. RF stands for radio frequency, FCC stands for Federal Communications Commission, and SWR stands for standing wave ratio.

35. C Relocate antennas
Relocating antennas can reduce exposure. Increasing duty cycle does not, since duty cycle affects average exposure. RF stands for radio frequency.

36. B The station licensee
The station licensee is responsible for keeping everyone within the Federal Communications Commission (FCC) exposure limits. RF stands for radio frequency.

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