Amateur Radio Basic Qualification – The Essentials

University of Waterloo Amateur Radio Club

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Introduction

These notes were prepared from the Basic Qualification Question Bank for Amateur Radio Operator Certificate Examinations, published by Industry Canada on June 18, 2017. Before using these notes to prepare for an amateur radio license examination, please ensure that you review the official question bank to ensure that you cover any material that has changed since this document was prepared.

This study guide covers 100% of testable material on the Basic Qualification examination, but does not go beyond what is absolutely necessary to know in order to pass the examination. The candidate is encouraged to perform their own research on topics that are not fully covered here.

1 Regulations, Legal, and Safety

1.1 Industry Canada

- Industry Canada is the department that is responsible for the administration of the Radiocommunication Act.
- The Radiocommunication Act grants authority to make "Radiocommunication Regulations" and "Standards for the Operation of Radio Stations in the Amateur Radio Service".
- The Radiocommunication Regulations defines the "amateur radio service". (Note that this is a *different* document from the Radiocommunication Act.)

1.2 Operator Certificates

- There is no fee associated with obtaining an Amateur Radio Operator Certificate.
- An Amateur Radio Operator Certificate is valid for life. (This is actually a relatively recent thing, effective April 1, 2000. Prior to that it was necessary to renew each year and there was an associated fee.)

- Industry Canada requires address information from you when you obtain a radio licence.
- Industry Canada must be notified of any change in postal address.
- The Amateur Radio Operator Certificate should be retained at the address given to Industry Canada, and a copy must be retained at the station (if that is at a different address).
- The holder of a radio authorization shall, at the request of a duly appointed radio inspector, show the radio authorization or a copy thereof to the inspector within 48 hours after the request.

1.3 Breaking the Rules

- Out of band transmissions are prohibited. You are only allowed to operate in designated amateur bands (frequency ranges).
- The sending of false or deceptive signals is prohibited. This includes sending false emergency signals when there is no real emergency.
- A person found guilty of transmitting a false or fraudulent distress signal, or interfering with or obstructing any radio communication without lawful cause, may be liable, on summary conviction, to a penalty of a fine not exceeding $5000, or a prison term of one year, or both.
- No person shall decode an encrypted subscription programming signal without permission of the lawful distributor.
- No person shall, without lawful cause, interfere with or obstruct any radiocommunication.
- The Minister may suspend a radio authorization where the holder has contravened the Act, the Regulations, or the terms and conditions of the authorization. This includes cases where the radio authorization was obtained through misrepresentation.
- If the holder of a radio authorization has failed to comply with a request to pay fees or interest due, the Minister may suspend their radio authorization. This is the *only case* where the Minister may suspend or revoke a radio authorization *without notice*.
- Radio inspectors are not above the law and require a warrant to enter dwellings without the consent of the occupant.

1.4 Basic Qualification

- There are no age limits with respect to eligibility to hold an Amateur Radio Operator Certificate.
- The Basic examination is the first and only examination that must be passed before an Amateur Radio Operator Certificate is issued.
- The holder of a Canadian Radiocommunication Operator General Certificate Maritime (RGMC) may also be issued an Amateur Radio Operator Certificate.
- After obtaining the Basic qualification, additional qualifications may be earned in *any order*.
- The only Morse code qualification available is "5 wpm" (words per minute).
- Candidates to amateur radio certification must have a valid address in Canada. There is no citizenship requirement.
- Holders of a Basic Qualification only cannot transmit on frequencies below 30 MHz (but more on this later).

1.5 Higher Qualifications

- Licensed radio amateurs may install, place in operation, repair, or maintain radio apparatus on behalf of another person if the other person is the holder of a radio authorization to operate in the amateur service. (If the other person *doesn't* have any type of radio operator certificate, they are out of luck – no one may operate on radio equipment on their behalf.)
- Individuals with Advanced Qualification may build transmitting equipment for use in the amateur service. (With Basic Qualification only, transmitting equipment must be either a commercial pre-assembled product or a packaged kit designated for amateur use.)
- Holders of a Morse Code qualification, Basic Qualification with Honours, or Advanced Qualification may transmit on frequencies below 30 MHz.

1.6 Licensing

- Amateur stations must be licensed (i.e. operated by licensed operators) at all times. There are no exemptions in the amateur service.
- Amateur stations may be used to communicate with other similarly licenced stations.

- Radio amateurs may not transmit superfluous signals, or profane or obscene language or messages.
- Radio amateurs may not operate or permit to be operated equipment that is not performing to the Radiocommunication Regulations.
- Radio amateurs may not use equipment to amplify the output of licence-exempt transmitters.

1.7 Communication

- Discussion on amateur bands is limited to messages of a technical nature or personal remarks of relative unimportance.
- Commercial or business use of amateur bands is prohibited.
- Radio amateurs may not broadcast information to the general public.
- False or deceptive amateur signals or communications may not be transmitted.
- Secret codes or ciphers may not be used in the amateur service. New encoding techniques can be used provided they are published in the public domain.
- Procedural signals or "prowords" may be used in the amateur service if they do not obscure the meaning of a message.
- Transmission of commercially recorded material on amateur bands is not allowed. It's recommended to turn down the volume of music playing in the background if you are operating an amateur station.

1.8 Location

- The holder of an Amateur Radio Operator Certificate may operate an amateur radio station *anywhere* in Canada.
- A "beacon" station may transmit one-way communications.
- Installation of a "repeater", or any other radio apparatus which automatically re-transmits radio signals *within the same frequency band*, can only be done by the holder of Basic and Advanced Qualifications.
- Installation of a radio apparatus to be used specifically for an amateur radio club station can only be done by the holder of Basic and Advanced Qualifications.

1.9 Responsibility

- Both the control operator and the station licensee are responsible for the proper operation of an amateur station.
- If you transmit from another amateur's station, both of you are responsible for proper operation.
- Any qualified amateur chosen by the station owner may be the control operator of an amateur station.
- An amateur station must have a control operator whenever the station is transmitting. The control operator must be at the station's control point.
- The owner of an amateur station may permit *any person* to operate the station under the supervision and in the presence of the holder of the operator certificate.

1.10 Interference

- A transmission that disturbs other communications is called "harmful interference".
- You may never deliberately interfere with another station's communications.
- Some amateur radio bands are designed "Amateur Secondary". Amateurs are allowed to use the frequency band only if they do not cause interference to primary users.
- If two amateur stations want to use the same frequency, both station operators have an equal right to operate on the frequency.
- Where interference to the reception of radiocommunications is caused by the operation of an amateur station, the Minister may require that the necessary steps for the prevention of the interference be taken by the radio amateur.
- Radio amateur operation must not cause interference to other radio services operating in the 430 to 450 MHz band and in the 902 to 928 MHz band. (This is because these bands, among others, are designated "Amateur Secondary".)
- The operator of an amateur station may conduct technical experiments, trials, or tests using station apparatus, provided that these experiments do not interfere with other stations.

1.11 Exceptional Circumstances

- In the amateur radio service, it is permissible to broadcast radio communications required for the immediate safety of life of individuals or the immediate protection of property.
- In an emergency situation, a large number of standard regulations cease to apply.
- Amateur radio stations may communicate with *any station* involved in a real or simulated emergency.
- Business communications are still not permitted under any circumstances, even in an emergency.
- If you hear an unanswered distress signal on an amateur band where you do not have privileges to communicate, those privileges are temporarily granted and you should offer assistance if possible.
- Similarly, an amateur radio station in distress may use *any means* of radiocommunication, including transmissions in unqualified bands.
- During a disaster, an amateur station may make transmissions necessary to meet essential communication needs and assist relief operations when normal communication systems are overloaded, damaged, or disrupted.
- In an emergency, *there are no limitations* on the power output that can be used by a station in distress.
- During a disaster, most communications are handled by "emergency nets" using predetermined frequencies in amateur bands. Operators not directly involved with disaster communications are requested to avoid making unnecessary transmissions on or near frequencies being used for disaster communications.
- Messages from a recognized public service agency may be handled by amateur radio stations during peacetime and civil emergencies and exercises.
- It is permissible to interfere with the working of another station if your station is directly involved with a distress situation.

1.12 Message Passing

- No payment of any kind is allowed for third-party messages sent by an amateur station. (If it were allowed, it would count as a commercial service, which cannot be operated with an amateur licence.)

- Radiocommunications transmitted by any amateur station may be divulged or used under any circumstances.
- Radiocommunications, other than broadcasts or amateur transmissions, may be subject to penalties of they are divulged, intercepted, or used. There are a few exceptions: where it is for the purpose of preserving or protecting proprty, or for the prevention of harm to a person; where it is for the purpose of giving evidence in a criminal or civil proceeding in which persons are required to give evidence; or where it is on behalf of Canada, for the purpose of international or national defence or security.

1.13 Identification

- Licenced amateur stations are given a “callsign” that is used to identify the licensee.
- The call sign of a Canadian amateur radio station typically starts with the letters “VA”, “VE”, “VO”, or “VY”.
- Amateur stations transmit their call sign to identify themselves on the air.
- Amateur stations must identify themselves at the beginning and end of a contact, and at least every thirty minutes during communication. (Each station transmits its own call sign at the beginning and end of communications.)
- Unidentified communications are usually not allowed, with the exception of control signals for model crafts.
- Either English or French may be used to identify a Canadian amateur station.

1.14 International Regulations and Third-Party Traffic

- If a non-amateur friend is using your station to talk to someone in Canada, and a foreign station breaks in to talk to your friend, you need to find out if Canada has a third-party agreement with the foreign station’s government to pass radio traffic before communications can continue.
- Radio amateurs may use their stations to transmit international communications on behalf of a third party only if such communications have been authorized by the countries concerned.
- The International Telecommunication Union regulates communication between countries, including international radiocommunication.
- If a country has notified the ITU that it objects to international amateur communications, a person operating a Canadian amateur station is forbidden from contacting them.

- Amateur third-party communications are transmissions of non-commercial or personal messages to or on behalf of a third party.
- International communications on behalf of third parties may only take place if the countries concerned have authorized such communications.
- Messages originated from the Canadian Forces Affiliated Radio Service (CFARS) and messages originated from the United States Military Affiliated Radio System (MARS) do not count as "communications on behalf of a third party".
- There exist a large number of countries with "reciprocal operating arrangements" with Canada. Essentially, what this means is that licenced Canadian amateurs automatically receive qualifications to operate in those countries, and amateurs licenced in those countries automatically receive qualifications to operate in Canada. One such country is the United States; it is *not necessary* for US radio amateurs to obtain a Canadian amateur station licence before operating in Canada.

1.15 Privileged Abilities

- When a station is used by someone other than the owner, the allowed operating privileges are defined by the largest set of privileges *shared* by both the station owner and the control operator. For example, if someone else with additional qualifications operates your station, only the privileges allowed by your qualifications are allowed.
- In order to operate below 30 MHz, you must earn any Morse code qualification, or an Advanced qualification, or attain a mark of 80% or higher on the Basic exam.
- The licensee of an amateur station may operate radio controlled models on all frequencies above 30 MHz.

1.16 Band Plan

- The band plan dictates the range of frequencies that are available for use in the amateur service. Each frequency range, or "band", has different electromagnetic characteristics associated with it – more on these later.
- Bands may also be divided into "sub-bands" for specific purposes. For example, the 144–148 MHz band has a sub-band for voice communications and a sub-band for digital communications.
- It is common practice to refer to bands by their wavelength instead of their frequency range. There is a simple equation that can be used to calculate the approximate operating frequency given the wavelength of a band. The general law is $f = \frac{c}{\lambda}$, where f is the frequency in Hertz, c is the speed of light in meters per second, and λ

is the wavelength in meters. If we wish to express the frequency in megahertz, we can write the constant c as "300 mega-meters per second". Then, keeping the wavelength λ in meters, take the approximate frequency in megahertz to be $f \approx \frac{300}{\lambda}$.

- Now, having said that, the correct value for c is slightly lower than this, so the value for f over-estimates the true value. This is important because on the Basic exam there are several questions which are of the form "The x-metre amateur band corresponds to which of the following frequency ranges?" and for very large or very small values of x the fact that this formula is an approximation can result in finding the wrong answer. So, if you don't feel that it's necessary for you to memorize the entire band plan and the frequency ranges for each named band, remember that the answer from this formula is always an over-estimate. Take the next smallest answer to the frequency you calculate if you don't fall within one of the given ranges. If there are two answers that would include the number you calculate, take the one that includes frequencies lower than your calculated f.

- Let's do an example that you might see on the exam. What's the frequency range for the 20-meter band? Calculate $f \approx \frac{300}{20} = 15$. There are two answers that might match this: one includes 15.000 MHz as the lower bound, and the other includes 14.350 MHz as the upper bound. These are the closest two answers, and the second one (14.000 to 14.350 MHz) turns out to be correct – remember that f *over*approximates the true frequency, so if your calculated f falls on the edge of one of the answers, that answer is wrong.

- There is one important exception to this rule regarding the "15 meter band". The frequency range for this band does not correspond to the given wavelength of the band, even when it is being calculated correctly. If you use the formula here, you will make a mistake; this one needs to be memorized. The 15 meter band corresponds to the 21.000 to 21.450 MHz frequency range.

1.16.1 Bandwidth

- You will learn more about the technical nature of bandwidth in a later section. For now it suffices to know a few basic facts and figures that pertain to regulations.

- The bandwidth of an amateur station is determined by measuring the frequency band occupied by the transmitted signal at a level of 26 dB below the maximum amplitude of that signal. (A 26 dB reduction corresponds to an amplitude that is $\frac{1}{400}$ of the original value.)

- Below 28 MHz, the maximum authorized bandwidth is 6 kHz, with the exception of the frequency range 10.1 to 10.15 MHz, where the maximum authorized bandwidth is 1 kHz.

- The maximum authorized bandwidth in the frequency range of 28 to 29.7 MHz is 20 kHz.
- The maximum authorized bandwidth in the frequency range of 50 to 148 MHz is 30 kHz.
- Bandwidth generally increases with frequency – consult the band plan for details.
- You will need to know the bandwidth required to use several modes of operation (which has implications for which frequency ranges can be used for these modes).
  - CW (Morse telegraphy) – 150 Hz
  - AMTOR/RTTY – 170 to 200 Hz
  - Packet radio – varies depending on the speed of data transfer, but can be done with less than 1000 Hz of bandwidth
  - SSB – 3000 Hz
  - Slow-scan television – 3000 Hz
  - FM – 5000 to 15000 Hz
  - Fast-scan television – 6 MHz

1.17 Transmit Power

- Radio amateurs must use only the minimum legal transmitter power necessary to communicate.
- Transceiver power is measured at the antenna terminals of the transmitter or amplifier.
- The holder of only a Basic qualification may use up to 250 watts of power, or 560 watts "peak equivalent power" (PEP) for single sideband operation.
- With an Advanced qualification, up to 1000 watts of power may be used.

1.18 Retransmission

- A repeater station is an amateur station that automatically retransmits the signals of other stations.
- An unmodulated carrier may be transmitted only for brief tests on frequencies below 30 MHz. (Above 30 MHz, you run the risk of accidentally activating a repeater with your carrier, which is a bad idea.)

- Radiotelephone signals in a frequency band below 29.5 MHz cannot be automatically retransmitted, unless these signals are received from a station operated by a person qualified to transmit on frequencies below 29.5 MHz.

1.19 Transmitter Control

- When operating on frequencies below 148 MHz, the frequency stability must be comparable to crystal control. (And above 148 MHz you're almost certainly using crystal control or something even better.)
- A reliable means to prevent or indicate overmodulation must be employed at an amateur station if radiotelephony (voice) is used.
- The maximum percentage of modulation permitted in the use of radiotelephony by an amateur station is 100 percent.
- All amateur stations, regardless of the mode of transmission used, must be equipped with a reliable means of determining the operating radio frequency.

1.20 ITU Regulations

- In addition to complying with the Radiocommunication Act and Radiocommunication Regulations, Canadian radio amateurs must also comply with the regulations of the International Telecommunication Union (ITU).
- Messages of a technical nature or personal remarks of relative unimportance may be transmitted to an amateur station in a foreign country.
- It is forbidden to transmit international messages on behalf of third parties unless those countries make special arrangements.
- Radiocommunications between countries shall be forbidden if the administration of one of the countries objects.
- Administrations shall take such measures as they judge necessary to verify the operational and technical qualifications of amateurs.
- The ITU Radio Regulations do not say anything about band restrictions for radio amateurs who have not demonstrated proficiency in Morse code. (This is why a Morse code qualification is no longer necessary.)

1.21 International Operation

- Canada is located in ITU Region 2.
- Australia, Japan, and Southeast Asia are in ITU Region 3.
- A Canadian radio amateur operating a station in the territory of another country is subject to frequency band limits applicable to radio amateurs licensed in that country. For example, a Canadian operator using a station in the United States is subject to whatever frequency band limits apply to US radio amateurs.
- The European Conference of Postal and Telecommunications Administrators (CEPT) license allows for international operation in any of the 32 CEPT countries.
- Canadian radio amateurs may apply for a CEPT licence in any CEPT country.
- Canadian radio amateurs holding Basic and 12 wpm qualifications will be granted CEPT Class 1 recognition.
- Canadian radio amateurs holding Basic qualification only will be granted CEPT Class 2 recognition (operation only above 30 MHz).
- The reverse also applies – foreign radio amateurs holding CEPT Class 1 licences will receive recognition in Canada equivalent to Basic and 12 wpm qualifications, and those with Class 2 licences receive recognition equivalent to Basic qualification only.

1.22 License Exams

- The fee for taking an examination for an Amateur Radio Operator Certificate by an accredited volunteer examiner is to be negotiated.
- The fee for taking the exam at an Industry Canada office is $20 per qualification.
- An accredited volunteer examiner must hold Basic, Advanced, and 12 wpm qualifications.
- A disabled candidate taking a Morse code sending test may be allowed to recite the examination text in Morse code sounds.
- Examinations for disabled candidates may be given orally or tailored to the candidate's ability to complete the examination.

1.23 Antenna Structures

- Radio amateurs who wish to install or modify antenna structures must follow Industry Canada's antenna siting procedures. Industry Canada expects radio amateurs to address community concerns in a responsible manner.
- Prior to an installation for which community concerns could be raised, radio amateurs may be required to consult with their land-use authority.
- The Minister of Industry has authority over antenna installations, including antenna masts and towers.
- If you are planning to install or modify an antenna system, you may not be required to contact land-use authorities to determine public consultation requirements when an exclusion criterion defined by Industry Canada applies. (See the Industry Canada website for more detailed information.)
- If the land use authority has not established a process for public consultation for antenna systems, the radio amateur planning to install or modify an antenna system must fulfill the public consultation requirements set out in Industry Canada's Default Public Consultation Process, unless the land use authority excludes their type of proposal from consultation or it is excluded by Industry Canada's process.
- The Industry Canada Public Consultation Process for antenna systems includes providing written notice, providing an opportunity for the public to respond regarding measures to address reasonable and relevant concerns, and answering relevant questions, comments, and concerns. Public meetings on the project are not part of these guidelines.
- The Default Public Consultation Process for antenna systems requires proponents to address reasonable and relevant concerns provided in writing within the 30 day public comment period.
- Where a municipality has developed a public consultation process, if exclusions listed in either CPC-2-0-03 or the local land use authority process apply, a public consultation may not be required.
- Where the proponent and a stakeholder other than the general public reach an impasse over a proposed antenna system, the final decision will be made by Industry Canada.
- In general, the tallest amateur radio antenna system excluded from the requirement to consult with the land use authority and the public is the taller of the height exclusion in the land use authority public consultation process and Industry Canada's antenna siting procedures.

1.24 RF Exposure

- Health Canada has published safety guidelines for the maximum limits of RF energy near the human body.
- Safety Code 6 gives RF exposure limits for the human body.
- According to Safety Code 6, frequencies in the range of 30 to 300 MHz cause the greatest risk from RF energy. The limit of exposure to RF in this frequency range is the lowest because the human body absorbs RF energy the most in this range.
- The maximum safe power output to the antenna of a VHF or UHF hand-held radio is not specified by Safety Code 6. The exemption for portable equipment was withdrawn in 1999.
- The maximum exposure levels of RF fields to the general population in the frequency range 10 to 300 MHz is 28 volts-RMS per meter. (This is a measurement of electric field strength, or "E-field".) In the frequency range 30 to 300 MHz, the maximum exposure level is 0.073 amperes-RMS per meter. (This is a measurement of *magnetic* field strength, or "H-field".)
- Permissible exposure levels of RF fields increase as frequency is increased above 300 MHz or below 10 MHz.

1.25 Interference

- "Radio-sensitive equipment" is defined as "any device, machinery, or equipment other than radio apparatus, the use or functioning of which is or can be adversely affected by radiocommunication emissions".
- EMCAB-2 is the name of the document for resolution of electronic interference complaints. This acronym is used on the exam but isn't tested.
- In the event of interference to third-party electronics systems, if the field strength of the amateur station signal is below 1.83 volts per meter, it will be deemed that the affected equipment's lack of immunity is the cause. If the field strength is above this, it will be deemed that the transmission is the cause of the problem.
- Broadcast transmitters are not included in the list of field strength criteria for resolution of immunity complaints.

2 Amateur Radio Operation Regulations

2.1 Repeaters

- A repeater is an autonomous amateur radio transceiver that receives a radio signal on one frequency (the "input" or "uplink" frequency) and automatically retransmits it on another frequency (the "output" or "downlink" frequency).

- Since repeaters are permanent installations with registered frequencies, they are usually a common meeting place on the air for local hams. Repeaters are useful because they can re-transmit a weak signal with much more power than was used to send it. For this reason, repeaters are mainly used to *increase the range* of portable and mobile stations.

- Some repeaters have an "autopatch", which is a device that allows repeater users to make telephone calls from their stations. These are not seen as often on newer installations because of the prevalence of cell phones.

- Most repeaters implement a "time-out timer" which limits the duration over which someone can transmit into the repeater continuously. If transmission continues after the time-out, the repeater will temporarily stop re-transmitting that signal until it stops. (This is useful if, for example, someone's push-to-talk button is stuck down.)

- Most repeaters use a system known as CTCSS (Continuous Tone-Coded Squelch System) or PL (Privacy Line) to filter unwanted interference on the repeater's input frequency. A simple explanation of PL tones is that every transmission into a PL-using repeater must have a certain predefined sub-audible tone added to the audio signal in order for the repeater to accept (and retransmit) that signal. For example, the VE3KSR repeater in the Waterloo region uses a PL tone of 131.8 Hz. If you transmit into the repeater without providing that tone on your signal, you won't make it through the repeater.

- Since repeaters are shared systems, you should pause briefly between transmissions when using a repeater to listen for anyone else wanting to use it. For the same reason, you should keep transmissions reasonably short because longer transmissions may prevent someone with an emergency from using the repeater and getting help.

- If you are trying to contact a specific individual on a repeater, say the call sign of the station you want to contact, then say your call sign.

- If you want to join a conversation on a repeater, wait for a break between transmissions and then say your call sign.

- The proper way to ask someone their location when using a repeater is simply to ask "Where are you?". Using CB radio slang like "What's your 20?" is universally discouraged, and you will sound like a fool.
- FM repeater operation on the two-meter band (144 – 148 MHz) separates the repeater's input and output frequencies by 600 kHz. For example, the VE3KSR repeater in the Waterloo region uses 146.970 MHz as the output frequency and 146.370 MHz as the input frequency.

2.2 Standard International Phonetics

To make your call sign better understood, and to spell words letter-by-letter when using voice transmissions, you can use Standard International Phonetics (also known as the NATO Phonetic Alphabet). You should learn this table and practice it in order to be a good operator who can use and recognize NATO phonetics on the air. (This will also help you off the air if you ever need to spell your email address over the telephone!)

Letter	Phonetic letter
A	Alpha
B	Bravo
C	Charlie
D	Delta
E	Echo
F	Foxtrot
G	Golf
H	Hotel
I	India
J	Juliet
K	Kilo
L	Lima
M	Mike
N	November
O	Oscar
P	Papa
Q	Quebec
R	Romeo
S	Sierra
T	Tango
U	Uniform
V	Victor
W	Whiskey
X	X-ray
Y	Yankee
Z	Zulu

Numbers are pronounced digit by digit in the usual way, with the caveat that the number 9 is prounced "nine-er" to distinguish it from "five".

2.3 Simplex Operation

- Simplex operation is transmitting and receiving on the same frequency. (Contrast with repeater operation, which transmits on one frequency and receives on another.)
- You should use simplex operation instead of a repeater when and if contact is possible without using a repeater. If for any reason you find yourself trying to operate simplex on a repeater frequency, it is a good idea to change your frequency because asking the repeater to change frequency is not practical.
- If you are talking to a station using a repeater, one thing to try is listening for that station on the repeater's *input* frequency. If you can copy the station clearly, it might be possible to communicate using simplex instead.

- It is possible to work simplex on VHF/UHF frequencies as well as HF frequencies. Because VHF and UHF frequencies are not usually capable of long-distance communications, it is recommended to reserve them for local calls and only use HF when it is desirable to comunicate over a longer distance. This reduces the interference on HF bands.

- If you want to use a simplex frequency, listen first so that you do not interrupt a communication already in progress.

- To put out a general call to "any listening station" is known as "calling CQ". (This is probably because saying the letters C-Q sounds like the phrase "seek you", like you are looking for someone.) To call CQ on voice, say "CQ" three times, followed by "this is", followed by your call sign spoken three times. To respond to a voice CQ call, say the other station's call sign once, then "this is", then your call sign given phonetically.

- Here's an example of that last one. Suppose I (VE3TUX) want to see if I can reach anyone on simplex. I start by picking a clear frequency, listening for a bit to make sure it really is free, and then saying "C Q C Q C Q this is Victor Echo Three Tango Uniform X-Ray Victor Echo Three Tango Uniform X-Ray Victor Echo Three Tango Uniform X-Ray". Now suppose my friend Peter (VA3VCF) hears my call and wants to respond. He will say "Victor Echo Three Tango Uniform X-Ray this is Victor Alpha Three Victor Charlie Foxtrot" and now that our handshake is complete we can have a nice conversation. Remember to give your callsign at least every 30 minutes if you continue talking for that long. A nice thing I might say when I am done is "Seven Three" (73), which is short for "best wishes". To end the conversation properly, I could say "Victor Echo Three Tango Uniform X-Ray signing off" or something like that, if I am going to stick around for a while, or "Victor Echo Three Tango Uniform X-Ray clear / shutting down" if I am turning off my radio.

- There is a mode of operation popular for voice called Single Sideband (SSB). You will learn more about it a bit later on, but it is most popular in the HF bands and rarely heard elsewhere. An important thing to know before you make or answer a call is which sideband to use. Typically, lower sideband (LSB) is used on the 40m and 80m bands (7 MHz and 3.5 MHz), and upper sideband (USB) is used elsewhere. This is primarily for historical reasons, but has become convention.

- The best way to tell if a certain band is "open" for communication with a particular distant location is to listen for signals from that area from an amateur beacon station or a foreign broadcast or television station on a nearby frequency.

2.4 Minimizing Interference

- It bears repeating, but before you transmit on any frequency, listen to make sure others are not already using the frequency.
- One way to shorten transmitter tune-up time on the air to cut down on interference is to tune into a "dummy load", which is an electrical device that does not radiate RF energy but has similar electrical properties to an antenna.
- If you contact another station and your signal is reported as extremely strong and perfectly readable, you may be able to reduce your power output to the minimum necessary. This reduces interference to others who may be operating nearby.
- Occasionally groups of hams may decide to meet on a pre-coordinated frequency at a specified time. This is known as a "net". If you are the net control station (coordinator) of a daily HF net, and you find the net frequency is in use just before the net begins, you should conduct the net on a frequency 3 to 5 kHz away from the regular net frequency. Conversely, if a net is about to begin on a frequency that you are using, as a courtesy to the net you should move to a different frequency.
- If propagation changes during your contact and you notice other activity nearby increasing interference, move your contact to a different frequency.
- To avoid interfering with other stations when operating on single sideband, allow a minimum frequency separation of 3 kHz from a contact in progress to minimize interference.

2.5 CW (Morse) Operation

- You should transmit on Morse at any speed which you can reliably receive.
- The procedural signal "CQ" means "calling any station".
- The procedural signal "DE" means "from" or "this is".
- The correct way to call CQ on Morse is to send the letters "CQ" three times, followed by "DE", then your call sign sent three times.
- To respond to a CQ call on Morse is to send the other station's call sign twice, followed by "DE", followed by your call sign twice.
- The procedural signal "K" means "any station transmit".
- The term "DX" means "distant station".
- The term "73" means "best regards" (also heard on voice as "seven three").

- "Full break-in telegraphy" means receiving incoming signals between outgoing Morse dots.
- When selecting a CW transmitting frequency, keep a minimum frequency separation of 150 to 500 Hz from a contact in progress.
- Good Morse telegraphy operators listen to the frequency to make sure that it is not in use before transmitting.

2.6 Signal Reports

- "RST" signal reports are a short way to describe signal reception. "RST" stands for "readability", "signal strength", and "tone". The signal report is given as a two-digit code (corresponding to R and S) or a three-digit code (corresponding to R, S, and T).
- The code for R goes from 1 to 5, where 1 means "unreadable" and 5 means "perfectly readable".
- The code for S goes from 1 to 9, where 1 means "faint signal" and 9 means "very strong".
- The code for T (only given during CW or digital) goes from 1 to 9, where 1 means "very rough tone" and 9 means "perfect tone".
- The "S" in RST is usually measured with an S meter, or a relative signal-strength indicator. If a signal report is given "9 plus N dB", it means that the reading is 20 decibels greater than strength 9 (which is an extremely strong signal).
- An increase in transmitter power of four times corresponds to an increase of approximately one S unit on an S meter.

2.7 Q Signals

Q signals are short three-letter abbreviations that all begin with the letter Q. They save time on CW and digital communications. Think of them as the "SMS speak" of the ham radio world. And now you know why they are a problem.

I'm really sorry about this part of the exam. This segment is pure memorization, even worse than anything else so far. The meaning of these signals is not at all obvious just by looking at or hearing them, and what's worse is that for the most part you won't encounter these unless you are operating CW (or very rarely on some digital modes) because they provide no benefit on voice. I'll spare you a lot of trouble by only putting the ones you will actually be tested on, and you can look up the rest yourself if you encounter them.

One thing to know is that you can put a question mark after any Q-signal to turn it into a question. For example, "QRS?" means "Should I send more slowly?". A response of "QRS" means "Send more slowly.".

- QRS – send more slowly
- QTH – my location is
- QRL? – is this frequency in use?
- QSY – change frequency
- QSO – contact in progress (this one is unfortunately somewhat common off the air as well, as in "I had a really nice cue-soh with John yesterday evening")
- QRZ? – is someone calling me?
- QRM – I am being interfered with
- QRN – I am troubled by static
- QRX – I will call you again
- QSL – I acknowledge receipt (most commonly seen with "QSL cards")

2.8 Emergency Operation

- If you are in contact with another station and you hear an emergency call for help on your frequency, immediately stop your contact and take the emergency call. Acknowledge the station in distress, determine its location, and find out what assistance may be needed. If you cannot render assistance, you should maintain watch until you are certain that assistance will be forthcoming.
- When operating voice, the proper distress call to use is "MAYDAY".
- When operating CW, the proper distress call to use is "SOS".
- You may only transmit "MAYDAY" or "SOS" in a life-threatening distress situation.
- The proper way to interrupt a repeater conversation to signal a distress call is to say "BREAK" twice, followed by your call sign.
- It is a good idea to have a way to operate your amateur statio without using commercial power lines (e.g. battery-powered handheld, generator) so you may provide communications in an emergency.

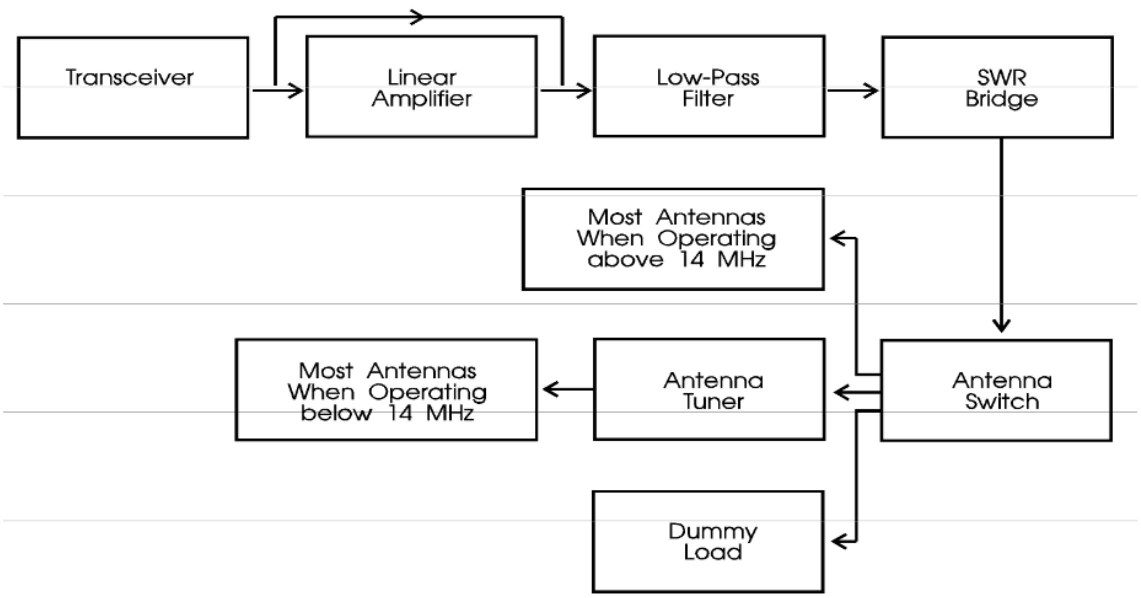
- The most important accessory to have for a hand-held radio in an emergency is a charged spare battery – preferably several.
- A dipole antenna is small, simple, and fast to set up and store. It is a good choice as part of a portable HF station that could be assembled in an emergency.
- In order of priority, a distress message comes before an urgency message, which comes before a safety message.

2.9 International Operation

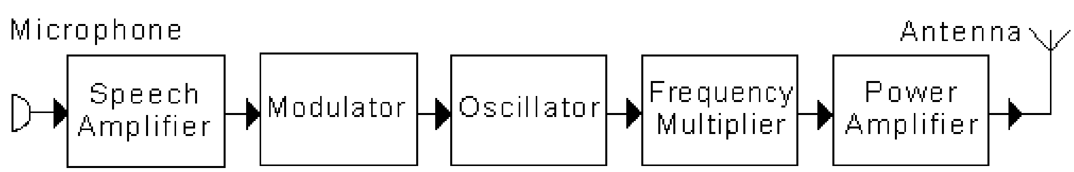
- A "QSL card" is a written proof of communication between two amateurs. They are typically exchanged for long-distance contacts made over HF.
- An azimuthal map is a map projection centered on a particular location that is used to determine the shortest path between points on the earth's surface. It is useful when orienting a directional HF antenna toward a distant station.
- When orienting a directional antenna, it may be pointed along the "short path", which is directly at the remote station, or along the "long path", which is 180 degrees away from the remote station. If you cannot hear a station on the short path, it may be worth trying the long path to see if propagation is different.
- A station logbook is important for recording contacts for operating awards, and very important for handling neighbour interference complaints. A well-kept log preserves your fondest amateur radio memories for years (this quoted verbatim from the question bank). However, Industry Canada does not formally require any operator to keep a logbook.
- Station logs and QSL cards are always kept in UTC (Coordinated Universal Time). This time is based in Greenwich, England (formerly Greenwich Mean Time, GMT).
- To set your station clock accurately to UTC, you could receive the most accurate time off the air from a time station such as CHU, WWV, or WWVH.

3 Amateur Radio Fundamentals and RF Safety

3.1 Components of an HF Station

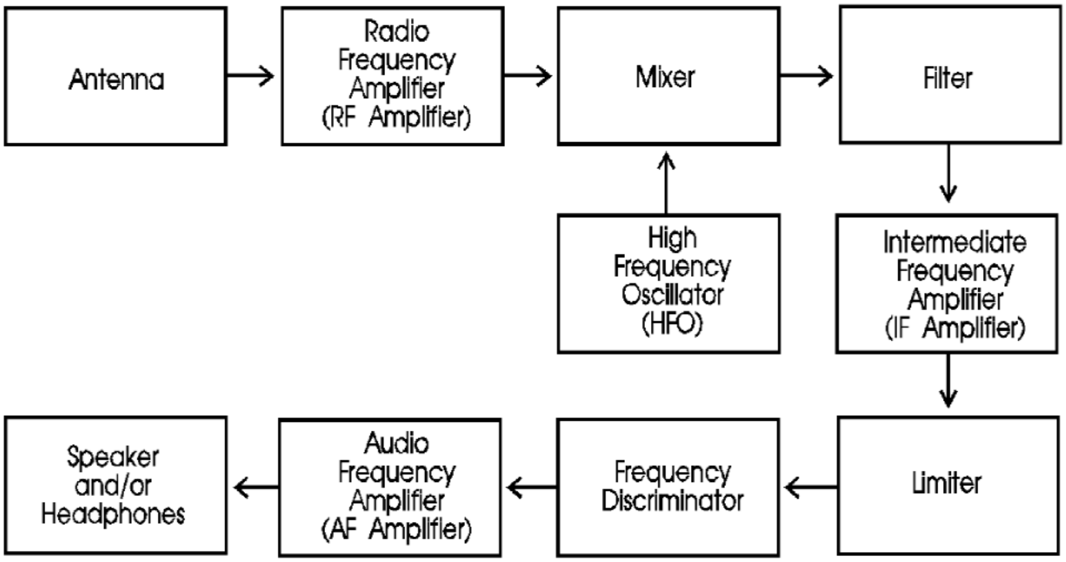


3.2 Frequency Modulation Transmitter

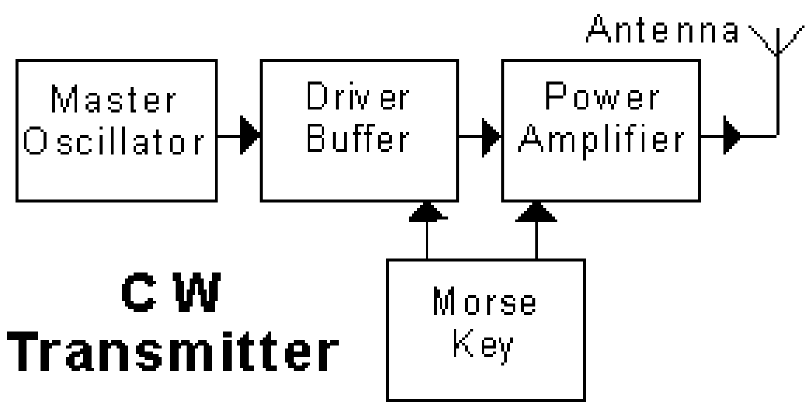


FM Transmitter

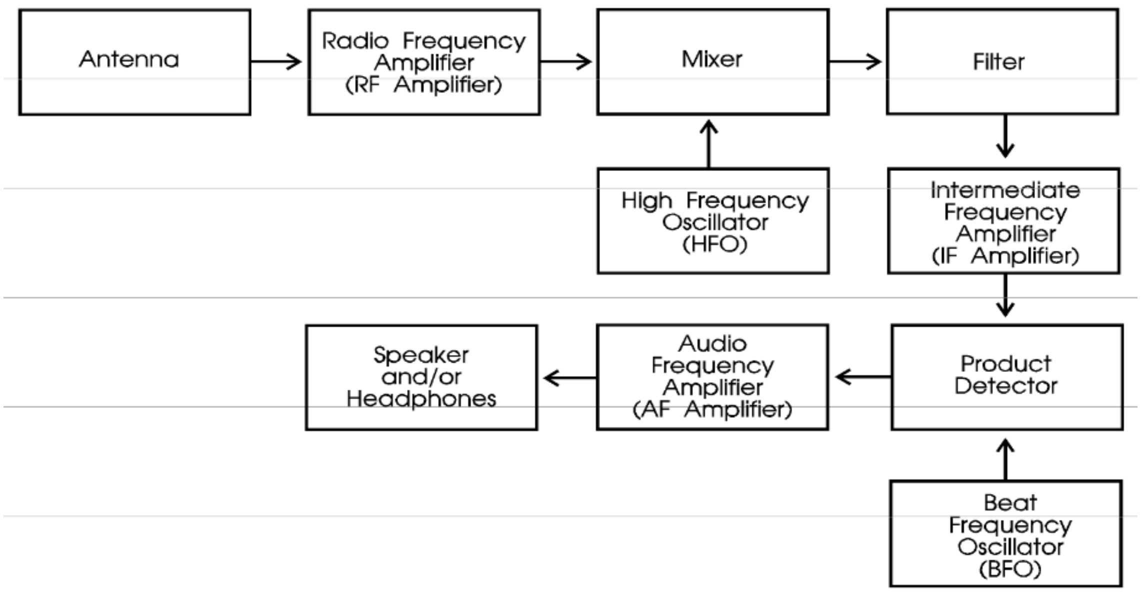
3.3 Frequency Modulation Receiver



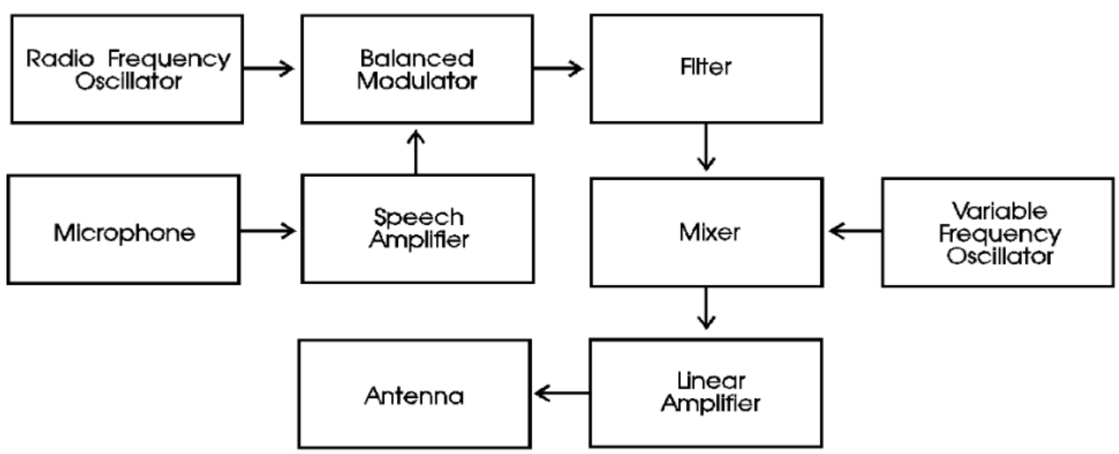
3.4 CW Transmitter



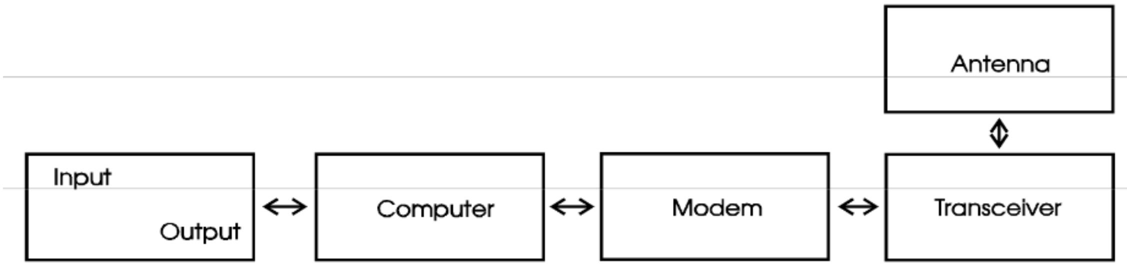
3.5 CW/SSB Receiver



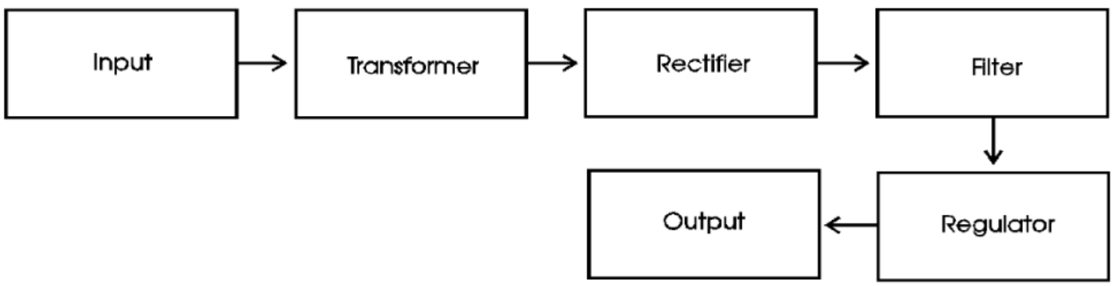
3.6 SSB Transmitter



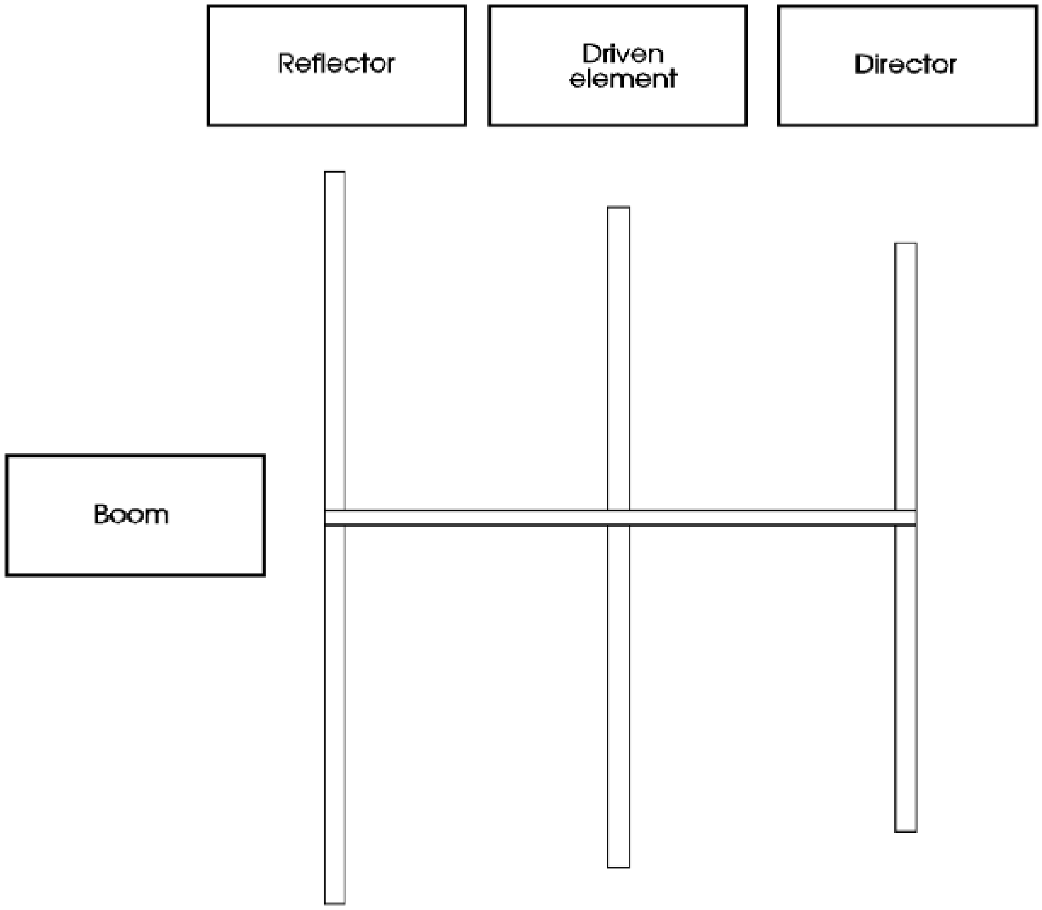
3.7 Digital System



3.8 Power Supply



3.9 Yagi-Uda Antenna



3.10 Receiver Fundamentals

- The three main parameters against which the quality of a receiver is measured are **sensitivity**, **selectivity**, and **stability**.
- In order from narrowest to widest bandwidth, typical radio emissions you might receive are CW, RTTY, SSB voice, and FM voice.
- The bandwidth of CW is about 250 Hz. A typical carrier frequency for CW is between 750 and 850 Hz.
- The bandwidth of single sideband is about 2.4 kHz.
- Signal-plus-noise to noise ratio (or just signal-to-noise ratio) is a measure of a receiver's sensitivity.

- If two receivers of different sensitivity are compared, the less sensitive receiver will produce less signal or more noise.
- Single sideband suppressed carrier is usually detected with a product detector.
- A receiver designed for SSB reception must have a beat frequency oscillator (BFO) because the suppressed carrier must be replaced for detection.
- A notch filter is a very, very narrow band-stop filter; its function is to attenuate a specific frequency as much as possible. A notch filter can be used to attenuate an interfering carrier signal when receiving an SSB transmission.

3.11 Transmitter Fundamentals

- **Chirp** is a small, audible change in a transmitter's frequency each time it is keyed. A malfunctioning CW transmitter may exhibit chirp that can be heard on air as a shift in the carrier tone. To keep such a transmitter from chirping, the power supply voltages must be kept very steady.
- A VFO-controlled transmitter has a variable-frequency oscillator connected to a driver and a power amplifier.
- Amplitude modulation is a scheme that changes the amplitude of an RF wave for the purpose of conveying information.
- Morse code is usually transmitted by radio as an interrupted carrier.
- A mismatched antenna or feedline may present an incorrect load to the transmitter. Since less than 100% of the power from the power amplifier will be transmitted to the load, the antenna will not radiate with as much energy as with a proper matching. Additionally, the "lost" power will be reflected back through the feedline and dissipated as heat. The result may be excessive heat produced in the final transmitter stage or in the cable.
- An RF oscillator should be electrically and mechanically stable. This is to ensure that the oscillator does not drift in frequency.

3.12 Single Sideband

- An SSB transmitter that is operated with the microphone gain set too high will cause splatter interference to other stations operating near its frequency. The same result will be observed if too much speech processing is used.
- **Peak envelope power** is the average power supplied to an antenna transmission line during one RF cycle at the crest of the modulation envelope.

- Suppressing the carrier in a double-sideband phone transmission means that more power can be put into the sidebands (because the carrier contains no useful information).

- The automatic level control (ALC) in an SSB transmitter controls the peak audio input so that the final amplifier is not overdriven. The microphone gain control should be adjusted on a single-sideband phone transmitter for slight movement of the ALC meter on modulation peaks.

3.13 Frequency Modulation

- If an FM transmitter is operated with the microphone gain or deviation set too high, it may cause interference to other stations operating near its frequency. This is called "overdeviation". If this is happening to you, talk farther away from the microphone or turn down the mic gain.

- An FM transmitter with a broken microphone produces an unmodulated carrier.

- FM voice is best for local VHF/UHF radio communications because it has high-fidelity audio which can be understood even when the signal is somewhat weak.

- The usual bandwidth of a frequency-modulated amateur signal is between 10 and 20 kHz. FM phone cannot be used below 29.5 MHz because the bandwidth would exceed limits in the regulations.

- FM receivers perform in an unusual manner when two or more stations are present. The loudest signal, even though it is only two or three times as loud as the other signals, will be the only transmission demodulated. This is called the **capture effect**.

3.14 Voice and CW Operation

- Many amateurs use an electronic keyer to help form good Morse code characters.

- It is a good idea to tune with a dummy load to reduce interference on the air. You can expect a dummy load to get warm when in use because it is essentially a giant resistor and dissipates RF energy as heat.

- A "VOX" circuit causes a transmitter to automatically transmit when an operator speaks into its microphone.

- A properly adjusted speech processor on a single-sideband transmitter will improve speech intelligibility at the receiver. If a single-sideband phone transmitter is 100% modulated, a speech processor will add nothing to the output power.

- When switching from receive to transmit, the receiver should be muted *first*, before the transmitter is enabled. This is a safety interlock that will save you from blowing up your receiver's front end.
- A speaker and a microphone are electrically identical. Yelling into a loudspeaker will cause it to function as a microphone, and vice versa.

3.15 Digital Operation

- A packet radio link is "connected" when a transmitting station is sending data to only one receiving station, which replies that the data is being received correctly.
- A packet radio station is "monitoring" when it is displaying messages that may not be sent to it and is not replying to any message.
- A **digipeater** is a packet radio station that retransmits only data that is marked to be retransmitted.
- A packet radio network connects multiple stations so that data can be sent over long distances.
- In packet radio, a transceiver and computer system are connected to a "terminal node controller" (TNC). The easiest and simplest way to accomplish this is to connect the TNC to the transceiver's microphone input and speaker/headphone output. Packet radio uses the ASCII encoding to express letters and numbers as digital information, and may also use a protocol called AX.25 to provide network control and link-level operations.
- RTTY communications should maintain a frequency separation of 250 to 500 Hz (center to center) from contacts in progress to minimize interference.
- Digital transmissions use signals called "mark" and "space" to transmit the states 1 and 0.
- AMTOR transmissions can be made in two modes. Mode A uses the "Automatic Repeat Request (ARQ)" protocol, and is normally used for communications after contact has been established (Mode B is faster but less reliable and is used for making calls).
- VHF packet communications most commonly use a data rate of 1200 baud. There is a very good reason for this. Most packet communications on VHF are done through a mode called "Audio Frequency Shift Keying (AFSK)", which uses audible frequencies transmitted and received directly through the microphone and speaker. There is an upper limit on the frequency of audio that can be passed through a VHF transceiver (in order to maintain maximum bandwidth of the modulated signal), and using a

higher data rate would necessitate the use of audio frequencies that would cause overdeviation of the transmitter.

3.16 Introduction to Electricity

- Current is the flow of electrical charge in a circuit. The symbol for current is I.
- Current is measured "through" a point in the circuit.
- The unit of current is the ampere or amp.
- There are two types of current. **Direct current (DC)** flows in one direction and does not vary with time; **alternating current (AC)** changes direction and varies with time (usually sinusoidally).
- A battery is a source of "EMF", or electromotive force. This is also known as "voltage".
- A lot of hams use the symbol E for voltage. From an engineering point of view, this is completely wrong. Despite all evidence to the contrary that you may find in ham radio literature, the symbol for voltage is and has always been V.
- Voltage is measured as a "potential difference", across two points in a circuit.
- The unit of voltage is the volt.
- A standard automobile battery supplies about 12 volts. An important distinction between this type of battery (a "lead acid battery") and a conventional flashlight battery is that the lead acid battery can be repeatedly recharged.
- All batteries have an internal resistance, which essentially behaves as a resistor in series with the battery. This internal resistance can cause the supplied voltage of the battery to drop when the current is high.
- Batteries should never be short-circuited (connecting the terminals directly to each other).
- All batteries have discharge limits. Nickel-cadmium batteries should not be discharged to less than 1.0 volts per cell.
- To increase the current capacity of a cell, several cells should be connected in parallel. To increase the voltage output, several cells should be connected in series.

3.17 Power Supplies Again

- Power is the amount of energy per unit time delivered to a device. The symbol for power is P.
- Power is measured in watts.
- The power delivered to an electrical device such as a resistor is equal to the voltage across its terminals multiplied by the current passing through it: $P = IV$. Knowing how to calculate power is important for determining what components to use – for example, most resistors have a specified "maximum power", and if more power is put through the resistor than the maximum, the resistor will blow up. The same is true of power supplies. If you want to supply 12 volts of power at 5 amperes of current, your power supply must be rated higher than 60 watts for safe operation.
- If your mobile transceiver works in your car but not in your home, the first thing to check is the power supply.
- A power supply converts household current (AC) into 12-volt DC.
- Transceivers usually need lots of power and therefore require heavy-duty power supplies.
- The diode is an important part of a simple power supply, and you will learn more about it in the section on semiconductors. It converts AC to DC, since it allows electrons to flow in only one direction (from cathode to anode).
- Power line voltages have been made standard over the years, and the voltages generally supplied to homes are approximately 120 and 240 volts. Power lines in North America provide alternating current power at a frequency of 60 Hz.
- So-called "transformerless" power supplies are used in some applications. When working on such equipment, one should be very careful because one side of the line cord is connected to the chassis.
- An autotransformer can be used as an efficient method of increasing or decreasing a voltage. They are especially useful in areas with poor electrical service when wall voltages are consistently high or low.
- Since power supplies use low-frequency alternating current, a very loud low-frequency hum in a transmission is almost certainly coming from the power supply.

3.18 Electricity Safety

- The best way to keep unauthorized individuals from using an amateur station at home is to use a key-operated on/off switch in the main power line.
- To lock out a mobile station, disconnect the microphone and lock it up when not in use.
- High-voltage power supplies often use a safety interlock consisting of a switch that breaks contact if the case is opened. This is to prevent anyone opening the cabinet from coming into contact with dangerous high voltages.
- As little as 0.1 A of current can be fatal to the human body.
- The heart is especially sensitive to very small amounts of electrical current, and can be fatally affected.
- The minimum voltage which is usually dangerous to humans is 30 V.
- If you discover someone being burned by high voltage, don't touch them or the wires; turn off the power, call for emergency help, and give CPR if needed.
- The safest method to remove an unconscious person from contact with a high voltage source is *turning off the power first*.
- The safest way to work on a transmitter or a power supply is *turning off the power first*.

3.19 Electrical Ground

- For best protection from electrical shock, all station equipment should be "grounded". This means that the chassis of the equipment is connected with a wire to an electrical ground. This can be a cold water pipe or an "earthing rod" driven into the ground.
- Earthing rods are typically made of copper-clad steel for superior electrical conductivity.
- A long ground wire can act like an antenna; this is especially notorious on HF bands, where stations that are in tall buildings are installed with long ground wires that are resonant on several HF bands and radiate RF energy, resulting in inexplicable RF burns. It is recommended to keep ground wires as short as possible.
- On mains-operated power supplies, the ground wire should be connected to the metal chassis of the power supply. This ensures that in case there is a fault in the power supply, the chassis does not develop a high voltage with respect to the ground.

- The purpose of using a three-wire power cord and plug on amateur radio equipment is to prevent the chassis from becoming live in case of an internal short (the third prong on the plug is a ground connection).

3.20 Antenna, Tower, and Lightning Safety

- All antenna and rotor cables should be grounded when not in use to protect the station and building from lightning damage.
- When working on an antenna tower, it is necessary to wear approved equipment in accordance with provincial safety standards concerning climbing.
- A safety belt should be worn when working on an antenna tower to prevent you from accidentally falling.
- A hard hat should be worn when working on an antenna tower to protect your head from something dropped from the tower.
- Horizontal wire antennas should be placed high enough so that no one can touch any part of the antenna from the ground. Touching an antenna can cause RF burns.
- Before beginning repairs on an antenna, turn off the transmitter and disconnect the feedline.

3.21 Radiation Safety

- When operating at 1200 MHz or above, keep the antenna away from your eyes when RF is applied. These frequencies are microwave and can cause tissue damage to your eyes.
- Before removing the shielding on a power amplifier, make sure the amplifier cannot accidentally be turned on.
- You should make sure the antenna of a handheld transceiver is not close to your head when transmitting in order to reduce your exposure to RF energy. The antenna should be positioned away from your head and away from others.
- Exposure to a large amount of RF energy will heat body tissue. The eyes are the most likely to be damaged from the heating effects of RF radiation.
- If you operate your amateur station with indoor antennas, locate them as far away as possible from living spaces that will be occupied while you are operating.
- Directional high-gain antennas should be mounted higher than nearby structures so they will not direct RF energy toward people in those structures.

- The ends and center of a dipole antenna should be as high as possible to prevent people from coming into contact with the antenna.

Notice

Up until now, these notes have been written with only the most important information in mind and have not covered a great deal of information that will not be directly tested on the Basic Qualification exam. When covering the topics of electronic circuits and components, most of the information here will not make sense without a good background. The goal of this section is to provide that background – which is not technically covered in the exam, but should prove extremely useful both for understanding the ideas here and for practical operation – and to introduce the most important electronic devices in amateur radio one at a time – which are pulled from the testable material – without breaching into the more complex territory of circuit analysis and design. The testable material that is covered in this section is presented in a slightly different order than it will appear on the exam.

4 Passive Electronic Devices

4.1 Particle Physics

- All matter is made up of atoms, which have a **nucleus** composed of neutrons (electrically neutral) and protons (electrically positive) and an **electron cloud** composed of electrons (electrically negative).

- In an atom, there are an equal number of protons and electrons. The atom is electrically neutral.

- An atom can gain electrons, resulting in a **negative ion**, or lose electrons, resulting in a **positive ion**.

- **Current** is the flow of electric charge (typically the flow of electrons).

- The unit of electric charge is the coulomb (C). One coulomb is equal to the charge on 6.28×10^{18} electrons.

- Current is measured in coulombs per second, or amperes (A). One ampere equals a flow of one coulomb per second through a conductor (such as a piece of copper wire).

- The symbol I is used to denote current in equations. You may also see a lowercase i to indicate a current that changes with time.

- One way to visualize current is to think of the flow of water in a canal. Here the water represents the electrons, and the canal is the conductor through which the current flows. The more water that moves past a point in the canal per unit time, the greater the current in the canal.

- **Voltage** is another name for "electrical potential energy".
- Voltage can be a bit tricky to understand. Going back to the water analogy, you might be familiar with the effects of gravity on liquids – water will flow from surfaces at high elevation down to surfaces at low elevation. Similarly, current flows from points in a circuit at high voltage towards points in a circuit at low voltage.
- It is important to distinguish between "conventional current" and "electron current" here. Back when electricity was just being discovered, it was believed that the particles that moved in a circuit were positively charged, and therefore would move from high voltage to low voltage. This is known as "conventional current" – thinking about a hypothetical positively-charged current. However, this is now known to be incorrect; we know that electrons move in a circuit, actually from low voltage to high voltage! Thinking of the current in this way, as a flow of electrons, is called "electron current". In most circuits, "conventional current" is used.
- The unit of electrical potential energy is the volt (V).
- We never measure electrical potential energy directly. Instead we measure the difference in potential between two points in a circuit. This potential difference is what is commonly referred to as "voltage". For example, the voltage rating of a flashlight battery is 1.5 V. This means that the difference in potential energy between the terminals of the battery is 1.5 volts.
- The symbol V is used to denote voltage in equations.
- Most hams will try to tell you that the symbol for voltage is E. This is incorrect, and bad engineering practice. As a good electrician, follow proper engineering convention and use V for voltage!
- Unfortunately, there are a handful of questions on the Basic Qualification exam that think that E is the symbol for voltage. Just play along. You know better.
- **Resistance** is the inherent opposition to the flow of electrons of a material.
- The unit of resistance is the ohm (Ω); the symbol for resistance is R.
- The resistance of a given conductor depends on the following factors:
  - The "specific resistance" of the material
  - The length of the conductor (longer conductors have a larger resistance)

  - The diameter or cross-section area of the conductor (larger cross-section means *lower* resistance; think of a water pipe – the wider pipe allows a larger amount of water to flow)
  - Temperature – every material has a "temperature coefficient", which affects how the resistance of the conductor changes when the temperature is raised or lowered. For some materials, the resistance increases at higher temperatures; for others, it will decrease.

- The higher the resistance of a material, the more difficult it is to get current to flow through it when a voltage is applied.
- But *how* difficult? There is an equation called "Ohm's Law" that tells us: $I = \frac{V}{R}$. The current that will flow through a resistor is equal to the voltage difference across the terminals of the resistor divided by its resistance.
- One ohm is defined as the resistance of a conductor that will allow a current of one amp to flow through it when a voltage of one volt is placed across it.
- The reciprocal of resistance is **conductance**.

4.2 Units and SI Prefixes

- Units such as volts and amperes can be prepended with an "SI prefix" to change the scale of the unit.
- For example, the prefix "mega-" means "one million". So, "one megadollar" is short for "one million dollars". "Two point five megadollars" is short for $\$2,500,000$.
- Here is a short list of useful SI prefixes:
  - "tera" (T) – 10^{12}
  - "giga" (G) – 10^{9}
  - "mega" (M) – 10^{6}
  - "kilo" (k) – 10^{3}
  - "milli" (m) – 10^{-3}
  - "micro" (μ) – 10^{-6}
  - "nano" (n) – 10^{-9}
  - "pico" (p) – 10^{-12}
- So, for example, one megahertz is equivalent to 1000 kilohertz, for example, or in short form, 1 MHz = 1000 kHz. Both are equivalent to one million hertz (1000000 Hz).

4.3 Conductors, Resistors, and Insulators

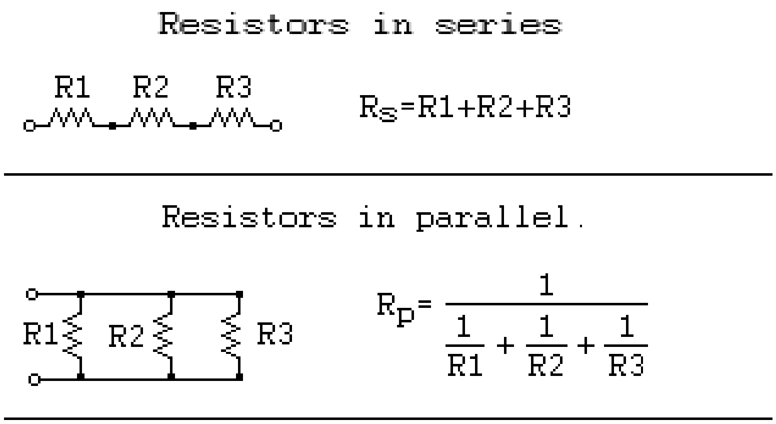
- Most metals are good **conductors** of electricity – they have relatively low resistance.
- Some materials such as plastic are **insulators**, which have relatively high resistance and do not conduct electricity very easily.
- Copper, silver, and aluminum are very good conductors. Lots of electric circuits use copper wires because copper is inexpensive and conducts electricity easily.
- Glass, plastic, porcelain, and air are good insulators.
- Gold is not a very good conductor, but it is typically used to plate the ends of connectors because it does not corrode very easily.
- An **open circuit** has infinite resistance, and therefore has no current.
- A **short circuit** has zero resistance, and passes too much current.
- Most resistors are made from carbon film.

4.4 Power

- When current flows through a conductor, some of the energy in the electrical current is dissipated as **heat**. In some cases, this is desired. For example, a hot element on an electric oven is more or less just a really big resistor that can sink a lot of heat. However, typically producing heat is not the desired function of a circuit and any heat that is dissipated in a component is considered to be "lost".
- Every resistor has a fixed amount of heat that it can dissipate before it is destroyed by the amount of energy that it is encountering. This limit is measured in **watts** (W), which is the SI unit for **power**.
- Power is defined as energy per unit time; one watt is equivalent to one joule of energy per second.
- A more useful expression in the context of electric circuits is $P = IV$, where P is power, I is current, and V is voltage.
- A resistor with a voltage drop of 5 volts across its terminals that is passing 3 amps of current is experiencing a total of $(5)(3) = 15$ watts of power. The resistor's power rating would have to be higher than 15W in order to be suitable for operation in this circuit.
- Some resistors are physically very large; this improves their power dissipation and allows them to handle much more power.

4.5 Resistors in Series and in Parallel

- It is possible to replace combinations of multiple resistors with a single "equivalent resistor" of that value without changing the behaviour of the circuit.



- When two resistors are connected with one common terminal, they are said to be connected **in series**.
- For any number of resistors connected in series, the total "equivalent resistance" is equal to the sum of the resistances of each individual resistor.
- $R_e = R_1 + R_2 + ... + R_n$
- For resistors connected in series, the current through each resistor is equal. However, the voltage drop across each resistor is not necessarily the same.
- When two resistors are connected with both terminals in common, they are said to be connected **in parallel**.
- For any number of resistors connected in parallel, the total "equivalent resistance" is equal to one divided by the sum of the reciprocals of the resistances of each individual resistor.
- $R_e = \dfrac{1}{\frac{1}{R_1} + \frac{1}{R_2} + ... + \frac{1}{R_n}}$
- For resistors connected in parallel, the total current through all resistors is equal to the sum of the current through each resistor. However, the voltage drop across any resistor is the same.

4.6 Resistor Colour Codes

- Most resistors are too small for the actual resistance value to be printed on them. Instead, a number of coloured bands are used to indicate the resistor's value.

- You will need to memorize the correspondance between band colour and value:

Black	0
Brown	1
Red	2
Orange	3
Yellow	4
Green	5
Blue	6
Violet	7
Grey	8
White	9

- Most colour-coded resistors have four bands. To calculate the value of a resistor you only need to know the colours of the first three bands. Concatenate the digits denoted by the first and second bands, then multiply by 10 to the power of the third band's digit.

- As an example, suppose the first three bands of a resistor you have are orange, white, red in that order. Orange is 3, and white is 9, so the value of the resistor is 39 times some power of 10. Red is 2, so the value is 39×10^2 or 3900Ω.

- The fourth band represents the tolerance of the resistor's value – by how much the value of the resistor may vary from its printed resistance. This is expressed as a percentage value. A 100 Ohm resistor with a tolerance of 5% will have a **gold band** in the fourth position.

- (Some resistors have five bands. These can be a bit confusing, as there are two possible ways of reading them: in one case, the first three bands are the first three digits, the fourth band is the multiplier, and the fifth band is the tolerance; in another case, the first four bands are read as on a four-band resistor, and the last band represents the component failure rate. There is a very rarely seen six-band resistor. The sixth band represents the temperature coefficient of the device.)

4.7 Alternating Current and Electromagnetic Waves

- Current that flows in one direction only is called **direct current (DC)**.

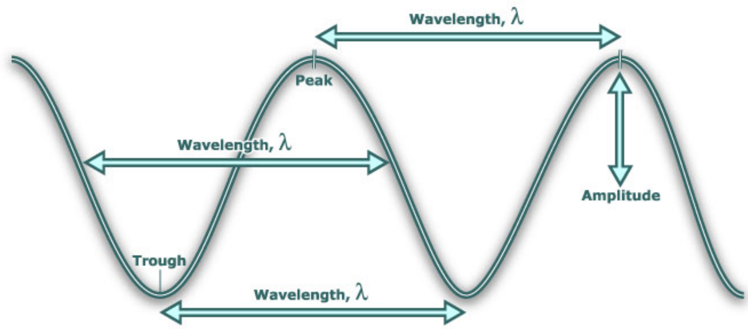
- Current that oscillates back and forth is called **alternating current (AC)**.

- The reversal of the direction of current happens periodically. The number of reversals per second is known as the **frequency** of the current.

- In North America, current alternates at a rate of 60 cycles per second, or 60 Hz.

- Most humans can hear sounds at frequencies between 20 and 20 000 Hz. (But these are sound waves, not electromagnetic waves. Here the frequency refers to how many times per second the air molecules vibrate in order to propagate the sound wave.) Signals with these frequencies are known as "Audio Frequency (AF)" signals.

- Signals at frequencies from 3 kHz to 300 GHz are known as "Radio Frequency (RF)" signals.



- There is a simple relationship between frequency and wavelength for an electromagnetic wave: $c = \lambda f$, where λ is the wavelength (in meters), f is the frequency (in Hertz), and c is the speed of light (299792458 meters per second, or approximately 300 million meters per second).

- From this you can see that because the speed of light is a constant, as the frequency of a wave increases its wavelength decreases, and vice versa.

- The **period** of a wave is the time required for one complete cycle of the wave to be observed. The period is usually denoted with the variable T, and can be calculated as $T = \frac{1}{f}$. So, if the frequency of a wave is 100 Hz, its period is $\frac{1}{100}$, or 0.01 seconds.

- The **amplitude** of a wave is the distance between the highest point (the crest) and the lowest point (the trough).

4.8 Decibels

- To express the ratio between two values – mostly power – we can use the decibel (dB).

- The ratio of a power value P_1 to another power value P_0 can be expressed in decibels using the following identity: $L_{dB} = 10 \log_{10} \frac{P_1}{P_0}$
- From this you can see that a "10 dB" increase is an increase of a factor of 10, while a "20 dB" increase is an increase of a factor of 100.
- Doubling the power corresponds to a gain of roughly 3 dB.

4.9 Capacitors and Inductors

- An **inductor** is an electronic device that can store energy in a magnetic field. Physically it looks like a spiral coil of wire, or a wire wrapped around a "doughnut" core (torus).
- Inductors are sometimes called "coils".
- Inductance is the ability of an inductor to store and supply energy through a magnetic field. The unit of inductance is the henry (H).
- The symbol for inductance is L.
- The inductance of an inductor depends on the core material, the core diameter, the length of the coil, and the number of turns of wire used to wind the coil.
- Just like resistors do, inductors that are connected in series or in parallel can be added together.
- For inductors connected in series, the total equivalent inductance is equal to the sum of each individual inductance.
- For inductors connected in parallel, the total equivalent inductance is given by $\frac{1}{\frac{1}{L_1} + \frac{1}{L_2} + ... + \frac{1}{L_n}}$ (similar to the formula for resistors in parallel).
- A **capacitor** is an electronic device that stores energy in an electric field. It is the dual of the inductor. Physically, it looks like a small metal can with two terminals coming out (although this actually describes a fair number of components), or a small flat circular disk with two terminals coming out.
- A capacitor is made from two parallel plates separated by some distance. Between the plates there can be a material, known as a **dielectric**.
- Capacitance is the ability of a capacitor to store and supply energy through an electric field. The unit of capacitance is the farad (F).
- The symbol for capacitance is C.

- The capacitance of a capacitor depends on the material between the plates, the area of each plate, the number of plates, and the distance between the plates.

- Capacitors can also be combined in series or in parallel, but the formulas are the other way around. Capacitors in *parallel* add their capacitances together, and capacitors in series have a total capacitance equivalent to $\frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + ... + \frac{1}{C_n}}$. This is the opposite of how resistors and inductors behave.

4.10 Transformers and also Magnets

- Electric current moving through a conductor produces a magnetic field around the conductor. The strength of this magnetic field is directly proportional to the current in the conductor.

- A voltage can be induced in a conductor when the conductor moves through a magnetic field. This voltage is at a maximum when the movement is perpendicular to the magnetic field lines ("lines of force").

- The maximum induced voltage in a coil occurs when the current is going through its greatest rate of change.

- Two nearby inductors can be "magnetically coupled" if they share the same magnetic field.

- **Mutual inductance** is the phenomenon whereby a changing current in one inductor causes a current to be induced in another inductor.

- A **transformer** is a device that uses mutual inductance to induce a voltage or current in another part of a circuit.

- A transformer has two coils, known as the "primary" and "secondary". A flow of current through the primary causes a flow of current through the secondary, by induction.

- The magnitude of the voltage induced in the secondary depends on the ratio of the number of turns in the primary and secondary. This is given by $\frac{V_2}{V_1} = \frac{N_2}{N_1}$, where V_2 is the voltage across the secondary, V_1 is the voltage across the primary, and N is the number of turns in the corresponding coil. The quantity $\frac{N_2}{N_1}$ is known as the "turns ratio" of the transformer (e.g. a transformer with a turns ratio of 5:2 has $\frac{N_2}{N_1} = \frac{5}{2}$.

- The total amount of power transferred through an ideal transformer is constant. That is, $V_1I_1 = V_2I_2$. (So, a transformer that steps up the voltage must also step down the current.)
- In a real transformer, energy transfer is not perfect and some power is lost. This might be dissipated as heat, for example.
- If no load is attached to the secondary winding of a transformer, the current in the primary winding is called "magnetizing current".
- Transformers can be used to match impedances through the formula $\frac{Z_2}{Z_1} = \frac{N_2^2}{N_1^2}$ where N_1 is the number of turns in the primary, N_2 is the number of turns in the secondary, and both Zs are given in ohms.
- A force of repulsion exists between two like magnetic poles (North repels North, South repels South).
- Good permanent magnets can be made from steel. *Really* good permanent magnets are made from neodymium, or some alloys.

4.11 Reactance

- Reactance is defined as the opposition to the flow of alternating current.
- Reactance is very similar to resistance, and it is also given in ohms. However, the symbol for reactance is X.
- Unlike a resistor, energy dissipated through a reactive component is always returned to the circuit.
- Reactance is **frequency-dependent**.
- The reactance of an inductor is given by $X_L = 2\pi fL$, where f is the frequency of the alternating current in Hertz and L is the inductance in Henrys.
- As the frequency increases, so does the inductive reactance.
- The reactance of a capacitor is given by $X_C = \frac{1}{2\pi fC}$, where f is the AC frequency in Hertz and C is the capacitance in Farads.
- As the frequency increases, the capacitive reactance decreases.
- When a circuit contains both resistance and reactance, it is useful to refer to a combined quantity known as **impedance**.

- Impedance is also measured in ohms, but uses the symbol Z.
- **Impedance matching** refers to the condition when two circuits connected to each other have the same impedance. Maximum power transfer occurs when the impedances are equal.

4.12 Resonance and Tuned Circuits

- Resonance occurs when the inductive reactance, X_L, and the capacitive reactance, X_C, are equal. This occurs at exactly one frequency in a circuit, known as the **resonant frequency**.
- The formula to calculate the resonant frequency is $f = \frac{1}{2\pi\sqrt{LC}}$, where f is the resonant frequency in Hertz, L is the inductance in henries, and C is the capacitance in farads.
- If we use a component in a circuit whose capacitance or inductance can be adjusted, we have created a **tuned circuit**, which can be used to select one frequency from many.
- A series resonant circuit consists of an inductor and a capacitor connected in series.
- At resonance, a series resonant circuit has *minimum impedance*. This can be used to select one frequency from many others.
- A parallel resonant circuit consists of an inductor and a capacitor connected in parallel.
- At resonance, a parallel resonant circuit has *maximum impedance*. This can be used to reject a specific frequency and pass all others.

4.13 Test Equipment

- A **voltmeter** measures voltage. It has two probes that must be connected in *parallel* with the circuit where the voltage is to be measured.
- An **ammeter** measures current. It also has two probes but must be connected in *series* where the current is to be measured.
- A multimeter, according to Industry Canada, measures voltage, current, and resistance.
- An ammeter in a circuit will act as a very small resistance. A voltmeter in a circuit will act as a very large resistance.

5 Active Electronic Devices

5.1 Amplifiers

- An amplifier is a circuit designed to increase the level of its input signal.
- The increase in signal level by an amplifier is called **gain**, which is usually measured in decibels (and is a positive number of decibels for an amplifier).
- Because this adds power to the circuit, an amplifier is an active device.
- Amplifiers can amplify current, voltage, or power.
- Amplifiers are typically designed to operate over a specific range of frequencies. For example, an audio amplifier works for audio frequencies, while a VHF amplifier works over radio frequencies in the 2m band.
- The range of frequencies typically amplified by a speech amplifier (into a transmitter) is 300 to 3400 Hz.
- Amplifiers have a specified minimum and maximum input level at which they operate "linearly" – that is, the output is equal to a constant times the input. If the level is too low or too high the amplifier becomes "non-linear" and the output signal becomes distorted.

5.2 Semiconductors

- A semiconductor is a material that is somewhere between a conductor and an insulator. One example of a semiconductor is silicon.
- In its pure state, a semiconductor can be a good insulator.
- In a semiconductor, the atoms of the material form a crystal lattice and share electrons with neighbouring atoms in order to form a stable configuration.
- Silicon, for example, has four valence electrons, but would like to have eight in order to be stable. It can do this by sharing electrons with neighbouring silicon atoms in order to have "effectively eight" valence electrons.
- To make a semiconductor, a crystal is **doped** with impurities. These impurities are composed of atoms that have either one more or one fewer valence electron than the atoms in the crystal.
- If there is an **extra valence electron** present in the dopant, the resulting material is an **N-type semiconductor**. The electron is the primary charge carrier.

- If there is a **missing valence electron** in the dopant, the resulting material is a **P-type semiconductor**. The "hole" – that is, the missing electron, into which other electrons can move – is the charge carrier.
- Semiconductors cannot tolerate excessive heat and will be destroyed if they get too hot.

5.3 Diodes

- When a P-type semiconductor and an N-type semiconductor are placed next to each other, we form a **PN junction**, the basis for a **diode**.
- In a diode, the N-type naterial is known as the **cathode** and the P-type material is known as the **anode**.
- Electrons in a diode flow from cathode to anode.
- If the voltage at the P-type material is higher than the voltage at the N-type material, electrons will flow readily. In this case the diode is said to be **forward biased**.
- If the voltage at the N-type material is higher, however, electrons will not move readily. The diode is said to be **reverse biased**. A very small current known as **leakage current** does flow, but it is almost negligible.
- Therefore, the function of a diode is to allow current to flow in one direction and one direction only. So, if alternating current is applied to the anode of a diode, you should see pulsating direct current at the cathode. This is called **rectification**.
- If the reverse bias voltage is too high, the diode will fail due to too much current.
- Zener diodes are designed to operate in the reverse breakdown region, and can be used as reliable voltage regulators.
- Light-emitting diodes glow with coloured light when they are forward-biased.
- Diodes can be used to recover information from transmitted signals, in a process called **demodulation**.

5.4 Bipolar Junction Transistors

- A **transistor**, or "transfer resistor", is a semiconductor with three pieces of doped material.
- A bipolar junction transistor (BJT) comes in two flavours: NPN (a P-type material between two N-type materials) and PNP (an N-type material between two P-type materials).

- The material that is in the center is known as the **base**. On either side of it are the **emitter** and the **collector**. This gives the transistor three (3) leads in total.
- The action of a transistor is to use a small input current as a means of controlling a larger output current. The output current can be switched on and off (as is the case in digital circuits) or controlled continuously (as desired for an analog amplifier).
- Transistors operate at low voltages and can amplify small signals.

5.5 Field Effect Transistors

- A field effect transistor, or FET, is a slightly different type of transistor from a BJT.
- FETs use only one type of semiconductor in their operation. Those that use N-type material are called "N-channel" and those using P-type material are "P-channel".
- The three leads on a FET are labelled **gate**, **drain**, and **source**.
- The gate controls the conductance of the channel. It is the voltage between the gate and the source that controls the current through the channel.
- Typically, charge carriers enter the channel at the source and leave it at the drain.
- To reduce the current flowing through a FET, you can increase the reverse bias voltage.
- The source of a FET corresponds to the emitter of a BJT; the drain of a FET corresponds to the collector of a BJT; the gate of a FET corresponds very roughly to the base of a BJT.
- Because of the way they are designed, the source and drain of a FET exhibit very similar characteristics and in some cases can be interchanged.

5.6 Vacuum Tubes

- Vacuum tubes are similar in function to transistors but rely on slightly different physical principles.
- Vacuum tubes are capable of amplifying signals just like transistors, and can provide extremely large gain, but must use very high voltages.
- Vacuum tubes can typically handle much higher power than most transistors.
- A vacuum tube consists of a wire filament plus one or more electrodes surrounded by a fragile glass (or metal) shell. Gas inside the shell has been pumped out to create a vacuum, which is required for correct operation.

- The filament acts as a heater and heats up the **cathode**, which is an electrode that acts as the source of electrons in the tube.
- Electrons form a cloud near the cathode called a "space charge". If another electrode in the vacuum tube, called the **plate**, is placed at a positive voltage with respect to the cathode, electrons in the space charge will be attracted to it. This causes a current to flow from the cathode to the plate. This two-electrode tube acts as a "vacuum diode", since current will only flow in one direction.
- We can make something more interesting by introducing a third electrode into the tube, called the **grid**. This is a wire mesh cylinder that is placed between the cathode and the plate. Electrons can pass through the holes in the grid and reach the plate. This three-electrode tube is called a **triode**.
- If the grid is connected to a voltage that is negative with respect to the cathode, the flow of electrons will be reduced. This can be used to control the current in the same way as a FET.
- The negative voltage applied to the grid is called "bias voltage".
- The base of a bipolar transistor compares closest to the grid of a triode.
- The collector of a bipolar transistor compares closest to the plate of a triode.
- The emitter of a bipolar transistor compares closest to the cathode of a triode.
- There are more exotic vacuum tubes that add more electrodes, such as tetrodes and pentodes, but understanding the triode is sufficient for the Basic Qualification.

6 Transmission Lines and Antennas

6.1 Characteristic Impedance

- A **feed line** connects your transceiver to your antenna.
- Every feedline has a **characteristic impedance**. It is determined by the physical dimensions and relative positions of the conductors. It is **not** a function of the length of the line, the velocity of energy on the line, or the frequency at which the line is operated.
- The characteristic impedance of a feedline is defined as the value of the pure resistance which, if connected to the end of the line, will absorb all the power arriving through it.

- Terminating a transmission line in its characteristic impedance makes it look like an infinitely long line.
- Generally the impedance of a line decreases as the diameter of the line increases.
- Transmission lines are very long and **propagation delay** is a factor in their operation.

6.2 Feedline

- Coaxial cable is a type of feedline where one conductor forms a cylinder or "shield" around the other (they are separated by a dielectric to prevent them from shorting together). Coaxial cable is also shielded on the outside, so the conductors are not exposed. Unlike some types of feedline where the conductors are unshielded, coax can be buried in the ground without the risk of adverse effects such as water leaks.
- Parallel-conductor feedline is made from two wires side-by-side held apart by insulating rods. (This is also known as "open-conductor ladder line" or "open-wire".)
- A "balanced line" is a transmission line whose two conductors have equal impedances. An "unbalanced line" is a transmission line where the two conductors have unequal impedances, such as a coaxial cable (in particular, it is a feedline where one conductor is connected to ground).
- A **balun**, or "balanced-to-unbalanced", allows a balanced antenna to be fed with an unbalanced feedline, or vice-versa.
- Baluns can also perform impedance conversion; for example, a 75-ohm line could be matched to a 300-ohm feedpoint with a 4-to-1 balun.

6.3 Practical Feedline

- Coaxial cable makes a good feedline because it is weatherproof and its impedance matches that of most amateur antennas. However, it is difficult to make at home. Coax is the best feedline to use if it must be put near metal objects.
- Parallel conductor feedline does not work well when tied down to metal objects, and it cannot operate under high power.
- A popular type of amateur feedline is known as RG-213. This is a great feedline on HF. The connector that is typically used with this is the PL-259 or, colloquially, "UHF" connector.
- Old handheld transceivers used a "BNC connector" to connect an antenna. (Modern handhelds use an "SMA connector".)

- An N-type connector has very low loss at UHF, since it is designed to operate at these frequencies. (SMA is also a good choice.)
- Antenna connectors should regularly be cleaned, tightened, and re-soldered to help keep their resistance at a minimum.
- Very old TV twin-lead feedline can be used for feedline in an amateur station, but if you still have some just lying around, *why?* Anyway, its impedance is approximately 300 ohms.

6.4 Loss

- Using good quality coaxial cable and connectors for a UHF antenna system is essential for keeping RF loss low.
- Parallel conductor feedline will operate well with a high SWR and has less loss than coaxial cable.
- You should always use the shortest amount of feedline possible in order to minimize loss. Remember that signal loss increases proportional to length.
- Signal loss also increases with increasing frequency.
- Losses occurring on a transmission line between the transmitter and the antenna results in less RF power being radiated.
- The lowest loss feedline on HF is open-wire ladder line.
- RF feedline losses are expressed in units of decibels per unit length. Doubling the amount of feedline used also doubles the line loss!

6.5 Standing Wave Ratio (SWR)

- Standing wave ratio, or SWR, is a measure of the efficiency of an antenna system in terms of the impedance match. Technically, it is defined as the ratio of maximum to minimum voltages on a feed line.
- An SWR meter measures the quality of the impedance match by measuring and comparing forward and reflected voltage in the antenna system.
- An SWR of "1:1" means the best possible impedance match has been obtained.
- Any SWR of less than "1.5:1" means the impedance match is fairly good.
- A very high SWR reading means that the antenna is the wrong length, or there may be an open or shorted connection somewhere in the feedline.

- A very jumpy SWR reading may mean poor electrical contact between parts of an antenna system.

- If your antenna feedline gets hot when you are transmitting, the SWR may be too high, or the feed line loss may be too high.

- If the characteristic impedance of the feedline does not match the antenna input impedance, standing waves are produced in the feedline and the SWR will be higher than "1:1". This leads to reduced transfer of RF energy to the antenna.

- The SWR can be calculated if the impedance of the feedline and the antenna are known. For example, if the antenna's impedance is 200 ohms and the feedline's impedance is 50 ohms, the SWR is "4:1".

6.6 Impedance Matching

- An antenna tuner might allow an antenna to be used on a band it was not designed for. The goal of an antenna tuner is to match a transceiver to a mismatched (wrong impedance) antenna system.

- A power source will deliver maximum power to the load when the impedance of the load is equal to the impedance of the source.

- If an antenna is correctly connected to a transmitter, the length of the transmission line will have no effect on the matching.

6.7 Polarization

- The polarization of an electromagnetic wave is given by the direction of its electric field vector. For example, a horizontally-polarized wave means the electric field is parallel to the earth's surface.

- A Yagi antenna has horizontal polarization when its elements are parallel to the earth's surface.

- A half-wavelength antenna has vertical polarization when it is perpendicular to the earth's surface.

- An "isotropic antenna" is a hypothetical, ideal point source that is useful for determining certain antenna parameters. Its radiation pattern is a perfect sphere.

- VHF signals from a mobile station using a vertical whip antenna will be best received using a vertical ground-plane antenna. (Remember to keep polarization in mind. A vertical antenna will receive a vertically polarized wave at greater strength than the equivalent horizontal antenna.)

6.8 Practical Antennas and Waves

- If an antenna is made longer, its resonant frequency decreases; conversely, shortening an antenna increases its resonant frequency. (Think about the antenna's length being correlated with the wavelength it is tuned for.)

- Adding a series inductance to an antenna has the effect of decreasing the resonant frequency. (Think of an inductor as a coiled-up wire, which effectively lengthens the antenna.)

- The speed of a radio wave is the same as the speed of light. (You should remember this from a previous chapter.)

- At the end of suspended antenna wire, insulators may be used to limit the electrical length of the antenna.

- One solution to multi-band operation with a shortened radiator is the "trap dipole" or "trap vertical". The traps used are actually parallel inductor-capacitor networks. However, trap antennas radiate harmonics.

6.9 Antenna Characteristics

- A parasitic beam antenna is an antenna where some elements obtain their radio energy by induction or radiation from a driven element.

- The bandwidth of a parasitic beam antenna can be increased by using larger diameter elements.

- Placing a slightly shorter parasitic element $\frac{1}{10}$ of a wavelength away from a dipole antenna has the effect of creating a major lobe in the antenna pattern in the horizontal plane, toward the parasitic element.

- Placing a slightly longer parasitic element $\frac{1}{10}$ of a wavelength away from a dipole antenna has the effect of creating a major lobe in the antenna pattern in the horizontal plane, away from the parasitic element and toward the dipole.

- The previous two points give a bit of the theory behind the Yagi-Uda antenna; more on this later.

- **Bandwidth** is the property of an antenna which defines the range of frequencies to which it will respond.

- A half-wave dipole has about 2.1 dB of gain over an isotropic radiator.

- Antenna **gain** is the numerical ratio relating the radiated signal strength of an antenna to that of another antenna. (Typically these are compared to an isotropic radiator, "dBi", or a dipole, "dBd".)
- The radiation characteristic of a half-wave dipole is minimum radiation from the ends and maximum radiation from broadside.
- The **front-to-back** ratio of a beam or directional antenna is the ratio of the maximum forward power in the major lobe to the maximum backward power radiation.

6.10 Quarter-Wave and Half-Wave Antennas

- To calculate the length in meters (feet) of a quarter-wavelength vertical antenna, divide 71.5 (234) by the antenna's operating frequency in megahertz.
- To calculate the length for a half-wavelength antenna, do it for a quarter-wave antenna and then multiply by 2.
- A 5/8-wavelength vertical antenna is better than a 1/4-wavelength vertical antenna for VHF or UHF mobile operations because it typically has better gain and the angle of radiation is low.
- If a magnetic-base whip antenna is placed on the roof of a car, radio energy goes out equally well in all horizontal directions.
- Downward sloping radials on a ground plane antenna are useful because they bring the feed point impedance closer to 50 ohms (in general, they increase the impedance over horizontal radials).
- The main characteristic of a vertical antenna is that it will receive signals equally well from all compass points around it.
- A loading coil is often used with an HF mobile vertical antenna to tune out capacitive reactance.

6.11 Yagi-Uda Antennas

- A typical Yagi-Uda antenna has one driven element.
- To calculate the length of a driven element for a Yagi-Uda antenna, calculate it as though it were a half-wavelength antenna. (See previous section.)
- The "director" element of a Yagi antenna is always about 10% shorter than the driven element; the "reflector" element is always about 10% longer. If you have to calculate their lengths, first find the length of the driven element and then apply the correction.

- Increasing the boom length and adding directors to a Yagi antenna has the effect of increasing the gain.
- A Yagi antenna with wide element spacing has high gain, less critical tuning, and wider bandwidth.
- Yagi antennas are often used for communication in the 20-meter bands because they help reduce interference from other stations off to the side or behind.
- A good way to get maximum performance from a Yagi antenna is to (use an antenna design and simulation program to) optimize the lengths and spacings of the elements.
- The best overall choice for spacing between elements of a Yagi antenna is 0.2 of a wavelength.
- "Stacking" two antennas has the effect of doubling the effective radiated power; therefore, stacking two 10 dB-gain antennas results in an antenna system with an overall 13 dB gain.

6.12 Dipole Antennas

- One disadvantage of a random wire antenna (i.e. just a long piece of wire that you found and hooked up) is that you may (read: will) experience RF feedback in your station (because your random wire is almost certainly mismatched).
- The low-angle radiation pattern of an ideal half-wavelength dipole HF antenna installed parallel to the earth is a figure-eight, perpendicular to the antenna.
- The impedance of a dipole antenna at the feedpoint is about 73 ohms; the impedance of a folded dipole at the feedpoint is about 300 ohms.
- The bandwidth of a folded dipole antenna is greater than that of a simple dipole antenna.
- A "doublet antenna" has the same electrical length as a half-wave dipole (so use the same formula to calculate its length).

6.13 Loop Antennas

- A "cubical quad antenna" is comprised of two or more parallel four-sided wire loops, each approximately one electrical wavelength long.
- A "delta loop antenna" is a type of cubical quad antenna, except with triangular elements rather than square ones.

- The total length of the driven element in a quad or delta loop antenna is approximately one wavelength. If you have to calculate the length of only one leg, calculate the length of the whole driven element and then divide by the number of sides.
- Two-element delta loops and quads compare favourably with a three-element Yagi.
- Compared to a dipole antenna, the cubical quad antenna has more directivity in both the horizontal and vertical planes.
- Moving the feed point of a multi-element quad antenna from a side parallel to the ground to a side perpendicular to the ground changes the antenna polarization from horizontal to vertical.

7 Propagation

7.1 Ground Waves and Sky Waves

- **Line-of-sight propagation** usually occurs from one handheld VHF transceiver to another nearby. Propagation occurs by direct wave, without interacting with the earth or the ionosphere.
- When a signal is returned to the earth by the ionosphere, this is called **sky-wave propagation** (also known as "ionospheric wave").
- Radiation that is affected by the surface of the earth is called **ground-wave propagation**.
- Sky-wave propagation has much longer range than ground-wave propagation. Reception of HF radio waves beyond 4000 km is generally possibly by sky-wave.
- At HF frequencies, line-of-sight transmission between two stations uses mainly the ground wave.
- The distance travelled by ground waves is less at higher frequencies.

7.2 The Ionosphere

- The ionosphere is a charged layer in the outer atmosphere formed by ionizing solar radiation. Ultraviolet (UV) radiation is most responsible for this ionization.
- The ionosphere is most ionized at midday and least ionized just before dawn.
- The ionosphere is composed of several "regions". The **D region** is the closest ionospheric region to earth. Because it is relatively close to the ground, it is the least useful for long-distance radio wave propagation.

- The **E region** exists above the D region and below the F region.
- The **F1 and F2 regions** of the ionosphere only exist in the daytime. They exist when the F region splits due to heavy ionization. These regions are the farthest from earth. The F2 region in particular is the highest ionospheric region and so it is responsible for the longest distance radio wave propagation.
- During the day, the D region is heavily ionized and absorbs low-frequency radio waves, and so the longest wavelength bands (160m, 80m, 40m) are next to useless for everything except short-distance communications while the sun is up.

7.3 Skip Zones and Ionospheric Interaction

- A **skip zone** is an area which is too far away for ground-wave propagation, but too close for sky-wave propagation. Technically, it is defined as the area between the end of the ground wave and the point where the first refracted (sky) wave returns to earth. (The distance from the transmitter to the end of the skip zone is the "skip distance".) Radio waves tend to "skip" over it when propagating.
- Skip effects are due to reflection and refraction from the ionosphere.
- The maximum distance along the earth's surface that is normally covered in one "hop" using the F2 region is 4500 km (2500 miles).
- The maximum distance normally covered in one "hop" using the E region is 2160 km (1200 miles).
- For radio signals, the skip distance is determined by the height of the ionosphere and the angle of radiation.
- The skip distance of a sky wave will be greatest when the angle between ground and radiation is smallest.
- If the height of the reflecting layer of the ionosphere increases, the skip distance of an HF transmission becomes greater.

7.4 Fading

- Two or more parts of a radio wave can follow different paths during propagation, and this may result in phase differences at the receiver. This "change" in signal strength is called **fading**.
- The usual effect of ionospheric storms is to cause a fade-out of sky-wave signals.

- On the VHF and UHF bands, polarization of the receiving antenna is very important, yet on HF hands it is relatively unimportant. This is because the ionosphere can (and will) change the polarization of the signal from moment to moment.
- Fading of a transmitted signal is much more pronounced at wider bandwidths.
- Reflections, refractions, and Faraday rotation (interaction with a magnetic field) all cause polarization changes. "Parabolic interaction" does not (I could not find a definition of this term).
- Reflection of an SSB transmission from the ionosphere causes relatively little (or no) phase-shift distortion.

7.5 Space Weather

- Solar activity influences all radiocommunication beyond ground-wave or line-of-sight ranges.
- **Sunspots** are magnetic anomalies on the surface of the sun. The more sunspots there are, the greater the ionization.
- An average sunspot cycle is 11 years.
- **Solar flux** is the amount of radio energy emitted by the sun. The solar flux index is a measure of solar activity that is taken at a specific frequency.
- Electromagnetic and particle emissions from the sun influence propagation.
- When sunspot numbers are high, frequencies up to 40 MHz or higher are normally usable for long-distance communication.
- The ability of the ionosphere to reflect high frequency radio signals depends on the amount of solar radiation.

7.6 Maximum Usable Frequency

- The **maximum usable frequency** (or "critical frequency") is the highest frequency signal that will reach its destination. The MUF will vary based on the amount of radiation, mainly UV radiation, received from the sun.
- Signals higher in frequency than the critical frequency will pass through the ionosphere without interacting. Signals lower than the MUF will be bent back to the earth.
- During a sudden ionospheric disturbance, trying a higher frequency might be possible in order to continue HF communications.

- HF beacons are useful to listen for in determining propagation. For example, to determine whether the MUF supports 28 MHz propagation between your station and western Europe, you can listen for signals on the 10-meter beacon frequency.
- The 20-meter band usually supports worldwide propagation during daylight hours at every point in the solar cycle.
- Due to high ionization and solar interaction, communication on the 80 meter band and 160 meter band is generally most difficult during daytime in summer.
- The "optimum working frequency" provides the best long-range HF communication capabilities. It is usually slightly lower than the maximum usable frequency.

7.7 Extended Propagation

- The E region most affects sky-wave propagation on the 6 meter band.
- The "tropospheric wave" is the portion of the radiation kept close to the earth's surface due to bending or ducting in the atmosphere.
- "Tropospheric ducting" of radio waves is caused by a temperature inversion in the atmosphere. It can affect VHF transmissions by allowing them to propagate much further away than normally possible.
- **Sporadic-E** is a condition of patches of dense ionization at E-region height. Sporadic-E typically allows for greatly extended propagation on the 6-meter band.
- Auroral propagation can be used to extend propagation as well, since it takes place at E-region height; in North America, pointing a directional antenna north will take maximum advantage of this effect.
- Modes such as CW and SSB are best for auroral propagation.
- Excluding enhanced propagation modes, the normal range of VHF tropospheric propagation is 800 km (500 miles).

7.8 Scatter

- Ground-wave propagation is the best propagation mode for two stations within each other's skip zone on a certain frequency.
- If you receive a weak, distorted signal from a distance, and close to the maximum usable frequency, you are probably experiencing **scatter** propagation. Scatter allows a signal to be detected at a distance too far for ground-wave propagation but too near for sky-wave propagation.

- HF scatter signals can be recognized by a wavering sound in the received signal. They may also sound distorted because of auroral activity and changes in the earth's magnetic field.
- HF scatter signals are usually very weak, because only a small part of the signal energy is scattered into the skip zone.
- Scatter propagation on HF most often occurs when communicating on frequencies above the maximum usable frequency.
- Meteor scatter, tropospheric scatter, and ionospheric scatter are all scatter modes; "absorption scatter" is not.
- Meteor scatter is most effective on the 6-meter band.
- Side scatter, back scatter, and forward scatter are all scatter modes; "inverted scatter" is not.

8 Interference

8.1 Receiver Overload

- Receiver overload (or front-end overload) occurs when a receiver experiences interference caused by strong signals from a nearby transmitter.
- If the interference is about the same no matter what frequency is being used for the transmitter, front-end overload is probably occurring. The overloading signal can appear wherever the receiver is tuned. This can also cause "cross-modulation", where two signals are received simultaneously; the undesired signal will be heard in the background of the desired signal.
- Analog televisions use frequencies around 54-82 MHz. If someone is still using an analog TV and you think your signals on HF are overloading its receiver, try connecting a *high-pass filter* to the receiver input. The idea is to attenuate your HF signals, which are on frequencies below 54 MHz, while still passing TV frequencies. (Careful application of filters is a good strategy for reducing interference in general; more on this later.)

8.2 Audio Interference

- Bypass capacitors can be used to reduce or eliminate audio-frequency interference in home entertainment systems.

- If a properly operating amateur station is the cause of interference to a nearby telephone, ask the telephone company to install RFI filters.
- If audio rectification of a nearby single-sideband phone transmission occurs in a public address system, you might hear distorted speech from the transmitter's signals. If a CW transmission gets into a PA system, you will hear on-and-off humming or clicking.
- A good way to minimize the possibility of audio rectification of your transmitter's signals is by ensuring that all station equipment is properly grounded.
- A ferrite core can be used to minimize the effect of RF pickup by audio wires connected to stereo speakers. Another way is to shorten the speaker wires (they can act as antennas).

8.3 Transmitter Interference

- In CW transmissions, key clicks (a form of local RF interference) are produced by the making and breaking of the circuit at the Morse key. They are the result of carrier rise and decay times that are too sharp.
- A "key-click filter" (typically made from a simple choke-capacitor circuit) can be used to prevent key clicks.
- If someone tells you that signals from your handheld are interfering with other signals on a nearby frequency, your handheld may be transmitting spurious emissions. This means your transmitter is sending signals outside the frequency or band where it is transmitting.
- Operating a transmitter without the cover and shielding may result in spurious emissions from unshielded RF electronics.
- A "parasitic oscillation" is an unwanted signal developed in a transmitter. They may be found at high or low frequencies, and on either side of the transmitter's displayed frequency.

8.4 Harmonic Radiation

- Harmonic radiation is a form of interference that manifests itself as unwanted signals at frequencies which are **multiples of the chosen transmit frequency**.
- Harmonic radiation may result in out-of-band signals due to the frequency multiplication that takes place.

- If a neighbour reports interference on one or two TV channels only when you transmit on 15 meters, the interference is probably caused by harmonic radiation.
- A poorly tuned transmitter connected to a multi-band antenna may end up transmitting harmonic radiation.
- "Splatter interference" is caused by overmodulation of a transmitter. This can often be caused by driving an amplifier stage into non-linear operation. The best way to fix this is to reduce the microphone gain.
- Excessive harmonics are usually produced by overdriven stages.

8.5 Filters

- A **low-pass filter** is most useful for eliminating harmonic radiation at the transmitter. Install it as close to the transmitter as possible.
- A **high-pass filter** is most useful for eliminating cross-modulation or unwanted RF interference at television sets, etc. Install it as close to the receiver as possible.
- A **band-pass filter** blocks RF energy above and below a certain range.
- A **band-reject filter** passes frequencies on each side of a certain range, but attenuates all frequencies that fall within that range.
- Filters have impedances too! Make sure that the impedance of a filter is matched with the impedance of the transmission lines being used.