Study guide for the

ELEMENT 3 - GENERAL CLASS

Amateur Radio License Exam

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For exams taken on or before 06/30/07 only!

The question pool is scheduled for change on July 1st 2007

This text has been edited to to reflect withdrawn questions due to changes in Part 97 rules that went into effect on 12/15/06

SUBELEMENT G1 -- COMMISSION'S RULES [6 Exam Questions -- 6 Groups]

G1A General control operator frequency privileges

There are 11 questions in subelement G1A asking for you to identify the general class frequency privilege in one of the amateur bands. The table below lists those frequency ranges for each band addressed by those questions. Some of the questions reference ITU Region 2. ITU Region 2 includes all of North America. * - withdrawn from the exam pool 12/15/2006, edited to show new frequencies that you should know anyway.

160-meter band (ITU Region 2) – 1800 - 2000-kHz
75/80-meter band (ITU Region 2) – 3525 - 3600-kHz and 3800 – 4000-kHz *
40-meter band (ITU Region 2) – 7025 - 7125-kHz and 7175 – 7300-kHz *
30-meter band – 10100 - 10150-kHz
20-meter band – 14025 - 14150-kHz and 14225 - 14350-kHz
15-meter band – 21025 - 21200-kHz and 21275 – 21450-kHz *
12-meter band – 24890 - 24990-kHz
10-meter band – 28000 - 29700-kHz
17-meter band – 18068 - 18168-kHz

The frequency segments for General class licensees within the 75/80-meter band in ITU Region 2 that are authorized for CW emissions are 3525 - 3600 kHz and 3800 - 4000 kHz. * It is important to note that CW is authorized anywhere that amateur transmissions are authorized except on the 5 channels of the 60 meter band.

The frequency segments within the 10-meter band authorized for phone emissions are 28300 - 29700 kHz. Frequencies on the 10 meter band below 28300 kHz are restricted to CW or digital modes only.

G1B Antenna structure limitations; good engineering and good amateur practice; beacon operation; restricted operation; retransmitting radio signals

Provided it is not at or near a public-use airport, 200 feet is the maximum height above ground an antenna structure may rise without requiring its owner to notify the FAA and register with the FCC. FAA regulations require lighting devices for towers over 200 feet in height to assist aircraft in avoiding your tower.

If the FCC Rules DO NOT specifically cover a situation, you must operate your amateur station in accordance with good engineering and good amateur practice.

An amateur station may not be used for the gathering of news information based upon the idea that the information is more quickly transmitted by amateur radio. While news organizations may obtain information from amateur radio communications, amateur radio may not be used directly as a news gathering/reporting system.

Amateur radio may not be used to transmit music, obscene or indecent words, or false or deceptive signals. With proper authorization, an amateur station may be used for the retransmission of space craft communications. The only limited circumstance where music may be transmitted by an amateur station is when it is an incidental part of an authorized space craft audio retransmission. * To prevent your station from accidentally re-transmitting music or signals from a non amateur station, you should turn down the volume of the background audio source.

An amateur station in two-way communication may never transmit a message in a secret code in order to obscure the meaning of the communication. Abbreviations or procedural signals may be used in the amateur service if they do not obscure the meaning of a message.

Beacon stations are a type of amateur station that may transmit only one-way communications. The FCC requirements regarding beacon stations are that only one signal per band is permitted from a given location, the transmitter power of the beacon station must not exceed 100 watts, the control operator of the beacon station must hold a valid amateur operator license of Technician class or higher. There is no requirement that all transmissions must use audio frequency shift keying (AFSK).

G1C Transmitter power standards; certification of external RF- power-amplifiers; standards for certification of external RF-power amplifiers; HF data emission standards

According to FCC rules, General class licensees are permitted to use the minimum power required to conduct communications up to a maximum power of 1500 watts PEP output. Different locations within the amateur bands may or may not have power restrictions that apply due to FCC rules and/or other treaty requirements.

The maximum transmitting power an amateur station may use on 3690 kHz is 200 watts PEP output because this frequency is assigned to Novice and Technician class operators who are restricted to 200 watts PEP output.

The maximum transmitting power an amateur station may use on 7080 kHz is 1500 watts PEP output. This frequency is part of the General class allocation on the 40 meter band.

The maximum transmitting power an amateur station may use on 10.140 MHz is 200 watts PEP output. This band is limited to 200 watts PEP output by international treaty and FCC rules because amateur radio is a secondary allocation on this band.

The maximum transmitting power an amateur station may use on 21.305 MHz is the minimum power necessary to carry out the desired communications, with a maximum of 1500 watts PEP output. 21.305 MHz is in the General class allocation on the 15 meter band.

The maximum transmitting power an amateur station may use on 24.950 MHz is 1500 watts PEP output. The entire 12 meter band is available to General class licensees.

The maximum transmitting power an amateur station may use on 7255 kHz is the minimum power necessary to carry out the desired communications, with a maximum of 1500 watts PEP output. 7255 kHz is in the General class allocation on the 40 meter band.

The maximum transmitting power an amateur station may use on 14.300 MHz is the minimum power necessary to carry out the desired communications, with a maximum of 1500 watts PEP output. 14.300 MHz is in the General class allocation on the 20 meter band.

The maximum transmitting power a station with a General Class control operator may use on 28.400 MHz is the minimum power necessary to carry out the desired communications, with a maximum of 1500 watts PEP output. While 28.400 MHz is authorized for use by Technician Plus operators who are restricted to 200 watts PEP output, there is no additional restriction for General class and higher licensees at this frequency.

The maximum transmitting power a station with a General Class control operator may use on 28.150 MHz is the minimum power necessary to carry out the desired communications, with a maximum of 1500 watts PEP output. 28.150 MHz is also authorized for use by Technician Plus operators who are restricted to 200 watts PEP output, there is no additional restriction for General class and higher licensees at this frequency.

The maximum transmitting power an amateur station may use on 1825 kHz is the minimum power necessary to carry out the desired communications, with a maximum of 1500 watts PEP output. The 160 meter band is only available to General class and higher licensees.

The requirements for when a station is transmitting on the 60-meter band are that all transmissions may only use Upper Sideband (USB); the 3-dB bandwidth of a signal shall not exceed 2.8 kHz, when centered on any of the five FCC- authorized transmitting frequencies; transmissions shall not exceed an effective radiated power of 50 W PEP. There is no requirement that antenna height shall not exceed 50 feet above mean sea level (AMSL). In fact most locations are above 50 feet mean sea level.

G1D Examination element preparation; examination administration; temporary station identification

There will be no Element 1 exams after 02/23/07, however these questions are still in the pool, as that change does not go into effect until that date.

An accredited VE holding a General Class operator license may prepare and/or administer examination Elements (1) Morse code and (2) Technician written exam. A minimum of three VEC-accredited General Class or higher VEs must be present to administer a Technician Class operator examination. To participate as an administering VE for a Technician Class operator license examination or Element 1 Morse Code examination, you must have been granted your FCC General class or higher operator license and must have received your VEC accreditation.

To obtain a Technician class operator license an applicant must pass the Element 2 Technician Class exam only. To obtain Morse Code credit to operate on the HF bands, the applicant must also pass Element 1, the five word per minute Morse Code exam.

If you are a Technician Class operator with a CSCE for General Class operator privileges, you would identify your station by giving your call sign, followed by the slant mark "/", followed by the identifier "AG" when transmitting on 14.035 MHz. This frequency is allocated to CW and digital modes only. When operating voice mode on 14.325 MHz, you would give your call sign followed by any suitable word such as “temporary” or “interim” that denotes the slant mark and the identifier "AG". Any time you are operating on your new General class privileges, you must add the special identifier "AG" after your call sign, until your upgrade is listed in the FCC /ULS database. This would apply any time you operate from 18068 - 18168-kHz ; 14025 - 14150-kHz and 14225 - 14350-kHz ; 10100 - 10150-kHz . These frequencies are specifically referenced in questions from the published exam pool but this would also be the case for any frequency not authorized to the Technician class licensee.

G1E Local control; repeater and harmful interference definitions; third party communications

As a General Class control operator at the station of a Technician Class operator, you must identify the station while transmitting on 7250 kHz with the Technician Class operator's station call sign, followed by the slant bar "/" (or any suitable word) and your own call sign.

A repeater station is an amateur station that simultaneously retransmits the signals of other stations on a different channel. A 10-meter repeater may retransmit the 2-meter signal from a station having a Technician Class control operator only if the 10-meter control operator holds at least a General class license.

Harmful interference is a name given to a form of interference that seriously degrades, obstructs or repeatedly interrupts a radiocommunication service.

Should a repeater cause harmful interference to another repeater when a frequency coordinator has recommended the operation of one station only, the licensee of the uncoordinated repeater is responsible for resolving the interference.

When the FCC rules say that the amateur service is a secondary user and another service is a primary user, amateur stations are allowed to use the frequency band only if they do not cause harmful interference to primary users. If you are using the 30 meter band and a station assigned to the band’s primary service is causing interference, you must change frequencies or stop transmitting because you may be causing harmful interference to the other station, in violation of FCC rules. Amateur radio stations have no protection from harmful interference caused by primary service users while operating in the 60-meter band. Amateur stations must not cause harmful interference to stations operating in other radio services.

If you are using a language other than English in making a contact, you must identify your station in English.

When transmitting third party messages an amateur station may be operated under local or remote station control. Remote control means that the control operator may not be at the same physical location as the transmitting equipment.

G1F Certification of external RF-power-amplifiers; standards for certification of external RF-power amplifiers; HF data emission standards

External RF power amplifiers designed to operate below 144 MHz may require FCC certification. Without a grant of FCC certification, only one external RF amplifier of a given design capable of operation below 144 MHz may built or modified in one calendar year. One requirement for receiving FCC certification is that the external RF amplifier must not be capable of reaching its designed output power when driven with less than 50 watts. The capability of being switched by the operator to all amateur service frequencies below 24 MHz would NOT disqualify an external RF power amplifier from a FCC certification grant. In order to receive a FCC grant of certification, an external RF amplifier must not be capable of operation on any frequency between 24 MHz and 35 MHz. The maximum power gain that a 10-meter RF amplifier can have to receive FCC certification is 6 dB.

The maximum symbol rate permitted for RTTY emissions transmitted on frequency bands below 10 meters is 300 baud.

The maximum symbol rate permitted for RTTY or data emission on the 10-meter band is 1200 baud.

The maximum symbol rate permitted for RTTY, packet, or data emission on the 6- and 2-meter bands is 19.6 kilobaud.. The maximum authorized bandwidth for RTTY, data or multiplexed emissions using an unspecified digital code transmitted on the 6- and 2-meter bands is 20 kHz.

SUBELEMENT G2 - OPERATING PROCEDURES [6 Exam Questions - 6 Groups]

G2A Phone operating procedures

Single sideband (SSB) is most commonly used on the High Frequency Amateur bands for voice or phone communications. Single sideband transmissions are used more frequently than Amplitude Modulation (AM) on the HF amateur bands because they use less spectrum space, are more power efficient, and no carrier is transmitted with a single sideband transmission. LSB or lower sideband means that only the lower sideband transmitted, and the upper sideband is suppressed while for USB or upper sideband transmission only the upper sideband is transmitted, and the lower sideband is suppressed. In both cases the carrier is also suppressed, and will be reconstructed by the receiving station to recover the transmitted audio signal. By tradition frequencies in the 160-, 75- and 40-meter bands use lower sideband (LSB) for phone operations. Frequencies above the 40 meter band use upper sideband (USB).

Upper sideband is commonly used for 20-meter phone operation..
Lower sideband is commonly used on 3925-kHz for phone operation in the 80 meter band
Lower sideband is commonly used for 40-meter phone operation.
Upper sideband is commonly used for 10-meter phone operation.
Upper sideband is commonly used for 15-Meter phone operation.
Upper sideband is commonly used for 17-Meter phone operation.

G2B Operating courtesy

If you are the net control station of a daily HF net, and the frequency on which you normally meet is in use just before the net begins you should conduct the net on a clear frequency 3 to 5-kHz away from the regular net frequency.

If a net is about to begin on a frequency which you and another station are using, you should, as a courtesy to the net, move to a different frequency.

If propagation changes during your contact and you notice increasing interference from other activity on the same frequency, you should move your contact to another frequency. You may be causing interference to other stations on the frequency.

When selecting a CW transmitting frequency, you should try to allow 150 to 500 Hz separation from a contact in progress to minimize interference. When selecting a single-sideband phone transmitting frequency, you should allow approximately 3 kHz separation (between suppressed carriers) from a contact in progress to minimize interference. When selecting a RTTY transmitting frequency, you should allow 250 to 500 Hz (center to center) separation from a contact in progress to minimize interference. Each operating mode has it’s own bandwidth requirement, and operating too close to a contact in progress will only result in interference for both contacts.

A "Band Plan"is another name for a voluntary guideline that guides amateur activities and extends beyond the divisions established by the FCC for using different operating modes within an amateur band.

The exam questions may ask you about selecting frequencies for Slow-Scan TV (SSTV) operation, radioteletype (RTTY) operation, or HF Packet operation. To comply with good amateur practice when choosing a frequency for any type of radio transmission, you should review FCC Part 97 Rules regarding permitted frequencies and emission types, follow the generally accepted gentleman's agreement band plans, and before transmitting be sure to listen to the frequency to be used to avoid interfering with an ongoing communication. When using phone (voice) a considerate way to avoid harmful interference is to ask if the frequency is in use, and say your call sign. When using Morse Code, send “QRL? de” followed by your call sign and listen for a response.

G2C Emergencies, including drills and emergency communications

An amateur station in distress may use any means of radio communication to attract attention, make known its condition and location, and obtain assistance. During an emergency, there are no power output limitations that must be observed by a station in distress. The station in distress may use any means required to summon assistance. During a disaster or emergency in the US, any frequency or mode of emission may be used to obtain assistance. You would use the frequency that has the best chance of communicating the distress message. Anyone who sends a distress transmission should give to stations who answer, the location and nature of the distress. If you are communicating with another amateur station and hear a station in distress break in, the first thing you should do is acknowledge the station in distress and determine its location and what assistance may be needed. You are not ever prohibited from helping any station in distress, even if doing so would require you to operate outside of the authorization of your amateur license. Remember, someday the roles may be reversed, and you would want someone to answer your call for help.

During a disaster in the US when normal communication systems are overloaded, damaged or disrupted , an amateur station can make transmissions necessary to meet essential communication needs and assist relief operations. If a disaster disrupts normal communications in your area, the FCC may declare a temporary state of communication emergency. This declaration would include any special conditions and special rules to be observed by stations during the emergency. When FCC declares a temporary state of communication emergency, you must abide by the limitations or conditions set forth in the FCC notice.

Stations in the Radio Amateur Civil Emergency Service (RACES) participate in training tests and drills to provide orderly and efficient operations for the civil defense organization they serve in the event of an emergency.

G2D Amateur auxiliary to the FCC's Compliance and Information Bureau; antenna orientation to minimize interference; HF operations, including logging practices

The Amateur Auxiliary to the FCC's Compliance and Information Bureau are amateur volunteers who are formally enlisted to monitor the airwaves for rules violations. The objective of this group is to encourage amateur self-regulation and compliance with the rules. Direction-finding "Fox Hunts" are important to the Amateur Auxiliary, as they provide an opportunity to practice direction-finding skills.

An azimuthal projection map is a map projection centered on a particular location, used to determine the shortest path between points on the surface of the earth. It is a useful type of map to use when orienting a directional HF antenna toward a distant station. This would be very important if you were using a unidirectional HF antenna to focus your signal to minimize interference. This would be some type of directional or “beam” antenna, rather than an omnidirectional antenna.

A directional antenna pointed in the long-path direction to another station is generally oriented 180 degrees from its short-path heading. A well-defined echo can be heard in a skywave signals sound if it arrives at your receiver by both short path and long path propagation.

If a visiting amateur transmits with permission from your station on 14.325 MHz, you should remember that the FCC may think you wer3e the stations operator at the time. While there is no requirement to keep in your station log the call sign of the visiting amateur together with the time and date of transmissions, it might be helpful to have that information later if there should be any question about who was operating the station. Also remember that you are both responsible for the correct operation of the station. To help with your reply, if FCC requests information on who was control operator of your station for a given date and time, a station log may provide information (callsigns, dates & times of contacts) used for many operating contests and awards; logs are necessary to accurately verify contacts made weeks, months or years earlier, especially when completing QSL cards. A log entry could contain the date and time of contact; band and/or frequency of the contact; call sign of station contacted and the RST signal report given. Most important, a station log can aid you in resolving interference complaints. It is important to remember that if you are operating on the 60 meter band and you are using other than a dipole antenna, you must keep a record of the gain of your antenna. The rules for the 60 meter band require you to have an effective radiated power of 50 watts or less.

G2E Third-party communications; ITU Regions; VOX operation

When communicating with an amateur station in a foreign country, only messages of a technical nature or personal remarks of relative unimportance should be sent. You may be all excited over the prospect of explaining what you think is wrong with the foreign ham's government but you need to remember that his government may not be so excited with having him participate in such an exchange. When handling messages for a third party to a foreign country where such traffic is permitted, only messages of a technical nature or remarks of a personal character may be transmitted.

VOX operation is a mode that allows "Hands Free' operation. The circuit called that causes a transmitter to automatically transmit when an operator speaks into its microphone is called a VOX. The user adjustable controls are usually associated with VOX circuitry are Anti-VOX, VOX Delay, and VOX Sensitivity. Anti-VOX is the setting that keeps received audio from the radio speaker from triggering the radio into transmit mode. VOX delay is the time that passes before the transmitter shuts off and the receiver switches back on. VOX sensitivity is used to set the audio level at which the transmitter activates. A good reason to use a headset with an attached microphone and VOX control when using a mobile station is that it provides safer hands free operation.

The International Telecommunications Union (ITU) is the organizations that is responsible for international regulation of the radio spectrum. The continental United States is in ITU Region 2. Europe and Africa are in Region 1. Australia is in Region 3.

The phrase, "End of message" would indicate the completion of the transmitting of a formal message when using phone.

G2F CW operating procedures, including procedural signals, Q signals and common abbreviations; full break-in; RTTY operating procedures, including procedural signals and common abbreviations and operating procedures for other digital modes, such as HF packet, AMTOR, PacTOR, G-TOR, Clover and PSK31

When using CW to the prosign that would be sent to indicate the end of a formal message is 'AR' - end of message.

The signal 'QSK' describes full break-in telegraphy, or a mode where incoming signals are received between transmitted key pulses.

In the 80-meter band, most data transmissions take place between 3580 - 3620-kHz.

The abbreviation "RTTY" stand for radioteletype. 170 Hz is the most common frequency shift for RTTY emissions in the amateur HF bands. When tuning up and preparing to send a message using RTTY, a string of letters R and Y (sent as "RYRYRYRY...") are sent to allow the receiving stations time to 'tune in' the sending station prior to the actual message being sent. In the old mechanical teleprinters, this also exercised all of the 'bits' of the printing mechanism as the Baudot codes for R and Y contained opposite bit patterns. This practice has been carried over into other types of data transmissions.

In the 20-meter band most RTTY transmissions take place between 14.070 - 14.095 MHz

Using RTTY or other data modes, you insert the character sequence 'NNNN" to indicate the end of a formal message.

ASCII is a 7-bit code, with start, stop and parity bits. Baudot is a 5-bit code, with additional start and stop bits. The number of bits in a PSK31 character is variable due to it being designed for very efficient use of spectrum bandwidth.

AMTOR is a data mode with good error detection and correction properties, but you should remember that on the exam, the two major AMTOR operating modes are **not** SELCAL and LISTEN.

The header part of a data packet contains the routing and handling information.

SUBELEMENT G3 -- RADIO WAVE PROPAGATION [3 Exam Questions -- 3 Groups]

G3A Ionospheric disturbances; sunspots and solar radiation

When a solar flare erupts from the surface of the Sun massive amounts of ultraviolet and X-ray arrive at the Earth about 8 minutes later. This blast of radiation can cause a condition known as a Sudden Ionospheric Disturbance. The effect of a sudden ionospheric disturbance on the day-time ionospheric propagation of HF radio waves is the disruption of signals on lower frequencies more than those on higher frequencies. To continue communications during a sudden ionospheric disturbance try a higher frequency. While the UV and X-ray radiation from coronal mass ejections (CMEs) associated with solar flares effect radio-wave propagation on the earth in about 8 minutes, the charged particles do not arrive until 20-40 hours later. tnx to KB8HFK!

The radio energy emitted by the sun is known as the solar flux. The solar-flux index is a measure of solar activity that is taken at a specific frequency.

A geomagnetic disturbance is a dramatic change in the earth's magnetic field over a short period of time. At latitudes greater than 45 degrees propagation paths more sensitive to geomagnetic disturbances. This can result in degraded high-latitude HF propagation during a major geomagnetic storm. In a propagation forecast, the K- index is a measure of geomagnetic stability. The A- index is a daily value measured on a scale from 0 to 400 to express the range of disturbance of the geomagnetic field. During periods of high geomagnetic activity there might be a visible aurora.

The sunspot number is a daily index of sunspot activity. When sunspot numbers are high, long-distance communication in the upper HF and lower VHF range is enhanced. The average sunspot number varies on an approximately 11- year cycle called the sunspot cycle.

A solar coronal hole will effect radio communications by emitting charged particles that usually disrupt HF radio communications.

G3B Maximum usable frequency; propagation "hops"

The MUF or Maximum Usable Frequency is the frequency above which communication with a location is not possible. This frequency will change from minute to minute and will vary over different paths. If the maximum usable frequency (MUF) on the path from Minnesota to France is 24 MHz, the 15 meters band should offer the best chance for a successful contact. If the maximum usable frequency (MUF) on the path from Ohio to Germany is 17 MHz, the 20 meter band should offer the best chance for a successful contact. When radio waves with frequencies below the maximum usable frequency (MUF) are sent into the ionosphere they are bent back to the earth. The factors that effect the maximum usable frequency (MUF) are path distance and locations, time of day, season, solar radiation, and ionospheric disturbances. The MUF has an opposite value known as the LUF or Lowest Usable Frequency. When the lowest usable frequency (LUF) exceeds the maximum usable frequency (MUF) no HF radio frequency will support communications along an ionospheric signal path.

If the HF radio-wave propagation (skip) is generally good on the 24-MHz and 28-MHz bands for several days, you might you expect a similar condition to occur 28 days later because the conditions may have been caused by a group of sunspots that will re-appear on the next rotation of the Sun

What is one way to determine if the maximum usable frequency (MUF) is high enough to support 28-MHz propagation between your station and western Europe is to listen for signals on a 10-meter beacon frequency. To hear beacons that would help you determine propagation conditions on the 20-meter band you would tune to 14.1 MHz.

During periods of low solar activity, frequencies above 20 MHz are the least reliable for long-distance communication. At any point in the solar cycle the 20-meter band usually supports worldwide propagation during daylight hours.

The maximum distance along the Earth's surface that is normally covered in one hop using the F2 region is about 2500 miles. The maximum distance along the Earth's surface that is normally covered in one hop using the E region is about 1200 miles.

A short distance hop on 10 meters might indicate that the MUF exceeds 50 MHz . This would meant that long distance propagation may be possible on the 6 meter band.

G3C Height of ionospheric regions; critical angle and frequency; HF scatter

What is the average height of maximum ionization of the E region is about 70 miles

The F2 region can be expected to reach its maximum height of about 250 miles at your location at noon during the summer. The F2 region mainly responsible for the longest-distance radio-wave propagation because it is the highest ionospheric region.

The "critical angle" as used in radio-wave propagation is the highest takeoff angle that will return a radio wave to the earth under specific ionospheric conditions.

The main reason the 160-, 80- and 40-meter amateur bands tend to be useful only for short-distance communications during daylight hours is because of D-region absorption. Daylight fading on the 40-meter band is associated most with The D layer. Ionospheric absorption will be minimum near the maximum usable frequency (MUF)?

HF scatter signals are a usually weak, wavering sound caused by radio energy scattered into the skip zone through several radio-wave paths. This type of radio-wave propagation allows a signal to be detected at a distance too far for ground-wave propagation but too near for normal sky-wave propagation. Scatter propagation on the HF bands most often occurs when communicating on frequencies above the maximum usable frequency (MUF).

SUBELEMENT G4 -- AMATEUR RADIO PRACTICES [5 Exam Questions -- 5 Groups]

G4A Two-tone test; electronic TR switch; amplifier neutralization

To test the amplitude linearity of a single-sideband phone transmitter, two audio-frequency sine waves that must be within the transmitter audio modulation passband, and should not be harmonically related are fed into the microphone input and the output is observed on an oscilloscope .

In an HF transceiver block diagram an electronic TR switch would normally appear between the transmitter and low-pass filter. An electronic TR switch preferable to a mechanical one because it has a higher operating speed.

Neutralization is necessary for some vacuum-tube amplifiers to cancel self oscillation caused by the effects of interelectrode capacitance. In a properly neutralized RF amplifier, enough negative feedback is introduced to cancel out the effects of positive feedback. As a power amplifier is tuned, a minimum change in grid current on its grid-current meter as the output circuit is changed, indicates the best neutralization.

In some applications a diode can act like a switch because it permits current flow when forward biased and blocks current when reverse biased.

G4B Test equipment: oscilloscope; signal tracer; antenna noise bridge; monitoring oscilloscope; field-strength meters

There are many types of test equipment you may use in your station, but for the exam you should be familiar with the ones listed below.

A monitoring oscilloscope is the best instrument to use to check the signal quality of a CW or single-sideband phone transmitter. An oscilloscope is an item of test equipment that contains horizontal and vertical channel amplifiers connected to a visual display. A digital oscilloscope is an oscilloscope designed around digital technology rather than analog technology. These often use and LCD display rather than a CRT, and can run on battery power. Most often, the input signal is displayed on the vertical axis plotted against time on the horizontal axis. To check the quality of the RF output of the transmitter you would connect a sample of the signal to the vertical input of a monitoring oscilloscope. To check transmitter modulation using double trapezoidal patterns an AM or SSB transmitter you would couple the RF output signal to the vertical plates and external trigger input and set the internal sweep to twice the modulating frequency.

A signal tracer can be used to identify an inoperative stage in a receiver.

A noise bridge can be connected between a receiver and an antenna of unknown impedance and is tuned for minimum noise. This is helpful when pre-tuning an antenna tuner before beginning transmissions. A noise bridge can also be used to determine characteristic impedance of an unknown length and type of transmission line.

A field-strength meter is a simple instrument may be used used to monitor relative RF output during antenna and transmitter adjustments. A field strength meter can also provide a measure of the field pattern of an antenna, or for close-in RDF or Radio Direction Finding work.

In order to raise the S-meter reading on a receiver from S8 to S9, the power output of a transmitter be increased approximately by a factor of 4.

G4C Audio rectification in consumer electronics; RF ground

You would install bypass capacitors in home-entertainment systems to reduce or eliminate audio-frequency interference, by creating a relatively low impedance path to ground for the RF energy.

If a properly operating amateur station is the cause of interference to a nearby telephone you could install RFI filters at the effected telephone

The sound that is heard from a public-address system if audio rectification of a nearby single-sideband phone transmission occurs is distorted speech from the transmitter's signals. A CW signal would sound like on-and-off humming or clicking. Unintended rectification of an RF signal is usually caused by induced currents in conductors that are in poor electrical contact.

If your third-floor amateur station has a ground wire running 33 feet down to a ground rod, you might get an RF burn if you touch the front panel of your HF transceiver because the ground wire is a resonant length on several HF bands and acts more like an antenna than an RF ground connection. One good way to avoid stray RF energy in your amateur station is to keep the station's ground wire as short as possible. RF hot spots can occur in a station located above the ground floor if the equipment is grounded by a long ground wire. A good station ground will reduce electrical noise, reduce interference, and reduce the possibility of electrical shock, but for the exam you need to know that it will not reduce the cost of operating a station. Braid from RG-213 coaxial cable makes a good conductor to tie station equipment together into a station ground. According to the National Electrical Code, there should be only one grounding system in a building.   The minimum length for a good ground rod is 8 feet. All station equipment needs to be tied into a station ground, not just the transceivers and power amplifiers. Severe, broadband radio frequency noise at an amateur radio station can be caused by an intermittent RF ground. To avoid creating a ground loop with all of it’s problems be sure to connect all of your stations ground conductors to a single point.

Additional information about grounding requirements and procedures may be found in the National Electrical Code. The RF exposure limits of the human body however are not addressed by the National Electrical Code.

G4D Speech processors; PEP calculations; wire sizes and fuses

The reason for using a properly adjusted speech processor with a single-sideband phone transmitter is to improve signal intelligibility at the receiver. If a single-sideband phone transmitter is 100% modulated, a speech processor will add nothing to the output PEP.

If the output PEP from a transmitter displayed on an oscilloscope measures 200 volts peak-to-peak across a 50-ohm resistor connected to the transmitter output, the transmitter output is 100 watts. If the output PEP from a transmitter if displayed on an oscilloscope measures 500 volts peak-to-peak across a 50-ohm resistor connected to the transmitter output, the transmitter output is 625 watts. Remember, peak-to-peak voltage describes the difference between the maximum positive going voltage and the maximum negative going voltage.

If the output of an unmodulated carrier transmitter shown on an average-reading wattmeter connected to the transmitter output indicates 1060 watts the PEP output is also 1060 watts. The averaging function of these meters is used to calculate the average PEP output of a modulated RF output.

Only the "hot" (black and red) wires in a four-conductor line cord should be attached to fuses in a 240-VAC primary (single phase) power supply. You do not want a fault in the power wiring in some piece of equipment to disconnect the ground (green) or neutral (white) wire because that could result in a voltage potential being present at the outside of the equipment.

What size wire is normally used on a 20-ampere, 120-VAC household appliance circuit would be AWG number 12. AWG number 12 wiring should never be fused at a value larger than 20 amperes.

Properly adjusted speech clipping prevents overdriving of the transmitter's modulator stage.

The voltage across a 50-ohm dummy load dissipating 1200 watts would be about 245 volts. This calculation is related to Ohm’s law. The formula to calculate this would be

$$E\ (\text{volts}) = \sqrt{P(watts) x R(ohms)}$$

G4E Common connectors used in amateur stations: types; when to use; fastening methods; precautions when using; HF mobile radio installations; emergency power systems; generators; battery storage devices and charging sources including solar; wind generation

Type N coaxial connector would be a good choice to use for 10 GHz feed-line connections. There are several different types of coaxial connectors used in amateur radio, but this one is the best choice for that frequency. The DB-25 connector is NOT designed for RF transmission lines, it is designed for connecting computer peripherals and other related devices.

When installing a power plug on a line cord, you should twist the wire strands neatly and fasten them so they don't cause a short circuit. Be sure to observe the correct wire color conventions for plug terminals and use proper grounding.

A direct, fused connection to the battery using heavy gauge wire would be best for a 100-watt HF mobile installation. A 100 watt transmitter will draw 20 amps on modulation peaks from a 12 volt source. It best NOT to draw the DC power for a 100-watt HF transceiver from an automobile's cigarette lighter socket because the socket's wiring may not be adequate for the current being drawn by the transceiver.

The main limit to the effectiveness of an HF mobile transceiver operating in the 75-meter band is the HF mobile antenna system.

An emergency generator, either permanent or temporary should be located in a well ventilated area and the installation should be grounded. When using a gasoline-fueled generator to power your home station always ground the frame of the generator and use only generators that produce a clean sine wave output. Be sure that the engine is well lubricated. Extra fuel supplies, especially gasoline, should not be stored in an inhabited area. You should avoid placing a gasoline-fueled generator to power your station inside a building or outside an open window. CO (carbon monoxide) is a colorless, odorless gas that will kill you. During a commercial power outage, it would be unwise to back feed the output of a gasoline generator into your house wiring by connecting the generator through an AC wall outlet because it presents a hazard for electric company workers and/or you may draw too much current, overloading your generator. If power is restored to your house before you disconnect the unit, it will damage your generator.

Lead-acid storage batteries when they are being charged give off explosive hydrogen gas.

Photovoltaic conversion is the name of the process by which sunlight is directly changed into electricity. The approximate open-circuit voltage from a modern, well illuminated photovoltaic cell is 0.5 VDC. To determine the proper size solar panel to use in a solar-powered battery-charging circuit you would need to consider the panel's voltage rating and maximum output current.

The biggest disadvantage to using wind power as the primary source of power for an emergency station is that a large electrical storage system is needed to supply power when the wind is not blowing.

SUBELEMENT G5 -- ELECTRICAL PRINCIPLES [2 Exam Questions -- 2 Groups]

G5A Impedance, including matching; resistance, including ohm; reactance; inductance; capacitance; and metric divisions of these values

Reactance is the opposition to AC caused by inductors and capacitors in a circuit. Impedance is the opposition to the flow of AC in a circuit and is the total of reactances and resistances in a circuit. The reactance of a coil or inductor increases as the frequency of the applied AC increases. The reactance of decreases as the frequency of the applied AC increases. When the impedance of an electrical load is equal to the internal impedance of the power source the source delivers maximum power to the load. Reactance and impedance values are expressed in Ohms. Core saturation of a conventional impedance matching transformer be avoided because harmonics and distortion could result from saturation.

G5B Decibel; Ohm's Law; current and voltage dividers; electrical power calculations and series and parallel components; transformers (either voltage or impedance); sine wave root-mean-square (RMS) value

A two-times increase in power results in a change of 3 dB.

In a parallel circuit with a voltage source and several branch resistors, the total current equals the sum of the branch current through each resistor.

It is sometimes necessary to calculate power, voltage or other circuit parameters using Ohm's Law. Remember the formulas..

$E(volts) = I(amps) x R(ohms)$ And $P(watts) = I(amps) x E(volts)$

Some of the questions turn these basic equations around to find different values, or require other simple algebraic conversion to obtain the correct formula. In the following section the question directly taken from the question pool is followed by the formula used to calculate the answer. The correct answer is also given. While there is no requirement to know these formulas, it will help you understand the concepts better if you can do these calculations and see how the result is arrived at.

The following examples are questions directly from the exam pool. Shown below each question is the formula used to calculate the answer. Remember when taking the exam, that you will choose the answer CLOSEST to the correct answer. The answer values are often rounded off to one or two decimal places.

How many watts of electrical power are used if 400 VDC is supplied to an 800-ohm load?

$$P(watts) = \frac{E(volts)^2}{R(ohms)} = 200 \text{ watts}$$

How many watts of electrical power are used by a 12-VDC light bulb that draws 0.2 amperes?

$$P(watts) = I(amps) x E(volts) = 2.4 \text{ watts}$$

How many watts are being dissipated when 7.0 milliamperes flow through 1.25 kilohms?

$$P(watts) = I(amps)^2 x R(ohms) = \text{Approximately 61 milliwatts (0.061 watts)}$$

What is the voltage across a 500-turn secondary winding in a transformer if the 2250-turn primary is connected to 120 VAC? (This is a simple ratio problem.)

$$\frac{SecondaryTurns}{PrimaryTurns} = \frac{OutputVolts}{InputVolts} \rightarrow \frac{500}{2250} = \frac{26.7}{120} = 26.7 \text{ volts}$$

What is the turns ratio of a transformer to match an audio amplifier having a 600-ohm output impedance to a speaker having a 4-ohm impedance? (This one is a little more complicated.)

$\frac{TURNSprimary}{TURNSsecondary} = \sqrt{\frac{Zprimary(ohms)}{Zsecondary(ohms)}}$ Or $\sqrt{\frac{600\Omega}{4\Omega}} = \sqrt{150} = 12.247$ or 12.2 : 1

A DC voltage equal to the value of an applied sine-wave AC voltage that would produce the same amount of heat over time in a resistive element is known as the RMS value. The RMS value of a sine wave is about .707 of the peak value. The peak value is about 1.414 times the RMS value.

What is the peak-to-peak voltage of a sine wave that has an RMS voltage of 120 volts?

$$120(voltRMS)x1.414 = 169.69(voltPeak)x2 = 339.36(voltPeaktoPeak)$$

339.4 volts Remember that peak-to-peak is the difference between the positive maximum and the negative maximum of the waveform, and is double the peak value.

A sine wave of 17 volts peak is equivalent to how many volts RMS?

17volts (peak) x .707 = 12 volts (RMS)

Mutual inductance is the property that causes a voltage to appear across the secondary winding of a transformer when a voltage source is connected across its primary winding?

If two capacitors of equal value and voltage rating are connected in a circuit in series, the capacitance value would be half that of each capacitor, and maximum voltage would be twice that of each capacitor.

A transmission line loss of 1 dB is equal to a 20.6% loss.

If three equal resistors in parallel produce 50-ohms of resistance and the same resistors in series produce 450-ohms, the value of each resistor is 150-ohms.

Resistors in series

$$Rtotal = R1 + R2 + R3...$$

Resistors in parallel

$$Rtotal = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}...}$$

Given the **equal** values stated above, the easiest way to solve it is to divide 450 by 3.

SUBELEMENT G6 -- CIRCUIT COMPONENTS [1 exam question -- 1 group]

G6A Resistors; capacitors; inductors; rectifiers and transistors; etc.

If a carbon resistor's temperature is increased, the resistance will change depending on the resistor's temperature coefficient rating.

The type of capacitor often used in power-supply circuits to filter the rectified AC is an electrolytic.

A suppressor capacitor is a capacitor used in a power-supply circuit to filter transient voltage spikes across the transformer's secondary winding.

The source of energy is connected to the primary winding in a transformer. If no load is attached to the secondary winding of a transformer, the current in the primary winding is called the magnetizing current.

The two major ratings that must not be exceeded for silicon-diode rectifiers used in power-supply circuits are peak inverse voltage, the maximum voltage the rectifier will handle in the non-conducting direction, and average forward current.

A half-wave rectifier conducts during 180 degrees of each cycle. A full-wave rectifier conducts during 360 degrees of each cycle. The output waveform of an unfiltered full-wave rectifier connected to a resistive load will be a series of pulses at twice the frequency of the AC input.

When two or more diodes are connected in parallel to increase the current-handling capacity of a power supply, a ballast resistor must be connected in series with each diode to ensure that one diode doesn't take most of the current and burn up due to overload.

It would not be a good idea to use a wire-wound resistor in a resonant circuit because the resistor's inductance would detune the circuit. A wire wound resistor acts like an inductor (coil) in a circuit, and it's inductance must be considered as a part of the overall circuit design.

Large values of inductance may be obtained by use of ferrite toroidal inductors. The toroidal inductor may be used in applications where core saturation is desirable. Most of the magnetic field is contained in the core, so a toroidal inductor is considered to be 'self-shielding' and will have little effect on other circuit components.

In a circuit containing two solenoid inductors they must be placed at right angles to their winding axis so as to minimize their mutual inductance. The magnetic field of one coil will cause an induced voltage in the second if their axis is aligned, and this may cause unwanted effects on the circuit. It might be important to minimize the mutual inductance between two inductors to reduce or eliminate stray coupling between RF stages.

The stable operating points for a bipolar transistor that is used as a switch in a logic circuit would be in its saturation and cut-off regions. As a switch, saturation is where the transistor conducts the maximum possible current, meaning the switch is turned on, and cutoff is where no current flows, and the switch is turned off.

SUBELEMENT G7 -- PRACTICAL CIRCUITS [1 exam question -- 1 group]

G7A Power supplies and filters; single-sideband transmitters and receivers

The power-supply filter network is a circuit made up of capacitors and inductors that removes AC noise from the DC output of the power supply. A safety feature that should be used in high voltage power supplies is a bleeder resistor across the terminals of the filter capacitors to provide a discharge path for the energy stored there.

The minimum peak-inverse-voltage rating of the rectifier in a full-wave power supply should be double the normal peak output voltage of the power supply. The minimum peak-inverse-voltage rating of the rectifier in a half-wave power supply should be one to two times the normal peak output voltage of the power supply. The rectifier in a full wave power supply circuit could be subjected to higher reverse voltage if one leg of the rectifier bridge fails. A crowbar circuit is often used to provide overvoltage protection at the output of a power supply.

In a switched-mode power supply, the first step in converting the 120 volt AC input voltage to a 12 volt DC output voltage is that the 120 volt AC is first rectified and filtered. The 120 volt DC is then switched by a high frequency oscillator and delivered to the step-down transformer. An advantage of a switched-mode power supply as compared to a linear power supply is that the relatively high frequency power oscillator allows the use of small, lightweight and low-cost transformers in the switched-mode supply. Capacitors with low equivalent series resistance should be used to filter the rectified DC output of a switching power supply.

The impedance of a low-pass filter inserted into a transmission line should be about the same as the impedance of the transmission line.

In a single-sideband phone transmitter, the balanced modulator processes signals from the carrier oscillator and the speech amplifier and sends signals to the filter.

In a typical single-sideband phone transmitter, the filter processes signals from the balanced modulator and sends signals to the mixer.

In a single-sideband phone superheterodyne receiver, the mixer processes signals from the RF amplifier and the local oscillator and sends signals to the IF filter.

In a single-sideband phone superheterodyne receiver, the detector processes signals from the IF amplifier and the BFO and sends signals to the AF amplifier.

SUBELEMENT G8 -- SIGNALS AND EMISSIONS [2 Exam Questions -- 2 Groups]

G8A Signal information; AM; FM; single and double sideband and carrier; bandwidth; modulation envelope; deviation; overmodulation

The amplitude modulation system changes the amplitude of an RF wave for the purpose of conveying information. The instantaneous amplitude (envelope) of the RF signal will vary in accordance with the modulating audio.

A phase modulation system changes the phase of an RF wave for the purpose of conveying information. Phase modulation is produced by a reactance modulator connected to an RF power amplifier.

Frequency modulation changes the frequency of an RF wave for the purpose of conveying information. The RF carrier frequency changes proportionally to the instantaneous amplitude of the modulating signal.

Both upper and lower sidebands would be found at the output of a properly adjusted balanced modulator. One advantage of carrier suppression in a double-sideband phone transmission is that more power can be put into the sidebands.

The popular phone emission that uses the narrowest frequency bandwidth is single-sideband.
If the signal of single-sideband or double-sideband phone transmitter is overmodulated, the output becomes distorted and occupies more bandwidth. To adjust for correct modulation the microphone gain control be adjusted on a single-sideband phone transmitter for slight movement of the ALC meter on modulation peaks.

Flattopping in a single-sideband phone transmission is signal distortion caused by excessive drive.

G8B Frequency mixing; multiplication; bandwidths; HF data communications

The receiver mixer stage combines an input RF signal with a local oscillator signal to produce an intermediate frequency (IF) signal. This process of mixing 2 RF signals is called Heterodyning. This IF signal would then be passed to the next stage of the receiver for additional processing. In any Heterodyning process you start with 2 frequencies, and the mixer output will contain those 2 frequencies and the SUM and DIFFERENCE of those 2 frequencies. The next statement built from a question in the question pool illustrates this process with frequencies listed so you can see how this works.

The receiver mixer stage combines a 14.25-MHz input signal with a 13.795-MHz oscillator signal to produce a 455-kHz intermediate frequency (IF) signal.

$$RFin - Localosc = IFout$$

The problem with this scheme in a simple receiver is that it can also respond to undesired signals. If a receiver mixes a 13.800-MHz VFO with a 14.255-MHz received signal to produce a 455-kHz intermediate frequency (IF) signal, it will also produce an Image response of a signal on 13.345-MHz in the receiver. Notice that the Image signal is on the other side of the VFO frequency by the same distance, in this case 455-kHz.

$RFin + Localosc = IFout$ or $RFin - Localosc = IFout$

Any signal converted to the IF frequency will be processed by the next stage in the receiver. Better receiver designs use several of these frequency conversions to prevent reproduction of these undesired Image signals. Heterodyning is also used in transmitter circuits. For example, the Mixer stage in a transmitter would change a 5.3-MHz input signal to 14.3 MHz. This is done to allow expensive components like sideband filters to be used at a fixed frequency so they can be shared on all bands and frequencies, and the resulting signal to be converted to the desired output frequency. In Heterodyning, the characteristics of the original signal are reproduced unchanged at the output frequency.

This are done a little differently in a VHF-FM system. A VHF -FM transmitter uses a circuit called a Multiplier that selects a harmonic of an HF signal to reach the desired operating frequency. A small deviation of the original signal is multiplied along with the frequency to result in the desired deviation (modulation) of the output signal. The 12.21-MHz of an FM-phone transmitter is reactance modulated plus and minus 416.7 Hz and when multiplied by 12 results in a signal at 146.52 MHz with a modulation deviation of plus or minus 5-KHz.

What is the total bandwidth of an FM-phone transmission having a 5-kHz deviation and a 3-kHz modulating frequency is 16 kHz. The use of frequency modulated (FM) phone below 29.5 MHz would violate FCC rules due to the bandwidth requirements. The bandwidth would exceed FCC limits.

When sending data modes, it is important to know the duty cycle of the mode you are using to prevent damage to your transmitter's final output stage due to its inability to dissipate excess heat. Some transmitters are not designed to operate 100% of the time.

Greater keying speeds in an FSK signal require greater frequency shifts.

RTTY, Morse code, PSK31 and packet communications are all digital communications.

Most PSK31 operations in the 20 meter band are found below the RTTY segment, near 14.070 MHz .

The maximum bandwidth permitted by FCC rules for amateur radio stations when operating on USB frequencies in the 60-meter band is 2.8 kHz

SUBELEMENT G9 -- ANTENNAS AND FEED-LINES [4 Exam Questions -- 4 Groups]

The "main lobe" of a directional antenna's radiation pattern is the direction of maximum radiated field strength from the antenna. The "antenna front-to-back ratio" is a comparison of the power radiated in the major radiation lobe compared to the power radiated in exactly the opposite direction.

G9A Yagi antennas - physical dimensions; impedance matching; radiation patterns; directivity and major lobes

A Yagi antenna is often used for radio communications on the 20-meter band because it helps reduce interference from other stations off to the side or behind. When designing a Yagi antenna, the SWR bandwidth can be increased by using larger diameter elements. A good way to get maximum performance from a Yagi antenna is to optimize the lengths and spacing of the elements. The polarization of the antenna elements is NOT a Yagi antenna design variable that should be considered to optimize the forward gain, front-to-rear ratio and SWR bandwidth.

The driven element of a Yagi antenna for 14.0 MHz is about 33 feet long.
The director element of a Yagi antenna for 21.1 MHz is about 21 feet long.
The reflector element of a Yagi antenna for 28.1 MHz is about 17.5 feet long.

In a three-element Yagi antenna the director is normally the shortest parasitic element.
Increasing the boom length and adding directors to a Yagi antenna will increase the gain of the antenna

G9B Loop antennas - physical dimensions; impedance matching; radiation patterns; directivity and major lobes

Most common loop antennas are based on a one wavelength wire supported on some type of frame. Cubical Quad antennas use crossed poles to support the wire in a square. A Delta Loop supports the wire at 3 points in a triangle. A formula for these loops when adjusted for the velocity factor of the wire would be

$$\frac{936}{F(MHz)} = Length(feet)$$

Divide the result by the number of sides.

A cubical-quad antenna driven element for 21.4 MHz will be 11.7 feet on each side.
A cubical-quad antenna driven element for 14.3 MHz will be 17.6 feet on each side.
A cubical-quad antenna reflector element for 29.6 MHz will be 8.7 feet on each side.
Remember that the reflector element is slightly larger than a driven element.

Each leg of a symmetrical delta-loop antenna driven element for 28.7 MHz will be 11.7 feet.
Each leg of a symmetrical delta-loop antenna driven element for 24.9 MHz will be 13.45 feet.
Each leg of a symmetrical delta-loop antenna reflector element for 14.1 MHz will be 24.35 feet.
Again, the reflector is slightly larger than a driven element.

Many operators choose a two-element quad antenna because it's performance will compare favorably with a three-element Yagi. The directional radiation characteristics of a cubical-quad antenna have more directivity in both horizontal and vertical planes than a dipole antenna.

Moving the feed point of a multielement quad antenna from a side parallel to the ground to a side perpendicular to the ground change the antenna polarization from horizontal to vertical.

G9C Random wire antennas - physical dimensions; impedance matching; radiation patterns; directivity and major lobes; feed point impedance of 1/2-wavelength dipole and 1/4-wavelength vertical antennas

One type of multiband transmitting antenna that does NOT require a feed-line is an end-fed random-wire antenna. The wire is usually connected directly to an antenna tuner. The main disadvantage of this antenna is that you may experience RF feedback in your station.

Sloping the radial of a ground plane antenna downward increases the feedpoint impedance bringing it closer to 50 ohms.

The low-angle radiation pattern of an ideal half-wavelength dipole HF antenna installed a half-wavelength high, parallel to the earth is a figure-eight at right angles to the antenna. If the antenna is less than one-half wavelength high, the azimuthal pattern is almost omnidirectional.

If the horizontal radiation pattern of an antenna shows a major lobe at 0 degrees and a minor lobe at 180 degrees, most of the signal would be radiated towards 0 degrees and a smaller amount would be radiated towards 180 degrees.

If a slightly shorter parasitic element is placed 0.1 wavelength away and parallel to an HF dipole antenna mounted above ground, a major lobe will develop in the horizontal plane, toward the parasitic element. If a slightly longer parasitic element is placed 0.1 wavelength away and parallel to an HF dipole antenna mounted above ground, a major lobe will develop in the horizontal plane, away from the parasitic element, toward the dipole.

The radial wires of a ground-mounted vertical antenna system should be placed on the surface or buried a few inches below the ground.

G9D Popular antenna feed-lines - characteristic impedance and impedance matching; SWR calculations

The distance between the centers of the conductors and the radius or diameter of the conductors are factors help determine the characteristic impedance of a parallel-conductor antenna feed-line. The insulation between the conductors may be air or plastic. In the case of air insulated lines, spacers will be used at regular intervals to hold the wires at the correct distance apart. The characteristic impedance of flat-ribbon TV-type twin-lead is 300 ohms.

Most of the typical coaxial cables used for antenna feed-lines at amateur stations have characteristic impedances of 50 and 75 ohms.

The typical cause of power being reflected back down an antenna feed-line is a difference between feed line impedance and antenna feed-point impedance. To prevent standing waves of voltage and current on an antenna feed-line the antenna feed-point impedance must be matched to the characteristic impedance of the feed-line.

On a dipole antenna fed with parallel-conductor feed line you would be use an inductively coupled matching network to match the unbalanced transmitter output to the balanced parallel-conductor feed line.

RF feed line losses are usually expressed dB/100 ft. As the frequency increases, the loss value will increase. If a 160-meter signal and a 2-meter signal pass through the same coaxial cable, the attenuation will be greater at 2 meters.

VSWR or SWR is a term used to describe the match or mismatch of antenna feedlines and feedpoints and /or the reflection of energy from an antenna that is operating off it's resonant frequency.. When all other considerations are removed and the system is operating at resonance the SWR will be expressed as a ratio of the impedance values being connected to each other.

The connection of a 50-ohm feed line to a resonant antenna having a 200-ohm feed-point impedance would be a 4:1 SWR.

The connection of a 50-ohm feed line to a resonant antenna having a 10-ohm feed-point impedance would be a 5:1 SWR.

The connection of a 50-ohm feed line to a resonant antenna having a 50-ohm feed-point impedance would be a 1:1 SWR.

The SWR if you feed a vertical antenna that has a 25-ohm feed-point impedance with 50-ohm coaxial cable would be 2:1.

The SWR if you feed a folded dipole antenna that has a 300-ohm feed-point impedance with 50-ohm coaxial cable would be 6:1.

SUBELEMENT G0 -- RF SAFETY [5 Exam Questions -- 5 Groups]

G0A RF Safety Principles

Depending on the wavelength of the signal, the energy density of the RF field, and other factors, RF energy can heat body tissue

Critical angle is NOT important in estimating RF energy's effect on body tissue.

The frequency (or wavelength) of the energy has the most direct effect on the permitted exposure level of RF radiation.

Specific absorption rate (W/kg) best describes the biological effects of RF fields at frequencies used by amateur operators.

RF radiation in the 1270-MHz range frequency ranges has the most effect on the human eyes.

The term "athermal effects" of RF radiation means biological effects from RF energy other than heating.

At the very-high-frequency (30-300-MHz) range the human body absorbs RF energy at a maximum rate.

When it applies to RF radiation exposure, the term "time averaging" means the total RF exposure averaged over a certain time.

As a guideline, if the transmitter's PEP and frequency are within certain limits given in Part 97, a routine RF evaluation for an amateur station must be performed.

If you perform a routine RF evaluation on your station and determine that its RF fields exceed the FCC's exposure limits in human-accessible areas, you are required to take action to prevent human exposure to the excessive RF fields.

At a site with multiple transmitters operating at the same time, each transmitter that produces more than 5% of the maximum permissible power density exposure limit for that transmitter must be included in the RF exposure site evaluation

The body part and duration of its exposure; frequency and power density; wave polarization are all factors can affect the thermal aspects of RF energy exposure to human body tissues.

G0B RF Safety Rules and Guidelines

The FCC's RF-safety rules are designed to control the maximum permissible human exposure to all RF radiated fields.

At a site with multiple transmitters, all licensees contributing more than 5% of the maximum permissible power density exposure for that transmitter are equally responsible for ensuring that all FCC RF-safety regulations are met.

When evaluating RF exposure low duty-cycle emissions permit greater short-term exposure levels.

The power levels used to determine if an RF environmental evaluation is required vary with frequency because Maximum Permissible Exposure (MPE) limits are frequency dependent.

50 watts PEP is the threshold power used to determine if an RF environmental evaluation is required when the operation takes place in the 10-meter band.

100 watts PEP is the threshold power used to determine if an RF environmental evaluation is required when the operation takes place in the 15-meter band.

225 watts PEP is the threshold power used to determine if an RF safety evaluation is required when the operation takes place in the 20-meter band.

500 watts PEP is the threshold power used to determine if an RF environmental evaluation is required for transmissions in the amateur bands with frequencies less than 10 MHz.

The amateur frequency bands that have the lowest power limits above which an RF environmental evaluation is required are all bands between 1.25 and 10 meters.

Amateur radio stations with transmitter output levels exceeding 500-watts PEP on the 40, 75/80 and 160 meter bands are subject to routine environmental evaluation.

G0C Routine Station Evaluation and Measurements (FCC Part 97 refers to RF Radiation Evaluation)

As the distance from a transmitting antenna increases the fields strength decreases proportionally.

If the free-space far-field strength of a 10-MHz dipole antenna measures 1.0 millivolts per meter at a distance of 5 wavelengths, at a distance of 10 wavelengths it will be 0.50 millivolts per meter.

If the free-space far-field strength of a 28-MHz Yagi antenna measures 4.0 millivolts per meter at a distance of 5 wavelengths, at a distance of 20 wavelengths it will be 1.0 millivolts per meter.

If the free-space far-field strength of a 1.8-MHz dipole antenna measures 9 microvolts per meter at a distance of 4 wavelengths, at a distance of 12 wavelengths it will be 3 microvolts per meter.

As the distance from a transmitting antenna increases, the power density decreases by the square of the distance. A way to visualize this would be to imagine a 1 foot square card held up 1 foot from a candle flame. At a distance of 2 feet the shadow of the card on a wall would be a 2 foot square, or 4 (2x2) square feet in size. If the light that was hitting the card (1 candlepower per square foot) was allowed to hit the wall at 2 feet it would be landing on an area 4 times the size, so the power density of the light would be 1/4 of the power density at 1 foot. The power density of the light would be 0.25 candlepower per square foor at a distance of 2 feet.

If the free-space far-field power density of a 18-MHz Yagi antenna measures 10 milliwatts per square meter at a distance of 3 wavelengths, at a distance of 6 wavelengths it will be 2.5 milliwatts per square meter.

If the free-space far-field power density of an antenna measures 9 milliwatts per square meter at a distance of 5 wavelengths, at a distance of 15 wavelengths it will be 1 milliwatt per square meter.

The factors that determine the location of the boundary between the near and far fields of an antenna are the wavelength of the signal and physical size of the antenna.

To ensure compliance with the RF safety regulations an amateur operator might perform a routine RF exposure evaluation.

In the free-space far field, the electric field (E field) and magnetic field (H field) field strength have a fixed impedance relationship of 377 ohms.

A calibrated field-strength meter with a calibrated antenna can be used to accurately measure an RF field.

If your station complies with the RF safety rules and you reduce its power output from 1000 to 500 watts or from 500 to 40 watts, you would not need to perform an RF safety evaluation, but your station would still need to be in compliance with the RF safety rules. Since your station was in compliance with RF safety rules at a higher power output, you need to do nothing more

G0D Practical RF-safety applications

Considering RF safety, if you install an indoor transmitting antenna you should locate the antenna as far away as possible from living spaces that will be occupied while you are operating.

Considering RF safety, the precaution should you take whenever you make adjustments to the feed line of a directional antenna system is to be sure no one can activate the transmitter.   Before beginning repairs on an antenna be sure to turn off the transmitter and disconnect the feed-line. Before beginning repairs on a microwave feed horn or waveguide be sure the transmitter is turned off and the power source is disconnected.

Constructing fencing to exclude people from getting too close to the antenna would help to ensure greater RF safety near a ground mounted vertical antenna. The best reason to place a protective fence around the base of a ground-mounted transmitting antenna is to reduce the possibility of persons being exposed to levels of RF in excess of the maximum permissible exposure (MPE) limits. When installing a ground-mounted antenna it should be installed so no one can be exposed to RF radiation in excess of the maximum permissible exposure (MPE) limits

Directional high-gain antennas should be mounted higher than nearby structures so they will not direct excessive amounts of RF energy toward people in nearby structures.

For best RF safety, the ends and center of a dipole antenna be located as far away as possible to minimize RF exposure to people near the antenna. Using attic-mounted antennas may expose people in the house to strong, near field RF energy.

To reduce RF radiation exposure when operating at 1270 MHz keep the antenna away from your eyes when RF is applied. Your eyes are especially sensitive to RF at this frequency.

Considering RF safety, the best reason to mount the antenna of a mobile VHF transceiver is in the center of a metal roof. The roof will greatly shield the driver and passengers from RF radiation.

You must be careful when aiming EME (moonbounce) arrays toward the horizon because their high ERP (Effective Radiated Power) may produce hazardous RF fields in uncontrolled areas, they could cause TVI/RFI for your neighbors, and reflections from nearby objects could detune the array.

G0E RF-safety solutions

If you receive minor burns every time you touch your microphone while you are transmitting, it is possible that you and others in your station may be exposed to more than the maximum permissible level of RF radiation. If measurements indicate that individuals in your station are exposed to more than the maximum permissible level of radiation, you should ensure proper grounding of the equipment, ensure that all equipment covers are tightly fastened, and use the minimum amount of transmitting power necessary.

If calculations show that you and your family may be receiving more than the maximum permissible RF radiation exposure from your 20-meter indoor dipole, it might be appropriate to move the antenna to a safe outdoor environment.

Considering RF exposure, when installing an antenna yuo should install the antenna as high and far away from populated areas as possible. If the antenna is a gain antenna, point it away from populated areas. Always take steps to minimize feed line radiation into populated areas.

If an RF radiation evaluation shows that your neighbors may be receiving more than the maximum RF radiation exposure limit from your Yagi or Quad antenna when it is pointed at their house you should take precautions to ensure you can't point your antenna at their house and/or reduce your transmitter power to a level that reduces their exposure to a value below the maximum permissible exposure (MPE) limit.

A dummy antenna provides an RF safe environment for transmitter adjusting because the RF energy is not radiated from a dummy antenna, but is converted to heat.

From an RF radiation exposure point of view, aluminum would be the best to use for your homemade transmatch enclosure.

From an RF radiation exposure point of view, the advantage to using a high-gain, narrow-beamwidth antenna for your VHF station is that the RF radiation can be focused in a direction away from populated areas. The disadvantage in using a high-gain, narrow-beamwidth antenna for your VHF station is that individuals in the main beam of the radiation pattern will receive a greater exposure than when a low-gain antenna is used.

If your station is located in a residential area, installing your antenna as high as possible to maximize the distance to nearby people would best help you reduce the RF exposure to your neighbors from your amateur station.

This concludes the study guide text. You have reviewed all the questions in the published exam question pool. Re-read this guide one more time just before you sit for the exam for best results.

Good luck on your exam!

73 de AD5FU & KD5QMD