E1 -- Commission Rules

When using a transceiver that displays the carrier frequency of phone signals, a displayed frequency 3 kHz below the upper band edge will result in a normal USB emission being within the band. When using a transceiver that displays the carrier frequency of phone signals, a displayed frequency 3 kHz above the lower band edge will result in a normal LSB emission being within the band.

With your transceiver displaying the carrier frequency of phone signals and you hear a DX station's CQ on 14.349 MHz USB, it is NOT legal to return the call using upper sideband on the same frequency. Your sidebands will extend beyond the band edge. With your transceiver displaying the carrier frequency of phone signals and you hear a DX station's CQ on 3.601 MHz LSB, it is NOT legal to return the call using lower sideband on the same frequency. Your sidebands will extend beyond the EDGE of the phone band segment.

The only amateur band that does not permit the transmission of phone or image emissions is 30 meters.

The maximum power output permitted on the 60 meter band is 50 watts PEP effective radiated power relative to a dipole. It is the only amateur band where transmission is permitted on specific channels rather than a range of frequencies. The only emission type permitted on the 60 meter band by an amateur station is single sideband, upper sideband.

The frequency bands which contain at least one segment authorized only to control operators holding an Amateur Extra Class operator license are 80/75, 40, 20 and 15 meters.

If a station in a message forwarding system inadvertently forwards a message that is in violation of FCC rules, the control operator of the originating station is primarily accountable for the rules violation. What is the first action you should take if your digital message forwarding station inadvertently forwards a communication that violates FCC rules is discontinue forwarding the communication as soon as you become aware of it.

Before operating an amateur station installed on board a ship or aircraft its operation must be approved by the master of the ship or the pilot in command of the aircraft. When a US-registered vessel is in international waters, any FCC amateur license or reciprocal permit for alien amateur licensee is required to transmit amateur communications from an on-board amateur transmitter.

A spurious emission is an emission outside its necessary bandwidth that can be reduced or eliminated without affecting the information transmitted.

Factors that might cause the physical location of an amateur station apparatus or antenna structure to be restricted are a location significant to our environment, American history, architecture, or culture. An amateur station must be 1 mile from an FCC monitoring facility to protect it from harmful interference. Before placing an amateur station within an officially designated wilderness area or wildlife preserve, or an area listed in the National Register of Historical Places, an Environmental Assessment must be submitted to the FCC.

An amateur station antenna structure must be no higher than 200 feet above ground level at its site if it is not close to a public use airport. If you are installing an amateur station antenna at a site within 20,000 feet of a public use airport you may have to notify the Federal Aviation Administration and register it with the FCC. Before erecting an amateur station antenna located at or near a public use airport, if the antenna exceeds a certain height, depending upon the antenna's distance from the nearest active runway, the FAA must be notified and it must be registered with the FCC.

Operation of an amateur station may be restricted on the interfering amateur service transmitting frequencies if its emissions cause interference to the reception of a domestic broadcast station on a receiver of good engineering design.

The Radio Amateur Civil Emergency Service (RACES) is a radio service of amateur stations for civil defense communications during periods of local, regional, or national civil emergencies. Amateur stations may be operated in RACES on any FCC-licensed amateur station certified by the responsible civil defense organization for the area served. An amateur station participating in RACES may operate on all amateur service frequencies otherwise authorized to the control operator. The frequencies authorized to an amateur station participating in RACES during a period when the President's War Emergency Powers are in force are specific amateur service frequency segments authorized in FCC Part 214. Communications permissible in RACES are those authorized civil defense emergency communications affecting the immediate safety of life and property.

Local control of an amateur radio station is the direct manipulation of the transmitter by a control operator.

A remotely controlled station is a station controlled indirectly through a control link. A control operator must be present at the control point of a remotely controlled amateur station. If its control link malfunctions, the maximum permissible duration of a remotely controlled station's transmissions is 3 minutes.

Automatic control of a station is the use of devices and procedures for control so that the control operator does not have to be present at a control point. The control operator responsibilities of a station under automatic control differ from one under local control in that under automatic control the control operator is not required to be present at the control point

An automatically controlled station may retransmit third party communications only when transmitting RTTY or data emissions. An automatically controlled station may never originate third party communications. The only types of amateur stations that may automatically retransmit the radio signals of other amateur stations are auxiliary, repeater or space stations. The control operator of an auxiliary station may be only Technician, General, Advanced or Amateur Extra Class operators. (Novice class licensees are excluded).

HF frequencies available for automatically controlled ground-station repeater operation are 29.500 - 29.700 MHz.

Telemetry is one-way transmission of measurements at a distance from the measuring instrument. A telecommand station in the amateur satellite service is an amateur station that transmits communications to initiate, modify or terminate certain functions of a space station. Any amateur station so designated by the space station licensee is eligible to be a telecommand station.

An Earth station in the amateur satellite service is an amateur station within 50 km of the Earth's surface for communications with amateur stations by means of objects in space. Any amateur station, subject to the privileges of the class of operator license held by the control operator, is eligible to operate as an Earth station.

The amateur-satellite service is a radio communications service using amateur stations on satellites. A holder of any class of license is authorized to be the control operator of a space station. The FCC's International Bureau, Washington DC, must be notified before launching an amateur space station. A special provision that a space station must incorporate in order to comply with space station requirements are the space station must be capable of effecting a cessation of transmissions by telecommand when so ordered by the FCC.

The amateur service HF bands that have frequencies authorized to space stations are only 40m, 20m, 17m, 15m, 12m and 10m. The only VHF amateur service bands that have frequencies available for space stations is 2 meters The three amateur service UHF bands that have frequencies available for a space station are 70 cm, 23 cm and 13 cm.

A Volunteer Examiner Coordinator is an organization that has entered into an agreement with the FCC to coordinate amateur operator license examinations. The questions for all written US amateur license examinations listed in the VEC-maintained question pool. All of the VECs are responsible for maintaining the question pools from which all amateur license examination questions must be taken.

The Volunteer Examiner accreditation process is best described as the procedure by which a VEC confirms that the VE applicant meets FCC requirements to serve as an examiner. A VE is an amateur operator who is approved by a VEC to administer amateur operator license examinations. The minimum age to be a volunteer examiner is 18 years old. Persons who have ever had an amateur operator or amateur station license suspended or revoked seeking to become VEs cannot be accredited.

A VE team is a group of at least three VEs who administer examinations for an amateur operator license. The minimum number of qualified VEs required to administer an Element 4 amateur operator license examination is 3.

Each administering VE is responsible for the proper conduct and necessary supervision during an amateur operator license examination session. While administering an examination all of the administering VEs must be present where they can observe the examinees throughout the entire examination. Out-of-pocket expenses that be reimbursed to VEs and VECs include preparing, processing, administering and coordinating an examination for an amateur radio license.

The penalty for a VE who fraudulently administers or certifies an examination is the revocation of the VE's amateur station license grant and the suspension of the VE's amateur operator license grant. A VE may not administer an examination to the VE's close relatives as listed in the FCC rules.

Once examinees have finished the examination the VE team must immediately collect and grade examinee's test papers. If the examinee does not pass the exam, the VE team must return the application document to the examinee. If an examinee scores a passing grade on all examination elements needed for an upgrade or new license three VEs of the VE team must certify that the examinee is qualified for the license grant and that they have complied with the VE requirements.

If a candidate fails to comply with the examiner's instructions during an amateur operator license examination, a VE should immediately terminate the candidate's examination. A consequence of failing to appear for re-administration of an examination when so directed by the FCC may be the licensee's license will be cancelled

The CEPT agreement is an operating arrangement that allows an FCC-licensed US citizen to operate in many European countries, and alien amateurs from many European countries to operate in the US.

The IARP agreement is an operating arrangement that allow an FCC-licensed US citizen and many Central and South American amateur operators to operate in each other's countries.

The types of communications that may be transmitted to amateur stations in foreign countries are only communications incidental to the purpose of the amateur service and remarks of a personal nature.

Under no circumstances may the control operator of a repeater accept payment for providing communication services to another party. An amateur station may send a message to a business when neither the amateur nor his or her employer has a pecuniary interest in the communications. Amateur-operator-to-amateur-operator communications transmitted for hire or material compensation, except as otherwise provided in the rules are prohibited.

"Line A" is a line roughly parallel to and south of the US-Canadian border. Amateur stations may not transmit in 420 - 430 MHz frequency segments if they are located north of Line A. The National Radio Quiet Zone is an area surrounding the National Radio Astronomy Observatory.

One of the standards that must be met by an external RF power amplifier if it is to qualify for a grant of FCC certification is it must satisfy the FCC's spurious emission standards when operated at its full output power. If an external RF amplifier is listed on the FCC database as certificated for use in the amateur service, that particular RF amplifier may be marketed for use in the amateur service. A dealer may sell an external RF power amplifier capable of operation below 144 MHz if it has not been granted FCC certification only if it was purchased in used condition from an amateur operator and is sold to another amateur operator for use at that operator's station

Spread spectrum transmissions are permitted only on amateur frequencies above 222 MHz. The maximum transmitter power for an amateur station transmitting spread spectrum communications is 100 W.

All of these choices are correct. FCC-licensed amateur stations may use spread spectrum (SS) emissions to communicate under all of the following conditions

- When the other station is in an area regulated by the FCC
- When the other station is in a country permitting SS communications
- When the transmission is not used to obscure the meaning of any communication

The FCC issue a "Special Temporary Authority" (STA) to an amateur station to provide for experimental amateur communications.

E2 -- Operating Practices And Procedures

The orbital period of a satellite is the time it takes for a satellite to complete one revolution around the Earth. The direction of an ascending pass for an amateur satellite is from south to north. A descending pass is from north to south. Due to the Doppler Effect, a satellite's transmitted signal appears to shift lower as the satellite passes overhead.

One way to predict the location of a satellite at a given time is by calculations using the Keplerian elements for the specified satellite.

A geosynchronous satellite appears to stay in one position in the sky.

The received signal from an amateur satellite exhibit a rapidly repeating fading effect is because the satellite is rotating. The type of antenna that can be used to minimize the effects of spin modulation and Faraday rotation is a circularly polarized antenna.

The primary reason for satellite users to limit their transmit ERP is because the satellite transmitter output power is limited.

All these answers are correct. The following types of signals that can be relayed through a linear transponder include

- FM and CW
- SSB and SSTV
- PSK and Packet

The term "mode" as applied to an amateur radio satellite is the satellite's uplink and downlink frequency bands. The letters in a satellite's mode designator specify the uplink and downlink frequencies. A satellite receives signals in the 432 MHz band is operating in mode U/V. The terms L band and S band with regard to satellite communications specify the 23 centimeter and 13 centimeter bands, respectively.

A new frame is transmitted 30 per second in a fast-scan (NTSC) television system. A fast-scan (NTSC) television frame is made up of 525 horizontal lines. An interlace scanning pattern generated in a fast-scan (NTSC) television system is made by scanning odd numbered lines in one field and even numbered ones in the next.

Vestigial sideband modulation is amplitude modulation in which one complete sideband and a portion of the other sideband is transmitted. An advantage of using vestigial sideband for standard fast scan TV transmissions is that it reduces bandwidth while allowing for simple video detector circuitry.

The name of the video signal component that carries color information is the Chroma.

Blanking in a video signal is the turning off the scanning beam while it is traveling from right to left or from bottom to top.

All of these choices are correct. The following are all common methods of transmitting accompanying audio with amateur fast-scan television.

- Frequency-modulated sub-carrier
- A separate VHF or UHF audio link
- Frequency modulation of the video carrier

Other than a transceiver with SSB capability and a suitable computer no other hardware is needed to decode SSTV based on Digital Radio Mondiale (DRM). An acceptable bandwidth for Digital Radio Mondiale (DRM) based voice or SSTV digital transmissions made on the HF amateur bands is 3 KHz.

Analog slow-scan television images are typically transmitted on the HF bands by varying tone frequencies representing the video using single sideband. The function of the Vertical Interval Signaling (VIS) code transmitted as part of an SSTV transmission is to identify the SSTV mode being used. The tone frequency of an amateur slow-scan television signal encodes the brightness of the picture. Specific tone frequencies are used in SSTV receiving equipment to signal the beginning of a new picture line. The number of lines commonly used in each frame on an amateur slow-scan color television picture is 128 or 256.

Special operating frequency restrictions imposed on slow scan TV transmissions are they are restricted to phone band segments and their bandwidth can be no greater than that of a voice signal of the same modulation type. The approximate bandwidth of a slow-scan TV signal is 3 kHz.

The video standard used by North American Fast Scan ATV stations is NTSC. If 100 IRE units correspond to the most-white level in the NTSC standard video format, the level of the most-black signal is 7.5 IRE units.

Immunity from fading due to limiting is NOT a characteristic of FMTV (Frequency-Modulated Amateur Television) as compared to vestigial sideband AM television. One is likely to find FMTV transmissions on 1255 MHz.

The frequency 14.310 MHz would generally be acceptable for U.S. stations to work other U.S. stations in a phone contest. The amateur radio 30 meter band is generally excluded in contesting. The frequency 146.52 MHz is generally discouraged for contacts in an amateur radio contest. (it is the national simplex calling frequency).

During a VHF/UHF contest, you expect to find the highest level of activity in the weak signal segment of the band, with most of the activity near the calling frequency.

One true fact in about contest operating is that operators are permitted to make contacts even if they do not submit a log. “Self spotting” in regards to contest operating is the generally prohibited practice of posting one's own call sign and frequency on a call sign spotting network.

When attempting to contact a DX station working a “pileup” or in a contest you should generally sign your call by sending your full call sign once or twice.

The Cabrillo format is a standard for organizing information in contest log files.

All of these choices are correct. A phone DX station may state that he is listening on another frequency

- because the DX station may be transmitting on a frequency that is prohibited to some responding stations
- to separate the calling stations from the DX station
- to reduce interference, thereby improving operating efficiency

In North America during low sunspot activity, when signals from Europe become weak and fluttery across an entire HF band two to three hours after sunset, to contact other European DX stations you might switch to a lower frequency HF band.

Received spread-spectrum signals are resistant to interference because signals not using the spectrum-spreading algorithm are suppressed in the receiver. The spread-spectrum technique of frequency hopping (FH) works well because the frequency of the transmitted signal is changed very rapidly according to a particular sequence also used by the receiving station.

Store-and-forward is a techniques normally used by low-earth orbiting digital satellites to relay messages around the world. The purpose of digital store-and-forward functions on an Amateur satellite is to store digital messages in the satellite for later download by other stations.

“Command mode” in packet operations is the state where the TNC is ready to receive instructions via the keyboard.

The definition of the term “baud” is the number of data symbols transmitted per second. When comparing HF and 2-meter packet operations, HF packet typically uses FSK with a data rate of 300 baud; 2-meter packet uses AFSK with a data rate of 1200 baud. Under clear communications conditions, the digital communications mode that has the fastest data throughput is 300-baud packet (compared to AMTOR, 170-Hz shift 45 baud RTTY or PSK31, which are all much slower).

An APRS station can be used to help support a public service communications activity because an APRS station with a GPS unit can automatically transmit information to show a mobile station's position during the event. The digital protocol is used by APRS is AX.25. A commonly used 2-meter APRS frequency is 144.39 MHz. Unnumbered Information frames are used to transmit APRS beacon data.

Any of these choices is correct. The following data sources can accurately transmit your geographical location over the APRS network

- the NMEA-0183 formatted data from a Global Positioning System (GPS) satellite receiver
- the latitude and longitude of your location, preferably in degrees, minutes and seconds, entered into the APRS computer software
- the NMEA-0183 formatted data from a LORAN navigation system

A common method of transmitting data emissions below 30 MHz is FSK/AFSK. When one of the ellipses in an FSK crossed-ellipse display suddenly disappears it indicates that selective fading has occurred.

The letters FEC, as they relate to digital operation, mean Forward Error Correction. Forward Error Correction is implemented by transmitting extra data that may be used to detect and correct transmission errors.

If errors are detected, ARQ accomplishes error correction by requesting a retransmission.

The most common data rate used for HF packet communications is 300 baud.

The typical bandwidth of a properly modulated MFSK16 signal is 316 Hz.

The HF digital mode PACTOR can be used to transfer binary files.

The digital communication mode that has the narrowest bandwidth is PSK31. The HF digital mode PSK31 uses variable-length coding for bandwidth efficiency.

The Baudot code is the International Telegraph Alphabet Number 2 (ITA2) which uses five data bits.

E3 - Radio Wave Propagation

The approximate maximum separation along the surface of the Earth between two stations communicating by moonbounce is 12,000 miles, as long as both can “see” the moon.

Libration fading of an earth-moon-earth signal is characterized by a fluttery irregular fading.

When scheduling EME contacts, the least path loss is when the moon is at perigee. The type of receiving system desirable for EME communications is equipment with very low noise figures.

Transmit and receive time sequencing is normally used on 144 MHz when attempting an EME contact. Two-minute sequences are used, where one station transmits for a full two minutes and then receives for the following two minutes. The time sequences normally used on 432 MHz are two-and-one-half minute sequences, where one station transmits for a full 2.5 minutes and then receives for the following 2.5 minutes.

The frequency range you would normally tune to find EME stations in the 2 meter band is 144.000 - 144.100 MHz. On the 70 cm band it is 432.000 - 432.100 MHz.

When a meteor strikes the Earth's atmosphere, a cylindrical region of free electrons is formed at the E layer of the ionosphere. The range of frequencies well suited for meteor-scatter communications is 28 - 148 MHz.

When attempting a meteor-scatter contact on 144 MHz, the transmit and receive time sequences normally used are 15-second sequences, where one station transmits for 15 seconds and then receives for the following 15 seconds.

Transequatorial propagation is propagation between two points at approximately the same distance north and south of the magnetic equator. The approximate maximum range for signals using transequatorial propagation is 5000 miles. The best time of day for transequatorial propagation is Afternoon or early evening.

If an HF beam antenna must be pointed in a direction 180 degrees away from a station to receive the strongest signals the type of propagation probably occurring is Long-path. The amateur bands that typically support long-path propagation are 160 to 10 meters. The amateur band that most frequently provides long-path propagation 20 meters.

Hearing an echo on the received signal of a distant station could be accounted by the receipt of a signal by more than one path.

If radio signals travel along the terminator between daylight and darkness, the type of propagation probably occurring is Gray-line propagation. Gray-line propagation is most prevalent at sunrise and sunset. Gray-line propagation occurs because at twilight, solar absorption drops greatly, while atmospheric ionization is not weakened enough to reduce the MUF. During gray-line propagation contacts up to 8,000 to 10,000 miles on three or four HF bands.

Auroral activity effects radio communications. It occurs in the ionosphere at E-region height. CW is the best emission mode for auroral propagation. CW signals have a fluttery tone. The cause of auroral activity is the emission of charged particles from the sun. From the contiguous 48 states, an antenna should be pointed North to take maximum advantage of auroral propagation.

Selective fading is caused by phase differences in the received signal caused by different paths.

The radio-path horizon distance exceeds the geometric horizon because radio waves may be bent. The VHF/UHF radio-path horizon distance exceeds the geometric horizon by approximately 15% of the distance. The radiation pattern of a 3-element, horizontally polarized beam antenna varies with height above ground. The main lobe takeoff angle decreases with increasing height. When mounted on the side of a hill, a horizontally polarized antenna's main lobe takeoff angle decreases in the downhill direction. The takeoff angle is lower compared with the same antenna mounted on flat ground.

As the frequency of a signal increases, its ground wave propagation decreases. Most ground-wave propagation has vertical polarization.

The name of the high-angle wave in HF propagation that travels for some distance within the F2 region is the Pedersen ray.

Tropospheric ducting is usually responsible for propagating a VHF signal over 500 miles.

E4 - Amateur Radio Technology And Measurements

A spectrum analyzer differs from a conventional oscilloscope in that a spectrum analyzer displays signals in the frequency domain; an oscilloscope displays signals in the time domain. A typical spectrum analyzer displays frequency on the horizontal axis and amplitude on the vertical axis.

A spectrum analyzer is a test instrument that can be used to display spurious signals from a radio transmitter. It can also be used to display intermodulation distortion products in an SSB transmission. An important precaution to follow when connecting a spectrum analyzer to a transmitter output is to attenuate the transmitter output going to the spectrum analyzer.

All of these choices are correct. A spectrum analyzer could be used to determined

- the degree of isolation between the input and output ports of a 2 meter duplexer
- whether a crystal is operating on its fundamental or overtone frequency
- the spectral output of a transmitter

A method to measure intermodulation distortion in an SSB transmitter is to modulate the transmitter with two non-harmonically related audio frequencies and observe the RF output with a spectrum analyzer.

An advantage of using an antenna analyzer vs. a SWR bridge to measure antenna SWR is that antenna analyzers typically do not need an external RF source. It would be best for measuring the SWR of a beam antenna.

When adjusting PSK31 transmitting levels the following most important setting is ALC level.

A useful test for a functioning NPN transistor in an active circuit, where the transistor should be biased "on", is to measure base-to-emitter voltage with a voltmeter; it should be approximately 0.6 to 0.7 volts.

A logic probe can be used to indicate pulse conditions in a digital logic circuit.

A characteristic of a good harmonic frequency marker is frequency stability. An important factor that affects the accuracy of a frequency counter is its time base accuracy. If a frequency counter with the specified accuracy in ppm reads 146,520,000 Hz, the most the actual frequency being measured could differ from the reading is given by the following table,

Accuracy in ppm	The largest difference from the reading
+/- 0.1 ppm	14.6520 Hz
+/- 1.0 ppm	146.520 Hz
+/- 10 ppm	1465.20 Hz

An advantage of using a bridge circuit to measure impedance is that the measurement is based on obtaining a null in voltage, which can be done very precisely.

When a directional power meter connected between a transmitter and a terminating load reads 100 watts forward power and 25 watts reflected power, 75 watts is being absorbed by the load.

When using an oscilloscope probe it is a good practice to keep the ground connection of the probe as short as possible.

A characteristic of a good DC voltmeter is high impedance input.

If the current reading on an RF ammeter placed in series with the antenna feedline of a transmitter increases as the transmitter is tuned to resonance it is a good indication that there is more power going into the antenna.

When measuring antenna resonance and feedpoint impedance with a portable SWR analyzer you should connect the antenna feed line directly to the analyzer's connector.

The voltmeter sensitivity expressed in volts per ohm can be used obtain the meter's impedance by taking the full scale reading of the voltmeter multiplied by its ohms per volt rating to get the input impedance of the voltmeter.

To adjust the compensation of an oscilloscope probe a square wave is observed and the probe is adjusted until the horizontal portions of the displayed wave is as nearly flat as possible.

If a dip-meter is too tightly coupled to the tuned circuit being checked a less accurate reading results.

Coil impedance limits the accuracy of a D'Arsonval-type meter.

The bandwidth of the circuit's frequency response can be used as a relative measurement of the Q for a series tuned circuit.

Excessive phase noise in the local oscillator section of a receiver can cause strong signals on nearby frequencies to interfere with reception of weak signals.

The result of the capture effect in an FM receiver is that the strongest signal received is the only demodulated signal. The term for the blocking of one FM phone signal by another, stronger FM phone signal is the capture effect.

The noise floor of a receiver is the equivalent input noise power when the antenna is replaced with a matched dummy load. The value of -174 dBm/Hz with regard to the noise floor of a receiver represents the theoretical noise at the input of a perfect receiver at room temperature. The thermal noise value of a receiver is -174 dBm/Hz. The theoretically best minimum detectable signal for a 400 Hz bandwidth receiver is -148 dBm. Lowering the noise figure of a receiver would increase signal to noise ratio.

The MDS of a receiver represents the Minimum Discernible Signal.

The most likely limiting condition for sensitivity in a modern communications receiver operating at 14 MHz is atmospheric noise.

An undesirable effect of using too wide a filter bandwidth in the IF section of a receiver is that undesired signals may be heard. The desirable amount of selectivity for an amateur receiver for the indicated mode is shown in the following table,

Type of Receiver	Desirable Selectivity	Notes
RTTY HF	300 Hz	100 Hz is too narrow for the typical 170Hz shift; 6000 Hz and 2400 Hz are too wide, letting in unwanted signals
Single Sideband Phone	2.4 kHz	1 kHz is too narrow for the typical 2.4 kHz phone signal; 4.2 kHz and 4.8 kHz are too wide, letting in unwanted signals
VHF FM	15 kHz	1 kHz.2.4 kHz and 4.2 kHz are all too narrow for the typical 15 kHz FM signal

A narrow band roofing filter improves the dynamic range of a receiver by keeping strong signals near the receive frequency out of the IF stages.

The primary source of noise that can be heard from an HF-band receiver with an antenna connected is atmospheric noise.

The blocking dynamic range of a receiver is the difference in dB between the level of an incoming signal which will cause 1 dB of gain compression, and the level of the noise floor. Two types of problems caused by poor dynamic range in a communications receiver are cross modulation of the desired signal and desensitization from strong adjacent signals.

Intermodulation interference between two repeaters occurs when the repeaters are in close proximity and the signals mix in one or both transmitter final amplifiers. An effective way to reduce or eliminate intermodulation interference between two repeater transmitters operating in close proximity to one another is to install a properly terminated circulator at the output of the transmitter.

The unwanted signals produced as the sum and difference of the original frequencies of two transmitters "mixing" together in one or both of their final amplifiers is called intermodulation interference. If a receiver tuned to 146.70 MHz receives an intermodulation-product signal whenever a nearby transmitter transmits on 146.52 MHz, the two most likely frequencies for the other interfering signal are 146.34 MHz and 146.61 MHz.

The most significant effect of an off-frequency signal causing cross-modulation interference to a desired signal is that the off-frequency unwanted signal is heard in addition to the desired signal.

Nonlinear circuits or devices cause intermodulation in an electronic circuit.

The purpose of the preselector in a communications receiver is to improve rejection of unwanted signals.

A third-order intercept level of 40 dBm mean with respect to receiver performance means that a pair of 40 dBm signals will theoretically generate the same output on the third order intermodulation frequency as on the input frequency.

The third-order intermodulation products within a receiver of particular interest compared to other products because the third-order product of two signals which are in the band is itself likely to be within the band.

The term for the reduction in receiver sensitivity caused by a strong signal near the received frequency is called desensitization. Strong adjacent-channel signals can cause receiver desensitization. A way to reduce the likelihood of receiver desensitization is to decrease the RF bandwidth of the receiver.

Ignition noise in a receiver can often be reduced by use of a receiver noise blanker. Signals which appear correlated across a wide bandwidth are the type that a receiver noise blanker might be able to remove from desired signals.

All of these choices are correct. All of the following types of receiver noise can often be reduced with a DSP noise filter,

- Broadband "white" noise
- Ignition noise
- Power line noise

Conducted and radiated noise caused by an automobile alternator be suppressed can be suppressed by connecting the radio's power leads directly to the battery and by installing coaxial capacitors in line with the alternator leads.

Noise from an electric motor can be suppressed by installing a brute-force AC-line filter in series with the motor leads.

A major cause of atmospheric static is thunderstorms.

The type of signal picked up by electrical wiring near a radio transmitter is a common-mode signal at the frequency of the radio transmitter. You can determine if line-noise interference is being generated within your home by turning off the AC power line main circuit breaker and listening on a battery operated radio.

An undesirable effect that can occur when using an IF type noise blanker is that nearby signals may appear to be excessively wide even if they meet emission standards.

All of the following answers are correct. A common characteristic of interference caused by a "touch controlled" electrical device includes all of the following,

- The interfering signal sounds like AC hum on an AM receiver or a carrier modulated by 60 Hz FM on a SSB or CW receiver
- The interfering signal may drift slowly across the HF spectrum
- The interfering signal can be several kHz in width and usually repeats at regular intervals across a HF band

If you are hearing combinations of local AM broadcast signals inside one or more of the MF or HF ham bands, the most likely cause is nearby corroded metal joints are mixing and re-radiating the BC signals.

One disadvantage of using some automatic DSP notch-filters when attempting to copy CW signals is that the DSP filter can remove the desired signal at the same time as it removes interfering signals.

All of these answers are correct. A loud "roaring" or "buzzing" AC line type of interference that comes and goes at intervals can be caused by,

- Arcing contacts in a thermostatically controlled device
- A defective doorbell or doorbell transformer inside a nearby residence
- A malfunctioning illuminated advertising display

One type of electrical interference that might be caused by the operation of a nearby personal computer is the appearance of unstable modulated or unmodulated signals at specific frequencies.

E5 - Electrical Principles

Resonance in an electrical circuit is the frequency at which the capacitive reactance equals the inductive reactance. The current through and the voltage across a series resonant circuit are in phase. Through a parallel resonant circuit they are also are in phase.

At resonance, the magnitude of the impedance of a circuit with a resistor, an inductor and a capacitor all in parallel is approximately equal to circuit resistance. The magnitude of the circulating current within the components of a parallel L-C circuit at resonance is at a maximum. But at the input of a parallel R-L-C circuit it is minimum.

As the frequency goes through resonance the input current of a series R-L-C circuit is a maximum. Resonance can cause the voltage across reactances in series to be larger than the voltage applied to them.

For questions on the exam, the half-power bandwidth of a parallel circuit for the given resonant frequency and Q is in the table below,

Frequency MHz	Frequency kHz	Circuit Q	Formula	Half-power Bandwidth
1.8 MHz	1800 kHz	95	$= \frac{kHz}{Q}$	18.9 kHz
3.7 MHz	3700 kHz	118		31.4 kHz
7.1 MHz	7100 kHz	150		47.3 kHz
14.25 MHz	14250 kHz	187		76.2 kHz

For questions on the exam, the resonant frequency of a series RLC circuit with given L and C values is in the table below (R is not relevant to resonance),

L	C	Formula*	Resonant Frequency
50 microhenrys	40 picofarads	$= \frac{1000}{2\pi\sqrt{LC}}$	3.56 MHz
40 microhenrys	200 picofarads		1.78 MHz
50 microhenrys	10 picofarads		7.12 MHz
25 microhenrys	10 picofarads		10.1 MHz
* The factor of 1000 adjusts for directly using microhenry and picofarad values instead of adjusting them to Henrys and Farads, respectively			

The term for the time required for the capacitor in an RC circuit to be charged to 63.2% of the supply voltage is one time constant. It is also the term for the time it takes for a charged capacitor in an RC circuit to discharge to 36.8% of its initial value of stored charge one time constant.

A capacitor in an RC circuit is discharged to 13.5% of the starting voltage after two time constants. **[.368×.368=.135]**.

There are two questions on the exam asking for computation of discharge time for an RC circuit and one asking for the time constant. All are really asking for the time constant of the circuit since the amount of discharge in the questions is exactly 36.8% -- one time constant. The table below shows the values in the questions and the computed results,

Initial Charge	Decreased Charge	Percent Discharge	Capacitor C	Resistor R	Formula[1]	Time (Sec.) TC
20 V DC	7.36 V DC	36.8%	0.01-microfarad	2-megohm	TC=R×C	0.02 seconds
800 V DC	294 V DC	36.8%	450-microfarad	1-megohm		450 seconds
Note[2]			220-microfarad	1-megohm		220 seconds

1 All time constant questions appear to have been selected so that if the nominal R and C values are multiplied you get the right answer, without having to move the decimal points or fool with powers of 10.

2 The time constant of a circuit having two 220-microfarad capacitors and two 1-megohm resistors all in parallel is 220 seconds. In theory the two capacitors in parallel double the capacitance and the two resistors halve the resistance. Because of this, If you make the "mistake" of using the values for one capacitor and one resistor, you still get the right answer.

Current through a capacitor leads the voltage across it by 90 degrees. The voltage across an inductor leads the current through it by 90 degrees.

The system often used to display the resistive, inductive, and/or capacitive reactance components of impedance is the rectangular coordinate system. The two numbers that are used to define a point on a graph using rectangular coordinates represent the coordinate values along the horizontal and vertical axes. When using rectangular coordinates to graph the impedance of a circuit, the horizontal axis represents the voltage or current associated with the resistive component. The vertical axis represents the voltage or current associated with the reactive component.

If you plot the impedance of a circuit using the rectangular coordinate system and find the impedance point falls on the right side of the graph on the horizontal line, what do you know about the circuit? It is equivalent to a pure resistance.

There are eight questions (one question appearing twice, is counted as two) in the exam pool that asks, either explicitly or implicitly from the choice of answers, the polar coordinate form of the impedance of a network composed of resistance and capacitive and/or inductive reactance in series. The following table shows how to do those calculations,

Resistance R	Capacitive Reactance X_C	Inductive Reactance X_L	Formula	Total Reactance X	Formula	Network Impedance Z	Formula	Phase Angle Θ
100-ohm	100-ohm	100-ohm		0-ohm		100 ohms		0°
400-ohm	300-ohm	600-ohm		300-ohm		500 ohms		37°
400-ohm		300-ohm		300-ohm		500 ohms		37°
4-ohm	1-ohm	4-ohm	$X=X_L-X_C$	3-ohm	$Z=\sqrt{R^2+X^2}$	5 ohms	$\Theta=\mathrm{Tan}^{-1}\left(\frac{X}{R}\right)$	37°
300-ohm	400-ohm			−400-ohm		500 ohms		−53°
100-ohm		100-ohm		100-ohm		141 ohms		45°
100-ohm*	100-ohm*			−100-ohm		141 ohms		−45°

* This problem occurs twice in the question pool, once explicitly specifying 100-ohm value for capacitive reactance, and once simply presenting the impedance as a complex number of the form 100 + j100.

There are two questions in the exam pool that ask the impedance of a network composed of resistance and capacitive or inductive reactance in parallel. The following table shows how to do those calculations,

Resistance R	Capacitive Reactance X_C	Inductive Reactance X_L	Formula*	Total Reactance X	Formula	Network Impedance Z	Formula	Phase Angle Θ
300-ohm		400-ohm	$X=X_L-X_C$	400-ohm	$Z=\frac{R\times X}{\sqrt{R^2+X^2}}$	240 ohms	$\Theta=\mathrm{Tan}^{-1}\left(\frac{R}{X}\right)$	37°
100-ohm	100-ohm			−100-ohm		71 ohms		−45°

*This is NOT the correct equation for reactances in parallel, but it works as a memory aid to remember the sign as long as either X_C or X_L is zero. It is used here simply because it's the same formula for reactances in series and makes it easier to remember the sign of the reactance. Nowhere in the exam question pool is there a problem with reactances in parallel.

The correct formula(s) depend on the topography of the network. A few simple rules about reactances in series and parallel are all that are needed to compute the impedance of any complex network. But since it is not required by any question in the Extra examination pool, it is not covered in this summary.

The system often used to display the phase angle of a circuit containing resistance, inductive and/or capacitive reactance is the polar coordinate system.

There are five questions asking for the phase angle from known x_C (capacitive reactance), x_L (inductive reactance) and R (resistance), all measured in ohms. Computation is unnecessary since all five answers are the same phase angle - 14 degrees, and by checking if x_L is greater than x_C you know if the voltage leads or lags the current. The table below summarizes the logic steps required,

Resistance R	Capacitive Reactance X_C	Inductive Reactance X_L	Formula	Phase Angle Θ	Is $X_L>X_C$?	Voltage Leads/Lags Current
100 ohms	25 ohms	50 ohms		14°	Yes	Leads
1 kilohm	500 ohms	250 ohms		−14°	No	Lags
100 ohms	100 ohms	75 ohms	$\Theta=\mathrm{Tan}^{-1}\left(\frac{X_L-X_C}{R}\right)$	−14°	No	Lags
100 ohms	75 ohms	50 ohms		−14°	No	Lags
1 kilohm	250 ohms	500 ohms		14°	Yes	Leads

There is one question in the exam requiring the computation of inductive reactance based on frequency before expressing the impedance as a complex number. This table shows the calculation,

Resistance R	Inductance L	Frequency f	Formula	Inductive Reactance X_L	Formula	Rectangular Coordinates
40-ohm	10-microhenry	500 MHz	$X_L=2\pi fL$	31,415-ohm	$=R+jX_L$	40 + j31,400

There are two questions that state the impedance of a circuit in polar coordinates as an admittance in millisiemens. Admittance is the reciprocal of impedance. Just divide the number of millisiemens into 1000 to get the impedance in ohms and change the sign of the angle from + to −, or vice versa. The table below shows this simple conversion,

Admittance M	Formula	Impedance Z	Phase Angle Θ_A	Formula	Phase Angle Θ
7.09 millisiemens	$Z=\frac{1000}{M}$	141 ohms	+45°	$\Theta=-\Theta_A$	−45°
5 millisiemens		200 ohms	−30°		+30°

In all the questions in Extra pool there is only one that calls for an impedance expressed in polar coordinates to be converted into rectangular coordinates. The conversion is shown below,

Impedance Z	Phase Angle Θ	Formula	Resistance R	Formula	Reactance X	Formula	Rectangular Coordinates
200-ohm	+30°	R = Z × Cos(Θ)	174-ohm	X = Z × Sin(Θ)	100-ohm	= R + jX	174 + j100

Four questions involve computing the impedance of a series circuit consisting of a resister, capacitor and/or inductor from their nominal values, operating at a given frequency and then locating correct impedance on Figure E5-2, where the horizontal axis represents resistance and the vertical axis reactance. Note that inductive reactance X_L is positive and capacitive reactance X_C is negative. Resistance is always positive so neither Point 5 nor Point 7 is an acceptable answer. The following table summarizes the computations,

Resistance R	Frequency f	Capacitance picofarads	Capacitance microfarads C	Formula	Capacitive Reactance X_C	Inductance microhenrys L	Formula	Inductive Reactance X_L	Formula	Reactance X	Point on Figure E5-2
300-ohm	24.9 MHz	85	.000085	$X_C = \frac{1}{2\pi fC}$	75-ohm	0.64	$X_L = 2\pi fL$	100-ohm	$X = X_L - X_C$	25-ohm	300 + j25 Point 8
300-ohm	3.505 MHz					18		396-ohm		396-ohm	300 + j396 Point 3
300-ohm	21.200 MHz	19	.000019		395-ohm					−395-ohm	300 − j395 Point 1
400-ohm	14 MHz	38	.000039		291-ohm					−291-ohm	400 − j291 Point 4

The phenomenon that as frequency increases, RF current flows in a thinner layer of the conductor, closer to the surface, is called the skin effect. Because of skin effect the resistance of a conductor is different for RF currents than for direct currents.

A capacitor is a device used to store electrical energy in an electrostatic field. The unit that measures electrical energy stored in an electrostatic field is the Joule.

A magnetic field is the region surrounding a magnet through which a magnetic force acts. The strength of a magnetic field around a conductor is determined by the amount of current. The magnetic field oriented about a conductor in relation to the direction of electron flow is in a direction determined by the left-hand rule.

The term for energy stored in electromagnetic or electrostatic fields is potential energy.

The term for an out-of-phase, nonproductive power associated with inductors and capacitors is reactive power. Reactive power is wattless, nonproductive power. In a circuit that has both inductors and capacitors, the reactive power is repeatedly exchanged between the associated magnetic and electric fields, but is not dissipated.

Given the phase angle between the voltage and current, there are three questions on the exam asking for the power factor of a R-L circuit. The mathematical answer is Trigonometric Cosine of the phase angle. A Math calculator can give you the answer but if you know how to use one, you probably have the values for 30°, 45° and 60° memorized. The table below gives the values,

Circuit Type	Phase Angle Θ	Formula	Power Factor PF
R-L	60°	PF = Cos(Θ)	0.500
R-L	45°		0.707
R-L	30°		0.866

The true power in an AC circuit where the voltage and current are out of phase is determined by multiplying the apparent power times the power factor. There are three questions in the exam asking to compute the power consumed in a circuit with a known power factor. The table below summarizes these calculations,

Voltage E	Current I	Formula	Power P	Power Factor PF	Formula	Power Consumed PC
100-V AC	4 amperes	P=E × I	400 Watts	0.2	PC=PF × P	80 watts
200-V AC	5 amperes		1000 Watts	0.6		600 watts
			500 Watts	0.71		355 watts

The power consumed in a circuit consisting of a 100 ohm resistor in series with a 100 ohm inductive reactance drawing 1 ampere is 100 Watts.

E6 - Circuit Components

The initials CMOS stand for Complementary Metal-Oxide Semiconductor. Two elements widely used in semiconductor devices that exhibit both metallic and nonmetallic characteristics are Silicon and germanium.

N-type semiconductor material contains more free electrons than pure germanium or silicon crystals. The majority charge carriers in N-type semiconductor material are free electrons.

The majority charge carriers in P-type semiconductor material are holes. P-type of semiconductor material contains fewer free electrons than pure germanium or silicon crystals. The name given to an impurity atom that adds holes to a semiconductor crystal structure is acceptor impurity.

In Figure E6-1, the schematic symbol for a PNP transistor is Symbol 1.

Many MOSFET devices have built-in gate-protective Zener diodes to reduce the chance of the gate insulation being punctured by static discharges or excessive voltages. In Figure E6-2, the schematic symbol for an N-channel dual-gate MOSFET is Symbol 4.

The alpha of a bipolar junction transistor is the change of collector current with respect to emitter current. The beta of a bipolar junction transistor is the change in collector current with respect to base current.

The names of the three terminals of a field-effect transistor (FET) are fate, drain, source. A FET (Field Effect Transistor) has high input impedance as compared to a bipolar transistor which has low input impedance. FET depletion-mode is when an FET that exhibits a current flow between source and drain when no gate voltage is applied. In Figure E6-2, the schematic symbol for a P-channel junction FET is Symbol 1.

The frequency at which a transistor grounded base current gain has decreased to 0.7 of the gain obtainable at 1 kHz is the Alpha cutoff frequency.

Gallium arsenide is used as a semiconductor material in preference to germanium or silicon at microwave frequencies.

The principal characteristic of a Zener diode is a constant voltage under conditions of varying current.

The principal characteristic of a tunnel diode is a negative resistance region. A tunnel diode is capable of both amplification and oscillation.

An important characteristic of a Schottky Barrier diode as compared to an ordinary silicon diode when used as a power supply rectifier is that it has less forward voltage drop.

A Varactor diode device varies its internal capacitance as the voltage applied to its terminals varies. In Figure E6-3, the schematic symbol for a varactor diode is 1.

A common use of a hot-carrier diode is as a VHF / UHF mixer or detector.

A metal-semiconductor junction is a type of semiconductor diode. Junction diodes are rated for maximum forward current and PIV. The junction temperature limits the maximum forward current rating in a junction diode.

A common use for point contact diodes is as an RF detector.

One common use for PIN diodes is as an RF switch.

Forward bias is required for an LED to produce luminescence. In Figure E6-3, the schematic symbol for a light-emitting diode is Symbol 5.

The recommended power supply voltage for TTL series integrated circuits 5 volts. If the inputs of a TTL device are left open they have a logic-high state. The level of input voltage that is a logic "high" in a TTL device operating with a positive 5-volt power supply is 2.0 to 5.5 volts. The level of input voltage that is a logic "low" in a TTL device operating with a positive 5-volt power-supply is 0.0 to 0.8 volts.

An advantage of CMOS logic devices over TTL devices is lower power consumption. CMOS digital integrated circuits have high immunity to noise on the input signal or power supply because the input switching threshold is about one-half the power supply voltage.

The correct basic Boolean logic schematic symbols shown in Figure E6-5 are summarized in the following table,

AND	Symbol 1
NAND	Symbol 2
OR	Symbol 3
NOR	Symbol 4
NOT	Symbol 5

The electron beam in a vidicon is deflected by varying electromagnetic fields. Persistance in a cathode ray tube (CRT) is the length of time the image remains on the screen after the beam is turned off. An electrostatic CRT deflection is better when high-frequency waves are to be displayed on the screen. If a cathode ray tube (CRT) is designed to operate with an anode voltage of 25,000 volts, if the anode voltage is increased to 35,000 volts the image size will decrease. Exceeding the anode voltage design rating can cause a cathode ray tube (CRT) to generate X-rays.

A charge-coupled device (CCD) samples an analog signal and passes it in stages from the input to the output. It is commonly used as an analog-to-digital converter. A charge-coupled device (CCD) in a modern video camera stores photogenerated charges as signals corresponding to pixels.

A liquid-crystal display (LCD) is a type of display that uses a crystalline liquid to change the way light is refracted. The principle advantage of liquid-crystal display (LCD) devices over other types of display devices is that they consume less power.

The material property that determines the inductance of a toroidal inductor with a 10-turn winding is core permeability. The usable frequency range of inductors that use toroidal cores, assuming a correct selection of core material for the frequency being used, is from less than 20 Hz to approximately 300 MHz. One important reason for using powdered-iron toroids rather than ferrite toroids in an inductor is that powdered-iron toroids generally have better temperature stability. Another reason is that ferrite toroids generally require fewer turns to produce a given inductance value.

A primary advantage of using a toroidal core instead of a solenoidal core in an inductor is that toroidal cores contain most of the magnetic field within the core material. 43 turns. would be required to produce a 1-mH inductor using a ferrite toroidal core that has an inductance index (A L) value of 523 millihenrys/1000 turns. 35 turns. would be required to produce a 5-microhenry inductor using a powdered iron toroidal core that has an inductance index (A L) value of 40 microhenrys/100 turns.

Ferrite beads are commonly used as VHF and UHF parasitic suppressors at the input and output terminals of transistorized HF amplifiers.

A filter with 2.4 kHz at -6 dB bandwidth would be a good choice for use in a SSB radiotelephone transmitter. A filter with 6 kHz at -6 dB bandwidths would be a good choice for use with standard doublesideband AM transmissions.

One aspect of the piezoelectric effect is the physical deformation of a crystal by the application of a voltage.

A crystal lattice filter is a filter with narrow bandwidth and steep skirts made using quartz crystals. The technique used to construct low-cost, high-performance crystal ladder filters is to measure crystal frequencies and carefully select units with a frequency variation of less than 10% of the desired filter bandwidth. The relative frequencies of the individual crystals are factors that have the greatest effect in helping determine the bandwidth and response shape of a crystal ladder filter.

A monolithic microwave integrated circuit (MMIC) is an amplifier device that consists of a small pill-type package with an input lead, an output lead and 2 ground leads. The characteristic impedance of circuits in which almost all MMICs are designed to work is 50 ohms. The typical noise figure of a monolithic microwave integrated circuit (MMIC) amplifier is approximately 3.5 to 6 dB. The microstrip construction technique is used when building an amplifier for the microwave bands containing a monolithic microwave integrated circuit (MMIC).

Plastic packages are the most common type used for inexpensive monolithic microwave integrated circuit (MMIC) amplifiers. The operating bias voltage normally supplied to the most common type of monolithic microwave integrated circuit (MMIC) is through a resistor and/or RF choke connected to the amplifier output lead. The supply voltage the monolithic microwave integrated circuits (MMIC) amplifiers typically require is 12 volts DC.

Photoconductivity is the increased conductivity of an illuminated semiconductor. The conductivity of a photoconductive material increases when light shines on it. Photoconductivity will cause the resistance of a crystalline solid to change. Electrons absorb the energy from light falling on a photovoltaic cell.

The material most affected by photoconductivity is a crystalline semiconductor. Cadmium sulfide will exhibit the greatest photoconductive effect when illuminated by visible light. Lead sulfide will exhibit the greatest photoconductive effect when illuminated by infrared light. Gallium arsenide photovoltaic cell have the highest efficiency.

The most common configuration for an optocoupler is an LED and a phototransistor. An optoisolator is an LED and a phototransistor. Optoisolators provide a very high degree of electrical isolation between a control circuit and a power circuit making them suitable for use with a triac to form the solid-state equivalent of a mechanical relay for a 120 V AC household circuit. Optoisolators are often used in power supplies because they have very high impedance between the light source and the phototransistor.

An optical shaft encoder is an array of optocouplers whose light transmission path is controlled by a rotating wheel.

Silicon is the most common type of photovoltaic cell used for electrical power generation. The approximate open-circuit voltage produced by a fully-illuminated silicon photovoltaic cell is 0.5 V.

E7 - Practical Circuits

A flip-flop is a bistable circuit. An astable Multivibrator is a circuit that continuously alternates between two unstable states without an external clock. Two output level changes are obtained for every two trigger pulses applied to the input of a "T" flip-flop circuit. A characteristic of a monostable multivibrator is that it switches momentarily to the opposite binary state and then returns, after a set time, to its original state. A flip-flop can divide the frequency of pulse train by 2. The number of flip-flops required to divide a signal frequency by 4 is 2.

A truth table is a list of inputs and corresponding outputs for a digital device. The truth tables for important logic elements are:

- An **AND gate** produces a logic "1" at its output only if all inputs are logic "1".
- A **NAND gate** produces a logic "0" at its output only when all inputs are logic "1".
- An **OR gate** produces a logic "1" at its output if any or all inputs are logic "1".
- A **NOR gate** produces a logic "0" at its output if any or all inputs are logic "1".

The name for the type of logic which represents a logic "1" as a high voltage is Positive Logic. The name for the type of logic which represents a logic "0" as a high voltage is Negative Logic.

A Class A common emitter amplifier bias would normally be set approximately half-way between saturation and cutoff.

A Class AB amplifier operates more than 180 degrees but less than 360 degrees.

A Push-pull reduces or eliminates even-order harmonics.

A Class C amplifier provides the highest efficiency. When a Class C rather than a class AB amplifier is used to amplify a single-sideband phone signal the signal may become distorted and occupy excessive bandwidth.

To prevent unwanted oscillations in a power amplifier you should install parasitic suppressors and/or neutralize the stage. A vacuum-tube power amplifier can be neutralized by feeding back an out-of-phase component of the output to the input.

When tuning a vacuum tube RF power amplifier that employs a pi-network output circuit, the tuning capacitor is adjusted for minimum plate current, while the loading capacitor is adjusted for maximum permissible plate current.

The circuit shown in Figure E7-1 is a common emitter amplifier and,

- **R1 and R2** are fixed bias
- **R3** is self bias

In the circuit shown in Figure E7-2,

- **C2** is output coupling
- **R** is the emitter load

One way to prevent thermal runaway in a transistor amplifier is to use degenerative emitter feedback.

The effect of intermodulation products in a linear power amplifier is the transmission of spurious signals. Third-order intermodulation distortion products are of particular concern in linear power amplifiers because they are relatively close in frequency to the desired signal.

Low input impedance is a characteristic of a grounded-grid amplifier.

A klystron is a VHF, UHF, or microwave vacuum tube that uses velocity modulation.

A parametric amplifier is a low-noise VHF or UHF amplifier relying on varying reactance for amplification.

A FET is generally best suited for UHF or microwave power amplifier applications.

The common name for a filter network which is equivalent to two L networks back-to-back is the Pi network. One advantage of a Pi matching network over an L matching network is that the Q of Pi networks can be varied depending on the component values chosen. The capacitors and inductors of a low-pass filter Pi-network are arranged so that a capacitor is in parallel with the input, another capacitor is in parallel with the output, and an inductor is in series between the two.

A Pi-L network is a network consisting of two series inductors and two shunt capacitors and is used when matching a vacuum-tube final amplifier to a 50-ohm unbalanced output. The advantage a Pi-L-network has over a Pi-network for impedance matching between the final amplifier of a vacuum-tube type transmitter and an antenna is greater harmonic suppression.

A T-network with series capacitors and a parallel (shunt) inductor transforms impedance and is a high-pass filter.

A network transforms a complex impedance to a resistive impedance by canceling the reactive part of the impedance and transforming the resistive part to the desired value.

A Chebyshev filter has ripple in the passband and a sharp cutoff.

An elliptical filter has extremely sharp cutoff, with one or more infinitely deep notches in the stop band. You would use a notch filter to attenuate an interfering carrier signal while receiving an SSB transmission.

An adaptive filter is a digital signal processing audio filter that might be used to remove unwanted noise from a received SSB signal.

A Hilbert-transform filter is a digital signal processing filter that might be used in generating an SSB signal.

A cavity filter would be the best choice for use in a 2-meter repeater duplexer.

Digital modes are most affected by non-linear phase response in a receiver IF filter.

One characteristic of a linear electronic voltage regulator is that the conduction of a control element is varied to maintain a constant output voltage.

One characteristic of a switching electronic voltage regulator is that the control device's duty cycle is controlled to produce a constant average output voltage.

A Zener diode is typically used as a stable reference voltage in a linear voltage regulator.

A series regulator is a type of linear regulator that makes the most efficient use of the primary power source.

A shunt regulator is a type of linear voltage regulator that places a constant load on the unregulated voltage source.

The circuit shown in Figure E7-3 is a linear voltage regulator. The purposes of the components in the circuit are:

- Q1 increases the current-handling capability of the regulator
- C1 filters the supply voltage
- C2 bypasses hum around D1
- C3 prevents self-oscillation
- R1 supplies current to D1
- R2 provides a constant minimum load for Q1
- D1 provides a voltage reference

Another purpose of a "bleeder" resistor in a conventional (unregulated) power supply is to improve output voltage regulation.

The purpose of a "step-start" circuit in a high-voltage power supply allows the filter capacitors to charge gradually.

All of the following answers are correct. When several electrolytic filter capacitors are connected in series to increase the operating voltage of a power supply filter circuit, resistors should be connected across each capacitor to:

- To equalize, as much as possible, the voltage drop across each capacitor
- To provide a safety bleeder to discharge the capacitors when the supply is off
- To provide a minimum load current to reduce voltage excursions at light loads

The primary reason that a high-frequency inverter type high-voltage power supply can be both less expensive and lighter in weight than a conventional power supply is that the high frequency inverter design uses much smaller transformers and filter components for an equivalent power output.

A reactance modulator on an oscillator can be used to generate FM-phone emissions. It can also be used to produce PM signals by using an electrically variable inductance or capacitance. A phase modulator varies the tuning of an amplifier tank circuit to produce PM signals.

A pre-emphasis network circuit is added to an FM transmitter to proportionally attenuate the lower audio frequencies. A de-emphasis network is added to an FM receiver to restore attenuated lower audio frequencies. A frequency discriminator is a circuit for detecting FM signals.

One result of the process of mixing two signals is the creation of new signals at the sum and difference frequencies. The principal frequencies that appear at the output of a mixer circuit are the original frequencies, and the sum and difference frequencies.

When an excessive amount of signal energy reaches a mixer circuit spurious mixer products are generated.

The process of detection is the recovery of information from a modulated RF signal. A diode detector functions by rectification and filtering of RF signals.

One way a single-sideband phone signal can be generated is by using a balanced modulator followed by a filter. Another common method of generating a SSB signal using digital signal processing is the phasing or quadrature method. A Product detector is well suited for demodulating SSB signals.

“Direct conversion”, when referring to a software defined receiver, is the process where incoming RF is mixed to “baseband” for analog-to-digital conversion and subsequent processing.

One purpose of a marker generator is to provide a means of calibrating a receiver's frequency settings.

A crystal marker generator is a crystal-controlled oscillator that generates a series of reference signals at known frequency intervals. A crystal oscillator followed by a frequency divider would be a good choice for generating a series of harmonically related receiver calibration signals. The additional circuitry that must be added to a 100-kHz crystal-controlled marker generator so as to provide markers at 50 and 25 kHz is two flip-flops.

A conventional frequency counter determines the frequency of a signal by counting the number of input pulses occurring within a specific period of time. The purpose of a frequency counter is to provide a digital representation of the frequency of a signal. The accuracy of a frequency counter is determined by the accuracy of the time base.

The purpose of a prescaler circuit is to divide a higher frequency signal so a low-frequency counter can display the operating frequency. A prescaler would be used to reduce a signal's frequency by a factor of ten. A decade counter digital IC produces one output pulse for every ten input pulses. A 1 MHz oscillator and a decade counter can be combined to produce a 100 kHz fundamental signal with harmonics at 100 kHz intervals.

Other than by directly counting input pulses, period measurement is used by some frequency counters as an alternate method of determining frequency. An advantage of a period-measuring frequency counter over a direct-count type is that it provides improved resolution of signals within a comparable time period.

An operational amplifier is a high-gain, direct-coupled differential amplifier whose characteristics are determined by components external to the amplifier. The most appropriate use of an op-amp RC active filter is as an audio receiving filter. The gain of a theoretically ideal operational amplifier does not vary with frequency.

The advantage of using an op-amp instead of LC elements in an audio filter is that op-amps exhibit gain rather than insertion loss. The gain and frequency characteristics of an op-amp RC active filter is determined by the values of capacitors and resistors external to the op-amp. The frequency and phase response of a filter can cause ringing in the filter. Unwanted ringing and audio instability be prevented in a multi-section op-amp RC audio filter circuit by restricting both gain and Q.

Polystyrene capacitor types are best suited for use in high-stability opamp RC active filter circuits. Sallen-Key is a type of active op-amp filter circuit.

The steps typically followed when selecting the external components for an opamp RC active filter are "standard capacitor values are chosen first, the resistances are calculated, and resistors of the nearest standard value are used". The voltage gain expected from the circuit in Figure E7-4 is given by,

$$\text{Voltage gain} = \frac{RF}{R1}$$

- A voltage gain of 47 can be expected when R1 is 10 ohms and RF is 470 ohms.
- A voltage gain of 38 can be expected when R1 is 1800 ohms and RF is 68 kilohms.
- A voltage gain of 14 can be expected when R1 is 3300 ohms and RF is 47 kilohms.
- An output voltage -2.3 volts can be expected if R1 is 1000 ohms, RF is 10,000 ohms, and 0.23 volts is applied to the input.

The term "op-amp input-offset voltage" is the potential between the amplifier input terminals of the op-amp in a closed-loop condition.

The typical input impedance of an integrated circuit op-amp is very high. The typical output impedance of an integrated circuit op-amp is very low.

Three major oscillator circuits often used in Amateur Radio equipment are Colpitts, Hartley and Pierce. A Colpitts and Hartley is the type of oscillator circuit commonly used in VFOs.

The condition that must exist for a circuit to oscillate is that it must have a positive feedback loop with a gain greater than 1. Positive feedback is supplied by a

- Hartley oscillator through a tapped coil.
- Colpitts oscillator through a capacitive divider.
- Pierce oscillator through a quartz crystal.

A phase-locked loop circuit is an electronic servo loop consisting of a phase detector, a low-pass filter and voltage-controlled oscillator. The capture range of a phase-locked loop circuit is the frequency range over which the circuit can lock.

A phase locked loop synthesizer is the type of frequency synthesizer circuit that uses a stable voltage-controlled oscillator, programmable divider, phase detector, loop filter and a reference frequency source.

A direct digital synthesizer is the type of frequency synthesizer circuit that uses a phase accumulator, lookup table, digital to analog converter and a low-pass anti-alias filter. Phase accumulator circuits are classified as a principal component of a direct digital synthesizer (DDS). The phase locked loop circuit is often used in conjunction with a direct digital synthesizer (DDS) to expand the available tuning range. The information contained in the lookup table of a direct digital frequency synthesizer are the amplitude values that represent a sine-wave output. The major spectral impurity components of direct digital synthesizers are spurs at discrete frequencies.

Frequency synthesis and FM demodulation are functions that can be performed by a phase-locked loop.

A stable reference oscillator is normally used as part of a phase locked loop (PLL) frequency synthesizer because any phase variations in the reference oscillator signal will produce phase noise in the synthesizer output. A phase-locked loop is often used as part of a variable frequency synthesizer for receivers and transmitters because it makes it possible for a VFO to have the same degree of stability as a crystal oscillator.

Broadband noise is a major spectral impurity of phase-locked loop synthesizers.

A magnetron oscillator is a UHF or microwave oscillator consisting of a diode vacuum tube with a specially shaped anode, surrounded by an external magnet.

A Gunn diode oscillator is an oscillator based on the negative resistance properties of properly-doped semiconductors.

E8 - Signals And Emissions

A square wave is made up of a sine wave plus all of its odd harmonics.

A sawtooth wave is made up of sine waves of a given fundamental frequency plus all its harmonics. A sawtooth wave has a rise time significantly faster than its fall time (or vice versa).

The root-mean-square value of an AC voltage is the DC voltage causing the same amount of heating in a resistor as the corresponding RMS AC voltage. The most accurate way of measuring the RMS voltage of a complex waveform is by measuring the heating effect in a known resistor.

The characteristics of the modulating signal determines the PEP-to-average power ratio of a single-sideband phone signal. The waveform produced by human speech is irregular. The approximate ratio of PEP-to-average power in a typical voice-modulated single-sideband phone signal is 2.5 to 1.

The period of a wave is the time required to complete one cycle.

The distinguishing characteristic of a pulse waveform is narrow bursts of energy separated by periods of no signal. One use for a pulse modulated signal is digital data transmission.

Sequential sampling is a methods commonly used to convert analog signals to digital signals. An advantage of using digital signals instead of analog signals to convey the same information is that digital signals can be regenerated multiple times without error. The waveform of a digital data stream signal look like a series of pulses with varying patterns on a conventional oscilloscope.

All of the following answers are correct. The information can be conveyed using digital waveforms include:

- Human speech
- Video signals
- Data

The modulation index is the ratio between the frequency deviation of an RF carrier wave, and the modulating frequency of its corresponding FM-phone signal. The deviation ratio is the ratio of the **maximum** carrier frequency deviation to the **highest** audio modulating frequency.

$$\text{Modulation Index} = \frac{\textbf{maximum}\text{ frequency deviation}}{\text{modulating frequency}} \qquad \text{Deviation Ratio} = \frac{\textbf{maximum}\text{ frequency deviation}}{\textbf{maximum}\text{ modulating frequency}}$$

The answers for the four problems in the question pool requiring calculation of a Modulation Index or a Deviation Ratio are:

- a maximum frequency deviation of 3000 Hz either side of the carrier frequency with a modulating frequency of 1000 Hz is 3
- a maximum carrier deviation of plus or minus 6 kHz with a 2-kHz modulating frequency is 3
- a maximum frequency swing of plus-or-minus 5 kHz with a maximum modulation rate of 3 kHz is 1.67
- a maximum frequency swing of plus or minus 7.5 kHz with a maximum modulation frequency of 3.5 kHz is 2.14.

The modulation index of a phase-modulated emission does not depend on the RF carrier frequency. It does not vary with RF carrier frequency (the modulated frequency).

When using a pulse-width modulation system, a transmitter's peak power is greater than its average power because the signal duty cycle is less than 100%.

The time at which each pulse occurs varies in a pulse-position modulation system. The pulses of a pulse-modulated signal are usually transmitted as a pulse of relatively short duration followed by a relatively long period of time separating each pulse.

Frequency division multiplexing can be used to combine several separate analog information streams into a single analog radio frequency signal. Frequency division multiplexing is when two or more information streams are merged into a "baseband", which then modulates the transmitter.

Time division multiplexing is when two or more signals are arranged to share discrete time slots of a digital data transmission.

Morse code is a digital code that consists of elements having unequal length.

Differences between the Baudot digital code and ASCII codes include, Baudot uses five data bits per character, ASCII uses seven; Baudot uses two characters as shift codes, ASCII has no shift code.

One advantage of using the ASCII code for data communications is that it is possible to transmit both upper and lower case text. The advantage of including a parity bit with an ASCII character stream is that some types of errors can be detected.

Use of sinusoidal data pulses minimizes the bandwidth requirements of a PSK-31 signal.

The bandwidth required for the following modes and transmission rates are:

- The bandwidth required for a 13-WPM international Morse code transmission is Approximately 52 Hz
- The bandwidth required for a 170-hertz shift, 300-baud ASCII transmission is 0.5 kHz
- The bandwidth required for a 4800-Hz frequency shift, 9600-baud ASCII FM transmission is 15.36 kHz

One advantage of using JT-65 coding is that virtually perfect decoding of signals well below the noise.

Spread-spectrum communication is a wide-bandwidth communications system in which the transmitted carrier frequency varies according to some predetermined sequence. In spread-spectrum communications frequency hopping alters the center frequency of a conventional carrier many times per second in accordance with a pseudo-random list of channels.

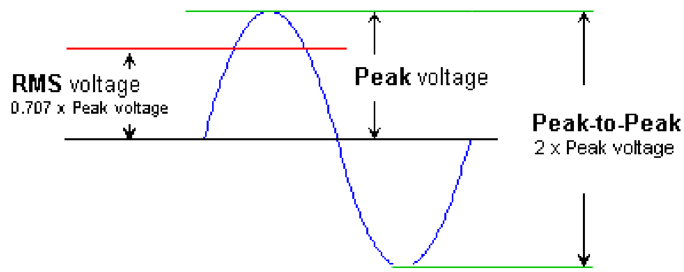
Spread-spectrum causes a digital signal to appear as wide-band noise to a conventional receiver. Spread-spectrum communications is resistant to interference because only signals using the correct spreading sequence are received.

In spread-spectrum communications direct sequence uses a high speed binary bit stream to shift the phase of an RF carrier.

The typical values at a common household electrical outlet are:

- The RMS voltage is 120-V AC
- The Peak voltage is 170 volts
- The Peak-to-Peak voltage is 340 volts

$$\text{Power} = \frac{(\text{RMS volts})^2}{R}$$



The easiest voltage amplitude parameter to measure when viewing a pure sine wave signal on an oscilloscope is its peak-to-peak voltage. The relationship between the **peak-to-peak** voltage and the **peak** voltage amplitude of a symmetrical waveform is 2:1.

The PEP output of a transmitter that has a maximum peak of 30 volts to a 50-ohm load as observed on an oscilloscope is 9 watts. The average power dissipated by a 50-ohm resistive load during one complete RF cycle having a peak voltage of 35 volts is 12.2 watts.

If an RMS reading voltmeter reads 34 volts on a sinusoidal waveform, the peak voltage is 48 volts. If an RMS-reading AC voltmeter reads 65 volts on a sinusoidal waveform, the peak-to-peak voltage is 184 volts.

The input-amplitude peak voltage is valuable in evaluating the signal-handling capability of a Class A amplifier.

The type of meter that should be used to monitor the output signal of a voice-modulated single-sideband transmitter to ensure you do not exceed the maximum allowable power is a peak-reading wattmeter. The advantage of using a peak-reading wattmeter to monitor the output of a SSB phone transmitter is that it gives a more accurate display of the PEP output when modulation is present.

An electromagnetic wave is a wave consisting of an electric field and a magnetic field oscillating at right angles to each other. The best description of electromagnetic waves traveling in free space is changing electric and magnetic fields that propagate energy.

The polarization of an electromagnetic wave with its magnetic field parallel to the surface of the Earth is vertical. The polarization of an electromagnetic wave with its magnetic field is perpendicular to the surface of the Earth is horizontal. Circularly polarized electromagnetic waves are waves with a rotating electric field.

The approximately speed that electromagnetic waves travel in free space is 300 million meters per second.

E9 -- Antennas And Transmission Lines

An isotropic Antenna is a theoretical antenna used as a reference for antenna gain. The antenna that has no gain in any direction is an isotropic antenna.

One needs to know the feed point impedance of an antenna to match impedances for maximum power transfer from a feed line.

The radiation resistance of an antenna is the value of a resistance that would dissipate the same amount of power as that radiated from an antenna. The total resistance of an antenna system is the radiation resistance plus ohmic resistance. Antenna efficiency is the term for the ratio of the radiation resistance of an antenna to the total resistance of the system. Antenna height and conductor length/diameter ratio, and location of nearby conductive objects are factors that determine the radiation resistance of an antenna.

Antenna gain is the numerical ratio relating the radiated signal strength of an antenna in the direction of maximum radiation to that of a reference antenna.

There are three questions in the pool asking to relate an antenna's gain to another antenna:

- The gain of a 1/2-wavelength dipole as compared to an isotropic antenna is 2.15 dB. [**Memorize 2.15 dB for the other questions!**]
- The gain of an antenna over a 1/2-wavelength dipole that has 6 dB gain over an isotropic antenna is 3.85 dB. [6 dB − **2.15 dB** = 3.85 dB]
- The gain of an antenna over a 1/2-wavelength dipole that has 12 dB gain over an isotropic antenna is 9.85 dB. [12 dB − **2.15 dB** = 9.85 dB]

A folded dipole antenna is a dipole constructed from one wavelength of wire forming a very thin loop.

Antenna efficiency calculated with the formula (radiation resistance / total resistance) x 100%.

The efficiency of an HF quarter-wave grounded vertical antenna can be improved by installing a good radial system. The most important factor that determines ground losses for a ground-mounted vertical antenna operating in the 3-30 MHz range is soil conductivity.

Antenna bandwidth is the frequency range over which an antenna satisfies a performance requirement.

The orientation of its electric field (E Field) is determined by the free-space polarization of an antenna.

In the antenna radiation pattern shown in Figure E9-1,

- **the 3-dB beamwidth is 50 degrees**
- **the front-to-back ratio is 18 dB**
- **the front-to-side ratio is 14 dB**

If a Yagi antenna is designed solely for maximum forward gain the front-to-back ratio decreases. If the boom of a Yagi antenna is lengthened and the elements are properly retuned, usually the gain increases.

When a directional antenna is operated at different frequencies within the band for which it was designed the gain may exhibit significant variations.

Assuming each antenna is driven by the same amount of power, there is no difference between the total amount of radiation emitted by a directional (gain) antenna compared with the total amount of radiation emitted from an isotropic antenna. It is just radiated in different directions.

The approximate beamwidth of a directional antenna can be determined by noting the two points where the signal strength of the antenna is 3 dB less than maximum and compute the angular difference.

The abbreviation NEC stands for Numerical Electromagnetics Code when applied to antenna modeling programs. A disadvantage of NEC-based antenna modeling programs is that the computing time increases as the number of wire segments is increased.

A computer program using the technique called "Method of Moments" is commonly used for modeling antennas. The principle used by the "Method of Moments" analysis is modeling a wire as a series of segments, each having a distinct value of current. A disadvantage of decreasing the number of wire segments in an antenna model below the guideline of 10 segments per half-wavelength is that the computed feed-point impedance may be incorrect.

All of the following answers are correct. The type of information that can be obtained by submitting the details of a proposed new antenna to a modeling program include:

- SWR vs. frequency charts
- Polar plots of the far-field elevation and azimuth patterns
- Antenna gain

The radiation pattern of two 1/4-wavelength vertical antennas spaced,

- 1/2-wavelength apart and fed in phase is a figure-8 broadside to the axis of the array
- 1/2-wavelength apart and fed 180 degrees out of phase is a figure-8 oriented along the axis of the array
- 1/4-wavelength apart and fed 90 degrees out of phase is a cardioid

A basic rhombic antenna is bidirectional; four-sided, each side one or more wavelengths long; open at the end opposite the transmission line connection. The main advantages of a terminated rhombic antenna is wide frequency range, high gain and high front-to-back ratio. Disadvantages of a terminated rhombic antenna for the HF bands are the antenna requires a large physical area and 4 separate supports. The effect of a terminating resistor on a rhombic antenna is to change the radiation pattern from bidirectional to unidirectional.

The type of antenna pattern over real ground shown in Figure E9-2 is elevation.

- **the elevation angle of peak response in the antenna radiation pattern shown is at** 7.5 degrees
- **the front-to-back ratio of the radiation pattern shown is** 28 dB
- **the number of elevation lobes in the forward direction of the antenna radiation pattern is** 4

The far-field elevation pattern of a vertically polarized antenna mounted over seawater increases low-angle radiation compared to a rocky ground. The main effect of placing a vertical antenna over an imperfect ground is that it reduces low-angle radiation. The conductivity and dielectric constant of the soil in the area of the antenna strongly affects the shape of the far-field, low-angle elevation pattern of a vertically polarized antenna.

For a Yagi with three elements mounted parallel to the ground, the electric field would be oriented horizontally.

To achieve good performance at the desired frequency, a Beverage antenna should be one or more wavelengths long.

When the operating frequency of a parabolic dish antenna is doubled, the gain increases 6 dB.

One way to produce circular polarization when using linearly polarized antennas is to arrange two Yagis perpendicular to each other with the driven elements at the same point on the boom and fed 90 degrees out of phase.

The beamwidth of an antenna decreases as the gain is increased.

It is desirable for a ground-mounted satellite communications antenna system to be able to move in both azimuth and elevation in order to track the satellite as it orbits the earth.

A loading coil is often used with an HF mobile antenna to cancel capacitive reactance. For a shortened vertical antenna, a loading coil be placed near the center of the vertical radiator to minimize losses and produce the most effective performance. An HF mobile antenna loading coil should have a high ratio of reactance to resistance to minimize losses. At the base feed-point of a fixed-length HF mobile antenna the resistance decreases and the capacitive reactance increases as the frequency of operation is lowered.

The bandwidth of an antenna decreases as it is shortened through the use of loading coils. An advantage of using top loading in a shortened HF vertical antenna is improved radiation efficiency.

An advantage of using a trapped antenna is that it may be used for multi-band operation. A disadvantage of using a multiband trapped antenna is that it might radiate harmonics.

The approximate feed-point impedance at the center of a folded dipole antenna is 300 ohms.

The type of conductor that would be best for minimizing losses in a station's RF ground system is a thin, flat copper strap several inches wide. A connection to 3 or 4 interconnected ground rods driven into the Earth would provide the best RF ground for your station.

The delta matching system matches a high-impedance transmission line to a lower impedance antenna by connecting the line to the driven element in two places spaced a fraction of a wavelength each side of element center.

The gamma match matches an unbalanced feed line to an antenna by feeding the driven element both at the center of the element and at a fraction of a wavelength to one side of center. The purpose of the series capacitor in a gamma-type antenna matching network is to compensate for the inductive reactance of the matching network. The Gamma match is an effective method of connecting a 50-ohm coaxial cable feed-line to a grounded tower so it can be used as a vertical antenna.

To use a hairpin matching system, the driven element in a 3-element Yagi must be tuned with capacitive reactance. The equivalent lumped-constant network for a hairpin matching system on a 3- element Yagi is an L network.

The parameter that best describes the interactions at the load end of a mismatched transmission line is the reflection coefficient. An SWR greater than 1:1 describes a mismatched transmission line.

The stub match uses a short perpendicular section of transmission line connected to the feed line near the antenna. An effective way of matching a feed-line to a VHF or UHF antenna when the impedances of both the antenna and feed-line are unknown is to use the "universal stub" matching technique. An effective way to match an antenna with a 100-ohm terminal impedance to a 50-ohm coaxial cable feed-line is to insert a 1/4-wavelength piece of 75-ohm coaxial cable transmission line in series between the antenna terminals and the 50-ohm feed cable.

The primary purpose of a "phasing line" when used with an antenna having multiple driven elements is to ensure that each driven element operates in concert with the others to create the desired antenna pattern.

The purpose of a "Wilkinson divider" is to divide power equally among multiple loads while preventing changes in one load from disturbing power flow to the others.

The physical length of a coaxial cable transmission line is shorter than its electrical length because electrical signals move more slowly in a coaxial cable than in air. Velocity factor is the term for the ratio of the actual speed at which a signal travels through a transmission line to the speed of light in a vacuum. Dielectric materials used in the line determine the velocity factor in a transmission line. The velocity factor of a transmission line is the velocity of the wave in the transmission line divided by the velocity of light in a vacuum. The typical velocity factor for a coaxial cable with solid polyethylene dielectric is 0.66.

The formula for the electrical length of a transmission line is

$$\textbf{One full wave length = velocity factor} \times \frac{\textbf{300}}{\textbf{frequency in MHz}}$$

- Assuming a velocity factor of 0.66., the physical length of a typical coaxial transmission line that is electrically one-quarter wavelength long at 7.2 MHz is 6.9 meters.
- Assuming a velocity factor of 0.66., the physical length of a coaxial transmission line that is electrically one-quarter wavelength long at 14.1 MHz is 3.5 meters.
- Assuming a velocity factor of 0.95., the physical length of a parallel conductor feed line that is electrically one-half wavelength long at 14.10 MHz is 10 meters.

A 450-ohm ladder line at 50 MHz, as compared to 0.195-inch diameter coaxial cable (such as RG-58) has lower loss.

A transmission line presents the characteristics shown in the table to a generator when the line is either open or shorted at the far end,

Transmission Line Length	Open	Shorted	Memory Note
1/8-wavelength	a capacitive reactance	an inductive reactance	**8CI**
1/4-wavelength	a very low impedance	a very high impedance	**4LH**
1/2-wavelength	a very high impedance	a very low impedance	**2HL**

All of the following answers are correct. The primary difference between foam-dielectric coaxial cable as opposed to solid-dielectric cable, assuming all other parameters are the same, include:

- Reduced safe operating voltage limits
- Reduced losses per unit of length
- Higher velocity factor

Impedance along transmission lines can be calculated using a Smith chart. The coordinate system used in a Smith chart is resistance circles and reactance arcs. Impedance and SWR values in transmission lines are often determined using a Smith chart. The two families of circles and arcs that make up a Smith chart are resistance and reactance.

The chart shown in Figure E9-3 is a Smith chart.

On the Smith chart shown in Figure E9-3,

- **the name for the large outer circle on which the reactance arcs terminate is the** reactance axis
- **the only straight line shown is** the resistance axis
- **the third family of circles often added to a Smith chart is the** standing-wave ratio circles
- the arcs on a Smith chart represent points with constant reactance

The wavelength scales on a Smith chart are calibrated in fractions of transmission line electrical wavelength.

The normalization process with regard to a Smith chart is the reassigning impedance values with regard to the prime center.

The term that describes station output (including the transmitter, antenna and everything in between), when considering transmitter power and system gains and losses, is effective radiated power.

There are three questions asking to compute the **E**ffective **R**adiated **P**ower (ERP) of transmitter given the feed line loss, duplexer/circulator loss and antenna gain. The losses and gains in dB can simply be added together to get the gain of the system,

$$\textbf{G [gain in dB]} = \textbf{antenna gain (dB)} - \textbf{feed line loss (dB)} - \textbf{duplexer loss (dB)} - \textbf{circulator loss (dB)}$$

The effective radiated power is then computed with the formula,

$$\textbf{ERP (watts)} = \textbf{transmitter power output (watts)} \times 10^{0.1\times G}$$

- A repeater station ERP with 150W transmitter, 2-dB feed line loss, 2.2-dB duplexer loss and 7-dBd antenna gain is $\mathbf{150W \times 10^{0.28} = 286W}$
- A repeater station ERP with 200W transmitter, 4-dB feed line loss, 3.2-dB duplexer loss, 0.8-dB circulator loss and 10-dBd antenna gain is $\mathbf{200W \times 10^{0.2} = 317W}$
- A repeater station ERP with 200W transmitter, 2-dB feed line loss, 2.8-dB duplexer loss, 1.2-dB circulator loss and 7-dBd antenna gain is $\mathbf{200W \times 10^{0.1} = 252W}$

The triangulation method of direction finding involves using antenna headings from several different receiving stations to locate the signal source. The main drawback of a wire-loop antenna for direction finding is that it has a bidirectional pattern. The function of a sense antenna is to modify the pattern of a DF antenna array to provide a null in one direction.

An antenna with a cardioid pattern is desirable for a direction-finding system because the response characteristics of the cardioid pattern can assist in determining the direction of the desired station. An RF attenuator is desirable in a receiver used for direction finding because it prevents receiver overload from extremely strong signals.

A receiving loop antenna is one or more turns of wire wound in the shape of a large open coil. The output voltage of a receiving loop antenna can be increased by increasing either the number of wire turns in the loop or the area of the loop structure. An advantage of using a shielded loop antenna for direction finding is that it is electro-statically balanced against ground, giving better nulls.

E0 - Safety

The differences between the radiation produced by radioactive materials and the electromagnetic energy radiated by an antenna is that RF radiation does not have sufficient energy to break apart atoms and molecules; radiation from radioactive sources does.

When evaluating exposure levels from your station at a neighbor's home, you must make sure signals from your station are less than the uncontrolled MPE limits. A practical way to estimate whether the RF fields produced by an amateur radio station are within permissible MPE limits is to use a computer-based antenna modeling program to calculate field strength at accessible locations.

When evaluating a site with multiple transmitters operating at the same time, the operators and licensees of each transmitter that produces 5% or more of its maximum permissible exposure limit at accessible locations are responsible for mitigating overexposure situations.

One of the potential hazards of using microwaves in the amateur radio bands is the high gain antennas commonly used can result in high exposure levels.

SAR measures the rate at which RF energy is absorbed by the body.

All of the following answers are correct. There are separate electric (E) and magnetic (H) field MPE limits because,

- The body reacts to electromagnetic radiation from both the E and H fields
- Ground reflections and scattering make the field impedance vary with location
- E field and H field radiation intensity peaks can occur at different locations

The "far-field" zone of an antenna is the area where the shape of the antenna pattern is independent of distance.

Beryllium Oxide insulating material is commonly used as a thermal conductor for some types of electronic devices. It is extremely toxic if broken or crushed and the particles are accidentally inhaled. Polychlorinated biphenyls found in some electronic components such as high-voltage capacitors and transformers is considered toxic.

Injury from radiation leaks that exceed the MPE limits might be a significant hazard when operating a klystron or cavity magnetron transmitter.