GENERAL LICENSE EXAM STUDY NOTES ——— PERTINENT INFORMATION FOR EXAM

RTTY and PSK31 use LSB on all bands

FCC rules do not permit wide band signals below 30MHz

Maximum bandwidth of an amateur digital signal on HF is limited to 1kHz

Image modes are prohibited on 60 metres

USB phone only on 60 metres

QRN: Atmospheric noise; also can be from man—made electronics

QRM: Interference from other HF signals

Receiver Incremental Tuning—ability to shift the receive frequency without changing the transmit frequency to fine—tune desired signals and avoid or minimize QRM

Prosign AR—end of message

K: Over

QSK: Full break in

QRS: Send slower

QRQ: Send faster

Prosign KN—prevents others from breaking in with contact

QRV: ready to copy

Prosign SK: Contact is completed

Prosign CL: Closing station

Most RTTY conversations on HF are conducted at 45 Baud

ASCII sent at 110 or 300 Baud

PSK31: 31 Baud and is less than 100Hz in bandwidth

MFSK16: Multi—frequency shift keying; 16 different tones; bandwidth is slightly higher than 300Hz with data exchanged at 42WPM

MT63: Multi—tone; 64 tones and bandwidth is 1kHz

WSJT/JT44/JT65—Used for VHF/UHF meteor scatter and moon bounce communications; uses DSP technology

International Telecommunication Union (ITU) — organization responsible for all international radio regulations

Federal Communications Commission (FCC) — Agency in the United States charged with writing and administering the rules for U.S. amateurs

Federal Aviation Administration (FAA) — They must be notified if an antenna structure over 200 feet is being constructed

WB1ILS/AG <=== that is the indicator for passing the general class license exam

General Class licensees are only restricted from using CW, RTTY and data at the lowest frequencies of 7000—7025kHz (40m)

On 40 metre phone, General privileges start at 7175kHz

On HF, generals have ALL amateur privileges on the 160, 30, 17, 12 and 10 metre bands.

60 metres has a power limit of 50W ERP

30 metres only permit CW, RTTY and data

A1A—Amplitude—modulated telegraphy for aural reception
F3B—Frequency—modulated telephony
J3E—Single—sideband, suppressed carrier telephony

For a beacon station, 100W PEP is the max

Third party communication—Send messages on behalf of someone who is not an amateur radio operator

QRP—Originally decrease power
QRO—Originally increase power

All classes are limited to a maximum transmitter output of 1500W PEP

200W PEP on the 30 metre band
50W ERP on the 60 metre band

ERP—Effective Radiated Power
==> ERP is calculated by multiplying the transmitter power by the gain of the antenna

Maximum Symbol Rates and Bandwidth

Band	Symbol Rate (baud)	Bandwidth (kHz)
Below 10m	300	1
10m	1200	1
6m, 2m	19.6k	20
1.25m / 70cm	56k	100
33cm and above	no limit	no limit

Electric Current (I) — flow of electrons, atomic particles that each carry one unit of negative electric charge
Current is measured in Amperes (A)
Voltage (E)
Power (P) — measured in Watts

Voltage drop—the voltage caused by current flowing through a resistance (E = I x R)

Cycle—a complete sequence of AC current flowing, stopping, reversing and stopping again
==> the number of cycles per second is the current's frequency (f) measured in Hertz (Hz)

Harmonic—frequency that is some integer of a lowest or fundamental frequency

Second Harmonic—the harmonic at twice the fundamental frequency

Third Harmonic—the harmonic at three times the fundamental frequency

Decibel (dB)
==> dB = 10 $\log_{10}$ (power ratio)
==> dB = 20 $\log_{10}$ (voltage ratio)

Gain—ratios greater than 1

Loss / Attenuation—ratios less than 1

RMS = Root Mean Square

Peak Envelope Power (PEP) — the average power during one RF cycle at the peak of the signal's envelope
==> PEP is equal to the average power if an amplitude modulated signal is not modulated

Nominal value—the rated amount of Ω, farads, henrys and so forth that the component is supposed to present in a circuit
Tolerance—the amount the actual value is allowed to vary from the nominal

value, usually expressed in percent

Temperature coefficient—the type of variation of the component's actual value with temperature

Power (or voltage or current) rating—the rated ability of the component to withstand heat or dissipate energy

Thermistor—has a very precisely controlled change in value with temperature and is used as a temperature sensor

Permeability—increasing the core's ability to store magnetic energy

Filter chokes—used to filter and smooth power supply output voltages similarly to large filter capacitors

Core saturation—the core of an inductor can only store a limited amount of energy; saturation occurs when the limit is reached

Coupling—occurs when two inductors are placed together with their axes aligned; the magnetic field from one inductor can also pass through the second inductor, sharing some of its energy

Mutual inductance—the ability of inductors to share or transfer magnetic energy

All capacitors have the same basic structure—two conducting surfaces separated by a dielectric that stores electrical energy while preventing DC current flow between the surfaces
==> the dielectric's ability to store energy is specified by a quantity called the K factor

Electrolytic capacitors—use meta foil for the conducting surfaces, but the dielectric is a wet paste or gel of chemicals (the electrolyte) that create an insulating layer on the foils

Tantalum capacitors—a porous mass of tantalum is immersed in an electrolyte

Both tantalum and electrolytic capacitors are also polarized, meaning a DC voltage may only be applied in one direction without damaging the electrolyte in the capacitor

Common capacitor types and their uses:
======================================
Ceramic—RF filtering and bypassing at high frequencies; inexpensive
Plastic film—circuits operating at audio and lower radio frequencies
Silvered—mica—highly stable, low—loss, used in RF circuits
Electrolytic and Tantalum—rectifier and power supply filter circuits
Air and vacuum dielectric—transmitting and RF circuits

Blocking capacitors—pass AC signals while blocking DC signals
Bypass capacitors — provide a low impedance path for AC signals around a higher—impedance component or circuit
Filter capacitors — smooth out the voltage pulses of rectified AC to even DC voltage
Suppressor capacitors — absorb the energy of voltage transients or "spikes"
Tuning capacitors — vary the frequency of resonant circuits or filters or adjust impedance matching circuits

Series circuit — the current is the same in all components and the voltages are summed
Parallel circuit — voltage across all components is the same and currents into and out of circuit junctions must be equal

Effect on Total Value of adding components in series or parallel

Component	Adding in Series	Adding in Parallel
Resistor	Increase	Decrease
Inductor	Increase	Decrease
Capacitor	Decrease	Increase

Transformer — transfer power between two or more inductors sharing a common core
==> inductors are called windings

Primary winding — the winding to which power is applied

Secondary winding — winding from which power is extracted

Transformers that are used in AC power circuits are often rated in volt—amperes as a measure of their power handling capability

Vacuum tube has three basic parts: a source of electrons, an electrode to collect the electrons, and intervening electrodes that control the electrons travelling from source to collector
==> each electrode of a tube is called an element

Most common tubes in amateur radio today are triodes and tetrodes

Filament or heater — heats the cathode, causing it to emit electrons
Cathode — the source of electrons

Control grid — the grid closest to the cathode, used to regulate electron travel between the cathode and plate

Screen grid — an electrode that reduces grid—to—plate capacitance that diminishes the tube's ability to amplify at high frequencies

Suppressor grid — an electrode that prevents electrons from travelling from the plate to the control or screen grid

Plate — the electrode that collects electrons, called plate current

All amplifying tubes have at least three electrodes —— a cathode (including a filament to heat it), a grid and a plate

Cutoff — the repelling of electrons and they are either slowed down, decreasing the plate current, or stopped altogether...all on a negatively charged control grid

Reactance — the resistance to AC current flow caused by capacitance or inductance

Impedance — the opposition to current flow in an AC circuit caused by resistance, reactance or any combination of the two
==> symbolized by the letter "Z"

Resonance — the condition in which there is a match between the frequency at which a circuit or antenna naturally responds and that of an applied signal
==> resonance occurs when the capacitive and inductive reactances present are equal

Amateur transmitting equipment is designed so that the source impedance at the output (or input impedance) is 50 Ω

Mismatch — results in an SWR greater than 1:1

Semiconductor — materials that conduct electricity better than an insulator but not as well as a metal
==> Silicon (Si) and Germanium (Ge) are examples of semiconductors that are used in radio electronics

The electrical properties of semiconductors can be controlled by the addition of small amounts of other materials such as Indium (In) or Phosphorus (P)

Dopants — impurities in semiconductors

Doping — adding Dopants to semiconductors

N—Type — result of more electrons being created to conduct electricity simply by the impurity's presence, otherwise it is P—Type

PN Junction — point of contact for the two types of material

Semiconductor diode — only allows current to flow in one direction

Junction diode — created from a layer of P—type (the anode) and N—type (the cathode) material

Forward Bias — current flowing when positive voltage is applied from the P—type to the N—type material

Reverse Bias — voltage applied in the reverse direction from N—type to P—type

Peak inverse (or reverse) voltage (PIV) — the maximum reverse voltage (voltage in the nonconducting direction) that may be applied before reverse breakdown occurs, allowing current to flow in the reverse direction

Average forward current (I\/f) — due to the forward voltage, current through the diode generates heat equal to If x Vf; exceeding this rating will destroy the diode

Junction capacitance — the capacitance formed by a junction diode's P— and N—type material

PIN diode — conducts AC signals with low forward voltage drop, used for RF switching and control
Schottky diode — low junction capacitance allows operation at high frequencies

Varacitor — the reverse—biased junction acts like a capacitor and can be used as a small variable capacitor

Zener diode — extra levels of doping allow Zeners to be used as voltage regulators while in reverse breakdown

Signal or switching diodes — diodes that are designed for circuits with low—power signals

Bipolar transistor — made from P— and N—type material and use current to control their operation
==> Bipolar transistors have three electrodes —— the collector (C), emitter (E) and base (B)

Current gain — the control of a large current by a smaller current is amplification and the ratio of the collector—emitter current to base—emitter current

Gain—bandwidth—product — the ability of a transistor to amplify high frequency signals

Analog IC — used for applications such as signal amplification, filtering, measurement and power control
Digital IC — operate with discrete values of range and current that represent

"0" and "1"; i.e. Binary
==> common gates are the inverter, NAND and NOR

Combinational logic — digital circuits that use gates to combine binary inputs to generate a binary output or combination of binary outputs

Sequential logic — depends on time and sequence of circuits, based on flip—flop which has two stable states

Counters and shift registers — created by connecting flip—flops together so that one flip—flop's outputs feed the next flip—flop's input

RF IC — designed for functions commonly required at radio frequencies, such as low—level high gain amplifiers, mixers, modulators and demodulators, to include filters

MMIC (monolithic microwave integrated circuit) — a special type of RF IC that works through microwave frequencies

Microprocessor — capable of performing millions of computing instructions per second; nearly all of them are built from CMOS logic

Machine language — a sequence of operations by a microprocessor as described by a program, also is in the form of binary data

Volatile memory — loses the data it stores when power is removed
Nonvolatile memory — stores data permanently, even if the power is removed

Random—access memory (RAM) — can be read from or written in any order
Read—only memory (ROM) — stores data permanently and cannot be changed

RS—232 interface — also known as the COM port on your desktop machine

Indicator — a device that presents on/off information visually by the presence, absence or colour of light
==> common indicators are the incandescent light bulb and the light emitting diode (LED)

Display — a device that is capable of presenting text or graphics information in visual form

Power supply — has three basic parts: an input transformer, a rectifier and a filter—regulator output circuit
==> the input transformer converts the 120V AC household power to a voltage closer to the desired 13.8V

Rectifier circuit — converts bipolar AC waveform into pulses of DC

Half—wave rectifier — permits current flow during one half of the input AC

waveform from the transformer
==> there is also one diode forward voltage drop in series with the load current that reduces the peak input voltage by 0.6V for regular silicon diodes

Full—wave rectifier — two half—wave rectifiers operating on alternate half—cycles

Full—wave bridge — a full wave rectifier that adds two diodes but eliminates the need for a centre—tapped, double voltage transformer

Ripple - the variation output voltage caused by the pulses in a current, which is measured as the percentage of the peak—to—peak variation compared to average output voltage
==> A common way to reduce ripple is to use a capacitor—input filter

Regulation - the percentage of variation in output voltage between no load and full load

Equivalent Series Resistance (ESR) - consists of several sources of capacitor losses such as the resistance of conducting surfaces and of the internal electrolyte paste; they are all lumped together in a single parasitic resistance

Bleeder resistors - used to discharge the stored energy when power is removed

Linear supplies - power supplies that use capacitor— or inductor—input filters and linear voltage regulators to provide filtering and regulation

Switch—mode supply / switching supply - another type of power supply filter and regulation circuit that uses high—frequency pulses of current to control the output voltage

Equivalent series inductance (ESL) - causes a capacitor to have some parasitic inductance which is modelled as a single inductance

Crowbar circuit - the most common over—voltage protection circuit

Primary battery - also known as disposable battery; is discarded after it is discharged
==> Examples of primary batteries are carbon—zinc, alkaline and silver—nickel

Secondary battery - a rechargeable battery that can be used many times
==> Examples of secondary batteries are nickel—cadmium (NiCd), nickel—metal hydride (NiMH), lithium—ion (Li—ion) and lead—acid

Larger secondary batteries are also known as storage batteries
==> Examples are deep—cycle lead—acid marine or RV storage batteries; they are often used as an emergency power source to replace a power supply

operating from AC power———they are rated as 12V but should actually be maintained at a voltage of 13.8V

Energy rating - describes a battery's ability to deliver current while still maintaining a steady output voltage, measured in ampere—hours (Ah)———power output us the product of a battery's voltage and current

Self—discharge - occurs when a battery is not in use

Solar power - also known as photovoltaic conversion of sunlight directly into electricity; panels are made of silicon PN junctions that are exposed to sunlight

Wind power - generated by thermal energy from the sun

Keyed connector - ensures that connectors can only go together one way, thus reducing the possibility of damage from incorrect mating

volt—ohm—meter (VOM) - measures voltage, current and resistance
Oscilloscope - provides a digital display of voltage against time; contains a cathode—ray tube, or CRT with a flat front surface

signal generator - a piece of equipment whose RF output signals are similar to those received over the air

signal tracer - can act as a simple RF signal generator or function generator, as well as detect and demodulate signals found at various points inside a receiver
==> signal tracers are used primarily to identify nonfunctional circuits or stages in receivers

noise bridge - a device that allows you to measure the impedance of antennas and other circuits at different frequencies

antenna analyzer - contains a CW signal generator, a frequency counter, an SWR bridge and an impedance metre

field strength meter - used to test the radiation efficiency and pattern of an antenna

directional wattmeter - placed in a transmission line, usually at the transmitter output, measures both forward and reflected power in a line

continuous wave (CW) - a radio signal at one frequency whose strength never changes

modulation - adding information to a signal by modifying it in some way, such as changing frequency, phase angle or amplitude mode – the method of modulation that carries the information

demodulation – recovering the information from a modulated signal

unmodulated – a signal that doesn't carry any information

Three characteristics that can be modulated are the signal's amplitude or strength, its frequency and its phase.

The term instantaneous when applied to amplitude, frequency or phase refers to the value of those characteristics at a specific instant in time.

Amplitude Modulation (AM) – varying the power or amplitude of a signal to add speech or data

envelope – the maximum values of the instantaneous power for each cycle

detection – the process of recovering speech or music by following the envelope of an AM signal
==> AM signals are composed of a carrier and two side bands; the total power of an AM signal is divided between the carrier and side bands

Upper sideband (USB) – higher in frequency than the carrier by the frequency of the tone

Lower sideband (LSB) – lower in frequency than the carrier

Single sideband signal (SSB) – an AM signal with the carrier and one sideband removed by electronic circuitry
==> SSB transmissions have a superior range compared to standard AM because all of the SSB signal's power is contained in the remaining sideband

Frequency Modulation (FM) – modes that vary the frequency of a signal to add speech or data information; the frequency is varied in proportion to the amplitude of the modulating signal

deviation – the amount that an FM signal's frequency varies when modulated

Phase Modulation (PM) – created by varying a signal's phase angle

Amateur Signal Bandwidths

Type of Signal	Typical Bandwidth
AM voice	6 kHz
Amateur Television	6 MHz
SSB voice	2 to 3 kHz
Digital using SSB	500 to 3000 Hz
CW	100 to 300 Hz
FM voice	5 to 15 kHz

bandwidth – the difference in frequency between the lowest and highest component of a composite signal

air link – the part of the communication system that involves radio transmission and reception of signals

modem (modulator—demodulator) – translates bits into tones and back again

bit rate – the number of digital bits sent from one computing system to the other per second

baud or bauds – the number of symbols that are sent from one computing system to the other per second, also known as signalling rate and symbol rate

duty cycle – the ratio of time that the transmitter is on to the total of on time and off time
protocol – the rules that control the method used to exchange data between two systems

mode (digital) – the combination of protocol and modulation method

stack – the set of software and hardware that implements a protocol in a computing system

Typical duty cycle for various amateur operations

Type	Duty Cycle
CW	40—50%
SSB voice	20—25%
RTTY	100%
PACTOR	100%
PSK31	100%

==> Reduce your transmitter power down to 50% of maximum output power for most data modes to prevent overheating
Frequency Shift Keying (FSK) – a method of digital communications in which

the individual bits of data are encoded as shifts in single frequency
==> uses binary
==> Audio Frequency Shift Keying (AFSK) is common
==> uses a 5 bit series of tones
==> LSB is the standard for AFSK

Radioteletype (RTTY) – uses the Baudot code that represents (encodes) each text character as a sequence of 5 bits
==> the standard tone frequencies are 2125 Hz (the mark tone) and 2295 Hz (the space tone); there is a 170 Hz difference, thus indicating the shift in signal

Multiple Frequency Shift Keying (MFSK16) – uses 16 separate tones, all 15.625 Hz apart, so that the entire set can be received through one HF CW 500 Hz filter.
==> this protocol will send error correction with the data
==> performs well in a weak signal HF environment

Multi Tone 63 (MT63) – uses 64 different tones spread over a 1 kHz channel
==> this is very effective even in the presence of severe noise
==> it has a wide bandwidth, which does make it difficult to use in crowded band segments

Phase Shift Keying 31 (PSK31) – 31 baud digital communications, which can support typing rates of up to 50 WPM under good atmospheric conditions

Packet Basics

header – contains bit patterns that allow the receiver to synchronize with the packet's structure, control and routing information, and occasionally error detection and correction information

data – the data to be exchanged between computing systems, which is often compressed or packed for efficiency

trailer – additional control or status information and data used for error detection

encapsulation – the process of packaging data within a packet structure
==> the most common error detection mechanism is a Cyclic Redundancy Check, or CRC for short

Packet Radio – used almost exclusively on VHF and UHF, based on the computer network protocol X.25
==> amateurs adapted this and renamed it AX.25
==> packets that are exchanged using VHF are at 1200 or 9600 Baud
==> packet does not work well on HF because the data is easily disrupted by noise and fading, even at slow signalling rates of 300 Baud

digipeaters - relay stations that store and forward packets to other stations

PACTOR - Teletype Over Radio (TOR) which was developed to combine the best features of packet protocols with the error management of TOR modes
==> used mostly on HF
==> PACTOR III is capable of 5.2kbps performance over HF under good atmospheric conditions
==> PACTOR I and II can be used with regular computers

FOUR BASIC CIRCUITS
==> Oscillators
==> Mixers
==> Multipliers
==> Modulators

Oscillator - consists of an amplifier that increases signal amplitude and a feedback circuit to route some of the amplifier's output signal back to its input

Mixer - required to change the frequency of a signal

Multiplier - acts similarly to a mixer, but creates an integer multiple of an input frequency

Modulator - the circuits that perform the task of adding information to a carrier signal, either as amplitude, frequency or phase variations
plate / collector modulation - carried voltage that is varied is connected to a vacuum tube plate or a transistor's collector or drain

reactance modulator - varies capacitance in response to the modulating signal's amplitude; the variations in capacitance shift the frequency of the tank circuit, thus producing phase modulation

NOTE: USB signals are the standard on the 20 metre band and LSB signals on the 40 and 80 metre bands

FCC requires that SSB signals are suppressed to at least 40dB below the signal's peak power output to prevent unnecessary interference

SSB signals should have a bandwidth of no more than 3 kHz and an AM signal about 6 kHz; on 60 metres, the FCC specifies that the USB signals should occupy no more than 2.8 kHz of bandwidth

over-modulation - occurs when an AM or SSB signal is varied excessively in response to the modulating signal, which also creates splatter

microphone gain - control used to adjust the amount by which speech modulates the transmitter output signal
flat—topping / clipping - occurs if the drive level to transmitter output

stages or external amplifiers is increased beyond the point of maximum output power level

carrier cutoff – results if the output signal is completely cut off between peaks

Automatic Level Control (ALC) – helps prevent over-modulation by reducing output power during voice peaks

harmonics – generated by nearly all kinds of circuits because of nonlinearities in their operation

spurs – unwanted outputs that are not harmonically related to the desired output

two—tone test – a test that consists of modulating your transmitter with a pair of audio tones that are not harmonically related (typically 700 and 1900 Hz) while watching the transmitted signal with an oscilloscope

speech processing – occurs by increasing the average power of the speech signal without excessively distorting the signal

compression – increases gain at low input levels while holding gain constant for louder speech components

NOTE: a common problem is having a ground loop that results in a 60 or 120 Hz hum on transmit or receive audio which can be fixed by using a transformer in both signal lines between the radio and computer

Class A Amplifier – the most linear of all classes and also the least efficient; the amplifying device in a Class A amplifier is on all the time, which means gain is limited

Class B Amplifier – also known as push—pull with a pair of amplifying devices, each active during complementary halves of the signal's cycle; good efficiency and linearity pending careful design and adjustment

Class AB Amplifier – midway between Classes A and B, the amplifying device is active for more than one—half but less than the entire signal cycle; linearity is not as good as Class A, but the efficiency is somewhat improved

Class C Amplifier – amplifying devices are active but less than one—half of the signal's cycle; these are efficient, but are best used for CW and for FM because of their poor linearity

==> most linear amplifiers can be operated in either Class AB for SSB operation or in Class C for CW; the efficiency of an amplifier is defined as the RF output power divided by the DC input power

Amplifiers have three primary operator adjustments - Band, Tune and Load

Drive power is important, particularly for grid—driven amplifier circuits in which the input power is applied to the tube's control grid

neutralization - the technique of preventing self—oscillation

A superheterodyne receiver converts signals to audio in two steps———the front end converts the frequency of a signal to the intermediate frequency (IF) where most of the gain of the receiver is provided, then a second mixer also known as the product detector, converts the signal to audio frequencies

product detector - used for demodulating SSB and CW signals

envelope detector - used in conjunction with a product detector for demodulating AM signals

preselector - used between the antenna and the RF amplifier to reject strong out—of—band signals

birdies - a flaw that is caused by the LO and other oscillator circuits inside a receiver; leakage of these signals into the signal path can cause steady signals to appear

Digital Signal Processing (DSP) systems consist an analog—to—digital converter (ADC) to change the signal to digital data. A special type of microprocessor then performs the mathematical operations on the data to accomplish filtering, noise reduction, or other functions. A digital—to—analog converter (DAC) changes the processed data back to analog form for output as audio.

Common DSP functions:

Signal filtering - Radios with DSP offer selectable preprogrammed filters and allow the operator to adjust the filter bandwidth and shape and even to define new filters.

Noise reduction - It is possible for DSP to distinguish noise and remove a great deal of it, leaving only the desired speech or CW for the operator to copy.

Notch filtering - Interfering signals, particularly carriers from broadcast stations, can be sensed and removed by DSP, including tracking them as they change frequency and even eliminating more than one at a time.

Audio frequency equalizing - the operator can adjust receive or transmit audio frequency response to suit his or her preferences, compensating for hearing loss or optimizing microphone audio.
A typical S meter will have S9 at the middle of it, indicating that the

operator is receiving a strong signal. To the right of S9, a person will see markings of 20, 40 and 60. These correspond to “dB over S9” thus a reading of S9 + 20 dB corresponds to a signal 20 dB (100 times) stronger than an S9 signal typically would be.

Overload / gain compression – occurs when an input signal is simply too strong for the circuitry to handle, which results in distortion

intermodulation – occurs when two strong signals combine in a mixer or amplifier, generating their own mixing products that are demodulated and heard along with regular signals

Mobile HF installations
==> mobile rig requires a solid power connection capable of 20 A
==> the best power connection is direct to the battery using heavy gauge wire with a fuse in both the positive and negative leads
==> using the cigarette lighter is not good, as it only rated for a few amperes and it uses wire too small to use a 100 W HF radio
==> ground the radio directly to the battery or to the battery ground strap where it attaches to the engine block or vehicle chassis
==> antennas must be smaller in terms of wavelength than a home station, which is particularly true on the lower frequencies, such as 75 metres
==> while mobiling, the entire vehicle will become part of the antenna system and attention to every detail is critical

RF Grounding
==> AC safety ground wiring usually acts more like an antenna than a ground
==> for amateur stations, it is necessary to provide a separate RF ground from the AC safety ground
==> keep all equipment as close to the same RF voltage as possible
==> keep the RF voltage as close to ground potential as possible
==> ground loops can cause audio distortion or erratic operation of computer interfaces, introduce noise into sensitive receivers and upset SWR measurements
==> if at all possible, connect all equipment enclosures or metal chassis to a common ground point, called a “star” ground, which would then be connected to a ground rod
==> an alternative to a star ground is a ground bus

BASICS FOR RF GROUNDING IN THE SHACK:

==> bond all metal equipment enclosures to a common ground bus
==> keep all connections, straps and wires short
==> connect the ground bus to a ground rod or grounded pipe with a short, wide conductor such as copper flashing or strip
==> in rather difficult situations, a piece of wide flashing or screen can be placed under the equipment and connected to the ground bus
==> such a ground system minimizes hot spots; conducting surfaces that have a high RF voltage

Any conductor more than 1/10 of a wavelength long acts as an antenna

The antenna feed line, equipment enclosures and the connections between them act as antennas for your transmitted signal

Ground connections that approach 1/4 wavelength at any frequency may begin to act as a resonant circuit, thus creating hot spots on the ground connection with the possibility of causing RF burns

A good RF ground also acts as a backup to your AC safety ground, thus reducing shock hazards and also helps to reduce interference

fundamental overload - usually exhibited by radio or TV receivers unable to reject a strong signal that causes the internal circuits to act improperly, distorting or wiping out the intended signal; prevent the offending signal from entering the equipment by using filters

direct detection - any type of electronic equipment with internal electronics can be effected by strong local signals. The signal is then conveyed into the equipment, where the electronics detects the signal's envelope, causing erratic operation or audio noise. The solution is to prevent RF signals from entering the equipment by using RFI filters or RF suppression chokes on the cables or connections picking up the RF current.

Harmonics - spurious emissions from an amateur station may be received by radio or TV equipment. The solution is to use a low—pass filter to remove the spurious emissions at the amateur station. It is important to match the low—pass filter's impedance with the characteristic impedance of the feed line into which it is inserted.

Rectification - poor contacts between conductors picking up RF signals can create a mixer and mixing products from the signals. If the mixing products are on the frequency that the receivers are tuned to, they will cause interference to the desired signal. The solution is to find and repair the poor contact.

Arcing - any spark or sustained arc creates radio noise over a wide range of frequencies and will interfere with both amateur and consumer reception. When created by the AC power lines, the result will be a crackling buzz. If the arc is from a motor or welding equipment, the buzz will come and go when the equipment is energized. Lightning strikes also generate a sudden static, which can easily be heard on the lower AM spectrum as well as many HF frequencies. Generally, poor contact between any current carrying conductors will cause interference. The solution is to isolate it to a single installation and then request that the power company make the necessary repairs

COMMON RFI SYMPTOMS

CW, FM or data - the interference will consist of buzzes, humming or thumps corresponding to the on—and—off pattern of the signal

AM phone - equipment experiencing overload or direct detection will often emit a replica of the speaker's voice

SSB voice - similar to AM phone, but the voice will be distorted or very garbled

==> best solution to many types of interference caused by proximity to an amateur station is to keep the RF signals from entering the equipment in the first place
==> the next approach is to prevent RF current flow by placing inductance or resistance in its path, which is done by forming the conductor carrying the RF current into a series inductor by winding it around a magnetic core or through a ferrite core
==> ferrite beads and cores can also be placed on cables to prevent RF current from flowing on the outside of cable braids or shields; the same beads and cores can be used to prevent signals from computers and computer accessories from causing interference to amateur communications
==> audio equipment responds well to placing a small 100 pico farad to 1 nano farad capacitor across balanced connections or from each connection to chassis ground

elements - the conducting portions of an antenna that radiate or receive a signal

polarization - the orientation of the elements with respect to the Earth's surface

feed point impedance - the ratio of radio frequency voltage to current at an antenna's feed point

radiation pattern - a graph of signal strength in every direction or at every vertical angle

azimuthal pattern - shows the strength of the radiated energy in horizontal directions

elevation pattern - shows the strength of the radiated energy in vertical directions

lobes - regions in the radiation pattern where the antenna is radiating signal

nulls - the points between lobes at which radiation is at a minimum

isotropic antenna - radiates equally in every possible direction

==> these do not exist in practice and are simply used as a reference

omnidirectional antenna - radiates signal of equal strength in every horizontal direction

directional antenna - radiates preferentially in one or more directions

gain - the concentration of signal transmitted toward or received from a preferred direction
==> antenna gain is specified in decibels (dB) with respect to an identified reference antenna
==> gain with respect to an isotropic antenna is called dBi
==> gain with respect to a dipole antenna's maximum radiation is called dBd
==> if no reference is specified, assume that the gain is in dBi

front—to—back—ratio (F/B) - the ratio of gain in the preferred or forward direction to the opposite direction

front—to—side—ratio (F/S) - the ratio of gain in the preferred or forward direction to directions at right angles
==> gain ratios are measured in dB

dipole - a straight conductor 1/2 wavelength long with its feed point in the middle
==> a dipole antenna radiates strongest broadside to its axis and weakest off the ends
==> current in half—wave dipole antennas is highest in the middle and zero at the ends
==> voltage along the dipole is highest at the ends and lowest in the middle
==> the feed point impedance of a centre—fed dipole in free—space is approximately 72 Ω, but it varies widely depending on its height above ground
==> impedance increases as the feed point is moved away from the centre and is several thousand Ω at the ends

To construct an HF dipole from wire, the formula for its length is:

Length in feet = 468 / f (frequency in MHz)
Length in metres = (468 / f) x 0.3048

Centre fed dipoles are easiest to use on the band for which they are resonant. The feed point impedance of such an antenna is a good match for the 50 or 75 Ohm coaxial cable that is used by most amateurs. The feed point impedance of a half—wave dipole is also a good match for coax on odd multiples of the fundamental frequency.

Ground plane - a one—half dipole with the missing portion made up by an electrical mirror
==> this can be made from sheet metal or a screen of radial wires
==> the basic ground plane antenna is 1/4 wavelength long with the feed point

at the junction of the antenna and ground plane
==> ground planes are often called “verticals”

The feed point impedance at the base of the ground plane is 35 Ω, half of a complete dipole's impedance, because only half of the antenna is physically there and able to radiate energy.

Drooping or sloping the radials of an elevated ground plane antenna raises the feed point impedance. A droop angle between 30 and 45 degrees results in the feed point impedance being raised to approximately 50 Ω, a perfect match for coaxial cable.

The formula for calculating the length of a ground plane is:

Length in feet = 234 / f (frequency in MHz)
Length in metres = (234 / f) x 0.3048

whip – a thin steel rod antenna that is mounted over the conducting surface on a vehicle, also gives omnidirectional coverage
==> a full sized 1/4 wave mobile whip is not feasible on the HF bands below 10 metres, so loading techniques are used to electrically increase the antenna's size

loading coils – a coil is added at the base or somewhere along the length of the antenna

capacitance hats – spokes or a wheel—shaped structure is added near the top of the antenna

linear loading – part of the antenna is folded back on itself

random wire – a random length of wire antenna deployed however possible
==> random wires are not intended to be resonant, are multiband antennas
==> the radiation pattern of a random wire is also unpredictable, sometimes with several lobes at different vertical and horizontal angles
==> random wires are connected directly to the output of the transmitter without a feed line
==> this type of antenna requires a good RF ground

An antenna's feed point impedance and radiation pattern are both affected by the antenna's physical height above ground. The effects are caused by the presence of the electrical image of the antenna created in the electrically conducting ground below the antenna.

Feed point impedance is affected because the electrical image, like all mirror images, is electrically reversed from the actual antenna. Height above ground also affects radiation patterns because of the reflection of the antenna's radiated energy by the ground.

At heights below 1/2 wavelength, the dipole's pattern is almost omnidirectional and is maximum straight up. As 1/2 wavelength in height is reached, the reflected and direct energy cancel in the vertical direction and add together at intermediate angles, creating a pattern of peaks and nulls in the radiation pattern for the antenna.

Polarization also affects the amount of signal that is lost from the resistance of the ground. Radio waves reflecting from the ground have lower losses when the polarization of the wave is parallel to the ground. Ground—mounted vertical antennas, however, are able to generate stronger signals at low angles of radiation than horizontally polarized antennas at low heights. This also means that they are often preferred for DX contacts on the lower HF bands where it is impractical to raise horizontally polarized antennas to the height necessary for strong low—angle signals.

Array antenna - consists of several elements that are used to direct the radiated energy in a specific direction, also called the main lobe or major lobe of the radiation pattern

driven array - all of the antenna elements are connected to the feed line and they are called driven elements

parasitic array - one or more of the elements are not connected to the feed line but influence the antenna's pattern by interacting with the radiated energy from the driven elements

The radiation pattern of a driven or parasitic array is determined by constructive and destructive interference

TWO REASONS YOU WANT TO BE ABLE TO AIM AN ANTENNA:

1.) to be heard better by a desired station
2.) to hear better a desired station

The typical radiation pattern of a unidirectional antenna has one main lobe and at least three nulls.

Rotator - the device that does the actual mechanical moving of an antenna

azimuthal projection map - this type of map shows the world squashed into a circle centred on your location so that the direction shown on the map is the true great circle route across the globe

main lobe - elements that are physically arranged to create gain along the axis of the antenna in a single primary region

directors - parasitic elements placed in the direction of maximum gain
reflectors - parasitic elements that are in the direction of minimum gain

The simplest two—element Yagi consists of a driven element and a reflector. The driven element (DE) is a resonant dipole, approximately 1/2 wavelength long. The reflector is slightly longer than 1/2 wavelength (by about 5%) and placed about 0.15 to 0.2 wavelength behind the DE, opposite the direction of maximum signal.

The original signal from the DE travels to the reflector where it causes current to flow, re-radiating the signal. Re-radiated signals are 180 degrees out of phase with the original signal, so the re-radiated DE signals cancel in the direction of the reflector. To the front of the antenna, the extra travel time for the re—radiated signal from the reflector causes it to reinforce the DE signal. The ratio of signal strength between those to the front of the antenna in the radiation pattern's major lobe to those to the back of the antenna is called the front—to—back ratio.

Neglecting the effects of height above ground, a two—element Yagi has a gain of approximately 7 dBi and about 5dBd. The front—to—back ratio is 10 to 15 dB. A director element, placed in front of the DE by the same amount, increases forward gain. It works similarly but is somewhat shorter than 1/2 wavelength. The resulting capacitive reactance subtracts a small amount of phase shift, so that the DE and director signals add to the front of the antenna, in the direction of the director.

With the addition of a single director, a 3—element Yagi's forward gain improves to a theoretical maximum of 9.7 dBi and the front—to—back ratio to 30 to 35 dBi. Additional reflectors make little difference in either gain or front—to—back ratio. Therefore, Yagi antennas have a single reflector. Adding more directors does not have a big effect on front—to—back ratio but does increase antenna gain, so it is not uncommon at HF to see Yagis with two to four directors. At VHF and UHF, there may be as many as a dozen or more directors, although each only adds a fraction of a dB in gain.

The primary design parameters for Yagi antennas are the length and diameter of each element and their placement along the boom of the antenna. These affect gain, SWR and front—to—back ratio in different ways:
==> More directors increase gain
==> A longer boom for a given number of directors increases gain up to a maximum length beyond which gain is reduced
==> Larger diameter elements reduce SWR variation with frequency
==> Placement and tuning of elements reduce SWR variation with frequency

optimizing - the process of modifying a design for a certain level of performance

Typical feed point impedance of Yagis is 20 to 25 Ω, which results in SWR readings greater than 2:1.

gamma match - a short section of parallel conductor transmission line that uses the driven element as one of its conductors

An adjustable capacitor —— either an actual variable capacitor or a short piece of insulated wire inside a hollow gamma rod —— is used to eliminate the undesired reactance for an SWR of 1:1.

Loop antennas completely enclose an area, usually one wavelength or more in circumference and can be oriented vertically or horizontally. On the various HF bands, loops are made of wire due to their large size. At VHF and UHF, loops may be made of tubing or metal strap, thus the loop is cut to attach to the feed line.

A square loop with each leg 1/4 wavelength long is called a quad loop. Triangular or delta loops are typically symmetrical, with each leg 1/3 wavelength long.

The radiation pattern of a 1 wavelength loop shows that the direction of maximum signal is broadside to the plane of the loop, whether round, quad or delta. If the loop is oriented horizontally, that means most of its signal will go straight up, making it a good antenna for local and regional contacts. Orienting the loop vertically aims the maximum signal toward the horizon, where it would be better for making DX contacts.

A popular variation of the Yagi beam uses quad loops for elements, which also means this is called a quad. They are 1 wavelength in circumference and operate on the same principles of re—radiation and phase shift as does the Yagi. Quad reflectors are about 5% longer in circumference than a quad driven element and the quad directors about 3% shorter.

A two element quad with the elements spaced about 0.2 wavelength apart appears almost to be a cube and is called a cubical quad.

The polarization of a vertical loop antenna depends on where the feed point is attached. Taking the quad loop, attaching the feed point in the middle of the bottom or top leg of the loop results in horizontal polarization. Moving the feed point of the very same loop to one of the vertical sides results in vertical polarization. It doesn't matter whether the loop is constructed with the top and bottom legs parallel to or at 45 degrees to the ground. The polarization of a horizontal loop is always horizontal, no matter where the feed point is located.

NVIS (Near—Vertical Incidence Sky—wave) - signals that go straight up

Ground wave will work on the lower HF bands out to several tens of miles or more, but covering an area several hundred miles is more logical. If the signal is low enough in frequency that the ionosphere can reflect a signal at any angle, this sort of coverage can be achieved by beaming the signal straight up.
An antenna that sends most of its signal at a high angle or straight up is used and the ionosphere reflects the signal back to Earth over a wide area is

“short skip”. On 75 metres, NVIS can cover an area 300 to 400 miles across, which is recommended for emergency communications. This will work even when the low—angle signals would likely be absorbed by the ionosphere.

Any antenna will work for NVIS. The best heights for NVIS communications are between 1/10 wavelength and 1/4 wavelength. Lower than that and the feed point impedance becomes too low to provide a good match to coaxial cable. Higher than that and the main lobe starts to send more signal at lower angles than the desired 90 degrees.

Stacking antennas results in more gain. A benefit to stacking antennas comes when studying the azimuthal radiation patterns of Yagis, you will notice that as more and more directors are added, the beamwidth of the main lobe narrows. Vertically stacking antennas increases gain and controls the elevation bandwidth...simply adding directors to a single Yagi narrows the azimuthal beamwidth. Switching the feed line between one or both of the antennas in a stack varies the elevation pattern.

Vertical stacks – antennas stacked one directly above the other, and they are spaced about 1/2 wavelength apart

horizontal stacks – antennas that are aligned such that the elements are parallel, but end—to—end to each other

log periodic antenna – designed to have a consistent radiation pattern and low SWR over a wide frequency bandwidth ——— as much as 10:1 ——— meaning the log periodic can be used over several bands

The short elements of a log periodic antenna are designed for use at high frequencies and the long elements are designed for use at low frequencies. The elements are approximately 1/2 wavelength dipoles at the frequency on which they are active. The log periodic antenna is one member of an entire family of frequency independent antennas whose characteristics are consistent over wide frequency ranges.

Beverage antennas are very inefficient, lacks sufficient gain, however the do reject noise. They are directional, less than 20 feet in length and one end is terminated in a resistor which is also the end in which the best reception is acquired.

All feed lines have two conductors. Parallel/balanced feed lines consist of two parallel conductors separated by insulating material in the form of strips or spacers.

Characteristic impedance – characterizes how electromagnetic energy is carried by the feed line.

For parallel feed lines, the radius of the conductors and the spacing between them are the parameters that determine Z_0.

Flat ribbon TV twin lead has a characteristic impedance of 300 Ω. Parallel—conductor feed lines have impedances of 300—600 Ω.

50 Ω is most common in radio applications and 75 Ω is common in video applications.

Matched – a feed line that transfers all of its power to an antenna when the antenna and feed line impedances are equal.
Forward Power – power travelling toward the antenna
Reflected Power – power reflected by the antenna
Standing Waves – waves carrying forward power and reflected power that form stationary interference patterns inside the feed line
Standing Wave Ratio (SWR) – the ratio of peak voltage in the standing wave to the minimum voltage

A device that is used to minimize SWR at the transmitter connection to the feed line is called an impedance matcher, a transmatch or an antenna tuner. It is also possible to use sections of transmission line called stubs to transform impedances from one value to another. Another type of impedance matching device that uses transmission line is the quarter—wave matching transformer. Regardless of what technique is used to transform impedances, it is important to remember that the SWR in the feed line between the impedance matching device and the antenna does not change.

Attenuation/loss – a feed line that dissipates a small amount of energy as heat.

Feed Line Characteristics

Type	Impedance	Loss per 100ft (dB) at 30 MHz	Loss per 150ft (dB) at 150 MHz
RG—8U	50 Ω	1.8	6.9
RG—8X	50 Ω	3.7	12.8
RG—58U	50 Ω	3.2	4
RG—174U	50 Ω	8.9	28.2
RG—213U	50 Ω	2.2	8
9913	50 Ω	1	4.5

The upper reaches of Earth's atmosphere are made up mainly of oxygen and nitrogen gas that gets thinner with distance from Earth. Starting at 30 miles (48km) in height, the gas is thin enough that UV radiation can break the molecules of gas into individual atoms and then knock electrons away from them. The gas becomes ionized. The lack of an electron causes an atom to become a positively charged ion and the electron a free electron. These charged particles, the ions and the electrons, can respond to voltages just as electrons in a conductor and so this region of the atmosphere becomes a very weak conductor and is called the ionosphere.

The D Region (30—60 miles in altitude) is only present when illuminated by the Sun. It disappears at night because the ions and free electrons are close enough together to recombine quickly when no UV is present and the gas returns to neutral position.

The E Region (60—70 miles in altitude) acts similarly to the D region. Because it is higher and less dense that the D region, it lasts longer after sunset but still disappears at night, returning to its neutral state.

The F Region (100—300 miles in altitude) is the least dense of the three and can remain partially ionized at night. During the day the F region splits into the F_1 and F_2 layers, which disappear back into the single F region at night. The height of the F region and the F1 and F2 layers varies quite a bit with local time, season, latitude and solar activity. At any particular location, the stronger the illumination from the Sun, the higher the F_2 layer will be, so the maximum height is reached at noon in the summer.

As the Earth turns, the ionosphere moves into and out of the sunlight, just as at the surface. The line between night and day is called the terminator. Because the ionosphere extends high above the Earth's surface, and because its regions appear and disappear with different speeds, different groupings of regions and layers are present at points near the terminator. Points at which only the upper F_1 and F_2 layers are present form a band near the terminator called the gray line.

In the thick ionosphere regions and layers, the wave is gradually bent or diffracted. The higher the region's ionization, the more the wave will be bent. The higher the frequency of the wave, the less it is bent; all VHF/UHF waves are hardly bent and are lost in space.

Critical angle – The highest takeoff angle at which a wave can be returned to Earth.

The companion to critical angle is critical frequency, thus being the highest frequency on which a signal transmitted straight up will be returned to Earth. The D layer absorbs all HF bands completely during the day. In general, absorption increases in the daytime and when solar UV is more intense. Lower frequency signals are most susceptible to ionospheric absorption.

Waves that leave the transmitter above the critical angle are refracted in the ionosphere, but not enough to return to Earth. Waves at and below the critical angle will return to Earth. The lowest angle waves return to Earth at the greatest distance, which is why low angles of radiation are often best for contacting DX stations.
Hop – a reflection from the ionosphere

Sky-wave - signals that are received by an ionospheric hop

Skip - propagation via the ionosphere

The higher the region from which the reflection takes place, the longer the hop. Signals reflected from the uppermost F2 layer can travel up to 2500 miles before returning to the ground. Hops that use the E layer are shorter, up to 1200 miles, because of the lower reflecting height. Sky—wave propagation can consist of multiple reflections because the Earth's surface also reflects radio waves. The highly conductive saltwater ocean is a particularly good reflector of radio waves.

Signals received via sky wave at much shorter than the maximum hop distance are called short skip. That is also a good indicator that there is sufficient ionization to support longer skip distances on higher frequency bands. Sky—wave signals also have a characteristic sound caused by the variations in density and height they encounter in the ionosphere. Receiving several of these multipath signals at once gives the signal a characteristic echo or flutter as the quality of reflection changes or as signals combine from different paths.

Ground—wave - signals that travel along the surface of the Earth between stations.

Long—path - propagation in which stations are contacted over a path that takes “the long way around”.

Short—path - propagation that is the shorter of two great circle paths between stations.

The bearing of the long path is 180 degrees away from the short path bearing. Occasionally, propagation over both the long and short paths will be supported. Unless the long and short paths are almost equal there will be an echo as the more delayed signal arrives a fraction of a second later. Occasionally, round—the—world propagation is supported and you can hear your own signal coming back around about 1/7 second later.

Sunspots vary in number over an approximately 11 year period known as the sunspot cycle or solar cycle. The number of sunspots and sunspot groups present on the solar disk at a particular time is the sunspot number. The more sunspots are observed on the face of the Sun, the more UV is generated, creating more intense ionization in the ionosphere and improving propagation on the HF bands above 10MHz and even into the lower VHF range. At the peak of the solar cycle, there may be sufficient solar UV to cause higher frequency bands such as 10 metres to stay open for long—distance contacts even at night. The high ionization takes a toll on the low frequency bands such as 80 and 160 metres as it increases absorption. Conversely, at the bottom of the solar cycle, the lower HF bands have good propagation and the higher HF bands above 20MHz (15 metres and up) are often closed. One band that seems to do well at all times in the solar cycle is 20 metres (14MHz), supporting daytime communications world wide nearly every day.

DAYTIME/NIGHTTIME HF PROPAGATION

HF Band (metres)	Daytime	Nighttime
160, 80, 60	Local/regional, 100—200 miles	Local to long distance with DX best near sunset at one or both ends of the contact
40, 30	Local/regional, 300—400 miles	Short—range (20/30 miles) and medium distances (150 miles) to worldwide
20, 17	Regional to long distance, opening at or near sunrise and and closing at night	20 metres is often open to the west at night and may be open 24 hours a day
15, 12, 10	Primarily long distance (1000 miles and more), opening to the east after sunrise and to the west in the afternoon	10 metres is often used for local communications 24 a day

Solar Flux Index (SFI) - describes the amount of 2800 MHz (10.7cm wavelength) radio energy coming from the Sun. This index corresponds well to the amount of solar UV that is hard to measure at ground level. SFI starts at a minimum of 65 and has no maximum value. Higher levels indicate higher solar activity and generally better HF propagation above 10 MHz.

K index - K values, from 0 to 9, represent the short—term stability of the Earth's geomagnetic field, updated every three hours at the National Institute of Science and Technology (NIST) in Boulder, Colorado. Steady values indicates stable geomagnetic field. Higher values indicate that the geomagnetic field is disturbed, which disrupts HF communications.

A index - based on the previous 8 values of the K—index from around the world, the A index gives a good picture of long—term geomagnetic field stability. The A index can have values from 0 (stable) to 400 (greatly disturbed).

An announcement of the values of SFI, K and A indices can be heard on the air by tuning in WWV or WWVH at 18 or 45 minutes past the hour, respectively.

Two key terms that are used by propagation prediction programs are of particular importance: MUF - maximum usable frequency and LUF - lowest usable frequency. Both the MUF and LUF depend on the specific path between two points, thus being their location and distance apart. MUF and LUF also vary with time of day, season, the amount of solar radiation and ionospheric stability.

Operating near the MUF often gives excellent results because absorption is lowest just below the MUF. Low takeoff angles also raise the MUF because the signals will need less bending to complete a hop.

==> If the MUF over a certain path is 19 MHz, the best band for that path is 17 metres (18 MHz).
==> If the MUF over a certain path is 25 MHz, the best band for that path is 12 metres (24 MHz).

One way to check the actual band conditions between two points is to listen for propagation beacons. There is an international network of beacon stations maintained by the Northern California DX Foundation that transmit continuously. In addition, there are many beacon stations between 28.190 and 28.225 MHz that are excellent sources of information about 10 metre propagation.

Solar flare - a large eruption of energy and solar material when magnetic field disruptions occur on the surface of the Sun.

Coronal hole - a weak area in the Sun's corona (the outer layer) through which plasma (ionized gas and charged particles) escapes the Sun's magnetic field and streams away into space at high velocities.

Coronal mass ejection (CME) - an ejection of large amounts of material from the corona. A CME may direct the material in a relatively narrow stream or in a wide spray.

When solar flares hit the ionosphere, the level of ionization increases rapidly, particularly in the D region. This increases absorption dramatically, causing a sudden ionospheric disturbance (SID) also known as a radio blackout. After a large flare, the HF bands can be completely devoid of sky—wave signals for a period of many seconds to hours, returning gradually to normal. The lower bands are affected first, so communications may still be possible on a higher band. SID's only affect the sunlit side of the Earth so dark—side communications may be relatively unaffected.

Charged particles and other material from coronal holes and coronal mass ejections travel considerably slower and take longer to reach Earth, up to 20—40 hours. They can be trapped near the north and south magnetic poles. They deposit their energy into the Earth's geomagnetic field, thus causing higher ionization in the E region of the ionosphere which in turn will cause auroral displays.

This will disrupt the upper layers of the ionosphere, causing HF communications and long distance paths at high latitudes to be completely wiped out for a period of hours to days. Auroral propagation is strongest on 6 and 2 metres, modulating the signals with a characteristic hiss or buzz.

Sporadic—E propagation is common on 6 metres. Scatter modes of propagation can be quite useful when regular sky—wave is unavailable.

Scatter signals on HF are usually weaker because the reflection is not very efficient and tends to spread out the signal and also sounds distorted. This is also known as a fluttering or wavering characteristic. Backscatter occurs when features on the Earth's surface such as the ocean or a mountain range returns some of the signal back toward the transmitting station. Scatter and backscatter help fill in the skip zone where signals would otherwise not be heard.

Vertical Incidence Sky—Wave (NVIS) - concentrating a signal so that it is radiated vertically, thus causing a reflection which scatters the signal back to Earth over a wide area around the transmitter.

It is important to have a master OFF/ON switch for your station and workbench, just as in a shop full of power tools and machinery. The switch should be clearly labelled and somewhat away from the equipment. Never assume equipment is off or de—energized - check with your metre or tester first.

Voltage is not responsible for causing shock, it is current flow. Electrical currents of 100mA or more may disrupt normal heart rhythm. Electrical currents of more than a few mA can cause involuntary muscle spasms that in turn cause falls and sudden large movements. The largest current that has been shown to have no adverse effects is 50 µA. 50 or 60 Hz household power can penetrate the body easier and stop the heart.

EFFECTS OF ELECTRIC CURRENT THROUGH THE BODY OF AN AVERAGE PERSON

Current (1 sec contact)	Effect
1 mA	Just perceptible.
5 mA	Maximum harmless current.
10—20 mA	Lower limit for sustained muscular contractions.
30—50 mA	Pain.
50 mA	Pain, possible fainting. “Can't let go” current.
100—300 mA	Normal heart rhythm disrupted. Electrocution if sustained current.
6 A	Sustained heart contractions.

The National Electric Code (NEC) contains detailed descriptions of how to handle AC wiring in your home and shack in a safe manner. Local building codes should also be followed so that your home is properly wired to meet any special local conditions. Wiring techniques for 120 V and 240 V AC plugs is critically important to follow. The white wire is neutral, the green wire is ground, and the black or red wire is the hot lead. Note that 240 V circuits have two hot wires and a neutral.

When wiring or repairing an AC power cord plug, be sure to follow the standard wire colour conventions:

==> Hot is black or red insulation, connect to the brass terminal of the screw.
==> Neutral is white insulation, connect to the silver terminal or screw.
==> Ground is green insulation or bare wire, connect to the green or bare copper terminal or screw.

CURRENT CARRYING CAPACITY OF SOME COMMON WIRE SIZES

Copper Wire Size (AWG)	Allowable Ampacity (A)	Max Fuse or Circuit Breaker (A)
6	55	50
8	40	40
10	30	30
12	25 (20)[1]	20
14	20 (15)[1]	15

[1] The National Electrical Code limits the fuse or circuit breaker size (and as such, the maximum allowable circuit load) to 15 A for #14 AWG copper wire and to 20 A for #12 AWG copper wire conductors.

The rating of wire to carry current is called its ampacity. For house AC wiring, the two most common sizes are AWG #12 wire for 20 A circuits and AWG #14 for 15 A circuits.

When the metal in a fuse melts or “blows”, the current path is broken. Substituting a 12 V rated fuse for one with a 120/240 V rating will result in arcs over instead of removing voltage from the circuit. “Slow—blow” fuses can withstand temporary overloads, but will blow if the overload is sustained.

A safety interlock is an example of a shock prevention device. They are switches that prevent dangerous voltages or intense RF from being present when a cabinet or enclosure is opened. One type of interlock physically disconnects high voltage (HV) or RF when activated. A second type shorts or grounds a HV circuit when activated, possibly blowing a circuit breaker or fuse in a power supply. Never bypass an interlock during testing unless specifically instructed to do so and then only in the way directed by the instructions.
Ground fault circuit interrupter (GFCI) circuit breakers are used in AC power circuits to prevent shock hazards. It will trip if an imbalance is sensed in

the currents carried by the hot and neutral conductors. Current imbalances indicate the presence of an electrical shock hazard because the unbalanced current must be flowing through an unintended path, such as through a person from the hot wire to the ground.

The metal frames of the generator housing and the engine act as an electrical ground, but they are not physically connected to the Earth. The best way to provide a generator safety ground is to use a ground rod near the generator and connected to the frame with heavy gauge wire. Most generators provide a special ground terminal just for this purpose.

If the generator is to be used at your home, connecting it to your household circuits requires special precautions. If you intend to connect the generator output directly to your home's wiring system, you must have the ability to disconnect your power service from the utility lines. This is usually accomplished by a pair of large circuit breakers labelled “Main”. Opening these breakers completely disconnects your power distribution panel from the external electrical service.

A transfer switch connects your household circuits to the AC line or to a generator and isolates the generator from the line. This device eliminates the possibility of feeding generator power back into the AC line, or damaging the generator if AC power is restored.

The best protection from lightning is to disconnect all cables outside the house and unplug equipment power cords inside the house during a storm. A metal entrance panel serves as a common grounding point for all coaxial cable antenna feed lines entering your home. This helps to prevent damage from nearby lightning strikes. The panel should be grounded to a nearby ground rod with a heavy, short metal strap. Lightning arrestors should also be installed at the entry panel.

Grounding wires and straps should be as short and direct as possible. All towers, masts and antenna mounts should be grounded. Lightning grounds should be bonded to other safety grounds. Do not use solder to make the connections because it will likely vaporize if hit with a lightning—sized current pulse. Use mechanical clamps, brazing, or welding to be sure that the ground connection is heavy enough.

Power density – the intensity of RF energy, which is measured in mW/cm^2

Specific absorption rate – the rate at which energy is absorbed from the power to which the body is exposed

The limbs and torso experience the highest SAR for RF fields in the VHF spectrum from 30 to 300 MHz. The head is most sensitive at UHF frequencies from 300 MHz to 3 GHz and the eyes are most affected by microwave signals above 1 GHz. The frequencies with the highest SAR are between 30 and 1500 MHz.

Maximum Permissible Exposure (MPE) limits vary with frequency because the body responds differently to energy at different frequencies. The controlled and uncontrolled limits refer to the environment in which people are exposed to the RF energy.

Controlled environments - people who are aware of their exposure and are expected to take reasonable steps to minimize exposure.

Uncontrolled environments - areas in which the general public has access and are not aware of their exposure, but are much less likely to receive continuous exposure.

The averaging period is 6 minutes for controlled environments and 30 minutes for uncontrolled environments.

Duty cycle is the ratio of the time the transmitter is on to the total time during the exposure. The lower the transmission duty cycle, the lower the average exposure. Operational duty cycle occurs when a lower transmission duty cycle permits greater short—term exposure levels for a given average exposure.

OPERATING DUTY FACTOR OF MODES COMMONLY USED BY AMATEURS

Mode	Duty Cycle	Notes
Conversational SSB	20%	1
Conversational SSB	40%	2
SSB AFSK	100%	
SSB SSTV	100%	
Voice AM, 50% modulation	50%	3
Voice AM, 100% modulation	25%	
Voice AM, no modulation	100%	
Voice FM	100%	
Digital FM	100%	
ATV, video portion, image	60%	
ATV, video portion, black screen	80%	
Conversational CW	40%	
Carrier	100%	4

1) Includes voice characteristics and syllabic duty factor. No speech processing.
2) Includes voice characteristics and syllabic duty factor. Heavy speech processing.
3) Full—carrier, double—sideband modulation, referenced to PEP. Typical for voice speech. Can range from 25% to 100% depending on modulation.
4) A full carrier is commonly used for tune—up purposes.

All fixed amateur stations must evaluate their capability to cause RF exposure, no matter whether they use high or low power. A routine evaluation must then be performed if the transmitter PEP and frequency are within the FCC rule limits. You are required to perform the RF exposure evaluation only if your transmitter output power exceeds the levels shown for any band.

You can perform the evaluation by actually measuring the RF field strength with calibrated field strength metres and calibrated antennas.

POWER THRESHOLDS FOR RF EXPOSURE EVALUATION

Band	Power (W)
160 metres	500
80	500
40	500
30	425
20	225
17	125
15	100
12	75
10	50
6	50
2	50
1.25	50
70 cm	70
33	150
23	200
13	250
SHF (all)	250
EHF (all)	250

Exposure can be evaluated in one of two ways. The first way is to determine the power density at a known distance to see if exposure at that distance meets the MPE limit. The second way is to determine the minimum distance from your antenna at which the MPE limit is satisfied. If you make changes to your station, such as changing to a higher power transmitter, increasing antenna gain or changing antenna height, you must re—evaluate the RF exposure from your station. If you reduce output power without making any other changes to a station already in compliance, you need not re—evaluate RF exposure.

There are many ways to reduce RF exposure to nearby people. Whatever lowers the power density in areas where people are present will work. Raising the antenna will even benefit your signal strength to other stations as it lowers power density on the ground.

IMPORTANT: Place all antennas and feed lines well clear of power lines!
A typical rule of thumb is to separate all parts of the antenna and support from the power lines by at least 150% of total height of tower or mast plus

antenna. Don't run feed lines over power lines or service drops from a transformer to the house. The most ignored safety advice is to follow the manufacturer's directions! Utility poles and power lines must be given wide clearance from your antenna system.

A fixed—length pipe mast of up to 20 feet is the simplest method of raising small antennas, such as ground planes or small directional antennas. Fixed towers are required for large antennas due to the weight and torque. Because the towers are constructed with pipe legs and across braces of rod welded to the legs, they are often referred to as lattice towers. Crank—up and tilt towers can support large antennas at heights up to 70 feet.

Building permits are generally required for lattice, crank—up and tilt—over towers. When erecting a tower near an airport, be sure to comply with FCC and FAA rules about maximum structure height near an airport. Towers should be grounded with separate 8—foot ground rods for each tower leg, with the ground rods bonded to the tower and each other. Hardware used outdoors should be stainless steel or galvanized.

When performing antenna and tower maintenance, both the climbers and ground crew should wear appropriate protective gear at all times. The climber must have a proper safety belt, or better yet a harness. Other needed gear includes a hard hat, gloves, sun block and even goggles. Wear boots or shoes to protect your feet and prevent sore arches from standing on tower rungs for extended periods.