SCARS

Technician / General

License Course

Week 5

Generalized Transceiver Categories

• Mobile	VHF/UHF FM
• Single Band	VHF or UHF FM
• Dual Band	VHF/UHF FM
• All Band	HF and VHF/UHF
• Multimode	VHF/UHF CW/SSB/FM
• Handheld (HT)	

Single-Band Mobile

- Single-band, 2 meter is a good starter radio.
- Operates from 13.8 volts dc, requires external power supply or car battery.
- Requires an external antenna.
- Can be operated mobile or as a base station.
- Limited to frequency modulation (FM) and usually either 2 meters or 70 cm bands.
- Up to approximately 50 watts output.

Dual-Band Mobile

- Same as the single-band transceiver but includes additional band(s).
- Most common are 2 meter and 70 cm bands.
- Could add 6 meters, 222 MHz or 1.2 GHz.
- Might have separate antenna connections for each band or a single connection for a dual-band antenna

Multimode Transceiver

- Nearly all HF rigs are multimode.
- VHF multimode operates on FM plus AM/SSB/CW modes.
  - Required for “weak-signal” operation on VHF/UHF
- More features add complexity and cost.
- More flexibility will allow you to explore new modes as you gain experience.

Multiband Transceiver

- Covers many bands – usually refers to coverage of HF + VHF/UHF.
- Also covers all modes.
- Frequently 100 watts on HF, some power limitations on high bands (25–50 watts).
- Larger units have internal power supplies, smaller units need external power supply.

Handheld (HT) Transceiver

- Small handheld FM units.
- Can be single band or dual band.
- Limited power (usually 5 watts or less).
- Includes power (battery) and antenna in one package.
- Often purchased as a starter rig but low power limits range.

Handheld (HT) Transceiver

- Single, dual and multiband versions (with increasing cost and complexity).
  - Some can receive outside the ham bands, such as aircraft, commercial FM broadcast, etc.
- Very portable and self-contained.
  - Internal microphone and speaker.
  - Rubber duck antenna.
  - Battery powered.

Handheld (HT) Transceiver

- Extra battery packs
  - AA cell pack useful in emergencies
- Drop-in, fast charger
- Extended antenna
- External microphone and speaker
- Headset

Side-by-Side

	Single Band	Dual Band	Multimode	Multiband	Handheld
Freq Agility	Limited	Medium	Medium	Full	Limited
Functionality	Limited	Limited	Full	Full	Limited
Ease of Use	Easy	Medium	Medium	Difficult	Easy
Programming	Easy	Easy	Medium	Challenging	Easy/Medium
Power	Low	Low	Medium	High	Low
Cost	Low	Modest	High	High	Low

Rig Vocabulary

- We will now go through some jargon and vocabulary specific to the receive and transmit functions and controls of a transceiver.

Band and Frequency Selection

- Fundamental to all amateur transceivers
- Can set by VFO (continuously variable) or by keypad “direct” entry
- Memories can generally store:
  - Frequency
  - Mode
  - Filter and similar settings
  - Alphanumeric labels

Transmitter Controls and Functions

- Main tuning display (both TX and RX):
  - Controls the frequency selection via the variable frequency oscillator (VFO).
  - Frequency can be set with a knob or keypad or programmed channels.
  - Variable frequency step size (tuning rate, resolution).
  - Rigs can usually store the information for two operating frequencies (VFO A and VFO B).

Transmitter Controls and Functions

- Mode selector (both TX and RX for multimode rigs).
  - AM/FM/SSB (LSB or USB)
  - CW
  - Data (RTTY or PSK)
- Could be automatic based on recognized band plan.

Transmitter Controls and Functions

- Microphone controls
  - –Gain
    - •Controls transmitter sensitivity to your voice
  - –Speech Compressor or Speech Processor
    - •Increases microphone gain at lower sound levels to increase overall signal strength or "punch"

Transmitter Controls and Functions

- Too much gain or compression can cause problems
  - Splatter
  - Over-deviation
  - Over-modulation

Transmitter Controls and Functions

- Automatic Level Control (ALC)
  - –Automatically limits speech modulation, reducing transmitter over-drive
  - –Causes some speech distortion
  - –Do NOT use for data modes like PSK
- Also prevents overdrive to external power amplifier

Microphones and Keys

- Microphones (mic)
  - Hand mics
  - Desk mics
    - Preamplified desk mics
  - Speaker-mics
  - Headsets or boom-sets
  - Internal mics
- Speak *across* the mic, not into the mic

Microphones and Keys

- Transmitter ON/OFF or “keying”
  - Push-to-Talk (PTT)
  - Voice-Operated Transmission (VOX)
    - VOX Gain
    - VOX Delay
    - Anti-VOX

Microphones and Keys

- –Key jack
- –Manually-Operating Transmission (MOX or SEND - varies with manufacturer)

- Morse code
  - –Straight key
  - –Electronic keyer and paddle
  - –Semi-automatic (Bug)

Receiver Controls and Functions

- AF Gain or Volume
  - Controls the audio level to the speaker or headphones
- RF Gain
  - Controls the gain of the receiver's input amplifiers
- Attenuator
  - Reduces signal at the receiver input

Receiver Controls and Functions

- Receive Incremental Tuning (RIT)
  - "Fine tuning"
  - Adjusts receive frequency independent of main VFO
  - Doesn't vary the transmitted frequency
  - Transmitters have a similar function (XIT)

Receiver Controls and Functions

- Automatic Gain Control (AGC)
  - –Automatically limits the incoming signals during signal (voice) peaks to maintain even volume
  - –Keeps strong signals from blasting the listener
  - –Different time response settings:
    - –Fast setting for CW
    - –Slow settings for SSB and AM
    - –Not used in FM because amplitude is constant

Receiver Controls and Functions

- Squelch
  - –Mutes audio to speaker when signal is not present
- Used in FM primarily
  - –Open – allows very weak signals to pass through (along with noise)
  - –Tight – allows only the strongest signals to pass

Receiver Controls and Functions

- Advance the squelch control until the noise just disappears
  - Also opened by MON (Monitor) control on handhelds

Receiver Controls and Functions

- Filters (can be electronic modules or DSP)
  - IF filter
    - Used to narrow the width of signal that is passed.
    - Can attenuate adjacent signals.
  - Notch filter
    - Very narrow filter that can be moved over an interfering signal to attenuate it.

Receiver Controls and Functions

- Noise blanker (NB)
  - Removes signal pulses that are frequently associated with random naturally generated noise
  - Can cause problems if strong signals are present
- Noise reduction (NR)
  - DSP function to remove noise from signal
- Noise limiter (NL)
  - Simply limits maximum volume of a noise pulse

Receiver Controls and Functions

- Preamplifier
  - Increases sensitivity but can cause overload
- Reception and Transmission Meter
  - In transmit, indicates output power or ALC or other functions as selected by switch setting
  - In receive, indicates signal strength
    - In “S” units S1 through S9 – S9 is strongest
    - Above S9, meter is calibrated in dB (i.e S9+10 dB)

Receiver Controls and Functions

- Receivers can be limited to ham bands or can cover other parts of the spectrum.
- General coverage receivers cover a wide area of the spectrum and can be used for shortwave listening (SWL).

Data Modes

- Computer-to-computer communication
- Specialized modems
  - Terminal Node Controller (TNC)
  - Multiple Protocol Controller (MPC)
- Computer sound card software
  - Requires radio interface

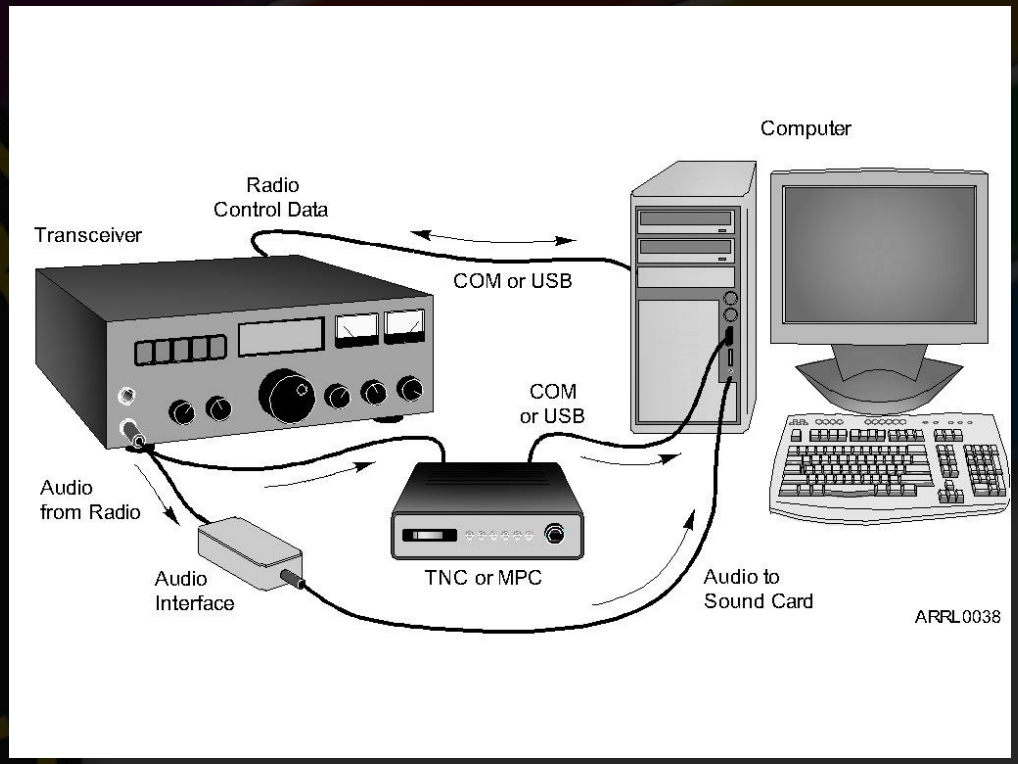
Popular Digital Modes & Systems

- Radioteletype (RTTY)
- PSK31
- MFSK
- Packet Radio and PACTOR
- CW (International Morse)
- Automatic Packet Reporting System (APRS)
- Winlink System

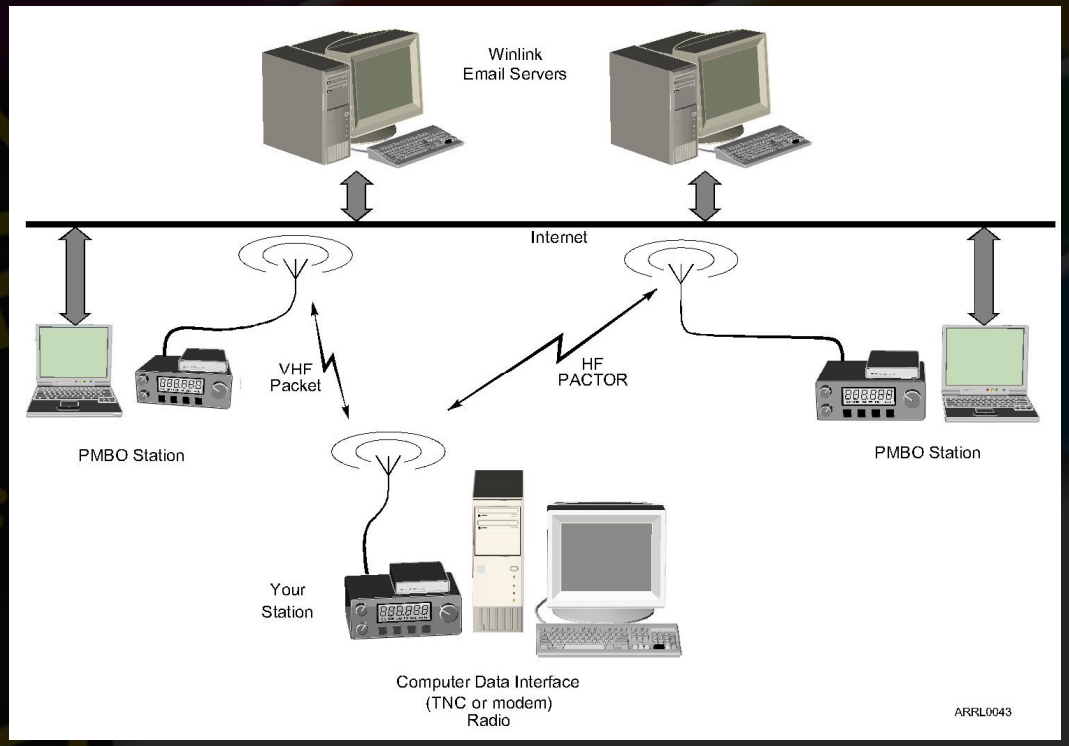
Popular Digital Modes & Systems

- Error detection
  - Yes: Packet radio, MFSK
  - No: RTTY, PSK31
  - Error correction
  - MFSK (forward error correction or FEC)
  - Packet radio
    - Checksums and call signs
    - Retransmission or ARQ

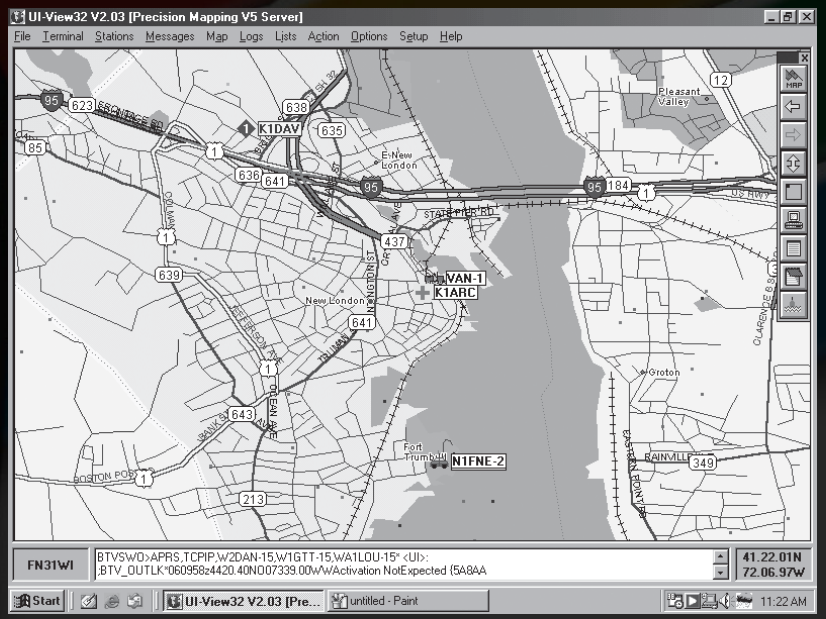
Data Station Setup



Internet Gateway



Automatic Position Reporting System (APRS)



Power Supplies

- Most modern radio equipment runs from 12 volts dc.
  - Actual preferred voltage is 13.8 volts.
- Household ac power is 120 volts ac.
- Power supplies convert 120 volts ac to regulated, filtered dc.
  - If you use a lab-type 12 volt power supply, be sure it is adjustable to 13.8 volts.

Types of Power Supplies

- Linear:
  - –Use iron transformers
  - –Heavy (physically)
  - –Do not emit RF, generally immune to strong RF
- Switching:
  - –Electronics instead of transformers
  - –Lightweight and small
  - –Can emit RF if not properly filtered
    - –Check product reviews

Power Supply Ratings - Voltage and Current

- Continuous duty – how much current can be supplied continuously.
- Intermittent duty – how much current can be supplied for short surges, such as on voice peaks.
- Regulation – how well the power supply maintains a constant output voltage.

Mobile Power Wiring Safety

- Car batteries hold lots of energy – shorting a battery could cause a fire.
- Special requirements for safe car wiring:
  - Use grommets or protective sleeves to protect wires.
  - Don't assume all metal in the car is grounded; modern cars are as much plastic as metal.

Batteries

- Create current through a chemical reaction
  - Individual cells connected in series or parallel
  - Cell chemistry determines voltage per cell
- Battery types
  - Disposable (primary batteries)
  - Rechargeable (secondary batteries)
  - Storage

Batteries

- Energy capabilities rated in Ampere-hours
  - –Amps X time (at a constant voltage)

Battery Charging

- Some batteries can be recharged, some cannot.
- Use the proper charger for the battery being charged.
- Batteries will lose capacity with each cycle.
- Best if batteries are maintained fully charged.
  - Over-charging will cause heating and could damage the battery.

Battery Charging

- Lead-acid batteries release explosive hydrogen during charging or rapid discharge so adequate ventilation is required.
- Automobiles can be a good emergency power source by recharging batteries
- A 12-volt lead-acid station battery can be recharged by connecting it to an automobile's electrical system

Battery Charging

- Monitor battery temperature
- Make sure battery is well-ventilated

Handheld Transceivers

- Battery packs – packages of several individual rechargeable batteries connected together.
  - NiCd (nickel-cadmium)
  - NiMH (nickel-metal hydride)
  - Li-ion (lithium-ion)
- For emergencies, have a battery pack that can use disposable batteries (AA size).

Radio Frequency Interference (RFI)

- Signals that interfere with radio reception.
- Interference can be FROM your station or TO your station.
- Solving the problem might take a little detective work!

Types of RFI

- Direct detection – offending signals get into the electronic circuits to cause interference.
- Overload – strong signal that overwhelms the ability of the receiver to reject it.
- RF Current – can be picked up by cables of consumer equipment.
- Transmitted harmonics – must be filtered out at the transmitter.

Filters

- Filters attenuate (reduce) signals
- High-pass – reduce low-frequency signals
- Low-pass – reduce high-frequency signals
- Band-pass – only pass a range of signals
- Notch – reduces a narrow range of signals
- Selecting correct filter requires understanding the source of the interference

Ferrite Chokes

- Creates impedance (opposition to ac) on cables and wires.
- Can be used to block RF current that causes interference to entertainment equipment, microphones, monitors, amplifiers, etc.
- Wind cable through ferrite core to create blocking impedance.

Cable TV Interference

- Usually the result of broken shielding somewhere in the cable.
  - –Loose connections
  - –Broken connections
  - –Corroded connections
- Usually solved by proper cable maintenance by cable supplier.

Noise Sources

- Electrical arcs (motors, thermostats, electric fences, neon signs)
- Power lines
- Motor vehicle ignitions or alternators
- Switching power supplies
- Computers, networks and TV sets

RFI Guidelines

- Operate your equipment properly.
- Eliminate interference in your own home.
- Use good station building practices to eliminate unwanted signals.
  - Shielded wire and cables
  - Shielded equipment
  - Good connections and filters

Dealing with RFI

- Take interference complaints seriously.
- Make sure that you're really not the cause (demonstrate that you don't interfere within your own home).
- Offer to help eliminate the RFI, even if you are not at fault.
- Consult ARRL RFI Resources for help and assistance.

Part 15 Rules

- Applies only to unlicensed devices
- Unlicensed devices may not interfere with licensed services, such as amateur radio
- Unlicensed devices must accept any interference they receive from licensed services
- RFI from and to unlicensed devices is the responsibility of the users of such devices

What the Rules Say

- Bottom line – If your station is operating properly, you are protected against interference complaints
- BUT – Be a good neighbor because they are probably not familiar with Part 15 rules and regulations

Electrical Safety Grounding and Circuit Protection (in the Home)

- Make sure your home is “up to code.”
- Most ham equipment does not require special wiring or circuits.
  - –Use 3-wire power cords.
  - –Use circuit breakers, circuit breaker outlets, or Ground Fault Interrupter (GFI) circuit breakers.

Electrical Safety Grounding and Circuit Protection (in the Home)

- Ground Fault Interrupter (GFI) circuit breakers.
- Use proper fuse or circuit breaker size.
- Don’t overload single outlets.

RF “Grounding”

- Not the same as ac safety grounding
- “Bonding” is more accurate
- Keep all equipment at the same RF voltage
  - Current will not flow between pieces of equipment which can cause RF feedback
  - Minimizes RF “hot spots” (RF burns)
  - Use solid strap or wire for best RF connection

Basic Operating

- Operating techniques on HF are similar to operating SSB or CW on 10 meters and 6 meters but are fairly different from VHF and UHF FM.
- CQ – Calling any station. CQ DX means calling stations other than in one's own country
- To join an on-going QSO, give your call sign during a break in the conversation

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Good Practices

- Choosing a frequency is most important
- Listen, listen, listen
- Ask if the frequency is in use ("*Is the frequency in use? This is WØPC*") then ask again, identifying your transmission
  - If using CW or digital modes, send: *QRL? DE WØPC*
- No one "owns" a frequency – have a "Plan B"

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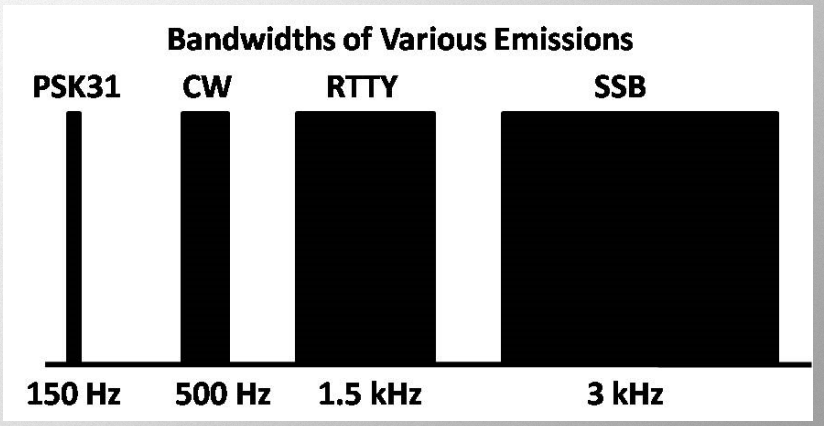
Good Practices

- Try to put enough separation between your signal and adjacent signals to minimize interference.

Recommended Signal Separation	
CW	150-500 Hz
SSB	Approximately 3 kHz
RTTY	250-500 Hz
PSK31	150-500 Hz



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Nets and Schedules

- Many on-the-air activities are scheduled in advance
- Courtesy and flexibility are required by everyone – have a backup plan
- If you're in a QSO and another station requests the use of the frequency for a scheduled activity, try to accommodate the request
- If you're the net control and the net's chosen frequency is busy, find a clear frequency

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Band Plans

- The FCC regulations help stations using compatible modes stay together by dividing the amateur frequency bands.
- Additional divisions of the band have been created by radio amateurs and are used on a strictly voluntary basis. These are called "*Band Plans.*"

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Band Plans

- Example of the 20 meter band plan:
  - 14.060 QRP CW calling frequency
  - 14.070-14.095 RTTY/Data
  - 14.095-14.0995 Automatically controlled data
  - 14.100 IBP/NCDXF beacons
  - 14.1005-14.112 Automatically controlled data
  - 14.230 SSTV
- Frequencies Modes/Activities
  - 14.233 D-SSTV
  - 14.236 Digital Voice
  - 14.285 QRP SSB calling frequency
  - 14.286 AM calling frequency

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Band Plans

- Band plans are not regulations and are only guidelines for operating under normal band conditions – be flexible!
- When choosing a frequency for SSTV, RTTY, or PSK31 operation, check the band plan for recommended frequencies
- DX windows are a section of the band where stations (other than U.S. stations in the contiguous 48 states) may be contacted

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Managing Interference

- Interference occurs for several reasons
  - QRM – Interference from other signals
  - QRN – Static (storms, motors, power lines, etc.)
- Harmful interference – Seriously degrades, obstructs, or repeatedly interrupts communication
- Deliberate interference – Malicious, willful
  - Rare – don't engage, just avoid it

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Managing Interference

- Learn the characteristics of each band
- Know the strengths and weaknesses of your station
- Keep your transmitted signal clean
- Use directional antennas
- Reacting to Interference
  - No one owns any frequency, be flexible
  - Change your frequency if necessary

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CW Mode

- CW (Morse code) – Found at the bottom of each HF band, but can be transmitted on almost any amateur frequency
- Speeds vary from 5 to 50 WPM
- Answer a CQ at the speed at which it was sent
- Most CW ops will slow down if you send “QRS” (send slower)
- Code is sent by keys, paddles, bugs, and keyboards

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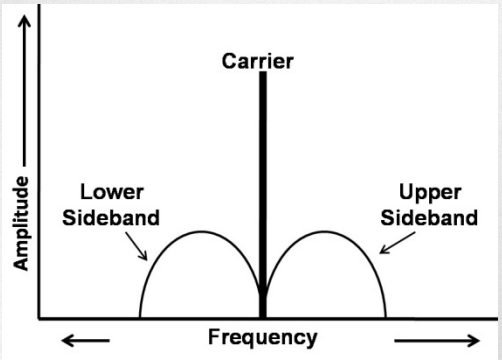
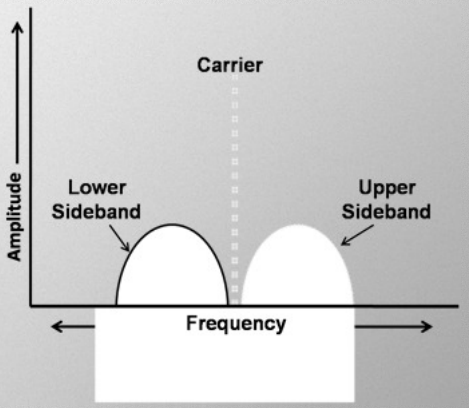
AM & SSB Modes

- AM and SSB phone (voice)
- On HF, SSB is the most common phone signal
- SSB (3 kHz) uses less spectrum than AM (6 kHz) because the carrier and one sideband are suppressed and not transmitted





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AM & SSB Modes

- Upper sideband (USB) is used above 9 MHz (20 meters – 10 meters) and on 60 meters
- Lower sideband (LSB) is used below 9 MHz (160 meters, 80 meters, and 40 meters)
- Upper sideband is used on VHF and UHF bands
- FM is found only on the upper portion of 10 meters

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Image Mode

- SSTV popular on HF
  - Permitted wherever phone transmissions are permitted, except 60 meters
  - Computer, soundcard, interface, and software are required
- Fast-scan (FSTV or ATV) used on UHF and up

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HF Receiving

- FM radios have controls for frequency or channel selection, squelch, and volume
- SSB/CW receivers have more controls
  - They are designed for non-channelized, continuous tuning operation
  - Squelch is generally not used on HF receivers because of the high noise levels
  - DSP features are used for noise reduction and filtering

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HF Transmitting – Phone

- Push-to-talk – Just like on VHF/UHF
- Voice-operated-transmit (VOX)
  - Hands-free operation
  - Great for contesting & roundtable operations
  - VOX also used for CW and digital transmissions

HF Transmitting – Phone

- VOX controls:
  - VOX Gain – The more sensitive the VOX circuit, the less audio it takes to key the transmitter
  - VOX Delay – VOX delay holds the transmitter on for a short period (it keeps the transmitter from continuously turning on and off)
  - Anti-VOX – The anti-VOX prevents received audio from turning on the VOX circuit

HF Phone Procedures and Abbreviations

- Same basic procedure as VHF/UHF
- Phonetics are important on HF
- Q-Signals – Heard on SSB even though they were designed as shorthand for CW
- Avoid “CB Talk” and 10-codes (“10-4”)
  - Obsolete and bad form
  - Plain speech is more effective

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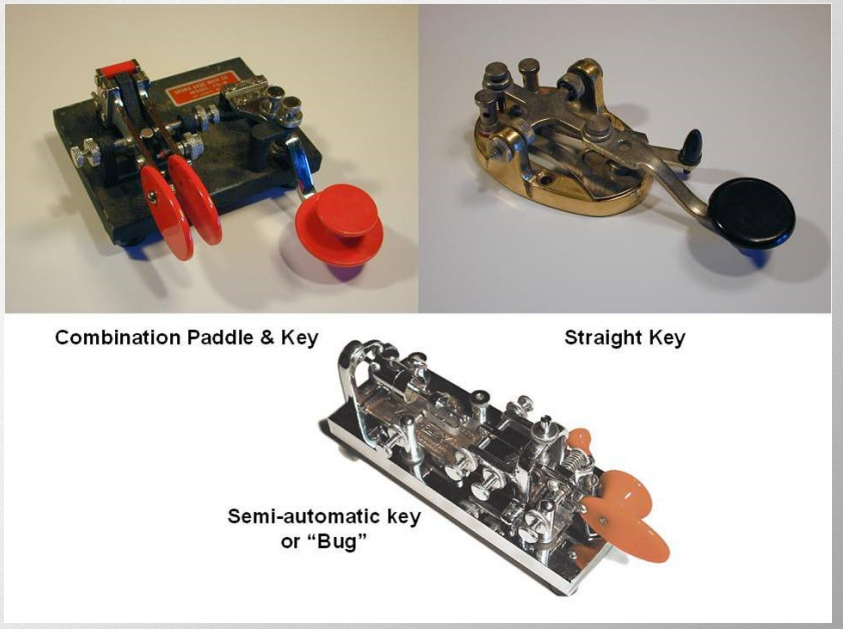
HF CW Transmitting

- Morse code is alive and well in Amateur Radio
- Morse ops use:
  - Straight keys
  - Iambic paddles
  - Bugs
  - Keyboards



- Most radios offer full break-in (QSK)

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HF CW Transmitting

- Zero beating is adjusting the transmitter frequency to the other station's transmitting frequency, producing the same audio tone
- "RST" (Readability, Strength, and Tone). The higher the number the better (e.g., 489, 579, 599, or 5NN)
- Readability (1-5) – Strength (1-9) – Tone (1-9)
- Add "C" to indicate "chirp" on transmission – 479C

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CW Procedures / Abbreviations

- *Procedural signals* like “K” (over) control the flow of the contact
- *Prosigns* are two letters sent as a single Morse character, written with an overscore

$\overline{\text{AR}}$ End of Message

$\overline{\text{SK}}$ End of Communication

$\overline{\text{BT}}$ Separation (between message text and other information)

$\overline{\text{KN}}$ Only the station with whom I am in contact should respond

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CW Procedures / Abbreviations

Abbreviations:

- WX – Weather
- CUL – See you later
- TNX – Thanks
- 73 – Best wishes
- CL – Clear, going off the air

Q-Signals:

- QRN – Atmospheric noise
- QRM – Man-made noise
- QRV – Ready to copy
- QSL – Acknowledge receipt
- QRL – Frequency is in use
- QRP – Low power, 5 W or less

Q-Signals (statement or made into a question)

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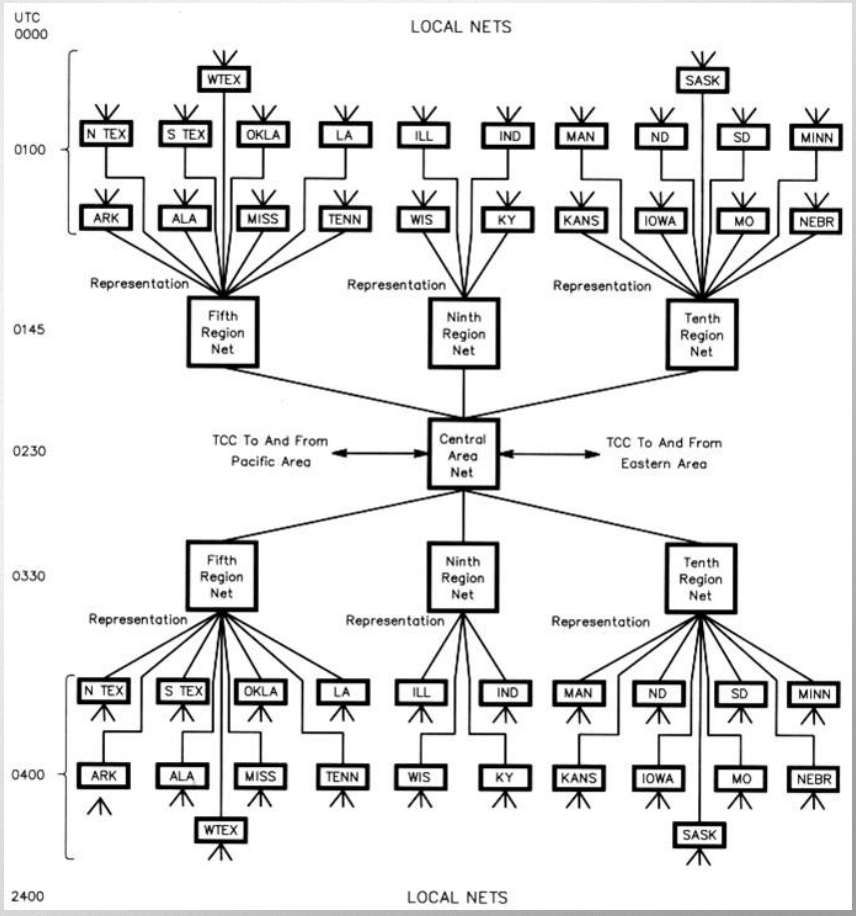
Nets and Emergency Operation

- Three basic net types:
  1. Traffic (relaying messages – shown at right)
  2. Emergency communications
  3. Social or topical



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Nets and Emergency Operation

- Net Control Station (NCS) – Directed nets have someone in charge.
- The NCS runs the net. A “directed net” means all contacts are routed through the NCS.
- Joining and leaving a net – checking in and checking out.
- Before joining a net, listen for a while to learn the procedures of the net.

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Emergency Operation

ARES – Amateur Radio Emergency Service is organized by the American Radio Relay League

- Any licensed ham can be a member
- ARRL membership is required for official appointments
- Teams are lead by Emergency Coordinators (ECs) at the local level, District Emergency Coordinators (DECs) in larger areas like counties
- Leadership is handled by the ARRL Section Emergency Coordinator (SEC)
- The mission is to provide communication assistance to local and regional government and relief agencies

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Emergency Operation

RACES – Radio Amateur Civil Emergency Service is sponsored through government agencies (City, County, State)

- RACES is a specific part of the Amateur Service and is governed by the FCC rules
- To participate, you must register with a local civil defense organization
- Only FCC licensed amateurs may be a control operator of a RACES station
- All RACES communication must be under the direction of a civil defense organization

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Emergency Operation

- Events around world have demonstrated the value of Amateur Radio in any disaster
- All Amateur Radio operators should be familiar with emergency rules and procedures so they can contribute effectively when normal communications are unavailable
- Emergency communications in any form take priority over all other types of amateur communication

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Emergency Operation

The FCC rules state that during an emergency or disaster, an amateur station may make "transmissions necessary to meet essential communication needs and to facilitate relief actions."

- Routine emergency communications are conducted on any frequencies authorized to the station control operator.
- There are exceptions to the rules that allow amateurs to use any means and any frequency necessary to provide emergency communication.

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Emergency Operation

FCC Rule Exceptions – When there is an immediate threat to the safety of life or property

1. "No provision of these rules prevents the use by an amateur station of any means of radio communication at its disposal to provide essential communication needs…"

2. If you hear another station in distress, the FCC rules state that "No provision of these rules prevents the use by a station…of any means of radio communication at its disposal to assist a station in distress."

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Distress Calls

- What do you do if you hear a distress call?
  - Do your best to obtain assistance for the station in distress
  - Immediately suspend your existing contact
  - Immediately acknowledge to the station calling for help that you hear them

Distress Calls

- Stand by to receive:
  - The location of the emergency
  - The nature of the emergency
  - What assistance is required
  - Relay the information to the proper authorities and stay on frequency for further information or until help arrives

Distress Calls

- What do you do if you are the station in distress?
  - On a voice mode say “Mayday Mayday Mayday” or on CW send “SOS SOS SOS” followed by “any station come in please”
  - Identify your transmission with your call sign
  - Give your location with enough detail to be located
  - State the nature of the situation/emergency
  - Describe the type of assistance you require and provide any other pertinent information

Distress Calls

- Unidentified transmissions outside the amateur bands are permitted if required to provide the necessary communications
  - The same rules apply to you if you hear a distress call
  - The risk of immediate loss of life and property overrides rules for normal operation

Finding Digital Activity

Where to Find Digital Signals on the HF Bands

Band (Meters)	*Notes (MHz)*
160	1.800 - 1.810
80	3.570 - 3.600
60	Data emission not permitted
40	7.080 - 7.125 RTTY DX calling frequency 7.040 MHz
30	10.130 - 10.150
20	14.070 - 14.0995 and 14.1005 - 14.112 PSK31 calling frequency 14.070 MHz
17	18.100 - 18.110
15	21.070 - 21.110
12	24.920 - 24.930
10	28.070 - 28.150

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Digital Modes

- Digital voice modes are regulated as voice emissions by the FCC
  - Icom's D-STAR, Yaesu's SystemFusion, AOR's digital voice, WinDRM, FreeDV
- Slow-scan TV (SSTV) is also regulated as an image mode on both HF and VHF/UHF
- Fast-scan TV (ATV) is not used on HF due to bandwidth requirements

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Digital Mode Overview

- Maximum data rates and bandwidths are specified by the FCC rules
- Digital codes other than those specified by the FCC must be public
  - Amateurs are not allowed to use secret or private codes
  - This requirement includes the protocols used to control communications

Modes

- Radioteletype (RTTY) – originally used mechanical teleprinters but migrated to computer sound cards
  - RTTY is popular on all the HF amateur bands (100% duty cycle)
- PSK31 – good weak signal mode using low transmitter power and very narrow bandwidth (computer sound card)

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Modes

- PACTOR and WINMOR: (Winlink 2000)
  - PACTOR stands for *PACket Teletype Over Radio*
  - WINMOR stands for *Windows Messaging Over Radio*
  - Both modes use advanced modulation techniques, including error correction and automatic communication control

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Modes

- Packet Radio – common on the VHF and UHF bands (1200 & 9600 baud)
  - Uses the AX.25 protocol standard
  - Not popular on HF due to transmission errors from noise and fading, can only use a 300 baud data rate on HF
- JT65 and JT9 are very effective at communicating at extremely low signal levels

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Definitions

- Bit – fundamental unit of data; 0 or 1
- Bit rate – number of digital bits per second sent from one computing system to the other
- Symbol – a characteristic of the transmitted signal that represents data
- Baud or bauds – number of symbols sent per second (symbol rate)

Definitions

- Duty cycle – the ratio of time that the transmitter is on to the total of on time plus off time
- Protocol – rules that control the method used to exchange data
- Mode – the combination of a protocol with a modulation method such as RTTY or PSK31

Protocol and Modulation

- Protocol – the set of rules that control the encoding, packaging, exchanging, and decoding of digital data
  - Specifies how each packet is constructed and exchanged, what characters are used
  - How errors are detected and managed
- Method of modulation chosen by convention
  - SSB or FM for packet radio, FSK or AFSK for RTTY

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Frequency Shift Keying (FSK)

- RTTY signal – two different tones shifting from one frequency to another
  - The rapidly changing tones are called *mark* and *space*
  - Space represents 0
  - Mark represents 1

FSK – AFSK

- FSK – the frequency of the transmitter's VFO is controlled directly by a digital data signal from the computer
- *Audio frequency shift keying* (*AFSK*) – audio tones are used to modulate an SSB or FM transmitter through the microphone input
  - Audio must be kept free of noise
  - ALC and compression must not be used to prevent distortion

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Radioteletype (RTTY)

- RTTY uses the Baudot code, which represents (encodes) each text character as a sequence of 5 bits
- An initial bit (the *start bit*) and an inter-character pause (the *stop bit*) are used to synchronize the transmitting and receiving stations

RTTY

- Baudot code uses 5 bits for encoding data (32 different characters)
  - Not enough for the entire English alphabet, numerals, and punctuation
  - Two special codes, LTRS and FIGS, are used to switch between two sets of characters, increasing the number of available characters to 62

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RTTY

- On HF, the most common speeds are 60, 75, and 100 WPM (corresponding to 45, 56, and 75 baud)
- Most RTTY conversations on HF are conducted at 45 baud and the most common shift between the mark and space frequencies is 170 Hz
- You must match your speed and shift to communicate with the other RTTY station

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Multiple Frequency Shift Keying

- MFSK16 uses 16 separate tones, all 15.625 Hz apart
  - Withstands fading and distortion better than FSK
  - DominoEX and Olivia are variations of MFSK
- MT63, “MT” stands for “multi-tone” data signal composed of 64 tones
  - Uses advanced DSP techniques which enable it to perform well under noisy and fading conditions

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PSK31

- The “31” stands for the symbol rate of the protocol, actually 31.25 baud
- PSK uses a variable length code called *Varicode* that assigns shorter codes to common characters and longer codes for others
- Capital letters and punctuation characters take more bits and thus slow the contact

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Packet Basics

- *Packet* refers to the transmission of data in structured groups
- *Header* – at the start of the packet – contains:
  - Synchronization patterns for the receiver
  - Control, routing and handling information
  - Error detection and correction information

Packet Basics

- Data – the data to be exchanged, often compressed for efficiency
  - Data can *encapsulate* another protocol's packets
- Trailer – additional control or status information and data used for error detection
- The most common error detection is a *cyclic redundancy check* (*CRC*)
  - The result of a calculation based on the values of packet characters

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Error Correction

- *Forward error correction* (*FEC*) –includes additional redundant encoded information with the data being transmitted
- *Automatic Repeat reQuest* (*ARQ*) – the protocol requires that a packet with errors in the data be retransmitted
  - Uses ACK (rcvd OK) and NAK (error detected) messages to the sending station

Error Correction

- ARQ protocols are designed to transfer data between two stations
- An *ACK* or *NAK* response to the sending station can only be received from one receiving station
- You can't "break in" to an ongoing contact between two stations using an ARQ mode

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Error Correction

- Monitoring or “MON” mode – stations can listen to the ARQ conversation and receive the data but without retransmission of “bad” packets
- Monitoring mode allows you to determine if a frequency is occupied
- PACTOR and WINMOR are ARQ protocols
  - Preferred method of HF data transmission for the popular Winlink email system

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Receiving and Transmitting Digital Modes

- RTTY on HF is transmitted as an LSB signal. JT65 and JT9 use USB.
  - USB/LSB selected by convention for each mode.
- Digital signals on the wrong sideband will not decode correctly because the relationship of the tones and the digital data will be inverted
- Know where your sidebands are with respect to the displayed frequency – stay in the band!

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Bandwidth of Digital Modes

- The FCC rules define the bandwidth of a digital mode signal in the same way as any other signal
- As the symbol rate of a signal increases, so does the bandwidth required to transmit that signal.
  - By packing more bits into a symbol the net bit rate can be increased while keeping symbol rate the same and without increasing bandwidth

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Bandwidth of Digital Modes

Table 6.2 – Bandwidth Comparison of Digital Modes

Mode	*Bandwidth (Hz)*
PSK31	50
RTTY	200
MFSK16	300
JT65	350
DominoEX	524
Olivia	1000
WINMOR	1600
MT63	2000
PACTOR-III, -IV	2300

Bandwidths are approximate for the highest commonly used symbol rate and are not specifications

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Transmitter Duty Cycle

- Most amateur transmitters are not designed to operate at full power output for an extended time
- RTTY, PSK31 – nearly 100% for extended periods
- ARQ modes – less than 100% but still high
- Reduce your transmitter power to about 50% of maximum output power for most digital modes

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Digital Mode Signal Quality

- Excess audio levels causes distortion and splatter just as for voice modes
- On a waterfall display, vertical lines to each side of the main signal represents a spurious emission
  - Distortion makes a signal harder to copy
  - Spurious emissions cause interference
  - Keep your data audio levels set correctly

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ALC and Digital Modes

- *Automatic Level Control* (*ALC*) is used to prevent excessive drive to amplifier inputs
- As it changes power levels, ALC can cause distortion of the original signal.
- Distortion caused by ALC makes the signal harder to decode and creates spurious emissions
  - Mild distortion caused by ALC is acceptable on voice modes

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ALC and Digital Modes

- When using a digital mode, your ALC system should be either disabled or the microphone input level and gain turned down to the point where the ALC system does not activate
  - Monitor ALC during digital transmission (usually a meter function selection)
  - The ALC should not activate during digital transmissions.

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Listening First

- To avoid causing interference, the control operator:
  - *Must* listen to the received audio or watch a waterfall-style display *before* transmitting
  - It's not enough to just check a BUSY light on a modem
  - Follow good amateur practice and listen, listen, listen!

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Gateway & Mailbox Stations

- Unmanned *gateway* and *mailbox* stations monitor a fixed frequency until another station attempts to connect to them
  - They respond without requiring a human control operator
  - The FCC classifies them as *automatically controlled digital stations*

Automatically Controlled Stations

- Automatically controlled stations are only permitted to use RTTY and data modes in the 1.25 meter band and band segments on the HF bands
  - A station operating under FCC rules must be operating under local or remote control (i.e., with a control operator in charge of all transmissions) to contact these stations legally

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Automatically Controlled Stations

Automatic Control Band Segments for RTTY and Data

Band (Meters)	*Frequency range (MHz)*
80	3.585-3.600
40	7.100-7.105
30	10.140-10.150
20	14.0950-14.0995 and 14.1005-14.112
17	18.105-18.110
15	21.090-21.100
12	24.925-24.930
10	28.120-28.189
6	50.1-50.4
2	144.1-148

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Automatically Controlled Stations

- Establishing a connection will vary with the equipment and mode being used
  - The contact starts with sending a CONNECT message to the station with which you want to connect
  - A training sequence then determines the best rate and modulation to use based on conditions
  - Once training is completed, a message can then be transferred

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Digital Contact Display

- The waterfall displays the presence of signals as a series of lines, each representing a scan across the frequency range
- The strength of the signals is represented as the brightness, intensity, or color of the line at each frequency on the display
- The display gives the impression of a “waterfall” as the data flows across the screen in successive scans

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Third Party Traffic

- All FCC rules about third-party messages apply to digital transmissions
- This includes all information included in email, digital images, or web pages transmitted via Amateur Radio
- Commercial messages such as advertisements or pertaining to your business may not be transmitted via Amateur Radio

Interfering Signals

- Symptoms of Interference:
  - Failure to connect
  - Frequent retries or transmission delays during data transfer, progress slow or erratic
  - Timeouts or dropped connections – in cases of strong or persistent interference, the number of requested retransmissions may exceed a preset limits

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Interfering Signals

- Remember, the interference may be accidental or the other station may not hear your signal at all
- Use a different frequency
- Aim directional antennas in another direction

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