

# Plan for today

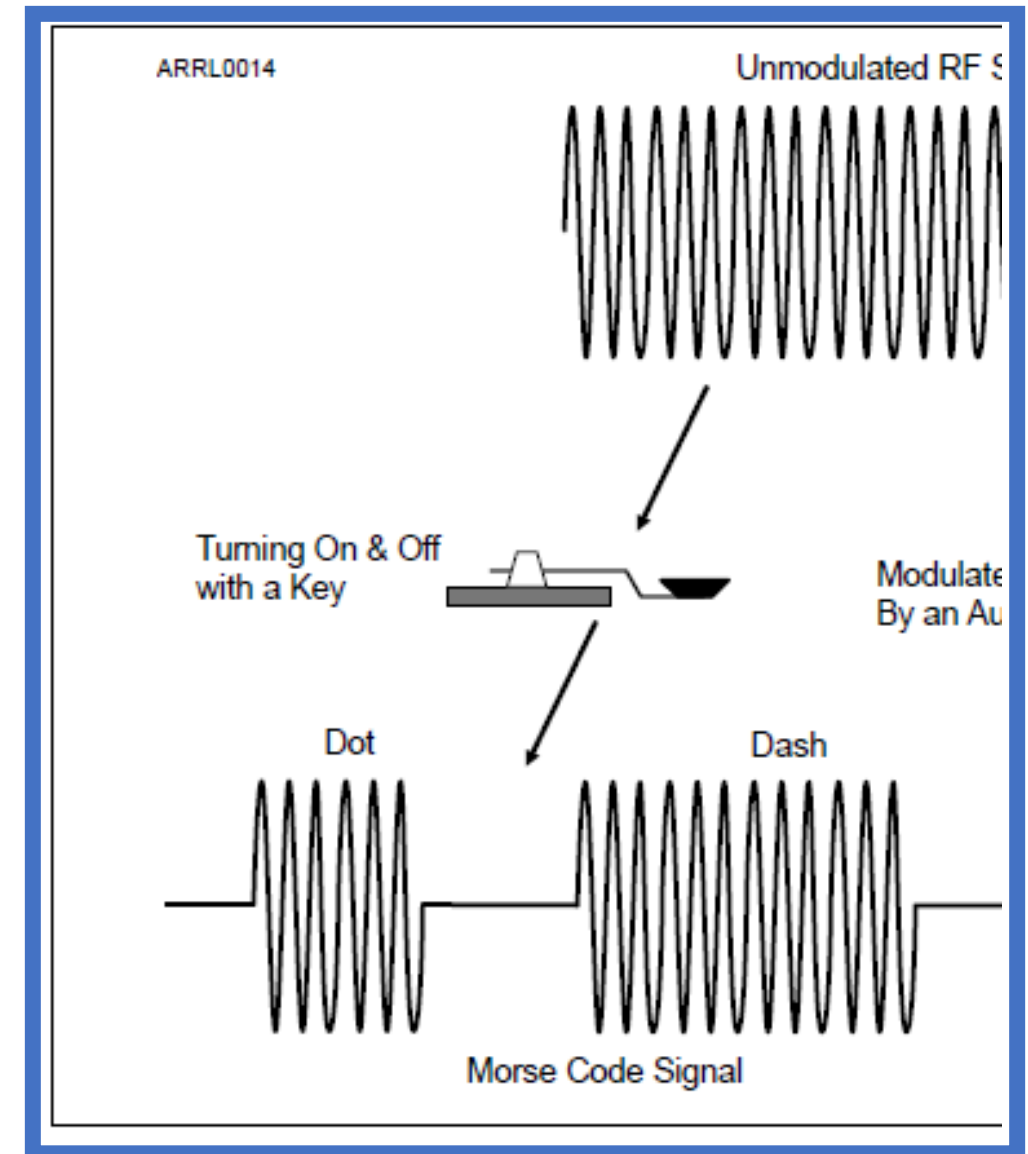
- Modulation
- Radio equipment
- Power supplies and batteries
- Interference
- Communicating with other hams

# Types of Modulation

- Information is encoded in different ways
  - Morse Code (CW)
  - Amplitude Modulation (AM)
  - Frequency Modulation (FM)
  - Phase Modulation (PM)
  - Many others

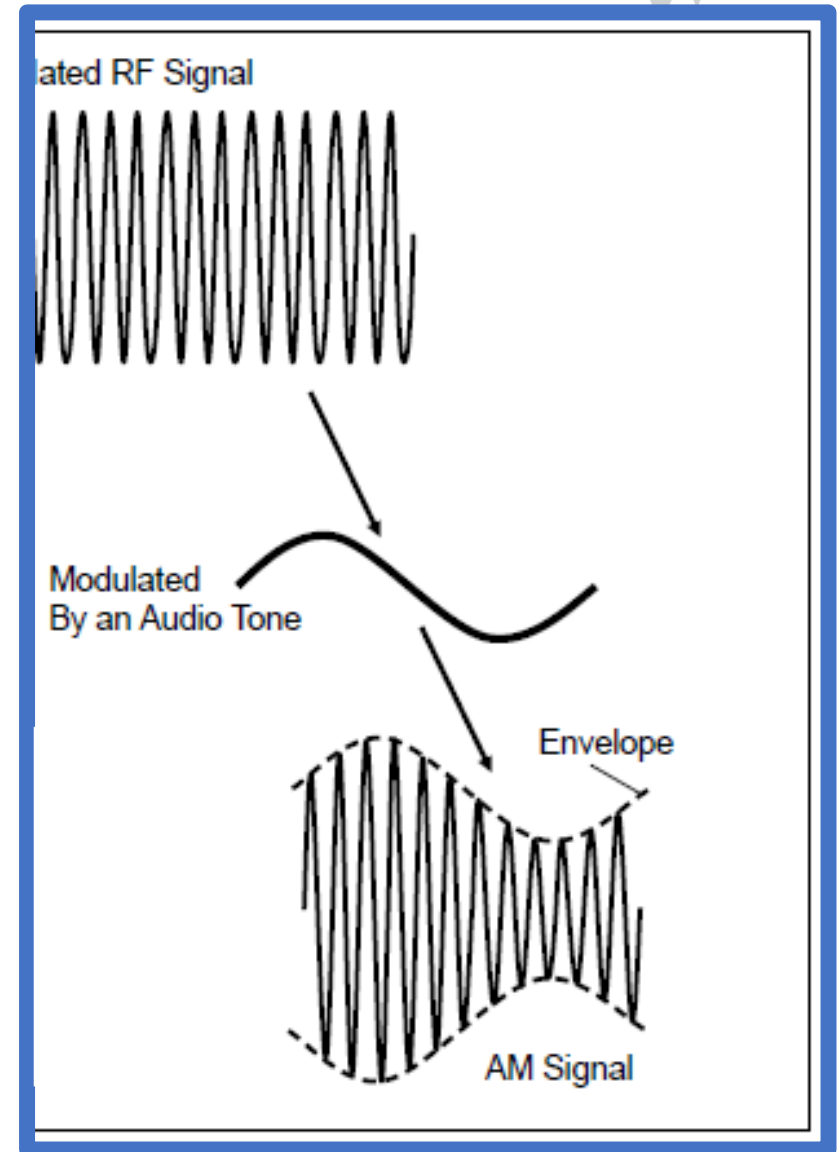
# Morse Code (“CW”)

- Sequence of Dots and Dashes
- Continuous carrier is either on or off
- Simplest form of Amplitude Modulation



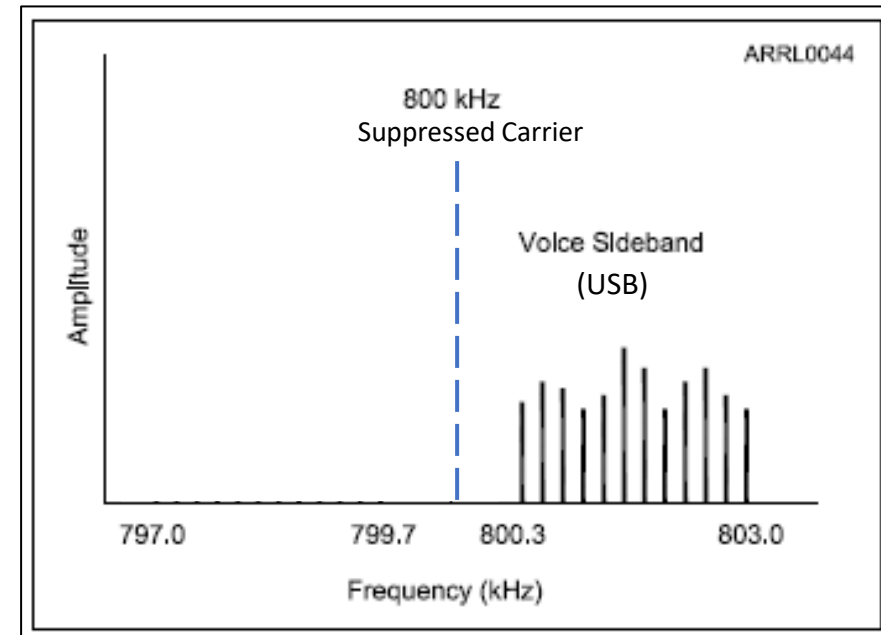
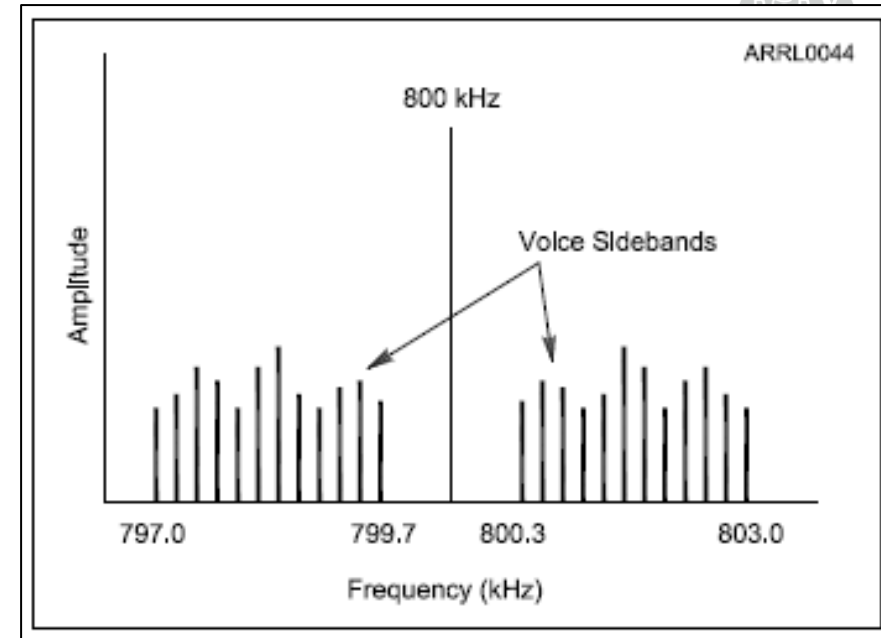
# Amplitude Modulation

- Amplitude of a carrier is modulated (multiplied) by the signal we want to transmit
- Several variations of AM



# AM Signal Spectrum

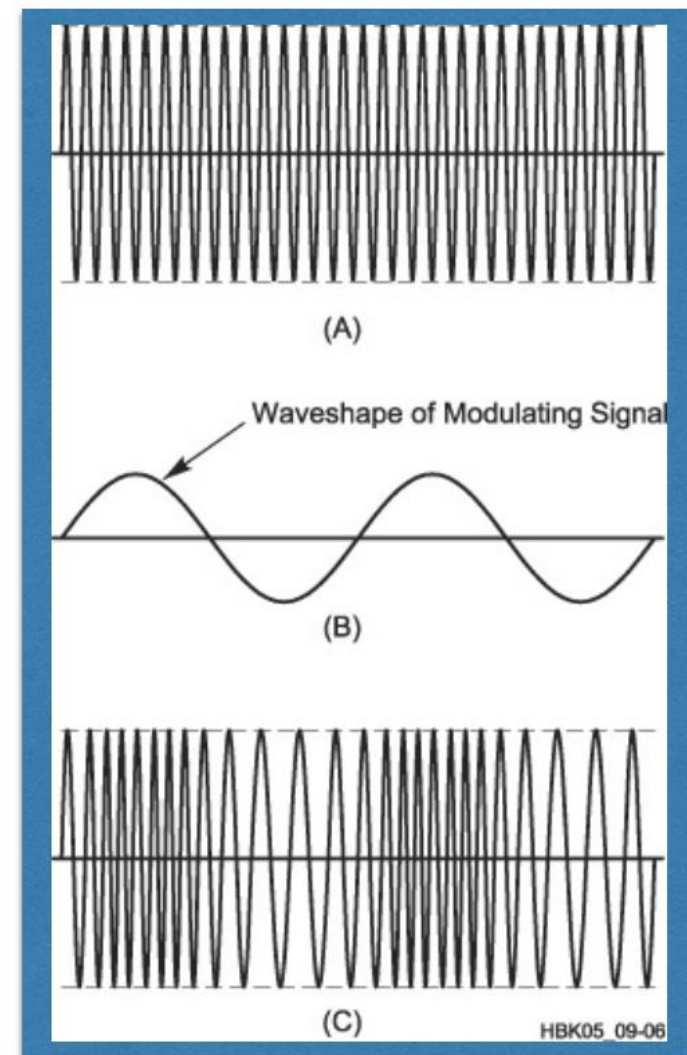
- Carrier
- Upper side band (USB)
- Lower side band (LSB)
- Either sideband is enough
- Voice bandwidth = 300Hz-3kHz
  - Full bandwidth = 6kHz
- With SSB, need 3kHz
- Common in HF
  - Also used in weak signal VHF, UHF





# Frequency Modulation

- Information encoded in the frequency of the carrier
- Wider bandwidth than AM
  - Voice = 5kHz – 15kHz
- More resistant to propagation effects
- Common for VHF/UHF handhelds, mobiles
- Also: digital packet/data, voice



# Typical Questions

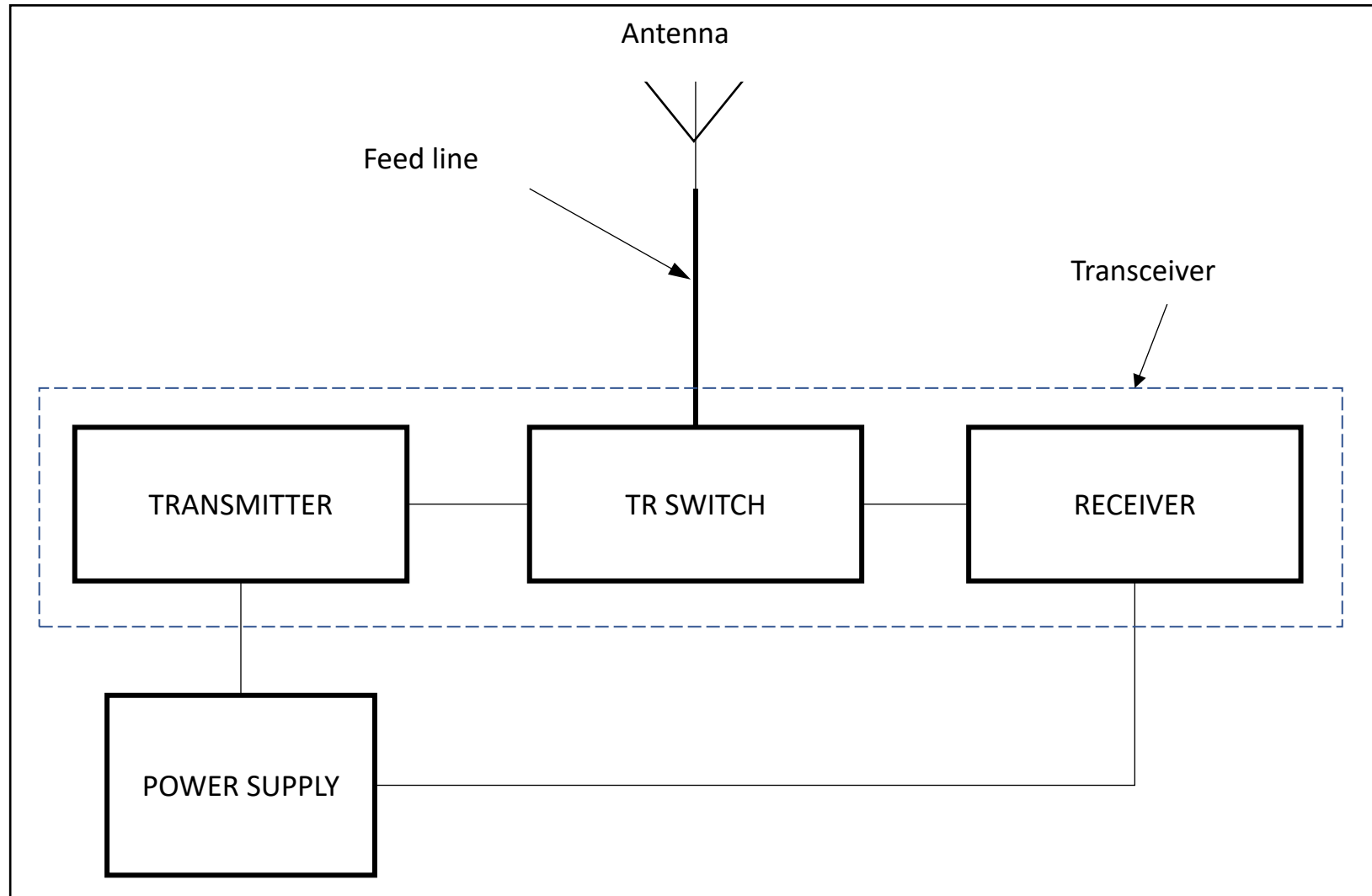
- Why should you not set your transmit frequency to be exactly at the edge of an amateur band or sub-band? (T1B09)
- What would cause your FM transmission audio to be distorted on voice peaks? (T2B05)
- Which type of modulation is commonly used for VHF and UHF voice repeaters? (T8A04)
- Which type of voice modulation is often used for long-distance (weak signal) contacts on the VHF and UHF bands? (T8A03)

# Signal Bandwidths

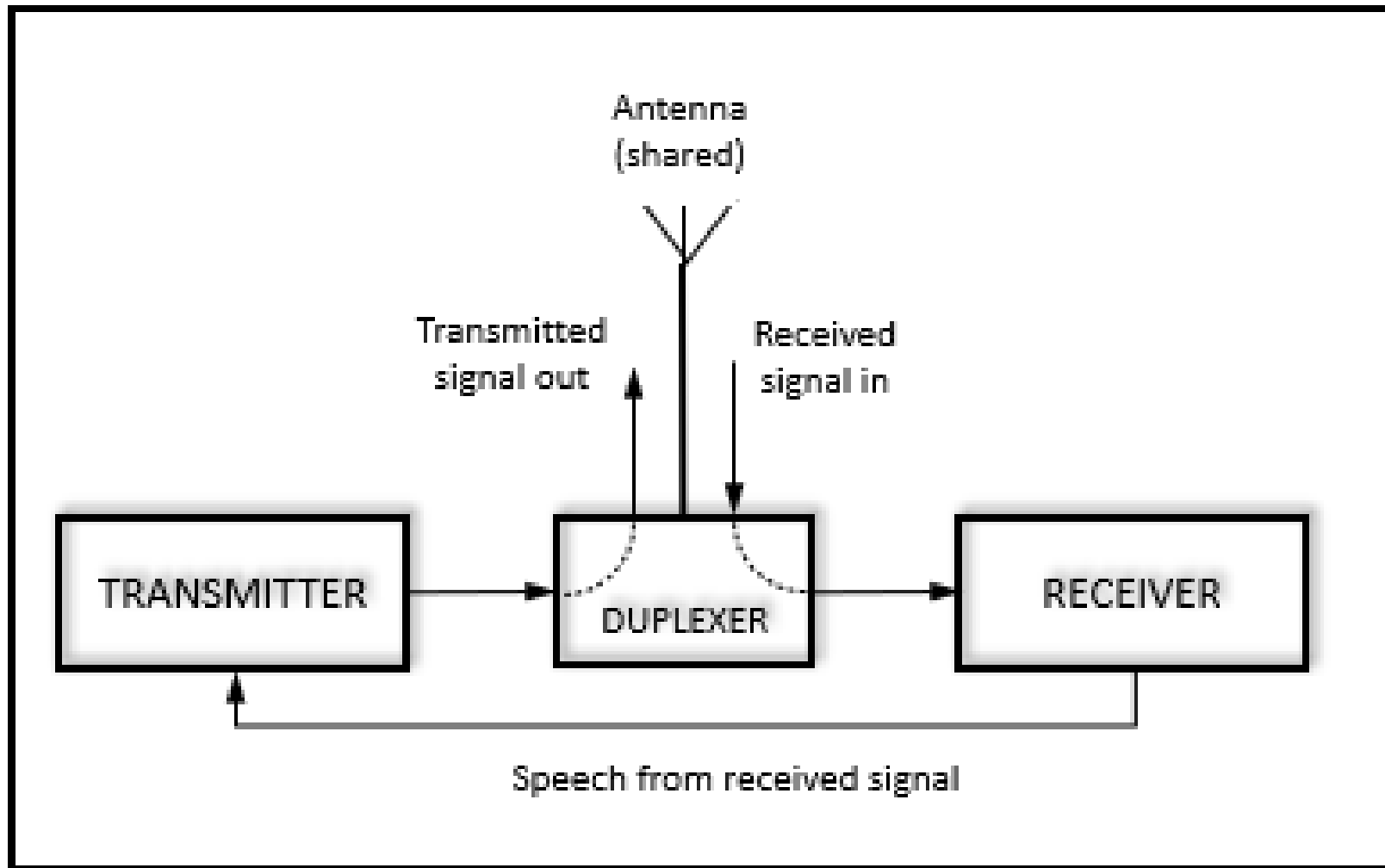
Signal Type	Bandwidth
AM Voice	6 kHz
AM Broadcast	10 kHz
Commercial Video	6 MHz
SSB Voice	3 kHz
SSB Digital	0.5-3 kHz
CW (Morse Code)	150 Hz
FM Voice	5-15 kHz
FM Broadcast	150 kHz



# Basic Radio Components



# Repeaters



# Radio Form Factors

- Desktop radios (“base stations”)
  - Often have many modes, are pretty complex
  - Mostly HF, 100W + power amplifiers
- Mobile
  - FM on one or more bands
  - Up to about 50W
- Handheld (“Handi-Talkie” or “HT”)
  - FM on one or more bands
  - Typically 5W, occasionally more
  - Simple, but lots of options
- Also (but not on the test)
  - Low-Power Radios (“QRP”)
    - Smaller radios, generally portable, generally HF
  - Software-Defined Radios (“SDR”)
    - Computer does the modulation/demodulation

# Desktop Radio

- HF, may also have VHF, UHF
- Lots of modes (FM, AM, SSB, Digital Voice, Digital Data)
- 100 Watts (+ power amplifiers = up to 1500 W)



# Mobile Radio

- Built to be used in a car
  - Can be used as a base station
- 50 Watts
- Always has FM, may have digital voice, data



# Handheld Radios

- VHF and/or UHF
  - Sometimes 220 MHz, 1.2 GHz
- 5 Watts
- Always has FM, may have digital voice and data
- Can be complex to operate
  - Every button does multiple things
  - Often has multiple layers of menus
  - Programmed with PC, software



# Major Transmitter Controls

- Tuning: VFO dial, numeric input
- Mode switch: FM, SSB, etc.
- Microphone: push-to-talk (PTT), voice-activated (VOX), CW key
- Automatic Level Control (“ALC”)



Mode Selector  
(touchscreen)

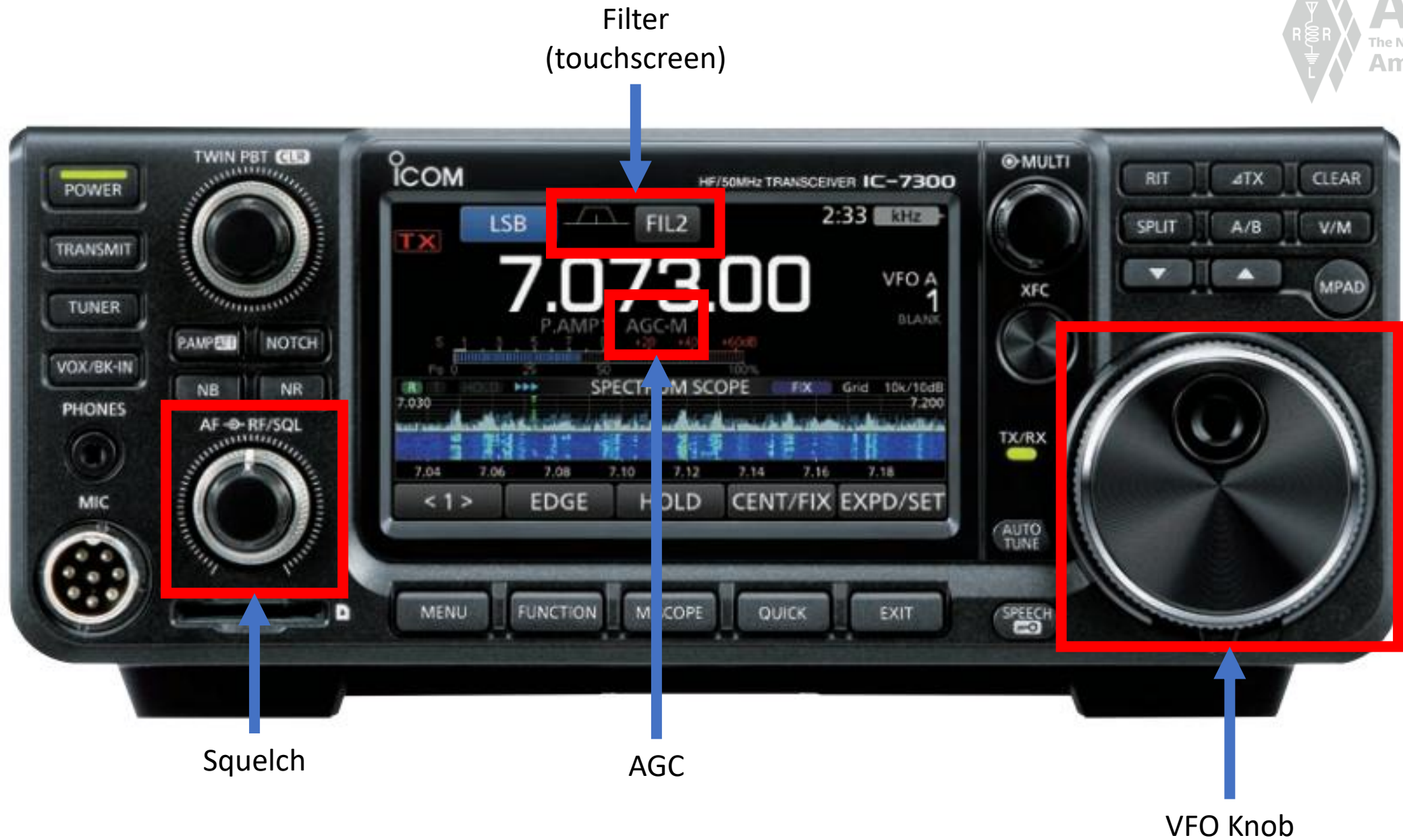


VFO Knob



# Major Receiver Controls

- Tuning (VFO dial, numeric input)
  - May be independent of transmit frequency
- Automatic gain control (AGC), typically not in FM
- Squelch control: shut off speaker if signal too low
  - Common for FM
- Noise filters
  - Match the bandwidth of the signal
  - Suppress adjacent signals
- Signal strength (S-meter): 1-9 plus additional steps
  - Logarithmic scale: 6dB per S-unit (factor of 4 in power)



# Digital Data Modes

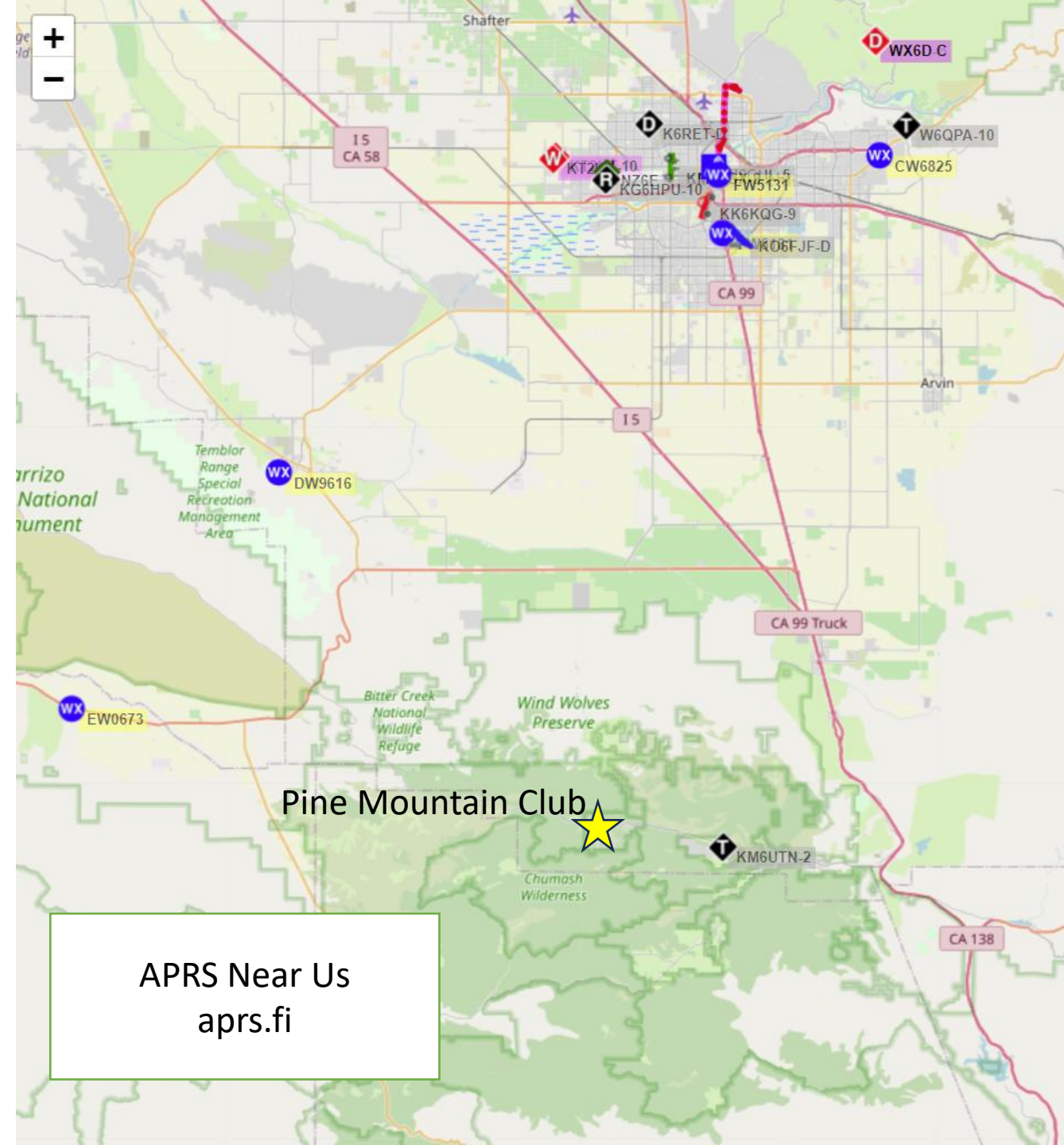
- Modem or sound card generates signals
  - “Terminal Node Controller” (TNC)
  - Some radios have built-in sound cards for direct connection to computer
- Many different modes
  - Radioteletype (RTTY)
  - PSK31
  - Packet AX.25
  - APRS
  - Winlink

# Packet Radio

- AX-25: radio version of X-25 packet switched networks
  - X-25 networks common in telecom in '70s – '90s, replaced by TCP/IP
- Packets have headers, checksums, request for repeats (ARQ)
- Can have direct connections, or relayed through digipeaters
  - Digipeater = digital repeater
- Equipment: your PC, radio, packet modem software
  - Example open-source software: “Direwolf”

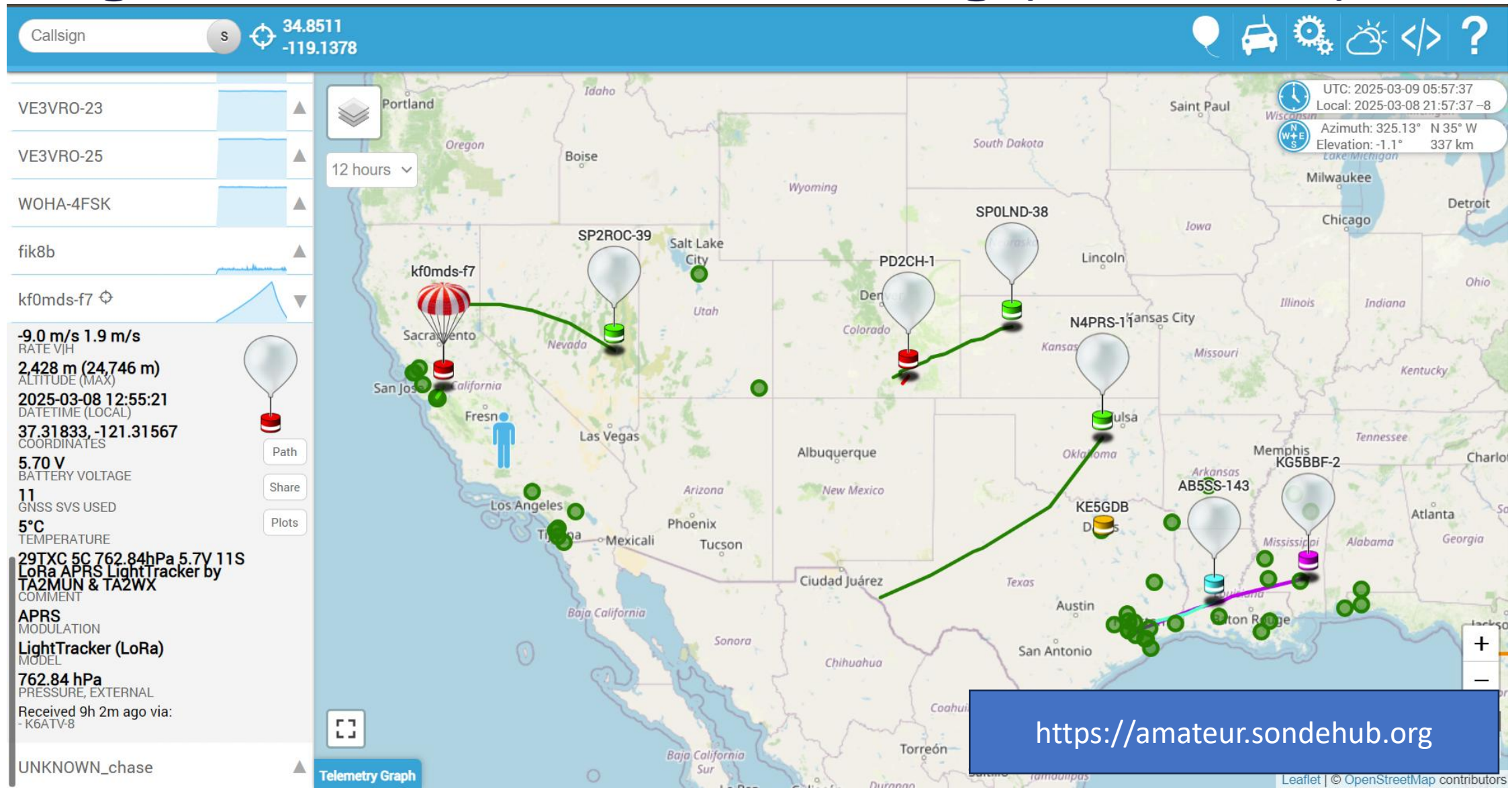
# APRS

- “Automatic Position Reporting System”
- Radio + GPS
- Reports data to internet servers
  - Typically position
  - Also text, email, weather, etc.
- Based on AX-25
- Phone apps can do APRS
  - License required to use





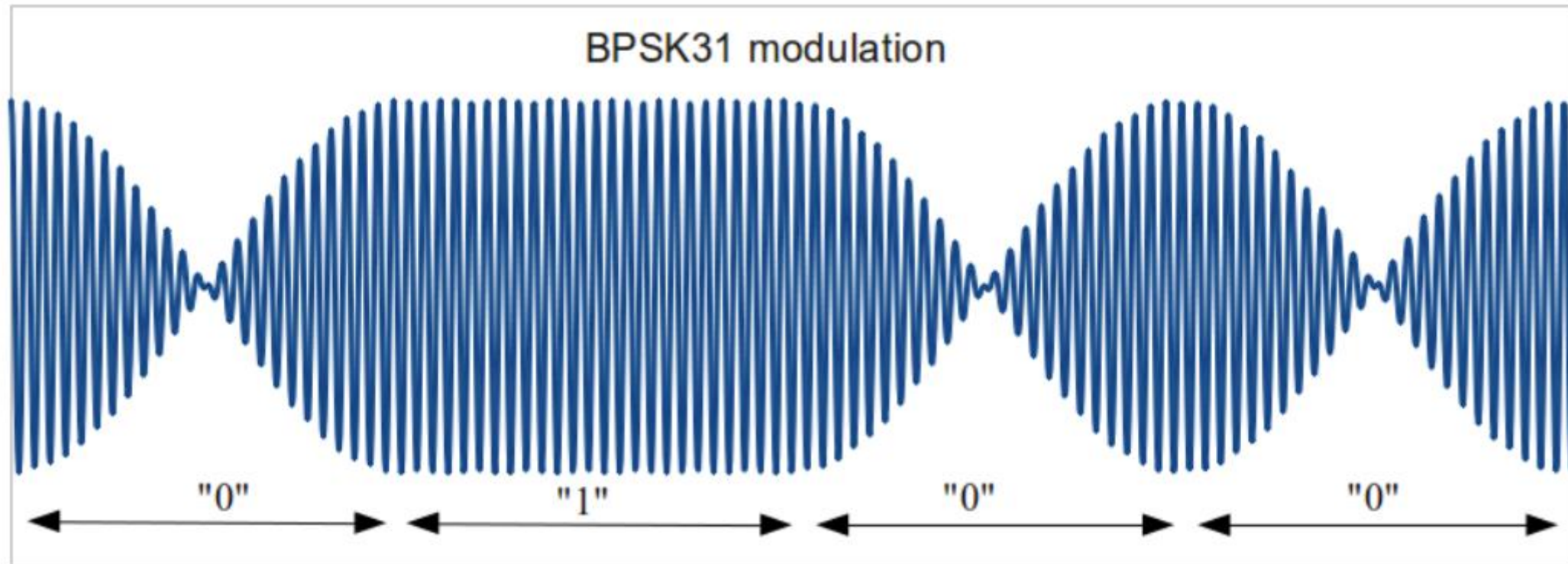
# High-Altitude Balloon Tracking (APRS use)



# Other Digital Modes

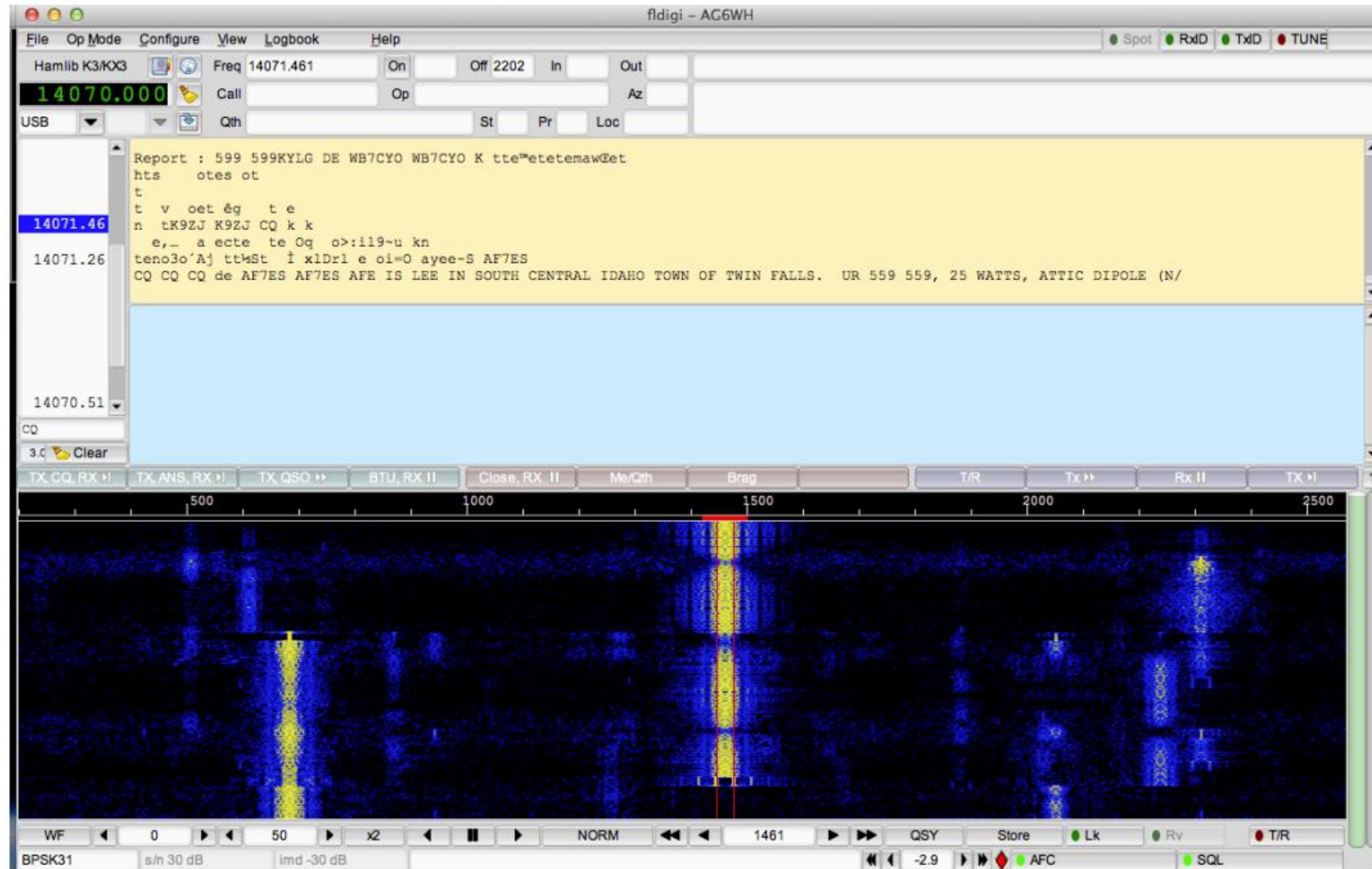
- RTTY: radioteletype – keyboard-to-keyboard
- PSK31: digital mode with low data rate, mostly HF
- JT65, JT9, FT8, FT4: digital modes with very low data rate, mostly HF
  - 73 bits/min(!), but very sensitive
- Winlink: radio email systems, common in emergency communications

# BPSK31 Waveform

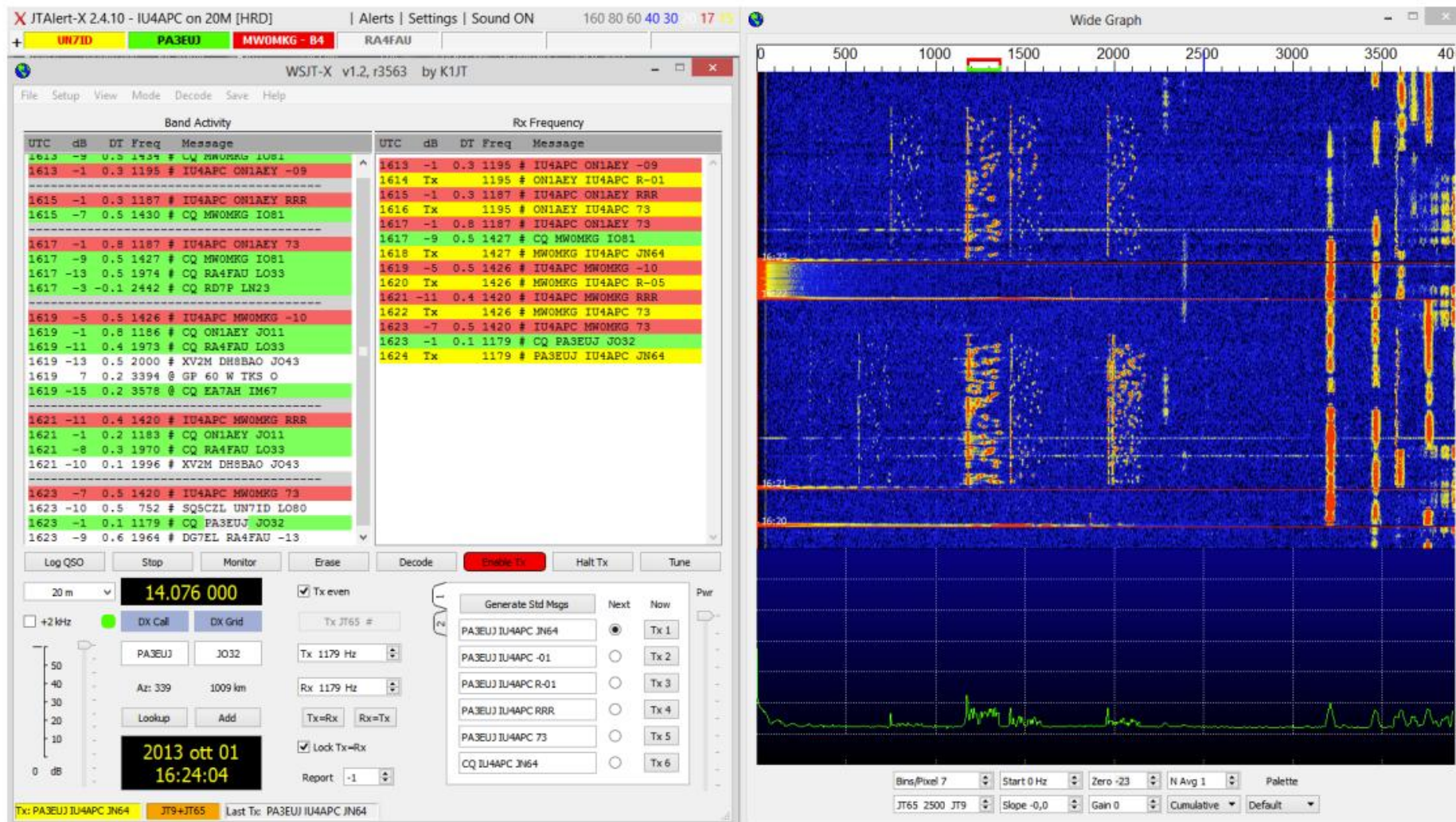




# PSK31 with fldigi



# JST65, JT9



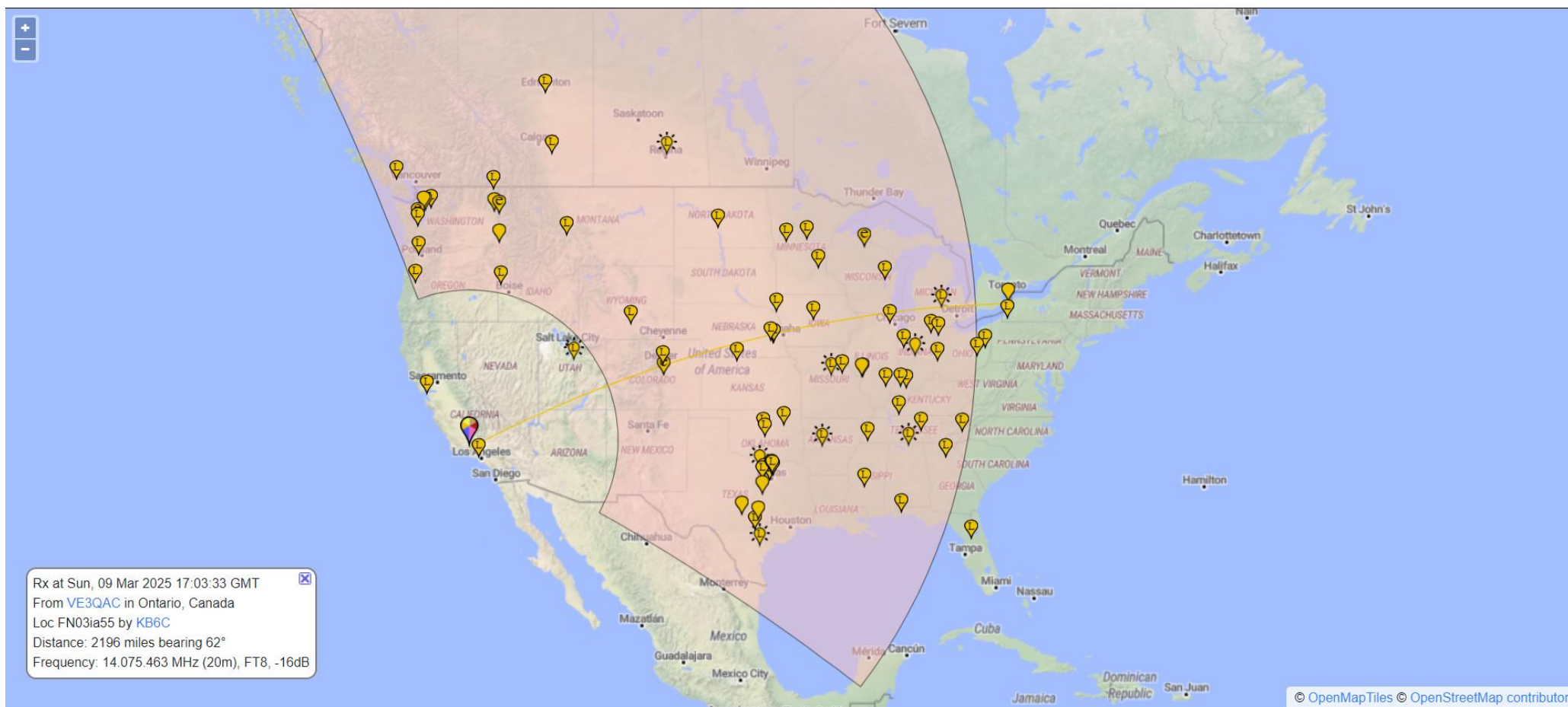


# PSK Reporter – pskreporter.info

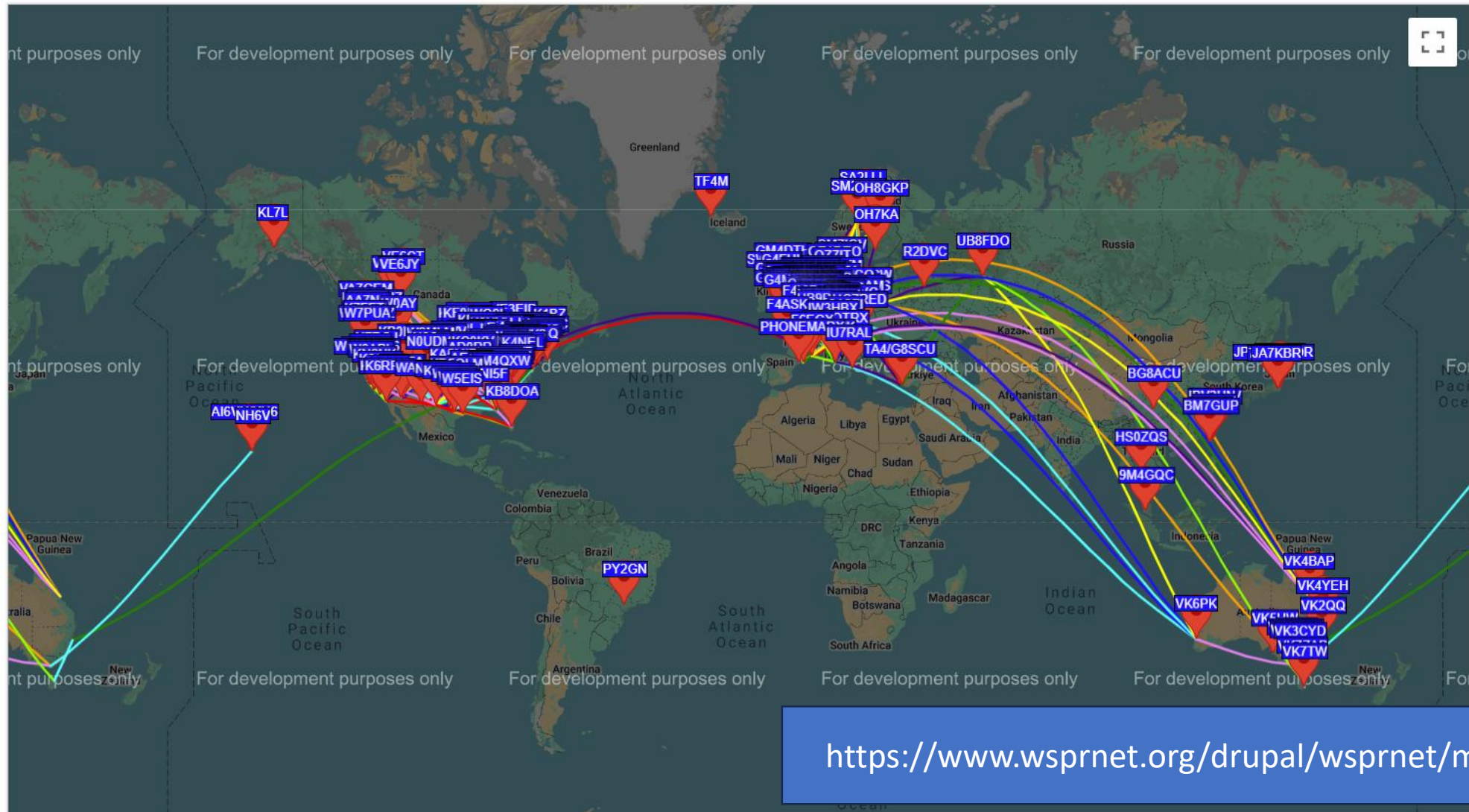
On  show  rcvd by   using  over the last   [Display options](#) [Permalink](#)

Monitoring KB6C (last report 3 mins ago). Automatic refresh in 5 minutes. Small markers are the 80 transmitters ([show logbook](#)) heard ([distance chart](#)) at KB6C (13001 reports, 92 countries last 24 hours; 87349 reports, [110 countries](#) last week).

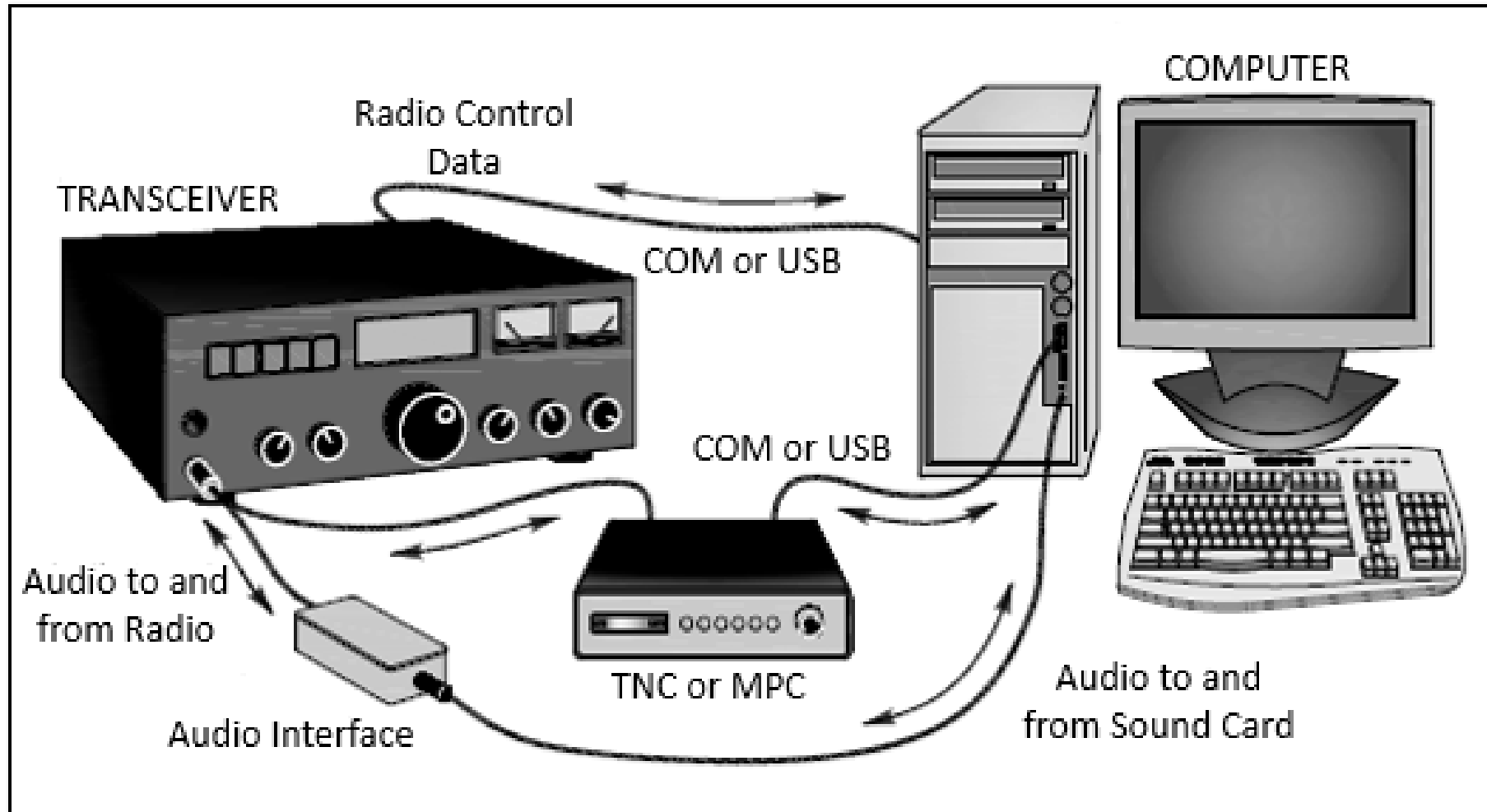
There are 2855 active monitors: [2764 on 20m](#), [472 on 15m](#), [453 on 10m](#), [403 on 17m](#), [388 on 40m](#), [363 on 12m](#), [350 on 30m](#), [203 on 80m](#), [87 on 60m](#), [78 on 160m](#), [37 on 6m](#), [31 on 2m](#), [13 on 600m](#), [6 on 2.4Ghz](#), [6 on 11m](#), [3 on 10Ghz](#), [2 on 70cm](#), [2 on 5m](#), [2 on 2200m](#), [1 on 8m](#), [1 on 4m](#), [1 on 23cm](#). [Legend](#)



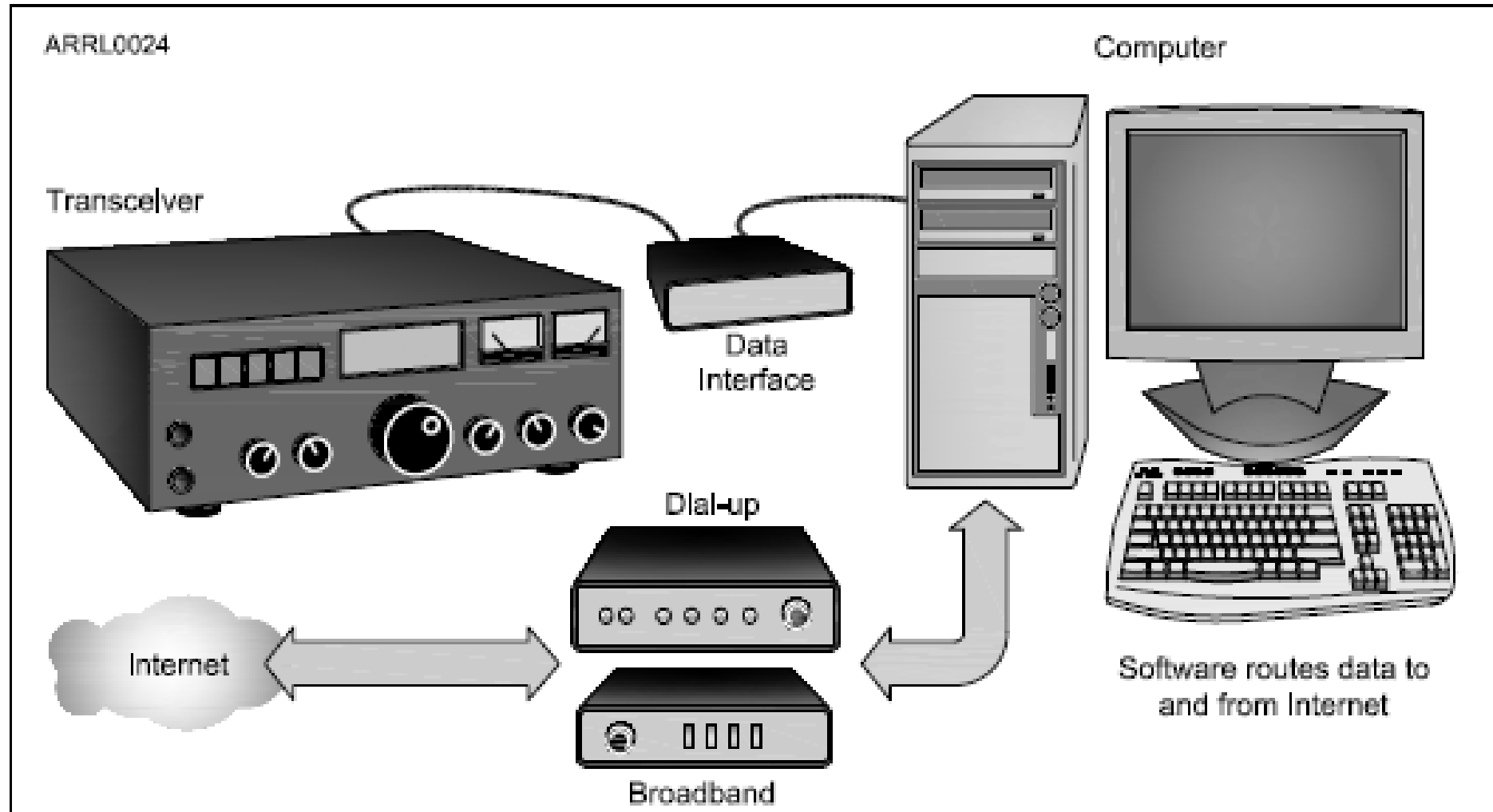
# WSPR – Weak Signal Propagation Reporter



# Digital Radio Connections



# Internet Gateway



# Power Sources

- Most radios use 12v power
- Common sources
  - DC power sources (desktop power supplies)
  - Batteries
- Radios typically do not provide a power source
- HTs use internal batteries, may have a different voltage



# 12v DC Power Supplies

- Linear power supplies
  - Big transformers
  - Heavy: iron core transformers
  - Expensive
  - Very clean power
- Switching power supplies
  - Small transformers
  - High-frequency switching between transformers
  - Lightweight, small, inexpensive
  - Often electrically noisy





# Batteries

- Types (can overlap): Disposable, Rechargeable, Storage
- Power storage measured in Ah
  - Amps x Hours, “Amp-Hours”
- Storage batteries (car batteries) have a whole set of potential issues
  - Store lots of energy – can be dangerous if things go wrong
  - If shorted, can overheat and vent hydrogen gas and combust
  - Should be well fused (both leads) and well-ventilated
  - Often require special chargers that adjust voltage as it charges
    - Can depend on the chemistry of the battery
    - What you use on a Lead-Acid battery can damage a Lithium-Ferrous battery

# Radios in Cars

- Power: where will you get it? How do you connect?
- Where will interference come from?
- Where do you put your antenna?
- Are you allowed to use a radio in your car?
  - Check the laws where you are travelling

# Radio Frequency Interference (RFI)

- Two situations:
  - Your radio interfering with other devices
  - Other devices interfering with you
- There are many unlicensed devices (FCC Part 15)
  - Must not cause interference with licensed users (you)
  - Must accept interference from users of properly operating equipment (you)
- Be diplomatic: first make sure your equipment is working, and then try to help them solve their problems

# Types of RFI

- Direct detection
  - Offending signals get into the electronics circuits to cause interference
- Overload
  - Strong signal that that overwhelms the weaker, wanted signals
- Harmonics
  - Multiples of the offending signal that coincide with the wanted signal

# How to Mitigate RFI?

- Filters
  - Highpass: receive
    - Higher-frequency signals pass through the filter
    - Removes lower “rumbles” like hum from power lines
  - Lowpass: transmit
    - Lower-frequency signals pass through the filter
    - Removes harmonics, which only happen on higher frequencies
  - Notch: suppress specific signals to reduce overload
- Ferrites
  - Chunks of metal you wrap cables with
  - “RF Chokes”

# RFI Sources

- Electrical arcs/sparks
  - Motors/generators, thermostats, electric fences, neon signs, etc.
- Power lines
- Motor vehicle ignitions/alternators
- Switching power supplies
- Computers, networks, TV sets
- Some light bulbs

# Electrical Grounding and Circuit Protection

- Make sure your home is “up to code”
- Most ham equipment does not require special wiring or circuits
- Use 3-wire power cords everywhere possible
- Use circuit breakers, circuit breaker outlets, or ground fault interrupter (GFI) circuit breakers
- Use proper fuse/circuit breaker ratings
- Don’t overload single outlets

# Communicating with Other Hams

- Connection methods
  - Simplex – radio-to-radio
  - Repeaters
- Band plans
- Nets

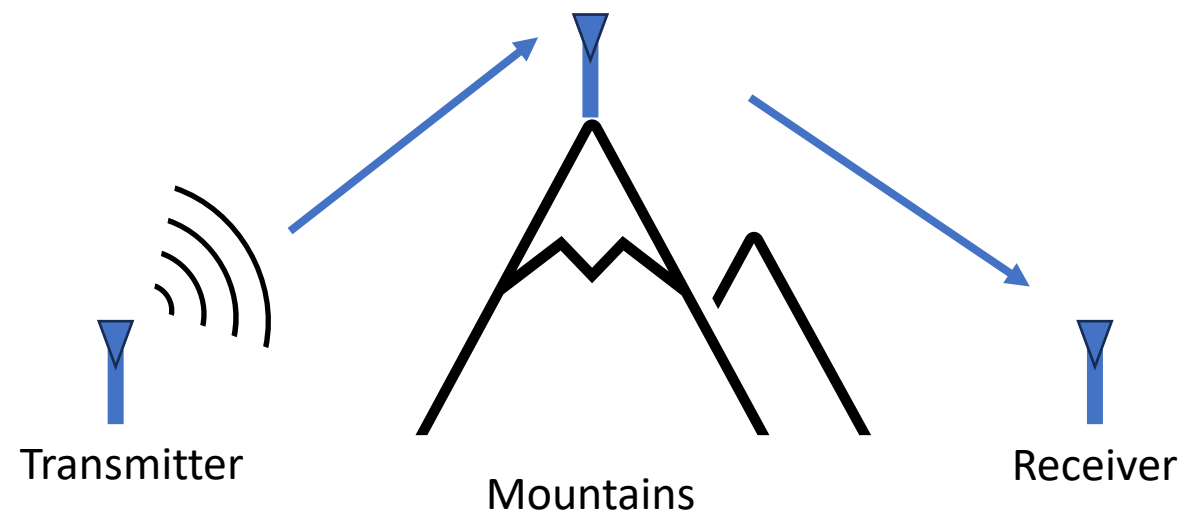


# Connection Methods

- Simplex – direct, radio-to-radio
  - You and your contact alternate talking on the same frequency
  - Typically limited in range (great if you have line-of-sight)
  - Calling frequencies
- Repeaters
  - You talk to a powerful radio in a high-elevation location, it rebroadcasts on a different frequency
  - You can talk to anyone who can see the same repeater
    - Higher elevation means this can cover a huge area!
  - You usually need an access code (CTCSS or DCS)

# Repeaters

- Relay signals from radios that normally can't reach each other
- Receives on one frequency transmits on another
- Common repeater splits:
  - +/- 500 kHz on 2m
  - +/- 5 MHz on 70cm
  - Your radio knows these!



# Access Tones

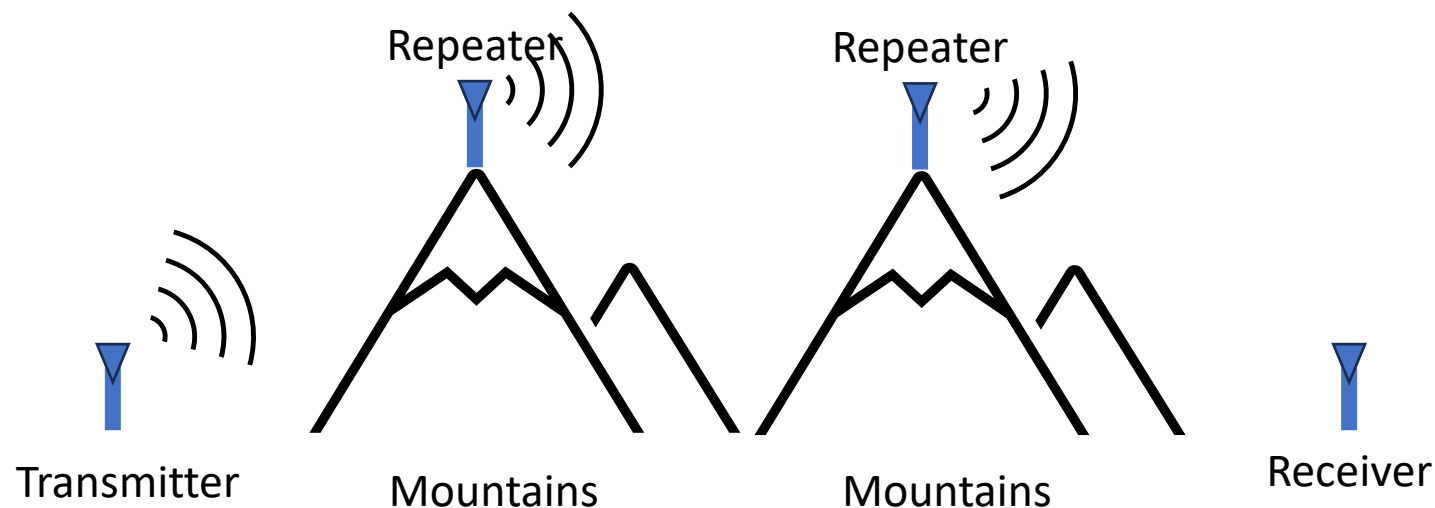
- Repeaters don't want to retransmit every signal they hear!
  - If repeaters can hear each other, would create a feedback loop
- Repeaters look for a sub-audible tone
  - CTCSS: Continuous Tone-Coded Squelch
  - PL: Motorola-specific, "Private Line"
  - Bursts of codes or tones
    - DCS: Digitally-coded squelch

# How to Find Repeaters

- Listed in repeater directories (websites, books, phone apps)
  - Example: <https://repeaterbook.com>
  - Key information:
    - Repeater output frequency
    - Repeater shift/offset
    - Access frequency (example: PL=100.0)
  - Example: **145.290 (+) 94.8 PL**
    - If the offset is not defined, the size is implied (600 kHz on 2m, 5 MHz on 70cm)
- Many, many open repeaters out there
- I recommend programming local repeaters into your area
  - I can help you with repeaters local to PMC

# Repeater Networks

- Repeaters can talk to other repeaters to cover a larger area
- Examples:
  - CARLA (all of CA, plus southern OR, western NV)
  - KERN system (San Joaquin Valley, channel islands)

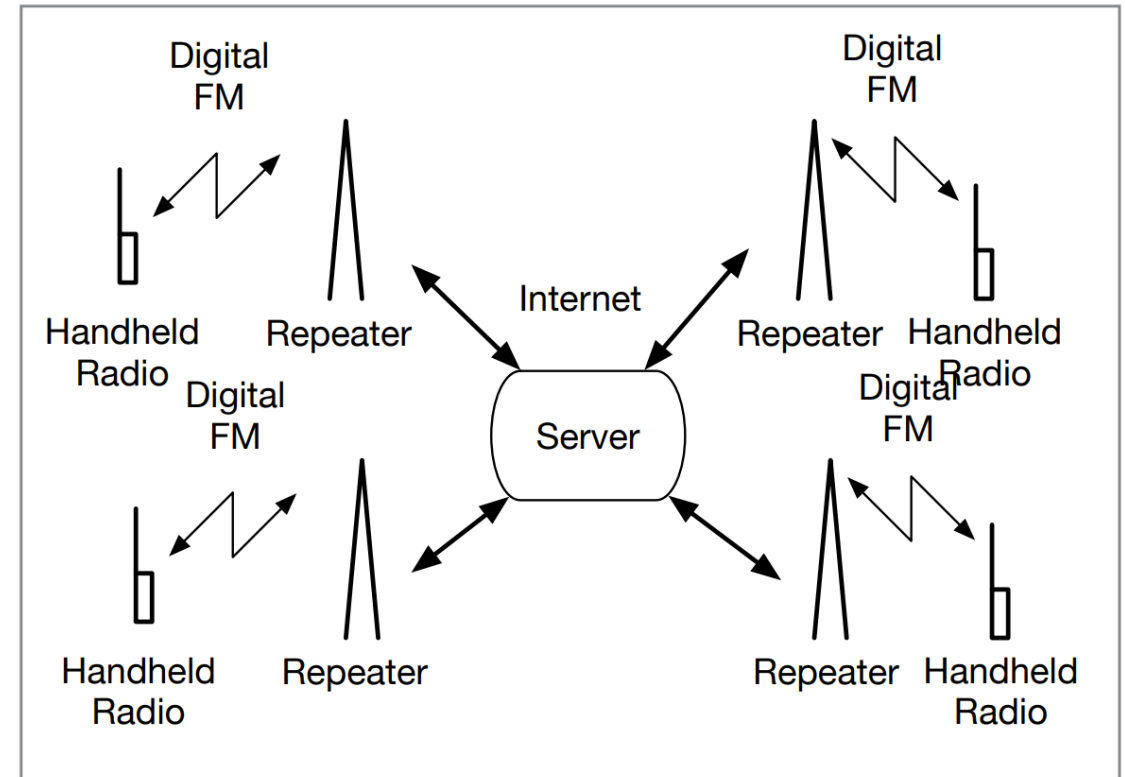


# Digital Repeater Networks: Echolink, IRLP

- Linked Repeaters connected by the internet (Voice-over-IP)
- Type in the access code, address of a computer to link to using DTMF tones (same tones a phone uses)
- Acts like one big repeater, even though far apart
- IRLP = RF on both ends
- Echolink can use a computer

# Digital Mobile Radio (DMR)

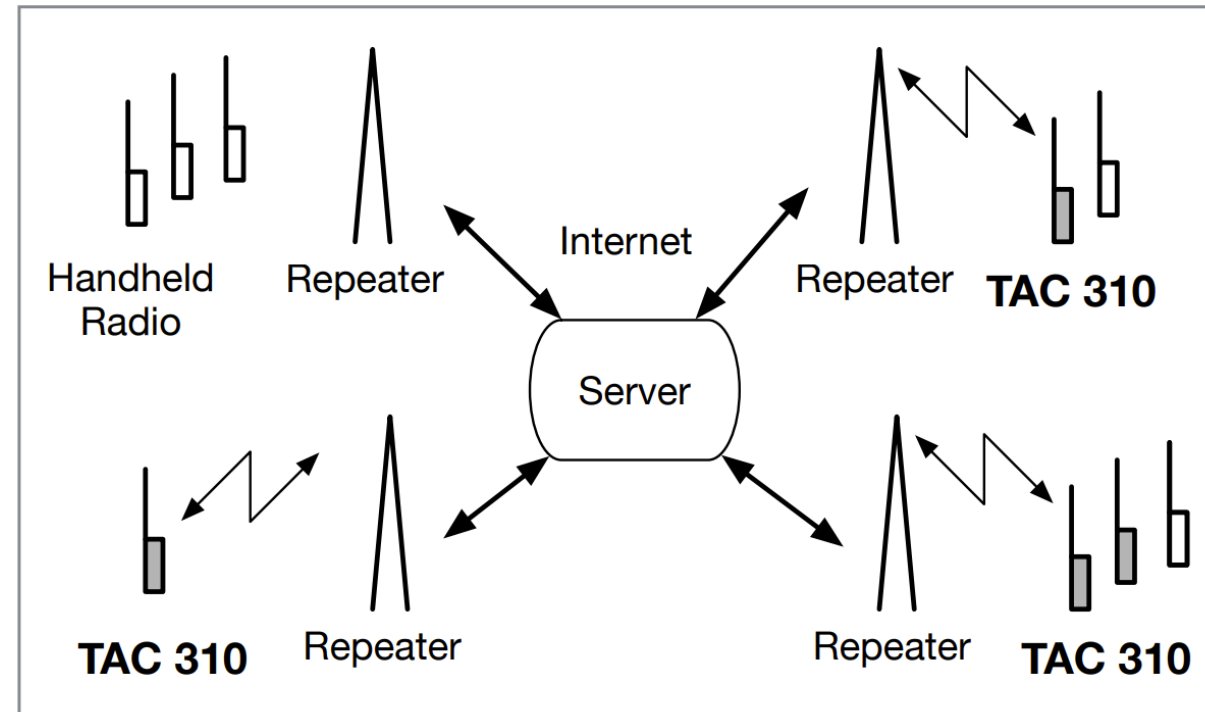
- Each user has an ID
- Your repeater tells the network you are there
- You can connect to an individual user directly (rare)
- You can connect to a talk group (most common)





# DMR Example

- TAC 310 is a talk group
- I tell the repeater I want to use TAC 310 by configuring my radio to use it
- Other people do the same thing on their repeaters
- We all hear traffic on the talk group, all over the world
- Need a specialized DMR radio to use this (or a DMR hotspot)



# Band Plans

- The FCC doesn't specify what you can do in parts of the ham bands
- Voluntary agreements define “band plans”
- Recommends frequencies for specific purposes
  - DX (long-range contacts)
  - Digital modes
  - Beacons
  - Satellites
  - Repeater inputs and outputs
  - Simplex
  - Control links

# Signal Reports

- Verbal: “you are just barely getting into the repeater”
- RST: three numbers
  - Readability 1-5
  - Signal strength 1-9
  - Tone 1-9 (CW)
  - Best is 599
- “Q” system
  - Barely understandable (1) to perfectly understandable (5)

# Calling Protocol

- Listen first to see if the frequency is free
  - The MONI button opens the squelch to hear weaker signals
- Push the PTT button, red light goes on, wait for ½ second, talk into the microphone
- Identify with your callsign every 10 minutes and when signing off
  - I'm KK6DZW "Kilo Kilo Six Delta Zulu Whiskey"
- If you are looking for someone to talk with, say something like:
  - "CQ CQ CQ this is KK6DZW"
  - "KK6DZW monitoring"
- When you are done, tell everyone that the frequency is open
  - "KK6DZW clear"

# Nets

- Common in public service communications (ARES, RACES)
- Also commonly used for event support
- Nets pass messages to other stations
  - Could be voice messages
  - Can follow a structure
    - “Radiogram” or ICS-213 form
- Traffic can be prioritized by severity
  - “routine”, “priority”, “emergency”

# Next Time

- Regulations
  - Licensing regulations
  - Operating regulations
- Recommended reading:
  - ARRL book: chapters 7 and 8
  - <https://hambook.org>: chapter 8