An Introduction to HF Communications

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What is “HF”

- HF – “High Frequency”
- Details later, but for now, if you aren’t familiar with the term, call it “shortwave radio”

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It Was A Dark And Stormy Night

- My introduction to HF
- Arlington, Texas, 1968 or so
- (yes, it really was dark and stormy)

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About Me

- Licensed since 1975 (age 13)
- Previously WN8YVI, WB8YVI, KC8ES
- Active on HF 1975-1981, some contesting at University of Michigan ARC W8UM
- Inactive on HF for many years
- Became active in MTV CERT/ARES around 2001
- Got back into HF + contesting in 2008

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Outline

1. The Electromagnetic Spectrum
2. The HF Amateur Radio Bands
3. Modes
4. HF Propagation Basics
5. HF Antennas
6. Operating Practices
7. Having Fun on HF

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Unit 1: The Electromagnetic Spectrum

- What is the electromagnetic spectrum?
- Who uses it?
- History

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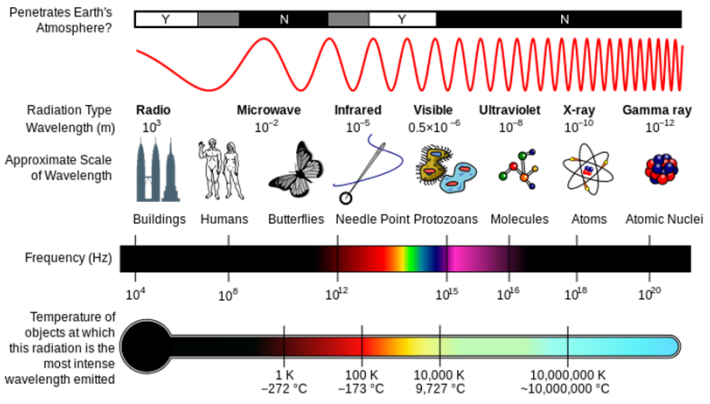

From https://en.wikipedia.org/wiki/Electromagnetic_spectrum

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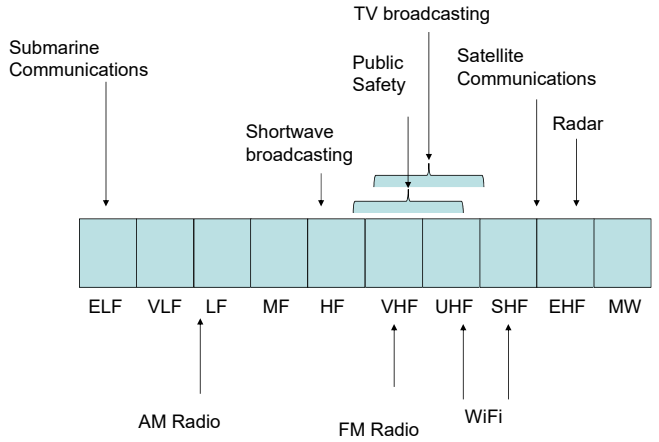

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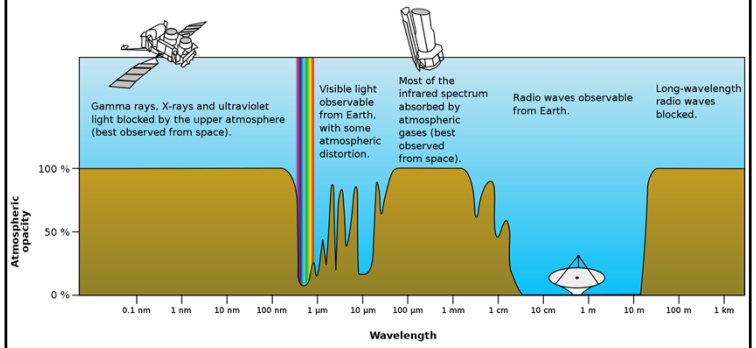

From https://en.wikipedia.org/wiki/Electromagnetic_spectrum

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Early Radio Experiments

- First observations of radio phenomena in late 18th century
- Mid-1800s – scientific foundation laid (Orsted, Henry, Faraday, Maxwell)
- Late 1800s – Marconi, Tesla conduct experiments
- 1901 – first claimed transatlantic wireless transmission

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Commercial Use

- First use of wireless was ship-to-shore communications using morse code
- First experimental audio broadcasts in 1906, first commercial station 1919
- Radio was largely unregulated – amateurs and ship-shore communications often interfered with each other
- Federal Radio Commission established 1926, replaced by the FCC in 1934

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Modern Telecommunications

- Using new modulation techniques (ways of encoding signals over radio)
- Digital communications
- Very high bandwidths (e.g. LTE wireless can achieve 300 Gb per second)
- Higher and higher frequencies
- Most innovation is at UHF/EHF frequencies which are all line-of-sight (max 40 miles or so)

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Amateur Radio Allocations

- Early innovations in radio came from ”citizen scientists”
- FRC/FCC has always recognized the value of amateur radio
- Even though radio spectrum is extremely valuable (e.g. spectrum auctions), hams have always had slices of spectrum
- Ham allocations range from longwave (135 KHz) to microwave and above

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Unit 2: The Amateur HF Bands

- HF Amateur Bands
- Sub-bands: license class, mode
- Sub-bands: considerate operators
- Special Considerations:
  - Primary vs. Secondary users
  - WARC
  - 60 meters

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HF Amateur Bands

- HF = High Frequency = 3 MHz – 30 MHz
- Amateur allocations at:
  - 1.8 – 2.0 MHz (160 meters)
  - 3.5 – 4.0 MHz (80/75 meters)
  - ~ 5.3 MHz (60 meters – 5 channels only)
  - 7.0 – 7.3 MHz (40 meters)
  - 10.1 – 10.15 MHz (30 meters)
  - 14.0 – 14.35 MHz (20 meters)
  - 18.068 – 18.168 MHz (17 meters)
  - 21.0 – 21.45 MHz (15 meters)
  - 24.89 – 24.99 MHz (12 meters)
  - 28.0 – 29.7 MHz (10 meters)

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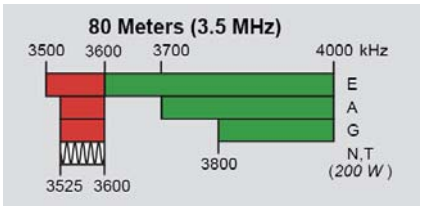
Sub-bands: license class, mode

- Within each HF band, operator privileges, modes, and power are limited by license class.



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Sub-bands: considerate operators

- Band plans lay out “gentleman’s agreements” about specific frequencies for specific modes, activities, etc.

3.500-3.510	CW DX window
3.560	QRP CW calling frequency
3.570-3.600	RTTY/Data
3.585-3.600	Automatically controlled data stations
3.590	RTTY/Data DX
3.790-3.800	DX window
3.845	SSTV
3.885	AM calling frequency
3.985	QRP SSB calling frequency

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Primary vs. Secondary Users

- Not all “ham bands” are exclusively for our use.
- In some bands, amateurs are secondary users. Must not interfere with primary users and are afforded no protection from primary users.
- 1900-2000 kHz shared with radiolocation (FCC considering returning entire band to hams)
- 30 m shared with fixed services in other parts of the world
- 60 m shared with mobile and fixed services

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WARC bands, 60 meters

- WARC = World Administrative Radio Conference (an ITU technical conference - now World Radiocommunication Conference - WRC)
- Additional bands authorized for amateur use at WARC-79
- 30m, 17m, 12m, gentleman’s agreement for no contesting, some international power limits
- 60 meter band = 5 specific channels at about 5.3 MHz, non-interference basis

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Unit 3: HF Modes

- Overview of Modes
- CW
- SSB
- Digital Modes
- New Digital Modes
- Other Modes

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Overview of HF Modes

- HF bands much narrower than VHF/UHF – implies narrower bandwidth modes
- Main 3 modes are CW, SSB, and Digital
- CW – morse code
- SSB – Single Sideband Voice
- Digital – catch-all for RTTY, PSK-31, FT-8, and other digital modes
- New digital modes
- Other modes you may hear

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CW

- AKA Morse Code
- CW = “Continuous Wave”
- Not actually continuous. Carrier wave is keyed on and off
- Is a digital mode in the strictest sense. Data rate slow enough for human brain to copy it
- Very narrow bandwidth. Depends on speed and keying envelope, but roughly 4x speed in WPM. 20 WPM ~= 80 Hz

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SSB

- SSB = an amplitude-modulated signal with one sideband and carrier suppressed
- Carrier conveys no information. Sidebands are redundant
- Allows all transmitter power to go into conveying information
- Receiver re-injects carrier

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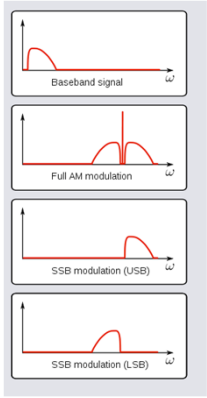
SSB



Source: http://en.wikipedia.org/wiki/File:SSB_bandform.svg

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Digital modes

- All - low b/w compared to WiFi, 3G/4G
- But low b/w is useful, esp in emergency
- RTTY –5-bit baudot code. No error correction or retry. Popular for contesting.
- PSK-31 No error correction or retry. Good for long contacts
- FT-8 Very efficient. Fixed exchange not suitable for EMCOMM.
- Many others: see http://www.kb9ukd.com/digital/

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New Digital Modes

- Implemented in software
- Enables rapid innovation. No new hardware. Runs on PC sound card
- Older radios may need isolation transformers + special cables
- Newer radios (e.g. Elecraft K3) plug directly into sound card with 1/8” cables
- Newest radios (Kenwood TS-590sg) have USB audio interfaces built in

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“JT” modes

- Excellent weak-signal performance
- Written by Joe Taylor, W1JT, astrophysicist and Nobel Prize winner
- Worldwide communications with low power and simple antennas
- Latest WSJT-X software is extremely easy to set up and use
- FT-8 has really taken off in 2017-2018, extremely popular

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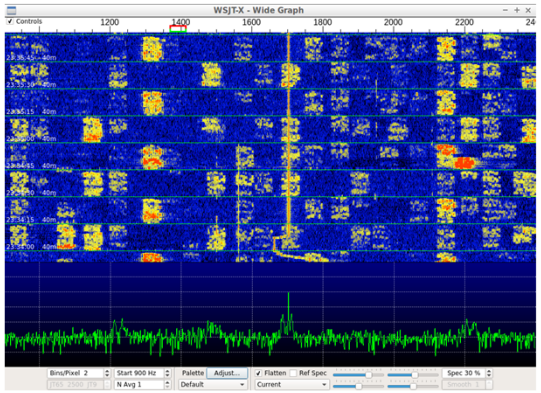

Note: 20+ simultaneous QSOs visible

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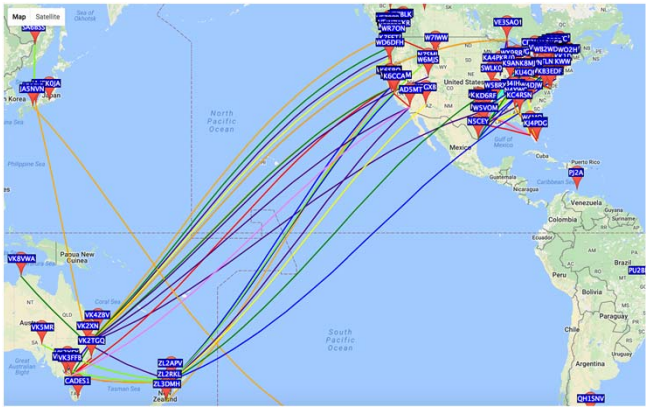
WSPRNet



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Other Modes

- Digital Voice
  - Example: FreeDV
    - 1600 bits/sec
    - 1.25 MHz bandwidth (similar to SSB)
- Tuning around the bands, you may hear:
  - AM - Amplitude Modulation, just like AM broadcast band. About 4 KHz wide
  - ESSB - Extended SSB. Wider bandwidth with wider audio frequency range

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Unit 4: HF propagation basics

- The Sun and the Ionosphere
- Sunspots and Solar Flux
- Rules of Thumb: what band, what time
- MUF
- K index, A index
- Refraction Angles
- NVIS and EMCOMM
- Propagation Predictions

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The Sun and the Ionosphere

- Ionosphere can refract HF signals, allows consistent over-the-horizon propagation
- More sunspots -> higher HF bands (typ. 14 Mhz and above) experience refraction
- Sun has an 11-year cycle (
- At a good solar peak in the 11-year cycle, 10m and higher produce amazing propagation (e.g. California -> Europe S9+), but...
- In mid 2016 we are on the downswing of cycle 24 (began in 2008), which turned out to be a dud.

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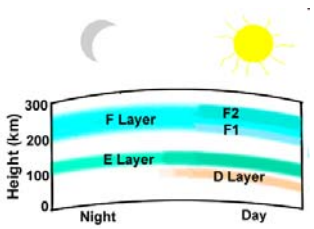
The Ionosphere

- Layers change day vs. night
- D absorbs 10 Mhz and below
- When F layer highly ionized, refracts higher frequencies, e.g. 14 Mhz +



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Sunspot Numbers, Solar Flux

- Ionizing radiation from the sun ionizes the ionosphere, enhances F layer propagation
- SSN (Smoothed Sunspot Number) from observations.
- Solar Flux – proxy for SSN, measures 2800 Mhz radiation from sun.
- Ranges from 0 to ~200 at highest peaks.

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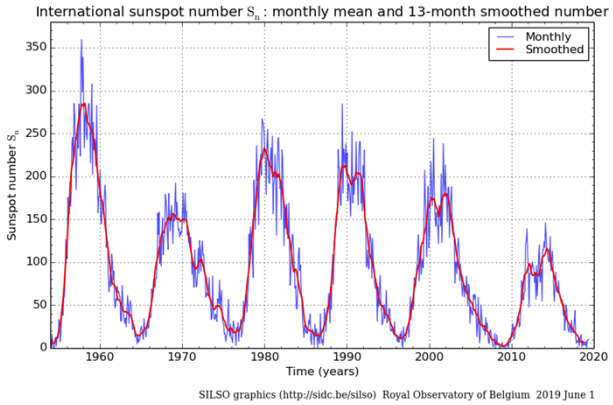
Historical Sunspot Numbers



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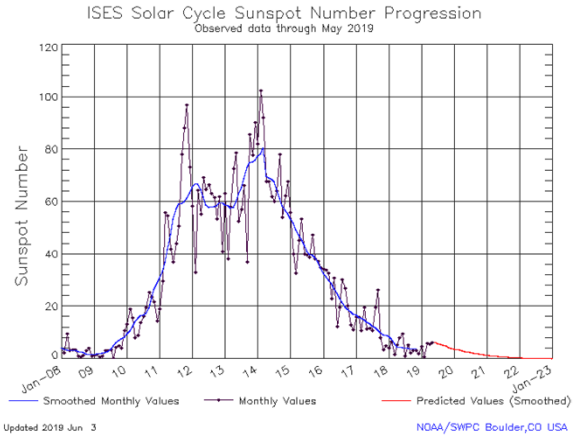
Cycle 24 into 25



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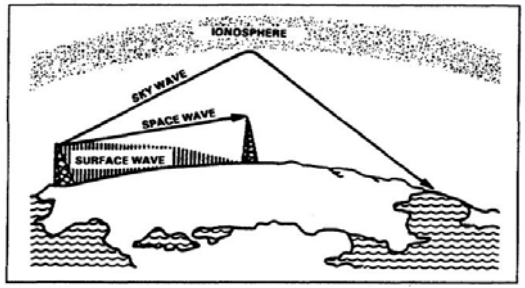
Ground Wave, Sky Wave



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Rules of thumb: band/time of day

- Daytime = more ionization = higher frequency bands (20m+) open (lower frequencies are absorbed and not refracted)
- Nighttime = less ionization = lower frequency bands (40m-80m) open (higher frequencies not refracted)
- Example: recent DX contest at KM6I
  - early afternoon local time: Japan on 15m, 80m dead
  - 2am local time: 20m dead, Japan on 80m
- 30m and 40m often offer some interesting propagation at all times

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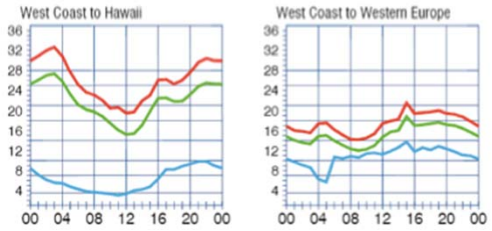
Maximum Usable Frequency

- Highest frequency that will allow communication between two points (via skywave)



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K-Index, A-Index

- Both measure geomagnetic activity.
- A-index linear, K-Index logarithmic
- High values -> geomagnetic storm, propagation may be compromised.
- Best conditions when K <= 3, A <= 15
- Solar flares and coronal mass ejections can cause a geomagnetic storm, which can cause an HF radio blackout. Often sudden onset.

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Refraction Angle

- Longer-path propagation implies lower takeoff angle from antenna.
- Close-in propagation implies high takeoff angle.

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NVIS and EMCOMM

- NVIS = Near-Vertical Incidence Skywave
- Signal goes pretty much straight up, refracted back to close-in targets.
- Useful for regional EMCOMM, e.g. Silicon Valley to Sacramento
- A half-wave dipole close to the ground exhibits very high takeoff angle = good NVIS antenna (but a poor DX antenna)
- More in next section

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Propagation Predictions

- We now have a good physical model of how the ionosphere behaves, and how radio waves interact with it.
- VOACAP engine (from US gov) implements this model.
- Takes into account sunspot number, time, produces estimate of propagation from one point to another
- VOAAREA program feeds model for many receiver points, produces graphs, e.g.

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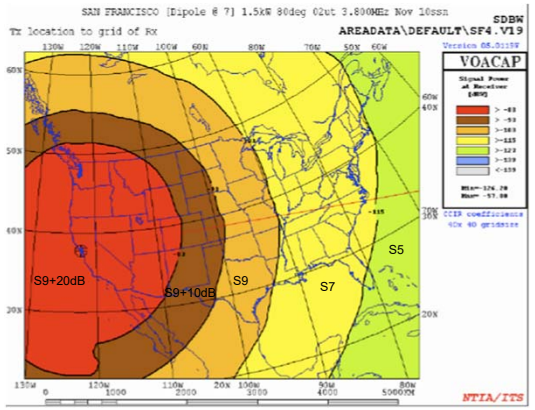
Example VOAAREA plot

from "Tactical Use of Propagation Predictions for HF Contesting", (Dean Straw, N6BV).
Available from http://nccc.cc/webinars.html



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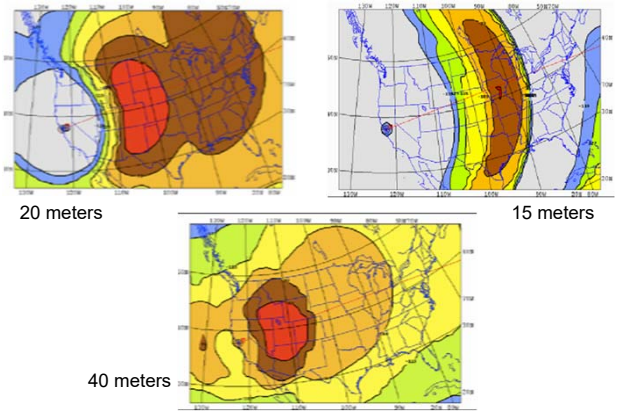
Three different bands at 2200 UTC (3 pm PST), moderate sunspot



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Unit 5: HF Antennas

- Overview
- Basic HF Antenna Types:
  - Wire dipoles
  - Verticals
  - Directional arrays
- Antenna Modeling

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HF Antenna Overview

- Tend to be large
- Two main types: horizontal and vertical
- Antenna Gain – a measure of how well the antenna transmits/receives in a given direction
- Gain is measured relative to a theoretical antenna that radiates equally well in all directions (e.g. a sphere)

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Wire dipoles

- A ½ wavelength wire, fed in the center, exhibits about a 50 ohm impedance (good match for amateur equipment that happens to have 50 ohm impedance)
- Easy to construct
- Can be large (1/2 wavelength on 80 meters is about 120 feet long)
- Unless about ½ wavelength above ground, tend to shoot straight up (NVIS)
- Great if you have tall trees

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Verticals

- Omnidirectional
- Performance highly dependent on quality of ground. Normal soil does not provide a good ground plane, so you need radials (wire on the ground). With a good radial field, verticals can have a low takeoff angle – good DX antenna.
- Raised radials are more effective, but must be resonant
- Salt water ***is*** a good ground plane (at that beachfront villa you own)
- Some "no radials required" verticals are actually dipoles, mounted vertically

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Typical "no-radials" vertical antenna

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Directional arrays

- Most common – yagi. Driven element plus parasitic elements (reflector, directors) turned by a rotator.
- Typical gain for a 3-element yagi is 7-9 dB.
- 9 dB is like going from 100 watts to 800 watts w/same antenna (1.5 S-Unit improvement)
- Yagis for lower bands (40, 80) can get big (75 foot boom for a 4 el 80 meter yagi), and need to be very high (120 ft on 80m)

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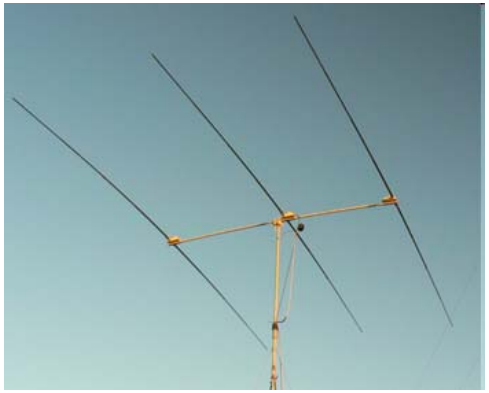
Typical HF Yagi



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A 160 meter (1.8 MHz) Yagi?

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It may end badly...

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Unit 6: Operating Practices

- Telling time
- Calling/Answering CQ
- Phonetics
- Q-codes
- Passing traffic on HF voice
- Sharing the bands
- Signal quality
- RFI

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Telling Time

- Since HF signals cross many time zones, UTC time is used (time in Greenwich, England)
- CA is UTC -8 hours, -7 hours during daylight savings time.
- Example: 1100 local time today is 1800 UTC (6 pm).

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Calling CQ

- Pick a frequency that's:
  - Not in use
  - On a frequency you're licensed for
  - Is not one with a gentleman's agreement
- Listen for a while
- If nothing heard, say "Is this frequency in use" (phone) or send "QRL?" (CW)
- Call CQ

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Example CQs

- Phone: "CQ, CQ, CQ 40 Meters. this is KM6I, Kilo Mike Six India calling CQ 40 Meters and listening."
- CW: "CQ CQ CQ DE KM6I KM6I KM6I K"
- Digital: (same as CW for some modes, others are Call + grid square)
- Several short CQs (with listening time between) are better than one long one

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Answering a CQ

- Be sure you're on the other station's frequency
- Be brief, e.g. "W1AW, this is K6MTV, Kilo Six Mike Tango Victor"

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Typical QSO Exchange

- First round: Signal report, QTH, name
- Second round: gear, occupation, etc.
- FT-8 has standard exchange:
  - Grid squares
  - Signal level in db above receiver noise floor

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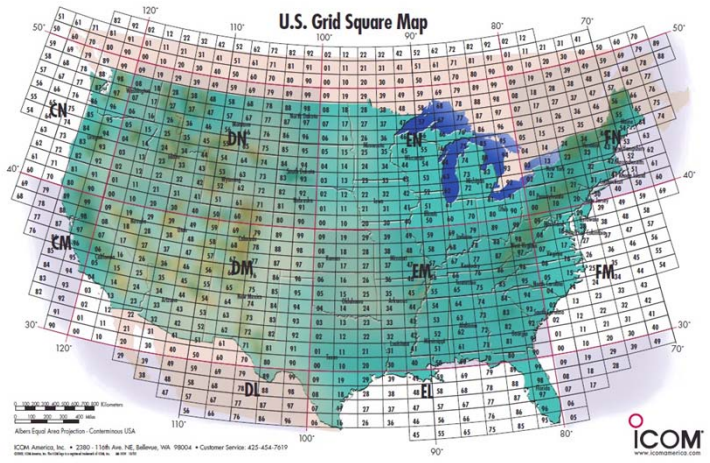
Grid Squares



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Signal Reports: RST

- RST = **R**eadability, **S**trength, **T**one
- Readability: 1 = unreadable, 5 = perfect copy
- Strength: 1 = very faint, 9 = very strong. Many report S-meter reading
- Tone: Not used on phone. On CW: 1 = 60 Hz harsh tone, 9 = perfect sine wave. On digital, has come to mean quality of transmitted digital signal, e.g. how much inter-modulation distortion
- In contests, everyone is 59 or 599

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Phonetics

- Same as we use in ARES, but some latitude.
- Especially in DX contests, some "alternate" phonetics are common:
  - India -> Italy
  - Mike -> Mexico
  - Zulu -> Zanzibar
- Sometimes these seem to "cut through" QRM a bit better, but don't use these on the ARES nets.

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Q-codes

- Discouraged on VHF
- Good for CW, also used on HF SSB
- Common:
  - QRZ? who is calling me
  - QRM interference
  - QRN noise
  - QRS send slower
  - QSY change frequency

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Passing traffic on HF voice

- ARRL Radiogram format is the “Lingua Franca” for messages traveling a long distance – much like our ARES/RACES ICS213 message form
- Otherwise, procedures are just like we teach in local ARES (spell phonetically, pause every 5 words, etc)

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Being a good sport about operating frequencies

- No one “owns” a frequency.
- Listen before transmitting. Then listen some more.
- If a net frequency is occupied, net control will politely ask others to vacate, and they usually do.
- Be aware that on HF, because of propagation, you might only hear one side of a conversation.
- Always ask: “QRL?” on CW, “Is the frequency in use?” on voice.
- Respect informal band plans (e.g. stay away from beacon frequencies).

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Transmitted signal quality

- It’s your responsibility to make sure your signal is clean.
- Ideally, all of us would have a monitor scope, but…
- Often signal reports from other amateurs are the tool we have.
- Become familiar with how to generate a clean signal on the modes you operate.

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RFI – Radio Frequency Interference

- RFI received by amateur:
  - Many consumer electronic devices emit stray RF
  - Chokes, shielding often help
- RFI “caused” by amateur:
  - Devices act as unintentional receivers
  - Chokes, shielding, shortening long wires are often helpful
- ARRL **RFI Handbook**
- **A Ham’s Guide to RFI, Ferrites, Baluns, and Audio Interfacing** – Jim Brown, K9YC, on web

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Unit 7: Having Fun on HF

- It's magic!
- DXing
- Contesting
- Weird stuff (e.g. "K" beacon)
- The missing Q codes

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It's Magic!

- Using about as much power as a light bulb, you can transmit a signal that will induce enough current in a piece of wire in Japan so that a ham there can communicate with you.
- On HF, you really feel connected with what's going on with the Sun, the Earth, and the ionosphere.

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DXing

- DXing = making contacts over long distances
- Awards granted for things like 100 countries (DX Century Club) etc.

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Casual DX vs. pileups

- For "non-rare" DX stations, you may be able to ragchew
- Rare countries produce pileups: many stations calling at once
- DX station's goal is to make as many contacts as possible, esp. for dxpeditions.
- Typical report during a pileup is **only** a signal exchange
- Good DX ops can do hundreds of QSOs per hour
- DX stations often listen on one frequency and listen on another

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Contesting

- My favorite aspect of the hobby
- General Objective: as many contacts as possible in a given time period
- Hones operator skills, especially for modest station (100 watts, wire antennas)
- Many different contests each year. See http://www.hornucopia.com/contestcal/
- Local club: Northern California Contest Club http://nccc.cc

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Contest Exchanges

- Each contest will have its own exchange. Need to read the rules
- ARRL Field Day in June is a great way to try contesting
- Many clubs have a GOTA (Get On The Air) station with mentors to help – show up and they'll help you try it out!
- Example: Field Day exchange is <Class> <ARRL Section>

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Let's Make a Field Day QSO

- We hear station W8UM calling CQ, and call:
  - *W8UM:* **"CQ Field Day. This is W8UM, Whiskey Eight Uniform Mike, Field Day"**
  - *K6MTV:* **"W8UM, Kilo Six Mike Tango Victor"**
  - *W8UM:* **"K6MTV, Three Alfa, Michigan"**
  - *K6MTV:* **"Roger. One Foxtrot, Sierra Charlie Victor"**
  - *W8UM:* **"Thanks and Good Luck. Whiskey Eight Uniform Mike, Field Day"**

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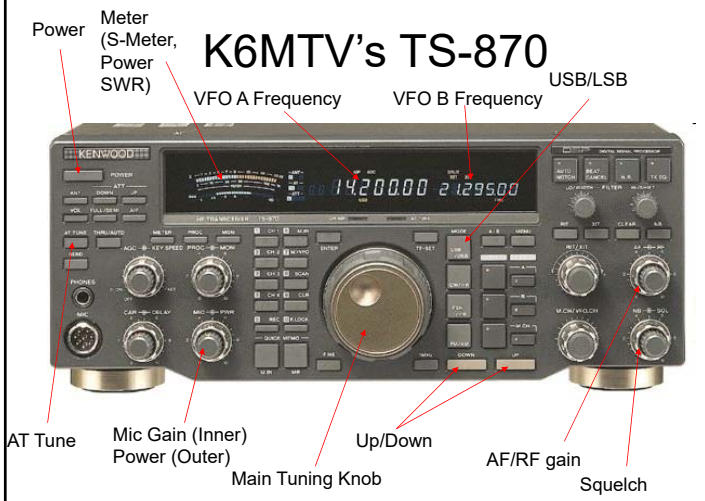
K6MTV's TS-870



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Computer Integration

- Computer logging programs can handle all logging and duping tasks
- Also can send CW and pre-recorded voice exchanges
- Most programs will interface with radio and will read frequency from radio and log it
- Other nice features: visual cues for duplicates, pre-fills, fast frequency switching
- First time I used N1MM, I thought I'd need scratch paper to jot down calls. Never used it!

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Contest Stations

- It's possible to have a lot of fun with a modest station:
  - 100 watts, wire antenna
  - special challenges in QRP (< 5 watts)
- some people take this very seriously, like the following:

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A "modest" contest station

http://www.arubaqth.com/index.html

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A not-so-modest station (N0NI)

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K3LR Multi-Op Station

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SO2R

- **S**ingle **O**perator **2 R**adios
- Two radios on different bands. Typically, one radio is the “run” radio and the other is used for S&P.
- While the run radio is calling CQ, operator tunes the other radio.
- Audio switching allows op to listen to run rig, S&P rig, or both (one in each ear).
- If no answer to CQ, make an S&P contact on the other radio.
- It’s rub-tummy-and-pat-head to the extreme!

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SO2R Station

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SO6V

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Resources

- Clubs with HF interests:
  - Palo Alto Amateur Radio Association http://paara.org/
  - Foothills Amateur Radio Society https://www.fars.k6ya.org/
  - Northern California DX Club http://ncdxc.org/
  - Northern California Contest Club http://nccc.cc/
- Events:
  - Pacificon (San Ramon Oct 20-22) http://pacificon.org/

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"Elmering"

- Elmer = one-on-one mentor
- NCDXC:
  - Helps you learn how to set up an HF station
  - Webinars + visits to elmer's stations
  - http://www.ncdxc.org/pages/elmer.html
- CW Operators Club CW Academy:
  - Mentors, one-on-one CW experience
  - https://www.cwops.org/cwacademy.html

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Thanks!
Any Questions?

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