

An Introduction to HF Communications

Gordon Good, KM6I

Assumptions

- Assume you are familiar with VHF/UHF from your EMC/COMM work.

About KM6I

- Licensed since 1975
- WN8YVI, WB8YVI, KC8ES
- Active on HF 1975-1981, some contesting at W8UM
- Inactive on HF for many years
- Got back into HF + contesting in 2008

Outline

1. The HF Bands
2. Modes
3. HF Propagation Basics
4. HF Antennas
5. Operating Practices
6. Having Fun on HF

Unit 1: The HF bands

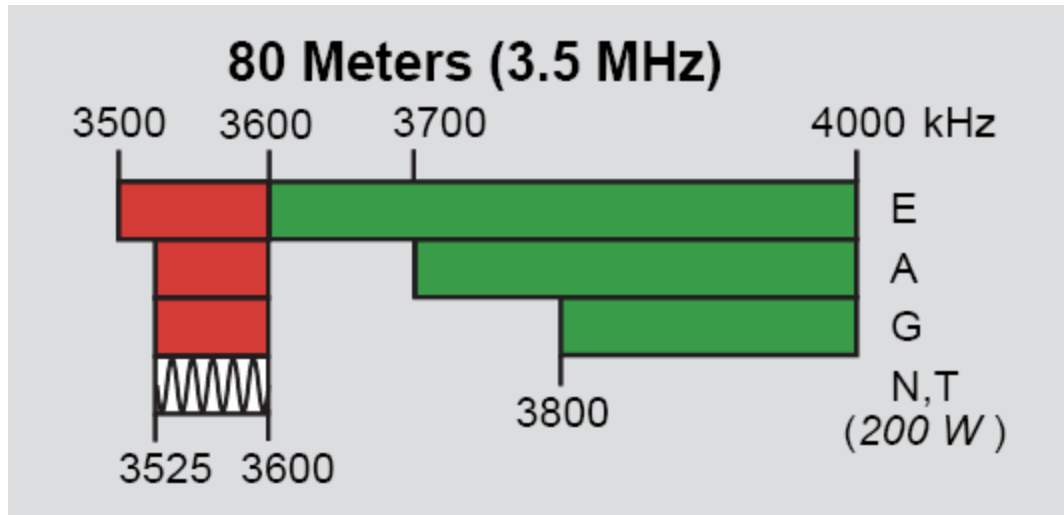
- HF Amateur Bands
- Sub-bands: license class, mode
- Sub-bands: considerate operators
- Special Considerations:
 - Primary vs. Secondary users
 - WARC
 - 60 meters

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)

Sub-bands: license class, mode

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



KEY

Note:
CW operation is permitted throughout all amateur bands except 60 meters.
MCW is authorized above 50.1 MHz, except for 219-220 MHz.
Test transmissions are authorized above 51 MHz, except for 219-220 MHz

Legend:

- Red = RTTY and data
- Green = phone and image
- Hatched = CW *only*
- Yellow = SSB phone
- Cyan = USB phone *only*
- Orange = Fixed digital message forwarding systems *only*

License Class Legend:

- E = Amateur Extra
- A = Advanced
- G = General
- T = Technician
- N = Novice

See ARRLWeb at www.arrl.org for more detailed band plans.

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

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
- 30 m shared with fixed services in other parts of the world
- 60 m shared with mobile and fixed services

WARC bands, 60 meters

- WARC = World Administrative Radio Conference
- 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

Unit 2: HF Modes

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

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, and other digital modes

CW

- 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 \approx 80 Hz



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



Digital modes

- RTTY – most popular, also most antiquated. 5-bit baudot code. No ECC or retry 📢
- PSK-31. No ECC/retry 📢
- 300-baud packet 📢
- PACTOR 📢
- Other modes, e.g. Olivia

Unit 3: HF propagation basics

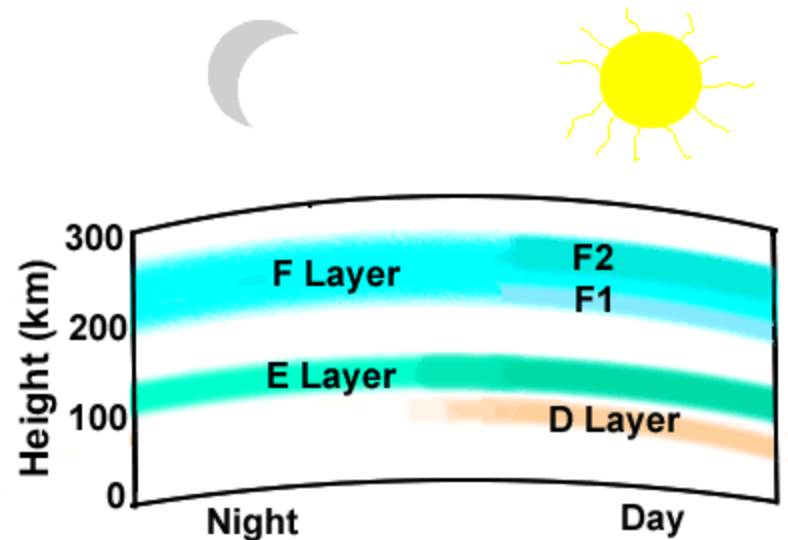
- The Sun and the Ionosphere
- Sunspots and Solar Flux
- Rules of Thumb: what band, what time
- MUF
- K index, A index
- Refraction Angles
- NVIS and EMCOMM
- Propagation Predictions

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
- We are emerging from the bottom now (mid 2010) – now seeing cycle 24 sunspots
- Now, 15m and above are rarely “open”
- At solar peak, 10m and higher produce amazing propagation (e.g. California -> Europe S9+)

The Ionosphere

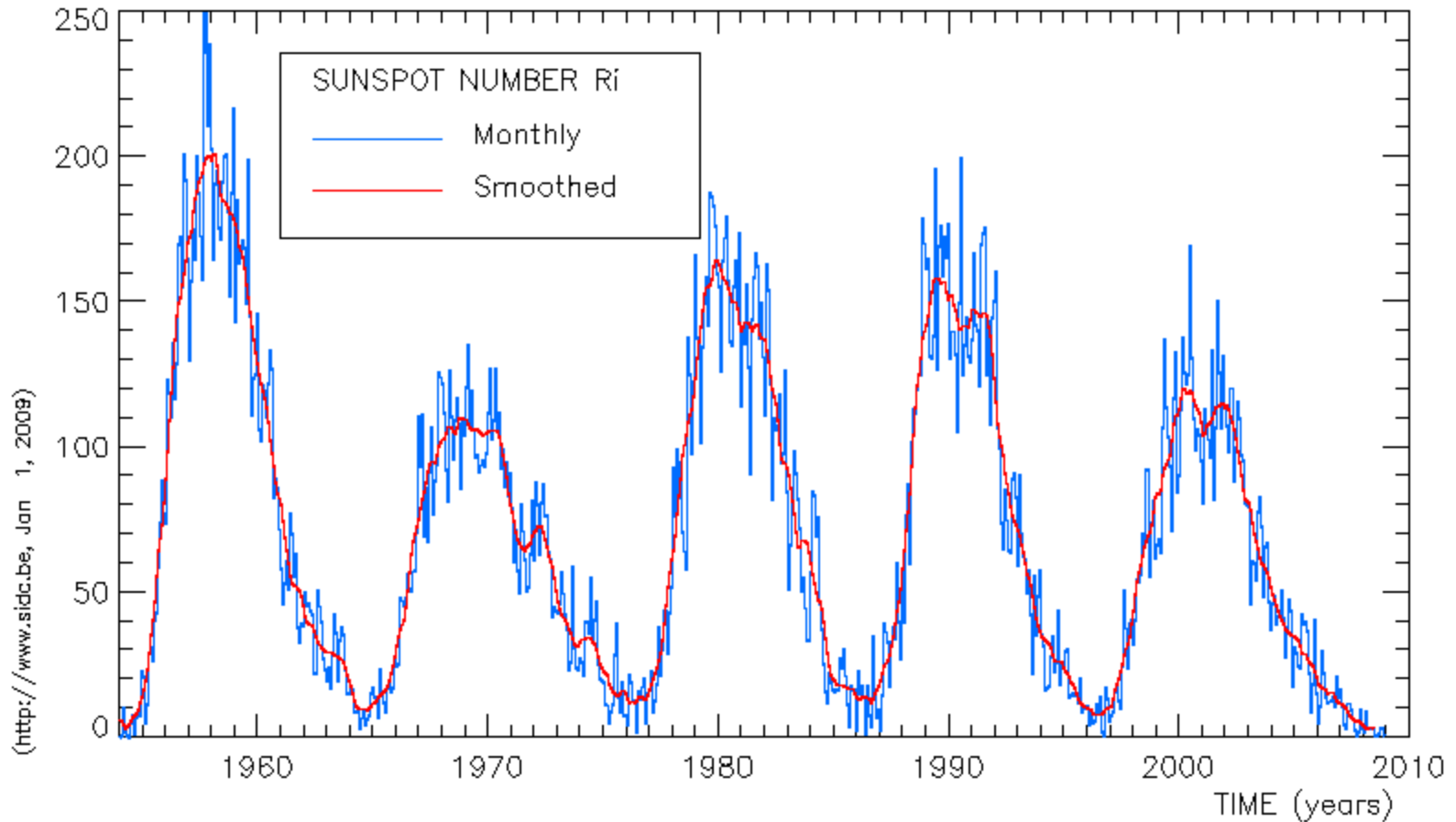
- Layers change day vs. night
- D absorbs 10 Mhz and below
- When F layer highly ionized, refracts higher frequencies, e.g. 14 Mhz +



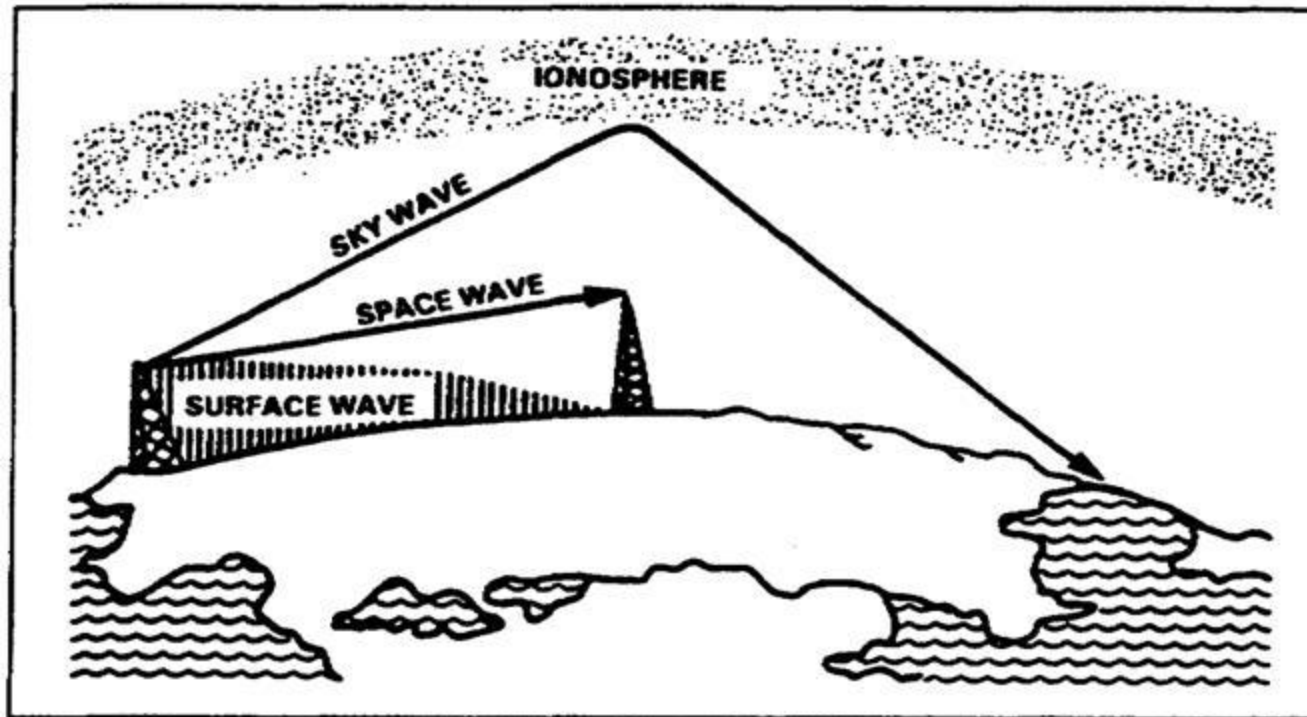
Sunspot Numbers, Solar Flux

- 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.

Historical Sunspot Numbers



Ground Wave, Sky Wave

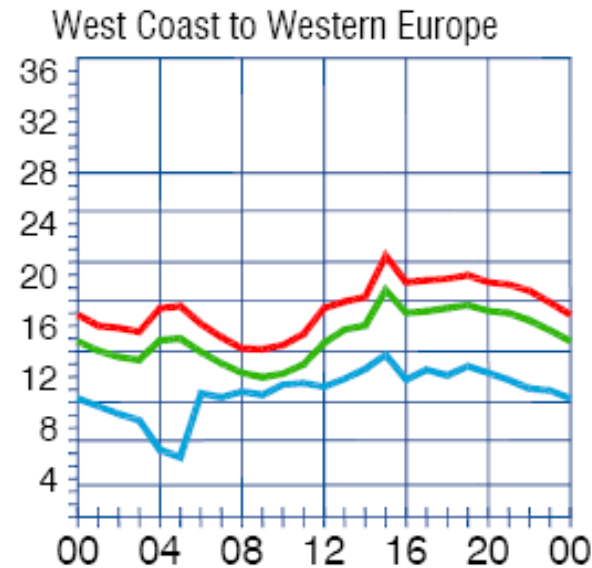
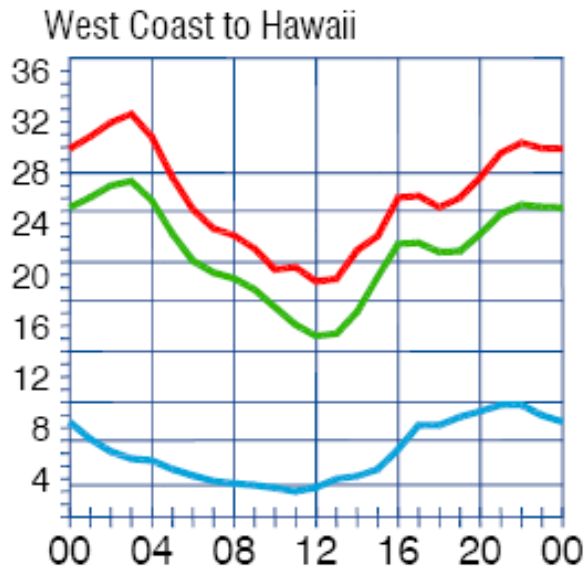


Rules of thumb: band/time of day

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

Maximum Usable Frequency

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



K-Index, A-Index

- Both measure geomagnetic activity.
- High values -> geomagnetic storm, propagation may be compromised.
- Best conditions when $K \leq 3$, $A \leq 15$
- Solar flares can cause a geomagnetic storm, which can cause an HF radio blackout. Often sudden onset.

Refraction Angle

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

NVIS and EMCOMM

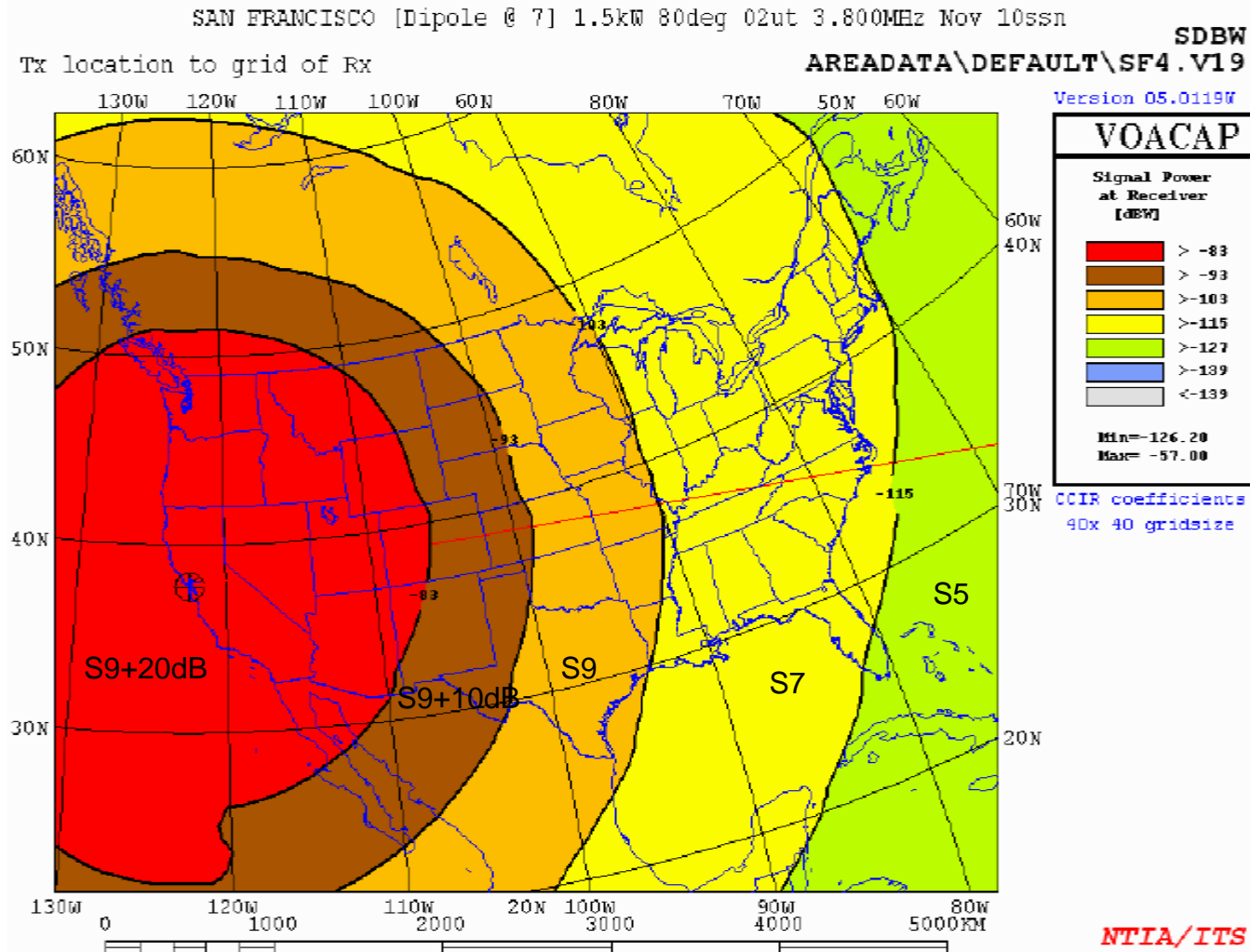
- NVIS = Near-Vertical Incidence Skywave
- Signal goes pretty much straight up, refracted back to close-in targets.
- Useful for regional EMCOMM, e.g. Silicon Valley to Sacramento
- A half-wave dipole close to the ground exhibits very high takeoff angle = good NVIS antenna (but a poor DX antenna)
- More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

Propagation Predictions

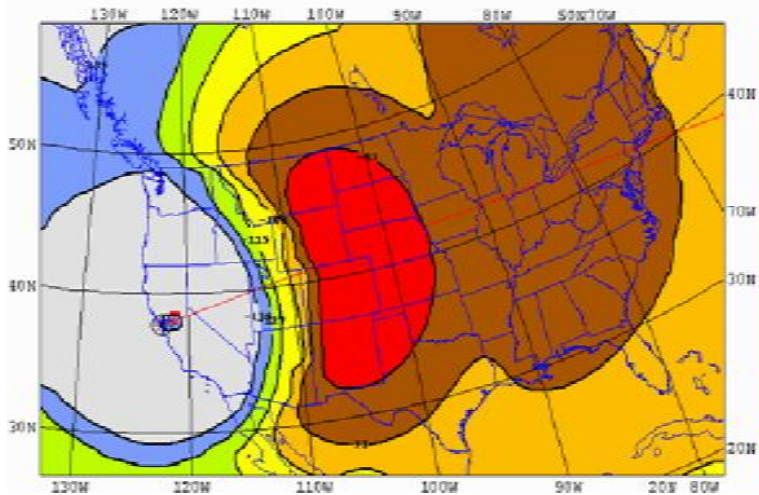
- We now have a good physical model of how the ionosphere behaves, and how radio waves interact with it.
- VOACAP engine (from US gov) implements this model.
- Takes into account sunspot number, time, produces estimate of propagation from one point to another
- VOAREEA program feeds model for many receiver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

Example VOAAREA plot

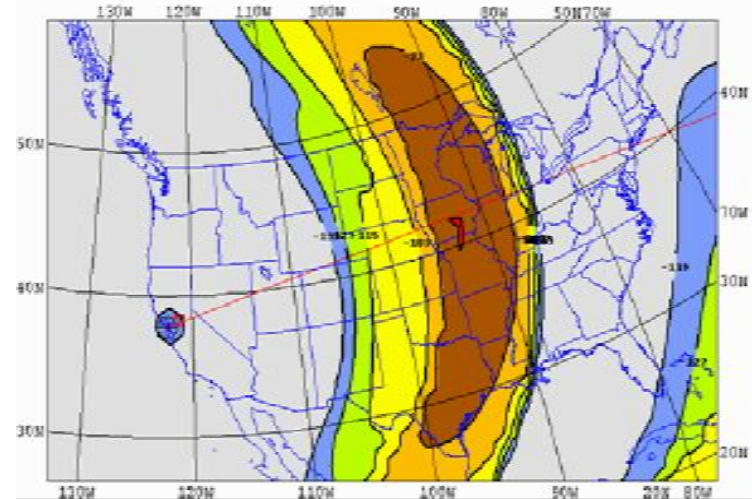
from "Tactical Use of Propagation Predictions for HF Contesting", (Dean Straw, N6BV).
Available from <http://nccc.cc/webinars.html>



Three different bands at 2200 UTC (3 pm PST)

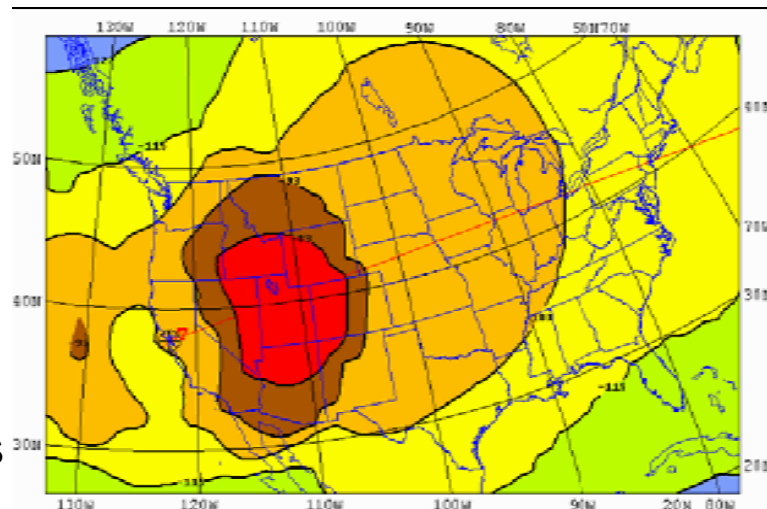


20 meters



15 meters

40 meters



Unit 4: HF Antennas

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

Antenna gain

- Isotropic Radiator: a theoretical antenna that radiates equally in all directions (e.g. a sphere).
- Practical antennas have asymmetrical patterns, and also interact with the earth.
- Antenna gain usually in reference to isotropic, e.g. an antenna with 3 dBi has 3 db more gain than an isotropic radiator.
- Typically 1 S-Unit is 6 dB

Wire dipoles

- A $\frac{1}{2}$ wavelength wire, fed in the center, exhibits about a 50 ohm impedance (good match for amateur equipment)
- Easy to construct
- Can be large (1/2 wavelength on 80 meters is about 120 feet long)
- Unless about $\frac{1}{2}$ wavelength above ground, tend to shoot straight up (NVIS)
- When higher, exhibit some directivity

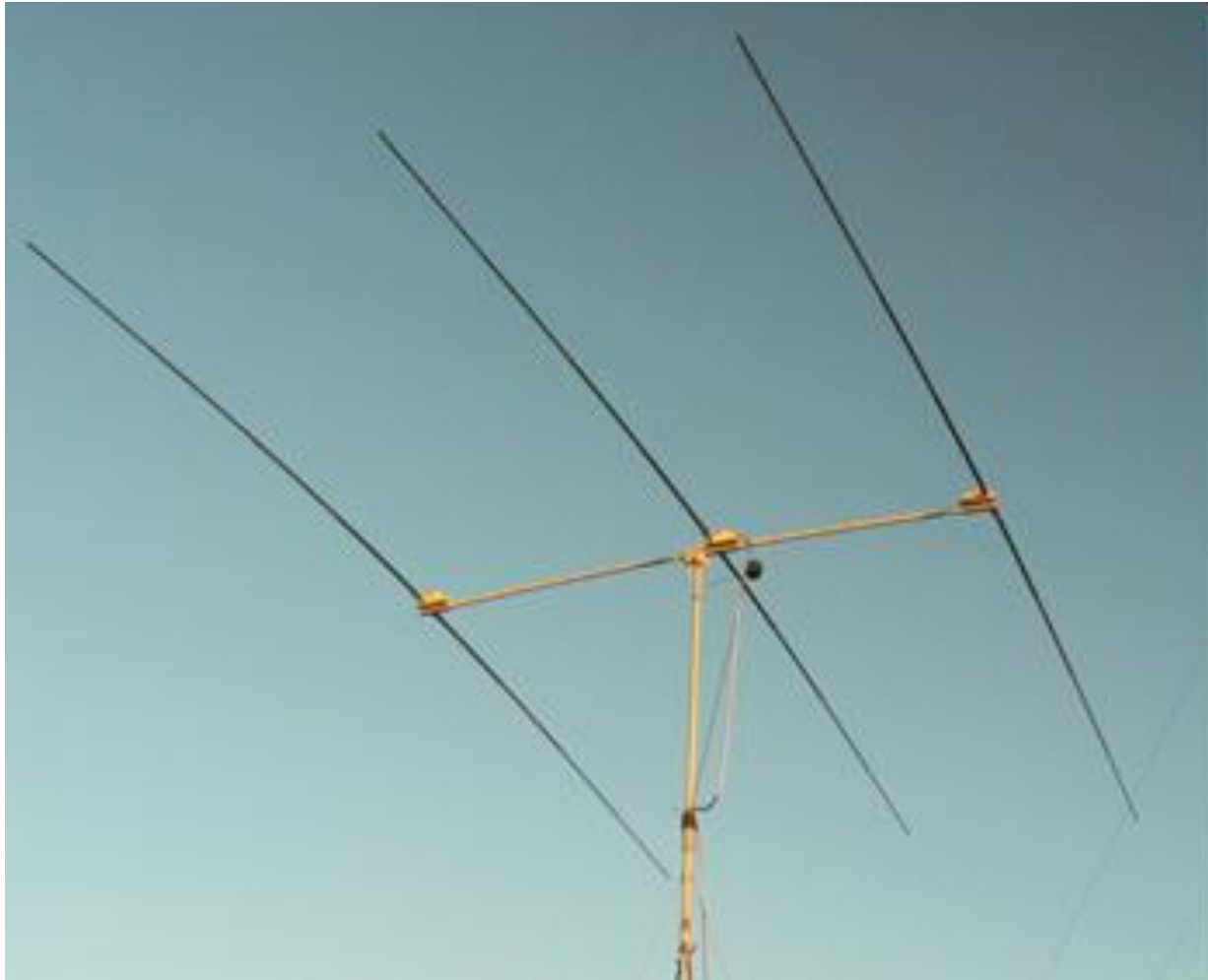
Verticals

- 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.
- Salt water *is* a good ground plane (at that beachfront villa you own)
- Some “no radials required” verticals are actually dipoles, mounted vertically

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 400 watts (1.5 S-Unit improvement)
- Yagis for lower bands (40, 80) can get big (75 foot boom for a 4 el 80 meter yagi)

Typical Yagi



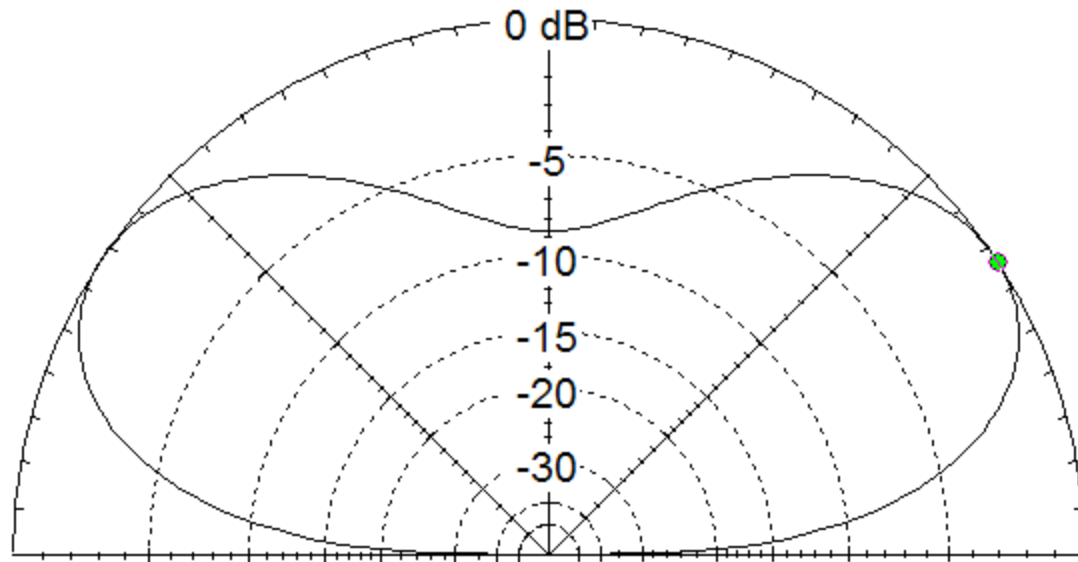
Antenna Radiation Patterns

- You can plot the gain of an antenna, either in 2d or 3d.
- A 2d elevation plot shows the gain at various elevations, e.g. looking at the antenna from the side
- A 2d azimuth plot shows the gain around the compass headings, e.g. looking down.
- A 3d plot shows both.

2d Elevation Plot

Total Field

EZNEC

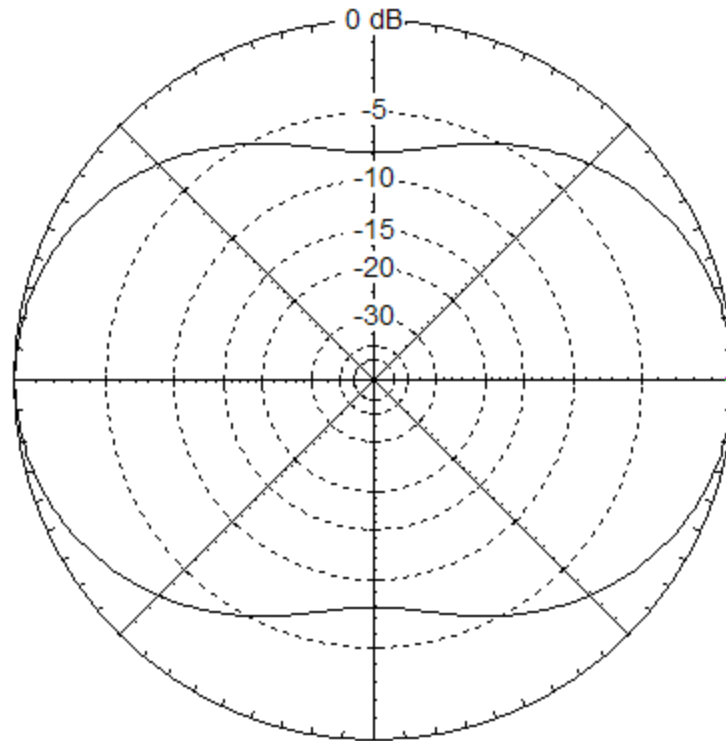


14 MHz

2d Azimuth Plot

Total Field

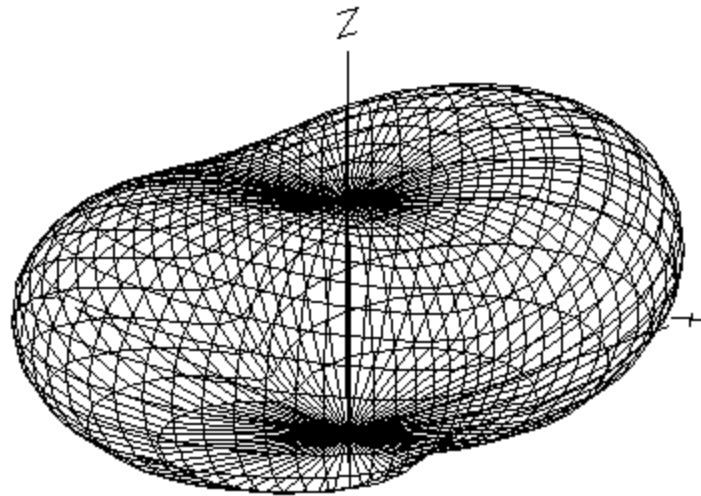
EZNEC



14 MHz

3d Plot

EZNEC



Antenna Modeling

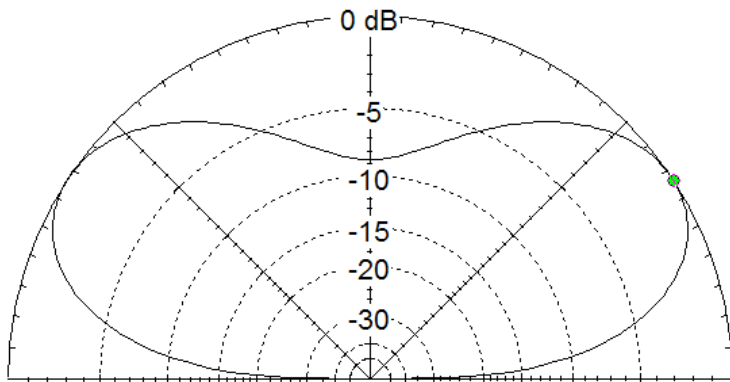
- You can model antennas using free or inexpensive software
- NEC-2 engine (Numerical Electromagnetic Code) was developed in 1970s, and is freely available
- A number of GUIs exist that make it easier to use. EZNEC by W7EL exists in both free and paid versions
- NEC-4 engine is more sophisticated, but is proprietary

Angle of elevation

- Generally, an antenna with a lower angle of radiation will produce better results for long-haul contacts.

Total Field

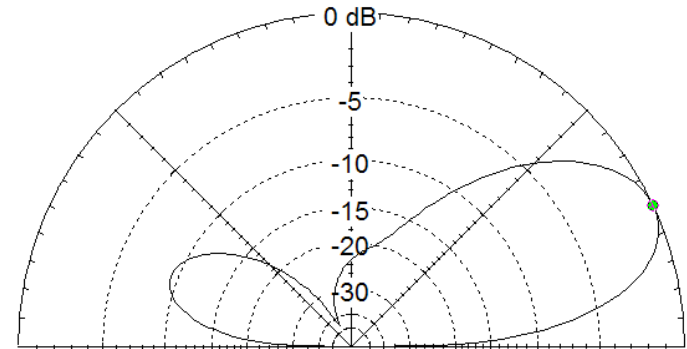
EZNEC



14 MHz

Total Field

EZNEC



21.2 MHz

Unit 5: Operating Practices

- Telling time
- Calling/Answering CQ
- Phonetics
- Q-codes
- Passing traffic on HF voice
- Sharing the bands
- Signal quality
- RFI
- The Kenwood TS-870 at K6MTV

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).

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

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)
- Several short CQs (with listening time between) are better than one long one

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"

Typical QSO Exchange

- First round: Signal report, QTH, name
- Second round: gear, occupation, etc.

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
- In contests, everyone is 59 or 599

Phonetics

- Same as we use in ARES, but some latitude.
- Especially in DX contests, some “alternate” phonetics are common:
 - Uniform -> United
 - Mike -> Mexico
 - Zulu -> Zanzibar
- Sometimes these seem to “cut through” QRM a bit better

Q-codes

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

Passing traffic on HF voice

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

Being a good sport about operating frequencies

- No one “owns” a frequency.
- If a net frequency is occupied, net control will usually ask others to vacate, and they usually do.
- Be aware that on HF, because of propagation, you might not hear a station on a frequency.
- Always ask: “QRL?” on CW, “Is the frequency in use?” on phone.
- Respect informal band plans (e.g. stay away from beacon frequencies).

HF and "good ears"

- HF just sounds a lot different than VHF-FM
- Know how to use your radio's features to eliminate interference. Tools:
 - Narrow filters
 - IF shift/passband tuning
 - Notch filters
 - Noise blankers

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.
- However, there are some rules of thumb, for each mode.

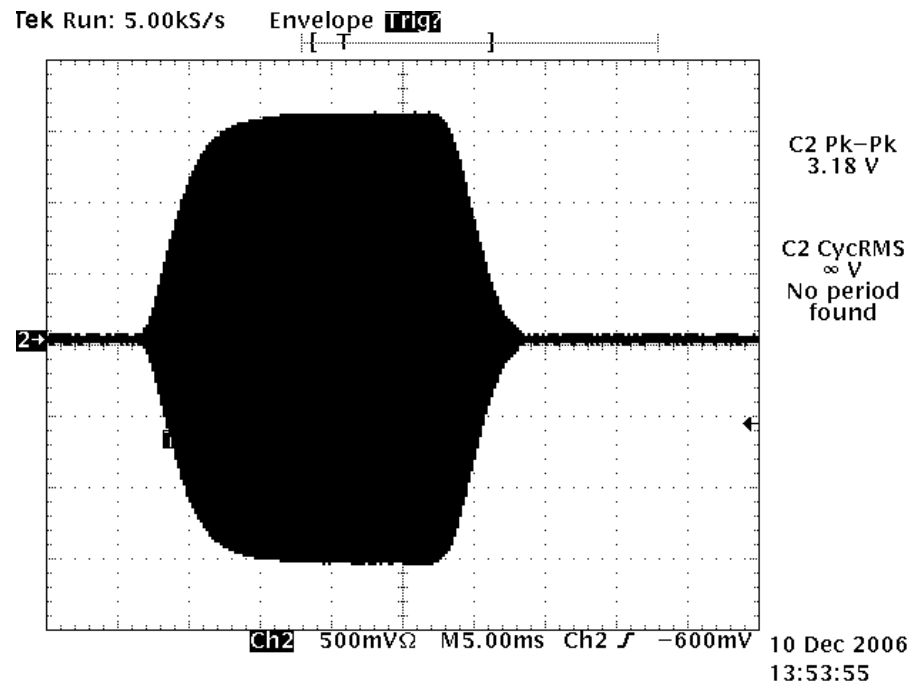
SSB: mic gain/processing/splatter

- Avoid background noise: use a good quality microphone, speak close to it.
- Don't overdrive the audio – you'll end up with a very wide signal.
- Speech processing can improve the “punch” but too much and you'll produce splatter.

CW: key clicks



- CW keying waveform – if rise or fall is too fast, you'll get key clicks. Generally requires rig mod to fix.



Digital mode and overdriving

- When using a computer sound card to generate digital signals (PSK31, RTTY), you need to avoid overdriving the rig.
- General rule of thumb: adjust sound card output level so that rig's ALC meter just barely moves.
- Too much drive causes Intermodulation Distortion (IMD – extra signals above/below the desired signal)

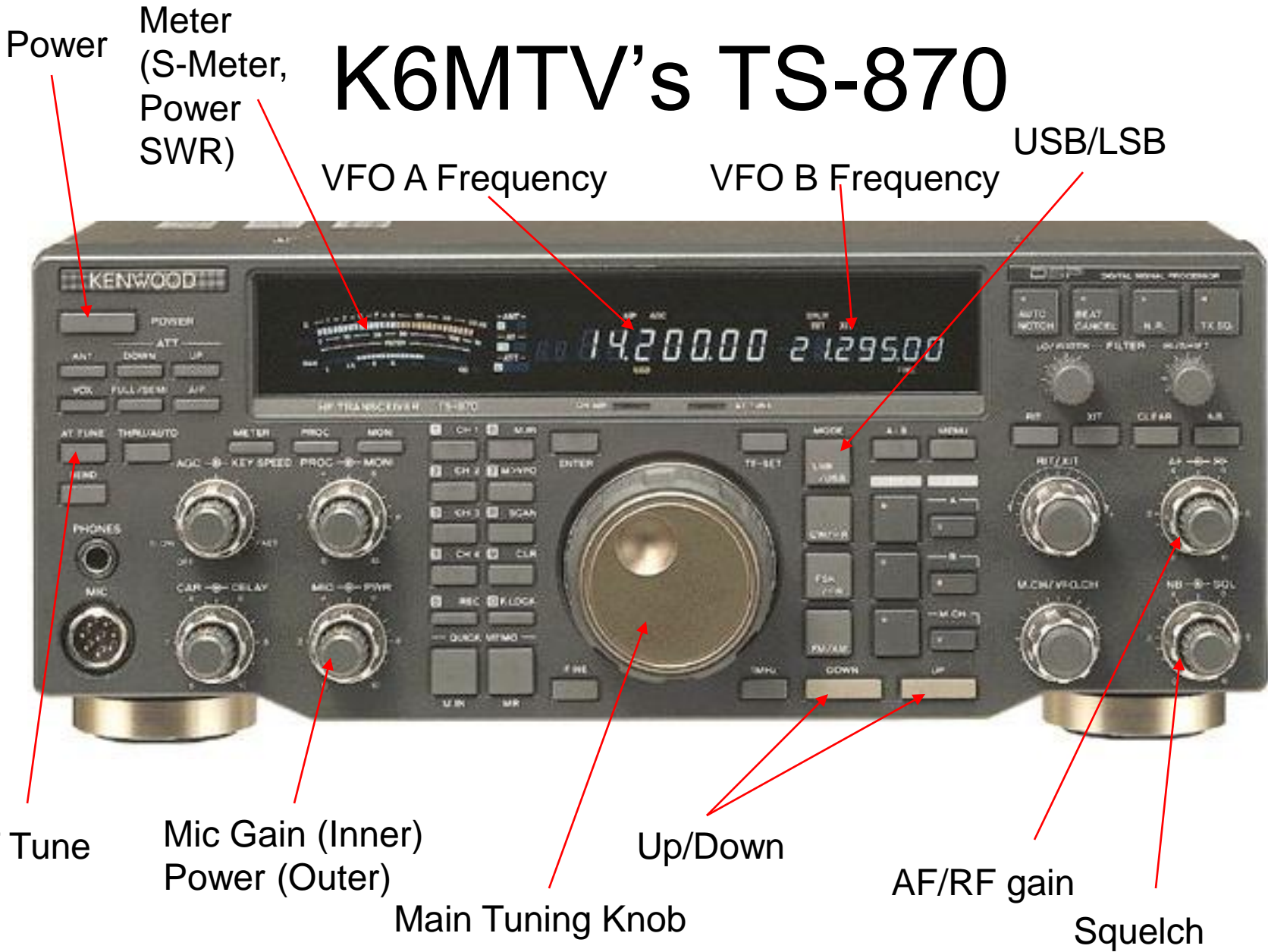
RFI

- RFI – Radio Frequency Interference
- Just plan for it, and approach it methodically
- 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

RFI Resources

- **ARRL RFI Handbook**
- **A Ham's Guide to RFI, Ferrites, Baluns, and Audio Interfacing** – Jim Brown, K9YC, on web

K6MTV's TS-870



Unit 6: Having Fun on HF

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

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.

DXing

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

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

Split mode

- Used often in pileups
- DX station transmits on one frequency, and listens on another.
- Calling stations expected to spread out across a few KHz, DX station tunes across callers and picks them out.
- Very easy to goof and transmit on top of DX station!

Contesting

- General Objective: as many contacts as possible in a given time period
- Hones operator skills, especially for modest station (100 watts, wire antennas)

Contest Exchanges

- Each contest will have its own exchange. Need to read the rules
- Field Day exchange is <Class> <ARRL Section>
- Class – designator based on how many simultaneously operating transmitters and power source.
- K6MTV is 1F (one transmitter, established EOC station), in SCV (Santa Clara Valley section)

An FD QSO

- Station W8UM is calling CQ, and is answered by K6MTV
 - *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"

Asking for repeats

- Need whole exchange again: “Again?”
- Need only class: “Your class?”
- Need only section “Your section?”
- If asked for a fill, only give the requested information. Probably good to give it twice, as there’s probably QRM that caused it to be missed the first time.

Running vs. Search and Pounce

- **Running:** calling CQ on a frequency.
- **Search and Pounce (S&P):** tuning around, finding stations not yet worked, and calling them.
- Key to running is having a good signal, and keeping the frequency.
- Key to S&P is to quickly determine the call of the other station and if it's a duplicate, and if not, pounce!
- Successful contesters do both (sometimes at the same time, a.k.a. SO2R, more later)

Computer Integration

- Computer logging programs can handle all logging and duping tasks
- Also can send CW and canned Phone exchanges
- Most programs will interface with radio. Read frequency from radio and log it
- Other nice features: visual cues for dupes, pre-fills, bandmap/DX cluster integration (click to S&P)
- First time I used N1MM, I thought I'd need scratch paper to jot down calls. Never used it!

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, e.g.

A “modest” contest station



A not-so-modest contest station



SO2R

- **Single Operator 2 Radios**
- 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!

SO2R Station



The missing Q signals

- QLF: “I am sending CW with my left foot”
- QBA: “My antenna is BIG”
- QKB?: “How many knobs does your radio have?”
- QZZ - I fell asleep at the mike
- QZZ? - Is that a 60Hz hum, or are you snoring?