HF Update: Making The Most of Your Operating Time

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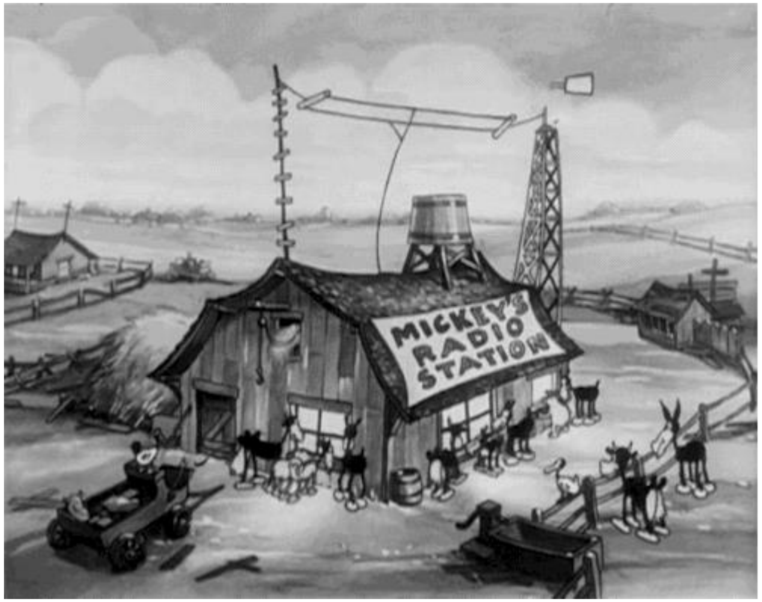
Topics

- Equipment overview
  - Transceivers
  - Antennas
- Using Propagation Data

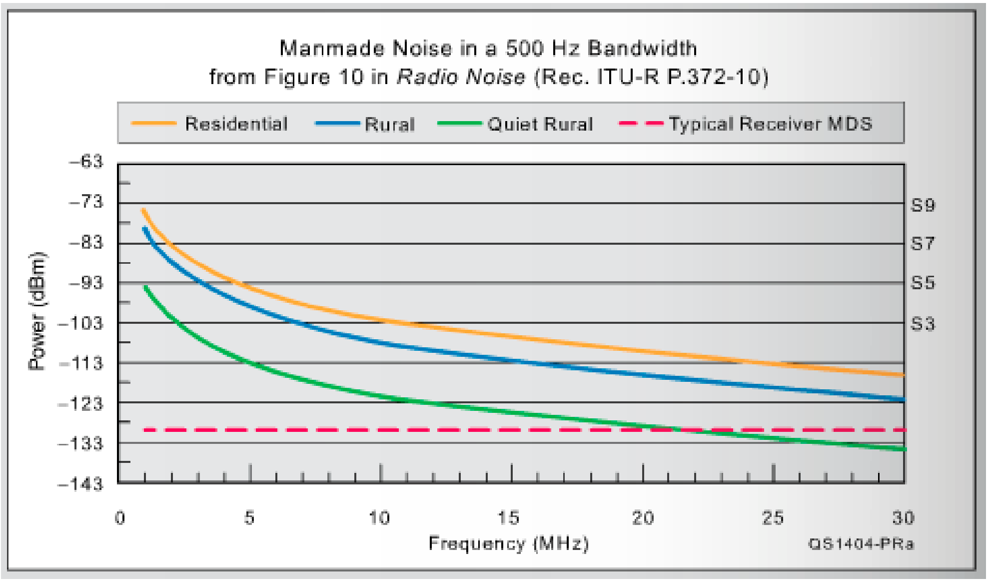
HF Station Requirements Overview

- Most folks think of a transceiver first. This is OK because it is the most expensive item you will need, but it is not the most important in terms of making contacts.
- The Antenna is the most important item when it comes to putting out a signal.
- Other considerations include:
  - Operating bench and its location. Many hams have no home station and only operate portable or mobile.
  - Basic understanding of propagation. You need to know when to get on each band so you can make contacts
  - Station grounding for safety and RF
  - Accessories such as a MIC, key, VSWR/Power meter, antenna tuner, etc.



Transceivers

- We are very fortunate to have so many excellent transceivers to choose from
- I agree with Rob Sherwood, NC0B, that a 90dB Third Order Dynamic Range (DR3) is adequate for most stations. This provides margin for stations with a triband Yagi up 50’ or so.
- You only need this much dynamic range on 10M since the lower frequency bands have higher noise levels which limit weak signal sensitivity



Receiver Performance Summary

Table 1: Dynamic Range by Radio

	2 kHz Spacing DR3	Signal Level Causing 3rd Order IMD = Noise Floor*	Radios in This Class			
**Res. QRN						
	55 dB	S9	FT-757			
40M	60	S9+5 dB	FT-101E			
	65	S9+10 dB	KWM-380	FT-2000	FT-1000D	
20M	70	S9+15 dB	TS-830	FTdx1200	IC-761	
	75	S9+20 dB	IC-756 Pro II/III TS-850	IC-7410/7600 /7700	FT-950 FT-450D IC-781	CW needs
10M	80	S9+25 dB	Ten-Tec Omni VI+/VII	IC-7800 IC-765	FTdx3000	Vertical or Low Dipole
	85	S9+30 dB	R9500, IC-705	TS-990/590S	FTdx9000	
Ref. Sig. Level	90	S9+35 dB	Ten Tec Eagle Ten Tec Orion I	FLEX 6400	TS-590SG	Yagi up >50’
	95	S9+40 dB	Ten-Tec Orion II	IC-7300 IC-7610	Flex 6600 /6700	
	100 dB	S9+45 dB	Elecraft K3, K4 KX3, TS-890, FT-710	FTdx5000, FTdx101D FTdx10	IC-7851 Apache ANAN 7000DLE	Big East Coast Contest Station

*Receiver Noise = -128dBm in a 500Hz BW. Chart Format copied from Rob Sherwood, NC0B

**Dynamic Range requirements are reduced by atmospheric noise at your location.

Other Transceiver Considerations

- Over the past 20 years receiver performance has greatly improved
  - Lower noise frequency synthesizers
  - Return to down-conversion architectures for higher close in dynamic range
  - High resolution spectrum scopes
  - Software defined radios
- Transmitter performance was largely neglected
  - CW waveforms were improved by the new synthesizers
  - SSB splatter is still a problem due to the limitations of 12V amplifier designs and solid-state power amplifiers
- The ARRL and Rob Sherwood have been pushing radio manufacturers to improve transmitter designs
- PA0Q has published a transceiver summary emphasizing SSB distortion https://www.remeeus.eu/hamradio/pa1hr/productreview.pdf

PA0Q QST Product Review Summary

QST Magazine Product Reviews - Key Measurements Summary - HF-Transceivers (page 2/8)

		Transmitter				Receiver							
	Subject of measurement, band: 14 MHz	**Transmit 3rd-order IMD typical**	Transmit 9th-order IMD typical	5 kHz Transmit keying bandwidtch	10 kHz Transmit phase noise	20 kHz reciprocal mixing dynamic range	2 kHz reciprocal mixing dynamic range	20 kHz blocking gain compression	2 kHz blocking gain compression	20 kHz 3rd-order dynamic range	2 kHz 3rd-order dynamic range	20 kHz 3rd-order intercept	2 kHz 3rd-order intercept
	Min/max of scale	**-20/-35 dB**	-20/-70 dB	-55/-95 dB	-110/-150 dB	-60/-140 dB	-60/-140 dB	70/140 dB	70/140 dB	50/110 dB	50/110 dB	-40/+35 dBm	-40/+35 dBm
	Transceivers sorted by Transmit 3rd-order IMD typical and if equal by Transmit 9th-order IMD typical (below PEP output)												
1	**Apache Labs ANAN-8000DLE, April and November 2018**	-54 dB & **	-60 dB &	-95 dB	-136 dB	-115 dB	-110 dB	125 dB	125 dB	100 dB	100 dB	N/M	N/M
2	**Apache Labs ANAN-7000DLE MkII, March 2021**	-51 dB & **	-71 dB & **	-95 dB	-131 dB	-117 dB	-112 dB	127 dB	127 dB	105 dB	104 dB	N/M	N/M
3	**Apache Labs ANAN-100D, October 2015**	-49 dB & **	-60 dB &	N/M	N/M	-117 dB	-105 dB	124 dB	122 dB	97 dB	96 dB	+22 dBm	+22 dBm
4	**FlexRadio FLEX-6600M, February 2020**	-45 dB **	-56 dB	-93 dB	-135 dB	-122 dB	-118 dB	122 dB	122 dB	105 dB	104 dB	N/M	N/M
5	**Yaesu FTdx9000C, March 2006**	-43 dB **	-80 dB **	N/M	N/M	N/M	N/M	128 dB	97 dB	101 dB	78 dB	+35 dBm	+1 dBm
6	**Yaesu FTdx5000D, December 2010**	-43 dB **	-72 dB **	N/M	N/M	N/M	N/M	136 dB *	136 dB *	114 dB **	114 dB **	+41 dBm **	+40 dBm **
7	**Kenwood TS-890S, June 2019**	-42 dB **	-62 dB	-95 dB	-123 dB	-130 dB	-125 dB	>140 dB **	>140 dB **	106 dB	104 dB	N/M	N/M
8	**Yaesu FTdx101d, November 2019**	-42 dB **	-58 dB	-95 dB	-152 dB **	-130 dB	-125 dB	>135 dB	>135 dB	111 dB **	110 dB	N/M	N/M
9	**Kenwood TS-590SG, July 2015**	-42 dB **	-58 dB	N/M	N/M	-118 dB	-94 dB	139 dB	130 dB	106 dB	106 dB	+29 dBm	+29 dBm
10	**Yaesu FT-2000D, October 2007**	-41 dB **	-65 dB	N/M	N/M	N/M	N/M	136 dB	87 dB	98 dB	69 dB	+26 dBm	-16 dBm
11	**Icom IC-7610, October 2018**	-41 dB **	-61 dB	-89 dB	-138 dB	-127 dB	-113 dB	120 dB	120 dB	101 dB	101 dB	N/M	N/M
12	**FlexRadio FLEX-6700, April 2015**	-41 dB **	-61 dB	N/M	N/M	-124 dB	-116 dB	128 dB	128 dB	103 dB	103 dB	+46 dBm **	+46 dBm **
13	**Lab599 Discovery TX500, August 2021**	-41 dB **	-58 dB	N/M	-128 dB	-119 dB	-106 dB	106 dB	105 dB	82 dB	82 dB	N/M	N/M
14	**FlexRadio FLEX-6400M, February 2019**	-41 dB **	-55 dB	-95 dB	-129 dB	-122 dB	-118 dB	123 dB	123 dB	95 dB	94 dB	N/M	N/M
15	**FlexRadio FLEX-6300, April 2015**	-41 dB **	-54 dB	N/M	N/M	-121 dB	-116 dB	127 dB	126 dB	92 dB	92 dB	+43 dBm **	+43 dBm **
16	**Icom IC-705, February 2021**	-40 dB **	-63 dB	-93 dB	-138 dB	-114 dB	-110 dB	124 dB	124 dB	90 dB	90 dB	N/M	N/M
17	**Yaesu FTdx10, June 2021**	-40 dB **	-62 dB	-95 dB	-143 dB	-124 dB	-118 dB	>137 dB	>137 dB	108 dB	108 dB	N/M	N/M
18	**ELAD FDM-DUO, May 2016**	-39 dB **	-70 dB	-88 dB	-141 dB	-108 dB	-104 dB	124 dB	106 dB	99 dB #	99 dB #	N/M	N/M
19	**Elecraft K4, September 2022**	-39 dB **	-57 dB	-97 dB	-137 dB	-127 dB	-118 dB	129 dB	129 dB	103 dB	102 dB	N/M	N/M
20	**Kenwood TS-990S, February 2014**	-39 dB **	-56 dB	N/M	N/M	-117 dB	-87 dB	138 dB	133 dB	112 dB **	101 dB	+44 dBm **	+35 dBm

QST Magazine Product Reviews - Key Measurements Summary - HF-Transceivers (page 3/8)

		Transmitter				Receiver							

Transceiver Purchase Considerations

- If you are considering a new transceiver purchase, I urge you to review the QST Product Reviews, Rob Sherwood's summary and PA0Q's data summary.
- If you are a CW operator look for CW features like an audio peaking filter and the ability to set the rise time to a value >6msec to prevent key clicks
- If you are an SSB operator look at the transmit IMD which causes splatter. Splatter can easily double the signal bandwidth
- SSB operators may also want a transceiver with good receive audio performance

Operational Considerations

- Power amplifiers also add to transmit intermodulation distortion
- Improper drive and ALC settings can make this worse
- Solid state amplifiers have higher IMD than tube amplifiers
- I’ve used both solid state and tube amplifiers and have found the time to retune a tube amplifier when changing bands is less than 30 seconds once you have determined the dial settings.
- Tube amplifiers can be tuned into a 2:1 VSWR with no problems, solid state amplifiers require a lower VSWR or a high-power tuner.
- Have a friend look at your transmit signal to make sure it is adjusted properly. Many hams overdrive the amp which increases IMD
- 100W transceivers can have high AM noise when backed off to drive an amplifier. This can be a problem for high gain amplifiers. This is not tested in the QST product reviews.

What Are Your Constraints?

- Space for your radios and/or antennas
  - HOA limitations drive many hams to portable and mobile operating
  - Remote operations
- Operating time limitations may influence equipment choices
  - For example: If you only operate in the mornings 80 & 40M are your best bands. Atmospheric noise is very high on the low bands, and you can use a radio with only 60dB DR3.
- Are you visually impaired?
  - Some radios have a speech button that announces frequency and mode information
- Budget
  - Consider used equipment
  - Most hams take good care of their equipment.
  - The last generation still has plenty of operating features
  - My IC-756Pro2 (2000 vintage) had a very nice spectrum scope and dual watch for DXing
- Brand Loyalty
- Family obligations

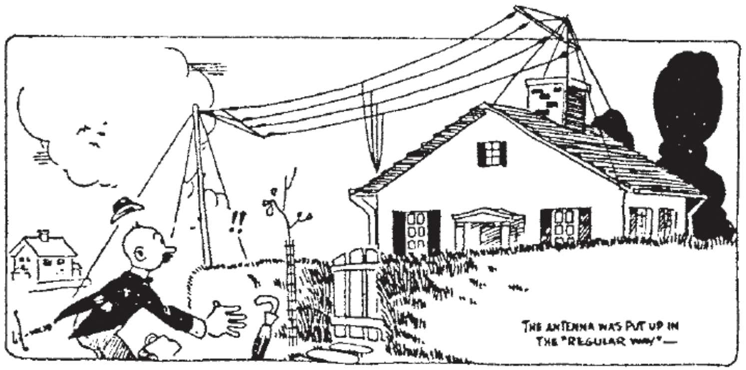
Radio Buying Considerations

- What activities do you participate in?
  - Casual Operation, rag chewing
  - DXing
  - Contesting
  - Primarily CW
  - Primarily SSB
  - Primarily Digital
  - Portable
  - Remote station
- What is your experience level?
  - Beginner
  - Experienced
  - Expert
- What is your budget?
- Ergonomics. The radio must be fun to operate.

Buy a radio that meets your needs, not someone else's. Buy one that you understand and is fun to use

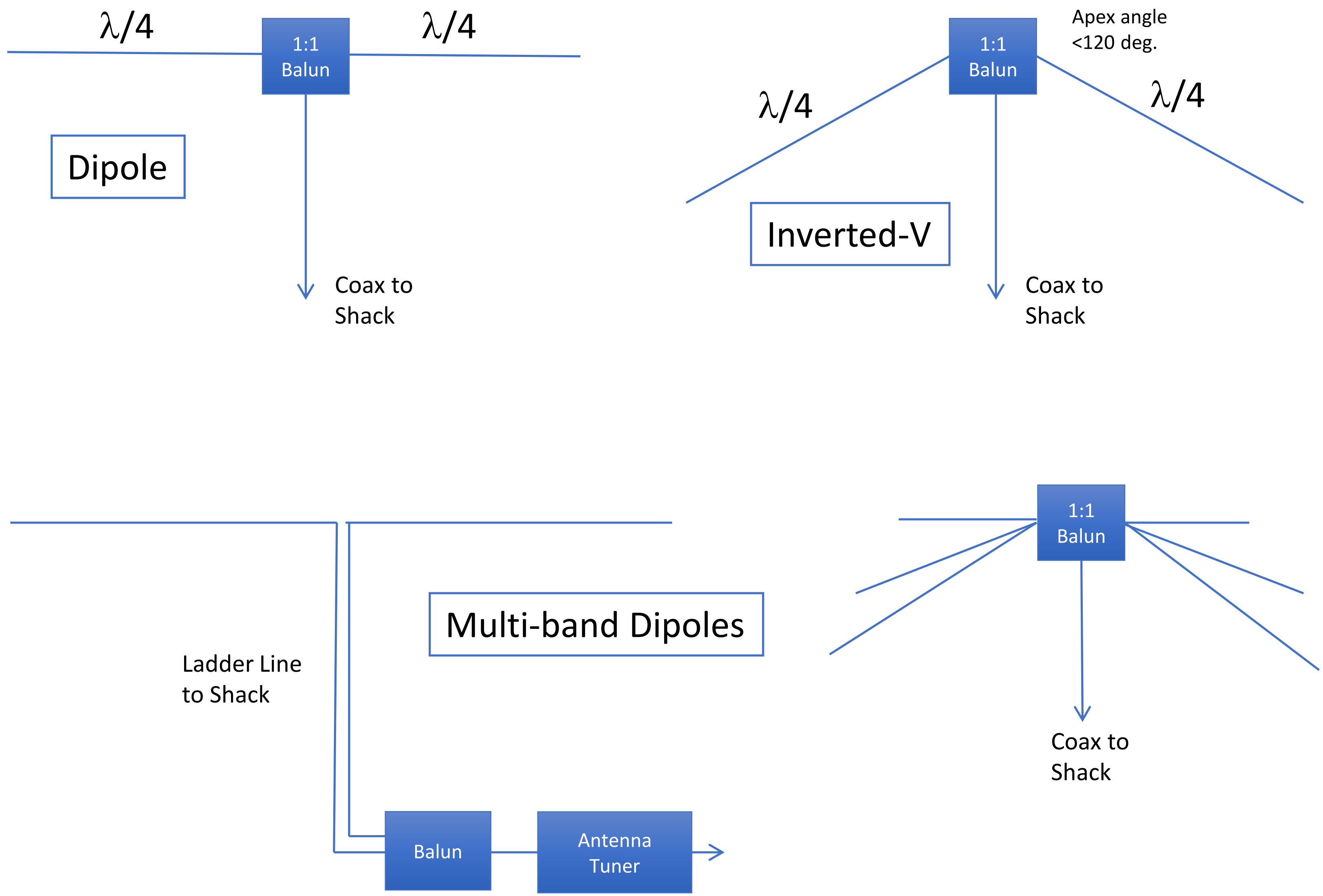
Antenna Overview: *It's All About The Antenna*

- The most important part of a HF station is the antenna
- The antenna couples radio frequency energy to free space in both directions, transmit and receive
- I'm going to use a dipole as my example. Adding more elements like a Yagi adds gain by reducing the azimuth angle, it does not change the elevation angle which is important for DXing
- Changing the feed point of a dipole does not change the radiation pattern. Traditional center fed dipoles have the same patterns as End Fed Half Wave Dipoles or Offset Fed Dipoles
- Changing the shape of a dipole does alter the radiation pattern

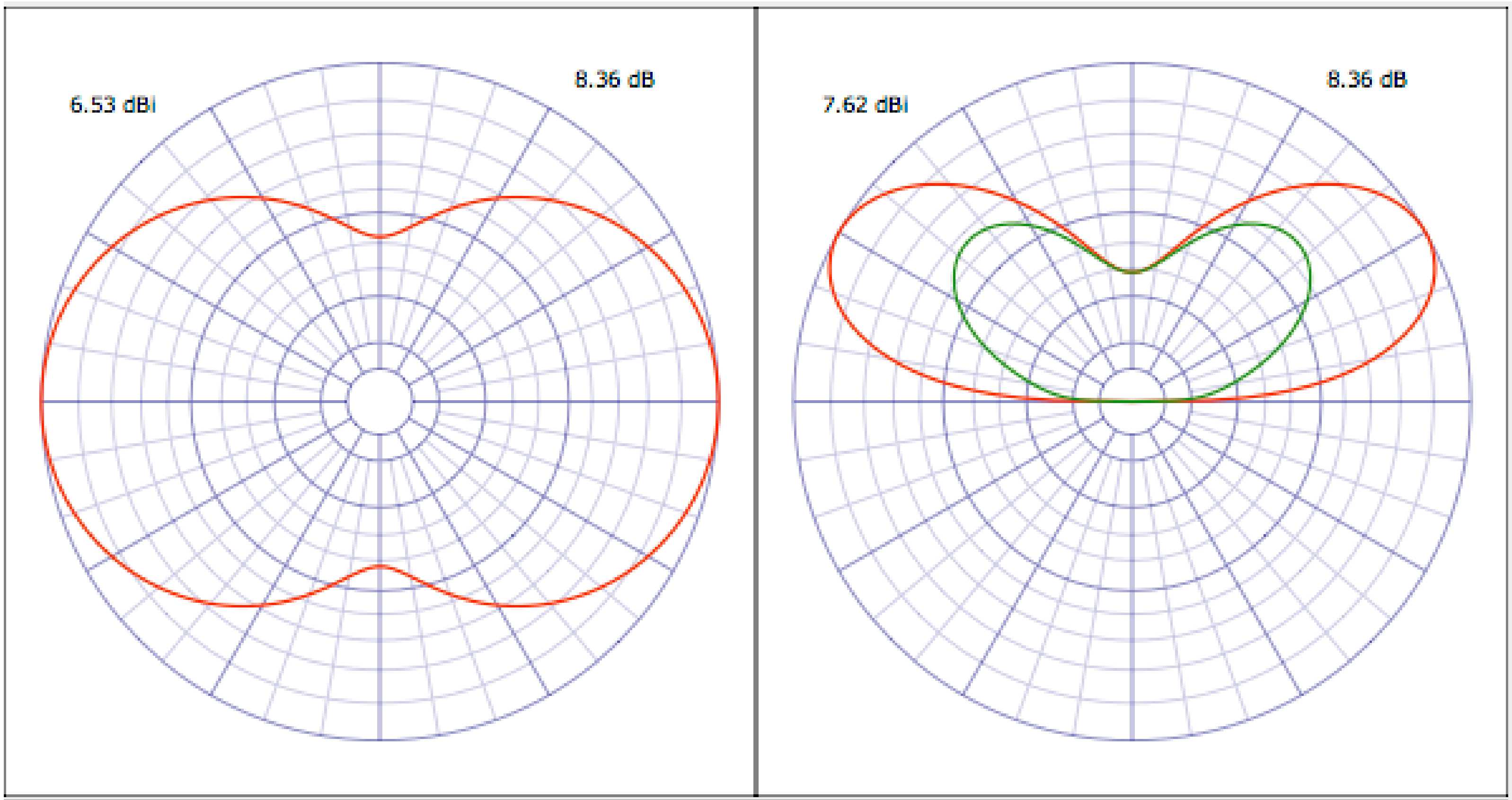


Antenna Modelling is the best way to predict performance for your antenna configuration

Dipole Configurations

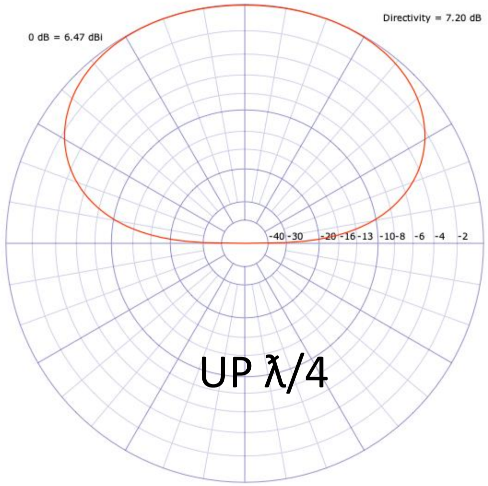


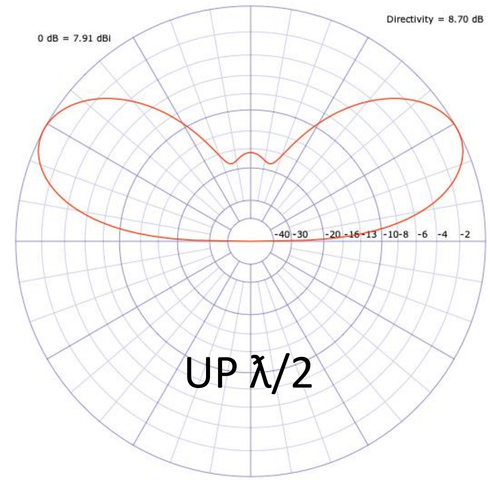
20M dipole up 33’

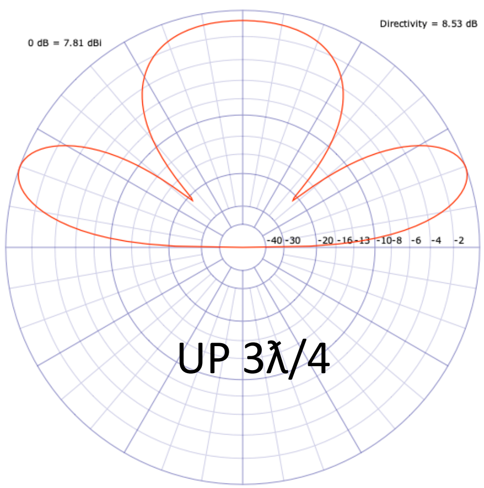


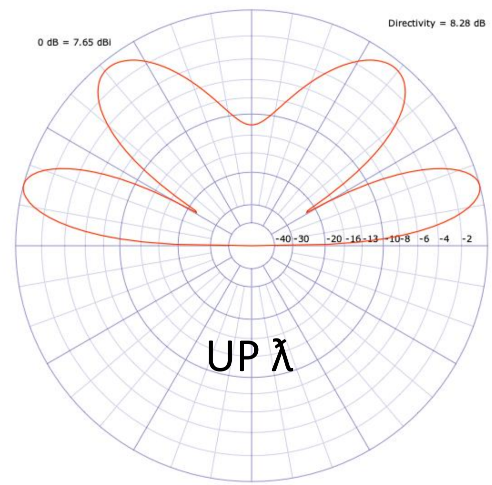
Red is broadside pattern
Green is off the ends

20M Dipole Performance vs. Height

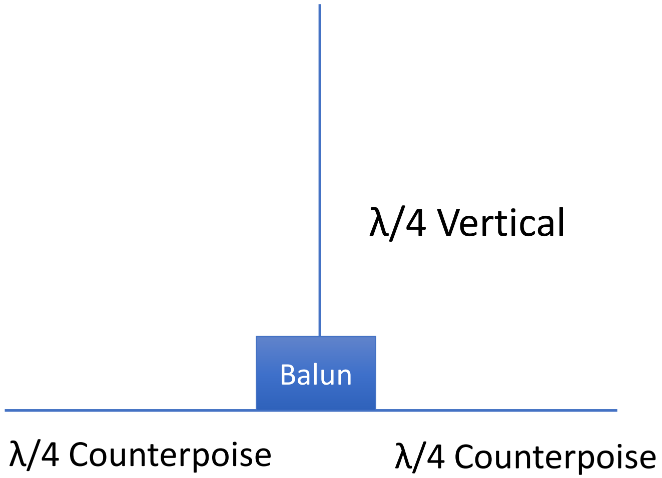




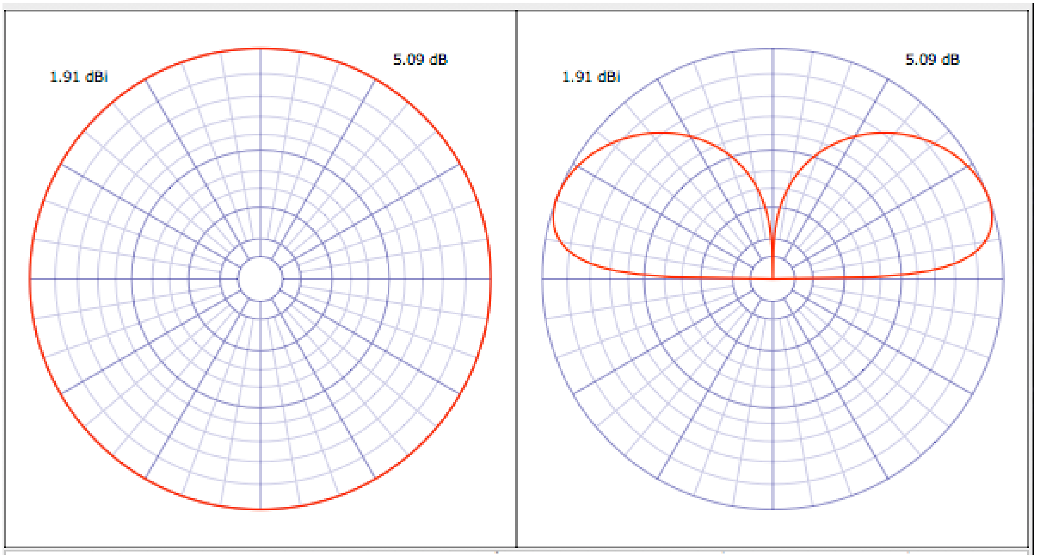




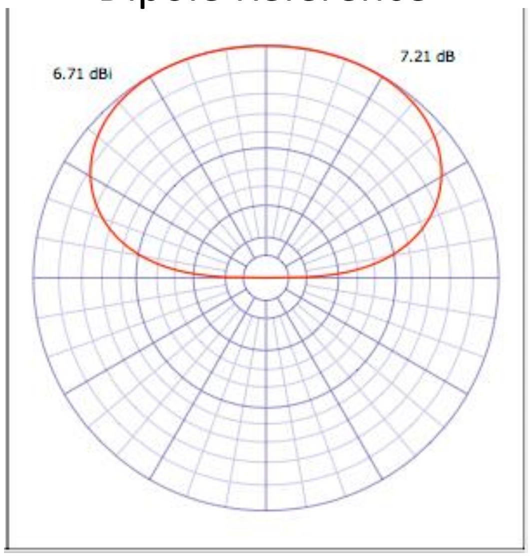
Quarter Wave Vertical



- The analysis shows 40M performance with 16 counterpoise wires
- Lower gain than a dipole
- Lower radiation angles
- Less high angle radiation, poor for local contacts



Dipole Reference



Dipole vs. Vertical Antenna Comparison

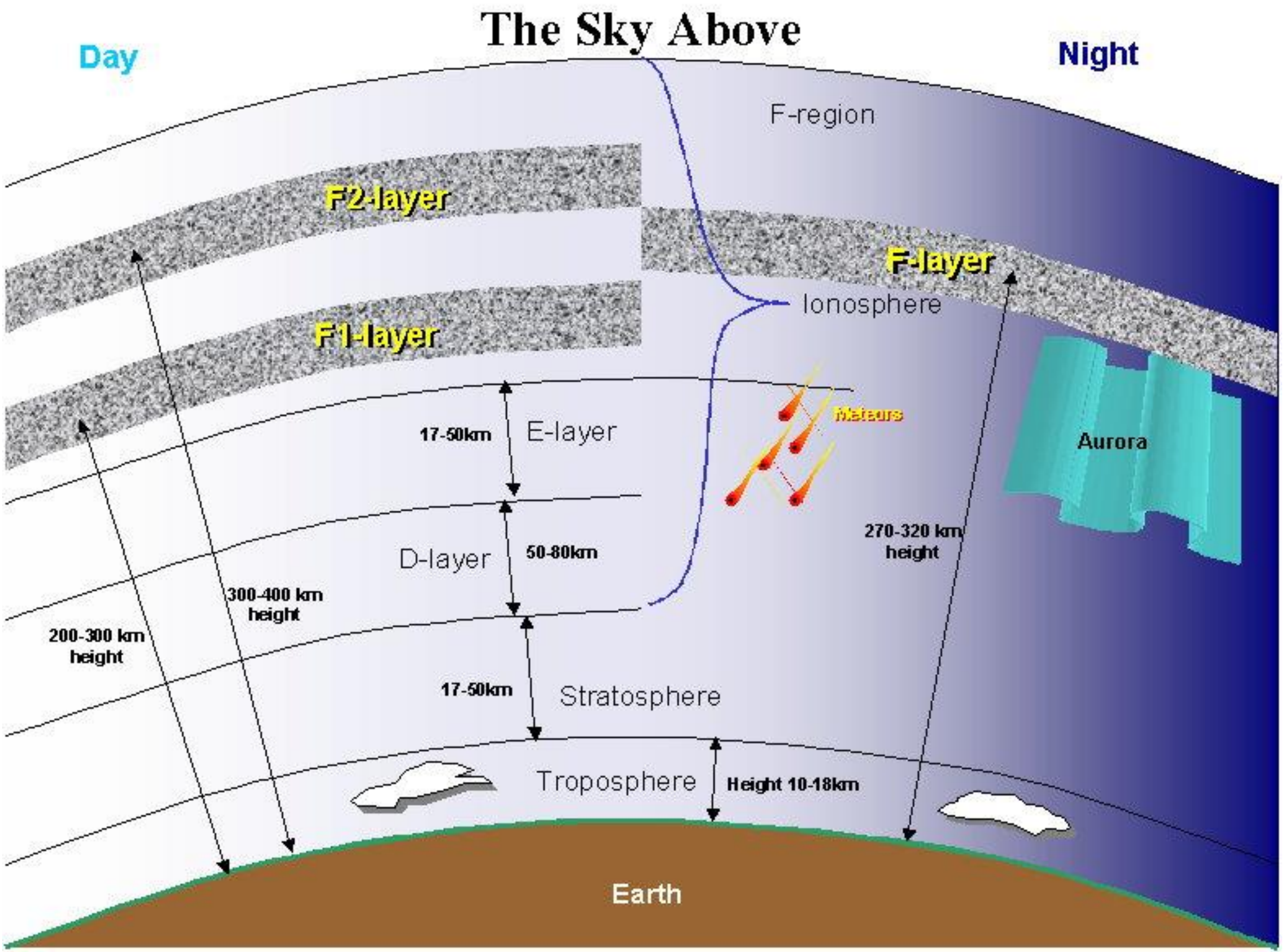
Radiation Angle	Single Hop Distance (miles)		Antenna Gain (dB)	
(degrees)	f1 layer	f2 layer	Vertical on Gnd	Dipole @ λ/4
5	1200	2300	-2	-8
10	800	2000	1	-3
20	500	1200	2	2
30	300	800	2	5
40	240	650	0	6
50	200	500	-2	7
60	200	400	-4	7

Note: A dipole at λ/2 matches the low angle performance of a vertical, but it also has an overhead null. Low antennas are best for local communications. DX is usually multi-hop at radiation angles between 3-20 degrees.

HF Propagation

- A basic understanding of antennas and propagation can help you avoid frustration
- Knowing what time to get on what band is important. Coupled with an understanding of your antenna characteristics helps you know what stations to call or when to look for that DX country you need
- Understanding how to use MUF and Critical Frequency (f0F2) is useful for propagation predictions and band behaviors.
- VOACAP Online for Ham Radio is the best propagation tool for the average ham. It allows you to set the antennas by band and noise levels to get more accurate predictions.
  - Multi-Hop predictions should be done using a program such as this
- I had to learn these skills to accommodate my wife and two kids and our busy schedule. I learned to optimize the time I had available and worked 250 countries in a 2-year period during Cycle 22.
- *The Complete DXer,* by Bob Locher, W9KNI, was also very helpful

The Ionosphere



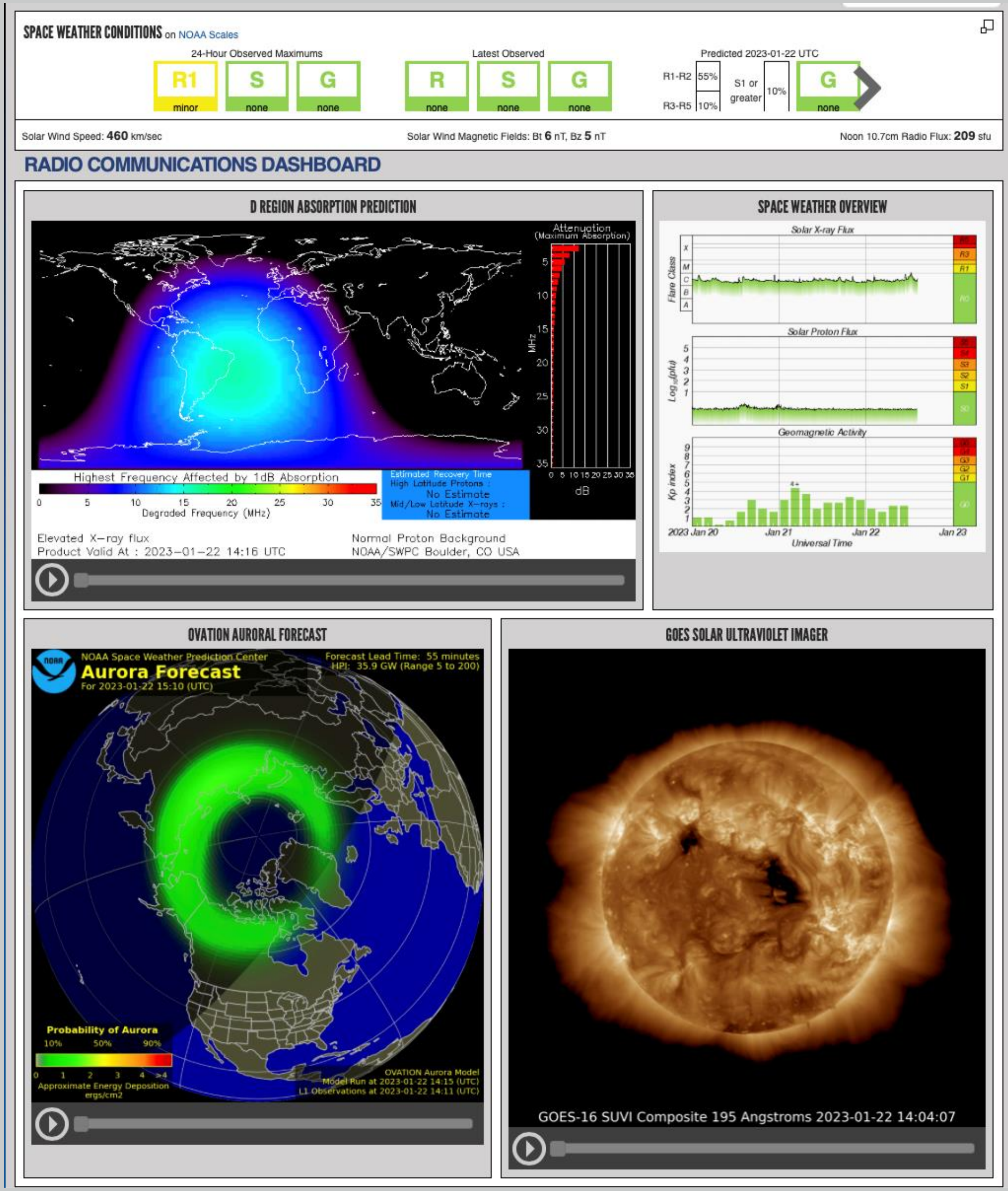
The Ionosphere

- EUV and X-Ray energy from the Sun ionizes the gases in our atmosphere to form the Ionosphere
  - The wavelength is on the order of 1-1000 Angstroms
  - These wavelengths have a million to a billion times more energy than the 10.7cm flux
- 10.7 cm Solar Flux and/or the number of sunspots is a measure of solar activity which may or may not relate directly to ionospheric propagation
- Fortunately, NOAA has a team of folks who analyze lots of satellite data and do a pretty good job at predicting ionospheric conditions.
  - http://www.swpc.noaa.gov/index.html
- F-layer and E-layer are responsible for HF propagation during the day
  - The E-Layer limits low band skip distance during the day, has little effect on higher bands
  - The F-layer is produced by EUV radiation (100-1000A), the E-region by soft X-Rays (10-100A)
- The F-layer hangs around at night as well
- D-layer absorbs RF during the day, worse at low frequencies like 40/80M
  - Produced by Hard X-Rays (<10A)
- K-index is a measure of short-term disturbances…what's happening now (3 hrs)
- A-index is a measure of longer-term disturbances…what has happened over the past day
- I use MiniProp Plus by W6EL and VOACAP for propagation predictions

X-Ray Flux is a better indicator of HF propagation than 10.7cm solar flux

HF Propagation Prediction

- Before turning the radio on I check propagation conditions using the NOAA website Radio Communication Dashboard
- This day the Solar Flux is over 200 and absorption is high for 20M and below during the day. 15-10M should be good
- Paths through the Auroral Oval will also be lossy

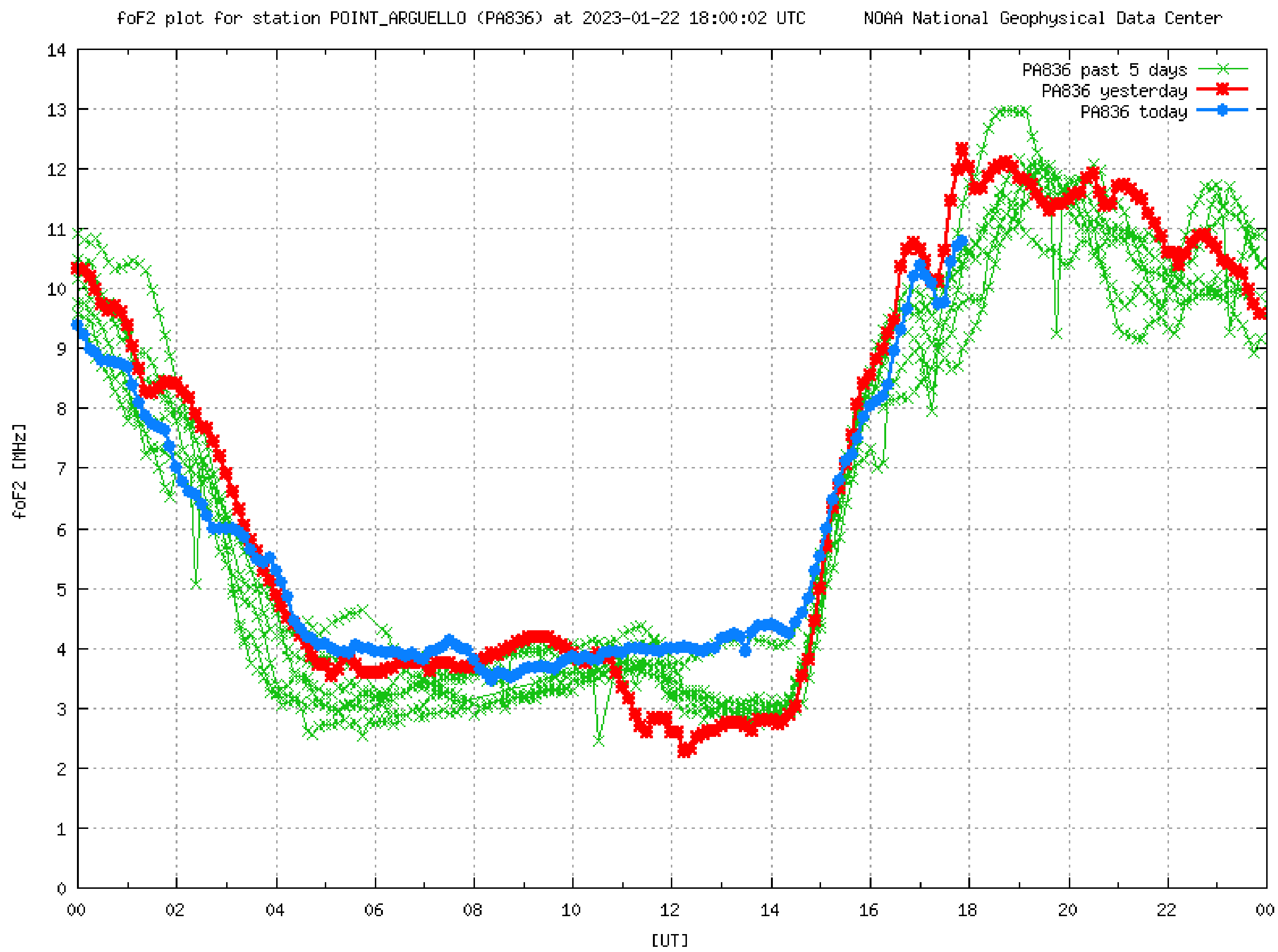


Critical Frequency

- Many of you may have noticed poor propagation for local signals early in the mornings and evenings
- This is due to a low critical frequency (foF2). The critical frequency is the highest frequency that will be reflected by the ionosphere for a vertical incidence signal (90 degrees elevation angle)
- The critical frequency is determined by the amount of ionization in the ionosphere
  - 3-4MHz at night
  - 10-12MHz daytime
  - Rapid increase after sunrise (7-10AM PST)
- Higher frequency reflections do take place at lower elevation angles. The maximum usable frequency (MUF) at a given elevation angle is foF2/Sin(elevation angle) or foF2/cos(zenith angle)
- The Critical Frequency in the middle of the reflection path determines the MUF for that path

MUF = Critical Frequency / Sin (elevation angle)

Critical Frequency measured at Pt. Arguello, CA



Maximum Usable Frequency - MUF

- The optimum frequency, FOT, is 85% of the MUF. This is the highest frequency where you will be able to make a contact 90% of the time on that path

Dipole height	Elev. Angle	MUF for 10MHz fc	FOT	MUF for 12MHz fc	FOT
ƛ/2	30º	20	17	24	20.4
3ƛ/4	20º	29.2	24.8	35	29,8
ƛ	10º	57.5	48.8	69	58.7

- Another way of using the fc data is to compute when the band will open at your location (fc=16.5MHz for FOT=14MHz)
  - For an antenna up one ƛ 20M will open around 6:30AM PST
  - For an antenna up ƛ/4 20M doesn't open until 8AM PST

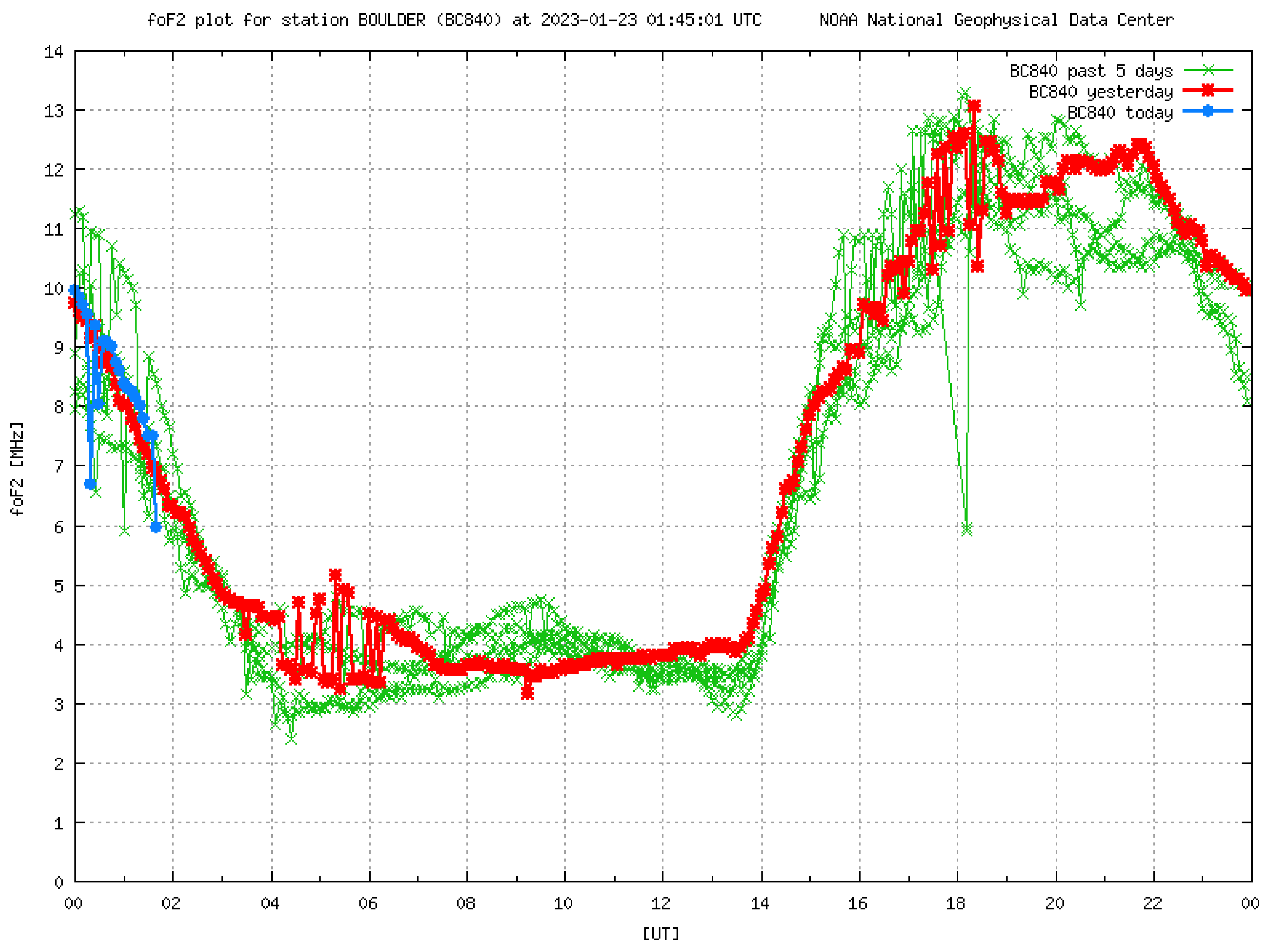
Propagation Analysis

- Now I take it one step farther and consider when the bands will open
- 40M is generally open all day for local contacts (i.e.: 1 Hop)
  - From Midnight to 6AM PST the Critical Frequency is 4MHZ. You must use 80M for local contacts, but 40M will support contacts for Radiation angles <35 degrees (>600 miles)
  - By 8AM 40M will support local contacts and is a popular SSB band for local round table QSOs until it goes long at around 9PM PST
- 20M opens around 8AM when the Critical Frequency reaches ~8MHz
  - This corresponds to a radiation angle of 30 degrees (>800 miles)
  - This is a good time to look for European DX since it is 5PM UTC
  - 20 stays open until sundown with the propagation paths getting longer in late afternoon, after 4PM.
  - Higher solar flux causes 20 to stay open into the evening hours for long distance contacts

Propagation Analysis (Cont’d)

- Now let’s talk about 10M where Technician Class Operators have SSB privileges. 10M is a long-distance band.
  - For radiation angles of 10 degrees, it opens when the critical frequency is 6MHz (around 7AM), 2000 miles distance
  - If you have a dipole (or better yet a small Yagi) up only 25’ your peak radiation is 20 degrees
  - The band will open when the critical frequency hits 11MHz, around 10AM, around 1200 miles
  - Short skip is usually limited to ~900 miles
  - 10M generally closes in mid-late afternoon
  - Sporadic E permits contacts within a few hundred miles
- 15M falls right in between 20 and 10M
- A vertical is a good antenna for the higher frequency bands where low radiation angles are best. 1 S-unit lower gain than a dipole
- A Moxon or 2/3 element Yagi will provide about 1 s-unit stronger signal than a dipole

Boulder, CO Critical Frequency



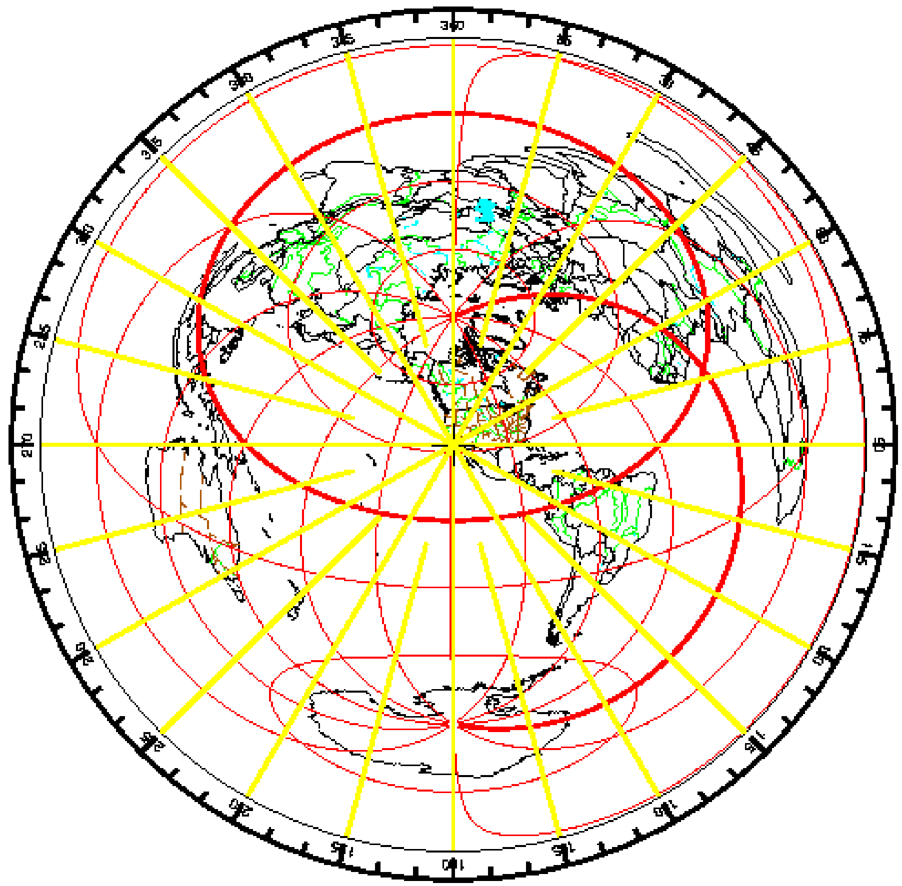
Example: Afternoon Propagation on 17M

- The Critical Frequency in the middle of the path you are communicating over is most important. For a single hop, that’s where the refraction occurs. This slide references the Boulder Critical Frequency.
- Let's say I’m in a QSO with a station at the MUF AT 2200UTC (2PM PST)
- The critical frequency drops from 12 to 11MHz over the next ½ hour
- This can cause fading or a complete loss of contact
- Fading like this is normal on the higher bands in the afternoon. It is usually preceded by slow deep fades (QSB)
- A check of the mid-path Critical Frequency plot to see when the afternoon drop occurs can help prevent this

Other Propagation Thoughts

- Just because the solar flux jumps from 100 to 200 that does not mean propagation improves immediately
  - It takes the ionosphere a while to change and stabilize, usually a few days to a week
- A low antenna has lower gain at low radiation angles. This translates to weaker signals (Tx and Rx)
  - My friend N6TT with his antennas up 100’ always hears band openings way before I do with my antennas up 35-45’
- Don’t get discouraged if you can’t get your antenna up high. Simply analyze your situation and look for contacts you can make
- If you are looking for DX, work a DX contest. The big contest stations have antennas with more gain and hear better. The second day the pile-ups will be reduced and even QRP stations can work them.

W6QR Map



Azimuthal Equidistant Projection
From W6QR
Radial scale: 2500km/cm

AZ_PROJ v1.1.6, Dec 2010, (C) 1994-2002,2010 Joseph Mack NA3T, Michael Katzmann NV3Z
http://www.wm7d.net/azproj.shtml

A Few Propagation Facts

- Propagation does not always follow great circle paths. The ionosphere can tilt, especially during sunrise or sunset times. The Earth's magnetic field also affects refraction direction
- Reciprocity does not always hold due to effect of the Earth's magnetic field
- Early morning on 40M high angle signals are often stronger to the west due to ionospheric tilt
- Ocean hops are less lossy than land hops (1dB vs. 5dB)
  - A low dipole will still put a good signal into Japan but not into Europe
- For local communications, a low horizontal antenna is best
  - The highest frequency that will be reflected vertically (MUF) goes down rapidly after sunset
  - Local signals on 40M will fade, then 80M may fade and only 160M may be useful for local contacts
- Ref: *Radio Amateurs Guide to the Ionosphere* by Leo McNamara

HF Band Summary

- 80M is a nighttime band, after the D-layer dissipates. Atmospheric noise limits receiver performance. It is very good for local communications in the early morning and evenings
- 40M is also a nighttime band. Atmospheric noise is lower and both DX and local communications are good in the early evening/early morning
- 30M shares characteristics of 40 and 20M
- 20M can be open 24 hours. It is the most consistent DX band and useful for local contacts during the day. D-layer absorption can be bad around local noon. Really good conditions when the solar flux >135
- 17/15M are good DX bands mid morning and again mid/late afternoon. During this relatively poor solar cycle they have been the best DX bands. Consistent openings when the solar flux >105
- 12/10M open during the day when the Solar Flux is high. The higher frequencies require more ionization for reflections to occur. Consistent openings when the solar flux >115

References and Resources

- The ARRL Handbook
- The ARRL Antenna Book
- HF Antennas for All Locations by Les Moxon, G6XN (SK)
- The Little Pistol's Guide to HF Propagation by Bob Brown, NM7M (SK), free download on K9LA's web page
- Propagation Predictions and Courses: Tamitha Skov, The Space Weather Woman: https://www.youtube.com/c/TamithaSkov
- NOAA Space Weather website: https://www.swpc.noaa.gov
- VOACAP for Ham Radio: https://www.voacap.com/hf/
- Rob Sherwood's Transceiver Performance Summary: http://www.sherweng.com/table.html