

Basics of HF Operating

Bands, modes, propagation, on-air procedures, and using rig controls to get the most out of your HF transceiver



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Ham Radio University
January 6, 2024

Our Founder



In Memoriam 1947 - 2020

Philip R. Lewis – N2MUN
Founding Father of Ham Radio University



Who's Here?



■ Show of Hands:

- How Many Techs?
- How Many Generals?
- How Many Advanced?
- How Many Extras?
- How Many Have Never Operated HF?
- How Many Operate HF Every Now and Then?
- How Many Operate HF A Lot?

What Are The HF Bands?

■ Ten Frequency Ranges Between 1.8 and 30 MHz

- 160 Meters ... 1.8 to 2.0 MHz
- 80 Meters ... 3.5 to 4.0 MHz
- 60 Meters ... 5332 to 5405 kHz (5 Specific 2.8 kHz Channels)
- 40 Meters ... 7.0 to 7.3 MHz
- 30 Meters ... 10.1 to 10.150 MHz
- 20 Meters ... 14.0 to 14.350 MHz
- 17 Meters ... 18.068 to 18.168 MHz
- 15 Meters ... 21.0 to 21.450 MHz
- 12 Meters ... 24.890 to 24.900 MHz
- 10 Meters ... 28.0 to 29.7 MHz

Why So Many Bands?



- Each HF band has particular propagation characteristics:
 - Long-range vs. Short-range
 - Daytime vs. Nighttime
 - Summer vs. Winter
 - Top vs. Bottom of Sunspot Cycle
- Also:
 - Noise Levels
 - Types of QSOs Found Most Often

“Lower” vs “Higher” Bands

■ *Generally Speaking:*

- Lower Bands (160-40 Meters)
 - | Better in Winter than Summer
 - | Better at Bottom of Sunspot Cycle
 - | Local/Regional Daytime -- DX at Night
- Higher Bands (30-10 Meters)
 - | Better in Summer Than Winter
 - | Better at Top of Sunspot Cycle
 - | DX Day and Night (at top of cycle)
 - | DX Day - Closed at Night (bottom of cycle)

HF Sub-Bands



- Each HF Band is divided into frequency ranges for specific:
 - Modes -- cw, digital/data, phone
 - License Classes
 - Novice / Technician
 - General
 - Advanced
 - Extra

HF Sub-Bands by Mode



■ CW

- Permitted on **any** frequency on **any** band
- Generally found in lowest part of each band

■ Digital/Data

- Permitted in lowest part of each band
- Generally found just above cw

■ Phone

- Permitted in the upper 1/2 to 3/4 of each band
 - LSB on 40 Meters and below
 - USB above 40 Meters

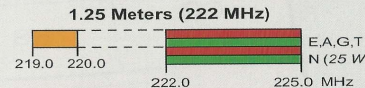
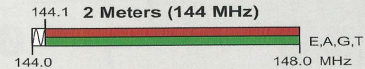
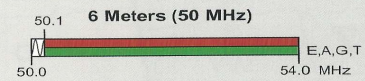
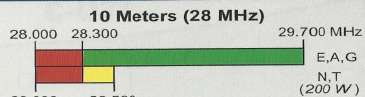
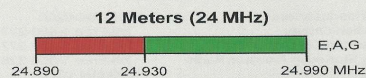
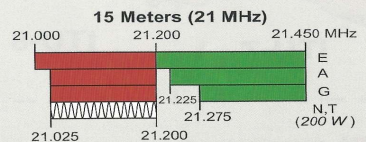
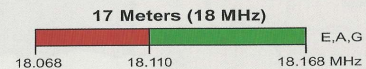
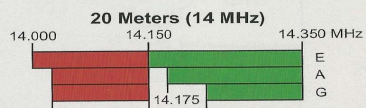
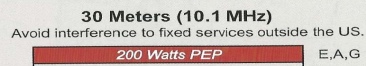
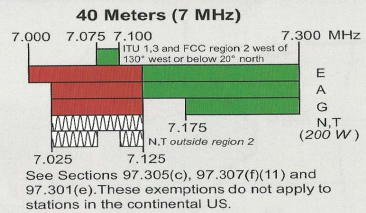
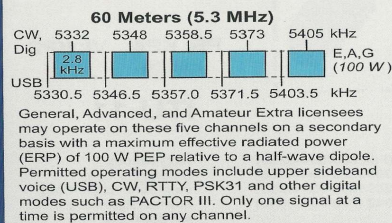
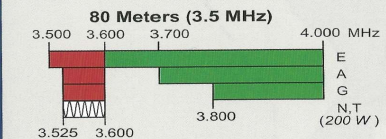
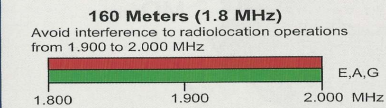
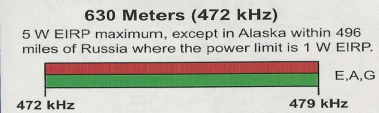
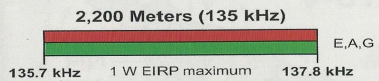
HF Sub-Bands by License

US Amateur Radio Bands

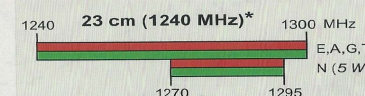
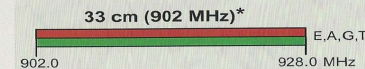
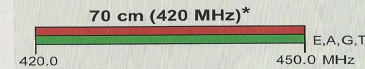
US AMATEUR POWER LIMITS — FCC 97.313 An amateur station must use the minimum transmitter power necessary to carry out the desired communications. (b) No station may transmit with a transmitter power exceeding 1.5 kW PEP.



Amateurs wishing to operate on either 2,200 or 630 meters must first register with the Utilities Technology Council online at <https://utc.org/plc-database-amateur-notification-process/>. You need only register once for each band.



*Geographical and power restrictions may apply to all bands above 420 MHz. See *The ARRL Operating Manual* for information about your area.



All licensees except Novices are authorized all modes on the following frequencies:

2300-2310 MHz	10.0-10.5 GHz ‡	122.25-123.0 GHz
2390-2450 MHz	24.0-24.25 GHz	134-141 GHz
3300-3500 MHz	47.0-47.2 GHz	241-250 GHz
5650-5925 MHz	76.0-81.0 GHz	All above 275 GHz

‡ No pulse emissions

KEY

- = RTTY and data
- = phone and image
- = CW only
- = SSB phone
- = USB phone, CW, RTTY, and data
- = Fixed digital message forwarding systems only

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

See *ARRL Web* at www.arrl.org for detailed band plans.

ARRL We're At Your Service

ARRL Headquarters:
860-594-0200 (Fax 860-594-0259)
email: hq@arrl.org

Publication Orders:
www.arrl.org/shop
Toll-Free 1-888-277-5289 (860-594-0355)
email: orders@arrl.org

Membership/Circulation Desk:
www.arrl.org/membership
Toll-Free 1-888-277-5289 (860-594-0358)
email: membership@arrl.org

Getting Started in Amateur Radio:
Toll-Free 1-800-326-3942 (860-594-0355)
email: newham@arrl.org

Exams: 860-594-0300 email: vec@arrl.org

HF Bands Not Channelized

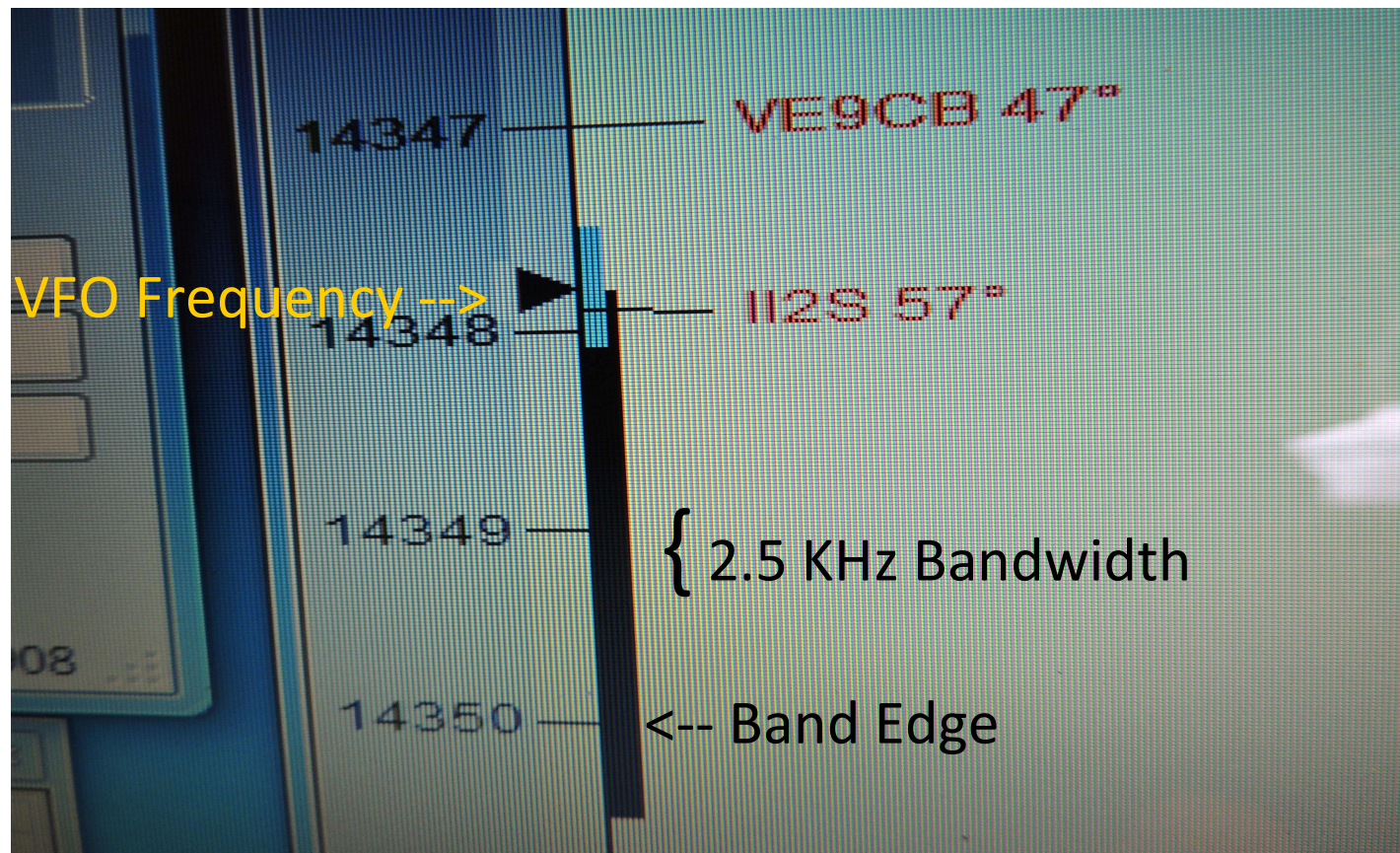


- You don't have to use any particular frequency.
 - You don't have to use a frequency that "ends in zero".
- EXCEPT!!
 - On 60 Meters:
 - Five specific 2.8 kHz-wide channels
 - Centered on:
 - 5332 - 5348 - 5358.5 - 5373 - 5405 kHz
 - Power limited to ERP equal to 100 watts PEP using a dipole

Be Aware of Band and Sub-Band Edges

- On SSB, Bandwidth typically is 2.5 - 3 KHz
 - Therefore ... stay at least 3 KHz from the edge of band or sub-band
 - On LSB ... 3 KHz **ABOVE** the bottom edge
 - On USB ... 3 KHz **BELOW** the top edge
- Examples:
 - **Bottom** of 40-Meter General Phone Sub-Band is 7.175 MHz. Transmit **no lower** than 7.178 MHz.
 - **Top** of 20-Meter Phone Band is 14.350 MHz. Transmit **no higher** than 14.347 MHz.

Out of Band!



What Modes Where On Each Band

The Considerate Operator's Frequency Guide

The following frequencies are generally recognized for certain modes or activities (all frequencies are in MHz) during normal conditions. These are not regulations and occasionally a high level of activity, such as during a period of emergency response, DXpedition or contest, may result in stations operating outside these frequency ranges.

Nothing in the rules recognizes a net's, group's or any individual's special privilege to any specific frequency. Section 97.101(b) of the Rules states that "Each station licensee and each control operator must cooperate in selecting transmitting channels and in making the most effective use of the amateur service frequencies. No frequency will be assigned for the exclusive use of any station." No one "owns" a frequency.

It's good practice — and plain old common sense — for any operator, regardless of mode, to check to see if the frequency is in use prior to engaging operation. If you are there first, other operators should make an effort to protect you from interference to the extent possible, given that 100% interference-free operation is an unrealistic expectation in today's congested bands.

Frequencies	Modes/Activities	Frequencies	Modes/Activities
1.800-2.000	CW	14.233	D-SSTV
1.800-1.810	Digital Modes	14.236	Digital Voice
1.810	CW QRP calling frequency	14.285	QRP SSB calling frequency
1.843-2.000	SSB, SSTV and other wideband modes	14.285	AM calling frequency
1.910	SSB QRP	18.100-18.105	RTTY/Data
1.995-2.000	Experimental	18.105-18.110	Automatically controlled data stations
1.999-2.000	Beacons	18.110	IBP/NCDXF beacons
		18.162.5	Digital Voice
3.500-3.510	CW DX window	21.060	QRP CW calling frequency
3.560	QRP CW calling frequency	21.070-21.110	RTTY/Data
3.570-3.600	RTTY/Data	21.090-21.100	Automatically controlled data stations
3.585-3.600	Automatically controlled data stations	21.150	IBP/NCDXF beacons
3.590	RTTY/Data DX	21.340	SSTV
3.790-3.800	DX window	21.385	QRP SSB calling frequency
3.845	SSTV		
3.885	AM calling frequency	24.920-24.925	RTTY/Data
3.985	QRP SSB calling frequency	24.925-24.930	Automatically controlled data stations
		24.930	IBP/NCDXF beacons
7.030	QRP CW calling frequency	28.060	QRP CW calling frequency
7.040	RTTY/Data DX	28.070-28.120	RTTY/Data
7.070-7.125	RTTY/Data	28.120-28.189	Automatically controlled data stations
7.100-7.105	Automatically controlled data stations	28.190-28.225	Beacons
7.171	SSTV	28.200	IBP/NCDXF beacons
7.173	D-SSTV	28.385	QRP SSB calling frequency
7.285	QRP SSB calling frequency	28.680	SSTV
7.290	AM calling frequency	29.000-29.200	AM
		29.300-29.510	Satellite downlinks
10.130-10.140	RTTY/Data	29.520-29.580	Repeater inputs
10.140-10.150	Automatically controlled data stations	29.600	FM simplex
		29.620-29.680	Repeater outputs
14.060	QRP CW calling frequency		
14.070-14.095	RTTY/Data		
14.095-14.0995	Automatically controlled data stations		
14.100	IBP/NCDXF beacons		
14.1005-14.112	Automatically controlled data stations		
14.230	SSTV		

ARRL band plans for frequencies above 28.300 MHz are shown in The ARRL Repeater Directory and on www.arrl.org.

<http://www.arrl.org/files/file/conop.pdf>

Digital Mode

“Watering Holes”

Amateur Radio HF Digital Mode Frequencies

(Primary frequency in bold red, secondary in bold black)

Mode	Sub-Mode	Dial Frequency (kHz)	Center Frequency (kHz)	Offset (Hz)	Region	Reference
PSK31		1,800.00				http://www.cqdx.com/psk31/
PSK31	Omni	1,801.20	1,801.20	120	USA	http://www.cqdx.com/psk31/psk31-ops-mode-frequencies
Omni	Omni	1,802.50	1,802.50	120		http://www.cqdx.com/psk31/
Omni	Omni	1,803.80	1,803.80	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,805.00	1,805.00	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,806.20	1,806.20	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,807.50	1,807.50	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,808.70	1,808.70	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,810.00	1,810.00	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,811.20	1,811.20	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,812.50	1,812.50	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,813.70	1,813.70	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,815.00	1,815.00	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,816.20	1,816.20	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,817.50	1,817.50	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,818.70	1,818.70	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,820.00	1,820.00	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,821.20	1,821.20	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,822.50	1,822.50	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,823.70	1,823.70	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,825.00	1,825.00	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,826.20	1,826.20	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,827.50	1,827.50	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,828.70	1,828.70	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,830.00	1,830.00	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,831.20	1,831.20	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,832.50	1,832.50	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,833.70	1,833.70	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,835.00	1,835.00	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,836.20	1,836.20	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,837.50	1,837.50	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,838.70	1,838.70	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,840.00	1,840.00	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,841.20	1,841.20	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,842.50	1,842.50	120		http://www.cqdx.com/psk31/
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PSK31	Omni	1,845.00	1,845.00	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,846.20	1,846.20	120		http://www.cqdx.com/psk31/
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PSK31	Omni	1,858.70	1,858.70	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,860.00	1,860.00	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,861.20	1,861.20	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,862.50	1,862.50	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,863.70	1,863.70	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,865.00	1,865.00	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,866.20	1,866.20	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,867.50	1,867.50	120		http://www.cqdx.com/psk31/
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PSK31	Omni	1,878.70	1,878.70	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,880.00	1,880.00	120		http://www.cqdx.com/psk31/
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PSK31	Omni	1,896.20	1,896.20	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,897.50	1,897.50	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,898.70	1,898.70	120		http://www.cqdx.com/psk31/
PSK31	Omni	1,900.00	1,900.00	120		http://www.cqdx.com/psk31/

Compiled from web sources by W4C24

<https://www.wx4car.org/digital-modes.html>

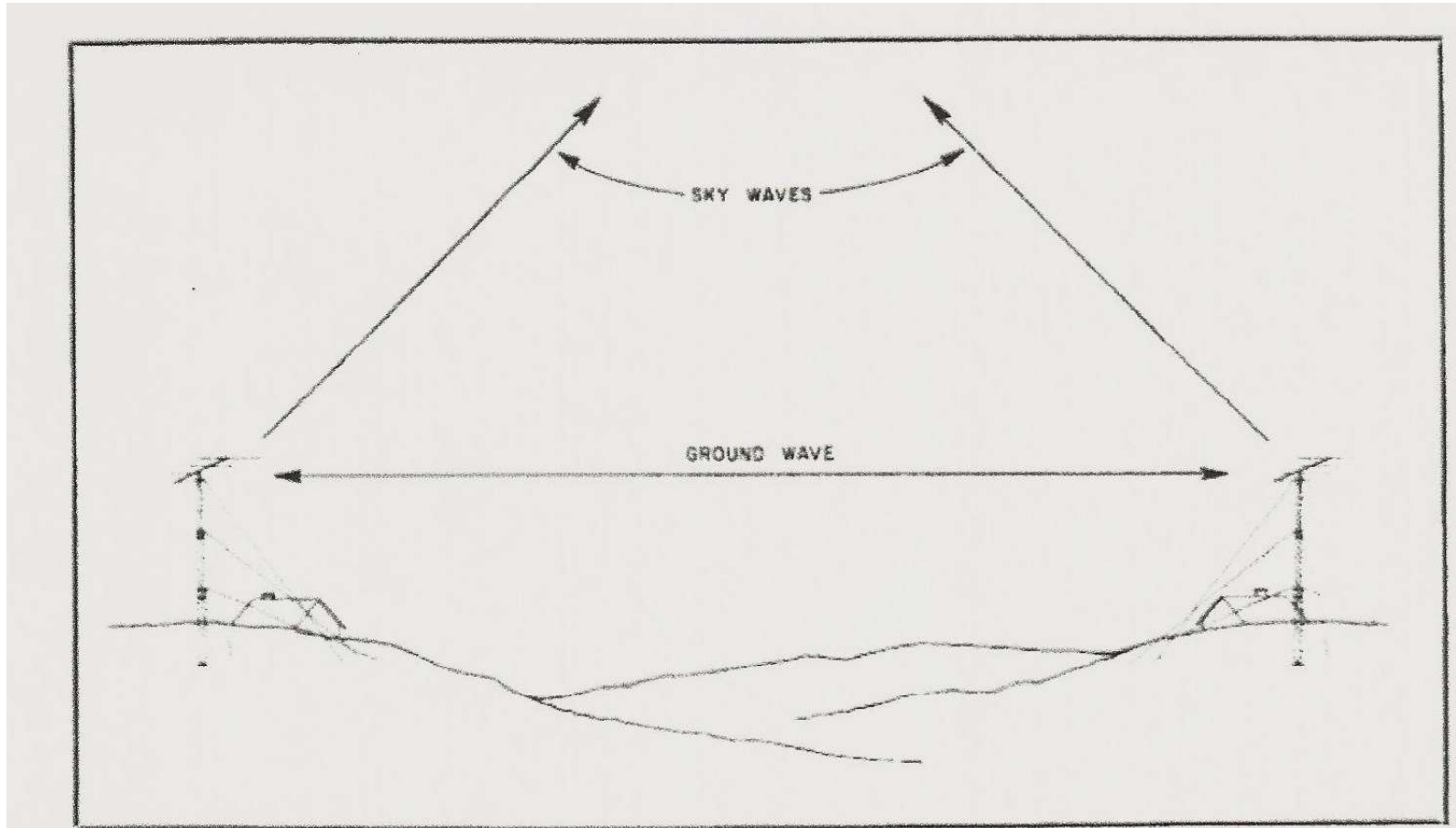
Frequencies For The Most Popular HF Digital Mode...

FT8

160m	1.840
80m	3.573
60m	5.357
40m	7.074
30m	10.136
20m	14.074
17m	18.100
15m	21.074
12m	24.915
10m	28.074
6m	50.313
	50.323- intercontinental

**By One Recent Estimate
FT8 Accounts For 75% Of All HF Activity**

HF Propagation: Ground Wave / Sky Waves



Ground Wave: Limited Distance

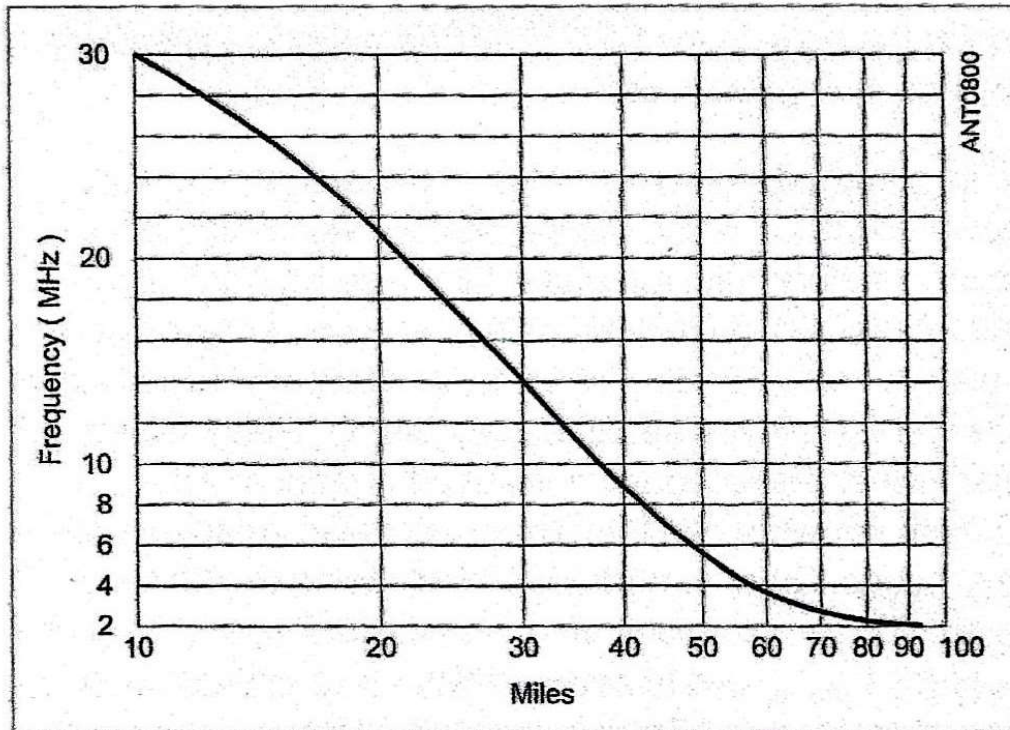
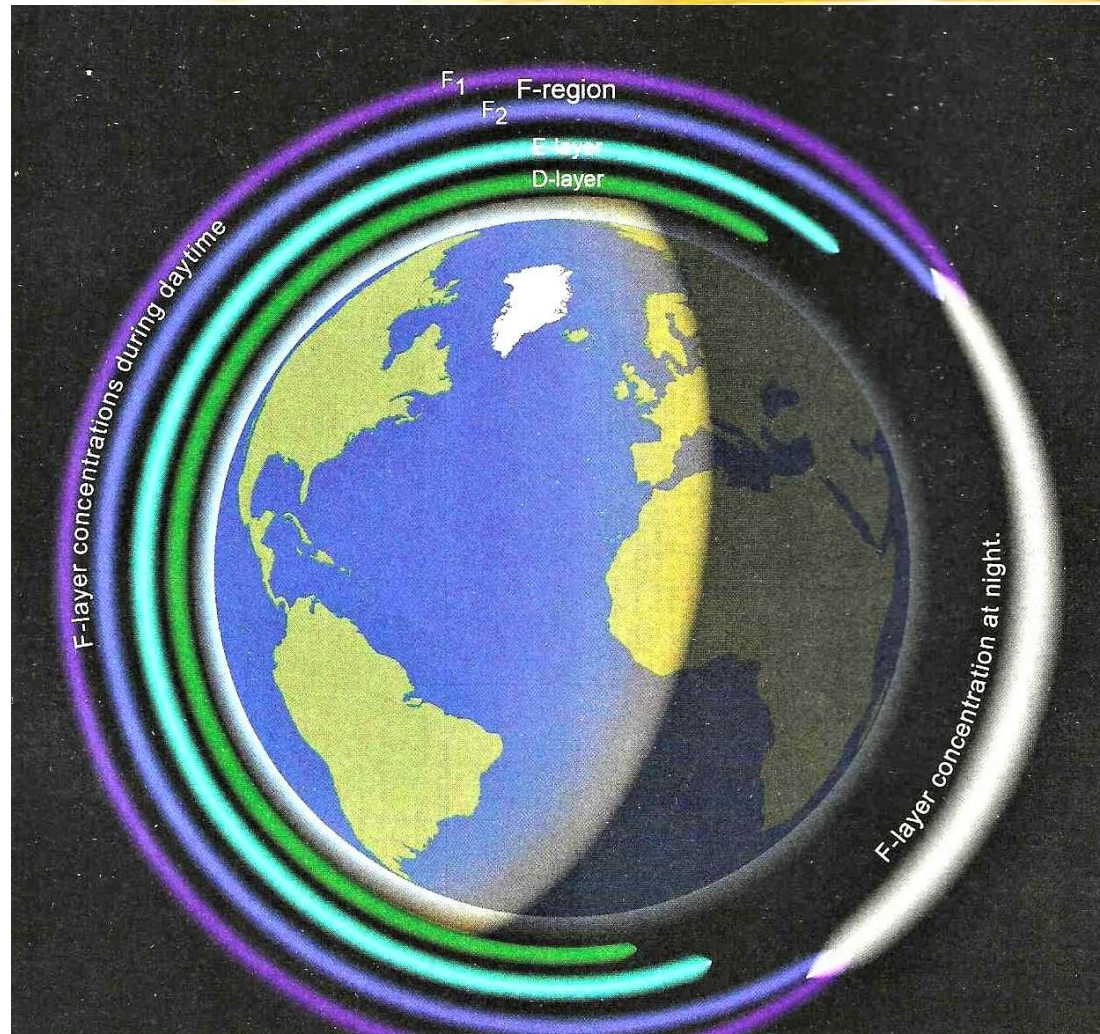
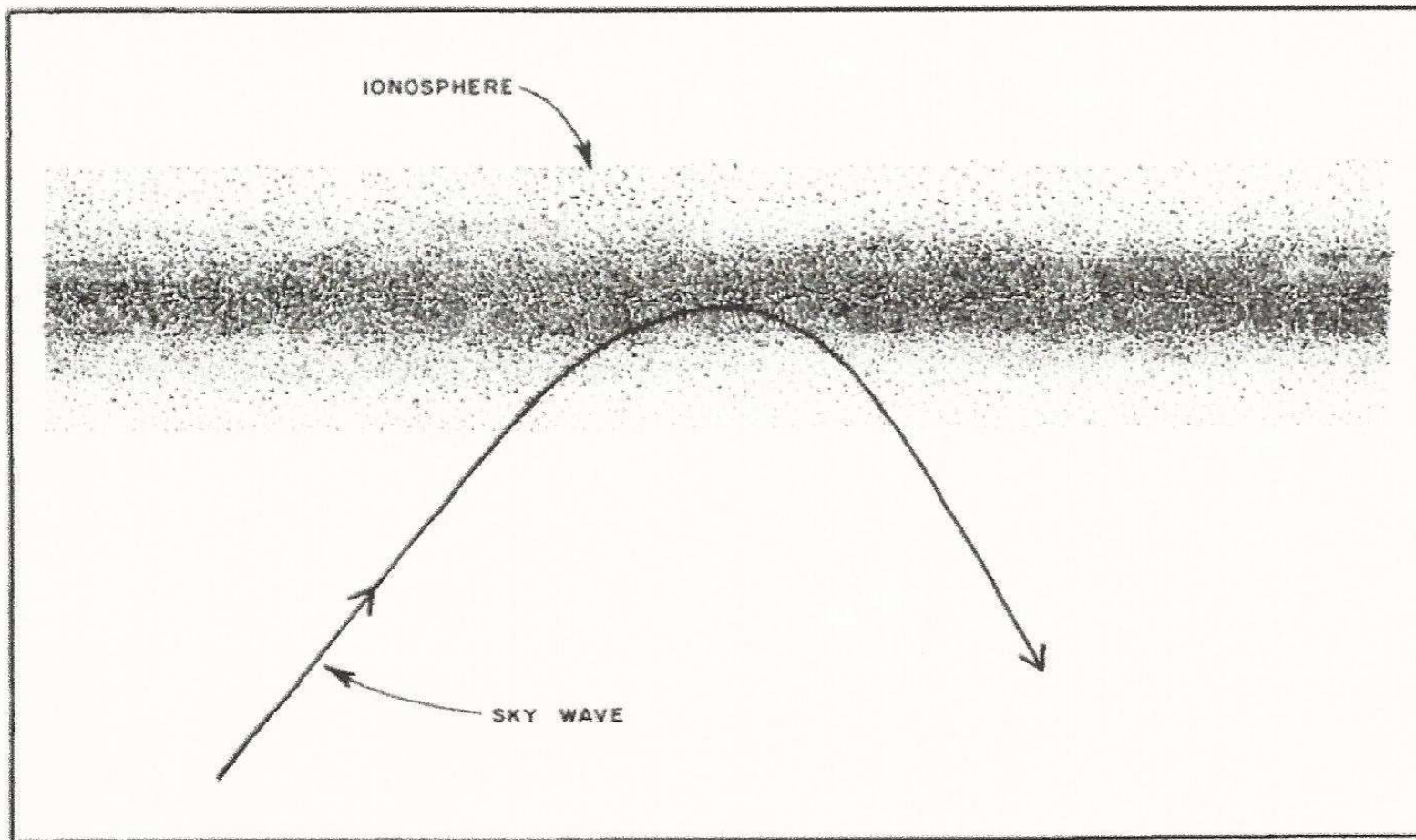


Figure 1 — Typical HF ground-wave range as a function of frequency.

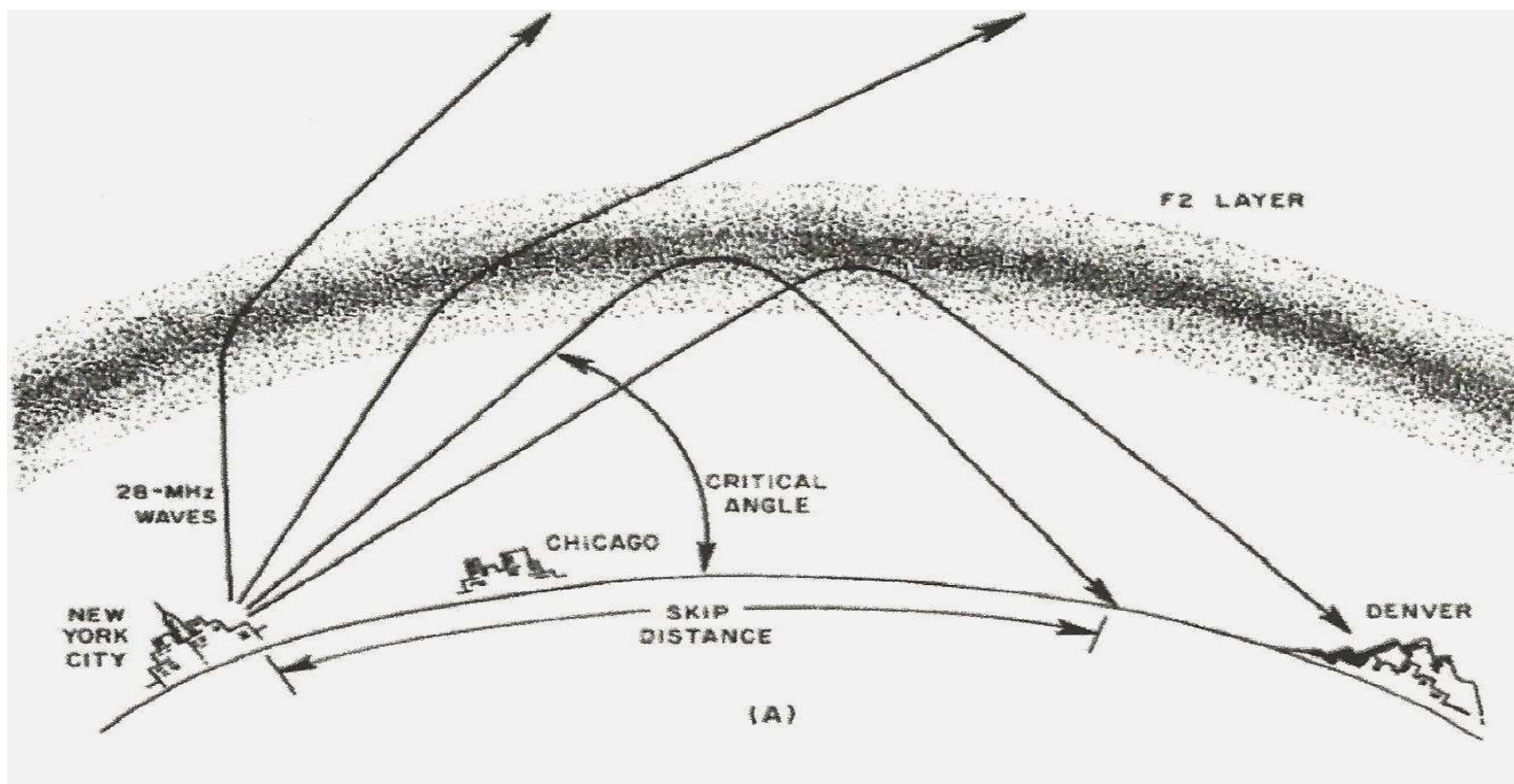
HF Propagation: The Ionosphere Layers



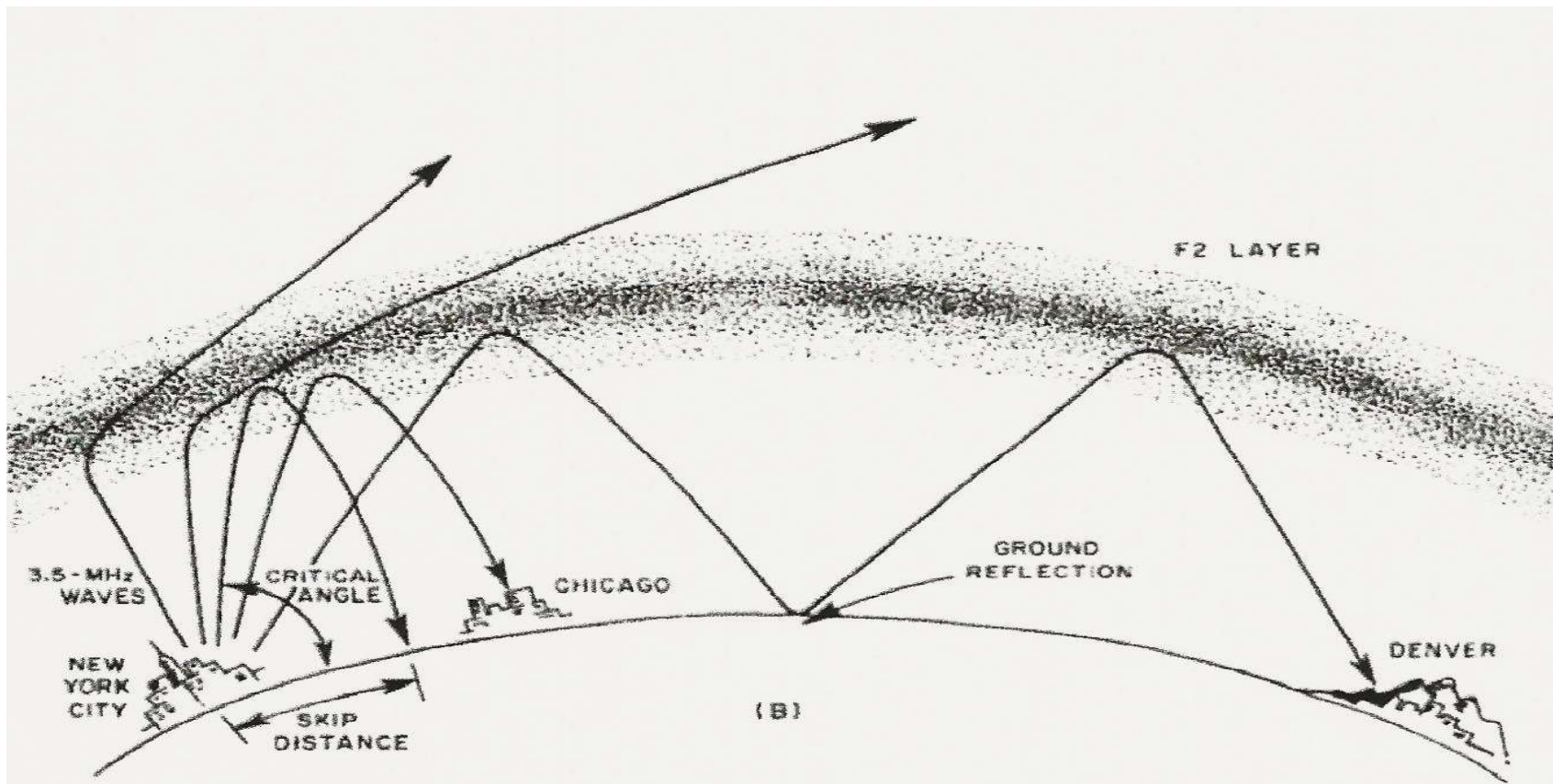
The Ionosphere Can *Refract* Sky Waves



Sky Wave Refraction: Long-Distance “Skip”



Multi-Hop Propagation



Which Bands When?



- Lower Frequency Bands

- 160, 80, 60, 40 Meters

- Ground Wave Daytime (Local / Regional)

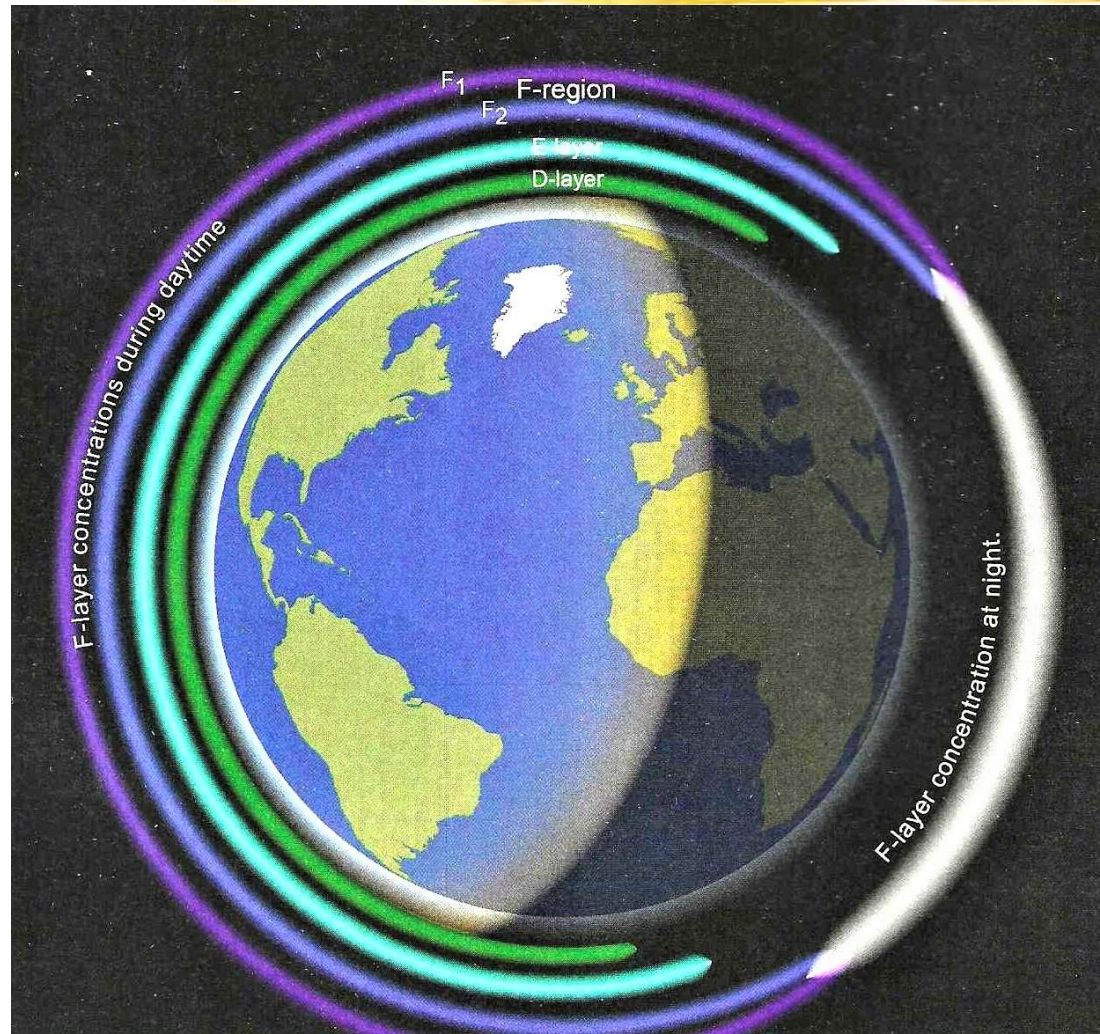
- Sky Wave Nighttime (DX)

- Upper Frequency Bands

- 30, 20, 17, 15, 10 Meters

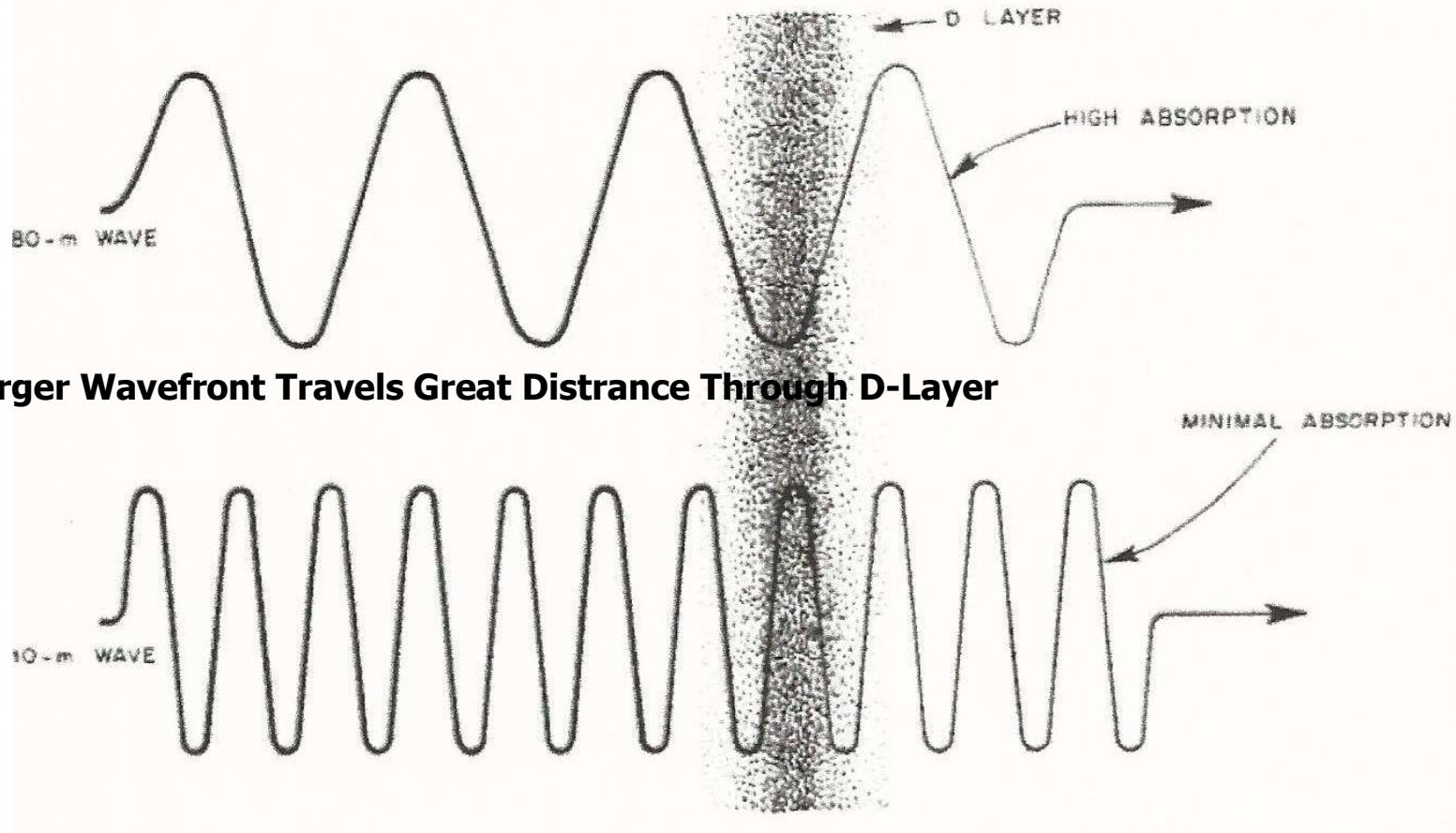
- Both Ground Wave & Sky Wave
Day and Night (When Open)

HF Propagation: The Key Role of the D-Layer



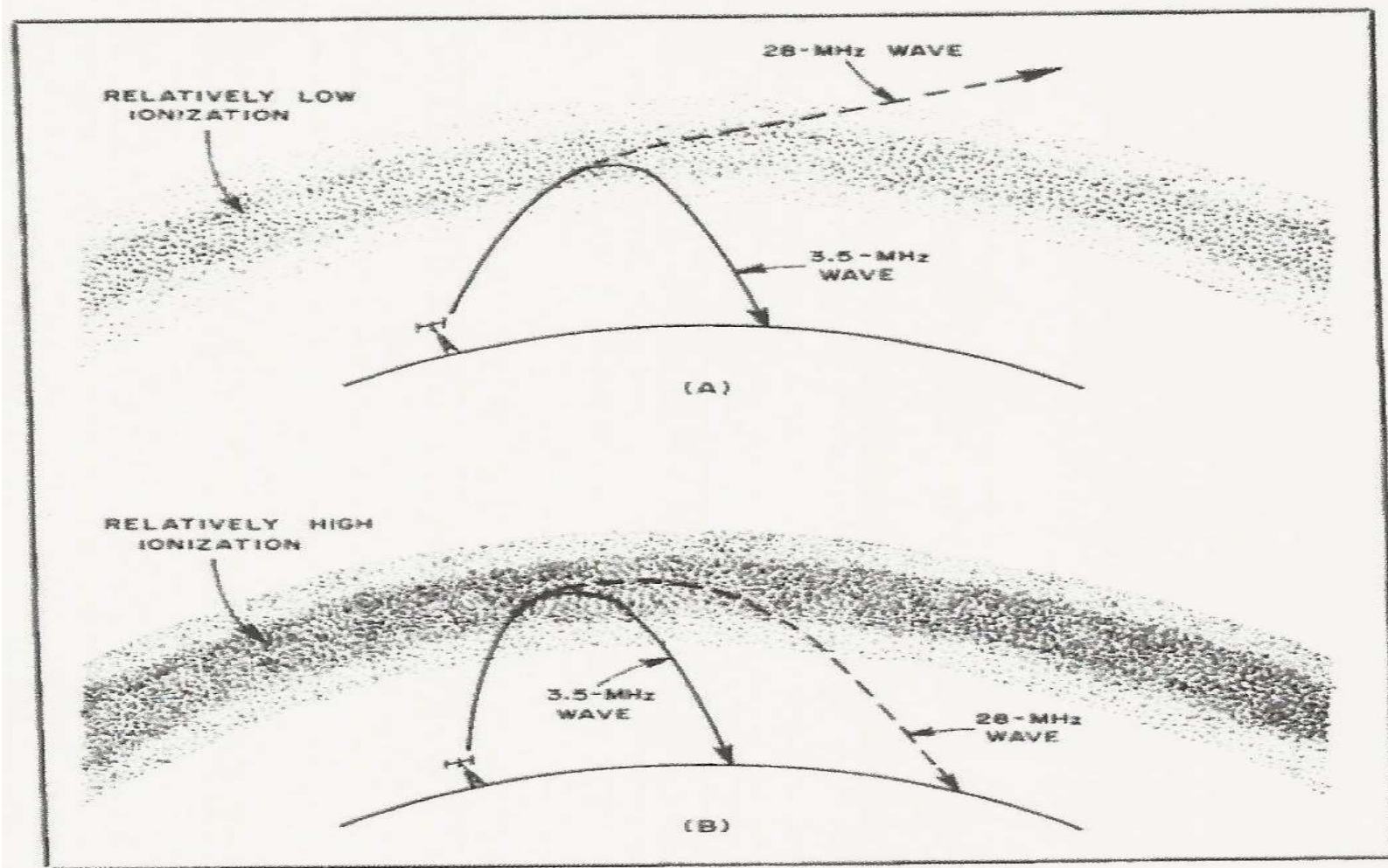
D-Layer Absorption

Lower Frequency = Higher Absorption



Larger Wavefront Travels Great Distance Through D-Layer

Frequency and Ionization Level



For A Detailed Explanation:

- Go To YouTube:
 - “The Effects Of The Ionosphere On Radio Wave Propagation”



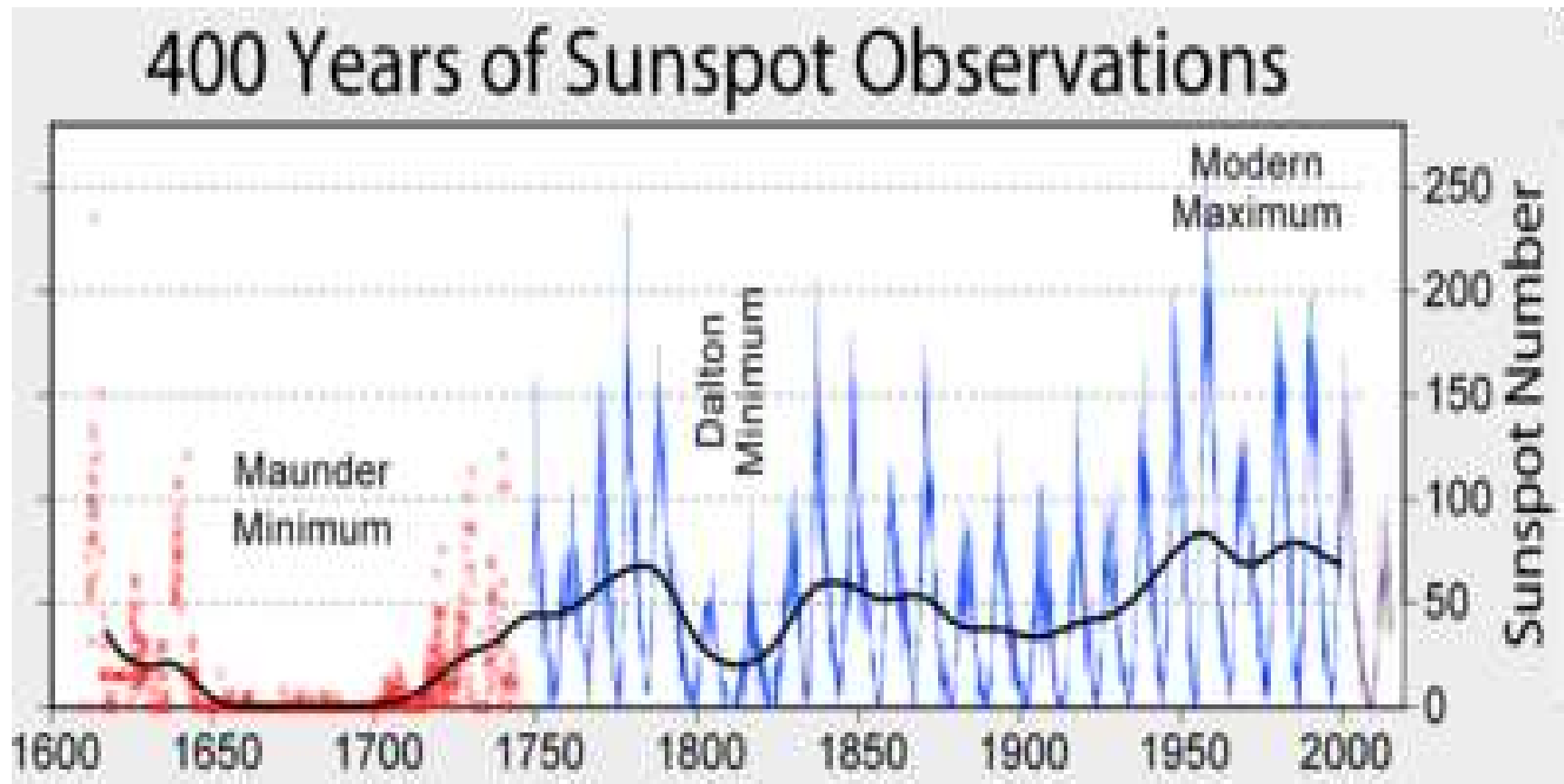
Sky Wave & Sunspots



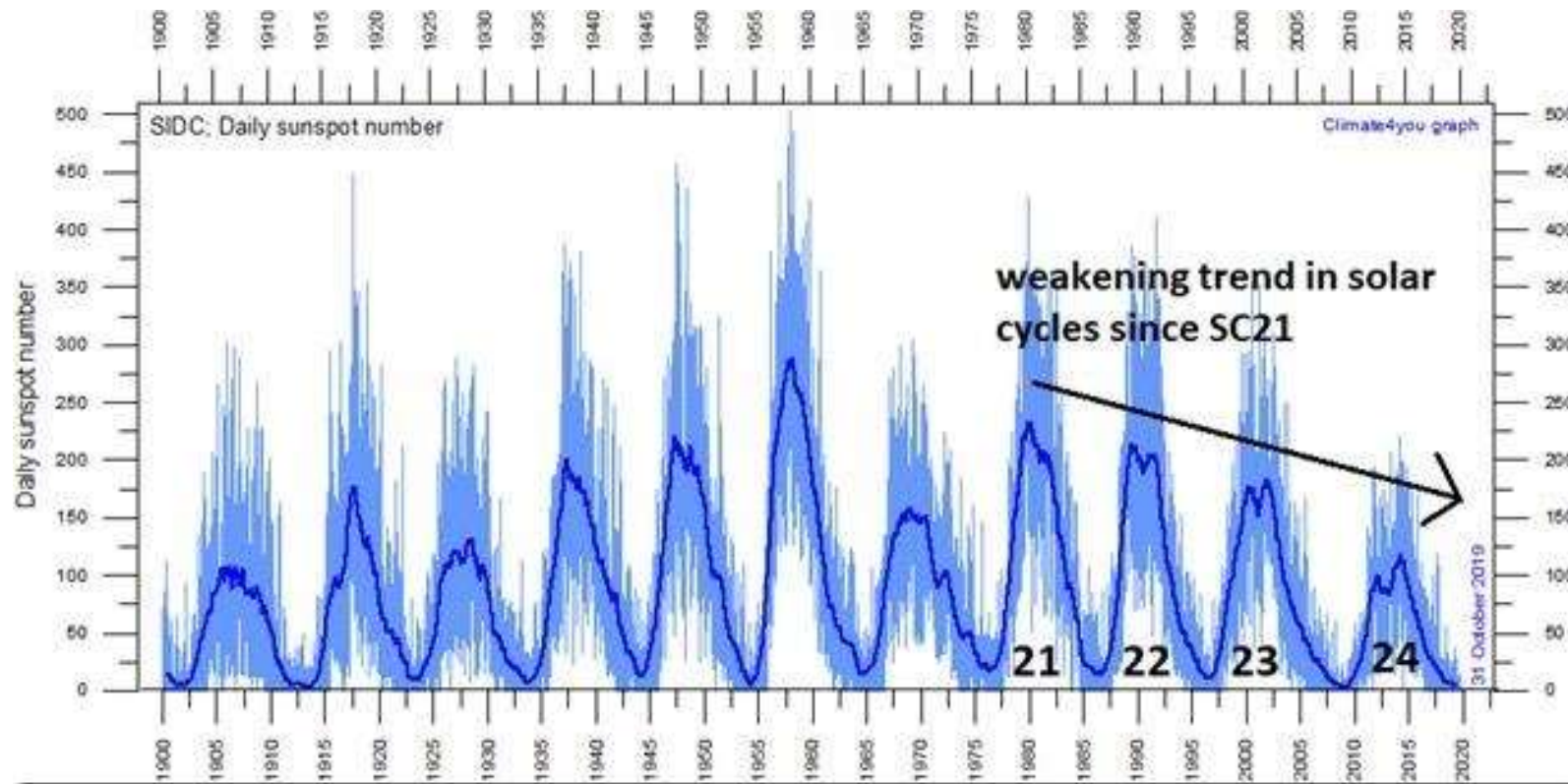
- Ionization Determined by **Sunspot Activity**
 - More Sunspots = More Ionization
 - More Ionization = More DX at Higher Frequencies

- **Sunspots Rise and Fall in 11-Year Cycles**
 - Discovered in 1843 by Samuel Heinrich Schwabe, who retrospectively started a numbering scheme with 1755-1766 as Cycle #1

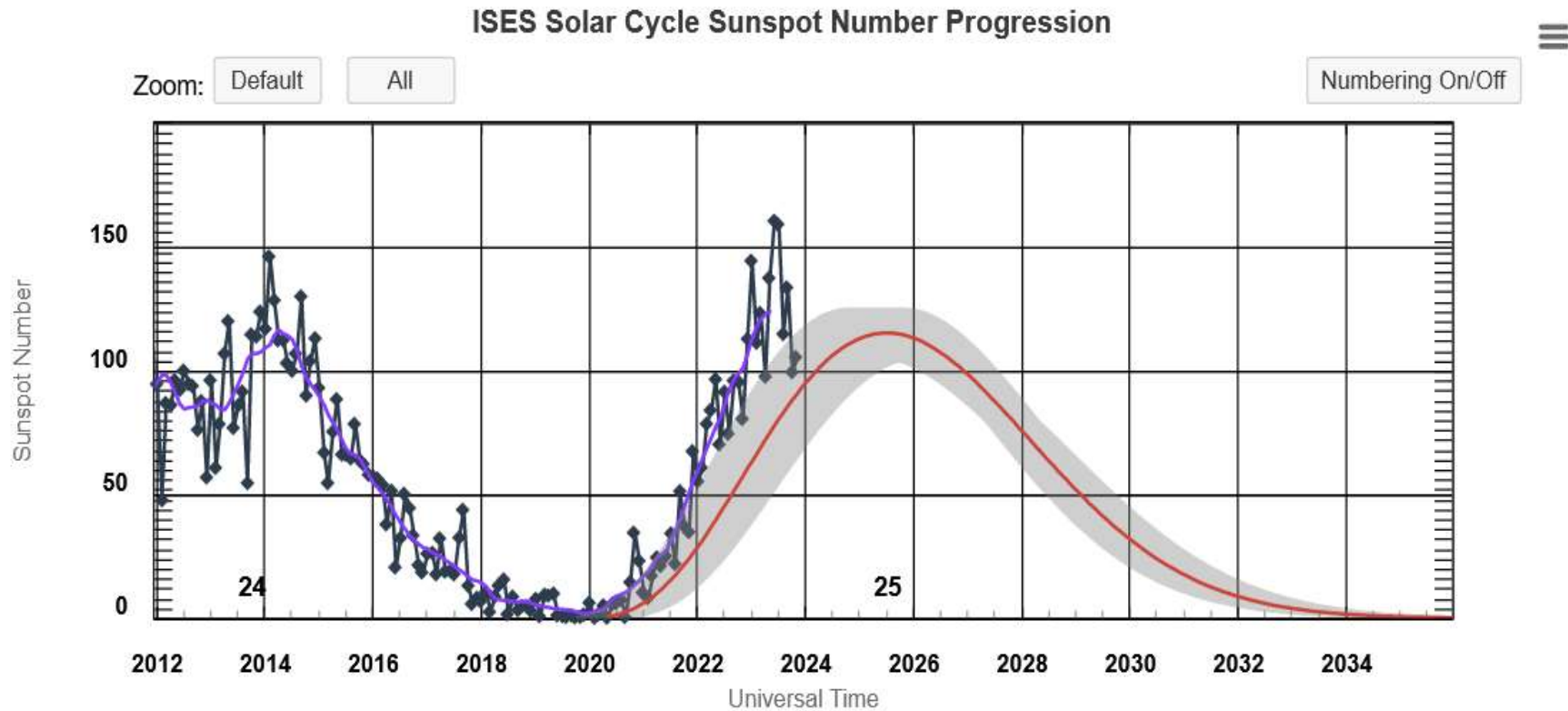
Modern Sunspot Maximum Was 1959 - Peak of Cycle 19



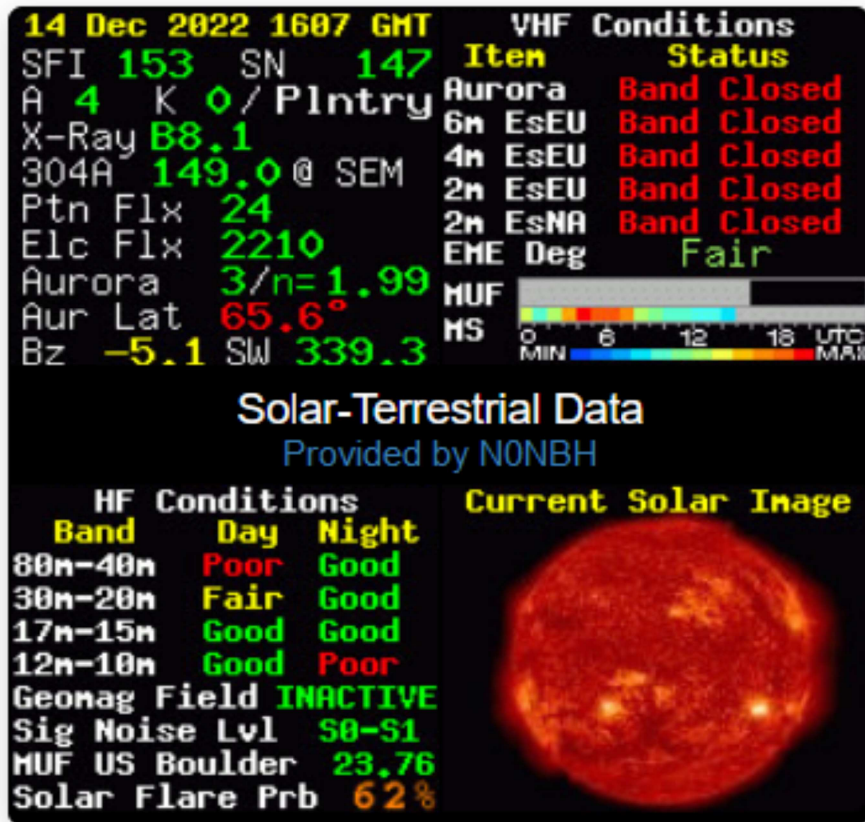
Strength of Cycles Has Been Declining



Solar Cycle 25 Began In December, 2019

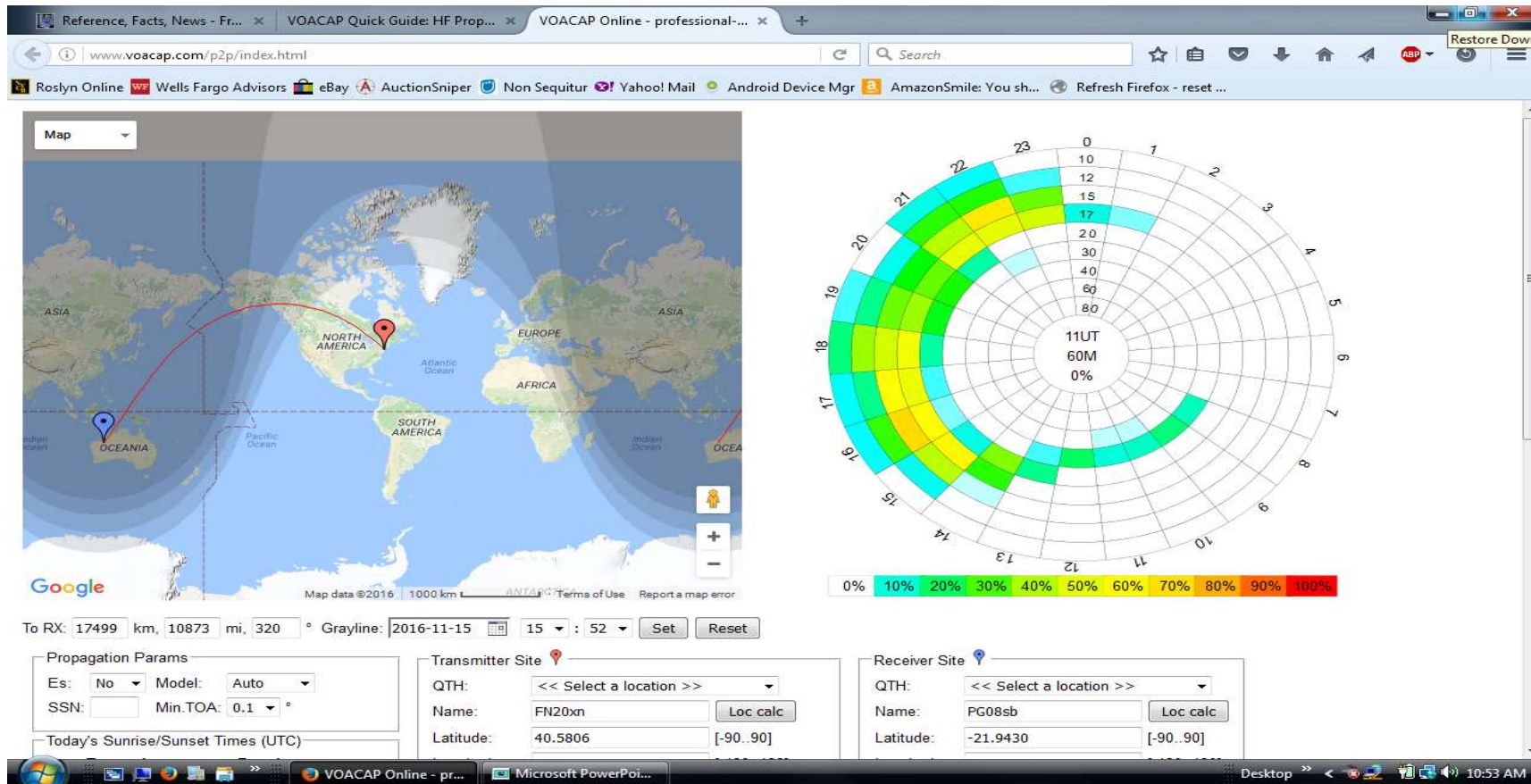


Solar Conditions Vary Day-to-Day ... Even Hour-to-Hour



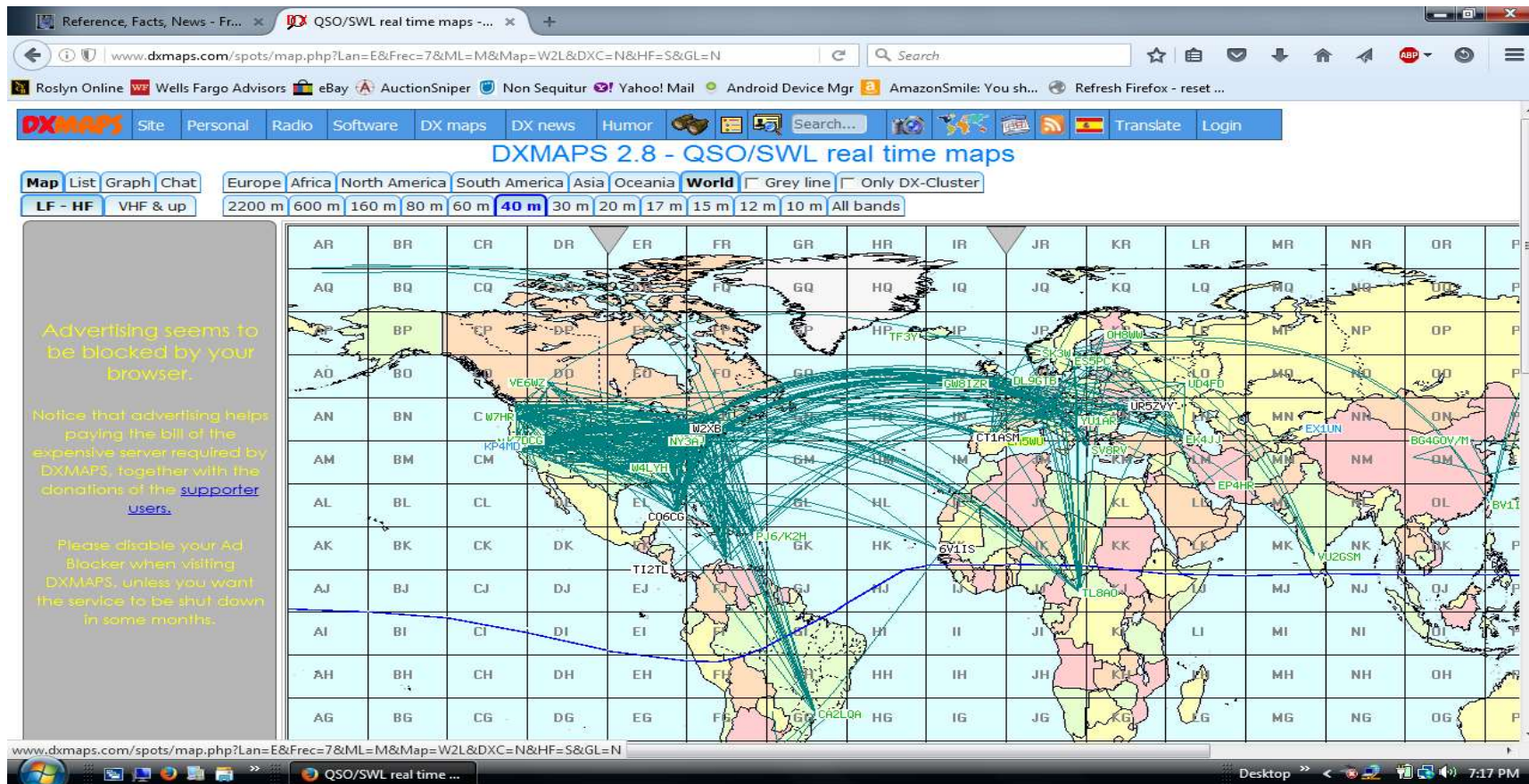
<https://www.hamqsl.com/solar.html>

Propagation Calculators



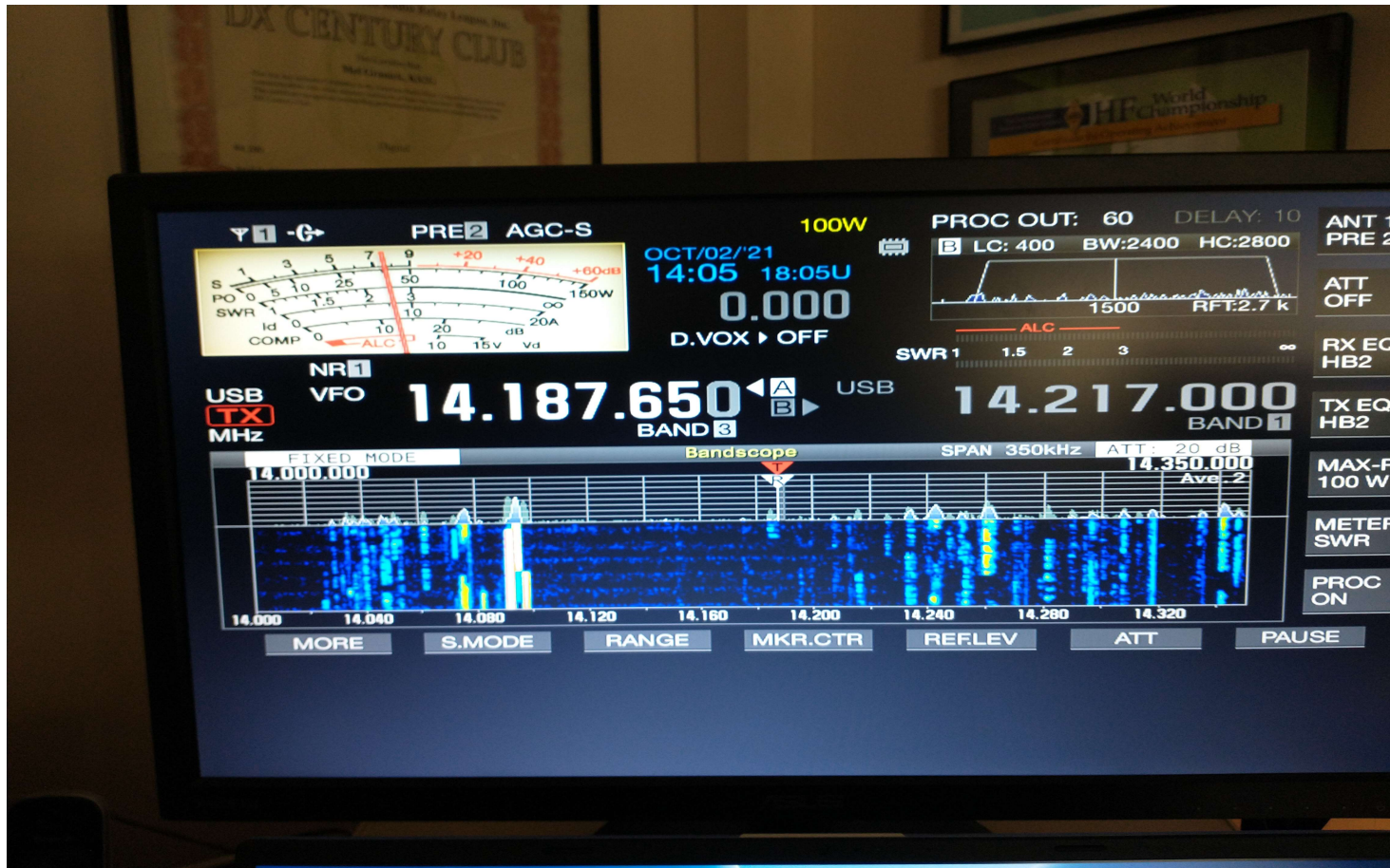
<http://www.voacap.com>

Real-Time Path Views



<http://www.dxmaps.com/spots/map.php>

Look For Yourself:



Making Contacts



■ Proactively:

■ Call CQ

| Tune The Band

- Get a “feel” for conditions and activity

| **LISTEN** for a clear frequency

- **ASK** “Is the Frequency in use?”
 - QRL? On CW
- Because of how HF propagation works you often hear only one side of a QSO. So what appears to be a clear frequency may be occupied by a QSO in which you’re not hearing one (or more) of the stations involved

Typical CQ Format



■ On Phone:

- CQ, CQ, CQ calling CQ 20 meters. This is KS2G calling. Kilo Sierra Two Golf, KS2G near New York City calling CQ 20 meters. Hello CQ, CQ, CQ calling CQ 20 meters and standing by for a call.

■ On CW / RTTY:

- CQ CQ DE KS2G KS2G CQ CQ DE KS2G KS2G K

Making Contacts



- Respond to CQ's
 - “Casual” Contacts
 - | Phone: W2HF This is KS2G OVER
 - | CW/RTTY: W2HF DE KS2G K
 - DX Pile-Ups & DXpeditions
 - | Just Give Your Callsign
 - Phonetically on Phone
 - | Is the DX Station Operating “Split?”
 - Almost All Dxpeditons Operate Split

Operating “Split”

■ Split-Frequency Operation

- | Transmit and Receive on Different Frequencies
- | Like the “offset” of repeater input/output

■ Almost All DXpeditions Operate “Split”

- | DX Station Will Say “Up 5” or “Up 5 to 10”
 - He’s listening 5 or 5-to-10 KHz up from his transmit frequency
- | DX Station on 14.160 MHz Will Say “200 to 225”
 - He’s listening 14.200 to 14.225 MHz

■ Learn how to use your rig’s dual VFO’s

Working Contests



- Competitive Operating:
 - Work as many stations as possible, in as many places as possible, as quickly as possible
 - Check Contest Rules For Contest “Exchange”
 - “Run” -- call CQ
 - “Search & Pounce” -- Tune the Band and Respond to Stations That Call CQ

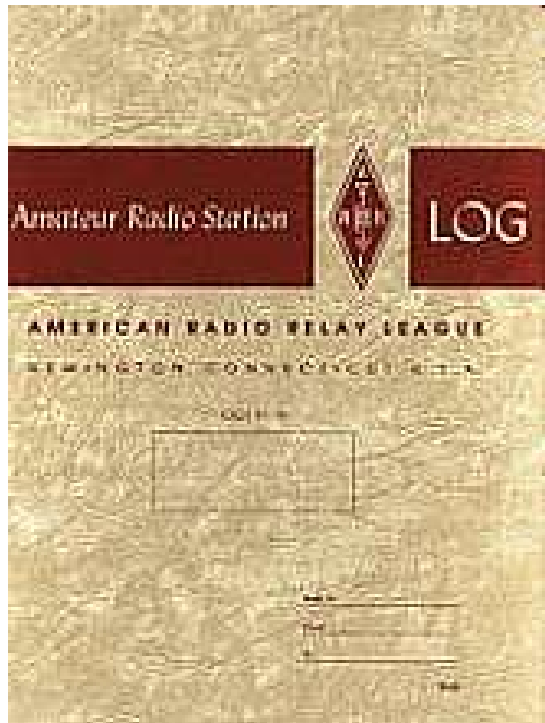
Logging



- No Legal Requirement To Log (since 1983)
- Useful Record of Operating Activity and Information Required For QLS'ing**
 - **Date & Time in UTC****
 - Frequency Band/Mode (cw, ssb, rtty, etc.)**
 - Callsign of Station Worked**
 - Signal Report
 - Notes -- Name, QTH, Equipment, Power, etc.

Logging - “Old School”

■ On Paper:



Computer Logging



■ General Purpose Loggers:

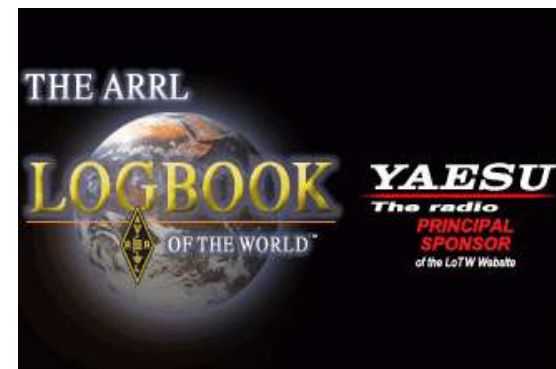
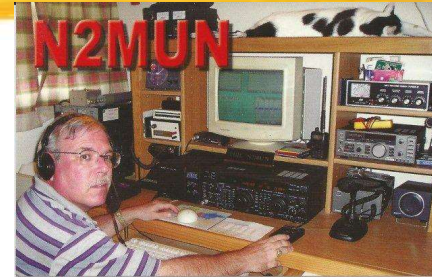
- DXLAB RumLog (Mac)
- DX 4 WIN MacLoggerDx (Mac)
- DXKeeper TWlog (Linux)

■ Specialized Contest Loggers:

- N1MM-Plus Skookumlogger (Mac)
- WriteLog Xlog (Linux)

QSLing: Confirmation of Contacts

- Direct - Printed Cards
 - SASE or "Green Stamps"
- QSL Managers
- QSL Bureaus
 - ARRL Outgoing QSL Service
 - 2nd District Incoming QSL Bureau
 - North Jersey DX Association
 - Purchase Return-Envelope "Credits"
- Electronic
 - ARRL Logbook of the World (LoTW)
 - eQSL
 - Club Log



Operating Awards



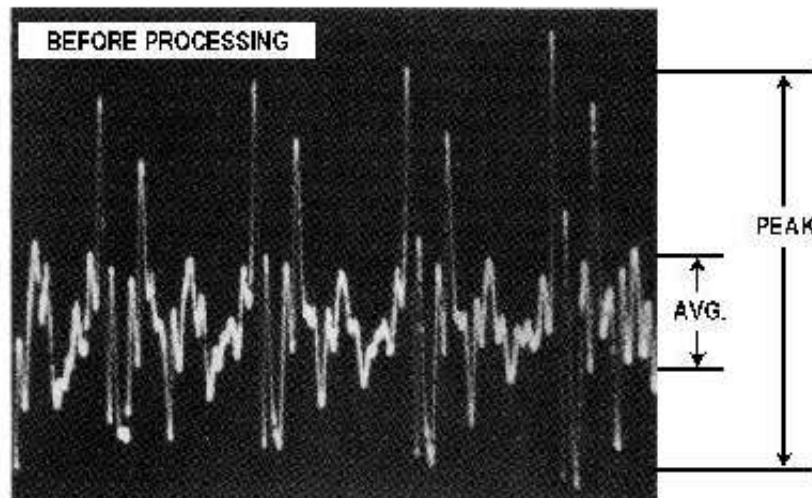
Getting The Most Out Of Your HF Transceiver



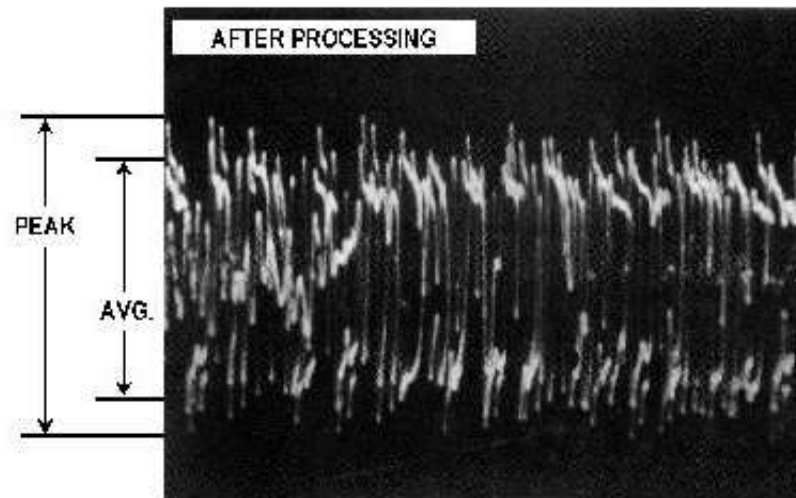
- Transmitter Controls:
 - RF Power Output - cw, digital, ssb
 - Microphone Level
 - | Speech Processing / Compression
 - Increases Average RF Power & Adds “Punch” To Audio
 - Observe ALC (Automatic Level Control) Limit
 - | Transmit Audio Equalization
 - Control “Highs” & “Lows” For Maximum Intelligibility
 - | Transmit Audio Monitor
 - Listen To Yourself As You Transmit
 - | Ask For Audio Reports From Stations You Work

Speech Processing

Also Known As Audio Compression
Increases SSB "Talk Power"



Actual speech waveform photograph with no processing, as it exists at the TX mike input. Note the very high peak amplitude when compared to the average levels.



Correctly processed speech waveform. The average amplitude *relative to the peaks* is now much higher. This is a dramatic increase in the average power output, but without the risk of distortion because the peaks have been limited by diode clipping.

Transmitter Keying Controls

- VOX (Voice Operated Transmit)
 - Transmitter is Keyed By Sensing Speech
 - Sensitivity / Delay (Hang) Time / Anti-VOX
- CW Break-In
 - Automatic Switching Between Transmit & Receive
 - Full Break-In (QSK)
 - Switches from transmit to receive immediately when key contacts open
 - Semi-Break-In
 - When key contacts open, switch to receive is delayed by a set duration (usually controlled by VOX setting)

Automatic Antenna Tuner



- Automatically “matches” out-of-resonance antenna impedance to 50 ohms
- Maintains Full Transmitter Power Output
 - Modern Solid-State Transmitters “Fold-Back” (Lower) Output Power to Mismatched Antenna Loads To Prevent Damage To Final Output Power Transistors

Receiver Audio Controls



- AF Gain
 - Audio Frequency Gain - Volume Control
- RF Gain
 - Radio Frequency Gain
 - Manually Adjusts Receiver Sensitivity
 - Usually Left at Maximum in Conjunction With AGC
- AGC - Automatic Gain Control
 - Automatically Adjusts Receiver Sensitivity In Response To Changes In Signal Strength
 - "Fast" Response For CW / "Slow" Response For SSB

Receiver Sensitivity Controls



- RF Attenuator
 - Reduces Receiver Sensitivity By A Set Amount
- RF Preamp
 - Increases Receiver Sensitivity By A Set Amount
- Squelch
 - Mutes Receiver When No Signal Is Present
 - Leave "Wide Open" Except For FM

Receiver Tuning Controls



■ RIT

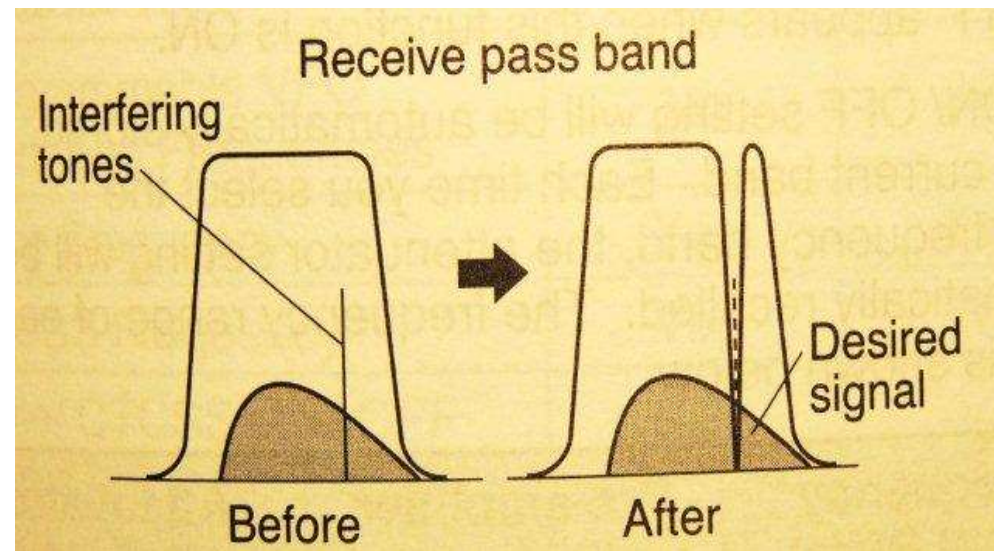
- Receiver Incremental Tuning
- “Clarifier” on Yaesu Radios
 - Changes Receive Frequency Without Changing Transmit Frequency

■ XIT

- Transmitter Incremental Tuning
 - Changes Transmit Frequency Without Changing Receive Frequency
 - Sometimes can be used for “split” in the absence of dual VFO’s

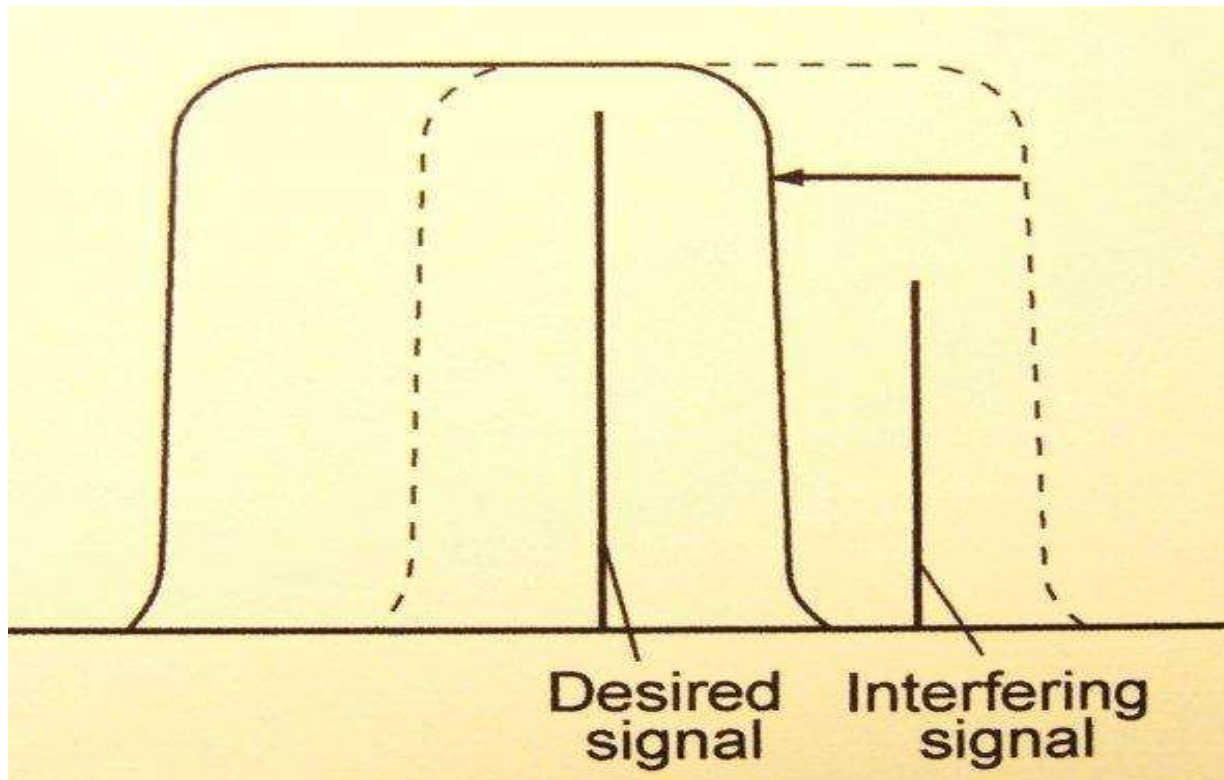
Interference Controls

- Noise Filter / Noise Reduction
 - Reduces Steady Background Noise
- Noise Blanker
 - Reduces Pulsing Background Noise
- Notch Filter
 - “Nulls” Specific Interfering Signal (e.g. Heterodynes)



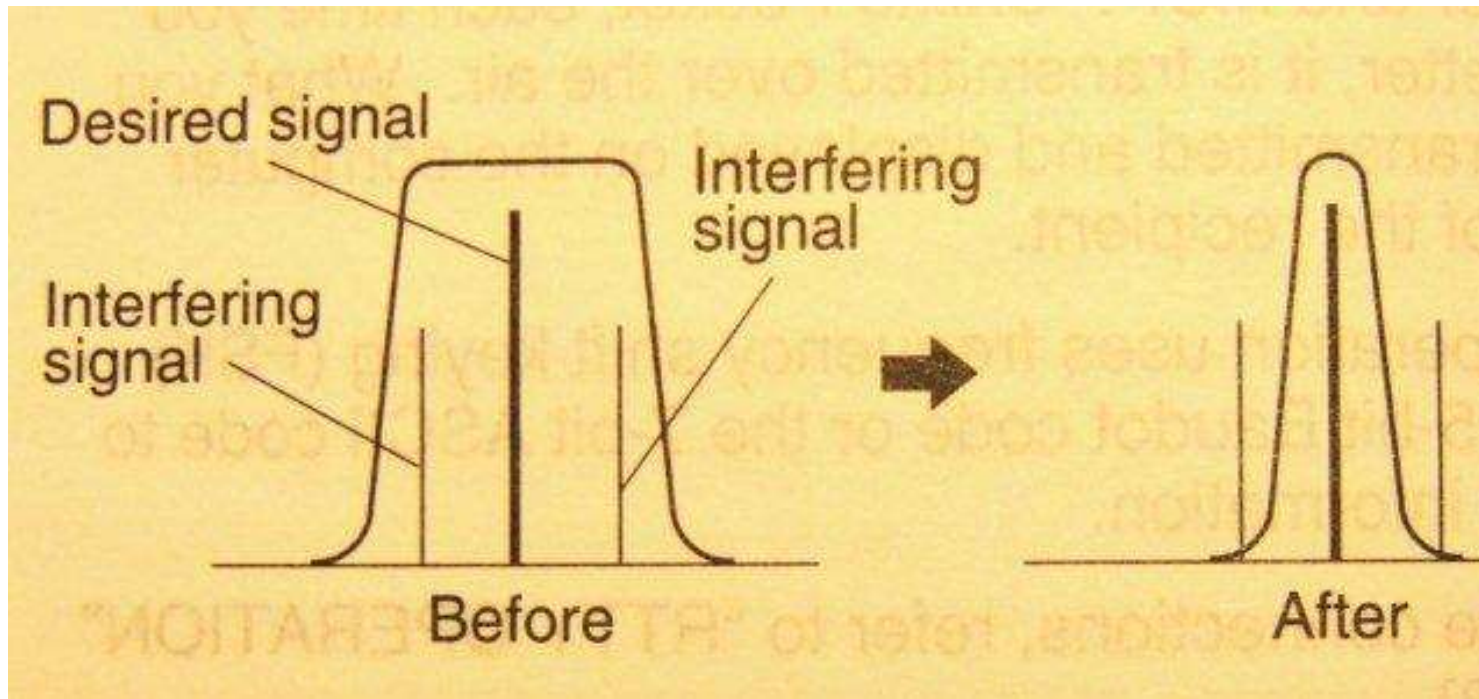
Bandwidth Controls

- IF Shift
 - Shifts Center Frequency of Pass Band



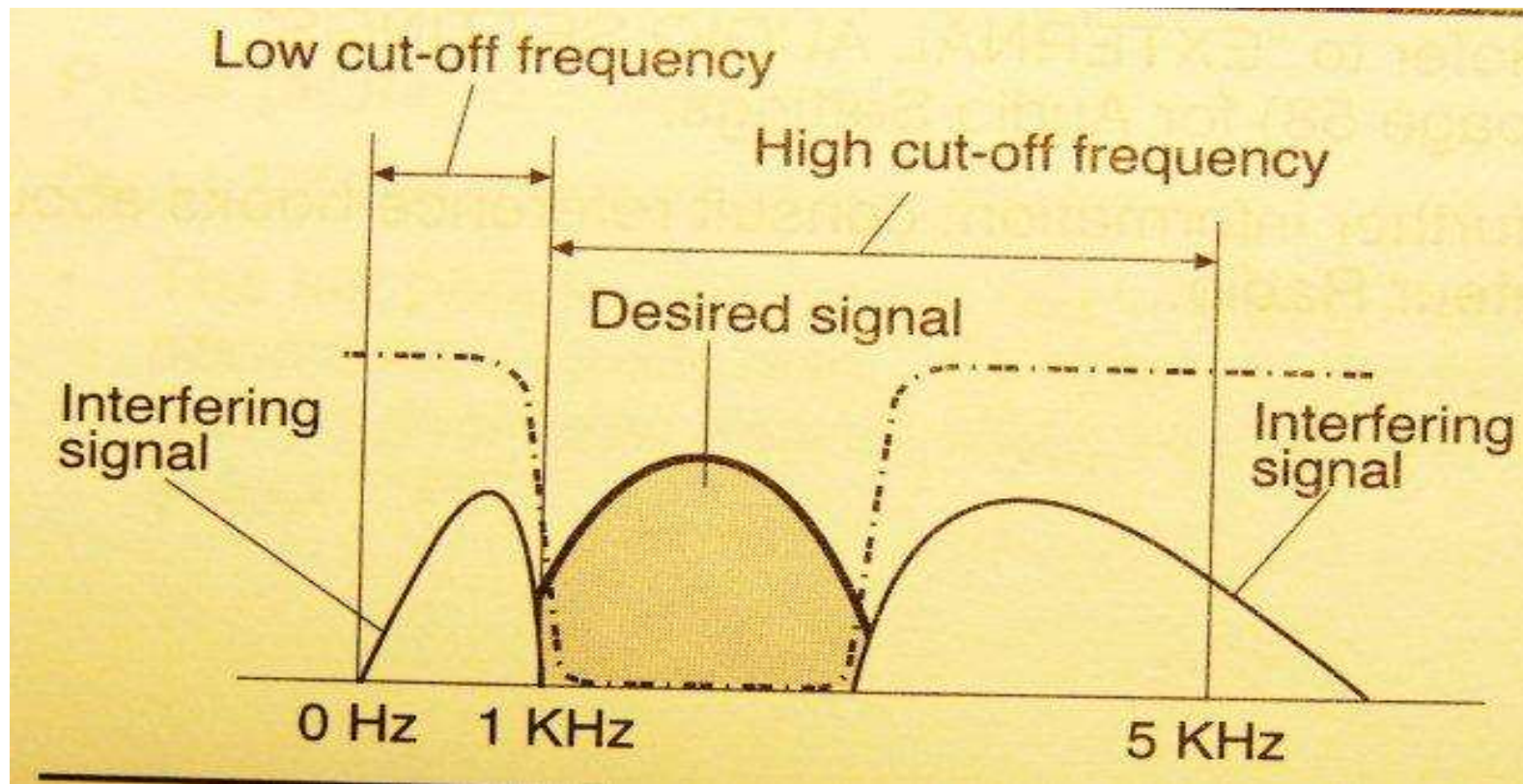
Bandwidth Controls

- Wide / Narrow (DSP & Roofing) Filters
 - Fixed Bandwidth (CW & FSK)



Bandwidth Controls

Variable Bandwidth Filters



73, CU On The Air!



**The slide deck of this presentation will be posted
on the HRU website:**

www.HamRadioUniversity.org

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If you Have Any Questions Email Me: ks2g@arrl.net