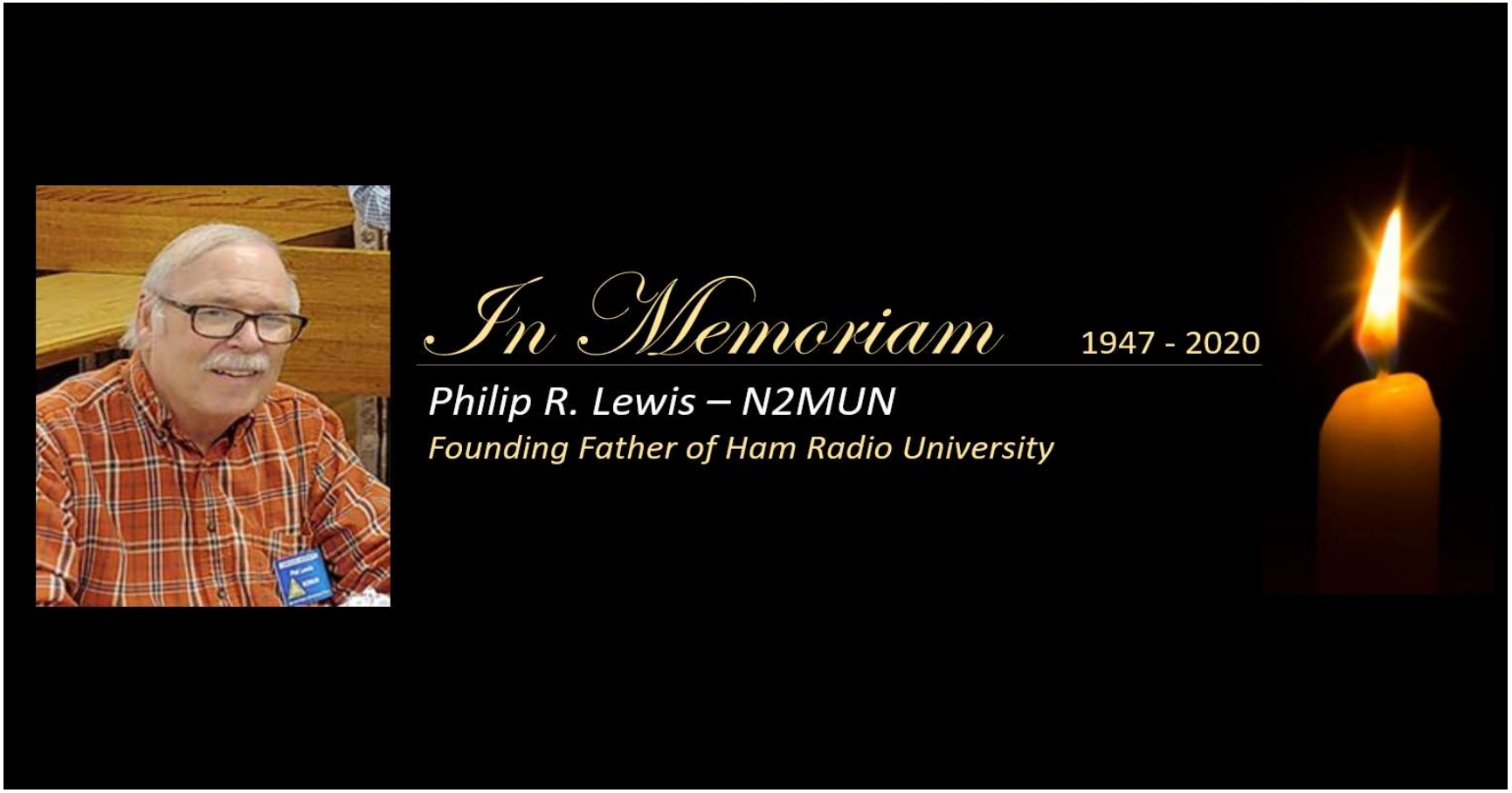
# Basics of HF Operating

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

**Mel Granick - KS2G**
**Ham Radio University**
**January 8, 2022**

# Our Founder


In Memoriam
1947 - 2020
Philip R. Lewis – N2MUN
Founding Father of Ham Radio University

# Who's Out There?

- A quick poll:
  - HF Operating Experience?
    - I've Never Operated HF
    - I Operate HF Every Now and Then
    - I Operate HF A Lot

# Please Note:

- All license, band-plan and regulatory information is applicable only to U.S. licensees.

# 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)

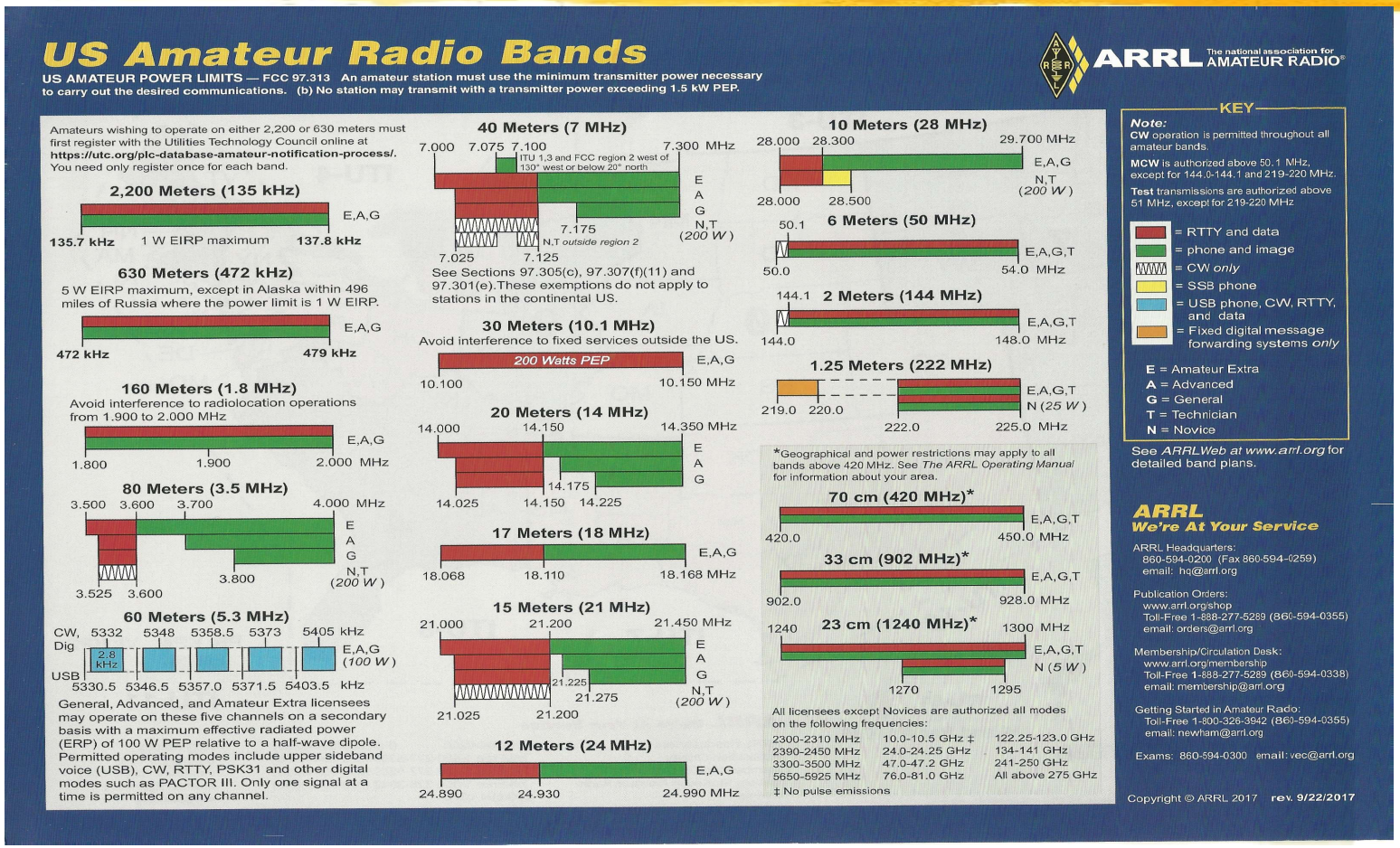
# HF Sub-Bands

- 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




http://www.arrl.org/graphical-frequency-allocations

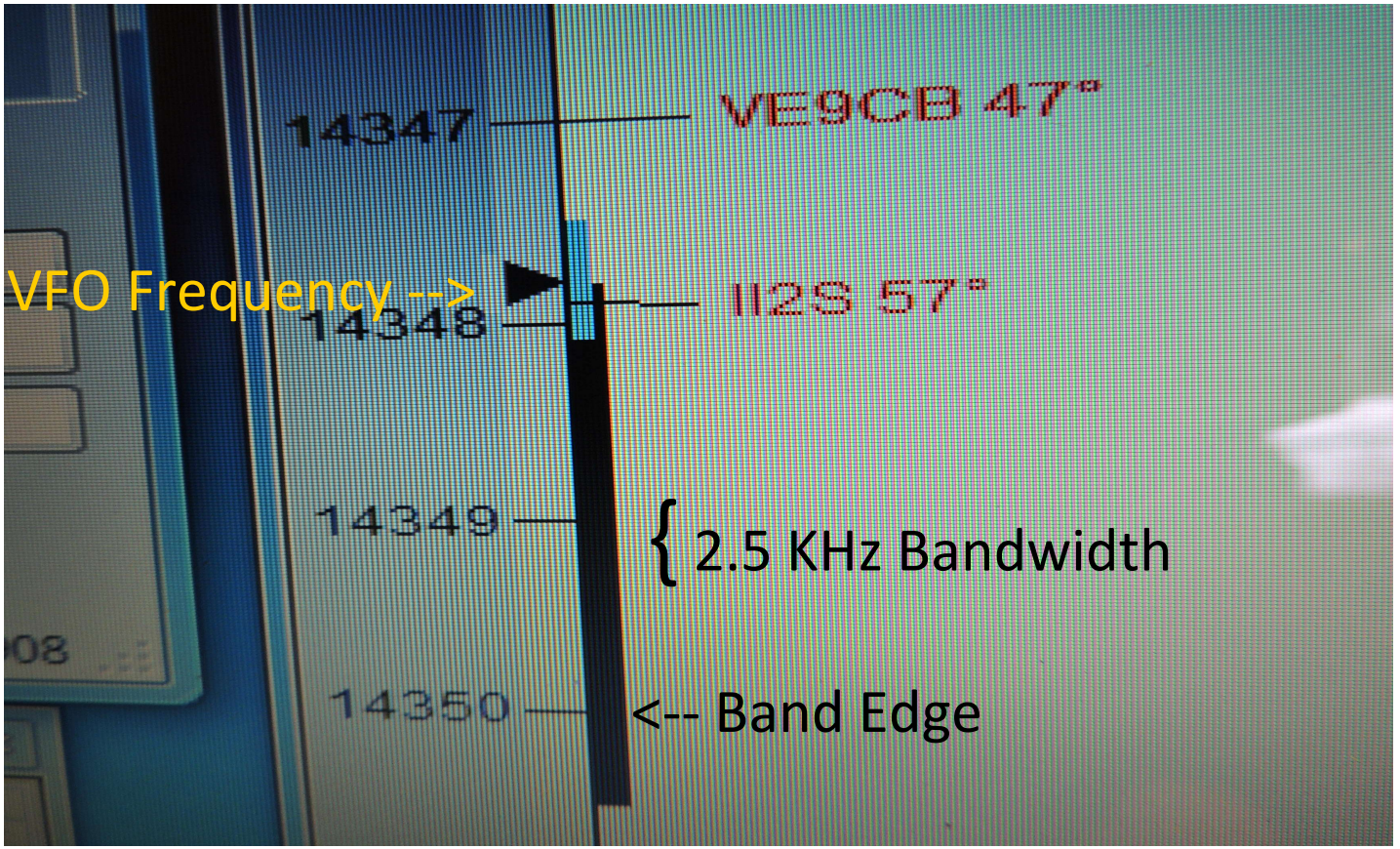
# HF Bands Not Channelized

- 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!


14347
VE9CB 47°
VFO Frequency -->
14348
II2S 57°
14349
{ 2.5 KHz Bandwidth
14350
<-- Band Edge

# 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 |
|---|---|
| 1.800-2.000 | CW |
| 1.800-1.810 | Digital Modes |
| 1.810 | CW QRP calling frequency |
| 1.843-2.000 | SSB, SSTV and other wideband modes |
| 1.910 | SSB QRP |
| 1.995-2.000 | Experimental |
| 1.999-2.000 | Beacons |
| 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 |
| 7.030 | QRP CW calling frequency |
| 7.040 | RTTY/Data DX |
| 7.070-7.125 | RTTY/Data |
| 7.100-7.105 | Automatically controlled data stations |
| 7.171 | SSTV |
| 7.173 | D-SSTV |
| 7.285 | QRP SSB calling frequency |
| 7.290 | AM calling frequency |
| 10.130-10.140 | RTTY/Data |
| 10.140-10.150 | Automatically controlled data stations |
| 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 |

| Frequencies | Modes/Activities |
|---|---|
| 14.233 | D-SSTV |
| 14.236 | Digital Voice |
| 14.285 | QRP SSB calling frequency |
| 14.286 | AM calling frequency |
| 18.100-18.105 | RTTY/Data |
| 18.105-18.110 | Automatically controlled data stations |
| 18.110 | IBP/NCDXF beacons |
| 18.162.5 | Digital Voice |
| 21.060 | QRP CW calling frequency |
| 21.070-21.110 | RTTY/Data |
| 21.090-21.100 | Automatically controlled data stations |
| 21.150 | IBP/NCDXF beacons |
| 21.340 | SSTV |
| 21.385 | QRP SSB calling frequency |
| 24.920-24.925 | RTTY/Data |
| 24.925-24.930 | Automatically controlled data stations |
| 24.930 | IBP/NCDXF beacons |
| 28.060 | QRP CW calling frequency |
| 28.070-28.120 | RTTY/Data |
| 28.120-28.189 | Automatically controlled data stations |
| 28.190-28.225 | Beacons |
| 28.200 | IBP/NCDXF beacons |
| 28.385 | QRP SSB calling frequency |
| 28.680 | SSTV |
| 29.000-29.200 | AM |
| 29.300-29.510 | Satellite downlinks |
| 29.520-29.580 | Repeater inputs |
| 29.600 | FM simplex |
| 29.620-29.680 | Repeater outputs |

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 | QTech Hz | Region | Reference |
|---|---|---|---|---|---|---|
| JT65-HF | | 1,838.00 | | | | http://[illegible] |
| PSK31 | | 1,837.30 | | | USA | http://www.[illegible] |
| Olivia | Olivia 16/500 | 1,836.00 | 1,838.15 | 750 | | http://[illegible] |
| Olivia | Olivia 16/500 | 1,836.00 | 1,838.15 | 750 | | http://[illegible] |
| JT65-HF | | 1,838.00 | | | | http://[illegible] |
| Olivia | Olivia 16/500 | 1,836.00 | 1,838.15 | 750 | | http://[illegible] |
| PSK31 | | 1,838.15 | | | Europe | http://[illegible] |
| Olivia | Olivia 16/500 | 3,577.00 | 3,579.15 | 750 | E. Asia | http://[illegible] |
| Olivia | Olivia 32/1000 | 3,577.00 | 3,579.15 | 1000 | E. Asia | http://[illegible] |
| JT65-HF | | 3,576.00 | | | | http://[illegible] |
| Olivia | Olivia 16/500 | 3,577.00 | 3,579.15 | 750 | | http://[illegible] |
| Olivia | Olivia 32/1000 | 3,577.00 | 3,579.15 | 1000 | E. Asia | http://[illegible] |
| PSK31 | | 3,580.15 | | | | http://[illegible] |
| Olivia | Olivia 16/500 | 3,582.50 | 3,583.25 | 750 | | http://[illegible] |
| Olivia | Olivia 32/1000 | 3,815.00 | 3,818.80 | 1000 | E. Asia | http://[illegible] |
| Olivia | Olivia 32/1000 | 3,822.00 | 3,822.80 | 1000 | Australia | http://[illegible] |
| Olivia | Olivia 16/500 | 7,035.50 | 7,035.25 | 750 | | http://[illegible] |
| PSK31 | | 7,035.00 | 7,035.15 | | EU | http://[illegible] |
| JT65-HF | | 7,076.00 | | | | http://[illegible] |
| JT65-HF | | 7,078.00 | | | | http://[illegible] |
| PSK31 | | 7,043.00 | | | JA | http://[illegible] |
| Olivia | Olivia 16/500 | 7,040.50 | 7,043.25 | 750 | | http://[illegible] |
| Olivia | Olivia 16/500 | 7,070.50 | 7,071.25 | 750 | | http://[illegible] |
| JT65-HF | | 10,138.00 | | | USA | http://[illegible] |
| PSK31 | | 7,080.00 | 7,080.15 | | EU | http://[illegible] |
| JT65-HF | | 10,137.00 | | | USA | http://[illegible] |
| JT65-HF | | 10,138.00 | | | | http://[illegible] |
| JT65-HF | | 10,139.00 | | | | http://[illegible] |
| Olivia | Olivia 16/500 | 10,139.50 | 10,139.25 | 750 | | http://[illegible] |
| PSK31 | | 10,140.00 | 10,140.15 | | | http://[illegible] |
| Olivia | Olivia 16/500 | 10,141.50 | 10,140.25 | 750 | | http://[illegible] |
| PSK31 | | 14,070.00 | 14,070.15 | | | http://[illegible] |
| Olivia | Olivia 16/500 | 14,071.50 | 14,074.40 | 750 | | http://[illegible] |
| Olivia | Olivia 16/500 | 14,074.65 | 14,075.40 | 750 | | http://[illegible] |
| JT65-HF | | 14,076.00 | | | | http://[illegible] |
| JT65-HF | | 14,078.00 | | | | http://[illegible] |
| Olivia | Olivia 16/500 | 14,077.65 | 14,076.40 | 750 | | http://[illegible] |
| Olivia | Olivia 32/1000 | 14,078.50 | 14,186.50 | 1000 | | http://[illegible] |
| Olivia | Olivia 32/1000 | 14,184.50 | 14,187.50 | 1000 | | http://[illegible] |
| JT65-HF | | 18,102.00 | | | | http://[illegible] |
| PSK31 | | 18,100.00 | 18,100.15 | | | http://[illegible] |
| JT65-HF | | 18,103.00 | | | | http://[illegible] |
| Olivia | Olivia 16/500 | 18,103.65 | 18,104.4 | 750 | | http://[illegible] |
| Olivia | Olivia 16/500 | 18,105.65 | 18,106.40 | 750 | | http://[illegible] |
| JT65-HF | | 20,076.00 | | | | http://[illegible] |
| PSK31 | | 21,070.00 | 21,070.15 | | | http://[illegible] |
| JT65-HF | | 21,076.00 | | | | http://[illegible] |
| PSK31 | | 21,080.00 | 21,080.15 | | | http://[illegible] |
| Olivia | Olivia 16/500 | 21,084.00 | 21,087.25 | 750 | | http://[illegible] |
| Olivia | Olivia 16/500 | 21,087.00 | 21,087.75 | 750 | | http://[illegible] |
| Olivia | Olivia 16/500 | 21,129.50 | 21,130.25 | 750 | | http://[illegible] |
| Olivia | Olivia 32/1000 | 21,153.50 | 21,153.50 | 1000 | | http://[illegible] |
| Olivia | Olivia 32/1000 | 21,183.50 | 21,184.50 | 1000 | | http://[illegible] |
| JT65-HF | | 24,917.00 | | | | http://[illegible] |
| JT65-HF | | 24,920.00 | | | | http://[illegible] |
| PSK31 | | 24,920.00 | 24,920.15 | | | http://[illegible] |
| Olivia | Olivia 16/500 | 24,921.50 | 24,922.25 | 750 | | http://[illegible] |
| JT65-HF | | 28,073.00 | | | | http://[illegible] |
| Olivia | Olivia 16/500 | 28,076.00 | 28,076.75 | 750 | | http://[illegible] |
| Olivia | Olivia 16/500 | 28,076.50 | 28,077.25 | 750 | | http://[illegible] |
| PSK31 | | 28,120.00 | 28,120.15 | | | http://[illegible] |

Compiled from web sources by W7CAR

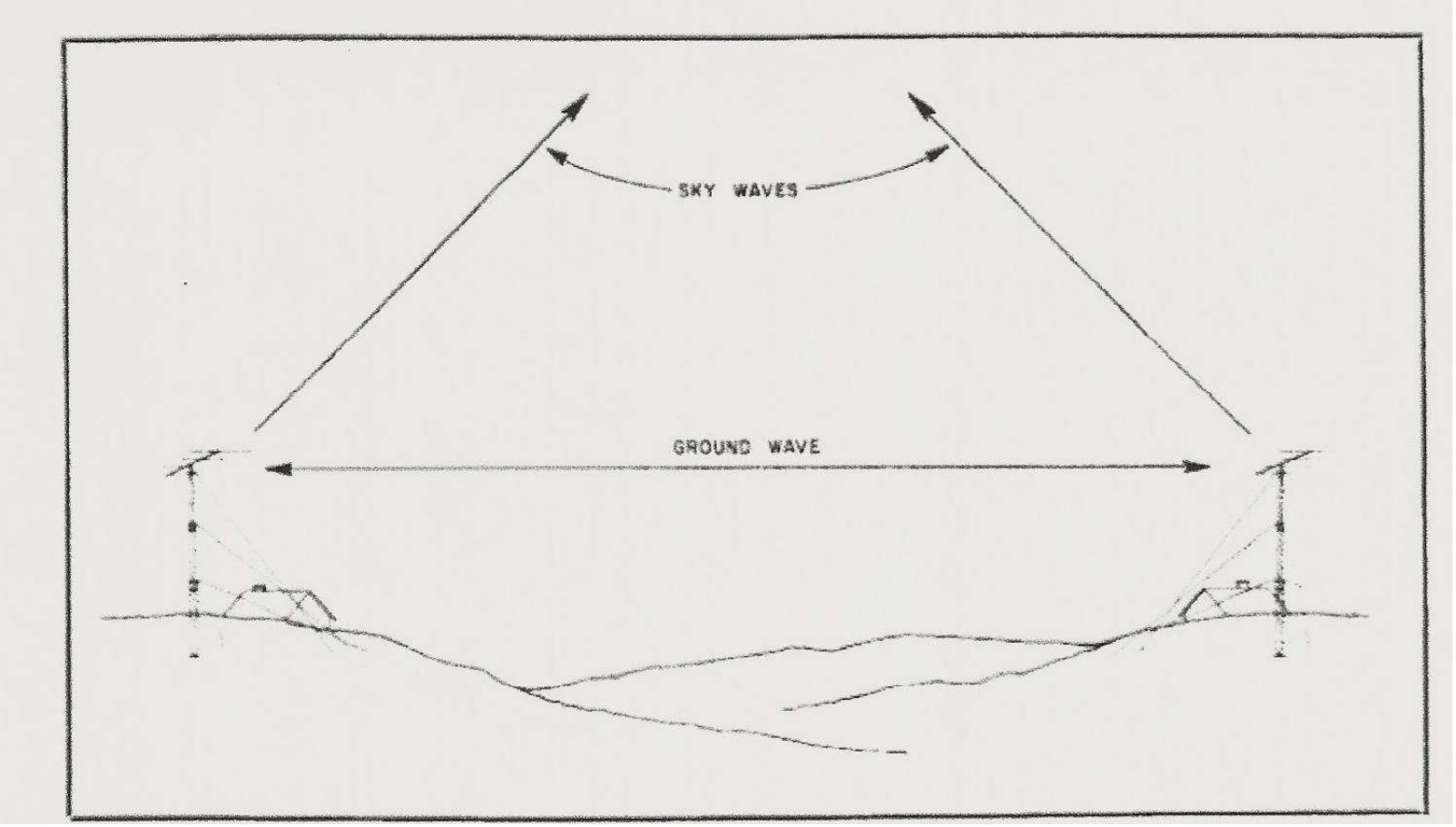
**https://www.wx4car.org/digital-modes.html**

# 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<br>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

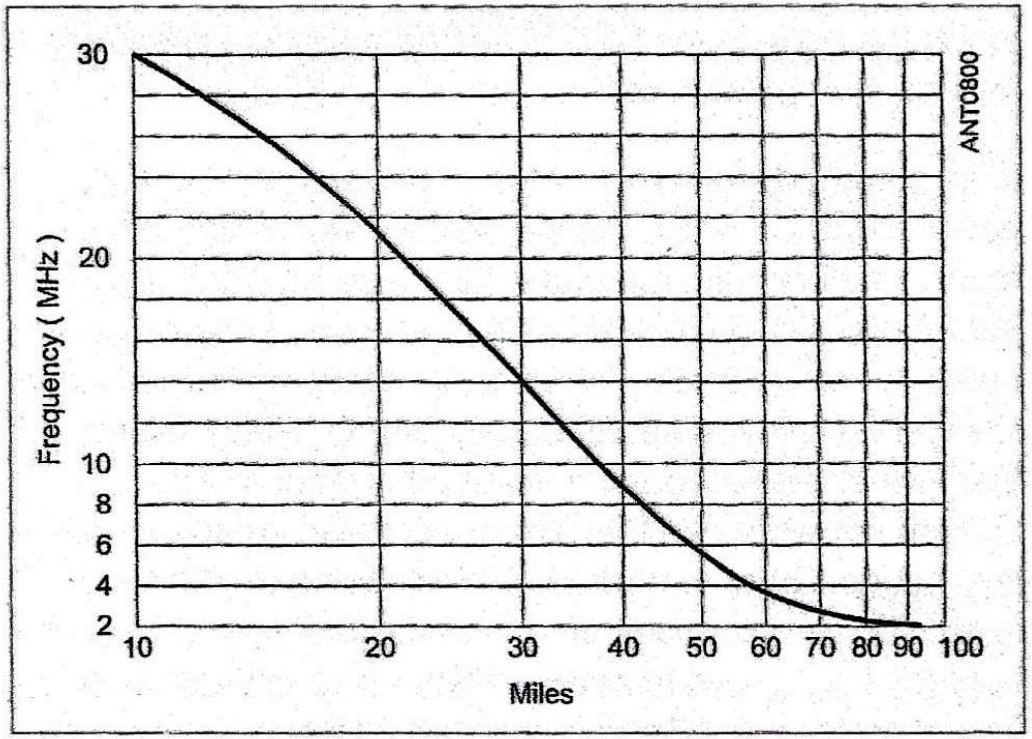
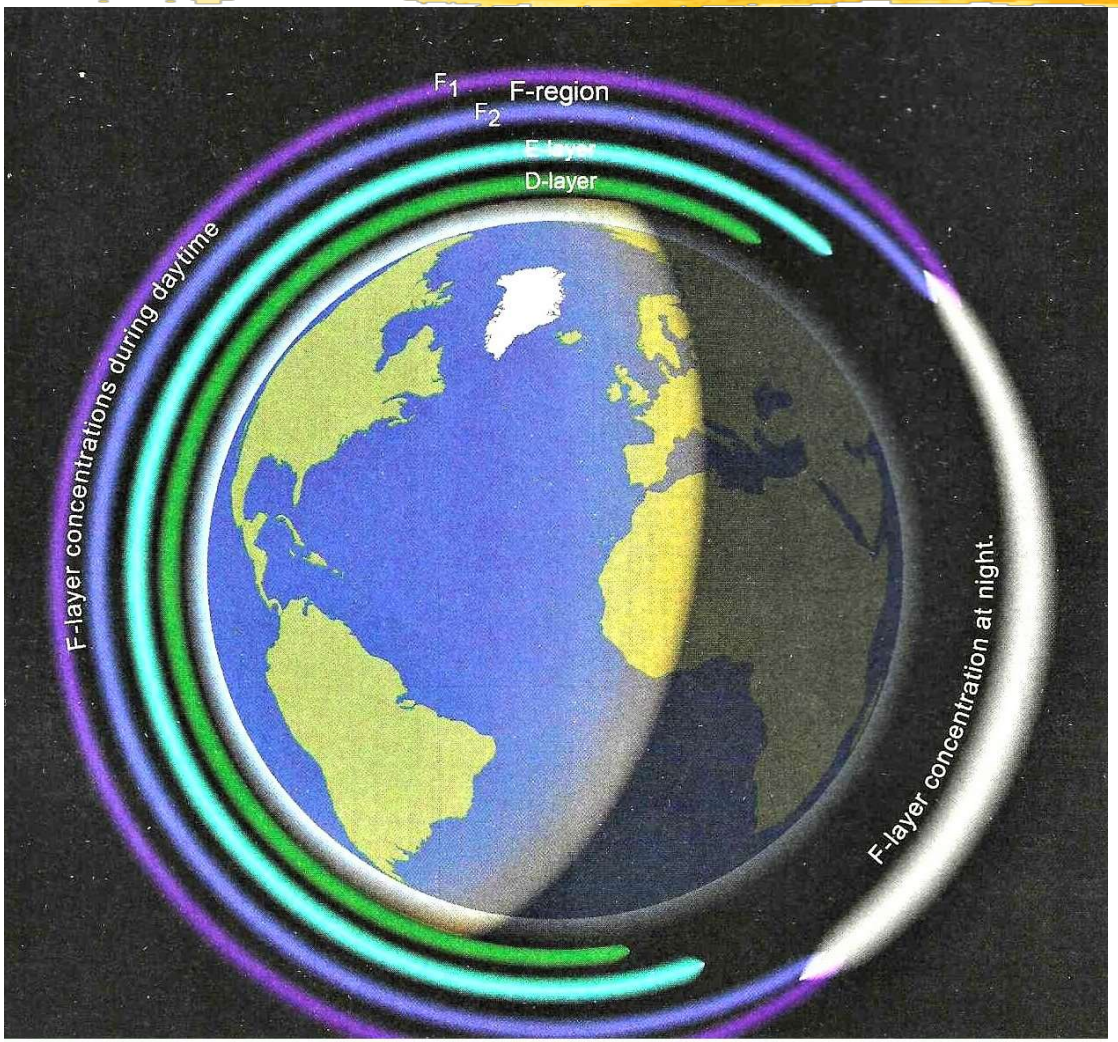
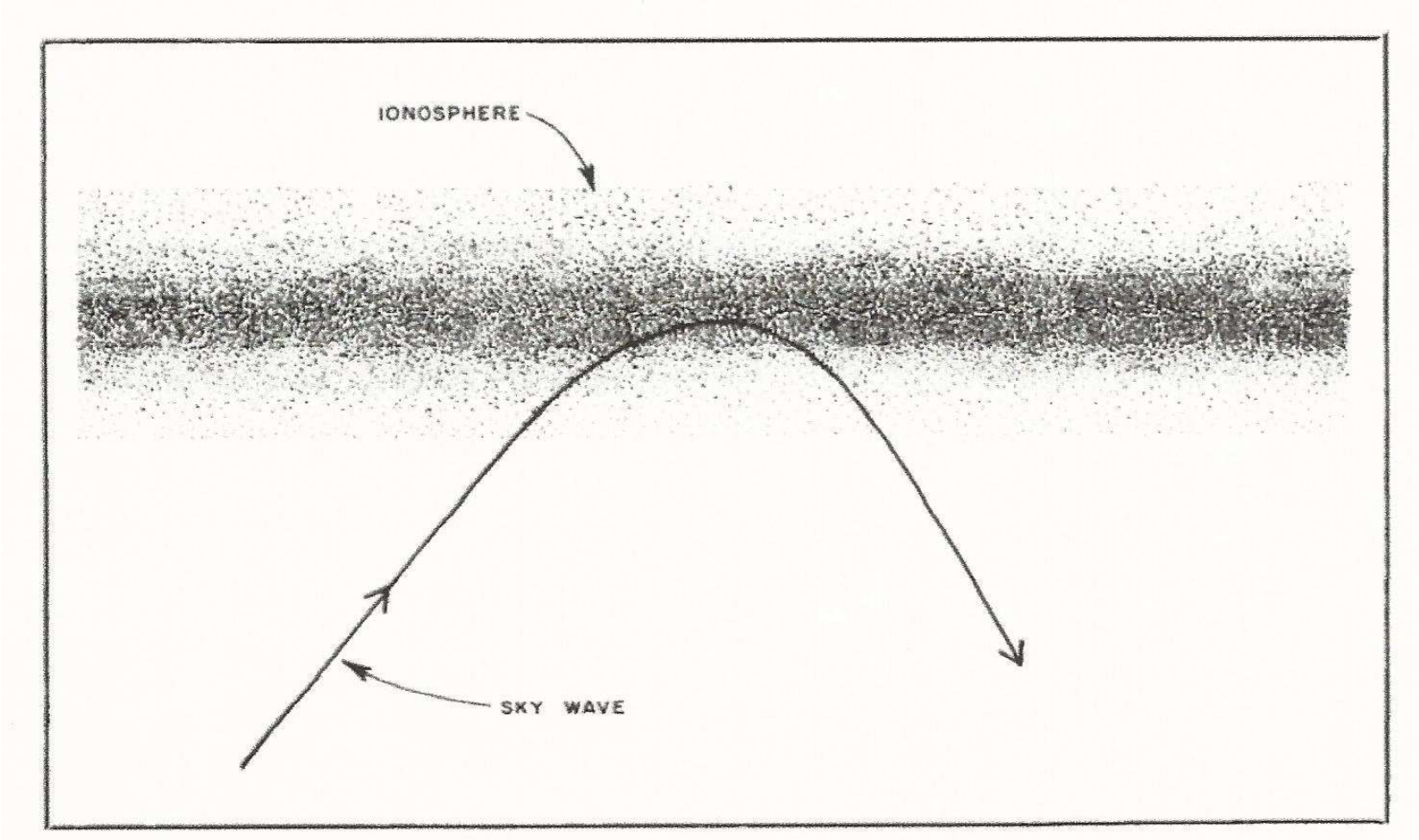



**Figure 1** — Typical HF ground-wave range as a function of frequency.

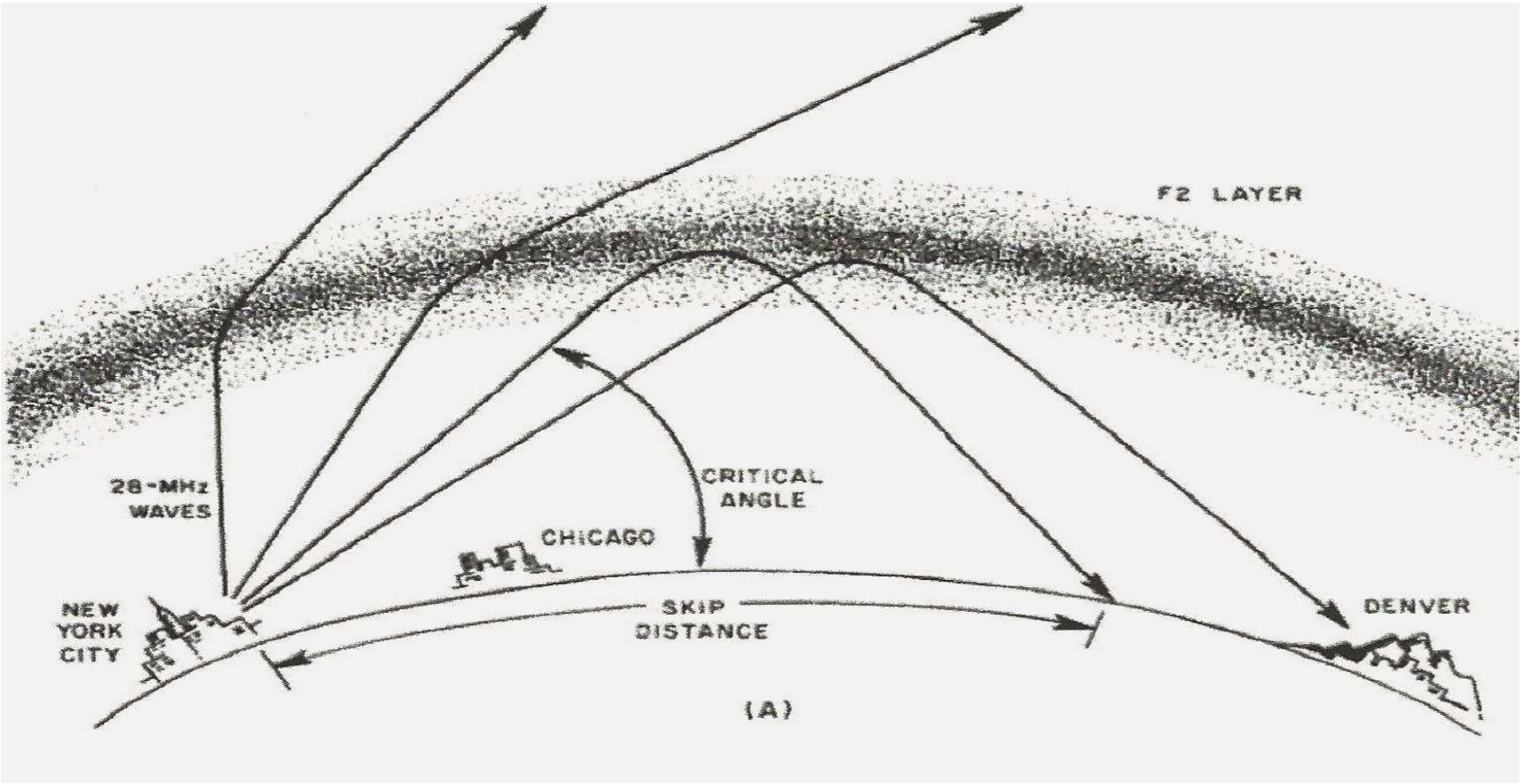
# HF Propagation:
# The Ionosphere Layers



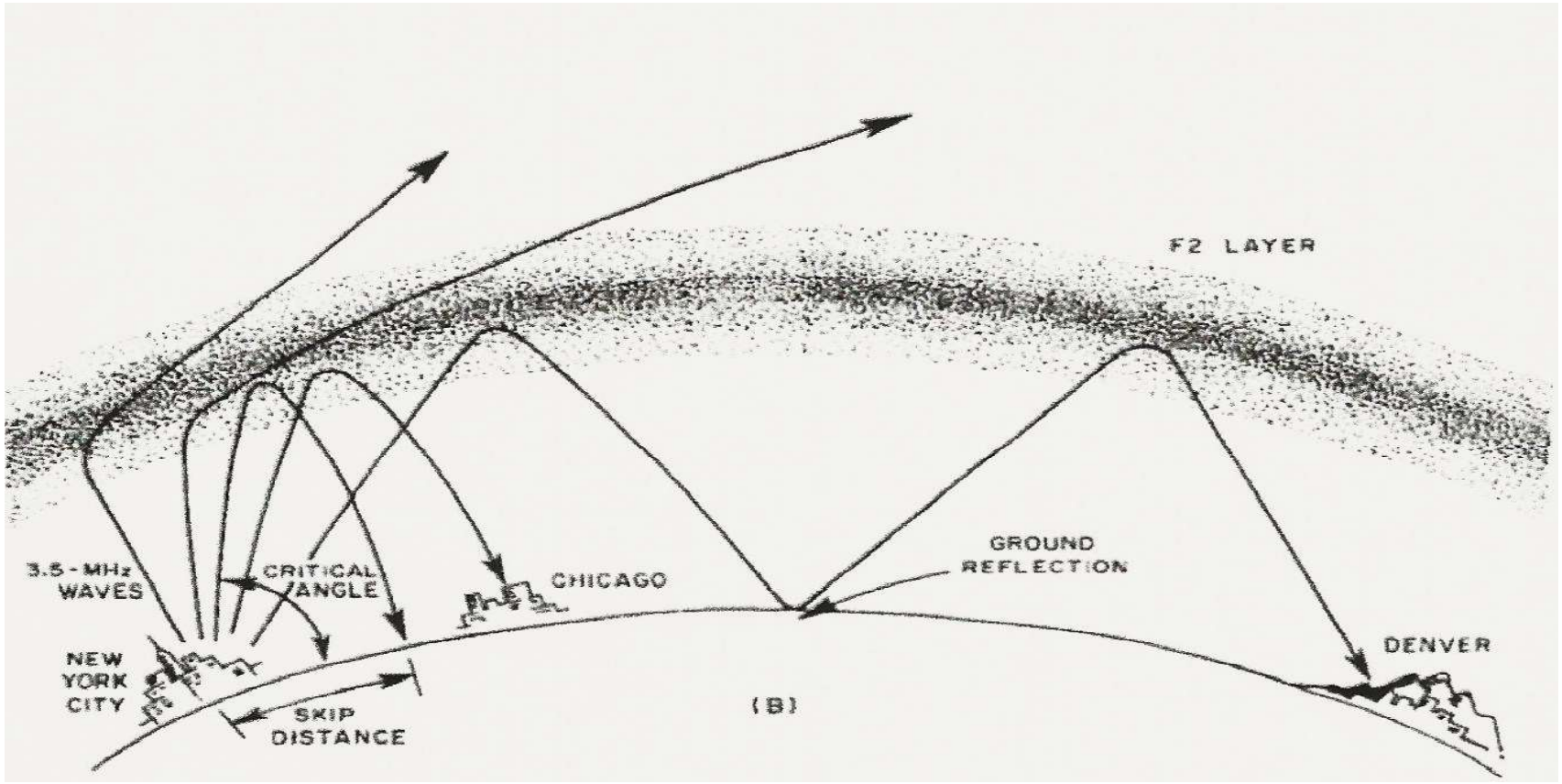
# The Ionosphere Can *Refract* Sky Waves



# Sky Wave Refraction: Long-Distance "Skip"



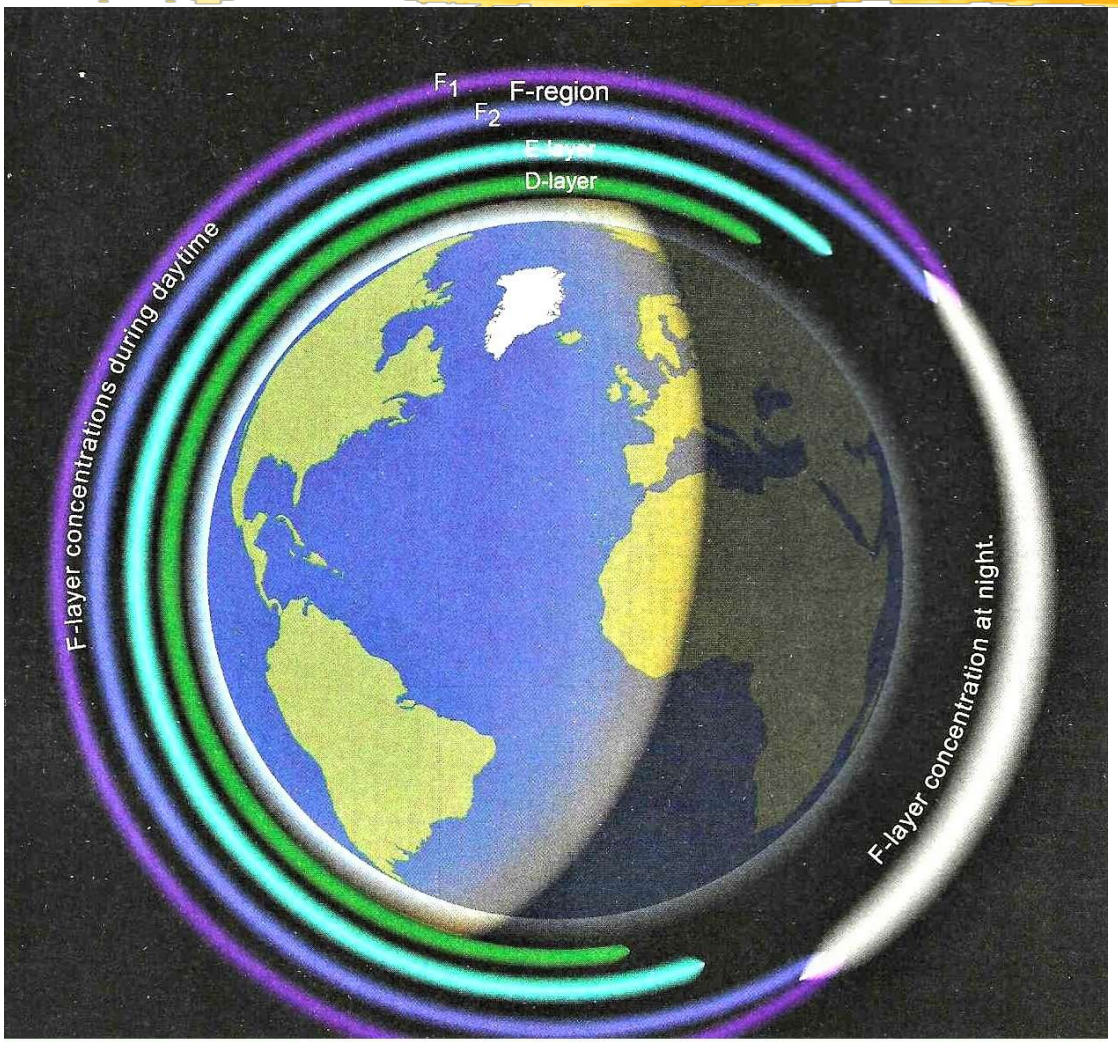
# Multi-Hop Propagation



# Which Bands When?

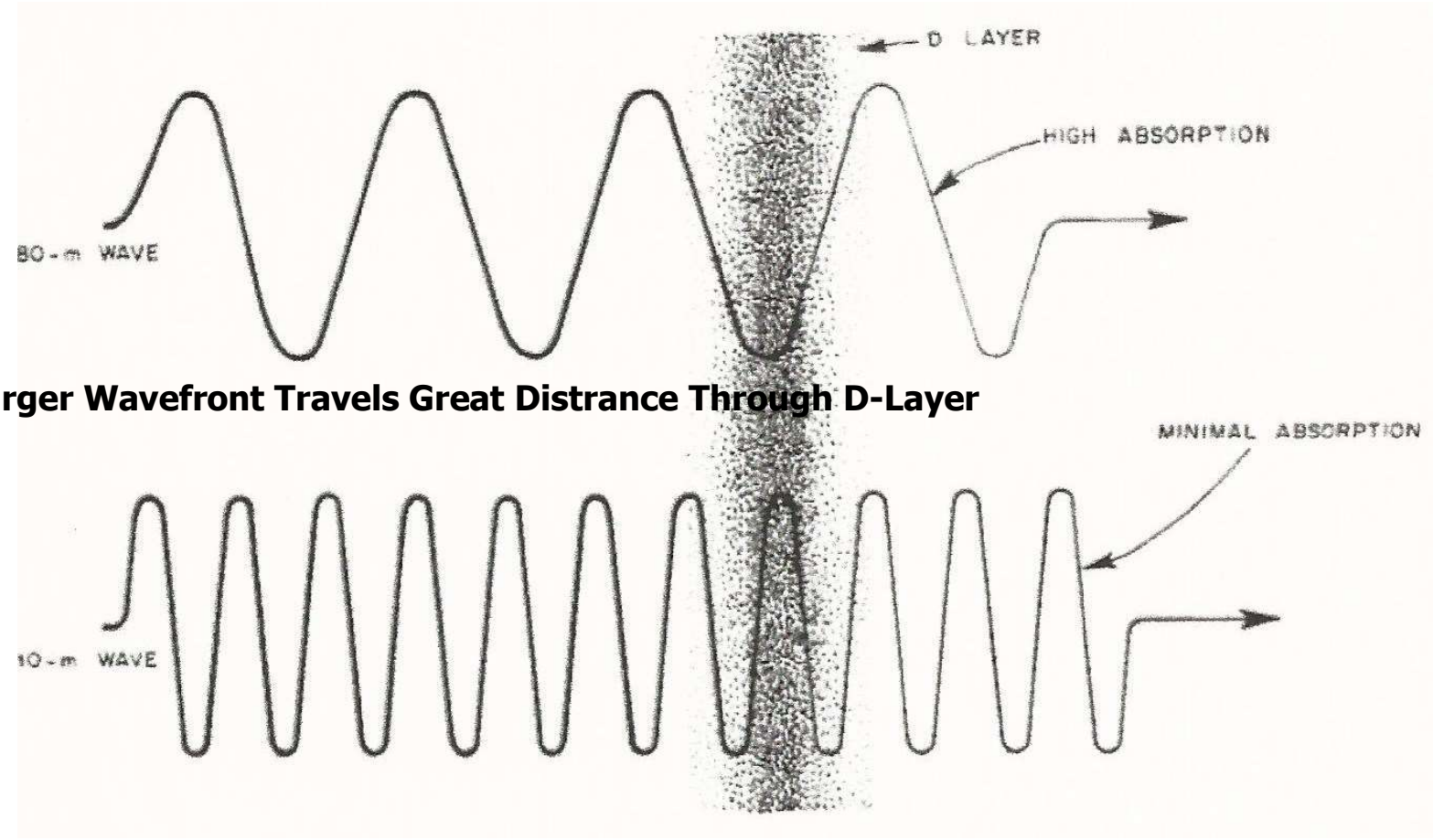
- Lower Frequency Bands
  - 160, 80, 60, 40 Meters
    - Ground Wave Daytime (Local / Regional)
    - Sky Wave Nighttime (DX)
- Upper Frequency Bands
  - 30, 20, 17, 15, 10 Meters
  - Both Ground Wave & Sky Wave Day and Night (When Open)

# HF Propagation:
# The Key Role of the D-Layer



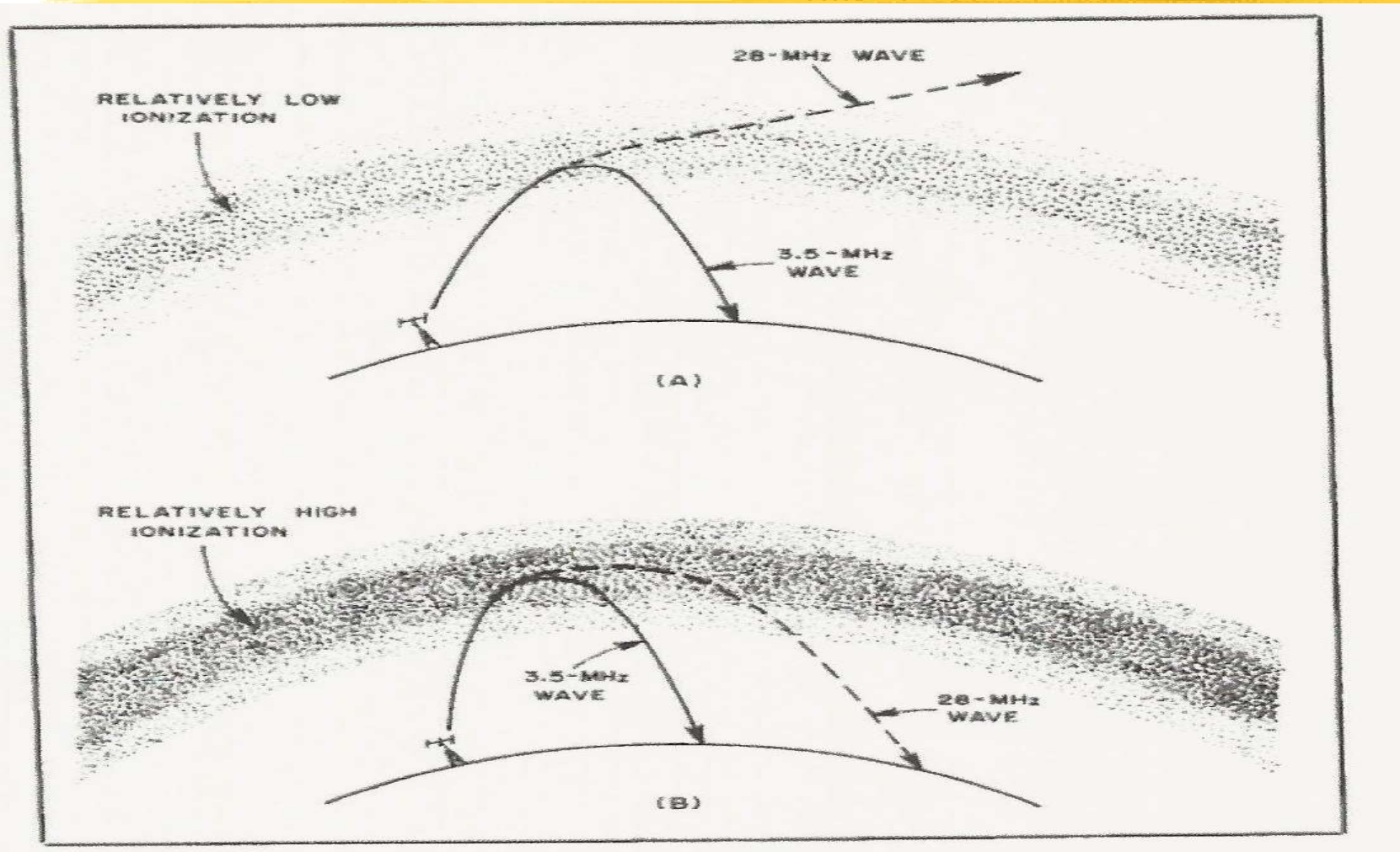
# D-Layer Absorption

**Lower Frequency = Higher Absorption**




**Larger Wavefront Travels Great Distrance Through D-Layer**

# Frequency and Ionization Level



# For A Detailed Explanation:

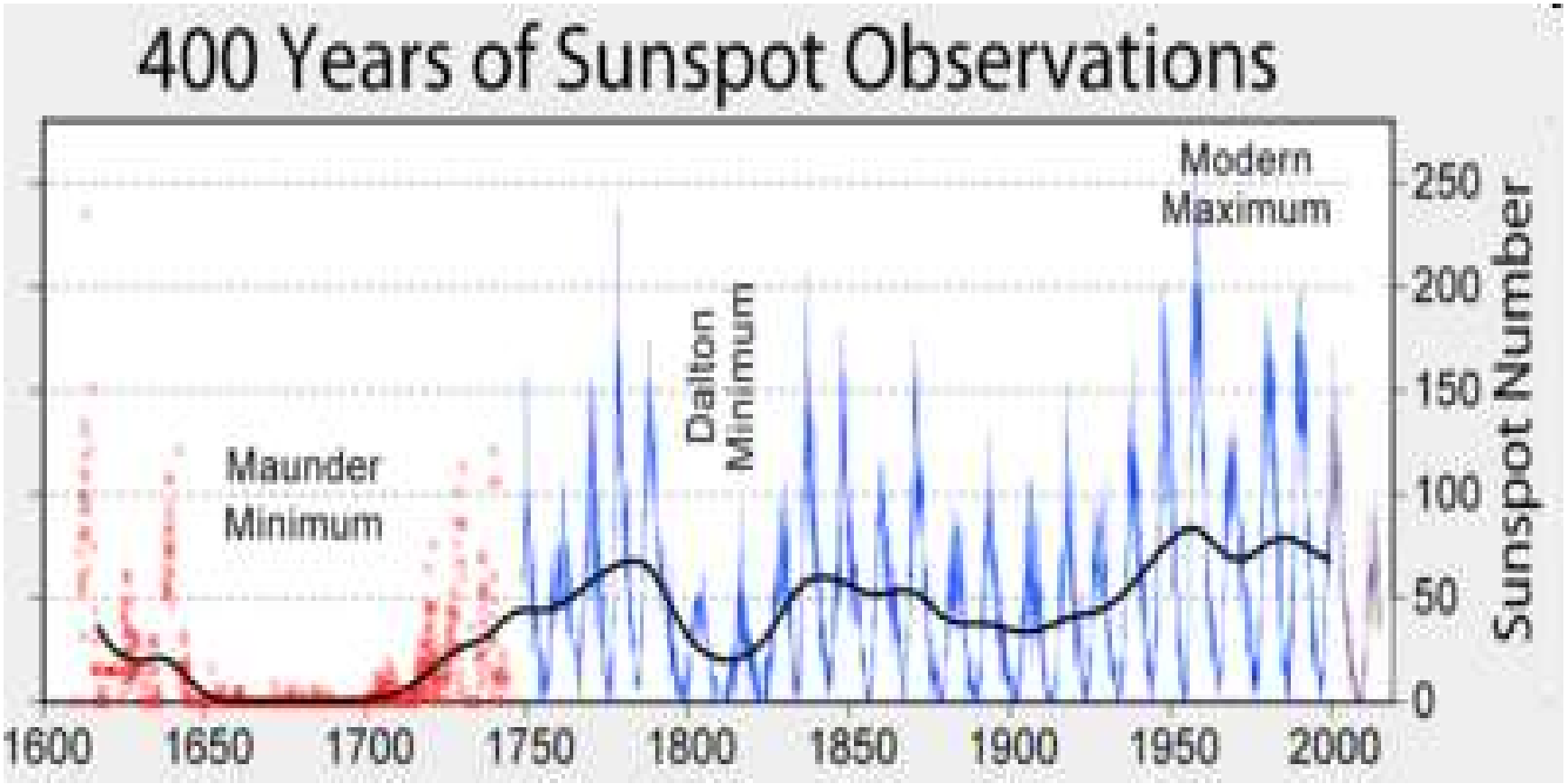
- Go To YouTube:
  - "The Effects Of The Ionosphere On Radio Wave Propagation"

# Sky Wave & Sunspots

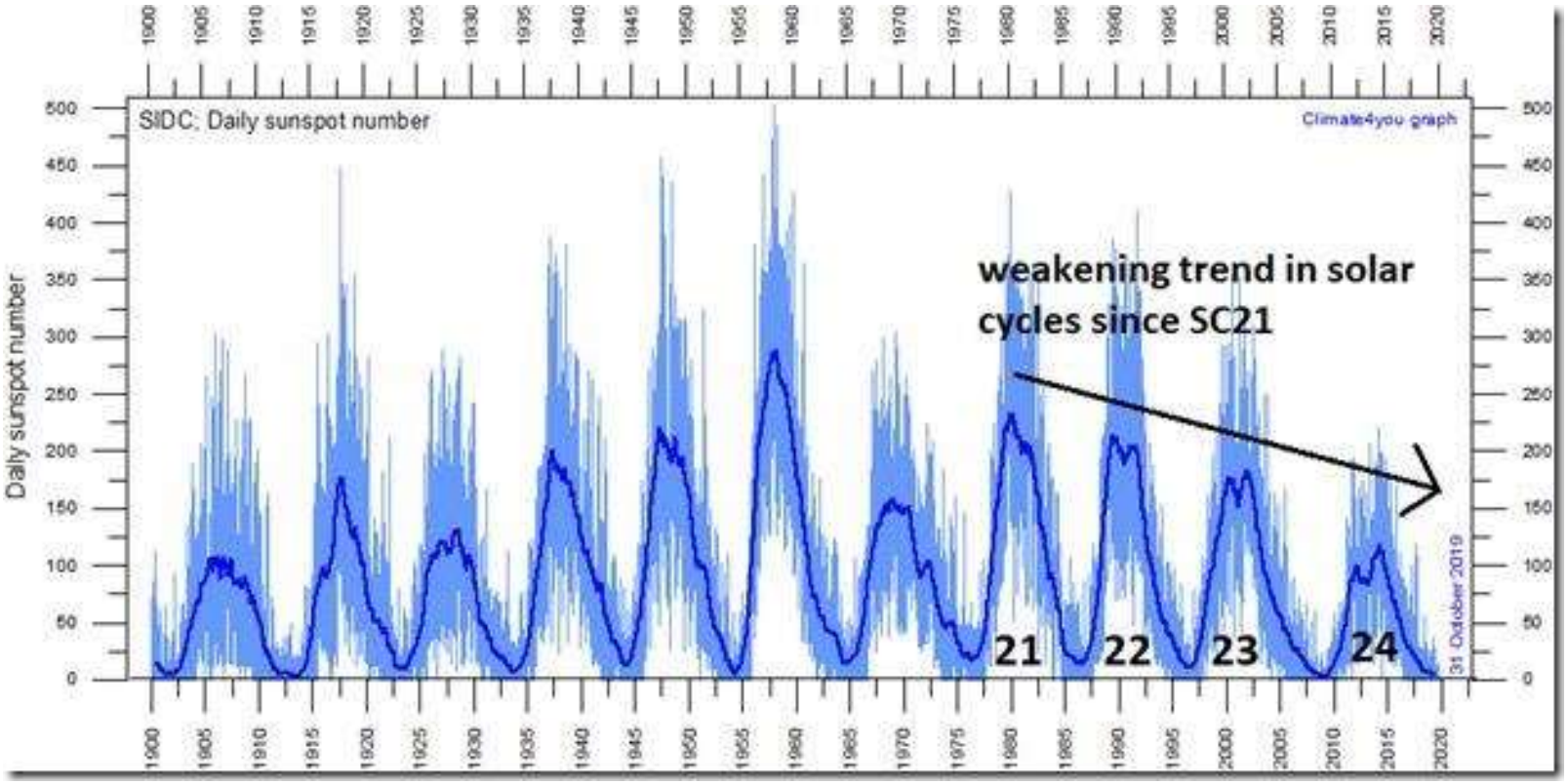
- Ionization Determined by **Sunspot Activity**
  - More Sunspots = More Ionization
  - More Ionization = More DX at Higher Frequencies

- **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

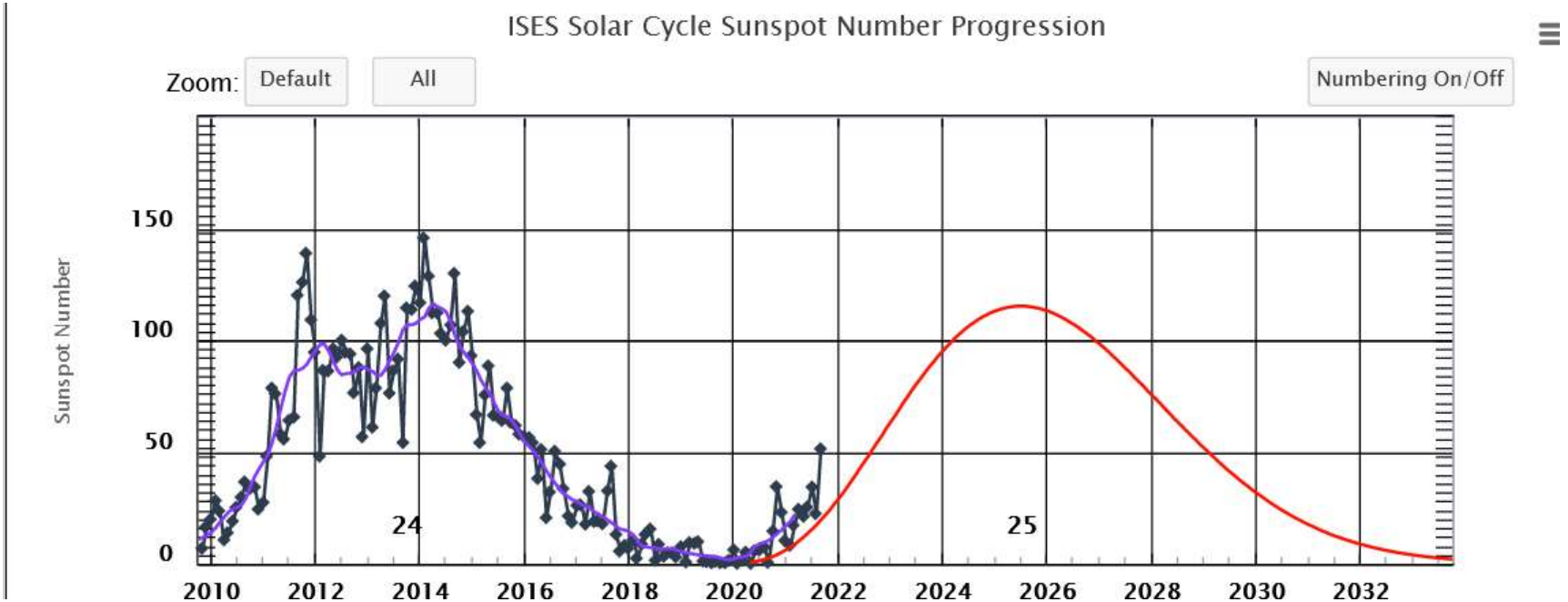
# Modern Sunspot Maximum Was 1959 - Peak of Cycle 19



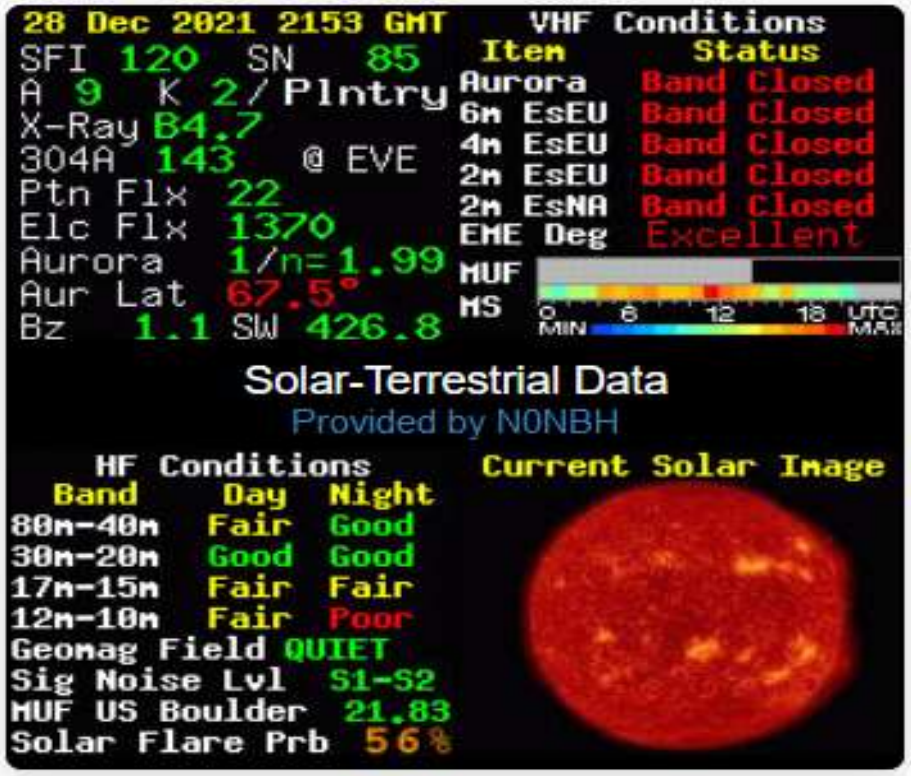
# Strength of Cycles Has Been Declining



# Solar Cycle 25 Began In December, 2019

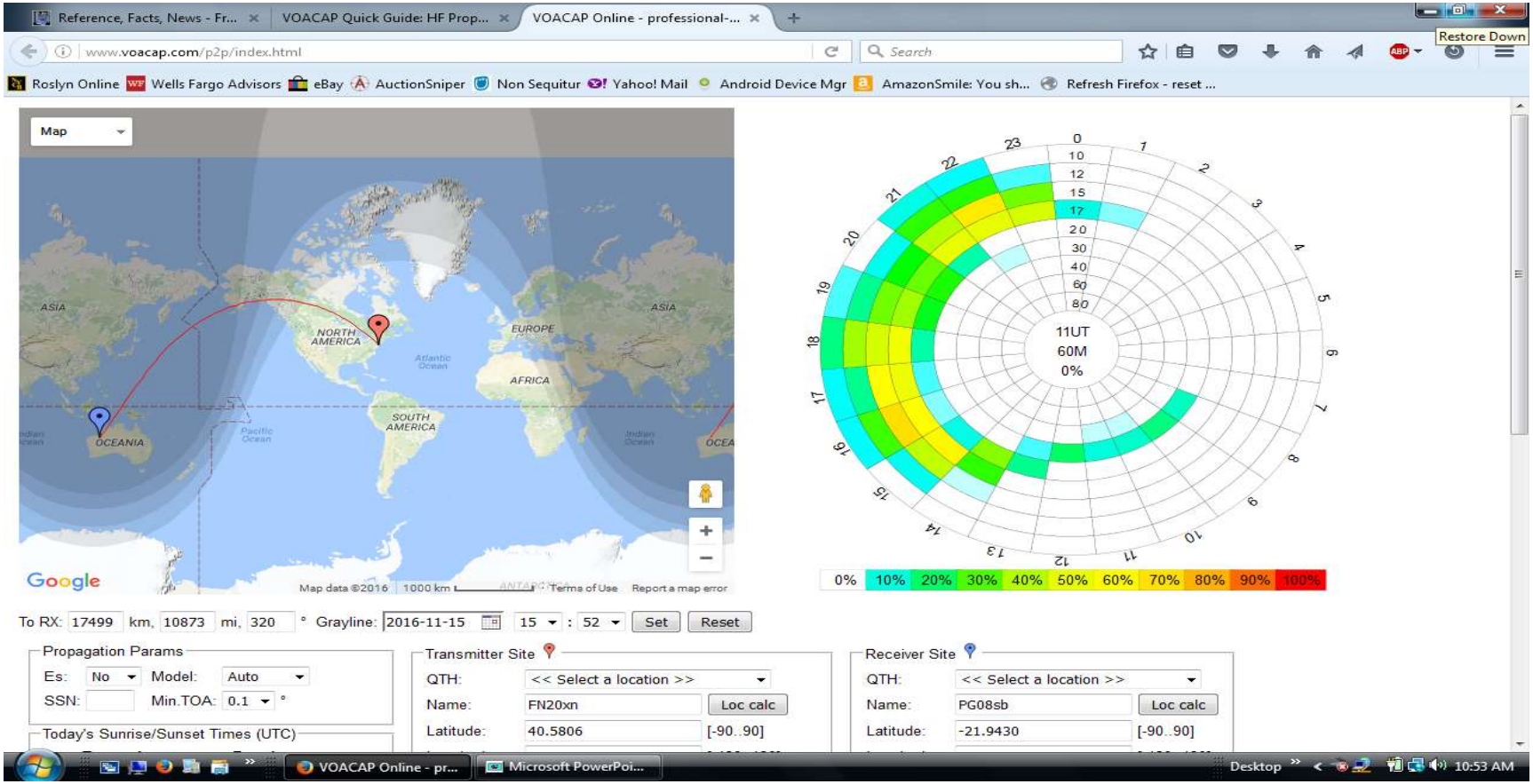


# Solar Conditions Vary Day-to-Day … Even Hour-to-Hour



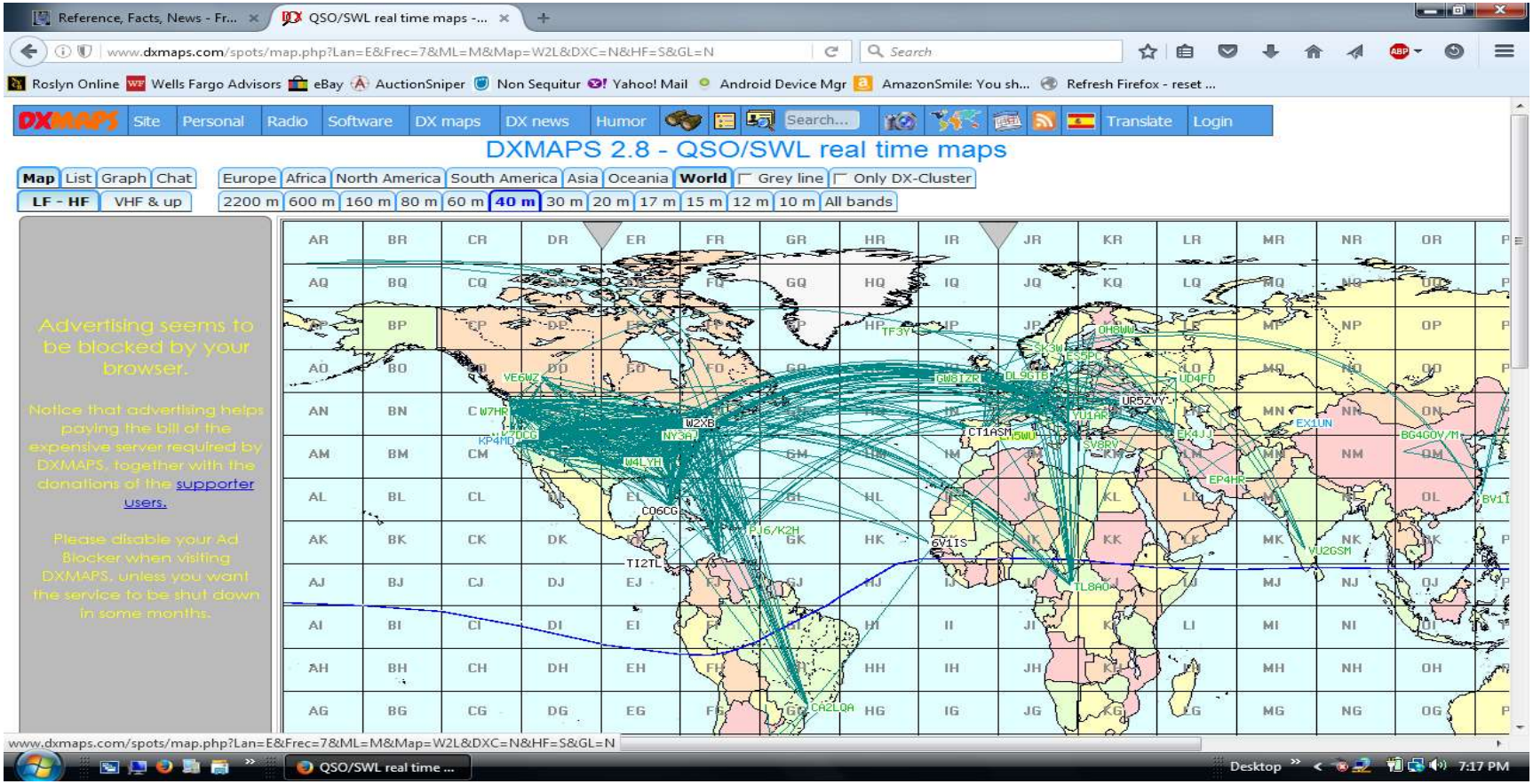

**https://www.hamqsl.com/solar.html**

# Propagation Calculators



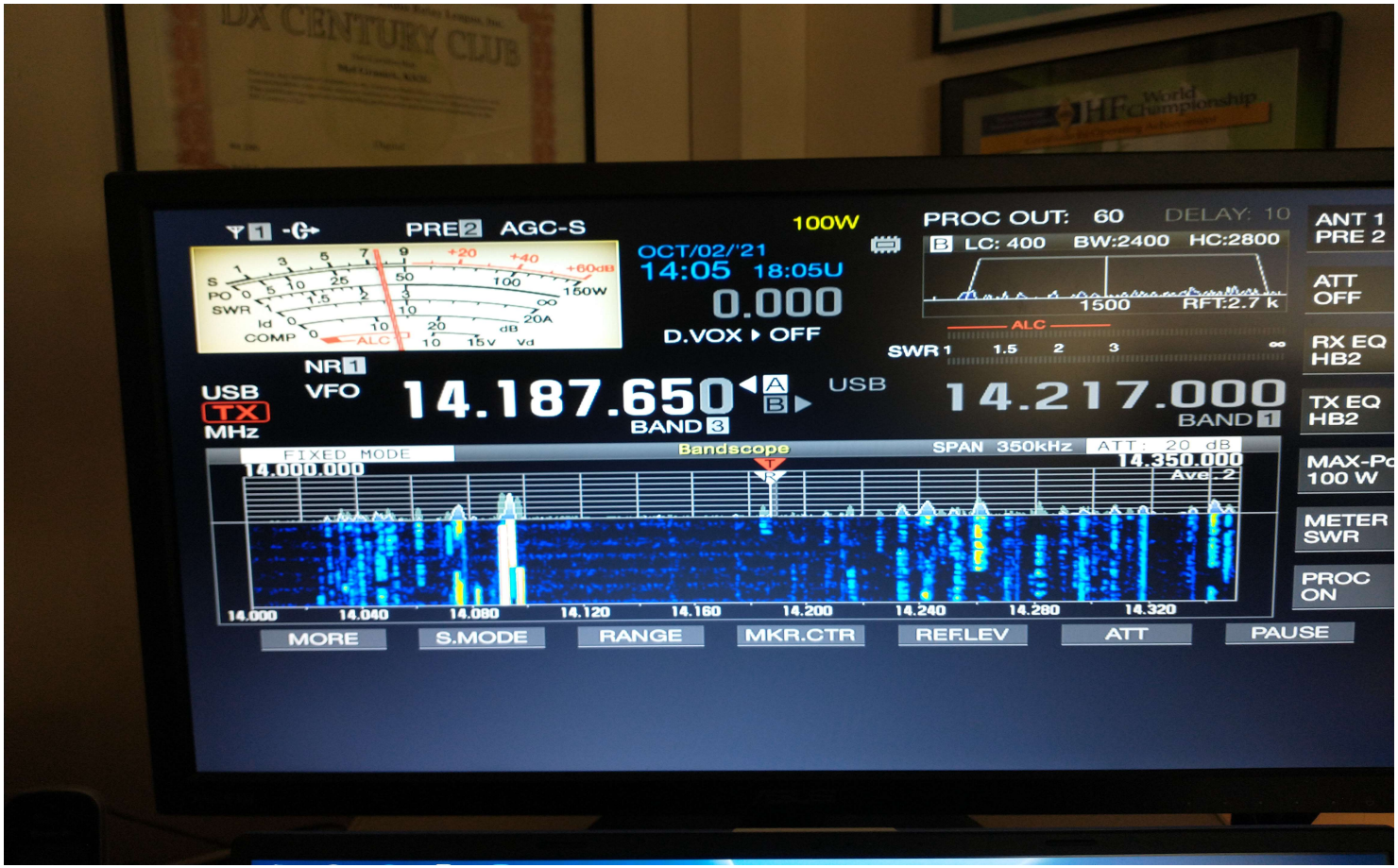

http://www.voacap.com

# 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 Dxpeditions 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

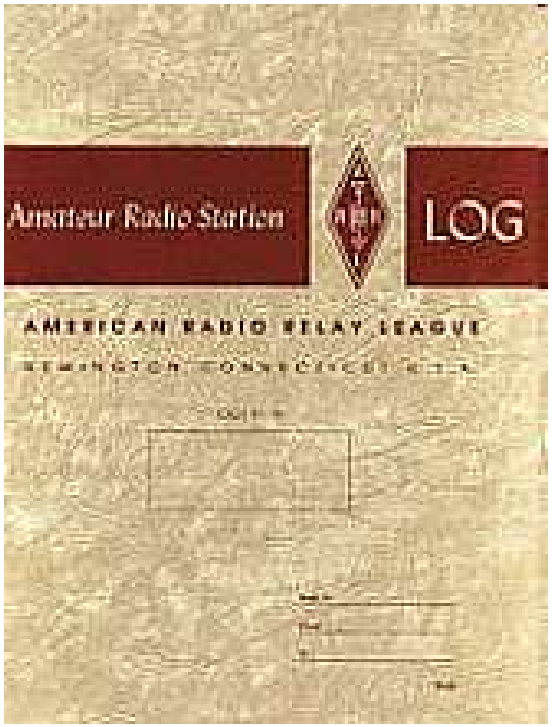
- Competitive Operating:
  - Work as many stations as possible, in as many places as possible, as quickly as possible
  - Check Contest Rules For Contest "Exchange"
  - "Run" -- call CQ
  - "Search & Pounce" -- Tune the Band and Respond to Stations That Call CQ

# 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:

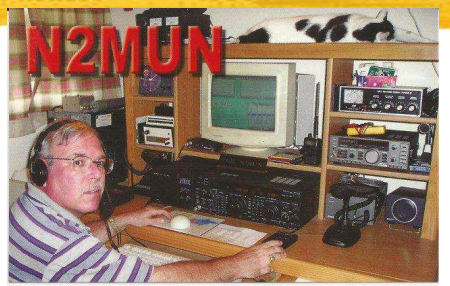


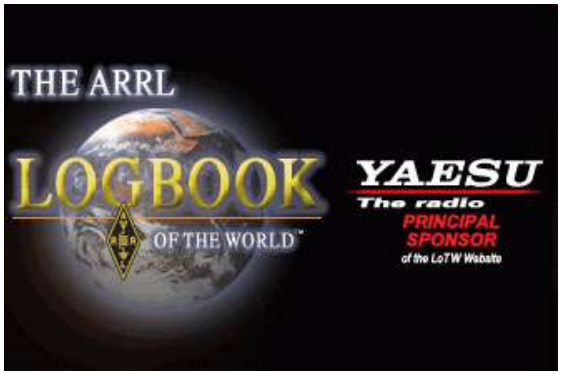
# Computer Logging

- General Purpose Loggers:
  - DXLAB
  - DX 4 WIN
  - DXKeeper
  - RumLog (Mac)
  - MacLoggerDx (Mac)
  - TWlog (Linux)
- Specialized Contest Loggers:
  - N1MM-Plus
  - WriteLog
  - Skookumlogger (Mac)
  - 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





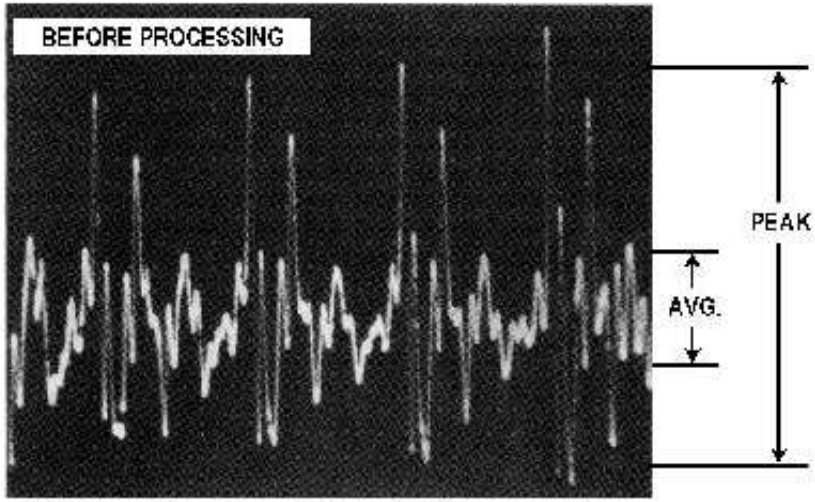
# Operating Awards

# Getting The Most Out Of Your HF Transceiver

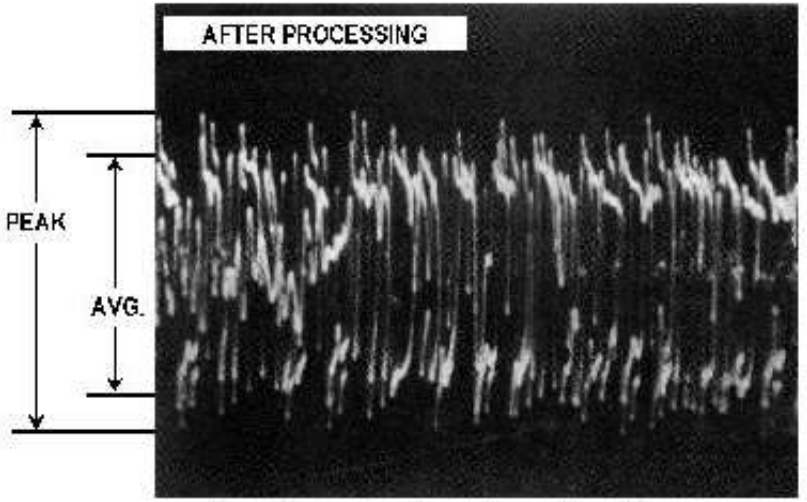
- Transmitter Controls:
  - RF Power Output - cw, digital, ssb
  - Microphone Level
    - Speech Processing / Compression
      - Increases Average RF Power & Adds "Punch" To Audio
      - Observe ALC (Automatic Level Control) Limit
    - Transmit Audio Equalization
      - Control "Highs" & "Lows" For 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

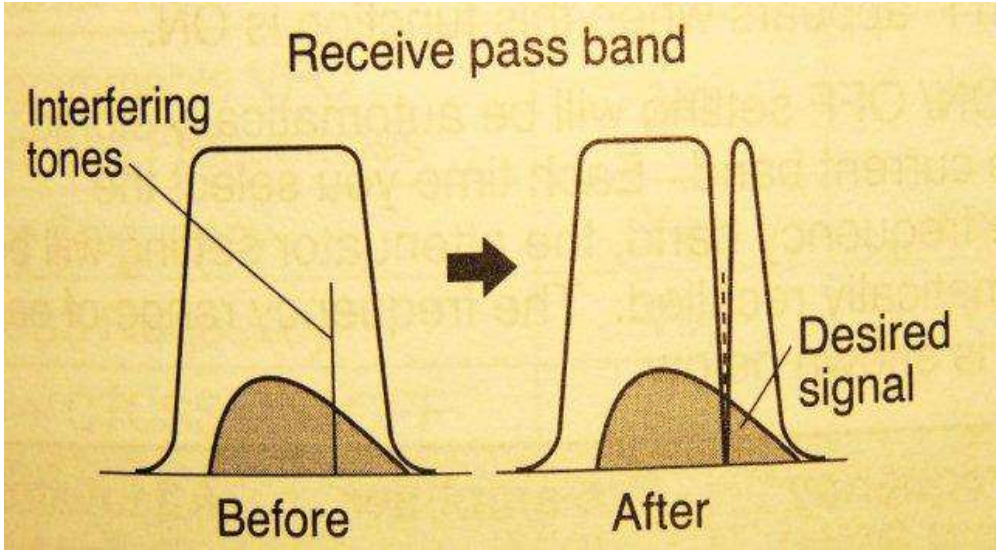
- RF Attenuator
  - Reduces Receiver Sensitivity By A Set Amount
- RF Preamp
  - Increases Receiver Sensitivity By A Set Amount
- Squelch
  - Mutes Receiver When No Signal Is Present
  - Leave “Wide Open” Except For FM

# 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

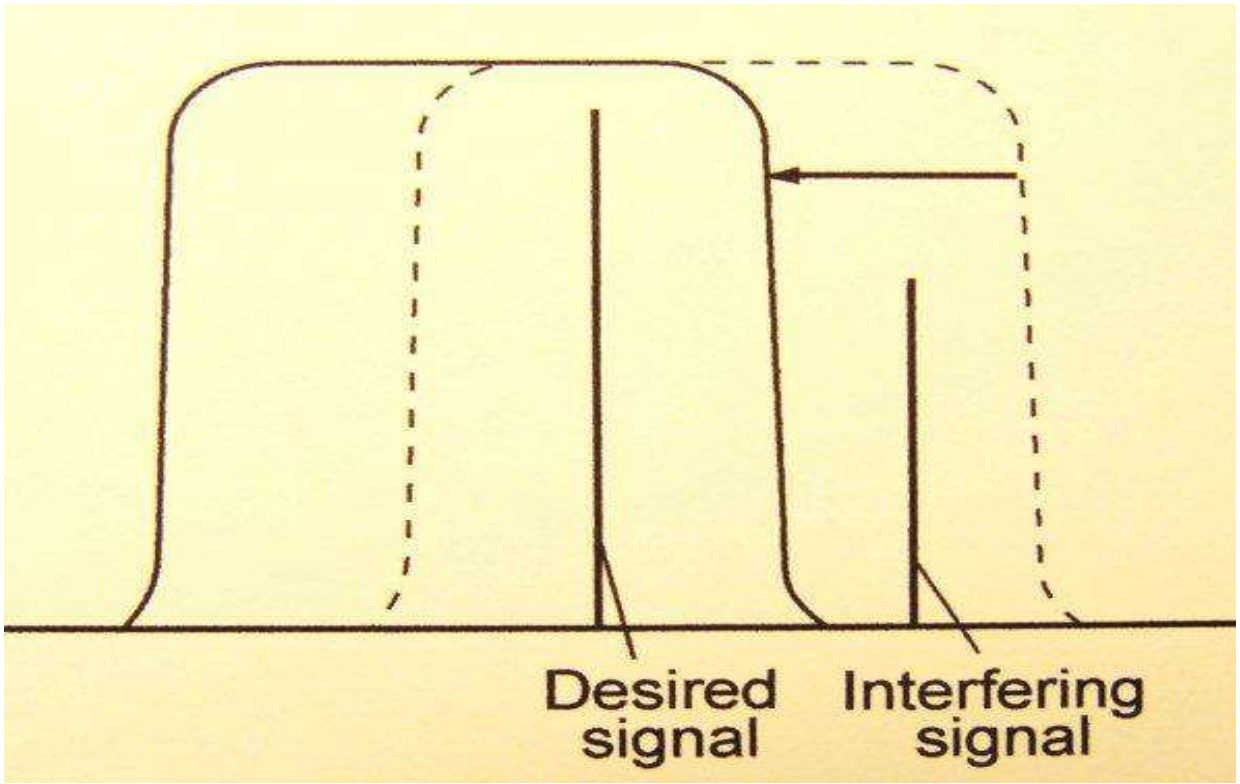
# Interference Controls

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



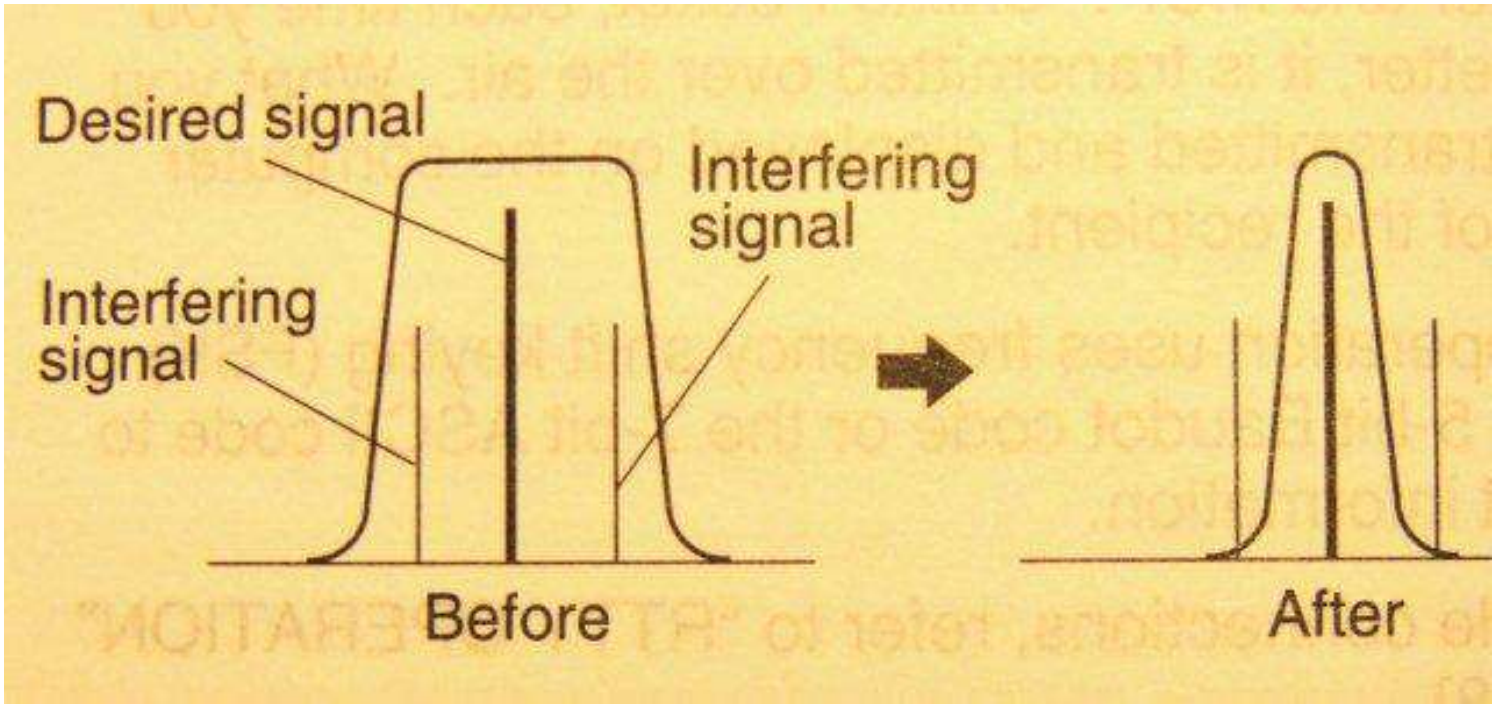
# Bandwidth Controls

- IF Shift
  - Shifts Center Frequency of Pass Band



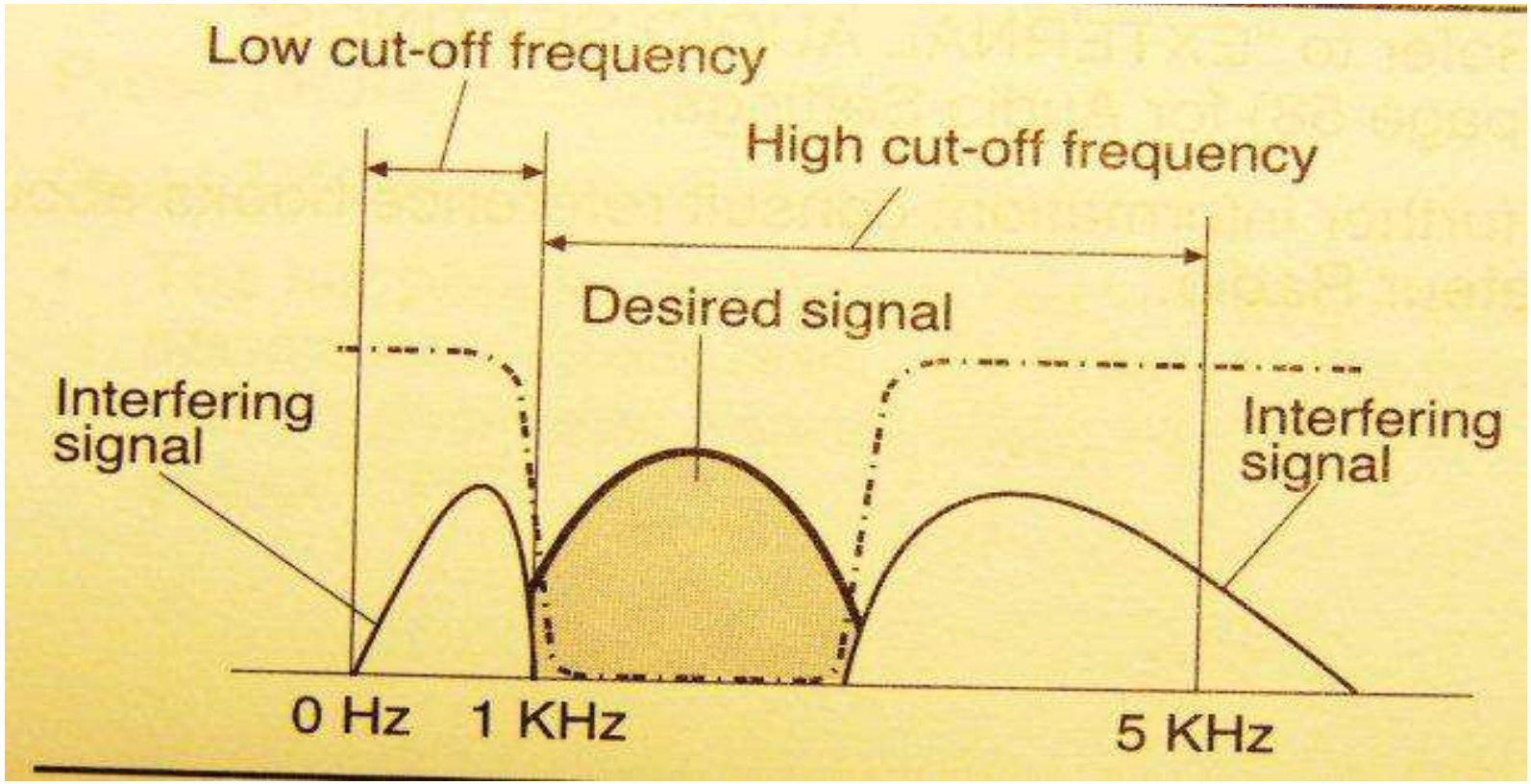
# Bandwidth Controls

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



# Bandwidth Controls

- Variable Bandwidth Filters



# 73, CU On The Air!

**This slide deck and a link to a recording of this presentation will be posted on the HRU website.**

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

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