HF and VHF Propagation

Joe Wilkes, PhD
WA2SFF

Joe's Background

- Licensed since 1961
  - Extra Class - WA2SFF
- Electrical Engineer
  - Studied Wireless Communications in Grad School
  - Thesis Topic: Mitigating the effects of multipath fading on FM radio signals
- Co-author of three books on Wireless Communications

Misconceptions

- 10 meters is dead
- 6 meters is dead
- Low sunspots means HF is useless
- 2 meter band openings are from skip

Outline

- HF Propagation
- Websites To Help DX
- VHF Propagation
  - If time permits

Radio Waves

- Radio Waves, like light travel in a straight line
- But the earth is a sphere and is not flat
  - Sorry "Flat Earth" people 
- To travel long distances, we need:
  - A "mirror" to reflect the waves – Ionosphere (HF/low VHF)
  - A way to bend the waves – Troposphere (VHF/UHF)
- For local communications, the atmosphere has some effect on bending the waves, depending on:
  - Antenna height (higher is better)
  - Frequency (lower is better)

Local HF Communication Range

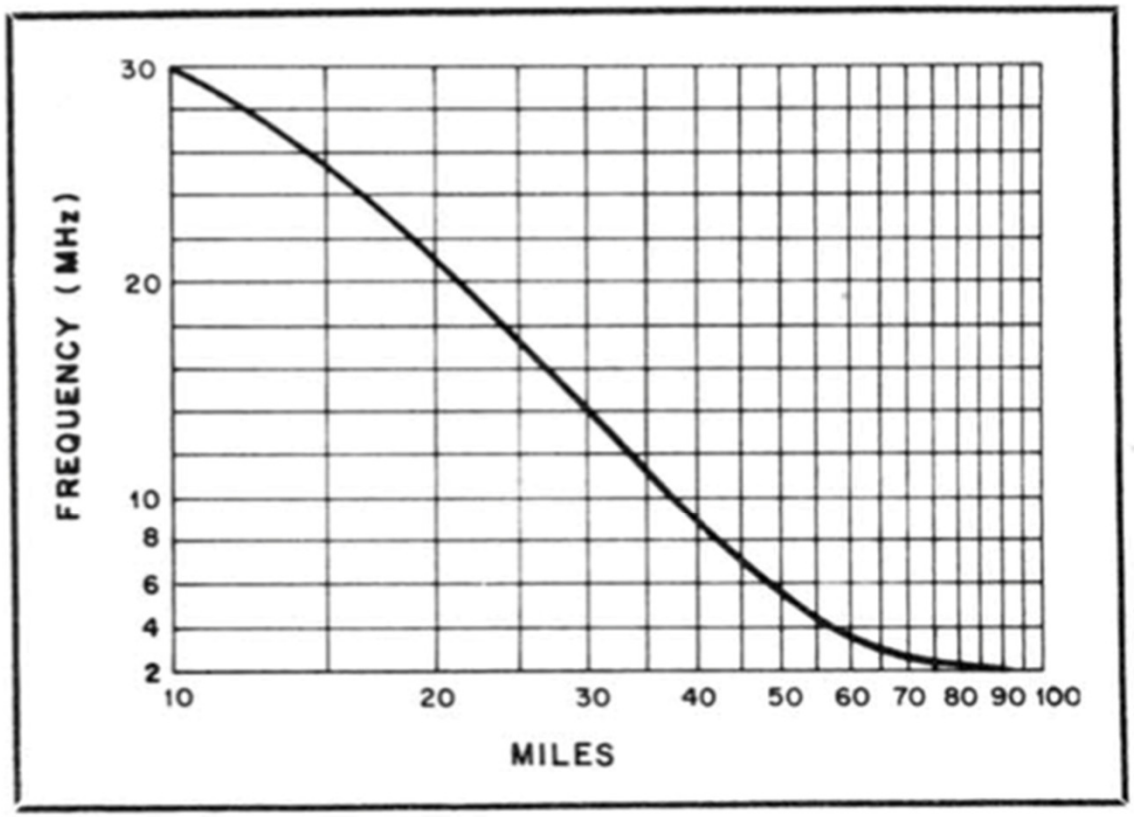
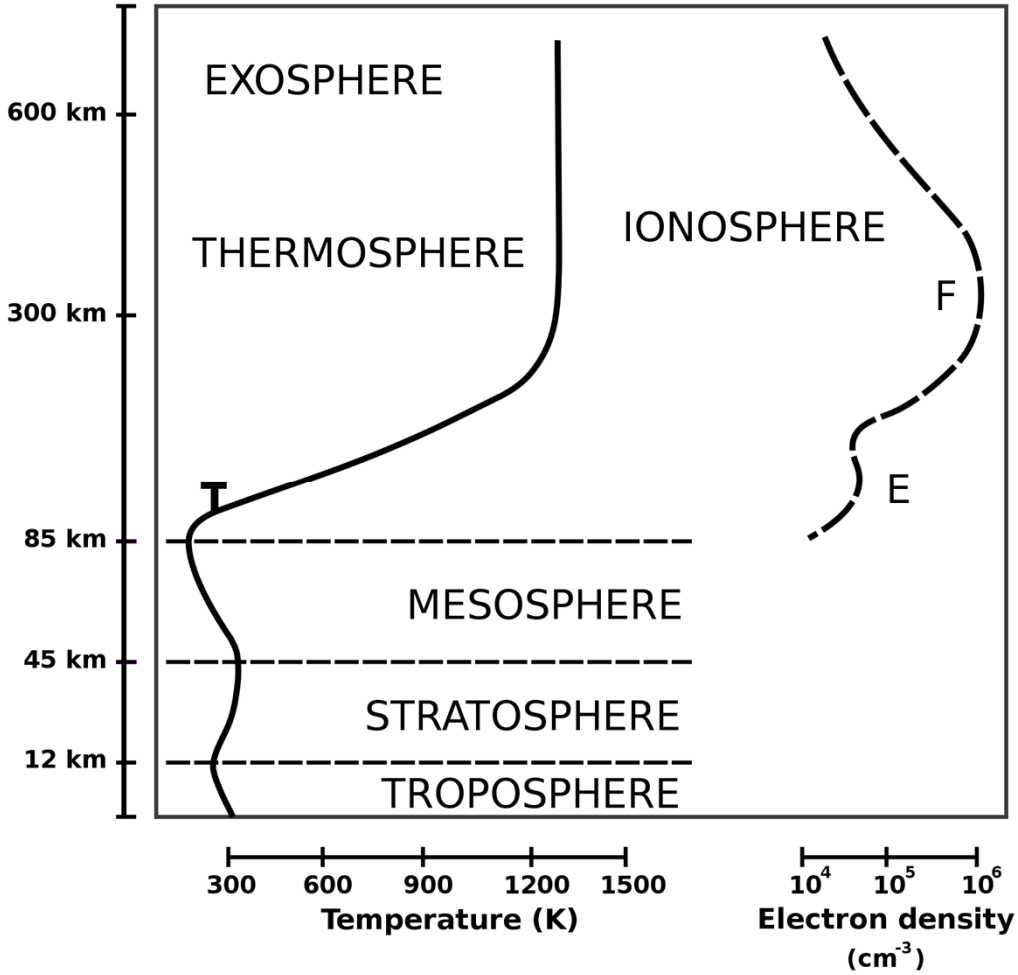


Fig. 1 — Typical high-frequency range, in miles, for ground waves compared to frequency. km = mi × 1.609.

QST
January 1985
"Radio Waves
and
Communications
Distance," W1FB

Layers in Earth's Atmosphere



For long distance
HF propagation,
we are interested
primarily in the Ionosphere

For Long Distance
VHF/UHF propagation,
The Troposphere is of interest

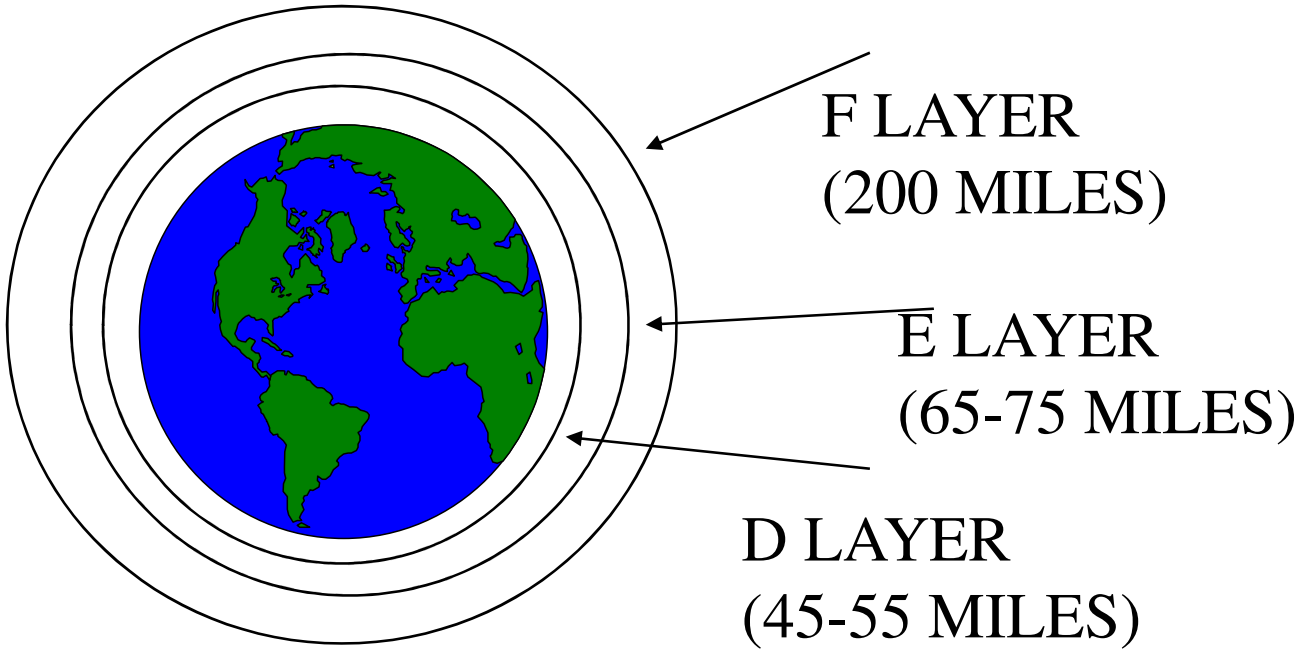
https://en.wikipedia.org/wiki/Ionosphere

The Ionosphere

- The ionosphere is a shell of electrons and electrically charged atoms and molecules that surrounds the Earth, stretching from a height of about 50 km (31 mi) to more than 1,000 km (620 mi).
- The amount of ionization in the ionosphere varies greatly with the amount of radiation received from the Sun.
- The ionization varies with:
  - Day or night
  - Location on the earth
  - Summer vs. Winter
  - The Sunspot Cycle of 11 years
- Solar Flares can disrupt the Ionosphere

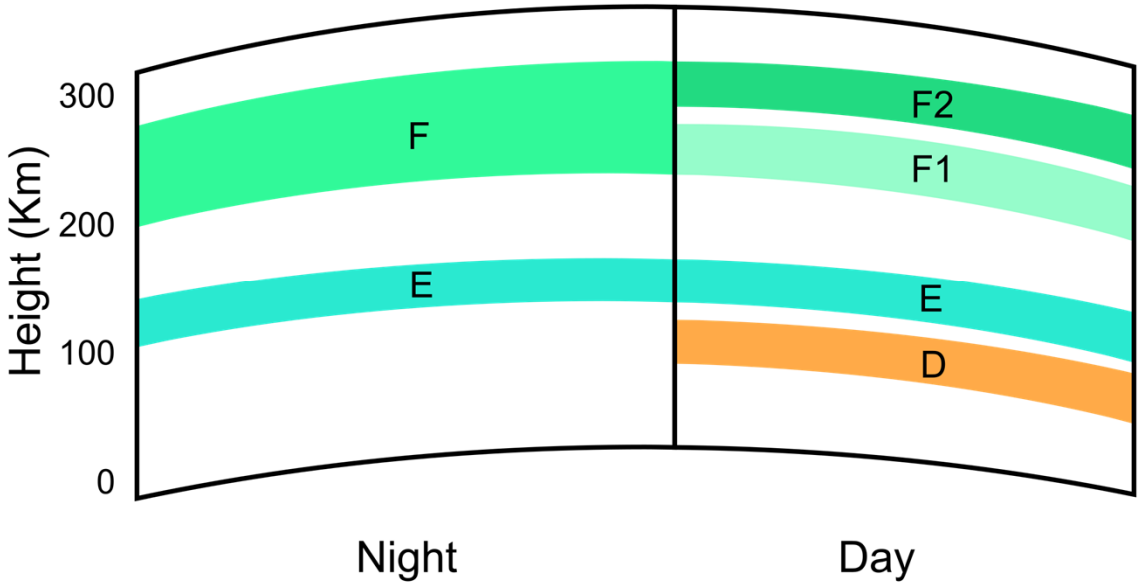
Fundamentals

- HF and low VHF propagation depends on the ionosphere
- Three layers are key
  - F
  - E
  - D



Layers of ionosphere

- F layer
  - Height ~ 200 miles
  - Reflects signals (HF & VHF)
- E layer
  - Height 65-75 miles
  - Reflects signals above ~ 15 meters
- D layer
  - Height 45-55 miles
  - Attenuates signals
  - Disappears at night

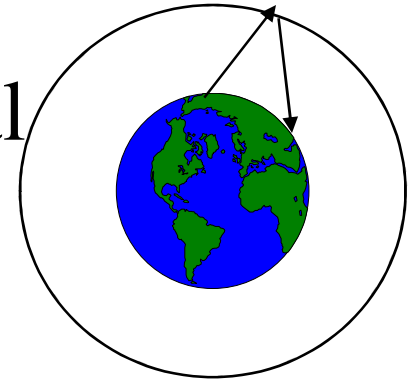


https://en.wikipedia.org/wiki/Ionosphere

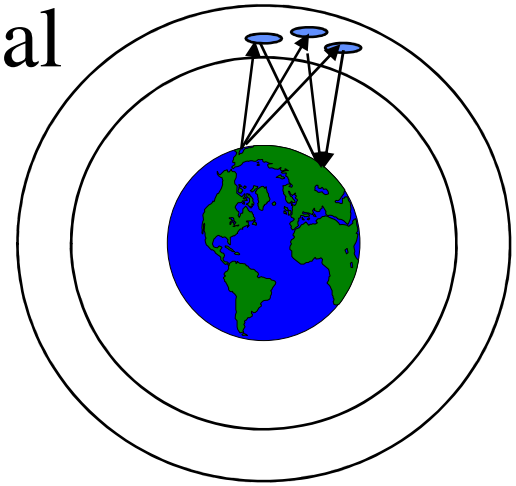
Ionosphere acts as mirror

- The mirror is not perfect
- Different parts of the ionosphere reflect signals at different times
- The received signal arrives from many spots in the Ionosphere
- The signals combine at the receiver
- As the ionosphere changes the paths change and the signal fades in and out
- This is called multipath fading

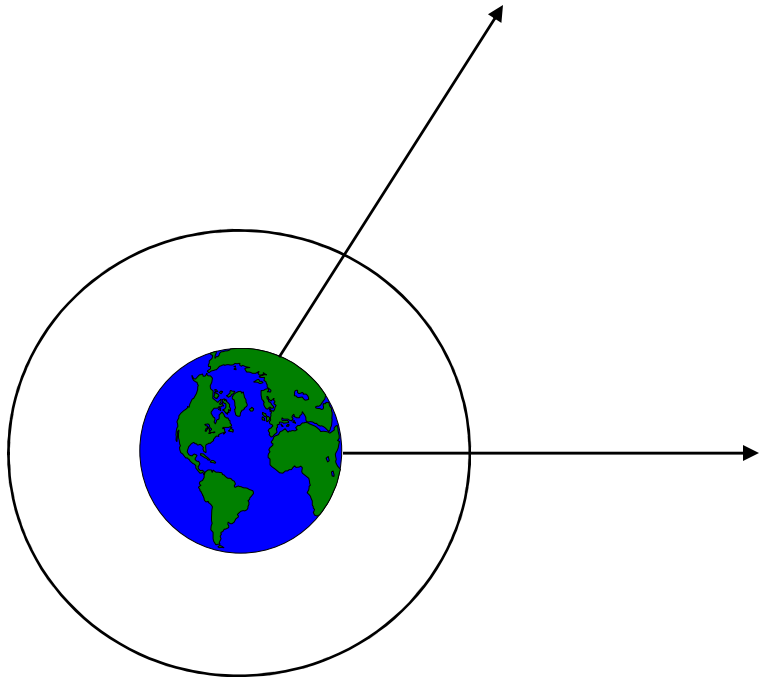
- Ideal



- Real



As the frequency gets higher the mirror stops working



Definitions

- Critical frequency
  - The highest frequency that will be reflected back to the earth when the antenna is aimed straight up
  - Higher frequencies are not reflected and pass through the Ionosphere
- Maximum Usable frequency (MUF)
  - The highest frequency that can be used to communicate between two points on the earth
  - The MUF is always lower than the critical frequency
- If we want to reflect at an angle, we need to use a lower frequency than the critical frequency
- Thus the further we want to talk, the lower the frequency

Lowest Usable Frequency (LUF)

- The D-layer attenuates signals
- The lowest frequency that will pass through the D-layer without significant attenuation is called the Lowest Useable Frequency (LUF)
- Frequencies lower than the LUF
  - Will not get though the D-layer
  - Therefore, will not be reflected off the F-layer or E-layer
- The D layer is primarily ionized by the Sun; so at night, the D layer disappears
- That's why we can hear AM broadcast from 1000's miles away at night.
- During eclipse's, the moon blocks the Sun and the D layer goes away.
- A few years ago, a few people thought they discovered a new propagation mode. It was just the D layer going away during the eclipse.

Why can’t we talk sometimes

- If the MUF is lower than the LUF
- Then we can’t talk

Single and Multiple Hops

- Long distance communications require multiple hops
  - The signal reflects off of the Ionosphere and then off the ground then off the Ionosphere
  - Around the world propagation requires 2-4 hops or more

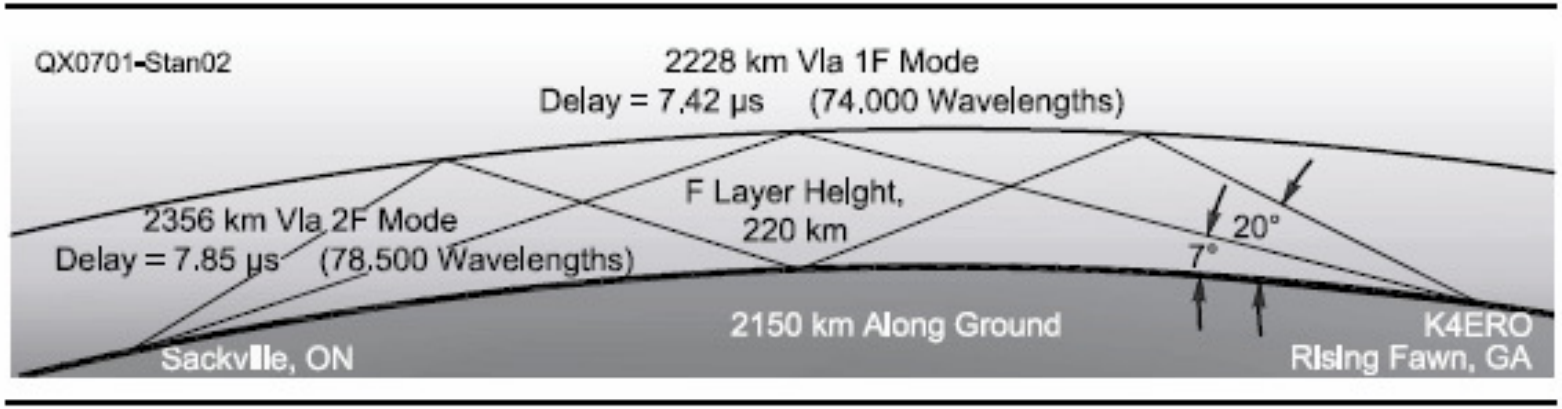


Figure 2 — Signals from Sackville, ON, can arrive at K4ERO in Rising Fawn, GA by one or two ionospheric hops.

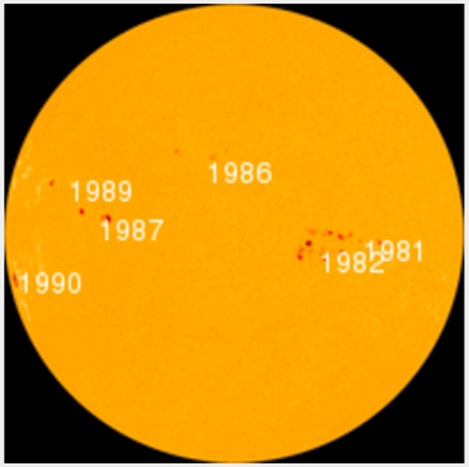
What are Sunspots

- Sunspots are dark/cooler areas on the Sun
  - Normal temperature of surface of Sun 5,500 °C
  - Sunspots are 2,700–4,200 °C
- But edges of sunspots radiate a lot of Ultra Violet Light
- Ultra Violet Light charges the ionosphere
- The more sun spots, the higher the charge, and the better the propagation
- Increase and decrease in an 11 year cycle
  - There are other cycles as well
  - We are still learning about sunspots and predictions are often wrong
- During Sunspot maximums
  - MUF can exceed 50 MHz

Sunspots

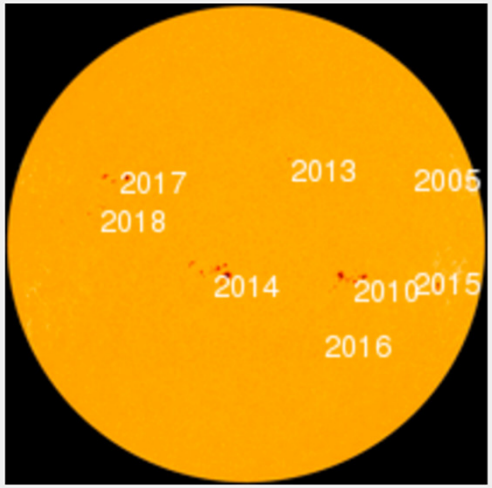
Never Look Directly at the Sun!

Daily Sun: 25 Feb 14



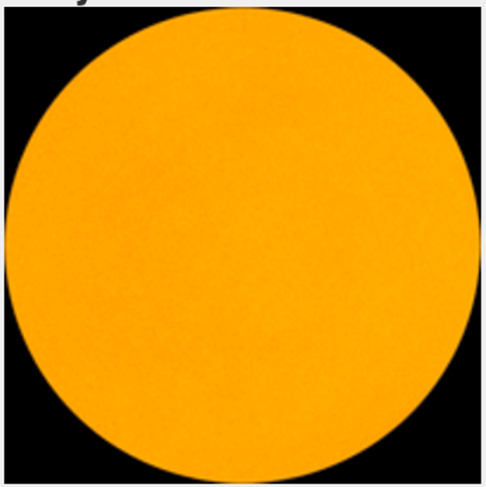
Active sunspot AR1990 (formerly AR1967) poses a threat for X-class solar flares. Credit: SDO/HMI

Daily Sun: 25 Mar 14



Sunspot AR2010 has a 'beta-gamma-delta' magnetic field that harbor energy for X-class solar flares. Credit: SDO/HMI

Daily Sun: 25 Feb 20



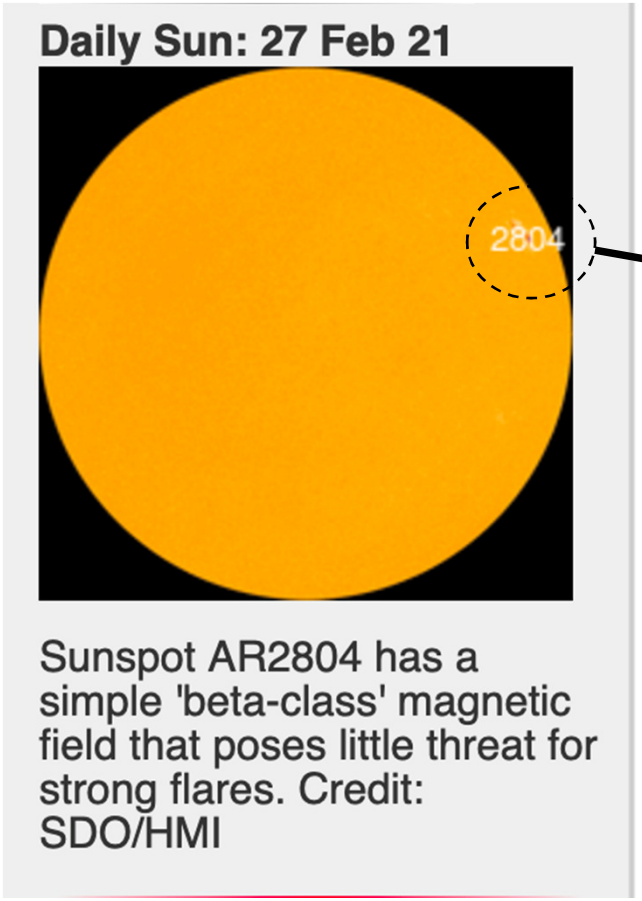
The sun is blank -- no sunspots. Credit: SDO/HMI

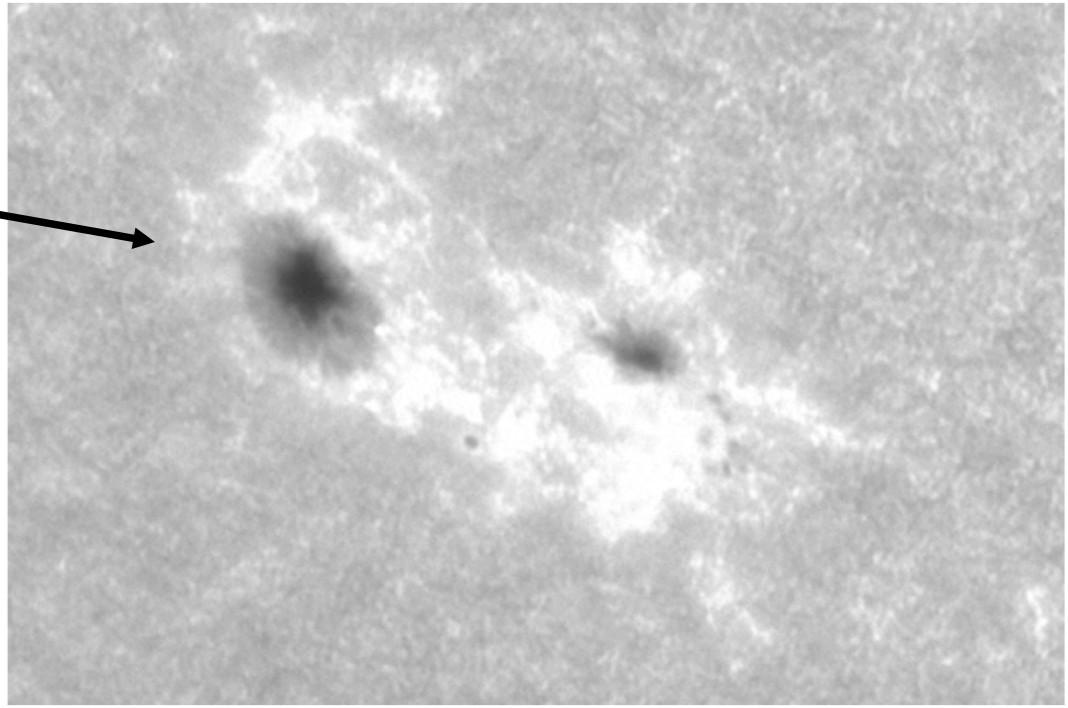
Last Solar Max 2014

Solar Min 2020

Recent Sunspots

Never Look Directly at the Sun!



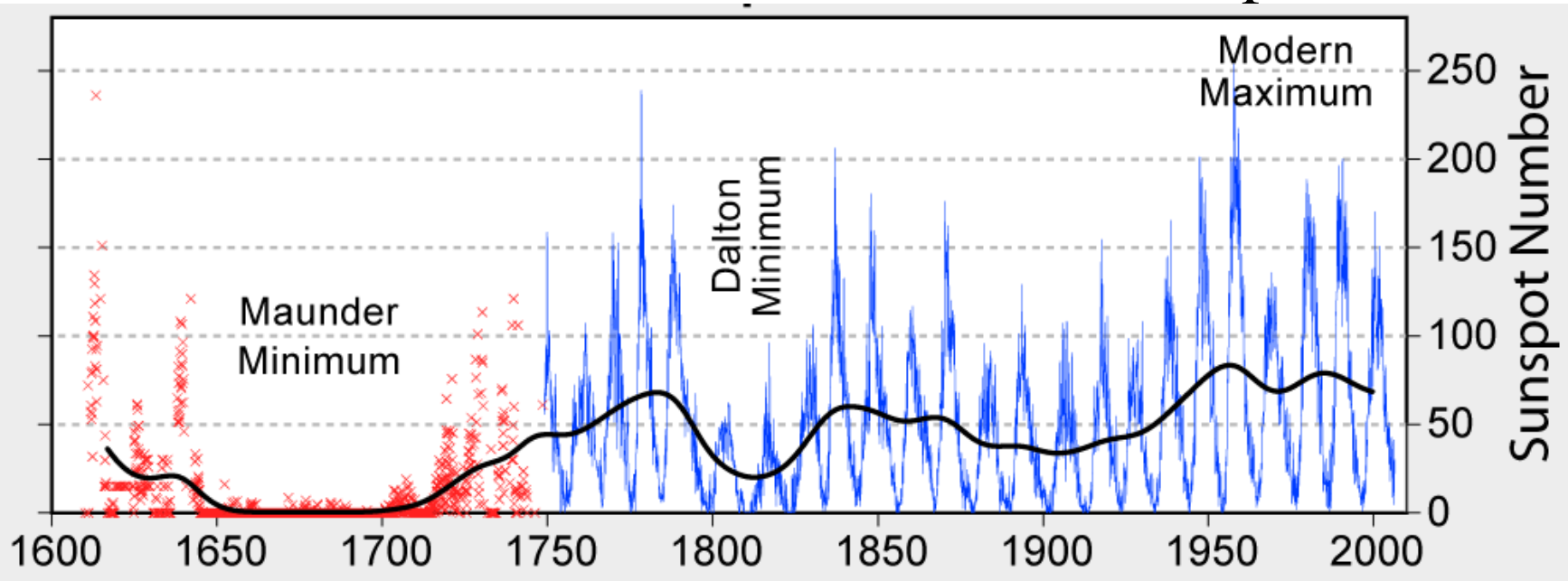


AR2804 is surrounded by a seething, white-hot foam of magnetized plasma.

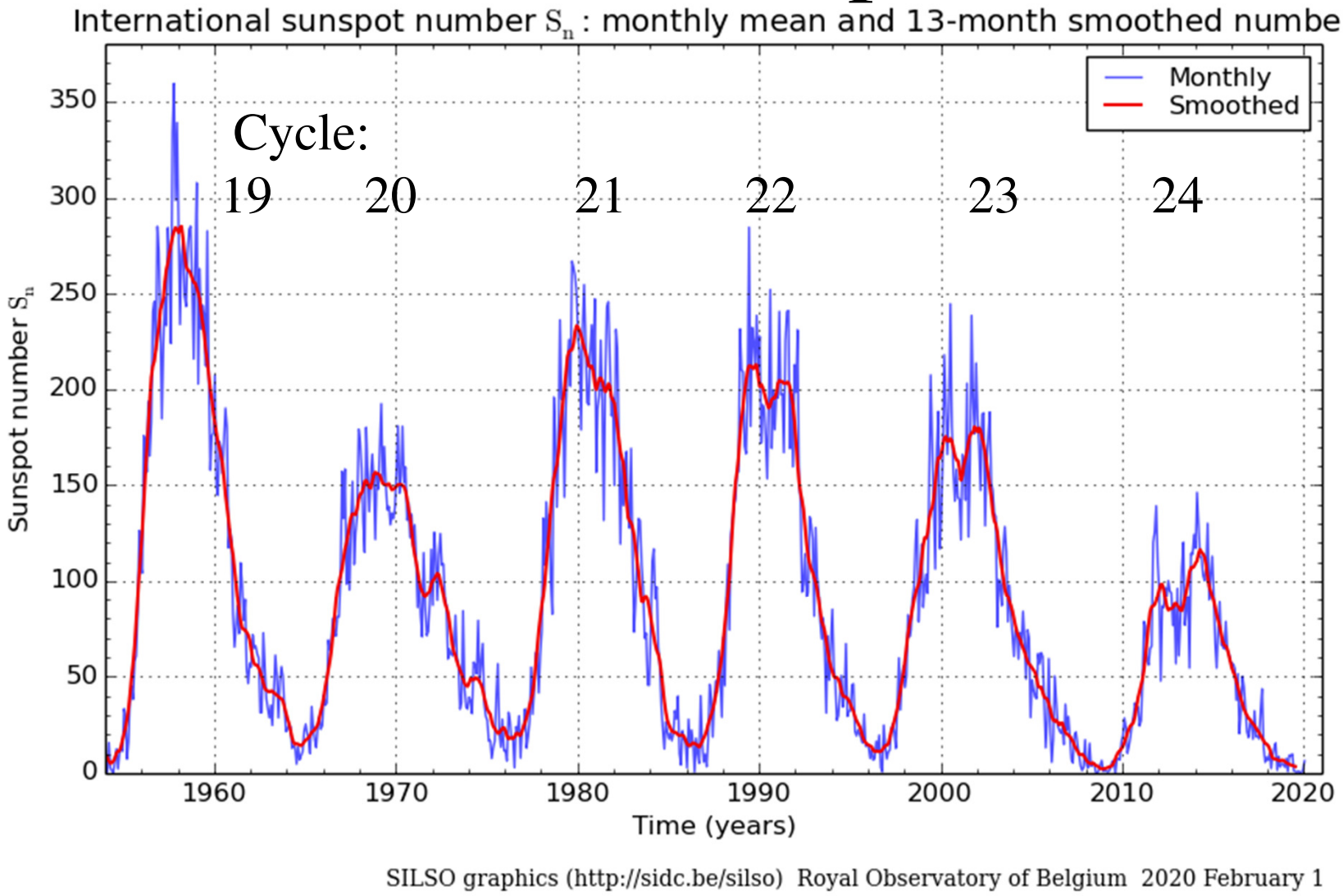
https://www.spaceweather.com/

Highest Sun Spots Ever in last 400 years

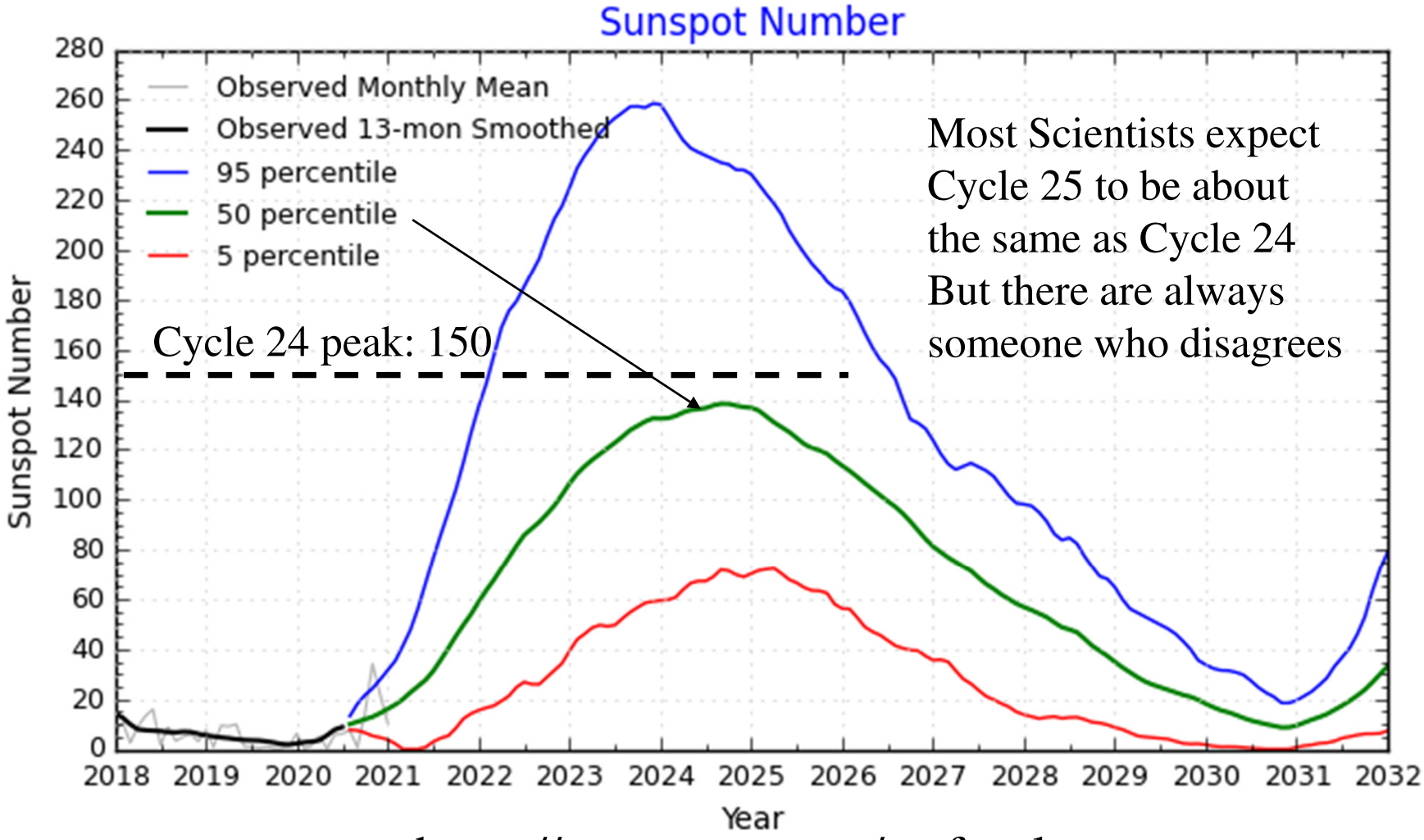
- 1958: MUF>60 MHz
- Some lucky hams worked Japan on 6 meters
  - I started out on 6 meters in 1961
  - Other hams told me how I missed the peak



Recent Sunspots



NASA Cycle 25 Predication



https://www.nasa.gov/msfcsolar

Propagation

- Random
- Never guaranteed
- Predictable
- Methods of predications
  - Charts (not used anymore)
  - Computer programs
  - Website with receivers

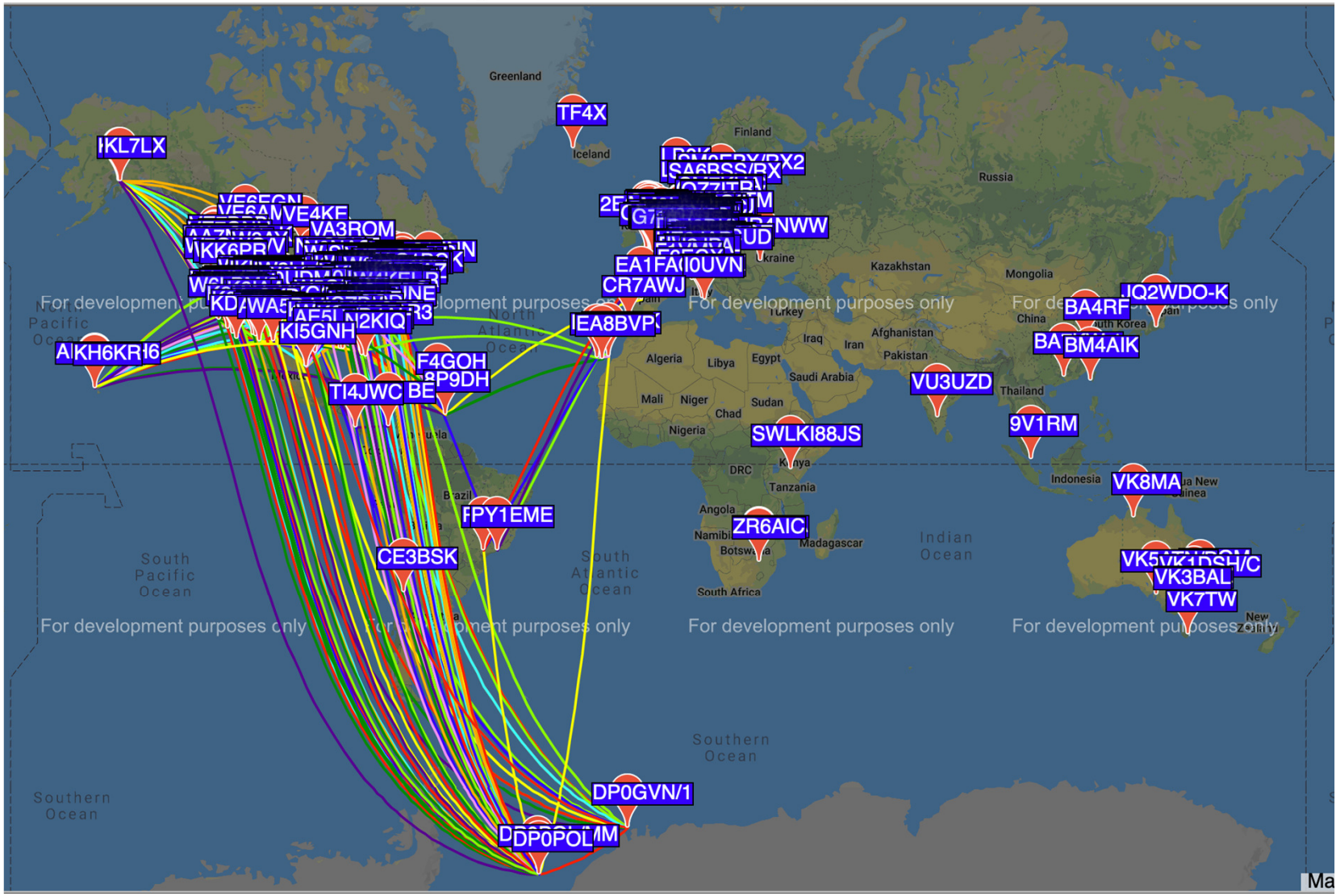
Tricks To Improve The Odds

- Listen to WWV and CHU
  - WWV 5, 10, 15, 20, 25 MHz
  - CHU 7333
- Listen to “freeband”, 27.5-28 MHz
- Listen to TV channels 2 or 3
  - May not be possible anymore
  - Most low VHF stations moved to UHF
- Listen on scanner to frequencies between 30-50 MHz

Propagation Aids

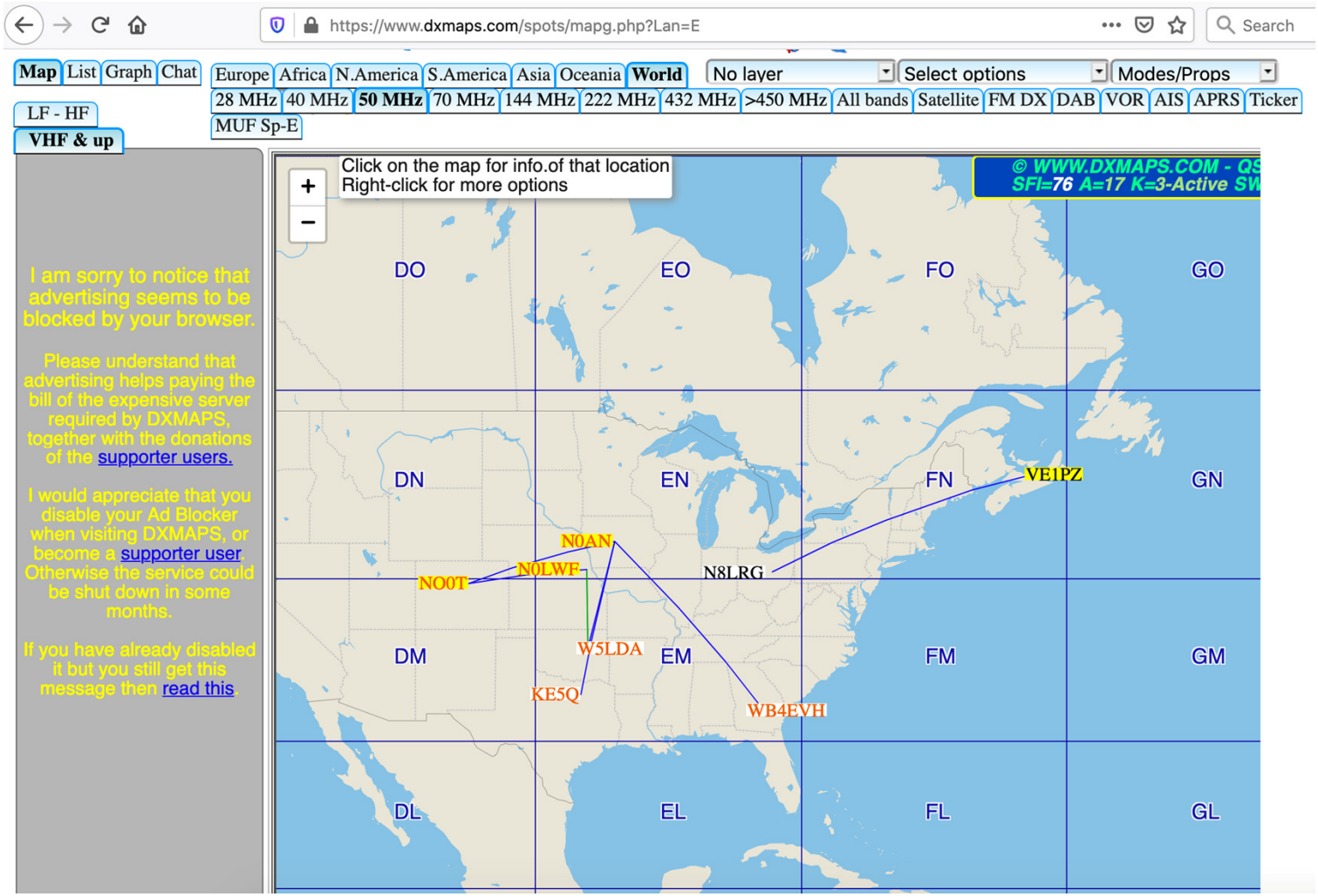
- http://wsprnet.org/drupal/wsprnet/map
- https://www.dxmaps.com/spots/mapg.php?lan=e
- sk6aw.net/cluster

wspernet.org



Radio Propagation

dxmaps.com


https://www.dxmaps.com/spots/mapg.php?Lan=E
Search
Map List Graph Chat
Europe Africa N.America S.America Asia Oceania World
No layer
Select options
Modes/Props
28 MHz 40 MHz 50 MHz 70 MHz 144 MHz 222 MHz 432 MHz >450 MHz All bands Satellite FM DX DAB VOR AIS APRS Ticker
LF - HF
VHF & up
MUF Sp-E
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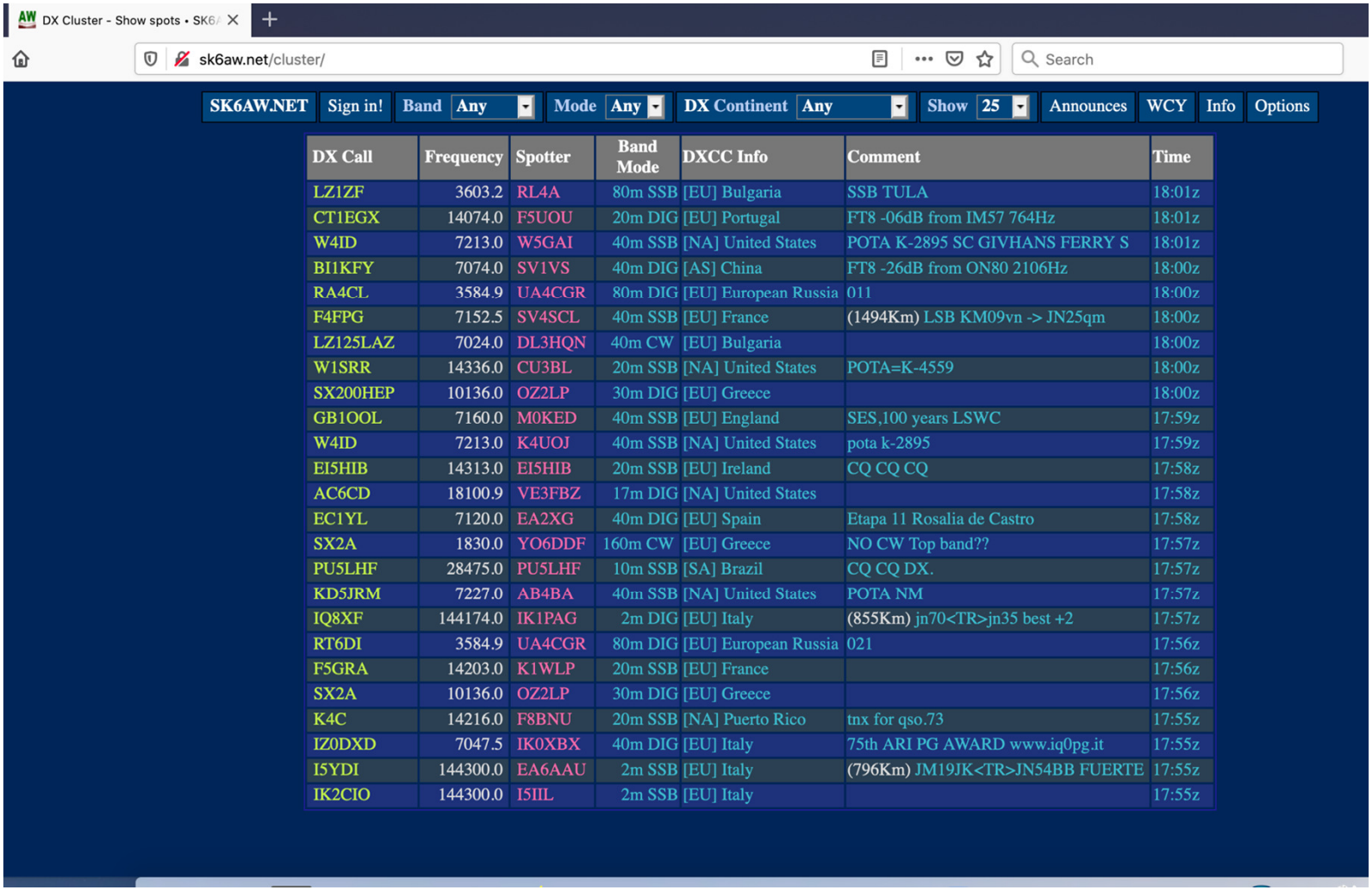

DX Call	Frequency	Spotter	Band Mode	DXCC Info	Comment	Time
LZ1ZF	3603.2	RL4A	80m SSB	[EU] Bulgaria	SSB TULA	18:01z
CT1EGX	14074.0	F5UOU	20m DIG	[EU] Portugal	FT8 -06dB from IM57 764Hz	18:01z
W4ID	7213.0	W5GAI	40m SSB	[NA] United States	POTA K-2895 SC GIVHANS FERRY S	18:01z
BI1KFY	7074.0	SV1VS	40m DIG	[AS] China	FT8 -26dB from ON80 2106Hz	18:00z
RA4CL	3584.9	UA4CGR	80m DIG	[EU] European Russia	011	18:00z
F4FPG	7152.5	SV4SCL	40m SSB	[EU] France	(1494Km) LSB KM09vn -> JN25qm	18:00z
LZ125LAZ	7024.0	DL3HQN	40m CW	[EU] Bulgaria		18:00z
W1SRR	14336.0	CU3BL	20m SSB	[NA] United States	POTA=K-4559	18:00z
SX200HEP	10136.0	OZ2LP	30m DIG	[EU] Greece		18:00z
GB1OOL	7160.0	M0KED	40m SSB	[EU] England	SES,100 years LSWC	17:59z
W4ID	7213.0	K4UOJ	40m SSB	[NA] United States	pota k-2895	17:59z
EI5HIB	14313.0	EI5HIB	20m SSB	[EU] Ireland	CQ CQ CQ	17:58z
AC6CD	18100.9	VE3FBZ	17m DIG	[NA] United States		17:58z
EC1YL	7120.0	EA2XG	40m DIG	[EU] Spain	Etapa 11 Rosalia de Castro	17:58z
SX2A	1830.0	YO6DDF	160m CW	[EU] Greece	NO CW Top band??	17:57z
PU5LHF	28475.0	PU5LHF	10m SSB	[SA] Brazil	CQ CQ DX.	17:57z
KD5JRM	7227.0	AB4BA	40m SSB	[NA] United States	POTA NM	17:57z
IQ8XF	144174.0	IK1PAG	2m DIG	[EU] Italy	(855Km) jn70<TR>jn35 best +2	17:57z
RT6DI	3584.9	UA4CGR	80m DIG	[EU] European Russia	021	17:56z
F5GRA	14203.0	K1WLP	20m SSB	[EU] France		17:56z
SX2A	10136.0	OZ2LP	30m DIG	[EU] Greece		17:56z
K4C	14216.0	F8BNU	20m SSB	[NA] Puerto Rico	tnx for qso.73	17:55z
IZ0DXD	7047.5	IK0XBX	40m DIG	[EU] Italy	75th ARI PG AWARD www.iq0pg.it	17:55z
I5YDI	144300.0	EA6AAU	2m SSB	[EU] Italy	(796Km) JM19JK<TR>JN54BB FUERTE	17:55z
IK2CIO	144300.0	I5IIL	2m SSB	[EU] Italy		17:55z

Summary

- Bands are not dead
- DX can be worked
- Web sites with beacon data can help
- GSARA Discord channel has a dx discussion group
- Listening to nearby frequencies can help

VHF Propagation

VHF Propagation

- E Skip
  - 10, 6 , 2, 1-1/4??
- F Skip
  - 6 meters
  - rare with current sunspot numbers
- Tropospheric ducting
- Aurora
- Meteor scatter
- Forward scatter
- Back scatter
- Moon bounce
- Satellites

Tropospheric ducting

- As various times of the year and depending on weather conditions, the troposphere can act as a duct for VHF/UHF radio waves
  - 2 m, 1.25M, ¾ m
- Also known as as temperature inversion where the temperature of the atmosphere goes up the higher the altitude.
- This creates a condition where signals are bent by the troposphere and we get very good long range (500-1000 miles or more) propagation
- This was used to set range records for VHF and UHF by hams between California and Hawaii.
- The higher the antenna the better to connection to the troposphere

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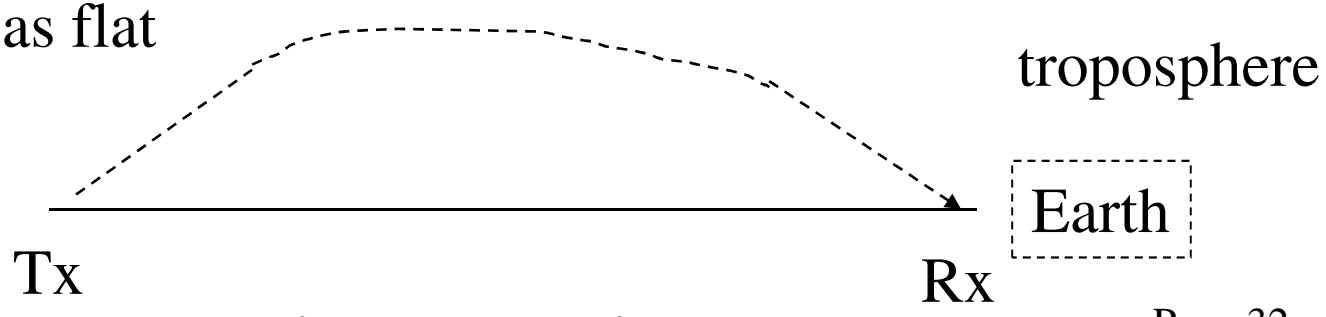
Earth is shown as flat
We know that
it is curved



Radio Propagation

Aurora

- When Aurora occurs, the upper atmosphere is charged and can reflect VHF/UHF signals
- Since the Aurora (or Northern Lights) are North of us, we need to point our antennas North (or at the Aurora)
- Aurora signals tend to be raspy because of the nature of the aurora, flickering

Meteor Scattering

- As a meteor passes through the atmosphere it heats up the air and ionizes it.
- Radio waves can reflect off the ionized path
- Because these ionization trails only exist for fractions of a second to as long as a few seconds in duration, they create only brief windows of opportunity for communications.
- Today, mostly high speed digital communications are used – WSJT-X modes (MSK144 is the most popular according to Wikipedia)

Earth is shown as flat
We know that
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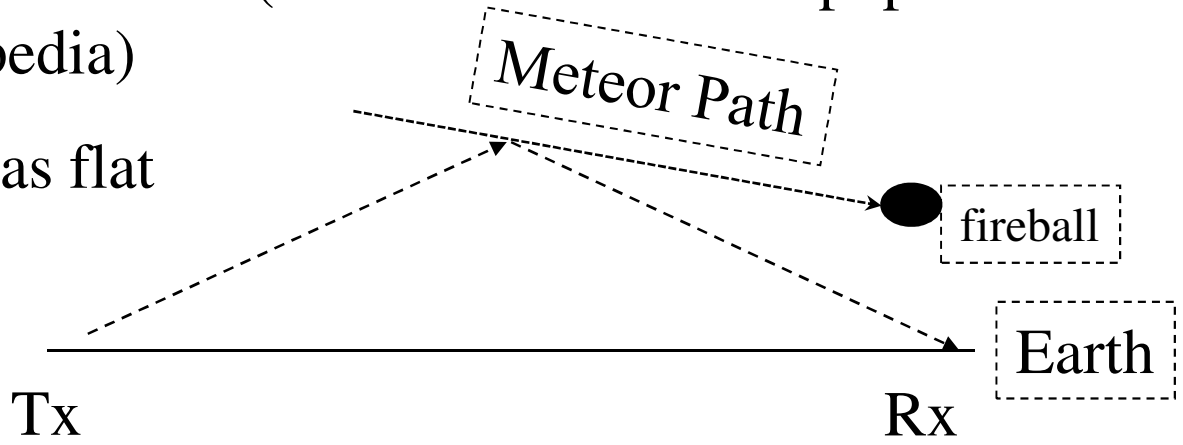
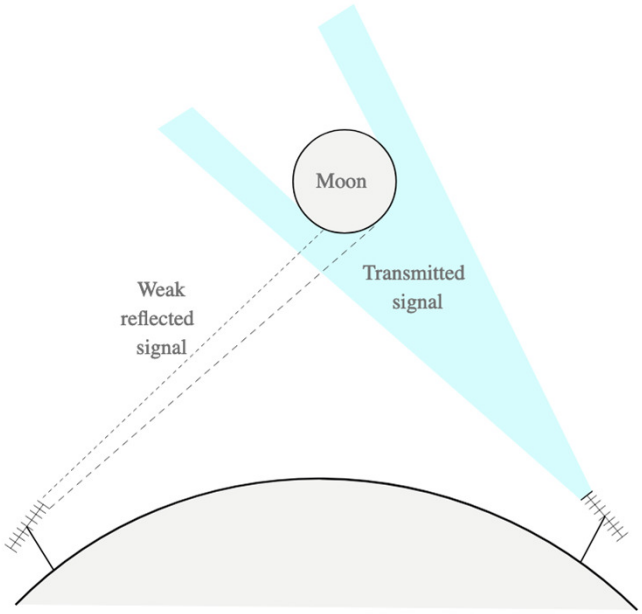


Forward and Back Scattering

- Scattering off of:
  - small ionized particles in the atmosphere,
  - ocean waves
  - Rain
  - Snow
- Path losses are very high
- Think of aiming a hose at a window screen: How much water is reflected off the screen

Moon Bounce

- With enough power and a big enough antenna, we can bounce our signals off the moon.
- the overall path loss is at best approximately
  252 dB on 144
  271 dB on 1296
- Need 1 KW,
  20-25 dBd antenna
- With WSJT-X, lower power, and smaller antennas can be used



Concept of Moonbounce EME propagation

Satellites

- There are multiple ham radio satellites in orbit around the earth
  - Orbital Satellites Carrying Amateur Radio (OSCAR)
- Most current activity is on 2 m and ¾ m
- Can be done with an HT and a handheld antenna
- From a talk a few months ago
  - See https://www.work-sat.com/ for details