The Computer Deconstruction Lab Presents HF and VHF Propagation

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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

Outline

- HF Propagation
- VHF Propagation

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)

Radio/Light Wave Definitions

Very Low Frequency (VLF)	3-30 Kilohertz (kHz)
Low Frequency	30-300 kHz
Medium Frequency (MF)	300-3000 kHz
High Frequency (HF)	3-30 Megahertz (MHz)
Very High Frequency (VHF)	30-300 MHz
Ultra High Frequency (UHF)	300-3000 MHz
Super High Frequency (SHF)	3000-30000 MHz
Extremely High Frequency (EHF)	30-300 Gigahertz (GHz)
Tremendously High Frequency (THF)	0.3 to 3 Terahertz (THz)
Far Infrared	20-300 THz
Visible	400-790 THz

Focus of this talk

HF Ham Radio Bands (measured in meters)

- 160 meters
- 80 meters
- 60 meters
- 40 meters
- 30 meters
- 20 meters
- 17 meters
- 15 meters
- 12 meters
- 10 meters

- 1.8-2.0 MHz
- 3.5-4.0 MHz
- 5 channels around 5.4 MHz
- 7.0-7.3 MHz
- 10.1-10.15 MHz
- 14.0-14.350 MHz
- 18.0-18.110 MHz
- 21.0-21.45 MHz
- 24.920-24.930 MHz
- 28.0-29.7 MHz

Other Ham Bands

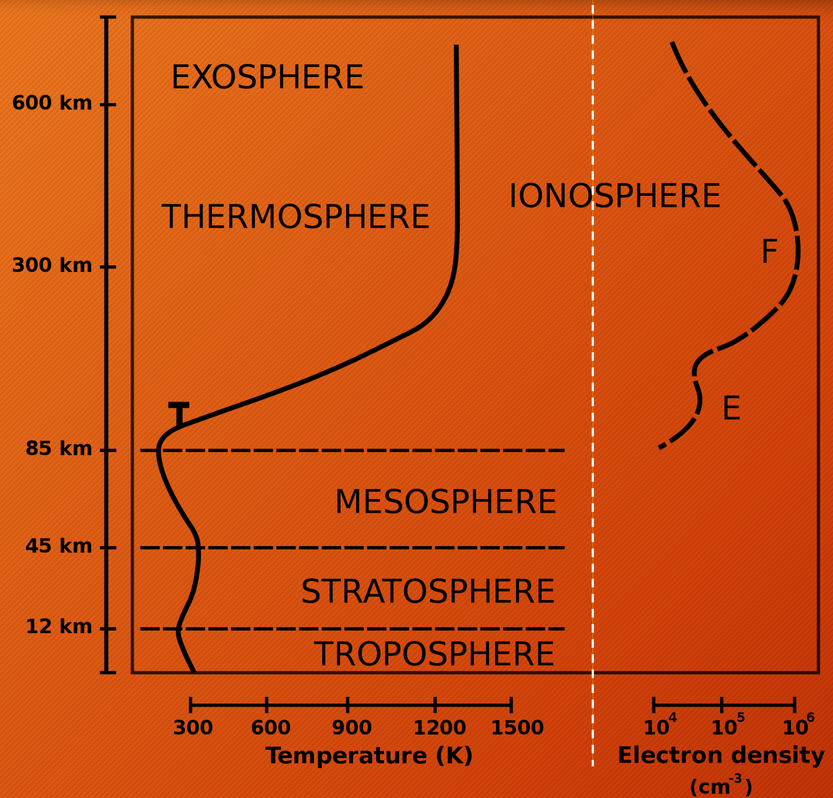
- 2200 meters
- 630 meters
- 6 meters
- 2 meters
- 1.25 meters
- ¾ meters
- 33 centimeters
- 23 centimeters
- other higher bands

- 135.7-135.8 kHz
- 472-479 kHz
- 50.0-54.0 MHz
- 144.0-148.0 MHz
- 220-225 MHz
- 420-450 MHz
- 902-928 MHz
- 1240-1300 MHz

How do we get the Definitions?

- When radio waves were first being used by Marconi and others they used frequencies less than 1.0 Megahertz
- It is believed that Marconi's trans-continental system was at around 800 kHz
- HF was considered useless
- Hams were given all frequencies above 200 meters (1.5 MHz)
- Scientists did not know/understand about the Ionosphere
- As the Ionosphere was discovered and studied, all frequencies above about 300 MHz were considered useless and called "Microwaves"
- There is no real official definition of Microwaves
- Today Microwaves are often used to imply cancer causing
  - i,e., "Microwave Radiation"

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

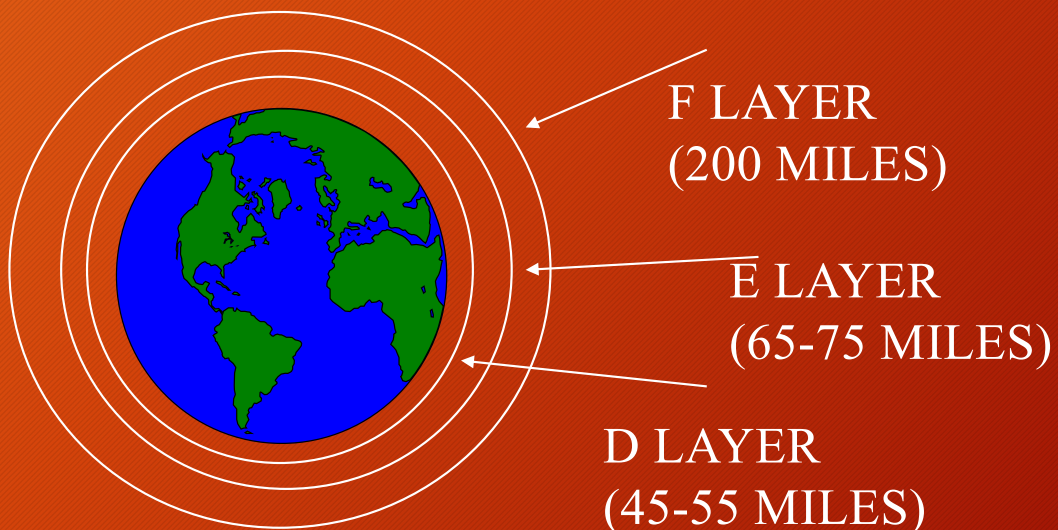
https://en.wikipedia.org/wiki/Ionosphere

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

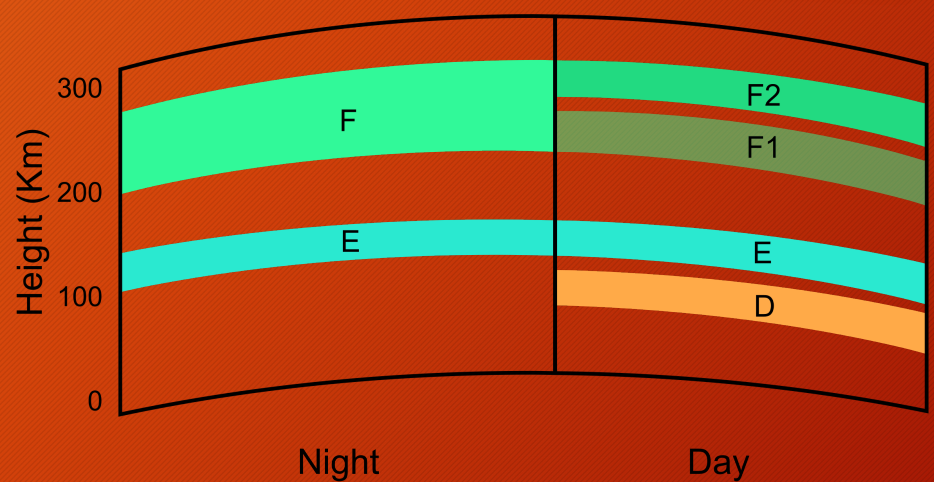
Fundamentals

- 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

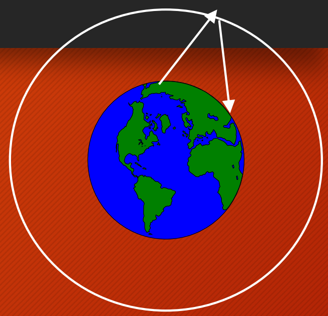


https://en.wikipedia.org/wiki/Ionosphere

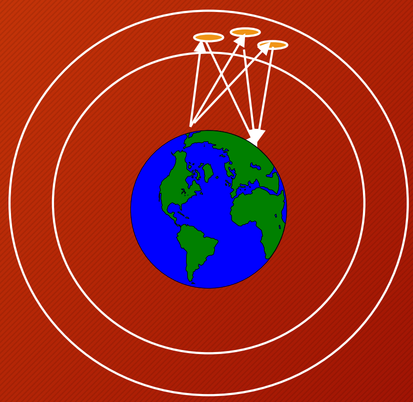
Ionosphere acts as mirror

- 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

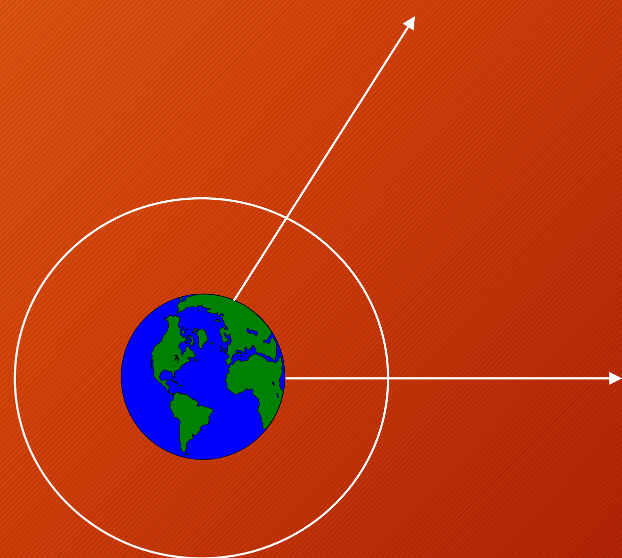
- Ideal



- 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.

Why can’t we hear/talk sometimes

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

Single and Multiple Hops

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

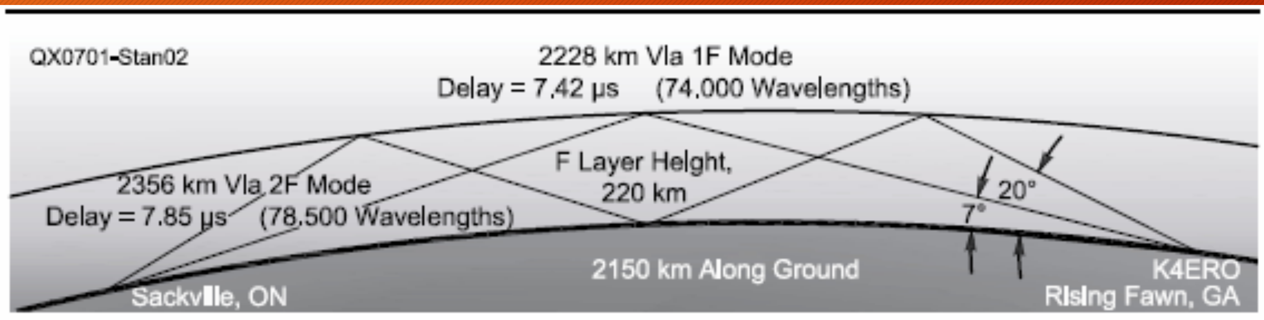


Figure 2 — Signals from Sackville, ON, can arrive at K4ERO in Rising Fawn, GA by one or two ionospheric hops.

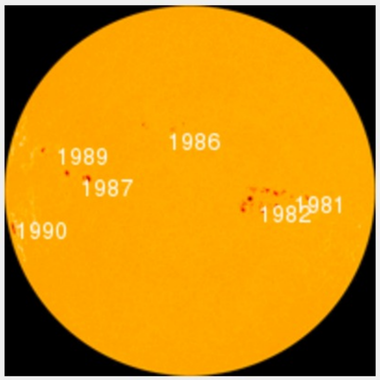
What are Sunspots

- Sunspots are dark/cooler areas on the Sun
  - Normal temperature of surface of Sun 5,500 ^{o}C
  - Sunspots are 2,700-4,200 $^{\circ}$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
- Sunspots 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

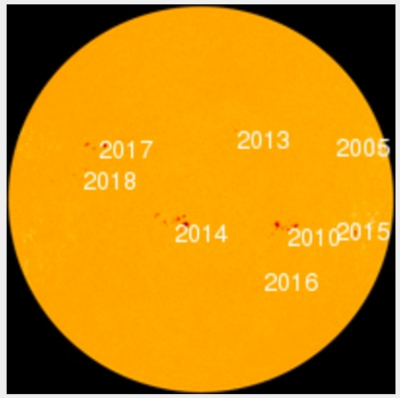
Never Look Directly at the Sun!

Daily Sun: 25 Feb 14



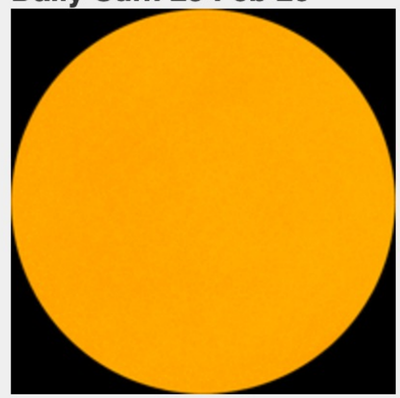
Active sunspot AR1990 (formerly AR1967) poses a threat for X-class solar flares. Credit: SDO/HMI

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

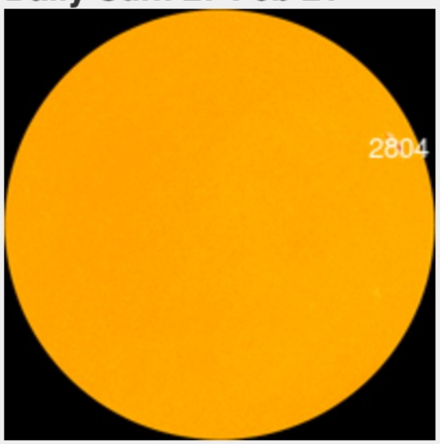
Last Solar Max 2014

Solar Min 2020

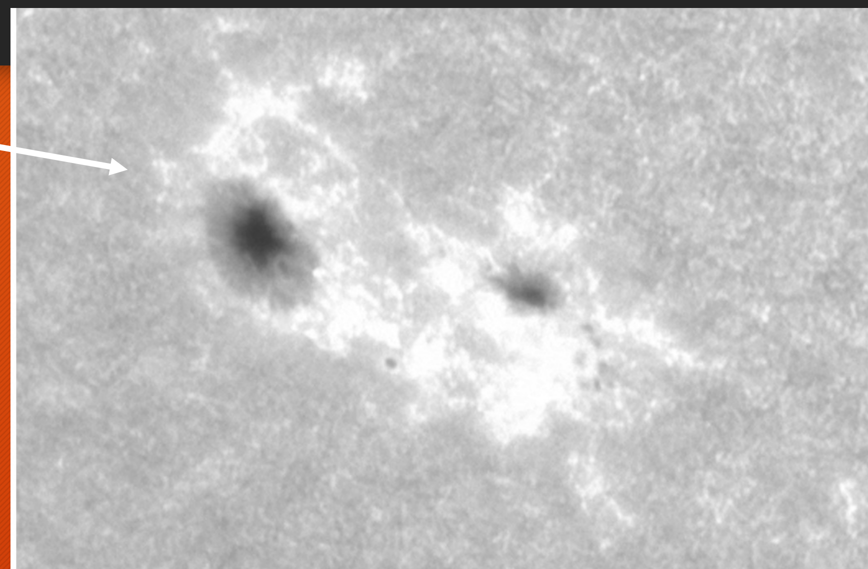
Never Look Directly at the Sun!

Expanded view of a Sunspot

Daily Sun: 27 Feb 21



Sunspot AR2804 has a simple 'beta-class' magnetic field that poses little threat for strong flares. Credit: SDO/HMI

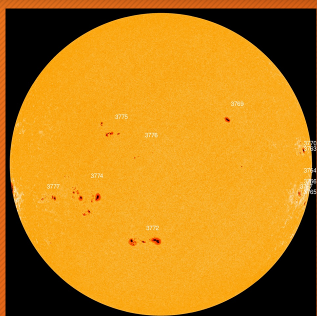
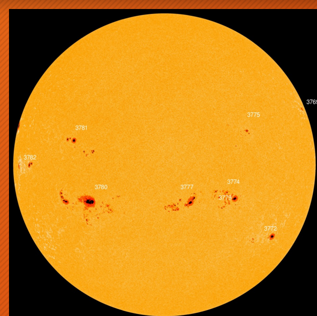
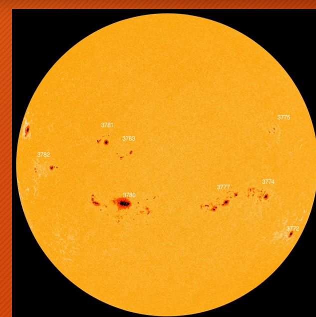


AR2804 is surrounded by a seething, white-hot foam of magnetized plasma.

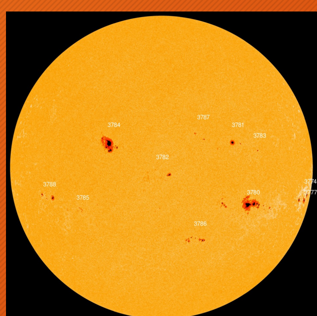
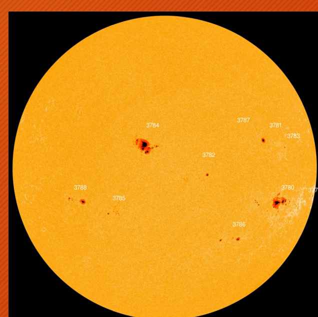
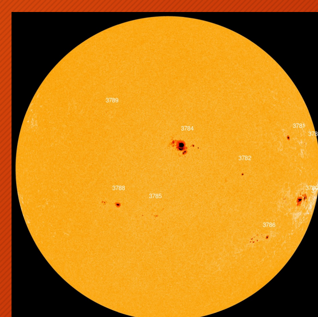
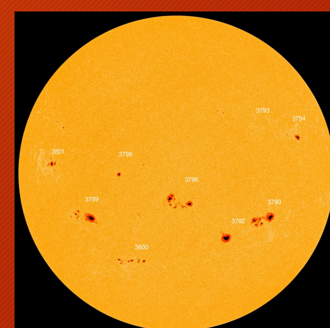
https://www.spaceweather.com/

Recent Sunspots

Never Look Directly at the Sun!

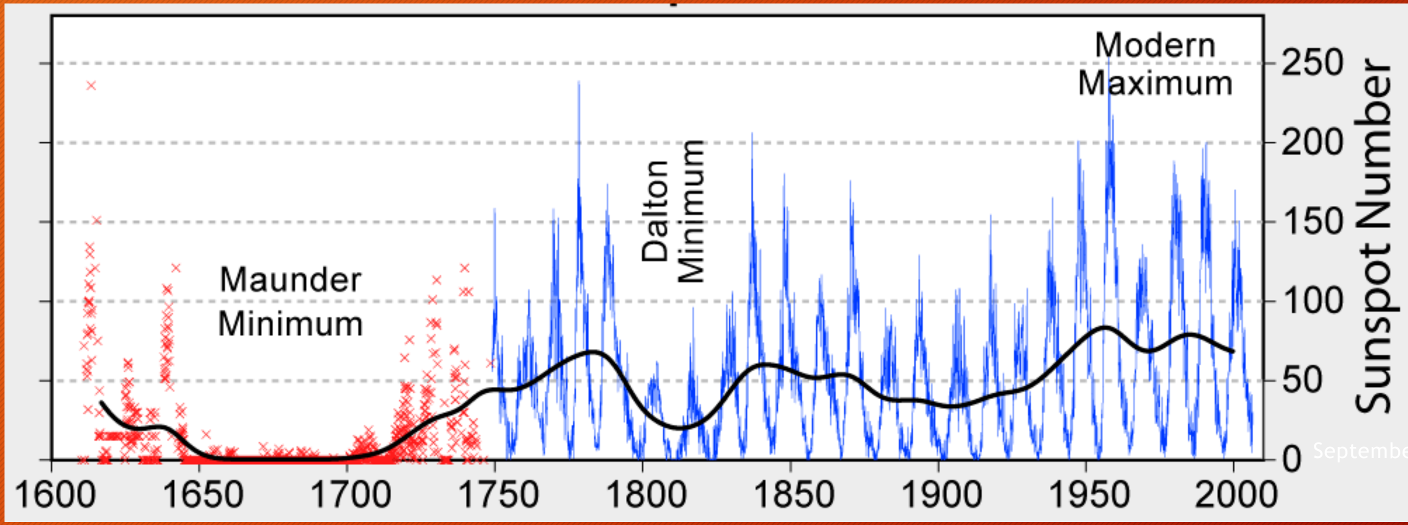




August 4-24, 2024

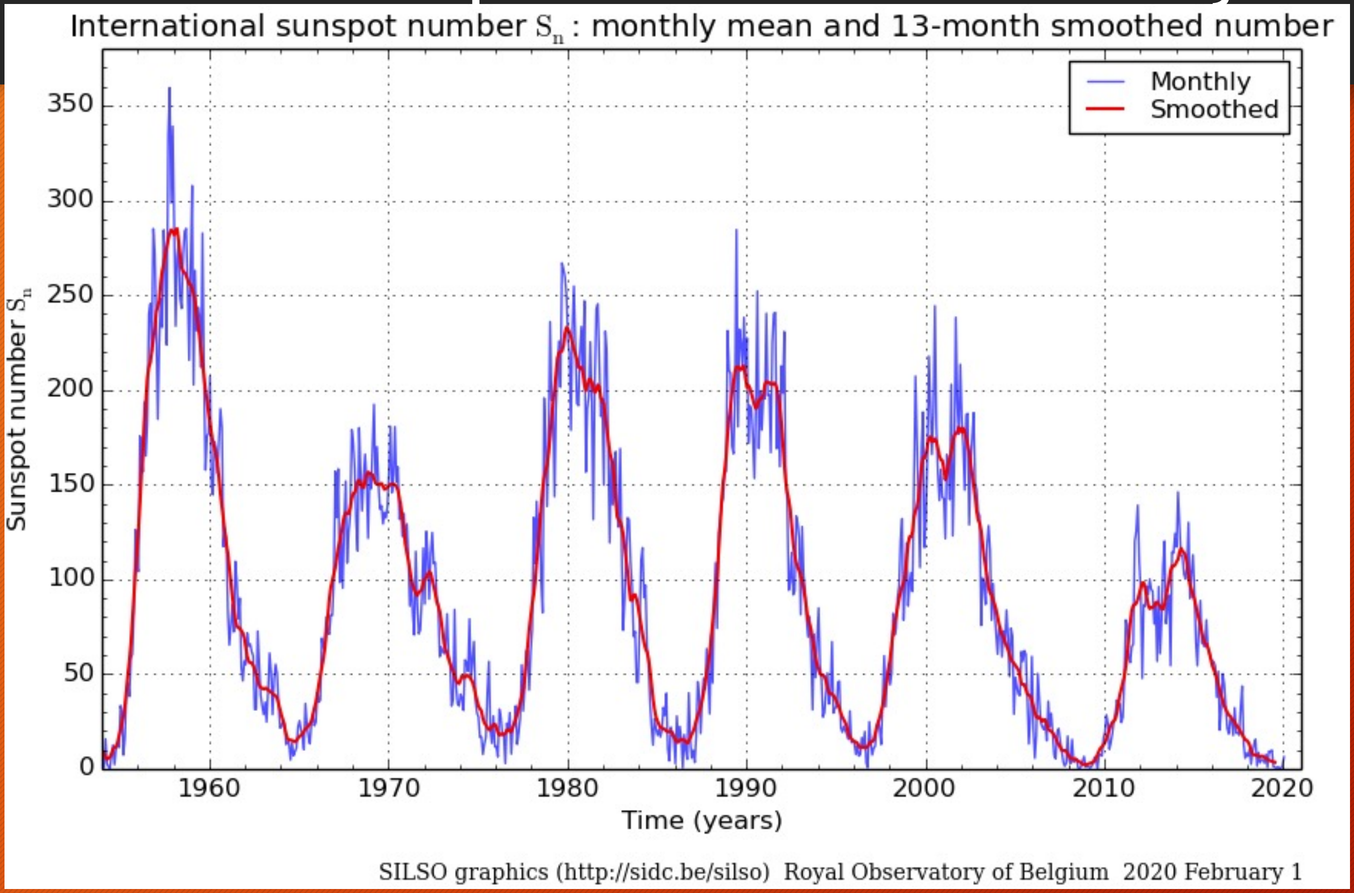





Highest Sun Spots Ever in last 400 years

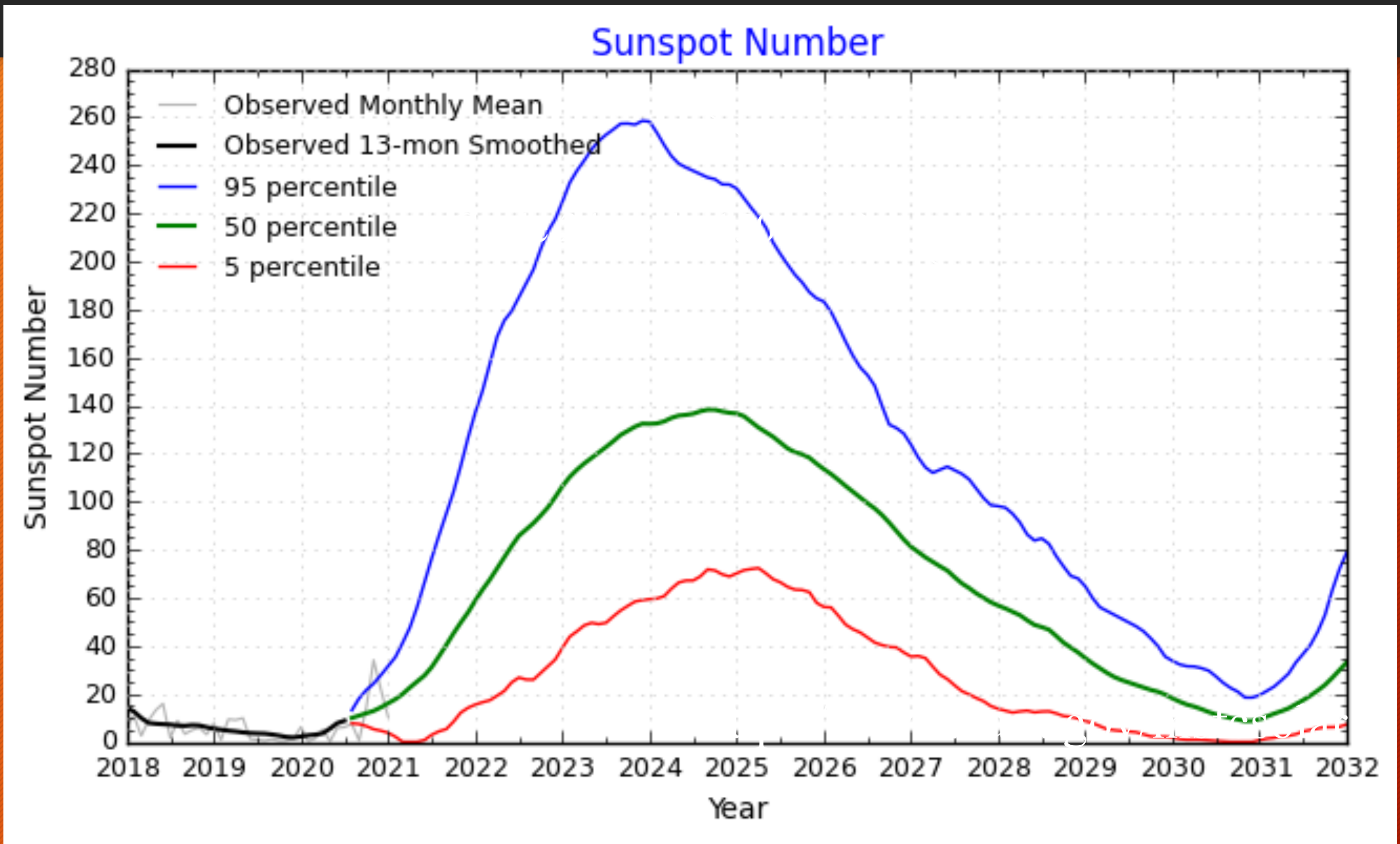
- 1958: MUF>60 MHz
- Some lucky hams worked Japan on 6 meters
  - I started out on 6 meters in 1961
  - Other hams told me how I missed the peak



Recents Sunspots before current cycle

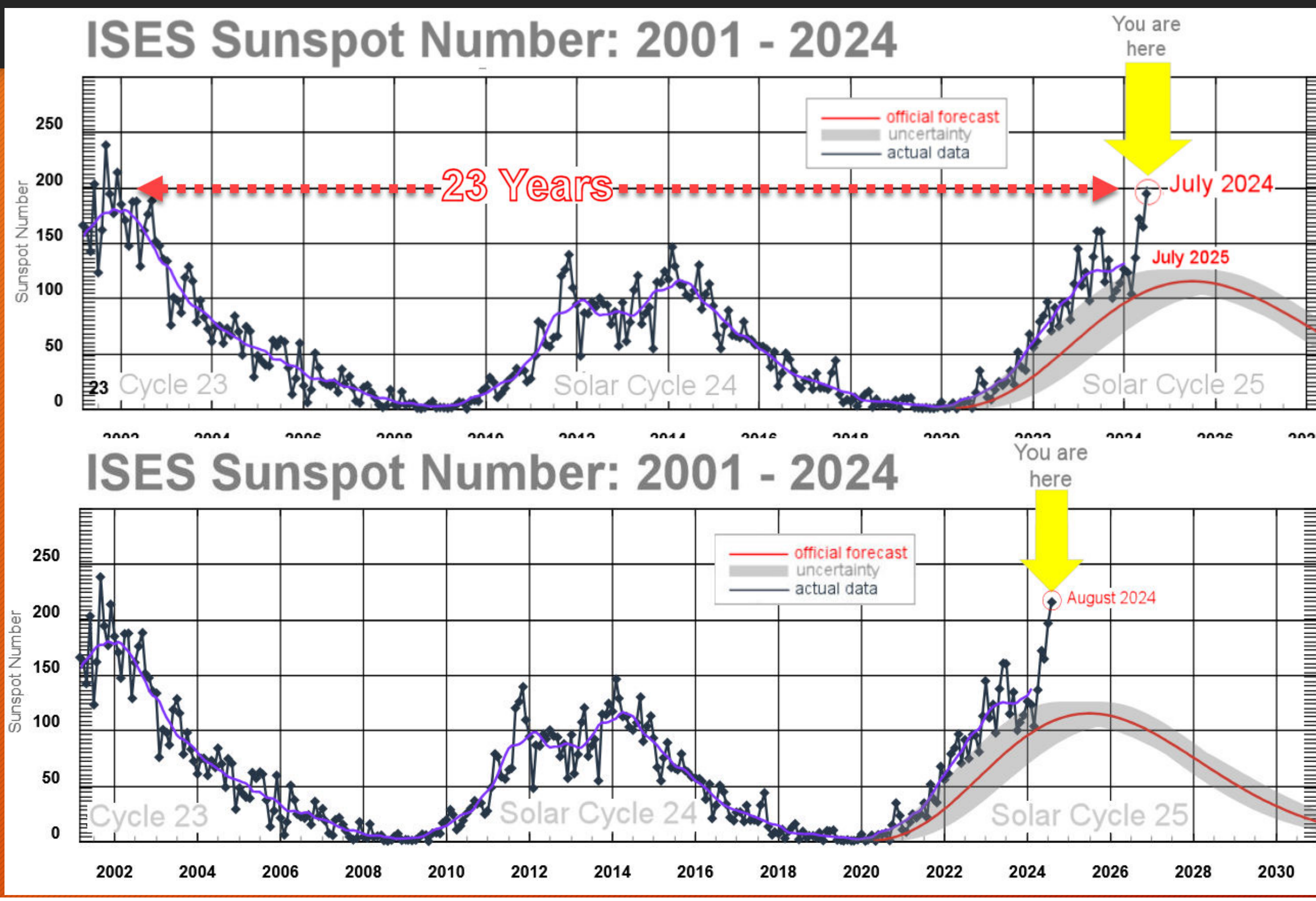


NASA Cycle 25 Predication



Before Cycle 25 started,
most Scientists expected
Cycle 25 to be about
the same as Cycle 24
But there was at least
one who disagrees

Cycle 25 So Far



The majority of the Scientists were wrong!

Only one person was right

Local HF Communication Range

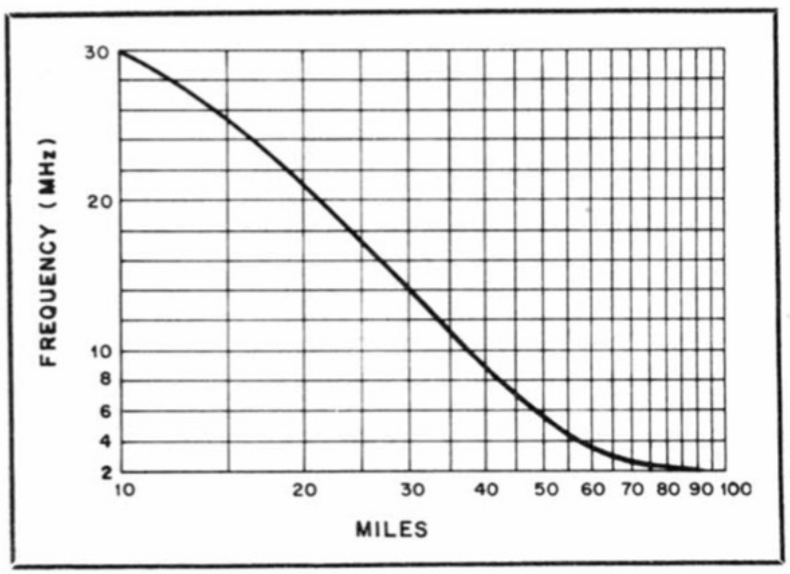


Fig. 1 — Typical high-frequency range, in miles, for ground waves compared to frequency. km = mi × 1.609.

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

Propagation

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

VHF Propagation

September 2024

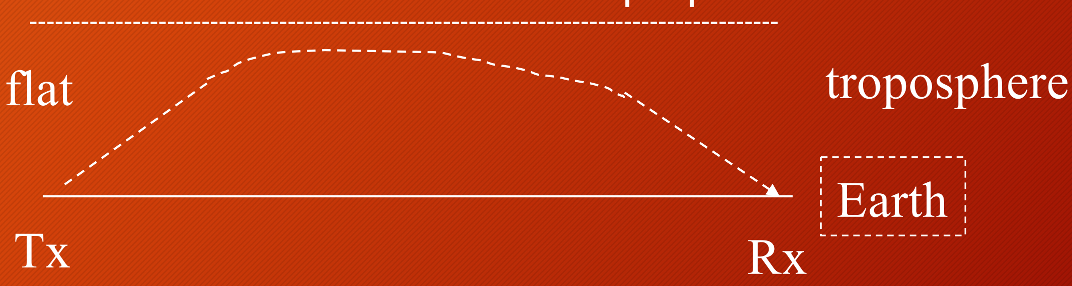
VHF Propagation

- E Skip
  - 10, 6 , 2, 1-1/4?? meters
- 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

Earth is shown as flat
We know that
it is curved



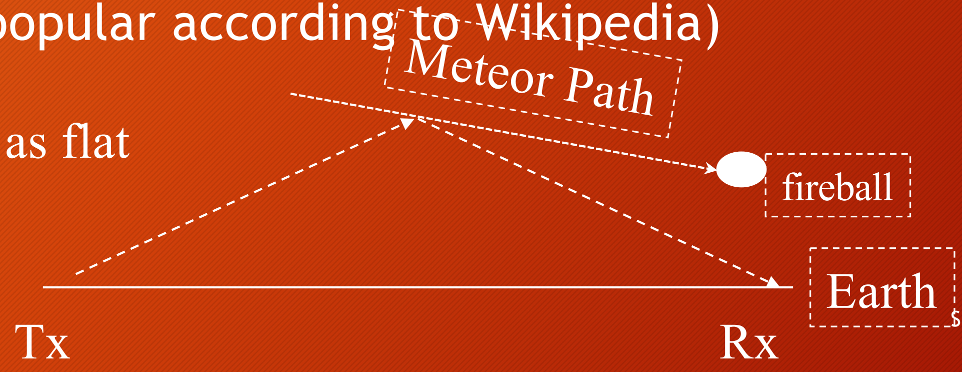
Aurora

- 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
it is curved

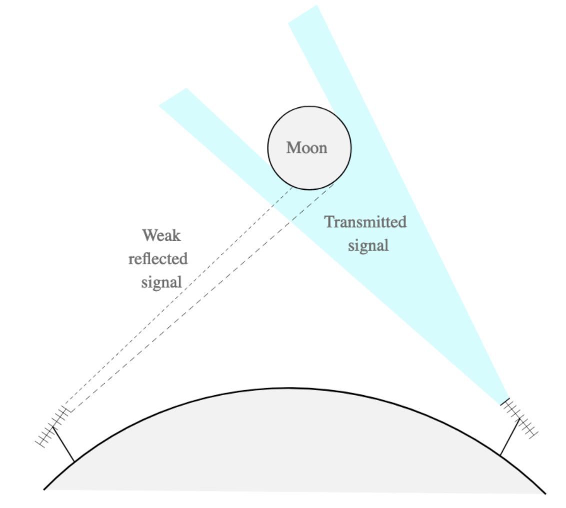


Forward and Back Scattering

- 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 (Earth-Moon-Earth/EME)

- 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, and 20-25 dBd antenna
- The ISEC antenna is great for Moon bounce
- With WSJT-X, lower power, and smaller antennas can be used



Concept of Moonbounce EME propagation

Planet Venus Bounce (Earth-Venus-Earth/EVE)

- Very very high path loss
- Some German hams have bounced their signal off of Venus
- Most recent was April 10, 2009
- They transmitted a continuous wave signal (no modulation) for about 5 minutes
- For receiving the EVE signals, an FFT analysis with an integration time of 5 minutes was used. After integrating for 2 minutes only, the reflected signals were clearly visible in the display.
- ISEC plans to try later next year when Venus is again close

https://amsat-dl.org/projects/venus-echos/

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

Questions?