Heliophysics 301

Class duration: 8 hours

Robert Anglin, WX5TEX

HF Propagation

Class duration: <8 hours

Robert Anglin, WX5TEX

Stradivari

What does this Stradivarius violin have to do with heliophysics and HF propagation?

3 Regions That Affect HF Propagation

- **The Sun**
- **Earths Ionosphere**
- **Earths Magnetosphere**

Variables to Skywave Propagation

Time of day

Time of year

Solar cycle

Solar activity

Suns rotation (27 days)

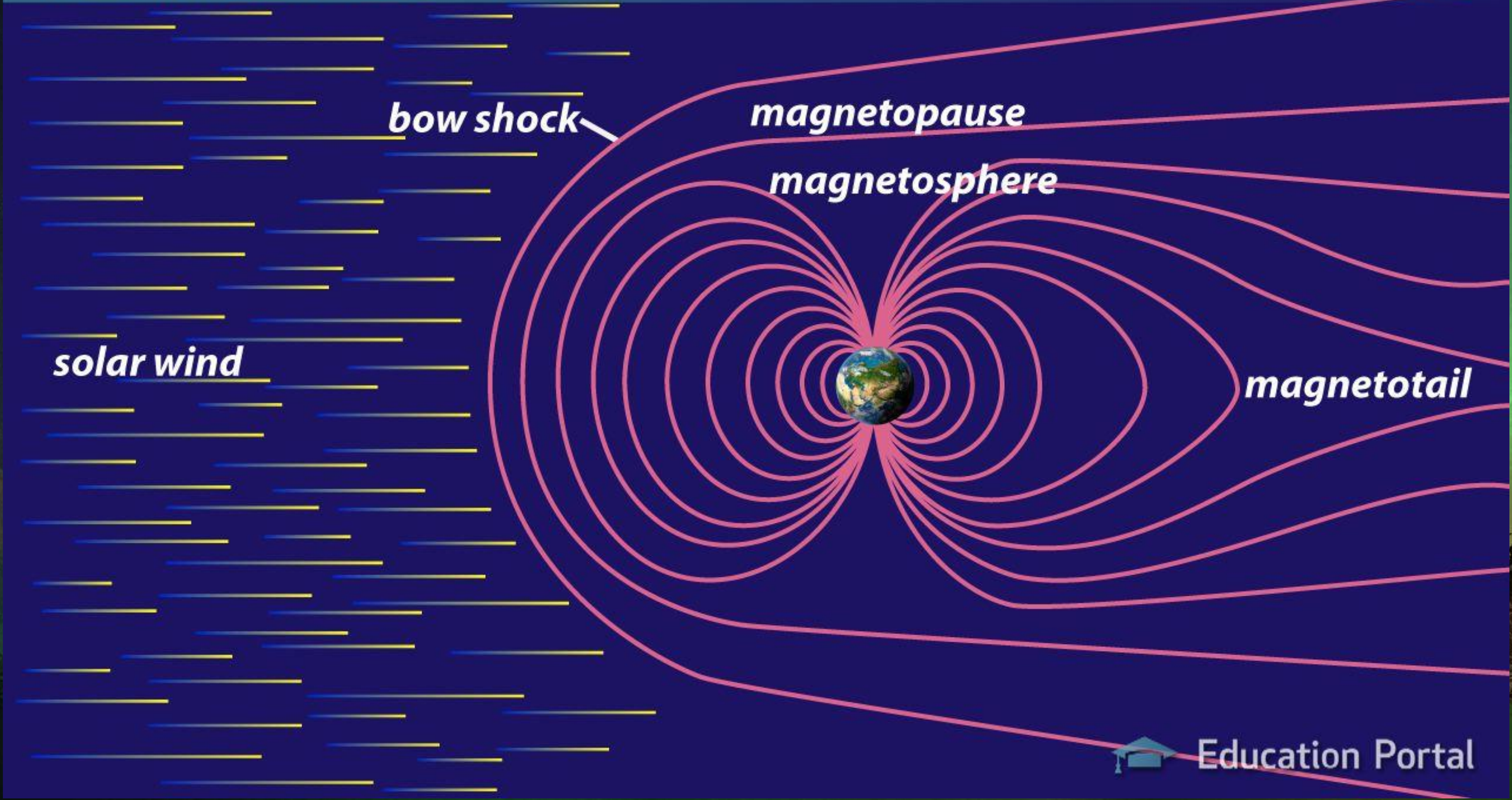
Antenna Height & polarization

Frequency

Magnetosphere status

Ionosphere status

THE VAN ALLEN BELTS



Magnetosphere

The magnetosphere protects the earth from solar radiation

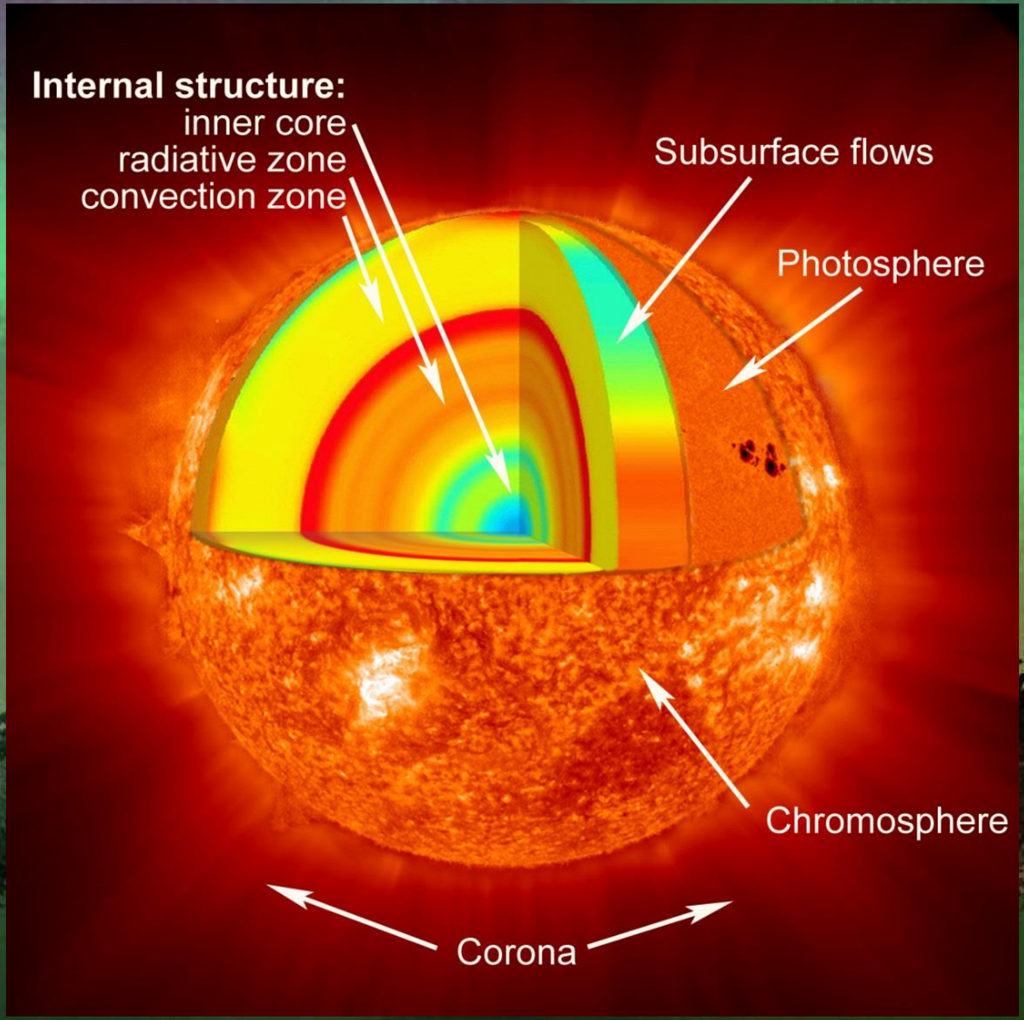
Increased solar winds and coronal mass ejections compress the magnetosphere like a balloon, causing it to vibrate, resulting in a geomagnetic storm.

The Sun

- Gravity in the sun's core causes hydrogen atoms to fuse together in a nuclear reaction, creating helium

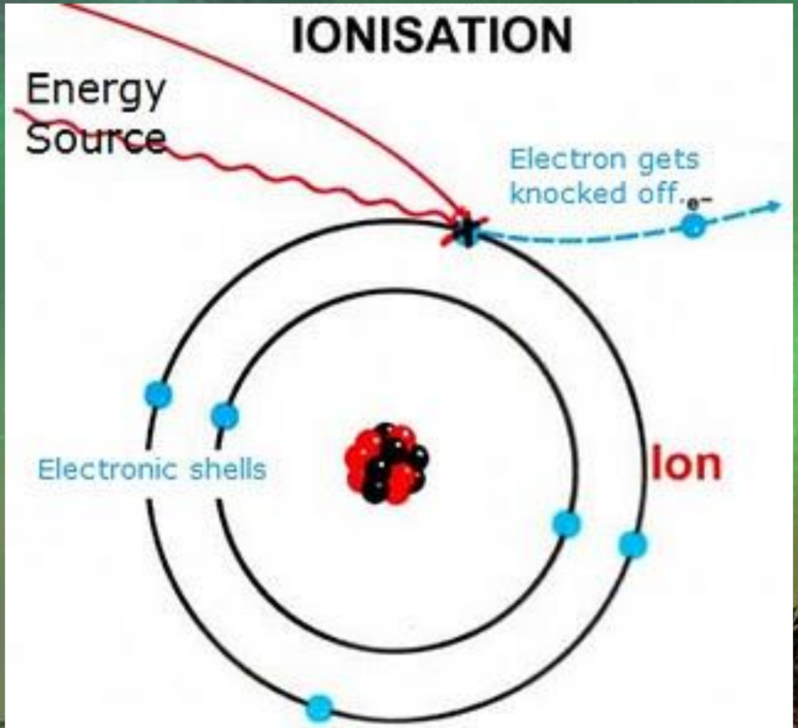
- This process also creates electromagnetic radiation (UV, IR, X-ray, visible light, radio waves)

- Helium-4 atoms take over 200,000 years to go from core to photosphere. Once particles leave photosphere, they take 8 minutes to reach Earth



Ionization

- Sun emits a steady stream of particles & radiation from the corona known as "Solar wind" (2,000,000 tons/ sec)
- UV and X-ray radiation in the solar wind collides with gases in the upper atmosphere, causing an electron to get knocked off each atom (ionization)
- The higher the altitude, atmosphere is less dense, therefore ionization decreases, radio signals are refracted instead of absorbed.

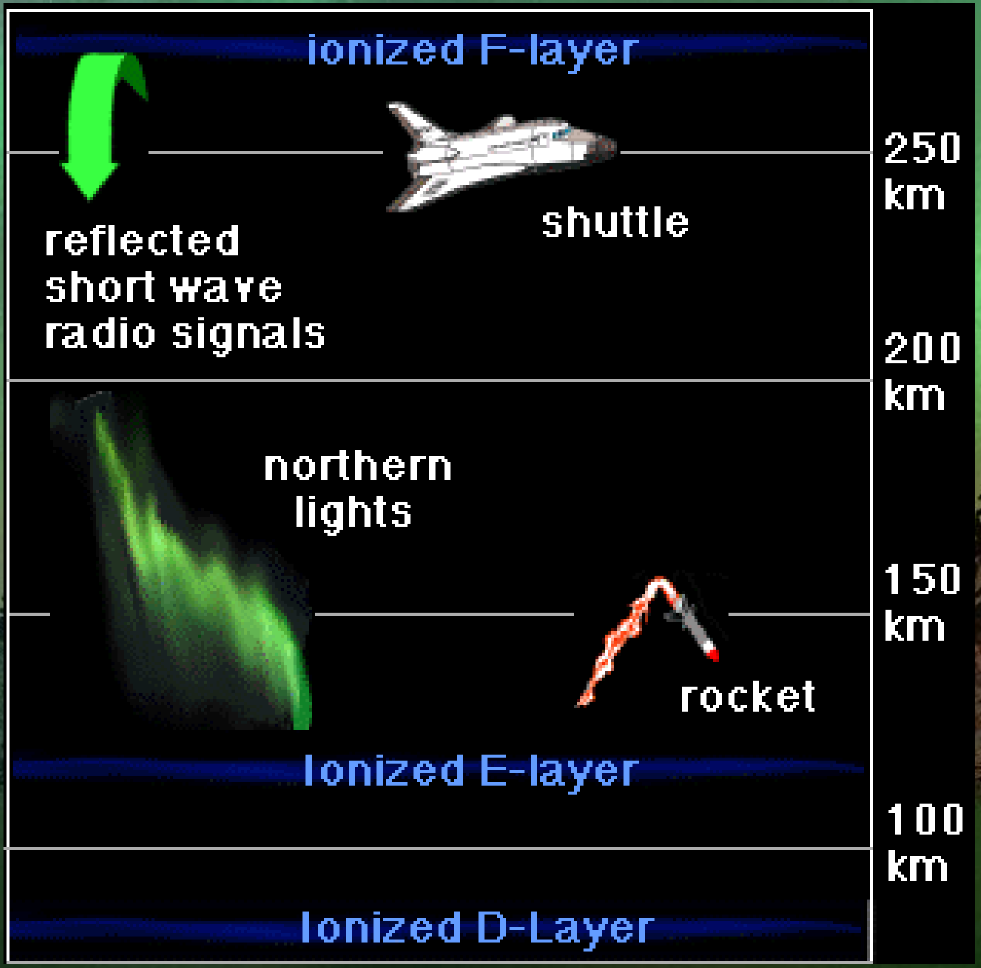


May 10-12, 1999

Ionosphere

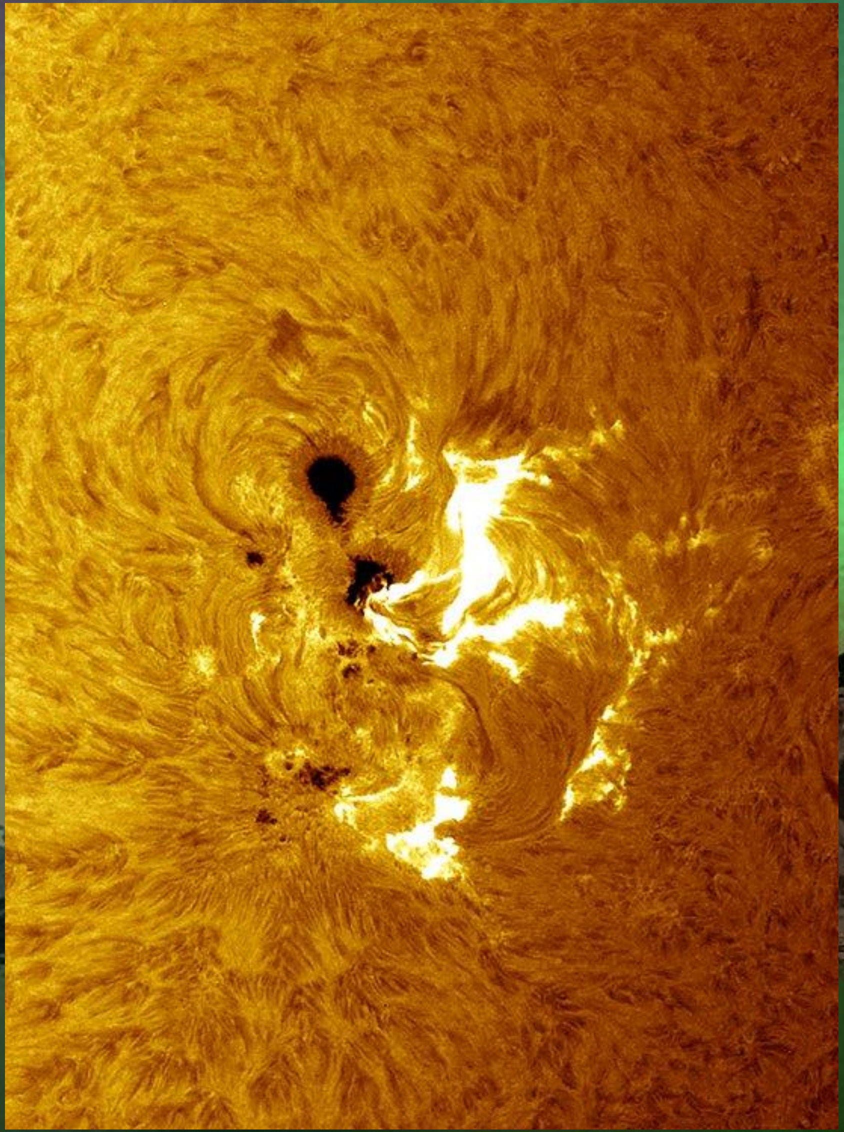
- Under normal conditions, radiation (solar wind) from the Sun interacts with gases in Earth's atmosphere, causing them to lose an electron (ionization), which forms the ionosphere
- Ionization occurs during daytime. Electrons are reabsorbed at night, causing ionosphere layers to disappear or decline

- D Layer: 35-50 miles up
  - Absorbs radio frequencies below 10mhz, attenuates others
  - Ionized by "hard" X-rays during daytime
- E Layer: 50-100 miles up
  - Refracts radio signals below 10mhz
  - During "Sporadic-E", can reflect VHF signals (summer)
  - Ionized by "soft" X-rays
- F Layer (F1 & F2) 100- 300 miles up
  - D & E layers disappear at night, so refracts RF at night
  - Ionized by UV radiation
  - Present day & night



Sunspots

- Occasionally, cooler areas of intense magnetic strength form (in pairs) on photosphere.
- These sunspots increase the ionization that occurs in Earth's atmosphere because increased levels of radiation are able to move more freely, causing more ionization on Earth
- Solar Cycles of maximum sunspots occur every 11 years
- As ionization is increased, higher frequencies can be refracted by ionosphere
- Sunspot number over 100 is great for long distance communications at higher frequencies



So What Does a Stradivarius Violin have to do with all of this?

- It's theorized that the time Antonio Stradivari was alive & making violins, was a time of extremely decreased solar activity and almost no sunspots- a radical solar minimum, resulting in slightly cooler temperatures on Earth, causing trees to grow more slowly, and therefore more densely. A drastic solar minimum that has yet to be repeated.

When Good Suns Go Bad

- Due to uneven rotation of the sun, magnetic lines can become twisted. When these lines snap, they produce solar flares (Rated at A, B, C, M, X)

- Gases in the chromosphere align themselves with these magnetic lines, causing coronal mass ejections which accompany solar flares (magnetized plasma)

- Flares affect HF radio immediately, while CME's take 48-72 hours to reach Earth

- Check the K-index & Radio Blackout level

Geomagnetic Storms

A geomagnetic storm is a significant disturbance of Earth's magnetosphere caused by solar activity.

It typically impacts Earth 24-36 hours after the solar event

Causes

- High speed solar winds
- Solar flares
- Coronal mass ejections
- Coronal holes

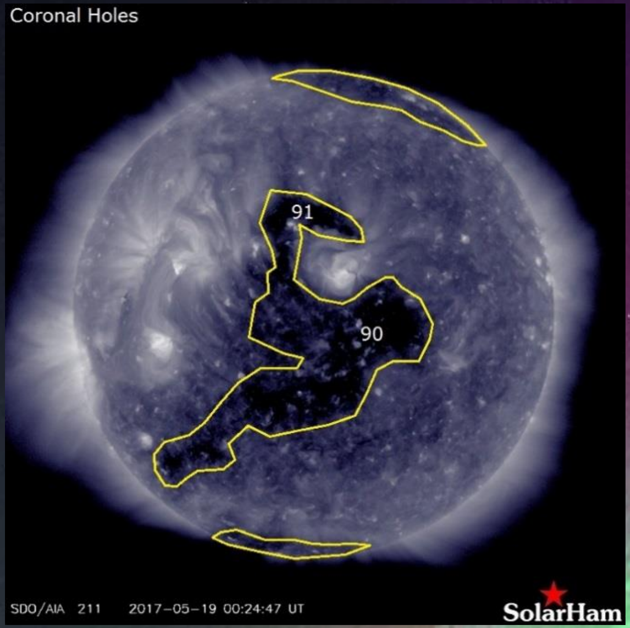
Effects

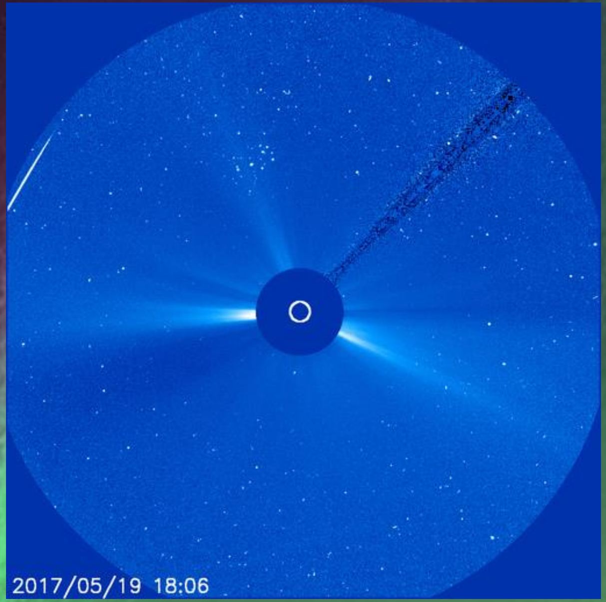
- Loss of HF communications
- High current induction into power lines causing power outages
- Loss of satellite hardware

The Carrington Event of 1859 was one of the strongest geomagnetic storms ever recorded. During the event, the aurora borealis was seen in the Caribbean and telegraph cables and keys arced from the high induced currents.

In 2012, the sun produced a solar flare that measured X45, the strongest ever recorded. Had it hit the Earth, it likely would have shut down the entire U.S. electrical grid

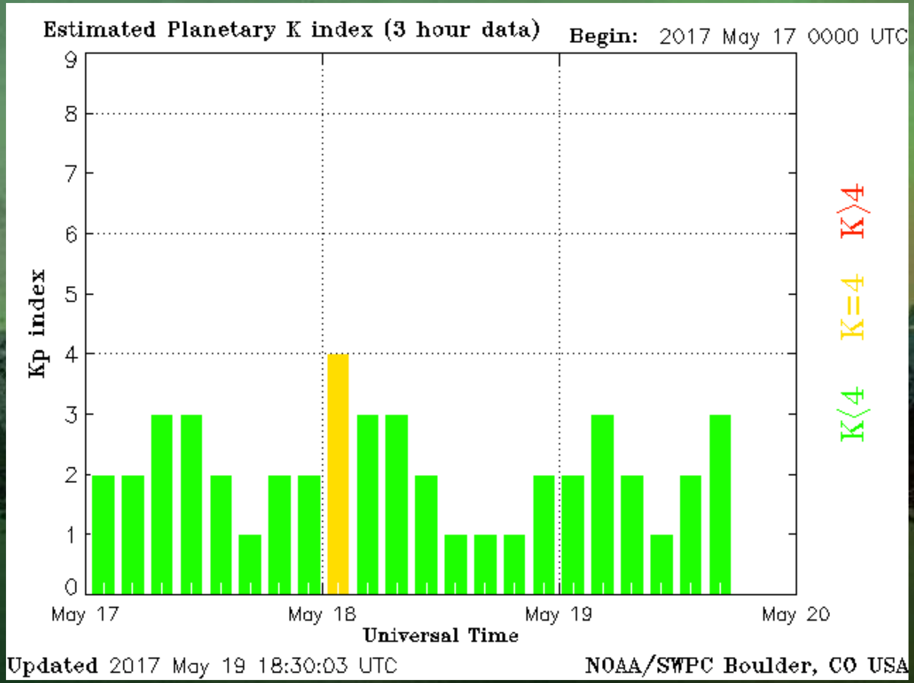
https://www.youtube.com/watch?v=TWjtYSRlOUI
https://www.youtube.com/watch?v=sg3NAdOYp8Q





Solar-Terrestrial Data
19 May 2017 1940 GMT

SFI: 72 SN: 24
304A: 53.0 @ EVE
A 11 K 3
X-Ray: A5.4
Aurora: 4/n= 1.99
Mag (Bz): -1.8
Solar Wind: 475.3
MUF Boulder 40.30



Measuring Space Weather

Speed

- Speed of solar wind
- 200-900
- Average: 400
- Lower is better

SFI

- Solar Flux Index
- Intensity of solar radiation
- 62-300
- Higher is better

SN

- Sunspot Number
- 0-250
- Higher is better

A-Index

- Daily average of geomagnetic activity
- 0-400
- Storm triggered at 30

K-Index

- Geomagnetic activity measured every 3 hours
- 0-9
- 5 is disturbed, no HF activity
- 7: aurora visible over OR

X-Ray

- Intensity of hard X-ray radiation
- A0.0 – X9.9+
- M level is disturbed

WWV/WWVB/H

- To help determine current propagation, use the time signal from NIST (Ft Collins, CO)

- 2.5 mHz
- 5 mHz
- 10 mHz
- 15 mHz
- 20 mHz
- 25 mHz (experimental)

Which Band to Use?

160 Meters

- Medium Wave
- Similar to AM, local during day, 500 miles @ night
- Longer distances in winter
- Not affected by solar cycles
- Use vertical antennas

80 Meters

- Similar to 160, but greater distances at night
- 200 miles daytime
- DX at night

40 Meters

- Summer: 300 miles daytime, 1000+ night
- Winter: 500 miles daytime, DX night
- Not affected by sunspots
- Very reliable

20 Meters

- Always a good time!
- Good for 500 miles plus, day and night
- Great for DX
- DX at sunspot minimum is rare
- Most popular band

Which Band to Use?

17 Meters

- Similar to 20 meters, but less crowded
- Good for mobile HF
- No contesting
- Best in daytime
- Where all the friendly people are

15 Meters

- Good for daytime activity
- Heavily influenced by sunspot activity
- Very little activity at sunspot minimum

12 Meters

- Heavily influenced by sunspots
- Sunspot maximum, 1000+ miles possible
- No contesting

10 Meters

- Most affected by sunspots
- At solar maximum, good for DX + very popular
- Ground wave only at sunspot minimum

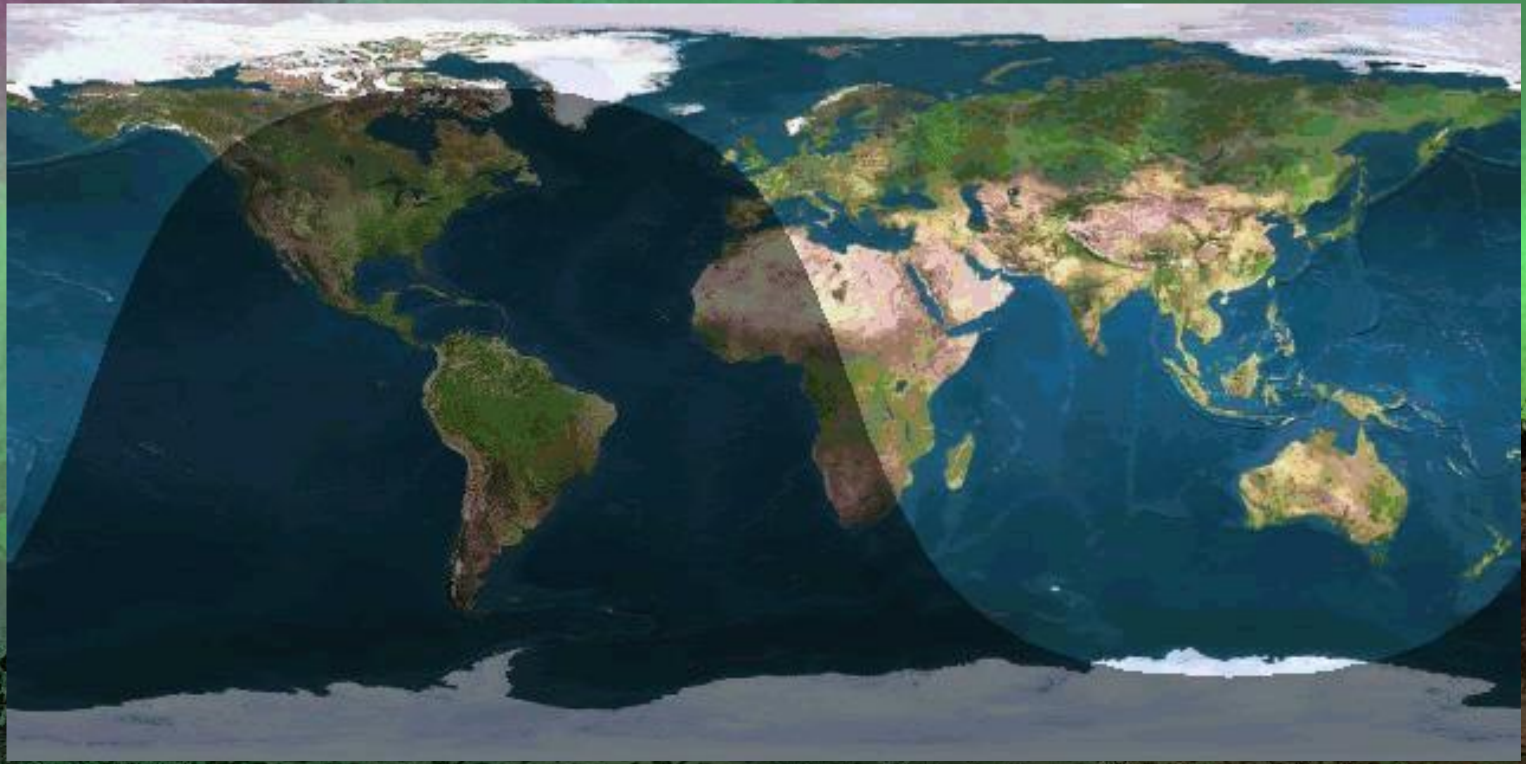
More dependent on sunspots. Better during geomagnetic storms

When In Doubt:

Use 20 meters

Gray Line Propagation

- Propagation is enhanced at the line that separates day & night
- The D-layer disappears very rapidly at this line at dusk and has yet to form at dawn
- Long distance QSO's, especially DX greatly increase during this time
- Both stations should be along this line



Maximum Usable Frequency

- Knowing MUF is critical to disaster HF communications b/c operations tend to cover less distance
- Its best to use the highest frequency possible to make a contact & determine transmission path, bc higher frequencies tend to refract at higher altitudes
- MUF takes into account solar & ionospheric conditions, distance between stations, time of day, antenna take off angle
- General rule: use frequency 20% lower than MUF

Operating Modes

- **FM Signals require too much bandwidth to be used on HF**
- **Morse Code: one of the most efficient modes**
- **Amplitude Modulation: Used by shortwave broadcasters, aviation, & hams on HF**
  - **Made up of a carrier signal and two sidebands, which actually transmit the information (voice)**
  - **Carrier signal uses about 2/3 of transmit power**
  - **6 kHz bandwidth**

What if there was a more efficient voice mode?

Single Sideband

- Single Sideband suppresses the carrier and one sideband of an AM signal
- All transmit power is used in transmitting the information
- Upon receive, transceiver re-injects a small carrier signal
- Signal is only being transmitted when you actually talk
- 3 kHz bandwidth

To USB or LSB? That is the question..

LSB: Below 10 mHz

USB: Above 10mhz & 60 meters

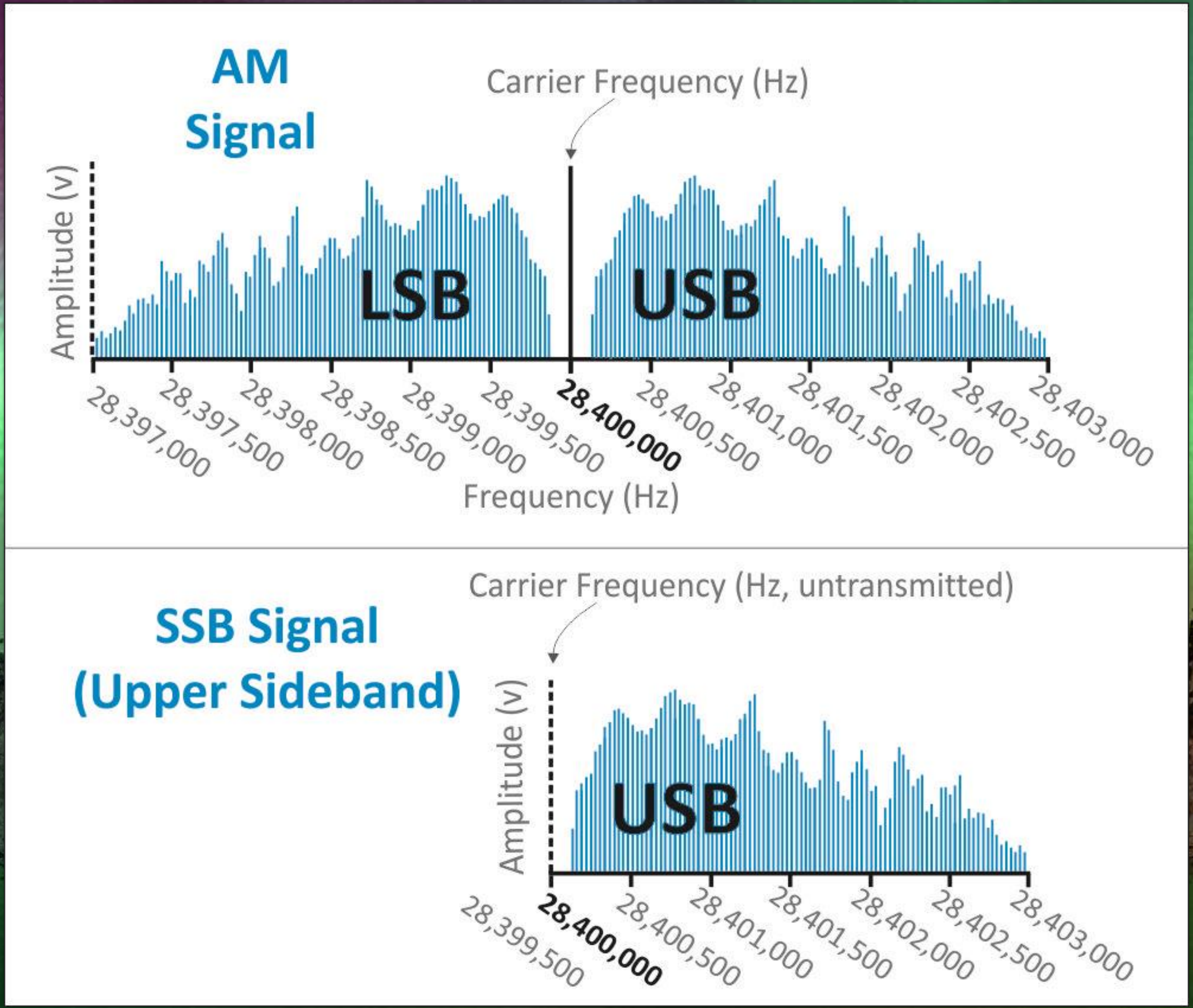
Single Sideband

In AM mode, the frequency displayed on your transceiver is the center of your transmitted signal, however this is not the case with SSB, therefore you must be mindful when operating near the band edges.

Displayed frequency is dependent on USB/LSB mode

In **upper sideband**, your displayed frequency is the **bottom** edge of your signal, so watch the **UPPER** edge of the band

In **lower sideband**, your displayed frequency is the **upper** edge of your signal, so watch the **LOWER** edge of the band



Propagation Resources

- **Prop.HFRadio.Org**
- **http://www.swpc.noaa.gov/**
- **www.Solarham.com**
- **www.Voacap.com/prediction.html**
- **www.NIST.gov**
- **www.sunspotwatch.org**