Upper Pinellas Amateur Radio Club

Tech Program Series

An Introduction to HF Propagation

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Credits

This presentation is adapted from an article by Dennis J. Lusis, W1LJ, appearing in QST magazine December, 1983.

Thank you to Paul White, N4WGL, for advice and counsel in creating this presentation.

Agenda

- Overview of Propagation
- The Ionosphere & Layers
- Refraction
- Multi-hop Propagation
- Effects of the Sun
- Propagation Predictions / Further Reference
- Summary / Q&A

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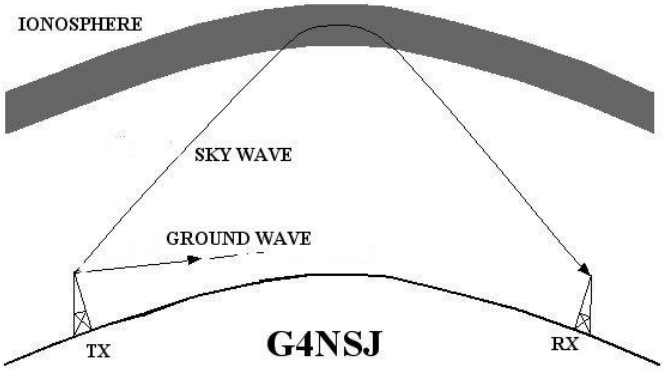
Overview of Propagation

- **Propagation: How radio waves travel**
- **Focus on HF Propagation**
- **VHF / UHF Propagation is completely different**

Overview of Propagation

- Your antenna generates radio waves.
- Two Categories:
  - Ground Waves vs. Sky Waves
    - Ground waves:
      - Station to Station
      - Do not leave the lower atmosphere
    - Sky Waves
      - Do not follow Earth's surface
      - Travel into the sky
      - Reflected by Ionosphere
      - Reflected signal can travel many miles



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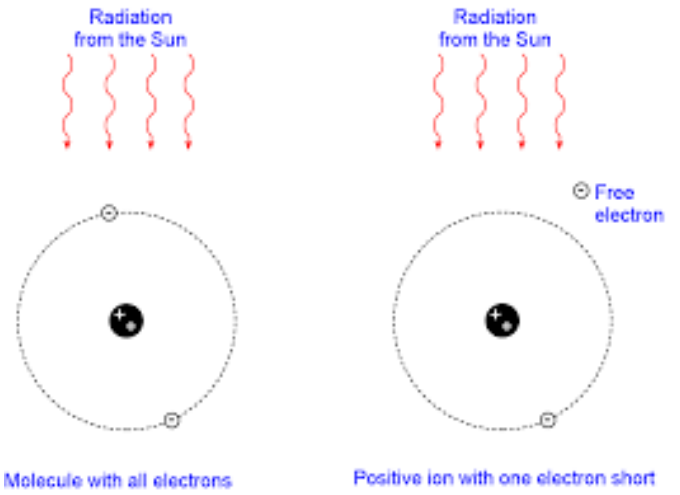
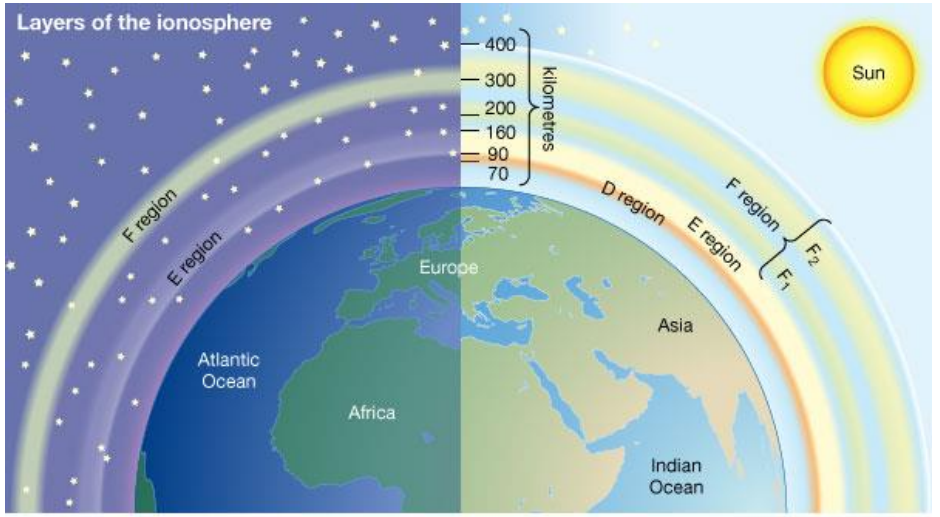
The Ionosphere & Layers

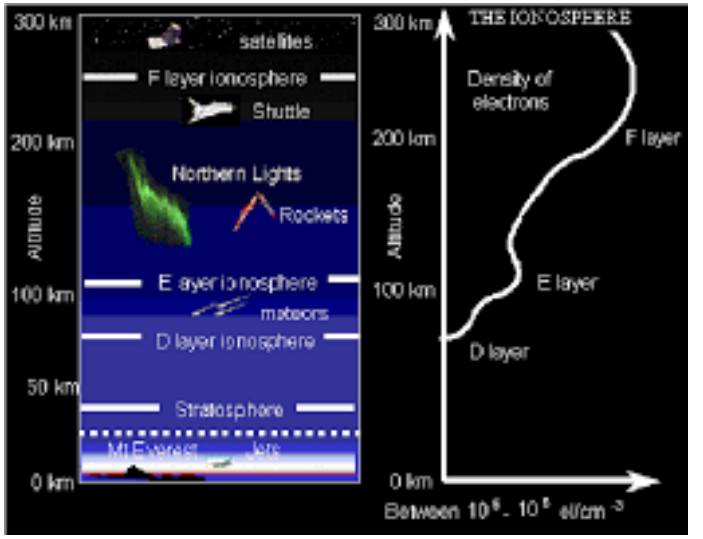
- 25 to 250 miles above Earth
- Named for ‘Ion’
  - “Free” electrons
  - Caused by ultraviolet heating from the Sun
  - Low air pressure (less dense)
  - Ions travel freely
- Ions ‘refract’ radio waves
  - Directed back to Earth
  - Solar conditions dictate strength of refraction



The Ionosphere & Layers

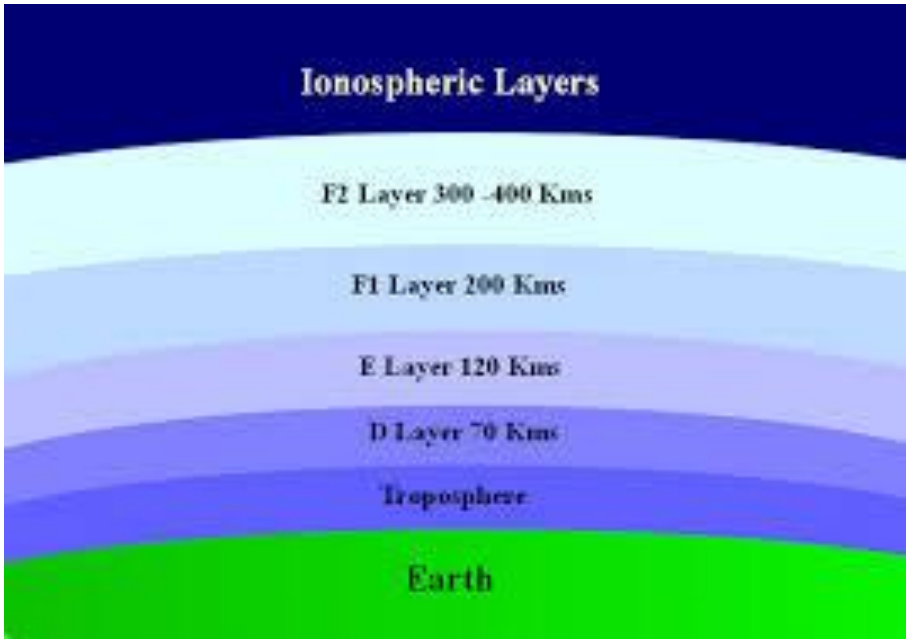
- **Ionosphere is divided into ‘Layers’**
  - **Concentric to Earth’s curve**
  - **Center of each Layer is more ‘ionized’**
  - **Ionization affected by season, time of day, solar conditions.**





The Ionosphere & Layers

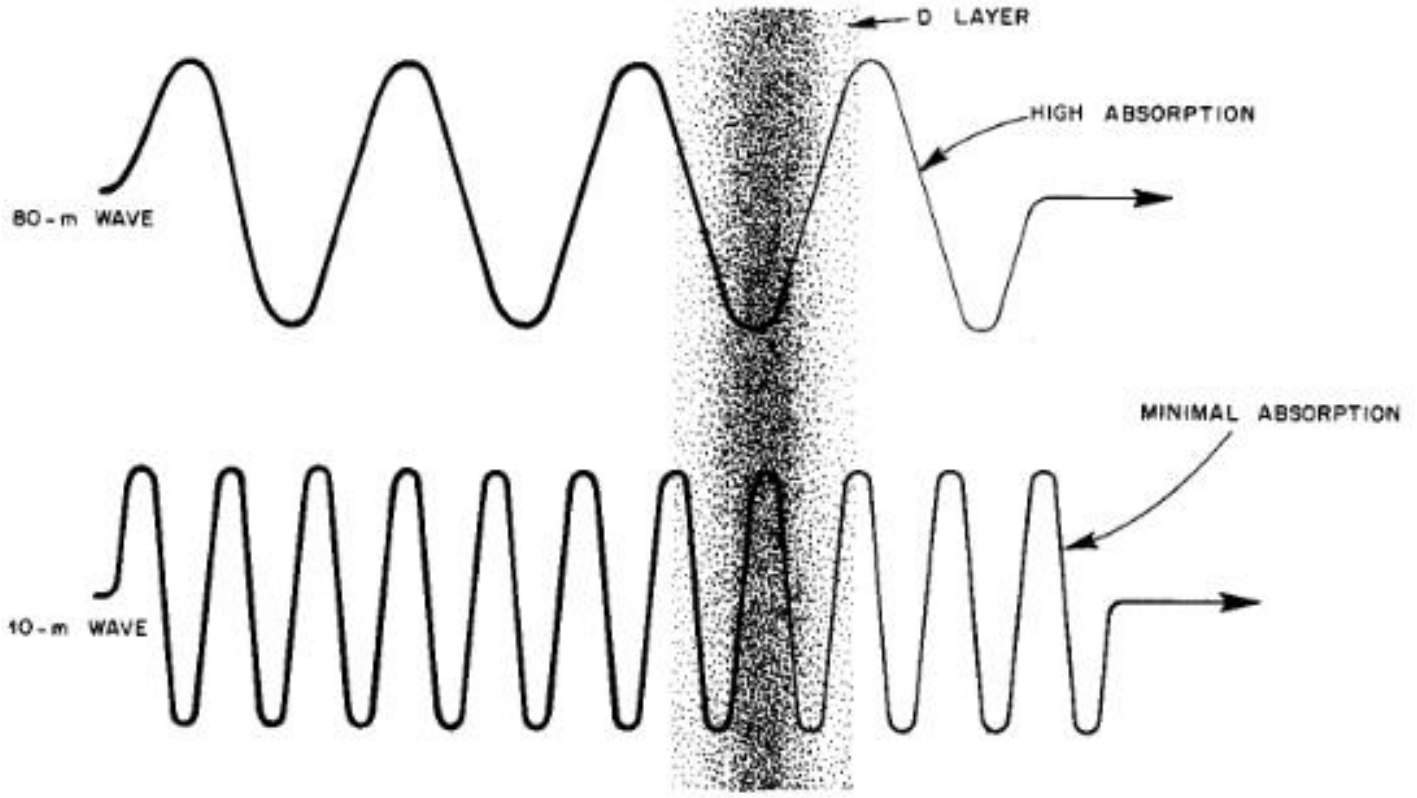
- **Ionosphere Layers:**
  - **D: 50-95Km**
    - **Absorbs some radio waves**
    - **Disappears at night**
  - **E: 90-140Km**
    - **Reflects radio waves**
  - **F: 160-400Km**
    - **Absorbs most UV radiation**
    - **Reflects radio waves**



The Ionosphere & Layers

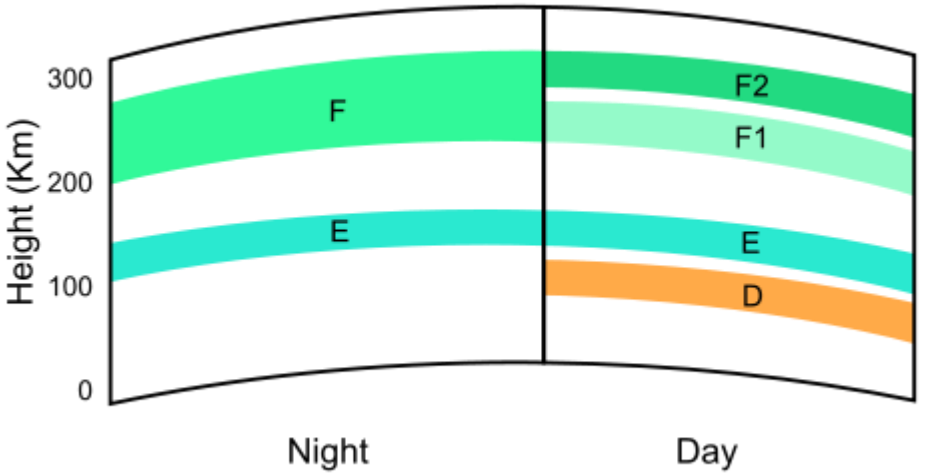
- **The ‘D’ Layer:**
  - **37-57 miles above the Earth**
  - **Exists only during daylight**
    - **Disappears 30 minutes after sunset**
  - **Particularly dense**
    - **Ions collide and recombine with loss of UV Rays**
  - **This Layer is less useful to Amateurs**
    - **Radio waves are absorbed as they set Ions in motion**
    - **Lower frequency waves set more Ions in motion**
      - **Energy is absorbed more than higher frequency waves**
      - **160, 80, 40 meters produce short distance DX in daytime**
    - **Low angle waves absorbed more than high angle**

The Ionosphere & Layers



The Ionosphere & Layers

- At night, D layer disappears
- 160, 80, & 40 meters usable for long distance DX
- 20 meters is unaffected by the D Layer
  - “Less absorbed”



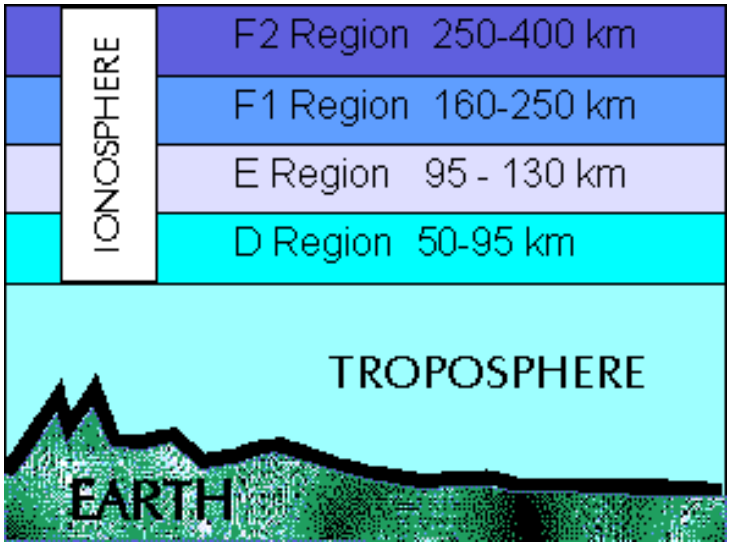
The Ionosphere & Layers

- The ‘E’ Layer
- 62-71 miles above the Earth
- Supports ‘occasional’ propagation
- Absorbs low frequency radio waves
  - Not nearly as much as the ‘D’ Layer
  - Peak ionization is at mid-day
- X-rays and meteors contribute to ionization
- Causes ‘Sporadic E’
  - “Clouds” of densely packed Ions
  - VHF propagation – 10 and 6 meters
  - Subject for a different Tech Program!

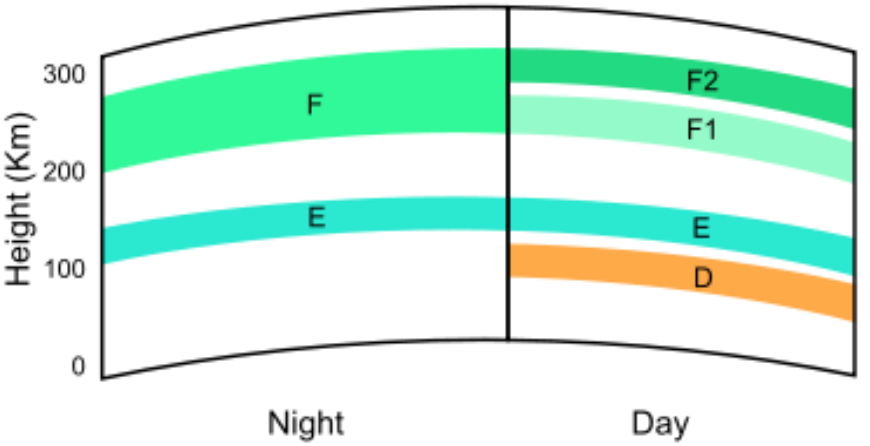
The Ionosphere & Layers

- **The ‘F’ Layer:**
  - **100-260 miles above the Earth**
  - **“Rarification” causes slower ion re-combination**
    - **Rarification – ‘less dense’**
    - **Thus, high ionization**
  - **Peak ionization mid-day**
    - **Least ionization just before sunrise**
  - **Provides best result for long distance HF**
  - **Divided into two sublayers:**
    - **F1 – Present at daytime, acts like ‘E’ Layer**
    - **F2 – Highly ionized, is at lower altitude at night**

The Ionosphere & Layers



F1 and F2 recombine at night



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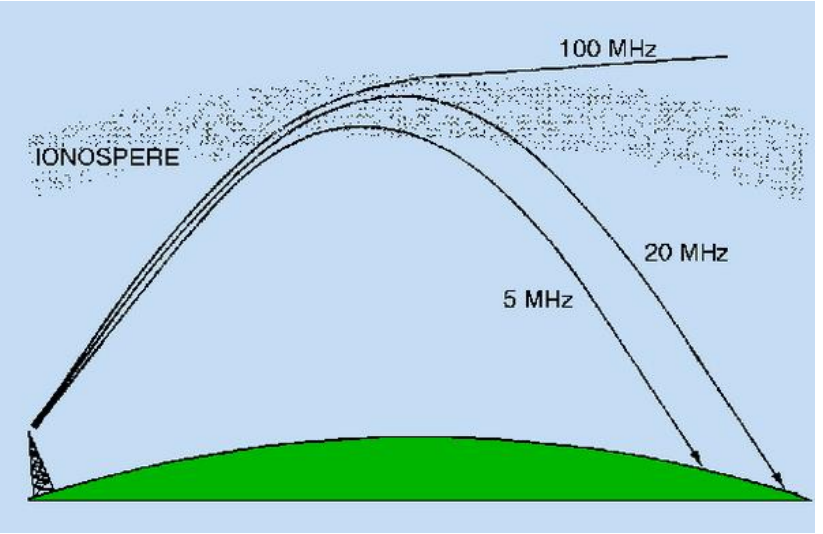
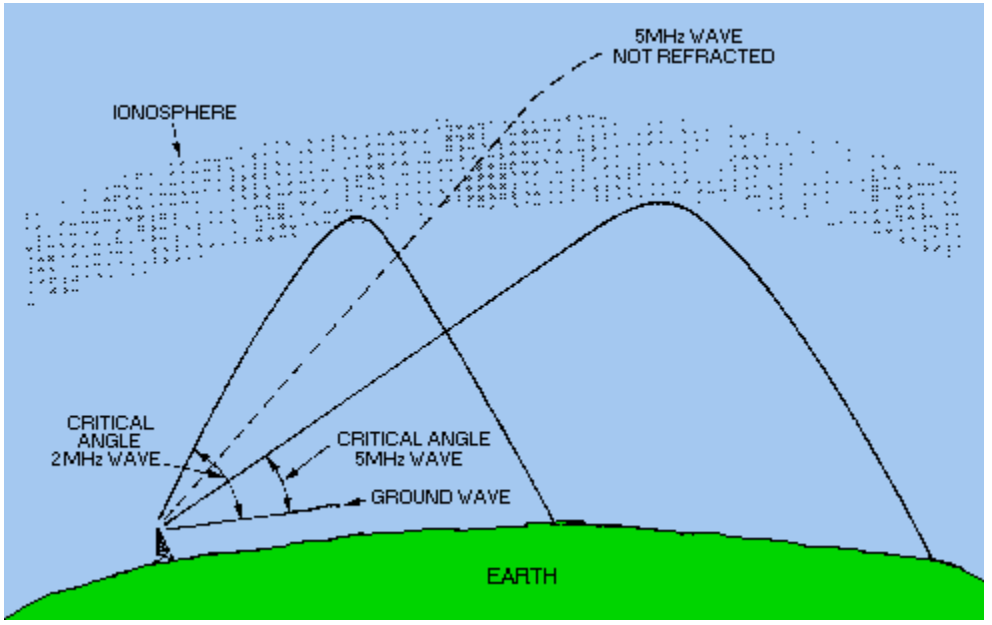
Refraction

- How the radio waves are ‘bent’ back to Earth
- Two factors affect refraction:
  - Ionization
  - Frequency
    - Occurs more often on lower frequencies



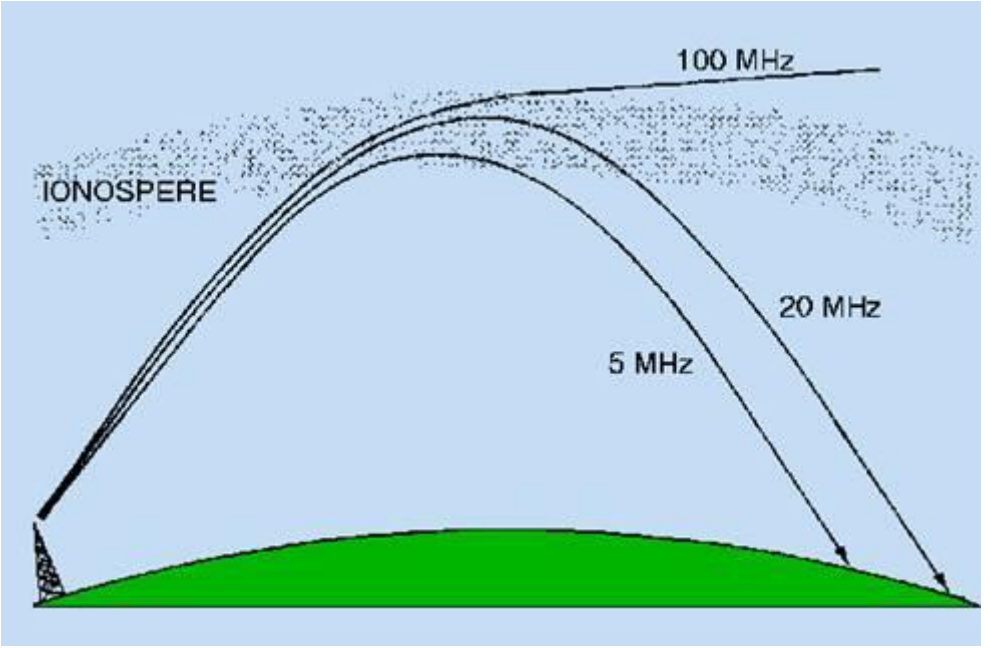
Refraction

- Angle entering the F Layer also affects refraction
- “Critical Angle” is highest angle achieving refraction
- Waves at and below “Critical Angle” are refracted



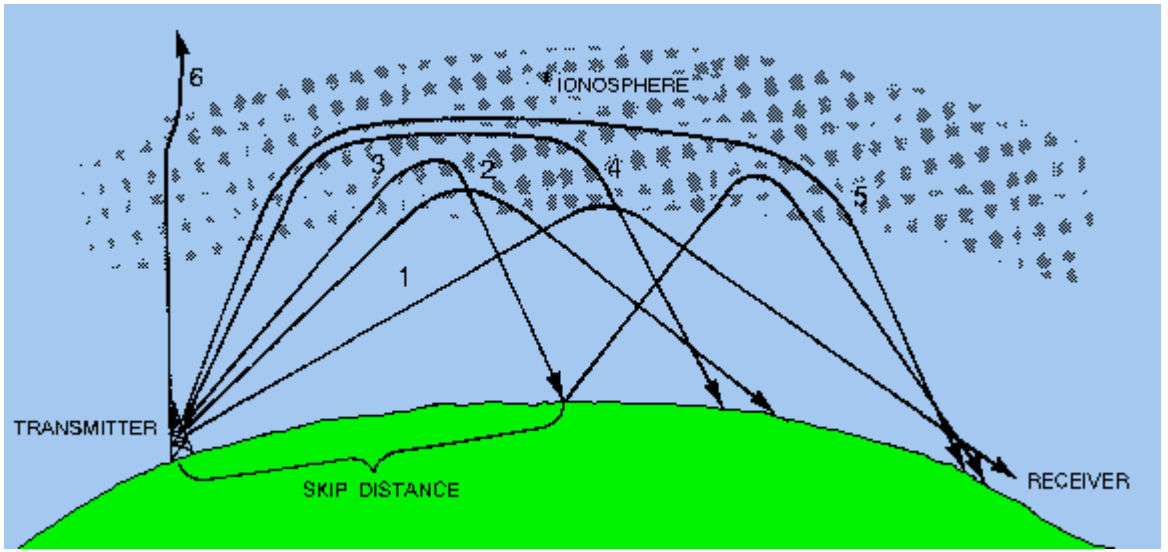
Refraction

- **Maximum Useable Frequency (muf)**
  - **Highest frequency achieving refraction between two points**
  - **May be different between any two stations at same time**



Refraction

- Critical Angle also related to ‘Skip Distance’
- Also called ‘Skip Zone’
- Varies by band



Approximate Skip Distances for the Amateur MF and HF Bands

Band	*Noon**	*Midnight**
160 m	0 mi	0 mi
80 m	0 mi	0 mi
40 m	50 mi	300 mi
30 m	300 mi	600 mi
20 m	500 mi	1000 mi
15 m	800 mi	(Daytime only)
10 m	1200 mi	(Daytime only)

*Local time at the midpoint of the path.

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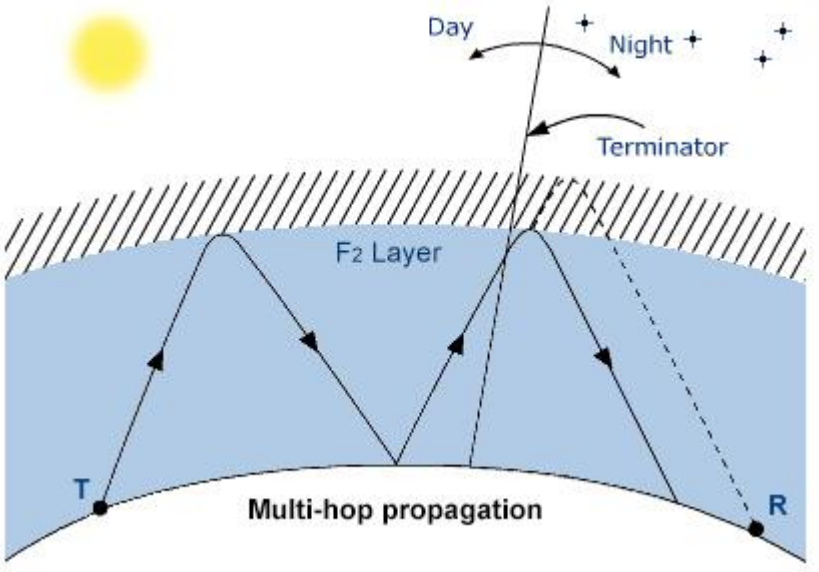
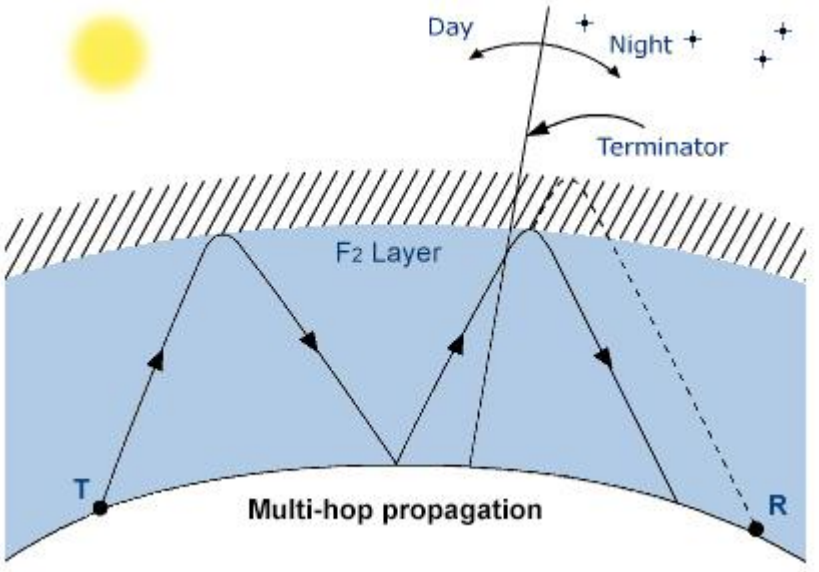
Multi-hop Propagation

- Waves returning to Earth are reflected back again
- Lowest angle produces longest hop
- Can occur several times
- Bodies of water are better reflectors



Multi-hop Propagation

- **Skip Distance can change from day to night**
- **Multi-hop effect increases**



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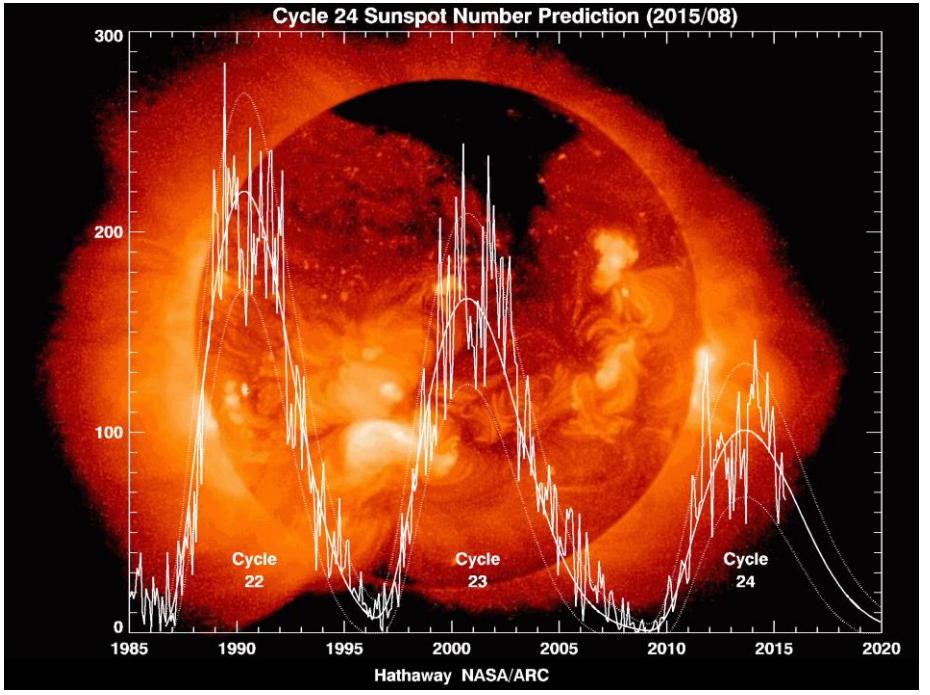
Effects of the Sun

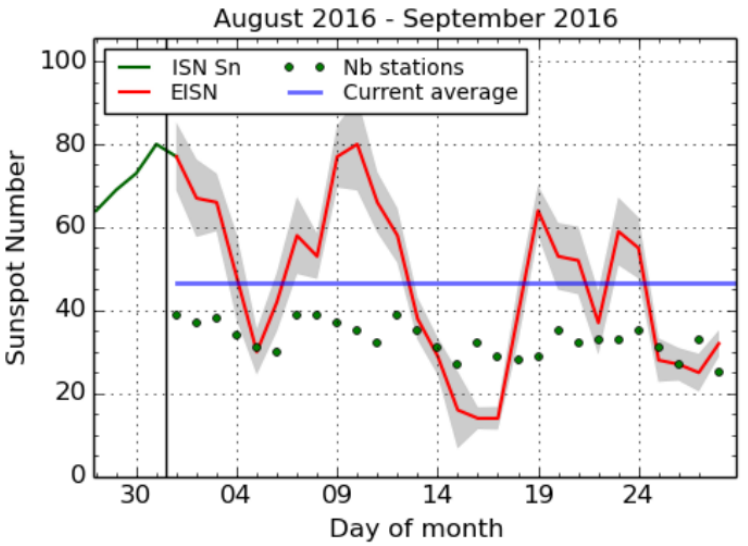
- **Sunspots and Solar Cycle**
  - **Increase Ionization – improves HF propagation**
  - **Peak in an 11-year cycle (give or take)**
  - **Last peak was between 2011 and 2014 (Cycle 24)**



Effects of the Sun

- **Sunspot Number**
  - **Also known as ‘Wolf’ number**
  - **‘Smoothed’ or ‘mean’ value of Sunspot activity**
  - **Can range from single digits to almost 200**
  - **Higher number = higher ionization = better HF propagation**

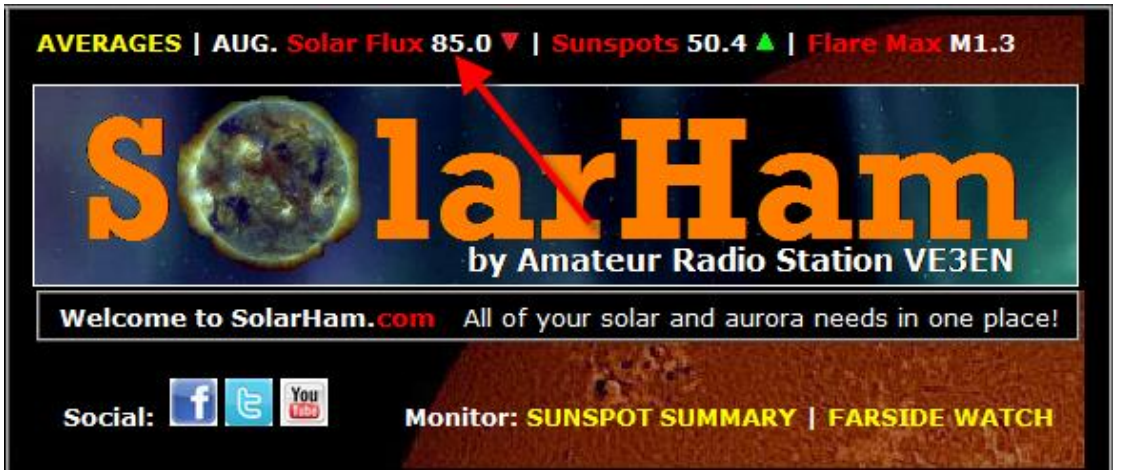
http://sidc.oma.be



Effects of the Sun

- **Solar Flux**
  - **Another indication of ionization**
  - **Ranges from 50 to 300**
  - **Measured by solar ‘noise’ in the 2800MHz band**
  - **High noise indicates high ionization of ‘F’ Layer**
  - **Higher Solar Flux number = higher ionization**

http://www.solarham.net/



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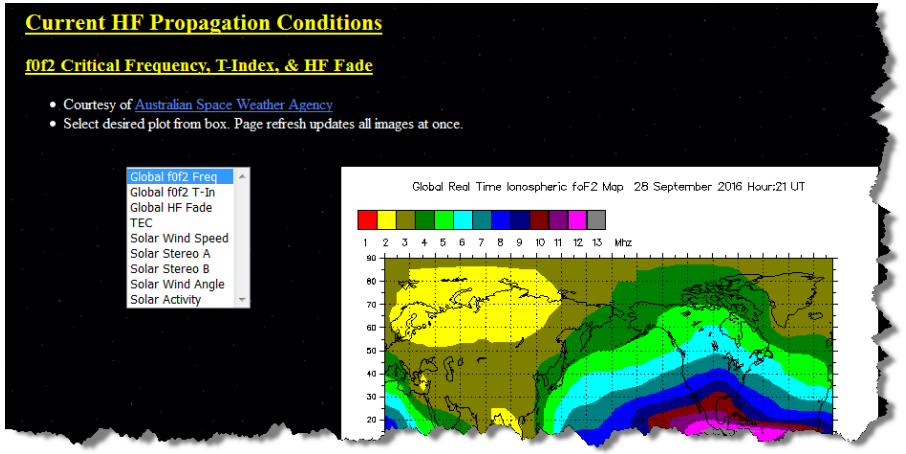
Propagation Predictions

- More difficult than weather forecasting
- Resources are in QST every month (How's DX?)
- Transmitted by W1AW
- Many Internet resources

http://www.hamqsl.com/solar3.html



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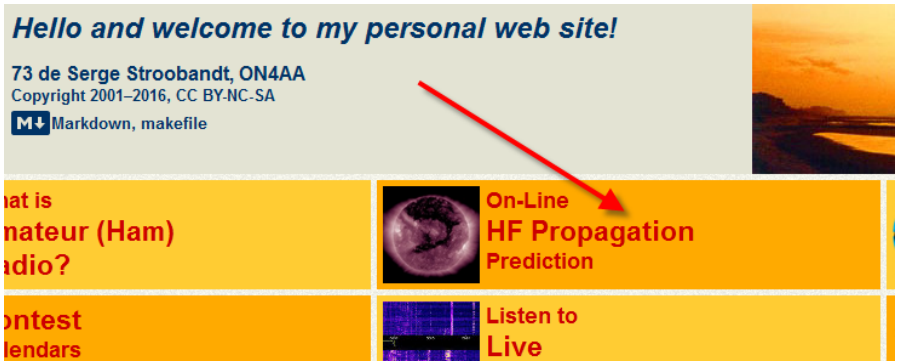

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Summary

...And, in conclusion

Questions, Comments -?

Thank you for listening! Look for more Tech Programs at future meetings! 73, and great DX'ing!

Steve Foy – Member-at-Large, UPARC

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Palm Harbor, Florida