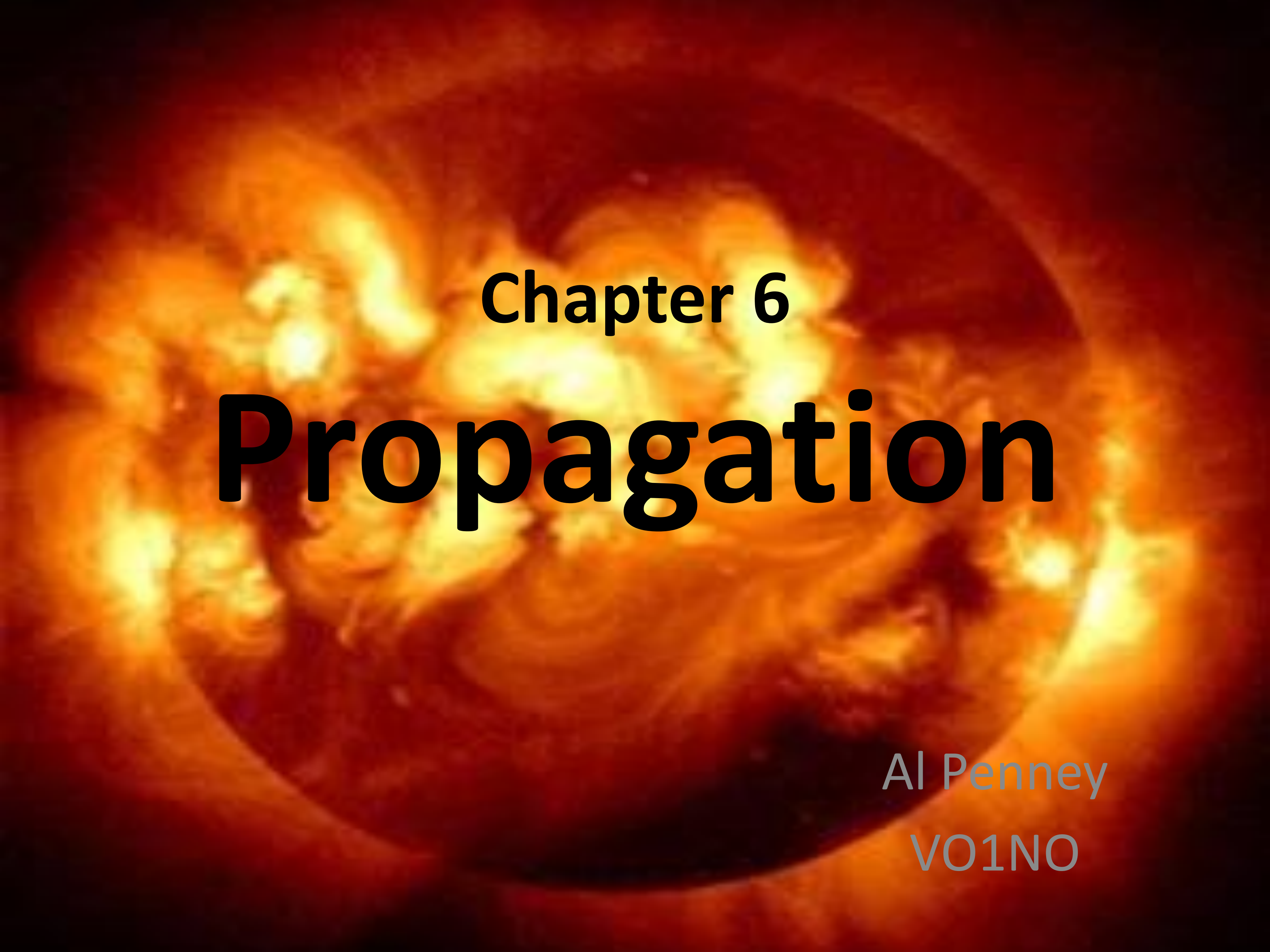

Chapter 6

Propagation

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Objectives

To become familiar with:

- Classification of waves wrt propagation;
- Factors that affect radio wave propagation; and
- Propagation characteristics of Amateur bands.

Propagation

- How signals get from Point A to Point B.

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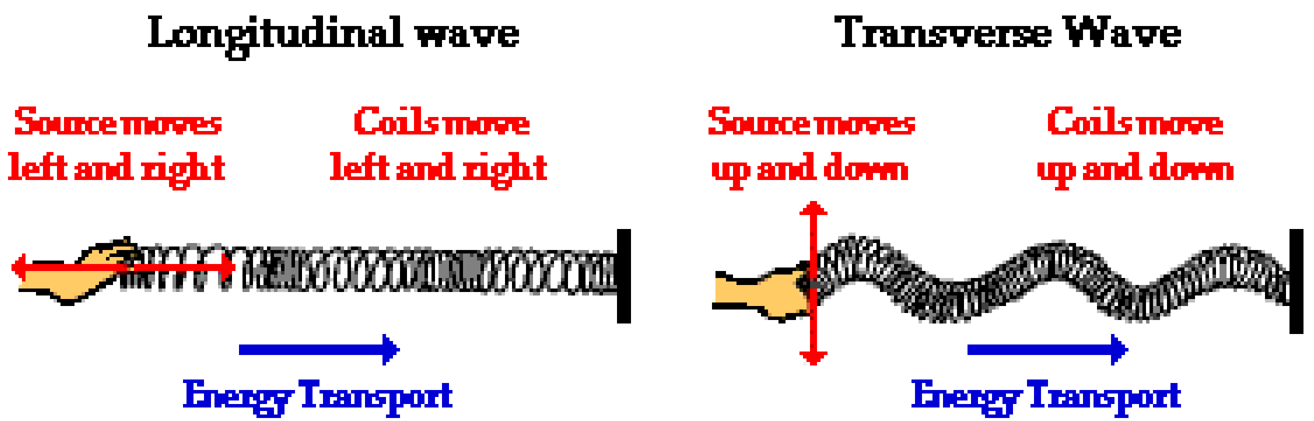
Waves

- Transverse
  - Vibration is at right angles to direction of propagation, e.g.: guitar string
- Longitudinal
  - Vibration is parallel to direction of propagation, e.g.: sound waves



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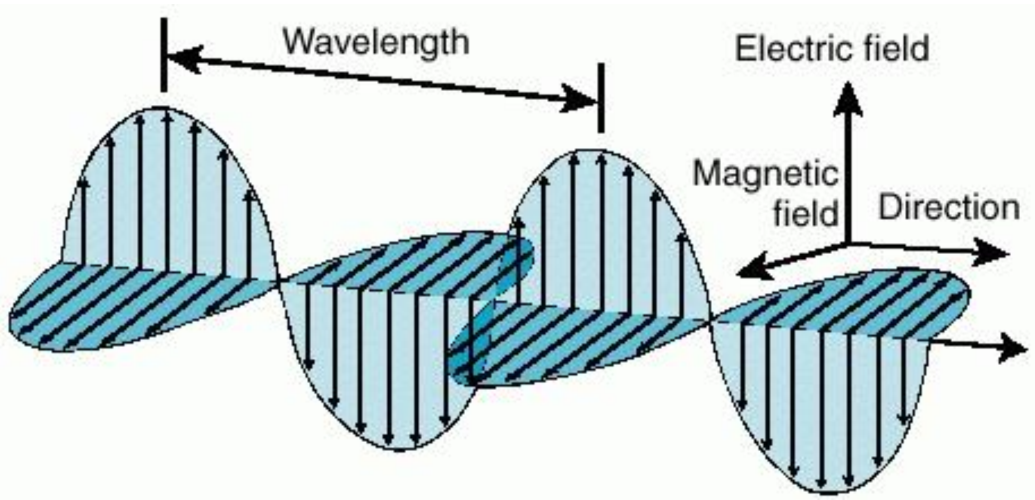
Electromagnetic (EM) Waves

- Transverse waves
- Consist of Electric and Magnetic components:
  - In phase with each other; and
  - At right angles to each other.
- Orientation of Electric field determines Polarization.



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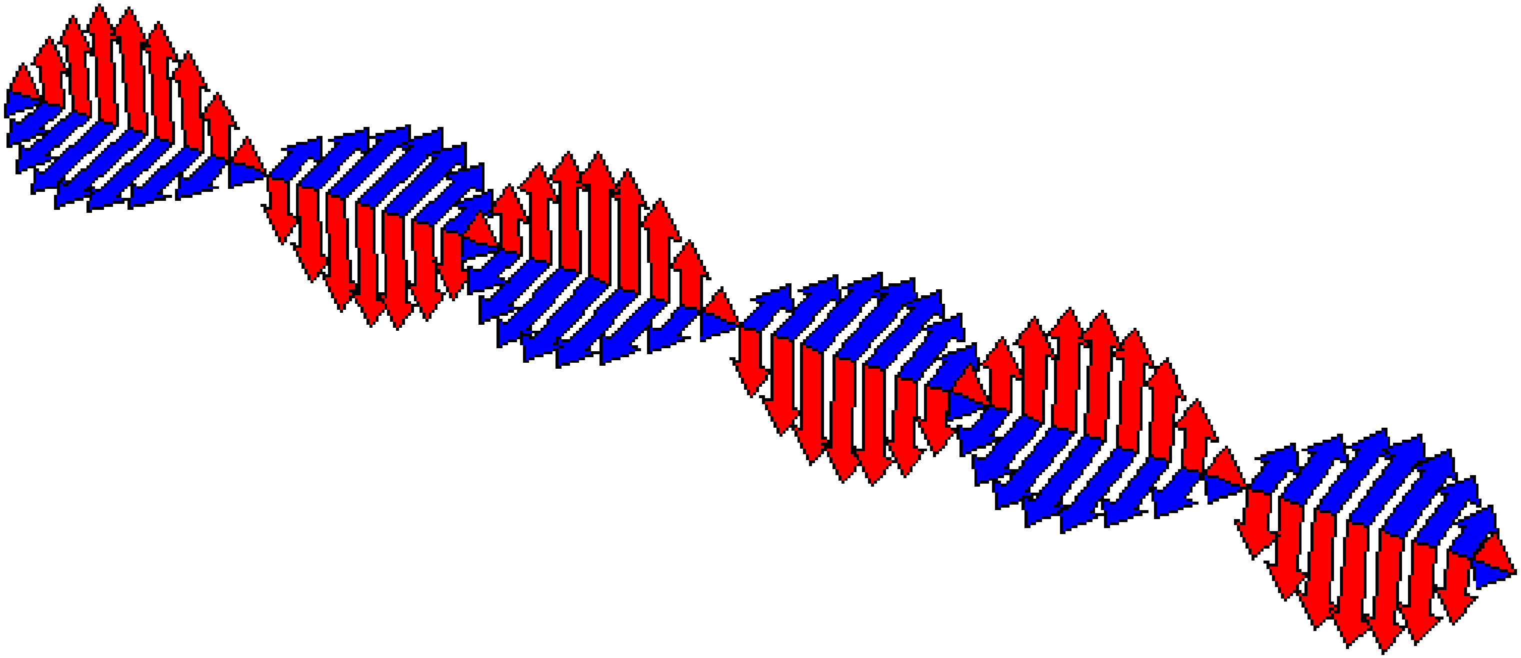

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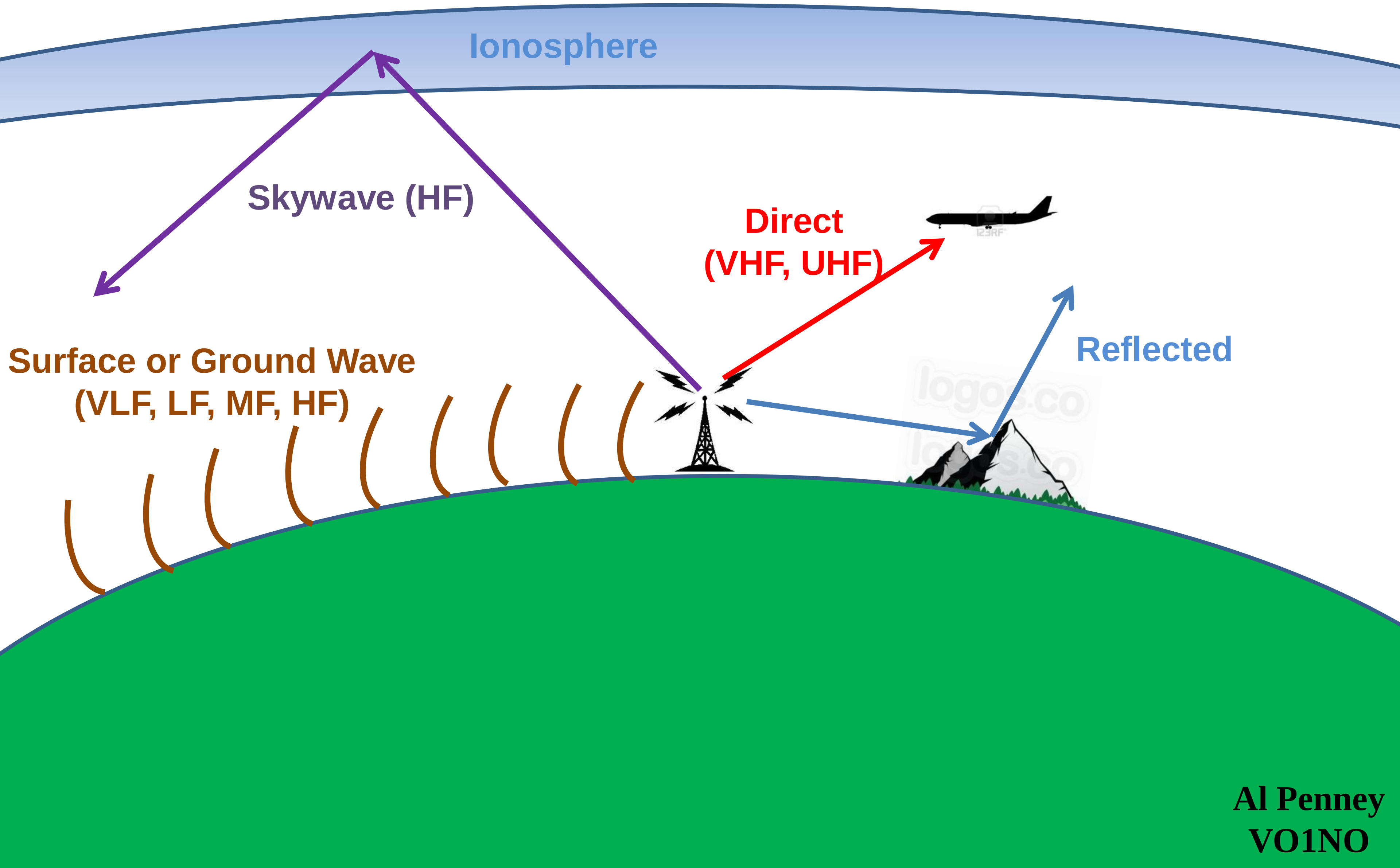
Classification of Waves



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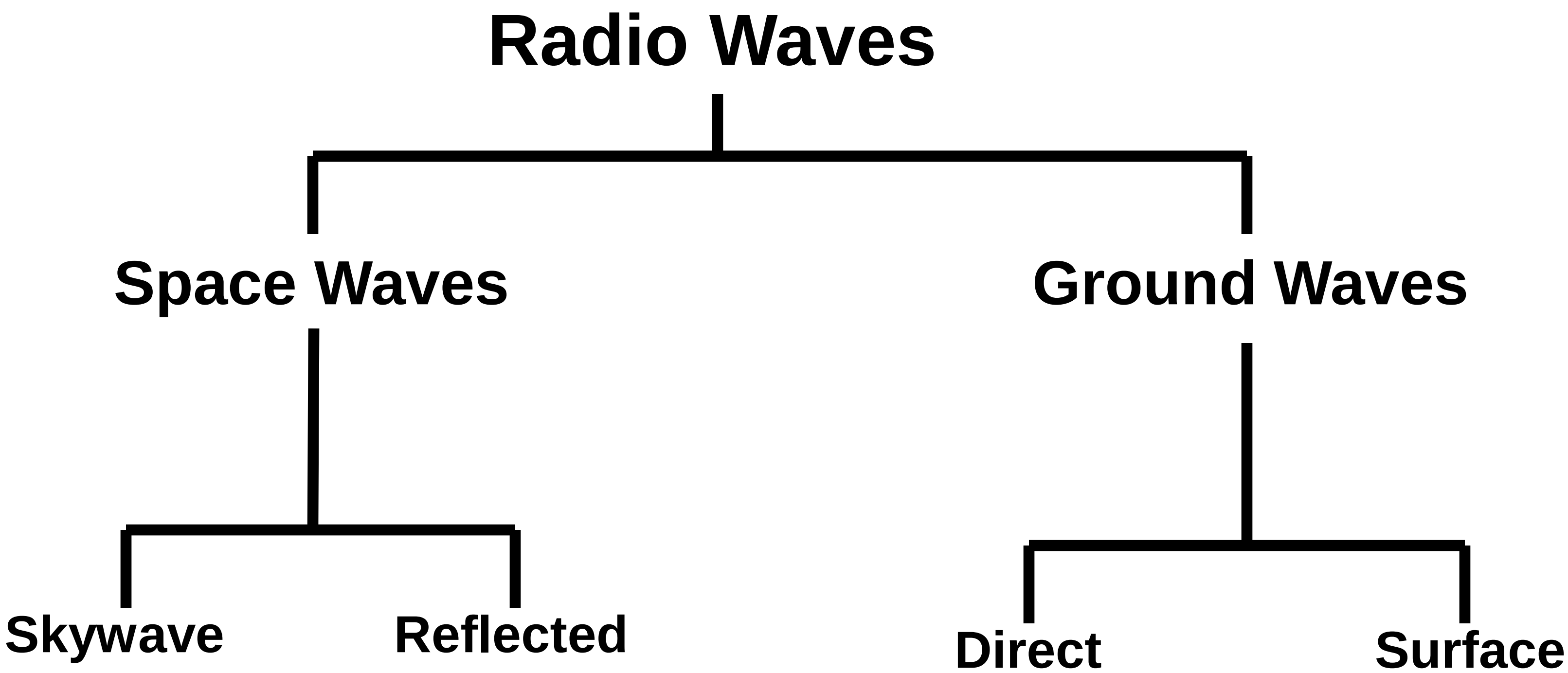
Classification of Waves



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Ionosphere

- 50 to 600 km above Earth's surface.
- Atmosphere very thin.
- Ultraviolet (UV) light, X-rays and cosmic radiation from Sun ionize molecules and atoms, a process called **Ionization**.
- Ionized particles concentrate into 4 distinct layers – **D, E, F1 and F2**.
- Layers change density and height due to **Recombination**.

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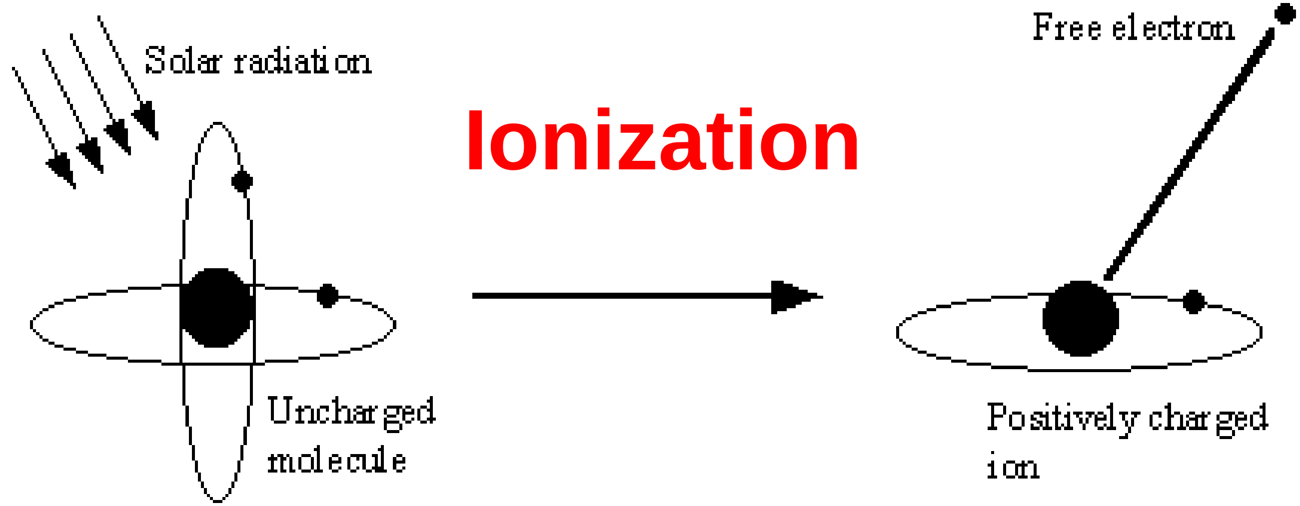
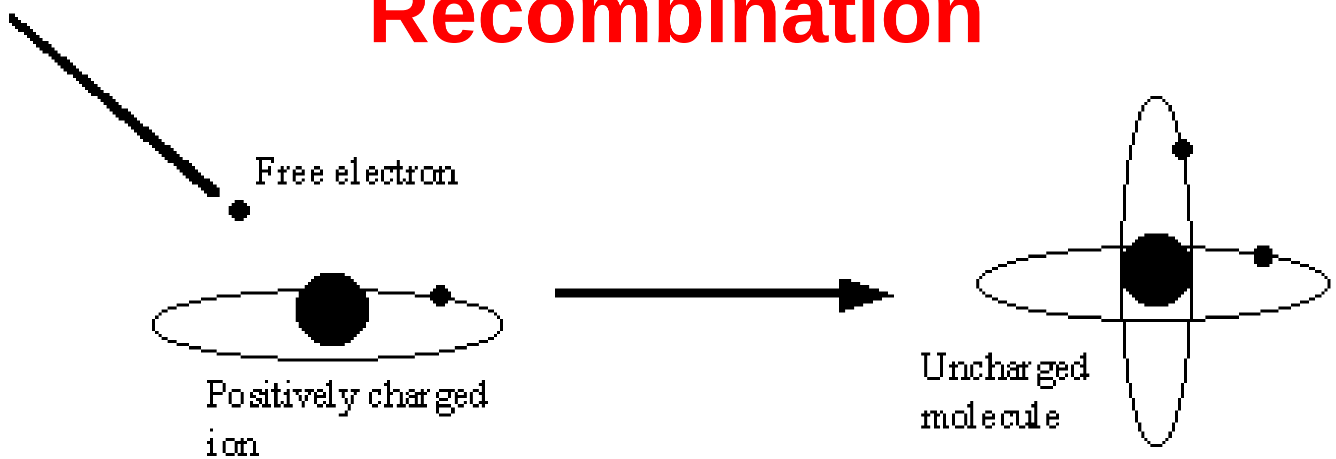
Ionization



Recombination



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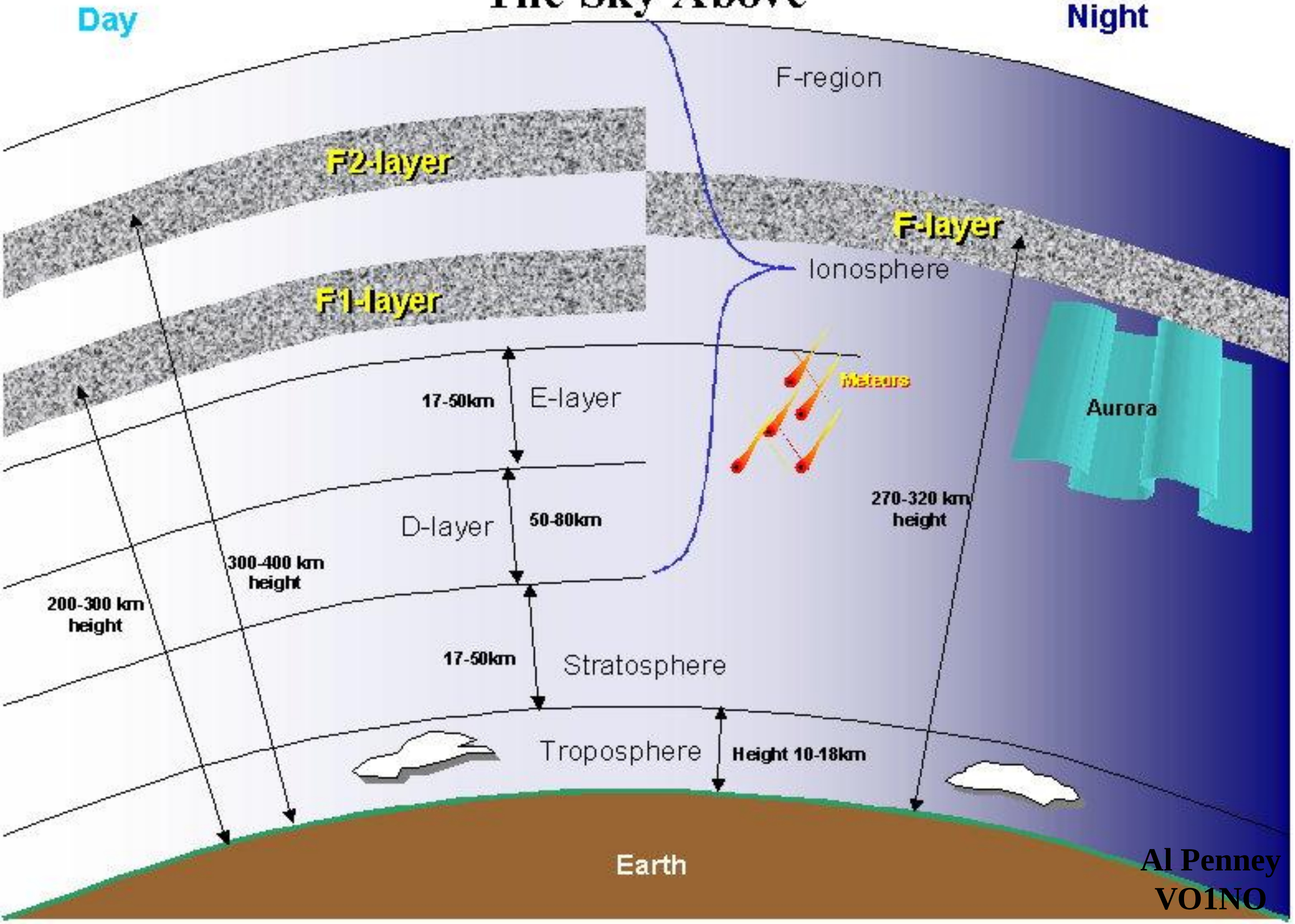
The Sky Above



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D Layer

- Innermost layer.
- Approximately 50 – 80km altitude.
- **Dense** in daylight, **disappears** at night.
- Not useful for long-distance propagation.
- **Absorbs signals** below approximately 10 MHz.

E Layer

- First to be discovered.
- Approximately 90 to 120 km altitude.
- Almost disappears at night.
- Usually does not play a part in long distance propagation.
- **Sporadic E** can reflect signals on 6M and 2M however.

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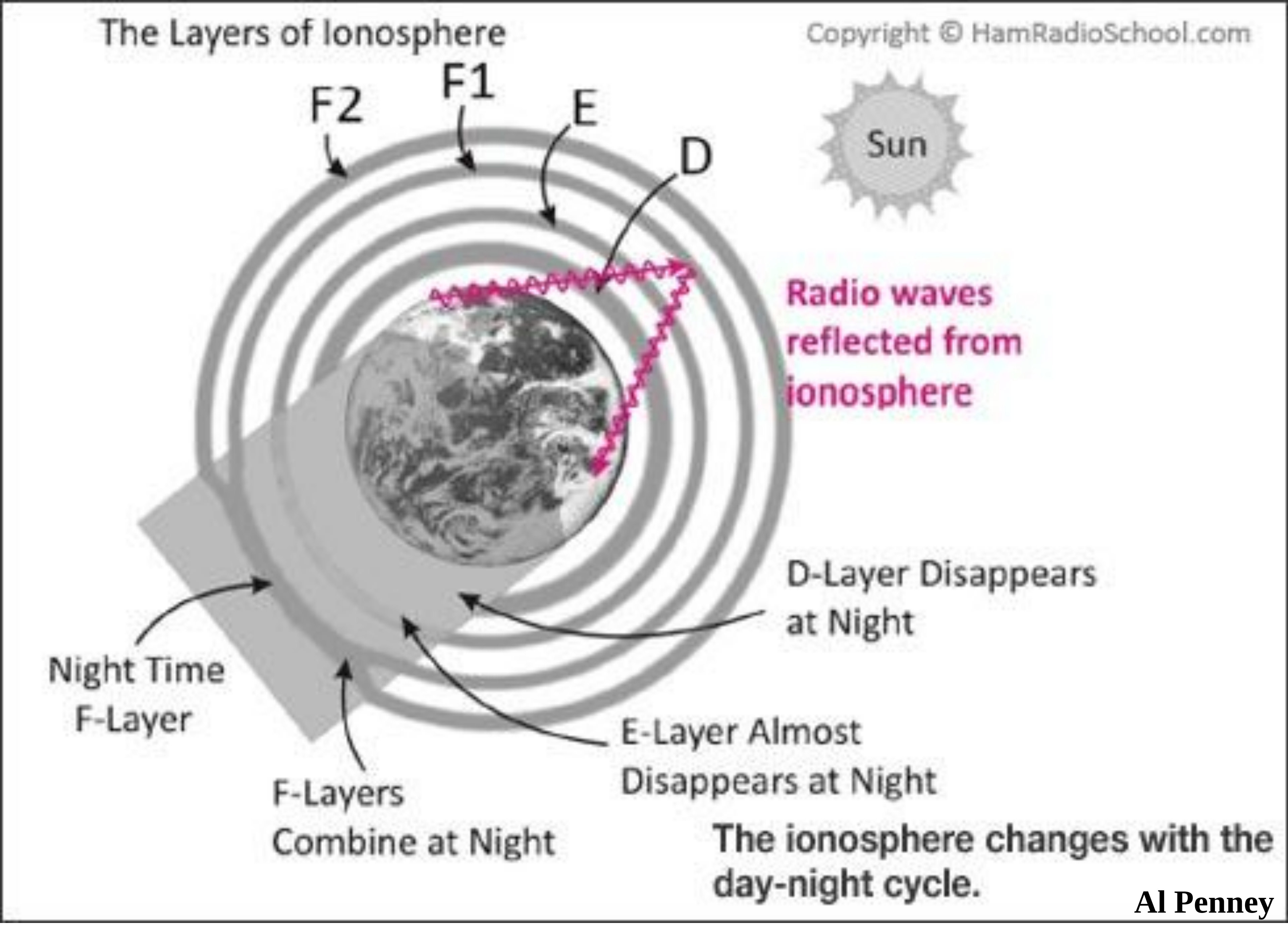
F Layer

- **Highest layer**.
- Approximately 150 to 600 km altitude.
- Responsible for most **long-distance** propagation on HF.
- Often 1 layer at night, breaking into 2 in daylight (**F1 and F2**).



The ionosphere changes with the day-night cycle.

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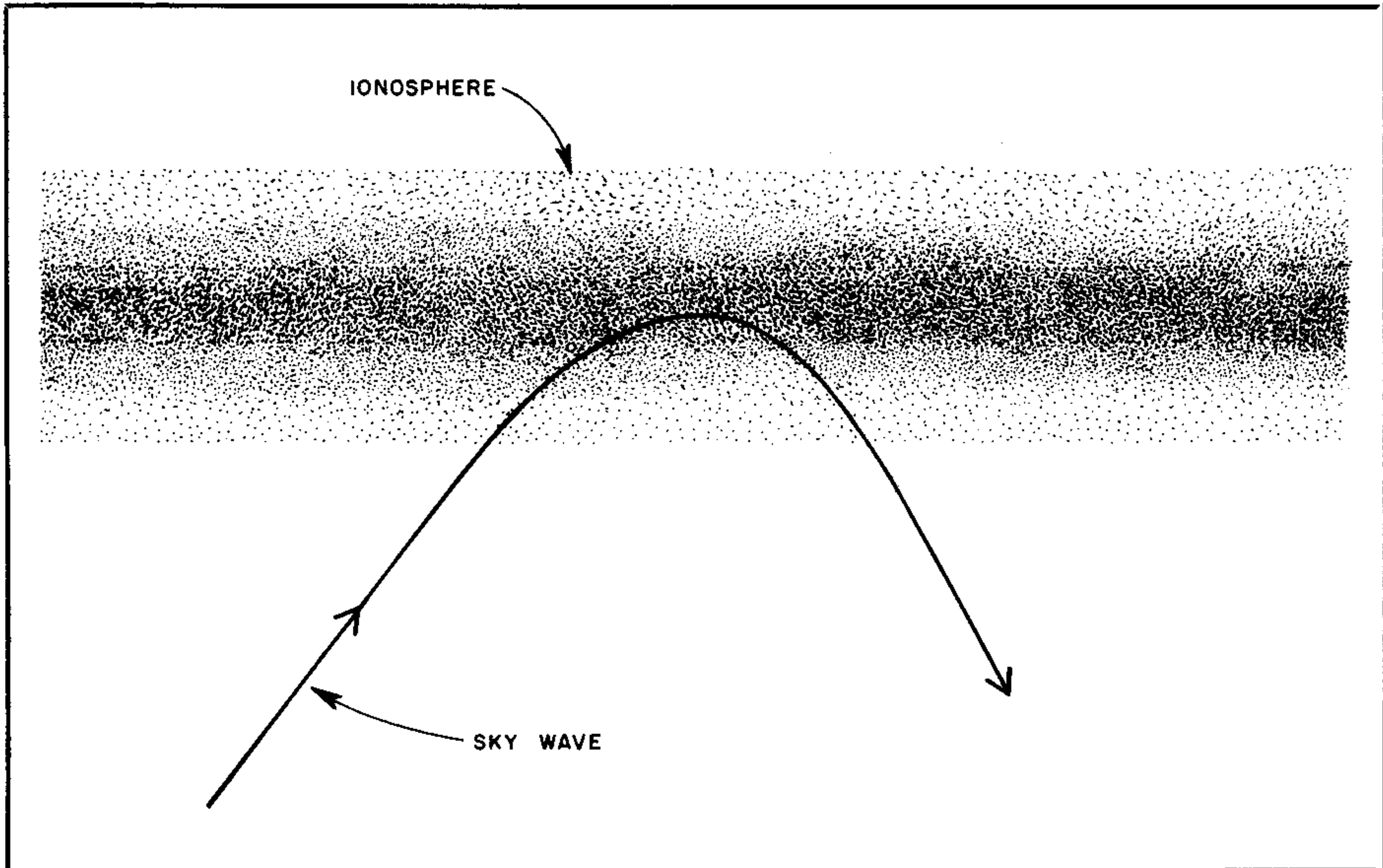

Fig. 2 — Under proper conditions, a radio wave entering the ionosphere will be refracted and follow a new course. This permits the signal to be heard on earth, perhaps thousands of miles from the transmitting antenna.

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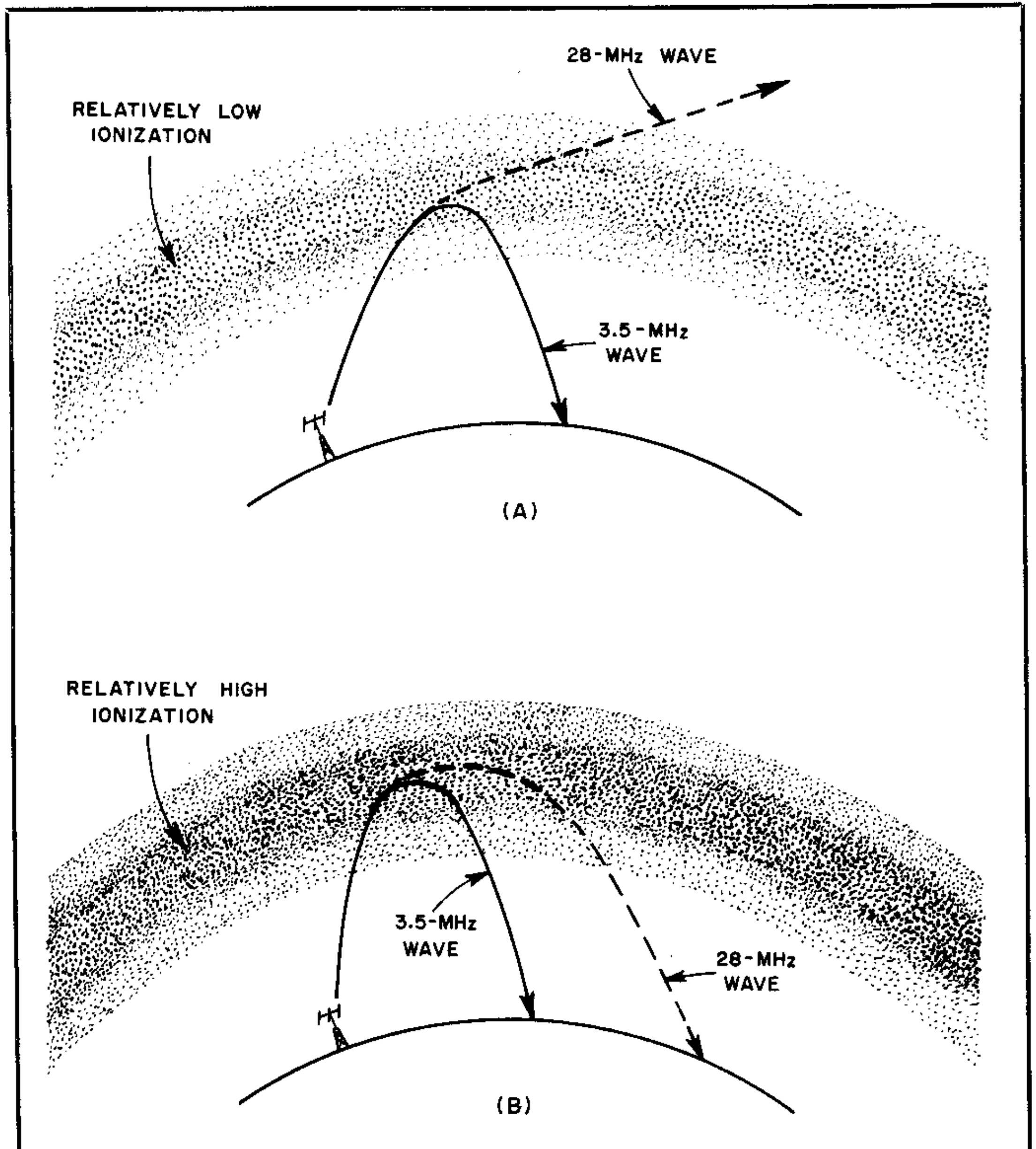

Fig. 5 — In A, the low-level ionization is insufficient to bend the 28-MHz wave back to earth; the level is high enough for 3.5-MHz propagation. Higher-level ionization in B is sufficient to refract the 28-MHz wave to earth.

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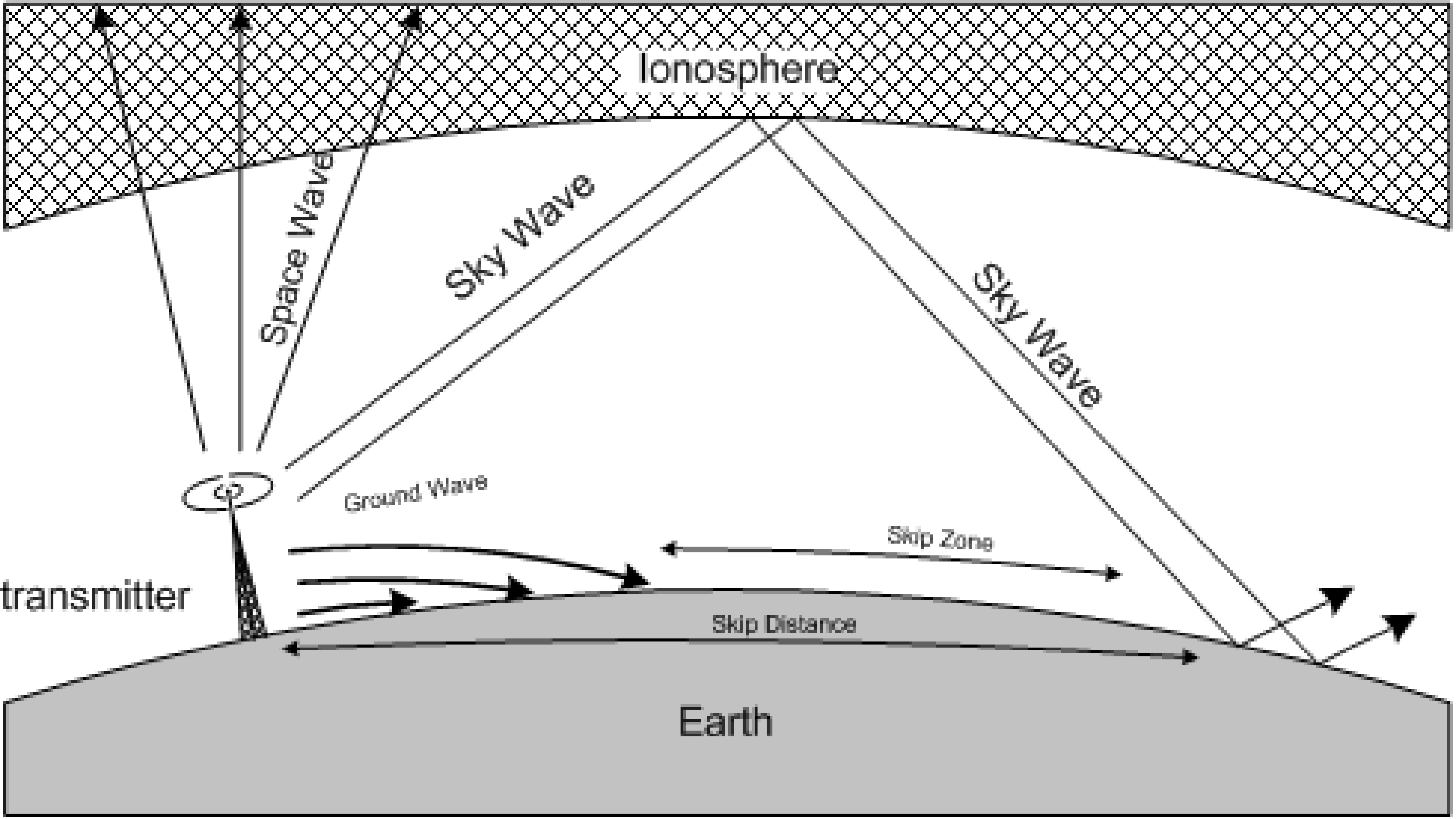

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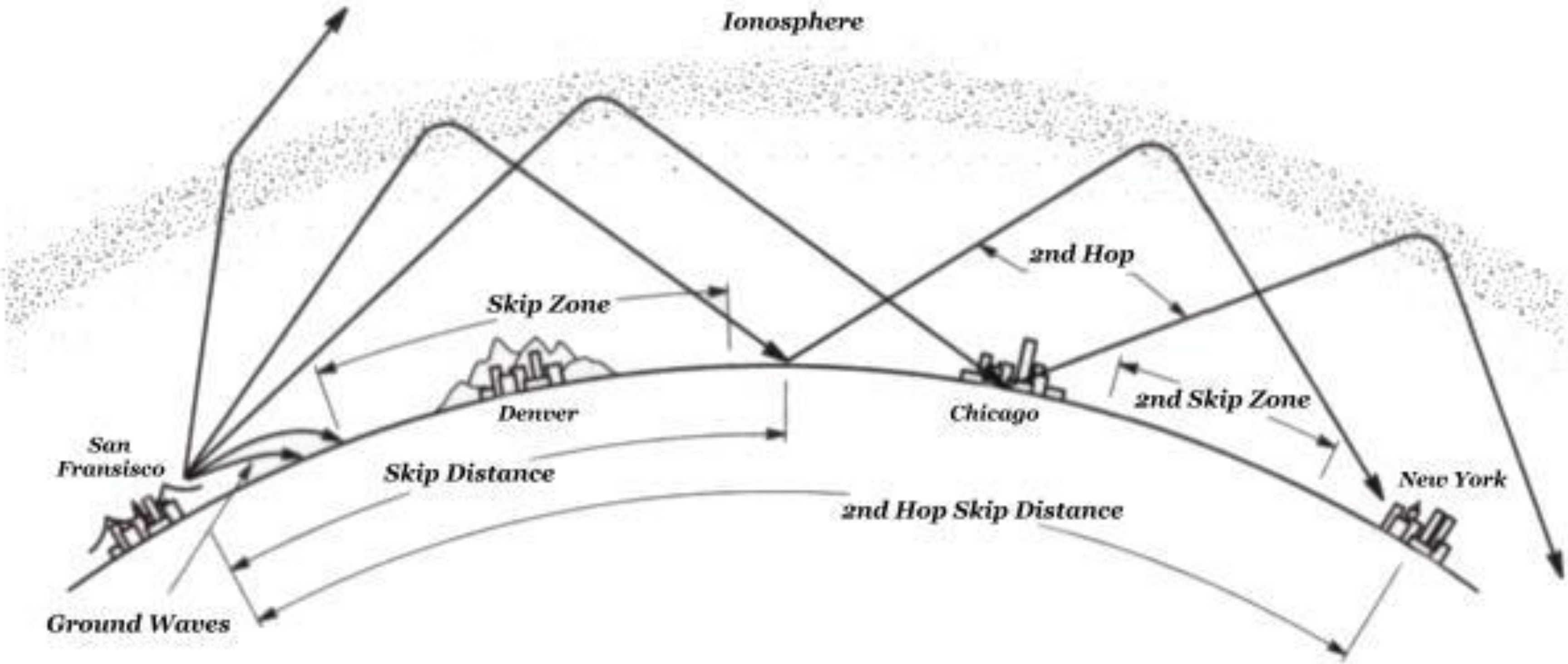

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Skip Zone and Skip Distance

- **Skip Zone** – The **area** between the furthest reach of the Ground Wave and the point where the Sky Wave is first refracted back to Earth. **No signal** is heard in the Skip Zone.
- **Skip Distance** – The **minimum distance** reached by a signal **after refraction** or reflection by the Ionosphere.

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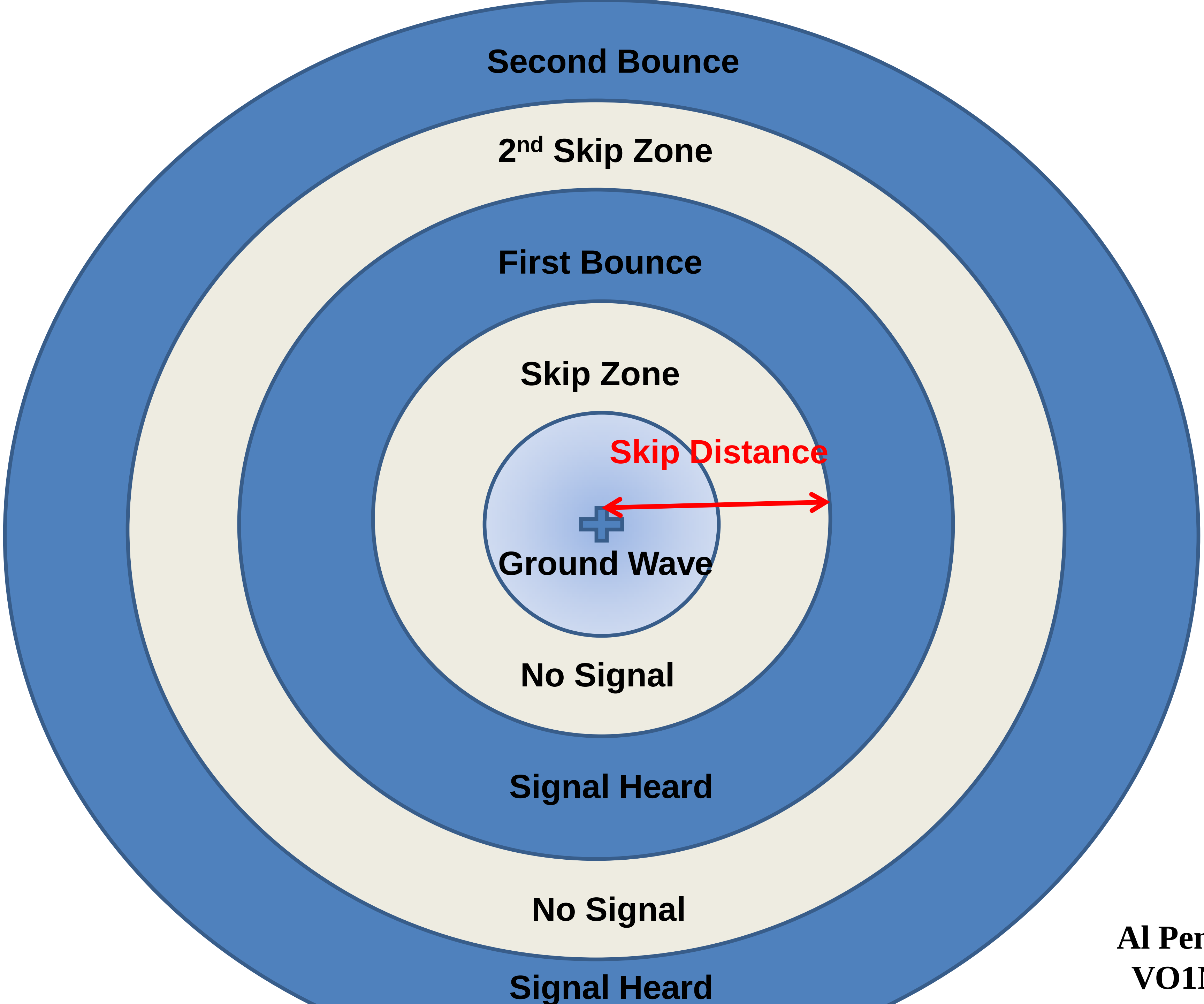

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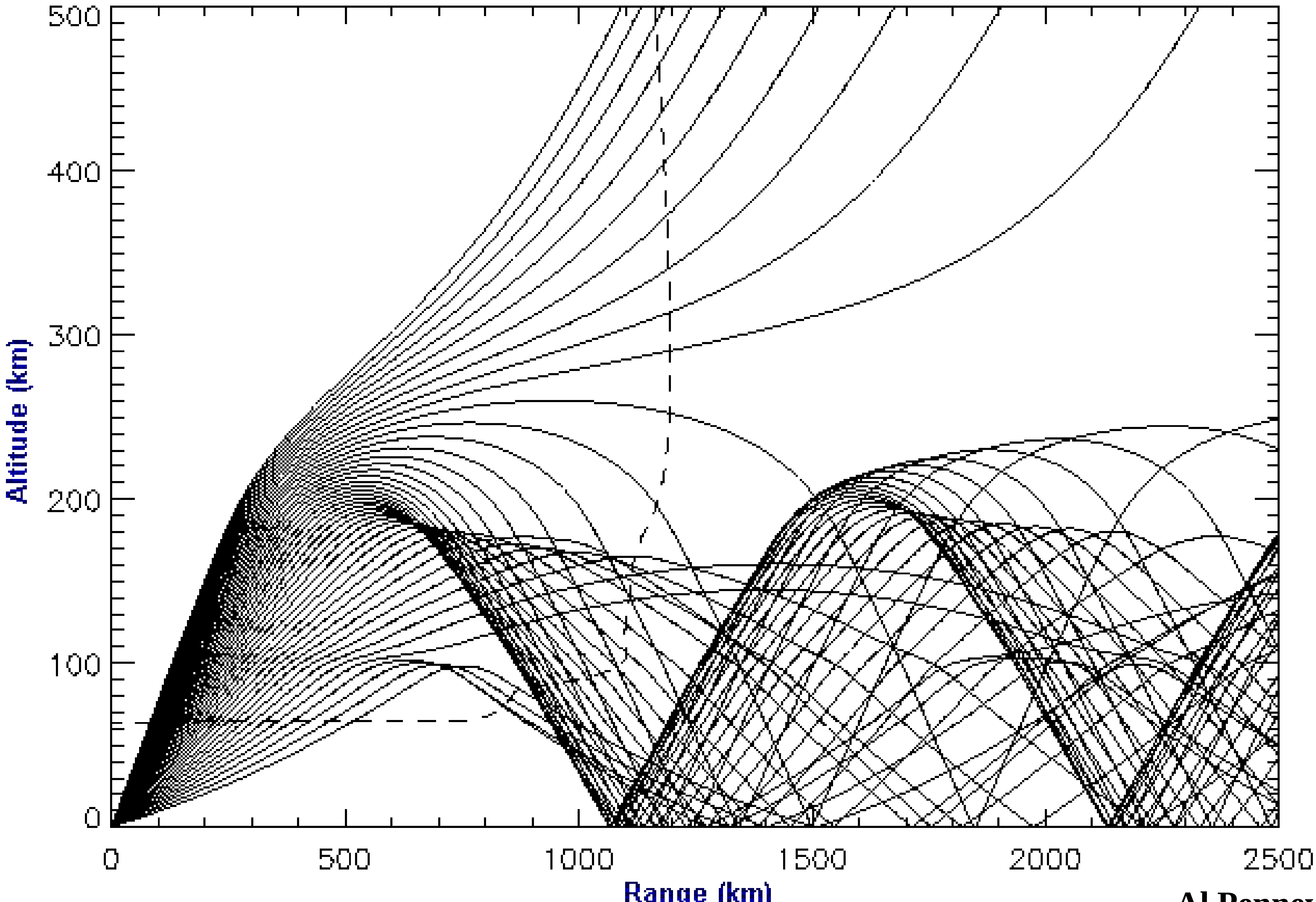

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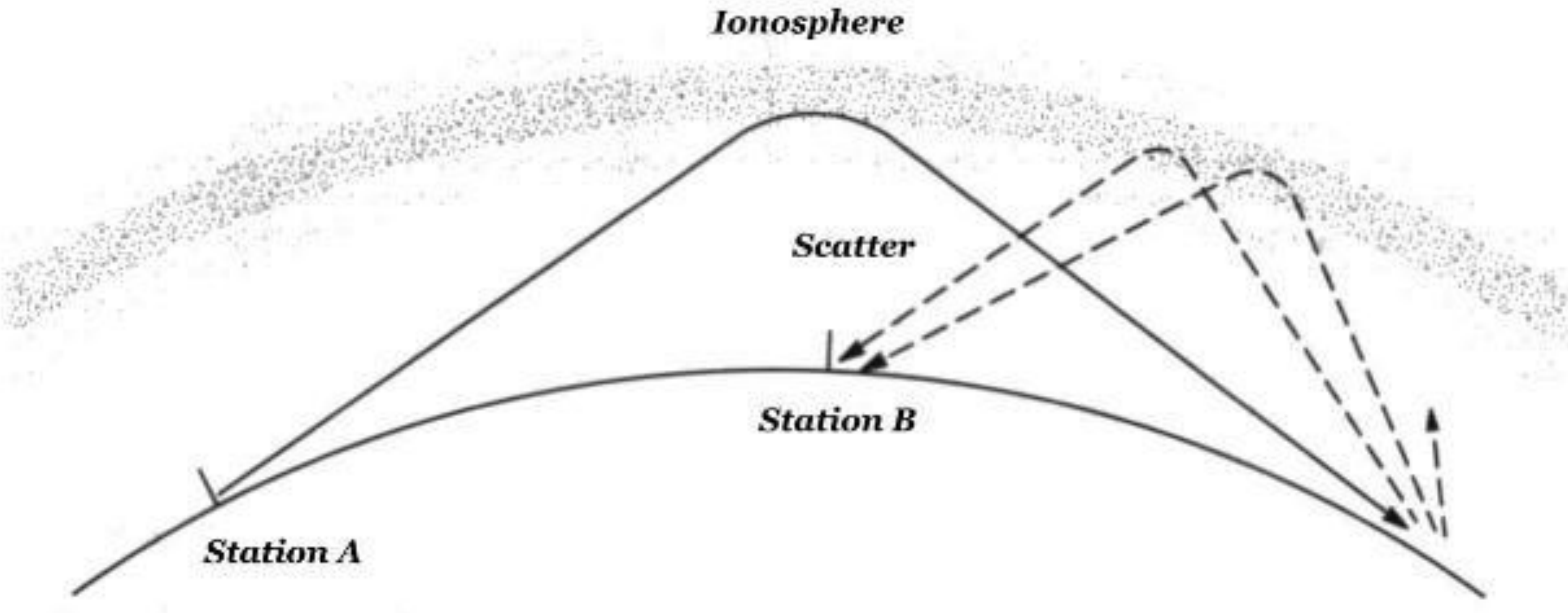

Backscatter

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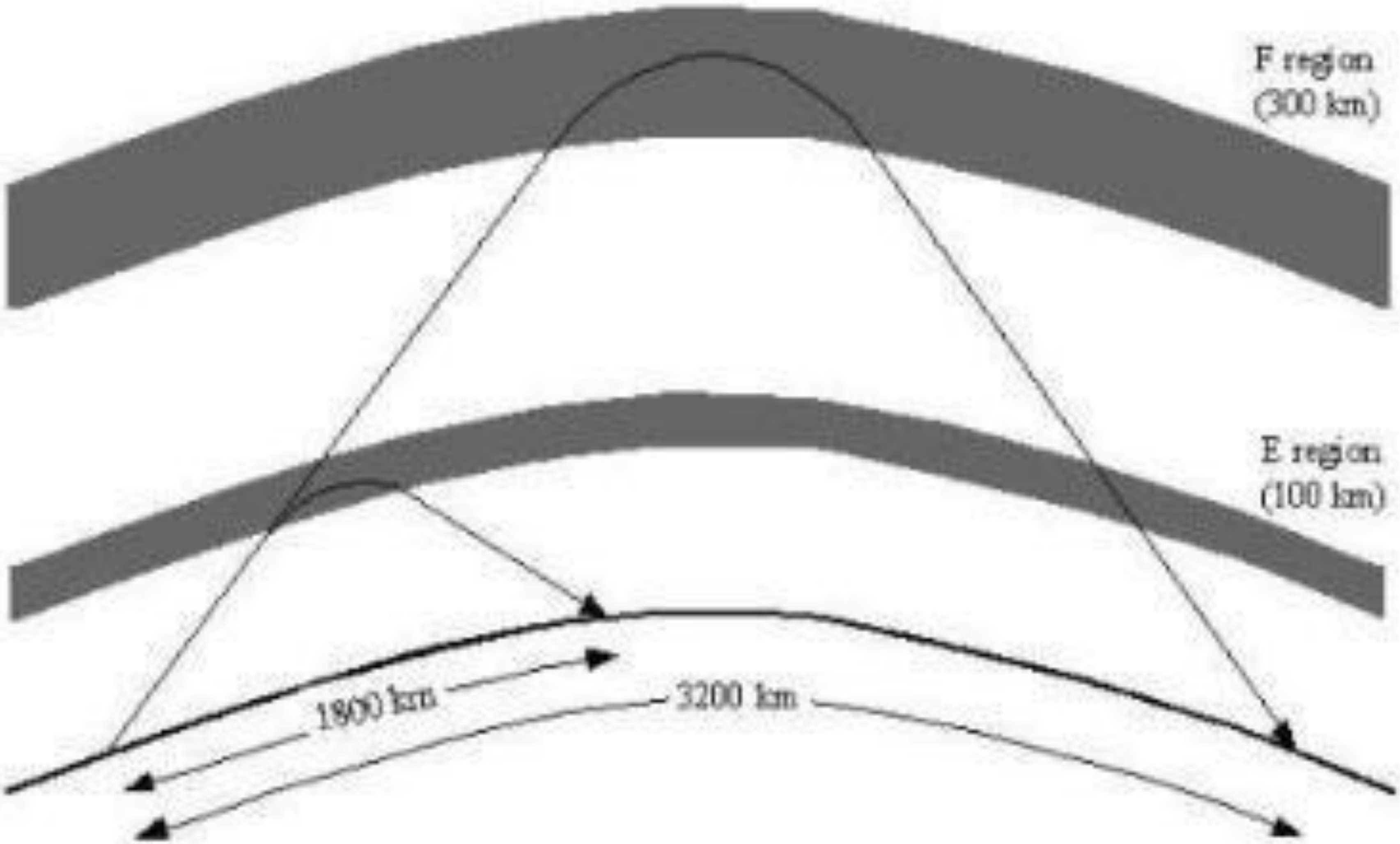

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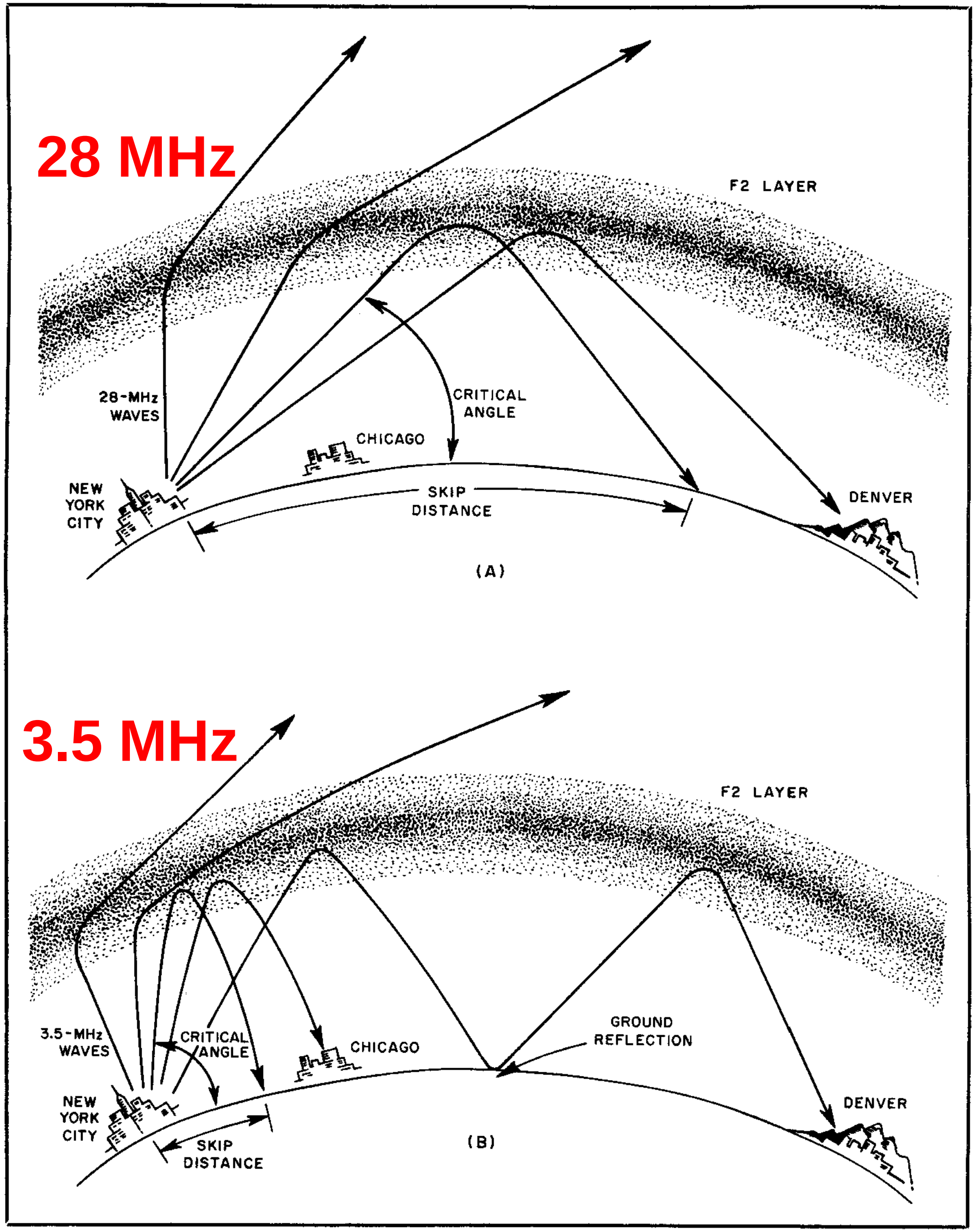

Fig. 6 — Illustration of how frequency, critical angle and skip distance are related. See text for explanation.

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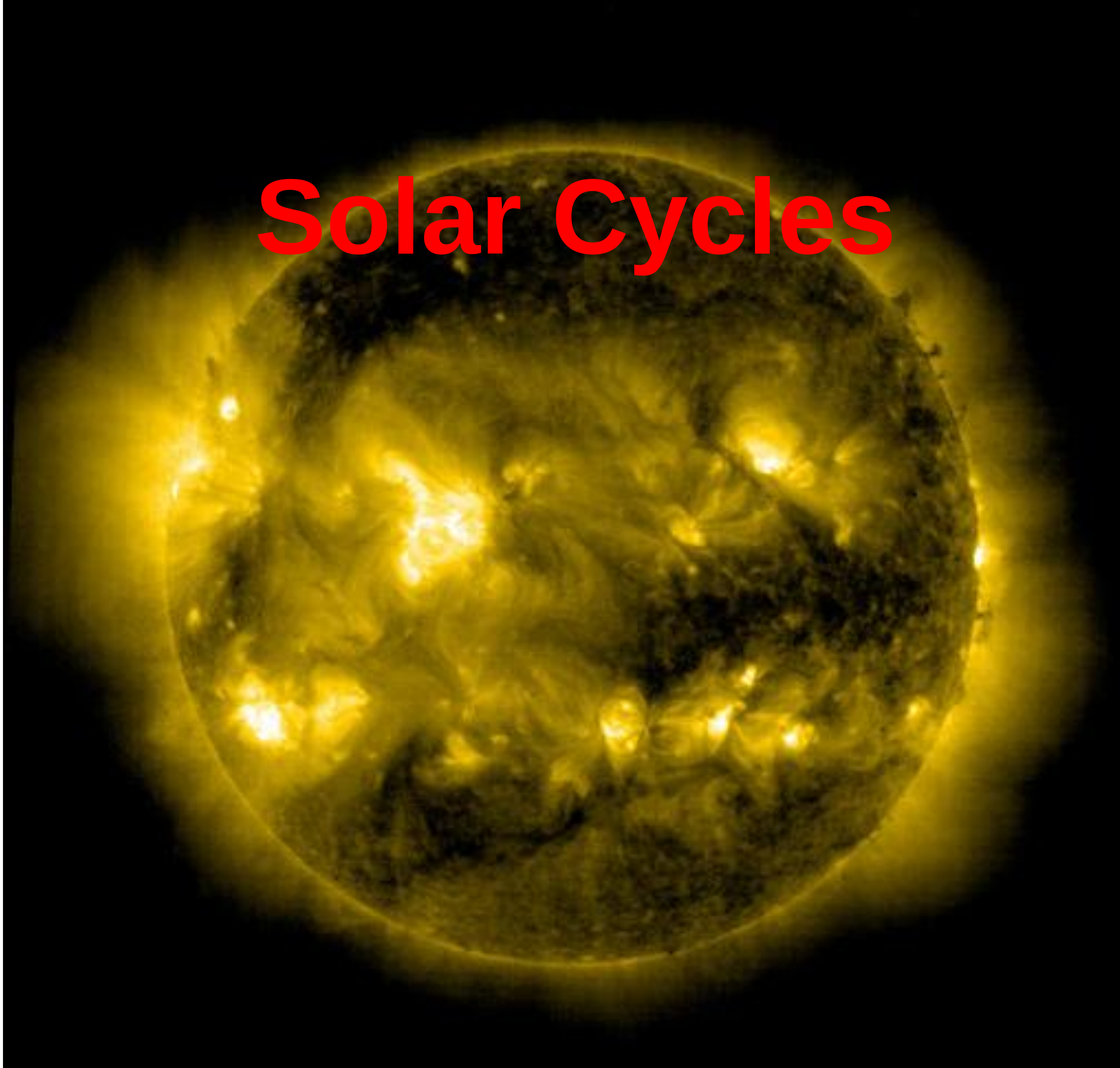
Solar Cycles



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Solar Cycle

- Periodic change in Sun’s activity and appearance.
- Includes:
  - Number of **sunspots**;
  - Level of solar radiation; and
  - Ejection of solar material.
- **22/11 year cycle**.

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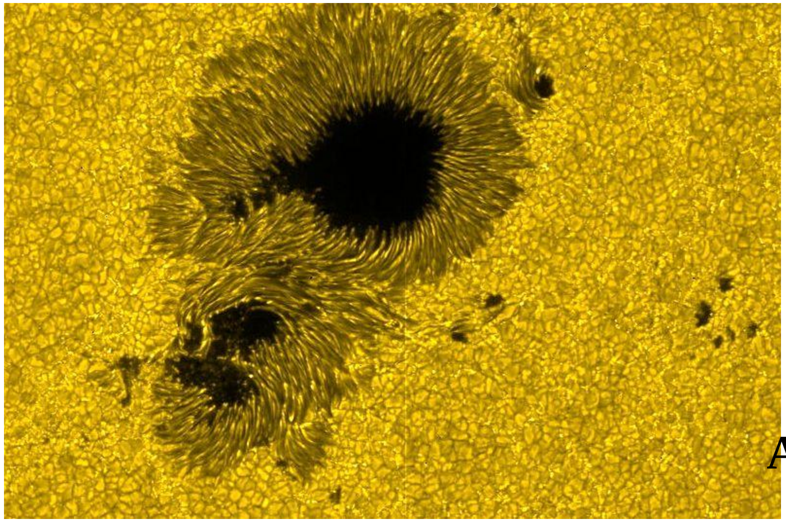
Sunspots

- **Dark spots** on the Sun's surface.
- Caused by intense magnetic activity that inhibits convection flow of Sun's interior.
- They host secondary phenomena such as **Solar Flares** and **Coronal Mass Ejections**.



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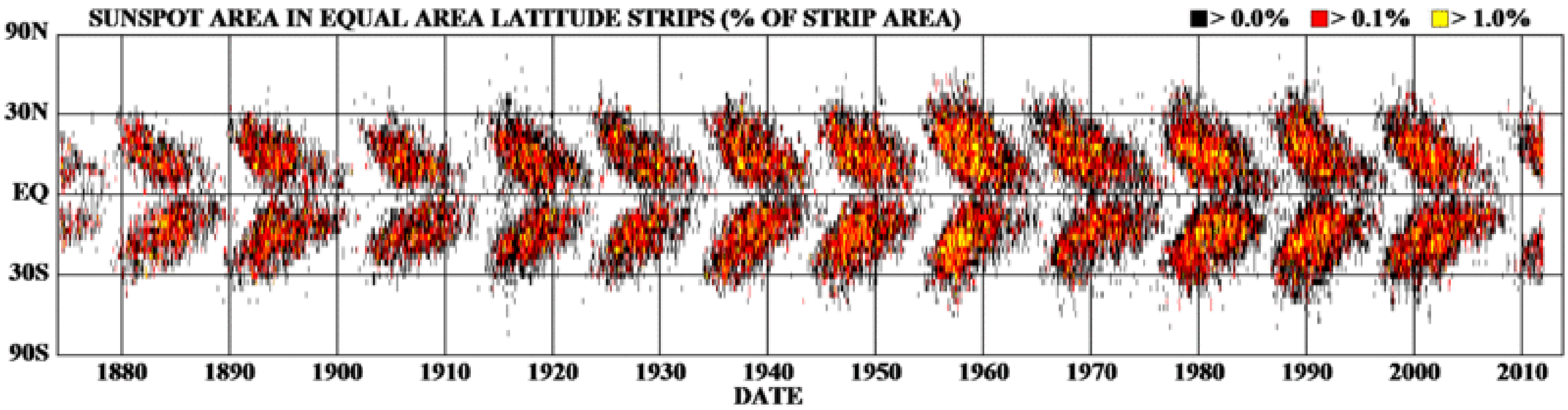

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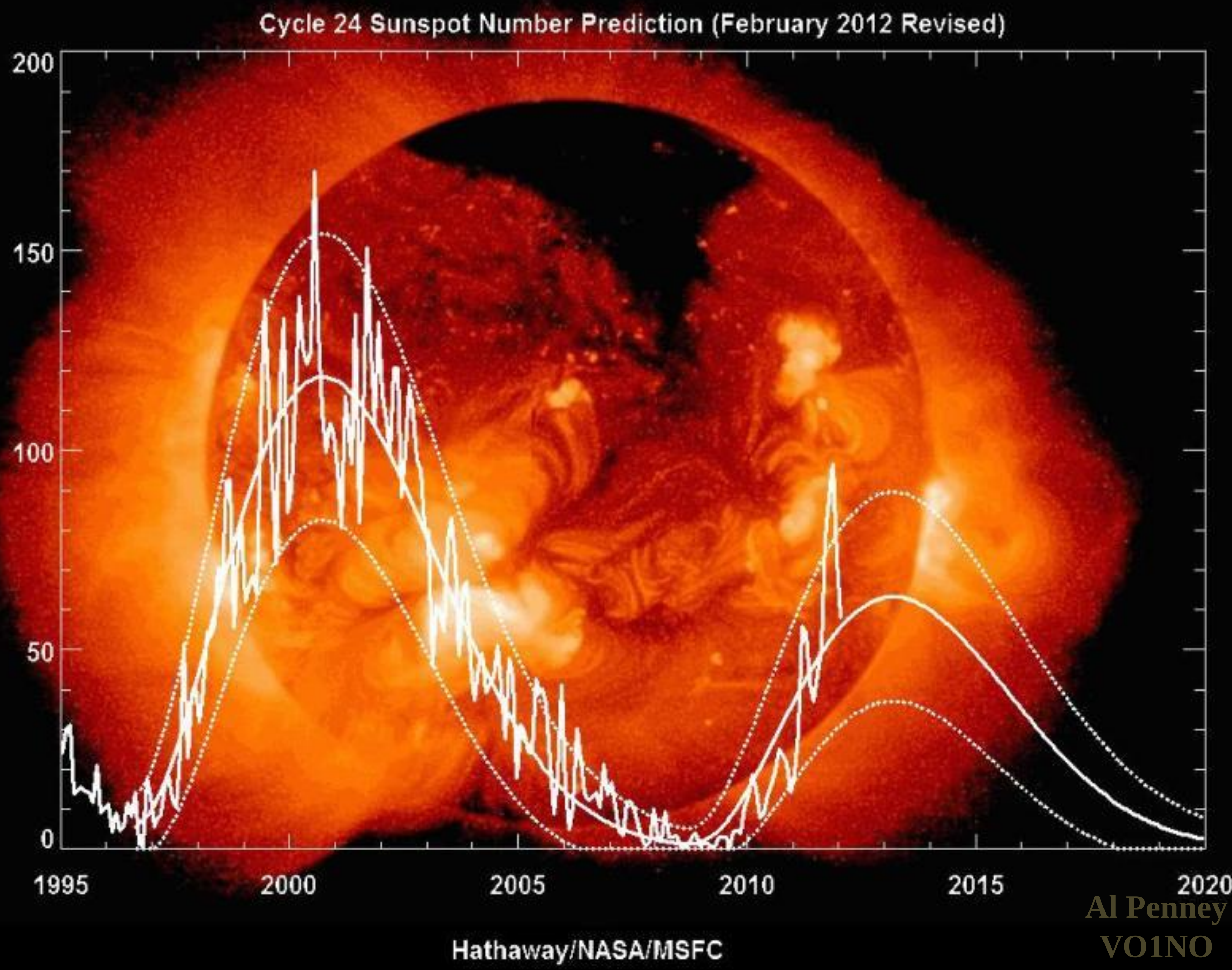

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Effect on Propagation

- **Low solar activity = less ionization**;
  – Higher frequencies pass through ionosphere into space.
- **High solar activity = more ionization**;
  – Higher frequencies refracted back to earth, and at greater distances.

Propagation – 160M

- 1.8 to 2.0 MHz
- Only Amateur band in MF region.
- Generally noisy, especially in summer.
- Daytime:
  - D layer absorption
  - local comms only, 100 km max.
- Nighttime:
  - Several thousand km possible
  - Greyline propagation

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Propagation – 80M

- 3.5 to 4.0 MHz
- Very popular band.
- D layer absorption in daylight, max 400 km.
- Several thousand km possible at night.
- Many regional nets in early evening.

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Propagation – 40M

- 7.0 to 7.3 MHz
- Similar to 80M, but overall greater distances possible.
- Worldwide communications at night.

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Propagation – 30M

- 10.1 to 10.15 MHz
- CW and digital modes only.
- “WARC band”.
- 1500 km during day.
- Worldwide distances at night.
- Less static than 160, 80 and 40M.
- Look for WWV and WWVH on 10 MHz.

Propagation – 20M

- 14.0 to 14.35 MHz
- Most popular DX band!
- Worldwide communications.
- Open around the clock at solar max.
- Open in daytime at solar minimum.
- Look to east in morning, and west later in day.

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Propagation – 17M

- 18.068 to 18.168 MHz
- “WARC Band”.
- Good DX band.
- Generally similar to 20M.
- No contesting allowed.

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Propagation – 15M

- 21.0 to 21.45 MHz
- Popular DX band.
- Open round the clock at solar maximum.
- Daytime band as solar flux declines.
- Can be dead during solar minimum.
- Can get Sporadic E in summer and December.

Propagation – 12M

- 24.89 to 24.99 MHz
- “WARC Band”.
- Excellent DX band at solar maximum.
- Similar to 15M and 10M.
- No contesting allowed.

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Propagation – 10M

- 28.0 to 29.7 MHz
- Last Amateur band in HF region.
- Has HF and VHF characteristics.
- Outstanding DX possible anytime at solar max.
- Band often dead at solar minimum.
- Sporadic E possible in summer and December.
- Monitor beacons to find openings.

Critical Frequency

- The **highest frequency** that, if directed **vertically upward**, will be **refracted back** to Earth by an ionized layer.
- Also called the Penetrating Frequency.

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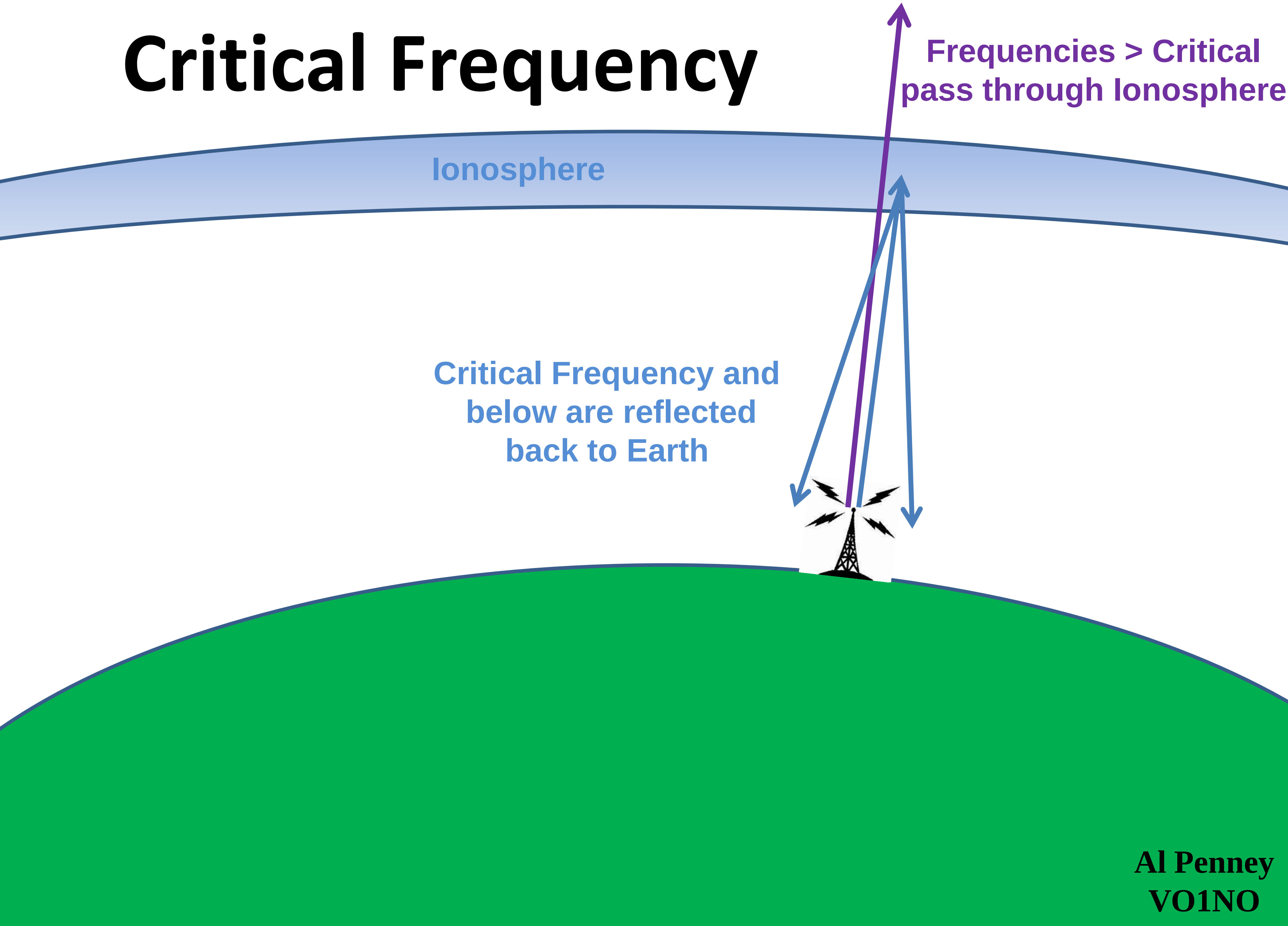
Critical Frequency



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Maximum Usable Frequency

- Known as **MUF**
- The **highest frequency** that will be **refracted back to Earth** by ionized layers over a specified path at a specified time.
- Above this frequency the signals land beyond the station, or travel into space.
- Depends on solar activity, time of day, time of year, and the location of the two stations.

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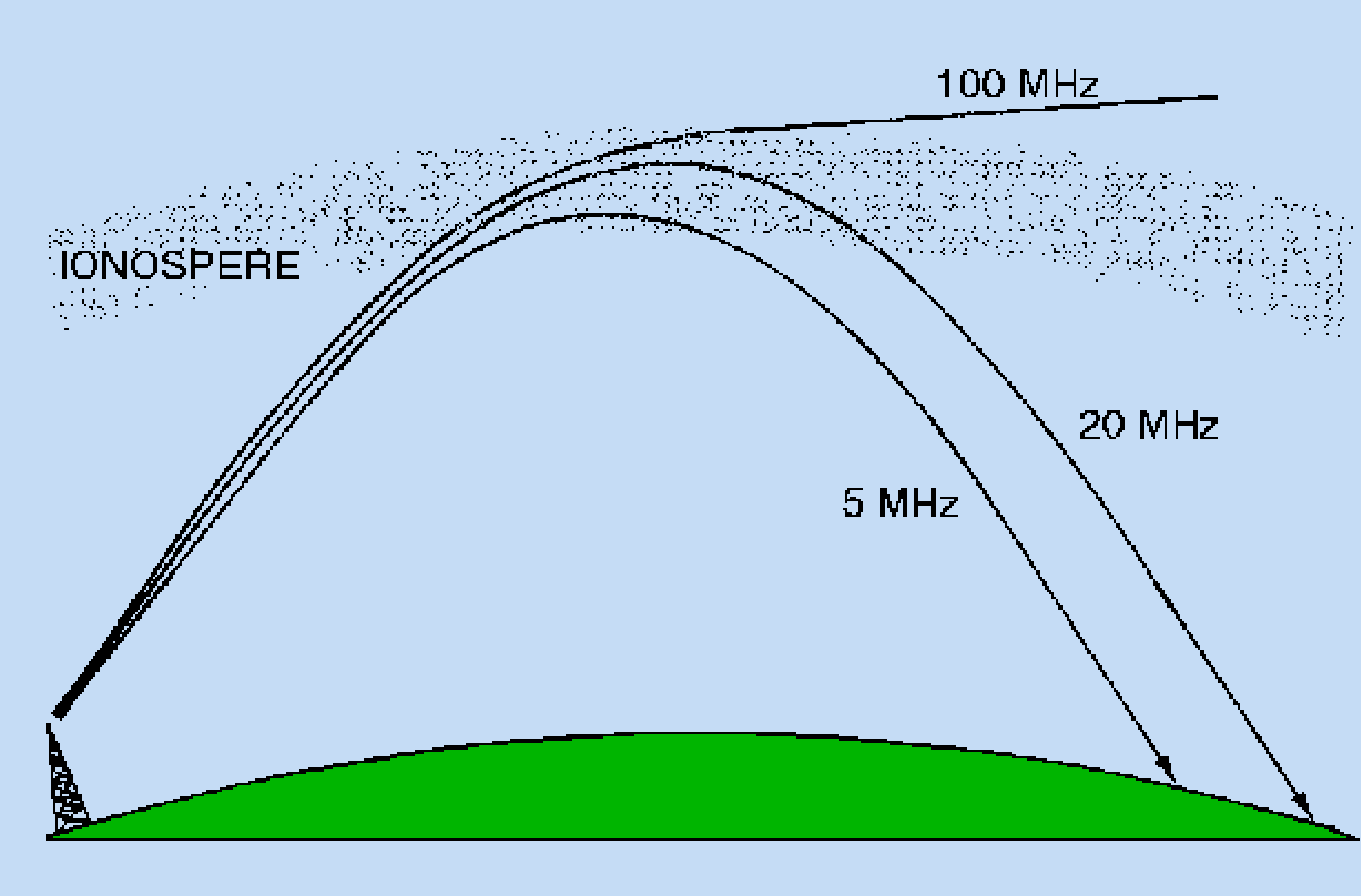

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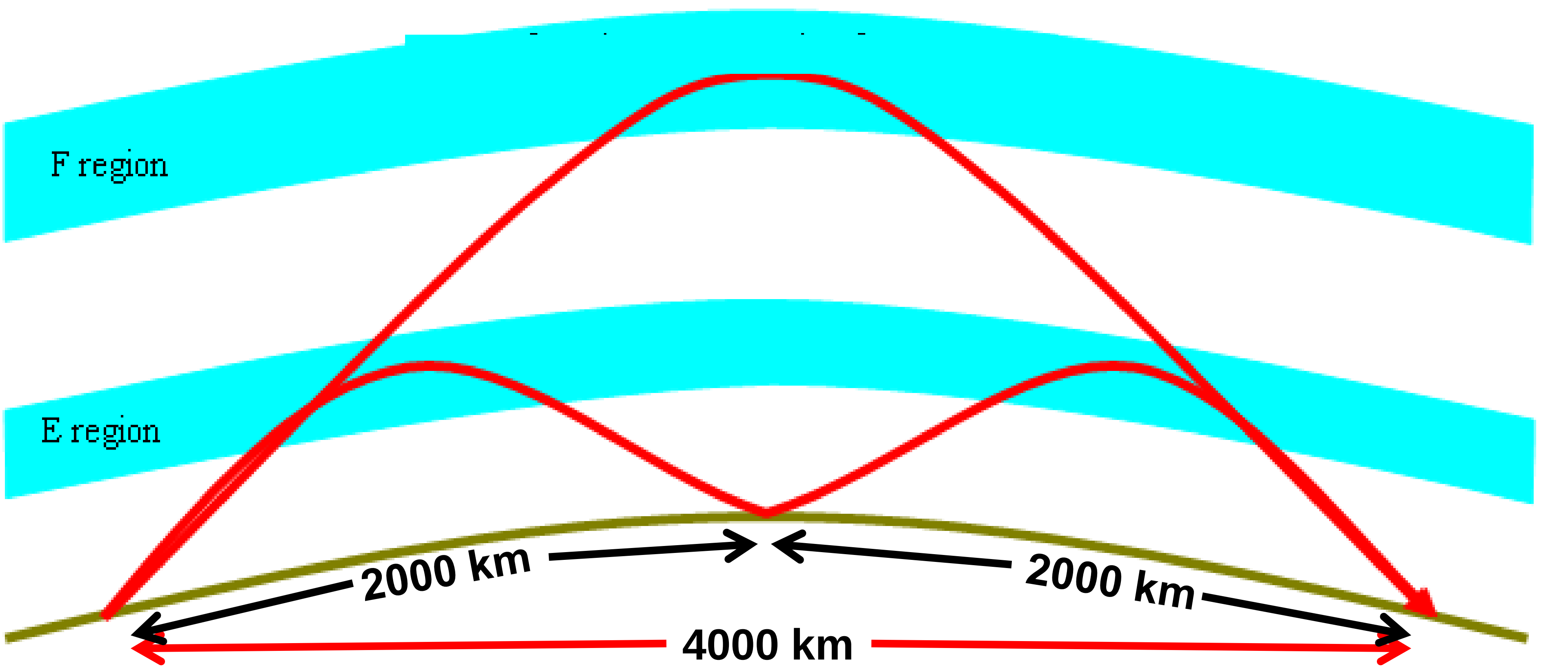

- For E layer distances of 2000km, MUF = 5 x Critical Frequency
- For F layer distances of 4000km, MUF = 3 x Critical Frequency

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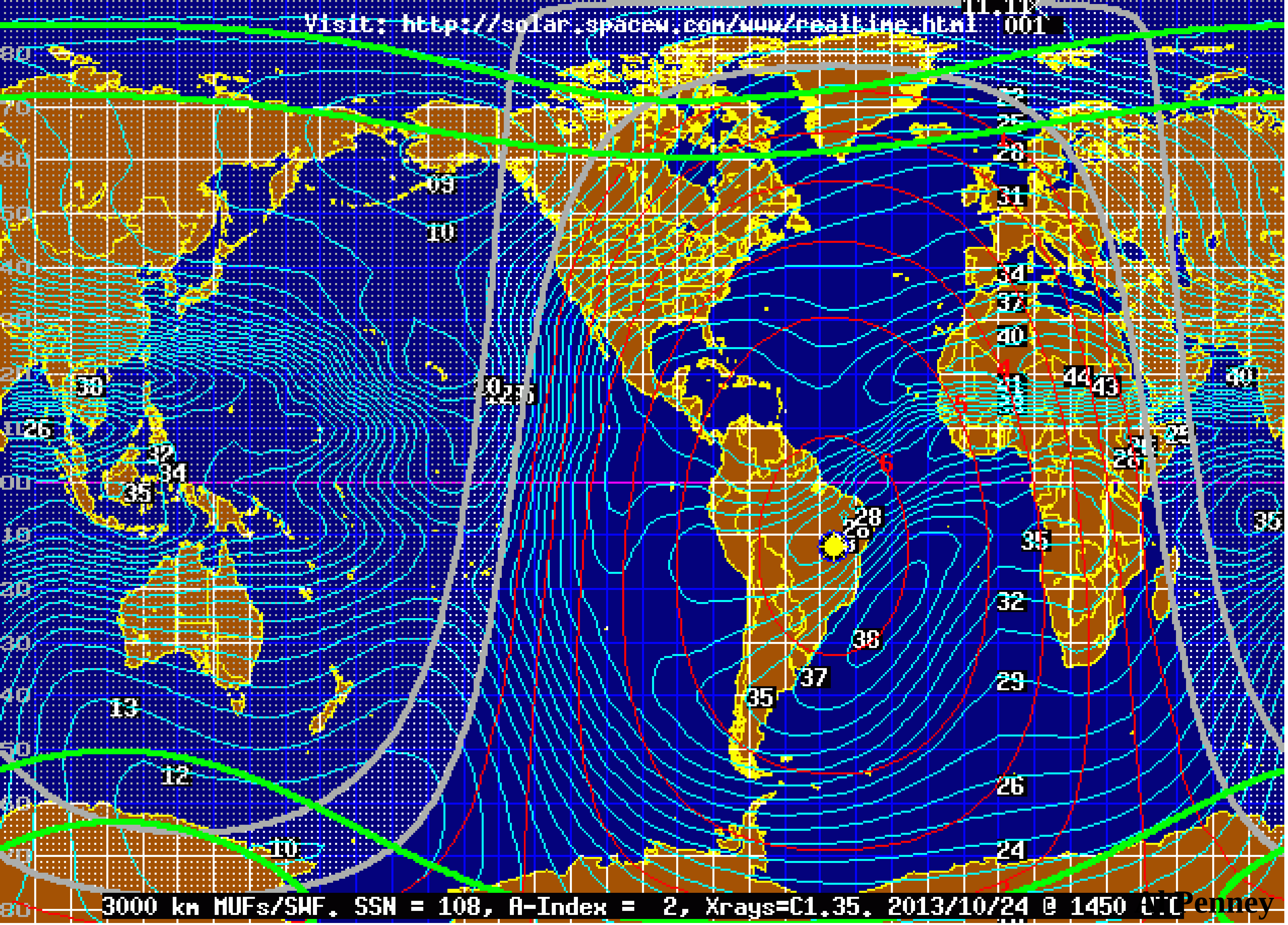

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Lowest Usable Frequency

- Known as **LUF**.
- The **lowest frequency** at which communications are possible over a given path at a specified time 90% of the undisturbed days of the month.
- The amount of energy absorbed by the **D layer** directly impacts the LUF.
- Based on signal to noise ratio, so exact frequency depends on mode, power, antenna gain etc.

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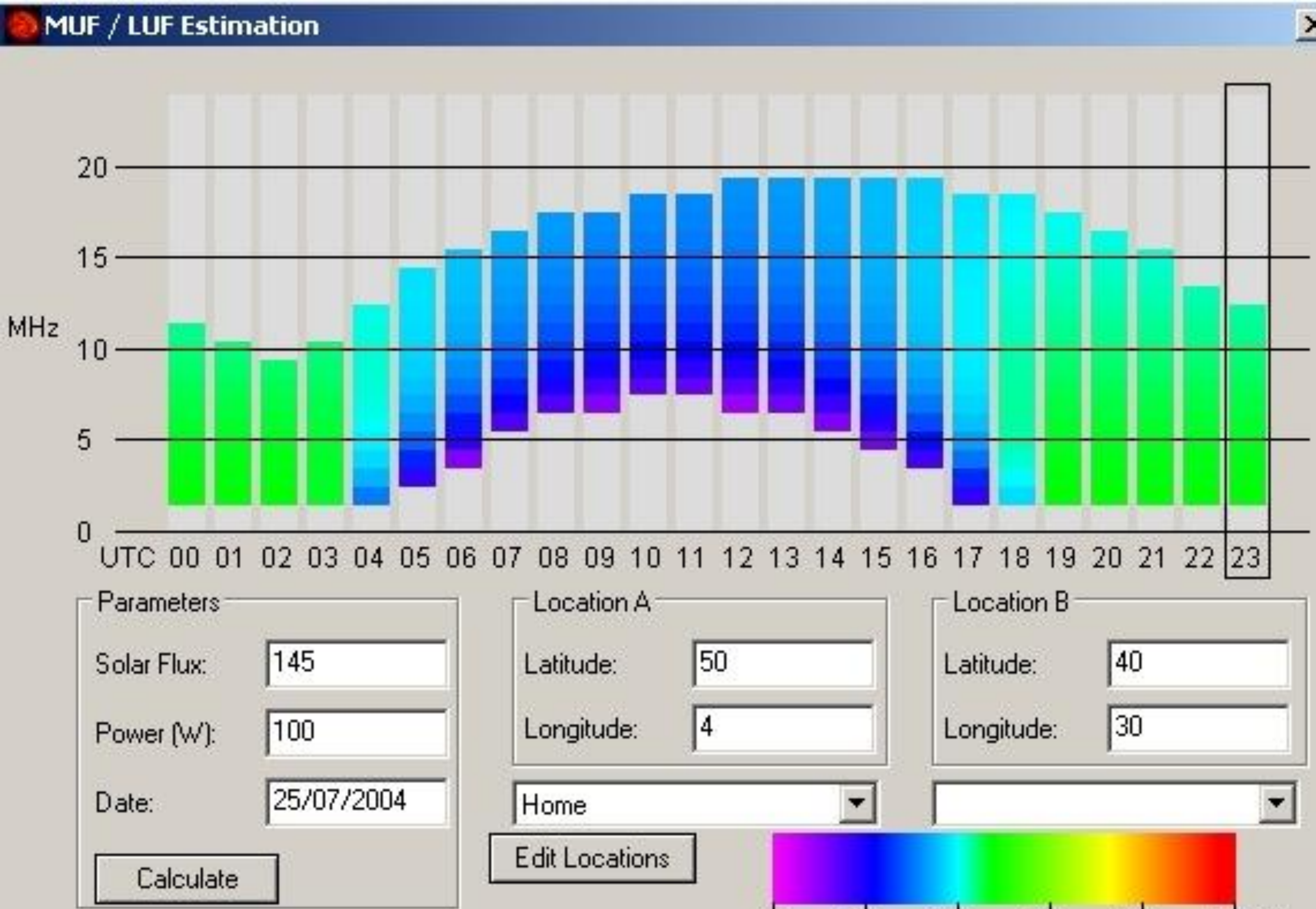

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Optimum Working Frequency

- A frequency approximately 15% less than the MUF that provides **usable communications** 90% of the time.
- Abbreviated FOT

Solar Flux

- A measure of **radio energy** emitted by the Sun.
- Considered to be one of the best ways to relate solar activity to propagation.
- Measured at 2800 MHZ (bandwith 100 MHz) at the Dominion Radio Astrophisical Observatory in Penticton, BC.
- At solar min, SF = 50 to 60
- At solar max, SF = 200 or more

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Fading

- Variations in received signal strength.
- Some reasons for these variations in signal strength:
  - Daily changes in ionosphere’s structure;
  - Variations in shape/density of the ionosphere;
  - Loss of signal due to multipath propagation; and
  - Ionospheric disturbances.

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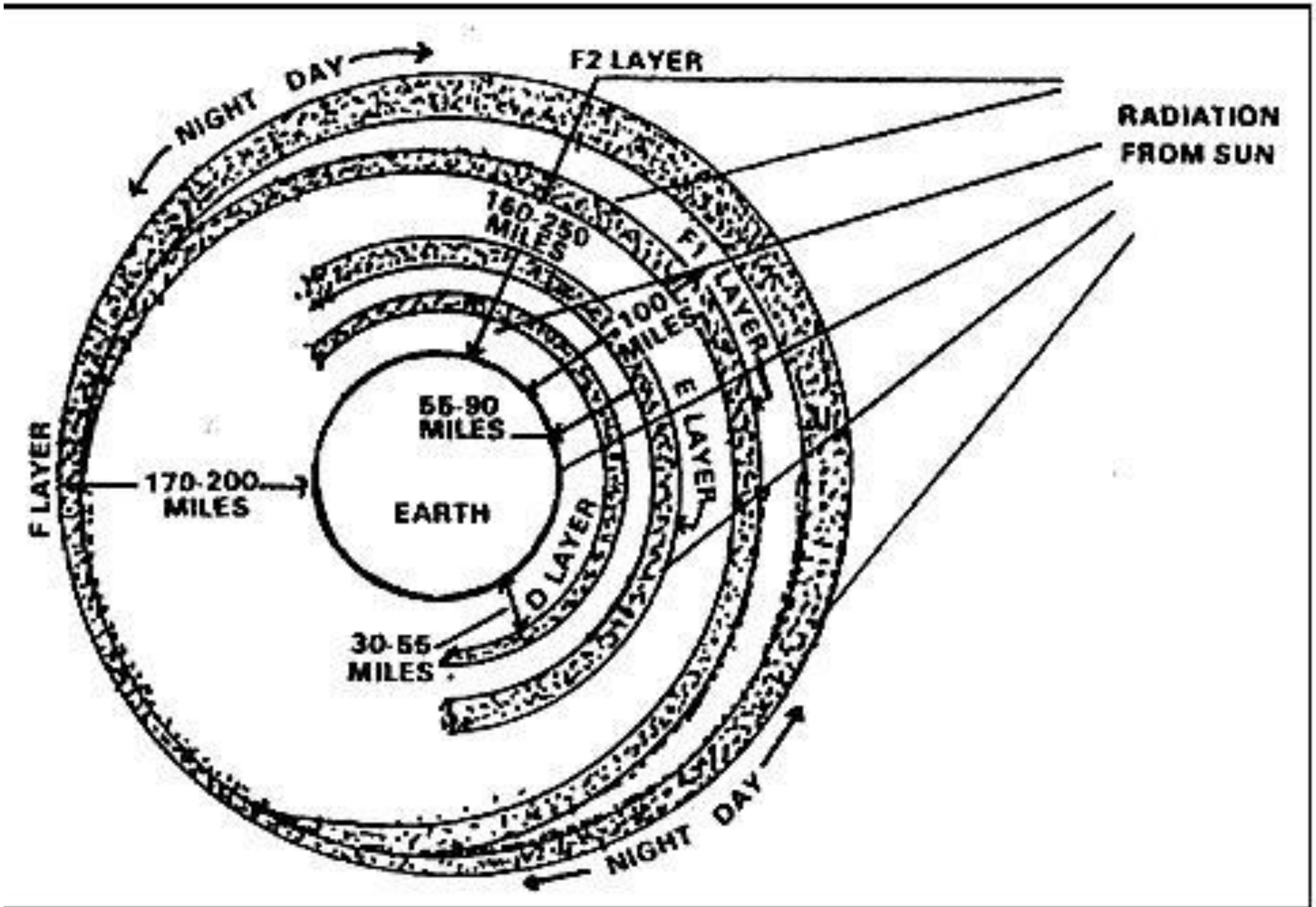

Daily Changes

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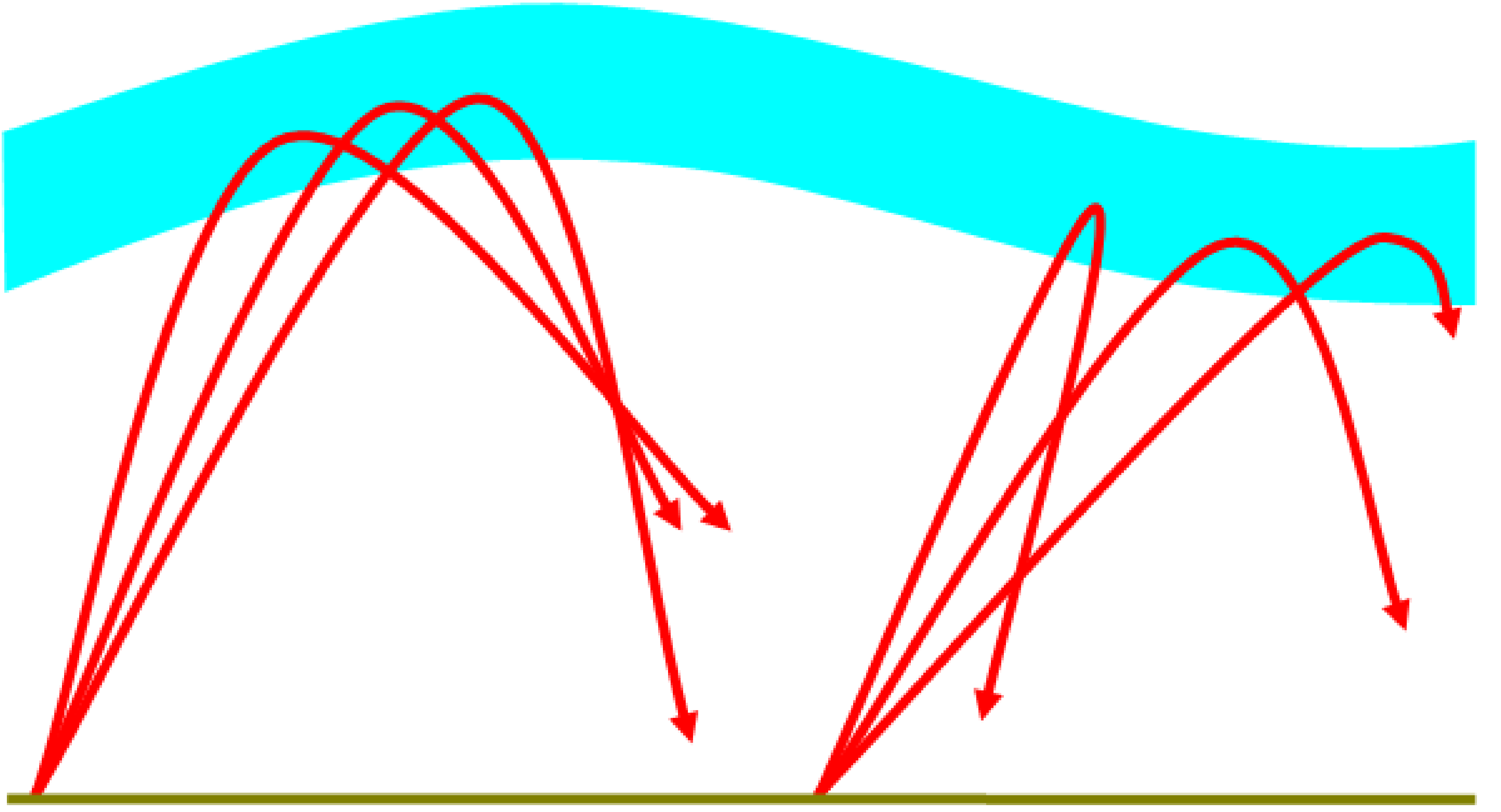

Shape/Density Variations

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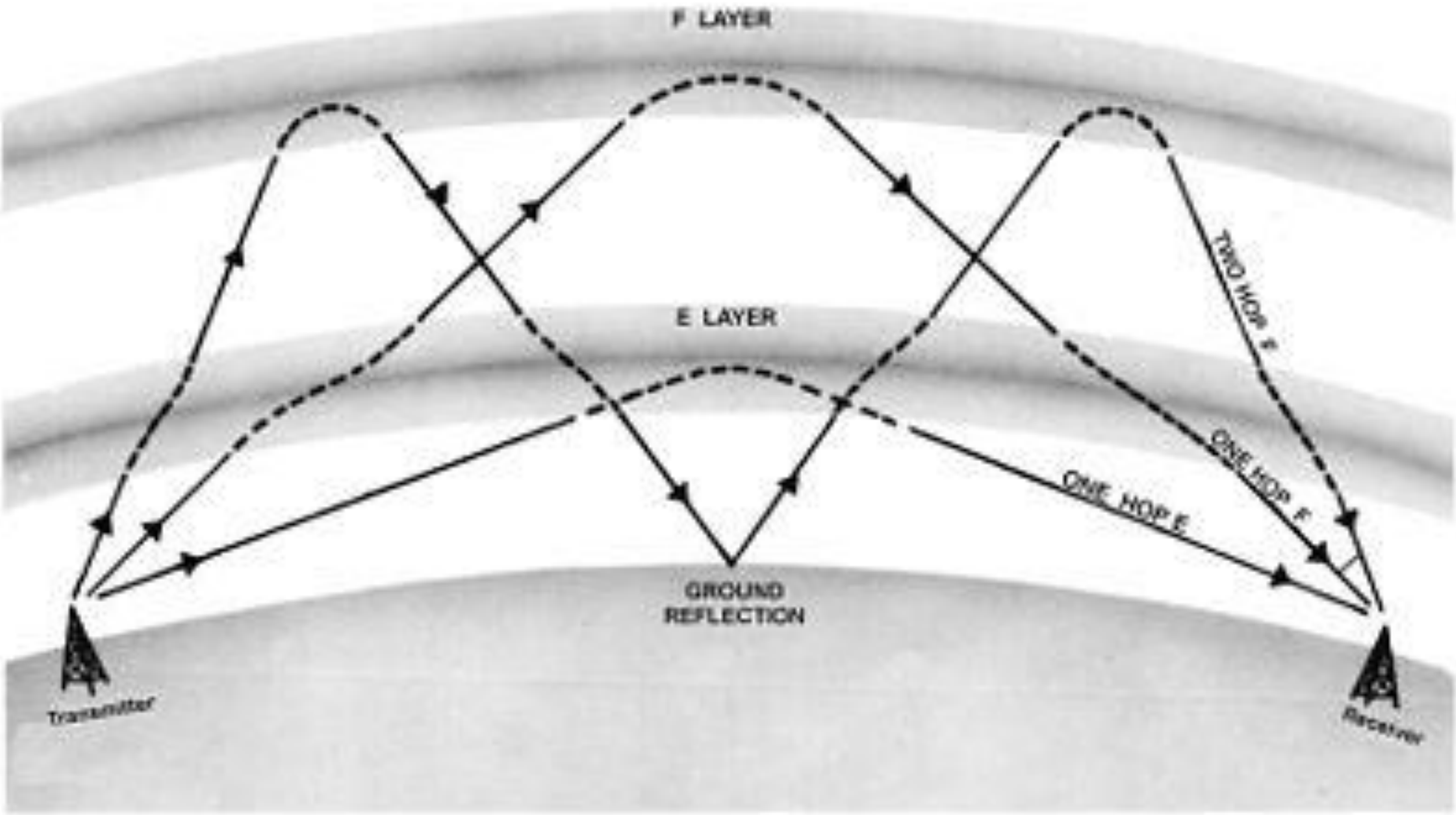

Multipath

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Earth’s Geomagnetic Field

- The **magnetic field** that extends from the Earth's interior to where it meets the solar wind, a stream of charged particles emanating from the Sun.
- Interaction with charged particles in the solar wind can affect propagation.

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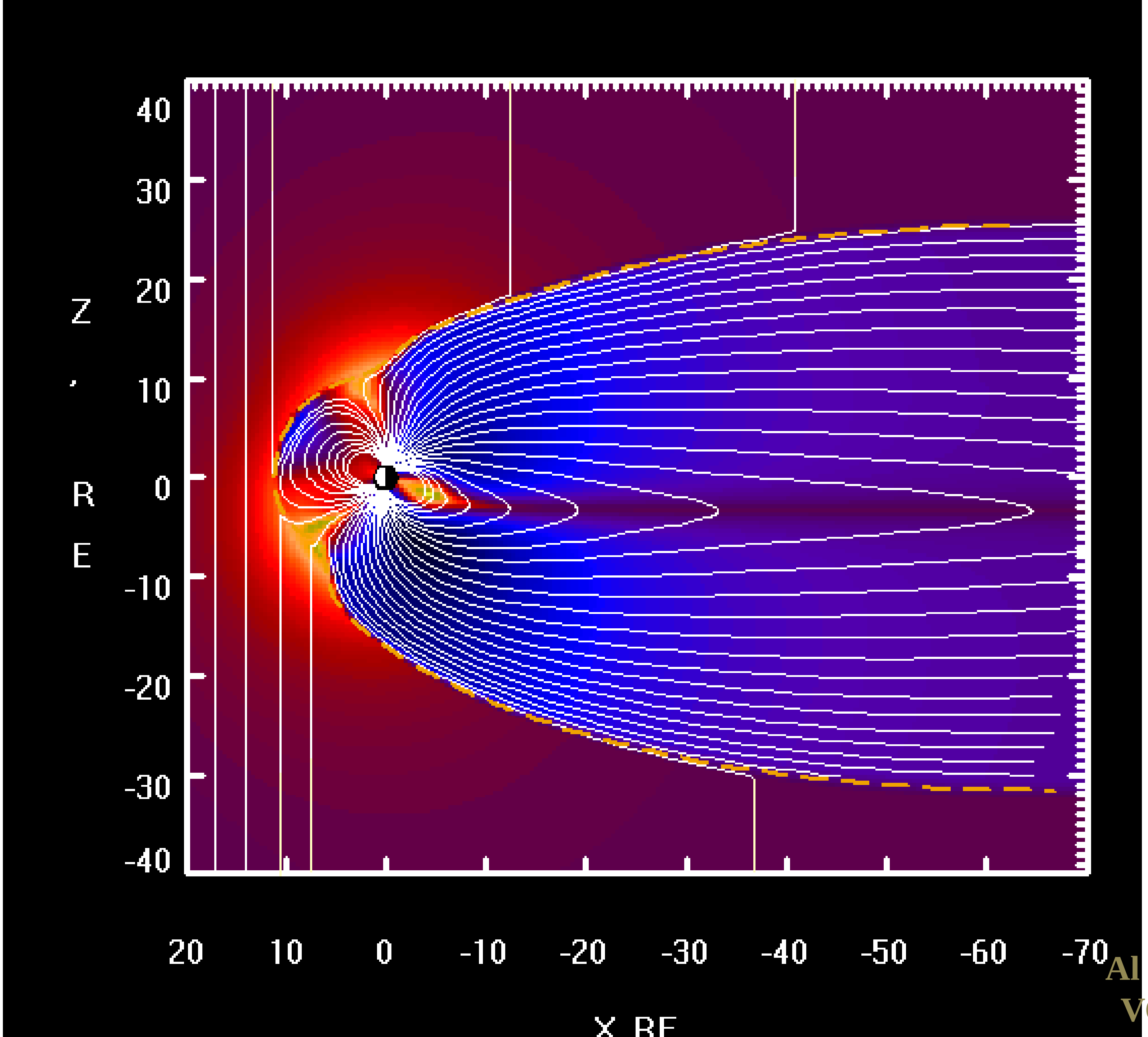

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Ionospheric Disturbances

- Characterized by:
  - Increased ionization in D Layer;
  - Weakening or decomposition of F Layer; or
  - Both.

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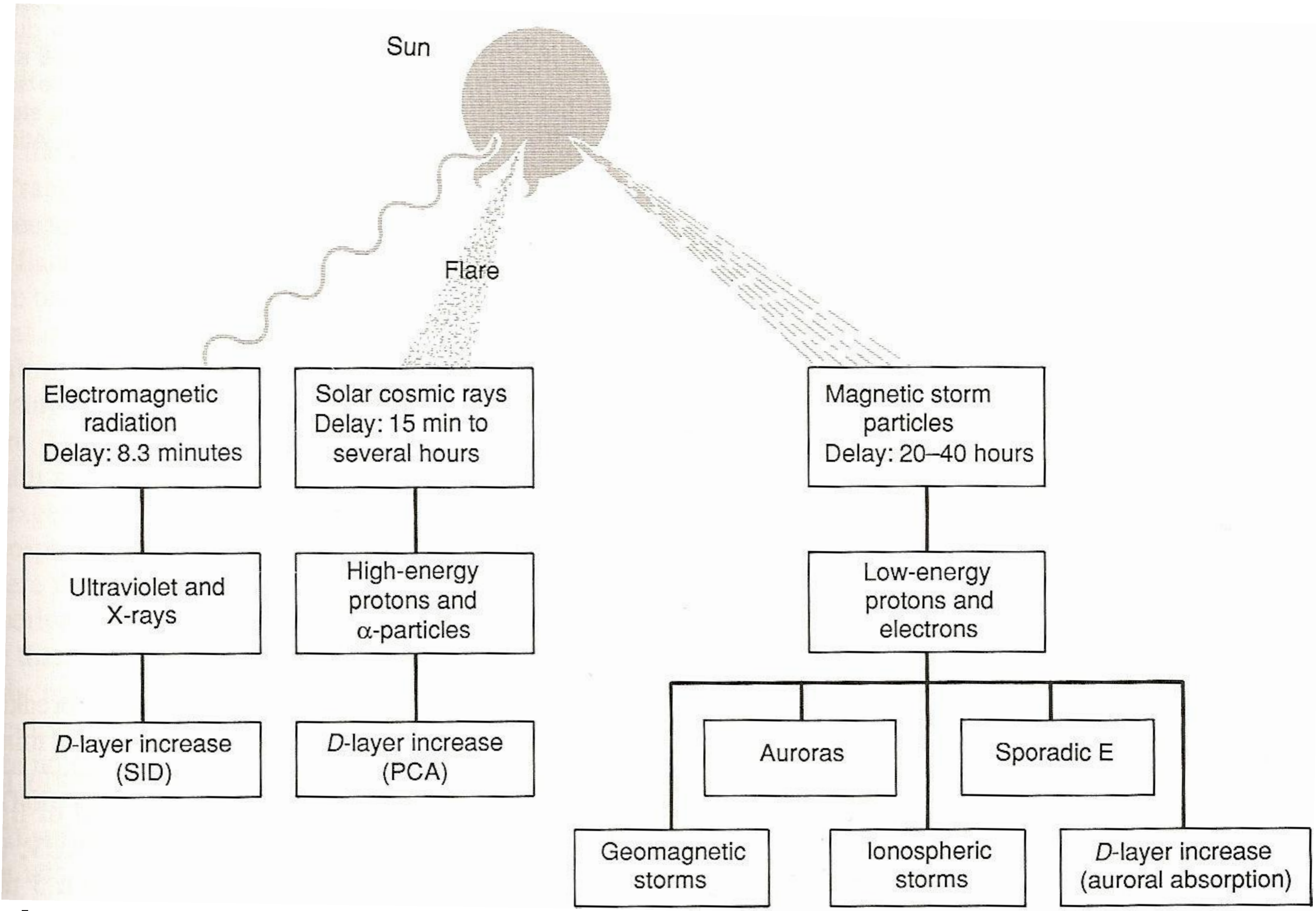

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Ionospheric Disturbances

	SID	Ionospheric Storm	Polar Blackout (PCA)	Polar Blackout (auroral)
Commences	Suddenly	Gradually	Suddenly	Gradually
Duration	Several Minutes to Several Hours	Several Hours to Several Days	Several Minutes to Several Hours	Several Hours to Several Days
Region Most Affected	Daylight Areas	Polar Regions and Mid-Latitudes, Day and Night	Polar Regions, Day or Night	Polar Regions and Mid-Latitudes Day and Night
Region Least Affected	Darkness Areas	Low Latitude and Equatorial Regions	Mid-Latitude and Equatorial Regions	Low Latitude and Equatorial Regions
Bands Most Affected	20–160 Meters	10–40 Meters	15–160 Meters	10–160 Meters
Bands Least Affected	10–15 Meters	80–160 Meters	—	—
Seasonal Peak	Any Season	Early Fall Through Spring	Any Season	Early Fall Through Spring
Sunspot Cycle	Peaks During High Period	Peaks During High and Medium Periods	Peaks During High Period	Peaks During High and Medium Periods
Corrective Action	Work Dark Paths. Go Higher in Freq-uency on Daylight Paths	Work Low Latitude and Equatorial Paths. Go Lower in Frequency on High Latitude and Trans-Polar Paths	Work Low Latitude and Equatorial Paths. Go Higher in Frequency on High Latitude and Trans-Polar Paths	Work Low Latitude and Equatorial Paths

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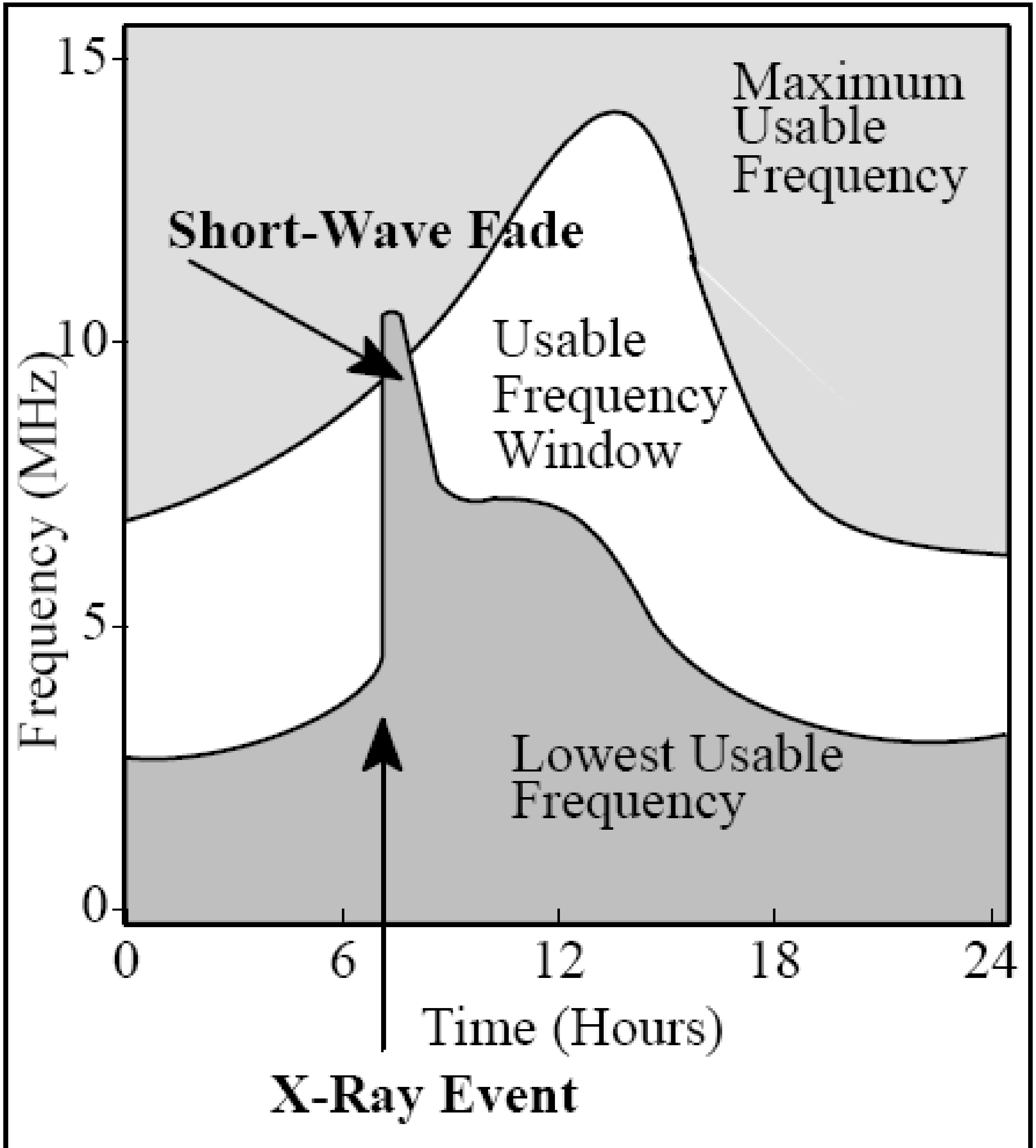

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K Index

- Quantifies **disturbances** in Earth's **magnetic field**.
- Quasi-logarithmic scale 0 to 9
- 1 = calm
- 5 or higher = geomagnetic storm
- Updated every 3 hours (8 measurements per day)
- Planet's K Index (K_p) is average of all observatories' K Index around the world.

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A Index

- Measure of **daily level** of geomagnetic activity.
- Values of 8 daily K indices at observatories around the world are used to calculate daily A Index for each observatory.
- Can range in value from 0 to 400 or so.
- 0 = very calm, while 400 = Very major magnetic storm!
- Planet’s overall A Index (A_p) is average of A indices for all observatories around the world.

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VHF / UHF Propagation

- In general, frequencies above 30 MHz not affected by ionosphere.
- Radio Horizon is actually ~ **1.15 x Visual Horizon**.
- This is due to slight effect of refraction.

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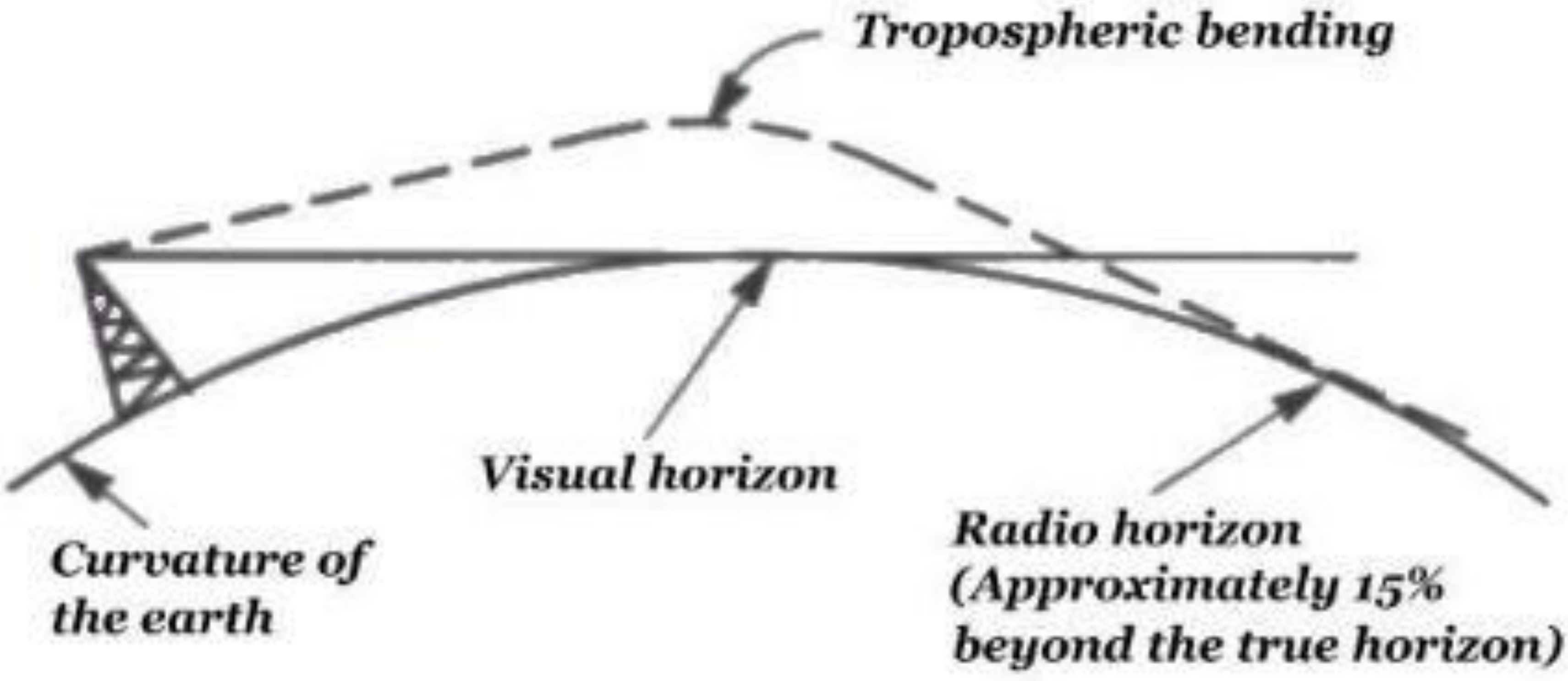

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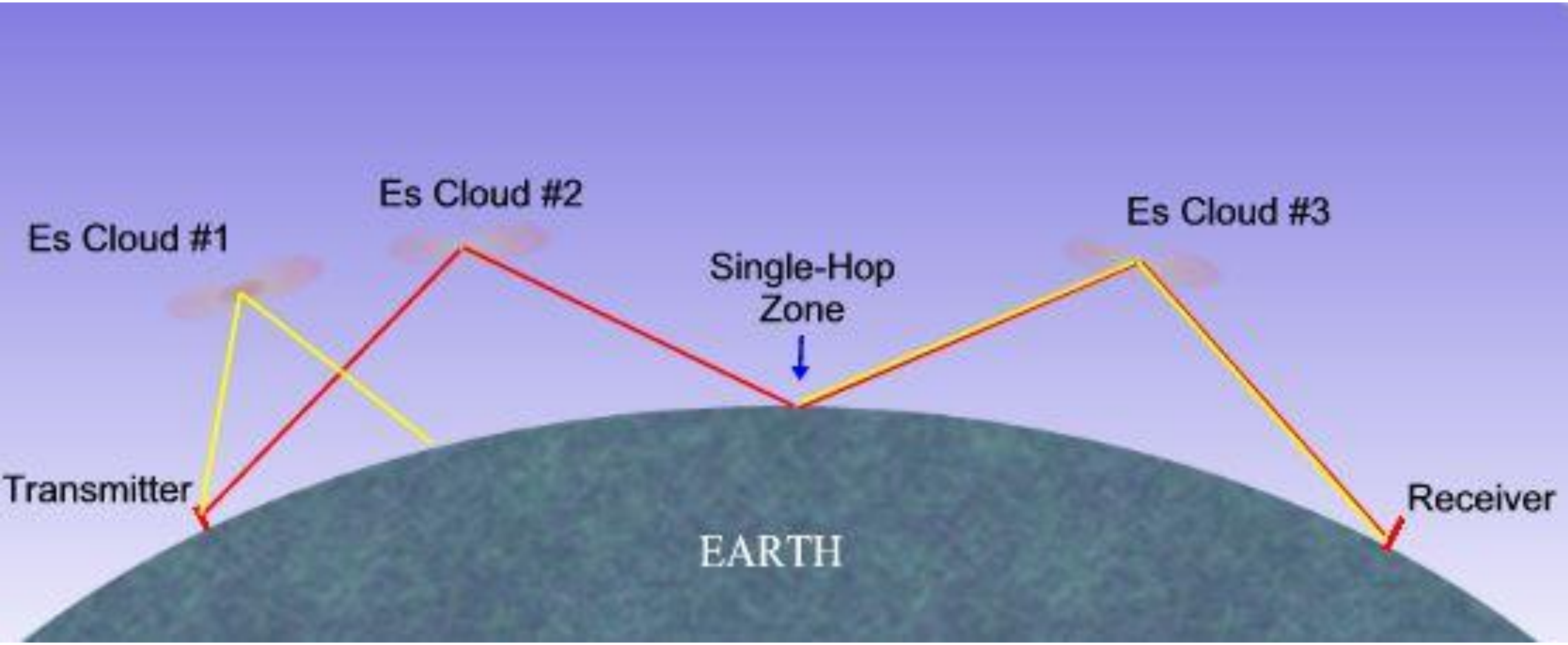
Sporadic E (Es)



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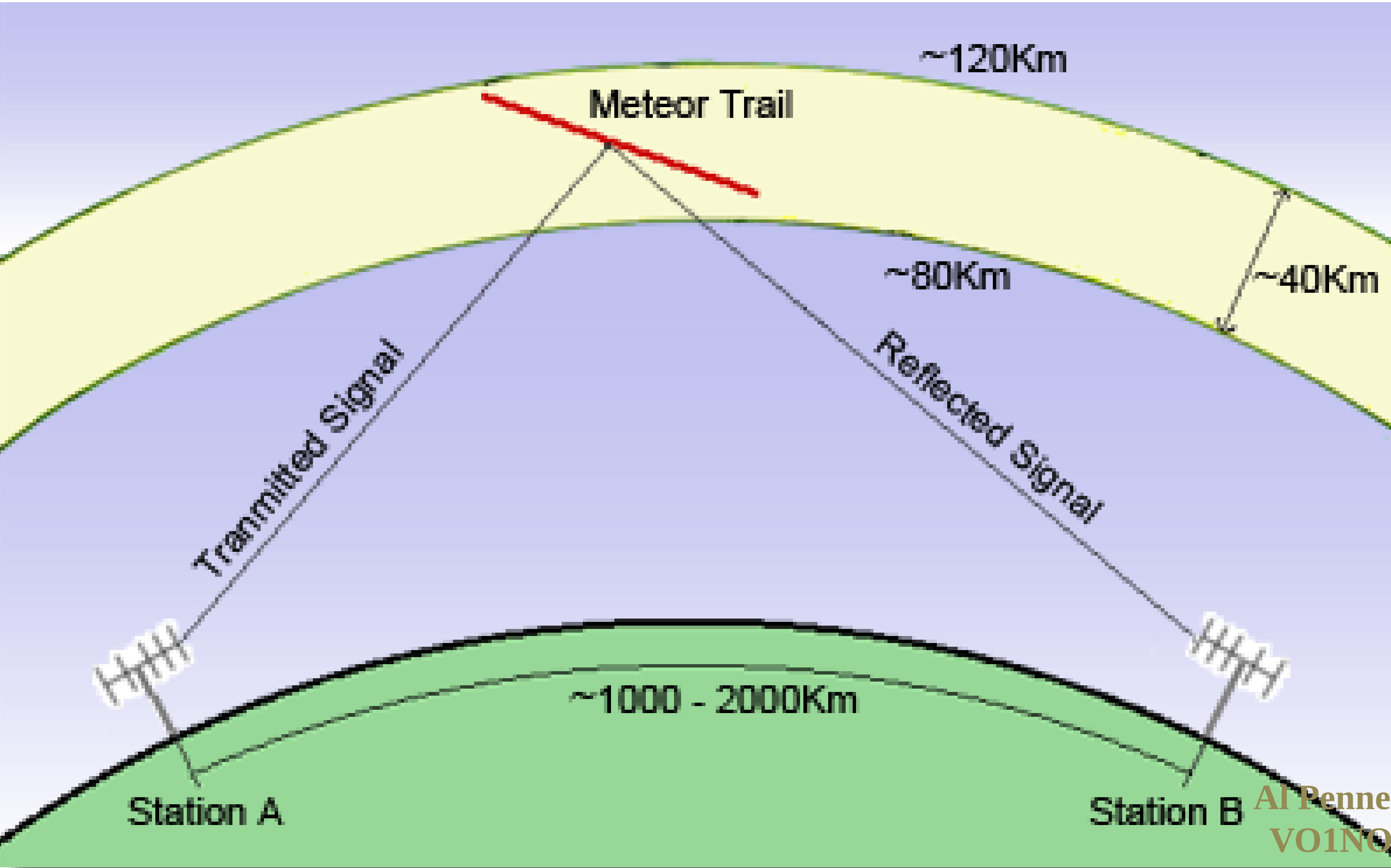
Meteor Scatter



Auroral Propagation

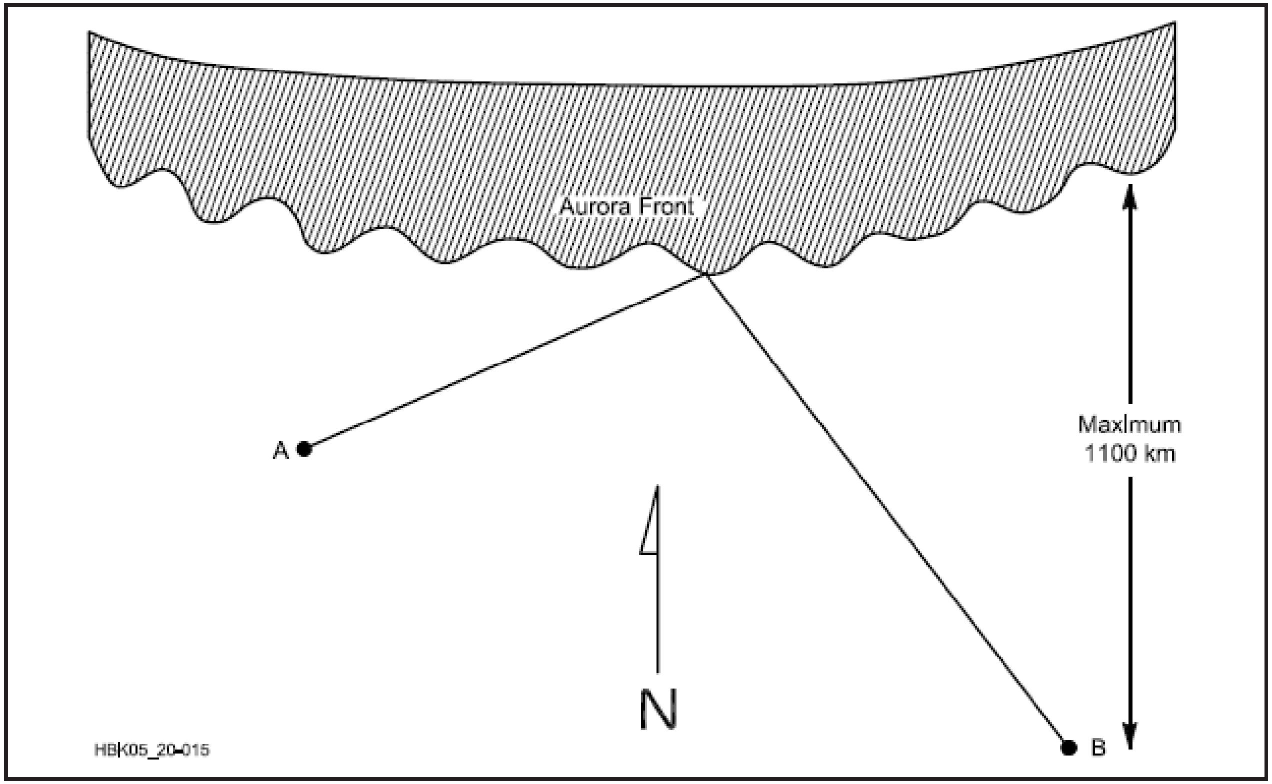


Fig 20.15—Point antennas generally north to make oblique long-distance contacts on 28 through 432 MHz via aurora scattering. Optimal antenna headings may shift considerably to the east or west depending on the location of the aurora.

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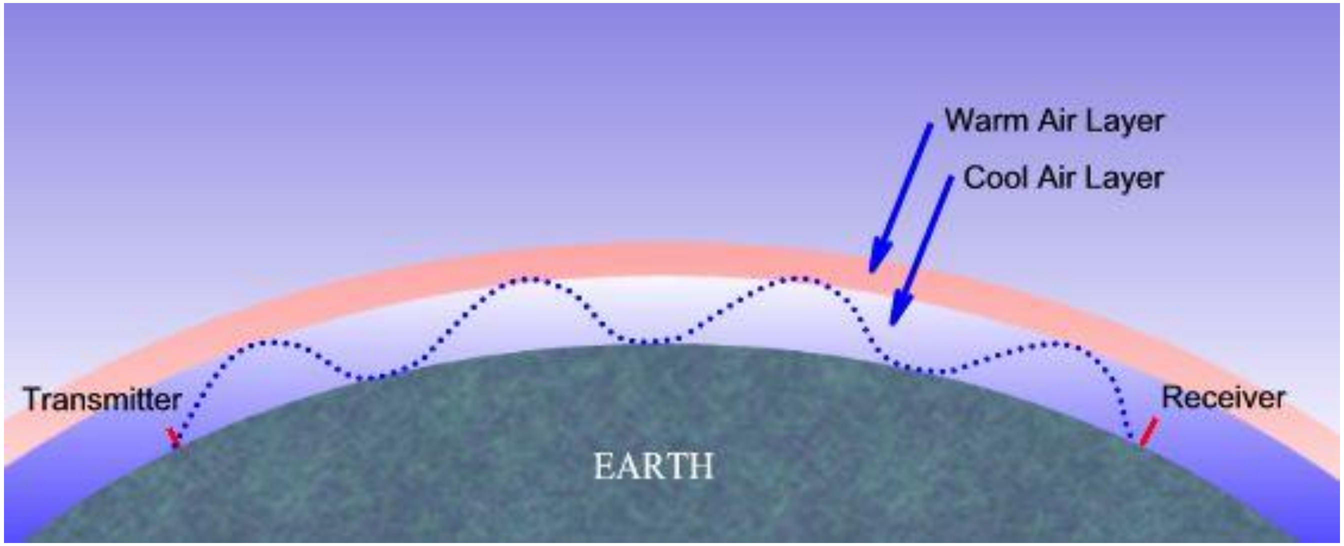
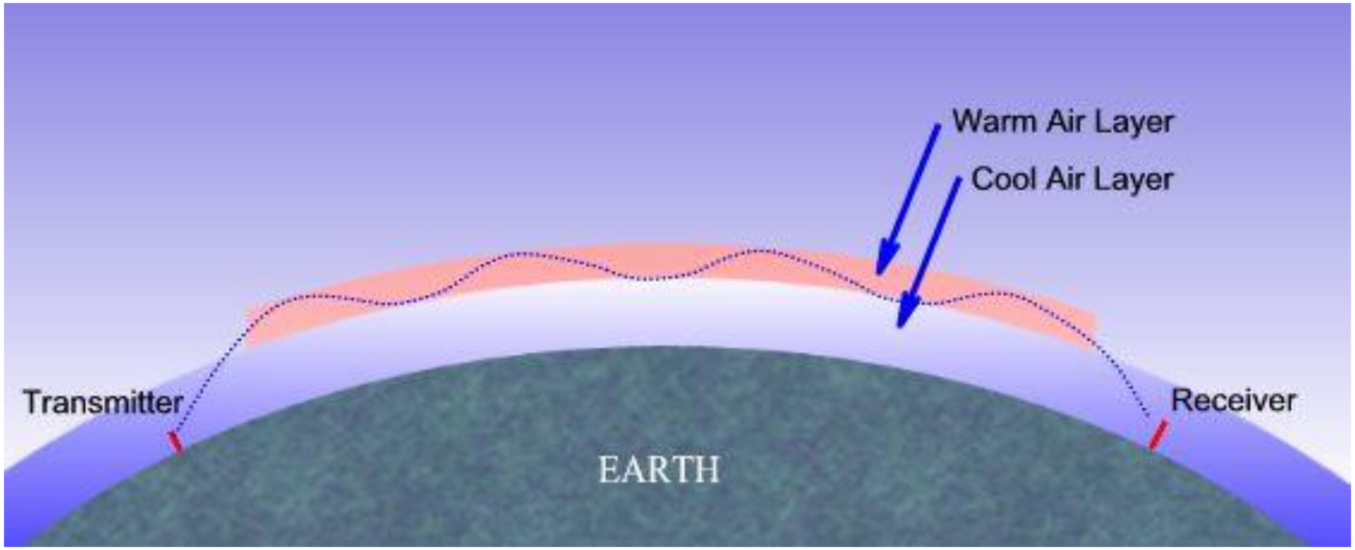
Tropospheric Ducting / Inversion





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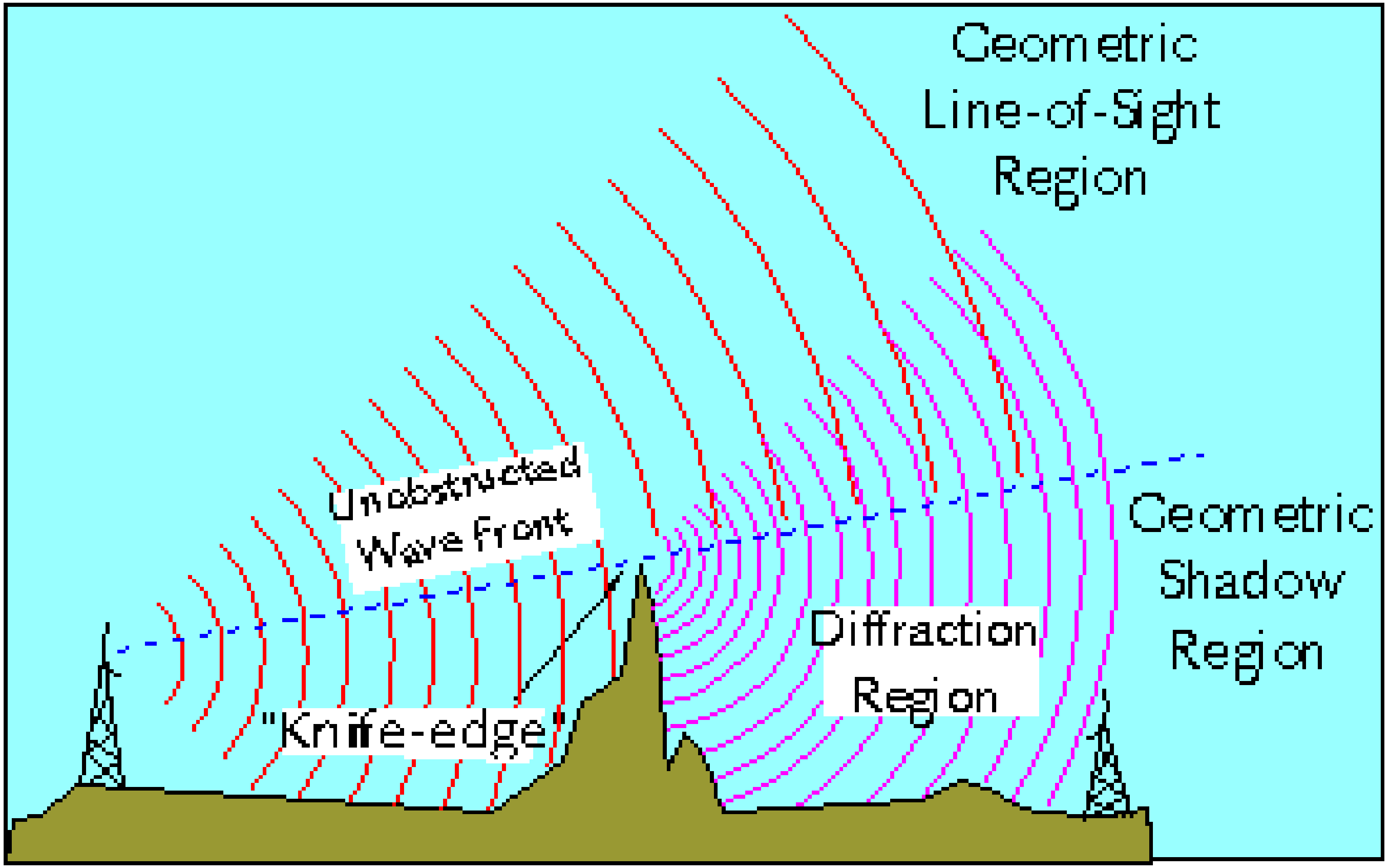
Knife-Edge Refraction



knife-edge effect

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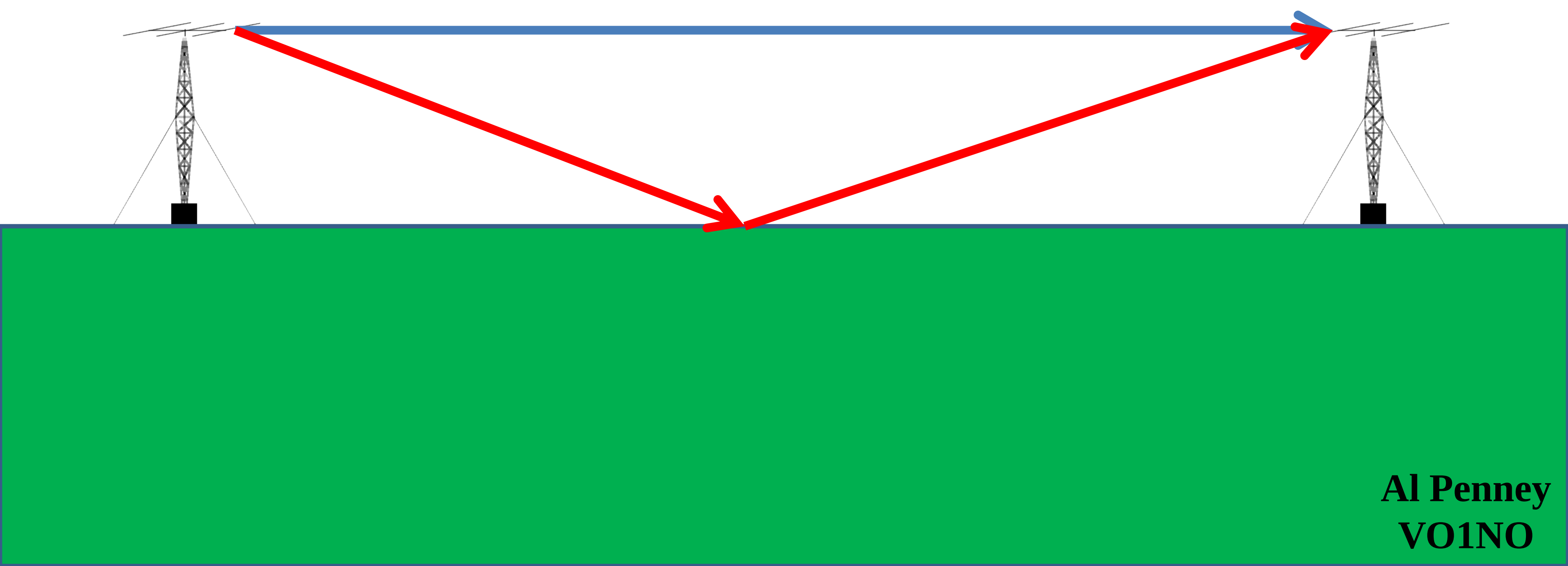
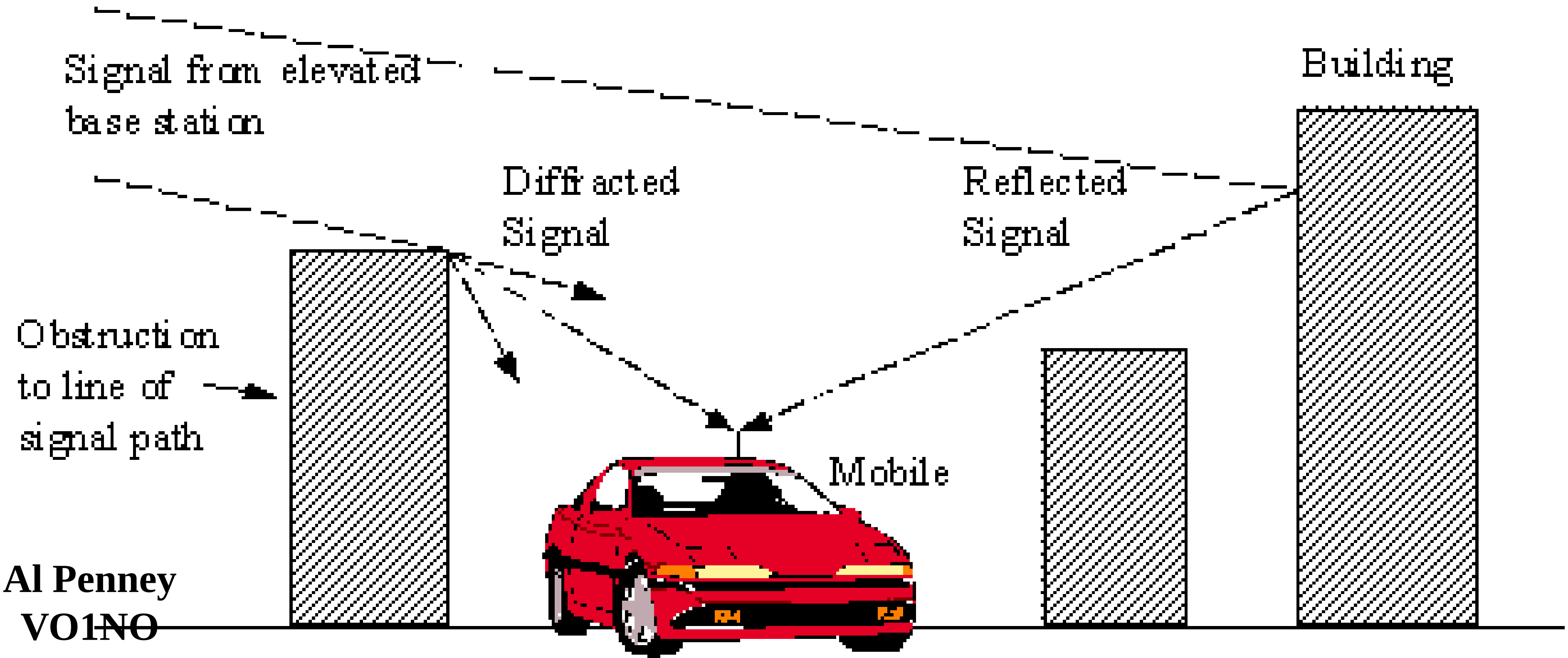
Flat Terrain



Concrete Jungle



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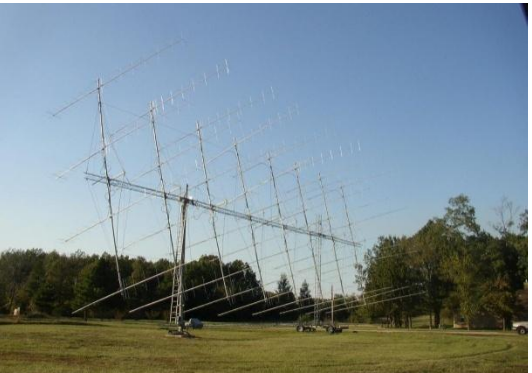
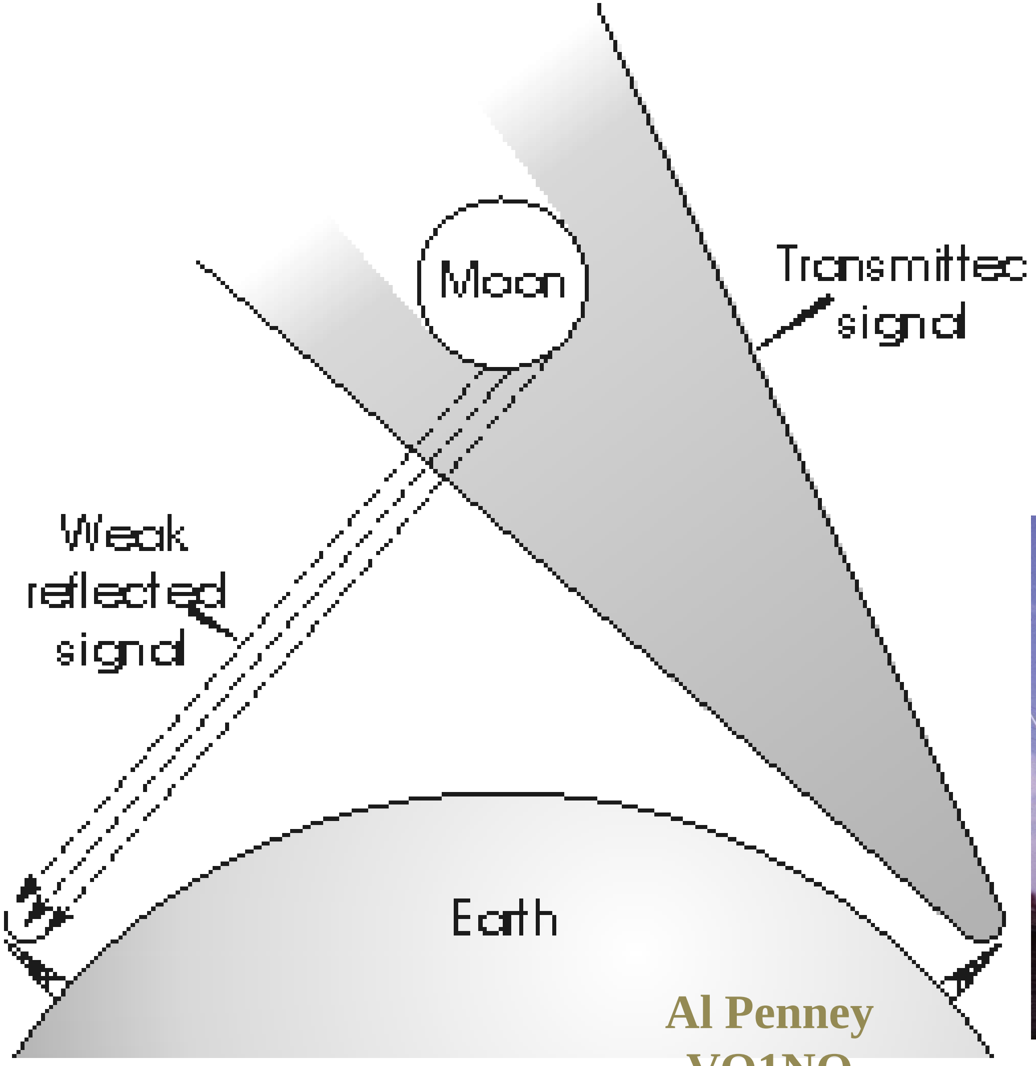
Moonbounce / EME



W5UN EME Array with 32 2M5WL horizontal antennas, and 32 front mounted ten element vertical antennas



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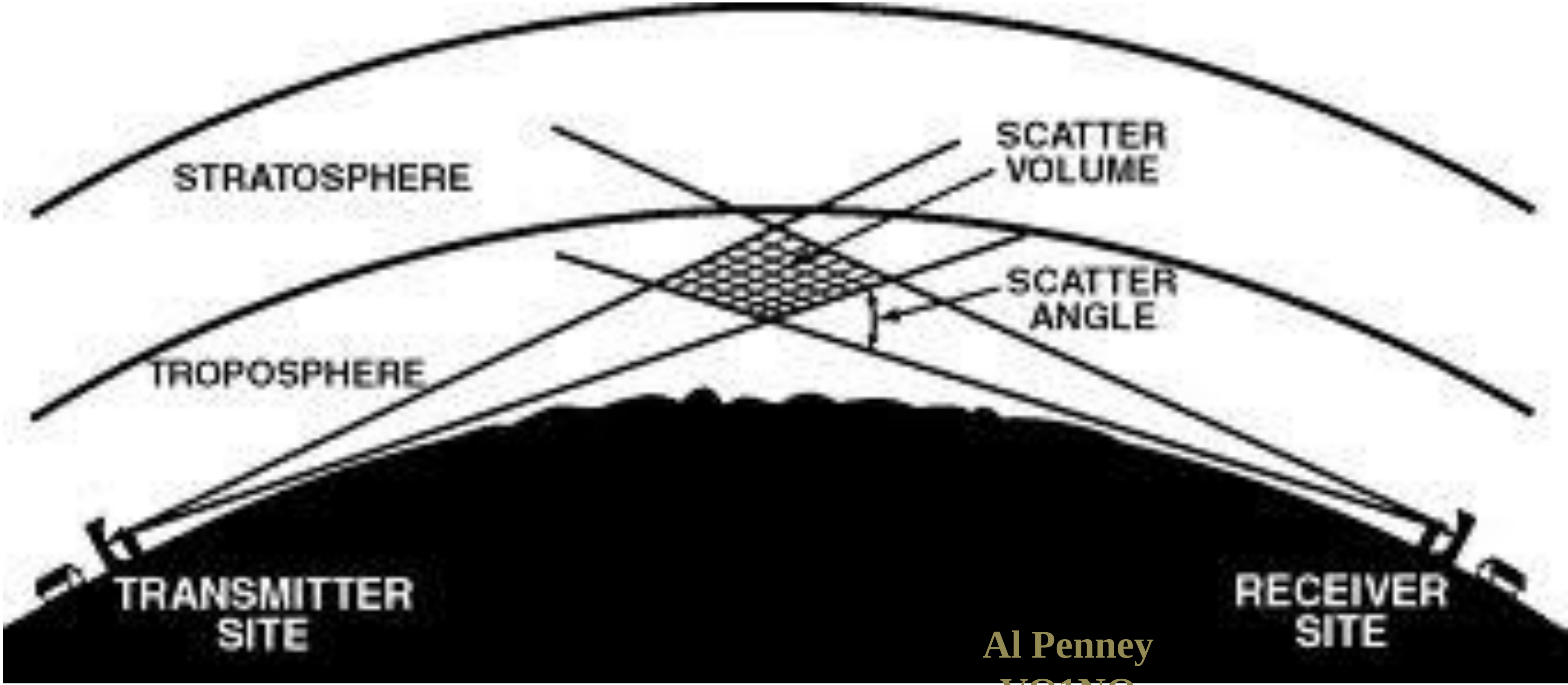
Tropospheric Scatter



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Propagation – 6M

- Mix between HF and VHF propagation.
- Long range F2 propagation during solar peak.
- Sporadic E 1500 to 3000 km, Jun and Dec.
- Some Aurora.
- Moonbounce becoming popular.

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Propagation – 2M

- Most popular Amateur band.
- FM and repeaters very common.
- Tropospheric ducting to several hundred km.
- Sporadic E not common, but possible.
- Meteor Scatter out to 1500 km or more.
- Most popular Moonbounce band.
- Also used for Amateur satellites.
- Aurora also possible.

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Propagation – 220 MHz

- Somewhat neglected band.
- Becoming more popular however.
- Propagation generally similar to 2M.
- Sporadic E is rare however.

Propagation – 70cm

- First Amateur band in UHF spectrum.
- Tropospheric ducting primary DX mode.
- FM, repeaters, Amateur Television.
- Sporadic E and Aurora rare.
- All Amateur bands from 70cm to 10 GHz are shared with other services.

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Questions?

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The Carrington Event

The Largest known geomagnetic storm caused by a massive solar flare in 1859

Aurora Australis was observed as far north as Queensland, Australia

Aurora Borealis as far south as the Caribbean and Hawaii

People in the Northern US could read the Newspaper at night from the aurora's light and telegraph systems went haywire

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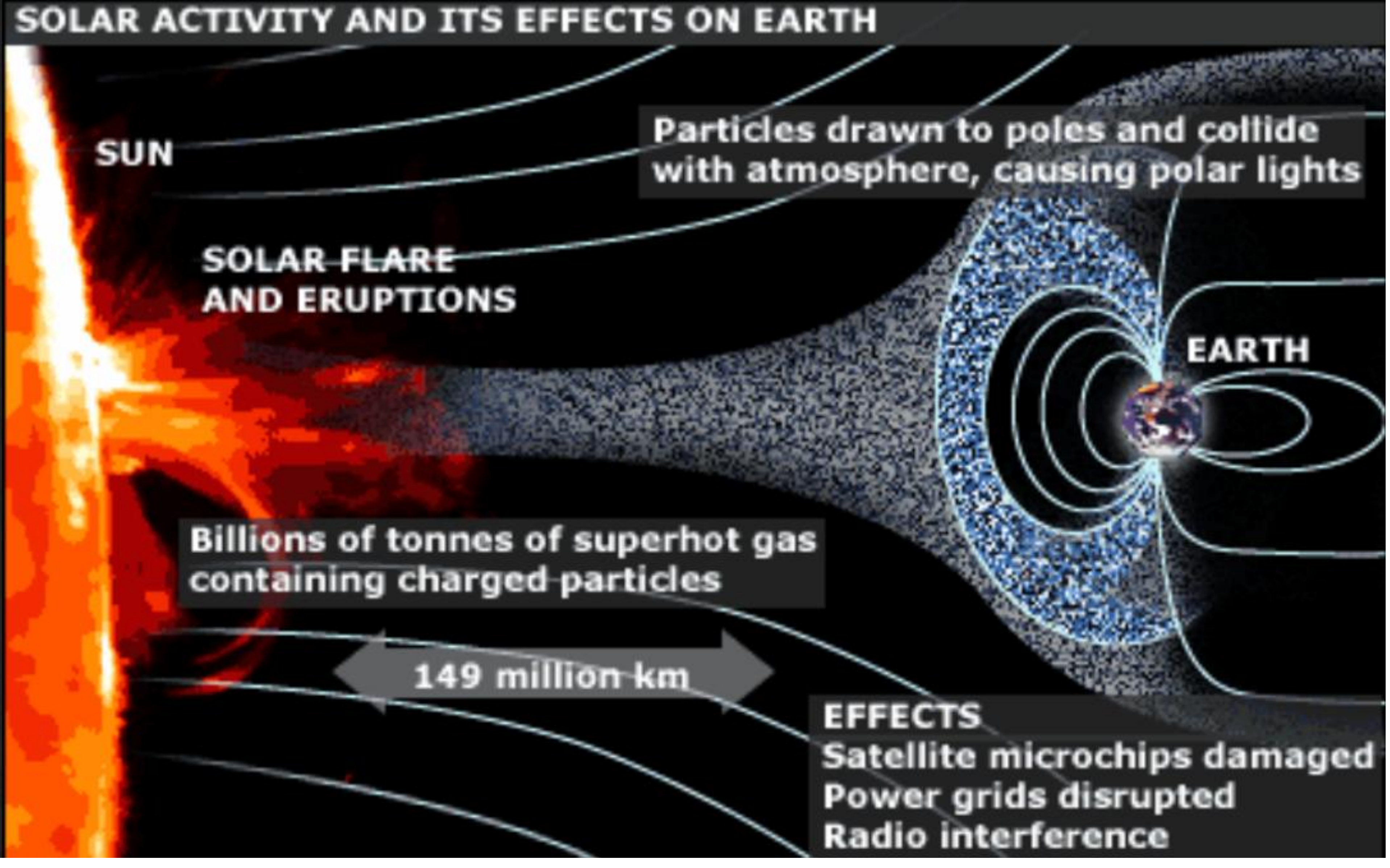

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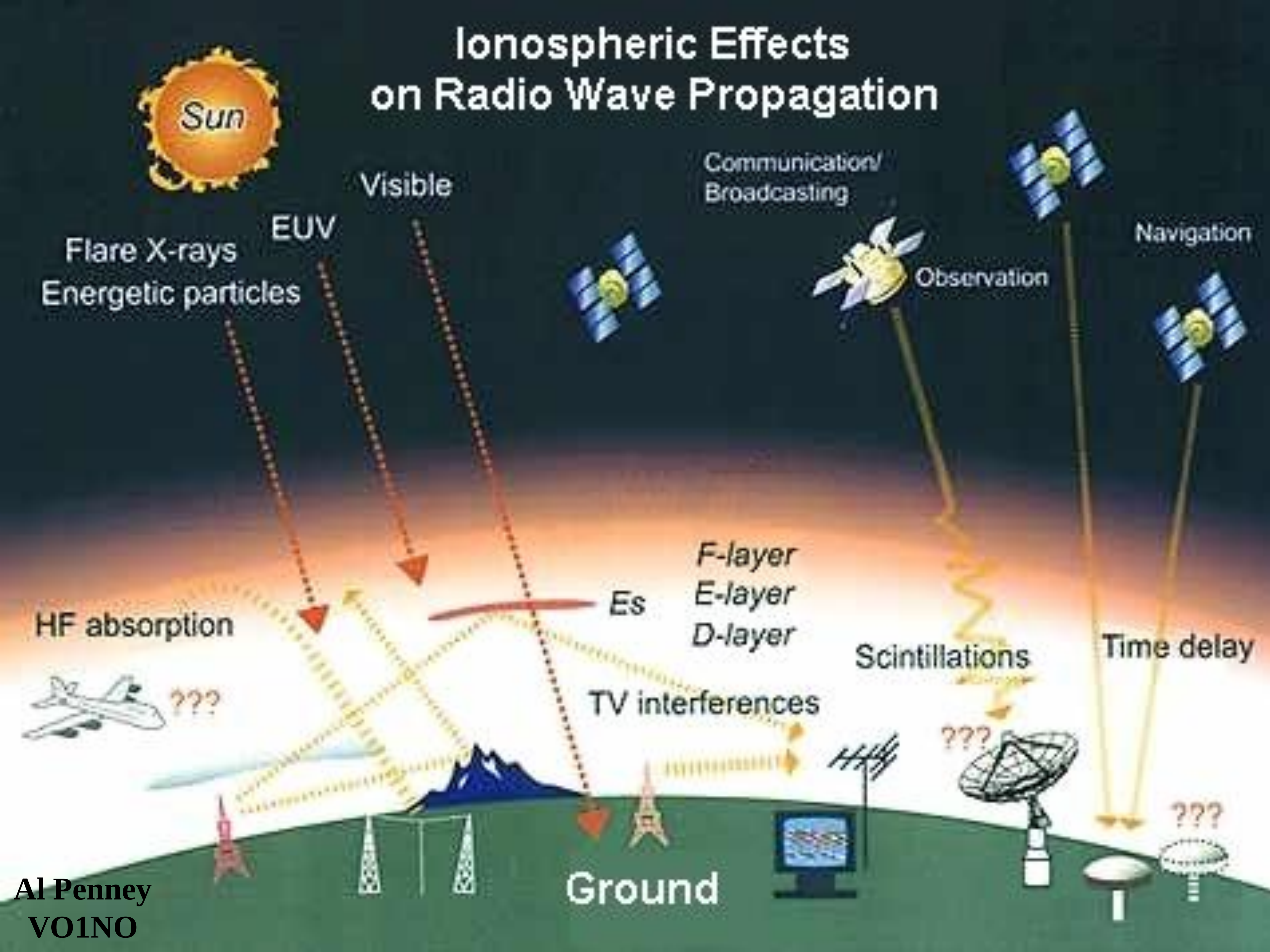

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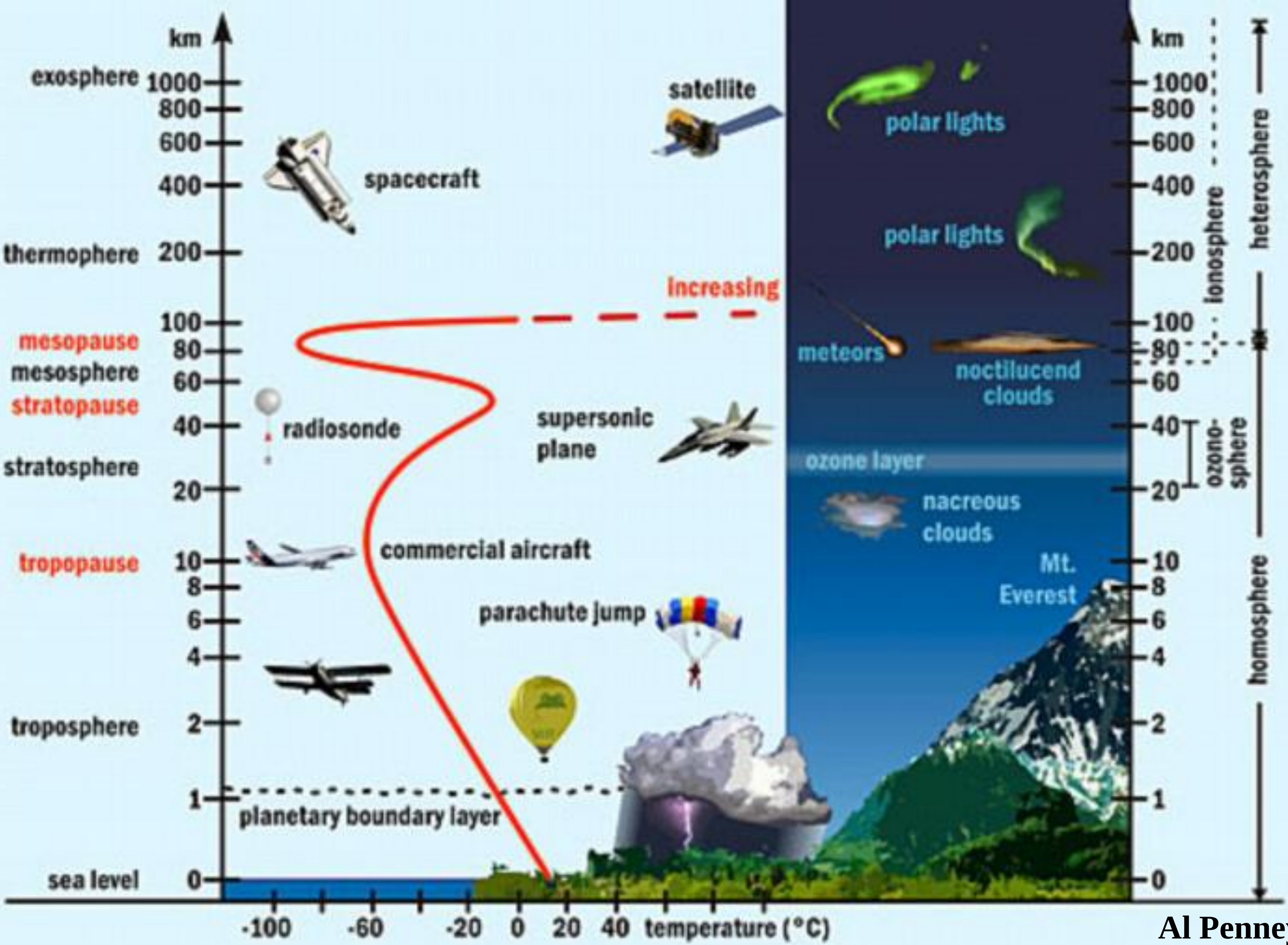

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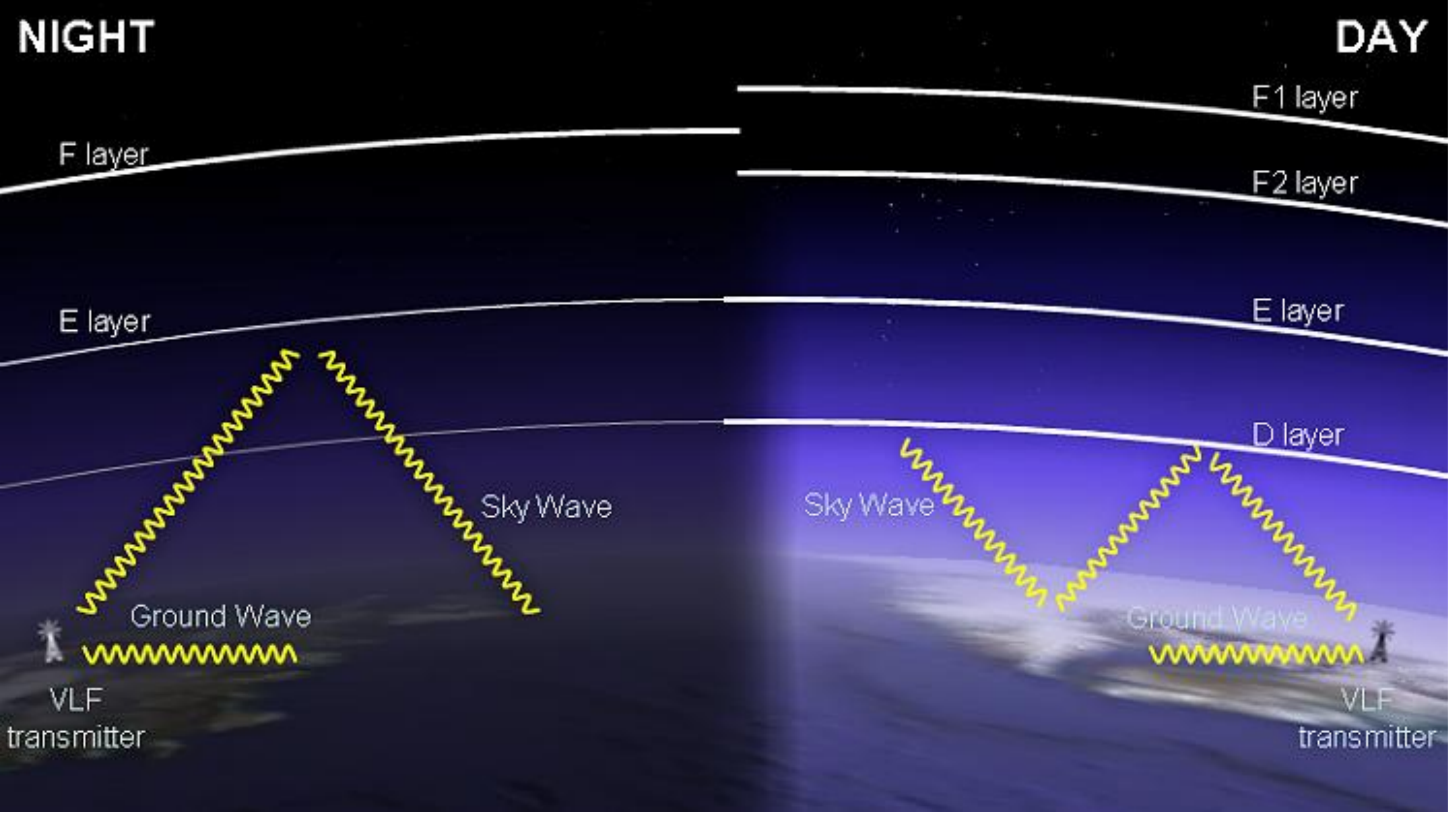

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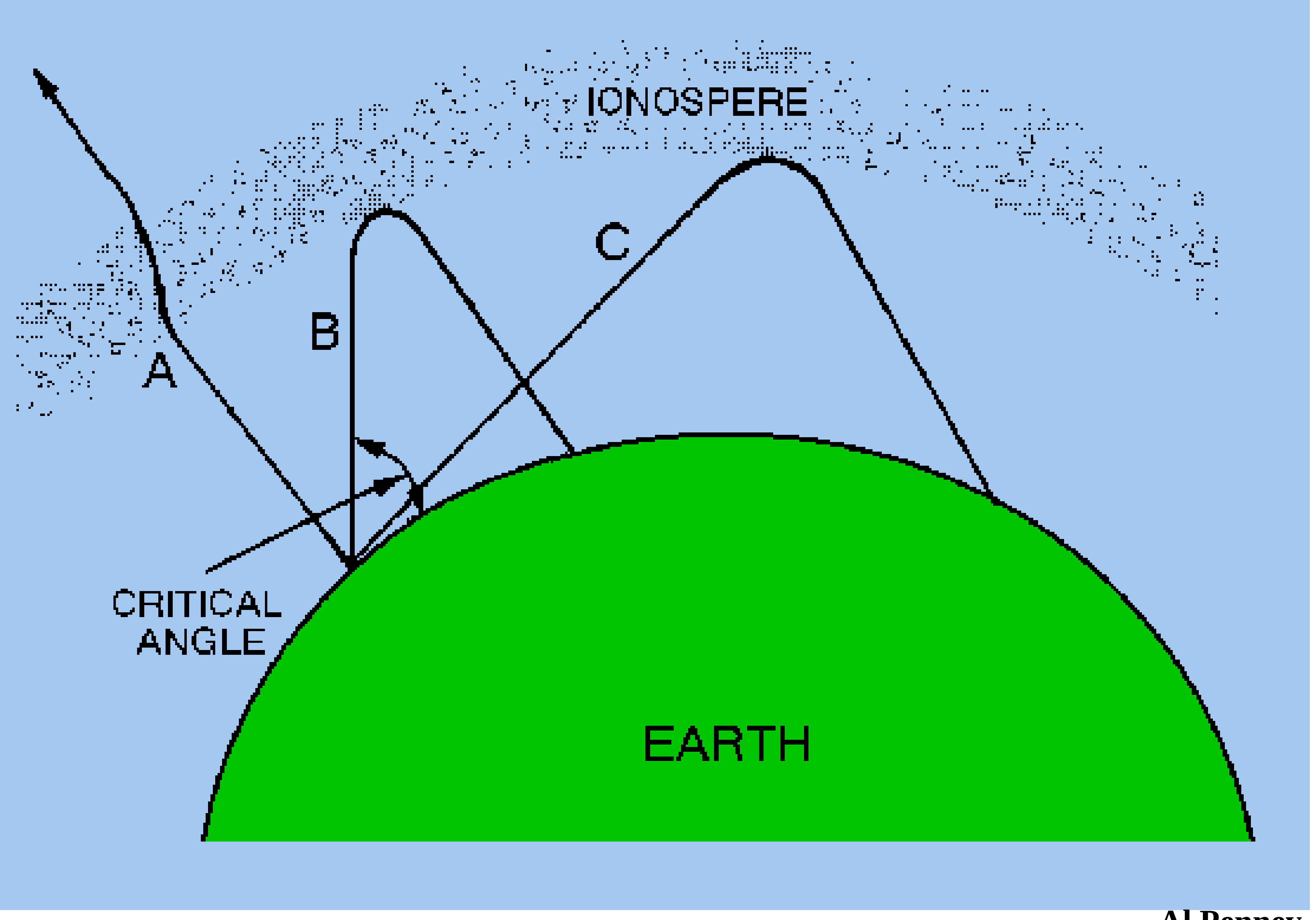

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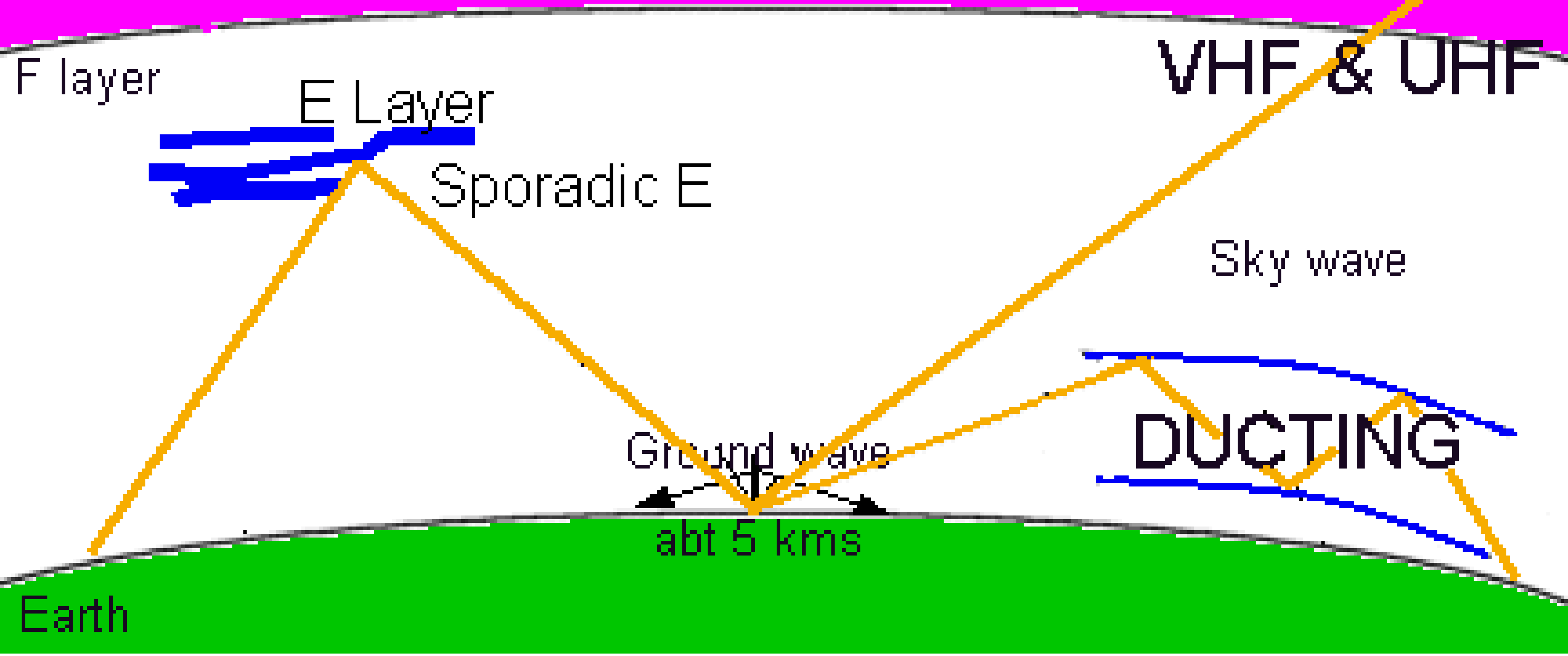

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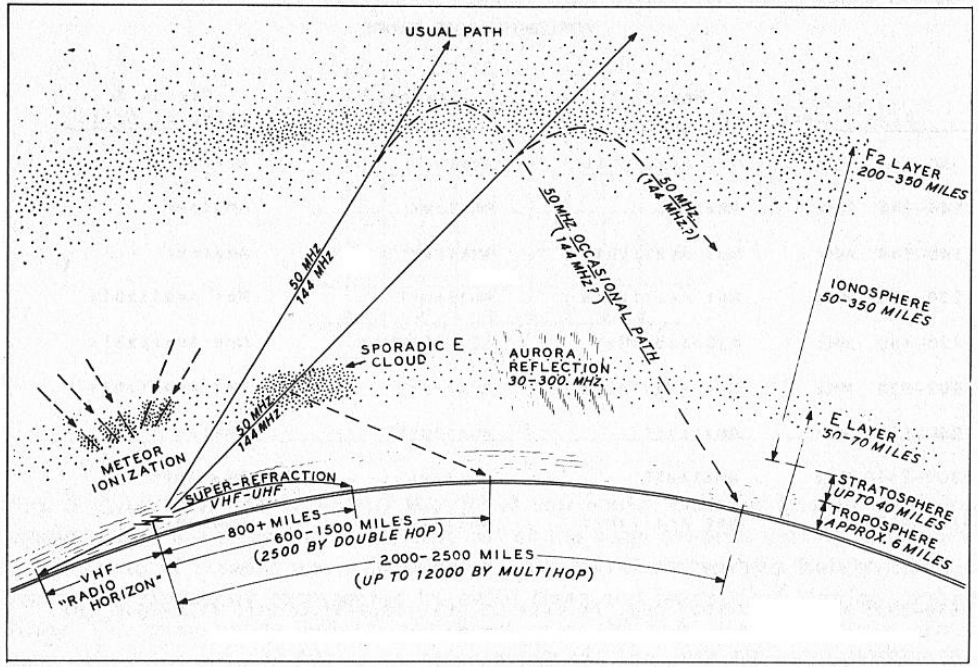
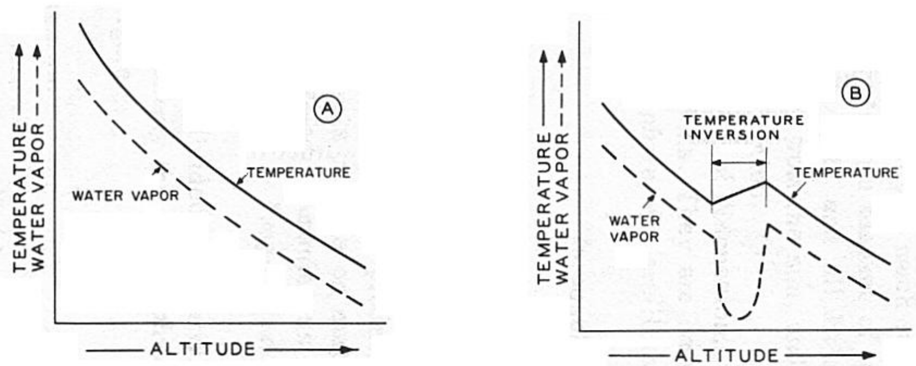


ATMOSPHERE OF THE EARTH is concentrated in a thin layer about 300 miles thick. The ionized layers of air within this span have the ability to reflect electromagnetic energy of certain frequencies. The atmosphere is divided into strata named the troposphere, the stratosphere and the ionosphere. It is in the latter region that radio reflection at the higher frequencies takes place.



LONG DISTANCE TROPOSPHERIC PROPAGATION takes place because of temperature inversion. Normal temperature and water vapor content of air decrease with altitude (A). Refractive index of the atmosphere can produce inversion area (B), showing an abrupt break in water vapor content. If the inversion is pronounced, the resulting bending of the radio wave will follow the curvature of the earth. Atmospheric ducts have propagated VHF signals over distances in excess of 2500 miles.

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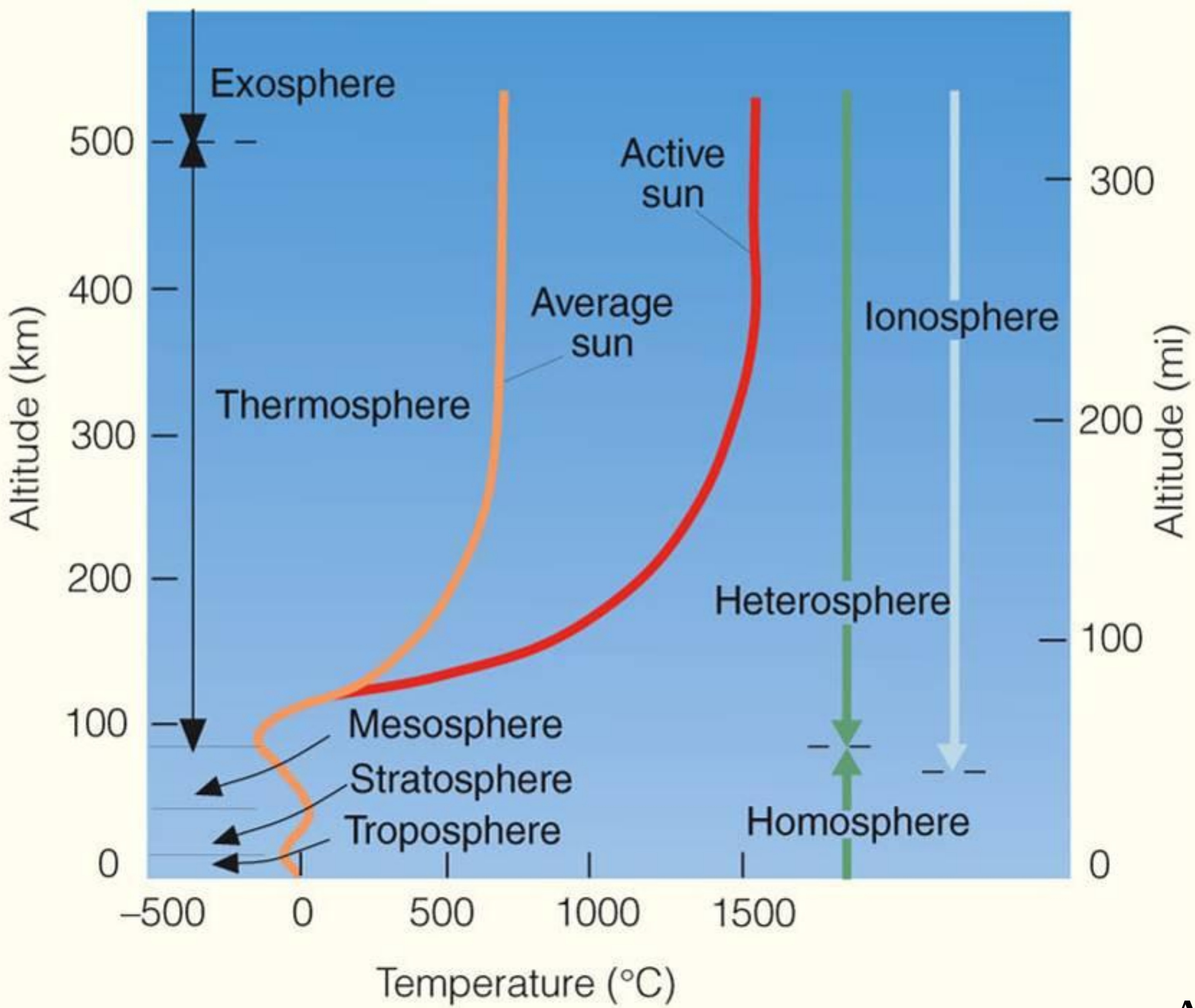

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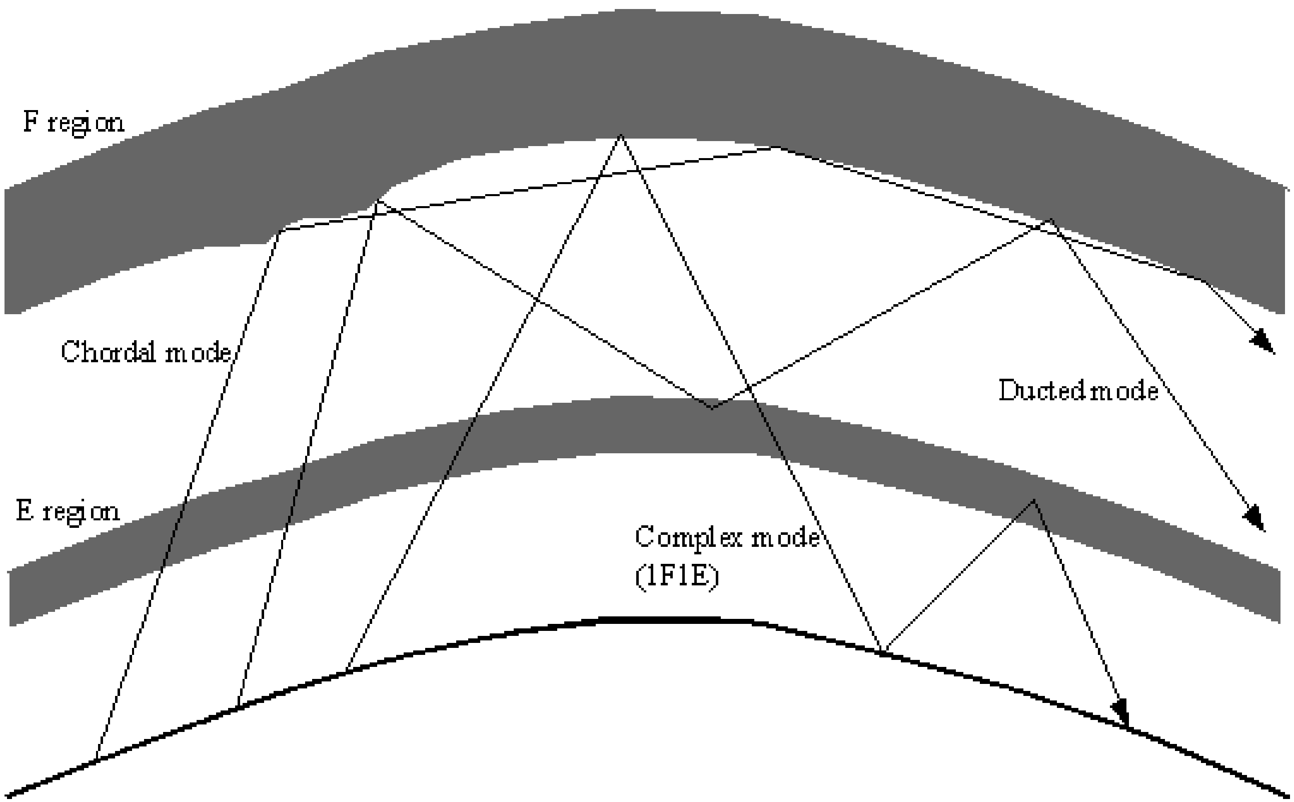

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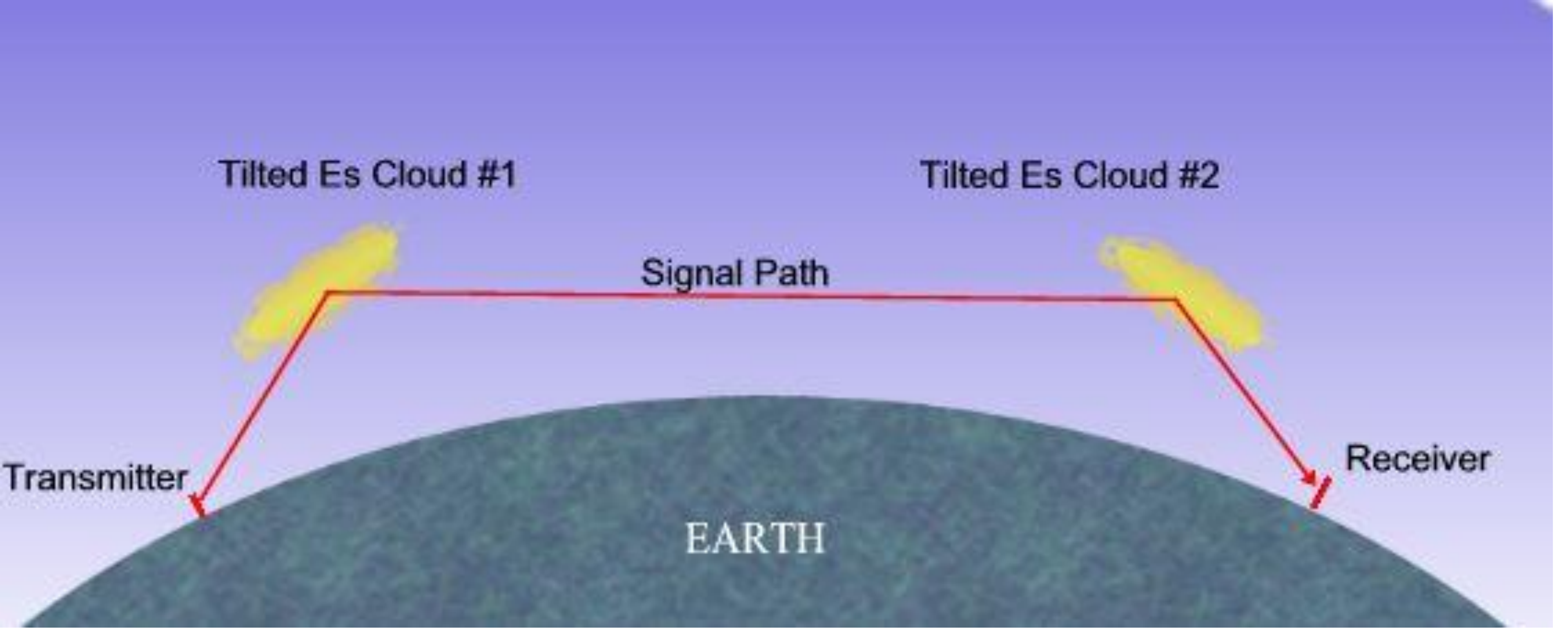

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