

ANTENNA SUMMITT

PROPAGATION

Spring 2021

Jack Lunsford, NT7MM



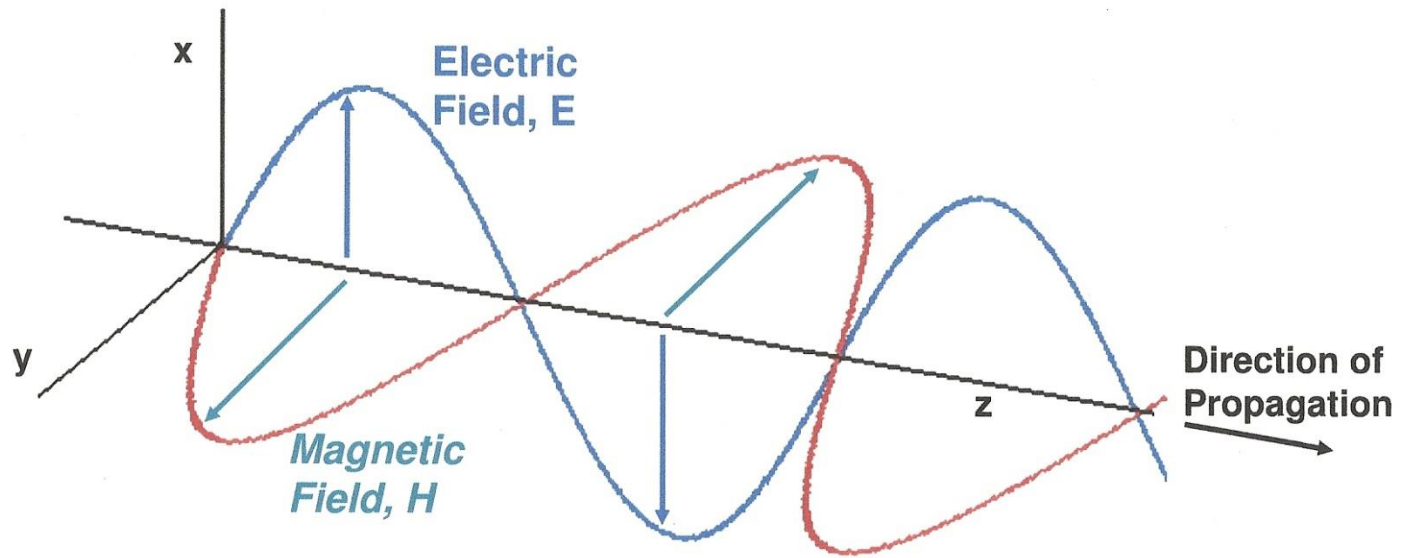
The antenna was optimized for best compromise gain and front to back ratio at half wavelength high over average ground.

- At full wavelength high both gain and front to back are slightly better.at expense of SWR still less than 2:1 for entire band.

PROPAGATION

- How radio waves get from point A to point B. The events occurring in the transmission path between two stations that affect the communications between the stations.
- When the electrons in a conductor, (antenna wire) are made to oscillate back and forth, **Electromagnetic Waves (EM Waves)** are produced.
- These waves radiate outwards from the source at the **speed of light, 300million meters per second.**
- Light waves and radio waves are both EM waves, differing only in **frequency** and **wavelength**.

RADIO WAVES



- Electromagnetic radiation comprises both an Electric and a Magnetic Field.
- The two fields are at right-angles to each other and the direction of propagation is at right-angles to both fields.
- The Plane of the Electric Field defines the Polarisation of the wave.

Antenna Summit

- λ Wavelength -- The distance the wave travels during one cycle
-
- c The speed of light – 300,000,000 meters/second 300 Mm
-
- f The frequency of the wave -- cycles/second -- Hz/second
-
- $\lambda = \frac{c}{f}$
-
- Signal 14.3 MHz = f
-
- $\lambda = \frac{300 \text{ Mms}}{14.3 \text{ MHzs}} = 20.97 \text{ m}$
-
-
- Signal 28.8MHz = f
-
- $\lambda = \frac{300 \text{ Mms}}{28.8\text{MHzs}} = 10.41 \text{ m}$
-

Some Ado about **Nothing**

Need to understand how electromagnetic waves behave in free space.

Free space is empty, **Nothing** there. OH REALLY ?

Actually it's a dense soup of trillions of trillions of particles and antiparticles constantly being created and annulated

Building Blocks

The frequency of the wave --
cycles/second -- Hz/second

$$\lambda = \frac{c}{f}$$



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How Waves Travel

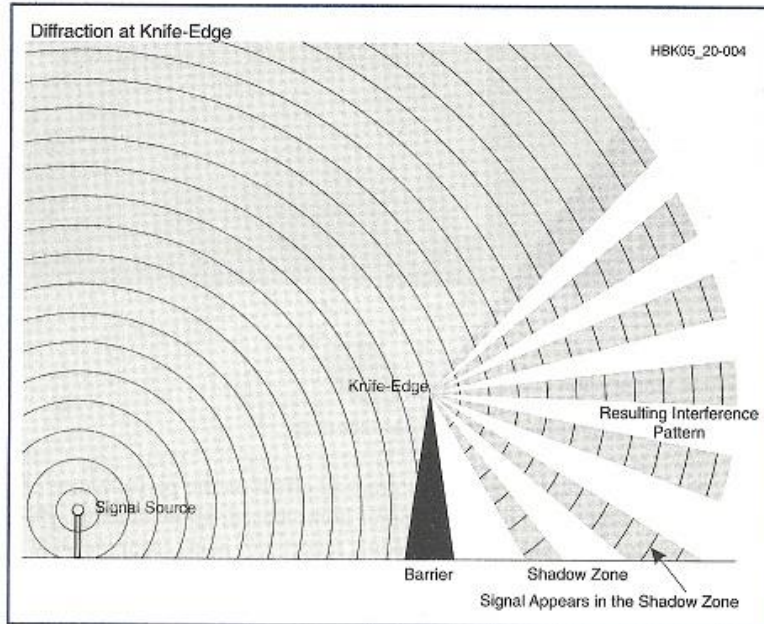
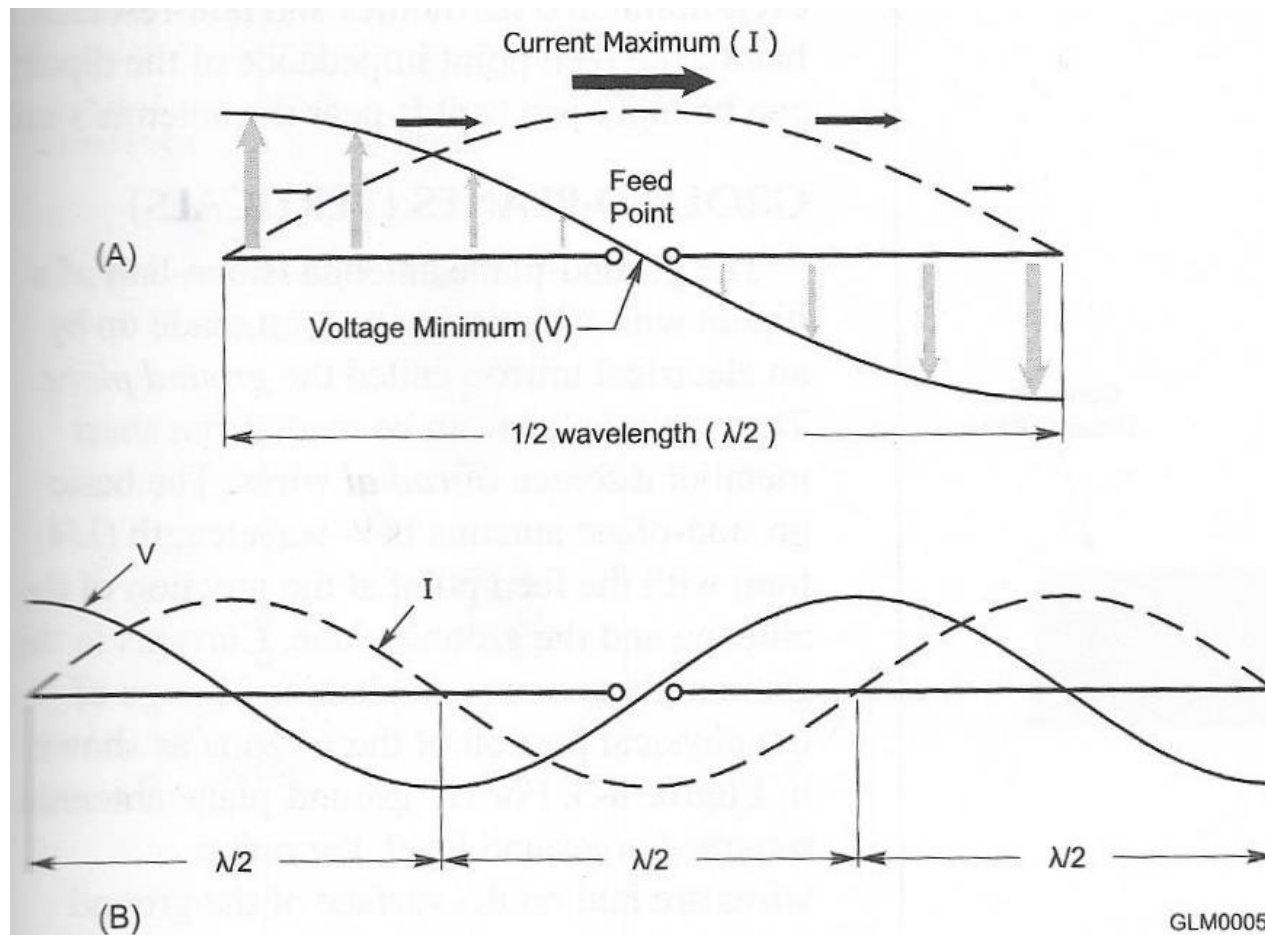
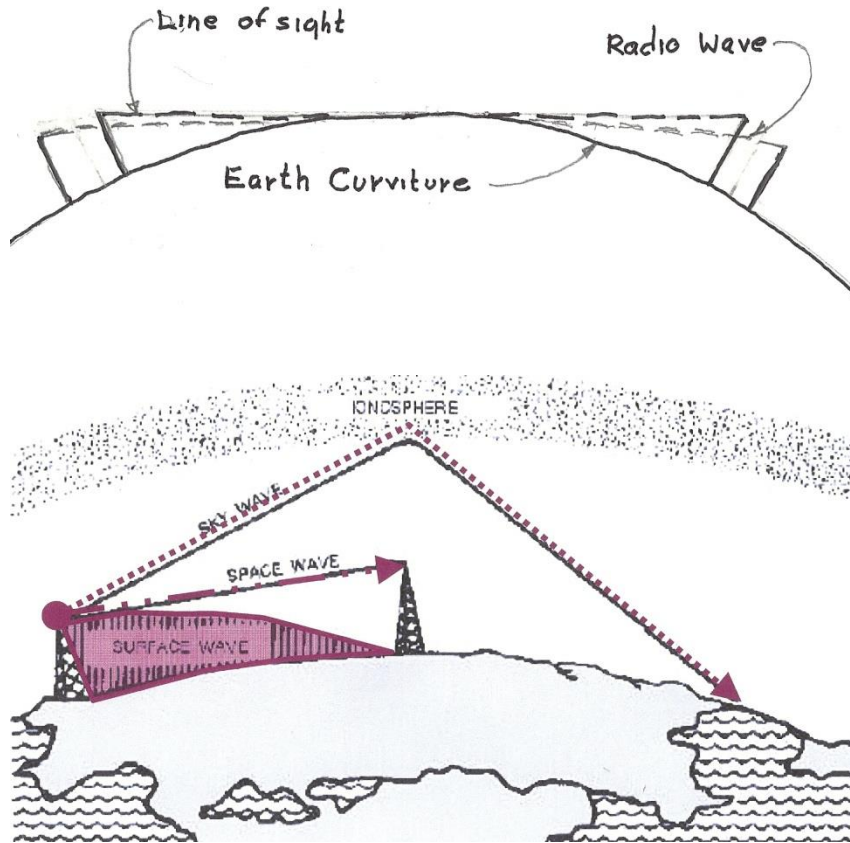


Figure 4-1 — VHF and UHF radio waves are diffracted around the sharp edge of a solid object, such as a building, hill or other obstruction. Some signals appear behind the obstruction as a result of interference between waves that are bent in different ways around the obstruction. The resulting interference pattern creates shadowed areas where little signal is present.

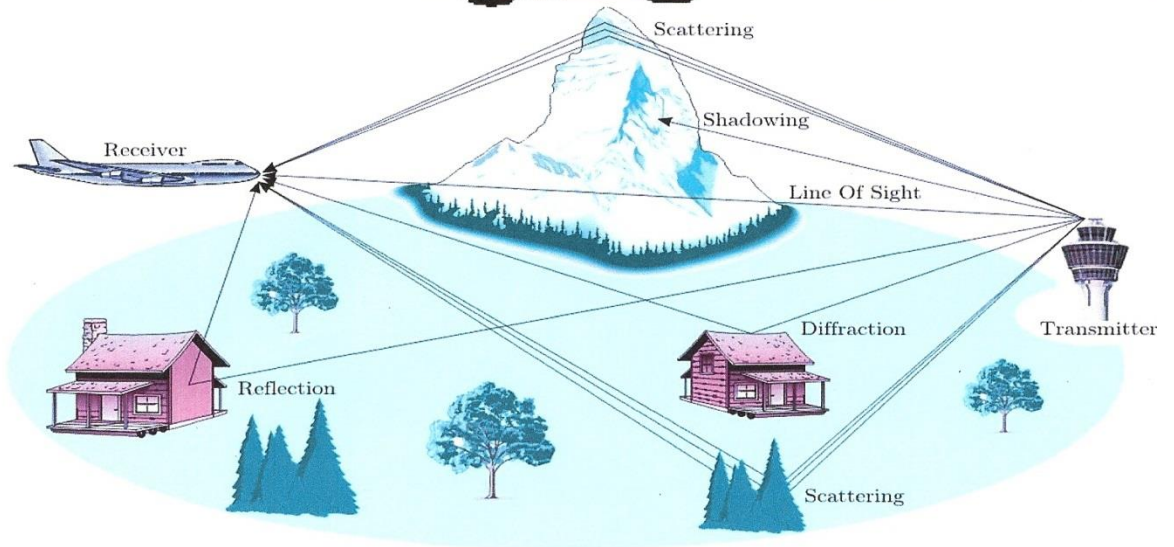
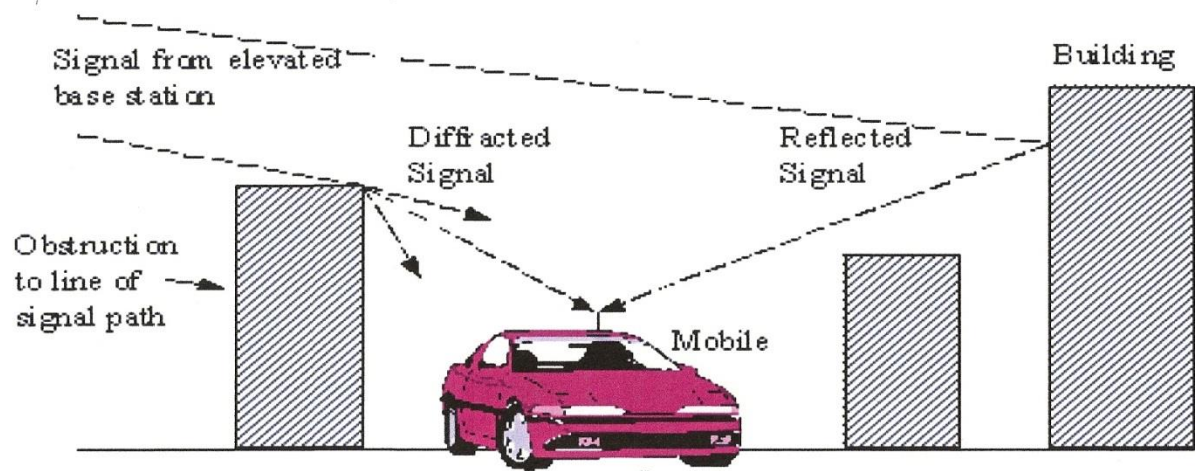
- Waves travel in straight lines **UNLESS**
- *REFLECTED*
- *REFRACTED*
- *DIFFRACTED*
- Wave strength decreases as they travel away from the *ANTENNA because they spread out.*
- A point source antenna in free space is an *ISOTROPIC* radiator.
- Waves travel at the speed of light 300 million meters per second



Radio Horizon

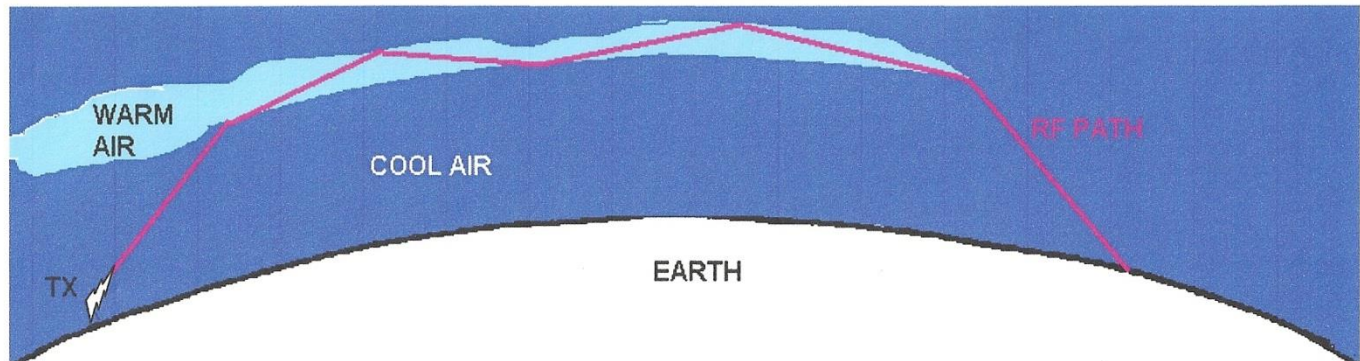


- Curvature of Earth sets range limit for most VHF & UHF frequencies.
- There is a slight bending due to refraction as the wave travels across the curve.
- Higher antenna and higher power increases range.
- Buildings or mountains along the path can reflect or block the waves.
- If signals arrive after taking different paths they interfere with each other. (Multipath).
- Waves can penetrate buildings if the openings are at least as long as $\frac{1}{2}$ wavelength.



UHF, VHF, SPORADIC E, AURORAS, DUCTING

Temperature Inversion / Troposphere Ducting: Certain weather conditions produce a layer of air in the Troposphere that will be at a higher temperature than the layers of air above and below it. Such a layer will provide a "duct" creating a path through the warmer layer of air which has less signal loss than cooler layers above and below. These ducts occur over relatively long distances and at varying heights from almost ground level to several hundred meters above the earth's surface. This propagation takes place when hot days are followed by rapid cooling at night and affects propagation in the 50 MHz - 450 MHz range (6 meter, 2 meter, 1 1/4 meter and 70 centimeter bands). Signals can propagate hundreds of kilometers up to about 2,000 kilometers (1,300 mi).



What is the radio horizon ?

- A. The distance at which radio signals between two points are effectively blocked by the curvature of the Earth
- B. The distance from the ground to a horizontally mounted antenna
 - The farthest point you can see when standing at the base of your antenna tower.
- A. The shortest distance between two points on the earth's surface.

What is meant by the term “knife edge” propagation ?

- A. Signals are reflected back toward the originating station at acute angles.
- B. Signals are sliced into discrete beams and arrive via different paths.
- C. Signals are partially refracted around solid objects exhibiting sharp edges.
- D. Signals are propagated close to the band edge exhibiting a sharp cut off.

T3C05

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- A. Radio signals move somewhat faster than the speed of light.
- B. Radio waves are not blocked by dust particles.
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What causes “tropospheric ducting” ?

- A. Discharges of lightening during electrical storms.
- B. Sunspots and solar flares.
- C. Uplifts from hurricanes and tornadoes.
- D. Temperature inversions in the atmosphere.

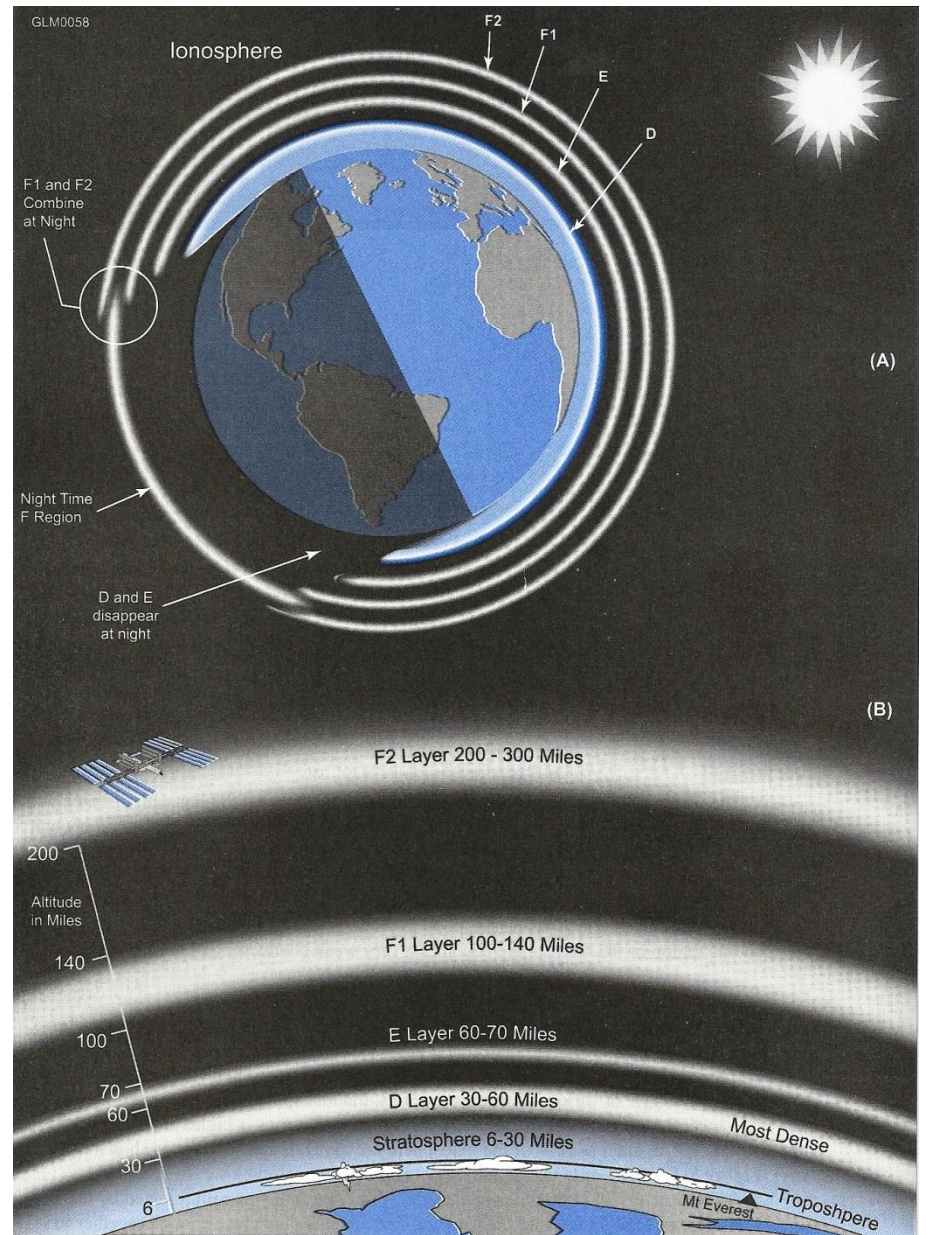
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THE

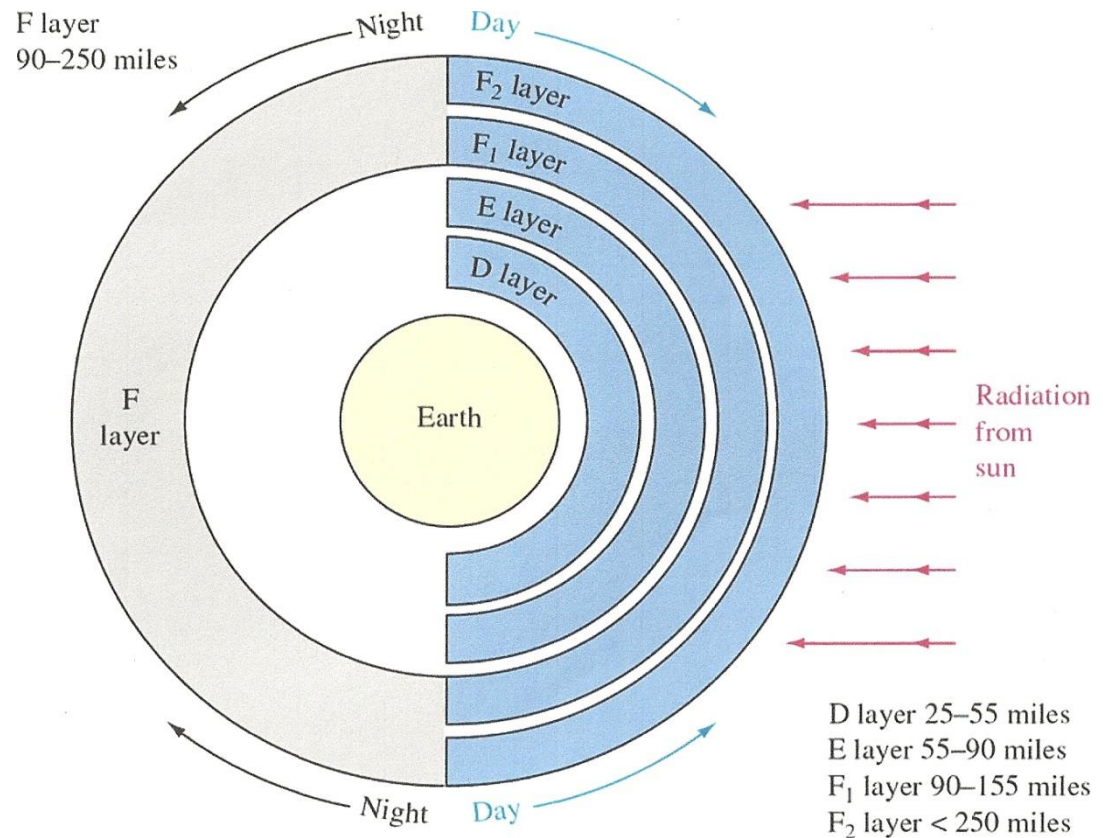
IONOSPHERE

- The region above the Earth from 30 miles to 260 miles.
- Above 260 miles it's the vacuum of space. (no air)
- Oxygen and Nitrogen in the Ionosphere is exposed to intense ultraviolet radiation from the Sun which knocks off electrons creating positively charged Ions.
- Regions (layers) of differing charge density are formed. D E F.



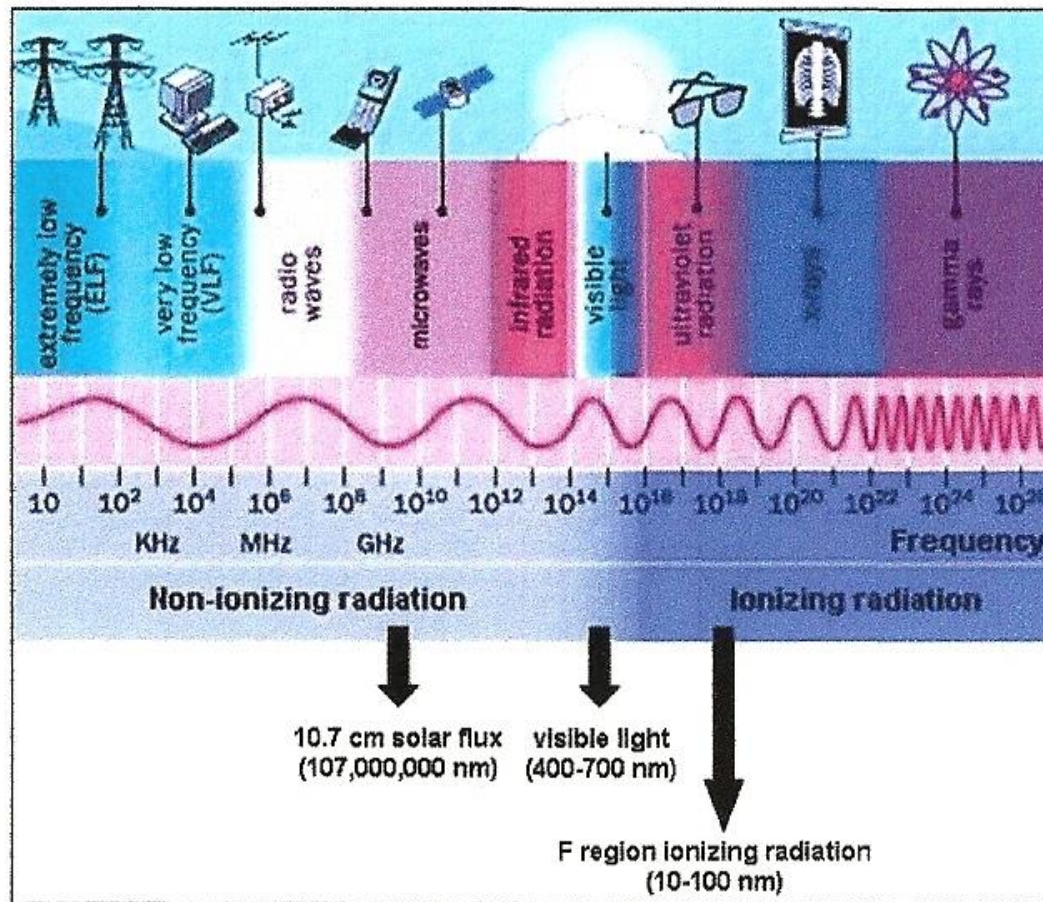
SIMPLIFIED DIAGRAM

- Daylight all layers receive radiation and are charged.
- Night time no radiation and atoms recombine (no charge)
- Well almost no charge, the F regions remain weakly charged and combine to form one region.
- We should be careful with the term layers regions is a better way.
- Area between regions has varying degree of charged ions.



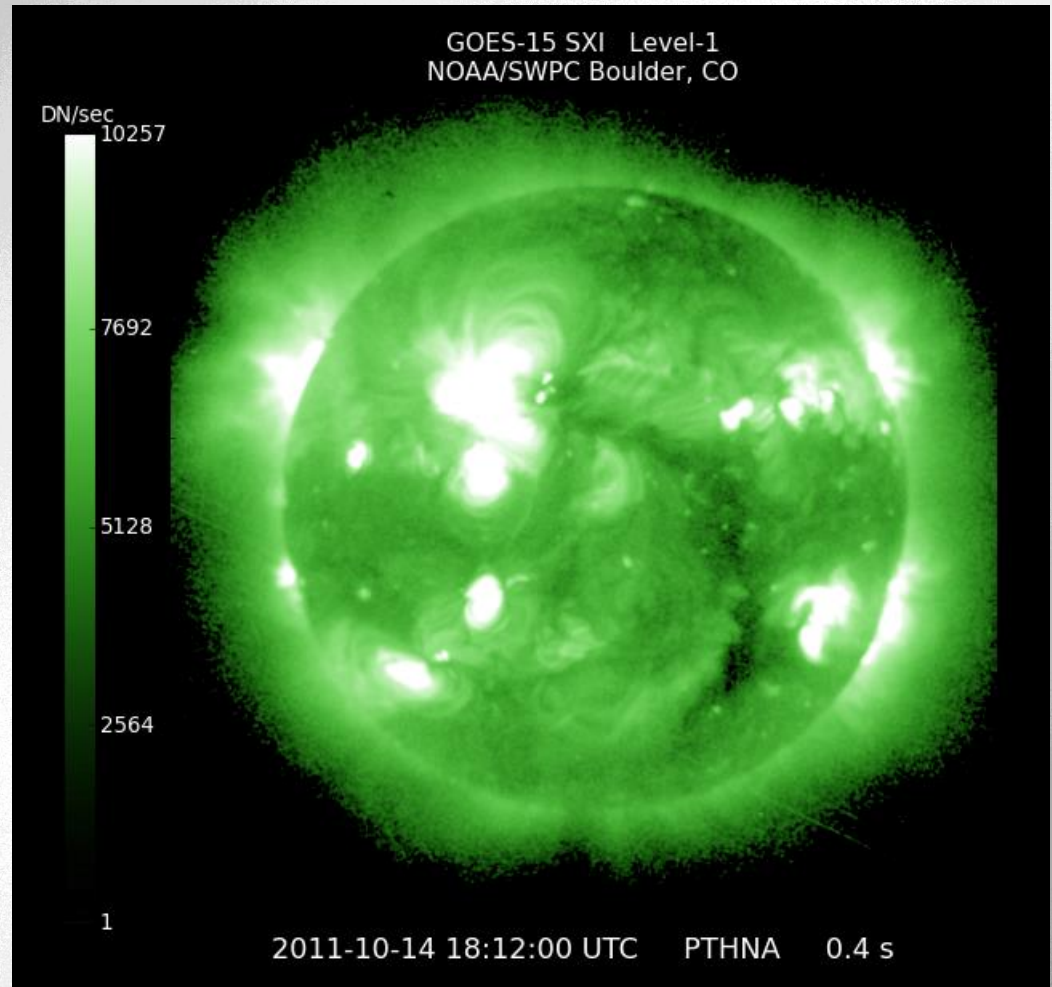
The Electromagnetic Spectrum , Solar Flux, and Ionizing Radiation

- Solar Flux is measured at wavelength of 10.7 cm.
- Ionizing radiation is at a wavelength of 10-100 nm no way to measure it until very recently.
- Enter - Sun Spots which are known to be associated with high levels of ultraviolet radiation.
- Sun spot count was used as a proxy for uv in developing forecast programs.



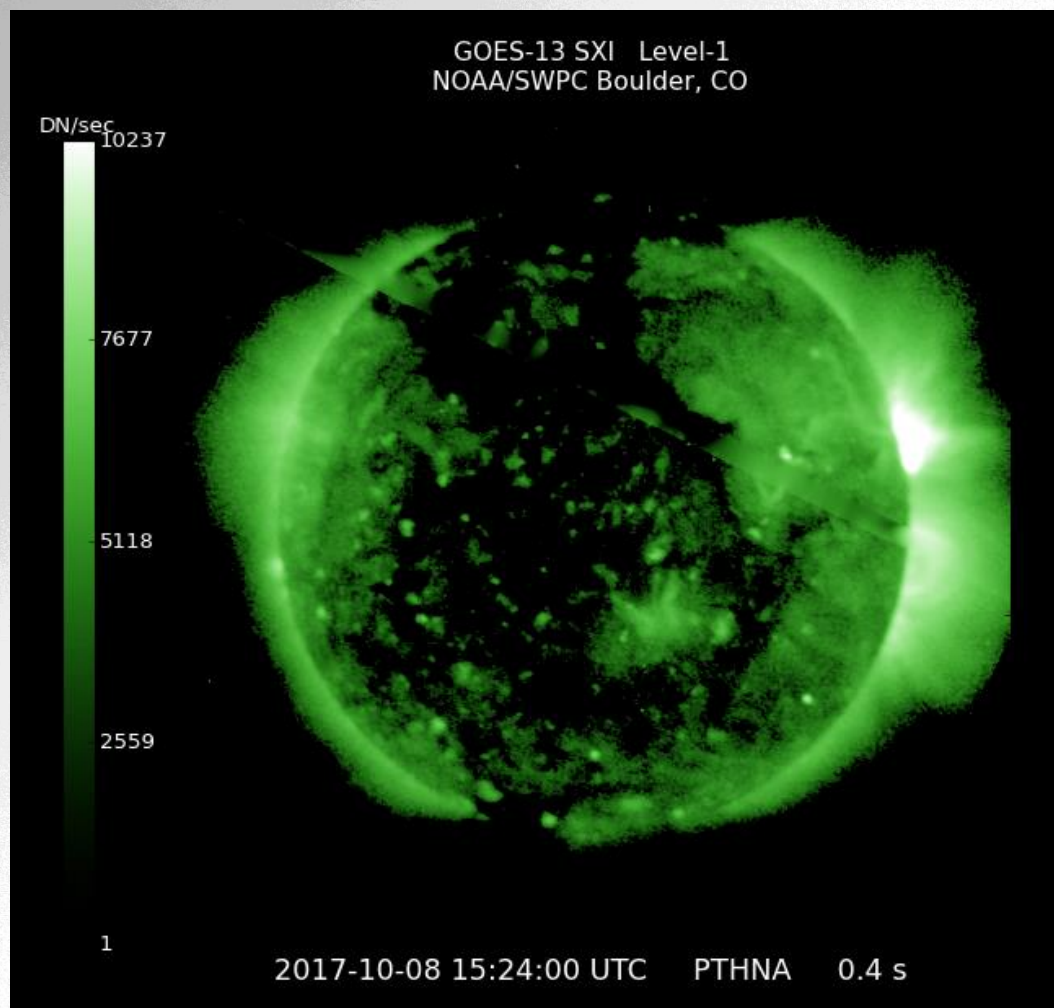
Sun Spots

- The sun spots seem to move across the surface of the sun because the sun rotates each 28 days.
- The number and size of sun spots varies.
- The more spots the higher is the uv (ionizing) radiation
- Higher radiation charges the ionosphere to higher levels.



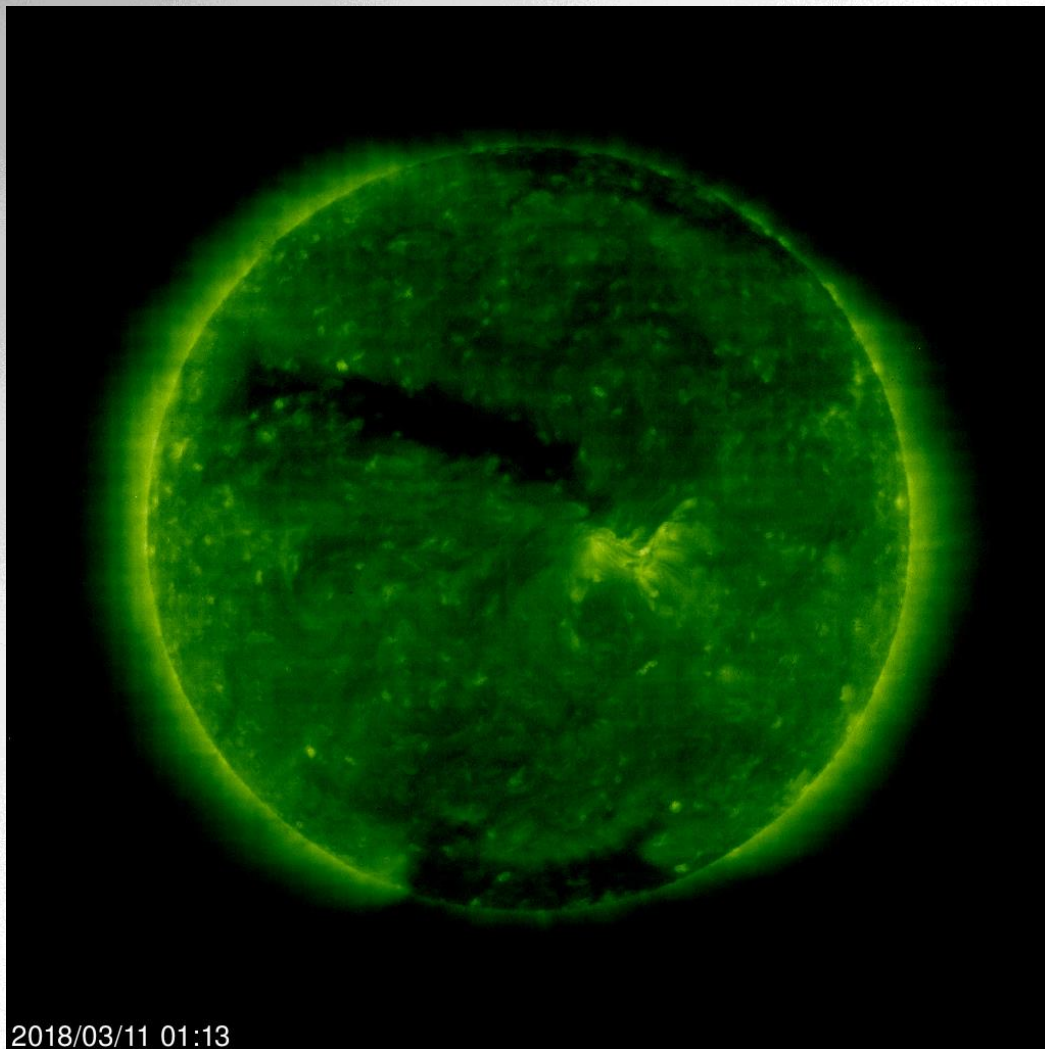
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Recent picture 2017



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Most Recent



2018/03/11 01:13



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Sun Spot Cycle

- The number of Spots at any one time varies from none to almost 200 during an 11 year period known as the solar cycle.

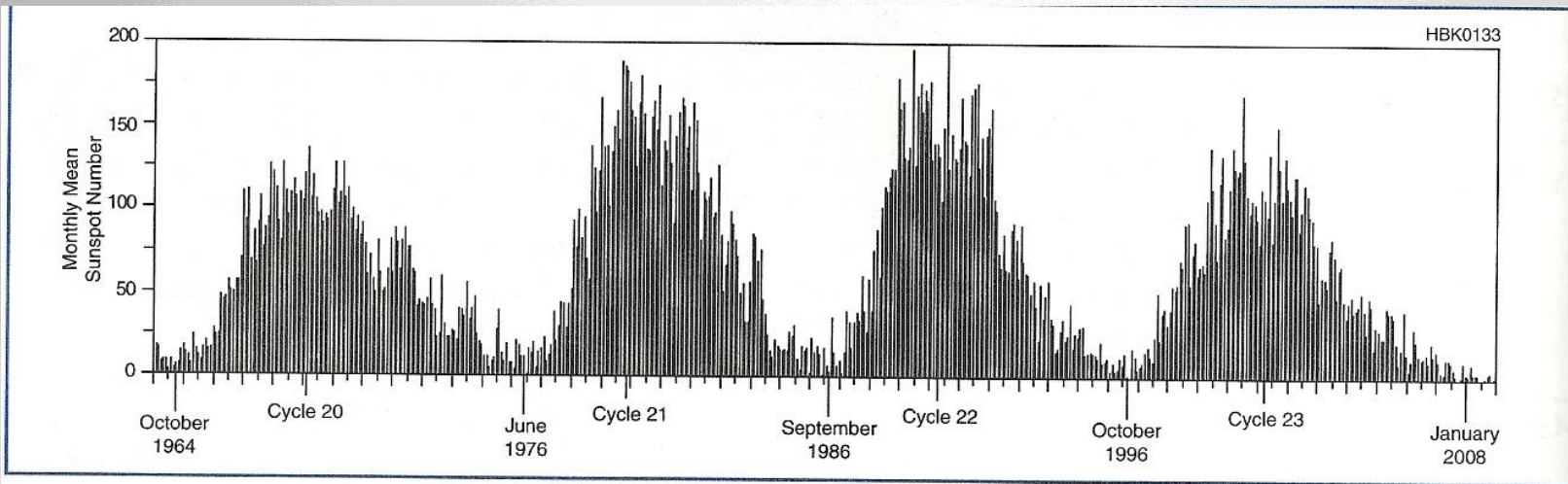


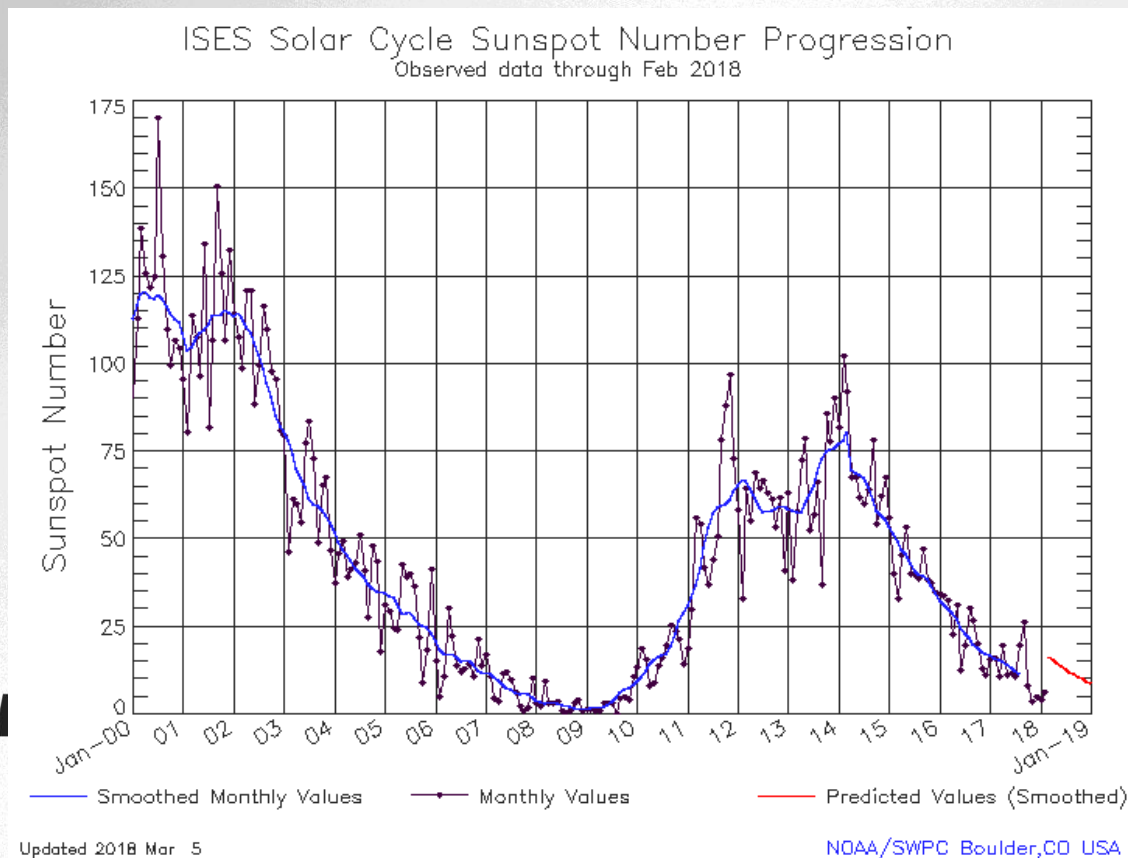
Figure 7-5 — One complete sunspot cycle lasts about 11 years, ramping up and down gradually. This graph shows the monthly sunspot numbers for several past cycles.



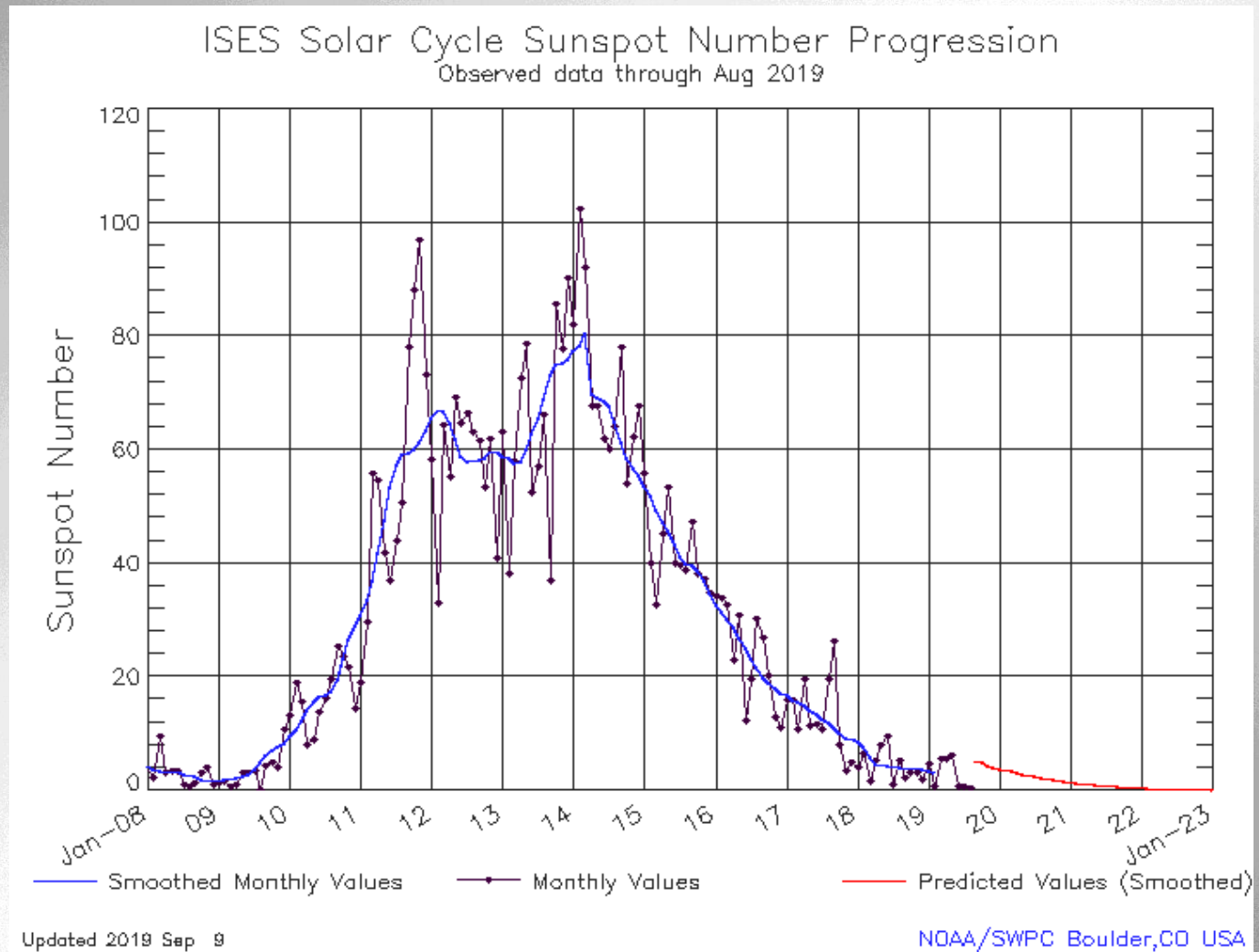
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Cycle 24 (the current cycle)

- Cycle 24 is not yet at the minimum.



Current Prediction



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MF, HF CRITICAL FREQUENCIES

- **Critical Frequency:** the penetrating frequency and the highest frequency at which a radio wave, if **directed vertically upward**, will be refracted back to earth by an ionized layer. Radio waves at a frequency above the Critical Frequency will not be refracted/reflected. This will create a zone around the transmitter that will not receive signals known as the Skip Zone. The size of this zone will vary with the layer in use and the frequency in use.
- **Maximum Usable Frequency (MUF):** the highest frequency that will be reflected back to earth by the ionized layers. Above this frequency there is no reflection and thus no skip. MUF depends on the layer that is responsible for refraction/reflection and so contact between two stations relying on skip will depend on the amount of sunspot activity, the time of day, and the time of year, latitude of the two stations and **antenna transmission angle**. The MUF is not significantly affected by transmitter power and receiver sensitivity
- **Frequency of optimum transmission:** is the highest effective (i.e. working) frequency that is predicted to be usable for a specified path and time for 90% of the days of the month. It is often abbreviated as FOT and normally just below the value of the maximum usable frequency (MUF). The FOT is usually the most effective frequency for ionospheric reflection of radio waves between two specified points on Earth
- **The lowest usable high frequency (LUF):** the frequency in the HF band at which the received field intensity is sufficient to provide the required signal-to-noise ratio. The amount of energy absorbed by the lower regions of the ionosphere (D region, primarily) directly impacts the LUF

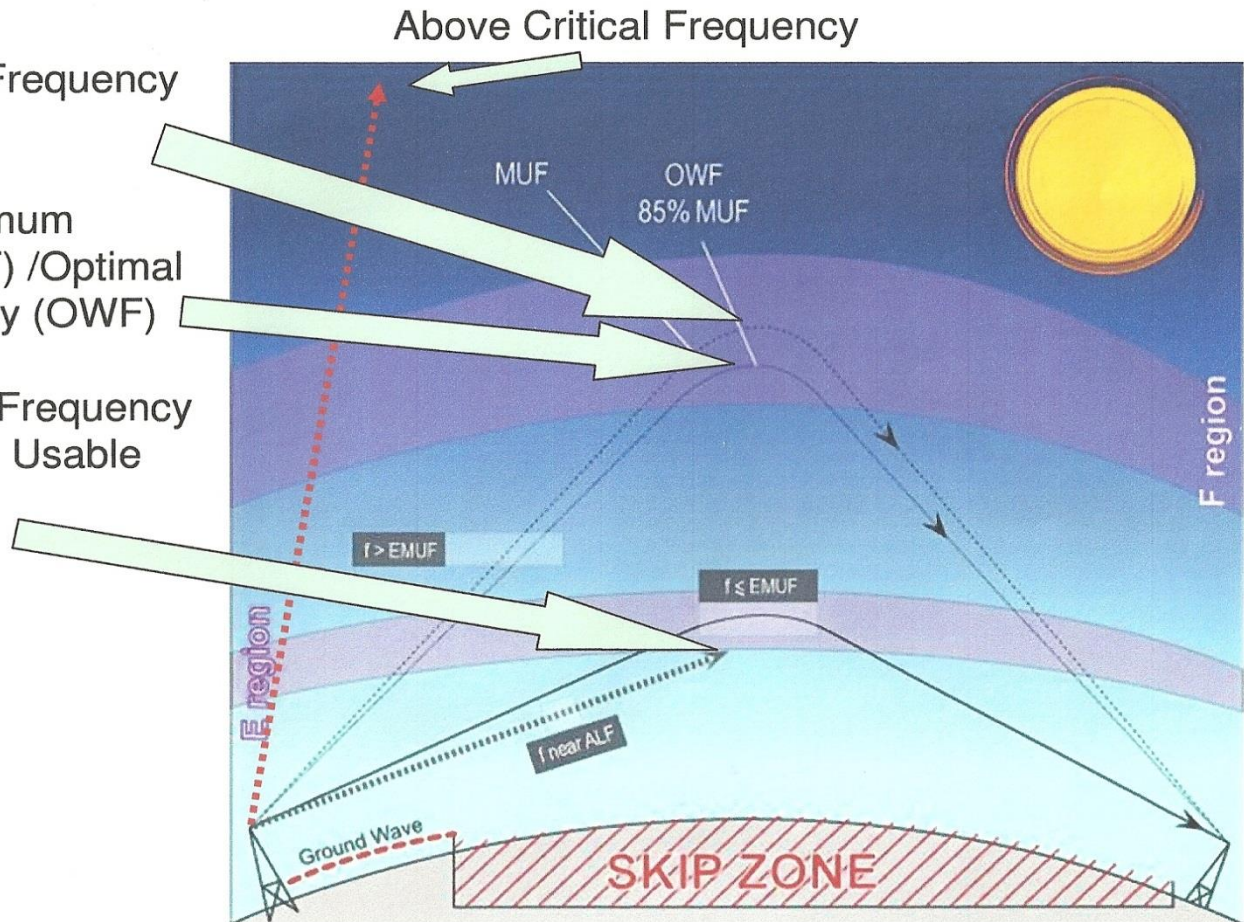
Angle of incidence: is a measure of deviation of something from "straight on", for example in the approach of a ray to a surface.

MF, HF CRITICAL FREQUENCIES

Maximum Useful Frequency (MUF)

Frequency of optimum transmission (FOT) / Optimal Working Frequency (OWF)

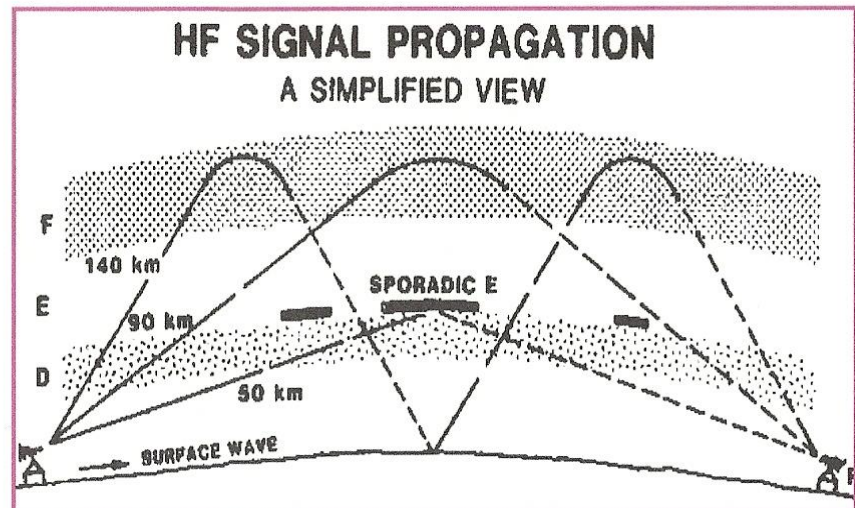
Lower Absorption Frequency (ALF) / The lowest Usable frequency (LUF):



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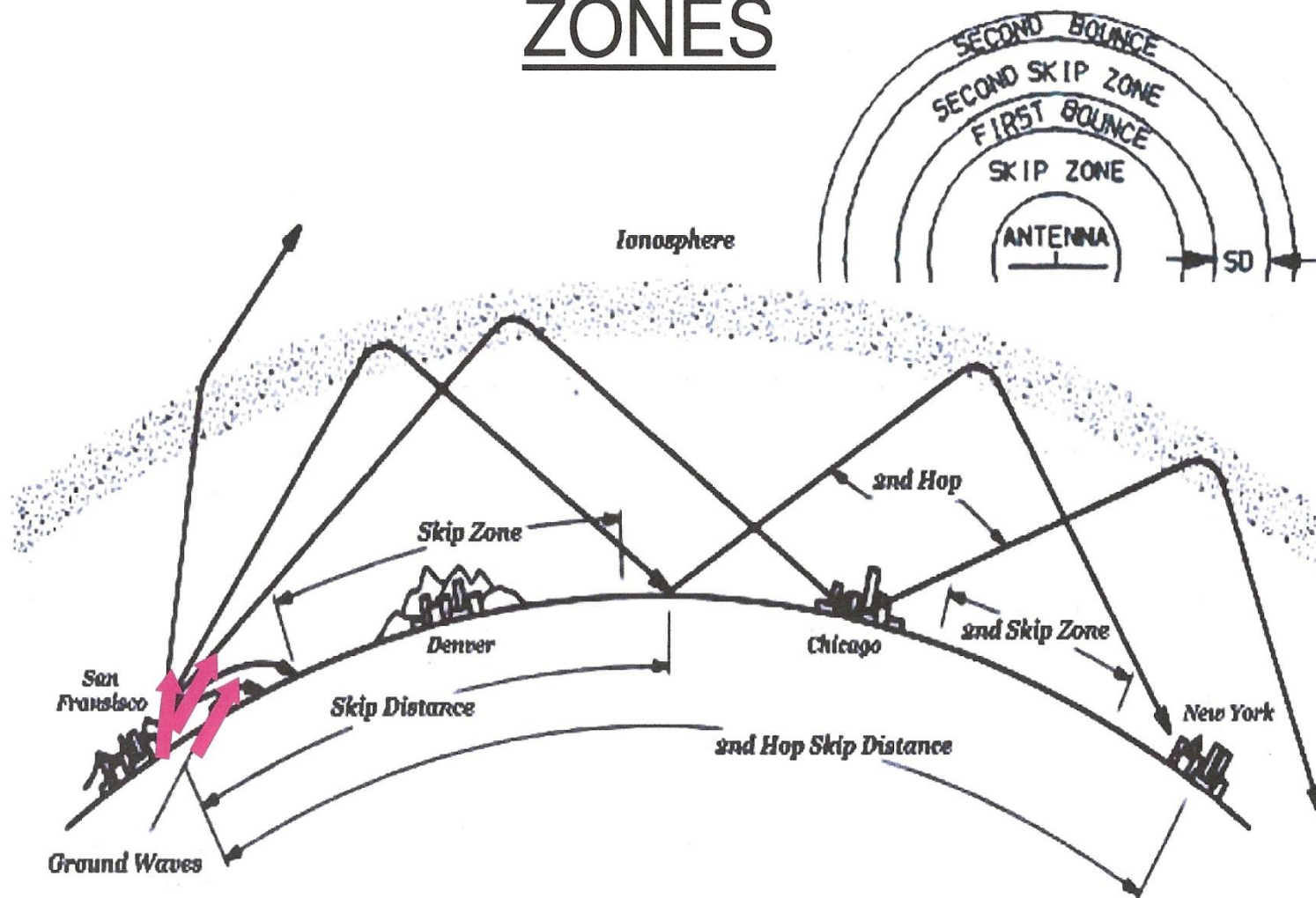
PROPAGATION, HOPS, SKIPS ZONES

- **Multihop:** via the F2-layer can reach DX stations in doing several hops communicating on the other side of the Earth.
- It's subject to fading and attenuation each time the radio wave is reflected or partially refracted at either the ground or ionosphere results in loss of energy signals, can also be stable with few attenuation if the ionospheric absorption is very weak.
- 20 and 15m are the best for this type of traffic. In these bands you can work stations located over 10000 km away, and, from Europe.

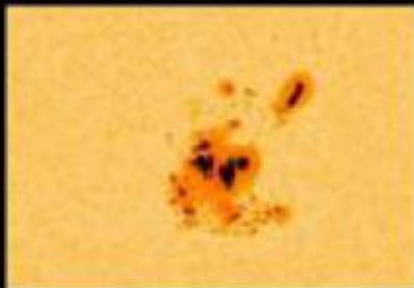
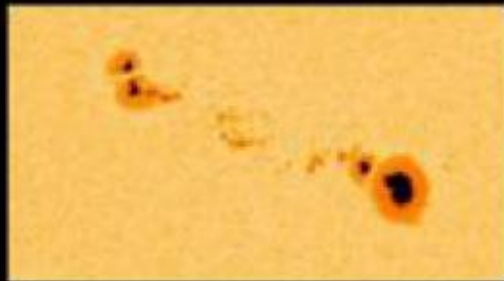


PROPAGATION, HOPS SKIPS

ZONES



Sun Spots



Top Left: Sunspot Group, Bottom Left: Sunspot Group, Right: Sunspot Group

CRITICAL ANGLE

- The enemy of propagation is absorption.
- Waves passing thru the D layer are partially absorbed.
- D layer does not refract signals well, if at all.
- Waves below 10 MHz are more susceptible to absorption and may be completely absorbed during the daylight hours especially the lower frequencies.
- Higher HF frequencies are refracted more easily when ionization is high and are less absorbed.

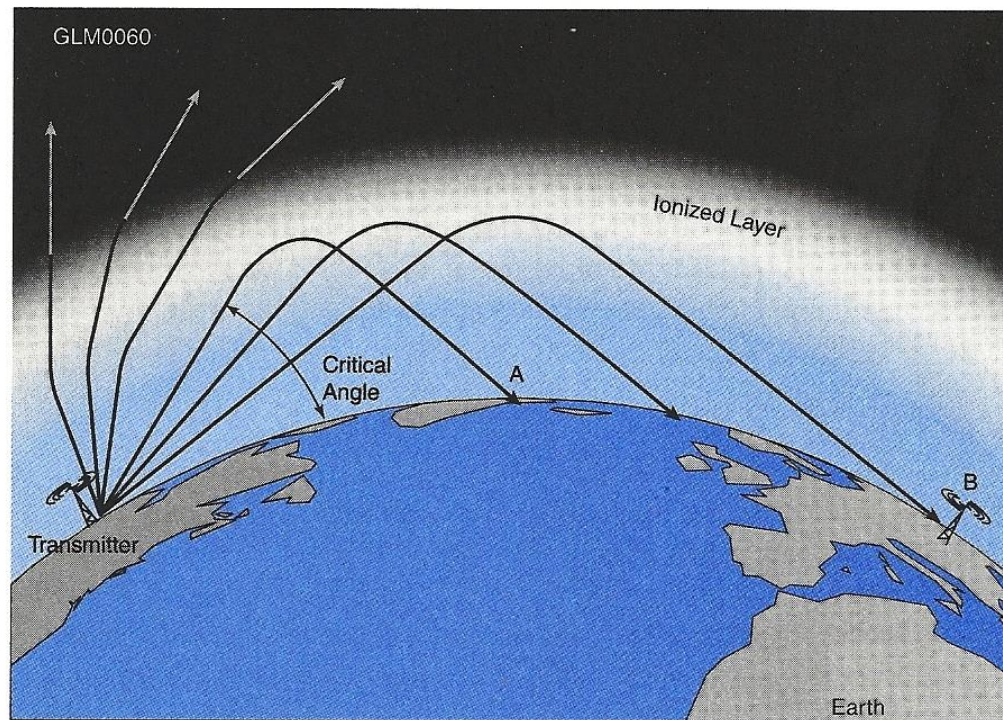


Figure 7-3 — Waves that leave the transmitter above the critical angle are refracted in the ionosphere, but not enough to return to Earth. Waves at and below the critical angle will return to Earth. The lowest angle waves return to Earth at the greatest distance, which is why low angles of radiation are often best for contacting DX stations.



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Long Path and Short Path

- Most contacts are made via the short path.
- Sometimes propagation is not supported in that direction and going “the long way around” is.

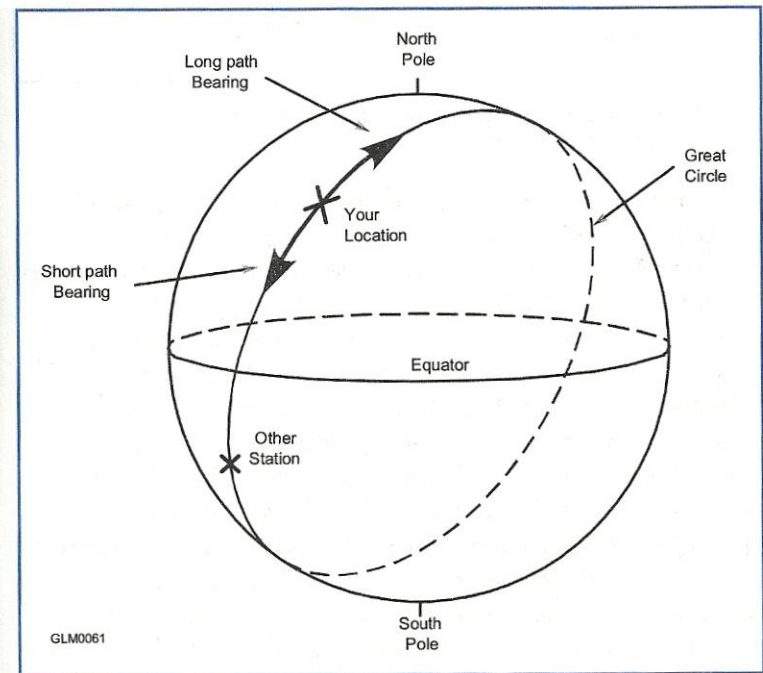
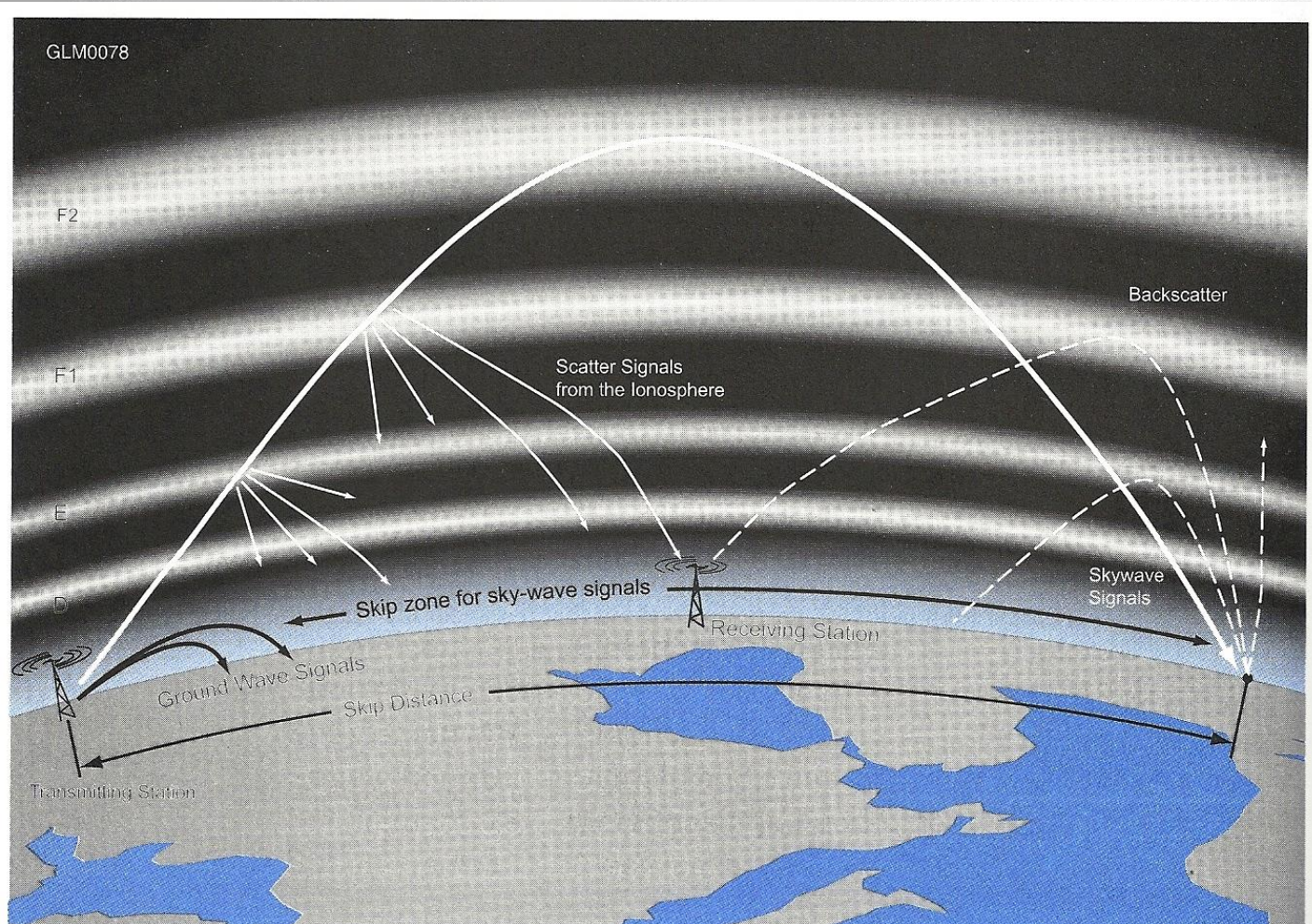


Figure 7-4 — This sketch of the Earth shows both great circle paths drawn between two stations. The bearings for the short path and the long path are shown from the Northern Hemisphere station.

Scatter Modes

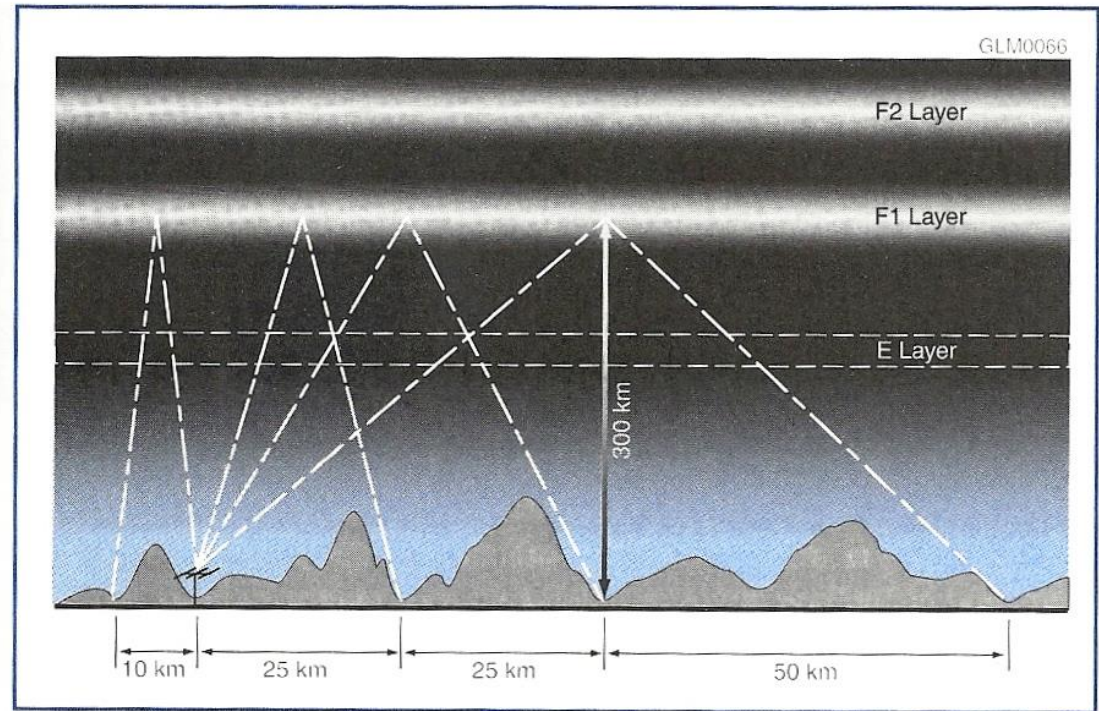


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NVIS

Near Vertical Incident Sky wave

- Signals below the critical frequency are reflected by the ionosphere.
- Critical frequency is always above 5 MHz
- Consecrated signals arriving vertically are scattered over a wide area. (up to 300 miles)
- Accomplished by placing a horizontal antenna close to the ground.



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HF Propagation Summary

HF Band (meters)	Center Frequency	Daytime	Nighttime
160 80 60	1.9 MHz 3.75 MHz 5.37 MHz	Local and regional up to about 200 miles (Ground Wave)	Local to long distance. DX best near sunset or sunrise at one or both ends. (less absorption)
40 30	7.15 MHz 10.125 MHz	Local and regional up to about 400 miles	Short and medium distances up to worldwide (ground wave and sky wave)
20 17	14.175 MHz 18.118 MHz	Regional to long distance, opening near sunrise closing at night. (Sky Wave)	Often open to the west at night and maybe 24 hours a day
15 12 10	21.225 MHz 24.895 MHz 28.85 MHz	Long distance opening to the East after sunrise and to the West in the afternoon. (Sky Wave)	Local via LOS 24 hours Closed for sky wave at night



Predicting Propagation

- Solar activity monitored round the clock by observatories all over the world.
- Sun Spot numbers and three primary indices are used
 1. Solar Flux Index (SFI), amount of extreme UV (10.7 cm 2800 MHZ)
 2. K index, values from 0 to 9 indicate short term stability of the Earth's magnetic field.
 3. A index, based on previous 8 K index values worldwide indicates long term stability of the magnetic field. 0 stable to 400 greatly disturbed.

Prediction Programs & Information

- ARRL – ARLPO44deK7RA (Propagation Bulletin)
- NOAA /NWS.Spaceweather
- QRZ.COM

Software

- Several software programs predict MUF and LUF for path to the desired contact. MUF and LUF are different for each path.
- Choose frequency just below MUF (absorption is lower at higher frequencies)
- Use lower take off angles for DX so fewer number of hops are required.
- LUF represents lowest frequency for which propagation exists between 2 points. Lower than LUF will be completely absorbed.
- No substitute for LESTENING, prediction software is not perfect and cannot take into account short term variations or unusual paths.



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BEACONS - 10 METERS

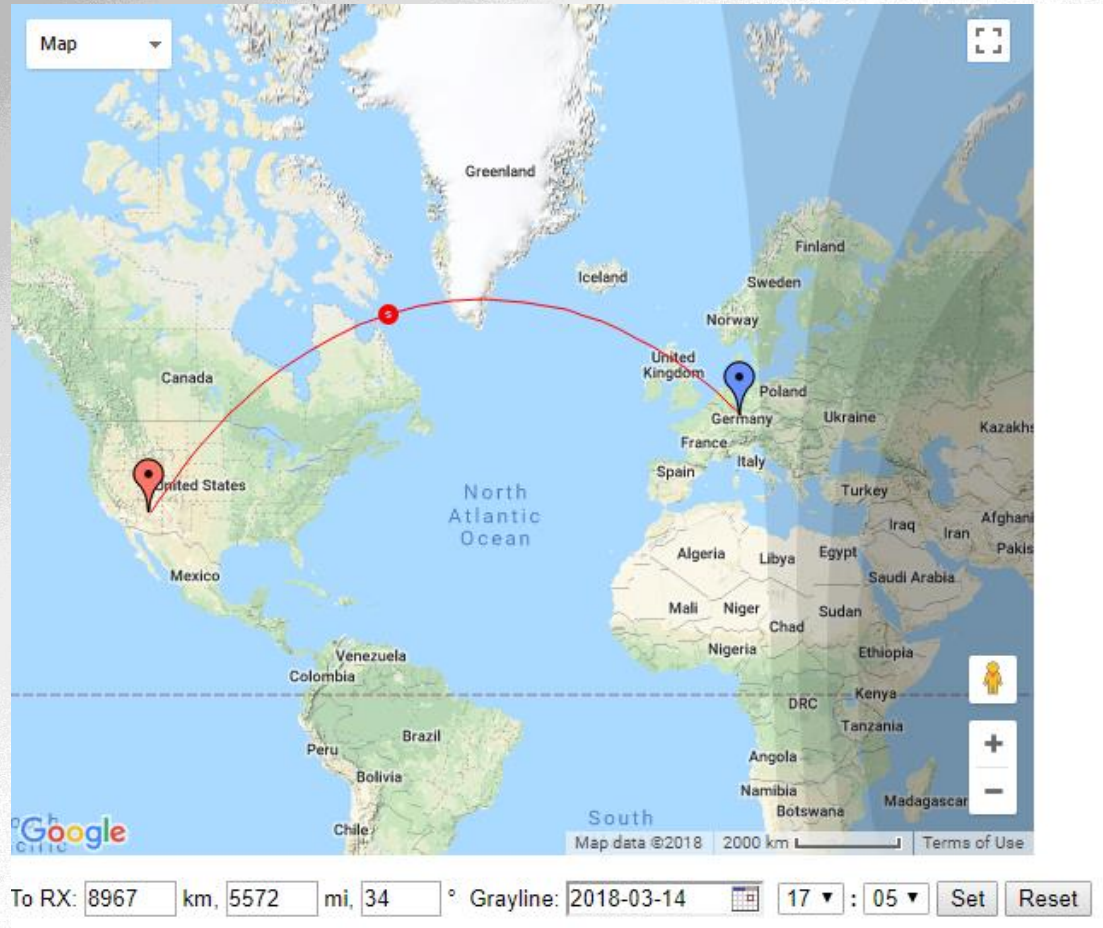
Operated by Amateur operators to determine propagation conditions. Ten meter beacons can be found between 28.175 and 28.300 MHZ. Beacons usually identify their location and power output by CW. Amateur operators can use this information to determine if favorable conditions exist between their location and the beacon's

NCDXF/IARU International Beacon Network

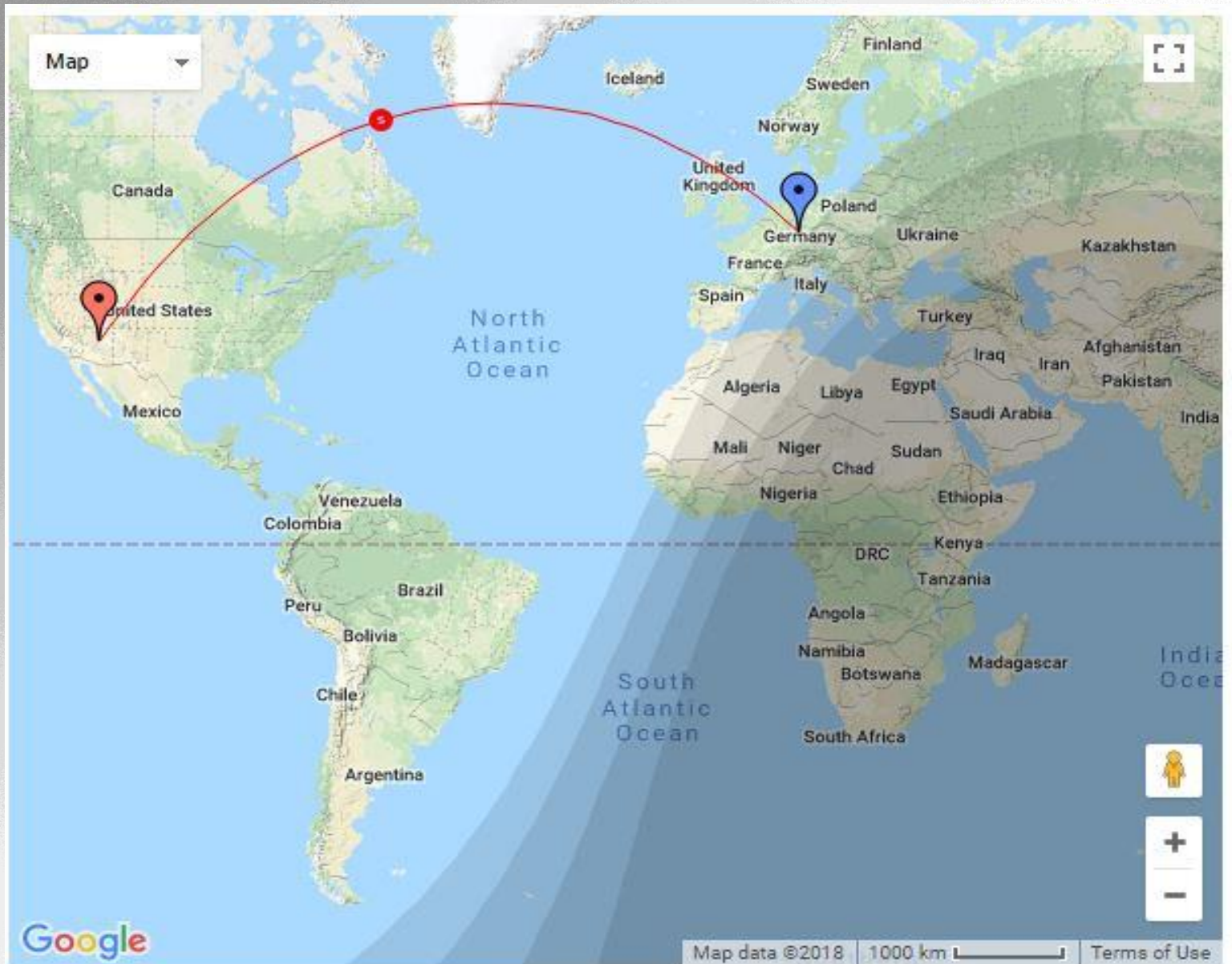


VOACAP

Voice Of America Coverage Analysis Program



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