PROPAGATION

Ionosphere and solar activity

Propagation

- - the study of the movement of radio waves through various mediums (air, ground, water, etc.)

Some Fundamentals

- All radio waves are the result of the acceleration of charged particles: f=ma
- Refraction is the bending of radio waves as a result of moving from one medium to another
- Radio waves generally attenuate with distance (inverse square law)
- Polarization of an electromagnetic wave is defined as the polarization of the electric field
- Electric field is the same polarization as the antenna

Ionosphere

- Starts at about 60 miles in altitude and ends at about 500 miles
- It consists of layers but the lines of demarcation between and within layers is a but fuzzy
- In a neutral atom there are equal charges (positive and negative), so there is n net charge for an intercepting radio signal to interact with

Ionosphere (cont.)

- To prepare a particle to respond to a , the radio signal, the electrons must be separated from the protons (or the nucleus) – a process called *ionization*
- The primary ionizing agent is radiation from the sun, primarily ultraviolet (UV)
- Not all atoms are ionized, so we have a mixture of ions and neutrals in the ionosphere

Ionosphere (cont.)

- The greatest amount of ionization should occur on the side facing the sun and at high noon
- There is a high degree of correlation between the height of the sun and the maximum usable frequency (MUF)
- The unpredictability of ionospheric propagation is due to the mixture of ions and neutrals and their interaction

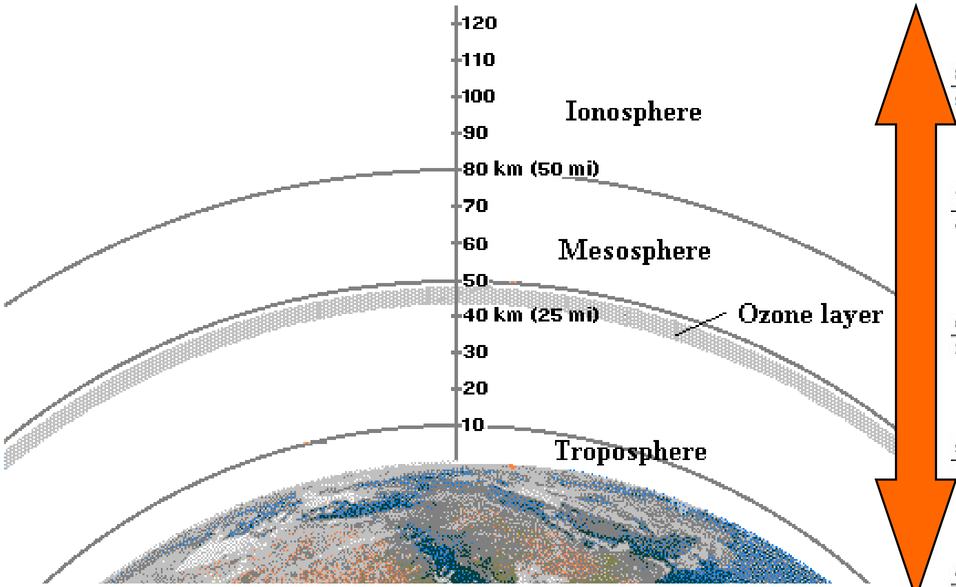
Ionosphere (cont.)

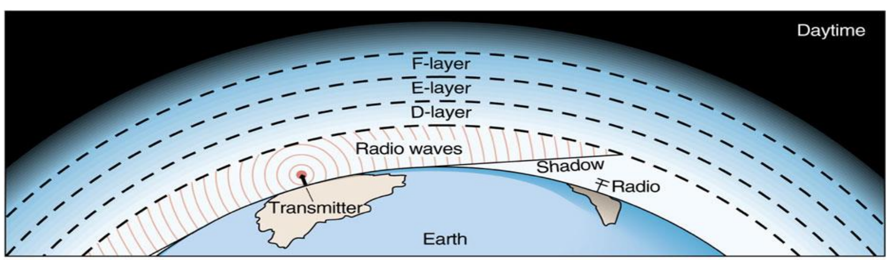
- Air pressure is dependent on altitude so particle density decreases as we move upward
- Since ions come from air, ion density decreases with altitude
- At high altitudes were air pressure is very low its easy to create ions (don’t need a lot of UV)
- Because the ionosphere is a refractor, not a reflector, the speed of a radio wave decreases as it penetrates the ionosphere so it appears that the reflection point is higher than it actually is

Layers of the Ionosphere

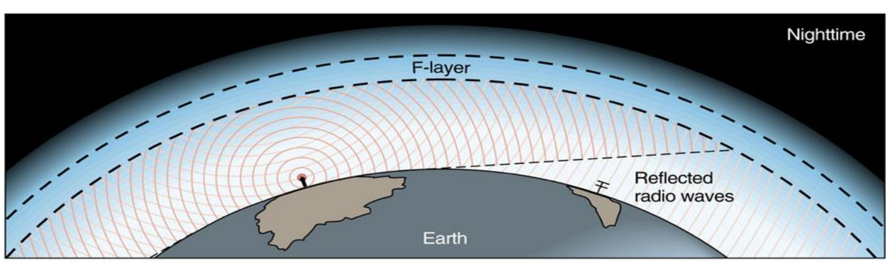
- Below the ionosphere there are three layers (part of our atmosphere)
  - Troposhpere (A layer)
  - Stratosphere (B layer)
  - Mesosphere (C layer)
- These layers are not ionized (radio waves go right through)
- The ionosphere consists of three layers: D, E and F

IONOSPHERE REGIONS





(a)



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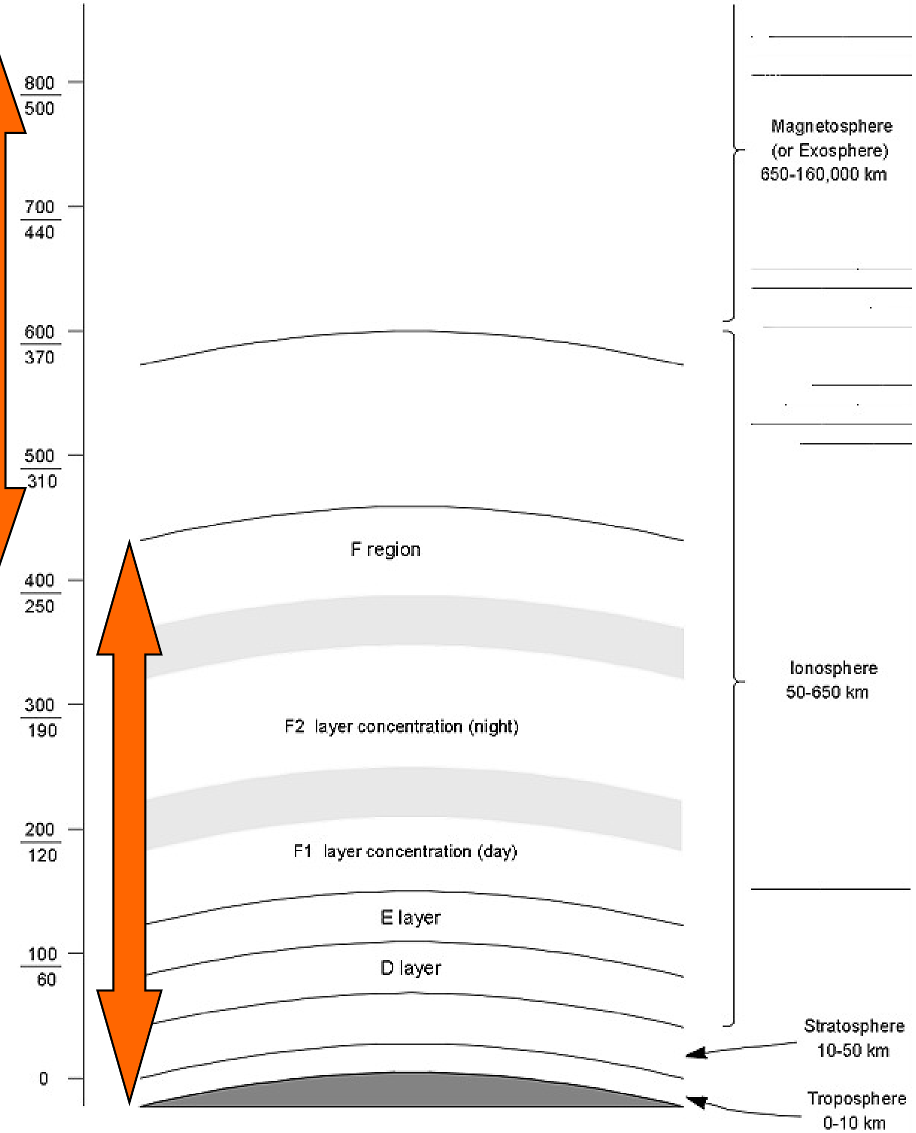


THE IONOSPHERIC LAYERS

The D layer (absportion layer): is the innermost layer, 50 km to 90 km above the surface of the Earth. when the sun is active with 50 or more sunspots, During the night cosmic rays produce a residual amount of ionization as a result high-frequency (HF) radio waves aren't reflected by the D layer. **The D layer is mainly responsible for absorption of HF radio waves**, particularly at 10 MHz and below, with progressively smaller absorption as the frequency gets higher. The **absorption is small at night** and **greatest about midday**. The layer reduces greatly after sunset. A common example of the D layer in action is the disappearance of distant AM broadcast band stations in the daytime.

The E layer: is the middle layer, 90 km to 120 km above the surface of the Earth. This layer can only reflect radio waves having frequencies less than about 10 MHz. It has a negative effect on frequencies above 10 MHz due to its partial absorption of these waves. At night the E layer begins to disappear because the primary source of ionization is no longer present. The increase in the height of the E layer maximum increases the range to which radio waves can travel by reflection from the layer.

The F layer: or region, is 120 km to 400 km above the surface of the Earth. It is the top most layer of the ionosphere. Here extreme ultraviolet (UV) (10-100 nm) solar radiation ionizes atomic oxygen (O). The F region is the most important part of the ionosphere in terms of HF communications. The F layer combines into one layer at night, and in the presence of sunlight (during daytime), it divides into two layers, the **F1 and F2**. The F1 layer consists of oxygen and nitrogen which don’t ionize easily. F2 consists of helium, hydorgen and noble gases which are ionized more easily, so the F2 is available for more hours than the F1.The F layers are responsible for most skywave propagation of radio waves, and are thickest and most reflective of radio on the side of the Earth facing the sun.

Ionospheric Layers

- During the daytime, in periods of high solar activity, the F region splits into two regions
- F2 remains thicker and plays the predominant role in HF communications
- As the sun goes down, the F region retreats from the bottom up (F1 goes away first and the band “goes long”

Ionogram

- Available at: www.digisonde.com/stationlist.php
- A graph generated by an ionosonde, which send short RF pulses straight up and receives the returning signal after reflection from the ionosphere
- The X-axis is the frequency and the Y-axis is the reflection height (km)

Ionogram (cont.)

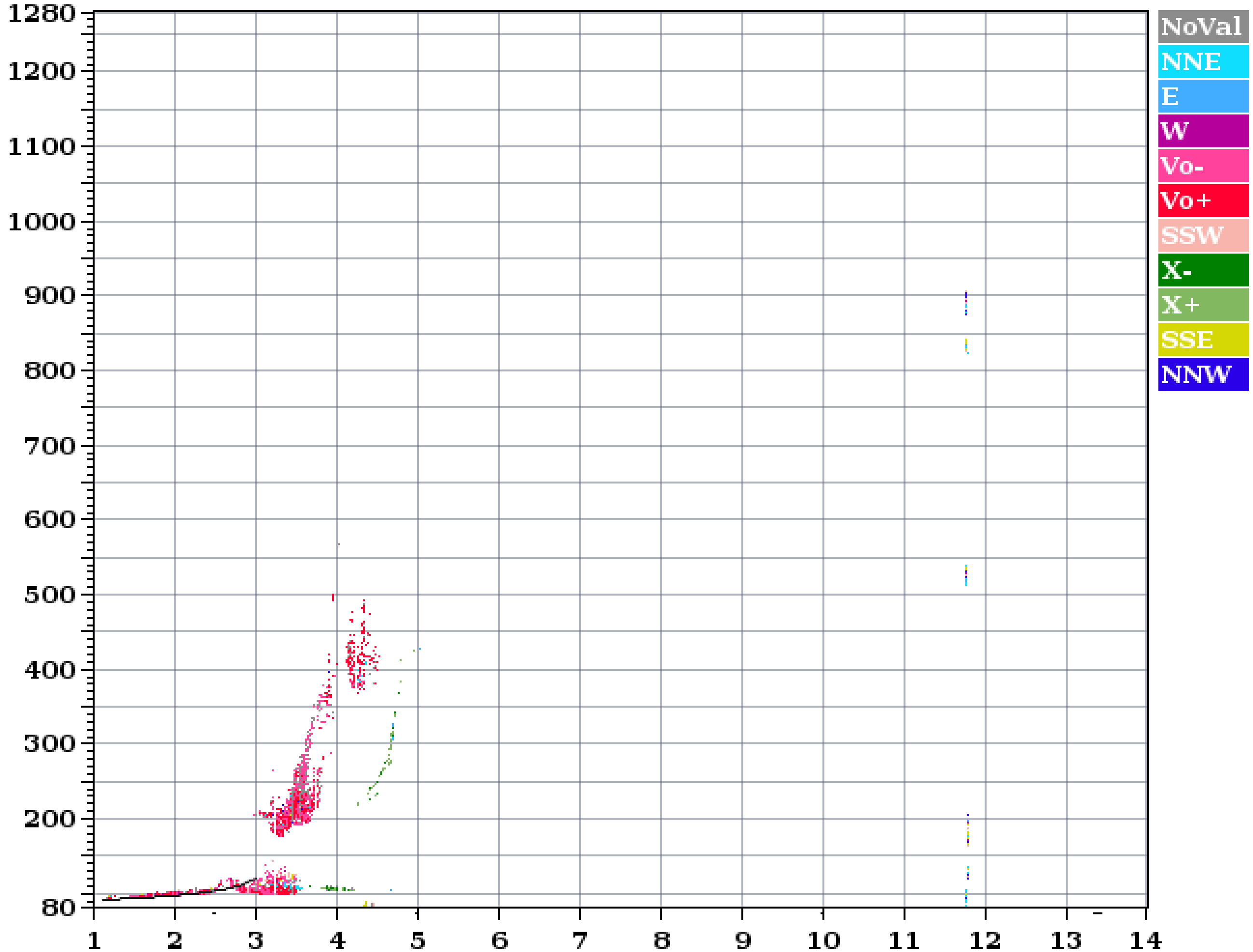
- When the curve becomes vertical, this is the *critical frequency* – the maximum frequency that will be reflected to earth for a vertical incident signal (not the same as MUF but they are related)
- foF2 is the critical frequency for the o-mode (F layer). There is also an E for the E-layer
- At the bottom, D is the distance per hop (km) – MUF increases proportionately to D

Lowell DIGISONDE

Statio YYYY DAY DDD HHMMSS P1 FFS S AXN PPS IGA PS
ALPENA 2019 Aug08 220 150000 RSF 005 2 713 100 03+ 79

foF2	N/A
foF1	N/A
foF1p	4.06
foE	3.00
foEp	2.99
fxI	N/A
foEs	3.63
fmin	1.13
MUF(D)	N/A
M(D)	N/A
D	N/A
h`F	N/A
h`F2	N/A
h`E	92.1
h`Es	100.0
hmF2	N/A
hmF1	N/A
hmE	N/A
yF2	N/A
yF1	N/A
yE	N/A
B0	N/A
B1	N/A
C-level	N/A

Manual:
SAO Explorer
Unknown Scaler



D	100	200	400	600	800	1000	1500	3000	[km]
MUF	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	[MHz]

70854675.tmp / 520fx512h 25 kHz 2.5 km / DPS-4D AL945 045 / 45.1 N 276.4 E

ShowIonogram v 1.0

Ionogram (cont.)

- Distance per hop is a function of the vertical launch angle and the reflection height
- MUF is dependent on the angle of the wave penetrating the ionosphere
- FxI is the critical frequency for the X-mode

Solar Activity

- The Sun’s atmosphere contains three parts:
  - Photosphere
  - Chromosphere
  - Corona
- The outer layer of the Sun contains a convection zone where hot gases are moved upward and downward on their way to the surface

Sunspots

- The surface of the Sun consists of *granules* – rising columns of hot gas surrounded by dark lanes which are cooler gas descending into the interior (last about 15 minutes, but 40% seem to explode, expanding horizontally)
- Sunspots are cool relatively dark on the photosphere caused by magnetic fields which become bent by differential rotation

Sunspots

- They are between 2500 km to 50,000 km in diameter and last from less than an hour to several months
- They are generally found in groups
- They have a dark central core – the *umbra*, and a brighter border – the *penumbra.* The umbra is about 4300 K and the penumbra is 5000 K (photosphere is 5800 K

Sunspots (cont.)

- The area around the sunspot is called an active region because flares and other events occur there
- Sunspots are associated with intense magnetic fields on the Sun
- The solar atmosphere is a gaseous mixture called *plasma* where elecrically charged ions and electrons move freely and are deflected by the magnetic field resulting in a region where the gas is relatively cool

Sunspots (cont.)

- The Sun rotates at different speeds (called differential rotation). At the equator it takes 25 days for a complete rotation while at the poles it takes 36 days
- This differential rotation causes the magnetic field in the photosphere to become wrapped around the Sun (east to west)
- As a result, the magnetic field becomes concentrated at certain latitudes on either side of the equator

Sunspots (cont.)

- Convection in the photosphere creates tangles in the concentrated magnetic field, and “kinks” erupt through the solar surface
- Sunspots appear where the magnetic field protrudes through the photosphere
- Sunspots go through a somewhat regular 11-year cycle.
- This cycle can be explained by the Babcock model

Babcock Model

- Starting from sunspot minimum, the magnetic field of the Sun is weak
- Magnetic lines emerge at latitudes greater than 55 degrees and connect back to the opposite polar region
- Since the rotation period is shorter at the equator, the equatorial field lines become stretched and twisted which increases the magnetic field strength

Babcock Model (cont.)

- Eventually twisted ropes of magnetic field lines erupt as loops through the Sun's surface and produce regions where sunspots appear
- Near the end of the cycle, the subsurface magnetic field is stretched and twisted so much that active regions of sunspot groups form near the equator
- Groups from the north and south have opposite magnetic polarity, so when they meet at the equator, they cancel each other out

Babcock Model (cont.)

- The Sun’s polarity pattern completely reverses itself every 11 years
- The hemisphere that has preceding north magnetic poles during one 11-year cycle will have preceding south magnetic poles during the next cycle
- North and south magnetic poles of the Sun reverse every 11 years (thus a 22-year cycle)

Sunspots and Propagation

- Ultraviolet radiation from the sun is the chief (though not the only) source of ionization in the upper atmosphere. During periods of low ultraviolet emission the ionization level of the ionosphere is low and radio signals with short wavelengths will pass through and be lost to space. During periods of high ultraviolet emission higher levels of ionization reflect higher frequencies and shorter wavelengths will propagate much longer distances
- The higher the solar activity, the stronger the ionization of the F-layer. A strong ionization of the F-layer increases its reflecting power. Stronger the ionization, the higher the **maximum usable frequency (MUF)**, exceeding regularly 40 or 50 MHz in such occasions.

Numbers

- $SF = 73.4 + 0.73R + 0.0009R^2$
- K index scale is 0-9 (prefer 0 or 1)
- A index scale is 0-400 (prefer 0-4)
- Charged particles are generally disruptive to propagation – best with high solar flux and low magnetic activity

Software

- www.arrl.org/propagation
- www.dxzone.com/catalog/Software