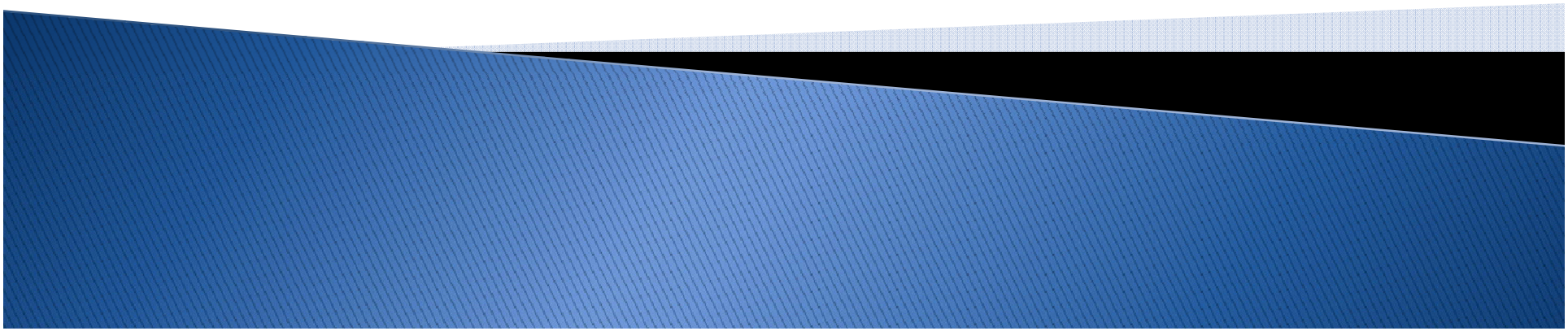
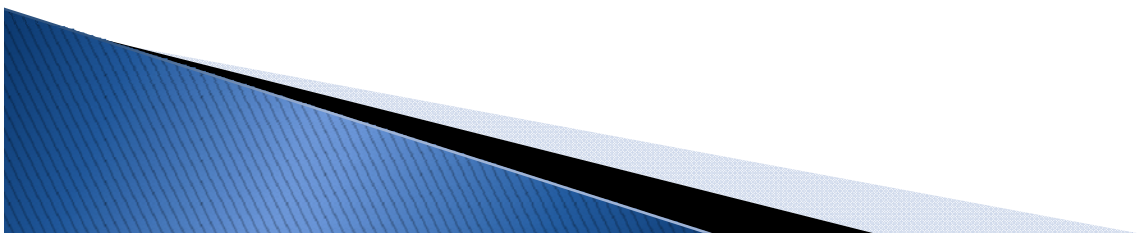
RF Propagation

By Tim Kuhlman, PE
KD7RUS



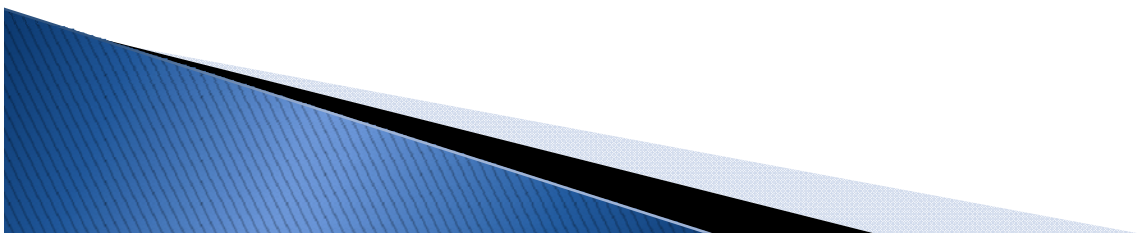
Purpose of this Seminar

- In this seminar we will attempt to answer the following questions:
  - What is RF Propagation
  - What are the different types of propagation?
  - How does our environment affect propagation?
  - How to Predict propagation.



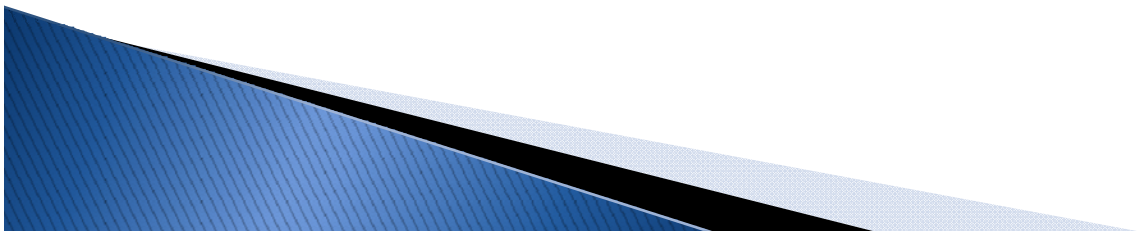
Contents for Discussion

- What are radio signals and how to they react?
- Four Different Modes of Radio Signal Travel
  - Free Space
  - Open Space
  - Ground Wave
  - Sky Wave
- The Earth Ionosphere
  - The D, F, & E Layers
  - The MUF – Maximum Useable Frequency
  - The affects of Sun Spots on the Ionosphere.



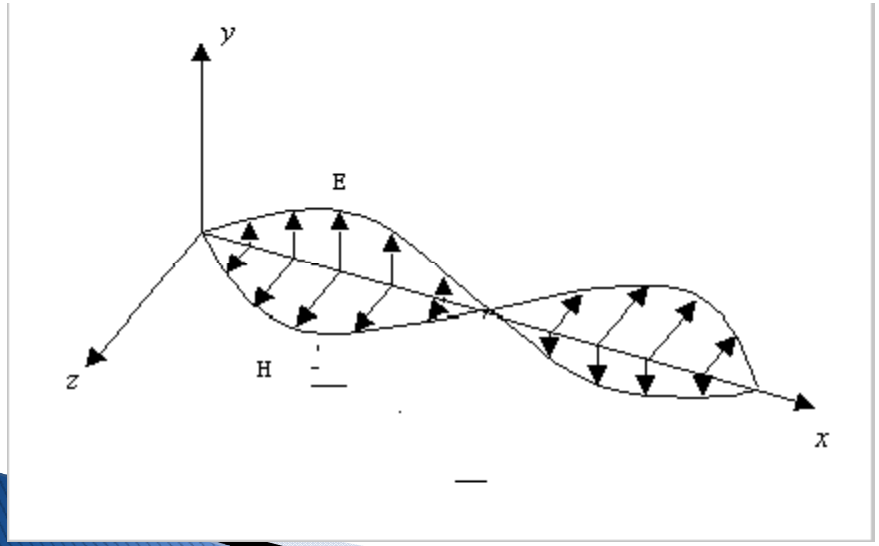
Contents for Discussion

- Predicting RF Propagation
  - Solar Reports
  - Beacons
  - Spotting Networks
- The Unpredictable
  - Sporadic E
  - Tropospheric Ducting
  - Magnetospheric Ducting.



What is RF Propagation?

- It is the means in which radio signals travel.
- Radio Signals are Electromagnetic waves. They were studied and quantified my James Maxwell in a set of equations named after him.



$$\nabla \cdot \mathbf{D} = \rho$$

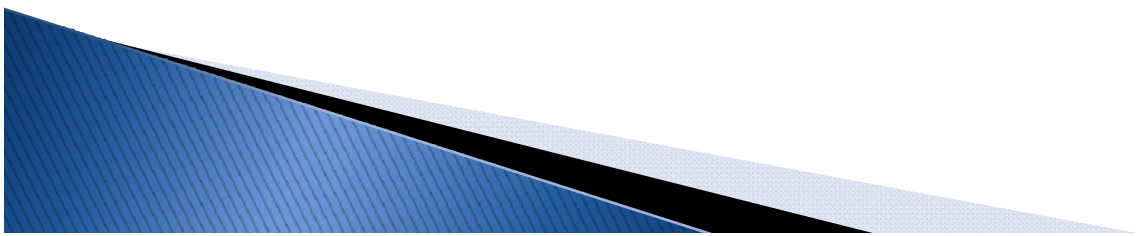
$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

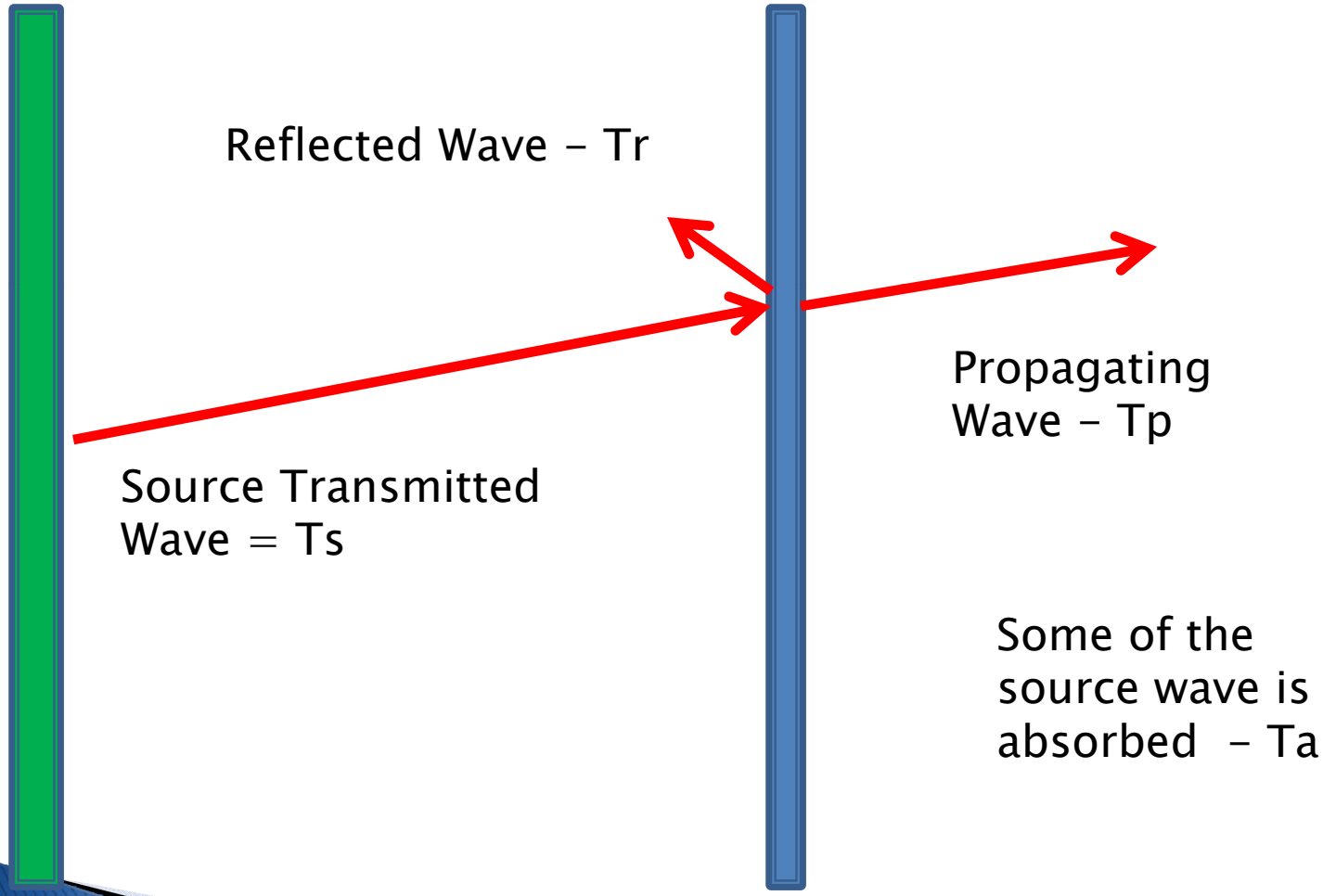
$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

What is RF Propagation?

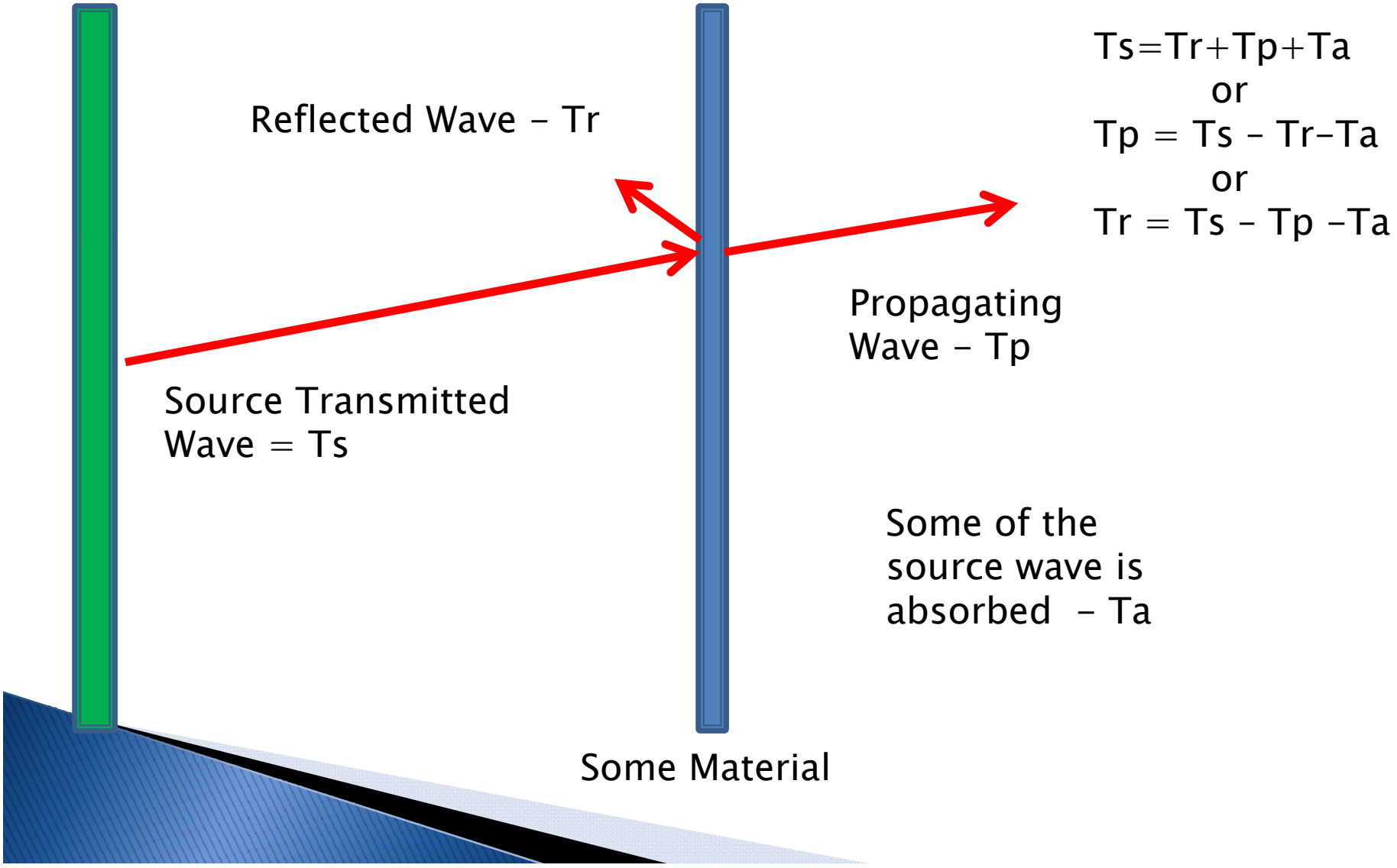
- Experiments relating to the work Maxwell work were performed by Heinrich Hertz.
- The research of both men, and other scientist showed a relationship between the electric field and magnetic field of a radio wave as it travels.
- As a wave travels it want to travel in a straight line and will be:
  - Conducted
  - Attenuated (absorbed, scattered)
  - Reflected
  - Refracted



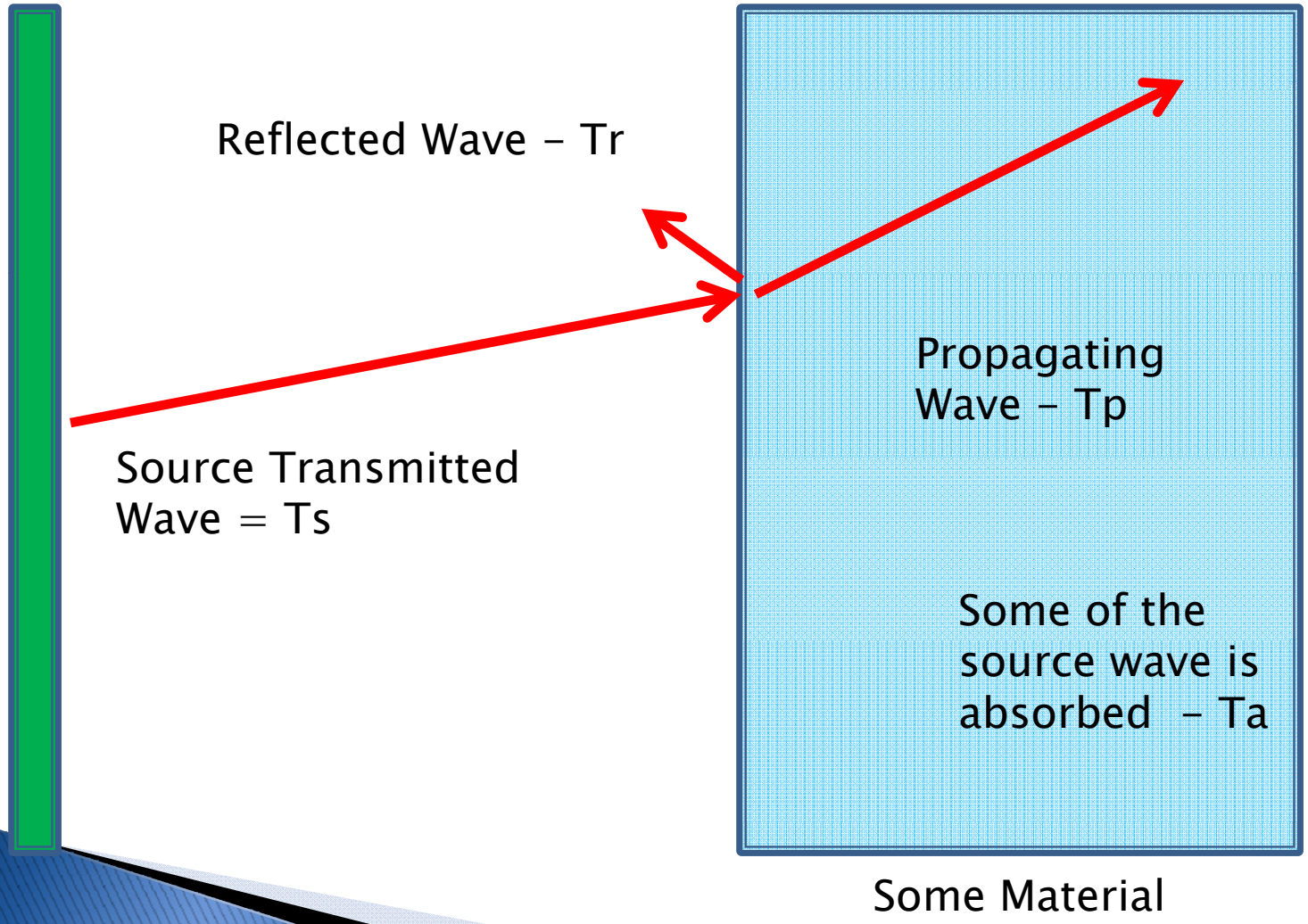
Traveling Signals – Basic



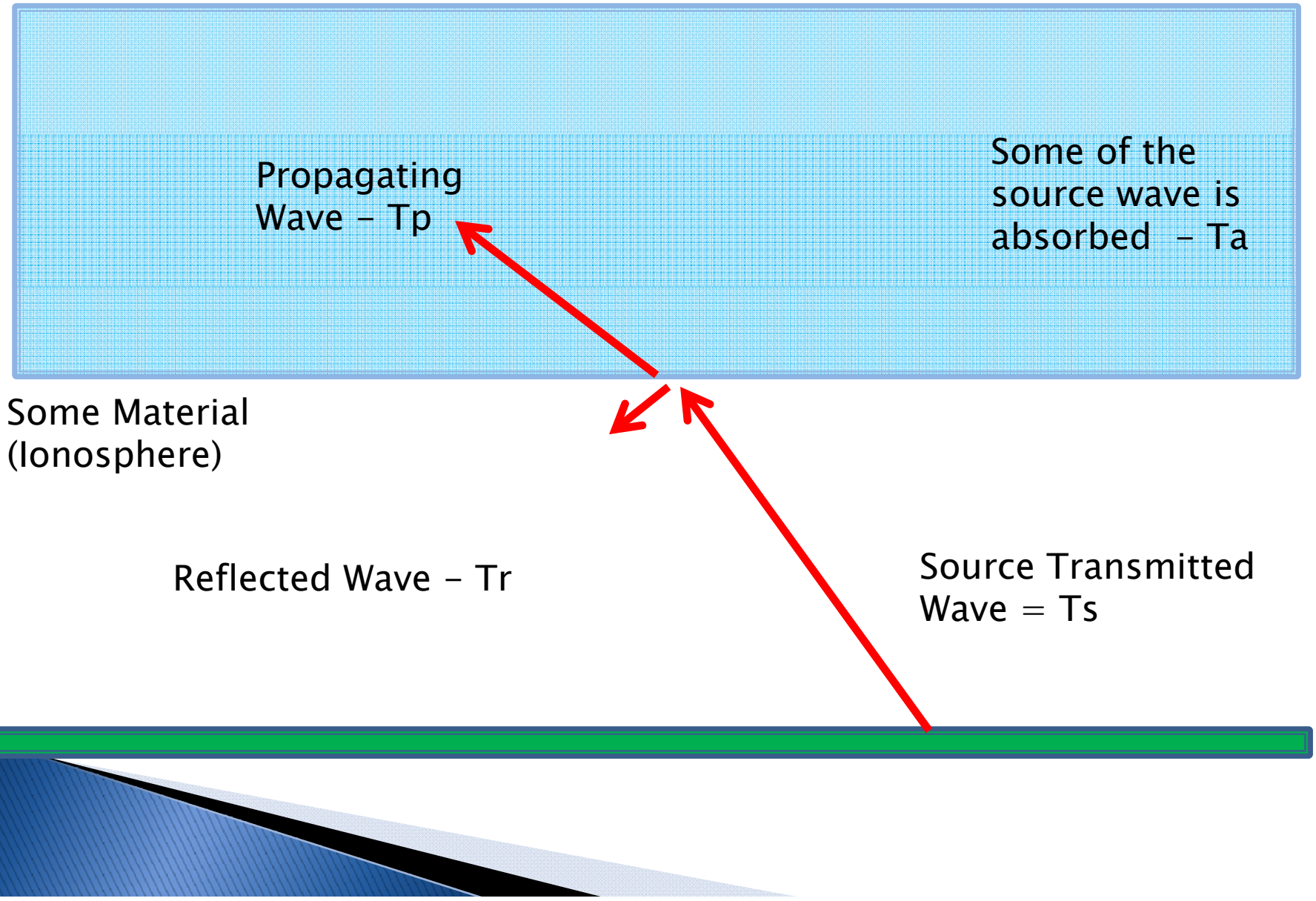
Traveling Signals – Basic



Traveling Signals – With refraction



Traveling Signals – Basic

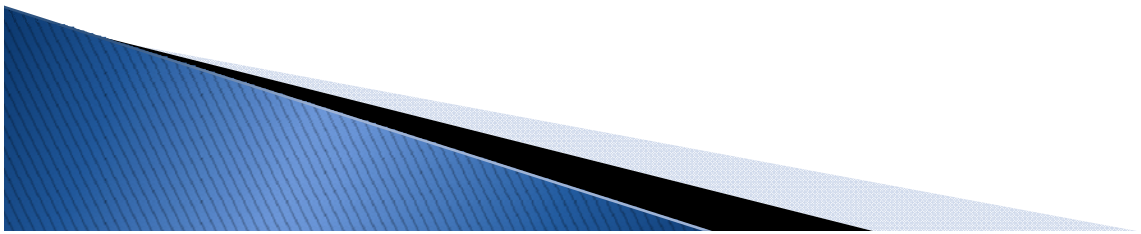


Modes of Radio Signal Travel.

- Free Space –
  - This is the ideal mode of transportation. There is nothing to get in the way or to interact with a signal.
  - In reality, this rarely ever occurs.

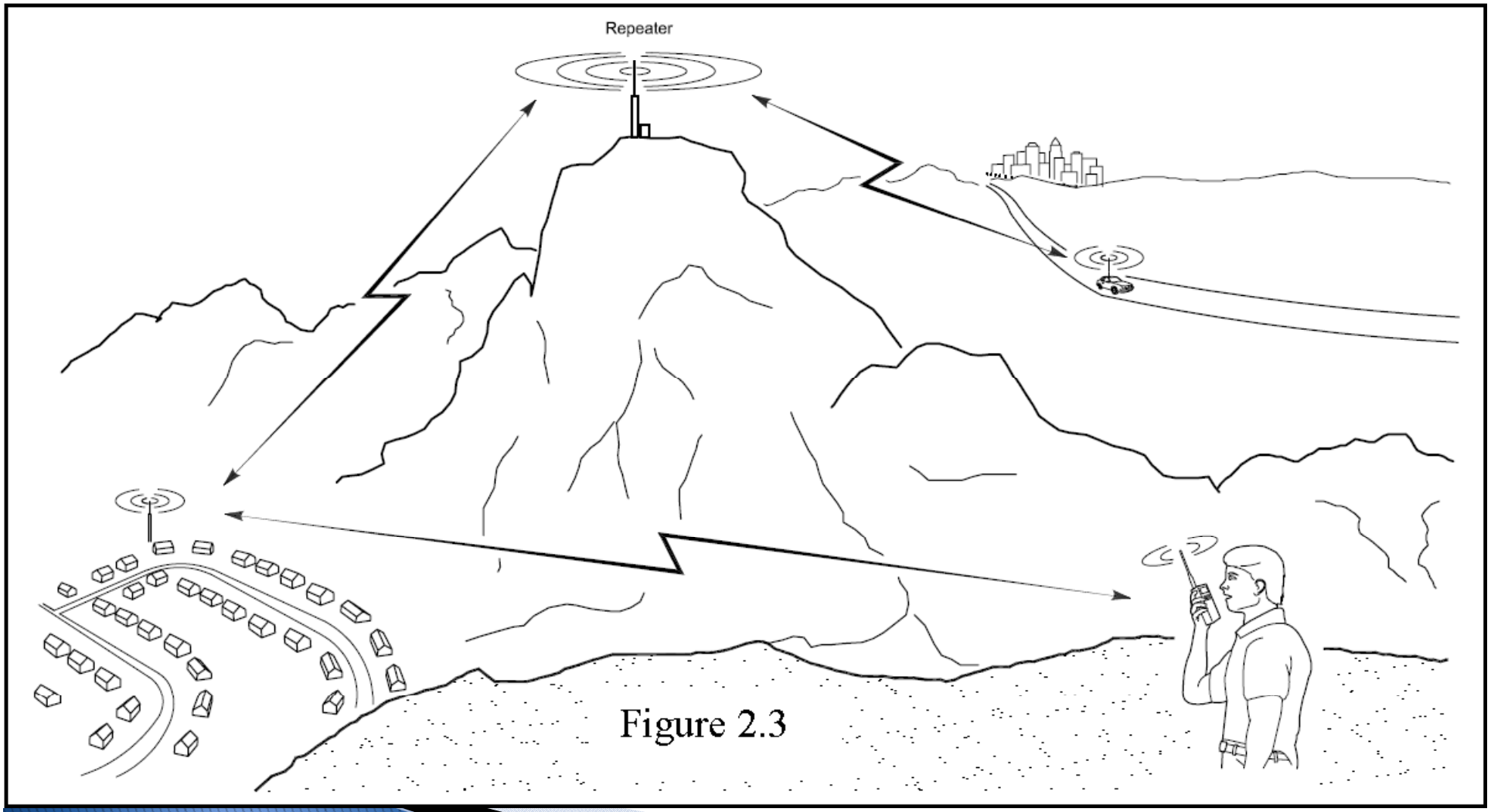
Modes of Radio Signal Travel.

- Open Space
  - Similar to Free space except there are obstacles such as buildings, trees, hills, people….
  - Buildings and hills can cause signals to be reflected or absorbed depending on the frequency. A phenomenon called knife edge refraction can diffract a signal around a corner.
  - Trees, hills and people can absorb signals.
  - These properties are most likely to be observed at VHF Frequencies (50 MHZ) and higher.
  - Reflected signals can cause a receiver to see multiple signals of the same transmission.



Modes of Radio Signal Travel.

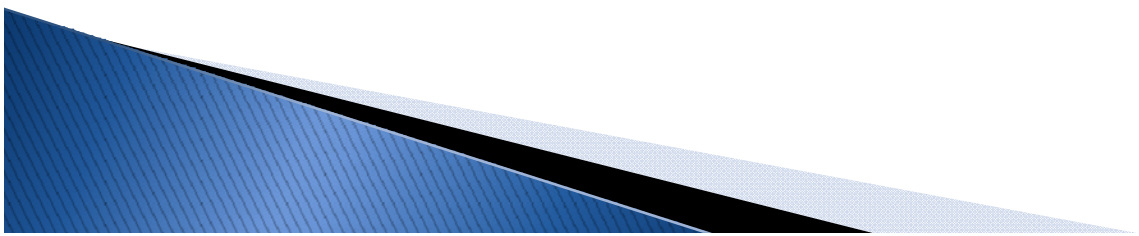
- Open Space



From ARRL Amateur Radio Education and Technology Program

Modes of Radio Signal Travel.

- Ground Wave
  - Ground wave propagation occurs at low frequencies. Typically 4 MHz and below.
  - In ground wave propagation, the magnetic field of the RF signal couples with the earth. A vertically polarized antenna works well for this type of propagation.
  - Often Ground Wave propagation is confused for Open Space propagation.



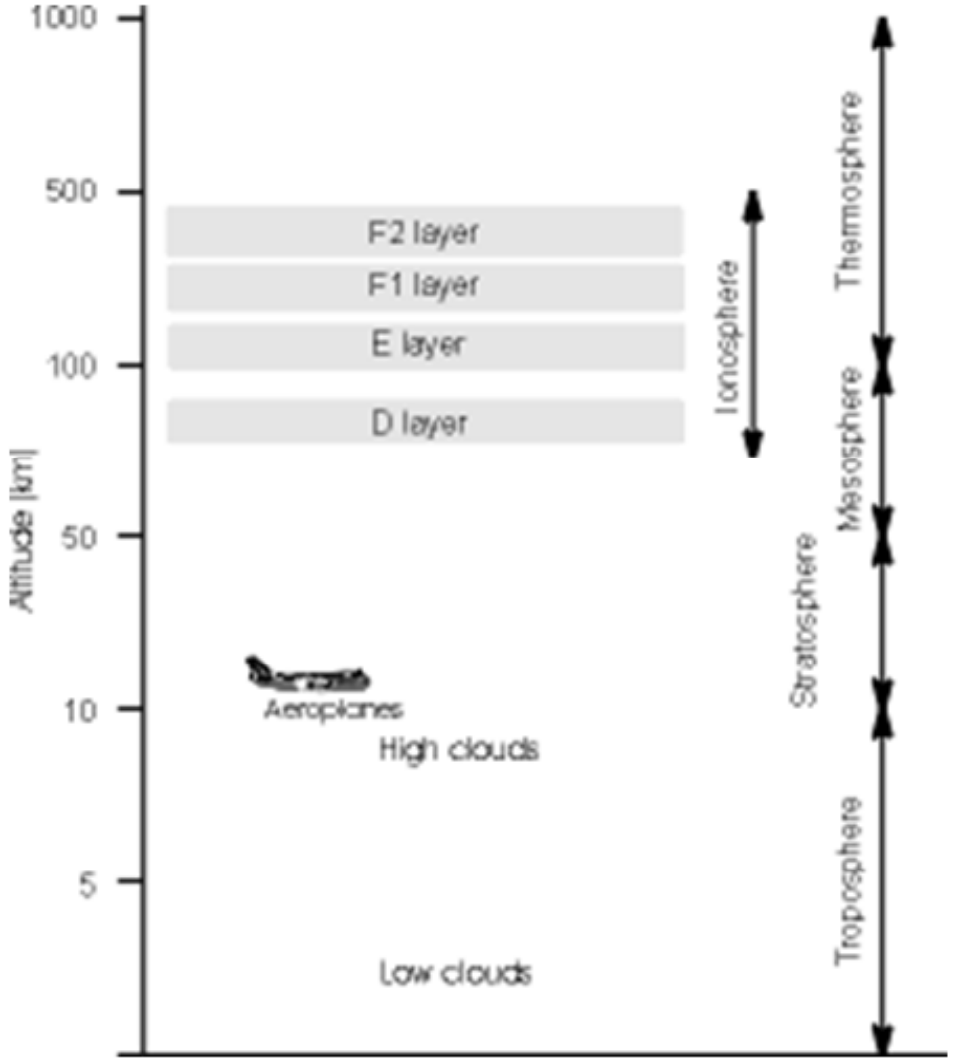
Modes of Radio Signal Travel.

- Sky Wave
  - Radio signals are refracted or reflected off of the earths upper atmosphere – the ionosphere.
  - By bouncing a signal off the ionosphere, radio signals can travel great distances.
  - The suns radiation acts directly on the atmosphere to ionize gas particles.
  - The higher the ionization, the more radio signal reflection.
  - The suns affect on the atmosphere changes based on the time of day and the solar activity as indicated by the sun spots.

The Atmosphere

F1 and F2 Layers combine at night to form 1 layer.

D Layer exists during the day.

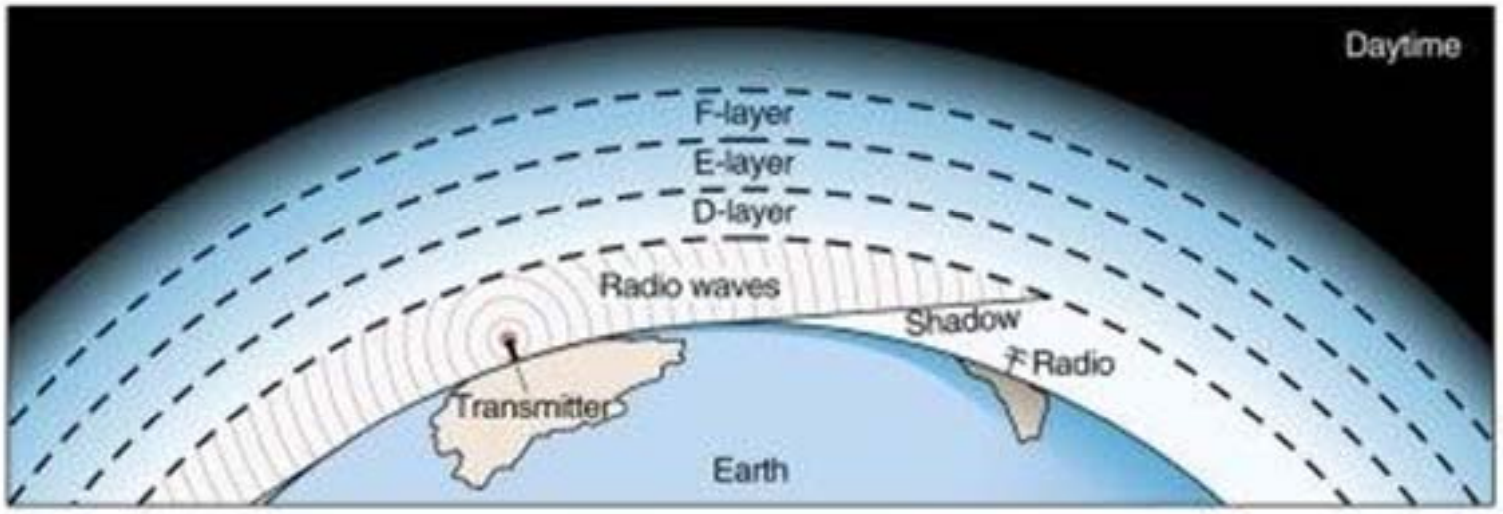


Regions of the Atmosphere

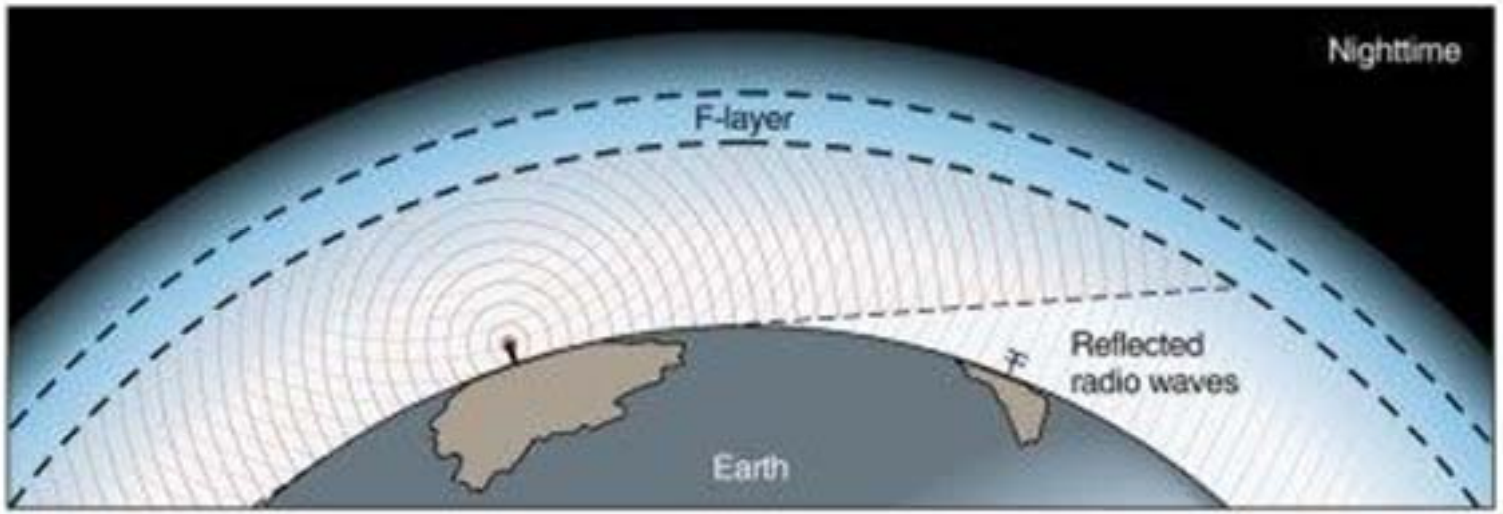
From Radio Electronics.com

The Atmosphere

From the G7LRR Web Page



(a)

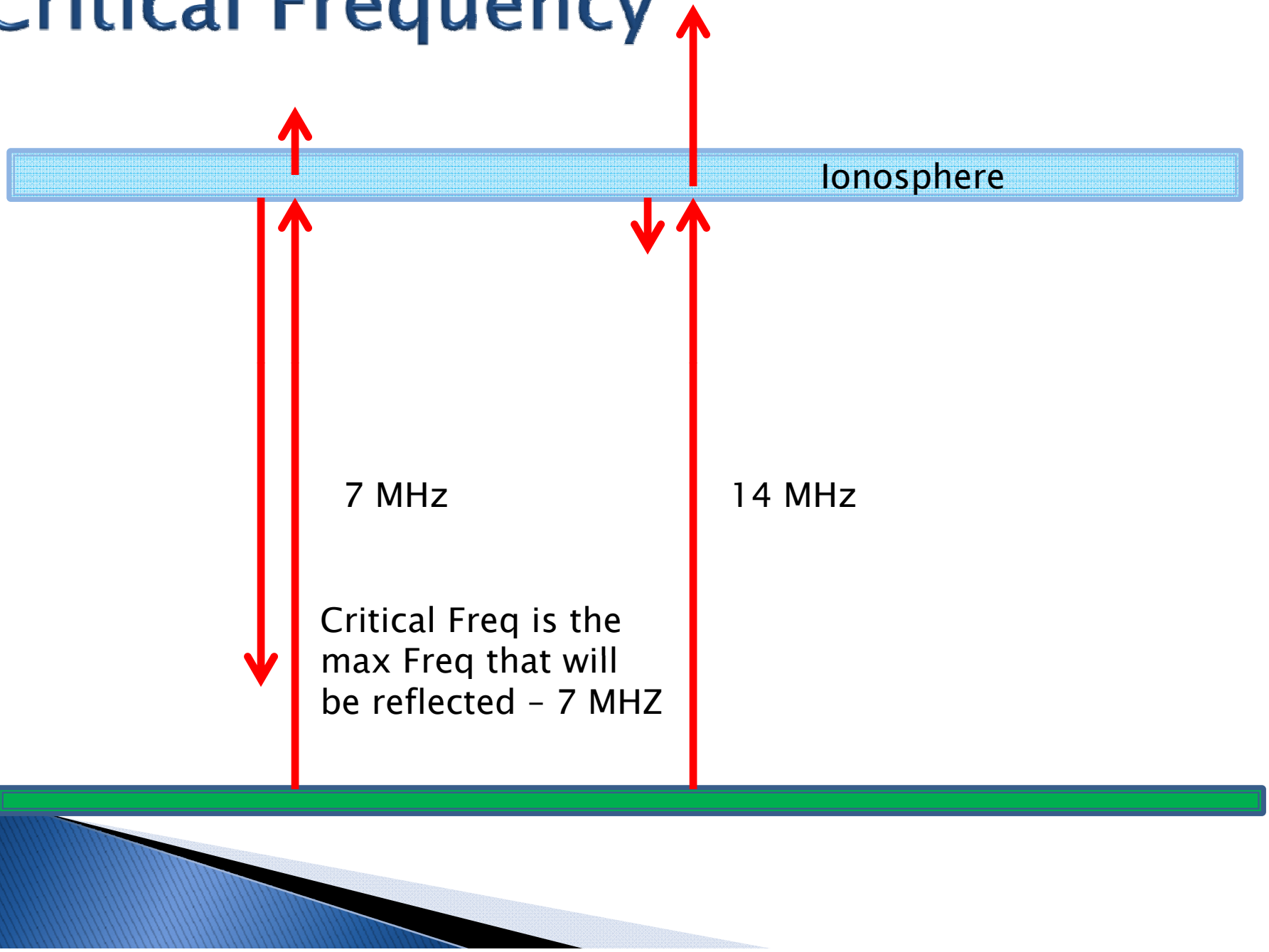


(b)

Sky Waves

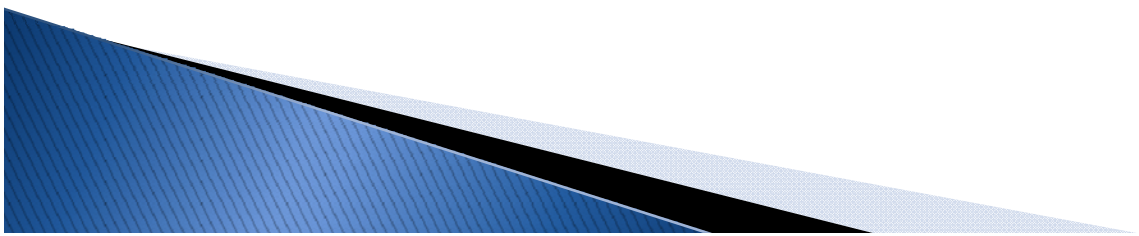
- As the charged particles of the ionosphere increases, the amount of RF reflections also increases.
- This is called the critical frequency and is measured by looking at the highest frequency that can bounce of the atmosphere.

Critical Frequency

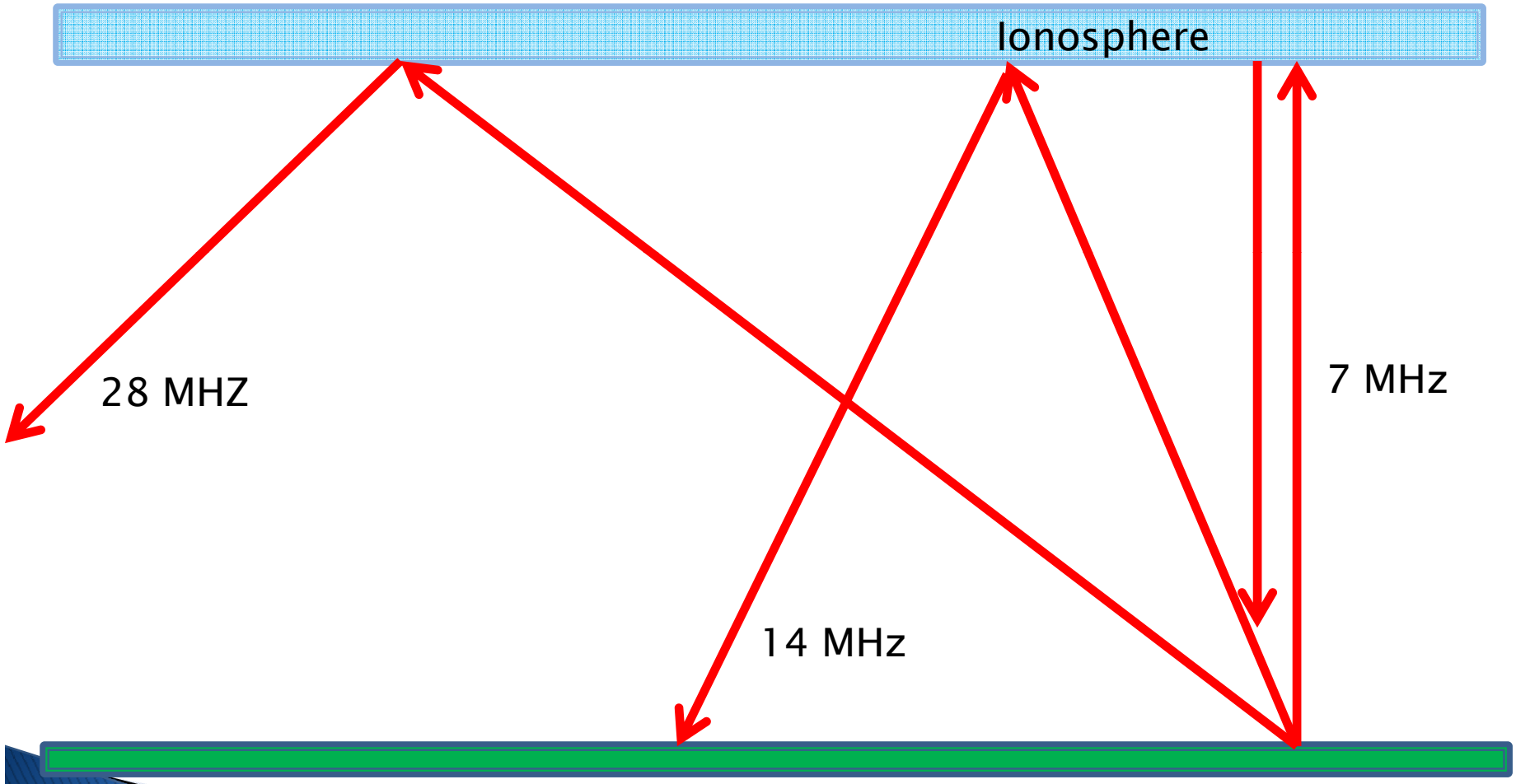


Sky Waves

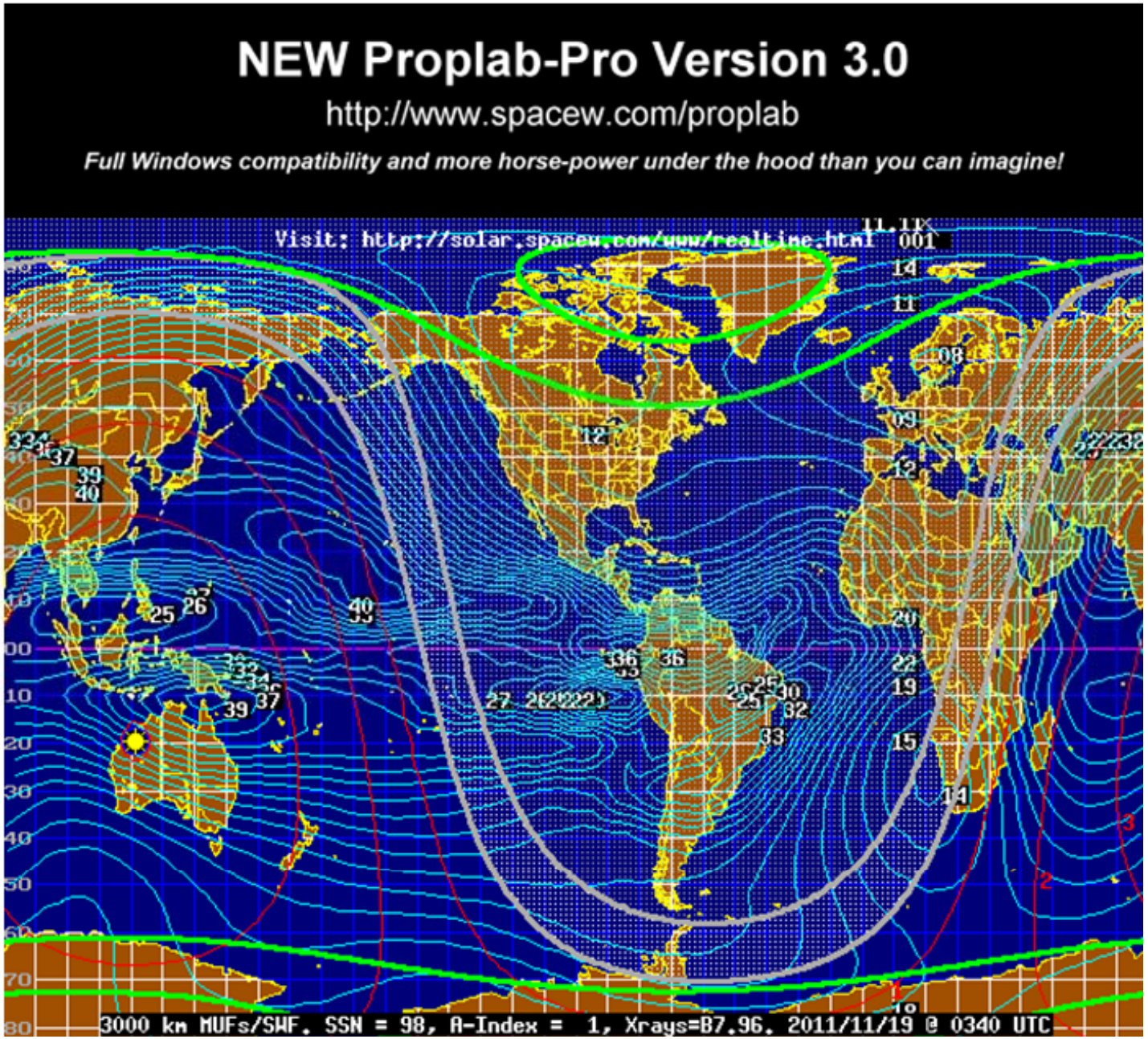
- The critical frequency is measured with a vertical signal, a signal point straight up. (Think NVIS antenna.)
- The upper limit of frequency that can be reflected can be increased by changing the angle that it hits the ionosphere.
- The sharper the angle, the higher the frequency until the maximum useable frequency (MUF) is achieved.



Maximum Usable Frequency (MUF)

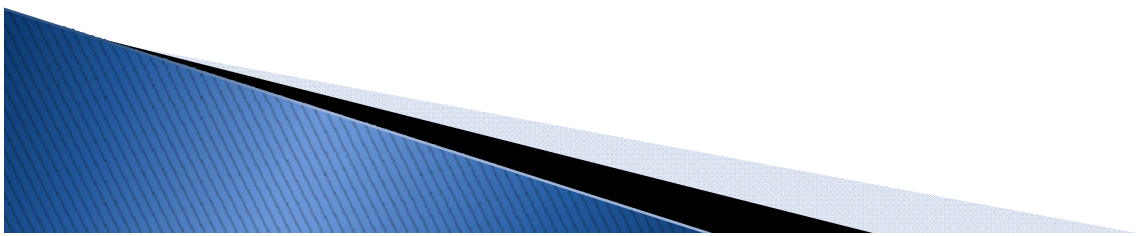


MUF MAP – www.spacew.com/www/realtime.php



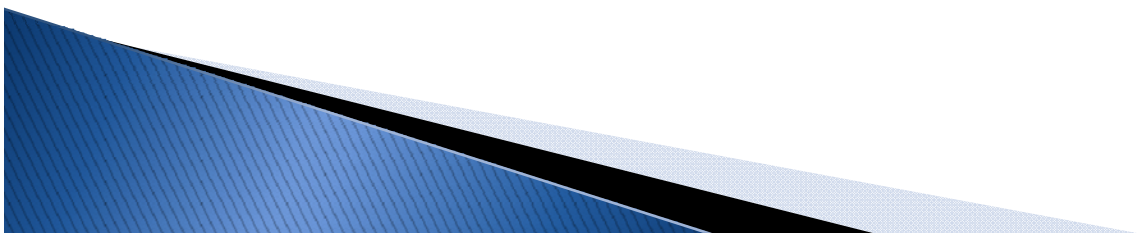
Predicting Propagation

- Follow the rules of the propagation summary.
  - Higher Frequencies during the day, 14MHz – 29 MHz.
  - Lower Frequencies at night. 1.6MHz to 14 MHz
  - During the solar minimum, Poor propagation on 10 MHz and higher, Good low frequency at night due to less atmospheric noise.
  - During the solar maximum, Good propagation on 14 MHz and higher even into the evening. Poor low Frequency due to higher atmospheric noise.



Predicting Propagation

- MUF Forecast
- Monitor the Solar index
  - http://www.wm7d.net/hamradio/solar/index.shtml
  - http://www.anzadx.net/
  - www.arrl.org K7RA Solar Update
  - Solar Flux index of 70 is low = poor DX
  - Solar Flux of 110 is moderate = good DX
  - Solar Flux of 150 is high = great DX
- Listen to HF Bands
- Listen to WWV



Predicting Propagation

- Listen to Beacons such as
  - http://www.ncdxf.org/beacon/beaconSchedule.html

NCDXF/IARU Beacon Transmission Schedule

Each beacon transmits every three minutes, day and night. This table gives the minute and second of the start of the first transmission within the hour for each beacon on each frequency. A transmission consists of the callsign of the beacon sent at 22 words per minute followed by four one-second dashes. The callsign and the first dash are sent at 100 watts. The remaining dashes are sent at 10 watts, 1 watt and 100 milliwatts.

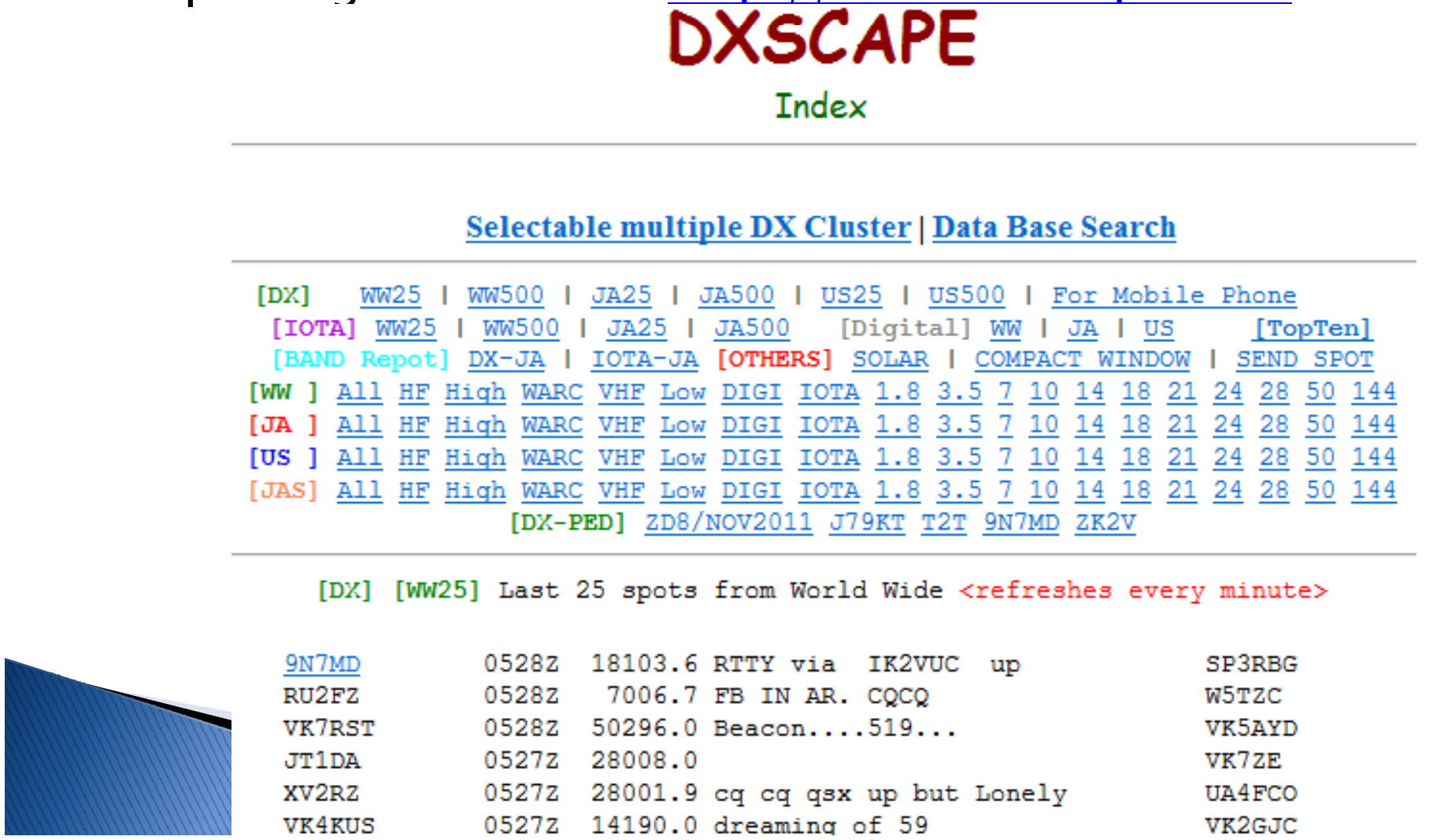
Search the DX Summit Database for recent reception reports by callsign.

If you can hear a beacon now, send a report to DX Summit.

Call		Location	14.100	18.110	21.150	24.930	28.200	Operator	Status
4U1UN		United Nations	00:00	00:10	00:20	00:30	00:40	UNRC	OFF[3]
VE8AT		Canada	00:10	00:20	00:30	00:40	00:50	RAC/NARC	OK[1]
W6WX		United States	00:20	00:30	00:40	00:50	01:00	NCDXF	OK
KH6WO		Hawaii	00:30	00:40	00:50	01:00	01:10	KH6BYU	ON
ZL6B		New Zealand	00:40	00:50	01:00	01:10	01:20	NZART	OK
VK6RBP		Australia	00:50	01:00	01:10	01:20	01:30	WIA	OFF[4]

Predicting Propagation

- Spotting Networks – http://www.dxscape.com



The Unpredictable

- Sporadic E
  - Affects Frequencies 28MHz to 222 MHz
  - May be intense for short periods
- Tropospheric Ducting
  - Can occur from changes in temperature, humidity and pressure.
  - Occurs when refraction is so great radio waves are bent back to the surface.
- Magnetospheric Ducting
  - A strange phenomenon where radio signals are expected to follow the earths magnetic field lines.

The End

- Refer to the ARRL Handbook Chapter 21 for more information on propagation.
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- Questions???
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  - Tim.kuhlman@ch2m.com