RF Propagation

By Tim Kuhlman, PE

KD7RUS

SEA PAC

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.

SEA PAC

Contents for Discussion

- What are radio signals and how 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.

SEA PAC

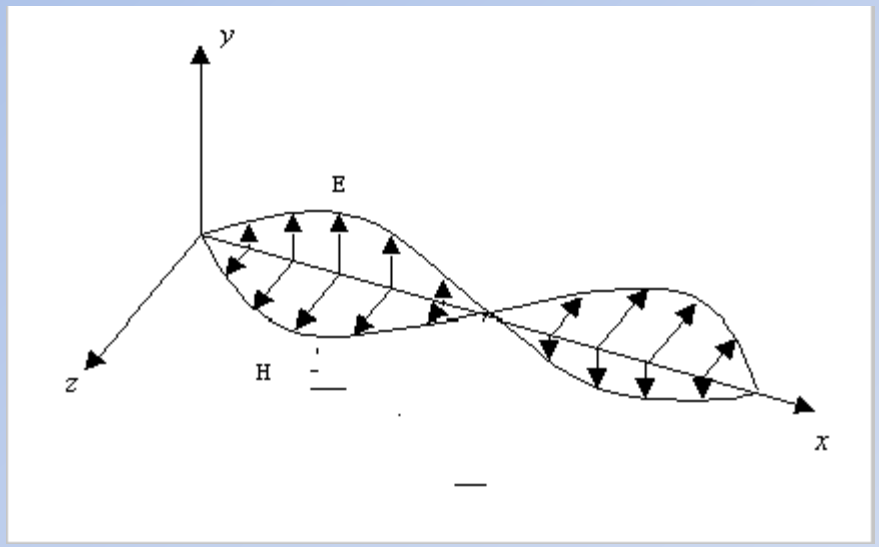
Contents for Discussion

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

SEA PAC

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.



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

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

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

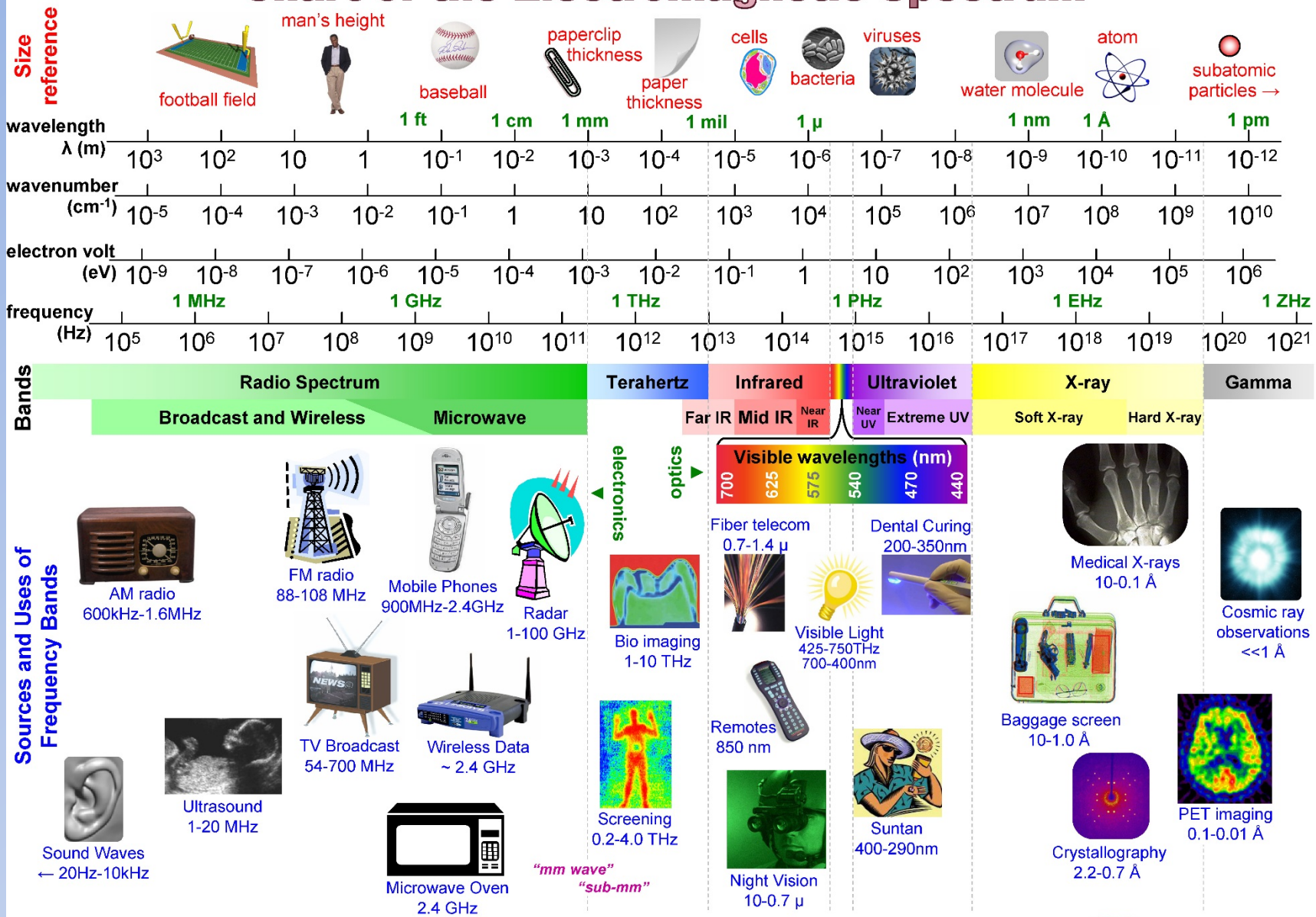
$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$

What is RF Propagation?

- Experiments relating to the work of Maxwell 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 wants to travel in a straight line and will be:
  - Conducted
  - Attenuated (absorbed, scattered)
  - Reflected
  - Refracted

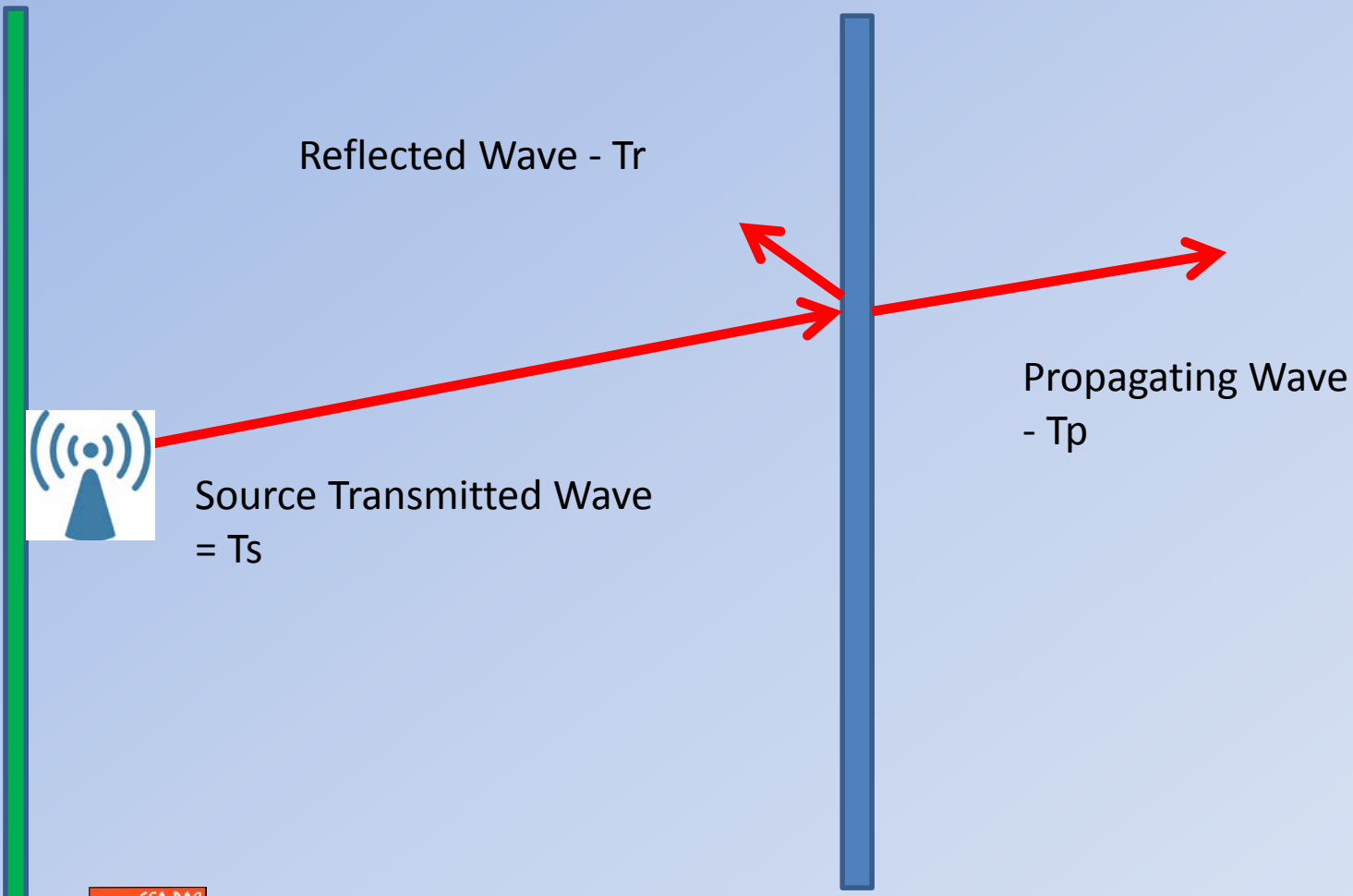
SEA PAC

Chart of the Electromagnetic Spectrum

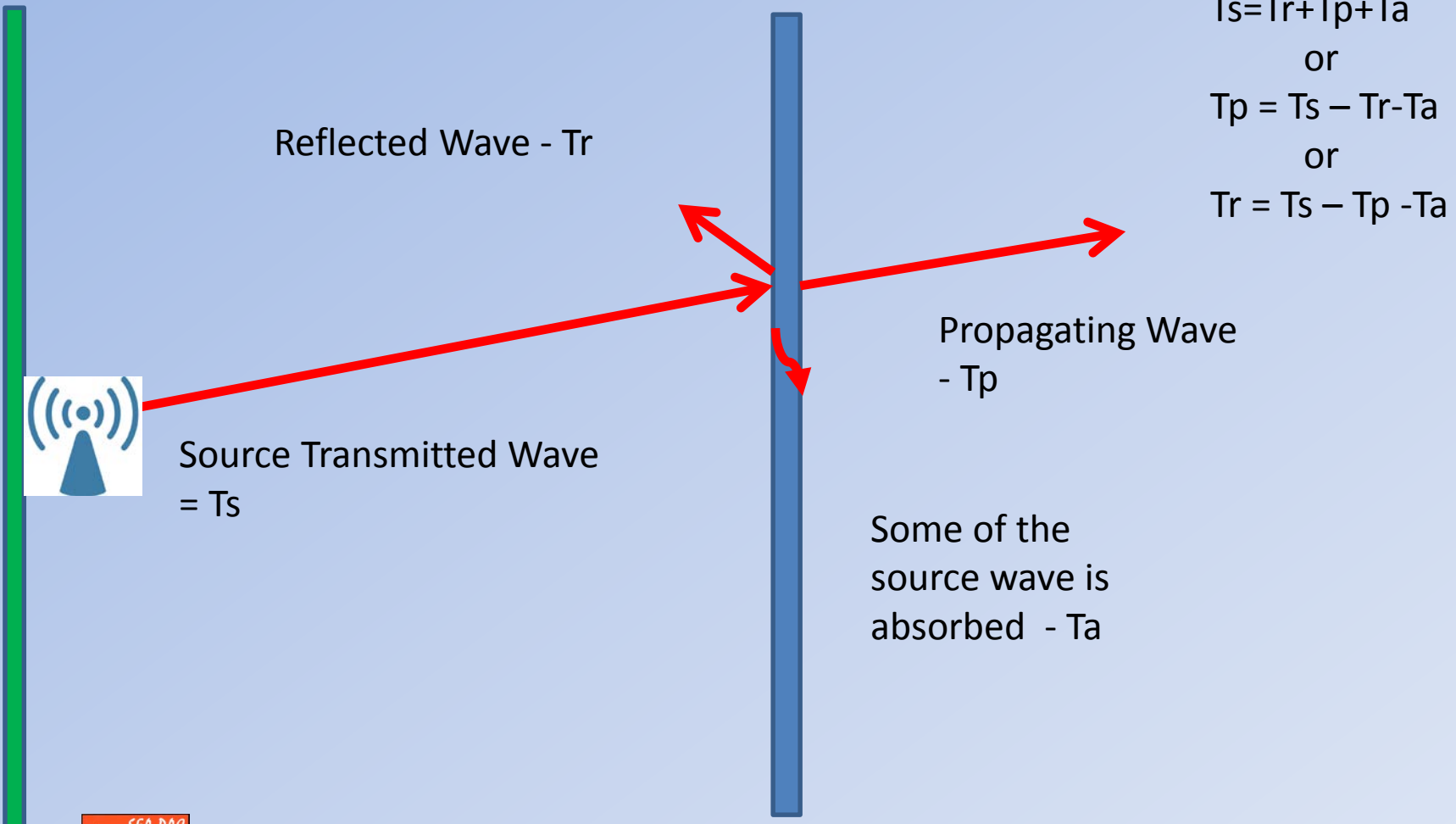


$\lambda = 3\times10^{8}/\text{freq} = 1/(\text{wn}*100) = 1.24\times10^{-6}/\text{eV}$

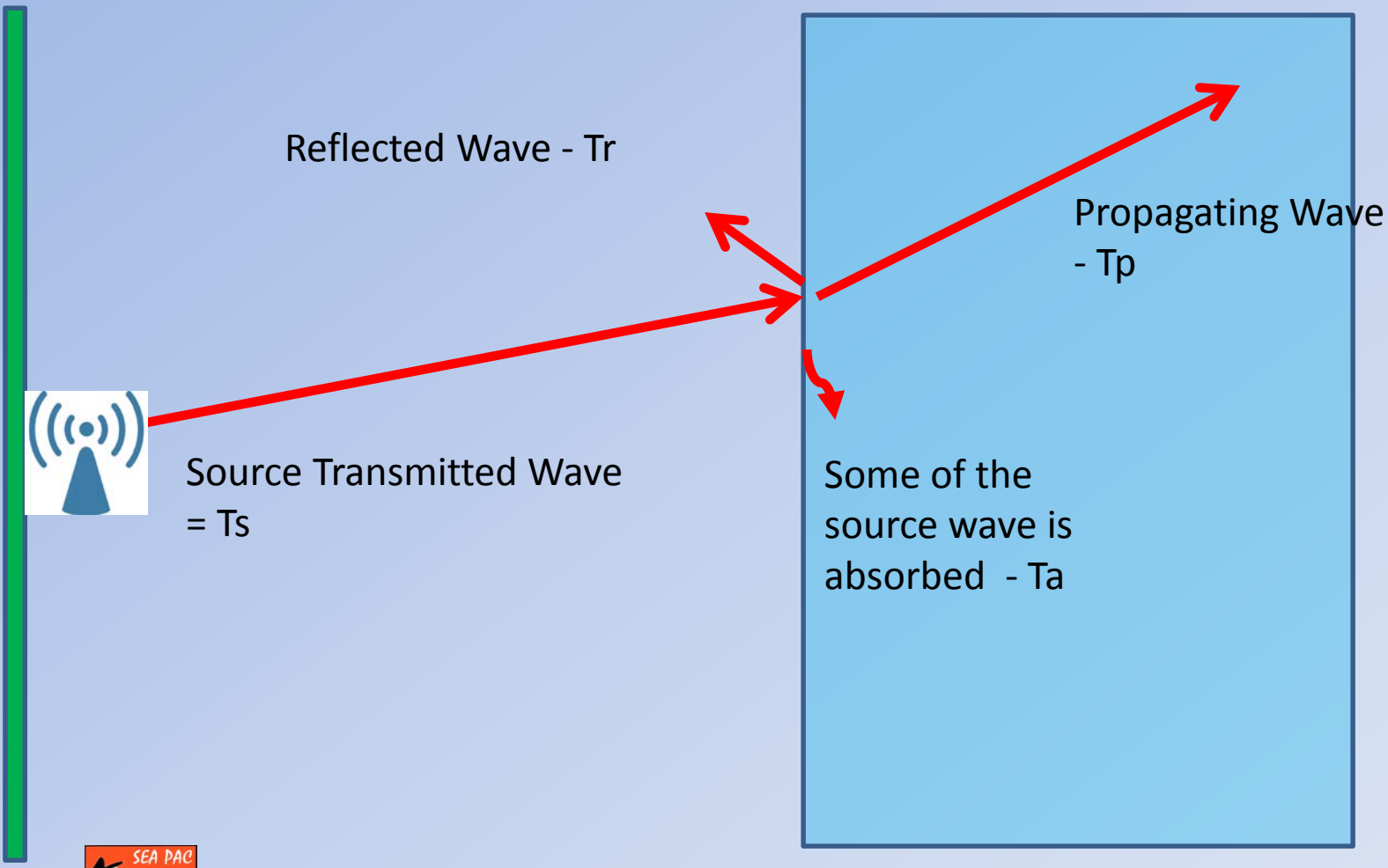
Traveling Signals - Basic



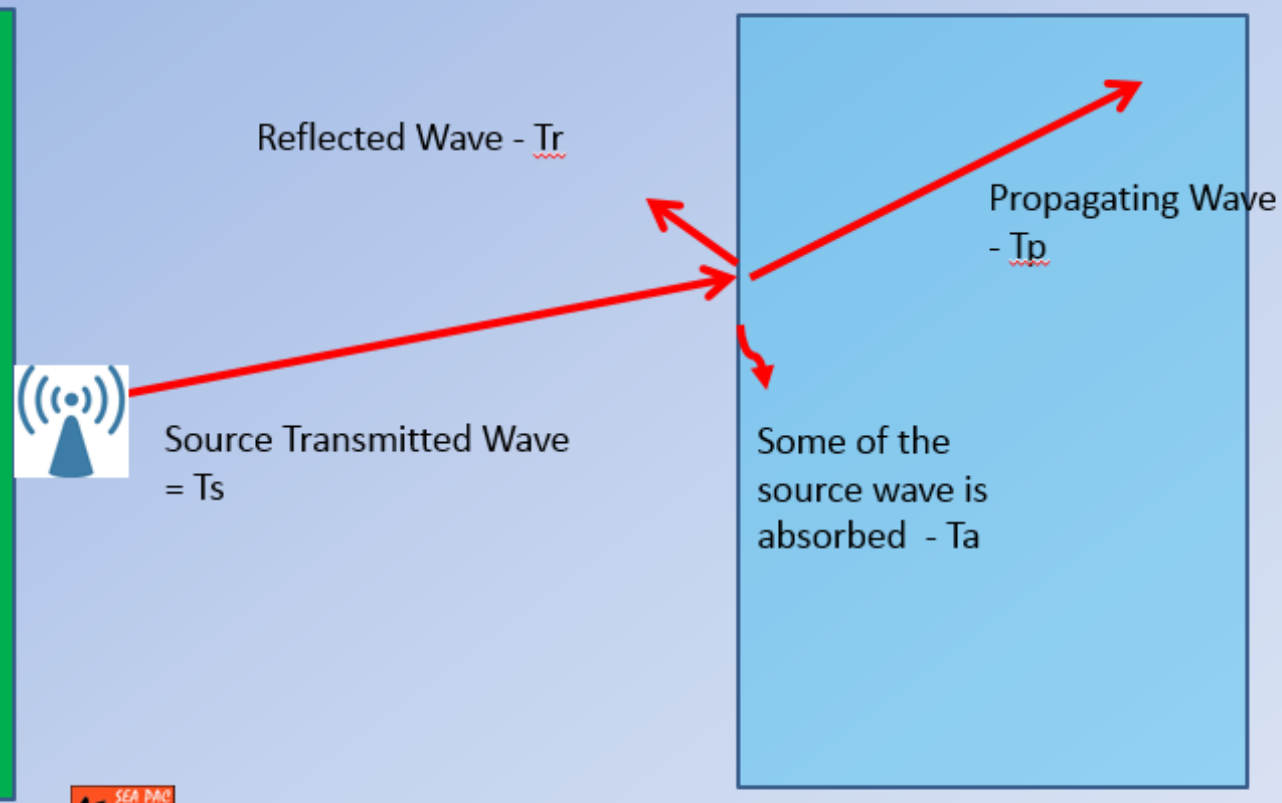
Traveling Signals - Basic



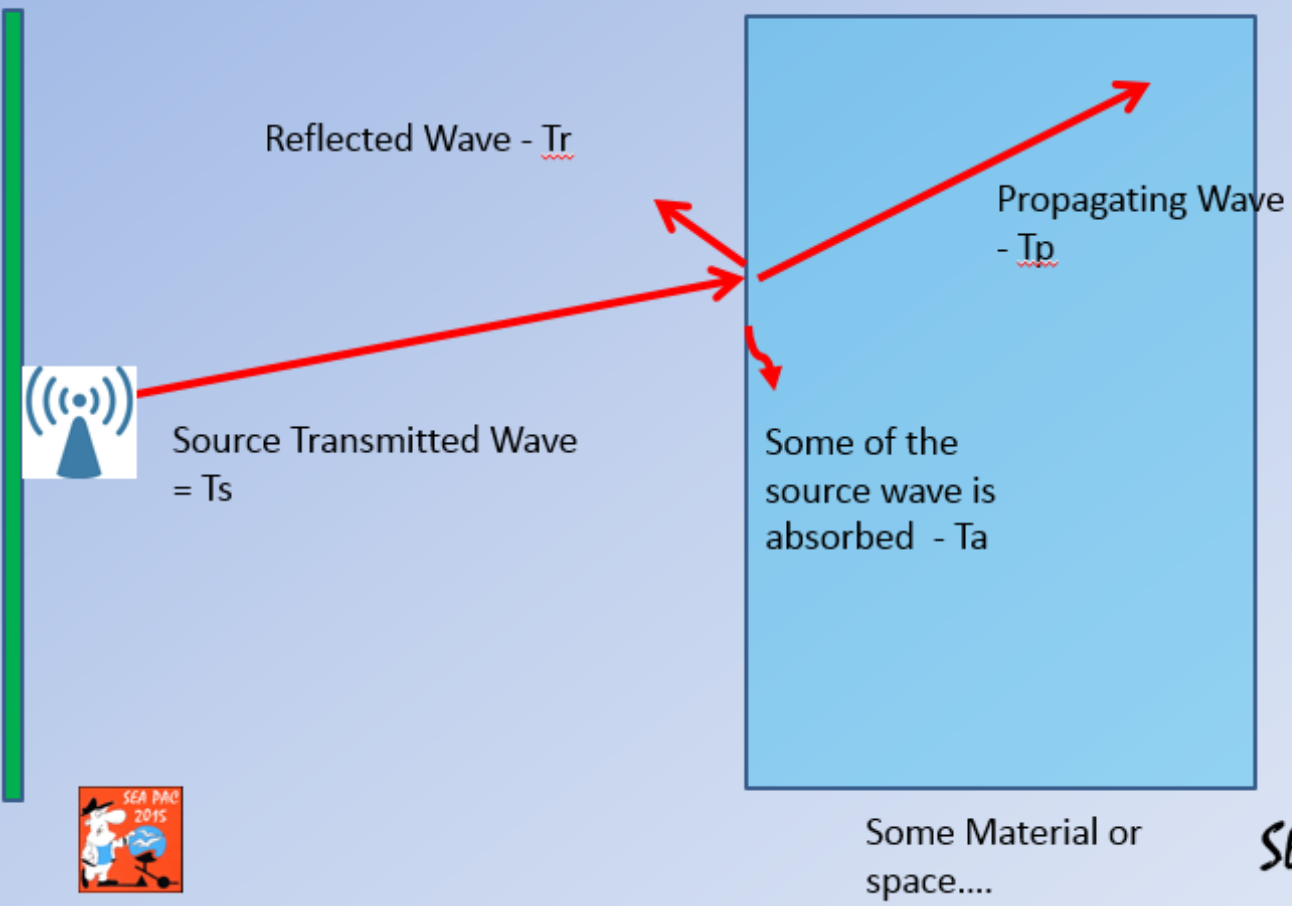
Traveling Signals – With refraction



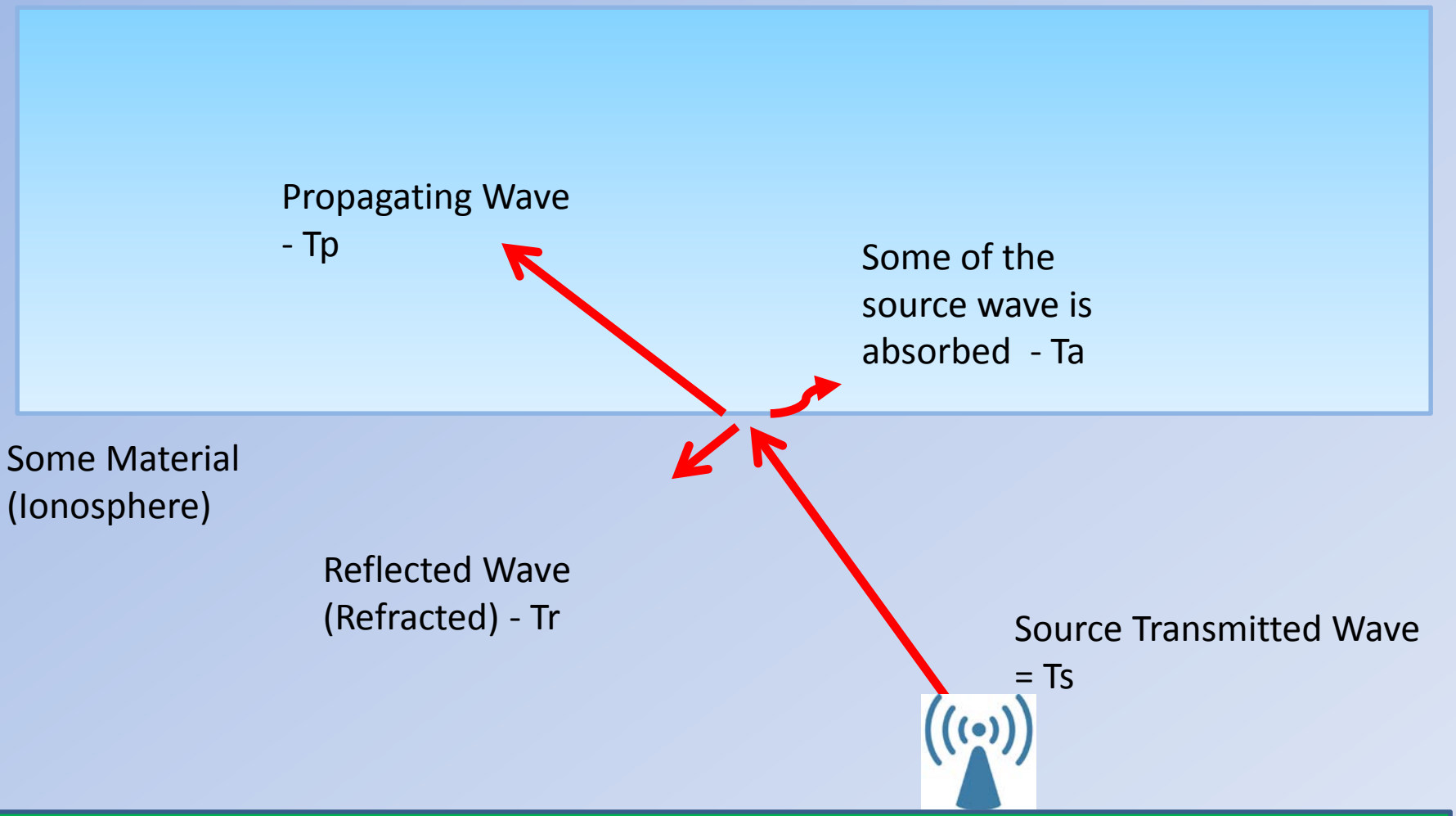
Traveling Signals – With refraction



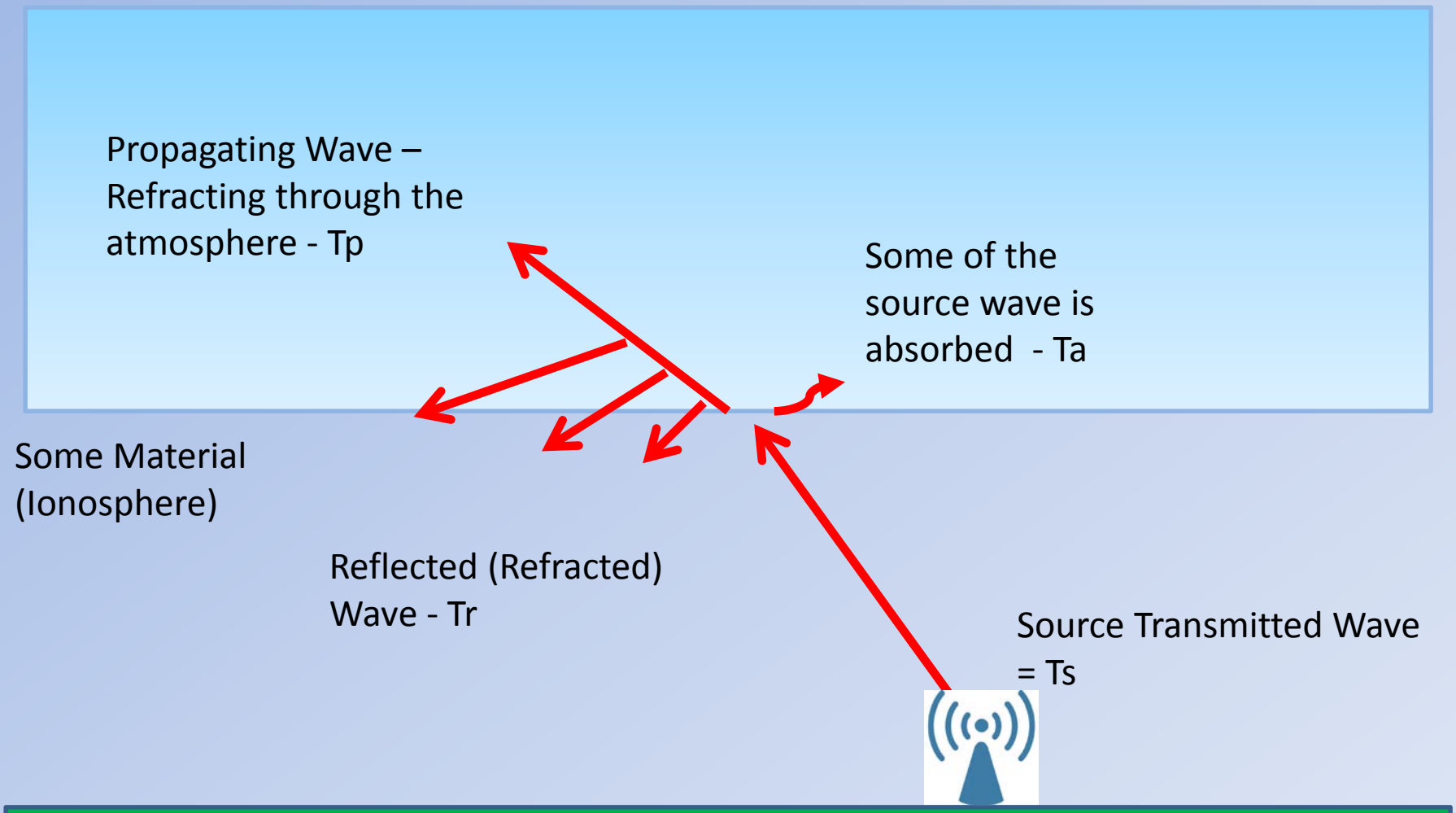
Traveling Signals – With refraction



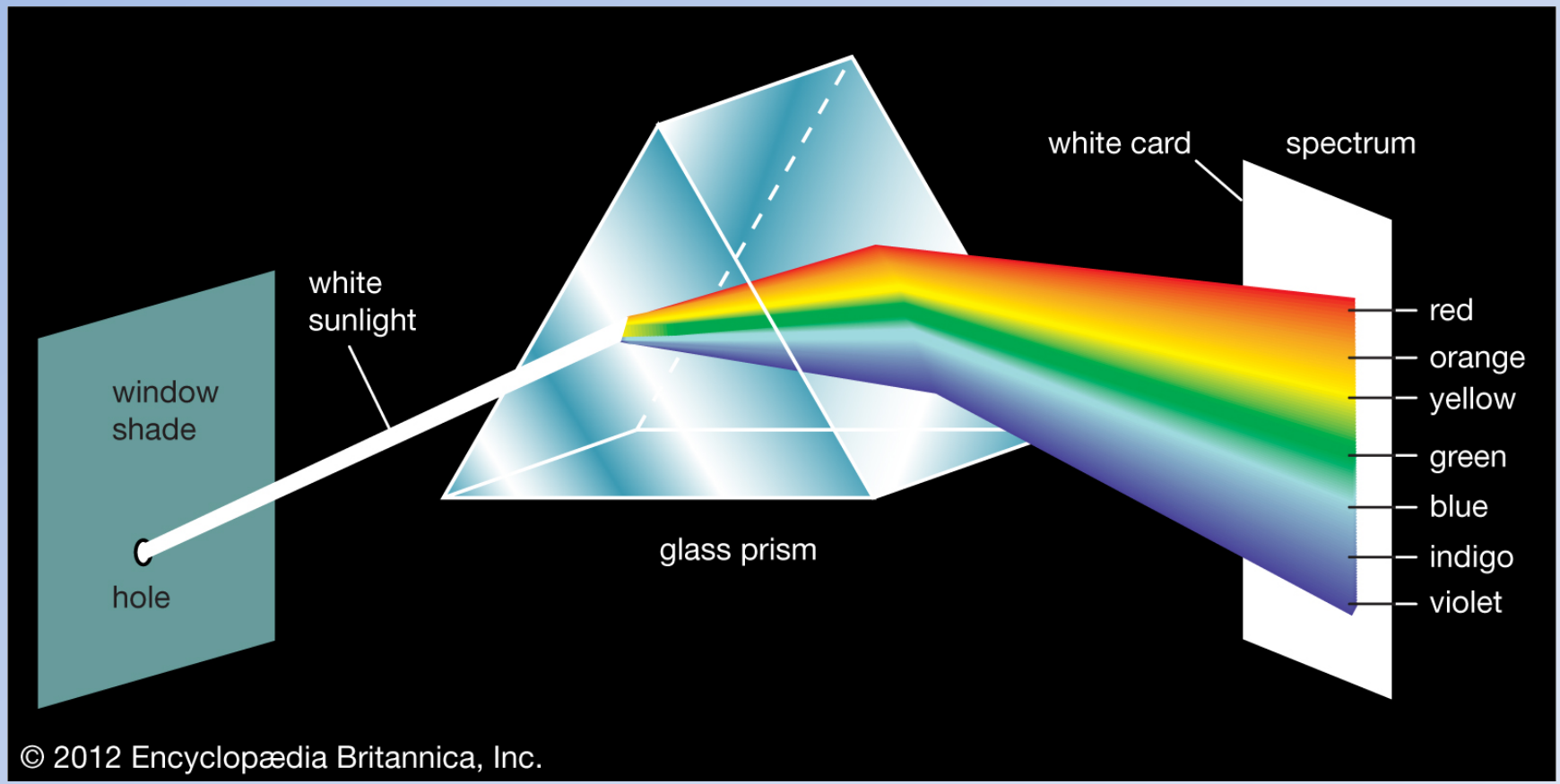
Traveling Signals - Basic



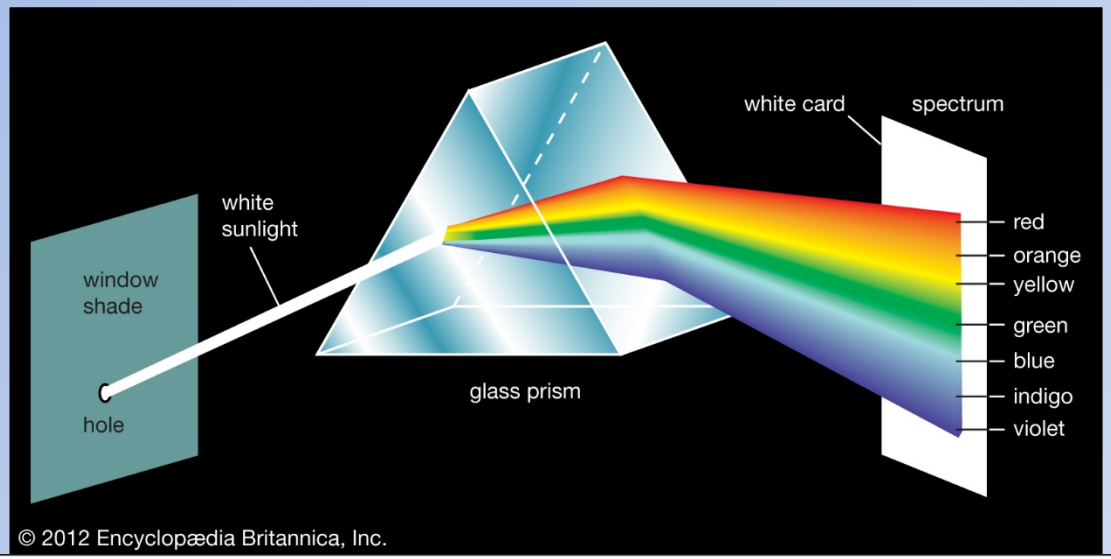
Traveling Signals - Basic

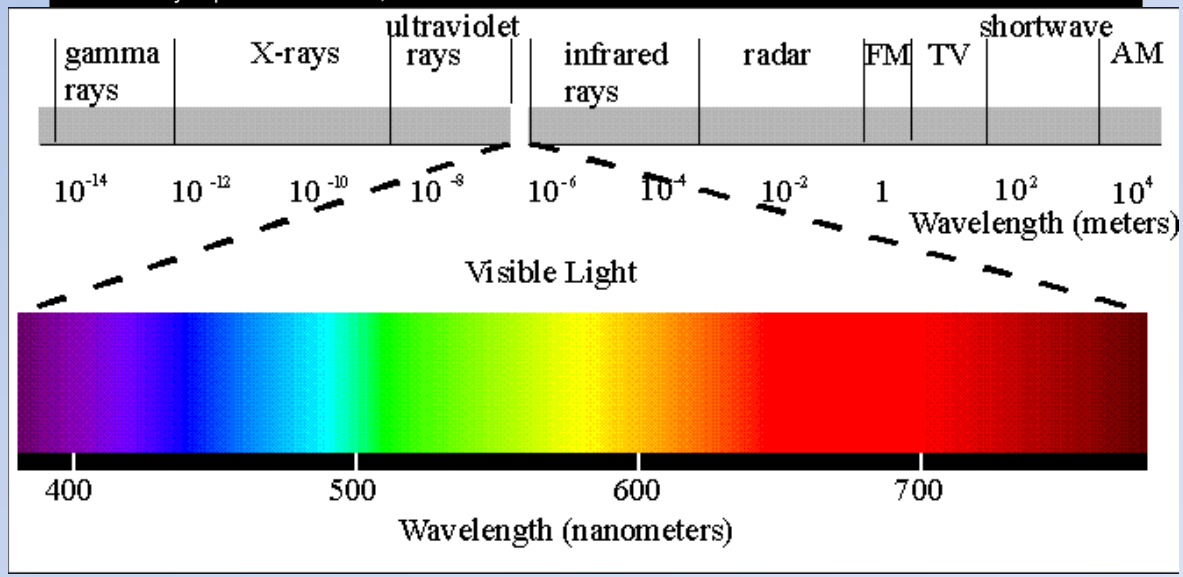


More On Refraction

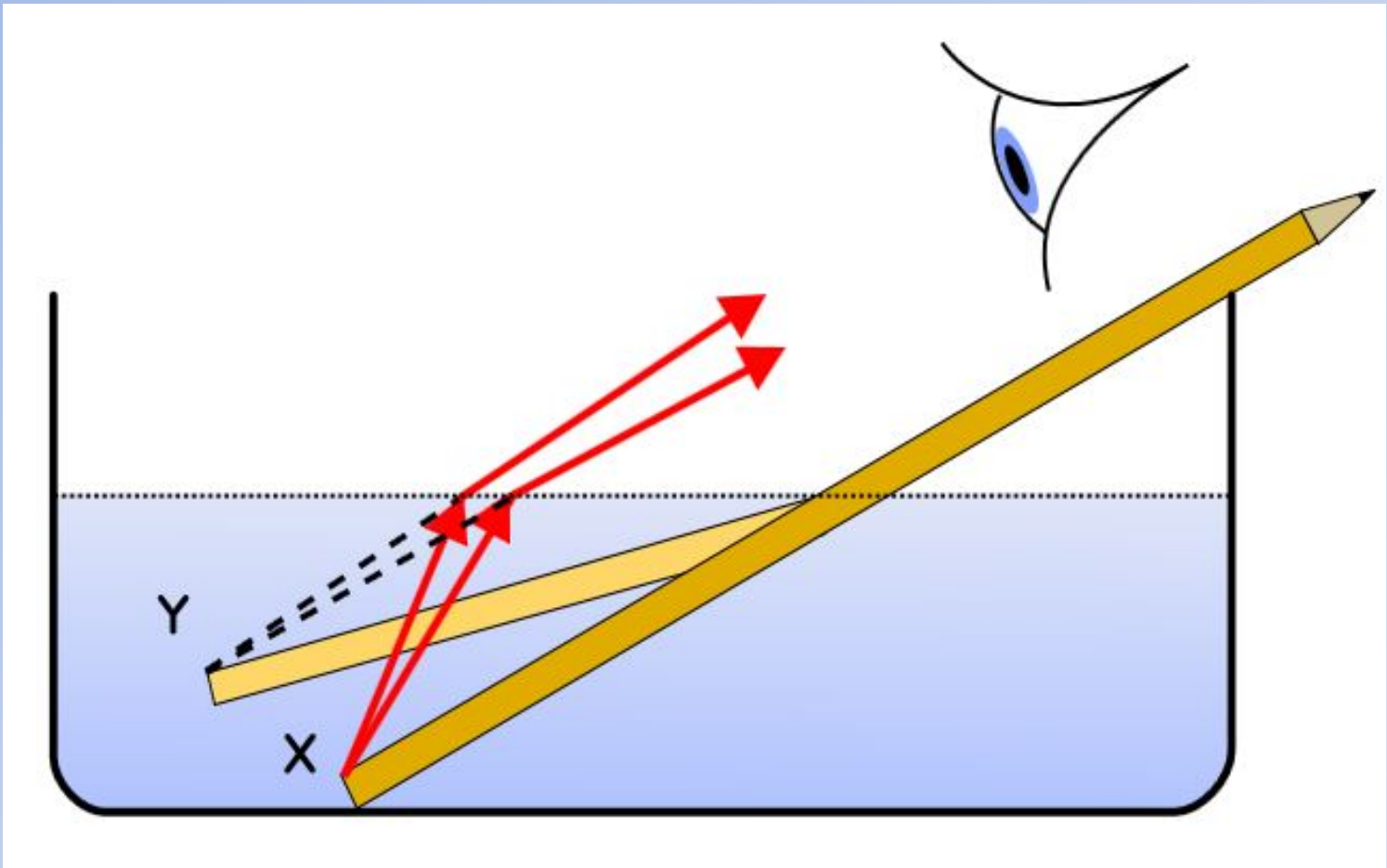


More On Refraction



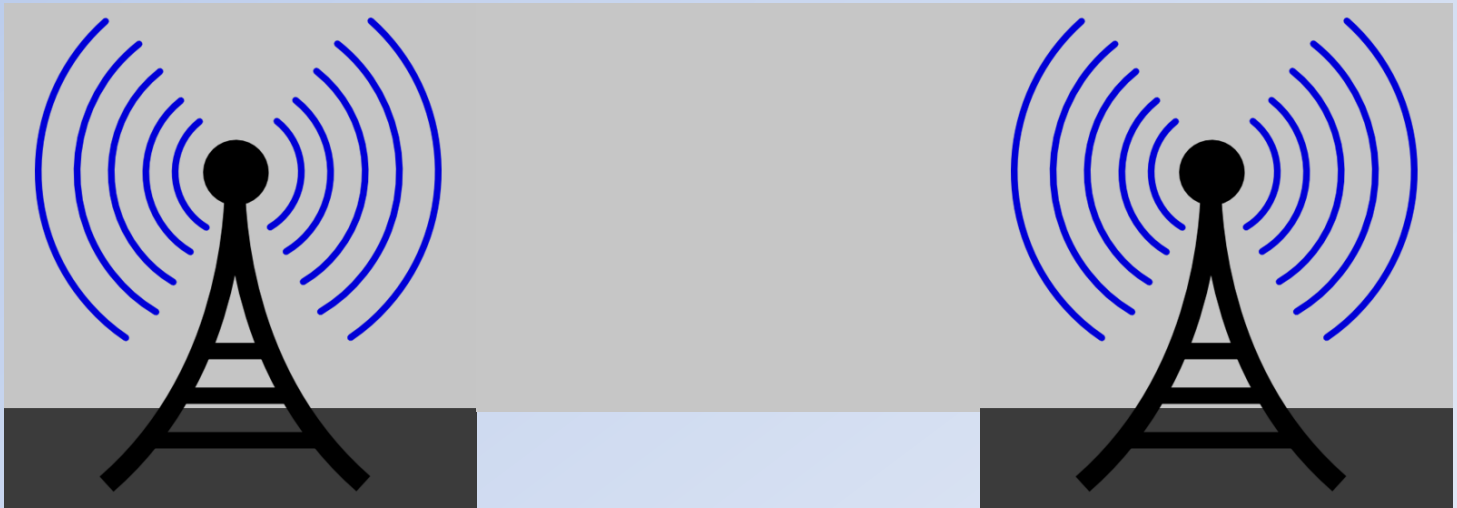


More On Refraction



Modes of Radio Signal Travel.

- Free Space –
  - This is the ideal mode of wave propagation. There is nothing to get in the way or to interact with the signal. In reality, this rarely ever occurs.
  - The best environment to test this is in outer space, outside our solar system. On earth, in an anechoic chamber.
  - Free Space and Open space are forms of “direct wave” propagation.



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 (multipath).

SEA PAC

Modes of Radio Signal Travel.

- Open Space

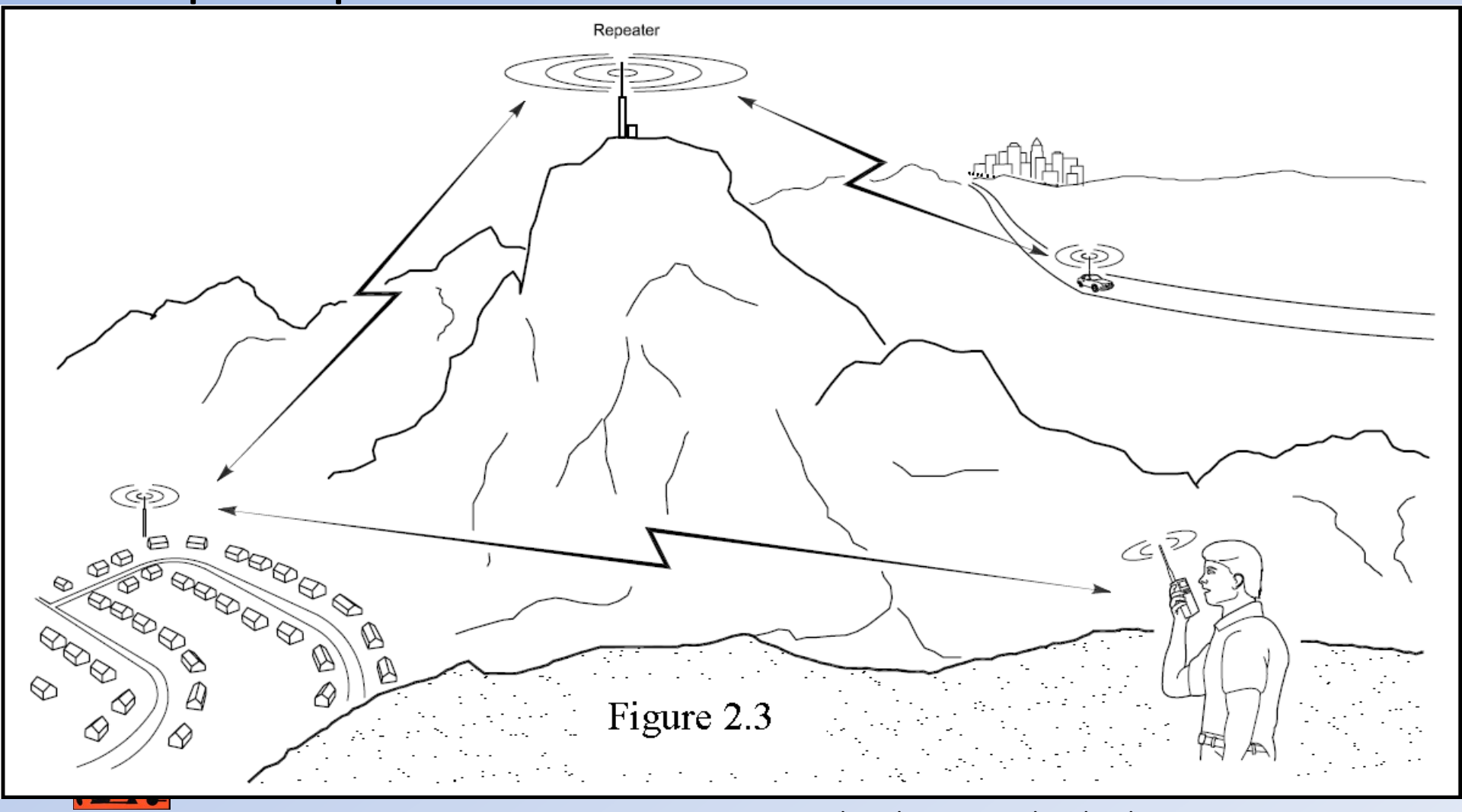


Figure 2.3

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 (direct wave) propagation.

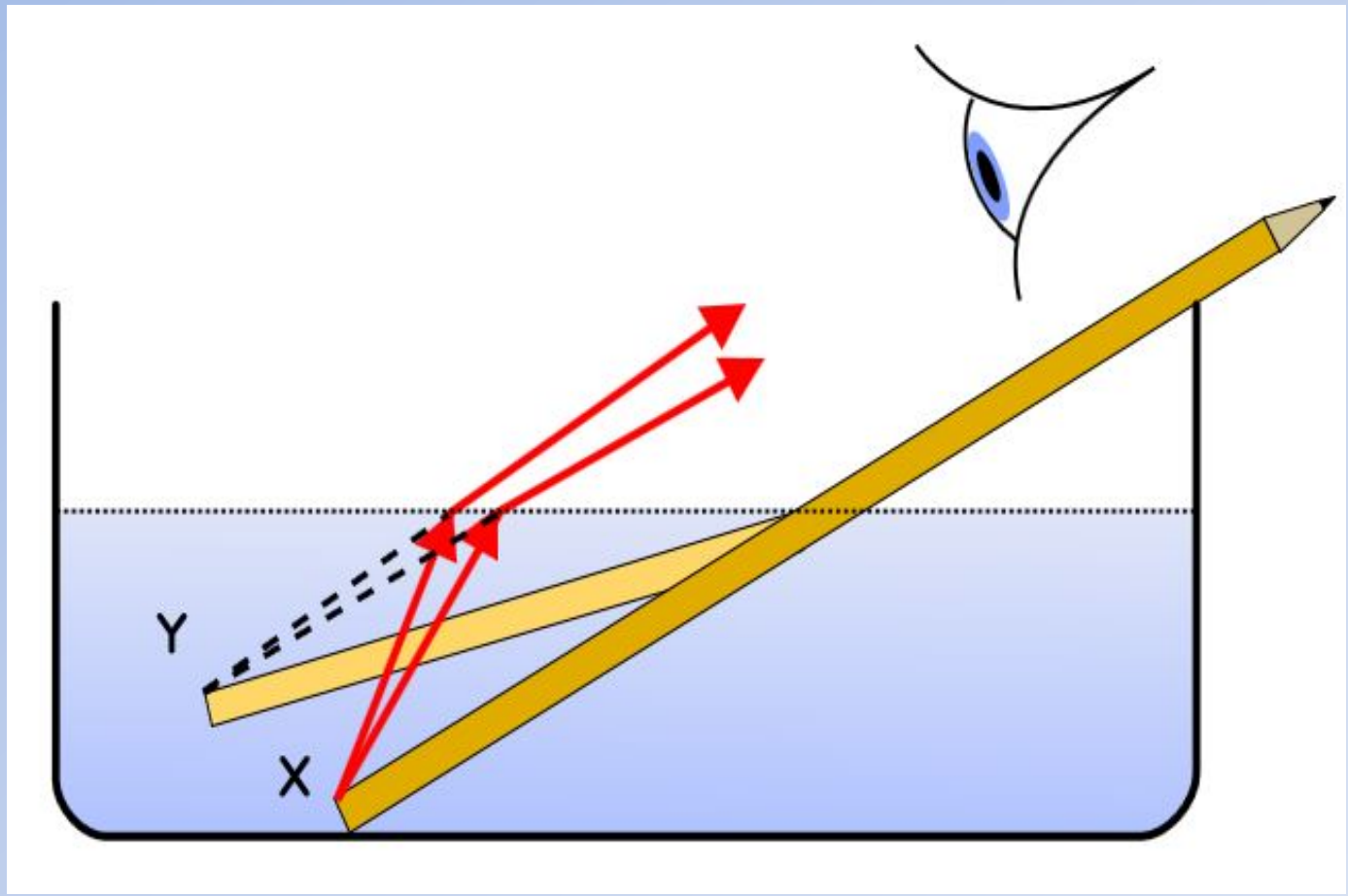
SEA PAC

Modes of Radio Signal Travel.

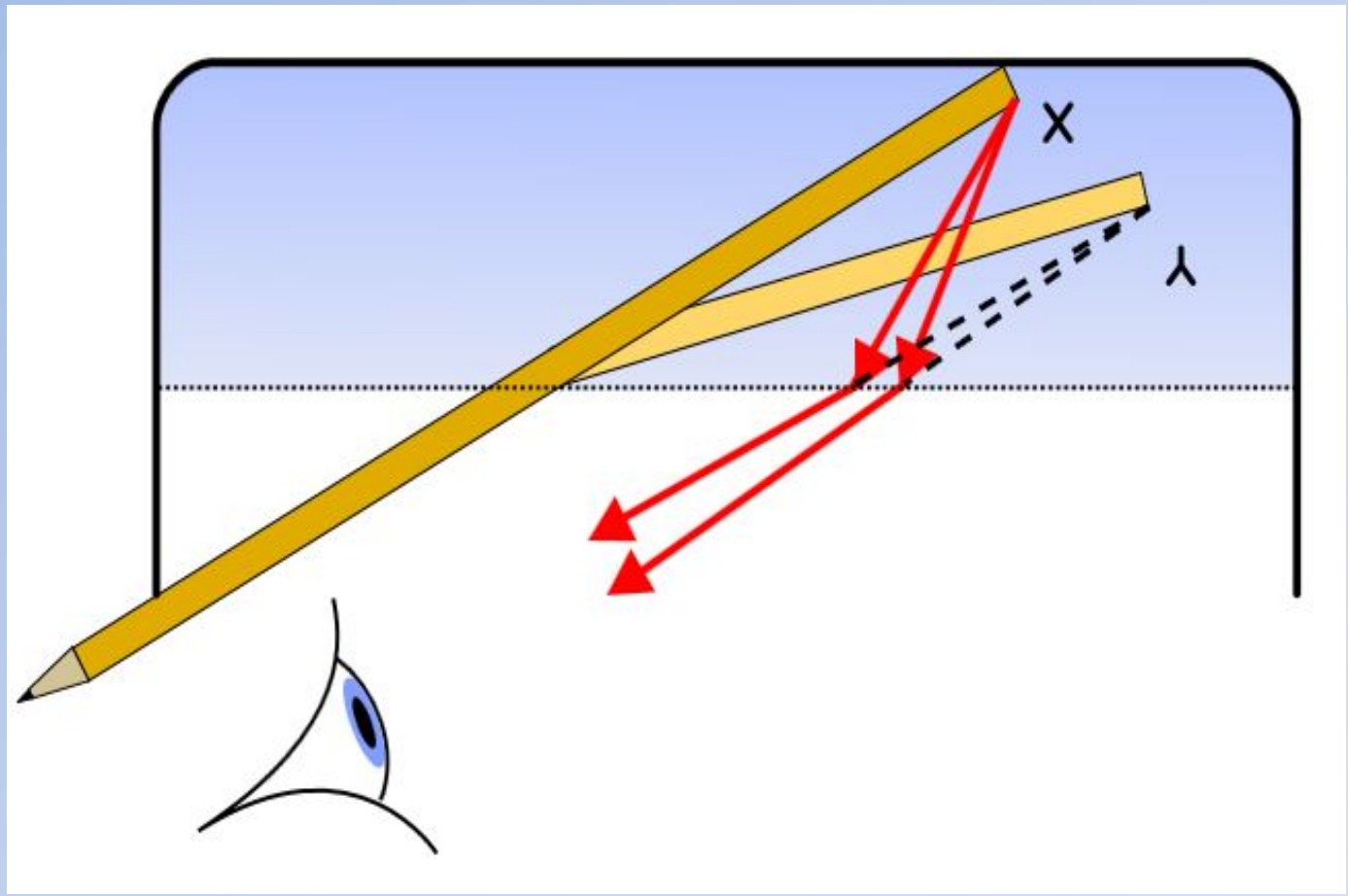
- Sky Wave
  - Radio signals are refracted or reflected off of the earths upper atmosphere – the ionosphere.
  - By bouncing a signal off the ionosphere, radio signals can travel great distances.
  - The suns radiation acts directly on the atmosphere to ionize gas particles.
  - The higher the ionization, 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.

SEA PAC

Sky Wave & Refraction



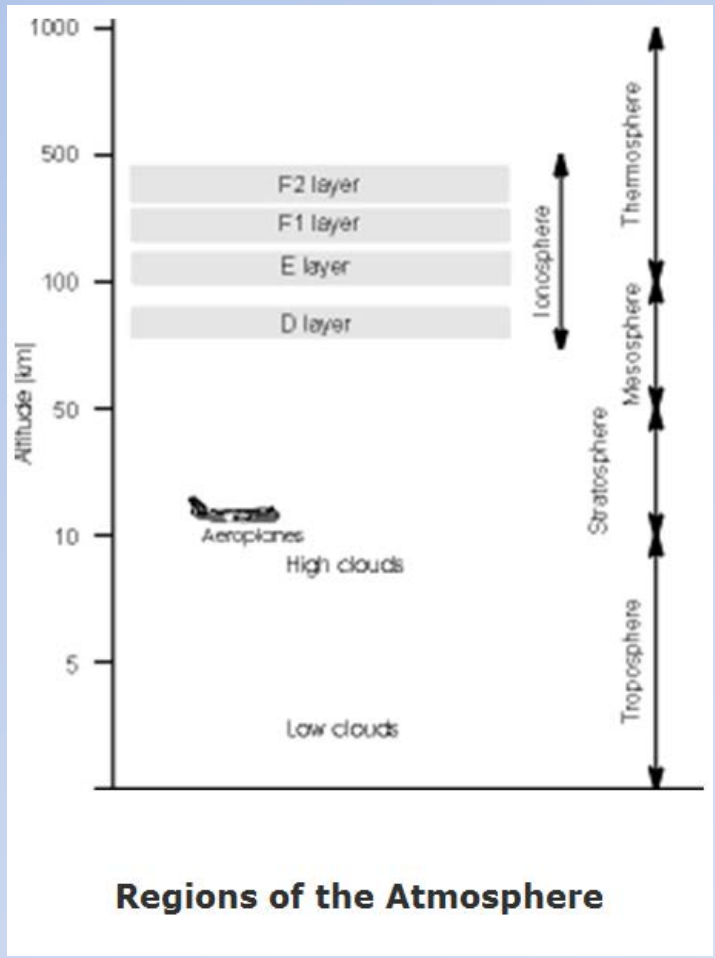
Sky Wave & Refraction



The Atmosphere

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

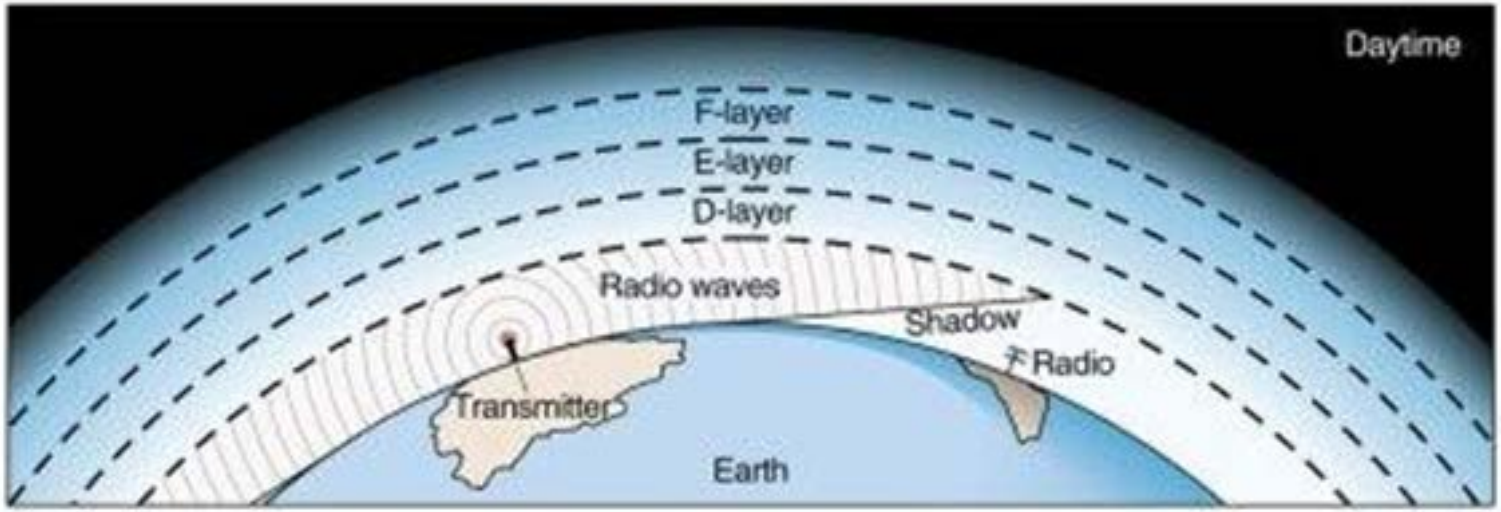
D Layer exists during the day.



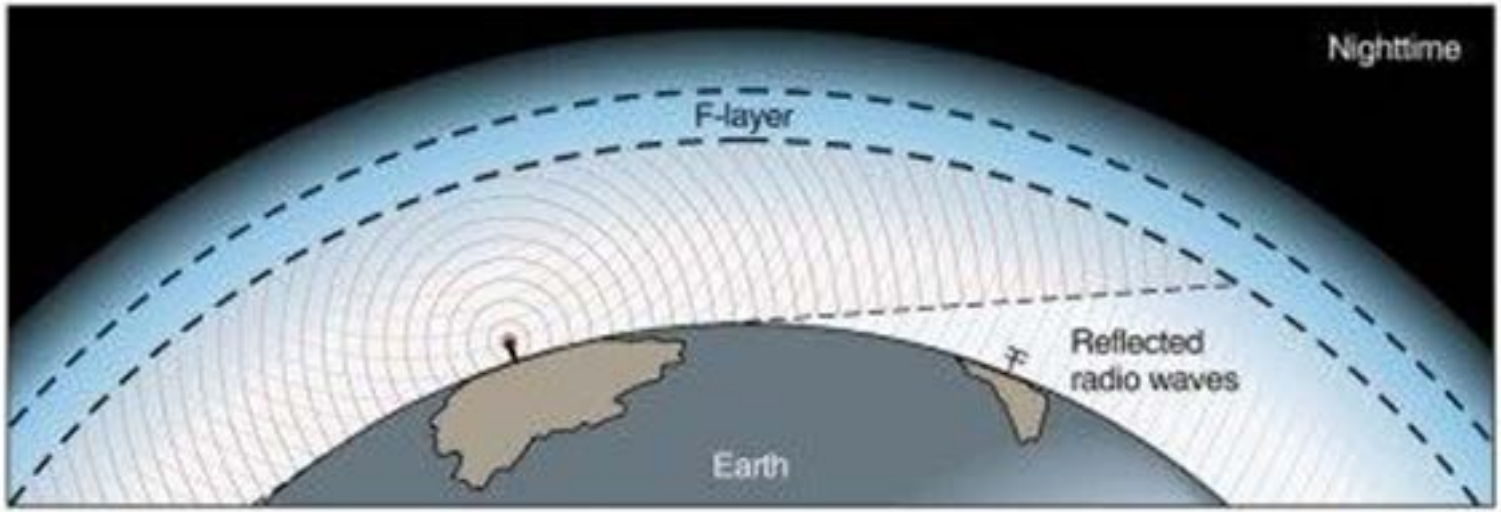
Regions of the Atmosphere

From Radio Electronics.com

The Atmosphere



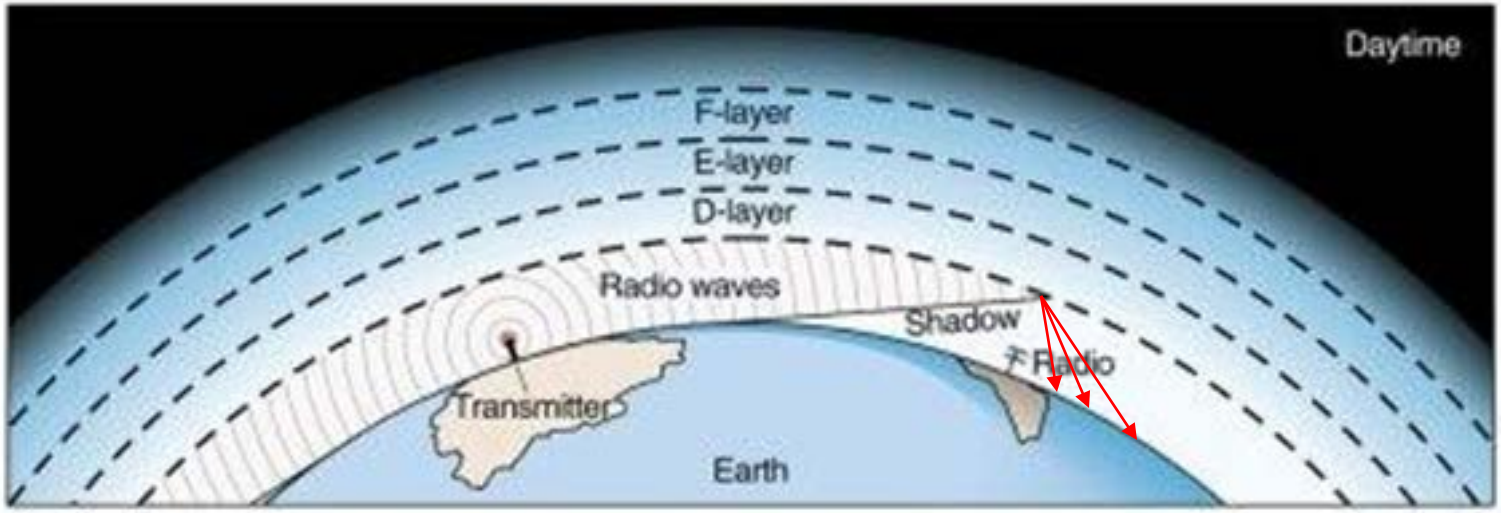
(a)



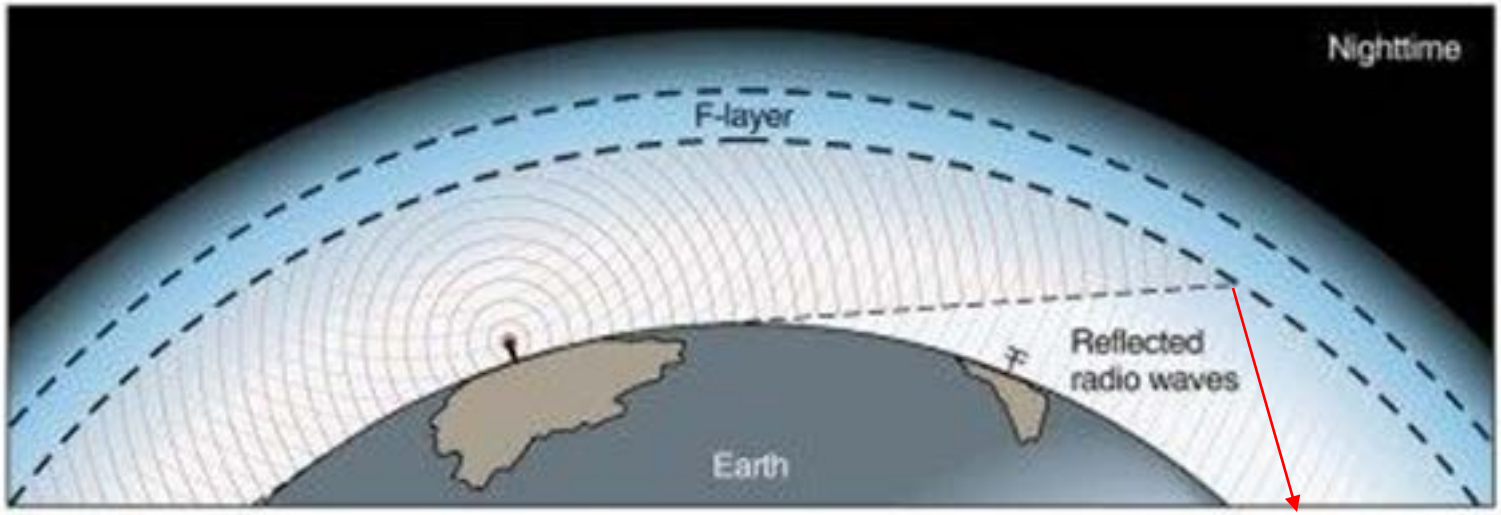
(b)

From the G7LRR Web Page

The Atmosphere



(a)



(b)

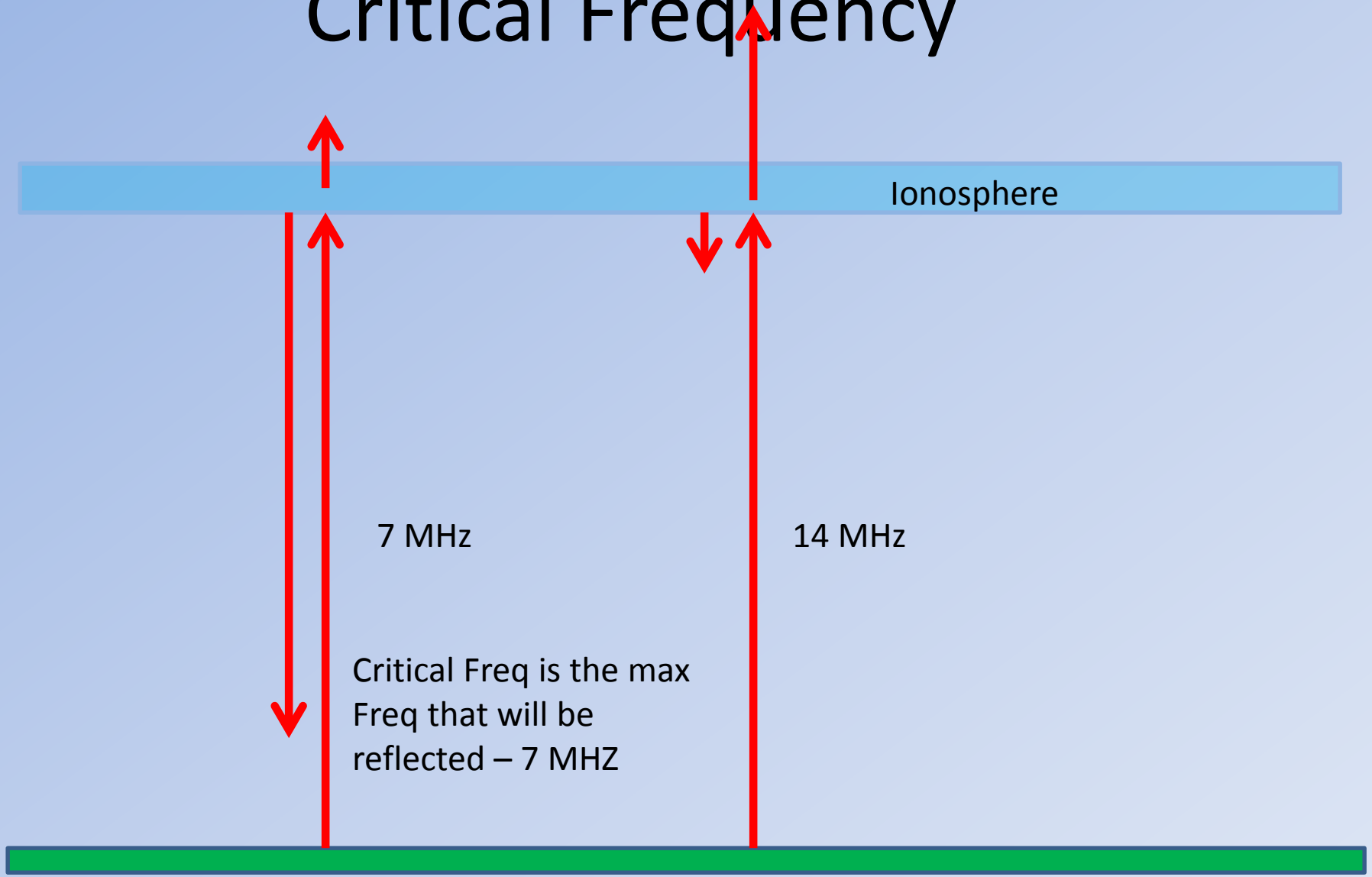
From the G7LRR Web Page

SEA PAC 2015

Sky Waves

- As the charged particles of the ionosphere increases, the amount of RF reflection (refraction) 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

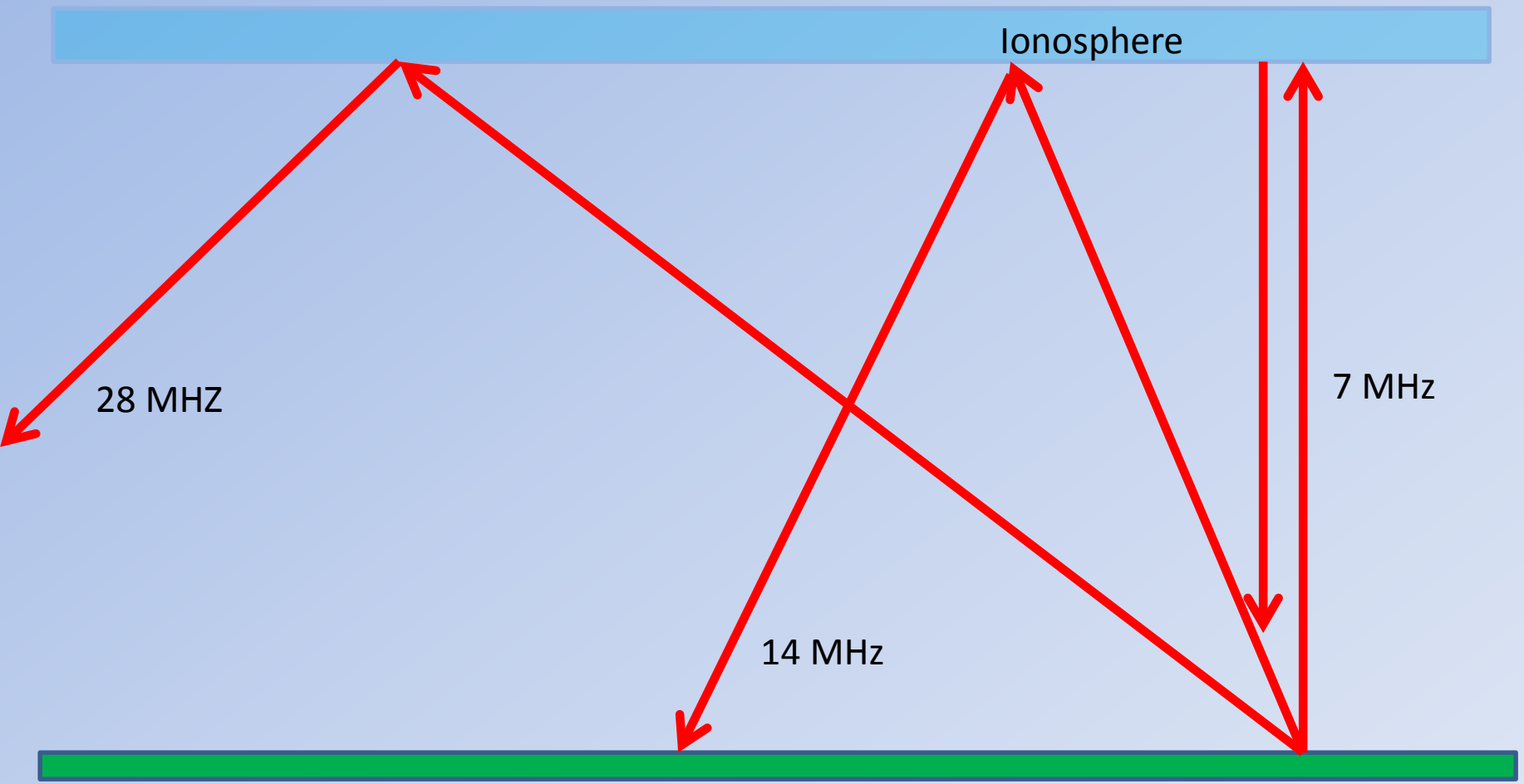


Sky Waves

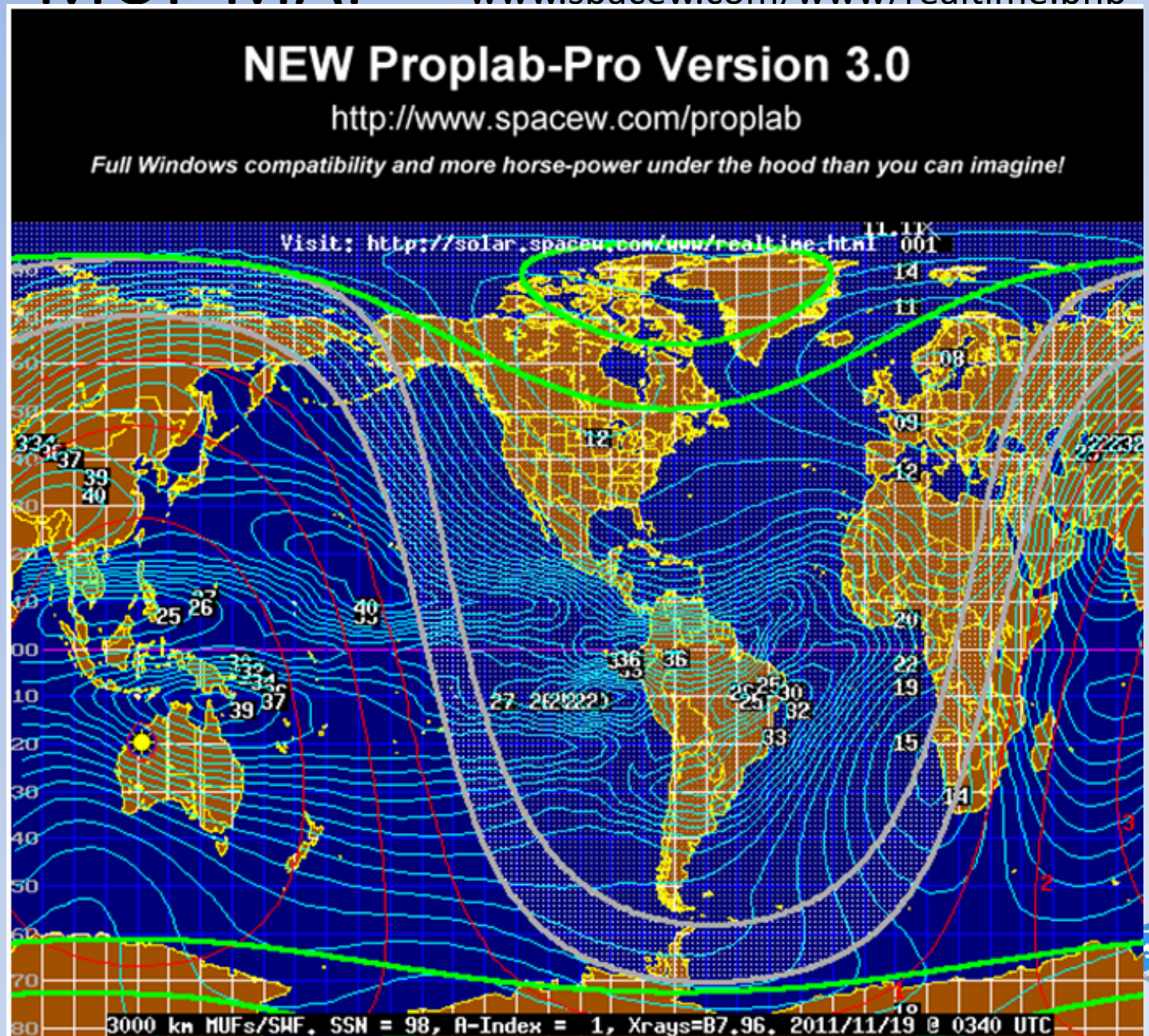
- The critical frequency is measured with a vertical signal, a signal point straight up. (Think NVIS antenna.)
- The upper limit of frequency that can be reflected can be increased by changing the angle that it hits the ionosphere.
- The sharper the angle, the higher the frequency until the maximum useable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

SEA PAC

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.

SEA PAC

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

SEA PAC

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.

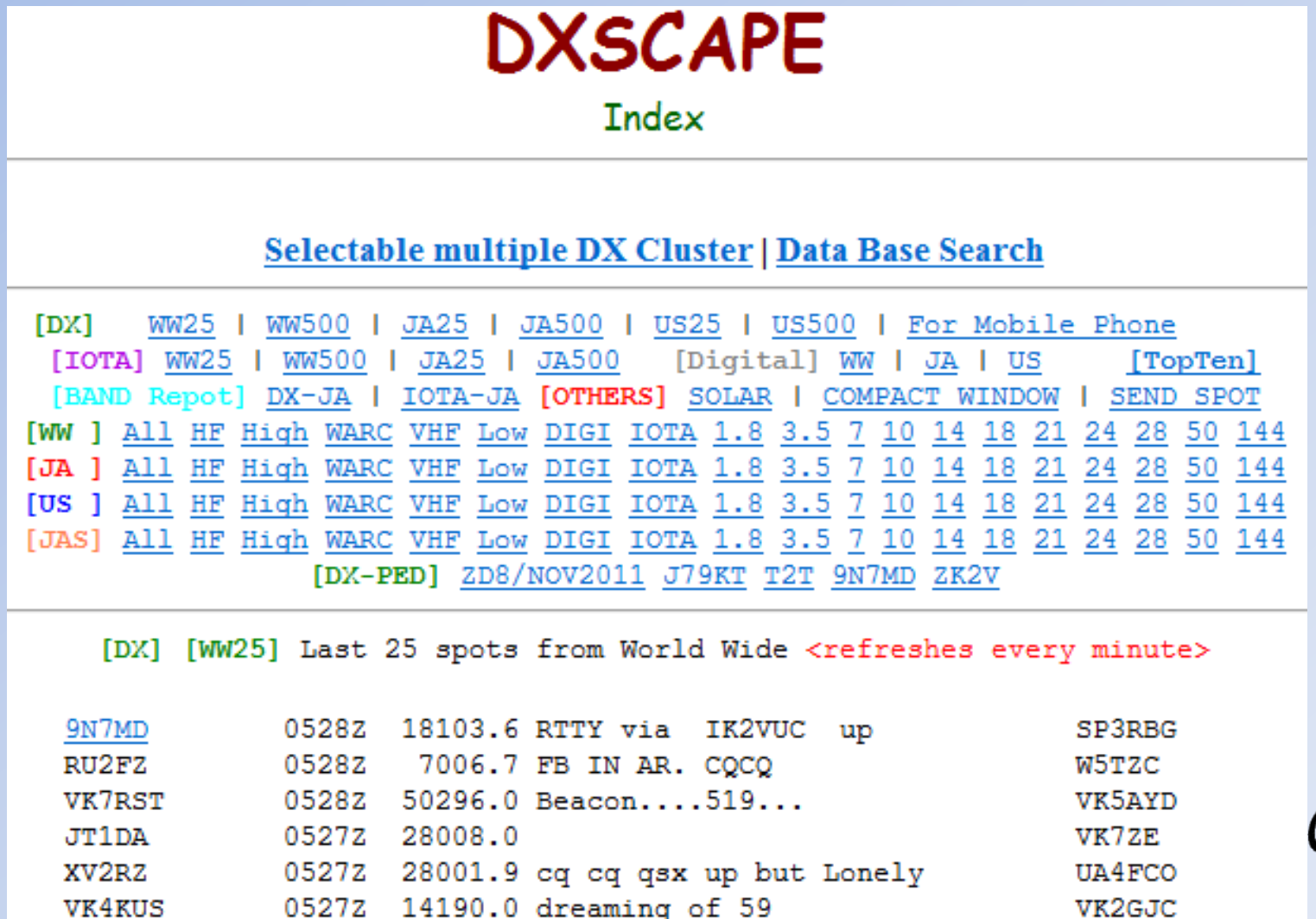
Search the DX Summit Database for recent reception reports by callsign.

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



DXSCAPE

Index

Selectable multiple DX Cluster | Data Base Search

[DX] WW25 | WW500 | JA25 | JA500 | US25 | US500 | For Mobile Phone
[IOTA] WW25 | WW500 | JA25 | JA500 [Digital] WW | JA | US [TopTen]
[BAND Repot] DX-JA | IOTA-JA [OTHERS] SOLAR | COMPACT WINDOW | SEND SPOT
[WW] All HF High WARC VHF Low DIGI IOTA 1.8 3.5 7 10 14 18 21 24 28 50 144
[JA] All HF High WARC VHF Low DIGI IOTA 1.8 3.5 7 10 14 18 21 24 28 50 144
[US] All HF High WARC VHF Low DIGI IOTA 1.8 3.5 7 10 14 18 21 24 28 50 144
[JAS] All HF High WARC VHF Low DIGI IOTA 1.8 3.5 7 10 14 18 21 24 28 50 144
[DX-PED] ZD8/NOV2011 J79KT T2T 9N7MD ZK2V

[DX] [WW25] Last 25 spots from World Wide <refreshes every minute>

9N7MD	0528Z	18103.6	RTTY via IK2VUC up	SP3RBG
RU2FZ	0528Z	7006.7	FB IN AR. CQCQ	W5TZC
VK7RST	0528Z	50296.0	Beacon....519...	VK5AYD
JT1DA	0527Z	28008.0		VK7ZE
XV2RZ	0527Z	28001.9	cq cq qsx up but Lonely	UA4FCO
VK4KUS	0527Z	14190.0	dreaming of 59	VK2GJC

Predicting Propagation

Solar-Terrestrial Data/Predictions at www.qrz.com

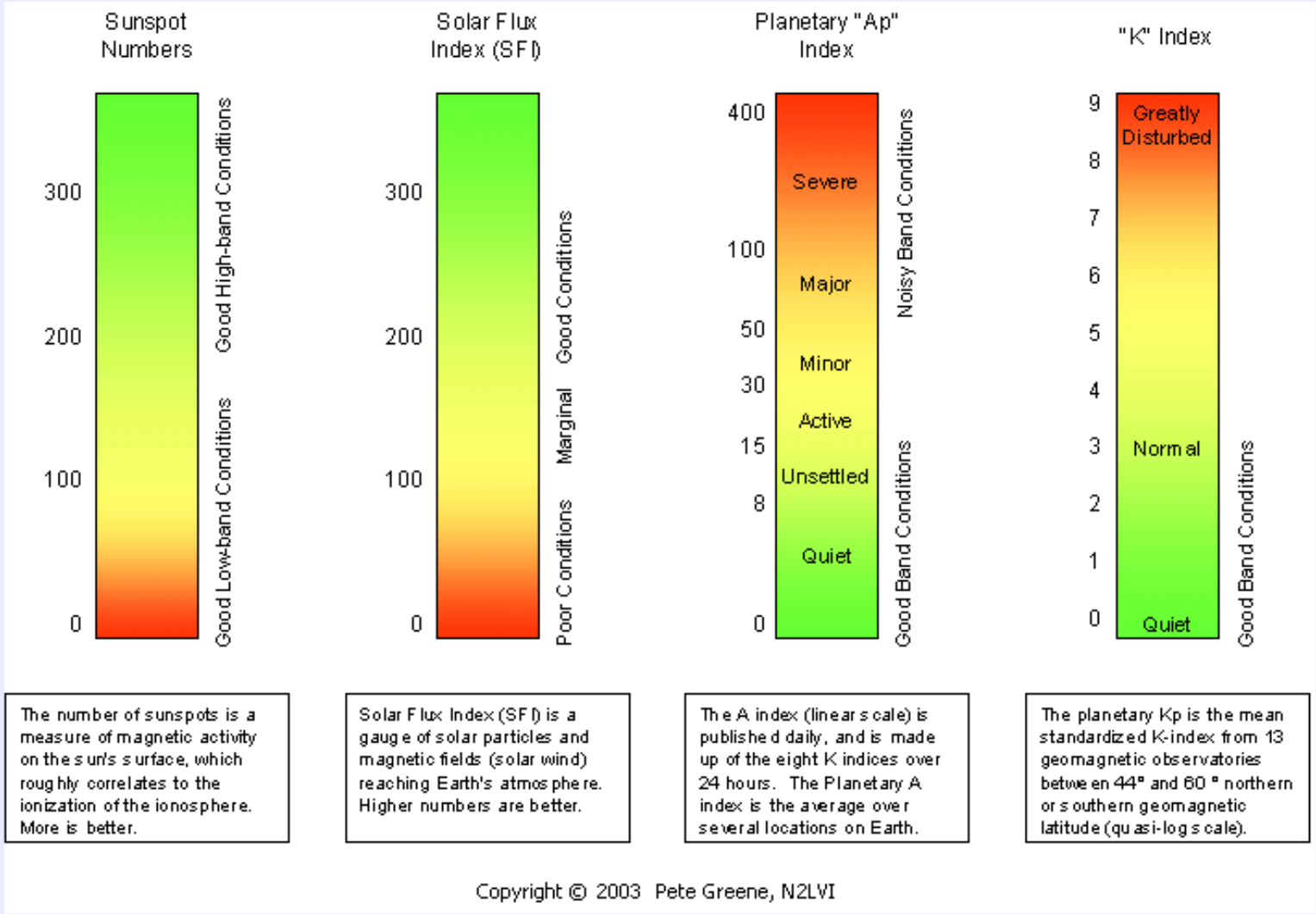
11 Jun 2015 2120 GMT		Current Solar	Band	Day	Night
SFI 137	SN 105		80m-40m	Fair	Good
A 012	K 2		30m-20m	Good	Good
XRY C2.3	304A 161.3		17m-15m	Good	Good
Aur 1	Lat 67.5°		12m-10m	Fair	Poor
Bz -0.0	SW 516.8		Geomag Field	QUIET	
PF 0.2	EF 4670.0		Sig Noise Lvl	S1-S2	
MUF Bdr 22.02 @ 2045			CME (UTC)	None	
EME Deg	Good		(C) P Herrman NONBH 2013		

SFI – Solar Flux Index
A Index
K Index
Signal Noise Level
Geomagnetic Field

SEA PAC

N2LVI's Quick Guide to HF Propagation Using Solar Indices

Graphics: Auroral Activity | Solar X-Ray Flux | Sunspots | SOHO | D-Region Asorbtion | MUF | Solar X-Ray Absorption | E-Layer



The number of sunspots is a measure of magnetic activity on the sun's surface, which roughly correlates to the ionization of the ionosphere. More is better.

Solar Flux Index (SFI) is a gauge of solar particles and magnetic fields (solar wind) reaching Earth's atmosphere. Higher numbers are better.

The A index (linear scale) is published daily, and is made up of the eight K indices over 24 hours. The Planetary A index is the average over several locations on Earth.

The planetary Kp is the mean standardized K-index from 13 geomagnetic observatories between 44° and 60° northern or southern geomagnetic latitude (quasi-log scale).

SEA PAC

Propagation & Refraction

Propagation & Refraction

The Strange

- Knife Edge Diffraction

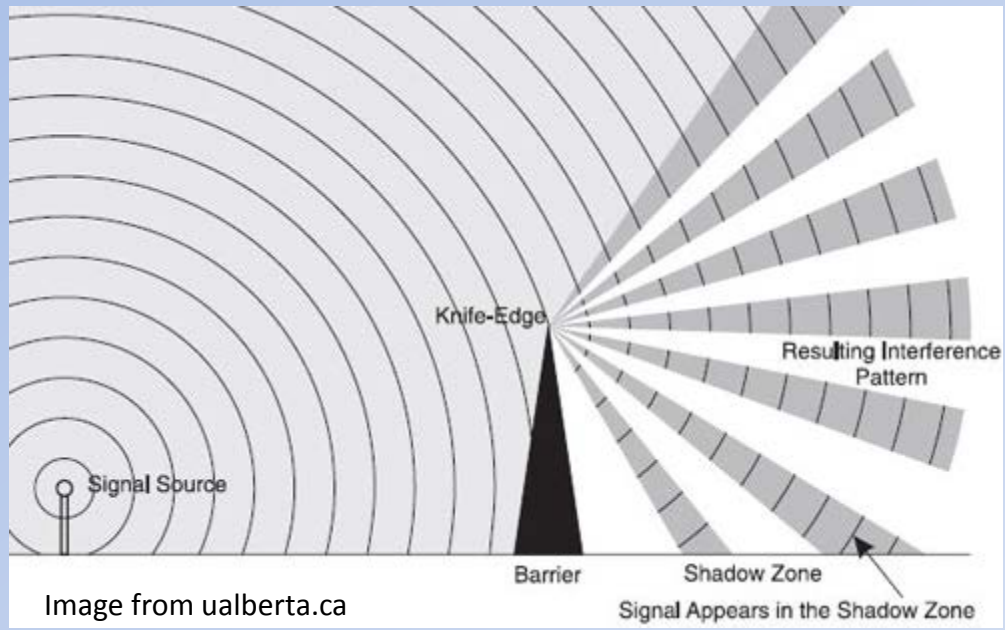


Image from ualberta.ca

- Fresnel Zone

Fresnel Zone in Feet

Link distance between antennas (d) in Miles
Link frequency (f) in GHz

$$r = 72.05 \times \sqrt{\frac{d\ (\text{Miles})}{4f\ (\text{GHz})}}$$

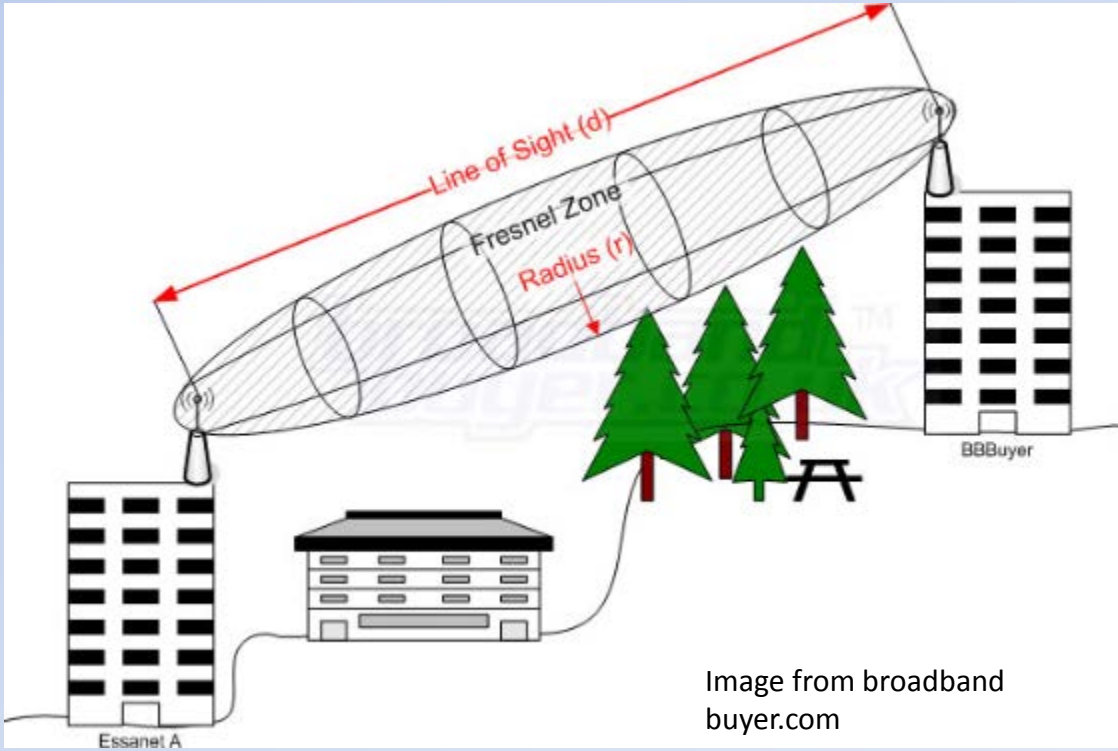


Image from broadband buyer.com

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 believe to follow the earths magnetic field lines.

SEA PAC

The End

- Refer to the ARRL Handbook Chapter 21 for more information on propagation.
- Refer to “Radio Propagation Principles and Practice” by Ian Poole, G3YWX

- Questions???

- Tim Kuhlman,KD7RUS KD7RUS@ARRL.NET

SEA PAC