

# Class 2

## Ham Radio Technician Course

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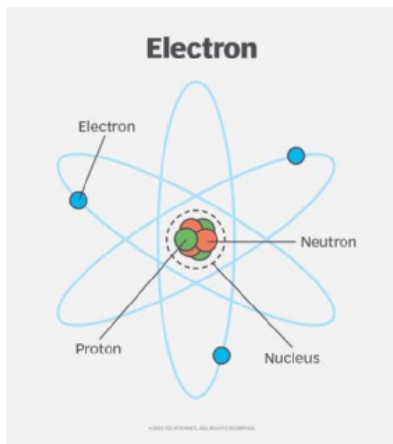
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# If Only Tennis Balls Could Talk



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# Physical Interactions are “Skin Deep”



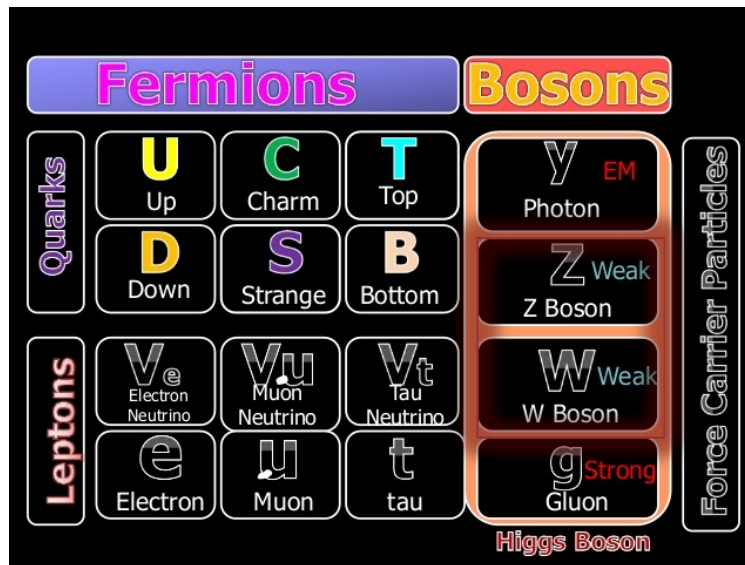
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EM is “The Force”

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# Standard Model of Particle Physics



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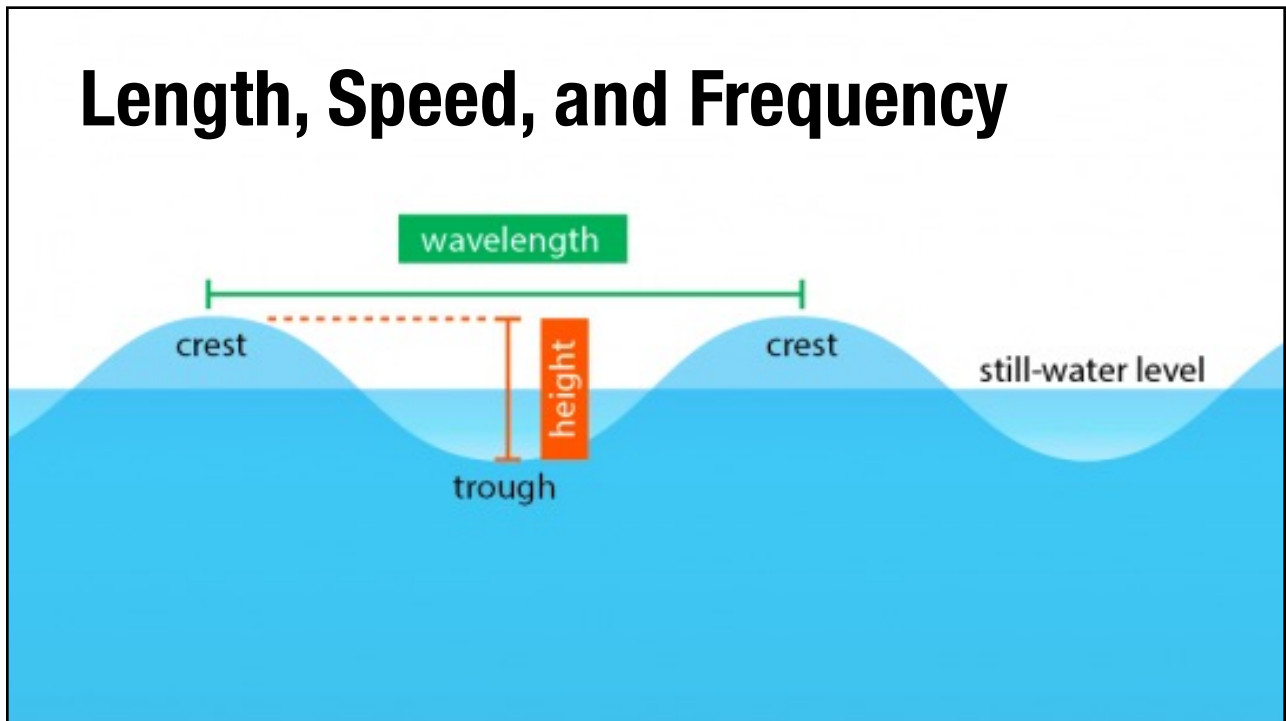


**Waves – Starting With Water**

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# Wave Interactions



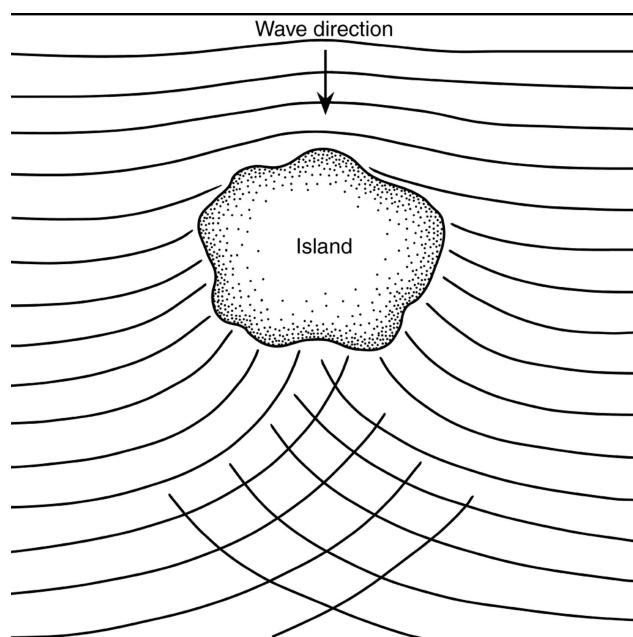
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# Diffraction



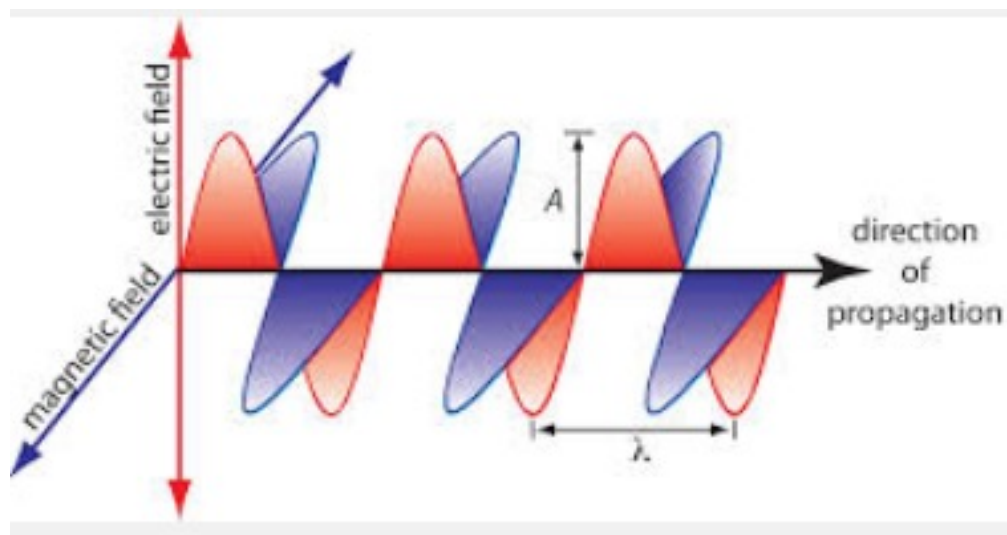
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# Interference



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# EM Waves (E+M)



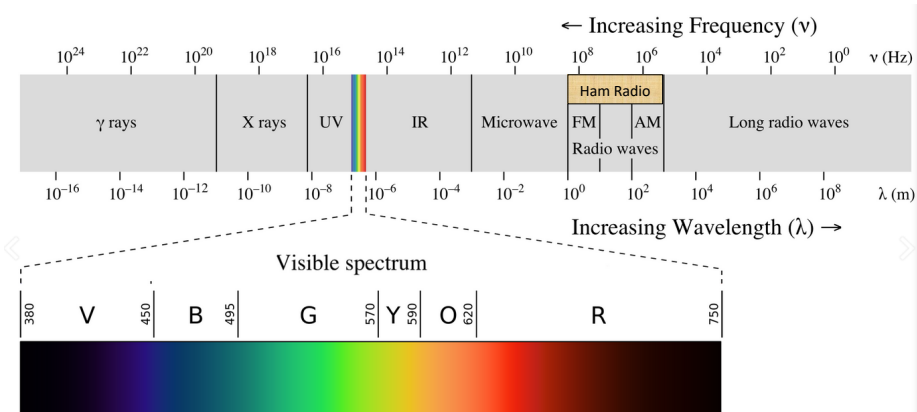
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# Frequency = Color



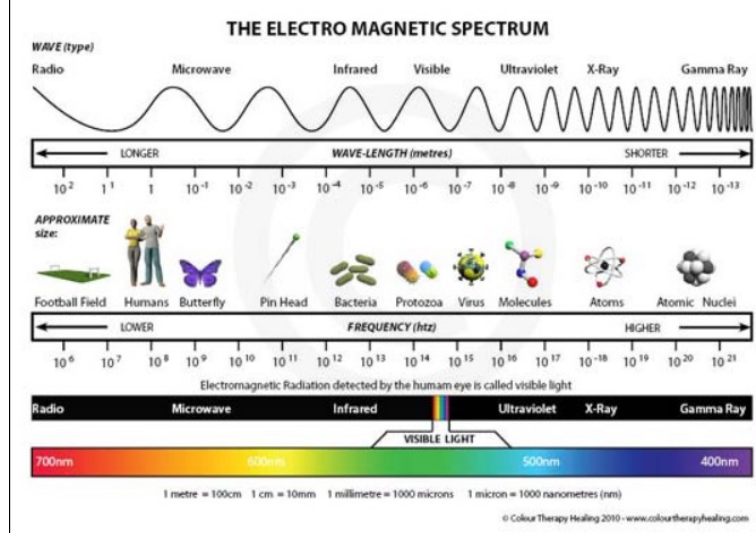
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# Most “Colors” You Can’t See



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# For Size Comparison



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# The "Speed of Light"

300,000,000 meters/sec



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## Converting Frequency to Wavelength

- Using ONLY meters and megahertz
- $300/\text{frequency} = \text{wavelength}$
- $300/\text{wavelength} = \text{frequency}$
- Don't overthink this!



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## For Example

- Frequency to Wavelength
  - $15\text{MHz} = 300/15 = 20 \text{ meters}$
  - $100\text{MHz} = 300/100 = 3 \text{ meters}$
- Wavelength to Frequency
  - $20 \text{ meters} = 300/20 = 15\text{MHz}$
  - $2 \text{ meters} = 300/2 = 150\text{MHz}$



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## EM Interacts With All Matter

- Interaction is frequency dependent (ex: RF vs light vs xrays)
- Interaction is material dependent
- In general, attenuation increases with frequency
  - Clouds block light more than they do radio
  - Walls block high frequency radio more than lower frequencies
  - The atmosphere (thankfully!) blocks UVC, but not visible light



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## Examples of EM interaction

- Light
  - window, mirror, fog, ultraviolet, heat
  - What gives paint it's color?
- RF:
  - metal vs. plastic
  - Copper wire vs. plastic fiber optic
- Both at the same time!
  - Transparent Conducting Film
  - Stealth Paint



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## Explain These Effects Using EM Physics

- Cell Phones in Elevators and Tunnels
- Using a Handheld Radio in a Car
- The Door of a Microwave Oven
- Rain and Satellite TV
- Wood Roof vs. Metal Roof
- What About Trees?



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## The Speed of Light

- Is not constant
- Is not really about light
- It's the ratio of space and time



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## The “Constant” is Computed

$$c = \sqrt{(\epsilon_0 \mu_0)}$$

$\epsilon_0$  – the electrical permittivity of space  
 $\mu_0$  – the magnetic permeability of space



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## C is Wildly Non-Constant

Material	Refractive index	Speed of light /ms <sup>-1</sup>
Air	1.00	3.0 x 10 <sup>8</sup>
Water	1.33	2.3 x 10 <sup>8</sup>
Perspex	1.49	2.0 x 10 <sup>8</sup>
Glass	1.50	2.0 x 10 <sup>8</sup>
Diamond	2.42	1.2 x 10 <sup>8</sup>



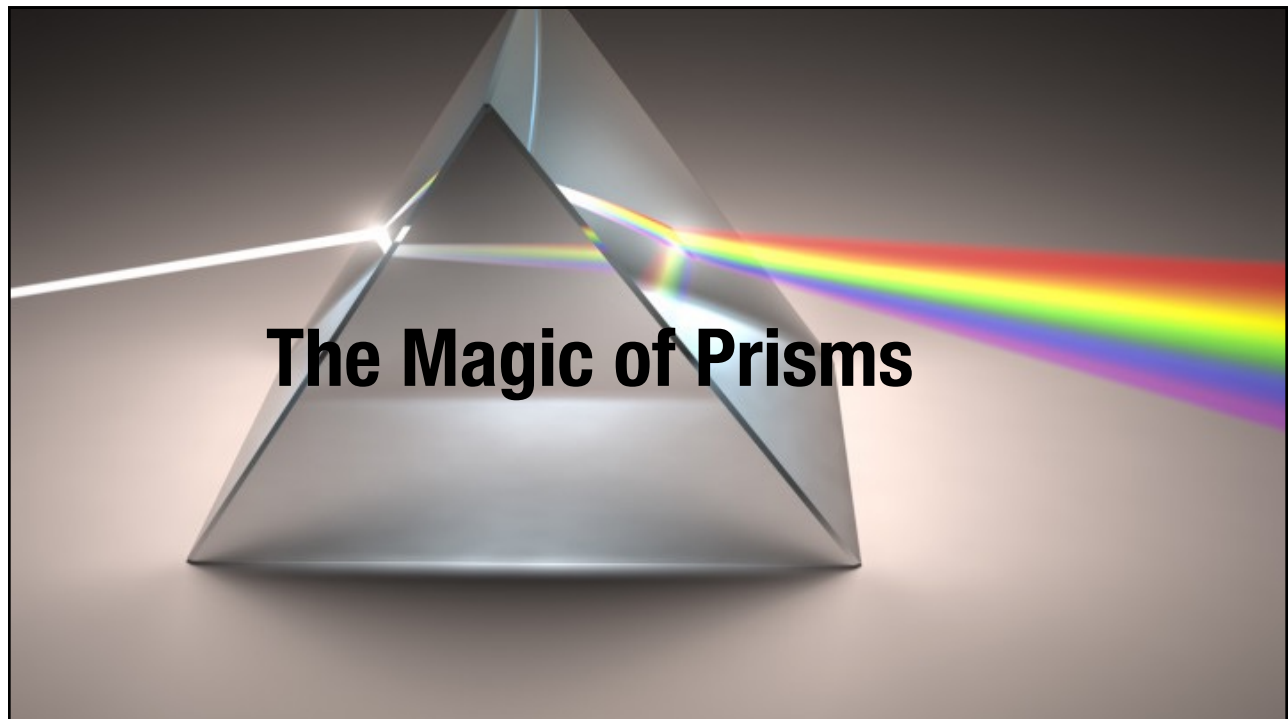
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## Ruining the Magic

- Different colors “bend” at different rates
- Higher frequency (ex: blue) refract faster than lower frequencies (ex: red)



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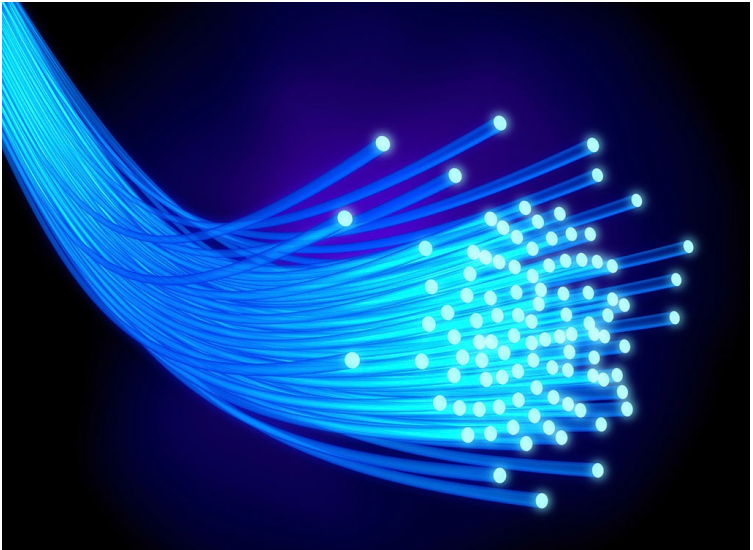


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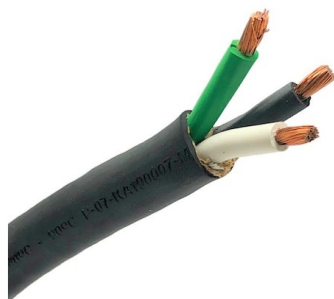
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# Why Does the Light Stay Inside? [mostly]



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# Why Does the Electricity Stay Inside? [mostly]



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# Why Does the Radio Stay Inside? [mostly]



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# Why Don't You Cook Too?



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# Propagation



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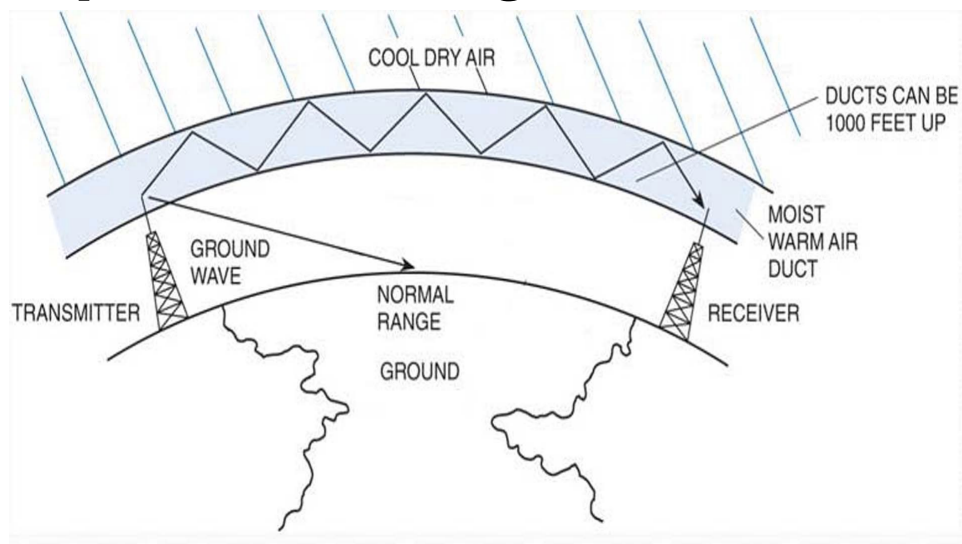
## Line of Sight – The Simplest Propagation

- Almost Like Light (Buildings, Trees, etc)
- The Horizon is ~ 30% Further
  - Refractive Index is Frequency Dependent
- Really Tall Repeater Towers
- 18+ Satellites and the ISS
- Meteors, Comets, Auroras, and the Moon



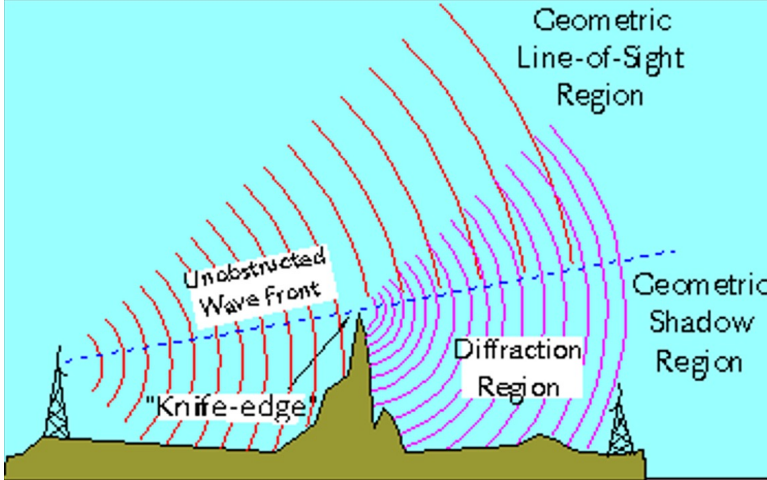
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## Tropospheric Ducting



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# Knife Edge Diffraction



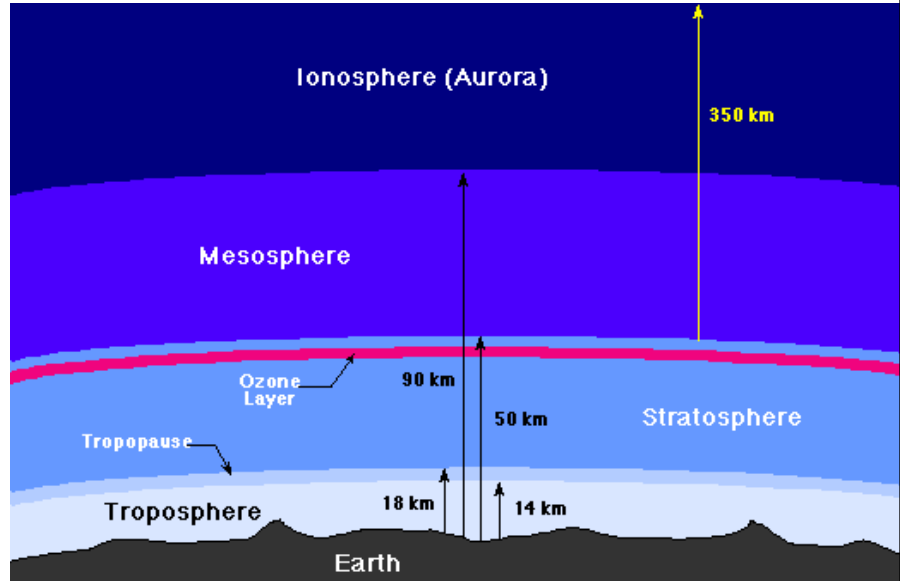
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# The Ionosphere(s)



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# Our Security Blanket



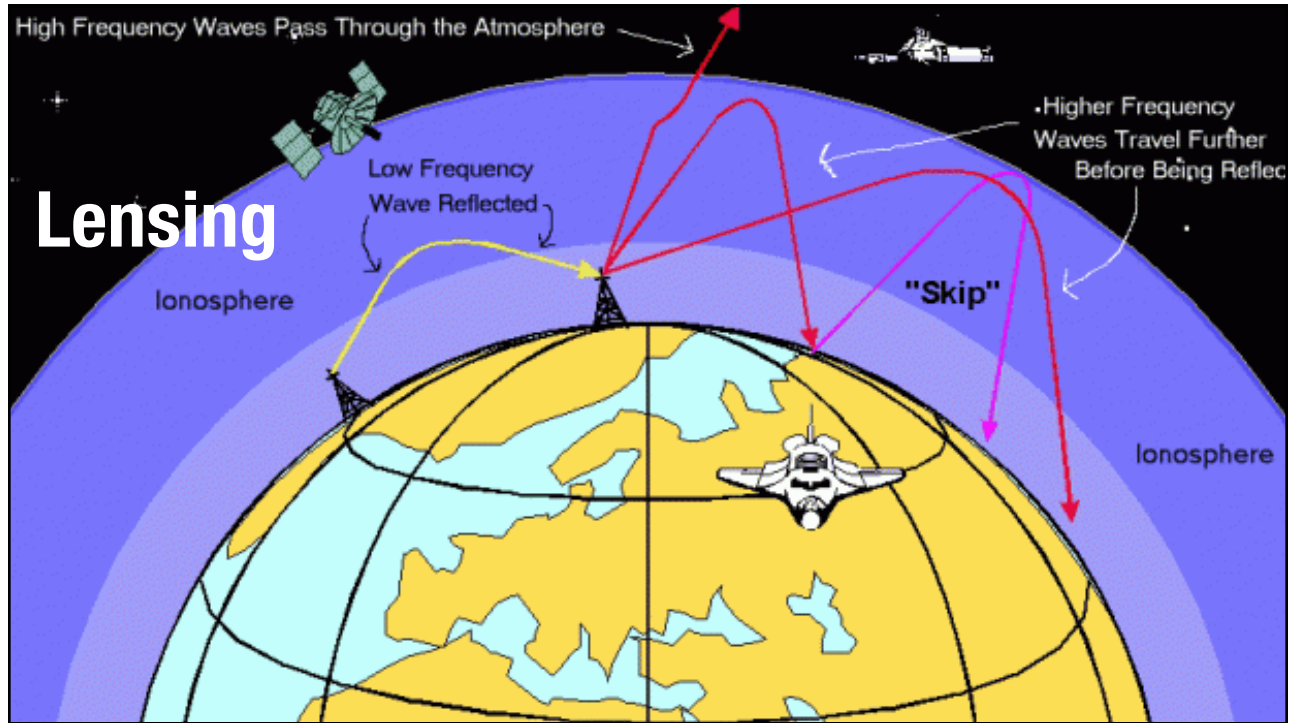
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## Ionospheric layers

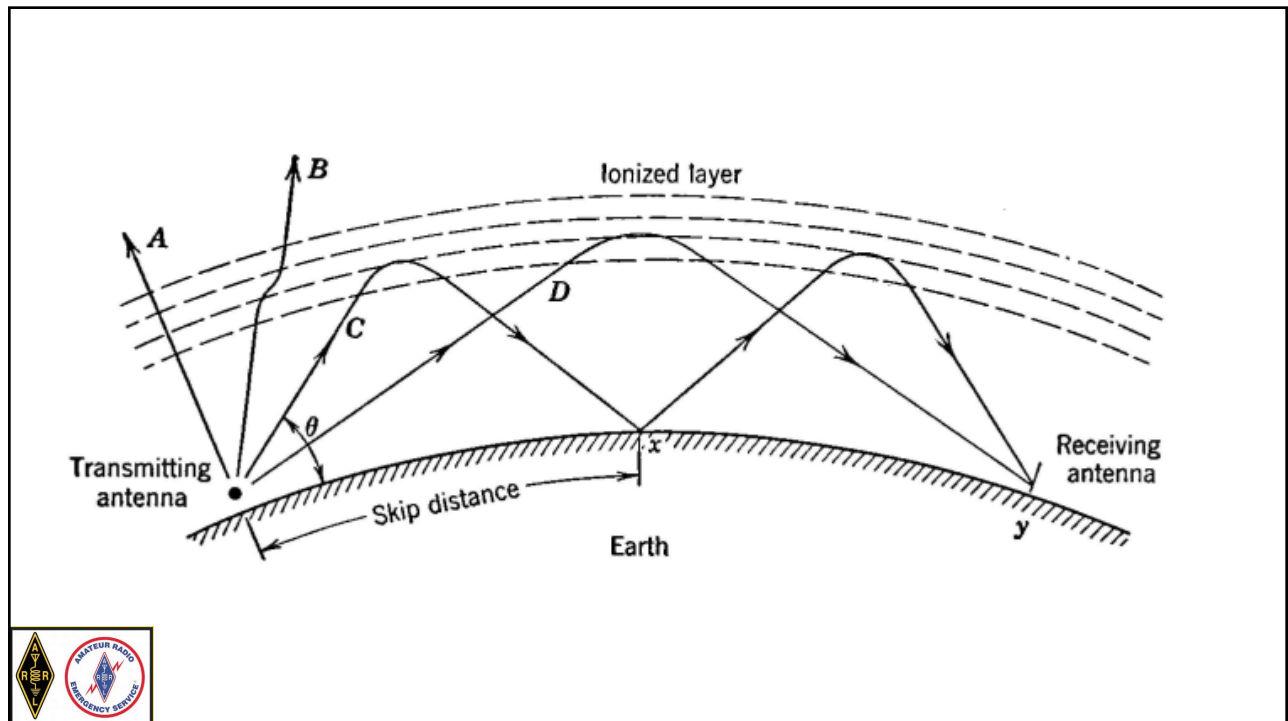
- During the day there may be four regions present called the D, E, F1 and F2 regions
- At certain times during the solar cycle the F regions may join
- At night the D, E and F1 regions become very much depleted of free electrons
- Only the E, F1 and F2 regions refract HF waves.
- The D region absorbs or attenuates them
- The F2 region is the most important region for HF because:
  - it is present 24 hours of the day
  - its high altitude allows the longest communication paths
  - it reflects the highest frequencies in the HF range.



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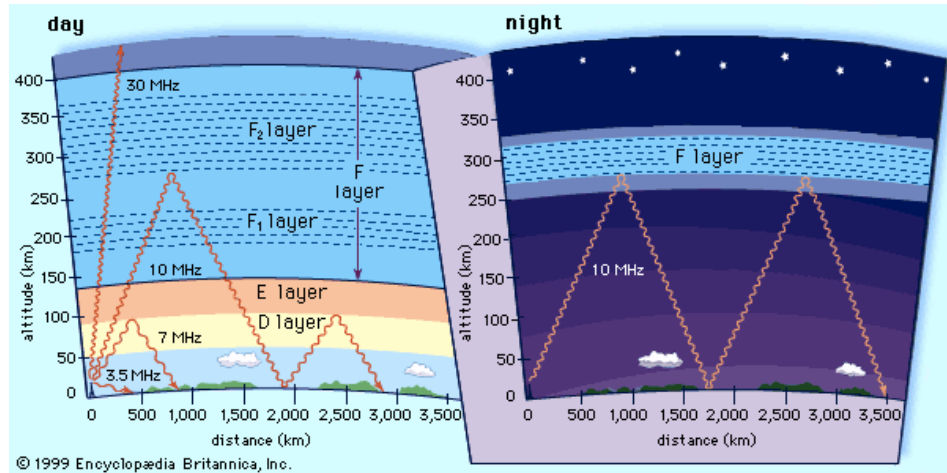
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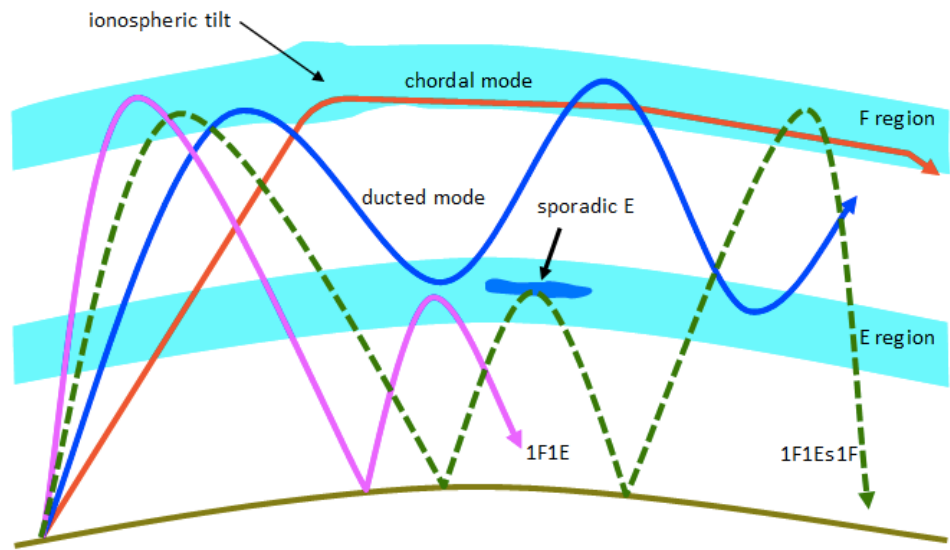


# As Different as Night and Day




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# The CHAOS That is Propagation



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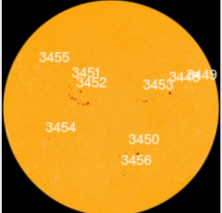
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### Current Conditions

**Solar wind**  
speed: **424.6** km/sec  
density: **6.12** protons/cm<sup>3</sup>  
more data: [ACE](#), [DSCOVR](#)  
Updated: Today at 0937 UT

**X-ray Solar Flares**  
6-hr max: **C1** 1941 UT Oct04  
24-hr: **C3** 0952 UT Oct04  
[explanation](#) | [more data](#)  
Updated: Today at: 2140 UT

**Daily Sun: 04 Oct 23**




Expand: [labels](#) | [no labels](#) | [Carrington](#)

Sunspot AR3450 has a beta-gamma magnetic field that harbors energy for

### What's up in space

Wednesday, Oct. 4, 2023


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archives


**HUGE NEW SATELLITE OUTSHINES ALMOST EVERY STAR:** A paper [published this week](#) in the research journal *Nature* examines the alarming brightness of Bluewalker 3 -- a communications satellite the size of a racquetball court. At times it outshines 99% of the stars in the sky. One such satellite is no problem, but it may soon be followed by hundreds more. [Full story.](#)

**WHAT WOULD GALILEO SAY?** Before you read any further, [click here](#). That's what Galileo saw in 1610 when he turned his primitive telescope toward Jupiter. The satellites were tiny specks of light with no discernable features. What a difference 400 years makes. On Oct. 3, 2023, Philip Smith looked through a modern backyard telescope and saw a full-fledged world:



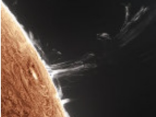


**Averted Imagination**



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